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WOMEN ASTRONOMERS THROUGH HISTORY

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Abstract. We review the contributions of women to astronomy starting from the antique Greece and Alexandria, and mention briefly some works of nun-scientists in the Middle Ages, which are of interest only for keeping alive the spirit of inquiry during this Dark Age. We discuss in more details important contributions coming after the Scientific Revolution and Enlightenment, made by women working within their families, as assistants to their brothers or husbands. We show that by the late 19^{th} century the role of women in astronomy becomes more independent, with more women working not only as "computers" in the great observatories, but also making important discoveries that placed them in a very high position as scientists at the dawn of 20^{th} century.

1. ANTIQUITY

The history of astronomy until the last century is dominated by the great discoveries made by brilliant male scientists, such as Tycho Brahe, Galileo, Kepler, William Herschel and others. The number of women recognized as innovators is very small. Several factors worked against them, from social pressures to the lack of opportunities in the institutions and the lack of systematic scientific education. Despite all this, history records occasional bright female stars.

Scientific education for women was known to take place in the antique Greece and although there were no strict division between the scientific disciplines as today, the most famous women scientist of this time could be called astronomers.

The first of them was **Theano** (c 520 BC), wife of Pythagoras. She was his student and collaborator, and after his death she succeeded him as leader of Pythagorean Community. Known as cosmologist, with the help of their two daughters, Theano spread the philosophy of Community throughout Greece and into Egypt. It is believed that great mathematical discoveries ascribed to Pythagoras, as the decimal system, the multiplication table and the famous theorem of the sum of squares, were in fact done by his school as a whole. Unfortunately, it is not known what the women's part in this was.

The women of Plato's Academy and those of the Epicurean School made also major contribution to the advancement of sciences. However, the Aristotle's Lyceum was forbidden to women. His contempt of women, which he considered inferior to men

even in the womb ("female is nothing else than deformed male") was later adopted by the Christian church. This negatively affected the social environment in which female scientists attempted to work, and this attitude lasted almost 2000 years.

In the pre-Christian era, women enjoyed a brief flowering of science in the 4^{th} century, in Egypt. Alexandria was the city of Claudius Ptolemy, the author of famous geocentric cosmological model. In this city there were a number of women alchemists. The most influential and the best known of women scientists in Alexandria was **Hypatia**, born about 370 AD. She is the earliest women scientist whose works have been documented. She was a noted lecturer on the doctrines of Plato and Aristotle. In addition to her mathematical works, and tables for the movements of the heavenly bodies based on the Ptolemaic model, Hypatia developed several instruments, among which a plane astrolabe for measuring the positions of the stars, planets, and sun.

Her philosophical beliefs were in conflict with the views of the Christian rulers of Alexandria. She was persecuted, arrested, tortured and killed in 415 AD. There was no significant progress in astronomy, physics and mathematics in the western world for almost 1000 years after Hypatia's death.

2. MIDDLE AGES

In the Middle Ages the education was related to the church, and the first universities in Paris, Bologna, Oxford and Cambridge were aimed at the education of future monks and priests. The system that was instituted was known as the seven liberal arts, among which were the geometry and the astronomy. However, the medieval universities were closed for women. Still, there was a possibility: in convents and abbeys, monks and nuns were instructed in the rudiment of the liberal arts. For a few lucky nuns, their convent has the "mission" to study the natural world.

One of the most well known nuns-scientists was **Hildegard of Bingen** (c 1136). Her cosmological model was a strange mixture of the Ptolemaic teaching and of the "truth" revealed in her mystic dreams. Her universe contained concentric spheres, dating back to Pythagoreans, and the "terrestrial sphere" consisting of four elements (earth, air, fire and water). When she learned about Aristotle's cosmology, Hildergard abandoned her own model for the Church-sanctioned one of Aristotle. She was beatified, and her day is September 17^{th}.

Another 12^{th} century nun-scientist was the abbess **Herrad de Landsberg** (c 1160). With her nuns, she wrote a significant examination of existing secular works through the Biblical lens, *Hortus Deliciarum*. A part of this work was the calendar with moveable feast days until the year 1706.

3. POST-RENAISSANCE

New flourishing of science, and of the women's contribution, comes with Scientific Revolution and Enlightenment. New scientific method, starting with Descartes, is based on measurements and reproducibility of the obtained results. With the discovery of the microscope, and on the other hand of the telescope, micro and macro world became accessible. This is the time of Copernicus, Galileo, Kepler and Newton, their

works being printed and distributed. Still, the university were not open to women. They could work on astronomy, as the one of seven liberal arts, considering this as a hobby. This could be done at home, assisting one's brother, husband or some other male relative.

One of the first "new breed" of women astronomers was **Sofie Brahe** (c 1600), sister and assistant of the famous astronomer of this time, Tycho Brahe. It seems that her critical new observations permitted later to Kepler to establish the elliptic orbits of the planets. Sofie worked with her brother during the whole term of his tenure at Uraniburg, and later compiled her own works into an unpublished, but preserved, memoir.

In the 17^{th} and the 18^{th} century there are at lest four women with some modest contributions to astronomy. As Sofie Brahe and later Caroline Hershel, they all relied on family connections to overcome obstacles due to their gender.

The first is and the most remarkable was **Maria Cunitz** (1610-64). She was the daughter of a wealthy Silesian landowner, who had her taught medicine, mathematics, and six languages. Later in Poland she prepared astronomical tables based on Kepler's Rudolphine tables of 1627. Her work was privately published in 1650.

The best known of four is **Catherina Elisabetha Koopman** (1647-93), second wife of a Danzig amateur astronomer Johannes Hevelius. She edited some of her husband works after his death, and she is shown in engravings as a partner in his observations.

The remaining two were respectively the wife and the daughter of Gottfried Kirsch, head of the Berlin Observatory, founded in 1700. **Maria Margarethe Kirsch** (1670-1720) helped her husband with observation, and discovered herself the comet of 1702. Together with her daughter **Christine** (1696-1782) she calculated the calendars and after her husband's death helped in other observatories. When her son Christfried became an observer at Berlin in 1716, both Maria and Christine assisted him with his observations and calculations.

But the great "star" among women astronomers, born in 1750 in Hanover, w**as Caroline Herschel**, the first salaried female in the history of astronomy. In an age when women were excluded from science, she played a crucial role in the partnership with her brother, Sir William Herschel, famous astronomer whose work altered the course of the history of astronomy.

When Caroline moved to England (c 1772) with her brother, who established him as a musician in Bath, she trained and performed as a soprano singer. William Herschel, beginning as an amateur astronomer, is perhaps best known for his discovery of the planet Uranus in 1781. After that discovery, William was offered the private office of court astronomer to George III, and both of them gave up their promising musical careers to focus on astronomy.

The Herschels built the largest telescopes in existence to that time, enabling them to find an entirely new branch of astronomy - sidereal or stellar astronomy, while most astronomers were focused on the solar system. In twenty years, brother and sister would discover more that 2500 new nebulae and star clusters. Caroline also began to make independent observation of her own. In addition to the nebulae, the Herschels also catalogued 1000 double stars, and Caroline discovered eight comets credited to

her alone. In 1787 the king gave her an annual pension of 50 in her capacity as her brother's assistant. In 1798 she presented to Royal Society an Index to Flamsted's observations, together with a catalogue of 60 stars omitted from the *British Catalogue*, with a list of the errata in this publication.

She returned to Hanover after William's death in 1822 and soon completed the cataloguing of 2.500 nebulae and star clusters. In 1828 (when she was 77) the Astronomical Society awarded her its gold medal. She lived some 20 years longer and continued to receive the respect and the admiration of both scientists and the general public.

In 18^{th} century, women begin to work at the **Paris Observatory**. Among them, a woman astronomer-amateur, **Mme Lepaute** (Nicole-Reine, 1723-1788) was engaged on predicting the exact date of the return of Halley's comet in 1759. She worked day and night together with the noted astronomer Clairaut. They released their findings in September of 1757, just a few months before the first sightings of the comet. The work was published by Clairaut, who in the first instance gave full credit to the contribution of Mme Lepaute. Unfortunately, Clairaut later retracted his statements, taking all merits for himself. Nevertheless, Mme Lepaute was engaged in many other projects, especially in calculating of 1762 and 1764 eclipses. Other female collaborators were **Mme du Piery**, an amateur who became the chief investigator of the lunar astronomy, and **Marie-Jeanne de Lalande**, niece of the Jerome Lalande, director of the Observatory.

4. 19^{th} CENTURY

Among the most prominent women scientist in 19^{th} century was **Mary Fairfax Somerville** (1780-1872). This twice-married Scotswoman gained international reputation in the intervals of raising a family of six children. Mary's second marriage, to Dr. William Somerville, was a marriage of true minds. They undertook together many new studies, including what we, today, would call astrophysics. Mary studied the electromagnetic effects of the solar wind, worked with the light spectra, and worked to translate and supplement Laplace's monumental work, *Mechanique Celeste* in 1827. The resulting book, *Mechanism of Heavens*, included history of astronomy and several mathematical derivations and proofs, which did not occur in the original. Mary's book remained a standard text at Oxford and Cambridge for the rest of the century. In her next book, *On the Connection of the Physical Sciences*, conceived to increase women's understanding of the sciences, she tied together astronomy with the physical sciences. This was the first book after *Principia* to do so. Together, Mary and William Somerville were another of the great collaborative couples, after the Herschels. By the time of her death, in 1872, the sciences were becoming carriers, for men *and* women.

Maria Mitchell is probably best known for being the first women astronomer in the U. S. She was born in 1818 and her father being an astronomer she helped him as a child with some mathematical calculations. On October 1847, while she was viewing the skies from a telescope at her parents' home, she discovered a new comet, now called Comet Mitchell 1847IV. Because she was the first person to discover a

"telescopic" comet, i.e. a comet visible only through a telescope, she was awarded a gold medal from the King of Denmark. Mitchell made several contributions to the field of astronomy and an enormous contribution to the rights of women. In 1848 she was appointed the first women in the American Academy of Arts and Sciences.

Although she has never been a student at college, in 1853 Mitchell was given an honorary degree from Indiana Hanover College. She was the first woman to be awarded a college degree. And later, she was given honorary degree of Doctor of Laws by Columbia University. In 1865 she became the first women professor and managed the observatory at Vassar College. Adding to her fame, she discovered several nebulae and she was the first American astronomer to create set of photographs of the sun's surface. In 1875 the American Association for the Advancement of Women elected Mitchell for their president. After her death in 1889 the Maria Mitchell Astronomical Society was named in tribute to her memory.

At the end of 19^{th} and the beginning of 20^{th} centuries, the development of larger, better, and more accurate telescopes lead to a pile of seemingly inexhaustible data that should be processed. Many tasks that required painful and precise work (for example cataloguing stars, nebulae and other, yet undetermined space objects) began, more frequently, to fall to women "computers". In particular, this was the case at the **Harvard College Observatory**, where the director, Edward Charles Pickering, was sincerely interested in increasing opportunity for women astronomers. He assembled a team of women astronomers, Pickering's "harem", as it was later named. Although a prime task of these "computers" was cataloguing and interpretation of data obtained by other researcher, several of Harvard women astronomers made significant innovative contributions. One of them was **Williamina Fleming** (c 1881) who began the work on an empirical classification system of spectral types in stars. In the meantime, she discovered ten novae, more then three hundred variable stars, and some sixty new nebulae. Fleming's classification system was further refined by **Annie Jump Cannon** (c 1896). The most innovative contribution came from **Henrietta Swan Leavitt** (1868-1921). She discovered the relation between the period and the luminosity of classical Cepheid variable stars. This period-luminosity relation made possible measurements of distances of the stars and determination of intergalactic distances by determining the distances from the earth of stars in galaxies outside of our own. The relation between the velocity of running away of these stars from the Earth (that can be determined from the red shift) and their distance (determined by the method of Leavitt), found by Hubble, was the key for the concept of the expansion of the Universe and the theoretical base for the concept of Big Bang.

Essentially, the Observatory women worked on Pickering's projects, an in general did not have the possibility of completing their dissertation and moving on to their own positions. While Fleming and Cannon were eventually assigned position as Professors of Astronomy at Harvard (Leavitt died before the honour could be conferred to her), these positions were mainly honorary.

5. CONCLUDING REMARKS

In the beginning of 20^{th} century women astronomers in Observatories across the United States and Western Europe obtained the possibility of doing meaningful work in their chosen field. This was the start of a new era in the women's research in astronomy, as well in the science in general. However, the centuries of social conditioning, relative to the roles of men and women in the science, will take time to readjust to modern realities of women in the society and the workforce. As they do, one can expect to see the gradual increase of the impact of women scientist in the innovative research, as one can already see from several brilliant contributions of women astronomers during the 20^{th} century.

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