Warren De La Rue— Pioneer astronomical photographer

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Warren De La Rue (1815-1889) was the quintessential Victorian wealthy amateur astronomer, operating at the centre of the astronomical scene in England in the third quarter of the nineteenth century. He stands pre-eminent in that country and period in the development and application of astro-photography. His achievements include improvements to the figuring of mirrors, the construction of a superb equatorial reflector and photoheliograph, detailed observations of the Sun, Moon and planets, photography of the Moon and of solar prominences, an extended series of photographic observations of the Sun over a solar cycle, and support for others engaged in the science of astronomy. He achieved all this while making innovations to mechanical systems, carrying out chemical and electrical research, and running a major company.

Fig. 1. Warren De La Rue.
Portrait by Maull & Polyblank. Courtesy of National Portrait Gallery.

Introduction

The January 2008 issue of *The Antiquarian Astronomer* contained a paper by the present author on the observations of the total solar eclipses of 1860 and 1870 by Warren De La Rue (1815-1889) and Paul Jacob Naftel (1817-1891),[1] respectively, both born in the Channel Island of Guernsey.[2] This paper deals in more detail with De La Rue's life generally, and his astronomical achievements in particular. He was a foremost pioneer in the application of the new art of photography to the science of astronomy, a researcher in chemistry, electricity and printing processes, and an outstanding Victorian businessman. James Nasmyth referred to him as the 'father of celestial photography'.[3] Agnes Clerke, the chronicler of nineteenth century astronomy, stated: 'To Mr Warren De La Rue belongs the honour of having obtained the earliest results of substantial value'.[4]

Family

Warren De La Rue was the eldest son of Thomas, founder of the De La Rue printing company. He was born in St Peter Port, Guernsey, in the Channel Islands, on 18 January 1815.[5] Being the son of a famous father implies a privileged head-start, but the circumstances of his birth were far from privileged. It would be several years before Thomas founded the business which still bears his name as a multinational company, and many more years before it became a successful one, and then only with the able assistance of his first-born son, Warren.

Indeed, Warren's grandfather, Eleazar, an unsuccessful farmer, had, twelve years previously, moved from the Guernsey countryside into the town of St Peter Port in a vain attempt to improve his lot. He fell considerably into debt, and it was left for Thomas to find his own way in life. By the time of Warren's birth, Thomas, then almost 22 years old, had established his own small printing business in the island, publishing the *Mirroir Politique*, following a short-lived venture in publishing the *Publiciste* with Thomas Greenslade, a relative of his Devonshire bride, Jane Warren (after whose family, Warren De La Rue was named). This new venture was financially supported by another relative, his brother-in-law, Jean Champion. But that too was short-lived, and in 1816, his father having died, Thomas moved his young family to Devon, and thence to London, leaving behind a number of debts.[6, 7]

Hence before his second birthday, Warren had left Guernsey for good. Throughout his life, however, he kept in contact with the island of his birth, visiting it at least once, having relations with whom he kept in touch, property interests, and, indeed, a Guernsey-born wife.[8]

In Guernsey Thomas had appeared to be more interested in improving the printing process and the paper quality than in editing newspapers. By 1819 he had established himself in Finsbury as a manufacturer of straw hats. This was not such a radical departure from printing as might first appear, as Thomas became interested in the use of straw in the manufacture of paper, and in paper bonnets. He experimented with the use of talc to make paper brighter, and with colour printing, and by 1830 had set up business as a manufacturer of playing cards. His subsequent development of uniformly patterned backs for the cards, so that marks caused by handling them did not give players an indication of the card face, led eventually to security printing of stamps and then bank notes. Security printing is still a major business of the Company.

The early years

Warren grew up in this background of investigation, experimentation and implementation. Through his printing interests, Thomas undoubtedly had contacts with France, and he sent the 15-year-old Warren to be educated in Paris, at the Collège Ste Barbé, where, unlike English public schools the emphasis was on science.ix Warren appears to have appreciated this, writing to his father: 'I perceive now that the French education is much superior to the English'. He appears to have shown intelligence, coped well with

French, Mathematics and Drawing, demonstrated more maturity than other children of his age, showed stable behaviour and a good character, was sensitive, honest with his teachers, and kind to his friends, but may have been too light-hearted outside the classroom.[10]

His French education, however, was cut short by the unrest of the July Revolution of 1830 and the abdication of Charles X, and he was brought back to London to enter his father's firm.

Business abilities and character

No doubt Thomas's motives in providing such a good education for his son were not entirely altruistic; he could undoubtedly see the benefits for the family business. It was a good investment, for in the subsequent years, scientifically-minded, multi-lingual Warren developed new processes which established the printing quality of the firm as second to none. As partner from 1839 to 1858, senior partner to 1869, and company Chairman from 1872 to 1880, he promoted the Company's interests internationally. Indeed, he can be credited with the majority of the firm's success during this period.

Warren had a profound knowledge of the scientific background to the printing process, and pioneered in the development of printing surfaces and inks, all of which expertise was applied to the benefit of De La Rue Press. To this day the Company retains in its archives a 'bible' in which he recorded his undoubtedly secret recipes for colourings.[11] He also had an outstanding business sense, as demonstrated by the huge advances made by the firm during his leadership, and the development of international markets all over the world. These were not easy times, and it took an astute man to steer the Company through a difficult course. He was clearly a 'formidable character', a hands-on leader, being the 'brains' of the business, involved directly in the engraving processes (he held the title of Engraver to the Board of Inland Revenue), voluminous correspondence, much foreign travel, and international negotiations, at a time when the firm had huge contracts for printing stamps, not only for the British Government, but also for India, Italy, Belgium, Australia, New Zealand, and Africa.[12] 'The points which really mattered were the scientific knowledge which was the very being of the De La Rues: the quality of the personal supervision … and finally the advantage that any firm who had devoted its mind to one highly specialised branch of printing, and could point to efficient service as well as results, must have over its rivals.'[13]

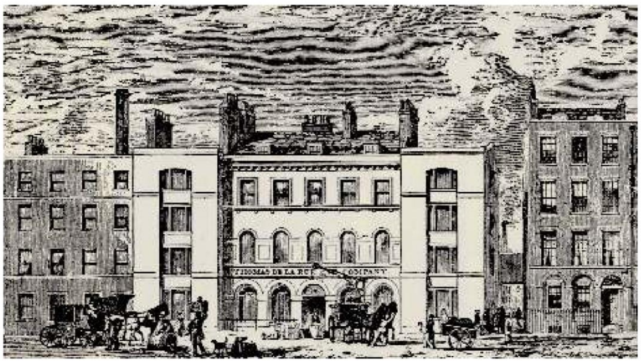


Fig. 2. Thomas De La Rue and Company building at Bunhill Row, London, 1856.
Easton, John., The De La Rue History of British & Foreign Postage Stamps, 1855 to 1901 *(London: Faber, 1958), p. xxii.*

The death of his father, in 1866, was followed soon after by what must have been an even greater loss, the death of his younger brother and business administrator, William, in 1870, putting even greater strain on Warren's energies.

An undoubted advantage was afforded by Warren's character. Time and again, he appears as a sympathetic person, with a good sense of humour, a caring attitude towards the workforce, an eye for opportunity, and a meticulous attention to detail. He is recorded as being 'a man of order and energy, on cordial terms with everyone'.[14] 'Warren … appears as a genial person with a strong sense of humour, howbeit exceedingly shrewd'.[15] His business correspondence dispels 'once and for all the idea that those in charge of the Bunhill Row factory had little but brains and cold blooded efficiency to commend them. Warren appears as a genial companion, clearly the 'boss', but combining humour with shrewdness – the kind of man who would meet trifling disaster with a chuckle rather than an oath'.[16] In giving advice to his brother over some particularly difficult negotiations in Italy, he said: 'Don't shut the door quite close against the foe; it may stop our chance of bleeding him'.[17]

His RAS Obituary records 'the wisdom and good sense of his counsel, his generous and disinterested devotion, and the charm and geniality of his manner'.[18] He used his increasing wealth to good effect, not only in the creation of innovative astronomical instrumentation, but in such personal gestures as providing RAS Fellows with copies of his astronomical drawings and photographs,[19] and financially supporting astronomical endeavours by others. 'He was always ready to assist important astronomical work with his purse and his influence'.[20] 'He was a man invaluable for his intelligence, for his persevering energy, for his promptness of resource, and for a generosity, princely, but discriminating'.[21]

It is astonishing that with all the business activity necessary to a rapidly growing, successful firm, Warren found time to extend his scientific researches into the field of astronomy. Having embarked on this course, however, he embraced it, as with everything in his life, with dedication. The President of the RAS, in presenting him with the Society's Gold Medal in 1862, said: '… for many years Mr. De La Rue has devoted the energies of his mind, a large expenditure, and such leisure as he could abstract from the complicated cares of an extensive and well-known commercial concern, to the earnest cultivation and systematic pursuit of practical Astronomy'.[22]

Marriage

There are few clues as to how Warren came to marry a young Guernsey-born lady, Georgiana Bowles, in London in 1840. He was just 25; she was 20. I have found no evidence that he revisited Guernsey after leaving it in 1816. She was the daughter of Thomas Bowles, who was from London, and his wife, Guernsey-born Marie-Marthe Bardel. There is evidence for a family relationship between the Bowles and the Greenslades, so that provides a possible explanation for a meeting between Warren and Georgiana.[23]

Georgiana, nicknamed Georgie, was to present Warren with a girl and four boys. She may well have assisted Warren in his photographic endeavours.[24] She lived to be 98, having survived her husband by 29 years, and is buried in the same grave as Warren, in Kensal Green, London.

Early researches

De La Rue embarked on scientific researches at an early age, demonstrating an eclectic approach, but focusing primarily on electricity and chemistry. His first papers, on the subject of the Daniell Battery, were published in 1837, when he was 22.[25] He was a founder member of the Chemical Society (1841).[26] With Charles Button, a wealthy chemist whose financial support had saved Thomas De La Rue's company during difficult times in 1837-8[27], he published *A Series of Tables of the elementary and compound bodies systematically arranged, in the form of labels*.[28] His chemical expertise was undoubtedly material in helping the Company at this time, and probably led to his being made a partner in 1839. He published a number of papers on chemistry in the 1840s, especially on cochineal, showed a passing interest in entomology, and briefly dabbled in microscopy.[29] When the College of Chemistry was established in 1845, he studied under its Director, August Wilhelm Hofmann,[30] and in the 1850s assisted Michael Faraday with studies on the optical properties of gold film.[31]

He showed a particular aptitude for invention, again especially that related to his father's printing business. He was granted no less than 14 patents between 1844 and 1866, mostly for mechanical devices.[32]

First steps in astronomy

It was, indirectly, his chemical pursuits and his father's firm which were responsible for the kindling of De La Rue's interest in astronomy. A major influence in the Company's improved fortunes had been the development of a white lead coating for playing cards, for which his father had been granted a patent. De La Rue engaged James Nasmyth, the engineer, astronomer and inventor of the steam hammer, to work on a new process for making the pigment, and he visited Nasmyth in 1840 to discuss this work. During his visit Nasmyth was casting a thirteen-inch mirror of speculum metal by a process of his own.[33] Reportedly, Nasmyth was also using another speculum to project an image of the Sun, and De La Rue pointed out what he assumed were defects in the mirror, but which were actually sunspots.[34] De La Rue became curious, and commissioned Nasmyth to cast a similar speculum for him, which he then ground and polished with a machine based on William Lassell's, but with improvements which he, De La Rue, had devised. He gave the speculum a rotating motion independent of the sliding plate, and cranked the polisher on its axis, so that it also had a rotating motion.[35]

With this mirror De La Rue created a superb 13-inch reflecting telescope,[36] with a focal length of 10 feet. Later in life, he was to acknowledge his debt to Nasmyth in sending him one of his astronomical photographs: 'No one has so great a claim on the fruit of my labours; for you inoculated me with the love of star-gazing'.[37]

He set up the telescope at his home in Canonbury, and proceeded to develop observing techniques with the meticulousness characteristic of all his work. He soon gained a reputation as an excellent and accurate observer. He was elected a Fellow of the Royal Astronomical Society in 1851, and in 1852 he commenced a long series of astronomical publications with a drawing of Saturn in the Monthly Notices.[38] There followed papers on detailed observations of Mars, Saturn and Jupiter, with particular emphasis on micrometric measurements of their diameters, and timings of occultations. *The Monthly Notices* contain numerous references to his generosity in making copies of his engravings, some of them coloured, for Fellows of the Society. These were, no doubt, the beneficial result of his ready access to printing facilities.

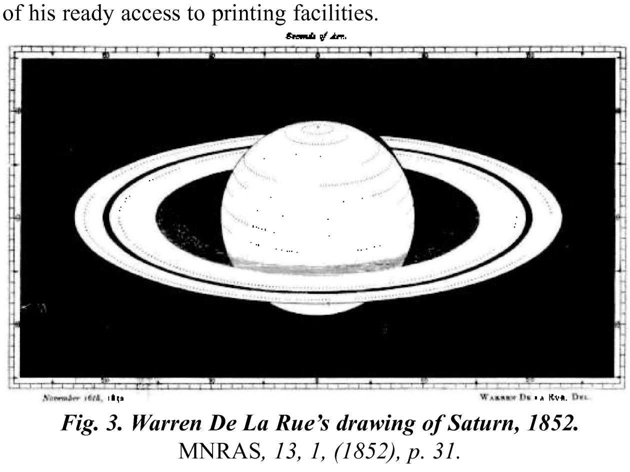


Fig. 3. Warren De La Rue's drawing of Saturn, 1852.
MNRAS, *13, 1, (1852), p. 31.*

His meticulous approach to observation is recorded in a lengthy letter to Sir John Herschel, which describes how it was his practice to observe Saturn over a long period of time, and take micrometrical measurements before making a final drawing in colour, and even then comparing the tints over and over again. Furthermore, 'I always etch the outline of the planet and all its details myself on the steel plate, as I do not find any of the engravers sufficiently skilful or rather I ought to say careful to undertake it." Even so, "I have been so long accustomed to doubt the results of my own observations, and even to delay their publication for an unreasonably long period, notwithstanding the risk of being forestalled, that I am neither surprised nor hurt when others do not immediately adopt them as correct'.[39]

First attempts at astronomical photography

In 1850 Warren was elected a Fellow of the Royal Society on the basis of his chemical researches.[40] The following year he his father Thomas were very much involved in the organisation of the Great Exhibition at Crystal Palace, sitting on several of the committees and acting as Jurors. De La Rue and Company had a stand at the Exhibition, the centrepiece of which was an envelope-making machine, capable of producing no less than 2,700 envelopes an hour.[41] The machine had been invented by Warren De La Rue and Edwin Hill, the brother of Rowland Hill, the postal reformer, and proved significant to the fortunes of the Company because of the advent, a decade earlier, of the penny post and the consequent demand for envelopes. Previously letters had been simply folded and sealed, and charged by the number of sheets.

Fig. 4 The De La Rue stand at the Great Exhibition, with the envelope-making machine.
Colour lithograph print published by Lloyd Brothers & Co., London, 1851 (Victoria and Albert Museum, 19538:7).

At the Great Exhibition was a large photographic display, and it was there that Warren saw a daguerreotype print of the Moon, taken with the 15-inch equatorial refracting telescope at Harvard College Observatory.[42] Although the daguerreotype process had been in existence for a dozen years, this was the best-defined astronomical image so far obtained. It stimulated the development of astronomical photography, and inspired Warren De La Rue to apply the newly-invented wet collodion process to the art.

Compared with later photographic processes, the wet collodion process, introduced in 1851 by Frederick Scott Archer, seems extremely cumbersome.[43] It involved adding cadmium iodide to a solution of cellulose nitrate (collodion), coating a glass plate with this mixture, sensitising it with silver nitrate in a darkroom, and then exposing the plate while still wet. After exposure the plate had to be

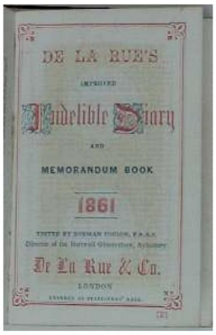
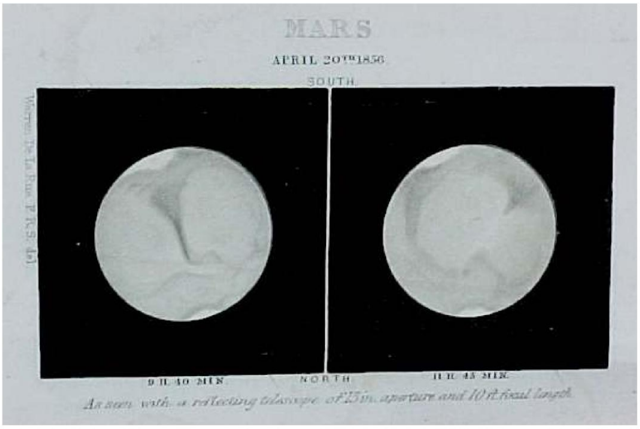


Fig. 5.1 (left) & 5.2 (below). The front page of the De La Rue diary for 1861, and a page showing Warren's sketches of Mars.
Courtesy of the archives of De La Rue plc, Basingstoke.



developed with pyrogallic acid, and fixed with a strong solution of sodium hyposulphite before the collodion dried, then washed, dried and varnished. So it was necessary that photographers carry a darkroom around with them.

Nevertheless, the wet collodion process had considerable advantages over the daguerreotype. It was more sensitive, so exposures could be much shorter, and it enabled reproductions on paper to be made of the image on the glass plate. It produced highly detailed photographs, and was the most popular method of photography until the dry-plate method was invented some 30 years later. Warren was the first person to use the wet collodion process for celestial photography, and it was this process which he used throughout his astronomical career.

The long exposures needed for daguerreotypes necessitated the telescope to be driven accurately to counteract the rotation of the Earth. By contrast, De La Rue, using the wet collodion process, was able in 1852 to produce his first successful photographs of the Moon with exposures of just a few seconds, driving the telescope by hand.[44] This, however, required an assistant 'and it was not easy to find a friend always disposed to wait up for hours, night after night, probably without obtaining any result'.[45] According to Norman Lockyer: 'He soon found that he was working against nature ? that nature refused to be wooed in this way, the moon in quite a decided manner declined to be photographed'.[46] He developed a sliding plate-holder, and, by viewing the image through the collodion film, was able to keep the telescope guided on the Moon. But the continued need for an assistant made him discontinue further photographic experiments for a while.

De La Rue diaries

There appears to have been considerable overlap between De La Rue's scientific and business interests. He undoubtedly made good use of the Company's engineering workshops, produced prints of his photographs for distribution to fellow astronomers, and made a number of business trips to the continent, during which he took the opportunity of visiting observatories and consulting with colleagues. Of interest is the annual publication by De La Rue & Company of diaries, edited by astronomers, and containing much astronomical information and reproductions of sketches by De La Rue and others.

For example, De La Rue's improved indelible Diary and Memorandum Book for 1859, edited by Norman Pogson, Assistant Observer of the Radcliffe Observatory, Oxford, contains not only Moon phases and sunrise and sunset times, but also: solar and lunar eclipses, occultations, eclipses of Jupiter's satellites, times of the Sun's southings, planetary risings, settings and transits, the difference between local and Greenwich time for a number of places, an explanation of astronomical terms, planetary phenomena, a detailed description of Saturn, and his sketch of the planet. The diary for 1861, also edited by Pogson (by then Director of the Hartwell Observatory, Aylesbury), included two of his sketches of Mars. In 1869 an article by Warren De La Rue about the Orion Nebula was included, illustrated with a sketch of the nebula as seen through Lord Rosse's telescope. That for 1871, edited by William Godward (Nautical Almanac Office) and Edward Thelwall (Trinity College, Cambridge), included sketches of solar prominences.[47]

The scientific journal *Nature* was moved to say, with respect to the De La Rue pocket and desk diaries for 1882:

> If possible all these are more beautiful examples of the printer's art than those produced in past years, and especially interesting from *Nature's* point of view, at all events is the fact that the amount of scientific facts packed into the closely-printed page is greater than ever. The mechanical equivalent of heat, the present magnetic elements, the mean distance of the sun, and such like data, are all to be found in their proper place, while the astronomical portion is so full that the amateur astronomer will be spared many references to his *Nautical Almanac*.[48]

Mounting of Huygens' object-glass

By 1854 De La Rue's reputation in the fields of mechanics, optics, and astronomy was well-enough established that the Council of the Royal Society asked him to superintend the remounting of an objective lens which had been made by Christiaan Huygens (1629-95), and presented to the Society by Sir Isaac Newton. Huygens had pioneered the development and use of aerial telescopes, that is tubeless instruments with extreme focal-length object-glasses mounted in short tubes held by cables, the image being observed with a handheld eyepiece, the observer being guided to the position of the objective by a 'bull's-eye lantern'. The Society's purpose in re-creating Huygens's telescope with his own object-glass was to resolve a theory proposed by Otto Struve that the rings of Saturn might be collapsing towards the planet, and that the change which had taken place since Huygens' observations two centuries earlier was measurable.[49] The rings were to appear at their extreme open position in 1855—the best alignment for this purpose for 15 years, and the opportunity was to be taken to make the observations and measurements.

In a detailed report for the Council De La Rue said that he had examined four object-glasses at the Kew Observatory,[50] of which at least two (focal lengths 122 feet and 170 feet) had been made and/or used by Huygens. He prepared proposals for the remounting of the 122-foot one, first examining whether it was possible to use the Kew Gardens Pagoda for its support, then using a pole, and concluded that the only practical method was to build a 120-foot tower in the form of a pyramid, on land adjacent to the Kew Observatory. He proposed a modern improvement on the guiding light: a platinum wire ignited by a voltaic battery. He had a model of the con-

Fig. 6. Huygens' 170-foot focal length object glass. *Royal Society MO/1/1/3 and No 23 of I/010. The object glass appears to have a diameter of about 10 inches.*

struction made (by De La Rue Company engineers) and, having an initial grant from the Society of £500, went so far as to rent the area of land needed, fencing it off from cattle, engaging an architect, and obtaining two estimates.[51] The estimated total cost was over £900 (£70,000 at today's values).

Having put forward his technical solution, De La Rue refrained from actually advocating the erection of the telescope, 'and more especially according to the plan that I have ventured to propose, as I wish to be considered merely as a willing agent to do that which I have been requested to do, in the manner seeming best to my humble judgment'.[52]

In the event, the object-glass selected for the project was the 170-foot one. It exists in the scientific instrument collection of the Royal Society, and is inscribed with Huygens', Newton's and De La Rue's names. It is not clear, however, whether the observations were actually carried out successfully, as no report on them has been identified. The inscription on its mount, however, which includes the date 1856, implies that it was in fact used.

The Royal Society Philosophical Club

In 1855, the same year of his report on the Huygens object-glass, De La Rue suffered an embarrassment involving the Royal Society Philosophical Club. The Club had been founded in April 1847, its stated purpose being to promote the Society's scientific objectives, to facilitate what we would today call networking amongst active Fellows, to increase attendance at meetings, and to encourage the contribution and discussion of papers. It was limited to 47 members who had to have published a scientific paper, and appears to have been something of an inner circle within the Society.

The Club had a curious set of rules. Meetings, which appear to have included a dinner, were held monthly from October to June, including the Anniversary Meeting held in April each year, at which new members were elected. They started at 5.00 pm 'precisely', and finished at 8.15 pm, members then being expected to attend the Society meeting which started at 8.30 pm 'unless unavoidably prevented'. Members chaired meetings in turn, in alphabetical order. There was a Committee of six members, and candidates for membership had to be proposed by three members who were not Committee members. The names of candidates thus proposed waited their turn for up to five years, and were dealt with in order of the date of their nomination. However, if the number of candidates exceeded the number of vacancies the Committee put forward the names of those (already proposed) candidates which they considered the most eligible. Those candidates recommended by the Committee had priority of ballot. At least 15 members had to be present at the election. Voting was carried out by secret ballot, a ballot box with black and white balls being used (or a box with partitions for 'yes' and 'no' into which balls could be dropped; such a box still exists in the Royal Society archives). The rules stated 'one black ball in three to exclude'. In other words, for a candidate to succeed two-thirds of those present had to vote in his favour.

Fig. 7. Royal Society ballot box.
Royal Society archives; photograph by author.

De La Rue had been elected a Fellow of the Royal Society on 6 June 1850, and in due course was nominated as a candidate for membership of the Philosophical Club. At the Anniversary Meeting held in April 1855 there were six vacancies and six candidates, including De La Rue, who was by then a member of the Council. However, there being only 14 members present the election was postponed to the meeting held on 10 May. At that meeting 18 members were present,[53] and the election proceeded. One candidate succeeded without a vote, having previously been a member, but having been abroad for a while. Of the other five candidates four were successful, but De La Rue failed to be elected; at least six members must have voted against him. It appears from a perusal of the Club Minutes that he may have been the only candidate not to be elected in the history of the Club.

The reasons for his non-election are not recorded. It might perhaps have reflected a prejudice of some members to a perception of 'trade'. A clue may be found in a letter by Charles Darwin, who had been elected to the Club the previous year, but who was not present at the meeting of May 1855. He wrote: 'I am glad to hear of the elections for the Club, but very sorry about De la Rue: he does not appear like a gentleman, but all that he says at the Council seems very gentlemanlike & nice: I would not have the blackballing of such a man on my conscience for a couple of hundred guineas: what a mortification for him'.[54]

De La Rue had to wait nearly thirty years to become a member of the Philosophical Club. He was finally elected, unanimously, on 28 April 1884, having been recommended by the Committee for priority of ballot. By then he was a prominent and respected Fellow of the Society, having been awarded the Royal Medal (1862), serving twice as Vice-President (1869-70 and 1883-5), and chairing the Society's Kew Committee. He remained a member of the Club for the remaining five years of his life, but rarely attended meetings. The Minutes of the Meeting held on 16 May 1889, held shortly after his death, record the unanimous wish that 'the deep regret of the members at the loss of a colleague so distinguished as the late Dr Warren de la Rue' be conveyed to his widow.[55]

Cranford Observatory

By 1857 he had moved his telescope to the darker, clearer and steadier skies of a substantial estate at Cranford in Middlesex, 15 miles outside of London, where he had built a new house, and entered into the life of the community, being Chairman of the Sewerage Committee at a time of major development of public sewers.[56] At Canonbury the telescope had been in the open air in his small garden. He now installed it in a purpose-built observatory, together with a small transit circle by Simms, and a clock by Condliffe of Liverpool. The telescope was mounted on a pier 15 feet high, and had a photographic laboratory beneath it.[57]

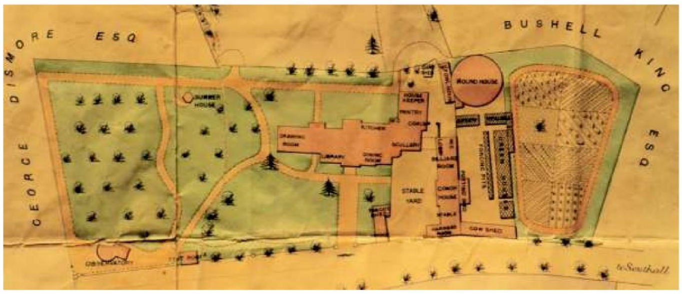


Fig. 8. Warren De La Rue's Cranford Estate in 1873. The observatory is shown at the lower left of the plan.
Hounslow Public Library, Q728.3/927.

Fig. 9. Warren De La Rue's house at Cranford in 1873.
Hounslow Public Library, Q728.3/927.

De La Rue provided the telescope with a clockwork drive, regulated by a governor, obviating the need for an assistant. This kept the object in the field for over an hour, and he constantly experimented with ways to improve it. It was not easy to adjust the drive to the accuracy required for photography, even at a sidereal rate, let alone that required for the Moon: 'we can fidget at it, and fidget at it, and at last get it; but … the moon is going in a reverse motion to the motion of the heavenly bodies … and it is going with a variable motion; and if we set the clock tonight, it will not follow to-morrow'. Even a dust particle or hair on the drive wheel could affect the accuracy of the drive.[58]

Sometimes, however, the drive did keep the object exactly on the cross-hairs for up to a minute. He was, therefore, able to resume his photographic experiments. He developed cameras for use at the Newtonian and prime foci. By November 1857 he was able to exhibit 'a great variety of beautiful photographs of the Moon.' His lunar pictures "brought to light details of dykes, and terraces, and furrows, and undulations on the lunar surface, of which no certain knowledge had previously existed'[59] and bore magnifications of 400 times. He changed from using positive photographs to negative ones, which not only enabled paper reproductions to be made but also had finer grain. By improvements to the development process he was able to reduce the exposure times to between 3 and 7 seconds, not only of the Moon but also of Jupiter, the latter showing the planet's belts. The short exposures assisted the photography by reducing the effects of irregularities in the drive and changes in the Moon's declination, and atmospheric disturbance. He foresaw that photography would supersede hand-drawing for mapping the Moon[60] and produced photographic enlargements of the Moon over three feet in diameter.[61] In later years (1866-9) he was to take part in a Moon-mapping project, serving on the lunar mapping committee of the British Association for the Advancement of Science (BAAS).[62]

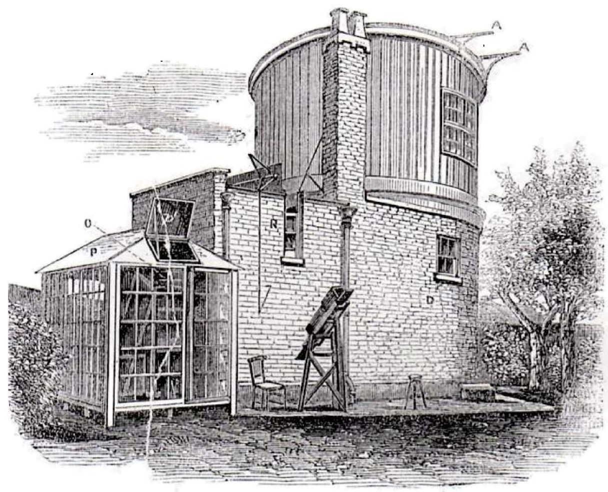


Fig. 10.1 and 10.2. Warren De La Rue's observatory and 13-inch equatorial (with De La Rue) at Cranford.
The Engineer *(May 22, 1868), pp. 374-6), reproduced in* The British Journal of Photography*, 15, May 29, 1868, pp.256-7 and June 5, 1868, pp.270-1. The observatory was eventually used as living accommodation, and came to an unfortunate end on 21 April 1966, when it burned down just before it was due to be demolished.* Middlesex Chronicle*, Hounslow and Brentford edition, 29 April 1966; RGO 6/172 534.*

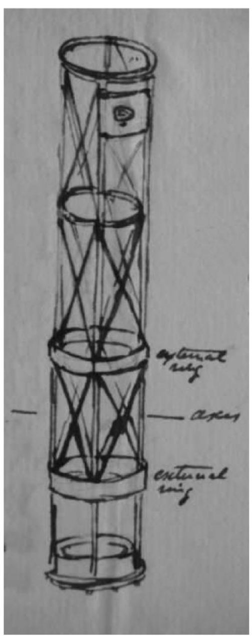
He also exhibited photographs of Saturn and Castor 'of great beauty and promise', and studied the relative illuminations of areas of the Moon, Jupiter, and Saturn, comparing the photographic and visible intensities, observing that oblique rays and the mare produced less 'photogenic power' than the direct rays and the mountains. His meticulous observations, however, were not matched by

***Figs. 11.1 and 11.2. Two images from* Photographs of the Moon.**

Photographs of the Moon *by Smith, Beck & Beck, from negatives taken by Warren De La Rue, published 1862. The set comprises 12 pictures taken at successive lunar phases. These two pictures are from the author's collection. They show the Moon at ages of 7 days and 15 days, and are telescope views, i.e. inverted and reversed. 'Mr De La Rue has made a series which shows the moon in all her different phases. They are remarkable …', Lockyer, J Norman.,* Stargazing: Past and Present *(London: Macmillan and Co.,1878), p. 464.*

his deductions: 'he inclines to the view that the Moon is surrounded by a comparatively dense atmosphere of small extent, and that vegetation exists on the lunar surface, particularly in those portions generally called seas'.[63] This opinion was noted by Jules Verne.[64] Having acquired a large number of pictures of the Moon, De La Rue was able to publish a compendium showing it at every phase.

In 1864 he briefly contemplated carrying out a systematic survey of nebulae, a project for which he felt his equatorial telescope was well suited, but decided that since that was being undertaken by Heinrich d'Arrest with an 11-inch refractor; it would be a waste of his time to do so. His 13-inch reflector had, until then, been enclosed in a wooden tube, but he decided to convert it into a skeleton structure, using four gas tubes. He carefully designed it with torsion wires, and reported that 'it is very rigid and looks an elegant piece of apparatus. It is a manifest improvement on the old tube as regards definition'. The new design was also of considerable benefit for solar observation and photography.[65]



Stereoscopy

De La Rue used his many lunar images to produce a number of stereoscopic pictures, by grouping pairs of photographs taken at different stages of lunar libration. This was a complex process, requiring the selection of pictures taken at similar phases but at extremes of libration in longitude only, often months apart. They were published in 1858, and created much interest. Sir John Herschel expressed his 'admiration of their transcendent and wonderful effect. It is a step in nature but beyond human nature as if a giant with eyes some thousands of miles apart looked at the Moon through a binocular. What surprises me most is the extraordinary difference in the two pictures as seen by either of the eyes separately not only in form but in shadow & light & the way in which they blend into one is something quite astonishing'.[66] These pictures were not only wonderful to look at, but also, De La

Fig. 12. De La Rue's drawing of his new tube.
Letter from De La Rue to Herschel, 25 October 1864; Royal Society HS6.D.161.

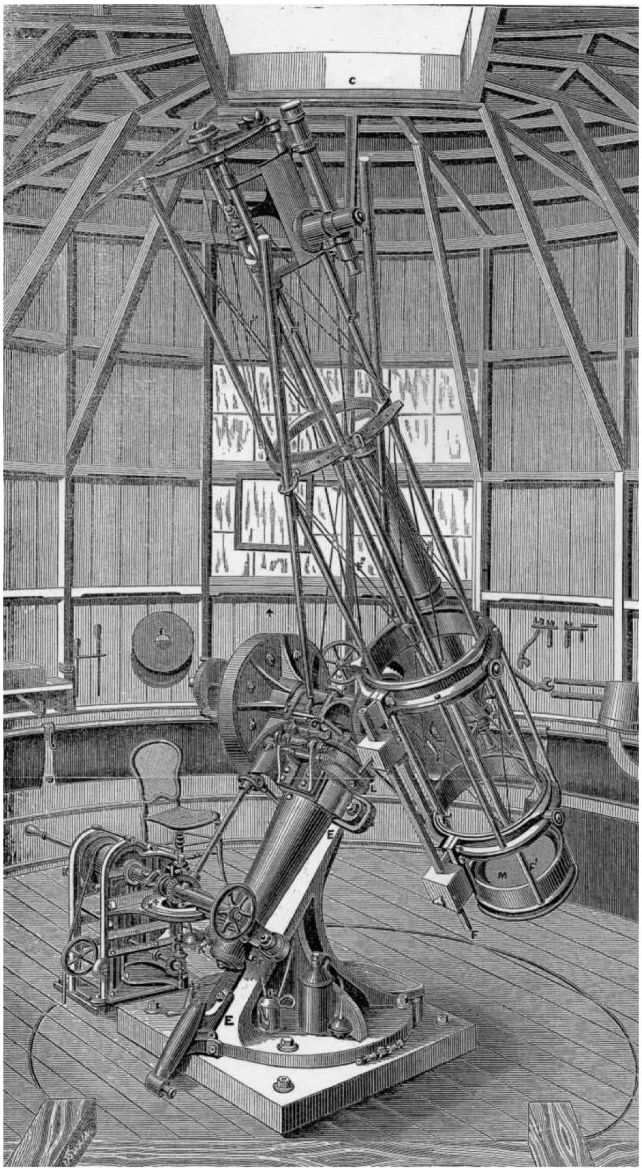


Fig. 13. The completed telescope.
'Mr Warren De La Rue's apparatus for photographing the Moon', The Engineer *(22 May 1868), p.374.*

Rue observed, revealed altitude differences, showing, for example, that Tycho's rays consisted of ridges and furrows, overlaid with craters.[67]

He described the production of the stereoscopic photographs in a comprehensive report which he presented to the BAAS meeting held in Aberdeen in 1859. Entitled *The present state of Celestial Photography in England*, it included a detailed account of his photographic techniques and manifold successes.[68] He somewhat immodestly, although undoubtedly truthfully, stated: 'In bringing before the Association the present Report it will be only necessary, after referring briefly to the labours of others, to confine myself to an account of my personal experience; for, although other observers have occasionally made experiments in Celestial Photography, there has not been any systematic pursuit of this branch of Astronomy in England, except in my Observatory, and under my immediate superintendence in the Kew Observatory'.[69]

His *Report* pointed out that his success was largely due to his use of a reflecting telescope, rather than the refractors used by others, as well, of course, as his persistent dedication to the task. The fact that his telescope was equatorially mounted was, of course, also highly beneficial. He gave an extremely detailed description of the very laborious preparation of the collodion plates, the development of the pictures, and his telescope driving mechanism, as well as the effects of atmospheric disturbance and lunar libration, together with simplified diagrams showing the stereoscopic technique. He noted that his lunar images of 1.1 inches diameter, and which he enlarged to 8 inches, could be examined at a magnification of over 16, showing details as small as two arc-seconds (one-thousandth of an inch on the original plate), or two to three miles on the surface of the Moon. He described in some detail the crater Copernicus, the Apennines and the ray system of Tycho.

De La Rue explained that, while he occasionally took pictures of the fixed stars, particularly the double star Castor, he generally left them to the Harvard Observatory, while he concentrated on the Moon. He did, however, take photographs of the planets when the atmospheric conditions were favourable, often several images on a single plate, by briefly disconnecting the drive from the telescope, allowing the next image to fall on a different area of the plate. Calculating that the optimum stereoscopic angle was 15.8º, and observing that the maximum lunar libration in longitude provided just this angle of parallax, he conjectured that it would be possible to use the rotations of Jupiter (26 minutes) and Mars (69 minutes) to produce stereoscopic images of those planets. He further surmised that the apparent opening and closing of Saturn's rings would afford a means of obtaining a stereoscopic picture. He stated that he had obtained a stereoscopic effect by pairing two drawings of Saturn which he had made in November 1852 and March 1856, but there is no record that he made stereoscopic photographs of other planets.

He did, however, succeed in making stereoscopic pairs of photographs of the Sun by using displacement of successive images by solar rotation. He found that any two photographs taken at intervals of about a day sufficed to produce satisfactory stereoscopic images. These confirmed Alexander Wilson's view of nearly a century earlier that sunspots were indentations in the solar photosphere, while solar faculae were high above it.[70]

Always busy, De La Rue was to be even more active in 1858 and the years immediately following. He tried to photograph the century's most spectacular Comet, Donati, but a 60-second exposure failed to produce an image. He attributed this to the low altitude of the comet at the time.[71] He did, however, send his sketch of it to Sir John Herschel.[72]

Fig. 14. Stereoscopic views of the Moon by Warren De La Rue, 1858.
Published as a stereoscopic slide by R & J Beck, London, 1858, author's collection. 'The appearance of rotundity over the whole surface of the Moon is perfect; and parts which are as plain surfaces in the single photograph in the stereoscope present the most remarkable undulations and irregularities',. MNRAS, 19, 1 (1858), p. 40.

Business and family developments

Further attempts at photography of Comet Donati were cut short by a 'severe domestic calamity'. His mother died in September, and two weeks later he left for a two-month business trip to Russia.[73] Soon afterwards his father remarried and retired from the firm, leaving Warren De La Rue, as senior partner, to run the business with his younger brother, William. While the two of them worked well together, William's considerable administrative expertise complementing Warren's technical abilities, their acrimonious relationship with their father, and the severe financial terms which he imposed upon them, must have made things very difficult for a while.[74] It must indeed have been hard for him to balance his major business responsibilities with his research interests.

Nevertheless, he continued research in astronomy and chemistry, and publishing papers. In addition to presenting his 1859 BAAS report on celestial photography, he was also preparing for the expedition to Spain to observe and photograph the 1860 solar eclipse, an event which was to occupy much of his analytical energies for the next two years.

Solar granulation

The first few years of the 1860s saw considerable debate about the nature of solar granulation. It started in 1861 when James Nasmyth reported seeing what he called 'willow-leaf shaped objects' on the Sun.[75] These lenticular bodies, he said, covered the entire photospheric surface, and were particularly noticeable against the dark umbrae of sunspots.[76]

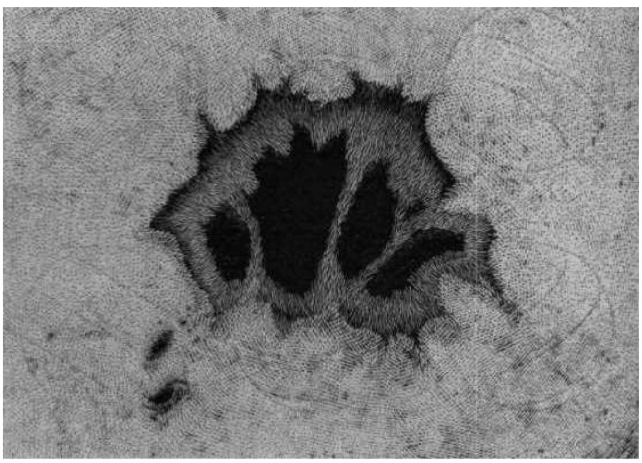


Fig. 15. Sunspot, by James Nasmyth.
Guillemin, Amédée., The Heavens *(London: Richard Bentley, 1868) p. 32.*

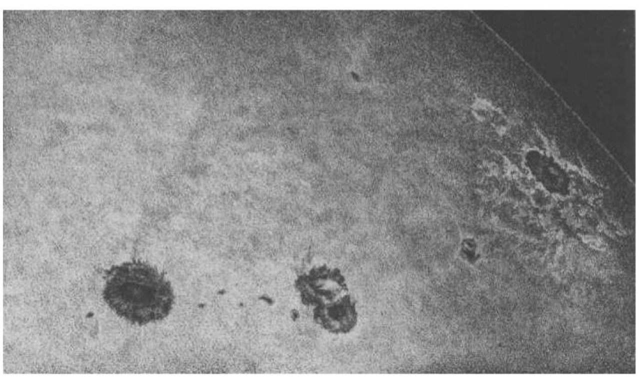


Fig. 16. Details of sunspots and faculæ, from a photograph by Warren De La Rue, 20 September 1861.
Sir Robert Ball, The Story of the Heavens *(London: Casell & Company, 1892) Plate III, opp. p. 41.*

Anxious that his discovery should be recognised and acknowledged, Nasmyth consulted a number of astronomers, including the Astronomer Royal, George Biddell Airy, Sir John Herschel and Warren De La Rue. Herschel endorsed the observations, noting that they supported the theory that the solar radiance must be produced by solid bodies, rather than gases. De La Rue also found evidence of the willow leaves, especially when examining an enlarged photograph of the Sun. In sending his first attempt at such an enlargement to Herschel in 1861 he wrote: 'An attentive examination without a magnifier or simply an amplifier will enable you to trace a little of Jas Nasmyth's willow leaf pattern in the fringing of the umbræ and penumbræ'.[77]

Others, however, notably the Rev. W. R. Dawes, did not subscribe to the willow leaf idea. In 1863 De La Rue himself confessed to some early scepticism, later dispelled by his own observations. He informed Herschel that he was convinced of their existence,[78] and expressed the following enlightening comments to Charles Pritchard, Secretary of the RAS. Note particularly his problems with solar observing:

> Mr Nasmyth sent to me as he did to many other persons a photographic reduction of a drawing he had made of a solar spot observed under particularly favourable circumstances with an (eight inch?) achromatic by Cook in which he noticed that the photosphere of the sun appeared to be made up of a conglomeration of spindle shaped components very uniform in size – and that on the edge of a spot they appeared to overhang the chasm and sometimes to bridge it over in parts – to explain to me his views he sent me a model made up of pieces of paper cut in the willow leaf form overlaying each other.
>
> I had and have a great confidence in Mr Nasmyth's power of delineating of any thing he observes—he has a wonderful eye and hand:- and when I received the drawing and model I believed in them, with a mental reservation however;- the markings as depicted seemed to me too uniform in size and too distinctly made out to be absolutely correct & I thought that Mr Nasmyth's artistic skill had too markedly outlined the peculiar kind of phenomenon he was desirous of calling attention to.
>
> I had never noticed any such markings on the Sun's surface but, at the same time, I felt that I was no authority on such a subject for, having injured one eye by an inadvertence in observing the Sun I had abstained from making the Sun's surface my particular study.
>
> Such, as I have described, were my feelings with respect to the willow leaves when I happened to call upon you at Clapham; you casually mentioned that you had been looking through your Cook's object glass at the Sun and I expressed a desire to have an opportunity of judging his productions as I had never observed with one of his glasses. We entered your observatory which we had recently left, so that the shutter was still open and therefore the conditions were so far favourable:- you had on the telescope a Dawes' eye-piece. As soon as I looked into the telescope I immediately exclaimed "you have a splendid object glass!- here are Nasmyth's willow leaves unmistakably brought out – have you an eye-piece with a diagonal glass reflector for I do not like this small field". The eye-piece was changed and the diagonal employed instead of Dawes', and the spot was severely scrutinized – it happened to be near the limb and I was surprised to see the spindle shaped markings end on, they resembled the fingers of one's hand held loosely together and viewed on

> end. The markings were observed to be extremely alike both in size and dimensions and very much as Nasmyth had represented them—whether or not they are quite so uniform in size as he has depicted them will be a matter for further investigation, but that the photosphere is composed of an aggregation of components having a well defined form cannot be disputed. I mentioned to you that I had not seen these markings with a splendid 4^{in} of Dallmeyer's—since then however I have on two or three occasions fully confirmed the existence of these markings with that object-glass and have, if I remember rightly, shown them to Carrington. It requires the very finest atmospheric conditions to permit of this phenomenon being seen and I should deem it useless to attempt the observation with any but an instrument of the greatest excellence.[79]

Pritchard clearly had great respect for De La Rue as an observer of detail, saying: 'Of all men's eyes in the matter of telescopic vision, De La Rue's are peculiarly trustworthy', and advocated Nasmyth's claims.[80]

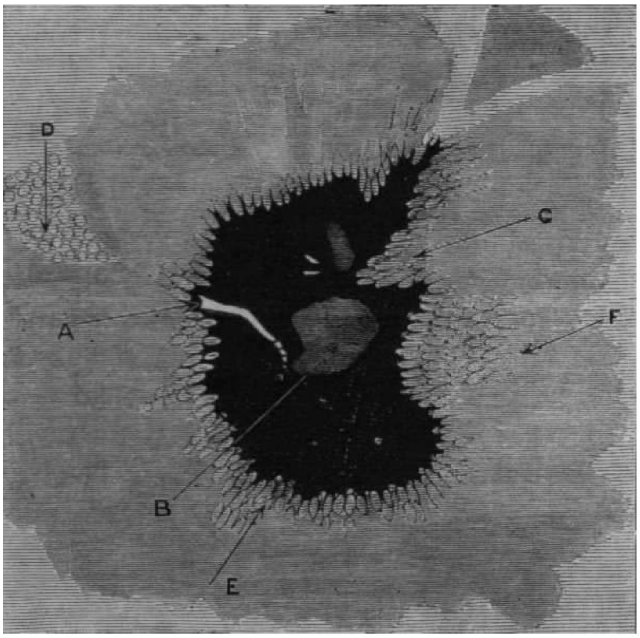


Fig. 17. Sunspot by Norman Lockyer, showing the 'willow leaves'.
Guillemin, Amédée., The Heavens (London: Richard Bentley, 1868) p. 42.

Encouraged by support from such respected astronomers as Herschel and De La Rue, Nasmyth persisted in his contention that the willow leaves existed, going so far as to say that: 'the grand fact of their existence is now proved beyond all doubt'.[81] Nevertheless, the dispute continued. It appeared to be agreed that there was some kind of nodular appearance to the solar surface, the main differences of view being whether the nodules were of uniform size and shape. No doubt the problem arose because, being only about an arc-second in size, they could be seen only with the highest quality instruments under the most favourable seeing conditions, and even then at the limit of visibility.

The disagreement was eventually settled in 1865 by a detailed description by William Huggins, who referred to them as granules or granulations, the term by which the small-scale structures of the photosphere are now known.[82] It is interesting to note that De La Rue had himself referred to them as granulations as early as 1861, and was probably the first to do so.[83]

Solar photographic survey

De La Rue's reputation as a pioneer astronomical photographer could certainly have been based solely on his early photographs of the Moon and the planets. But he is best known for his success in solar photography, and especially for his observations of the 1860 total eclipse of the Sun, which, as has already been described in some detail by this author,[84] demonstrated that prominences were genuine features of the Sun. De La Rue's development of the Kew photoheliograph was briefly described in the same paper.

Fig. 18. The Kew Observatory building today.
Photograph by author. The observatory is now an office building.

The proposal for a daily photographic survey of sunspots had been made by Sir John Herschel in 1854: 'I consider it an object of very considerable importance to secure at some observatory, and indeed at more than one, in different localities, daily photographic representations of the sun, with a view to keep up a consecutive and perfectly faithful record of the history of the spots'.[85] He provided specifications for the instruments, which would have apertures of 3 inches, their locations, and recording schedules.

De La Rue advised that such an instrument could be built for £150. This was provided by the Royal Society, and De La Rue proceeded to design it and have it constructed for the BAAS. By 1856 the resulting photoheliograph had been completed by the instrument maker Andrew Ross, and installed in the dome at the top of Kew Observatory, where it commenced operations in March 1858.

The brightness of the Sun's image required considerable experimentation in order that satisfactory photographs could be obtained. The object glass was stopped down from 3.4 inches to 2 inches, the image was enlarged by secondary optics within the instrument from 0.466 inches to 4 inches diameter (decreasing the light intensity 64 times), a filter was introduced in the light path, and experiments were conducted with different forms of collodion. Nevertheless, the over-exposure of images persisted. The solution was eventually found in the design of a spring-loaded shutter with an adjustable aperture, placed near the plane of the primary focus.[86]

With such very short exposures, it was found unnecessary to drive the telescope. A finder telescope mounted on the clamped telescope projected an image of the Sun onto a brass plate on which were inscribed lines corresponding to the Sun's diameter. When the Sun moved into the central position, a lighted match was used to burn a thread holding the spring-loaded shutter, whose aperture then flashed across the field. Wires fixed across the field were used to determine the positions of sunspots. Possible image distortion was checked by photographing a 15-foot scale mounted on the Kew Gardens pagoda, 1466 yards away.[87]

Fig. 19.1. The Kew Observatory, with the Kew Gardens Pagoda. The Observatory in Richmond Gardens, *by T Cadell, London, 1792 (British Library).*

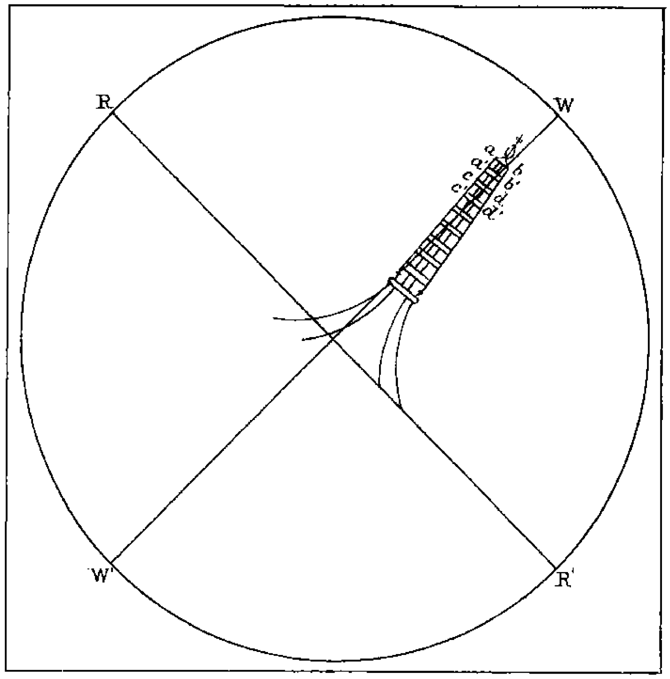


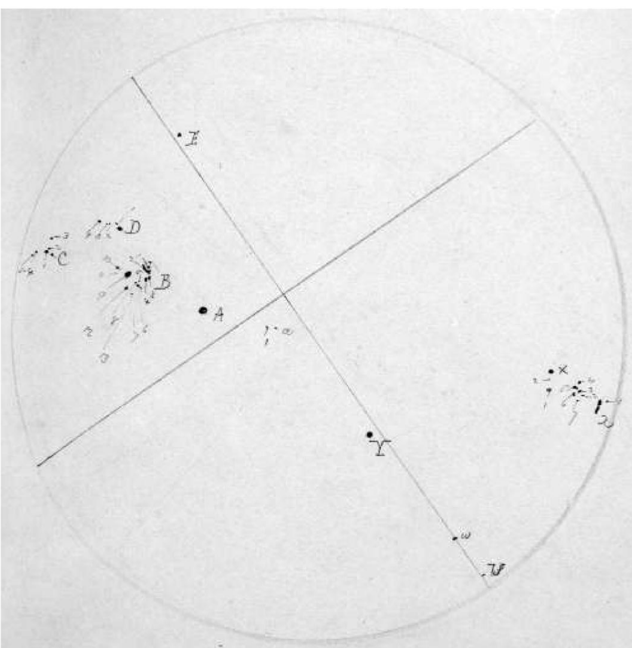
Fig. 19.2. View of the Kew Pagoda with photoheliograph.
Phil.Trans. *159 (1868), Plate II, No 2.*

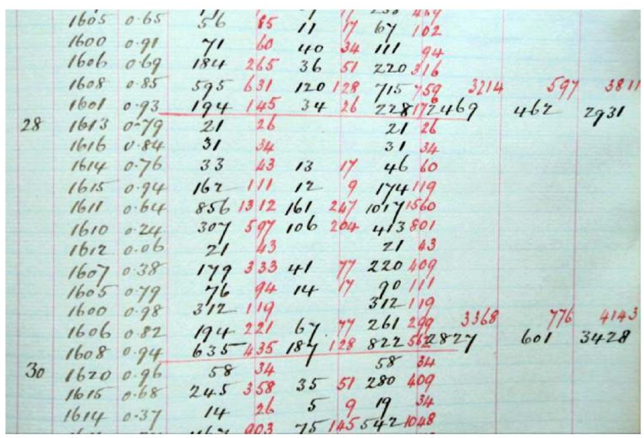
The programme of daily solar photographs was interrupted for the 1860 solar eclipse, when De La Rue, largely at his own expense, took it to Spain. There was then a delay in returning it to Kew because of a dearth of assistants to operate it. During this time it remained at De La Rue's Cranford Observatory. Operations at Kew were recommenced in February 1862, and continued until March 1872, so that essentially a complete solar cycle was covered. Several photographs were taken daily, whenever weather permitted.[88] In addition to sunspot numbers, the position (heliographic latitude and longitude) and area of each spot were measured.[89]

The results were reported at length in several series of reports, some by De La Rue alone, but most by him jointly with Balfour Stewart (Superintendent of the Kew Observatory) and Benjamin Loewy (Observer and Computer to the Kew Observatory). These reports were initially published for private circulation at De La Rue's expense, and then by the Royal Society.[90] They included an analysis of Hofrath Schwabe's records (1832-1854), and those of Richard Carrington (1854-1860 and 1868), as well as those of Kew, and conformed to an average sunspot cycle of just over eleven years.[91]

The published reports of sunspot areas from the Kew photographs start with observations made on 7 February 1862,[92] and do not, therefore include the major solar storm observed by Carrington and Hodgson on 1 September 1859.[93] They do, however, include the areas from Carrington's own observations, and show that the mean sunspot coverage area for the relevant two weeks (August/September), at 0.3365% the area of the solar disc, was a maximum.[94] Hodgson reported that a photograph taken at Kew the previous day showed that the sunspot group was about 60,000 miles in diameter.[95]

By the conclusion of the Kew observations in 1872 supervision of the Observatory had passed from the British Association to the Royal Society. The photoheliograph was moved to the Royal Observatory Greenwich, where it was used from April 1874 to September 1875.[96]





	1605	0·65	56	85	11	17	67	102			
	1600	0·91	71	60	40	34	111	94			
	1606	0·69	184	265	36	51	220	316			
	1608	0·85	595	631	120	128	715	759	3214	597	3811
	1601	0·93	194	145	34	26	228	172	2469	467	2931
28	1613	0·79	21	26			21	26			
	1616	0·84	31	34			31	34			
	1614	0·76	33	43	13	17	46	60			
	1615	0·94	162	111	12	9	174	119			
	1611	0·64	856	1312	161	247	1017	1560			
	1610	0·24	307	597	106	204	413	801			
	1612	0·06	21	43			21	43			
	1607	0·38	179	333	41	77	220	409			
	1605	0·79	76	94	14	17	90	111			
	1600	0·98	312	119			312	119			
	1606	0·82	194	221	67	77	261	299	3368	776	4143
	1608	0·94	635	435	187	128	822	562	2877	601	3428
30	1620	0·96	58	34			58	34			
	1615	0·68	245	358	35	51	280	409			
	1614	0·37	14	26	5	9	19	34			

Fig. 20.1 & 2. Record of sunspot observations, 28 March 1871.
Royal Society MS265. The columns show the sunspot group number, its radial distance, the areas of the penumbra, umbra and whole spot, and the totals for the day.

Sunspots and planets

In their second report series, in 1865, De La Rue, Stewart and Loewy explored the idea that the pattern of growth and decline of sunspots showed that some external influence might be at work, and they suggested that this could be the planets. Their initial analysis led them to the conclusion that the behaviour of spots might be influenced by Venus, without, however, suggesting that Venus was the cause of the solar cycle.[97] They felt that spots attained their maximum size when on the side of the Sun away from Venus, and their minimum size when on the side facing Venus.

De La Rue was clearly enamoured of this idea, and must have spent considerable time in following it up. He is attributed as saying: 'solar activity, as shown in the phenomena of sun-spots, would not exist but for planetary motion, any more than certain physical phenomena of the planets would be produced without solar influence'.[98]

In a subsequent paper (1870), however, the authors expressed more caution, stating: 'We were induced to imagine from our preliminary researches that the amount of spotted area may possibly be influenced by the positions of the planets in such a way as to exhibit excessive solar action when two influential planets are together at the same ecliptical longitude'.[99] They proceeded to test this hypothesis by an analysis of conjunctions of Venus and Jupiter, and of Venus and Mercury, and relate them to their own and Carrington's observations. They drew no specific conclusions, but felt that their results lent some support to the idea, and that it warranted further investigation.

Clearly, this hypothesis must have drawn some critical comments, for in a further paper they defended the idea that sunspots may be subject to external influences, there being no evidence for a mechanism within the Sun which could cause the observed changes in sunspot appearances.[100] They carried out a much more detailed analysis, the results of which, they suggested, appeared to indicate that Mercury and Venus (but not Jupiter) had such an influence.

The 1874 transit of Venus

De La Rue proposed to photograph the transit of Mercury on 12 November 1861 at Cranford, and requested that the Kew photoheliograph attempt it also.[100] However, we must assume that this was unsuccessful, as no report of a Cranford or Kew observation appears in the collection of reports on the transit published in the *Monthly Notices* of the Royal Society.[102] The transit occurred at sunrise, and it could well have been cloudy, although it was observed in some other parts of the country.

By the late 1860s planning was engaged in earnest for observations of the transits of Venus across the disc of the Sun in 1874 and 1882, in order to determine the elusive solar parallax, and hence an accurate measure of the scale of the solar system. This was to be a major international undertaking, with expeditions being sent by many countries all over the world. The contribution by Britain to this enterprise was, therefore, considered to be of much importance, and the Astronomer Royal, Airy, who was strongly supportive of the application of photography to astronomy, asked De La Rue to give thought as to how it might be used for the transits.[103]

In 1868 De La Rue responded by submitting a paper to the Royal Astronomical Society suggesting that if two or more timed photographs were taken during the transit, and the distance between the centre of the Sun and that of Venus measured by a micrometer similar to that which he had devised for measuring the 1860 eclipse plates, the solar parallax could be determined with high precision. Furthermore, the photographs did not need to be taken at the exact contacts of the planet with the solar limb, as with the optical methods. A series of such photographs could be taken at intervals of a few minutes, and multiple measurements obtained, thereby increasing the accuracy of the method. He calculated that it could provide an accuracy of 0.185 arc-seconds in parallax, and possibly much better. He advocated that six such instruments be used at various locations, and concluded by saying: 'no strain on the nerves would occur [compared with that of observing a solar eclipse] … All the operations could be conducted with that calm so essential for such a problem as the determination of the Solar Parallax'.[104]

De La Rue was able to convince Airy of the reliability of the photographic method[105] and five instruments, being a modified design of the Kew photoheliograph, were duly built by Dallmeyer, and sent with expeditions to their respective locations around the world (the Sandwich Islands, Egypt, Rodriguez Island, Kerguelen Island, and New Zealand) for the 1874 transit. The instruments incorporated a form of shutter facilitating the making of multiple exposures on a single plate, devised by Jules Janssen and modified by De La Rue and Dallmeyer, called the '*Révolver Photographique*'.[106]

Fig. 21. The photoheliograph used for the 1874 transit of Venus.
Royal Astronomical Society ADD MS 93/105.

In the meantime, however, there had been some dispute about whether to use Halley's method (which relies on observers at sites far north and far south to record accurate times of the contacts of Venus with the limb of the Sun, in order to compare the lengths of the transit chords), or Delisle's (which relies on accurate knowledge of the observers' longitudes). In 1868 Airy had announced his selection of observing sites for the 1874 transit, based on the view that Halley's method was unsuitable for this transit.[107] This view, together with the sites selected, was challenged by Richard Proctor, then Secretary of the RAS, and became the subject of a public and acrimonious correspondence between Proctor and De La Rue in the pages of *The Times* in early 1874. Proctor accused De La Rue of making an attack upon him at a meeting of the RAS, in his absence, for a paper he, as (temporary) Editor, had inserted in the *Monthly Notices*. De La Rue defended his action, referring to what he viewed as improper remarks contained in the paper, pointing out that the paper had not been sanctioned by the RAS Council, and that the Council had passed a Resolution 'expressing their strong disapprobation' of Proctor's remarks.[108]

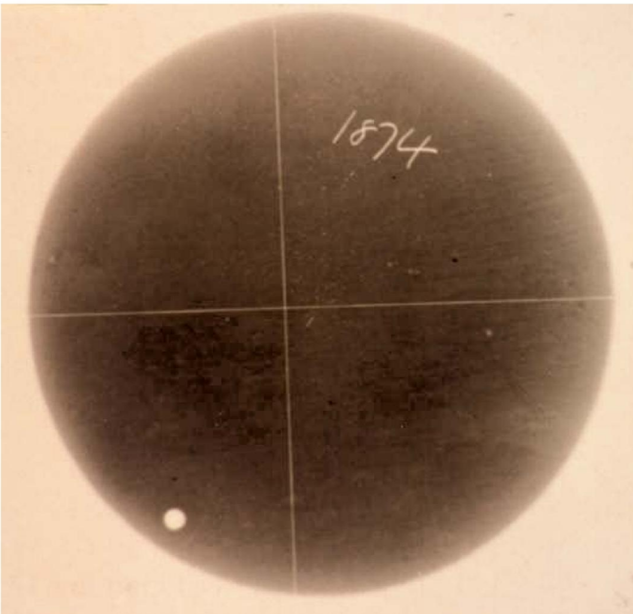


Fig. 22. Photograph of the 1874 transit of Venus, taken with the photoheliograph.
Royal Greenwich Observatory archives.

In the event, the photographic method devised by De La Rue and used by the British expeditions, in common with other European attempts, proved a complete and costly failure. The small solar images had to be enlarged before measurement, and it was found impossible to determine the limbs of the Sun and Venus with sufficient accuracy. Airy did not blame De La Rue, but rather the human computers carrying out the measurements.[109] Nevertheless, it seems clear that the method was unsuited to its task; the American expeditions, with long focal-length telescopes, faired rather better.[110] De La Rue publicly held himself 'responsible for having sanctioned so much expense and labour'.[111] Needless to say, the British expeditions for the 1882 transit abandoned photography as a method.

Endowment of scientific research

In 1872 a heated debate within the scientific community led to the resignation of De La Rue from the RAS Council. The matter had commenced in 1868, when Council member Lieut.-Colonel Alexander Strange had presented a paper to the BAAS, advocating State endowment of scientific research.[112] This led to the establishment of a Committee within the BAAS. Two years later, on the recommendation of the BAAS Committee, there was established the *Royal Commission on Scientific Instruction and the Advancement of Science*, chaired by the scientifically qualified William Cavendish, Duke of Devonshire, with Norman Lockyer as Secretary. The Devonshire Commission met for six years, took evidence from 150 people, including De La Rue, and produced eight reports.

In his evidence to the Commission De La Rue advocated the appointment of a Science Minister, assisted by secretaries, and advised by a Board 'of men eminent in different departments of science. … Then we should get prompt action, instead of questions being allowed to drag over years and years without any practical solution being come to'. He contrasted the poor progress in English science, especially chemistry, with that of Germany, where science enjoyed considerable patronage. He stressed the need for a major chemical laboratory, as well as a physical laboratory. With regard to the physics of astronomy, he recommended that the State provide support for physical observations, especially those that 'require the devotion of so long a time and are so expensive that private individuals can hardly be expected to carry them on for a sufficiently long period', such as large-scale solar photography. He further proposed that, in order to ensure daily photographs of the Sun, there should be one or two observatories in India and another at the Cape of Good Hope. Lunar libration and stellar motions were also considered worthy of study. He concluded: 'We want science really cared for in England by the State, and we want all State questions relating to science properly considered by a body capable of dealing with them. … There is great difficulty in fact under existing circumstances in the State dealing at all with science or with scientific men. There is no department of the Government, so far as I know, which is able to fully appreciate the advantages that science confers on the State'.[113]

In the meantime, Strange had read a paper to the RAS, in 1872, on the need for official observatories to carry out fundamental research. He argued that the relatively narrow research focus of the Royal Observatory at Greenwich (which concentrated on observations necessary for navigation, including time-keeping and time distribution), meant that there was a dearth of research into the physics of astronomy by official institutions.[114] He received support from De La Rue, who pointed out the need for solar studies to establish any connection between activity on the Sun and meteorological changes on Earth. The Astronomer Royal, Airy, however, took the view that observatories had to have objectives which were of practical use. At a subsequent RAS Council meeting Strange and De La Rue attempted, unsuccessfully, to get a resolution passed supporting the establishment of an observatory for basic research, and for several branch observatories in British territories overseas for solar photography.

Leading the opposition to this proposal was Richard Proctor, and the dispute became very personal. There appears to have been particular animosity between Proctor and Lockyer, which had been simmering for some time. The outcome was the resignation of Strange, De La Rue and Lockyer from the RAS Council in November 1872, because of its deference to Airy's opposition to a specialist observatory independent of his control. The dispute did not stop there, however, since there were disagreements over the award of the Gold Medal in 1873, with Strange proposing an alternative list of candidates for Council. It continued into 1881 when a further proposition was considered opposing the granting of public money for basic research, and specifically the establishment of a physical observatory, and that the Government grant to Lockyer's South Kensington Solar Observatory should be discontinued. The endowment of research debate clearly polarised views within the scientific community, and specifically within the RAS. While De La Rue appears to have been on the losing side for a time, the situation had started turning by 1881, and, following a rather spirited session, the proposition failed to be carried, no doubt to the relief of De La Rue, Strange, and especially Lockyer. In due course there was a gradual acceptance of the principle of endowment, and government support resulted in the establishment of a number of scientific institutions.[115]

Oxford University Observatory

In 1873, at the age of 58, his health and eyesight lessening, De La Rue retired from active observing, sold his estate at Cranford, and moved back to London, settling at 73 Portland Place, between the Langham Hotel (where he had often stayed) and Regents Park.[116] He presented his equatorial telescope and the contents of his observatory to Oxford University, where his friend Charles Pritchard had become Savilian Professor of Astronomy. His generosity was in response to the welcome news that the University would build a new University Observatory, and his desire to find a home for his telescope where he could be sure that it would be applied to worthwhile research. The recognition which the University had given to him by awarding him an honorary DCL three years earlier, and the obvious trust which he placed in Pritchard, clearly also played a role.[117]

Pritchard put the telescope to good use as a core instrument for the development of the Observatory into one appropriate for a major university. Indeed, it appears that the gift of De La Rue's equatorial reflector hastened the progress of a development which the University was already embarking upon, and the University readily committed to the additional building works necessary to house the instrument. The original plan was thereby transformed, and De La Rue was thus a co-founder and vital on-going benefactor of the new observatory (since the University did not itself provide adequately for assistants or research). His donation, indeed, accorded with the need he had expressed to the Royal Commission the previous year, and led to what Pritchard himself referred to as 'the first foundation [in England] of an observatory for astronomical physics'. Pritchard gave full credit for this achievement to De La Rue, and supported him in his dispute with Proctor by writing to *The Times*, pointing out De La Rue's role with respect to the Observatory.[118] De La Rue modestly responded in a further letter, stating that the discussions in the RAS Council which had influenced the foundation of the new Observatory arose out of resolutions proposed by Lieut-Col. Strange, which he had seconded, and were based on Strange's 1872 paper to the RAS on the subject of national observatories.[119]

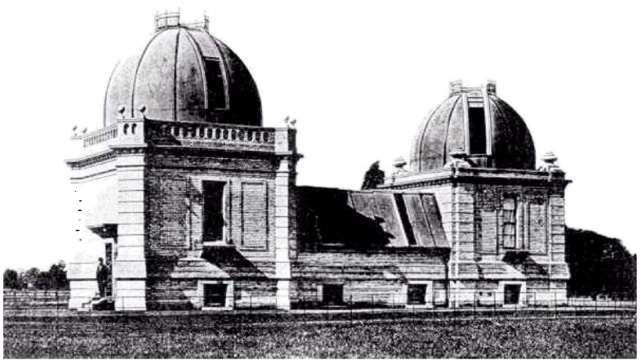


Fig. 23. The Oxford University Observatory in 1875. The De La Rue dome is on the right.
MNRAS*, 36, 1 (1875), cover page.*

The only condition which De La Rue placed on his gift was that it was to be usefully employed. He further urged: 'One use [to] which I should like to see my reflector applied is the determining whether or not the moon has a physical libration; for this purpose, photograms of this planet would have to be taken as often as practicable, and the original negatives measured by means of a properly constructed micrometer, so as to determine the apparent distance of selected craters from the moon's limb — after allowance for the shifting produced by the optical (latitude), the orbital (longitude) and terrestrial station librations, the residue would be the true libration due to the centre of gravity not coinciding with the centre of figure ...'.[120]

To this end, De La Rue met the cost of an assistant for four years, provided a plate measuring machine, and continued to support and advise the Observatory. However, despite the dedication of the assistant to the task, hundreds of lunar pictures being taken annually, their micrometrical measurement, and a statement, in 1880, that the lunar libration work had been completed, it was never published in a complete form. In January 1881 Pritchard stated that he hoped 'speedily to lay the results before the RAS, but he only reported: 'There does exist a real, but inconsiderable, [physical] libration in Longitude, less than five minutes of arc, and probably not ascertainable within some decades of seconds'.[121] His biographer does know why the work was laid aside.[122] Pritchard did, however, carry out a considerable amount of work on stellar parallax and photometry.

In 1887 the Observatory agreed to participate in a collaborative photographic survey for the production of an international chart of the heavens, but lacked a suitable refracting telescope. De La Rue not only provided two 15-inch mirrors of different focal lengths, in order to test whether wide-field photography was feasible,[123] but also provided £600 for the purchase of a 13-inch Grubb astrograph to be mounted coaxially on the 12-inch refractor, asking only that an inscription be affixed to it, saying 'The gift of Warren De La Rue in honour of Professor Pritchard'.[124]

Fig. 24 The Oxford Observatory building in 1994, showing the De La Rue dome.
Photograph by the author.

The Observatory is now a cluster of buildings no longer having an astronomical function. The De La Rue reflectior is stored in a dismantled state at the Museum of the History of Science in Oxford. The Museum also has several of his cameras, two of the 13-inch specula, and a box of eyepieces.[125]

Cape Observatory telescope

In 1880 De La Rue, now aged 65, was heavily involved in a proposal for a major new telescope at the Cape of Good Hope Observatory. A year earlier David (later Sir David) Gill had been appointed Her Majesty's Astronomer at the Cape. The Observatory at that time had only a transit-circle, a 7-inch equatorial, and one of the Dallmeyer photoheliographs which had been made for the 1874 transit of Venus. Gill was eager for the Observatory to possess a large equatorial refracting telescope, of the order of 20 inches aperture and 30 feet focal length, and sought support from the Government. Correctly anticipating difficulties with Airy, he enlisted De La Rue's assistance and influence.[126] Airy was very lukewarm about the project, saying that Gill had to decide whether to be a meridian observer or an equatorial one, and bemoaning how little had come out of the 48-inch Great Melbourne Telescope.[127] He suggested that Robert Newall's instrument be obtained on loan.[128]

Not one to turn down anyone asking for help, De La Rue took up the cause. There ensued a round of correspondence between Gill, De La Rue and Airy. De La Rue and Gill felt that a loan instrument

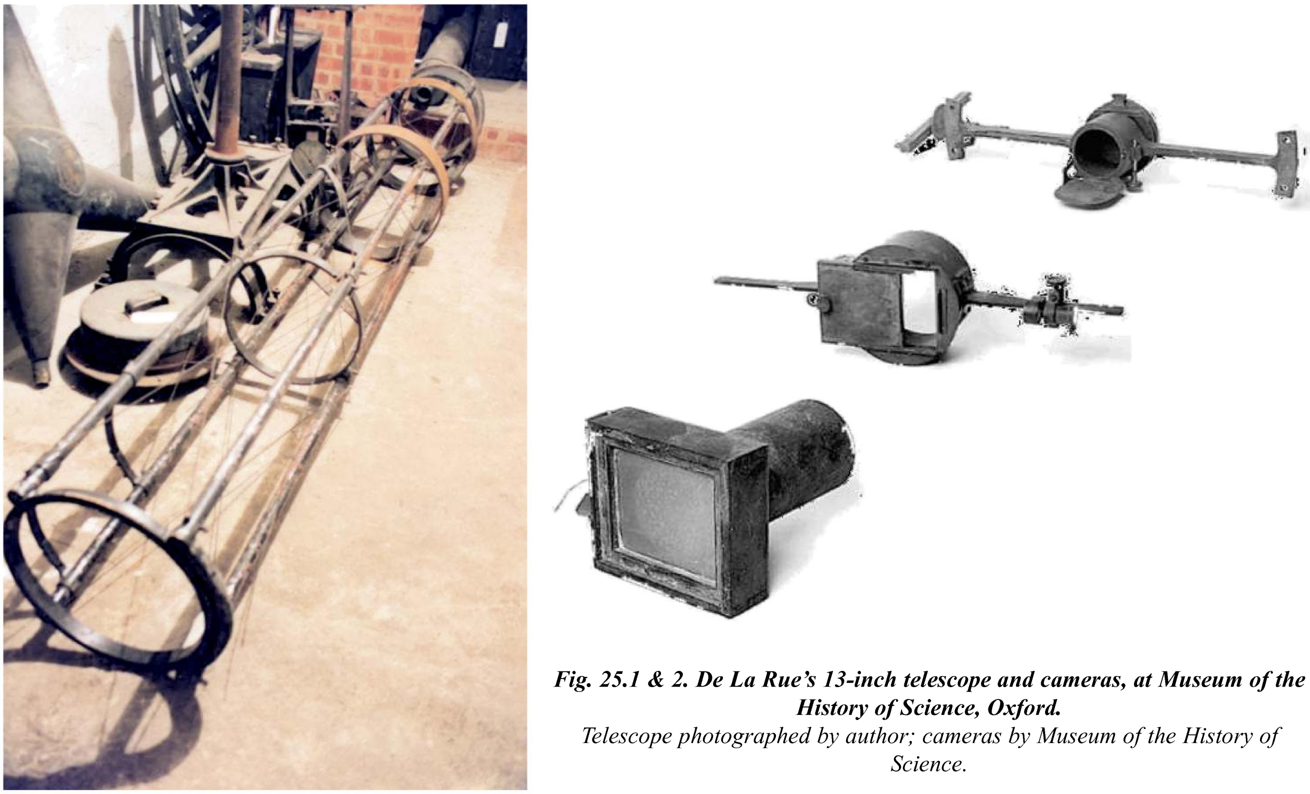


Fig. 25.1 & 2. ***De La Rue's 13-inch telescope and cameras, at Museum of the History of Science, Oxford.***
Telescope photographed by author; cameras by Museum of the History of Science.

was not desirable for a Government observatory, and that either Newall's telescope be purchased, if he was willing to sell, or that an object glass which Grubb already had be purchased immediately. Their idea was that the telescope would be paid for by public subscription (£6,500 or £7,640 depending on which option was adopted), and that the Government assist with its transport.

In an attempt to press the matter towards an early resolution, Gill suggested that the approaching transit of Venus in 1882 would require a large telescope in South Africa, to match those in the northern hemisphere. He asked De La Rue to lay the matter before the Royal Society, and for the Society to approach the Government.[129] De La Rue responded by setting up a Cape Telescope Committee within the Royal Society, in order to raise the money needed. Although there was some response,[130] De La Rue soon expressed despair of reaching the required sum. He advised Gill to apply direct to the Government, while he (De La Rue) left for a two-month trip to the Continent. This Gill did, by writing to the Secretary to the Admiralty, but Airy expressed the view: 'I greatly fear that Mr. Gill is preparing for himself much disappointment'. This was evidently the case, and by the end of 1880 the support of the Cape Telescope Committee appears to have been withdrawn. Gill had to wait a further two decades before he got the telescope he wanted, and only then after many more difficulties, and the intervention of a major gift by Frank McClean – the Victoria Telescope.[131]

His final years

In his later years, his position as a serious and accomplished scientist firmly established, Warren De La Rue continued to play a significant part in Victorian business and astronomy, in England and in international circles. He served on the Melbourne telescope committee, the design of this giant 4-foot reflector and its photographic equipment being based on his celebrated 13-inch equatorial.[132]

He made further experiments to determine whether it would be possible to photograph the prominences without the Sun being eclipsed, using prisms with gold-coated faces and fluid filters. These produced negative results, although he felt it would be possible to photograph them as dark markings against the bright background of the photosphere. Philosophically, he said: 'The progress of scientific discovery may be promoted by the record of one's failures, for it tends to prevent the same paths from being trodden by future explorers'.[133]

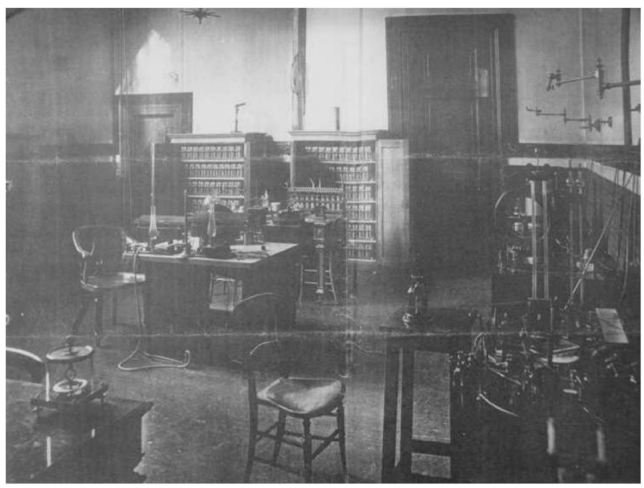


Fig. 26. Warren De La Rue's laboratory.
Science Museum, London (Inv. No. 1876-63).

He set up a laboratory near his house in Portland Place, and, with his chemist friend Hugo Müller, renewed with vigour researches on what must have been spectacular electrical discharges using thousands of silver chloride batteries, and published a large number of papers on the subject.[134] Their studies included electrical discharge through gases, which Balfour Stewart had suggested might explain aurorae as solar-terrestrial phenomena. Indeed, one of their papers drew conclusions about the height of the aurora borealis (37.67 miles, visible for 585 miles) at its maximum brilliancy, and its various colours at different heights.[135]

De La Rue apparently did not neglect his chemical studies entirely, and it is recorded that he was of assistance to Louis Pasteur when the latter visited London in September 1871, probably not least because Whitbread's Brewery, which Pasteur visited, was in Chiswell Street, just around the corner from the De La Rue factory in Bunhill Row.[136]

Although appearing generally to have a robust constitution, he occasionally suffered from health problems, and clearly increasingly found it difficult to maintain the energy and mental capacity which characterised his life. Nevertheless, despite his expressed profound dislike of lecturing,[137] he gave a memorable discourse at the Royal Institution on electrical discharge with 14,000 Sodium Chloride batteries, complete with demonstrations.[138] That was in early 1881, but by December of that year his letter of resignation as Secretary of the Royal Institution gave some insight into his difficulties:

> With great emotion I write this letter to let you know that it is essential to my health and to the interests of the Institution that I should resign the Secretaryship. It is possibly due to my age combined with past brain work that I am unable to do without worry to myself the work which tougher men could do easily.… I ought to be able to get through the work without strain; but somehow or other, work which has to be accomplished at particular times is always present before and worries me.[139]

The end came quickly. He attended the Royal Institution Managers meeting on 1 April 1889,[140] but some two weeks later, on Good Friday, 19 April, died from pneumonia at his house in Portland Place. He left an estate worth over £300,000 (over £20 million at today's values). In his will he remembered his family and servants, but the bulk of his estate went to his widow, who presented his laboratory apparatus to the Royal Institution.[141] In his memory his son, Warren William, presented to the Victoria and Albert Museum a painting of the opening of the 1851 Great Exhibition, which includes Warren and his father amongst the guests.

Tributes

Warren De La Rue was lauded in many obituaries which recorded his character, his business acumen, his expertise and contributions in a number of scientific fields. Books on the history of astronomy invariably give due recognition to his pre-eminent role in early astronomical photography, especially solar photography, in which, in the words of the address given on the presentation of the Royal Astronomical Society's Gold Medal, 'he stands almost alone'. That same address summarized his astronomical achievements: 'the perfecting of the figures of mirrors, the graphic observations of the planets, the incomparable photographs of the Moon, the invention of the photoheliograph, the observations of the solar eclipse, the invention of the new method of obtaining numerical data, the application of the stereoscope to the examination of the surface of the Moon, and afterwards to that of the Sun'.[142]

The scientific journal *Nature*, in a lengthy obituary, stated that his efforts during the 1860 eclipse 'laid the foundation of that wonderful structure of solar physics which is daily enlarging our knowledge of the true nature of the sidereal universe', and went on to conclude:

> The space which can be here afforded to the memoir even of an illustrious man precludes more than a passing allusion to the honours and social distinctions which always accompany the efforts of a life such as Warren de la Rue's; and upon him they were accumulated in abundance. The abiding honour lies in the contemplation of the man. A career like his dignifies the daily life of a manufacturer, giving it an aim and an object apart from the accumulation of wealth; it humanizes, warms and illuminates the absorbing abstraction of the solitary student; and it illustrates the fact of an Aristocracy of Nature.[143]

An equally lengthy RAS obituary stated: 'In the history of celestial photography in this country Mr. De La Rue stands pre-eminent'.[144] *The Observatory* praised 'his wise and liberal assistance to science by presence and sympathy as well as by gifts', and his skill in committee. 'His insight, his judgment, his ready tact, his conciliatoriness – combined to make him a power in council and committee. Conciliatoriness he regarded as a most valuable quality. "I am the man with the oil-can," I have heard him say; and the description was as true as it was graphic'.[145] He was also remembered in Guernsey, the island of his birth, the *Star* and *Comet* newspapers recording his death and publishing brief accounts of his life's work.[146]

Fig. 27. Warren De La Rue's grave, Kensal Green, London.
Photograph by the author.

Conclusion

Warren De La Rue is not now a household name, even amongst astronomers. Unlike his contemporaries and colleagues, Airy, Faraday and Carrington, for example, there is nothing named after him. There is no De La Rue disc, De La Rue effect, or De La Rue

Fig. 28. De La Rue crater.
The De La Rue crater is the large one surrounding the small bright one in the centre of the picture. From Clementine Lunar Map (Deep Space Program Science Experiment), U.S. Naval Research Laboratory (1994).

rotation. He does, however, deserve to have his name listed amongst these more familiar scientists. For it is clear that he was an important and talented figure, highly regarded by everyone, welcomed especially for his technical skill and his genial character. A consummate amateur scientist, inventor and successful businessman, he made significant contributions to astronomy, chemistry, electricity, physics, printing, and particularly to the development of astronomical photography. His one 'discovery', however, was perhaps really a demonstration—that solar prominences emanated from the Sun.

He made some errors of interpretation of his observations. He expressed the view that the appearance of the solar corona was the result of light from solar prominences.[147] He persisted in claiming that the solar chromosphere was nothing more than a continuous encirclement of prominences,[148] and that Baily's Beads were caused by defects in the telescopes used to observe solar eclipses.[149]

It has been suggested that his early publications show that 'he was very adroit at self-promotion'.[150] The implication is that he gave insufficient credit to the work of others. I do not believe this to be the case. His motives in publishing thorough accounts of his work were, in my view, genuine attempts to inform the scientific community of the rapid developments of the third quarter of the nineteenth century, especially those of astro-photography and its contribution to astronomical knowledge. His scientific publications are, quite properly, replete with references to others, and many of his papers were of joint authorship. At times he shows deference surprising in a man of such eminent achievements. He himself said that he 'knew something of manufactures, and had also dabbled a little in science'.[151]

There is a lasting tribute to him in the form of the lunar crater which bears his name. Its appearance and position, however, reflects his position in history. It is not prominent, and few would be able to pinpoint it. Although sizeable (135 km diameter), it is indistinct, and non-central, lying on the northern edge of the Moon, best visible when libration carries it into a favourable aspect.

Warren De La Rue was not only Britain's leading exponent of the emerging technology of astro-photography, but was a meticulous observer and experimenter, with a gift for mechanical and optical innovation. His holding of many influential offices, and his extraordinary achievements suggest that he is deserving of much further recognition than he has heretofore been granted.

Awards and positions

Juror, Class XXIX (Miscellaneous manufactures), Great Exhibition, 1851; Juror, Class X (Chemical manufactures, including paper), Exhibition Universelle, Paris 1855. (He also exhibited products of cochineal, and his model of the mounting of Huygens's lens); Founder Member, Chemical Society (1841-89), President (1867-9 and 1879-80); Fellow, Royal Astronomical Society (1851-89), Secretary (1855-63), Council Member (1862-72), Gold Medal (1862), President (1864-66); Fellow, Royal Society (1850-89), Royal Medal (1864), Vice-President, (1869-70 and 1883-85); Chairman, Royal Society Kew Committee; Member, Royal Society Grants Committee; Member, Meteorological Council (1881); Member, BAAS Committee for lunar mapping (1866-9); President, BAAS Section 'A' (1872); President, London Institution; Secretary, Royal Institution (1879-82); Vice-President, Royal Institution; Honorary D.C.L., Oxford (1870); Master of Arts, Oxford; Commander of the Legion of Honour; Commander of the Order of St Maurice and St Lazarus; Knight of the Order of the Rose, Brazil; Member, The Photographic Society; Medal, French Photographic Society; Member, The Microscopical Society; Engraver to the Board of Inland Revenue (1888); Society of Arts (1847-; Council Member and Committee Member); Member, International Electrical Congress (Paris, 1881); Juror, Electrical Exhibition, Paris, 1881; Member, Consulting Council, Electrical Exhibition, Crystal Palace, Sydenham, 1882.

Acknowledgements

A number of people have assisted in this research. I am particularly grateful to Peter Hingley (Royal Astronomical Society), Adam Perkins (Cambridge University Library), and Kevin Johnson (Science Museum).

Notes and References

1 The literature contains various permutations of upper and lower case D and L in the name De La Rue, but Warren always signed with upper case for both letters.

2 Le Conte, David: 'Two Guernseymen and Two Eclipses', *The Antiquarian Astronomer*, **4** (January 2008), 55-68.

3 Nasmyth, James, and Carpenter, James., *The Moon considered as a planet, a world, and a satellite* (London: John Murray, third edition 1885), p. 62.

4 Clerke, Agnes., *A Popular History of Astronomy during the Nineteenth Century* (London: Adam & Charles Black, third edition 1893), p. 190.

5. Curiously, his baptism in the St Peter Port Town Church is omitted from the register, a fact recognised in a letter from Matthew Gallienne of Guernsey to Warren De La Rue on 31 January 1856. The priest did, however, furnish a certified extract of a registry entry in 1882. (University of Reading Special Collections MS937, 9/7, 9/35 and 9/50). It has been suggested that registry details were sometimes written on pieces of paper for later entry into the register, and that occasionally these pieces may have been lost. (Gregory Stevens Cox, historian, and Amanda Bennett, Guernsey Priaulx Library, personal communications.)

6. Houseman, Lorna., *The House that Thomas Built* (London: Chatto & Windus, 1968), p. 18.

7. Thomas owed £254-8s-6d to Jean Champion, £25 to Thomas Lenfestey, £34 to George Lucas, and £25 to Henri de Garis (Greffe, Guernsey: Décrets, 1816-1820, p. 27).

8. It is recorded that Warren visited Guernsey early in 1834 (*Autobiographical Twaddle*, Samuel Elliott Hoskins, Guernsey Archives AQ 0843/02), and was clearly close to some of his Guernsey relations. A letter to him dated 28 November 1882 from his cousin, Rachel Aubert (daughter of John Champion and Thomas's sister Rachel), then living at Vine Grove, Mount Durand, St Peter Port, about his grandparents' headstone is written in terms of close endearment (Reading University Special Collections MS 937 9/7). His property interests in Guernsey derived from an 1850 contract of 'délaissance' of property owned by his father-in-law, Thomas Bowles (Guernsey Greffe, *Contrats pour la date*, book 60, p. 41), and appear to have included properties in the High Street and Hauteville, St Peter Port (Reading University Special Collections MS937 9/48, 9/50 and 9/52).

9. The lack of science educators, and therefore science education, in England was an issue to scientists like Michael Faraday, who is reported to have told a Royal Commission: 'If you want science, you must begin by creating science teachers'. (G.M. Young, 'Portrait of an age', in *Early Victorian England*, II, Chapter 27 (Oxford: OUP,1934), p. 498).

10. Houseman (1968), p. 23, and school report (Paris Archives).

11. Archives of De La Rue plc, Basingstoke.

12. For a detailed description of Warren De La Rue's role in the business see Easton, John., *The De La Rue History of British & Foreign Postage Stamps, 1855 to 1901* (London: Faber and Faber, for the Royal Philatelic Society, 1958).

13. Easton (1958), pp. 91-92.

14. Newall, H.F., 'The decade 1860-1870', in *History of the Royal Astronomical Society*, I, Chapter 5 (J.L.E. Dreyer and H.H. Turner, eds., (London: RAS, 1923, reprinted 1987), p. 165.

15. Easton (1958), p.xvii.

16. Easton (1958), pp. 766-7.

17. Letter from Warren De La Rue to William Frederick De La Rue, 4 January 1864, De La Rue Company Correspondence Books. Quoted by Easton (1958), p. 777.

18. Knobel, Edward., 'Warren De La Rue', *Monthly Notices of the Royal Astronomical Society* [hereafter *MNRAS*], 50, 4 (1890), 155-64, p. 163.

19. *MNRAS*, 17, 1 (1856), p. 19; *MNRAS*, 17, 1 (1857), p. 221: 'Mr. De La Rue exhibited finished engravings of the planets Jupiter and Saturn, the latter printed in colours, copies of which he most handsomely offers to Fellows of the Society'.

20. Knobel (1890), p. 163.

21. 'Warren De La Rue', *Nature*, 40 (9 May 1889), 26-28.

22. *MNRAS*, 22, 4 (1862),131-40.

23. A godmother of one of Georgiana's sisters, Henrietta, was a Marie Bardel Greenslade (ref. St Peter Port Church baptism records 1812-1832, p. 144). The Greenslades were related to Warren's mother's family. Thomas Greenslade, who came from the same Devon village (Bishop's Nympton) as Warren's mother, had briefly been Warren's father's publishing partner in Guernsey. It seems probable that one of Georgiana's mother's family had married a Greenslade, and that there was, therefore, a loose family link between the Bowles and the De La Rues. This appears to be supported by the reference to an Osborne Greenslade as having an interest in the estate of Marie Bardel Bowles (ref. Guernsey Greffe: *Contrats pour la date*, book 75, p. 494). It is also probable that Thomas Bowles and his family had reason to visit London, or perhaps move there, as he originated from Cripplegate.

24. In a letter of 1 May 1860 the Astronomer Royal refers to the possibility of Mrs De La Rue 'who I believe aids her husband in photography', accompanying Warren on the eclipse expedition. In the event she did not go. (Royal Greenwich Observatory – hereafter RGO - 6/123 22).

25. De La Rue, Warren., 'On the effects of a battery charged with sulphate of copper' *Journal of the Franklin Institute*, 19, S (1837), pp. 229-31. Also De La Rue, Warren., 'Ueber die Wirkungen einer mit schwefelsaurem Kupferoxyd geladenen Voltaschen Säule', *Annalen der Physik und Chemie*, 116, 4 (1837), pp. 628-31.

26. *Memoirs of the Chemical Society of London*, 1841-43, *Proceedings*, p. 1, House of the Society of Arts, John Street, Adelphi, 23 February 1841.

27. Houseman (1968), 48-51. The Company was in such a bad state of affairs that Warren's salary was in arrears.

28. Published by De La Rue & Co., London, 1843.

29. De La Rue was a founder member of the Microscopical Society of London (1839). He published a paper on microscopic observations of a butterfly: 'On the Markings of the Scales of the Amathusia Horsfieldii', *Transactions of the Microscopical Society of London*, 3, (1852), pp. 36-40.

30. Hoffman and De La Rue jointly edited the first two volumes of the *Annual Report of the Progress of Chemistry and the allied sciences, Physics, Mineralogy and Geology*, by J Leibig and H Kopp (London: 1847-8). They also contributed a paper in one of the Jurors' Reports of the Great Exhibition, 1851.

31. Martin, Thomas, (ed)., *Faraday's Diary* (London: G Bell & Sons, 1936) contains many references to De La Rue.

32. De La Rue's first patent was for a machine to apply colour to the surface of paper. He had three patents for the manufacture of envelopes, and even one for a method of treating printers' rags so that they could be re-used. (British Library, Business and IP Centre: patent nos. GB 10436 (1844), GB10565 (1845), GB12084 (1848), GB12904 (1849), GB1123 (1852), GB1051 (1854), GB2719 (1854), GB843 (1855), GB2002 (1855), GB890 (1856), GB1860 (1859), GB1248 (1866), GB1381 (1866), GB 1383 (1866)). He is also widely credited on Internet websites with inventing the first light bulb, a platinum fila-

ment lamp, but this is almost certainly a misattribution, as I have found no primary evidence. This claim is discussed by Edward J Covington at http://home.frognet.net/~ejcov/delarue.html, where it is suggested that it may be traced to a statement by Edwin J. Houston, *Electricity in Every-Day Life*, 2 (New York: P. F. Collier & Son, 1905), p. 247.

33. Warren De La Rue's visit to James Nasmyth is recorded in Samuel Smiles (ed)., *James Nasmyth, Engineer; An autobiography*, (London: John Murray, 1897), chapter 18.

34. Edwards, Ernest., *Portraits of Men of Eminence in Literature, Science, and Art, with Biographical Memoirs: The Photographs from life,* 3 (London: A. W. Bennet, 1865), p. 37.

35. De La Rue, Warren., 'On the Figuring of Specula', *MNRAS*, 13, 1 (1852), 44-51. See also Lockyer, J Norman., *Stargazing: Past and Present* (London: Macmillan and Co., 1878), p. 134.

36. De La Rue's telescope was 'designed by himself and constructed in his own workshops', Natural History Museum, L MSS HUN/4, 26 January 1866. This document is an account of his astronomical work, written in his own hand, 'as the justification to be read at the "Academie des Sciences" for the Lalande prize of Astronomy'.

37. Letter from De La Rue to Nasmyth, 26 October, 1864 (quoted in *Nasmyth* (1885), Chapter 21).

38. The first mention of De La Rue in the *MNRAS* was a note that his 'very beautiful drawing of Saturn' would be exhibited at the Royal Astronomical Society meeting in January 1851, *MNRAS* 11, 1, (1850), p. 22.

39. Letter from De La Rue to Herschel, 12 October 1856 (Royal Society, HS.6.D.137). The letter includes a number of detailed sketches of Saturn's rings.

40. De La Rue's nomination as a Fellow of the Royal Society referred to him as a 'Card maker and engineer', the inventor of 'the envelope machine and other mechanical contrivances', and cited his paper on cochineal. It was signed by 16 Fellows, including Faraday. (Roy. Soc. EC/1850/10).

41. *Great Exhibition of the Works of Industry of All Nations, 1851: Official Descriptive and Illustrated Catalogue*, Vol. 2, Section 3, *Manufactures*, Class 17 *Paper, printing, and bookbinding*, exhibit 76, pp. 541-3. Edwin Hill and Warren De La Rue took out a patent for cutting and folding machinery in 1845. Previously, envelopes had been folded by hand, an experienced workman achieving 3,000 a day. The machine still exists, in working order, and is housed at the Company's headquarters in Basingstoke.

42. *Report of the 29th meeting of the British Association for the Advancement of Science* (1859), p. 131.

43. Frederick Scott Archer first published his description of the wet collodion process in 'On the use of collodion in photography', *The Chemist* (March 1851), p. 257.

44. Harvard's 15-inch refractor required exposures of 20 minutes to produce a Daguerreotype image of the Moon, whereas De La Rue's 13-inch reflector produced a strong collodion image of the Moon in 4 seconds. (King, Henry C., *The History of the Telescope* (New York: Charles Griffin & Co. Ltd., 1955, Dover Edition 2003), p. 249). In 1853-4 De La Rue exhibited his photographic apparatus to the RAS, and had obtained a good collodion picture of the Moon in 30 seconds (*MNRAS* 14, 1 (1853), p. 134).

45. *MNRAS,* 18, 1 (1857), 16-18, p. 16.

46. Lockyer, J Norman., *Stargazing: Past and Present* (London: Macmillan and Co., 1878), p. 464.

47. Archives of De La Rue plc, Basingstoke.

48. *Nature*, 25 (15 December, 1881), p. 161.

49. Clerke (1893), p. 366.

50. De La Rue, Warren: *Report of Warren De La Rue FRS on the proposal to remount the Object Glass of Huyghens* [sic], 22 January 1855, Royal Society MM11, 27.

51. The model was displayed at the 1855 Exhibition Universelle in Paris (*Catalog des Objets Exposé dans le Section Britannique de L'Exposition*, Class VIII, Section 3, item 393, p. 23), and at the South Kensington Museum's 1876 exhibition of the Special Loan Collection of Scientific Instruments (catalogue, 1877, p. 421, item 1852a).

52. De La Rue, Warren., 'Report of Warren De La Rue FRS on the proposal to remount the Object Glass of Huygens [sic]', 22 January 1855 Royal Society MM11, 27, p. 11.

53. One of the members present was geologist David Thomas Ansted, a founder member of the Club, and later co-author of the comprehensive book *The Channel Islands* (Wm H. Allen & Co., London, 1862), which he wrote following a four-year residence in Guernsey, De La Rue's birthplace. The list of contributors of information contained in the book includes George Busk, who was a successful candidate at the election at which De La Rue failed.

54. Letter from Charles Darwin to J.D. Hooker, 18 May 1855 (Burkhardt *et al*., *The Correspondence of Charles Darwin, vol. 5: 1851–1855* (Cambridge; CUP, 1985, letter 1681).

55. The prime sources of information about the Philosophical Club appear in T.G. Bonney, *Annals of the Philosophical Club of the Royal Society* (London: Macmillan and Co. Ltd., 1919), and the Club's Minute Books (Royal Society MS721 and MS722) and Rules. The Club was disbanded in 1901 through decreasing interest.

56. University of Reading Special Collections MS937.

57. *MNRAS,* 18, 4 (1858), pp. 110-12.

58. *The Photographic Journal*, 15 January 1861, 80-85, p. 83. This paper, entitled 'Lunar Photography' by Samuel Fry is followed by a detailed discussion by De La Rue, not only of his telescope drive, but also the chemicals used and the method of obtaining stereoscopic image pairs.

59. 'Address delivered by the President, Dr Lee, on presenting the Gold Medal of the Society to Mr Warren De La Rue', *MNRAS*, 22, 4 (1862), 131-39, p. 136.

60. The description of these developments appears in an account of the meeting of the RAS held on 13 November 1857, *MNRAS,* 18, 1 (1857), 16-18.

61. *MNRAS,* 25, 1 (1864), p. 116.

62. Hutchins, Roger., 'John Phillips, "Geologist-Astronomer", and the Origins of the Oxford University Observatory, 1853-1875', in Peter Denley (ed.), *History of Universities*, 13 (Oxford: OUP, 1994), 194-249, p. 220.

63. *MNRAS,* 18, 4 (1858), pp. 110-2. See also *MNRAS* 18, 1 (1857),16-18, p. 18, and *Report of the 29th meeting* of the *British Association for the Advancement of Science* (1859), 145-6.

64. 'Are these plains composed of arid sand, as the first astronomer[s] maintained? Or are they nothing but immense forests, according to M Warren de la Rue's opinion, who gives the moon an atmosphere, though a very low and a very dense one? That we shall know by and by. We must affirm nothing until we are in a position to do so'. Jules Verne: *Around the Moon*, chapter 12, translation by Lewis Page

Mercer and Eleanor E King (Sampson Low, 1873) of *Autour de la Lune* (1870).

65. Letter from De La Rue to Herschel, 25 October 1864 (Royal Society HS6.D.161).

66. Letter from Herschel to De La Rue, 10 October 1858 (Royal Society HS.6.D.143).

67. *MNRAS,* 18, 4 (1858), 110-2, p. 111, and *Report of the 29th meeting* of the BAAS (1859), p. 146.

68. De La Rue, Warren., 'The present state of Celestial Photography in England', in *Report of the 29th meeting* of the *British Association for the Advancement of Science* (1859), 130-53. It also appears in the *Photographic Journal*, 1 October 1859, and in a reprint by Taylor and Francis, London, 1860. See also *MNRAS,* 19, 10 (1859), 353-8.

69. De La Rue, Warren., *The present state…*, p. 130. De La Rue emphasised the dedication needed in the following terms: 'to photograph the moon continuously is a laborious undertaking, and affords full occupation for one observer, who must not fail to pay unremitting attention to the condition of the various chemicals employed, so as to be always prepared for a fine night with such as will work. I would therefore strongly urge the claims of this new branch of astronomical science to a more extended cultivation than it has hitherto received, with the conviction that it will require the ardent co-operation of many astronomers to develop fully its rich resources', p. 149.

70. *MNRAS,* 19, 10 (1859), 353-8, p. 357; *MNRAS*, 22, 4 (1862), 120-1, p. 121; *MNRAS* 22, 4 (1862), 131-40, p. 137; *MNRAS* 25, 1 (1865), 115-6. De La Rue, Warren., *The present state…*, p. 153. Proceedings of the Royal Society 16 (1868), 447. I have been unable to find any examples of these stereoscopic pictures of the Sun; De La Rue probably did not mount the pictures permanently together.

71. *MNRAS,* 19, 4 (1859), 138-9. Had he succeeded, De La Rue would have been the first to photograph a comet, a feat accomplished by Mr Usherwood ('an artist residing on Walton Common', reportedly with an exposure of just 7 seconds, and G.P. Bond of Harvard, with an exposure of 6 minutes (Olsen and Pasachoff, *Fire in the Sky* (Cambridge: CUP, 1999), 250-4.

72. Letter from De La Rue to Herschel, 15 September 1858 (Royal Society HS6, D142). The sketch, however, is not with the letter.

73. Letter from De La Rue to Airy, 5 October 1858 (RGO 6/169, 563).

74. Houseman (1968), pp. 89-90.

75. Nasmyth, James., 'On the Structure of the Luminous Envelope of the Sun', *Memoirs of the Literary and Philosophical Society of Manchester*, 3rd series, I (1862), 407-11.

76. A detailed account of the willow-leaf controversy appears in Bartholemew, C.F., 'The Discovery of the Solar Granulation', *Quarterly Journal of the Royal Astronomical Society*, 17 (1976), 263-89. There is also an account in Rothermel, Holly., 'Images of the sun: Warren De la Rue, George Biddell Airy and celestial photography', *British Journal for the History of Science* [hereafter *BJHS*], 26 (1993), 137-69, especially pp.160-2.

77. Letter from De La Rue to Herschel, 24 August 1861 (Royal Society HS.6.147).

78. Letter from De La Rue to Herschel, 24 October 1863 (Royal Society HS.6.D.152).

79. Letter from De La Rue to Pritchard, 24 October 1863 (Royal Society HS.6.D.151). Twelve years later De La Rue, when referring to the installation of his instruments at the University of Oxford, mentioned that his eyesight had improved: 'While making observations for the preliminary adjustments I inadvertently used my left eye, and was surprised and delighted to find that I had recovered perfect vision with it, the granulations in the centre of the retina having disappeared', *MNRAS*, 35, 8 (1875) p. 376.

80. Letter from Charles Pritchard to Sir John Herschel, 19 October 1863, cited by H.H. Turner, in Ada Pritchard, *Charles Pritchard - Memoirs of his life* (London: Seeley & Co. Ltd., 1897), pp. 240 & 243.

81. *Astronomical Register*, 3 (1865), pp. 81-82.

82. Huggins, William., 'Results of some Observations on the Bright Granules of the Solar Surface, with Remarks on the Nature of these Bodies', *MNRAS*, 26, 5 (1866), 260-65.

83. In a letter to Herschel on 26 August 1861, De La Rue said: 'perhaps more than all in importance is peculiar granulation which comes on the surface and which betokens a great amount of activity in the photosphere', Royal Society HS.6.148.

84. Le Conte, see note 2 above, p. 56.

85. Letter from Sir John Herschel to Colonel Edward Sabine, 24 April 1854, *MNRAS*, 15, 4 (1855), 158-9.

86. The shutter mechanism is fully described in De La Rue, Warren: *The present state…*, p. 151.

87. *Philosophical Transactions of the Royal Society* [hereafter *Phil.Trans.*], 159 (1868),17-20.

88. The photographs were initially taken by B. Loewy, Chief Observer (Jacobs, L., 'The 200-years' story of Kew Observatory', *Meteorological Magazine*, 98 (1969), p. 165). By 1866, however, they were taken by Miss Beckley, the daughter of the mechanical assistant. De La Rue reported that 'it seems to be a work peculiarly fitting for a lady. During the day she watches for opportunities for photographing the Sun with that patience for which the sex is distinguished, and she never lets an opportunity escape her'. She also carried out some analysis of the sunspot pictures *MNRAS*, 26, 1 (1866), 74-77.

89. The results for 7 February 1862 to 31 December 1863 appear in *Phil.Trans.,* 159,1-110, which also contains a detailed description of the methodology and reductions. Results for 1864-5 are in *Phil.Trans* 160 (1870), 389-496 (abstract in *Proc.Roy.Soc*. 18 (1870), 263-4, which includes an analysis of the records of Hofrath Schwabe (for 1832-1853 and 1861), Richard Carrington (for 1854-1860), as well as those of Kew (1862-1865). These conformed with an average sunspot cycle of just over 11 years. See also Proc.Roy.Soc.20, 1871, pp.82-87 and 1872, p.289.

90. 'Researches on Solar Physics: On the nature of sunspots', by Warren De La Rue, Balfour Stewart and Benjamin Loewy (London: Taylor & Francis, 1865). 'Researches on Solar Physics: Area Measurements of the Sun Spots observed by Carrington during the seven years from 1854-1860 inclusive and deductions there from', by the same authors and printer, 1866. 'Tables for the Reduction of Solar Observations, No. 2: Table giving the values of log sin ? and log cos ? corresponding to the values of r/R, r being the measured distance of the spot from the centre and R the radius of the sun's disk, while ? is the heliocentric angle between the spot and the earth', by Warren De La Rue (London: Taylor & Francis, 1878). 'Researches on Solar Physics: On the Distribution of the Heliographic Latitude of the Sun Spots observed by Carrington, 1868', *Proc.Roy.Soc*., 14 (1865), 37-39. Phil.Trans., 14 (1865), 59-63. *Proc.Roy.Soc*., 16 (1867) p.336. *Proc.Roy.Soc*., 16 (1868), p. 447. *Proc.Roy.Soc*., 18 (1870), 263-64. *Proc.Roy.Soc*., 20 (1871), 82-87. *Proc.Roy.Soc*., 20 (1872), 198-9. *Proc.Roy.Soc*., 20 (1872), 210-8. *Proc.Roy.Soc*., 20 (1872), p.289. *Proc.Roy.Soc*., 21 (1873), 399-402. *Phil.Trans*. 159 (1869), 1-110. *Phil.Trans*., 160 (1870), 389-496. *MNRAS* 25, 1 (1864), p. 76. *MNRAS,* 26, 1 (1866), 74-77. *MNRAS,* 27, 1 (1866), 12-14. *MNRAS,* 27, 1 (1866), p. 91. *MNRAS,* 27, 8 (1867), p. 286. *MNRAS,* 28, 1 (1867), 44-45. *MNRAS,*

29, 1 (1868), 3-4. *MNRAS,* 29, 3 (1868), p. 95. *MNRAS,* 30, 3 (1870), p. 60. *MNRAS,* 31, 3 (1871), 79-80. *MNRAS,* 32, 5 (1872), 225-6. *MNRAS,* 33, 3 (1873), 173-174. *American Journal of Science*, 43 (1867), 179-92 and 322-30. *Philosophical Magazine*, 29 (1865), 237-9. *Phil.Mag*., 29 (1865), 390-4. *Phil.Mag*., 31 (1866), 243-4. *Phil.Mag*., 33 (1867), pp.79-80. *Phil.Mag*., 40 (1870), 53-54. *Phil.Mag.,* 43 (1872), 385-90.

91. *Phil.Trans*., 160 (1870), 389-496, p. 393. The sunspot records have been reviewed by Vaquero, J. M., Sánchez-Bayo, F., and Gallego, M.C., 'On the reliability of the de la Rue sunspot area measurements', *Solar Physics*, 209, 2 (October 2002), 311-9, and 'Periodicities of the de la Rue sunspot area measurements', *Solar Physics*, 218, 1-2 (December 2003), 307-17).

92. *Phil.Trans*., 160 (1870), 389-496.

93. *MNRAS,* 20, 1 (1859), 13-16.

94. *Phil,Trans*., 160 (1870), p.404 & plate XXXI.

95. *MNRAS,* 20, 1 (1859), 15-16.

96. Howse, Derek., *Greenwich Observatory, Volume 3: The Buildings and Instruments* (London: Taylor & Francis, 1975) p. 93. The photo-heliograph is now in the collections of the London Science Museum.

97. *Proc.Roy.Soc*., 14 (1865), 59-63. *MNRAS,* 25, 4 (1865), 115-16; *MNRAS* 26, 1 (1866), 74-77.

98. Letter from "Athenæum", published in the *Daily News*, 5 January 1867 (Royal Society archives).

99. *Phil.Trans*., 160 (1870), 394-6.

100. *Proc.Roy.Soc*., 20, 1872, pp.210-8.

101. Letter from De La Rue to Herschel, 10 November 1861, Royal Society HS.6.D.149.

102. *MNRAS,* 22, 1 (1861), 38-42.

103. Airy saw great potential for the application of photography to solving astronomical questions, and consistently encouraged De La Rue in his photographic endeavours. As early as 1857, in a letter to De La Rue, he said: 'In due time we may make Astronomy self-acting', by which he meant avoiding the human equation which adversely affected the achievement of consistency. (24 September 1857, RGO 6/169, 549/50.)

104. *MNRAS,* 29, 2 (1868), 48-53. The paper was followed by constructive comments by Major Tennant *MNRAS,* 29, 7 (1869), 280-2, and a response by De La Rue *MNRAS* 29, 7 (1869), 282-4.

105. The deliberation between De La Rue and Airy over the application of photography to the transit of Venus has been discussed in Rothermel, Holly., 'Images of the sun: Warren De la Rue, George Biddell Airy and celestial photography', *BJHS*, 26 (1993), 137-169, especially pp. 163-8.

106. The shutter is described by De La Rue in *MNRAS* 34, 7 (1874), 347-53, and by Françoise Launay and Peter Hingley in *Journal for the History of Astronomy*, 36, 1 (February 2005), 57-79.

107. The debate within the RAS about the preparations for the 1874 transit of Venus is covered by Hollis, H.P., 'The decade 1870-1880', in Dreyer, J.L.E., and Turner, H.H. (eds)., *History of the Royal Astronomical Society*, Vol. 1, 1820-1920, (London: RAS, 1923, reprinted 1987), Chapter 6, p. 168 and pp.178-85.

108. Letter to the Editor by Richard A Proctor, *The Times*, 30 December, 1873, p. 9. Letter by Warren De La Rue, *The Times,* 31 December, 1873, p. 8. Letter by 'C.P.' [Charles Pritchard], *The Times*, 3 January, 1874, p. 8. Letter by Warren De La Rue, 5 January 1874. Letters by Richard A Proctor and Alex Strange, *The Times*, 6 February 1874, p. 7. The first two letters and a further letter to *The Times* by E.B. Denison, were also published in the *Astronomical Register*, 134 (February 1874), 39-43. It is interesting to note that, despite the acrimony between Proctor and De La Rue, the former 'respectfully Dedicated' to the latter his 1873 book about the Moon, 'in recognition of those important additions to our knowledge of the celestial bodies, and especially of the Sun and Moon, which have resulted from his photographic and other scientific researches', Proctor, Richard A., *The Moon: Her motions, aspect, scenery, and physical condition* (London: Longmans, Green, and Co., 1873).

109. Rothermel, Holly., 'Images of the sun: Warren De la Rue, George Biddell Airy and celestial photography', *BJHS*, 26 (1993), 137-69, especially pp. 166-8.

110. Clerke (1893), pp. 291-2.

111. *Astronomical Register*, 18 (1878), p. 174.

112. Strange, Lieut-Col. Alexander., 'On the Necessity for State Intervention to Secure the Progress of Physical Science', *Report of the British Association* (Norwich, 1868), pp. 6-8.

113. *Royal Commission on Scientific Instruction, etc.: – Minutes of evidence*, 22 (1874), 300-6. De La Rue was examined by the Commission on 12 July 1872.

114. Strange, Lieut-Col. Alexander., 'On the insufficiency of existing national observatories', *MNRAS,* 32, 6 (1872), 238-41. See also *Astronomical Register*, 10 (1872), 113-20, and *Nature,* 5 (April 25, 1872), p. 497.

115. A general account of the endowment of research debate appears in Macleod, Roy M., 'Resources of Science in Victorian England: The Endowment of Science Movement, 1868-1900', in Peter Mathias (ed.), *Science and Society* (Cambridge, CUP, 1972). An account of the debate and dispute within the RAS appears in Hollis, note 107, 173-78 and 207-11.

116. 73 Portland Place suffered damage during the World War II blitz, and the present building on this site dates from after that time. De La Rue's house appears to have been similar to those extant in the neighbouring terrace. (London County Council Bomb Damage Maps 1939-1945, published by London Topographical Society, 2005; Guildhall Library, London, personal communication.)

117. Turner, H.H., note 107, 263-67, p. 272, and 308-309. De La Rue's role in the development of the Oxford University Observatory, is addressed in detail by Hutchins, note 62, 193-249. He also gained an MA, reportedly an honorary one from Oxford University, but the University has no record of it.

118. Letter from 'C.P. Oxford, Jan. 1' to the Editor of *The Times*, published 3 January 1874, p. 8, under the heading 'The New Observatory at Oxford'.

119. Letter from Warren De La Rue to the Editor of *The Times*, published 5 January 1874, p. 11.

120. Turner, note 107, pp. 266-7.

121. *MNRAS*, 41, 5 (1881), 306-9.

122. Turner, note 107, 281-2.

123. Pritchard, Charles: 'Remarks on some of the present Aspects of Celestial Photography', *MNRAS,* 47, 6 (1887), 322-4.

124. Turner, note 107, p. 309. The fate of the astrograph is not known.

125. Cameras inventory nos 63460, 73104, 81324 and 81544, eyepieces inventory no. 22368, Museum of the History of Science, Oxford.

126. Letter from Gill to De La Rue, 22 March 1880, Royal Society MM12.99: 'Regarding the Telescope. Dr. Huggins tells me the only man who can manage the matter is yourself, and I need hardly say how greatly indebted I shall be to you if you can arrange it.'.

127. Letters from Airy to De La Rue, 13 April 1880, Royal Society MM12.100, and from Airy to Gill, 19 April 1880, Roy.Soc. MM12.103.

128. Letter from Airy to De La Rue, 15 April 1880, Royal Society MM12.102. Newall had a 25-inch refractor, Hollis, note 107, p.189.

129. The lengthy correspondence is at Royal Society MM12.94 to MM12.134.

130. The largest donation was from Nasmyth, in the amount of £1,000. Others gave lesser amounts, and Airy also subscribed, but the correspondence does not record the amount.

131. Gill, Sir David., *A History and description of The Royal Observatory, Cape of Good Hope* (London: HMSO, 1913) p. xliii.

132. *Proc.Roy.Soc.* 16 (1868), 434-7.

133. Letter from De La Rue to George Stokes, 17 December 1868 (Exeter University archives), and letter from De La Rue to Airy, 6 June 1872 (Royal Greenwich Observatory 6/17 40-41). *MNRAS,* 30, 1 (1869), 22-24; *MNRAS*, 30, 2 (1869), 36-37; *MNRAS*, 30, 4 (1870), p.98.

134. *Journal of the Chemical Society* 6 (1868), 488-95. *Acad.Sci.Compt.Rend*., 67 (1868), 794-8. *Deutsch.Chem.Gesell.Ber*. 1 (1868), 276-82. *Proc.Roy.Soc.,* 23 (1875), 356-61. *Proc.Roy.Soc.,* 24 (1876), 167-70. *Acad.Sci.Compt.Rend*., 81 (1875), 686-8 and 746-9. *Annalen der Physik und Chemie*, 233, 2 (1876), 290-4 & 294-7. *Proc.Roy.Soc*., 25 (1876), 258-9. *Journ. Chem.Soc*., 29 (1876), p. 334. *Proc.Roy.Soc*., 26 (1877), p.227, 324-5 and 519-23. . *Phil.Trans.,* 169 (1878), 55-121 and 155-241. *Acad.Sci.Compt.Rend*., 85 (1877), 791-4. *Acad.Sci.Compt.Rend*., 86 (1878),1071-5.

135. *Proc.Roy.Soc*., 30 (1880), 332-4.

136. Letter from Louis Pasteur to Jean-Baptiste Dumas, 8 September 1871 (Marie Claude Fortier of Arbois, France, personal communication). See also Redman, Nick., 'Louis Pasteur and the Brewing Industry', *The Brewer* (September, 1995), 369-380.

137. Letter from De La Rue to Airy, 24 April 1861 (RGO 6/123 346). This apparently refers to a lecture about the 1860 eclipse observations, given to the Royal Institution , in L. Pearce Williams, Rosemary Fitzgerald, and Oliver Stallybrass (eds.), *The Selected Correspondence of Michael Faraday*, Volume 2, 1849-1866, letter 530, pp.996-7. De La Rue's 1862 Bakerian lecture to the Royal Society, about the 1860 eclipse, 'was illustrated most brilliantly by apparatus, reproducing some of the phenomena of a total eclipse', (Edwards, note 34, p. 39).

138. *Royal Institution Managers' Minutes*, xiv, 181 (6 May 1889).

139. Letter from De La Rue to John Tyndall, 3 December 1881, *Roy.Inst. Managers' Minutes*, xiii, 284, 5 (December 1881).

140. *Royal Institution Managers' Minutes*, xiv, 172 (1 April 1889).

141. *Nature* , 10, (16 May 1889), pp.60-63.

142. *MNRAS,* 22, 4 (1862), 131-39, p. 136 and p. 139.

143. *Nature* (9 May 1889), 28.

144. Knobel, Edward.,'Warren De La Rue'*, MNRAS,* 50, 4 (1890), 155-64, p. 161.

145. Huggins, Margaret., 'Warren De La Rue', *The Observatory*, 150 (1889), 244-50.

146. *The Star, Guernsey*, 25 April 1889, and *The Comet*, 24 April 1889.

147. Note from De La Rue to Airy, 18 July 1860, Royal Greenwich Observatory 6/123 284.

148. Letter from De La Rue to Lockyer, 26 November 1868, and from De La Rue to Stokes, 17 December 1868, University of Exeter archives.

149. *Phil.Trans*., 52, (1862), 333-16, p. 358.

150. Hutchins*, note 62*, p. 213.

151. *Journal of the Society of .Arts*, 26 July 1872, p. 733.

The Author

David Le Conte was born in the Channel Island of Guernsey. After working briefly at the Royal Observatory Edinburgh and the University College of Wales in Aberystwyth, he went to the United States to work at the Smithsonian Astrophysical Observatory. He became Executive Director of the Smithsonian Research Foundation in Washington DC, and has worked as a department manager at Kitt Peak National Observatory in Arizona. Returning to Guernsey in 1978, he joined the local astronomical society and led the creation of the island's observatory in 1991. He has served as President of La Société Guernesiaise, the island's local studies and natural history society. In 2005 he was elected to the position of Jurat of the Royal Court of Guernsey. He is a founder member of the Society for the History of Astronomy. He has been researching the life of Warren De La Rue for some years, his interest being sparked by the fact that De La Rue was also born in Guernsey, and is the island's most famous astronomer.