The Life and Times of John Rand Capron (1829-1888)

Paul Fuller

Solent Amateur Astronomers &
Society for the History of Astronomy

Although he was interested in a wide variety of natural atmospheric and astronomical phenomena John Rand Capron was most well-known to the general public for his auroral research and his promotion of 'Rainband' spectroscopy. He contributed more than 100 letters and articles to the science books and journals of the 1870s and 1880s, was a Fellow of the Royal Astronomical Society from 1877-1888, becoming a Council Member in 1883, and was a Fellow of the Meteorological Society. He wrote three books: *Photographed Spectra* (1877), *Aurorae: their characters and spectra* (1879) and *A Plea for the Rainband and The Rainband Vindicated* (1886).

Fig. 1 Photograph of John Rand Capron
Copyright, The Guildford Institute

Introduction

John Rand Capron fits a well-established stereotype of the 'grand amateur' gentleman scientist of the late Victorian period. Despite his parents' 'trade' background Capron rose above this, rapidly establishing his niche in the study of the aurora borealis. He was particularly interested in spectroscopic investigations of the principal auroral line and as a result of this work he was respected by many of his astronomical contemporaries. His rise to fame owed much to his association with Charles Piazzi Smyth, the Astronomer Royal for Scotland. Capron wrote about a wide variety of astronomical and meteorological subjects, but the highlights of his regrettably brief scientific life were probably his analysis of the 'auroral beam' observations of 1882 and his lecture to the British Association in 1883.

Early Life

Capron was born in King (now Rufus) Street, Hoxton Square, Shoreditch, London, on 19th February 1829. He was the son of Maria and John Anthony Capron, a leather merchant living at 23 Bishopsgate Street Without. He was baptised at nearby St. Leonard's Church on 3rd March and a year later his brother Edward was born. A sister, Suzannah, followed in 1838.

Little is known about John Rand Capron's life in 1830s London but we do know that he was attending lectures and demonstrations at the Polytechnic Institution in Regent Street. In his second book *Aurorae: their characters and spectra*, Capron refers to 'vacuum experiments', which were 'dear to my boyhood'.[1] The Polytechnic opened on 6th August 1838 and the experiments Capron recalled nearly 40 years later included Michael Faraday's demonstration that he could create an auroral-like phosphorescent glow by passing an electrical current through an evacuated glass tube.[2]

The Move to Guildford

According to the 1841 Census John Rand Capron was attending the Royal Grammar School at Guildford when he was lodging with his uncle John Rand. It is likely that Capron's parents decided to move him to Guildford because this small country town was considered a far healthier place to live than London, where often fatal diseases like cholera were endemic.

John Rand was a country solicitor living at 55 Quarry Street, opposite St Mary's church and overlooking the River Wey. He was a freeman of the borough, had been Conservative Mayor of Guildford in 1827, 1834 and 1835, and was an upwardly mobile businessman who had been involved in major schemes such as the introduction of gas to the borough (1824) and the River Wey Navigation.[3] At various times, John Rand was Town Clerk, Coroner and Clerk of the Peace for the Borough. Rand would also be a key player in bringing the railway to Guildford in 1845.[4]

In 1844 John Rand Capron's life changed forever when he suffered a severe attack of typhoid fever. This potentially fatal disease is caused by eating food or drinking water infected with *Salmonella enteric*. A local doctor, Henry Sharp Taylor, lent Capron a compound microscope and the recuperating Capron quickly developed a keen interest in the study of fossils and minerals.[5] Capron's search for knowledge was encouraged by his uncle's membership of the Guildford Institute. It is likely that his exposure to the scientific controversies of the day was also encouraged by his headmaster, the Rev. Charles Joseph de Belin, a graduate of New College, Oxford, who was also a member of the Guildford Institute.[6]

In 1845 Capron was articled to John Rand and in 1850 he entered into partnership with him. When John Rand died on 3rd April 1854 Capron took over the family business and on 13th April he replaced Rand as Borough Coroner and Clerk of the Peace. Capron married Fanny Niblett, the daughter of his uncle's late business partner Charles William Niblett, on 17th June 1856. Their only son John was born in September 1858 but he sadly died in February 1860.

Great Expectations

In June 1862 the Caprons became the major beneficiaries of their aunt's will. Susannah Sarah Jenkins Rand left John and Edward over £ 3,333 each – about £ 140,000 in today's money.[7] It was this legacy that enabled Capron to build his home *The Loquats* on

Fig.2 *The Loquats*, Capron's home in Guildford
Photograph by the author

Guildown Road on the south-west of the town. The house was completed in January 1867 and Capron soon established an astronomical observatory which eventually contained three telescopes and a variety of scientific instruments. He also began making astronomical and auroral observations from nearby Booker's Tower.[8] By now Capron had gone into partnership with Richard Sparkes, a graduate of Marlborough College. The partnership proved very convenient for Capron as it released him from the pressure of ordinary work. His new-found wealth and growing interest in science meant that in May 1867 Capron resigned his position of Borough Coroner. The partnership Capron and Sparkes flourished and survives to this day as the firm of Barlow Robbins with 180 employees.

Fig.3 Booker's Tower, Guildford
Photograph by the author

Sunspots and Aurorae

Capron was fascinated by all kinds of natural phenomena but he developed a particular interest in the aurora borealis after witnessing stunning displays over Guildford in 1870 and 1872. On Saturday 24th September 1870 he observed two large sunspots which were visible through a dark glass without any magnification. He examined the spots using his 8¼-inch Browning reflector, noting that the spots exhibited '... many curious details' with 'penumbrous margins and "luminous bridges"...'. That same evening he observed a 'very fine display' of the aurora:

> About half-past nine, I noticed a beautiful auroral arch of silver light under Ursa Major, from which arch at times brilliant streams of light flickered up to the zenith. About ten o'clock a cloud or patch of crimson light formed at the eastern end of the arch, and would, if taken alone, have induced the belief that a large fire was raging over the old castle as seen from the Mill Mead. Not many minutes after, vivid streaks of light with crimson patches of intense colour rushed upwards and spread overhead.
>
> These appearances extended round to the west and south-west (with the crimson colour still very prominent) and ceased about half-past 10. The contrast between the illuminated portion of the sky and the opposite parts was very remarkable, the latter seeming an indigo-black by comparison, though the stars were shining brightly all the time.[9]

Capron observed a second aurora on 24th October and the following day he wrote to both the *Surrey Advertiser* and *Nature* to describe the phenomenon.[10] Using a small 5-prism direct vision spectroscope Capron described two prominent bright spectroscopic lines – one flickering eerily in the green and one in the red. Capron pointed out that 'probably due to differences in temperature or pressure' both lines did not quite agree with those produced in a vacuum tube.

History repeated itself in 1872 when Capron's was lucky enough to witness an auroral corona form directly above him. His description in *Nature* is particularly striking:

> ... While looking upwards I saw a stellar-shaped mass of white light form in the clear blue sky immediately above my head, not by small clouds collecting, but apparently forming itself in the same way as a cloud forms by condensation in a clear sky on a mountain top, or a crystal shoots out in a transparent liquid, leaving, as I fancied, an almost traceable nucleus or centre with spear-like rays projecting from it; and from this in a few seconds shot forth diverging streamers of golden light, which descending met and mingled with the rosy patches of the aurora hanging about the horizon.[11]

At the same time that Capron saw his stellar-shaped mass of light, telegraph engineers all over the world were experiencing one of the most intense magnetic storms they had ever seen as 'earth currents' played havoc with their lines. In Boston, USA, sparks flew out of the system and some operators even received shocks. The Society of Telegraph Engineers took a keen interest in the readings of the Greenwich Obser-

Fig.4 Lithograph from water colour of aurora sketched by Capron at Guildford, 24 Oct. 1870
Capron, J.R., *Aurorae: Their Characters and Spectra* (London, 1879), Pl. 3
Courtesy of Taylor & Francis

vatory magnetometers and galvanometers, so the Astronomer Royal, G. B. Airy, sent copies to the Society, who published a series of articles in their Journal about the world-wide manifestation of the troublesome earth currents.

Fig.5 Lithograph from water colour of aurora sketched by Capron at Guildford, 4 Feb. 1872
Capron 1879 (Op Cit), Pl.4
Courtesy of Taylor & Francis

It is clear from these accounts that Capron understood the strongly suspected link between auroral displays, magnetic earth currents, severe electrical interference with the telegraph system and the appearance of sunspots. The aurora maxima of September 1859 had also been accompanied by a terrestrial magnetic storm and it was suspected then that there was a link with the appearance of a large sunspot.[12]

Capron observed both of these aurorae with his John Browning direct-vision pocket spectroscope. On both occasions he drew attention to the characteristic bright auroral line in the yellow-green area of the spectrum which had first been identified by Angström in 1867. Capron pointed out that this line did not quite agree with the spectroscopic lines produced by vacuum tube experiments.

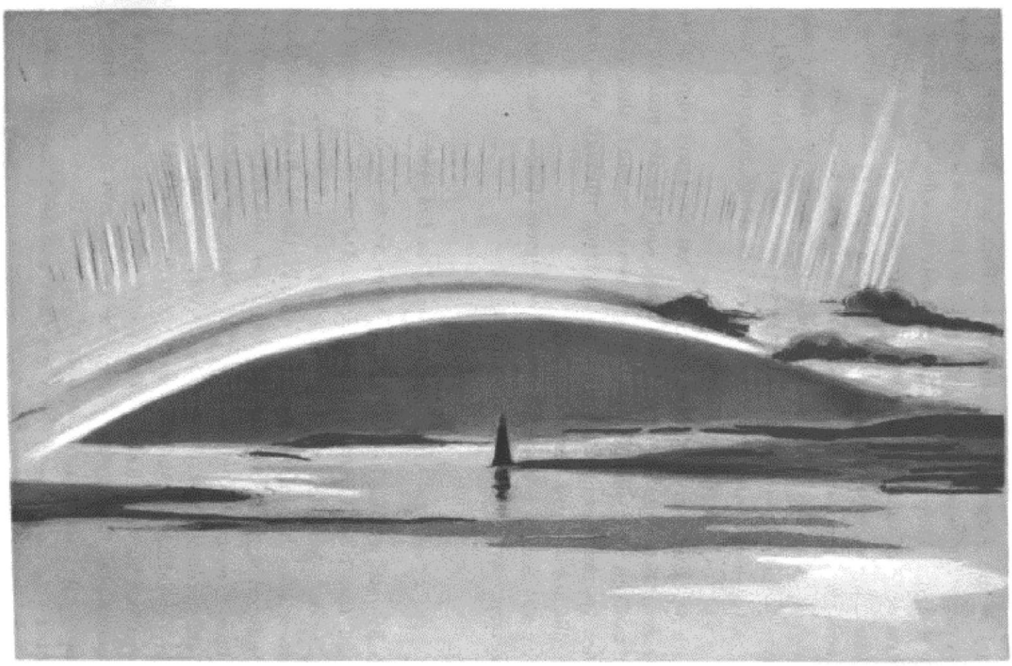
More Aurorae

Capron witnessed a rare white aurora from Kyleakin on the Isle of Skye, Scotland, on September 11th 1874. He saw, '... a long low-lying arc of the purest white light' which was a double arc surrounding a dark internal band. 'Occasional streamers of equally pure white light ran upwards from either end of the bow.' With the moon only a day old Capron was enthralled to see the entire landscape and sea lit up as if by a full moon. He described the spectacle as, '... a true thing of beauty, forming as it did a quiet contrast to the more brilliant but restless forms of aurorae generally seen'.[13]

On this occasion Capron was caught without his pocket spectroscope, but much of his early scientific work reflected his keen interest in the developing science of spectroscopy, the aurora and sunspots. In 1859 Kirchoff and Bunsen founded the science of spectral analysis when they realised that if they heated an element in a flame and analysed the resulting spectra each element produced its own characteristic set of lines. William Huggins (1824-1910) and his neighbour William Allen Miller (1817-1870), a chemist at King's College London, also began studying the spectral signature of the main elements. When they attached a large spectroscope to Huggins's telescope they immediately began making discoveries about the stars and gaseous nebulae. Astrophysics had been born![14]

Capron obviously read about this work, but he realised that one of the key issues was the reliability of the instruments. This was hampered by a lack of standardised measurements – there were several different scales – and misunderstandings about the variety of independent variables which affected readings. Capron's first major spectroscopic paper, 'On the Comparison of some Tube and Other Spectra with the Spectrum of the Aurora' appeared in April 1875, where he compared the accuracy of the various spectral lines reported by leading researchers.[15] This was followed by, 'On the Spectrum of the Aurora', a subject Capron returned to in many of his subsequent articles.[16]

Capron's fascination with spectroscopy culminated in the publication of his first book *Photographed Spectra, 136 Photographs of Metallic, Gaseous, and Other Spectra Printed by the Permanent Autotype Process* (E. and F. N. Spon) in 1877. This was the first book to present photographs of artificially created spectra in vacuum tubes to the public. Capron examined the spectra of about forty metals extending from about b to H by using both spark and an electric arc. He used Browning's direct vision spectroscope which he had previously used for auroral observations. The prism was an inch in aperture and this was attached to a collimator with a 1.25-inch achromatic lens of 6-



AURORA. KYLE AKIN. ISLE OF SKYE. SEP 11. 1874.
FAC-SIMILE OF WATER COLOUR DRAWING.

Fig.6 Lithograph of Aurora sketched by Capron at Kyle Akin, Isle of Skye 11 Sept., 1874
Capron, J.R., *Aurorae: Their Characters and Spectra* (London, 1879), Pl.7
Courtesy of Taylor & Francis

inch focus. The telescope and eyepiece were removed and the focal length increased to 9 inches by inserting a second lens. This was then connected by a black velvet bag to a camera which projected onto a collodion wet plate. Sparks were generated by a large Rhümkorff coil attached to a battery with four double plates and a half gallon of bichromate. This apparatus produced thick strong sparks two inches in length, a large condenser was used to reduce the spark size and increase the brilliancy. Despite these precautions exposure times were often considerable, averaging 15 minutes. Arc spectra were generated by a 40-pint Grove cell, but Capron was well aware that the resulting spectra could be contaminated so the carbon points were routinely cleaned with sulphuric acid and purified water. Exposure times varied from three to five minutes and Capron used three different spectroscopes – two of which were specifically manufactured by Browning for these experiments. Some of the spectra were very faint and required photographic enlargement up to five times the original size.

Norman Lockyer, the Editor of the science journal 'Nature', favourably reviewed Capron's book stating that, 'The spectra are sharp and clear, and the autotype process has lent itself well to this reproduction. The results are all the more commendable because Mr Capron has not had the advantage of considerable dispersion'.[17] A second excellent review appears in *The Observatory*.[18] Lockyer later described Capron's first book as an 'extraordinary success'.[19]

The failed search for Planet Vulcan

Capron applied for admission to the Royal Astronomical Society on 23 December 1876. His nominees were the scientific instrument maker John Browning (1831-1925), the pioneer of astronomical spectroscopy William Huggins (1824-1910) and the astronomical photographer Warren De La Rue (1815-1889). He was admitted to the Society on 9th March 1877 during the growing controversy over the intra-Mercurial Planet, Vulcan. Popular belief in an intra-Mercurial planet had been triggered by observations of small dark spots transiting the sun dating back to 1802. Another key factor in the generation of the Vulcan myth was the anomalous advance in the position of perihelion in Mercury's orbit. The influential French astronomer Urbain Le Verrier (1811-1877), who had successfully predicted the location of Neptune in 1846, concluded that there must be a small planet positioned between the Sun and Mercury. He confidently announced the discovery of this new planet in 1859, following the observation of an enigmatic dark spot crossing the sun's disk by the French amateur Edmond Modeste Lescarbault (1814-1894).

Unfortunately there was a major problem with the popular belief in Planet Vulcan because some of the world's most experienced solar observers, such as Samuel Heinrich Schwabe (1789-1875) and Richard Carrington (1826-1875), had seen nothing to suggest that Vulcan existed, despite their decades of solar research. Nothing suspicious had been photographed with the British Association's 'Photoheliograph' at Kew Observatory, which had begun work in March 1858. However, Le Verrier persisted with another failed prediction for Vulcan during the eclipse of 1860. Belief in Vulcan was probably encouraged because professional astronomers could not accurately predict the precise location of some of the planets and amateurs continued reporting seeing anomalous phenomena – probably asteroids and cometary heads – transiting the sun.

The controversy dragged on and Le Verrier made a further prediction for a transit in March 1877, writing to the Royal Astronomical Society. The Astronomer Royal, George Airy, responded by telegraphing observatories around the world to warn them to keep a continuous watch and to photograph the sun's disk.[20]

Capron detailed his intensive search for Vulcan in a paper, 'Report of Examination of the Sun's Disk at Guildown, Guildford, on 21st, 22nd, and 23rd March 1877, for the suspected planet Vulcan'.[21] On Wednesday, 21st March 1877 he spent from 9 am to 4 pm examining the sun and practising how he would photo-graph any suspicious objects using his 8¼-inch reflector. However, after 10 am observing conditions deteriorated and he took no photographs.

The following day weather conditions were well suited to solar observation as the sun appeared in light misty clouds thus aiding safe visual observation. Capron began his observations at just past 7 am and continued all day until 5.25 pm. Despite falling snowflakes, Capron described seeing 'spot and faculæ seen on Sun's edge' and he took nine photographs using the camera attached to his larger reflector. His last examination of the sun took place on Friday, 23rd March, when he began his observations at 6.58 am and ended them at 5.10 pm. This time there was a sharp frost and the sun appeared in a slight mist which became denser – conditions well suited to solar observation. Capron saw two solar halos – caused by the mist – and described seeing a precise 'pure' solar disk, but he saw no sunspots and took no photographs.

Extracts from Capron's paper were read at a meeting of the Royal Astronomical Society on April 13th 1877:

> Nothing like a planet had been seen upon the sun's disc. Mr. Rand-Capron had rendered his negative evidence permanent by taking photographs of the sun's disc with an ordinary camera box placed so as to receive the image from the telescope. In order to give the short exposures which were necessary he had contrived screens of zinc with slits in them, which were allowed to fall though the camera by their own weight.

During the same meeting, Father Perry of Stonyhurst Observatory in Lancashire reported on his own unsuccessful search for Vulcan:

> We made use of our large instrument of 8 inches aperture equatorially mounted, and projected the sun on a screen, and got beautiful definition. Three of my assistants were watching, but no planet was seen, though there were some beautiful sun-spots.[22]

Observers around the globe failed to notice anything untoward and the official history of the Royal Astronomical Society states:

> The total failure of the observations both in the opposite hemisphere and in our own, renders it certain that no such object crossed the sun's disk at the predicted time. The Rev. Stephen Perry at Stonyhurst and Mr. Rand Capron at Guildford kept careful and continuous watch during the three days, the weather being very favourable at both places, but saw no trace of the object they were seeking.[23]

Science had to wait for Albert Einstein (1879-1955) to finally lay Planet Vulcan to rest. His General Theory of Relativity, published in November 1915, demonstrated that Newton's laws of planetary motion worked perfectly when close to the Earth, but near a massive body like the Sun there was significant curvature in space-time which produces a non-Newtonian warp in the trajectory of nearby bodies such as the planet Mercury. His argument was clinched when he showed that Mercury's precession should be slightly faster than Newton's predicted rate – by 43 arc seconds per century – a figure that had already been established from observational data. This successful prediction finally explained the anomalous advance in the perihelion of Mercury, thus doing away with the need for a rapidly moving inner planet.[24]

Aurorae: their characters and spectra

About one quarter of Capron's articles and letters in the scientific journals of the 1870s and 1880s dealt with the scientific mystery of the aurora. In February 1879 Capron published what would prove to be his most popular work *Aurorae: their characters and spectra*. The book was well received and reviewers loved it. The book was divided into three sections: Part I dealt with subjects such as the number and duration of auroras, their geographical distributions and their relationships with other natural phenomena – such as thunderstorms, magnetic disturbances and the Zodiacal Light. There were many historical accounts, particularly from arctic explorers, and there was also a short section on the leading theories of the day. In Part II Capron dealt with the Spectrum of the Aurora, describing a variety of experiments which had been designed to demonstrate which elements were involved in the production of auroral light. In Part III Capron described a large number of Magneto-Electric Experiments carried out by himself and other researchers who were attempting to replicate the auroral spectrum by applying magnets to air and flame spectra. There was an extensive appendix, including an article on spectroscopy by Norman Lockyer and numerous lithographs.

Lockyer very favourably reviewed Capron's book in *Nature*, stating that, 'Mr Capron has done good service to science by collecting in a compact form the whole information which we possess on the subject.' The cover was illustrated by Capron's own water colour of the stunning 1870 aurora he witnessed, whilst the book contained numerous illustrations and tables of data. Lockyer praised Capron's book with '... the whole appearance of the book suggests at first glance art rather than science, and we should suppose it is but rarely that a purely scientific treatise has appeared in so ornamental a dress'.[25] A second even more praiseworthy review appeared in *The Philosophical Magazine,* where *Aurorae* was described as '...all the voluntary, spirited, generous work of a private gentleman, J. Rand Capron, Esq.,'.[26] A third excellent review appeared in the *Journal of Science*, whilst Lockyer quoted a number of Capron's spectroscopic conclusions from *Aurorae* in his own book *The Meteoritic Hypothesis*.[27]

Capron and Piazzi Smyth

Although Capron developed good working relationships with many prominent Victorian scientists his rise to prominence probably owes most to Charles Piazzi Smyth (1819-1900). Smyth began his astronomical career as a computer at the Royal Observatory, Cape of Good Hope. He later triangulated the districts of Southern Africa, enjoyed landscape painting and took possibly the first ever photograph on the continent of Africa. In 1856 he founded the first high-altitude observatory on Tenerife to demonstrate the benefits of using a high-altitude location. Smyth also pioneered infra-red astronomy, when he estimated the amount of heat radiation received from the moon. Later, Smyth returned to Britain to take up the post of Astronomer Royal for Scotland (1846-1888).

Capron and Piazzi Smyth shared a series of intellectual interests which were under-pinned by an intensive visual culture. These included photography, astronomy, spectroscopy, the aurora and meteorology. Both men enjoyed collecting reams of scientific data, both delighted in producing water colour illustrations of what they had observed and both were committed Christians. There is an unconfirmed story that Capron and Smyth astonished passengers on the London to Edinburgh train by pointing their pocket spectroscopes out of the window to examine the spectra of clouds.[28]

Smyth was a Fellow of the Royal Society but his scientific career was marred by eccentricity, out-spokenness and his confrontational letters to Nature.[29] In 1864, Smyth wrote the first of three highly popular accounts of the Great Pyramid at Gizeh, a manmade object which Smyth was convinced held deeply mystical – almost divine – mathematical properties.[30]

In 1871 Piazzi Smyth accused the Royal Society of having a 'secret committee' which had engaged in 'despotic dispatches' to ensure that his paper on the alleged relationship between the frequency of sun spots and earth temperature would never see the light of day.[31] On another occasion Piazzi Smyth attacked the respected spectroscopist Marshall Watts, author of an important work *Index of Spectra,* in the pages of the *Philosophical Magazine.* Here he accused the Royal Astronomical Society of having a secret anti Smyth-like committee.[32] In 1874 he resigned his membership of the Royal Society because of their refusal to publish his paper on the (alleged) mathematical properties of the Great Pyramid at Giza. Despite all this Capron still devoted *Aurorae* to his 'friend', Charles Piazzi Smyth. Why? It is tempting to attribute this to elitism but this would be totally out of character for a man who was well known for his philanthropy and benevolence.

The Rainband

It was Piazzi Smyth's work on spectroscopy which led to Capron's misjudged acceptance and promotion of the so-called 'rainband'. Piazzi Smyth first noticed this alleged phenomenon at noon on 24th March 1872 at Palermo in Sicily. Using a pocket spectroscope only a few inches in length he observed 'striking variations' in the solar spectrum near the double D (sodium) lines. His diagram shows that the following day at noon many of the spectroscopic lines had disappeared, but he noted that it had rained the previous afternoon at 4pm.

In July 1875 *Nature* published a major article by Piazzi Smyth which described how using his barometer Le Verrier had predicted a period of fine weather, but then for a whole week Paris and London were struck by 'deluges' of rain. Smyth claimed that whilst travelling through London his pocket spectroscope displayed 'a broad dark band on the less refrangible side of D and partly in place of it'. However, by the time Smyth reached York the rain had ceased, the dark spectral band decreased and fine weather prevailed. His pocket spectroscope once again revealed the double D lines and by the time he reached Edinburgh the weather had returned with a 'glorious blue sky, transparent atmosphere, delicious temperature, and light N.E. wind'.[33]

Smyth discovered that whenever there was rain a band of dark lines appeared in his spectroscope but as soon as the rain disappeared, this band was absent. Almost accidentally, Piazzi Smyth had initiated a whole new area of scientific study which quickly attracted both its supporters and detractors. In May 1876, during a trip to the south of France, Smyth again predicted heavy downpours 'to the surprise of the natives' who had only consulted their barometers. He followed up this work with a major publication 'Meteorological Spectroscopy in the small and rough' which set out the scientific case for his discovery of the 'rain band'.[34]

Capron was obviously interested in Piazzi Smyth's work and soon began his own data collection using a McLean's star spectroscope. He found that he too could identify the rainband. For two periods in 1880 and 1881 he recorded both the strength of the rainband – on a scale from 1 to 5 – and the amount of rain which fell in the 24 hours following the rainband reading. His charts (see Fig.7) seem to show a strong positive association between the two data sets, but when this data is correctly combined onto a scatter gram (Fig.8) the linear correlation coefficient is only + 0·26. Unfortunately the statistical technique of correlation was not available to Capron and Piazzi Smyth in the 1880s. Had it been so they would surely have understood the weakness of their case.

In 1881 Capron published an article, 'A Plea for the Rainband'.[35] In 1883, Capron's rainband appeared in colour in the 2nd edition of John Browning's popular handbook *How to work with the Spectroscope*. The realisation that, for the first time, it might be possible to predict rainfall made for big news and both John Browning and his rival Adam Hilger quickly issued a variety of pocket spectroscopes and pamphlets which explained how to use them.

Despite the enthusiasm of Capron and Smyth for their subject many people had problems actually seeing the rainband. This debate even took to the pages of the

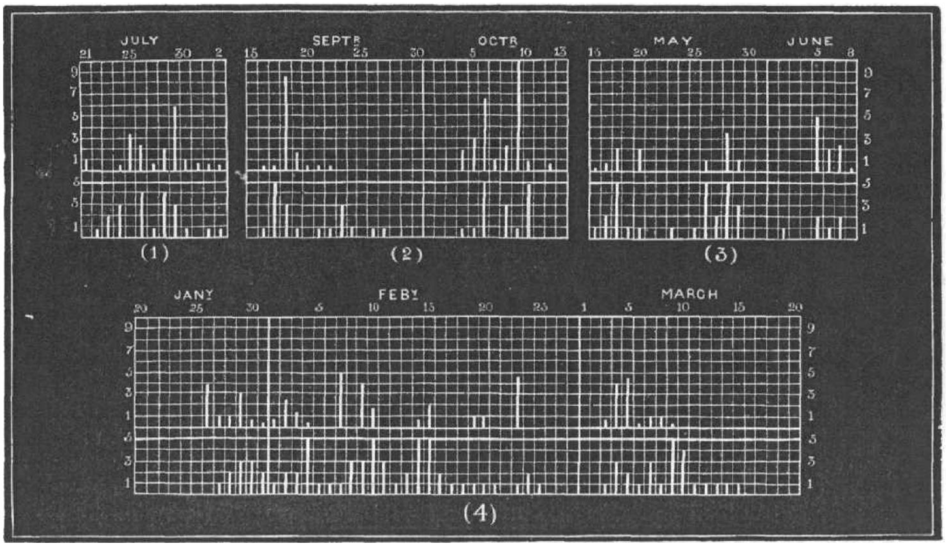


Fig.7 Capron's rainband chart for 1880 and 1881
Capron 1881 'A Plea for the Rainband…'
Courtesy of Edward Stanford Ltd., London

Times, when both Ralph Abercrombie of the Meteorological Society and the Duke of Argyll (FRS) wrote in to say that they could see no value in the technique.[36] Capron himself admitted that the rainband 'does not claim absolute infallibility', but Capron and Piazzi Smyth never really understood that their method relied on subjective estimates of the state of the bands to the left of the D lines.[37] Neither did they understand that variations in viewing conditions introduced a further subjectivity into what was seen and how the lines should be interpreted. Capron even admitted that there were 'discrepancies and irregularities' in the relationship between the strength of the rainband and the amount of rainfall. However, he attempted to

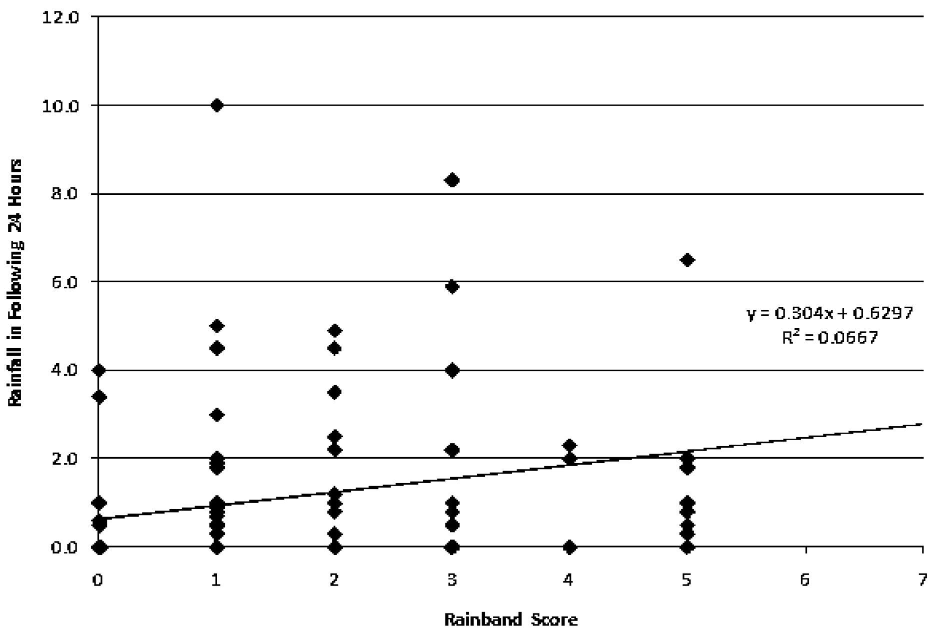


Fig.8 Capron's rainband replotted as a scattergram
Plotted by the author

explain this away as being caused by changes of intensity in the rainband between the three daily readings. Unfortunately he never presented any data to demonstrate such an effect.

In 1886 Capron republished 'A Plea for the Rainband' alongside a new article 'The Rainband Vindicated', but by now interest was dying away and the problems with the technique were becoming obvious. Piazzi Smyth continued to mount a vigorous rearguard action against criticisms raised by American scientists and both men continued with their fallacious claim that they could identify atmospheric water vapour with such tiny instruments before it had even begun falling![38]

A leading spectroscopic historian, Klaus Hentschel, has criticised Capron's role in the promotion of the rainband and the quality of the photographs in *Photographed Spectra*. Aside from the subjective nature of the observations:

> The user of Capron's manual had the task of deciding which among the several printed samples [rainband photographs] was most similar to the real spectrum observed in his rainband spectroscope, that is, to match his visual field against a whole array of categories provided by the manual's author.[39]

Capron and Smyth assumed that their instruments were capable of identifying all the main lines in the solar spectrum, but both men grossly underestimated the number of solar lines. By the 1960s it was established that there are over 24,000 solar lines so probably less than 1 per cent of these lines could have been seen in the pocket spectroscopes of the 1880s.

The promotion of Smyth's rainband by Capron seems like an example of cronyism on Capron's part but we are still left with the term 'rainband' in today's weather forecasting, albeit used in a non-spectroscopic sense.

The Auroral Beam, 17th November 1882

In November 1882 Capron witnessed an extra-ordinarily rare phenomenon during a vivid auroral display. He stated that:

> At a little before 6 o'clock a strange and most unusual phenomenon was seen. I happened to turn to the south, where the moon (with a very pronounced *lumière cendrèe* on its dark part) was nearly on the meridian, when I saw a spindle-shaped beam of glowing white light, quite unlike an auroral ray, had formed in the east. As I looked this slowly mounted from its position, rose to the zenith, and passed it, gradually crossing apparently above the moon, and then sank into the west, slowly lessening in size and brilliancy as it did so, and fading away as it reached the horizon.

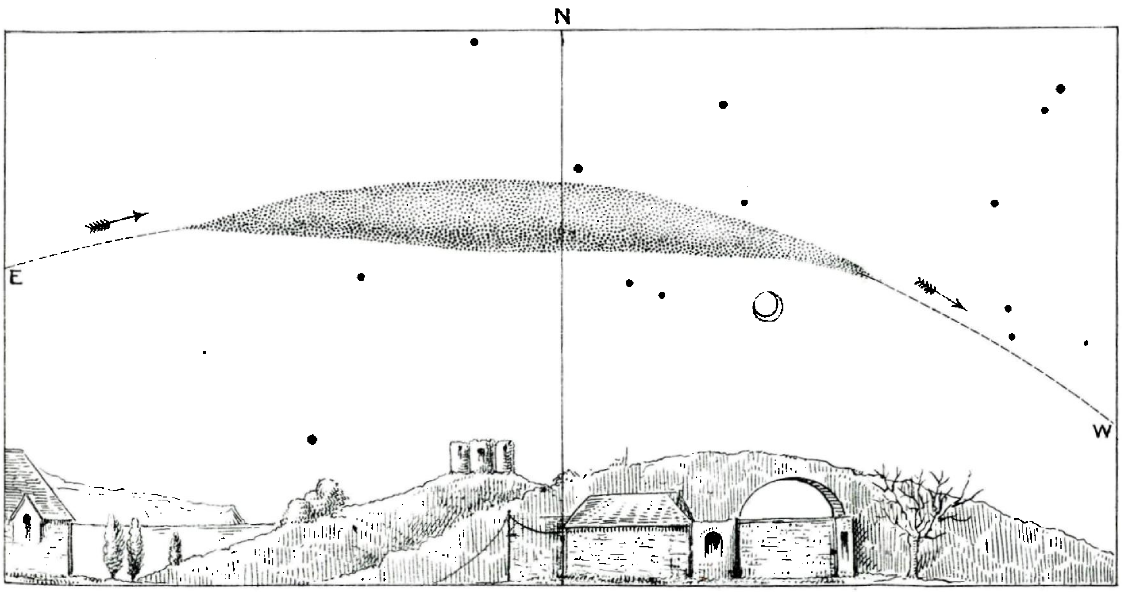


Fig.9 Capron's drawing of the auroral beam and his observatory in Guildford

Philosophical Journal, 15, (May 1883), 318-39

Courtesy of the Science Museum, London

The peculiar long spindle shape, slow gliding motion and glowing silver light, and the marked isolation of this cloud from the other portions of the aurora made it a most remarkable object and I do not recollect in any former aurora to have seen anything similar. About 6 o'clock the aurora gradually died away, to revive again at 9 in the shape of a white semicircle of light in a point north by west, which did not last long. Owing to moonlight, but little could be done with the spectroscope with a wide split on the most glowing parts of the red patches only the usual green line, with a faint continuous spectrum towards the violet could be made out.

At times I thought I caught traces of other lines, but with no certainty at all. The spindle-shaped beam was also examined with the spectroscope, but only gave the green line. Even in the brightest parts of the red glow, the red line could not be made out. The peculiarity of the moving beam of light was its absolute southern position. Its apparent passage across the sky was only a few degrees above the moon, then at a comparatively low altitude.[40]

This phenomenon was probably observed by thousands of people across northern Europe but surprisingly Capron could find no observers in Britain north of York. Fortuitously, a number of excellent accounts of the phenomenon have survived. William Christie (1845-1922), The Astronomer Royal, observed the beam from Greenwich, stating that:

In the evening, as soon as it was dark, a brilliant aurora was seen, commencing with a bright glow of red light extending from the north and west beyond the zenith, interspersed with pale green phosphorescent light and streamers. At 6h. 4m. a very brilliant streak of greenish light about 20° long appeared in the east-north-east, and, rising slowly, passed nearly along a parallel of declination, a little above the moon, disappearing at 6h. 5m. 59s. in the west, about two minutes after it was first seen. The whole aurora had faded away by about 7h., but it burst out again at 11h. 45m., when an auroral arch, with brilliant streamers reaching nearly to the zenith, was seen from north-north-east to north-west. It faded away about 12h. 10m.[41]

The Remarkable Magnetic Storm

The November 1882 auroral beam observations coincided with a 'remarkable magnetic storm'. A detailed account by Norman Lockyer and William Christie appeared in *Nature.*[42] The storm reached its climax between 10am and 11am on November 17th when earth currents measuring 50 milli-amperes – 5 times the normal working current – were measured. Christie also drew attention to a huge sunspot which was visible to the naked eye and which covered 2,470 millionths of the sun's visible surface. At that time this was the largest sun spot ever photographed by the Royal Observatory.

At Kew Observatory G. M. Whipple wrote to *Nature* to describe how the Kew magnetographs began showing small deflections from about 8.30 p.m. on Saturday 11th November. These continued throughout the week and were so trivial as to resemble the effect of tremors. However, all that changed on Friday morning when the magnetic storm became 'violent' and from then until Saturday morning 'the oscillations of the magnet and the changes of force were incessant and frequently enormous, the declination needle ranging at times through almost 2°. Correspondingly large variations were also exhibited by the bifilar and balance magnetometer'. Throughout Sunday 19th November the deflections reduced in character but early on Monday morning they again intensified.

In 1916 the Editors of 'The Observatory' asked a number of prominent astronomers to contribute to their 500th edition. Edward Maunder, a former Editor of the journal, stated that the auroral beam was the most striking experience he could recall in his 43 years of observation. He stated that:

…a great circular disc of greenish light suddenly appeared low down in the E.N.E., as though it had just risen, and moved across the sky, as smoothly and steadily as the Sun, Moon, stars, and planets moved, but nearly a thousand times as quickly. The circularity of its shape when first seen was evidently merely the effect of foreshortening, for as it moved it lengthened out, and when it crossed the meridian and passed just above the Moon its form was that almost of a very elongated ellipse, and various observers spoke of it as "cigar-shaped," "like a torpedo," or "a spindle" or "shuttle."

Had the incident occurred a third of a century later, beyond doubt everyone would have selected the same simile – it would have been "just like a Zeppelin." After crossing the meridian its length seemed to contract, and it disappeared somewhat to the south of the west point. Its entire passage from rising to setting took less than two minutes to complete, and it disappeared at $6^h 5^m 59^s$ G.M.T.

in colour the light of the 'torpedo' was evidently the same as that of the auroral glow in the north, and this showed me in the spectroscope the familiar auroral line in the "citron-green,".

This "torpedo-shaped" beam of light was unlike any other celestial object that I have ever seen. The

> quality of its light, and its occurrence while a great magnetic storm and a bright aurora were in progress, seem to establish its auroral origin. But it differed very widely in appearance from any other aurora that I have ever seen.[43]

With such a brief and spectacular phenomenon a huge debate quickly erupted over the cause of the apparition. This correspondence is briefly summarised in Table 1. Not surprisingly many of the published accounts varied enormously and it was by no means obvious that the phenomenon was auroral in nature. As a witness to the beam and the celebrated author of *Aurorae* Capron soon found himself at the centre of the controversy so he decided to try and make sense of what had been reported.

The Philosophical Journal

Capron's paper 'The Auroral Beam of November 17, 1882' appeared in the *Philosophical Journal* in May, 1883.[44] His paper was a masterpiece of the scientific method and was taken by most Victorians to be the final word on the subject. He began by drawing together as many of the observations as possible. It is clear that many more people observed the 'beam' than the accounts summarised by Capron but he chose 28 where he had full details. Table 2 summarises what we know today about these 28 observers.

Capron understood that the location of the observer and the relationship of the phenomenon to the Moon were important factors in determining the size, height and trajectory of the phenomenon so he summarised these accounts in a table of key features.

The appearance of the beam took all its observers by surprise. For this reason there are significant discrepancies between the accounts. Taking just the 23 British observations the phenomenon was seen between 5.25 pm and 6.06 pm. Capron points out that we do not know if these are GMT or local times. Most observations clustered around 6-6.15 pm but two, the accounts by Clark in Leeds (observer 22) and T.R. Clapham (observer 23), are timed much earlier. Capron argues, quite reasonably, that these were not the same phenomenon. This seems borne out not only by the discrepancy in times, but also by the fact that these men reported seeing different auroral forms. A similar problem exists with the duration of the phenomenon, which ranged from 'about six seconds' to 'less than four minutes'. Capron appreciated that the observers were taken by surprise and that typically people over-estimate the duration of events. He noted that most observers thought they saw the phenomenon for between 1 and 2 minutes. For these reasons he took an average of the 18 most reliable observations, finding that the phenomenon was probably seen for approximately 75 seconds. As some observers qualified their estimates with 'less than' and 'about' this seems a reasonable method.

Estimates of the length of the phenomenon varied tremendously, from just 15° of arc in Hungerford in Berkshire, to an astonishing 80-100° in Péruwelz, about 10 miles north of Valenciennes on the Belgian/French border. In Holland, H. J. H. Groneman stated that at Utrecht the phenomenon was 90° in length for 'a few seconds'

Capron cautioned against higher estimates of the length on the basis that some of these observers were located on the continent and saw the phenomenon from a different perspective. Also, he argued that most observers saw the light lengthen out as it neared the zenith and then appear to shrink as it raced towards the horizon. This makes it difficult to judge its true size because observers located in the south would have been closer to the phenomenon and would have seen it larger than those situated in the north. This perspective effect seems only partly borne out by the data and so Capron was forced to choose the 11 best estimates to produce an average of 27° in length and of nine estimates to give 3.33° breadth.

These same considerations affected estimates of the direction of flight. Capron judged that the only really reliable estimates were those provided by Professor Oudemans in Utrecht and by Pieter Zeeman at Zonnemaire (Zierikree), both locations in the Netherlands. These gave estimates of E. 20° N. to W. 20° S. as the trajectory. Of course it is dangerous to infer the true direction of flight from only two observations, but most observers reported that the phenomenon moved from approximately east to west.

Descriptions of the phenomenon's colour varied from 'white', 'pearl white' and 'greenish white' to 'yellow white'. Capron pointed out that two observers made independent spectroscopic readings of the beam and that he had also seen the 'principal citron auroral line' – incorrectly reported as 5569, it is really 5577. Capron noted that this line was not present on the adjacent sky. F.W. Cory of Buckhurst Hill, Essex, wrote to the journal 'Knowledge', stating:

> I think there can be no doubt in regard to the connection between the torpedo-shaped body that was seen on November 17 at 6h 5m p.m. and the aurora, as the spectroscopic examination gave the same line for both; and this was situated between D and E in the spectrum, but nearer the former.[45]

Two inconsistencies involve the appearance and quality of light exhibited by the beam. Some observers claimed that they saw a 'spindly-shaped' phenomenon,

Table 1: Accounts of the "Auroral Beam", 17th November 1882

Ref. in *Nature**	Observer	Location	Notes
Nov. 23, 1882, page 86	Stephen H. Saxby	East Clevedon Vicarage, Somerset	Describes seeing the beam at 6.15 pm, length an astonishing 35°. Observed a second smaller phenomenon moving parallel to the first
Nov. 23, 1882, 86-87	Hubert Airy	Woodbridge, Suffolk	Estimated the beam to be about 40° in length
Nov. 23, 1882, page 87	J. Herschel	London	Quotes a description of the phenomenon seen from North Devon
Nov. 23, 1882, page 87	A.S.P.	Cambridge	Observed 'a well-defined spindle-shaped body of a cloudy consistency, having a brilliant white colour'.
Nov. 23, 1882, page 87	H.D. Taylor	Heworth Green, York	Observed object form out of 'a long patch of white light'
Nov. 23, 1882, page 87	John L. Dobson	Beaumont College, Old Windsor, Berkshire	Observed 'a bright, cloud-like object, in shape like a fish-torpedo or a weaver's shuttle'
Nov. 30, 1882, page 99	Herbert McLeod	Royal Indian Engineering College, Cooper's Hill, Egham, London	Reported that four students at the College also observed the 'Whitehead-torpedo-shaped streak of light'
Nov. 30, 1882, 99-100	Charles J. Taylor	Toppesfield Rectory, Halstead, Essex	Described seeing 'a white cloud' about 20° long and 2° wide.
Nov. 30, 1882, page 100	Stephen H. Saxby	East Clevedon Vicarage, Somerset	Saxby becomes the first person to try to triangulate the position and path of the 'electric meteoroid'
Nov. 30, 1882, page 100	Alfred Batson	The Rookery, Ramsbury, near Hungerford, Berkshire	Described seeing a 'monster meteor' and a 'torpedo'. Hoped to produce a photographic representation of the beam to compare it with the Great Comet of 1882.
Nov. 30, 1882, page 113	Reported by Norman Lockyer	Eskibstuna, 54 miles south of Stockholm, Sweden	The first reported sighting from outside Britain. Described as an oblong object which resembled a bow
Dec. 7, 1882, page 139	J.R.C.	Guildford, Surrey	Reports a sighting of a similar 'bright beam' by Charles Leeson Prince of Crowborough on October 3rd. Also describes his spectroscopic observations of the beam in more detail
Dec. 7, 1882, Page 139	W.M. Flinders Petrie	Bromley, Kent	Casts doubt on the factual accuracy of the accounts by Taylor and Elger
Dec. 7, 1882, page 140	H. Dennis Taylor	Heworth Green, York	Calculates the height of the beam as 212 miles
Dec. 7, 1882, page 141	Edward Pollock	Regent's Park, London	Describes seeing 'a broad band of light having somewhat the appearance of a light cloud, only much brighter'
Dec. 7, 1882, page 141	J.R.C.	Guildford, Surrey	Adds additional accounts of the aurora which contradict what was seen in the south
Dec. 14, 1882, page 149	J.R.C.	Guildford, Surrey	JRC casts considerable doubt on the various heights of the beam that have been calculated
Dec. 21, 1882, page 173	W.M. Flinders Petrie	Bromley, Kent	Claims to agree with JRC's letter of Dec. 14th, stating that this proves that the beam was meteoric in nature
Dec. 28, 1882, page198	Thomas William Backhouse	Sunderland	Argues that the height of the 'spindle-shaped object' has no bearing on its auroral character. Argues that the beam must have been auroral because it moved along a parallel of magnetic latitude

Ref. in *Nature**	Observer	Location	Notes
Dec. 28, 1882, page 198	J.R.C.	Guildford, Surrey	Responding to Flinders Petrie's letter reaffirming his belief in the heights quoted in his earlier letter and the auroral nature of the object
Jan. 25, 1883, 296-298	H.J.H. Groneman	Groningen, Netherlands	'Remarks on and Observations of the Meteoric Auroral Phenomenon of November 17, 1882'. This article contains the first exposition of the meteoritic dust theory for the beam
Feb. 1, 1883, page 315	Thomas William Backhouse	Sunderland	Questions H.J.H. Groneman's application of a straight line path for an auroral effect, pointing out that meteors would move in all directions
Feb. 1, 1883, page 315	W.M. Flinders Petrie	Bromley, Kent	Responding to Dr. Groneman's paper and casting doubt on the interpretation of the spectroscopic analysis.
Feb. 1, 1883, page 315	Henry Muirhead	Cambuslang, Scotland	Reports seeing something similar to the beam on October 14th 1870
Feb. 8, 1883, page 338	Stephen H. Saxby	East Clevedon Vicarage, Somerset	Reaffirming his estimate of the height of the beam made in his earlier letter of Nov. 17th 1882
Feb. 15, 1883, page 365	H. Dennis Taylor	Heworth Green, York	Draws attention to the difficulty in reconciling the differing accounts of the 'mysterious meteoroid'
Feb. 22, 1883, page 388	H.J.H. Groneman	Groningen, Netherlands	Responds to Thomas Backhouse's letter of Feb. 1
March 1, 1883, page 412	Thomas William Backhouse	Sunderland	Responding to Dr Groneman's letter of Feb. 22, casting doubt on the ability of observers to judge a straight-line trajectory for a very high object
March 1, 1883, page 412	?	?	Calls for a meeting to be held in London or Bristol for observers to meet to ensure that all accounts are noted. Agrees that if the object split then this would account for many of the discrepancies. No evidence exists that such a meeting took place
March 8, 1883, page 434	H. Dennis Taylor	Heworth Green, York	Clarifies the bearings given in his original account
May 31, 1883, 105-107	H.J.H. Groneman	Groningen, Netherlands	'The True Orbit of the Auroral Meteoroid of November 17, 1882'
Philosophical Magazine, 15, (1883), 318-39	J.R.C.	Guildford, Surrey	JRC's major article on the auroral beam.
June 28, 1883, 196-197	J.A.C. Oudemans	Utrecht, Netherlands	Corrects JRC's translations of his observations of Oct. 2 and Nov. 17 that appeared in the *Philosophical Journal*, 15, (1883), 318-39
The Observatory, 6, (1883),192-3	Edward Walter Maunder	Greenwich Park, London	Describes Capron's paper in the *Philosophical Journal*, agreeing that Capron's own spectroscopic observations prove the beam to be of auroral origin and that his estimates of its height and velocity appear to be accurate
The Observatory, 39, 500 (May, 1916), 213-214	Edward Walter Maunder	Greenwich Park, London	Invited to recall significant events in his astronomical life Maunder describes the auroral beam nearly 34 years after the event

* Other periodicals as indicated

Table 2: Observers of the Auroral Beam, 17 November 1882

No.	Capron's ref. - *The Philosophical Magazine*	Observer	Location	WIKI Entry**	Observer details
1	*Standard* - newspaper	Unknown	Sidmouth, Devon		Railway Signalman
2	*Nature*, pages 27, 84 and 149	John Rand Capron (1829-1888)	Guildown, Guildford, Surrey	Yes	Grand amateur. FRAS, FMS
3	*Nature*, pages 27 and 83	W.H.M. Christie (1845-1922)	Greenwich Observatory, London	Yes	The Astronomer Royal (1881-1910), Elected Secretary of the RAS at the sixty-first AGM, reported in the *MNRAS* (Feb. 11, 1881) 61, 4
4	*Ibid.*, pages 100, 141 & 412	Alfred Batson (aged 61, 1881)	The Rookery, Ramsbury, Hungerford, Berkshire		*Nature* (Mar. 1, 1883), 27, 412-413. Chairman of the local School Board. – Information supplied by Ruth King, Berkshire Record Office
5	*Ibid.*, page 87	John J. Dobson (aged 27, 1881)	Old Windsor, Berkshire		Teacher at Beaumont (Jesuit) College – closed in 1967
6	*Ibid.*, page 141	Edward Pollock (aged 46, 1881)	Lincolns Inn Fields, London		A practising barrister living at 20 York Terrace, Regents Park, London
7	*Standard*	J. Woodruff	Broxbourne, Hertford		Not yet traced
8	*Nature*, page 87	Hubert Airy (1838-1903)	Woodbridge, Suffolk		Son of George Biddell Airy (1835-1881), The Astronomer Royal. Became a pioneer in the treatment of migraine
9	Letter sent to the RAS	William Munro (aged 24, 1881)	Chatham, Kent		A Royal Navy engineer living at 6 Green Street, Minster, Isle of Sheppey. Father a Chelsea Pensioner
10	*Nature*, page 84	Joseph Clark III (1840-1928)	Street, Somerset		Son of Joseph Clark II, the elder brother of Cyrus and James Clark, who co-founded Clark's shoe company of Street, Somerset. Cousin to observer 22. Elected to the British Association in 1877. Also collected meteorological data. Information from Judeth Saunders, Alfred Gillett Trust (C & J Clark Ltd), Street, Somerset
11	*Nature,* pages 86, 100 and 338	Rev. Stephen Henry Saxby (1831-1886)	East Clevedon, Somerset		Elected FRAS, Nov. 13, 1885. See *MNRAS*, 46, 1, p. 1. Lived at Mount Eldon, Clevedon. Was the first vicar of All Saints Church
12	*Ibid.*, page 85	Thomas Gwyn Empy Elger (1836-1897)	Incorrectly reported as Hempston, Bedford, Bedfordshire (actually Kempton)	Yes	Studied at University College London and initially became a civil engineer. Lived at St Mary, Bedford in 1882. Elected to the British Association in 1868. 'Auroral Display', *Nature*, 25 (Feb. 23, 1882), p. 386. An English lunar mapper and first director of the Lunar Section of the BAA. Member of the RAS and the Selenographical Society. Founded the Bedfordshire Natural History Society and Field Club. Published *The Moon: A full Description and Map of its Principal Physical Features* (1895). Has a lunar crater Elger named after him
13	*Standard* - newspaper	Thomas Woodruff	St. Ives, Huntingdon		Probably Thomas Woodruff, rector of Wistrow, 1840-1891 (aged 76, 1881 Census), but possibly Thomas Woodruff, a local watchmaker, of 24 Main St. Somerton (aged 45, 1881 Census) from Laura Ibbett, Huntingdonshire Archives

No.	Capron's ref. - *The Philosophical Magazine*	Observer	Location	WIKI Entry*	Observer details
14	*Nature*, pages 87, 146, 365 and 434	Henry Dennis Taylor (1862-1943)	Heworth, York		Taylor was an optical designer for the telescope makers Thomas Cooke and Sons. See home.europa.com/~telscope/ hdtaylor.doc for details of his considerable astronomical work
15	*Ibid.*, page 85	Arthur Mason Worthington (1852-1916)	Durdham Down, Clifton, Bristol	Yes	Assistant Master of Physics at Clifton College (1880-85). Published *An Elementary Course of Practical Physics* in 1881. Reviewed in *Nature* 24 (May 12, 1881), p. 28. Later CB & FRS. Obituary in *Nature*, 98 (Dec. 14, 1916), No. 2459, 293-294
16	*Ibid.*, page 99	Herbert McLeod FRS, FCS (1841-1923)	Indian Civil Engineering College, Cooper's Hill, Egham, Surrey	Yes	See entry in the *ODNB*. Elected to the British Association in 1868. 'Electricity of the Blowpipe Flame', *Nature*, 21 (Feb. 12, 1880), p. 347; 'Hot Ice', *Nature* 24 (May 12, 1881), 28-9. 'On the Pressure of the Vapour of Mercury at the Ordinary Temperature', BA Annual Conference 1883, p. 443
17	*Ibid.*, page 85	Elizabeth Brown (1830-1899)	Cirencester, Gloucestershire		Lived at Further Barton, Cirencester. Noted for her work recording sunspots. See Brown's letter 'Aurorae', *Nature* 31 (Mar. 19, 1885), p. 458. Obituary, *The Times* (Mar. 16, 1899) and *The Illustrated London News* (Mar. 25, 1899). Gloucestershire Archives holds additional information – see file SR3.43GS
18	*Ibid.*, page 87	A.S.P.	Cambridge, England		No obvious candidate found in the BA membership lists or the *MNRAS*
19	*Times* – paper	Charles M. Ramus (1822- ?)	Rye, East Sussex		The curate of Playden Rectory, Rye, East Sussex. Lived at 58 Saltcote Street. Later became the curate of Patrixbourne church, nr. Canterbury, Kent
20	*Ibid.*	J.P.K.	Wimbledon, Surrey		No obvious candidate found in the BA membership lists or the *MNRAS*
21	*Nature*, page 100	Charles J. Taylor	Ilford, Essex		Lived at Toppesfield Rectory, Halstead, Essex. See 'The Recent Weather', *Nature*, 25 (Feb. 16, 1882), p. 365. Moved to Banstead, Surrey, June 1889. MA, FCS.
22	*Ibid.*, page 84	J.E. Clark[e] (1850-1944)	Leeds, Yorkshire		James Edmund Clark of Bootham, York, BA, BSC, FGS. Clark was the 11th of James and Eleanor Clark's 14 children – James Clark was the co-founder, with his brother Cyrus, of Clark's shoe company of Street, Somerset. Cousin to observer no. 10. Clark was Educated at Bootham, the Flounders Institute and University College, London. He attended Heidelberg University from 1873 to 1875, specialising in Natural Science. Was Junior Master at Bootham from 1869 to 1872, Science Master from 1875 to 1897. He was the oldest contributor to *The Friend* (an obit. appears in Dec. 29, 1944, 861-862). He was editor, with B.B. Le Tall, of the *Natural History Journal*, and for 25 years he presented the Phenological Report annually to the RMS. See 'Phenological Observations on Early Flowers and Winter Temperatures', *Nature* 25 (April 13, 1882), 552-4. Involved in agricultural experiments in the Bridgewater, Somerset area. Read 'Glacial Sections at York, and their relation to the later deposits', BA annual conference at York, 1881. Information from Judeth Saunders, Alfred Gillett Trust (C & J Clark Ltd), Street, Somerset.

No.	Capron's ref. - *The Philosophical Magazine*	Observer	Location	WIKI Entry*	Observer details
23	*Ibid.*, page 141	F.R. Clapham – In fact Thomas Richard Clapham (1837-1909)	Clapham, Lancashire (actually the West Riding of Yorkshire)		A land owner living at Austwick Hall, Austwick. Educated at nearby Giggleswick School. Clapham was an auroral observer who built an astronomical observatory in his garden in 1884 (cost £ 26). Elected FRAS March 13, 1891 (*MNRAS*, 51, 5, p. 277), proposed by Herbert Sadler. See www.austwickhall.co.uk
24	*Ibid.*, page 296	Professor J.A. C. Oudemans	Utrecht, Holland		*Nature*, 28 (June 28, 1883), page 196
25	*Ibid.*, ...	Pieter Zeeman (1865-1943)	Zonnemaire (Zierikree), Holland	Yes	Shared the 1902 Nobel Prize for Physics with Hendrik Lorentz for his discovery of the Zeeman effect where a spectral line is split into its components by the presence of a magnetic field. This discovery helped to elucidate the structure of the atom. Became Professor of Physics at the University of Amsterdam.
26	*Ciel et Terre*, 20, p. 465	Prof. Prignon	Péruwelz, Hainault		
27	*Ibid.*, p. 466	M. Thooris	Bruges, Belgium		
28	*Ibid.*	Editor	Bruxelles, Belgium		

* http://en.wikipedia.org/wiki/Main_Page

others 'torpedo or weavers-shuttle'. Others described a 'cigar-ship', 'lenticular' (i.e. cloud-like) and a 'comet's tail'. Another observer compared it with the Andromeda nebula. The quality of light was described as 'glowing', 'shining' and 'phosphorescent'. The light reminded Capron of the glow in a carbon Geissler tube experiment.

Some observers described the edges of the phenomenon as being feather-like, but most (including Capron) did not see this. Capron thought he saw a 'sort of broken and clouded structure' whilst others reported seeing a kind of 'dark nucleus' or 'central dullness'. Professor Oudemans in Utrecht claimed that when the phenomenon was 90 $^{\circ}$ in length it split into two whilst the Reverend Saxby in north Somerset claims that he saw a second beam 7° to the north running on a parallel track. Of course if the beam really did split into two this might explain why the English observers saw a smaller phenomenon than their European counterparts.

Capron was aided in his analysis by Professor Alexander Stewart Herschel (1836-1907), the son of Sir John Herschel, who established that the auroral beam moved approximately from east to west along a magnetic meridian. He claimed that the beam actually traversed France at a height of approximately 133 miles and he drew two shadow lines on a stellar map to show the 'shadow path' of the phenomenon. This estimate might explain why European observers saw a darker area inside the phenomenon, as to them the beam was directly overhead. However, his trigonometric method was based on only four accurate angular measurements so there must be significant error bounds. Another problem is that more than half of Capron's published longitudes and latitudes were wrong, some considerably so. If Herschel used these figures then his estimates of the height and position of the beam would be in error.[46]

Capron finished his article by casting doubt on Professor Groneman's 'cosmic dust' theory of aurorae by pointing out that meteors can fly in any direction whilst auroral arches and beams must follow courses along magnetic latitudes. He also pointed out that bolides move at between 40 and 130 miles per second, whereas the auroral beam moved at only 10 miles a second. Of course this estimate was based on the assumption that the beam was relatively close to the

Earth – today we know that some meteors move at slower speeds than those quoted by Capron. His most serious objection to Groneman's theory was that the spectrum of the aurora was unique and not the same as meteoritic spectra – which of course usually includes lines created by heavy metals like iron, nickel, cobalt and manganese.

Later in 1883, Edward Maunder supported Capron's auroral beam conclusions in *The Observatory*, where he repeated Capron's description of Prof. Herschel's observations of 'abortive bright streamers', which move along 'stationary milk-white auroral bands'.[47] Maunder concluded that '... the beam itself may have been the transient lighting-up by a passing glow of an otherwise invisible arc'. Given what is now known about how aurorae are triggered by energetic solar particles moving down magnetic field lines this seems a very apt description.

Contemporary Magnetic and Meteorological Observations

One key piece of evidence Capron only vaguely refers to was the 'Magnetical and Meteorological Observations' at the Royal Observatory Greenwich (ROG). This data includes near continuous measurements of the horizontal and vertical force, and the declination of the Earth's magnetic field.[48]

Two earth currents were also measured in loops measuring 7.5 and 5 miles in length. During 1882 there were 15 days when great disturbances were registered, April 16, 17, 19, 20; June 24, August 4, October 2, 5 and November 12, 13, 17, 18, 19, 20 and 21st.[49] The official record describes how during the last two hours of November 16th (i.e. 10.00 to 13.00 hours GMT on November 17th) and between 15.30 and 18.00 hours GMT on November 17th 'during great magnetic disturbance, the earth current motions were so violent that the records could not be traced'.[50]

At the same time there were also large fluctuations in the three magnetic readings and between 10.00 and 13.00 hours GMT the vertical force magnet was vibrating rapidly.[51] At various times between 17.00 and 18.00 GMT the vertical force and the first earth current readings disappeared out of range so great were the magnetic fluctuations. Unfortunately, measurements of the declination were lost between 10.30 and 11.30 GMT, and measurements of the vertical force were lost between 15.30 and 19.00 GMT.

During this period of exceptional magnetic activity the great solar spot appeared on the sun's limb on November 11th and eventually disappeared on November 25th.[52]

Writing in *Nature* Lockyer states that telegraph engineers in the United States and Canada reported that the electrical disturbances on their systems were '... unlike any heretofore known, acting on the wires in strong waves which produced constant changes in the polarity of the current. A magnificent aurora appeared on Friday night [17th] and was visible at all points, except where clouds obscured it'.[53]

Observer no 1 in the Capron article, a railway signalman at Sidmouth in Devon, also reported 'much telegraphic disturbance' during this event.[54]

Further problems

One issue brushed aside by Capron was whether or not the auroral beam was a unique occurrence. If it was a unique event then one could argue against any natural explanation let alone an auroral explanation. Lockyer later stated that:

> During the great aurora of January 1831 ... a bright yellow streak was seen to rise with common cloud velocity, forming an arch from west to east, becoming invisible in the west by the time it had reached the east. During the same aurora Professor Bischoff in Burgboohl, saw a moving cloud, as bright as the Milky Way, pass from east to west in five minutes.
>
> During another aurora, December 1870, Professor Rudberg, of Uppsala, saw a very bright patch, of double the dimensions of the moon's disk, moving with great velocity behind the auroral beams.[55]

These events seem to demonstrate that similar, though perhaps not absolutely identical beams, had been seen before and have probably been seen since. Surprisingly, Maunder concurred with Professor Groneman's 'meteoritic dust' theory for the beam, pointing out that there were strong similarities between the spectrum of the aurora and that of the Zodiacal Light. Groneman responded to Capron and Herschel's conclusions by recalculating 'The True Orbit of the Auroral Meteoroid of November 17, 1882', but J.A.C. Oudemans had the last word when he corrected Capron's translation of his original description of the event in *Nature*.[56]

Historical Context

In December 1899, William Ellis, FRS, published an important paper 'On the Relation between Magnetic Disturbance and the Period of Solar Spot Frequency'.[57] Ellis examined 50 years of magnetic observations recorded at the ROG, classifying the daily magnetic disturbances into five categories – none, minor, moderate, active and great. 'Great' disturbance was classified as days when the declination was disturbed by more than 60' of arc or when the horizontal force was disturbed by more than 300'. Ellis tabulated the number of days during each quarter when magnetic disturbances fell into each of his five somewhat-arbitrary categories.

During the entire 50 years between 1848 and 1897 Ellis found that the highest number of 'great' disturbances was in the last quarter of 1882 when 5 days were so classified. 4 of these days took place between November 16th and 20th, while the 18th was classified as only 'active'. Ellis states that November 17th was accompanied by 'a very remarkable aurora'. In a follow-up paper, E. Walter Maunder states that there were only 19 'great' magnetic storms in the period 1875-1903 when 'the extreme amplitude of movement in declination has amounted to one degree of arc'. [58] He described storm No. 7 - 1882, November 17-21, as 'A very long-continued disturbance' and that sunspot group 885, 'the largest in the whole [solar] cycle, 1878 to 1889' which coincided with Storm No. 7, '... the most violent magnetic storm in the same period'.[59]

These papers, all published long after Capron's death, established once and for all that the 'auroral beam' occurred at the peak of one of the greatest magnetic storms of the past fifty years. In fact, only the storm of October 31, 1903 had a larger displacement in declination and horizontal force than the storm of November 17th, 1882.[60]

Conclusions about the Auroral Beam

Despite the many discrepancies and disagreements over the appearance, height and trajectory of the 'auroral beam', it does seem from all this evidence that this unusual phenomenon approximately flew along a magnetic meridian, gave the characteristic auroral spectral line, appeared at the height of a violent – almost unprecedented – solar storm and was coincident with the appearance of an enormous sun spot. The additional magnetic data and strong earth currents strongly support Capron's conclusion that the phenomenon was a very rare form of the aurora borealis.

Today we know that the auroral beam was caused by the interaction between hot magnetised plasma and the Earth's magnetosphere. The plasma was created by a Coronal Mass Ejection which also triggered the massive earth currents. These violent solar events can produce highly structured clouds of material which would inevitably follow a magnetic meridian when hitting the magnetosphere. This explanation would also account for why the 'beam' was seen to split into two by Professor Oudemans and why the Reverend Saxby saw a second beam 7 degrees to the north as the primary beam approached the western horizon. That no other beams have been subsequently reported, or presented as unusual, seems strange given the current belief in more exotic solutions for unusual aerial phenomena.

British Association Annual Conference, Southport, 25th September 1883

Because he was so well-known for his work on the aurora, and perhaps because of his paper on the 'auroral beam' in May, it was no surprise when Capron was invited to address the British Association's conference at Southport in September 1883. Capron would have enjoyed his five minutes of fame, but most of the plaudits went to Professor Robert Ball, Astronomer Royal for Ireland, who delivered a lecture on the estimated distance between the Earth and the Sun.

Capron's talk was titled 'On some points in Lemström's recent Auroral Experiments in Lapland'.[61] Professor Karl Selim Lemström of the University of Helsingfors, Helsingfors [Helsinki] was the chief of the Finnish Meteorological Service and a respected auroral expert. During the Swedish Polar Expedition of 1868 Lemström had observed small luminous discharges around projecting objects such as mountain peaks and ridges. He examined these with his spectroscope and demonstrated to his satisfaction that they were auroral phenomena. On another occasion Lemström observed a luminous phenomenon rise up from the ground, but which lasted for only a few seconds. Lemström concluded from these observations that the aurora was a slow form of lightning caused by the discharge of electricity from the earth to the lower atmosphere.[62]

Three years later, Lemström was a member of the Finnish Society of Science constructing a prototype auroral-generating machine on Luosmavaara, a mountain-top 520 feet above Lake Enare, in Lapland. The machine was quite a modest affair, consisting of some fine points of copper wire laid out in the shape of a wreath two square metres in diameter. The wreath was attached to a tall pole which itself was connected to a single copper wire only 4mm in diameter which ran to a galvanometer located two miles away. This in turn was connected to a disk of platinum buried in the earth to capture Earth Currents. On the evening of November 22nd the machine was turned on and a single column of light appeared for a few seconds above the mountain. Quite what that light was is still not clear today.

Lemström examined this light with his spectroscope and noted that this gave the usual yellow-green auroral line. He also observed this same spectroscopic line from other luminous phenomena which appeared that evening. From this ambiguous evidence the professor concluded that he was surrounded by a large zone of electrical activity which had been triggered by his machine. Unfortunately the following morning it was discovered that the line connecting the auroral machine had been damaged by grouse, but this did not seem to deter Lemström from his conclusion that he needed to build a much bigger auroral machine to prove his discovery to the world.

Like Capron, Lemström began experimenting with Geissler tubes to see if he could recreate the auroral citron line. He was astounded when he accidentally discovered that he could recreate the auroral line using a Geissler tube with no electric current provided the tube was connected to the earth and the air was *very rare*. In November 1882, during the first ever International Polar Year, he began a series of experiments involving an 'utströmnings' or discharging apparatus. This was a large array of bare copper wire 2 mm in diameter mounted on hundreds of pointed poles 2.5 metres in height and arranged in a maze-formation. The largest such machine covered an area of 900 square metres on top of a hill at Oratunturi near the town of Sodankylä. From the inner end of the wire a long insulated wire was connected to a galvanometer which in turn was connected to a zinc disk buried in the mountain 180 metres below the main apparatus.

The *utströmnings* was first used on the night of December 5th and almost every night during the experiments a weak yellow-white luminosity appeared around this mountain. Curiously none of the other nearby mountains exhibited this same phenomenon. Three times this glow was examined spectroscopically, and each time the standard auroral line was found, albeit faintly. A second *utströmnings* was set up on the mountain at Pietarintunturi and this too soon gave positive results.

Lemström's sensational research soon attracted widespread popular interest in the newspapers of the day and a series of articles appeared in *Nature*. [63] The famous meteorologist George James Symons (1838-1900) even compared Lemström's findings with Benjamin Franklin's kite experiment.[64]

In his lecture to the British Association Capron applauded the Lemström experiments, but urged caution because no proper measurement of the 'citron' auroral line took place using an insulated spectroscope and a comparison spectrum. He also questioned discrepancies between the discharges produced by the four different collecting instruments, which were all constructed using the same materials, and he contrasted these measurements with those registered by the galvanometers. Capron had seen Lemström's prototype auroral machine during the special loan exhibition at the South Kensington Museum in 1876 so he was well informed as to its potential.

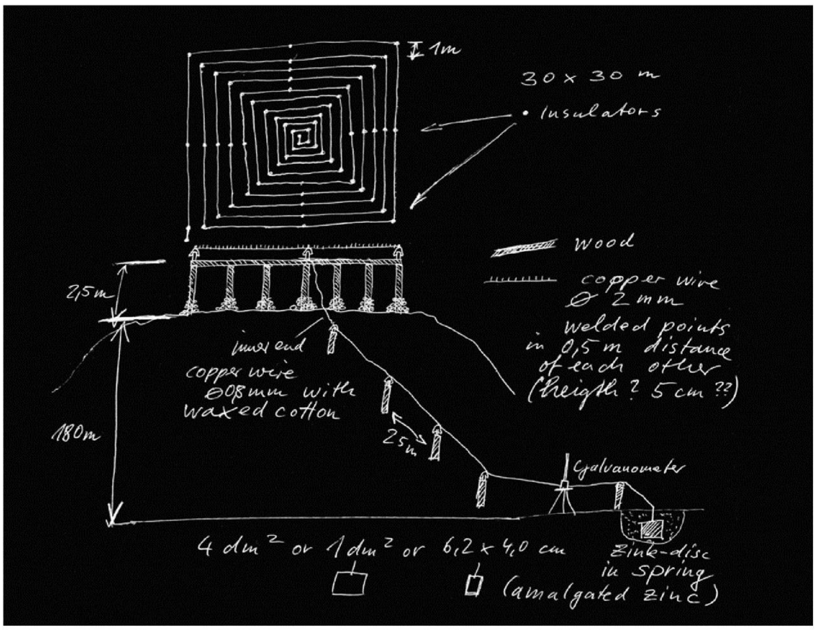


Fig.10 Lemström's Auroral Generating Machine 1882
Copyright Oliver Kochta

Capron suggested that to confirm Lemström's findings one should use a specialised form of spectroscope which would only examine the auroral lines whilst all other extraneous light was excluded. He also suggested using a separate galvanometer to measure earth currents, an electrometer for measuring atmospheric electricity and a theodolite for measuring the directions of the auroral arches and beams. Capron stated that he had already collected these instruments and would be erecting them on a tower – obviously Booker's Tower – close to his observatory. As far as we know, no such experiments ever took place.[65]

Capron's caution was well founded. The following spring the Danish auroral scientist Sophus Tromholt (1851-1896) repeated Lemström's experiments on Esja, a mountain lying just two miles north east of Reykjavik in Iceland. Tromholt constructed a far larger *utströmnings* using more than one thousand points on the flat roof of a stone tower some 30-40 feet in height. The apparatus covered more than 4,100 square feet and was positioned 2,616 feet above sea level. Like Lemström, Tromholt connected the apparatus with a telegraph wire 3,200 feet in length which in turn was attached to an insulated conductor buried in the ground 714 feet above sea level. Tromholt concluded, 'As I had anticipated, the *utströmnings* apparatus has up to the present shown no signs of life whatever. I can see it plainly with a good telescope from my residence, and thus ascertain that it is in perfect order'.[66]

A second experiment, by C. Vaussenat on the Pic Du Midi in France between 1883 and 1885 involving 200 posts covering an area of 7,000 square feet, also failed to replicate Lemström's findings.[67] Professor Lemström explained Tromholt's failure by blaming the unusually adverse winter, heavy snowfall, and great moisture. [68] Despite these negative findings Lemström persuaded the Finnish Government to provide further funds for an expedition in 1883-84. According to Lemström this expedition also yielded positive results with the creation of artificial aurorae, but no other auroral researchers ever managed to replicate Lemström's experiment. [69] As a result his theory of an auroral belt of electrical currents lying close to the ground slowly discharging into the atmosphere faded into history. It was convincingly disproven when it became possible to accurately determine auroral heights by the use of photography. The first really good auroral photographs were taken by Carl Störmer (1874-1957) in 1910. These were used to accurately calculate an average height of approximately 100 km, but some auroral heights varied from only 36 km to 461 km.[70]

By this time Lemström's theory had been overtaken by Kristian Olaf Birkeland's (1867-1917) terella experiments. These consisted of an evacuated glass box with a cathode emitting an electron stream towards an anode at the other end with a terella, a small globe representing the Earth. It contained a small electromagnet that replicated the Earth's magnetic field lines when turned on. Birkeland successfully recreated the oval-shaped auroral zones, thus replicating the interaction of the solar wind with the earth's magnetosphere. This experiment could be repeated without fail. Unfortunately Birkeland's theories were well ahead of their time and British Scientists quickly rejected them. It was not until the advent of earth-orbiting communication satellites in the 1960s that Birkeland's polar sub storms were finally confirmed and accepted as the answer to the aurora.[71]

It seems strange that Capron, Lemström and the many other auroral researchers of the 1870s and 1880s failed to attempt Birkeland's terella experiments. Capron carried out many experiments with magnetic fields and he understood that the aurora featured a strong electro-magnetic component. He knew that vacuum tubes created a similar visual effect to the aurora, but in the experiments he had witnessed the vacuums were not perfect enough to create the effects Birkeland would later search for. Neither Capron, nor Lemström, made the vital conceptual leap to fire electrons at a magnetised 'Earth' inside a vacuum chamber. Their failure to do so left the field open for Birkeland to make the breakthrough to leave his name emblazoned in the history of science.

Capron's Death

Capron died of a kidney infection at a guest house on South Cliff, Eastbourne, Sussex, on 12th November 1888. He is buried with his wife Fanny and son John at The Mount Cemetery in Guildford.

At the time of his death Capron had been Clerk of the Peace for Guildford for 38 years and the Borough Coroner for 14 years up to 1867. Accordingly the Borough of Guildford honoured Capron with a full civic funeral possession and many shops in the High Street shut on the day of the funeral.

The Royal Astronomical Society carried a brief note in the December 1888 issue of *The Astronomical Register*:

> We regret to hear of the death of Mr. John Rand Capron, of Guildown, Guildford, who has been for some years a prominent member of the Royal Astronomical Society. He was on the Council from 1883 to 1887. His most important astronomical work has been in connection with auroræ, and his 'Auroræ, their Character and Spectra,' published in 1879, is a standard book on the subject. He has also published 'Photographed Spectra' ... and has contributed many papers to the Society. His health had not been good for some time, and he became seriously ill towards the end of October. He died on November 13 at the age of 59 years, leaving a widow, but no family.[72]

Conclusion

It is a remarkable fact that Capron was able to contribute more than 100 letters and articles to the scientific journals of the day and to write three highly technical books without any university training in mathematics, physics or chemistry. He lived at a time when it was still possible for one man to know something important about all the 'pure' sciences and to become respected across several fields of study. One obituary states that 'His study of the heavens amounted almost to a passion'. His poetic descriptions of the phenomena he observed, his boyhood brush with death and his strong religious upbringing were probably the inspiration behind much of his scientific work. Capron felt that science, art and religion were interchangeable and that all reflected God's Glory.

Further Lines of Enquiry

To locate Capron's personal papers, telescopes and private papers which have all disappeared. Any assistance in locating them will be gratefully received.

Acknowledgements

Jennifer Higham, Librarian at the Royal Astronomical Society, Mark Hurn, Librarian at the Institute of Astronomy, University of Cambridge, The British Association for the Advancement of Science (now the British Science Association), all the staff at the Surrey History Centre, Woking, Surrey, the University of Southampton (Hartley Library), Clare Miles and Roger Nicholas of the Guildford Institute, Anthony Jenkins and William Norris (Barlow Robbins), Dr Allan Chapman, Peter van Doorn, Mike Frost (BAA Historical Section), Norman Keer, Oliver Kochta, Ron Livesey, Theo Pajmans, David Robinson and Don Simpson. Special thanks are due to the Editorial Team of the AA and Lee McDonald for reviewing the paper.

Notes and References

1. See *Symons's Monthly Meteorological Magazine* (May 1883), page 55; Capron, John Rand, *Aurorae: their characters and spectra* (London: E. & F.N. Spon, 1879), page 75.
2. According to *Faraday's Diary* this was experiment number 3137, conducted on 21st June 1836, in which he evacuated a glass tube and ran a direct current through an airless tube, creating 'a peculiar and constant appearance of great beauty' as the contacts were parted. Mr Hawksbee had discovered this effect some years earlier.
3. File 5102/1, Surrey History Centre (hereafter SHC), Woking.
4. *Guildford Bibliographies* (1888), 1, SHC, Woking.
5. Beck, G.M.A., 'Notes on John Rand Capron of Guildford, 23 March 1979', Guildford Muniment Room, SHC, Woking. *Pamphlet* 920CAPp; See also 'Appendix IV, Obituary Notices', *Quarterly Journal of the Meteorological Society*, New Series (1889), 15, 85-86; and 'Legal Obituary', *The Law Times* (December 8, 1888), page 116.
6. Sturley, D.M., *The Royal Grammar School, Guildford* (The Royal Grammar School at Guildford, 1979), 39-42 and page 93.
7. www.nationalarchives.gov.uk/currency/results.asp#mind
8. This folly was built by Charles Booker, Liberal Mayor of Guildford in 1823 and 1831, to commemorate his teenage sons Charles (died of smallpox in 1824) and Henry (drowned in the nearby River Wey in 1827). The tower was completed in 1839. SHC, Woking.
9. Capron, J.R., 'Sun Spots and the Aurora' (letter dated 27th Sept., 1870) *Surrey Advertiser*; *County Times* (1st October, 1870), page 3, column 1.
10. 'The Aurora Borealis' (letter dated 25th Oct., 1870), *Surrey Advertiser*; *County Times,* 29th October, 1870, page 3, column 5; Capron, J.R., Letters to the Editor, 'The Aurora Borealis', *Nature* (Nov. 10, 1870), 3, p.28.
11. Capron, J.R., Letters to the Editor, 'The Aurora Borealis of Feb. 4th', *Nature* (Feb. 8, 1872), 5, 284-5.
12. Stuart Clark, *The Sun Kings* (Princeton, 2007), esp. Ch. 1.
13. Capron, J.R., Letters to the Editor, 'Aurora', *Nature* (Oct. 8th, 1874), 10, 460-1.
14. Becker, Barbara J. *Unravelling Starlight,* (Cambridge University Press, 2011); Kitchin, Chris, 'First astrophysics', *Astronomy Now* (May 1997), 49-51; Wood, Edmund, 'William Huggins, pioneer of the new astronomy', *Astronomy Now* (May 2005), 73-5.
15. Capron, J.R., 'On the Comparison of some Tube and Other Spectra with the Spectrum of the Aurora', *The Philosophical Magazine* (April 1875), Series 5, 49 (325), 249-60.
16. Capron, J.R., 'On the Spectrum of the Aurora', *The Philosophical Magazine* (April 1875), Series 5, 49 (327), page 481.
17. Lockyer, J.N. Our Book Shelf, 'Photographic [sic] Spectra', *Nature* (Jan. 31, 1878), 17, page 259.

18. Anon. 'Rand Capron's Photographed Spectra', *The Observatory* (1878), No.14, 56-8.
19. Lockyer, N.J., 'Aurorae: their Characters and Spectra', *Nature* (Dec. 11, 1879), 21, page128.
20. *Our Astronomical Column. The Suspected Intra-Mercurial Planet Nature* (Mar. 15, 1877), 15, 437-8; Oral address on the suspected intra-mercurial planet and an approaching opposition of Mars, *Monthly Notices of the Royal Astronomical Society* – Hereafter *MNRAS* (Mar. 1877), 37, page 246; See also 'Astronomical Notes', *Nature*, (Jan 25, 1877), 15, page 282.
21. *MNRAS* (March 1877), 37, 348-9.
22. *The Astronomical Register* (April 1877), 15 (172), 117-8.
23. Dreyer, J.L.E. and Turner, H.H. *History of the Royal Astronomical Society 1820-1920* (London, RAS 1923).
24. Baum, Richard and Sheehan, William. *In Search of Planet Vulcan, The Ghost in Newton's Clockwork Universe* (New York, Plenum Trade, 1997); Stuart, Clark, 'The search for planet Vulcan', *Astronomy Now* (June 2000), 50-53.
25. Lockyer, N.J., 'Aurorae: their Characters and Spectra'. *Nature* (Dec. 11, 1879), 21, p.129.
26. 'VIII Notices respecting New Books', *The Philosophical Magazine and Journal of Science* – Series 5 (Jan. 1880), IX, 65-70.
27. *Journal of Science* (1880), 32, 376-380; Lockyer, Norman Joseph. The Meteoritic Hypothesis (London, Macmillan & Co, 1890), pages 74, 76-78 and 99.
28. Personal communication from Dr Alan Chapman dated 17th January 2002.
29. Hermann and Mary Brück, *The Peripatetic Astronomer* (Adam Hilger, 1988).
30. Eggen, Olin, J., 'Charles Piazzi Smyth', *Astronomical Society of the Pacific* (June 1955), Leaflet No. 313.
31. Smyth, Piazzi, 'Solar Science at the pleasure of *Secret* Referees', Letters to the Editor, *Nature*, (Apr. 13, 1871), 3, 468-9.
32. Piazzi Smyth, 'Carbon and Hydrocarbon in the Modern Spectroscope', *The Philosophical Magazine* – Series 4 (January 1875), 49 (322), 24-33; 'End-on Tubes, brought to Bear upon the Carbon and Carbo-Hydrogen Question', Letters to the Editor, *Nature* (May 22, 1879), 20, 75-6.
33. Piazzi Smyth, 'Spectroscopic prévision of Rain with a high barometer', Letters to the Editor, *Nature* (July 22, 1875), 12, 231-232.
34. Piazzi Smyth, 'Meteorological Spectroscopy in the small and rough', *Edinburgh Astronomical Observations* (1870-1877), Royal Observatory Edinburgh.
35. Capron, J.R., 'A Plea for the Rainband', *Symons's Monthly Meteorological Magazine* (Dec. 1881), 16, 181-190.
36. Abercromby, R., '*The Spectroscope and Weather Forecasting*', *The Times* (Sept. 19, 1882), page 8, column c; Argyll (Duke of), '*Prevision of Weather by the Spectroscope*', The Times (Sept. 22, 1882), page 6, column c.
37. Capron, J.R., *A Plea for the Rainband*, (London, Edward Stanford, 1882), page 8.
38. See for example Piazzi Smyth, C., 'Rain-band Spectroscopy Attacked Again', Letters to the Editor, *Nature* (Apr. 1 3, 1884), 29, page 525.
39. Hentschel, Klaus, 'The Phenomenology of the rainband' in *Mapping the Spectrum, Techniques of Visual Representation in Research and Teaching* (Oxford University Press, 2002), 104-10 and 219-225; 'Photographic Mapping of the Solar Spectrum 1864-1900, Part 1', *Journal for the History of Astronomy* (May 1999), 30 (2), 93-119.
40. 'The Magnetic Storm and Aurora', *Nature* (Nov. 23, 1882), 27, 82-4.
41. Ibid, page 83.
42. Ibid, page 82
43. Maunder, E.W., 'A Strange Celestial Visitor', *The Observatory*, (May 1916), 39 (500), page 213.
44. Capron, J.R., 'The Auroral Beam of November 17, 1882', *The Philosophical Journal* (May, 1883), Series 5, 15 (95), 318-39.
45. Cory, F.W., *Knowledge, 1883*, 3 (62).
46. Capron's hand writing was atrocious. It is possible that his longitudes and latitudes were correct, but transcribed incorrectly.
47. Maunder, E., 'Notes. The Auroral Beam of 1882, November 17', *The Observatory* (1883), 6 (74), pages 192-3.
48. Magnetic declination is the angular difference between true north and magnetic north. This value varies from place to place and over time because of variations in the strength of the Earth's magnetic field. It should not be confused with celestial declination, which is the angle of an astronomical object above the celestial equator.
49. Christie, W.H.M., *Results of the Magnetical and Meteorological Observations made at the Royal Observatory, Greenwich in the year 1882* (London: Published for HMSO, 1884), xxvi-xxvii.

50. Ibid, page xxxii.
51. Ibid, page xxviii.
52. Ibid, page xxx; See also Brodie, Frederick, 'Observations of the Solar Spots of November 1882' and 'The Spectrum of the Great Sun-spot of 1882, November 12-25, observed at the Royal Observatory, Greenwich', by the Astronomer Royal, *MNRAS* (Jan. 1883), 43 (3), 76-80. Note that these latter observations were made by Maunder.
53. 'The Magnetic Storm and Aurora', *Nature* (Nov. 23, 1882), 27, page 82.
54. See also Graves, J., 'On the Magnetic Storm of November 17th, 1882', *Journal of Telegraph Engineers and Electricians*' (1883), XII, 30-4.
55. Lockyer, N.J., *The Meteoritic Hypothesis* (London, Macmillan & Co, 1890), page 98.
56. Groneman, H.J.H., 'The True Orbit of the Auroral Meteoroid of November 17, 1882', *Nature* (May 31, 1883), 28, 105-7; J.A.C.O. [Oudemans], 'Aurorae of October 2 and November 17, 1882', Letters to the Editor, *Nature,* (June 28, 1883), 28, 196-7.
57. Ellis, W., 'On the Relation between Magnetic Disturbance and the Period of Solar Spot Frequency' *MNRAS* (Dec., 1899), 60, 142-57.
58. Maunder, E.W., 'The 'Great' Magnetic Storms, 1875 to 1903, and their association with Sunspots, as recorded at the Royal Observatory Greenwich', *MNRAS* (Jan., 1904) 64, 205-22.
59. Maunder, E.W., 'Magnetic Disturbances, 1882 to 1903, as recorded at the Royal Observatory, Greenwich, and their Association with Sun-Spots', *MNRAS* (Nov., 1904). 65, 2-34.; It was these three papers which first established the strong statistical relationship between magnetic storms and sun spots; The additional relationship between these phenomena and aurorae were commented on by Mrs Walter Maunder in, 'Suggested Connection between Sunspot Activity and the Secular Change in Magnetic Declination', *MNRAS* (Jan., 1904), 64, 224-8; Ellis, W., 'The Aurora and Magnetic Disturbance', *MNRAS* (Jan., 1904), 228-236.
60. Ibid, Table 1, storms 19 and 7.
61. Capron, J. Rand, 'On some points in Lemström's recent Auroral Experiments in Lapland', *Report of the Fifty-Third Meeting of the British Association for the Advancement of Science* (John Murray, London, 1884), 439-40.
62. Persistent accounts of very low aurorae have existed since at least the 1820s. Adam Paulsen of the Danish Meteorological Station reports that in 1839-40 aurorae hid the top of Esja – a mountain 600 metres in height near Reykjavik in Iceland – and these auroral streamers even appeared between three ground-based observers – see *Nature*, Feb. 7, 1884, volume 29, pp 337-338. The belief that some aurorae could occur close to the ground was given added support by Warren de la Rue's and Hugo Muller's vacuum tube experiments reported to the Royal Society in 1880 (*Philosophical Transactions*, Part 1, 171). By varying the pressure of hydrogen it was claimed that a discharge resembling the brilliance of the aurora could be maximised at only 37.67 miles altitude. The authors concluded that 'It is conceivable that the aurora may occur at times at an altitude of a few thousand feet' [*Nature* (May 13, 1880) 22, 34-5]. Piazzi Smyth questioned this claim (page 76) asking whether the principal auroral line could be seen in their chamber – a claim both men sidestep in their response (page 96).
63. 'Notes', *Nature*, (Feb.1, 1883), 27, page 322 &.(Nov., 29, 1883), 29, 110-1; Lemström, S., 'Auroral Experiments in Finland', *Nature* (Feb. 22, 1883), 27, page 389; Lemström*, S.*, 'The Auroral Borealis', *Nature* (May 17, 1883), 28, 60-3; Lemström (May 31, 1883), 28, 107-9; Lemström (Jun. 7, 1883), 128-30; 'The Mystery of Professor Lemström', http://home.arcor.de/000000/page/projects/northernlight.html (Oliver Kochta, 2011); For a review of Lemström's 1886 book, *L'Aurore Borele* by A.M. Clerke, see *Nature* (Mar., 10, 1887), 35, 433-436.
64. Symons, G. J., 'Artificial Aurorae', *Symons's Monthly Meteorological Magazine* (Apr., 1883), 18, 33-6.
65. Capron, J. R., 'On some points in Professor Lemström's experiments in Lapland', *Symons's Monthly Meteorological Magazine* (Oct., 1883), 23, 147-8; Capron, J.R., 'Professor Lemström's Auroral Experiments in Lapland', *The Observatory* (Sept. 1, 1883), 77, 259-66; Anon, 'The British Association, Mathematical and Physical Science', *The Times*, (Sept., 27, 1883), page 5, column 1 (lower middle).
66. Tromholt, Sophus, 'On the Auroral Borealis in Iceland', *Nature* (Apr. 3, 1884), 29, pages 537-538 and Auroral Researches in Iceland, Nature, (May 22, 1884), 30, 80-1.
67. Eather, Robert H., *Majestic Lights: The Aurora in Science, History and the Arts* (American Geophysical Union, 1980), page 236.
68. 'Notes', *Nature*, (Jul. 10, 1884), 30, page 252.

69. Lemström, S. 'The Results of the Scientific Expedition to Sodankylä', *Nature* (Feb. 19, 1885), 31, 372-6; 'Sophus Peter Tromholt: an outstanding pioneer in auroral research', Moss, K. And Stauning, M., History of Geo and Space Sciences, 3 (2012) , 53-72 (www.hist-geo-space-sci.net/3/53/2-012/)
70. Chree, C., Studies of Aurora, *Nature* (Sept. 12, 1912), 90, 38-40.
71. Jago, Lucy, *The Northern Lights, How One Man Sacrificed Love, Happiness and Sanity to Unlock the Secrets of Space* (London: Hamish Hamilton, 2001), p.277.
72. A full obituary appeared in the *MNRAS* (Feb., 1889), 49 (4), 159-61.

The Author

Paul Fuller is a graduate in geography (Sheffield, 1982) with a postgraduate diploma in statistics (University of Kent, 1983). Following his scary encounter with a Noctilucent cloud in 1967 he has held a long-standing interest in astronomy. He is co-author with Jenny Randles of *Crop Circles: A Mystery Solved* (Robert Hale, 1990, 1993). In this book Paul and Jenny proposed the theory that some crop circles are made by people and that others – perhaps the simpler kind – by wind vortices. His interest in Capron's life was triggered by Peter Van Doorn's rediscovery of Capron's investigation of a field full of circular spots which was reported in *Nature* – Letters to the Editor, 'Storm Effects', July 29, 1880, 22, 290-291. For many years Paul investigated UFO reports for the British UFO Research Association. He works in local government and lives in Hampshire.