A pioneer of solar astronomy

WOMEN & THE RAS

Silvia Dalla and **Lyndsay Fletcher** assess the work of Annie Maunder, an outstanding observer and interpreter of observations, who argued for her innovative ideas with power and eloquence.

The butterfly diagram, first drawn in 1904 (figure 2), is one of the most powerful representations of the inner workings of the Sun. It describes the cyclic restructuring of the dynamo-driven magnetic fields, as well as the birth of strong field regions, dominating the activity of our star. It is therefore rather surprising that, as solar astronomers, we know little about its discovery and the two scientists responsible. One of them, Annie Maunder, wrote in a letter many years later: "We made this diagram in a week of evenings, one dictating and the other ruling these little lines that show the spots in any given latitude at any time in the sunspot period. Every half hour or so we exchanged the dictating and ruling according as voice or hand got tired … This diagram, as you see, has three desiccated butterflies on it; It originally for this paper had two only, but we added a third cycle when it had gone its 11–12 years complete course." For Annie and Walter Maunder, the discovery of the butterfly diagram was the culmination of decades of work on the observation, cataloguing and analysis of sunspots, which they carried out at the Royal Observatory at Greenwich and at their home.

Annie Maunder (figure 1) is being honoured this year by the RAS as one of the first women elected as Fellows (Bailey 2016). She was born Annie Scott Dill Russell in 1868 in Strabane, in what is now Northern Ireland. She had a university education, having sat the Mathematical Tripos at the University of Cambridge in 1889, but was not awarded a degree; this was not possible for women at the time. After working for a short time as a school teacher, in 1891 she accepted a paid position as "lady computer" at Greenwich, where she was assigned to work in the solar department (Brück 1994, 2009, Ogilvie 2000).

Her duties at the ROG involved taking daily solar photographs using the Dallmeyer photo-heliograph (figure 3) and analysing them, determining the position of the sunspots in heliographic coordinates and measuring their properties, such as the area. She reported to the first assistant for photographic and spectroscopic

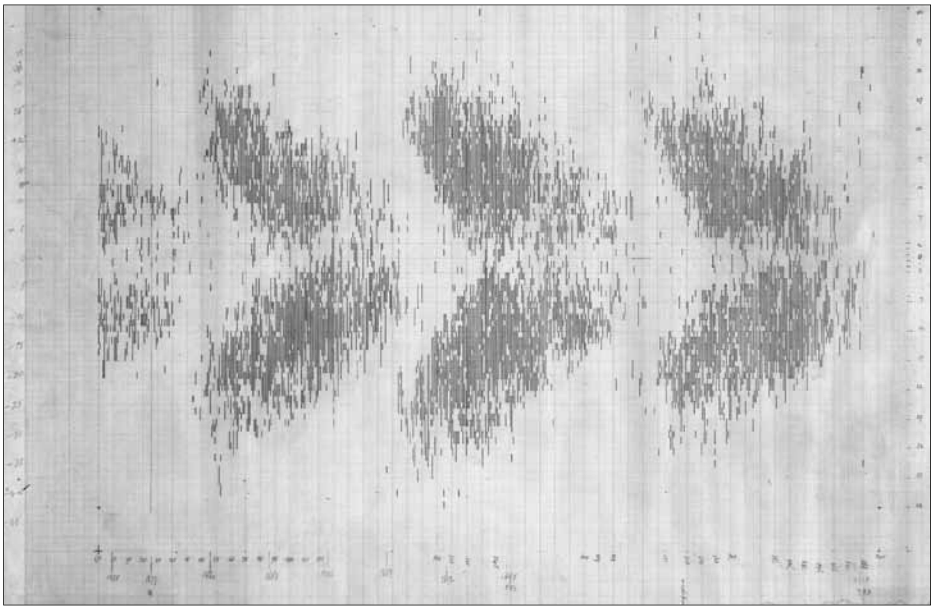
1 Annie Maunder, 1931. (© National Portrait Gallery)

observations, Edward Walter Maunder, with whom she developed a close working collaboration and friendship. In 1892, together with Elizabeth Brown and Alice Everett, she was put forward for Fellowship of the RAS, but the secret ballot did not reach the required number of votes in their favour. Around the same time, she became involved in the activities of the British Astronomical Association, which she supported enthusiastically for most of her career. She planned the structure of its *Journal* and was its first editor from 1894–1896, a task that she resumed later, between 1917 and 1930. In 1895, she and Walter Maunder married and, as was required for women by the rules of the civil service at the time, she resigned from her post as lady computer. This did not affect her interest in science and participation in solar physics research, which she continued over the following years at a high pace.

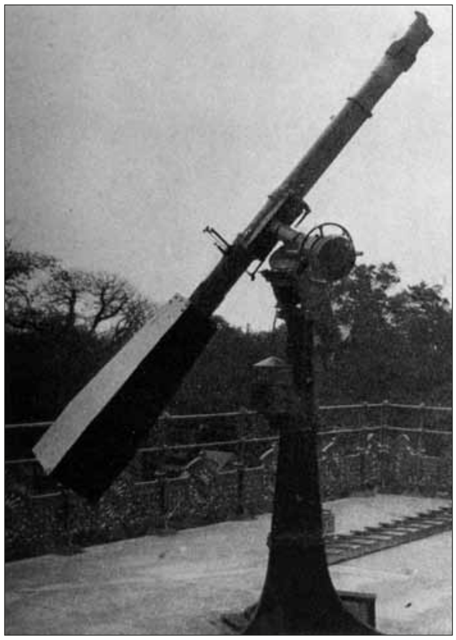
"She married and, as required by civil service rules, resigned from her post"

Eclipse expeditions

In 1896, she joined the BAA eclipse expedition in Norway, the first of five expeditions in which she took part. For the eclipse in 1898 in India, she designed and operated her own equipment and achieved spectacular results, capturing "the longest ray",



2 The Maunders' original butterfly diagram, showing the latitude at which sunspots are located over time. On 21 May 1940, Annie mailed it from London to her friend Stephen Ionides in the US, to save it from possible destruction during the Blitz. It was then given on indefinite loan to Walter Orr Roberts of Harvard College Observatory (renamed the High Altitude Observatory in 1946 and now part of NCAR in Boulder, Colorado), where it is on display. (Bogdan 2000)



3 The Dallmeyer photo-heliograph used to take daily solar images at the Royal Observatory Greenwich. It was one of five photo-heliographs originally ordered by the ROG for British expeditions to view the transit of Venus in 1874. (EW Maunder)

the longest coronal streamer ever imaged at the time (figure 4). Maunder wrote in one of her letters: "There were 4 principal coronal streamers; their lengths were 3, 4, 4.5, and 6 diameters of the Sun, respectively. Indeed under suitable illumination, we could trace the longest to a much greater distance still, and of course we do not know how much it was foreshortened." Maunder's camera, which she had designed with a large field-of-view for photography of the Milky Way, had good image quality right to the edge of the image, making it possible to examine the sky for signs of the faint and distant corona. Her interpretation of "the longest ray" was prescient; she associated the structure with a long-lived region of solar activity, and proposed that each particle in the structure was "(keeping) the direction and motion which it had when it left the Sun" so that the rays "remain as spirals behind (the Sun) as he turns continually on his axis" (Maunder & Maunder 1908). This description is a good qualitative picture of the now accepted Parker Spiral structure of the solar wind.

"I am working on sunspot groups – they have the most weird idiosyncrasies"

Another example of Maunder's abilities as an observer is her image of the corona during the 1901 solar eclipse in Mauritius (figure 5) showing what she described as "plume"-like rays, terminology we still use today. As was the case for her "longest ray" image, this photograph was the result of her meticulous planning prior to the trip. It was included in the official published records of the expedition (Brück 2009).

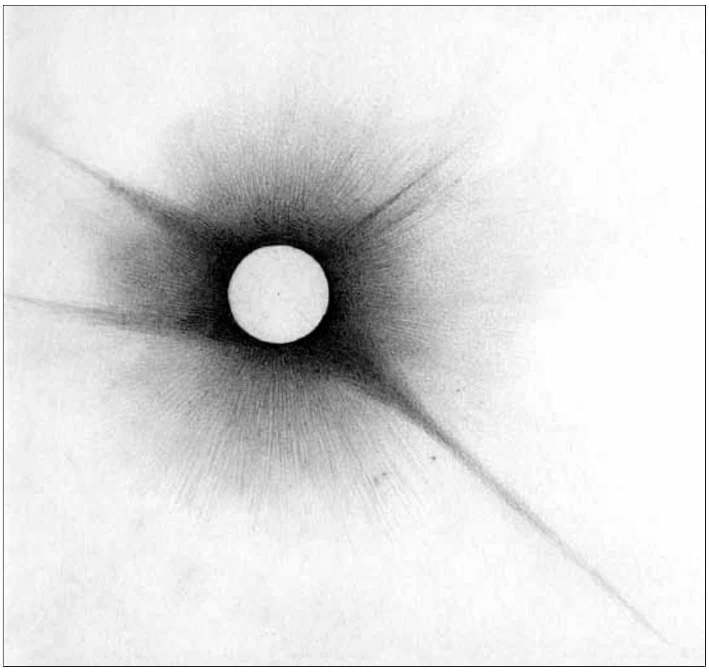
Researcher and communicator

Annie Maunder, described by Walter as his "helper in all things", was a co-author on some of her husband's papers, though not on the butterfly diagram paper despite her clear input to its production. In 1907, she published, as sole author, an analysis of the formidable sunspot dataset that had been gathered at the ROG, covering 1889–1901 (Maunder 1907). This very dense publication contains 19 tables of results summarizing the patterns shown by sunspot numbers, areas and lifetimes over the 13-year period, an analysis that must have been a monumental task. Its main results concern the detection of several east–west asymmetries in sunspot parameters, as viewed by an Earth observer, for which she could find no explanation. She states in her paper that the observations "must be laid to the account of some influence exercised by the Earth", though she is careful to describe this as "an apparent influence". She acknowledges the results to be completely unexpected and such an influence to be implausible, but it is the direction that the data leads her in as a scientist, and she honestly admits that "I have no speculations to offer as to the nature of this terrestrial influence upon the solar spot groups".

As solar physicists we became interested in a specific asymmetry presented in the paper, namely the asymmetry in the location at which new, young sunspots are observed to emerge on the solar disc. This observation, reported in table VIII of Maunder's paper, was controversial when first presented during an RAS meeting by Walter Maunder (women were not allowed to speak at meetings at the time), but was confirmed some years later by one of the most famous physicists of the era, Arthur Schuster. He also proposed an explanation for the asymmetric pattern as a combination of the change in sunspot visibility over the disc, the Sun's rotation and the evolution of a spot's area over time (Schuster 1911, also Minnaert 1939). Our own analysis using modern datasets confirmed the correctness of Maunder's emergence asymmetry observations (Dalla *et al.* 2008). To aid the study of large active regions that remained visible over more than one solar rotation, in 1909 Annie Maunder published a *Catalogue of Recurrent Groups of Sun Spots for the Years 1874 to 1906*, tabulating information on 624 recurrent groups.

The Maunders had already made the important connection between large solar active regions and geomagnetic activity, the cornerstone of space weather. Annie described this research in a letter to Major Molesworth in October 1904: "We have been working very hard this summer on the connection between sunspot activity and the magnetic storms. We have got I think some very interesting results out, which are however not very accordant with those of Father Sidgreaves and Father Costie. While my husband is in Ireland I am working on the behaviour of the sunspot groups themselves. They have the most weird idiosyncrasies."

In 1908, Annie and Walter published a book entitled *The Heavens and their Story*, aimed at an amateur audience and "written



4 Reproduction of Maunder's photograph showing "the longest ray", made by Mr Wesley, Secretary of the RAS, from the negative (on display at NCAR). From one of her letters: "It is the enlarged drawing of the 'longest coronal ray', which I photographed during the eclipse of 1898 January 22 in India. I took the original on a Sandall triple-coated plate which was then taken home undeveloped, and Mr Sandall himself developed it for me."

5 A photograph of the corona taken by Maunder during the 1901 solar eclipse in Mauritius. She published it in her book *The Heavens and their Story* with the caption: "Southern region of the corona of May 18, 1901, showing the polar 'plumes'."

with the hope that the reader may be drawn by it to study astronomy by himself". In the preface, Walter acknowledged that it was almost entirely the work of his wife. The book was popular and very favourably reviewed. In one of its chapters, she describes the passage of a "monster sunspot" over the solar disc in November 1882, and how a violent geomagnetic storm was recorded when the spot was about half way across the disc. In their book they also argue that the sudden onset of terrestrial magnetic storms, and the fact that they recur on the sunspot synodic rotation period of 27 days, was consistent with the Earth encountering a "ray", such as had been seen in her 1898 eclipse photographs. This they speculated was composed of electrified particles, both negative and positive, supplied by an extended area of the photosphere (Maunder & Maunder 1924). This insight far predates Allen's (1944) better-known statements on the same matter, and has much in common with our present-day understanding of the source and impact of fast solar wind streams, though it misses the influence of the more transient and irregular coronal mass ejections.

"Her work on sunspots laid the foundations for our understanding of solar activity"

The Maunders' work on sunspot observations led them to contribute to the then active discussion on the existence of canals on Mars, a topic of great excitement among the general public. Having noticed the eye's ability to detect elongated groups of small spots whereas single large spots of a larger total area go undetected, the Maunders speculated that "minute irregular markings beyond the range of distinct vision (give) the impression of straight lines when summed up together by the eye", and conducted a series of visual experiments to demonstrate this. Their paper on the experiments effectively dismisses martian canals as an optical illusion (Maunder & Maunder 1903).

The Maunder minimum

Most readers will associate the name "Maunder" with the extended period in the 17th century during which sunspots all but disappeared. Its existence was well known to astronomers, but in 1887 Spörer was the first to recognize its relevance, not long after the discovery of the solar cycle. Walter Maunder presented reports of Spörer's findings in papers published in 1890 and 1894, trying to make a case within the scientific community that the observations were highly interesting and related to important phenomena; in 1922 he wrote a longer paper that summarized all the available data (Maunder 1922). He was the first to point out the implications of a period without sunspots not only for the Sun but also for Earth (Eddy 1976). Eddy opted to refer to the phenomenon as the "Maunder Minimum" in recognition of this. Whether Annie Maunder herself contributed to the 1894 and 1922 publications is not known but it seems likely, given her close scientific partnership with her husband.

Annie Maunder was finally elected to RAS Fellowship in 1916. In 1928, her husband died but she continued her work in astronomy and with the BAA. She died in 1947. Her work on observing, analysing and synthesizing sunspot observations laid the foundations for our understanding of solar activity and the Sun–Earth connection. In recognition of the contribution to astronomy by both Annie and Walter, the Maunder impact crater on the Moon is named after them. In 2016, the RAS established the Annie Maunder medal for an outstanding contribution to outreach and public engagement in astronomy or geophysics. ●

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REFERENCES

Allen C W 1944 *Mon. Not. Roy. Astron. Soc.* **104** 13

Bailey M 2016 *Astron. & Geophys.* **57** 1.19

Bogdan T 2000 *On the Disposition of Maunders' Original Butterfly Diagram* AAS 196th Meeting, June 2000

Brück M 1994 *Irish Astr. J.* **21** 281

Brück M 2009 *Women in Early British and Irish Astronomy: Stars and Satellites* (Springer)

Dalla S et al. 2008 *Astron. & Astrophys.* **479** L1

Eddy J A 1976 *Science* **192** 4245

Maunder A S D 1907 *Mon. Not. Roy. Astron. Soc.* **67** 451

Maunder E W 1922 *J. Brit. Astron. Assoc.* **32** 140

Maunder E W & Maunder A S D 1903 *J. Brit. Astron. Assoc.* **13** 344

Maunder E W & Maunder A S D 1908 *The Heavens and their Story* (R Culley, London) available at https://archive.org/details/heavenstheirstor00maunrich

Maunder E W & Maunder A S D 1924 *Mon. Not. Roy. Astron. Soc.* **84** 610

Minnaert M 1939 *Astron. Nachr.* **269** 48

Ogilvie M B 2000 *Brit. J. Hist. Sci.* **33** 67

Schuster A 1911 *Proc. Roy. Soc. London A* **85** 309