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ST. THOMAS AQUINAS, GALILEO, AND EINSTEIN

IT is frequently said of St. Thomas Aquinas that the man has been lost behind the voluminous quantity of his writing. Commenting further on this literary output of the Common Doctor, one could say that his valuable contributions to the development of physical science have been lost in the great mass of his writing on theology and philosophy. In this vein, it might not be amiss to bring out of the shadows cast by Aquinas' more famous works a few specimens of his thought on the subject of scientific knowledge, contributions that, had they been those of a lesser genius, might have been appreciated the more by assessors of the medieval scientific tradition.

To those who are friends and admirers of St. Thomas, no apology is needed for treating the question of his basic theory of physical knowledge. But even should the reader make no commitment whatsoever to Thomism, it could well be profitable to reconsider some of the perennial problems of the universe in the light of Aquinas' conception of physical science. Such a consideration need not be anachronistic. As Burtt has pointed out in his *Metaphysical Foundations of Modern Science,* every age has its unconscious presuppositions, and these can sometimes be brought to light by setting off current views against those of an earlier period, when prevailing notions were not so commonly entertained.[1] And if every age has its hidden presuppositions, it is also true that every age has its problems—not unconnected, possibly, with these same suppositions. We in America are now very much preoccupied with the study of the physical universe: on the surface, great progress is being made in science and technology, but at the heart of the matter, when scientists ask how much is really known about the world in which we live, there is a gnawing doubt that makes itself increasingly felt about our ability ever to reach any definitive answers. It is on such a problem of the validity of scientific knowledge that Thomas Aquinas may have something worthwhile to offer to the modern mind, and this proposal will therefore be the burden of our study.

St. Thomas Aquinas (1225-1274)

The intellectual atmosphere that Aquinas breathed at the University of Paris in the mid-thirteenth century was not sympathetic to natural science; in fact, it was markedly hostile to the influx of Aristotelian and Arabian thought into Western Europe—an influx that brought with it much of the scientific learning of the ancient world. This attitude of hostility at Paris, however, was not apparent at the other great center of studies in medieval Christendom, Oxford University. There the discovery of Aristotle's logical works, and particularly the translation of the *Posterior Analytics* (with commentary) by Robert Grosseteste, Bishop of Lincoln (1175-1253), had stimulated great interest in a type of mathematical physics which accented studies in optical science.[2] This had resulted in what Baeumker has called a " metaphysics of light," a philosophy immediately put to the service of theology to develop the

[1] E. A. Burtt, (London: 1932), pp. 15-17.

[2] A. C. Crombie, *Robert Grosseteste and the Origins of Experimental Science,* (Oxford: 1953), pp. 91-134.

Christian Platonism of the Oxford school.[3] What is of more importance, however, in this scientific revival at Oxford was its insistence on the role of mathematics in physical proof. In this school a pure mathematical structure was commonly conceived as objectively existing in things, before their physical properties, and giving the only adequate explanation of observed reality. Possibly through Roger Bacon, the influence of Grosseteste's work was gradually felt on the continent, and provoked a decided reaction from the pen of St. Albert the Great (1206-1280), the teacher of St. Thomas Aquinas. Albert himself, unique among the Paris Masters, had been sympathetic to the influx of Aristotelian thought, had done extensive observational and experimental work in biology, meteorology and alchemy, and had reconstructed a physical theory from Aristotle's *Physics* that was opposed to the mathematical realism of the Oxford school.[4] The young Aquinas then built upon Albert's foundations, and elaborated this theory that was primarily physical, but at the same time allowed for a legitimate use of mathematics in obtaining strict physical explanation or proof.[5]

For Aquinas, as for Albert, mathematical structure is not imposed on reality by the mind, but rather is abstracted from reality by a mental process that leaves aside all the irregularities of matter and the flux of movement and time. More basic than this mathematical structure is the physical nature of the reality studied, which is determined to express itself in a certain figure—by which, for example, we can easily recognize a horse, and distinguish it from a cow. The quantitative characteristics that are thus expressive of a type are not themselves mathematical entities, but rather are physical ones,

[3] C. Baeumker, "Der Platonismus im Mittelalter," in Studien und Charakteristiken zur Geschichte der Philosophie insbesondere des Mittelalters, *Beiträge zur Geschichte der Philosophie des Mittelalters,* Bd. 25, 1-2, Münster-i-W.: 1927, p. 160 ff.

[4] J. A. Weisheipl, O. P., "Albertus Magnus and the Oxford Platonists," *Proceedings of the American Catholic Philosophical Association,* Vol. 32 (1958), pp. 124-139.

[5] J. A. Weisheipl, O. P., *The Development of Physical Theory in the Middle Ages,* (London: 1959), pp. 27-62.

although originative sources of the idealized static structure studied by the mathematician. Thus, in Aquinas' view, the insight afforded by mathematics is not deeper—or more " divine," as the Platonists would have it—but actually is more superficial than a physical insight. As a consequence, explanation through mathematics does not explain the physical nature, but it does accurately describe that nature, and it can help in discovering a physical explanation or proof.[6]

The help that mathematics gives to the physicist was conceived by Aquinas as being of two kinds, one which functions at the level of hypothesis to suggest *possible* physical explanations, the other which functions conjointly with physical reasoning to give *conclusive* explanation or proof.[7] An example of the first would be the Thomistic evaluation of Ptolemy's explanation of the motion of the heavens through eccentrics and epicycles. Viewed mathematically, Aquinas noted, the observed appearances of the stars result " either from the motion of the object seen or from the motion of the observer, . . . it makes no difference which is moving." [8] But as a physical explanation he showed considerable reserve towards the Ptolemaic hypotheses, noting that while they do account for the stellar appearances, " we must not say that they are thereby proved to be facts, because perhaps it would be possible to explain the apparent movements of the stars by some other method which men have not yet thought out." [9] His whole treatment of astronomical and meteorological problems, in fact, seems aimed at correcting a naive mathematicism among medieval Aristotelians, for he points out that Aristotle, in dealing with the heavenly spheres, had mistaken a suppositional theory for established fact.[10] He himself is at pains to elaborate the reasons why we cannot have certain judgments about the heavenly bodies; [11] yet, he observes, it is not stupid or neces-

[6] Cf. *In I de Caelo,* lect. 1, n. 2, and lect. 3, n. 6; *In II Phys.,* lect. 3; *Summa Theologiae,* I, q. 1, a. 1, ad 2.

[7] Cf. *Summa Theologiae,* I, q. 32, a. 1, ad 2; *In II Phys.,* lect. 3, n. 9.

[8] *In II de Caelo,* lect. II, n. 2, and lect. 12, n. 4.

[9] *Ibid.,* lect. 17, n. 2. [10] *Ibid.* [11] *Ibid.,* lect. 4, n. 3.

sarily precipitate to venture an explanation, for he holds that a theory or supposition that does not conflict with the facts is far better than no explanation at all.[12]

In addition to this first, or hypothetical use of mathematics in seeking a possible explanation, Aquinas also conceived of mathematics as functioning directly in physical argument to furnish a conclusive explanation or proof.[13] This too can best be illustrated by an example.[14] In discussing the shape of the earth, he notes that the latter can be proved to be a sphere merely by an analysis of measurements made on its surface—essentially a mathematical proof.[15] But he regards as more conclusive for the physicist a proof which arises not simply from a mathematical description of the earth's surface, but which leads to a knowledge of the *physical causes* that make the earth to be a sphere. Thus he observes, " all gravitating bodies . . . approach the earth at the same angle, that is, at a right angle . . . and not in parallel lines." [16] This universal mode of gravitation " is what makes the earth to be spherical by nature," he says, because the spherical shape alone can satisfy the uniform tendency of all parts to a common center of gravity.[17] " If the earth were naturally flat, as some have said," he continues, " then bodies would not gravitate everywhere towards the earth at the same angle." [18] It should be noted in this proof that the physical cause Aquinas assigns need not make the earth a perfect sphere—" irregularities such as mountains and valleys arise," he concedes, although " not of notable dimensions compared with those of the earth," and he attributes them to " some other incidental cause." [19] Thus pure or perfect mathematical shape, for Aquinas, does not exist in physical reality: it is only the human mind, abstracting

[12] *Ibid.*, lect. 7, nn. 4-5; *In I Meteorologicorum,* lect. 11, n. 1.

[13] *In I Post. Anal.*, lect. 25, nn. 5-6.

[14] For other examples, together with some applications to modern science, see my " Some Demonstrations in the Science of Nature," *The Thomist Reader 1957* (Washington, D. C.: 1957), pp. 90-118.

[15] *In II de Caelo,* lect. 28, n. 4.

[16] *Ibid.*, n. 1.

[17] *Ibid* .

[18] *Ibid.*

[19] *Ibid.*

from material irregularities such as mountains and valleys, that can conceive of the earth as a perfect sphere.[20] But the earth does have a natural or physical shape which is approximately spherical, and this shape can reveal to the inquiring mind the physical reason which makes the earth to have this shape in the first place.[21]

Space does not permit even a sketch of the historical consequences of this theory of physical proof developed by Albert and Aquinas. It is indisputable, however, that this theory made clear, at a critical period of medieval thought, the distinction between hypothetical explanation and proven fact, while allowing for a legitimate use of mathematics in both types of reasoning. To this one might add that some recently edited texts can be used to argue to the existence of a " Dominican school " in optical science, beginning with encyclopedic collections of data by Thomas of Cantimpré, Vincent of Beauvais and Albert the Great, developing through the theoretical speculations of Thomas Aquinas, John of Paris and Peter of Alvernia, and culminating in the brilliant experimental researches and physico-mathematical theories of Theodoric of Freiburg.[22] The historical import is not insignificant: in less than a century, this line of thought, quite independent of the Oxford school, furnished the first correct fundamental theory of the rainbow—and this more than three hundred years before the publication of Descartes' *Discours de la Méthode* and *Les Météores,* where basically the same explanation of the rainbow is cited as one of the brilliant achievements of the new Cartesian methodology.[23]

[20] *In II Phys.,* lect. 3, nn. 4-6.

[21] *Summa Theologiae,* p. I, q. 1, a. 1, ad 2; *In I de Caelo,* lect. 3, n. 6.

[22] See my *The Scientific Methodology of Theodoric of Freiburg,* Studia Friburgensia No. 26 (Fribourg: 1959), pp. 132-249. Newly edited texts are contained in Appendix III, pp. 305-376.

[23] The full title of Descartes' work on methodology reads: "Discours de la Méthode pour bien conduire sa raison, et chercher la vérité dans les sciences. Plus la Dioptrique, les Météores, et la Géométrie, qui sont des essais de cette Méthode," (Leyde: 1637). The explicit statement from *Les Météores* is contained in Descartes' *Oeuvres,* ed. C. Adam and P. Tannery (Paris: 1897-1910), Vol. VI, p. 231.

Galileo Galilei (1564-1642)

While not belittling the importance of Descartes' influence on modern thought, we may turn now to one of his contemporaries, Galileo Galilei, to whom the accolade is commonly given for having procured the " downfall of Aristotle " and the beginning of a new era in science. Some might quibble on the phrase " downfall of Aristotle " and urge that this was more a downfall of a caricature of Aristotle drawn by third-rate scholastics,[24] but without gainsaying the point, the effect was pretty much as popularly conceived. One of Galileo's admirers, Fr. Paolo Sarpi, registered a not uncommon reaction when he said: " To give us the science of motion God and Nature have joined hands and created the intellect of Galileo." [25] In our own day, the popular image is that of an indefatigable experimenter climbing the leaning tower of Pisa to put the Aristotelians to rout with his measurements of falling bodies.[26] Recent studies point more significantly to the Renaissance reaction to Galileo's *Message of the Stars.* Thus Koyré summarizes:

> Mountains on the moon, new ' planets ' in the sky, new fixed stars in tremendous numbers, things that no human eye had ever seen, and no human mind conceived before. And not only this . . . also the description of an astonishing invention . . . the first scientific instrument, the telescope, which made all these discoveries and enabled Galileo to transcend the limitation imposed by nature—or by God—on human senses and human knowledge.[27]

The experimental work of Galileo might easily—though falsely—be interpreted as the beginning of modern scientific method, with its accent on postulational procedures subsequently verified by experimental proof. Actually Galileo's method was more closely patterned on that of the late Aristo-

[24] Cf. G. de Santillana, *The Crime of Galileo* (Chicago: 1955), pp. 24, 56, 69.

[25] Cited by Burtt, *op. cit.*, p. 74.

[26] But see L. Cooper, Aristotle, *Galileo & the Tower of Pisa* (Ithaca: 1935); also E. A. Moody, " Galileo and Avempace: The Dynamics of the Leaning Tower Experiment," *Journal of the History of Ideas,* 12 (1951), pp. 163-193, 375-422.

[27] A. Koyré, *From the Closed World to the Infinite Universe*, (New York: 1957), p. 90.

telians of the Paduan school,[28] and its most significant aspect was not its insistence on experiment, but rather on the fact that " the book of nature " is written *only* in the language of mathematics.[29] " This book is written in the mathematical language," wrote Galileo, " and the symbols are triangles, circles, and other geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders in vain through a dark labyrinth." [30] Galileo was quite convinced of the absolute truth of the heliocentric theory, maintaining that it was not merely a possible explanation, a " saving of the appearances," as Osiander had indicated in his preface to Copernicus' work,[31] but rather that it expressed a certain truth with which one could even contest traditional interpretations of Sacred Scripture. " Although [a theory that saves the appearances] satisfies an astronomer merely arithmetical," he said, " it does not afford satisfaction or content to the astronomer philosophical." [32] His own metaphysical option, according to Burtt, was for a much refined Platonism that was actually a strict mathematical realism [33]—one could almost call it a revival of the Pythagorean doctrine of twenty centuries previous.[34] Experiments had no probative value for Galileo; they were meant to appeal to the popular mind—those who knew mathematics really had no need of them. But the popular mind also needed convincing, and here Galileo's genius for stirring up trouble came to the fore. His wit and sarcasm in controversy are well known, and on hearing

[28] Cf. J. H. Randall, Jr., " The Development of Scientific Method in the School at Padua," *Journal of the History of Ideas,* 1 (1940), pp. 177-206; P. R. Wiener, " The Tradition Behind Galileo's Methodology," *Osiris,* 1 (1936), p. 733 ff.

[29] See, for example, J. Collins, *A History of Modern European Philosophy,* (Milwaukee: 1954), pp. 79-81.

[30] Galileo, *Il Saggiatore* (Florence: 1842), p. 171.

[31] For a detailed examination of the relations between Copernicus and Galileo, see P. Conway, O. P., " Aristotle, Copernicus and Galileo," *The New Scholasticism* 23 (1949), pp. 38-61, 129-146.

[32] Galileo, *Dialogue on the Great World Systems,* Third Day, ed. G. de Santillana, pp. 349-350.

[33] Burtt, *op. cit.,* pp. 82, 84; cf. A. Koyré, " Galileo and Plato," *Journal of the History of Ideas,* 4 (1943), pp. 400-428.

[34] Cf. G. de Santillana, *The Crime of Galileo,* p. 69.

this brief excerpt from a letter, one can imagine the hot arguments he provoked. He writes:

> Oh, my dear Kepler, how I wish that we could have one hearty laugh together! Here at Padua is the principal professor of philosophy, whom I have repeatedly and urgently requested to look at the moon and planets through my telescope, which he pertinaciously refuses to do. Why are you not here? What shouts of laughter we should have at this glorious folly! And to hear the professor of philosophy at Pisa laboring before the Grand Duke with logical arguments, as if with magical incantations, to charm the new planets out of the sky! [35]

In sober fact, Galileo Galilei never did prove that the earth went around the sun, and not vice versa. Conclusive proof of the type Aquinas would have sanctioned, such as is found now, for instance, in our astronomy textbooks, had to wait two more centuries for the contributions of Foucault and Bessel.[36] Galileo's real " crime " had nothing to do with revealed religion: it consisted merely in this, that he saw proof too easily, and thus obscured (in his own mind, at least) the distinction between hypothetical explanation and proven fact already well known to Aquinas. Yet there was much that was good in his work—he had offered new evidence that should have been taken into account by the philosophers of his day. As de Santillana remarks, " Had there been in Rome, at the time of the first crisis of 1616, a youthful Aquinas . . . instead of an aged Bellarmine," history might have been written differently.[37] But " there was no Aquinas," [38] and well known is the unfortunate stand taken by those who were in Rome, to bring about what history will always regard as a tragic ending in a most unsatisfactory case.

[35] Letter to Kepler, 1610; cited by Burtt, *op. cit.*, p. 77.

[36] Cf. A. C. Crombie, " Galileo's ' Dialogues Concerning the Two Principal Systems of the World,' " *Dominican Studies,* 3 (1950), pp. 105-138.

[37] *The Crime of Galileo,* p. ix.

[38] *Ibid.*

Albert Einstein (1879-1955)

Crombie has suggested that the great genius of Albert Einstein, working three centuries after Galileo to elaborate the theory of relativity, consisted in his breaking away from the spell under which the great Italian had put mathematical physics from its inception. " Einstein was able to advance the theory of relativity," Crombie writes, " because he acted on the principle that the object of physical science is to ' save the appearances ' by mathematical abstractions postulated *for no other purpose* than to ' save the appearances.' " [39] Einstein seems to have had little hope of penetrating to the reality behind his equations, and there can be little doubt that recent revolutions in physics, traceable in large measure to Einstein, show a decided break with the Galilean concept of proof. In fact, with Einstein ends the naive optimism of a classical physics that saw the book of nature written in the language of mathematics.[40] Proficiency in mathematics, it is true, enabled this modern scientist to achieve brilliant successes in theoretical physics, but the more he worked, the more he doubted the exact correspondence of pure mathematics to physical reality. " As far as the laws of mathematics refer to reality," he says, " they are not certain; and as far as they are certain, they do not refer to reality." [41] In fact, Einstein would go even further; for him, fundamental principles cannot be " abstracted " from sensory experience—they are " free inventions of the human intellect." [42] Far from subscribing to the strict mathematical realism of Galileo, he oscillates between positivism and idealism, while ever leaving a provisional cast to his conclusions.[43] " Our notions of physical reality can never

[39] A. C. Crombie, *Augustine to Galileo,* (London: 1952), p. 328 (italics added).

[40] In writing this, we are aware that Niels Bohr and the Copenhagen school are even more radical in their renunciation of classical physics than Einstein, but the latter's position is sufficiently representative for our purposes.

[41] *Geometrie und Erfahrung,* cited in *Albert Einstein, Philosopher-Scientist,* Library of Living Philosophers, Vol. VII, (Evanston: 1949), p. 380.

[42] *Herbert Spencer Lecture,* 1933 cited *ibid.,* p. 273.

[43] Cf. P. G. Frank, " Einstein, Mach and Logical Positivism," *ibid.,* pp. 269-286;

be final," he states. " We must always be ready to change those notions . . . in order to do justice to perceived facts in the most logically perfect way." [44]

Compared to the physical views of Aquinas and Galileo, those of Einstein stand in proper relief. Seven centuries ago, Aquinas saw the possibility of a mathematical physics that could provide both provisional explanation and conclusive proof, although he had no illusions about the difficulties involved in unveiling the ultimate secrets of the physical universe.[45] Three centuries ago, flushed with his dramatic conquest over the popular mind, Galileo saw proof too easily in the mathematics he had learned to read in the book of nature; in his view, conclusive proof was quickly had—all one need do was study his new science of motion, and the Ptolemaic-Copernican controversy would perforce come to an end. In our own day, Einstein went to the other extreme, for where Galileo saw proof as too easy, he saw it as too difficult—hence an essential relativism in his physical theory which permits no final answers about the physical universe. Aquinas would look for the evidence of Bessel and Foucault to decide the Copernican controversy; Galileo would say that the mathematical simplicity of his laws had already decided it; Einstein would say that his general theory of relativity had made it forever undecidable.[46]

The Problem

This brings us to the problem that is vexing modern science, to the solution of which the physical theory of Aquinas might be able to register a contribution. In the popular mind, science

V. F. Lenzen, " Einstein's Theory of Knowledge," *ibid.*, pp. 355-384; H. Margenau, " Einstein's Conception of Reality," *ibid.*, pp. 243-268.

[44] " Clerk Maxwell's Influence on the Idea of Physical Reality," cited *ibid.*, p. 248.

[45] Cf. *In I Meteorologicorum,* lect. 1, n. 9.

[46] " The struggle, so violent in the early days of science, between the views of Ptolemy and Copernicus would then be quite meaningless. Either CS [coordinate system] could be used with equal justification. The two sentences, ' the sun is at rest and the earth moves,' or ' the sun moves and the earth is at rest,' would simply mean two different conventions concerning two different CS."—A. Einstein and L. Infeld, *The Evolution of Physics,* (New York: 1942), p. 224.

is making great strides forward, finding out new truths everyday that undermine traditional philosophies and even religious beliefs, supplying definitive answers to questions that have plagued men's minds since the dawn of civilization. But within the scientific fraternity itself, there is no such optimism—at least not so far as the question of conclusive proof is concerned. "*Proof*," writes Eddington, "is an idol before whom the pure mathematician tortures himself. In physics we are generally content to sacrifice before the lesser shrine of *plausibility*." [47] Relativity and quantum theories are now the standards against which scientific achievement is measured. One is not surprised that some now hold that whether the earth goes around the sun or vice versa depends strictly on one's point of view, and cannot be proved one way or another. Not long ago, a methodologist told the writer that it was merely a *theory* that the earth is round! Today the whole world is talking of "molecules" and "atoms" and "electrons" and "cosmic rays"; even high-school children can tell us of "evolving galaxies" and the "expanding universe." Has science proved that such things exist? Or are they merely "free inventions of the human mind"? Is the hard core of scientific fact softer than we think? Or is it possibly even an empty shell?

Einstein, we may presume, would want to disabuse the modern mind of its confidence in the permanent achievements of science. Galileo, no doubt, would be tremendously surprised at the state of affairs that has arisen in the science that he fathered, but one may surmise that he would still champion the absolute power of mathematics to give certain truth. Aquinas, we can be sure, would temper the optimism of Galileo, but—realist that he was—he would also temper the pessimism of Einstein by bridging the gap between science and common sense. While denying that mathematics is the skeleton key that opens *all* the doors of knowledge, he would say that it has a proper role to play in physical research, that it can lead to conclusive physical proof, that some final answers can be given about the world in which we live.

[47] A. S. Eddington, *The Nature of the Physical World,* (New York, 1928), p. 337.

Three divergent answers to a perennial question about the physical universe. Which is correct? While recognizing that the latter question would be regarded as unanswerable (if not meaningless, in Wittgenstein's sense) by some philosophers of science, and while conceding that the extreme polarity between the positions of Galileo and Einstein is more by way of suggestion than by way of explicit commitment in the writings of these scientists, we should like to propose a somewhat novel evaluation of the three possible alternatives. It is this, namely, that Aquinas' answer—the teaching of the analytical school to the contrary—is still the one implicitly subscribed to by the practicing scientist, and that the essential contribution of Einstein is to cancel out the excessive mathematical realism of Galileo, while still leaving open the possibility of a type of physical certainty and proof as conceived by Thomas Aquinas.

A Thomistic Proposal

The justification for this view may perhaps be seen if we analyze the scientific evidence commonly adduced to prove (1) that the earth rotates on its axis, and (2) that its shape is approximately that of an oblate spheroid. In the interests of rigor, and to facilitate discussion of the central issue, we shall frame both arguments in the form of a syllogism, then answer an objection that is commonly encountered against each argument, and with that draw some inferences about the current status of physical proof in modern science.

The first argument may be stated as follows:

A body on which a freely swinging pendulum deviates at the rate of one revolution per twenty four hours at the poles, decreasing according to the sine of the latitude to zero deviation at the equator *is* rotating on its polar axis once every twenty-four hours.

But the earth *is* a body on which a freely swinging pendulum deviates at the rate of one revolution per twenty-four hours at the poles, decreasing according to the sine of the latitude to zero deviation at the equator.

Therefore the earth *is* rotating on its polar axis once every twenty-four hours.

The second argument then reads:

A body on which a freely swinging pendulum of fixed length has periods of oscillation which increase slightly with increasing latitude from the equator to both poles *is* an oblate spheroid slightly flattened at the poles.

But the earth *is* a body on which a freely swinging pendulum of fixed length has periods of oscillation which increase slightly with increasing latitude from the equator to both poles.

Therefore the earth *is* an oblate spheroid slightly flattened at the poles (and here we add parenthetically—although this does not follow logically—the flattening being caused by the centrifugal force of its daily rotation).

Here, then, are two demonstrations which conclude to some predication about the earth, namely, (1) that it is an oblate spheroid, and (2) that it rotates on its axis of symmetry once every twenty-four hours, both arguments using as the middle term some aspect of the behavior of a pendulum on the earth's surface, which is discovered to be *caused* by the shape and rotation of the earth itself.

Some will object against the second argument—the one concluding to the shape of the earth—that this was regarded as valid in the pre-Einstein period, when it was thought that Euclidean geometry was uniquely applicable to the physical universe. But in the present day, when non-Euclidean geometries have proved to be remarkably fruitful in explaining physical phenomena, one cannot say *for sure* that the earth is a sphere or an oblate spheroid; in another geometry it might be another mathematical figure, and thus the argument no longer truly demonstrates.

To this objection we answer that, if relativity theory has shown anything, it has shown that the geometry used by the physicist to describe the shape of the earth is basically immaterial. For dimensions as small as those of the earth, it is of no physical importance whatsoever whether the geometry is Euclidean, or Riemannian, or Lobatchewskian. But the very objection reveals one thing that is quite important, namely, that the objector is a mathematical realist who conceives pure mathematical form as objectively existing in, and determining, the universe to a particular geometry. As has been shown earlier, this is not the Thomistic concept: physical quantity is much too irregular, it is much too perturbed by physical factors—such as matter and motion and time, and their means of measurement—to yield pure geometrical form, except through a process of mathematical abstraction. Thus, when the physicist says that the earth is an oblate spheroid, just as he prescinds from the mountains and valleys and other physical irregularities, so he prescinds from the slight differences associated with alternative *pure* geometries, to say something that is physically meaningful about the shape of the earth.

The first argument also seems to be vulnerable—this time to an objection drawn from the general theory of relativity. We have argued that it is possible to *demonstrate* that the earth is actually rotating on its axis once every twenty-four hours. Now Einstein, and before him the great German physicist, Ernst Mach—who undoubtedly gave inspiration to Einstein's new theories—have held that it is impossible to detect an *absolute* rotation in the universe. Thus they would argue that the cause assigned above for the deviation of the pendulum on the earth's surface (or for the bulge at the equator) need not be the rotation of the earth: the same effect can be correlated mathematically with the apparent motion of the " fixed " stars, and thus one cannot be absolutely sure that the earth's rotation is causing the pendulum phenomena or the bulge at the center, since these *might be* caused by other forces connected with the diurnal motion of the stars.[48]

A Thomistic answer to this difficulty is suggested by that of the English astronomer and commentator on general relativity theory, Sir A. S. Eddington, who writes in this connection:

I doubt whether anyone will persuade himself that the stars have anything to do with the phenomenon. We do not believe that if the heavenly bodies were all annihilated it would upset the gyrocompass. In any case, precise calculation shows that the centrifugal

[48] For a fuller statement of this position, see H. Reichenbach, *Modern Philosophy of Science,* (New York: 1959), p. 12.

force could not be produced by the motion of the stars, so far as they are known.[49]

As for the search for some unknown force that *might* explain the phenomenon, Eddington becomes more caustic:

As we go further into space to look for a cause, the centrifugal force becomes greater and greater, so that the more we defer the debt the heavier the payment demanded in the end. Our present theory is like the debtor who does not mind how big an obligation accumulates, satisfied that he can always put off the payment. It chases the cause away to infinity, content that the laws of nature . . . are satisfied all the way.[50]

In this matter, Thomas Aquinas, we may be reasonably sure, would be content with a physical explanation of the motion of the pendulum or of the bulge at the equator in terms of known causes, and would be quite unhappy with an explanation, or a methodology, that would remove a hypothetical cause to infinity. As to the mathematical correlation with the fixed stars mentioned by Mach and Einstein, this would not disturb him: he would say, as has already been pointed out, that *mathematically* it makes no difference whether either one, the earth or the fixed stars, is conceived as moving. But once he saw the physical evidence available today to show that the plane of oscillation of a pendulum is independent of the motion of its support and is determined uniquely by its point of suspension, the center of gravity of its bob and the center of gravity of the local region, or once he convinced himself that there are centrifugal forces connected with every rotation that *we* initiate, he would look no further for a causal explanation in the remote depths of space to account for the deviation of a pendulum on the earth's surface, or for the observed bulge in the earth's contour at the equator. He would conclude, as do most modern scientists, that these are caused by the rotation of the earth, and that the earth therefore is actually spinning on its axis.[51]

[49] *Space, Time and Gravitation* (Cambridge: 1920), p. 153.

[50] *Ibid.*

[51] This argument can be stated more technically by referring the motion of the pendulum to the local inertial axes of the Copernican coordinate system. Thus

This conclusion, it should be noted, does not commit the Thomist to the Newtonian conception of a subsistent absolute space (or absolute time) in which such spinning motion is executed. The notion of absolute space is again an extreme of mathematical realism which attributes static, extra-mental existence to an extension that has been abstracted by the mind from bodies in motion. Space, for St. Thomas, does not exist apart from *bodies* that are extended and in motion; itself based on the relation of distance between bodies, it is rather a relative thing, not an absolute. More properly it is a mathematical concept that abstracts from matter and motion, and as such is conceived statically by us. This need not, therefore, be interpreted to mean that it also exists statically outside the mind as an independent subsistent reality.[52]

A similar observation might be made about the existence of privileged frames of reference or inertial systems which correspond, in the language of relativity, to the absolute space of Newton. Motions within the solar system—or in any local region, for that matter—can be investigated without referring them, in a larger context, to the motions of other systems. The difficulty arises only when space (or the space-time continuum) is hypostasized to be a subsistent background, sometimes conceived physically as an " aether," against which the frames of reference of various systems are actually moving. Operating with such a supposition, the question can be raised as to which system is " really " at rest, or what is the privileged frame of reference in terms of which " absolute " motion and rest in the universe can be detected. It is to the merit of Einstein that his theories of relativity make clear how such a question, if raised, is unanswerable in terms of the data available to the physicist

our analysis accords with the view of Whittaker, recently taken up by Polanyi: " Sir Edmund Whittaker ('Obituary Notice on Einstein,' *Biogr. Mem. Roy. Soc.*, 1955, p. 48) points out that, contrary to widespread opinion, the physical significance of Copernicanism is not impaired by relativity. For the Copernican axes are inertial, while the Ptolemaic are not, and the earth rotates with respect to the local inertial axes."—M. Polanyi, *Personal Knowledge,* (Chicago: 1958), p. 147, fn. 1.

[52] Cf. J. A. Weisheipl, O. P. " Space and Gravitation," *The New Scholasticism,* 29 (1955), pp. 175-223.

in any system. The Thomistic position would rather seem to be that the question should not be asked in the first place, because of the uncritical supposition on which it is based.

Physical Proof

It is interesting that the view of St. Thomas that has been urged in this paper, namely, that there can be some " final answers " in physical science, is once again finding support from scientists. Heisenberg, for example, who seemed to shake traditional thought to its foundations when he enunciated his " principle of uncertainty," has written in a recent work:

> With respect to the finality of the results, we must remind the reader that in the realm of the exact sciences there have always been *final solutions* for certain limited domains of experience. Thus, for instance, the questions posed by Newton's concept of mechanics found an answer *valid for all time* in Newton's law and in its mathematical consequences. . . . In the exact sciences the word ' final ' obviously means that there are always self-contained, mathematically representable, systems of concepts and laws applicable to certain realms of experience, in which realms *they are always valid for the entire cosmos and cannot be changed or improved.* Obviously, however, we cannot expect these concepts and laws to be suitable for the subsequent description of new realms of experience.[53]

With this, we think St. Thomas would heartily agree. In a very real sense, in physical research one never knows what the morrow will bring, but the scientist can know that if he does his work well, and does not read into his results more than the evidence warrants, he can gain *new* knowledge without thereby destroying the science he has previously acquired.

This view, we would maintain, is the one implicitly held by the practicing scientist.[54] Yet there remains the difficulty,

[53] W. Heisenberg, *The Physicist's Conception of Nature,* (London: 1958—translation by A. J. Pomerans of *Das Naturbils der heutigen Physik,* Hamburg: 1955), pp. 26-27 (italics added).

[54] It has also been stated explicitly by Oppenheimer, in his third Reich lecture, as reported by Hall: " In its [science's] progress since 1800 the later discoveries have always embraced the earlier: Newton was not proved wrong by Einstein, nor Lavoisier by Rutherford. The formulation of a scientific proposition may be

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continually raised by logical empiricists, that such a position—no matter how commonly it may be accepted—is still naive and *a priori,* that it does not make sufficient allowance for future discoveries, and in effect represents a nineteenth-century attitude of mind which is unprepared for revolutionary developments that may further advance scientific thought. They would argue that to maintain *anything* as certain or final is to close the mind to new knowledge, that the very *possibility* of someone's making a new discovery forces the scientist to be hesitant about ever saying the " last word," or to despair even of proposing a " final answer " in the area of his investigations.

Aquinas' concept of physical proof, surprisingly enough, is not vulnerable to this objection, and in fact might even be said to have anticipated difficulties of this type that await anyone who would claim too facile a " final explanation " of physical phenomena. For one thing, St. Thomas insisted that the logical procedure that most characterizes physical science is not *a priori,* but is rather *a posteriori,* based on a patient study of the world of nature, not starting with any preconceived knowledge of essences, but rather arguing from effect to cause solely on the basis of observed facts.[55] In this matter, he was insistent that a basic and irreconcilable difference exists between the canons for physical proof and those for mathematical proof. He was aware that the mathematician could have *absolute* certitude, and that the very abstractness and necessity of his subject matter permit him to proceed *a priori* and with the most exacting standards of proof. The certitude he ascribed to physical science, on the other hand, was somewhat circum-

modified, and limitations to its applicability recognized, without affecting its propriety in the context to which it was originally found appropriate. We do not need sledge-hammers to crack nuts; we do not need the Principle of Indeterminacy in calculating the future position of the moon: 'the old knowledge, as the very means of coming upon the new, must in its old realm be left intact; only when we have left that realm can it be transcended' (J. R. Oppenheimer)."—A. R. Hall, *The Scientific Revolution,* 1500-1800: *The Formation of the Modern Scientific Attitude,* (Boston: 1954), p. xiii.

[55] Cf. *In II de Anima,* lect. 3, n. 245; for a full treatment, see M. A. Glutz, C.P., *The Manner of Demonstrating in Natural Philosophy,* (River Forest, Ill.: 1956), pp. 84-102.

scribed: he referred to it as a "*supositional* certitude," and gave detailed instructions for attaining it when working with the contingent or non-necessary matter of the physical world.[56] His methodological precisions need not concern us here, but certainly one of its suppositions was entirely consistent with Heisenberg's *proviso,* namely, that results are valid *only* for the realm of experience from which they are derived. Thomas, as a matter of fact, would go even further than Heisenberg, and maintain that, even within this realm, final explanations can only be expected, and are only valid, for events that happen "regularly or for the most part," for these alone are sufficient to manifest some type of dependence on the antecedents which produce them, and thus induce a causal necessity into the proof.[57]

Implicit in Aquinas' treatment is also allowance for the acquisition of new knowledge, either by way of refinement within an existing realm of experience, or by revolutionary extension to completely new realms, and both without jeopardizing explanations that have already been conclusively established in science. An example of the first type is the proof already discussed for the sphericity of the earth. Thomas argues that the earth is approximately a sphere because this shape is caused by the uniform action of the gravitational forces of its components; at the same time, he admits that other causes are at work that further modify this shape from that of a perfect sphere. In his day, science had not advanced sufficiently to detect the earth's rotation or the resultant bulge at the equator; yet this advance in knowledge does not nullify his reasoning or his basic explanation. Modern science holds that the earth is an oblate spheroid, and assigns this modification of the spherical shape to rotational forces which are *superadded* to the gravitational forces, but which do not *replace* them. And both Aquinas and the modern scientist would pre-

[56] *In II Post Anal.,* lect. 7, nn. 2-3; *In II Phys.,* lect. 15, nn. 2, 5 and 6.

[57] The details of such a methodology, as applied to the late medieval theory of the rainbow, will be found in my *The Scientific Methodology of Theodoric of Freiburg,* pp. 237-245.

sumably be open-minded to the discovery of further irregularities in the observed shape of the earth's surface, which might be traceable to yet unknown causes still awaiting our investigation, but would not force us to re-open our minds again to the possibility that the earth is flat.

With regard to revolutionary knowledge applicable to completely new realms of experience, we can only surmise how Aquinas would proceed because of the very rudimentary state of science in his day. A not too far-fetched example may perhaps be taken from his generalization, derived from empirical data, that material objects tend in a straight line towards a center of gravity, elaborated mathematically by Newton, over four centuries later, into the law of universal gravitational attraction. It is possible, on the basis of this generalization, to say that *all matter* is ponderable or massive, a statement not inconsistent with the definition frequently found in science textbooks to the effect that matter is whatever has mass and occupies space. Yet such a definition does not close the physicist's mind to other possibilities: in theoretical cosmology, for instance, he will speculate about " anti-gravitation " as accounting for the recession of galaxies, while in fundamental particle theory he will speak of " anti-matter " (or anti-terrestial matter) as having properties radically different from the matter we observe macroscopically. The very fact that he assigns new terms to such entities is evidence that he regards the phenomena on which their existence is based as constituting, in Heisenberg's phrase, a " new realm of experience," about which he can freely speculate, and for which he can even seek hyper-generalizations, without relinquishing a single theorem in classical mechanics. And St. Thomas' willingness to countenance such a procedure is at least implicit in his recognition that celestial matter might be radically different from terrestial matter, while allowing for some common features and a diversity in the laws applicable to each—although there is no doubt that he was mistaken on many details clarified by subsequent investigators.

It would thus seem that the essentially philosophical suggestion of Einstein, taken up by logical positivists, to the effect that " our notions of physical reality can never be final," performs too radical a surgery on the corpus of scientific knowledge. Some surgery was undoubtedly necessary after nineteenth-century excesses in mechanism had pushed to further extremes the mathematical realism sponsored by Galileo in the seventeenth century. But scientific agnosticism is also an extreme, and it can do more harm in the long run than an over-acclerated mathematical or mechanist development, for it eliminates the very possibility of organic growth within science itself. Heisenberg's reaction is thus an encouraging one: it stresses the continuity of science, the assimilation of the new to the old, while insisting on a rigorous methodology that would not over-assert the objective value of mathematical theorizing in recent science. To those who appreciate the essential contribution of Albert and Thomas to medieval science, the parallel between their correctives to the mathematicism of Grosseteste and Heisenberg's emendations to the idealism of Einstein is as interesting as it is unexpected.

Einstein does have a message for the modern mind, and it is this, namely, that the mathematical realism of a Galileo, or the space-time absolutism of a Newton, are antiquated notions that can no longer function fruitfully for the modern scientist. We propose that the same cannot be said for the theory of physical proof proposed seven centuries ago by St. Thomas Aquinas.

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