

WOMEN'S HISTORY IN ASTRONOMY OR FEMININE HISTORY OF ASTRONOMY: MUCH UNKNOWN CONTRIBUTIONS

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Abstract. Historically, women have had very little place in science and it is sad to see that nowadays things have not improved much. Recent studies confirm that stereotypes die hard: according to an international study in 2015 by the L'Oréal Foundation and Opinion Way (with 6035 respondents), 67% of Europeans begin their answer to the question "How would you describe a scientist?", first by: "He is a man". And this frightening proportion: for 89% of them, women would be good at everything except science!... The prejudices are really tenacious because, there are always been women scientists for a very long time but society has not kept the memory of them and their work had often been attributed to men. We would like to remind or put the light on some of these women astronomer who worked in astronomy since ancient times.

A way to give back to Cleopatra what belongs to Cleopatra!

Keywords: women in science, astronomy, gender equality

1 Introduction

Astronomy is one of the oldest science and it's quite easy to find a long list of famous astronomers, male astronomers. But it's really rare to find such lists including famous female astronomers. Yet, over the centuries, they have been numerous. Who remembers or has ever heard the name of Aglaonice of Thessaly, Sophie Brahé, Nicole-Reine Lepaute or Annie Cannon? There are many many other women but society has simply forgotten them, ignored them although their contributions are outstanding. It's time to give them the place and notoriety they should always have had. Even today, women in science do not benefit in many aspects from the same conditions as their male colleagues. The Femmes et Astro commission of SFA2 works to promote gender equality into the french astronomers community and decided to organise a session dedicated to gender inequalities in astronomy. In this perspective, it's important first of all to rise awareness that the problem is a long-standing issue and is still present nowadays. We would like to improve the visibility of women astronomers whose work has marked the history of astronomy. Of course, we are far to be exhaustive and we present here only very few of these women astronomers who significantly contributed to the progress of astronomy over the centuries. This presentation has been made on behalf of the SF2A 'Femmes et Astro' commission.

2 Some historical women figures in astronomy

We must keep in mind that women had to overcome a lot of obstacles if they wanted to study and do science. At a time when only boys could study, the access to education was reserved for a very small number of privileged women, who were educated thanks to the open-mindedness and the goodwill of a father, a husband or a brother. Even then, special conditions were needed to keep track of their work. There is therefore in this (very incomplete) list an important bias on the major contributions of a lucky few women, often with exceptional intelligence, whereas there probably existed a much larger number of anonymous "little hands".

If we try to find their marks, we realise that the list of women scientists is long. With the overview, very far from being exhaustive, limited to the field of astronomy, we realize that women have widely participated to the progress of knowledge.

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2.1 Antiquity and the Middle-Ages

Living in the 23rd century BC in the Sumerian city of Ur, **Enheduanna** was *High Priestess of the Moon Goddess of the city*. From her temple, she performed astronomical observations of the moon's phases and planets positions, one of the activities falling in her duty. Daughter of the King Sargon I of Akkad, she is probably the oldest author whose name and a significant part of her work had come down to us (37 cuneiform tablets found, mainly poems). So, she is perhaps the oldest female writer known today.

Jumping forward in time, we meet **Aglaonike of Thessaly**, living in the 2nd century BC in the misogynistic Greek society. Nonetheless her father allowed her to study Babylonian astronomy and she can be considered as the first women astronomer. According to the testimony of Plutarch, she "knew the cause of complete eclipses of the Moon and predicted the moment when it happens to the Moon to enter the shadow of the Earth". Thus, she had understood the phenomenon of eclipses, knew the Saros cycle but these skills led her to be regarded as a witch because of her apparent control of the phenomena... This has been too often the burden of many female scientists in the past, considered as dangerous by most of the others !

Hypatia of Alexandria (350 or 370 - 415) was a brilliant mathematician and philosopher, one of the most famous of the past. Aware of the intelligence of his daughter, her father Theon of Alexandria educated her in mathematics and philosophy. Highly educated, very intelligent and wise, Hypatia succeeded her father at the head of the Academy where a large number of people came from far away to attend her classes. Convinced of the heliocentric system, pagan, defending the separation between science and religion, she displeased to many religious persons and was savagely murdered by Christian's fanatic led by the bishop Cyril in 415. Hypatia's death marks the beginning of the decline of science which lasts during the medieval period. Access to science was even more difficult for women; only convents offered them protective and cultural environment allowing them to study scientific writings and to use their skills, like Hildegard of Bingen could.

2.2 Domestic helpers and calculators of the Renaissance

We have to wait until the 16th century to find a breakthrough (for an improvement), which begins with **Sophia Brahe** (1559-1643, Denmark), unknown sister of the well-known astronomer Tycho Brahe. Self-educated, Sophie Brahe showed such a talent that her brother Tycho eventually considered her as his assistant. She was the first of a long list of domestic helpers. None of these talented and devoted women would ever be paid for their work... Sophia Brahe assisted her older brother with making astronomical measurements. The many results attributed to Tycho Brahe were in fact the result of a joint effort with Sophia. In particular, the precision of their observations of Mars' position allowed Kepler to find the three laws describing the orbits of planets.

At that time, women were still excluded from education and knowledge because an educated woman was still considered as dangerous for men thus impossible to marry. In these conditions, very few women have benefited from an education thanks to the good will of their father, brother or husband, and often also thanks to their widowhood. Among them, we can mention the Polish **Maria Cunitz** and **Catherina Hevelius** and the Prussian **Maria Kirch**. Those three women carried out remarkable works in collaboration with their husband and/or son but also published alone their own work (like *Urania propitia* by Maria Cunitz which had an impact at the European level).

The conditions were really difficult during this period for female scientists because they were always mocked as seen through for instance Molière's plays "*Les femmes savantes*" or "*les précieuses ridicules*". We will stop on **Jeanne Dumée** (1660-1706, Paris) who took advantage of the "salons" (gathering distinguished guests around noble clever ladies) to expose the Copernican theses that she defended with conviction. Independent and convinced, she went further in her manuscript *Entretiens sur l'opinion de Copernicus touchant à la mobilité de la Terre* by writing: "... since between the brain of a woman and that of a man there is no difference, I wish my book could give them some emulation...". She really was ahead of her time! Just like **Mary Somerville** (1780-1872, Scotland), a very brilliant mathematician, who studied without telling her parents. They married their daughter to prevent her from doing science. Widow of Mr. Greig in 1807, she finally has the possibility to pursue her intellectual interests and could study the Celestial Mechanics of Laplace, that she translated in English. By the way, Laplace told her "Only three women have understood me. It is you, Mrs Somerville, Caroline Herschel and a Mrs Greig of whom I know nothing". Besides that, she defended women's rights (we understand her!) and signed in 1868 a petition calling for women's right to vote !

Totally devoted to her brother's work, **Caroline Herschel** (1750-1848, Silesia) is the sister of the famous William Herschel. Her unknown contribution to her brother's work of is however remarkable because she helped him to build his telescopes, to polish the mirrors, to make long night observations and she discovered alone

eight comets, she doubled the number of known nebulae, she made the first attempt to represent the Milky Way. The magnitude of her work is such that she receives in 1828 the gold medal of the Royal Astronomical Society, first woman (and the only one for 170 years!) to receive this distinction.

Some others brilliant mathematician women have been called calculators. This is the case of **Emilie du Chatelet** (1706-1749, France) whose intellectual capabilities allowed her to study mathematics, physics, mechanics, chemistry and astronomy. Outstanding mathematician, she mastered analytic geometry and infinitesimal analysis which allowed her to understand Newton's *Philosophiae Naturalis Principia Mathematica*, of which she made the first translation in 1745 which is still a reference. She is unfortunately more criticised for her way of living and her friendship with Voltaire than known for the importance of her scientific works.

A few years later, **Nicole-Reine Lepaute** (1723-1788, France) was another very gifted mathematician whose contributions were remarkable: she began calculating the tables of oscillations of the pendulum for her husband, a clockmaker. This work led her to meet Lalande and Clairaut, with whom she made the tremendously difficult calculations necessary to accurately predict (to the month!) the return of Halley's comet in 1759, taking into account the influence of Jupiter and Saturn on its trajectoire. But in 1760, Lalande fell out with Clairaut who published without mentioning Lepaute's contribution his *Théorie des comètes*. Reine continued her work with Lalande calculating the ephemerides, among others, for the transit of Venus in 1761, the elements of the comet of 1762 and the annular eclipse of April 1, 1764.

2.3 The 19th century: from Harvard computers to professionals

As observing facilities improved, the data to be processed and calibrated became increasingly numerous. Women were hired to carry out these long, tedious and repetitive tasks that required patience and precision, while being paid very little. A group of women has had an immense contribution to stellar spectroscopy but they are simply called the Harvard computers or Pickering's harem. Indeed, from 1875 onwards, E. Pickering, Harvard Observatory director, hired women to process the phenomenal quantity of stellar spectra recorded by the new telescopes. He even encouraged his colleagues to do the same, writing "women are able of doing as much good routine work as men... and for the same amount of money, three to four times as many female assistants can be employed" (sic!). Paid less than a secretary, these 80 or so women processed more than 390,000 stellar spectra, but were never called astronomers, just computers.

So please, try to remember the names of at least some of them: **Williamina Fleming** the first, initially Pickering's servant, she set up a classification of stars according to the prominence of hydrogen lines based on more than 10,000 spectra; **Antonia Maury** the rebel, an astronomy graduate from Vassar College, who got angry with Pickering because she wanted her name to appear in publications. She created a system of luminosity classes based on the width of the stellar lines, a system adopted by the International Astronomical Union (IAU); **Annie Cannon** who classified 350 000 stars (!), she rearranged the Fleming's classification to adopt a sequence more logical to her: O B A F G K M, the first fundamental attempt of stars' classification based on the strength of the Balmer absorption lines. These seven spectral types are still the basis of any study of stellar physics. Her tremendous work has been of primary importance for the understanding of stellar evolution, but Harvard University, without shame, gives her a position of astronomer at the age of 75 years! We cannot omit **Cecilia Payne-Gaposchkin** who proves that spectral types are related to the temperature of stars. By a step further, she came to the conclusion that stars are composed mainly of hydrogen. But her idea went against the consensus of the time. Henry Russell dissuaded her from publishing her result which he did not believe. Five years later, Russell published an article in which he said that hydrogen is the major component of stars, just forgetting to mention that this idea was first that of Cecilia ...

The colossal work carried out by Pickering's women included that of **Henrietta Leavitt**, as exceptional as she was discreet. Undisputed expert in stellar photometry, she rigorously studied stars of the Small Magellanic Cloud and founded a new category of variable stars, the Cepheids. Her great discovery was to highlight a relationship between the period and luminosity of these variable stars and to understand what this implied. With her 'Period-luminosity relationship of Cepheids', Henrietta Leavitt has given a way to reach the depth of the universe. In 1908, she published her results in the Annals of the Astronomical Observatory of Harvard College and confirmed in 1912 that Cepheid Variables of greater intrinsic luminosity have longer periods. Using the P-L relationship, Edwin Hubble will obtain the distance of the Andromeda galaxy in 1925. When a colleague wanted to nominate her for the 1926 Nobel Prize for her discovery, she had been dead for 4 years ...

2.4 The 20th century: finally women researchers with a position

In France, **Edmée Chandon** was the first woman to have a "real" position as astronomer. She obtained a degree in mathematics in 1908, and this position in 1911 at Paris' Observatory. The second woman "astronomer" of France is Calixtina Bac who obtains a position at Lyon Observatory in 1912.

The number of women astronomers has increased steadily since then but we are still far from parity in astronomy: the International Astronomical Union counted only 18% of female astronomers in 2019. I would like to mention three of them whose remarkable careers are also indicative of the difficulties women have still faced just to work in the last century.

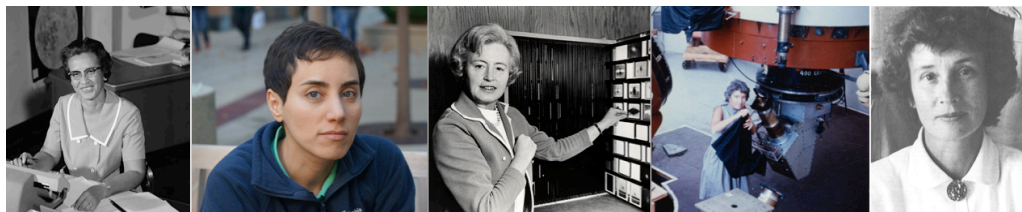


Fig. 1. Some exceptional female scientists of the 20th century: Katherine Johnson, Maryam Mirzakhani, Margaret Burbidge, Vera Rubin, Tatiana Proskouriakoff

The English **Margaret Burbidge** (1919-2020) obtained her degree in astronomy in 1939 at the University College London and because of the Second World War, she had to take charge of the UCL. But when men returned after the war, she found herself back in a position of second assistant. Margaret apply in 1946 to observe at Mount Wilson. This was refused because the observatory was forbidden to women... She had to wait until 1955 to have access to Mount Wilson and only as an "assistant" to her husband, even though she was the one making the observations! In 1957, Margaret publishes with her husband, W. Fowler and F. Hoyle an impressive article Burbidge et al. (1957), called B2FH, which demonstrates that all but the lightest elements are synthesised by nuclear reactions within stars. Margaret does not stop at this success and received many awards including the gold medal of the Royal Astronomical Society with her husband in 2005.

The American **Vera Rubin** (1928-2016), another great lady of astronomy, had the unfortunately classic fate of women scientists: she is one of those pioneers whose fame is inversely proportional to the importance of her work. She demonstrated that the galaxies seem to be heading towards an unknown point, which will be called the Great Attractor. Her article is refused. She then showed that the Universe is not homogeneous, galaxies gathering in vast clusters. Her results were ignored for twenty years before being widely confirmed. In 1964, she applied for telescope time at Mount Palomar, but women were still not allowed to make observations there... Tenacious, one year later, Vera created a small revolution by becoming the first woman to obtain the right to make observations at the observatory. With H. Ford, she studied the rotation curve of spiral galaxies and demonstrated an anomaly: far from the center of their galaxy, the stars rotate much faster than they should if gravitational force was due only to luminous matter. Their results gave a proof of the existence of the dark matter predicted by Zwicky. Throughout her life as an astronomer, Vera Rubin had to face difficult conditions because she was a woman. She often denounced *"the way girls are brought up, and it starts very early"*; she worked her life long against the unconscious mechanisms, conveyed by education and society, which lead to the persistence of gender inequalities. She was fond of reminding us that *"half of the world's neurons belong to women"*.

The Irish **Jocelyn Bell** (1943-) built during her thesis, with the help of some PhD students, the 2048 antennas radio telescope which she needed to observe quasars. Two months later, she records a strange signal that returns every 23h56 min. She had just discovered the first pulsar but her thesis director, A. Hewish, laughed at her. Finally convinced, Hewish published an article in Nature but Jocelyn is only 2nd author Hewish et al. (1968)... In 1974, the Nobel Prize was given to her thesis director alone. A very lively controversy broke out, led by Fred Hoyle and other colleagues, scandalised by the fact that the person who had made the discovery was not associated with this prestigious prize. Because she was merely a student or because she is a woman? Jocelyn Bell never complain about it but she has invested in improving the status and number of women with academic positions in physics and astronomy.

3 20th and 21st centuries: the (non) recognition and Matilda effect

We have seen that women have always contributed to the progress of astronomy, their work has led to major and even capital advances. However, their presence has been largely ignored by society and their work has received very little recognition. The problem is that it continues to be so. If we refer to the Nobel Prize, since its creation in 1901, only 57 women have been laureates (out of 958), which represents 5.9 % of all Nobel Prize winners. For physics, chemistry and medicine or physiology prize, the proportion of women is even lower as there have been 23 women awarded for 620 laureates, which is only 3.7 % of the Nobel Prize winners.

Today, it's usually recognised that several women should have received the Nobel Prize but that only their male colleagues or husbands were rewarded without associating her. This is the *Mathilda effect*, it refers to the recurrent denial or the systematic minimisation of the contribution of women scientists to research, their work being attributed to their male colleagues. The most blatant cases of unjustly ignored women scientists are: **Lise Meitner** for the discovery of nuclear fission in 1938 (her colleague Otto Hahn received alone the award for their joint work); **Nettie Maria Stevens** discovered the role of X-Y chromosomes in the determination of the sex of the embryo (the director of her laboratory received the Nobel Prize for this discovery); **Rosalind Elsie Franklin** for her discovery of the double helix structure of DNA (her colleagues Crick and Watson had access to her research without her knowledge, they received the Nobel Prize without her. The second on the structure of viruses, Klug receive the prize in 1982 but Rosalind is dead since 1958); **Jocelyn Bell Burnell** as said above her thesis' director awarded the Nobel Prize alone); **Esther Lederberg** for the replication of bacterial culture (her husband alone received the Nobel Prize!); **Daisy Dussoix** discovered the phenomenon of restriction enzymes (her thesis director received the Nobel Prize without mentioning her).

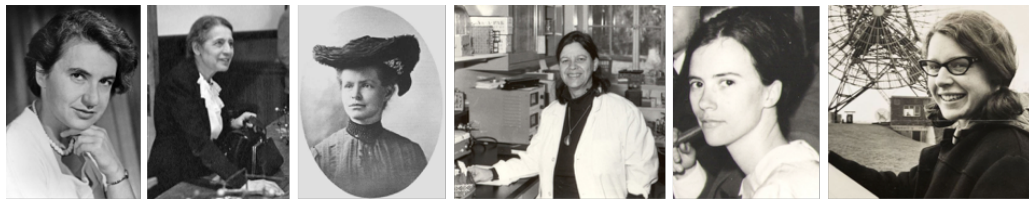


Fig. 2. "Forgotten" Nobel Prize winners: Rosalind Franklin, Lise Meitner, Netty Stevens, Esther Lederberg, Daisy Dussoix, Jocelyn Bell

Mathematicians do perhaps worse with the Fields Medal: in 83 years of existence, the Iranian **Maryam Mirzakhani** (1977-2017), winner in 2014 is the only one woman who has been awarded for 60 men, that's a very little 1.7 %... In mathematics people often think that there have been no female mathematicians in history, ignoring the work of Maria Gaetana Agnesi (1718-1799, published at the age of 30 "Analytical Institutions"), of Ada Lovelace (1815-1852, 1st algorithm to calculate Bernoulli numbers), Sofia Kovalevskaja (1850-1891, Equations of motion of the spinning top), Emmy Noether (1850-1891, Noether's theorem), Betty Holberton (1917-2001, programming the ENIAC), Karen Uhlenbeck (1942- , differential calculus, 1st woman Abel prize in 2019) and so many others...

It took the movie "Hidden figures" for people to realize that the success of the Apollo missions owes much to women, even black women in segregationist state like for example Katherine Johnson, Dorothy Vaughan or Mary Jackson.

Another example in another field? Everyone knows JF Champollion for having deciphered hieroglyphs but **Tatiana Proskouriakoff** who made the breakthrough for Maya glyphic decipherment is totally unknown. Would she remained so invisible if she had been a man? We can at least ask ourselves the question.

4 Concluding remarks and hope!

We just gave a short overview of female astronomers from Antiquity to present days and the major contributions they left. The history of women in science is a story of exclusion. Girls were excluded from schools and women were denied access to high schools and universities until very recently, all over the world. Only few exceptional women managed to go through a mountain of difficulties to become scientist but even with these conditions, society has ignored them, forgotten them. Sometimes worse, their work has been attributed to their male colleagues.

Conditions are now changing, there is a trend towards greater gender equality in many countries. We would like that the girls will henceforth get rid of gender bias and will choose science in large numbers. Society needs their talents to solve the immense challenges we face!

References

- Baudet, J. 2010, *Curieuses histoires des dames de la science*, eds. Jourdan
- Bernardi, G. 2016, *The unforgotten sisters - female astronomers and scientists before Caroline Herschel*, eds. Springer
- Burbidge, M., Burbidge, G. R., Fowler, W.A. & Hoyle, F. 1957, *Reviews of Modern Physics*, vol. 29, no 4, 547
- Hewish, A., Bell, S. J., Pilkington, J. D. H., Scott, P. F., Collins, R. A. 1968, *Nature* 217 (5130), 709
- Nazé, Y. 2008, *L'astronomie au féminin*, eds. Vuibert
- Vauglin, I. 2021, *Mémoires de l'Académie des Sciences, Belles-Lettres et Arts de Lyon*, vol. 20, 125