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ANCIENT RECORDS AND THE CRAB NEBULA SUPERNOVA

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Established and suspected records of the guest star of A.D. 1054 and their relationship to the Crab Nebula supernova event are discussed. The well-known Suzhou (Soochow) star map appears to depict the guest star and to show it in the correct orientation with respect to ζ Tauri (*i.e.* northwest), a circumstance that has been generally overlooked in the West. Thus, there seems little reason to doubt the standard interpretation, that the guest star was in fact the progenitor of the Crab Nebula. A European account, proposed as a possible record of the A.D. 1054 guest star, is interesting, but not convincing. The fragmentary information concerning the light-curve of the guest star as deduced from the oriental records does not itself determine whether the event was a Type I or a Type II supernova, and in fact is not inconsistent with the light-curve of a slow nova. (It has recently been claimed that the guest star was a nova and hence not associated with the Crab. In that event, however, the old nova would have been readily detected in X-ray sky surveys, but it has not been found.)

The identification of the present-day Crab Nebula supernova remnant as the result of a supernova that occurred in Taurus on or about 1054 July 4 has been reviewed previously[1,2]. While the preponderance of the evidence supports such an association, discrepancies in Chinese and Japanese reports of the dates of appearance of the 'guest star' and of its location with respect to the bright star called T'ien-kuan by the Chinese (and identified with ζ Tauri) have led some authors[3,4] to question the association.

Europe and the Near East. In addition to the questions concerning the putative oriental records of the Crab supernova, it has been a persistent puzzle that such a brilliant event is absent from the astronomical records of other cultures. Reasons proposed for the absence of contemporary references to the Crab event in Europe and the Near East have varied widely. The historian of science George Sarton remarked[5], "The failure of medieval Europeans and Arabs to recognize such phenomena was not due to any difficulty in seeing them, but to prejudice and spiritual inertia connected with the groundless belief in celestial perfection." Nonetheless, there are both European and Arabic records of the supernova that occurred in A.D. 1006, which is thought to have been about three to four magnitudes brighter than the A.D. 1054 event. A few months of persistent bad weather would have greatly reduced the chances of the event being noticed in Europe, and more than one author has offered this as an explanation for the absence of such records. For example, in a fanciful weather report for 1054 July, prepared by scholars[6] interested in the history of the guest star and the Crab Nebula, we read, "Chinese weather: Manchuria, Central China, Korea and Japan will be sunny and bright and all clouds will disappear by sunset. The night will be exceptionally clear—a good night for having guests visit. European weather: All of northern Christendom will be subject to early evening Aurora Borealis with intermittent rain and meteors. In the south, late afternoon comets will give way to cloudiness and storms by evening. Otherwise, the heavens remain unchanged and unchangeable as they have since creation."

A more likely explanation for the lack of widespread European reports of the A.D. 1054 event was offered by Zalcman[7] and by Thomas[8], who ascribe it to the Great Schism, which split Christianity into the Roman Catholic Church in the West and the Orthodox Church in the East. The immediate events leading to the split occurred during 1054 July 16–24. Zalcman and Thomas suggest that church fathers would naturally have chosen to ignore the celestial event, rather than taking a chance on its misinterpretation as a portent. Political necessity rather than ideology (or failure of observation) is offered as the cause for the absence of such reports.

None of the above explanations is very satisfactory. Indeed, it is gratifying that a probable report of the A.D. 1054 event, by an observer in the Near East, recently came to light[9]. Ibn Buṭlān, a Christian physician from Bagdad, who lived in Cairo and then in Constantinople between A.D. 1052 and 1055 was reported (Fig. 1) in a book by Ibn Abī Uṣaybiᶜa (composed around A.D. 1242) to have written: "One of the well known epidemics of our time is that which occurred when the spectacular star (*athari kawkab*) appeared in Gemini in the year 446 H." (1054 April 12–1055 April 1). The internal details and consistency of the report identify the location of the star in Taurus (with the then-astrological sign of Gemini) during the early summer of A.D. 1054, in good agreement with the oriental reports*.

There have been some recent developments in the quest for European records of the A.D. 1054 event. In *Medieval Chronicles and the Rotation of the Earth*[10], there is an entry for the year A.D. 1058 under the heading of "Mis-

*Ibn Abī Usaybiᶜa mentions that Ibn Butlān died childless and unmarried, and hence had composed the verse, "Nobody will lament my death, when I die, save my medical companions and my books which are left lamenting." Perhaps none would be more surprised than Ibn Butlān at the niche he now occupies in astronomical rather than medical history.

الخلفاء المصريين وجرت بين ابن بطلان وابن رضوان وقائع كثيرة فى ذلك الوقت ونوادر
نظر يقة لا تخلو من فائدة وقد تضمن كثيرا من هذه الاشياء كتاب ألفه ابن بطلان بعد
خروجه من ديار مصر واجتماعه بابن رضوان ولابن رضوان كتاب فى الرد عليه وكان ابن
بطلان أعذب ألفاظا وأكثر ظرفا وأميز فى الادب وما يتعلق به ومما يدل على ذلك ما ذكره
فى رسالته التى وسمها بدعوة الاطباء وكان ابن رضوان أطب وأعلم بالعلوم الحكمية وما
يتعلق بها وكان ابن رضوان أسود اللون ولم يكن بالجميل الصورة وله مقالة فى ذلك يرد فيها
على من عيره بقبح الخلقة وقد بين فيها بزعمه أن الطبيب الفاضل لا يجب أن يكون وجهه
جميلا وكان ابن بطلان أكثر ما يقع فى على بن رضوان من هذا القبيل وأشباهه ولذلك يقول
فيه فى الرسالة التى وسمها بوقعة الاطباء (الطويل)

فلما تبدى للفوابل وجهه * تكمن على أعقابهن من الندم
وقلن وأخفين الكلام تسترا * ألا ليتنا كنا تركناه فى الرحم

وكان يلقبه بمساح الجن وسافر ابن بطلان من ديار مصر الى القسطنطينية وأقام بها سنة
وعرضت فى زمنه أوباء كثيرة (ونقلت) من خطه فيما ذكره من ذلك ما هذا مثاله قال
ومن مشاهير الاوباء فى زماننا الذى عرض عند طلوع الكوكب الاثارى فى الجوزاء من
سنة ست وأربعين وأربعمائة فان فى تلك السنة دفن فى كنيسة لوقا بعد أن امتلأت جميع
المدافن التى فى القسطنطينية أربعة عشر ألف نسمة فى الخريف فلما توسط الصيف
فى سنة سبع وأربعين لهوف النيل فمات فى القسطاط والشأم أكثر أهلها وجميع الغرباء
الا من شاء الله وانتقل الوباء الى العراق فأتى على أكثر أهله واستولى عليه الخراب
بطروق العساكر المتعادية واتصل ذلك بها الى سنة أربع وخمسين وأربعمائة وعرض
للناس فى أكثر البلاد قروح سوداوية وأورام الطحال وتغير ترتيب نوائب الحميات
واضطرب نظام البحارين فاختلف علم القضاء فى تقدمة المعرفة وقال أيضا بعد ذلك
ولان هذا الكوكب الاثارى طلع فى برج الجوزاء وهو طالع مصر أوقع الوباء فى القسطاط
بنقصان النيل فى وقت ظهوره فى سنة خمس وأربعين وأربعمائة وصح انذار بطلميوس
القائل الويل لأهل مصر اذا طلع أحد ذوات الذوائب وانجهم فى الجوزاء ولما نزل
زحل برج السرطان تكامل خراب العراق والموصل والجزيرة واختلت ديار بكر وربيعة
ومضر وفارس وكرمان وبلاد المغرب واليمن والقسطاط والشأم واضطربت أحوال
ملوك الارض وكثرت الحروب والغلاء والوباء وصح حكم بطلميوس فى قوله ان زحل
والمريخ متى اقترنا فى السرطان زلزل العالم (ونقلت) أيضا من خط ابن بطلان فيما ذكره
من الاوباء العظيمة العارضة للعلم بفقد العلماء فى زمانه قال ما عرض فى مدة بضع عشرة
سنة بوفاة الاجل المرتضى والشيخ أبى الحسن البصرى والفقيه أبى الحسن القدورى
والقضى القضاة الماوردى وابن الطيب الطبرى على جماعتهم رضوان الله ومن أصحاب
علوم القدماء أبو على بن الهيثم وأبو سعيد اليمامى وأبو على بن السمح وساعد الطبيب

وابو

FIG. 1

Facsimile of text page 242, Vol. 1, of *ʿUyūn al-Anbāʾ* by Ibn Abī Usaybiʿa, with an account of a spectacular star seen by Ibn Butlān and identified as the Crab Nebula supernova by Brecher *et al.*[9]

cellaneous Astronomical Observations" that reads, "Rampona, a bright light within the circle of the new moon". Williams[4] suggests that this may be a European record of the guest star observed in the Orient in A.D. 1054 although he also asserts that the event in question was a nova rather than a supernova and that it was not the event that produced the Crab Nebula. One of us (K.B.) independently examined this reference in 1977 and found the case for the European sighting of the A.D. 1054 event weak. The astronomically most significant part of the mediæval Latin text reads "Tempore huius stella clarissima in circuitu prime lune ingressa est, 13 Kalendas in nocte initio." This translates as: "At this time, the brightest (or a very bright) star entered into the circuit (path or circle) of the first moon, 13 days before the Kalends (1st of the month) at the beginning of night." Although in mediæval times the expression "first moon" refers to the shape (crescent) rather than the time of the month, the time of observation is given as the beginning of night. However, the location of the Crab Nebula was close to that of the crescent moon just defore dawn in 1054 July (see the discussion below of possible North American records). Thus, both the year and the time of day disagree with the Eastern reports of the A.D. 1054 event and it seems unlikely that both would be copying or recording errors in the chronicle. (Note, however, that Williams[4] suggests that "1054" rather than "1058" is meant in the Rampona chronicle.) Conceivably, the association of a bright star with the crescent moon near the beginning of an unidentified month might refer to an observation of the A.D. 1054 guest star six months after its appearance in July, but there are no solid grounds for drawing that conclusion.

The absence of a definitive European record of the A.D. 1054 star seems less surprising when we consider that there is only one European record of the much brighter (apparent magnitude -8 or -9) A.D. 1006 supernova and none of the fainter yet still very bright (0 magnitude) A.D. 1181 supernova. Thus, the lack of such a record cannot be used to impugn the oriental records, which imply a peak apparent visual magnitude of about -5 for the A.D. 1054 event.

A Chinese map shows the Guest Star of A.D. 1054. A discrepancy in the position of the A.D. 1054 guest star with respect to ζ Tauri, as recorded in a Chinese annal, has been cited by historians to question the identification of the A.D. 1054 guest star with the Crab supernova[3,4]. However, an interpretation of a well-known Chinese star map which suggests the guest star *is depicted on the map* and located in the correct orientation with respect to ζ Tauri was published several years ago in China and apparently has escaped the notice of most historians and astronomers interested in the Crab Nebula. The map in question is the famous Suzhou (Soochow) planisphere[11], which was inscribed on a stele in A.D. 1247. The stone stood, along with three other steles, outside the Confucian Temple of Suzhou for many years and is now kept in the Municipal Museum. The four steles were derived from a set of eight charts made by Huang Shang in about A.D. 1193. Pan Nai, a modern historian of astronomy at Shanghai, has suggested that the charts represent data from about A.D. 1100 (N. Sivin, private communication). The star positions are, in general, accurate to a few degrees, and of the approximately 1500 stars known at the time only about 50 are missing from the steles. The map has even been discussed in the context of the Crab (see the review by Oort[12]), but the suggestion that the guest star is actually shown on the map apparently was not made until 1978.

In an addendum[13] to a little-noticed 1978 article on the identification of the Crab supernova with the A.D. 1054 guest star, the modern historians of astronomy Bo Shu-ren, Wang Jian-min and Liu Jin-yi address the discrepancy between the Chinese record which states that the guest star appeared to the southeast of T'ien-kuan (ζ Tauri) and the standard interpretation that the A.D. 1054 guest star *was* the Crab supernova and hence must have been northwest of ζ Tauri. Although this might simply have been a mental or copying error, it is now gratifying to recognize the visual evidence, from the Suzhou star map, that the guest star appeared northwest of ζ Tauri. Note that the latest date associated with the Suzhou star map, 1247, is still almost seven centuries before the earliest time at which anyone suggested an identification of the guest star with the presently-observed nebula! Bo *et al.*[13] write, "After this article had been sent to press, we again found another important record which proved that a guest star had been seen in the North Sung Dynasty to the north west of the T'ien-kuan star. This record is the famous carved stone star map of Suzhou. On this map, there is a cut (or indentation) to the north-west side of the T'ien-kuan star. We have investigated the original stone carving and found there is a circular notch (or indentation) inside it (the mark). This probably is the record of the guest star of A.D. 1054. We cannot discuss here this record in detail, but just point out: a reliable argument for the fact that the T'ien-kuan guest star was located to the northwest of the T'ien-kuan star may be found on the Suzhou stone carved star map." Ho Peng Yoke, who has previously argued[3] that the discrepancy in the Chinese texts undermines the identification of the A.D. 1054 guest star with the Crab supernova event, now finds the Bo *et al.*[13] interpretation convincing (private communication).

In the spirit of the Chinese proverb, that "One picture is worth more than ten thousand words", we show as Plate I a photographic reproduction of the relevant portion of a rubbing of the Suzhou stone star map that hangs on the premises of the National Academy of Sciences in Washington, D.C. The mark identified as the guest star by Bo *et al.* appears near the centre of the image, to the lower left of the southernmost star (Elnath, or β Tauri) in the large polygonal asterism or chinese constellation. The mark is closer to β Tauri and farther from ζ Tauri than the position of the Crab Nebula; the Chinese character for T'ien-kuan is located at the nebula position. Note also, as Davis[14] has emphasized, that "Oriental star maps make unlimited use of the principle of 'idealization', the art of making the form of the asterism fit the name or the idea it is supposed to represent . . . ". Thus, a modest distortion in the chart is not unexpected.

There is even some confusion about the number of discrepant reports. Ho Peng Yoke *et al.*[3] reported that two independent Chinese reports put the guest star south east of ζ Tauri, but Clark & Stephenson[1] later found that this positional discrepancy occurs in only one independent source. It seems unavoidable that there are errors in the ancient records; one Chinese account even puts the position of the guest star in the Pleiades! Certainly a mistake of the nature of the discrepancy at hand (southeast *v.* northwest) is not unusual; even in the *Cambridge Encyclopædia of Astronomy*, edited by the author of a monograph on the Crab Nebula, the wrong star (the northern one rather than the southern one) of the optical pair near the centre of the nebula is marked as the pulsar in the colour plate of the nebula that appears in the *Encyclopædia*. As previous authors have noted, positional descriptions

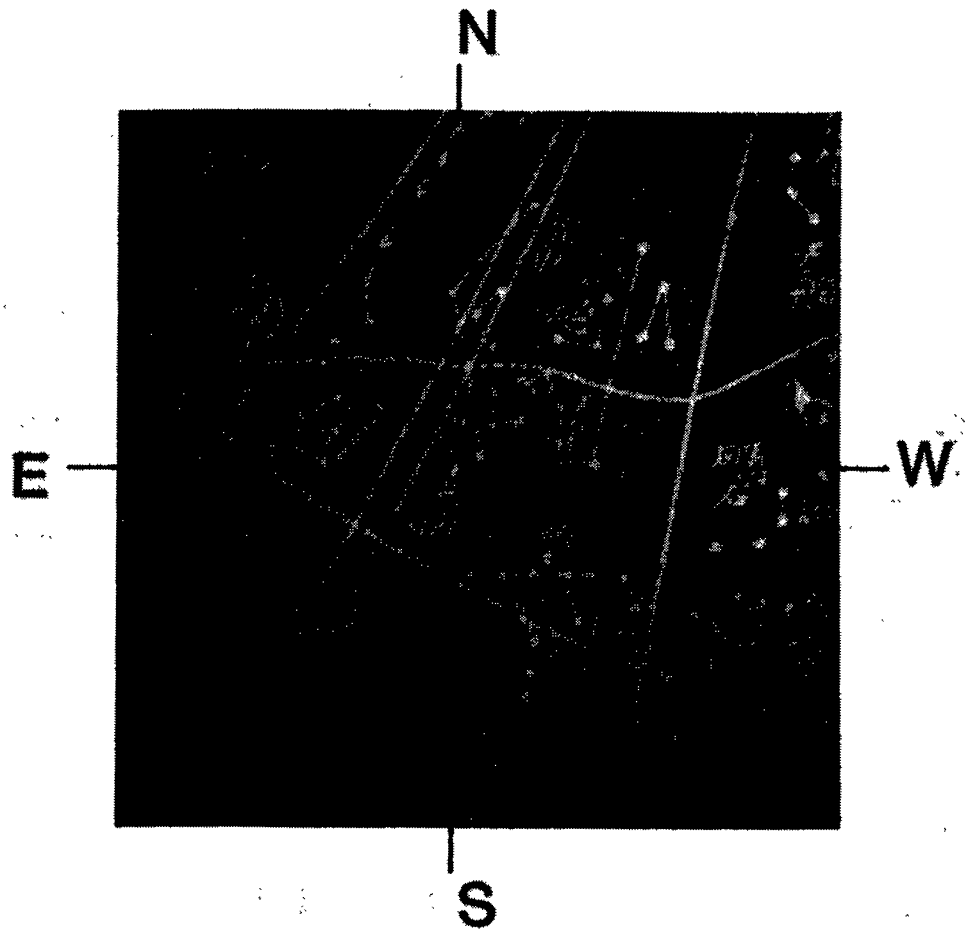

PLATE I

A section of the Suzhou star map. The mark identified as the guest star of A.D. 1054, which is interpreted as the Crab Nebula supernova, is located at the projected intersection of the four short lines indicating the cardinal directions. It is just above the Chinese character for T'ien-kuan (the modern ζ Tauri) and just below and left of the star (β Tauri) at the southeast corner of the large polygonal asterism. Photographed by K. Brecher from a rubbing taken from the stone chart. The rubbing is at the National Academy of Sciences in Washington, D.C.

[*Facing page 110*

PLATE II

Candidate rock art record of the A.D. 1054 supernova. This pictograph is on a horizontal sandstone surface in Chaco Canyon, New Mexico. The photograph was taken with the camera pointed vertically upward. The pictograph element that appears to represent a human hand is approximately life size. (NASA photograph.)

Facing page 111]

in the Chinese annals are not always very accurate and are sometimes unreliable or mis-copied from earlier records. An important point is that the Chinese astronomers used equatorial coördinates exclusively, so an object described as "below" a star was south of it, and not necessarily at a lower altitude. Needless to say, if "below" meant "at a lower altitude", the comment would be of little use to readers of the annals unless the time of observation were stated[5].

Although the Chinese and Japanese records provide apparent evidence of the Crab supernova, a Korean account has not been found. Clark & Stephenson[1] suspect that the pertinent Korean records may have been lost.

North American rock art. An interesting circumstantial case has been made that certain elements found in North-American rock art are representations of the Crab supernova, which we take to be the guest star of A.D. 1054. Miller[15] first noted this possibility in a discussion of two rock-art images found in northern Arizona. On the morning of 1054 July 5, the crescent waning Moon passed within three degrees of the supernova position. The two bright objects would have been seen in proximity from the longitudes of the present western United States; the hourly motion of the Moon would have made the conjunction less striking from the Eastern Hemisphere. Several additional examples of what is interpreted as a star-and-crescent motif have been found elsewhere in the western United States and in Baja California, Mexico. The example shown in Plate II comes from Chaco Canyon, New Mexico. Elsewhere in Chaco Canyon, there is evidence that the Anasazi made both solar and lunar observations[16]. A Moon-watcher would surely have noticed the new star near the Moon. The crescent is rare in native American rock art such as this, which appears to pre-date occupancy of the respective areas by the peoples present there at the time of the European discovery and exploration of the Americas. Archæological evidence is consistent with occupancy of many of these areas by Anasazi and other earlier peoples in the eleventh century. The subject is reviewed by Brandt & Williamson[17]; contrary opinions have also been published[4,18]. In any case, the residents of the American west in A.D. 1054 must have seen the supernova. Weather permitting, some saw it close to the crescent Moon and it is plausible that they recorded the event in rock art, although this intriguing hypothesis may never be proved or disproved with certainty.

Astrophysical implications of the oriental records. The connection of the Crab Nebula with the guest star of A.D. 1054 July, already accepted by nearly all astrophysicists who have investigated the question, gains added support from the Suzhou star map. This identification is important astrophysically because (1) it precisely dates the origin of the Crab Nebula; (2) it supports the concept of acceleration of the filaments, believed to be powered by the rotating magnetic neutron star, or alternatively it indicates a systematic error in the astrometric solution for the date of origin of the filamentary expansion, perhaps arising from uncertainty in the location of the expansion centre in the solution; (3) it establishes the relevance of the oriental records to the Crab supernova and from those records an unusual nature of the supernova light curve may be inferred; (4) the records then provide a direct estimate of the absolute magnitude of the supernova at the time of outburst. Note in regard to (4) that the distance and interstellar extinction of the Crab Nebula are among the best-established such quantities for any supernova remnant[19,20]. Thus, the positive identification of the Crab Nebula with the

A.D. 1054 guest star tells us much about the supernova that would otherwise be obscure.

From the Chinese and Japanese records[1], the Crab supernova was visible in daytime for up to 23 days and had pointed rays, a phenomenon that sometimes occurs in naked-eye observations of very bright stars and planets. Various estimates[1,21] of the peak brightness suggest an apparent visual magnitude at maximum of -4 to -6. The observations indicate that the total duration of naked-eye visibility was 653 days. Although we do not find Williams' claim[4] that the A.D. 1054 guest star was a nova rather than a supernova convincing, we have reviewed the astrophysical literature in which identification as a nova is rejected on the grounds of the light-curve and we find it unconvincing. The usual argument[1], that the observed duration of the guest star is too long for a nova, is not correct. Although many Galactic novae do last for less than six months, some very slow novae (*e.g.* HR Del) may last for years[22]. It appears that a better argument that the A.D. 1054 guest star was not a nova comes from its apparent magnitude at maximum. The absolute brightness of a nova outburst is inversely proportional to the decay rate, and the very slow novae reach absolute magnitudes around -6 to -7 at maximum[22]. If the A.D. 1054 guest star were a nova with m_v of -5 at maximum, its distance from the Sun is small and interstellar extinction can be neglected. In that case, from the well-established properties of old novae, the present remnant star of the purported nova, at 10 magnitudes below maximum light, would have m_v of about $+5$ and would thus be visible to the naked eye. Of course, no such star has been found; in fact, surveys for quiescent novae are thought to be complete down to m_v of at least $+7$ and perhaps a few magnitudes fainter. Further, by analogy with many observed old novae, the present X-ray luminosity would be about 5×10^{31} erg/s, which, for the 10–30-pc distance implied by the nova interpretation of the A.D. 1054 guest star observations, implies a flux at the Earth greater than the limit of about 4×10^{-11} erg/cm^2/s typical of X-ray surveys of the pre-*Einstein* era. *Uhuru*, *Ariel 5*, *HEAO 1*, or a rocket instrument, would have found a source corresponding to the A.D. 1054 "nova", and such a source would have been readily identified. Of course, such surveys show the Crab supernova remnant, but they do not reveal an ancient nova in the indicated region[23].

To the extent that it fits an existing category of supernovae, the Crab has been regarded as a Type II supernova. However, from what little information on the light curve is available in the historical records of the A.D. 1054 guest star, it could almost equally be the light curve of a 'slow' Type I supernova or that of a Type II supernova[24,25]. The Crab pulsar is clearly not a binary star, as expected in Type I supernovae, but the explosion might have disrupted a binary system. Astrophysics rather than history must be appealed to; the velocity of expansion of the Crab is an order of magnitude too small for a Type I supernova.

Acceleration and the astrophysical dating of the Crab supernova. Measurements of the filaments indicate that, if one assumes a constant rate of expansion, the date at which the expansion of the Crab Nebula began is A.D. 1140 $\pm$10 years[26]. Both the filaments and the pulsar[27] have moved since the supernova occurred. From an historian's perspective, Williams[4] asks whether, if it were not for the A.D. 1054 guest-star records, astronomers wouldn't be looking for a guest star or nova that occurred in the middle of the twelfth century. Perhaps so; however, the deduced mean acceleration of the nebula

(0·0014 cm/s^2) is readily accounted for by the 30-Hz magnetic waves expected from the pulsar (rather than by relativistic plasma pressure, for example)[28,29]. Once it is understood that the persistence of X-ray synchrotron radiation from the Crab Nebula means that a continuing source of energy (identified as the pulsar) exists in the Crab Nebula, it is reasonable to conclude that the apparent acceleration may be real rather than a product of systematic error in astrometry of the filaments. Indeed, it is just this discrepancy of extrapolated and historical data for the event that led some astrophysicists[2] to investigate the mechanism of acceleration. Had the investigators believed more strongly in the need to explain this anomaly, the history of discovery of neutron stars might have been quite different.

We conclude that the historical records of the A.D. 1054 guest star are in satisfactory agreement with the interpretation that the star was indeed the supernova that produced the Crab Nebula.

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