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WOMEN IN ASTRONOMY: A PERSISTENT BUT OVERLOOKED CONTRIBUTION TO HISTORY

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Abstract. While many renowned astronomers from history are widely recognized, only a few female astronomers among them have achieved recognition. However, women have consistently made significant contributions to the advancement of astronomical knowledge. Although their numbers were smaller due to the formidable barriers they faced, their impact is undeniable. The 'Matilda effect' has unjustly rendered these pioneering women invisible in the annals of history. In this work, we highlight some of these remarkable women, bringing their achievements out of obscurity and acknowledging their valuable contributions. By shedding light on the challenges they faced - obstacles imposed solely because of their gender- we aim to restore their rightful place in history and provide young girls with inspirational role models in astronomy.

Keywords: women astronomers, Matilda effect, gender biais in science

1 Introduction

Astronomy has a rich history spanning thousands of years, with the names of many prominent ancient astronomers well-known today. However, it is far more challenging to name even a few women astronomers from history. Does this imply that women were absent from the field? Absolutely not! Women have made significant contributions to the progress of astronomy, yet society has unjustly overlooked or forgotten their achievements. Despite facing formidable barriers and prohibitions, these women persevered and overcame immense challenges to pursue their passion for the sciences. In this work, we aim to highlight a few of these trailblazing women, showing that the history of astronomy should also be written in the feminine. More importantly, we seek to provide girls with female role models, so that gender parity in astronomy-science as a whole - can continue to advance.

2 The Matilda effect

The marginalization of women in science is such a widespread issue that it has its own name: the Matilda effect. Coined by science historian Margaret Rossiter in 1993, the term emerged from her work on the challenges women in science face and the lack of recognition they often receive. The Matilda effect describes the recurring minimization or denial of women scientists' contributions, with their work frequently being attributed to male colleagues. The phenomenon is named after Matilda Joslyn Gage (1826-1898), an American writer, suffragette, and feminist who fought against all forms of oppression. Gage was among the first to critique the exclusion of women from scientific spaces and the systemic invisibility they faced, an issue that is even more pronounced when it comes to women scientists.

Margaret Rossiter expanded upon the work of sociologist Robert King Merton, who in the 1960s explored how certain prominent figures are celebrated at the expense of those who collaborated closely with them. He developed the 'Matthew effect', based on a verse from the Gospel of Matthew (13:12), to describe the unequal distribution of recognition and fame. The Matilda effect is evident across all levels, even in its most prestigious

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honors, such as the Nobel Prize, which was established in 1901. Of all Nobel laureates since then, only 6.7% have been women. Excluding the Nobel Peace Prize and the Nobel Prize in Literature, the percentage drops to a mere 3.9%! The 2024 Nobel Prizes do little to change this imbalance.

The situation is equally bleak in mathematics. Since the Fields Medal was first awarded 88 years ago, only two women have received it -Maryam Mirzakhani of Iran in 2014 and Maryna Viazovska of Ukraine in 2022- compared to 62 male recipients. Computer science shows similar disparities. Frances E. Allen became the first woman to receive the Turing Award in 2006, 40 years after the prize's inception. Since then, only two more women - Barbara Liskov in 2008 and Shafi Goldwasser in 2012- have been honored, while 74 men have won the award.

3 The forgotten women of astronomy

It is often claimed that there have been no notable women astronomers throughout history. Nothing could be further from the truth. Below are just a few examples, though a more comprehensive list can be found in Vauglin (2021), along with the references included in that work.

3.1 Antiquity

Despite being largely excluded from formal education, women have contributed to the advancement of astronomical knowledge since antiquity, only to be unjustly forgotten over time. These pioneering women recorded star positions, studied eclipses, and explored celestial systems. One of the earliest known is **Enheduanna** (circa 2300 BC), who conducted her observations from a temple in Mesopotamia. Another is **Aglaonike of Thessaly** (2nd century BC), who, according to Plutarch, "understood the cause of total eclipses of the Moon and could predict when it would enter the Earth's shadow". And of course, there is **Hypatia of Alexandria** (350 or 370-415), one of the most extraordinary figures of the ancient world. A brilliant mathematician and philosopher, she was highly esteemed, drawing students from far and wide to attend her lectures. However, her support for the heliocentric model, her pagan beliefs, and her advocacy for the separation of science and religion drew the ire of powerful religious figures. Despite her prominence and numerous scholarly works, she was brutally murdered in March 415 by a mob incited by Bishop Cyril and his followers.

3.2 the Renaissance and domestic assistants

At that time, girls still had no access to formal education, except through the goodwill of their fathers, brothers, or husbands. Of course, they never held formal jobs or received payment for their contributions. In such difficult circumstances, only the most fortunate and tenacious women managed to make their mark. It should be noted, however, that behind many great astronomers, there was often an invisible yet efficient female collaborator-one who later disappeared from history.

For example, Tycho's sister, **Sophie Brahe**, whose early widowhood granted her the independence to pursue her passion for astronomy, became a true collaborator to her brother. Similarly, **Elisabetha Caterina Hevelius** constantly observed the stars alongside her husband and, after his death, published *Prodromus astronomiae* (1690), the most comprehensive star catalog of its time, listing 1,564 stars before instruments were commonly used. Arago would say of her: "The first woman to my knowledge who was not afraid to face the fatigue of astronomical observations and calculations." **Maria Winkelmann-Kirch** was more problematic because she refused to remain invisible. After her husband's death, she sought to succeed him as an astronomer at the Royal Prussian Academy of Sciences, a position that was, unsurprisingly, denied to her. Along with her daughter Christine, she later assisted her son, who eventually became the academy's director. **Caroline Herschel** is another example of a so-called domestic assistant whose immense skills were inversely proportional to her current level of fame. For her brother, William Herschel, in England, she polished mirrors, assembled increasingly large telescopes, and assisted him in observations and calculations. She also made her own discoveries, including several comets and nebulae. Her contributions were recognized during her lifetime, and in 1828, she became the first woman to receive the Gold Medal of the Royal Astronomical Society (the second woman to receive this honor would be Vera Rubin in 1996). **Maria Cunitz** is yet another woman who has largely fallen into oblivion, despite being widely respected in her time. Her husband, the mathematician Elias von Löwen, encouraged her extraordinary work. The publication of her *Urania propitia* (1650) brought her widespread recognition across Europe. Written in both Latin and German to increase accessibility, *Urania propitia* presented a simpler algorithm for calculating planetary positions than Kepler's. Cunitz was hailed as

the most learned woman in astronomy since Hypatia. It is difficult to comprehend how scientists and society allowed her legacy to fade from memory.

3.3 18th and 19th Centuries: Women Calculators

Despite the Enlightenment's new currents of thought, women were still not afforded the recognition they deserved. Nevertheless, they continued to contribute to the advancement of knowledge, albeit relegated to the unflattering category of "calculators".

For example, **Emilie du Châtelet** is often remembered more for her romantic liaisons than for her scientific contributions. Her father provided her with the same education as his sons, and her indulgent husband allowed her the freedom to pursue her intellectual pursuits, recognizing her remarkable abilities. A brilliant mathematician and astronomer, her translation of Newton's *Philosophi Naturalis Principia Mathematica* remains a landmark achievement. Similarly, **Mary Somerville** caused distress among her parents due to her strong interest in mathematics, leading them to marry her off. After becoming a widow, she finally had the opportunity to study. An exceptional mathematician, she understood, translated, and completed Laplace's *Mécanique Céleste* (*Mechanism of the Heavens*, 1831). Her personal experiences inspired her to sign a petition for women's suffrage in 1868. **Nicole-Reine Lepaute** calculated pendulum oscillation tables for her clockmaker husband, which led to her meeting Jérôme Lalande. Lalande and Alexis Clairaut invited her to participate in the particularly challenging calculations needed to determine Halley's comet's precise return date. However, Clairaut published his *Théorie des Comètes* without mentioning Lepaute's contributions, causing a rift with Lalande. In the 19th century, advancements in observational instruments did not equate to changes in societal attitudes. For instance, Charles Pickering surrounded himself with numerous women to process over 390,000 star spectra, praising their skills to his colleagues while encouraging them to employ these women as calculators as well. Despite their efficiency, innovation, and high performance, these approximately 80 women were derogatorily referred to as "Harvard computers", or even worse, "Pickering's harem". They invented the classification of stars into spectral types, yet their immense contributions to stellar spectroscopy did not prevent them from fading into obscurity, much like their predecessors. Among them, we must highlight **Williamina Fleming**, the trailblazer; **Antonia Maury**, the rebel who sought acknowledgment in publications; **Annie Cannon**, the efficient classifier of 350,000 stars; **Cecilia Payne-Gaposchkin**, who discovered the relationship between spectral types and star temperatures, proposing that stars are primarily composed of hydrogen; and **Henrietta Leavitt**, the discreet one who established the Period-Luminosity relationship of Cepheids, thus providing depth to the universe. Other notable figures included **Anna Winlock, Florence Cushman, Evelyn F. Leland, Ida E. Woods, Mabel Gill, Grace Brooks, Mary Vann, R.G. Saunders**, and many others.

3.4 20th Century: Professionals at Last!

The 20th century finally saw women taking up positions as astronomers. In France, **Edmée Chandon** became the first woman to join the astronomical corps at the Paris Observatory in 1911. Yet, who remembers her today? Chandon obtained two baccalaureates - one in arts and another in science - as a free candidate, since girls' high schools at the time did not grant access to the baccalauréat. She achieved first place in the agrégation in mathematics in 1908, at a time when higher education was largely inaccessible to women in France. However, it was not until 1965 that another woman, Renée Herman, attained the rank of full astronomer.

While an increasing number of women began to occupy positions in astronomy, I would like to highlight three women whose prestigious careers illustrate that discrimination against women persisted for a long time.

Margaret Burbidge was the first woman to become Director of the Greenwich Observatory, yet she was denied the honorary title of Royal Astronomer, a distinction that had been conferred upon the incumbent for 300 years. Instead, this title was awarded to a man, Martin Ryle. Margaret Burbidge emerged as one of the most influential figures in the fight to end discrimination against women in astronomy.

The American **Vera Rubin**, whose fame is inversely proportional to the significance of her contributions, also faced challenges. She had to fight for the right of women to conduct observations at the Mount Palomar Observatory, which was obtained in 1965! She articulated her beliefs when she stated: "There is no scientific problem that a man can solve that a woman cannot."

The Matilda effect is perhaps best exemplified by Irishwoman **Jocelyn Bell**, who discovered the first pulsar using the radio telescope she had built for her thesis. However, the Nobel Prize for this groundbreaking discovery was awarded to her thesis supervisor in 1974...

4 Many Missing Women in a Truncated History of Astronomy

All these remarkable women whose work has led to major advances in astronomy and astrophysics remain largely unknown to our contemporaries, who often assume that only men have propelled the sciences forward. This issue is prevalent across every field of science: who knows **Maria Agnesi, Sofia Kovalevskaia, Emmy Noether, Hedy Lamarr, Adele Golstine, Ruth Teitelbaum, Betty Holberton, Grace Hopper, Karen Uhlenbeck, Margaret Hamilton**, or even **Alice Recoque**? All of these individuals are eminent mathematicians and/or computer scientists, rendered invisible among countless others.

Who could have named **Katherine Johnson, Dorothy Vaughan**, and **Mary Jackson** if the film *Hidden Figures* hadn't brought their stories to the screen? These three names represent just a few among the dozens of black women (**Annie Easley, Kathryn Peddrew, Gladys West**, and many more) who contributed their indispensable skills at NASA to the success of the Apollo program, often under undignified working conditions that compounded the challenges of being both women and black.

The history of women in science is a story of exclusion. We must (re)give these outstanding, determined women their rightful place. Their excellence must be acknowledged, their invisibility must be ended, and we must recognise the obstacles they faced and the specific difficulties they endured solely because of their gender.

4.1 What Are the Consequences of This Lack?

The history of astronomy could have been written differently, with women included as role models with whom young girls could identify! A more equitable and balanced account of scientific history might have led to higher proportions of women in the field today. For instance, as reported by the CNRS (cf. bilan social CNRS (2022)), only 10.5% to 20% of researchers in physics, computer science, nanotechnology, electronics, mechanics, materials, and mathematics are women; astrophysics fares slightly better at 23%. Among engineers and technicians, the numbers are even lower, with just 12.7% of women in engineering sciences and instrumentation and 19.5% in computer science and scientific computing, compared to 84.4% of women in administrative positions of research.

The issue originates upstream, as there is a lack of necessary support and encouragement at the high school level. Overall, the differences in career orientation between boys and girls have not significantly diminished over time; the number of girls pursuing higher scientific and technical studies remains insufficient. Currently, in France, only a quarter of engineering degrees are awarded to women. Young girls cannot envision themselves in these professions or consider studying them, primarily because they lack exposure to female scientists who could serve as role models. Identification with role models is crucial for young girls to project themselves into careers that might otherwise seem unattainable.

Contrary to common arguments justifying these disparities, gender inequalities in science are not a matter of cognitive ability (as shown by brain imaging studies - Granon & Vidal (2001)), performance (as evidenced by French baccalaureate pass rates: girls at 93% and boys at 88.5%), or personal preferences (at least up to middle school - see OCDE (2023) 2015 and 2023 `https://www.oecd.org/`).

So why do young girls lose interest in science and doubt their abilities? The root cause lies in gender stereotypes, which perpetuate mechanisms of exclusion. Engaging in science is closely linked to self-confidence and interest in scientific subjects, provided the educational environment fosters such development. Numerous studies, such as Perronnet, Marc & Paris-Romaneskvich (2024) have demonstrated how our self-confidence and interests are shaped by societal influences.

We are all influenced by family, the educational system, society, and the media, all of which are saturated with stereotypes. These stereotypes foster persistent prejudices, resulting in the collective unconscious of 2024 still not associating women with science. Figure 1 illustrates just a few examples of how deeply ingrained stereotypes persist in society.

Girls do not censor themselves; rather, they are constrained by social representations, education, and the shackles of stereotypes and preconceived notions prevalent in society. Because of these prejudices, young girls often do not pursue scientific studies after the baccalaureate.

4.2 Do We Really Need Women in Science?

The lack of women in scientific and technological professions has negative consequences for both women and society as a whole. First and foremost, we require all available skills to address the significant challenges posed by climate change. To tackle issues related to food security, energy production, and water resources within the framework of sustainable development, we cannot afford to overlook the talents of half of humanity. The diverse

Fig. 1. a) an exercise in an elementary school book: children practice sentences like 'I'm the king of the castle' and 'Girls play with dolls'. Why not use 'I'm the queen of the castle' and 'Boys play with dolls' instead?
b) same product for children of the same age: why not a boy on the pink box and a girl on the blue one?
c) Putting a young woman to illustrate studies in the French Grandes Ecoles and a young man for paramedical studies would have shocked people?
d) same studies but different jobs: for the ministry, in 2023, women take care of elementary school children and men take care of secondary school classes! can't we swap roles?

social positions and experiences of women contribute valuable insights, and research shows that mixed-gender teams are more innovative and effective than those composed solely of one gender.

Moreover, today's scientists are responsible for shaping tomorrow's world. The under-representation of women in these fields will undoubtedly impact future generations. When science is perceived as being created by men, for men, and tested on men, it reinforces and perpetuates harmful gender stereotypes. We also need women in computer science, as the digital revolution and ongoing advancements in artificial intelligence will take an increasing place in our lives in the future. Unsurprisingly, current artificial intelligence systems often reproduce existing sexist biases, leading to outcomes that hinder women's success in the sciences. It is crucial that these fields are also shaped by women, yet they remain among the least feminized. Finally, consider some problems that arise from teams lacking sufficient female representation. Car airbag systems and seatbelts are typically designed based on male body types, rendering them unsuitable or even dangerous for smaller individuals or pregnant women. Medications are often dosed for men, resulting in women experiencing 1.5 to 2 times more side effects than men (cf. Buclin et al. (2021)). This discrepancy arises because clinical trials for new pharmaceuticals are commonly conducted on cohorts that are 80% male mice and, at the human testing stage, predominantly male participants (for instance, only 19% of participants in antiviral trials are women). Such practices are often justified by the complexities associated with hormonal cycles and the risk of pregnancy in female subjects. Yentl syndrome exemplifies how gender bias in healthcare affects the diagnosis and treatment of women, who are frequently not taken seriously and are under-diagnosed. Despite cardiovascular disease being the leading cause of death among women in Europe, myocardial infarction, for instance, often goes unmanaged in women (see Salle & Vidal (2017)). This neglect contributes to a significant excess mortality rate, with 49% of women dying from it compared to 40% of men, both in France and across Europe.

5 Conclusion

Promoting the contributions of both past and present women scientists is essential for inspiring girls to pursue studies in these fields. Increasing the representation of women in science goes beyond achieving equality; it is crucial for enhancing the quality of scientific research and fostering a more efficient and inclusive society. The L'Oréal Foundation's motto encapsulates this idea perfectly: "The world needs Science and Science needs women". We still have a long way to go to achieve parity in science...

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