

A WOMAN'S PLACE IS IN THE DOME
LUNAR SOCIETY BOULTON & WATT LECTURE 18 SEPTEMBER 2010

This talk is about some remarkable individuals who've contributed to our understanding of the universe. Their achievements are specially notable because they were - or are - all female. It's still the case that women astronomers are in the minority. Although the numbers vary considerably from country to country, typically, between 10 and 20 per cent are female. But 300 years ago, female astronomers were virtually unheard of. So my aim is show how women have fought for their 'place in the dome' over the last three centuries.

A hundred years ago, Bruno Burgel, who was a kind of Patrick Moore of his day in Germany, took the unusual step of including a chapter on Women as Astronomers in his popular book 'Astronomy for All'. He pointed out the social attitudes that held women back - the poor opinion even great and learned men had of studious women - not to mention the lack of educational opportunities. All the same, Burgel patronisingly repeated the prevailing attitude - that women have their uses in astronomy but are more suited to the tedious, routine aspects. But the reality was that women who were keen to work in astronomy took the lowly jobs because they had no alternative. And to say as he did that women in 1908 had every possible encouragement held out to them was an exaggeration. For instance, the Royal Astronomical Society did not admit women as Fellows until 1916 and a woman who did get a paid professional job usually had to give it up if she got married. Women were studying at university but were not allowed to take degrees. Nevertheless, by the turn of the 20th century, the determined ladies of science were beginning to push hard at the barriers in their path.

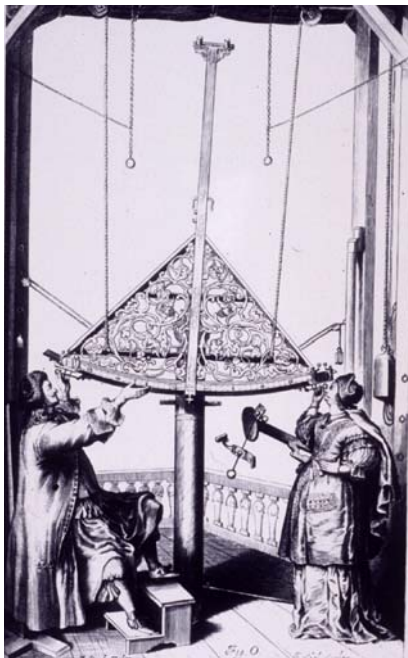
Over the last few years, much more has come to light about the unsung astronomical heroines of the last few centuries. In fact, there are so many stories to tell, it's not possible to mention all the women who deserve recognition. This is a personal choice, and we start in the 17th century.

ELIZABETHA KOOPMAN HEVELIUS (1647-93)

Elisabetha Koopman was very unusual, being well educated for a woman at that time. She could write Latin and she did mathematical calculations. She was the daughter of a rich merchant in Danzig, then in Poland. As a child she was fascinated by astronomy. Luckily for her, another

resident of Danzig was Johannes Hevelius. He was a wealthy brewer but also an internationally famous astronomer. He had built the best observatory in the world around a complex of three houses in the city and the young Elisabetha went to see the great man.

Shortly after Johannes first wife died in 1662, Elisabetha went to see him again. She was still only 15 and he was 36 years older than her. But the next year they were married and she joined him in his astronomical work. Together they began a major project, making observations for a new star catalogue. Elisabetha is one of the earliest woman astronomers of whom any records survive and the first of whom we have contemporary pictures showing her observing the heavens. An engraving from a book published by Hevelius describing his observatory shows the pair of them measuring star positions with a sextant.



Johannes and Elisabetha Hevelius

After Johannes died in 1687, Elisabetha finished preparing their unfinished joint work for publication. The three volumes included the star catalogue and constellation charts. They introduced 11 new constellations, seven of which astronomers still use, including Sextans, the Sextant, to commemorate the instrument they used. There is no doubt that Elisabetha herself was responsible for much of the contents, though the books were attributed to her famous husband.

CAROLINE HERSCHEL (1750–1848)

Female astronomers were so scarce in this period we now move forward a whole century.

Caroline Herschel is probably the most well-known of early women astronomers. She was the younger sister of William Herschel, who shot to fame after discovering the planet Uranus in 1781. Caroline came to England in 1772, 15 years after William arrived from Hanover. He was still working mainly as a musician and the idea was for his sister to develop a career as a singer. But after the discovery of Uranus, William was awarded a pension by the king and devoted himself to astronomy. Caroline too switched from music to helping William with his astronomy.



Caroline Herschel

Matthew Boulton and James Watt, the prominent members of the original Lunar Society after whom this lecture is named, knew William and Caroline Herschel well. Boulton in particular took a keen interest in astronomy.

William was a very skilled telescope-maker as well as a great observer. He made Caroline her own telescope, which she began to use in 1782 to search for comets and nebulae when she could get time to herself. It was when William was away that she devoted long hours to her own observations and increasing her own knowledge of the sky. So it was that in 1786, when William was absent, delivering a telescope, she discovered her first comet. This resulted in public recognition, and a modest pension in her own right as 'assistant to the court astronomer'. In total Caroline discovered eight comets between 1786

and 1797. In the following years she worked on an important star cataloguing task. The results of this were published by the Royal Society. By now Caroline's own achievements were being recognised and her status as an astronomer increased.

After William died in 1822 she returned to live in Hanover and would stay there until she died at the age of 98. But she carried on with astronomical work, making a catalogue from William's observations of nebulae to assist his son, John, who also became a distinguished astronomer. In 1828 the Royal Astronomical Society presented her with its Gold Medal for this work - no woman would be awarded it again until 1996. In 1835 she was elected to honorary membership of the Royal Astronomical Society and in 1846 at the age of 96, she was awarded the Gold Medal for Science by the King of Prussia.

MARY SOMERVILLE (1780–1872)

When Caroline Herschel was made an honorary member of the Royal Astronomical Society in 1835, honorary membership was also given to Mary Somerville. She is regarded as one of the greatest women scientists of the 19th century. Somerville College in Oxford, founded as a women's college in 1879 (after her death), was named in her honour and an early portrait of her adorns its dining hall.



Mary Somerville

Mary was born into a well-to-do Scottish family and brought up in this house in Burntisland. In her recollections, she records how she studied her brother's maths books in bed by the light of a candle, trying not to get caught, because she did not have the same access to formal education, other than in the things thought appropriate for a young lady. Eventually, she got help from her brother's tutor and read all she could to increase her knowledge of mathematics.

She married at 24 and within three years was the mother of two sons and a widow. However, widowhood left Mary freer to continue her studies and, at 32, she married her cousin William Somerville, who was her devoted admirer and supporter.

Though her abilities were apparent to her circle of well-to-do friends, it was her book, 'Mechanism of the Heavens', published in 1831 when she was turned 50, that first drew real attention to her. This was a translation and explanation of a landmark work on celestial mechanics by the great French mathematician Laplace, which was widely regarded in Britain as abominably difficult to understand. Mary's version revolutionised the teaching of mathematics in Britain and was used as a basic text in advanced astronomy for the rest of the century.

But her wider fame came with her 1834 book 'On the Connexion of the Physical Sciences' a more popular but still quite serious work. She dedicated it to the Queen and was rewarded with a government pension of £300 a year. The book went into 10 editions over more than 30 years.

Mary Somerville became famous as a scientist in her own right who was not working with a male relative. In fact the term 'scientist' was invented and first used to describe her. As well as being a gifted mathematician and communicator, she was charming, multi-talented - and socially accepted. She showed that women could be both brainy and feminine.

MARIA MITCHELL (1818-89)

The story now takes us across the Atlantic and to the first female astronomer in the United States, Maria Mitchell. Maria was born into a devout Quaker family in Nantucket, when the area was the centre of a whaling industry. Her father William counted practical astronomy among his numerous occupations and they had a rooftop observatory. Maria assisted him and from a young age spent many nights at the telescope learning basic

observational skills. At age 18 she was offered a prestigious position in a newly established library. There she had the time and the access to books she needed to improve her education generally, but especially to learn languages and advanced mathematics.

Maria was propelled to nationwide fame when she discovered a comet in 1847, at the age of 28. At this time, astronomy was in its infancy in America. The first organised observatory in the country with a telescope of any size had been open in Cincinnati for only two years. Twenty years earlier, the King of Denmark had offered a medal for the discovery of a telescopic comet but it had remained unawarded. William Mitchell's friends at Harvard College pressed Maria's claim, seeing it as a way of bringing prestige to America as well as to Maria herself. Though modest and retiring, Maria found herself a celebrity - one of the most well-known women in America. She was asked to join a small group of mathematicians, as the human 'computer of Venus', calculating the tables for the American Ephemeris and Nautical Almanac, to be published each year. No other woman in America was being paid to do astronomical work.

In 1861, Vassar College for women was founded in New York state. Mitchell was invited to become the first Professor of Astronomy, though not without the opposition of some trustees who could not stomach appointing a woman. The College commissioned a 12-inch refracting telescope and Maria, with her widowed father William, lived in the observatory building.



Maria Mitchell (seated) in the dome at Vassar College

Maria's place was truly 'in the dome'. Her students could come and go at any time of day or night without any impropriety, her father acting as chaperone. A contemporary writer recorded, 'Men are employed at the observatory only for heavy lifting, all the intellectual work being accomplished by Miss Mitchell and her students.'

She was famous for her annual 'dome parties', which one attendee described as follows: 'When all have arrived, breakfast is announced, and the company form in a procession. Two large baize doors then swing open, and the party, mounting a short flight of stairs, find themselves in the dome itself, with the great equatorial telescope overhead, pointing to the sky. Here the repast is served, upon tables arranged in a circle around the walls, a rosebud and a tiny photograph of the dome being laid at each plate.'

Maria is not noted for any significant advance in astronomical research, but her legacy was far-reaching for astronomy and education. From when she was young, Maria had been an avid reader of the stories and writings of the English novelist Maria Edgeworth. Edgeworth was the daughter of one of the original Lunar

Men, Richard Lovell Edgeworth. Father and daughter together had produced a book in 1798 called *Practical Education*. Critical of how women were typically educated, they advocated hands-on learning and the study of subjects in real depth. This was the philosophy adopted by Maria Mitchell and a succession of women educated at Vassar College became torch-bearers for the cause of women in astronomy.

MARY WATSON WHITNEY (1847–1921)

Mary Watson Whitney was one of Maria's first group of six astronomy students, known as 'the hexagon'. She was a talented mathematician but, unlike her brother she could not enrol at Harvard, which did not admit women. Later though, she was invited as a guest of a professor to attend classes in advanced mathematics at Harvard. Despite her exceptional ability, as a woman she did not get formal employment in astronomy except at Vassar College. One of Whitney's students wrote, 'She could not help feeling resentful, not at her fellow students, who were not to blame, but at the prejudice existing against the progress of women'.



Mary Whitney

In 1887, Whitney was invited to do research at Harvard observatory but she gave this up two years later when asked if she would to take the place of the frail and ailing Maria Mitchell as Director of the Observatory at Vassar. She spent many hours observing with the 12-inch telescope there to perfect her technique.

Whitney felt strongly about advancing both astronomy and the rights of women and set out to show that women could undertake serious scientific research.

CAROLINE FURNESS (1869–1936)

When Mary Whitney needed an assistant she used her own money to pay her talented former student, Caroline Furness. As a student, Furness had written to her sister, 'I shall devote myself entirely to Mathematics and Science, and when I develop into a second Mary Somerville or Maria Mitchell, then you will be proud of me. I like the mathematics course and find that Astronomy is just exactly what I want; everything in it is just as easy and clear to me as anything I ever studied.' And to her parents she wrote, 'I only want to prepare myself for the highest place—just as any young man might... I want to prepare myself to live a useful and happy life without marriage, and then, if the right one comes along, well and good, I shall take him, but I shall not be obliged to take a man just for the sake of a home... If I were your son instead of your daughter, you would fully approve of my ambition.'



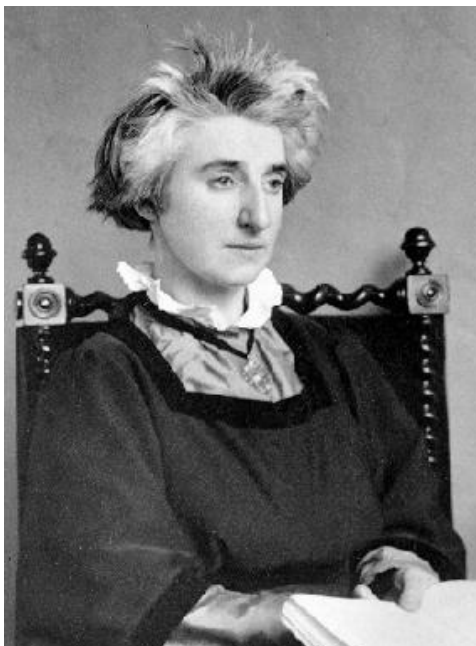
Caroline Furness

Furness became Whitney's assistant in 1894 at the age of 25 and was appointed instructor in mathematics the following year. She began to travel to New York weekly to discuss research methods with a professor at Columbia University then became his graduate student, the first woman to be allowed to study in the faculty of science

and astronomy there. She was awarded a PhD in 1900. When Whitney retired in 1915, Caroline took over her role. She was an acknowledged expert on variable stars and her book on the subject became a standard work.

MARGARET HUGGINS (1848–1915) and AGNES CLERKE (1842–1907) While Mitchell and Whitney were furthering the cause of women astronomers in the USA, two Irish women were also making an impact. One of them was Margaret Lindsay Huggins.

Margaret was born in Dublin and became interested in astronomy as a child. She was fascinated by astronomical spectroscopy, which was being pioneered by an English astronomer named William Huggins. Huggins was a wealthy man who built himself an observatory near London in 1856 and devoted himself to astronomy. His many important discoveries included that nebulae such as the Orion Nebula, are made of gas. Some of his instruments were made by firm in Dublin, and it was through that connection that he first met Margaret. They were married in 1875 when he was 51 and she 27. It was a highly productive astronomical partnership.



Margaret Huggins

Margaret was already a skilled photographer when she married. Together the Hugginses pioneered practical photography of astronomical spectra and published papers jointly. These pages from Margaret's notebooks record the

results of photographing the spectra of the star Sirius and the planet Venus in 1876 and a design for a spectrograph. When William was knighted in 1897, the citation specifically referred to 'the collaboration of his gifted wife'.

Margaret's friend, Agnes Mary Clerke made her name as an outstanding writer and historian with an immense breadth of knowledge about astronomy. She earned high praise from many prominent astronomers of the day and her books are still sought after. Membership of the Royal Astronomical Society, however, remained closed to these distinguished women, though finally, in 1903, both Agnes Clerke and Margaret Huggins were made honorary members.



Agnes Clerke

ELIZABETH BROWN (1830–99) AND THE BRITISH ASTRONOMICAL ASSOCIATION

The Royal Astronomical Society's refusal to admit women was one of the reasons the call went out in 1890 for a new astronomical society to be formed. The most prominent voice was that of Elizabeth Brown, Director of the Solar Section of the Liverpool Astronomical Society.



Elizabeth Brown

In that capacity she knew Walter Maunder, who from 1881 had been in charge of the solar programme at the Royal Observatory. Maunder was sympathetic to the cause of women astronomers and had unsuccessfully lobbied the RAS to admit women since being elected a Fellow himself in 1875. Brown urged him to start a new national society, and would not take 'no' for an answer.

The new British Astronomical Association declared itself 'open to ladies as well as gentlemen'. Both Margaret Huggins and Agnes Clerke were members of the first Council. Elizabeth Brown directed the Solar Section vigorously for 9 years until her death. She went on several eclipse expeditions and appealed to other women to come forward as observers.

ANNIE MAUNDER (1868–1947)

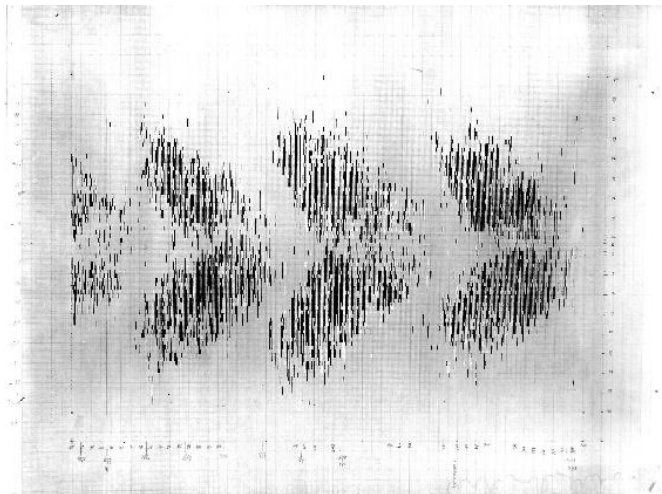
Walter Maunder's wife, Annie Russell, was another prominent solar astronomer. She studied mathematics at Girton College, Cambridge. Despite ranking at the top of her class upon graduation in 1889, as a woman she was not awarded a formal degree. In 1891 she was hired by the Astronomer Royal as a 'human calculator' and assistant to Walter Maunder at the Royal Observatory. Maunder noticed Annie's exceptional abilities, and she was soon working as his fully-fledged collaborator. On 18 December 1895 she married Walter but then had to resign her job. She went on eclipse expeditions, designed a camera for

photographing the solar corona and investigated the period in the seventeenth century, now known as the Maunder Minimum, when there were hardly any sunspots for 70 years.



Annie Maunder

Together, Annie and Walter constructed the first 'Maunder diagram' or 'butterfly diagram'. It showed how sunspots appear nearer to the Sun's equator as the Sun's 11-year cycle of activity progresses. Annie records the impact this diagram had when first presented to the Royal Astronomical Society. The original survives, now in an archive in the USA where it was sent for safe-keeping during World War 2. Up-to-date versions can be found in countless astronomy books.



The Maunder's original 'butterfly' sunspot diagram

In 1916 Annie Maunder became one of the first women elected to the Royal Astronomical Society.

THE WOMEN OF HARVARD COLLEGE OBSERVATORY

In the late 19th and early 20th centuries, the place that took on the most women to work in astronomy was Harvard College Observatory in the USA. Edward Charles Pickering was appointed Director in 1876 and started to employ women for copying, computing and tabulating. He had six on his staff in the early 1880s. For a huge star cataloguing project, he needed more hands and could afford to pay for at least some of them. Critics say the women were just cheap labour and were not allowed to develop their own research interests. However, by the standards of the day, Pickering was keen to promote opportunities for women and during his directorship took on nearly 40 as volunteers or in paid positions. People jokingly referred to 'Pickering's harem'!



William Pickering and his female staff at Harvard College Observatory, c. 1913

Several of Pickering's female staff stand out for their individual contributions, but I will mention just two. The first is Henrietta Swan Leavitt (1868–1921). She started work as a volunteer in 1895 and got a permanent position in 1902, which she kept until her death. Measuring the brightness of stars on photographs, she discovered around half of all the variable stars known at the time. Her most significant discovery was a relationship between the periods of variation and the luminosity of a particular class of variables, known as Cepheids. This discovery was profoundly important because it opened up a way of measuring the distances of stars and galaxies for the first time.



Henrietta Leavitt

Pickering has been criticised for not allowing Leavitt to pursue more original research on her discovery but, in his defence, he saw the mission of the Observatory as being to provide astronomers with extensive amounts of high-quality data, and that was what Leavitt was employed to do.

The other I will mention from the many who worked for Pickering at Harvard is Annie Jump Cannon (1863–1941). After a college education she started work at Harvard Observatory in 1896. Partially deaf, she had a great power of concentration and a good memory. She developed the system of classifying the spectra of stars - like these - still used by astronomers today. Working by eye, and using a magnifying glass to study glass photographic plates, she classified the spectra of 350,000 stars in her lifetime.



Annie Jump Cannon

Cannon achieved international fame. She was the first woman to receive an honorary doctorate from Oxford University and in 1938, she was finally made a professor

by Harvard. When she died in 1941 she was described as 'the world's most notable woman astronomer'.

When Cecilia Payne (1900–79) arrived at Harvard in 1923, it was not as an assistant but to pursue research for a PhD. She'd graduated from Newnham College Cambridge, but was advised she'd have better opportunities for advanced study in the USA.



Cecilia Payne-Gaposchkin

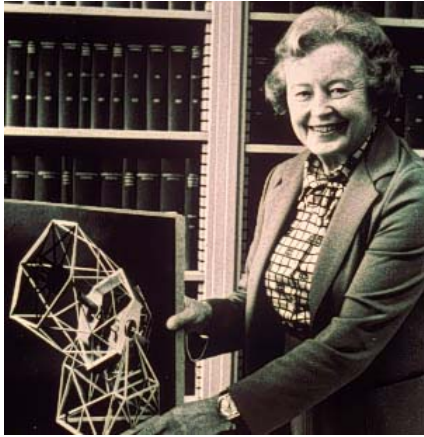
At Harvard, she was given Henrietta Leavitt's old desk. In her work for her PhD, Payne discovered for the first time that the Sun - and other stars - consist overwhelmingly of hydrogen and helium, with all the other elements making up just a small fraction. The result was so surprising and fundamental that she and many eminent astronomers could not believe it at first. It was a truly remarkable achievement.

Despite her ability, she was unable to get a job with any status. She married (changing her name to Payne-Gaposchkin) and continued to work at Harvard on routine programmes for many years. She did however receive numerous awards and honours for her work. In 1956 she was finally made a full professor and became Chair of Harvard's astronomy department - the first woman to hold such a position open to both men and women.

PROGRESS SINCE THE 1950S

It has taken a long time to break down the barriers standing in the way of women who wanted to be astronomers. In the 1950s, the British-born astronomer Margaret Burbidge (b. 1919) only gained access to the telescopes in the USA she needed for her research by having her husband apply to use them, then accompanying him as his assistant! The couple also fell foul of rules that said that husband and wife could not be appointed to the same department. Not surprising then that she has

fought all her life to end discrimination against women in astronomy.



Margaret Burbidge

Burbidge gained widespread respect for her original research a time when successful women astronomers were a rarity. She has received many honours, is one of only four women to be awarded the Gold Medal of the Royal Astronomical Society, and was the first female President of the American Astronomical Society, elected in 1976.

Since then, the American Astronomical Society has had five further female Presidents. Maria Mitchell would be proud of the fact that the current President, Debra Elmegreen, is her latest successor as Professor of Astronomy at Vassar College.

Lagging behind, the Royal Astronomical Society has had only three, the first being elected in 1994. The most well-known among them is Dame Jocelyn Bell-Burnell. As a research student at Cambridge in the 1960s, Bell-Burnell played a crucial role in the discovery pulsars. She has received many honours in recognition of achievements, though famously was not included in the Nobel Prize awarded to her supervisor and head of department.



Jocelyn Bell-Burnell

More gifted women astronomers continued to make an impact throughout the 20th century. Carolyn Shoemaker, for example, has been a record-breaking discoverer of comets and asteroids, while Vera Rubin's work on how galaxies rotate led directly to the discovery of dark matter in the universe. Some have been appointed to the most prestigious and powerful positions in astronomy. Nancy Roman became Chief of NASA's astronomy programs. Wendy Freedman was named Director of the Carnegie Observatories in 2003.

One of the final hurdles fell in 2006, when Catherine Cesarsky, for 8 years Director General of one of the world's largest most modern observatories, the European Southern Observatory, became the first women President of the International Astronomical Union.



Catherine Cesarsky at the European Southern Observatory

Women have had to fight for their 'place in the dome' but now, in the 21st century, perhaps we can say they have achieved it. At last women can aspire to rewarding careers in astronomy on an equal basis with men.