The Antiquarian Astronomer

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Margaret Bryan (c.1759–1836)

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An early eclipse cruise

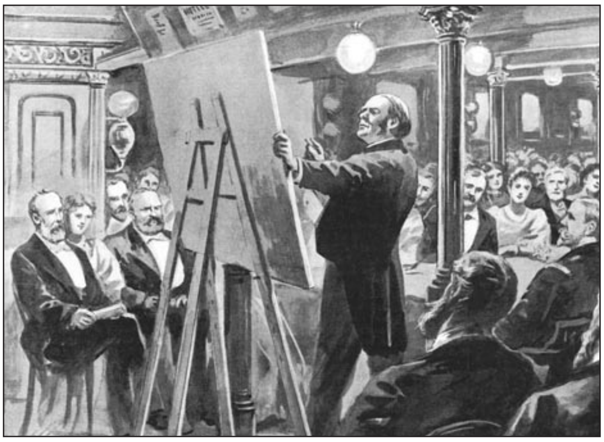
These days cruises to see celestial events such as total solar eclipses and the northern lights are common, but they were a novelty in 1896 when a party of 165 eclipse chasers set sail from Tilbury docks on the steam ship *Norse King* to Vadsø in north-eastern Norway to view the total solar eclipse of 1896 August 9.

Aboard the *Norse King* were astronomers of the Joint Permanent Eclipse Committee of the Royal Astronomical Society and Royal Society, along with 58 members and guests of the British Astronomical Association including its president, E. W. Maunder.* Arrangements for the expedition were made by the London travel agent Henry Gaze and Sons who advertised the *Norse King* as a ‘splendid pleasure yacht’.

Among the Eclipse Committee’s members was Sir Robert Ball, Lowndean Professor of Astronomy and Geometry at Cambridge, who gave a series of lectures on board in what must be the first example of astronomical cruise ship lecturing. In the lively illustration shown here Ball bears a remarkable resemblance to our own Allan Chapman.

After an eight-day voyage the *Norse King* anchored off Vadsø in the Varanger fjord and the observers spent the next few days setting up their equipment on shore. The track of totality crossed northern Scandinavia before moving across Russia to Japan. Vadsø was on the centre line, with a duration of just over 1 minute 40 seconds, the longest possible without going to Russia. Over the following days the fjord filled with other ships bringing more hopeful spectators.

However, the eclipse chasers were to be disappointed. ‘A drenching of rain in the early morning of the day of the eclipse got us into the proper frame of mind to meet the disappointment we experienced some hours later,’ reported A. A. Common, the head of the Eclipse Committee. Apart from some weather observations and some timings of the length of darkness – ‘the only night we had experienced during that Arctic summer’, as Ball later wrote – clouds hid the Sun during totality.



Sir Robert Ball lecturing about the eclipse of 1896 August in the saloon of the Norse King, in a watercolour by Herbert Johnson published in The Graphic, an illustrated weekly newspaper. There is no key to identify members of the audience, but E. W. Maunder and A. A. Common are recognizable at left; the lady between them is presumably Annie Maunder. The original illustration is in the RAS archives. (Author’s collection)

Although little was seen of the eclipse, the voyage proved fruitful in other ways. It was the start of a romance between John Evershed and Mary Acworth Orr which led to their marriage in 1906. Mary later became director of the BAA’s Historical Section from its inception in 1930 until 1944. In another pairing, the pioneer astrophotographer Isaac Roberts met the American astronomer Dorothea Klumpke, who at that time was working at the Paris Observatory, and they married in 1901 despite a 32-year age gap (her 35th birthday was on the day of the eclipse). Roberts died three years later but Dorothea continued his photographic work.

As Simon Mitton notes in this issue, picture postcards can provide valuable historical information on past events. Should any emerge of this expedition they would be of great interest.

* The full list of BAA participants, as well as reports from the various observers, can be found in *Memoirs of the BAA*, 6 (1898), 32–3.

COVER: Watercolour portrait of Margaret Bryan and her daughters by Samuel Shelley. See ‘Margaret Bryan: Georgian crowdfunder and pioneer of women’s education’ on page 22. (Herschel Museum of Astronomy – Bath Preservation Trust)

From the Editor

William Rowan Hamilton was a highly distinguished Irish scientist: director of Dunsink Observatory, Andrews Professor of Astronomy at Trinity College Dublin, and Royal Astronomer of Ireland. Yet despite those impressive titles he is better known not as an astronomer but as one of the greatest mathematicians of his day. Hamilton discovered a new system of four-dimensional numbers he called 'quaternions' which still have widespread application, from space missions to video gaming. By contrast, Hamilton's abilities as an astronomer have been somewhat disparaged, as has his personal reputation which suffered because of rumours about his fondness for drink and an unhappy home life. However, as Miguel DeArce shows in this issue of *The Antiquarian Astronomer*, Hamilton was fully capable of the routine work of astronomers at the time, but the instruments available to him were antiquated, and he lacked the team of assistants that would have been necessary to compete with better-equipped observatories. As well as taking a clearer look at Hamilton's astronomical background, the paper provides an overdue reassessment of his personal reputation.

Margaret Bryan was a Georgian-era educator best known for her book *A Compendious System of Astronomy* first published in 1797. Its famous frontispiece of her and her two daughters was based on an original watercolour portrait that graces our cover. But apart from her books little was known about Margaret herself until our own Paul Haley published some preliminary research in the *SHA Bulletin* in autumn 2021. In this issue we publish new research by Nikki Lee who has uncovered what she terms 'the triumphs and tragedies' of Margaret's life. This included being widowed at a young age, authoring three textbooks, and setting up schools in Margate and Blackheath. Margaret Bryan emerges from the shadows as a talented, determined, and well-connected lady who helped establish a new attitude towards scientific education for young women.

This issue marks the end of a multi-year project by our most prolific contributor, Paul Haley. The second part of his paper on Mary Watson Whitney is the fifth and last in a series on women astronomers in the United States, the first of which appeared in 2017. During that time he has also published several articles in the *SHA Bulletin*. We warmly thank Paul for his many contributions to the SHA over the years. Paul claims he is now going into retirement, but we hope it will not be permanent. Also in this issue another regular contributor, Timothy Baker, explains how experiments that were undertaken in the London suburb of Clapham by Henry Cavendish and James Clerk Maxwell have affected our understanding of the wider Universe. We end with two shorter papers. Matthew McMahon and his colleagues explore the life of a lesser-known Irish astronomer, William John Roberts, while Simon Mitton looks at the historical information we can glean from old picture postcards, in this case a total solar eclipse in 1936.

Finally, after ten years in the editorial chair, I will be handing over to Peter Morris as from the next issue. He was editor of *Ambix*, the journal of the Society for the History of Alchemy and Chemistry, between 2001 and 2012. He is also the editor of the Kosmos series of astronomy books published by Reaktion. I wish him well. I will continue to be involved with *The Antiquarian Astronomer* as the Deputy Editor.

Ian Ridpath

Information about the Society for the History of Astronomy, including its aims and publications, can be found on page 108.

Sir William Rowan Hamilton (1805–65)
Royal Astronomer of Ireland

Miguel DeArce

William Rowan Hamilton, a mathematician who became Royal Astronomer of Ireland, was a man of mixed reputation. This paper reassesses his life and work. We first look at his family, his choice of women to whom he proposed marriage, and his alleged alcoholism. After considering the institution of Dunsink Observatory, where he was director, and his post as Andrews Professor of Astronomy at Trinity College Dublin, the paper focuses on why Hamilton applied for the position of Royal Astronomer of Ireland despite being not primarily an astronomer but a mathematician. Hamilton's astronomical work is compared to his output in related fields of science, the output of contemporary astronomers, and his later acceptance that he had lost interest in astronomy. Nonetheless, top astronomers of the day looked up to him for his ground-breaking work in optics and fundamental mechanics, for which he was aptly compared to Isaac Newton and Joseph-Louis Lagrange. His discovery of quaternions in 1843, which opened new vistas on algebra, overshadowed many of his astronomical achievements.

1. Biographies of Hamilton

Three biographies of William Rowan Hamilton (Figures 1 and 3) are the main sources of this discussion. The first, published in three volumes in the 1880s, was authored by the Irish clergyman Robert Perceval Graves (1810–93) who wrote at the request of Hamilton and his family and was given privileged access to the Hamilton papers by Trinity College Dublin (TCD).[1] Graves came from a distinguished family of TCD mathematicians who were colleagues and friends of Hamilton. The image of Hamilton conveyed by Graves is well-informed, full of admiration and praise, but it is also a frank portrait not ignoring his real or imagined character flaws.

The second biography, published in 1980, was by Thomas Leroy Hankins (b. 1933), an American historian of science who emphasized Hamilton's work on physics and mathematics, and underscored Hamilton's mixed character as Graves had reported.[2] Both biographies complement each other well, and both are critical of the way Hamilton's wife, Helen, managed their household, presenting her husband as a victim.

The third book-length study, published in 2017, is by the Dutch historian Anne van Weerden, who argued against what she saw as the unwarranted impression given by the two previous authors that Hamilton's wife was to blame for his domestic unhappiness.[3] Instead, van Weerden presents Helen as unafraid to stand against the prevailing attitude to married women, and also capable of standing up to her husband when he did not fulfil his side of their pre-nuptial promises.[4] Coming at a time when gender politics is playing an important role in revising history, van Weerden's book reinterprets our understanding of the Hamiltons and their marriage, and also the role women played in his life.

Between these major biographical works there have been various shorter studies focusing on aspects of his life and work.[5] These shorter pieces tended to repeat un-

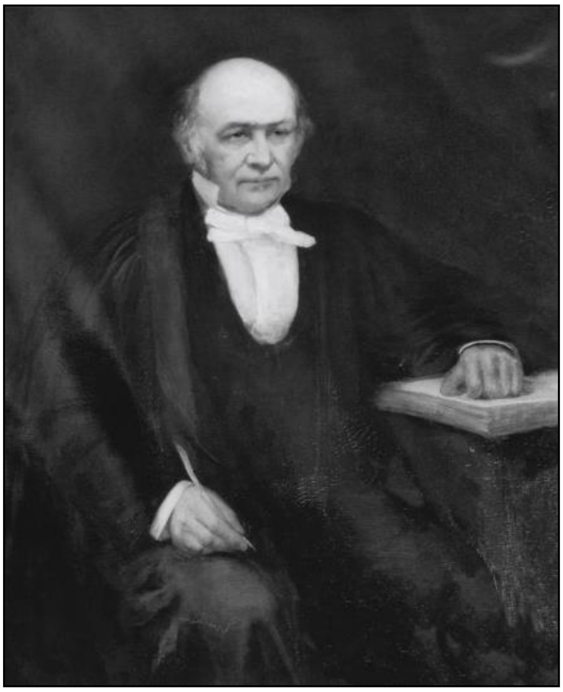


Fig. 1: Sir William Rowan Hamilton, by Sarah Henrietta Purser, undated. Purser's portrait was commissioned some thirty years after Hamilton's death. It is very likely that she never met Sir William but got his likeness from the marble bust by John Henry Foley (1818–74), now in the Long Room in Trinity College Dublin Library, and which Graves so greatly appreciated. Like Purser, Foley did not know Hamilton personally either. A sideways photograph of that bust illustrates the opening pages of Graves's biography of Hamilton, Vol. III (1889), p. 120. (Royal Irish Academy)

critically the image of Hamilton given in the biographies by Graves and Haskins.

Van Weerden's volume on Hamilton's marriage is complemented by her shorter volume on Catherine Barlow née Disney (1800–53), who was Hamilton's first experience, albeit frustrated, of reciprocated love.[6] The feelings evoked by this adolescent love bothered him still at the age of 50, and were fed by an unhappily married Catherine.[7] This is part of the reason why even today's popular image of Hamilton is that of a troubled man unsuccessful in love.

Among the other resources used in this paper, special mention is due to *The Transactions of the Royal Irish Academy*, accessible online.[8] Reading even the Index of the successive volumes gives an inkling of the intellectual effervescence created in those decades of the 19th century among the young talented scholars then working at Trinity College. David Wilkins's website at TCD contains all edited work by Hamilton plus several useful 19th-century perspectives.[9]

2. Early life and education

Hamilton was born at midnight on 1805 August 3/4, the fourth child of Archibald Hamilton (1778–1819), a businessman from Dublin, and Sarah Hutton (1780–1817).[10] They had nine children in all, but three died very young, one of them shortly after Hamilton's birth.[11] They lived in what we now call a flat in an apartment block in Dominick Street, Dublin.

The parents detected the early signs of special talents in young William. His father was desirous that this child would follow in his footsteps, working in the East India Company.[12] Archibald's brother James Hamilton (1776–1847), henceforth called Uncle James, was a graduate of TCD and was ordained for the Church of Ireland, running a Diocesan school in Trim, County Meath, 40 km (25 miles) north-west of Dublin, that prepared students for the entrance examinations to Trinity.

Uncle James had an academic interest in Oriental languages and the Classics, and William's parents saw in that an opportunity to provide the child with an early education that would be beneficial to pursue his father's plan for him. William was sent to Uncle James's school shortly before his third birthday, accompanied by his older sister Eliza. This was not unusual, as wealthier families sent their children to private schools or hired teachers or governesses to teach them at home, and three was not exceptionally young, given the fact that in Trim young Hamilton had friends of his age and was surrounded by caring relatives.

Such is van Weerden's reading of Hamilton's early years. For Hankins, though, the parents sent two of their children away because of the family's 'worsening financial situation'.[13] When Hankins was writing in the 1980s, Dominick Street in Dublin and the surrounding area had fallen into bad times, and the image of a large family living in a small tenement in a poor district could easily conjure up visions of the same extreme poverty that could then be seen in that area, but that is an anachronism. In the early 1800s that area of Dublin (today Dublin 1) was home to distinguished families. It is true that Hamilton's father was bankrupt for a period because he was owed money, but this did not last long as he won his lawsuit against his debtors and was in employment shortly afterwards as Solicitor to the Company of Fishmongers in London.[14]

However, a double tragedy was soon to strike; before William reached the age of 14 his mother had died, and his father had re-married and also died.

2.1. *Catherine Disney and Hamilton's Valentine*

Hamilton met the Disney family first on 1824 August 17, when he was 19, and he was immediately smitten by their daughter Catherine who was some four or five years older than him (her birth date is not known exactly). The Disneys lived in Summerhill, near Trim, and young Hamilton was introduced to them by Uncle James. On the following Valentine's Day in 1825 Hamilton, following custom, sent Catherine a Valentine's poem, declaring his love for her.[15]

As attested by many Victorian novels, Valentines sometimes lead to tragedy.[16] Marriage at the time was much of a business transaction between the suitor and the parents of the bride-to-be, who sought above all evidence of the man's capacity to provide for her. Graves speaks of the Disney family and their affection for the young Hamilton, known to them as a personable and bright scholar who was respected in the highest circles in TCD.

If, as van Weerden suggests,[17] Catherine's parents screened the Hamilton family to assess the young man's wherewithal in case of a union, all they could find was an orphan with no money of his own.[18] In their view, the future promise of his talent could not eclipse the certainties provided by another, more substantial, and older suitor, the Rev. James Barlow (1792–1871). Catherine was young and beholden to her parents. It was not until much later that Hamilton discovered that Catherine had been forced into an arranged marriage with Barlow.

In 1848 the deeply unhappy Catherine, now 48 and having borne seven children, two of whom had died in infancy, attempted suicide by taking laudanum (a mixture of opium and alcohol).[19] The attempt failed and she survived, but was permanently weakened. Afterwards, she and her husband apparently lived separately.

In 1853 October, sensing she was dying, Catherine sent Hamilton an affectionate message 'From one whom you must never forget, nor think unkindly of, and who would have died more contented if we had once more met'.[20] Taking the hint, Hamilton called on her at her brother's house in Donnybrook. There he finally learned from her the truth about her marriage to Barlow, and 'the two friends, who under other circumstances might have been more than friends', as Graves delicately put it, were able to express their true feelings for each other, which it transpired had never changed since they first met.[21]

Ironically, when the young Hamilton wrote the Valentine to Catherine in 1825 he was considering applying for a Fellowship at TCD that was 'clogged with the obligation of celibacy',[22] an unfortunate requirement for anyone contemplating marriage. That might have been a contributing factor to his giving up later on the idea of the Fellowship and applying instead for the post of Royal Astronomer of Ireland, which offered accommodation at Dunsink Observatory, far from the constant social pressure of the TCD campus and a better salary.

After his disappointment with Catherine, Hamilton proposed unsuccessfully to Ellen de Vere, a sister of his friend Viscount de Vere of the Curragh Chase in County Limerick. This romance was probably quite one-sided and ended without excessive drama when Hamilton was 26.[23]

2.2. *Meeting Helen Bayly*

In 1827 Hamilton was appointed Royal Astronomer of Ireland and took up residence in Dunsink Observatory (Figure 2). By 1831 his work on optics was going well, and he was well-known in Europe. Among the few neighbours he had near Dunsink were Mr and Mrs William Rathborne of Scripplestown. Their two sons had married two daughters of the large Bayly family, who lived in Bayly Farm near Neenagh, Co. Tipperary. At the time Hamilton was introduced to the family Mrs Bayly (1762–1837, born Anne Penelope Grueber) was a widow; her husband Rev. Henry O'Neale Bayly (1756–1826), the Rector of Nenagh, had died a few years earlier.[24] Graves refers to her always as 'Mrs Bayly'.[25]

She and her daughter Helen Maria Bayly (1804–69) made their first known appearance in Hamilton's life in 1831 August when Hamilton had a favour to ask of Mr and Mrs Rathborne.[26] Professor Airy of Cambridge and other scientists were coming to dinner in the Observatory the following day, and Hamilton wanted to offer them the pleasure

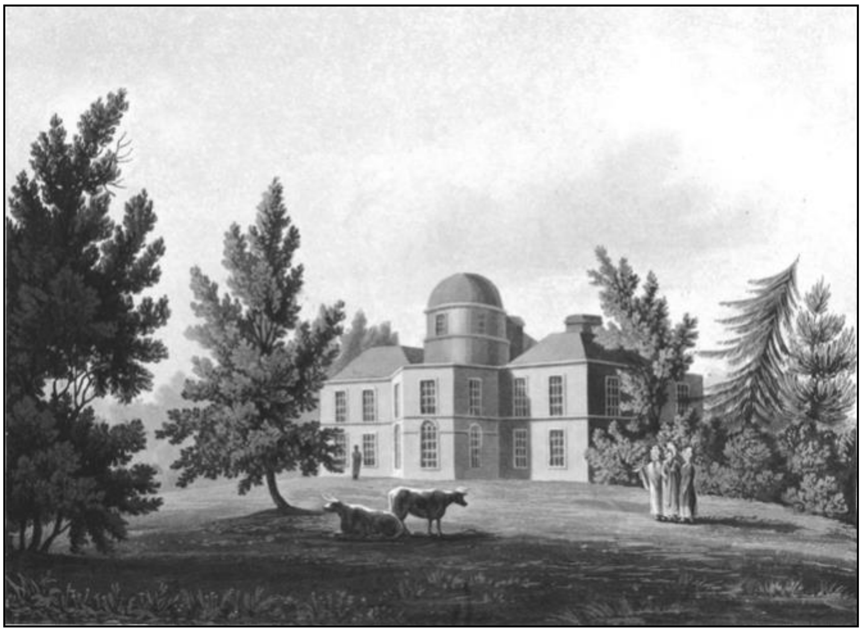


Fig. 2: Dunsink Observatory. Aquatint of the main building at Dunsink Observatory, near Dublin, Ireland, seen from the north-east. This scene dates from 1820, during the time of John Brinkley, the first Royal Astronomer of Ireland. (RAS MSS Add 94, no. 104)

of meeting his sisters and some neighbours to provide a break in the scientific conversation. The women were versed in poetry and two of his sisters helped in the Observatory. Hamilton asked Mrs Rathborne to invite Mrs Bayly and Helen to join them for tea with the professors in the Observatory.

Mrs Bayly must have been pleased with Hamilton's interest in her remaining unmarried daughter. On 1832 November 12 Hamilton wrote to his friend Aubrey de Vere, whose sister he had recently unsuccessfully proposed to, that he now had a new love. Before the end of the year Hamilton had been accepted by Miss Bayly (and by her mother).[27]

Helen was not at first enthusiastic about a possible marriage, and initially had refused. She knew herself to be too shy and weak in health to be his wife. On Hamilton's persistence she relented, but on the condition that he promised to lead a quiet life in the Observatory, to which he agreed.[28] Hamilton's non-compliance with this promise is one likely explanation for the times they were later to live apart.[29]

Hamilton's engagement to Helen came at a time when he had arrived at his discovery of conical refraction (published 1832 November 8) which catapulted him to fame, with many academic and social engagements. This gave Helen, then in bad health and six months before her marriage, an inkling of what she was getting into by marrying a mathematical genius. She could not understand the kernel of his success, but found that he was invited far and wide to talk about it, or brought visitors to the Observatory. These visits put additional burdens on her.

2.3. *Marriage to Helen Bayly*

Hamilton and Helen married on 1833 April 9 in Ballinaclough, near Nenagh, Co. Tipperary, where her family lived. He was 27 and she 29.

The couple had three children: William Edwin (1834–1902), Archibald Henry (1835–1914), and Helen Eliza Amelia (1840–70). These arrived at a time when Hamilton was fully immersed in his work. For the period 1834–43, until the youngest was three, leaving them at home and embarking on a trip to Britain, or even to Dublin, was difficult.

In these years when the family was growing (1834–40) Graves describes Hamilton as a devoted father. When Helen went to Bayly Farm for reasons of her or her mother's health, taking one or more of the children with her, Hamilton wrote tender letters and poems to her, saying that he worked better on his investigations when they were around, to the point that he moved to Bayly Farm himself for long periods while Helen and the children were there.[30] Graves quotes a touching note written by Mrs Bayly before her death, which occurred at Dunsink Observatory, addressed to Hamilton and showing her appreciation for his care of herself and Helen.[31]

His involvement with the British Association for the Advancement of Science (BAAS),[32] where he had to give a great deal of time to administrative duties, and his meetings at the Royal Irish Academy (RIA), where he was President for the period 1837–46, took him away from home at least once a month, contrary to his pre-nuptial agreement. He explained on his resignation as President of the RIA that he wanted to spend more time at home.[33] His visits to colleagues, mostly in the UK, sometimes occurred in years when he attended the BAAS, but receiving them as his guests in the Observatory were situations that Helen preferred to miss.

Helen did not remain at home all the time, though, and Graves mentions occasions when she and William travelled together. For instance, in 1838 they visited Lord Northampton in Castle Ashby, Northamptonshire, spending three weeks there.[34] In 1853 they went to the Viceregal Lodge in Phoenix Park, Dublin, the residence of the Lord Lieutenant of Ireland, to meet Queen Victoria, Prince Albert, and other dignitaries, where he was to address the Prince, a patron of the sciences.[35]

Fig. 3: Sir William Rowan Hamilton, seated in the Presidential Chair of the Royal Irish Academy. Attributed to John Kirkwood, after an original painting by Charles Grey. (National Portrait Gallery)

2.4. *Marriage strains*

Graves and Hankins both regarded Helen's inherent poor health, which caused her to spend time at her sisters' nearby homes or at Bayly Farm, as the reason why Hamilton felt lonely and gradually turned to drink.

Van Weerden notices in Graves's work an absence of opinions about the newlyweds originating from their close relatives. Graves's references to the marriage come from people in high society, showing the exalted circles where Hamilton moved, which Graves desired to emphasize as Hamilton's natural environment but one in which his wife did not move naturally.

She did not go with him to the yearly meetings of the British Association, did not establish a household routine where family meals were predictable, she disliked visitors, could not engage in meaningful conversations beyond religious subjects, and frequently absented herself from the Observatory for days and weeks, on one occasion for two years, alleging illness, either her own or her mother's.

Van Weerden observes that callers at the Observatory would put Helen under additional pressure, especially since high society visitors in those times usually brought some of their own servants, making such events rather complicated. Encumbered with children, Helen did not feel up to such additions, or simply refused to engage in the formalities involved. Rather than shyness, her absences on these occasions reflected her underlying strength of character.

On the other hand, Hamilton's habit of working well into the night disturbed the household pattern of meals. All she could do if he did not come to the family dinner would be to send it to him, but he frequently did not touch it. His work as an astronomer, such as it was, required nights spent in the meridian room, open to the nocturnal damps and chills, which caused him recurring colds and chest problems.[36] But that went with the territory, and was common in astronomers. Writing in 1865 April, the year of his death, he noted that his health had not been good 'for some years past'.[37] Just over four months later he died of a combination of gout and bronchitis.[38]

2.5. *A tarnished image*

Writing of events in 1846, Graves strikes an alarming note when he mentions for the first time what he termed 'the infirmity which was the one shadow on the brightness of Hamilton's life and character … a tendency to indulge to excess in alcoholic stimulants'.[39] This problem became public after an unfortunate incident at a dinner of the Geological Society of Ireland (TCD) in 1846 February, where Hamilton apparently drank too much, became violent, and had to be restrained, a painful event that became much talked of, according to Graves.[40]

Graves puts the blame squarely on Helen: 'No one ever needed a capable wife more than Hamilton, and this blessing he now ceased to possess'.[41] Hankins also blames Helen's long absences as the cause of his drink problem.[42] These judgements are unfair. Hamilton's Ireland, and the College where he worked, had a deeply engrained culture of drinking. He was exposed to it as an undergraduate, and further as a Professor. This level of consumption would not make an alcoholic today.

Van Weerden observes that the origin of that tarnished image was Robert Graves himself, by his disingenuous reporting of events. At the time of the publication of the biography, more than twenty years after Hamilton's death, Robert Graves and his brother Charles (1812–99), who had been very close to Hamilton, were personally involved in the abstinence campaigns that were active in Dublin. By bluntly revealing Hamilton's bad habit, and perhaps even exaggerating it, Graves would be emphasizing the evils of drink, even if he had to take some liberties with the truth.

To sum up, the two full-length biographies of Hamilton are scholarly and in many ways complementary, but they reveal their disapproval about his choice of Helen Bayly for his wife, avoiding interpretations of her behaviour that would leave her in a better and more truthful light. Van Weerden, on the other hand, shows herself to be a fine psychologist and expert on the customs of the period, with an empathy for her characters, specially the women. After reading her, Graves and Hankins look biased against Helen.

Fig. 4: Portrait of Francis Andrews, oil on canvas, by Anton van Maron. (Collection of Trinity College Dublin)

3. Dunsink Observatory and the Andrews Chair of Astronomy

Dunsink Observatory had been established in 1785 within walking distance of central Dublin. In the absence of a home-grown Irish Navy, Dunsink and its directors had an academic rather than a navigational focus as defined by the Observatory's founder, the Irish politician Francis Andrews (1718–74) (Figure 4), Provost of Trinity College Dublin.

Andrews ordered in his will that the College should raise £3,000 from his estates for the construction of an astronomical observatory with the necessary furnishings, plus another £250 as annual pay to the person chosen by the Provost, Fellows, and scholars (the Board of the College), 'to make astronomical observations in those places as they should see most convenient'.[43]

Sir Robert Stawell Ball (1840–1913), a Dublin man and graduate of TCD, assistant to Lord Rosse, Royal Astronomer of Ireland, and Director of Dunsink from 1874 to 1892, was well-placed to summarize the story of the Observatory and to evaluate its early contributions to astronomy.[44] He revealed how the early decades of the project were mired in litigation.

The relatives of the deceased Provost objected in court to the donation to the College to maintain 'a purely ornamental institution'. The plan by the first director, Henry Ussher (1741–90), for the construction project was carried out with some unexplained omissions. Ball indicated, quoting Ussher, that the College had already advanced a large sum for the project, suggesting that the Provost's fund for the Observatory was used to refund the College's expenses.[45]

Jesse Ramsden (1735–1800), an otherwise excellent instrument-maker, procrastinated on the delivery of some of the equipment ordered for Dunsink, for which he had been paid in advance.[46] In the case of the meridian circle the delay was seven years, and the College considered taking Ramsden to court, but in the end did nothing. After Ussher's death, his widow requested a pension from the College on the grounds that Ussher's death was caused by the many cold nights spent making observations, to which the College only agreed in part. Other promises of the Board to his widow, such as funding to publish his sermons and astronomical works, never materialized.

When the time came to elect a new Andrews Professor of Astronomy, two candidates came forward: John Mortimer Brinkley (1766–1835), from Suffolk, trained at Greenwich and recommended by Nevil Maskelyne, the Astronomer Royal; and John Stack (1760–1813), a TCD graduate who had written a manual of optics for students and was well-liked by the Junior Fellows. After a protracted argument that spilled into the Dublin press the Provost, John Hely-Hutchinson (1724–94), evoked an old College regulation that, in elections, gave him a veto, and the Englishman Brinkley was chosen over Stack, the Irishman. The College saw an opportunity to tighten up future elections for the job as well as the duties of the post.

Letters Patent for the Observatory were obtained in 1792,[47] whereby 'We grant and ordain that there shall be forever hereafter a Chair of Astronomy on the foundation of Professor Andrews, to be called and known as The Royal Astronomer of Ireland'. This is why Ussher was Andrews Professor of Astronomy but not Royal Astronomer of Ireland.

Hence from 1792 onwards, the Andrews Professor also bore the title of Royal Astronomer of Ireland. Both the professorship and the title of Royal Astronomer of Ireland fell into disuse after 1921, when Henry Plummer resigned. The Andrews Professorship was revived in 1984, but not the title of Royal Astronomer. Table 1 lists the first five Directors of Dunsink Observatory.[48]

Table 1

The first five Directors of Dunsink Observatory

Name	Term of office
Rev. Henry Ussher (1741–1790)	1783–1790
Rev. John Mortimer Brinkley (1766–1835)	1790–1826
Sir William Rowan Hamilton (1805–1865)	1827–1865
Franz Friedrich Ernst Brünnow (1821–1891)	1865–1874
Sir Robert Stawell Ball (1840–1913)	1874–1892

When Hamilton acceded to the post in 1827 the salary of £250 established by Andrews was seen as insufficient. In the absence of other arrangements that sum was to pay both director and assistant, and other household personnel. The salary was doubled in 1832, and doubled again later. In 1865 Hamilton's declared annual income was £607.[49] For comparison, Thomas Romney Robinson, the incumbent at Armagh Observatory, had a salary of £1,500, supplemented with a living of £900 for the parish at Carrickmacross.[50]

That Hamilton's appointment under such conditions was a very mixed blessing was not immediately apparent to the young man, at that time 22, single, and still reeling from the Catherine emotional rollercoaster. He saw in Dunsink primarily the advantages of a home and an independent life. The limitations were more obvious to his predecessor Brinkley, who in 1826 had found an alternative job and was leaving Dunsink pressed by a lowly salary and a wife and family and poor prospects of advancement as an astronomer.[51]

Now we come to consider Hamilton's experience in astronomy before he sought the post of Professor of Astronomy. It was these experiences that gave him confidence to face a rich field of other worthy applicants.[52]

4. Hamilton, schoolboy astronomer 1819–23

More than a dozen kinds of telescopic observations from Hamilton's schoolboy years are mentioned in Graves's biography: planets, eclipses (which featured in his poems), occultations, Jupiter's moons, Saturn's rings, comets, stars, and constellations. In Trim he used a hand-held Dollond refractor,[53] a rudimentary quadrant, and later a tripod-mounted telescope. He also used the *Nautical Almanac* proficiently.[54]

Describing Hamilton's observations in 1820 (aged 15) Graves commented:

> Astronomy, and especially eclipses, occupied during this year much of his attention … his journal often notes his observation of the planets and their satellites, their conjunctions and occultations. But the occurrence of two lunar eclipses, one on the 29th March, and the other on the 22nd September, and of an intervening [partial] Solar Eclipse on the 7th September, all visible at Trim, became of absorbing interest to him.[55]

Hamilton's calculating mind reflected upon these observations, trying to draw information from them. On lunar occultations of stars he calculated times of immersion and emersion.[56] On the configuration of the Galilean moons of Jupiter[57] he made an unusual comment about their occultation by their planet and the simultaneous occultation of the planet by the Moon.[58] He noticed the varying aspects of the rings of Saturn depending of the angle of view.[59] He knew the zodiacal and other constellations and their stars.

The accuracy of such observations can be easily confirmed today by modern planetarium software. At this point it is worth noting that all the times given in this paper are in Dublin Mean Time, not Greenwich Mean Time, as this was the standard time in Dublin in this period. Dublin Mean Time was measured at the Dunsink Observatory and was 25 minutes 21 seconds behind Greenwich Mean Time. It became the standard time in all of Ireland in 1880, but was abolished in favour of Greenwich Mean Time on 1916 October 1 during the First World War.

These early observations were made with simple instruments and in relative isolation from academics, although he had read many books on astronomy. The fact that Hamilton's critics, at the time and later, pointed to his lack of experience as an observer before taking the Chair of Astronomy was thus somewhat unfounded. Together with his advanced reading they certainly prepared him for the intended job.

4.1. *Occultation observations*

Graves documented Hamilton's treatment of occultations when Hamilton was 16. On 1821 May 28 William wrote to his cousin Arthur from Trim about an upcoming occultation of 3rd-magnitude Tau Sagittarii:

> There will be an occultation on the night of the 16th next, or rather on the morning of the 17th, Trinity Sunday. I am calculating the circumstances of this, and drawing up a view of it.[60]

Unfortunately the drawing appears to be lost. He then went to visit Arthur, who lived in Cumberland Street in Dublin. Having returned to Trim, on 1821 July 14 William wrote to his sister Eliza:

> Cousin Arthur procured me a good telescope from Mr. Mason the optician, with which I sat up on Saturday night, the 16th of June, till three o'clock the following morning, observing the moon and planets. An occultation of a fixed star took place that morning at 24½ minutes after three, by my calculation; but although the night was extremely clear, I did not see it, for just about the time, or a little before it, the moon disappeared behind the wall of the house in Cumberland-street, and there was no part of the house from which I could get a sight of it. But before it vanished I observed the star approaching directly to the moon's disc, and at a very little distance to the east of it.[61]

It is likely that instead of 'after three' he meant 'after two', because sunrise that day was at 03.30.[62] Moreover, the complete occultation could not have been seen at his stated time, as he went to bed at three o'clock. In fact, this occultation was very difficult to observe as the Moon was very low in the sky (it was 7 degrees high when the occultation started) and was setting at the time of emersion, just as the Sun was rising.

This raises the question of why Hamilton did not seek a clearer view to the south. The writing error had no consequences; this was a letter to his sister, not a record of his calculations. Figure 5 helps illustrate what Hamilton partly saw.

4.2. *Lunar eclipses*

The young astronomer treated eclipses of the Moon with the same interest. A remarkable case was the lunar eclipse visible from Trim on 1823 January 26. He was at the time preparing for his entrance to Trinity College. William wrote to Eliza about the eclipse:

> I must tell you about the eclipse of the moon, last Sunday evening. I had made calculations of all the circumstances six months ago ... When the time of emersion approached, for the moon was totally eclipsed, I went out to the garden: the stars and planets were glowing, but their queen was absent. I sought her, but her place was nowhere to be found.[63]

This was a central lunar eclipse, dark and of long duration. In Trim the Moon rose eclipsed at 16.24 Dublin mean time, and must have been very dark indeed. As given on the website EclipseWise, corrected for Dublin mean time, maximum immersion occurred at 17.00, and the end of totality was at 17.49. William continued:

> I saw through my telescope the first Satellite of Jupiter [Io, Figure 6] – and knew that the emersion of the moon must have taken place. For it is a remarkable coincidence that Jupiter's moon emerged from a total eclipse only three minutes and a-half before ours did. At the same time Saturn was on the meridian … I went out and saw that the moon had just begun to emerge.[64]

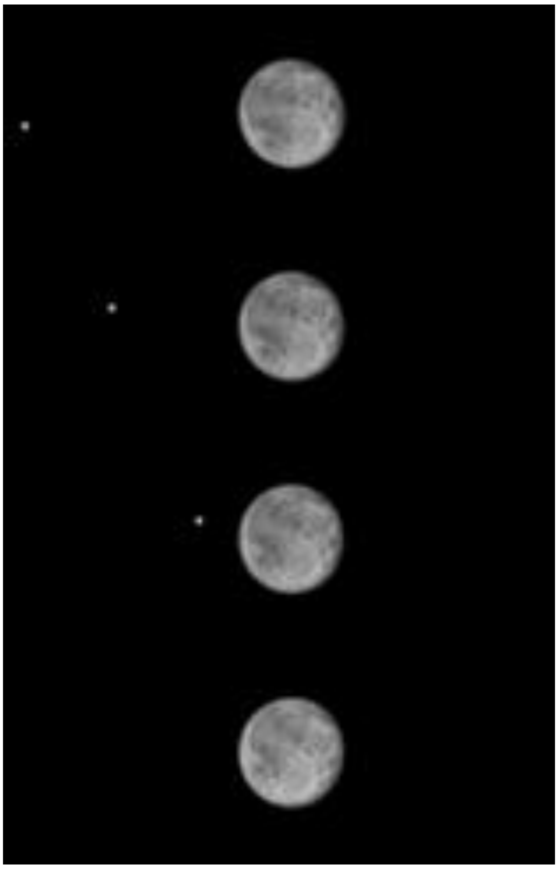


Fig. 5: Composite of four consecutive shots from Stellarium planetarium software, showing the occultation of τ Sagittarii by the Moon as seen from Dublin, in the early hours of 1821 June 17. Immersion took place at 02h 29, and emersion at 03h 38. The configurations shown here are from 00h to 03h. A screenshot was made for every hour. (Adapted from an original by Anne van Weerden)

5. Astronomical research as an undergraduate 1823–27

A little-known eight-page manuscript in the Library in TCD captures the 19-year-old Hamilton immersed in his astronomical work while an undergraduate.[65] Most of it consists of tightly written calculations concerning the occultation of Jupiter by the Moon on 1824 April 4–5 (Figure 7) for which, fortunately, Hamilton gave references.[66] These are lengthy algorithms that take hours to compute. Hamilton proceeded first to gather from the *Nautical Almanac* and other sources all the preliminary data relevant to the occultation. Unfortunately, Vince’s Figure 145 that he mentioned to illustrate his method was missing, but this did not stop Hamilton.[67] I have not found any record of Hamilton having observed this event, though.

His method of calculating the details of the occultation was not original as he followed the manuals, taking certain liberties. The *Nautical Almanac* for 1824 contained an explicit prediction of the April 5 occultation of Jupiter but the times predicted (11h 29¼m for immersion, and 12h 22¼m for emersion, giving a total time of invisibility of some 53m) were given as morning hours, while Hamilton took them to be afternoon. Hamilton bracketed the time of the event correctly, but he did not explain how he found those times. Simpler methods of calculating occultations for the specific situation of the observer would take decades to develop.[68, 69]

5.1. *Hamilton’s Theory of Systems of Rays, 1823–27*

While still an undergraduate, Hamilton had already begun his work concerning the path of light through optical systems, titled ‘Systems of Rays’. He presented the first draft to the Royal Irish Academy in 1824.[70] The paper was not accepted for publication then, as the reviewing panel concluded that some changes were needed to make it clearer.[71] But it already contained elements of enduring value that Hamilton developed in the following years as a generalized theory of the path of light through any optical system symmetric around its axis, including reflection, refraction, and colour. The theory was applicable to the construction of telescopes.

Duly expanded into ‘Theory of Systems of Rays’ in three parts, the paper was presented anew to the RIA on 1827 April 23, shortly before he was appointed to Dunsink Observatory, and published the following year.[72] This was his first academic publication, written when he was still only 21 years of age. This essay contained the first theoretical proposal of conical refraction, mentioned specifically when in 1835 the Royal Society awarded him their Royal Medal.[73] His final development of the theory came a decade later, and was also presented to the RIA.[74]

Hamilton’s theory of systems of rays established him as a mathematical genius. Both George Airy and John Herschel praised his paper in the highest possible terms.[75] The theory of systems of rays, touching on the nature of light, whether it was a wave or a particle, would become of interest to astronomers in later decades.

With this background in mind, we need now to consider the dispute surrounding his appointment as Andrews Professor of Astronomy.

6. Election as Royal Astronomer of Ireland, 1827

The post of Andrews Professor of Astronomy at Trinity College Dublin with all its nominal additions became vacant in 1826 on the resignation of John Brinkley. Brinkley discouraged Hamilton from applying for the post because he knew Hamilton’s professional strengths and weaknesses; namely that he was not a practical man but more suited to abstract mathematical thinking. Instead, Brinkley tried to steer him towards a fellowship in mathematics, which Hamilton gently but firmly dismissed. He was eager to obtain independence and status, both in academia and as a man who aspired to have a family.

Among the other contestants for the professorship were Humphrey Lloyd (1800–81), Junior Fellow at the time, and Dionysius Lardner (1793–1859), who later that year became first Professor of Natural Philosophy and Astronomy in the newly founded London University. Lardner went on to publish several books on astronomy, but little original research. Lloyd later worked with Hamilton to confirm his prediction of conical refraction.

Fig. 6: Using Stellarium to read off the time that Jupiter's first satellite to emerge from Jupiter's shadow on 1823 January 26 we find, rounded off, 17.46 Dublin mean time. Geographical data for Trim as used in Stellarium are latitude N 53° 13' 17.00", longitude W 6° 47' 30.00", altitude 56 m.

Lastly among the applicants was George Biddell Airy (1801–92), a distinguished mathematician and later to become Astronomer Royal at Greenwich. Airy’s application for the Dublin post was backed by personal recommendations from John Herschel (1792–1871) and Francis Beaufort (1774–1857), Hydrographer of the Navy. At the time of the interview in Dublin Airy had about ten publications relevant to practical and theoretical aspects of astronomy[76] and he was two years older than Hamilton, whose first paper on Systems of Rays was to be published later that year. Hamilton’s paper had been in the making since 1822, when he was 17 years old, and would continue to be developed. By contrast, Airy’s papers up to then were somewhat less ambitious.

Hamilton was elected by the Board unanimously on 1827 June 16.[77] From a strictly academic and astronomical point of view Hamilton was a candidate of great promise backed by remarkable experience, but the election was surrounded by a dispute that was more political in nature. This brought the Junior Fellows, perhaps more anti-establishment and inclined towards Irish Nationalism, into confrontation with the Provost and some Senior Fellows.

Ussher and Brinkley, the previous incumbents in Dunsink, had come to Dunsink from their previous posts at Greenwich, and were therefore British-trained and considered to be parts of the British establishment (although Ussher was born in Wicklow). The Junior Fellows, more naturally inclined towards an Irishman, saw Hamilton as their candidate. In this case, the Provost agreed.

Shortly after the appointment, Thomas Romney Robinson at Armagh, John Herschel, and Airy himself were among the many who sent Hamilton letters of congratulation. Airy said: 'I am glad … that you are placed in a situation which will allow you more liberty of thought than any other in the University'.[78] Unfortunately, he was only partly right.

7. Hamilton's work at Dunsink 1827–65

The records of Dunsink show that up to 1843, when Hamilton had his eureka moment in the calculus of quaternions, the Observatory was engaged in daily routine observations such as meridian crossings of the Sun and stars. These observations and their reduction were seldom made by Hamilton himself, but by Charles Duncan Thompson (c.1794–1876), his assistant, or by his sisters Grace or Eliza; a practice that was then acceptable.

One of Brinkley's observational projects at Dunsink had been an attempt to detect stellar parallax. In 1815 he published results in which he claimed to have detected parallaxes for Vega, Altair, Arcturus, and Deneb.[79] Needless to say, these parallaxes were entirely spurious. Hamilton was not interested in following up Brinkley's observing programme, which is just as well given the inadequacy of the instruments available to him for the task.

Hamilton did not seem to have had in mind a new programme of observations, but at least up to 1843 he was satisfied that the routine observations were carried out under his remote supervision. But he was less than enthusiastic about positional astronomy, and said so. The routine of his observations at Dunsink can be traced by looking into the record books for each of the instruments then at the Observatory, which have been summarized by Hoskin,[80] Macmillan,[81] and particularly by Wayman who read the Report of the 1850 Royal Visitation to Dunsink.[82]

While identifying Hamilton's limitations as a practical astronomer, the report underscored the failure of the Board of the College to help by appointing additional assistants. Wayman also noted that the Royal Visitation

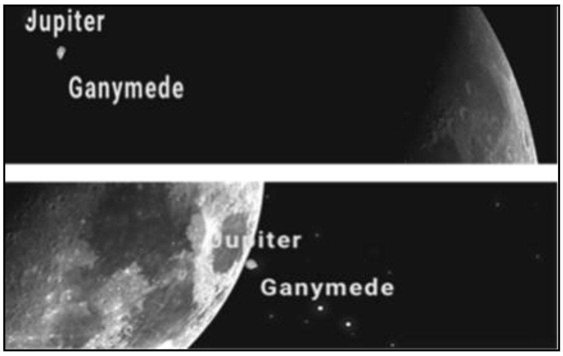


Fig. 7: Top, a slice of the Moon showing Jupiter partly immersed behind its western limb. Ganymede is already behind the Moon. Below, Jupiter is just exiting the bright limb of the Moon, following Ganymede by some minutes. Screenshots from Stellarium for the coordinates of Dublin and for the night of 1824 April 4–5.

managed to underestimate the real extent of Hamilton's observational work, reducing it to a fraction of what it actually was.[83]

In 1835 Hamilton had been knighted, and shortly afterwards he was elected President of the Royal Irish Academy, which was not simply a ceremonial role. He was invited to become an FRS on more than one occasion although he declined, citing among other reasons the cost of the subscription.[84] These were hardly signs of discontent by Academia.

Peter Guthrie Tait (1831–1901), Professor of Natural Philosophy at the University of Edinburgh, visited Hamilton at Dunsink, and hinted at another obstacle to his astronomical observations there; namely the quality of the instruments and facilities available. (Brinkley, in late 1827, had already warned Hamilton about problems with the 8-ft meridian circle.[85]) In Tait's view, the instruments of the Observatory, 'however good in their day, are totally unfit for the delicate requirements of modern astronomy … Had he devoted himself to practical astronomy, [the College authorities] would assuredly have furnished him with modern instruments and an adequate staff of assistants'.[86] Lastly, frequent night observations had inherent health risks for all astronomers, who were more or less effective at protecting themselves against them.[87]

7.1. *Hamilton the Royal Astronomer*

Then as now, an official astronomer was a public figure, attracting the attention of the media and the public. Hamilton was at his best in that capacity when he acted to calm the fears then circulating about the sighting of a new comet, identified as Biela's Comet, visible in the Irish night sky in 1832–3.[88, 89] Due to a careless reading of a report by the French astronomer François Arago[90] it was being said that the comet would cross the Earth's orbit, which caused much public alarm.

In his two-part contribution to *The Dublin Penny Journal*, Hamilton explained first that Biela's comet was one of many comets that had been visible from Ireland through the years, noting that their visits are recurrent and predictable. In the second part he dwelt on the distances between the orbits of the comet and Earth, explaining that the nearest the two bodies actually came to each other was about 50 million miles. Donati's Comet, discovered in 1858, was also the subject of numerous inquiries to the Royal Astronomer. The general public kept writing to him because they knew he responded courteously.

Another characteristic intervention of the Royal Astronomer occurred in 1842 when he refined the date of the spring equinox at the time of the Council of Nicaea.[91] This he later extended to a dating of the Feast of the Ascension, although his reasoning in this case was not astronomical.[92, 93]

The March equinox is one of the factors used to determine the date of Easter. The Gregorian reform of the calendar declared March 21 to be the date for the ecclesiastical equinox, and it is this fixed date (rather than the date of the actual astronomical event) that is used for the Catholic dating of Easter. Hamilton's calculations placed the vernal equinox of the year AD 325 about 1½ hours before midnight, thus making it on the evening of March 20. Hamilton also calculated the date of the Muslim Hegira as AD 622 July 15, which was in remarkable agreement with the date worked out by John Herschel.[94]

In 1837, when he took up the chair as President of the Royal Irish Academy, Hamilton revealed a new topic that was on his mind: his insight about a Universe full of 'dark matter', remains of stars and planets that were no longer emitting or reflecting light, which could be detectable only by their gravitational effects on visible bodies. His reflections to his friend Lord Adare on the 'dynamics of darkness' seem to have been an insightful glimpse into one of the concerns of 21st-century science.[95]

7.2. *Hamilton and quaternions*

Since quaternions are the best-known of Hamilton's contributions to mathematics, a few words are needed on the subject, particularly since this was what competed with astronomy in Hamilton's mind from the early 1830s.

'Quaternions' is the name he gave to his invention of an entire system of numbers and the algebraic operations (addition, subtraction, multiplication, and division) that can be defined among them. Several mathematicians, including Carl Friedrich Gauss (1777–1855), had attempted before Hamilton to define algebraic operations among vectors in space, in three dimensions. For this reason, they spoke about 'triplets' of numbers. By coining the term 'quaternion' to name his discovery, Hamilton was breaking away from the pursuit of triplets, and introduced a fourth component in this new number system, a scalar.

As Hamilton realized, quaternions had the potential to revolutionize developments in mathematics, algebra, and dynamics. It was a far cry from the daily struggle with the temperamental telescopes in Dunsink.

In a letter to his son Archibald written in 1865 August, Hamilton recalled the moment of inspiration that led to his formula for quaternions. It occurred on 1843 October 16 as he was walking with Helen into Dublin along the Royal Canal to preside at a council meeting of the Royal Irish Academy:

> Although she talked with me now and then, yet an *under-current* of thought was going on in my mind, which gave at last a *result*, whereof it is not too much to say that I felt at once the importance. An electric circuit seemed to close; and a spark flashed forth, the herald … of many long years to come of definitely directed thought and work.[96]

Hamilton took out his pocket-book and jotted down his formula, which he also engraved into a stone on Brougham Bridge, now known as Broom Bridge, which they happened to be passing. The original inscription no longer exists, but a modern plaque on the bridge wall (Figure 8) announces:

> Here as he walked by on the 16th of October 1843 Sir William Rowan Hamilton in a flash of genius discovered the fundamental formula for quaternion multiplication
>
> $$i^2 = j^2 = k^2 = ijk = -1$$
>
> & cut it on a stone of this bridge.

Rarely has the time and place of a mathematical discovery been so clearly defined. Mathematicians now undertake an annual Hamilton Walk from Dunsink to the bridge.

Hamilton was quick to apply quaternion calculus to astronomy. Having proposed a solution of the three-body problem based on vectors,[97] he was able to show that his quaternion calculus offered immediate applications in astronomy. Considering the three bodies to be the Earth, the Moon, and the Sun, he obtained an equation for the motion of the Moon considering the effect of both Sun and Earth, their distances, and their masses.[98] Another application of quaternions to astronomy permitted him to derive another equation to calculate the distance between the Earth and any new comet or asteroid.[99] Quaternion calculus still finds new applications in astronomy today such as software for telescope pointing[100] and control of satellite attitude, including the James Webb Space Telescope.[101, 102] There are also applications in robotics.[103]

8. Hamilton's Irish colleague-astronomers

Aside from Dunsink, in Hamilton's professional lifetime there were at least four other observatories in Ireland that have since ceased to rely on their 19th-century telescopes for their work. Armagh, Birr, Markree in Sligo (the private observatory of Edward Joshua Cooper), and Millbrook in Co. Galway (the private observatory of John Birmingham) were all well-known.

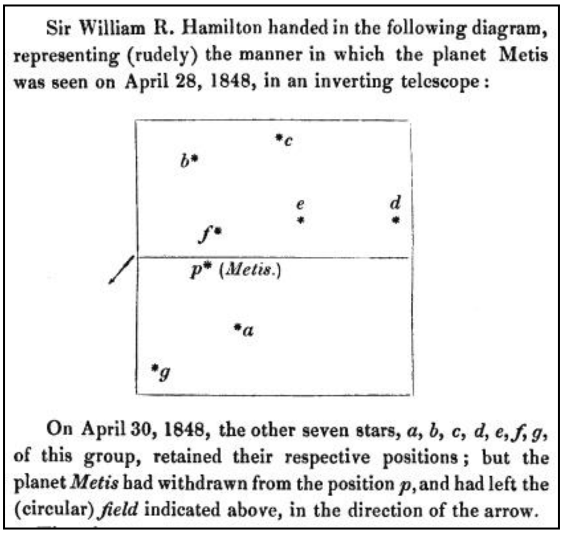
8.1. *Hamilton and Thomas Romney Robinson*

Hamilton had a good relationship with Thomas Romney Robinson (1792–1882), a graduate of TCD who was director of Armagh Observatory during Hamilton's tenure at Dunsink. Robinson produced a catalogue of 5,345 stars, sometimes known as the Armagh Catalogue, which was published in 1859.[104] A handful of these observations were made by Hamilton.

Hamilton participated in some of Robinson's experiments, one of which involved determining the longitude of Armagh by transporting two crates containing fifteen chronometers by train, boat, and horse-drawn coach over the 500 miles from Greenwich to Armagh via Dublin.[105] Another involved an attempt to measure the difference in longitude between Armagh and Dublin observatories by means of rocket signals.[106] After the initial report by Robinson, this plan came to nothing. Hamilton and Robinson also shared a common interest in the bizarre idea of a seasonal variation of the coordinates of their respective observatories which Hamilton attributed to an expansion and contraction of the Earth's crust.[107]

Hamilton paid several visits to Birr Castle and was there in 1845 February for an early trial of the power of Lord Rosse's great 72-inch telescope, the Leviathan.[108] In 1848 Hamilton received from Lord Rosse a letter inviting him to meet Professor Airy and Colonel Sabine at Birr Castle, holding out a

Fig. 8: Plaque on Broom Bridge, Dublin, commemorating William Rowan Hamilton's discovery of quaternions. (Wikimedia Commons)


Sir William R. Hamilton handed in the following diagram, representing (rudely) the manner in which the planet Metis was seen on April 28, 1848, in an inverting telescope:

On April 30, 1848, the other seven stars, *a, b, c, d, e, f, g*, of this group, retained their respective positions; but the planet *Metis* had withdrawn from the position *p*, and had left the (circular) *field* indicated above, in the direction of the arrow.

Fig. 9: Page 169 from ref. 113 showing Hamilton's diagram of Metis and surrounding stars as seen on 1848 April 28. Metis is magnitude 9.6, barely visible on Virgo's left leg.

prospect of carrying on some study of nebulae with the Leviathan.[109] At that time the nature of the nebulae was still not understood.

8.2. *Hamilton and Markree Observatory*

Markree Observatory, near the town of Sligo, was the private property of Edward Joshua Cooper (1798–1863), a wealthy amateur astronomer who had met Hamilton and made original contributions through the RIA.[110, 111] With his dedicated assistant Andrew Graham (1815–1908) Cooper prepared a catalogue of over 60,000 stars within 3° of the ecliptic known as the Markree Catalogue, which was published in four volumes in 1851–6.[112]

Markree had the distinction of having been the first Irish observatory to discover an asteroid, found on 1848 April 25 by Graham and Cooper, which they named Metis (now '9 Metis', not to be confused with Metis the innermost moon of Jupiter).[113] A paper reporting the asteroid's elements computed by Graham was accompanied by a sketch of the star field containing Metis as observed by Hamilton at Dunsink, the only astronomical diagram he ever published (Figure 9).[114] The diagram is not very informative since no stars are identified, and the name of Hamilton is not included as co-author, suggesting that perhaps he contributed the diagram reluctantly.

No mention is made of Metis in the context of any of Hamilton's visits to Markree, but there are mentions in 1835 of Hamilton looking through Cooper's 13.3-inch (0.34-m) refractor, the largest in the world at that time.[115] The archives for both Dunsink and Markree have been summarized by Hoskin.[116]

8.3. *Millbrook Observatory*

Another Irish astronomer of that era was John Birmingham (1816–84), a landlord from Millbrook near Tuam, Co. Galway, who in 1879 published a catalogue of 658 red stars observed with his 4.5-inch refractor.[117] However, his relationship with Hamilton seems to have been nil, as he is not mentioned in Graves's biography of Hamilton. Instead, Birmingham communicated directly with the Astronomer Royal at Greenwich.

9. Hamilton under scrutiny as Royal Astronomer

By 1843 the Board of Trinity College was aware of Hamilton's awkward position, at the peak of his productive career as a mathematician but burdened with a Chair of Astronomy that was rather a hindrance. Certainly Hamilton was well aware of his 'astronomical insignificance', as he told John Herschel.[118]

In 1843 March Hamilton received from the Board a communication including the yearly report from the Astronomer Royal at Greenwich, 'suggesting that a similar Annual Report, drawn up by Hamilton, and printed for distribution by the College, would prove satisfactory to the public'.[119] This was followed shortly by a move to switch Hamilton from his current chair to that of mathematics, which was expected to become vacant soon. The move was proposed by Viscount Adare and Humphrey Lloyd of TCD, both Hamilton's close friends, but nothing came of it.

Hamilton's performance as Royal Astronomer of Ireland was investigated more seriously in 1853 in the formal process of a Royal Commission visiting the College and reporting to Parliament.[120] It examined the records of the usage of the telescopes in Dunsink, finding them less than satisfactory, as mentioned in Section 7. Other issues were also reported.[121, 122]

Hankins remarks on the great difference between the mind of Airy – orderly, methodical, and steady – and that of Hamilton, imaginative, emotional, and disorganized.[123] Wayman, who was Director of Dunsink Observatory from 1964 to 1992, observed that the Royal Commission's report, usually interpreted as negative for Hamilton, was also critical of the Board, where Hamilton's difficulties were well known. Nothing was done to assist him in spite of the supposed statutory yearly visits by the Board to the Observatory, of which there is no record and probably did not happen. The report had a devastating effect on Hamilton, who thought that he was going to be forced to abandon his mathematical investigations and concentrate on astronomy.

Lastly, in 1863 an unfortunate dispute broke out between the Royal Dublin Society (RDS) and the RIA in which the former argued from its seniority as an institution, and from a little-known Royal visitation, that it had a right to control the latter.[124] This made Hamilton quite furious, and for once he did not mince his words in speeches against such a scheme, as if it had been directed personally against him.[125]

10. Recognition abroad

In 1835 the Royal Society of London awarded Hamilton its Royal Medal for his discoveries in optics, most notably conical refraction. Hamilton already had a high reputation in Europe, which the discovery of conical refraction helped cement: 'I owe many thanks to [Adolphe] Quetelet, whose translations must help much to make my writings known in Europe. The Conical Refraction Papers of [Humphrey] Lloyd are translated in the same German Periodical, the *Annalen der Physik und Chemie* of Poggendorf and so are my mathematical Papers'.[126]

On 1835 August 14 Hamilton was knighted by the Lord Lieutenant of Ireland at the Dublin Meeting of the British Association for the Advancement of Science.[127] In a speech during the evening banquet, William Whewell (1794–1866) of Cambridge made a short comparison between Hamilton and Isaac Newton, the only other man of science up to that time granted a knighthood.[128]

Perhaps the comparison was lost among the attendees, but it was very apt because Hamilton, like the Frenchman Joseph-Louis Lagrange (1736–1813), had invented a completely new method of looking at physics in general, and mechanics and optics in particular, distinct from the Newtonian system. The German mathematician Carl Gustav Jacob Jacobi (1804–51), speaking of Hamilton at the BAAS meeting of 1842 held in Manchester, echoed the same theme when he described Hamilton as 'le Lagrange de votre pays'.[129]

Conclusion

Aside from some remarks about his unsuitability for the job, biographies of Hamilton as an academic have barely touched on his astronomy. In this paper I have tried to avoid taking too narrow a view about that discipline, as it was in the first half of the 19th century. It is easy to see that Hamilton's astronomical contributions did not compare with those of leading observers such as Bessel or the Herschels. But the more pertinent question is whether he contributed anything to astronomy from his physical optics or his quaternion theories. The fact that his mathematical methods are still in use in present-day space exploration mark him out as not just another positional astronomer but an innovator, even if the applications came much later.

If we focus on his purely astronomical output we can only conclude that it was more modest than could have been expected from a genius. But even geniuses have their limitations. From his overall academic output we see that it was not that he was idle, but simply that his interests had gone in a different direction. What has been said above with regard to Hamilton's parental home and early education, his early relationships with women, and his alleged disorderly domestic life and drink problem is generally in agreement with van Weerden's proposition that a new look at the life of William Rowan Hamilton is needed.

While it is easier now, and timely, to review the effects of a strongly male-dominated society on the writing of biography, we should avoid falling into the opposite excess, an over-enthusiastic feminism that could devalue the intended correction.

Hamilton never forgot his position as Royal Astronomer and made serious efforts to comply with requests for information from the public and cooperation with his colleagues. But still, he made mistakes in his personal life. Perhaps his Valentine to Catherine Disney was in hindsight his first big mistake, for which he paid dearly in the form of disturbing emotional upheavals.

Later, Hamilton wanted to leave his incipient career in science for the sake of poetry, which he continued writing for most of his life. Some would argue that this fixation with poetry was, if not a mistake, at least a waste of time; but for his private use it was simply a natural mode of personal expression to balance his tendency to isolate himself in abstractions. Deep immersion in his work, to the exclusion of a correct balance with other aspects of life, was a notable aspect of Hamilton's personality and career.

Clearly his application for the Andrews Chair of Astronomy offered him several important advantages. It went with a home, which would give him a better prospect of marrying, and gave him distance and independence from the main Trinity campus. Otherwise, he was an orphan with no land or property and, as far as we know, little or no money in the bank and no investments. Later in life he spent much of what little capital he had in publishing his 700-page book on quaternions, his life's work. Without Dunsink, the best he could offer to any potential bride was his brilliant talent as a guarantee for the future, which is not something that everyone would take unquestioningly.

The option to take the Andrews chair in 1826 came at a time of personal transition. When that post came up Hamilton had fresh experiences of enjoying astronomy quite successfully at a certain level, but that was clearly receding into the background. His approach was changing from the keen amateur astronomer to the committed abstract mathematician. His colleague astronomers respected his intellect, and took his title of Royal Astronomer of Ireland more seriously than he took it himself. The Board of Trinity College was only prepared to countenance one model of working astronomer, and was less prepared to make a genius comfortable. I do not think they could be blamed for that either.

After 1827 Hamilton was attracted by wide-ranging generalizations about how the sciences work rather than in solving particular problems by traditional methods. All astronomers at the time had to be good calculators, and Hamilton went through such a 'calculator' phase in his adolescent years. Although this facility with mental arithmetic never left him, his mathematical talent was much more original and innovative, and he always believed, once he realized he had such talent, that it was worth dedicating all his time and energy to his mathematical investigations. The accolades and personal tributes that Hamilton received in his lifetime from highly respected astronomers, publicly and privately, should speak to us much louder than any ill-founded personal criticisms that emerged after his death.

We leave Hamilton with the final word on his own judgement and that of his astronomical colleagues:

> Such has been the reward, or the natural fruit, of a taste, amounting to a passion, for the most abstract parts of science, which has been steadily cultivated and laboriously acted on by me from early boyhood. In practical astronomy, on the other hand – though I never grudge the loss of a night's sleep, when anything interesting is to be done or seen – I could not hope, by the devotion of my whole remaining life, to rival (for example) my friend [F. G. W.] Struve, of Russia; who in the strongest terms represented to me, at Oxford, during the Meeting of the British Association in 1847, that, though I held the title of Royal Astronomer of Ireland, my astronomical brethren on the Continent would decidedly prefer my never looking through a telescope to my giving up or less ardently pursuing mathematics. 'You are', he was pleased to say, 'our teacher'.[130]

Acknowledgements

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Notes and references

1. Graves, Robert Perceval, *Life of Sir William Rowan Hamilton* (Hodges, Figgis, & Co., three volumes, 1882, 1885, 1889).

   Vol. I 1882, https://archive.org/details/lifeofsirwilliam01gravuoft

   Vol. II 1885, https://archive.org/details/lifeofsirwilliam02gravuoft

   Vol. III 1889, https://archive.org/details/lifeofsirwilliam03gravuoft

2. Hankins, Thomas Leroy, *Sir William Rowan Hamilton* (The Johns Hopkins University Press, 1980).

3. van Weerden, Anne, *A Victorian marriage: Sir William Rowan Hamilton* (J. Fransje van

Weerden, 2017).

https://archive.org/details/a-victorian-marriage-sir-william-rowan-hamilton

A good summary of van Weerden's book is: van Weerden, Anne, and Wepster, Steven, 'A most gossiped about genius: Sir William Rowan Hamilton', *British Society for the History of Mathematics Bulletin*, 33 (2017), 2–20.

https://www.researchgate.net/publication/321757988_A_most_gossiped_about_genius_Sir_William_Rowan_Hamilton#pf2

4. Ibid., 144–6.
5. Ball, Robert S., *Great Astronomers* (George Bell and Sons, 1895), p. 310.

   https://archive.org/details/greatastronomers00ball

   Wayman, Patrick A., *Dunsink Observatory 1785–1985; a Bicentennial History* (Royal Dublin Society: Dublin Institute for Advanced Studies, 1987).

   Hoskin, Michael, 'William Rowan Hamilton's astronomical correspondence', *Journal for the History of Astronomy*, 15 (1984), 70–71.

   Lewis, Albert C., 'Hamilton, Sir William Rowan (1805–1865)', in: *Oxford Dictionary of National Biography* (Oxford University Press, 2004). doi:10.1093/ref:odnb/12148.

   Mactutor, https://mathshistory.st-andrews.ac.uk/Biographies/Hamilton/

   Spearman, T. D., 'William Rowan Hamilton 1805–1865', *Proceedings of the Royal Irish Academy. Section A: Mathematical and Physical Sciences*, 95A (1995), 1–12.

   https://www.jstor.org/stable/20490182
6. van Weerden, Anne, *Catherine Disney: a biographical sketch* (J. Fransje van Weerden, 2019).

   https://archive.org/details/catherine-disney
7. Graves, op. cit. (ref. 1), Vol. III, p. 39.
8. *Transactions Royal Irish Academy*.

   https://www.jstor.org/journal/tranroyairisacad
9. Sir William Rowan Hamilton TCD Website.

   https://www.maths.tcd.ie/pub/HistMath/People/Hamilton/
10. Graves, op. cit. (ref. 1), Vol. I, 1–2.
11. Ibid., p. 1.
12. Ibid., p. 53.
13. Hankins, op. cit. (ref. 2), p. 5.
14. Graves, op. cit. (ref. 1), Vol. I, p. 14.
15. Ibid., 174–6. 'To Miss C. D. A Valentine Ode'. It does not read as an urgent, or even distant, marriage proposal, but rather as a youthful first encounter with beauty.
16. Hardy, Thomas, *Far from the Madding Crowd* (1874).
17. van Weerden, op. cit. (ref. 6), p. 38.
18. Graves, op. cit. (ref. 1), Vol. I, pp. 74 and 235. The 'PEN' in Hamilton's entrance record stands for pensioner, i.e. someone who paid for his own tuition rather than having a scholarship.
19. van Weerden, op. cit. (ref. 6), p. 70.
20. Hankins, op. cit. (ref. 2), p. 351.
21. Graves, op. cit. (ref. 1), Vol. II, 691–2.
22. Ibid., p. 169. The requirement was withdrawn in 1840.
23. Ibid., p. 563. Two sonnets to Ellen de Vere express the idea of one-sidedness.
24. Ferran, Jean, *Ohanov, Fiechter, Ferran, Persohn & Co*.

    http://www.monchique.com/Ochanoff/ohanov/ochanoff/2633.htm
25. Graves, op. cit. (ref. 1), Vol. II, 1–2.
26. Graves, op. cit. (ref. 1), Vol. I, 442–3; van Weerden, op. cit. (ref. 3), 129–30.
27. Ibid., 16–19.
28. van Weerden, op. cit. (ref. 3), p. 141.
29. van Weerden, Anne, 'Helen Bayly and Catherine Disney as influences in the life of Sir William Rowan Hamilton', *Irish Mathematical Society Bulletin*, 82 (2018), 91–103.

    https://www.maths.tcd.ie/pub/ims/bull82/Articles/vanWeerden/vanWeerden.pdf
30. Graves, op. cit. (ref. 1), Vol. II, p. 110. He did not work well alone at the Observatory, p. 118.
31. Ibid., p. 210. The note said: 'This is to be read by my dear Son, Sir William Hamilton, who has been a comfort and a blessing to me from the day that united him to my daughter to this day: and I am sure I shall say so when I am leaving this world'.
32. Between 1832 and 1853 Hamilton attended at least 15 of the 21 BAAS meetings. From the narratives given by Graves, the importance of these meetings for Hamilton's self-esteem and sense of belonging cannot be overestimated.
33. Hamilton to his sister Eliza, 1845, in Graves, op. cit. (ref. 1), Vol. II, p. 500.
34. Graves, op. cit. (ref. 1), Vol. II, p. 277.
35. Ibid., p. 689.
36. van Weerden, Anne, *Sir William Rowan Hamilton – Illnesses and Astronomy*, p. 13.

    https://annevanweerden.nl/docs/Illnesses_and_astronomy.pdf
37. Graves, op. cit. (ref. 1), Vol. III, p. 202.
38. Ibid., p. 193.

39. Ibid., Vol. II, p. 505.
40. Ibid., p. 507.
41. Ibid., p. 335.
42. Hankins, op. cit. (ref. 2), p. 125.
43. Andrews, Francis, 'Last Will and Testament', in Wayman, op. cit. (ref. 5), 281–2.
44. Dolan, Anne, 'Sir Robert Stawell Ball', in *Dictionary of Irish Biography*.

    https://www.dib.ie/biography/ball-sir-robert-stawell-a0352
45. Ball, op. cit. (ref. 5), p. 234.

    https://archive.org/details/greatastronomers00ball
46. Ibid., p. 242.
47. Ball, op. cit. (ref. 5), p. 238.
48. Table from Wayman, Patrick A., 'The Andrews Professors of Astronomy', *Irish Astronomical Journal*, 17 (1986), p. 168.

    https://adsabs.harvard.edu/full/1986IrAJ...17..167W
49. Hankins, op. cit. (ref. 2), p. 377.
50. Anonymous, 'Mullingar Grand Meeting', *The Freeman's Journal*, 1828 November 3, p. 2, rightmost column.
51. Dixon, F. E., 'Dunsink Observatory and its Astronomers', *Dublin Historical Record*, 11 (1950), 33–50.
52. DeArce, Miguel, 'Hamilton's School Days in Trim, 1808–1823', *IHoM4* Dublin, 2017.

    https://rhimeblog.files.wordpress.com/2017/07/ihom4dearce.pdf
53. Graves, op. cit. (ref. 1), Vol. I, p. 118, and Vol. III, p. 334.
54. Ibid., p. 99, at age 16.
55. Ibid., p. 81.
56. Ibid., p. 112.
57. Ibid., p. 66, 'I continue to view the moons of Jupiter with my large telescope'.
58. Ibid., p. 129, 'I ascertained that there were places (not in this earth) at which the emersion of Jupiter's moon and the middle of the eclipse of ours would have appeared to synchronise' (1822).
59. Ibid., p. 66, letter 1819 (aged 14).
60. Ibid., Vol. I, 89–90.
61. Ibid., p. 91.
62. timeanddate.com, Sunrise, Sunset, and Daylength for Dublin, 1821 June.

    https://www.timeanddate.com/sun/ireland/dublin?month=6&year=1821
63. Graves, op. cit. (ref. 1), Vol. I, 126–7.
64. Ibid.
65. MS TCD #1492, and not #1493 as reported in Hoskin, M., 'Astronomical correspondence of William Rowan Hamilton', *Journal for the History of Astronomy*, 15 (1984), p. 71.
66. Brinkley, John, 'A Practical Method of computing the Latitude at Sea', *Nautical Almanac 1822*, 2–16.

    https://babel.hathitrust.org/cgi/pt?id=mdp.39015037925990&view=1up&seq=23

    Woodhouse, R., *Elementary Treatise on Astronomy* (J. Smith, 1812), 361–74.

    Vince, Samuel, *Complete System of Astronomy* (G. Woodfall, 1814), 384–94.
67. Vince's Figure 145 is missing in two copies consulted by this author, as are all other figures mentioned in the margins of the book. This makes following the algorithm virtually impossible.
68. Rigge, William F., 'The Graphic Construction of Eclipses and Occultations', *Publications of the Astronomical Society of the Pacific*, 37 (1925), 37–43.
69. Grant, S. C. N., 'Diagram for Determining the Parallaxes in Declination and Right Ascension of a Heavenly Body, and Its Application to the Prediction of Occultations', *The Geographical Journal*, 7 (1896), 649–54.
70. Graves, op. cit. (ref. 1), Vol. I, p. 163.
71. Ibid., 186–7.
72. Hamilton, William Rowan, 'Theory of Systems of Rays', *Transactions of the Royal Irish Academy*, 15 (1828), 69–174.

    https://www.maths.tcd.ie/pub/HistMath/People/Hamilton/Rays/PtFst.pdf
73. The citation reads: 'For the papers published by him in the 16th and 17th volumes of the Transactions of the Royal Irish Academy, entitled Supplement to an Essay on the Theory of Systems of Rays, and more particularly for those investigations at the conclusion of the third and last supplement, which relate to the discovery of conic refraction'.
74. Hamilton, William Rowan, 'Third Supplement to an Essay on the Theory of Systems of Rays', *Transactions of the Royal Irish Academy*, 17 (1837), 1–144.

    https://www.emis.de/classics/Hamilton/ThrdSup.pdf
75. Graves, op. cit. (ref. 1), Vol. I, p. 231.
76. Airy, George Biddell, *Autobiography of Sir George Biddell Airy* (Cambridge University Press, 1896), 373–4.

    https://ia800504.us.archive.org/17/items/

b21777986/b21777986.pdf
77. Ball, op. cit. (ref. 5), p. 309.
78. Graves, op. cit. (ref. 1), Vol. I, p. 273.
79. Brinkley, John, 'An Account of Observations made at the Observatory of Trinity College, Dublin, with an Astronomical Circle, eight feet in diameter, which appear to point out an annual parallax in certain fixed stars', *Transactions of The Royal Irish Academy*, 12 (1815), 33–75.
80. Hoskin, M., 'Archives of Dunsink and Markree Observatories', *Journal for the History of Astronomy*, 13 (1982), 146–54.
81. Macmillan, Norman D., 'Organization and achievements of Irish Astronomy in the Nineteenth Century: Evidence for a "Network"', *Irish Astronomical Journal*, 19 (1990), 101–18.
82. Wayman, Patrick A., *Dunsink Observatory 1785–1985; a Bicentennial History* (Royal Dublin Society: Dublin Institute for Advanced Studies, 1987), p. 67ff.
83. Graves, op. cit. (ref. 1), Vol. III, p. 453, letter to De Morgan dated 1853 June 30, cited by Wayman (ref. 82), p. 70. For other observatories, the Commissioners counted the number of lines in the observing books taken up by the observations. For Dunsink, this came to 44,430 lines of text. However, the objective of the transit instrument at Dunsink had five vertical wires, so the Commissioners divided this number by 120 (5 wires x 24 years) to obtain a total of a mere 370 observations from 1828–52.
84. Sen, Siddhartha, 'Why William Rowan Hamilton was not an FRS', *Notes and Records of The Royal Society*, 59 (2005), 305–8.
https://royalsocietypublishing.org/doi/10.1098/rsnr.2005.0100
85. Graves, op. cit. (ref. 1), Vol. I, 243–5. Brinkley and Hamilton discussed the advantages and disadvantages of the equipment in Dunsink against that at Greenwich.
86. Tait, Peter Guthrie, 'Sir William Rowan Hamilton', *North British Review*, 45 (1866), p. 22.
https://archive.org/details/northbritishrevi45edinrich
87. van Weerden, op. cit. (ref. 36), p. 2.
88. Hamilton, William Rowan, (signing as 'H.'), 'The Comet', *Dublin Penny Journal*, Part 1, Vol. 1, No. 26 (1832 December 22), 207–8; Part 2, Vol. 1, No. 28 (1833 January 5), 22–4.
89. Graves, op. cit. (ref. 1), Vol. I, p. 657. See also Anonymous, 'The Comet', *Belfast Newsletter*, 1832 October 26, p. 4, col. 3.
90. Arago, F., (trans. Farrar, J.), *Tract on comets; and particularly on the comet that is to intersect the earth's path in October, 1832* (Hillard, Gray and Co., 1832).
91. Hamilton, William Rowan, 'On the day of the Vernal Equinox at the time of the Council of Nicaea', *Proceedings of the Royal Irish Academy*, 2 (1843), 249–51.
92. Hamilton, William Rowan, 'The day of the Ascension of the Lord', *Irish Ecclesiastical Journal*, 23 (1842), 400–1.
93. Graves, op. cit. (ref. 1), Vol. II, p. 380.
94. Ibid., Vol. III, p. 170, letter dated 1864 June 21.
95. Ibid., Vol. II, p. 287ff.
96. Ibid., Vol. II, 434–5.
97. Hamilton, William Rowan, Meeting of the Royal Irish Academy, 1845 July.
98. Hamilton, William Rowan, 'On the Application of the Calculus of Quaternions to the Theory of the Moon', *Proceedings of the Royal Irish Academy*, 3 (1847), 507–21.
See also Wilkins, David R., (ed.), 'Sir William Rowan Hamilton: Mathematical Papers', Paper No. 57.
https://www.emis.de/classics/Hamilton/index.html
99. Hamilton, William Rowan, 'On the Application of Quaternions to the Determination of the Distance of any recently discovered Comet or Planet from the Earth', *Proceedings of the Royal Irish Academy*, 4 (1850), p. 75.
See also Wilkins, David R., (ed.), 'Sir William Rowan Hamilton: Mathematical Papers', Paper No. 62.
https://www.emis.de/classics/Hamilton/index.html
100. Riesing, K. M., Yoon, H., and Cahoy, K. L., 'Rapid telescope pointing calibration: a quaternion-based solution using low-cost hardware', *Journal of Astronomical Telescopes, Instruments, and Systems*, 4 (2018), 034002. doi:10.1117/1.JATIS.4.3.034002.
101. Svehla, D., 'Earth Orientation Quaternion', in: *Geometrical Theory of Satellite Orbits and Gravity Field* (Springer, 2018), 355–61.
102. Grossekatthöfer, K., and Yoon, Z., *Introduction into quaternions for spacecraft attitude representation* (Technical University of Berlin, 2012).
103. Gouasmi, Mohahmoud, Ouali, Mohammed, and Brahim, Fernini, 'Robot Kinematics Using Dual Quaternions', *International Journal of Robotics and Automation*, 1 (2012), 13–30.
104. Robinson, T. R., *Places of 5,345 stars observed from 1828 to 1854 at the Armagh Observatory* (Alex Thom & Sons, 1859).
105. Robinson, T. R., 'On the Longitude of the

Armagh Observatory, given by fifteen chronometers of Arnold and Dent', *Transactions of the Royal Irish Academy*, 19 (1843), 110–20.
https://www.jstor.org/stable/30079128
106. Robinson, T. R., 'On the difference of Longitude between the Observatories of Armagh and Dublin, determined by Rocket Signals', *Transactions of the Royal Irish Academy*, 19 (1843), 121–46.
https://www.jstor.org/stable/30079129
107. Graves, op. cit. (ref. 1), Vol. II, 508–9.
108. Ibid., p. 485.
109. Ibid., p. 614.
110. Cooper, Edward J., 'On the Determination of Differences of Longitude by Means of Shooting Stars', *Transactions of the Royal Irish Academy*, 4 (1847), 6–14.
https://www.jstor.org/stable/20520224
111. Cooper, Edward J., 'Observations on Comets, made at the Observatory of Markree, during the first six Months of the Year 1846', *Transactions of the Royal Irish Academy*, 21 (1846), 114–23.
https://www.jstor.org/stable/30079001
112. Cooper, Edward J., *Catalogue of Stars Near the Ecliptic* (Alex Thom, 1851, 1853, 1854, 1856).
113. Graham, A., 'New Planet discovered at Mr. Cooper's Observatory, Markree Castle, Sligo', *Monthly Notices of the Royal Astronomical Society*, 8 (1848), p. 146.
114. Graham, A., 'On the New Planet Metis', *Proceedings of the Royal Irish Academy*, 4 (1848), 167–9.
https://www.jstor.org/stable/20520259
115. Graves, op. cit. (ref. 1), Vol. II, p. 161.
116. Hoskin, M., 'Archives of Dunsink and Markree Observatories', *Journal for the History of Astronomy*, 13 (1982), 146–54.
117. Birmingham, J., 'The Red Stars: Observations and Catalogue', *Transactions of the Royal Irish Academy*, 26 (1879), 249–354.
https://www.jstor.org/stable/30079086
118. Graves, op. cit. (ref. 1), Vol. II, p. 452.
119. Ibid., p. 410.
120. Hamilton, W. R., 1853, letter to De Morgan, in Graves, op. cit. (ref. 1), Vol. II, p. 686. The report is summarized by Wayman (ref. 82), 67–8.
121. Wayman, op. cit. (ref. 82), 66–70.
122. Parliamentary Papers of Great Britain, Vol. 45, no. 1637, 1852/53, 81–2.
123. Hankins, op. cit. (ref. 2), 138–9.
124. Minutes RIA meeting, 1863 July 6, Vol. 4, 370–1.
125. Graves, op. cit. (ref. 1), Vol. III, 160–2.
126. Ibid., Vol. II, p. 102.
127. Ibid., 157–9.
128. Brinkley had said many years before that Hamilton could be 'a second Newton' – see Ball, op. cit. (ref. 5), p. 307.
129. Graves, op. cit. (ref. 1), Vol. II, p. 388.
130. Ibid., p. 585, note.

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Margaret Bryan (c.1759–1836):
Georgian crowdfunder and pioneer of women's education

Nikki Lee

This paper presents new information about the life of Margaret Bryan, an English natural philosopher, author, and educator who taught science to women and girls in Margate and London. Widowed at a young age, with two young daughters to raise, Margaret went on to open two schools and publish three highly regarded educational textbooks. Using information gathered from a wide range of genealogical records, personal letters, newspapers, and wills, this paper reveals previously unknown information about the lives of Margaret, her husband William, and her two daughters, Anne and Sarah.

1. Introduction

Margaret Bryan (c.1759–1836) was a Georgian-era English educator who authored three textbooks: *A Compendious System of Astronomy, In a Course of Familiar Lectures* (three editions in 1797, 1799, and 1804), *Lectures on Natural Philosophy* (1806), and *A Comprehensive Astronomical and Geographical Class-book, for the Use of Schools and Private Families* (1815).[1]

Margaret's status as a female science teacher and entrepreneur is admirable in itself, but what makes her story so extraordinary is that many of her pupils were young women at a time when scientific education was almost exclusively reserved for men.[2]

Such was the respect and affection afforded to Margaret that her portrait adorned the study wall of William Herschel and her first book, *A Compendious System of Astronomy*, published in 1797, opens with a letter of recommendation from the mathematician Sir Charles Hutton (1737–1823), who refers to her manuscript as 'ingenious'.[3]

Margaret's second book, *Lectures on Natural Philosophy* (1806), is dedicated to Princess Charlotte of Wales, daughter of King George III, and offers teachings on hydrostatics, optics, pneumatics, and acoustics.[4] It lists the Duke of Sussex as its principal subscriber alongside many other distinguished figures, including former Prime Minister Spencer Perceval, the Astronomer Royal Nevil Maskelyne, and the Duchess of Grafton.

Yet despite such prestigious patronage, very little has been known about this pioneering female academic who frequently referred to herself as simply 'Mrs Bryan'. Margaret's achievements have been largely overshadowed by her female contemporaries such as Caroline Herschel (1750–1848),[5] Jane Marcet (1769–1858) whose ground-breaking book *Conversations in Chemistry* (1805) is often misattributed to Margaret,[6] or Mary Somerville (1780–1872), who wrote *Mechanism of the Heavens* (1831).[7]

My research began in 2019 when I first heard about Margaret Bryan following a visit to Margate Caves in Kent, which is located beneath the site of Margaret's first school.

Using long-buried archive material from across the globe and clues taken from the lists of subscribers mentioned in her books, I have uncovered the triumphs and tragedies of Margaret's story, shining a light on the remarkable contribution she made to female education, and placing her firmly where she belongs among the ranks of celebrated women in science.

2. Family background

I initially searched the genealogy website Ancestry.co.uk for marriage records covering a 20-year period where the bride's first name was 'Margaret' and the groom's surname was 'Bryan'. By cross-referencing the maiden names of each bride against the list of subscribers in Margaret's first book, I matched the surname 'Haverkam' to subscriber James Haverkam, who I later discovered was Margaret's brother. I could also match the surnames of the two witnesses to the wedding, S. King and B. Angier.[8]

This process of elimination confirmed Margaret's marriage to William Bryan in 1783.[9] It provided the key to further investigation of Haverkam family records on Ancestry.co.uk, where I discovered that Margaret was born in West Ham (then a village in Essex, now in the London Borough of Newham)[10] to Oswald Haverkam (bap. 1732),[11] of Dutch descent, and Sarah Wall (bap. 1729),[12] from a local family of apothecaries. Margaret's exact birth date is unknown, but she was baptized on 1759 October 12 at All Saints Anglican church in West Ham.[13]

Further genealogical records show that Margaret's parents, Oswald and Sarah, married in 1752 at St George's in Hanover Square, London,[14] an elegant new church where the baroque composer George Frideric Handel regularly worshipped.[15]

Oswald's family were early entrepreneurs in the English calico printing industry.[16] Originally nicknamed 'calicuts', the name calico was given to plain-weave cottons from Calcutta in India.[17] Calico printing proliferated in East London, and the area between Abbey Road and Stratford became known as the 'Calico Grounds'. By 1747, the Haverkams owned the most extensive acreage of calico grounds in West Ham. In 1768 Oswald received a substantial inheritance from his grandfather, Coen Haverkam, of £200 (c.£30k in today's money).[18] The 1774 will of Margaret's maternal grandfather, James Wall, shows that her mother's family were also wealthy landowners in possession of rural estates and properties throughout Essex.[19, 20]

It is clear that Margaret was born into a comfortable lifestyle, but tragically, in 1764, when Margaret was about five years old, her mother died and was buried in West Ham at the church where Margaret was baptized.[21] Five years later, in 1769, Margaret's father, Oswald, by then in his mid-thirties, remarried to Mary Rutland of Paddington, a young woman of 21. The wedding took place at St Anne's church in Soho.[22] Around this time, there is a record of Oswald Haverkam being apprenticed as a mercer to a gentleman called Jonathan Page who lived on Chandois *(sic)* Street off St Martin's Lane, who may have been her brother.

Oswald and Mary had three children together: John, baptized in 1772,[23] Sarah in 1775,[24] and Mary in 1777,[25] who were all under the age of ten when Oswald died in 1781.[26] He is buried at St Mary's church in Lambeth, where his second wife, Mary, was buried 11 years later in 1792.[27]

It is possible that Oswald abandoned his old family to start a new life with his young bride because, by the time Margaret was about 12 years old in 1771, she and her two siblings were living under the guardianship of her maternal grandfather's friend Joseph Green, a gentleman of Stratford. This is evidenced in the will of James Wall and in court documents held by The National Archives that reveal a dispute between Margaret's grandfather and Oswald Haverkam over some shares in the notorious South Sea Company.[28]

2.1. *Other family members*

Margaret's aunt, Ann Wall (1734–99), married Thomas Nottidge (1734–1816) of Bocking, Essex, in 1765.[29] Regardless of this earlier dispute over money, Ann, Thomas and other members of the prominent Nottidge family appear to have been very supportive of Margaret's work – many of them are listed as subscribers to Margaret's first two books. It is in Thomas Nottidge's will in 1816 that I first found reference to Margaret's daughters, Anne Marian Bryan and Sarah Maria Bryan (whom he refers to as Maria), to whom he left land and property across Essex.[30]

When Margaret's grandfather James Wall died in 1774, he left all of his rural estates and £1,000 (approximately £140k in today's money) plus interest in trust for each of his three grandchildren, i.e. Margaret and her two brothers James and Oswald the younger, to be paid when they reached the age of 21. He also left money to their guardian, Joseph Green. Margaret's father was excluded from the will, further evidence perhaps of Oswald's abandonment. Parish records indicate that Margaret's brother Oswald died in his early twenties in 1776 and is buried alongside their mother at All Saints church in West Ham.[31]

Margaret's other brother, James, married Mary Kirwan in Antigua in 1783.[32] After a long military career, he retired from the 11th Royal Veteran Battalion in 1812 and later received half-pay – an allowance paid to retired officers or those not in active service.[33] Newspapers announced military promotions, and when Margaret's first book was published in 1797,[34] James had reached the rank of Captain in the British Army. The serving Secretary of War in 1797, William Windham (1750–1810), was also a subscriber to Margaret's first book.

Further evidence of James's wealth and social standing appears in livery company documents from 1796 October when he was granted Freedom of the City of London by redemption to the Company of Musicians. 'Redemption' refers to the process of paying a fee to obtain membership in a livery company following nomination from an existing member. For this privilege, James paid 46 shillings and 8 pence (approximately £230 today).[35]

I have not discovered where Margaret received her education, but her guardianship under Joseph Green might have sparked her interest in science. In her first book, one of the subscribers is a William Green, based at the Academy Deptford, a boy's school affiliated with the Royal Military Academy at Woolwich, where William was the master of classics, writing, and arithmetic.[36] Joseph's will of 1782 does mention that he had a son called William,[37] so it is possible that there is a connection here. From the preface of her second book we know that Margaret was inspired by the natural theologian William Paley (1743–1805) whose son, the Reverend Edmund Paley, was a subscriber to her second book.

2.2. *Marriage and children*

Margaret married William Bryan, a merchant, on 1783 July 12 at St Michael Bassishaw church in London, when she was about 24. Now demolished, this church once stood in Basinghall Street, on the site of today's Barbican complex.[38] Shortly after her marriage Margaret purchased a 4-inch Georgian reflector telescope from W. & J. Jones of Holborn, suggesting that her husband supported her work.[39]

Although William was living in London at the time of their marriage it is not known precisely when or where he was born, but he was probably of Irish descent. Land tax records show that a William Bryan was living in Upper Berkeley Street in Marylebone, London, in 1780,[40] although there is no definite proof that this is him. However, Irish records confirm that after just five years of marriage, William Bryan died in Cork on 1788 September 11 when Margaret was aged just 29 (approximately). It is recorded in the *Hibernian Chronicle* that he died on Merchant Quay 'after a tedious illness'.[41-43]

William died intestate, and an advertisement in the *Dublin Gazette* on 1788 October 11 announces that William Willcocks was appointed administrator of his estate:

> William Willcocks, of the City of Cork, Merchant, gives Notice that he has been appointed Administrator of the Goods, Rights, Credits and Chattels of William Bryan, late of the same, Merchant, deceased and defines that those who are indebted to the said William Bryan will not pay any debts to him, but to his said Administrator.[44]

There is a record of a William Willcocks in the *Dictionary of Canadian Biography* who later became the Mayor of Cork in 1793.[45]

A search of genealogical records uncovered a letter of administration listing one of William's creditors dated 1789 May 2 which confirmed the names of Margaret and William's two daughters as Anne and Sarah Maria.[46]

In 1799 another wealthy Irish merchant called William Bryan died in Dublin. This could be a relative because the executor of that will was Sir Simon John Newport (1756–1843) of the influential Newport family, who owned Waterford Bank.[47, 48] The Newports are listed as subscribers in Margaret's first and second books.

There is also a record of Robert Butler-Bryan, a lawyer who lived at 20 Eccles Street, Dublin.[49] A 'Mrs Bryan' of the same address, possibly a relation to Robert, is a subscriber to Margaret's second book and is noted as ordering two copies, so it is possible that Margaret's husband is somehow related to either, or both, of these Bryan families.

Margaret's lifelong loyalty to her husband is evident. In both of her portraits Margaret wears a traditional Georgian mourning dress.[50] In the later 1801 portrait of her, engraved by James Heath, her loss is made strikingly apparent through her melancholic gaze from where she is painted against a bleak background (Figure 1).

In the closing address of her second book we get a strong sense of Margaret's values and

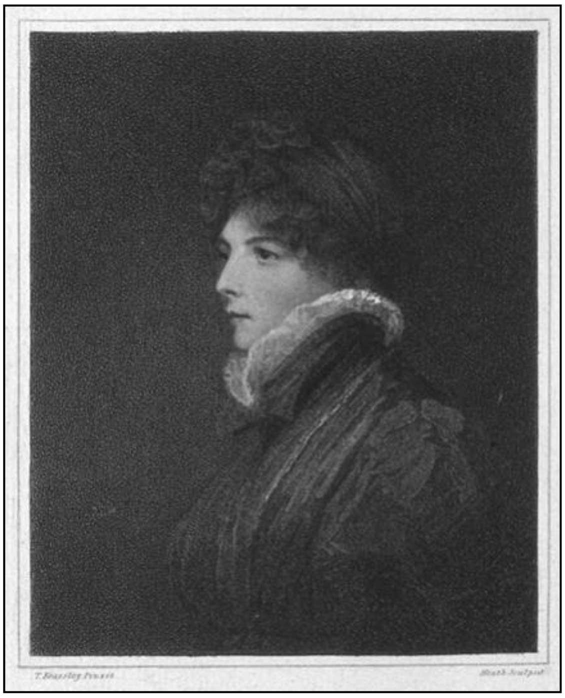

Fig. 1: Margaret Bryan in 1801. Stipple engraving by James Heath, after T. Kearsley. (Wellcome Collection)

her attitude towards marriage when she counsels her pupils that when they become wives they should 'consider the solemn oath pledged before God, and strictly obey its mandates'.[51]

William Bryan was likely a man of devout faith, a quality she further expounds on:

> I think it my duty to impress on your minds the indispensable qualifications of both a friend and a husband – religious principles and practice. Never make your choice of either of these till you have discovered that they not only profess to be religious, but are truly so, in thought, word, and deed.[52]

William's burial place is unknown, but shortly after his death Margaret made the decision to move with her daughters to Margate in Kent.

3. Margate

While it is not clear exactly when or why Margaret chose to move to Margate, I have uncovered evidence that her cousin, the Rev. John Thomas Nottidge (1776–1847), lived there too. This is revealed in a 1794 letter to Nottidge from his friend Claudius Buchanan who writes, 'I should gladly accept of your invitation to Margate, but I have already engaged myself for the summer on a plan of improvement and pleasure'.[53]

Margaret may also have had other connections in Margate, given her husband's line of work and Margate's status as an essential merchant port.

In 1791, when her children were still under the age of 10, Margaret announced in the *Kentish Gazette* her intention to open a school on Lady Day (March 25) (Figure 2).[54]

Eight of Margaret's pupils at Bryan House are listed as subscribers to her first book: Miss Braban, Miss Frances Cawne, Miss E. Cawne, Miss Cook, Miss Crawford, Miss Le Geyt, and Miss M. A. Sotheby. Margaret inspired her pupils to such an extent that in 1793 one of them, Mary Le Geyt, aged 16, the second daughter of Captain Le Geyt of Dover, also became an apprentice at Margaret's school.[55] Tragically, Mary died aged 19 on February 1 that same year while at the house of a Mrs Byrche in Canterbury (also a subscriber). Her death was announced in the *Kentish Weekly Post*.[56] While Mary could not realize her teaching ambitions, it is a fitting tribute that her name is immortalized in Margaret's book.

3.1. *First publication*

It was during her time at Margate that Margaret wrote her first book, *A Compendious System of Astronomy, In a Course of Familiar Lectures*, published in 1797. The book's first edition was printed by George Kearsley (fl.1797–1813), who was a subscriber along with his family. Margaret had first sent a copy of the manuscript to the mathematician Charles Hutton (1737–1823), whose public endorsement gave her the courage to publish it and she included a copy of his letter of support at the front of the book.

Publishing was an expensive business in the 18th century. Authors often funded their work by subscription,[57] and this is the route Margaret took when she placed an advert in the *Kentish Gazette* on 1797 April 4 announcing her intention to publish and requesting patronage.[58]

In the introduction to her first book Margaret expressed her hope that her efforts would gain approval from the more learned and liberal members of society who 'judge impartially – for they, rising superior to the false and vulgar prejudices of many, who suppose these subjects too sublime for female introspection … invalidate the idea'.[59]

Yet Margaret also adopted a far more self-deprecating tone when she made it clear that she believed her knowledge to be inferior to that of men, reflecting the prevailing attitude of the time towards female education.[60] It is also likely that Margaret had a shrewd understanding that writing about her achievements in such a modest way would gain her support from a male audience on whom she could then rely to help publicize her book.

Despite Margaret's concerns about the book's reception it appears to have been well-received by reviewers. A second edition was published in 1799 and reviewed in *The Monthly Visitor and Entertaining Pocket Companion* which made clear that the sanctioning of this work by Charles Hutton had enhanced its reception.[61] A later review in *The Lady's Monthly Museum or Polite Repository* in 1801 was equally complimentary, remarking that 'it appears to us to be a concise, perspicuous, and masterly compendium of astronomical knowledge'.[62]

The exquisite illustrations in the book were created to Margaret's design by Thomas Conder (1746/7–1831), an English engraver and bookseller.[63] The iconic frontispiece of the book (Figure 3) is from an engraving by William Nutter (c.1759–1802), copied from an original colour portrait by miniaturist Samuel Shelley (1750?–1808) (featured on the cover).[64]

When adapting the painting into an engraving for the book, Nutter, possibly at Margaret's request, moved the placement of her hand so that we can clearly see her wedding band, and placed a pen and a copy of the letter from Charles Hutton on the table. He also significantly lowered the lining of Anne's dress so that her chest is more exposed, perhaps to reflect the fashion of the day.

The original painting by Shelley was displayed in the 1797 exhibition at the Royal Academy, where it was listed in the exhibition catalogue as item 1053. The catalogue erroneously states that the portrait is for a book written by Mr (not Mrs) Bryan.[65]

3.2. *Leaving Margate*

At some point, Margaret dedicated a beautifully bound first-edition copy of her book to a gentleman called Thomas Pinkett referring to him as 'a friend of the fatherless and widow'.[66] The book is decorated with a beautiful metal clasp and must have been expensive to produce. Pinkett was a solicitor at Essex Court, Temple, and when he died in 1839 he left £50 (£5k today) in his will to Margaret's youngest daughter, Sarah, referring to her as Maria.[67]

In 1798, a year after the publication of Margaret's book, the Irish Rebellion broke out in protest against British rule in Ireland.[68] On March 22 that year, in an advertisement in the *Kentish Gazette*, Francis Cobb, Jr, of Cobb's Bank whose head office was in Margate, asked the inhabitants of Margate to donate funds 'in Aid of Government, at this important crisis'. Donations from 'Mrs. Bryan and the Ladies of her Family' are included in the list of voluntary subscriptions having gifted six guineas, the equivalent of £650 today.[69] This may explain why there is just one member of the Bryan family named as a subscriber in Margaret's books and why she chose not to settle in Ireland after William's death. Could it be that Margaret's faith was at odds with the beliefs of William's family? Or were the family perhaps staunch nationalists who resented that William had married an English woman?

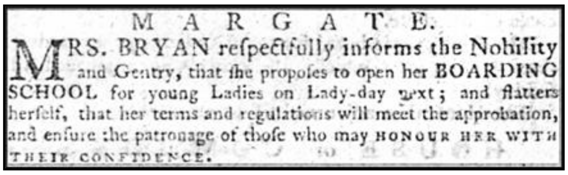
MARGATE.
MRS. BRYAN respectfully informs the Nobility and Gentry, that she proposes to open her BOARDING SCHOOL for young Ladies on Lady-day next; and flatters herself, that her terms and regulations will meet the approbation, and ensure the patronage of those who may HONOUR HER WITH THEIR CONFIDENCE.

Fig. 2: Advertisement in the Kentish Gazette *in 1791 March announcing Margaret's new school. (British Newspaper Archive)*

Later that year Margaret announced the sale of Bryan House in the *Kentish Gazette*, confirming that she planned to move her seminary to Blackheath.[70] The announcement also informed the public that Margaret's book was available in bookshops in London and at libraries in Canterbury, Margate, Ramsgate, and Deal. The property was listed multiple times until 1802 and the advertisements reveal the generous layout and size of the property.[71]

A Margate travel guide from 1809 lists several school establishments and states that 'the boys are taught reading, writing and arithmetic; the girls forwarded in knitting stockings, plain-work and marking (needlework)'.[72] One of the schools is listed as being owned by a Mrs Oldfield, who is listed as a subscriber to Margaret's second book – so perhaps not all the schools in Margate were so prescriptive and Mrs Oldfield shared Margaret's teachings with girls as well as boys.

4. Blackheath

Blackheath is an elegant area in south-east London, bordering Greenwich. Many of the houses date from the Georgian era, while the heath itself and Greenwich Park offer vast

Fig. 3: Margaret Bryan and her two daughters by William Nutter, after Samuel Shelley, from the frontispiece of her first book, A Compendious System of Astronomy. *(National Portrait Gallery)*

open spaces that made it a popular spot for golfers during the 19th century.[73]

It is possible that Margaret had at least one relation nearby because in 1799 a Joseph Nesbitt Bryan died in Blackheath after being thrown from his carriage and was buried at St Mary's church in nearby Lewisham.[74] There is evidence that he was an insurance broker who had gone bankrupt a year earlier in 1798.[75] Margaret may also have been drawn to Blackheath because of its proximity to the Royal Observatory in Greenwich. Nevil Maskelyne, Astronomer Royal from 1765 to 1811, was a subscriber to her first book.

Whatever the reason, Margaret moved into her new home 'Bryan House', a grand detached building on the edge of the heath. A drawing of Bryan House, dated around 1800, is held by the Royal Institute of British Architects and notes the architect as Michael Searles (1751–1813).[76] As with her property in Margate, it is not known whether Margaret named the building herself or whether it was commissioned by her or a family connection, but during its construction its width was extended by a further two bays.

A contemporary illustration of Bryan House depicts the building in more detail with its rooftop wooden observatory (Figure 4). It is tempting to speculate that the lone figure of the woman in black at the front of the building, or the woman feeding ducks by the pond, is Margaret Bryan.[77]

Margaret likely had staff helping her run the household and school, but she often handled business matters herself. This is evidenced in a letter she wrote to the bankers Francis Cobb and Son of Margate apologizing for the late payment of a draft into Esdaile's, a private bank based on Lombard Street in the City of London:

> Gentlemen,
>
> Your draft for £88 was duly paid into Sir James Esdaile's for you on the 19th of April therefore I am much astonished to find they did not inform you of it. I assure you I would on no account have forfeited my word after you had so obligingly accommodated me.
>
> Messrs. Stephenson not honouring the draft for £60 was owing to a gentleman, who was to have paid in some money last week not doing so till this – but which money will be paid in two or three days, and is for Mr John Brown to whom I beg you to transfer it. I must think them very negligent at Esdaile's not to give you a full account on sending the £60 note.
>
> With respect I am, gentlemen, your much obliged humble servant
>
> M. Bryan.[78]

Ever seeking to refine and improve her teachings, Margaret published a second edition of her first book in 1799,[79] with a final third edition in 1804, which she noted was 'revised and corrected'.[80]

It is clear that Margaret's reputation as an excellent teacher was well known by this time, because she was featured in a children's storybook called *The English Girl; A Tale for Children*, written anonymously but published in Belfast. Margaret is featured in Chapter Two:

> At the elegant seminary of Bryan House, upon Blackheath, little Mary was placed by her kind guardian, who was anxious to give her a polite and useful education. The amiable Mrs. Bryan's instructions were not lost upon Mary, whose capacity seemed to keep pace with the sweetness of her disposition. In two years Mary's improvement was so great that Mr. Arnold thought it unnecessary to leave her longer at school: she read the best English authors with propriety, had a perfect knowledge of plain and

Fig. 4: Watercolour illustration of Bryan House. (The Blackheath Society)

> fancy work, had made a tolerable progress in French and music; in the two last accomplishments Mr Arnold excelled, and it was his intention to become her tutor, and to enlarge her knowledge in both.[81]

The book was priced at a modest 5 pence (£1.60 in today's money).

Margaret's earlier letter to Cobb and Son hinted at cash flow problems, so it is interesting that four years later, in 1804 August, she felt compelled to place an advertisement in *The Morning Post* to quell rumours of plans to leave Bryan House.[82]

There is no firm evidence to suggest what may have started the rumour, but it is possible that Margaret had run into money problems. A year earlier, in 1803, there are records of a highly wealthy merchant called William Bryan, formerly of Jamaica, but lately of Camberwell in Surrey, going bankrupt and owing the equivalent of millions of pounds in today's money.[83] However, there is no evidence that that William was related to Margaret or that she had any financial dependency on him.

Meanwhile, Margaret's professional credibility was flourishing. In 1804 December she was consulted on the production of an astronomy-themed board game called *Science in Sport, or the Pleasures of Astronomy* marketed as 'A New & Instructive Pastime. Revised & approved by M. Bryan' (Figure 5).[84]

The website of the Royal Museums Greenwich describes it as follows:

> The game is based on the traditional Game of the Goose, which was adapted to a wide range of themed boards, many produced by John Wallis, one of the leading publishers of board games in the early 19th century. The board has 35 numbered 'squares' depicting astronomical objects, instruments and principles as well as astronomers (Ptolemy, Tycho Brahe, Nicholas Copernicus, Isaac Newton) and moral lessons (e.g. a studious and idle boy, the county gaol and an army volunteer). One square shows the man in the moon as an example of ignorance in astronomy. By spinning a 'tetotum', players can travel over the board, the object being to spin numbers up to 35 and reach the final 'square', depicting Flamsteed House: 'Whoever first arrives here is to take the title of Astronomer Royal'. The game involves much rote learning as well as moral lessons en route.[85]

4.1. *Second publication*

Ever industrious, by 1805, Margaret had completed her second book, *Lectures on Natural*

Philosophy, and announced that she intended to publish once again by subscription.[86] Margaret was juggling many responsibilities, and in the book's introduction confessed that the lectures had been 'revised under the disadvantages of a desultory mode of conducting that important business; for which the various professional claims on my time can alone apologise'.[87]

The book was published in 1806 and opens with a letter of dedication and thanks from Margaret to Charles Hutton. There is no printed response, but Hutton and many other eminent academics are listed as subscribers alongside the great and good of Georgian Society. These included Lady Scott at Great Barr Hall, Staffordshire, a venue used by members of The Lunar Society, a British dinner club for learned men, so-called because they preferred to gather when there was a full moon.[88]

In the preface Margaret seems to pre-empt negative judgment of the book by stating modestly that 'So many learned men having communicated their philosophical researches, and illustrated them by the sublimest mathematical demonstrations, it may appear vain and presumptuous in me to expect public notice', but she goes on to qualify her credibility by outlining her eight years' study of the facts, aided by seven years' practical experience.

Margaret's growth in confidence and faith in her abilities are apparent when she closes her address by saying 'I now with less timidity than formerly submit myself to the tribunal of public candour and criticism, having experienced its kind indulgence; and being encouraged by its reception of my first essay'.[89]

Sadly, these hopes were dashed when the book received a scathing review in *Monthly Literary Recreations*: 'Her style is awkward and uncouth; the expression imperfect and inadequate'. She is also accused here of plagiarizing two other authors: 'the work, upon the whole, seems to be only a compound of Ferguson's Lectures and Paley's Natural Theology'.[90]

The less-than-positive reception of her second book seemed to mark the start of a turbulent period in Margaret's life. In 1807, with her daughters entering young adulthood, Margaret finally decided to sell Bryan House.[91]

Both Bryan Houses, in Margate and Blackheath, were bombed during World War II. Dan Thompson, a writer and artist in Margate, has retained a single brick from the school's former location in Margate,[92] but not even that much remains of the Blackheath site. However, the building next to Bryan House in Blackheath, Paragon House, matches the original design of Bryan House and still stands today (Figure 6).[93]

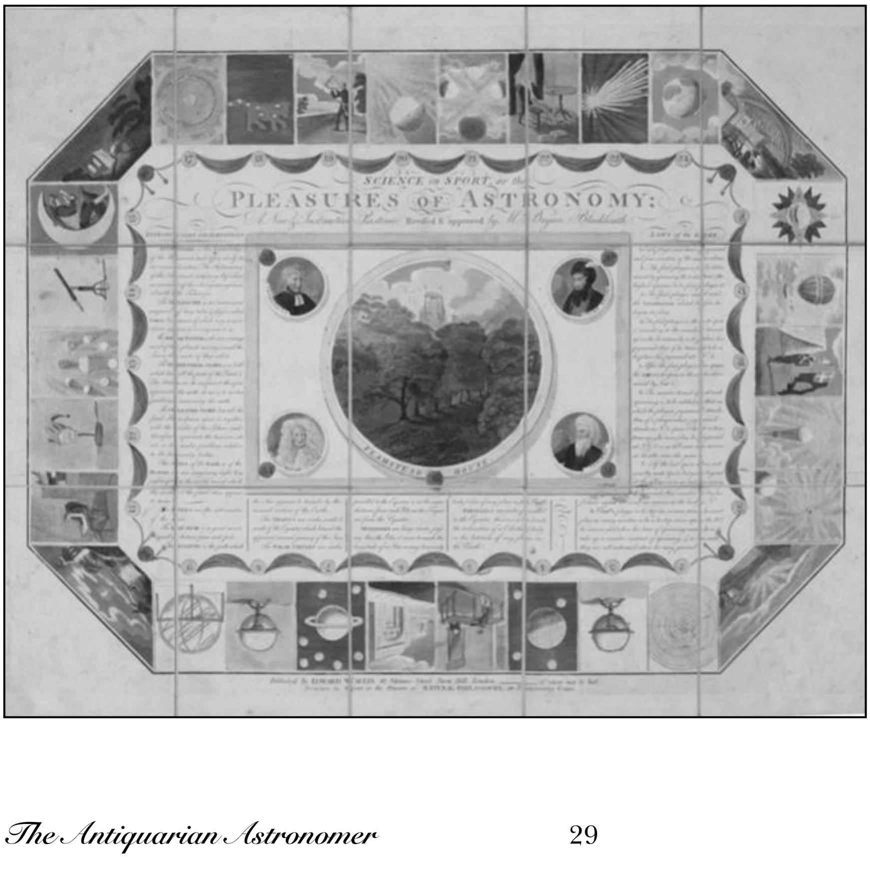

Fig. 5: 'The Pleasures of Astronomy' board game. (© Victoria and Albert Museum, London)

Fig. 6: The site on Blackheath of Bryan House today, with Paragon House on the other side of the road, on the left. (Author's photograph)

5. London and Bath

By 1808 Margaret had left Blackheath and moved to Lower Cadogan Place in Chelsea. It is possible that Margaret had relatives there. Wills show that Mary Bryan, a wealthy property heiress (d. 1835) and her husband Thomas Bryan, a Justice of the Peace and Deputy Lieutenant of Middlesex (d. 1830), owned numbers 18, 21, and 25 Upper Cadogan Place,[94] although neither of them were subscribers to Margaret's books. There is evidence from records held on Ancestry that Margaret lived for a time at number 21 Lower Cadogan Place and had a cook and housekeeper called Martha Green.[95]

5.1. *Financial struggles*

Despite her upper-class surroundings, records suggest Margaret was indeed in some financial difficulty. One of the subscribers to her second book was an E. D. Batson, who died in 1808. A record held at The National Archives lists debtors owing to Mr Batson at the time of his demise, and Margaret is listed as owing £1,052 (nearly £90k in today's money) in rent or mortgage arrears, although it is unclear for which property.[96]

At this time, eager to provide future security for her daughters and keen to ensure that her debts would be paid should she die, the document also shows that Margaret, then aged about 50, took out a life insurance policy with the London Life Assurance Company at Cannon Street.

A Mrs Compton of Booth Street, Spitalfields, was a subscriber to Margaret's second book and in 1806 a William Bryan and William Compton were partners in a cloth company on Booth Street. In 1806, a dyer called William Bryan of Booth Street appears in Boyd's roll as the father of an apprentice called Elijah Bryan, both possibly further relations.[97] Compton & Bryan went bankrupt in 1808, and the large premises they owned were sold off,[98] but it is unknown whether the financial misfortunes of this company have any association with Margaret.

5.2. *Gloucester Place*

By 1809 Margaret had moved again, this time to 1 Gloucester Place, Marylebone.[99] A series of letters written by Margaret held at the British Library demonstrate Margaret's business acumen. In 1811 January a member of her household wrote on her behalf to Messrs. Lackington & Co., a bookshop in Finsbury Square, to barter a sale of one of her publications. Lackington & Co. was one of the first modern bookstores, known as the 'Temple of the Muses' (Figure 7).[100]

Letter to Messrs. Lackington & Co., Finsbury Square, from 1 Gloucester Place, 1811:

> Mrs. Bryan presents her compliments to Messrs. Lackington & Co. and proposes to let them have the remainder of the copies of her Philosophy in sheets at the same price as before on condition that she may take out the value in school books as she may want them and any other books in their exchange catalogue.
>
> Mrs. Bryan has got the abridgement of the philosophical transactions in [*illegible*]

as published by Baldwin's Bridge Street, Blackfriars which she wishes to dispose of and begs to know what they will give her for that work. The favour of an early answer will oblige Mrs. Bryan.[101]

Two further letters dated 1811 February and 1813 November, held at the New York Public Library, show Margaret further negotiating sales with Lackingtons.[102] Part of a letter to Lackingtons, 1811 February:

Mrs. Bryan's compliments to Messrs. Lackington & Allen,

And if they will send from the books ordered on Monday [*illegible*], she will send them copies of the Philosophy in Boards, as before, as she thinks she has enough for that purpose; but she requests to know what will be the difference between these in sheets and those in boards for her future government.

Part of a letter to Lackingtons, date uncertain:

Mrs. Bryan requests the favour of Messrs. Lackington & Co. to send them by the lady who delivers this, a memorandum of the no. of copies of her work exchanged with them, at each time that she sold them a [*illegible*] of her Philosophy. Also, the dates if they can.

From her London rooftop, Margaret continued to observe the Universe and, ever the expert networker, in October of that year she wrote to William Herschel, evidently keen to retain and expand her connections within the scientific community. Letter to Dr William Herschel from 1 Gloucester Place, Portman Square, 1811 October 3:

Sir,

Will you pardon this intrusion? I once had the pleasure of being introduced to you by my friend Dr Hutton and was most delightfully and politely entertained by you at Slough and was particularly gratified by perceiving you had afforded me the distinction of placing my portrait in your study. I mention this circumstance that you may recollect who I am. I avail myself of the obliging attention I then received to solicit your kindness to communicate the result of your observations on the present comet so far as relates to its current path and its situation in respect to the sun and our earth.

I have for some time past been taking its right ascension and declination and by comparing them with the same of the sun, I conceive that it is departing from the sun and the earth and I am not supplied with the means of more accurate observation – when I had the pleasure of waiting on you I lived at Blackheath. My present residence

Fig. 7: The interior of Lackington & Co., trade card, hand-coloured aquatint (1809). Rendition of the interior of Lackington's 'Temple of the Muses' bookstore. (© The Trustees of the British Museum, CC BY-NC-SA 4.0)

is 1 Gloucester Place, Portman Square and your communications will be most gratefully received by her who with high esteem & respect for your abilities is very truly Sir, your very sensibly obliged humble servant, Margaret Bryan.

May I take the liberty to request you to present me most respectfully to Mrs. and Miss Herschel.[103]

By 1812 September Margaret had decided to vacate her home at 1 Gloucester Place. She stated her intention of retiring to her country residence in an advertisement in *The Morning Herald*, which paints an opulent picture of Margaret's home with its ebonized Grecian couches and mahogany four-poster bed.[104]

5.3. *A course of lectures*

Newspaper evidence also confirms that the country residence that Margaret referred to is 12 George Street, Bath. In 1813 March she announced in the *Bath Chronicle* her plans to deliver a series of lectures from that address, commencing December 23.[105]

That same year, Margaret also planned to host the same set of lectures in April at the Argyll rooms, an entertainment venue on Regent Street, London.[106] She placed a notice in the *London Courier and Evening Gazette* which also showed that Margaret's daughters were planning to earn money by giving music lessons.[107]

However, it seems that something catastrophic happened in Margaret's life some time during 1813 because by 1814 she was living in Lamb's Conduit Place, Holborn, and in a letter to a friend she referred to the cancellation of her planned 1813 lectures, blaming her 'deranged state of affairs'. Yet, despite this setback, Margaret once again flexed her networking muscles and requested the help of a Mr Hewlett to help promote her upcoming plans, as indicated by a letter she wrote on April 1:[108]

Dear Sir,

How very unfortunate it was for me to be from home when you so obligingly called at my apartments. I duly appreciate your friendly visit [*illegible*] intention in bringing Mr. Hewlett, I should long since have made my personal acknowledgements to you for your distinguishing attentions and flattering good opinion, expressed by allowing your daughters to attend my lectures last spring, had not the deranged state of my affairs prevented my having that satisfaction; allow me now to [*illegible*] with them, together for the same for your present very friendly exertions to promote my interest as communicated by Doctor Hutton, as well as evinced in your recent kind visit.

Should you again be this way, perhaps you will do me the honour of calling. I understand you are to be at Doctor Hutton's on Sunday, hoping that you may do me the favour of a call, I will remain at home to have the pleasure of receiving you. I would wait on you, but cannot walk so far and I know it is uncertain finding you at home and disengaged. I understand from Doctor Hutton that you are endeavouring to procure me a lady patronage for my lecture, should you be able to do so you will most essentially serve me. I know your influence with learned people so well that it will be a host in my favour. Mr Hewlett also may serve me very much in this neighbourhood and probably he will do me that kindness through your solicitation.

I will call on that gentleman if you approve of me doing so, you are already acquainted with our future plans. I now take the liberty of enclosing some cards of my lectures.

Margaret Bryan.

My best wishes to Mrs Kelly and love to the dear young ladies.[109]

Margaret was likely referring to the famed metrologist Patrick Kelly (1756–1842), who ran an Academy in Finsbury Square, close to Lackington's Bookshop and was a subscriber to her second book.[110]

Whatever misfortune caused Margaret to cancel her lectures, by 1814 September rumours were circulating that she had given up teaching, but she reasserted her position by placing a notice in *The Morning Post* that she intended to continue teaching. The address she lists is 31 Margaret Street, the home of Thomas Kearsley, the son of bookseller George Kearsley who had published Margaret's previous books.[111]

By 1815 February the debts that Margaret owed to E. D. Batson were still being paid back. In a statement of arrears, a repayment plan was outlined because of what was said to be Mrs Bryan's 'poverty'.[112]

5.4. *Third publication*

Yet despite her financial turmoil Margaret

Fig. 8: 48 Cadogan Place (formerly 21 Lower Cadogan Place) as it appears today. (Author's photograph)

continued to write. On 1815 November 11 her third and final book, *A Comprehensive Astronomical and Geographical Class-book, for the Use of Schools and Private Families*, was published.[113]

In this, the writing style is far more constrained and formal than in her previous books, with no hint of the lyrical and impassioned language that Margaret was known for. It opens with a far more earnest introduction where she expresses her hope that the book will be useful to 'children of both sexes and all ages'.[114] A notice printed on the opening page states that Margaret was conducting private tuition from 27 Lower Cadogan Place, near Hyde Park Corner.

Happily, the book received a glowing write-up in *The Critical Review*, and Margaret's reputation as a scientific educator was fully restored among the literary establishment, as this statement illustrates: 'The volume now before us will be found a very instructive companion to the globes, and is so perspicuous and well-arranged, that the want of any other teacher will scarcely be felt by the student'.[115]

On 1819 May 5 Margaret wrote again to Lackington & Co., this time from her residence at 21 Lower Cadogan Place (Figure 8):

> Mrs. Bryan presents her compliments to Messrs. Lackington & Co. and requests them to have two copies of her natural philosophy bound up in strong but not too expensive binding, the edges of the leaves yellow. Mr L told her that for each copy in sheets for the use of her seminary he would charge her only 12 [*illegible*] she will allow 8 for the binding to have it very neat and handsome but not too showy. She wishes to have them as soon as possible and if they are approved hopefully she may order more.[116]

Records suggest that it is likely that Margaret is the Lady referred to in a notice announcing the sale of belongings, including mathematical instruments, at 21 Lower Cadogan Place in 1824 June.[117]

6. Death and legacy

Sadly, in her later years Margaret developed dementia, referred to then as 'senility'. She died in 1836 in London at a property on Fortess Terrace.[118] Fortess Terrace covered the length of 28–98 Fortess Road and is featured on a map of the parishes of St Marylebone and St Pancras from 1834. Newspaper advertisements for properties at that address portrayed it as a sophisticated street full of large houses that offered beautiful and extensive views, so we can assume that Margaret enjoyed pleasant surroundings as her mental health declined.[119] The date of her death is confirmed as 1836 March 31 within the E. D. Batson Executorship document.

A simple yet poignant notice in *The Morning Post* publicly announced her death.[120] On the brink of the Victorian era Margaret was laid to rest on 1836 April 7 at St Luke's church in Chelsea.[121]

6.1. *Descendants*

Very few details are available about Margaret's eldest daughter, Anne Marian Bryan, who was born around 1784, most likely in Ireland. In 1816, aged about 32, she received an inheritance from an uncle, Thomas Nottidge, who left her land and property across Essex,[122] but I have not found mention of her in other wills. She died aged about 48 on 1833 August 11 in Euston Place, St Pancras, three years before the death of her mother.[123] Her cause of death is noted as 'decline' (probably tuberculosis). Anne was buried on August 14 at St Luke's church in Chelsea.[124]

The sole survivor of Margaret's family was Sarah, who was aged around 50 at the time of Margaret's death. According to the 1851 census she lived in Ipswich as an annuitant with her 57-year-old housekeeper, Elizabeth Rice, and 13-year-old servant Ann Cooper.[125] Sarah's birthplace is confirmed as Ireland.

Having already benefitted from the inheritance left to her in 1816 by her uncle, Thomas Nottidge, Sarah would also have been the primary beneficiary of Margaret's life insurance policy once any outstanding debts were paid in 1836.

Sarah received a further £1,000 (nearly £100k) from her cousin, the Reverend John Thomas Nottidge, in 1847[126] and £50 (£5,000) from Thomas Pinkett in 1839,[127] allowing her to live out a quiet and comfortable life in rural Suffolk. A notice was placed in the *Bury and Norwich Post* confirming that she was the cousin of J. T. Nottidge[128] and that she died on 1852 November 25 at her home on Albion Hill, aged 63.[129] Her death certificate states the cause of death as 'chronic marasmus mesenterica – upwards of a year'. This was a then-common disease, a tuberculosis of the abdominal cavity, which caused malnutrition ('marasmus'). In this period it was mostly a disease of infants, but could occur in adults as well.[130]

In her will, Sarah left her alabaster globe, her china ornaments, and her mother's portrait to a Sophia Moore of The Rectory in St Giles, Dorset. She left her plate linen, clothes, and £300 to her housekeeper Elizabeth, and her writing desk and seals to Agnes of the vicarage in Godmanchester. To Caroline Head she left her pearl brooch, and to Maria Gilder of Queen Anne Street, London, her quarto Bible in six volumes. She left all of her other household furniture, possessions, monies, and securities to her valued friend and the executor of her will, Reverend Walter Webb Woodhouse of Ipswich.[131]

Curiously, Sarah also referred to some books she bequeathed to 'the kind friends from whom I received them according to a list which will be found in my possession'. When the will was proved, Reverend Woodhouse stated that the list could not be found, but that the value of the books did not exceed three pounds (c.£500 today).

And so Margaret's direct line of family descent ended in 1852. Yet, as one of the earliest proponents of women's access to scientific education, Margaret left a legacy of inspiration to generations of chemists, physicists, astronomers, and engineers, amateur and professional alike.

7. Conclusions

Until recently, very little has been known about the details of Margaret Bryan's life, but conclusive evidence about her husband, children, career, and death have now come to light. Margaret married in 1783 in London to William Bryan, a merchant who died in Cork, Ireland, in 1788. They had two children, Anne Marian, who died in London in 1833, and Sarah Maria, who died in Ipswich in 1852.

Margaret and her daughters, who were themselves accomplished musicians, lived in various locations throughout the UK, including Bath, London, and Margate. Margaret died with dementia in 1836 and is buried at St Luke's church in Chelsea. Neither of her children married or had children of their own.

In her lifetime, Margaret demonstrated a fierce entrepreneurial spirit, which helped her endure grief, financial hardship, and professional criticism while proving herself to be a talented astronomer and renowned educator whose impressive networking and crowdfunding skills enabled her to distribute her educational textbooks through a wide range of libraries and booksellers.

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References and notes

1. Keller, Nicole Infanta, 'Making Her Case: Gendered Evidence and Women's Astronomical Writing of the Long Eighteenth Century', Northeastern University, Boston, Mass., PhD thesis 2018, chapter three.
https://repository.library.northeastern.edu/files/neu:cj82sv80n
2. Saridakis, Voula, 'The Astronomical and Educational Legacy of Margaret Bryan', *Culture and Cosmos*, 16 (2012), 241–2.
https://www.cultureandcosmos.org/pdfs/16/Saridakis_INSAPVII_Margaret_Bryan.pdf
3. Bryan, Margaret, *A Compendious System of Astronomy, in a Course of Familiar Lectures* (printed for the Author and sold by Leigh and Sotheby, and G. Kearsley, 1797), p. xi.
https://archive.org/details/compendioussyste00brya/page/n16/mode/1up
4. Bryan, Margaret, *Lectures on Natural Philosophy* (George Kearsley and James Carpenter, 1806).
https://archive.org/details/b22012850/page/n9/mode/2up
5. Ogilvie, Marilyn B., *Searching the Stars: The Story of Caroline Herschel* (The History Press, 2008).
6. Lindee, M. S., 'The American Career of Jane Marcet's Conversations on Chemistry, 1806–1853', *Isis*, 82 (1991), p. 10.
http://dx.doi.org/10.1086/355635
7. Chapman, Allan, *Mary Somerville and the World of Science* (Springer, 2015).
DOI: 10.1007/978-3-319-09399-4
8. Bryan, op. cit. (ref. 3), pp. 13, 18.
9. 'London, England, Church of England Marriages and Banns, 1754–1936', Reference Number: P69/Mic1/A/01/Ms 6990/1, Ancestry.co.uk, marriage of Margaret Haverkam and William Bryan.
https://www.ancestry.co.uk/discoveryui-content/view/1454269:1623?ssrc=pt&tid=179408357&pid=232339543143
10. 'Essex, England, Church of England Baptisms, Marriages and Burials, 1538–1812', Ancestry.co.uk, baptism of Margaret Haverkam.
https://www.ancestry.co.uk/discoveryui-content/view/1790050:61698?ssrc=pt&tid=179408357&pid=232339543143
11. Ibid., baptism of Oswald Haverkam.
https://www.ancestry.co.uk/discoveryui-content/view/1784320:61698?ssrc=pt&tid=179408357&pid=232339543418
12. Ibid., baptism of Sarah Wall.
https://www.ancestry.co.uk/discoveryui-content/view/1784028:61698?ssrc=pt&tid=179408357&pid=232339543463
13. Ibid., baptism of Margaret Haverkam.
https://www.ancestry.co.uk/discoveryui-content/view/1790050:61698?ssrc=pt&tid=179408357&pid=232339543143
14. 'England, Select Marriages, 1538–1973', Ancestry.co.uk, marriage of Oswald Haverkam to Sarah Wall.
https://www.ancestry.co.uk/discoveryui-content/view/3525531:9852?ssrc=pt&tid=179408357&pid=232339543418
15. Online article detailing the history of St George's Hanover Square: https://www.stgeorgeshanoversquare.org/history/handel-and-st-george.html
16. Clayton, Muriel, and Oakes, Alma, 'Early Calico Printers around London', *The Burlington Magazine*, 96 (1954), 135–9.
https://www.jstor.org/stable/i236447
17. Fabric UK, Calico Fabric History: https://blog.fabricuk.com/calico-fabric-origins/
18. The National Archives: Prerogative Court of Canterbury and related Probate jurisdictions, Will of Coen Haverkam, 1768 August 15. PROB 11/941/304.
https://discovery.nationalarchives.gov.uk/details/r/D503538
19. The National Archives: Prerogative Court of Canterbury and related Probate jurisdictions, Will of James Wall, 1774 November 11. PROB 11/1002/218.
https://discovery.nationalarchives.gov.uk/details/r/D456805
20. Girolami, Gregory S., 'Margaret Bryan: Newly Discovered Biographical Information about the Author of *A Compendious System of Astronomy* (1797)', *Notes and Records* (2023), 6–7.
https://royalsocietypublishing.org/doi/full/10.1098/rsnr.2022.0052
21. 'Essex, England, Church of England Baptisms, Marriages and Burials, 1538–1812', Ancestry.co.uk, burial of Sarah Haverkam, 1764 September 11.
https://www.ancestry.co.uk/discoveryui-content/view/1796830:61698?ssrc=pt&tid=179408357&pid=232339543463
22. 'England, Select Marriages, 1538–1973', Ancestry.co.uk, marriage of Oswald Haverkam to Mary Rutland.
https://www.ancestry.co.uk/discoveryui-

content/view/25677445:9852?ssrc=pt&tid=179408357&pid=232339543418

23. 'Essex, England, Church of England Baptisms, Marriages and Burials, 1538–1812', Ancestry.co.uk, birth of John Haverkam.
https://www.ancestry.co.uk/discoveryui-content/view/1792170:61698?ssrc=pt&tid=179408357&pid=232462088381
24. Ibid., birth of Sarah Haverkam.
https://www.ancestry.co.uk/discoveryui-content/view/102810825:9841?ssrc=pt&tid=179408357&pid=232462088012
25. Ibid., birth of Mary Haverkam.
https://www.ancestry.co.uk/discoveryui-content/view/99287688:9841?ssrc=pt&tid=179408357&pid=232462073383
26. Ibid., burial of Oswald Haverkam.
https://www.ancestry.co.uk/discoveryui-content/view/922398988:1624?ssrc=pt&tid=179408357&pid=232339543418
27. Ibid., burial of Mary Haverkam.
https://www.ancestry.co.uk/discoveryui-content/view/3003995:1624?ssrc=pt&tid=179408357&pid=232339543828
28. The National Archives: C 12 – 'Court of Chancery: Six Clerks Office: Pleadings 1758 to 1800', C 12/1634/2, 'Nottidge v Haverkam b.r.r', 1774.
https://discovery.nationalarchives.gov.uk/details/r/C9624932
29. 'Essex, England, Church of England Marriages, 1754–1937', Ancestry.co.uk, marriage of Thomas Nottidge.
https://www.ancestry.co.uk/discoveryui-content/view/1785349:61700?ssrc=pt&tid=179408357&pid=232436836338
30. The National Archives: Prerogative Court of Canterbury and related Probate jurisdictions, Will of Thomas Nottidge, 1816 June 15. PROB11/1581/211.
https://discovery.nationalarchives.gov.uk/results/r?_fn=Thomas&_ln=NOttidge&_occ=&_pl=essex&_q=&_sd=&_ed=&discoveryCustomSearch=true&_cr1=PROB+11&_col=200&_hb=tna
31. 'London, England, Church of England Baptisms, Marriages and Burials, 1538–1812', Ancestry.co.uk, burial of Oswald Haverkam.
https://www.ancestry.co.uk/discoveryui-content/view/1799099:61698?ssrc=pt&tid=179408357&pid=232436835618
32. 'UK, British Army and Navy Birth, Marriage and Death Records, 1730–1960', Ancestry.co.uk, British Officers and their Families; Class: WO 42; Piece: 021; Piece Description: Piece 021: H. 101–217 (1776–1881), marriage of James Haverkam.
https://www.ancestry.co.uk/discoveryui-content/view/334634:60931?ssrc=pt&tid=179408357&pid=232339543677
33. *Oxford English Dictionary*, s.v. 'half pay (n.)', July 2023.
https://doi.org/10.1093/OED/8678235309
34. Bryan, op. cit. (ref. 3).
35. 'London, England, Freedom of the City Admission Papers, 1681–1930', Ancestry.co.uk, Reference Number: COL/CHD/FR/02/1197-1202, Freedom of the City awarded to James Haverkam.
https://www.ancestry.co.uk/discoveryui-content/view/789491:2052?ssrc=pt&tid=179408357&pid=232339543677
36. *Survey of London*, English Heritage (2012), p. 4, via University College London online article:
https://www.ucl.ac.uk/bartlett/architecture/sites/bartlett/files/48.5_wellington_street_area.pdf
37. The National Archives: Prerogative Court of Canterbury and related Probate jurisdictions, Will of Joseph Green, Factor of West Ham, Essex, 1782 November 4. PROB 11/1097/36.
https://discovery.nationalarchives.gov.uk/details/r/D402999
38. The Worshipful Company of Parish Clerks, London, website article: https://londonparishclerks.smugmug.com/Parishes-Churches/Individual-Parish-Info/St-Michael-Bassishaw
39. Haley, Paul, 'In Search of Mrs Bryan: a working hypothesis', *SHA Bulletin*, 36 (2021), p. 40.
https://societyforthehistoryofastronomy.com/wp-content/uploads/2023/10/Bulletin-36-pdf.pdf
40. 'London, England, Land Tax Records, 1692–1932', Ancestry.co.uk, Land Tax record for William Bryan 1780.
https://www.ancestry.co.uk/discoveryui-content/view/15093528:2170?tid=&pid=&queryId=5e122fbc73484308ee56afc101dffda9&_phsrc=zsa1479&_phstart=successSource
41. 'ffolliott Newspaper Transcript Archive

1756–1850', Findmypast.co.uk, Estate of Rosemary ffolliot.

https://search.findmypast.co.uk/record?id=S2%2FIRE%2FWATERFORD%2FFFFOLLIOTT-REGISTERS-51%2F00194&parentid=IRE%2FFFFOLLIOTT%2FNP2%2F007357

42. 'Ireland Diocesan and Prerogative Wills & Administrations indexes 1595–1858', Findmypast.co.uk, record of death of William Bryan in Cork.

    https://search.findmypast.co.uk/record?id=IRE%2FDIOC%2F007246605%2F00252&parentid=IRE%2FDIOC%2FWILL%2F00077223

43. 'Ireland Diocesan and Prerogative Wills & Administrations indexes 1595–1858', Findmypast.co.uk, record of Administration Bond for William Bryan in Cork.

    https://search.findmypast.co.uk/record?id=IRE%2FDIOC%2F007246587%2F00162&parentid=IRE%2FDIOC%2FWILL%2F00195410

44. *Dublin Gazette 1750–1800*, Findmypast.co.uk, notice of William Bryan's death and Administration of affairs.

    https://search.findmypast.co.uk/record?id=GBOR%2FDUBLIN-GAZETTE%2FDC016847%2F0501&parentid=GBOR%2FDUB-GAZ%2F0324644

45. Firth, Edith G., 'Willcocks, William', *Dictionary of Canadian Biography*, Vol. 5 (University of Toronto/Université Laval, 1983), online dictionary.

    http://www.biographi.ca/en/bio/willcocks_william_5E.html

46. Ireland, Betham Genealogical Abstracts of records of the Prerogative Court of Armagh 1179–1830, FamilySearch.org: Letter of Administration, William Bryan, 1789.

    https://www.familysearch.org/ark:/61903/1:1:6JXT-S25Q

47. The National Archives: Prerogative Court of Canterbury and related Probate jurisdictions, Will of William Bryan, Merchant of Dublin, 1798 March 17. PROB 11/1303/164.

    https://discovery.nationalarchives.gov.uk/details/r/D336174

48. *Dictionary of Irish Biography*, online database: https://www.dib.ie/biography/newport-sir-simon-john-a6181

49. *Wilson's 1820 Dublin Directory*, Ancestry.co.uk, address of Robert Bryan, 20 Eccles Street, Dublin.

    https://www.ancestry.co.uk/discoveryui-content/view/7044:70781?ssrc=pt&tid=187118010&pid=402443811936

50. Murden, Sarah, 'The Colour of Mourning' (2020), online article: https://georgianera.wordpress.com/2020/06/17/the-colour-of-mourning/

51. Bryan (1806), op. cit. (ref. 4), p. 290.

52. Ibid., p. 293.

53. Nottidge, J. T., Buchanan, C., and Bridges, C., *A Selection from the Correspondence of the Rev. J. T. Nottidge, M.A., Late Rector of St. Helen's, and St. Clements, Ipswich* (Seeleys, 1849), p. 8.

54. British Newspaper Archive, *Kentish Gazette*, 1791 March 11.

    https://www.britishnewspaperarchive.co.uk/viewer/bl/0000235/17910311/006/0001

    Lady Day, the Feast of the Annunciation, was a legal Quarter Day when rents and fees were paid.

55. 'Register of Duties Paid for Apprentices' Indentures, 1710–1811', Collection: Board of Stamps: Apprenticeship Books: Series IR 1; Class: IR 1; Piece: 66, Ancestry.co.uk, record of indenture for Mary LeGeyt.

    https://www.ancestry.co.uk/discoveryui-content/view/689712:1851?ssrc=pt&tid=179408357&pid=232339543143

56. British Newspaper Archive, *Kentish Weekly Post or Canterbury Journal*, 1797 February 3.

    https://www.britishnewspaperarchive.co.uk/viewer/bl/0001409/17970203/012/0004

57. Prescott, S., 'Making a Living: Booksellers, Patronage and Subscription', in: *Women, Authorship and Literary Culture 1690–1740* (Palgrave Macmillan, 2003).

    https://doi.org/10.1057/9780230597082_5

58. British Newspaper Archive, *Kentish Gazette*, 1797 April 4.

    https://www.britishnewspaperarchive.co.uk/viewer/bl/0000235/17970404/004/0001

59. Bryan, op. cit. (ref. 3), p. ix.

60. Ibid.

61. *The Monthly Visitor, and Pocket Companion*, 8 (1799), p. 93.

    https://babel.hathitrust.org/cgi/pt?id=nyp.33433081756706&view=1up&seq=101&q1=margaret+bryan

62. *The Lady's monthly museum, or Polite repository of amusement and instruction: being an assemblage of whatever can tend to please the fancy, interest the mind, or exalt the character of the British fair. By a society of ladies*, 7 (1801), p. 74.

    https://babel.hathitrust.org/cgi/pt?id=chi.74726059&view=1up&seq=87&q1=margaret+bryan

63. Online excerpt from The Irish Art Group: https://irishartgroup.co.uk/works/ulster-1786-thomas-conder/
64. Painting by miniaturist Samuel Shelley on display at The Herschel Museum in Bath, England.
https://herschelmuseum.org.uk/explore/
65. The Exhibition of the Royal Academy, MDCCXCVII [1797].
https://www.royalacademy.org.uk/art-artists/exhibition-catalogue/ra-sec-vol29-1797?all_fields=shelley&commit=Search&date=1797&form=exhibition_catalogues&index=1&q=shelley&title=&total_entries=1&utf8=%E2%9C%93
66. Milestones of Science Books, Ritterhude, Germany.
https://www.milestone-books.de/pages/books/003362/margaret-bryan/a-compendious-system-of-astronomy-in-a-course-of-familiar-lectures?soldItem=true
67. The National Archives: Prerogative Court of Canterbury and related Probate jurisdictions, Will of Thomas Pinkett, Solicitor, 1839 August 24. PROB 11/1915/246.
https://discovery.nationalarchives.gov.uk/details/r/D613371
68. National Archives of Ireland, online educational article: https://www.nationalarchives.ie/PDF/1798.pdf
69. British Newspaper Archive, *Kentish Weekly Post or Canterbury Journal*, 1798 April 13.
https://www.britishnewspaperarchive.co.uk/viewer/bl/0001409/17980413/005/0001
70. British Newspaper Archive, *Kentish Weekly Post or Canterbury Journal*, 1798 May 11.
https://www.britishnewspaperarchive.co.uk/viewer/bl/0001409/17980511/002/0001
71. British Newspaper Archive, *Oracle and Daily Advertiser*, 1801 September 23.
https://www.britishnewspaperarchive.co.uk/viewer/bl/0002428/18010923/005/0001
72. Anon., *Picture of Margate, Being a Complete Guide to All Persons visiting Margate, Ramsgate, and Broadstairs* (Bousfield & Co., 1809), p. 36.
https://books.google.co.uk/books?id=nqNfAAAAcAAJ&pg=PA36#v=onepage&q&f=false
73. Online article, 'Scottish Golf History': https://www.scottishgolfhistory.org/oldest-golf-clubs-societies/1766-royal-blackheath-golf-club/
74. 'Church of England Baptisms, Marriages and Burials, 1538–1812', London Church of England Parish Registers; Reference Number: P86/Mry/006, Ancestry.co.uk, burial record of Joseph Nesbitt Bryan, 1799.
https://www.ancestry.co.uk/imageviewer/collections/1624/images/32184_218921-00177?pId=30145668
75. British Newspaper Archive, *Hampshire Chronicle*, 1798 November 19.
https://www.britishnewspaperarchive.co.uk/viewer/bl/0000230/17981119/023/0004
76. Searles, Michael, 'Design for Bryan House, South Row, Blackheath, London: elevation of street front', online catalogue, RIBA Collections, SC112/17.
https://www.ribapix.com/design-for-bryan-house-south-row-blackheath-london-elevation-of-street-front_riba67229
77. The Blackheath Society Archive, Blackheath – Cator Estate, 00067. South Row including Bryan House.
Online catalogue: https://www.blackheatharchive.org/p266919089/ha08c1d87#ha08c1d87
78. Kent History and Library Centre, Cobb of Margate Family and Business Papers, correspondence with Mrs. M. Bryan of Blackheath, 1800. EK-U1453/B3/15/270.
https://discovery.nationalarchives.gov.uk/details/r/1bea0fab-fe92-4987-be2b-a95bd052d212
79. British Newspaper Archive, *Porcupine*, 1800 November 10.
https://www.britishnewspaperarchive.co.uk/viewer/bl/0002586/18001110/030/0001
80. British Newspaper Archive, *Star (London)*, 1804 November 8.
https://www.britishnewspaperarchive.co.uk/viewer/bl/0002646/18041108/006/0001
81. Anon., *The Little English Girl; A Tale for Children* (Simms and McIntyre, undated), 9–10.
https://archive.org/details/littleenglishgir00belfiala/mode/2up
82. British Newspaper Archive, *The Morning Post*, 1804 August 13.
https://www.britishnewspaperarchive.co.uk/viewer/bl/0000174/18040813/002/0004
83. British Newspaper Archive, *Leeds Intelligencer*, 1803 June 20.
https://www.britishnewspaperarchive.co.uk/viewer/bl/0000236/18030620/005/0002
84. *Science in sport, or, The Pleasures of Astronomy; a new & Instructive Pastime. Revised and approved by M. Bryan, of Blackheath, London* (Edward Wallis, 1804).
https://hdl.handle.net/10079/bibid/13690672
85. National Maritime Museum, Greenwich, London, online catalogue: https://

www.rmg.co.uk/collections/objects/rmgc-object-264736

86. British Newspaper Archive, *Sun (London)*, 1805 November 15.

    https://www.britishnewspaperarchive.co.uk/viewer/bl/0002194/18051115/002/0001

87. Bryan (1806), op. cit. (ref. 4), preface.
88. Schofield, Robert E., *The Lunar Society of Birmingham: A Social History of Provincial Science and Industry in Eighteenth-century England* (Clarendon Press, 1963).
89. Bryan (1806), op. cit. (ref. 4), preface.
90. *Monthly Literary Recreations, or, Magazine of general information and amusement*, 1 (1807), p. 157.

    https://hdl.handle.net/2027/chi.79289135?urlappend=%3Bseq=191

91. British Newspaper Archive, *Sun (London)*, 1807 June 10.

    https://www.britishnewspaperarchive.co.uk/viewer/bl/0002194/18070610/002/0001

92. Bailes, Kathy, 'Margate artist uncovers town's first "crowdfunder" – in the 18th century', *The Isle of Thanet News*, 2018 September 13.

    https://theisleofthanetnews.com/2018/09/13/margate-artist-uncovers-towns-first-crowdfunder-in-the-18th-century/

93. Searles, Michael, 'Design for Paragon House, South Row, Blackheath, London: plan and elevation of front to South Row', online catalogue, RIBA Collections, SC112/16.

    https://www.ribapix.com/Design-for-Paragon-House-South-Row-Blackheath-London-plan-and-elevation-of-front-to-South-Row_RIBA67228

94. The National Archives: Prerogative Court of Canterbury and related Probate jurisdictions, Will of Mary Bryan, 1835 March 9. PROB 11/1843/353.

    https://discovery.nationalarchives.gov.uk/details/r/D257632

95. Ancestry.co.uk. London, England, Selected Poor Law Removal and Settlement Records, 1698–1922 citing London Metropolitan Archives; Dublin, Ireland; London Poor Law Registers, Mrs. Margaret Bryan, Settlement papers.

    https://www.ancestry.co.uk/discoveryui-content/view/394935:2651?ssrc=pt&tid=179408357&pid=232339543143

96. Lincolnshire Archives, Executorships and Trusteeships (including wills), Executorship of E. D. Batson [banker] (d. 1808). 1 FANE 5/10.

    https://discovery.nationalarchives.gov.uk/details/r/0c69509e-b5b2-4eb1-87c5-49a061335738

97. Records of London's Livery Companies online, Apprentices and Freemen 1400–1900, 1805 December 4.

    https://www.londonroll.org/event/?company=clw&event_id=CLEB19749

98. British Newspaper Archive, *National Register (London)*, 1808 April 25.

    https://www.britishnewspaperarchive.co.uk/viewer/bl/0002644/18080425/045/0009

99. 'London, England, Land Tax Records, 1692–1932', London Metropolitan Archives, Ancestry.co.uk, Land Tax record for Margaret Bryan, 1809.

    https://www.ancestry.co.uk/discoveryui-content/view/515881:2170?ssrc=pt&tid=179408357&pid=232339543143

100. Lackington, J., *Memoirs of the First Forty-Five Years of the Life of James Lackington* (printed and sold by the author, 1791).

     https://www.britishmuseum.org/collection/term/BIOG158211

101. British Library, Evelyn Papers. Vol. dxix. Letters and documents, 41–43. Margaret Bryan to Messrs Lackington; 1811–1819, n.d.

     https://searcharchives.bl.uk/primo-explore/fulldisplay?docid=IAMS040-002037642&vid=IAMS_VU2&search_scope=LSCOP_BL&tab=local&lang=en_US&context=L

102. Carl H. Pforzheimer Collection of Shelley and His Circle, New York Public Library, Astor, Lenox, and Tilden Foundations.
103. Royal Astronomical Society Library, RAS MSS Herschel W.1, 3 Oct. 1811, 13.B.162.

     https://ras.ac.uk/library/about-the-library%3Fid%3D78

     This was the Great Comet of 1811, which was visible to the naked eye for longer than any other comet before Hale-Bopp (1997).

104. British Newspaper Archive, *Morning Herald (London)*, 1812 September 19.

     https://www.britishnewspaperarchive.co.uk/viewer/bl/0002408/18120919/035/0004

105. British Newspaper Archive, *Bath Chronicle and Weekly Gazette*, 1813 March 18.

     https://www.britishnewspaperarchive.co.uk/viewer/BL/0000221/18130318/008/0002?browse=False

106. *Survey of London, Volumes 31 and 32, St James Westminster, Part 2* (London County Council, 1963), 284–307.

     https://www.british-history.ac.uk/survey-london/vols31-2/pt2/pp284-307#h3-0014

107. British Newspaper Archive, *London Courier and Evening Gazette*, 1813 April 6.

https://www.britishnewspaperarchive.co.uk/viewer/bl/0001476/18130406/001/0001

108. The year is hard to interpret, but 1814 would correspond with the date of the advertised lectures.
109. British Library, Evelyn Papers. Vol. dxix. Letters and documents, 41–43. Margaret Bryan to Messrs Lackington; 1811–1819, n.d.

    https://searcharchives.bl.uk/primo-explore/fulldisplay?docid=IAMS040-002037642&vid=IAMS_VU2&search_scope=LSCOP_BL&tab=local&lang=en_US&context=L
110. Kelly, Patrick, by Robert Edward Anderson, *Dictionary of National Biography, 1885–1900*.

    https://en.wikisource.org/wiki/Dictionary_of_National_Biography,_1885–1900/Kelly,_Patrick
111. British Newspaper Archive, *The Morning Post*, 1814 September 2.

    https://www.britishnewspaperarchive.co.uk/viewer/bl/0000174/18140902/002/0004
112. Lincolnshire Archives, Executorships and Trusteeships (including wills), Executorship of E. D. Batson [banker] (d. 1808). 1 FANE 5/10.

    https://discovery.nationalarchives.gov.uk/details/r/0c69509e-b5b2-4eb1-87c5-49a061335738
113. British Newspaper Archive, *The Globe*, 1815 November 11.

    https://www.britishnewspaperarchive.co.uk/viewer/BL/0001651/18151111/005/0001?browse=False
114. Bryan, Margaret, *A Comprehensive Astronomical and Geographical Class-book for the Use of Schools and Private Families* (Baldwin, Cradock, and Joy, 1815), p. 4.
115. *The Critical review, or, Annals of literature*, Ser. 5, Vol. 3 (1816 January–June), p. 89.

    https://babel.hathitrust.org/cgi/pt?id=nyp.33433066597117&seq=8&q1=Bryan.
116. British Library, Evelyn Papers. Vol. dxix. Letters and documents, 41–43. Margaret Bryan to Messrs Lackington; 1811–1819, n.d.

    https://searcharchives.bl.uk/primo-explore/fulldisplay?docid=IAMS040-002037642&vid=IAMS_VU2&search_scope=LSCOP_BL&tab=local&lang=en_US&context=L
117. British Newspaper Archive, *Morning Herald (London)*, 1824 June 25.

    https://www.britishnewspaperarchive.co.uk/viewer/bl/0002408/18240625/088/0004
118. 'London, England, Church of England Deaths and Burials, 1813–2003', Ancestry.co.uk, death of Margaret Bryan, 1836 April 7. P74/Luk/284.

    https://www.ancestry.co.uk/discoveryui-content/view/9018224:1559?ssrc=pt&tid=179408357&pid=232339543143
119. British Newspaper Archive, *Morning Herald (London)*, 1832 May 22.

    https://www.britishnewspaperarchive.co.uk/viewer/bl/0002408/18320522/115/0002
120. British Newspaper Archive, *The Morning Post*, 1836 April 8.

    https://www.britishnewspaperarchive.co.uk/viewer/bl/0000174/18360408/033/0004
121. 'London, England, Church of England Deaths and Burials, 1813–2003', Ancestry.co.uk, burial of Margaret Bryan, 1836 April 7 at St Luke's Church, Chelsea, London. P74/Luk/263.

    https://www.ancestry.co.uk/discoveryui-content/view/9058994:1559?ssrc=pt&tid=10516760&pid=262414312392
122. The National Archives: Prerogative Court of Canterbury and related Probate jurisdictions, Will of Thomas Nottidge, 1816 June 15. PROB11/1581/211.

    https://discovery.nationalarchives.gov.uk/results/r?_fn=Thomas&_ln=NOttidge&_occ=&_pl=essex&_q=&_sd=&_ed=&discoveryCustomSearch=true&_cr1=PROB+11&_col=200&_hb=tna
123. British Newspaper Archive, *The Morning Post*, 1833 August 16.

    https://www.britishnewspaperarchive.co.uk/viewer/bl/0000174/18330816/041/0004
124. England, Select Deaths and Burials, 1538–1991, Ancestry.co.uk: burial of Marian Bryan, 1833 August 14.

    https://www.ancestry.co.uk/discoveryui-content/view/46408:9840?tid=&pid=&queryId=5a175d95be0a66d1a965c3bc7ea6db03&_phsrc=zsa1523&_phstart=successSource
125. Ancestry.co.uk. England Census citing Census Returns of England and Wales, 1851. The National Archives: Public Record Office (PRO), 1851, Class: HO107; Piece: 1800; Folio: 469; Page: 26; GSU roll: 207449, census for residence of Maria Sarah Bryan.

    https://www.ancestry.co.uk/discoveryui-content/view/4898506:8860?tid=&pid=&queryId=b7959edb3f1dad5aa3548247cffe9596&_phsrc=zsa1522&_phstart=successSource
126. The National Archives: Prerogative Court of Canterbury and related Probate

jurisdictions, Will of Reverend John Thomas Nottidge, Clerk of Ipswich, Suffolk, 1847 May 3. PROB 11/2056/215.

https://discovery.nationalarchives.gov.uk/details/r/D120274

127. The National Archives: Prerogative Court of Canterbury and related Probate jurisdictions, Will of Thomas Pinkett, Gentleman of Lambeth, Surrey, 1839 August 24. PROB 11/1915/246.

https://discovery.nationalarchives.gov.uk/details/r/D613371)

128. British Newspaper Archive, *Bury and Norwich Post*, 1852 December 1.

https://www.britishnewspaperarchive.co.uk/viewer/bl/0000156/18521201/024/0002

129. 'England & Wales, Civil Registration Death Index, 1837–1915', Ancestry.co.uk, registration of death for Sarah Maria Bryan.

https://www.ancestry.co.uk/discoveryui-content/view/4655116:8914?tid=&pid=&queryId=57a5a838a170850dd58952b3f0e0f8d2&_phsrc=zsa1454&_phstart=successSource

130. Breathnach, C. S., Moynihan, J. B., 'William Wilde and the Early Records of Consumption in Ireland', *Ulster Medical Journal,* 80 (2011), 42–48.

131. The National Archives: Prerogative Court of Canterbury and related Probate jurisdictions, Will of Sarah Maria Bryan, Spinster, Suffolk, 1852 December 20. PROB 11/2162/381.

https://discovery.nationalarchives.gov.uk/details/r/D30455

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Mary Watson Whitney:
From Vassar to Nantucket (1901–16)

Paul A. Haley

Vassar College Observatory (VCO) was initially directed by America's first professional woman astronomer, Maria Mitchell. Her successor as Professor of Astronomy was Mary Watson Whitney (1847–1921), who in turn nurtured a strong partnership with student Caroline Ellen Furness (1869–1936). In this paper the astronomical work of Mary Whitney and Caroline Furness is examined across each lustrum (5-year period) for the years 1901–16. Significant relationships with other American observatories are explored. These intertwined areas contributed to both the international legacy of Maria Mitchell and the numerous women astronomers trained at Vassar, and provide insights into how the life of Maria Mitchell inspired successive generations of women trained in America.

1. Introduction

The writer's first paper on Mary Whitney's period in office from 1880 to 1901 appeared in *The Antiquarian Astronomer* in 2023.[1] This second paper covers the period to 1916 and completes the writer's quintet of contributions on women astronomers in the United States.[2] A continuing theme throughout the series is the exploration of the legacy of the first professor of astronomy at Vassar College, Maria Mitchell (1818–89), while a secondary theme links to the career of Williamina (Mina) Fleming (1857–1911) at Harvard College Observatory (HCO), whose astronomical career paralleled Mary Whitney's.

2. Mary Whitney's fourth lustrum (1901–06)

On Saturday afternoon 1903 January 31 Mary Whitney (Figure 1), director of Vassar College Observatory, arrived at Delmonico's, the famous fine-dining restaurant on the corner of Fifth Avenue and 44th Street in New York City. She had travelled by train seventy miles south from Poughkeepsie on a dry cold winter's day for the inaugural meeting of the Nantucket Maria Mitchell Association. As chairman she knew the group of ladies in the restaurant would be excited to hear her views, not least because she had first met the celebrated astronomer after whom the Association was named over three decades earlier.

A few hours later, having enjoyed its excellent cuisine, she left the restaurant as the newly elected president of the Association. Other women had taken office as vice-presidents, treasurer, and secretary; a Nantucket group had volunteered to form the house committee. Mary, Eliza, and Lydia, cousins of Maria Mitchell, had opted to initially play their roles in the background, having already secured the Memorial House.

As well as the honour of becoming president of the Nantucket Maria Mitchell Association, during her fourth lustrum at Vassar Mary Whitney consolidated her astrophysics courses, trained graduates to work in the major American observatories, initiated the productive observation of variable stars at VCO, and secured Carnegie funding for a computer team to reduce a second North Polar Catalogue.

2.1. *Variable stars (1901–02)*

As the 20th century began the Astronomy Department of Vassar College held a unique position. Delivery of VCO undergraduate and postgraduate courses reflected the growing demand for training in astrophysics and ensured students were equipped with skills for both data acquisition and the best methods for reduction and analysis. In part this was due to excellent role models for the students with exemplary practice for networking, observation, and publication of papers. Other American colleges had yet to achieve the VCO model for efficiency and their growth was restricted by inadequate funding.

The development of the study of astronomy across American universities in the late 19th and early 20th centuries is summarized in Table 1.

Mary Whitney was acutely aware of the traditional tensions facing her students, namely careers too often spent in collegiate teaching, with limited potential; family responsibilities, especially for unmarried daughters; relocation expenses, for graduates moving to opportunities near the west coast; and limited intellectual debate or peer-assessment of papers.[3] The prevailing view remained that women were ill-equipped for night observing and better suited to low-paid office working, reducing observations made by male colleagues.

A good example of the dilemma faced by a young woman seeking an astronomical career involved Mary Swain Wagner (1869–1937). Three years after working for Mary Whitney this former Vassar student graduated in 1897 at the University of Minnesota. Her work included measures of three double stars with the Minneapolis 10-inch equatorial, under the direction of Francis (Frank) Preserved Leavenworth (1858–1928).[4] After graduation she taught astronomy part-time to high-school educators, but a permanent position proved impossible. Mary Wagner resumed her life in Poughkeepsie and employed a local architect to design a small boarding inn near the college. A year later (1902 fall), working with another Vassar graduate, accommodation was offered to visiting parents and the tea-room proved popular with both students and Vassar staff; the Wagner Inn operated for fifteen years.[5]

Having established her astrophysics course, with thirty students in 1900–01, Mary Whitney believed a way to induce a paradigm shift for women was to secure opportunities in the growing number of American observatories. Teaching careers continued to be the main career paths for most graduates. Women computers offered a partial solution, with Columbia University recruiting some Vassar alumnae. The largest computing team, led by Williamina (Mina) Fleming in Cambridge, offered few vacancies; her efficient approach ensured most women remained in post for life.[6] Fortunately, Yerkes Observatory needed computers and Mary enjoyed a good working relationship with both director George Ellery Hale (1868–1938) and Edwin Brant Frost (1866–1935). (Key people at VCO are listed in Table 2.)

Fig. 1: Mary Watson Whitney, first president of the Nantucket Maria Mitchell Association, c.1905. (MMA Archives)

A new international link followed VCO's invitation by the Astronomische Gesellschaft in Germany to help secure definitive orbits of comets. Graduate student Elizabeth Buchanan Cowley (1874–1945) was assigned comet 1826 II by Heinrich Kreutz (1854–1907) and she calculated its orbit for her A.M. degree.[7]

Meanwhile, VCO work on the polar plates had stalled, due to larger classes in descriptive astronomy and the greater number of graduate students needing support. To increase her computing team Mary sought alternative funding. A welcome distraction was the visit of Sir Robert Ball (1840–1913), whom Mary and Caroline Furness had met in Cambridge in

Table 1

Astronomy in American colleges

Institution	Founder	Astronomy	Instruments	Astronomy Department
Amherst College Amherst Massachusetts	1821	1825 – Astronomy courses begin 1848 – Lawrence Observatory // 50-ft octagon tower + 17-ft dome 1903 – Wilder Obs // 33-ft dome	1853 – 7-inch Clark, $2k 1905 – 18-inch Clark, $12k	**William Cole Esty** (1838–1916) '60 … also taught at Smith College '76–81 **David Peck Todd** (1855–1939) '75, '78 [1881–….] Also, Smith '82–86 // solar eclipse expeditions ('78–19)
Carleton College Observatory Northfield Minnesota	C. Goodsell 1866	1882 – *Sidereal Messenger*, 1893 *Popular Astronomy* 1887 – Goodsell Obs // 1892 *Astro & Astrophysics* 1904 – Mary Emma Byrd PhD (Payne) // asst '83–87	1878 – 8-inch Clark + Obs, $7k 5-inch Repsold meridian circle 16-inch Brashear '90, $15k	**William Wallace Payne** (1837–1928) '63, '66 [1871–1908] time service with meridian instruments, '88 **Herbert Couper Wilson** (1858–1940) [1887–1926]
Columbia College Morningside Heights New York	1857	1900 – Caroline Ellen Furness PhD (Jacoby) 1906 – Anne Sewell Young PhD (Jacoby) 1907 – Wilde Observatory	1884 – 13-inch Rutherfurd equatorial 1897 – computing bureau Repsold measuring machines	**John Krom Rees** (1851–1907) '72, '95 [1881–1902] **Harold Jacoby** (1865–1932) '85, '96 [1885–1920] Rutherfurd plate measures // solar parallax // geodesy
Harvard College Cambridge Massachusetts	Massachusetts Bay Colony 1636	1875 – women computers, $500 per year 1881 – **Williamina Fleming** (1857–1911) [1881–1911] 1886 – Henry Draper Memorial // Harvard Plate Store 1895 – HCO *Circulars* // photometry // spectroscopy	1847 – 15-inch Merz equatorial, $26k 1870 – 8-inch T&S meridian circle 1885 – 8-inch astrograph 1890 – 13-inch (Arequipa)	**William Cranch Bond** (1789–1859) [1839–59] **George Phillips Bond** (1825–65) [1859–65] **Joseph Winlock** (1826–75) [1866–75] **Edward Charles Pickering** (1846–1919) [1877–1919]
Mount Holyoke College South Hadley Massachusetts	Mary Lyon 1837	1851 – small observatory // sunspots 1881 – John Payson Williston Obs, 18-ft dome, $10k 1888 – collegiate … first graduates, class of '93 1896 – $350 // 330 students, 61 taking Astronomy	1853 – 6-inch Fitz refractor 1881 – 8-inch Clark equatorial 1881 – 3-inch Fauth meridian circle	**Elisabeth Miller Bardwell** (1831–99) [1866–99] **Anne Sewell Young** (1871–1961) '92, '97 [1899–1936] '00 – observational course // sunspots '02 – celestial mechanics // variables

Institution	Founder	Astronomy	Instruments	Astronomy Department
Smith College Northampton Massachusetts	Sophia Smith 1871	1879 – collegiate … first graduates // 1891 – AM 1892 – over 125 students // 1894 – assistant 1899 – *Laboratory Manual in Astronomy* 1913 – *First Observations in Astronomy*	11-inch Merz + Warner & Swasey equatorial 4-inch f/10 Warner & Swasey meridian circle	**Mary Emma Byrd** (1849–1934) [1887–1906] $1000/year ’88 – Longitude (+ Mary Whitney) // comets ’06 – resignation (Carnegie funding issue) **Harriet Williams Bigelow** (1879–1934) ’93, ’04 [1906–1934]
Swarthmore College Philadelphia Pennsylvania	Deborah Wharton Society of Friends 1864	1869 – $350 per year, tuition & board // ’73 collegiate 1888 – Cunningham Observatory, 15-ft dome 1903 – $450 per year, tuition & board 1913 – Sproul Observatory, 45-ft dome	1868 – 6-inch Clark equatorial 1868 – 3-inch Clark transit 1908 – 9-inch f/7 astrograph 1912 – 24-inch f/18 equatorial	**Susan Jane Cunningham** (1842–1921) [1867–1906] ’66 – VCO + HCO + Princeton + Cambridge + RGO **John Anthony Miller** (1859–1946) ’99 [1906–36] solar eclipses // parallax
Vassar College Poughkeepsie New York	Matthew Vassar 1861	1865 – $350 per year, tuition & board // ’68 collegiate 1865 – Vassar College Observatory, 26-ft dome 1871 – sunspot photography // ’72 AM degrees 1909 – $500 per year, tuition & board	1865 – 12-inch Fitz equatorial 1865 – 3.7-inch Young transit 1888 – 5-inch Clark equatorial 1896 – Repsold measuring machine	**Maria Mitchell** (1818–89) Nantucket [1818–61], [1865–86] **Mary Watson Whitney** (1847–1921) ’68, ’72 [1881–1915] Astrophysics courses, variable stars, graduate students **Caroline Ellen Furness** (1869–1936) ’91, ’00 [1894–1936]
Wellesley College Wellesley Massachusetts	Henry & Pauline Durant 1870	1880 – Astronomy courses // **Annie Jump Cannon** ’84 1900 – Whitin Observatory, 20-ft dome // 1906 – celestial mechanics	1880 – 6-inch Fitz equatorial 1900 – 12-inch Fitz/Clark equatorial 1900 – 3-inch transit	**Sarah Francis Whiting** (1847–1927) ’65 [1876–1916] physicist // observed with Pickering at MIT // 1896 – X-rays **Ellen Amanda Hayes** (1851–1930) ’78 [1879–1916]
Yale College New Haven Connecticut	1718	1830 – The Atheneum Observatory 1884 – stellar parallax 1889 – **Margaretta Palmer** (1862–1924) ’94 PhD Yale	1828 – 5-inch Dollond, $1.2k 1870 – 9-inch Clark equatorial 1882 – 6-inch Repsold heliometer	**Hubert Anson Newton** (1830–96) ’50 [1856–96] Leonids // meteors and comets **William Lewis Elkin** (1855–1933) ’80 [1884–1910] parallax

Notes:
Names shown in bold are mentioned in the text.
Figures between square brackets indicate years at institution; double-digit figures preceded with an apostrophe indicate year of degree.
Anne Sewell Young – one of the 8 original members (only woman) of the AAVSO, in 1911 founded by William Tyler Olcott // 37y at MHC // BL degree at Carleton // 96–97 AM Carleton // 1898 spring at Yerkes // Sept 1899 to Mount Holyoke Observatory as Head of Dept and Asst Director // φβκ Honor Society

Table 2

Key astronomers for Vassar College Observatory

Class of	Name	Years	Notes
	Maria Mitchell	1818–89	18–61 Nantucket // 61–89 Lynn // 65–87 VCO, 1^{st} director VCO // retired to Lynn at end of 87
1868	**Mary Watson Whitney**	1847–1921	69 Iowa solar eclipse // 72 AM // 80–87 VCO asst // 88–89 acting director VCO // 89–15 2^{nd} director VCO
1891	**Caroline Ellen Furness**	1869–1936	94–98 VCO asst // 00 PhD Columbia // 10–15 acting director VCO // 1915–36 3^{rd} director VCO
HCO	**Edward Charles Pickering**	1846–1919	HCO director 1877–1919
HCO	**Williamina Fleming**	1857–1911	HCO curator of astronomical photographs 1899–1911
Whitney's fourth lustrum (1901–06)			
Minn-esota	Mary Swain Wagner	1869–1937	92–93 VCO asst // 93 HCO // 97 AB // 02–17 Wagner Inn, Poughkeepsie
1897	Elizabeth Buchanan Cowley	1874–1945	98 AM comet orbits // 03 Columbia PhD // 02–29 VC Maths professor
1901	Ida Isabel Watson	unknown	variables (with HMS) // 02–07 teaching // Mrs Lippert, 2 children
1901	Helen Margaret Swartz	1878–1959	variables (with IIW) // 03 AM // 10–11 p/t asst VCO // Norwalk, Connecticut
1899	Elizabeth Tompkins	unknown	99 & 04–05 VCO computer // teaching // 15 AM Columbia
1904	Emma Phoebe Waterman	1882–1967	06 AM // 07–08 VCO asst // 09–11 MWSO computer // 14 Mrs Haas, 2 ch
1904	Frederica Chase	1879–1973	05–13 Lick Obs // 07 Mrs Moore, 2 ch // 09–13 in Chile //
1896	Mary Edith Tarbox	1873–1963	98–02 Columbia computer // teaching // 05 Mrs Babbitt, 3 ch
- - - -	Elise Crehore Whitney	1883–1934	MWW's niece // 10 Mrs Seikel
1881	Alice Caroline Henck	1857–1916	donated 4-inch French equatorial in memory of her father
1904	Ida Whiteside	1883–1966	06 AM variables // 07–09 HCO // Nantucket // 13–49 Asyut, Egypt
- - - -	Helen van Kleek	1875–1954	Poughkeepsie // clerical work // Mrs Devens
1900	Louise Wheaton Ware	1875–1953	01–03 teaching // 03–05 Yerkes // 06–42 1^{st} MWSO computer
1906	Ruth Emily Smith	1885–1971	06–15 2^{nd} MWSO computer // 15 Mrs Bakker, 1 ch
- - - -	Alvin Egan Paddock	1868–1953	MMA volunteer in charge of telescopes // Coffin school teacher
Welles-ley	Annie Jump Cannon	1863–1941	84 AB // HCO, trained by Mina Fleming // 06–36 helped MMA // 11–32 Curator

Table 2 (continued)			
Whitney's fifth lustrum (1906–11)			
1868	Anna Evans Bailie	1848–1906	08 $1000 donation – Zeiss stereo-comparator
1907	Lillian Maud Wickham	1885–1920	MWSO // married boss, Walter Sydney Adams, 10
1903	Florence Mary Bennett	1883–1968	from Nantucket // Vassar College Greek instructor // author
Carleton	Florence Ellen Harpham	1860–1925	88 AB // Smith College // Columbia computer // MMO
1909	Psyche Rebecca Sutton	1888–1916	10 AM // 11–12 VCO asst // 12 Mrs Underwood, 1 ch
1909	Clementina de Forest Griffin	1886–1980	MWSO 5th // teaching // AM sociology // aviator
	Clara L Allen	unknown	MMO // MMA $300 scholarship
1909	Martha A Renner	1887–1974	MWSO computer, 2 months // Mrs Sandy
1911	Mary Wanda Sheldon	1890–	MWSO computer // Mrs Nichols, 3 ch
Whitney's sixth lustrum (1911–16)			
1912	Frances Montgomery Cowan	1890–1971	12 Pulkovo paper // 15 Mrs Bowman, 3 ch
1899	Eda C Bowman	unknown	00 AM // 00–06 teaching // 10–12 MWSO // missionary Philippines
Radcliffe	Margaret Harwood	1885–1979	07 AB // HCO 4y // Nantucket MMO 45y // 4th season at Lick Obs
1911	Mary Fowler	unknown	13 computer – HCO, Allegheny & Princeton // eclipsing binaries
1912	Jessamine May White	1891–1991	12–13 VCO asst // 13 Mrs Hawley, 4 ch
1908	Edith Clarke	1883–1959	08–12 teaching // 12–17 AT&T computer // 47–57 prof. electrical engineer
Welles-ley	Ernestine Wells Fuller	1884–1969	08 AB, 09 AM // VCO instr. 13–15 // 20–33 librarian // 44 Mrs Mather
Radcliffe	Genevieve Matthews	1890–1965	11 AB // 1st MM Fellow at HCO, 12–16 // Mrs Hubbard, 1 ch
Smith	Susan Raymond	1892–1970	13 AB // 14–18 HCO, MMO // 19 AM Radcliffe // 22 Mrs King, 2 ch
Others			
Radcliffe	Maxine Alberta Hawes	1890–1985	14 AB, 22 AM, 29 PhD Michigan // 26–27 acting director VCO
North-Western Uni	Laura Elizabeth Hill	1893–1991	VCO asst // Mrs McLaughlin, 5 ch, Detroit Observatory
Geneva Uni	Georgette Camille Maulbetsch	1900–1960	Swiss graduate // longitude reductions // Mrs Scania
Uni of Calif-ornia	**Maud Worcester Makemson**	1891–1977	32–33 Instructor VCO // 36–57 4th director VCO
1915	Harriet McWilliams Parsons	1892–1986	15–16 Yerkes // 16–19 VCO asst // 21 PhD Chicago // 23 Mrs Hall, 3 ch
1916	Evelyn Wornham Wickham	1895–1988	16–19 Yerkes // 19–26 AT&T // Mrs Hale
1937	Helen Mary Wright	1914–1997	37–39 VCO asst // AM // MM – 2nd biography // 36 Orionids, VCO roof
1948	Vera Florence Cooper	1928–2016	photo with 8-inch equatorial // Mrs Rubin

Note: double-digit figures in the Notes column indicate year(s) of event stated

Table 3

Mount Wilson Solar Observatory, Nantucket, and Vassar astronomy

Academic year	MWSO	Nantucket Maria Mitchell Association	Comets	Stars	Notes	Observatory
			Whitney's fourth lustrum (1901–06)			
1901–02		Vestal Street property MM's 3 cousins	*1826 II* *orbit calculated* 1902b	Nova Persei	Curriculum courses A to G Astron. Gesellschaft link 8 minor planets	
1902–03		Circular proposal MMA founded with MWW president	1903a 1903c	Pleiades tests W Ursae Majoris Z Draconis	A&ASA – Washington Carnegie grant app, $1000 9 minor planets	Rumford photometer VCO computing team Elise Whitney asst
1903–04	Mt Wilson site tests	Memorial House open	1904c	U Pegasi SS Cygni	Senior class excellent 8 North Polar Catalogue plates measured 1 minor planet	4-inch equatorial gift
1904–05	Snow telescope Pasadena office	Moon evenings with 2.7-inch Dollond Aug 30 solar eclipse	*1826 II* *1886 III* *orbit calc* 1904e	RR Persei RV Andromedae RS Cassiopeiae U Ursae Minoris	NPC, 5 minor planets	4-inch building, $200
1905–06	2 Vassar computers	Observatory site MM's 5-inch Clark Annie Cannon (HCO)	1905e 1906a 1906b	Maxima of 9 long-period variables [lpv]	Curriculum course H 1 minor planet *PVasO..2* – Stars 2° north celestial pole	

Academic year	MWSO	Nantucket Maria Mitchell Association	Comets	Stars	Notes	Observatory
			Whitney's fifth lustrum (1906–11)			
1906–07	Int Solar U Meudon	MM – Hall of Fame MWW – MMO plans		RS Cas – 'Algol' 14 stars [lpv]	Class A – 100 students Isis – final minor planet	
1907–08	3rd Vassar computer Hα images	MMO dedication $4k summer Observer Ida Whiteside – 3 wks		19 stars [lpv] Hagen charts	CEF – Groningen MWW + niece to UK CEF – IWSA meeting	Phebe Waterman asst stereo-comparator order (Zeiss) $1000
1908–09	4th Vassar computer	Florrie Harpham 1st Fellowship – $25k aim		SS Cygni 14 stars [lpv]	Women's suffrage issue CEF – variable stars	
1909–10	5th Vassar computer Solar U	Florrie Harpham 2nd Clara Allen $300 sch Astronomy group	1P/Halley	SX Draconis 'Algol-type' TY Aquilae	Boston AAAS mtg final MWW measures in March … then stroke	Helen Swartz asst
1910–11	+2 Vassar computers	CEF – Carnegie $10k brass tube for 5-inch Florrie Harpham 3rd		22 stars [lpv]	CEF – acting director Williamina Fleming dies A&ASA – Ottawa	Psyche Sutton asst Clara Allen trained stereo-comp arrives
			Whitney's sixth lustrum (1911–16)			
1911–12	+1 Vassar computer	MWW honorary pres M. Harwood Ast Fell	1911c 1911f	editing MWW results 1901–10	History – Pulkovo Obs A&ASA – Allegheny	MWSO images electric lighting
1912–13		7.5-inch ordered MH also at HCO		~4800 reductions for *PVasO..3*	CEF – associate professor Kapteyn visit in fall	Jessamine White asst
1913–14	+1 Vassar computer	HCO fellowship plan 7.5-inch astrograph tests		>320 copies distributed		Ernestine Fuller asst
1914–15		polar alignment tests Eros images/research MH – 3rd summer		*An Introduction to the study of variable stars*	MWW retirement MWW – professor emeritus Vassar – 50 years anniv	Ernestine Fuller asst
1915–16		MH – Lick Obs Susan Raymond appt			CEF – Alumna Maria Mitchell Prof of Astronomy	CEF salary $2400

1901 during their European tour. His lecture, entitled 'Time and Tide' (1901 November 18) explained the effects of the Moon on the Earth, the possible origin of meteors, and volcanic activity.[8]

For variable stars Mary began a series of observations 'to which I hope I may direct the serious attention of some of our graduates … an almost unlimited field … it requires neither large mathematical resources nor large instrumental equipment … patience, persistence, and a love of the work are enough to ensure valuable results'.[9] Her judgement proved sound and she noted in 1902 May: 'The new star in Perseus which appeared a year ago last February [GK Persei] has continued to occupy our attention in its variations in magnitude'.[10]

Regular monitoring by students of long-period variable stars became a popular and absorbing task. Two outlets for results quickly emerged: increased collaboration with Harvard College Observatory in Cambridge, which frequently issued circulars requesting cooperation among non-professional observers;[11] and the enterprising approach shown by two graduate students, Helen Margaret Swartz (1878–1959) and Ida Isabel Watson, who began a series of ephemerides of long-period variable stars in *Popular Astronomy*.[12]

Alongside these new developments normal VCO work continued, with fifty-two measurements of eight minor planets completed during the year.[13] With student numbers continuing to rise Mary's salary increased to c.$1,800 (c.£36k today), while Caroline's rate as Instructor was c.$1,200 (c.£24k today).[14]

Table 3 summarizes key events across the three lustrums, and also indicates how Vassar graduates uniquely underpinned the development of the solar observatory at Mt Wilson.

2.2. *The Nantucket Maria Mitchell Association (1902–03)*

The new academic year brought a celestial visitor: 'A fairly bright comet appeared in October and claimed our special attention for about two months'.[15] Mary had redefined her courses. A and B were descriptive; C and D were observational courses; and E, F, and G, mathematical courses. Class sizes remained high: 'Dr Furness [now an Instructor] has been in charge of classes C and D and nearly all the laboratory work. The remaining classes A, B, E, F and G have been in my charge.

'In course B, besides an hour's instruction in the use of the telescope, each student has had two hours instruction in the use of the spectroscope upon the study of the solar spectrum, one hour in the study of the terrestrial elements found in the sun, and one hour in the dome in the study of special parts of the sun's surface. In the observational course D, special stress has been laid upon the observation and study of variable stars, since this field has grown into great importance in recent years.

'Two graduate scholars have been members of class G, astronomy having been elected as their minor. A graduate student of last year, Miss Swartz, has spent considerable time at the Observatory gathering material for her thesis for the A.M. degree'.[16]

Mary's approach and pedagogy were later recalled by Caroline Furness:

> Her research work was marked by accuracy and thoroughness … as a teacher she was noted for her clearness in explaining difficult mathematical points and for the vividness and elegance with which she presented the more descriptive topics. Many students elected her courses merely to come in contact with her personality. As a member of the faculty, she was highly esteemed for her soundness of judgement and her progressive ideas. As a scholar she was a constant stimulus to her younger colleagues. She read extensively on political and philosophical topics, and had highly developed tastes in literature and music.[17]

Meanwhile, two hundred miles east of Vassar College, the death of Maria Mitchell's aunt, Mary Russell Mitchell (1811–1902), at her home in Vestal Street had created a unique opportunity for her three daughters, Mary, Eliza, and Lydia, whose shared childhood memories forever linked them to the past. They secured the deeds to their parents' former home, where their uncle William and cousin Maria had together watched the stars.

Contact with Mary Whitney quickly led to a circular (1902 September) proposing the formation of a Nantucket Maria Mitchell Association (MMA). The three sisters, from a base in Philadelphia, believed the old house should be preserved as a memorial to celebrate the life and legacy of America's first female professional astronomer. Although it was four decades since their cousin had moved off-island they resolved to create a scientific centre, for both Nantucket residents and visitors to the island, which would incorporate scientific research.[18] The circular was targeted at Vassar alumnae, scientists, and friends and family of Maria Mitchell, and Mary Whitney was named as chairman.

At VCO Mary decided to replicate the Cambridge and Columbia models by establishing her own computing team. In 1903 she was awarded a grant of a thousand dollars by the Carnegie Institution, in quarterly instalments, for the measurement and reduction of the remaining eight plates of the set taken at Helsingfors, Finland, the results of which comprised Publication No. 2 of the VCO.[19]

The fourth meeting of the Astronomical and Astrophysical Society of America (A&ASA, now the American Astronomical Society) was held in Washington across the New Year from 1902 December 29 to January 1. Dinner invitations at one point seemed to exclude women, until president Simon Newcomb (1835–1909) intervened: 'You may be under a misapprehension, supposing the dinner is only for the men of the society … [I] … assure you that all members are equal, and that we should like very much to have our lady members with us'.[20]

A few weeks later, at the end of 1903 January, Mary Whitney was elected MMA president at the meeting in Delmonico's restaurant in New York mentioned on page 42. The new group resolved to have the Memorial House open to the public for the first time by the summer.[21] Three months later, by the first annual meeting held in Philadelphia, there were 220 members in the MMA. Hydrographer Henry Mitchell (1830–1902) had bequeathed his sister's scientific library, and Maria's nephew, Clifford Mitchell (1854–1939), had lent the 'little Dollond' telescope.

Fig. 2: Whitney photometer acquired by VCO in 1903. (National Museum of American History, Catalogue No. 1980.0318.10)

Mary increased her outreach work, giving public lectures on 'the value of research' to the Association of Collegiate Alumnae (1902 November), 'the new star in Perseus' in Waltham, Massachusetts (1902 December), and 'light and colour in astronomy' to the Brooklyn Institute (1903 March). In her May report Mary explained: 'The annual pamphlet from Berlin has been received and several of the asteroids contained in it have been observed. The faint new star discovered in April is upon our working list. The new variable discovered by the Potsdam observers, which presents the shortest period yet known, about four hours, is at present claiming our attention. The new photometer received this year … is used in these last two observations. It is proving very satisfactory'.[22] During the year sixteen measurements of nine minor planets were completed, together with comets 1903a and 1903c, with results later published in the *Astronomical Journal*.[23]

Edward Charles Pickering (1846–1919), director of HCO, had designed a number of photometers for his personal research in Cambridge. Five small grants were secured through the Rumford Fund (1882–1903): grant no. 78 ($500 in 1900, c.£10k today) enabled five identical wedge photometers to be used with large telescopes at Harvard, Princeton, McCormick, Lick, and Yerkes; grant no. 97 ($150 in 1903, c.£3k today) extended the provision. Mary's excellent working relationship with Pickering enabled VCO to borrow one of these instruments for six months (Figure 2).[24]

During the spring of 1903 Mary tested her Rumford photometer on the variable star W Ursae Majoris. She identified ten comparison stars, with magnitudes taken from the supplement to the *Revised Harvard Photometry* catalogue. Measured magnitudes were determined to three significant figures using the 12-inch equatorial. An average of four measurements were taken across eighteen nights (April 27–July 10) with observing times ranging from one to four hours. The star was found to vary from magnitude 7.18 to 8.94 during this period.[25]

A tougher challenge was then undertaken

during the summer of 1903 with the faint Algol-type variable star Z Draconis. Its variability had been discovered in 1903 February by Lidiya Ceraski (1855–1931) at Moscow Observatory and announced in the April issue of *Astronomische Nachrichten*.[26] Mary began investigating it using the 12-inch Vassar equatorial across seven summer nights in July with the photometer and naked eye. The star was found to vary from magnitude 10.58 to 13.1 during this period.[27] A short paper duly appeared in *Popular Astronomy* in 1903 October.[28] Coincidentally, two positional measurements of Comet 1903c (Borrelly) were also obtained during July.[29]

Mary was deservedly proud of her investigative approach. She had also enjoyed her summer rambles across the Vassar campus, identifying different birds and plants normally unseen during the academic year. During the same month the Maria Mitchell Association received its charter of incorporation on 1903 July 18. Teacher Mary Ann Mitchell (Mrs Benjamin Albertson, 1838–1914) became the first curator of the Memorial House. She was an amateur botanist and set up the department of Natural Science, initially with collections of shells and flowers. Her sister Lydia (Mrs Charles Shoemaker Hinchman, 1846–1938) effectively led the MMA for the first 30 years.

2.3. *Consolidating work (1903–04)*

After six months using the Rumford photometer on the 12-inch equatorial, she evaluated her progress. Observations of W UMa, Z Dra, and U Peg had all evidenced their short-period variability and probable eclipsing binary nature. However, short-period variables required several hours of consecutive observation, but as the observing hours usually lasted only until eleven or occasionally midnight Mary decided it was better to focus on long-period variables.[30] Caroline later revealed that in the summer Mary usually took her own 3-inch telescope with her to Waltham and followed variables which were passing through their maxima.[31]

Anomalous changes in SS Cygni had been highlighted in 1903 September by Zaccheus Daniel (1874–1964), of the Halsted Observatory, Princeton.[32] Mary immediately added it to her observing programme, making photometric measurements of its brightness across 24 nights from 1903 October 20 to 1904 January 19; during this time its magnitude declined from 9.0 to 11.4 (November 9) before recovering to 8.6 (November 19) and then falling to 11.6 (December 15 and January 19).[33]

In her annual report for 1904 May Mary noted: 'I have found my senior class of unusual ability … we have endeavored to enlarge the study of changing stellar magnitude in the Senior course G and the observational course … work on variable stars … which is especially suited to home life and requires small equipment … Frau Prittwitz of Berlin and Madame Ceraski of Moscow and others have shown what women in their homes can do in this line if they are ready to put by the unessential demands of social life, they are regular contributors to the *Astronomische Nachrichten*'.[34]

During the summer the VCO backlog of results was tackled. Scattered observations made since 1903 were prepared for publication by Mary Edith Tarbox (1873–1963). Her paper in the 1905 January *Astrophysical Journal* also included more recent results, for minor planet Bamberga and Comet 1904c (Tempel).[35] Mary Tarbox had shown great commitment to VCO since her graduation, but then started a new chapter in her life with an autumn marriage.

Outreach talks continued: 'from nebula to moon' in Amesbury, Massachusetts (1904 March), and 'modern astronomy' (1904 April) in Waltham. On 1904 June 8, at the end of a busy year, Vassar used its new Chapel for its largest ever graduating class, of 126 students receiving their degrees. At VCO, Mary was delighted to receive the donation of a second instrument for student use, a fine 4-inch French telescope with equatorial mounting, from a former student, Alice Caroline Henck (1857–1916).[36] Mary had published a historical review of the 'problem of solar motion' in *Popular Astronomy* (1897 October). Seven years later (1904 March) she wrote a pair of papers for the same journal with a more mathematical treatment.[37]

Site-testing had begun 2,800 miles from Poughkeepsie in southern California in 1904 March, leading to a grant of $10,000 from the Carnegie Institution for George Hale to transfer the Snow telescope of the Yerkes Observatory to Mount Wilson. The mountain site offered excellent definition and his first priority was to establish a solar observatory. At this stage opportunities for VCO graduates were uncertain, but this situation would soon change.[38]

On Nantucket, the Memorial House was preserved as an example of an early 19thcentury Quaker house, with one room used as a museum for conchology, mineralogy, and botany. The Folger family donated a small telescope (1904) made on the island by Gideon Folger (1780–1863).[39] Then, nearly seven decades after the Mitchell family moved from Vestal Street to the Pacific Bank, telescopic work resumed at Maria's birthplace, with the 2.7-inch f/17 'little Dollond' on its altazimuth mount giving an upright 2° field of view of the crescent Moon. The assembled group of sixty people, led by librarian and curator Mary Ann Albertson, observed from the yard opposite the Memorial House one summer's evening.

2.4. *Vassar expansion continues (1904–05)*
Classes in 1904–05 were unchanged. Elizabeth Buchanan Cowley (1874–1945) had returned to Vassar as Instructor in Mathematics; she supported graduate student Ida Whiteside (dates unknown) to complete the computation of the orbit of Comet 1826 II, for which they received a prize of 100 German marks from the Astronomische Gesellschaft; the letter announcing the award was written by Hugo von Seeliger (1849–1924), who ten years earlier had been opposed to admitting women into the AGS.[40] In addition, Ida Whiteside studied variable stars, reporting her results in the monthly circulars of Harvard Observatory.

Mary continued her outreach activities, lecturing on 'the Solar System' (1904 December) in her home town of Waltham, Massachusetts.[41] VCO work focused on completion of the North Polar Catalogue. During the year 17 measurements of five minor planets were completed, together with a few observations of Comet 1904e.[42]

Commencement week (1905 June) included both a graduating class of 200 students and the opening of the Thompson Memorial Library, which was able to accommodate 360 readers. For the incoming class of 1909 tuition and residence fees (unchanged since 1866, at $100 and $300 per annum) both increased by $50, making the cost of a four-year Vassar degree $2,000 (c.£10k per year today, including tuition and boarding). College enrolment now accepted one thousand women.

In 1905 Mary published observations of four new variables at the request of the Astronomische Gesellschaft: RR Persei (fourteen measures from 1904 February to 1905 March, suggesting a period of 374 days and maximum in 1904 January); RV Andromedae (six measures from 1905 January to April, showing a rise from a minimum of mag. 10.6 to a maximum of 9.1); RS Cassiopeiae (six measures, 1905 January to April, suggesting a maximum in early March); and the red star U Ursae Minoris (four measures from 1905 January to April which revealed a brightening from magnitude 10.2 to 9.1). Encouraged by her results, Mary added the quartet to her regular observing programme at VCO.[43]

Progress in southern California was beginning to attract world-wide attention. The Snow telescope was set up on Mount Wilson in 1905 January and was operational two months later. Solar images 6.7 inches in diameter could be photographed and a 5-ft spectroheliograph had been constructed; a 30-ft design was also planned. A Zeiss stereocomparator facilitated high-precision comparison of plates for sunspot detail. To measure the heliographic latitude and longitude of points on the photosphere, images were projected onto a ruled globe in the Pasadena laboratory.

As Mary absorbed the implications of Hale's ambitious undertaking, she must have recalled her own sunspot photographs taken two decades earlier at VCO. Although she could not replicate Hale's instruments, she appreciated that Vassar was in a unique position to supply the world's greatest solar observatory with a steady supply of essential resources – highly trained women who would be needed to measure and reduce the vast amount of research material.[44]

On Nantucket, the highlight of the MMA summer astronomical programme was the solar eclipse of 1905 August 30. The island lay to the south of the path of totality and the maximum phase was 60% with the early morning Sun at an altitude of 16°. The eclipse was preceded a few evenings before by a talk on eclipses given by Harriet Elizabeth Caryl (1834–1918) followed by a glimpse of the Moon through the 'Little Dollond'.[45] At this time the MMA recognized three key problems for astronomy: there was limited space for visitors to observe from at the Memorial House site; only small telescopes were available; and volunteers with an interest in observing were needed. Within the year all three issues would be partially resolved.

2.5. *Maria Mitchell's telescope (1905–06)*
In 1905–6 a new course began, Class H,

ASTRONOMY

PROFESSOR WHITNEY AND DR. FURNESS.

The courses in Astronomy are presented under three main divisions, descriptive, observational and mathematical. Courses A and B are descriptive, C, D and H observational, E, F and G mathematical.

Course A. Descriptive Astronomy. First semester [3].
The Celestial Sphere. The Solar System.
PROFESSOR WHITNEY.

A general study, without mathematical processes, of the phenomena of the sky and of the relations of the solar system. Lectures and topical reading. A limited amount of sky observation.

Course B. Descriptive Astronomy. Second semester [3].
The Stellar System. Astrophysics.
PROFESSOR WHITNEY.

A study of the luminous bodies of space from the point of view of astronomy; of their nature and constitution by the methods of spectroscopic investigation. The latter part presents in an elementary form the principles and methods of the new astronomy. Observational work with the spectroscope.

Course C. Observational Astronomy. First semester [2].

Course D. Observational Astronomy. Second semester [2].
DR. FURNESS.

Courses conducted by observational and laboratory methods. Study of stellar and planetary positions and motions; surface phenomena of sun, moon and planets. Use of portable and mounted telescopes. Study of almanacs, maps and globes.

Students desiring to elect Course D, who have not had a previous course in Astronomy, must consult the department.

Course E. General Astronomy. Second semester [3].
PROFESSOR WHITNEY.

A mathematical treatment of the principal branches of astronomy.

Spherical trigonometry is briefly presented in introductory lectures. The course presupposes the required mathematics of the college curriculum. Astronomy A is recommended as a preliminary course, but it is not required.

Course F. Spherical and Practical Astronomy. First semester [3].
PROFESSOR WHITNEY.

A somewhat detailed study of certain departments of spherical astronomy: time; apparent right ascension; occultations. Practical work: adjustments and use of the transit circle.

Prerequisites: Astronomy, Course E, and Mathematics, Course C.
PROFESSOR WHITNEY.

Course G. Theoretical and Practical Astronomy. Second semester [2 or 3].
PROFESSOR WHITNEY.

Parabolic orbit of comet. Orbit of binary star.

Practical work: adjustments and use of the equatorial telescope.

Prerequisite: Course F.

The third hour of Course G will be devoted to the study of current astronomical literature in some selected branch.

Course H. Variable Stars. First or second semesters [3].
PROFESSOR WHITNEY AND DR. FURNESS.

A detailed treatment of variation in stellar magnitude, based upon observation.

This course is suitable for a graduate minor.

Prerequisite: Two courses in Astronomy. Students desiring to elect Course H must consult the department.

Fig. 3: Curriculum courses for 1905–06. (41st Annual Catalogue of Vassar College, pp. 60–61)

which Mary described as ‘a somewhat specialized course in magnitudes of stars and variable stars … [so that] … amateur workers may make valuable contributions. Miss Whiteside has mounted a small telescope at her own home and has contributed observations monthly to the variable star circulars of HCO, and has published a separate paper of her own in the *Astronomical Journal*’.[46] Mary was now teaching the bulk of the students, with each class requiring three hours per week, while Caroline taught classes C and D for two hours each per week; both astronomers taught class H (Figure 3).

A final revision of the polar catalogue was completed. Publication costs for the *Catalogue of Stars within two degrees of the North Pole* were met by both the Carnegie Institution (225 copies) and Mrs Mary Thompson (200 copies), enabling its distribution to libraries and observatories in the United States and also foreign observatories. For Caroline Furness, who directed the project, publication of the Catalogue was a major accomplishment.[47] Following the increase in student fees and the publication of the Catalogue Mary negotiated a further increase in her salary, to c.$2,000 (c.£40k today), with Caroline receiving c.$1,400 (c.$28k today).

Donations to Vassar College from alumnae played an important role across all faculties. The 4-inch Henck telescope had proved useful for students during the two years since its arrival. Mary reported in 1906: ‘The class of 1881, about to celebrate the 25th anniversary of its graduation, has decided to build a suitable observatory or shelter for this telescope. This is now being erected and will be completed by Commencement week. The cost of the building and apparatus for rolling the shelter off and on the telescope, involving also the placing of the pier, will be about $200’ (Figure 4).[48]

In 1906 Mary published a summary of her long-period variable star observations for the preceding year in the *Astronomical Journal*.[49] She chose to focus on observing the date of maximum brightness for nine stars: T Dra, R Dra, R Boo, S Her, R CVn, U Per, W Her, T Her, and V Boo. Since these were all between 7th and 10th magnitude she used the 5-inch Clark refractor at VCO and, during fifteen nights (1905 July–August), her own 3-inch Clark at Waltham. During the year six measurements of two minor planets were completed, together with observations of comets 1905e, 1906a, and 1906b.[50]

In southern California, George Hale was

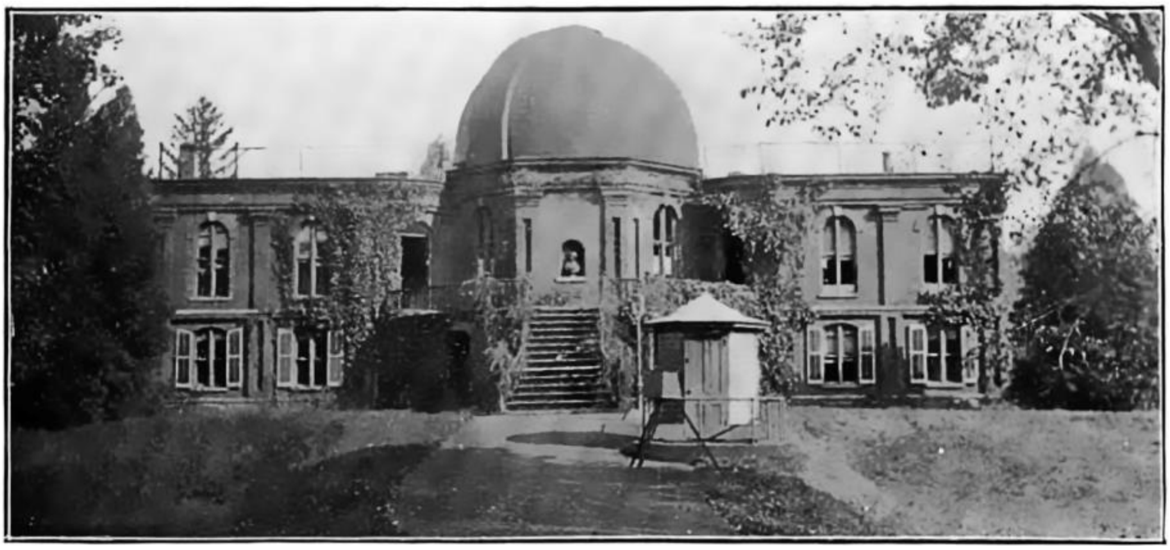

*Fig. 4: In 1904 Alice Henck donated a 4-inch French equatorial to VCO for students to use. For their 25th anniversary the class of '81 funded a small building, erected in front of the observatory on the west side. Including a pier, it cost $200 (1906, c. $4k today). The VCO frontage is 82 ft, with a 27-ft dome, making this wooden hexagonal building c. 12 ft wide. A portable 3-inch telescope is visible on a tripod outside. The wooden structure lasted over four decades and later (1942) housed the 5-inch Clark telescope. (*The Vassarian *1909, p. 98)*

skilfully securing funding for the Mount Wilson Solar Observatory (MWSO). This included $45,000 from the businessman and philanthropist John Daggett Hooker (1838–1911) of Los Angeles for a 100-inch mirror; $150,000 for construction and maintenance work; and presidential support for an access road from Pasadena up Mount Wilson.

The computing division began in the enlarged Pasadena building with Walter Sydney Adams (1876–1956) in charge. The first two women computers were appointed in 1906 July and August, both Vassar graduates: Louise Wheaton Ware (1875–1953) and Ruth Emily Smith (1885–1971). One of their first tasks was to use the redesigned heliomicrometer globe to measure heliographic positions of flocculi for solar rotation. MWSO was now linked globally via the International Union for Cooperation in Solar Research which had been formally constituted in Oxford in 1905 September. The future was looking very promising.[51]

Mary was unable to attend the fourth MMA meeting in Boston (1906 March) but wrote instead: 'Through Maria Mitchell I became acquainted with Nantucket and her early life … Professor Mitchell's affections clustered about the old home. She would have rejoiced to know that this home was to become a center … toward a knowledge and a love of science among the young people of Nantucket'. [52]

During 1906 several problems limiting astronomy on the island were addressed: the purchase of an adjoining property to the west of the Memorial House and donation of the site for an observatory; donation of Maria's 5-inch refracting telescope; and recruitment of two key volunteers.

William Herbert Rollins (1852–1929) and his wife Miriam (1849–1925) had purchased the 5-inch f/15 Clark equatorial, formerly owned by Maria Mitchell, but her observatory at Lynn was not acquired. For eight years the instrument was rarely used – few astronomers would ever be able to claim that X-rays had ended their observing career. William was an innovative Boston dentist and physician who suffered a severe radiation burn to his hand (1898) during his pioneering work with 'X-light' and medical radiography. Using the refractor after the accident became too difficult and so the couple decided it should return to its original home on Nantucket. The MMA were naturally delighted with the donation and began planning an observatory for their site.[53]

More good news concerned the recruitment of a volunteer, Alvin Egan Paddock (1868–1953), a Nantucket craftsman and teacher at the Coffin School, which solved the issue of equipment maintenance. His assistance on popular 'Moon evenings' ensured the best use of the telescopes available. In another initiative, Harvard Observatory in Cambridge was contacted for support. Edward Pickering encouraged Annie Jump Cannon (1863–1941) to visit Nantucket in the summer of 1906 to initiate an astronomy class. Her involvement with the MMA would continue for the next 36 years.

3. Whitney's fifth lustrum (1906–11)

On Wednesday 1908 July 15 a red-brick building with a copper dome was surrounded by a large crowd of enthusiastic supporters. Within its walls an 11-ft-square room had a central pedestal topped by the famous Clark telescope that had started its life on the island nearly five decades earlier. Maria Mitchell's 5-inch refractor had come home. As the tributes to its former owner were delivered, a former Vassar graduate looked forward to her three-week residency. Across the Atlantic Ocean Mary Whitney and Caroline Furness were nearing the end of their second trip to England, but their thoughts inevitably drifted back to the dedication ceremony on Nantucket.

During her fifth lustrum Mary Whitney strengthened links with Yerkes Observatory, Mount Wilson Solar Observatory, and the Groningen Laboratory; broadened her observing programme for variable stars; visited Nantucket to help establish the Maria Mitchell Observatory (MMO); encouraged Caroline to take a sabbatical in the Netherlands; secured funding for a stereo-comparator; made a second trip to England; and facilitated the appointment of three women observers at Maria Mitchell's childhood home.

3.1. *A trip to Nantucket (1906–07)*

VCO classes A to H continued broadly unchanged but class A numbers increased to a hundred students. Fortunately, the 4-inch Henck telescope was available for the observational classes.[54] Signing off work undertaken on cometary orbits proved more frustrating. Complications arose: 'Our computing force has been occupied on comet reductions … the comets orbits undertaken at the request of the German Committee have developed special points of difficulty … we are much indebted to the suggestion and assistance of Prof Peck of Syracuse University; also, to Prof Kreutz, chairman of the comet committee'.[55]

During the year Mary gave lectures at the new Ossining School, New York, and the Brooklyn Woman's Club. She particularly valued Vassar's link with HCO for variable stars: 'Our research in this line of observation can be made immediately available, without reduction, through cooperation with Harvard College Observatory which solicits contributions and incorporates them in its circulars, distributed to observatories at regular intervals'.[56] Another important resource was the *Atlas Stellarum Variabilium* (ASV) by Johann Georg Hagen (1847–1930), director of the Vatican Observatory. These charts now included Series IV, with details for one hundred variables whose entire range could be observed with small apertures.

In 1907, Mary published further results on the four new variable stars identified in 1904.[57] For RV Andromedae, 16 measures (1905 September to 1907 April) showed a magnitude variation between 8.8 and 10.8 and included two maxima, which suggested a period of 170 days. For RR Persei, 20 measures (1905 April to 1907 April) gave a magnitude range 8.5 to 13, with a maximum in 1907 January. For the red star U Ursae Minoris, 22 measures (1905 April to 1907 April) revealed magnitudes from 8.1 to 11.2, with evidence of maxima in 1905 May and 1906 March; Mary predicted its next minimum should occur 1907 August 11.

For RS Cassiopeiae Mary noted: 'During the earlier observations of this star, it was supposed to be a long period variable. In January last it was decided it must be of short period, and more frequent observations were made'. Mary completed 29 measures with the 12-inch equatorial during a three-month period (1907 January to April), finding a magnitude range of 9.3 to 10.5 and a period of about 6.4 days. In her final paragraph she noted, with pride: 'In Bulletin No. 10 of Laws Observatory, recently received, Professor Seares publishes the periods of two of these variables. For RV Andromedae he finds 169 days, from 62 photometric comparisons. For RS Cassiopeiae, he finds 6.298 days from 258 comparisons'.[58]

Mary had successfully refined her observing technique to accurately deduce different types of variable star, without the need to rely on photometric measurements. Time spent investigating variable stars now replaced the earlier VCO focus on minor planets. After 12 years of measurements of over one hundred asteroids, this line of work ended in 1906 September with four measurements of Isis.[59]

The discovery of variable stars was increasing rapidly at this time. Seth Carlo Chandler (1846–1913) produced three catalogues: in

1888, with 225 stars; 1893 (260 stars); and 1896 (386 stars). By 1904 he had revised the elements of the variables in his third catalogue, which enabled Mary Whitney to select which stars to observe for their predicted maxima and minima. Importantly, the Hagen Series IV charts incorporated the Chandler elements and also Harvard Photometry magnitudes, making the resource invaluable to her students.

In 1907 July she summarized her 1906–07 work on long-period variables for the *Astronomical Journal*.[60] Fourteen stars were identified: T Cas, U Cas, S Cas, U Per, R Tri, T UMa, S UMa, R CVn, R Boo, R Ser, U Her, RT Cyg, Z Cyg, and V Cas. One hundred and twenty measures (1905 February to 1907 April) were made to test the maxima dates. Mary used 3, 5, and 12-inch apertures as the magnitude range varied from 7 to 13.[61]

In 1907 May the Hall of Fame for Great Americans at New York University inducted its first three women, all educators: Emma Hart Willard (1787–1870), Mary Mason Lyon (1797–1849), and Maria Mitchell. Attending the ceremony to view the bronze tablets were Mary Whitney, Lydia Hinchman, and Mary Ann Albertson. The tablet was inscribed: 'Maria Mitchell, 1818–89, every formula which expresses a law of nature is a hymn of praise to God'. At the unveiling ceremony Mary reflected poignantly on her mentor as being 'devoted to the education of young women because she wished their lives to be governed by the harmonies of truth rather than the vagaries of tradition, by the "infinities rather than by the infinitesimals" … a leader among women scientists; she was a character influence of unique and telling quality'.[62]

At Mount Wilson Solar Observatory in Califfornia, George Hale was preparing work programmes for the new 60-inch reflector and was keen to cooperate with the Dutch astronomer Jacobus Cornelius Kapteyn (1851–1922), who was investigating the structure of the Milky Way. Kapteyn had selected a number of areas distributed across the celestial sphere and had proposed a global collaboration of observatories. Measurement of the brightness, proper motion, parallax, spectral type, and radial velocity of all the stars within each area would improve understanding of the structure of the Universe. Hale invited Kapteyn to spend his summer months at Mount Wilson to oversee the project.

Meanwhile the computing division at Pasadena had doubled in size, with the arrival of two women computers from Mt Holyoke.[63] The Vassar recruits had become invaluable: Louise Ware continued her study of flocculi and solar rotation, while Ruth Smith determined measurements of the areas covered by the calcium flocculi.[64] George Hale highlighted the success of MWSO with delegates attending the third International Union for Cooperation in Solar Research, which met in Meudon, Paris (1907 May). The fourth meeting would be held at MWSO.

On Nantucket, the sad news of the death of Maria Mitchell's sister Phebe Mitchell Kendall (1828–1907) on June 4 was followed by the family donation of a plaster bust of Maria to the MMA.[65] The island summer season began (early July) with the astronomy class studying the Moon, using a distance-learning approach facilitated by Annie Cannon. They were greatly assisted and encouraged by a visit from John Tracey Edson (1850–1928), 'whose talk and experiments were replete with valuable suggestions'.[66]

Mary, the MMA president, delivered two talks, at the Memorial House and in the Congregational Church, the latter entitled 'Some Recent Discoveries in the Solar System'.[67] During her visit she met the MMO building committee, on 1907 July 22. At the Memorial Grounds Mary helped design a suitable structure for both present and future needs, bearing in mind that the MMO would have the dual function of public outreach and research. The committee agreed to appoint an architect during the winter months and aimed for building plan approval by 1908 April.

The next astronomical visitors to Nantucket were both from Cambridge: summer talks given by John Rayner Edmands (1850–1910) of Harvard Observatory and Annie Cannon, who reviewed the work already done by the astronomy group and suggested the study of variable stars, for which their telescope was well suited.[68]

3.2. *A new observatory on Nantucket (1907–08)*

The importance of regular sabbaticals for women scientists had been promoted by Maria Mitchell.[69] Mary Whitney adopted the same strategy by encouraging Caroline Furness to broaden her networks. Initially this involved the observatories at Columbia and Yerkes, but in 1907 fall Mary Whitney established a valuable link with Jacobus Kapteyn in the Netherlands.[70] Caroline later explained: 'In 1907 after the reduction of the Helsingfors polar plates was completed, we were considering what to undertake next in the way of photographic work, when Kapteyn's first pamphlet on the 'Plan of Selected Areas' appeared. This project seemed a most suitable one in which to co-operate, and as … [I] … was expecting soon to take a semester for study, Professor Whitney arranged with Kapteyn to spend it working under his direction in his laboratory in Groningen'.[71]

On 1907 November 8 Mary hosted an MMA meeting at VCO where a decision to appoint an 'Observer' at Nantucket for 1908 summer was agreed.[72] The Observatory committee, chaired by Miss Cannon, allocated funding and subsequently selected Ida Whiteside, Vassar alumna and assistant in the Whitin Observatory of Wellesley College.[73] Mary endorsed the choice in her annual report (1908 May):

> Miss Whiteside is already one of the largest contributors of observations to the AJ. She is now carrying on investigations based upon photographic plates loaned her by Prof Pickering of HO (she is teaching at Wellesley) and has discovered a new variable from these plates … [and] determined the period … Miss Whiteside has also been appointed observer for the coming summer at the Maria Mitchell Observatory, Nantucket, Mass., … [which] … will contain the telescope used by Maria Mitchell and recently donated to the MMA. The Association proposes to appoint an observer each summer for a period of five weeks with salary to carry on some line of work and to conduct a class in Astronomy.[74]

In 1908 June a special reunion occurred on the 40th anniversary of the graduation of the class of '68 when alumnae of Miss Whitney's class met again in the Observatory. Among the guests was John Wesley Bailie (?–1910), the husband of one of their deceased members, Anna Marie Evans (1848–1906), who wished to give Vassar $1,000 in memory of his wife. Mary wrote: 'At Kapteyn's suggestion I decided to secure for our observatory a stereo-comparator … the Jena firm who constructs it does excellent work but is notoriously slow'.[75] The instrument was ordered from Zeiss in 1908 August but took three years to arrive; it would be the last major item that Mary purchased for VCO. During Commencement week, Mary summarized her ongoing work on long-period variables for the *Astronomische Nachrichten*, identifying 19 stars to target for the coming year.[76]

During the summer Mary, accompanied by her 25-year-old niece Elise, crossed the Atlantic to meet Caroline Furness in England, where they spent a leisurely two months. There was a short visit to London, and a second trip to 90 Upper Tulse Hill to visit the Hugginses once more, 'more lovely and also more frail than at our first visit … her bright red cape, his dark velveteen jacket, the two silver heads made a picture that will never fade'.[77] The Vassar astronomers also visited the two Oxford observatories, but were unsuccessful in their attempt to meet Kapteyn's close friend Sir David Gill (1843–1914).

Caroline was delighted to learn that funding for a stereo-comparator at VCO had already been secured. She was also excited to update Mary on the fourth International Woman Suffrage Alliance (IWSA) conference which she had attended in Amsterdam; this was a political issue that she felt passionately about and one that would soon impact across Vassar College.[78]

At MWSO the computing division gained its fifth member, and third Vassar graduate, with the arrival in 1908 February of Lillian Maud Wickham (1885–1920). She used the Zeiss stereo-comparator to measure line intensities on photographic plates; more significantly, she began a romance with the head of the computing bureau, Walter Sydney Adams, whom she married in 1910. This was an exciting time at Pasadena: detection of the Zeeman effect, causing splitting of lines in sunspot spectra, suggested the presence of strong solar magnetic fields; the first hydrogen-alpha images of the solar disc had also just been achieved.[79]

The Maria Mitchell Observatory (MMO) was built on Nantucket during the spring of 1908. The astronomy class (25 members) studied the care and operation of the 5-inch f/15 Clark equatorial; the theory of the spectroscope and types of stellar spectra; and variable stars.[80]

On 1908 July 15 a dedication ceremony for the red brick observatory included a presentation by Vassar alumna Elizabeth Rebecca Coffin (1850–1930) celebrating the life of Maria Mitchell.[81] The seventh MMA annual report later revealed the following payments: $2,715 (fire-proof structure); $607 (copper dome build); and $232 (telescope installation), giving a total cost of $3,972 for the brick observatory

(Figure 5).[82]

Mary Whitney was in Europe during the summer, so celebrated the occasion by letter: 'A fitting memorial to a remarkable woman … a pleasing thought that the first person to use the telescope after its mounting is completed, will be a young woman educated at Vassar College … where Prof Mitchell spent her last twenty years of active service'.[83]

The MMA annual report noted that Miss Whiteside had reached Nantucket on July 15 and remained three weeks during which she held three public evenings and gave five lectures to the class. An open-air study of the constellations attracted over fifty people. At a second public meeting, held in the Memorial House because of cloud, she gave a talk on the planets. Her last public evening, devoted to the study of the Moon, was attended by 150 to 200 people.[84] It seems probable that MMA officers had expected her to arrive sooner and remain for a longer time. They also added that in 1908 August 'another successful moon evening was given … by Mr. Brock and Mr. Paddock … 75 people'.[85]

3.3. *Women's suffrage (1908–09)*

During 1908 spring, while Caroline Furness was in Holland, two significant women's suffrage events occurred at Vassar. In March, president Taylor refused to allow a lecture by suffragist Jane Addams (1860–1935), and two months later junior student activist Inez Milholland (1886–1916) held her first 'suffrage in the cemetery' rally adjacent to the Vassar campus.[86]

Taylor was a staunch opponent of women's voting rights, arguing that Vassar's mission was 'not to reform society but to educate women'. However, Caroline Furness had been inspired

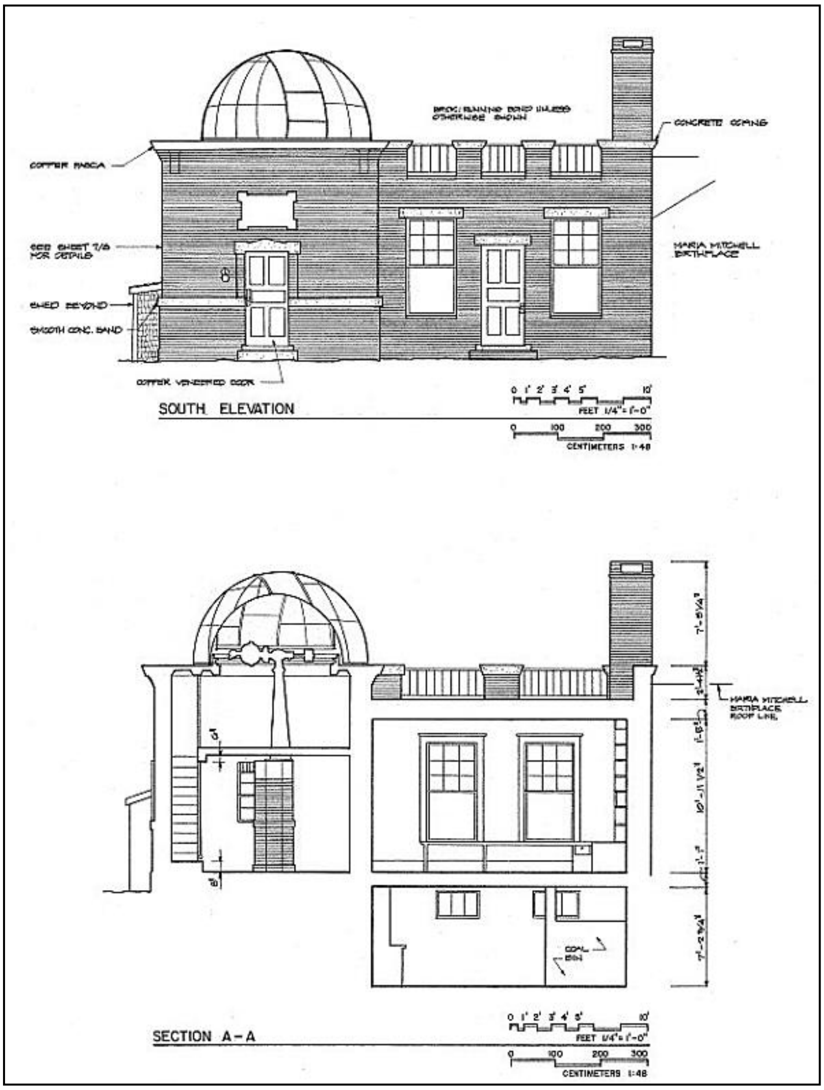

Fig. 5: Maria Mitchell Observatory, 3 Vestal Street, Nantucket. (Historic American Buildings Survey: MA-1276, Library of Congress)

by the Amsterdam IWSA conference and during 1908 fall, despite the views of the president and Vassar trustees, helped gather signatures for a petition to Congress in favour of women's suffrage. She defended her position in two ways: the college's founder, Matthew Vassar (1792–1868), had supported women's suffrage; and Maria Mitchell had regularly invited suffragist leaders to speak on campus.

Taylor became increasingly isolated as more faculty staff voiced their opinions. His situation worsened when three Vassar professors, who had already moved off-campus into Poughkeepsie, formed an Equal Suffrage League (1909).[87] When, in 1912 April, Taylor finally allowed a college debate his plea to not have faculty contributions failed. In early 1913 he submitted his resignation. In contrast, his successor, Henry Noble MacCracken (1880–1970), the fifth president of Vassar College, would prove vocal in his support of the movement.[88]

In 1908 December Mary highlighted the 'unusual variations' observed in the variable SS Cygni, which she had regularly monitored for five years. The star was a favourite object of study due to its frequent outbursts, which occurred every four to ten weeks, when it would brighten quickly from magnitude 12 to 8 for about a week, before returning to its usual faint appearance. Mary made up to fifty measures of its brightness each year, including in her summer vacations. Her results (1908 October to December) revealed a significantly reduced magnitude range, from 11.0 to 8.8, which invited further scrutiny.[89]

Four months later (1909 April) Mary and Caroline, in their first joint paper on variable stars, summarized their work on long-period variables for the *Astronomische Nachrichten*.[90] Fourteen stars were targeted with their predicted light curves checked by observation.

In her annual report (1909 May) Mary again praised the work of her independent student Ida Whiteside at Wellesley College. During 1908 she had contributed 700 observa-

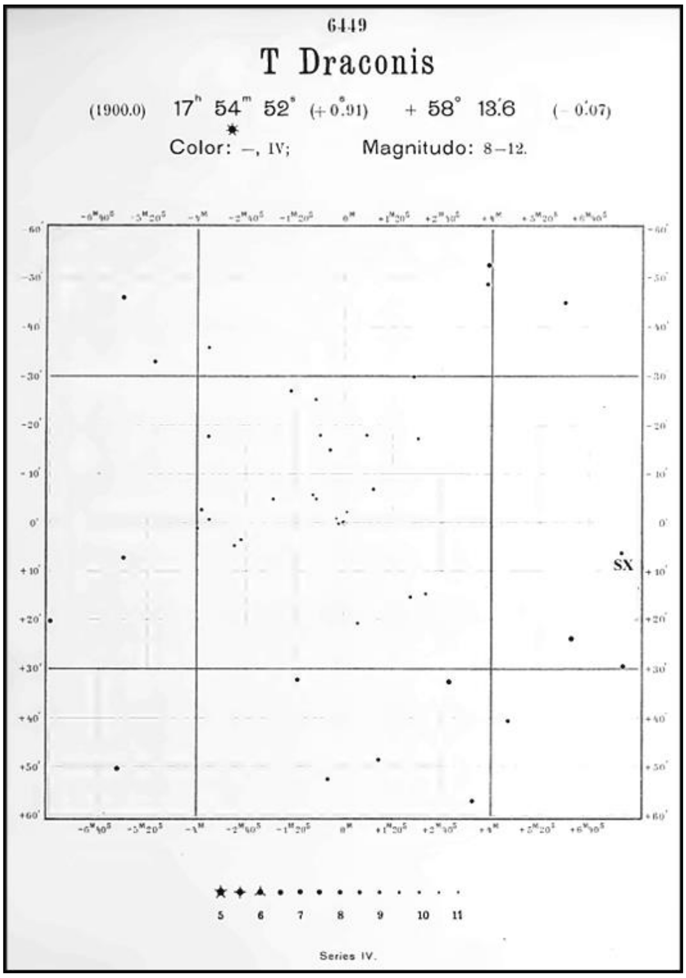

Fig. 6: Map for T Draconis, and the location of Mary Whitney's discovery of SX Draconis. (Johann Georg Hagen, Atlas Stellarum Variabilium*, series 4 part 1, Berlin, 1899)*

tions to the Harvard monthly publications, more than any other observer outside the Cambridge observatory. Pickering, perceiving her unusual capacity in this direction, advised her to give up teaching and devote herself to research. Unfortunately she had already arranged to go to Asyut in Egypt, some 230 miles south of Cairo, to teach in a mission college.[91]

Mary continued to promote the opportunities at Mount Wilson: 'A fourth of our graduates is now added to the Vassar group serving as assistants in the Solar Observatory at Mt. Wilson, Pasadena. This observatory is beyond question the leading observatory in the world in its line of research'.[92] Simultaneously, she further developed VCO's link with the Groningen Laboratory: 'Photographs of stars designed for our observatory are being taken by Donner of Helsingfors, Finland'.[93]

On 1909 June 14, immediately after Commencement week, Mary made her first observation of a 9th-magnitude star in Draco, later named SX Draconis. Using the 5-inch Clark equatorial she noted it fading slightly over a fortnight, from magnitude 9.6 to 10.0. At Waltham, using her 3-inch Clark, she observed it on four nights during August when it was as faint as 11th magnitude.[94] Further investigation required a more accurate list of comparison stars and she requested a photograph of the region from Pickering at Cambridge. Potentially, the star might be her first astronomical discovery.

During the Nantucket fall of 1908 the MMO operated intermittently: 'At one of the openings more than 30 were present. Another was attended by girls and boys from the High School. The Moon, Saturn and the Nebula of Orion were special objects of interest'.

The seventh annual meeting was held in 1909 April in Boston. Members were reminded that on Nantucket in 1835 Maria Mitchell's father was one of the first observers of Halley's Comet on its periodic return. For its reappearance in 1910 Florence Ellen Harpham (1860–1925), Professor of Astronomy at Columbia College, South Carolina, was appointed as Observer at Nantucket for six weeks, beginning in early July.[95]

The Boston meeting also confirmed a key decision to fund-raise for a 'Memorial Research Fellowship of Nantucket MMA', to cover the expenses of an Observer for several months' study in one of the larger observatories; the remaining months were to be served at the MMO conducting original research along with classes in astronomy. According to the terms of the Fellowship, which was for four years in total, the appointee was preferably to be a woman 'if equally competent with other applicants'. This undertaking was an ambitious target, requiring $1,000 annually and a Permanent Observatory Fund of c.$25,000.[96]

The second season of observation and instruction at the MMO began on 1909 July 9 with a lecture to 36 people on 'Halley's Comet', given by Annie Cannon, with also observation of Jupiter using the 5-inch refractor. A week later, on July 13, Florence Harpham gave her first public lecture (title: 'The Wonders of the Heavens') in the North Church; Alvin Paddock projected 62 lantern slides loaned by professor Harold Jacoby (1865–1932), of Columbia University Observatory. The Astronomy class was taught regularly on Wednesday evenings, with topics including 'How Worlds are Made', 'The Sun and his Family', 'Double Stars and Nebulae', 'Variable Stars', 'The History of Astronomy', and 'Is Mars Inhabited?'.

A smaller group received special guidance, such as the motion of the Big Dipper in 45 minutes, a study of the colours and magnitudes of bright stars, and tracing the ecliptic among the stars. Telescopic observations were made of the Moon, as well as several double stars and nebulae, and variable stars. Two other public meetings were held, one afternoon for observing sunspots and a study of the constellations.[97] After a very successful first season Florence Harpham left the island on August 13.

3.4. *New discoveries (1909–10)*

On her return to VCO Mary compiled a list of a dozen comparison stars for her suspected variable in Draco; it now had the provisional identity of '43.1909 Draconis'. From observations between 1909 August and October Mary provisionally concluded 'it may be of the Algol type'.[98] Two months later she confirmed her initial assessment and deduced an approximate period of 5d 4.27h with a minimum lasting about 14 hours.[99] Altogether, Mary and Caroline observed SX Draconis across 37 evenings and four minima before finalizing their results just before Christmas. The last minimum Mary observed of her discovery was on the evening of 1910 January 11 (Figure 6).[100]

Not to be outdone, Caroline now also made her first discovery of a short-period variable in Aquila. The star BD –7° 4896 had been used as a comparison star by her for nearby W Aquilae. Eight observations from 1909 October 6 to December 19 with the 12-inch equatorial revealed a magnitude variation from 10.2 to 11.4. Variability was then confirmed by Pickering and Fleming using Harvard plates; it was later designated TY Aquilae.[101] During 1909 Caroline began observing variable stars regularly and summarized the VCO investigative method two years later.[102]

In late December Mary and Caroline attended the AAAS meeting in Boston, where a paper by the noted variable-star observer Leon Campbell (1881–1951) on visual observation of variable stars at the Harvard College Observatory was relevant to their work.[103] A useful resource promoted to students at VCO was a revised edition of Schurig's *Himmels-Atlas*: 'New plates have been made so that star images and names stand out with perfect clearness even by dim lantern light'.[104]

Halley's Comet continued its approach towards perihelion, as Caroline later described: 'By February 6, the comet presented a sharp central condensation of about the ninth magnitude. It grew steadily brighter, and by February 10, the narrow cone-shaped tail had disappeared, and had given place to a tail made up of several fine streamers, radiating from the head and traced about twenty minutes from it. There was a daily variation … at times the tail presented three streamers, two of them straight, the third, the most northerly one, slightly curved'.[105]

At the beginning of 1910 March, after several weeks with few clear nights, a spell of four evenings enabled Mary to use the 5-inch for monitoring variable stars, while Caroline used the 12-inch for fainter objects. Halley's Comet was first viewed in Pisces as darkness fell; the telescope then turned to higher altitudes for the winter constellations. Magnitudes of seven variables were determined on the first night (March 3) but conditions only allowed two variables, T Cam and S CMi, on the last night (March 7). Altogether twenty variable stars were observed by Mary in this clear spell with two of them (V Tau and U UMa) glimpsed near the 12.5-magnitude limit of the Clark refractor.[106]

Sadly, these proved the final astronomical observations that Mary would make. Caroline later recounted: 'In March she was stricken as her sister was and became an invalid'.[107] Few details exist but it was probably due to a cerebral haemorrhage, incurred after a morning class, leading to an immediate paralysis of her left side. Their summer plans to attend the Astronomical and Astrophysical Society of America conference in Cambridge and then travel to Pasadena for the fourth Solar Union conference became impossible and Mary returned to her home in Waltham.[108]

Fig. 7: Photograph of Halley's Comet by Harold Knox-Shaw, Helwan Observatory, Egypt, 1910. (Science Museum, Great Britain, under a CC BY-NC-SA 4.0 Licence)

Meanwhile, Halley's Comet (Figure 7) continued to speed towards perihelion. As Caroline recounted in her Commencement week lecture in 1910 June the comet reached its greatest elongation west of the Sun on May 8, and a week later it was possible to trace the tail for a distance of 50°. The comet's head was due to be in line with the Sun and Earth on the evening of May 18; on the evening of the 19th at Vassar a somewhat narrow band of light was detected passing through the square of Pegasus, and tapered rapidly as it rose towards Aquila, where it became pretty well defined. On each side of the shaft of light, the sky was dark.[109] Caroline observed the tail with Helen Swartz; it is unknown if Mary was able to make any observations.

In her final report Mary contrasted the fortunes of her final two graduate scholars, one of whom was called home by the serious illness of her father and was not able to return. The other, Psyche Rebecca Sutton (1888–1916), had completed her A.M. thesis on δ Cephei variables. As part of it she measured about 20 photographic plates furnished by John Adelbert

Parkhurst (1861–1925) of Yerkes Observatory. Mary added poignantly: 'I have been unable to take charge of my classes since the middle of March'.[110] They were taken instead by Caroline Furness assisted by Helen Swartz who came for two months to take charge of the observational work.

A joint paper, 'Observations of long-period variables', appeared in the *Astronomical Journal* in 1910 May, in which Mary and Caroline reported details of 270 observations for 28 variable stars. It included most of Mary's final observations which were aimed to test the predicted maxima and minima from the ephemerides by Carl Ernst Albrecht Hartwig (1851–1923).[111]

The Pasadena computing division romance between Lillian Wickham and her boss Walter S. Adams resulted in their marriage in 1910. She resigned in 1910 February and her position was taken by Clementina de Forest Griffin (1886–1980) who became the seventh MWSO computer, and the fifth graduate from Vassar (Figure 8).[112]

On Nantucket, a fall astronomy evening class at the high school proved popular. Winter observing averaged 26 people with the MMO opened on the first Monday evening of each month by Clara Allen, assisted by Lydia Freeborn.[113] In the summer Florence Harpham returned for her second season, spending eight weeks on the island. She began with a public lecture on Halley's Comet with 35 stereopticon illustrations. Eight public evenings covered topics from 'the universe' to 'present problems in astronomy'. Unfortunately, the weekly open evenings at MMO were limited by an unusual amount of fog and haze.

The astronomy class had 21 sessions, working in smaller groups of two to five students, for instruction in using the telescope and the theory of the spectroscope. Florence also began training two students, including Clara Allen, in mathematical astronomy.

3.5. *Acting director Caroline Furness (1910–11)*

As there was no improvement in Mary Whitney's condition in the six months after her stroke, the new academic year began with Caroline continuing as acting director and Psyche Sutton taking the assistant's role; their salaries were c.$700 and $1,600 respectively (c.£14k and £32k today).

Caroline attended an MMA meeting on 1910 November 26 to review the report from summer observer Florence Harpham, and suggested inviting Andrew Carnegie (1835–1919), the industrialist and philanthropist, to support the proposed lectureship in memory of Maria Mitchell. On March 14 a $10,000 gift was gratefully received, completing the fellowship endowment.[114]

During the fall VCO had gained a major accessory instrument: the stereo-comparator recommended by Kapteyn and contracted for in 1908 August.[115] The 25% price increase of the Zeiss instrument initially caused concern, until Mary gave an additional sum herself.[116] The amount was c.$250 (c.£5k today) and,

Fig. 8: Relaxing at the 4th Solar Union conference in Pasadena (1910). From left: Phoebe Waterman, Ruth Smith, Clementina Griffin, and Cora Burwell (the 6th, 2nd, 7th and 4th MWSO computers respectively, with the first three from Vassar and CB from Mt Holyoke)

writing from her Waltham home in early December Mary relayed her thoughts to Caroline (whom she called 'Eleanor'):

> Dear Eleanor … the day is grey and cold. It is going to snow again. I have not been out for several days and I shall not go till conditions improve. A week from today you will be here … we must not be too stiff in our requirements for the MM Fellowship. We know how many astronomers of note made no showing in college records. We want efficient workers, not work giants. I don't know why Miss Harpham might not have it … after we get at work with the Stereo, the Fellow will like to work with us. You have a wide future before you in your astronomical influence between Vassar & its Stereo & the MM Assoc & its Fellow … now I will sit in the window just for a while … I will write more this PM or tomorrow.[117]

At VCO the taught courses continued practically unchanged. In F and G were students who were considered likely to do graduate work, or who could be recommended to positions in other observatories. H concerned variable stars, the outgrowth of Mary's own experience in the observation of these stars. It consisted of observation, plotting of light curves, and reading the literature. Three of its students had gone on to work at MWSO, and one bought a telescope for use at home.[118]

Two more Vassar graduates were appointed to MWSO during the year: Martha Renner (1911 February) worked for two months but then resigned in April due to family reasons; and Mary Wanda Sheldon (1911 July) who replaced her. Caroline worked hard to extend her networks, and assumed responsibility for organizing trips for her undergraduates. Four students accompanied her on a visit to the Dudley Observatory in Albany, and two others to the meeting of the A&ASA in Ottawa, Canada, during the summer.[119]

In a joint paper in 1911 Caroline and Psyche Sutton summarized the year's work on 22 long-period variables.[120] Inevitably the astronomical work of VCO was reduced by Mary Whitney's absence. Caroline continued the observation of variable stars with the 12-inch. Harvard Observatory asked them to cooperate in following certain stars.[121] In 1911 May the Cambridge observatory suffered a major blow when Mina Fleming died from pneumonia. America had now lost its two leading women astronomers in just 14 months.

On Nantucket, Clara Allen was the beneficiary of the MMA's $300 year's scholarship (c.£1.2k today). It involved four months of mathematical instruction under a private tutor in Nantucket, followed by nine weeks' instruction at Vassar College by Caroline Furness in the methods of observing variable stars. Completion of the new MMA Fellowship endowment was confirmed at the ninth annual meeting on 1911 April 26 and a four-year plan was adopted for the scheme (Figure 9).

Also in the spring of 1911 an important instrument modification was arranged with Alvan Clark and Sons, makers of the Maria Mitchell telescope, to replace the original wooden tube, warped by age, with one of brass. It was remounted by the Clark company employee Carl Axel Robert Lundin Jr (1880–1962) on July 15. Another necessary change was removing the Maria Mitchell library from the lower room to the library of the house.[122]

Florence Harpham returned to Nantucket for her third and final summer season. Her first talk on July 5 was on 'our celestial neighbours' to 75 people. Memorial House lectures continued for five weeks, averaging 20 people, and covering topics from terrestrial planets to astronomers and their work. Weekly visitor nights were offered, but cloud and fog interrupted viewing at times. Florence also instructed Clara Allen in reduction methods and the theory of measurement with a comparator. The MMA had agreed to undertake photographic measurements, and Edwin Frost, director of Yerkes Observatory, had agreed to furnish spectrograms.[123] Unfortunately the comparator order for measuring spectral lines, from Gaertner and Co., for the 1911 summer was delayed by a defective screw.[124]

4. Whitney's sixth lustrum (1911–16) and final years

On Monday 1912 February 5 the annual ice carnival on Vassar Lake included five hundred girls skating silently in white robes with silver scarves, while bonfires and Japanese lanterns adorned the banks. Watching the spectacle were dozens of faculty staff but, for the second successive year, one familiar face from the astronomy department was missing: Mary Whitney.

She remained trapped in Waltham, confined to home and relying on the care and support of family and friends. She would never see the ripple of change underway: electric

Astronomical Fellowship
OF
The Nantucket Maria Mitchell Association

The Nantucket Maria Mitchell Association offers an Astronomical Fellowship of one thousand dollars to a woman for the year beginning June 15, 1912, under the following conditions:

The year shall be divided into two periods, approximately as follows:

June fifteenth to December fifteenth, on Nantucket. This period shall be occupied in observation, research or study, and in lectures or instruction to classes or individuals.

February first to June fifteenth at one of the larger observatories. This semester shall be occupied in original research and study. During this period a distinct plan for the following Nantucket period shall be formulated.

Every fourth year the fellowship shall be available during the entire year for study at one of the larger observatories in Europe or America.

The fellowship shall be awarded annually, but in order that the work at Nantucket may be combined advantageously with the work at the selected observatory, the preference will be given to the same candidate for three successive years. This candidate shall have first consideration among applicants for the special quadrennial appointment.

A competitive examination will not be held. The candidate must present evidence of qualifications under the following heads:

1. A letter from the candidate addressed to the secretary of the committee, giving an account of previous educational opportunities and training, and of plans for future work.

2. College diploma or a certificate from the registrar of her college, and if she has already held a position as instructor or teacher in any college or other institution, a clear statement of the work done, together with a certificate as to the quality of her work.

3. Examples of work already accomplished.
4. Testimonials as to ability and character.
5. Satisfactory evidence of thoroughly good health.

The fellowship at all times must be used for purposes of serious study, and the fellow should be as free as possible from other responsibilities.

Application for the year beginning June 15, 1912, should be made under the above heads and must be in the hands of the secretary of the committee, Mrs. Charles S. Hinchman, 3635 Chestnut Street, Philadelphia, Pennsylvania, on or before March 1st, 1912.

Committee.
- Prof. Mary W. Whitney, Director of Vassar College Observatory, Chairman.
- Annie J. Cannon, A.M., Harvard Observatory, Vice-Chairman.
- Prof. Anne S. Young, Ph.D., Mt. Holyoke Observatory.
- Dr. Edward C. Pickering, Director of Harvard Observatory.
- Elizabeth R. Coffin, Nantucket, Mass., A.B. Vassar College, 1870.
- Florence M. Cushing, Boston, A.B. Vassar College, 1874.
- Lydia S. Hinchman, Philadelphia, Secretary.

Fig. 9: Astronomical Fellowship of the Nantucket MMA – the four-year plan adopted by the Board of Managers at its annual meeting, held 1911 April 26. (1911MMAAR..9..22)

lighting in Main replacing traditional gaslights, extending across the whole campus six months later; soot and cinders accumulating on VCO instruments after the switch from gas combustion to burning coal and the teams of men needed to shovel fuel into boilers day and night; the first mass suffrage meeting on the campus, following a petition by nearly half the student body, immediately regretted by president Taylor; and, at the end of the academic year, 243 young women graduating – the largest ever number in nearly five decades.[125]

4.1. *A new face on Nantucket (1911–12)*

The new academic year began with observations of two comets, 1911c (Brooks) and 1911f (Quenisset), across eight nights.[126] Eighteen months after Mary Whitney's departure her astronomical courses continued as usual. Caroline was able to introduce an element of personal interest through graduates who had gone on to be employed at various observatories. One of them, Ruth Smith, presented a set of photographs of the Sun taken with the Mt Wilson spectroheliograph which were of great value in the classroom.[127]

Class sizes were however falling, despite Vassar student enrolment continuing to rise. Classes B, F, and G were most affected. In the observational class D poor spring weather, few planets visible, and a sunspot minimum limited opportunities. Caroline was pleased with her development of the history of astronomy in class G which included topics such as the history of the leading observatories, their instruments, and the work undertaken. Caroline suggested to student Frances Montgomery Cowan (1890–1971) that she should write a popular account of the great Russian observatory at Pulkovo for *Popular Astronomy* magazine, which was duly published.[128] Students in the variable star course H reported their results to Harvard Observatory, which were included in the annual reports.

At VCO the working time was given over entirely to the editing of Mary's observations on variable stars which were begun in 1901. This was published in 1913 as Volume 3 of the publications of the Vassar College Observatory.[129]

Caroline concluded her second annual report in 1912 May with a request for $50 (c.£1k today) to cover 'repairs, slides and slide boxes' and also 'a case which can be securely locked for keeping our valuable records'. She also noted: 'A new portrait of Prof. Whitney has recently been given to the Observatory to hang in the Clock room … an enlargement of the photograph most admired by her friends. It will hang next to one of Prof. Mitchell'.[130]

On receiving the resignation of Mary Whitney as MMA president in 1911 October officers praised her 'long and wise' administration and appointed her Honorary President of the Association.[131] Membership of the group now exceeded five hundred people. An interesting aspect of MMA's approach during its first decade was the establishment of an Advisory Council, which by 1912 included a dozen (male) educators and astronomers.[132]

The international distribution of a circular in 1911 October advertising the MMA endowment fellowship opportunity resulted in eight applicants. Caroline awarded the Fellowship for the year 1912–13 to Margaret Harwood (1885–1979), of Littleton, Massachusetts, a graduate of Radcliffe College, who had been engaged in research at Harvard Observatory for four years.[133]

MMA winter activities broadened with the cooperation of Nantucket County Teachers' Association. An astronomical lecture by Garrett Putnam Serviss (1851–1929) of New York included a tribute to 'Professor Mitchell, the Island Astronomer', stereopticon slides, and lucid explanations of modern astronomy.[134] In 1912 January Clara Allen received training at the Harvard Observatory, where she learned to make identifications of stars marked on photographic plates and to estimate the brightness of variables. Her work was supervised by Annie Cannon, who had taken over Mina Fleming's role as Curator of Astronomical Photographs.[135]

Margaret Harwood arrived at Nantucket on 1912 June 14 and remained until December 14; her commitment to MMO would continue for 45 years. MMA officers found that her service was 'highly satisfactory in every way to all associated with her, and her enthusiasm for her chosen science tended to interest many, both residents of the island and summer visitors'.[136]

Margaret's six-month residency as Astronomical Fellow facilitated public lectures, training, and a special scientific investigation. At the first Monday open evening fifty guests arrived, with over three hundred attending during the summer season. The outer planets, Pleiades, Double Cluster, Orion nebula, and the Moon's phases were observed with alternate Monday talks in the Memorial House covering Jupiter, sunspots, meteors, and eclipses. One Nantucket resident joined Margaret for twelve mornings at 3 a.m. for observations of the zodiacal light. Special classes ran weekly for five local people and also a Nantucket boys group became keenly interested; Margaret proved to be an effective communicator.

In July Edward Pickering and Annie Cannon arrived from Cambridge. Pickering suggested that useful work might be done at Nantucket with a 6- or 7-inch photographic telescope devoted to the study of asteroids. At that time approximately eight hundred minor planets had been discovered. Significantly, the MMO had been designed to accommodate a larger instrument when funding allowed. Having sowed the seed of the idea Pickering and Cannon returned to Harvard. Pickering had also planned an additional idea for the MMA to support, which would directly honour the memory of Maria Mitchell.

4.2. *A photographic telescope for Nantucket (1912–13)*

Between 1912 and 1915 Caroline Furness served Vassar as an Associate Professor, with an annual salary of $1,400 (c.£28k today). In 1912 October her assistant Psyche Sutton had left to get married and was replaced by graduate Jessamine May White (1891–1991) who served until the following year.

Student numbers in astronomy had increased and the observational classes C and D benefitted from three well-placed planets, Venus, Jupiter, and Saturn. The installation of electric lighting at VCO proved successful and the Vassar carpenter had been busy: 'A case has been constructed for the special purpose of storing records of the Observatory … all of Prof. Mitchell's old notes including her observations for the determination of the latitude and longitude, her drawings of planets, and other observations … there is room also for our stock of astronomical photographs, from the observatories at Helsingfors and Cambridge, Mass'.[137]

Caroline devoted significant time to networking. She had attended the dedication of the new Allegheny Observatory, Pittsburgh in 1912 August together with Helen Swartz and Jessamine White, which also hosted the 14th meeting of the A&ASA where she presented a paper on variable stars. Harvard Observatory was visited twice, once with three students from the B class. Early in the fall she welcomed her Dutch friends Jacobus Kapteyn and his wife, who had spent the summer at Mt Wilson.

Time was also needed tracking former students. Computer Mary Fowler transferred from HCO to Princeton, where she investigated eclipsing binaries; Phoebe Waterman, together with fellow Berkeley PhD Anna Estelle Glancy (1883–1975), was appointed assistant astronomer in the Observatory at Cordoba, Argentina; and Edith Clarke was successful as a research engineer in the American Telephone and Telegraph Company. More unexpected outcomes occurred with Pasadena graduates: three of them retired to marry astronomers who they worked with.

Closer to home Jessamine White announced her intention to also marry at the end of the year, causing Caroline to reflect: 'I can not help feeling that the department will build up faster, and sooner return to its old standing, if we can secure someone as a helper, who is interested in Astronomy as a life work, and who is ambitious to do some piece of investigation'.[138]

Her main work as acting director involved completing the reduction of nearly 5,000 variable star observations, which necessitated determination of the magnitudes of comparison stars. The regular publication fund of VCO was $100 per year (c.£2k today), with Mary Thaw Thompson and Mary Whitney contributing similar sums. The exchange list for VCO included over 300 observatories and astronomers, requiring a source of extra funding for printing and distribution.

Despite these pressures Caroline continued her own variable observations with the 12-inch equatorial, achieving some 500 estimates during the year.

On 1912 October 8 the MMA Board of Managers agreed to fund a 7.5-inch Cooke photographic telescope for the Maria Mitchell Observatory. The Clark mount would accommodate the 5-inch telescope as a guide instrument. The committee adopted the advice of Edward Pickering and Annie Cannon and agreed to raise the $3,300 (c.£6.6k today) funds required; fortunately, they already had $1,600 reserved for a telescope upgrade.

Margaret Harwood spent the first half of 1913 at Harvard Observatory, investigating periods and light curves for Algol-type variables. She practised taking star photographs with different Harvard instruments and in 1913 June received delivery of the 7.5-inch Cooke photographic lens at MMO. Initial tests revealed a misalignment of the middle component, probably caused by the ocean voyage from England, but fortunately expertise was close at hand. Among the helpers was clergyman Joel Hastings Metcalf (1866–1925) who later loaned the MMO his 6-inch comet-seeker. Margaret's second Nantucket residence from 1913 July to December enabled nearly four hundred people to use the 5-inch refractor before it was returned in mid-August to Alvan Clark and Sons in Cambridge for its upgrade.

4.3. *Maria Mitchell fellowships at Harvard Observatory (1913–14)*

For the next two years the VCO assistant was Ernestine Wells Fuller (1884–1969), a graduate of Wellesley College. In Caroline's last letter to president Taylor, in 1914 January, she recommend that Ernestine be promoted to the grade of instructor.[139]

Two key decisions in 1913 fall involved astronomical fellowships. To enable Margaret Harwood to take her quadrennial year at a different observatory, the MMA agreed a $500 (c.£10k today) fellowship to cover her absence from 1915 June. Secondly, the MMA agreed a series of $500 fellowships, targeting graduates of women's colleges, to spend time at both HCO and MMO.[140]

During the three-month telescope upgrade Margaret Harwood used smaller apertures belonging to the Coffin School and Nantucket High School to observe variable stars. On November 15 the new instrument, consisting of the 7.5-inch photographic telescope and the old 5-inch with new mountings, was set up in the Observatory and a few photographs were taken before Margaret left the Island on December 15.[141]

The MMA astronomical equipment fund revealed costings: Thomas Cooke & Son photographic telescope, $950; Alvan Clark Corporation pier, clockwork, and mount, $2,165; installation, accessories, plumbing for dark room, and photographic materials, $379, giving a total cost of $3,494 (c.£7k today).

After her second season at Nantucket Margaret returned to Harvard Observatory and began researching the minor planet Eros. In the spring of 1914 the MMA announced that Genevieve Matthews (1890–1965) from Radcliffe had been appointed the first Maria Mitchell Fellow at Harvard Observatory, and was measuring the photographic brightness of the satellites of Saturn.[142]

5. Retirement of Mary Whitney (1914–15)

Mary Watson Whitney retired in the academic year 1914–15, fifty years after she first entered Vassar College in the class of '68, and was awarded the title Professor Emeritus. She never recovered from the paralysis of her left side, as Caroline later explained: 'Ten years of inactivity awaited her which required all of her fortitude to bear, until in January 1921 she died, being in her 74th year'.[143]

Having reduced and published nearly five thousand variable star observations, Caroline next focused on teaching this branch of practical astronomy. Most of the year was spent writing *An Introduction to the Study of Variable Stars* which appeared in 1915 in the Vassar semi-centennial series.[144] The observing guide, the first ever published in English, was dedicated to Mary W. Whitney, 'in memory of many happy hours spent together in the pursuit of our loved science'. Within its 327 pages the topics of star charts, catalogues, magnitudes, photometry, light curves, eclipsing binaries, long-period variables, and hints for observers were lucidly explained. In recognition of her effort Henry Noble MacCracken, president of Vassar College, appointed Caroline Ellen Furness as Alumna Maria Mitchell Professor of Astronomy (1916), on a salary of $2,400 (c.£48k today).

The third year of Margaret Harwood's service as Fellow of the MMA began on Nantucket in 1914 June with a few months spent readjusting the telescope pier to improve polar alignment. By mid-December photographic images were much improved and 21 exposures were made of Eros; other subjects included Delavan's comet, the Orion nebula, and the Pleiades.[145]

Another volunteer, Mary E. Morris (1874–1937), became an active student, observing β Lyrae with the 3-inch Coffin telescope. Lectures were given on 'the Earth', 'geology of Nantucket', and, by visiting guest Harold Jacoby of Columbia, 'how to navigate a ship'; numbers rose from 19 to 200. Nearly three hundred visitors used the telescope, including 23 on September 23 at 3 a.m. to view Delavan's comet. On the morning of November 7 fifteen people observed the transit of Mercury. To cover the planned quadrennial year absence of Margaret her replacement, Susan Raymond, spent June at Harvard Observatory followed by a fortnight's training on Nantucket.

Margaret Harwood opted to spend her quadrennial leave of absence taking a master's degree in astronomy at Berkeley, with two months' spectroscopic work at the Lick Observatory on Mount Hamilton, California. Annie Cannon wrote with admiration of the progress achieved: 'The Maria Mitchell Association now has an Observatory equipped with an excellent photographic telescope, and three fellowships, under which young women of the best college training are actively and enthusiastically engaged upon some of the problems connected with the great sidereal universe'.[146]

5.1. *Final years (1916–21)*

When Vassar College opened in 1865, with director Maria Mitchell and student Mary Watson Whitney, a 48-ft chimney stood above the boiler house due south of VCO. Seven years later, by the time Mary had earned her A.M. degree, a second 90-ft chimney had been erected. These chimneys were to prove fatal to VCO instruments.

The problem began in 1912 when Vassar switched from gas combustion to using direct current generated by burning coal. By 1923 the powerhouse consumed 10,000 tons of fuel per year. The Vassar central heating plant used five Babcock & Wilcox hand-fired boilers and required a team of 40 men working eight-hour shifts. The situation only changed in 1955 when Vassar trustees opted to purchase electricity from a local energy company.

Caroline complained to president MacCracken in 1918 May about 'the cloud of smoke and cinders which frequently pours from the tall chimney of the boiler house … the cinders sift in and get into all the delicate bearings'. She described it as 'not a soft soot which crushes easily but a hard cinder which if allowed to remain will scratch and injure the mountings … is it not possible to have some kind of smoke consumer attached?'

Nearly a decade later, in 1927 May, the problem had worsened, as explained by acting director Maxine Alberta Hawes (1890–1985): 'The observatory instruments have always suffered from the smoke and cinders from the power house, but this year conditions have been much worse, due to the added grit and cinders resulting from so much construction around us'.[147]

The problem was never addressed; as reported by Caroline in 1930 May: 'Cinders from the college smoke stack … blow into the observing room through crevices in the trap doors and sometimes get into the bearings of the telescope mountings and roughen them. They also get into the eyes of the students as they are looking up at the sky'. Damage to VCO instruments proved permanent; they would later be transferred to the Smithsonian Institution.[148]

During 1916–17, practical classes were delivered by Harriet McWilliams Parsons (1892–1986) who combined her VCO work with regular trips to Yerkes observatory.[149] The Vassar astronomers were keen to use the stereo-comparator, as it offered an alternative line of research. Caroline was also keen to ensure her mentor's financial commitment proved a sound investment.

Dutch astronomer Jan van der Bilt (1876–1962), returning from MWSO, visited them for two months in 1917 to discuss his studies on variable stars. While there he used the stereo-comparator to determine the proper motions of stars in the Kapteyn areas on plates taken at Helsingfors.[150]

The stereo-comparator continued to be used intermittently for examination of plates taken at Helsingfors, as Caroline reported five years later: 'Tests were first made of the stability of the instrument which, on account of its large size, is usually susceptible to changes in temperature … further tests will be required to show whether the interval in time between the plates, ten years, is sufficient to determine proper motion on plates of such small scale … the measurements and reductions were made by Miss M. Alberta Hawes'.[151]

Mary and Caroline were founder members of the A&ASA, whose second president was Edward Pickering. Under his leadership closer links between professional and amateur astronomers had been forged, especially for variable-star astronomy. American colleges regularly hosted meetings, with Smith and Mt Holyoke the location for the 24th session, held in 1920 August (Figure 10). It proved to be the last occasion Caroline was able to discuss the outcomes with her mentor. The women's group photo included three of her former students, with a fourth operating the camera. Unfortunately, time was now rapidly ebbing away for Mary, and five months later she died from pneumonia at her Waltham home on 1921 January 20.

Caroline's personal appraisal of Mary's life and achievements appeared posthumously in *Popular Astronomy* in 1923:

> In 1889, when Miss Whitney became Professor of Astronomy at Vassar, she was forty-one years old and in her prime, strong in mind and body, and strong in character … there was about Miss Whitney herself, a loftiness, a selflessness, a nobility which made her almost an ideal and which drew many to her in lifelong devotion … her first love was pure mathematics and its corresponding branch in astronomy, celestial mechanics … in 1901, the appearance of Nova Persei revived Professor Whitney's interest in variable stars, and thereafter she gave most of her attention to that line of research … in [1910] March she was stricken as her sister was and became an invalid. Ten years of inactivity awaited her which required all of her fortitude to bear, until in January 1921 she died, being in her 74th year … in her will Professor Whitney left a sum of five thousand dollars to the College for the benefit of the astronomical department, the income of which is to be used solely for research … she was in intellect and character the finest type of New England woman; in intellect, steadfastly devoted to the truth; in character as steadfastly holding to the highest ideals, with a gentle humanity and forgetfulness of self that made her a sincere friend of everyone … a procession of Vassar graduates went to many of the leading observatories of America: Yerkes, Lick, Mount Wilson, Allegheny, Columbia … without such assistance as this, the science of astronomy would not have made the wonderful progress it has during the past twenty-five years in America. In discovering such talents and in giving them preliminary training, Miss Whitney made a greater contribution to astronomy than she had any conception.[152]

Caroline fulfilled her mentor's wish to use her bequest to ensure VCO's ambitious plans for observing the total solar eclipse of 1925 January 24 were fulfilled. The path of totality linked seven American observatories, including Vassar, Yale, and Nantucket. Three previous solar eclipse expeditions from Vassar had taken place, to Iowa (1869), Denver (1878), and

Fig. 10: The 24th AAS meeting (1920 August) was held at Smith and Mt Holyoke colleges. Four former students of Mary Whitney were present: Margaretta Palmer (Yale, far left), Antonia Maury and Caroline Furness (both to the right of Annie Cannon, who is sixth from the right) and, taking the picture, Helen Swartz (inset). (From Pamela Etter Mack, Women in Astronomy in the United States 1875–1920, BA thesis, Harvard, 1977, p. 49)

Wadesboro (1900), but this time the whole of the college could participate in a momentous astronomical event.[153]

Following Mary's second request, Caroline reinvestigated the longitude of the VCO using radio time-signals from Arlington.[154] The work was completed in 1926–7 by Laura Elizabeth Hill (1893–1991) and M. Alberta Hawes.[155]

After Laura Hill's departure the Whitney fund was again used for the reduction of measures, by Swiss graduate student Georgette Camille Maulbetsch (c.1900–60).[156] Following completion of this fourth publication of VCO in 1934 Caroline took a sabbatical break at MWSO where she researched infra-red lines in the solar spectrum before illness halted her studies. She died in a New York hospital on 1836 February 9.

Her successor at Vassar, Maud Worcester Makemson (1891–1977) reported: 'Miss Furness left her three-inch telescope, inherited from Miss Whitney, and a fine sextant, to the Observatory, as well as a fund to encourage research and purchase new instruments'.[157]

The first three directors of VCO had passed on, but together they had inspired generations of women, summed up well by the final two lines of Mitchell's famous poem:

> as sisters or daughters, or mothers or wives,
> will take the starlight into their lives.

Conclusion

After writing a quintet of papers for *The Antiquarian Astronomer* on women astronomers in the United States over the past eight years it is appropriate for the writer to reflect on the outcomes. A few statements may appear contentious, but may help other investigators to add their own interpretations.

First is the legacy of Maria Mitchell, resulting from her Vassar College directorship. During her two decades of leadership, she was significantly handicapped by the inadequacies of her 12-inch Fitz equatorial, coupled with the difficulties of using the dome. Little wonder her visual work with the refractor focused on the major planets, observed during evening periods with the telescope effectively always in the same position. This plan naturally limited the need to rotate the dome too far, readjust counterweights, or roll the heavy observing steps around the pier. Whole-sky surveys from within the dome were simply impossible.

In contrast, the doors of the meridian room opened easily allowing the Young circle to quickly be operational. Mitchell may even have felt a little imprisoned beneath her silvery dome; she certainly would have welcomed using a smaller aperture, perhaps like the 8-inch f/15 equatorial that Vassar later received (1941). For this reason, she utilized the dome space for alternative activities, notably annual dome parties for her students and discussion meetings, thereby creating lasting memories for all participants. Sensibly she devoted her energies in her final years to improving instruments for her successor and fund-raising to ensure the future survival of VCO.

Suggestions that she personally took hundreds of sunspot photographs or time measurements are inaccurate; she certainly set up and monitored these systems, but delegated daily operations to her assistants. This is not to undermine Mitchell as an astronomer – she achieved an amazing amount of work before coming to Vassar – but to challenge some misguided judgements.

Second, the legacy of Mary Watson Whitney, which has often been severely undervalued by biographers. Much of the international reputation VCO gained during her directorship was earned through her commitment and tenacity to secure both a research programme and output a steady stream of publications. She benefitted hugely from having an operational 12-inch equatorial, enabling minor planets to be tracked across the sky and light-curves of faint variable stars to be investigated. To have achieved this during a period of massive college expansion is impressive, but to have also found the energy to support dozens of graduate students and develop networks across all the major American observatories is an even greater achievement.

Third, Mary's oft-quoted reflection from her later years, 'I hope that when I get to heaven, I shall not find the women playing second fiddle', has a poignancy even today, but no one should doubt her dedication to addressing the needs of women. It is interesting to compare the Whitney quote with one from Mitchell, often said in her later years: 'She did not know which was her greatest feat, to discover the comet which made her famous, or to find Mary Whitney'. Certainly the Mitchell–Whitney partnership shares parallels with the Whitney–Furness collaboration, but the latter had a much greater reliance on equality and mutual promotion.

Fourth, both Mitchell and Whitney began their directorships with the need to support their families. The key difference is the importance of Maria's father William Mitchell (1791–1869), who was the first person to introduce Mary to VCO, while his daughter was busy greeting parents in the Main building. The bond between the old astronomer and the young student grew ever stronger, especially following the death of her own father midway through her degree. Further exploration of their relationship would be worthwhile for a future researcher.

Fifth, the parallel astronomical careers of Williamina Fleming and Mary Whitney, the two greatest women astronomers in America at this time. Mary must have reflected on her colleagues' achievements during her lonely years in Waltham – perhaps a future analysis of the Whitney–Furness letters held in Vassar Archives will reveal more. It is not important to judge which person made the larger contribution to the progress of astronomy – and the writer would still love to watch them battling over the chessboard – so perhaps it is best to say that both of their contributions proved vital.

At the very end of a research project, it is difficult to say exactly where a story should begin or end. Perhaps it should begin on Nantucket, when a young male astronomer and a young female librarian met, married, and started a family. Their second child, a girl, when aged seven was inspired by both the comet her father showed her, and equally, by the books her mother was reading aloud. The rest of the story is never-ending.

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Contributing to the number of historical papers for women astronomers has been a motivating factor for the writer. The experience of working with Vassar College Archive primary material has proved especially rewarding.

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References and notes

1. Haley, P. A., 'Mary Watson Whitney and the Vassar College Observatory', *The Antiquarian Astronomer*, 17 (2023), 2–27.
2. Haley, P. A., 'Maria Mitchell and the Vassar College Observatory', *The Antiquarian Astronomer*, 16 (2022), 2–36.

   Haley, P. A., 'Maria Mitchell (1818–89): from Nantucket to Vassar', *The Antiquarian Astronomer*, 15 (2021), 40–79.

   Haley, P. A., 'Williamina Fleming and the Harvard College Observatory', *The Antiquarian Astronomer*, 11 (2017), 2–32.
3. Lankford, John, *American Astronomy: Community, Careers, and Power, 1859–1940* (University of Chicago Press, 1997), Chapter 9, 'Science and Gender: Women in the American Astronomical Community'; Creese, Mary R. S., *Ladies in the Laboratory?* (Scarecrow Press, 1998), Chapter 10, 'Women in Astronomy'.
4. Mary Swain Wagner worked at both VCO (1892–3) and HCO (1893 fall). She returned to Minneapolis to care for her invalid mother. See Wagner, M. S., *Double-star measures*, 1897AJ..18..13W. Xi Scorpii was the closest pair measured at 1″.37 using the new 10.5-inch Warner & Swasey equatorial. Double-star observer Frank Leavenworth was director from 1892–1927.
5. Mary Wagner and Anne Edith Lapham established their business on Raymond Avenue. After three years Anne married and moved away. The popular 6-bed property was first known as the *Wagner Inn*, and then the *College Inn* (1817–24), after which it served students as the *Vassar Bank*. See also: Wagner, Mary S., *The Inner Life of an Inn being a true story of an inn near Vassar College* (A. V. Haight Co., 1919).
6. Haley (2017, ref. 2), p. 4, Table 1, *Female assistants at HCO 1875–1911*.
7. VCO Annual Report 1902. Annual reports (AR) were produced towards the end of each academic year, in May. Heinrich Carl Friedrich Kreutz (1854–1907) was editor of the *Astronomische Nachrichten*, in which VCO results appeared. He specialized in cometary orbits, especially sungrazing comets. Work on the orbit of comet 1886 III continued at VCO until the end of 1907.
8. *Vassar Miscellany*, 31 (1891), p. 127.
9. VCO AR 1902. Elizabeth Buchanan Cowley from Pittsburgh worked as an Associate Professor of Mathematics at Vassar (1902–29). For her A.M. she calculated an orbit for Comet 1826 II which involved correspondence with the observatories at Naples, Florence, Algiers, Milan, Kiel, and Göttingen, two weeks at the US Naval Observatory, and research at the Harvard and Columbia libraries.

   Helen Margaret Swartz (1878–1959) from Norwalk, Connecticut, later worked as an insurance investigator.

   Ida Isabel Watson, from Port Washington, became a teacher (1902–07) then married Frank Lippert (1907).
10. VCO AR 1902.
11. VCO AR 1902. Over sixty HCO *Circulars* had been circulated, each one compiled by Mina Fleming under the direction of Edward Pickering.
12. VCO AR 1901. See 1902PA..10..47, *Maxima and minima of long-period variables* for an example of an ephemeris calculated by Helen Swartz and Ida Watson.

    See also: Williams, Thomas R., and Saladyga, Michael, 'Some Personalities from Variable Star History', *JAAVSO*, 43 (2015), 86–101 for biographical sketches of many early observers.
13. Eight asteroids were measured in 1901–02, with results published in *AN* 2795 (1902 June), *AJ* 534 (1903 March), and *AJ* 570 (1905 January).
14. The writer has used a currency conversion of £1 = $5 for this paper, with the assumption that costs have risen by a factor of 100 since 1900.
15. VCO AR 1903. The 'October comet' 1902b (Perrine) was observed on 15 nights (September 22 to November 1) with measurements published in *AJ* 528 (1902 December).
16. VCO AR 1903.
17. Furness, Caroline, 'Mary W. Whitney and the VCO', *Vassar Quarterly*, 6.3 (1921).
18. The Vestal Street home of the Mitchell family was built in 1790. It was owned by Maria Mitchell's aunt, Mrs Peleg Mitchell, whose husband bought it in 1836 from Maria's father William Mitchell. Maria Mitchell lived there 1818–36.
19. Furness, Caroline E., 'Catalogue of Stars Within Two Degrees of the North Pole', *Publications of the Vassar College Observatory*, 2 (1905). The main computer was Elizabeth Tompkins. Others were students Phoebe Waterman and Frederica Chase, Mary Tarbox, and Elise Whitney (Mary's niece).
20. Furness, Caroline E., 'Mary W. Whitney', *Popular Astronomy*, 30 (1922), 597–608, and 31 (1923), 25–35.
21. Hinchman, Lydia S., 'A History of the Astronomical Fellowship of the Nantucket Maria Mitchell Association', *Vassar Miscellany*, 154.1 (1914). Initially the by-laws of the MMA required that a 'majority of our Board shall have been at some time students of Vassar College or affiliated with

it'. For several years a majority of the Association were students, graduates or professors of Vassar College; by 1914, only 228 out of a total membership of 560 were of Vassar affiliation.

22. VCO AR 1903.
23. Nine asteroids were measured in 1902–03. Comet 1903a was observed on 11 nights (January 30 to March 13), with results published in *AJ* 570 (1905).
24. 'The Rumford Fund. Awards of the Premium and Grants of Research in Light and Heat', *Proc. Am. Acad. Arts and Sciences*, 56 (1921), 355–73. After six months Mary decided not to purchase a wedge photometer and chose instead to focus on long-period variable stars. Mary spent three months determining the constant of the wedge, using settings on 33 pairs of stars, mainly in the Pleiades.
25. 1913PVasO..3..93–4 gives tabulated results. W Ursae Majoris is a low-mass contact binary star of apparent magnitude 7.9 and period 8h 26s, with a 0.7-magnitude variation.
26. 1903AN..161..159. Lidiya Ceraski was born Lidiya Petrovna Shelekhova (1855–1931). In 1884 she married Vitold Karlovich Ceraski (1849–1925) who directed Moscow University Observatory 1890–1916. By 1899 Lidiya Ceraski had visually discovered two Algol-type variables – see HCO Bulletins 47 and 69. Fifty years earlier, Maria Mitchell recorded minima of Algol using her 3-inch Fitz refractor on Nantucket.
27. 1913PVasO..3..101–2. VCO was one of the first observatories to study Z Draconis. On the night of July 15 astronomers using the 23-inch equatorial of the Halsted Observatory at Princeton recorded a minimum of magnitude 12.8; at VCO on the same night Mary measured 12.9.
28. Whitney, Mary W., 'Comparison stars for the Algol variable 4.1903', 1903PA..11..428W.

    See also: Dugan, Raymond Smith, *Photometric Researches: The Algol-system Z Draconis* (Princeton, 1912); and Russell, Henry Norris, and Shapley, Harlow, 'Elements of the Eclipsing Variable Stars Z Draconis and RT Persei', 1914ApJ..39..405R.
29. Comet 1903c was observed on two nights (July 17 and 23), with results published in *AJ* 570 (1905 January).
30. 1913PVasO..3..13–14. Section 8: Photometric Observations [1903–05].
31. Mary Whitney had excellent vision. The limiting magnitudes of the three instruments she used (3, 5, and 12-inch) were 11.4, 12.5, and 14.2. Using an illuminated filar micrometer, comparison stars of magnitude 13.5 were observable with the 12-inch equatorial.
32. Daniel, Zaccheus, 'Observations of 7793 SS Cygni', 1903AJ..23..182D. Astronomy at Princeton University had been developed by Mary's colleague Charles Augustus Young (1834–1908).
33. 1913PVasO..3..1W, 173–7.
34. VCO AR 1904.
35. VCO AR 1904. In 1903–04 asteroid Bamberga was measured on one night (October 3) and Comet 1904c was observed on six nights (May 2–16), with results published in *AJ* 570 (1905 January). Mary Tarbox became Mrs Babbitt (1905).
36. VCO AR 1906. Alice Henck, from Boston, Massachusetts, worked as an artist at Vassar (1886). The instrument was in memory of her father, John Benjamin Henck, head of the engineering department of MIT (*Vassar Miscellany*, 33 (1904), p. 447).
37. Whitney, Mary W., 'Problem of Solar Motion', 1897PA..5..309, Mary's original paper; 'The Determination of Solar Motion', 1904PA..12..226W and 1904PA..12..311 explained the mathematical concepts.
38. Hale, George E., *Report of Director of the Solar Observatory, Mount Wilson, California* (1905).
39. Maria Mitchell Association Annual Report, 1904, issue 2. Gideon Folger was the younger brother of Walter Folger (1765–1849).
40. VCO AR 1904–05, and Furness (1923), op. cit. (ref. 20), 31–2.

    For more on Elizabeth Cowley see ref. 9.

    Ida Whiteside from South Cambridge was one of the more able senior students in class G.
41. VCO AR 1902–03 and 1905.
42. Five asteroids were measured in 1904–05. Comet 1904e was observed on three nights (February 23–25), with results published in *AJ* 587 (1906 July).
43. 1905AN..169..279W, *Observations of new variables*, dated 1905 April 7. RS Cas was later classified as a Cepheid-type variable, with a period of 6.3 days. See also: 1913PVasO..3.. pp. 34, 40, 119, and 193.
44. Hale, George E., *Report of Director of the Solar Observatory, Mount Wilson, California* (1906).
45. 1906MMAAR..4..6. A partial lunar eclipse was also visible from Nantucket on 1905 August 14–15. Harriet Elizabeth Caryl taught at Boston High School for Girls for

five decades up to 1903, and she was a keen astronomer. Sadly, she became almost totally blind soon after this talk. Her mother's name was 'Whitney'; it is possible she was related to Mary Whitney as they lived in the same area of Massachusetts. See also: Dix, Florence, *A Memorial of Harriet Elizabeth Caryl* (1919, Boston, privately printed).

46. VCO AR 1906, and Whiteside, Ida, 'Maxima of Long-Period Variables', *Astronomical Journal*, 26 (1908), 17–18.
47. Furness (1905), op. cit. (ref. 19).
48. VCO AR 1906. The larger student observatory, with a roll-off roof design (1898), was located on the south side of VCO. It housed the 5-inch f/15 Clark equatorial, donated (1889) by Cora Harrison, for over four decades.

    In 1941, an excellent 8-inch refractor, property of the late Worcester Reed Warner of the Warner and Swasey Company, was presented by Mrs Warner. Four years later the Henck telescope was sold to the Peekskill Amateur Astronomers group for $200, with the money used to purchase a thermograph and barograph (VCO AR 1945).
49. 1906AJ..25..83W (No. 586), *Maxima of long-period variables*, dated 1906 April 21.
50. Only one asteroid was measured in 1905–06, which was Cybele. Three comets were observed: 1905e on one night (January 4); 1906a on four nights (January 30 to February 16); and 1906b on four nights (April 13–18). Results were published in *AJ* 587 (1906 July) and *AJ* 595 (1907 June).
51. Hale, George E., *Report of Director of the Solar Observatory, Mount Wilson, California* (1905).
52. 1906MMAAR..4..13. Letter from Mary Whitney to the MMA, dated 1906 March 16, for the annual meeting on March 29. Mary's three visits to Nantucket were probably with the Hexagon group (an informal name given to Maria Mitchell's first advanced astronomy class) (1868), for William Mitchell's funeral (1869), and for Maria Mitchell's funeral (1889).

    For a photograph of the Hexagon group, see Figure 3 of Haley, op. cit. (ref. 1), p. 7.
53. 1907MMAAR..5..7. Lydia Hinchman directed operations from Philadelphia, steadily developing the MMA base; she also established the Permanent Funds committee which built up an endowment for running expenses and salaries.

    William Herbert Rollins and Miriam Whalley Phillips Rollins donated Maria's 5-inch Clark in 1906. It is unknown when Rollins purchased the telescope but his interest in astronomy is demonstrated by a paper on Long-Focus Telescopes in *Astronomy & Astrophysics,* 13 (1894), 199–200.
54. VCO AR 1907.
55. VCO AR 1907. Henry Allen Peck (1863–1921) was director of the Holden Observatory, Syracuse University.
56. VCO AR 1904. Mary added that 'Princeton College Observatory and University of Virginia Observatory were among the other contributors'.
57. 1907AN..176..65 (*AN* 4205, 1907 October), *Observations of variables*, dated 1907 May 8.
58. Frederick Hanley Seares (1873–1964) was director of Laws Observatory, University of Missouri (1901–08). Two years after his measurements of RS Cas he joined George Hale at MWSO, as superintendent of the computing division overseeing several Vassar graduates trained by Mary Whitney.
59. The VCO programme of asteroid work had begun when Caroline Furness started as assistant in 1894. It was to restart 25 years later, following the arrival of assistant Maud Worcester Makemson (1891–1977), who computed orbits of several minor planets for the Berlin Rechen-Institut.

    A 15th-magnitude asteroid, discovered at Yerkes on 1933 July 27, was subsequently named 'Vassar' by Maud Makemson, in honour of the VCO work first undertaken by Mary Whitney.
60. 1908AJ..25..198W, 'Maxima and Minima of long-period variables, during 1906–7'.
61. 1913PVasO..3..19–190.
62. 1908MMAAR..6..11.
63. The Mt Holyoke graduates were Jennie B. Lasby (1906 October) and Cora G. Burwell (1907 July).
64. *MWSO of the Carnegie Institution of Washington, annual report of the director* (1907).
65. The sculptor Emma Frances Brigham (1850–81) modelled Mitchell at the request of Cora Harrison. At least three plaster copies were produced from the clay model.

    Phebe Mitchell Kendall was buried in Waltham, Massachusetts. As this was Mary's home town it is possible she attended the funeral, but the relationship between Phebe Mitchell and Mary Whitney is uncertain. Mary would certainly have read her 1896 biography, *Maria Mitchell: Life, Letters, and Journals.*
66. 1908MMAAR..6..12. John Tracey Edson was a physician in New York City. A keen yachtsman, he was also a member of the Nantucket Historical Association.
67. 1908MMAAR..6..12. This was Mary's

fourth and final visit to Nantucket. She was in Europe during the summer of 1908.

68. 1908MMAAR..6..12. John Rayner Edmands was appointed to Harvard in 1883 and was in charge of the Observatory time service. His talks were on 1905 August 7.
69. Haley (2022), op. cit. (ref. 2), 22–3.
70. Mary knew of George Hale's invitation to Kapteyn to spend his summers at MWSO.
71. Furness (1923), op. cit. (ref. 20), p. 32. Phoebe Waterman covered Caroline's sabbatical absence.
72. 1908MMAAR..6..9.
73. 1908MMAAR..6..9 and 1909MMAAR..7..21. Treasurer's report (1909 January) shows payment of $175.75, from the Observatory Fund for Ida Whiteside's salary and expenses.
74. VCO AR 1908.
75. VCO AR 1909. The stereo-comparator, designed by Carl Pulfrich (1899), utilized binocular vision to view two images of the same region taken at different times (a forerunner of the blink comparator). During testing (1901) it facilitated discovery of ten variable stars in the Orion nebula. Mary and Caroline first saw this apparatus used at Yerkes in 1899.

    Anna Marie Evans graduated in the same year as Mary Whitney. In 1875 she married Pittsburgh lawyer John Wesley Bailie and they had nine children; two daughters, Mary Evans and Anna Forbes, graduated from Vassar in 1897 and 1908. When Anna died in 1906 she left a $1,000 bequest to VCO.
76. 1908AN..178..317 (*AN* 4267), *Maxima and minima of long-period variables*, dated 1908 June 9.
77. Furness (1923), op. cit. (ref. 20), p.32.
78. The fourth IWSA meeting was held in Amsterdam in 1908 June. Maria Mitchell had been an early advocate of women's suffrage.
79. *MWSO of the Carnegie Institution of Washington, annual report of the director* (1908).
80. 1909MMAAR..9..16.
81. 1909MMAAR...7...32G. A good tribute poem by Lucretia M. Gardner is also included in this reference. Vassar College was represented by Greek instructor Florence Mary Bennett (1883–1968), a former student of the Coffin School, Nantucket.
82. 1909MMAAR..7..14. The 5-inch refractor had been stored in the fireproof building of the Nantucket Historical Society.
83. 1909MMAAR..7..30. Letter from Mary Whitney, written during her Europe trip.
84. 1909MMAAR..7..15. Report of the Observatory Committee, by chairman Annie Cannon.
85. 1909MMAAR..9..15. Albert Gardener Brock (1862–1938) founded a Nantucket insurance company (1886). He was chair of the MMO building committee.
86. Jane Addams delivered her women's suffrage lecture tour (1908 spring) to Bryn Mawr, Smith, Wellesley, Mt Holyoke, and Radcliffe colleges – so Vassar students naturally questioned Taylor's decision. Inez Milholland overcame Taylor's ban on women's suffrage meetings by holding one (just) off-campus; it was attended by 40 undergraduates and 10 alumnae.
87. The three Vassar professors were from the History and English departments: Lucy Maynard Salmon (1853–1927), Laura Johnson Wylie (1855–1932), and Gertrude Buck (1871–1922). See also: *Vassar Quarterly*, 1973 spring issue. A suffrage poll (1911) of Vassar seniors revealed 57% agreed that women should have the vote. A Suffrage Club at Vassar was allowed in 1915–16; it had 175 members.
88. Cohen, Miriam, *'Votes for Women': Vassar and the Politics of Women's Suffrage*, (Vassar College Library, 2020) provides a useful modern interpretation of this period.

    Mary Whitney's views on women's suffrage are unknown, but she certainly attended some of Maria Mitchell's meetings at VCO in the 1880s. Ratification of the 19th Amendment in 1920 enabled most women to have the vote.
89. 1909AN..1800..47 (*AN* 4299), SS Cygni, dated 1908 December 21.
90. 1909AN..181..91 (*AN* 4326), *Observations of long-period variables*, dated 1909 April 6.
91. VCO AR 1909.
92. VCO AR 1909.
93. VCO AR 1909. 'Donner' was Anders Donner (1854–1938), professor of astronomy at the University of Helsinki.
94. 1913PVasO..3..140–5. VCO results for SX Draconis, from 1909 June 14 to 1912 March 22.
95. 1909MMAAR..7..7. The Treasurer's Report for 1911 (p. 22) includes $180 for 'Instructor and observer during summer'. In 1911 Florence Harpham was at Vanderbilt University in Nashville, Tennessee.
96. 1909MMAAR..7..7. Annual meeting held 1909 April 28 in Boston.
97. 1910MMAAR..8..18. Report of the Observatory Committee.
98. 1910AN..183..47 (*AN* 4371), *New variable*

43.1909 Draconis, dated 1909 October 23. Another important 'discovery' at Vassar in mid-October was Halley's Comet, which was observed in Orion at 13th magnitude.

99. 1910AN..183..207 (*AN* 4381), *Variable star 43.1909 Draconis*, dated 1909 December 22.
100. 1911AN..187..383 (*AN* 4483, 1911 March), Var. SX Draconis, dated 1911 February 25. Caroline continued to monitor her mentor's discovery for many years.

    Ideally, Mary would have liked to calculate the orbital elements; these were later published by Walter Van B. Roberts of Princeton University Observatory [1915ApJ..43..312R].
101. 1910AJ..26..74 (*AJ* 609), 'New variable in Aquila', communicated by Mary Whitney, dated 1910 February 1. See also 1913 PVasO..3..149.
102. Furness, Caroline E., 1912PA..20..645F, 'Observations of variable stars made at the VCO'.
103. *Proceedings of the AAAS: 59th, 60th and 61st meetings* (1910), p. 524. This was the 61st meeting of the group and the third time it had been in Boston. It was the last meeting Mary Whitney attended.
104. 1910PA..18..62F, *Schurig's Himmels-Atlas*, by Caroline Furness. Richard Schurig (1820–96) was a Leipzig astronomer. The 58-page atlas was recommended for observers using a 3-inch telescope.
105. *Vassar Miscellany*, 39 (1909–10), 693–4, Lecture: 'Halley's Comet' by Caroline Furness given during Commencement Week (1910 June).
106. Furness, Caroline E., *Publications of the Vassar College Observatory, No. 3: Observations of Variable Stars made during the years 1901–12* (1913). Analysis of these observations shows that Caroline Furness was also observing on the four nights (March 3–5 and 7); she also observed variables on March 15, 23, and 26. Psyche Sutton used the 5-inch on March 8, 15, and 23 for variable stars. The exact date of Mary's stroke is unknown, but no observations after March 7 are found.
107. Furness (1923), op. cit. (ref. 20), p. 33.
108. In Waltham Mary Whitney lived at 238 Bacon Street; her brother's family, including niece Elise, nearby, at 306 Lexington Street. From the few clues available it seems probable that Mary had impaired speech, limb paralysis (left side) and was immobile. She was granted an 'extended leave of absence' until her retirement (1915).

    One source described greeting her outside her Waltham home while she was 'listening to the birds', suggesting that her sense of hearing and possibly vision were reasonable. It is likely that she would have suffered from fatigue and found her concentration and memory functions impaired.

    Elise Crehore Whitney (1883–1934) married Hugo Bruno Seikel (1881–1982) on 1910 September 19. They moved to Orleans, Massachusetts. No children listed.
109. *Vassar Miscellany*, 39 (1910 June), 693–4, 'Halley's Comet', lecture by Caroline Furness. She described observations by Barnard, Campbell, and Douglas.
110. VCO AR 1909–10. See also 1911PA..19..408–14, 'A review of some theories advanced in explanation of the δ Cephei type of variable', by P. R. Sutton. Psyche Rebecca Sutton continued as VCO assistant in 1911–12. In 1912 she married Harold James Underwood (1888–1955).
111. 1910AJ..26..103F (*AJ* 613, 1910 May), 'Observations of long-period variables', by Mary Whitney and Caroline Furness, dated 1910 May 4.

    Carl Ernst Albrecht Hartwig (1851–1923), director of the Remeis Observatory, Bamberg, produced a quarterly publication of ephemerides of variable stars.
112. Clementina Griffin later followed a teaching career. She gained two A.M. sociology degrees and at the age of fifty (1935) became an aviator.

    Lillian Wickham was the first wife of Walter Sydney Adams. She died ten years after their marriage from influenza, two days after their son was stillborn.

    The eighth MWSO computer, Jessica Mary Haines (1879–1920), worked as a librarian (1910–16) and then married (Mrs Longacre).
113. 1910MMAAR..8..18, *Report of the Observatory Committee*, by Annie J. Cannon, dated 1910 January 5.
114. 1911MMAAR..8..19, 'Report of Astronomical Fellowship Committee' by Lydia S. Hinchman.
115. VCO AR 1911. Caroline Furness's first annual report.
116. Furness (1923), op. cit. (ref. 20), p. 33. The Pulfrich design cost $1,250 (1913) so Mary Whitney funded at least $250 for this instrument.
117. Letter from Mary Whitney to Caroline Furness dated 1910 December 4–5, from the Caroline Furness papers, Vassar College Archives; thanks to Dean Rogers for sending digital copies of a small sample (for 1910–13). Mary used the name 'Eleanor' in her personal correspondence to Caroline.

118. VCO AR 1911.
119. VCO AR 1912. Caroline was accompanied by Helen Swartz and two Juniors, Jane Schoolcraft and Beatrice Farrall.
120. 1911AJ..27..24F (*AJ* 627) and 1911AJ..27..28F (*AJ* 628).
121. VCO AR 1911. 'Long period variable stars' (*AJ* 613).
122. 1912MMAAR..10..8 and 17. The Treasurer's Report includes a sum of $450 transferred to the 'astronomical equipment fund' – presumably for the brass tube from Clark & Son. 'Repairs to telescope' cost $120.25 and carriage was $3.50. Carl Axel Robert Lundin Jr, like his father of the same name (1851–1915) worked for the Clarks.
123. 1911MMAAR..9..20. A good example of the way Lydia Hinchman steered the MMA towards productive research.
124. 1912MMAAR..10..17, 'Report of the Observatory Committee'. Frost at Yerkes recommended the A1201 comparator which used a 0.5mm pitch screw; the A1202 model was $450.
125. The annual ice carnival occurred on Vassar Lake (1897–1912) and then on the artificially created Sunset Lake (1913–40). Electric lighting began in Main in 1911 November.

     The first women's suffrage meeting on the Vassar campus in 1912 April contributed to the resignation of president Taylor.
126. 1912AJ..27..58F (*AJ* 631, 1912 January).
127. VCO AR 1912. Caroline's second report.
128. VCO AR 1912. Cowan, Frances M., 'An account of the founding of the Central Observatory of Poulkova, Russia', 1912PA..20..415C.
129. *Observations of Variable Stars Made During the Years 1901–12*, 1913PVasO…3….1W.
130. VCO AR 1912.
131. 1912MMAAR..10..6.
132. 1912MMAAR..10..3, 'Advisory Council'. The evolution of this group shows the networking undertaken to facilitate the aspirations of the MMA.
133. 1912MMAAR..10.17.
134. 1912MMAAR..10..9. Garrett Putnam Serviss was a well-known astronomy popularizer. His fee for a 2-hour illustrated talk was $51.
135. 1912MMAAR..10..17.
136. 1913MMAAR..11..19.
137. VCO AR 1913.
138. VCO AR 1913.
139. Letter from Caroline Furness to president Taylor, dated 1914 January 10, attached to VCO AR 1914. Ernestine Wells Fuller graduated A.B. and A.M. at Wellesley before becoming an Instructor ($800 salary) at VCO for two years. She then transferred to Princeton, working as a computer with Mary Fowler. Between 1920–33 she worked as a librarian in different locations.
140. *Vassar Miscellany*, 43 (1914 January), 187–91. Announcing fellowships for Harvard Observatory at $500/year enabled Pickering to maintain the pay inequality of his female computers.
141. 1914MMAAR..12..17.
142. *Vassar Miscellany*, 43 (1914 April), p. 441.
143. Furness (1923), op. cit. (ref. 20), p. 33.
144. Furness, Caroline E., *An Introduction to the Study of Variable Stars* (Houghton Mifflin, 1915). See 1915PASP..27..252A and 1916ApJ..43..86P for reviews by R. G. Aitken and J. A. Parkhurst respectively. At the Century of Progress exposition (1933) judges included the work among the 100 most valuable books written by American women during the past century.
145. Comet 1913f (Delavan's comet) reached perihelion 1914 October 26 and brightened to magnitude 3, exhibiting both a 10° ion tail and a 6–8° dust tail.
146. 1015MMAAR..13..21. Plate exposures of one hour were possible by 1914 December 16. The mechanical adjustments of the telescope pier were completed by Alvin Paddock and machinist Peter Hussey. By the time Margaret Harwood left the Island for the third time 95 plates had been taken with the Nantucket triplet lens. The comet-seeker loaned by Joel Metcalf was used from 1913 December to 1914 October.
147. VCO AR 1927.
148. Henry Albers (1925–2009) succeeded Maud Makemson in 1958 as the fifth director of VCO. During the summer of 1963 the 12-inch refracting telescope housed in the Observatory was dismantled; the gears had become badly worn and the wooden tube showed signs of age. During the last week in October the telescope was shipped to Washington where it has found a permanent home at the Smithsonian Institution as part of a permanent exhibit of the optical work of Henry Fitz.

     In its place Albers installed a 15-inch reflecting telescope, made by J. W. Fecker of Pittsburgh, equipped with photoelectric equipment. Smithsonian accession numbers are: 12-inch equatorial (248757); Young meridian circle (1980.0318); and Fitz 1865 filar micrometer (1980.0318.09).
149. Harriet McWilliams Parsons received a Vassar fellowship in 1919 for her doctorate work at Yerkes. She married in 1923 (Mrs

Hall); her thesis was published in 1927. Also at Yerkes was Evelyn Wornham Wickham (1895–1988), Mrs Hale (1925); unrelated to Lillian Wickham.
150. 1917AJ..30..181F, 'New variable star in Cygnus', by Caroline Furness, (*AJ* 716, 1917 June). The plates had been taken at Helsingfors, Finland in 1906 and 1908 and van der Bilt noted one 12.8-magnitude star in Cygnus that was missing on the earlier date. Pickering and Leavitt (HCO) subsequently confirmed the discovery using 16 Harvard plates. Bilt never published his proper-motion results from VCO. See also: 1917PASP..29..41V, *Transparency of Atmosphere at MWSO*.
151. Furness, Caroline E., 'The use of the stereo-comparator in determining proper motion', 1922PAAS..4..313F. Paper presented at the 27th meeting of the AAS held at Swarthmore college (1921 December). The 28th AAS meeting was held at Vassar.
152. Furness (1923), op. cit. (ref. 20), 25–35.
153. Furness, Caroline E., 'Eclipse Observations at Vassar College', *Popular Astronomy*, 33 (1925), 221–5.
154. 1934PVasO..4..3F. This publication includes a historical review of Maria Mitchell's original work and the 'discovery' of her lost records. The investigation (1926–7), by Laura E. Hill and M. Alberta Hawes, employed long-wave radio signals from Arlington which were detected by a Grebe radio receiver at VCO. The final value was found to be: 4h 55m 35.16s ± 0.024s.
155. Laura Elizabeth Hill (1893–1991) had worked with Dean Benjamin McLaughlin (1901–65), from Swarthmore Observatory, at VCO during the total solar eclipse. Shortly after the longitude investigation they married and both astronomers continued their careers at Detroit Observatory; they also had five children. So indirectly, Mary's bequest of $5,000 (c. 100k today) helped set up the first VCO romance!
156. Georgette Camille Maulbetsch was an exchange student from the University of Geneva. She completed her A.M. at Vassar prior to becoming a Pickering Fellow at HCO.
157. VCO AR 1936. See also 1936PA..44..233M for obituary of Caroline Furness.

The author

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His other interests include Pyrenean Mountain Dogs and detailed planning for a 'Trans Cuillin Odyssey', which will focus on the southern half of the Isle of Skye.

Clapham Common constants:
Henry Cavendish, James Clerk Maxwell, gravitation, and the speed of light

Timothy M. M. Baker

Two of the earliest and most influential experiments to measure fundamental physical constants took place 70 years apart within 500 yards of each other on the edge of Clapham Common, in south London. They were conducted by two giants of physics: Henry Cavendish and James Clerk Maxwell. Both had underlying astronomical themes. Cavendish's experiment, which had been begun by the clergyman-scientist John Michell, was a major part of the exploration of gravitation set in motion by Isaac Newton's *Principia* in 1687, while Clerk Maxwell's experiment was to verify his contention that the ratio of electrodynamic and electrostatic units corresponded to a constant that was also the speed of light. The implications of Clerk Maxwell's identification of the constancy of the speed of light were later absorbed by Albert Einstein in his Special Theory of Relativity in 1905 and the General Theory of Relativity in 1915. Several winding threads link Newton's gravitation in 1687 to Einstein's gravitation in 1915. This paper is about how, coincidentally, two of the most important threads happened to pass through Clapham Common.

1. Scientists at Clapham

Four miles south of London, where the Surrey hills begin to rise from the Thames floodplain, the village of Clapham became from the late 17th century onwards a favoured rural retreat for City gentlemen, whose houses lined the fringes of the 200 acres of Clapham and Battersea Commons (now collectively known as Clapham Common) (Figure 1). Among its residents were gentleman scientists, some of them City merchants investigating natural phenomena at their suburban homes in their spare time.

Best-known of these scientific residents of Clapham was Henry Cavendish (1731–1810), famous for 'weighing the world' in 1797–8 at Cavendish House on Clapham Common South Side. Cavendish was in fact measuring the relative density of the Earth, a quantity from which it became possible to derive a value not only for the Earth's mass, a quantity that was essential to understanding of the scale of the Solar System, but also for the Newtonian gravitational constant, the number that in classical theory governs the gravitational attraction between masses.

Less well-known was John Peter Gassiot (1797–1877), a City of London wine merchant who was an enthusiastic amateur electrical experimenter. At his house, The Lawn, also on Clapham Common South Side, Gassiot built a succession of powerful batteries for his research on electric arcs. He made his equipment available for other experimenters to use. The most significant of the experiments conducted at The Lawn was that in 1868 by James Clerk Maxwell (1831–79)[1] to measure the ratio of electrodynamic and electrostatic units, in an attempt to verify his theoretical contention that the ratio corresponded to the speed of light. The universal constancy of the speed of light went on to become the mainspring of Albert Einstein's theories of relativity.

Both experiments by Cavendish and Clerk Maxwell used the torsion balance, a remarkable instrument that had been invented by the

Fig. 1: Clapham Common South Side, H. N. Batten's map (detail, north-west at the top), 1827, showing: (1) Cavendish House; (2) its outbuilding, which is probably Cavendish's transit room where he did his experiment, as the orientation is correct; (3) The Lawn. (This image was reproduced by kind permission of London Borough of Lambeth Archives Department.)

Yorkshire clergyman-scientist John Michell (1724–93) in the early 1780s specifically to measure the density of the Earth, although he never lived to perform the experiment himself (Section 2.3).[2]

2. The Michell–Cavendish Experiment

Henry Cavendish (Figure 2), a grandson of the 2nd Duke of Devonshire and noted amateur scientist, acquired what became known as Cavendish House (Figure 3) in 1785 September, having recently inherited vast wealth. The house was a large one, standing in extensive gardens at the southern end of Clapham Common beside the road to Epsom, Surrey. It was close to the south corner of Dragmire Lane, now Cavendish Road, part of London's present-day South Circular Road. It was demolished in 1906. Englewood Road now runs directly across where the house stood.

Cavendish, an unmarried and undomesticated recluse who lived for science, devoted some of the best rooms in the house to his laboratory, where he conducted a range of experiments on gases, heat, light, and electricity. These continued ground-breaking, but largely unpublished, programmes of research from his previous residences in central London and at Hampstead. Although he continued to keep his scientific library at his London house, 11 Bedford Square, Bloomsbury, he also had at Clapham Common a meteorological and astronomical observatory, including a ship's mast in the garden which he used in 1785 to test the lenses of an 'aerial telescope' given to the Royal Society by Christiaan Huygens in the late 17th century.

We know the location of Cavendish House particularly precisely because in the 1780s Cavendish advised on William Roy's (1726–90) contribution to the Anglo-French geodetic triangulation between the Greenwich and Paris observatories which was undertaken to determine precisely the relative positions of their meridians. Cavendish House was one of the stations for Roy's secondary triangulation of the London area; he determined its position relative to the primary stations at Severndroog Castle on Shooters Hill, Kent, and Hundred Acres, on Banstead Downs, Surrey. Roy was thus able to compute the coordinates of Cavendish's Transit Room at Cavendish House at 51° 27′ 12.7″ N, 0° 8′ 39.2″ W; 24,563 feet and six inches from the dome of St Paul's Cathedral in the City of London, on a bearing of 206° 29′ 52″.[3]

Cavendish's experiment to 'weigh the Earth' took place in 1797–8 in an outbuilding of Cavendish House. This was probably one shown in H. N. Batten's 1827 plan of Clapham (detail, Figure 1), lying just east of the house, approximately on the site of the present 4 Cavendish Road; it had been demolished by the time of the 1874 25-inch Ordnance Survey map.[4] Given its orientation, this building may well have been the 'Transit Room' of Cavendish's observatory, triangulated by William Roy in 1787.

In his description of the experiment in the Royal Society's *Philosophical Transactions*,[5] Cavendish described the building as 'the Observatory', referring to a visit by 'M. Cassini', presumably Jean-Dominique Cassini (1748–1845), the fourth and last of the Cassini dynasty at the Paris Observatory, who visited England in connection with the Greenwich–Paris triangulation.

Fig. 2: Henry Cavendish, probably by Christian Rosenberg, after an 1812 sketch by William Alexander. Cavendish refused to have his portrait taken, but John Barrow arranged for Alexander to draw Cavendish secretly, without his knowledge, at a meeting of the Royal Society Club. (National Portrait Gallery)

2.1. *Henry Cavendish's research on the Earth*

Along with the length of the astronomical unit, which was first measured by observing the transits of Venus in 1639 (an estimate, about two-thirds of the true figure, based on a single observation by Jeremiah Horrocks), and in 1761 and 1769 (a much more accurate estimate, based on a worldwide programme of observations, whose results were collated by the Oxford astronomer Thomas Hornsby), accurate measurement of the Earth's mass would enable the masses of other bodies in the Solar System to be computed from Johannes Kepler's laws of planetary motion and Isaac Newton's law of universal gravitation.

Cavendish had a long-standing interest, dating from the 1760s, in the distorting effect of gravity on astronomical and geodetical measurements. In 1763–7 Charles Mason (1728–86), an assistant at the Royal Observatory, Greenwich, and Jeremiah Dixon (1733–79) surveyed the boundary between Pennsylvania and Maryland, and between Maryland and Delaware. The need to define these boundaries, which together became known as the Mason-Dixon line, had arisen because of border disputes between Maryland and its two neighbours.[6]

In addition, Mason and Dixon also measured the length of the roughly north–south boundary between Maryland and Delaware in order to calculate an exact degree of latitude, as part of the Royal Society's research on the figure of the Earth.

Cavendish suggested that a discrepancy of 725 feet (221 m) between the astronomically and geodetically measured length of this 69-mile (111-km) 'Maryland arc' was caused by what he termed 'the deficiency of oceans' – the gravitational deflection of Mason and Dixon's plumb-lines from the true vertical caused by the relatively lower density of the nearby Atlantic Ocean compared to that of continental North America.

2.2. *The attraction of mountains*

The 'deficiency of oceans' was the opposite effect to the 'attraction of mountains'. Cavendish's direct involvement in measuring the gravitational attraction of the Earth began with his assistance to the Astronomer Royal, Nevil Maskelyne (1732–1811), in planning his 1774 experiment to use the attraction of mountains to measure the Earth's relative density.

In 1773 the Royal Society had commissioned Maskelyne to determine the ratio of the horizontal gravitational attraction of a mountain and the vertical gravitational attraction of the Earth; from this it would be possible to estimate distortions in astronomical latitude and longitude measurements that arose from the slight deflection of plumb-lines from the vertical.[7] Charles Mason, back from Maryland, surveyed Scotland and northern England for a suitably symmetrical mountain with an east–west orientation. He selected Schiehallion, a 3,553-ft (1,083-m) cone of quartzite between Loch Rannoch and Loch Tay, in the Breadalbane Highlands thirty miles north-west of Perth.

With his assistant Reuben Burrow (1747–92) Maskelyne compared astronomical and trigonometrical measurements of the distance between stations on opposite sides of Schiehallion. From these observations, in 1778 Charles Hutton (1737–1823), of the Royal Military Academy at Woolwich, calculated that the deflection of the plumb-line caused by the mass of the mountain was 5.8 arcseconds, making for a discrepancy of about 600 feet (180 m).

Hutton thence calculated the ratio of the density of the Earth and the density of the mountain as 17781/9933 and, assuming that stone was 2.5 times as dense as water, made the first objective estimate of the relative density of the Earth at 4.48 times the density of water.

Hutton revised this estimate upwards to 4.7 times in 1815 on the basis of a more thorough analysis of Schiehallion's geology and density by the Scottish scientist John Playfair (1748–1819). This second estimate was some 14.8 per cent less than the modern value of 5.515. Hutton's result disproved previous theories that the Earth was hollow, and indicated the presence within it of heavy, dense metals.[8]

2.3. *John Michell and the torsion balance*

Cavendish determined to improve on Maskelyne and Hutton's result with a controlled laboratory experiment (Figure 4).[9] He used the torsion balance designed for the purpose in 1783 by John Michell, rector of Thornhill, Yorkshire. Michell, one of the most remarkable scientific minds of his generation but little recognized today, was a polymath: a pioneer of geological stratigraphy and seismology, and a leading theoretical and practical astronomer.

Cavendish and Michell were friends, possibly from as far back as their Cambridge days in the late 1740s. Michell was twice an unsuccessful candidate to become Astronomer Royal, losing out to Nathaniel Bliss in 1762 and to Nevil Maskelyne in 1765. Although he continued to visit London annually after his move to Yorkshire in 1767, Michell relied heavily on Cavendish for scientific news from the metropolis. Michell and Cavendish aimed to extend Newtonian gravitational mechanics beyond the Solar System to all scales from the smallest to the observable Universe.[10]

Michell had hoped to perform an experiment to 'weigh' the Earth, for which he invented and built the torsion balance, but died be-

Fig. 3: Cavendish House, circa 1870, as rebuilt by Thomas Cubitt, who lived there 1827–32. The central, three-storey section and the inner, lower, part of its wings may represent Henry Cavendish's house. The outbuilding where Cavendish probably did his experiment would have been near the cedar tree on the right. (This image was reproduced by kind permission of London Borough of Lambeth Archives Department.)

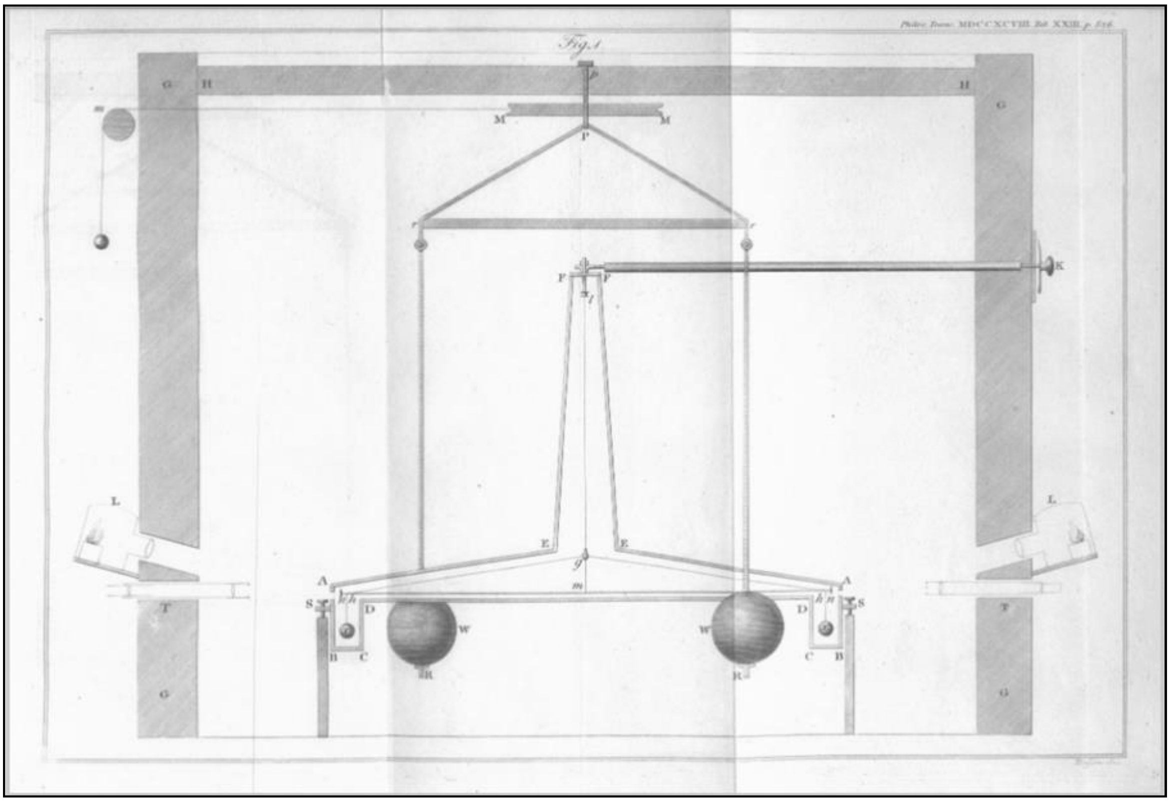


Fig. 4: Section of Cavendish's apparatus. Philosophical Transactions of the Royal Society of London, *88 (1798), after p. 526. ABCDEF is the case enclosing the torsion balance, its wire, rod, and suspended spheres. W are the rotatable weights, suspended from the pivot P and pulley M. T are the telescopes trained on Verniers at either end of the spheres' suspending rod, illuminated by the lamps L. GHG is the enclosing room. As P. F. Titchmarsh pointed out, this diagram omits the lower part of the 'room', since it does not allow enough space at the bottom for the observer to sit.*

fore he could do so. He bequeathed the apparatus to his alma mater, Queens' College, Cambridge, whence it was acquired by Francis John Hyde Wollaston (1762–1823), Jacksonian Professor of Natural Philosophy at that University. Wollaston passed it on to Cavendish at Clapham Common, who rebuilt and improved it for what became known as the 'Cavendish Experiment', but should more properly be called the Michell–Cavendish Experiment.

In all, Cavendish conducted 17 separate experiments with the apparatus, eight in 1797 August and September, and another nine in 1798 April and May.[11] For the last two, he was assisted by astronomer George Gilpin (1754–1810), who was then clerk to the Royal Society.

2.4. *Cavendish measures the density of the Earth*

Whereas the common balance weighs parallel forces vertically against a fulcrum, Michell's torsion balance, and its modification by Cavendish, used horizontal torsion to weigh opposing forces.

The balance consisted of two main assemblies. First was a pair of 2-inch-diameter lead spheres, hanging from either end of a 6-ft wooden rod, which was suspended in its middle from a copper wire so that the assembly could twist horizontally. Second were two weights, 12-inch-diameter lead spheres, 216 times as massive as the 2-inch ones,[12] suspended with iron or copper rods from either end of a 6-ft horizontal beam. This assembly could be rotated by a pulley so that the large spheres could be brought to hang close to the small ones on either side of them.

When the large weights were rotated close to the smaller ones, the gravitational attraction between them would twist the smaller spheres and their suspending rod towards the larger weights, until the elastic torque on their suspending wire countered the gravitational attraction. There ensued a slow oscillation of the smaller spheres' suspending rod as the gravitational and torsional forces reacted against each other. From the deflection of the small hanging spheres and the period of oscillation, Cavendish could calculate the gravitational force between the weights and the smaller spheres.

Separately, he could also calculate the gravitational force between the small spheres and the Earth by weighing them on a common balance. The ratio of the force between the spheres and the Earth, and the force between the spheres and the weights, allowed Cavendish to calculate the density of the Earth relative to the density of the lead, and then convert it to the density relative to that of water.

Cavendish housed the small spheres and their suspending apparatus in a fixed narrow wooden case to minimize observational errors arising from draughts and temperature variations. This and the weights apparatus were in turn enclosed in a specially built room about 10 ft on a side, with walls a foot thick, housed in the outbuilding of Cavendish House.

To minimize disturbance by the observer, Cavendish measured the gravitational movement of the small lead spheres from outside the enclosing room, using telescopes inserted through its walls, trained on Vernier scales at either end of the small spheres' suspending rod. He worked the weights' pulley from outside the room as well.

The only light inside the room came from two lamps outside the room that illuminated the Vernier scales through convex-lens windows. Cavendish needed to measure the period of the slow oscillation of the twisting of the suspension wire, and the mid-point of the oscillation. He then compared the mid-point with where the small spheres hung at rest while the weights were rotated to 90°, equidistant between them. The difference represented the gravitational deflection caused by the weights. Because of the slowness of the oscillation, an experiment would last for two and a half hours. With this technique he was able to measure the horizontal deviation of the mid-point as about 0.16 inches (4 mm), accurate to one-hundredth of an inch.

Cavendish's final result for the Earth's density, 5.48 times that of water, was considerably greater than Hutton's. Cavendish estimated its error as not more than one fourteenth; in fact, it was accurate to within 1 per cent of what turned out to be the true figure of 5.515 – although an arithmetical error not discovered until 1842 by Francis Baily (1774–1844) meant that Cavendish's figure should have been 5.448 times the density of water, making his estimate 1¼ per cent too small in total. From the density could be derived both the mass of the Earth – now measured at 5.972×10^{24} kg – and, in due course, the value of Isaac Newton's gravitational constant, a concept introduced in 1893 by the English physicist John Henry Poynting (1855–1914).

Cavendish's apparatus was at the Royal Institution by 1840, when Francis Baily borrowed it for his own repeat of the experiment.[13] Its fate since then is unknown.

2.5. *From universal gravitation to the speed of light*
By comparison with the Schiehallion Experiment, the Cavendish Experiment was a remarkable demonstration of the greater accuracy that could be obtained from laboratory experiment as opposed to field observation. It showed that gravity, which had previously been proved to apply to astronomical bodies across the Solar System, also operated between bodies weighing a few pounds; a force so small that Newton had considered it would be unmeasurable.

Fig. 5: Photograph of John Peter Gassiot, by Henry Joseph Whitlock, 1860s. (National Portrait Gallery)

Fig. 6: The Lawn, John Peter Gassiot's house, drawn c.1900; artist unknown. (This image was reproduced by kind permission of London Borough of Lambeth Archives Department.)

Michell's apparatus, as improved by Cavendish, formed the basis for subsequent experiments to refine the measurement of the gravitational constant, *G*, notably those by Poynting at Cambridge in the 1880s and Charles Vernon Boys (1855–1944) at Oxford in 1895; and also of experiments to measure other fundamental physical constants, including that by James Clerk Maxwell to measure the ratio of electrical forces (see Section 3 below).

The gravitational constant is unusual in that, because of its relative weakness, it is not very precisely known. It is also anomalous (at any rate under current theory) in standing alone, unrelated to other physical constants. It thus differs profoundly from the speed of light, which is known to such a level of precision that it now has a defined value, from which other units of measurement are derived.

James Clerk Maxwell was the first to understand the fundamental theoretical importance of the speed of light, and one of the first to measure its basis as a balance of electrical forces. And, as it happens, he made his measurements just along Clapham Common South Side from Cavendish House, which is where we turn next.

3. The Clerk Maxwell experiment

John Peter Gassiot (Figure 5), born in London in 1797, the year that Cavendish began his and Michell's experiment, was a partner in the firm of Martinez, Gassiot & Co. (now Martinez, a part of the Symington port business), wine merchants in the City of London, importing sherry, port, and cigars.[14]

In 1836 Gassiot acquired The Lawn (Figure 6), a house in the middle of the south-east side of Clapham Common, about 500 yards north-east of Cavendish House, opposite the Windmill Inn. The house was demolished in 1902 to make way for the Clapham High School for Girls, which was in turn removed in the 1980s. The site is now the north corner of St Gerard's Close.[15]

Gassiot was a polymath with interests in banking (he was on the board of the London and Westminster Bank), insurance, administrative reform, education, and, as a member of the committee that managed Clapham Common, open spaces preservation.

From the late 1830s he became an enthusiastic amateur electrician, making experimental discoveries which helped clarify the theory of how batteries produce electricity and the nature of high-voltage electric arcs. In order to achieve the necessary high voltages, he acquired and installed at The Lawn a series of powerful batteries, made variously from water cells, Daniell cells, Grove cells, and Leclanché cells.

A fellow of the Royal Society, Gassiot established trust funds to support scientists in financial difficulty, and to enable the Kew Observatory to continue geomagnetic observations. He also provided practical support to electrical scientists by making his laboratory at The

Lawn, and in particular his powerful electric batteries, available to other researchers.

3.1. *Maxwell's equations and the electromagnetic nature of light*

The most significant of the experiments conducted by others using Gassiot's apparatus was James Clerk Maxwell's in 1868 to measure the ratio of electrodynamic to electrostatic units of electricity, and thus to check its correspondence with the observed speed of light. As Clerk Maxwell reported in the Royal Society's *Philosophical Transactions*, 'I should not … have been able to do this, had not Mr Gassiot, with his usual liberality, placed at my disposal his magnificent battery of 2600 cells charged with corrosive sublimate [mercury dichloride], with the use of his laboratory to work in'.[16] The battery was able to produce about 3,000 volts.

Clerk Maxwell (Figure 7) devised his theory of electromagnetism as a student at Cambridge, and later as a Professor at Aberdeen University and at King's College London. In his papers 'On Faraday's Lines of Force', 1855–6,[17] and 'On Physical Lines of Force', 1861–2,[18] he developed a quantitative geometrical and physical description of the electric and magnetic field theory of Michael Faraday (1791–1867), partly on the basis of Faraday's 1854 interpretation of signal retardation in telegraph wires, and partly on an analogy with fluid flow.

Clerk Maxwell replaced Faraday's 'lines of force' with the quantitative concept of 'flux' in an electric or magnetic field. His theory yielded electric and magnetic waves which would travel at the speed of light, from which he postulated that light, electricity, and magnetism were all forms of vibration of the same medium. He developed these ideas further in a paper for the Royal Society, 'A Dynamical Theory of the Electromagnetic Field', in 1864.[19] In this (and later in his textbook *Treatise on Electricity and Magnetism*) he set out what are now known as 'Maxwell's Equations': the definitive mathematical unification of electricity, magnetism, and optics into a unified theory of electromagnetism. This was the second stage, after Isaac Newton's combination of terrestrial and celestial gravity, in the unification of fundamental physical forces.

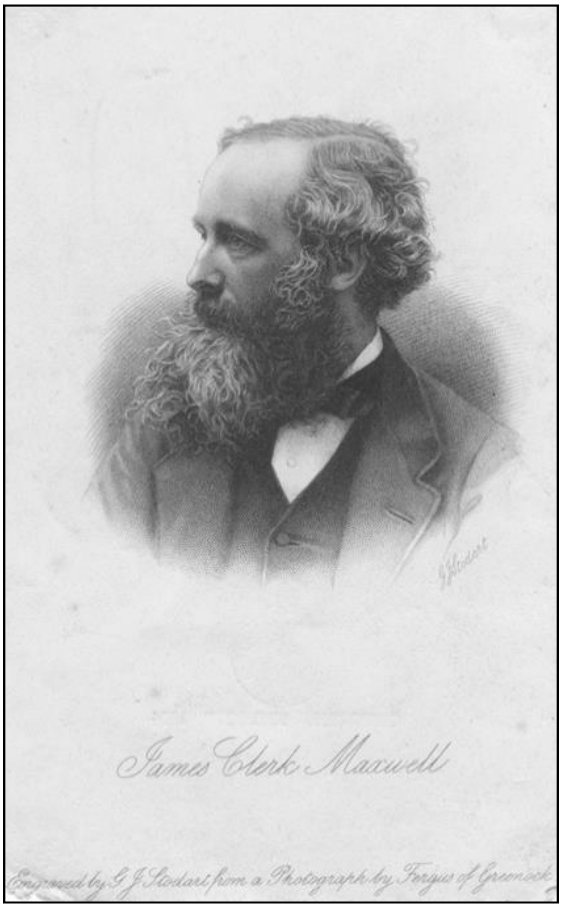
Maxwell's equations predicted that a changing electromagnetic field travels as a wave, and included a constant, v, the ratio of electrodynamic and electrostatic units, which Clerk Maxwell was the first to identify as corresponding approximately to the observed speed of light.[20] This led him to conclude that light (including other forms of radiation) is indeed a self-sustaining wave propagated in the electromagnetic field, as he had predicted in 1862.

3.2. *The electric telegraph and definition of units of electrical measurement*

The ratio of electrodynamic and electrostatic units had been a matter of interest to scientists and engineers for a number of years, particularly because of so-called 'signal retardation', the delay and blurring of messages sent by the electric telegraph, which threatened the efficiency of this new method of near-instant communication that was transforming the world.[21]

While telegraph cables suspended in air caused few difficulties, retardation became a significant problem for underground and submarine cables. Retardation, which increased with the square of the length of a cable, made early submarine telegraphy slow, costly, and potentially uneconomic or impractical. Michael

Fig. 7: James Clerk Maxwell. Stipple engraving by George Stodart, after photograph by John Fergus. (National Portrait Gallery)



Faraday, and William Thomson (later Lord Kelvin) (1824–1907) of Glasgow University, concluded that retardation arose from the electrostatic and inductive interaction between the wire cable, its insulating sheath, and the surrounding water as the electric current propagated along the wire. The ratio of units was fundamental to their theory, since the current along the cable and its associated voltage involved interchange between electrodynamic and electrostatic forms of energy.

At Greenwich, the Astronomer Royal, George Airy (1801–92), was attempting to improve measurements of longitude by synchronizing electrical time signals from the Royal Observatory with those from Paris and Brussels, but retardation was thwarting his efforts. In 1855, based on Airy's measurements of the retardation in the cross-Channel cables, Thomson made the first estimate of the ratio of electrodynamic to electrostatic units: between 104,000,000 and 419,000,000 ft/s (32,700 and 127,700 km/s). For various reasons this estimate was well below the true value.

Telegraph cables had initially been designed by rule of thumb without any detailed control over the quality of their materials. A series of costly failures, notably of the first transatlantic cable after only a few weeks' operation in 1858, together with Thomson's demonstration that the electrical quality of manufactured cables varied widely because of impurities in the copper wires, led to the need for precise specification of the materials of which they were made. At Thomson's instigation, in 1861 the British Association for the Advancement of Science established a Committee on Electrical Standards to address the needs of the telegraphy industry.

Spurred by his realization that light is an electromagnetic phenomenon, Clerk Maxwell joined the British Association Committee in 1862. He proceeded, with Fleeming Jenkin (1833–85), a telegraph engineer and secretary of the British Association Committee, to conduct delicate experiments at King's College London to determine standard units of electrical measurement, in particular a standard unit of resistance.

Assisted by Charles Hockin (1840–82), a fellow of St John's College, Cambridge, and an expert in submarine telegraphy,[22] Clerk Maxwell and Jenkin measured the deflection of a suspended magnet from geomagnetic north caused by spinning a coil of wire around it.

The movement of the coil through the Earth's magnetic field induced an electric current which in turn induced a deflection of the magnet. The amount of deflection of the magnet depended solely on the dimensions, speed, and – the unknown quantity – the resistance of the coil. The result of these experiments was the 'British Association unit of resistance', published in 1865, later renamed the ohm.[23]

As part of their research for the British Association Committee, Clerk Maxwell and Jenkin also published 'On the Elementary Relations between Electrical Measurements' in 1863.[24] This was an exposition of the principles, importance, and practice of precise measurement of electrical quantities, including the ratio of electrodynamic and electrostatic units as a velocity. As Clerk Maxwell and Jenkin wrote: 'the redetermination of v will form part of the Committee's business'.[25] Clerk Maxwell proceeded to plan the experiment with Hockin, writing to him on 1864 September 7: 'We may safely determine the velocity of light by measuring the attraction between bodies kept at a given difference of potential, the value of which is known in electromagnetic measure'.

3.3. *Clerk Maxwell's experiment at Gassiot's laboratory*

Clerk Maxwell conducted his experiment to measure the ratio of electrodynamic and electrostatic units in 1868 May, using Gassiot's powerful battery at Clapham Common. As he wrote in the *Philosophical Transactions of the Royal Society*: 'The importance of the determination of this ratio in all cases in which electrostatic and electromagnetic actions are combined is obvious. … But a knowledge of this ratio is, I think, of still greater scientific importance when we consider that the velocity of propagation of electromagnetic disturbances through a dielectric medium depends on this ratio, and, according to my calculations, is expressed by the very same number'.[26] Clerk Maxwell, who by then had departed from King's College and was based at his country house, Glenlair in Kirkcudbright, but regularly visited London, was once again assisted in the Clapham Common experiment by Charles Hockin.

At The Lawn, Clerk Maxwell designed and built apparatus to balance, first, the electrostatic attraction between two charged metal discs, held by Gassiot's batteries at a specific potential difference; and, second, the magnetic repul-

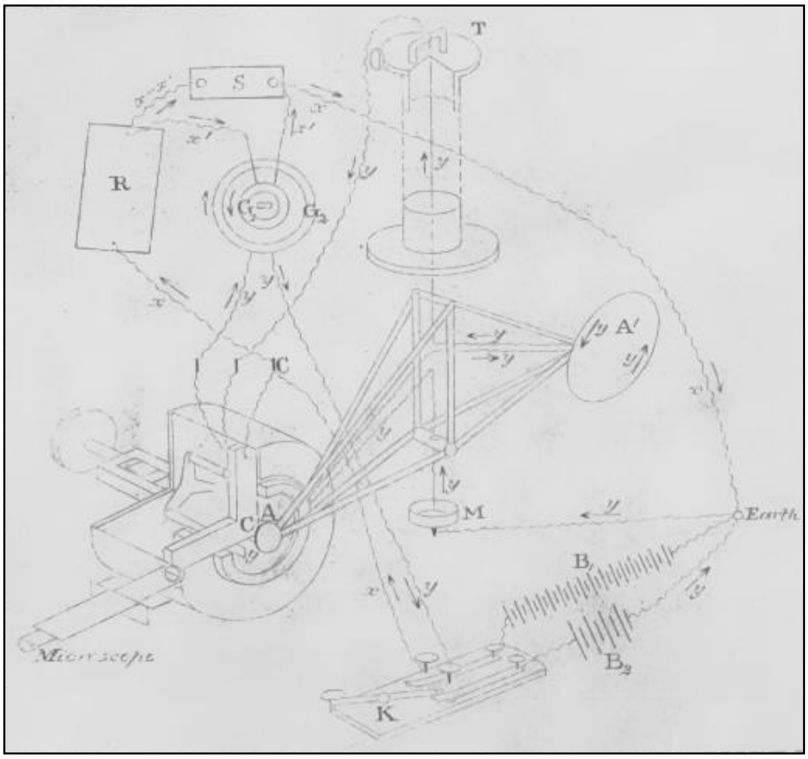


Fig. 8: Circuit diagram of Clerk Maxwell's apparatus (negative of original image, for clarity). Philosophical Transactions of the Royal Society, *158 (1868), p. 646. A is the suspended disc and coil. A′ is the counterpoise disc and coil, attached to the opposite end of the torsion balance. C is the fixed disc and coil. B_1 is Gassiot's great battery. B_2 is the small battery. G is the galvanometer. g is the glass scale.*
K is the double key for closing both circuits simultaneously.
R is the resistor.
S is the shunt. x, x′, x–x′, and y show the currents through the circuits.

sion between two current-carrying coils. To do so, he once again used the torsion balance.

As in the Michell–Cavendish experiment, the core of the apparatus was a rod – or in this case a trapezoidal frame (see Figure 8) – suspended from a wire, so that forces of attraction or repulsion reacted against the torsion of the wire. To the end of one arm of the frame, where Cavendish had placed one of his small spheres, Clerk Maxwell attached one of the metal discs, with one of the coils behind it.

The second disc and coil (analogously to Cavendish's large weight) were fixed in position a short distance away from the movable suspended disc and coil. A guard ring around the fixed disc allowed its distance from the moving disc to be gauged precisely. The charge on the fixed disc was provided by Gassiot's great battery. A separate Grove battery provided the current for the coils, flowing in opposite directions in order to produce a repulsion, and the charge for the suspended disc.

To the opposite arm of the torsion balance was attached a counterpoise coil, through which flowed part of the Grove current, in the opposite direction from the first suspended coil, to cancel out the couple on the torsion balance deriving from the Earth's magnetic field. Resistance coils and other parts of the apparatus were provided by Willoughby Smith (1828–91), an electrical engineer; Henry Charles Forde (1827–97), a telegraph engineer; and Fleeming Jenkin.

When the circuits were closed, the electrostatic attraction between the fixed disc and the suspended disc needed to be equal and opposite to the electromagnetic repulsion between the fixed and suspended coils. Hockin adjusted the resistance through the coils by means of a shunt to reach an equilibrium of the attractive electrostatic and repulsive electromagnetic forces. At equilibrium, Clerk Maxwell himself measured the distance between the suspended disc and the fixed disc, by microscopic examination of a glass scale attached to the former, which allowed accuracy to one thousandth of an inch. Meanwhile Hockin measured this equilibrium resistance with a galvanometer. Because of the balance of opposing forces, the equilibrium resistance then corresponded to the ratio of electrodynamic and electrostatic units.

Working and taking measurements quickly was essential because of the different rates at which the two batteries ran down.[27] As Cavendish had done in his measurement of relative density, Clerk Maxwell undertook a number of separate experiments in order to derive a mean measure. Coincidentally, like Cavendish he conducted 17 experiments, although he rejected five of them because of an additional attraction between the discs when the micrometer was touched by hand, which he attributed to the leakage of part of the great battery's charge through the floor of the laboratory.

From the twelve remaining experiments Clerk Maxwell obtained a mean measured value of the equilibrium resistance of 28.798 ohms, corresponding to a ratio of units of 287,980,000 m/s. The actual speed of light through a vacuum is 299,792,458 m/s, 4.1 per cent greater than Clerk Maxwell's estimate.

An earlier measurement of the ratio had been made in 1856 at Göttingen by Wilhelm Weber (1804–91) and Rudolf Kohlrausch (1809–58). Weber and Kohlrausch had derived the ratio of units by measuring the time taken by a Leyden jar capacitor to discharge a known quantity of electric charge.[28] They noted the ratio's closeness to the speed of light, but unlike Clerk Maxwell thought this was coincidence rather than having any physical significance.[29]

Clerk Maxwell's result was 7.3 per cent below Weber and Kohlrausch's measurement of the ratio at 310,740,000 m/s; 8.1 per cent below Hippolyte Fizeau's (1819–96) 1849 directly measured value of the speed of light through air at 313,274,304 m/s; and 3.4 per cent below Léon Foucault's (1819–68) 1862 directly measured value of the speed of light through air at 298,000,000 m/s. Despite the relatively broad spread of these results, the scope for experimental error meant that the discrepancy was not surprising, and the fact that they were of the same order of magnitude provided important support for Clerk Maxwell's theory.[30]

The significance of Clerk Maxwell's experiment was not its accuracy, but the fact that it was the first such measurement to be informed by a theoretical understanding of what light is, and why it behaves as it does.

3.4. *The influence of James Clerk Maxwell's results*

The theoretical and experimental evidence for a constant speed of light was strong enough for Clerk Maxwell to suggest at the 1870 Liverpool meeting of the British Association that the properties of atoms and the light they produce should replace reference lengths and weights as the standard of physical measurement, as eventually agreed with the adoption of the SI system from 1960.

The process of replacing traditional reference standards with the speed of light and quantum vibrations of atoms as the basis for defining all the fundamental units of measurement was completed with the redefinition of the kilogram, the unit of mass, in 2019, since when all standards of measurement have been related to defined physical constants.

Clerk Maxwell's work initiated the study of light as an electromagnetic interaction with matter, leading to the identification by Hendrik Lorentz (1853–1928) in 1892 that light is caused by the vibration of electrons; the identification by Pieter Zeeman (1865–1943) in 1897 of the Zeeman effect, i.e. that a magnetic field splits spectral lines; Albert Einstein's (1879–1955) explanation in 1905 of the photoelectric effect; and ultimately to quantum mechanics, relativity theory, quantum field theory, and the 'Standard Model' of particle physics.

The fact that in Maxwell's equations c is constant regardless of how the observer is moving (contrary to Newtonian classical mechanics) was initially interpreted as a flaw in the theory, but was the starting point of Einstein's speculations, which led to the 1905 Theory of Special Relativity. This was further developed in 1908 by Hermann Minkowski's (1864–1909) model of four-dimensional spacetime, and Einstein's 1915 General Theory of Relativity.

In 1878 Clerk Maxwell suggested that instruments were not sensitive enough to detect by experiment whether the speed of light was independent of the motion of the observer, and in the process show whether the 'ether' – the hypothetical medium through which it was speculated that electromagnetic waves propagated – existed or not. This assertion spurred Albert Michelson (1852–1931) and Edward Morley (1838–1923) to design an interferometer to perform the experiment in 1887, confirming that c does not vary, whatever the direction the observer is moving. Thus the constancy of c enabled the final disproof of 'ether' as a medium of physical interaction.

Among the astronomical consequences of Clerk Maxwell's theory was his prediction of radiation pressure, the force that pushes the dust tails of comets away from the Sun. Its existence was confirmed experimentally in 1900 by the Russian physicist Pyotr Nikolaevich Lebedev (1866–1912) and was used by Arthur Eddington (1882–1944) to determine the dynamics of stars. Even more significant was Eddington's demonstration in 1919 of how the constant speed of light governs the gravitational curvature of spacetime as predicted by Einstein's General Theory of Relativity.

The influence of Clerk Maxwell's theory of electromagnetism can be summed up in the opinions of two of his great successors. Marking the centenary of Clerk Maxwell's birth in 1931, Albert Einstein observed:

> Before Maxwell people thought of physical reality – in so far as it represented events in nature – as material points, whose changes consist only in motions which are subject to total differential equations. After Maxwell they thought of physical reality as represented by continuous fields, not mechanically explicable, which are subject to partial differential equations. This change in the conception of reality is the most profound and the most fruitful that physics has experienced since Newton.[31]

In his 1964 *Lectures on Physics*, Richard Feynman (1918–88), the theorist of quantum electrodynamics, opined: 'From a long view of the history of mankind … the most significant event of the nineteenth century will be judged as Maxwell's discovery of the laws of electrodynamics'.[32]

4. Conclusion

Thus did the work at Clapham Common of Henry Cavendish on the density of the Earth, and of James Clerk Maxwell on the nature of light, contribute to fundamental shifts in our understanding of nature. Eighteenth-century experimental demonstrations of Newton's theory of universal gravitation arose from navigational and geodetical needs for accurate astronomy. Twentieth-century observational demonstrations of its replacement, encompassing electromagnetism and light as well as gravity, in Einstein's General Theory of Relativity, demonstrated the need to take account of the effect of curved spacetime and the constant speed of light on our observations of the Universe.

Acknowledgements

The author is grateful for the assistance of Michael Tuffrey, of the Clapham Society.

Notes and references

1. James Clerk Maxwell was the son of John Clerk (1790–1856), a Scottish advocate who took 'Maxwell' as an additional surname because he had inherited his country estate, at Middlebie, Dumfriesshire, from his grandmother, Dorothea Clerk Maxwell; she had herself taken 'Maxwell' as an additional surname by inheritance of Middlebie through her mother, Agnes Maxwell. Clerk Maxwell is therefore a double surname. Although James is often referred to as 'Maxwell' (most notably in 'Maxwell's Equations'), this paper refers to him by both his surnames.
2. The torsion balance was also independently invented at about the same time in France by Charles-Augustin de Coulomb (1736–1806) for his electrical experiments. Coulomb used the balance from the late 1770s for the experiments on electrostatic forces which resulted in his publication in 1785 of Coulomb's Law, the inverse-square attraction or repulsion between electric charges.

   Henry Cavendish himself, independently of Coulomb, also discovered the inverse-square law of electrical forces in the 1770s, by performing experiments on concentric conducting spheres, but did not publish his result. Cavendish's parallel priority with Coulomb was not discovered, by James Clerk Maxwell, until the 1870s. Michell had also earlier suggested an inverse-square law for magnetic forces.
3. Roy, William, 'An Account of the trigonometrical operation, whereby the distance between the meridians of the observatories of Greenwich and Paris has been determined', *Philosophical Transactions of the Royal Society of London*, 80 (1790), 111–614. Most of Roy's stations in the London area were either church steeples or prominent hilltops.

   The other observatories that he used perhaps give some idea of the prominence of Cavendish in the enterprise: the King's Observatory at Richmond, Surrey (Kew Observatory); Alexander Aubert's successive observatories at Loampit Hill, Deptford, Kent, and Highbury House, Middlesex (whose meridian mark was the cupola of St Paul's itself); and Roy's own observatory at 12 Argyll Street, Westminster. Spring Grove, Isleworth, Middlesex, the house of Sir Joseph Banks, President of the Royal Society, was another station.
4. Batten's Plan of Clapham, 1827 (detail, Fig. 1), also reproduced in Jungnickel, Christa, and McCormmach, Russell, *Cavendish* (American Philosophical Society, 1996); the

same authors' revision of this book, *Cavendish, The Experimental Life*, 1999; and Titchmarsh, P. F., 'The Michell–Cavendish Experiment', *School Science Review*, 162 (1966), 320–30, shows an outbuilding in this position, at some 45° to the House, but aligned east–west. The evidence that this is where Cavendish did his experiments, as noted by Francis Baily in 1842 (ref. 13), is that he referred in the *Philosophical Transactions* paper (ref. 5) to the fact that his apparatus was aligned west–east.

GPS puts the site of Cavendish House in Englewood Road at 52° 27′ 13″ N, 0° 8′ 47″ W; and of the pavement outside 4 Cavendish Road 3 arcseconds to the east; taking account of GPS's location of the Greenwich Meridian at 0° 0′ 5.562″ W, Roy's coordinates seem compatible with the possibility that the outbuilding on Batten's plan was Cavendish's Transit Room. Despite the contemporary and later fame of the Experiment, there is nothing on the site, today occupied by Edwardian terraces, to commemorate the event.

Jungnickel and McCormmach's book includes a detailed analysis of the Cavendish Experiment. Cavendish House is also marked, and The Lawn shown, in the Ordnance Survey's 25-inch map, *London LXXV*, 1874 (surveyed 1869–1870), published online by the National Library of Scotland. On this map The Lawn is the house with the broad frontage and large back lawn, directly opposite Windmill Place.

5. Cavendish, Henry, 'Experiments to Determine the Density of the Earth', *Philosophical Transactions of the Royal Society of London*, 88 (1798), 469–526.
6. A detailed account of Mason and Dixon's survey is in Danson, Edwin, *Drawing the Line: How Mason and Dixon Surveyed the Most Famous Border in America* (Jossey Bass, 2001, revised edition 2016).
7. The effect had been theoretically predicted by Isaac Newton in *Principia*, 1687. Newton predicted a deflection of some 2 arcseconds from a hemispherical mountain with a radius of three miles. The first measurement of the 'attraction of mountains' was made by Pierre Bouguer in 1738 at Chimborazo, a 20,549-ft (6,263-m) volcano just south of the Equator in Ecuador (then part of Peru) during the French expedition to measure the length of a degree of latitude at the Equator, and thence to derive the figure of the Earth, by comparisons with similar measurements of a degree in temperate and polar latitudes. Bouguer claimed a deflection of 8 arcseconds. Because, as Newton had also predicted and the French expedition proved, the figure of the Earth is an oblate spheroid, Chimborazo happens to be the farthest point on the surface of the Earth from the planet's centre.

   A detailed account of the Schiehallion experiment is in Danson, Edwin, *Weighing the World: The Quest to Measure the Earth* (Oxford University Press, 2006), which however gives only summary treatment to the Cavendish Experiment.
8. Maskelyne won the Royal Society's 1775 Copley Medal, the highest scientific award of its time, for this work. Cavendish had won the Copley Medal for his chemical researches in 1766; Hutton won it for research on ballistics in 1778; and Roy in 1785 for his measurement of the Hounslow Heath baseline for the Greenwich–Paris triangulation and the geodetic mapping of Britain.
9. The Michell–Cavendish Experiment is described in detail in Cavendish, op. cit. (ref. 5).
10. Michell's assumption that corpuscles of light might be subject to gravity led him to suggest a retardation of light by massive stars, such that there might exist astronomical bodies so massive that the light they emitted would be unable to escape from them. Michell's belief that the gravitational retardation of light might allow him to 'weigh the stars' by using prisms to measure its refractive effect was the context for his unsuccessful attempt to build a giant telescope of huge light-gathering power.

    In 1783 Cavendish suggested lenses, rather than Michell's prisms, to measure the supposed retardation. Cavendish and Michell concluded, however, that observable stars might not be massive enough for the predicted retardation of their light to be measurable. So Cavendish suggested that Michell abandon the giant telescope and instead attempt 'the easier and less laborious employment of weighing the world'. Detailed accounts of Michell's work are in McCormmach, Russell, 'John Michell and Henry Cavendish: Weighing the Stars', *British Journal for the History of Science*, 4 (1968), 126–55, and McCormmach's book *Weighing the World: the Reverend John Michell of Thornhill* (Springer, 2011).
11. Given the need to avoid thermal distortions, it must have been too cold during the autumn and winter for Cavendish to spend hours sitting still in an unheated outhouse to observe the slow motion of the balance.
12. Michell had intended 8-inch 'weights'. Cavendish's were 3.375 times heavier.

Michell also intended to support the weights from below, and to move them into position by hand. It was Cavendish who, to minimize disturbance by the observer, introduced the pulley system.

13. Baily, Francis, 'An Account of Some Experiments with the Torsion-rod, for Determining the Mean Density of the Earth', *Monthly Notices of the Royal Astronomical Society*, 5 (1842), 197–206; and *Memoirs of the Royal Astronomical Society*, 14 (1843).
14. Information about Gassiot from *Dictionary of National Biography*, article by W. H. Harrison, 2004, revised by Iwan Rhys Morus, 2011; personal memorials by Eric Smith, 1945 and 1968, in the Lambeth Archives; and personal communication from Michael Tuffrey of the Clapham Society, 2023.
15. As in the case of Cavendish House, there is nothing on the site today to commemorate either Gassiot's residence or Clerk Maxwell's historic experiment. Only two images of The Lawn appear to exist: a drawing in the Lambeth Archives of its garden frontage (Fig. 6 in this paper), and a photograph looking down its garden, after the house had been demolished, in a 1904 prospectus for the Clapham High School for Girls, a copy of which is in the Bodleian Library, Oxford, Shelfmark: X09.F05412 (Box B000001117109).

    The Lawn is not to be confused with 'The Lawns', another house shown on the 1874 Ordnance Survey map 150 yards to the south of Cavendish House. The Girls' Public Day School Trust acquired The Lawn in 1882, and the next-door house in 1901, demolishing both for its new building. Among the alumnae of the school, in the 1880s when it still occupied The Lawn, was Philippa Garrett Fawcett (1868–1948), the first woman to score 'Above the Senior Wrangler' in the Cambridge Mathematical Tripos examination, in 1890 (at that time only men were awarded the title Senior Wrangler). Clerk Maxwell had been merely Second Wrangler in 1854.
16. Clerk Maxwell, James, 'On a Method of Making a Direct Comparison of Electrostatic with Electromotive Force; with a Note on the Electromagnetic Theory of Light', *Philosophical Transactions of the Royal Society of London*, 158 (1868), 643–57. Clerk Maxwell's summary of the experiment is in *Proceedings of the Royal Society*, 16 (1868), 449–50.

    A short account of the experiment is in Basil Mahon's biography of Clerk Maxwell, *The Man Who Changed Everything* (Wiley, 2003).
17. Clerk Maxwell, James, 'On Faraday's Lines of Force', *Transactions of the Cambridge Philosophical Society*, X (1855–56), 155–229.
18. Clerk Maxwell, James, 'On Physical Lines of Force', *Philosophical Magazine*, 90 (1865), 11–23.
19. Clerk Maxwell, James, 'A Dynamical Theory of the Electromagnetic Field', *Philosophical Transactions of the Royal Society of London,* 155 (1865), 459–512.
20. Electrodynamics describes the combined influence of electricity and magnetism when electric charges are moving, whereas electrostatics describes the forces between electrically charged bodies at rest. Mathematically, the ratio between electrodynamic and electrostatic units is a velocity, which has the same absolute magnitude regardless of the units used to measure it. It corresponds to the velocity of a wire of unit length through a magnetic field of unit strength that causes a one unit electric current to flow through the wire. It is also the velocity of the 'virtual photons' whose exchange between charged particles mediates the electromagnetic force.
21. A detailed account of the influence of the electric telegraph on the development of electrical measurement and electromagnetic theory is in Hunt, Bruce J., *Imperial Science: Cable Telegraphy and Electrical Physics in the Victorian British Empire* (Cambridge University Press, 2021), which also describes George Airy's attempt to use the telegraph to improve measurement of longitude.
22. Venn, John Archibald, *Alumni Cantabrigienses*, 1947.
23. The British Association Unit of Resistance was intended to be set at a velocity of 10,000,000,000 cm/s (100,000,000 m/s). Experiments in 1880 by John Strutt, 3rd Baron Rayleigh, showed that the initial value was understated by 1.3%.

    Adjustments in the measured value of the ohm in the late 19th century, and changes in the technology of reference standards, meant that the ohm was not finally defined in terms of absolute units of length and time until 1948.
24. 'On the Elementary Relations between Electrical Measurements', published in the *British Association Report* in 1863, and again in the *Report* of the British Association Committee, 1864, and *Philosophical Magazine* (1865), 436–60, and (1865 supplement), 507–25.
25. Ibid.
26. Clerk Maxwell, op. cit. (ref. 16).
27. Ibid.

28. Weber, Wolfgang, and Kohlrausch, Rudolf, 'Elektrodynamische Maassbestimmungen inbesondere Zurückführung der Strömintensitäts-messungen auf mechanisches Maass', *Abhandlungen der Königlich Säxischen Gesellschaft der Wissenschaften*, 3 (1856), 221–92.
29. Weber and Kohlrausch used the letter *c* (probably short for 'constant') to denote the ratio of electrodynamic and electrostatic measures in 1856. Clerk Maxwell however used the symbol *E*, and later *v* for the ratio, and *V* for the speed of light, as did Einstein until 1907, when he adopted *c*. By the late 19th century *c* was widely used to designate the ratio, but its first use specifically for the speed of light appears to have been by the German physicist Max Abraham (1875–1922) in 1903. A detailed account of the history of this symbolism is in Mendelson, Kenneth S., 'The Story of *c*', *American Journal of Physics*, 74 (2006), 995–8.
30. A correction for the British Association Committee's under-measurement of the ohm (ref. 23) would have reduced the value of Clerk Maxwell's estimate by 1.3%.
31. Einstein, Albert, 'Maxwell's influence on the development of the conception of physical reality'. In *James Clerk Maxwell: A Commemoration Volume, 1831–1931* (Cambridge University Press, 1931), 66–73.
32. Feynman, Richard, *The Feynman Lectures on Physics*, 1964.

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William John Roberts (1867–1942)
Science communicator, astronomer, and engineer

Matthew McMahon, Mark E. Bailey, and
John Christopher Roberts Seager

William John Roberts (1867–1942) was a skilled Irish science communicator, astronomer, and engineer. Largely self-taught, he engaged with professional astronomers across Ireland and Europe. Here we review his life and career, the instruments he used, his observatory at Tullyroan, Co. Armagh, and the network of astronomers of which he was part. We have drawn upon family archives, newspaper articles, and the Armagh Observatory and Planetarium library and archives.

1. Introduction

At the start of the 20th century, Ireland – which for 72 years from 1845 was the home of the largest telescope in the world, that of Lord Rosse at Birr Castle – found itself in possession of a talented and energetic pool of 'amateur' astronomers who contributed articles and original results to journals in the United Kingdom and farther afield.

William John Roberts of County Armagh was one such amateur, although, as in much of the 19th century and now again in the 21st, use of the term 'amateur' does not imply amateurish; rather, such amateurs often displayed a deep knowledge of their subject and adopted a highly professional approach to astronomy.

Following the significant advances made in the 19th century by observatories such as Dunsink, Daramona, Cork, Birr, and Armagh, by the early 20th century Irish astronomy was entering a period of relative decline on the UK national and world stage. Work continued, but at a lesser pace than that of the previous century when results from revolutionary new instruments were matched by astronomical minds such as those of John Thomas Romney Robinson, William Rowan Hamilton, and John Louis Emil Dreyer.[1]

2. Early life

William Roberts (Figure 1) was born on 1867 April 16 in Dungannon, Co. Tyrone.[2] He was the eldest son of Neason Roberts, a saddler of Irish Street, Dungannon, and his wife Eliza.[3] William left school at 12 years of age and soon found work in the clerical department of Hale, Martin and Company's flax-spinning mill in Dungannon. Showing aptitude and a keen mind, he was soon promoted to Secretary and would go on to become Secretary of the Roan Spinning Mill in Coalisland where he remained until retiring in the early 1930s.[4]

In later years he recalled that he had had an interest in astronomy since childhood. He had attended science and art classes to continue his schooling, but according to his family and newspaper articles he was largely self-taught through books and experimentation.

He would later be engaged as an instructor in magnetism and electricity in Dungannon Technical School. His interests in electricity were also practical; for example, designing and building a windmill for the house at Tullyroan, which he used to charge lead Winchester batteries.

He was fluent in French by his late twenties, and a silver medal was later found in Tullyroan

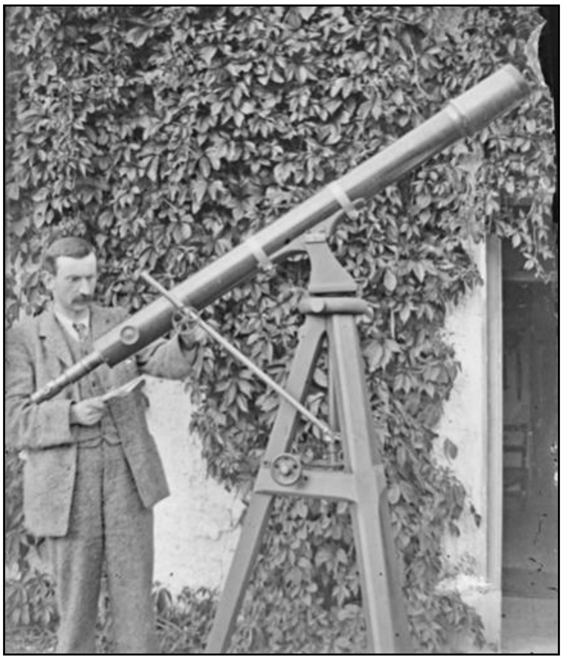


Fig. 1: William Roberts beside the front door of his home in Tullyroan with the 5¼-inch telescope made around 1920 by W. F. A. Ellison. (Seager family)

from the Society of French Astronomy of which he was a member. The medal is shown in Figure 2; it is engraved with his name and dated 1897. Such medals were sold through the *Bulletin de la Société Astronomique de France* (1897) and were made by Alphée Dubois, a highly regarded medalist. The medals were only available to members of the society and this one was most likely purchased by Roberts to mark his 30th birthday.

3. Astronomy and observatories

William Roberts built his first observatory at Lakeview House, Dungannon, around 1905, and was featured in the *Tyrone Courier* on August 31 that year observing a deep partial solar eclipse the day before. This had a magnitude of around 78 per cent as seen from Northern Ireland. At that time, he was with some schoolboys and their teacher, Robert Foster Dill (1859–1947), from the Royal School Dungannon. The observatory at Lakeview House was equipped with several telescopes including a 4-inch refractor that would have been an impressive instrument for the period.[5]

On 1905 July 25 Roberts married Anna Matilda Tate at Tullyroan Methodist church, less than a mile from her home in Tullyroan. After their marriage the couple moved into her family home at Tullyroan and he began to rent out his house at Lakeview. Thereafter he appears to have begun construction of a new observatory on the hill behind their home, from which he would go on to make many observations over the decades. They would have three children together: Elizabeth, who went by the name of Elsie, who was born on 1908 July 18, Eileen, born 1912 April 12, and Mary (known as May), born 1917 March 27.

The remains of this observatory can still be seen (Figure 3). The central telescope pier exists, and this would have supplied a sturdy mount for any telescope that Roberts had access to. The pier is made from a cast-iron pipe with the remains of a dark green paint on its surface and secured in a cement and gravel base. The construction followed the recommendations of the Reverend William Frederick Archdall Ellison (1864–1936), the sixth director of Armagh Observatory, as described in his book *The Amateur's Telescope*, published in 1920 shortly after completion of William Roberts's observatory at Tullyroan.[6]

Roberts noted in a newspaper interview that he kept the dome unheated even in winter to prevent errors in the observations.[7] John Seager, grandson of William Roberts and a co-author of this paper, remembers that the

Fig. 2: Obverse and reverse of William Roberts's silver medal, dated 1897. (Seager family)

observatory was covered in a tarpaulin when it was not in use. The material may have been Ruberoid, a bituminous material recommended by Ellison.

Given the observatory's location, Roberts would have enjoyed uninterrupted views of the sky to the south, but would have lost part of the northern sky to the hill on which the observatory was built. Even today Tullyroan is still a relatively dark site. In an *Irish Independent* interview published a few months before his death in 1942 he noted the benefit of a view 'unspoilt by the glare of big cities'.[8]

3.1. *W. F. A. Ellison*

In passing, we note that Ellison was director of Armagh Observatory for nearly twenty years. He was an exceptionally skilled astronomer and instrument-maker and an experienced planetary observer and meteorologist. His work was praised in his own time and his third son, Mervyn Archdall Ellison (1909–63), was steeped in astronomy from a young age.

For example, father and son conducted a joint project with a focus on binary stars. Mervyn would later develop a special interest in solar physics and became director of Dunsink Observatory, Dublin. Ellison's second son, Henry Havelock Ellison (1902–79), known as Harry, made a particular impression as the driving force behind a project to obtain a full set of high-resolution aerial photographs of the six counties of Northern Ireland.

These unique images give investigators a valuable insight into the land and townscapes of Northern Ireland as they appeared from the air in the 1920s, as well as revealing new archaeological features. Harry Ellison was noteworthy too for being an extremely good shot and marksman, and one of the first pilots to carry out bombing raids into Germany and environs in World War II.[9]

Ellison senior had begun to make his own instruments as early as 1900 when his family were living in Fethard-on-Sea, Co. Wexford, and the instruments he later built at Armagh were used all over the world, from Ceylon to Buenos Aires. Ellison specialized in building both refractors and reflectors, but he was equally adept at repairing, maintaining, and improving existing instruments.

4. Instrumentation

William Roberts's name appears in Ellison's optical notebook three times. In the first reference, the 5¼-inch telescope (Figures 1 and 4) then in use at Armagh Observatory was noted as having been sold to a 'J. Roberts FRAS'.[10] William Roberts also owned an unnamed 4-inch refractor and a 4-inch Broadhurst and Clarkson telescope, both of which were worked on by Ellison. In addition to these principal instruments, William Roberts had several smaller telescopes including one made by London instrument makers Negretti & Zambra.

Fig. 3: Remains of the telescope pillar and mount; the walls and roof are completely removed and only sections of the poured concrete floor are left. (Authors)

The 5¼-inch refractor was one of Ellison's first projects upon beginning his tenure at the Armagh Observatory. He completed the telescope in 1920, whereafter it was sold to William Roberts.[11] The telescope was documented by the local historian of astronomy, named John McConnell, as being in the Royal School Armagh in 1988. Unfortunately, its present location is unknown, and it no longer appears as part of the Royal School's collection (Figure 5).

The 4-inch Broadhurst and Clarkson telescope is still with the Seager family, with a choice of associated eyepieces in a factory-supplied transport case padded with green felt. The case has suffered some wear over the last century with expansion and contraction of the wood. The telescope itself is in good condition and has all the parts it would have been shipped with. Only a small dent around the eyepiece and some corrosion along the main body hint as to its age. The lenses are in good condition, as is the sunshield. In short, it is a high-quality instrument, indicative of Roberts's professional approach and interest in astronomy. Like the 5¼-inch it too appears in the list of telescopes on which Ellison worked and he noted it as an excellent instrument.[12]

During the summer of 1918 William Roberts observed the famous Nova Aquilae and his observations were included in an article in the *Bulletin of the Société Belge d'Astronomie* in 1920.[13] His observations were consistent with others published in the same article. He was the only astronomer on the island of Ireland to appear in the report, having most likely become aware of the nova from his membership of the British Astronomical Association.

At the meeting of the Royal Astronomical Society on 1918 May 10, William Roberts was proposed for election as a Fellow by William Redfern Kelly (1845–1928) of Belfast from personal knowledge.[14] He was elected on 1918 November 8 and began to add the title FRAS to his writings thereafter.

4.1. *William Kelly*

William Kelly, Roberts's proposer, was 18 years his senior and worked as the Assistant Chief Engineer for the Belfast Harbour Commissioners.[15] A frequent traveller to the continent and a French speaker, Kelly was a member of both the *Société Belge d'Astronomie* and the *Société Astronomique de France*, groups with which Roberts was also involved. Kelly also served as the honorary secretary of the short-lived (1890–1894) Ulster Astronomical Society (UAS), of which he was a founding member.[16]

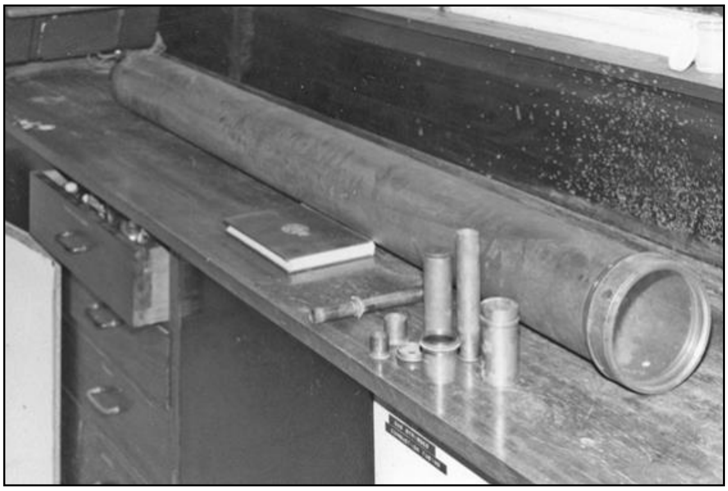
Such amateurs were inspired by the works of the English astronomy popularizer Richard Anthony Proctor (1837–88), who had written several excellent and affordable books on astronomy. Proctor's second wife, Sallie, an American, moved to Ireland following his death and brought a library of popular astronomy with her. She gave two well-attended lectures to the UAS in Belfast in 1891.

Like William Roberts, William Kelly also contributed to public understanding of science by contributing articles and letters to local newspapers. Unlike William Roberts he published in the Belfast newspapers as opposed to the Dublin-based *Irish Independent,* of which Roberts was a frequent contributor.

Both men wrote in a conversational style, explaining astronomical concepts and discoveries in layman's terms and keeping people informed about developments and upcoming events such as eclipses. For example, writing about the solar eclipse of 1900 May 28, William Roberts gives the sort of practical advice needed for typical working-class astronomers of the day on how to make observations: 'To see the eclipse it will be necessary to use a piece of glass smoked over a candle. If in addition an opera glass or small telescope be used, the effect will be enhanced, but, above all, a cloudless sky is indispensable'.[17]

Fig. 4: W. J. Roberts and family observing a solar eclipse with the Ellison 5¼-inch telescope and a smaller refractor in the background. This was possibly the deep partial eclipse of 1927 June 29 (magnitude c.97% from Northern Ireland), which was total across a swathe of central England. (Seager family)

Fig. 5: *What is thought to be part of the 5¼-inch telescope made by W. F. A. Ellison for William Roberts around 1920, as it appeared in the Royal School Armagh around 1988. (John McConnell)*



William Roberts continued to write in the *Irish Independent* right up his death in 1942. His articles followed a pattern, typically focusing on a single theme such as an astronomical concept, or an event such as one published in 1940 April which was focused on the interactions between the Sun and the radio. He set aside a portion of each article for the most recent discoveries that had been published in the *Monthly Notices of the Royal Astronomical Society* and other journals. His language is, as we have seen, conversational but it is also communal, referring frequently to his audience and all mankind as 'we' and 'our own Earth'.[18]

5. Beyond astronomy

William Roberts had wide interests beyond astronomy, for example performing field work as an amateur archaeologist. Writing in the *Tyrone Courier* in 1902 March he documented the discovery of an ancient canoe and human remains in Crossdernott bog, five miles northwest of Dungannon.[19]

The discovery had been made in 1901 June, and he photographed the relics and helped with the excavation, taking detailed field notes on which he based the article for the newspaper. The article displays the easy, conversational style that he would employ in later work, as well as a deep understanding of the contemporary archaeological landscape of Ireland.[20] The human remains were entrusted to the Dungannon morgue and the boat to the Rev. James Hamilton of Thornhill Church.

Neither the boat nor the body appear in lists of bog finds in Ireland today (Roberts noted that that the body had already begun to decompose when brought to the morgue). Later authors writing about the event assume that the body was buried by the morticians at Dungannon. The boat is noted in the book *Coití: Logboats from Northern Ireland,* but its present location is listed as unknown.[21]

5.1. *Religious and political leanings*

His approach to public education and curiosity about science were underpinned by a strong Christian faith and Methodist theology. Indeed, the interest in science of John Wesley, founder of Methodism, has been covered extensively by John Haas.[22] Sharing the same spiritual and intellectual approach, William Roberts saw his scientific and educational activities as an extension of his faith. It was his personal duty to teach, as he himself had been taught as a young man, and he felt that class should never be a barrier to learning.[23]

William Roberts was also heavily involved in the unionist community during a period of considerable unrest and upheaval in Ireland. He was a company commander in the Ulster Volunteer Force during the 1910s, and in the 1920s served as a Special Constable in the Ulster Special Constabulary. He was a member of the Orange Order throughout his adult life and in later life joined the Royal Black Institution.[24]

Roberts enthusiastically adopted the magic lantern projection system, for example showing slides in 1909 in Moy Methodist Church. Several boxes of slides are still in the Seager family collection to this day. The slides were highly praised, and his talks well-attended throughout his lifetime. Some of the slides were crafted by Roberts himself, some bought from the Royal Astronomical Society, and others the result of collaborations.

His talks were not restricted to astronomy,

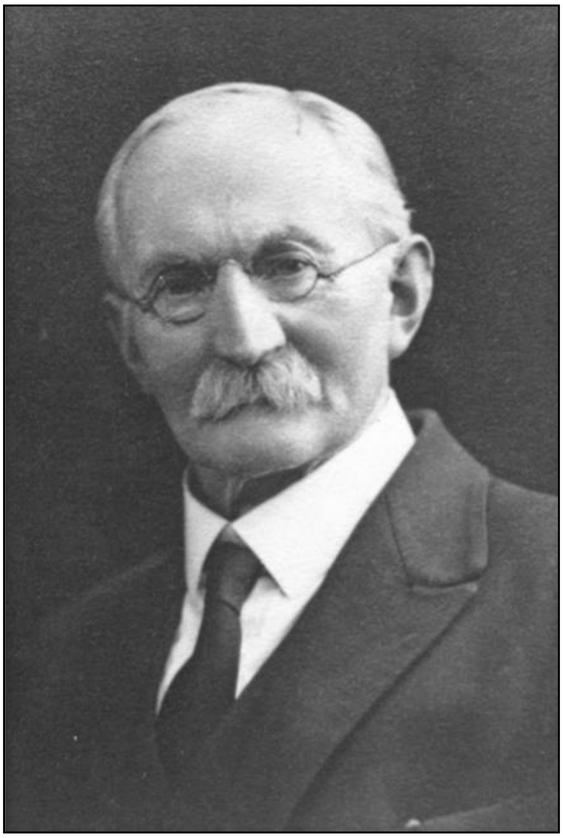


Fig. 6: Undated portrait of W. J. Roberts used with his obituary in local papers. (John McConnell)

and although he would often give lectures on astronomy in local church halls he acted as a magic-lantern operator for other speakers. He was a highly regarded minister in local Methodist congregations, where he acted as a lay preacher for over fifty years. He appears to have read as widely on theology as he did on astronomy, and his personal library contained several commentaries and textbooks on the subject.

He held a deep interest in the Book of Revelation and British Israelism (i.e. the pseudo-historical belief that the British, Scandinavian, and Germanic people are the direct descendants of the Ten Lost Tribes of ancient Israel), both of which he lectured on. A ticket stub to one of his lectures on the subject of British Israelism survives in the collection of the Armagh County Museum.

William Roberts died on 1942 August 9, aged 75, in his home at Tullyroan where his workshop, observatory, and library had served him for over thirty-five years (Figure 6). He was survived by his wife and three daughters, May, Elsie, and Eileen, each of whom were distinguished in their respective fields; he had always prioritized their education and celebrated their successes. The daughters were partially funded in their education by relatives in the United States. Eileen became an advisor in the Northern Ireland Civil Service, while May and Elsie became doctors after qualifying from Trinity College Dublin.

Conclusion

In summary, William Roberts was one of several 'professional' amateur astronomers active in Ireland during the late 19th and early 20th centuries. These individuals occupy a central position between the height of Victorian discovery in Ireland and the beginning of the modern era and play a correspondingly important role in widening and strengthening the tradition of scientific enquiry in Ireland.

A turning point came with the appointment of Dr Eric Mervyn Lindsay (1907–74) to Armagh Observatory in 1937, at that time the only professional astronomer on the island of Ireland, and the founding of the Irish Astronomical Society in the same year. Later developments soon followed: the establishment of the Dublin Institute for Advanced Studies in 1940; the reopening of Dunsink in 1947; the funding and construction of the Armagh-Dunsink-Harvard (ADH) telescope in Boyden, South Africa, in 1950; and the formation of university groups.

William J. Roberts contributed to astronomy through accurate and timely observations, his collection of high-quality instruments, and involvement in international discourse in various journals. But it is his commitment to public understanding of science at a time when this was still unfashionable among professionals that shines through in his obituaries. He kept his readers abreast of developments and always wrote with the lay person in mind.

Acknowledgements

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References and notes

1. Bennett, J. C., *Church, State and Astronomy in Ireland* (Armagh Observatory, 1990), p. 153.
2. Obituary Notice, William John Roberts, *Monthly Notices of the Royal Astronomical Society*, 103 (1943), 72–3.

   https://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1943MNRAS.103...72.
3. Library Ireland, *Belfast and Ulster Towns Directory for 1910* (2007). Available at:

   www.libraryireland.com/UlsterDirectory1910/Contents.php
4. 'Ulster Astronomer's Death', *Portadown News*, 1942 August 15, p. 6.
5. *Tyrone Courier*, 1905 August 31, p. 1.
6. Ellison, W. F. A., *The Amateur's Telescope* (R. Carswell & Son, 1920), p. 97.
7. 'Story of Mars', *Irish Independent*, 1942 May 5, p. 2.
8. Ibid.
9. Ellison, W. F. A., *The Amateur's Telescope to IGY Solar Patrol: An Irish Family's Astronomy Story* (self-published, 2012), p. 18. Its author is the grandson of the Rev. Ellison.
10. Ellison, W. F. A., Optical Notebook, *Ellison Library Collection* (Armagh Observatory and Planetarium, 1922, ARM ELC 6.4) p. 1.
11. Armagh Observatory Board of Governors (1921), Annual Report of the Astronomer, *Manuscript Collection*, Armagh Observatory and Planetarium, M 136.
12. Ellison, op. cit. (ref. 10).
13. Roy, F. De, 'Premiers observateurs de Nova Aquilae, No 3, le 8 juin 1918 dans different pays', *Bulletin of the Société Belge d'Astronomie*, 36 (1920), p. 95.
14. 'Meeting of the Royal Astronomical Society [No. 527]', *The Observatory*, 41 (1918), p. 242.
15. *Dictionary of Irish Architects*, 1720–1940.

    https://www.dia.ie/architects/view/2949/KELLY-WILLIAMREDFERN
16. Hayward, R., and McElderry, J. H., 'Astronomy Sixty Years Ago: the Ulster Astronomical Society 1890/1894', *Irish Astronomical Journal*, 1 (1950), p. 75.
17. Roberts, W. J., *Tyrone Constitution*, 1900 May 18, p. 6.
18. Roberts, W. J., 'How The Sun Affects Our Radios', *Irish Independent*, 1940 April 8, p. 8.
19. Roberts, W. J., 'Sensational Discovery in an Irish Bog', *Tyrone Courier*, 1902 March 6, p. 8.
20. Ibid.
21. Fry, Malcolm F., *Coití: Logboats from Northern Ireland* (Greystone Books, 2000).
22. Haas, J. W., Jr., 'John Wesley's Views on Science and Christianity: An Examination of the Charge of Antiscience', *Church History*, 63 (1994), 378–92.
23. Astronomical Lecture, *Tyrone Courier*, 1906 February 1, p. 1.
24. *Portadown News*, op. cit. (ref. 4).

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Astronomical Postcards as a Research Resource:
A case study of the 1936 total solar eclipse

Simon Mitton

Scholars have recently suggested that picture postcards from the 1890s onwards are an important but overlooked archive for heritage studies. This paper presents a worked example of how to examine postcards with an astronomical theme in order to enrich our understanding of astronomical history, heritage, and culture. The topic is introduced with a brief history of the postcard as a means of exchanging short messages – forerunners of the modern 'tweets'. The worked example is a postcard of astronomers in action at the total solar eclipse of 1936 June 19. Biographical vignettes summarize the backgrounds and careers of the participants. The novel telescopic instrument employed, a chronocinematograph, is described. The message on the card records the difficulty of making accurate time measurements with pendulum clocks.

1. A short social history of postcards

Picture postcards are a valuable and yet under-appreciated source of visual images for communicating with the public on the heritage and social history of astronomy in the 20th century.[1] I was introduced to the advantages of collecting picture postcard images when assisting our daughter with the illustrations for her short book on Victorian hospitals.[2] No reproduction or clearance fees are payable for the use of postcard images, which simplifies the formal process of submitting a paper or book for publication. Scholars are increasingly turning their attention to the cultural value of postcards, recognizing their potential second life as heritage assets.[3, 4]

I have collected postcards with an astronomy theme for half a century, beginning with making acquisitions from traders in the Paris flea markets, then combing through offerings sourced from online vendors. The variety of astronomical images is striking: observatories and their telescopes obviously, but also instruments, buildings, sculptures, works of art, and astronomers at work. The message transmitted on a postcard can likewise open a window on social contexts: why, where, when, who, what? In this paper I introduce use of a 'why, where, when, who, what' approach for a heritage and history examination of one card from my collection.

1.1. *The Republic of Letters*

To introduce the examination of postcards of astronomical interest for heritage purposes, I first offer a brief overview of the development of communication networks for long-distance intellectual engagement. In the late 17th and 18th centuries the rise of an international network of intellectuals enabled, and indeed encouraged, European intellectuals to exchange new knowledge and engage in philosophical debate.[5] Members of this cluster of learned scholars (the so-called Republic of Letters) exchanged notes, letters, and their published papers, considering it important to widen the reach of their correspondence.

In London the Royal Society welcomed the Republic of Letters: from 1665 March the Society published notes and letters in its *Philosophical Transactions*, the world's first and longest-running scientific journal.[6] The net-

Fig. 1: Verso: In preparation for the 1936 June 19 total eclipse of the Sun, Stefan Piotrowski and Włodzimierz Zonn adjust the chronocinematograph developed by Tadeusz Banachiewicz. (Simon Mitton, personal collection)

work extended to colonial America after Benjamin Franklin was appointed colonial postmaster-general in 1775. He introduced post offices and the use of fast packet-boats for the transatlantic mails. American intellectuals hugely benefitted from the immediacy of reading European papers and journals (albeit with a latency of two or three months) and enjoying affinity with their European colleagues.

From the 1820s geomagnetic, meteorological, and astronomical observatories commenced operations throughout Queen Victoria's vast empire of colonies and dominions.[7] By the middle of the century global exchanges of data and the annual reports of observatories had become commonplace.

In 1863 an international conference in Paris established guidelines for an international postal service, paving the way for the Bern Treaty of 1874, which adopted many practical measures to ease the transmission of international mail.

The post office of Austria-Hungary authorized official postal cards for mail in 1869: three million were sold in the first three months. By 1874, dozens of postal services had authorized postcards for transmission via international mail. In this period the sender wrote the address on the front (*verso*) and their short message on the back (*recto*). In the archives of the Royal Astronomical Society there is a scattering of late-19th-century correspondence postcards (often with the postage stamp removed) with an acknowledgement or receipt penned on the reverse.

1.2. *Picture postcards*

Picture postcards date from the late 1880s. They rapidly gained popularity. From 1894 the British Post Office allowed an image on the verso, so long as space was left to cram in an address. By 1902 the permitted design had evolved to allow images to fill the verso, with address, message, and postage stamp on the recto. In 1903 Kodak introduced a pocket camera designed for postcard-size film, enabling the public to take personal photographs and have them printed on postcard backs. A postcard mania ensued, reaching its peak in England by 1903 when 600 million cards passed through the post in one year.[8]

Soon billions of view cards were being mailed annually in a worldwide craze that came to a shuddering pause with the outbreak of war in 1914, but revived somewhat in the 1920s and 1940s. It was the first global social network for exchanging images, a century before contemporary digital social networks such as Facebook, Snapchat, and Instagram.[9]

2. Astronomers in action at the eclipse of 1936 June 19

In 2019 I acquired a fascinating postcard, privately produced, of two observers in action at the total solar eclipse of 1936 June 19 (Fig-

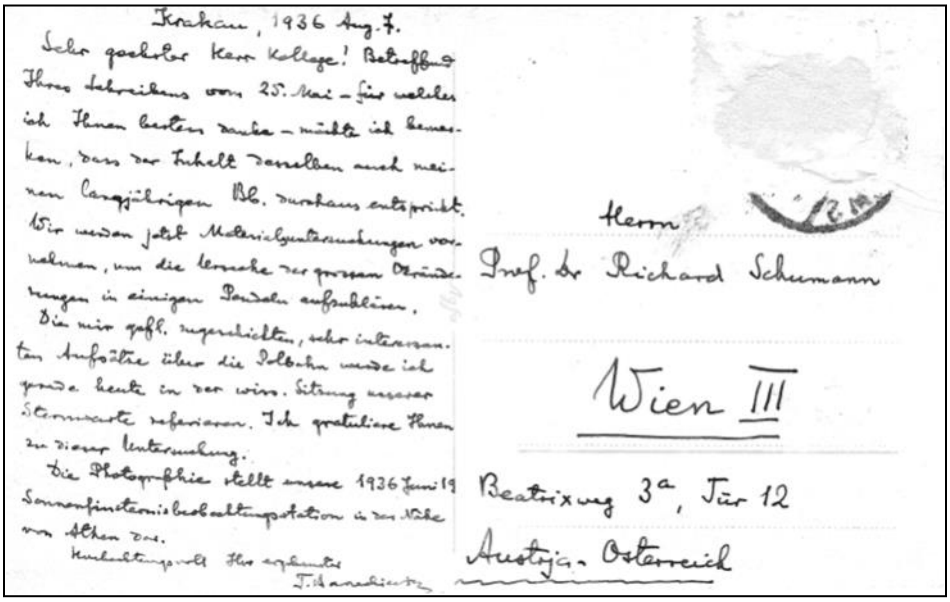

Fig. 2: Recto: Seven weeks after the eclipse, Tadeusz Banachiewicz writes from Kraków to his colleague Dr Richard Schumann in Vienna. (Simon Mitton, personal collection)

ure 1). They are stationed about 20 km south-east of Athens. The verso features Stefan Leon Piotrowski (1910–85) on the left: his pose suggests he has been disturbed for a moment from using an eyepiece and is straightening his back. On the right we have Włodzimierz Zonn (1905–75) looking relaxed and composed, left arm behind his back. He appears to be wearing knickerbockers. The photographer, and writer of the manuscript text on the recto, was Tadeusz Julian Banachiewicz (1882–1954) (Figure 2).

This card captures a fleeting moment in the lives of three highly accomplished astronomers, each of whom contributed significantly to the advancement of astronomy in Poland in the first half of the 20th century. Here is what I have learned about each of them.

2.1. *Tadeusz Julian Banachiewicz*

Tadeusz Banachiewicz, the senior member of this Polish trio of eclipse chasers, had graduated in mathematics and physics in 1904 at Warsaw University.[10] Like many of his generation of academics in Eastern Europe he had to progress as best he could despite war and revolutions. After graduation he was offered a bursary by the department of astronomy; sadly his ambition was shattered when the Russian authorities cracked down on higher education institutions in response to riots, student unrest, and strikes in support of the Polish independence movement.[11]

Banachiewicz relocated to Göttingen where, from 1906 to 1907, he studied astrophysics under the supervision of Karl Schwarzschild.[12] That experience opened a position for him at Pulkovo Observatory, on the outskirts of St Petersburg. After a few months he was engaged as an assistant by Engelhardt Observatory near Kazan, Russia. His observing campaigns focused on determining the principal physical parameters of lunar libration.

In 1915 he was appointed to an assistant professorship at Dorpat (now Tartu, Estonia) and later became director of its astronomical observatory. After the German authorities shut down the university, Banachiewicz spent a few weeks in Russia, followed by six months with the University of Warsaw in lowly circumstances lecturing on astronomy and geodesy.

Finally, a turn of fortune's wheel led to Banachiewicz being invited to the Jagiellonian University in Kraków in 1919, where he took up the position of professor and director of its Astronomical Observatory.

In 1919 the state of astronomy was grim; war and conquest had devastated the observatory, and although Poland had just regained its independence the economic outlook was dire. Nevertheless he was not dismayed; he worked effectively and the remaining thirty years of his life were crammed with scientific and organizational successes.

2.2. *Włodzimierz Zonn*

Włodzimierz Zonn, born in Vilnius in 1905, studied mathematics and astronomy at Stefan Batory University, Vilnius, from 1923. In 1927 he gained employment as deputy assistant at the university observatory. While working towards his doctorate in observational astrophysics he participated in lunar occultation campaigns during lunar eclipses.[13, 14] From Vilnius Observatory reports and papers it appears he had an active role in nine team campaigns. This gave him invaluable training on how to plan and conduct eclipse observations.

Early in 1939 September Zonn was captured by German forces after the German invasion of Poland. He was despatched to Oflag VII-A POW camp for Polish officers in Murnau in Bavaria.[15] At the end of the war he became a lecturer on astronomy at the University of Warsaw, and from 1950 he was director at the Astrophysical Observatory. He was one of Poland's most prolific popularizers of astronomy. In the literature I found just two short notes by Zonn on his coronal studies of the 1936 eclipse.[16, 17]

2.3. *Stefan Leon Piotrowski*

Stefan Piotrowski, born in Kraków in 1910, studied mathematics and astronomy at Kraków Jagiellonian University.[18] In 1933 Banachiewicz offered him a predoctoral position at the Astronomical Observatory. After gaining his PhD in 1938 his life was brutally interrupted by World War II. After six years of struggling to survive he emerged unscathed. During a postdoctoral fellowship at Harvard College Observatory, Harlow Shapley introduced him to the study of light-curves of eclipsing variables, particularly eclipsing binaries.

In 1952 he moved to Warsaw, remaining there until retirement in 1980. He succeeded Zonn as director of the Warsaw observatory from 1975. During his tenure at Warsaw he trained a handful of younger colleagues who went on to become outstanding professionals with international recognition, among them Bohdan Paczyński. Zonn and Piotrowski wrote a Polish textbook on general astrophysics which was released in 1955 by the National Publishing House, Warsaw.

3. Observation of the 1936 eclipse

The postcard features a chronocinematograph (Figures 3 and 4), an astronomical instrument that was invented by Banachiewicz in 1927 for timed observations during total eclipses.

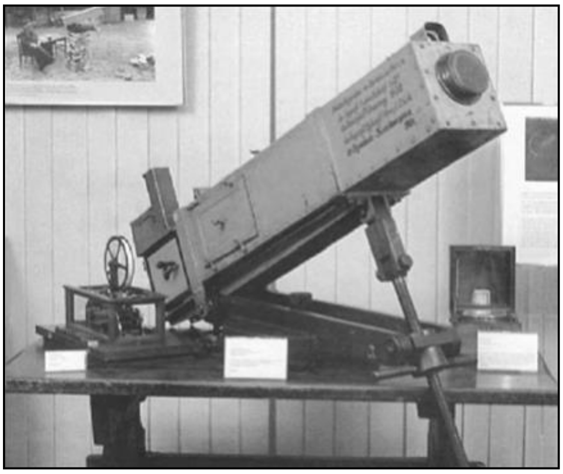

Fig. 3: The chronocinematograph on display in the physics and astronomy section of the Jagiellonian University Museum Collegium Maius. On the table from the left: chronograph, chronocinematograph, and chronometer. (From the collection of the Jagiellonian University Museum Collegium Maius. Photo: G. Zygier)

It consisted of a film (movie) camera, a chronograph, and a chronometer for recording images with a precise timeline. It was designed for making movies of the coronal and chromospheric phenomena during a solar eclipse. Accurate timing of the appearance of Baily's beads allowed precise measurement of the beginning and end of the eclipse.

These instruments were used on five expeditions organized by Banachiewicz: in 1927 to Swedish Lapland, in 1932 to New England in the US, and in 1936 to Greece, Siberia, and Japan. These eclipse observations were a continuation of his interest in the movements and figure of the Moon. Banachiewicz had spent decades wrestling with observational and theoretical challenges to improve our knowledge of the lunar motion. His derivation of the lunar libration parameters was very close to modern values determined by lunar laser ranging.[19]

The central line of the 1936 eclipse began in the Mediterranean south-west of Athens, then swept across Siberia and China to the Japanese island of Hokkaido, terminating in the Pacific. In Greece and Turkey the eclipse occurred a couple of hours after dawn, which is why the telescope in the image is at a low angle of elevation.

The Polish party assembled their equipment on the centre line, about 30 km south-

Fig. 4: Tadeusz Banachiewicz and his chrono-cinematograph in 1932. Note the dire state of the courtyard and the ad hoc arrangement of a pile of bricks for a telescope mount. A spade in the background hints at work in progress. (The Jerzy M. Kreiner private collection, CC BY-NC-ND 4.0)

east of Piraeus, in readiness for viewing 68 seconds of totality at 05h 59m local time. In the background we can see a group of eight curious locals, two of whom appear to be older children. Images of onlookers at the 1936 eclipse seem to be rare.

3.1. *Images from other groups*

There is a striking image of a dozen unidentified men clustering round a small optical instrument that appears to be a theodolite (Figure 5).[20] Did they use that to view the eclipse by projection? The venue is Mount Uludag, Turkey; today it is Turkey's largest ski resort. In the 1930s there were guest houses for winter sports enthusiasts. The three elegantly dressed gentlemen on the right of the Wikipedia image are behatted in homburgs and sporting black ties. They appear to be dressed for fine dining. Did they dine at the resort the previous evening, then linger overnight for the chilly dawn spectacle?

The most impressive collection of images can be found in Martin Mobberley's paper on the British Astronomical Association's expedition, which was led by Leslie John Comrie (1893–1950), Superintendent of the Nautical Almanac Office.[21] The BAA party was on board the P&O cruise liner *Strathaird*. From her gently swaying deck about 80 km south of Piraeus they had a splendid view of the eclipse (totality 57 seconds; 11 seconds less than expected, as they were some way off the centre line).

3.2. *The message on the postcard*

The text of the reverse of the card was written by Banachiewicz to his colleague Richard Schumann (1864–1945), a retired professor of the Technical University in Vienna and a great-nephew of the composer Robert Schumann. After studying mathematics, physics, and astronomy in Leipzig and Vienna, Richard Schumann began working as a professor of geodetic surveying, first at Aachen and then in Vienna from 1911. He became full professor of higher geodesy and spherical astronomy from 1914, and by 1937 had attained full membership of the Austrian Academy of Science. In this message Banachiewicz refers to problems encountered dur-

Fig. 5: Eclipse enthusiasts at Mount Uludag, Turkey, assembled for the solar eclipse on 1936 June 19. (Wikipedia, CC BY-SA 3.0)

ing the use of pendulum clocks at eclipses. Here is a translation:

> Krakau [Kraków] 1936 Aug. 7.
>
> Dear Colleague
>
> Concerning your letter of 23 May [1936], for which my best thanks, I should like to comment that the content of the same also corresponds thoroughly to my own many years of observations. We shall now undertake examinations of the material in order to clarify the cause of the large changes in some pendulums. I shall discuss the very interesting essays on the centrode [which you] kindly sent me during the scientific meeting of our observatory [Kraków] today. I congratulate you on this examination. The photograph shows our observations of the eclipse of the sun near Athens on 1936 June 19.

4. Concluding remarks

Above I introduced a 'why, where, when, who, what' protocol for uncovering the heritage of a historic image captured at the moment when the photographer is composing the picture. Concerning this postcard, my answers to these five questions are:

Why: To perform timed positional measurements of the Moon during a total eclipse.

Where: On the centre line near Athens, Greece.

When: 1936 June 19, an hour or so after sunrise.

Who: Three professional astronomers of the Jagiellonian University, Kraków, Poland.

What: Chronocinematograph invented by Tadeusz Banachiewicz.

Once I started on my research, I quickly became absorbed in the challenge of answering the 'Who?' and 'What?' questions. On one level this was easy; their names are written in manuscript on the card. That gave me a head start.

The name Stefan Piotrowski jogged my memory and I suddenly recalled that I had encountered him in Warsaw on 1978 May 24 during the inaugural ceremonies for the new Nicolaus Copernicus Astronomical Centre which he had co-founded. That sparked my enthusiasm to dig deeper; first by using standard internet searches, plus Google Translate for translation on the fly. Then I turned to the key papers published by this trio of astronomers. Much of Zonn's early output was published in *Acta Astronomica,* where it lies forgotten, as there are no accessible online sources. I had little difficulty in reading papers by Banachiewicz and Piotrowski.

I came away from that exercise full of admiration for the trio, because of the violent times in which they lived. When Banachiewicz graduated in 1904 the prospects for intellectuals in Russian Poland were terrifying.[22] Zonn was captured by Germans in the first week of World War II. Fortunately for him, as an officer, the conditions in the POW camp were just about adequate for survival. Piotrowski kept a low profile; he was not drafted into the Polish army because of a heart condition but spent the war on the family estate working in isolation on radiative transfer.

In conclusion I am fully in agreement with László Szabados on 'the usefulness of postcards as tools for communicating astronomy with the public'.[23] In this paper I have sought to demonstrate how to interrogate such postcards to uncover astronomical history and heritage, and in particular to create vividly the backgrounds and social contexts of its participants.

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I am indebted to my colleague emeritus Professor Leigh H. Bailey of the University of Vienna for translating the message on the recto and for his forensic work on identifying the addressee. Thanks also to Jacqueline Mitton for much encouragement and general support throughout the preparation this paper, and for her many editorial contributions to the final draft.

References and notes

1. Szabados, László, 'The use of picture postcards in disseminating astronomy', *Communicating Astronomy with the Public,* 25 (2019), 12–14.
2. Mitton, Lavinia, *The Victorian Hospital* (Shire Publications, 2008).
3. Stevens, Norman D., *Postcards in the Library: Invaluable visual resources* (Routledge, 1996).
4. Schrire, Dani, 'Postcards of the Holy Land: kaleidoscopic heritage offered by a modern global object', *International Journal of Heritage Studies,* 29 (2023), 441–66.
5. Mayhew, Robert, 'British geography's Republic of Letters: mapping an imagined community, 1600–1800', *Journal of the History of Ideas,* 65 (2004), 251–76.

6. The Society's first secretary, Henry Oldenburg (1618–77), corresponded with an extensive network of continental colleagues for submission of papers and their participation in peer-review, a protocol that he invented.
7. The Observatory at the Cape of Good Hope dates from 1820; it was the first astronomical observatory in the southern hemisphere. Victoria's government established magnetic observatories from 1839 but initially it proved challenging to persuade foreign observatories to participate in the exchange of data and reports.

   That changed following an international conference in 1845. Thereafter geomagnetic data flowed in from Austria, Belgium, Russia, Prussia, Spain, and Sweden. In 1851 an analysis of the data from the geomagnetic network revealed a correlation between the 11-year sunspot cycle and the frequency of magnetic storms.

   This discovery could never have been made by a single observatory: it required a global network freely transmitting data by international mail. See: Mitton, Simon, *From Crust to Core: a history of deep carbon science* (Cambridge University Press, 2021), 92–95.
8. Rogan, Bjarne, 'Stamps and Postcards – Science or Play?', *Ethnologia Europaea*, 31 (2001), 37–54.
9. Pyne, Lydia, *Postcards: The Rise and Fall of the World's First Social Network* (Reaktion Books, 2021).
10. Bujakiewicz-Korońska, Renata, and Koroński, Jan, 'The life of Tadeusz Banachiewicz and his scientific activity', *Studia Historiae Scientiarum*, 15 (2016), 275–300.
11. Blobaum, Robert E., *Rewolucja: Russian Poland 1904–1907* (Cornell University Press, 1995), 44–45, 51–52, 61–65.
12. The small university town of Göttingen was the most productive centre of mathematics in history. In 1734 George II of the United Kingdom and Elector of Hanover founded the university as a research intensive centre of intellectual enquiry with freedom from close religious supervision.

    Karl Schwarzschild taught there from 1901 to 1909; he became director of the university observatory. Source: *The Conversation*, 2019 January 14.
13. Dziewulski, W., et al., 'Observations faites pendant l'Éclipse totale de Lune du 8 décembre 1927, à l'Observatoire de l'Université de Wilno', *Journal des Observateurs,* 11 (1928), 114–6.
14. NASA Astrophysics Data System, 'Zonn, W'; accessed 2024 February 26.
15. Włodzimierz Zonn took part in World War II as a second lieutenant. Initially Oflag VII-A held about a thousand Polish officers. As the war ground on, Polish officers were transferred from other camps. The prisoners organized language classes, music concerts, theatre performances, and enrichment courses.

    Camp food was basic: thin soup and potatoes. Regular food parcels from families and the Red Cross made life tolerable until the closing months of the war. The camp was liberated on 1945 April 29 by the US Army.
16. Zonn, W., 'Photometric study of two solar corona photographs', *Acta Astronomica,* 3 (1937), p. 135.
17. Zonn, W., 'On the changes within the solar corona during the eclipse of 1936 June 19', *Acta Astronomica,* 4 (1937), p. 1.
18. Iwanowska, W., and Kopal, Z., 'In Memoriam: Stefan L. Piotrowski (1910–1985)', *Astrophysics and Space Science,* 117 (1985), 1–3.
19. Mietelski, J., 'The Moon's Physical Libration from the Observations of T. Banachiewitz', *Acta Astronomica,* 18 (1968), 91–147.
20. Wikipedia, 'Solar eclipse of June 19, 1936'.

    https://en.wikipedia.org/wiki/Solar_eclipse_of_June_19,_1936
21. Mobberley, Martin, 'The BAA total solar eclipse expeditions of 1936', *Journal of the British Astronomical Association*, 126 (2016), 15–28.
22. Blobaum, op. cit. (ref. 11).
23. Szabados, op. cit. (ref. 1).

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