W. F. Denning: In Quest of Meteors.

Martin Beech, Campion College, The University of Regina.

Abstract: In this article we continue our look into the life and works of William Denning. We now focus our attention towards his contributions on meteor astronomy, and consider his observational methods.

1. Introduction:

In the course of its orbit around the Sun the Earth encounters a multitude of meteoroid streams. About a dozen of these streams produce strong and reliable meteor showers, each year, at the present epoch. When a meteor shower is active the meteor rate from a localized section of the sky is enhanced over that of the so-called sporadic background.

The sporadic background is the average number of meteors that a visual observer might see on any given night of the year irrespective of shower activity. The sporadic rate does vary with the time of day and the season, but for visual observers the rate is typically about eight to ten meteors per hour on a clear moonless night. A meteor shower is deemed to be active if it can be unambiguously distinguished above the sporadic background level [1].

In 1864, the Reverend Charles Pritchard reviewed the state of meteor astronomy for the RAS and noted [2], "it is to amateurs in astronomy especially that we must look for assistance in this interesting branch of celestial mechanics: these mineral fragments, these celestial rockets, this fiery dust from the lathe of the Omnipotent Worker, will furnish to him the correlative to that which the naturalist so fondly traces in the organic regions of creation - all space teeming with life - beauty, order, scattered on all sides with a lavish hand - yet everywhere, and in all things, amenable to the control of law." Pritchard's comments seem, in retrospect, to be almost tailor-made for Denning. Indeed, circa 1860 meteor astronomy was primed and waiting for an enthusiastic and dedicated observer to appear on the scene - Denning was destined to be the observer required.

2. The Quest Begins:

According to an interview [3] Denning gave to Tit Bits magazine in 1895, it would appear that he first turned his “full time” attention to astronomy in the mid-1860s. In the same article Denning also commented, "I have witnessed some wonderful phenomena, and amongst these I should regard as the best the transit of Venus in December, 1882; the great meteoric showers of November, 1866, 1872, and 1885." From the earliest times, therefore, it appears that Denning was interested in observing meteors. Since Denning's initial interests were many and varied, however, he only slowly turned to the full time study of meteors and meteor showers. Denning's first few notes on meteors reflect this situation in the sense that they are merely matter-of-fact accounts of observing sessions. During the 1870s, however, Denning developed a more intensive and directed meteor-observing program.

Denning's first radiant catalogue was published [4] in the MNRAS. This catalogue was based on "nearly 900 shooting stars" observed from Bristol between 1872 and 1876. A total of 27 meteor radiants were derived from the data set by "penciling the courses [of the meteors] on a Cary's 18-inch globe, and prolonging them backwards, the average places of convergence being selected as the approximate areas of radiation." (We shall have more to say on Denning's reduction methods shortly). A second article, also published [5] in 1876, gives some indication of Denning's dedication to observing at that time. He wrote, "Between October 13 and November 28, watching for forty-nine hours, I observed 367 shooting stars, 306 of which were well seen and their paths registered." Given the typically poor weather in Britain during the autumnal months, Denning must have been observing at virtually every opportunity to collect so many hours of observations.

Denning's observational intentions were made clear in an article published in 1879. He explained, "In March, 1876, I commenced a series of watches for shooting stars, and have continued them to the present time; the result of the two years' work being that I have observed 3,749 of these bodies in 368 hours of work. My chief object all through has been to discover as many new systems as possible and to get the radiant points with accuracy.”[6] This approach was typical of Denning's observing philosophy, and we find echoes of this ideology appearing in his Telescopic Work For Starlight Evenings (published in 1891). There he comments, "Nearly all the most successful observers have been men of method. The work they took in hand had been followed persistently and with certain definite ends in view. They recognized that there should be a purpose in every observation.” [7] He further noted, "It need hardly be said, however, that every difficulty may be surmounted by perseverance, and that a man's enthusiasm is often the measure of his success, and success is rarely denied to him whose heart is in his work." The benefits of adopting such an approach to observing soon paid dividends for Denning, and his first genuinely new contribution to meteor astronomy was announced in 1877, in a short article [8] published in the journal Nature. Denning's important announcement was concerned with observations of the radiant of the Perseids.

The Perseid meteoroid stream is an annual meteor shower that returns each August. The stream also produces a steady display of meteors over several nights [1]. For such 'long lived' meteor showers it had been predicted that the radiant point should show a night by night shift in its position with respect to the background stars. This shift is due to the Earth's movement through the stream. Through his accurate and near continuous observation of meteors in the summer of 1877, Denning was able to not only show that the Perseid meteor shower first commenced activity in early August, but that its radiant point shifted across the sky as predicted. Denning continued to monitor the Perseid stream for many more years, and in 1884 published [9] a complete review of his observations.

In addition to making his own observations Denning also worked with data obtained by other observers. In 1877, for example, Denning published [10] a radiant catalogue from data collected by Captain George Lyon Tupman between 1869 - 1871. Tupman's observations amounted to about 300 meteor trails, from which Denning derived 20 radiants. A year later (1878) Denning published [11] another radiant catalogue. This time the catalogue was based upon observations collected by several Italian observers in 1872. Denning projected 4,143 meteor trails from the Italian observations, and found 315 radiant points. Denning was clearly spending a large amount of time on meteor reductions in the late 1870s. A measure of Denning's commitment can be found in an 1897 article published [12] in the Bristol Naturalists Society Proceedings. He comments, "The number of meteors actually projected by me on star charts, including those observed and those selected from published catalogues, reaches over 10,000; but, in addition to this, the paths of fully 20,000 others were examined." Denning believed that his observations and reductions indicated the existence of at least several hundred annual meteor showers. This number is an overestimate, in modern terms, of the actual number of annual meteor showers by a factor of about 4 or 5. We shall see later, however, that Denning's estimate of the number of active meteor showers was to become even more extreme. At the present time it is believed that there is good evidence to support the existence of some 50 to 60 annual meteor showers. It is important therefore to explore the reasons why Denning believed that so many meteor showers existed.

Denning's belief in the existence of many hundreds (and later, circa 1900, many thousands) of meteor radiants is an example of what might be called the Philosophical Parallel [13]. That is, Denning was led to his erroneous conclusions by the unquestioned acceptance of a theoretic paradigm that in reality was untrue. The modern day meteor astronomer now knows that probably only 10 to 30 per cent of the observed meteors actually belong to well-defined meteoroid streams [14]. What this means is that the vast majority of observed meteors cannot in fact be traced to common radiant points. This principal while clear to modern astronomers was not, however, known to Denning or his contemporaries. They believed, in contrast, that all meteors could be traced to a radiant point, and that each radiant point could probably be associated with the orbit of a comet. The paradigm under which Denning operated was that all meteors could be traced to a radiant. In modern terms a meteor shower is deemed to be active if at least four meteors can be unambiguously associated with a radiant during the course of one night's observing session (i.e., within a time span of some six to eight hours) by a single observer. Denning would on occasion deem a shower to be active on the basis of observing just one meteor per night.

Working in the late 1840s to early 1860s, Edmund Heiss and co-workers distinguished between the periodic meteors, which they believed returned in yearly showers, and those which fell outside of the times of yearly activity [15]. These later non-periodic meteors were called sporadic or wandering meteors. More extensive analysis by A. S. Herschel, and Denning began to indicate, however, that more and more periodic meteor showers existed. Consequently it was believed that fewer and fewer meteors were actually sporadic. Denning, and Herschel found few sporadic meteors, of course, because they believed that all meteors could be traced to radiants. In 1885, Denning was to write [16] of sporadic meteors "the term hardly seems to me a commendable one, though undoubtedly useful to cancel our ignorance of the contemporary streams supplying meteors unconformable to any special display that may be under observation." Norman Lockyer also commented [17] on sporadic meteors in his book, The Meteoric Hypothesis (published 1890), and exclaimed that, "the term sporadic [is] simply a measure of our ignorance." To this he added, "with every new radiant thus established the number of sporadic meteors naturally become less and less." The reason that Denning found so many radiants, therefore, is explained on the basis that he believed every meteor issued from an active radiant. The vast majority of his radiants, however, where chance groupings in what we now call the sporadic background.

The crowning achievement to Denning's study of meteor radiants was the publication, in 1899, of his General Catalogue. This catalogue was not only a summary of Denning's observations, but was a summary of the collected observations of many other observers. The catalogue contained information on 43,647 radiants, and Denning commented that, "the total number of projected meteor-paths from which they were determined is approximately 120,000.” [18] Denning's catalogue was a monumental work, but even so he did not claim that it was complete, he merely believed that it, "includes the bulk of such radiants as have hitherto been published." Denning further suggested that, "there are considerably more than 50 showers in play on any and every night of the year, and, moreover, certain (in fact the great majority) of these are not confined to limited periods, but extend their activity over several weeks, and in some cases over several months." As we explained earlier Denning's belief in the existence of many shower radaints is unfounded in reality, and virtually all of the radiants listed in his catalogue are spurious. This is not to say, however, that Denning's catalogue is of no contemporary value. Certainly all the major, and lesser meteor showers are included within its pages, and it is likely that there are some weaker showers in the catalogue that do exist, but have not been confirmed as such to date [19].

3. Observing Conditions and Methods:

Having discussed the main achievements and problems associated with Denning's work on meteor radiants, it is worth saying a few words about where Denning was observing from. We should also discuss his observing methods and philosophy since how an astronomer observes is just as important as what an astronomer observes. It is clear from his many works that Denning was a man of method. Indeed, he held this principle highly. Writing in his *Telescopic Work For Starlight Evenings* Denning noted that "if the 100 hours of exceptionally good seeing [in England],..., are to be profitably employed, we must be continually prepared with a scheme of systematic work.” [20]

Some insight into how Denning collected his observations can be gleaned from his meteor catalogue of 1890. There he explained, "my plan of working may be briefly described as follows:- All the observations were made in the open air and from the garden adjoining the house. Attention was almost invariably given to the eastern sky. In mild weather I sat in a chair with the back inclined at a suitable angle; but on cold, frosty nights I found it expedient to maintain a standing posture, and sometimes to pace to and fro, always, however, keeping the eyes directed towards the firmament in quest of meteors.” [21]

Working from an urban, Bristol back-street garden was probably not as problematic in Denning's day as it would be now [22]. This being said, however, Denning's garden was far from an ideal observing site and one can find occasional references to this fact in his observing journals. He noted [23] on one night, for example, "Depiction bad through smoke from adjoining chimneys." In spite of such drawbacks Denning recounted in one interview [6] that, "I have sometimes watched from my garden for meteors for ten or eleven hours continuously.... The hours spent in this way have been intensely enjoyable. Amidst the trees and shrubs in the garden, solitary and with no sheltering canopy but the sky above, I have rarely experienced a feeling of loneliness or nervousness, or have had to make an effort to continue work."

The manner in which Denning recorded his meteor data was innovative, yet simple. His main observing aid was a straight stick, or wand [24]. Held at arms length, he used the wand to 'fix' the meteor’s path across the sky. Then, by making a mental note of the star fields through which the meteor had passed he marked its corresponding trail on an 18-inch celestial globe [25]. The time, magnitude, appearances, and position of the meteor where then recorded. Again, from Denning's 1890 radiant catalogue [21] we learn, "at the end of each period of observation I finally discussed the materials collected and deduced the radiants. In some instances a very definite little shower would be manifest from a single night's work, but I generally found it advisable to combine the paths recorded on several dates in order to obtain satisfactory positions." The pooling of data over several nights, to 'bring out' meteor radiants was common practice prior to the early years of this century. Indeed, in the very earliest of meteor radiant catalogues data would be pooled over several weeks, and on occasion months. As our earlier discussion on modern methods of radiant reduction explained, however, a reliable radiant can only be deduced from meteors observed on the same night. The pooling process was a major factor in Denning's erroneous detection of stationary radiants. This was so because such a process considerably enhances the chances of finding a radiant within the sporadic background [26].

With regard to his reduction procedures Denning fell into a situation against which he had warned in his

Telescopic Work For Starlight Evenings. In chapter 4 of his text Denning considered "Notes on Telescopic Work", and remarked [27] "a person who relies upon guidance from prior experimentalists will probably make rapid headway... The want of this foreknowledge has often been the main cause of failure, and it has sometimes led to misconceptions and imaginary discoveries." To this he later added "let every observer judge for himself to a certain extent and let him follow original plans whenever he regards them as feasible. Let him test preceding results whenever he doubts their accuracy... An observer should take the direction of his labours from previous workers, but be prepared to diverge from acknowledged rules should he feel justified in doing so from his new experiences.". Denning did not strongly question the radiant reduction procedure because as far as he was concerned it was correctly placing all the observed meteors in one group radiant or another. His working hypothesis being, as we saw earlier, that all meteors are derived from well-defined meteoroid streams with group radiants. It was only during the first few decades of this century that meteor astronomers began to seriously question the concept of pooling meteor observations [28].

4. A. S. Herschel and Meteor Theory

The early years of Denning's meteor observing career were nurtured by Alexander Stewart Herschel (1836 - 1907). Herschel was then one of Britain's foremost authorities on meteor astronomy, and he was a prominent member of the Luminous Meteors Committee which reported to the British Association for the Advancement of Science. Denning's first contact with Herschel was prompted by the appearance of a bright fireball seen on the night of November 6th, 1869. At that time Denning was 21 years old, and Herschel 43. A steady correspondence developed between the two observers, and the surviving letters clearly indicate that an extensive dialogue on meteor astronomy took place [29]. In the early letters, Herschel was the more experienced meteor observer, and through his office with the Luminous Meteors Committee he encouraged Denning to submit his observations for the yearly reports. Denning acknowledged his great gratitude to Herschel in 1907 when writing his obituary account for the journal Nature. Denning noted [30], "the writer of this notice will always have reason to be grateful to him [Herschel] for kind encouragement, advice, and instruction in the early years of his observing career."

Denning and Herschel pursued a campaign of systematic meteor observations. Indeed, the greater bulk of extant correspondence between Herschel and Denning is concerned with observations of meteor paths and the exchange of meteor observing notes.

Denning and his collaborators were interested in the determination of meteor heights for several reasons. Firstly, knowledge of a meteor's beginning and end height offers important information about the meteor ablation process, and second the true path of a meteor can be used to estimate the initial velocity with which the meteoroid entered the Earth's atmosphere.

Systematic timing errors led early meteor astronomers to the belief that the majority of meteoroids entered the Earth's atmosphere with so-called hyperbolic velocities. The apparent observation of very high velocities was significant since it implied that the meteoroids had an origin from outside of the Solar System. This implication followed since basic orbital-motion theory imposes an upper limit to the velocity that an object can have and still remain in a bound orbit about the Sun [31]. We now know (from radar and photographic studies) that virtually all meteors are produced from meteoroids moving along bound, elliptical orbits – although there are indeed interstellar meteoroids. It took meteor astronomers some time to resolve the hyperbolic velocity problem [1], but since Denning was not a major player in the debate we do not follow its course here.

Towards the end of the nineteenth century astronomers and physicists began to question the physical processes that accompanied the appearance of meteors [32]. The first real attempt at a detailed theory of meteoroid ablation was that presented by F. A. Lindemann and G. M. B. Dobson [33] in 1922. Since the structure of the Earth's atmosphere was completely unknown in the regions where meteoroids ablated (about 80km), Lindemann and Dobson used data compiled by Denning to show that the density of the Earth's atmosphere was much higher than had previously been thought. Denning's height and velocity data was used since it was deemed to be both the most accurate and the most extensive data set available.

Denning was never truly bothered with the physical details of meteor ablation theory, although he did discuss the topic with A. S. Herschel on several occasions. Writing on December 28th, 1872, for example, Herschel explained to Denning that there was "no possibility of any bolide-looking meteor being of atmospheric origin." As we have discussed in previous installments, the idea that meteors might result from the ignition of gases collected in the Earth's upper atmosphere was essentially due to Aristotle. The correctness of Aristotle's ideas on meteor origins were first seriously questioned by Edmund Halley in 1714, but it was not until 1794 that Ernst Chladni was able to show that the ideas were most probably wrong. What Halley suggested, and Chladni was able to confirm was that meteors, fireballs, and meteorites were essentially one and the same phenomena [1]. Chladni correctly reasoned that meteors were caused by solid objects (what we now call meteoroids) hitting the Earth's atmosphere.

Denning did not write extensively on either meteorites or meteorite falls, although he did own at least one meteorite sample. The fragment in Denning's possession had been presented to him by Mr. J. T. Ward, Director of the Wanganui Observatory, in 1909 and was a piece of the Mokoia meteorite which fell in New Zealand on November 26th, 1908. Clearly fascinated by the meteorite Denning wrote, "it is interesting, after a person has habitually watched the luminous careers of these bodies during many years, to hold a similar object in one's hand and contemplate it from a much nearer point of view!" [35]

Towards the close of his life, meteor astronomy had in many ways out-stripped Denning in both its development and requirements. Denning literally became the 'old guard' of meteor astronomy, and his influence waned. Perhaps ultimately, however, it was Denning's continued belief in stationary radiants that compromised his later astronomical career [26].

References:

[1] Several good texts on meteor physics are available, and that by A. C. B. Lovell, Meteor Astronomy, The Clarendon Press, Oxford, 1954., can be recommended as a detailed guide. D. W. Hughes', The History of Meteors and Meteor Showers, Vistas in Astronomy, 1982, 26, 325 - 345 is also highly recommended. A general discussion of meteor showers may be found in G. W. Kronk's, Meteor Showers: A Descriptive Catalogue. Enslow Publishers, Aldershot, 1988.
[2] Pritchard, C. 1864, Monthly Notices of the Royal Astronomical Society, 24, 139.
[3] Experiences During thirty years Star Gazing, in Tit Bits magazine, August 31st, 1895.
[4] Denning, W. F. 1876, Radiant-Points of Shooting Stars, Monthly Notices of the Royal Astronomical Society, 36, 283 - 285.
[5] Denning, W. F. 1876, Radiant Points of Shooting Stars, Nature, 15, 158.
[6] Denning, W. F. 1879, Shooting Stars, in Proceedings of the Bristol Naturalists Society, 2, 264 - 278.
[7] Denning, W. F. 1891, Telescopic Work for Starlight Evenings, Taylor and Francis, London., p. 78.
[8] Denning, W. F. 1877, The Radiant Centre of the Perseids, Nature, 16, 362.
[9] Denning, W. F. 1884. The Long Duration of Meteoric Radiant Points, Monthly Notices of the Royal Astronomical Society, 45, 93 - 116.
[10] Denning, W. F. 1877, Radiant Points of Shooting Stars. From Captain Tupman's unreduced Observations 1869 - 71. Monthly Notices of the Royal Astronomical Society, 37, 349 - 351.
[11] Denning, W. F. 1878, Radiant Points deduced from the Paths of 4,143 Shooting Stars observed by the Members of the Italian Meteoric Association in the year 1872. Monthly Notices of the Royal Astronomical Society, 38, 315 - 317.
[12] Ref. 6., p. 271. It is one of those sad ironies that virtually all of Denning's hard work on meteor trail projection is of little contemporary value.
[13] That meteors were once thought to be observable in the Moon's supposed atmosphere is another example of the philosophical parallel.
[14] Hughes, D. W. 1990, Monthly Notices of the Royal Astronomical Society, 245, 198 - 203.
[15] Phipson, T. L. 1867, Meteors, Aerolites, and Falling Stars, p. 160 - 161. Lovell Reeve, and Co, London.
[16] Denning, W. F. 1885, The Great Shower of Andromedes, November 26, 27, 28, and 30, 1885. Monthly Notices of the Royal Astronomical Society, 46, 67.
[17] Lockyer, J. N. 1890, The Meteoritic Hypothesis, Macmillan and Co., London. p. 135.
[18] Denning, W. F. 1899. General Catalogue of the Radiant Points of Meteoric Showers and of Fireballs and Shooting Stars observed at more than one Station. Memoirs of the Royal Astronomical. Society, 53, 203 - 292.
[19] Hawkins, G. S. 1958, Catalogues of Meteor Radiants. Smithsonian Contr. Astrophys., 3, (2), 7 - 8.
[20] Ref. 7 p. 68. Denning's estimate that only 100 hours of good seeing is available to British observers follows the earlier remarks on the same subject by Sir William Herschel.
[21] Denning, W. F. 1890. Catalogue of 918 Radiant Points of Shooting Stars Observed at Bristol. Monthly Notices of the Royal Astronomical Society, 50, 410 - 467.
[22] Denning did claim that the skies were sufficiently clear over Bristol that the aurora could be plainly seen on many nights (Nature, 33, 1885, 152). Suffice it to say here that this claim is quite impossible.
[23] Only one of Denning's meteor observing note books appears to have survived to the present day. This journal, which contains his observations for the year 1922 is held in the Denning archive of the British Astronomical Association's Meteor Section. Several other note books have survived, but these contain various planetary, and meteor observations along with newspaper and journal cuttings.

[24] Many aids for visual meteor observing have been developed over the years. James Challis of Cambridge University Observatory, for example, designed a Meteoroscope to observe the 1866 Leonid meteors (Monthly Notices of the Royal Astronomical Society, 27, 1867, 75 - 77). This was the forerunner of Denning's 'meteor-wand', and consisted of a pointer mounted on a tripod. The idea was to use the pointer to 'mark' the altitude and azimuth positions of the beginning and end points of a meteor's train. Later, Ernst Opick was to advocate the use of wire grids, or reticules (National Academy of Sciences, 18, 1932, 16 - 23) to record meteor beginning and end points. Other observers have suggested the use of a flexible string, or wire to aid in identifying meteor paths (see, for example, Prentice, J. P. M, 1948, Memoirs of the British Astronomical Association, 36, (2), 107). Such aids are not in common use today, and observers tend to simply mark observed paths on specially drawn star charts.

[25] Denning's celestial globe was donated to the Royal Astronomical Society's archive in 1942 (Quarterly Journal of the Royal astronomical Society, 27, 1986, 212 - 236), and can be found in the societies library. The fate that befell Denning's several telescopes is not so clear. It is likely that they may no longer exist as functioning instruments.

[26] Beech, M. 1991, The Stationary Radiant Debate Revisited, Quarterly Journal of the Royal Astronomical Society, 32, 245 - 264.

[27] Ref. 7, p. 66. Denning's views on the education, and instruction of novice astronomers are further explored in chapter 3.

[28] Olivier, C. P. 1925, Meteors, Williams and Wilkins, Baltimore.

[29] Beech, M. 1992, The Herschel - Denning Correspondence. Vistas in Astronomy, 34, 425 - 447.

[30] Denning, W. F. 1907, Professor A. S. Herschel, F.R.S, Nature, 76, 202 - 203.

[31] The constraints on orbital dynamics are explained, for example, in J. C. Brandt and R. D. Chapman's Introduction to Comets (1981, Cambridge University Press, Cambridge) p. 61 - 65.

[32] A summary of the early work on meteor physics is given by Opick, E. 1958, Physics of Meteor Flight in the Atmosphere. Interescience Publishers, Inc, New York.

[33] Lindemann, F. A., and Dobson, G. M. B., 1922. A Theory of Meteors, and the density and Temperature of the Outer Atmosphere to which it leads. Proc. Royal Society, 102, 411 - 437.

[34] Halley's early discussion on meteor origins are further explored in Beech, M. Halley's Meteoric Hypothesis, The Astronomy Quarterly, 7, 1990, 3 - 18.

[35] Denning, W. F. 1909, Fall of an Aerolite in Mokoia, New Zealand, on November 26, 1908. Nature, 80, 128. It is not clear what happened to the sample that Denning received. Inquiries to the City Museum at Bristol have revealed that it was not donated to their collection (Clark, R. D., Assistant Curator, Geology, 1991. Personal communication).