David Gill: clock maker to global astronomer

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Reduction in the uncertainty of physical measurements underpinned many advances in solar and stellar parallax, the determination of longitude, geodesy, and the accurate mapping of the heavens using celestial photography in the late nineteenth century. A pioneer in these areas, who successfully made the transition from clock maker in Aberdeen to H.M. Astronomer at the Cape of Good Hope was David Gill (1843-1914); Sir David Gill, K.C.B. from 1900. This paper celebrates the first third of Gill's career in astronomy and geodesy up to the time he was made redundant from Dun Echt Observatory at the end of 1875. It highlights how his horological skills were applied to telescope design and also how his aspirations to become a global astronomer started. The paper is timed to coincide with Gill's centenary anniversary year – he died 24 January 1914.

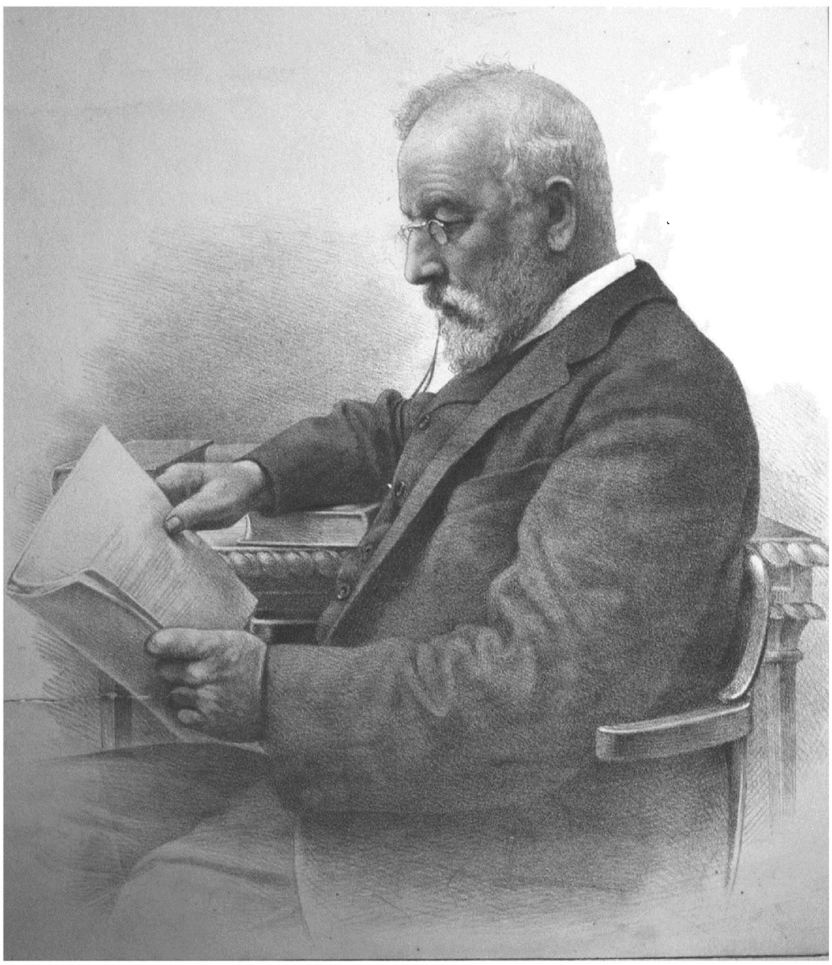

Fig.1 Engraving of Sir David Gill, c.1909.
Courtesy of the Royal Astronomical Society

Early days in Aberdeen

Horology and Astronomy were closely linked during the nineteenth century and could occasionally lead a man with an engineering outlook into an exciting new domain. In October 1897 David Gill (1843-1914) responded to an enquiry from Bryan Cookson (1874-1909) about becoming an astronomer:

> My own experience in life is that a man is happy when his heart is in his work and unhappy when his work is uncongenial. I was removed from Aberdeen University before I had completed my 4th year course to fill a place in my father's business which became suddenly vacant by difference between my Father & his partner. I was in business for 8 years had married was making £1500 a year and working in my own observatory when Lord Crawford offered me £300 a year to take the director of Dun Echt observatory. We had no children my wife knew where my heart lay. I had a little money with reasonable expectation of more and in 24 hours Lord Crawford had my answer – yes. I never regretted the decision – my life became full of interest, and has so continued ever since.[1]

Gill outlined his early life in his work, *A History and Description of the Royal Observatory Cape of Good Hope* (HMSO, 1913). He was the eldest surviving son of David Gill (1789-1878) of Blairythan, Aberdeenshire and Margaret Mitchell (1809-1870) of Savock, Aberdeenshire and was born in Aberdeen on 12 June 1843. Educated first at Bellevue Academy and then Dollar Academy where he cited the influence of Dr Lindsay's teaching in mathematics, physics and chemistry as 'inspiring'. At Marischal College, Aberdeen he enrolled as a private student from 1858-60. Donati's comet (C/1858 L1) was then a magnificent object in the autumnal skies. Gill received private tuition in mathematics from Dr Rennett and attended classes of the celebrated James Clerk Maxwell (1831-1879). Maxwell had married Katherine Dewar, a daughter of the Principal of Marischal College in 1858 and had just secured the Adams Prize for his 1859 essay *On the Stability of Saturn's rings* which correctly argued that the rings must be composed of numerous small particles. Maxwell's teaching style combined detailed lecture notes, which could be copied, with impromptu blackboard expositions of theories, often extended for hours beyond the normal lecture period for the keener students. Here Gill was introduced to a tin-plated and wooden model of a transit instrument used by Maxwell to illustrate its purpose, adjustment and practical use. Gill described these opportunities as providing: 'hours of purest delight to me' and 'his teaching influenced the whole of my future life'. Maxwell in a testimonial in 1869 said: 'David Gill was one of my ablest students in Marischal College, Aberdeen. He was even then devising methods for the experimental determination of physical quantities'.[2]

Coincidentally Aberdeen hosted a meeting of the British Association (BA) and it is likely that Gill attended several lectures or at the very least studied the *Report of the Twenty-ninth Meeting of the British Association for the Advancement of Science; held at Aberdeen in September 1859* (John Murray, 1860). The presence of his HRH Prince Consort (1819-1861) as President of the BA guaranteed a large audience in the New Music Hall at Aberdeen. In practice the total of 2564 guests, including 821 ladies, exceeded all previous meetings since the BA's launch in York in 1831.[3] Gill would have been inspired by such a gathering of British scientists in his home city, with personalities such as Sir David Brewster (1781-1868), Sir John F. W. Herschel (1792-1871) and Lord John Wrottesley (1798-1867) in attendance. Astronomical topics included the acceleration of the Moon's motion by Astronomer Royal George B. Airy (1801-1892) and a suggested improvement to the heliometer instrument by Norman Pogson (1829-1891). However the impact of the paper by Warren De La Rue (1815-1889) *The present state of Celestial Photography in England* may well have encouraged the teenage Gill to attempt lunar photography for himself by replicating, even improving, on the technology used by De La Rue at Cranford.[4]

Meanwhile at the family home, 48 Skene Terrace Aberdeen, Gill developed a small laboratory for electrical circuits and chemical experiments. He was interested in the science of measurement and the errors of optical instruments. Maxwell's proposal that a truly scientific standard of length should be measured with reference to a wavelength of light would later influence Gill's contributions to the Inter-national Bureau of Weights and Measures meetings in Paris in 1907. However two events in 1860 initially threatened Gill's aspirations. The first followed the merger of Marischal College with neighbouring King's College to form the University of Aberdeen. Maxwells's comparative youth denied him the chair of Natural Philosophy and after surviving a summer bout of smallpox he moved south to King's College in London.[5] The second involved David Gill's father, then aged 71, insisting his eldest son should enter the family watch and clock making business. In Gill's words, 'I very unwillingly yielded, and after some years my father retired, leaving his business in my hands'.[6]

Clocks, chronometers and time-keeping

The years 1861-62 found Gill away from home learning the trade of watch-making. Horological centres in Clerkenwell and Coventry, Besançon and Switzerland developed his engineering abilities, his dexterity and also proficiency in the French language. Besançon's watch-making business had begun in 1793 when the Swiss clock and watch industry was struck by unemployment and workers moved across the border into France. In 1860 the Watchmaking School had been founded and it is probable that Gill examined the magnificent Besançon astronomical clock by Auguste-Lucien Vérité (1806-1887), installed in 1860 in the town's Saint-Jean Cathedral, with its seventy dials driven by thirty thousand mechanical parts.[7] Writing to James Nasmyth (1808-1890) in 1886 Gill reflected on his dexterity: 'the best part of my astronomical education was the time I spent in a workshop' adding 'many a change of great practical utility I have made on the instruments here [at the Cape] with my own hands'.[8] By the end of 1862 Gill was competent enough to construct a marine chronometer incorporating his own adaptation of the compensation balance wheel.[9] Whilst studying an instrument in a Glasgow optician's shop Gill was spotted by his former professor. Maxwell introduced him to his colleague William Thomson (1824-1907) who was then wrestling with the challenge of laying the Atlantic telegraph cable. So began a lifelong friendship between Gill and the later Lord Kelvin.[10] Rather less inspiring, in 1863 he became junior partner in 'David Gill and Son' with an outlet at 78 Union Street, Aberdeen. Thus began a working period up to 1872 of: 'a lot of distasteful drudgery and uninteresting work, with few holidays and no deer stalking'.[11]

Gill's return to Aberdeen soon facilitated a liaison with David Thomson (1817-1880), Professor of Natural Philosophy, who had campaigned for the amalgamation of the two colleges and who lectured on the top floor of Cromwell Tower at the King's College site. Gill recalled in 1908: 'it was very much owing to Thomson and his sympathy that I began my astronomical career'. Gill and 'Davie' were keen on smoking and found: 'the observatory was a convenient place' to spend time indulging their habit.[12] Thomson wrote in November 1863 to Charles Piazzi Smyth

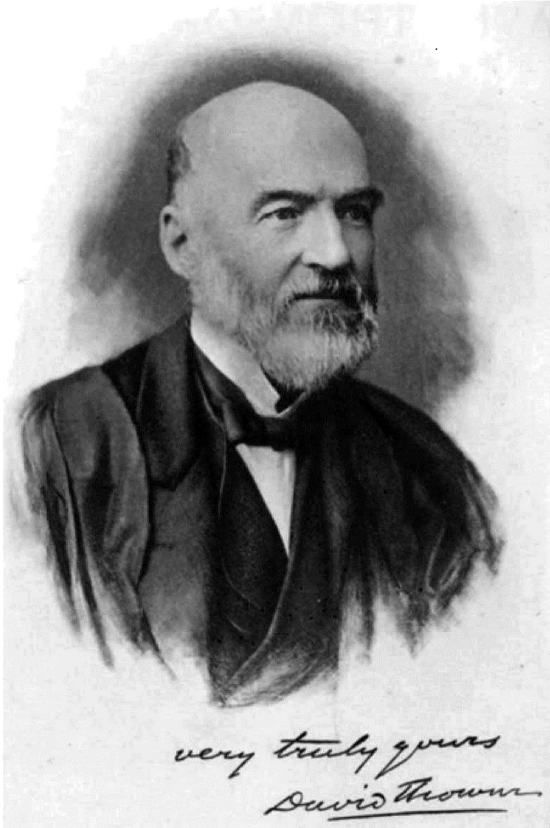

Fig.2 Engraving of David Thomson, c.1860.
Courtesy of the University of Aberdeen.

(1819-1900) the Astronomer Royal for Scotland to suggest that Gill should examine the Edinburgh time-gun system and transit instrument. Smyth had begun his astronomical training at his father's observatory in Bedford and had been an assistant to Thomas Maclear (1794-1879) H.M. Astronomer at the Cape of Good Hope before his appointment to the Calton Hill Observatory in Edinburgh and Professor of Astronomy at the University of Edinburgh in 1846. In 1852 he had installed a time-ball on top of Nelson's Monument at Calton Hill which was supplemented by the One O'Clock Gun at Edinburgh Castle in 1861. Ships' captains at Edinburgh's port of Leith were thus provided with both a visual and audible signal to set their chronometers.[13]

Gill admired Smyth's global travels and achievements. The accuracy of the Edinburgh time system had been proven in 1858 when at the suggestion of Astronomer Royal Airy the transits of twenty-two stars were observed simultaneously at both Greenwich and Edinburgh. The time differences were used to determine the longitude of Edinburgh as nearly thirteen minutes west of Greenwich. Smyth had further improved the system in 1861 by using the recommendations of John Hartnup (1841-1892) at Liverpool Observatory and Maclear at the Cape to introduce a two-clock system with a master and slave operation.[14] Gill proposed a similar system for Aberdeen and the dormant observatory at Cromwell Tower was brought into use by 1865. It included a 30-inch transit telescope by Thomas Jones mounted on masonry piers in the north dome of the observatory.[15] Gill and Thomson used an electrically controlled pendulum clock to drive slave clocks with wires connecting first to Marischal College and later to Gill's shop in Union Street. In this way Aberdeen gained its first time service operated from the transit telescope at King's College.[16] Gill's first experiences involved a little practice: 'I remember well my delight when my eye and ear observations of the seven wires of a transit, when reduced to the middle wire, began to agree with the mean to one-tenth of a second'.[17] Such measurements soon become routine for Gill and he longed to do practical astronomy work of more interest and permanent value.

Election as a Fellow of the Royal Astronomical Society (RAS) resulted through a recommendation in June 1867 from Robert Grant (1814-1892), Professor of Astronomy at the University and Director of the Observatory in Glasgow.[18] Grant had received the Gold Medal of the RAS in 1856 for his work, *History of Physical Astronomy* (Robert Baldwin, 1852). Through this book Gill may well have developed his interest in the achievements of Edmond Halley (1656-1742), James Bradley (1693-1762), Friedrich W. Bessel (1754-1846) and F. G. Wilhelm Struve (1793-1864) through whom positional astronomy had advanced. By the time of his support for Gill's election Grant had introduced a time system for public clocks in Glasgow, begun work on his star catalogue of 6415 stars, cooperated with Airy on longitude determinations by interchange of galvanic signals and calculated the radiant of the great meteor shower of Leonids observed in November 1866. Grant's refurbishment of the Observatory in Glasgow included provision of a 6-inch transit circle by Ertel and Sons of Munich and the 9-inch Cooke 'Ochtertyre' equatorial – instruments that undoubtedly inspired Gill.[19]

Back in Aberdeen Gill persuaded Thomson to purchase a Ross telescope of 3⅜ inches aperture and 4 feet focus to be mounted in the South dome of Cromwell Tower.[20] Although the object glass was excellent the mounting, clockwork and slow motions were all found inadequate for measuring double stars. The Ross telescope was operational by February 1867 as Gill reported: 'I had been measuring the position and distances of two components of the multiple star θ *Orionis*'.[21] Two fainter stars within the Trapezium system were noted. Meanwhile Thompson reported observing the final stages of the solar eclipse visible in Aberdeen in March.[22] Gill's keen eyesight was further evidenced in November when he reported the ease of splitting ε Lyrae with the naked eye.[23]

FRAS and Skene Observatory

In December 1867 Gill's election as a Fellow of the RAS was confirmed.[24] *Monthly Notices* for this year reveal a large number of papers that would have attracted his attention. At the Royal Observatory Greenwich Bradley's stars in Bessel's Fundamental catalogue were being re-observed, the Atlantic telegraph was underway and longitudes were being measured by chronometric transfer. At Liverpool, Hartnup was setting up his chronometer room at Bidston and improving the time gun facility. In Dunsink, Franz Brünnow (1821-1891) was quantifying errors in meridian observations of Iris and Vesta. In America, Lewis M. Rutherford (1816-1892) was describing his photographic study of forty stars in the Pleiades whilst Simon Newcomb (1835-1909) was investigating systematic errors within tables for the planet Neptune. The mathematical studies of Edward J. Stone (1831-1897) for proper motions, the motion of the solar system in space and solar parallax would also have fascinated Gill. Geodesy work may also have struck a chord. James F. Tennant (1829-1915) was measuring the coefficient of expansion of the brass pendulums used in the Great Trigonometric Survey of India and reducing errors in oscillation by using a vacuum apparatus. The obituary of Sir George Everest (1790-1866) would have emphasized further the importance to science of measuring an Arc of Meridian. So although the 1867 RAS Gold Medal was awarded to William Huggins (1924-1910) and William A. Miller (1817-1870) for their spectroscopic study of the composition of stars David Gill was in all probability already aligning his future towards positional astronomy work.

In June 1868 Gill was observing faint stars near α *Lyrae* from Skene Terrace.[25] He was at this time the proud owner of a silvered glass Newtonian of 12-inch aperture with a mirror made by Rev Henry Cooper Key (1819-1879) of Stretton Rectory, Hereford. It used a flat by John Browning (1835-1925) with powers up to x250 in a solid tube which could be rotated to a convenient position. By November Gill had upgraded the flat to: 'a rectangular glass prism of 2⅛ inch aperture, from Steinheil of Munich' which required no re-silvering. Gill also mentions his observatory but provides no details of its construction.[26] At this time the Romsey design of Edward L. Berthon (1813-1899) was becoming popular although a design of wood and canvas would be no protection for Scottish gales and 'Skene Observatory' proved unable to withstand such a gale a few years later. Low altitudes could not be accessed from Skene Terrace so Gill's observation of the Transit of Mercury in November 1868 was once again using the Ross telescope in Cromwell Tower.[27]

Key was the first astronomer in the Britain to produce silvered-glass mirrors and had advertised his 12-inch mirror of 10-foot 6-inch focus up to the end of 1866.[28] At Gill's request he had sent the mirror for trial on a rough wooden stand and since it gave: 'admirable definition' it was duly purchased. Gill supplied working drawings for an equatorial mount using a double polar axis in an iron frame which were produced by Hall, Russell Co., Shipbuilders in Aberdeen. A driving circle, tangent screw and slow motion in R.A. and declination circle were purchased from T. Cooke and Sons of York.[29] The driving clock was Gill's own design with a train of wheels driving a conical pendulum suspended by two pairs of springs arranged at right angles. Gill was by now well aware of the backlash inherent in many equatorial mounts and advocated reducing periodic errors by fine grinding gear systems and employing friction clutch drives to avoid the need to disengage a worm drive. His adoption of a massive iron frame also reflected his dislike of insufficient rigidity in many equatorial designs.[30]

At the RAS meeting in December 1868 Airy was outlining preparations for the Transits of Venus in 1874 and 1882 which would include determinations of absolute longitudes of the selected observing stations. Airy described this work as: 'a duty of the British nation' adding 'the expedition sent into the Pacific for the observation of the Transit of Venus in 1769, has always been esteemed as one of the highest scientific glories of Britain in the last century; and I may be permitted to express my hope that it will be surpassed by the efforts which our country will make, with the same object, in the present century'.[31] Airy's challenge to the scientific community must have resonated with Gill's desire to be involved in useful astronomical work. Unfortunately his family and business commitments dominated his life at this time.

In May 1869 Gill was at last in a position to replicate De La Rue's lunar photographic experiments as described in the BA meeting ten years earlier. A close parallel exists between De La Rue's description and Gill's approach. They both used a similar aperture and focal length of mirror, prime focus photography using hexagonal glass wet-plates prepared using the collodion process and invited the specialist knowledge of a photographer. In Gill's case this was George W. Wilson (1823-1893), the respected Aberdeen photographer.[32] During the middle of May they photographed the First Quarter and Gibbous Moon with an image size of 1⅛ inch.[33] The accuracy of Gill's driving clock and ruggedness of his equatorial mount overcame many of the problems of achieving a sharp image. Similarly Skene Observatory would have provided shelter from any wind vibration and a ready-made darkroom for Wilson to work quickly during the time-consuming process of coating, exposure and development. The collodion process produced a negative image on the glass plate from which printing onto albumen paper would have been possible.

The outcome proved a turning point in Gill's astronomical career. He was certainly delighted with the results and he sent a print to Huggins at Tulse Hill Observatory. Huggins had attempted wet-plate photography of the spectrum of Capella and Sirius in

Fig.3 Painting of Lord Lindsay by William Quiller Orchardson, c.1890
Courtesy of the Crawford Library, Royal Observatory Edinburgh.

1863 so could fully appreciate the difficulty involved. Within a year the print was noticed by Lord (James Ludovic) Lindsay (1847-1913) whose astronomical ambitions were beginning to take shape.[34] Significantly Lindsay lived at the family estate at Dun Echt which was only 13 miles west of Aberdeen.

Meanwhile Gill's expertise with small bore rifle shooting was flourishing. From 1864 with his younger brother Jamie they had frequented the Bay of Nigg, south-east of Aberdeen, shooting distances up to 1000 yards. Between 1868 and 1872, Gill had a commission as Lieutenant in the first Aberdeenshire Rifle Volunteer Corps, during which time he acted as head of the family and gained full control of the family business.[35] Shooting would remain a significant pastime throughout Gill's life and can be used to illustrate his clear understanding of accuracy and precision. For example if a target shows a random scatter of shots around a bulls-eye it may indicate accuracy but not precision, whereas closely grouped shots away from the bulls-eye indicate precision rather than accuracy. By careful adjustment and calibration of the sight all of the shots can be grouped closely around the bulls-eye indicating both accuracy and precision. In this example accuracy is defined as the degree of closeness to the desired value, whereas precision is defined as how tightly the shots are spaced or the reproducibility of the result. Gill's genius was to apply these concepts rigorously to all the types of instrumentation he used throughout his life, allowing the uncertainties of measurement due to random and systematic errors to be assessed and the uncertainty of the result to be quantified. Much of Gill's later astronomical research included a detailed analysis of the personal equation of each observer and such measurements were always built in to his planning to improve the measured value of physical quantities.

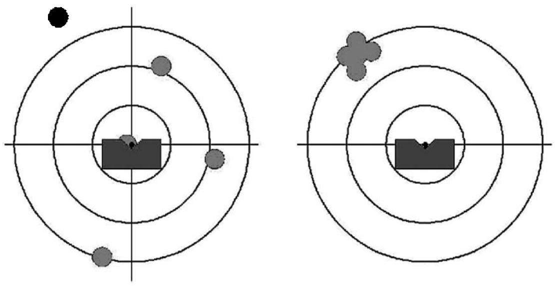

Fig.4 Diagram to explain accuracy (left) and precision (right).
Illustration by the author.

Marriage and a new opportunity

After a five year courtship David Gill married Isobel Sarah Black (1849-1919) on 7 July 1870. 'Bella' was the middle surviving daughter of John Black (1807-1885) and Elizabeth Garden (1812-1892) from Foveran, 12 miles north of Aberdeen.[36] Her first impressions include a description of Gill's eyes which possessed: 'a compelling power, an unconscious strength which held one, and which showed that, although unconscious of it, he had already found himself'. Bella recounted in later life: 'at twenty-two he was as old for his age as he was young at seventy' adding 'the eagerness, the honest frankness, the vitality, the quickness to perceive and to respond, the humour, the humanity, the joyousness were all their when we first met and walked together to church'.[37] Other traits of Gill included a loudly pitched voice with a very pronounced Scottish accent. His voice had a compelling quality and an extraordinary variety of tone which ensured listeners remembered his ideas. The couple honeymooned in Pitlochry and set up home close to Skene Observatory at 26 North Silver Street.

Fig.5 David Gill and Isobel Sarah Black:
Gill was a Lieutenant in the 1st Aberdeenshire Rifle Volunteer Corps, before their marriage.
Forbes, George, *David Gill, Man and Astronomer* (London, Murray, 1916).
By courtesy of the Institute of Astronomy, University of Cambridge.

In September 1870 Key and his wife Ellen visited Nairn in Scotland and also the newly-weds in Aberdeen. During 1871 Gill was advising Key about the Hereford time-gun. Key responded: 'your suggestions for the automatic firing of our proposed time-gun are admirable and yet simple'.[38] He further added: 'the Astronomer Royal fully approves of your scheme for an independent clock and automatic firing'.[39] At this stage Key was supplying a time-service to Hereford from his observatory at Stretton Rectory in which he now had set up an 18-inch silvered-glass reflector, the second largest in the world at this time.[40]

Solar eclipse expeditions were major events for Victorian scientists. For the total eclipse in December 1870 Lord Lindsay organized a group to the 'Le Maria Luisa' vineyard in Cadiz.[41] The group, including photographer Henry Davis, arrived at the beginning of the month and set up a temporary observatory and darkroom. Wet-plate photographs were taken during the short totality period of just over two minutes. Sadly Gill himself missed this opportunity, due to the illness and death of his mother. He would never have another opportunity. By 1871 Gill had invested in a Steinheil filar micrometer to facilitate measurements of double stars. He had tentative plans to attempt measurement of the parallaxes of some stars. In the Edinburgh BA meeting in August Gill announced that he had detected a parallax of nearly two seconds of arc in the case of the planetary nebula 37 H.iv, close to the pole of the ecliptic.[42]

As a young married couple David and Bella both soon realized that the family business, while fairly lucrative, could never fulfil Gill's ambitions. In Bella's words: '26 North Silver Street was a comfortable but rather ugly little house'. She highlighted: 'the intensity of David's love of Astronomy' adding 'the radiant look on his face, and the exultation in his voice after a night spent with his telescope'. Bella prayed for some sort of opportunity for her husband: 'in 1872 the miracle happened'.[43] It was in December 1871 that a letter from Lord Lindsay was hand delivered to the Gill's home. Referring to the planned new observatory at Dun Echt, Lindsay explained:

> To this end my Father is interested to build a small house in conjunction with the observatory, and proposes to offer £200 to £300 a year to an observer or resident astronomer. Under these circumstances although I know you have a vocation […] I have sometimes thought that you might, in the interests of science, and from your love of astronomy, be willing to accept the post of Resident Astronomer were I to offer it to you, with such advantages as the instruments <u>we</u> are now getting together would afford […] I know of no one more capable of taking these large instruments, or whom I should prefer to have as Astronomer of Dun Echt Observatory than yourself. Of course we should if you like make a new home for your 13-inch baby.[44]

Despite the significant drop in salary the offer was accepted immediately and the Gills moved near to the Crawford family estate at Dun Echt the following summer.

Dun Echt Observatory

Selection of equipment for Dun Echt Observatory appears to have been a joint enterprise by Gill and Lindsay although it was Lindsay who was initially travelling around Europe. Writing from Rome in February 1872: 'I saw today the object glass prism that Secchi has, and shall see its performance some evening soon' adding 'a very satisfactory letter from Davis who seems to have succeeded admirably'.[45] Henry Davis had obtained five photographs of the solar eclipse of December 1871 in Baikul, India which were used to form a composite image for the solar corona.[46] Lindsay, writing from Munich in July 1872, had decided to invest in object glass prisms by Merz: 'send him a line giving the exact dimensions of the

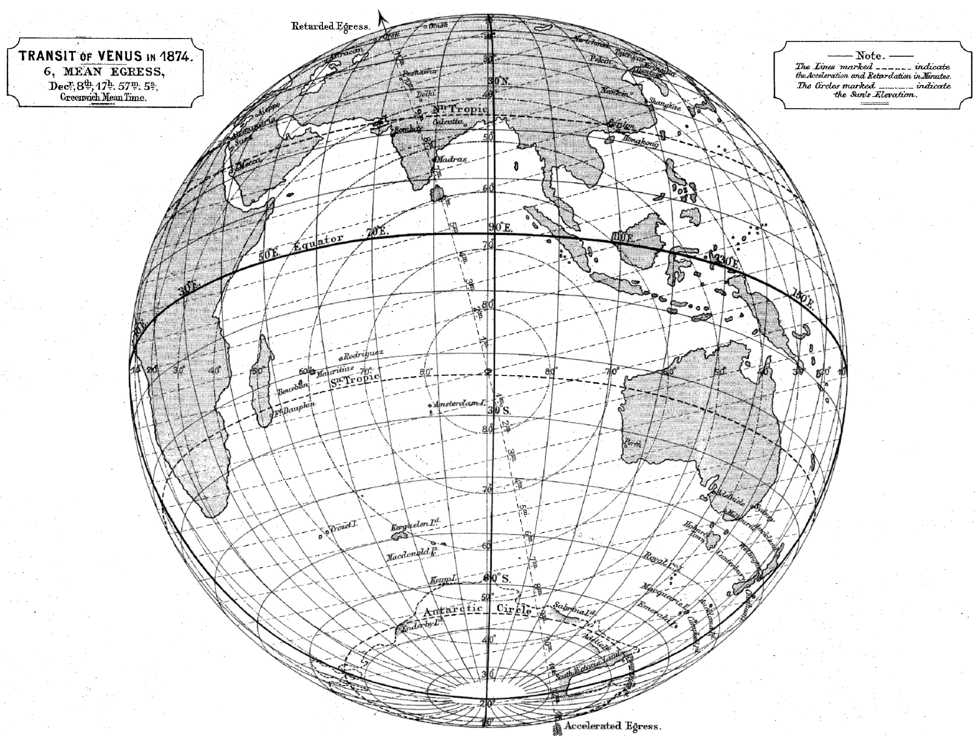

Fig.6 Transit of Venus in 1874 showing the favourable location of Mauritius
Proctor, Richard A., *MNRAS*, 29, 8 (1869), 306-317, pl. 6.

cell of the 6-inch O.G. on which the fitting of the prism will be placed – also try and get the same dimensions from Grubb for the 15-inch'. Lindsay was clearly in spending mode: 'I have also ordered 3 ring micrometers of Steinheil 2″, 1.5″ and 1″ which will be roughly on the great equatorial 96, 139 and 196 power – these will do for comet work'.[47] Six months later Lindsay, writing from Wigan in January 1873: 'in passing through Paris I went to see Eichens, the siderostat is in a forward state and I have since heard that both mirrors are complete. I saw Dallmeyer, but he is not ready yet with the 40-foot lens'.[48]

Airy's 1868 challenge undoubtedly influenced Gill's decision to move to Dun Echt. In collaborating with Lord Lindsay he would have seen the possibility for the wealthy Crawford family to mount an independent expedition to the southern hemisphere to complement the Government plans being organised by Airy.[49] Richard A. Proctor (1837-1888) had published a detailed map for the Indian Ocean and Gill would have quickly realized that the location of fellow-Scot Charles Meldrum (1821-1901), Director of the Royal Alfred Observatory in Mauritius, supported the choice of this site.[50] Proctor agreed in a letter to Gill in October 1872: 'Mauritius is at any rate a very important southern station, and may be one of the best if not the very best so far as observations actually made are concerned' calculating for the Transit of Venus 'I make the solar elevation about 14° at ingress and about 61° at egress'.[51]

Gill's approach at both this time and later in his career resembled that of a positional chess player. Rather than try to seek an exact combination of moves he would develop a strategy liable to bring success. This frequently involved personnel, choice of instrumentation and the power of personal persuasion. Despite the higher social status of Lord Lindsay Gill found it possible to suggest many ideas to his younger employer. However he would always maintain, with one notable exception, their respective roles. For example in October 1872 *Monthly Notices* Gill's influence clearly appears in their joint paper, 'On Lord Lindsay's Preparations for Observations of the Transit of Venus, 1874' in which their cooperation with other expeditions is highlighted:

> We believe Germany also intends to send an expedition to Mauritius, which will also probably be provided with the means of determining its geographical position, so that connecting the two stations by triangulation, a combination of the observations of both parties will give more quickly an accurate result [...] new heliometers, by Repsold of Hamburg, of greater power, viz., of 4 inches aperture, and 4½ to 5 feet focus. Messrs Repsold have undertaken to complete for Lord Lindsay an instrument almost precisely the same as the large Russian heliometers [...] the motions of the two halves of the objective take place in curved slides – slides which are portions of a cylinder whose axis passes through the focus of the object-glass. Thus whatever the separation of the two halves of the object-glass, the images remain constantly in the focus of the eye-piece.[52]

Gill's further discussion of the results clearly demonstrates how he had absorbed the suggestions of both German and Russian astronomers who keenly promoted the Repsold heliometer design. Gill and Lindsay's paper suggests the probable error of a single observation would not exceed half a second of arc and the uncertainty of the deduced solar parallax would be less than two-hundredths of a second.[53]

In contrast to the excitement at Dun Echt progress in Edinburgh at the Royal Observatory was stalling. Smyth had ordered a 24-inch equatorial reflector from Howard Grubb (1844-1931) and progress viewed during his summer visit to Dublin had appeared promising. As a precaution Smyth asked Gill to inspect the telescope during one of his autumn meetings with Grubb. Gill queried the ruggedness of the mounting and the limited size of the dome in Edinburgh.[54] By November 1872 Smyth explained how Government cutbacks were undermining his plans for photographic materials and a chronograph, adding: 'I am happy in thinking that Scotland will nevertheless through Lord Lindsay and you have a good Observatory, and whether for one variety of instrument or another I shall look up to Dun Echt for example, and shall wish you every success'.[55] By Christmas Day Smyth had become exasperated with Grubb and his workmen who had been working night and day to install the telescope: 'I tried the first motions of the instrument and found the polar axis jammed at one point, and could not be got past it, without filing away certain parts' adding 'the early days of erecting the instrument when you were present were pleasant ones'.[56] By February 1873 Smyth's list of complaints had grown further and included concerns over the quality of the silvered mirror, which Key would independently test two years later. Sadly the instrument was little ever used.

Returning to Dun Echt Observatory, the final list of equipment included: a 15-inch f/12 Grubb refractor with a Merz object glass prism, an 8-inch f/13 Troughton and Simms transit circle, a 6-inch f/12 Cooke refractor, a 4-inch f/15 Repsold heliometer, Gill's 12-inch f/10 reflector, an altazimuth with 12-

inch circles by Troughton and Simms, a Cooke chronograph with four barrels, a Zöllner photometer, a 16-inch Foucault siderostat for a 4-inch f/120 horizontal telescope, and a portable 4-inch transit mounted for both meridian and prime vertical work.[57] Gill's work included oversight of the construction of observatories and domes and the testing of all equipment. His dreams were becoming a reality.

Contact with Mauritius had now been established with Meldrum writing in May 1873: 'I was delighted to learn that Lord Lindsay proposes coming to Mauritius to observe the Transit of Venus' continuing 'I send per post a map of the Colony. I believe the N.E. part of the Island will be best for observation'.[58] Meldrum's work chiefly focused on meteorology and magnetism and he subsequently forwarded twenty years of weather data to Gill suggesting the prospects for clear or cloudy skies were roughly equal.

Initial plans for the Transit of Venus

Global excitement was now building as the first Transit of Venus in over one hundred years approached. This inspired both Lindsay and Gill to maximize their links internationally. Pulkovo Observatory was the leading institution in the world so an invitation from its Director Otto Wilhelm von Struve (1819-1905) in February 1873 to attend the meeting of the Astronomische Gesellschaft - established in 1863 and the second oldest astronomical society after the RAS - at Hamburg and the meeting of the German

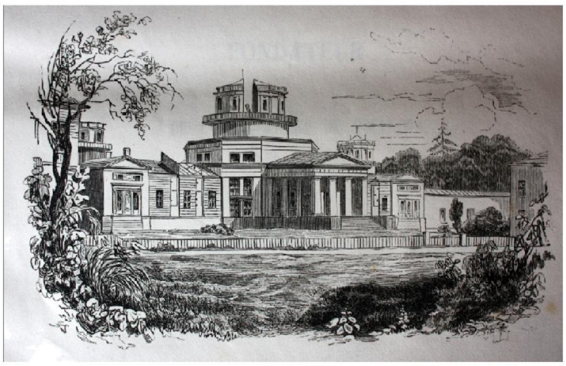

Fig.7 Pulkovo Observatory c.1840.
Struve F. G. Wilhelm, *Description de l'Observatoire Astronomique Central de Pulkowa*, (1845) frontspiece.
Courtesy of the Institute of Astronomy, University of Cambridge.

Committee for the Transit of Venus at Hanover was priceless.[59] It enabled Gill to design his first European tour of observatories. In a letter to his brother Jamie, Gill described his August steamer journey from Leith via Hamburg to Copenhagen where he: 'visited the Observatory, Prof. D'Arrest and Schjellerup'. Gill continued by steamer via Stockholm onto St Petersburg finding: 'two astronomers and a carriage waiting me, to drive me out to Pulkowa, thirteen miles off, where I arrived at 11p.m'. Gill's week at Pulkovo as the guest of Struve proved a significant impact on his life; he later would model many aspects of his work at the Cape of Good Hope on the Russian model. After recovering from a short illness he travelled by train via Berlin to Hamburg with Struve who kindly facilitated introductions to his extensive network of friends and astronomers. Lindsay joined him in Germany and Gill's tour finished in Aberdeen via Paris.[60]

The Hamburg meeting was chaired by Frederick W.A. Argelander (1799-1875) and Otto Struve, with Arthur von Auwers (1838-1915), Friedrich Winnecke (1835-1897), Johann Adolf Repsold (1838-1919); John Couch Adams (1819-1892), Huggins, George Forbes (1849-1936) from the UK and Newcomb from the US, all in attendance. Whilst there Gill and Forbes took the opportunity of inspecting Repsold's works and the heliometer ordered by Lord Lindsay.[61] Twenty years later Gill reminded Newcomb:

> Do you remember our Congress of 1873 – at Hamburg and Hanover? There I first met you, my good friend, and Auwers and Winnecke and a host of others who have been dear to me ever since. The stimulus which that meeting gave me goes on still. What did I not learn in that short time? What friendships, useful and dear to me ever since.[62]

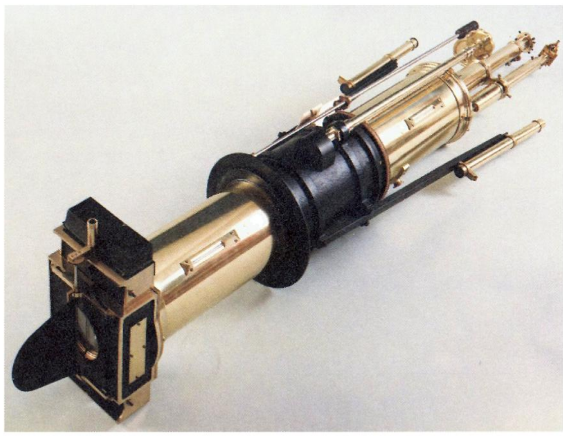

Fig.8 The Repsold heliometer used by David Gill at Dun Echt, Mauritius, Ascension and the Cape of Good Hope for measuring angular distances accurately up to 2º.
Courtesy of the Royal Observatory Edinburgh

The impact of this European tour on Gill was immediate and far-reaching. He would subsequently devote many thousands of hours letter writing to cultivate such friendships. By beginning with European networks he had climbed the first rung on his global astronomical ladder. Writing from Here-ford, Key remarked: 'I envy you your visit to the great Observatory of the Struves' adding 'your time now is employed in what you must consider the most delightful manner'.[63] A month later, after Key had spotted the Dun Echt transit circle at the Simms's factory in Charlton, London he congratulated Gill: 'you want to produce results superior even to those of Greenwich, you are going in for perfection in the most delicate astronomical observations'.[64]

Gill was by now applying his horological skills to astronomical instruments. In March 1872 he had proposed a chronometric method for reducing the uncertainty caused by temperature variation.[65] In the October 1872 joint paper with Lindsay he described for Mauritius: 'the clock is a very excellent one by the late Charles Frodsham, with dead-beat escapement and mercurial pendulum, and is fitted with the necessary connections for registering its beats on the chronograph boards'. He continued to explain the four barrels of the Cooke chronograph: 'these barrels are 2 feet long and 1 foot in diameter. In the Observatory each barrel revolves once a minute and contains records for two hours'. In this way Gill made provision for each instrument to have its own barrel.[66] The intricacy of Gill's work is similarly evidenced by the driving clock design for the 15-inch equatorial at Dun Echt in which he incorporated electrical control from the standard clock of the Observatory: 'control so perfect that no variation whatever can be perceived on the second hand of the driving clock from that of the standard clock, during any number of hours, and no sensible oscillation of a star relative to the micrometer web under high powers'.[67]

At this stage Gill and Lindsay expected the greatest success for the Transit of Venus would be achieved by either the photographic or heliometric methods. The former would rely on: 'Winlock's method of using a telescope of about 40 feet focus; the Sun's rays being reflected into it horizontally' and Lindsay had been very impressed 'when visiting the Imperial Observatory at Paris, he saw the Great Siderostat of Foucault'.[68] The heliometer although unpopular in the UK, with the exception of the Oxford 7-inch instrument, was endorsed by leading Russian and German astronomers. F. G. Wilhelm Struve had an immense influence on Gill's work as an astronomer and geodesist. At the end of his life Gill records: 'the book to which I turned, and found to be the most suggestive and useful in these circumstances was F.G.W. Struve's *Description de l'Observatoire Astronomique Central de Pulkowa*; and no one, even in the present day, who may be charged with the design and erection of a great Observatory, can afford to neglect this work. There is inspiration to be found in nearly every page of it, for its author had the true genius and spirit of the practical astronomer'.[69]

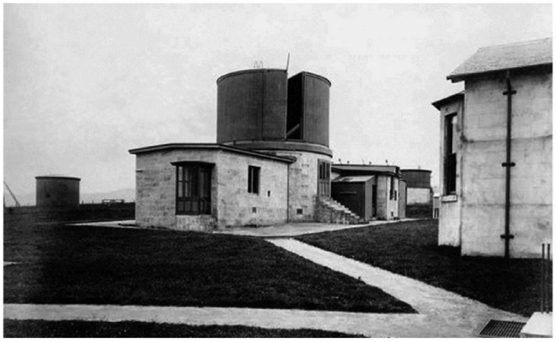

Fig.9 Dun Echt Observatory, c.1875.
Courtesy of the Royal Observatory Edinburgh

Following the return of Gill from his continental tour Dun Echt became a hive of activity. The Observatory Report for 1873 included:

> …in September Mr Grubb arrived with the object glass and some of the smaller fittings of the Great Equatoreal; these were duly put up and adjusted. The object-glass appears to be a very excellent one. In October the Astronomer's house was completed, about the same time the heliometer arrived from Messrs. Repsold. It has since been constantly employed in a determination of the division errors of its scale, the thermal coefficient, the absolute value of the scale, the change of focal length of object-glass by temperature and the position of the focal point.[70]

Gill measured the distances and position angle of the brighter stars in the Pleiades from *η Tauri* in order to compare with Bessel's observations of the same objects. In conjunction with his new German colleague Auwers he also measured fifteen zone stars in Perseus simultaneously with German observers to calibrate the heliometer scale. December saw the erection of the transit circle with James Simms (1828-1915). Its similarity with the Cambridge instrument enabled Gill to compare its errors with those reported by Adams by studying the flexure of the tube at every altitude. The 4-inch f/40 objective arrived from Dallmeyer and a 13-inch Cassegrain reflector from Grubb was also delivered. Following the erection of the transit circle: 'a six-pounder cannon charged with 2lbs of gunpowder has been fired daily as a time-signal, and has been found to be a great boon to the district for many miles round, as previously no standard of time existed'.[71]

At the end of February 1874 Gill reported to Lindsay the outcome of a major gale:

about 1.30 with a fearful gust it veered more to the East, caught the Siderostat house on the side, threw it over and smashed it to pieces carrying with it Siderostat, 40-ft. O.G. stand and all. The same gust, getting under the floor of my old observatory, forced open the door, lifted off the roof, and threw it smashed in pieces fifty yards off.

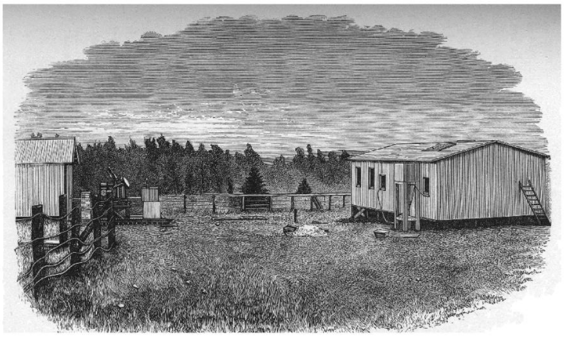

Fig.10 Engraving of the Siderostat at Dun Echt Observatory.
Lockyer, J. Norman, *Stargazing: past and present,* (London, Macmillan, 1878), Fig. 157.
Courtesy of The Share Initiative.

Gill explained his relief on finding the damage was not too great and dispatched the dented 40-ft lens cell to Dallmeyer in London. The gale continued with Gill adding: 'it was just touch and go with the big dome. I don't think I ever spent such an anxious day'.[72] Dallmeyer duly repaired the lens cell, but subsequent testing revealed a problem in April with the curvature of the crown-glass; fortunately a successful replacement was secured by the end of May.

Final plans for Mauritius

Despite continual pressure over ordering and testing equipment Gill's admiration of the accuracy of the Repsold instrument gave him cause to plan for an alternative method for measuring the solar parallax at Mauritius, by measuring the position of the minor planet Juno either side of opposition. Writing to Auwers in March: 'the heliometer observations come out so beautifully that I almost think a good determination of the parallax of Juno might be made from the parallactic displacement due to the Earth's rotation'.[73] Gill was using an idea suggested by Airy in 1857 for measuring the diurnal parallax of a planet, which had the advantage that a single observer at one site could take all the measurements. Applying the method using a wire micrometer to a minor planet near opposition had been attempted for Flora by the discoverer of the planet Neptune, Johann G. Galle (1812-1910) in October 1873. Gill selected Juno because its opposition would be one month before the Transit of Venus, on 5 November and: 'by the extreme precision with which a minute point of light can be bisected as compared with that with which a web can be brought into contact with a disk'.[74]

A joint paper by Lindsay and Gill explaining the new proposal duly appeared in the April *Monthly Notices* in which Gill explained in great depth the Juno method. Measurement with the heliometer during its rising at altitudes of 20º to 40º and setting at altitudes of 40º to 20º were calculated to give a displacement of 14″ with 86 minutes at rising & setting to make the necessary observations. Gill envis-

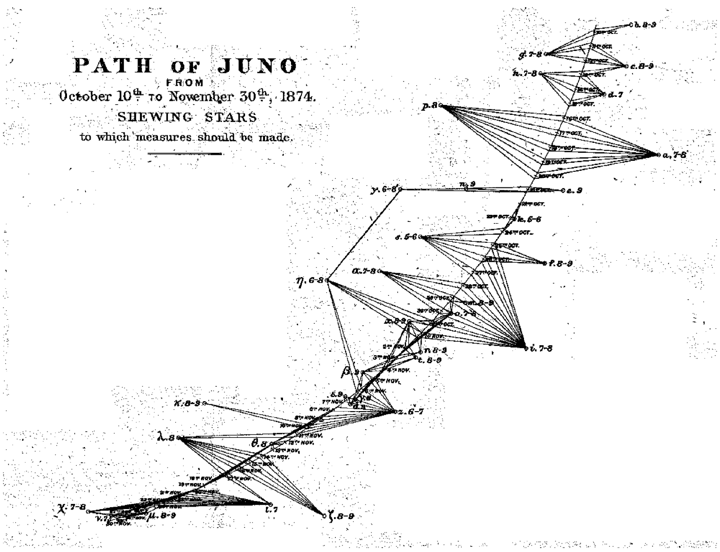

Fig.11 Diagram of the path of Juno at opposition in 1874 – used to locate comparison stars for determining parallax.
Gill, David; Lindsay, Lord, *MNRAS,* 34, 6 (1874), plate facing p. 279.

aged these would be taken a month before and a month after opposition giving up to fifty nights observations. One challenge was the selection of nearby comparison stars. Gill explained how design improvements by Struve, Auwers and Winnecke had been incorporated by Repsold: 'both halves of the divided object-glass are moved in equal and opposite directions by a single movement, and thus the extent of angle which can be measured is doubled, and the instrument can measure completely an angle of 2°'.[75] A chart prepared from the Berlin Equatorial Star Charts for 2h to 3h details *The Path of Juno* and shows the comparison stars chosen. At this stage another astronomer was being recruited by Lindsay. Writing from Parsonstown, Ralph Copeland (1837-1905): 'I have looked out the Berlin and Bonn images and catalogues from which I can select the Juno stars'.[76] Copeland would travel with Lindsay to Mauritius aboard a Three-Masted Schooner of 398 tons.[77] Lindsay named his yacht 'Venus' but unfortunately his late arrival with the heliometer limited Gill's observations to only fifteen nights and the Juno opposition date was missed.

To determine the longitude of Mauritius Gill and Lindsay had opted for an ambitious plan. An advertisement in *Nature* invited the collection, loan, hire or purchase of fifty chronometers which would be used between Aden and Mauritius for a differential longitude determination. Greenwich and Aden were already connected by telegraph so it was decided that Gill should take the chronometers and the portable altazimuth through the Suez Canal whilst Lindsay, Copeland, Davis and a crew of 22 men would transfer the bulk of the equipment by sea voyage around the Cape of Good Hope. As Forbes described, '[Gill] was able to witness the transport of his portable astronomical village by steam traction engine into Aberdeen for shipment'.[78]

Lindsay and Gill had clearly defined roles for the Mauritius expedition. Lindsay was effectively the producer and Gill the director of operations. However the vast majority of the workload fell to Gill as evidenced by the *Dun Echt Observatory Publications* for which *Volume 2* published in 1877 includes description of the heliometer and Juno opposition method. *Volume 3* published in 1885 covers the determination of longitude and latitude during the expedition. In practice whilst Gill spent five months at Mauritius and further time on longitude operations Lindsay was there for only three months and was ill for a good part of this period. Copeland was also poorly at a critical moment so Gill was effectively managing most of the activities. This included developing valuable contacts with both Admiralty personnel and the German and Dutch expeditions at nearby stations.

Gill's work at Mauritius

Gill had completed a thorough study of the heliometer at Dun Echt. This included investigation of the errors of division of the instrument scales and errors of the screw used to separate the two halves of the object glass.[79] After overseeing the instruments departure, he then left on 14 June to collect fifty chronometers from Liverpool Observatory where their temperature coefficients had been determined by Hartnup. Continuing by train to the Royal Observatory at Greenwich, Gill reached Southampton a few days later. The chronometers were carried in six large padded boxes lined with silk, each capable of carrying nine instruments.[80] At Southampton Docks they were mounted in gimbals in a cabin of the 'Mirzapore' steamer, of the Peninsular and Oriental line, which sailed on 19 June via Malta, Alexandria, and Suez reaching Aden on 15 July. Gill completed time and latitude determinations at Suez and Aden, including a telegraphic link with Auwers in Berlin. The chronometers were transferred to the 'Godavery' steamer, of the Messageries Maritimes, which sailed on 20 July arriving at Port Louis, Mauritius on 3 August where Gill was met by Meldrum, Director of the Royal Alfred Observatory at Pamplemousses.[81]

Meldrum had proposed a site at Belmont which linked Port Louis and Pamplemousses by railway with Poudre d'Or. A field telegraph was used to complete the telegraphic link to Belmont and chronometers were exchanged and transits measured at each site to determine longitude differences. At one stage this involved night firing of rockets from a point midway between Pamplemousses and Belmont with simultaneous observations of the explosions from both sites. Further links were repeated in December to connect with the German team consisting of Hungarian astronomer Moritz Löw (1841-1900) and Danish astronomer Carl F. Pechüle (1843-1914) at their Solitude site.[82] Links were also made with the British expedition led by Lieutenant Charles B. Neate (1847-1916) on the island of Rodriguez, 350 miles east of Mauritius. During September Commander William J. L. Wharton (1843-1905) completed double runs with 'HMS Shearwater' carrying over forty chronometers to facilitate the Rodriguez link.[83] Gill and Wharton developed a close bond through this collaboration which would last until the death of his colleague at the British Association meeting in South Africa more than thirty years later.

The Belmont estate belonged to the De Chazal family and was in the district of Poudre d'Or, in the north-east part of the island, about sixteen miles from Port Louis. Here Gill oversaw the levelling of the observatory site and erection of concrete pillars for collimation lenses. In September the Dun Echt joiner Thomas Kirkwood arrived with the wooden houses and domes which were soon erected ready for the arrival of Lord Lindsay.[84] Unfortunately despite sailing from England on 9 July he did not reach Port Louis until 2 November. He was accompanied by astronomer Ralph Copeland, photographer Henry Davis and surgeon George Blackley.

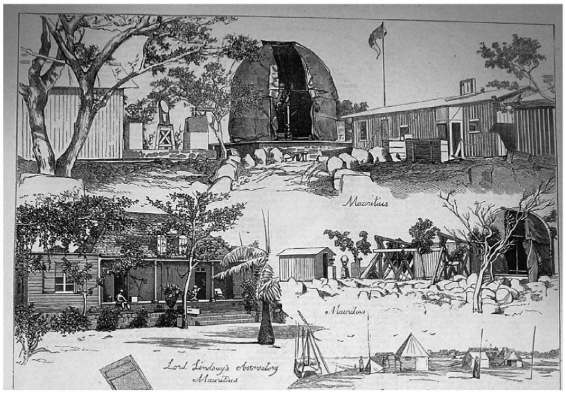

Fig.12 Engraving of the Belmont site at Mauritius.
London Illustrated News, 12 December 1874.
Courtesy of The Share Initiative.

Observations of Juno at Mauritius were planned from 10 October but the late arrival of Lord Lindsay' yacht 'Venus' prevented unpacking the heliometer at Belmont until the Juno opposition date of 5 November. Reliable measurements were only possible a week later after cloudy weather passed. Measurements continued to the end of the month.[85] Zone stars in Perseus and Hydra together with detailed temperature and barometric pressure, zenith distance and mean refraction calculations, measures of brighter stars for the zero of position circle (Auwers and Winnecke method) continued through to Christmas. At this stage the longitude and latitude determinations took precedence together with: 'preparations for the chronometer expedition homewards'. Meridian observations of Juno from Greenwich, Washington and Cambridge, U.S. were also investigated to check for consistent tables for Juno.[86] The final solar parallax determined by all of this work gave a result of 8.77 +/- 0.041 arc seconds which Gill and Lindsay judged a relatively poor value due to insufficient results. They emphasized instead: 'we have at least now sound data upon which to found calculation as to the value of the opposition of any minor planet for the future determination of the solar parallax'.[87]

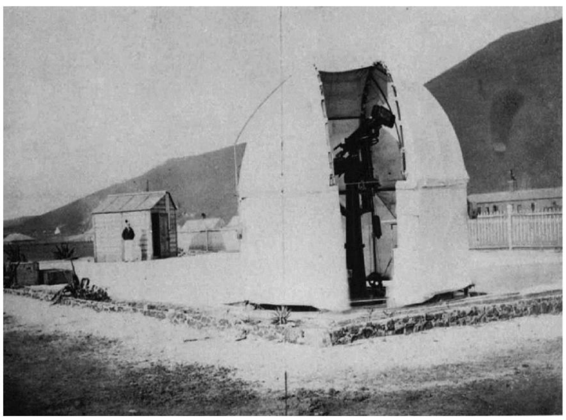

Fig.13 Heliometer at Belmont in 1874.
Courtesy of the Royal Observatory Edinburgh.

Lindsay judged his expedition: 'in a great measure successful'. Unfortunately clouds masked the beginning of the Transit of Venus. The photographic methods employed promised some success despite: 'temperature varying from 96º to 116º [F]' with over one hundred considered 'of value'. Gill observed the last internal contact with a 4-inch equatorial using a Merz polarising eyepiece and the last external contact with the Repsold heliometer. Copeland and Gill agreed: 'that any phenomena which could be classed under the head "Black Drop" took place and disappeared within a period of five seconds'.[88]

Chronometric expedition for longitudes

Gill sailed from Mauritius in the Messageries steamer 'Dupleix' on 9 January. He was accompanied by members of the German Transit of Venus expedition and they reached overnight Réunion after a voyage of 120 miles south-west. Here they met with Jean A. C. Oudemans (1827-1906) and other members of the Dutch team. Comparison of chronometers enabled the longitude of Réunion to be determined.[89] Four days later the 'Dupleix' reached Mahé, Seychelles where, due to an outbreak of measles at Réunion, she was put in quarantine. Fortunately the HMS 'Shearwater' was also at the Seychelles and Commander Wharton facilitated an exchange of two chronometers: 'formally disinfected with vinegar, were placed in a boat and dropped astern, where they were received by Wharton, taken on board the 'Shearwater', and compared'.[90] Combined with sextant results of the sun taken by Wharton's officers Gill was able to determine the longitude of Mahé. A week later the 'Dupleix' reached Aden. Löw continued onto Suez enabling Gill to exchange telegraphic signals of time between Aden and Suez. Gill had met Charles Chambers (1834-1896), director of the Colaba Observatory, Bombay on his outward journey on the 'Mirzapore' and planned an Aden and Bombay exchange of signals to enable the longitude of this observatory to be deduced. During February Gill and Löw continued the telegraphic exchange from Alexandria and Suez respectively. Gill also exchanged signals with Auwers in Berlin. In March Löw had moved on to Malta and the chronometric expedition was completed with links between Alexandria, Berlin and Malta.[91] By completing these observations, connecting Europe with islands in the Indian Ocean, Gill had now climbed the second rung on his global astronomical ladder.

Geodesy in Egypt

The Mauritius trip had proved very challenging for the 'Venus' party. They had taken nearly four months to reach their destination and subsequently illness overtook them. In May 1875 Meldrum wrote to Gill about Lord Lindsay's illness and the also the rest of the group: 'I hope poor Davis got home alive and that he and Copeland and the Doctor are well – George [Blackley] looked like death when he left'.[92] Meldrum's next letter to Gill in February 1876 included: 'I was very sorry to hear of the death of George. The Manager of the Mauritius Docks behaved very badly by detaining the 'Venus' for several days at the head of the Harbour in a most unhealthy spot'.[93] However Gill seems to have avoided major illness and was joined at Alexandria by his wife. His expertise had been realized by Ismail Pasha (1830-1879), the Khedive of Egypt. In a letter to Lady Crawford (1824-1909) from Aden in January 1875 Gill explained:

> In passing through Egypt I happened to meet one of the surveyors of Egypt – he told me of the commencement of a Survey of the Country. I enquired about the plan of operations, and suggested a great many amendments. I also told them of Lord Lindsay's base apparatus and the consequence was first a private letter asking if I would undertake to measure a base line in Egypt – I asked Lord Lindsay's consent and he has kindly given it and the use of his apparatus also.[94]

Gill also continued to correspond with astronomers he had met in Europe. For example a letter to Newcomb in February 1875 included: '[Grubb] tells me that you have been making the round of the European optical workshops in quest of a maker for the great telescope of the new Californian observatory'. Gill gives his experience of the different instrument makers he has encountered, praising Repsold for: 'a carefully constructed divided instrument', Troughton and Simms for 'the best micrometer screws, microscopes and divided circles', and Cooke's of York for 'a small equatorial'. For Grubb himself Gill praised his workmanship, internal resources, energy and skill as being 'un-approached'. In the same letter Gill summarised the Transit of Venus outcomes: 'we lost first contact at Mauritius but got a very fine lot of photographs, some good heliometer measures and some double image measures of Venus' diameter. In November I got a fine set of determinations of the diurnal parallax of Juno which I believe will give a very accurate result of the solar parallax'. Gill concluded: 'I am here for some time to measure a base line and commence the triangulation of Egypt for the Khedive – a determination of an Arc of Meridian'.[95]

The Gills were provided by the Khedive with accommodation at the Pyramids. Here Gill renewed his acquaintance with Wilhelm Döllen (1820-1897) whom he had met at Pulkovo two years earlier. Gill informed Lindsay in May:

> I have measured a very, very accurate kilometre, established the latitude and longitude of the Great Pyramid, and measured the sides and height of the Great Pyramid to +/- one millimetre, and their exact azimuths by a triangulation. Döllen and I began a determination of the deviation of the plumb line by the Great Pyramid, but poor Döllen was seized with a return of haemorrhage of the lung and compelled to go. Professor Watson of Ann Arbour has been here for the last fortnight and has helped me very much.[96]

James C. Watson (1838-1880) was Observatory Director at Michigan and Wisconsin and had with his wife successfully observed the Transit of Venus from China. On his return journey he kindly agreed to help Gill complete his work.

The Pyramids survey led to Gill being provisionally offered by the Khedive the larger projects of surveying the whole of Egypt and establishing a new Observatory. Lindsay, who was recovering in Florence, advised Gill on the offers of the Egyptian Government by letter in March: 'I cannot tell you how strongly I advise you to go back on the first proposition, viz. to take the post of Chief of the Survey and to withdraw your refusal' adding 'the Khedive would found as perfect an Observatory as you could desire in such a Latitude and with such a sky' and 'if you accept this post you will gain a position which you could not possibly attain with me'. Lindsay concluded with a reminder to Gill: 'you have already had in your life one great decision to make, that of leaving Commerce to devote yourself to Science' and 'there now arises another crisis, which without doubt is the turning point of your life'.[97] Gill replied to Lindsay in April in an undecided frame of mind:

> When I wrote you for two months leave a year to direct this Survey I thought only of being able to advance Science in the same way that Struve divided both the Observatory at Pulkowa and the Survey of Russia. I admit there is much in what you say on the supposition that the Khedive would furnish at the same time a properly equipped observatory – but there is at present an Observatory and an Astronomer and I do not know if any improvement on existing matters in that way is intended. I must also confess to a very, very strong feeling towards Dun Echt, for I seem to have built myself into its piers and instruments, and though I am not necessarily permanently there yet, I had hoped and still believe that our relations were such that for some years at least I should work there and realise some of the results for which I had worked and thought so much. On the other hand I feel the force of much you say and you must forgive me if between the two positions I feel much difficulty in deciding. You must not think I have been dissatisfied with my position at Echt – very much the reverse. The Laboratory with all its new means of research is another inducement to remain.[98]

However the provisional offer was withdrawn once the incumbent heads of Geodesy and Astronomy in Egypt heard of the Khedive's plans and Gill was able to admit in May: 'almost the feeling of thankfulness that I am not called upon to do it and can return to the work at Dun Echt'.[99]

Dun Echt dismissal

Fig.14 Astronomer's house at Dun Echt, c.1875. Courtesy of the Royal Observatory Edinburgh.

However on the Gill's return to the Astronomer's house at Dun Echt their plans were upset by a letter from Lady Crawford in June 1875:

> …on returning home I hear from Lord Lindsay that Mr Carpenter and his family at Dun Echt is quite unable to manage in his very restricted quarters, which I can quite understand, poor man having but one room and a little closet' adding 'the only remedy I can find is to give him the room over the sitting room. He now has downstairs and this makes him as it were have that wing of the [Astronomer's] house. I do not think that you will feel any inconvenience from its loss'.[100]

Henry J. Carpenter (1849-1899) had been recruited by Lindsay as an assistant to Gill to manage Dun Echt Observatory during his absence. He was an experienced computer having formerly worked at the Royal Observatory Greenwich.[101] Gill's protests were in vain with Margaret Crawford writing explicitly in July:

> …you will forgive me when I remind you of the manner in which the relations between yourself and Lord Lindsay, or I should say us as regards this particular subject – Dun Echt – commenced. You were then in a far more humble position, your wishes and expectations were moderate and much more limited. When Lord Crawford agreed to build a house for your accommodation there was certainly no contemplation on his part to build one of such a character or pretension as the one you now have [...] you have friends coming to you whose carriage and horses you direct to our stables and the whole position seems to me now changed from what I originally calculated upon.[102]

Amongst Gill's visitors had been the Australian astronomer Henry C. Russell (1836-1907), Director of Sydney Observatory, who wrote to Gill in July after enjoying the Scottish loch scenery: 'at Oxford I saw both the old and new observatories' and 'do not forget the eclipse of 1876 – I want to see you in our young country'.[103] In September Gill also received a letter from Watson who mentioned: 'I saw Struve in Paris and he told me he had visited you at Dun Echt'. As Gill's biographer Forbes recounted: 'Gill was no longer the young amateur hoping for some opportunity to leave a commercial career for astronomy. He had already become an astronomical observer and organizer, with a scientific reputation, living in close intimacy and continuous correspondence with many of the greatest living astronomers'.[104]

Having so recently returned from the greatest adventure of his life Gill proved a willing respondent to an invitation by the Aberdeen Philosophical Society to give a talk on his work. The first part of his paper was delivered at the beginning of November 1875. It provoked an immediate rebuke from Lindsay:

> I learnt yesterday in Aberdeen with very great surprise, that you had been reading a paper on Tuesday evening on the subject of my expedition to observe the Transit of Venus at Mauritius, and that you have announced a second lecture on the same subject. That this should have been done without obtaining my permission previously is sufficiently startling to me, but that you should have done it against my express disapprobation and virtual prohibition, when you mentioned the idea to me some time ago, and indicated your acquiescence, demonstrates such a total and confirmed misunderstanding of the relations between us, that I have no recourse, either in self-respect or self-protection than to announce the approaching termination of our connection [...] I have therefore instructed Mr Yeats to communicate to you the formal six months notice in termination of our engagement.

Lindsay concluded Gill's redundancy letter with: 'I shall have the greatest pleasure in testifying to your abilities and good services not only in my present work, but in reply to any enquiries' and 'we part, as I trust, friends, and you will have my best wishes for what I am sure will await you, a useful and honourable career in the future'.[105]

Gill replied admitting partial responsibility:

> I confess on mature deliberation that it would have been better had I mentioned that I was about to read this paper and would now express any great regret that I did not do so, but that I knowingly and deliberately did so 'against your expressed disapprobation or virtual prohibition' I cannot admit [...] I do remember when I was asked at Mauritius to give a public lecture on the Transit you said 'I don't think you should do that, you should not go doing Lockyer all [over] the place' but with regard to a paper at the Aberdeen Philosophical Society, or on any occasion and whatever except that I have mentioned I have no recollection of the subject ever having been mooted. I cannot help thinking also that you have entirely misconceived the nature of the paper and the constitution and rules of the Society to which it was communicated. The Society is entirely of a private character, many of the communications being portions of books or articles to be afterwards published in some other form, all the communications being strictly private and not the property of the Society, but of the Member. The paper itself was only a personal narrative accompanied by such an exposition of principles as would enable the narrative to be intelligible to the Society, but it contained no breach of scientific trust such as your letter implies, no reference whatever to the scientific results of the expedition, nor anything which so far as I know could prejudice any future publication and I trust when you have read the paper which I send with this, you will exonerate me from any such imputation.

Gill admitted: 'an error of judgement on my part has laid me open to such misconceptions' but 'I cannot allow you to think me capable of doing anything deliberately unjust behind your back.[106]

Lindsay stuck to his decision:

> …now our great and important work in connection with the Transit of Venus has been successfully carried through, and that the reduction of the observations is in a fair way towards completion, that we should both of us work to more advantage and more satisfactorily apart. You have different ideas on various points from myself and the relation in which we stand to each other might, in many ways, prove onerous to us in the future. Besides which, I should wish to make some changes in the organisation of the Observatory, which you might not feel to be quite agreeable to yourself [...] I look forward to your being in some future day, one of the masters in the noble science of Astronomy. I must of course regret to have been forced to this conclusion, but I feel persuaded that, in the interests of both, it is better that we should part.[107]

Gill responded: 'I fully understand and under the circumstances quite agree in the decision you have arrived at. I have also to thank you for the expressions of and feeling contained in your letter and desire fully to reciprocate your wish to part in a perfectly friendly manner'.[108]

The acceptance of his fate surprised some of his friends. John F. White (1831-1904) the famous Aberdeen merchant, pioneer photographer and arts patron wrote in early December:

> …with what infinite sorrow I heard yesterday of your wrongs – I could not have believed that you and your dear wife could have been subjected by any family of standing to such barbarous treatment. That 'the great Lindsays' could have acted so makes me doubly sorry for their sakes, as I had looked on them, in my ignorance, as the flower of chivalry [...] how you have shed it so quickly with your impulsive manner puzzles me. It is only your devotion to your work that could have made you put up with it.[109]

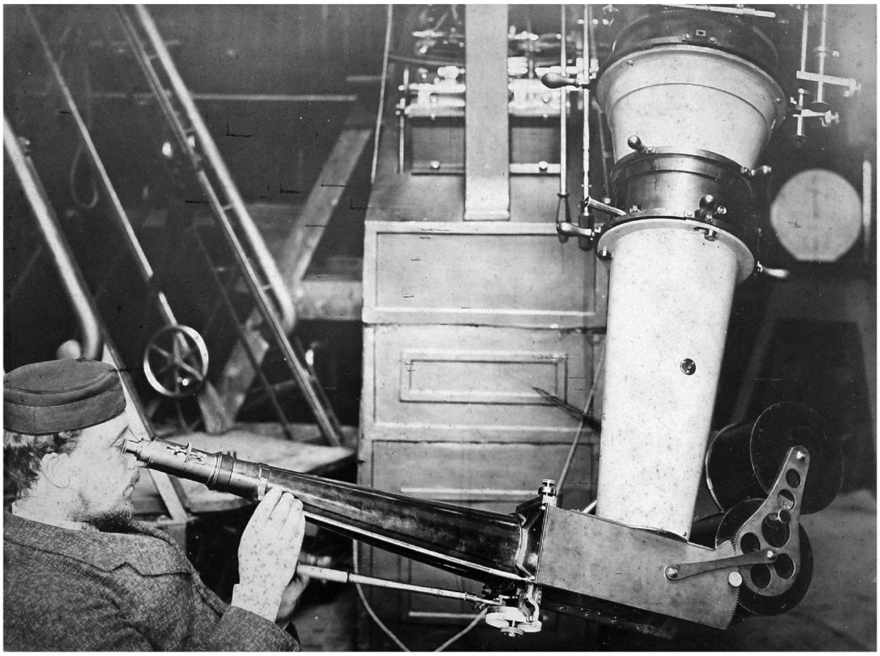

Fig.15 David Gill at the spectroscope of the 15-inch refractor at Dun Echt, c.1875.
Courtesy of the South African Astronomical Observatory.

Across Europe astronomers were similarly surprised by the news. Auwers in Berlin commiserated in early January: 'I could not read your letter of 14 December without deep regret, that you feel yourself obliged to leave Dun Echt and its beautiful collection of instruments, with which I hoped you would render a long series of good services to Science'.[110] Fortunately Gill and Lindsay's friendship survived this difficult episode which temporarily halted Gill's ascendancy in the astronomical world. Indeed Lindsay would subsequently play a significant role three years later in supporting Gill's application to the Royal Observatory at the Cape of Good Hope in 1879.

Conclusion

In this paper the first third of Gill's career has been examined using a chronological approach to evidence some of the important foundations that influenced his future direction in both astronomy and geodesy. The concept of a 'global astronomical ladder' has been introduced. Within two years of his departure from Dun Echt he had successfully observed (with Bella) the opposition of Mars from Ascension Island with his beloved heliometer and calculated a significantly improved value for the solar parallax. Soon after he embarked on a 28-year career as H.M. Astronomer at the Royal Observatory, Cape of Good Hope during which time he developed facilities modelled on the pioneering work of Wilhelm Struve at Pulkovo. At the same time he undertook leadership of a major Geodetic Survey of Southern Africa as a vital contribution towards linking a southern Arc of Meridian with Struve's work in the northern hemisphere. Gill's liaison with Jacobus C. Kapteyn (1851-1922) for the *Cape Photographic Durchmusterung* extended naturally to his involvement in the Astrographic Chart and Catalogue, popularly known as the *Carte du Ciel* project. Finally, during his 'retirement' Gill continued to work from London as a consultant for many of the leading astronomers in the world, including George E. Hale (1868-1938) with the design of the 100-inch Hooker Telescope at Mount Wilson in California.

Throughout his life David Gill maintained a vast global network of friends and colleagues. A biography of his life by Alex W. Roberts (1857-1938), the Scottish variable star observer of Lovedale, South Africa, provides further insights into Gill's character:

> Outstanding among his peers in science, a worker whose energy was boundless, whose industry was untiring, a thinker whose thoughts and visions outran the advancing march of astronomical progress, he yet found time for, and delight in, the discharge of a multitude of tender charities of hearth and home and friendship.[111]

With his centenary year in 2014 it is perhaps timely to re-examine the contributions to astronomy and geodesy that David Gill delivered on a global scale. This paper is an initial contribution towards a better appreciation of a man often called a 'real astronomer'.[112]

Acknowledgements

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The Author

Paul Haley was born in 1956 and became interested in astronomy at the age of 9 after a visit to the London Planetarium. His first article, on the Crab Nebula, was published in the Junior Astronomical Society journal *Hermes* five years later. Following twenty years teaching in secondary education and advisory work he started two family businesses in Herefordshire – The Share Initiative (www.tsieuropean.co.uk) and Space Today UK – both of which have coordinated astronomical heritage projects across Europe. Details of these regularly appear in the Society for the History of Astronomy *Bulletin*. In 2010 he began researching the life of Sir David Gill for a new biography, touring exhibition and DVD. This has involved transcribing more than one thousand letters held in the DOG archive at the Royal Geographical Society, together with other archives in the UK and the Netherlands. Future work on astronomical heritage will include the design and production of stained glass panels to commemorate different aspects of the History of Astronomy.