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Plurality of Worlds and Natural Philosophy: An Historical Study of the Origins of Belief in Other Worlds and Extraterrestrial Life

Steven J. Dick

Submitted to the faculty of the Graduate School
in partial fulfillment of the requirements
for the degree Doctor of Philosophy
in the Department of History and
Philosophy of Science
Indiana University

February 1977

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He, who through vast immensity can pierce,
See worlds on worlds compose one universe,
Observe how system into system runs,
What other planets circle other suns,
What varied Being peoples every star,
May tell why Heaven has made us as we are.

Alexander Pope
"An Essay on Man" 1733-34

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ANALYTICAL TABLE OF CONTENTS

INTRODUCTION

CHAPTER ONE Atomism and the plurality of kosmoi

Atomist meaning of innumerable worlds, 9. Leucippus and Democritus, 11. Epicurus and Lucretius: the atomist arguments in their final classical form, 13. Eclipse of atomism until 17th century, 16. Early influence of Lucretius: Michel de Montaigne's Essais (1588), 20, and Giordano Bruno's works, 22. Northumberland Circle atomists: Nicholas Hill's Philosophia Epicurea (1601), 24. Magnenus' Democritus reviviscens (1640), 26. Henry More's Democritus Platonissans (1646), 28. Margaret Cavendish Poems and Fancies (1653), 31. Pierre Gassendi's atomism: the Animadversions (1649) and the Syntagma philosophiae (1658), 32. Walter Charleton's Physiologia Epicuro-Gassendo-Charltonia (1654), 40. Newton's Principia, the Newton-Bentley correspondence, and the Opticks, 42. The Role of the Deity, 49. Conclusion, 52.

CHAPTER TWO Aristotelianism and the Plurality of Worlds

Aristotle's meaning of "world", 64. Aristotle's De caelo, I, 8: the argument from natural place, 65. De caelo, I, 9: the argument from form and matter, 69. The Medieval tradition, 71. Duhem's research, 72. Pre-1277 arguments: Roger Bacon and Thomas Aquinas, 76. Post-1277 arguments: Jean Buridan's commentary on De caelo, 82; William of Ockham's Sentence commentary, 86; Nicole Oresme's Le Livre du ciel et du monde(1377), 93. Later Middle Ages: Crescas and John Major, 99; Leonardo da Vinci, 101; Nicholas of Cusa, 103; William Vorilong, 107; Giordano Bruno, 108.

CHAPTER THREE The Heliocentric Theory and the Plurality of Earths

A shift in the tradition, 118. Copernicus vs. Copernicanism, 120. PRE-TELESCOPIC ERA: Bruno's De l' infinito universo e mondi (1584), 122; Kepler's Optics (1604); Kepler's De stella nova (1606), 131; Brennger, 136. TELESCOPIC ERA, 138; Galileo's Nuncius (1610), 139; Kepler's Dissertatio (1610), 139; Kepler's Somnium (1634), 145; Julius Caesar La Galla's De phaenomenis (1612), 148; Galileo's opinion prior to the 1616 condemnation, 149; Galileo's Dialogi (1632), 151. THEOLOGICAL CONSIDERATIONS, 155; Melancthon, 156; Mersenne's Quaestiones (1623), 158; Campanella's Apologia (1622), 163. THE TRADITION CONSOLIDATED: John Wilkins' Discovery (1638), 167. Conclusion, 175.

CHAPTER FOUR Cartesian Vortices and the Plurality of Solar Systems

The role of Cartesianism in the plurality of worlds tradition: Lovejoy and Rossi, 193. Cartesian cosmology: refutation of more

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CHAPTER FOUR (cont.)

than one cosmos, 194. Descartes' Copernicanism, 196. Cartesian vortices, 197. Descartes' failure to assert inhabited planets, 199. Cartesianism in treatises on plurality of worlds: Henry More's Democritus Platonissans (1646), 202; Pierre Borel's Discours nouveau (1657), 206; DeVries' Dissertatio ... de lunicolis (1676), 210. Plurality of worlds in Cartesian treatises: Regius in Holland (1646, 1661), 214; Rohault (1671) and Gadroys (1675) in France, 215. Ideas of Athanasius Kircher and Otto von Guericke in Germany, 220. Fontenelle's Entretiens (1686): why it was written, 221; how serious, 222; role of Copernicanism, 224; role of Cartesianism, 225; the spread of the vortex cosmology and the plurality of worlds idea: editions altered by Fontenelle himself, 228; subsequent editions of Entretiens. Other thinkers: Diderot, 231; Traite de l'infini cree (1761), 232. Later annotated editions of Entretiens, 235. Vortices not equated with plurality of inhabited solar systems, 235. Huet (1689), 236. Gabriel Daniel, 237. Huygens' Cosmotheoros (1698), 239. Importance of Cartesianism to plurality of worlds tradition, 240.

CHAPTER FIVE Newtonianism: the Plurality of Solar and Stellar Systems

Newton's rejection of Cartesian vortices, 254. Newton's remarks on other solar systems, 254. Other solar systems not as necessary as in Cartesian cosmology, 256. The role of natural theology: Bentley's Confutation (1693), 258; role of final causes and God's attributes, 262. Bentley's originality: plurality of worlds not a standard tenet of natural theology in the seventeenth century, 263. John Ray's Wisdom of God (1691), 265. Nehemiah Grew's Cosmologia Sacra (1701), 266. Whiston's Astronomical Principles of Religion (1725), 266. Derham's Astrotheology (1715), 266. Spread of belief in plurality of solar systems to astronomical treatises: Whiston and Keill, 272. Reasons for plurality of worlds becoming a part of natural theology in late 17th century, 272. Role of Newtonian physical principles: Whiston, 277; Thomas Wright's Original Theory (1750), 279; the plurality of stellar systems, 290; Kant's Allgemeine Naturgeschichte (1755), 291. Other 18th century Newtonians, 299. Relationship of extraterrestrial life concept to evolutionary view of the universe and Newtonian natural law, 300. Importance of the idea to 18th century, 306.

CHAPTER SIX Astronomical Observation and the Plurality of Worlds

Role of observation, 317. Planetary physics, 318. THE MOON: Kepler's Somnium (1634), 319; lunar temperature, 321; lunar water, clouds, and rain, 323; lunar atmosphere, 326; role of metaphysics, 331; lunar towns, 332. Wilkins' Discovery (1638), 335; chief sources not observational, 337; role of metaphysics, 343; lunar

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CHAPTER SIX (cont.)

atmosphere, 344; "exhalations", 345. Arntzen's Dissertatio (1726), 347; change in intellectual climate at Utrecht, 348; comparison with Wilkins' treatise, 349; lunar spots, 353; lunar atmosphere, 359; Scriptural arguments, 364. Engman's Dissertatio (1740), 366; lunar atmosphere the central issue, 367. THE PLANETS: Huygens' Cosmotheoros (1698), 372; comparison with Fontenelle's work, 373; Systema Saturnium (1659), 374; Fabri and Divini, 376; "Pensees Meslees", 379; Cosmotheoros, 384. Schudt and Hennings, 393.

CONCLUSION

BIBLIOGRAPHY

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Science microfiche series, edited by Duane H.D. Roller, also proved indispensible, as it will to many historians of science in the future.

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Introduction

In 1903 Alfred Russel Wallace, the aged and famous discoverer with Darwin of the biological theory of natural selection, published an astronomical work whose purpose was to deny on scientific grounds the existence of inhabited worlds, and to denounce the scientific veracity of those who upheld that idea in his own time and in the past. Wallace ventured both a scientific and an historical claim when he pronounced in Man's Place in the Universe: a Study of the Results of Scientific Research in Relation to the Unity or Plurality of Worlds, that the modern belief in other worlds, like the earlier belief, was "founded more upon religious ideas than upon a scientific and careful examination of the whole of the facts both astronomical, physical, and biological, and we must agree with the late Dr. Whewell, that the belief that other planets are inhabited has been generally entertained, not in consequence of the physical reasons but in spite of them."[1] A "scientific and careful examination" is precisely what Wallace set out to offer his readers, and his interesting book stands as one piece of evidence that at least by the beginning of the twentieth century, the question was being treated with scholarly criticism.

Considering the interest that the subject of other worlds generated at the beginning of the twentieth century, and still generates today, it is surprising that no careful historical treatment has yet been given. The most widely known historical

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study which touches upon the subject at all - itself inadequate and now some 40 years old[2] - supports Wallace's opinion that metaphysical considerations played a predominant role. This conclusion, oversimplified as it may be, nevertheless draws attention to basic questions of considerable interest to the historian of science. What in fact were the origins of belief in other worlds and extraterrestrial life? Who were the chief figures in the debate, what was their motivation, their intellectual background, and the nature of their arguments? Was the debate primarily scientific or religious in tone, and to the extent that natural philosophers were involved, what does it reveal about the nature of science?

Even the passing and entirely inadequate historical discussion presented in the opening pages of Wallace's treatise is sufficient to indicate the seminal role of the natural philosopher in the tradition of thought surrounding the subject of extraterrestrial life. Having read Whewell, Wallace knew of the early ideas of Kepler, Wilkins, Huygens, and Fontenelle, as well as the later contributions of John and William Herschel, Chalmers, Arago, and Whewell himself. The very fact that Wallace wrote the 1903 treatise in full cognizance of the debate which had come before him illustrates a point of fundamental importance for the historian: the discussion of extraterrestrial life does not consist of ideas scattered indiscriminately throughout history, lacking coherence and dialogue, but instead, to a large degree, is embodied in a distinct and identifiable tradition known as

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that of the "plurality of worlds". Many saw themselves as contributing to this tradition of thought and argument stretching back to antiquity; others set forth their ideas without explicitly acknowledging their predecessors, but were placed in the tradition by their contemporaries and successors, and the historian may legitimately do the same.

It is upon studying in detail this historically cohesive plurality of worlds tradition that one is struck by that pattern visible only in outline in Wallace's treatise, and which he himself clearly exemplifies: that to a large extent, eminent natural philosophers and scientists were responsible for the origin, critical examination, dissemination, and vitality of these ideas. It is the intent of this study to determine the details and significance of this pattern of relationship between the concept of other worlds and the scientific enterprise, by examining to what extent the concept was both inspired by, and treated in accordance with, the principles of some of the major scientific traditions.

The pursuit of the historical relationship between the plurality of worlds tradition and the scientific enterprise cannot be resolved in the nineteenth century but instead plunges the historian into two of the most fertile periods of Western science, that of Greece in the fifth and fourth centuries B.C., and of the seventeenth century scientific revolution as it developed in Western Europe. One soon finds that much more is involved in the debate than the question which was of primary interest to Wallace, as it is to us today, of the determination of the physical

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conditions on the planets, and the possibility of the existence of life forms adaptable to those conditions. As with many other concepts in the history of science, there is an evolution in the concept of a plurality of worlds itself and the questions associated with it. Historically antecedent to the task of determining specific planetary conditions was the resolution of the more basic problem of whether there was any celestial body in the cosmos similar to the earth in elementary substance. The issue of a plurality of earth-like worlds was nourished in the midst of the seventeenth century scientific revolution, which saw the downfall of the long-cherished Aristotelian principle that there was a qualitative distinction between the earth and all other celestial bodies.

Moreover, long before the overthrow of Aristotle's dichotomized universe in the seventeenth century, the central concern of the plurality of worlds tradition was not the existence of many celestial bodies similar to the earth, but of many kosmoi - cosmic systems composed of earth, planets, and fixed stars, like our cosmos. It was the multiplication of the world as "cosmos" which occupied the minds of the fifth century Greek atomists and Aristotle himself, and the arguments brought to bear for and against such a notion were accordingly quite distinct from those now current. But it was with this older concept and its associated arguments clearly in mind that Renaissance thinkers shifted the focus and the concentration to celestial bodies as worlds in themselves, a concept in which extraterrestrial life now became

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prominent. The earlier ideas are thus an integral part of the plurality of worlds tradition in its fullest historical sense; I have therefore deemed it necessary to treat the earlier parts of the tradition with the same degree of thoroughness as those more recognizable elements which subsequently developed.

The birth of the idea of other worlds in its earliest form, then, is almost coincident with the birth of Western science in ancient Greece. The belief in an infinity of kosmoi formed the core of the ancient atomist cosmology which was carried to the Roman world by Lucretius and expounded in the seventeenth century by Gassendi and others. This atomist tradition, along with the diametrically opposed Aristotelian teaching of the unity of the cosmos, as expounded in the De caelo and institutionalized in the medieval commentaries on that treatise, are examined in the first two chapters.

Each of the following three chapters is similarly organized around one of the great scientific traditions which emerged from the scientific revolution: Copernicanism, Cartesianism, and Newtonianism. They seek to understand not only those well-known treatises on the plurality of worlds by Bruno, Wilkins, Fontenelle, and Huygens, along with lesser known treatises, but also the role that the concept of other worlds played in general among the natural philosophers steeped in these scientific traditions. This study carries us chronologically as far as the works of Thomas Wright and Immanuel Kant in the mid-eighteenth century. A final chapter examines the role of observation -

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a methodology given great impetus by the scientific revolution - in supporting or denying a belief in other worlds among seventeenth and early eighteenth century thinkers.

The tradition which we here undertake to study has not gone entirely unrecognized by historians and historians of science; rather, the nature of the remarks and the general work on the subject so far has indicated the need for additional research with specific questions in mind. Thus Marshall Clagett places the idea of a plurality or infinity of worlds among some eight "stock ideas" of the Presocratics and their successors, ideas which he notes "were to reappear again and again in the history of Western science and thought in constantly more subtle and expressive forms."[3] Our subject is here juxtaposed with such ideas as atomism, force, and infinity - all of which have been well treated by historians of science. But no detailed explication of the idea of a plurality of worlds as related to "Western science" has yet appeared.

Again, Kuhn makes many allusions to the concept in his work on the Copernican revolution, but does not specifically address himself in detail to the question of the association of heliocentrism and the plurality of worlds.[4] The majority of articles which deal specifically with an historical view of the plurality of worlds tradition are aimed merely at showing the widespread acceptance of the doctrine, its metaphysical importance, or its literary impact.[5] Lovejoy devotes a chapter of his classical work The Great Chain of Being to an attempt to show the

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overriding importance of his metaphysical principle of plenitude as opposed to scientific considerations in the acceptance of the plurality of worlds concept.[6] Only the work of the French historian Pierre Duhem approaches the question, for a limited period (the Middle Ages), substantively from the point of view of its relation with the history of concurrent scientific developments.[7]

In spite of the diverse goals of the various treatments of the question, their combined effect is again to indicate the close involvement of natural philosophers with the elucidation and argument of ideas concerning other worlds. It cannot be doubted that the serious contemplation of this problem is a thread of thought running throughout the history of science, and that an historical understanding of the plurality of worlds tradition must be sought in the full context of both the metaphysical and physical precepts which in some form have constituted the scientific enterprise from its beginnings.

I am not unmindful of the fact that my search for the origins of belief in other worlds and extraterrestrial life has been suspended at mid-eighteenth century, a century and a half short of Wallace's work, and that even this period is of such length as to assure omissions. But I am convinced that the patterns discovered therein hold much significance for nineteenth and twentieth century discussions of the subject. At the same time, this study remains only a beginning. My only hope is to remedy unnecessarily harsh and inadequate judgements of the tradition

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such as Wallace's, and finally to clarify with the historian's perspective, the origins and growth of this long-debated subject.

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Notes

[1] (London, 1903), p. 7. The "Dr. Whewell" to whom Wallace refers is William Whewell, who in 1853 wrote Of the Plurality of Worlds: an Essay (London, 1853).

[2] Arthur O. Lovejoy, The Great Chain of Being (Cambridge, Mass., 1936), chapter 4, "The Principle of Plenitude and the New Cosmography".

[3] Greek Science in Antiquity (New York, 1955), p. 36.

[4] The Copernican Revolution (Cambridge, 1957). See especially pp. 143, 199, 222, 235-37, 240-42.

[5] In the first category are R.V. Chamberlin, "Life in other Worlds: a Study in the History of Opinion," Bulletin of the University of Utah (Biological Series), vol. 22, no. 3, Feb., 1932; Grant McColley, "The Seventeenth Century Doctrine of a Plurality of Worlds," Annals of Science, I (1936), pp. 385-430; and the more perceptive article of Milton Munitz, "One Universe or Many?", Roots of Scientific Thought, eds, Noland and Wiener (New York, 1957), pp. 593-617. Paolo Rossi brings out some of the more metaphysical considerations in "Nobility of Man and Plurality of Worlds," Science, Medicine and Society in the Renaissance, ed. Allen Debus, pp. 131-162. Marjorie Nicholson studies the literary impact in "The Telescope and the Imagination," Modern Philology, vol. 32 (1934-35).

[6] Op. cit. (note 2).

[7] Le Système du monde (Paris, 1958), vol. IX, pp. 363-430; and Etudes sur Leonard da Vinci (Paris, 1955), vol. II, pp. 57-96 and pp. 408-423.

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Chapter One

ATOMISM AND THE PLURALITY OF KOSMOI

> Now since there is illimitable space in every direction, and since seeds innumerable in number and unfathomable in sum are flying about in many ways driven in everlasting movement, it cannot by any means be thought likely that this is the only round earth and sky that has been made, that all those bodies of matter without have nothing to do: especially since this world was made by nature ...
>
> LUCRETIUS[1] c. 55 B.C.

> INFINITIE OF WORLDS! A thing monstrous if assented to, and to be startled at ...
>
> HENRY MORE[2] 1646

Even a cursory study of the system of the early atomists Leucippus and Democritus and their successors Epicurus and Lucretius, reveals a consistent concern with the macroscopic no less than the microscopic. Each of these thinkers is of course eager to apply his speculations on the nature of matter to the explication of everyday phenomena; such explanatory power supposedly provides the root inspiration for such a theory, and is the criterion upon which its vitality depends. But not only do the atomists assert that matter is composed of small indivisible particles in motion and that many terrestrial phenomena are accounted for by this fact, their system carries them far beyond the earth, into the realms of cosmology and cosmogony. Indeed, armed with their atomism they venture even beyond the visible cosmos and embrace a belief in innumerable worlds (aperoi kosmoi), the forerunner

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to the later doctrine of a plurality of worlds. Simply stated, these terms signify a belief in more worlds than ours, in a sense which will be clarified shortly.

A closer study of the ideas of the atomists shows that the discussion of other worlds arises not from the fact that these early philosophers speculated on anything and everything, and therefore incidentally on a plurality of worlds, nor does it arise by a simple microcosm-macrocosm analogy. To the contrary, the concept of a plurality of worlds, of which innumerable worlds is the extreme case, arises in the context for which the atomist are most famous: their atomism. More specifically, it arises in the context of what we shall term the cosmogonic assumption of ancient atomism: the belief that the constituent bodies of the cosmos are formed by the fortuitous coalescence of moving atoms. While this fact is undeniably evident in atomist thought, the natural tendency of the historian to discard aspects only very peripherally associated with the central concern of his history has tended to obscure the fact that atomism and the plurality of worlds were ever associated, and that we must look to atomism for the early instances of belief in this important cosmological doctrine. Conversely, the scope and power of the atomist system is more fully appreciated when one realizes that it includes theories of cosmic origin and indeed of the origin of a plurality of kosmoi.

We will be concerned here to investigate primarily two fundamental questions: first, the nature of the original

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association of two such seemingly incongruous subjects as atomism and the plurality of worlds; secondly, how this association fared in the seventeenth century with the revival of atomism, especially at the hands of Pierre Gassendi, and the extent to which the many-worlds claim constituted a viable issue in the milieu of seventeenth century mechanism.

It is essential to understand at the outset that the term "world" (kosmos) is not used in this early period of history to denote the earth or a body like it; rather, in the words of Epicurus

> A world (kosmos) is a circumscribed portion of the sky (ouranos), containing heavenly bodies and an earth and all the heavenly phenomena, whose dissolution will cause all within it to fall into confusion: it is a piece cut off from the infinite (apeiron) and ends in a boundary either rare or dense, either revolving or stationary: its outline may be spherical, or three-cornered, or any kind of shape.[3]

For the atomists, then, a world is considered to be that which encompasses all visible phenomena as seen from our earth; the earth itself, along with the sun, moon, planets, and fixed stars are part of our world. The question which the atomists pose is whether this visible world is the all (πᾶν), the universe (ὅλον), or whether innumerable such kosmoi coexist, each with its own planets and stars.

When one returns to the beginnings of Western science as it developed in Greece from the sixth to the fourth centuries B.C., it is often necessary to speak of ontology, for in the discussion of the material universe the nature of being and

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reality is a fundamental question. The rudiments of ancient atomism arose in reaction to the Parmenidean system, in which even the potential existence of many worlds was impossible. According to Parmenides, whatever exists "is uncreated and imperishable, for it is entire, immovable and without end. It was not in the past, nor shall it be, since it is now, all at once, one, continuous."[4] In short, the very antithesis of a setting conducive to the generation or existence of other worlds.

In contrast, atomism provided for the existence of atoms and the existence of void. Furthermore, there was change in the system; the atoms were in motion, colliding, sticking together. Given the occurrence of these natural processes, and the obvious example of potential stability revealed in our own finite world, it was not unreasonable to suppose the existence of other stable conglomerations. The operative principle among the atomists was that when causes were present effects must occur.[5] Atoms were the agent of causality and they were infinite in number. Innumerable worlds in formation, in collision, and in decay were the effects. A point evident but important is thus made: on the most basic level, the ontology of the atomists was conducive to the possibility of other worlds. While the ontology of the earlier Ionian monists such as Anaximander and Anaximenes may have permitted this, it is most likely that it was the atomists in the fifth century B.C. who were the first to espouse a belief in the plurality of coexistent worlds.[6]

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An ontology compatible with the formation of worlds does not necessitate that such a belief be adopted. Indeed, there was good reason to refrain from such far-fetched claims, since our own cosmos was so little understood. Thus a seventeenth century opponent of this particular atomist assertion found it remarkable that whole schools of philosophers "extended their disquisitions beyond the Extremes or Confines of this adspectable World to a multitude of others without it, as vast, as glorious, as rich in variety of Forms: when, indeed, their Understandings came so much short of conquering all the obvious Difficulties of this one, that even the grass they trod on, and the smallest of Insects, a Handworm, must put their Curiosity to a stand".[7] Nevertheless the earliest founders of the atomist school, Leucippus and Democritus, already proposed such a belief a century before Aristotle did so much to advance natural philosophy. Neither of their works is extant, but accounts of their ideas have survived. Diogenes Laertius, a compiler in the third century of the Christian era, records one of the few references to the belief of the earliest atomist: "Leucippus holds that the whole is infinite ... part of it is full and part void ... Hence arise innumerable worlds, and are resolved again into these elements".[8] We note at the outset the close association of existent worlds with the basic ontology; atoms ("part full") and void are the elements emphasized in the passage. Motion is the other quality essential for the formation of worlds, and its pivotal role for Leucippus becomes immediately evident as Diogenes continues his account.

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> The worlds come into being as follows: many bodies of all sorts and shapes move by abscission from the infinite into a great void; they come together there and produce a single whirl, in which, colliding with one another and revolving in all manner of ways, they begin to separate, like to like.[9]

The thrust of this passage, which Diogenes continues at some length, is to describe the details of the formation of one world. It is an expression of that cosmogonic assumption peculiar to the atomist system, whereby a single cosmos arises from a single whirl merely by the fortuitous coalescence of atoms. Aside from the fact that it is a fortuitous cosmogony, the details of world formation are not important to us here.[10] Rather, we must ask why this theory, which is not an empirical one even for our own cosmos, is extended to the universe as a whole. The passage from Diogenes implies that such an occurrence is repeated many times in the universe, but there is no explicit justification of why this should be so. Presumably the "abscission from the infinite" which begins the cosmogonic process is not a unique event.

No clarification on this point is forthcoming from the independent account which has come down to us of Democritus' ideas on this subject, an account which nevertheless agrees with the view of Leucippus and adds some interesting thoughts on the state of the worlds after they have been formed and their relationship.

> Democritus holds the same view as Leucippus about the elements, full and void ... he spoke as if the things that are, were in constant motion in the void; and there are innumerable worlds, which differ in size. In some worlds there is no sun and moon, in others they are larger than in our world, and in others more numerous.

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> The intervals between the worlds are unequal; in some parts there are more worlds, in others fewer; some are increasing, some at their height, some decreasing; in some parts they are arising, in others failing. They are destroyed by collision with one another. There are some worlds devoid of living creatures or plants or any moisture.[11]

While such vivid details as are indicated in these passages betray a solid commitment by the fifth century atomists to cosmogony and its application to the formation of an infinite number of kosmoi, it is only in turning to Epicurus and his faithful Roman follower Lucretius that lines of inference between atomism and the infinity of worlds are made explicit. Epicurus wrote in the "Letter to Herodotus"

> There are infinite worlds both like and unlike this world of ours. For the atoms being infinite in number, as was already proved, are borne on far out into space. For those atoms which are of such nature that a world could be created by them or made by them, have not been used up either on one world or a limited number of worlds, nor again on worlds which are alike, or on those which are different from these. So that there nowhere exists an obstacle to the infinite number of worlds.[12]

From this statement Cyril Bailey, in his important study of ancient atomism, has concluded that the infinity of worlds was "practically a direct deduction from the infinity of the universe".[13] More specifically, such a belief follows closely from the assumption of an infinite number of atoms (which Epicurus considers proven) and from the finitude of our cosmos, which leaves many atoms to be used in the formation of other worlds. Bailey calls this a typically Epicurean inference: when there is nothing in the phenomena to contradict the hypothesis, it may then be assumed to be true.

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Indeed, even more strongly it might have been argued by the ancient atomists that within the tenets of their system, given the empirical fact of the stability of our own system, to declare our world unique would require a special argument. This is in fact implicit in Epicurus' statement, and is even clearer in Lucretius, the Roman expounder of Greek atomism.

> Now since there is illimitable space in every direction, and since seeds innumerable in number and unfathomable in sum are flying about in many ways driven in everlasting movement, it cannot by any means be thought likely that this is the only round earth and sky that has been made, that all those bodies of matter without have nothing to do: especially since this world was made by nature ... wherefore again and again I say you must confess that there are other assemblages of matter in other places, such as this which the air holds in greedy embrace.[14]

Nor did Lucretius stop with this one argument drawn directly from atomism. As Epicurus asserted infinite worlds from the tenet that there nowhere existed any obstacle, so Lucretius professed "when abundant matter is ready, when space is to hand, and no thing and no cause hinders, things must assuredly be done and completed".[15] This argument can be seen as a manifestation of what Lovejoy has called the principle of plenitude: if something can potentially be effected, it must be effected.[16] Again, our world gives ample evidence of the potentiality of world formation; the application of the principle of plenitude clinches the argument that as many are being made as can be made. The more strictly scientific atomist principles are not really dependent upon or subservient to the principle of plenitude in the total argument for other worlds; it is rather an argument added to strengthen the conclusions reached from atomist principles.

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Lucretius added yet another interesting argument against the uniqueness of our world, one not based directly on atoms, but which embodied the atomist philosophy of generation and corruption, birth and decay, while showing a surprising tendency toward organic explanation of the inanimate world and perhaps the influence of Aristotle.

> There is no one thing in the whole sum which is produced unique, and grows up unique and alone, so as not to belong to some kind and to be one of many like it. To begin with cast your mind to the animals: you will find that this is so with the mountain-ranging generation of wild beasts, this is so with the double breed of men, so also with the dumb scaly fish and all creatures that fly. Wherefore you must in like manner confess for sky and earth, for sun, moon, sea and all else that exists, that they are not unique but of number innumerable; since there is a deepset limit of life equally awaiting them, and they are as much made of a perishable body as any kind here on earth which has so many specimens of its kind.[17]

By the time of Lucretius, then, the concept of infinite worlds was firmly fixed in the atomist system by a number of independent arguments. There were other less important details associated with the concept, not the least of which was the assumption of life in the other worlds. Whereas Democritus is said to have pronounced that there were some worlds devoid of life, Epicurus and Lucretius made a more positive assertion for living creatures and plants within the other worlds. Here Epicurus used his usual type of argument when he held that he could see no reason for the exclusion of the seeds of living things from other worlds.[18]

But the existence of extracosmic life was not of primary importance to the atomists. It was only a detail of a much more basic assertion; that from an infinite number of atoms in

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motion in an infinite void, and from the order and stability of one finite system (our own), one could deduce the great probability of other such ordered systems. The most basic reason that all of the atomists could hold a belief in a plurality of worlds was that throughout the course of ancient atomism the fundamental ontology of the system did not change. That all of them did in fact hold such a belief with ever increasing conviction betrays the compelling solidity of the lines of inference from atomist principles to infinity of worlds, at least to the ancient Greek mind.

* * *

The atomist tradition did not inspire a large following in antiquity; to the contrary, throughout the Middle Ages it was all but overshadowed by Aristotle's tightly knit system. Not until the seventeenth century, when Aristotelianism was immensely weakened by the events of the scientific revolution, did atomism come to the fore in the milieu of the mechanical philosophy. In that context the atomist system presented grave problems to an era which was seeking a workable physical system at the least expense to theology. On the one hand there was the explanatory power which Epicurean atoms provided within the framework of the mechanical philosophy; on the other hand there was the strong atheistic tendency associated with the atomist system.

Even a brief perusal of Lucretius' De rerum natura, the chief Renaissance source of atomist ideology, is sufficient to show the extent of the theological problems raised by

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Epicurean natural philosophy. One of the major themes of the book, along with the atomic theory of matter, was the expulsion of the gods from any role in the explication of natural phenomena. The harangue against the evils of superstition is unrelenting: the "carefree gods" are incapable of an active role in nature or in human affairs. To Lucretius a cause assigned to the supernatural gods is no cause at all, but superstition; fear of death and of punishment in hell is also a manifestation of superstition. This conviction can be seen as at once the source and inspiration of the poem. Four of the six parts into which De rerum natura is divided (and to which Lucretius himself gave no headings), have within their opening paragraphs this identical exhortation: "This terror of mind therefore and this gloom must be dispelled, not by the sun's rays or the bright shafts of day, but by the aspect (species) and law (ratio) of nature".[19] The workings of nature, it is continually emphasized, are to be understood "without the aid of the gods."

Moreover, the atomist system as exemplified in Lucretius expounded not only a theory of matter, but covered a very broad spectrum of human knowledge. While the first two books set forth the atomic cosmology and cosmogony and the theories of atoms in motion in an infinite void (it is here that the question of infinite worlds is discussed at length), the subsequent four books went on to elucidate the nature of mind (animus), spirit (anima), and life in terms of indivisible particles. One of Lucretius' chief conclusions was that the body, mind, and soul of man are mortal - nothing remains after

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death. Small wonder that the revival of atomism in the seventeenth century provoked cries of atheism and materialism!

It is not difficult to grasp the extent to which the idea of an infinite number of worlds posed a potential dilemma to the seventeenth century. The atheism of the atomist system is nowhere illustrated more clearly than in its cosmogony, and it was through the universal application of that cosmogony that the concept of infinite worlds was espoused. Our world was formed by the random coalescence of atoms moving in an infinite void. The assertion that infinite worlds were formed in the same way was tantamount to a denial of God's power throughout the whole universe. At the same time, to deny the necessary existence of infinite worlds was to detract from the beauty and magnificence of the universe, which after all was God's universe whether he had a hand in its construction at every step or not. The obvious solution was simply to assimilate the atomist conception of nature's plenitude into that of Divine plenitude, thereby assuring that God had created many worlds which manifested his omnipotence and glory for all eternity. But such a solution does justice neither to the determination of the seventeenth century to understand nature in natural terms nor to the Scriptural subtleties on the theological side. The resolution of all of these factors was the central concern of the plurality of worlds controversy in the context of the revival of atomism. The further problems associated with placing inhabitants within these worlds, while undoubtedly recognized by the atomists, were only peripheral to the direct problems raised by the atomist philosophy.

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In addition, the seventeenth century was witnessing a scientific revolution in which powerful forces were at work striving to put science on a mathematical basis and to prevent rampant speculation and banish occult qualities. Was not the hypothesis of infinite worlds in fact wildly speculative according to this century's criteria? It was an hypothesis which could never be tested: other worlds could never be observed, since by the atomist definition, everything that could be observed was in our world. Therefore, the assertion maintained a certain immunity because it was unaffected by anything observational astronomy could offer. This immunity did not add to its truth, but historically did facilitate its transmission without fear of observational contradiction. Was not such a theory so out of touch with reality, unverifiable even in principle, against the very trend of the scientific revolution toward empiricism? Such questions point out the conflicting passions which, as we shall see, impinged upon the seventeenth century mind confronted with this one small but significant part of the atomist system. We thus have in seventeenth century atomism a rich opportunity to test the strengths of the link between atomism and the plurality of worlds.

The great figure of this period associated with the revival of ancient atomism and demanding our attention is the French thinker Pierre Gassendi. But well before the posthumous publication of his Syntagma Philosophiae in 1658, the Epicurean philosophy was widely known. Lucretius had been rediscovered

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in 1417 in the midst of the Italian humanist movement and for a century-and-a-half was admired primarily for his literary style.[20] One did not have to accept Lucretius' system to admire his poetry, which after all, was written before mankind had been enlightened by the coming of Christ. But as the seventeenth century approached there was a remarkable revival of interest in the substance of the atomic philosophy. And with it, in the half-century before the crystallization of Gassendi's own ideas, came a rejuvenation of interest in the concept of an infinite number of worlds.

The years 1563-64 saw the publication in Paris of the Lambinus edition of Lucretius, a landmark in Lucretian studies because it remained the authoritative edition for almost three-hundred years. It was the first Lambinus edition which Michel de Montaigne had at his side as he composed his famous Essais in the 1570's and 1580's, essays in which he not only praised the style of Lucretius as many French and Italian writers had before him, but in which he was also sympathetic to many of the Roman's ideas. The majority of the 148 citations from Lucretius found in the 1588 edition of the Essais have been shown to originate from books III, IV, and V where Lucretius set forth his ideas on death and the mortality of the soul, on the passions and senses of man, and on the development of the world, man, and civilization. But the 29 citations from books I and II of Lucretius show that Montaigne also favored the immense atomist universe and the idea of a plurality of worlds.[21]

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Montaigne, however, was not an atomist or even a scientific thinker, and his acceptance of other worlds was not based on a belief in the cosmogonic assumption of ancient atomism or any other atomist principle. He serves to remind us that in the transmission of ideas, concepts originally associated are often separated and the lines of inference are lost or totally ignored, as a particular individual selectively chooses only those ideas suited to his own needs or his fancy. Such was the case with Montaigne's belief in a plurality of worlds. Since he believed that man could have no true and absolute knowledge there is certain irony in his claim that "Your reason is never more plausible and on more solid ground than when it convinces you of a plurality of worlds," and, now directly quoting Lucretius, that "earth, and sun, and moon, and all that we behold, are not unique but infinitely manifold." For Montaigne used this deduction from "reason" to bolster his philosophy of skepticism.

> Now if there are many worlds, as Democritus, Epicurus, and almost all philosophy has taught, how do we know whether the principles and rules of this one apply similarly to the others? Perchance they have a different appearance and different laws.[22]

It is clear that Mongaigne has indeed taken the Epicurean doctrine of the plurality of worlds from Lucretius, but he has used it to support an epistemology completely antithetical to the spirit of Lucretius' work. His message is that even if man can fathom the laws of our world, he cannot bind God to those laws. God can enforce different laws in different worlds, and so man's knowledge of the laws of nature is limited and purely relative.

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The Italian philosopher Giordano Bruno exemplifies much the same piecemeal influence by Lucretius, although his case is much more complex than that of Montaigne. The idea of an infinite number of worlds was assuming a central role in his philosophy at the same time as Montaigne was composing his Essais in France. In 1576 Bruno fled the ranks of the Dominicans who had accused him of heresy, and began the wanderings which took him through France and eventually to England, where in 1584 he composed De l'infinito universo e mondi and two other treatises which passionately asserted a belief in an infinity of worlds. Bruno was profoundly influenced by Lucretius; as one of his biographers has pointed out, he shared not only the Lucretian passion for truth, the rejection of imposed religious doctrine, and the belief in an infinite universe, but more than that

> To Bruno, Lucretius was as a living teacher, and many elements in his philosophy were direct developments from Lucretius. Thus the behaviour of the Lucretian atoms provided something closely akin to Bruno's view of cosmic metabolism and suggested to Bruno the "minimum" and the "discrete continuum." On another level Bruno received from Lucretius the vision of the dignity of the human soul. But especially the view of an infinite universe which constituted the field of the ceaseless motion of the Lucretian atoms foreshadows some of Bruno's arguments.[23]

In contrast to Montaigne, most of the Lucretian material for Bruno's cosmological works was taken from books I and II of De rerum natura. In De l'infinito Lucretius I 968-1007 was cited verbatim in support of arguments for infinity, and Lucretius II 1040-1076 in support of the idea of infinite worlds. The latter set of verses includes those already cited above in which Lucretius asserted an infinity of worlds based

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upon the fortuitous coalescence of atoms in motion, and upon what Lovejoy has called the principle of plenitude. And in Bruno's own words too, there is the certain echo of Lucretius when he remarks "concerning those prime indivisible bodies from which the whole universe was originally composed, we must believe that they undergo certain vicissitudes through the immensity of space whereby they ebb and flow, now hither, now thither. And if by divine providence they do not form new bodies nor dissolve from the old, they are at least able to do so."[24]

Yet Bruno's "prime indivisible bodies" were not at all Epicurean atoms, and his willingness to allow divine providence a role in nature to the extent that the formation and dissolution of worlds might be altogether stymied, indicates the greatly diluted importance of the atomist cosmogonic assumption to Bruno's belief in infinite worlds. In fact that particular atomist idea is not at all a prominent one in Bruno's cosmological works. Even more than this, recent scholarship has pointed out forcefully that Lucretian ideas, when placed within the Hermetic and Platonic context which Bruno embraced, are absolutely transformed.[25] Bruno's infinite worlds are now alive, great animals moving through space, and all matter in the universe is divine - notions totally foreign to Lucretius. Finally, Bruno's worlds are no longer kosmoi, but planetary and stellar bodies themselves existing in a single all-embracing cosmos. This change of terms, along with the confluence of diverse philosophies, quite altered the impact and the meaning of Bruno's assertion

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in comparison with that of the atomists, and Gassendi later placed Bruno's belief in a category of the plurality of worlds tradition entirely separate from that of the atomist discussion.[26]

Both Montaigne and Bruno were clearly influenced by Lucretius, but neither can be considered to be a reviver of Epicurean atomism by any stretch of the imagination. In contrast, a group of intellectuals flourishing in London at the end of the sixteenth century, whose significance has only recently been brought to the attention of historians of science, may be considered the advance guard of such a revival. The group was known as the Northumberland Circle, and its most important single scientific member was the astronomer and mathematician Thomas Hariot, who was joined by less well known men with an interest in natural philosophy including Robert Hues, Thomas Allen, Walter Warner, Robert Norton, Nathanael Torporley and Nicholas Hill along with the famous literary figures John Donne, Chapman, and Peel.[27]

One of the overriding characteristics of this group was its adherence to an atomic view of nature: "According to Hariot the universe is composed of atoms with void space interposed. The atoms themselves are eternal and continuous. Physical qualities result from the magnitude, shape and motion of these atoms, or corpuscles compounded of them."[28] Hariot applied this atomic theory to optics, chemical changes, and properties of matter. With the exception of Torporley, everyone in the group was an avowed atomist, and all were Copernicans. And combined with the Copernican view and the atomist view was

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the espousal of an infinity of worlds.[29]

We cannot hope here to determine the precise sources or even the extent of the Northumberland Circle's belief in other worlds. Very little work has been done on this group, and Kargon can only say that the sources of its atomism are obscure, although he does conclude from his limited study that Hariot's theory of matter is virtually that of Democritus, Hero of Alexandria, Epicurus and Lucretius.[30] While research is hampered by a paucity of sources, there is one work which was published during the group's existence, Nicholas Hill's Philosophia Epicurea, Democriteana, Theophrastica, propositer simpliciter non edocta.[31] This rambling piece consists of some 509 propositions, not arranged by subject and often only one sentence in length. Most are simply statements, with no lines of inference to indicate how the statements were arrived at, in keeping with the promise of the title that this is an Epicurean philosophy "simply proposed, not dogmatically taught," an expression undoubtedly reflecting the caution still essential in such matters at this time. But the document is valuable as a record of the beliefs which Hill held, and undoubtedly indicates the types of questions with which his colleagues in the Northumberland Circle were concerned. Among the propositions there are three which deal specifically with the plurality of worlds.[32] Hill uses both the terms mundorum pluralitas and mundorum innumerabilitates, and it seems clear that he has chiefly in mind Bruno's conception. Thus "the superior globes (as they are commonly spoken of) are made of the same matter as

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the globe in which we live, and by analogy contain all things which we have on our world," including living creatures adapted to the conditions of their own planet.[33] The earth, sun, and all the celestial globes visible to us are insignificant in comparison with the infinite universe. Man is accordingly diminished, but the existence of men on other worlds greatly increases the number of souls, an overall positive effect. While these comments are Brunonian in nature, the further statement that the plurality of worlds does not destroy the unity of God or of the first efficient Cause, is a corruption of an Aristotelian argument which was applied to the atomist conception of the world as cosmos.[34] Hill was undoubtedly influenced by both the atomist and the Brunonian conceptions, and although the cosmogonic assumption was not explicitly linked with the assertion of a plurality of worlds, that assertion was now found in an avowed atomist treatise. Hill saw the doctrine as part of a "philosophia Epicurea, Democriteana, Theophrastica," and as that philosophy was propogated in the 1601 Paris edition and furthermore in the 1619 Geneva edition, so also was the doctrine of an infinite number of worlds.

One of the early revivers of atomism in Italy, whom Partington singles out as of special importance,[35] and with whom Robert Boyle was familiar, was J. C. Magnenus. His Democritus reviviscens sive de atomis (1640) was a lengthy attempt, much better organized than Hill's, to set forth the atomist philosophy as compatible with seventeenth century

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ideals. Its three disputations held closely to the basic tenets of ancient atomism, but when it came to the atomist cosmogony, Magnenus was more critical. In the second *disputatio* "on the composition of things from atoms" we find a chapter "on the genesis of the world through atoms according to Democritus." The close association of the idea of infinite worlds with the genesis of our own world is evident in the opening lines, and so is Magnenus' opinion on the subject.

> There is no doubt that Democritus erred *in crassis gentilium tenebris* when he asserted innumerable worlds to have coalesced from the fortuitous concourse of atoms, forming and dissolving, with other shapes and other ornaments. But in fact the opinion which simply admits atoms destroys in no way God the Creator: to the contrary, Democritus called the world a work of God.[36]

The existence of worlds deduced solely from atomic principles was thus denied. But on what basis could a consequence so emphatically asserted as an integral part of the atomist philosophy since Leucippus, be denied? In addition to citing the Stoic Cleanthes who recorded that Democritus called the world a work of God, Magnenus simply downplayed Lucretius' account, especially "at the end of book II where he tries to prove a *mundorum pluralitas*" by claiming that "such things illustrate in some measure the opinion of Democritus, but do not report the genuine opinion (*sententiam sinceram*)."[37] In the same way, Magnenus believed, Lucretius' claim that Empedocles asserted infinite principles instead of only a great number, was another example of unreliable reporting. While Magnenus seemed to realize himself that he was on very weak ground in undermining the idea of infinite worlds in this way (he cited the separate account of Diogenes concerning Leucippus,

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which we quoted at the beginning of the chapter), he was certain of one thing: in one way or another the idea of the formation of the world by chance, and still more of infinite worlds by chance, had to be refuted, for it was unacceptable to seventeenth century thinking. Magnenus concluded by giving his own version of Democritus' doctrine of the formation of the world, drawn chiefly from Aristotle's Generation of Animals, book II, chapter 4, which made use of the organic analogy of the formation of a silkworm.[38]

In contrast to Magnenus, the Cambridge scholar Henry More early in his career was attracted to the idea of infinite worlds and devoted a brief but enthusiastic work to it entitled Democritus Platonissans, or, an Essay upon the Infinity of Worlds out of Platonick Principles (1646). Although More was by no means an orthodox Epicurean, this work undoubtedly emerged under the growing influence of that system. As the title indicates, the essay was an attempt to reconcile the Democritean and Platonic world views in this one significant respect; the idea of infinite worlds was clearly an atomist principle sufficiently important to More to inspire him to make it compatible with the Platonic system which was to be made famous by his "Cambridge Platonism."

More begged the reader at the outset to appeal more to his reason than to his senses, and although the concept of infinity of worlds was "a thing monstrous if assented to, and to be startled at," like Hill he demurred that he was only making a suggestion, not a dogmatic proposal like the ancients

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Democritus Platoniſſans,

OR,

AN ESSAY

UPON THE

INFINITY OF WORLDS

OUT OF

PLATONICK PRINCIPLES.

Hereunto is annexed

CUPIDS CONFLICT

together with

THE PHILOSOPHERS DEVOTION:

And a Particular Interpretation appertaining to the three laſt books of the *Song of the Soul.*

By *H. More* Maſter of Arts, and Fellow of Chriſts Colledge in Cambridge.

Ἀγαθὸς ἦν τὸ πᾶν τόδε ὁ συνιστὰς, ἀγαθῷ δὲ οὐδεὶς περὶ οὐδενὸς οὐδέποτε ἐγγίνεται φθόνος. Τούτου δ' ἐκτὸς ὢν πάντα ὅτι μάλιστα ἐβουλήθη γενέσθαι παραπλήσια αὑτῷ. Plat.

Pythagoras Terram Planetam quendam eſſe cenſuit qui circa ſolem in centro mundi defixum converteretur. Pythagoram ſecuti ſunt Philolaus, Seleucus, Cleanthes, &c. *imò* PLATO *jam ſenex, ut narrat Theophraſtus.* Libert. Fromond. de Orbe terræ immobili.

CAMBRIDGE
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Democritus, Epicurus, and Lucretius, who were "either very wise or exceeding fortunate to light on so probable and specious an opinion, in which notwithstanding there is so much difficultie and seeming inconsistencie."[39] Why does More broach a subject fraught with so many difficulties and even contrary to some of his own former beliefs? Because, as he clearly put it "I have sworn more faithful friendship with Truth than with myself," and again "though I detest the sect of Epicurus for their manners vile, yet what is true I may not well reject."[40] We thus have the spectacle of an apparent anti-Epicurean adopting the atomist tenet of infinity of worlds, whereas the true atomist Magnenus rejected it in no uncertain terms. This perhaps does not bespeak a situation in which infinite worlds are directly deducible from atomist principles! But the difference in More is his Platonism.

Although More's use of the term "world" was once again different from that of the atomists since it signified a single star and its accompanying planets, the association with atomic principles now combined with NeoPlatonism was still evident. The planets in our world or system were in Platonic language

> ...knots in th' universal stole
> Of sacred Psyche; which at first was fine,
> Pure, thin, and pervious till hid powers did pull
> Together in severall points and did encline
> The nearer parts in one clod to combine.[41]

There was thus an organizing principle in our world, and it was operative throughout the universe:

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> And what is done in this Terrestriall starre
> The same is done in every Orb beside.
> Each flaming circle that we see from farre
> Is but a knot in Psyches garment tied.
>
> ... not matter but some living sprite
> Of nimble Nature which this lower mist
> And immense field of Atoms doth excite,
> And wake into such life as best doth fit
> With his own self. As we change phantasies
> The essence of our soul not chang'd a whit,
> So do these Atoms change their energies
> Themselves unchanged into new Centreities.
>
> ... from their inmost Centre [the atoms] project
> Their vitall rayes, not merely passive be,
> But by occasion wak'd rouze up themselves on high.
>
> So that they're life, form, sprite, not matter pure[42]...

Since all of this activity in the end presumably had some connection with God as the First Cause, More actually circumvented the atheistic tendency in the atomist cosmogony which Magnenus, for one, found objectionable.

More brought many other arguments to his essay in favor of an infinity of worlds, including God's plenitude, the possibility of an infinite magnitude and extension, and the similitude between the fixed stars and our sun. All of these arguments pointed to one truth:

> I will not say our world is infinite
> But that infinitie of worlds there be.

Just as the Sun is the center of our solar system, so

> The skirts of his large Kingdome surely lie
> Near to the confines of some other worlds
> Whose Centres are the fixed starres on high,
> 'Bout which as their own proper Suns are hurld
> Joves, Earths and Saturns; round on their own axes twurld.[43]

In this early essay Henry More thus espoused his own brand of cosmogony. While greatly changed in the method of

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formation to accomodate Platonism and theology, More's concept of infinite worlds is undoubtedly inspired by the atomist philosophy. Beneath the Platonic Psyche which operated throughout the universe were the Epicurean atoms which were the basis of all matter - and the seventeenth century mechanical philosophy.

At mid-century there were still those atomists who simply followed the ancient atomist tenets without change. Shortly after More's brief treatise, Margaret Cavendish, duchess of Newcastle and the center of yet another atomist school in England, published her influential Poems and Fancies (1653), which were more than poems - they were a philosophy of nature. The collection included such poems as "A World made by Atoms," "The Infinities of Matter," and "Of Stars," which return pure and simple to the ancient doctrine of the formation of infinite worlds through the random and fortuitous coalescence of atoms, and which view the stars as suns with their own planets.[44]

Finally, it should be noted that Descartes, that dean of mechanical philosophers who stuffed the universe so full of atoms that there could be no void space, gave rise to a new tradition of infinite worlds which indeed is partially reflected in Henry More. His system, which undoubtedly owed much to ancient atomism even though Descartes publicly sought to dissociate himself from Epicureanism,[45] necessitated the denial of the atomist concept of an infinite number of kosmoi, but nurtured the idea of an infinite number of solar systems or vortices. Like Bruno, Descartes built a system of his own

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which incorporated parts of ancient atomism, but which in the end was so unique as to demand examination on its own merits, and which in Descartes' case even served as an alternative mechanical philosophy to that which Gassendi propounded at about the same time.[46]

Descartes and Bruno aside, it appears clear that as Gassendi was working out his great synthesis of atomism and theology, the generation of an infinite number of worlds was already being treated by some as a uniquely atomist tenet sufficiently important to warrant analysis, whether in the end the fact of such generation was to be repudiated as it was by Magninus, altered as by More, or embraced as the Northumberland and Newcastle circles in England seemed to with great enthusiasm.

* * *

While Pierre Gassendi was not the first thinker in the seventeenth century to propound a form of Epicurean atomism, all other attempts assuredly pale in comparison with the system he built and with his fidelity to the fundamentals of the Epicurean system. From about 1628, when the adversary of Aristotle became the apologist of Epicurus, to his death in 1654, Gassendi strove to revivify a workable atomist system compatible with his century's ideal to seek a physical system viable in terms of both the observed phenomena and revered theology. As a Catholic priest, Gassendi's work was to eliminate all traces of atheism from Epicurean atomism. Such a revamping of ancient atomism implied a mastery of the total

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system by Gassendi; he must alter it appreciably while maintaining its coherence and vitality. He must scrutinize the consequences of the system and be prepared to reject them if incompatible with theology. In the end this process resulted in no change of ontolgoy, only changes in details.

> In Gassendi's interpretation the atoms are not eternal but created by God. Neither is their motion eternal; it is a force with which God has endowed them for the purpose of motion and mutual connection. Gassendi also rejects Epicurus' opinion that atoms are infinite in number. Generally speaking, however, his theories are the same as those of Democritus.[47]

As a recent study of Gassendi's system has pointed out, one of the issues between the truths of faith and the truths of reason was indeed the concept of infinite worlds.[48] Already in the "plan of 1631," a list of chapters which Gassendi drew up in a letter to Pereisc, and which proved to be an outline of his final systhesis of atomism and theology as it appeared in the Syntagma philosophicum of 1658, there was a projected chapter on "infiniti mundi."[49] The source of Gassendi's concern can be seen to have developed directly out of specific passages in Diogenes Laertius' account of Epicurus, which we have already discussed. The first extensive atomist work which Gassendi published, the Animadversions in decimum librum Diogenes Laertius (1649), was an extended philological and philosophical commentary on this account of Diogenes, along with its translation from the Greek. Gassendi's philosophical commentary on the Epicurean doctrine of infinite worlds reflected a clear decision at this stage: it was one of the atomist principles which would have to be sacrificed

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to the demands of theology. The idea received a good share of attention in this work, and perhaps even more importantly in terms of its subsequent exposure and dissemination, it formed an entire chapter prominently displayed at the opening of Walter Charleton's 1654 English version of the Animadversions.[50]

The plurality of worlds issue in Gassendi is best examined in the context of his final complete and integrated system of atomism as set forth in the Syntagma philosophicum or Philosophical System published in 1658. The Syntagma consists of the first two volumes of the six volume Opera, and is divided according to a Platonic trifurcation into the "Logic," the "Physics," and the "Ethics," of which the "Physics" forms by far the largest part. It is undoubtedly indicative of the close association of plurality of worlds with the basic principles of atomism that the subject is taken up in the first section of the "Physics," where the topics of space and time, the production of qualities by atoms, and generation and corruption are also found, rather than in the second section which discusses astronomy proper. The very first book of the "Physics," significantly headed "De universo et mundo..." to stress that the two terms were not synonymous, contains a chapter which examines the various meanings that philosophers have attached to the word universus, followed by a second chapter "whether or not this world is to be taken uniquely as the universe," which Gassendi notes is the same as asking whether there is one world or many.[51] Here at some length Gassendi sets forth a mid-seventeenth century view of the

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plurality of worlds question, whose main purpose and import is to react to the atomist formulation of the question. But in the process he gives a very informative perspective on the whole question as it was perceived at this time, and which was broader than the atomist assertion, a perspective which is important in understanding that various forms of the question were now becoming intermingled as the consequences of Copernicanism were debated.

Gassendi distinguishes first of all believers in a simple plurality of worlds as opposed to those holding the doctrine of the infinity of worlds. From the first group he excludes those who asserted a plurality of successive worlds (Heraclitus, the Stoics, and Origen), but includes those who held a plurality of coexistent worlds (Plutarch).[52] He is most interested in the second group, which espoused the infinite number of worlds, and here he makes an interesting distinction: there are those who asserted infinite worlds each having relation to each other, mundi communicanteis invicem (Seleucus, Heraclides, the Pythagorean and Orphic sects, and Giordano Bruno), and there are those who asserted worlds lying apart, mundi dissiti (Anaximander, Anaximenes, Archelaus, Xenophanes, Diogenes of Appolonia, Leucippus and Democritus, and Epicurus; also Zeno of Elea, Alexander the Great, and Metrodorus).[53] The atomist worlds are thus to be distinguished from what might be called the Pythagorean or Brunonian interpretation of worlds which holds that

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> ... Each star in the infinite ether is a world, which also contains an earth, air, and ether ... they consider the Dog star, and Aristo, and the other fixed stars to be just like the sun around which there may or may not be special planets, so that special forms of the world appear to such a degree that it is able to be called another world of the Dog star, Aristo another, Capella another, Lyre another, etc., and this world of ours can be called "solar," since the Sun with every satellite seen from those worlds would be equally numbered among the fixed stars, as those are so counted by us living in the solar world. To this end, they consider such various worlds inter se communicare ...[54]

Both this assertion and the Epicurean form are labelled fabulae. Although the former is not difficult to imagine, Gassendi opines that such stellar worlds are only visions of the mind (insomnia), visions which are not necessary to pursue. The Epicurean claim, however, must be taken more seriously, and it is the task of the remainder of the chapter to undermine that claim. For the opinion of a single world is the one which "is most in conformity with the principles of the Sacred Faith and religion ... namely, there is no mention in Sacred Scripture of many worlds, and what is discussed there with regard to the origins of things, all indicate a single world."[55] Thus, ostensibly on the grounds of discordance with Scripture, Gassendi sets out to refute this ancient atomist tenet.

There is another factor at work in Gassendi's rejection which reflects the seventeenth century mind, and that is the unverifiability of the atomist assertion of other worlds. Gassendi insists with St. Augustine on the distinction between

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what is, and what the Divine virtue can do.[56] God's inexhaustible power could have produced innumerable worlds and still could, and "it must be confessed that it cannot be clearly proven by demonstration that there are not other worlds existing beside this one." This failure of the phenomena to contradict the hypothesis might have been sufficient for Epicurus to proclaim the reality of other worlds, but for Gassendi such a reality is "above argument in general, both because God wished nothing to become known except as regards this world, and because the arguments opposing it are either frivolous or without much probability."[57] Gassendi therefore is not impressed with the arguments of Aristotle for the unity of the world, arguments which he is aware that Plutarch has already spoken against and which are adverse to the freedom of divine power. But neither is he willing to set about proving an atomist tenet he believes is beyond empirical argument.

Gassendi places himself in a remarkable position by insisting that the reality of other worlds cannot be asserted or denied on scientific grounds. He must argue against the recentiores, the moderns who have been impressed with Plutarch's argument that divine nature is more agreeable to many worlds than to one and that therefore the existence of other worlds must be a fact. He must deny the principle of plenitude while maintaining the doctrine of God's omnipotence. This Gassendi proceeds to do in great detail. While some claim that infinite

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causes must have infinite effects, either in magnitude or multitude, to Gassendi "there seems to be no reason why an infinite cause should act outside its own nature; part of its own power is to be able to produce the finite."[58] Thus a great and excellent world such as ours, although it may not be infinite, still declares a cause whose virtue is infinite. And that God does have infinite power can be seen in "that infinite distance by which an effect is produced ex nihilo." Moreover, even if God had made an infinite universe, it would not be an effect commensurate with his causative power, because he could always produce more in infinitum. By this, "God commends more his own Divine majesty, from that which gives occasion for understanding and recognizing that there is nothing in the nature of things which is infinite except God."[59]

Gassendi has little trouble in setting aside the Lucretian argument from "many individuals in one species," arguing that "the world" is not among the members of that class which must exist in plurality. To that class belongs only those things which would cease to exist when one perished and there were no others; if the world perished it would be tantamount to the dissolution of all Nature, in which case the plurality rule does not hold. And even if the world did perish, God could create another one at his leisure![60]

While Gassendi reacts with concern to the issue of Divine power and to the Lucretian argument of many particulars, he gives most attention to the atomist assertion of other worlds

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grounded in the cosmogonic assumption. He cites Epicurus' letter to Herodotus (recorded by Diogenes) along with book II of Lucretius and a passage from the church father Lactantius as certain evidence that Epicurus held this view. How can such a firmly established atomist argument be subverted, as it must be if atomism is to be in accord with Scripture which, at least, does not positively assert such a belief? Gassendi has already gone a long way in arguing for a denial of the principle of plenitude as it relates to God. But God had played no role in ancient atomism, and Gassendi had to speak more directly to their arguments if he was to be effective.

We have already seen that the ancient atomist argument was supported by the application of the principle of plenitude to the infinite number of atoms: the atoms are the agents of causality, and infinite causes must have infinite effects. In order to counter this argument, Gassendi goes further than denying the principle of plenitude as it applies to atomic causes; he denies that the number of atoms is infinite. At least an "impromptu" argument can be given for this case.

> ... Even if infinite space is conceded, nevertheless an infinite number of atoms is not conceded ... since it is begging the question to assert infinite atoms because there are infinite worlds which ought to be made from them; and to assert infinite worlds because there are atoms from which an infinite number should be made. Moreover, when it is conceded that atoms are the principia rerum, this does still not imply an infinite number of atoms, since those alone could have been made, from which this one world is constituted.[61]

And Gassendi indeed wishes to argue that only that number of

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atoms exist from which this world was made. Indeed, he had argued this already in the Animadversions in almost the identical terms used in the Syntagma, and was therefore echoed in Charleton's translation as it appeared to English readers in 1654. The finite number of atoms follows from the creation by God of the initial Chaos, a proposition foreign to the atomists, who

> take it for granted, that the Chaos of Atoms was not only eternal and Increate, but also that it was disposed and compacted itself into that Form, which constitutes the World, by the spontaneous motion inhaerent in Atoms, and their fortuitous coalescence in such and such respective Figures: when to a sober judgement it appears the highest Impossibility imaginable, that either the Chaos of Atoms could be eternal, self-principate, or increate, or dispose and fix itself into so vast, so splendid, so symmetrical, so universally harmonical, or Analogical a structure, as this of the World. For, as the Disposition or Dispensation of the Chaos of Atoms into so excellent a form, can be ascribed to no other Cause, but an Infinite Wisdom: so neither can the Production or Creation of the same Chaos be ascribed to any other Cause, but an Infinite Power ...[62]

Therefore, since God not only set the atomic Chaos in order, but also created the atoms out of which the Chaos itself was composed, "we may adventure to affirm that God created exactly such a proportion of Atoms, as might be sufficient to the making up so vast a Bulk, as this of the World, and that there remained no one superfluous." To acknowledge superfluity in Nature was unworthy of a philosopher, and to say that God created more atoms than he knew what to do with bordered on heresy. And if this argument were deemed unacceptable because we could not presume to know the will of God, Charleton himself had immediately added a forceful argument typical of the seventeenth century.

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> Nay the greatest weight of Reason hangs on our end of the scale; for, we ground our Opinion upon that stable Criterion, our sense, and asserting the singularity of the World, discourse of what our sight apprehends: but they found theirs upon the fragil reed of wild Imagination, and affirming a Plurality discourse of what neither the information of their sense, nor solid reason, nor judicious Authority hath learned them enough to warrant even Conjecture.

That was not an opinion which would have convinced Henry More, at least in his early years when he wrote the Democritus Platonissans. But it does reflect the trend of seventeenth century thought and perhaps the ultimate reason for the downfall of the atomist assertion of infinite worlds, certainly in the original atomist terms in which another world was a cosmos completely impenetrable to the senses.

In conclusion we may say that Gassendi's treatment is significant in that it reveals several aspects of the mid-seventeenth century plurality of worlds tradition. Gassendi's succinct overview of the entire tradition in all its aspects is striking, and suggests that there was indeed a coherent body of ideas subject to lively debate, as Gassendi's treatment of the atomist issues alone confirms. The profuse reference to both scientific and religious thinkers of the ancient Greek and Roman worlds, reminds us of the antiquity and extent of the debate in science and philosophy, and the mention of the moderns who insist on infinite worlds as the alternative most compatible with God's plenitude indicates that the debate is ongoing. The segregation of the various forms of the plurality of worlds tradition into those holding worlds lying apart and those holding worlds

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having relation to one another is also revealing. For by demolishing the mundi dissiti of the ancient atomists, the Pythagorean or Brunonian mundi communicanteis, although labelled a fable and unsubstantiated vision, are left untouched. Indeed, it has been maintained that Gassendi elsewhere gives some credence to the plurality of worlds concept in the latter form, where it is a matter of astronomy instead of theology, of observable Copernican mundi in our own solar system instead of hypothetical atomist kosmoi.[63]

Gassendi's treatment did not bring a sudden end to the tenacious association of atomism and the plurality of worlds. Rather, the association was modified to reflect the more limited and accessible controversy over the plurality of solar systems (whose central suns were at least visible), a form of the argument already exploited by Henry More in 1646. Bereft of More's Platonism, the subject once again arose in the context of the cosmogonic assumption within a new system which owed much to atomism - that of Isaac Newton. In conclusion we may examine briefly those elements of the Newtonian philosophy which clearly indicate a continuation of the old association in new terms.

* * *

While Newton's thought was the product of a wide number of influences, the influence of Epicurean atomism, through Gassendi and directly through Charleton, was very considerable. Several headings in Newton's early notebook, in the section termed "quaestiones quaedam philosophiae," were taken

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verbatim from Charleton, and the ideas expressed in his texts profess a detailed knowledge of the atomist tenets revived by Gassendi, knowledge which undoubtedly played its part in the formulation of his mechanical philsophy.[64] But Newton in no way swallowed ancient atomism or Gassendi's atomism unaltered; indeed, by admitting forces of attraction and repulsion into the universe along with atoms and void, he transformed the very ontology first established by Leucippus and Democritus. With this change, every particle in the universe became subject to the forces of other particles acting at a distance, a radical departure certain to have consequences for the notion of process and becoming in the universe, including the formation of our world and of others.

It is remarkable that Newton did not show a great interest in expounding a rational cosmogony. In the whole of the Principia Mathematica (1687), while the details of the system of the world as Newton and his contemporaries observed it were set forth, there was no attempt to explain the origin of the system on mechanical principles. Since the atomist belief in infinite worlds was reached only through the universal application of the cosmogonical processes which were believed to have formed our world, neither did Newton show any interest in other worlds inspired by this connection. Perhaps he sympathized with Charleton's argument that to expound the system of our own world, even as it presently existed, was quite enough!

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Five years after the publication of the Principia, Newton was finally drawn into cosmogonical speculation in his brief but significant correspondence with the theologian Richard Bentley. Moreover, he was drawn into the discussion in the context of the Lucretian system. Bentley, wishing to put proofs of a Deity on a purely rational basis, took it upon himself to write the embodiment of rationality in natural philosophy, Newton himself, to request clarification on some points in his lecture A Confutation of Atheism. More specifically Bentley worried "for fear he had not sufficiently disposed of the theory of Lucretius that the cosmic system began with chance bumpings together of descending atoms, each endowed with an innate power of gravity."[65] Newton's reply, recorded for posterity in four letters written from December, 1692 to February, 1693, sheds light on his thoughts not only on the formation of our solar system, but also on the possible formation of other solar systems within the "cosmic system."

We discover first of all why Newton had heretofore ignored the cosmogonical question.

> The Hypothesis of deriving the Frame of the World by Mechanical Principles from Matter evenly spread through the Heavens, being inconsistent with my System, I had considered it very little before your letters put me upon it.[66]

Newton had not expounded a theory of the origin of the world in 1687 because, on the mechanical principles which were at the heart of the Principia, he could not. Even in the second edition of 1713, he could only assert that "This most beautiful system of the sun, planets, and comets, could only proceed

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from the counsel and dominion of an intelligent and powerful Being."[67] Bentley thus sought specific reasons for a denial of the atomist hypothesis, and hoped that its cosmogony might be proven inconsistent with Newtonian principles. For example, given the innate gravity of atoms which Lucretius espoused, would not all matter, originally spread evenly through the universe as the atomist chaos was, have convened into one mass without the aid of God? Newton replied that this would only happen in a finite universe; in the infinite universe which Lucretius and Newton himself espoused, an infinite number of great masses would indeed form.[68] But this was as far as the atomist cosmogony could go in the absence of God: infinite masses scattered throughout the universe. Separation of the opaque matter from the shining matter to form the planets and the sun respectively could never have occurred without the aid of God; neither would only one sun have formed in our system and many planets. Nor, Newton insisted in the following letters, could the planets, descending toward the sun under the power of the gravitational force, have been given the transverse motion of their orbits except by the impress of a "Divine arm," much less all revolve about the sun in the same direction, in the same plane, and with just the right velocity to give them all approximately concentric orbits.

In short, not only could the entire atomist cosmos not have been given the order which it exhibited through purely mechanical principles, even the solar system could not have been so arranged with out the aid of God. Furthermore, Newton

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decided in his final letter,

> I would now add, that the Hypothesis of Matter's being at first evenly spread through the Heavens, is, in my Opinion, inconsistent with the Hypothesis of innate Gravity, without a supernatural Power to reconcile them, and therefore it infers a Deity. For if there be innate Gravity, it is impossible now for the Matter of the Earth and all the Planets and Stars to fly up from them, and become evenly spread throughout the Heavens, without a supernatural Power; and certainly that which can never be hereafter without a supernatural Power, could never be heretofore without the same Power.[69]

Therefore the atheistic atomist cosmogony was denied because God was a necessary element if the initial assumptions of innate gravity and chaos were to hold true, and if the observed phenomena of planetary motions were to be explained. There could be no system and therefore no cosmos (a word which implied order relative to the chaos) without God.

What are the implications of Newton's theistic atomist cosmogony for the doctrine of a plurality of worlds? It is important to note that the question for Newton had shifted from the plurality of kosmoi to the plurality of systems like that which was centered on our sun. With Newton the closed world had become the infinite universe in no uncertain terms. The atomist usage of world as "circumscribed portion of the sky" was no longer meaningful, since there were no circumscribed regions, only infinite Euclidean space with infinite numbers of stars. The central question now, still related to the older atomist problem since the prime concern of both was with the production of order from atoms, was whether God had created ordered systems around each of the

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visible stars as he had around our sun. Bentley apparently had tried to argue at least that there could not be an infinite number of such systems by denying that there could be any infinite magnitude. But the rational mind of the Newton who had composed the Principia objected strenuously.

> In your first argument you seem to make a petitio principii; for whereas many ancient philosophers and others, as well theists as atheists, have all allowed that there may be worlds and parcels of matter innumerable or infinite; you deny this by representing it as absurd as that there should be positively an infinite arithmetical sum or number, which is a contradiction in terminis; but you do not prove it as absurd. Neither do you prove that what men mean by an infinite sum or number, is a contradiction in Nature, for a contradiction in terminis implies no more than an impropriety in speech.[70]

Infinite numbers of anything, including atoms and systems of the world, were not impossible a priori. Contrary to Gassendi, Newton held the infinite number of atoms as fact in the case of infinite space,[71] but infinite systems were contingent on God's action.

The letters to Bentley indicate above all the extent to which Newton was interested in keeping an active God in the universe. The plurality of worlds question was now reduced to fathoming the action of God, and this Newton did not presume to do. He could not prove or disprove a plurality of worlds, either from the propositions of the atomists or any others. He could only insist that if many worlds were to exist, God was a necessary ingredient in addition to atoms, void, and motion. Bentley, reassured of the necessary role of God in the universe, but not so cautious as Newton in the exercise of his

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imagination, could go on to assert the "great multitude of lucid stars ... every visible star with opaque planets ... each for their own inhabitants which have life and understanding."[72]

In 1706 Newton returned very briefly to the subject of other worlds in the first Latin edition of his Opticks, and in no less a position than Query 23 (numbered Query 31 in subsequent editions), which Westfall has stated embraces his ultimate philosophy of nature to a greater degree than any other single writing.[73] Once again atomism and the plurality of worlds were juxtaposed. Following closely on the heels of Newton's classic statement of atomism that "God in the Beginning form'd Matter in solid, massy, hard, impenetrable, movable Particles" was the denial of the old atheistic atomist cosmogony which had already been formulated in the letters to Bentley.

> ... all material Things seem to have been composed of the hard and solid Particles above-mention'd, variously associated in the first Creation by the Counsel of an intelligent Agent. For it became him who created them to set them in order. And if he did so, it's unphilosophical to seek for any other Origin of the World, or to pretend that it might arise out of a Chaos by the mere laws of Nature.[74]

And following this was a statement which is rendered less cryptic and incongruous by our knowledge of the long association of atomism and the idea of other worlds.

> And since Space is divisible in infinitum, and Matter is not necessarily in all places, it may be also allow'd that God is able to create Particles of Matter of several Sizes and Figures, and in several Proportions to Space, and perhaps of different Densities and Forces, and thereby to vary the Laws of Nature, and make Worlds of several sorts in several Parts of the Universe. At least I see nothing of contradiction in all this.[75]

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The passage is an intriguing and revealing one, because along with the usual Newtonian opinion that God might create other worlds if he wished, there is the curious and unexpected suggestion that entirely different laws of nature might apply in each world. Neither the precise meaning nor the motivation for this passage is immediately clear. Did Newton mean to suggest that each potential system around each visible fixed star might be subject of different laws of Nature, or was he reverting to a more literal atomist meaning of world, whereby another invisible cosmos beyond the visible fixed stars might have different laws of Nature? The word mundus as always is ambiguous, but the latter interpretation makes little sense either in the context of Newton's own previous statements or of the background of the late seventeenth century. The key to Newton's real meaning may be found in his opening premises: "since Space is divisible in infinitum, and Matter is not necessarily in all places ... ." Although the inverse square law of gravity which Newton had deduced for our solar system was a law of action at a distance, Newton realized that at the immense distances of the fixed stars the mutual gravitational effect of one system on another would be effectively imperceptible. This isolation allowed God to create other laws of Nature in each solar system without contradiction, a situation very much like the isolated atomist kosmoi in spirit, if not in the precise ancient meaning of the word.

But why did Newton broach such a radical notion at all, especially since it was inherently unverifiable? We have

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already seen that Montaigne (using the precise Lucretian meaning of kosmos) asserted that there was a plurality of worlds each with its own laws, and that he did this in order to stress the limited scope and the relativity of man's knowledge. But Newton's statement is undoubtedly to be contrasted with that of another Frenchman who overcame the absolute skepticism of Montaigne. In his famous Discours de la méthode (1637) Descartes succinctly described the cosmology of his treatise Le Monde, which for fear of religious persecution would not be published until 1664. His strategy, Descartes tells us, was to speak of an imaginary world in the "espaces imaginaires" beyond the fixed stars, a subterfuge which fooled no one. It was a world in which God created the matter, agitated it into chaos, and then "concluded His work by merely lending His concurrence to Nature in the usual way, leaving her to act in accordance with the laws which he had established."[76] Descartes enumerated these laws in Le Monde and, he reiterates in the Discours, "tried to demonstrate all those of which one could have any doubt, and to show that they are of such a nature that even if God had created other worlds, He could not have created any in which these laws would fail to be observed."[77] The laws of that world, and every world, therefore resulted in all of the same phenomena as we saw in our world.

Descartes' discussion of other worlds in Le Monde was only hypothetical, a device whereby he could expound the nature of our world without encountering excessive criticism. In fact Descartes taught in the Principia (1644) that there could not

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be other worlds, since the Cartesian plenum which he propounded there consisted of all created matter and left no room for any other worlds.[78] And this plenum necessitated the uniformity of Nature's laws throughout his infinite universe, since matter was one continuous whole. It was perhaps with this in mind that Newton insisted that within his own natural philosophy God could vary the laws of nature "since Space is divisible in infinitum, and Matter is not necessarily in all places ... ." Indeed, the contrast between Newton's passage in the Opticks and Descartes' whole discussion is striking. Descartes believed that once the chaos was formed, God could not tamper with nature anywhere in the universe, a belief he could well afford since his a priori proof of God made him less reliant on proofs from natural theology. But Newton constantly sought a role for the Deity, and not only allowed him a role in creating order in our system and other systems, but even allowed him to vary the laws of nature among systems.

Although Newton had no way of knowing whether God had formed other solar systems or varied the laws in them, an addition to the Principia in 1713 underscored what he was certain of. Just as "this most beautiful system of the sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent and powerful Being," so "if the fixed stars are the centres of other like systems, these, being formed by the like wise counsel, must be all subject to the dominion of One; especially since the light of the fixed stars is of the same nature with the light of the sun, and from

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every system light passes into all the other systems ... ."[79] Although light passed between the systems and gave them a certain unity, still the laws of nature among them might vary, for, Newton added in 1726, "lest the systems of the fixed stars should, by their gravity, fall on each other, he hath placed those systems at immense distances from one another."

This is where the matter rested for Newton. The actual existence of a plurality of worlds was not for him an overwhelming issue, and he never bothered to invoke the principle of God's plenitude which would have positively assured other worlds. It was solely a problem raised by his adherence to an atomic view of nature, a view which since the fifth century B.C. had associated the random motion of an infinite number of atoms with the formation of an infinite number of worlds. Newton retained both the infinite space and the infinite number of atoms of the ancients, but he did not deduce from them a plurality of worlds. The difference was not so much in Newton's laws as in the Deity to which the seventeenth century was so committed. It was now God who would create worlds; Nature, while leaving it possible for such worlds to exist, was powerless to produce such order from chaos. Formation of this world, and other worlds, was banished from purely natural process. To think that order arose from chaos in and of itself, as did the ancient atomists, was simply "unphilosophical" in Newton's view. As in Charleton and Gassendi, only by divine act could a plurality of worlds become reality.

Atomism, therefore, was not only a theory of matter applied

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to the explication of everyday phenomena, it was also a system which expounded a cosmogony and a cosmology. It was through the universal application of the cosmogonic assumption that the doctrine of an infinite number of worlds assumed significance as an integral part of the atomist cosmology. This doctrine was taken seriously in antiquity, and in the seventeenth century revival of atomism, when it maintained its identity in only slightly altered fashion in the midst of a new but distinct strain of argument concerning Copernican worlds in our own solar system. A viable issue if not a pervasive one, it was embraced unaltered by a few, critically rejected by others, imbued with Platonic ideas by More, and given over to the purview of the Deity by Gassendi, Charleton, and Newton.

The plurality of worlds was not in itself an atheistic concept, nor even an anti-Scriptural one in any directly obvious sense, as evidenced by Gassendi's willingness to keep an open mind once he had proven that the atomist assertion was not a necessary one. Rather, the Scriptural arguments raged in the concurrent but more strictly Copernican debate over the possibility of inhabitants in our solar system. The atomist battle was really fought on another level, and even on that level the plurality of worlds was not as widespread an issue as the cosmogonic assumption - the formation of our world by the fortuitous coalescence of atoms - from which it arose, and which clearly was atheistic.

But the plurality of worlds was one of the difficulties

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that had to be resolved with the revival of Epicurean atomism, and an important one because it had such broad implications for cosmological thought. Although the atomist system was certainly neither rejected nor accepted by anyone solely on its merits, the debate is undoubtedly a significant part of the history of atomism which makes us more fully realize the extent of its claims. By the same token, then, atomism was most assuredly one of the traditions through which the concept of a plurality of worlds entered the stream of European consciousness.

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NOTES

[1] De rerum natura, trans. W.H.D. Rowe, Loeb Classical Library (Cambridge, Mass., 1924), Book II, 1052-58.

[2] Democritus Platonissans, or, an Essay upon the Infinity of Worlds out of Platonick Principles (Cambridge, 1646; reprinted Los Angelos, 1968), "To the Reader".

[3] Epicurus: the Extant Remains, ed. and trans. Cyril Bailey (Oxford, 1926), p. 59. This statement is found in the "Letter to Pythocles," a part of the tenth book of Diogenes Laertius.

[4] G.S. Kirk and J.E. Raven, The Presocratic Philosophers (Cambridge, 1966), p. 273. Kirk and Raven place Parmenides' birth at between 515-510 B.C. His writings survive chiefly through Simplicius' transcription of them in the latter's commentaries on Aristotle; the passage here cited is from Simplicius' commentary on Aristotle's Physics.

[5] As Lucretius put it, "when abundant matter is ready, when space is to hand, and no thing and no cause hinders, things must assuredly be done and completed," II, 1067-69.

[6] F.M. Cornford had convincingly demonstrated that the atomists were the first to hold the plurality or infinity of coexistent worlds, as opposed to temporally successive worlds held by some sixth century Ionians. "Innumerable Worlds in Presocratic Philosophy," Classical Quarterly, XXVIII (1934), pp. 1-16. Cornford's estimate is accepted by most scholars today, including Guthrie, A History of Greek Philosophy (Cambridge, 1967), I, p. 111, and Kirk and Raven, pp. 121-22. This is also the view expressed by Charles Mugler in his thought-provoking essay Deux themes de la cosmologie grecque: devenir cyclique et pluralite des mondes (Paris, 1953), especially pp. 145 ff. Mugler sees a fundamental difference between the sixth century Ionian belief in innumerable successive worlds, which he ties to the myth of the eternal return, and the fifth century atomist view of innumerable coexistent worlds, which he sees as a replacement for the old myth of the eternal return.

[7] Walter Charleton, Physiologia Epicuro-Gassendo-Charltoniana: or a Fabrick of Science Natural Founded upon the Hypothesis of Atoms (London, 1654), p. 9. We will have more to say later about this popularizer of Gassendi in England.

[8] G.S. Kirk and J.E. Raven, The Presocratic Philosophers, pp. 409-410. Diogenes' Lives and Opinions of the Philosophers is one of the chief sources of ancient atomist thought, and the whole tenth book is devoted to Epicurus. Very little is known of Leucippus, but Kirk and Raven (p. 403) put his floruit at around 440-435 B.C.

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[9] Ibid., p. 410.

[10] The details of world formation are elaborated upon by both Epicurus and Lucretius, with minor variations; see Bailey, Epicurus, pp. 47 and 61, and Lucretius, Books I, II, and V.

[11] Kirk and Raven, p. 411. The passage is found in the treatise of the third century theologian Hippolytus, Philosophoumena, or Refutation of all Heresies. Democritus may have flourished around 430 B.C.

[12] Bailey, Epicurus, p. 25. According to Bailey, the "Letter to Herodotus" contained in Diogenes Laertius is "the most complete exposition of Epicurus' philosophy which we possess," with the exception of Lucretius.

[13] Bailey, The Greek Atomists and Epicurus (New York, 1964), p. 361. Bailey examines and compares the theories of world formation of Leucippus (pp. 90-101), Democritus (pp. 138-48), and Epicurus (pp. 359-383) in this work.

[14] De rerum natura, op. cit. (note 1), II, 1052-1066.

[15] Ibid., II, 1067-1069.

[16] Arthur O. Lovejoy, The Great Chain of Being (Cambridge, Mass., 1971; 1st ed., 1936).

[17] De rerum natura, II, 1077-1089. For a similar argument in Aristotle from many particulars in a single species to a plurality of worlds (an argument, however, which Aristotle himself denied was valid) see De caelo, I, 9. and infra, Ch. II.

[18] Epicurus wrote in the "Letter to Herodotus" "furthermore, we must believe that in all worlds there are living creatures and plants and other things we see in this world; for indeed no one could prove that in a world of one kind there might or might not have been included the kinds of seeds from which living things and plants and all the rest of the things we see are composed, and that in a world of another kind they could not have been." Bailey, Epicurus, p. 47. Lucretius wrote in II, 1070-1075 "And if there is at this moment both so great store of seeds as all the time of living existence could not suffice to tell, and if the same power and the same nature abides, able to throw the seeds of things together in any place in the same way as they have been thrown together into this place, then you are bound to confess that there are other worlds in other regions and different races of men and generations of wild beasts."

[19] Books I, II, III, and VI.

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[20] On the impact of Lucretius see G.D. Hadszits, Lucretius and His Influence (New York, 1935); Fraisse, L'influence de Lucrece en France au seizieme siecle (Paris, 1962); and Thomas F. Mayo, Epicurus in England: 1650-1725 (Dallas, 1934). It has been claimed, without documentation, that the famous German thinker Nicholas of Cusa (1401-1464) was substantially influenced by the thought of Lucretius very soon after the discovery of the manuscript in 1417. Dorothea W. Singer, Giordano Bruno: His Life and Thought (New York, 1950), p. 52. In fact this seems practically impossible. Cusa did study at Padua for six years (1417-1423) before returning to Germany in 1425. But while Poggio had discovered the manuscript in 1417, the sole copy remained in the hands of Niccoli at Florence until 1434. Even in 1436 Filelfo found it impossible to obtain a copy which he knew of at Siena, and it is unlikely that Cusa could have seen a copy after he left Italy. Although Cusa's De docta ignorantia does show some general parallels with Lucretius, including the idea of other worlds presented in an entirely non-atomic metaphysical way, Cusa nowhere mentions Lucretius as he surely would have had he known of the manuscript. In a whole chapter on the sources of Cusa's thought in Edmond VanSteenberghe, Le cardinal Nicholas de Cues (Paris, 1920), there is no mention of Lucretius. Cusa is one of those figures who stands astride the Middle ages and the Renaissance, and whose thought cannot be readily categorized.

[21] Pierre de Villey, Les sources & l'evolution des essais de Montaigne (Paris, 1933), vol. I, p. 188.

[22] The Complete Works of Montaigne, trans. Donald F. Frame (Stanford, 1958), p. 390. On Montaigne's place in the tradition of skepticism, see Richard H. Popkin, The History of Scepticism from Erasmus to Descartes (Assen, 1964), ch. III.

[23] Dorothea W. Singer, Giordano Bruno: His Life and Thought (New York, 1950), p. 51.

[24] Ibid., p. 332.

[25] Frances Yates, Giordano Bruno and the Hermetic Tradition (New York, 1969), pp. 246-247.

[26] Pierre Gassendi, Opera Omnia (Lugduni, 1658; Stuttgart, 1964), vol. I, p. 140. See below, p. 35.

[27] Robert Kargon, Atomism in England from Hariot to Newton (Oxford, 1966). The Northumberland group takes its name from its patron Henry Percy (1564-1632), who became ninth Earl of Northumberland, seventh in line to the throne of England, upon the death of his father in 1585. Sir Walter Raleigh was a good friend of Percy, and Christopher Marlowe is also sometimes associated with the group. Indeed, the latest scholarship

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asserts that there was considerable communication between John Dee's circle and the Northumberland group. Peter French, John Dee: The World of the Elizabethan Magus (London, 1972), p. 171. It was Sir Walter Raleigh who introduced Hariot to Percy in 1588 or 1589, the beginning of a long and fruitful association which was responsible for Hariot's activity and important work from 1590 to 1615, which included the use of telescopes as early as July, 1609, before Galileo's work could have been known to them.

[28] Kargon, p. 26.

[29] Ibid., p. 11.

[30] Ibid., p. 26.

[31] (Paris, 1601; Geneva, 1619). The first edition of this work has been examined by Grant McColley, "Nicholas Hill and the Philosophia Epicurea," Annals of Science, vol. 4, no. 4 (1939), pp. 390-405.

[32] Propositions 278, 482, and 508 in the Geneva, 1619 ed.

[33] Proposition 278, my translation from the Latin. See also McColley (1939), pp. 398-399.

[34] Aristotle argued in the Metaphysics that the plurality of kosmoi entailed the plurality of first movers, and was therefore impossible. Trans. Hugh Tredennick, Loeb Classical Library (London, 1960), 1074a 33 ff.

[35] J.R. Partington, "The Origins of the Atomic Theory," Annals of Science, vol. 4, no. 3, July 15, 1939.

[36] (Londini, 1658), pp. 267-68. Magnenus gives "Cleanthes, l. de atomis" as the source of the statement that Democritus called the world a work of God.

[37] Ibid., p. 270.

[38] Ibid., pp. 271-278.

[39] Democritus Platonissans, or, an Essay upon the Infinity of Worlds out of Platonick Principles (Cambridge, 1646; Los Angelos, 1968), "To the Reader".

[40] Ibid., "To the Reader" and verse 20.

[41] Ibid., verse 12.

[42] Ibid., verses 13-16.

[43] Ibid., verses 21-22.

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[44] Reprinted in Yorkshire, England, 1972, pp. 5-6, 30, 35-36.

[45] The Philosophical Works of Descartes, trans. Elizabeth S. Haldane and G.T.R. Ross (Cambridge, 1972), I, 298-99.

[46] On the Cartesian tradition of plurality of worlds, see infra, Ch. 4.

[47] Andrew G. Van Melsen, From Atomos to Atom (Pittsburg, 1952), p. 92. On Gassendi see Bernard Rochot, Les travaux de Gassendi sur Epicure et sur atomisme, 1619-1658 (Paris, 1944) and especially O.R. Bloch, La philosophie de Gassendi (La Haye, 1971).

[48] Bloch, La philosophie, pp. 334-338.

[49] Rochot, Les travaux, p. 46.

[50] Animadversiones in decimum librum Diogenis Laertii, qui est de vita, moribus, placitisque Epicuri (Lugduni, 1649), pp. 232-236. Walter Charleton, Physiologia Epicuro-Gassendo-Charltoniana: or a Fabrick or Science Natural upon the Hypothesis of Atoms, Founded by Epicurus, Repaired by Petrus Gassendus, Augmented by Walter Charleton (London, 1654), pp. 9-15. The Animadversions was not included in the 1658 edition of Gassendi's Opera, since the Syntagma represented an expanded version of the philosophical portion of the Animadversions, and the more complete Syntagma was included in the Opera.

[51] Opera omnia (Lugduni, 1658; Stuttgart, 1964), I, 139-144. All translations from Gassendi's Latin will be mine, unless otherwise noted.

[52] For Origen's belief in successive worlds, Gassendi cites the works of Saints Jerome, Basil, and Methodius, and Origen's own work "2. de princ." For Plutarch's tendency toward a belief in coexistent worlds, he cites "De Orac. def." and "1. plac. 5". Gassendi also notes here that in Plutarch's De defectu oraculorum, or The Obsolescence of Oracles, there is a discussion of Plato's belief in five distinct worlds, and Petron's belief in 183 worlds. See Plutarch's Moralia, trans. Frank Cole Babbitt, Loeb Classical Library (Cambridge, Mass., 1936), pp. 415 ff. Gassendi himself realized, however, that Plato argued for the unity of the world. See infra, ch. 2.

[53] For Seleucus, Heraclides, and the Pythagorean and Orphic sects Gassendi cites Plutarch "2. plac. 13", and for Bruno "Jord. Brun. in quaest. Plat.". The long list from Anaximander through the atomists was taken from Stobaeus, Ecl. Phys., supplemented for the atomists by the tenth book of Diogenes Laertius and Lucretius.

[54] Opera omnia, I, 140.

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[55] Ibid., p. 141.

[56] Arguing against the infinity of time and space asserted by some philosophers, St. Augustine wrote that "if they imagine that there were infinite stretches of time before the world existed, an infinity in which they cannot conceive of God's being inactive, they will, on the same showing, imagine infinite stretches of space; and if anyone says that the Omnipotent could have been inoperative anywhere in that infinity, it will follow that they are compelled to share the Epicurean fantasy of innumerable worlds. The only difference would be that while Epicurus asserts that these worlds come into being and then disintegrate through the fortuitous movements of atoms, the Platonists will say that they are created by the action of God. This infinite number of worlds must follow, if they refuse to allow God to be inactive throughout the boundless immensity of space which stretches everywhere around the world, and if they hold that nothing can cause the destruction of those worlds, which is what they believe about this world of ours." Concerning the City of God against the Pagans, trans. Henry Bettenson (Middlesex, England, 1972), p. 434, Book XI, ch. 5. Gassendi seems to have been much influenced by this passage.

[57] Opera omnia, I, 141.

[58] Ibid., p. 142.

[59] Ibid., p. 142.

[60] Ibid., pp. 142-43.

[61] Ibid., p. 144.

[62] Charleton, Physiologia, pp. 12-13. Animadversiones, p. 235. Charleton notes that he has demonstrated this in his Darkness of Atheism, ch. 2.

[63] Bloch, La philosophie, pp. 337-338. Gassendi discussed the habitability of planets in a separate section of the Physics "De rebus caelestibus," Book I, ch. 6, "sint-ne caelum & sidera habitabilia," I, 524. On the Copernican tradition of a plurality of worlds, see infra, ch. 3.

[64] Richard S. Westfall, "The Foundations of Newton's Philosophy of Nature," British Journal for the History of Science, I (1962), 171-182, and Force in Newton's Physics (New York, 1971), pp. 325-27.

[65] Perry Miller, "Bentley and Newton," Isaac Newton's Papers and Letters on Natural Philosophy, ed. I.B. Cohen (Cambridge, Mass., 1958), p. 274.

[66] Four Letters from Sir Isaac Newton to Doctor Bentley containing some arguments in Proof of a Deity (London, 1756), in Cohen, Isaac Newton's Papers, p. 310.

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67 Sir Isaac Newton's Mathematical Principles of Natural Philosophy and his System of the World, Motte's translation revised by Cajori (Berkeley, 1960), p. 544.

68 Cohen, Isaac Newton's Papers, pp. 281-82.

69 Ibid., p. 311.

70 Ibid., p. 304.

71 Ibid., p. 292.

72 Ibid., pp. 357-58.

73 R. S. Westfall, Force, p. 379.

74 Opticks or a Treatise of the Reflections, Refractions, Inflections & Colours of Light (New York, 1952, based on London, 1730), p. 400, 402. Contrast with Lucretius V, 431-33: "Certainly the atoms did not post themselves purposefully in due order by an act of intelligence ... ." The direct influence of Lucretius' work on Newton is an interesting question which has been touched upon by I. Bernard Cohen, " 'Quantum in se est': Newton's concept of Inertia in Relation to Descartes and Lucretius," Notes and Records of the Royal Society of London, vol. 19 (1964), pp. 131-155.

75 Ibid., pp. 403-404. The Latin original from the 1706 edition reads as follows: "Porro, quoniam Spatium divisibile est in infinitum; Materia autem, non est necessario in omnibus partibus Spatii; illud insuper concedi necesse est, utiq; posse Deum creare Materia particulas variis magnitudibibus & figuris, vario quoq; numero & quantitate pro ratione Spatii in quo insunt, forte etiam & diversis densitatibus diversisq; viribus; eoq; pacto variare Leges Naturae, Mundosq; condere diversa Specie, in diversis Spatii universi partibus. Certe in his omnibus nihil est, quod velsecum ipsum, vel cum ratione pugnet." Optice: sive de reflexionibus, refractionibus, inflexionibus & coloribus lucis libri tres (Londini, 1706), pp. 346-347.

76 The Philosophical Works, I, 107.

77 Ibid., I, 108.

78 Sir Isaac Newton's Mathematical Principles, p. 544.

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Chapter Two

Aristotelianism and the Plurality of Worlds

> Since one of the most wondrous and noble questions in Nature is whether there is one world or many, a question which the human mind desires to understand per se, it seems desirable for us to inquire about it.
>
> Albertus Magnus[1] 13th century

> We have to consider, saith Aristotle, whether there existeth an infinite body as some ancient philosophers have averred, or whether this be impossible; further we have to consider whether there be one world or more. Most important is the resolution of these questions, for the acceptance of either of the opposed solutions is of such consequence as to give rise to one of two entirely opposed and contrary philosophies.
>
> Giordano Bruno[2] 1584

It is one of the great ironies in the history of the plurality of worlds tradition that while the passionate atomist espousal of that doctrine fell for the most part on deaf ears (along with the rest of the atomist system) until the end of the sixteenth century, the Aristotelian rejection of the idea inspired critical discussion of the issue already at the beginning of the thirteenth century in the Latin West. Moreover, prodded by two centuries of theological wrangling, the orthodox opinion which emerged out of that discussion was transformed from outright rejection of other worlds to the insistence that they were possible according to natural law. And although the Scholastics inevitably stopped short of the assertion of the reality of other worlds, the debate which raged in the thirteenth and fourteenth centuries played a significant role in the arguments of those at the end of the

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Renaissance who affirmed not only the possibility but the reality of other worlds than ours. The story of the plurality of worlds in the centuries immediately prior to the scientific revolution is thus not the story of the concept espoused in atomist terms, but of the critical discussion of the problem in Aristotelian terms.

Aristotle directly confronts the subject of other worlds only in his cosmological treatise De caelo, although he mentions it in passing in two other works.[3] The discussion arises quite incidentally in the midst of his rejection of the idea of infinite magnitude, and thus of an infinite world, when he remarks that the question might still be raised whether or not several worlds of finite extent could exist aside from our own.[4] While the twin problems of infinite magnitude and other worlds are thus physically juxtaposed in Book I of De caelo, the juxtaposition indicates rather a contrast of ideas than a close association, unlike the atomist arguments for an infinite number of worlds which were intimately tied to the ideas of infinite space and infinite numbers of atoms. The two chapters which Aristotle subsequently devotes exclusively to the question confirm that his concern is solely with a simple plurality of worlds; indeed, his arguments are designed to demonstrate that even two worlds could not exist simultaneously.

Although Aristotle's concern is with plurality rather than infinity of worlds, it is entirely possible that his thoughts may have been initially motivated by the atomist

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tenet of innumerable worlds. There is no obvious necessity or motivation internal to Aristotle's physics or cosmology that dictates that the subject be taken up. To the contrary, given the accepted meaning of another world as an entity which could not be apprehended by the senses, the subject of other worlds seems incongrous in a system whose purpose was to understand the world of everyday terrestrial and celestial phenomena. But Aristotle undoubtedly knew of the atomist belief;[5] if he could refute the idea that there were even two worlds, how ridiculous would the atomist assertion of an infinite number of worlds seem! It would be one satisfying demonstration of the truth of his system as opposed to that of the atomists, from which he differed in so many other respects.

Aristotle's concept of a world is also similar to that of the atomists: just as Epicurus defined it as a "circumscribed portion of the sky, containing heavenly bodies and an earth and all the heavenly phenomena," so Aristotle held it to signify in its most general sense "the body enclosed by the outermost circumference."[6] To be sure, the outermost circumference for Aristotle is the sphere of fixed stars, one of many spheres in Aristotle's refined concept of the structure of the kosmos, a structure which was absent in the atomist system of the previous century. But in their bare outlines the concepts of "world" are the same: one which includes all the heavenly phenomena, not one confined to a single celestial body, or local systems. Thus Aristotle could engage in a meaningful

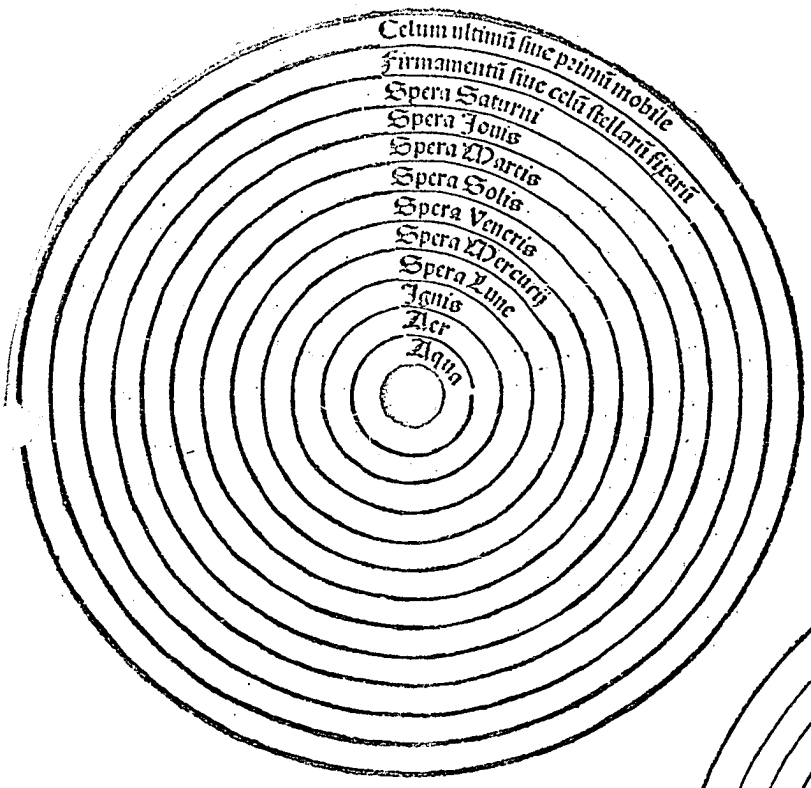
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battle with the atomists on the subject of a plurality of kosmoi.

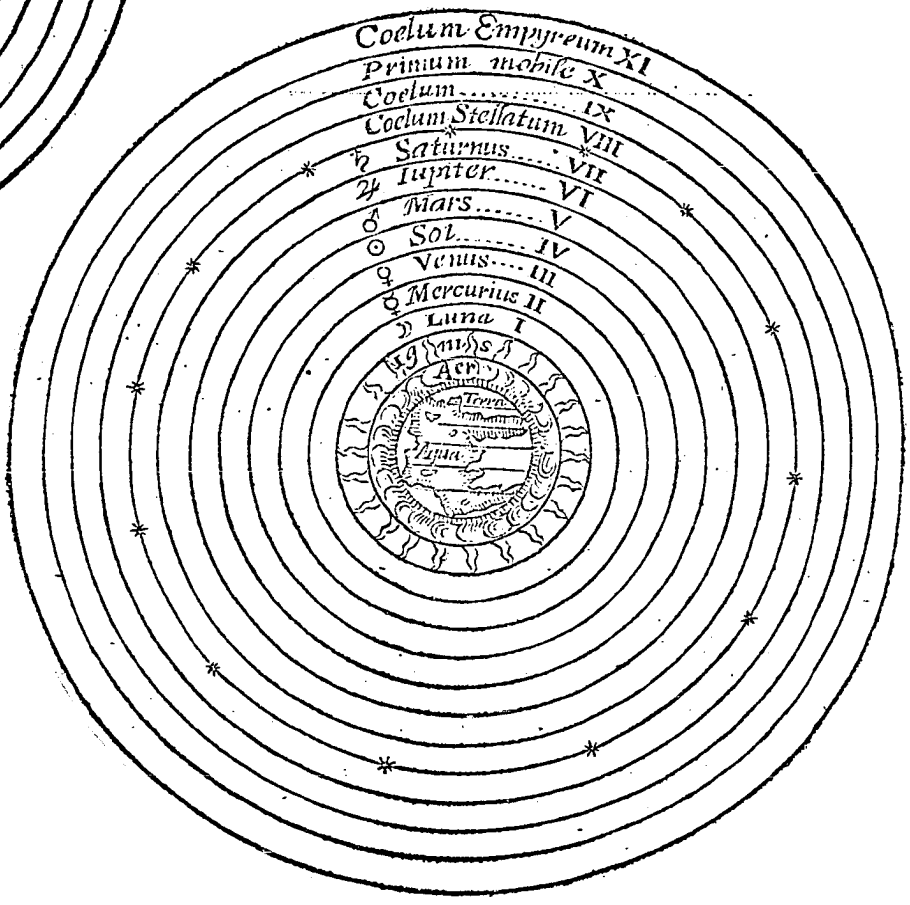
Plato himself may have been another external influence which helped to shape Aristotle's initial opinion, for Plato expressed the belief in the Timaeus that "To the end that this world may be like the complete and living Creature in respect of its uniqueness, for that reason its maker did not make two worlds nor yet an indefinite number, but the Heaven has come to be and is and shall be hereafter one and unique."[7] It is clear that Aristotle was not impressed by such a purely philosophical argument as the one given here that uniqueness is perfection, nor was he to put any trust in the actions of the Platonic Demiurge. He never urged or mentioned these arguments in the De caelo. Rather, as the atomists had deduced innumerable worlds from their physical system, so Aristotle set about to deduce the opposite from the principles of his physical system.

Two arguments from Aristotle's refutation were to assume dominance in the medieval commentaries: the arguments from the doctrine of natural motion and place, and from form and matter. The former was of the most fundamental importance to Aristotle's system; much more than the plurality of worlds rested on its acceptance. The heart of the teleological system, the theory of natural motion and place held that every simple or elemental body of which our world was composed was continually striving toward a certain spatial position - its natural place. For Aristotle this meant that earth, air, fire,

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Sacrobosco, 1478



Regius, 1654

Two representations of the medieval kosmos. The first (upper left) is from a 15th century edition of the most popular medieval astronomical text, Johann Sacrobosco's Sphaera mundi (Venice, 1478), which embraced this world view. The second (lower right) is from a 17th century treatise, Henry Regius' Philosophia naturalis (Amstelaedami, 1654), which sought to replace it with the heliocentric world of Copernicus and Descartes (see below, pp. 216-217). Although the number of spheres sometimes varied, the framework of the medieval view was always the same, with the central earth the point from which all motion was defined, according to Aristotle's physics. Based primarily on these definitions of motion, Aristotle held that there was only one such kosmos or world.

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and water each had a natural place toward which it would move "by nature" and away from which it would move only "by violence." The natural place of the elemental body "earth" was the center of the world, which coincided with the center of the earth, and every particle of earth moved naturally toward that center. Similarly, from empirical observation Aristotle held that the simple body "fire", being light by nature, moved away from the center of the earth naturally, and toward the outer circumference. The remaining simple bodies "air" and "water" assumed intermediate natural places. A tightly knit system was thus set up in which every body had its proper place with respect to the center of the world, and all motion could be classified as natural or violent with respect to that place.

The problem introduced by speaking of more than one world is evident. In doing so one simultaneously posits more than one center, and an immediate contradiction arises; given even two worlds, an element of earth moving from one world to the other would be moving violently with respect to one, and naturally with respect to the other. This clear contradiction, in Aristotle's estimation, proves that there can only be one world. In his own words,

> It must be natural therefore for the particles of earth in another world to move towards the centre of this one also, and for the fire in that world to move towards the circumference of this. This is impossible, for if it were to happen the earth would have to move upwards in its own world and the fire to the center; and similarly earth from our own world would have to move naturally away from the center, as it made its way to the center of the other, owing to the assumed situation of the worlds relative to each other. Either, in fact, we

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> must deny that the simple bodies of the several worlds have the same natures, or if we admit it we must, as I have said, make the center and the circumference one for all; and this means that there cannot be more worlds than one.[8]

This deceptively simple argument provided the basis for numerous commentaries in the medieval scholastic tradition, for there was more to it than met the eye. As was customary, Aristotle sought in this case to forestall any possible objections to his assertions, and it is here that his claims would be contested. In the above passage he has joined the issue quite sharply: either there is only one world, one center, and one circumference, or the elements in the other proposed worlds are of a different nature so that they would not seek the same natural place as the elements of our world. If the former is to be upheld with any validity at all, the latter must be denied, and instead "all the worlds must be composed of the same bodies, being similar in nature. At the same time each of these bodies must have the same potentialities; fire, that is to say, and earth, and the bodies intermediate between them."[9]

What is the basis, then, on which Aristotle can verify the assumption of similar natures? Aristotle first makes the unconvincing, question-begging statement that "if the bodies of another world resemble our own in name only, and not in virtue of having the same form, then it would only be in name that the whole which they compose could be pronounced a world." But the "necessity" of the assertion of similar natures "emerges clearly from our assumptions about the motions of

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simple bodies, namely that they are limited in number and that each of the elements has a particular motion assigned to it. Consequently if the motions are the same, the elements must also be the same wherever they are."[10]

But even if one accepts the fact that the elements of another world are of the same form and nature as ours, might it not still be argued that throughout the universe there are many natural places toward which a body of earth or a body of fire would tend, especially if such bodies were located very far from our cosmos? Aristotle's answer is in the negative, and it is not really in the nature of a proof but rather of a definition.

> The same rule must apply to all, since all alike exhibit formal identity with each other but numerical individuality. My meaning is this, that if the relation of particles in this world to each other and their relation to those in another world are the same, then any given particle from this world will not behave otherwise towards the particles in another world, than towards those in its own, but similarly; for in form they do not differ from one another at all.[11]

This statement amounts to a declaration of the universal mutual relationship of all particles of the same form, and results in a doctrine of <u>absolute</u> natural place, namely, that no matter how distant from our world, particles of the same form must tend toward the same unique natural place. Every particle of earth in the universe must tend toward the center of our earth, which is the center of the world.

With these arguments the contradiction originally deduced from the doctrine of natural place stands firm. Each type of

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body - earth, air, fire and water - must have the same nature in all worlds because each type must have the same unique motion. And each body which has the same nature must tend toward the same natural place. Therefore there is only one center and one circumference, that of our world. It is clear that this chain of reasoning is ultimately dependent for its validity upon a belief in a limited number of types of motion, and a unique motion assigned to each element. The issue of a plurality of worlds is thus a confrontation with the most basic assumptions of Aristotle's system. Aristotle himself indicates as much in the summary to his argument: "Either, therefore, the initial assumptions must be rejected, or there must be only one center and one circumference; and given this latter fact, it follows from the same evidence and by the same compulsion, that the world must be unique. There cannot be several worlds."[12]

The seemingly independent argument of Aristotle from the doctrine of form and matter given in chapter nine of De caelo is not nearly so involved, but also not nearly so independent from the preceding argument as it might seem. The basis for the argument is the assertion that since our world is perceptible, it has the status of a "particular" bound up in matter, not a "universal". Given this fact, then

> "This world" and "world in general" are two different things, the latter being distinguishable as form or shape and the former as compounded with matter ... and it is universal in our experience that, among things whose substance is bound up with matter, there are many - indeed an infinite number - of particulars similar in form, so that there either are or can be many worlds.[13]

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The doctrine of form and matter thus supports the existence of a plurality of worlds. But, Aristotle is quick to add, this possibility is in the end precluded by the fact that our world consists of all material body in existence, and therefore there is no matter which could be used to constitute another world. And how does Aristotle know this? Again it is because of the doctrine of natural place that no simple body can exist outside our world. For no such bodies could exist there naturally with respect to our world, since their natural places are within our world. Nor could they exist there unnaturally with respect to our world and naturally with respect to another world since all of the possible types of bodies, limited in number by the types of motion uniquely assigned to each, already exist in our world.[14] So what appears at first to be an independent argument in reality reverts again to the doctrine of natural place and motion and those initial assumptions about limited types of bodies from limited types of motion.

Finally, Aristotle wishes to claim that a plurality of worlds is denied "from the arguments of first philosophy."[15] Although he does not elaborate more at this point, this is usually taken to be a reference to his statement in the Metaphysics that a plurality of worlds entails a plurality of first movers.

One is thus struck by the intimate relation of the plurality of worlds discussion in Aristotle with the most

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basic physical principles of his system. Given his theory of four elements and the initial assumptions which he emphasized so strongly precisely in connection with the plurality of worlds, the rejection of that idea was held up by Aristotle as effectively an immediate consequence. Just as the atomists considered they had practically deduced the necessity of a plurality of worlds from their most basic assumptions of atoms and void along with random motion, so Aristotle's theory of elements together with his basic assumptions of natural motion and natural place guaranteed the rejection of other worlds; at least Aristotle would have us think so. As such Aristotle himself must have seen his arguments against a plurality of worlds as a triumph for a system which was opposed in so many other ways to the atomists, since they served as an impressive demonstration of the power of Aristotelian physical principles even outside the confines of the single world whose phenomena they attempted to explain. But the neat package presented by Aristotle was not fully accepted by the Middle Ages, and in fact was so battered as to pose a serious threat to the survival of the Aristotelian cosmos itself.

* * *

It was in Aristotelian terms that the concept of a plurality of worlds first impinged upon the medieval European mind.[16] The corpus of ideas surrounding it was only a small part of the general twelfth century recovery and translation of Aristotle's works - the "twelfth century renaissance," as

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Haskins has termed it.[17] The De caelo itself first became available to the Latin West about 1170 in a translation by Gerard of Cremona, and soon the Greek and Arab commentaries in translation, especially those of Simplicius (sixth century) and Averroes (c. 1126-1198), provided a greatly expanded set of arguments. With the rise of the universities and the mendicant orders in the thirteenth century, critical discussion reached new heights; together with sacred Scripture, the Aristotelian corpus formed the core of all knowledge. The commentaries on the various treatises of Aristotle were often undertaken line-by-line, and incorporated alterations made necessary in light of the demands of Christianity. De caelo treated the time-honored subject of cosmology, and was no exception to this critical examination. The question of a plurality of worlds thus became conventionalized in the quaestiones and commentaries on De caelo, where Aristotle's devotion of two entire chapters to the topic provided ample material for commentary.

The research of Pierre Duhem on medieval science has shown not only that the medieval discussion of a plurality of worlds dealt with some of the basic concepts of Aristotelian physics, which is no surprise at all given Aristotle's discussion, but also that there was an evolution of thought within the medieval tradition.[18] For a century following the introduction of De caelo into the Latin West (c. 1170), Aristotle's assertions concerning the plurality of worlds went virtually unchallenged. According to Duhem, the

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earliest writers in the thirteenth century who were familiar with the ideas of De caelo (Michael Scot in the court of Frederick II of Spain, the bishop of Paris William of Auvergne, and later Roger Bacon in England) did not even bother to invoke Aristotle's detailed arguments to uphold his view of the unity of the world; they merely rejected other worlds on the grounds of the impossibility of a void, which would have to exist between the putative worlds no matter how they were situated.[19] Their contemporaries Albertus Magnus and his student Thomas Aquinas both wrote detailed commentaries on De caelo, but assessed Aristotle's arguments from natural place in different ways. Albert followed closely the commentary of Averroes which reasserted the fundamental position that the natural motion of any element was independent of the distance from its natural place, while Aquinas allowed for the departure from Aristotle introduced by the recently translated commentary of Simplicius, that the distance of a body from the center of the world could vary the intensity of the form, but not the form itself.[20] But both of these positions were affirmations of Aristotle's insistence that the natures or forms of the elements were the same everywhere. They were thus also affirmations of his rejection of a plurality of worlds.

The last quarter of the thirteenth century, however, witnessed a remarkable turnabout. At Paris Godefroid of Fontaine, Henry of Ghent, and Richard of Middleton held that a plurality of worlds was not theologically impossible -

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that God could create other worlds and that every possible world could determine the natural motions of its own bodies, whether those bodies were different in form from those of our world or the same.[21] Moreover, matter for another world could be created ex nihilo by God, and neither were the arguments of the earlier writers from the impossibility of a void compelling. At Oxford William of Ware, Jean of Bassols, and Thomas of Strasbourg made similar claims.[22] Those claims became established in the fourteenth century at the hands of such important university masters as John Buridan. And the fourteenth century saw such theologically inspired departures also justified naturally by the denial of Aristotle's arguments. William of Ockham opted for a new, wider view of natural place; bodies of the same form but situated in different worlds could move to places formally identical but numerically distinct, a situation which allowed for a plurality of worlds. Robert Holk followed his Oxford colleague in this view. And by the end of the fourteenth century Nicole Oresme at Paris was formulating a new "natural law" for heavy and light bodies, which Duhem characterizes as not Aristotelian at all, but rather Platonic, and which also allowed for the possibility of a plurality of worlds naturaliter loquendo.[23]

It should be noted that in spite of the recognizable evolution in the medieval discussion of a plurality of worlds, the evolution was no more unanimous than in most other questions in medieval physics. In the fourteenth century

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John of Jandun asserted the impossibility of the creation of other worlds by God, and Albert of Saxony claimed that other worlds could only be created by a permanent suspension of the laws of nature - a perpetual supernatural act - in contrast to most others who claimed that it was a natural possibility after the initial supernatural intervention.[24] It should also be noted that even the departures from Aristotle allowed for only the possibility of other worlds, not for their existence in reality. Every Scholastic without exception shrank from asserting the reality of a plurality of worlds.

But why all of this critical examination, this subtle argumentation against the Greek thinker whom all still acknowledged as "master", merely to assert the possibility of other worlds? In the answer to that question is also found the cause for the sudden turnabout in opinion during the fourth quarter of the thirteenth century. This occurrence Duhem ascribes in no uncertain terms to the condemnation of 1277, an event whose import is disputed today among scholars, but which seems to have had a remarkable effect on the plurality of worlds discussion. The condemnation was applied by Etienne Tempier, the bishop of Paris, to some 219 articles commonly held in the universities which Tempier considered heretical because they infringed on the power of God. Among those articles condemned was "that the First Cause cannot make many worlds." The university masters, deeply religious and fearful of excommunication if they ignored a promulgation

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of the Church, thus turned after 1277 to a more critical examination of the Aristotelian principles on which the impossibility of a plurality of worlds was based.

In order to appreciate more fully the asserted effect of the condemnation of 1277, and to come to grips with the medieval argument in its various phases, it will be helpful to examine in detail the treatment of several of the more important medieval writers. Duhem's study shows that the arguments at any given stage were very repetitive among various writers; an exposition of the viewpoint of one author therefore indicates quite well the arguments of all who agree with him.

Roger Bacon (c. 1214-1292) gives a particularly succinct formulation of the argument of the early writers against the possibility of the plurality of worlds from the impossibility of a void, and characterizes the argument as "geometrical reasoning."

> If there were another universe (mundus), it would be of spherical figure, like this one, and there cannot be distance between them, because in that case there would be a vacant space without a body between them, which is false. Therefore they must touch; but they cannot touch each other except in one point by the twelfth proposition of the third book of the Elements, as has already been shown by circles. Hence elsewhere than in that point there will be vacant space between them.[25]

This argument from Bacon's Opus maius, composed about 1266, was one which Aristotle himself had not raised in opposition to a plurality of worlds; perhaps because it would have been viciously circular, since one of the proofs of the non-

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existence of void was that there could be no body outside the world, which in general is the same argument as that against a plurality of worlds. In any case, Bacon's argument was later denied by some who examined exactly what "void" was, and quoted Aristotle himself against Bacon.

To Thomas Aquinas (c. 1224-1274), engaged in the synthesis of Christianity and Aristotelian science, the idea of other worlds presented itself as more of a dilemma than a clear-cut case. In contrast to some of Aristotle's principles such as the eternity of the world and the mortality of the soul, which had to be denied as contradictory to the doctrines of Christianity, the denial of other worlds was not prima facie opposed to any Church doctrine. But even though Aquinas wrote before the condemnation of 1277, he was not insensitive to the fact that the issue impinged on the question of God's omnipotence and glory. In the end, however, this concern was manifested not by challenging Aristotle, but by showing how one world was most agreeable to God's omnipotence.

In his expositio of the De caelo (c. 1273) Aquinas thus followed the essentials of Aristotle's argument against a plurality of worlds based on the doctrine of natural place; if there were another world with another center, then a mass of earth placed outside our world would necessarily move naturally with respect to one center and violently with respect to another, and this was a contradiction in the laws of physics.[26] But the question did provide a forum through

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which Aquinas raised some basic questions.[27] Was the cause of "heaviness" an attraction exerted between similar simple bodies, such as earth to earth and fire to fire, in which case other worlds would be possible? Aquinas thought not. Was it then an intrinsic tendency of the body by which its substantial form sought its place of perfection? Aquinas thought this was the case, and with Aristotle believed that this place of perfection was numerically unique for all bodies of the same form. Was heaviness a quantity which remained independent of the distance of the body from its natural place? Here Aquinas answered no, and held that such a variation of the intensity of the form with its distance from its natural place could account for the observed acceleration of falling bodies. But again such a concept, while a definite departure from Aristotle, did not alter the conclusion of the impossibility of a plurality of worlds according to the Aristotelian laws of nature.

Aquinas also concurred with Aristotle's second argument. Although it is true that many particulars may be multiplied from one form or species, the world is composed of all existent matter, so the argument that there must be many copies of our world is negated. Aquinas knew that our world consisted of all the matter in existence because "it is not possible for there to be another earth than this one, since every earth would naturally be carried to this central one, wherever it was. The same applies to other bodies which are part of the world."[28] The argument from natural place was thus of paramount importance.

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Aquinas had thus arrived at Aristotle's basic conclusion, and he was now compelled to justify theologically that denial of a plurality of worlds which might easily be seen as a position which compromised God's omnipotence. The theological points of the question were aired in both the expositio of De caelo and in his great synthetic work, the Summa theologica. The basic issue which arises in both of these works is simply that of God's power to create. Would not many worlds be more indicative of an omnipotent God than only one? And even if they did not exist, could not God create them if he so desired, Aristotle's contradictions notwithstanding? Aquinas had a definite answer, expressed in different but compatible terms in both the Summa and the Expositio.

The strategy of Aquinas was to preserve an omnipotent God not by allowing the creation of other worlds, but by arguing that the existence of only a single world did not infringe on the idea of omnipotence as it should truly be understood. For Aquinas the meaning of God's omnipotence was guided by the perfection which the Deity sought to achieve. Aquinas finds perfection in unity; one world constituted of everything that exists is perfect, whereas many worlds would not contain all sensible bodies and therefore would each be imperfect.[29] Given this Platonic definition of the perfection of the world, it would be more agreeable to God's omnipotence that he produce a single perfect world than a great number of necessarily imperfect worlds. The unity of the world is the very reason for its

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goodness, and Aquinas holds that by division anything declines in goodness. God's plenitude is therefore not to be found in plurality; in the slightly different terms of the Summa "no agent intends material plurality as the end; forasmuch as material multitude has no certain limit, but of itself tends to infinity; and the infinite is opposed to the notion of end."[30] A single world is therefore most agreeable to an omnipotent God.

A single world was more in accord with God's attributes in yet another way. For Aquinas finds not only perfection in unity, but also order. The main argument of the Summa was based on the concept of order: "This world is called one by the unity of order whereby some things are ordered to others," and since it is axiomatic that "whatever things come from God, have relation of order to each other, and to God himself ... hence it must be that all things should belong to one world."[31] The concept of order was absolutely essential to Aquinas. A hierarchy in which everything had its relation to the Creator was compatible with the Aristotelian hierarchy of spheres; to introduce other worlds, perhaps with their own bodies and spheres, but necessarily in no way ordered with respect to our world and the Creator, was to shatter the concepts of unity, perfection, and order.

This was a convincing argument, for the alternative to order was the chaos of the atomists. It was on a note of triumph that Aquinas concluded "those can only assert that many worlds exist who do not acknowledge any ordaining wisdom,

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but rather believe in chance, as Democritus, who said that this world, beside an infinite number of other worlds, was made from a casual concourse of atoms."[32] It is significant that Aquinas here contrasts the atomist and the Aristotelian positions. In that formal and explicit contrast, and in the preservation of God's omnipotence, Aquinas found his triumph. So convincing did he find these arguments that he mentioned only in passing that a Scriptural passage (Jo., i, 10), "the world was made by Him", could also be taken as an indication that God had created only a single world. But this passage and others from Scripture would play a crucial role in the seventeenth century discussion.

The intricate arguments by which Aquinas and his predecessors asserted that a single world was not adverse to an omnipotent God must have seemed too esoteric or too little to the Church authorities. Only three years after Aquinas' death, his position that God could not create other worlds was included in the 1277 list of 219 articles which were condemned for their infringement on God's power. The insistence that God could indeed create other worlds if he wished meant two things; either God could act supernaturally, that is, above and beyond the Aristotelian laws of nature, to produce another world, or Aristotelian physics could be altered sufficiently to allow for the possible existence of other worlds within natural law. Both of these strategies, or some combination thereof, were in fact to be utilized.

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Jean Buridan was one of the Paris masters who typified the post-1277 period in his assertion that God could indeed create other worlds. In his Quaestiones on De caelo, which served as the substance of his lectures at Paris from 1328-1358, Buridan pointed out that Aristotle's claim of the impossibility of worlds must be qualified, for "it must be realized that while another world than this is not possible per naturam, this is possible simpliciter; since we hold from faith that just as God made this world, so he could make another or several worlds."[33] By simpliciter Buridan means to say that a plurality of worlds entails no logical contradiction, a situation which even God could not have overcome.

Buridan devotes the entire questio 18 to an examination of Aristotle's argument against plurality of worlds from natural place. He accepts Aristotle's general tenet that a heavy or light body outside of its natural place will return naturaliter to its natural place; that a heavy body moves naturally to the center and a light body moves naturally upward is apparent to us per experientiam. Nor does Buridan wish to redefine natural place in terms of many centers, and allow a natural place for earth at the center of each possible world. There must be only one natural place for each form or element, because in general "heavy and light bodies are moved through their own intrinsic natures and not by an outside mover (per suas naturas intrinsecas et non per movens extrinsicum,"[34] such as an impulse (pulsum) from the spheres above or an attraction (tractum) from a place below. This Buridan proves

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by some interesting observations which touch on his impetus concept of motion. Aristotle's argument against the plurality of worlds thus stands because "a heavy body is moved neither more nor less to a center because it is more or less distant from it, since it is not moved except by its own nature, which is always within it, and since it may not be moved by an attraction from that center nor by a pushing from the other center."[35]

We have already seen in the treatment of Aristotle that the doctrine of an absolute natural place is totally dependent on the assumption that if there were other worlds, their matter would be of the same kind and subject to the same laws as this world; without this assumption there is no argument against a plurality of worlds from Aristotelian principles. It is here that the condemnation of 1277 shows its effect on Buridan, who holds that this basic assumption underlying the whole argument must not necessarily be conceded "because God through His omnipotence and free will can produce dissimilar effects. Therefore, when they say that the same undiversified cause cannot produce dissimilar effects, this must be conceded de causis naturalibus, but not for voluntary and free causes."[36] Therefore, through the intervention of God there could be other worlds.

By the same token, moving bodies are ordered by God, and God could order the things in another world with relation to that world instead of to ours, so that "the earth of that world would not descend naturaliter except to the middle of

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that world, and in no way to the middle of this world."[37]

With these assertions, Buridan's initial claim that other worlds are not naturally possible still stands. God's intervention is necessary, either to produce a world composed of the same kinds of bodies as ours, or of different kinds. But it is noteworthy that a momentary action of God would suffice to make other worlds possible naturally forever. In the first case, the newly created elementary bodies would be of a different form than those of our world and would thus tend naturally to their own natural places. In the second case, each of the elements would be universally the same in form, and once God had ordered his newly created world, all motion of the elements would be natural with respect to their own world. In this way Buridan satisfied the demands of the two sources of truth: Aristotle and the Church.

All of this is only one aspect of the general issue of a plurality of worlds, and is preparatory to quaestio 19, where Buridan takes up the broader arguments relating to the issue. With Aristotle he denies the argument for many worlds from form and matter, not because the world contains all the matter, but simply because he believes that the argument does not apply to the term "world" any more than it applies to "God". To the argument that many things are better than one, Buridan, not acknowledging Aquinas' intricate arguments against this assertion, again claims that this is certainly not so with God and it is also not so with regard to the world.[38]

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In this quaestio Buridan also launches untypically into the issue of successive worlds, as opposed to coexistent worlds which are the prime issue in Aristotle. The discussion of this aspect of the question gives rise to certain distinctions, not met with in previous commentaries on De caelo, which help to define, clarify, and resolve the issue of successive worlds. Buridan's discussion recalls the fact that each possible world consists of the earth and the heavens, and that these two parts are to be kept entirely distinct, since the elements of the terrestrial region are subject to generation and corruption, while the "fifth essence" of which the heavens are composed is ungenerable and incorruptible. With this in mind Buridan holds that worlds may logically be considered to exist successively either in terms of their total diversity (secundum diversitatem totalem ipsorum), or in terms of the diversity of their parts (secundum diversitatem partialem). He concludes that the world taken as the whole of the terrestrial and celestial regions could be successively created and destroyed only per potentiam divinam, sed non per potentiam naturalem, since the celestial bodies are not naturally generable or corruptible and would require the action of God to make them so.[39] The parts of the world must be considered separately as the principal parts and the lesser parts, the celestial bodies and the elements respectively. As with the world as a whole, the celestial bodies could not be created or destroyed except by a divine power. As for the lesser parts, they are indeed

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generated and corrupted daily, and Buridan notes that in this sense one could say that we have a new world every day. But that is a trivial case, and Buridan concludes that Nature does not allow successive worlds, since the principal parts of the world unaltered and eternal according to natural law. The combined effect of quaestio 19 is thus to reassert that although more than one world in any sense cannot exist naturally, God could create as many successive or coexistent worlds as he wished, since his power is not less now than when he made our world.

*

An even bolder assertion of the possibility of other worlds, which leaves even less to the Deity and more to Nature than did Buridan, is contained in the Sentence Commentary of perhaps the most important philosopher of the fourteenth century, William of Ockham, composed a few years before Buridan began his lectures at Paris based on the Quaestiones. In issues like the plurality of worlds, the master of arts such as Buridan and the master of theology such as Ockham met on common ground; both were forced to come to grips with the theological and scientific realities. The master of theology frequently did so in commentaries on the Sentences, a mid-twelfth century compilation of theological opinion by a former Bishop of Paris Peter Lombard (c. 1095-1160), and a genre well represented because such commentaries were required of all who aspired to the master of theology degree.

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The specific question of other worlds arose in the Sentence commentaries within the context of a very general question posed in Distinction XLIV of Book I: "Whether God could make anything better than he has made."[40] It is indicative of the increasing importance of the question of a plurality of worlds that Distinction XLIV, in which Lombard himself made no reference to other worlds, was in the thirteenth and fourteenth centuries given over partially or entirely to it. Even before 1277, a part of this general question was "Whether God is able to make the world better than he has made it."[41] This did not in itself necessitate a discussion of <u>other</u> worlds; its thrust was to determine whether God could make <u>this</u> world better. The latter was the main concern, for example, of Thomas Aquinas in Distinction XLIV of his commentary composed between 1254 and 1257. The detailed terms in which he discussed this particular part of the question may be seen in an outline of his treatment (next page), which also shows that even before 1277 the question of <u>other</u> worlds was gaining a foothold in Distinction XLIV, for Aquinas concluded that if God made this world better in essential goodness, he would in effect be creating a new world. Such a case would seem to entail the idea of successive worlds, not the coexistent worlds which were the main concern of Aristotle. But successive worlds too were a part of the general question of other worlds, and Buridan's treatment of successive worlds which we have briefly recounted above may have been influenced not so much by Aristotle as by

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Structure of Distinction XLIV, Quaestio I, Article II of Thomas Aquinas' Sentence Commentary

Whether God is able to make the universe better (Utrum Deus potuerit facere universum melius)

Solutio

Goodness of the universe can be taken as:

I. Mutual order of the parts (in ordine ad invicem)

- A. Ordered parts themselves made better
  - 1. By the addition of more parts (per modum quantitatis discretae)
  - 2. Intensively, by changing the parts to be better
    - a. in accidental goodness (= the same universe)
    - ****b. in essential goodness (the result would not be the same universe)

- B. Order of the parts
  - 1. Not possible per modum quantitatis discretae, because in the universe nothing is unordered
  - 2. Intensively
    - a. in accidental goodness; it is possible to be better
    - ****b. in essential goodness; not possible unless other parts and another universe are made (nisi fierent aliae partes et aliud universum)

II. Order of the parts toward an end, which is God (ordo qui est ad finem)

- A. From the standpoint of the end itself (ex parte ipsius finis): not possible because nothing is better than God

- B. From the standpoint of the order itself (ad ipsum ordinem): the closer to the end (God), the better

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considerations arising from Distinction XLIV of the various Sentence commentaries, some of which he was certainly familiar with.

It is evident that there was much interchange of ideas between commentaries on the two relevant chapters of the first Book of De caelo and commentaries on Distinction XLIV of Lombard's Sentences. This is emphasized by the fact that in William of Ockham's Sentence commentary, as opposed to that of Aquinas, the main concerns were essentially the same as those of the De caelo tradition. By the fourteenth century, Distinction XLIV served as a vehicle for Ockham to depart from the Aristotelian position more than his master of arts colleagues had dared in their commentaries on De caelo.

Ockham devotes the entirety of Distinction XLIV to the question "Whether God can make a better world than this world."[42] According to Ockham, there are three ways in which this question may be taken: the world can be made better in essential goodness and thus "distinct in kind or species;" secondly, a better world can be made of the same kind as this world, but separate from it or "distinct in number" as Ockham terms it; thirdly, it can be made better in accidental goodness.[43] Now the first two of these cases in fact entail a discussion of a plurality of worlds, for when a world is distinct in species or distinct in number, one is speaking not of a single world, but many. The third case, the creation of a world better in accidental goodness, has nothing to do with plurality of worlds; it is purely a

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Prōdūct

ꝙ creature esse factibile. g̃ nō sit. Dicēdū ꝙ q̃cq̃d creatura bz reale tāꝙ aliq̃d sibi inherēs bz a deo tāꝙ a ꝓncipio. ꝑ nō q̃cq̃d cōperit sibi i ꝑdicatiōe bz ꝓncipatiue a deo. nisi illo mō ꝙ deꝰ bz tales ꝑdicatiōes a deo. qz tales ꝑdicationes qñ sūt i actu ⁊ realr tūc sūt a deo. et iō eē possibile cōperit creature ex se ñ realr tāꝙ aliq̃d sibi inherēs. ꝑ nec ē possibil ex se. sic nō ex se ē nō asin?. ⁊ g̃ talia argumēta nō valēt nisi d̄ cō uenienti realr. quō totū bz ptes ⁊ accidētia sua nec ē ꝓꝑus mod? loquēdi dicere ꝙ eē possibile cōperit creature. ꝑ magis ꝓꝑe dz dici ꝙ creatura ē possibil nō ꝓꝑe aliq̃d qđ sibi cōueniat. ꝑ qz pōt eē i rerū natura. Ad argumētū ꝓncipale dico ꝙ nō ꝓꝑus ē deꝰ factiū ꝙ creatura ē factibil. imo ita ꝓmo ē creatura factibilis si esset deꝰ ē factiu?. Dist. xliii. Questio vnica.

Ad principale

Distin. XLIIII

A

Questio I

Circa distinctionē q̃dragesimāquartā q̃ro.

c

Argūtur primo

Vtrū deꝰ possz facere mūdū meliorē isto mūdo vel nō. qz illō qđ nō recipit magis et min? nō pōt fieri melꝰ. ꝑ mūdus nō recipit magis et min?. g̃ ñ pt vn? mūd? eē melior alio. g̃ ⁊ c. maior pz. qz mūd? ꝓstat ex substātijs q̃ nō suscipiunt magis ⁊ min?.

Secūdo

Preterea q̃ rōe deꝰ posset facere mūdū meliorē isto mūdo. eadē rōe posset facere mūdū i ifinitū meliorē isto mūdo. qđ ē ipossibile.

B

Circa q. ria sūt

Ad oppositū ē mgr i lra.

Circa ista q. ꝓmo videndū ē q̃d iportet ꝑ mūdū.

Primū qđ mūd?

Secūdo q̃d ꝑ meli?. Tertio ad q. Circa ꝓmū dico ꝙ mūd? dupl̄r accipit. Aliq̃n ꝓ toto ꝙdā cōposito vl aggregato ex multis cōcretis sub vno corpe ex illo cōtinēte. Et ꝑ dupl̄r. vl ꝑcise ꝓ prib?. q̃ sūt sbe vl idifferēter ꝓ oib?. Sz i ista q. accipiēdus ē mūd? ꝑcise ꝓ vno vniuerso q̃si cōposito ex pribus q̃ sūt sbe. ⁊ ñ bz ꝙ icludit accidētia cū sbā.

Secundū

Circa secōm dico ꝙ aliq̃d pōt eē melꝰ alio. vl bonitate cēntiali vl sbali vl bonitate accidētali.

Tertiū iterū triplicit

Circa tertiū ꝓmo videndū ē. vtrū posset facere mūdū meliorē isto bonitate cēntiali siue sbali. ⁊ ꝑ distinctū spē. Secō vtrū possz facere mūdū meliorē distinctū solo numero. Tertio vtrū posset facere mūdū meliorē bonitate accidētali.

E

Circa primū dubitatur

Circa ꝓmū ē dubiū q̃d sit tenēdū. Nā si teneat opi. ꝙ deꝰ pōt facere sbas ꝓfectiores oi sba facta. ⁊ ꝑ i ifinitū. sic pōt augere q̃litatē recipiēte magis ⁊ min? i ifinitū. ita ꝙ nō ē ponere statū. Dicēdū ē ꝓnter ꝙ deꝰ pōt facere mūdū meliorē distinctū spē. qz poterit facere alia idiuidua sbalia distincta spē meliora illis q̃ nūc sūt. Sz tenēdo ꝙ ē stat? i talib?. ita ꝙ ē dare aliq̃ sbaz ꝓfectissimā possibilē a deo fieri. ē magis dubiū qz tenēdo opi. illā pōt ꝓbabiliter teneri. vtraq; ꝓs. s. ꝙ pōt facere aliū mūdū distinctū spē. ⁊ ꝓ ista ꝑte videt esse opinio augustini ⁊ mgrī in lra. q̃ dicit talē potuit deꝰ fecisse boiem q̃ non peccare posset nec vellet. Ex hoc arguo sic. q̃cq̃d ꝓuenit alicui spēi spēialissime nulli indiuiduo eiusdē spēi spēialissime repugnat formalr cōsidē. ꝑ isti hōi cōuenit posse peccare. manifestū ē. g̃ nulli hōi eiusdē spēi repugnat formalr peccare. ꝑ deꝰ pōt facere hominē cui repugnaret peccare. g̃ talis hō nō esset eiusdē spēi spēialissime cū isto hōie. g̃ ecc alterius spēi. et ꝓ ꝓns deꝰ pōt facere indiuiduū alterius spēi q̃ fecit. ⁊ ꝓ ꝓns mūdū alterius spēi. ⁊ cadē rōne melioꝛē.

D

Instat ꝓmo

Et si instet cōtra illaz rōnē ꝙ assumptū ē falsum. Nā isti hōi cōuenit posse peccare. ⁊ tñ isti hōi demōstrādo xp̄m repugnat posse peccare. nō obstante ꝙ sit eiusdē spēi spēialissime cū isto hōie q̃ pōt peccare.

Secundo

Sili hō ē spēi spēialissima. g̃ nō pōt eē hō alterius q̃s alterius spēi q̃ sit iste homo q̃ pōt peccare.

Ad ꝓmū

Primū istoꝝ nō cōcludit. nā q̃uis ꝙdo diuino repugnet posse peccare. tñ illi nature q̃ē vnita verbo nō repugnat posse peccare. q̃a si dimitteret a verbo posset peccare. ⁊ natura ē eiusdē spēi spēialissime cū isto hōie q̃ pōt peccare. nō aūt ē eiusdē spēi spēialissime cū verbo cō ñ pōt peccare.

Ad secūdum

Secz etiā nō ꝓcludit. Nō hō dupl̄r accipi pōt. vno mō ꝓ oi cōpositō ex corpore ⁊ natura ītellectuali. et homo sic sumptꝰ nō essz spēi spēialissima. ⁊ iō iste homo si fieret impeccabil. ꝑ naturā nō esset eiusdē spēi spēialissime. cū isto hōie qui pōt peccare. Aliter accipit homo ꝓ cōpositō ex corpore ⁊ tali aīa intellectiua qualē nos habem?. ⁊ hō sic sumptꝰ est spēi spēialissima. nec ille qui fieret impeccabilis esset homo taliter accipiendo hominem. Tenēdo g̃ statū in idiuiduis distinctis specie posset teneri ꝙ deus nō posset facere aliud in diuiduū speciei distincte. qz si sit status in talibus. oēs spēs substātie factibiles a deo sūt in certo numero. et per ꝓns difficile est ꝓbare ꝙ aliqua indiuidua aliquarū spērū sint ꝓducta a deo. ⁊ aliqua nō sint ꝓducta a deo. Nec videtur posse haberi ad hoc aliq̃ cōgruētia nisi forte ex aliqua auctō. quā difficile est inuenire in scriptura. ⁊ ꝑ istā opi. deꝰ nō possz facere aliū mūdū distinctū specie ab isto. Tertio modo posset poni talis status ponendo ꝙ aliqua indiuidua aliquarū specierū ꝓducibilia a deo nō sint producta. tñ aliquod idiuiduū speciei supreme est productum. quia non videt verisimile ꝙ deus ꝓduxerit idiuidua specierū in

The opening portion of Distinction XLIV of William of Ockham's Sentence Commentary, as it appeared in an early edition of his Opera Plurima (Lyon, 1494-96).

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question about our world and involves only accidents, although it is nearest in meaning to the import of Distinction XLIV in thirteenth century commentaries such as those of Aquinas. Clearly, however, Ockham is most interested in the first two cases, since he gives only a one sentence approval to the third case with no further discussion. Distinction XLIV therefore can be seen in Ockham as effectively devoted entirely to the question of a plurality of worlds.

The thrust of Ockham's first case, whether God can make a world better in essential goodness and thus distinct in species, is precisely what Aristotle had denied could happen in nature when he argued that any supposed worlds would have to be of the same nature as this world because a limited number of types of motion dictated a limited number of types of elements. As Buridan would later assert that God was able to create different kinds of worlds, so Ockham claimed "I repute that it is probable that God could make another world better than this one and distinct in species from it."[44] Buridan gave no argument to back up his assertion, but Ockham was a master of theology, and his resolution of the argument was given in theological terms. He quoted Augustine's assertion that God could make a perfect man, i.e. one who could not sin or wish to sin, and Ockham argued from this that such a man in effect would be of another species, which indicates that God can make an individual of another species, and therefore a world of another species, and a better world.[45]

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But Ockham's second case is of most interest to us; it is the one to which he gives by far the most attention, and it is the one which directly relates to the Aristotelian arguments. Ockham asserts at the outset that God can make another world.

> The reason for this is that God could produce an infinite number of individuals of the same species as those which now exist, therefore God could produce as many individuals and many more than are now produced, and of the same species; but he is not limited to producing them in this world, therefore he could produce them outside this world and make a world of them just as he made this world from those things which he produced here now.[46]

This is in direct opposition to Aristotle, and Ockham immediately undertakes to answer Aristotle's objections.

> I say that although all individuals of the same species can be naturally moved to the same place and number, yet if they should occupy the same place outside their natural place, at least successively, then it is not necessary that they always be moved to the same place in number naturally, but it is possible that they could be moved simultaneously to different places according to number.[47]

Here is a profound departure from Aristotelian physics; bodies of the same kind, when placed outside of their natural place, must not necessarily return to a <u>unique</u> natural place. Rather they will return to a natural place dependent on their situation. This is similar to Buridan's claim, but whereas Buridan had justified it by God ordering the parts of the new world, Ockham proceeds to do so by altering Aristotle's principle of natural place.

In order to clarify his meaning, Ockham gives an example

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of two fires of the same kind, one at Paris and one at Oxford, which are moved naturally toward the circumference of the sky. The one fire tends naturally toward one point on the circumference, the other tends toward a different point. If now the fire at Paris were to move to Oxford, and vice versa, each would tend, not toward its own original point, but to the point dictated by its new situation - that of its predecessor. Thus

> It would happen in the proposed situation (of other worlds) that if the earth of another world was assumed within the heaven of this earth, it would be moved toward the same place in number to which the earth of this world is moved. But when it is outside this world, and within the heaven of another world, then it will not be moved to the middle of this world, no more than fire existing at Oxford would be moved to that place in number to which it would be moved if it were at Paris. But it will be moved to the center of its own world and thus it is obvious that these two earths ... would be moved to different places in number because of the different situations (propter diversa situatione) between the two heavens.[48]

Here is a kind of relativism totally foreign to Aristotle's concept of an absolute natural place. Natural place is not dependent on the initial position of a body, but on its situation at the time in question. This was not a view which would satisfy the Peripatetics, but Ockham set it forth in all seriousness, even though the supernatural creation of matter ex nihilo was still a prerequisite before natural law could be invoked. It was a position which was compatible not only with natural philosophy, but also with some of the broader elements of Ockham's famous nominalist philosophy.[49]

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Precisely 100 years after the condemnation of 1277, the Paris master Nicole Oresme composed a French translation and commentary on the De caelo, written in that language by the specific order of Charles V of France. Oresme's discussion of the plurality of worlds was in general couched in the same terms as those we have already related. His line-by-line commentary is profuse with skeptical statements which challenge the validity of Aristotle's arguments and the truth of his conclusions. And following the commentary on chapters eight and nine, Oresme sets aside a lengthy discussion to an overview of the ideas of other worlds, as he often did for some of the more important ideas encountered in De caelo: "Now we have finished the chapters in which Aristotle undertook to prove that a plurality of worlds is impossible, and it is good to consider the truth of this matter without considering the authority of any human, but only that of pure reason."[50]

Oresme's review of concepts of other worlds first raises the question of successive worlds. He notes that Aristotle had rejected the plurality of successive worlds, but that the Church Father Origen, according to St. Jerome, had favored the idea that God "could annihilate this world and create another thereafter."[51] Oresme himself offers only that God could certainly do this if he wished. He then conceives the case concentric worlds, in which "at one and the same time one world is inside another so that inside and beneath the

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circumference of this world there was another world similar but smaller."[52] The surprisingly lengthy discussion of this case, admittedly a "mental exercise", makes it clear that Oresme has in mind the existence of an entire world consisting of earth and heavens within our earth, or alternatively one enclosing our cosmos, and in yet a third version "we might assume another world like our own to exist in the moon or some other star." Oresme concludes that although these cases seem absurd, the contrary cannot be proven by either reason or experience, but "it is good to have considered whether such opinion is impossible."

Finally, Oresme comes to the most substantive case.

> The third manner of speculating about the possibility of several worlds is that one world should be conceived entirely outside the other in space imagined to exist, as Anaxagoras held. This solitary type of other world is refuted here by Aristotle as impossible. But it seems to me that his arguments are not clearly conclusive ...[53]

Here we come to grips once again with the old issues. Against Aristotle's argument from natural place, Oresme finds it necessary to formulate a new definition of "up" and "down". These terms are not to be used in the normal absolute sense, but rather

> Up and down are used otherwise with respect to heavy and light objects, as when we say the heavy bodies tend downward and the light tend upward. Therefore, I say that up and down in this second usage indicate nothing more than <u>the natural law concerning heavy and light bodies</u>, which is that all the heavy bodies so far as possible are located in the middle of the light bodies without setting up for them any other motionless or natural place.[54]

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In one stroke, Oresme transfers significance from the earth-outer sphere relation to a heavy body-light body relation. The new relation is solely in terms of the heavy and light bodies, wherever they may be without reference to our world. Naturally speaking, these bodies exist nowhere except in our world, and thus "taking up in the second sense above, beyond or outside of this circumference or heaven there is no up nor down."[55] Thus if God were to create an earth or a particle of earth outside of our world, "this earth would have no tendency whatsoever to be moved toward the center of our world," for according to Oresme's definition both heavy and light bodies in association are needed to define up and down. And if God would create another world in its entirety, including both heavy and light bodies, then the natural law does become operative, and since this natural law is the only condition that needs to be satisfied, there is no contradiction about movement being violent with respect to one center and natural with respect to another. In essence Oresme is denying Aristotle's main argument, and also the insistence of Aquinas that all things in the universe have relation to one another. Two worlds sufficiently removed need not have relation to one another, but only to their own parts. Thus God does not suspend natural law except for the moment of creation of a new world; after this, natural law again takes its course.

To the related argument that since all parts of our

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earth tend toward one place in number, then the earth of each of the other worlds taken together should tend toward one place in number, Oresme simply declares that they need only tend toward one place in form or species. Thus, all the particles of earth in the other world would tend toward the center of that world, "and these two bodies or masses would be of one kind, their natural places would be formally identical, and likewise the two worlds."[56]

To the argument from form and matter which Aristotle disproved by claiming that our world contained all existing matter, Oresme counters that God could create more matter ex nihilo; but realizing that Aristotle would not admit this, Oresme does not hesitate to confront him directly by pointing out that "he does not prove that another or more than one world besides our own could not now exist, or may not always have existed, just as he states this world of ours to exist without beginning or end."[57] Finally, in answer to Aristotle's metaphysical argument that one prime mover could move only one world, Oresme reasserts an answer with which Bishop Tempier would have been happy: that the Christian God "is infinite in His immensity, and if several worlds existed, no one of them would be outside Him nor outside His power."[58]

With the claim that matter can exist outside our world, Oresme has opened a Pandora's box of implications. For Aristotle's argument against the existence of place, void,

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or time outside the world was based in part on the assertion that no body could exist there. By maintaining that matter can exist there, and by natural law newly defined, Oresme opens the possibility of the existence of place, void, and time beyond the world. It is an implication which does not escape the scrutiny of Oresme, and he declares that these things are in fact possible. Moreover, unlike Ockham, he argues for their existence beyond the fact that he believes there can be body outside our world. The idea that there is space beyond our world seems to Oresme "a reasonable opinion." For example, if God created a hump on the outermost heaven, then this hump of the circularly moving heaven would have to move through the void. Again, if God destroyed everything below the sphere of the moon, but the heavens remained, "it would necessarily follow that in this concavity there would be a great expanse and empty space."[59]

These thought experiments were not original with Oresme, but more than anyone else he grasps the radically new view of the world toward which they point.

> Outside the heavens, then, is an empty incorporeal space quite different from any other plenum or corporeal space ... this space of which we are talking is infinite and indivisible, and is the immensity of God and God Himself .... Since apperception of our understanding depends upon our corporeal senses, we cannot comprehend nor conceive this incorporeal space which exists beyond the heavens. Reason and truth, however, informs us that it exists.[60]

All of this is bound up with the discussion of the Aristotelian concept of a plurality of worlds, and Oresme now comes full

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circle and confidently concludes "that God can and could in His omnipotence make another world besides this one or several like or unlike it. Nor will Aristotle or anyone else be able to prove completely the contrary." But Oresme's final sentence on the subject expresses the traditional Scholastic opinion. Now matter how effectively Aristotle's arguments have been destroyed, "there has never been nor will there be more than world."

In Oresme we see how far the Scholastic tradition, propelled by the condemnation of 1277, has gone toward undermining Aristotle, yet how close even this advanced medieval thinker remained in the end to the belief of Aristotle that there were not in fact more worlds than one. The thirteenth and fourteenth centuries saw the evolution of plurality of worlds from impossibility, to theological possibility, to natural possibility, but never to reality. That evolution is perhaps a prime example of the uniquely medieval mixture of boldness and conservatism, of the appeal to reason still dominated by appeal to authority. But it is small wonder that Albertus Magnus, often termed one of the most "scientific" of the Scholastics from a modern viewpoint, considered a plurality of worlds "one of the most wondrous and noble questions in nature." Even before theological necessity set a new course for the question, it was not difficult to perceive its essential intimacy with Aristotelian principles: the concepts of natural motion and natural place, the associated notion of "heaviness",

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the denial of the void, all fell within the realm of its discussion. Surely Albert's judgement of the situation in the thirteenth century, made as Aquinas was still formulating his ideas, was even more true for the fourteenth.

* * *

The critical discussion of the plurality of worlds concept in Aristotelian terms did not come to an end with Oresme or the fourteenth century. The fate of the question in the fifteenth and sixteenth century commentaries on De caelo is not well known and demands further research, as does the whole question of the relationship between medieval and Renaissance science. But some plausible generalizations can be made based upon a variety of evidence. Duhem's brief examination of two fifteenth century figures, Paul Nicoletti of Venice and John Major, is sufficient to show that no consensus was reached on the subject during the transition period. On the one hand Paul of Venice in his Summa totius philosophiae still held to Albert of Saxony's position that no worlds could exist unless God permanently suspended the laws of nature, a position even more conservative than that of Buridan a century before.[61] On the other hand the Scottish theologian and Parisian master John Major (1469-1550) made the startling assertion that there was no barrier to the natural existence of even an infinite number of worlds.[62]

The case of an infinite number of worlds had already

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been broached by the Spanish Jew Hasdai Crescas (1340-1410) at the beginning of the fifteenth century, but was not positively asserted even though he destroyed many of Aristotle's arguments.[63] In contrast Major's Propositum de infinito not only demolished Aristotle's arguments against infinity, but also asserted that infinite magnitudes were a reality in nature. One of the proofs of this was his assertion of an infinite number of worlds, and this naturaliter loquendo, against which Major held every argument of Aristotle could be easily refuted.

> As to the stated confirmation, it seems to me that naturaliter loquendo one cannot prove in a convincing manner the opinion opposed to ours, to know that there exists only a single world, meaning by mundus, conforming to the common usage, the aggregate of celestial spheres and that which they enclose. If you say that all those worlds together form only a single world, you do not yourself understand your own words; Aristotle had nothing to say using that meaning. I believe, as the master Democritus thought, that there are an infinite number of excentric and perhaps concentric worlds. If you say there is void space between the worlds, I respond that this argument is equally valid against Aristotle, because there actually is void outside of the heavens. Aristotle argued very subtly that the heavens did not extend to infinity, but that affirmation is not valid, first, because his arguments against a plurality of worlds do not follow, secondly, because his arguments against the infinity of the heavens do not follow ... If you ask of me the reasons I conclude a plurality of worlds, I ask you what are those by which you conclude the opposite opinion, and this I say naturaliter loquendo.[64]

Although Major could give no more positive argument for other worlds than the pourquoi non expressed above, the open defiance of Aristotle demonstrates once again how far the Scholastic tradition had carried some, even to the point of invoking favorably the name of Democritus.

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Duhem's research has also shown the influence of the plurality of worlds discussion on a much more famous Renaissance figure - Leonardo da Vinci (1452-1519).[65] At least one specific passage in Leonardo's notebooks indicates that he was directly influenced by Albert of Saxony's discussion of a plurality of worlds. Here Leonardo posed the problem of what would happen to a body placed at an equal distance between two worlds, and concluded that it would go to the center of neither, but would stop at a point equidistant from both centers. Duhem finds that the smallest details of Leonardo's discussion have been suggested by Albert's commentary on De caelo, from which Leonardo elsewhere quotes verbatim.

The Scholastic discussion of other worlds thus impinged upon Leonardo's mind in connection with the physical problem of the "composition of forces", but it has also been pointed out that Leonardo associated it with the problem of infinity, and that in this latter association he was sympathetic to the natural possibility of other worlds.[66] Leonardo's belief that our cosmos was finite, but that a possible infinite void stretched beyond that cosmos, provided a receptacle for other worlds in a way which seems to go beyond the usual Scholastic conception of an "imaginary extramundane space".[67] Linked with his solution to the problem of the composition of forces - that there can indeed be more than one center of force - Leonardo's acceptance of an infinite magnitude allowed him to overcome Albert of Saxony's conclusion that

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other worlds would be possible only by the perpetual supernatural suspension of natural law.

Even more - and this is a crucial point - Leonardo's notebooks show that he did not even regard the earth as the only center of attraction within our own cosmos. They reveal his belief that "the earth is a star" and that in a proposed book he intended " to show, how the ocean and the other seas must, by means of the sun, make our world shine with the appearance of a moon, and to the remoter worlds it looks like a star; and this I shall prove."[68] The comparison of the earth with the moon and other celestial bodies is important, and for the moon Leonardo carried his argument much further than appearances. He pondered "as to whether the moon is situated in the center of its elements or not. And, if it has no proper place of its own, like the earth, in the midst of its elements, why does it not fall to the centre of our elements."[69] Repeating the question later - how could the moon sustain itself in space? - Leonardo answered "But as this does not happen, as might in reason be expected [that the moon would fall from the sky] it is a manifest sign that the moon is surrounded by its own elements: that is to say water, air and fire; and thus is, of itself and by itself, suspended in that part of space, as our earth with its element is in this part of space; and that heavy bodies act in the midst of its elements just as other heavy bodies do in ours."[70] These ideas are bold and original, but not entirely unique in the fifteenth and

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sixteenth centuries. Part of Plutarch's Moralia, first printed by Aldus in 1509, was a treatise De facie in orbe lunae which contained the same ideas as to the composition of the moon and its role as a center of motion.[71] And even before this, there were the works of the German theologian, philosopher, and Cardinal Nicholas of Cusa (1401-1464), whom Duhem has shown exerted a substantial influence on Leonardo in many ways.[72]

These two figures, Leonardo and Cusa, represent an important juncture in the plurality of worlds tradition, not for any immediate influence they exerted on the debate, but rather because their ideas anticipate the future direction of the controversy and the means by which the shift was made to the concept of the celestial bodies themselves as worlds. Cusa's universe was devoid of an absolute center because it was boundless; in Cusa's phrase its "center is everywhere and its circumference nowhere," a characterization normally applied to God himself.[73] There was therefore no barrier to the existence of other worlds in such an homogenous space. In addition Cusa sought to homogenize the earth and celestial bodies, and accordingly asserted the similarity of their composition, argued for the nobility of the earth as "a stately and spherical figure whose movement is circular," and characterized it as a "brilliant star having a light, heat and influence distinctively its own."[74] Most of these ideas are echoed in Leonardo.

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Although Cusa was mistaken in his belief that the earth and moon had their own intrinsic light like the sun - and here Leonardo did not follow him - the important point is that all celestial bodies were now composed of the same elements, including the sun: "Like the earth, the sun has its peculiar constitution. On examination the body of the sun is found to be disposed like this: nearer the centre there is a sort of earth, at the circumference a sort of fiery brightness and midway between them a kind of watery cloud and clearer air."[75] This is precisely the old Aristotelian structure of the terrestrial region, and although Cusa does not discuss the kinematic consequences of his assertion at this point, the implications are inescapable. In such a universe there are as many centers of attraction as there are celestial bodies. The point was not lost to the mind of Leonardo, and it seems likely that it was through this concept of "center of attraction" that the plurality of worlds tradition shifted its focus of attention from the plurality of Aristotelian kosmoi to the plurality of earth-like planets.

Cusa is important for another reason, which is again associated with his desire to place the earth high among the rank of celestial bodies even in a boundless universe. His assertion of life throughout the universe was even more bold, original, and dangerous than his belief in a boundless homogenous universe; not since Epicurus and Lucretius had mentioned in passing that the seeds of life were undoubtedly

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spread through innumerable worlds had this been a prominent idea. But Cusa stresses the point without apology, and argues that the inhabitants of the earth cannot denigrate its nobility.

> Life, as it exists here on earth in the form of men, animals and plants, is to be found, let us suppose, in a higher form in the solar and stellar regions. Rather than think that so many stars and parts of the heavens are uninhabited and that this earth of ours alone is peopled - and that with beings, perhaps of an inferior type - we will suppose that in every region there are inhabitants, differing in nature by rank and all owing their origin to God, who is the centre and circumference of all stellar regions.[76]

Although the inhabitants of the earth itself might not be the highest form in the whole scale of nature throughout the universe, Cusa nevertheless holds that "even if inhabitants of another kind should exist in the other stars, it seems inconceivable that, in the line of nature, anything more noble and perfect could be found than the intellectual nature that exists here on this earth and its region."[77] At least, then, when "this earth and its region" are considered together - the earth, the visible planets, and the sun itself - our part of the universe is found to be as noble as any other, by virtue of the excellence of the solar inhabitants:

> It may be conjectured that in the area of the sun there exist solar beings, bright and enlightened intellectual denizens, and by nature more spiritual than such as may inhabit the moon - who are possibly lunatics - whilst those on earth are more gross and material. It may be supposed that those solar intelligences are highly actualized and little in potency, while the earth-denizens are much in potency and little in act, and the moon-dwellers betwixt and between.[78]

In spite of his boundless universe, Cusa has set up a kind of

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intellectual hierarchy, one not based on spatial position but rather on the composition of a particular celestial body. Although all are in fact of the same composition, some of the celestial bodies have a predominance of certain elements which affects the nature of their inhabitants, so that Cusa could state that he made his conjectures "from a consideration of the fiery nature of the sun, the water and air elements in the moon and the weighty bulk of the earth."

It was a bold view of the universe, one in which man had a definite place of honor, so much so that he "has no longing for any other nature but desires only to be perfect in his own." The assertion of celestial life had very little to do with Aristotle, except that along with Cusa's whole program to confer upon the earth the status of a celestial body, it was antithetical to Aristotle's natural philosophy. As Lovejoy has pointed out, the rationale for Cusa's inhabitants as for his entire system was metaphysical, and involved theology and the principles of plenitude and sufficient reason.[79] Still, Cusa is a turning point, because for the first time he extended the scale of living being beyond the earth and indeed into the whole universe: "And we may make parallel surmise of other stellar areas that none of them lack inhabitants, as being each, like the world we live in, a particular area of one universe, which contains as many such areas as there are uncountable stars."[80]

We do not know what Leonardo made of these passages regarding life; although he did not positively exclude the

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possibility of life, neither did he affirm it.[81] The assertion that the moon and each of the celestial bodies was a world in the sense of acting as a center of attraction was bold enough in itself, but the question of celestial life raised even more problems. Nevertheless, there is evidence that this latter question was beginning to come to the fore as part of the natural evolution of the Scholastic tradition, although with much more caution than was shown by the cardinal Cusa. An examination of the Sentence commentary of Cusa's contemporary William of Vorilong reveals that the question of life was raised in Distinction XLIV of Book I, that very Distinction in which Ockham in the fourteenth century had redefined Aristotle's concept of natural place in connection with the existance of other worlds.

> If it be inquired whether a whole world is able to be made more perfect than this universe, I answer that not one world alone, but that infinite worlds, more perfect than this one, lie hid in the mind of God. If Democritus, who posits actual infinite worlds, rightly understood this fact, he would have understood rightly.
>
> Now doubt arises, by what means we are able to have knowledge of that world. I answer by angelic revelation or by divine means. If it be inquired whether men exist on that world, and whether they have sinned as Adam sinned, I answer no, for they would not exist in sin and did not spring from Adam. But it is shown that they would exist from the virtue of God, transported into that world, as Enoch and Elias (Helyas) in the earthly paradise. As to the question whether Christ by dying on this earth could redeem the inhabitants of another world, I answer that he is able to do this even if the worlds were infinite, but it would not be fitting for Him to go into another world that he must die again.[82]

The invocation of Democritus and his belief in infinite

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worlds, the focus on the question of life, and the serious thought given to the reinterpretation of fundamental Christian beliefs, presage a new direction for the plurality of worlds tradition, even if other worlds are not here positively asserted.

In both the concept of a celestial body as a world in itself, a center of attraction, and in the question of extraterrestrial life there is thus an association between the medieval and the Renaissance-seventeenth century traditions of a plurality of worlds. This is clearly evident in Giordano Bruno's De l' infinito universo et mondi (1584), which cannot be understood without a knowledge of the Aristotelian arguments, but which must also be looked at in light of the new heliocentric theory of Copernicus.

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NOTES

[1] Alberti Magni opera omnia (Aschendorff, 1971), vol. V, part I, p. 55. My translation from the Latin.

[2] Dorothea W. Singer, Giordano Bruno: His Life and Thought. With an annotated translation of his work On the Infinite Universe and Worlds (New York, 1950), p. 275.

[3] The subject arises four times in the Physics and once in the Metaphysics. It first comes up in Book II of the Physics where Aristotle is discussing natural science and explanation, and specifically opinions concerning luck and chance: "Some indeed attribute our Heaven and all the worlds to chance happenings, saying that the vortex and shifting that disentangled the chaos and established the cosmic order came by chance." trans. Philip H. Wicksteed and F. M. Cornford, Loeb Classical Library (Cambridge, Mass., 1935), Book II, ch. 4, 196a 25 ff. Unlike the atomists, Aristotle goes on to say that he is unwilling to assert the operation of chance in the heavens, precisely the place where we see the most regular movements. In Book III, ch. 4 Aristotle recounts some considerations which lead to the conviction (for others) that the infinite exists, and says that "The most effective consideration, the weight of which all thinkers alike have felt, is that the imagination can always conceive a 'beyond' reaching out from any limit, so that the series of numerals seems to have no limit, nor mathematical magnitudes, nor the 'beyond the heavens'. Moreover, it seems to follow from the 'beyond' being unlimited that 'body' must be unlimited, and that there must be unlimited worlds. For why should there be more vacancy in one place than in another? So if mass is anywhere, must it not be everywhere?" 203b 20 ff. Aristotle in the end wishes to refute the existence of an infinite, and this particular argument for the infinite he refutes only by saying that it is absurd to rely on our imagination.

In Book IV, ch. 10 in the midst of his discussion of time, Aristotle notes that if time is identified with the revolution of the heavens, then "if there were more universes than one, the reentrant circumlations of each of them would be time, so that several different times would exist at once." 218b 6 ff. The implication is that there cannot be more than one world. Finally, in the opening paragraphs of Book VIII in the discussion on movement as ungenerated and incorruptible, there is the following passage: "Whereas those who believe in innumerable cosmoi, some coming into being and others passing out of it, say that motion is ever existing, for the

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3 (cont.) genesis and evanishment of these cosmoi must needs involve motion, those on the other hand who believe that there is a single cosmos, and perhaps that there is not always a cosmos in existence hold views as to motion consonant with their general theory." 250b 19 ff. It is notable that in all four of these passages in the Physics, there is no hint of the arguments against the plurality of worlds which will be found in De caelo.

The brief argument given in the Metaphysics consists of the assertion that there is only one world because there is only one prime mover: "It is evident that there is only one heaven. For if there is a plurality of heavens (ouranoi)(as there is of men), the principle of each must be one in kind but many in number. But all things which are many in number have matter (for one and the same definition applies to many individuals, e.g. that of 'man'; but Socrates is one), but the primary essence has no matter, because it is complete reality. Therefore the prime mover, which is immovable, is one both in formula and in number; and therefore so also is that which is eternally and continuously in motion. Therefore there is only one heaven." trans. Hugh Tredennick, Loeb Classical Library (London, 1961), Book XII, ch. 8, 1074a 33 ff. Tredennick notes that this passage may belong to an earlier period of Aristotle's thought, since he asserts elsewhere that there are 55 immaterial movers.

4 On the Heavens, trans. W.K.C. Guthrie, Loeb Classical Library (London, 1953), 274a 24-28.

5 Aristotle makes explicit reference to the atomist belief in the Physics; see note 3 above.

6 For the Epicurean definition of a world, see p. 9 above. Aristotle speaks both of a plurality of kosmoi and a plurality of ouranoi, where the former is a special instance of the latter. It is interesting that already in the fourth century B.C. Aristotle saw the necessity of distinguishing the various meanings of ouranos: "Let us first establish what we mean by ouranos, and in how many senses the word is used, in order that we may more clearly understand the object of our questions. (1) In one sense we apply the word ouranos to the substance of the outermost circumference of the world, or to the natural body which is at the outermost circumference of the world; for it is customary to give the name of ouranos especially to the outermost and uppermost region, in which also we believe all divinity to have its seat. (2) Secondly we apply it to that body which occupies the next place to the outermost circumference of the world, in which are the moon and the sun and certain of the stars; for these, we say, are in the ouranos. (3) We apply the word in yet another sense to the body which is enclosed by the outermost circumference; for it is customary to give the name of ouranos to the world

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6 (cont.) as a whole." 278b 10-21. Aristotle makes it clear that he is using the latter meaning in the plurality of worlds discussion, so that even when he speaks of plurality of ouranoi, he is always referring to ouranos as kosmos. The Latin commentators translated these Greek words faithfully as caelum and mundus respectively.

7 F. M. Cornford, Plato's Cosmology: the Timaeus of Plato (New York, 1937), p. 42.

8 On the Heavens, I, 8, 276b 12 ff.

9 Ibid., 276a 31 ff.

10 Ibid., 276b 7 ff.

11 Ibid., 277a 1 ff.

12 Ibid., 277a 11 ff.

13 Ibid., 278a 15 ff.

14 Ibid., 278b 8 ff.

15 Ibid., 277b 10 ff. On this passage see the end of note 3 above.

16 I have found no trace of a medieval plurality of worlds tradition in the Latin West before the entry of De caelo. It does not appear to have been discussed in the school of Chartres, which was nevertheless interested in the structure of the cosmos. Again, although Adelard's Questiones naturales poses several questions of a cosmological nature, he does not hint at the subject of other worlds. And Peter Lombard's Sentences, although a source for later speculation on the plurality of worlds (see below), does not itself mention that doctrine. Grant McColley notes that at mid-twelfth century, the Decretum of Franciscus Gratianus condemned under the heading "other heresies without author and without name" that "aliae innumerabiles mundos opinantur." "The Seventeenth Century Doctrine of a Plurality of Worlds," Annals of Science, I (1936), p. 395.

17 Charles Homer Haskins, The Renaissance of the Twelfth Century (Cambridge, 1928). On the recovery of Aristotelian texts in the West see Fernand Van Steenberghen, Aristotle in the West: the Origins of Latin Aristotelianism (Louvain, 1970). On the earlier tradition in the East see F. E. Peters, Aristotle and the Arabs: The Aristotelian Tradition in Islam (New York, 1968).

18 Pierre Duhem, Le système du monde (Paris, 1958), vol. IX, pp. 363-430. Also his Études sur Léonard de Vinci (Paris, 1955), vol. II, pp. 57-96 and pp. 408-423.

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[19] Système, pp. 365-369.

[20] Ibid., pp. 370-373.

[21] Ibid., pp. 373-378.

[22] Ibid., pp. 380-387.

[23] Ibid., pp. 389-408 for Oresme and the 14th century thinkers.

[24] Ibid., pp. 387-389 and pp. 395-399.

[25] The Opus Majus of Roger Bacon, trans. Robert Burke (Philadelphia, 1928), vol. I, p. 185: "Whether there can be more universes and whether the matter of the universe may be extended to infinity." Burke's translation of mundus as "universe" is unfortunate in the context of this question. For the original Latin see The Opus Majus of Roger Bacon, ed. John Henry Bridges (London, 1900), vol. 1, p. 164: "An possint esse plures mundi, et an materia mundi sit extensa in infinitum."

[26] Expositio in Aristotelis libros de caelo et mundo (Romae, 1952), Lectio XVI, pp. 76 ff.

[27] Duhem has pointed this out in both the Systeme and the Études; see especially Études, II, p. 72.

[28] Expositio, Lectio XX, pp. 96 ff.

[29] Ibid., Lectio XIX, p. 94.

[30] The "Summa Theologica" of St. Thomas Aquinas, trans. Fathers of the English Dominican Province (London, 1921), Part I, question 47, article 3: "Whether there is only one world?"

[31] Ibid., pp. 261-62.

[32] Ibid., p. 262.

[33] Quaestiones super libris quattuor de caelo et mundo, ed. Ernest A. Moody (Cambridge, Mass, 1942), p. 84: "Utrum, si essent plures mundi, terra unius mundi moveretur naturaliter ad medium alterius mundi." All translations from Buridan are my own.

[34] Ibid., p. 85.

[35] Ibid., p. 86.

[36] Ibid., p. 85.

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[37] Ibid., p. 87.

[38] Ibid., p. 87, quaestio 19: "Utrum possibile est esse plures mundos."

[39] Ibid., p. 89.

[40] Peter Lombard, In quattour libros sententiarum (Frankfurt a.M., 1967), columns 640-641: "An Deus possit facere aliquid melius quam facit."

[41] "Utrum Deus potuerit facere universum melius" in the Sentence commentary of Thomas Aquinas discussed below and outlined on page 88 below. My translation from Scriptum super libros sententiarum magistri Petri Lombardi episcopi parisiensis (Paris, 1929-1947), vol. I, Distinction XLIV, quaestio I, Article II, pp. 1018-1021.

[42] Opera plurima: super 4 libros sententiarum, in sententiarum I (Belgium, 1962), vol. III, Distinction XLIV" "Utrum deus posse facere mundum meliore isto mundo". All translations from Ockham are my own.

[43] Ibid., sections B and C.

[44] Ibid., section E.

[45] Ibid., sections C and D. For a fuller discussion of this argument and some of Ockham's other arguments, see Mary Anne Pernoud, "Tradition and Innovation in Ockham's Theory of the Possibility of other Worlds," Antonianum, 48 (1973), p. 216.

[46] Ibid., section E.

[47] Ibid., section F.

[48] Ibid., section F.

[49] It is these broader elements to which Mary Ann Pernoud gives most attention in "Tradition and Innovation in Ockham's Theory of the Possibility of other Worlds," Antonianum, 48 (1973), pp. 209-229. Of Ockham's discussion of other worlds in Distinction XLIV she concludes "The basic assumption upon which these conclusions are based is Ockham's insistence upon the power of God to create, conserve and annihilate one individual thing without essentially affecting another. This power necessarily demands the unique individuality and separability of each singular thing, for should things share any sort of universal, God would be unable to annihilate one individual without at the same time destroying the universal within it which is also within others and would so affect them essentially."

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[50] Le livre du ciel et du monde, eds. Albert Menut and Alexander Denomy, trans. Albert Menut (Madison, 1968), pp. 167-79.

[51] Ibid., p. 167. For the passage in St. Jerome, Menut and Denomy cite Sancti Eusebii Hieronymi epistulae, CXXIV, ad Avitum, ed. Isidorus Hilberg (Vienna, 1918), pp. 101, 107. Origen was a third century Christian theologian at Alexandria. His early work De principiis favored the idea of successive worlds.

[52] Ibid., p. 167.

[53] Ibid., p. 171.

[54] Ibid., p. 173.

[55] Ibid., p. 173.

[56] Ibid., p. 175.

[57] Ibid., p. 175.

[58] Ibid., p. 175.

[59] Ibid., p. 177.

[60] Ibid., pp. 177-179.

[61] Pierre Duhem, Etudes sur Leonardo de Vinci (Paris, 1955), vol. II, pp. 91-92.

[62] Ibid., p. 92-94.

[63] H. A. Wolfson, Crescas' Critique of Aristotle (Cambridge, 1929), pp. 215-217. "For having first proved to his own satisfaction that outside the world there is neither a plenum nor a vacuum, he argued therefrom that there cannot be many worlds, and he further argued that if there were many worlds the elements would move from one world to another, to which arguments he added many other fanciful speculations and 'words that increase vanity'. But since the error of his initial premise is manifest, for it has already been shown before that an infinite magnitude must exist and that outside the world there must exist an infinite plenum or vacuum, it clearly follows that the existence of many worlds is possible. Nor can it be contended that the elements would move from one world to another, for it is quite possible that each element would move within the periphery of its own sphere towards its own suitable place. Thus everything said in negation of the possibility of many worlds is 'vanity and a striving after the wind.'"

"Inasmuch as the existence of many worlds is a possibility true and unimpeachable, yet as we are unable by means of

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63 (cont.) mere speculation to ascertain the true nature of what is outside this world, our sages, peace be upon them, have seen fit to warn against searching and inquiring into 'what is above and what is below, what is before and what is behind.'"

64 Le Traite 'De l' infini' de Jean Mair, ed. and trans. (French) Hubert Elie (Paris, 1938), p. . My translation. This treatise first appeared in a 1506 edition of Major's first complete logical treatise.

65 Études sur Léonard de Vinci, vol. II, pp. 57-96; especially pp. 57-59 and 94-96. In his independent research on the plurality of worlds tradition Grant McColley has come to the surprising conclusion that the opposition to the doctrine increased in the fifteenth and sixteenth centuries to a pre-1277 level. In addition to Paul of Venice, he cites the rejections of John the Master and Caitan of Tiene. He notes that Marsilio Ficino used a theological-Platonic argument that the world is one because its cause is one. John of Celaya held that the Catholic faith provided no authority for a belief in other worlds, and Luiz Nunez (apparently referring to the Decretum of Gratianum) asserted that the proposition was condemned and that Catholics should not regard it as an open question. The famous encyclopedist Giorgio Valla also rejected a plurality or infinity of worlds according to McColley. "The Seventeenth Century Doctrine of a Plurality of Worlds," Annals of Science, I (1936), pp. 403-405. This demonstrates once again that the Scholastic tradition was not a process of unanimous progress away from Aristotle. But there were undoubtedly many who followed the more liberal line of thought of Leonardo and Cusa, whom we will now discuss.

66 Paul-Henri Michel, "Léonard de Vinci et le problem de la pluralite des mondes," Léonard de Vinci et l' experience scientifique au XVIe siecle (Paris, 1953), pp. 34-38.

67 On the traditional scholastic conception, see Edward Grant, "Medieval and Seventeenth Century Conceptions of an Infinite Void Space beyond the Cosmos," ISIS, vol. 60, no. 201 (1969), pp. 39-60.

68 The Notebooks of Leonardo Da Vinci, ed. Jean Paul Richter (New York, 1970; first published London, 1883 under the title The Literary Works of Leonardo da Vinci), p. 139, no. 865 and p. 144, no. 874.

69 Ibid., p. 155, no. 892.

70 Ibid., p. 163, no. 902.

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[71] "If there is a body, however, that was not originally allotted to the earth or detached from it but has somewhere independently a constitution and nature of its own, as those men would say of the moon, what is to hinder it from being permanently separate in its own place, compressed and bound together by its own parts? For it has not been proved that the earth is the centre of the sum of things, and the way in which things in our region press together and concentrate upon the earth suggests how in all probability things in that region converge upon the moon and remain there. The man who drives together into a single region all earthy and heavy things and makes them part of a single body - I do not see for what reason he does not apply the same compulsion to light objects in their turn but allows so many separate concentrations of fire and, since he does not collect all the stars together, clearly does not think that there must also be a body common to all things that are fiery and have an upward tendency." Plutarch's Moralia: Concerning the Face which Appears in the Orb of the Moon, trans. Harold Cherniss, Loeb Classical Library (London, 1957), vol. XII, p. 71. See also Duhem, Système, vol. IX, pp. 409-430. On the editio princeps of Plutarch's Moralia see John Edwin Sandys, A History of Classical Scholarship (New York, 1964), vol. II, p. 104.

[72] Duhem, Etudes, vol. II, pp. 97-280: "Nicolas de Cues et Leonard de Vinci."

[73] Of Learned Ignorance, trans. Fr. Germain Heron (New Haven, 1954), p. 111. On Cusa's conception of a boundless universe see Alexandre Koyré, From the Closed World to the Infinite Universe (Baltimore, 1970), pp. 5-24.

[74] Ibid., pp. 112-113.

[75] Ibid., p. 112. Leonardo believed that the moon's light was actually sunlight reflected by the lunar seas: "The moon has no light in itself; but so much of it as faces the sun is illuminated, and of that illumined portion we see so much as faces the earth. And the moon's night receives just as much light as is lent it by our waters as they reflect the image of the sun, which is mirrored in all those waters which are on the side towards the sun. The outside or surface of the waters forming the seas of the moon and of the seas of our globe is always ruffled little or much, or more or less - and this roughness causes an extension of the numberless images of the sun which are repeated in the ridges and hollows, the sides and fronts of the innumerable waves ... ". Notebooks, p. 157. Leonardo was in the majority of his contemporaries in thinking that the moon had no light of its own, but in the minority when he asserted the existence of water on the moon.

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[76] Ibid., pp. 114-115. For the Latin original see Nicolai de Cusa de docta ignorantia, eds. Ernest Hoffmann and Raymund Klibansky (Lipsiae, 1932), p. 107.

[77] Ibid., p. 115.

[78] Ibid., p. 116.

[79] Arthur O. Lovejoy, The Great Chain of Being (Cambridge, Mass., 1971), pp. 112-115.

[80] Of Learned Ignorance, p. 116.

[81] Paul-Henri Michel, "Leonard De Vinci ...", p. 38.

[82] Grant McColley and H.W. Miller, "Saint Bonaventure, Francis Mayron, William Vorilong, and the Doctrine of a Plurality of Worlds," Speculum, XII (1937), p. 388. McColley and Miller note that in the century following Vorilong, the doctrine of inhabited worlds was attacked on religious grounds by Melancthon, Initia doctrinae physicae (Wittenberg, 1567), Lambert Daneau, Physica christiana, English trans. The Wonderfull Workmanship of the World (London, 1578), and undoubtedly others.

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Chapter Three

The Heliocentric Theory and the Plurality of Earths

> May the Peripatetics therefore not be angry with Plutarch because he has placed the earth in the heavens, that is, because he treats the body of the moon to be earth-like, since they can see that it is settled by very certain experiments, in that indeed the moon proves to be of the same nature as our earth in the participation of light. Indeed, then, when Plutarch and Maestlin will have been accepted with unprejudiced ears in philosophy, then Aristarchus with his student Copernicus may well begin to hope.
>
> Kepler[1] 1604

One might have expected with good reason that the Renaissance and seventeenth century would witness the demise of the plurality of worlds tradition. The pros and cons of the Aristotelian arguments had been repeatedly and fully exploited, but even more to the point, the Aristotelian cosmos itself - the very world which had been the object of the classical debate that we have recorded in previous chapters - was at this time crumbling under the assault on Aristotelian physical principles.[2] In the wake of the scientific revolution, the plurality of worlds discussion should have become a relic of an abandoned system. Such was not the case. To be sure, there were some who continued the old discussion in accordance with their world view. But the more important development was that the conception of other worlds became dissociated from the fate of the cosmos: the very meaning of the question changed in the same way as the essential terms of many questions changed in the seventeenth century.

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In the year 1584 there erupted onto the European scene a detailed and systematic discussion of other worlds in a new sense, related to the old, but with firm ties to the new science. That year saw the young Giordano Bruno arrive in Oxford to spread his radically new ideas on natural and moral philosophy. No small part of that natural philosophy was a profound belief not only in a plurality of worlds but in an infinity of them. For Bruno, however, the sphere of fixed stars which had marked the limits of the cosmos was abolished, as were the crystalline spheres of the planets which had carried them around the central earth. That earth itself was now termed a world, and so too were the other planets. Indeed, every visible star now became a fiery world around which their earthy worlds revolved. With this new understanding, the plurality of worlds tradition embarked with renewed vitality upon a history which continues today.

It is striking that this abrupt change of the essential terms in which our subject was discussed came about less than a half-century after the De revolutionibus of Copernicus was published. A prima facie case can easily be made for the heliocentric theory as a causal factor for this change, for it was Copernicus who gave the earth and planets the same kinematic status and thus raised the question as to whether the planets were not similar to the earth in composition and function. Since Bruno was a Copernican, we may well ask whether his belief in other worlds stemmed from his

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knowledge of that system. The question of the debt of Bruno to Copernicus is part of the larger problem of the mutual relationship between the Copernican theory and the plurality of worlds as a doctrine known to have been widely espoused in the seventeenth century.[3] In this chapter we will examine that relationship in the first century of Copernicanism, a period which ends with the early works of John Wilkins.

It is necessary to insist at the outset that the plurality of worlds doctrine and the heliocentric theory as propounded in the De revolutionibus are not coextensive; in what follows we must separate Copernicus from Copernicanism, just as Darwin can and must be distinguished from Darwinism. Copernicus' primary aim was not to make earths of the planets in every respect, or in any respect for that matter, but rather to account for the phenomena by a system based on consistent principles and hypotheses, something which he perceived that past mathematicians had failed to achieve. The single consistent hypothesis that the earth was in motion achieved that goal. Copernicus thus insisted that the motion of the earth and the planets was the same; all moved alike around the sun.

The concern and the achievement of the De revolutionibus was the construction of a detailed technical system based on that principle of terrestrial motion, and while Copernicus certainly put forth a theory which he believed represented physical reality, he showed little interest in the physical implications of his theory. One of those implications, and

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the one of most immediate and paramount importance, centered around the very fact of terrestrial orbital motion, for many non-trivial common-sensical arguments could be brought against such a view, not to mention the fact that it destroyed the Aristotelian physics of motion which depended upon a central immovable earth. This set of arguments is well known and its importance much appreciated by historians of science.[4] With these arguments, however, we will have very little to do here. Rather, our attention will be centered on another implication of heliocentricity whose arguments may be studied in virtual isolation from those associated with earth-motion, that of the similarity of the earth and planets in physical nature. This is the essence of the new plurality of worlds tradition - an explicit comparison of the physical characteristics of the celestial bodies and the earth, ranging from questions of composition, physical features, and environmental conditions, to the possibility of inhabitants and cities.

In short, the term "world" carries a specific denotation in which similar kinematic status may constitute a necessary but not a sufficient condition. Thus heliocentricity did not automatically confer the status of "world" upon the planets; this was an implication which had to be explicitly determined. To those who looked upon heliocentricism only as an hypothesis to facilitate calculation, it would hardly be a concern. The realists, on the other hand, would soon have to take it into account. It was an idea that went beyond the De revolutionibus to an extent which was perhaps

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uncomfortable to many Copernicans. We are thus examining the degree to which a very specific implication of heliocentricity was responsible for the rise of the new plurality of worlds tradition, and also whether this implication of the planets as worlds may have affected the acceptance of heliocentricity.

Pre-Telescopic Era

The record is clear in establishing that Bruno not only had a knowledge of the heliocentric theory of Copernicus but also was a Copernican himself.[5] The earliest of Bruno's Italian cosmological works, La cena de le ceneri (The Ash Wednesday Supper, 1584), reveals Bruno's opinion of Copernicus offered during a banquet held in London on Ash Wednesday, 1584. The book purports to record the philosophical discussion of the participants at the banquet; the Copernican theory was an important topic. Theophilus, representing the opinion of Bruno, describes Copernicus as "a grave spirit, meditative, penetrating, and mature; a man who did not surrender himself to any past astronomers and who by natural judgment has risen above Ptolemy, Hipparchus, Eudoxus, and others who are their followers, a man who freed himself from certain erroneous postulates of the common and vulgar philosophy."[6] The ensuing discussion makes it clear that Bruno accepts not only the thesis of heliocentricity and earth motion, but also advances the thesis of the infinite universe and innumerable worlds. But at no point are strong

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connections drawn between the Copernican theory and the doctrine of infinite worlds. Indeed the idea of the infinite is foreign to Copernicus.[7] Rather, Bruno sets himself off from Copernicus, remarking that he sees not by the eyes of Copernicus nor by those of Ptolemy, but by his own, when it comes to all judgments and interpretations.[8] In spite of the merits of Copernicus, Bruno emphasizes that it is only he himself who "has penetrated into the heavens, past the frontiers of the world, shattered the fantastic walls of the spheres..." and put inhabitants in the sun, moon, and other stars.[9]

The conscious contrast drawn by Bruno between himself and Copernicus does not in itself deny the possibility that Bruno's philosophy was a personal development of his Copernicanism, even in the absence of explicit lines of inference. But his other works make it clear that such an interpretation is unlikely. In another work of the same year, Bruno set out to discuss systematically and in great detail his ideas on the infinite universe and innumerable worlds. De l' infinito universo et mondi is the most important of the Italian cosmological dialogues which were a product of Bruno's years in England. It is striking for the absence of any reference to Copernicus, and only the most fleeting allusions to his theory. Here then we come face-to-face with the origin of Bruno's ideas, and there is no lack of evidence as to what those origins were.

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A passage at the opening of the treatise indicates both the roots of Bruno's philosophy and his hopes for its future, when he pronounces that what "is inseminated in the Dialogues concerning Cause, Origin and Unity and hath come to birth in these Dialogues on the Infinite Universe and Worlds shall germinate in yet others, and in others shall grow and ripen, in yet others works shall enrich us with a precious harvest that shall satisfy us exceedingly."[10]

Bruno's reference here is to yet another work published in 1584, De la causa, principio et uno,[11] in which the primacy of the concept of unity is elicited. It is this strictly metaphysical principle which is applied to the physical universe in the De l' infinito, with the result that from first principles Bruno deduces the impossibility of any dichotomy in the universe such as the celestial-terrestrial one which Aristotle taught. With this concept of unity we are still a long way from a universe filled with infinite worlds, but it is "unity" which is the driving force behind Bruno's philosophy; "It is Unity that doth enchant me",[12] he declared at the opening of the De l' infinito.

Both the De l' infinito and a later Latin work De immenso et innumerabilibus[13] treat the same basic theme. Both presentations follow the pattern of Book I of Aristotle's De caelo; the De immenso, partially in verse, is often more mature and precise in its arguments. In both works the arguments of Aristotle against the possibility of infinite magnitude are systematically refuted.[14] Bruno's own ideas

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regarding the universe and the worlds are then demonstrated,[15] and Aristotle's arguments against even a plurality of worlds are refuted one-by-one.[16] The thrust of the treatment is thus not in any way a defense of Copernicus, but rather a polemic against Aristotle. In a real sense, then, Bruno belongs to the Aristotelian tradition of plurality of worlds. Just as the Scholastics commented upon Aristotle's ideas on this subject, so did Bruno, with the crucial difference that Bruno was ready and eager to overthrow Aristotle's basic principles.

Although Aristotle's arguments dealt with many kosmoi and Bruno's with many earth-like celestial bodies, Bruno of course recognized the differences.

> Concerning this question, [of Aristotle whether beyond this world there lieth another,] you know that his interpretation of this word world [mondi] is different from ours. For we join world to world and star to star in this vast ethereal bosom, as is seemly and hath been understood by all those wise men who have believed in innumerable and infinite worlds. But he applieth the name world to an aggregate of all those ranged elements and fantastic spheres reaching to the convex surface of that primum mobile .... It will be well and expedient to overthrow his arguments insofar as they conflict with our judgment, and to ignore those which do not so conflict.[17]

Bruno thus does not fail to make clear the abyss which separates his conception from Aristotle's; but it is precisely the explicit realization of these differences which makes the two points of view variants of one and the same tradition. Henceforth, "plurality of worlds" could have another meaning, and while the old and the new lingered

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on for the best part of a century pending the destruction of the cosmos, it was the new meaning which eventually became dominant in such treatments as Fontenelle's popular Entretriens sur la pluràlité des mondes. We thus stand at a crucial juncture in the history of the plurality of worlds tradition.

Bruno's assertion, then, is one of an infinite homogeneous universe with innumerable celestial bodies. Our own earth is only one of these celestial bodies, a "star", and "the worlds are those whose brilliant shining surfaces are distinctly visible to us, and they are all placed at certain intervàls from one another."[18] All are basically of the same nature as our earth in that all are composed of the same four Aristotelian elements. On a more refined scale Bruno does distinguish between stars and planets, for "there are two sorts of bright bodies, fiery bodies which give their own primary light, and aqueous or crystalline bodies which give reflected or secondary light."[19] In some celestial bodies the element "fire" predominates, in others the element "water" predominates; there are fiery worlds (called sun) and watery worlds (called tellurial body).[20] Moreover, fiery bodies can be distinguished from earths because the former are fixed, the latter in motion, the former scintillate, the latter do not. But both types of bodies are sufficiently similar that they can harbor inhabitants.[21] Finally, these

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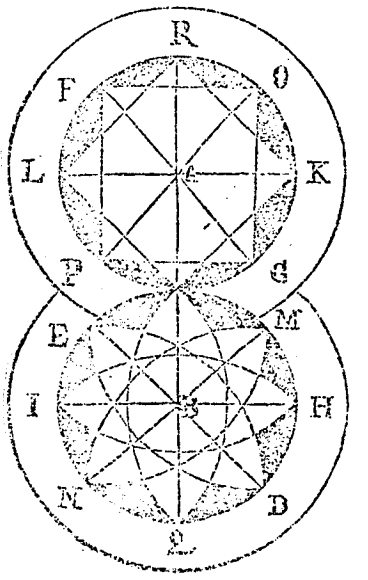
worlds move through infinite space by an internal principle which is their own soul,[22] and are divine living creatures.[23]

The arguments which Bruno uses to support this vision of the universe against that of Aristotle are both physical and metaphysical. His basic principle of the unity of the universe was that worked out in the De la causa. But how do innumerable worlds follow from a principle of unity? Bruno's conviction was that both the greatness of the divine power and the perfection of nature lay in the existence of infinite individuals. Unity, even a unity of infinite extent, was not enough. This crucial belief may be seen as an example of what Lovejoy has called the principle of plenitude, in essence an insistence that God must actualize his potential power, a belief which has its roots in ancient Greece.[24] Indeed, both the ideas of the unity and the plenitude of nature show the influence of the atomist tradition on Bruno, whose enormous admiration for Lucretius stands at variance with his usual scorn for authority. In spite of the fact that Bruno infused the atomist universe with Platonic animism, his extensive citations from Lucretius show that the atomist concept of innumerable worlds was a seminal influence.

Given an infinite universe, many of Aristotle's arguments against a plurality of worlds fell by the wayside. With the destruction of the cosmos, Bruno declared, there was no absolute centre or circumference.[25]

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Aristotle's most substantial argument was denied - that regarding the impossibility of any ordered motion of elements in a universe with more than one world and thus more than one center. The particles of each world are related only to their own center, and as Copernicus had hinted,[26] each celestial body functioned as a center of motion. Bruno thus saw this particular argument of Aristotle as relevant to his own view, but easily circumvented given an infinite universe and the assertion that gravity and levity were relative concepts.

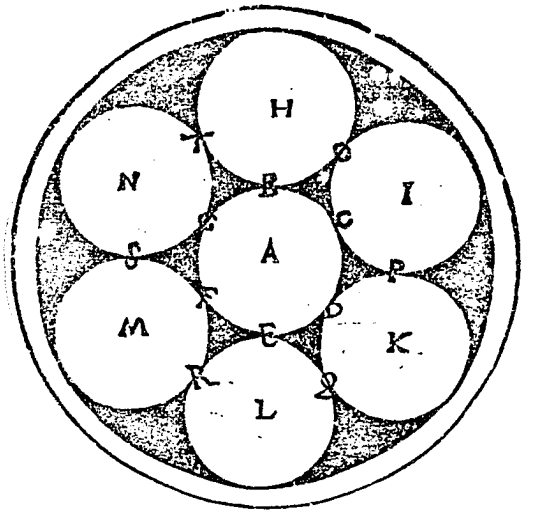


"Just as in world A all semi-diameters pertain to A, thus in world B all semi-diameters are referred to B." For Bruno A and B could represent the moon and the earth or any other two celestial bodies. Figure from De immenso, VI, 4.

Bruno's system also transcended the Aristotelian objection that many worlds implied the existence of void space between those worlds, a reductio ad absurdum to Aristotle. The triangular void spaces supposed to exist between contiguous worlds would not have bothered Bruno at all, but in any case he postulated "a single heaven in which the worlds have their own spaces,

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regions and convenient distances. It diffuseth throughout all, penetrateth all and envelopeth, toucheth, and is closely attached to all, leaving nowhere any vacant space; unless, indeed, like many others, thou prefereth to give the name of void to this which is the site and position of all motion, the space in which all have their course."[27] "Unity" once again overcomes Aristotle's limited vision.



Another diagram used by Bruno to illustrate that "a part of world H placed at B cannot and ought not to drive toward the center A of another system, but toward the center of its own system." As for the triangular space shown here, Bruno's worlds, as celestial bodies, did not touch at all, but rather were separated within the one immense space. The diagram appears in De immenso, VII, 5 and VII, 11; and a more simplified version in the De l' infinito, Singer, p. 357.

Finally, to the Platonic derivation of a single world from the belief that unity is more natural than plurality and embodies perfection, Bruno declares that it is he who incorporates the ultimate unity into his system - that of the universe, not just of an enclosed cosmos - and that the infinite worlds contained in that ultimate unity are the very basis of the perfection of the unity.[28] Thus there is irony in Bruno's passionate espousal of a doctrine

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of infinite worlds, for its basis was the principle of unity, the same metaphysical concept which Plato and Aristotle had used to argue for a single world. For Plato unity meant perfection, for Aristotle it meant a single center on which a whole system of physics could be based. But Bruno transcended his predecessors. For him perfection was found only in a unity consisting of infinite diversity; innumerable worlds were the basis of that diversity.

It can now be seen that Copernicus in fact had little to do with Bruno's transformation of every celestial body into a world. While Copernicus was indeed influenced by the Neoplatonic idea of the dominance of the sun, Bruno took as his starting point a more fundamental Platonic concept: unity. Transformed through the arguments of Lucretius, unity for Bruno meant an all-embracing space in which earth and celestial bodies were of one and the same kind; it meant the destruction of the tightly knit Aristotelian world which perpetuated dichotomy rather than unity; it meant instead the existence of a universe (and we can now appreciate the literal meaning of that word!) in which every celestial body functioned as the earth had in the old system - as a center of attraction. Along with the infinite universe came an infinite number of centers of attraction, an infinite number of worlds.

* * *

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As Bruno's De immenso appeared in Frankfort in 1591, the young Johannes Kepler was in the midst of his studies at the University of Tübingen, and was soon to launch himself on one of the most distinguished of astronomical careers. Whether he knew Bruno's work as a student we can only guess; in all his works, Kepler refers to Bruno only a few times.[29] One might surmise that Kepler found little of value in Bruno, for their metaphysics differed so greatly. Kepler's universe was finite,[30] sense data was important, and mathematics was the key to unlocking the secrets of nature. Yet, within the domain of our study, the two do have something in common. While Kepler rejected Bruno's vision of infinite worlds, by a gradual process he came to admit that the moon, planets, and even the stars might be bodies of a nature similar to the earth, each with its own inhabitants. It can be shown that this gradual process was one in which empirical observation and the Copernican theory played the greatest role.

The development of Kepler's ideas on the physical nature of celestial bodies began with that body most accessible to empirical observation, the moon. Moreover, it began some years before the telescope was available as an observational tool. In the Dissertatio cum nuncio sidereo (1610), Kepler told Galileo that the telescopic observations as reported in the Sidereus nuncius reminded him of what he had already concluded - on the basis of Plutarch, Maestlin, Pythagoras, and his own observations.[31] Indeed, Kepler's ruminations

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on the nature of the moon had begun during his student days at Tübingen; in 1593 he was hard at work on a "lunar dissertation" which formed the basis of the Somnium finally published posthumously in 1634.[32] This was at a time before Kepler knew Plutarch's work De facie in orbe lunae, but after he had become a convinced Copernican under the influence of Maestlin.

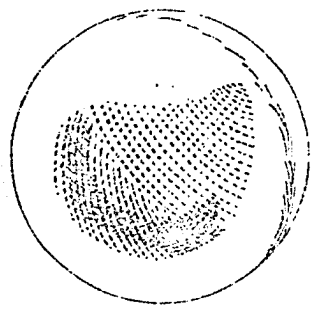
Kepler's empirical approach to the problem of the nature of the moon is evident in the 1604 Optics. Optics dealt with light and since the celestial bodies were sources of light , optics was an important tool for the astronomer interested not only in the motion of the celestial bodies, but also in their physical nature. It is therefore not surprising to find a section in the Optics entitled "On the spots of the moon", a section whose significance is indicated by Kepler's frequent references to it in his later writings, particularly in the context of Galileo's discoveries.

The discussion of the lunar spots indicates the seminal role which Plutarch's De facie played in Kepler's thought. While Maestlin, ignorant of Plutarch's work, had deduced much the same properties concerning the nature of the moon, Kepler had learned about the work in 1595 from a reference in Reinhold,[33] and thought the work "most elegant, festive, and worthy". Kepler continued:

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> I will without jealousy agree with the author of that opinion, which my teacher Maestlin promoted even before now, and will assert that the body of the moon is of such a kind as is this our earth, comprising one globe out of water and land. Indeed, Plutarch presented many arguments and oratory gathered against many objections - so that any Peripatetic can justly wonder how so many serious things can be set out against the opinions of his own sect. These things are confirmed most powerfully by me.[34]

Plutarch had refuted "by weighty arguments" the contention that the spots on the moon were not real but an illusion caused by human eyesight. Kepler confirmed this by an ocular experiment (experimentum oculare) in which he used the camera obscura to form an image of the moon on paper, an image which contained dark spots no matter how the paper was moved around. This proved to Kepler's satisfaction that the spots were real and not a product of eyesight. Moreover, other observations of the moon and its eclipses, along with a series of simple calculations proved to Kepler that the apparent mountains seen on the moon during a partial lunar eclipse were not shadows projected from the earth's mountains, but uneven and "tortuous" surface features of the moon itself.[35]



Kepler's simple, but to him significant, drawing obtained from the image of the camera obscura at six in the morning of 21/31 Dec., 1602: "The spot always hurled itself onto the paper along with the light, so that it is impossible to be a product of the sight alone". GW, II, p. 217.

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It is Witelo's principles of optics, however, which are of paramount importance. Although both Kepler and Plutarch believe the moon to be earth-like, Kepler wishes to reverse Plutarch's interpretation of the dark spots as seas and the bright spots as land; the opposite he says with confidence in his principles, "is very much confirmed by experience demonstrated from optics, that aqueous surfaces are very resplendent, if they are put next to earthy matter...."[36] This was one conclusion which Kepler would very soon have to alter in the face of even more compelling optical evidence.

Kepler thus felt confidence in his general conclusion:

> All of these things demonstrate the argument which I have related: the moon is correctly called by Plutarch a body such as the earth is, uneven and mountainous, and with even more mountains in proportion to its own globe, than there are on the earth in proportion to it.[37]

Then, giving free rein to his remarkable imagination, but expressing some caution by his use of the word <u>jocemur</u> (we may jest), Kepler continues:

> And with Plutarch we may jest: because as it happens with us, that for utility men and animals follow the natural disposition of the land or of their own province; therefore there are on the moon living creatures, with by far a larger body and hardness of temperment than ours, to be sure, because if there are any there, their day is fifteen of our days long and they endure both the ineffable heat and the vertical rays of the sun. And not absurdly has the moon been believed by superstition to be the place for the purification of souls.[38]

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In the end, Kepler's "jest" must be taken as something more, for the idea was not abandoned to a few pages of the Optics. We shall see that they were elaborated upon in the 1610 Dissertatio and again in the Geographical Appendix to the Somnium, composed between 1622-30.

Kepler's eagerness to bring empirical evidence to bear in support of a world in the moon even before the advent of the telescope points strongly to the important early role of Copernicanism. Kepler's deductions were carried out under the influence of the Copernican theory, and although the same conclusions had been reached by a few even in ancient Greece, theory and observation were now more closely linked than ever before. It is with this attitude that Kepler urged, a half-dozen years before Galileo's observations,

> May the Peripatetics therefore not be angry with Plutarch because he has placed the earth in the heavens, that is, because he treats the body of the moon to be earth-like, since they can see that it is settled by very certain experiments, in that indeed the moon proves to be of the same nature as our earth in the participation of light. Indeed, then, when Plutarch and Maestlin will have been accepted with unprejudiced ears in philosophy, then Aristarchus with his student Copernicus may well begin to hope.[39]

There is further evidence which indicates that, already in the pre-telescopic era, what Kepler held to be true or possible for the moon was true or possible for the planets and even the stars in general. In the 1606 De stella nova he was forced to ask such questions as what matter the new star was composed of, whether the matter

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of the heavens could be altered to form such a new star, and to what end this new star might have been set afire. In answering these questions, Kepler makes explicit the principle which he had used in the Optics to draw conclusions regarding the moon: that there was no dissimilitude of essence between the earth and the celestial region, because Copernicus had "given the earth the status of legal citizenship in the heavens".[40] Extending this principle, Kepler concluded that the new star might be composed of the same elements as the earth; from scintillation (again an optical consideration) he thought the fiery or watery element predominated in such a star.[41] The new star might have been generated by the natural architechtonic faculty of the other celestial bodies, which have this faculty no less than the earth: the matter of the heavens is indeed changeable.[42] Finally, this new star was ignited not for the purpose of men on earth, which is small beyond measure on such a scale, but for the inhabitants of other globes, an opinion which certain ancient philosophers and Tycho Brahe held.[43]

Not everyone was willing to follow such a philosophy. Kepler soon received a letter from one J.G. Brennger, a physician at Kaufbern, who was in correspondence with Kepler chiefly in regard to his Optics. Brennger wrote that he had long been compelled by the evidence of the comets to conclude that the heavens were alterable, but he still

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maintained that "Our earth is different than the stars; indeed the bodies of those stars are simple, similar, and according to the Philosopher most pure; our earth, however, is not simple but dissimilar and impure".[44] Kepler's reply three months later was uncompromising.

> You think the stellar globes are pure and simple... they seem to me to be similar to our earth. As a philosopher you quote a philosopher: if he is asked, he will point to experience. But experience is silent, since no one has been there; therefore it is neither affirmed nor denied. I myself argue the probability by analogy, as you do by intuition for the moon, which has many things similar to the earth. Therefore, I attribute humors to the stars, and regions which from the exhalations of the humors are rained upon, and living creatures, to whom this is useful. For not only that unfortunate Bruno, burned on hot coals at Rome, but also my Brahe held this opinion, that there were stellar inhabitants. I too follow such an opinion because I affirm with Aristarchus that with the planets the earth also has motion...[45]

Brennger, reflecting the reluctancy of many of his time, answered that Kepler's speculations had little to recommend them, were it not for Copernicus. And he too was a Copernican. It was within the framework of the heliocentric theory that Plutarch could come to the fore in the latter half of the sixteenth century, that Kepler's optical experiments and observations with regard to the moon might become compelling, and that speculations about the nature of the stars themselves could be taken seriously. Two years after Brennger's letter, Galileo turned his telescope heavenward.

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Telescopic Era

Cautious Copernicans like Brennger might have remained forever dubious of assertions such as Kepler's regarding the physical nature of the celestial bodies, had it not been for what one might broadly classify as new "optical arguments". The telescope was indeed a triumph of optics, and the extension which it gave to the human eye provided strong empirical arguments for Copernicanism. For, while this new instrument did not provide indisputable proof of heliocentricity and the motion of the earth, it did show that certain empirical observations, heretofore unknown, were compatible with some of the implications of heliocentricity.

To state that these telescopic observations had an effect on Copernicanism is to state what was immediately recognized by Copernicans and has long been recognized by historians of science.[46] The moon was clearly not the perfectly polished Aristotelian sphere, and the moons of Jupiter gave clear evidence that Jupiter acts as a center of motion - a function Aristotle had reserved only for the earth. And what was bad for Aristotle was good for Copernicus. On the other hand, to claim that the idea of a lunar or Jovian world had an effect on Copernicanism is something rather different, for the term "world" applied to a celestial body implies an explicit and detailed comparison with the physical nature of the earth. In what follows our purpose is strictly limited to an examination

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of the many-worlds idea and the theory of Copernicus. Telescopic discoveries at this early stage provide only the background for the plurality of worlds tradition.

Galileo's Sidereal Messenger, published in Venice in March of 1610, contained telescopic observations of four essentially separate phenomena: the surface of the moon, the fixed stars, the Milky Way and nebulous stars, and the four satellites of Jupiter. All of these discoveries in one way or another were to have a profound effect on the revitalization of a doctrine of plurality of worlds. It was a timid Galileo who mentioned only that the surface of the moon was "not unlike the face of the earth", and that "if anyone wished to revise the old Pythagorean opinion that the moon is like another earth, its brighter part might very fitly represent the surface of the land and its darker region that of the water."[47] But within a matter of weeks the implications of the full range of Galileo's discoveries for the idea of other worlds had been set forth by Kepler. Galileo had sent Kepler a copy of his work asking for his reactions; those reactions were recorded between April 8-13, 1610 in the Dissertatio cum nuncio sidereo. The document is thus invaluable as an immediate reaction of an important astronomer to the first telescopic revelations.

True to his character, Kepler plunged in where Galileo feared to tread. Questions abounded as Kepler

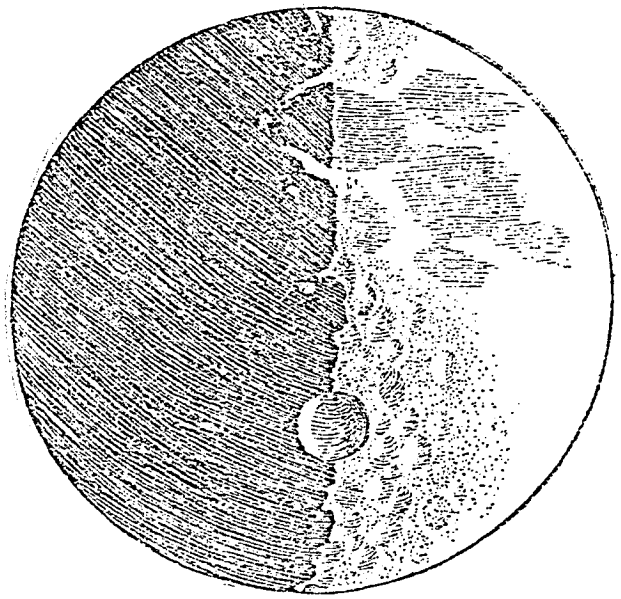
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raced from conjecture to conjecture. Was the remarkably circular cavity on the moon the work of lunar inhabitants, and did the moon have an atmosphere which, incidentally, would moderate the heat they receive? Was our world only one of an undifferentiated swarm of countless others now indicated by the telescope, as Bruno had insisted? Must not the moons of Jupiter, heretofore entirely unknown to the inhabitants of the earth, exist for the sake of Jovians? In carrying out his declared purpose to "touch upon all parts of philosophy which are threatened with destruction or strengthened or clarified by Galileo's Messenger",[48] Kepler laid the foundations in the Dissertatio for a broad range of basic ideas, many of which related to the plurality of worlds. These ideas would be scattered throughout his later works, destined to influence subsequent discussions of the question.

Kepler saw Copernicus as greatly strengthened, while Bruno's extreme view of infinite worlds was "corrected and in part unsettled",[49] or at least certainly not strengthened. But the idea of earth-like bodies within our solar system fascinated him and did not seem beyond the reach of scientific reasoning. Kepler first reminded Galileo of the ideas on the moon already presented in his own Optics, but on the basis of Galileo's "mathematical arguments" (showing how sunlight catches the peaks of mountains in the bright areas and gradually spreads) was obliged to switch his interpretation of the bright and dark areas to

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land and sea, respectively, in agreement with Galileo (and Plutarch!).[50] After drawing other analogies with the earth, Kepler offered a remarkable explanation for the origin of a large circular cavity detected by Galileo. Where Galileo had only expressed wonder, Kepler proposed that it was formed by intelligent inhabitants who "make their homes in numerous caves hewn out of that circular embankment."[51]



The diagram from Galileo's Sidereal Messenger, clearly showing the circular surface feature which Kepler saw as evidence of Lunar inhabitants. From Galileo's Opere, III, pt. 1 p. 66.

Finally, from the perfectly smooth apparent edge of the moon, Kepler argued that it might be wrapped in a sphere of air, which moderated the heat with its moisture and allowed the inhabitants to bear the intense heat of the sun. Kepler cited Maestlin in support of this atmosphere, and noted that his teacher even saw rains there.[52]

Kepler was no less serious about earth-like planets. In the preface to the Dioptrice of 1611, he labelled as "most admirable of all"

> that section of the Sidereal Messenger where the story is told of the discovery, by the aid of a very good telescope, of another world similar to ours in

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> the planet Jupiter: and not without amazement does the mind of the philosopher realize that there is another vast globe, fourteen times the size of the terrestrial globe, around which revolve four moons not dissimilar to that of our moon.[53]

The four satellites of Jupiter, he conjectured in the Dissertatio, must be meant for the Jovians, not for us who never see them. The existence of such beings is made all the more certain by the fact that God does nothing useless. Also from the astrological point of view there must be Jovians, for the small arcs which the orbits of the new planets subtend can be of significance only to the Jovians. In summary

> The conclusion is quite clear. Our moon exists for us on the earth, not the other globes. Those four little moons exist for Jupiter, not for us. Each planet in turn, together with its occupants, is served by its own satellites. From this line of reasoning we deduce with the highest degree of probability that Jupiter is inhabited. Tycho Brahe likewise drew the same inference based exclusively on a consideration of the largeness of those globes.[54]

In the absence of the detailed surface observations of the other planets, Kepler does resort here to more metaphysical arguments for planetary worlds, arguments, however, which do not invoke a priori principles such as that of plenitude, but which are applied a posteriori to God's visible creation. There can be little doubt that the cornerstone for even these arguments is the heliocentricity which gives the earth and planets equal status.

In the hands of Kepler, Galileo's discoveries would seem to demand a complete re-evaluation of the role of man in the universe: even more than heliocentricity, the

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population of celestial bodies with thinking creatures diminished man's stature. Kepler himself posed the problem:

> Well, then someone may say, if there are globes in the heaven similar to our earth, do we vie with them over who occupies a better portion of the universe? For if their globes are nobler, we are not the noblest of rational creatures. Then how can all things be for man's sake? How can we be the masters of God's handiwork?[55]

In spite of his belief in inhabitants on other worlds, it was Kepler's firm conviction that Galileo's observations of the fixed stars demonstrated the primacy at least of our solar system, and that other arguments indicated the dominance of our earth within that system. First of all, Galileo's observation that the fixed stars sparkle as opposed to the planets (which showed circular disks), revealed an essential difference between those bodies: "The fixed stars generate their light from within, whereas the planets, being opaque, are illuminated from without; that is, to use Bruno's terms, the former are suns, the latter moons or earths".[56] Galileo's revelation, then is one of countless new suns in the Milky Way and elsewhere, and Kepler believed that no one of them could be of the same brilliance as the sun. Even taking into account their distance and possible obscuration by the intervening aether, Kepler concluded from the dimness of the total light received from the stars that even if they were all placed together in a single surface, the brightness of our sun would dwarf them. The more stars that were discovered with even dimmer apparent magnitude and thus

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(Kepler thought) dimmer absolute magnitude, the more was the dominance of the sun proven.[57]

On the basis of geometry too, Kepler held that the dominance of our system might be proven. Employing a variation of an old medieval argument against a plurality of worlds, Kepler reasoned that if there were other systems of undetected earths circling suns, these systems or worlds would be either unlike ours, or like it. But they would not have been made like it, because then every world would contain all perfection; if they would be made unlike it, then they would be based on something other than the five perfect solids (which Kepler showed to be the basis of our system in the Mysterium Cosmographicum), and would therefore be less noble. Therefore "It follows that this world of ours is the most excellent of them all, if there should be a plurality of worlds."[58]

All of this led to Kepler's conclusion that "this world of ours does not belong to an undifferentiated swarm of countless others,"[59] and by a series of less compelling arguments he tried to show that, next to the sun, our earth was the noblest of the planets within the system, a fitting place for the noblest of all creatures. But aside from these anthropocentric restrictions, it was quite obvious to Kepler that there were other abodes of life. There was a world in the moon; it was composed of the same substance as the earth, had similar surface features,

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and perhaps even inhabitants. While the surfaces of the planets could not be so easily studied, Jupiter did have moons, and thus it served as a center of attraction of its own. This in itself qualified it as a mundus Jovialis,[60] and it seemed probable that other planets too had as yet undiscovered satellites, worlds revolving around a central world.

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The implications of a world in the moon were never far from Kepler's mind. The importance of the concept for Copernicanism is even more clearly evident in the structure and content of the Somnium (1634), a work which occupied Kepler's attention at intervals from his student days to the end of his life. As a general indication of emphasis, the body of the Somnium itself (exclusive of notes) may be divided into several parts, each of which reflects a specific content and goal. Approximately 20 percent of the treatise consists of introductory remarks preparatory to the moon voyage which carries an observer to his station on the moon, 10 percent comprises the moon journey itself, 60 percent exhibits the astronomical phenomena as seen from both hemispheres of the moon, and somewhat more than 10 percent discusses the body of the moon and its inhabitants. From this breakdown it is evident that, once transported to the moon, Kepler's main purpose is to set forth the lunar astronomy, to indicate the apparent movements of the sun, the eclipses of the earth, and the planetary motions.

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Such are the immediate goals, but Kepler himself directly enunciates the ultimate purpose of the Somnium in his notes to that work: "The purpose of my Dream is to use the example of the moon to build up an argument in favor of the motion of the earth, or rather to overcome objections taken from the universal opposition of mankind..."[61] In short, it is a treatise designed to support the Copernican system, by showing that the senses which fuel the opposition to the theory are only ambiguous indicators of truth. Thus Kepler's lunar observer will find that "Levania [the moon] seems to its inhabitants to remain just as motionless among the moving stars as does our earth to us humans".[62] By thus undermining the accuracy of the senses with a whole host of lunar astronomical phenomena, Kepler renders the belief in a moving earth more palatable.

But the treatise does not end there. Rather, Kepler declares "From these phenomena, even without my saying anything, it is not difficult to infer how much the Subvolvans differ from the Privolans in all other respects".[63] Whereupon he proceeds to give a few details about the nature of the lunar surface and then launches into a remarkably detailed discussion of the nature of the inhabitants. When commented upon in the "Notes" added by Kepler from 1622-1630, the content and detail of this concluding section cannot be ignored, and may be seen as furthering his aims at supporting the Copernican theory, not only by putting the earth in motion, but also by making the moon an earth. Indeed, this latter aim

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must have been the entire purpose of the immensely interesting "Geographical or Selenographical Appendix" which Kepler added to the Somnium and elaborated with yet more notes.[64]

The fascinating details of the Somnium are of great interest in providing Kepler's detailed view of the nature of the moon world, as well as illustrating his method of argumentation in arriving at such details.[65] What needs emphasis here, however, is that Kepler did not hesitate to use the moon world in support of the Copernican system. Although the prime purpose of the Somnium was not to demonstrate that the moon was a world with its own inhabitants, Kepler's lengthy discussion of the nature of the lunar globe itself and its inhabitants indicates, nonetheless, that he employed a second strategy against Aristotle and in support of the Copernican theory: to demonstrate that the moon was a body similar to the earth in nature, and that to populate it with inhabitants was not incompatible with reason, but with Aristotle. Kepler's theoretical observer on the moon stood not on a polished Aristotelian sphere, but on a Copernican world. It was a double-barrelled argument for Copernicanism.

Kepler's moon world was thus proposed in all seriousness. Already in 1610, with a considerable scientific reputation at stake, Kepler did not hesitate to emphasize his long-standing belief in lunar inhabitants. He declared

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that, following the footsteps of Pythagoras and Plutarch, he had "enjoyed toying with this idea long ago in a disputation written at Tubingen in 1593, later on in my Optics on page 250, and most recently in my aforementioned lunar geography."[66] Implanted in his youthful days as a student, confirmed by the telescope, and solidified over his entire career, Kepler's moon world was an important argument in its own right, which foretold the destruction of Aristotle, and the rise of a new system in which earth, moon, planets, and even the stars had a similar status with regard to physical nature.

* * *

Kepler stands as an extremely important transitional figure in understanding the emerging relationship between heliocentricity and the plurality of worlds. But while he did not hesitate to accept the reality of other worlds as a part of the new physical system, given the metaphysically relevant restrictions placed on the idea, there were others, both Copernicans and Peripatetics, who were extremely sensitive to any such proposal. Abhorrence to the concept of other worlds played an important part in a work of at least one Peripatetic intent on the denial of Galileo's observations and the refutation of Copernicanism. Julius Caesar La Galla, a professor of philosophy in Rome, published in 1612 De phaenomenis in orbe lunae... physica disputatio, a work which gave La Galla the distinction of being labelled by John Wilkins the "chief

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opponent" to the ideas expressed in Wilkins' 1638 Discovery of a World in the Moon.[67] La Galla pointed out that his work was solely a physical disputation, intent on the refutation of the notion of "Orpheus, Thales, Philolaus, Pythagoras, Heraclitus Ponticus, and Copernicus" that the earth is a star, by proving the foolishness of the implication that there would then be many worlds, as Democritus thought.[68] The newly discovered phenomena on the moon might be taken by some as confirming this opinion of Democritus, and La Galla's "proof" consists in denying the reality of the mountains on the moon and the validity of Galileo's observations in general. It was a diehard Peripatetic attempt, one which seems to have been inspired chiefly by the association of the new discoveries with the ancient doctrine of other worlds. Hostility to that doctrine was thus used as the basis of an independent argument against the new discoveries and against Copernicanism.

Among the Copernicans too, however, there was an initial attitude of skepticism and caution toward the comparison of other celestial bodies, such as the moon, with the earth. Galileo expressed himself only very briefly in this regard in the Sidereal Messenger, drawing vague comparisons between earth and moon.[69] Already in January, 1611 the Dominican monk Campanella wrote Galileo in support of Kepler's belief in the inhabitants on the moon and planets.[70] Scheiner in 1612 apparently remarked negatively on Kepler's belief, and evoked a firm expression of Galileo's opposition

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to Kepler on this point also. In the third letter on sunspots in 1612, Galileo noted "I agree with Apelles [Scheiner] in regarding as false and damnable the view of those who put inhabitants on Jupiter, Venus, Saturn and the moon, meaning by inhabitants, animals like ours, and men in particular".[71] He goes on to say that he could prove this much, and as to whether there exist inhabitants different in nature from terrestrial ones, he leaves this to wiser men than he. Other Copernicans too were curious, and Galileo reiterated to an inquiring Cesi in 1613 that there could be no firm answer to the question of life on other planets.[72]

Galileo's judicious conservatism on this issue undoubtedly does not derive from a more restrained imagination in comparison with Kepler. Rather, it reflects a theological factor, one which is explicit in his statement in the letters on sunspots, where he emphasized the denial of extraterrestrial "animals like ours, and men in particular". Such a pronouncement could clearly have grave implications for Church doctrine, and the Roman Inquisition would not be slow to see those implications. Galileo's friends too saw them. Ciampoli wrote him from Rome with reference to the relatively harmless remarks in the Sidereal Messenger: "Be careful of your words because when you simply establish some resemblance between the terrestrial globe and the lunar globe, another outdoes that, and says that you suppose there are men living on the moon, and another begins to discuss how they can be

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descended from Adam, and come from Noah's Ark, and a great many other extravagances of which you would never dream."[73] On the face of it, Copernicanism was condemned by the Church on numerous and (to it) compelling grounds unrelated to the speculations about possible inhabited planets, speculations which Galileo largely denied. But it is reasonable to conjecture that the issue of other worlds was not far below the surface. Many Copernicans might indulge in Kepler's boldness instead of Galileo's conservatism, as when Campanella in 1616 wrote Galileo that inhabitants on other celestial bodies seemed likely to him.[74]

Galileo had not yet written his last word on the issue of inhabited worlds, and while the precise role the issue played in the 1616 condemnation of Copernicanism by the Church remains problematical, its relations to that theory are made clear in the 1632 Dialogues on the Two Chief World Systems. The discussion by Simplicio, Salviati, and Sagredo in the "First Day" of that classical work had as its general purpose to argue the view that there was no disparity between the parts of the world, no dichotomy, as Aristotle had held, between terrestrial and celestial. This was argued following the pattern of the initial chapters of Book I of the De caelo. Galileo first deals with Aristotle's arguments for a celestial-terrestrial dichotomy based on the differences of simple motions.[75] This he refutes by simply denying

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Aristotle's principles of motion - that circular motion, for example, is peculiar to celestial bodies. Then Simplicio, representing the Aristotelian point of view, brings up "two powerful demonstrations proving the earth to be very different from celestial bodies."[76] The first claims that experience shows us that generation and corruption occurs constantly on the earth, whereas no change has ever been detected in the heavens. Galileo counters by citing the changes recently observed in the heavens: the comets, the new stars of 1572 and 1604, and the spots on the sun which he believed were continually dissipated and generated.[77] After this embarrassingly simple retort Simplicio tries to lure the participants into a discussion of the moon as a world. Behold where the denial of dichotomy leads, Simplicio admonishes his listeners. Generations and alterations in the celestial bodies would be vain and useless, unrelated to us on earth. But natura nihil frustra facit, so perhaps his opponents would like to propose men on the moon, "an idea which if not mythical is impious".[78] Galileo, through Sagredo, lets it be known that he does not suppose that "herbs or plants or animals similar to ours are propagated on the moon, or that rains or winds or thunderstorms occur there as on the earth; much less that it is inhabited by men".[79] Rather, generations might occur there which form or are useful to creatures of a type unimaginable to us. Salviati agrees in general with

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Sagredo and notes that many times he has "given rein to my fancies about these things,"[80] and is certain of one thing, that if there are creatures there, they would serve and praise the one true God.

Simplicio does not quite know what to make of all of this (we may judge from his silence), and the participants take up his second argument in favor of maintaining a dichotomy between earth and heavens, based on the belief that bodies naturally giving light are different than dark ones: since the earth is dark and the celestial bodies are "full of light", the dichotomy must hold. Galileo proceeds with great caution here. While agreeing that "the lunar globe is very different from the terrestrial", he notes the many similarities in shape, substance, surface features, and opacity, so that they reciprocally illuminate each other, eclipse each other, and proceed through phases.[81] Still, after a lengthy discussion of the details,[82] Galileo concludes that "Quite apart from this I consider the moon very different from the earth".[83] His reluctance to proclaim the moon and the earth essentially similar is most probably attributable to the theological implications that would flow from such an identification. Galileo thus sought to dissociate moon and earth, arguing that neither rains nor any form of water existed on the moon, so that "generations and alterations" similar to ours could not occur there. Even if there were land and water, Galileo

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thought, life similar to ours would be ruled out, because of the length of the day and night on the moon, which together amounted to a month. A sun beating down on the earth for fifteen successive days without pause would destroy all life on earth; any species of life on the moon would have to be far different from ours to withstand such conditions.[84] The repeated assertion of the possibility of life on the moon only as "extremely diverse and far beyond all our imaginings"[85] also fit in nicely with the idea of the richness of nature and the omnipotence of God, a point which Galileo does not fail to emphasize. As the discussions of the first day draw to a close, then, Galileo does indeed invoke a metaphysical principle related to God's plenitude. But it is a very limited invocation compared to Bruno's infinite worlds, one constrained by the general empirical indications.

Galileo had thus come to a theologically satisfying compromise with regard to the conception of the moon or any other celestial body as a world. He clearly believed that the heavens, including the moon and the other celestial bodies themselves, were subject to alteration and generation, and that this was no barrier to the Copernican hypothesis, That this same hypothesis led to the more particular and radical conception of other worlds is evident as we witness Galileo's struggle in the Dialogues to prevent that idea from

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becoming a major argument against Copernicanism on theological grounds. The potential theological ramifications were indeed grave if not insurmountable, and the issues had already been delineated and heatedly debated in the decades before the publication of the Dialogues.

Theological Considerations

The theological problems associated with a plurality of earth-like planets have their roots in the Aristotelian demonstration of the impossibility of the existence of more than one cosmos. We have already seen in a previous chapter that theology shattered this orthodox attitude in the medieval period. The promulgation issued in 1277 by the Bishop of Paris condemned the belief that God could not make many worlds. It was out of a consideration of God's omnipotence that the Church felt compelled to insist that God could create another cosmos if he wished, although even the strictest medieval theologians unanimously agreed that he had not in fact done so. This dichotomy between the possibility and the reality of other worlds was a precarious one; the possibility was necessary to preserve God's omnipotence, but the reality would clearly raise many more theological problems.

Nevertheless, late medieval and Renaissance theologians were already beginning to explore problems concerned with the possible inhabitants of other worlds. At least one fifteenth century Sentence commentator, although still clearly Aristotelian in outlook in important ways, wrote

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with unknowing prescience of some of the issues which would become important in the aftermath of the Copernican revolution.

> If it be inquired whether men exist on that world and whether they have sinned as Adam sinned, I answer no, for they would not exist in sin and did not spring from Adam...As to the question whether Christ by dying on this earth could redeem the inhabitants of another world, I answer that he is able to do this even if the worlds were infinite, but it would not be fitting for Him to go into another world so that he must die again.[86]

At mid-sixteenth century Philip Melancthon, the systematic expositor of Luther's theology, forcefully expressed the initial Protestant position that any sound mind would totally reject the possibility of other worlds, both on the basis of Aristotelian physical principles and Scriptural doctrine.[87] This Protestant position is in striking contrast to the medieval view after 1277. Melancthon placed no credence in promulgations of the Roman Church such as that issued by the Bishop of Paris. Instead, he turned to the "doctrine of the heavens" as set forth in Genesis. The second chapter of the very first Book sufficed to show that after God had made the sun, moon, and stars of our cosmos, he created nothing else, least of all another cosmos.

Although at mid-sixteenth century Melancthon was still arguing within the Aristotelian paradigm and was unconcerned about the plurality of earth-like planets, as the paradigms shifted the same strategy could easily be applied to the

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latter assertion. Scripture made no mention of the creation of man anywhere except on earth, be it on the central body of another cosmos, or on bodies within our cosmos. Melancthon wished to retain the comfortable one-to-one relationship between mankind and God; more worlds than one would destroy or attenuate that relationship, and Melancthon wanted no competition for the attention of the Creator. His theological objections reflected late medieval concerns and would be repeated again and again in the seventeenth century.

> We know God is a citizen of this world with us, custodian and server of this world, ruling the motion of the heavens, guiding the constellations, making this earth fruitful, and indeed watching over us; we do not contrive to have him in another world, and to watch over other men also ... the Son of God is One; our master Jesus Christ was born, died, and resurrected in this world. Nor does he manifest Himself elsewhere, nor elsewhere has He died or resurrected. Therefore it must not be imagined that there are many worlds, because it must not be imagined that Christ died and was resurrected more often, nor must it be thought that in any other world without the knowledge of the Son of God, that men would be restored to eternal life.[88]

Melancthon's treatise went through many editions, and such arguments were undoubtedly in the air in the latter half of the sixteenth century, fanned by this and other such treatments.

The concerns of Galileo were thus well placed, for the reaction of many Catholics was similar to the Protestant view. The conclusion reached by one influential Catholic contemporary of Galileo was identical to that of Melancthon,

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although much more carefully reasoned. The French Minim friar Mersenne still spoke with the Aristotelian tradition of other worlds in mind when he took up the question in one of his earliest works, the mammoth Questiones in Genesim... (1623), written against the atheists and the Deists.[89] As with Melancthon, the question again arose in relation to Chapter 2, verse 2 of Genesis: "On the sixth day God finished the work he had been doing. And he rested on the seventh from all the work he had done". The issue was "Whether aside from this world, which we see was made perfect in seven days, there is another one unknown to us",[90] and the solution to the issue manifests the coexistent strains of the plurality of worlds tradition present in this transition period.

Mersenne opens with a brief statement which indicates the notoriety this issue had gained. No one, he says, will be surprised to find this quesion taken up, even though some theologians claim to destroy it through interpretations of Scripture; there are many in this century who not only propose it but cherish its affirmation. Indeed, one of his dearest friends has done so, and Mersenne sees the issue as one very current and relevant.

Recounting the current opinions, Mersenne points out that some hold that there is in man a deep-seated innate desire to discover other worlds, and indeed many philosophers of the past took up the question and admitted their existence.

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Some think that God's virtue and omnipotence demand that he ought to produce many worlds; that many worlds are better than one, and that God always does what is best; that there are many species between God and the angels which are not represented in this world but in others. Finally, (and here we see the interaction of the old and new views), there are those who hold that the recent discoveries of Galileo, Kepler, and Tycho confirm that there are other worlds distinct from ours.[91] Of this kind is the discovery of "large provinces that have been seen in the moon by the tubus Batavicorum, but especially with the help of the conspicilium of Galileo, by which the moon is magnified so much, that in it are seen large forests, fields, caverns, and similar things not only by Galileo as recorded in his Nuncius siderius, but also Kepler the Imperial mathematician, who asserted in his dissertation with the aforementioned, that men are present in these caverns to dwell there, and insinuates that they probably flee there so they may not be hurt by the sun's rays".[92] That there are other worlds with their own suns, moons, and inhabitants as Democritus thought might also be confirmed by the discovery of "three or four" planets around Jupiter. And the new stars which Tycho has studied, and the comets beyond the moon - perhaps they come to us from another world.[93]

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Mersenne answers all of these assertions in article two, "in which it is shown that the world is unique, and the arguments are responded to by objections".[94] The article is fascinating because it reveals the early seventeenth century theological mind at work in the midst of the new scientific discoveries. Mersenne points out first that certitude is many-faceted; it has as its sources experience, reason, and human authority on the one hand, and faith as determined by tradition, the Church, synods, and definitions. In contrast to Melancthon, Mersenne of course does take Church opinion into account. But he goes to great lengths to show that there is no certainty de fide as regards the unity of plurality of worlds. The issue has not been defined by any ecumenical council, there is no Apostolic tradition, and Scripture does not give a clear answer, even though Origen (according to Methodius) claimed that Ecclesiastes 1 supported many worlds in succession.[95] Therefore to deny the concept of other worlds on the grounds of Catholic faith, one would have to deal "argumentatively", that is, drawing a conclusion from the premises of faith by the use of a syllogism. When both premises are de fide, then the conclusion reached in this way will be de fide. That which opposes such a conclusion is not heretical, but to the highest degree temerious; the conclusion must be adhered to if the Church so decrees.[96]

Mersenne has grave doubts whether even on this "argumentative" basis the unity of the world can be concluded,

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and cannot himself find two premises from the faith which allow a deductive conclusion. He denies the following syllogism which some have used:[97]

MAJOR: All things are created by God.

MINOR: Other worlds or men are not created by God.

CONCLUSION: There are no other worlds.

In opposition to Melancthon, Mersenne holds that the minor premise cannot be found in Scripture or any decree of the Church. Nor does Mersenne accept the arguments of those who say there cannot be other worlds because they are not mentioned in Scripture: there are in his opinion many things not mentioned in Scripture. Bringing together all the facets of theology does not help in this issue. "From which it seems to me that this truth must be concluded: that the statement which asserts there are not many worlds, or what is the same, that this world of ours, whose parts we see, is unique, is not concluded from the Faith".[98] The opinion of the Church Fathers, who held almost unanimously that the world was unique, is therefore also temerarious as many of their opinions have been shown to be, such as that there were no antipodes. And Mersenne displays his knowledge of the history of the question when he points out that G.F. Pico della Mirandola, following Robert Holkot, also came to the conclusion that the issue of the reality of other worlds (as opposed to the possibility, which was guaranteed by God's omnipotence) could not be determined de fide.[99]

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Even though Mersenne could come to no conclusion from theology, he did have his own opinion: that our world was unique. God's power was not a barrier to this opinion; Mersenne believed that the unity of God was manifested in the unity of the world, and that it would not have been better for God to create more worlds than one, since all things which are from God are ex omni parte infinite, and if there were more worlds, they would be finite and not better. It was enough that God manifested himself externally through the creation of a single world, in which all things were ordered, as Thomas Aquinas had argued. Nor did God need to produce all possible species - God was not obliged to do anything.[100]

As for the recent discoveries in natural philosophy, Mersenne believed them to be weak as an argument for other worlds. But Mersenne's reason is disappointing to us. Why, he asked, should the new planets, stars, and other phenomena be seen in this world if they were in another? Would they constitute messengers from another world? If so, what did they signify?[101] Caught in the midst of the transition to the "new" plurality of worlds tradition begun by Bruno, Mersenne did not yet see the relevance of his discussion in the Quaestiones to the Copernican theory.[102] But when the term "world" came to be applied to a celestial body in the context of Copernicanism, many of Mersenne's arguments were easily transferrable. Indeed, in Italy the Dominican Campanella

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was already using these and other theological arguments related to the many-worlds issue, with Copernicanism clearly in mind.

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For many theologians, Scriptural arguments against the motion of the earth were quite sufficient to demonstrate the falsity of the heliocentric theory, but in addition to this, there were some who realized the serious implications of many worlds and used them to indicate the foolishness and danger of believing in the Copernican theory. That both were factors in the situation is seen in Campanella's Apologia pro Galileo. Written in the very year of the Church's condemnation of Copernicanism (1616) and published in 1622, the purpose of the work is clearly indicated by its subtitle: "An inquiry as to whether that kind of philosophy which Galileo has made famous, is in harmony with or is opposed to the Holy Scriptures".[103] Campanella lists the arguments brought against Galileo, most of them having to do with specific Scriptural objections to the motion of the earth. Two of the eleven objections, however, deal with the subject of other worlds. According to Campanella, it has been charged

> Galileo says that water exists on the moon and the planets, which cannot be. These bodies are incorruptible, for do not all Scholastics contend with Aristotle that they endure without change throughout all time? He describes lands and mountains in the moon and other celestial globes, and not only vilifies immeasurably the homes of the angels, but lessens our hope regarding heaven.[104]

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There was another related charge:

> If the four elements which form our world exist in the stars, it follows from the doctrine of Galileo that, as Mohammed declared, there are many worlds with lands and seas, and with human inhabitants. However, Scripture speaks of only one world and of one created man, so that this belief is opposed to Scripture.[105]

Campanella says that he will pass without comment the charge that Christ must die again for the men who inhabit each of the stars. He clearly thinks that this belief holds no weight, and compares it to a former belief that Christ had to be crucified again for those who lived in the antipodes, a belief now recognized as ridiculous.

Campanella's defense of Galileo against these two charges is executed with a vigor and detail which reflects the spirited concern which this particular consequence of Copernicanism must have raised throughout intellectual Christendom. In response to the question of water on the moon, Campanella turns the tables on his opponents. To be sure, the idea of water in the celestial regions is against Aristotle, but it is amply supported by Sacred Scriptures. The first book of Genesis stated that God made the firmament, "dividing the waters that were below the firmament from those that were above it". David wrote in Psalm 103 (104) "Who stretchest out the heaven like a pavilion, who coverest the higher rooms thereof with water," and in Psalm 148 "Let all the waters that are above the heavens praise the name of the Lord". Campanella makes it clear that this question has a long history of controversy from

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the time of the Church Fathers, down through Aquinas and the Sentences of Lombard, and into his time, with varying interpretations as to whether the water is real or not, and attempted reconciliations with Aristotle's philosophy.[106]

If such passages were taken literally, how could the subtle matter of the heavens support such water, and would not the heat of the stars turn it to mist? Perhaps the water was frozen? Such interpretations of these passages have twisted the true meaning of Scripture, and even forced some to give mystical interpretations. But the Scriptures should always be interpretated literally, Campanella thinks, and now Galileo has shown us the truth of the literal interpretation. Only the solidity of land will retain water in the heavens. And if "the stars are regarded as worlds in which there are natural waters, as there are on earth,"[107] we have an explanation which accords perfectly with natural philosophy and Scripture. And Proverbs 7 can now be explained: "When he established the sky above, and with a certain law enclosed the depths, and poised the fountains of the waters...". The fountains of the waters are those contained by the earths and stars.

All Scriptural interpretations must be subjected to the actual appearances made known in recent years. The new stars and the comets, now known to be beyond the region of the moon, and the "cloudy spots" which move around the sun could not have arisen from any vapors carried from the earth. Their distance from the earth dictates that there are vapors in

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the stars from which these phenomena arise, or perhaps more specifically, "from the earths among the stars."[108] Galileo's discovery of mountains on the moon is in accord with Genesis 49 and Deuteronomy which mention fruit trees, mountains and hills in the heavens.

As for the idea of "other worlds" in itself (referring now to the second charge against Galileo), Campanella asserted as would Mersenne in 1623, that no decree in the canons of the Church prohibited such a belief. As Aquinas had pointed out long ago, the belief that many worlds are made by chance rather than by God is against the faith. On the other hand, to place many small systems or worlds within one great system was not contrary to Scripture, but to Aristotle. And Campanella indicated his scorn of Aristotle's arguments. Referring specifically to Aristotle's insistence on a single center to maintain order and the physics of motion, he reasons:

> My heart would not move to the place of yours. All things remain fixed in their own centres, and are preserved by and rejoice in the great similarity of their own parts. Lunary things strive to reach the centre of the Moon, the Mercurial the centre of Mercury. Beyond their own orb they find nothing so pleasing to them.[109]

Moreover, while Campanella believed in inhabitants on other worlds, he did not believe in the necessity that they be of many different species, and that Christ died again for them; he thought that they were not affected by Adam's original sin, and thus had no need for redemption, unless they had committed some other sin.[110]

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It was perhaps with a view towards appeasement of the Church that Campanella pointed out that one could say that Galileo disclosed not a plurality of worlds, but one world with many systems. Indeed, his overall answer to the charge that the belief in other worlds contradicted Scripture was to deny the consequence that Galileo asserted a plurality of worlds. But Campanella clearly realized that this was begging the question, and proceeded to the details related above, which pointed out that the existence of other worlds was not against Scripture or faith, and indeed would rather serve to clarify many passages in Scripture. The overall result was that the 1622 Apologia was a defense not only of terrestrial motion, but also of another implication of Copernicanism - that of a plurality of worlds.

The Tradition Consolidated: John Wilkins

As the centenary of the publication of the De revolutionibus approached, two books of great interest for the history of astronomy appeared in England, written by the Protestant divine John Wilkins. The Discovery of a World in the Moone appeared in 1638 and was followed in 1640 by A Discourse concerning a New Planet, Tending to prove, that 'tis probable our earth is one of the Planets. The purpose of the latter treatise is made explicit in the title - to demonstrate that there were substantial arguments

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which could be adduced in support of the motion of the earth, and thus in support of the Copernican theory. As such, the 1640 work is very interesting in itself, but our attention must be focused rather on the earlier treatise, the Discovery, which went through two printings in 1638, a third printing with substantial additions in 1640 in conjunction with the first appearance of the Discourse, and others in 1684, 1707, and 1802. It is this treatise which may be viewed as part of the mainstream of the plurality of worlds tradition.

One can well question at the outset just how seriously Wilkins took the task indicated in the subtitle of his 1638 work, namely, to "prove, that 'tis probable there may be another habitable world in that Planet," and thus in what light the twentieth century historian of science should study the treatise. After all, Wilkins does open with the remarks that the book was "the fruit of some lighter studies," was not an "exact accurate treatise" but rather contained only probable arguments, and was "first thought of and finished in the space of some few weekes".[111] These are hardly the kind of remarks which invite critical examination. On the other hand, the treatise had a demonstrable impact on intellectual thought, it had popular support, and was added to and improved upon by Wilkins himself. Moreover, it displays enormous erudition, a documentation of sources unusual for the seventeenth century, and a convergence of many opinions of interest to the historian of astronomy.

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The announced purpose of the Discovery, to demonstrate a world in the moon, is achieved by a very rationally ordered series of propositions, proceeding from the most general to the most specific, from the denial of the Aristotelian celestial-terrestrial dichotomy which will then allow an earth-like body in the heavens, to placing inhabitants on the lunar surface and (in the 1640 edition) an exploration of possible means of conveyance to this newly discovered world.

Only the slightest appreciation may be given here of the enormous breadth of the intellectual tradition, both scientific and theological, which Wilkins drew upon in support of his thesis.[112] Like Melancthon, Wilkins was a Protestant, but he was a Protestant concerned to reconcile science and theology, and here was obviously an issue in need of such reconciliation. As for the Aristotelian celestial-terrestrial dichotomy in general, Wilkins points out that many of the Church Fathers had been of the opposite opinion, that the "subtill braines"of the Coimbra Jesuits had not been able to demonstrate the necessity of such a principle, and that there was plenty of recent evidence for the corruptibility of the heavens.[113] A wide variety of authors concluded that there were no solid crystalline orbs, no sphere of fire, and no music of the spheres.[114] As for the moon, "the most and best Philosophers" now thought that it was a solid, compact and opaceous body, in contrast to many past authors, and even some few present ones such as Julius Caesar La Galla, who still

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believed it to be diaphanous like crystal or glass.[115] Moreover, the moon's light was not intrinsic, but entirely reflected, as Albertus Magnus, Reinhold, Maestlin, Scaliger, Tycho, Mulapertius, Kepler and many others confirmed.[116] In this it was entirely similar to the earth, and in fact our earth would appear as a "moon" to any lunar inhabitants: "as their world is our Moone so our world is their moon" (Prop. 11).

Proceeding to the more specific aspects of the moon world, Wilkins sets forth innumerable ancient and modern opinions on the nature of the moon spots, asserting that they represent the difference between land and sea (Prop. 7), and that in particular the spots represent water and the brighter regions land, in accordance with Galileo's interpretation (Prop. 8). The land consists of mountains, valleys and plains as shown by Galileo (Prop. 9). The existence of an atmosphere Wilkins believed affirmed by Maestlin, Galileo, Kepler, Scheiner, and others (Prop. 10), and of inhabitants by Nicholas of Cusa, Campanella, and Plutarch (Prop. 13).

Firmly in the plurality of worlds tradition, Wilkins argues that a belief in other worlds contradicts not reason, but Aristotle. The two are no longer equivalent. Making direct reference to Book I, chapters 8 and 9, Wilkins calls Aristotle's arguments "very weake, and farre enough from having in them any convincing power".[117] To the chief

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argument of Aristotle, by now very familiar to us, that the physics of motion demands a single centre from which all motion is reckoned absolutely, Wilkins echoes the solution which the Scholastics worked out in the aftermath of 1277:

> If you well consider the nature of gravity, you will plainely see there is no ground to feare any such confusion; for heaviness is nothing else but such a quality as causes a propension in its subject to tend downwards towards its owne Center ... If you reply that then according to this, there must be more centers of gravity than one, I answer "Tis very probable there are, nor can we well conceive, what any piece of the Moon would doe being severed from the rest in the free and open ayre, but return unto it againe.[118]

With such an argument, a major foundation of Aristotelian physics was undermined, and Wilkins knew it. Who, then, could hold such a dangerous opinion as the plurality of worlds? Campanella, for one, had defended it, and Wilkins cites the Apologia pro Galileo praising its championship of freedom from Aristotle whenever observations deemed this necessary. Wilkins himself was convinced that a belief in other worlds as part of one's natural philosophy "doth not bring any inconvenience to the rest, since 'tis not Aristotle, but truth that should be the rule of our opinions . . . . "

As for the doctrine of other worlds in relation to Scripture, Wilkins in general follows the opinions of Campanella and Mersenne. One cannot argue against other worlds from its absence in Scriputre; the "negative authority of Scripture" does not hold in those things which are not the fundamentals of religion. And while the

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opinion has been counted a heresy in ancient times,[119] this only shows the ignorance of those times, which condemned what they did not understand.

Finally, many of the specific theological objections do not obtain because of Wilkins' new conception of "plurality of worlds". While he associates his treatise with that tradition in its ancient expression, Wilkins makes explicit the new variant of that tradition which he now represents:

> The term World may be taken in a double sense, more generally for the whole Universe, as it implies in it the elementary and aethereall bodies, the starres and the earth. Secondly, more particularly for an Inferior World consisting of elements.... In this opinion, which is here delivered , this World is said to be in the Moone, whose creation is particularly exprest ... So that in the first sense I yeeld, that there is but one world, which is all that the arguments do prove; but understand it in the second sense, and so I affirm there may be more, nor doe any of the above named objections prove the contrary.[120]

With this shift, initiated by Bruno, a new set of arguments became relevant, apropos of the physical nature of the moon and other celestial bodies.

Such was the nature of Wilkins' 1638 treatise. In conclusion, an all-important question remains: why was the treatise written? It was written,of course, because the author wanted to make a case for a world in the moon. He had often thought such an idea possible, he says, but it seemed an "uncouth opinion" which might be ridiculed. It was after reading "Plutarch, Galileus, Kepler, with some

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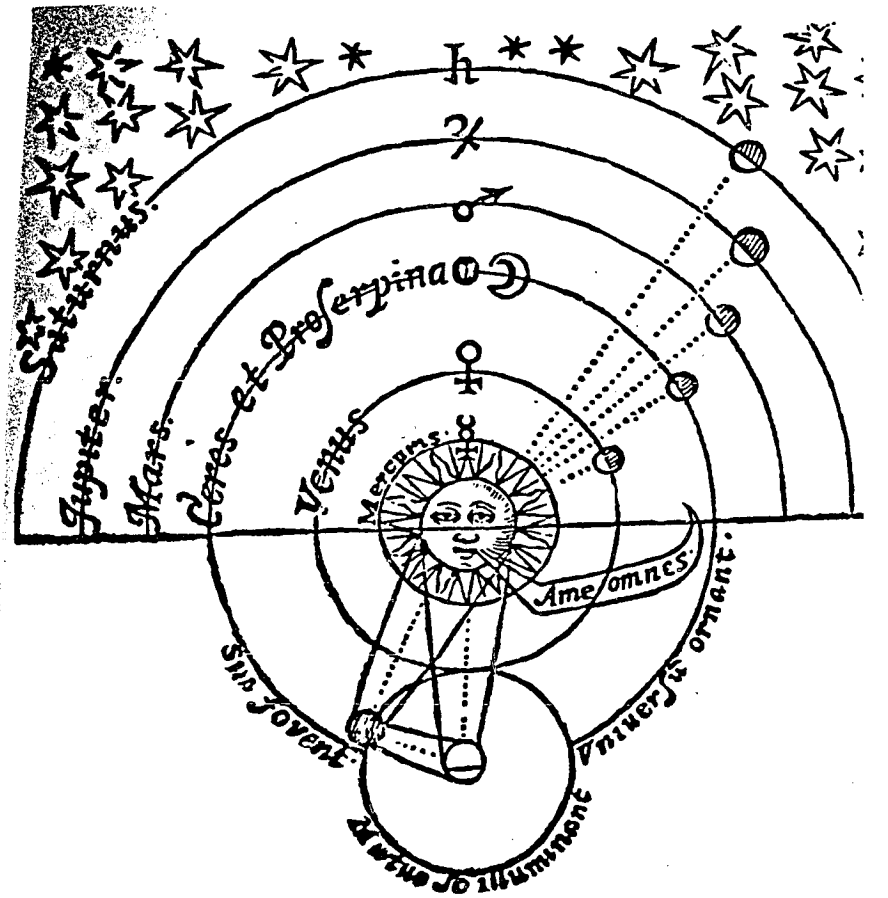
others" that Wilkins concluded the probability of a habitable world in the moon.[121] In addition he was impressed by the weakness of the anti-Galilean arguments of his "chief opponent", Julius Caesar La Galla.

The proof of a world in the moon, however, did not serve as an end in itself. Wilkins wrote the treatise within the framework of the new astronomy. In the midst of his arguments, Wilkins set aside a proposition to demonstrate that a world in the moon "hath beene the direct opinion of many ancients with some modern Mathematicians, and may probably be deduced from the tenets of others". Among those who directly maintained the opinion Wilkins cites Orpheus, Anaxagoras, Xenophanes, Pythagoras, and Plutarch; more modern expositors were Cusa and Bruno, Nicholas Hill, Galileo and Kepler. But those from whose tenets Wilkins' thesis could be deduced are of most interest to us:

> Such were Aristarchus, Philolaeus, and Copernicus, with many other later Writers who assented to their hypothesis; so Joach. Rheticus, David Origanus Lansbergius, Guil. Gilbert, and (if I may believe Campanella) Innumeri alii Angli & Galli, very many others, both English and French, all who affirmed our Earth to be one of the planets, and the Sun to be the center of all, about which the heavenly bodies did move. And how horrid soever this may seem at first, yet it is likely enough to be true, nor is there any maxime or observation in Opticks (saith Pena)that can disprove it.[122]

For Wilkins the idea of a world in the moon was perceived as an obstacle to heliocentricity which had to be

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THE DISCOVERY OF A WORLD IN THE MOONE.

The title page of the 1638 edition of the Discovery, depicting the Copernican system. The moon and earth are shown to receive their light from the sun and then to mutually illuminate each other, thus emphasizing their equal reciprocal relationship. The planets appear in phases like the moon.

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clarified and surmounted no less than the arguments against heliocentricity taken directly from earth motion. Not without reason was the 1638 Discovery, its thesis expanded upon and solidified with even more references, bound together with the 1640 Discourse. Both had the same purpose and were bound by a consistent logic: "If our earth were one of the Planets (as it is according to them [the



This elaboration of the title page from the 1638 Discovery appeared in the combined 1640 Discovery and Discourse. Copernicus, Galileo and Kepler are now shown. Galileo offers his telescope; Kepler wishes for wings so that he might visit the new world. The sun says "I give light, heat, and motion to all."

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Copernicans] then why may not another of the Planets be an earth?"[123] In the Discovery Wilkins showed that the "planet" most directly observable was in all probability indeed an earth, in accordance with the Copernican system. It was a solid step into a solar system soon to be filled with more such worlds.[124]

* * *

The concept of a plurality of worlds was not much discussed among natural philosophers or the populace in the first century following Copernicus. The idea may rather be shown to stem from several sources which are understood best when viewed in relation to the Copernican theory. Aristotle's refutation in the De caelo of a plurality of kosmoi (and thereby of a plurality of centers), commented upon through the Middle Ages and still part of the collective intellectual consciousness in the Renaissance, was shown to be indefensible in the face of the moving earth which Copernicus posited. In place of a single centre of motion arose a system in which each of the bodies in the solar system and even each of the fixed stars represented a center of motion - a world of its own.

Secondly, there were the infinite worlds of Giordano Bruno. Related to Copernicanism only peripherally, Bruno's worlds drew rather on metaphysical principles, especially that of "unity", unity made perfect by infinite diversity -

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diversity which was found in an infinite number of worlds. It is true that in expounding his philosophy Bruno did effectively destroy many of Aristotle's arguments. And although very few thinkers identified with his vision of infinite worlds, there is little doubt that elements of his arguments were influential in supporting the more conservative plurality of worlds tradition.

Finally, there was the tradition of empirical observation of the moon. While Aristotle had seen it as a perfect polished sphere, Plutarch already in the early Christian era had described it in detail, in his De facie in orbe lunae, as a body similar to the earth in so many respects that it might be considered an inhabited world. Renaissance thinkers like Leonardo da Vinci found much to agree with in Plutarch, and the latter's conceptions undermined the Aristotelian position. But only within the framework of the Copernican theory could Plutarch's ideas thrive. Kepler's teacher Maestlin saw rains on the moon; Kepler himself employed the principle of optics to determine its nature. Such principles had been applied less forcefully by Witelo, Reinhold, and others before, but within the Copernican paradigm the results they gave now became more compelling. Galileo's discoveries solidified Kepler's belief in the moon world, and by 1638 Wilkins too was convinced.

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The moon was thus absolutely crucial to the early success of the plurality of worlds tradition. To be sure, Bruno had little need for the moon in deducing his infinite worlds, but to the more empirical minded men of science it was compelling evidence that there might be more worlds in the planets and stars. Bruno aside, it was not solely or consistently on the basis of Lovejoy's principle of plenitude that the issue of other worlds was decided.

It was thus as an implication of Copernicanism that the plurality of worlds idea became viable in a new form. To a thorough-going Peripatetic such as La Galla, it was a ridiculous and heretical idea, one of the consequences of Copernicanism which proved the falsity of that theory. Kepler's word notwithstanding, to a geocentrist such as Tycho, other worlds were a redundancy. Even to an ardent Copernican like Galileo, it was theologically and metaphysically a profoundly disturbing idea, one which Campanella had shown could be grappled with successfully, but which Galileo sought to minimize without abandoning the necessity for the uniformity of nature. Finally, with Wilkins, the issue of a plurality of worlds received a systematic and critical review understandable to laymen and convincing to many natural philosophers. Wilkins was no Bruno to be cast aside as a heretic, but rather one of the new breed of critically thinking natural philosophers that emerged in the seventeenth century. Along with other more pervasive

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and in some ways more important arguments, the plurality of worlds idea remained one to be grappled with by Copernicans, one not to be accepted or rejected without direct consequences for one's belief in the true system of the world.

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NOTES

[1] "Desinant igitur Peripatetici succensere Plutarcho, quod Terram is in coelum intulerit, hoc ist Lunae corpus terrestre esse tradat: cum videant certissimis experimentis constare, quod in lucis consortium, qualem quidem Luna obtinet, haec nostra terra venerit. Tandem vero, ubi Plutarchus, ubi Moestlinus aequis in Philosophia auribus fuerint accepti: tum bene Aristarchus cum Copernico suo discipulo sperare incipiat." Johannes Kepler, Astronomiae pars optica, in Gesammelte Werke, eds. Walther von Dyck, Max Caspar, Franz Hammer (Munchen, 1937-), II, p. 224, section 10, "De illustratione mutua Lunae et Terrae". My translation.

[2] The destruction of the cosmos is documented in Alexandre Koyre, From the Closed World to the Infinite Universe (Baltimore and London, 1970).

[3] Grant McColley, "The Seventeenth Century Doctrine of a Plurality of Worlds," Annals of Science, I, 1936, pp. 385-430.

[4] I.B. Cohen, The Birth of a New Physics (New York, 1960), presents one of the more simplified but lucid accounts of how these obstacles to the Copernican theory were overcome in the seventeenth century. Koyre's work, beginning with his classic Etudes Galileennes (Paris, 1939), also has done much to clarify how this revolution in physics took shape in the minds of natural philosophers.

[5] The point of some contention among scholars is rather the role of the Copernican theory in Bruno's philosophy. Paul-Henri Michel, La cosmologie de Giordano Bruno (Paris, 1962), English translation The Cosmology of Giordano Bruno (New York, 1973) is among the recent accounts which puts forth the more widely accepted view that Bruno's debt to Copernicus was very limited. cf. pp. 196 ff. in the French original; pp. 180 ff, in the English translation. Antoinette Paterson, The Infinite Worlds of Giordano Bruno (Springfield, 1970) is a rather tendentious book which casts Bruno in the role of hero, and sees Copernicus as the starting point and continuing inspiration for Bruno's entire philosophy. Frances A. Yates, Giordano Bruno and the Hermetic Tradition (New York, 1969) interprets Bruno's Copernicanism as only a small part of his much broader Hermetic philosophy, and sees the Hermetic tradition as the driving force behind much of Bruno's thought. cf. especially Chapter VIII.

[6] The original Italian, complete with notes and bibliography, may be found in Giovanni Aquilecchia, La cena de le ceneri (1955), p. 92; a French precis-translation is given in La cena de le ceneri, le banquet des cendres, trans. Emile Namer (Paris, 1965), p. 64. An English translation by Stanley L. Jaki is in press; the present translations are mine.

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[7] De revolutionibus, Book I, sec. 8: "Let us leave to the Physicists the question whether the universe is finite or no, holding only to this, that the Earth is finite and spherical."

[8] Aquilecchia, p. 90; Namer, p. 63.

[9] Aquilecchia, p. 98-9; Namer, pp. 65-66.

[10] Dorothea Singer, Giordano Bruno: His Life and Thought, with annotated translation of his work On the Infinite Universe and Worlds (New York, 1950), p. 246. The original Italian may be found in Opera Italiane (Bari, 1925), ed. by G. Gentile.

[11] Op. Ital., ibid. English translation Cause, Principle, and Unity (Essex, 1962), trans. by Jack Lindsay.

[12] Singer, p. 229.

[13] (Frankfort, 1591). The modern edition is that of Fiorentino, Giordani Bruni Nolani Opera Latine conscripta, I, pt. 1, pp. 191-398 and I, pt. 2, pp. 1-318.

[14] De l' infinito, Dial. II; De immenso, Book II.

[15] De l' infinito, Dial. III; De immenso, Bks. III-IV.

[16] De l' infinito, Dials. IV-V; De immenso, Bks. VI-VII.

[17] Singer, p. 329.

[18] Ibid., pp. 370-71.

[19] Ibid., p. 310.

[20] Ibid., p. 314.

[21] Ibid., p. 306.

[22] Ibid., p. 266.

[23] Ibid., P. 362.

[24] Arthur O. Lovejoy, The Great Chain of Being (Cambridge, Mass., 1971). cf. esp. Chapter IV, "The Principle of Plenitude and the New Cosmography", and on Bruno pp. 116 ff.

[25] Singer, p. 367. Bruno found additional metaphysical support for such a view in Nicholas of Cusa, a Catholic reformer of the Quattrocento, who, based on his own principle of "coindidence of contraries", concluded that in an infinite universe the center is everywhere, and the circumference nowhere. This idea is

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even older than Cusa, but Bruno was much influenced by Cusa's De docta ignorantia (c. 1440), and quotes from that work in the De l' infinito (Singer, pp. 307-308). Bruno discusses the "coincidence of contraries" in his treatise explicitly in relation to the assertion of many centers: Dial. V, p. 367.

[26] De revolutionibus, I, 9. "Now it seems to me gravity is but a natural inclination, bestowed on the parts of bodies by the Creator so as to combine the parts in the form of a sphere and thus contribute to their unity and integrity. And we may believe this property present even in the Sun, Moon, and Planets, so that thereby they retain their spherical form notwithstanding their various paths." I have followed the translation of Dobson and Brodetsky in Occasional Notes of the Royal Astronomical Society, No. 10, May, 1947. For a more literal, but less intelligible rendering, see the Great Books of the Western World, vol. 16, p. 521.

[27] Singer, p. 373.

[28] Ibid. p. 374.

[29] As early as November 5, 1603, the Englishman Edmund Bruce had written to Kepler from Venice expressing the Brunonian view: "I have many doubts in astronomy in which you alone make me more certain. For I am of the opinion that there are infinite worlds . . . ." Kepler, Gesammelte Werke, XIV, p. 450, hereafter cited as GW. A general interest in the fate of Bruno is expressed in passing in a series of letters that passed between Kepler and Brennger, a physician at Kaufbern, from September, 1607 to June, 1608, in which Kepler says that he first learned from the follower of Bruno, J.M. Wackher von Wackenfels, that Bruno was burned at Rome. Both correspondents indicate their belief that Bruno was a heretic, but Brennger nevertheless admits he "feels sorry for the man". The Kepler-Brennger letters may be found in GW, XVI, pp. 134-170. By 1610 Kepler displays a familiarity with Bruno's doctrines in some detail; cf. below, pp. 138 ff.

[30] Koyre, From the Closed World to the Infinite Universe, Chapter 3.

[31] Edward Rosen, Kepler's Conversation with Galileo's Sidereal Messenger (New York and London, 1965), pp. 23, 28. All future citations to the Dissertatio will be to this excellent annotated translation by Rosen.

[32] The evidence for this early interest in the moon is Kepler's own remarks regarding the now lost "lunar dissertation" in the 1610 Dissertatio (Ibid., p. 28), and also in his notes to the Somnium: Edward Rosen, Kepler's Somnium (London, 1967), p. 129 et passim. Rosen's Appendix C to the Somnium points out

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that Kepler was not allowed to defend the 1593 thesis because of the prevalent anti-Copernican attitude of the university. If Kepler discussed lunar inhabitants in addition to terrestrial motion, it is not difficult to understand why the defense was refused and how the anti-Copernicanism of some may have been strengthened!

[33] Kepler's Somnium, p. 33. Kepler's reference is to Reinhold's commentary on Peurbach's Theoricae novae planetarum, first published in 1542, which included a section "De illuminatione lunae". In this section Reinhold made the reference to Plutarch, and added to his own ideas regarding the nature of the moon, ideas which Kepler also cited in Chapter VI of the Optics. Once discovered by Kepler, Plutarch seems to have had a seminal influence on his ideas regarding the moon, to the extent that Kepler translated Plutarch's entire De facie from Greek to Latin. Kepler's translation is reprinted in Frisch, Johannis Kepleri Astronomi Opera Omnia (Frankofurti A.M. et Erlangae, 1859), VIII.

[34] GW. II, p. 218. This and the following translations from the Latin are mine unless otherwise indicated. On Kepler's phrase "comprising one globe out of water and land," see Copernicus, De rev., I, 3.

[35] Ibid., p. 218.

[36] Ibid., p. 220.

[37] Ibid., p. 220.

[38] Ibid., p. 220. Kepler's allusion to the belief that the soul was cleansed on the moon after death is taken from Plutarch. cf. Concerning the Face which appears in the Orb of the Moon, trans., Harold Cherniss, Loeb Classical Library, (Cambridge, Mass., 1957), pp. 209 ff: "Just as our earth contains gulfs that are deep and extensive . . . so those features are depths and hollows of the moon. The largest of them is called "Hecate's Recess," where the souls suffer and exact penalties for whatever they have endured or committed after having already become Spirit; and the two long ones are called "the Gates", for through them pass the souls now to the side of the moon that faces heaven and now back to the side that faces earth."

[39] Ibid, p. 224.

[40] GW, I, De stella nova serpentarii, p. 246. "Ut Copernicum etiam mittam, qui Telluri ipsi jus civitatis in coelo dedit."

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[41] Ibid., Ch. 19, "De materia novi sideris".

[42] Ibid., Ch. 24, "De efficiente novi sideris".

[43] Ibid., Ch. 30, "Quo fine praecipue incensum sit novum sidus". On the Tycho reference cf. note 45 below.

[44] Brennger to Kepler, September 1, 1607, GW, XVI, p. 39. "Nosti mi Keplere longe aliam esse nostrae terrae quam stellarum rationem, siquidem harum corpora sunt simplicia, similaria, et teste Philosopho purissima: nostra autem terra non simplex sed dissimilaris et impura . . . ."

[45] Kepler to Brennger, November 30, 1607, GW, XVI, p. 86. "Stellarum globos putas purissimos simplicissimosque, mihi videntur esse similes nostrae Telluris. Tu philosophum allegas philosophus: si rogaretur experientiam diceret. At tacet experientia, cum nemo ibi fuerit, igitur nec negat, nec affirmat. Ipse vero argumentor probabiliter a similitudine, et ut tu inductione a Luna, quae multa habet similia terrestribus. Itaque et humorem stellis tribuo et regiones, quae ab exhalatione humoris compluantur et creaturas viventes, quibus id utilitati cedit. Nec enim solus infelix ille Brunus prunis tostus Romae, sed etiam Braheus meus in hanc concessit sententiam, esse stellis incolas. Id ego tanto etiam ferre affirmo cum Aristarcho." This is one of several references by Kepler to Tycho's belief in "stellar inhabitants" (esse stellis incolas) (For more references see footnote 54). If Kepler's reference is to a discussion in Tycho's Epistolarum astronomicarum libri (Uraniburgi, 1596), as it almost certainly is, then Kepler seems to have rather badly represented Tycho's true opinion. The relevant passage (J.L.E. Dreyer, Tychonis Brahe Dani Opera omnia, Hauniae, 1919, vol. VI, p. 222), in which Tycho is replying to Rothmann in their controversy over the Copernican system, translates as follows:

"That annual motion attributed by Copernicus to the earth in addition to the diurnal motion would cause much to be in vain, as we have said before: Nevertheless, that resultant absurdity which we have adduced in a prior letter to Rothmann he does not seem to think adequate. He thinks there is nothing to abhor when the space from the sun (then in the center of the universe) to Saturn could be placed many times in that empty space out to the fixed stars; and all that space out to the stellar orb would have neither a reason nor a use for which it might be necessary. And thus also Rothmann thinks it is not abhorrent for the stars of the third magnitude to equal in size the whole annual orbit of the earth, which is in effect to assert that the sphere of the sun should not be

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(45 cont.)

held in awe; and to admit nothing to be absurd, excusing its infinite possibility and the asymmetry of the universe as due to the Divine will."

"What can one say here? That the Divine will acts somewhere irregularly and inordinately, against what appears otherwise in the whole theatre of the world? Where everything is disposed by its just time, measure, and weight, everywhere in due form? Nothing is idle, nothing in vain, nothing without a certain harmony among all things, and a corresponding proportion. Certainly from Saturn to the fixed stars, an interval of more than 7 000 000 semi-diameters of the earth, nothing would be contained of use to the inhabitants of the earth,who are exalted by the much higher fixed stars, and nevertheless not least served by them. Also it is certain that some of the fixed stars would then equal in size the whole annual orbit which the sun describes (or as he wishes, the earth), others indeed would be far larger. The sun itself, the principle body and luminary of the world has hardly been given so much matter, although the stars constituted in the heavenly expanse should obtain less priority with respect to the sun in the plan for the creation of the world, so that also by comparison they should be lesser bodies than it. But as it is, the rest of the planets depend on the authority and pre-eminence of the sun."

"And I ask what kind of visible symmetry the world will exhibit, if the greatest part will be destitute of creatures that see; this is the case if indeed certain celestial bodies are enlarged almost immeasurably and if there is a purpose for their size in itself, since [such creatures] may scarcely be conferred upon those bodies. [Et qualis quaeso Mundi visibilis Symmetria sic prodibit, si maxima pars Creaturis visibilibus destituta erit: Quaedam vero corpora coelestia in immensum ferme augeantur, quaedam vero utut per se vasta, cum his tamen vix conferri possint?] Such "ageometry", asymmetry, and inordinate arguments for philosophizing is most alien from the Divine wisdom and providence, which things even Rothmann himself when he was with me did not dare to defend further, but confessed the great absurdity to be evident..."

*

Tycho thus seems to be making a reductio ad absurdum argument against Copernicanism: if the annual motion of the earth is a fact, then there will be a great empty space between Saturn and the fixed stars, and moreover the stars themselves will be immeasurably large. Thus the largest part of creation is of no use to anyone, unless there are stellar inhabitants. Stellar inhabitants are impossible. Since "nothing has been created in vain" is axiomatic for Tycho, the Copernican system is therefore impossible. Q.E.D.

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(45 cont.)

Kepler, as a Copernican, saw this not as a reductio ad absurdum for Copernicanism, but as a good argument for stellar inhabitants! Tycho, of course, had his own geostatic system, and thus had no need to propose stellar inhabitants.

That this is indeed the passage that Kepler had in mind is supported by the fact that another early seventeenth century author referred to this belief of Tycho, and cited the Astronomical Letters of 1596. Robert Burton's famous Anatomy of Melancholy, which first appeared in 1621, with subsequent editions in 1624, 1628, 1632, 1638, 1651, 1660, and 1676, contained a "Digression on Air" in which Burton digressed even further to give a sampling of current astronomical opinion. In connection with the Copernican theory, Burton noted that the tenet of earth motion made the earth a planet, and raised the possibility that the planets might be inhabited like the earth, and that planets might circle other suns elsewhere. Burton cites Kepler as agreeing with this in part, "and so doth Tycho in his Astronomical Epistles, out of a consideration of their vastity and greatness, break out into some such like speeches, that he will never believe those great and huge bodies were made to no other use than this we perceive, to illuminate the earth, a point insensible in respect of the whole." cf. (London, 1893: reprinted New York, 1973), pp. 60 ff. esp. pp. 62-4). The passage from Tycho is further pinpointed by Burton's reference a few pages previous to "such an incredible and vast space or distance (7 000 000 semidiameters of the earth, as Tycho calculated)" between Saturn and the fixed stars. This is the exact figure which Tycho cites in the passage concerning stellar inhabitants. On Burton's discussion of other worlds, see Richard G. Barlow, "Infinite Worlds: Robert Burton's Cosmic Voyage," Journal of the History of Ideas, April-June, 1973, pp. 291-302.

[46] Although even here there exists no definitive study, some account of the influence of the telescope in general on the Copernican hypothesis may be found in the standard histories of astronomy. See also Marjorie Nicholson "The Telescope and the Imagination" Modern Philology, XXXII (1934-35), pp. 233-260, and "A World in the Moon", Smith College Studies in Modern Languages, XVII, no. 2 (Jan. 1936), pp. i-72.

[47] Stillman Drake, Discoveries and Opinions of Galileo (new York, 1957), p. 31; p. 34.

[48] Rosen, Kepler's Conversation, p. 14.

[49] Ibid., p. 38.

[50] Ibid., p. 27.

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[51] Ibid., p. 28.

[52] Ibid., pp. 29-30. Kepler cites Maestlin's "little book published at Tubingen in the year 1606." Frisch (according to Rosen) supplies the title as "Disputation concerning the Manifold Apparent Irregularities, or Regular non-Uniformities, in the Motions of the Planets in the Heavens, and their Astronomical Causes." Kepler cites the following passage from Maestlin's work, now lost: "The moon was eclipsed during the evening of Palm Sunday in the year 1605. On the body of the moon, in the north, a certain blackish spot was seen, darker than all the rest of the body, which looked like red hot iron. You might have called the spot a cloud, which was spread over a wide area and laden with rain and stormy showers. This kind of formation may be seen not infrequently stretching from the lofty mountain chains to the lower depths of the valleys." However seriously Maestlin took such "rains", Kepler's further account of the 1606 work shows that Maestlin found many "bonds of kinship" between the earth and the moon, based on an analysis of their density, shadow, atmosphere, light borrowed from the sun, and rough surfaces.

[53] GW, IV, p. 343. "Sed omnem admirationem superat illud caput nuncii siderii, ubi Perspicilli perfectissimi beneficio alter nobis velut mundus Jovialis detectus narratur: et mens Philosophi non sine stupore considerat, esse ingentem aliquem globum, qui mole corporis quatuordecim globos terrestres adaequat . . . circa quem quatuor Lunae nostrae huic Lunae non absimiles, circumcurrant. . ." One year after the Dioptrice was published, Simon Marius published a treatise entitled Mundus Jovialis, which dealt with the discovery of Jupiter's moon system, analagous to the earth-moon system, thus a "mundus".

[54] Rosen, Kepler's Conversation, p. 42. The general argument that nothing in the universe has been created in vain, the mention of inhabitants, the "largeness of those globes factor", and the reference to Tycho make it a virtual certainty that Kepler is again referring to the passage in Tycho's 1596 Astronomical Letters (cf. note 45 above). Now, however, Kepler has corrupted even further Tycho's argument, which had to do with the size of the fixed stars if the earth were in motion. Kepler here applies the "largeness factor" to Jupiter in arguing for inhabitants there. For still another reference by Kepler to Tycho's belief in inhabitants in the same context see Book V of the Harmonies of the World, section 10 "Epilogue Concerning the Sun, by way of Conjecture," in Great Books, vol. 16, p. 1084.

[55] Ibid., p. 43. This passage has retained its dramatic appeal from the time it was cited by Burton in his Anatomy of Melancholy (1621), through the twentieth century when H.G. Wells used it to preface his War of the Worlds.

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[56] Ibid., p. 34.

[57] Ibid., pp. 34-36.

[58] Ibid., p. 44. On the medieval version of this argument, see infra, ch. 2.

[59] Ibid., p. 36.

[60] The idea of a "center of attraction", or perhaps more accurately "center of motion", again emerges as an important concept in the shift from the ancient view of mundus as kosmos to the new view. The ancient cosmos and the 17th century celestial body had one thing in common in being called "worlds": each embodied a single center of motion.

[61] Kepler's Somnium, p. 36.

[62] Ibid., p. 17.

[63] Ibid., pp. 26-27.

[64] Ibid., pp. 149-174. The "Geographical or Selenographical Appendix" originated as a letter written to Paul Guldin (1577-1643), a Jesuit friend, a fact which makes one wonder just how widespread was the interest in such matters. On the Kepler-Guldin relation cf. Rosen's Appendix L to this work.

[65] For an analysis of Kepler's use of observation in the Somnium, see infra, ch. 6.

[66] Kepler's Conversation, p. 28. Kepler was working on the Somnium in the summer of 1609, thus the reference to the "lunar geography".

[67] For a recent brief discussion of La Galla and the moon cf. O. Van de Vyver, S.J., "Original Sources of Some Early Lunar Maps", Journal of the History of Astronomy, II, part 2, June, 1971, pp. 86 ff.

[68] La Galla's work is reprinted in the National Edition of Galileo's Opere, III, part 1, hereafter cited as Opere. cf. esp. chapters 6-8.

[69] See above, p. 139. It is interesting to note that the moon was not Galileo's first encounter with other worlds. In the Juvenalia, he had taken up the standard medieval questions "De unitate mundi et perfectione", Opere, I, pp. 27-31, tractatio prima, quaestio tertia. Here Galileo showed his mastery of the arguments of Plato, Aristotle, and the Aristotelian commentators, especially Albertus Magnus and Thomas Aquinas. Galileo believed that it followed from Scripture that there was only one cosmos, since Moses spoke only of the creation of one

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(69 cont.)

world. But he also believed that the unity of the world could not be demonstrated, either by the senses, by experiment, or by reason, since the arguments of Aristotle were easily overcome and God could make many worlds if He wished.

[70] Opere, XI, pp. 21-26.

[71] Discoveries and Opinions of Galileo, trans., Stillman Drake (New York, 1957), p. 137.

[72] Galileo to Cesi, January 25, 1613, Opere, XI, p. 467.

[73] Ciampoli to Galileo, February, 1615, Opere, XII, pp. 145-47. For more of Ciampoli's letter cf. Drake, Discoveries and Opinions, p. 158.

[74] Campanella to Galileo, November 3, 1616.

[75] Dialogue Concerning the Two Chief World Systems: Ptolemaic and Copernican, trans., Stillman Drake (Berkeley, 1962), pp. 9-46.

[76] Ibid., p. 47.

[77] Ibid., p. 47-62.

[78] Ibid., p. 61.

[79] Ibid., p. 61.

[80] Ibid., p. 62.

[81] Ibid., p. 62.

[82] Ibid., pp. 62-99.

[83] Ibid., p. 99. Galileo continues "though I fancy to myself that its regions are not idle and dead, still I do not assert that life and motion exist there, and much less that plants, animals, or other things similar to ours are generated there. Even if they were, they would be extremely diverse, and far beyond all our imaginings!"

[84] Ibid., pp. 99-100.

[85] Ibid., p. 100.

[86] Grant McColley and H.W. Miller, "Saint Bonaventure, Francis Mayron, William Vorilong and the Doctrine of a plurality of worlds," Speculum, XII, 1937, p. 388. The quotation is from William Vorilong.

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[87] Melancthon's Scriptural argument ran as follows:

> "To us in the Church, it is both easy and necessary to assert that the world is unique, because the doctrine of the heavens confirms that this world alone has been preserved, in which God makes himself manifest, in which he entrusts his doctrine to men, and into which he sent his Son in human form. And then it adds expressly, that God was idle, and did not preserve another huge mass or living being. Thus the passage in the second chapter of the first book of Moses must be understood, namely this, "He ceased from all His work," that is, He did not form other worlds, other living beings, or any new species. It is therefore necessary that there be only this world, not many other worlds, and for that one reason this one world is called the seat of God, as is said in the Psalm "God prepared his seat in the heavens". Initia doctrinae physicae (Whitebergae, 1550), fol. 43 recto-verso.

[88] Initia doctrinae physicae (Witebergae, 1550), fol. 43.

[89] The best study of Mersenne's natural philosophy remains that of Robert Lenoble, Mersenne ou La Naissance du Mecanisme (Paris, 1943).

[90] Quaestiones celeberrimae in Genesim, cum accurata textus explicatione (Lutetiae Parisorum, 1623). Quaestio XX "De Mundis", Article I, cols. 1074-75 (incorrectly numbered 1081-82). All translations from Mersenne are my own.

[91] The list of some 8 current arguments for a plurality of worlds occurs on cols. 1074 (i.e. "1082") -1076.

[92] Ibid., cols. 1075-76.

[93] Ibid., col. 1076.

[94] Ibid., cols. 1077-1088 (i.e. 1077-"1096").

[95] Ibid., col. 1079. Methodius de Resurrectione is cited.

[96] Ibid., cols, 1079-80.

[97] Ibid., cols. 1079-80.

[98] Ibid., col. 1080.

[99] "Franciscus Picus lib. sexto examinis doctrinae gentium" is cited. This is the Examen vanitatis Doctrinae Gentium, & veritatis Christinae disciplinae which does just what the title proposes: exposes the vanity of the doctrines of secular philosophers in comparison to the truths of Christianity. In Book VI, Ch. 9 Pico examines "Quod in Libris de Caelo et Quinta essentia, et alia multa, quae Aristoteles asseverat, negari possunt, & quod eius rationes de mundi unitate ab aliis debilia argumenta existimantur,"

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(99 cont.)

pp. 1202-08 in the recent reprint of the Basel, 1573 edition. The discussion de mundi & terrae unitate covers pp. 1205-08. Pico puts no credence in the arguments of Aristotle, although he does believe our world to be unique. Much of the discussion centers around Plutarch's treatment of other worlds in his de defectu oraculum. Pico follows Robert Holkot's confutation of Aristotle's arguments against other worlds as set forth in the second book of Holkot's Sentence commentary, article 6 of the second question. Holkot was a contemporary of Ockham (14th century); both were influenced by the condemnation of 1277 which insisted that other worlds were possible on theological grounds. Mersenne's opinion is thus conditioned by that formulated in the aftermath of that 1277 condemnation. For the medieval tradition of plurality of worlds, see infra, Ch.2.

100 Mersenne, cols. 1082-83 (i.e. "1090-1091).

101 Ibid., col. 1083 (i.e. "1091")

102 On Mersenne's ambiguous attitude toward the Copernican theory, see William L. Hine, "Mersenne and Copernicanism," ISIS, vol. 64, no. 221, pp. 18-32.

103 The Apologia has been translated into English by Grant McColley, "The Defense of Galileo", Smith College Studies in History, XXII, nos. 3-4, Apr.-July, 1937. The Latin edition may be found in Tommaso Campanella, Apologia di Galileo (Torino, 1968).

104 McColley, p. 8, charge # 8.

105 Ibid., p. 8, charge #9.

106 Ibid., pp. 56-64. Campanella discusses the opinions of Basil, Chrysotom, Ambrose, and Augustine among others.

107 Ibid., p. 61.

108 Ibid., pp. 63-4.

109 Ibid., p. 65.

110 Ibid., p. 66.

111 "To the Reader". I am using the 1640 edition, since it is more complete than that of 1638. Since there are so many editions, I will merely cite the specific Proposition involved, since they are relatively short and common to all editions. There is a recent facsimile reprint of the 1638 edition (new York, 1973).

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[112] For an analysis of Wilkins sources and the role of observation in his work, see infra, Ch. 6.

[113] Prop. 3.

[114] Ibid. Wilkins cites here the opinions of various Church Fathers, Scheiner, Cardan, Pena, Tycho, Rothmann, and Plutarch among others.

[115] Prop. 4.

[116] Prop. 5.

[117] Prop. 2.

[118] Ibid.

[119] Wilkins cites Baronius: Annot. eccl. A.D. 748, to the effect that a certain Virgilius was cast out of his Bishopric and excommunicated from the Church for a belief in plurality of worlds.

[120] Prop. 2.

[121] Prop. 1.

[122] Prop. 6.

[123] Ibid.

[124] The relationship between Copernicanism and the plurality of worlds can of course be followed beyond Wilkens, as will be reflected in later chapters. Particularly relevant is the opening paragraph of Christian Huygens' Cosmotheoros:

> A man that is of Copernicus' opinion, that this Earth of ours is a planet, carry'd round and enlightened by the Sun, like the rest of them, cannot but sometimes have a fancy, that its not improbable that the rest of the Planets have their Dress and Furniture, nay and their inhabitants too as well as this Earth of ours, especially if he considers the later Discoveries made since Copernicus' time of the attendants of Jupiter and Saturn, and the Champain and hilly countrys in the moon, which are an argument of a relation and Kin between our earth and them, as well as a proof of the truth of that system.

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Chapter Four

Cartesian Vortices and the Plurality of Solar Systems

> It seems to me that the mystery of the incarnation and all the other advantages which God bestowed on man do not preclude the possibility that he might have granted infinitely many others, very great, to an infinity of other creatures. And, not even inferring from this that there may be intelligent creatures on the stars or elsewhere, I still do not see that there would be any reason by which to prove that there are not; but I always leave these questions, once posed, suspended, preferring not to deny and not to affirm anything.
>
> Descartes[1] 1647

> ... If the fix'd Stars are so many Suns, and our Sun the centre of a Vortex that turns round him, why may not every fix'd Star be the centre of a Vortex that turns round the fix'd Star? Our Sun enlightens the Planets; why may not every fix'd Star have Planets to which they give light?
>
> Fontenelle[2] 1686

Even as the aged Galileo faced the condemnation of the Church in Rome following the publication of his Dialogues in 1632, the young French philosopher Descartes was completing the first sketch of his novel physics and cosmology. In every way it was a cosmology more innovative and more revolutionary than that which Galileo had espoused: it absorbed Copernicanism and went on to spread Copernican systems throughout an infinite universe, but even more it embodied a new physics and metaphysics, and new principles of epistemology and methodology. The publication of Descartes' Principles in 1644 signalled the birth of the first complete physical system since that propounded by Aristotle some 2,000 years earlier. Although subsequently superseded by Newtonian mechanics, the Cartesian system caught the imagination and withstood the scrutiny of many a natural philo-

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sopher in the course of the seventeenth and eighteenth centuries.

Historians have long recognized an association between Cartesianism and the plurality of worlds tradition, but the precise nature and strength of the bonds have never been explored in satisfactory detail. In a work which has become a classic in the history of ideas, Arthur O. Lovejoy asserts that "it was probably to the vogue of Cartesianism rather than to any direct influence of the writings of Bruno that the rapidly growing acceptance of the theories of the plurality and infinity of worlds in the second half of the seventeenth century was chiefly due."[3] It is not, however, Cartesian physics and astronomy which Lovejoy identifies as significant in this respect, but rather Descartes' invocation of a "principle of plenitude" - the notion that the full power of the Creator must be realized in his creations. Upon this metaphysical premise, Lovejoy claims "chiefly rested [Descartes'] further assurance of the existence of innumerable other stars and systems invisible to us,"[4] and it is this principle, along with Descartes' rejection of anthropocentricity, to which Lovejoy points in the works of Henry More, Fontenelle and others in the seventeenth and eighteenth centuries. Paolo Rossi agrees that plenitude plays a role and especially emphasizes Descartes' abandonment of anthropocentricity, but in addition he suggests that "the mechanistic cosmology of Descartes lent itself to wide use in affirming the thesis of an infinitely populated universe - one may simply think of Fontenelle."[5] The reference is to Bernard le Bovier de Fontenelle's famous Entretiens sur la pluralité des mondes (1686), which makes such wide use of Cartesian vortices

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to expound its thesis that it has been called "the apogee of Cartesianism in French thought."[6]

There is undoubtedly a certain amount of truth in the claims of both Lovejoy and Rossi, yet they fall short of demonstrating the extent to which distinctly Cartesian elements did indeed contribute to the spread of the idea of a plurality of worlds. Lovejoy leans heavily on the principle of plenitude, hardly a "Cartesian" idea in itself, and therefore one he presumably takes to have been utilized in conjunction with Descartes' cosmology. Rossi suggests that Descartes' mechanical cosmology is indeed a significant factor in the relationship, but fails to document the case aside from the passing reference to Fontenelle. How justified, then, is the claim for a significant influence by Cartesianism on the idea of inhabited planets? Was it chiefly a general metaphysical principle of plenitude or Descartes' unique physical system which advanced the cause of other worlds? Was Fontenelle's use of vortices to expound the theme of the Entretiens exceptional or part of a widespread pattern? What precisely are the most important elements of Cartesianism which historically have had a bearing on the plurality of worlds tradition?

The old atomist problem of more than one cosmos received a very direct answer in the Cartesian system. The essence of that system, as set forth in the 1644 Principles, was the identification of extension and matter; to the mind of Descartes, it was

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a self-evident, or "clear and distinct", idea that whatever was extended was material. The atomist conception of void space was an impossible one; such purported "space" was obviously extended and thus it was not space at all, but matter, according to Descartes' precept. Two principles in Descartes' treatise made the controversy over other kosmoi a closed case, if one accepted this basic idea of the equation of extension and matter. Principle 21 in Part II held that the extension of the world was indefinite: Descartes could imagine no limit to the world, therefore there was no limit, a classic illustration of the application of a "clear and distinct idea". Principle 22 went on to point out the uniformity of matter throughout the universe which must result, and concluded that "even were there an infinitude of worlds, they would all be formed of this matter,"

> from which it follows that there cannot be a plurality of worlds, because we clearly perceive that the matter whose nature consists in its being an extended substance only, now occupies all the imaginable spaces where these other worlds could alone be, and we cannot find in ourselves the idea of any other matter.[6]

This was an ironic variation of the same argument that Aristotle had employed to prove the unity of the cosmos. For Aristotle there was not enough matter: beyond our finite cosmos there was no matter out of which another world might be composed; indeed there was neither space, nor void, nor time. For Descartes there was too much matter: the plenum filled all the infinite spaces, forming one continuous world. There was no room for another world in the sense of an Aristotelian cosmos.[7]

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While the Aristotelian cosmos was thus destroyed and the possibility of more than one cosmos was precluded, the third part of the Principles set forth a cosmology that would add a new dimension to the plurality of worlds tradition. Descartes opens his section on the visible astronomical world by asserting the greatness and power of the Creator, and by cautioning that man cannot presume to know for what ends all things were created, except that in all probability they were not created for man himself. It is necessary to keep this non-anthropocentric view in mind "in order that we may philosophise correctly in this matter,"[8] and with characteristic self-confidence Descartes now proceeds to this task.

The first 41 of 157 principles of Descartes' cosmology discuss the distances and sizes of the sun, moon, planets and fixed stars (principles 5-8), along with their physical nature (9-13), and apparent motions (14-41). Here we discover that Descartes is a Copernican, although he claims to "deny the movement of the earth more carefully than Copernicus, and more truthfully than Tycho,"[9] because he believes that the heavens are composed of a subtle matter with respect to which the denser earth and planets are at rest. He clearly distinguishes between the planets and the sun, the former shining by reflected light and the latter by intrinsic light. And of great significance for our subject, in principles 9 and 13 Descartes identifies the sun and fixed stars as precisely the same in nature, the apparent differences caused only by distance. This was an idea that had been championed by Bruno and admitted by Kepler and others,

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but here it is incorporated into a widely acceptable physical system and is utilized as a prominent axiom of the system.

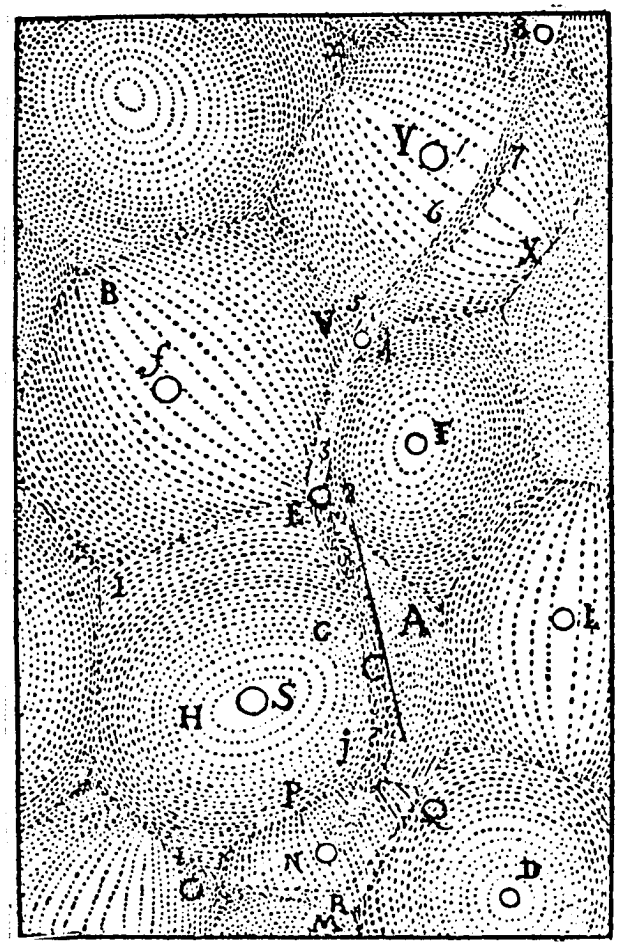
The middle set of roughly 50 principles (42-93) sets forth the details of the vortex theory, that uniquely Cartesian concept which emerged as a direct and inescapable consequence of motion in a plenum. In a universe completely filled with particles, if one particle is to move, another must move out of its path and yet another move into that vacated position, and so on. In this way a circulation is set up, a vortex, each of which has a center, such as that of the sun in our planetary system. Here was a mechanism that might be used to explain the physical movements of the planets in our system based upon Kepler's laws.[10] But our sun is only one such center; the fixed stars, which are identical in nature to our sun, are treated in precisely the same way, as centers of their respective vortices.

This group of principles also sets forth the Cartesian cosmogony, the means by which, from one uniform type of matter, three "elements" were separated from each other by the vortical motion of the particles, a motion which God impressed upon them in the beginning.[11] These elements compose the various parts of the visible world. The most subtle is luminous and forms the sun and fixed stars, the second element is transparent and is found diffused throughout the heavens, and the third constitutes the earth, planets, and comets, and is opaque. The details of planetary and stellar formation, the nature of light, and the flow of material

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between vortices are all discussed. A concluding set of principles presents specific explanations of phenomena which may be derived from the vortex theory, including sunspots (94-101), new stars (119-139), and planetary motions (140-157).

The final product which emerges from part three of the Principles is epitomized in a diagram which appears again and again in that part and in subsequent discussions of it by others, until it must have been as familiar to the seventeenth century reader as the earlier schematized concentric spheres of the Aristotelian cosmos. It depicts a universe of vortices, and at the center of each vortex is a fixed star. Our sun has precisely the same status as the other fixed stars, which cannot then be



construed as imbedded in a sphere, since the sun itself clearly is not. Instead, the sun is "completely surrounded by a vast space, where there is no fixed star at all, in the same way that each fixed star is very distant from all the others, and each one of these fixed stars is as distant from us and from the sun as from each other. So that, if S for example is the

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sun, F and f will be the fixed stars, and we can conceive others without number, above, below, and beyond the plane of that figure, scattered throughout all the dimensions of space."[12]

It is now clear how Descartes set the stage for the introduction of new strains of argument into the plurality of worlds tradition. The Cartesian plenum precluded the possibility of more than one cosmos, but in the same direct way an infinite plenum gave rise to an infinite number of large vortices each of which was analogous to our solar system. It was the inexorable motion of the plenum which initially divided all matter into particles, and it was mechanical necessity which in turn forced these particles to rotate around centers now visible to us as fixed stars. Given Cartesian principles operative in an infinite universe, orthodox Cartesians must arrive at the same conclusion as did Descartes: that "there are as many different vortices (tourbillons) as there are now stars in the world."[13]

Beyond this explicit claim the important question for the plurality of worlds tradition now becomes one of precisely how analogous these vortices are to our own. Descartes' emphasis on a non-anthropocentric outlook at the opening of his cosmological section gives the reader every reason to consider each vortex of matter as analogous in every detail to our solar system. Both this metaphysical precept and the doctrine of the uniformity of nature's laws embraced by Descartes pointed to vortices not only endowed with planets but also with inhabited planets. The point could not have been lost to many of Descartes' readers. A case

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in point is his friend and patron Christina, queen of Sweden, who was disturbed by the implication that a Cartesian must "most probably hold that all these stars have inhabitants, or, still better, that they have earths around them, full of creatures more intelligent and better than he."[14]

Compelling though the inference from vortices to an infinity of inhabited planets might be, it was not one which Descartes made in the Principles itself or in his private correspondence. His failure to emphasize even that the vortices contained planets hardly sufficed to dispel the feeling that, given the obvious example of our solar system, the mechanical necessity for the universal formation of planets was just as necessary as the initial formation of rotating vortices of particulate matter. His silence undoubtedly reflects his remembrance of the fate of Bruno at Rome less than a half century before,aand of Galileo at Rome a dozen years before. The explicit assertion of an infinite number of planets was simply too reminiscent of Bruno's infinity of inhabited worlds.

Descartes walked this fine line: the explicit assertion of an infinite number of systems similar to ours, but not of an infinite number of inhabited planets. The man who in his early correspondence expressed an interest in determining with improved telescopes "whether there are animals on the moon",[15] at the end of his life still wondered whether "perhaps elsewhere there exist innumerable other creatures of higher quality than ourselves."[16] He never made an issue of the question

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in his published works, but did express a guarded opinion in answer to the query of Christina of Sweden:

> It seems to me that the mystery of the incarnation and all the other advantages which God bestowed on man do not preclude the possibility that he might have granted infinitely many others, very great, to an infinity of other creatures. And,not even inferring from this that there may be intelligent creatures on the stars or elsewhere, I still do not see that there would be any reason by which to prove that there are not; but I always leave these questions, once posed, suspended, preferring not to deny and not to affirm anything.[17]

It was not theological doctrine but Descartes' fear of reprisal from the church, which motivated his public silence on the issue.

Many other readers of the Principles must have asked the same questions as Christina. It is nevertheless necessary to separate the content of the Principles from the questions it generated. That seminal work broadcast a whole range of both well-known and original elements germane to the plurality of worlds tradition. It explicitly furthered the well-known Copernican idea of an earth-like moon and planets in our solar system. It identified the nature of the fixed stars with that of the sun, and asserted that these stars were the center of their own systems of matter. It did not - and this is an important, if subtle, point - explicitly assert the existence of an infinite number of planets inhabited or otherwise, or address itself to the theological issues which would have been raised by such an assertion. Descartes' physical principles demanded the existence of an infinite number of systems and his non-anthropo-

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centric metaphysics indicated inhabited solar systems. But Descartes left the latter question for others to ponder. The influence of Cartesianism on the plurality of worlds tradition depends on the extent to which both the followers and the opponents of Descartes made an issue of the question, and on the degree to which Cartesian principles were incorporated into treatises on the plurality of worlds.

* * *

Was the challenge and the opportunity of Cartesian vortices seized upon by those anxious to promote the doctrine of an infinity of inhabited planets? The question is most directly answered by an examination of treatises on the plurality of worlds, which number at least three in the period between the publication of the Principles (1644) and Fontenelle's Entretiens (1686). The treatises were written in England, France, and Holland, clear evidence that the interest in the subject was not confined by national boundaries.

Only two years after the publication of Descartes' Principles, Henry More's Democritus Platonissans, or, An Essay upon the Infinity of Worlds (1646) enthusiastically urged upon the English-speaking world the belief in an infinite number of inhabited planets. In support of a case for a causal link between the Principles and More's treatise, we may note that More quickly

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embraced important elements of Cartesian thought, and in fact was himself largely responsible for creating an atmosphere of initial enthusiasm for Cartesianism in England. Although the enthusiasm of both More and most of his countrymen was followed by critical examination and then rejection, More did translate the cosmological part of the Principles into English for his own use, and still taught at at Cambridge in the 1670's.[18]

As the title indicates, the Democritus Platonissans must be seen first as an attempt at reconciliation of the atomist doctrine of infinity of worlds with Neoplatonic cosmology, and More expresses his indebtedness to Democritus, Epicurus, and Lucretius at the outset.[19] But at the beginning of the book we find a passage cited from part three of the Principles which indicates More's agreement with Descartes' initial metaphysical assumptions concerning the omnipotence of God and man's place in the universe. And after his mention of the ancient atomists, More noted the belief of "that sublime and subtil Mechanick too, DesChartes [sic] ", who "though he seem to mince it must hold infinitude of worlds, or which is as harsh one infinite one. For what is his mundus indefinite extensus, but extensus infinite?"[20] When one considers that More in this work reversed his previous negative opinion on the infinity of the world held just a few years before, the seminal influence of Descartes appears obvious.

Yet, the telltale vortices are not conspicuously present in More's work. Their absence,however, is not keenly felt, if

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only because elsewhere in the treatise More argues in distinctly Cartesian fashion that the universe is "corporeall", that corporeity is extension, and that extension can admit of infinity; therefore the universe can be infinite and it can contain an infinity of solar systems.[21] The mechanical details of vortices, and certainly of planetary formation, are unimportant at More's level of argument. What is important is that More operates within the ontological framework of an infinite plenum; this, together with other principles also found in Descartes and other atomists, sufficed to clinch a compelling case for an infinite number of solar systems, even though it initially seemed a "monstrous" opinion and one with "much difficultie and seeming inconsistencie".

Although More mentions Descartes by name only in the initial passage that rejects anthropocentricity, there is ample evidence throughout the treatise of the indebtedness of the Englishman to his older French contemporary. Aside from the main task of expounding an atomist cosmogony in a universe infused with a Platonic soul of the world, a major theme which More constantly emphasizes is that of the status of the fixed stars as suns similar to our own. Beginning with stanza 22, More takes pains to give a vivid picture of each fixed star as surrounded by planets which are warmed by the star's "vital heat" as our sun warms us. At the end of the treatise he returns to the theme of the similitude of the fixed stars with the sun, and extends his

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argument to the faintest stars and to those beyond which must exist but are invisible to us. Now this idea which More seizes upon is one which, aside from Bruno's works, was nowhere more significantly displayed than in Descartes' Principles. Although More may well have read Bruno, when he makes the statement that "our world's sun becomes a star elsewhere",[22] he is also following an argument of Descartes.

Between More and Descartes, then, there is a marked sympathy of both physical and metaphysical principles, but More boldly dares to declare what the Frenchman avidly avoids. Not only are there an infinite number of stars surrounded by planets, but these stars also allow life on their planets:

> . . . their main work is vitall heat t' inspire
> Into the frigid spheres that 'bout them fare,
> Which of themselves quite dead and barren are.
> But by the wakening warmth of kindly dayes,
> And the sweet dewie nights they well declare
> Their seminall virtue in due courses raise
> Long hidden shapes and life, to their great Makers praise.

More thus implicitly follows the theological tradition of his countryman Wilkins and of the Italian Campanella, whose treatises of 1638 and 1622 argued that the existence of other worlds would benefit the doctrines of God's omnipotence and would not contradict Scriputral or theological doctrines.[23] At this stage in his intellectual career, More apparently found the physical reasoning for an infinity of inhabited worlds more compelling than objections to Scripture or to the theological doctrines of the redemption and incarnation. Those objections - that Scripture spoke

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of man upon earth as the only intelligent creature in the universe, and that the sole object of Christ's redemption was man - had been convincing to Melancthon a century before, and still worried Galileo, Descartes, and others. This balance between theological doctrines and physical theory in relation to the doctrine of other worlds was one which every natural philosopher would have to measure himself.

Eleven years after More's treatise, Descartes' countryman Pierre Borel published his Discours nouveau prouvant la pluralite des mondes (1657).[24] Borel, eventually an active member of the Academie des Sciences, was a practicing physician noted for his collection of both natural and historical artifacts from his native Castres.[25] His Discours nouveau is so titled in deference to a work which had appeared in 1655 called Le monde dans la lune, by I. de la Montagne, which in reality was a translation of Wilkins' 1638 Discovery of a World in the Moone. This is undoubtedly the "book on the same subject which has recently appeared," of which Borel speaks in a statement to the reader as having prompted the publication of his own work. For Borel informs us here that his work was ready for the printer in 1648, but was only published in 1657 at the demand of those who had seen Borel's manuscript, and thought it much superior to the recent translation of Wilkins. This is why he has finally broken his silence, in contrast to "many of the most subtle minds of France," who, Borel tells us revealingly, "have similar opinions, but keep them secret for fear of being ridiculed by the vulgar ignorant."[26]

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Borel must have known that there was more in his treatise than would offend simply the "vulgar ignorant". Like More, he deduced from Copernican heliocentricity that the planets within our own solar system were earths, and the earth a planet.[27] Having weighed the arguments of Galileo, Kepler, Campanella and Wilkins, of the ancient atomists, and even of the Hermetic - Platonic philosophy found in Bruno and More, Borel argued that this belief is in accordance with Sacred Scripture and that it was more compatible with the nature of the Creator.[28] Moreover, he embraced the idea of the "infinite spaces of the Aire, wherein are lodged an infinite number of great Globes of diverse natures, or inhabited by several living Creatures . . ."[29]

In spite of these similarities with the Democritus Platonissans, there is a crucial distinction to be made between it and the Discours. Borel has recently been portrayed in connection with this 1657 treatise as a "man between two worlds" - the old man-centered Aristotelian world, and the emerging infinite universe with all of its implications for man's diminished stature.[30] Nowhere is this better corroborated than in Borel's belief that the infinite inhabited globes of the universe are all enlightened by our central sun.[31] The idea of the fixed stars as suns, so prominent in the third part of Descartes' Principles and in More's treatise, is not to be found in the Discours. Nowhere are Descartes' vortices hinted at, because Borel's universe is not one of a plurality of systems, but simply of an infinite number of earth-like bodies.

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What compels Borel to his vision of an infinity of inhabited worlds is not the physical principles of the infinite mechanical universe of Descartes, but rather a metaphysical principle borne of the Copernican revolution and thoroughly embraced by Descartes. Borel could not persuade himself to believe that the immense number of visible stars, much larger in size than the earth, were created for man alone: "natural reason doth sufficiently disswade us to believe, that the greater things serve the lesser; and that those that are the noblest, serve the vilest . . ."[32] Copernican theory had jolted man from the center of the solar system, and the earth was only one of many planets. Yet, spanning two worlds, Borel was not willing to abandon the universal significance of our Sun by placing it on an equal footing with the fixed stars.

The cosmological influence of Descartes on Borel is thus apparently negligible, but the man who in 1656 demonstrated his interest in Descartes by composing the Vitae R. Cartesii summi philosophi compendium most likely was not unaffected by Descartes' more general feelings, even if he was unwilling or unable to embrace the cosmology. In opening his treatise Borel decried "This age wherein men live but by imitation, wherein learned men are despised ... wherein no new proposition can be admitted ...", and thrust an eloquent challenge at his reader:

> Why open ye not your eyes, O ye learned and wise men? And why awake ye not out of your slumber, and deep sleep? Awake up the eyes of your Understanding and Reason towards the Heavens, comtemplating the wonderful things thereof.[33]

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If Borel had not read or accepted the Principles, the single reference to Descartes in the treatise shows that Borel had read the Discours de la methode and the accompanying essays, which had been published for ten years when Borel began to write his treatise.[34] Borel's challenge represents not merely the argument currently raging between the ancients and moderns (for Borel in part portrays himself as reviving the thought of Democritus), but also a response to the recent official condemnation of Cartesian teachings in the universities.[35] Descartes' condemnation in France would not have prevented Borel from using those ideas had he so desired. Part of the reason is found in Descartes himself. It has been said elsewhere of Borel and his Discours that "Borel obviously strives, in this endeavor, toward an idea of Cartesian reason, activating an intelligence freed from prejudices, from what he calls "preoccupation . . . that horrible monster which brings destruction into the human mind, stops progress in the sciences and keeps man stagnating forever in ignorance."[36] In evoking the spirit of the times it is perhaps revealing to recall that in the same year as Borel's Discours appeared, Descartes' friend Cyrano de Bergerac published his imaginary voyage to the moon, a bold venture in reasoned imagination if ever there was one.[37] Aside from his cosmology, the impetus which Descartes gave to the free-thought movement cannot be ignored as a factor in the promulgation of the idea of a plurality of worlds.

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In Holland too there was concern over the question of a plurality of worlds, as exemplified in a treatise on lunar inhabitants which was first delivered as a lecture to a scholarly audience at the university of Utrecht on June 19, 1677. The author was Gerhard DeVries, and the occasion was DeVries' promotion to a chair of philosophy at Utrecht, where he had studied under one of the most notorious peripatetics in all of Europe, Gisbert Voet.[38] The Dissertatio Academica de Lunicolis first appeared in printed form appended to DeVries' 1678 edition of a peripatetic treatise on natural philosophy by Daniel Voet, son of Gisbert and also a former porfessor of philosophy at Utrecht. The immediate motivation for DeVries' work can undoubtedly be found in the fact that he was the praeses or director of a 1676 dissertation on the subject, the Disputatio . . . de plurium mundorum possibili existentia by Caspar of Heymenberg.[39] The very fact of the existence of a student dissertation and a response by the praeses at an important university, the latter delivered in public lecture and reprinted several times in a peripatetic work, should give us cause to reflect on what this subject meant to seventeenth century natural philosophy. The Dissertatio appeared at a time when Cartesianism was still a subject of vehement debate in Holland, as throughout Europe, and more specifically at Utrecht where it was opposed most ably by the elder Voet, who died the year before its delivery.[40] In fact, DeVries was the director of another dissertation in 1676 which examined the relative merits of the Cartesian and Aristotelian

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philosophy. The victory of Cartesianism, even of Copernicanism, was far from complete at Utrecht in 1677, a fact essential toaa proper understanding of DeVries' work.

DeVries begins by remarking that while most able thinkers have believed the moon to be a celestial body, some now wish to turn it into an earth "with its own seas and islands, mountains and valleys, forests and fields . . . nay more, we are made to believe, with its own inhabited colonies, not of beasts, but of men."[41] On this new earth DeVries now declares war, and promises to eject the lunar inhabitants, and thereby all celestial inhabitants. He is familiar with the opinions of Plutarch, Pythagoras, and the followers of Copernicus such as Galileo, Kepler, and Campanella. But there is a perceived threat from another set of thinkers:

> Finally, it does not displease the followers of that more subtle philosophy invented by Descartes, and those who accept its concepts;in particular that concordant idea by which they build the mechanical universe out of the structure of vortices.[42]

Far from turning aside the threat with frivolties, DeVries acknowledges the gravity of the issue. Although he would rather let the matter rest as an absurdity, his motivation for a systematic examination is explicit:

> These things deserve to be set forth more diligently, if only by reason of the name of Descartes. For such is the authority of this man among many today, that it is deemed worthy that even his visions be constantly examined. Especially because we do not lack theologians on whom the light of Cartesian philosophy shines, so that it may seem more probable to them, that men live on the moon than not. There are indeed many and weighty authors who would stand in the battle line for the lunar inhabitants. Nevertheless, victory is certainly ours, for they are not easily armed by faith or reason. And both are fighting for me.[43]

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Here then, we again come face-to-face with faith and reason, the twin components of the issue of other worlds. And we are made to see the relativity of both components, for if More and Borel herald change in natural philosophy and theology, DeVries represents the entrenched forces of medieval scientific and theological thought. DeVries first musters his arguments ex fide, and points to that passage of Scripture where the moon is compared to the sun as the lesser light, and not to the earth; it is thus placed in the heavens and is a celestial body, not a terrestrial one. No sacred writer has written of any forests and seas upon the moon, although the earth is described in detail. Moreover, he continues, if there were inhabitants on the moon with a rationality equal to ours, and they were saved by the Creator, it would reduce the number of those saved on earth.

From the realm of reason DeVries notes that any lunar inhabitants would have to endure the vicissitudes of light and darkness for long periods of time. He rejects Kepler's suggestion that the putative inhabitants shelter themselves in cavities of their own construction. His critical faculty is quite impressive as he insists that one can and must compare the conditions on the moon with those on the earth, and that on these grounds the possibility of life is ruled out. Finally, DeVries pleads, if the moon is considered as an earth-like world, what will be the end to the number of terrestrial globes in the heavens?

> For what is asserted concerning the moon, can and ought to be affirmed in the same way for the other planets. And for the innumerable multitude of fixed stars, which the Lunatic

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> philosophers multiply in the number of vortices in the heavens, when they teach that each of those has not one planetary globe, not one or two, not ten or twenty, but as many earths made by God as grass grows on the plains or ears of corn in the fields.[44]

There was much more at stake in DeVries' treatise than the moon itself. The moon was seen only as a test case for the whole celestial region, and if an earth-like moon was admitted, innumerable planets imbedded in Cartesian vortices would have to be considered a step closer to reality.

It seems clear that DeVries, at least, perceived a real threat from the Cartesian philosophy with regard to a plurality of worlds. Far from asserting that lunar inhabitants are more in keeping with God's omnipotence, DeVries labels this claim "a common refuge of those who presume to defend absurd and false opinions of every kind as truth,"[45] and instead finds his own refuge in Scripture, which to his mind makes it clear that God has not and does not wish to supply the moon or any other celestial body with living beings. Within ten years, the threat which the Dutch peripatetic perceived from Cartesianism would be realized beyond his wildest fears in the treatise of Fontenelle.

*

Of the three treatises on plurality of worlds published after Descartes' Principles and before Fontenelle's Entretiens, two show the definite influence of Descartes' cosmology and the third the probable influence of his leadership in the French free-thought movement. The negative reaction of DeVries to Cartesian cosmology in terms of an infinite number of inhabited

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planets is intriguing, for it suggests that the Dutch thinker was reacting to specific claims of an infinity of inhabited worlds. We have already seen that Descartes himself did not raise the latter issue in his published works, and there is no reason to believe that DeVries knew of the works of More or Borel. While his treatise was undoubtedly in part a response simply to the threat from Copernicans such as Galileo, Kepler, and Campanella, (all of whom he argues against, especially the author of the Somnium), the crucial question that lingers is to what degree DeVries would have found the issue of inhabited planets championed in Cartesian treatises.

A very early and highly influential Cartesian treatise was the Fundamenta physices of Henry Regius, which appeared in 1646 in DeVries' native country Holland.[46] Had DeVries read this work of his countryman or any of its numerous editions, he would have found the standard exposition of Cartesian vortices, but no emphasis on the implications for an infinity of potentially inhabited planets. The Cartesian reluctance to intimate even the existence of the extra-solar planets themselves is graphically illustrated in a novel diagram which depicts the extension of the Copernican system by Descartes.[47] Apparently for the clarification of those still unfamiliar with the meaning of the standard picture of vortices, Regius shows first the usual Copernican scheme encircled by fixed stars, and then each of the fixed stars themselves encircled in order to indicate that they too are systems. But it is notable that while the path of each

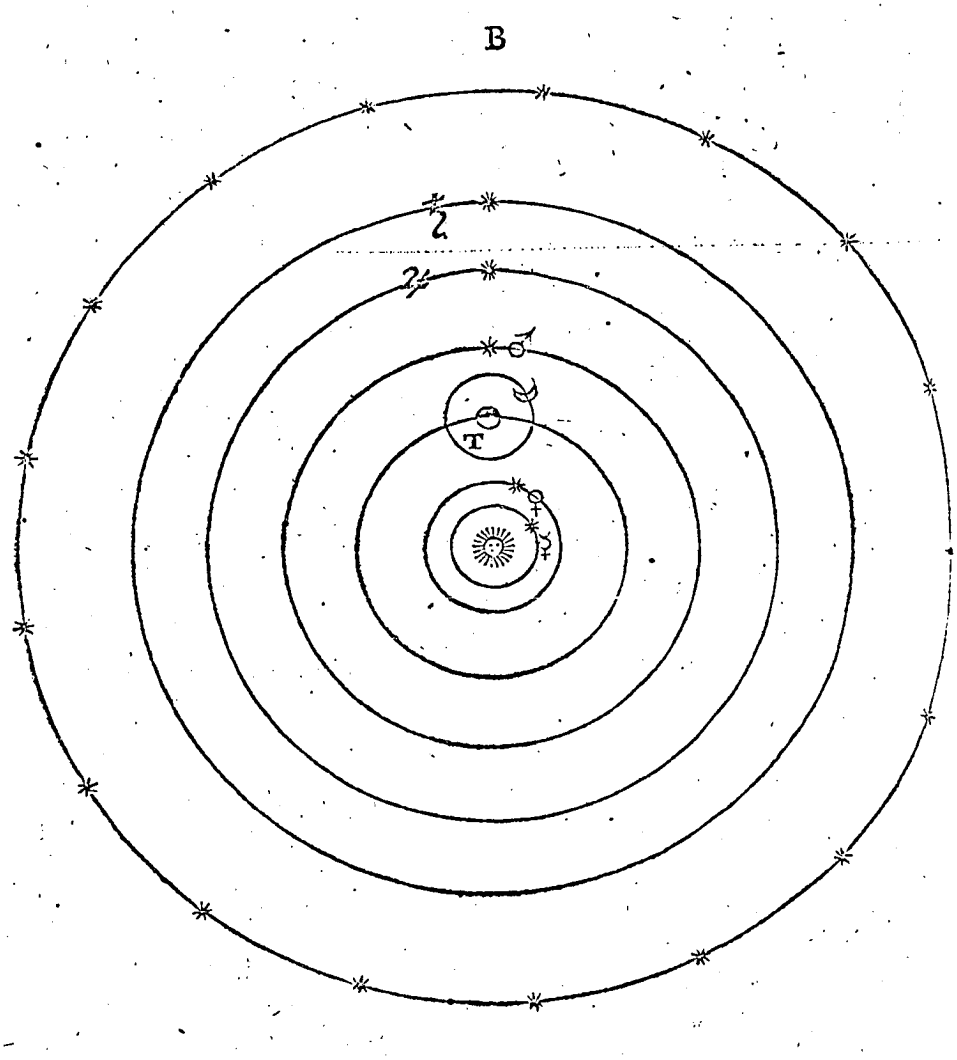
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planet in our solar system is clearly shown, the analogy to the other systems is not made complete by the addition of planetary paths within their indicated boundaries, as it easily could have been had Regius wanted to stress the point. To be sure, the standard Cartesian depiction of vortices indicated pathways of the encircling material, but these need only be interpreted as the pathways of the particulate matter of the plenum, and not necessarily of coalesced planets. Although the uniformity of nature's laws pointed to precisely analogous systems, when Regius was faced with making a more explicit comparison between our system and others, he refused to allow each their respective planets. The same is true of perhaps the sole orthodox English Cartesian, Antoine LeGrand, who in his Institutio Philosophiae borrowed Regius' diagram unchanged.[48]

The treatise of Reguis influenced Jacob Rohault's Traite de physique (1671), the most popular and widespread of Cartesian treatises, and one typical of the treatment given to Descartes' cosmology by his followers.[49] Cosmology was only a small part of the treatise, which included physics and chemistry, geology and meteorology, and physiology. Although Rohault placed more emphasis upon expounding the actual phenomena of motion of the various heavenly bodies than did many of his Cartesian counterparts, he nevertheless, in compact form, touched upon all of the major points which were basic to the Cartesian cosmology.

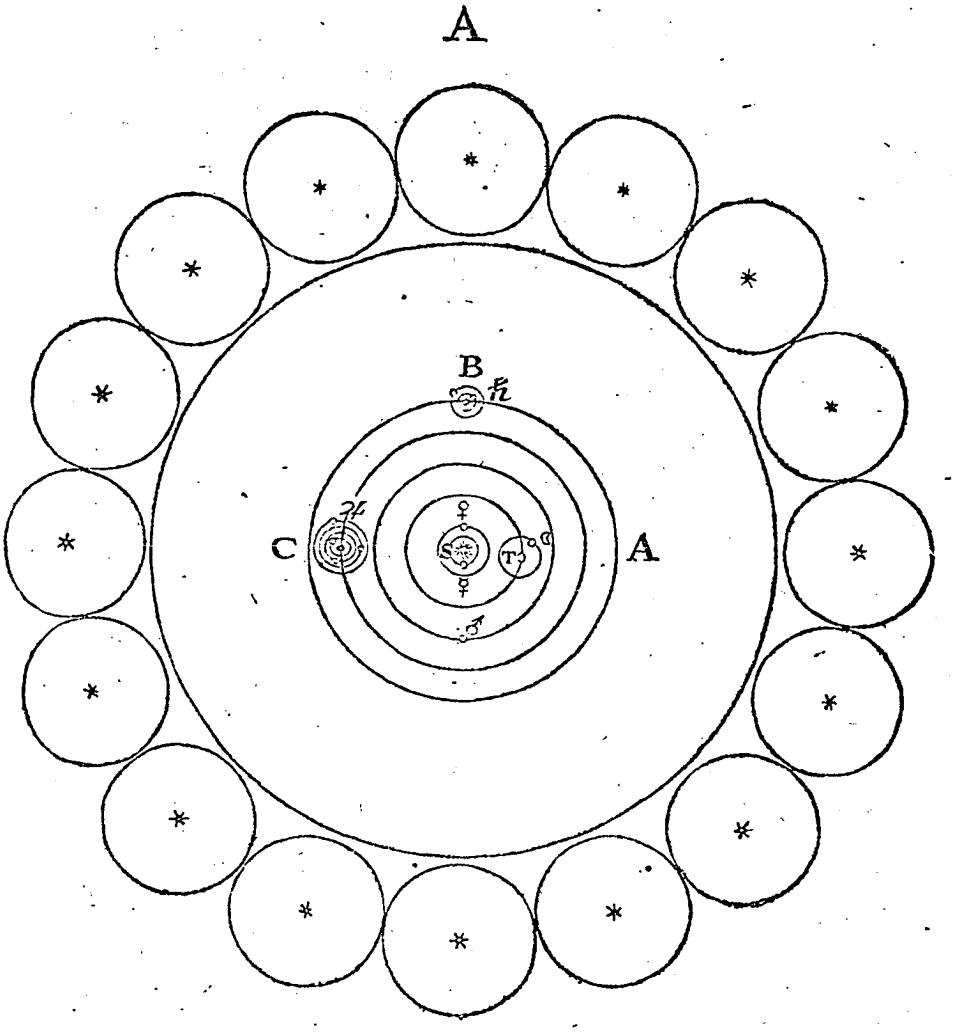
Especially in a section on the nature of celestial bodies (astra), we find many of the ideas which directly bear upon the

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The Copernican system according to Henry Regius, Philosophia naturalis (Amstelaedami, 1654), the second edition of his Fundamenta physices (1646). This depiction formed the basis for the illustration on the following page.

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By drawing circles around the fixed stars in the standard diagram of the Copernican system (preceding page), the Cartesian Henry Regius indicated his belief in a plurality of systems. He did not go so far, however, as to depict planetary orbits in these other systems, preferring to leave them vaguely defined instead. The diagram appears four times in Book II of the Philosophia naturalis (Amstelaedami, 1654), along with the standard depiction of Cartesian vortices (above, p. 198).

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concept of other worlds. It appears from observation, Rohault stresses, that the moon is a rugged body, and similarly "we cannot but think that the planets are very like our earth," since they all shine by light reflected from the sun, and since "the pretended smoothness of the superficies of the planets does not agree with experience."[50] The sun shines by its own light, and "the fixed stars are so many suns, placed in different parts of the world"; the detailed explication of the nature and properties of the sun thus serves to explain the nature and properties of all the stars.[51] Just as our sun is formed in the center of its vortex when matter of the first element is forced there by indubitable mechanical principles, so will other stars be formed at the center of their respective vortices. Nowhere, however, does Rohault stress that planets circle their respective suns.

A similar treatment will be found routinely in the cosmological sections of most Cartesian treatises, and it must be noted that Rohault is typical in that these ideas basic to the Cartesian cosmology are no further developed than they were in Descartes' Principles. Far from stressing the idea of a universe filled with inhabited planets circling an infinite number of suns, Rohault concludes his section on the nature of the celestial bodies with the remark that he would not even "venture to affirm that there are living Creatures in the moon, or that they generate in the same manner as upon the earth, because though this be a thing possible, yet it is also possible that it may not be so.[52]

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Even a French treatise devoted exclusively to an exposition of the Cartesian cosmology, Claude Gadroys' Le systeme du monde (1675), did not push the idea of a plurality, much less an infinity, of earth-like worlds. As a good Copernican and Cartesian, Gadroys was only too happy to admit that the planets were "hard, opaque, and solid bodies."[53] But to populate them with inhabitants was another matter. In his discussion of the moon Gadroys acknowledges that Anaxagoras, Democritus, Heraclides, Pythagoras "and several moderns among whom are Galileo and Kepler," had held the moon to be a world with its own plains, seas, forests, and mountains like the earth. Gadroys himself, however, offers only that "this is indeed an extraordinary opinion, but for all those who have seem that body, it is not one to be rejected,"[54] an open-minded but hardly enthusiastically assertive statement.

How does one explain the reluctance of Cartesians to promote a concept toward which their physical system so clearly pointed? The answer must again be found chiefly in that ongoing assessment of the proper balance between the Scriptural objections involved and the doctrine of God's omnipotence. Among Cartesians it would seem that the former prevailed over the latter, at least in this particular area. The absence even of a discussion of the theological factors indicates that the majority of the followers of Desaartes, no less than Descartes himself, simply did not wish this issue to become associated with Cartesian cosmology, which had enough intrinsic difficulties of its own. But the

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inevitable strain thus generated by the necessity for supporting some form of the orthodox doctrine of vortices while ignoring the dangerous belief in inhabited solar systems, could not long be maintained.

Already in Germany, where orthodox Cartesianism never gained a foothold, several prominent thinkers embraced the belief that the fixed stars were surrounded by planets and spread throughout an infinite universe. The Iter exstaticum coeleste (1656) of Athanasius Kircher explicitly characterized the fixed stars as suns with encircling planets, although it denied inhabitants even to the planets of our solar system and to the moon.[55] The extent of Kircher's familiarity with Descartes' ideas is uncertain,[56] but his final position again reflects a compromise between those two theological components with which Descartes had grappled and which had long been associated with the problem of other worlds.

On the one hand the doctrine of God's omnipotence, so eloquently championed by Descartes at the opening of the cosmological section of the Principles, pointed directly to an infinitely populated universe. On the other hand the opinion of Scripture had to be considered, along with the theological doctrines of redemption and incarnation. The doctrine of God's omnipotence led Kircher beyond Descartes to the assertion of the existance of an infinite number of planets. It would lead Otto von Guericke, another German influenced by both Descartes and Kircher, to devote a whole section of his famous Experimenta nova (1672) to an examination and endorsement of

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Kircher's view of other planetary systems.[57] Here von Guericke explicitly cited Descartes' statement from the Principles that God's omnipotence could not be underestimated. Von Guericke even noted the possibility of an inhabited moon and planets, although he emphasized that any inhabitants would not be men, but rather diverse creatures beyond all our imaginings.[58]

Even as Cartesians maintained their silence, powerful but conflicting forces were acting to compel a discussion of the issue, if not an immediate resolution. Early Cartesians could mask the real theological issues and instead invoke the dictum with which Rohault had justified his opinion in not affirming or even discussing in any detail the idea of an inhabited moon: "For in things which cannot be certainly determined by Reason, I think it very rash to persist in an Opinion contrary to the common notions."[59] But the combination of their non-anthropocentric metaphysics, their belief in God's omnipotence, and above all, their vortex cosmology, always brought them face-to-face with the question of an infinity of inhabited planets. The Cartesian position of reluctance was soon to disappear, and the "common notions" soon to alter at the hands of Fontenelle.

* * *

Considering the conservatism of his fellow Cartesians, the first question which must be asked of Fontenelle is why he chose to write a treatise in which this heretofore delicate subject was suddenly plucked from the obscurity of brief and

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peripheral mention in Cartesian treatises or an occasional work like that of Wilkins, More, or Borel, and put into the full light of public and scientific discussion. Aside from the compelling argument from God's omnipotence, the answer must certainly be related to the blossoming of the French Enlightenment, of which Fontenelle himself was a major figure during the one-hundred years of his life (1657-1757).[60] Fontenelle was a champion of new ideas, and indeed stoutly defended the modern cause in his Discourse Concerning the Ancients and Moderns. In the increasingly free-thinking atmosphere of Paris, the idea of other worlds was one which could both delight and instruct both scholars and the common educated person. This purpose is reflected in the format of the treatise, a series of conversations with a lady of some learning.

Even in the atmosphere of the Enlightenment, Fontenelle could not fail to be cognizant of the inherent dangers of his proposal. The casual and sometimes flippant presentation serves not only to appeal to a wide audience, but also to downplay the dangers. Fontenelle suggests that his work be read with no more concentration than one reads a romance or a novel, but then hastens to add "I have not composed an aery system which hath no foundation at all: I have made use of some true philosophical arguments."[61] At another point in the preface he says that he will not undertake to justify "so fantasticall and odd a composition" as his, after he had just defended it by pronouncing "I have fancy'd nothing

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concerning the inhabitants of the many worlds which is wholly fabulous; I have said all that can reasonably be thought of them, and the visions which I have added, have some real foundation." When chastised by the lady in the course of the treatise that a philosopher such as he will never make a good martyr, since he is continually shifting his opinion, Fontenelle answers "Why truly, Madam, there is a time for all things, and your true philosopher believes anything or nothing, as the maggot bites. Had you taken me in a sceptical vein, I would have as soon granted a nation in a mustard Ball, as a living creature in the moon ... ".[62]

Such pleasantries convey the flavor of Fontenelle's art of dialogue, but must not conceal the fact that the author takes his subject very seriously. One need only note that Fontenelle insists that the ideas contained in his book are neither against reason nor Scripture, and that, by asserting that the inhabitants of these worlds were not truly men or descendants of Adam, he seeks to circumvent the arguments of those who thought such ideas dangerous to the religious doctrines of the redemption and incarnation. Moreover, he emphasizes that other worlds with creatures different from men actually display the infinite diversity and variety of nature and the greater glory of God.[63] He destroys that apparent tension in Descartes' published works between the assertion of God's omnipotence and the denial of an infinity of inhabited planets. Fontenelle's treatise was not a work of fiction as was Cyrano's thirty years before, nor was it taken as such by those who sought its censure.[64]

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These metaphysical principles are secondary to what Fontenelle takes to be the scientific realities, the realities of cosmology. It is most important to realize that Fontenelle had more than a casual interest in the science of his day. Only 29 years of age at the time the Entretiens appeared, in 1697 he was to become the secretary of the Academie des Sciences. He would hold this post for almost a half century, during which time he was recognized as a dominant figure in French science by laymen and scientists alike, even though his own scientific contributions were not particularly original. It was as an advocate for the new science, and more specifically as a Copernican and a Cartesian, that Fontenelle wrote his popular treatise;[65] both of these philosophies of nature formed the foundation of his famous essay.

Although occasional remarks reveal Fontenelle's alliance with Cartesianism, the first three of the five original "conversations" (a sixth was added in 1687), could almost have been written by Wilkins or Borel. The first conversation sets forth in the "gay and pleasant dress" which Fontenelle had promised, the Copernican system as the one most likely to be true, while the second and third conversations make the case for the world in the moon. Here Fontenelle asserts his belief that there is no water on the moon, based on the fact that no clouds are observed there, and that the common belief that the dark spots are seas may not be true at all.[66] But the moon may have "exhalations and vapors" different from water which do not form perceptible clouds, and he is certain that it is surrounded by

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an atmosphere, by comparison with which our air consists of "thicker and grosser vapors." This difference in atmosphere precludes any visit by us to the lunar world and vice versa; we are each of us the prisoners of our respective atmospheres, just as the birds and fish are of theirs.[67] The influence of Kepler is evident as Fontenelle describes the universe from the vantage point of the moon, and opines that some of its great cavities might provide shelter for the inhabitants from the excessive heat of the long lunar day.[68]

The fourth and fifth conversations take up the subjects of the planets and the fixed stars respectively, and it is here that Fontenelle's Cartesian convictions become apparent. Already in the first part, Fontenelle had spoken of the mechanical tendencies of philosophy by which the world was compared to a watch, and in his treatment of the Copernican system depicted our earth and all the planets as borne up by a celestial matter a thousand times more fluid than water. In the course of explaining in the fourth conversation why it is that Jupiter should have lesser satellites circling it, Fontenelle cites the vortex cosmology of Descartes. Defining a vortex as a mass of parts which are separated from one another yet travel with one uniform motion around a particular center, Fontenelle explains that there are greater and lesser vortices; there is the great vortex "of which the sun is Lord", and each of the planets in turn has its own lesser vortex depending upon the mass of the planet.[69] The satellites of Jupiter, then, and the satellites of all the other

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planets, are swept around the centers of their planetary vortices.

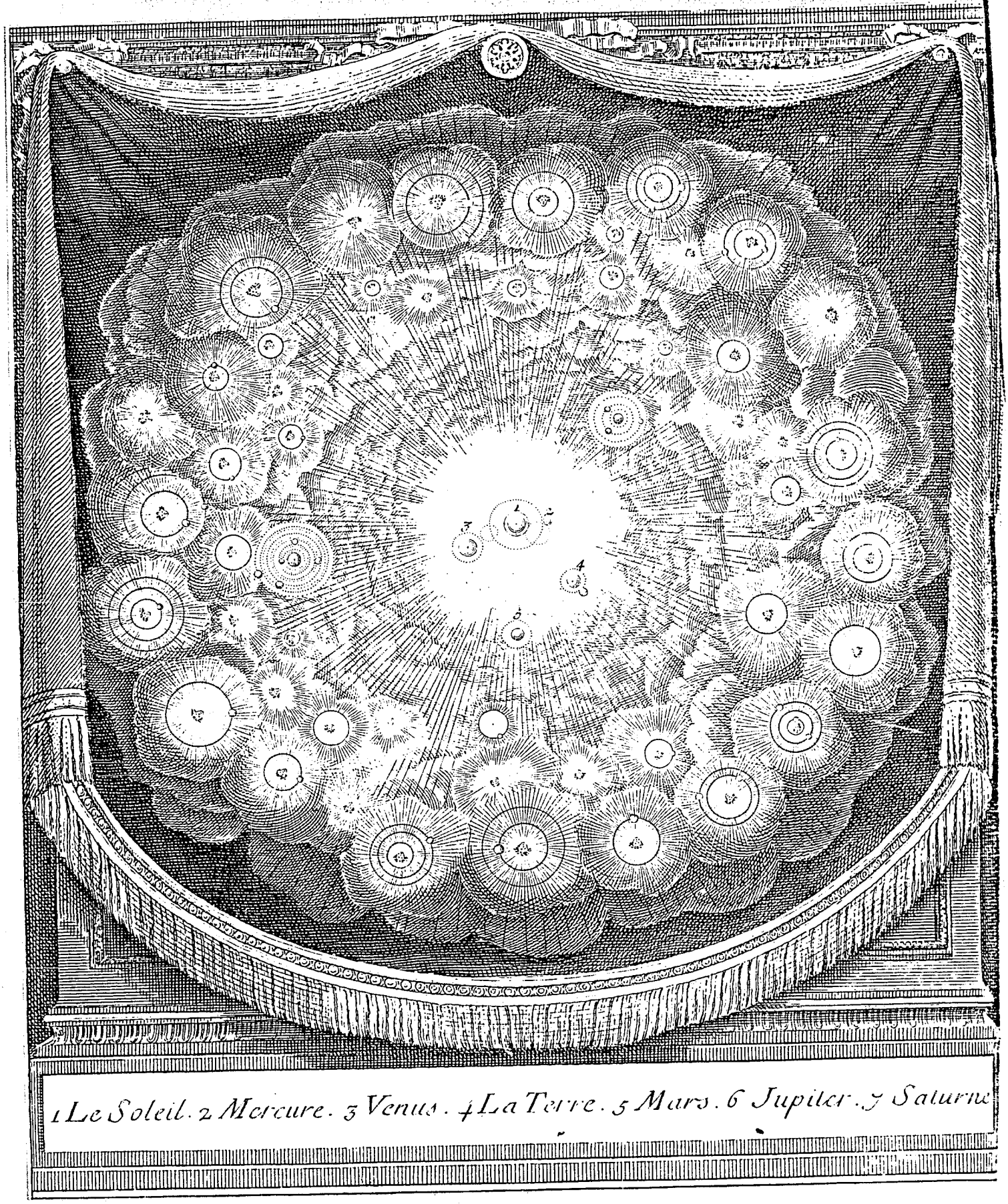
In the fifth conversation Fontenelle proposes the infinite number of planets in a forthright way which had not been done since Henry More's treatise forty years before, but this time in unmistakably Cartesian terms:

> ... If the fix'd Stars are so many Suns, and our Sun the centre of a Vortex that turns round him, why may not every fix'd Star be the centre of a Vortex that turns round the fix'd Star? Our Sun enlightens the Planets; why may not every fix'd Star have Planets to which they give light?[70]

Unlike the diagrams in the Cartesian works of Regius and LeGrand, the frontispiece to the first edition and many subsequent editions of the Entretiens clearly depicted planets circling the fixed stars. When his companion in the dialogue demands to know whether there is an absolute necessity of other planetary systems, Fontenelle answers that he is only making use of analogy, but does not see the necessity that every vortex be like ours; some may contain more or less planets, and some none at all.[71] This too is borne out in the diagram, and the remark points out the separation which was possible between the concept of vortices and that of planets contained in them; most Cartesians accepted the former, but stopped short of the latter.

The remainder of the conversation extends Fontenelle's vision to the milky way, which he terms a "cluster of worlds", and applies it even to all the stars invisible to the naked eye. In addition the phenomena of sunspots, variable stars, and comets are discussed in a way entirely analogous to that of part three of Descartes' Principles, but with one difference: the perspective is now that of the inhabitants of those various bodies.

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This frontispiece to the first edition, and many subsequent editions, of Fontenelle's Entretiens clearly shows his belief in the plurality of planetary systems, and clearly depicts planets circling other fixed stars. Compare with the diagram of Regius, above, p. 217.

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* * *

Fontenelle marks a true watershed in the history of the plurality of worlds concept. By tying the existance of innumerable planets to the image of vortices in explicit terms, the Cartesian cosmology played a central role in extending the idea of a plurality of earth-like planets to that of a plurality of solar systems. This extension was accomplished in a treatise written in terms that the normal educated person could understand, and as a result of which he would be made to see the basic concepts of the new Copernican astronomy as supplemented by Descartes. The idea of other inhabited worlds was one which could excite the common curiosity. In the context of the scientific knowledge available, Fontenelle's treatise conveyed that excitement, and in this fact is to be found not the least of its significance for the history of astronomy.

Even if no other Cartesians had embraced Fontenelle's ideas, his treatise would suffice in itself to make a case for the substantial influence of Cartesian cosmology on the plurality of worlds tradition. The Entretiens was disseminated throughout Europe in an extraordinary number of editions and in a variety of languages. A glance at the table on the following page suffices to demonstrate the popularity of the treatise, especially in France and England. It also indicates that the substance of the treatise did not remain static, but rather underwent a marked evolution. Fontenelle himself altered his work several times to reflect new astronomical knowledge, most notable in the 1708 and 1742 editions.[72] In

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TABLE I PARIS, ENGLISH, AND GERMAN EDITIONS OF FONTENELLE'S ENTRETIENS THROUGH THE EIGHTEENTH CENTURY[a]

Paris editions[b]	English translations						German translations	
	Knight	Behn	Glanville	Gardiner	"a gentleman of the inner temple"	Gunning (Plunkett)	Gottsched	Bode
1686[c]								
1687-sixth conversation added	D1687[d]	L1688[e]	L1688[g]					
1694			L1695[g]					
1698		L1700[f]						
1702			L1702[g,h]					
1703								
1708-very extensive revisions by Fontenelle								
1714								
1715				L1715[k]				
		L1718[f]	L1719[h]					
1724							1725	
			L1728[h]	L1728[i]			1730	
			L1737[i]	L1737[i]				
1742-last changes decisively made by Fontenelle, text								
1752 followed by Calame and Shackleton				L1751[i]			1751[l]	
1758				L1757[i]				
				L1758[j]				
					L1760[k]		1760	
1762					D1761[k]	trans?		
1766					L1767[k]			
1769				L1769[j]				
				L1774[j]				
				L1777[j]				
				L1783[j]				1780[m]
1796			L1801[i]					
			Ph1803[i]			L1801[k]		
			E1809[i]			L1803[k]		
			L1809[k]			L1809[k]		

L=London D=Dublin E=Edinburgh Ph=Philadelphia

NOTES ON NEXT PAGE

Notes to Table I

[a] English editions compiled from the National Union Catalogue of pre-56 Imprints (Mansell); Paris editions also from Shackleton; German editions from Mansell, references in Gottsched (1751), and contemporary citations.

[b] These are only the Paris editions, in which any changes made by Fontenelle were originally reflected, and not by any means all of the French editions, which were also printed in Amsterdam, La HaYe, etc. For an exhaustive listing of French editions, cf. Calame, pp. 181-88, where 33 French editions are listed up to the time of Fontenelle's death in 1757 alone. For the relationship of the editions, cf. Shackleton, p. 46.

[c] All Paris editions have the title Entretiens sur la pluralite des mondes.

[d] A Discourse of the Plurality of Worlds.

[e] A Discovery of New Worlds. ... To which is prefixed a preface ... wherein the arguments of Father Tacquet, and others against the system of Copernicus (as to the motion of the earth) are likewise considered, and answered; wholly new.

[f] The Theory or System of Several New Inhabited Worlds ...

[g] A Plurality of Worlds.

[h] Conversations with a Lady, on the Plurality of Worlds.

[i] A Week's Conversation on the Plurality of Worlds. Beginning with the Gardiner translation of London, 1728, all editions of his translation have added "Mr. Addison's Defence of the Newtonian Philosophy".

[j] A Conversation on the Plurality of Worlds.

[k] Conversations on the Plurality of Worlds. The London, 1760 and 1767 editions were published "with great additions, extracted from the best modern authors, on many curious and entertaining subjects". The London, 1767 edition is listed as the "2nd edition" of this translation. The Dublin 1761 edition has no indication of the translator, but does have the same title, and is "illustrated with notes, collected from the most approved writers; and containing all the late discoveries in astronomy."

[l] Herrn Bernhards von Fontenelle, Auserlesene Schriften, [illegible] von mehr als einer Welt, Gesprache der Todten, und die [illegible]er hendnischen Orakel ... (Leipzig, 1751). See Note 79 at the end of this chapter.

[m] ...Dialogen uber die Mehrheit der Welten. Mit Anmerkungen und Kupfertalen von Johann Elert Bode (Berlin, 1780).

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England no less than five separate translations had seen light by the end of the eighteenth century, and more often than not the various editions were accompanied by a supplement or annotations testifying to the role of the work in the spread of the new philosophy. An "argument against the system of Copernicus by Tacquet answered" was added to the 1688 Behn translation; "Mr. Addison's Defence of the New Philosophy" (spoken at the Theatre at Oxford, July 7, 1693) was attached to the majority of English editions after 1728; and the London, 1760 edition appeared "with great additions from the best modern authors." In Germany, first at the hand of the Enlightenment figure Gottsched in 1725, and then by the astronomer Bode in 1780, a running commentary and update of the text was accomplished through voluminous notes.

In spite of his astronomical revisions, Fontenelle clung to the cosmological concept of vortices throughout his life. Indeed, at the age of 95 he wrote a Theorie des tourbillons (1752) which to his mind justified the vortices in greater detail than ever before. The Fontenellian association of the twin ideas of the vortex cosmology and inhabited solar systems was thus spread wherever the Entretiens was reprinted.

There were others who perpetuated the Fontenellian association well into the eighteenth century. Vartanian, in the course of tracing the influence of Cartesian naturalism in the Enlightenment, has cited the interesting statement of Diderot in the Encyclopédie that "the plurality of worlds is

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not an absurd notion. It is possible that there are other worlds like ours, as well as different ones. One must conceive of them as large tourbillons supported each against the other, and between which are compressed many smaller tourbillons, that all together fill up the infinity of space."[73] Vartanian also notes that the Cartesian author of a treatise written sometime before 1746, but not published until 1769, accepted the Fontenellian thesis with all of its Cartesian associations, and moreover implied that others did also: "We know very well that in admitting an infinite number of inhabited planets we are teaching nothing new to real Cartesians."[74]

A closer look at this latter treatise, the Traite de l' infini crée, reveals in detail the Cartesian foundation upon which the author built, and the evolution of the theological arguments relevant to other worlds in the eighteenth century. The author of the Traite explicitly viewed himself as extending those claims which Descartes had stopped short of for religious reasons. Shunning Descartes' notion of an "indefinite" universe, he proclaimed its absolute infinity both in space and in duration, and moreover insisted on "an infinity of earths sprinkled in the universe, and in each one some men who profit from the space wherein they are enclosed. In a word, we admit the tourbillons of Descartes purely and simply as he has explained them ..."[75] The motivation for these strong assertions is also theological: "We raise our proofs from the side of God, and we join theology to philosophy, the only good way to establish and prove a system."[76] More than

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ever, the Traite manifests the complimentary role of both natural philosophy and metaphysics in the advance of the concept of a plurality of inhabited solar systems.

The Cartesian author of the Traite sought also to supplement and clarify Fontenelle's statements on planetary inhabitants. He denies Fontenelle's contention that extra-terrestrial inhabitants would not be of the same basic nature as men, and justifies this in incredible detail on the basis of the variety of nature, and by reinterpreting the religious doctrines of redemption and incarnation. Nature, he insists, has two equal laws, that of uniformity and that of variety, but the former applies to the essence of things and the latter to the accidents. If Fontenelle applies the law of uniformity to arrive at other planetary systems, he must also apply it to the inhabitants, although the law of variety will operate on the accidental properties of these inhabitants: "He calls the planets in a hundred places earths; he must then call the inhabitants men: it is the law of uniformity. But in deference to the law of variety, these men should be smaller or larger, more or less proud, stronger or weaker than us."[77]

This conclusion from natural philosophy is in agreement with the author's reinterpretation of the religious doctrines of redemption and incarnation, wherein he expounds with obvious expertise the theological subtleties involved, and concludes that the one Eternal Word representing the one true God can unite "hypostatically" with many men. This hypostatical union

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produces what he terms many "hommes-Dieu", "man in the plural, God in the singular, because the hommes-Dieu would be several in number as to human nature, but only one as to Divine nature."[78] The author admitted that this reinterpretation from terrestrial to universal incarnation might "alarm timid minds", an understatement which cannot conceal the height of audacity to which the Fontenellian thesis had now pushed even the religiously sophisticated.

In spite of the close association that Fontenelle and others effected between Cartesian vortices and inhabited solar systems, it must be realized that the bond between those two ideas was not by any means inseparable. That unique Cartesian physical concept served only to bring the issue of inhabited planetary systems to the forefront of consciousness, at which point complex theological and metaphysical considerations took precedence. Eighteenth century Cartesians were no more obliged to accept the Fontenellian association than those who had gone before Fontenelle - and many did not. In fact, most Cartesians were apparently satisfied to keep to the religiously safer, but also unsuccessful, attempt to devise some mathematical justification for vortices.

That the mathematical contradictions inherent in Cartesian vortices did not entail the downfall of Fontenelle's work or of his ideas demonstrates what one might have suspected all along: the popularity of the Entretiens was due not to its Cartesianism, but to the stylistically irresistable presentation of the fascinating idea of extraterrestrial inhabitants. And

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at least in the latter part of the eighteenth century, the probable falsity of the vortex theory was pointed out to the reader in many of the annotated editions. While Gottsched in the notes to the 1751 edition of his German translation of Fontenelle apparently accepted the Cartesian vortices,[79] in Britain the anonymous author of the copious notes to a 1761 edition of the work continually put the Cartesian cosmology in an unfavorable light compared to the Newtonian.[80] And in France the astronomer Lalande in his notes remarked simply that Descartes' vortices occupied the attention of the learned for nearly a century, but that "this hypothesis was superseded by the discovery of the laws of attraction."[81] To the minds of these annotators and their readers, the downfall of vortices as a viable scientific hypothesis obviously did not negate the central theme of the book.

Further evidence from Descartes' opponents also indicates that the seventeenth and eighteenth century mind did not equate vortices with inhabited solar systems, even in the aftermath of Fontenelle. While the theologians of the Sorbonne considered censuring the Entretiens, they in fact never did so, and refutations in the tradition of DeVries at Utrecht, which castigated the belief in Cartesian vortices in part because they implied other planetary systems, are not to be found. Although few were still willing to make the diehard peripatetic claim of DeVries that the moon was one of the most perfect celestial bodies, neither did anyone

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seize upon the much more flagrant idea of an infinity of inhabited planets which was the ultimate consequence to which Fontenelle had carried the vortex cosmology.

This is not so strange as it first seems when it is realized that, in addition to the fact that most Cartesians did not champion the idea of extraterrestrial inhabitants (at least explicitly), any real anti-Cartesian found much more fundamental and apparent reasons for the rejection of vortices than the ultimate possibility of inhabited planets. This is the case in one of the best known confutations of Cartesianism, Daniel Huet's Censura philosophiae Cartesianae, even though it appeared three years after Fontenelle's work when the time was ripe for a rebuttal. In this work Huet denied the equation of matter and extension, the very basis of Descartes' plenum cosmology, along with the particulars of his cosmogony such as the three element theory. Given the rejection of such fundamental Cartesian doctrines, the idea of other inhabited solar systems must have been deemed as too ludicrous to be taken seriously.

Yet, there is undoubtedly another reason for the silence of Descartes' opponents on this particular issue, one which goes to the heart of that tension between theology and Cartesian cosmology that has been apparent throughout this controversy. If Descartes' silence on this issue stems from his fear of the implications for theological doctrine and Scriptural orthodoxy, the silence of his opponents also betrays their recognition that the Fontenellian vision of

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of infinite worlds could be used to extoll the glory, power, and plenitude of God, a point which those Cartesian authors who accepted Fontenelle never failed to emphasize. Cartesian and anti-Cartesian alike were anxious to extol the virtues of their God, a point which ironically is made in Huet's treatise in the context of the older tradition of the plurality of kosmoi, an idea which Cartesianism denied. In his confutation of the Cartesian doctrine that God could not make another cosmos since ours was already indefinite, Huet argued that such a view reduced the power of God: not only could he not create another world, he could not even create another particle in the Cartesian plenum.[82] In response to this remark of Huet, the French Cartesian Pierre Sylvain Regis (not to be confused with Henry Regius in Holland) found it strange that men like Huet would "remove from God the glory of having make this immense world, in order to attribute to him only the glory of making another."[83] To which the author of the Traite de l'infini cree would later add in defense of Descartes and Fontenelle, "the infinite power of God does not at all consist in being able to infinitely add to his work ... but it consists in making at one time a work to which one can add nothing."[84]

It is with these theological considerations in mind that we may understand why another work, written expressly to refute the Cartesian vortices, did not directly tackle Fontenelle's claim of other planerary systems, in spite of its appearance only four years after the Entretiens. Gabriel Daniel's Voyage to the World of Cartesius sought to establish this o

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this one proposition "often advanced but still repulsed," that there is "scaree any philosophical hypothesis more unjust and incoherent, or whose conclusions have less connections with its principles, than that of Cartesius."[85] Daniel promises to dwell mainly on the vortex cosmology, which he believes is entirely false, but which of all Descartes' doctrines "hath hithrto bestaescaped the Censure." His strategy is Kircherian in that he makes his points during a voyage to the imaginary spaces of Descartes' third heaven, and it is Fontenellian in that he makes ample use of the art of dialogue. Stopping along the way at the moon, Daniel remarks that it has an atmosphere like the earth "that by moderate computation may amount to three French leagues in height."[86] In a remark which shows how much ground the peripatetics had lost in this particular argument by the end of the seventeenth century, Daniel finds the moon to be "a mass of matter much like that of which the earth is composed. There you have Fields and Forests, Seas and Rivers. I saw no Animals indeed, but I am of the opinion if there were some transported, they would thrive and probably multiply. 'Tis false that there Men there, as Cyrano reports; but 'twas undesignedly that he deceiv'd us, having first been deceived himself."[87]

But when Daniel comes to a discussion of the details of the vortex cosmology, once again a plurality of inhabited planets is not even mentioned, much less refuted. As with

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Huet and most other anti-Cartesians, Daniel questioned the Cartesian cosmology, but did not use the plurality of worlds idea per se as an element in the refutation of the Cartesian system. Beyond the extremely important case of Fontenelle, the idea of vortices as inhabited planetary systems simply seems not to have become a widespread controversy in Cartesian terms.

A final illuminating and surprising confirmation of the separation of the concept of vortices from inhabited solar systems is the treatise on plurality of worlds written by the astronomer Christaan Huygens. Huygens was a man educated in Cartesian thought and immersed in it throughout his life, but he never accepted the Cartesian cosmology to the extent that Fontenelle did. The posthumous Cosmotheoros (1698) has often been compared to the Entretiens, and has even been called an imitation of it.[88] It is true that Huygens here sets forth his belief in inhabited planets in our system and furthermore declares that the fixed stars are suns with their own planets. But the latter claim is based mainly on the old assertion, presented with renewed force, that an observer removed an equal distance from the sun and fixed stars would perceive no difference in their appearance. The stars are therefore entirely similar in nature to the sun, and on the basis of the uniformity of nature must be given their proper planets.[89]

It is only at the end of the treatise, after he has already proven to his satisfaction the existence of other planetary systems, that Huygens indicates his belief in a type of

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vortex cosmology.

> All that I shall do more is to add somewhat of my opinion concerning the world, as it is a place for the reception of the Suns or fix'd Stars, every one of which I have show'd may have their planetary systems about them.
>
> I am of the opinion that every Sun is surrounded with a whirlpool or vortex of matter in very swift motion; tho not in the least like Cartes' either in their bulk or manner of motion.[90]

Far from the pervasive role that vortices play in those conversations of Fontenelle where he proposes other planetary systems, the concept in Huygens is more in the nature of a non-essential addition. Huygens' attitude encapsulates the general role of vortices in the plurality of worlds controversy: they were a part of his world view which lent a certain plausibility to the existence of other planetary systems, but the arguments of the Cosmotheoros do not stand or fall on the fate of Cartesian vortices. Neither, however, are the roots of Huygens thoughts on the subject to be found in theological considerations - although theology is involved - but rather in an empirical tradition associated with his astronomical research and antedating Fontenelle's work.[91]

In the end it was not the mechanical details of the vortices themselves which were essential to the spread of the concept of a plurality of planetary systems, but simply the fact that this uniquely Cartesian concept ingrained in the seventeenth century mind the essential similarity of the laws of the entire universe to that small part which man occupied. There was no reason that there should not be other planetary systems, and if Descartes had not found the correct laws, his

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faith in the uniformity of nature and in man's ability to understand that uniformity, was carried on by others.

The lack of a widespread Cartesian controversy involving inhabited solar systems should not obscure the fundamental contribution of Descartes' ideas to the plurality of worlds tradition. His Principles contained a whole spectrum of ideas conducive to the belief in a plurality of worlds, and many of those ideas at the more conservative end of the spectrum, such as an earth-like moon and planets, and self-luminous fixed stars, were shared and spread by Cartesians everywhere. The Cartesian cosmology was of primary importance in motivating the composition of Fontenelle's Entretiens in the first instance, and through Fontenelle the Cartesian vortices played a central role in extending the idea of other worlds beyond our solar system. If the vast majority of Cartesians, both before and after Fontenelle, did not explicitly discuss, much less champion, that idea at the most radical end of the spectrum - the infinite number of inhabited solar systems - this only demonstrates the still powerful and complex grasp of religious thought in seventeenth century natural philosophy, a grasp which had stifled Descartes himself on this particular issue. It also demonstrates that much more was involved than the straightforward invocation of a principle of plenitude.

When the whole history of Cartesianism is taken into account, the link between the twin ideas of vortices and plurality of worlds is temporary and intermittent. This does not mitigate the fact that it was the vortex cosmology in Fontenelle's

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treatise which ingrained the concept of other solar systems into the minds of laymen and natural philosophers alike. The universe would never again be quite the same. Long after the vortices themselves had ceased to represent reality in the minds of most people, the idea of a plurality of planetary systems remained a challenge to be scrutinized by natural philosophers of whatever persuasion.

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NOTES

[1] Descartes to Chanut, June 6, 1647, Correspondence, ed. Adam and Milhaud, VII, 347-349; cited by Paolo Rossi, "Nobility of Man and Plurality of Worlds," trans. Arthur Brickmann, in Science, Medicine and Society in the Renaissance, ed. Allen G. Debus, II, 124.

[2] Bernard le Bovier de Fontenelle, Entretiens sur la pluralité des mondes, 1688 English translation by Joseph Glanville, A Plurality of Worlds, in Leonard M. Marsak, The Achievement of Bernard le Bovier de Fontenelle (New York and London, 1970), p. 125.

[3] Arthur O. Lovejoy, The Great Chain of Being (Cambridge, Mass., 1971; first ed., 1936), p. 124.

[4] Ibid., p. 123.

[5] Paolo Rossi, "Nobility of Man and Plurality of Worlds," in Science, Medicine and Society in the Renaissance, ed. Allen G. Debus, II, 154.

[6] P. Mouy, Le developpement de la physique Cartesienne (Paris, 1934), p. 176.

[6a] The Philosophical Works of Descartes, trans. Elizabeth S. Haldane and G.T.R. Ross (Cambridge, 1972), I, 265. The Latin original, soon translated into French by Descartes' friend Picot, reads as follows: "Hincque etiam colligi facile potest, non aliam esse materiam coeli quam terrae; atque omnino, si mundi essent infiniti, non posse non illos omnes ex una & eadem materia constare; nec proinde plures, sed unum tantur, esse posse: quia perspicue intelligimus illam materiam, cujus natura in eo solo consistit quod sit substantia extensa, omnia omnino spatia imaginabilia in quibus alii isti mundi esse deberent, jam occupare: nec ullius alterius materiae ideam in nobis reperimus." Oeuvres de Descartes, Charles Adam and Paul Tannery, eds. (Paris, 1964), vol. 8, part 1, p. 52. It need hardly be pointed out that this refutation of other kosmoi was not accepted by everyone, least of all by non-Cartesians. Having acquired a copy of Descartes' Principles with some difficulty, a certain Frère Gabriel Thibaut, a Minim of the province of Lyon, wrote to Mersenne sometime between 1646-1648 with regard to Descartes' principle 22 of part 2 cited above: "This he does not prove; because although God could make everything a hundred million times greater than he has, it does not follow that he has done so, and we have neither authority nor reason to persuade us." In other words, Thibaut does not accept the infinite or indefinite Cartesian plenum, and still holds that other worlds might exist in space outside our world. Nevertheless, Thibaut probably did not believe in the actual existence of such kosmoi: "As for the repugnance of plural worlds, Alliacensis

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6a (cont.) Pierre d' Ailly and certain others have discussed this, founded on other principles." Oeuvres de Descartes, Adam and Tannery, eds.,(Paris, 1974), vol. 5, p. 69. My translation from the French. Mersenne elsewhere agrees that the issue can neither be decided by faith or reason, cf. infra, pp. 158 ff.

Nevertheless, Cartesians did often seize upon this argument in their works. An elaboration of the standard Cartesian argument is found, for example, in Antoine LeGrand, An Entire Body of Philosophy according to the Principles of the Famous Renate Des Cartes (London, 1694), part V, pp. 134-35: "The world is but one only, neither can a plurality of worlds be conceived without a contradiction; for there can be no more than one Universal comprehension of bodies, seeing that many worlds cannot be conceived without Distance, neither can Distance be without Extension, nor that without a Body, which mediating Body would then join both worlds together; for the conjunction of the parts of the world consists in nothing else but this, that all the parts in it touch one another. But to imagine two worlds separated by a vacuum or Imaginary Space, that is, two bodies distanced from each other by Nothing, is meer folly, because to this Distance by Nothing would belong Extension, Divisibility and Mensurability, and it might be either nearer or farther off." In these terms the old scholastic argument was continued in the seventeenth century.

7 In his posthumously published Le monde; however, Descartes speaks of a new world in the imaginary spaces beyond our world. Even though this was only a literary device used to expound controversial points about our own world, it nevertheless might indicate something about Descartes' belief in an "imaginary space" beyond our world.

8 Principles, part III, principle 1, Haldane and Ross translation. To my knowledge there exists no English translation of the whole of part III of Descartes' Principles, although the first three principles and the headings for the remaining principles are translated in Haldane and Ross, as cited here. I will thus be using the Latin and French versions of the Principles given in Adam and Tannery, Oeuvres, vol. 8, part 1 and vol. 9, part 2, and will cite the part of the treatise and the number of the principle involved.

9 Ibid., part III, principle 19.

10 Descartes himself did not know of Kepler's laws, and thus did not try to reconcile his theory with those laws. Later Cartesians did make some gallant and plausible attempts. For the details of these attempts, and for a treatment of the complex details of the vortex theory and its history, cf. E. J. Aiton, The Vortex Theory of Planetary Motions (London and New York, 1972).

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[11] Principles, part III, principle 46.

[12] Ibid., part II, principle 23.

[13] Ibid., part III, principle 46.

[14] P. Chanut to Descartes, May 11, 1647; cited by Paolo Rossi, "Nobility of Man and Plurality of Worlds,", p. 153.

[15] Not yet realizing the limitations of the telescope, Descartes wrote to Ferrier on 13 November, 1629 " ... i'oserois esperer que nous verrions, parrvostre moyen, s'il y a des animaux dans la Lune." Oeuvres (Paris, 1897), I, 69.

[16] Oeuvres, V, p. 168, cited by Paolo Rossi, "Nobility of Man and Plurality of Worlds," p. 154. Lovejoy notwithstanding (Great Chain of Being, p. 123), Descartes does not in this passage positively assert the existence of extraterrestrial creatures based on God's plenitude.

[17] Deacartes to Chanut, June 6, 1647, Correspondence, VII, 347-349, cited by Rossi, p. 154.

[18] On More's Cartesianism, see Marjorie Nicholson, "The Early Stage of Cartesianism in England," Studies in Philology, vol. XXVI, no. 3, pp. 356-74, and C. Webster, "Henry More and Descartes: some new Sources," British Journal for the History of Science, 1969, vol. 4, pp. 359 ff. On More's belief in an infinite universe, and on his differences with Descartes, see Alexandre Koyre, From the Closed World to the Infinite Universe (Baltimore, 1957; reprinted 1970), chapters V and VI. On Cartesianism in general in seventeenth century England, see Nicholson, op. cit., and Sterling P. Lamprecht, "The Role of Descartes in Seventeenth Century England," Studies in the History of Ideas (New York, 1935), III, 181-240. Lamprecht concludes that although most English thinkers were influenced by Descartes' ideas, the latter did not gain a single true follower in that country "in the sense of a sworn propagation of strict Cartesian orthodoxy", p. 182. A possible exception is the Frenchman Antoine LeGrand, who lived in England for thirty years (see last paragraph of note 6a above).

[19] See infra, chapter 1, pp. 28-31.

[20] Reprinted in Los Angelos, 1968, "To the Reader".

[21] Ibid., stanza 35. More's later uncertainties with regard to Descartes' doctrine of extension and matter, as contained in correspondence between the two philosophers in 1648-49 and More's later works, have been examined in depth by Alexandre Koyre, From the Closed World to the Infinite Universe (Baltimore, 1957; reprinted 1970), chapters V and VI.

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[22] Ibid., stanza 24.

[23] For the details of the theological ramifications of the doctrine of a plurality of worlds, see above, chapter 3, pp. 155 ff, and passim.

[24] The full title is Discours nouveau prouvant la pluralite des mondes, que les astres sont des terres habitees, & la terre un estoile, qu' elle est hors du centre du monde dans le troisiesme ciel, & se tourne devant le soleil qui est fixe, & autres choses tres-curieuses (Geneve, 1657). An English edition appeared in 1658 under the title A New Treatise Proving a Multiplicity of Worlds. That the Planets are Regions inhabited and the Earth a Star, and that it is out of the center of the World in the third Heaven, and turns round before the Sun which is fixed. And other most rare and curious things (London, 1658). All citations, unless otherwise noted, will be from the English edition, although I have checked the French edition for accuracy when it seemed necessary.

[25] Borel published catalogs of his collections and of others in 1645 and 1649. In 1653 he became physician to the king and soon after published a catalog of some 4000 books and manuscripts of the Hermetic philosophy. Among his other works are one on the true inventor of the telescope (1655), a life of Descartes (1656), and a book of observations with the microscope (1656). It was 1674 when he became a member of the Academie des Sciences. For more on Borel's life and work, cf. Dictionary of Scientific Biography, also P. Chabbert, "P. Borel," Revue de l'histoire des sciences, 1968, vol. 21, pp. 303-343.

[26] My translation from the "au lecteur" of the French edition, which was not included in the English translation of the work, undoubtedly because of the aspersions which it cast on Wilkins' book.

[27] The relationship between the Copernican theory and the plurality of worlds is explicitly discussed by Borel especially in chapters 5, 10, and 11, and chapter 12 is given over to proofs of the motion of the earth!

[28] The accord of the concept of a plurality of earths with sacred Scripture is declared in chapters 9 and 12, and the arguments from the omnipotence of the Creator are found in chapters 8, 13, and 18.

[29] Ibid., chapter 5.

[30] Marie-Rose Carre, "A Man between Two Worlds: Pierre Borel and his Discours nouveau prouvant la pluralite des mondes of 1657", Isis, vol. 65 (1974), pp. 322-335.

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[31] A New Treatise, chapter 5.

[32] Ibid., chapters 6 and 7. The same type of argument was put forth already by Tycho Brahe in the 16th century, but as a reductio ad absurdum argument against Copernicanism. It became a very prominent argument in the course of the 17th century.

[33] Ibid., chapter 1.

[34] Ibid., chapter 44: " ... Galileus and Descartes declare that there may be made Prospective glasses, that shall multiply the object a thousand times in his bignesse: if it be so, what is there in the Firmament that may not perspicuously be seen?" In the Optics attached to his Discourse on Method, Descartes spoke of perfecting telescopes by making larger lenses with longer focal lengths, and remarked that "If the hand of the workers does not fail us, we will be able through this invention to see objects as particular and as small among the stars, as those that we commonly see on the earth." Discourse on Method, Optics, Geometry, and Meteorology, Paul J. Olscamp, trans. (Indianapolis, 1965), p. 157. This agrees with Descartes' earlier expressed hope that by means of the telescope, one might determine whether there were animals on the moon (note 15).

[35] In France the universities were stringently controlled by the ecclesiastical authorities with political sanctions. Although this meant that the official condemnation of Cartesian doctrines was enforced in the universities, outside of them enforcement was not possible. In private gatherings and in the academies, Cartesianism flourished. Mersenne was a faithful friend of Descartes, and through him and dedicated adherents like Rohault, Gadroys, Cordemoy and Regis, the Cartesian philosophy was widely disseminated throughout France. On the fate of Cartesianism in France, cf. Bouillier, Histoire de la philosophie Cartesienne (Paris, 1868; reprinted New York, 1972), vol. I, pp. 429-446; P. Mouy, Le developpment de la physique Cartesienne (Paris, 1934); and Leonard M. Marsak, "Cartesianism in Fontenelle and French Science, 1686-1752", Isis, vol. 50 (1959), pp. 51-60. On the eighteenth century elements of Cartesian thought in France, cf. Aram Vartanian, Diderot and Descartes: A Study of Scientific Naturalism in the Enlightenment (Princeton, 1953). On Cartesian opponents in seventeenth century France, cf. L.C. Rosenfield, "Peripatetic Adversaries of Cartesianism in 17th Century France," The Review of Religion, vol. XXII (1957), pp. 14-40.

[36] Marie-Rose Carre, "A Man between Two Worlds: Pierre Borel and His Discours nouveau prouvant la pluralite des mondes of 1657," Isis, vol. 65 (1974), p. 324. Also p. 335: "Borel's reasoning evidently bears the mark of Cartesianism, as he concludes that man can only grow in strength by not shrinking from the truths of the physical world."

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[37] Les estats et empires de la lune (1657) was followed by Les estats et empires du soleil in 1662; both were probably written in the 1640's and may have been circulated in manuscript before publication. Madelaine Alcover, La pensee philosophique et scientifique de Cyrano de Bergerac (Geneve, 1970), p. 107 concludes "L' influence de Descartes sur la pensee de De Bergerac ne fait aucun doute, mais elle est ici tres faible."

[38] On DeVries cf. Nieuw Nederlandsch biografisch woorderbock, vol. 10, p. 1140, and C. Louise Thijssen Schoute, Nederlands Cartesianisme (Amsterdam, 1954), pp. 226-28.

[39] This work, which I have not seen, is listed in the British Museum Catalogue of Printed Books under "Vries, Gerhard de", one of almost 70 dissertations for which DeVries served as praeses during his career at Utrecht.

[40] By all odds it was Holland, long-time refuge of Descartes from his native France, which at the outset was most receptive to his ideas. In spite of official prohibitions and the protestations of orthodox theologians and peripatetics such as Gisbert Voet, the two great universities of Holland responded strongly to Descartes, and became the base from which Cartesianism sent forth its most vigorous branches. Already at Utrecht in the early 1640's, Reneri taught the Discours and the Essais, and his successor Regius taught the Meditations and the Principles. Later at Leiden under Herreboord and Jean de Raey, Cartesianism found an open forum, if not always a friendly one. After a period of initial resistance, and despite a peripatetic reaction around 1670, Cartesian ideas enjoyed great popularity in Dutch universities until the end of the century, when they began to give way to Newtonian concepts. See Stephen d'Irsay, Histoire des universites Francaises et etrangeres (Paris, 1933-35), vol. II, pp. 36-41, and Francisque Bouillier, Histoire de la philosophie Cartesienne (Paris, 1868; reprinted New York, 1972), vol. I, pp. 279-300. Also on Holland Cartesianism see Mouy, op. cit., pp. 73-97; Edward Grant Ruestow, Physics at 17th and 18th century Leiden (The Hague, 1973); E.J. Dijksterhuis et al., Descartes et le Cartesianisme Hollandais (Paris and Amsterdam, 1950); and C. Louise Thijssen-Schoute, Nederlands Cartesianisme, Verhandelingen der koninklijke Nederlandre Akademie van wetenschappen (Amsterdam, 1954), new series, vol. 60.

[41] "Dissertatio academica de lunicolis", in Daniel Voet, Physiologia, sive, de natura rerum libri sex, recogniti, ac notis illustrati a Gerardo De Vries ... accedit hujus Dissertatio gemina, altera de lumine, altera de lunicolis. Editio tertia (Trajecti ad Rhenum, 1694), p. 250.

[42] Ibid., p. 252.

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[43] Ibid., p. 254.

[44] Ibid., p. 259.

[45] Ibid., p. 259.

[46] I am using the third edition, re-entitled Philosophia naturalis; in qua tota rerum universitas, per clara & facilia principia, expàanantur (Amstelaedami, 1661). I have not seen the earlier editions, but Mouy, Le developpement de la physique Cartesianne (Paris, 1934), points out that each edition was much enriched from the previous one. For a detailed examination of the various editions of the treatise, see Mouy, pp. 73 ff.

[47] Philosophia naturalis (Amstelaedami, 1661), pp. 158-59.

[48] The Institutio was published in London in 1672. I have seen only the 1694 English edition, An Entire Body of Philosophy, according to the Principles of the famous Renate DesCartes ... (London, 1694). The diagram referred to appears in plate 1, figure 19.

[49] On the influence of Rohault and his relationship to other Cartesians, see Mouy, op. cit.

[50] Rohault's System of Natural Philosophy, illustrated with Dr. Samuel Clarke's Notes, taken mostly out of Sir Isaac Newton's Philosophy ... the second edition, corrected ... (London, 1728), pp. 76-77.

[51] Ibid., pp. 64-66.

[52] Ibid., pp. 78-79.

[53] Le systeme du monde, selon les trois hypotheses, ou conformement aux loix de la mechanique l'on explicque dans la supposition du movement de la Terre. Les apparences des astres, la fabrique du monde, la formation des planetes, la lumiere, la pesanteur, & c. Et cela par de nouvelles demonstrations (Paris, 1675), Question IV, chapter 3.

[54] Ibid., p. 306.

[55] Athanasius Kircher, Iter exstaticum coeleste, quo mundi opificium, id est, coelestis expansi, siderumq; tam errantium, quam fixorum natura, vires, proprietates, singulorumq; compositio & structura, ab infimo Telluris globo, usq; ad ultima mundi confinia, per ficti raptus integumentum explorata, nova hypothesi exponitur ad veritatem, interlocutoribus Cosmiele et Theodidacto. Hac secunda editione praelusionibus & scholiis illustratum ... a P. Gaspare Schotto ... (Herbipoli, 1660), pp. 341 ff. and p. 45.

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[56] Kircher at the end of his treatise does cite "Renatus Descartes Fundamenta novae philosoph." (the Principles?) as one of 37 authorities for celestial observations which he used. But in the text and in another more comprehensive list of authorities whose writings confirm the hypothesis put forth in hsi work, there is no trace of Descartes.

[57] Ottonis de Guericke Experimenta nova (ut vocantur) Magdeburgica de vacuo spatio, primum a R.P. Gaspare Schotto, e Societate Jesu ... nunc vero ab ipso auctore perfectius edita, variisque aliis experimentis aucta. Quibus accesserunt simul certa quaedam, de aeris pondere circa terram; de virtutibus mundanis, & systemate mundi planetario; sicut & de stellis fixis ac spatio illo immenso, quod tam intra quam extra eas funditur.(Amstelodami, 1672; facsimile reprint, 1962), Book VII, pp. 229 ff. Von Guericke often refers to Part II of Descartes' Principles in refuting the equation of extension and matter presented there, while instead putting forth his belief in a vacuum, which he believed the "Magdeburg experiments" proved. But there is no reference to Descartes' belief in fixed stars as suns, or the vortex theory. Von Guericke instead traces the idea to Galileo, Kepler, Antonius de Rheita, Mersenne, Bruno, and Cusa, before he begins his annotations of Kircher.

[58] Ibid., Book V, chapter 23, "An in luna sint animalia".

[59] Rohault, op. cit., p. 79.

[60] On Fontenelle and the French Enlightenment, see Leonard M. Marsak, "Bernard de Fontenelle: the Idea of Science in the French Enlightenment," Transactions of the American Philosophical Society, new series, vol. 49, part 7, 1959, pp. 12 ff. Also by the same author, "Cartesianism in Fontenelle and French Science, 1686-1752", Isis, vol. 50, 1959, pp. 51-60.

[61] 1688 English translation by Joseph Glanville, A Plurality of Worlds, in Leonard M. Marsak, The Achievement of Bernard le Bovier de Fontenelle (New York and London). From "The Preface" to A Plurality of Worlds.

[62] Ibid., p. 87.

[63] It is this aspect of Fontenelle which Lovejoy discusses in The Great Chain of Being, pp. 130-133.

[64] Writing about 1767, the author of a "Memoire presente a Monsieur De Sartine, Directeur General de la Libraire de France, par ** Libraire, au sujet de la visite faite par ses ordres, & de la suspension de l' impression du Traite de l' infini cree, ourrage du Pere Malebranche" had this to say: "If one had listened to certain pious persons and critics, always a very numerous people, France would still regret the Mondes of

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64 (cont.) M. de Fontenelle. You know, Monsieur, the uproar that it made at its birth, as the Sorbonne gathered several times on that subject, and considered censuring that charming work, which was read and republished, and which today has the approval of even the most severe theologians." The "Memoire" appeared appended to an edition of the Traite published in Amsterdam in 1769, p. 43. My translation from the French.

65 On Fontenelle's Cartesianism see Marsak, "Cartesianism in Fontenelle and French Science, 1686-1752", Isis, vol. 50, 1959, pp. 51-60. One of Marsak's chief themes here and elsewhere is that labeling Fontenelle a "Cartesian" entails a serious misuse of the term, since, he argues, Fontenelle accepts only Descartes' cosmology and not his metaphysics or method.

66 A Plurality of Worlds, pp. 68 ff.

67 Ibid., p. 74.

68 Ibid., p. 82. " ... Nature hath made great Cavities in the Moon; we can discern 'em easily with our Tellescopes, for they are not mountains, but so many Wells or Vaults in the middle of a Plain; and what do we know but the Inhabitants of the Moon, being continually broil'd by the excessive heat of the Sun, do retire into those great Wells; perhaps they live no where else, and 'tis there they build 'em Cities ...". Compare with Kepler's statement: "The moon is all porous and, so to say, perforated with caves and grottoes everywhere ... ; these recesses are the inhabitants' principal protection from heat and cold." Kepler's Somnium: The Dream, or Posthumous Work on Lunar Astronomy (Madison, 1967), p. 27. Kepler had put forth the same idea in his Dissertatio cum nuncio sidereo (1610), so that it is impossible to say with certainty which work Fontenelle had read.

69 Ibid., pp. 105-107.

70 Ibid., p. 125.

71 Ibid., pp. 131-33.

72 On the changes made by Fontenelle, see Robert Shackleton, Entretiens sur la pluralité des mondes; Digression sur les anciens et les modernes (Oxford, 1955), pp. 40-47 ff. Also Alexandre Calame, Entretiens sur la pluralite des mondes (Paris, 1966), pp. vii-xiii and "Apendice bibliographique".

73 Aram Vartanian, Diderot and Descartes: A Study of Scientific Naturalism in the Enlightenment (Princeton, 1953), p. 123.

74 Ibid., p. 74.

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[75] Traite de l'infini cree, avec l'explication de la possibilite de la transsubstantiation. Traite de la confession & de la communion. Par le Pere Malebranche, de l'Oratoire (Amsterdam, 1769), pp. 92-93. It is generally accepted by scholars that this work was in fact not written by Malebranche, Vartanian asserting that it was "almost certainly composed by the abbe Jean Terrasson who, with Fontenelle and Mairan, was reputed one of the eighteenth century's leading Cartesians ... ". Diderot and Descartes, p. 73. Vartanian's page references to the Traite do not coincide with those of the copy which I have used, therefore there must have been two "Amsterdam, 1769" editions. All following translations are mine from the French.

[76] Ibid., p. 94.

[77] Ibid., p. 98.

[78] Ibid., p. 100.

[79] Herrn Bernhards von Fontenelle, Auserlesene Schriften, namlich von mehr als einer Welt, Gesprache der Todten, und die Historie der hendnischen Orakel ... (Leipzig, 1751), pp. 111-113 and 134 ff. The first edition of this work was apparently published in 1725, since the 1751 edition contains a "Vorrede des uebersetzers den der ersten ausgabe von 1725", pp. LXV-LXVII. The "Nachricht zur zwenten ausgabe" is not dated, but external evidence indicates the second edition may have been published in 1730.

[80] Conversations on the Plurality of Worlds, translated from the last edition of the French. Illustrated with notes collected from the most approved writers, and containing all the late discoveries in astronomy ... printed for P. Wilson, in Dame Street, 1761. The "Preface by the editor of this Dublin edition" makes it clear that this is the Dublin, 1761, and not a London, 1761 edition, as it has been catalogued at the University of Oklahoma Library. A London, 1761 edition is apparently spurious.

[81] Conversations on the Plurality of Worlds ... with notes and a critical account of the author's writings, by Jerome De La Lande, translated from a late Paris edition, by Miss Elizabeth Gunning (London, 1803), p. 2.

[82] Response au livre qui a pour titre P. Danielis Huetii, episcopi Suessionis designati, Censura philosophiae Cartesianae. Servant d' eclaircissement a toutes les parties de la philosophie, sur tout a la metaphysique, par Pierre Silvain Regis (Paris, 1691), p. 258. Regis reprints the text of Huet interspersed with his own commentary. The passage cited above is from the Huet reprint.

[83] Ibid., p. 265.

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[84] Traite, p. 54.

[85] Gabriel Daniel, A Voyage to the World of Cartesius, written originally in French, translated into English by T. Taylor (London, 1694), "Avertissement of the Author".

[86] Ibid., p. 68.

[87] Ibid., pp. 97-98.

[88] "The little work, Cosmotheoros, written by Huygens, and pyblished posthumously in 1698, appears therefore to have been written in imitation of Fontenelle, and its chief interest is that it shows Huygens, at the time of its composition, as notably Cartesian in outlook." A.E. Bell, Christian Huygens and the Development of Science in the Seventeenth Century (London, 1947), p. 200. Bell's only argument is that Huygens' work follows Fontenelle's chronologically. Mouy, op. cit., p. 214, repeats this view.

[89] Huygens, The Celestial Worlds Discover'd (London, 1968), pp. 149-157.

[90] Ibid., p. 157. On Huygens' Cartesianism see Aant Elzinga, On a Research Program in Early Modern Physics (New York, 1972), pp. 27-30; also Rene Dugas, "Sur la cartesianisme de Huygens", Revue d' Histoire des Sciences, vol. 54, no. 7, pp. 22-33.

[91] We will explore this tradition in depth in chapter 6.

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Chapter Five

Newtonianism: The Plurality of Solar and Stellar Systems

> This most beautiful system of the sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent and powerful Being. And if the fixed stars are the centres of other like systems, these, being formed by the like wise counsel, must be all subject to the dominion of the One.
>
> Isaac Newton[1] 1713

> If the fixed stars constitute a system whose extent is determined by the sphere of attraction of that body which is situated in the centre, shall there not have arisen more Solar Systems, and, so to speak, more Milky Ways, which have been produced in the boundless field of space?
>
> Immanuel Kant[2] 1755

It was only one year after the publication of Fontenelle's Entretiens that Newton, through the enunciation of an entirely new system in the Principia mathematica, cast aside the vortex cosmology which had thrust the plurality of worlds tradition into the realm of the infinite universe. The 1713 edition of the Principia explicitly proclaimed that "the hypothesis of vortices is pressed with many difficulties", and although even by that time the Cartesian system had not been entirely abandoned, least of all by Fontenelle himself, in the end those difficulties of which Newton spoke would prove overwhelming.

We have already detailed in an earlier chapter - in connection with the atomist tradition - Newton's occasional remarks regarding the existence of other solar systems.[3] In contrast to the ancient atomists Lucretius and Epicurus who deduced the existence of an infinite number of kosmoi from

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the random coalescence of matter, and in contrast to their seventeenth century counterparts Gassendi and Charleton who greatly influenced Newton and who flatly denied this doctrine because of theological objections, Newton insisted that the formation of all ordered systems was entirely contingent upon God's action. Newton revealed in his letters of 1692-1693 to the theologian Richard Bentley his belief that even our own solar system could not have been formed from an initial chaos without the aid of God.[4] He did not see how any natural law could have separated the luminous matter of the sun from the opaque matter of the planets, nor did he understand how the planets could have attained their present orbits without the aid of a "Divine arm". Newton made an even stronger statement in the 1706 Opticks, when he asserted that God could vary the laws of Nature in other worlds:

> ... since Space is divisible in infinitum, and Matter is not necessarily in all places, it may be also allow'd that God is able to create Particles of Matter of several Sizes and Figures, and in several Proportions to Space, and perhaps of different Densities and Forces, and thereby to vary the Laws of Nature, and make Worlds of several sorts in several Parts of the Universe. At least I see nothing of contradiction in all this.[5]

But Newton's final position is perhaps best summarized in a comment added to the second edition of the Principia (1713): "This most beautiful system of the sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent and powerful Being, and if the fixed stars are the centres of other like systems, these, being formed by the like wise counsel, must be all subject to the dominion of the One."[6]

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The statement encapsulates both Newton's belief in the necessary role of God in the formation of ordered systems, and his reluctance to assert the actual existence of such systems.

The Newtonian universe, then, was one in which the existence of innumerable systems was by no means an integral part of the cosmology as it had been in the Cartesian scheme. The generation of systems according to natural law was inherent in Descartes' plenum ontology; once God created matter and agitated it to produce the chaos, he "concluded his work by merely lending his concurrence to Nature in the usual way, leaving her to act in accordance with the laws which he had established."[7] These laws led directly to the vortices which were the hallmark of Cartesian cosmology.

Newton, on the other hand, insisted that in his universe of matter, void, and an active Deity, the generation of other systems was impossible by nature alone, and even though God could produce other systems if he wished, it was by no means established that he had done so. Cosmological questions which probed beyond our own solar system were not one of Newton's prime concerns, and his own universal laws of gravitation notwithstanding, the question of other solar systems for him implied knowledge of God's actions, a knowledge which the great English scientist did not presume to possess. In spite of many general similarities of Newton's cosmology with Descartes'[8] - both are mechanical philosophies which strive to

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banish occult qualities, both enunciate physical laws generally considered applicable to the whole universe (in spite of Newton's statement in the Opticks), and both in effect espouse an infinite universe - the question of other solar systems for Newton was much more closely tied to the Deity than it was for Descartes.

At the same time it is true that in spite of his vortices, Descartes himself did not explicitly assert the existence of a plurality of inhabited solar systems. Newton's position with regard to his followers on this issue is therefore similar to that of Descartes in relation to the Cartesians. Like Descartes, Newton provided the kernel for a renewed discussion of the old atomist problem of a plurality of worlds, in which the question of more than one cosmos was replaced by that of more than one solar system (and which for later Newtonians was joined by issue of more than one stellar system). The central question for Newtonians was the same as it had been for Cartesians: were there or were there not other solar systems similar to ours, and if so, how similar? The followers of Newton were left to puzzle over the contingency of such systems upon the action of God, part of the larger question of the role of the Deity in the workings of nature. Both groups pondered the picture of a universe filled with planets and populated with intelligent inhabitants, and asked themselves whether such a universe would not immeasurably strengthen the scope and the claims of natural theology. As had been the case among the Cartesians, in the absence of observational data the resolution of such questions

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still depended upon two considerations: the universal application of appropriate physical principles, and a theological system which had to decide whether its various entangled doctrines of God's providence, his attributes, and his design in the universe, along with the opinion of sacred Scripture, would be better served by affirming or denying the reality of other solar systems, or by remaining essentially uncommitted on this particular question as Newton and Descartes preferred.

*

In spite of Descartes' belief that it would be the height of presumption for man to believe that his mind could comprehend the ends for which God created the various things in his universe,[9] the seventeenth century virtuosi, Newton included, almost unanimously agreed that some of the chief proofs of God's existence could be drawn from the observation of nature.[10] That natural phenomena could not be explained without reference to an active Deity was precisely the thesis of Richard Bentley, a younger contemporary of Newton, whose Confutation of Atheism from the Origin and Frame of the World (1693) formed a part of the inaugural series of illustrious Boyle lectures instituted by that famous virtuoso especially to combat atheism.[11] Bentley's treatise hammered away at the old atomist belief that the world was formed out of atoms by chance. It is of interest chiefly in that this task is undertaken in the context of Newtonian principles of gravitation, surely one of the earliest treatises to do so, since the Principia had only appeared some

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half-dozen years before. More especially, the work is important to our subject because Bentley carries his arguments beyond the confines of our solar system to the entire visible universe.

> The proposition to be proven is this:
>
> That the Atoms or Particles which now constitute Heaven and Earth, being once separated and diffused in the Mundane Space like the supposed Chaos, could never without a God by their mechanical affections have convened into this present Frame of things or any other like it.[12]

Bentley's strategy is to demonstrate "the great Rarity and Tenuity of the imaginary Chaos", and thus the unlikelihood that atoms could convene into masses under their own power. Beginning first with our solar system and using contemporary values for the extent of our system and the mass of its members, Bentley calculates that the void space is "8575 hundred thousand million million times more ample than all the corporeal substance in it."[13] This calculation is made on the basis of "our system" extending one-half the distance to the nearest fixed star, where the system of that star would begin; Bentley thus in passing reveals his belief that every fixed star is at the center of a system like ours. That belief is soon made more explicit as Bentley seeks to emphasize that the proportion of void to matter in the entire universe is the same as it is in our system. This is true, Bentley holds, if it is supposed that every fixed star is considered similar to our sun, a supposition which he points out is "supposed by astronomers", and if in addition one accepts that these suns "may very possibly have Planets about them",[14] a more daring

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corollary which Bentley conspicuously does not ascribe to astronomers. Given this set of circumstances, Bentley triumphantly concludes that if all matter were originally evenly diffused throughout space, then each particle of matter would be so far distant from each other (each "above nine-million times their own length") that one atom would never be attracted to or make contact with another. Even less, then, would the universe as we presently observe it have been formed by any natural process, whether it be that of the ancient atomists or Newtonian attraction.

Nor is this the only occasion on which Bentley's discussion spills out of the confines of our own solar system. Although the remainder of this seventh Boyle lecture is largely devoted to proofs of a Deity from the particulars of our own system, appeal is once again made to the larger universe at its conclusion. Here Bentley makes the point that if there were only one system in the universe, with a single sun at the center and all the planets revolving about it, such a solitary system in a Newtonian universe might endure by itself, once the planets were put in motion. But the present world, Bentley persisted, was quite different:

> Here's an innumerable multitude of Fixt Stars or Suns; all of which are demonstrated (and supposed also by our Adversaries) to have mutual Attraction ... I say, all the Fixt Stars have a principle of Mutual Gravitation; and yet they are neither revolved about a common Center, nor have any Transverse Impulse nor anything else to restrain them from approaching toward each other, as their Gravitating powers incite them. Now what Natural Cause can overcome Nature itself?[15]

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Bentley's answer, of course, was that at least in a finite universe, it was the Deity who must hold "the outward stars with their systems of planets" at intervals, and keep them from coming together to form one system. And even in the case of an infinite universe, which Bentley (contrary to Newton) does not think is the case, the fixed stars would probably naturally convene and "confound system with system".[16] Bentley's goal was accomplished; he had demonstrated the necessity of a Deity in the Newtonian universe.

In conclusion, Bentley's seventh Boyle lecture concurs with Newton (with whom he had corresponded on this matter)[17] that the role of providence in the universe is necessary, but in contrast to Newton, it also reveals Bentley's explicit belief in the plurality of solar systems. This belief, however, is justified on neither physical nor theological grounds. Aside from adducing from astronomers the notion that the fixed stars are suns, the belief in other solar systems is simply assumed.

It is in the eighth Boyle lecture, given over entirely to a proof of the Deity based upon the wisdom and goodness displayed in our own solar system, that Bentley also reveals his justification - a theological one - for the belief in other solar systems. In order to speak of the wisdom and goodness of the Creator as opposed to his power already spoken of, Bentley proposes, perhaps with Descartes' anthropocentric admonition in mind, to adopt the proposition that "We need not

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nor do not confine and determine the purposes of God in creating all Mundane Bodies, merely to human ends and Uses."[18] He has in mind here not so much the planets of our own system as the innumerable stars. He emphasizes that he would not hesitate to put all the matter of the universe on one side of a scale against the mind of man - the soul of one virtuous man being of more worth than all the stars in the universe - but that he would rather believe that those innumerable stars were created for a nobler purpose than merely to excite the curiosity and praise of man.

Bentley is here on the brink of revealing his justification for the belief in other solar systems. Of what possible use, he inquires, could those innumerable stars be, some undoubtedly invisible to us, and yet many thousands of times bigger than the earth itself. "Who will deny", he challenges, "but that there are great Multitudes of lucid Starrs even beyond the reach of the best Telescopes; and that every visible Starr may have opake Planets revolve about them, which we cannot discover?" These things were not made for us, nor were they made for their own sakes. Rather, "All Bodies were formed for the Sake of Intelligent Minds: As the Earth was principally designed for the Being and Service and Contemplation of Men; why may not all other Planets be created for the like uses, each for their own Inhabitants who have Life and Understanding?"[19]

Given the immense universe with stars invisible to us, it

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was thus on the basis of the pure and simple Aristotelian concept of final causes that Bentley assured himself of the existence of other solar systems. The whole enterprise of demonstrating the existence of the Deity from the desigh of the universe was of course a teleological one, but it was one in which the emphasis had been shifted to the workings of the universe and its parts rather than the ancient and medieval question of why they existed. Here we have the pure question "why?": why should these distant parts of the universe exist? The answer to that question in itself did not serve to render proof of the Deity, but once the existence of creatures in other solar systmes was asserted on the basis of strict teleology, they could easily be adduced as evidence of God's attributes: of his benificence and wisdom, of his omnipotence and majesty, of the universality of a providence which Newton had only provisionally proclaimed on the basis of actual observation.

*

In order to appreciate the boldness and the originality of Bentley's assertions, it is necessary to emphasize that they are remarkable on several counts. As Bentley had pointed out, the idea that every fixed star was a sun was one generally accepted by astronomers in the late seventeenth century, and we have seen that it was already an integral tenet of the Cartesian cosmology. But the assertion that God's power was manifested through his actual production of a great number

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and variety of inhabited worlds in other systems, while it seems an obvious and logical point to be championed by the seventeenth century virtuosi, who were the masters of natural religion, was actually a new and radical concept for a treatise on natural religion such as Bentley's indeed was.

To be sure, Bruno, Borel, Fontenelle, and Huygens, those men who actually wrote treatises on the plurality of worlds, were not slow to point out that their thesis might be seen as more in accord with the nature of the Divine than if there were only a single world. But Gassendi and Charleton, for example, in the course of their denial of the atomist doctrine of infinite worlds, vehemently deny any connection between God's power and the existence of other worlds. God's omnipotence, they held, is sufficiently established by his creation of Nature ex nihilo, and by the excellence of this world; moreover, sacred Scripture indicates that there is only one world.[20] One can be sure that in the Darkness of Atheism Dispelled by the Light of Nature (1652), where Charleton attacked the same atomist tenet of chance formation of our world as Bentley later did, there was no assertion of other inhabited solar systems. In a similar vein, while Mersenne held that no conclusion could be reached from Scripture, which did not mention other worlds, he himself still felt that our world was unique, and that the existence of one ordered world was enough to demonstrate God's power.[21]

Even Robert Boyle, that most vigorous of virtuosi who

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never lost an occasion to praise the Creator on the basis of the visible creation, never went so far as to propose other inhabited planets in our own system, much less in others. Some Considerations of the Usefullness of Experimental Natural Philosophy (1663) agreed with Charleton and virtually all of the virtuosi that the study of nature pointed to the existence of God, and once again did this specifically in the context of refuting the atomist tenet of the world's chance formation. But far from taking the steps that Bentley did, Boyle in his Disquisition about Final Causes (1688) placed limits on the teleological arguments that could be used in support of the Deity, and explicitly warned that one must beware of asserting the final causes of the heavenly bodies beyond the fact that they are of use to man.[22] But this is precisely the grounds on which Bentley was to infer other inhabited systems only five years later. The denial of the belief of most virtuosi that the universe was made for man[23] lay at the very heart of the reasoning for Bentley's assertion of other inhabited systems.

Bentley's treatise is an aberration only when considered with respect to what came before it; he was far from alone in his assertion in the later Newtonian era. In the opening pages of his Wisdom of God Manifested in the Works of Creation (1691), John Ray, the Englishman later to become famous for his work on the classification of plants, held that while the universe was not infinite or indefinite, the fixed stars were suns around which circles inhabited planets. There were thus an

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"unmeasurably great" number of creatures in the universe, a fact which afforded "demonstrative Proof of the unlimited extent of the Creator's Skill, and the foecundity of his Wisdom and Power."[24] Nehemiah Grew, like Ray a member of the Royal Society, proposed in his Cosmologia Sacra: or a Discourse of the Universe as it is the Creature and Kingdom of God (1701), that the moon and planets were earths, and that every fixed star was a sun, which must have inhabited planets in order that their respective suns have some purpose, again the argument from final causes.[25] And William Whiston wrote more cautiously in his Astronomical Principles of Religion (1725) that every fixed star may perhaps be the center of another system, although we can know very little of such systems. He urged that what we know of the planetary worlds in our own system, along with the probability of similar worlds in other systems, is sufficient for us to recognize the glory of God in his creation.[26] In spite of this cautious approach, the idea of "systems of worlds scattered everywhere in the Universal immense void," appears frequently throughout Whiston's treatise.

Suddenly, natural religion seems to have found a powerful new argument, one which it proceeded to spread with great enthusiasm. But nowhere was the belief in other inhabited planets and solar systems in the service of God more indelibly impressed upon the eighteenth century mind than in the work of yet another Englishman, William Derham. His Astro-Theology: or a Demonstration of the Being and Attributes

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of God, from a Survey of the Heavens (1715) was also a treatise on natural religion, one that was very widely read. In this work every variety of argument, from the magnitude of the universe, to the size, shape and motion of its bodies, was seen as evidence of the Deity. Of particular interest is the fact that the moon and planets were looked upon as inhabited. This was justified in general by the idea of final causes, but was supported for the planets by the fact that they were opaque bodies similar to the earth, in all probability having hills, seas, and atmospheres of their own.[27] The case for the planets was further supported by the observation of the moon, whose dark spots Derham thought were seas, and whose atmosphere he thought had been observed during a recent eclipse.[28]

But it is the idea that the fixed stars are suns, each with its own planets, which Derham sees as the very crux of his treatise. Derham's work opens with a "Preliminary Discourse concerning the System of the Heavens, the Habitability of the Planets, and the Plurality of Worlds useful for the reading of the following Book," a section which emphasized the importance of the plurality of worlds concept to his ultimate goal. In this lengthy prefatory section Derham champions the improvements of the Copernican theory over the Ptolemaic in a manner by now routine, but then goes on to discuss a third system, not the usual Tychonic one (which he ignores), but a "new system". He points out that this new system encompasses the Copernican system, but extends

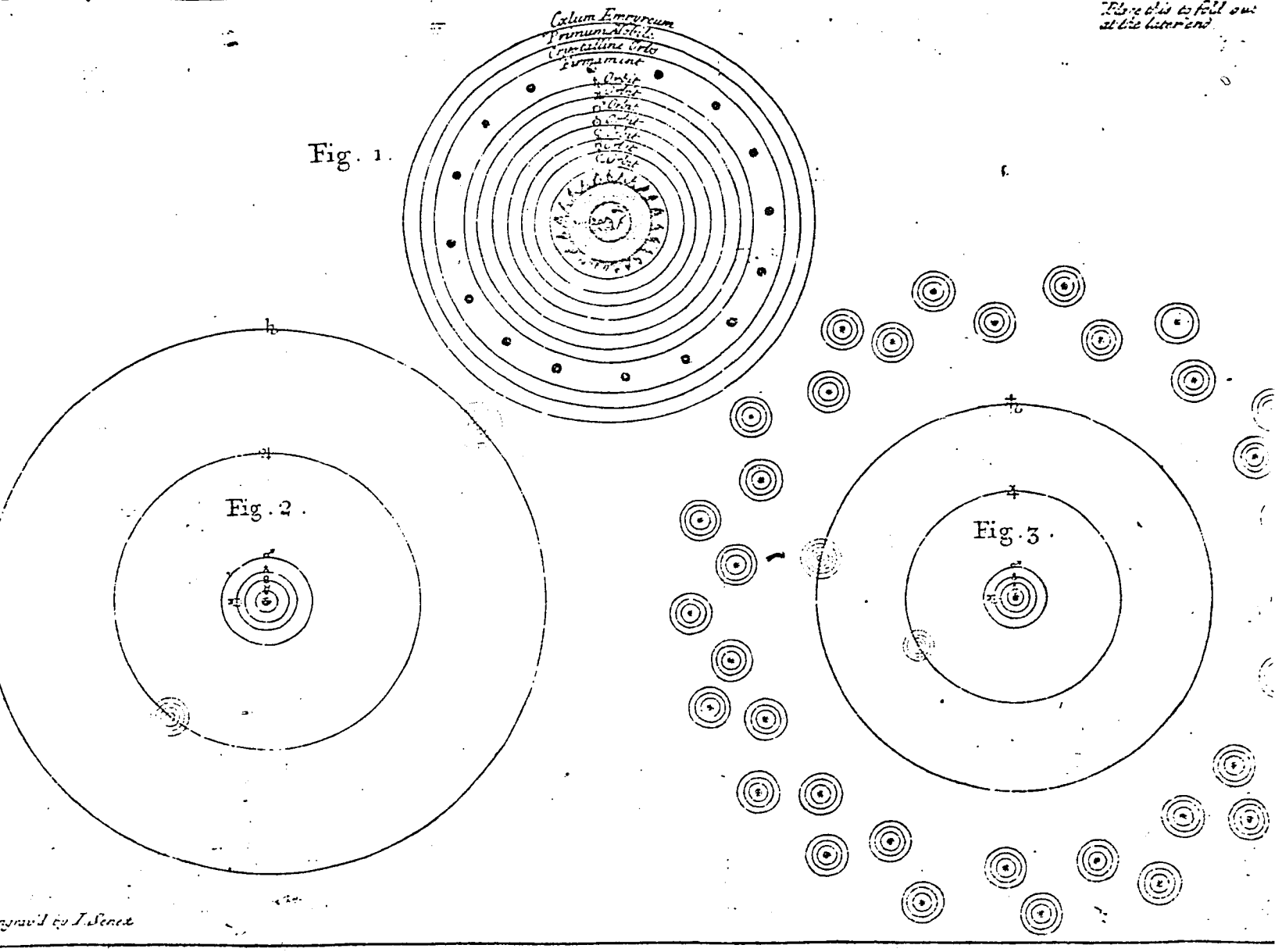
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it into indefinite space. Moreover, "The new system supposeth that there are many other systems of suns and planets, besides that in which we have our residence: namely that every fixt star is a sun, and encompassed with a system of planets, both primary and secondary, as well as ours."[29] An accompanying figure illustrating the new system depicts our solar system at the center of the whole, a case which Derham thought not improbable, although admittedly physically impossible to demonstrate. The new system contained no sphere of fixed stars; rather, the various apparent magnitudes of the stars are assumed to arise from their different distances.

It is this system, then, that Derham adopts throughout the book whose purpose is to manifest the glory of God. Although he claims that the works of God "manifest their excellence and magnificence" in whatever system one chooses to believe, he hastens to add that this new system does seem to him "far the most magnificent of any; and worthy of an infinite Creator: whose power and wisdom, as they are without bounds or measure, so may in all probability exert themselves in the creation of many systems as well as one."[30]

To let the matter rest there is to assume what is to be proven, a pitfall common enough in natural theology, but one which Derham tries to avoid. Rather, he says, this new system is "very highly probable ... by reason," because "we see it is really so," and he proposes to accept this system of the universe not only on theological grounds, but also "as it

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The Ptolemaic, Copernican, and the "new system" according to William Derham. The new system as depicted in figure 3 indicates Derham's belief in a plurality of solar systems, a concept which plays a significant role in his Astro-Theology (1715).

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is physically demonstrable."[31] Since Derham himself admitted in this preliminary discourse that no planets could actually be seen around other fixed stars, it is interesting to note how this physical demonstration is carried out in the text.

The idea that the fixed stars are suns surrounded by planets is one put forth in the text as supposed by "the best and most learned astronomers."[32] Derham supports this basic idea by arguing that so great are the distances of the stars that they could not shine by the light of the sun, and therefore they must generate their own intrinsic light. He reiterates that the stars are bodies of the same size as the sun, appearing more or less faint only because of their different distances, an assumption which then allows him to deduce elsewhere the distances involved when speaking of the fixed stars, distances which in turn manifest the glory of the Creator.

The more daring idea that the fixed stars have planets of their own Derham supports by three arguments, all of which we have seen before. Bentley's argument from final causes is prominently represented as Derham insists that all the myriads of visible suns could be of no use to us, much less those which are invisible. They are instead intended to heat and light their own inhabited planets.[33] Again, Derham urges that "the parity and constant uniformity observable in all God's works" points to the existence of such extra-solar planets.[34] In spite of the reference to God, this is not really a theological argument, but one of the uniformity of nature, a fact made

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clear when Huygens is cited as demonstrating that if an observer were placed in the heavenly regions, he could not discern the difference between the sun and the other stars. Fair judgment thus demands that we not treat our particular sun in a biased manner. Finally, the clearly theological argument already expressed in the Preliminary Discourse is repeated: "This account of the universe is far more magnificent, worthy of, and becoming the infinite Creator, than any of the other narrower schemes."[35]

Yet another argument, one strange and unique to Derham, was founded upon the notion that the phenomena of new stars might actually be due to planets "revolving around such suns, as cast a much fiercer and more vigorous light than our Sun doth."[36] The idea here is that as these brightly reflecting planets revolve around their suns and emerge from behind, they appear as a "new star". There were of course many arguments against such a view, a fact which Derham himself realized, but it was an interesting early attempt to verify empirically the existence of other planets outside of our own system.

The weakness of this last argument did not shake Derham's conviction, expressed repeatedly throughout his treatise and still supported by other arguments mentioned above, that such planets do indeed exist. With Derham every trace of Scriptural objection was suppressed in favor of the benefits which accrued to natural theology. All of this, it must not be forgotten, was expounded in a dominantly Newtonian milieu. Derham praised

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Newtonian natural philosophy, adopted many of the facts and concepts from the Principia, including universal gravitation, and indeed was a Newtonian himself.

The new argument for the extension of God's dominion and power from the existence of other planetary systems did not confine itself to treatises on natural religion, but soon spread into astronomical texts themselves. Whiston himself was an astronomer, and his Astronomical Lectures (1715) also spoke of other systems as an indication of God's attributes.[37] John Keill, one of the earliest expounders of Newtonian natural philosophy at Oxford, used the argument from final causes to assert the existence of other solar systems, and added that "Hence we are to consider the whole Universe as a glorious palace for an infinitely great and everywhere present God; and that all the worlds or systems of worlds, are as so many theatres, in which He displays his Divine Power, Wisdom, and Goodness."[38] In the course of a few decades centered around the turn of the eighteenth century, the ideas embodied in such statements moved from the status of radical to commonplace, from Scriptural heresies to potent weapons in the arsenal of natural theology.[39]

*

The central question which confronts the historian at this point is why these men, many theologians of some renown, chose to deviate from the standard arguments of seventeenth century natural religion and ignore scriptural objections in

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order to assert the existence of other inhabited solar systems. The reasons for this rather sudden turnabout on the part of the virtuosi are undoubtedly manifold, and represent the mutually constructive confluence of ideas and events in both theology and science.

An immediate consideration which comes to mind is the appearance of Fontenelle's Entretiens in 1686 and of Huygens' Cosmotheoros in 1698. The nearly simultaneous and extremely popular English translations of these works soon made the subject of a plurality of inhabited planetary systems more widespread than it had ever been. These works may have served at last to force upon the seventeenth century a resolution of the issue which heretofore had been tossed back and forth by a handful of intellectuals, and completely ignored by most others. The crucial decision would now have to be made whether to battle the extraterrestrial inhabitants, or embrace them.

The groundwork for the decision had been long prepared, in those scattered treatises on the plurality of worlds which had pointed out both the theological and the scientific arguments in favor of extraterrestrial intelligence. As early as 1638 Wilkins had pointed out directly that Scripture did not contradict such an idea. His assertion was most often greeted with rejection or silence, but at the end of the century Bentley apparently spoke for many of his colleagues when he counselled his reader that "the Holy Scriptures do not forbid him to

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suppose as great a multitude of Systems and as much inhabited, as he pleases."[40] Bentley pointed out that although Scripture spoke only of terrestrial creatures, this did not prove that there were no extraterrestrial ones. And Bentley further proposed, as Fontenelle had before him, that the extraterrestrial inhabitants, though rational, need not be considered men. This point mitigated the question of the relation of such creatures to the doctrines of Incarnation and Redemption based on the fall of Adam.

The enormous benefits for natural theology had also been emphasized in treatises on the plurality of worlds since the time of Giordano Bruno. Why was it only in England at the end of the seventeenth century that this argument began to take hold? Or more to the point, why not earlier among continental Cartesians, whose cosmology graphically brought them to the brink of an infinity of inhabited solar systems? The answer may lie not chiefly in a closer link between a plurality of solar systems and Newtonian physical principles as compared with Cartesian physical principles, but rather in the evolution of natural theology itself as affected by Newtonian natural philosophy.

Although natural religion has its roots in the early history of Christianity, it was the seventeenth century virtuosi who perfected the arguments and raised them in importance above all else.[41] Newton himself was not a beginning but a culmination of this movement.[42] Yet, in several respects,

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he may have hastened the acceptance of the plurality of worlds doctrine. It is remarkable that Ray, Grew, Bentley, Whiston and Derham were all English, and that at least the latter three demonstrated their clear allegiance to Newton in their own natural philosophy. And it is significant that Whiston's Astronomical Principles of Religion was dedicated to Isaac Newton and the members of the Royal Society. The English virtuosi who were first convinced that the Newtonian system was the true one were anxious to demonstrate that it still required the existence of a Deity. If, by surrendering to natural law what had been the province of God, the Newtonian mechanical philosophy was perceivable by some as conflicting with the Divine Providence component of natural theology, then an even more spectacular extension of natural theology in another direction was a sure antidote.

The insistence on the reality of inhabited solar systems may be seen as a partial remedy for the perceived attack on Newtonian natural philosophy. While the Clarke-Leibnitz correspondence, in which Leibnitz explicitly charged Newton with having contributed to a decline of natural religion in England,[43] came a little too late to be of direct influence on Bentley, Ray, and Grew, it may still help to understand the context in which Derham's treatise was written, and in which Whiston among others emphasized that all the consequences of God's providence, wisdom, and goodness were duplicated many times in each of the many solar systems which might exist.[44]

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Whatever the specific reasons for the growth of natural religion, the emergence in the 1690's of the concept of other worlds into a broad acceptance never before achieved may be seen as an aspect of that growth. That this broad acceptance did not begin to develop until the end of the century - chiefly by Newtonians and not Cartesians, and long after most other arguments for natural theology had become firmly entrenched - is testimony to the gravity of this particular assertion. The projection of intellect into the universe was a step which required considerably more audacity than the usual arguments for God from design in his universe. When the step was taken at the end of the seventeenth century by a large number of natural philosophers and theolgoians, it marked an important stage in the growth of natural theology, and in freedom from literal interpretations of Scripture. Although many battles remained to be fought on the basis of doctrinal theology, notably those involving the beliefs of the Incarnation and Redemption, the plurality of worlds tradition too had surmounted a formidable obstacle.

Underlying all of this was the physical system of Newton itself. Although the earliest Newtonians did not attempt to deduce the existence of other solar systems from the physical principles of their master, the notion that, in Bentley's words, "All the Fixt Stars have a principle of Mutual Gravitation,"[45] undoubtedly lent credence to their belief. Indeed, it is likely that aside from the desire simply to bolster natural theology,

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this notion was crucial in the decision of Bentley and others to rise above the usual Scriptural objections, to seek the final causes of the heavenly bodies aside from their possible use to man, and to undermine the old concept of the virtuosi that the universe was made for man. We will now explore the extent to which natural theology and Newtonian physical principles interacted to promote the concept of other solar systems among eighteenth century Newtonians.

* * *

It may seem ironic that natural theology, as part of a larger movement toward rational thought in the seventeenth century, should lend support to a belief which could never be corroborated by the senses. The supposed plurality of systems even today remains beyond the sensibility of the best telescopes, yet these seventeenth and eighteenth century natural philosophers who prided themselves on the use of empirical research positively asserted their existence. This would indeed be an anomalous situation were it not for the fact that physical principles, if not empiricism, played a significant role in the assertion. This had also been true among the Cartesians, but with the acceptance of a plurality of worlds as a theologically orthodox concept, Newtonian principles could be brought to bear without reluctance.

That this was indeed the case we have already seen in Richard Bentley, but stronger evidence may be obtained from the works of those who followed him. The astronomer and

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natural theologian William Whiston is the beginning of an unbroken chain of men whose works exhibit the significant role played by Newtonian physical principles in supporting the belief in other solar systems. Already in 1725 he had explicitly set forth what must have been in the minds of those who had previously suggested the existence of other systems of planets. He observed simply but significantly that "The spherical figures, with the original native light of the fixed stars, and all other circumstances, do show that they belong to our Universe, or grand system, and are subject to the same law of gravity, which our particular system is governed by."[46] Given this, Whiston concluded that all of the consequences of God's providence, wisdom, and goodness might be duplicated many times in other solar systems: "It follows, that the foregoing consequences regarding the Author of the Law already drawn, as to one System, are also true, relating to all those other systems."[47] It was a compelling application of universal gravitation and natural theology to produce a harmonious picture of the universe.

The passage from Whiston also points to an imminent development of great importance to the plurality of worlds tradition, the suggestion that the fixed stars might be part of a "grand system". The idea that there was an attraction between every star had been used by Bentley to emphasize the fact that in a Newtonian universe the power of a Deity is a necessity if those stars were to remain at their respective distances instead of convening into one mass. Whiston agreed that this had to be so, since "the Sun and

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Fixed Stars do not revolve about one another, or about any common Center of Gravity."[48] The implication is that if the various fixed stars were in motion about a common center, the balance between their centrifugal and centripetal forces would keep them apart without the aid of a Deity, and the result would be a self-sustaining "grand system" of fixed stars. Whiston in 1725 had no inkling that this might be the real case, and along with Bentley and undoubtedly others, he used the idea of universal gravitation among the stars for the proof of the Deity who held them apart.

It was a quarter-century later that another Englishman, Thomas Wright of Durham, actually proposed the existence of such a self-sustaining grand system of stars, rotating in accordance with Newtonian principles of gravitation. With this development, yet another element was added to what was rapidly becoming a hierarchy of systems. An examination of Wright's work shows that he was clearly and profoundly influenced by the plurality of worlds tradition. It also helps to shed light on the role of Newtonian principles in spreading the belief in other systems, since Wright makes explicit for the visible galactic system what could only be guessed at for the invisible solar systems.

In contrast to the works discussed heretofore, Wright's Original Theory or New Hypothesis of the Universe (1750) had an apparent scientific aim. To judge by the full title of the treatise, its chief purpose is to solve the general

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phenomena of the visible stellar creation, especially the Milky Way, in accordance with mathematical principles and the laws of nature. As the text quickly reveals, however, there is also a very strong theological component, for this scientific task is to be carried out under the guiding principle that "the Glory of the Divine Being of course must be the principal Object in View."[49] The recent scholarship of M.A. Hoskin had emphasized just how closely Wright interweaves science and theology, and that the Original Theory needs to be looked upon "as one stage in a lifelong struggle to integrate scientific knowledge into a satisfying religious vision of the universe."[50]

One cannot read the Original Theory without becoming acutely aware of the pervasive presence of the whole spectrum of ideas integral to the plurality of worlds tradition. This is surprising, since there is no evident necessity to talk about the habitability of planets in our solar system in explaining the phenomenon of the Milky Way. Nor does the explanation of a band of light across the nighttime sky rest upon the existance of other solar systems, much less the habitability of their supposed planets. One might immediately suspect that these ideas are of theological importance, and indeed they are; but in addition Wright takes from the plurality of worlds tradition a physically significant concept, one which is made explicit already in the first "Letter", as the divisions of the work are termed.

In the first Letter, Wright reveals the point from which

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he will undertake his ambitious program to elucidate the physical basis of the hitherto unexplained phenomenon of the Milky Way, this "beginning of a new Science, before unattempted in any Language," as he himself dramatically puts it. The initial fundamental physical assumption is one by now familiar to us, for it is the very one which had been emphasized most by the plurality of worlds tradition: "the now generally received Notion, that the Stars are all Suns, and surrounded with planetary Bodies."[51] Wright makes it clear that this is not a wild assumption of his own, but one espoused by many writers whose works he has read. He cites those parts of Toland's account of Bruno's works, where the magnificence of God's attributes is deduced from his production of numberless suns.[52] He quotes passages from Huygens' Cosmotheoros and Derham's Astrotheology, as well as the passage in the second edition of the Principia in which Newton insists upon the dominion of God over all systems. He mentions Fontenelle only in a footnote, perhaps because Wright had no sympathy with the Cartesian vortices, but he evokes further support by appropriate passages from Pope, Milton, and Young, and thereby infuses his work with a theological, emotional, and scientific unity hard to resist.

Wright's identification of the nature of the sun with that of the fixed stars, a concept which had previously been most cogently argued mainly in those treatises on the plurality of worlds which he cites, is clear evidence of the importance

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of that tradition to his treatise. The significance that Wright placed upon the idea that the fixed stars were suns each with its own intrinsic light, is further emphasized in the fourth Letter, where he sought to strengthen its validity with arguments of his own. Here he insists that "any tolerable Optician" would be satisfied with the knowledge that the sun, when viewed from a sufficient distance, would appear to be only a star, and in this way we are viewing the suns of other systems as stars.[53] He cites the opinions of some of the ancient philsoophers, including Zoroaster, Empedocles, Plato, and Heraclides, all of whom held the stars to be of a fiery nature.[54] Even Aristotle, he reminds the reader, considered the stars to be made of an ethereal substance, the same substance as all the celestial bodies, including the planets. The idea that the stars are in some sense secondary to the sun, receiving their light from it, is a prejudice of common sense and learning which must be discarded upon reasoned reflection. The telescopic appearance of such stars, he points out, is not characterized by "loss of light" as the images of the planets are, rather the stars appear brighter, a fact which may be seen as evidence of their intrinsic illumination.[55] In the fifth Letter Wright applies this belief to the Milky Way, and argues that it is composed of innumerable stars, all of which are suns like our own. When in the sixth Letter he gives to these suns a motion around a common center, the stage is set for his theory.

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Wright took from the plurality of worlds tradition not only the fundamental and comparatively modest belief that the fixed stars are suns, but also the more daring ideas that the planets in our own system are earth-like, and that earth-like planets surround those other suns also. The second concept was at least partially supported by physical reasoning already in the third Letter, where Wright argued that the planets within our solar system are all dark opaque bodies of the same nature as the earth, both because they have the same geometrical status in the Copernican system, and also because observation indicates that this is so.

The moon was a crucial test case for the nature of the planets, and Wright proposed for it the "natural and simple experiment," that if one observes our closest neighbor at the time of the setting sun, and at the same time observes any bright clouds that happen to be near it, then one will see that the light of the moon and the light of the cloud are of one and the same nature; and if a "thin light fluid" such as a cloud could reflect such a great light, then so also could the moon, which is a solid body. Neither body has any light of its own, but owes it entirely to the sun.[56] The same could be said for the other planets, when allowance was made for the diminution of light caused by distance. Thus Wright believed that both the theoretical status of the planets in a heliocentric system and empirical observations confirmed that "the planetary Bodies, in general, are meer terrestrial, if not terraqueous

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Bodies, such as this we live upon", and further expressed the hope that the reader would "receive the Idea of a Plurality of Worlds more favorably, and look upon astronomical Conjectures in a less ridiculous Light than you used to."[57]

Unlike Derham, Wright did not pretend to support empirically the still more radical idea of a plurality of solar systems. Yet he totally accepted the idea. Given the fact that the fixed stars were suns, Wright asked what would be the use of so many suns like our own. If such stars exist, he pressed, surely neither nature nor God do anything in vain. He rejected as totally absurd the idea that they are all made for the use of "this diminutive World, our little trifling Earth." A conceptual abyss separated Wright from his colleagues a century before, who thought that the heavenly splendors were made solely for man, and who denied the possibility of other earth-like planets or solar systems on grounds of the uniqueness of the relationship between God and man. Such a supposition, Wright charged, not only "implies a profound Ignorance of the Divine Attributes, but is as impious and full of Vanity, as it is erroneous and absurd, and even a Blindness sufficient of itself, were there no other Cause for it, to introduce Idolatry in the Minds of Mortals by sinking the Divine Nature so near the human."[58] His argument for the alternative, that these suns are all surrounded by planets with inhabitants, was identical to that of the natural theologians of the early eighteenth century. Given the status of the stars as suns, it was then on the basis of

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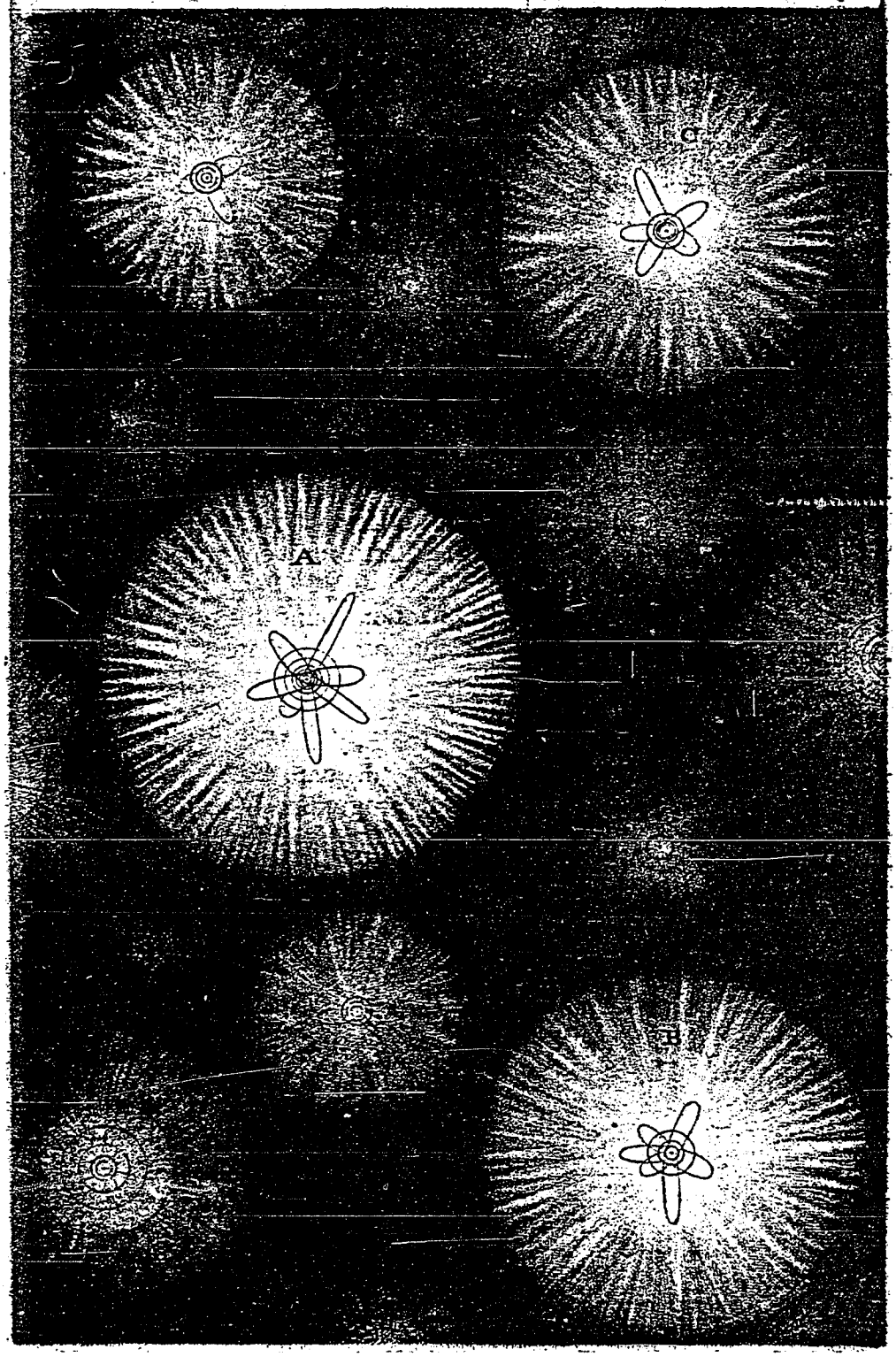
final causes that Wright came to view the universe as filled with inhabited solar systems, a view which he vividly conveyed to the reader in one of the many drawings interspersed throughout his treatise (next page).

Unlike the conception of the fixed stars as suns, these ideas of inhabited planets within our solar systems and of the existence of other such systems were not essential physical assumptions to Wright's thesis. But Wright was seeking a coherent and unified theory of the universe. The earth-like nature of the planets in our system was supported on the basis of theory and observation, and their inhabitants on the basis of theology and final causes. The idea of other solar systems was both physically and theologically important, theologically for the reasons mentioned above, physically because the existence of many solar systems fit in harmoniously with the idea of a larger system of fixed stars. Wright found in the plurality of worlds tradition the support for the kind of unified universe that he envisioned, a picture entirely compatible with the original step he was about to take himself.

Such, then, was Wright's vision of the universe as he began his attempt, in the last third of the treatise, to set forth his original theory of the nature of the Milky Way. It was an infinite universe, in which every stars was a sun surrounded by planets of its own, each of which harbored intelligent beings. Thus, "instead of discovering a vast unbounded Negation of Beings," the stars recognized as suns

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PLATE XVII.



"Plate XVII represents a kind of perspective View of the visible Creation, wherein A represents the System of our Sun, B, that supposed round Syrius, and C, the region about Rigel. The rest is a promiscuous Disposition of all the Variety of Systems within our finite Vision, as they are supposed to be posited behind one another, in the infinite Space, and round every visible Star. That round every Star then we may justly conjecture a similar System of Bodies, governed by the same Laws and Principles with this our Solar one, though to us at the Earth for very good Reasons invisible." Thomas Wright, Original Theory (1750).

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"display an infinite shapeless Universe, crowded with Myriads of glorious Worlds, all variously revolving round them; and which form an Atom to an indefinite Creation, with an inconceivable Variety of Beings and States, animate and fill the endless orb of Immensity."[59] Again and again Wright insists upon the "Universality of rational Creatures to people Infinity", and speaks of the universe as a "vast Ocean of Beings."[60] Only one of the many ecstatic outbursts in evidence throughout the treatise suffices to indicate the theological significance of this kind of universe with its universality of rational creatures.

> What inconceivable Vastness and Magnificence of Power does such a Frame unfold! Suns crowding upon Suns, to our weake Sense, indefinitely distant from each other; and Miriads of Miriads of Mansions, like our own, peopling Infinity, all subject to the same Creator's Will; a Universe of Worlds, all deck'd with Mountains, Lakes, and Seas, Herbs, Animals, and Rivers, Rocks, Caves, and Trees; and all the Produce of indulgent Wisdom, to chear Infinity with endless Beings, to whom his Omnipotence may give a variegated eternal Life.[61]

As Hoskin's research into the origins of Wright's cosmology has shown, it was also a universe whose theological and physical core were quite literally conjoined in a central point from which both the moral and the physical order sprang. In a document entitled "The Elements of Existence, or a Theory of the Universe",written in 1734, and in its accompanying "explanation", Hoskin finds two seminal themes of overriding importance throughout Wright's cosmological speculations: "First, the centre of universe in the moral order, referred to by such titles as 'the Sacred Throne', is also the centre of the universe in the physical order, the gravitational centre

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and source of the laws of nature. Second, and as a consequence of the existence of such a focal point, both morally and physically the rest of creation is arranged symetrically about this centre."[62] Hoskin proposes that it is this extra-scientific principle of symmetry about the Divine center which goes a long way toward explaining the motivation for Writht's theory of the Milky Way.[63]

Wright's position in the plurality of worlds tradition provides additional insight into the formulation of his theory of the Milky Way as a rotating shell of stars. It is clear that Wright was deeply influenced by the various elements of the plurality of worlds tradition, and it is no less evident that the product of his own making, his "original theory" of the nature of the Milky Way, added a new dimension to that tradition which had acted as such a rich source of ideas for him. Wright's explanation of the phenomenon of the Milky Way, that it was the result of stars in motion around a common center forming one gigantic system, was undoubtedly heavily influenced at the outset by his metaphysical concept of the "Divine Center" about which the entire Creation was symmetrical. The actual motion of the stars about this center was supported by Halley's claim in 1718 that three stars had changed their latitude since the time of the ancients. But such a rotating system was also a natural extension for one who believed that there were innumerable solar systems. Wright's description of a physical scheme representing his 1734 hypothesis as depicting

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"several thousand Worlds and Systems", as well as the content of the hypothesis itself, indicates that quite as much as the idea of a Divine Center, the notion of a plurality of worlds and systems was present in his thought from the beginning.[64]

It was a notion which Wright found in Fontenelle and Cartesian principles, but as we have seen, it was an idea chiefly disseminated in the early eighteenth century by Newtonians. Wright was happy to accept their extension of natural theology, but he also made more explicit the physical foundation which Newtonian natural philosophy gave to the concept of ordered systems. In the title of his work Wright claimed that his original theory would be "founded upon the laws of nature" and the phenomenon of the Milky Way solved "by mathematical principles". The laws and principles to which Wright refers are those of his countryman Isaac Newton, whose ideas he praises at several points in the treatise. Many times Wright makes use of specific figures taken from the Principia, and when he actually comes down to presenting his theory in the seventh Letter, refers to "the known Laws of orbicular Motion", in deciding that the stars must be moving in closed curved orbits.[65] Even more explicitly, Wright had spoken in the sixth Letter, with reference to the stars, of "the projectile, or centrifugal Force, which not only preserves them in their Orbits, but prevents them from rushing all together, by the common universal Law of Gravity, which otherwise, as a finite Distribution of either regular or irregular Bodies, they must at length do by Necessity."[66]

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To be sure, Wright was making use of only the most general qualitative notions of Newtonian physics when he declared that for the stars to move rectilinearly would be "contrary to all the Laws and Principles we at present know of",[67] and that therefore they must move, if they move at all, in curved orbits. The closed orbits deduced in this way left two possibilities, to Wright's mind, for solving the phenomenon of the Milky Way. Either all the stars are moving in the same direction, and nearly in the same plane, or they are moving in different directions round a common center, "but in a kind of Shell, or concave Orb."[68] Wright considered one of these models to be more probable for our Milky Way, but allowed that throughout the infinity of space, both models were undoubtedly realized, perhaps in the very nebulae which were observed to be composed of stars like the Milky Way.[69]

Throughout Wright's infinite universe, all matter was ordered and ruled by physical law. Wright's view of the role of the Deity and of physical principles in the universe was identical to that of Newton. In a statement which could be considered a paraphrase of Bentley and Newton, Wright marvelled that "the wise Creator hath so disposed all the independent Parts of the Creation, such as the several Systems of primary and secondary Planets, & c. at so great a Distance from each other, that the Laws of any one in no wise shall interfere with, disturb, or interrupt the Principles of another."[70]

Although Wright did not make use of the rigorous math-

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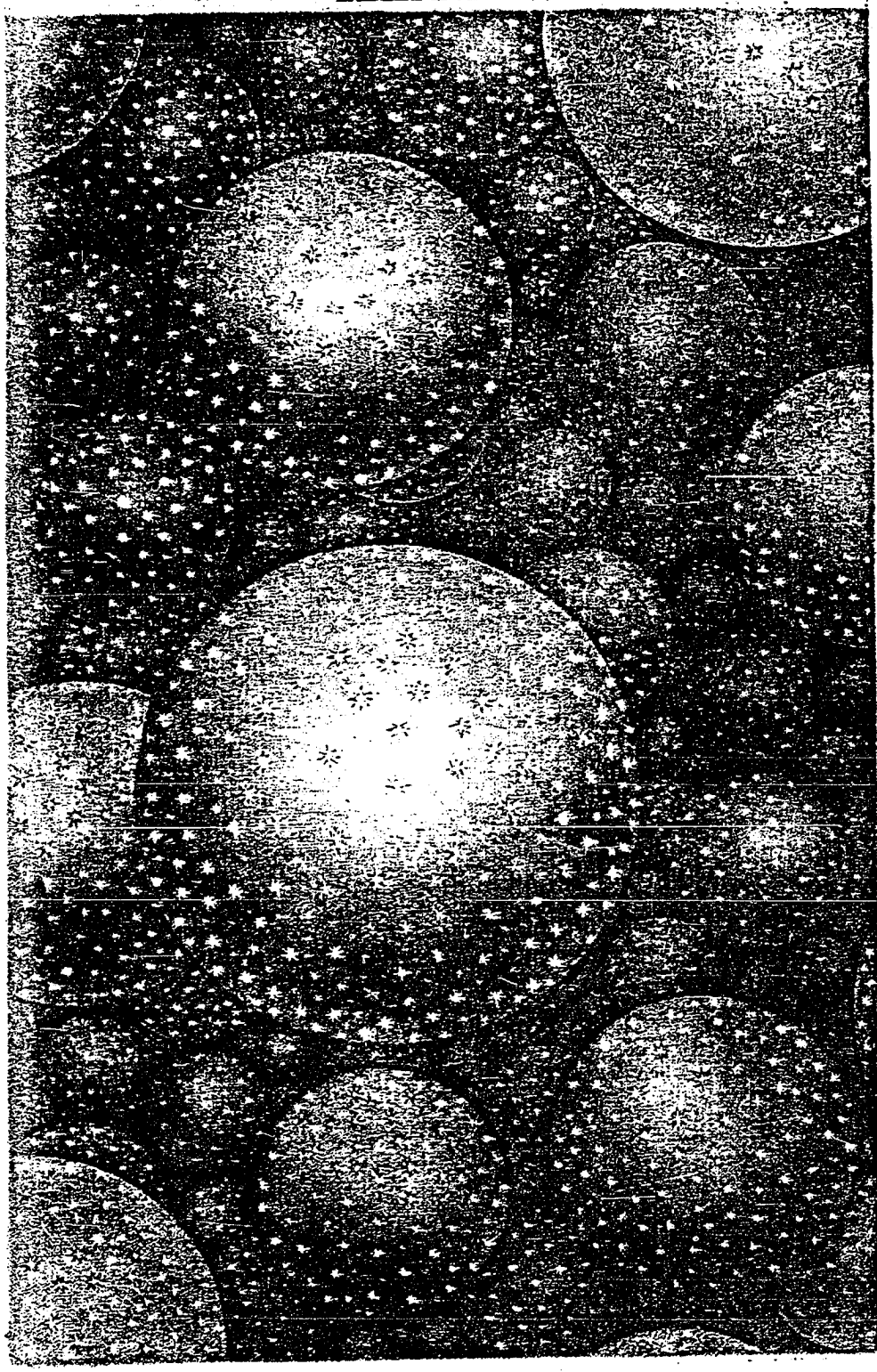
ematical laws of Newtonian physics in the formulation of his theory, it is doubtful whether in the absence of a qualitative Newtonian physics, supported by Newtonian natural theology, the new theory of the Milky Way would have ever seen light. Along with the metaphysical concept of a united Divine and physical center of the universe, and along with the empirical indications of stellar motion, it was the idea of universal gravitation that gave plausibility to Wright's belief in innumerable solar systems and that led him on toward the formulation of a theory of the "grand system" foreshadowed in Whiston.

Once that step had been taken, a unified picture of the universe emerged. Newton had demonstrated that gravity assuredly operates in our solar system, and observation now indicated that it was at work in our stellar system also. Although other solar systems could never be empirically proven, the fact that gravity rules our small system, and an immensely larger stellar system, went a long way toward confirming that opinion of those before who had proposed the plurality of solar systems on purely metaphysical grounds.

In the final Letter of his treatise Wright applied the concept of star systems to the universe as a whole, leaving the reader with a picture of infinite such structures as he had proposed for our visible creation (see next page). It is appropriate, as Hoskin has pointed out, that at this stage of system-building, the supernatural intervened to prevent Wright from proposing systems of star systems,[71] for this

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PLATE. XXXI.



"And farther since without any Impiety; since as the Creation is, so is the Creator also magnified, we may conclude in Consequence of an Infinity, and an infinite all-active Power; that as the visible Creation is supposed to be full of siderial Systems and Planetary Worlds, so on, in like similar Manner, the endless Immensity is an unlimited Plenum of Creations not unlike the known Universe. See Plate XXXI, which you may if you please, call a partial View of Immensity, or without much Impropriety perhaps, a finite View of Infinity, and all these together, probably diversified ... ". Thomas Wright, Original Theory (1750).

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belief would have required one Divine Center to be satellite to another.

Wright, therefore, went only a single step beyond Newton, Fontenelle, Huygens, Derham, and many Newtonians, to propose not only the plurality of solar systems, but also the plurality of star systems. With this the plurality of worlds tradition had taken yet another step in its long evolution, and come almost full circle to the ideas of the ancient atomists, who proposed the existence of an infinite number of kosmoi, of systems of stars separated from one another and uninfluenced by one another.

*

If it is with initial surprise that we find the various elements of the plurality of worlds tradition to have had such an influence in Wright's treatise, our surprise is redoubled when we at last leave England and turn to Immanuel Kant's Allgemeine Naturgeschichte und Theorie des Himmels (1755). Kant knew of Wright's treatise only through a brief account in a German journal, and although this account did stress at the outset Wright's belief that "we look upon the universe as a vast infinity of worlds acted upon by an eternal Agent, and crowded full of Beings",[72] Kant was under no obligation to adopt such a view in his own work. Yet, if anything, those elements of the plurality of worlds tradition of which we have spoken in Wright's treatise are even more pervasive in Kant, and their connections with Newtonianism made more explicit.

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While Wright perceived as part of his task the demonstration that the fixed stars are suns, Kant in his Universal Natural History assumed this as given and concentrated instead on demonstrating, with Wright, the "systematic constitution" of the fixed stars, and beyond Wright, made a major point of identifying the visible nebulae as other such systems. This "sketch of a systematic constitution among the fixed stars, likewise of the plurality of such systems," is achieved in the first third of Kant's work. The main body of the treatise fulfills the promise of the title to explicate the "mechanical origin of the universe treated according to Newton's principles." Kant's work is thus both a cosmology and a cosmogony, in contrast to Wright's work, which is only a cosmology.

In undertaking this task, Kant is intensely aware of the relevance of his subject to religion, in particular to the proof of a Deity, in the tradition of Bentley's Confutation of Atheism from the Origin and Frame of the World. His lengthy preface is largely an attempt to reconcile the positions of the "defenders of religion" (Vertheideger der Religion) and the "advocates of Naturalism" (Naturalisten), and to assure the reader that he finds only the greatest harmony between his theory and religion. He does not, however, agree with those who see in Nature the immediate and direct action of God; such a middle position he looks upon only as perpetuating the conflict. Instead, matter is governed by the general laws of Nature, and it is the laws of Nature which are the evidence of

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a Supreme Being: "Matter determining itself according to its most general laws by its natural procedure, or - if anyone will so call it - by a blind mechanism, brings forth appropriate effects which appear to constitute the scheme of a Supreme Wisdom."[73] All the harmony and beauty of the universe is a result of the Divine plan, without which natural laws might have operated, but to a less harmonious or even harmful end. The laws of Nature form and shape the matter out of the primordial chaos, but in a way wholly unexpected without the Divine plan. Such a position is essentially a Leibnitzian one, where the plan of the universe is so perfect that it sustains itself, and evolves without the need of God's intervention.

Forseeing that his system would bring charges of Epicureanism, Kant sought at the outset to delineate the similarities and the differences of his system with that of the ancient atomists. Like the ancient atomists, Kant points out that he holds that the original state of matter was one of universal diffusion of every particle, that the "weight" which Epicurus assigned to these particles and which caused them to fall was similar to Newtonian attraction, and that even the deviation of the falling particle from a straight line which Epicurus posited was similar to the action caused by Newtonian repulsion of particles. In addition, the vortical motion which the atomists posited also appeared in his system.

But Kant cautioned that "something true will always be

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found even in the most nonsensical opinions that have ever obtained the consent of man," and went on to point out that in his system matter was formed according to necessary laws rather than subject to blind chance, from which reasoning the atheistic implications of Epicureanism could be avoided in the manner already described, the natural laws being evidence of a supreme plan. In spite of this crucial difference, it should be obvious that Kant was very much influenced not only by Newtonian natural philosophy, but also by the system of the ancient atomists. When the two were conjoined and infused with the theological necessities prevalent in Kant's day, the formula for Kant's cosmogony was complete.

Kant leaves no doubt that the laws of nature which he adopts are those of Newton.

> I have with the greatest carefulness kept clear of all arbitrary hypotheses. After having resolved the world into the simplest chaos, I have applied no other forces than those of attraction and repulsion to the evolution of the great order of nature: two forces which are both equally certain, equally simple, and, at the same time, equally original and universal. They are both borrowed from the Natural Philosophy of Newton.[74]

He thus proposes to accomplish here what Newton said could not be done, what Bentley had applied himself to with a view toward new arguments for natural theology, and what Derham and even the astronomer Wright had not attempted: a rational analysis of the <u>origin</u> of the world.

It is significant that Kant attributes the last important development in understanding the structure of the universe, aside from the recent contributions of Wright, to Christiaan

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Huygens, who had argued in the most cogent and detailed manner of his time, that the stars were all suns, each the center of its own system.[75] The reference is undoubtedly to the 1698 Cosmotheoros, a work which begins to take on more significance than one might have expected from its speculative nature. Once again this concept of the stars as suns, which was formulated and discussed in most detail within the plurality of worlds tradition, is seen to be the backbone of a much larger theory of the structure of the universe.

Kant, too, took more from Huygens than simply the concept that the fixed stars were suns, for the "world" idiom is carried throughout his discussion just as it was in Wright's. The stars of the Milky Way are seen as revolving around a common center, comparable to the planets in our solar system moving around the sun, and these wandering stars form a "higher order of worlds".[76] The stellar system is referred to as a "world of fixed stars" and a "world of worlds".[77] The usage of this idiom is not an accident, but rather reveals something about how Kant formulated his "theory of the heavens". For although the bulk of the treatise deals with the details of the origin of our own solar system, details which we need not expound here, Kant makes it clear that the origin of our system is only a specific case of what he sees happening throughout the universe, not only in other solar systems, but also in the higher orders of stellar systems:

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> With what astonishment are we transported when we behold the infinite multitude of worlds and systems which fill the extension of the Milky Way! But how is this astonishment increased, when we become aware of the fact that all these immense orders of star-worlds again form but one of a number whose termination we do not know, and which perhaps, like the former, is a system inconceivably vast - and yet again but one member in a new combination of numbers! We see the first members of a progressive relationship of worlds and systems; and the first part of this infinite progression enables us already to recognize what must be conjectured of the whole.[78]

The last sentence of this passage is crucial to an understanding of why the idea of other worlds plays such an important role in the treatises of Wright and Kant. Put another way, with specific reference to other solar systems, Kant declared that "Analogy does not leave us to doubt that these systems have been formed and produced in the same way as the one in which we find ourselves, namely, out of the smallest particles of elementary matter that filled empty space - that infinite receptacle of the Divine Presence."[79] This analogy in a Newtonian universe was not a careless or flimsy one, for it was specifically linked to the idea of universal gravitation.

> If, then, all the worlds and systems acknowledge the same kind of origin, if attraction is unlimited and universal, while the repulsion of the elements is likewise everywhere active; if, in the presence of the infinite, the great and the small are small alike; have not all the universes received a relative constitution and systematic connection similar to what the haevenly bodies of our solar world have on the small scale - such as Saturn, Jupiter, and the Earth, which are particular systems by themselves, and yet are connected with each other as members of a still greater system?[80]

Given this rationale, Kant went on to proclaim his belief that there was a point around which all these solar systems

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revolved, a point where "the largest mass and a body of extraordinary attraction will have arisen,"[81] so that all of these solar systems display a systematic constitution of a still higher order. It was observation, Kant insisted, which "puts this conjecture almost beyond doubt", since we see the majority of stars in the band which is the Milky Way.[82] The Milky Way is the "zodiac of those higher worlds". It was again on observational grounds that Kant held that there were other galaxies like ours: one need only look at the nebulae for confirmation of this theory.[83] And once again, he held that these galaxies would have to revolve around some central point where there was "a body of incomparably mightier attraction, and acting from the centre of their regulated positions."[84] Although this latter conjecture was not based on observation, Kant felt that it was deducible from the Newtonian principle of universal gravitation. For Kant thought that the gravitational attraction of our galaxy would extend even to these other galaxies, and that "unless the regularly distributed forces of rotation formed a counterpoise or equilibrium with attraction", the galaxies would all come crashing together.[85]

Kant's imagination took him even beyond the visible nebulae. Where empiricism did not lend a hand to theory, theology took up. As many had argued before him with much less qualification, Kant reasoned thus:

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> Now it would be absurd to represent the Deity as passing into action with an infinitely small part of His potency, and to think of his Infinite Power - the storehouse of a true immensity of natures and worlds- as inactive, and as shut up eternally in a state of not being exercised. Is it not much more reasonable, or to say it better, is it not necessary to represent the system of creation as it must be in order to be a witness of that power which cannot be measured by any standard?[86]

Following this reasoning, Kant conjectured that "the whole of space will be animated with worlds without number and without end," And in a final application of Newtonian principles, he asserted that the totality of creation was embraced in one single all-encompassing systematic constitution, the balance between gravitational attraction and centrifugal force thus being carried to its ultimate extent.

It was in such a universe that the principles of cosmogony were continually being carried out. At some point from the center of creation, Kant held, the formation of worlds was still taking place, and at other points worlds were being dissolved. The universe was thus in a state of dynamic evolution, and Kant's final vision bordered on the poetry of Alexander Pope which he so often quoted: "Whole worlds and systems quit the stage of the universe after they have played out their parts. The infinitude of the creation is great enough to make a world, or a Milky Way of worlds, look in comparison with it, what a flower or an insect does in comparison with the earth."[87] Newton perhaps never dreamed that his principles would lead to the universe which Kant set forth in his Universal Natural History. Yet, notwithstanding the

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theological axioms of the age, the Kantian universe with its hierarchy of world systems would never have been proposed had it not been for Newton.

A clear pattern has thus emerged among eighteenth century Newtonians, one which would be carried on especially after the works of Wright and Kant.[88] When James Ferguson, in his Astronomy Explained upon Sir Isaac Newton's Principles (1756), speaks of other solar systems as "worlds peopled with myriads of intelligent beings, formed for endless progression in perfection and felicity",[89] it is clear that he has read the treatise of his countryman Thomas Wright of Durham. When in 1761 Johann Heinrich Lambert, a scientist of the highest repute especially noted for his photometrical researches, begins, with remarkable similarity to Wright and Kant (although apparently independently), with an exposition of our solar system and promises that "thence we will ascend towards those Suns and innumerable worlds which are scattered through the immensity of space,"[90] we have once again confirmation of the role of Newtonianism in the plurality of worlds tradition. And when in 1775 Buffon concludes in one of the many supplements to his monumental Histoire naturelle, that every star is a sun and that "each of the suns being endowed like ours, and like all matter, with an attractive power ... analogy leads us to imagine that within each of their spheres there exists a great number of opaque bodies, planets, or comets, which circulate round them ..."[91] he is only echoing a general

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sentiment voiced with varying degrees of theological and scientific logic since the appearance of Newton's Principia almost a century before.

Popularized by Fontenelle, the idea of other planetary systems was therefore not uniquely or even chiefly disseminated by Cartesians, but by Newtonians, who in the first half of the eighteenth century used the idea, stripped of its vortex imagery, in support of a natural theology within the Newtonian universe, and later attempted to prove this by Newtonian principles.

* * *

A final word remains to be said in order to emphasize the importance of inhabitants, of Wright's "Ocean of Beings" and Kant's "Bewohnern der Gestirne", in the universe of the mid-eighteenth century. Wright set forth the alternatives sharply; either "an inconceivable Variety of Beings and States, animate and fill the endless Orb of Immensity," or the universe is "a vast unbounded desolate Negation of Beings."[92] Wright chose the former, although he admitted it was a conclusion out of reach of the science of his time. His reasoning was both analogical and theological; analogical to the point of putting inhabitants on every planet in the visible universe, just as there were fish in every river,[93] theological when he extended this view to infinity, in accordance with the "infinite all-active Power of the Creator. It was theological too in that Wright's celestial beings were "tending through

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their various States to a final Perfection," which is God.[94] Wright's inhabitants were thus not necessarily of the same nature as man. Fontenelle, too, had argued that his extra-terrestrial inhabitants were not men. But this had been a matter of circumventing objections based on religious doctrines such as the Incarnation and the Redemption. How completely the reasoning had changed by the mid-eighteenth century! An inhabited universe was now seen as a theological necessity. The fate of man was now intimately connected to the fate of all thinking creatures in the universe; man was only a small part of the "vast visible chain of our Existence, which clearly connects all Beings and States as under the direction of one Supreme Agent."[95]

Such a view was indeed theological in tone, but it was also compatible with, and perhaps partially motivated by, the new idea of nature. To suppose that the fixed stars were not part of a grand system but that they were "dispersed in an endless Disorder thro' the infinite Expanse," would be, Wright asserted, to "reduce the whole Frame of Nature, and all corporeal Beings to a wild unmeaning Chance arising from an unnatural Discord and Confusion."[96] Wright wanted neither inanimate nature nor its thinking creatures to be disordered, and in proposing a hierarchy of systems, extended also the animate chain of being far beyond its classical limits, far beyond anything that Fontenelle or Huygens or even the Newtonian natural theologians had ever supposed.

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In his search for order, Wright in his final Letter proposed the ultimate system, the focus or center of creation, the common center of gravity around which all the stars may move. At this center Wright placed "a primitive Fountain, perpetually overflowing with Divine grace, from whence all the Laws of Nature have their Origin." To this center of gravitation, at once Divine and material, he believed "all Beings as to Perfection may tend; and from hence all Bodies first derive their spring of action, and are directed in their various motions."[97] Thus the animate and the inanimate, the laws of nature and the fate of thinking creatures, were both tied to the same center, and were inseparable.

Even more in Immanuel Kant's work was the existence of inhabitants tied to the new natural order. His work was a cosmogony, one in which matter evolved from a primitive state into masses and systems and still larger systems, but also in which these worlds and systems would one day perish once again. The inanimate and the animate alike suffered a similar fate in this evolution.

> Innumerable animals and plants are daily destroyed and disappear as the victims of time; but not the less does nature by her unexhausted power of reproduction , bring forth others in other places to fill up the void. Considerable portions of the earth which we inhabit are being buried again in the sea, from which a favorable period has drawn them forth; but at other places nature repairs the loss and brings forth other regions which were hidden in the depths of being in order to spread over them the new wealth of her fertility. In the same way worlds and systems perish and are swallowed up in the abyss of eternity; but at the same time creation is always busy constructing new formations in the heavens, and advantageously making up for the loss.[98]

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Moreover, Kant believed that the generation and destruction of the worlds and systems, "as of all natural things" was subject to a certain law. Under this law, heavenly bodies and systems were being destroyed near the absolute center of the universe where the creation had begun, but were forming out of the chaos at the periphery. It is not hard to deduce that in such a universe the fate of its inhabitants would similarly constantly be changing, over the eons of time of which Kant was speaking. This fate of the celestial inhabitants was indeed an integral part of Kant's evolutionary picture of the universe. Unlike Wright, he believed that the periphery, not the center, was primary, a judgement which was based entirely upon the nature of the inhabitants at various distances from the center. The inhabitants, Kant reasoned, would have to be composed of the matter available in their part of the universe, matter which would be densest at the absolute center, with finer and finer matter at the periphery, according to the laws of nature. Given this, Kant then proposed a relationship between the kind of matter of which the inhabitants were composed, and their thinking capacity.

> The perfection of creatures endowed with reason, insofar as it depends on the quality of the matter in whose bonds they are confined, turns very much on the fineness of the matter which influences and determines them to their perception of the world and their reaction to it. The inertia and resistance of matter limits very much the freedom of the spiritual being for action and the distinctness of its sense of external things; this makes its faculties dull and obtuse, so that it does not respond to their outward movements with sufficient facility.[99]

With this interesting Kantian reflection from his pre-critical

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days, which foreshadows his later devotion to epistemological considerations, one has the picture of a universe with all grades of rational beings, from the origins of rationality at the center where the creatures are "plunged in a rigid and immobile kind of matter which holds their powers shut up in insuperable inertness,"[100] to the periphery, where creatures of successively higher degrees of rationality and spirituality are being born.

This is the nature of Kant's universe, one whose stages of progression are reversed from Wright's because of Kant's insistence that life must be evolving in the universe along with worlds and systems. The "initial point of the whole universe" is at the center, and "it must be so located in order that, along with the movement of the universe in its equable progression, that life may also go on which has to fill all the infinitude of time and space with stages of perfection in thought that grow on to infinity, and which has to approach, as it were, step by step, the goal of the supreme excellence of the Deity, without, however, being ever able to reach it."[101]

It was a sobering view of the universe, and lest it be thought that it was only a passing one hidden away in a few passages of the real cosmogony, it must be pointed out that the final part of the Universal Natural History was devoted entirely to expounding in detail those ideas which Kant set forth in general outline at the end of the cosmogony in the

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second part. This final part, which has never been translated into English, was in Kant's words "An attempt founded upon the analogy of nature, to make a comparison between the inhabitants of the various planetary bodies." It reveals exactly that evolution of mind and spirit in the universe which Kant had proposed for matter in the other two parts of his work. Kant begged in the preface to his work that this final part not be judged with the utmost geometrical rigor, admitting that "there will always be found in it something more than what is merely arbitrary, although always something less than the indubitable."[102]

But this final section was based, as Kant had also said, primarily on the analogy of nature, not on theology: "It is a certain law of nature that everything which has a beginning comes constantly closer to its destruction, and is just so much nearer, as much as it has come from the point of its beginning."[103] Kant used this evolutionary view of the universe to arrive at his belief that all of the planets, in our system and in the universe, might not now be inhabited, but that each one will be when its time is fulfilled. In this regard Kant felt that the planet Jupiter was still not in a fulfilled stage, but one day would be, just as our earth had taken thousands of years to reach its present stage.[104] Much of this final part was devoted to our solar system, which in a refinement of his theory Kant believed followed the same law as the universe in general: the most rational creatures would be located at

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the outskirts of our system, since that was where the finest matter of the system would be found.[105]

Such a view left the inhabitants of the earth in a clearly subordinate position, but it was a position to which the eighteenth century was rapidly becoming accustomed. "For what is man?", Richard Bentley had queried already at the end of the seventeenth century, while contemplating the possibility of extraterrestrial life. "Not a Reasonable Animal merely, for that is not an adequate and distinguishing Definition; but a Rational Mind of such particular Faculties, united to an Organical Body of such a certain Structure and Form, in such peculiar Laws of Connection between the Operations and Affections of the Mind and the Motions of the Body."[106] The concept of extraterrestrial life forced man in the seventeenth and eighteenth centuries to take a second look at himself, and to attempt to fit himself into the scheme not only of the vastly expanded physical universe, but also of the similarly enlarged biological universe. In this endeavor, the adaptation of the laws of inanimate nature to man, to celestial inhabitants, and to the evolution of those inhabitants, was the ultimate end of one thread of Newtonian natural philosophy.

In view of the evidence, one cannot help but feel that the universe of Wright and Kant, the heritage of Isaac Newton's universe, and the progenitor of today's, was one in which the existence of extraterrestrial rational beings was of utmost significance. In this historical fact is found the impetus for

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the controversy which has continued ever since, and which remains unresolved today.

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NOTES

[1] Sir Isaac Newton's Mathematical Principles of Natural Philosophy and his System of the World, Motte's translation revised by Cajori (Berkeley, 1960), p. 544.

[2] Universal Natural History and Theory of the Heavens (Ann Arbor, 1969), trans., W. Hastie, p. 137. This translation of the 1755 Allgemeine Naturgeschichte und Theorie des Himmels originally appeared in a volume entitled Kant's Cosmogony (Glasgow, 1900.

[3] Chapter 1, pp. 42-54.

[4] Infra, chapter 1, p. 45.

[5] Opticks or a Treatise of the Reflections, Refractions, Inflections and Colours of Light (New York, 1952; based on London, 1730), pp. 403-404. For the Latin original see infra, chapter 1, note 75, and for a discussion of this passage pp. 49 ff.

[6] Sir Isaac Newton's Mathematical Principles, p. 544.

[7] The Philosophical Works of Descartes (Cambridge, 1972; first edition, 1911), trans. E.S. Haldane and G.T.R. Ross, vol. 1, Discourse on Method, p. 107.

[8] For an enlightening comparison of the philosophies of nature of these two thinkers, see Alexandre Koyre, "Newton and Descartes", in Newtonian Studies (Chicago, 1968), pp. 53-114.

[9] The Philosophical Works, op. cit., vol. 1, Principles, part III, principle 2, pp. 270-271.

[10] For the history of natural religion in seventeenth century England through Newton, see Richard S. Westfall, Science and Religion in Seventeenth Century England (Ann Arbor, 1973; first edition, 1958).

[11] The Confutation formed only three of the eight Boyle lectures presented by Bentley.

[12] Richard Bentley, A Confutation of Atheism from the Origin and Frame of the World (London, 1693), in Isaac Newton's Papers and Letters on Natural Philosophy, ed. I. Bernard Cohen (Cambridge, Mass., 1958), p. 319. In order to avoid confusion, it should be noted that the title pages to the seventh and eighth lectures have been mistakenly switched in Cohen's edition. The lectures themselves are presented in correct order, although the title pages are not.

[13] Ibid., p. 327.

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[14] Ibid., p. 326.

[15] Ibid., p. 349.

[16] Ibid., p. 351.

[17] On the Newton-Bentley correspondence, see infra, ch. 1, pp. 44 ff.

[18] Ibid., p. 356.

[19] Ibid., p. 358.

[20] See infra, chapter 1, pp. 36. ff.

[21] See infra, chapter 3, pp. 158 ff.

[22] "I must premise, that though it may be presumption in man ... precisely and peremptorily to define all the ends and aims of the omniscient God in his great work of the creation; yet, perhaps, it will be no great venture to suppose that at least in the creating of the sublunary world, and the more conspicuous stars, two of God's principle ends were, the manifestation of his own Glory, and the good of men." Some Considerations touching the usefullness of Experimental Natural Philosophy, propos'd in Familiar Discourses to a Friend, by Way of Invitation to the Study of it (Oxford, 1663), p. 23. Essay IV of this treatise forms "a requisite digression concerning those that would exclude the Deity from intermeddling with matter," in which Boyle rejects the Epicurean concept of the chance formation of this world, and an infinity of others. Westfall, Science and Religion, p. 53 summarizes Boyle's position in the later Disquisition as follows: "Boyle believed that the Christian philosopher especially must observe final causes, because they are a powerful argument for the existence of God. On the other hand he recognized that teleology could be - indeed had been - carried to the bounds of absurdity, and he surveyed nature to mark out those areas where its use is safe. The heavenly bodies are of some service to man, but it is doubtful whether they do not fulfill a higher end as well. One must beware of asserting their final cause. The ends of most inanimate objects are obscure at best; while it is not unreasonable to think that they were made for particular purposes, they may well have been the chance productions of matter in motion."

[23] The universality of the belief that the universe was made for man, at least among seventeenth century English thinkers, is pointed out by Westfall, Science and Religion, p. 52.

[24] (London, 1691), p. 1.

[25] (London, 1701), p. 10.

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[26] (London, 1725), p. 25. Whiston's treatise raises the whole range of ideas related to the plurality of worlds tradition. He believes that the moon has its land and seas, clouds and vapors, and an atmosphere much rarer than the earth's (p. 68). He allows for the possibility of inhabited planets and even inhabited comets, and broaches the unique idea that the concave (inside) surfaces of the planets, comets, and sun might be inhabited (91 ff.). However, the astronomer reminds the reader that these are conjectures, not assertions. Whiston's treatise shows the substantial influence of Newton, William Derham, and Christiaan Huygens.

[27] (Edinburgh, 1777), xxxii, ff.

[28] Ibid., xxxii-xxxiii, and p. 154.

[29] Ibid., xxv.

[30] Ibid., xxvii-xxviii.

[31] Ibid., xxvii-xxviii.

[32] Ibid., p. 60.

[33] Ibid., pp. 61, 145.

[34] Ibid., p. 62.

[35] Ibid., p. 63.

[36] Ibid., p. 69.

[37] William Whiston, Astronomical Lectures Read in the Public Schools at Cambridge (London, 1728), pp. 38-42. This work first appeared in Latin in 1707, and in English in 1715.

[38] John Keill, An Introduction to the true Astronomy: or Astronomical Lectures, Read in the Astronomical School of the University of Oxford ... the 4th edition, corrected (London, 1748), pp. 40-41.

[39] It must not be thought, however, that the plurality of solar systems was an idea universally made a part of natural theology. The Newtonian David Gregory in his Physical and Geometrical Elements of Astronomy (London, 1702), p. 3, agreed that aside from our solar system " . . . the rest of the Mundane Space is to be conceived as divided into spaces just like that we have been describing, each having one of those Stars in its Center, which are called Fix'd Stars, performing the office of a sun to it, and having, it may be, Planets and Comets of its own revolving about it." But Gregory did not use this idea in the service of natural theology, and also did

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not "believe, much less affirm", that there were extraterrestrial inhabitants.

Even more to the point, a nineteenth century treatise on the plurality of worlds reveals that at least one sect of anti-Newtonian natural philosophers in the eighteenth century - the followers of John Hutchinson - "gave no countenance to the doctrine of a plurality of worlds; and for a very obvious reason - because they adhered to the language of the scriptures," and moreover labelled the Newtonians as visionaries because of their belief in a plurality of worlds. Alexander Maxwell, Plurality of Worlds: or Letters, Notes, and Memoranda, Philosophical and Critical ... (London, 1820), second edition enlarged, pp. 198 ff. These remarks are also interesting because we see that in retrospect from the nineteenth century, Newtonians were indeed associated with the affirmation of the idea of a plurality of worlds.

[40] Bentley, Confutation, p. 358.

[41] Westfall, Science and Religion, p. 117: "The virtuosi's employment of natural religion in defense of Christianity was not in itself anything new; the alliance of Christianity with natural religion was centuries old. The distinctive feature of natural religion in their hands was the prestige and importance that they assigned to it ...".

[42] Ibid., p. 193: "As Newton the scientist summed up and in a sense completed the 17th century's progress in scientific knowledge, so also Newton the Christian virtuoso may be seen as a synthesizing figure. Standing at the end of the century, he summarized the religious attitudes that had developed among the virtuosi as they had hammered out their reconciliation of Christianity and natural science."

[43] The Leibniz-Clarke Correspondence, ed. H.G. Alexander (Manchester, 1956), pp. xv, 11-12.

[44] Whiston, Astronomical Principles of Religion, pp. 87-88.

[45] Bentley, Confutation, p. 349.

[46] Whiston, Astronomical Principles of Religion, p. 87.

[47] Ibid., pp. 87-88.

[48] Ibid., p. 88; also cited by M.A. Hoskin in his Introduction to the facsimile reprint of Thomas Wright's An Original Theory or New Hypothesis of the Universe (London and New York, 1971), xvii.

[49] An Original Theory, p. iv. All references are to the facsimile reprint cited in note 48, and the page numbers are those of Wright's treatise itself. On Wright's life and work, see Hoskin's introduction.

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[50] "The Cosmology of Thomas Wright of Durham", Journal for the History of Astronomy, I (1970), p. 44.

[51] An Original Theory, p. 3.

[52] "An Account of Jordano Bruno, and his celebrated Book on the Innumerable Worlds" appeared in The Miscellaneous Works of Mr. John Toland (London, 1747), vol. I, pp. 316-349. This actually consisted of an English translation of Bruno's own summary of his De l'infinito universo et mondi, a summary with which Bruno opened the treatise.

[53] An Original Theory, p. 28.

[54] Ibid., p. 30.

[55] Ibid., p. 31.

[56] Ibid., pp. 23-24.

[57] Ibid., p. 26.

[58] Ibid., p. 33.

[59] Ibid., p. 33.

[60] Ibid., pp. v, 12, et passim.

[61] Ibid., p. 46.

[62] "The Cosmology of Thomas Wright of Durham", op. cit., p. 46.

[63] Ibid., p. 47.

[64] An Original Theory, p. 1, footnote. In the early work referred to, which Hoskin reprints along with the Original Theory, Wright speaks of "this vast creation of worlds" (p. 9), and "those Eternal Mansions appropriated by ye Devine Being for his first born, or Eldest Son, begotten of his Sacred Will before all Worlds" (p. 7.).

[65] An Original Theory, p. 63.

[66] Ibid., p. 57.

[67] Ibid., p. 63.

[68] Ibid., p. 64.

[69] Ibid., p. 65.

[70] Ibid., p. 70.

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[71] "The Cosmology of Thomas Wright of Durham", op. cit., p. 49.

[72] An English translation of this account from the journal Freye Urtheile und Nachrichten zum aufnehmen der Wissenschaften und der Historie uberhaupt (Hamburg, 1751), appears along with the English translation of Kant's Allgemeine Naturgeschichte in Kant's Cosmogony (Glasgow, 1900), trans. W. Hastie, reprinted under the title Universal Natural History and Theory of the Heavens (Ann Arbor, 1969). The passage cited above appears on p. 169 of the 1969 reprint. All citations from Kant's work, unless otherwise specified, will be from this translation, which has recently had three separate reprints: (New York, 1968) with an introduction by Willy Ley; (New York and London, 1970) with an introduction by G.J. Whitrow; and (Ann Arbor, 1969) with an introduction by Milton Munitz. The latter reprint has the same pagination as the original edition.

[73] Universal Natural History and Theory of the Heavens (Ann Arbor, 1969), p. 22.

[74] Ibid., p. 35.

[75] The actual body of Kant's text opens with the statement that "The scientific theory of the Universal Constitution of the World has obtained no remarkable addition since the time of Huygens." Ibid., p. 53.

[76] Ibid., p. 57.

[77] Ibid., pp. 62,64.

[78] Ibid., p. 65. Kant later reiterates this methodology: "In order to make the formation of the world more distinctly conceivable, we will limit our view by withdrawing it from the infinite universe of nature and directing it to a particular system, as the one which belongs to our sun. Having considered the generation of this system, we shall be able to advance to a similar consideration of the origin of the greater world-systems, and thus to embrace the infinitude of the whole creation in one conception." Ibid., p. 76.

[79] Ibid., pp. 135-36.

[80] Ibid., p. 136.

[81] Ibid., p. 136.

[82] Ibid., p. 136.

[83] Kenneth Glyn Jones, "The Observational Basis for Kant's Cosmogony: a Critical Analysis", Journal for the History of

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Astronomy, II (1971), pp. 29-34, has argued cogently that the actual observational basis for nebulae, and for Kant's whole theory, was very slim. It is important, however, that Kant thought there was good observational evidence for his claim.

[84] Universal Natural History, pp. 137-38.

[85] Ibid., p. 138.

[86] Ibid., p. 139.

[87] Ibid., pp. 150-151.

[88] The influence of Kant's work was limited due to the fact that the publisher went bankrupt just as Kant's work was being printed, and most copies of the book were therefore impounded. For the printing history of the Allgemeine Naturgeschichte and Kant's other cosmological works, see the New York, 1968 reprint, appendix C, pp. 180-183.

[89] (London, 1799), the tenth edition, p. 6.

[90] Cosmologische Briefe über die Einrichtung des Weltbaues (Augsburg, 1761), digested into English as The System of the World (London, 1800), introduction. In his treatise Lambert explicitly delineates four tools with which one may build a cosmological system: considerations from final causes, the general laws of motion which he takes to be the Newtonian laws, observation, and probable conjectures by analogy. With these tools in hand, Lambert proceeds not only to deduce a hierarchy of systems from the Newtonian principle of gravitation, but also populates them with rational beings. Lambert even spends a great deal of time arguing for inhabited comets, whose inhabitants he acknowledges would require "a more vigorous frame, and a constitution differently formed from ours." Ibid., p. 18. A full English translation of Lambert's work by Stanley Jaki is in press.

[91] Georges Louis LeClerc Buffon, Natural History (London, 1807), vol. 10, p. 286.

[92] An Original Theory, p. 33.

[93] Ibid., p. 12. Wright's entire second Letter is a very interesting epistemological one "Concerning the Nature of Mathematical Certainty, and the various Degrees of Moral Probability proper for Conjecture." Wright here contends that "To say that the Stars, which are a certain visible sort of Cotemporaries in Space with the Sun, have no like planetary Bodies with ours moving round them, because we cannot possibly see them, is no less absurd and ridiculous, than to argue,

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that we can have no Reason to expect to find, in the proper Season, Grapes upon every Vine - Figs upon every Tree - Roses upon every Bush - only because some of them are at such a Distance, that neither Rose, Fig or Grape, can be discovered by the Eye."

"This sort of Reasoning, though some perhaps may neglect it, I am perswaded you will look upon as abundantly sufficient for Things out of the Reach of Science to determine; and that the collective Body of Stars have not been discovered, to be together a proper Subject for such Conjectures before, can surely only proceed from the Want of Time, necessary to compleat the Observations proper for a Foundation to build such an Hypothesis, or Theory upon. This is the great Article in which the Moderns have so much, and ever will have, an Advantage over the Antients." Ibid., p. 12.

[94] Ibid., p. viii.

[95] Ibid., p. 61.

[96] Ibid., p. 49.

[97] Ibid., p. 79.

[98] Universal Natural History, p. 149.

[99] Ibid., p. 166.

[100] Ibid., p. 166.

[101] Ibid., p. 167.

[102] Ibid., p. 37.

[103] Immanuel Kant's Sammtliche Werke (Leipzig, 1867), vol. 1, p. 331. This and the following passages from Kant are my translations from the German.

[104] Ibid., p. 330. "I am of the opinion, that it may not be a necessity to maintain that all planets must be inhabited, although it is uncertain in the visible universe whether to deny all or only most of them their inhabitants. . . . Perhaps all heavenly bodies have not been fully formed; perhaps it takes centuries, thousands of years for this to happen, that a great heavenly body gains a full grasp on its matter. Jupiter appears to still be in this struggle . . . One can still suppose with more contentment that if it is now uninhabited, it will be inhabited when the time of its construction is fulfilled. Our earth was perhaps a thousand years or more at hand before it was in the state where it could support men, animals, and plants. That a planet several thousand years later comes to this perfection, does no violence to the purpose of its design.. . .".

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[105] Ibid., pp. 335 ff. " . . . It is then clear that the strength of the human mind suffers from the hindrance of coarse matter in which it is bound, enclosed, and hemmed, but it is furthermore noteworthy that the specific property of the matter has a certain relation to the degree of influence, which the Sun exerts on the masses at its distance, and makes efficient through the performance of animal economy. This noteworthy relationship of the fire which burns in the middle of our system, to the matter in its reign, is the source of an Analogy between the different inhabitants of the planets. . .".

[106] A Confutation of Atheism from the Origin and Frame of the World, op. cit., p. 359.

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Chapter Six

Astronomical Observation and the Plurality of Worlds

> Who does not see how far the contemplation of nature will extend her boundaries, when we ask for whose good there are tracts of mountains and valleys on the moon, and wide expanses of seas; and whether there may not be imagined some creature less noble than man, which might inhabit those tracts?
>
> Johann Kepler[1] 1611

> If you direct your mind to the towns on the moon, I shall prove to you that I see them.
>
> Johann Kepler[2] 1634

The works of Kepler, Wilkins, Fontenelle, and Huygens repeatedly confirm that the theoretical foundation for the assertion of earth-like planets in the seventeenth century is to be found in the Copernican theory. Again and again they note that the terrestrial-celestial dichotomy has been destroyed, that the earth and the planets alike have motion, and that therefore it is highly probable that the planets are similar to the earth in other respects. The critical question was precisely how deeply the similarities ran, and the answer to this question was not to be found in the heliocentric theory alone. Nor was it to be found entirely in theological or metaphysical claims. Instead, as in much scientific discourse in the seventeenth century, observational data became an increasingly desired and an increasingly attainable element, and accordingly assumed a significant role in the debate. The role of observation in the discussion of planetary worlds and its interplay with those

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theoretical and metaphysical considerations already treated, forms an essential part of the study of the plurality of worlds tradition in the seventeenth and eighteenth centuries.

An examination of the importance of observation in the determination of the habitability of planets brings to the fore an aspect of the plurality of worlds debate which heretofore has not been emphasized. The treatises on the plurality of worlds were at the forefront of a new area of investigation in the seventeenth century, a new physics, not the physics of motion that usually comes to mind when one thinks of the seventeenth century, but the physics of the celestial bodies themselves. The study of the composition, surface features, and environmental conditions of the planets had been thwarted both by Aristotelian dogma which declared them unchangeable polished spheres, and by the lack of empirical evidence to refute such an assertion. Like the new physics of motion, the study of the physical nature of the celestial bodies was a post-Copernican development,[3] an underlying consequence of that system which, although only implicit, would nevertheless inevitably have to be reckoned with as surely as would the physics of motion.

The ever-bold Kepler was one of the first to seize the initiative and realize the fertility of a symbiotic relationship between the physicus and astronomus based on the heliocentric theory. It was as a Copernican that Kepler approached the ancient question of the nature of the lunar spots, and

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declared that here was an opportunity for both the traditionally terrestrially-oriented and the astronomically-oriented natural philosopher to bring his expertise to bear: "Even if the physicist would unravel the question completely," Kepler remarked already in the pre-telescopic era, "these things can also be spoken of by the astronomer ... in truth the astronomer can supply the physicist with many things for expounding proofs of the question."[4] The structure of this statement makes it clear that Kepler considered the question of composition an unusual one to be asked by the astronomer, who heretofore had been concerned only with celestial motions; it was on the other hand a standard question for the physicist, although the object of his inquiry was also a new one. Long before Newton would unite the terrestrial and celestial laws which comprise the physics of motion, the union of astronomy and physics to form a planetary physics was well under way. It was a union largely driven by the plurality of worlds debate, a debate which added a sense of urgency and gravity to observations of the moon and planets.

THE MOON

Kepler's Somnium (1634)

Nowhere can one find a more intense and imaginative effort to utilize observation in the service of planetary physics than in Kepler's Somnium (1634). Had Bruno been more empirically inclined, he undoubtedly could have added the nature of the moon as a significant component of support

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to his argument for the existence of earths throughout the universe. For the telescope was not a prerequisite to this task; even before the discovery of the telescope Kepler had brought the science of optics to bear on the problem of the nature of the moon. Both the camera obscura and the principles of optics demonstrated to Kepler's satisfaction the reality of the lunar spots, seas, and mountains, a belief later confirmed by the telescope. But the moon did not serve as a stepping-stone for Bruno to his infinity of earths. That assertion was neither chiefly inspired by Copernicanism, nor confirmed by observation. Rather, his ideas grew out of the metaphysics of "unity", a metaphysics which happened also to be compatible with Copernicanism, since like the heliocentric theory, it destroyed the terrestrial-celestial dichotomy.[5]

Bruno's lack of attention to empirical concerns in this matter makes Kepler's Somnium all the more interesting by contrast. Although Kepler spoke of the moon in many of his works, including the 1604 Optics and the 1610 Conversation, the whole of his mature thought on the nature of the moon is summarized in the final pages of the dream itself (following the discussion of the astronomical phenomena seen from the moon), in the profuse notes to these pages, and in the Selenographical appendix and its notes which Kepler added in 1623 "on the basis of observations with my telescope, which I recently acquired."[6] Taken together, these pages

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contain an incredible wealth of data which Kepler had amassed over his entire career in his attempt to determine the nature of the moon. The means by which these data were gathered, integrated, elaborated upon, or in the end rejected, lies at the heart of the plurality of worlds tradition and planetary physics in general.

Three distinct levels of concern may be distinguished in those parts of the Somnium that deal with the nature of the moon, levels which are reflected to a greater or lesser extent in all treatises on the plurality of worlds: composition and surface features, climatic conditions, and the nature of the indigenous inhabitants. Although there is some degree of overlap among all of these areas (the nature of the inhabitants, for example, being in part dependent upon climatic conditions, which in turn may be dependent upon surface observations, such as the identification of the dark spots as water), we will initially be concerned primarily with Kepler's determination of the conditions on the moon and their relation, in his mind, to the existence of life.

Perhaps the most obvious and unambiguously determinable climatic factor was that of temperature. Kepler had no trouble realizing that the moon would be subject to great extremes of heat and cold for long periods of time. The astronomy of the situation simply left no doubt that the sun would beat down incessantly on a given area of the moon

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for "fifteen or sixteen of our days and nights," and that the cold would then take over for "as long as fourteen of our days and nights."[7] But Kepler refined his idea of the temperature on the moon, and reasoned that tne long cold night might be moderated on the near siae by warmth received from our earthlight. As was his custom whenever possible, Kepler supported this claim made in the general body of the Somnium with a note, in this case pointing out that when moonlight was collected at the focus of a mirror a certain warmth was felt. The passage leaves no doubt that Kepler actually performed this experiment, although the observation was made quite by accident.

> The warmth of moonlight (even though barely 1/15 of Volva's [earth's] light) we may investigate with our sense of touch, aided of course by art. For if you receive the rays of the full moon on a concave parabolic, or even spherical, mirror, at the focal point, where the rays come together, you will feel a certain warm breath, as it were. This happened to me at Linz, when I was busy with other mirror experiments and not thinking about the warmth of light. For I began looking around to see whether anybody was blowing on my hand.[8]

If moonlight conveyed such warmth to the earth, Kepler reasoned quite logically, then surely earthlight, which he calculated was some 15 times stronger, would impart an even greater warmth to the near side of the moon.

At another point Kepler addressed himself briefly to the complementary temperature problem, that of the great heat of the lunar day. Relief from this heat, he asserted "is provided chiefly by the constant cloud cover and rain, which

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sometimes prevail over half the region or more."[9] The belief that the dark spots on the moon were actually great bodies of water made clouds and rain possible for Kepler, but it is remarkable that he also thought that this claim had been borne out by actual observation. With great excitement Kepler cited an observation made during a lunar eclipse by Maestlin, his teacher, on Palm Sunday, 1605. Maestlin claimed to have seen on the copper-colored eclipsed moon "a blackish spot darker than the rest of the body ... you would have said that extending over a wide area there were clouds laden with rain and stormy showers of the kind which it frequently happens, is seen by those who look down from the summits of high mountains toward the lower places in the valley."[10] Kepler was so much taken by this observation that he tells us he later spoke to Maestlin about it in person, and discovered that the spot had taken up about half the lunar diameter. This was the origin of his statement in the Somnium that clouds and rain sometimes "prevail over half the region or more."

While one might wonder what Maestlin actually saw on this Palm Sunday, there is no doubt of what he thought he saw. The willingness to transfer the experience of terrestrial observations to the interpretation of lunar phenomena was a method at the heart of the new physics, and it was this method which allowed him to conjecture that he had seen clouds and rain. Maestlin, only a wavering Copernican, certainly had

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no stake in inventing such an observation, one which could have put him in instant disfavor with theological authorities. In the end, however, Maestlin's Palm Sunday observation remained a unique one through the remainder of Kepler's life, and its very uniqueness must have raised as many questions for Kepler as it answered. Why was such a phenomenon not observed more often? Should not clouds, if they existed, at times obscure the lunar surface features, or did the difficulty of the observation preclude this? It was probably with such doubts in mind that Kepler concentrated in this note on merely proving the existence of an atmosphere which might support clouds and which might in itself moderate the heat of the lunar day to some extent, and then along with Maestlin's observation, cited another passage in which Maestlin said only "Whether that air, like ours, condenses into clouds which, on account of their opacity, take on the appearance of very solid bodies ... I leave undecided. Experience has certainly taught us that that enveloping brightness appears at various times more or less limpid."[11]

The existence of clouds, then, was a subject in which Kepler had a great interest in their role as a moderating factor of heat, but the observational evidence for their existence was indeed tenuous. Even if earthlight and clouds did act as moderating factors, Kepler still believed that the moon would be subject to some extremes of heat and cold. Beyond what point these extremes would have to go for life to

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be precluded, Kepler was not in a position to judge.

Frequent and undisputed observations of clouds on the moon would have gone a long way toward providing a solid indication of the climatic conditions on the moon, for their existence would not only make it possible that extreme temperatures might be moderated, but also would have provided proof of the existence of water and an atmosphere on the moon. As matters stood, however, the presence or absence of water and an atmosphere had to be determined by more reliable observations. Kepler never doubted the existence of large bodies of water on the moon, chiefly because of his fundamental assumption that the very apparent dark and bright spots represented differences of composition, and analogy with the earth demonstrated that these differences must be due to the existence of both land and water on the moon. Kepler's initial opinion in the 1604 Optics had been that the bright spots were water; Galileo's observations of elevated areas on these bright spots forced Kepler to reverse his interpretation in the 1610 Conversation. The existence of such vast bodies of water is taken for granted by Kepler in the Somnium, where he only pauses to reaffirm that the dark spots are a liquid which "by its color and softness, dulls sunlight," while the dry and hard mountains reflect the sunlight brilliantly.[12] The power of terrestrial analogy is evident as Kepler also refines this idea by noting that the degree of darkness might be attributed to the degree of

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wetness: "Hence there is something like our swamps and something like our pure seas. For in like manner in our swamps, too, grasses, reeds, rushes, and canes grow, while everywhere there are also hard, dry, and white soils, which reflect the sun's rays more brightly."[13]

The most elaborate arguments related to the climatic conditions on the moon were reserved for the determination of its atmosphere. This was a question which Kepler had already discussed in the Conversation,[14] and one of the longest notes of the Somnium was devoted to it. It must be remembered that for Kepler the idea of an atmosphere was equivalent to that of "air", one of the Aristotelian elements, whose function in the life process was not understood in the same terms as we understand it today. Kepler seems to find the importance of an atmosphere for life chiefly in its moderating and moisturizing qualities which we have discussed before: "I certainly do not understand how those inhabitants of the moon can bear the sun's terrific heat at full moon ... unless the dense air covers the sun for them frequently, as happens among the Peruvians, and moderates the heat with its moisture."[15] Water as a moderating factor for heat and as a necessity for life in itself was intimately connected to the existence of an atmosphere.

The starting point for Kepler's ideas on the lunar atmosphere, he explicitly tells us, was a work of his teacher Maestlin, published in 1606 and entitled The Phenomena of the

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Planets.[16] This work, the same one which contained Maestlin's Palm Sunday observation of possible clouds and rain on the moon, consisted of some 153 "theses", and became the subject of a public disputation by Samuel Hafenreffer, presided over by Maestlin. From theses 136, 143, and 148-152, Kepler distinguished five separate arguments propounded by Maestlin in favor of a lunar atmosphere. Four of the arguments are based on four separate phenomena which suggest that the apparent diameter of the moon is larger than the diameter of the body of the moon itself, the discrepancy being due to the existence of a surrounding atmosphere.

Perhaps the most important phenomenon, and the one to which Kepler gives the most attention, is that the diameter of the moon during a solar eclipse, as observed with a camera obscura, appears smaller than that of the sun, whereas "the full moon generally has a bigger diameter than the sun." The larger diameter of the moon in general, Maestlin contended, was caused by the protruding lunar atmosphere, which during a solar eclipse was transparent to sunlight.[17] Kepler emphatically agreed that the diameter of the moon during a solar eclipse did appear to be smaller than otherwise, when viewed by means of the camera obscura: "It is entirely correct, I repeat, that when the image of the eclipsed sun is introduced through a small hole, the convex circumference is a part of a bigger circle, whereas the concave circumference is a part of a smaller circle."[18] And he noted that

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Tycho and his student Longomontanus asserted that the diameter of the new moon was less than the diameter of the full moon, and that on this basis the astronomer David Fabricius too had favored the "nightshirt of the moon".

It is testimony to Kepler's objectivity that he asserted that the cause of this phenomenon was not to be found in the lunar atmosphere, but instead was an optical phenomenon directly related to the radius of the aperture of the camera obscura itself.[19] This solution to the problem had been presented already in the Optics, and Kepler spoke as a man of authority when he cautioned the disputant of the theses, who had bypassed the optical explanation in favor of that of the lunar atmosphere, that an atmosphere could not in any case be the cause of this particular phenomenon.[20]

A second argument of this type, destined to become the crucial one in the quest for a lunar atmosphere, focused on the phenomenon of occultation, the eclipse of a star by the body of the moon. The crucial observation here was the precise behavior of the star in the moments before its complete eclipse. Thesis 148 had given Maestlin's opinion: "When the full moon is about to occult stars, it seems to take them first within the embrace of this bright tunic, through which they shine; then, finally, it hides them behind its body and occults them completely."[21] Once again Kepler agreed with this phenomenon and even cited from the introduction to his Rudolphine Tables the case of a 1625 occultation of Venus

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which exhibited this behavior. But once again, he did not believe that this observation proved unambigously the existence of a lunar atmosphere. Instead, it could be explained in the same way as the final two arguments of this type which Maestlin presented, arguments that the young crescent moon appeared slightly larger in diameter than the old moon which it embraced, and that the extremely slim crescent sometimes seen immediately after the new moon might actually be only a manifestation of its atmosphere.[22]

The cause of these three phenomena, the authority on optics again declares, is not to be found in anything involving the nature of the moon itself, but in the process of vision: "For at night the pupil of the eye dilates in a natural movement. More abundant light enters from a point of the visible source and broadly affects the visual spirits in the retina. The same spreading on the retina happens by day also, when the eye is turned toward a strong light. In this way the image of visible objects on the retina is spoiled, since the bright parts expand and encroach on the bordering region. But this picture on the concave retina within the eye corresponds exactly and invertedly to the vision of the external visible object."[23] The "expansion and encroachment" of the bright light on the bordering dark region constitutes Kepler's illuminating physiological explanation of Maestlin's reported occultation observation, as well as of the remaining two arguments.

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In spite of Kepler's rejection of the majority of Maestlin's arguments on the basis of instrumental effects, either of the camera obscura or of the eye itself, he did indeed believe in the existence of a lunar atmosphere. Maestlin's fifth argument was that the rim of the moon appears bright without spots, in contrast to the middle which is full of spots. Kepler apparently accepted this observation as the most forceful of the whole group, for he repeated Maestlin's explanation and elaborated upon it uncritically: "the reason undoubtedly is that the lunar air is thin in the middle of the body and shallow on the sides, but toward the edges it looks deep to the eye. For in like manner, on the plains of the earth, the air overhead, even though lit up by the sun, does not affect the vision strongly, and does not hide the bigger stars from those who look up from a deep well."[24] The method of bringing terrestrial experiences to bear as explanatory factors for celestial phenomena once again proved successful for Kepler, as he noted that a distant mountain appeared white because of the depth of the layer of air between the observer and the mountain.

Kepler's discussion in the Somnium of the climatic conditions on the moon reveals a surprisingly large corpus of respectable, if not indisputable, arguments, many of them directly based on observation. This is especially true in the all-important question of the existence of a lunar atmosphere. But a moment's reflection suffices to indicate that

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observation does not stand alone as the arbiter of truth in natural philosophy. To be sure, there is the matter of interpretation of observations; it was on the basis of different interpretations that Kepler rejected four out of five of Maestlin's arguments in favor of a lunar atmosphere. But even more than this, one might well ask why the controversy over a lunar atmosphere is not as ancient and as prominent as that of the theory of lunar motion. The answer must certainly be sought not in terms of technical competence, for Maestlin's arguments were published in a treatise that antedates the Galilean telescope by four years, but rather in terms of the metaphysical framework within which observations are undertaken. It is surely no coincidence that the lunar atmosphere debate raged concurrently with the debate over the heliocentric theory which made possible the existence of earth-like bodies throughout the universe. Indeed, the whole controversy over the existence of a plurality of worlds can only confirm the complementary roles of metaphysics and observation. Arguments of interpretation and arguments grounded in metaphysical predispositions made it a virtual certainty that observation would provide no speedy solution to the problem of a world in the moon and planets. It is with this in mind that the role of observation in the seventeenth and eighteenth century tradition must be approached.

There was metaphysics involved, too, in the final and boldest observational claim made by Kepler in the Somnium,

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a claim so bold that it was universally rejected even by Kepler's admirers in the seventeenth century. It was an argument which went back to the 1610 Conversation, and which was confirmed and elaborated upon in the Somnium. "If you direct your mind to the towns on the moon," Kepler began in the Selenographical appendix, "I shall prove to you that I see them."[25] Not only did he proceed to expound a detailed proof of this, but he also conjectured at length on the means by which the population built their great constructions. The proof of these conclusions is to be founded "piece by piece on the basis of phenomena discovered by the telescope, if those phenomena are brought into agreement with these conclusions by means of the axioms of optics, physics, and metaphysics."[26]

In a note more than ten times longer than the Selenographical appendix itself, Kepler set forth a whole system of phenomena and axioms which he believed proved the truth of his view that the moon was an earth-like body and that it was not only habitable, but actually inhabited. Comprised of 34 sections which alternate the phenomena, axioms, and conclusions, the first 17 sections briefly recapitulate in a systematic manner the general judgements already reached with regard to lunar surface features. The eighteenth section begins a discussion of the causes which shape the surface features of a planet; herein lies Kepler's strategy for proving the existence of inhabitants. He notes that on the

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earth there are two kinds of surface features: those shaped consciously like the cultivation of land and the diversion of rivers, and those "produced by the movement of elements," the elementary qualities causing the movement being wetness and dryness, hardness and friability.[27] Some geological observations of Silesia follow, and then one of Kepler's metaphysical axioms:

> The mind is the source of orderliness. Nothing arranged by the mind is out of order and confused unless the mind, using its own judgement, has given free rein to instrumental causes different from itself. It therefore follows that those things which are out of order, insofar as they are out of order, are the result of the movement of the elements and the composition of matter.[28]

The force of this axiom is then to relegate the general disorder observed on the moon - the high, low, and rugged parts - to elemental causes. It is therefore established that the hard, soft, dry and wet qualities are found on the moon.

A second metaphysical axiom addressed itself to the case where the observer perceives order: "When things are in order, if the cause of the orderliness cannot be deduced from the motion of the elements or from the composition of matter, it is quite probably a cause possessing a mind."[29] Thus, Kepler tells us, a straight line is an orderly thing. But a speeding bullet travels in a straight line not because of a mind, but because gunpowder and the surrounding iron barrel caused it to behave in this way. Similarly, the rectilinear motion of falling bodies and of light rays is

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a property of heavy bodies and of light rays. And in the biological realm, the spiralled snail shell proceeds not from mind, but because the snail twists istelf into this shape, and the same is the case with the hexagonal honeybee comb. In the same way, then, most of the features on the lunar surface can be ascribed to material causes such as erosion.[30]

On the other hand, just as the "arrangement by fives in flowers" cannot be ascribed to matter, but to a "creative faculty, which somehow participates in number and thus in reason," so "in the spotted parts of the moon the perfectly round shape of the hollows and their arrangement, or a certain equality of the distances between them, are artificial and produced by some architectural mind. For that scooping out into the form of a circle cannot be accomplished by any motion of the elements ... ."[31] It is from these metaphysical axioms and observed phenomena that Kepler concludes that there must be living creatures on the moon "capable of reasoning with a view to constructing those orderly things."[32] Not only did the individual constructions demonstrate order, but also the arrangement of them, an observation which led Kepler to assert the mutual harmony and understanding among the creators of the various hollows.

Such was Kepler's axiomatic demonstration of the existence of lunar inhabitants. It is for us instead a demonstration of the role of metaphysics in observation.

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For in the end Kepler's axiom that "the mind is the source of orderliness" took a paradoxical twist. Originally intended to refer to the mind of the intelligent being whose works of art were perceived by an observer, it ended up saying more about the mind of Kepler, the observer himself, who found order where in fact there was none. Moreover, it is difficult to assess how this belief in the actual existence of inhabitants might have affected Kepler's interpretation of those phenomena which had a bearing on the climatic conditions on the moon. For if the inhabitants actually existed there, then the climatic conditions, the temperature factor and the existence of water and an atmosphere, must have been conducive to intelligent life on the moon. It remains true that Kepler rejected four out of five of Maestlin's arguments for a lunar atmosphere, but he nevertheless championed the existence of water and an atmosphere on the moon. And although he accepted the existence of these life-giving elements on the moon in the years before the telescopic observations which led to his belief in the actual existence of intelligent Selenites, after the acceptance of the Selenites, he could hardly have done otherwise. With the acceptance of that belief, an even tighter metaphysical framework wrapped itself around any lunar observations.

Wilkins' Discovery (1638)

The remark by one of Galileo's correspondents that the

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Somnium seemed to him a "strange and bizarre" book may well reflect the opinion of most of its readers.[33] But the ideas on the lunar world expressed in the Somnium, and those presented in a less developed but more palatable form in the 1610 Conversation, were destined to exert considerable influence on seventeenth century thought. John Wilkins' 1638 Discovery of a World in the Moone shows only the influence of the Conversation, but by the time of the appearance of the second edition of the Discovery in 1640, the Somnium too had reached the hands of the Englishman.

At the time of the conception of his book, then, Wilkins had access to the basic ideas of Kepler through the Conversation, but did not yet know of the posthumous work on lunar astronomy. A comparison of their approaches to the problem of the nature of the moon clearly reflects the fact that the author of one was an observational and theoretical astronomer, while the other was a classical scholar, a connoisseur of a wide range of both scientific and theological works, as well as the purely literary. Where the only authority for Kepler's statements was his own observation and imagination (along with that of a very few others such as Plutarch, Maestlin, and Galileo), Wilkins by contrast cited the opinions of others at every turn. Indeed, one of the most striking aspects of Wilkins' treatise is its scrupulous documentation of opinion both opposing and supporting his own view that the moon is a habitable world. Not the least significance of the treatise is that it juxtaposes

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an unexpected variety of opinions related not only to the nature of the moon, but also to the new planetary physics in general.

An analysis of Wilkins' sources demonstrates that the variety of opinion does not by any means represent a large body of observational knowledge. If such a body of knowledge had existed, Wilkins would certainly have known of it, but the art of telescopic observation simply had not added much in 1638 beyond the initial observations and interpretations of Galileo and Kepler in 1610. Instead the plethora of sources - some 60 authors are cited (see Table I) - represent to a large extent a pre-telescopic and even a pre-Copernican tradition of thought on the moon. That is not to say that Wilkins blindly accepted ancient opinion; to the contrary, it reflects his technique of citing all known opinions on a given aspect of his subject, and then proceeding to refute or support these opinions based on his own reasoning and more recently gained knowledge.

Among other things, this technique highlights the important point that the Aristotelian insistence on a terrestrial-celestial dichotomy was not the universal pre-Copernican opinion. The Coimbra Jesuits, Wilkins noted, were not able to convince themselves of the necessity of such a doctrine, and moreover the general consent of the Church fathers and Lombard went to the opposite opinion. Indeed, St. Ambrose considered the Aristotelian opinion a heresy.[34] Although Wilkins made it

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TABLE I

Authors cited in Wilkins' Discovery of a World in the Moone (1638)

com = arguments concerning composition of moon, including general arguments about celestial/terrestrial dichotomy

sur = arguments related to surface features of moon

atm = arguments related to existence of a lunar atmosphere

inh = arguments related to existence of lunar inhabitants

wor = authors reputed to have argued for (+) and against (-) a world in the moon in general similar to the earth

No designation indicates a miscellaneous reference.

(1640) indicates some of the more important references added in the 1640 edition.

Agrippa, Occulta ad philos., Bk. 1, ch. 6	sur
Albergettus	
Albertus Magnus, De 4^{r} coevis. Q. 4^{2}, Art. 21	com, sur
De coelo, Bk. 2	com
Alcinous, Instit. ad discip. Plat.	
Ambrose, In Hexam., Bk. 4	com
Aquinas, Part 1, Q. 47, Art. 3	
Part 1, Q. 68, Art. 3	
Aristotle, De caelo, Bk. I, ch. 2	com
Bk. I, ch. 3	com
ch. 8,9	
Bk. II, ch. 13 (Pythagoras)	wor+
In lib. de animalib.	com
Meteor., Bk. I, ch. 11	sur
Metaphys., Bk.12, ch. 8	
Ethic., Bk. I, ch. 6	
De gen. animal., Bk. 4, 12.	
Augustine, In lib. sup. Gen. ad lit.	com
Confession, Bk. 13, ch. 32	sur
De Civ. Dei, Bk. 16, ch. 9	
Bk. 22, ch. 16	inh
Averroes, De caelo, Bk. 2, comm. 49	com
Baronius, Annal. Eccles. A.D. 748	

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Basil

Bede, In lib. de mundi constit. — com & sur
In lib. de natur. rerum — com
De ratione tempor., ch. 4 — com

Bible, many verses relating to com, sur, inh

Blancanus, De mundi fab., pars 3^2, ch. 3
ch. 4 — sur

Exposi. in loc. Math. Arlis., loc. 148 — sur

Bruno, — wor+

Campanella, Apologia pro Galileo — wor+, sur, inh

Cardan, De Subtil., Bk. 3 — com, sur

Cisatus, — atm

Coimbra Jesuits, de caelo, Bk. 1, ch. 2, Q.6,art. 3 — com
Q.4,art 21 — sur

Comes, Natales, Mytholog., Bk. 3, ch. 17
Bk. 3, ch. 19 — inh

Cusa, Nicholas, De docta ign., Bk. 2, ch. 12 — wor+

Fabricius, Johannes, De macula in sole obser.

Fromondus, De Meteorus, Bk. 1, ch. 2, art 2
Bk. 3, ch. 2, art. 6.
Bk. 5, ch. 1, art. 1 — sur

Galileo, Nunc. Syd. — sur
Syst. Mund., colloq. 1 (1640) — com, sur
colloq. 3 (1640)

Gazaeus, Procopius, Comment. in I cap. Gen.

Gloriosus, De comet., Bk. 5, ch. 4.

Godwin, Nuncius inanimatus

Hackwell, Apol. — com

Herodotus, Bk. 7, ch. 37 — com

Hill, Nicholas, Philos. epicur., part 378
part 434 — wor+

Isidore of Seville, Originum, Bk. 3, ch. 60 — com

Josephus, Bk. 2, con. App. Aug. de Civit. Dei,
Bk. 18, ch. 41 (Anaxagoras)

Juven., Sat. 6.

Kepler, Opt. Astron., ch. 7, num. 3 — com
ch. 6, num. 9 — sur
dissertatio cum Nuncius Sydereus — wor+, sur
Epit. Coper., Bk. 1, p. 3 (1640)
Somnium Astron., Note 66 and Note 207 (1640)
Append. Selenogr (1640) — sur

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Lactantius, Institut., Bk. 3, ch. 24.

LaGalla, Julius Caesar, De phenom. in orbe lunae, ch. 1
ch. 4 wor⁻
ch. 5
ch. 11 com,sur

Lessius, De morib. div., Bk. 13, ch. 24 inh

Lombard, com

Lucretius, De nat. rerum, Bk. I

Macrobius, Somnium Scip., Bk. 1, ch. 11 wor⁺
Bk. 1, ch. 20 com

Maestlin, Epitome Astron., Bk. 4, part 2
Bk. 4, part 12 com, atm

In Thesibus wor

Mahomet, Azaora, 57 & 65 wor⁺

Mazonius, Comparatio Arist. cum Platone sur

Molina

Mulapertius, Treatise concerning the Austrica Sydera com
De Heliocyc.

Nirembergius, Eusebius, Hist. nat., Bk. 2, ch. 11-13 com
Bk. 8, ch. 15

Nisus, Augustinus, De caelo, Bk. 2, p. 49 sur

Ovid, Metam., Bk. 4.

Pena, Preface to Euclid's Optics com

Pererius

Philo, De somniis com, sur

Plato, de conviviis

Pliny, Nat. Hist., Bk. 2, ch. 9 sur, com
ch. 12
ch. 16
Bk. 36, ch. 1 sur

Plutarch, De placit. philos., Bk. 2, ch. 17 (Heraclitus) com
Bk. 2, ch. 13 (Diogenes) com
Bk. 2, ch. 13 (Orpheus) wor+
Bk. 2, ch. 25 (Xenophanes, Anaxagoras, Democritus, Heraclitus) wor+
ch. 25 (Stoics, Anaxagoras, Democritus) sur
ch. 30 (Pythagoras) wor+

De fac. lunae wor+, com, sur,
cur silent oracula inh

Ptolemy, 1 Apost. com

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Rawleigh, Hist., Bk. 1, ch. 7, sect. 11 sur
sect. 6

Rheinhold, Com. Purbac. Theor., p. 164 com, sur

Rhodiginus, Caelius, Ant. lect., Bk. I, ch. 4 com
ch. 15 com, sur
Bk. 20, ch. 4 com

Francis Ribera, Comment. on the Revelations

Rothmann, Christopher

Ruvio, De caelo, Bk. I, ch. 9, q. 1

Scaliger, Julius, exercit. 80, sec. 13 com
62 com, sur
62 wor-
38 sur

Scheiner, Rosa Ursina, Bk. 4, pars 2, ch. 24, 35 com
pars 11(?), ch. 7, 26, 30 com
pars 2, ch. 27 atm

Seneca, Nat. Quaest., Bk. 2, ch. 5
Epist. 95

Solinus, Poly. histor., ch. 21 sur

Tostatus, in 1 Gen. Hieron. de 5 Hide (Rabbi Simeon) com
in Genes. inh
2^2 Quest. in hoc. cap. com

Tycho, De stella 1572, Bk. 7, ch. 9 com
De nova Stella, Bk. 1, ch. 10 com
Progym. 1, ch. 9

Vitello, Opt., Bk. 4 com
Bk. 9 sur

Vitruvius, Bk. 9, Architecture in enarrat. psalmorum com

Wright, master, Epist. ad in Gilbert

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clear that seventeenth century peripatetics who held to the Aristotelian dichotomy still abounded, including his "chief adversary" Julius Caesar La Galla, he had no trouble putting together an impressive array of classical authorities in favor of the corruptibility of the heavens. Some modern thinkers too held the latter view, and the problem was to reconcile the two opinions. It was in this all-important process that observational evidence, little as it was, once again played a significant role. Motivated by the Copernican theory,[35] Wilkins' task in the Discovery was to resolve an ancient problem with new knowledge, among which knowledge observation held a high rank.

On the most general level, Wilkins began by rejecting the idea of an incorruptible celestial region. He pointed to the difficulty of observing any detailed alterations in the heavens, but then cited the observation of comets above the sphere of the moon, and "those spots or clouds" around the sun, which he noted were continually being destroyed and formed anew. He referred to Scheiner's Rosa Ursina for further elaboration of the corruptibility of the heavens, and concluded simply that "though Aristotle's consequence were sufficient, when he proved that the heavens were not corruptible, because there have not any changes been discovered in it; yet this by the same reason must be as prevalent, that the heavens are corruptible, because there have been so many alterations observed there."[36]

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In spite of the persistent claims of peripatetics even in the telescopic era that the moon was a perfectly smooth body, the belief that it was in fact rugged like the earth was championed already by Anaxagoras and Democritus, and affirmed by moderns such as Blancanus. But the deciding factor for Wilkins was "the eye-witness of Galileus, on which I most of all depend for the proof of this proposition."[37] Even in relating the simple observations of Galileo of the lunar surface, Wilkins found it necessary to take into account the objections of the peripatetic Julius Caesar La Galla, who explained those observations in terms of the transparency and opacity of different parts of the moon, rather than in terms of real surface features. Not without justice, Wilkins charged that La Galla came to the observations of Galileo with the intent of contradiction, and that for himself and most others Galileo's telescope "can shew to the senses a proof beyond exception; and certainly that man must needs be of a most timorous faith, who dares not believe his own eye."[38] The case of La Galla is an example almost to the point of absurdity of how metaphysical predisposition can affect the interpretation of observations, but it alerts us to the possibility of more subtle influences of metaphysics on seemingly objective observational data.

Indeed, one does not have to look far for evidence that metaphysical reasoning of another sort - teleological - affected Wilkins' own discussion of the nature of the spotted

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body of the moon. Relying on the belief that "nature frames every thing fully perfect for that office to which she intends it," Wilkins pointed out that a spotted moon would not have been necessary if the only purpose of the moon was to reflect sunlight toward the earth; indeed such spots would be detrimental to such a purpose. Nature, then, must have had some other end in view in forming the moon as it did, to wit, "to make it a fit body for habitation, with the same conveniences of sea and land, as this inferior world doth partake of."[39] In this way, one of the prime conditions for the existence of life on the moon was established, and observation was shown to be compatible with this view and even refined it, by demonstrating that the dark areas must be water, since the bright spots were rugged in places. The old opinions cited by Wilkins of Witelo, Reinhold, and La Galla that the dark spots were thicker parts of the moon, and "the more common and general opinion" of Albertus Magnus and the Coimbra Jesuits that they were thinner parts of the moon, were swiftly bypassed by this metaphysical tour-de-force. Once Wilkins demonstrated even further the compatibility of this view with observation and reason, and then added Campanella's theological proof of the existence of water in the heavens, it must all have seemed a very convincing argument to many seventeenth century readers.[40]

Having proved to his satisfaction the existence of rugged lands and smooth waters on the moon, Wilkins turned to the question of a lunar atmosphere, a phenomenon, he noted, first

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observed by Maestlin and later assented to by Kepler, Galileo, Baptista Cittacus, Scheiner, and others. The six arguments which he presents are gathered from all of these authors; four of them are identical to those cited by Kepler from Maestlin, and are presented without any additional elaboration. It is curious that even in the later editions when he knew of the Somnium (as his citations indicate), Wilkins did not introduce into the discussion Kepler's optical objections to these four arguments, and moreover, that he never included the one argument which Kepler had accepted without reservation since 1610, that of the bright rim of the moon.

A fifth argument for the lunar atmosphere was taken from Scheiner's Rosa Ursina: "It is observed in the solary eclipses, that there is sometimes a great trepidation about the body of the moon, from which we may likewise argue an atmosphaera, since we cannot well conceive what so probable a cause there should be of such an appearance as this ... that the sun-beams were broken and refracted by the vapours that encompassed the moon."[41] But perhaps the most original argument found in the Discovery for an orb of air around the moon was based not on the direct observation of such an atmosphere, but on a theory of the origin of atmospheres. The air closest to the earth was conceived by Wilkins to be composed of a "thicker substance" than the aethereal air spread throughout space, the reason being that "it is always mixed with some vapours which are continually exhaled into it" from the earth.[42] Such "exhalations"

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or "evaporations" were also observed to proceed from the sun in the form of the spots or clouds recently discovered.[43] Although such clouds have not been directly observed around the moon, Wilkins concluded, what happened on the sun was much more likely to happen on the moon "which does consist of a more gross and impure substance."[44]

The theory of exhalations, whose origin is found in Aristotle's Meteorology, had significance for another area related to the lunar world, for it was intimately associated with the existence of "meteors" on the moon, a term that refers to wind and rain, dew and moisture, those "means of growth and fructifying ... which might serve for refreshing and nourishment of the inhabitants and plants in that other world."[45] Wilkins' proof of the existence of such meteors on the moon had its unlikely origin in another astronomical problem, the origin of comets and new stars. The point of connection of the two problems was found in the theory of exhalations, for it was the contention of Wilkins, following Camillus Gloriosus, Thomas Campanella, and Fromondus, that comets were formed from exhalations emitted from the bodies of all the planets, not only from the earth as the standard Aristotelian theory held. This followed from observational evidence that comets were actually in the supralunar region, and from calculations that even one of them was 300 times larger than the earth.[46] If such exhalations proceeded from all of the planets, then those same exhalations provided each

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of the planets with an atmosphere, and produced "meteors" in this continuous process. As observational proof of the existence of such meteors, Wilkins cited that old Palm Sunday, 1605 observation of possible clouds on the moon reported by Maestlin, along with a similar observation made by Cisatus in 1628.[47]

For all its laudable efforts to bring together critically a wide variety of opinion, the confluence of ideas found in the Discovery represents a confluence of prejudices, as does even the final opinion wrought so diligently by Wilkins. In the midst of theology, teleology, heliocentrism, and theories of "exhalations" and "meteors", observation was only beginning to emerge as an objective criterion in the controversy over the habitability of the moon. More restrained than Kepler's Somnium, since it made no claims about the actual existence, nature, or activities of the lunar inhabitants, the Discovery was only the beginning of what was to be a long, heated, and at times frustrating controversy.

Arntzen's Dissertatio (1726)

No more compelling proof of the increasing yet indecisive role of observation in the lunar debate could be offered than that of the existence of two treatises which, although published a century after the Discovery, nevertneless arrived at opposite conclusions. The Dissertatio astronomico-physica de luna habitabili (1726) and the Dissertatio astronomico-physica de luna non habitabili (1740) indicate by their very titles[48]

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the diametrically opposed viewpoints which respectable and critically-thinking men could hold even in the eighteenth century, after a considerable body of observational evidence had become available. The fact that both were university dissertations, the former written at Utrecht and the latter at Uppsala under the direction of prominent professors, only accentuates the surprise of the extraordinarily disparate conclusions at so late a date in the telescopic era. Where is the cause to be sought? In a still inadequate body of observations? In differing interpretations of those observations? Or in lingering metaphysical and theological prejudices?

A comparison of the 1726 treatise with that of Wilkins published in 1638, both of which had identical purposes, serves well to indicate the intervening progress of the debate. The 1726 treatise was the work of William Arntzen, a student at Utrecht promoted to the doctor of philosophy in 1728, who also wrote a Dissertatio de origine animae humanae and practiced medicine before his very early death in 1735. Arntzen's work on the moon was directed by Jacob Ode, a professor at Utrecht who had written a Dissertatio de atmosphaero and perhaps influenced the young Arntzen to take up the related subject of the habitability of the moon. The degree to which the intellectual climate had changed at Utrecht since the days in 1676 when Gerhard DeVries had rejected lunar inhabitants in his Dissertatio academica de lunicolis under the influence of the predominantly anti-Cartesian environment,[49] can best be

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seen in the fact that Arntzen also studied under Pieter van Musschenbroek, a staunch Newtonian and professor of philosophy and mathematics at Utrecht from 1723-1739. Arntzen was assuredly no peripatetic following the battle cry of DeVries 50 years before to eject inhabitants from the incorruptible celestial regions. To the contrary, he was willing and anxious to bring all the knowledge of the new natural philosophy to bear on the time-honored problem of the habitability of the moon.

Arntzen's technique for expounding his subject was much the same as that of Wilkins. He brought together ideas from an immense number of authors, and then attempted to separate fact from fable, good reasoning from faulty reasoning. An analysis of his sources shows that he drew upon a much more modern tradition of thought than Wilkins. The 74 authors cited by Arntzen (see Table II) were not all by any means astronomers who had made original observations of the lunar surface, but the majority of them did use observations as the basis of their opinions or interpretations.

In addition to the prominent attention given to the opinions of Galileo and Kepler, Arntzen's synthesis shows the great impact on the debate of the Selenographia of Hevelius, the Almagestum novum of Riccioli, the works of Gassendi, Athanasius Kircher, and von Guericke, along with the treatises on the plurality of worlds of Fontenelle and Huygens. It also demonstrates that the subject of a lunar world had penetrated

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TABLE II

Authors cited in Arntzen's Dissertatio ... de luna habitabili (1726)

* indicates a major source for Arntzen, i.e., cited more than 5 times

Acad. Royale des Sciences, Memoires, 1704
Hist., 1694

Acta Erud., A. 1698, 1706

Andala, Exercit. Acad., part II, 2, sect. 10-19

Appolodorus, Biblioth., Lib. I, c. 2, sect. 2

Apuleius, de Deo Socratis

Aristotle, De caelo, Bk. II, c. 11

Auzout

Bacon, Francis (Baron de Verulam), Nov. Org., Bk. II, Aphor. 36, p. 373 ff.

Baile, Franciscus, Inst. Phys., T. II, pp. 137-38

Berneccerus

*Blancanus, Sphaera Mundi, part II, sect. II, tract 1, ch. 3, p. 150.
tract 2, chps. 3-4.

Boyle, Robt., de atmosphaera dissertatione

Brahe, Tycho, Progymn., Tom I, p.m. 439

Cassini, in Memoires de l'Acad. Royale des Sciences, A. 1699

Chauvinus, in Lex. Philos. in V Luna

Cicero, Quaest. Acad., ch. 123, Bk. IV

Clauberg, Disp. Phys. XXVIII, sections 7-10

*Clarke, Sammuel, in Rohault Phys., I, 34, sect. 8
II, 25, sect 24

Clericus, Phys. I, 6, sect. 12
8, sect. 11, 12, 19

*Coimbra Jesuits, in Arist. de coelo, Bk. II, ch. 4, p. 255, 259
ch. 7, pp. 327 ff.
ch. 11, p. 361

Commerlinus

Connor, Bernard, in diss. Medico-phys., II, pag. 4.

Delacampius

*Descartes, Princ., Part III, sections 33, 10, 12, 152

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De la Hire, Memoires de l'Adad. Royale des Sciences, A. 1701

*DeVries, (Gerhard), de lunicolis, pp. 251-260.

DeVries, Simon, Med. Libr., recens edit., p. 113.

Diogenes Laertius

Dougtaeus

*DuHamel, Astron. Phys., Lib. II, ch. 4, pp. 97-99, 118
in Hist. Acad. Reg., Lib. VI, part I, sect 2, ch. 1, pp. 553-4
Lib. III, part I,sect 3, ch. 2 p. 256

*Fabri, Honoratus, Phys., T. IV, tract. VIII, Lib. I, props. 34-74, 88

Feuillée, Journal des observ. Phys. Math. & Bot. T. I, p. 338
II, p. 369
Histoire de l'Acad. Royale des Sc., A. 1699, p. 96 ff.
Memoires de l'Acad. Royale des Sc., A. 1701, p. 388 ff.
Act. Erud., A. 1725, p. 272.

Fontenelle, Entretiens, p. 33, 38 ff., 42

*Galileo, De syst. mundi, Dial. 1, p. 54 ff, 58, 63, 72 ff, 82 ff 89, 91

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Ursinus, in Analect. Sacr., part II, Bk. II, pp. 96 ff.

Virgil

Weigelius, in Sphaer. Euclid, p. 31 ff.
Supp. Act. Erud., T. II, p. 451.

*Wolf, in Elem. Math. Univ., II, pp. 466-471 especially.

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into general works of natural philosophy, most notably Sammuel Clarke's commentary on Rohault's Physics, Keill's Introduction to the True Astronomy, J.B. DuHamel's Astronomia physica, the physical works of Sturmy, and at least one widely known work of Christian Wolff.

The Dissertatio is thus a veritable source book for anyone interested in the early history of planetary physics, for Arntzen conceives his purpose very broadly as the compilation of all knowledge about the nature of the moon: its composition, surface features, the nature of its light, its spots, and the climatic conditions prevailing there. Not all of this, of course, is directly relevant to the question of habitability; indeed, the first 19 of 30 sections which constitute Part One are only preliminary to the actual determination of conditions on the moon, namely, the existence of water (sections 20-23) and of an atmosphere (sections 24-28).

As we well know by now, the existence of water was directly tied to the nature of the lunar spots, and Arntzen began his discussion in section 20 by expounding some of the standard opinions concerning the nature of these spots, many of which we have already seen in Wilkins: that of Clearchus, who thought that the lunar spots were only images of the earth reflected on the polished sphere of the moon; of the ancient Stoics who believed the spots were cavities filled with air; the "more famous and elegant" opinion of the peripatetics that the appearance of spots on the moon was

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caused by a difference in the density of its parts, the denser parts reflecting more light than the less dense parts. But for Arntzen the dark spots were not simply less dense parts of the moon. Rather, he held that it was much more likely that these spots represented seas and lakes, an opinion, he was quick to point out, which was held by the Pythagoreans, Plutarch, and one which "almost all of the more celebrated modern astronomers, Huygens excepted, demonstrate solidly with diverse arguments."[50]

In fact, however, the "diverse arguments" of the modern astronomers added little that was fundamentally new to the arguments already found in Wilkins. Galileo's remark that the surface of water appeared less bright in general than rugged land, supported by the experience that from a very high mountain on earth the water always appeared to reflect light less than the surrounding land, could only be repeated and given the added weight of the assent of Antonius De Rheita and Gaspar Schott.[51] A further assertion culled from Gassendi, Fabri, and DuHamel to the effect that the generally smooth surface exhibited by the dark lunar spots agreed very well with the "laws of fluids" was hardly earth-shaking, although the related point that the small depressions which some astronomers had observed there might be whirlpools of water "flowing toward the center of its motion," was more subtle and ingenious.[52] Perhaps the most important piece of new evidence presented in support

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of the existence of seas on the moon was Hevelius' observation reported in the Selenographia that certain points on the moon underwent sudden and fleeting changes in color. Arntzen proposed that a plausible explanation for such color changes might be found in the large-scale motions of the lunar seas, for he agreed with Kepler (although he did not cite him here) that any seas on the moon should indeed be subject to tides just as seas on the earth were.

At this point early in the eighteenth century, Arntzen perceived especially three opponents to the hypothesis of lunar seas: Huygens, Francis Baile, and John Keill.[53] The objection of Huygens, supported by Keill, was that with a long telescope round cavities could be observed in those dark spots of the moon which were supposed to be water. This was not a problem to be taken lightly, and, apparently not impressed with the "whirlpool" theory mentioned earlier, Arntzen countered that islands, peninsulas, and rocky areas which might contain such depressions should be found in lunar seas no less than terrestrial seas. In fact, again drawing upon Hevelius, he noted that astronomers had even given the name of "islands" to such appearances in the midst of the dark spots. The objection of Baile that clouds should form and be observed above any lunar seas was considered less forceful, for Arntzen believed that there were regions of the earth where water was abundant but clouds did not form.[54]

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Some measure of the progress of observational astronomy since the time of Wilkins is inherent in the very fact of Arntzen's discussion of the existence of rivers on the moon, a discussion less significant for the general debate over lunar water than for what it tells us about the current limits of telescopic resolution. Arntzen strongly favored lunar seas and even lakes, but he considered the existence of rivers on the moon "a more intricate matter" precisely because of the problems of the resolution. He was aware that Huygens held that the resolution of his telescopes would not permit such rivers to be observed, and furthermore that Nicholas Hartsoeker had calculated in his Dioptrics that a lunar feature observed with a 36 foot telescope to subtend an angle of only six minutes would be 14,000 feet wide, from which Hartsoeker came to the same conclusion as had Huygens.[55] On the other hand Cassini, according to Fontenelle, had observed certain features on the moon "which separate into two lines, and then come together again," a feature, Arntzen concluded, which could only be explained as analogous to terrestrial rivers.

Thus, almost a century after the publication of Wilkins' Discovery, the moon for Arntzen was a world of continents, seas, lakes, rivers, and islands. It was not so for everyone, but it is clear that the issue of water on the moon was diffused throughout the learned world not only as expected through the works of Hevelius, Fontenelle, and Huygens, but also by the likes of Riccioli,, Sturmy, Wolff, Hartsoeker, and Gassendi.[56] The

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famed astronomical observer Auzout declared in the Philosophical Transactions of 1665 that judgement should be suspended on the issue, and although the features on Riccioli's famous lunar map (see next page) were designated by the suggestive names "sea", "land", "island", and "peninsula", a sensitive Riccioli made his position abundantly clear in the caption above the map: "Nec homines lunam incolunt, nec anime in lunam migrant" ("no men live on the moon, and no souls wander there").

In spite of an improved corpus of observations, the controversy continued. A measure of explanation is found in the thought processes of Arntzen, which reveal a powerful force operating in conjunction with the increasing body of observational data. That force was the invocation of analogy with the earth in cases when it was often unjustified. Once the gross similarities between the earth and the moon had been established, the tendency was to search for more and more similarities. It was only with this in mind that a relatively innocent flash of color could be interpreted as the effect of lunar tides, an interpretation built upon another interpretation that the dark spots were seas. Arntzen's statement that "since it is agreed the moon consists of the same matter as the earth, we are able to find nothing which agrees more with that observation of Cassini than if we assert it to have been a river,"[56a] betrays the fallacy which prevented a quick solution by means of observation to the problem of the nature of the moon.

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VI FIGURA PRONOMENCLATVRAE LIBRATIONE LUNARI
Nec Homines Lunam incolunt
II OCTANS
Nec Animæ in Lunam migrant
I OCTANS
III OCTANS
TERRA
SICCITATIS
Mare Frigoris
Terra Grandium
Mare Imbrium
Mare Serenitatis
Mare Vaporum
Mare Tranquillitatis
Mare Nubium
Mare Humorum
Mare Crisium
Lacus Somniorum
Lacus Mortis
Palus Putredinis
Palus Nebularum
Sinus Iridum
Sinus Aestuum
Sinus Roris
Sinus Medii
Oceanus Procellarum
Pericula Tempestatum
Promontorium Acutum
Promontorium Taurorum
Promontorium Heraclides
Promontorium Laplacium
Promontorium Agarum
Promontorium Archimedis
Promontorium Agassiz
Promontorium Deville
Promontorium Kelvin
Promontorium Fresnel
Promontorium Fabricius
Promontorium Ampere
Promontorium Cauchy
Promontorium Kepler
Promontorium Copernicus
Promontorium Laplace
Promontorium Gay-Lussac
Promontorium Olbers
Promontorium Archerusia
Promontorium Heraclides
Promontorium Taenarium
Promontorium Carpatus
Promontorium Pyrenaeum
Promontorium Caucasus
Promontorium Caucasus
Promontorium Caucasus


TERRA
Mare Nubium
Mare Tranquillitatis
Mare Crisium
Mare
Terra
Humorum
CALORIS
TERRA STERILITATIS
VOLUPTATIS
Tycho
Copernicus
Kepler
Aristarchus
Plato
Archimedes
Eratosthenes
Timocharis
Aristoteles
Endymion
Posidonius
Manilius
Menelaus
Autolycus
Aristillus
Theophilus
Cyrillus
Catharina
Langrenus
Petavius
Vendelinus
Furnerius
Abulfedea
Albategnius
Hipparchus
Ptolemaeus
Alphonsus
Arzachel
Thebit
Sacrobosc
Fracastor
Piccolomini
Zagut
Purbachius
Regiomontanus
Walterus
Werner
Apianus
Blanchinus
Gemma Frisius
Nonius
Maurolycus
Stöfflerus
Metius
Rothmannus
Gallet-Hall
Hainzelius
Phocylides
Bayerus
Longomontan
Scheiner
Blancan.
Gruemberger
Clavius
Bettinus
Riccher
Moretus
Hagecius
Fabricius
Lubienitzius
Clavius
Barrelus
Calvus
Linné
Ausa
Cleomedes
Firmicus
Agrippa
Sosigenes
Taruntius
Fracastorius
Julius Caesar
Cassini
Hesiodus
Agrippa
Sosigenes
Mare Crisium
Mare Tranquillitatis
Mare Nubium
Mare Humorum
Terra Nivium
Mare Vaporum
Mare Serenitatis
Mare Fecunditatis
Mare Foecunditatis
Mare Marginis
Mare Australe
Mare Australe
Mare Australe

The problem of a lunar atmosphere also remained unresolved in 1726. The strength of Arntzen's conviction that an atmosphere was crucial to the habitability of the moon was undoubtedly affected by the Dissertatio de atmosphaero of his dissertation director, from which he took his definition of "atmosphere": "By atmosphere (atmosphaera) philosophers and mathematicians understand that air (aer) surrounding the earth, in which vapors are collected, clouds float, and which furnishes the matter for respiration ... from which we conceive that if we consider the moon to be habitable, it cannot lack an atmosphere."[57] The reference to the atmosphere as the receptacle of vapors undoubtedly reflects the still current "exhalation" theory of which Wilkins had spoken. But to judge from Arntzen, the many prominent thinkers since the time of Kepler and Wilkins who had opposed the idea of a lunar atmosphere, including Riccioli, Huygens, Whiston, Keill, Cassini, De la Hire and Newton, did so not on the basis of the possible origin of such an atmosphere, but on the basis of direct observation. For during the seventeenth and early eighteenth centuries a new but controversial body of observational data had accumulated especially around three of those phenomena which Kepler and Wilkins had used as proof of a lunar atmosphere: the solar eclipse annulus, occultations, and "trepidations" or flashes of color around the rim of the moon. It is to an examination of this disputed body of evidence that Arntzen now turned.

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Arntzen himself felt that the most compelling demonstration of a lunar atmosphere was that observation during a solar eclipse of a "certain illuminated part appearing around the moon, as if the globe of the moon contained an annulus."[58] Kepler had argued that this was only an optical effect due to the camera obscura with which the eclipse was observed. But perhaps because he believed the naked eye showed the same phenomenon, Arntzen ignored Kepler's argument and cited him along with Vendelinus, Wolff, Fabri, DuHamel, and Sturmy as accepting this observation as proof of a lunar atmosphere.[59] Such a phenomenon would be caused when the solar rays incident on a circumfused lunar atmosphere underwent refraction, and thus generated to our eyes the appearance of a ring around the moon.

The thrust of the controversy since Kepler, Arntzen leads us to believe, had not centered around the possibility that this phenomenon was an optical effect, but rather around the contention that this annulus might be the substance of the sun itself, a belief held by Riccioli, Cassini, and Newton.[60] The whole controversy hinged on a determination of the relative diameters of the sun and moon, for if the apparent diameter of the moon was never smaller than that of the sun, the annulus could not represent a direct observation of the substance of the sun itself. Kepler, Duhamel, and Wolff, according to Arntzen, had argued that the apparent diameter of the moon was greater than that of the sun during a solar eclipse, thus proving the existence of a lunar atmosphere. DuHamel, for example, made the following statement in his Astronomia physica:

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> The annulus around the moon produced in a total solar eclipse proves that the moon has an atmosphere. Nor is it permitted for them to say that it happened because the moon did not entirely cover the sun; for in the year 1560 an eclipse was observed by Clavius, in which the moon was certainly at perigee, and the diameter of the moon, if not more, was certainly as great as that of the sun, and nevertheless an annulus was seen, which can be deduced in no other way, than from the refraction of the rays in the atmosphere of the moon; therefore, it is not abhorrent from the truth that the moon, like the earth, is surrounded by a certain dense nebulous air.[61]

The fact that the moon was at perigee meant that its apparent diameter was as large as it would ever be; the presence of an annulus under this extreme circumstance, DuHamel thought, destroyed the "solar substance" theory.

Another relevant passage was cited from Christian Wolff:

> An observation of great worth was a lucid annulus around the moon, parallel to the limb of the moon, which I clearly distinguished from the lucid part of the sun, since I was able to contemplate it with some care: For the splendor of the sun was not the only splendor of the ring which had a silvery color, but much surpassed it, and indeed also the lucid part of the sun did not end in the same place with the periphery of the ring. The annulus was observed more dense in the obverse part of the moon, more rare in the averse part, nevertheless ending in an exact periphery.[62]

This latter observation, Arntzen noted, contradicted the theory of Cassini and Muller that the ring might consist of a vaporous material diffused into the ether by the sun (again an exhalation theory) by means of which solar rays through the reflection or refraction might produce such a "corona". For Wolf had observed the annulus to end at an exact periphery, and moreover pointed out that on the theory of Cassini and Muller there should be an even stronger annulus around the planets Mercury and Venus which were closer to the sun than the moon, but this was seen not to

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be the case. Thus, with the continued proliferation of interpretations, the lunar annulus remained intimately associated with the question of a lunar atmosphere.

A second body of observations bearing on the question of a lunar atmosphere was that of occultations. The gradual occultation of a star by the moon was affirmed by DuHamel, and especially by Feuillée as recently as the 1725 Acta Eruditorum, the year before Arntzen published his dissertation.[63] Not only did DuHamel's Astronomia physica assert that this gradual diminution of light indicated the existence of a lunar atmosphere, but also that the height of such an atmosphere might be determined by careful observation; in one particular observation he noted that the star entered the lucid part of the moon at a distance of $1\frac{1}{2}$ diameters of the star from the body of the moon itself. But 40 years later, Arntzen noted, DuHamel had changed his mind, and followed Phillipe De la Hire. DuHamel wrote in 1699 that

> Certain objects appear brighter to us than they ought to, for by reason of their distance these rays easily come together and paint a bigger, but confused, image on the retina. Telescopes do not altogether remove this false increase in bodies. Therefore, it is suspected that a star observed for a space of time in the lunar disc runs together with that increased image of the moon, but is in reality occulted by the exact body of the moon.[64]

Arntzen did not accept this explanation, and argued that an occultation of Venus disproved this theory, for here it was seen that the actual body of Venus, without any increase size of its own, began to be diminished before it was covered by the true body of the moon. It is not clear that this rejoinder, or

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Arntzen's further comparison of occultation phenomena with images received through the microscope, really went to the heart of the matter, but the fact remains that the optical effect theory was rejected.

In order to conclude his discussion of the lunar atmosphere, Arntzen brought forth more "no less elegant observations". Along with the annulus sometimes observed during a solar eclipse were those trepidations and fluctuations around the periphery of the moon cited by Scheiner, Kircher, and Wolf.[65] Cassini and Wolf mentioned a change in shape of Jupiter and the fixed stars as they approached the body of the moon. And although the existence of clouds was a "very intricate matter" which had been denied by Galileo, DeRheita, Fabri, Keill, Auzout, and Muller among others, nevertheless Vendelinus and Wolf affirmed them, and Arntzen thought that there might be some observations here which at least required explanation.[66] Combined with the opinion of the famous Robert Boyle that no body was devoid of an atmosphere, with this body of observations Arntzen had at least given his readers ample food for thought.[67]

In the first part of his treatise, then, Arntzen had proven to his satisfaction that "the moon may with merit be called another earth, and in it may be discovered all those attributes, properties, and qualities which can make possible the existence of animals on the moon."[68] It would seem at this point that the author had achieved his goal, but the existence of a second section betrays Arntzen's realization that human reasoning, even when aided by the best tools of observation, is not a simple or perfect

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process. It is not simple because more than observation is involved; it is not perfect because even if observation were paramount, there would be diverse interpretations of observations. Thus Arntzen noted that no less than among the ancients, modern thinkers too were found on both sides of the debate over the lunar world,[69] and he attempted to analyze the reasons for this in the light of present knowledge. Many of the reasons were metaphysical, and Arntzen found that some considered the habitability of the moon to be a rash opinion, because the Creator would have made such a great manifestation of his power and wisdom much more evident to the human mind than it was; others argued for the habitability of the moon because they believed the Divine wisdom and power must necessarily have been exercised in this way. Arntzen put no faith in either of these types of arguments, and pointed out that "the logicians teach that to proceed from the posse to the esse is not a valid conclusion," and that it would be better to wait for the perfection of the telescope to prove the actual existence of lunar inhabitants.[70] Those were therefore more prudent who did not assert that the moon was actually inhabited.[71]

Scriptural arguments too were made, as when Adam Tanner, Andala, DeVries, and Muller insisted that a lunar world would necessarily have been revealed in the Bible, and the latter two added that the focus on the earth in the Genesis story was proof enough of its uniqueness in the universe. On this basis, Arntzen answered, all telescopic observations would have to be rejected,

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for Scripture also said nothing about the moons of Jupiter.[72]

The remainder of Arntzen's treatise was a resounding defense of what had gone before. One by one the objections against the habitability of the moon are paraded before the reader and dealt with: that the moon lacks clouds (section 7 and 8), that its temperature extremes are too great to support life (sections 9 and 10), that it is composed of rocks too hard for plants to grow in, without which plants there can be no animals (section 12), and that it lacks an atmosphere (section 13). All of these objections are rejected or circumvented based on what had been presented before in detail.

Arntzen saved for last that objection which he perhaps considered most inimical, one which, if accepted, would undermine all of his other arguments. It had been championed by Gerhard DeVries in the Dissertatio academica de lunicolis written and delivered in public lecture at Utrecht precisely 50 years before. Simply stated, it asserted that observations of the moon were illusory, due to the testimony of "weak eyes, fallacious instruments, and the prejudice of the imagination," and that anyone who accepted the primacy of reason in natural philosophy should certainly not be convinced by these arguments taken from the senses.[73] Arntzen, who had founded the arguments in his own Dissertatio largely on observation, took violent exception. Anyone, he fumed, who denied observations made not once but a hundred times and who denied thus in general the faith of the senses, pursued not a "more sublime philosophy", not truth,

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but merely the confirmation of his own preconceived opinion. The honest man, he continued without pause, does not teach others to deny the faith of observations, especially if there are many of them, but rather to detect any contradictions or absurdities among them.[74]

It was a laudable statement from the young student at Utrecht who had been tutored well in the new trend of natural philosophy. But there was an ironic twist of truth in the warning of the peripatetic DeVries. Although Arntzen felt that there were no absurdities or contradictions of a fundamental kind in the corpus of lunar observations, he would be the first to admit that there were certainly a variety of interpretations of those observations, for his treatise had scrupously set them forth. He truly believed in his interpretation of the dark lunar spots as water, and of the lunar annulus, occultation phenomena, and flashes of color as manifestations of a lunar atmosphere. While he had successfully jettisoned any religious prejudice, Arntzen yet remained the unsuspecting victim of an equally pernicious metaphysical framework, one which caused him to overzealously transfer terrestrial experience to his interpretation of lunar phenomena.

Engman's Dissertatio (1740)

A brief examination of the Dissertatio astronomico-physica de luna non habitabili (1740) will suffice to show the dramatic result when metaphysics is at last successfully divorced from observation in the debate over the lunar world. It is perhaps

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no coincidence that this divorce occurred in a work directed by Anders Celsius, a Swedish astronomer known for his skill as an observer, and who had only two years before returned from an expedition with Maupertuis to report in De observationibus pro figura telluris determinada (1738) that Newton's theory of flattened poles had been verified by observation. It is likely that Celsius independently influenced his student Eric Engman to write this treatise,[75] since there is no evidence that either knew of Arntzen's work, in spite of the precise asymmetry of titles.

Engman's work is much briefer than that of Arntzen, for he wasted no time coming to the central issue: "Whoever holds the moon to be habitable must propose that it will be surrounded with an atmosphere."[76] Engman noted that he was well aware of many observations which seemed to support the hypothesis of a habitable moon, but he immediately reveals an approach to these observations far different from that of Arntzen. Instead of "prejudging" that the moon had an atmosphere and accumulating more and more arguments in favor of this hypothesis, he would ask "whether the phenomena which occur in the body of the moon, from whence they conclude it is surrounded by air like the earth, can be explained in another way ..."[77]

There was no doubt concerning the primary phenomena at issue, only of their explanation. Engman noted that Feuille and De la Hire had observed an occultation of Aldebaran by the moon, in which the star entered a "lucid disk" before it disappeared

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behind the moon. Celsius himself had observed on July 22, 1736 with a one foot Gregorian telescope that a star gradually disappeared into the lucid limb over a period of 2 or 3 seconds, and De L'Isle observed the same phenomenon in an occultation of Venus on June 28, 1715 at Paris. In accordance with his prescribed program, Engman noted that all luminous bodies, even when viewed with a telescope, "have a larger diameter in the retina, so that the true image is confounded with other light," a phenomenon called adscititium by Galileo, adventitum by Horrox, erraticum by Newton, and dissipatum or penumbra annularis by Jurin. In stark contrast to Arntzen but reminiscent of Kepler, Engman believed that this was an optical effect demonstrated by experiment,[78] and that therefore when a star is gradually occulted by the moon, it "enters not the atmosphere of the moon, but its erratic light, which our sight confounds with the body of the moon itself, and is occulted by the true limb of the moon."[79]

An optical effect of another kind was put forth as the explanation for the annulus phenomenon during a solar eclipse. Again, the phenomenon was not disputed, and Engman cited as an example the solar eclipse of April 22, 1715 which was observed in both England and Sweden, and for which Louville had observed that the moon's apparent diameter was 33' 28" and the sun's 31' 54", so that the body of the sun itself could not be the cause of the annulus. But the explanation for Engman was not the existence of a lunar atmosphere, but rather an effect variously referred to as "inflexion, reflection, and refraction," by which

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"rays of light are deflected from a right line when they approach the extreme edge of an opaque body," and which had been supported by the experiments of Grimaldi, Newton, De L'Isle, and others.[80]

The claim of color changes of an occulted body (as opposed to color changes during solar eclipses which Arntzen had mentioned) provided another test for Engman's critical faculty, but this time he did not even need to invoke optics. Although he reported that Louville, De L'Isle, and Charledon had observed such a color shift during an occultation of Venus at 1:30 a.m. on June 28, 1715, he pointed out that it was also true that Malezieu, Cassini, and Maraldi had observed precisely the same occultation and observed no color change.[81] And an occultation of the planet Jupiter on 25 July, 1715, for example, showed no such color change. On the grounds that the same cause would always produce the same effect, Engman rejected the validity of these observations, and suggested that they might be due to the objective lens of a particular telescope.

Stripped in this way of its atmosphere, there was no doubt in Engman's mind that it could not support life, and with gathering momentum he went on to assert that neither was there any solid observational evidence of the existence of water. He emphasized that Christian Huygens among others had observed cavities in those dark spots which were supposed to represent water, an observation sufficient in itself to disprove this theory. But this conclusion was supported on theoretical grounds that, according to Newton, the moon was more dense than the earth in the ratio of 11:9, and therefore could not contain large bodies

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of water which would be of low density.[82] The absence of water and an atmosphere, Engman continued ever more confident, meant that there were no clouds, rivers, or streams on the moon, a fact accepted by Huygens in the Cosmotheoros, but which had become questionable on the basis of observations reported by Kepler and Cassini.[83] Neither did observation reveal forests, and least of all, cities, on the moon.

In a simple and direct manner not at all characteristic of Arntzen's treatise, Engman had found plausible alternatives for all of the observations which had been put forth in favor of a habitable world. The fourteen years which had intervened since Arntzen's work had not brought new and crucial observations, nor did Engman have access in general to a better or different body of data. The essential difference was one of approach, the willingness and indeed the insistence by Engman that alternative explanations be given due weight, expecially when founded on well known laws of optics. Like Arntzen, Engman shunned obvious metaphysical arguments. He did not see the force of the argument "that God, whose every action has a sufficient reason, would not produce in vain a most vast body in the moon with its own decorations and qualities," not because he denied teleological reasoning, but because he thought the moon had a great effect on terrestrial life, lighting the night, distinguishing the times of the months and festivals, and guiding ships in their navigation.[84] He equally denied Christian Wolff's argument that the power, perfection, and wisdom of God demanded that there

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be creatures of reason on the moon, since there were no such creatures in the water or the air even on earth.

The difference between Engman and Arntzen, then, distilled to the observations themselves and the paths of reasoning immediately surrounding them. Unlike Arntzen, Engman denied in his concluding section the essential similitude of the earth with the moon. That denial was not only a conclusion, it was also an important part of Engman's approach to the observations, and it prevented him from making some of the dubious inferences which Arntzen had made when the observations were ambigious. "From similitude," Engman admitted, "philosophers often deduce many truths, and indeed with merit. Which method of philosophizing also has its place when we deny or embrace or construct by the power of the analogy of nature, the firmest physical principles."[85] But,he cautioned, when it comes to the fine points of investigation, one must not transmute similitude into identity. If similitude allows us to concede the possibility of inhabitants on the moon and the planets no less than on the earth, it denies that they could be of the same nature or sustained in the same way as terrestrial inhabitants. Engman did not allow the process of observation to become overpowered by the argument from similitude, a mistake which had yielded Arntzen's results.

Engman had spoken wisely and from experience when he remarked at the opening of his treatise that "No one will deny that physics, when associated with the word 'celestial', is involved with many difficulties, since its certainty is permitted

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only through arguments deduced with many ambiguities from the analogy of nature and from appearances."[86] Even in the case of the moon, where by virtue of its proximity to the earth the "appearances" were most easily determined, celestial physics was a difficult undertaking.[86a] But, inspite of the inherent difficulties, the treatises of Kepler, Wilkins, Arntzen, and Engman, and the much more broadly based tradition of opinion which they embody, represent the determination of 17th and 18th century natural philisophers to answer as best they could a question of utmost importance.

THE PLANETS

Huygens' Cosmotheoros (1698)

It is remarkable that the two most significant thinkers at the end of the seventeenth century to proclaim the habitability of planets at the same time denied any inhabitants to the moon. For most of the century the habitability of the moon and of the planets were closely associated; Wilkins' passing remark that each of the planets "may be a several world ... but this would be too much for to vent at the first ..."[87] represents the attitude that even if separate arguments would eventually be presented for the planets, the proof of a world in the moon was fully intended to ease the seventeenth century into a solar system filled with inhabitants. Some explicitly saw the moon as the crucial test case for the whole extraterrestrial life

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controversy, as when DeVries declared that he would banish inhabitants from the celesial regions by disproving the habitability of the moon. But when Fontenelle and Huygens firmly took the larger steps into the solar system, it was not at all on the basis of what had been learned about the moon. Their denial of life on the moon indicates that more than mere extrapolation was involved in the population of the planets.

The treatises of Fontenelle and Huygens have much in common, and it is not surprising that the 1698 Cosmotheoros has often been seen as an imitation of the Entretiens published only 13 years earlier. Both authors had been immersed in a similar Parisian cultural and intellectual milieu. Both of their works were clearly influenced by the heliocentric theory and the theory of Cartesian vortices, although Huygens was much more sceptical of the details of the Cartesian theory than was Fontenelle. And each work denied the habitability of the moon, asserted the habitability of the planets, and in the end carried the reader into an infinite universe of suns and planetary systems.

There was, however, a major difference in the specific background and experience of the two authors at the time they wrote their treatises. The Entretiens was one of Fontenelle's earliest works, the product of a burst of literary compositions which from 1680 to 1688 brought forth also the Dialogues of the Dead, The History of Oracles, and the Discourse concerning the

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Ancients and Moderns. It was as a young man of 29 that Fontenelle produced his work on the plurality of worlds, with his career as the chief French spokesman of science still far in the future. The Cosmotheoros, on the other hand, was the final work of a man who had been not only one of the seventeenth century's greatest scientists, but also its most accomplished observational astronomer. By the time he began work on his last treatise, Huygens had made significant contributions to the study of motion and gravity, invented the pendulum clock, proposed a wave theory of light, mastered the art of telescope making as no one had before, and used his telescopes to make many astronomical discoveries.[88] Given this disparity of backgrounds and Huygens' apparent feeling that Fontenelle's Entretiens needed to be improved upon, it is perhaps more fruitful to probe the differences in the two treatises than the similarities. This approach indicates that while the roots of Fontenelle's work may be found in his devotion to the theory of vortices,[89] Huygens is rather motivated to a great extent by his experience as an observational astronomer, an experience which led him to the question of the habitability of planets while Fontenelle was still an infant.

Already in the Systema Saturnium (1659), an early work in which Huygens first correctly interpreted the phenomena related to Saturn's ring, Huygens made widespread use of fictitious inhabitants of Saturn in order to discuss various astronomical phenomena as seen from Saturn itself. The use of Saturnians

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was put forth ostensibly as a heuristic device for studying and presenting these phenomena, yet the status of the inhabitants was not made entirely clear as Huygens began his explication.

> Now it will perhaps not seem strange to the nature of our subject if, just as up to new we have regarded the system of Saturn from our terrestrial point of view, we now transport our contemplations to the globe of Saturn itself, and examine how the universe appears from there, what must be the intervals of years, months, and days there, and how the seasons succeed one another, and above all what the effects must be of having a ring which surrounds the planet for those who inhabit it: because it must deprive certain of the inhabitants during a great lapse of time of the sight of the sun, and at other times diminish the nocturnal shadows, raising itself above their horizon under the form of a luminous arc.[90]

In a remark which further undermined the supposedly fictitious nature of the Saturnians and which indicated the sensitivity of the subject of extraterrestrial inhabitants at mid-century, Huygens went on to point out that he hesitated to speak publicly in such terms because other astronomers could easily deduce these Saturnian phenomena themselves, "and also because among the same astronomers (not to mention others) there must be a great many to whom a study of this kind would seem useless and vain, and moreover they might think it absurd to believe that beings endowed with reason could inhabit Saturn and the other planets."[91] While admitting that others might consider such an idea absurd, Huygens himself did not make a commitment here, and much of the ensuing discussion of Saturn was couched in terms of its inhabitants.

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Huygens' failure in the Systema to deny clearly the reality of Saturnians caused him trouble a few years later when the Italians Fabri and Divini chided him on this point while rejecting his interpretation of Saturn's rings. In the Brevis annotatio in systema saturnium (1660) Fabri and Divini declared it "useless to say anything about the inhabitants of Saturn; that invention is better refuted by laughter than by argument, moreover it is here in opposition to Catholic dogma, which only recognizes men descended from Adam."[92] Although this was only a minor part of the total rejection of the ideas in Huygens' Systema, it undoubtedly reflects the dominant opinion in Catholic Italy; Moreover, this criticism evoked a response from Huygens which makes his position in 1660 quite clear. Huygens replied that he was not at all surprised that Fabri, at least, "cannot endure my mention of the inhabitants of Saturn," since the Italian was a Tychonian for whom the planets are consequently in no way similar to the earth. Huygens further noted that he himself "would not have been the first to promulgate that idea, and it would not be so ridiculous in the eyes of philosophers as he [Fabri] thinks."[93] Although at this point Huygens declined to defend any further the reality of extraterrestrial inhabitants, he clearly numbered himself among those philosophers for whom the idea was not so ridiculous. For the present he claimed only that Fabri and Divini had falsely accused him, since in the Systema he meant only to use the inhabitants as fictitious observers, having no basis in reality, a technique which he pointed out was often employed by astronomers.[94]

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This brief encounter with the question of the habitability of planets, together with the ongoing controversy generated by the works of Kepler, Wilkins, and Borel, undoubtedly entrenched the matter in Huygens' mind as an issue which demanded serious thought.[95] But how could one answer such a "noble and sublime" question, as Huygens would later term it? For more than two decades the problem must have lingered in Huygens' mind, as he occupied himself with other studies of profound importance for natural philosophy. Then in the early 1680's a renewed interest in the habitability of planets occurred, as is indicated by a remark in the Cosmotheoros that the subject "has often been our talk, I remember, good Brother, over a large Telescope, when we have been viewing those Bodies, a study that your continual business and absence have interrupted for this many years."[96] The remark was addressed to Christian's brother Constantine, who had been his companion in observation in the years following 1681. It was thus in the context of planetary observation that Huygens was launched on the path that culminated with the Cosmotheoros.

Observation, however, was far from providing a solution to the problem, and indeed Huygens admitted that he and his brother "were always apt to conclude, that'twas in vain to enquire after what Nature had been pleased to do there, seeing there was no likelihood of ever coming to an end of the Enquiry."[97] This attitude of the early 1680's is confirmed in the Astroscopia compendaria (1684), the treatise where Huygens proposed the construction of tubeless telescopes of long focal length. Here the

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famed astronomer remarked that although he did not wish to impose any precise limits on the improvement of the telescope, he nevertheless did not think that either the moon or the planets would ever be observed with a telescope so closely that one could tell directly whether there were animals, a hope which had been expressed by Descartes.[98]

If extraterrestrial life could never be detected directly by observation, Huygens gradually became convinced that the subject might still be discussed fruitfully. He recalled again in the Cosmotheoros that "a while ago thinking somewhat seriously of this matter ... methoughts the enquiry was not so impracticable, nor the way so stopt up with Difficulties, but that there was very good room left for probable Conjectures."[99] But what good were probable conjectures to a man who by this time had made so many solid advances in natural philosophy, what good a subject which by his own admission was "not of that nature as to admit of a certain knwoledge"? Huygens had an answer to this question which is worth repeating, since it bears on his natural philosophy as a whole, and indicates how the subject of the habitability of planets found a place in that natural pholosophy.

> I can't pretend to assert anything as positively true (for that would be madness) but only to advance a probable guess, the truth of which every one is at his own liberty to examine. If any one therefore shall gravely tell me, that I have spent my time idly in a vain and fruitless enquiry after what by my own acknowledgement I can never come to be sure of; the answer is, that at this rate he would put down all Natural Philosophy as far as it concerns it self in searching into the Nature

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> of things: In such noble and sublime Studies as these, 'tis a Glory to arrive at Probability, and the search it self rewards the pains.[100]

The chief role of the natural philosopher, Huygens continued, was to exercise his judgement to determine which of all the possible probabilities was nearest to the truth, a continuing process which would be aided by new insights and techniques. The importance of this attitude cannot be overemphasized in any attempt to understand the true place of the Cosmotheoros among the rest of Huygens' works.

It was with this kind of epistemology in mind that Huygens began to formulate in late 1686 his probable conjectures, and "as they came into my head ... clapt them down into common places," finally to be synthesized in the Cosmotheoros.[101] These early disjointed thoughts may be identified among those pages which have first been printed in the latest edition of Huygens Oeuvres under the title which Huygens himself gave them, the "Pensees Meslees". Here are found the bare outlines of thought, free from the verbiage and hedging inevitably present in the more refined work meant for publication; here are the spontaneous thought processes of a great natural philosopher set down on paper; here the beginnings of Huygens' most serious attempt to come to grips with the problem of the habitability of planets.

As a set of spontaneous thoughts, the 59 brief sections of the "Pensees" exhibit no conscious structure except that of Huygens' own train of thought. They range from discussions of a model of the solar system that Huygens had built in 1682

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(sections 1-4, 14, 20-21) to the real solar system itself (especially sections 6, 17-18, 24-29, 36-41, 44-49, and 52-54) and cosmological and philosophical remarks about the world beyond the solar system (especially sections 30-35, 47, 55-59). It is evident throughout all of this that one thought in particular preyed upon Huygens' mind at this early stage, a thought which his scientific integrity forced him to carry to its logical consequences. In Latin and in French and once in Latin verse, as an isolated thought and as part of a larger context, Huygens wrote four time throughout the "Pensees" the phrase "that we are in the heavens".[102] The power of this thought for Huygens and its direct link to the subject of the habitability of planets becomes evident when he follows it in one case with the further thought "that what seemed to be chimerical has become truth. Democritus. Bruno, but in what he has erred."[103] The ancient atomist doctrine of an infinite number of worlds suddenly seemed to contain an element of truth, all the more so because Huygens realized that even more was at stake than our own solar system. The Copernican system made clear too the immense distances of the fixed stars, and revealed another truth which Huygens jotted down with devastating logic:

> How small the sun appears from the fixed stars. Smaller than they do to us. Then they cannot be illuminated by the sun any more than the earth can by the fixed stars. Therefore they have their own light. That they have their own light like the sun, and that they are not smaller than it, is to say that they are suns.[104]

Here is the kernel of the Cosmotheoros, the seminal thoughts which drive Huygens onward in his quest for truth.

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Viewed as an attempt to work out the physical consequences of the Copernican theory, the diversity of the "pensees" becomes more understandable. The concern for the reconciliation of Descartes' vortex theory with Kepler's laws, in the midst of the discussion of the nature of the planets and with intermittent remarks about the world at large, is an expression of Huygens' deep desire to arrive at a philosophically and scientifically satisfactory picture of the physical world. If in this year before the publication of Newton's Principia Huygens was still uncertain about the physical basis for the motion of the planets (as he would be even after the Principia appeared), his knowledge of the physical nature of the planets themselves was more assured. It was Huygens the observational astronomer who now wrote "that the planets are similar to the earth. their movement on their axis. the moons of Jupiter and Saturn, discovered by myself and Cassini. They present Jupiter and Saturn with the same view as does ours."[105]

It was also the seasoned observational astronomer, whose instruments had far surpassed those available to Kepler or Wilkins, who now insisted on a distinction between the moon and planets: "the moon different. without seas or clouds or atmosphere. clouds in Jupiter. that there is the probability of creatures and animals in the planets. very reasonable. argument from fruit trees. trees on an island. the rings of Saturn. what appearances it has to the inhabitants of Saturn."[106] And so the transition was made to the subject of inhabitants. Those inhabitants of Saturn, first spoken of in the Systema almost 30

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years before, had never been forgotten. A much more experienced observational astronomer now, Huygens had begun to formulate an argument based at least in part on observation. The observation of clouds on Jupiter is seen to play an important part in the judgement that it might be inhabited, although the "argument from fruit trees" indicates already Huygens' realization of the type of metaphysical arguments which would inevitably need to accompany any positive assertion of Jovians or Saturnians.

The "Pensees" reveals that by 1686 a confluence of observation, theory, and deep philosophical thought had produced in Huygens the conviction that life might be spread throughout the universe. Other solar systems certainly could not be detected by observation, but Huygens acknowledged the influence of "Descartes and others" in his belief that the fixed stars were suns, surrounded by tourbillons similar to that of our solar system, but not contiguous as Descartes had insisted. Such a universe, without life, might conceivably have been formed by matter and motion alone, Huygens noted, but a universe filled with life would be different: "When one considers animals and plants, the admirable construction of their parts, for each use, the astonishing manner of their generation, it seems to me impossible that only movement given to matter would have caused this without the cooperation of an infinitely intelligent and powerful being."[107] The grandeur of the heavens, he continued, proved to him less the existence of a providence than the eye of a man or animal, or the wing of a bird. If, then, life existed on planets throughout the universe, with "a variety of creatures like those on the

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earth," the magnificence, power, and wisdom of the Creator would be manifest.[108]

That same broad intellectual curiosity which drove Huygens to become one of the most productive natural philosophers of the seventeenth century, is seen at work in even broader terms in the "Pensees". "Who is there who cannot imagine the pleasure of being able to know what happens in only one of these planets or unknown earths?", Huygens exclaimed. The thought of being able to observe daily events on Jupiter, or of a Jovian visiting the earth, Huygens noted, has served "to reawaken in my mind the attention for the contemplation of natural things, and has driven away that insensibility which birth makes us accustomed to." Huygens' fascination with the subject went even far beyond the bounds of natural science: "I imagine the relation that there would be between that pilgrim of the earth in Saturn or Jupiter. How first he would describe the difference of their celestial view from ours. Then of our elements. trees. animals, men. their shape. arts, sciences, constructions. nourishment. government. wars, death (?). religion."[109] The program for the Cosmotheoros had been set forth, its very scope not the least of its significance.

In the years 1689-90 Huygens produced an intermediate draft of the Cosmotheoros in which he elaborated upon some of the thoughts in the "Pensees", added others, and divided all of them into four categories, each with a separate title.[110] A section "On reasoning from probability", in which it was asserted that so-called clear

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and distinct ideas had various degrees of probability which each individual had to judge for himself, first reveals Huygens' concern for establishing the status of knowledge relating to the habitability of planets. This epistemological principle was applied in the longest section "probabilities concerning the planets", where Huygens began to fill in the details of the outline in the "Pensees" arguing for the existence and nature of the inhabitants. The fact that Huygens devoted a separate section to the idea "that the production of animals, and especially of man, and especially of wisdom and intelligence, is a Divine work" indicates how high a position this metaphysical claim would hold in his thinking. A final section on "the unaccustomed spectacle od a traveller from Jupiter" also manifests that philosophical and aesthetic bent of mind which Huygens had already displayed in the "Pensees" and which he would carry into the Cosmotheoros.

The five years which followed were the last of Huygens' life, and he spent them in part working on the final form of his ideas on extraterrestrial life which would be presented to the public. It was undoubtedly with some hesitation that he did so, for in the "Pensees" Huygens admitted he thought the subject "above the capacity of common men" and he wondered "if it would be better not to expose this publicly to everyone".[111] He hoped for some way of communicating his thoughts only to a chosen few, but then decided that most common men would exclude themselves naturally because, having no knowledge of the astronomer's tools, they would reject his speculations as absurd. In the end, Huygens

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did determine to publish his treatise not in the vernacular but in Latin, even though he had written it in French. By March, 1694 Christian wrote his brother Constatine that the translation was half finished; by January 1695 it was complete. Six months later the author was dead, and the Cosmotheoros did not appear until 1698.

In its final form the Cosmotheoros was divided into two parts whose strikingly different approach and content reflect Huygens's awareness not only that both metaphysical and empirical elements played a role in the controversy, but also that they might be kept separate to some extent. The first part is almost totally lacking in any empirical content, and discusses the possibility of planetary inhabitants and their nature from only the most general physical and metaphysical principles. The Copernican theory is put forward as the "chief argument" for the similarity of the planets with the earth.[112] The planets have vegetation and animals because such life manifests better divine providence, and without life "we should sink them below the Earth in Beauty and Dignity; a thing that no Reason will permit."[113] The same argument is used to give the planets creatures endowed with reason, for the earth must not be considered the only part of the universe boasting of "a Creature that has a Divine somewhat within him, that knows, and understands, and remembers such an innumerable number of things; that deliberates, weighs and judges of the Truth: a Creature upon whose account,, and for whose use, whatsoever the Earth brings forth seems to be provided."[114]

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Having allowed the planets their plants, animals, and rational creatures on the basis of such broad metaphysical principles, Huygens went on to discuss planetary life in more detail from equally broad and general principles such as the uniformity and diversity of nature.[114a] The bulk of part one was spent discussing the nature of intelligent beings, and how they might employ their reason, essentially a fulfillment of that program initially implanted in the "Pensees" when Huygens wrote in one of his jottings "arts, sciences, constructions. nourishment. government. wars. death (?). religion." While all of this is very interesting from a social historian's standpoint, as far as Part One in its entirity is concerned, we may well agree in the most literal sense with Huygens' statement that his chief method of argument is "to reason from what we see and are sure of, to what we cannot ... wherein from the Nature and Circumstances of that Planet which we see before our eyes, we may guess at those that are farther distant from us."[115] Nothing said in Part One was based on what could be observed. Huygens had long before (in the Astroscopia) given up the idea that creatures would ever be seen directly even on the moon; here we see his willingness to invoke metaphysics where the eye could not probe.

Part II of the Cosmotheoros was quite different, and carried out for the planets much the same program that Kepler had for the moon, although Huygens labeled Kepler's Somnium a "pretty Fairy Story". This harsh judgement of the Somnium was undoubtedly due to Kepler's assertion that artificial constructions could be

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observed on the moon. Huygens did not make such claims for observational astronomy. His equally harsh judgement of Athanasius Kircher's Ecstatick Journey as "a company of idle unreasonable stuff" was doubtless rendered precisely because its astrological excesses and a priori insistence that the planets were lifeless likewise gave no role whatsoever to observation.[116] The second part of the Cosmotheoros tackled each of the planets in turn, describing their nature and the astronomical phenomena seen from each, then treated the satellites or "secondary planets" as a group of which the moon was representative, and finally went on to discuss the plurality of solar systems. This was a task in which observation would play an important role, and although the methodology of Part I "to reason from what we see and are sure of, to what we cannot" still operated in general, it was now invoked only when there were gaps in the observational evidence. In short, Part II represents Huygens' realization that the great generalizing principles of Part I were contingent upon the habitability of the planets.

Even with the advantage of a half-century of observations since the time of Wilkins, there was little that Huygens could say about Mercury, Venus, and Mars, the planets closest to the earth. It was easy enough to deduce from their distances the apparent size of the sun seen by any inhabitants that might be on each planet, and that the amount of heat and light received by them would be roughly inversely proportional to the distance from the sun. Although on this principle Mercury would receive nine times the amount of heat and light that the earth did and

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Mars two or three times less depending on where it was in its eccentric orbit, Huygens felt that the constitution of any inhabitants would be adaptable to these conditions of heat and cold.[117] Beyond this Huygens could only point out that Mars exhibited dark markings, from which a diurnal rotation similar in length to that of the earth could be deduced, and that since the axis of that planet was only very slightly inclined to the plane of its orbit, there would not be much difference in seasons to the inhabitants of Mars. For Mercury and Venus even this much could not be deduced, since no surface markings were evident. Huygens could only puzzle that when he observed Venus with a 45 or 60 foot long telescope "she always appeared to me all over equally lucid, that I can't say I observ'd so much as one spot in her, though in Jupiter and Mars, which seem much less to us, they are very plainly perceived."[118] Even when he used a smoked eyeglass to cut down the perhaps "too brisk" light of Venus, Huygens reported that only a uniformly bright disk could be seen, and he was finally led to conclude that an atmosphere thicker than that of Mars or Jupiter might surround Venus and prevent us from seeing its surface markings.

Compared with what we know today about Venus, Huygens' remark about its atmosphere seems remarkably perceptive; but considering his assertions made in Part I, it might also be interpreted as wishful thinking. It is ironic, however, that Huygens found observational support for the existence of planetary atmosphere in the more distant planet Jupiter. In one of the rare empirical statements of the first part of the Cosmotheoros,

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Huygens had already noted that clouds were observed on Jupiter which underwent continual change, in contrast to the more permanent "spots" of Jupiter.[119] When these clouds disappeared spots brighter than the surrounding area were sometimes observed, spots which the astronomer Cassini interpreted as reflections from the snow-covered hills of Jupiter, but which Huygens thought were only glimpses of the surface rarely observed. This observation of clouds on Jupiter was one of the seminal observations present already in the "Pensees", one which had entrenched in Huygens' mind the similarity of the planets with the earth.

Huygens for the most part considered the planets as a group, and if one could be shown to be similar to the earth, the probality that the rest might be also similar was accordingly increased. But one aspect unique to Jupiter and Saturn was the remarkable extent of their satellite systems, as well as the size of the planets themselves. Huygens delighted in describing these two giants and their systems, and especially in elaborating upon the astronomy of the inhabitants of Saturn which he had begun in the Systema Saturnium, and which now had grown more complicated with Cassini's discovery of four more satellites (two of which Huygens admitted "I can't positively say I had ever that happiness" of seeing). Although all of this discussion hardly proved directly the existence of Jovians and Saturnians, Huygens proposed that such grandeur pointed to the conclusion that these immense worlds were made for inhabitants,and not to "be studied by some few perhaps of us poor fellows" on earth.[120]

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While we are thus constantly reminded of the complementary role of metaphysics and observation in the controversy, it remains true that observation did prevent Huygens from asserting an inhabited moon, indicating that for him metaphysical presuppositions might be overcome by the power of observational evidence. The moon played only a minor role in the Cosmotheoros, perhaps because it was considered of a different species from the primary planets, but the little that Huygens does say about the nearest celestial body reveals him as the keen observer that he was. He agreed that with a 3 or 4 foot telescope the surface of the moon would be seen to be covered with mountains whose shadows might also be detected, in addition to broad valleys and little round valleys "with a hillock or two perhaps rising out of them."[121] But contrary to Arntzen and many others who came after him, he could not accept the opinion of Kepler and those who thought that the dark spots known as seas were actually water. For "a good long Telescope", Huygens noted simply, suffices to show that these spots are full of little round cavities, and otherwise not always smooth, neither of which observation can agree with the interpretation that the dark areas are composed of water or any liquid. The difference must simply lie in different sorts of matter which compose the bright and dark spots. In addition, Huygens concluded forcefully, no rivers have been observed there nor any clouds which might furnish such rivers with water.

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It was the lack of water on the moon that was crucial for Huygens, for without water there could be no vapors for an atmosphere, in addition to the fact that he could not imagine "how any Plants or Animals, whose whole nourishment comes from liquid Bodies, can thrive in a dry, waterless, parch'd Soil."[122] But Huygens believed that the lack of atmosphere, and thus the lack of water, was confirmed by the immediate occultation of a body by the moon, without passing through any apparent atmosphere. That observation was disputed by some, and would be for many years, but Huygens accepted it as true, in spite of the fact that it assuredly left him with a lifeless moon. It was not a vision with which Huygens was comfortable, this deserted and sterile moon, but he could only conclude that if there was any life there, it would have to be entirely different from ours, and this was even beyond the realm of probable conjecture.

The Cosmotheoros concluded with a final and daring leap into the world beyond our solar system. Once again observation could provide no direct answer to the question of the habitability of planets in such far-flung regions, or even of the existence of planets. But once again Huygens did the best he could in a difficult situation. Given the opinion of "the greatest philosophers of the age" that the fixed stars were suns, Huygens' strategy for proving the existence of planets around such suns was to demonstrate that they would be invisible to us. If we were placed an equal distance between the sun and the fixed stars, Huygens pointed out, we would observe no

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difference between them, for the planets of our own system would be invisible at such a distance . If we knew the nature of one of these stars and its environs in such a situation, we would not hesitate to make it the standard of all the rest. Since we do know the nature of one of them, Huygens concludes in characteristic fashion, "Why then shall not we make use of the same Judgement that we would in that case; and conclude that our Star has no better attendance than the others? So that what we allow'd the Planets, upon the account of our enjoying it, we must likewise grant to all those Planets that surround that prodigious number of Suns."[123]

It is noteworthy that in the end, Huygens did not simply proclaim the existence of other solar systems based on his acceptance of a type of Cartesian vortex surrounding each fixed star. In addition, he had also to reconcile this assertion of other solar systems with observation, if only to point out that we should not expect to be able to observe such distant planets. It was a final instance of Huygens' preference for observational arguments whenever they could be summoned, but at the same time of his willingness to bridge the gap of ignorance with plausible conjectures when necessary, as it very often was in the course of the difficult question undertaken in the Cosmotheoros.

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Schudt's De probabili mundorum pluralitate (1721) and Hennings' Specimen planetographie physicae (1738)

The treatises of Fontenelle and Huygens were destined to exert a great influence on eighteenth century thought. The Entretiens went through more editions and undoubtedly was more widely read among the masses, while Huygens' work was more widely respected in academic circles (compare Table III of this chapter with Table I of chapter four). As we have already seen, the subject was debated both in treatises on natural philosophy such as Thomas Wright's Original Theory and Immanuel Kant's Allgemeine Naturgeschichte and in innumerable treatises devoted more strictly to natural theology. In addition there were other treatises on the plurality of worlds, much less well known than those of Fontenelle and Huygens, which attempted to review and advance the debate. A brief examination of only two of those early eighteenth century treatises will suffice to indicate the two boundaries of thought within which the controversy reverberated with varying degrees of mixture: metaphysics and observation.

De probabili mundorum pluralitate (1721) was the work of Johann Jacob Schudt, a German polyhistor and Orientalist who had studied theology at Wittenberg and become famous for his writings on the history of the Jews. He came to the plurality of worlds debate with entirely theological purposes, and his treatise illustrates how metaphysics could be emphasized to the complete

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Table III

Editions of Huygens' Cosmotheoros[a]

Latin	English	French
Hagae-Comitum, 1698[b]	London, 1698[c]	
Hagae-Comitum, 1699[b]		
		Paris, 1702[f]
Francofurte & Lipsiae, 1704[b]		
		Amsterdam, 1718[f]
	London, 1722[c]	
		La Haye, 1724[g]
	Glasgow, 1757[d]	
	Glasgow, 1762?[d]	
	n.p., 17__?[e]	

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[a] Compiled from the National Union Catalogue of pre-56 imprints (Mansell).

[b] Kosmotheoros, sive, de terris coelestibus earumque ornatu conjecturae.

[c] The Celestial Worlds Discover'd: or, Conjectures concerning the inhabitants, plants and productions of the worlds in the planets.

[d] Cosmotheoros: or, Conjectures concerning the Inhabitants of the Planets

[e] New Conjectures concerning the Planetary Worlds, their Inhabitants and Productions

[f] Nouveau traite de la pluralite des mondes, traduit du latin en francois par M.D.***.

[g] De la pluralite des mondes: ouvrage dans le gout de celui de Mr. de Fontenelee, sur le meme sujet, mais ou l'on etablit, par des raisons philosophiques, & par des conjectures tout-a-fait vraisemblables, ce qu'il n'a propose que comme un simple jeu d'esprit.

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neglect of observation. Although the basis of Schudt's treatise is once again the Copernican principle that the earth and planets have many similarities, it is the theological assertions which have the most force and are most abundant throughout the treatise. Jupiter and Saturn are inhabited because they have moons, which have no other purpose than to be of use to the inhabitants of their planets.[124] The existence of many inhabited worlds "makes clear the wisdom, power, and goodness of the Creator, and inspires praise of the Divine."[125] And the idea is not against sacred Scripture because Scripture does not treat of every particular throughout the universe.[126]

Although Schudt is familiar with the works of Fontenelle and Huygens, he does not hesitate to assert the habitability of the moon. His treatise stands as an example of the blinding effect of metaphysics to observational considerations. It is of interest not for anything new or creative, but because in the course of his discussion Schudt reveals the existence of an unexpected concern with the plurality of worlds tradition in Germany, including not only German translations of Wilkins, Fontenelle, and Huygens at a relatively early date, but also other works indigenous to Germany.[127]

In contrast to Schudt's work, the Specimen planetographie physicaè, inquirens praecipue an planetae sint habitabiles (1738) reflects the development of the plurality of worlds tradition based on increased observational evidence.[128] Hennings had studied at Lübeck, Jena, and Strasbourg, and was appointed

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professor of physics and metaphysics at the university of Kiel in 1738, the very year that his work on the habitability of planets appeared. After a prelimilary section devoted to the history of opinion on his subject, the pattern of Hennings' work is essentially that of Part II of the Cosmotheoros, and deals as Huygens did in that part of his work, with the relevant observations of the planets. It does not mimic Huygens' work to the extent of setting forth again the astronomical phenomena seen from the planets, a task which Hennings undoubtedly considered Huygens had done well enough, but concentrates instead entirely on telescopic observations, including those made in the 40 years since the Cosmotheoros. In doing so, Hennings documents his work very diligently, as Arntzen had for the case of the moon at Utrecht a dozen years before, and provides us with a picture of the progress of planetary observation in the early eighteenth century.

Hennings first gave his reader an idea of the type of instruments available to the astronomer, citing Huygens' 125 foot telescope, Hevelius' 140 foot, and the excellent telescopes made by Campani and used by Blanchini and Cassini to make great discoveries. He noted Newton's description of the reflecting telescope in the Optics, the catadioptric telescope developed by Cassegrain, and cited at length from the Acta eruditorum of 1730 a description of a 6 foot octangular-tubed telescope used by John Hadley.[129] The controversy over the resolving power of such telescopes was also described, from the claim of David

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Fabricius that he could see creatures on the moon, through the Hooke-Auzout controversy, and finally Hartsoeker's calculations disproving the ability of any telescope to observe small objects even on the moon.[130]

Another section set forth the "general requisites for the habitability of planets", the chief among which Hennings proclaimed to be the existence of a water-like fluid, an atmosphere, and an abundance of heat and light. Air was especially perceived as crucial, "for air is that entity not only of utmost importance for respiration, which is intimately connected with life, but it also takes an important part in that faculty of perception and directs numberless other functions, since it is the source of all things which serve for the sustenance of that life."[131] Such an atmosphere would also allow "meteors", those meteorological phenomena which Wilkins had spoken of exactly a century before in the Discovery.

Although Hennings' work dealt with all of the known planets in the solar system, it gave considerably more attention to the moon than did Huygens. Approximately one quarter of the treatise (sections VI-XXI) was devoted to a review of old and new observations of the moon, covering much the same material as Arntzenis treatise had a dozen years before, but in the end concluding with Huygens that it was very likely uninhabited and uninhabitable. The conclusion that the situation of the moon also reflected the situation of all the other secondary planets

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(section XXXIII) also shows the influence of the Cosmotheoros.

The following ten sections took up the planets (XXII-XXXII), and Hennings' strategy here was to give a chronological record of the observations of each planet, from the time of the earliest telescopes to the latest information reported in journals, especially the Acta eruditorum. Again as with Huygens, the systems of Jupiter (sections XXV-XXVII) and Saturn (sections XXIX-XXXI) gained most attention, precisely because there was more observational evidence for the nature of these giant planets. Since Mercury never appeared more than 28 degrees from the sun, Hennings pointed out that it was always difficult to observe, but Gassendi's observation of the 1631 transit proved at least that it was solid and opaque. Aside from noting Kepler's determination of its distance from the sun and the length of its year, Hennings could only point to dubious observations of surface features claimed by Cassini and more recently by the German astronomer Weidler.

Venus too was dark and opaque in its transit across the face of the sun in 1639, as testified by Horrox, and although Huygens claimed that no spots could be observed on it, Hennings tells us that several observers since the time of Huygens believe that they have seen surface features, including William Derham, de la Hire, and Blanchini.[132] Huygens himself had admitted the existence of features on Mars, and they had been abundantly confirmed in the eighteenth century by Maraldi using a 34 foot Campanian telescope, when he reported in the Memoires

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de l'Academie Royale among other things the appearance of a "certain bright circular part" around the Martian south pole.[133] The surface features on these planets closest to the earth were so important to the eighteenth century mind because they indicated a compositional differentiation which might be interpreted as the difference between land and water, although the moon had already shown that this need not be the case.

Jupiter had been scrutinized since the time of Huygens especially by DuHamel and Maraldi, and Hennings reported in some detail the spots, bands, and mutations observed on its surface. In addition he discussed its satellite system, and the possibility that Maraldi had observed spots on some of these satellites with his 34 foot telescope. Saturn was given much the same treatment, with Huygens' Systema Saturnium still an important source, supplemented by the observations of Cassini and Maraldi as reported in the Memoires of the French academy.

Throughout all of this discussion of the planets Hennings had been concerned not only with surface features, but also with the existence of an atmosphere and the amount of heat and light received by each planet. He agreed with Huygens that nature would give to the inhabitants of each planet such a constitution that would be suited to the conditions of heat or cold. An atmosphere on Mars was indicated by observations of certain rapid changes in surface markings and by its reddish color, but

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even more clearly indicated by the clouds observed on Jupiter and Saturn. And what was true of Jupiter and Saturn, Hennings felt with Huygens, was true in general for the other primary planets as well.

It was only in the last paragraph of his work that Hennings finally yielded to the temptation to sermonize on the magnificence of the universe as a work of God when it was furnished with so many inhabitants. For the physical reasoning set forth in the Cosmotheoros indicated also to Hennings that our solar system was only one of many around other suns spread throughout an infinite universe.

* * *

Hennings' treatise concentrated almost exclusively on observational aspects of the question of the habitability of planets, and in this respect it represents the method upon which a resolution of the question would depend increasingly in the future, as the art of planetary observation became more and more refined. This method, too, did not offer certainty, but one must wonder how often repeated was the frame of mind symbolized by the Huygens brothers at their telescope, discussing the habitability of planets.[134] The problem of extraterrestrial life was powerful and compelling, and although a question of degree will perhaps always remain, one can only conclude with A. Pannekoek, himself an astronomer, that it was undoubtedly "a silent force in astronomical research."[135]

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NOTES

[1] "Quis non videt, quam longe contemplatio naturae sua pomoeria prolatura sit: dum quaerimus, cui bono in Luna sint montium valliumque tractus, marium amplissima spatia; et an non ignobilior aliqua creatura quam homo statui possit, quae tractus illos inhabitet?" Preface to the Dioptrice, in Frisch, Johannis Kepleri astronomi opera omnia (Frankofurti A.M. et Erlangae, 1859), II, p. 525. My translation.

[2] Kepler's Somnium: the Dream or Posthumous Work on Lunar Astronomy, trans. Edward Rosen (Madison, 1967), p. 151.

[3] This does not mean to imply that the nature of the heavenly bodies was entirely excluded from discussion in the pre-Copernican period, but only that the subject gained a great deal of impetus when the Copernican theory destroyed the distinction between earth and heavens. Although a general history of early ideas regarding the physical nature of the heavenly bodies has yet to be written, some of the pre-Copernican ideas opposed to Aristotle may be seen in John Wilkins' Discovery of a World in the Moone (1638); see below, pp. 335 ff.

[4] Astronomiae pars optica, Gesammelte Werke, II, pp. 216-217.

[5] On Bruno's ideas and their relation to Copernicanism, see Chapter 3, pp. 122 ff, and on Kepler's pre-telescopic ideas, see Chapter 3, pp. 131 ff.

[6] Based on internal evidence, Edward Rosen gives the chronology of the composition of the Somnium as follows: "When Kepler was a student at Tübingen, he composed a dissertation about the moon in 1593. In 1609, when he was engaged in playful astronomical altercations at Prague, he added the Dream framework. Between 1622 and 1630, years darkened by somber tragedy, both personal and national, he drafted the Notes. In 1623, he wrote a letter which he later used as the Geographical Appendix to the Dream; his Notes on the Geographical Appendix were apparently composed after he moved to Silesia in 1628." Kepler's Somnium: the Dream or Posthumous Work on Lunar Astronomy, trans. Edward Rosen (Madison, 1967), introduction, p. xx. The statement quoted above is found in a letter from Kepler to Bernegger of December 4, 1623, where Kepler informed Bernegger that he was going to append to the Somnium a letter he had written earlier in the year to the Jesuit Paul Guldin concerning the circular "towns and mounds" on the moon. Ibid., p. 166, Rosen's footnote 20. This letter formed the Geographical or Selenographical appendix. On Guldin, see Rosen's appendix L. All further citations from the Somnium will be from Rosen's translation.

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[7] Kepler's Somnium, p. 27.

[8] Ibid., pp. 122-23, Note 200. Kepler added to this experimental evidence the statement that "No proof is in fact required that this bright light of Volva (that is, of our earth illumined by the sun) belongs to the category of producers of heat. For sometimes in the summer the strength of the sun's rays is so great that trees and wooden roofs burst into flames, when the common people subject suspects to charges of arson. What does it matter, then, if the moon if fifty thousand miles away from this heat, when that distance brings into view at one and the same time, as the nearest part of the terrestrial globe, a portion which is even greater than a full hemisphere."

[9] Ibid., p. 28.

[10] Ibid., Note 223, pp. 146-47. Kepler's note 223, which we will now examine in detail, was the last and longest note to the body of the Dream itself. Since Kepler says these notes were written in order between the years 1620 and 1630, this particular note may be dated as close to 1630.

[11] Ibid., Note 223, p. 146.

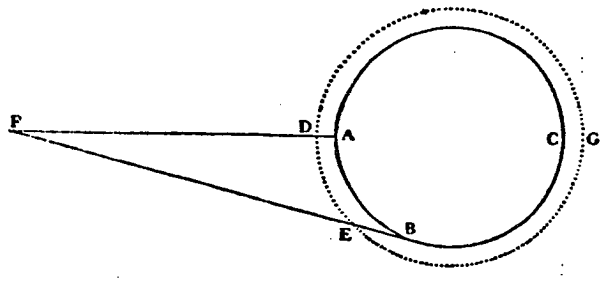
[12] Ibid., Note 1 to the Selenographical Appendix, section XXI, p. 158.

[13] Ibid., Note 1 to the Selenographical Appendix, Section XXIII, p. 158.

[14] Kepler's Conversation with Galileo's Sidereal Messenger (New York and London, 1965), trans. Edward Rosen, pp. 29-31. Kepler's 1610 discussion of the lunar atmosphere was a direct response to Galileo's hypothesis put forth in the Siderius nuncius to explain why the periphery of the mountainous moon did not appear rough or serrated to the terrestrial observer. Galileo first pointed out that many mountain peaks crowded one behind another might produce this apparently smooth periphery, and then continued: "To the above explanation another may be added; namely, that there exists around the body of the moon, just as around the earth, a globe of some substance denser than the rest of the aether. This may serve to receive and reflect the sun's radiations without being sufficiently opaque to prevent our seeing through it, especially when it is not illuminated. Such a globe, lighted by the sun's rays, makes the body of the moon appear larger than it really is, and if it were thicker it would be able to prevent our seeing the actual body of the moon. And it actually is thicker near the circumference of the moon; I do not mean in an absolute sense, but relatively to the rays of our vision, which cut it obliquely there. Thus

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14 (cont.) it may obstruct our vision, especially when it is lighted, and cloud the lunar periphery that is exposed to the sun. This may be more clearly understood from the figure below, in which the body of the moon, ABC, is surrounded by the vaporous globe DEG."



"The eyesight from F reaches the moon in the central region, at A for example, through a lesser thickness of the vapors DA, while toward the extreme edges a deeper stratum of vapors, EB, limits and shuts out our sight. One indication of this is that the illuminated portion of the moon appears to be larger in circumference than the rest of the orb, which lies in shadow. And perhaps the same cause will appeal to some as reasonable explaining why the larger spots on the moon are nowhere seen to reach the very edge, probable though it is that some should occur there. Possibly they are invisible by being hidden under a thicker and more luminous mass of vapors." Discoveries and Opinions of Galileo, trans. Stillman Drake (New York, 1957), pp. 39-40. Later in his Dialogue Concerning the Two Chief World Systems (1632), Galileo no longer asserted the existence of a lunar atmosphere, undoubtedly because of his intervening troubles with the Church.

Kepler had briefly asserted the existence of a lunar atmosphere already in the 1604 Optics (Gesammelte Werke, pp. 221; 261-62), but was not able to support this assertion with any solid arguments. The arguments presented in the 1610 Conversation in reply to Galileo were greatly affected by a 1606 work of Maestlin (see footnote 16). It is these arguments which then were elaborated upon in the Somnium, in note 223 written about 1630.

15 Kepler made this statement already in 1610; Kepler's Conversation, p. 29, and it is cited by Rosen in the Somnium as footnote 365 to Kepler's note 223, p. 135.

16 Kepler's Somnium, Note 223, p. 135. Rosen gives the full title of Maestlin's Tübingen, 1606 work as Disputatio de multifariis motuum planetarum in coelo apparentibus irregularitatibus, seu regularibus inaequalitatibus, earumque causis astronomicis, or Disputation about the Manifold Apparent

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Non-uniformities, or Uniform Inequalities, in the Motions of the Planets in the Heavens, and the Astronomical Causes of the Inequalities. Rosen notes that although Frisch had access to this work in the 19th century, and Franz Hammer in the 20th, a copy of it can no longer be located. Note 223 is largely a summary of Maestlin's arguments for a lunar atmosphere, with Kepler's own commentary.

[17] Ibid., Note 223, p. 137.

[18] Ibid., Note 223, p. 140.

[19] "For the phenomenon has a different explanation, namely, the radius of the aperture through which the sun's ray enters. A bright fringe as wide as this radius attaches itself all around the sickle-shaped image of the sun, including the cusps of the horns, with the result that they become blunted. When this bright fringe had been cleared away, what remains is a pure image, whose outer circumference now is narrower, whereas the inner, concave circumference is broader. Thus, if this remedy is employed, the diameter of the moon when it covers the sun is found to match the diameter of the full moon." Ibid., Note 223, p. 141.

[20] "The reason unquestionably is that when transparent objects are placed in sunlight, they, too, cast a shadow. I proved this in my Optics by experiments with a glass sphere full of water. The sphere both permits the sun's rays to pass through it, and also concentrates them to such an extent that they set clothing on fire and ignite powder. But it deflects the transmitted rays into a different place, whereas the edges of the sphere meanwhile cast their shadow in straight lines from the sun." Ibid., Note 223, p. 143.

[21] Ibid., Note 223, p. 144.

[22] Ibid., Note 223, p. 144.

[23] Ibid., Note 223, p. 145.

[24] Ibid., Note 223, p. 146. This was an effect independently proposed by Galileo in the Sidereus nuncius, where he noted that the lunar atmosphere "will appeal to some as reasonably explaining why the larger spots on the moon are nowhere seen to reach the very edge, probable though it is that some should occur there. Possibly they are invisible by being hidden under a thicker and more luminous mass of vapors." Discoveries and Opinions, p. 40. See footnote 14 above.

[25] Ibid., Selenographical Appendix, p. 151.

[26] Ibid., Selenographical Appendix, p. 152.

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[27] Ibid., Note 1 to the Selenographical Appendix, section XVIII, pp. 155-56. Section XVIII shows Kepler to be quite a perceptive geological observer.

[28] Ibid., Note 1 to the Selenographical Appendix, section XIX, p. 157. The passage can only be understood if the "mind" spoken of here is the mind of the builder of the supposed lunar construction, not the mind of the observer of them.

[29] Ibid., Note 1 to the Selenographical Appendix, section XXVI, p. 159.

[30] Ibid., Note 1 to the Selenographical Appendix, section XXVIII, p. 160: "In general on the surface of the lunar sphere, so far as the mixture of high and low parts is concerned, chance and the composition of matter are predominant. Soil is eroded away from the underground rocky ribs. Valleys are washed out, so that mountains rise up. Water flows down into the low-lying areas, marked by the spots. There it is distributed in a state of equilibrium by the rectilinear tendency of all its parts toward the same center of the lunar globe."

[31] Ibid., Note 1 to the Selenographical Appendix, sections XXVI-XXVIII, p. 160.

[32] Ibid., Note 1 to the Selenographical Appendix, section XXIX, p. 161.

[33] The remark was made by Giovanni Pieroni in a letter of December 31, 1631 to Galileo; Kepler's Somnium, xxii.

[34] Discovery of a World in the Moone (London, 1638; facsimile reprint New York, 1973), proposition 3, p. 46. Ambrose, "in Hexam. lib. 4" is cited by Wilkins.

[35] On the role of the Copernican theory in Wilkins' work, see chapter 3, pp. 167 ff.

[36] Discovery, prop. 3, p. 51. Why did Wilkins refer the reader to Scheiner's Rosa ursina (1626-30) for arguments on the corruptibility of the heavens, rather than to the First Day of Galileo's Dialogue (1632)? Perhaps because he did not yet have the Dialogue in hand. There is a single fleeting mention of that treatise "which Galilaeus calls Systema Mundi" in proposition 11 of the 1638 edition, but by the 1640 edition at least three specific references to "coll. 1" and "coll. 3" of the Syst. Mundi (propositions 8, 9, and 12). And in proposition 9 of the 1640 edition Wilkins said in reference to one of his arguments "That instance of Galilaeus would have been a better evasion, had this author been acquainted with it." Wilkins therefore may have received a copy of the Dialogue sometime between 1638 and 1640.

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[37] Discovery, prop. 9, p. 125.

[38] Discovery, prop. 9, p. 133. On LaGalla's De phaenomenis in orbe lunae ... physicae disputatio (1612), see chapter 3, 148 ff.

[39] Discovery, prop. 7, p. 103.

[40] Discovery, prop. 8, pp. 107-110. In proof of his claim that the dark lunar spots were seas, Wilkins noted that from a high mountain on earth land always appeared brighter than water. As an analogy, Wilkins added that a mirror hanging on a sunlit wall was less bright than the wall itself, unless the mirror was seen in the direct line of reflection of the sunlight. Campanella's theological proof, cited by Wilkins from the Apologia pro Galileo (1622), sought to interpret the waters above the firmament spoken of in Genesis as identical to the lunar seas. For the details of this argument and others by Campanella related to the plurality of worlds, see above, chapter 3, 163 ff.

[41] Discovery, prop. 10, p. 140.

[42] Discovery, prop. 10, pp. 138-39. The theory of exhalations has its origins in Aristotle's Meteorologica: "But we must understand that of what we call air the part which immediately surrounds the earth is moist and hot because it is vaporous and contains exhalations from the earth, but that the part above this is hot and dry. For vapour is naturally moist and cold and exhalation hot and dry: and vapour is potentially like water, exhalation like fire ...". Meteorologica (Cambridge, Mass., 1952), Loeb classical library, trans. H.D.P. Lee, Book I, ch. 3, p. 21. The theory is discussed in great detail in Book I, ch. 4, and plays an important role in the whole of the Meteorologica. This is another physical theory whose evolution needs to be traced through the scientific revolution, especially since it is also involved in the explanation of the origin of comets and new stars.

[43] Discovery, prop. 10. This remark concerning the sun was only added in the 1640 edition.

[44] Discovery, prop. 10, 1640 edition.

[45] Discovery, prop. 12, pp. 166-67.

[46] Discovery, prop. 12, p. 178. Wilkins notes that, according to Tycho Brahe ("Progym. 1. c.9"), Pena, Rothmann, and Galileo held the Aristotelian belief that comets were produced exclusively from exhalations from the earth. On the other hand, Gloriosus, Campanella, and Fromondus believed that comets were formed from exhalations from all the planets. Wilkins cites respectively "De comet. l.5. c.4; Apol.; and Meteor. l.3. c.2. art.6."

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[47] Wilkins quoted from a letter written by "that diligent and judicious astronomer" Bapt. Cisatus, found in the Hist. nat. l.2., c. 11 of Eusebius Nierembergius: "In that late solary eclipse which happened on Christmas day, when the moon was just under the sun, I plainly discerned that in her which may clearly confirm what the comet's and sun's spots do seem to prove, viz. That the heavens are not so solid, nor freed from those changes which our air is liable unto; for about the moon I perceived such an orb, or vaporous air as that is which doth encompass our earth; and as vapours and exhalations are raised from our earth into this air, so are they also from the moon." Prop. 12, pp. 185-86.

[48] The complete title page of the 1726 treatise reads as follows: Dissertatio astronomico-physica de luna habitabili, quam favente numine sub praesidio viri celeberrimi Jacobi Ode, A.L.M. & Philos. Doct. ejusdemque facultatis in Academia Trajectina professoris ordinarii, publico examini exponit auctor Gulielmus Arntzenius, Arenaco-Gelrus. A.D. 10 Aprilis, ab hora 2 in 4 pomeridiana (Trajecti ad Rhenum Utrecht : apud Guilielmum Vande Water, Academiae typographum, MDCCXXVI), or Astronomical Physical Dissertation on the Habitability of the Moon, which the author William Arntzen, Arenaco-Gelrus, set forth in a public examination on the 10th of April, A.D. from 2 to 4 in the afternoon, with Divine favor and that most celebrated man Jacob Ode presiding ... . The complete title page of the 1740 treatise reads Dissertatio astronomico-physica de luna non habitabili, quam consensu ampliss. facultat. philosoph. in Reg. Acad. Upsal., praeside viro amplissimo & celeberrimo, Mag. Andrea Celsio, astronom. profess. Reg. & Ord. nec non R.S.L. & S. Secr., publicae bonorum disquisitioni modeste subjecit Stipendiarius Regius, Ericus Engman, Uplandus. In audit. Gust. Maj. ad d. 16 Decemb. An. MDCCXL. horis ante meridiem solitis (Upsaliae impressa), or Astronomical-Physical Dissertation on the non-Habitability of the Moon, which, with the fullest consent of the faculty of philosophy in the Royal Academy of Upsala, Eric Engman, a stipendary of the king, subjected to a modest disquisition for the benefit of the public, with the most famous and celebrated Master Andreas Celsius presiding ... on the 16th of December, 1740 at the accustomed hours before noon.

[49] On DeVries see above, ch. 4, pp. 210 ff.

[50] Dissertatio astronomico-physica de luna habitabili (1726), Part I, section XXI, p. 25. All translations of this work, which to my knowledge has not been analyzed elsewhere, are my own.

[51] Ibid., Part I, section XXI, p. 25. For further arguments of this kind, Arntzen refers the reader to Kepler, Epit. Astron. Copern., Lib. VI, p. 831; Galileo, Syst. Mund., Dial. I,p. 88 ff;

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51 (cont.) Gassendi, Phys. sect. II., Lib. IV, c. 3, p. 661 & in X Diog. Laert. T. I, p. 453; and Hevelius, Selenogr., p. 150 ff.

52 Ibid., part I, section XXI, p. 25. The references to Gassendi, Fabri, and DuHamel respectively are Phys; prop. 65; and Astron. Phys. Lib. II. c.4, p. 99.

53 Ibid., part I, section XXII, p. 27. Huygens, Cosm., Lib. II, p. 114; Keill, Intr. ad Ver. Astron. Lect. X, p. 395; Francis Baile, Inst. Phys. T. II, p. 138.

54 Ibid., part I, section XXII, p. 28. Arntzen took this idea from Sturmy, Phys. Elect., T. II, p. 894, who in turn had taken it from "Varenius & Dapperus".

55 Ibid., part I, section XXIII, p. 29. Hartsoeker's Dioptr., ch. 10, p. 172 is cited.

56 Ibid., part I, section XXI, p. 26. The specific passages mentioned with regard to lunar water are Riccioli, Alm. Nov., T. I, Lib. IV, c. 8, p. 206; Sturmy, Math. Juv., T. II, p. 340; Wolf, Elem. Math. Univ., T. II, p. 470; William Nicholls the Englishmen, Act. Erud., A. 1696, p. 541; and Hevelius, Selen., p. 149.

56a Ibid., part I, section XXIII, p. 29.

57 Ibid., part I, section XXIV, p. 30. This definition of "atmosphere" was taken from Jacob Ode, Dissert. de Atmosph., c. 1, sect. 1.

58 Ibid., part I, section XXIV, p. 30.

59 Ibid., part I, section XXIV, p. 30. The observations of Vendelinus and Anonymous are taken from Riccioli, Alm. Novum, T. I, Lib. V, p. 376 &384. The rest are Kepler, Epit. Astr. Coper., Lib. VI, p. 893; Wolf, Elem. Math. Univ., T. II, p. 366; Fabri, Phys., T. IV, Tract. VIII, Lib. I, prop. 88; DuHamel, Astron. Phys., p. 118; and Sturmy, Phys. Elect.,T. II, p. 669.

60 Ibid., part I, section XXIV, p. 32. Riccioli, Alm. Nov., T. I, Lib. IV, p. 199; Cassini, in Memoires de l'Acad. Royale des Sciences, A. 1699, p. 221; and Newton according to Muller, Diss. II de Nat. Stell., sect. 1, # 38.

61 Ibid., part I, section XXIV, p. 32, passage cited from DuHamel, Astron. Phys. p. 118.

62 Ibid., part I, section XXIV, p. 32, passage cited from Wolf, Elem. Math. Univ., T. II, p. 466.

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63 Ibid., part I, section XXV, p. 33. DuHamel, Hist. Acad. Reg., Lib. VI, part I, sect. 2, ch. 1, p. 553. A whole series of articles by Feuillée are cited: Journal des observ. Phys. Math. & Bot., T. I, p. 338 & T. II, p. 369; Histoire de l'Acad. Royale des Sciences, A. 1701, p. 388 ff; Act. Erud., A. 1725, p. 272.

64 Ibid., part I, section XXV, p. 34. The passage is from Histoire de l'Acad. Royale des Sciences, A. 1699. De la Hire, Memoires of the Academy for 1701 is also cited.

65 Ibid., part I, section XXVI, p. 35. Scheiner, Rosa Urs. p. 740; Wolf, Elem. Math. Univ., T. II, p. 466; and Kircher, in Praelus. ad Itin. Ecstat., p. 48 ff.

66 Ibid., part I, sections XXVI-XXVII, pp. 35-36. Huygens denied clouds on the moon, as did Galileo, Syst. Mundi, Dial. I, p. 91; De Rheita, Ocul. En. & El., Lib. IV, c. 2, p. 245; Fabri, Phys., T. IV, Tract. VIII, Lib. I, prop. 73; Keill, introd. in Ver. Astron., Lect. X, p. 296; Auzout according to Oldenburg; Muller, de Nat. Stell. Diss., II, sect. I, # 36. For more on the lunar atmosphere, Arntzen refers the reader to Sturmy, Phys. Elect. T. II, p. 888 ff. and Philos. Elect., T. II, Exerc. 3, c. 3; Galileo, Nunc. Sid., c. 12 ff.; De Rheita, Oc. En. & El., Lib. IV, c. 2, p. 245; Oldenburg, in Act. Angl. A. 1666, p. 255 and Ephemerides Erud., A. 1666, p. 328; Chauvinus, in Lex. Philos. in Atmosphaera; Weigelius, in Sphaer. Euclid., p. 31 ff. and Suppl. Act. Erud., T. I, p. 451. Among those against a lunar atmosphere, Arntzen cited Huygens, Cosmoth., Lib. II, p. 115; and Keill, Introd. ad Ver. Astron., Lect. X, p. 296.

67 Ibid., part I, section XXVI, p. 35. Boyle's de Atmosphaera dissertatione is cited.

68 Ibid., part II, section I, p. 41.

69 Ibid., part II, sections I-II, pp. 41-44. In favor of a world in the moon, Arntzen lists the Pythagoreans according to Plutarch, de Plac. Philos., Lib. II, c. 30; Platonists according to the Coimbra Jesuits on Aristotle De Coelo, Lib. II, c. 7, p. 327; Xenophanes according to Cicero, in Quaest. Acad., Lib. IV, c. 123; Macrobius, in Somn. Scipion, Lib. I, c. 11; and many other ancients according to Gassendi, Phys., sect. II, Lib. I, c.16, p. 524. Among the modern believers in a world in the moon, Arntzen cites Nicolaus Cusanus, Lib. de Docta Ignorantia; Franc. Godwin, Wilkins, and Rob. Burton according to Act. Erud. A. 1692, p. 36; Kepler, Jordanus Brunus, and (according to Kepler) Tycho Brahe; De Rheita, Oc. En. & El., Lib. III, c. 1, p. 182; Fontenelle, Entretiens sur la Pluralite des Mondes; David Fabricius according to Riccioli in his Novo

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69 (cont) Almagesto; finally Jacob Bartsch, the relative of Kepler, according to DeVries, de. Lunic., p. 253.

Against a world in the moon were Kircher, in Itin. Ecst., p. 92; Schottus in Scholio ad Itin. Ecst., p. 94; Galileo, in Syst. Mundi, Dial. 1, p. 91; Guericke, de Syst. M., Lib. V, c. 23; Fabri, Phys., T. IV, Tract. VIII, Lib. I, prop. 72; Andala, in Exerc. Acad., part III, ex. 21, section 22; Huygens, Cosmoth., Lib. II, p. 116; Auzout, in Ephemerid. Erud., A. 1666, p. 28; DuHamel, Astron. Phys., Lib. II, c. 4, p. 100; Muller, de Nat. Stell. diss. II, sect. 1.

70 Ibid., part II, section III, p. 45. Arntzen notes that Descartes and Hooke had believed that the improved telescope might eventually be able to detect lunar inhabitants directly, but that this was denied by Auzout, according to Oldenburg, Act. Philos. Angl., A. 1666, p. 18, 29 & 30.

71 Ibid., part II, section IV, p. 45-46. Those who did not assert that the moon was actually inhabited included, according to Arntzen, Gassendi, Phys., sect. II, Lib, I, c. 6, p. 526; Rohault, Phys., part II, c. 25, sect 24; Sturmy, Phys. Mod., p. 395; Hevelius, Selenogr. p. 119; Baile, Phys. Inst., T. II, p. 139; Niewventitius, Contempl., XXV, sect 105; Geringius, De facie Lunae, sect. 13, among others.

72 Ibid., Part II, section V, p. 48.

73 Ibid., part II, section XIV, p. 58.

74 Ibid., part II, section XIV, p. 59.

75 Although Celsius himself is usually cited as the author of this 1740 treatise (Poggendorff, Lalande, Weidler), the title page and internal evidence clearly establish that the famous astronomer only directed the work which was actually written by his student Eric Engman. Internal evidence includes a prefatory eulogy to the author "Engman", and references in the body of the text to the praeses, or "praeses Celsius" (Part I, sections II and VIII).

76 Dissertatio astronomico-physica de luna non habitabili (1740), part I, p. 2, section I. All translations from the Latin of this work are my own.

77 Ibid., part I, p. 2, section I.

78 Ibid., part I, pp. 2-3, section II. Engman cites Newton, System. Mund., p. 18; Smith, Compleat System of Opticks, Art. 1088 & Remarks, p. 126; Memoires de l'Acad. des sciences, A. 1699.

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[79] Ibid., part I, p. 3, section II.

[80] Ibid., part I, p. 6, section VII.

[81] Ibid., part I, p. 5, section IV.

[82] Ibid., part I, pp. 10-11, section XIV. Newton, Princ., Bk. III, Prop. 37, coroll. 3 is cited by Engman.

[83] Ibid., part I, pp. 12-13, section XV. Cassini had seen in a lunar eclipse "a shadow around the center of the moon denser than the rest" according to DuHamel, Historia Acad. Reg., Lib. III, sect. II, cap. 2, p. 248. Kepler, Lib. de stella nova, cap. 23 is also cited.

[84] Ibid., part II, p. 19, section XXVI.

[85] Ibid., part II, p. 22, section XXIX.

[86] Ibid., p. 1.

[86a] Only 13 years after Engman's work, the famed Jesuit natural philosopher Roger Joseph Boscovich published De lunae atmosphaera (Romae, 1753), in which he denied the existence of a lunar atmosphere based on the instantaneous disappearance of stars occulted by the moon. This work in only mentioned in Roger Joseph Boscovich, S.J., F.R.S., 1711-1787, Studies of his Life and Work on the 250th Anniversary of his Birthday, Lancelot Law Whyte, ed. (New York, 1961), p. 179. But even in the mid-nineteenth century Robert Grant in his History of Physical Astronomy (London, 1852) admitted that there was some evidence to the contrary, although not enough to assert "so delicate a point as the existence of a lunar atmosphere." He notes that the astronomer Arago observed from the Royal Observatory in Paris an occultation in which the star "exhibited a very sensible diminution of brightness during a short time previous to its immersion," and on another occasion observed the star 49 Librae "to diminish in lustre three or four seconds previous to its immersion". Other astronomers had perceived similar effects, but the phenomenon was not a general one. Based on the refraction of light from the sun during a solar eclipse, the French astronomer Du Sejour determined in 1764 that if there was a lunar atmosphere, it must be 1400 times rarer than the earth's. Grant, pp. 230-232.

[87] Discovery, proposition 12.

[88] Huygens' voluminous works containing all of these contributions, along with others, have been collected in the 22 volumes of the monumental edition of his complete works: Oeuvres completes de Christiaan Huygens, publiees par la Societe Hollandaise des Sciences (La Haye, 1888-1950). In spite of the

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88 (cont.) accessibility of the complete corpus of Huygens' writings, very little secondary material on his life and work exists in English, but see Bell, Christian Huygens and the Development of Science in the Seventeenth Century (London, 1947), and especially Aant Elzinga, On a Research Program in Early Modern Physics (New York, 1972).

89 See above, ch. 4, pp. 221 ff.

90 Oeuvres, XV, p. 340; see also XV, pp. 260, 326. This translation, and all translations from the Oeuvres (except for the Cosmotheoros) are my own from the original Latin or French. Volume XV of the Oeuvres contains exclusively astronomical works and observations from 1658-1666.

91 Oeuvres, XV, p. 342. A series of jottings from the year 1658, when Huygens was writing the Systema, show his concern already for the question "whether there were men" on Saturn. XV, p. 366.

92 Oeuvres, XV, p. 418. Eustachio Divini (1620-1664?) was an Italian telescope maker and physician, a competitor of the Roman telescope maker Joseph Campani. Honore Fabri (1607-1688), French Jesuit and philosopher, is the same Fabri often cited by Arntzen as denying inhabitants to the moon. He was the author of many works, and a few years after this controversy with Huygens, published at Lyon Dialogi physici, in quibus de motu terrae disputatur, marini aestus nova causa proponitur, nec non aquarum et mercurii supra libellam elevatio examinatur. The Brevis annotatio was published under the name of Divini, whose ideas were indeed expressed there, but was written by Fabri, who was a better Latinist. Huygens knew that Fabri had a hand in the Annotatio because of a letter he received from Guisony on 1 Aug., 1660. That the words were Fabri's and the ideas Divini's was later affirmed by Divini in a letter to Leopold de Medici.

93 Brevis assertio systematis Saturnii (Hagae-Comitis, 1660), Oeuvres, XV, p. 460.

94 Ibid., Oeuvres, XV, p. 462.

95 It cannot be established with certainty that Huygens knew the works of Kepler, Wilkins, or Borel on the plurality of worlds, but in 1655 a work had appeared at Rouen entitled Le monde dans la lune, by I. de La Montagne, which was in reality a translation of Wilkins' Discovery; and in 1657 Borel's work Discours nouveau prouvant la pluralite des mondes, que les astres sont des terres habitees, & la terre un estoile, qu' elle est hors du centre du monde dans le troisiesme ciel, & se tourne devant le soleil qui est fixe, & autres choses tres-curieuses (Geneve, 1657).

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[96] The Celestial Worlds Discover'd: or, Conjectures concerning the Inhabitants, Plants and Productions of the Worlds in the Planets (London, 1698; facsimile, London, 1968), p. 2. Oeuvres, XXI, p. 681. I will be citing from this first English translation of the Cosmotheoros, and will also give the reference to the Oeuvres, which contains both the Latin original and a French translation by the editors. Volume XXI of the Oeuvres is a cosmological volume, as opposed to the astronomical volume XV.

[97] Ibid., p. 2; Oeuvres, XXI, p. 681.

[98] Oeuvres, XV, p. 228. Arntzen was also aware of this hope of Descartes, and of the ensuing controversy between Hooke and Auzout. See footnote 70 above, and for the actual passage from Descartes, see above, ch. 4, footnote 15.

[99] Celestial Worlds Discover'd, pp. 3-4; Oeuvres, XXI, p. 683.

[100] Ibid., pp. 9-10; Oeuvres, XXI, p. 698.

[101] Ibid., p. 4. Oeuvres, p. 683. Although the "Pensees" which we will now be discussing dates from 1686, the very year of the appearance of Fontenelle's Entretiens, there is no evidence that Huygens knew of Fontenelle's work at this time. Huygens was in Holland, and as we have shown, the time was ripe for him to begin a serious discussion of this subject based simply on his own background and experiences. Since the "Pensees" were private jottings, there is no reason that Huygens should not have noted the existence of Fontenelle's work had he known of it.

[102] "Pensees", sections 11, 28, 37, 45; Oeuvres, XXI, pp. 351, 359, 362, 266.

[103] "Pensees", section 11; Oeuvres, XXI, p. 351.

[104] "Pensees", section 32; Oeuvres, XXI, p. 360.

[105] "Pensees", section 36; Oeuvres, XXI, p. 362.

[106] "Pensees", section 38; Oeuvres, XXI, p. 362. See also sections 52, 53; Oeuvres, pp. 367-68.

[107] "Pensees", section 42; Oeuvres, XXI, p. 363.

[108] "Pensees", section 59; Oeuvres, XXI, p. 371.

[109] "Pensees", section 52; Oeuvres, XXI, pp. 367-68.

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[110] Oeuvres, XXI, pp. 539-568. The editors' title for these sections is "Reflexions sur la probabilite de nos conclusions et discussion de la question de l'existence d' etres vivants sur les autres planetes." Huygens himself entitled the first three sections separately: "De probatione ex verisimili," "Verisimilia de planetis," and "Quod animalium productio, praesertim hominum, praecipuum sapientiae intelligentiaeque Divina sit opus."

[111] "Pensees", section 33; Oeuvres, XXI, pp. 360-61.

[112] Celestial Worlds Discover'd, p. 11; Oeuvres, XXI, p. 689.

[113] Ibid., p. 21; Oeuvres, XXI, p. 701.

[114] Ibid., pp. 37-38; Oeuvres, XXI, p. 715.

[114a] Ibid., pp. 21-23; Oeuvres, p. 703. On this argument see David M. Knight, "Uniformity and Diversity of Nature in 17th century Treatises on the Plurality of Worlds," Organon, 4, 1967, pp. 61-68.

[115] Ibid., pp. 18-19; Oeuvres, XXI, p. 699.

[116] Ibid., pp. 101 ff; Oeuvres, XXI, pp. 765 ff.

[117] Ibid., p. 106: "And yet I warrant the Animals there on Mercury are made of such a temper, as to be but moderately warm, and the Plants such as to be able to endure the Heat. The Inhabitants of Mercury, it's likely, have the same opinion of us that we have of Saturn, that we must be intolerably cold, and have little or no Light, we are so far from the Sun. There's reason to doubt, whether the Mercurians, tho they live so much nearer the Sun, the Fountain of Life and Vigour, are much more airy and ingenious than we ... Nor can I be willing to make all that vast number that must inhabit those two large Planets, Jupiter and Saturn, and have such noble Attendance, mere dull Blockheads, or without as much Wit as ourselves, tho they are so far more distant from the Sun." This discussion later influenced Thomas Wright and Immanuel Kant, although Kant inverted the relationship between the intelligence of inhabitants and distance from the sun, asserting that those more distant from the sun would be composed of finer matter, and thus have a greater thinking capacity than those bound up in coarser matter nearer the sun. See above, ch. 5, pp. 303 ff.

[118] Ibid., p. 109; Oeuvres, XXI, p. 773.

[119] Ibid., p. 26; Oeuvres, XXI, p. 705.

[120] Ibid., p. 117; Oeuvres, XXI, p. 781.

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[121] Ibid., p. 129; Oeuvres, XXI, p. 793.

[122] Ibid., pp. 131-32; Oeuvres, XXI, p. 795.

[123] Ibid., p. 150; Oeuvres, XXI, p. 813.

[124] pp. 26-27. The complete title of Schudt's treatise is Libri duo de probabili mundorum pluralitate, cum appendice orationis de nihilo. Qua per varias hominum aetates, ordines atque studia probatur: Hominum plerosque, quando vel maxime se negotiosos arbitrantur, circa id, quod NIHIL est, versari, ac reipsa, magno conatu, nihil agere (Francofurti ad Moenum, 1721). Schudt tells us in the preface that he has delivered his work in public lectures on 25 April, 1720 and also on 26 September, 1720, and discussed it with friends.

[125] De probabili mundorum pluralitate, p. 28.

[126] Ibid., pp. 35 ff.

[127] On pp. 17-18 Schudt cites Huygens, Kosmotheoros, sive de terris coelestibus, earumque ornatu conjecturae ... editio altera, Francof. & Lips. Lecburg, an. 1704, in 8. Editio Germanica: Weltbetrachtende Muthmassungen von denen himmlischen Erd-Kugeln und deren Schmuck ... Leipz. 1703, in 4. Also Fontenelle, Dialogues sur la pluralite des mondes. Germanica editio: Gesprach von mehr als einer Welt/ zwischen einen Frauenzimmer und einen Gelahrten/ Leipzig, 1698, in 12. And Wilkins, Bischoffs zu Chester vertheidigter Copernicus, oder/ curioser und grundlicher Beweis der Copernicanischen Grunsage/ in 2 theilen verfasset und dargethan: I. Das der Mond eine Welt oder Erde. II. Das die Erde ein Planet sene. Leipz., 1713, in 4. In addition to these translations, Schudt cites the original German works, Haren. Geierbrand, Curieuse und wohlgegrundete Gedanken von mehr als einer bewohnten Welt, 1711 in 12, second edition Jenae, 1718, in 12; and Andreas Ehrenbergern, Die noch unumgestossene Vielheit der Welt-Kugeln/ oder/ das die Planeten Welt-Kugeln senn, Jenae, 1717, in 12. Although Schudt does not seem to have been aware of it, Geierbrand was actually a pseudonym for Ehrenberg, so that both works were written by the same author.

[128] The complete title of Hennings' work is "Specimen planetographiae physicae inquirens praecipue an planetae sint habitabiles ... indulgente amplissimo philosophorum ordine modestae eruditorum disquisitioni, in alma Kiliensi Academia A. MDCCXXXVIII, D. XXI. Maii submittet Jo. Christoph. Hennings, philos. mag., respondente Jo. Jac. Volckmanno, philos. et theol. cult. (Kilonii, typis Godofr. Bartschii, Acad. Typogr.); or, Specimen of physical planetography, inquiring especially whether the Planets are Habitable, which on the 21st of May, 1738 Johann Christopher Hennings submitted to a disquisition with

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128 (cont.) Johann Jacob Volckmann responding, in the Academy of Kiel, with the fullest indulgence of the philosophers." Although Volckmann responded, Hennings himself seems to have been the author.

129 Ibid., part II, section II, p. 17.

130 Ibid., part II, section III, pp. 20-21.

131 Ibid., part II, section IV, p. 22.

132 Ibid., part II, section XXIII, pp. 48-49.

133 Ibid., part II, section XXIV, p. 52.

134 See p. 377 above.

135 A. Pannekoek, A History of Astronomy (London, 1969), p. 371.

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Conclusion

I can't pretend to assert anything as positively true (for that would be madness) but only to advance a probable guess, the truth of which every one is at his own liberty to examine. If any one therefore shall gravely tell me, that I have spent my time idly in a vain and fruitless enquiry after what by my own acknowledgement I can never come to be sure of; the answer is, that at this rate he would put down all Natural Philosophy as far as it concerns itself in searching into the Nature of things: In such noble and sublime Studies as these, 'tis a Glory to arrive at Probability, and the search it self rewards the pains.

Christiaan Huygens[1] 1698

All Bodies were formed for the Sake of Intelligent Minds: As the Earth was principally designed for the Being and Service and Contemplation of Men, why may not all other Planets be created for the like uses, each for their own Inhabitants who have Life and Understanding?

Richard Bentley[2] 1693

No period in Western civilization confirmed more the power of the human mind to comprehend nature than did the seventeenth century. The era of Galileo and Kepler, Descartes and Newton, exhibited as never before the ability of intellect to perceive order and to frame laws, in short, to understand and potentially to rule the immense universe of matter. Even in their own time these men understood, undoubtedly with more than a little awe, the uniqueness of mind. Descartes gave to it an ontology separate from matter, the res cogitans as opposed to the res extensa, and most thinkers would have agreed with Richard Bentley's assessment of man as "not a Reasonable Animal merely, for that is not an adequate and distinguishing Definition, but a Rational Mind ...".[3] Mind seemed to be a unique quality of man, which allowed him to rule over the material universe and

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the animal kingdom alike, to stand alone at the pinnacle of creation.

The projection of mind into space is thus a striking development, a watershed in the history of thought. More daring than the decentralization of the earth, or the accompanying move from the closed world to the infinite universe, it was a step which filled the formerly Divine celestial region with intellect. In striking contrast to the medieval world view, with its supernatural celestial intelligences who aided in the movement of the heavenly spheres, man now sought to project what he himself perceived as his most important and unique attribute - his rational mind - into the universe at large. Just as there could be no separate celestial and terrestrial laws, and just as these laws could not cease to operate throughout the universe, it seemed that there could be no qualitative dichotomy between terrestrial and celestial mind, and equally, no absence of mind throughout the universe. This step may thus be viewed as a metaphysical completion of the scientific revolution, the final act which in the aftermath of man's greatest triumphs in understanding nature, removed from him, on the universal scale, the only unique quality he still possessed, that of mind.

The plurality of worlds tradition which embodied this final revolution of the seventeenth century was, moreover, forged predominantly by natural philosophers themselves. As Huygens' pertinent passage (cited above) clearly demonstrates, the question was perceived as a legitimate, even a "noble and sublime",

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part of natural philosophy. The emergence of the concept of extraterrestrial life into the mainstream of European consciousness occurred only after complex, painstaking, and reasoned analysis, led by natural philosophers who drew upon a tradition of thought stretching back to antiquity. That tradition, as with all natural philosophy, drew upon both metaphysical and physical principles. From the infinite number of kosmoi of the ancient atomists to the infinity of stellar systems expounded by Immanuel Kant, metaphysical concepts such as Divine omnipotence, teleology, and plenitude played a significant role. But they played this role only in the larger context of contemporary physical theory, and consistent with whatever observational evidence was available.

There is historical logic in the fact that it was only at the beginning of the seventeenth century that the concept of extraterrestrial life became a serious question in the minds of certain critically-thinking men. It was only at that time that the Copernican theory began to take hold, and, even before the advent of the telescope, the implications of that theory were not to be denied to the minds - and the imaginations - of men like Kepler. There is logic, too, in the circumstance that it was the end of the seventeenth century and the beginning of the eighteenth before the existence of such extraterrestrials was widely accepted. A myriad of theological implications needed to be explored in the intervening century, and in the end, at least for a time, both science and theology found

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reason for comfort: science had its terrestrial physics generalized into a planetary physics, complete with extraterrestrials, and natural theology had a powerful argument for the magnificence of God's universe. The Copernican theory, Cartesian vortices, Newtonian universal gravitation, and the observation of planetary surfaces and atmospheres all prepared the way for celestial inhabitants; the increasing freedom from theological restrictions which emerged in the seventeenth century, and the growth of natural theology, hastened their arrival.

It was, overwhelmingly, intelligent extraterrestrial life which concerned the men of the seventeenth and eighteenth centuries. In this may be found the reason that it was physical theory, and not biological theory, which played the major role in this revolution. Before intelligence could be spread throughout the universe, one needed to establish the existence of earth-like planets, subject to similar physical processes, and with the basic perceived necessities of an atmosphere and water. This endeavor, of course, did involve some details of interest from the standpoint of contemporary biological knowledge - as when Kepler described his lunar inhabitants as massive in size and having a spongy or porous rind for skin.[4] It might be interesting to know whether any biological knowledge underpins these and similar statements of Kepler and others. But the most fruitful study in this direction would certainly come in later periods, when men began to wonder about the origin and existence of lower forms of life on other worlds, when terrestrial biological theory

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began to flower, and when the search for extraterrestrial life provided the ultimate generalization into which this theory might be incorporated.

In the end, the existence of extraterrestrial intelligence could never be directly proven by scientific theory or observation, notwithstanding Kepler's claimed observation of lunar towns (which is, incidentally, an interesting precursor to Percival Lowell and the canals of Mars). Observational techniques would be immensely improved, notably by the development of spectroscopy in the nineteenth century, and of space probes in our own time, events beyond even the imagination of seventeenth century thinkers. And still the answer would remain in doubt.

That seventeenth and eighteenth century natural philosophers nevertheless relentlessly pursued the subject, is a tribute in part to metaphysics, in part to the impetus of contemporary scientific developments, and above all, to the sine qua non which fostered the scientific revolution in the first instance, the curiosity and boldness of the mind in search of knowledge.

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Notes

[1] The Celestial Worlds Discover'd: or, Conjectures concerning the Inhabitants, Plants and Productions of the Worlds in the Planets (London, 1698; facsimile, London, 1968), pp. 9-10. Oeuvres, XXI, p. 698.

[2] A Confutation of Atheism from the Origin and Frame of the World (London, 1693), in Isaac Newton's Papers and Letters on Natural Philosophy, ed. I. Bernard Cohen (Cambridge, Mass., 1958), p. 358.

[3] Ibid., p. 359.

[4] For these and other biological details, see Kepler's Somnium: the Dream or Posthumous Work on Lunar Astronomy (Madison, 1967), pp. 27-28 and Kepler's accompanying notes.

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