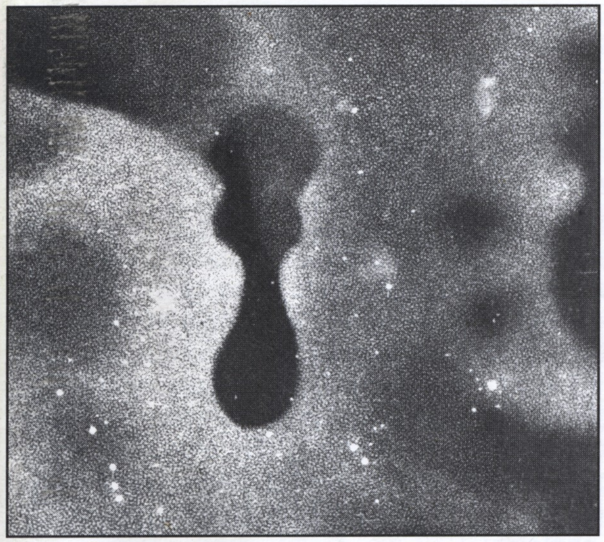
Journal of Astronomical History and Heritage

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Observation and interpretation of the Leonid meteors over the last millennium

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Abstract
With a possible 'storm' of Leonid meteors due in 1998 or 1999 November, interest in the Leonids is once again at a peak. The history of the Leonids is of particular importance, not only because they are closely associated with the origins of meteor science, but also because historical observations extending back a millennium are a substantial aid in increasing our knowledge of the Leonid meteor stream. Leonid history is thus a prime example of applied historical astronomy. In this review paper, we recount the origins of meteor science with the Leonids, the discovery of the historical observations and their scientific and cultural interpretations, and the application of this information to characterize the meteor stream and to predict the strength of the 1998-1999 event. These predictions are now of more than passing interest, as meteor storms pose a potential threat to spacecraft.

Key words: *comet, Leonids, meteor, meteor stream, solar system*

1 INTRODUCTION

Of the classes of solar system objects known today, meteors were among the last to be recognized as astronomical in origin. The wandering planets had been known since antiquity; comets were recognized as astronomical rather than meteorological after Tycho Brahe and others placed the great comet of 1577 beyond the Moon; the abundance of circumplanetary objects became known with Galileo's discovery of the Jovian satellites in 1610; and Giuseppe Piazzi discovered the first asteroid on the first day of the 19th century, 1801 January 1. If one considers the recently-detected Kuiper belt objects and the supposed Oort cloud objects to constitute new classes of solar system bodies, like the meteors discussed here, they have a likely cometary connection; they are believed to be the sources of short-period and long-period comets rather than cometary debris. Oort cloud and Kuiper belt objects, however, remain at a safe distance until they are perturbed into the inner solar system, giving us not only cometary phenomena, but also eventually the meteor phenomena described here.

The phenomenon of 'shooting stars' has been widely observed throughout history; catalogues of meteors record observations dating back at least to the 7th century BC, and they were, of course, observed long before that. The Roman poet Virgil, in Book I of the *Georgics*, ll. 365-367 (30 BC), wrote

Oft you shall see the stars, when wind is near
Shoot headlong from the sky and through the night
Leave in their wake long whitening seas of flame

Some have even claimed that meteor storms and larger cometary debris have had a strong impact on historical events (Bailey, 1996; Bailey *et al.*, 1989; Clube, 1996; Clube and Napier, 1990). Although the suspicion that meteors were of cosmic origin dates at least to Edmond Halley in the 18th century (Hughes, 1982), it was not until 1863 that they were definitely proven to be astronomical. This proof was based largely on observations of the Leonid meteors, so-called because their 'radiant point' was in the constellation Leo. The celestial origin of the Leonids, the determination of their periodic nature, the recognition that they resulted from an orbiting stream of objects, and the identification of this stream with a parent comet, are all landmark events that take on added significance because they represent the origin of the relatively-recent science of meteor studies. Although the 'August meteors' (now known as the Perseids) also played a concurrent role (Littman, 1996), they were not so important as the 'November meteors' (later known as the Leonids), which periodically tended to storm, and thus demanded an immediate explanation.

Since the recognition of their celestial origin in the 19th century, records of Leonid observations have been discovered over the last millennium, dating back at least to AD 902. Historical records of meteors in general are of more than passing interest; indeed, they have proved essential to meteor astronomy by making possible conclusions about the orbits of the meteor streams and their parent bodies. They were of critical importance to the birth of meteor science in the 19th century, and they remain no less important today.

2 THE LEONIDS IN THE LAST TWO CENTURIES

It was the Leonid storm of 1799 November 11-12, observed by the German naturalist Alexander von Humboldt among others, that first established the simultaneous geographical extent of the meteor phenomenon. From his location while on travel in Cumana, east of Caracas, von Humboldt wrote that towards the morning of November 12, after half past two, "... thousands of bolides and falling stars succeeded each other during four hours. Their direction was very regularly from north to south ... All these meteors left luminous traces from five to ten degrees in length." (von Humboldt and Bonpland, 1818:331). Curious as to how widespread the phenomenon was, von Humboldt gathered reports from South America and elsewhere. The result was that meteors were reported across 90 degrees of longitude from South America to Germany, and across 60 degrees of latitude from South America to Greenland. Von Humboldt also heard reports of a similar event in South America in 1766. Significant meteor showers are possible in years preceding and following meteor storms; Steel (1998) has argued that a noteworthy Leonid shower in England on the night of 1797 November 12/13 may have inspired Samuel Taylor Coleridge's *The Rime of the Ancient Mariner*, one of the greatest poems of the English language.

The geographic extent of the 1799 storm was a good clue that the phenomenon might be celestial, but the origins of meteor studies awaited the great storm of 1833.

2.1 The Leonids and the Origins of Meteor Studies

Although a storm of meteors occurred in 1832 in eastern Europe and the Middle East, only the 1833 storm inspired astronomers to action. The latter meteor storm peaked in the Eastern part of North America (Figure 1), and it is no coincidence that this was the birthplace of modern meteor studies, though there were antecedents (Hughes, 1982). Denison Olmsted (Figure 2), Professor of Mathematics and Natural Philosophy at Yale University in New Haven, Connecticut, was the crucial figure in this birth. His connection to meteor studies has been detailed in Hoffleit (1992:24-32) in the context of his work at Yale. Olmsted (1834:363) captured the uniqueness of the 1833 November 12/13 event when he wrote

> Probably no celestial phenomenon has ever occurred in this country, since its first settlement, which was viewed with so much admiration and delight by one class of spectators, or with so much astonishment and fear by another class. For some time after the occurrence, the 'Meteoric Phenomenon' was the

principal topic of conversation in every circle, and the descriptions that were published by different observers were rapidly circulated by the newspapers, through all parts of the United States.

His interest ignited by the phenomenon, Olmsted collected and published in *The American Journal of Science and Arts* twelve descriptions of the event as seen from Massachusetts to Georgia. From these and other sources he collated data relating to weather, time and duration, number, variety, sound, and apparent origin. After

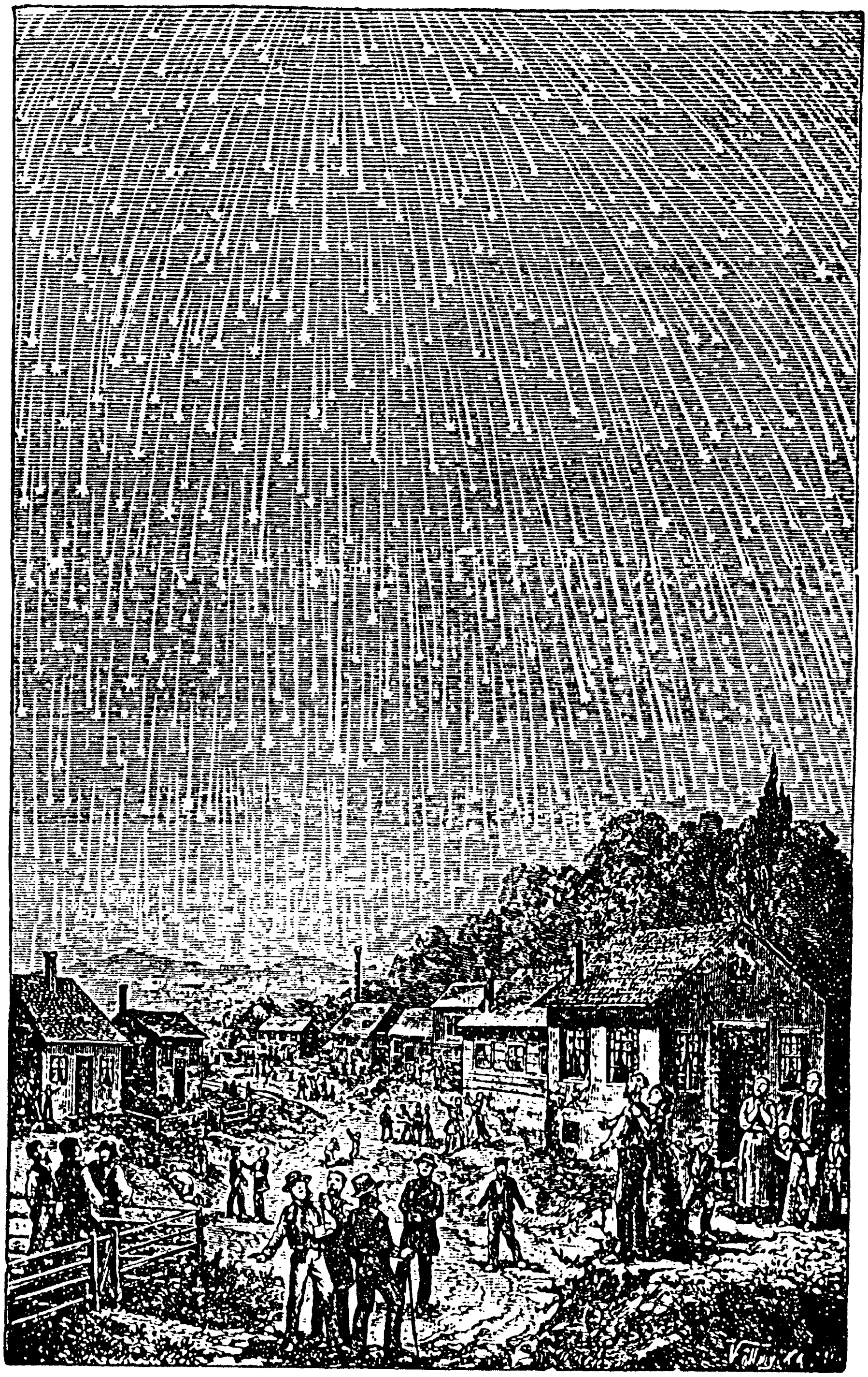


Figure 1. This view of the 1833 Leonid storm, probably the most widely-seen depiction of a meteor event, first appeared in the 1880s. It was produced by Karl Jauslin (1842-1904) and engraved by Adolf Vollmy (1864-1914). See Hughes (1995) for the history of the illustration.

Figure 2. Denison Olmsted, 1791-1859. (Courtesy Dorrit Hoffleit and Yale University Archives)

considering accounts of other meteor showers, Olmsted concluded that the meteors of 1833 originated beyond the Earth's atmosphere, became luminous upon entering the atmosphere at high velocities up to four miles per second, and "appeared to proceed from a fixed point in the heavens ... Those who marked its position among the fixed stars, observed it to be in the constellation Leo, in which it appeared stationary, accompanying that constellation in its diurnal progress" (Olmsted, 1834:394). With that statement, confirmed by the independent accounts of other observers during the storm, Leo was established as the 'radiant' of these meteors. From this time, increasingly the 'November meteors' were referred to as the 'Leonid meteors'.

Olmsted (1834:172) also conjectured that

> ... the meteors of Nov. 13th consisted of portions of the extreme parts of a nebulous body, which revolves around the sun in an orbit interior to that of the earth, but little inclined to the plane of the ecliptic, having its aphelion near to the earth's path, and having a periodic time of 182 days, nearly.

Though Olmsted even identified the nebulous body as possibly a comet, he was wrong in believing that its orbit was between the Earth and the Sun. Thus, Olmsted is generally credited with establishing the Leonid radiant, and beginning the study of meteors as a science. Alexander C Twining, a civil engineer at West Point, New York, who published his ideas in the same journal in 1834, is often also given credit for determining the radiant point, and the same claim is even made for von Humboldt (Hughes, 1982). One may conclude that there is nothing like an impressive natural phenomenon to stimulate scientific thinking, at least if cultural conditions are conducive to such thinking. And in the United States in the 1830s, science was budding into a much more substantial enterprise, as exemplified by the *American Journal of Science and Arts* itself and a variety of other activities (Dupree, 1957; Struik, 1962).

The subsequent history of meteor showers and their eventual connection with comets has been recounted in Yeomans (1991:188-201), but we may here summarize the highlights based upon the original sources. Despite Olmsted's conclusion of a cosmic origin for meteors, even that much was not as yet certain in the first half of the 19th century. So great an authority as Brussels Observatory Director, Lambert-Adolphe-Jacques Quetelet, equivocated in the chapter on meteors in his influential *Sur la Physique du Globe* (Quetelet, 1861), causing Hubert A Newton (1863) to insist that Quetelet's own chapter gave a very strong argument that star-showers, and probably sporadic meteors as well, "... are caused by the entrance into our atmosphere of bodies revolving
about the sun."

The clinching argument for the cosmic origin of meteors came when Newton (Figure 3) determined that the cycle repeated in intervals of sidereal years, not tropical years. Hoffleit (1992:47-56) has also placed Newton's work in the context of 19th century astronomy at Yale University, where he was a Professor of Mathematics. If meteors were due to terrestrial phenomena such as magnetism, heat, or electricity, he reasoned, meteor events should repeat in intervals of the tropical year. But Newton (1863) cited historical dates of known meteor showers to "... show quite clearly that the true period is not widely different from the sidereal year." Moreover, based upon his historical data, Newton calculated the interval between Leonid showers to be 33.25 years, and predicted that the meteor shower would return in 1866. Finally, Newton speculated that the meteor shower was caused by small bodies in elliptical orbit around the Sun. He determined five possible periods for the orbit of these bodies, including 33.25 years, but did not calculate a definitive orbit.

Newton's prediction proved true, but the peak of the 1866 storm occurred in Europe rather than in the United States. And sure enough, this time astronomers in four European countries were inspired to solve the riddle of the orbit of the meteor stream and its parent body. The largely independent and almost simultaneous work in 1866-1867 of John Couch Adams in England, Giovanni Schiaparelli in Italy, U J J Le Verrier in France, and Theodor von Oppolzer and C F W. Peters in Germany, are often cited together in this respect. But in his paper 'On the Orbit of the November Meteors', Adams (1867), famous for his earlier work leading to the discovery of Neptune, provides a contemporary account of the chronology and a hint of the international rivalry that must have taken place during a few crucial months in 1866-1867.

Adams tells us that Schiaparelli, the Director of the Milan Observatory, showed in four letters to Angelo Secchi (Schiaparelli, 1866-67) that the orbits of meteor streams around the Sun are very elongated, as are those of the comets, and that "... both these classes of bodies originally come into our system from very distant regions of space." More specifically, in Schiaparelli's last letter, dated 1866 December 31, he remarked on the very close agreement in the orbital elements of the August meteors (now known as the Perseids) and Comet II 1862. To the Italian astronomer thus goes the credit of showing that the comet now known as 109P/Swift-Tuttle is the source of the Perseids. Schiaparelli also attempted to find a comet with elements similar to those of the November meteors, but failed because the inaccurate radiant point he used yielded erroneous orbital elements for the meteor stream.

According to Adams, on 1867 January 21, Le Verrier (1867) communicated to the French Academy of Sciences a theory similar to Schiaparelli's, but with more accurate elements, including a period of 33.25 years. It was left to Peters (1867) of Altona, Germany, to notice one week later that Le Verrier's elements agreed closely with a certain Comet I 1866, discovered by Tempel 1865 December 19, and which passed perihelion in early 1866 January. The elements of what is today known as Comet 55P/Tempel-Tuttle had been determined by Theodor von Oppolzer (1867), who calculated a period of 33.18 years for the comet. A few days after Peters's announcement, Schiaparelli (1867) independently noticed the same agreement between Le Verrier's elements of the meteor stream and the comet. Thus, in the space of only one month, the connection that we accept today between comets and meteors was established beyond doubt.

Figure 3. H A Newton, 1830-1889. (Courtesy Dorrit Hoffleit, Yale University)

Adams's own paper appeared in the 1867 April 12 issue of *Monthly Notices of the Royal Astronomical Society*. Referring to the papers of 1863 and 1864, where Newton identified 13 displays of the Leonids, Adams recalled Newton's estimate of 33.25 years for the recurrence of the displays. He also recalled Newton's conclusion that the November meteors "... belong to a system of small bodies describing an elliptic orbit about the Sun, and extending in the form of a stream along an arc of that orbit which is of such a length that the whole stream occupies about one-tenth or one-fifteenth of the periodic time in passing any particular point." (Adams, 1867:248). In one year, Newton had concluded, this group must revolve about the Sun in 2 ± 1/33.25 revolutions, or 1 ± 33.25 revolutions, or 1/33.25 revolutions. In other words, the period corresponded to either 180 days, 185.4 days, 354.6 days, 376.6 days, or 33.25 years. Adams's own contribution was to show that the actual period was the last of these, 33.25 years. This he did by first assuming that period, and showing that during this time the longitude of the node would be increased by 20 arc seconds by the perturbation of Jupiter, seven more arc seconds by Saturn, and one arc second by Uranus, for a total of 28 arc seconds compared to the 29 arc seconds actually observed. This "... remarkable accordance between the results of theory and observation ..." allowed Adams to then determine independently elements very similar to those of Le Verrier.

We thus see during the 19th century the progression in understanding of meteors from establishing the radiant and a probable celestial origin in 1834, to a definite celestial origin and an accurate interval between showers with Newton (1863), a definite period for the meteor stream (Adams, 1867), and finally identification of meteors with comets as parent bodies, first by Schiaparelli (1866-1867), who identified the August Perseids with the comet now known as 109P/Swift-Tuttle, then by Peters (1867), who identified the November Leonids with the comet now known as 55P/Tempel-Tuttle. Only a few months later, the Irish astronomer, G Johnstone Stoney (1867), wrote a paper on the connection between meteors and comets, the beginning of a long series of such studies that has continued to the present day. Further significant showers in North America, in 1867 and 1868, which Mason (1995) classifies as storms, inspired E L Trouvelot to a memorable artistic rendering (see Figure 4).

Figure 4. Trouvelot's painting of the November 13/14, 1868 Leonid meteor storm. Trouvelot himself observed the event from midnight to sunrise. The drawing shows all forms of meteors observed during the night, not necessarily appearing simultaneously. Trouvelot (1882) describes the drawing in detail. (Courtesy Dorrit Hoffleit and Mt. Holyoke College Library)

But there was still more to learn about the Leonids, in particular about the distribution of the material in the meteor stream. Just when astronomers thought they had a good understanding of the November meteors, the predicted storm of 1899 failed to appear. In 1925, the astronomer Charles Olivier called this "... the worst blow ever suffered by astronomy in the eyes of the public ..." (Olivier 1925:38). This is a public relations problem which astronomers can still sympathize with today.

2.2 The Twentieth Century

Leonid studies in the 20th century were marked by good showers in 1930-1932, the strongest storm witnessed in modern times in 1966, and steady progress in understanding meteors and meteor streams with the help of new techniques of observation.

The 1930-32 showers were best seen from North America, and exhibited rates of about 240 per hour (Kronk, 1988; Mason, 1995). Following the disappointments of 1899 and 1930-32, Lovell (1954:338) concluded that "It now seems certain that the main part of the Leonid orbit has been removed from the Earth's orbit by successive perturbations, and the recurrence of the tremendous meteoric storms of the Leonids in the future seems unlikely."

Many were surprised, then, when a storm was visible in Europe in 1965, and even more so when an estimated 100,000 meteors per hour were observed at the peak of the 1966 Leonid storm in the south-western United States (Kronk, 1988; Mason, 1995; Milon, 1967). The descriptions were less hysterical than in the previous centuries, but the event was clearly awe-inspiring nonetheless. "The sky began to rain shooting stars," one observer wrote. "By 11:30 there were several hundred a minute. A quarter-hour later, the meteors were so intense that we were guessing how many could be seen in a one-second sweep of the observer's head. The fantastic rate of 40 per second was reached at 11:54, difficult to gauge but the consensus of our observing group." (Great Leonid meteor shower ..., 1967:5).

Visual, photographic and radar techniques helped make the 1965-66 storms the most studied on record (Figure 5). The techniques available by that time are systematically summarized in Millman and McKinley (1963). The development of radar techniques, which detect the ionization trail of meteors, was intimately connected with the development of radar in World War II (Lovell, 1954; Butrica, 1996). Pioneered by the group of radio astronomers led by Bernard Lovell at Jodrell Bank, the 'radio-echo' technique not only gave a scientific record of observations, but for the first time allowed observations in daylight. The technique also refined Newton's thesis that meteors were of cosmic origin. By showing there was no significant hyperbolic velocity component, meteors were determined to be orbiting the Sun rather than of interstellar origin.

Photographic techniques were systematically used by the Harvard University projects led by Fred Whipple during the 1930s and 1940s (Lovell, 1954), and became widely successful with the development of the Baker Super Schmidt cameras. The primary purpose of these cameras, developed by James G Baker in the 1950s, was to give excellent image-definition over a wide field up to 55 degrees. The context of Whipple's work is described in Doel (1996).

Our modern view of the Leonids, shaped over the last two centuries, thus envisions them as a stream of particles in the orbit of Comet 55P/Tempel-Tuttle (Figure 6), a retrograde orbit (compared to Earth's) that has its aphelion just beyond the orbit of Uranus. The comet has spewed out these particles along its orbit in a complex distribution pattern, the outlines of which were recognized already at the end of the 19th century by Stoney and Downing (1899). Some, now widely scattered all along the orbit of the comet, are called the clino-Leonids and produce the weak annual Leonid showers. But a dense swarm of particles, known as the ortho-Leonids, remains within a few astronomical units of the comet. The apparent weakness of the clino-Leonids and the density of the ortho-Leonids are anomalous for such an old meteor stream, and Williams (1997) has proposed that this may be due to perturbations by Uranus. In any case, it is

Figure 5. Photograph of Leonid storm of 1966 showing the radiant in Leo. Regulus is the bright star at the bottom of the sickle. This 3.5 minute exposure was taken from Kitt Peak, Arizona. (Photograph by Dennis Milon, distributed by Scott Milon)

the length of the dense swarm that gives us the chance for greatly-increased activity in November, over several sequential years. The width of the narrow swarm, however, is perhaps only 35,000 kilometres, so that the activity will last only a few hours - and will be visible only for that part of the Earth that happens to be turned in the right direction, speeding head-on into the meteor stream. We observe the meteors as they ignite in the atmosphere at an average height of 70-110 kilometres.

A great deal of work has subsequently gone into the study of meteors, and the volumes of Kresak and Millman (1968) and Stohl and Williams (1993) are representative of the research that has refined our knowledge of the nature of meteor streams and their relationship to comets.

2.3 Assessment: Why the Nineteenth Century?

We may well ask why meteor science began only in the 19th century, and why meteors took so long to be recognized as astronomical. For most of the period prior to the 17th century, the answer is that acceptance of the celestial-terrestrial dichotomy of Aristotelian cosmology prevented the identification of meteors as cosmic in origin. Aristotle believed the heavens were unchangeable, and that any observed change had to be Earthly or meteorological. Thus, comets were long held to be atmospheric phenomena, and there was a crisis when Tycho Brahe proved the comet of 1577 to be located beyond Earth.

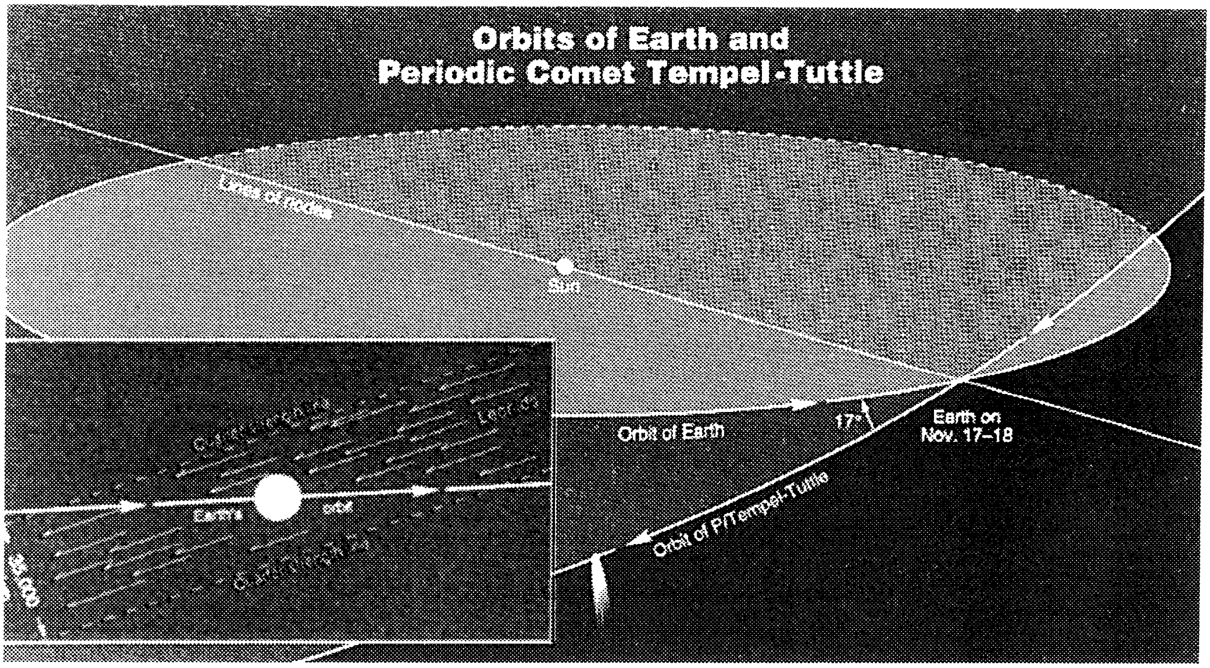


Figure 6. Orbits of Earth and Comet 55P/Tempel-Tuttle. Because the orbit of the comet is retrograde compared to Earth's orbit, Earth moves head-on into the stream. The particles are scattered all around the orbit of the comet, but are particularly dense within a few astronomical units of the comet. The width of this dense swarm is only about 35,000 kilometres. (By permission of Sky Publishing Corporation)

On the assumption that a major storm was necessary to trigger a new explanation of meteors rather than the few sporadic meteors occasionally observed, one may wonder about the other Leonid storms during and after the 17th century. We note from Table 1 that the 17th century Leonid storms of 1601-02 and 1666 were visible only in China, where the Scientific Revolution under way in Europe had yet to take place (for Chinese natural philosophers still laboured under Aristotelian assumptions). The 1698 Leonid storm, by contrast, was visible in Europe and Japan. One might have thought this would trigger a search for a celestial origin, at least in Europe, but of this there is no record. And in the 18th century, when Leonid storms were reported in 1766 in South America, and in 1799 in eastern North and South America, astronomy had not yet advanced far enough in those locales to trigger a crisis that demanded explanation in scientific terms.

The storm of 1832, visible in eastern Europe and the Middle East, might have triggered renewed attempts at explanation. In his pioneering account of historical Leonids, Newton (1863) noted that descriptions of the 1832 display were given in many newspapers and scientific journals throughout Europe, and that Le Verrier himself saw them and noted "... it would have taken several hours to count those visible at one instant, supposing them fixed." Why there was not more of an attempt to provide a scientific explanation of this impressive display, in sophisticated Europe, remains a mystery. For whatever reasons, that role was left to the storm of 1833, when fledgling American science, represented by Olmsted and Twining, precipitated the events we have described earlier.

Table 1. Probable Leonid meteor storms excerpted from Mason (1995)

Date		Where Observed
902	Oct 12-13	Southern Europe and North Africa
934	Oct 13-14	Europe, North Africa and China
	Oct 14-15	
1002	Oct 14-15	China and Japan
1202	Oct 18-19	Middle East and China
1237	Oct 18-19	Japan
1238	Oct 18-19	Japan
1366	Oct 21-22	Europe and China
1532	Oct 24-25	China and Korea
	Oct 25-26	
1533	Oct 24-25	Europe, China, Korea, Japan
	Oct 25-26	
1566	Oct 25-26	China and Korea
	Oct 26-27	
1601	Nov 5-6	China
1602	Nov 6-7	China
1666	Nov 6-7	China
1698	Nov 8-9	Europe and Japan
1766	Nov 11-12	South America
1799	Nov 11-12	Eastern parts of North and South America
1832	Nov 12-13	Eastern Europe and Middle East
1833	Nov 12-13	Eastern parts of North America
1834	Nov 12-13	North America
1866	Nov 13-14	Europe
1867	Nov 13-14	Eastern parts of North America
1868	Nov 13-14	North America
1965	Nov 16-17	Eastern Europe
1966	Nov 16-17	Central/South-west North America

3 HISTORICAL OBSERVATIONS OF THE LEONIDS PRIOR TO 1799

3.1 Early Meteor Catalogues and Cultural Effects of Meteors

The observations over the last two centuries might have been the only Leonid observations known had not scholars begun systematically examining the historical literature. Catalogues of falling stars were compiled before they were studied as groups of particular showers or storms. Among the earliest of these was Adolphe Quetelet's 1839 *Catalogue des Principales Apparitions d'Étoiles Filantes* (Figure 7), which was widely used for subsequent meteor studies. It was followed by the catalogues of Yale librarian and amateur astronomer, Edward Herrick (1841); the Frenchman, Edouard C Biot (1841); the French astronomer and popularizer, Francois Arago (1860); and by Quetelet's own update, in 1861. Biot's catalogue covered 24 centuries of Chinese observations, from 687 BC to AD 1644. Arago's catalogue, in his *Astronomie Populaire*, was entirely a compilation from other catalogues, listed by month, from which the prominence of the August Perseids and the November Leonids was evident, but still unexplained.

But it was only in the 1860s that H A Newton set out to identify Leonid events more systematically, using previous catalogues and the historical record. He found six possible Leonid events (Newton, 1863), including the 1799 and 1833 apparitions described by Humboldt and Olmsted. In 1864 he extended these to 13 Leonid events, dating between AD 902 and 1833 (Newton, 1864). Most of Newton's accounts were cited in previous catalogues, but he took the precaution of going back to the original sources wherever possible.

The identification of these early accounts of the Leonids naturally raises the question of their effect on the cultures of the times, for given the impact of the Leonids in 1833, one can imagine the effect that such storms had on the population in pre-scientific

ACADÉMIE ROYALE DE BRUXELLES.

CATALOGUE

DES

PRINCIPALES APPARITIONS

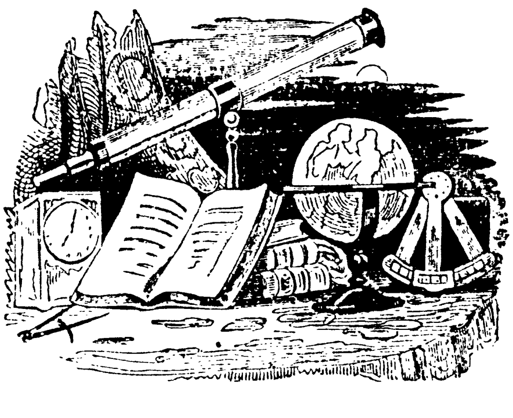
D'ÉTOILES FILANTES,

PAR

A. QUETELET,

Secrétaire perpétuel de l'Académie Royale et directeur de l'Observatoire de Bruxelles; chevalier des ordres de Léopold, d'Ernest de Saxe et du Christ; correspondant de l'Institut de France; de l'Institut des Pays-Bas; des Académies Royales de Berlin, de Turin, de Naples, de Lisbonne et de Palerme; de la Société Royale astronomique et de la Société météorologique de Londres; de la Société Royale d'Édimbourg; de la Société philosophique de Philadelphie; de l'Académie américaine de Boston; de l'Institut d'Albany; de l'Académie des lyncées de Rome; des Sociétés des sciences naturelles de Genève, de Heidelberg, de Wurzbourg, de Lille, de Nancy, du grand-duché de Bade, de Dresde, etc.

(MÉMOIRE LU A LA SÉANCE DU 8 JUIN 1839.)



BRUXELLES,

M. HAYEZ, IMPRIMEUR DE L'ACADÉMIE ROYALE.

1839.

Figure 7. Title page from Adolphe Quetelet's 1839 catalogue of meteors, among the earliest catalogues of 'falling stars'.

cultures. The 'interpretation' of these early events was not physical, but cultural, political, and religious. Even more than for comets, which appeared relatively calm and distant by comparison, such apparitions were often associated with great, and usually catastrophic, events. This was the case for the earliest of these accounts, in AD 902, which was visible in Southern Europe and North Africa, where Islamic civilization was in full bloom. For this event, Newton (1864:378) translated from the original Spanish of Conde's *Historia de la Dominacion de los Arabes en Espana*, where the dates were based on the Islamic calendar reckoned from the start of the Hegira (AD 622, July 16 or 17):

> In the month Dhu-l-Ka'dah of this same year (289 A.H.) died king Ibrahim bin Ahmad, and that night there were seen, as it were lances, an infinite number of stars, which scattered themselves like rain to right and left, and that year was called the year of the stars.

Dhu-l-Ka'dah is the tenth month of the Islamic calendar. And regarding the same event, from a history of the Saracens:

> In the year 286 [Newton believes it was AH 289, and thus the same year as in the above account] there happened in Egypt an earthquake, on the Fourth Day [of the week], on the 7th of Dhu-l-Ka'dah, lasting from the middle of the night until morning; and so-called flaming stars struck one against another violently, while being borne eastward and westward, northward and southward; and no one could bear to look toward the heavens, on account of this phenomenon. (Newton, 1864:380).

Not only the death of a king and an earthquake, but also the razing of the Italian city of Castellum Lucullanum from fear of the Saracens, the removal of its population to Naples, and various Christian events are associated with this astronomical event, which Newton (1864:381) dates as 902 October 13.

The 934 event, classed as a Leonid storm by Mason (1995), and visible in Africa, China, and a Europe still deep in the so-called 'Dark Ages', was also associated with an earthquake:

> And there was an earthquake, in Egypt, on the third day of Dhu-l-Ka'dah of the year [AH 323]; and flaming stars struck against one another violently. (Newton, 1864:382).

The 1002 event was seen in China and Japan, and refers with some precision to positions of the meteors in the sky:

> Period Khien-ping, fifth year, ninth month, 35th day of the cycle (October 14th) there were seen moreover thousands of small stars, which appeared in the group alpha, gamma, delta Cancri, and went as far as the group lambda, mu, Ursae Majoris. Generally a large star was seen followed by a half score of small stars. Among them were seen two stars as large as a quart measure; these went, one to the star Sirius, the other to the group phi, rho, tau Sagittarii, and vanished. (ibid.).

Had this event been viewed in the Western world, it would undoubtedly have been imbued with millennial fear; even though no catastrophic connection is specified in this account, we may well imagine that such connections were made.

An Arab account of the AD 1202 storm, visible in the Middle East and China, refers to a religious reaction:

> And in the year 599 [AH], on the night of Saturday, on the last day of Muharram, stars shot hither and thither in the heavens, eastward and westward, and flew against one another, like a scattering swarm of locusts, to

> the right and left; this phenomenon lasted until day-break; people were thrown into consternation, and cried to God the Most High with confused clamor; the like of it never happened except in the year of the mission of the Prophet, and in the year 241. (Newton, 1864:383).

The 1366 event, also believed to have been a Leonid storm, was visible in Europe and China. The original source was Duarte Nunez do Liao, *Chronicas dos Reis de Portugal Reformadas* (Lisbon, 1600), and was quoted by von Humboldt in his *Kosmos* (1850), whence Newton (1864:384) took it:

> In the year 1366, and xxii days of the month of October being past, three months before the death of the King Don Pedro (of Portugal), there was in the heavens a movement of stars, such as men never before saw or heard of. From midnight onward, all the stars moved from the east to the west; and after being together they began to move, some in one direction, and others in another. And afterward they fell from the sky in such numbers, and so thickly together, that as they descended low in the air, they seemed large and fiery, and the sky and the air seemed to be in flames, and even the earth appeared as if ready to take fire. That portion of the sky where there were no stars seemed to be divided into many parts, and this lasted for a long time. Those who saw it were filled with such great fear and dismay, that they were astounded, imagining they were all dead men, and that the end of the world had come.

The 1533 Leonid storm is of interest because it was visible not only in China, Korea, and Japan, but also in Europe, where Copernicus was about to shock the world with his *De Revolutionibus*. Newton (ibid.) gives only one account, and it is Oriental:

> Period Kia'tsing, twelfth year, ninth month, the 13th day of the cycle (October 24th) ... from the fourth to the fifth watch (from 2 to 4 am), in the four parts of the heavens, there were innumerable shooting stars, great and small, moving together in straight and oblique lines. This continued until daylight.

One may wonder whether some of the early figures of the scientific revolution in the western world viewed this event.

The 1602 storm, which might have been of interest for the reaction of a scientifically-enlightened individual in western Europe like Kepler, was visible only in China, as was the 1666 event. Even the 1833 storm had cultural implications, for renditions of the falling stars from this storm were used to illustrate the Day of Judgment, an allusion that undoubtedly came to mind for more than a few individuals who observed the event.

The cultural effects of the Leonid meteor storms and other meteor events may be put in context by reference to the claims of Bailey *et al.* (1989), and Clube and Napier (1990), who have suggested that high points in the meteor flux caused by the debris of giant comets may have affected historical events more than we might think. As Bailey (1996:659) most recently puts it, "Episodes of bombardment ... may provide an explanation for periods of global cooling as registered in the historical record, even for type. The logical extension of this punctuated equilibrium backward through geological time is manifested in the record of major extinctions of terrestrial life, including the one believed to have caused the demise of the dinosaurs.

3.2 Modern Catalogues and the Problem of Interpretation

The pioneering modern catalogue of meteor showers is that of Imoto and Hasegawa (1958), first published in Japanese in 1956. It contained 118 meteor showers recorded in the Orient in the last 25 centuries, including 18 Leonid events. In 1993, Hasegawa updated his earlier catalogue, incorporating Chinese records (Beijing Observatory, 1988; Tian-shan, 1977) and European records (Dall'olmo, 1978). His new catalogue (Hasegawa, 1993) includes 331 meteor showers, 48 of which are Leonid events.

In 1992, Rada and Stephenson examined medieval Arab chronicles, and Kidger (1993) used their data to identify seven possible Leonid events, including one in AD 855, 14 years before a Leonid storm would be due. Kidger remarks that this could have been an anomalously-strong annual Leonid shower, which, if true, would make it the earliest recorded Leonid event yet found. Hasegawa (1996) makes further refinements in the Rada and Stephenson data, based upon the solar longitudes at the time of the meteor shower maximum. In his comprehensive review of all Leonid data, Mason (1995) found 58 Leonid events, including 23 probable storms.

Table 2 summarizes the growth in our knowledge of the historical Leonids. While in 1863 only six historical Leonid events were known, 58 are now on record, thanks to the detective work of many astronomers and historians. Most of that increase has come since 1956, and we can be sure that many more events remain to be discovered. The discovery of meteor events in the historical literature remains a promising field, one that will shed more light on the Leonids as we approach future potential Leonid storms.

Table 2. Growth in knowledge of historical Leonids

Author	Year	No. of Leonid Events Identified
Newton	1863	6
Newton	1864	13
Imoto & Hasegawa	1956	18
Hasegawa	1993	48
Mason	1995	58

As the early accounts given above clearly illustrate, historical accounts of meteor observations are subject to various problems. Not the least of these is dating, including conversions among the calendars of different cultures, an essential determination if an event is to be classified as a Leonid. In classifying an event as a shower or a storm, subjective accounts are not always reliable. Moreover, astronomical considerations must also be taken into account, for the difference between the sidereal year and the tropical year causes a 1.4 day per century delay in the maxima of Leonid events, while the nodal advancement due to planetary perturbations causes another 1.4 day delay per century, giving a total of 2.8 days per century. Thus, as we see in Table 1, the 902 event took place on October 12-13, compared to November 16-17, in 1966, when the last Leonid storm occurred. The data contained in Table 1 are thus a triumph not only of observation, but also of interpretation over the last 130 years.

4 APPLICATIONS OF HISTORICAL DATA

As we have seen, historical observations of the Leonids were used by Newton and others to determine the basic elements of the meteor stream orbit in the 19th century. Such observations continue to be used for modern scientific purposes. The volumes of Kresak and Millman (1968) and Stohl and Williams (1993), for example, illustrate how these observations have contributed to our knowledge of the dynamical and physical nature of meteor streams.

It was Yeomans (1981), however, who used the full range of Leonid meteor shower data from the period 902-1969 to map the distribution of dust surrounding the parent comet Tempel-Tuttle, to predict the strength of the Leonid event in 1998-1999, and to redetermine the orbit of Tempel-Tuttle. Using these historical data, Yeomans graphically presented the dust distribution (Figure 8), and demonstrated that most of the dust resides outside the orbit of the comet, and behind or just slightly ahead of it. This led him to conclude from the position of the dust that radiation pressure and planetary perturbations, rather than ejection processes, control the dynamic evolution of the Leonid stream. Plotting past Leonid events on this graph, Yeomans concluded that "... the likelihood of an unusual Leonid shower event in 1998 and 1999 is very good but by no means certain." (Yeomans 1981:498-499). Certainty cannot be obtained because of the uneven distributions within the larger body of dust.

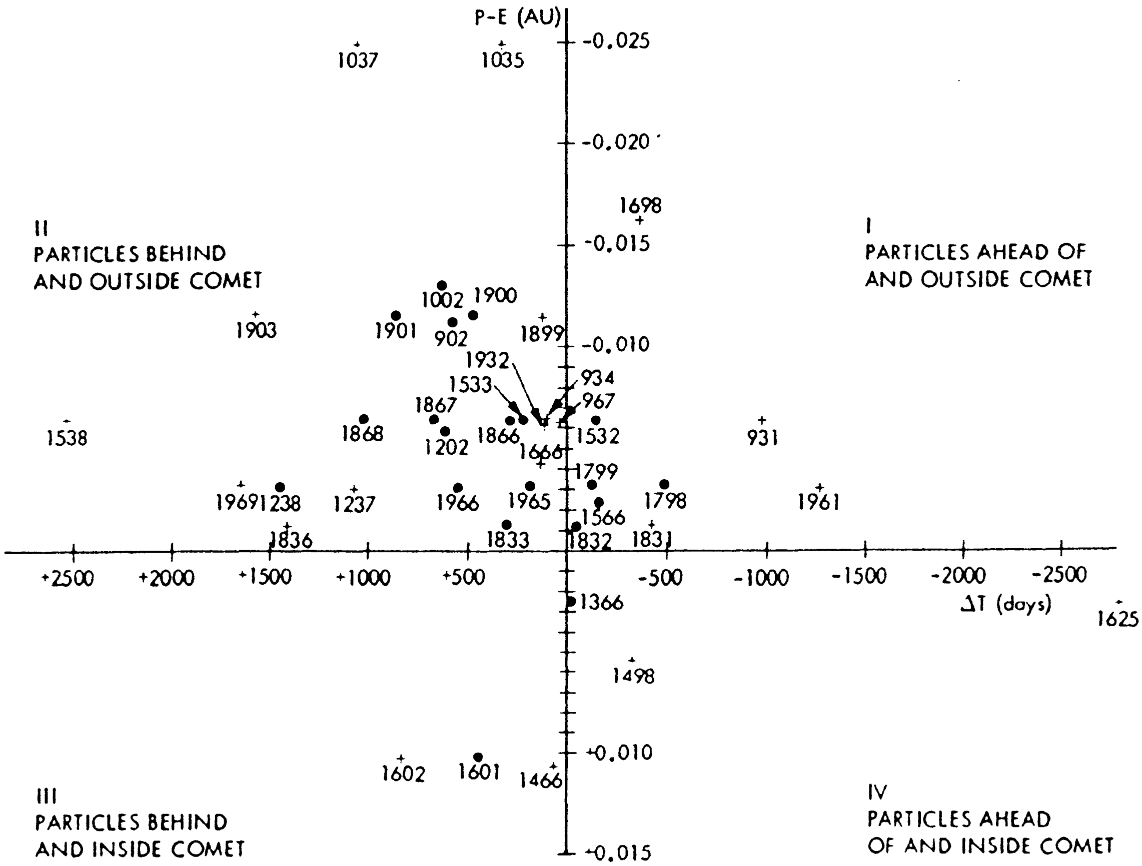


Figure 8. Distribution of dust around Comet Tempel-Tuttle, from the study of Yeomans (1981). The vertical line represents the distance in astronomical units that the Leonid particles were inside or outside the orbit of the parent comet, and the horizontal line gives the times in days that these particles lag or lead the parent comet. A + sign represents a meteor shower, while a filled circle represents a meteor storm. (From *Icarus* **47** (1981), 492-499, by permission of Academic Press, Inc. and D. K. Yeomans)

Mason undertook a similar study of the historical evidence, which resulted in more precise predictions. His study found that "Of the 58 Leonid displays researched, 27 of the 35 outstanding showers, and all 23 meteor storms, have occurred between 750 days before and 1750 days after the parent comet's passage through the descending node ..."

(Mason 1995:219). Of those, "A total of 19 meteor storms took place between 250 days before and 750 days after the comet's nodal passage." (Mason 1995:232). The study also showed that most of the dust was concentrated outside the comet's orbit, where 41 of the 58 documented Leonid events, including 18 of the 23 storms, occurred. Based upon these findings Mason believes the circumstances for 1997-2000 are comparable to those of 1865-1868. He concludes (Mason 1995:234) that there is "... an excellent chance of enhanced Leonid activity ..." between 1996 and 2002. More specifically, "A Leonid meteor storm is most likely, but by no means certain, in November 1998 or 1999 or both, with probable noteworthy showers in 1997 and 2000." (Mason 1995:219). For 1998 November 17, the Leonid events are likely to peak in eastern and central Asia, and in the early morning hours of 1999 November 18, they will peak in eastern and central Europe and in north Africa.

These expectations are being carefully monitored by both amateur and professional astronomers (Rao, 1995). Since 1991, the International Meteor Organization has sponsored a co-ordinated International Leonid Watch (Jenniskens and Butow, 1998; MacRobert, 1995, 1996). Actual observations of the Leonids in the last few years have shown modestly increased activity; both the predictions and observations are updated on the World Wide Web (Jenniskens and Butow, 1998). A large audience attended a Joint Discussion on 'The Leonid Meteor Storms: Historical Significance and Upcoming Opportunities' at the IAU General Assembly in Kyoto in 1997 August, where a variety of observing techniques was also discussed and at least one attendee vividly recalled his observations of the 1966 storm. The concerns, however, are more than academic; in light of the potential Leonid event, a Conference on 'Leonid Meteoroids Storm and Satellite Threat' was held in California in 1998.

Those who view the Leonids as a threat to satellites may hope for little activity, but far more numerous are those who wish to see a rare astronomical event. If it does not materialize, humanity may have to wait a long time for another display equal to the great storms of the past. Mason (1995) concludes that significant Leonid activity during the period 2029-2033 is unlikely. Yeomans *et al.* (1996) go even further, stating that because of planetary perturbations on the Leonid stream, significant Leonid events are not likely for another century after 1999 (Rao, 1996). This is graphically apparent in the plot of minimum distances between Comet Tempel-Tuttle and Earth at the time of the comet's passage through its descending node (Figure 9).

And what of the comet itself, the cause of all this agony and ecstasy? Observations of Comet 55P/Tempel-Tuttle have been much rarer than observations of its debris. Yeomans *et al.* (1996) have recently recomputed its orbit, using the only known observations of the comet as it appeared in 1366, 1699, 1865-66 and 1965. As Yeomans *et al.* show in a revealing plot, on most of Tempel-Tuttle's returns it has been too faint to reach naked-eye visibility. In 1997 March, it was recovered at 22.5 magnitude, on its way to perihelion passage on 1998 February 28. At its minimum geocentric distance in 1998, it will be under tenth magnitude, and so easily within reach of moderate telescopes, but not the naked eye.

Whether or not the Leonid predictions for 1998 and 1999 are borne out will soon be known. In any event, meteors are an important case study of the growth in understanding of one class of solar system objects, a story that is unique and equally interesting for each class of astronomical bodies. Perhaps for few other classes of objects, however, have historic observations played such an important role in both discovery and elaboration, although we know from the work of Clark and Stephenson (1977), Stephenson (1978), and others that they do play a significant role in understanding such diverse phenomena as comets, eclipses, and supernovae. The role of historical data in meteor studies is thus only one example of how the history of astronomy demonstrates its usefulness to science. And the very existence of these data reminds us of how much astronomical phenomena have affected the civilizations of the past (Schaefer, 1992, 1994, 1997a, 1997b), perhaps more than we yet realize.

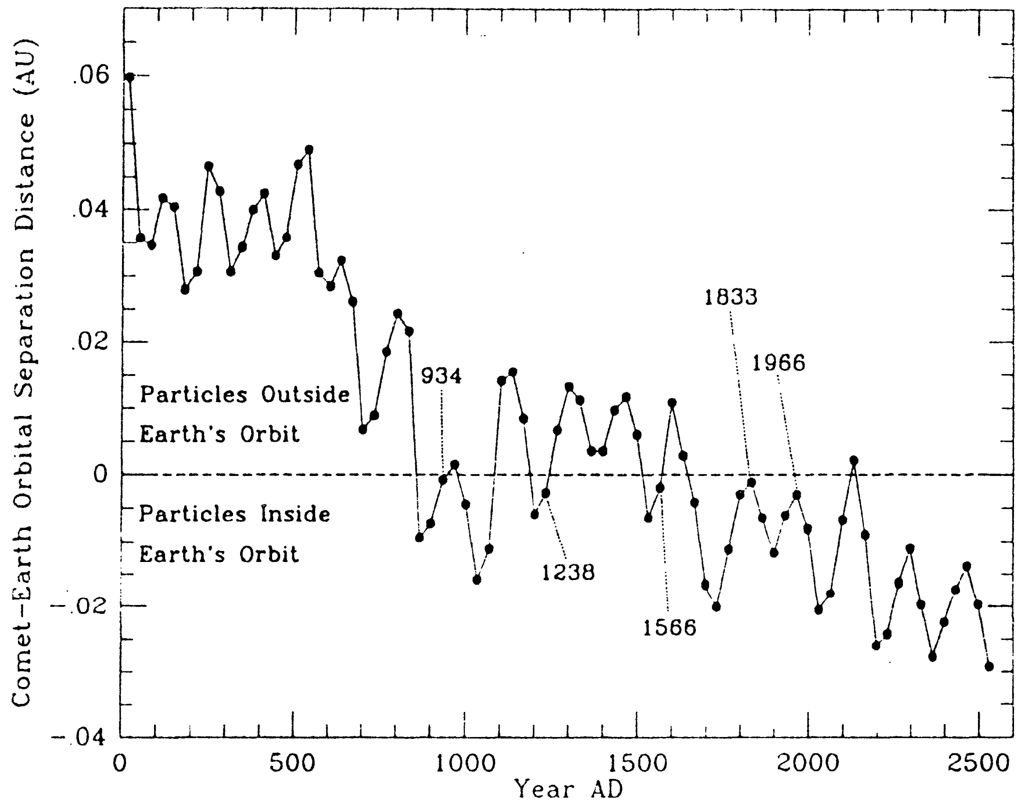


Figure 9. Minimum distances between Comet Tempel-Tuttle and Earth orbit at the time of the comet's passage through its descending node, from Yeomans *et al.* (1996). The plot indicates that after 1999 significant Leonids will be very rare. (From *Icarus* **124** (1996), 407-413, by permission of Academic Press, Inc. and D. K. Yeomans)

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Mission impossible: William Scott and the first Sydney Observatory directorship

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Abstract
The Reverend William Scott (1825-1917) was the founding Director of the Sydney Observatory, and succeeded in acquiring state-of-the art astronomical instruments, establishing a network of country meteorological stations, and conducting a range of astronomical observations. He also worked to promote popular interest in astronomy, and immersed himself in the scientific culture of New South Wales. This paper examines Scott's achievements in astronomy and meteorology, the reasons for his premature resignation in 1862, and the search for his successor.

Key Words: *William Scott, Sydney Observatory, Government Astronomer of NSW*

1 INTRODUCTION

The 1850s witnessed a blossoming of astronomy in Australia, with the founding of professional observatories at Williamstown (see Figure 1 for Australian localities mentioned in the text) and Sydney (Haynes *et al.*, 1996; Orchiston, 1988a) and the emergence of two notable amateur astronomers, Francis Abbott in Hobart (Orchiston, 1992) and John Tebbutt in Windsor (Haynes *et al.*, 1996).

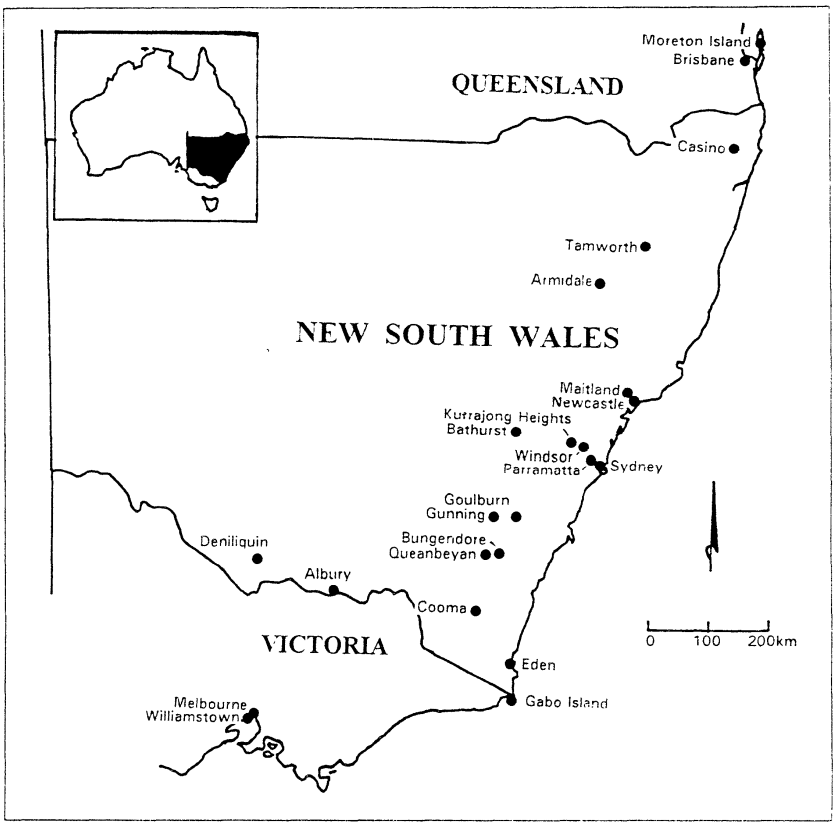

Figure 1. Australian localities mentioned in the text.

Sydney Observatory was the third colonial observatory to be founded in New South Wales (Baracchi, 1914), and grew from the ashes of the Parramatta Observatory which had closed in 1847 (Saunders, 1990). The history of the Sydney Observatory has been reviewed by Baracchi (1914), Orchiston (1988b), and Wood (1958, 1982, 1983), amongst others.

Two individuals were largely instrumental in the founding of the Sydney Observatory, Captain Phillip Parker King (Orchiston, 1988d) and Sir William Denison, the Governor-General of New South Wales (Currey, 1972). In 1855 October, Denison wrote to Sir George Airy, the Astronomer Royal, asking him to select a suitable person to serve as both founding director of the Observatory and Government Astronomer of New South Wales. The post was accepted by the Reverend William Scott (see Colonial Astronomer, 1857), who was later to write: "Regarding it as a life appointment, as in all other national observatories, I abandoned a more lucrative position with all prospects of preferment in Cambridge." (Scott, 1861j). His annual salary was £500 (Wood, 1958).

This paper, which expands on Orchiston (1988c), is about Scott's term as Government Astronomer of New South Wales, and examines the early history of the Sydney Observatory, factors leading to Scott's premature resignation in 1862, and relations between Scott and Tebbutt. It is the story of the trials and tribulations of a British scientist with limited observational experience who ended up directing a fledgling colonial observatory far from the astronomical centres of Britain, Europe, and North America.

2 WILLIAM SCOTT: A BIOGRAPHICAL SKETCH

The Reverend William Scott (Figure 2) was born at Hartland in North Devon on 1825 October 8 and completed his B.A. degree at Cambridge University in 1848, "... taking honours as Third Wrangler at the same time as the late Isaac Todhunter, the well-known

Figure 2. Reverend William Scott, M.A. 1825-1917. (After Russell, 1892)

mathematician." (Houghton, 1917). He was made a deacon in 1849 and was ordained a priest in 1850. In 1851 he received his M.A. degree. That same year he married a widow with three sons, and Cable (1976) claims that it was these newly-inherited family responsibilities which prompted Scott to become a successful mathematics coach. Scott (1860j), however, provides another perspective on his flight from the church, describing how he tended

> ... the death beds of men and women dying in the full conviction and rejoicing in the truth of those Doctrines which I there taught but have now learned to disbelieve. It was this gradually increasing change of belief, which I kept down as much as I could and scarcely dared acknowledge to myself, that made me eager to give up the Clerical professional altogether, as I have now done. I regard the system of Divinity adopted by the Christian Churches as almost wholly of human intervention .... Now I do not want to shake your faith or destroy your peace of mind, as mine has been for many a year, but I do want you to believe that a man's salvation does not depend on theories about things which he cannot possibly understand ....

Whatever the facts of the matter, in 1853 Scott went on to publish a small textbook titled *Elementary Treatise on Plane Co-ordinate Geometry* (Lynn, 1904), and when offered the Sydney Observatory post in early 1856 was a Mathematical Lecturer at Sidney Sussex College, Cambridge (Scott, 1860a).

Scott officially commenced duties as Government Astronomer of New South Wales on 1856 April 16 (Scott, 1859c), and spent much of the next two months at the Royal Observatory, Greenwich,

> ... where he received every assistance from the Astronomer Royal in completing his knowledge of practical Astronomy, and in making himself familiar with the most recent improvements in the construction and use of Astronomical Instruments. (Scott, 1860a:iii).

In addition, he made himself "... familiar with the routine of an observatory ..." (Scott, 1859c). In this regard it is significant that Airy selected a non-astronomer for the post, especially given his earlier antagonism towards astronomy in Sydney (see Orchiston 1988d).

On 1856 July 1, William Scott, his pregnant wife and their three sons sailed from England, reaching Sydney on October 31 (ibid.). A daughter who was born in September died during the voyage (Scott, 1859a). In 1858 July, Scott was blessed with a second daughter, but she died just five months later, prompting him to lament: "There is something in the air of Sydney peculiarly fatal to young children though it is healthy enough in general." (ibid.). In 1860, a third daughter was born (Scott, 1860g).

After resigning from the Sydney Observatory post in 1862, Scott turned to teaching and took over the Cook's River Collegiate school in Sydney (Our first astronomer, 1915). From 1865 to 1878 he was Warden of St Paul's College at the University of Sydney, and given his earlier disenchantment with religion it is all the more remarkable that he then committed the remainder of his working life to the ministry (Lynn, 1904), serving at Bungendore, Gunning and Queanbeyan. After his retirement in 1882, Scott and his wife visited England and then settled at Kurrajong Heights north-west of Sydney where they had purchased an orchard in 1860 (Our first astronomer, 1915). Scott lived in good health to the ripe old age of 91, dying at Chatswood, Sydney, on 1917 March 29 (Houghton, 1917). He was survived by a son and two daughters, and had an estate worth nearly £7,500 (Cable, 1976).

Despite his short career as a professional astronomer, Scott retained an active interest in science, serving as Honorary Secretary of the Royal Society of New South Wales from 1867 to 1874 and as Treasurer for a number of years (Maiden, 1918).

However, his only significant involvement in astronomy during this period was as part of Russell's 1874 transit of Venus programme, when he led the Sydney Observatory group based at Eden that successfully observed the transit (see Russell, 1883, 1892; Scott, 1874).

3 THE SYDNEY OBSERVATORY YEARS: A RECORD OF ACHIEVEMENT IN COLONIAL SCIENCE

3.1 Necessary Groundwork

When Scott arrived in Sydney in 1856 October, he immediately set to work by confirming the site for the Observatory at Fort Phillip recommended by Denison (see Scott, 1859c) and advising on the plans drawn up by a previous Colonial Architect. The final design merely marked the end-point in a lengthy period of negotiation which saw the building grow from a small simple time ball station to a substantial stone structure costing £7,000 (see Orchiston, 1988d). The Colonial Architect actually superintended the construction of the building, which commenced in 1857 May, with Scott (1859c) providing input only when 'scientific requirements' were concerned. The result was an imposing stone building which for the first time in a major Sydney building combined two different architectural streams:

> The first was the Italian High Renaissance *palazzo* mode for banks, clubs and town houses popularized by Charles Barry in London during the 1830s .... The second was the picturesquely asymmetrical "Italian villa" form – a form which became common for stately free-standing mansions. (Kerr, 1991:21-22).

The building was completed in 1859 January, and comprised an equatorial dome, transit room, time ball tower, and astronomer's residence (Figure 3).

Scott (1859c:293) was careful to point out that

> ... having had a sufficient sum placed at my disposal for the establishment of an Observatory on a good and substantial scale, I have felt it my duty not to be led by false economy to proportion the building to the present state of the instruments at my disposal, but to erect an Observatory sufficiently comprehensive and commodious to satisfy all the astronomical requirements of the colony for the next century.

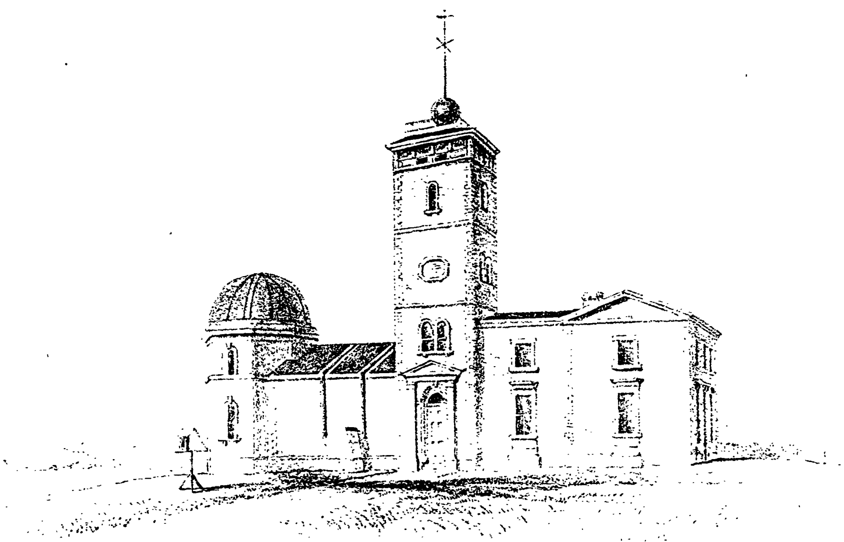

Figure 3. The Sydney Observatory in 1859. (After Scott, 1860a)

In this regard, he was openly challenging Cassini's views on observatory architecture: that all possible funds should be expended on the instruments and that the building itself should be kept as simple and undecorated as possible (see Donnelly, 1973). But to Haynes *et al.* (1996:52), this elegant building "... signalled something more than wealth; it testified to the Colony's aspirations to the Renaissance tradition of learning, a marriage of science and the arts."

The floor plan of the Observatory also differed markedly from most other observatories constructed prior to 1860 (e.g. see plans in Donnelly, 1973). If there was one major architectural drawback it was the time ball tower which, in the original plan, was already "objectionably high". Its construction took place while Scott was away from the Observatory, and he returned to find it even taller than anticipated (Scott, 1861a)! It was 17.7 m high, and consequently a sizeable portion of the eastern sky was inaccessible from the western dome. Scott was mortified.

While the building was being erected, Scott began planning the programmes of the Observatory which, as was common practice at the time, were to encompass astronomy, meteorology, geomagnetism, and tidal studies. He also saw that the Observatory would have an important educational role.

His first duty was to assess the equipment at his disposal and so he gathered together the remaining instruments from the Parramatta Observatory that King had placed in storage after that institution closed (Scott, 1859b). There were two chronometers, and four different astronomical clocks, two of which were of little value (Scott, 1859c). Scott also discovered a mural circle 61 cm in diameter and a 9.5-cm aperture transit telescope, both by Troughton (ibid.); a second transit telescope (manufacturer unknown); a 41 cm diameter repeating circle by Reichenbach; an 8.3-cm aperture refracting telescope by Banks; a sextant; a smaller refracting telescope; and assorted magnetic and meteorological instruments (for a full listing see Table 2 in Orchiston, 1988d). Originally, the storage cases had also included a defective 9.5-cm aperture transit circle by Jones, with a circle 1.07 m in diameter (Scott, 1860a), but in 1855 Denison had sent this to England and asked Airy to supervise its repair (Wood, 1958). Scott found the remaining instruments "... so bad that I can do nothing with them ..." (Scott, 1859a), describing the Banks equatorial as:

> ... a portable Telescope, with an equatorial mounting and wire Micrometer, but the instability of its original mounting had been so much increased by use, that it was impossible to make any micrometrical measurements with it. (Scott, 1860a:v).

A first-class equatorial telescope was vital for the Observatory's non-meridian work, and Scott (1860g) did well to convince the Government to commit the not inconsiderable sum of £800 for the purchase of a new 18.4-cm Merz refractor. At the time, Merz of Germany was one of the leading manufacturers of astronomical telescopes (Brachner, 1987; Chance, 1937). While the largest instruments in the world were the 38-cm refractors at the Pulkovo and Harvard College Observatories (Welther, 1984) and apertures in excess of 18.4 cm were not uncommon by 1860 (see King, 1979), the new Sydney telescope would still be capable of useful work.

A reliable astronomical clock was also essential, and after further appraisal Scott decided that only one of the ex-Parramatta Observatory clocks (the one by Hardy) was reliable. He therefore proceeded to order a new clock, by Frodsham (Scott, 1861a).

Scott (1859c, 1861o) also sent off letters to the Royal Astronomical Society and astronomers at the Chilean National Observatory (Santiago) and the Royal Observatory at the Cape of Good Hope, requesting publications so that he could establish an astronomical library, and soliciting ideas on suitable research projects. He even took the unusual step of appealing, in one of his papers in *Monthly Notices of the Royal*

Astronomical Society, for "... any suggestions from your Society as to the best mode of co-operating (when my new instrument arrives) with the astronomers of Europe and America." (Scott, 1861q).

At the very end of 1858, Scott (1858c) succeeded in increasing the staff of the Observatory when 22 year old Henry Chamberlain Russell was appointed as a 'computer' on a salary of £200. Despite being a recent B.A. graduate from the University of Sydney and their top student in mathematics and physics, Scott (ibid.) felt that Russell "... will have much to learn before he can be considered fully official ...", and in writing to a clerical colleague in England the following year described him as "... rather a slow coach but steady and hard working." (Scott, 1859a). Given this assessment, Scott must have been surprised to see Russell emerge as a major figure in New South Wales science later in the century (see Bhathal, 1991).

Finally, Scott also succeeded in forming an Observatory Board, comprising the Governor-General, Colonial Secretary, Surveyor General, Professor of Mathematics at the University of Sydney, and the Commanders of any Royal Navy warships which happened to be in the harbour at the time of a meeting (Wood, 1958). At the first meeting of the Board, on 1858 December 2, Scott had obtained support for the purchase of the Merz telescope and for Russell's appointment.

3.2 Observational Astronomy

By 1858 June, construction of the Observatory building was sufficiently advanced for the time service to be initiated, even though Scott was concerned about several defects of the transit instrument "... which destroyed all confidence in the results furnished by it." (Scott, 1859c:295)! It was only by taking the mean of a considerable number of star transits that "... even a tolerable approximation to the time could be obtained." (Scott, 1860a:v). It became the practice to raise the time ball to the top of the mast on the time ball tower at five minutes before 1300 h each day and drop it precisely on the hour. Given the Observatory's elevated situation, this signal was readily observable by people in the nearby port and fledgling settlement (Tebbutt, 1866).

The transit telescope was also used to observe the Moon and Moon-culminating stars, in order to determine the longitude of the Observatory. The first value published was 10 h 04 m 49 s.0 East of Greenwich based upon just 21 observations but, as Scott (1859c:296) was quick to point, "This determination is, of course, unsatisfactory, owing to the defects of the transit-instrument ...". As if to emphasize the point, he produced a significantly-different figure of 10 h 04 m 59 s.86 in 1859, following the return of the repaired Jones transit circle (Scott, 1860m). Further observations were made in 1860 and 1861, and when these were combined with those of 1859, Scott (1862g) derived a mean value for the longitude of the Sydney Observatory of 10 h 04 m 45 s.79 (cf. Scott, 1862a). Later in the century, this figure was the subject of considerable debate (see Russell, 1878; Tebbutt, 1878, 1880).

Scott (1860m) also investigated the latitude of the Observatory, and observations of 24 different southern stars produced a figure of 33 ° 51 ' 41 ".1 South. Further observations (Scott, 1860a) led to a slightly revised value of 33 ° 51 ' 40 ".8 South, and only a minor correction to this figure was thought necessary in 1861 (Scott, 1862a).

Apart from the transit telescope, the only other astronomical instrument which Scott initially could use for observational astronomy was the old 8.3-cm refractor, until the arrival of the Merz telescope in 1861 May. He decided to follow international custom and use both telescopes to observe "phenomena of an occasional nature" such as comets, eclipses, transits of Mercury and lunar occultations. He also decided (Scott 1861a; 1861i) to investigate some of the double stars that had been observed by Sir John Herschel (1847). Let us review Scott's observations.

The first major comet to appear in Sydney skies following Scott's appointment was C/1858 L1 (Donati), which was visible from the middle of October. Scott (1858a) reported in the *Sydney Morning Herald* that he had made several attempts to determine its position using the old Parramatta Observatory refractor, "... but the results are not such as could be published in any degree of satisfaction." He also used the sextant to take distances between the comet and selected stars, but again felt the results were too imprecise to be used in any orbital computation. In a follow-up article published three days later (Scott, 1858b), he lamented the circumstances in which he found himself:

> ... possessing no instrumental means of determining the comet's position with accuracy, I can expect no greater weight to be attached to my remarks than to those of any amateur astronomer similarly situated.

In 1860 July, a new Great Comet (C/1860 M1) was reported from various localities in Australia, and Scott caught his first fleeting glimpse of it on July 9 just before it was obscured by clouds. At the time is was "... a brilliant object, and being near the horizon its tail extended upwards at an angle of about 60 °." (Scott, 1860c:359). In a marked departure from 1858, he used the old Parramatta Observatory refractor and its ring micrometer to obtain positions of the comet on six different evenings between July 12 and 18 (inclusive) and these were subsequently published in *Monthly Notices of the Royal Astronomical Society* (ibid.). Scott reports that throughout this series of observations

> ... I have not been able to distinguish any marked peculiarity in its appearance. There was a decided brilliant nucleus, but not sufficiently well defined to form a good subject for observation, around which the light appeared diffused very uniformly. (ibid.)

Further observations followed until August 18 (see Scott, 1861a), and in all Scott made 140 different positional measures of this comet on nine different nights in July and August. Some of these are published in Scott (1860l).

As Scott continued to observe this comet, he shared this experience with the readers of the *Sydney Morning Herald*. His first account appeared on July 16 (Scott, 1860e) and reported that the comet was moving eastward in right ascension and southward in declination at a rate of about 3 degrees per day. In a follow-up letter, published on July 23, he noted (Scott, 1860n) that the comet had remained a naked-eye object until the 18th. In this same letter, Scott supplied those who wished to attempt their own orbital computations with positional data for three different nights, but he was later obliged to provide a correction to one of the values and an apology for any confusion which this may have caused (Scott, 1860b).

While Scott's account of this comet usefully supplemented those provided by other professional astronomers, by far the most significant cometary observations that he made were of the Great Comet of 1861, now known as Comet C/1861 J1 (Tebbutt) (see Orchiston, 1998).

On 1861 May 13 the Windsor amateur astronomer, John Tebbutt, discovered what was destined to become one of the major comets of the nineteenth century (Figure 4). Even before he had confirmed the discovery, Tebbutt (1908) sent a letter off to the Sydney Observatory, and as a result this comet was to occupy Scott's attention for more than a month (see Scott, 1862a).

When he received Tebbutt's letter on May 22, Scott was busy installing the new Merz refractor (see Figure 5), and he was forced to use the old Parramatta Observatory telescope to obtain an approximate position. Two days later, he adapted the micrometer that came with the new telescope to the Parramatta refractor and was able to obtain an accurate position of the comet's head (Scott, 1861l). Further micrometric observations were made on May 27 and 30. By June 4 the Merz refractor was operational, and from June 8 to 26 (inclusive) Scott obtained positions on 12 different evenings and published these in *Monthly Notices of the Royal Astronomical Society* (Scott, 1861p). He also made information on the comet available to the local public through the *Sydney Morning*

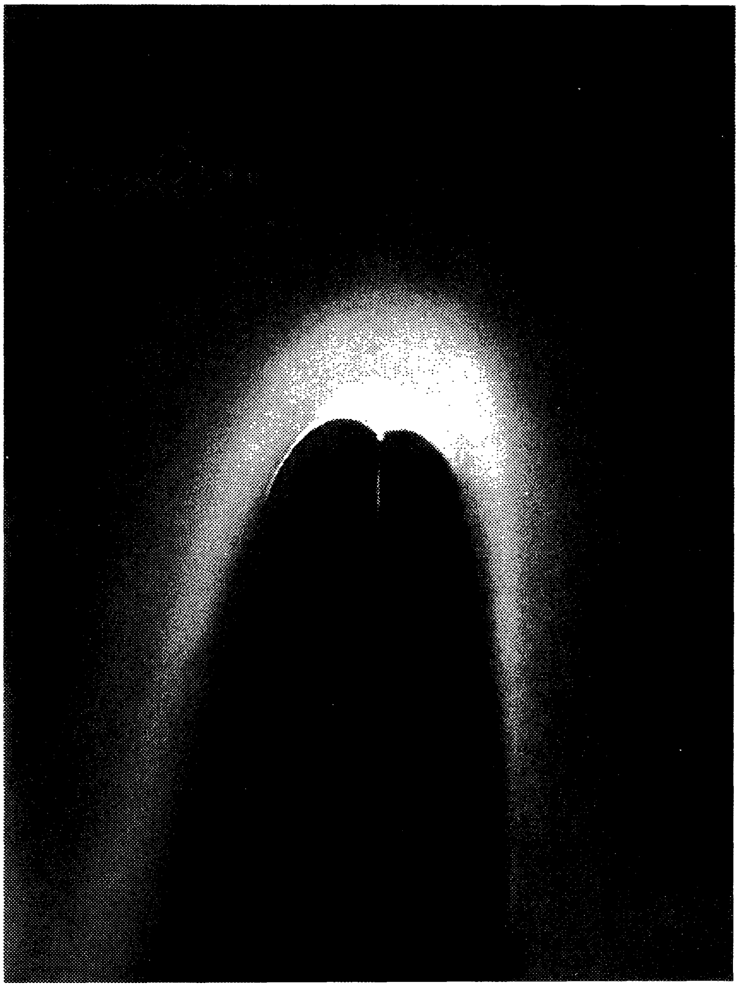

Figure 4. Head of Comet C/1861 (Tebbutt). (After Guillemin, 1877:Frontispiece)

Herald newspaper, and on May 31 reported his positional observations of May 24, 27, and 29, and noted that on the 27th he had "... detected the existence of a tail, very faint and diffused, pointing nearly to the south pole." (Scott, 1861m). On June 17, he published an account in *The Empire*, describing the tail as then 18 degrees in length (Scott, 1861t).

These attempts to share observations of the comet with the public ultimately backfired when an anonymous writer using the pseudonym 'Orion' criticized Scott for not providing enough "... *popular* information respecting the new comet ...", including its period, the nature of its orbit, and its location and day-by-day motion in the sky. He also asked Scott to

> ... give us a brief outline of the theories of Lardner, Arago, and others on "Cometary Influences", showing that no possible danger can arise to our earth from their presence, and thus allay or prevent the terror of the alarmist. (Orion, 1861).

On June 22 Scott responded to 'Orion', and in the process included an account of the tail:

> The most remarkable feature I have noticed is the formation of the tail; the usual diverging brush-like appearance extends for about eight degrees ... and

> beyond it extends a narrow stream of light in the same direction, and reaching to about ten degrees further ... (Scott, 1861r).

Immediately following Scott's letter in the *Sydney Morning Herald* was another anonymous one, this time by 'F.C.B.' (1861) supporting Scott and the work of the Sydney Observatory.

Yet another attack on Scott appeared in the *Sydney Morning Herald* on June 26, but written in an rather novel way. In a letter titled "The Comet's Grievance", a correspondent using the name 'Comet of 1861' writes:

> It is not often that I honour the people of New South Wales with a visit, but after the extremely shabby manner in which I have been treated by the local astronomers, I take good care that my future visitations shall be "far between". Through my influence, I have kept the elements clear, in order to allow your "scientific few" to have their eyes on me to make their observations of my onward progress, yet nothing has officially appeared in print about me....
>
> My object, in appearing in this hemisphere, was to put the ability of your local (paid and amateur) astronomers to the test, in order to give them an opportunity of furnishing an interesting dissertation to the common people, but my object and wishes were frustrated. I must confess that had it not been for the "amateur" at Windsor, in all probability my visit would have passed off unreported. Mr. Tebbutt has my thanks for informing Mr. Scott of my visit and whereabouts. At the same time it is very humiliating for a great man so often to play "second fiddle". (Comet of 1861, 1861).

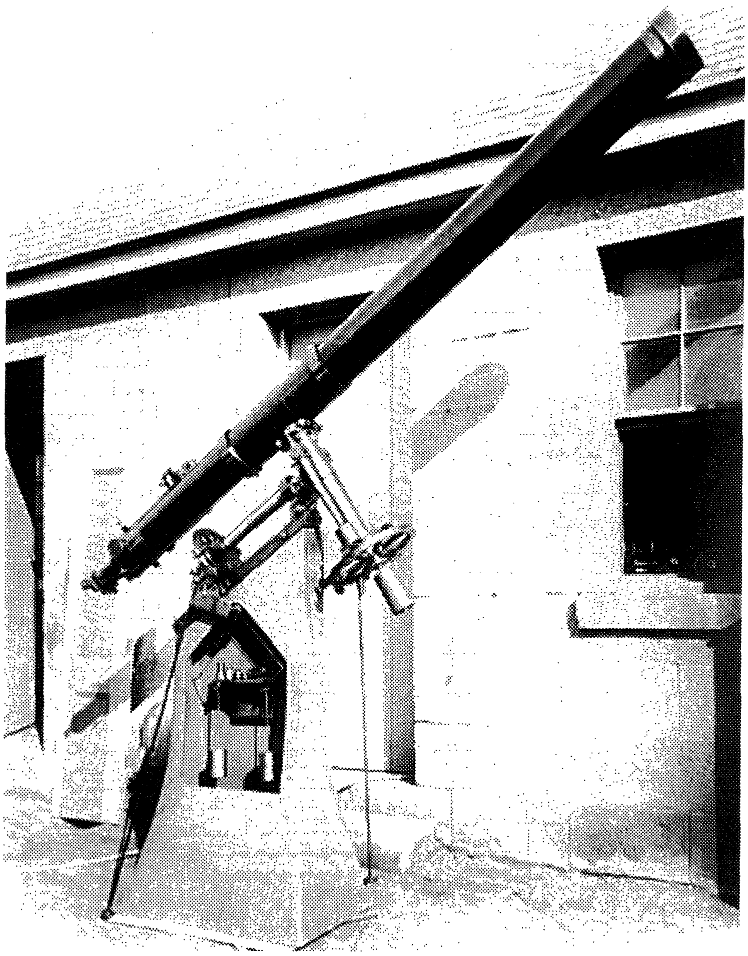

Figure 5. The 18.4-cm Merz refractor. (Photograph courtesy Royal Astronomical Society).

As might be expected, this letter elicited a stern reply from Scott (1861s). He pointed out that he had submitted papers on the comet to overseas journals (e.g. see Scott, 1861p) and saw no point in reproducing their full contents in the local media, there being "... but two or three persons in the colony to whom they could be of any service ..." (Scott, 1861s). Despite this, he included the comet's orbital elements which he had calculated and, as Table 1 indicates, these are very similar to the elements published earlier by Tebbutt (1861) and subsequently by Hawkins (1861), Kreutz (1880) and White (1861). What Scott did not do, despite Orion's prompting, was provide a popular account of the various theories about comets.

Table 1. Orbital elements of Comet C/1861 J1 (Tebbutt) according to different computers

Computer	Tebbutt	Scott	Hawkins	White	Kreutz
Perihelion passage, June	13.7253	11.6892	11.75	11.2035	12.0068
Perihelion distance (in AU)	0.82033	0.82218	0.82215	0.82156	0.82238
Longitude of ascending node	280°00'44"	278°57'52"	279°01'41"	278°58'36"	280°12'39"
Inclination of the orbit	86°18'42"	85°38'11"	85°37'46"	85°25'42"	85°26'27"
Distance of perihelion from node		29°42'58"	29°38'59"		29°54' 35"
Heliocentric motion	Direct	Direct	Direct	Direct	Direct

In the same issue of the *Sydney Morning Herald* was a second letter from 'F.C.B.' (1861b) supporting Scott against the attack by the 'Comet of 1861', and less than a week later, 'X.X.' (1861) added his support.

The departure of the comet from southern skies did not end the media interest in it, and on 2 July Scott (1861u) brought his entire suite of positional observations together in *The Empire* for anyone who wished to use them for their own orbital computations. He then prepared a synthesis of all of his own observations and descriptions, and details of the initial discovery by Tebbutt, and presented this paper at a meeting of the Philosophical Society of New South Wales. Since the Society had not begun publishing its *Transactions* at this time, Scott's paper was reproduced in its entirety in both *The Empire* and the *Sydney Morning Herald* (e.g. see Philosophical Society, 1861) on July 18. Thus ended Scott's investigation of Comet C/1861 J1 (Tebbutt).

The fourth comet that Scott observed was P2/Encke in 1862. Because of cloudy and hazy weather, he was only able to obtain micrometric positions on February 23 and 24, and noted that the comet at best was "... very indistinct and ill defined." His twelve micrometric positions, involving two different comparison stars, were published in *Monthly Notices of the Royal Astronomical Society* (Scott, 1862h).

Undoubtedly, the most significant astronomical event to grace Sydney skies soon after Scott's arrival was the total solar eclipse of 1857 March 26. Such eclipses offered astronomers all-too-brief opportunities to study prominences, the solar chromosphere and corona, and Baily's Beads, and the 1857 event was eagerly awaited by Scott and other local astronomers. And as the first total solar eclipse visible from Sydney since European settlement, it also attracted considerable public interest. The event was scheduled to begin at 05 h 55 m 12 s local time, about 13 minutes before sunrise, and end at 07 h 53 m 49 s. Totality was restricted to just 1 m 32 s, starting at 06 h 51 m 19 s (Scott, 1857a).

Both Scott (ibid.) and Tebbutt (1857a, 1857b) discussed the event beforehand in the *Sydney Morning Herald*, but in Scott's case it is somewhat surprising that he neglected to warn people of the inherent dangers of directly viewing the partially eclipsed Sun with the unshielded eye. As it turned out, all this publicity was to little avail for the day dawned cloudy. Armed with Governor-General Denison's equatorial telescope, Scott (1857b) was stationed at the South Head Lighthouse, but all he saw were fourteen minutes of the partial phase shortly after the Sun rose. The Sun was completely obscured by clouds during totality.

Four years later, on 1861 January 11, there wasScott a partial solar eclipse (Scott, 1861k), which Scott observed. Because there was some cloud cover, he was unable to obtain precise contact times or carry out micrometric measurements of the eclipsed portion of the Sun's disk. Despite this, he forwarded an account to England, including 16 temperature readings extending over a 2 h 20 m period (Scott, 1861q).

Another solar-related event that drew Scott's attention was his first ever observation of a transit of Mercury. This occurred on 1861 November 12, and was recorded in Sydney, Melbourne and Adelaide (Observations in Australia ..., 1861). In Sydney, Scott (1861n) observed the second ingress contact and then followed Mercury as "... a well-defined circular black spot, slowly traversing the disc." During the transit, he succeeded in obtaining a few micrometric measurements of the planet's position relative to the solar limb.

According to Tebbutt (1866), after the arrival of the Merz refractor Scott added lunar occultations and southern double stars to his observing programme, although there is no evidence that he published any results of these investigations. We do know that from 1861 February Tebbutt was computing the local occurrence times of lunar occultations for Sydney Observatory (see Scott, 1861f), so that Scott could observe these events if he wished to.

The renovated ex-Parramatta Observatory transit circle arrived back in Sydney towards the end of 1858 December, and in 1859 June Scott began to make regular observations with it (Tebbutt, 1904). His project was a survey of stars culminating near the zenith at Sydney, and the very numerous results appeared in four successive annual monographs produced by the Observatory and published by the Government (Scott, 1860a, 1861a, 1862a, 1865). Tebbutt (1866:59) reports that even though

> The transit circle is described as only a second-class instrument ... considering the care and skill employed in the use of it, the volumes referred to will be found to be a very valuable contribution to science.

Although the Sydney survey proved complementary to the survey of stars near the south celestial pole conducted by the Royal Observatory at the Cape of Good Hope, Dewhirst (1985) has used the benefit of hindsight to query the utility of many of these types of programmes.

One other notable celestial observation that Scott made was of his first aurora australis in 1859 August (Scott, 1859e). The observation itself was only important because of Scott's foray into solar-terrestrial relations less than one year later:

> There has been detected a connection between Solar spots and magnetic variations, and the Aurora is due to or accompanied by magnetic disturbances. There is probably a similar connection between its appearance and solar spots – but I have not met with any statement of such connection having been observed. (Scott, 1860h).

As Haynes *et al.* (1996:53) have pointed out, this important deduction was largely overlooked at the time, but it was "... to have a major impact on radio communications, radio astronomy and geomagnetic work in the next century."

3.3 Astronomical Education

Denison also saw the role of the Sydney Observatory as "... to provide service, including education, to the community ..." (Wood, 1958:30), and Scott responded to this whenever possible by sending the Sydney newspapers information on astronomical objects or events of likely popular interest. In addition to the articles already referred to about comets, eclipses, the transit of Mercury and the aurora, he also wrote about a second partial solar eclipse in 1861 (Scott, 1861b) and compass errors in iron sailing ships (Scott, 1860f).

Scott also offered to take astronomy to interested members of the general public by conducting formal classes at the Observatory, and although he managed to attract a small group, "... no one persisted to the stage of undertaking useful amateur work for which he was willing to provide facilities ..." (Wood, 1958:10). In contrast, he found a captive audience at the University of Sydney where he was appointed Mathematics Examiner, but he was far from impressed by the standard: "... there are about 25 men or rather boys and their Mathematical reading in no case extends beyond mild mechanics." (Scott, 1859a).

3.4 Religion and Astronomy

As we have noted, by the time he accepted the Sydney posting, Scott had become disenchanted with Christian religion, yet in what could be described as his only foray into 'theoretical astronomy', he brings science and religion to bear on the vexed question of life in the universe. In an interesting review paper (Scott, 1859d) published in *The Sydney Magazine of Science and Art* under the authorship of 'Rev. W. Scott, M.A.', with no mention of his Sydney Observatory affiliation, he explained that

> Some are kept back from the subject by the amount of reading requisite for its full consideration; others by fear that their astronomical knowledge will hardly enable them to understand all the arguments employed in the discussion; others again finding such great names ranged on opposite sides feel it impossible to come to any conclusion on a question on which such authorities are unable to agree. (Scott, 1859d:131).

These considerations did not deter Scott, who proceeded to discuss the following four questions:

1. Are the other planets of the Solar System occupied by living beings?
2. Are the stars associated with planetary systems, and if so, are their planets inhabited by living beings?
3. Are the Sun and stars also inhabited?
4. Are there among the inhabitants (if any) of those bodies, reasonable beings equal or superior to man?

After reviewing the available scientific evidence, Scott concluded that life is likely to exist on some of the planets in our Solar System; that some stars are accompanied by planets; and that some of these are also inhabited. In sympathy with a theory championed by Sir William Herschel, he believed that the Sun may also be inhabited and, that being the case, he saw not reason why other stars should not be. Finally, in examining the question of intelligent human life, he concluded: "... if the celestial bodies are inhabited at all there is a strong probability of their being inhabited by beings analogous to ourselves." (Scott, 1859d:134).

In completing his interesting review, Scott compared and contrasted the conflicting viewpoints of science and religion, pointing out that

> Revealed religion ... although it allows of the existence of animal life in innumerable worlds, is yet opposed in some degree to the existence of a race resembling ourselves in their higher faculties and in their relation to the Creator. (Scott, 1859d:136).

While both scientific and religious viewpoints were cleverly presented, the reader is left wondering exactly where Scott's true sentiments lay!

3.5 Meteorology

As was the custom with many professional observatories at this time, the Sydney Observatory was also involved in disciplines other than astronomy, and meteorology undoubtedly was the most important of these. In a newly-settled colony, meteorology had a special place, and Scott was very aware of this:

> Our little observatories [= meteorological stations] scattered about the colony, besides collecting data on which the future Newton of meteorology may, perhaps, ground his great harmony of the wind and clouds, besides distinguishing between the characteristics of different localities in such a manner as to guide the sickly in his search for a climate suitable for his constitution, the engineer in providing the water supply for our towns and cities, the agriculturist and gardener in the cultivation of particular crops and plants, will do something also towards the encouraging a habit of thought, and promoting the pursuit of science in the colony. (Scott, 1857d:129).

Soon after his arrival in Sydney, he began planning the Observatory's meteorological programme which involved the establishment of a network of country stations throughout the colony.

His first task was to unpack the twelve sets of meteorological instruments (see Table 2) which had previously been ordered from England (Wood, 1958), and to decide on the siting of his meteorological stations. By 1857 October, the following locations (see Figure 1) had been chosen: Albury, Armidale, Bathurst, Cooma, Deniliquin, Goulburn, Maitland and Parramatta, plus the lighthouses at Gabo Island, Moreton Island (Brisbane) and Newcastle (Scott, 1857d). In addition to the lighthouses, country stations were to be located in such varied institutions as a parsonage, a school, a jail, and a hospital!

Table 2: Meteorological instruments used at the Sydney Observatory and at each of the country meteorological stations (after Scott 1857c).

1. Barometer with attached Thermometer
2. Wet and Dry Bulb Thermometers
3. Daniell's Hygrometer
4. Negretti and Zambra's Self-registering Maximum Thermometer
5. Solar Radiation Thermometer
6. Rutherford's Minimum Thermometer
7. Terrestrial Radiation Thermometer
8. Rain Gauge
9. Double Gold Leaf Electroscope
10. Wind Vane

Scott (1857c) also prepared detailed instructions for his country meteorological observers. They were to read all of the instruments three times daily, at 0900 h, 1500 h, and 2100 h, and also were expected to note

> ... any phenomena which are probably occasioned by the state of the atmosphere, such as epidemic diseases, blights, extraordinary numbers of insects, changes in the times of flowering of plants, &c. (Scott, 1857c:9).

By mid-1858, Scott (1859c) had spent considerable time visiting all of the country stations, and had installed the meteorological instruments and instructed the observers in their duties. In addition to his personal visits, this exercise involved him in a voluminous correspondence (Wood, 1958).

On 1858 August 11, Scott (1858d) provided his first meteorological 'progress report' to the Philosophical Society of New South Wales, noting that the reduction and copying of the data from all stations in the Sydney Observatory network involved about forty-eight hours of intensive work each month (ibid.; cf. Scott, 1859a). A direct result of this considerable expenditure of effort and energy was that summaries of the observations taken at the country meteorological stations were published each month in the *Sydney Morning Herald*, while reports from Sydney Observatory itself appeared weekly. These latter listed daily values for barometric pressure; maximum and minimum shade temperatures; maximum sun temperature; humidity; rainfall; and wind direction and force, and cloud cover, at 0900 h, 1500 h, and 2100 h; together with general remarks about the overall weather. By 1859 (Scott, 1860a), there were 12 meteorological stations involved in the Sydney Observatory meteorological network (the Observatory included), the lighthouse station at Gabo Island having been taken over by the Victorian Government (Scott, 1958d).

With the passage of time, there were on-going problems with the country meteorological network caused by a combination of equipment breakages and the use of unskilled and, in some cases, unreliable observers. By 1860 October the situation had become intolerable, and Scott recommended that eight sets of instruments should to be transferred to government telegraph stations where a part of the telegraph clerk's duty would be to take the meteorological observations and transmit monthly returns to the Observatory. This was implemented in 1861, and led to some wholesale changes to the actual location of country stations (see Table 3): the Rockhampton station was closed down on October 1, and the instruments at Maitland Gaol were transferred to the Newcastle Telegraph office and those at Parramatta to the Telegraph Station at Windsor. Wood (1958:8) believes that these new arrangements involving the telegraph stations "... played an important part in developing Australian meteorological services."

Table 3. The Sydney Observatory meteorological network, 1858-1862. (After Scott 1859d, 1861a, 1862a and 1865)

Station	1858	1860	1861	1862
Albury	x	x	x	x
Armidale	x	x	x	x
Bathurst	x	x	x	x
Brisbane	x	x	x	
Casino	(x)	x	x	x
Cooma	x	x	x	x
Deniliquin	x	x	x	x
Goulburn	x	x	x	x
Maitland	x	x	(x)	
Newcastle	(x)		(x)	x
Parramatta	x	x	(x)	
Rockhampton		x	(x)	
Sydney	x	x	x	x
Windsor			(x)	x

Key: (x) = part of year only

3.6 Tidal Studies

In 1860, Scott arranged with the Harbour Master for daily tidal readings and seawater temperature measurements to be taken at Woolloomooloo Bay in Sydney Harbour (Scott, 1861a; Wood, 1958).

3.7 Magnetic Studies

In addition to his administrative commitments and his astronomical, meteorological, and tidal studies, Scott somehow thought that he would find the time and energy to conduct a magnetic survey of the colony (Cable, 1976), and in 1860 the Government approved the purchase of an inclinometer and a unifilar magnetometer. In writing to Major-General Sabine about these acquisitions, Scott (1860k) pointed out that because a geomagnetic observatory had recently been set up by Neumayer in Melbourne (see Perdrix, 1990; Weiderkehr, 1988) a full magnetic facility would not be needed in Sydney.

4 SCOTT'S PREMATURE RESIGNATION

By accepting the Sydney appointment, Scott inherited a 'mission impossible'. The meridian and non-meridian astronomical programmes alone generated more work than a staff of just two could easily cope with (Scott, 1859c), but Scott also had to contend with an ambitious meteorological programme which demanded incessant correspondence and frequent travel. He was not alone in this regard, for Dewhirst (1985) has shown that chronic understaffing was also a common feature of British professional observatories at this time.

The inhuman workload eventually impacted on Scott's health. In 1860 April he was much bothered by colds "... brought on by observing at night in a draught which is sometimes in winter enough to cut one in two ..." (Scott, 1860g), and during the year his health continued to deteriorate. By 1861 he was totally disillusioned, as other matters continued to trouble him deeply.

For instance, he was only too willing to point out that he was by training a mathematician and not an astronomer, and was therefore "... a novice in practical astronomy ..." (Scott, 1861q). Indeed, as he indicated in a letter to Airy (Scott, 1861c), he had never even made a serious astronomical observation before coming to Sydney! Given this background, it is perhaps not surprising that he experienced considerable difficulty making the transition from academic to observer. He seemed ill at ease with the Observatory's instruments (Scott, 1861g), although the arrival of the Merz refractor did, for a short while, at least inspire him "... with new spirit." (Scott, 1861d).

Appropriate staffing of the Observatory would have rectified this situation to some degree, but Russell did not offer this prospect. Although Scott found him an adequate computer, he would have preferred someone who was also an experienced observer (Scott, 1862c). Russell was, after all, in his own mould, an academic who had come to the Observatory straight out of university.

What was needed was a 'practical astronomer', with obvious mathematical skills, and Scott saw Tebbutt (Figure 6) as the ideal solution to his problems and as his ultimate successor. Soon after his arrival in Sydney, Scott had struck up a friendship with the amateur astronomer from Windsor (Tebbutt, 1875), and with the passage of time this proved to be mutually beneficial. While Scott (1860h) was happy to provide Tebbutt with advice on possible observational programmes and made him welcome at the Observatory (Tebbutt, 1859-63), Tebbutt for his part furnished Scott with eclipse and occultation predictions (see Scott, 1861e) and with other astronomical information (particularly about comets). Scott (1860d) also welcomed "... at any time suggestions or information that you may be inclined to send; as my time is so much occupied that I find little time for reading, and many important novelties may escape my notice."

As early as 1860 April, Scott was thinking of premature retirement, and he saw Tebbutt as part of his plans. He was impressed with Tebbutt's knowledge, enthusiasm, and mathematical skills (Scott, 1860i, 1861e), and prophesied a brilliant future for the young amateur astronomer from Windsor:

> With your enthusiastic love of Astronomy mathematical ability and industry you might become one of the distinguished Astronomers of the age in fact Australia's first Astronomer ... Why not come to Sydney give some proof of your powers at the University; work as an amateur at the Observatory (The Equatorial would be at your disposal) and take possession of my place when I give it up, which I hope to do in a few years? (Scott, 1860h).

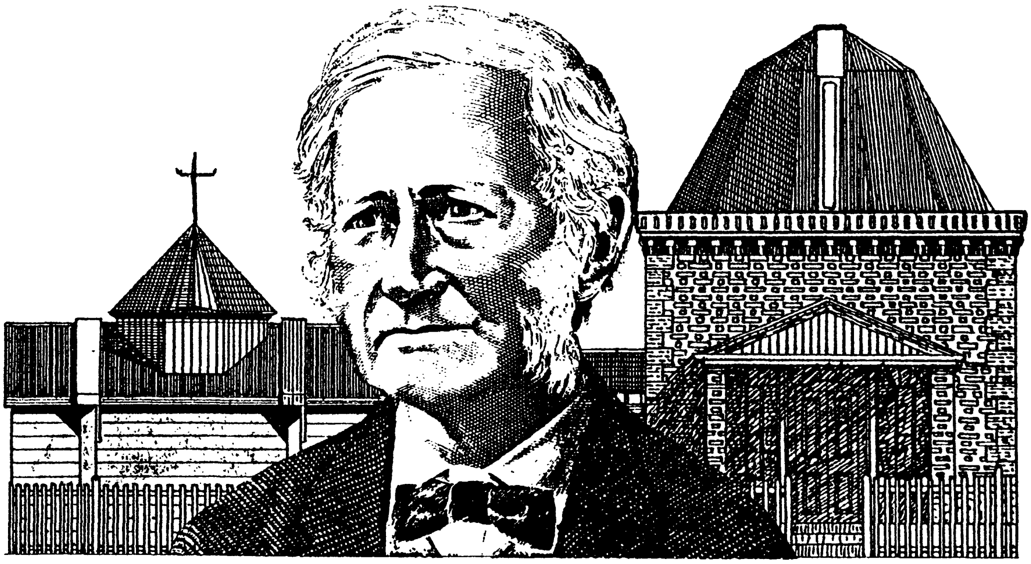

Figure 6. John Tebbutt, 1834-1916.

Circumstances prompted him to take this scenario a step further at the end of 1861:

> Will you now allow me to ask you in confidence these two questions which you may be assured I would not ask without reason.
>
> 1. Would you be prepared, four or five years hence, to accept, if offered, the appointment which I now hold.
> 2. Would you object to take the office and Salary (£300) of Computer, on a more independent footing than that which the present computer occupies, with the understanding that you should succeed to my post when vacant.
>
> I should be greatly obliged if you will explain to me as candidly as you think proper what are your feelings with regard to these two questions. (Scott, 1861h).

In order to accomplish the latter staffing change, Russell would be offered employment elsewhere in the Public Service, in a post "... equivalent to that which he now holds." (Scott, 1862c). Much to Scott's frustration, Tebbutt turned down the offers, preferring instead "... an unofficial life ..." when it came to astronomy (N.S.W., 1893).

In addition, Scott was very disappointed with the lack of serious interest shown in his astronomy classes (Scott, 1860a, 1861j), and he also resented the mounting public criticism that was directed towards his person and the Observatory. Following the discovery of Comet C/1861 J1 by Tebbutt, he wrote to McClear at the Royal Observatory, Cape of Good Hope: "[I] ... am continually attacked in the public papers for not making more a plaything of the Observatory. The late Comet's appearance called forth attack innumerable especially for not being the first to observe it." (Scott, 1861d). But public concerns went far beyond the comet, judging from the following letter written by the influential J. Dunmore Lang in 1860:

> Our Astronomer ... is certainly not a very Scientific character for when he was found fault with through the press of the day for not giving notice of an Eclipse or not having seen it himself, made some lame apology that he did not understand well astronomy. When he ... got the appointment in London as

> astronomer to go out here, he told the one high in office that he did not understand all the points and difficulties of the office He was comforted by the same official, replying that all he would require to do to be master of all that was necessary for the appointment could be gathered from books which he could very easily procure and consult. What ignorance this displayed to give such an important & highly interesting a post to one entirely ignorant of the Duties of Astronomers .... (Lang, 1860).

While this is a private letter and questions Airy's competence, the views presented were hardly flattering to Scott and he expressed some of his frustration in the following letter to a non-astronomical colleague in England: "... people are always expecting me to write to the papers announcing some grand discoveries, but I have not made any just yet and don't much like manufacturing them to the public taste." (Scott, 1860g).

As we have already seen, Scott also encountered on-going problems with both equipment and personnel associated with the country meteorological network, and it was only after the system was rationalised in 1861 that some of these were eliminated.

Cable (1976) has suggested that Scott may also have become discouraged following the departure of Denison as Governor-General in 1860 (Currey, 1972). Denison certainly had a special interest in astronomy (e.g. see Denison, 1858; Obituary, 1872; Scott, 1857b), and was a very public champion of the Observatory. While that situation prevailed Scott was able to make good progress, despite his own troubles and the underlying concerns that some citizens had regarding his competence and the cost-effectiveness of a colonial observatory. That the Government was prepared to outlay considerable funds for the new Merz refractor, the Frodsham clock, repair of the old transit circle, and purchase of numerous sets of meteorological instruments, reflects Denison's support and runs counter to Tebbutt's (1904) much later claim that "Mr. Scott encountered great difficulty in securing proper instruments for the new establishment under his direction." However, Russell also had concerns about the Observatory's initial instrumentation:

> Sir William Denison made a serious mistake when he spent £7000 on the Building and handed a number of almost useless instruments to Mr Scott expecting him to work with them. Long before this with a good transit circle we should have had a long catalogue of star positions of real value. (Russell, 1876).

After Denison's departure, Scott did indeed become immersed in the petty bureaucracy which can become so much a part of Government, and eventually reminded the Colonial Secretary that he was appointed by the Home Government (in England) "... without any intimation that I should at any time be dependent on the legislation of the Colony." (Scott, 1861j). In early 1862 he discovered that payment for the new Merz telescope had been disallowed because the invoice was presented in the year after the vote was allocated (Scott, 1862b). This led him to worry about other financial allocations to the Observatory, and over the next three months several letters were dispatched to the Colonial Secretary and the Auditor General, some of them marked 'Great Urgency'. These must have been trying times for Scott as he contemplated his resignation.

Finally, Scott (1861o, 1861q) sorely felt his geographical isolation from the main centres of astronomical activity, in Europe, Britain, and the United States. It would seem that the only compensation he found was the close friendship that he struck up with Tebbutt.

Despite this, Scott eventually found the overall situation intolerable, and on 1862 May 9 penned his letter of resignation:

> I have the honour to inform you that four years of close application to my duties have so affected my sight, as to convince me that I could not much longer continue to perform those duties in a manner satisfactory to myself. I have therefore thought it my duty to resign my appointment as soon as I should be able to do so without altogether ruining myself by so doing. Such an opportunity has just now occurred and ... I shall be unable to attend fully to my official duties later than the end of July next. (Scott, 1862d).

When he turned down the offer of employment in 1861 December, Tebbutt could hardly have imagined that the office of Government Astronomer of New South Wales would be vacant a mere five months later, rather than in five years as Scott had anticipated!

The search was now on for a new Government Astronomer, and although Scott had accepted a teaching post at the Cook's River Collegiate school owned by the Reverend W H Savigny (Cable, 1976), he agreed to maintain an on-going supervisory brief over the Observatory while Russell attended to the day-to-day running of the institution (Parliament of New South Wales, 1862).

5 THE QUEST FOR A NEW GOVERNMENT ASTRONOMER

In a letter to the Colonial Secretary dated 1862 June 5, Scott (1862e) stressed that applicants must be competent mathematicians; have extensive observational experience, particularly with a large equatorial telescope; and be prepared to do most, or even all, of the observing.

Scott was impressed with Tebbutt's high public profile (mainly through his discovery of the Great Comet of 1861) and with his business acumen, mathematical skills, observational experience, commitment to astronomical research and education, and sympathy for meteorology (see Orchiston, 1988c). Accordingly, he once again recommended Tebbutt for the post (Tebbutt, 1875).

In an account of the proceedings of the New South Wales Legislative Council for 1862 October 29 published in *The Empire*, the Colonial Secretary, Mr Cowper, was quizzed about Scott's resignation and the search for a new Government Astronomer. After comments by a Mr Dalgleish about John Tebbutt's observations and discoveries, Cowper responded:

> As to Mr Tebbutt, he had only to say the Government would be happy to give that gentleman the position; but he had refused it over and over again. (Parliament of New South Wales, 1862).

When pressed further by Dalgleish on whether it was the office of Astronomer or Assistant Astronomer (i.e. Russell's post) that Tebbutt had been offered, Cowper elaborated: "... he had repeatedly refused the offer of assistant, and had as much as said that he would not accept the office of astronomer." (ibid.).

Others besides Scott (1862f) then tried to talk Tebbutt into changing his mind. One of these was the Sydney optical instrument-maker, Angelo Tornaghi (see Maguire, 1985), who was later to provide the Windsor Observatory with a transit telescope and other equipment:

> I wish you would accept the place of Colonial Astronomer, as you are the only only [*sic*] compitent for it is well known. trusting you will axept the ofar. I know the Revd Scott is very anseous you should and so am I many others besides. (Tornaghi, 1862).

While Tornaghi may win no prizes for spelling and punctuation, his sentiments are clear. They did not, however, bring about the desired result. At a later date doubt was cast as to whether Tebbutt really was offered the vacant directorship (Tebbutt, 1908), but Scott's own public testimony put the matter beyond dispute:

> Mr. Tebbutt always had my friendly sympathy in his work, but the only occasion on which I had an opportunity of encouraging him was when I resigned my office of Astronomer in 1862, and recommended the Colonial Secretary to appoint him in my place. This recommendation, no doubt, would have been acted on had not Mr. Tebbutt communicated to Mr. Cowper, through me, his unwillingness to accept the appointment. (Scott, 1875).

With Tebbutt's continued refusal, the New South Wales Government turned once more to England for assistance, and in due course Airy and Sir John Herschel arranged for a mathematician and astronomer named George Robarts Smalley to replace Scott. Yet another Cambridge graduate (see Wood, 1976), Smalley arrived at the Sydney Observatory on 1864 January 7.

6 CONCLUSION

This study illustrates the colonial domination that England maintained in New South Wales astronomy during the middle of last century, and the trials and tribulations to be faced by appointing an inappropriate Englishman to establish a professional astronomical observatory in Australia.

Under the circumstances, we can only be impressed by Scott's remarkable record of achievement in his six short years as Government Astronomer of New South Wales. He spent just five-and-a-half of these in Australia, and during that time obtained a state-of-the-art equatorial telescope and astronomical clock, determined the latitude and longitude of the Sydney Observatory, prepared a catalogue of zenith stars as seen from Sydney, published important observations of Comet C/1861 J1 (Tebbutt), carried out a range of other useful positional observations, established a network of meteorological stations throughout New South Wales, published four volumes totalling 854 pages reporting the astronomical and meteorological observations made at the Observatory, and brought information on these two disciplines to the people of Sydney by way of local newspapers. Through dedication, hard work, and political acumen, Scott was able to establish a firm foundation for Sydney Observatory, one which Russell was able to build on later in the century.

What is even more remarkable, Scott was able to achieve all this despite on-going problems. He endured an intolerable work load, found the public service difficult to deal with at times, and was ill equipped to accommodate or counter public criticism (much of it unwarranted) directed at both his person and the Observatory. Nor was he happy with Russell's background or his performance as 'Computer', and he was frustrated when Tebbutt refused to accept a position at the Observatory or to succeed him as Director and Government Astronomer of New South Wales.

While Henry Russell and Dr Harley Wood are traditionally held up as the two outstanding Government Astronomers of New South Wales (e.g. see Bhathal and White, 1991; Haynes *et al.*, 1996; Nightingale, 1958; Orchiston, 1988b; Robertson, 1985), Scott's contribution has not hitherto been fully documented. His achievements during the critical formative years of the Sydney Observatory were remarkable and deserve to be more widely recognized.

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TL = *Letters to J. Tebbutt*. Bound manuscript letters in the Mitchell Library, Sydney.

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Mary Ackworth Evershed née Orr (1867-1949), solar physicist and Dante scholar

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Abstract
Mrs Mary Evershed is principally remembered in astronomical circles as the wife and collaborator of John Evershed, Director of the Kodaikanal Observatory in India in the early part of the twentieth century. Her own independent work on the astronomy of the poet Dante, written under her maiden name M A Orr, remains better known today among Dante scholars than among astronomers. This paper outlines her life and records her contributions to solar observations, to the history of astronomy, and to Dante studies.

Key Words: *solar physics, Moon, Dante, India, Australia*

1 EARLY LIFE

Mary Ackworth Orr was born at Plymouth Hoe, England, on 1867 January 1, the fifth child and third daughter of Andrew Orr, an officer in the Royal Artillery, and his wife Lucy née Ackworth (Thackeray, 1950; Ellison, 1950). The father died when Mary was only three years old and the family went to live with the maternal grandfather, a clergyman, first at Wimbourne and then at a large country vicarage at South Stoke near Bath. Mary and her youngest sister Lucy, the close companion of her childhood, were educated entirely at home by governesses, the last of whom was an exceptional woman who was in charge of them for ten years. When Mary was 20 the sisters travelled abroad to study languages and the arts in Germany and Italy. They spent the years 1888-1890 in Florence where they studied the writings of Dante and where Mary, who from an early age had an interest in astronomy, became fascinated by the astronomical references in Dante's poetry.

2 AUSTRALIA 1890-1895

Following those years of education in Europe the Orr family – mother and daughters – lived from 1890 to 1895 in Australia, with addresses in the vicinity of Sydney in New South Wales, where the eldest daughter appears to have already been living. There the two youngest sisters continued their studies of Dante, and Mary resumed her active interest in astronomy. She was encouraged by the astronomer John Tebbutt (1834-1916), discoverer of the Great Comets of 1861 and 1881 (see Orchiston, 1998 and 1981, respectively), who had a well-equipped private observatory at Windsor, New South Wales, and at the time was Australia's leading astronomer (Haynes *et al.*, 1996). His observatory is now a museum.

Endeavouring to familiarize herself with the southern constellations, Mary Orr found that there existed no simple maps of the southern sky such, as those of James Gall (1866) from which she had learned her way around the northern constellations. She therefore prepared *An Easy Guide to the Southern Stars*, a pocket-sized booklet similar in format to Gall's guide, containing maps of recognizable naked-eye star groups observable from latitude 34° S. Her motive, she wrote to Tebbutt, was

> ... to get people (children and adults) on the track of observing for themselves the movements of the heavenly bodies, to help them recognize and admire the stars and constellations on the Australian skies, and then to interest them generally in astronomy. (Orr, 1895).

The book (Orr, 1897) with a Foreword by John Tebbutt recommending the work of "the enterprising authoress", was published by Gall and Inglis (publishers of Gall's book) after its author's return to England. A second edition was printed in 1911.

In 1891, Mary Orr became a member of the California-based Astronomical Society of the Pacific of which Tebbutt was also a member. The publications of this fast-growing society kept its members – who included women – informed of progress in astronomy worldwide, but especially in the United States. The British Astronomical Association, set up in London in 1890 and also open to women, extended its activities overseas in 1895 with the founding of the New South Wales branch with Tebbutt as President (see Orchiston, 1988). In that same year the Orr family returned to Britain, to a home in Kent, when Mary was able to join the parent Association in London. She also took up the study of mathematics, and decided to acquire a telescope (Orr, 1896).

3 LIFE IN ENGLAND

3.1 The British Astronomical Association

The British Astronomical Association (BAA) offered Mary Orr a very congenial milieu. Its membership included women who were debarred from the all-male Royal Astronomical Society, among them Agnes Clerke, Annie Maunder, and Mary Proctor. These women were well versed in astronomy and interested in its historical as well as in its scientific aspects. Agnes Clerke, 25 years older than Mary Orr, was a recognized authority on the history of astronomy and the foremost commentator on astronomy in the English-speaking world (Brück, 1994). She was also an admirer of the poetry of Dante. Agnes Clerke welcomed and encouraged the newcomer. Many years later, on the centenary of Clerke's birth in 1942, Mary, by then Mrs Evershed, paid tribute to their twenty years' friendship: "As one who had the privilege of knowing her personally since 1895 I can testify that her influence was inspiring to beginners of the science she so much loved." (Evershed, 1943)

Annie Maunder, at 28 the same age as Mary Orr, was the newly-married wife of the astronomer Edward Walter Maunder. Formerly Annie Russell, she had spent 3 years prior to her marriage on the staff of the Royal Observatory at Greenwich and continued to help her husband in his researches in solar physics throughout his lifetime (Brück, 1995). E W Maunder was one of the founders of the British Astronomical Association, and both he and his wife were active in its running: Annie was editor of the Association's *Journal* for thirty years. Mary Proctor, the daughter of R A Proctor, the noted popularizer of astronomy, then in her early thirties, followed her father's footsteps as an amateur astronomer and writer (Chapman, 1998).

3.2 Eclipse Expeditions

The British Astronomical Association became a centre of Mary Orr's life and activity. An early exciting event was the Association's expedition to observe the total solar eclipse in Norway of 1896 August (Marriott, 1991). The central line ran through Vadsö, at latitude 70° on the east coast of Finnmark, chosen as the site of the BAA expedition and of many other groups. The BAA party of 58 amateur astronomers and their friends was led by Maunder. Many of the participants had brought their own instruments; others (like Mary Orr) acted as their assistants. Unfortunately, the crucial morning of August 9 was cloudy. It was, however, a memorable social event for Mary Orr, as it was on this expedition that she first met her future husband John Evershed whom she was to marry ten years later.

The next expedition organized by the BAA was to Algiers, to observe the total eclipse of 1900 May 28 (Maunder, 1900). On this occasion Mary had her own instrument, a 7.6-cm (3-inch) refractor, and was in a contingent of four women who had their observation post on the roof of the British Consul's villa. "Miss Orr [Mary's sister], high up among the chimneys, watch in hand, gave the time."; Mary reported on the appearance of the landscape during totality, and observed Baily's Beads with her telescope.

3.3 Variable Star Observer

In this same year, 1900, Mary Orr, having lived at various addresses in the Home Counties, settled in Frimley, Surrey, where she set up a little observatory equipped with her 7.6-cm refractor with which to observe variable stars and the Moon. Her instrument and her fields of work are recorded in Stroobant's first list of the world's observatories and astronomers compiled in 1902 (Stroobant *et al.*, 1907). She also, as she wrote to Tebbutt, had begun to study the history of astronomy (Orr, 1898).

Variable stars were the subject of Miss Orr's first scientific paper which shows her as already a competent observer (Orr, 1904). She clearly had an ambition to make a career in this field. In early 1906, Edmund T Whittaker FRS, mathematician at Cambridge and Secretary of the Royal Astronomical Society, who was married to a cousin of hers, was appointed Professor of Astronomy at Trinity College Dublin and Director of Dunsink Observatory outside Dublin. Arrangements were in hand for Miss Orr to go to work with Whittaker in Ireland (Thackeray, 1950) where she would presumably have lived with the family in their observatory residence and worked as a volunteer. Whittaker planned a programme of observation of red stars, many of which were variable, and began a systematic search for variable stars using photographs taken with the 15-inch Roberts reflector at Dunsink (Wayman, 1987), a project which would have well suited Miss Orr's taste[1]. However, by the time Whittaker took up his appointment in 1906 June, Mary Orr was engaged to be married (Evershed, 1906a).

Mary Orr and John Evershed were married on 1906 September 4 at St. Mary's Parish Church, Cloughton near Scarborough in Yorkshire. She was 39; her husband was 42 (Figure 1). They had no children, but their nephew, Andrew David Thackeray (1910-1978), son of Mary's sister Lucy, stimulated by their example, became an astronomer and Director of the Radcliffe Observatory, Pretoria, South Africa (Feast, 1979).

4 THE EVERSHEDS

4.1 John Evershed

John Evershed, who until then had been employed as an industrial chemist, had been interested in astronomy from childhood. In his recollections (Evershed, 1955), written when he was ninety years old, he described his excitement as a small boy at being shown a projection of a partial eclipse of the spotted Sun and how, later, he constructed a spectroscope attached to a small telescope to view prominences at the Sun's limb. In 1891 he read about George Ellery Hale's invention of the spectroheliosope and set about constructing one for himself. Hale, then only 22 years of age, paid his first visit to Britain that year when he addressed the British Association for the Advancement of Science. On his next visit to London two years later, Cowper Ranyard, a well-known amateur astronomer, introduced Evershed to him. It was the beginning of a lasting and fruitful friendship. Hale declared that Evershed was the only person besides himself to have built a true spectroheliosope by 1893 (Wright, 1966).

Evershed took part in the British Astronomical Association's eclipse expeditions to India in 1898 and to Algeria in 1900. In both instances, using his own improved solar spectrograph, he obtained ultra-violet spectra of prominences showing the continuum beyond the Balmer limit, the first person to make this observation. The results aroused the interest of Sir William Huggins through whose influence Evershed was offered the post of assistant astronomer at the Kodaikanal Observatory in 1906. He took up duties there in 1907.

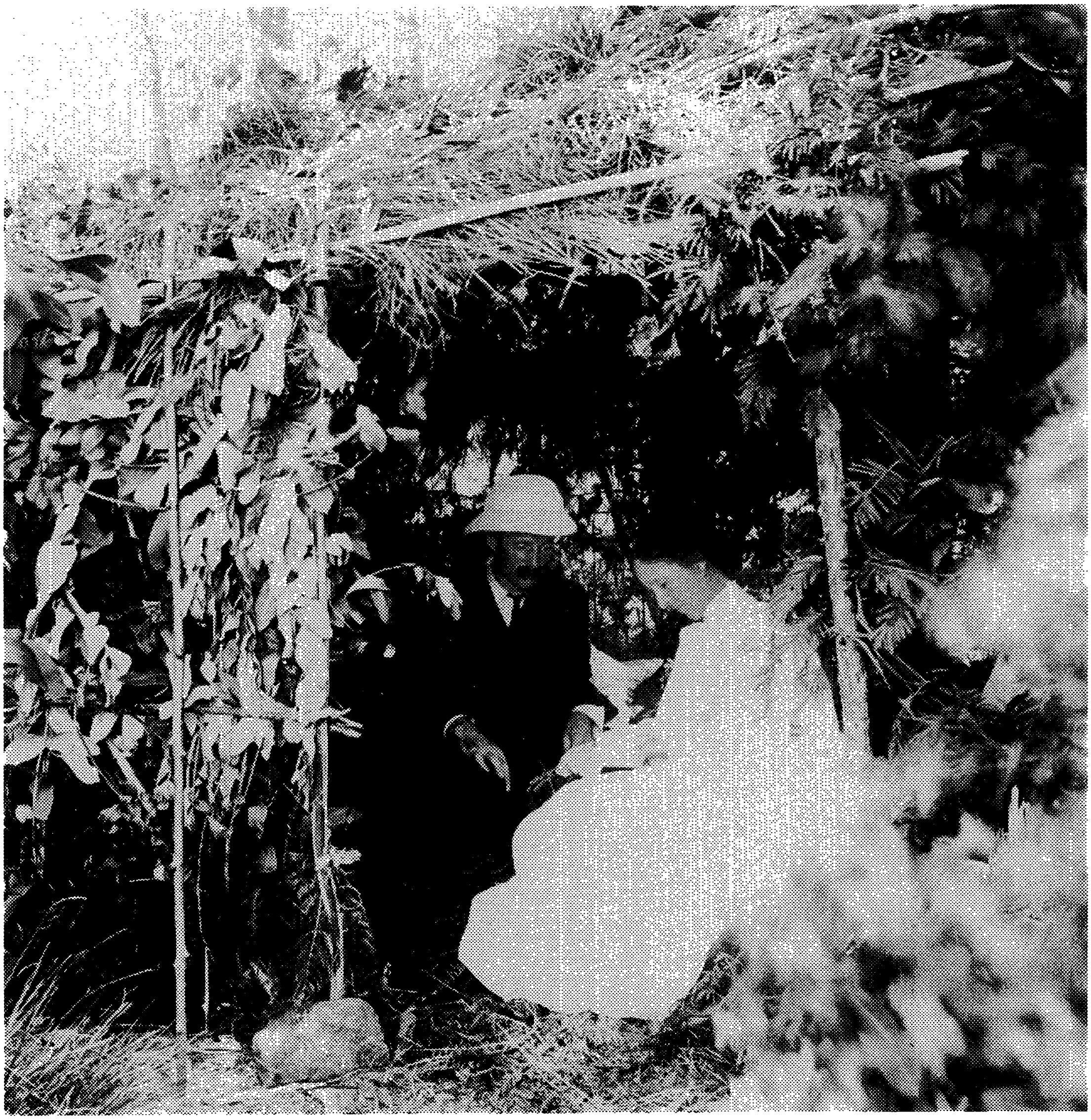

Figure 1. John and Mary Evershed photographed in Kashmir in 1913 (Royal Astronomical Society).

4.2 Visit to Mount Wilson

The Eversheds travelled to India via the United States and Japan, visiting several observatories on the way. Their most important call was at Mount Wilson where Hale had for two years been busy erecting the famous observatory, and where the solar installation with his new spectroheliograph had not long been in operation. The Eversheds spent some weeks at Mount Wilson, "... studying the instruments and methods and the work being carried out under the inspiring direction of Professor Hale." (Evershed, 1955). There was some confusion in the timetable, Hale having planned an extended trip east at about the same time (Brashear, private information, 1997). However, the visitors were well looked after in his absence. "We are both quite well and much enjoy life here. Mr Ellerman and the others do everything possible to make our visit a pleasant and profitable one.", wrote Evershed to Hale (Evershed, 1906b). Ellerman was Hale's major collaborator. Their work, especially the extension of the use of the spectrohelioscope to the red H-alpha line of hydrogen in 1904, was imitated successfully by the Eversheds in Kodaikanal.

5 INDIA 1907-1923

5.1 Astronomy in India

Astronomy in India had a long history. During the early 19th century the principal activities there were classical meridian astronomy. The solar physics observatory in Kodaikanal in the Palani Hills of South India, to which astronomical activity at the existing Madras Observatory was transferred, was opened in 1899 with Charles Michie Smith (1854-1922), a former Director of Madras, in charge (Kochhar, 1991; Kochhar and Narlikar, 1994). The new institution had a variety of instruments including a photoheliograph for daily photography of the Sun and a grating spectroscope, to which were added in 1903 a spectroheliograph, a solar telescope, and a siderostat (Figure 2).

Figure 2. Kodaikanal Observatory today. The building in the foreground was Evershed's laboratory (Courtesy R H Kochhar).

5.2 Evershed's Era

Evershed's arrival at Kodaikanal heralded the observatory's 'golden age' (Kochhar, 1991). He brought the existing spectroheliograph into working order and added his own spectroscopic equipment. He built a number of spectroscopes, and continued his work, begun in England, of sunspot spectroscopy (Stratton, 1957). It was in this latter field that he discovered the radial motions of material in the spots known as the 'Evershed Effect', published in 1910. In 1911 he succeeded Michie Smith as director of the Madras and Kodaikanal Observatories. His staff consisted of his replacement as Chief Assistant, T Royds, and four Indian astronomers. His wife assisted in an unofficial capacity, such as in observing and photographing Halley's Comet "... in the beautiful early dawns..." of 1910 May (Orr, 1914:423), though her name rarely appears in the formal observatory Reports.

In 1915 Evershed was elected a Fellow of the Royal Society. Later, he set up a second spectroheliograph for recording the Sun in the light of the red hydrogen line H-alpha, thereafter taking daily spectroheliograms in both calcium and hydrogen light. He was awarded the Gold Medal of the Royal Astronomical Society in 1918.

5.3 Solar Prominences

For Mrs Evershed, the sixteen years spent in the beautiful surroundings of the mountain-top observatory were the happiest of her life (Figure 3). During the first few years she was able to complete her study of Dante's astronomy (Section 6). At the same time she had the opportunity of learning and practising a new branch of astronomy – solar physics.

Figure 3. The Eversheds' home at Kodaikanal Observatory, now Evershed House, a guest house for visiting scientists. (Courtesy R H Kochhar)

Her special interest was in solar prominences; Evershed refers in his recollections to their studying them together with the fine Kodaikanal equipment. Mary also did her own independent research using the Kodaikanal spectroheliograms, and in 1913 published a substantial paper in which she analysed observations of prominences associated with sunspots made between 1908-10 (Evershed, 1913). She was able to classify the prominences into various active and eruptive types, and to draw conclusions regarding their motions in the fields of sunspots (Figure 4). The work, as Thackeray (1950) has remarked, showing series of photographs of moving prominences was a precursor of prominence cine-photography with the coronograph, a technique then far in the future. The paper, illustrated by 40 slides of spectroheliograms, was read by Mary in person at the meeting of the Royal Astronomical Society on 1913 April 11 (Report in *Nature*, 1913) when the Eversheds were presumably in London on leave.

Mary pursued the same research topic in a joint paper with her husband (Evershed and Evershed, 1917). The actual analysis was principally hers; it was noted in the Introduction that "The Memoir was drawn up by Mrs Evershed under the supervision of the Director ..." with the help of two other members of staff. This substantial piece of work filling 126 pages involved almost 60,000 individual prominence observations over an entire 11 year sunspot cycle. This huge and important sample of data was analysed in great detail using statistics, diagrams, and photographs, clearly establishing a relation

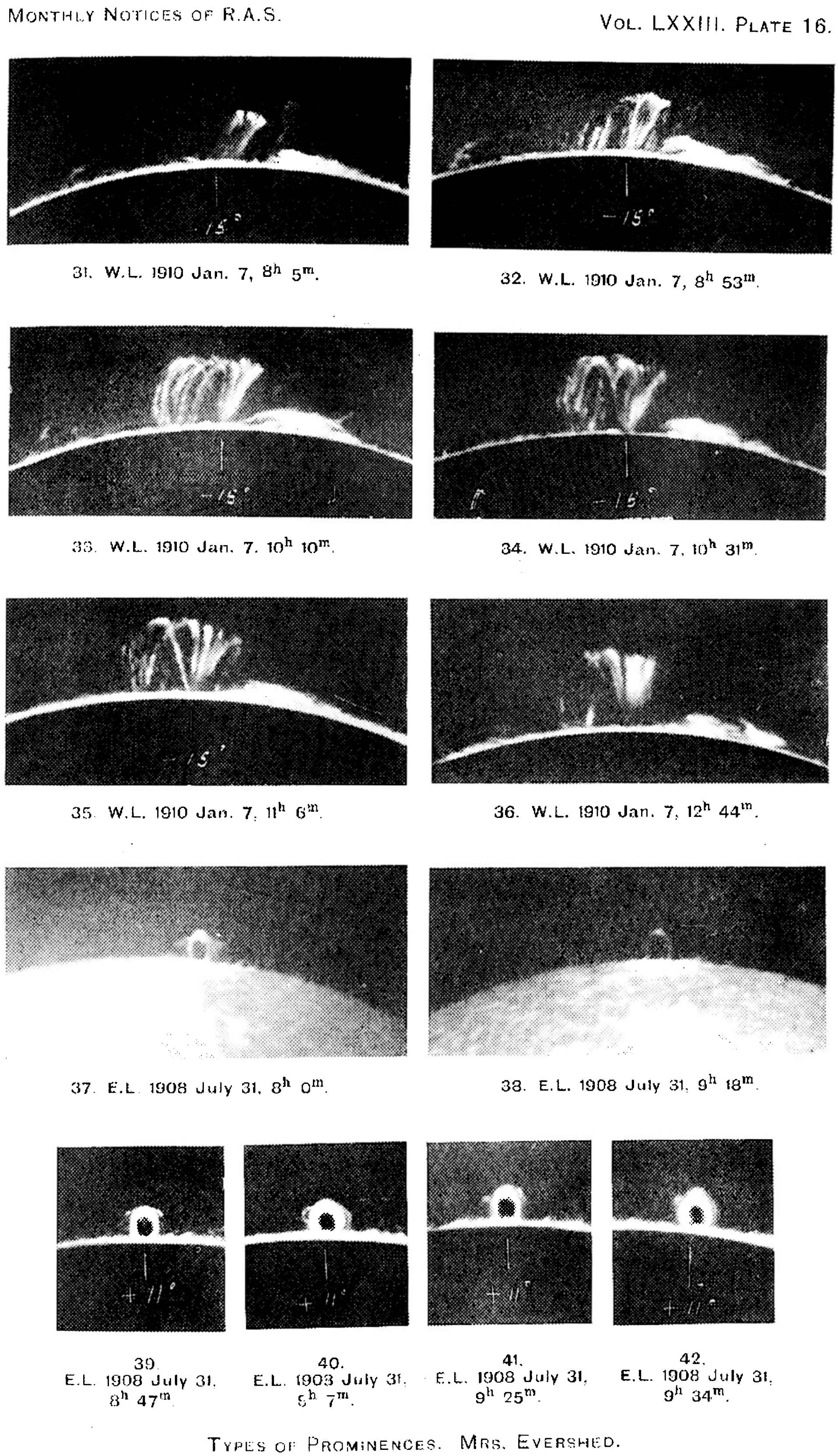

Figure 4. Example of prominence photographs from M A Evershed's paper of 1913. The series of photographs at intervals illustrates the motions of the prominence material.

between prominence types and sunspots (Ellison, 1944). With this, and her earlier paper, Mary Evershed was a pioneer of solar prominence research. She has not always been given due recognition for her contribution to this field.[2]

5.4 Expeditions

The years in India also brought opportunities for travel. These included two site-testing expeditions to Kashmir and one to the South Island of New Zealand, between 1913 and 1915. The total solar eclipse of 1922, their last year in the East, was the occasion of another absorbing journey for the Eversheds who travelled to Wallal, Western Australia, to observe it, but were unfortunately frustrated by the weather. "As the funds available would not admit of a large party to Australia, I was compelled to limit the personel to three only, including myself and Mrs Evershed.", wrote her husband in his official Report (Evershed, 1923). To the end of their Indian years, therefore, Mrs Evershed was her husband's constant companion and collaborator.

6 DANTE AND THE EARLY ASTRONOMERS

6.1 Dante

Mary Evershed's enthusiasm for Dante began, as already mentioned, in her days as a student in Italy (Figure 5). Surviving notebooks indicate that she started to outline her book as early as 1896 (Reynolds, 1956). The labour came to fruition in the tranquillity of Kodaikanal, "... an ideal place in which to write on astronomy and poetry ..." (Orr, 1914, Preface). The book, *Dante and the Early Astronomers* (Orr, 1914), was a study of astronomy as found in Dante's writings, both prose and poetry, but quite particularily in the Divine Comedy. That unique work of poetic imagination narrates the poet's fictitious journey through Hell, Purgatory, and Paradise, finally reaching the abode of God in the Empyrean beyond space and time. The poem incorporates Dante's vision of the physical universe, derived from the cosmology of his day. It also includes numerous references to the positions and movements of the heavenly bodies on the celestial sphere, and the use of astronomical descriptions to indicate date, hour, or passage of time. These references can be baffling to readers not conversant with the elements of spherical astronomy. Mrs Evershed's book was the first, at least in English, expressly written to help readers to understand these references and to appreciate the poetry and symbolism of Dante's allusions to the heavenly bodies.

In her book, Mrs Evershed revealed Dante's considerable knowledge of astronomy by surveying the textbooks which he is known to have used in his studies and which are quoted in his own various writings. Dante's favourite book on astronomy was the *Elements of Astronomy and Chronology* by the 9th century Arab scholar Alfraganus (the latinised name of Al-Farghani), available to him in a Latin translation. Dante's other authority was Aristotle with his doctrine of the four elements. Mrs Evershed could herself consult these works first-hand in Latin editions.

The cosmology of Dante's day was Ptolemy's Earth-centred model with the Sun, Moon and planets each occupying its own sphere and moving in epicycles. Two further spheres took account of the stars and finally, embracing them all, was the Empyrean of the 13th century Christian theologians. "Then arose one of the world's greatest poets and a thousand years after Ptolemy's death, immortalized his work ...", wrote Mrs Evershed, who devoted the extensive first part of her book to the history and development of astronomy from its beginnings up to Dante's day.

6.2 Astronomical Allusions

The second part of the book examined and explained specific astronomical allusions in Dante's writings. In the famous verses in the first Canto of Purgatory, for instance, the poet emerging from the gloom of Hell sees the sky once again:

Figure 5. Dante Alighieri. From a fresco by Luca Signorelli in Orvieto Cathedral. The portrait was used as the frontispiece in M A Orr's book.

The fair planet which inspires love
Was making all the orient smile,
Veiling the Fishes which were in her train.

The planet is Venus; the time of year is Spring when the Sun is in Aries and when the Fishes, the next zodiacal sign, is in the dawn. It is a sight which many astronomers have experienced; Mrs Evershed recalled enjoying it while observing Halley's comet in 1910, an occasion that inspired a paper on Dante's references to comets (Evershed, 1914). The Divine Comedy abounds with such astronomical riddles.

The poet's eight day-long visionary journey takes him through the underground levels of Hell, out again to the island of Purgatory, and finally through the ever higher spheres of the planets to Paradise. Mrs Evershed reconstructed the itinerary step by step from the astronomical references. In Dante's imaginative scheme, Purgatory is an island in the middle of the ocean in the antipodes of Jerusalem, that is at latitude 32°S, not very different from that of New South Wales. The poet's path through Purgatory was, therefore, of particular interest to Mrs Evershed who produced a map of the heavens as seen from 'Purgatory' before dawn and discussed the question of how much of these skies might have been known in Dante's time.

6.3 The Date of Dante's Vision

The action of the Divine Comedy is set at Easter-time. The imaginary journey had always been supposed, from historical and other clues, to have taken place in the year 1300. The question of whether the astronomical particulars described in the course of that journey conformed to the actual situation in that year was much debated by certain nineteenth century Dante scholars. Technicalities about the calendar and astronomical tables were introduced, and much was made of the fact that Venus was not a morning star in 1300, as described by Dante in the passage already quoted. It was suggested that 1301 would better fit the astronomical data in the Comedy. The matter was fully discussed by the eminent scholar Edward Moore (Moore, 1887) who maintained that the date of Easter 1300 had been chosen by the poet to suit his artistic purpose. "Let us always remember that we are interpreting a poem, not examining a scientific treatise." The matter, however, did not rest there.

The Italian astronomer, Filippo Angelitti (1856-1931), director of the observatory of Palermo, now entered the fray. Struck with failing eyesight, Angelitti devoted much time and energy to astronomical-literary matters (Caldo, 1931). In a series of papers he argued for the date 1301 with an elaborate analysis of the astronomical references in the poem. Mrs Evershed examined the problem in her book, listing the astronomical pros and cons for each date and discussing how the Venus anomaly might have arisen. She was insistent, however, that the astronomy is there for the poetry, not the other way round. "No-one will dispute a poet's right to arrange the skies as he thinks fit.", she wrote. She rejected Angelitti's claim, attractive though it appeared at first sight. Angelitti later (in 1921) conceded that, notwithstanding his earlier arguments, the year 1300 was to be preferred on historical and aesthetic grounds (Gizzi, 1974). The debate has long lost its interest for scholars. Far from being mistaken in his astronomical arrangement, the distinguished Dante expert Professor Patrick Boyde tells us, Dante had deliberately chosen it to represent symbolically an ideal Easter week in an ideal universe (Boyde, 1981).

While the astronomical exposition in *Dante and the Early Astronomers* was its most special feature, Mrs Evershed consulted the works of leading contemporary Dante scholars in English, German and Italian. She is known to have corresponded with G V Schiaparelli (1835-1910) of Milan, an authority on medieval astronomy, though only one letter survives (Schiaparelli, 1909).[3] She does not appear to have communicated directly with Angelliti.[4]

The book was published by Gall and Inglis in 1914. That firm had produced a second edition of *Southern Constellations*, still under the author's maiden name. Mrs Evershed chose to retain the same name for her second book but added her married surname, styling herself "M A Orr (Mrs John Evershed)".

6.4 Expert Opinions

A full page review of *Dante and the Early Astronomers* by J L E Dreyer, the astronomer and historian of astronomy, appeared in *Nature* in 1914 December (Dreyer, 1914). Dreyer approached the book as a popular history of astronomy – which indeed in part it was (his *History of Astronomy from Thales to Kepler* was one of Mrs Evershed's authorities) – and gave it his somewhat qualified approval. He made some criticisms of her historical judgment, but had no fault to find with her assessment of

Dante's astronomical knowledge and considered that she had done good and valuable work. The magazine *The Observatory* in a short note called the book "charming" but did not enter deeply into the subject matter (Review, *The Observatory*, 1914). These seem to have been the book's only notices on its first appearance. The circumstances of its publication were perhaps unfavourable: the author was back in India, cut off by the First World War which broke out in 1914, and students of literature were not likely to come across the catalogue of a scientific publisher. It was to be over 30 years before the book came to the notice of Dante scholars (see Section 9, below).

In Italy, however, it was not so quickly forgotten. On the death of Angelitti in 1931 a tribute in an Italian newspaper to his work on Dante included a reference to M A Orr's "beautiful book" as the only one to treat Dante's astronomy in a complete and logical fashion (Emanuelli, 1931). The writer, Pio Emanuelli (1888-1946), was a respected scientific journalist and broadcaster who began his career at the Vatican Observatory and served as a lecturer at the Universities of Rome and Perugia (Fracastoro, 1948; Maffeo, 1991).

7 RETURN TO ENGLAND

The Eversheds returned to England in 1923 on the husband's official retirement. They settled in Ewhurst, Surrey, where John Evershed continued his researches with undiminished vigour for a further thirty years. He published several papers of which one only, a description of the new solar observatory at Arcetri, Florence, was in collaboration with his wife (Evershed and Evershed, 1932). Together they took part in two further solar eclipses, though unlucky with the weather, in England in 1927 and in Greece in 1936 and attended meetings of the International Astronomical Union from 1928 onwards, John being a member. Mary resumed her participation in the work of the British Astronomical Association and was elected a Fellow of the Royal Astronomical Society, serving for many years on the Society's library committee.

8 HISTORY OF ASTRONOMY

8.1 Historical Section of the British Astronomical Association

Mary Evershed's chief interest in this last phase of her life was in matters historical. Within months of her return to England she contributed a long essay on "The astronomy of Dante" in the Association's *Journal* (Evershed, 1924), which is still worth reading. She curiously made no mention of her book in that essay.

Her most far-reaching piece of work was the foundation of the British Astronomical Association's Historical Section in 1930. The BAA was traditionally organized in Sections, each with its own Director. The Historical Section was set up in the same manner, with Mrs Evershed as Director and with a membership of knowledgeable enthusiasts such as Mrs Maunder. She outlined its aims: "To study the history of astronomy and to co-operate in research, helping to bring new facts to light and unearthing facts now buried in old books and papers." (Evershed, 1930). This placing of research into the history of astronomy on an organized basis was a milestone in the annals of the Association and indeed of astronomy generally. It has to be recalled that 'history of science' was not a formal branch of knowledge in those days and that journals devoted to the history of science did not exist (*The Journal for the History of Astronomy* was founded only in 1970). The Historical Section, which she directed for 14 years, until her health began to fail, throve, and remains active today.

Over the years, Mrs Evershed made her own erudite and charmingly-written contributions to the Section's work and elsewhere with articles covering a range of periods of history: on Arab astronomy (1935), Dante's Virgil (1931a) (i.e. astronomy in the Roman Empire: Virgil was the poet's guide in Dante's Hell and Purgatory), and Flamsteed (1934a). She also reviewed a book about Kepler (1934b).

8.2 Who's Who in the Moon

As head of the Historical Section of the BAA, Mrs Evershed's most ambitious project was a directory aptly named *Who's Who in the Moon* (Evershed, 1938) which identified every person commemorated by name in lunar formations. The Introduction, written by her with her usual thoroughness, traced the history of lunar nomenclature from the map of Langrenus of Brussels published in 1645 to date. A number of catalogues and maps had been published in the 19th century, between which there had been a certain amount of confusion. A collated list drawn up in 1913 by Mary Blagg (1858-1944), a BAA member and Fellow of the Royal Astronomical Society, was followed by a catalogue and map by Mary Blagg and K Muller of Vienna, published by the International Astronomical Union in 1935. Using this catalogue as its basis, Mrs Evershed and her team undertook to identify all 672 names listed there of which 609 were personal names, and to write mini-biographies of these persons. Besides members of the BAA, the team of 30 had outside contributors, including Pio Emanuelli of Rome, already known to Mrs Evershed through studies of Dante. The dictionary was published as a Memoir of the BAA and distributed as a separate booklet. It was – and remains – extremely useful not only in satisfying the curiosity of lunar observers but as a biographical dictionary of astronomers, many of them obscure, who had been honoured in the distant past by places on the Moon. Where else could one hope to find out painlessly about astronomers such as Abraham Abenezra (*c.* 1092-1167) who tops the list, or Rudolf Goclenius (1572-1621)?

Among Mrs Evershed's lesser writings, it is worth recording a note written in 1931 on the subject of women astronomers. It began with the 17th century and ended with "... one young astronomer, of English birth and parentage, trained in Cambridge, [who] is now working at the other Cambridge across the seas.... Astronomers confidently await further important results from Cecilia Payne." (Evershed, 1931b).

9 "A DANTIST NO LESS THAN AN ASTRONOMER"

9.1 Dante Rediscovered

A happy occurrence in the last years of Mrs Evershed's life was the discovery of her *Dante and the Early Astronomers* by those for whom it had been principally intended – readers of Dante's poetry (Reynolds, 1956; see also Brück, 1997). It came about when the Italianist and Dante scholar Dr Barbara Reynolds, at Cambridge, came across the book by chance in the University library. "From then on," she wrote, "I was able to explain the astronomical references to my students, instead of saying, as T S Eliot did, that they don't matter and you can skip them." Soon afterwards she met A D Thackeray, the author's astronomer nephew, then at the Cambridge Observatory. In the summer of 1949 she visited the Eversheds, conversed with Mrs Evershed who was already seriously ill, and was shown round the observatory by her husband. Mrs Evershed died a few months later.

After Mrs Evershed's death, Dr Reynolds wrote an Obituary Notice together with a retrospective review of *Dante and the Early Astronomers* (Reynolds, 1950). She was warm in its praise. The author, she said, had come to the rescue of non-scientific readers while never losing sight of the fact that "... the Divina Commedia is a poem and not a scientific treatise." The admirable clarity of the author's style and her use of excellent diagrams and illustrations had made the history of astronomical ideas intelligible and attractive to the layman. The writer Dorothy L Sayers, who was engaged in translating the *Divine Comedy* and to whom Dr Reynolds introduced the book, described it as "...quite the best guide available to Ptolemaic Astronomy and to Dante's handling of celestial phenomena." (Sayers, 1955). Dorothy Sayers died in 1957. Her work was brought to conclusion by Barbara Reynolds who translated the last 13 cantos of the Paradise and wrote all the commentaries on that volume (Sayers and Reynolds, 1962). The translators recommend M A Orr's book to their readers in their bibliography.

9.2 Second Edition of Dante and the Early Astronomers

A new edition of *Dante and the Early Astronomers* – the first being long out of print – was prepared by Dr Reynolds and published in 1956 (Orr, 1956). The fate of this edition was the reverse of that of the first: it was welcomed by students of Dante but went largely unnoticed by astronomers, even in the book pages of *The Observatory*. A review by A C Crombie, the philosopher and historian of science, predicted that on the main theme of Dante's astronomy "Mrs Evershed's book has been and is likely to remain a standby for a considerable time." (Crombie, 1956). In this he has proved right. His own monumental study of medieval science (Crombie, 1994) lists M A Orr's book among references to Dante's astronomy. So does Boyde's comprehensive examination of Dante's philosophy and science (Boyde, 1981). In a recent study of astrological references in the Paradise (Kay, 1994), the author points out that M A Orr's book is still the only one in English devoted specifically to Dante's astronomy. Dr Reynolds' description of Mrs Evershed in her Introduction to the second edition as "a Dantist no less than an astronomer" is indeed justified.

10 CONCLUDING REMARKS

Mary Evershed died at her home in her 83rd year, on 1949 October 25. Fifty years after her death one may look back at her not inconsiderable legacy to astronomy: her collaboration with John Evershed in the establishment of Kodaikanal Observatory as a major scientific institution; her contributions to solar physics; her work on Dante that has helped readers enjoy that great poet's view of the universe; and her enthusiasm for history of astronomy which still bears fruit. She did not work for money or prestige, but out of pure interest, and was remembered by those who knew her for her willingness to enlighten and her unfailing courtesy (Obituary in *Nature*, 1950).

11 ACKNOWLEDGEMENTS

I should like to acknowledge very specially the kindness of Dr Barbara Reynolds, the custodian of Mrs Evershed's notes on Dante, who has shared her memories of her with me and helped me with references. I am also most grateful to Professor Patrick Boyde whose *Dante Philomythes and Philosopher: Man in the Cosmos* I have found a marvellous source of illumination on medieval science. For practical help I should like to thank Professor R K Kochhar and Dr W Orchiston for material about India and Australia, respectively; and also those who searched archives on my behalf: Drs R Brashear of the Huntington Library, San Marino, California, I Elliott of Dunsink Observatory, L Pastori of the Observatory of Brera-Merate, and Donata Randazzo of Palermo. Finally, as always, my thanks go to my friends Mr A MacDonald and Ms S MacEachern at the library of the Royal Observatory Edinburgh.

12 NOTES

1. There is no reference to the plan in the Dunsink archives. A student, perhaps a substitute for Mary Orr, helped for some time as a volunteer.
2. Sir H Spencer Jones (1951) for example, in his popular textbook *General Astronomy* attributes the original classification of prominences into quiescent and active to John Evershed alone.
3. Schiaparelli was by this time retired and some of his correspondence may have been kept in his home. This may explain why no correspondence with Mrs Evershed has been found in the archives of the Observatory of Brera-Merate. I thank Dr Livio Pastori for this comment.
4. Dr Donata Randazzo, librarian, Historical Collections at the Observatory of Palermo, has failed to find any trace of letters to or from Mrs Evershed among Angelitti's correspondence.

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Mary Brück, now retired from her post as Senior Lecturer in Astronomy at the University of Edinburgh, takes a particular interest in women astronomers of the 19th century. She is joint author with her husband, H A Brück, of *The Peripatetic Astronomer*, a biography of Charles Piazzi Smyth (1988).

In addition to their fine telescopes, Cookes also became known for their domes, including the famous Onion Dome at Greenwich. But their focus extended far beyond astronomy, and they too were particularly well-known for their surveying instruments. Towards the end of the nineteenth century 'optical munitions' became important.

Early in the 1880s, the firm acquired "A brilliant and inventive young man ... " named Dennis Taylor (1861-1943), who was to assemble some 50 patents for a variety of optical instruments. One of these was the photovisual objective, and the Carter Observatory telescope was furnished with an early example of this. In 1891, Taylor's book, *The Adjusting and Testing of Telescope Objectives*, was published, and this quickly became the standard work in this field. For many years, Taylor was a Cooke stalwart, and he made an important contribution to astronomical optics. McConnell tells us that he counted "... gardening, astronomy, photography and natural history among his hobbies ..." (page 71).

From these dizzy heights, it is remarkable to reflect on how quickly the fortunes of the company changed. In 1922 it was reconstituted as Cooke, Troughton & Simms, and despite their long and successful collective track records as manufacturers of astronomical equipment of all kinds, it took just two years before the new business was up for sale. They were bought out by Vickers, who after the depths of the Great Depression transferred the astronomical side of the business to Grubb, Parsons Ltd. in 1938. After precisely 100 years the Cooke telescope, a respected British institution, was no more.

For those of us with a love of old refractors, Cooke or otherwise, McConnell's book tells a tantalizing tale, and it will find a place in many a bookcase. I thoroughly recommend it.

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Vultus Uraniae, by Laura Peperoni and Marina Zuccoli (Biblioteca Universitaria di Bologna, 1996), 32 pp. paperback, A4.
Ex libris stellarum, edited by Remo Palmirani and Marina Zuccoli (Editrice Lo Scarabeo, Bologna, 1998), 38 pp., paperback, B5.

It is not very often that there is the offer of two charming little books just for the price of a letter requesting same from the University. *The Countenance of Urania* is written in both Italian and English in adjoining columns and was made available originally at the time of an exhibition of volumes from the library of the Department of Astronomy of the University of Bologna and the University Center for Museums and Archives.

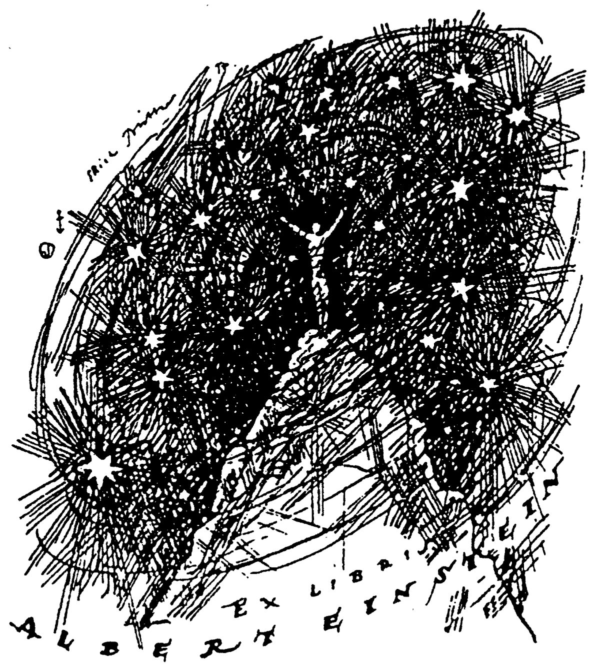
The reader is given a brief introduction to the mythology of the Muse Urania and her sisters. This is followed by a description of some literary and astronomical works which mention Urania in their titles. The first illustration is not of the 'vultus Uraniae', but of Sextans Uraniae in Hevelius' *Star Atlas* of 1690; however, the frontispiece his earlier work Selenographia shows Urania between the Moon and the Sun seated upon an eagle. For this and most of the other engravings depicting Urania there are notes on the artists who did the engravings.

For those interested in books and particularly astronomical books, there is a wealth of information to be culled from this delightful little book. To whet your appetite, the frontispiece from La Caille's *Ephemerides des mouvemens célestes, pour dix années, depuis 1765 jusqu'en 1775, et pour le meridien de la ville de Paris*, 1763 is reproduced on the inside backcover; the engraving is signed by Simon Challe and François Antoine Aveline.

It is pleasing to see that the delightful practice of personalizing your books with your very own book-plate has not gone the way of many other traditions. I remember designing and printing one whilst a student which depicted the three branches of science in which I was employed. The book-plates described and depicted in *Ex libris stellarum* are divided into seven categories, with illustrations in all sections; thirty-five of the sixty-five book-plates are illustrated.

Book-plates have been used since the end of the eighteenth century, and we are usually greeted with the heraldic shield or just the coat of arms for those found in old books. Later, they were designed to show the particular interest(s) of the proud owner of the book in which they had been placed. The categories into which *Ex libris stellarum* is divided are those which you would expect, especially by an older reader, except section six, L'esplorazione spaziale, here one of the two illustrated examples shows Jurij Gagarin, the other Neil Armstrong.

The time spanned is from 1864 to 1998 with the vast majority being from the last thirty years. Two are reproduced here with the owner's name clearly visible; however, if you wish to know who designed them, then read the booklet. As can be seen, Urania also appears in one of them.



Both these items are available from: Department of Astronomy, Attention M. Zuccoli, University of Bologna, via Zamboni 33, I-40126 Bologna, ITALY.

John Perdrix

Nautical astronomy in New Zealand, the voyages of James Cook, by Wayne Orchiston (Carter Observatory Board, Wellington, 1998), 131 pp., ISBN 0-473-05303-9, NZ$29.95 + postage and packing, paperback, A4.

As stated in Patrick Moore's foreword, "... this monograph represents a very clear, informative and readable account of the New Zealand component of the Cook voyages ...", but it contains much more not indicated by the title with which I had difficulty towards the end of the volume. Although explained in the introduction, I failed to see what "... summarise international developments in research astronomy during the eighteenth and nineteenth centuries, and trace the evolution of New Zealand astronomy through to the end of the nineteenth century." has to do with the voyages of James Cook.

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Williams College's Hopkins Observatory: the oldest extant observatory in the United States

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Abstract
The Hopkins Observatory, built at Williams College in 1836-8, is the oldest astronomical observatory extant in the United States. Founded by Professor Albert Hopkins and built together with his students, it still contains the oldest known Alvan Clark telescope. Some of its historic instruments are mounted in its wings, known as the Mehlin Museum of Astronomy, and its central internal domed-ceiling room is the Milham Planetarium.

Key Words: *history, observatories, Williams College, Alvan Clark*

1 INTRODUCTION

Williams College was founded in 1793 as an enlargement of the Free School founded in 1791 with money from the will of Ephraim Williams. Williams, a soldier, had died in 1758 in the French and Indian war. Astronomy first appeared with Professor Chester Dewey, who taught at Williams from 1809 to 1836. It was taught as part of the junior-year (3rd year) course in Natural Philosophy. Much of the chronology here reported, from Dewey through Hopkins and on into the 20th century, comes from Milham (1937a). See also Milham (1937b).

As Milham relates, the Board of Trustees of Williams College, as reported in their minutes for 1802 September 1, voted "... to procure a telescope for the college apparatus." But this telescope, presumably portable, did not lead immediately to a permanent installation. By 1806, Williams College had a "three foot reflecting telescope, with two eye pieces," in its inventory (Williams College, 1806). A planetarium, actually an orrery, was on the list for the previous year's purchases.

2 ALBERT HOPKINS AND ASTRONOMY AT WILLIAMS

Astronomy's major impetus at Williams resulted from the appointment of Albert Hopkins (Figure 1), a member of the Williams College class of 1826 and who began as Tutor at Williams in 1828. Though in astronomical history he is noted for the foundation of the Hopkins Observatory, he is best known as the brother of the educator Mark Hopkins, who was president of Williams from 1836 to 1872. When James Garfield, the only Williams College alumnus ever to become President of the United States, spoke at Williams College in 1871 as a U.S. Representative, he famously said, "Give me a log hut, with only a simple bench, Mark Hopkins on one end and I on the other, and you may have all the buildings, apparatus and libraries without him." (Garfield was President in 1881; he was assassinated, dying only months after taking office.) "Mark Hopkins and his log", as the story is often oversimplified, is well known in American education as a symbol of good, personal teaching.

In 1834 June, the Board of Trustees of Williams College decided that Professor Hopkins should travel to Europe to improve scientific education at Williams. Accordingly,

Figure 1. Albert Hopkins

> ... the sum of $4,000 has been raised by subscription by the Alumni of the college and other liberal patrons of the institution, to be applied to the purchase of Philosophical and Chemical apparatus for the use of the institution, and that it will be necessary to send an Agent to Europe to purchase the same, recommended to the Board that Prof. Albert Hopkins have permission to be absent for that purpose from the 1st day of September next to the first day of May following and that during that time he be allowed his salary as usual he paying all his expenses during his absence. (Milham, 1937b)

Milham reports that Hopkins sailed on 1834 September 18 on the packet-ship *Hibernia* for Liverpool and returned in 1835 May. The astronomical apparatus he brought back included a 9-cm (3.5-inch) Troughton and Simms transit, a Molyneux and Cope mercury-compensated regulator, a Troughton and Simms rule, and a Herschelian reflector of 10 feet focal length. All but the last are still in the collection of the Hopkins

Observatory, and are displayed in it in the Mehlin Museum of Astronomy. The transit was used in one of the wings of the observatory, mounted on marble piers that are now in storage. No doubt, the apparition of Halley's Comet of 1835 reinforced Hopkins's desire to erect an observatory building. Also in 1835, Hopkins took undergraduates to Nova Scotia on the first such undergraduate scientific expedition in American education, a type of undergraduate involvement that still continues at the Hopkins Observatory in particular and Williams College in general.

Hopkins and his students began constructing a permanent observatory in 1836. Quarrying began in the autumn. Milham (ibid.) elaborates:

> ... the records of the trustees show that the observatory cost $2,075, that $1,200 was voted by the trustees, that $400 was contributed by friends, and that Professor Hopkins himself gave $475. The students too helped and in those days they often turned out almost in a body to help build the observatory which was to mean so much to them and the college.

The centre of the Hopkins Observatory is a domed room on the ground floor, entered on both the north and south sides. Mehlin (1962) reports that gold stars were pasted to the ceiling to mark out the constellations, making it perhaps the earliest American example of what we today call a planetarium: "Strips of paper, marked off in degrees or hours, indicated the ecliptic, equator, and other circles on the ceiling sky."

The Hopkins Observatory was dedicated on 1838 June 12. Figure 2 shows a woodcut of the observatory from the cover of the catalogue of courses for the following academic year, 1838-1839. Hopkins is newly listed as Professor of Natural Philosophy and Astronomy.

Rudolph (1956) reports that Hopkins, in a newspaper clipping from 1841, stated:

> ... the leading idea ... which lay at [the Hopkins Observatory's] foundation, was *that nature is to be studied rather than books*. Why, Albert made explicitly clear in the address which he delivered at the dedication of the observatory. In their worship of the practical, he declared, men were losing sight of the moral. Education itself was being subverted by a prevailing notion that it was intended to whet the intellect, sharpen mental powers, and prepare 'for action, action, action.' To counteract these influences, he confessed, he had decided that what Williams College needed most was an astronomical observatory, where the students could elevate their thoughts 'toward that fathomless fountain and author of being, who has constituted matter and all its accidents as lively emblems of the immaterial kingdom.'

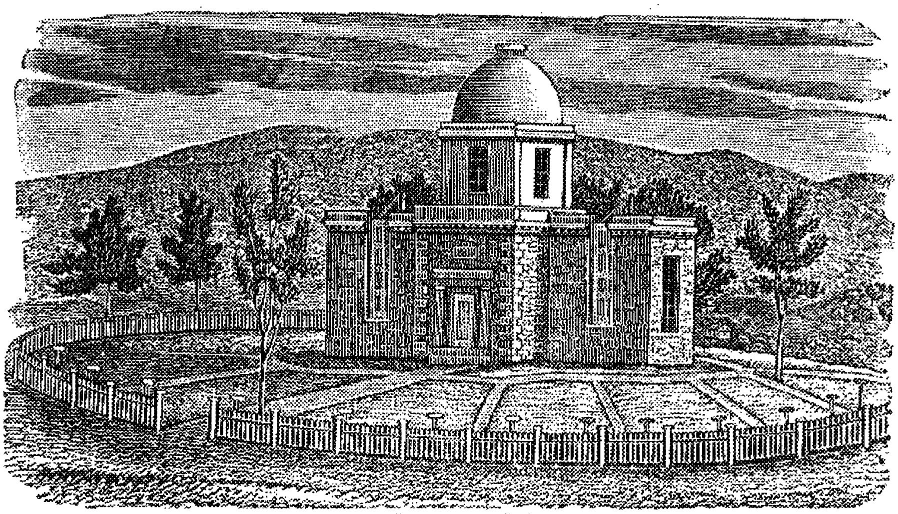

Figure 2. The Hopkins Observatory, a woodcut from the Williams College catalogue from 1838-9

Rothenberg (1986) writes:

> I have studied the history of Hopkins observatory and its first director, Albert Hopkins. In my dissertation (1974), I contend briefly that Hopkins's career was representative of an entire generation of teachers of astronomy at American liberal arts colleges, trained during the period 1818-1834, and active through the Civil War and beyond. Subsequent research has given my view of that generation more depth and breadth but has not changed my conclusion. What does distinguish Hopkins from most of his contemporaries was his ability to leave behind a permanent physical legacy – the observatory.

Rothenberg (ibid.) further suggests that Hopkins was "... a representative of the generation of professors who changed the way astronomy was taught at American liberal arts colleges and helped set the stage for the great growth in American astronomical research during the second half of the nineteenth century."

Hopkins was a minister, and his interest in astronomy was related to his interest in religion (Rudolph, 1956). The inscriptions over the north and south doors of the Hopkins Observatory (Figure 3) reveal this connection, and respectively, read: "Lift up your eyes on high and behold who hath created these" and "For thus saith the Lord, yet once, it is a little while, and I will shake the heavens, and the earth, and the sea, and the dry land."

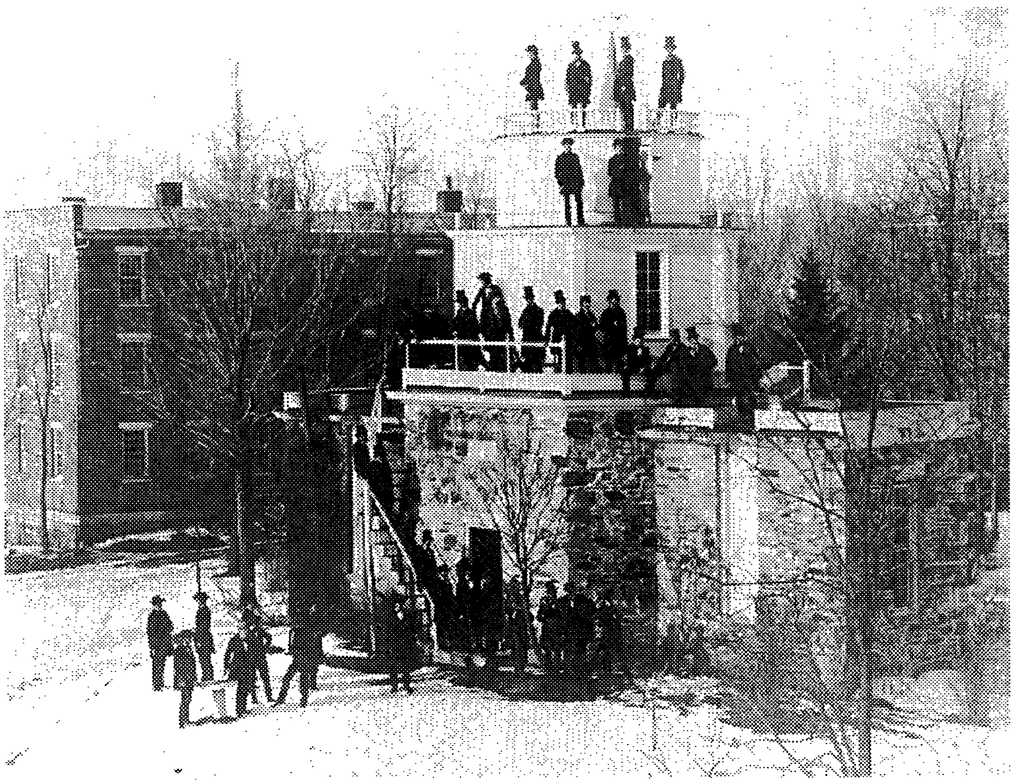

Figure 3. The Hopkins Observatory, a nineteenth-century photograph, from 1859. The identities of the individuals are unknown. Gift of John S Sheldon '05.

3 NATHANIEL HAWTHORNE VISITS WILLIAMSTOWN

In 1838, the author Nathaniel Hawthorne, noted not only for his *Tanglewood Tales* set about 40 km south of Williamstown but also for *The Scarlet Letter*, travelled into northern Berkshire County. The entry for July 26 states,

> Left Pittsfield about eight o'clock in the Bennington stage, intending to go to Williamstown .... I pointed to a hill at some distance before us, and asked what it was. 'That, Sir, said he, 'is a very high hill. It is known by the name of Graylock.' He seemed to feel that this was a more poetical epithet than Saddleback, which is a more usual name for it.
>
> Graylock, or Saddleback, is a quite respectable mountain; and I suppose the former name has been given it, because it often has a gray cloud, or lock of gray mist, upon his head; it does not ascend into a peak, but heaves up a round ball, and has supporting ridges on each side. Its summit is not bare, like Mt Washington, but covered with forest. The driver said, that several years since the students of Williams' [*sic.*] college erected a building for an observatory on the top of this mountain, and employed him to haul the materials for constructing it; and he was the only man that had ever driven an ox-team up Graylock. (Hawthorne, 1838).

The story apparently deals with an observing tower on top of Mt. Greylock; Albert Hopkins participated in building a second tower in 1841. It was used for meteorological observing (Burns and Stevens, 1988). The story does not match the construction of the Hopkins Observatory on the Williams College campus, at an altitude of only a few hundred meters and far below the summit of Mt. Greylock (as it is now spelled) at 1064 m. (Mt. Greylock is the highest mountain in Massachusetts.) Further, the entry is only about a month after the dedication of the Hopkins Observatory, which would therefore have been current news at the time of Hawthorne's visit.

4 THE OLDEST EXTANT OBSERVATORY

Milham (1937a:11-28) addresses at length the question of which American observatory is the oldest. He considers eleven observatories, "... all fully erected and equipped before 1840":

> The David Rittenhouse Observatories at Norriton from 1769 and at Philadelphia from before 1786 to 1796. The Observatory of the College of William and Mary before 1789. William Cranch Bond's Observatory at Dorchester from 1823 to 1839. Yale Observatory in the Athenaeum Tower from 1830. The Observatory of the University of North Carolina at Chapel Hill, North Carolina, from 1831 to 1838. The private Observatory of Wilkes and Gilliss or the Depot of Charts and Instruments at Washington from 1833 to 1842 [which became the U.S. Naval Observatory; see Rothenberg (1993)]. The Observatory of Wesleyan University at Middletown, Connecticut, from 1836. The Hopkins Observatory of Williams College from 1838 on. The Observatory of Western Reserve College at Hudson, Ohio, from 1838 on. The Observatory of Miami University at Oxford, Ohio, 1838 to 1840. Harvard College Observatory at Dana House from 1839 on. All of these were temporary or makeshift observatories or of fairly short duration with the exception of two. These are the Hopkins Observatory of Williams College and the Observatory of Western Reserve College ... [now part of Case Western Reserve University] which followed it by less than a year. Both of these are still in existence in essentially their original condition. The Hopkins Observatory of Williams College is thus the oldest extant Astronomical Observatory in America. The reader is left to judge which was the first Astronomical Observatory in America.

Murphey (1987) speaks of Elias Loomis, who went from Yale to Western Reserve College and "... had a 37-by-16 foot observatory built by September 1838. Williams College in Williamstown, Mass., completed its observatory three months earlier, making [the] Loomis [Observatory] the second-oldest in the country." Yowell (1943) gives 1845

January for the Cincinnati Observatory's telescope. See Musto (1967) for a discussion of the construction of various observatories in the early nineteenth century and their sources of financial support. He also discusses the reasons for the lack of Federal support, and how the enthusiasm created by the Comet of 1843 (for which see also Olson and Pasachoff, 1997) led to the formation of the Harvard College Observatory through private subscription.

Milham (1950) describes how meteorological observations, already being made in Williamstown, were transferred to the Hopkins Observatory in 1838, where they continued under the direction of Hopkins until 1872.

Through another Williams College professor, Ebenezer Emmons, Williams College has a link to the formation of the American Association to the Advancement of Science (AAAS). The AAAS developed from the Association of American Geologists, which formed at a meeting at Emmons' home in Albany in 1838 (Schneer, 1971). The current Hopkins Observatory Director is now Chair of the Astronomy Division of the AAAS.

5 ALVAN CLARK AND HIS TELESCOPES

The original Williams College telescope, now lost, was replaced in the Hopkins Observatory in 1852. Mehlin (1962) reports that "The only clue to its fate is a note in the trustees' records of 1852 that reads, 'Professor Hopkins may exchange the old telescope for the bones of some animal found in Pennsylvania.'"

Warner and Ariail (1995) relate how Williams College commissioned Alvan Clark, a young optician from Cambridgeport, Massachusetts (now part of Cambridge), to make a telescope. Clark took the opportunity to strike out in business for himself, leading to the firm that was to make refracting telescopes in the 19th century up to and including the 40-inch (1-m) telescope at the Yerkes Observatory, that is still the largest refractor in the world. The Hopkins Observatory telescope was "... financed by Amos Lawrence, a Boston industrialist who had been a principal benefactor of the College and who had devoted much of his wealth to improving the 'character' of the citizenry through education."

Though there might have been one earlier telescope, the list of Warner and Ariail shows that the Hopkins Observatory's 18-cm (7$^{1}/_{8}$-inch) refractor is certainly one of the first telescopes Clark made and is probably the earliest Clark telescope now surviving. The rotunda, a cylindrical structure that was a forerunner of today's telescope domes (and which we will call a dome), has a very narrow slit and is thus difficult to rotate in synchrony with the telescope's tracking. Thus, though the telescope is occasionally looked through, it is not in regular use. The dome still rotates with a mechanical crank at the floor level linked with a corner-turning gear to the gear that rotates the dome itself.

The telescope objective, a doublet, was restored by Dennis di Cicco in the period 1974 onward, and a videotape exists showing its disassembling. More recent work on restoration, mainly of the tube and drive, has been carried out by Williams College students Kevin Reardon (1992), Christina Reynolds (1997), and James Bates (1998). Bates concentrated on putting together a tracking drive from the several partial drives and gear trains existing; the dates of the various drives are unknown (Figure 4).

6 RALPH WALDO EMERSON AND THE HOPKINS OBSERVATORY

On 1865 November 14, the philosopher/essayist Ralph Waldo Emerson visited the Hopkins Observatory. In his journal, he wrote:

> I saw tonight in the Observatory, through Alvan Clark's telescope, the Dumb-Bell nebula in the Fox and Geese constellation;
> the four double stars in Lyra;
> the double stars of Castor;
> the 200 stars of the Pleiades
> the nebula in (Perseus?)

Mr. Button, Professor Hopkins' assistant, was our star showman, and [Mr] J. H. Stanbrough and [blank] Hutton, who have been my committee of the "Adelphic Union", inviting me here, carried me thither. I have rarely been so much gratified....

Of all tools, an observatory is the most sublime. And these mountains give an inestimable worth to Williamstown and Massachusetts. But for the mountains, I don't quite like the proximity of a college and its noisy students. To enjoy the hills as a poet, I prefer the simple farmers.

The dim lanthorn which the astronomer used at first to find his object glasses, &c. seemed to disturb & hinder him, preventing his seeing his heavens, &, though it was turned down lower & lower, he was still impatient, & could not see until it was put out. When it had long been gone, & I had looked through the telescope a few times, the little garrett at last grew positively lightsome, & the lamp would have been annoying to all of us. What is so good in a college as an observatory? The sublime attaches to the door & to the first stair as you ascend; that this is the road to the stars. Every fixture & instrument in the building, every nail & pin has a direct reference to the Milky-Way, the fixed stars, & the nebulae. & we leave Massachusetts & the Americas & history at the door, when we came in. (Allardt *et al.*, 1982; quoted in Milham, 1937a).

Figure 4. The Clark refractor, installed in 1852. It is the oldest known Alvan Clark telescope.

7 LATER HISTORY

Edward Morley of the Williams College class of 1860, renowned especially for his later collaboration with A A Michelson in their joint experiment that demolished the idea of the luminiferous ether, was the first to make a good determination of the latitude of the

Hopkins Observatory (Milham, 1937a). He learned his experimental technique and the concept of accuracy of observation under Albert Hopkins in the course of his work, which involved mounting the meridian circle outside the observatory. Thus the Hopkins Observatory and Albert Hopkins can be placed in a chain that led to Einstein's special theory of relativity.

In 1866, David Dudley Field and his family established a Chair of Astronomy in memory of his daughter. Hopkins died in 1872 and was succeeded as Field Memorial Professor by Truman Henry Safford (Figure 5) in 1876. In the interim four years, Safford had been Lecturer in Astronomy for one year and Charles A. Young, later professor at Princeton and famous as a textbook author, had been Lecturer in Astronomy for two years. Safford had been known as a child prodigy and a prodigious computer. A primitive oil of Safford as a child, once in the collection of Harvard University, now hangs in the Hopkins Observatory.

Before he came to Williams, Safford had been director of the Dearborn Observatory. He specialized in star positions. In 1882, the original Troughton and Simms transit was succeeded by a larger and much more elaborate meridian circle, by Repsold. Donated by Field, it has a 11-cm (4.5-inch) objective, and is *f*/12. Because of trees on the horizon, it was installed in a new structure made of sheet iron, the Field Memorial Observatory. This transit is also in the Mehlin Museum, at the side of the old meridian transit room and next to the Molyneux and Cope regulator with which it was used. The Repsold meridian circle has finely engraved silver inserts for the elevation angles, and candle holders to aid with illuminating them. The astronomer would have called out the times at which stars crossed a cross-hair on the meridian, and his assistant would have noted the time from the clock. "The clock is an old and good one by Molyneux and Cope; and is amply sufficient for work of this kind." (Safford, 1888b).

Figure 5. Truman Henry Safford. He used his cholderen as assistants, whom he paid five cents a night (information from Louis Safford (THS's grandson) and his wife , Midge, 1998).

It is from observations like these that it was noted that individual astronomers called the transits slightly differently, perhaps some lagging and some leading the actual transit. Such observations led to the development of the personal equation, which, in turn, led to the development of the science known today as psychology. The debt to astronomy is noted in some contemporary psychology textbooks. I like to think of psychology, therefore, as one of several spin-offs of astronomy.

Safford (ibid.) used the new equipment to amass the data that were used in the *Williams College Catalogue of North Polar Stars for Epoch 1885.0*. Even at that time, it was noted that the site of the Hopkins Observatory was not a desirable observing location (see Figures 6 and 7). A new site was thus used for a metal building, the Field Memorial Observatory, and the Repsold meridian circle was installed in it. "It [The Field Memorial Observatory] is not in the same situation as the Hopkins Observatory, built in 1836-38; the older house is now too thickly surrounded with trees; it serves as a location for the older instruments, and is in many ways useful, while it is desirable to preserve it as long as possible as a picturesque and historic landmark." Safford presided over the fiftieth anniversary of the dedication of the Hopkins Observatory, at which time he summarized the relevant history (Safford, 1888a).

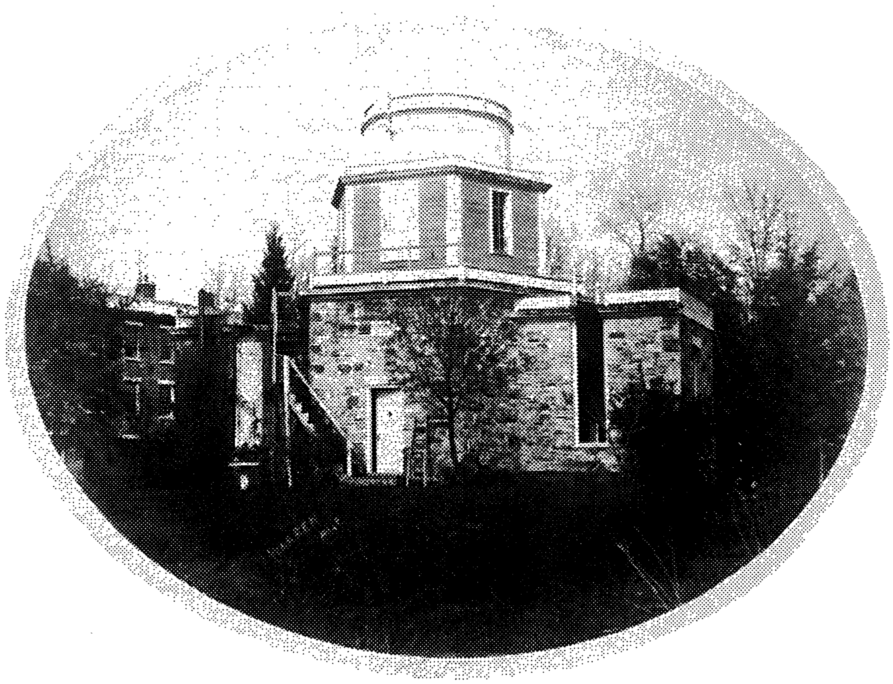

Figure 6. An early photograph of the Hopkins Observatory, from 1865. One of the inscriptions is visible over the portico. The photograph is credited to Geo K Warner.

Willis Isbister Milham (Figure 8) succeeded to the Directorship in 1902 and became the longest-serving director; his term lasted 40 years (Table 1). Milham was more of a meteorologist and horologist than an astronomer. In Milham (1950), he described the history of meteorology at Williams College. Mehlin (1962) writes:

> He wrote a long-used textbook on meteorology in 1912, and his *Time and Timekeepers* of 1923 was published in popular form in 1941. An extremely orderly individual, Professor Milham was said to use the bell that ended class as the punctuation for the final sentence of his lecture! His 47 years of teaching at Williams was the longest for any faculty member except Mark Hopkins.

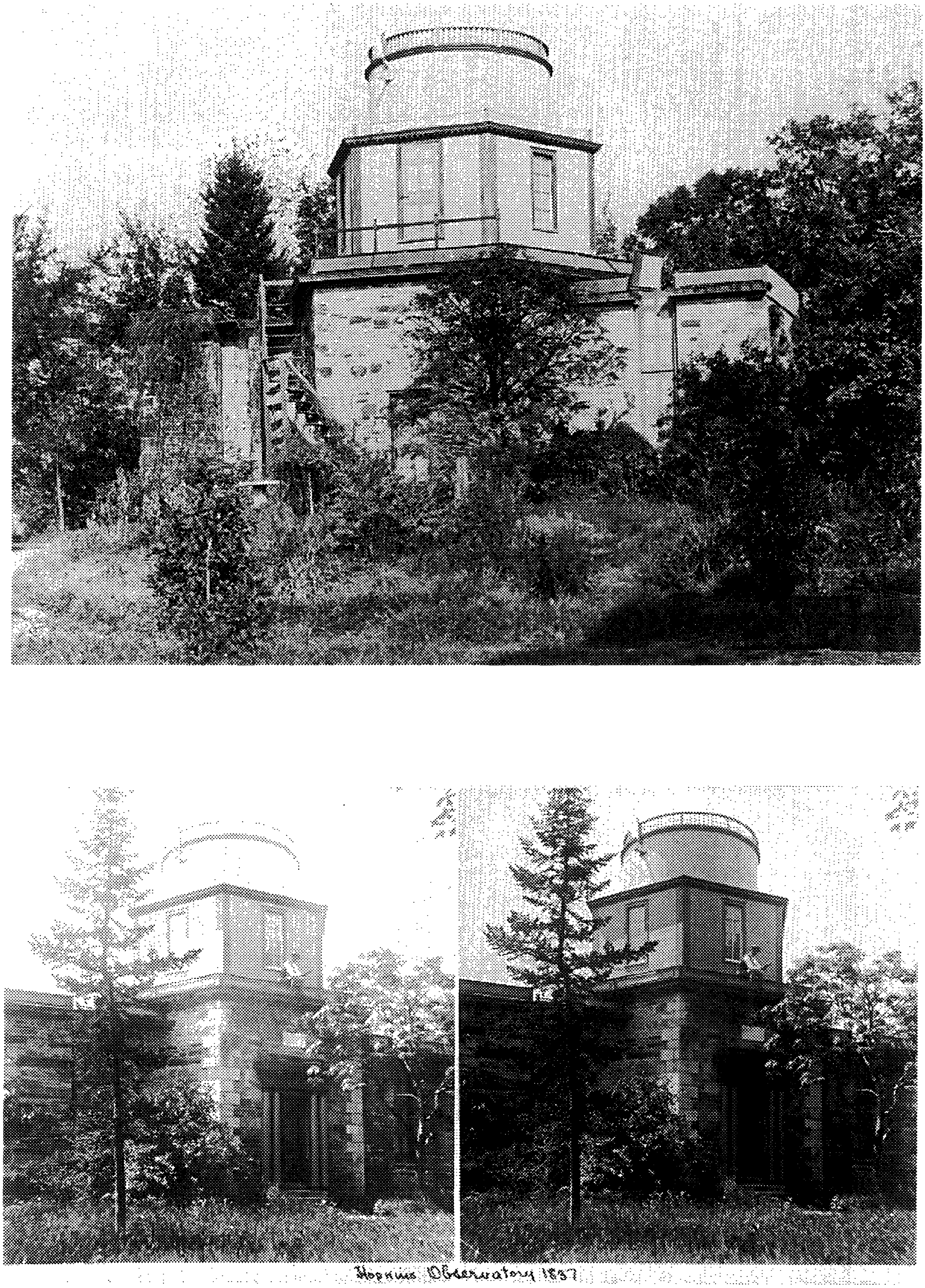

Figure 7. The Hopkins Observatory, nineteenth-century photographs. *Top*: north side with sundial amongst vegetation, 1874. *Bottom*: a stereogram pair. Credited to J L Lovell.

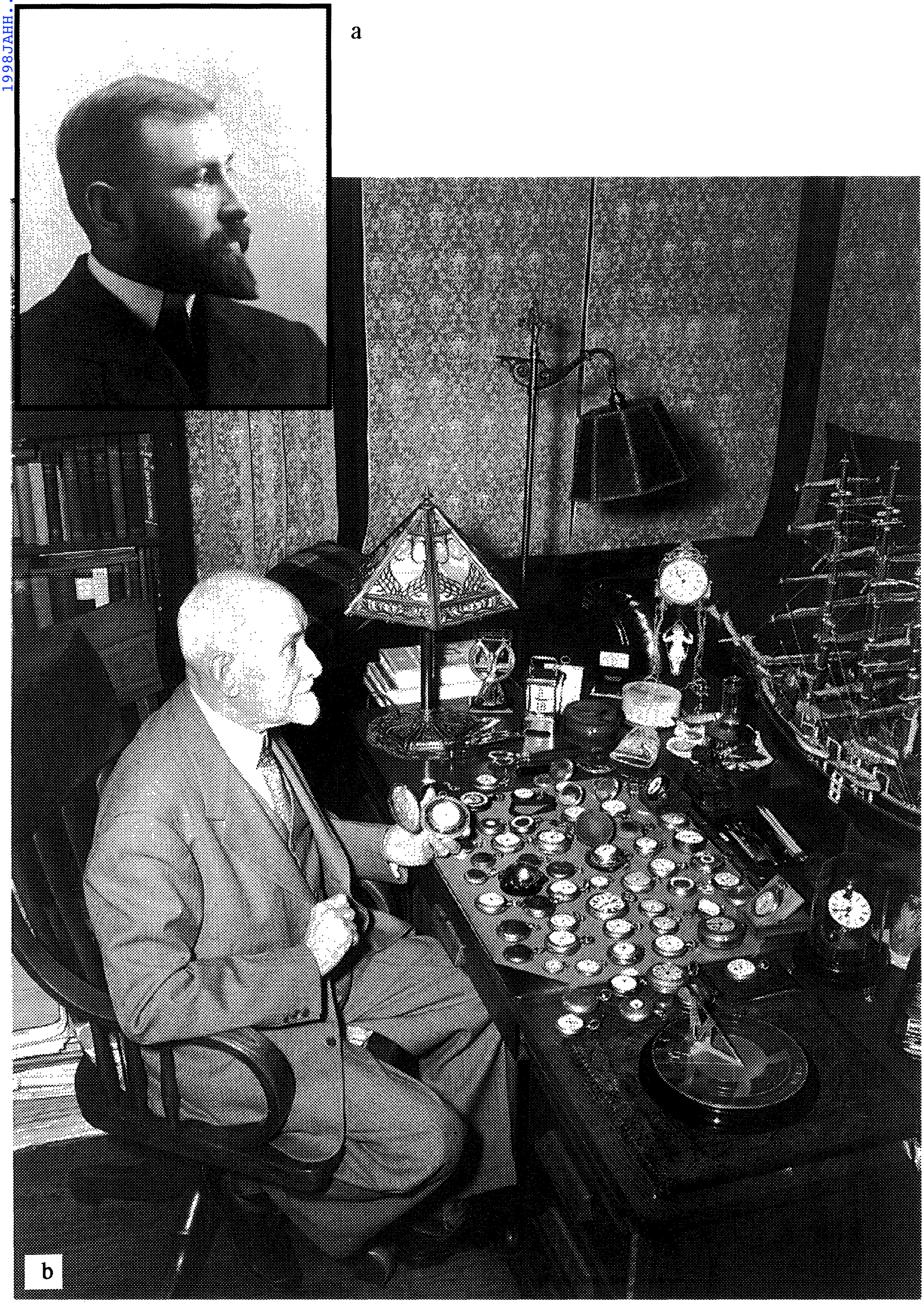

Figure 8. a, Willis Isbister Milham. b, with some of his clock and sundial collection.

His horological interest no doubt led him to supervise the time on the gymnasium clock at the head of Spring Street on the Williams College campus, a custom that became linked to the Directorship until the death of his successor.

Table 1. Directors of the Hopkins Observatory.

Name	Years as Director	Duration
Albert Hopkins Born 1807 July 14; graduated Williams College 1826; died 1872 May 24. Spouses: Louisa Payson Hopkins, Elizabeth Kilby Hopkins.	1836-1872	36 years
Truman Henry Safford Born 1836 January 6; graduated Harvard 1854; died 1901 June 12. Spouse: Elizabeth Bradbury Safford.	1876-1901	25 years
Willis Isbister Milham Born 1874 February 11; graduated Williams College 1894, Ph.D. Strasbourg 1901; died 1957 March 23. Spouse: Betsey Morgan Fairweather.	1902-1942	40 years
Theodore Grefe Mehlin Born 1906 June 13; graduated Duke University 1927, Ph.D. Yale 1935; died 1971 December 5. Became Field Memorial Professor as of 1950. Spouse: Helen M. Roche Mehlin.	1942-1971	29 years
Jay Myron Pasachoff Born 1943 July 1; graduated Harvard College 1963, Ph.D. Harvard 1969. Became Field Memorial Professor as of 1985. Spouse: Naomi Schwartz Pasachoff.	1972-present	26 years
Acting director:		
Karen Beth Kwitter Born 1951 March 20; graduated Wellesley College 1972, Ph.D. UCLA. Spouse: Steven Souza.	Occasionally	(5 years)

In 1942, Theodore G. Mehlin (Figure 9) became director. "U.S. Navy personnel were instructed in the astronomy department during the war years," he wrote (Mehlin 1962). "In 1951, the college provided new quarters consisting of a lecture room, laboratory, darkroom, two offices, and an observing deck." This facility was an addition to the Thompson Physical Laboratory, on another part of the Williams College campus.

8 MOVING THE OBSERVATORY

The Hopkins Observatory was erected in the centre of what is now known as the Greylock Quadrangle at Williams College. To complete the quadrangle, given the existence of East College and Fayerweather Hall to the west and the new Berkshire Hall (now Fitch) and Currier Hall to the east, the building was moved to the south end in 1908. *The Williams Alumni Review* of June 1909 reported: "A substantial terrace of brick and stone joins the old Observatory to the buildings on either side of it, thus completing the symmetry of this latest addition (the quadrangle) to the College campus." (New Berkshire Quadrangle, 1909). In this move, the Observatory was rotated slightly to make it in line with campus buildings instead of oriented north-south. The meridian slit in the east wing was skewed to accommodate the angle (see Figure 10).

From 1882 to 1895, the Field Memorial sheet-iron observatory had been more used than the Hopkins Observatory, and had the Repsold meridian circle in it. It was little used because of Safford's illness after 1895, and equipment was moved from it in 1908. The Repsold meridian circle remained in it until 1927, when the site was sold and the sheet-iron observatory demolished.

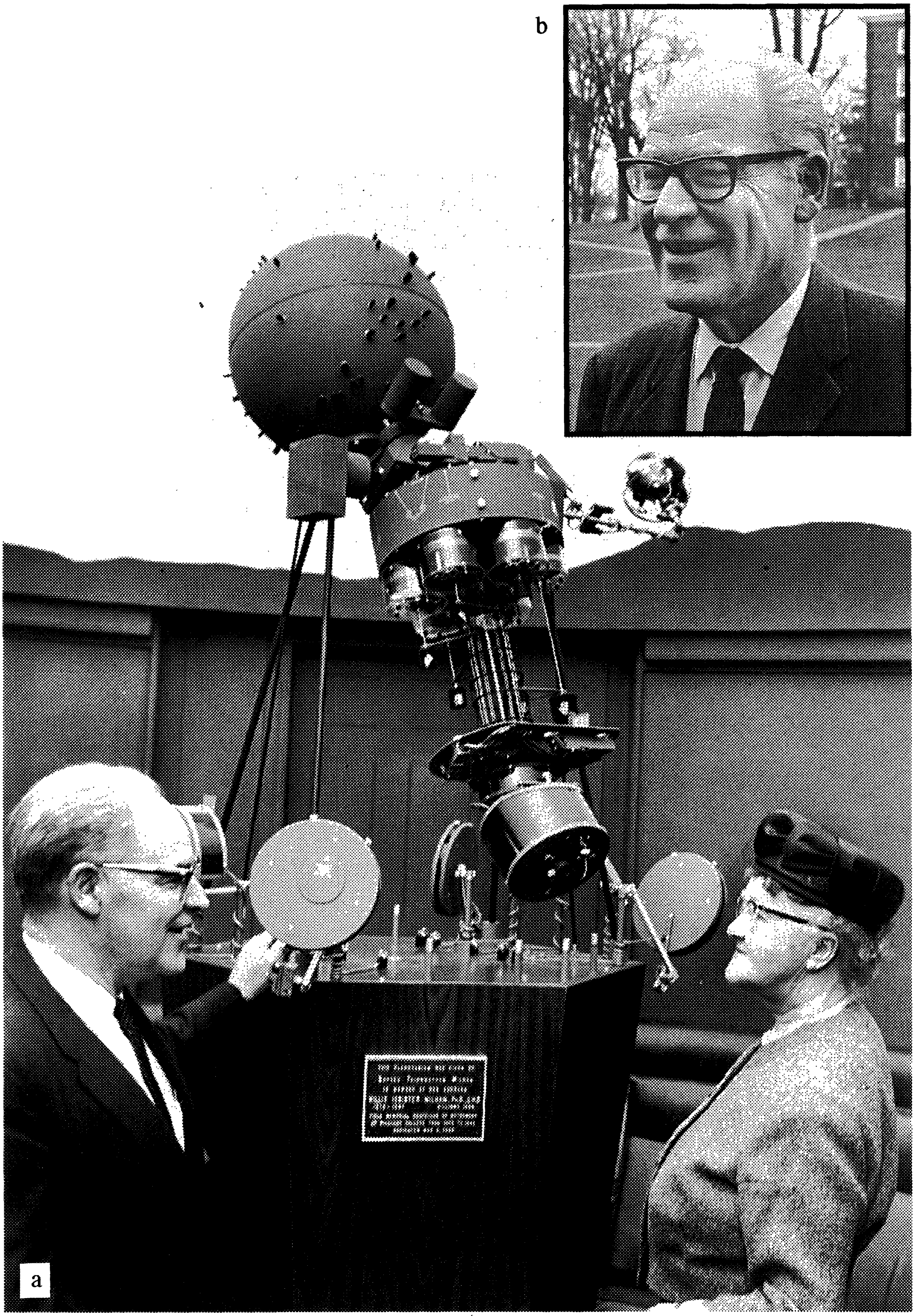

Figure 9. a, Theodore G Mehlin at the dedication of the planetarium in 1963, posing with the widow of Prof. Milham. b, Mehlin in 1969, outside West College (1793), Williams College's oldest building. Photograph by William H Tague, Williams College.

The Observatory was moved once again in 1961 (Mehlin 1962), this time to its current resting place at the north end of the Berkshire Quadrangle. Another dormitory, Prospect Hall, was erected at the south end, where the Observatory had been. Mehlin reported that the structure was 254 tons and was moved 350 feet northward:

> First, a two-layer grid of steel I-beams was placed as a platform under the observatory, which was then inched along twin sets of steel rails. The propelling power came from two heavy jacks, pressing against blocks wedged to the rear ends of the rails. Later, a winch was added to pull from the front, supplementing the jacks.

In 1963, Mehlin oversaw the installation of a Spitz A3P planetarium (Figure 9a) in an internal domed rotunda in the center of the Hopkins Observatory, under the telescope. This planetarium is still in use today, seating up to about 40 people. A mountain skyline of the horizon as seen from the site was cut out of wood and installed.

The wings of the Hopkins Observatory were converted into a museum in 1973 in honour of Mehlin. David Mehlin, his son, was the architect.

9 THE MODERN ERA

Mehlin, in 1971, prepared for his retirement, and I was appointed to the Directorship, to begin 1972 July 1. Unfortunately, Mehlin died in late 1971, before he could enjoy his retirement.

My directorship began, even before classes, with a total eclipse expedition to Prince Edward Island in 1972 July, including four Williams sophomores, two of whom are now

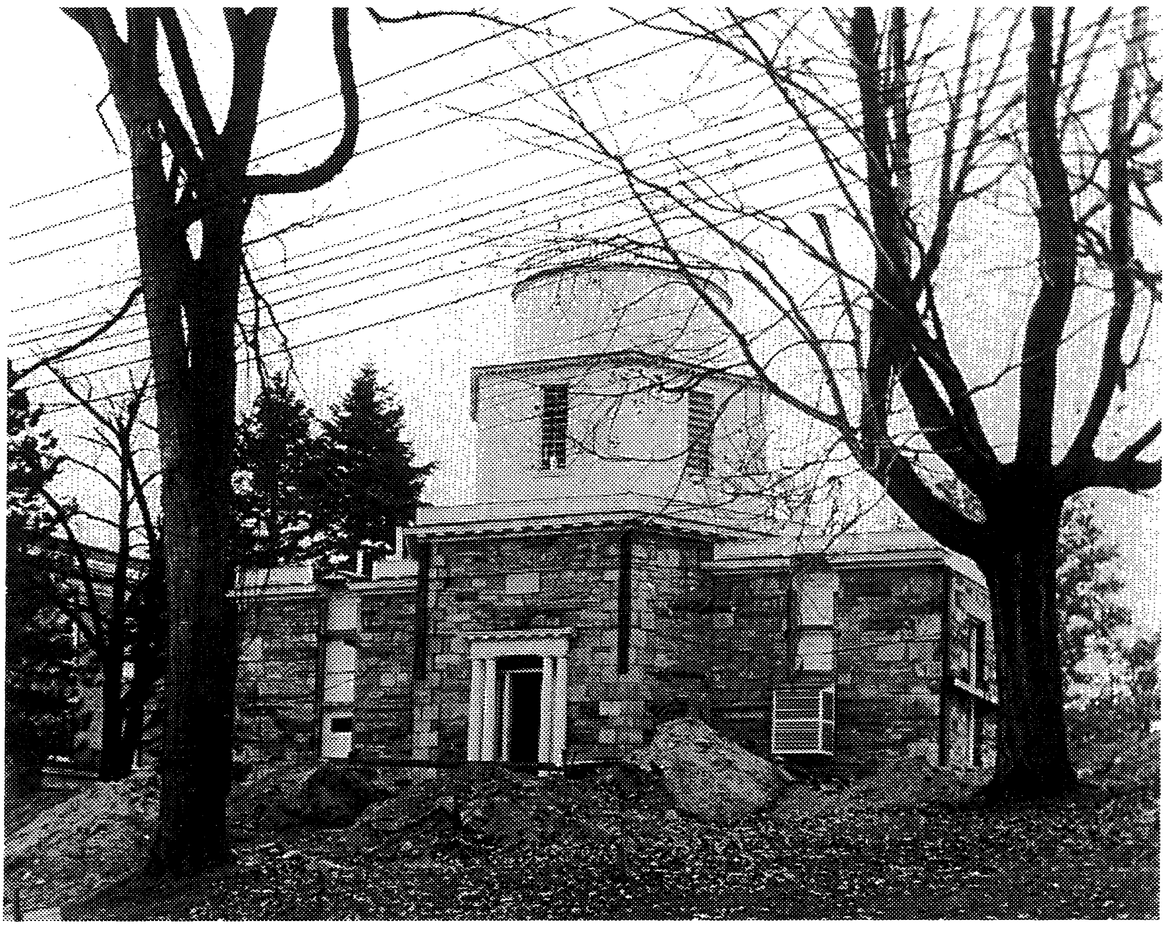

Figure 10. The Hopkins Observatory, moved in 1908 and 1961.

professors of astronomy and a third who served for a time Director of the Fels Planetarium. Inclusion of students on solar eclipse expeditions has been a hallmark of my tenure. Another continuing project has related to observational cosmology through studies of interstellar deuterium. The history of astronomy has been another thread, most recently leading to the publication of a book on comet images in British art and science (Olson and Pasachoff, 1997).

A major in astronomy and physics, jointly between the Astronomy and Physics Departments, had been approved but not activated until my arrival. It is now known as 'Astrophysics', and a separate 'Astronomy' major has been started within the Astronomy Department alone. The increase in student enrolment in astronomy courses and the growth of apparatus led to the appointment of first, a part-time Instructor and Observatory Supervisor in 1974, a position that has continued with varying status until this day. Then a half-time additional faculty position, shared with the Physics Department, was awarded to John Lathrop. This position was later converted to a full-time astronomy position, and is held by Karen B Kwitter, now Professor of Astronomy and occasionally Acting Director of the Hopkins Observatory. She specializes in spectroscopic observations of planetary nebulae. Visiting professorships have been held, during leaves by Professors Pasachoff or Kwitter, by Thomas Balonek, now at Colgate University; David Friend, now at the University of Minnesota; James Voelkel, now at the Dibner Institute for the History of Science at MIT, and Marek Demianski, of the Copernicus Astronomical Institute in Poland. Demianski, who has returned several times, held a Bernhard Visiting Professorship on one of the occasions. An Instructor/Observatory (or Observing) Supervisor position has existed since 1974. Several individuals have also been appointed Associates of the Hopkins Observatory, either coordinated with their instructorships or professorships or because of their participation in research projects, such as J Phil Schierer of Tektronix, Inc., who participated in various eclipse expeditions, and now Bryce A Babcock, staff physicist and Coordinator of the Bronfman Science Center at Williams.

The sesquicentennial of the Hopkins Observatory occurred in 1988 (A College's 'Road to the Stars' ..., 1988; Pasachoff *et al.*, 1988). It was marked by an official cancellation of the United States Postal Service, and by International Astronomical Union Colloquium #105 on the Teaching of Astronomy (Pasachoff and Percy, 1990) – see Figure 11. An exhibition of astronomical art was held at the Clark Art Institute in conjunction with the colloquium (Fernandez *et al.*, 1990).

The major change in equipment came in 1991, with the installation of a DFM 0.6-m (24-inch) professional-grade telescope in a dome on top of the Thompson Physical Laboratory (Figure 12). It was largely funded by the Kresge Foundation, with matching funds from the Keck Foundation and Williams College sources. A substantial upgrade to the telescope was funded by the National Science Foundation in 1995.

Williams College has remained a 'small college', not choosing to become a university. It has 2,000 students, all undergraduates (except for two special programmes) and a faculty of about 175. Of overriding importance now for astronomy students and faculty is Williams College's participation in the Keck Northeast Astronomy Consortium, an eight-college group funded by the W M Keck Foundation. Members, besides Williams, are Wellesley, Middlebury, Colgate, Wesleyan, Vassar, Swarthmore, and Haverford. The other members of the Consortium are also small colleges, a type most prevalent in the north-east United States. The original Keck grant included a CCD detector and related workstation running IRAF (Image Reduction and Analysis Facility software out of the National Optical Astronomy Observatories); an NSF grant has since provided a workstation upgrade as well as additional graphics terminals. Much of the continuing Keck grants pay for student participation in research, including summer jobs at other institutions in the Consortium for students from any given institution, and a student research symposium each fall. See, for example, symposium proceedings edited by Pasachoff (1993) and Balonek (1997).

Figure 11. The group picture taken at the 58th meeting of the American Astronomical Association, held in Williamstown in 1937 September.

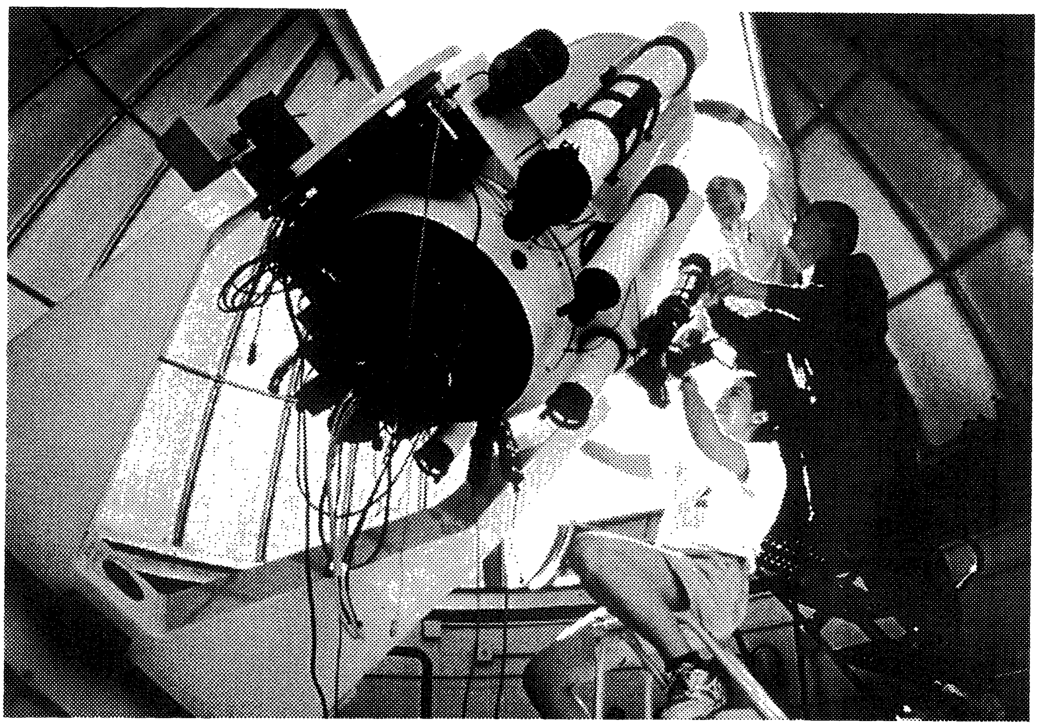

Figure 12. Jay M Pasachoff with Instructor/Observing Supervisor Stephen Martin and undergraduate Christina Reynolds. The photograph was taken in 1997 for a Williams College admissions brochure.

With its activities at several sites, including the planetarium and museum in the original 1836-8 building, in addition to telescopes and teaching facilities nearby and field sites for expeditions, the Hopkins Observatory enters the new millennium as a vibrant organization dedicated to teaching and research.

For further contemporary information, see http://www.williams.edu/Astronomy and the yearly Observatory Reports in the *Bulletin of the American Astronomical Society*.

10 ACKNOWLEDGMENTS

I thank Sylvia Kennick Brown, College Archivist, and Lynne K Fonteneau McCann, Archives Assistant, for their assistance with the Williams College archives, which provided most of the photographs used here. I am grateful to Susan Kaufman for miscellaneous assistance. The students and faculty at the Hopkins Observatory still benefit from the Brandi Fund set up by the father of one of his students to honour Professor Mehlin and from the Safford Fund set up by his descendants, including the current families Mr and Mrs Arthur Safford and their daughter Jean Safford Wright and Mr and Mrs Louis Safford. The former directors of the Hopkins Observatory are also now immortalized by having their forenames used for the current computer workstations (albert, willis, isbister, truman, henry, and ted).

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About a work in Tampa entitled *Solar Rotary*, described as "a contemporary time-dial, where the point is not to measure the precise time of day, as was the case of the medieval sundial, but rather to focus on our relationship to the solar system and planetary movements, as well as our own history." The structure is designed so that on pertinent dates the central ring, at an elevation of 20 feet, will cast a circular shadow around one of five plaques on the ground, each describing an event of importance in the history of Florida.

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See also "Mostra di strumenti scientifici settecenteschi nella casa di Giorgione," by Gian Antonio Salandin (p. 375–390), which includes a section on optics and astronomy (p. 378–382), with related illustrations (fig. 6 and 7).

Pustiļniks, Izolds. E. Epiks un Tartu astrofizikas un zvaigžņu astronomijas skola (1922–1945). [E. Öpik and the Tartu School of Astrophysics and Stellar Astronomy (1922–1945)] Zvaigžņotā debess, 1996. gada rudens: 36–39. port.

The portrait shows Öpik at age 30.

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"Gravitational lensing, now taken as an important astrophysical consequence of the general theory of relativity, was found even before this theory was formulated but was discarded as a speculative idea without any chance of empirical confirmation. Reconstruction of some of Einstein's research notes dating back to 1912 reveals that he explored the possibility of gravitational lensing 3 years before completing his general theory of relativity. On the basis of preliminary insights into this theory, Einstein had already derived the basic features of the lensing effect. When he finally published the very same results 24 years later, it was only in response to prodding by an amateur scientist."

See also the illustrated reports by Eugen Hintsches, "Gravitationslinsen erschienen sogar Einstein zu phantastisch," in *MPG Spiegel*, Nr. 1, 1997, p. 11–13, and Erick Vermeulen, "Einsteins bewijslast," in *Natuur & Techniek*, 65. jaarg., apr. 1997, p. 22–29.

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"We report a detailed summary of the scientific meeting held in March, 1996, to honor Albert Whitford on the occasion of his 90th birthday. We give a description of his life and scientific accomplishments followed by a report on the research presented in the meeting, mostly concerning the Galactic bulge."

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Ruiz Maldonado, Margarita. Precisiones acerca del calendario de Treviño. Boletín del Museo e Instituto "Camón Aznar," no. 47, 1992: 5–31. illus.

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"On 25 September 1344, Pope Clement VI wrote to the astronomers John of Murs and Firmin of Beauval, asking them to come to Avignon to reform the calendar ...

"The suggestions of John of Murs and Firmin of Beauval concerning the reform of the solar and lunar calendar were not implemented, probably because Clement was too busy with other matters. In addition, the Black Death may have made plans for the next nine thousand years seem unnecessary. John and Firmin's suggestions for reform, however, are reasonable and presented very clearly. Interestingly, the authors are convinced that more recent astronomers should, in this case, be believed more than the ancients, because later men had at their disposition observations over a longer period of time, and thus were able to see small imprecisions by their accumulation ... This seems to be an early instance of scholars saying that it was possible that they knew better than the ancients. Indeed the authors' calculations for both the solar and lunar calendars are almost exactly those used in the Gregorian reform in 1582, so the reform could have been accomplished just as well astronomically in 1345 ..."

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"The wire eyepiece micrometer made by Jacob Lusverg (1636–1689) dated 1677, was found in the seminary of Treviso in 1991. An original contribution on Jacob Lusverg's biography is given from unpublished documents. In this paper the structure and the operating use of the micrometer is described. The micrometer was restored in the laboratory of the Museum of Phisics [sic] in Bologna by A. Grilli. It is also described the small telescope, whose objective glass is signed Domenico Selva. This item was recently used by M. Toulmonde, in the Observatory of Paris, in order to repeat a series of historical measures of the Sun's diameter, made by A. Azout in the XVII Century."
Toulmonde's report was cited in *H.A.D. News* no. 42.

Teper, Wojciech, *and* Andrzej Ceglarz. Tajemnica Gwiazdy Betlejemskiej. Fizyka w szkole, r. 43, wrzes./paźdz. 1997: 244–248. illus.

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"The 'constant' H, whose customary units are (km/sec)/Megaparsecs, is a measure of the distance scale, expansion rate, and (indirectly) age of the universe. The first determinations of its value, by Hubble himself, between 1929 and 1936, were in the range 500–550 km/sec/Mpc, implying a universe only about 2 Gyr old (less than the age of the earth as understood even then). In a series of quick steps from 1952 to 1975, the best value dropped from 500 to 250 to 125 to 50–100 km/sec/Mpc. And there it has remained ever since, with a factor of two uncertainty. The continuing discrepancies among values found by different workers using

different methods are an inconvenience to the entire astronomical community, because the value of H enters into our determinations of masses and luminosities of distant objects, of the fraction of the closure density of the universe that can be present in ordinary baryonic matter, and many other things we would like to know. It is not clear that the issue will be firmly resolved in the near future, despite the ever-increasing rate of publications on the subject."

Includes a table of recently published (Sept. 1992-early March 1996) determinations of the Hubble constant.

Turner, Gerard L'E. An astrolabe belonging to Galileo? Nuncius, anno 12, fasc. 1, 1997: 87–92. illus., facsim.

"An unexceptional German astrolabe of 1537 (IC 262) has two curious features that could make it a striking document connected with Galileo Galilei, one of the world's greatest natural philosophers. The facts are straightforward. Having stated them, I then offer reasoned speculation, which others may develop or try to refute, to show that the astrolabe was modified in Florence and was owned by Galileo in the 1580s."

The astrolabe is in the collections of the National Museum of American History.

Upgren, Arthur R. Astronomy at Minnesota. *In* Proper motions and galactic astronomy. A small topical workshop at the University of Minnesota, Minneapolis, Minnesota, 12–13 December 1996, in recognition of its first 100 years in astronomy. Edited by Roberta M. Humphreys. San Francisco, Astronomical Society of the Pacific, 1997. (Astronomical Society of the Pacific conference series, v. 127) p. 3–11. illus., ports.

Viacheslav Mikhalovich Kovtunenko (1921–1995). Astronomicheski vestnik, t. 30, mart/apr. 1996: 189–190.

An English translation, "Vyacheslav Mikhailovich Kovtunenko (1921–1995)," appears in *Solar System Research*, v. 30, Mar./Apr. 1996, p. 166.

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Wilson, Peter R. Historical survey. *In his* Solar and stellar activity cycles. Cambridge, New York, Cambridge University Press, 1994. (Cambridge astrophysical series, 24) p. 9–24. illus., port.

Wolbarsht, Myron L. Contesting constellations. American scientist, v. 85, Nov./Dec. 1997: 500–501.

Letter commenting on some of the statements in A. A. Gurshten's article, "The Origin of the Constellations," published in the May/June 1997 issue, with Gurshten's response.

Wuttke, Dieter. Sebastian Brants Verhältnis zu Wunderdeutung und Astrologie. Sebastian Brant und Maximilian I.: eine Studie zu Brants Donnerstein-Flugblatt des Jahres 1492. *In his* Dazwischen; Kulturwissenschaft auf Warburgs Spuren. Bd. 1. Baden-Baden, V. Koerner, 1996. (Saecvla spiritalia, Bd. 29) p. 195–250. facsims.

Reprints, with supplementary references and comments, of papers first published in 1974 and 1976. The "Donnerstein-Flugblatt" examined in the second study reported the fall of the Ensisheim meteorite.

An extensive index at the end of v. 2 provides page references to discussions involving astronomy and astrology in other studies, and the bibliography of Wuttke's writings (also in v. 2, p. 769–789) provides details about earlier publication of reprinted essays.

Zanda, Brigitte, Roger H. Hewins, *and* Jean P. Bibring. Memorial: Paul Pellas (1924–1997). Meteoritics & planetary science, v. 32, Nov. 1997: 983–984. port.

Ziggelaar, August. Astronomie der Jesuiten nördlich der Alpen. Vier unveröffentlichte Jesuitenbriefe 1611–1620. *In* Historischer Verein Ingolstadt. Sammelblatt. 102./103. Jahrg.; 1993–94. Ingolstadt, 1995. p. 369–384. illus.

Translation by Ernst Goercke of an essay published (in English) in *Christoph Clavius e l'attività scientifica dei Gesuiti nell'età di Galileo*, p. 101–116 (Roma, Bulzoni editore, 1995). The text of the four letters, published (in Latin) in the cited book, is not included with the German translation of the essay.

R. S. Freitag
Library of Congress
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Essay review

Victorian Telescope Makers, The lives and letters of Thomas and Howard Grubb, by I S Glass (Institute of Physics Publishing, Bristol, 1997), xiii + 279 pp. ISBN 0 7503 0454 5, £25, hardback, 160 ×240 mm.

With his crude telescope, constructed in 1610, Galileo Galilei made many striking discoveries. With his findings and persuasion to investigate the laws of nature, he laid down the elementary concepts of modern experimental science. The invention of a telescope immensely enhanced our vision and awareness of the universe.

Astronomical telescopes have undergone enduring improvements in accuracy and optical sophistication so as to become the most important tool which permits astronomers exploration of the immense space of the tantalizing to us natural world. The aperture of the modern telescope's optic now reaches double digits in metres and optical lenses are replaced by optical mirrors of glass ceramic, with zero expansion coefficient. One pair or several telescopes can be connected by optical fibres to form a single combined image equivalent to an increased telescope aperture. Segmented thin mirror telescopes of 10 metre aperture are now assembled supported by innovative devices - the so-called 'active optic' where the primary, segmented mirror is supported on many points by computer operated alignments to correct for distortions of the mirror shape due to transfer of weight during changes in the pointing of the telescope. The recent introduction of 'adaptive optics' provides a corrected image, nearly free of distortions caused by Earth's atmosphere.

Visual observations with an eyepiece are seldom performed at present. Photographic plates, photocells, photomultipliers, television cameras, deep cooled charged Couple Devices, and computer sampling techniques have replaced the observer and allow speedy, high volume, and more reliable collection of data. Robotic telescopes are interfaced on-line to computers to exploit the immense potential of this technique in otherwise laborious and time-consuming data acquisition. The Hubble Space Telescope has proven its advantage in exploration of both deep-space and solar-system objects. Communications technology facilitates the transmission of commands and data to and from the space telescopes. Numerous space probes and orbiting satellites, operating at wavelengths not obtainable from Earth's surface, now can access the entire electromagnetic spectrum.

All current technological developments were easily and successfully achieved due to the steady improvement in telescopes and auxiliary equipment design.

This volume by Ian S Glass outlines the efforts of the Victorian nineteenth-century enterprise of Thomas and Howard Grubb, father and son, of Dublin, Ireland, to achieve excellence in their telescope making, specifically to equip telescopes with sturdy, durable mounting, providing the stability essential for pointing and tracking accuracy.

The author, who grew up in Dublin close to the Grubbs and their facilities, was astonished that so little had been documented about the work and high standard telescope-making firm of Thomas and Howard Grubb. Having access to extensive collections of the Grubbs' surviving correspondence he succeeds, through numerous quotations from their own letters and business replies, to present their struggles and triumphs and provide a perspective of their private lives.

The book's 279 pages and many illustrations begin with the author's acknowledgements for help received with the preparation of this volume and a forward by Patrick Moore. The lives and contributions of these celebrated telescope makers to produce worldwide so many and some of the largest and most famous telescopes of their time is given in another ten chapters, followed by three Appendices: A– Publications by T Grubb, B – Publications by H Grubb, and C – List of Grubb Telescopes.

Thomas Grubb (1800-1878), by nature an inventive person, abandoned his position as clerk in a Dublin house in favour of his hobby in optics. He was inspired in astronomy through his acquaintance with the Revd Thomas Romney Robinson, Director of Armagh Observatory, however other important people played an important part. In 1832, he constructed a small observatory and established an engineering business, producing machine tools and astronomical instruments, as well as cast iron billiard tables and beds. This unusual blend of activity led later to the typical strong, cast iron construction of the housing accommodating the telescope drive mechanism together with gears and drive sector and formed support for the polar axis. This type of assembly was a marked improvement in stability compared to previous designs. To relieve the friction between the moving parts, in the absence of ball bearings, different devices were applied without compromising the stability of the axial systems. 'The Equilibrated Lever' system of mirror support, the cell holding the primary mirror and minimizing distortion, was first applied by T Grubb. He also contributed to the development of engraving machines, microscopes with angle adjustment of the specimen illumination, and magnetometers to measure the strength of Earth's magnetic field. Thomas Grubb was highly interested in photography and patented camera lenses. Ireland and England experienced an inventive period with tools and manufacturing industry developing rapidly along with economic prosperity.

The production of a good telescope demands maximum precision in optical and mechanical accuracy. Exceptionally exact tools and uncommon machines to achieve this goal must be developed. This applies to grinding, polishing, and figuring of the glass optic as much as to the required mechanical tolerances. Most of the needed equipment was built in the Grubb Optical and Mechanical Works in Rathmines. Suitable optical quality glass discs of large diameter were not readily available to the Grubbs and extraordinary effort was required in manufacturing and testing the vital telescope objectives and mirror optics. Lens and mirror figuring was a laborious task due to bad quality glass and the inability at this time to produce homogeneous glass over large discs. Each time, with every new attempt, a new set of conditions not met before were experienced. Lens making was considered an art, dependent largely on the intuition and experience of the maker to improve on both spherical and chromatic aberration along with image quality.

The Grubbs built more refracting than reflecting telescopes, but were quite aware of the advantages of large mirror telescopes and the limitation in the production of larger optical objectives. The customers' demand was, however, directed more towards refractors at this time and for this reason they endeavoured to supply the astronomical community with these. In astronomical research, the telescope type used depends sometimes upon the specific aim of the investigations and the advantages which this telescope type offers.

After the retirement of his father and notwithstanding a high school and university education, Howard Grubb (1844-1931) had, by nature, rather a practical than theoretical aptitude and used to solve problems experimentally. He expanded the company quickly and was very busy, with the greatest turnaround occurring from 1880 to 1894. He was very inventive and manufactured telescope objective lenses of exceptionally-high quality. He improved considerably the accuracy and free movement of worm-screw and drive sector-arc by grinding the two together. The periodic error caused by eccentricity of the wheels of the clock drive was eliminated and a satisfactory slow motion, free of backlash was provided. Clamps in right ascension and declination, which did not change the setting position of the telescope when applied, were realized. Furthermore, he furnished facility for the focussing and alignment of the photographic plate-holder to be made perpendicular to and centred on the optical axis, as well as a better arrangement for attaching the objective on the opposite end of the tube. All such improvements contributed to better image quality and to a steady drive of the telescope during long exposures. For setting the guiding star in the field of view, a micrometer and cross-wire was employed, instead of a circular hole as used before and utilized microscopes for reading the setting circles from the eyepiece end.

With the advancement of photography and resulting application in astronomy, the Grubbs turned their attention to equip astronomers with telescopes suitable for astrophotography. Following a decision made in 1887 to map the entire sky photographically, the so-called *Carte du Ciel*, a standard photographic telescope of 33 centimetres aperture and 3.43 metre focal length was proposed. Since the early photographic emulsion was most sensitive to blue light, the Astrographic Telescope was built so as to give best performance at 4308 Å wavelength of the electromagnetic spectrum. Later, with the improvement of the photographic emulsion to be sensitive for the entire visual spectrum, the visually-corrected telescopes also became available for celestial photography.

With constant development, the advancement of astronomical telescopes and auxiliary equipment accelerated and diversified. A new type, the so-called Siderostatic telescope or 'polar refractor', was designed by Grubb. This is to some degree the predecessor of the Coudé focus configuration with telescopes used mainly for spectroscopy, but differs from the Coudé (elbow) telescope of Loewy in Paris. Heliostat steerable plain-mirrors mounted on top of observing towers to track the Sun and reflect its image for observation and spectroscopy down in a shaft where a fixed telescope arrangement was located, were built by Grubb. Also for long focus photographs of the Sun during eclipse events, to measure the deflection of light by gravity according to the Einstein theory of relativity, heliostats were employed to reflect the Sun's image in fixed telescopes mounted horizontally on Earth's surface. Heliometers, for accurate measuring of very small angles between celestial objects, were mounted on telescopes to be used during the transit of Venus expedition. Spectrographs, objective prisms, circle division machines, micrometers, numerous telescope domes and entire rising floors were a successful preoccupation of the Grubbs. At the end of his career, H Grubb preferred to build twin refractors and full worm-wheels instead of worm-sectors, to eliminate rewinding and provide for more even wear.

Hopes for even larger telescopes were maintained for the future by H Grubb and the use of reflectors was proposed. A schema for a large reflector with a primary mirror constructed of speculum metal mounted in a telescope tube and enclosed in a spherical segment to be supported by water flotation, was outlined. Proposal for an extremely large, fixed reflector telescopes with an equal diameter steerable flat mirror were discussed but found not realistic.

Consecutively with the famous 27-inch refracting telescope of the Vienna Observatory in Austria, the Transit of Venus expedition telescopes as well as the *Carte du Ciel* Astrographic telescopes, there are short accounts given in the book of many notable telescopes made by the Grubbs. The list of Grubb designed, improved, or entirely newly built telescopes with apertures from 3-inch to 48-inch (the Great Melbourne Telescope with speculum mirrors) and located in different parts of the globe exceeds 120.

Howard Grubb invented for use in the gun turrets of battleships an outstanding device, a type of periscope. Later he improved on its design to be used with submarines. It is claimed that that he supplied 95% of the British submarine periscopes during WWI.

But there were also difficult years in the life of H Grubb with labour troubles and strikes and telescopes remaining unfinished during the war period. The factory was moved from Dublin to the Fleet Works, St. Albans (Hertfordshire, England) to avoid threat by German submarines in the Irish Sea. After the war it became evident that their financial position had become more critical and the established firm of Sir Howard Grubb and Son Ltd., St. Albans, went into voluntary liquidation and was subsequently sold. In 1925, Sir Charles A Parsons, youngest son of Lord Rosse, purchased from the liquidator the Grubb enterprise and a new company trading as Sir Howard Grubb, Parsons and Co. was formed and workshops were erected at Heaton, Newcastle-on-Tyne. There the Pulkovo solar spectrograph and the Simeis reflector for Soviet Russia were completed. Unfortunately, this firm discontinued manufacture of astronomical equipment in 1985.

The Grubbs were prominent in the scientific community in Ireland and England and attained worldwide recognition for their contribution to telescope technology. They both were elected Fellows of the Royal Society, London, with Howard being knighted in 1887.

I have had the opportunity to use the Vienna 27-inch refractor, the largest in the world when commissioned, also the 13-inch Astrographic telescope of the Perth Observatory at Bickley, Western Australia. Both, with slight improvements, are still in continuous use as evidence of their durable construction and superior quality of workmanship.

The book is well presented and makes for pleasant reading and is certainly of historical value for astronomers, telescope makers, students of technology and science, and surely for anyone with curiosity about the achievements of the past century..

Looking to past achievements can help us to meet the future with greater confidence.

Ivan Nikoloff

Review

Astronomy before the Telescope, edited by Christopher Walker (British Museum Press, London), 352 pp. + 20 colour plates, ISBN 0-7141-1746-3, £25.00, hardback, 195 × 250 mm.

Nineteen authors (including the editor) conduct the reader back in time to most areas of the world, which still leave some areas and cultures to be researched, and some excluded from the book for one reason or another. Astronomy and/or astrology do not go back as far in time as some mythological concepts, such as those of the Australian Aborigine, who had not developed the art of written records before the arrival of Europeans on the continent during the seventeenth century and permanent European settlement at the end of the eighteenth century. This same unfolding of information applies to the bulk of the continent of Africa.

The volume is divided into a Foreword by Patrick Moore and seventeen chapters, the last of which deals with the ancient recorded observations and their application in modern astronomy. The other sixteen chapters are devoted to geographic regions, races, periods, cultures, or religions so that some cross referencing is necessary for they are in themselves separate entities. 'Astronomical records' prior to 1609 can be broadly divided into six groups: archaeological, visual observations, instruments, agricultural/calendar, mathematical interpretations of observations, and cosmological/mythological ideas all of these are covered in this volume.

Beside the one hundred plus excellent illustrations and twenty colour plates, there are eleven maps for ten of the chapters which make it so much easier to visulize the locations about which the author is writing. There is a good index which details the various aspects of the book, although I found difficulty with the use of continuous figure numbers when I started looking at the page number instead (if all else fails, read the instruction manual). The extensive bibliographies to be found at the end of each chapter are most useful, and those readers not greatly familiar with the subject will find them very useful.

The first essay describes archaeoastronomy in Europe, which, like the Great Pyramid, suggest an association with astronomical objects, but no practical applications. This is followed by the Egytpian contributions to our knowledge of a 365-day year and a 12-hour day and night. They were amongst the first to use astronomical phenomena for practical purposes – agriculture. Two thousand years of Mesopotamian astronomy are succinctly covered, despite the mathematical nature of its contribution to future generations of Greek philosophers. The latter are covered in two essays on pre- and post-Ptolemaic astronomy, when celestial phenomena were studied in a scientific fashion. The part played by the Romans is considered briefly in their ability to spread existing knowledge.

Four essays are devoted to European astronomy – archaeological, Middle Ages, Renaissance, and pre-telescopic instruments – occupy a quarter of the book and give an erudite summary of our present knowledge of the area's astronomical history and heritage.

The remaining six essays are of geographical or religious disciplines. David King in his essay on Islamic astronomy starts with, "From the ninth century to the fifteenth, Muslin scholars excelled in every branch of scientific knowledge. In particular their contributions to astronomy and mathematics are impressive". Impressive is the word to describe the work carried out by Muslin scholars in the three sides of the Mediterranean Sea. Indian, Far East, American, African, and Australasian astronomical concepts are considered in the remaining six essays. It is a pity that more space could not have been devoted to such a large part of the globe, perhaps some other publisher will take up the task of welding together authorities on their parts of astronomical history.

Astronomy before the Telescope is a book which can be picked up for a short reading session without loosing the thread, and for an abstract of the book, Patrick Moore's Foreward is excellent. At the end of his forward, he gives the rationale behind the book "It was designed to complement the range of the British Museum's own archaeological and historical collections, and to look beyond mathematics and trigonometry to the contemporary cultural milieux and the surviving material remains." This it does.

John Perdrix

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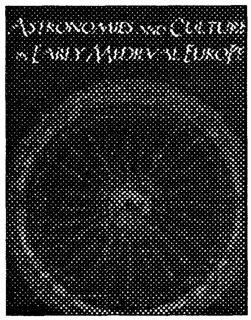

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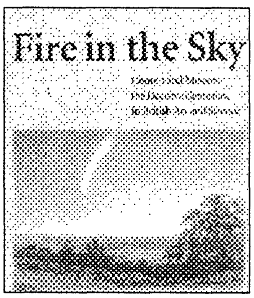

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Cover illustrations show a series of images of the η Carinae area beginning with a drawing by John Herschel published in 1847, a black and white photograph taken by Ben Gascoigne with the MSSSO 40-inch reflecter at Siding Spring, a colour photograph taken by David Malin with the AAO 150-inch at Siding Spring, and a view taken with the Hubble Space Telescope, courtesy J Morse (U. CO), K Davidson (U. MN), and NASA.