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Women as calculators in a military Observatory in Spain

Abstract. *The Royal Astronomical Observatory of the Navy in San Fernando is one of Spain's oldest and most important scientific institutions, and led by director Cecilio Pujazón, actively participated in the international astronomy cooperation project The Sky Map, launched in Paris in 1887 in the Conference of Astronomists and proposed by Mouchez. As a military institution, women's access to its work was historically difficult, compounding the already difficult access of women to the world of science. However, like other observatories, the Observatory of San Fernando hired women to perform measurements and calculations for astrophotographic plates, a painstaking task requiring many hours of work. This strategy was implemented because hiring women was more economical and submissive. This study, with a methodology of bibliography and documental research which includes consultation of the Observatory of San Fernando's historical archives (especially the Master Books), seeks to discover, make visible, and empower the presence of these women from a gender perspective. Information was found on 30 women hired between 1919 and 1967 and this period coincided with a very difficult political and social time for women in Spain. They were hired in lower positions and were fired when they got married. Although their work was rendered invisible and their roles subordinate, their presence in a male-dominated military institution paved the way for future hiring. The analysis concludes that, both in this observatory and in others, the discriminatory circumstances of their work highlight the persistent gender inequality in science. This study joins others already underway at observatories around the world (Harvard, Melbourne, Paris, the Vatican) where women were also hired under similar circumstances. All these studies aim to bring these women out of anonymity and conduct gender studies within the scientific community. At the international level, it has been agreed to rename them as Women Astronomical Computers, and in future research, the aim is to create a common bank of digitized documentation of their work.*

Keywords: *Royal Astronomical Observatory of the Navy of San Fernando; Women Astronomical Computers; History of Science; gender studies*

Introduction.

With over 250 years of uninterrupted scientific activity, the Royal Astronomical Observatory of the Navy of San Fernando, Spain (Hereinafter, ROA), the oldest in the country, is one of its most important scientific institutions (Lafuente & Selles, 1988). Being a military institution from its origins, this further hampered the already difficult access of women to participate in its projects and work. In 1887 the international astronomical cooperation project The Sky Map was launched in Paris and the ROA participated in this project (Fundación Descubre, 2025). It was one of the most active observatories in the project, one of the few that completed its assigned work, and almost the only one that today preserves all the instruments used and the plates generated during the project. Its commission ended in 1923, at the same time as Greenwich and Oxford, but the Gautier astrograph continued to be used for other projects until 2008. At the ROA, as at other observatories around the world, women were also hired to perform measurements and calculations for astrophotographic plates, as they were more economical and thorough.

The first question I must address, is explain where we are, because the ROA is a sometimes-unknown observatory and to understand its importance also. The ROA is in a very strategic location, especially in the 18th century, which was the point of contact between Europe and Africa and the passage from the Mediterranean Sea to the Atlantic Ocean, with all that this entailed for Spain's control of commercial routes, especially its monopoly with America and, therefore, its military and political position (Orozco, 1988). Cádiz is a city open to the ocean, very close to Gibraltar and it sits on an island overlooking the Bay of Cádiz, surrounded by other small cities such as Rota, Puerto de Santa María, Puerto Real, and San Fernando, where the ROA will be relocated after being initially founded in the city of Cádiz.

In 1753, the Royal Observatory of Cádiz, the southernmost in Europe and the oldest in Spain in this time, was created as an annex to the Academy of Marine Guards in the Castle of the Villa de Cádiz, by order of the Marquis of Ensenada (1702–1781) and King Charles III (1716–1788), at the request of the naval officer and scientist Jorge Juan Santacilia (1713–1773). But, after, in 1798, the Observatory was moved to the city of San Fernando, to a new building, which has survived to this day, designed by the Marquis of Ureña (1741–1806) based on the plan of the Oxford Observatory (La Fuente & Sellés, 1988).

In the 18th and 19th centuries, the observatory had an important history and played an important role in the country's economy and politics. For example: it had very important naval officers, scientists, and directors such as Jorge Juan Santacilia (1713–1773), Luis Godin (1704–1760), Vicente Tofiño (1732–1795), Saturnino Montojo (1796–1856), José Sánchez Cerquero (1784–1850), Cecilio Pujazón (1833–1891), Tomás Azcárate (1849–1921), León Herrero (1862–1947), and Wenceslao Benítez (1879–1954), and it participated in the great expeditions of the last third of the 18th century, such as the measurement of the Transit of Venus in 1769 and the Malaspina Expedition in 1789, etc. The 0-meridian passed through this Observatory for more than 100 years until 1884, when it was finally established in Greenwich. As

Routine Activities it was calculation of the Ephemerides, publication of the Nautical Almanac, Advanced Studies Course, depot for Chronometers and Naval Instruments, meteorological, seismic, and magnetic observations, and scientific determination of time (González, 1992).

During the 20th century, despite the country's political crisis, the ROA did not stop its scientific activity, despite after the Spanish Civil War, many of its scientists went into exile. During the dictatorship of Franco, there was a setback, but the ROA continued to function and even collaborated with NASA in the space race (González, 1992). Since the democratic era in Spain, from 1975, the ROA has participated in sounding rocket programs, artificial satellites, and expeditions to Antarctica. At the end of the 20th century, it began to recognize its historical heritage and initiated programs for its conservation.

Nowadays, the ROA has an important scientific activity adapted to the changing times and it is one of the most important scientific institutions in the country. Today the ROA has the next organization and sections: Ephemerides Section, Positional Astronomy Section, Time Section, Geophysics Section, Senior Assistant, School of Advanced Studies (for military people), Management, and Library, which is responsible for the management of historical heritage (Ministerio de Defensa & Real Observatorio de la Armada de San Fernando, 2020). Each of these sections has several units.

The ROA, located on a hill of bedrock in the highest part of the city (which is also an island), is surrounded by the city today. Therefore, due to light pollution, it has had to relocate its nighttime sky observation activities to the Observatory located in the Canary Islands, and the ROA has focused on other astronomical activities and projects. The ROA has a new clock building for the calculation of official time, and a laser system used to monitor the satellites and the space debris.

The ROA today has the following routine scientific activities: calculation of Ephemerides, collaboration on projects with the International Astronomical Union and other similar institutions, determination, maintenance, and dissemination of physical and astronomical time scales, in accordance with international requirements, collaboration with the International Geodetic and Geophysical Union and other similar institutions, research works assigned by the Naval Staff, including the training and development of its own scientific and military staff, acquisition, maintenance, inspection, classification, repair, and study of the Navy's chronometric equipment, participation and leadership in international research projects such as space debris tracking, and recovery, conservation, management, and dissemination of its historical heritage.

About the historical heritage, the most important thing is that the ROA has preserved almost all its heritage, and it is *in situ*, contextualized (Muñoz, 2001). The ROA has a Library, with thirty thousand volumes (González, 1997; González, Gutiérrez & Merino, 1993), a Cartographic Collection, with three thousand five hundred maps (González, 2002), an Historical Archive, with six hundred and three boxes, so one thousand one hundred eighty-seven volumes (González, García &

Merino, 1988), and a Collection of Historical Instruments, with one thousand two hundred and forty-five instruments (González, López & Espada, 2020). All of them are inventoried and catalogued, and there is free access to researchers to them.

Despite being a military institution, that is a problem to open itself, in recent years the ROA has begun to open to the public and carry out various scientific divulgation activities, for example: the celebration of Seminar on Astronomical Navigation for 20 years; the organization of exhibitions and concerts, so we can see in the closed park an installation that commemorates the crossing of the 0-meridian; also, in collaboration with the city council and the tourist office, they organize guided tours with different topics throughout the year.

Research Methods.

The objective of our study is to recover information about the women who worked at the Observatory and to empower their presence by conducting a gender analysis, since we believe that their contribution has been silenced not only socially but also in documentation.

So, we conducted a study of bibliographic sources and contacted other researchers working on this topic to understand the reality of this case in other observatories (for example, Harvard, Paris, Vaticano, and Melbourne). We also studied the historical circumstances of the ROA regarding the subject of study and the conclusions presented in relevant gender studies. Finally, we consulted the ROA's Historical Archive (1887–1985) to identify and retrieve existing data on women employed there. We have consulted boxes 144, 1780, 1781 and 1658 of the Archive, as well as the Master Book. After presenting the contrasting results of all this, we conducted an analysis of the topic from a gender perspective.

With this study, we hope to discover, make visible, empower, and contribute important conclusions from a gender perspective and analysis about the presence of women in the history of ROA as Women Astronomical Computers. Following this investigation, and in line with other research being conducted by other observatories, we have located information on 30 women hired between 1919 and 1967 at the ROA. The results, that we are going to expose next section, have been highly significant, as this period also coincides with a very difficult political and social times for women in Spain, so their impact, although weak, is particularly noteworthy. Today, women are present in the ROA in technical and highly qualified scientific positions, although they remain a very small minority. These include, for example, the author (Muñoz, 2001), who designed the museum program for the ROA, and Gabriella di Florio (2021), who carried out the restoration of the plaques of the Sky Map. We have also studied the books published by them.

Results and Discussion.

The ROA in the Sky Map Project.

Since approximately 1874, photography has opened a new era in observational astronomy, both in determining positions (astrometry) and in the physical study of

celestial bodies (astrophysics). Its advantages include maintaining a faithful and lasting image in the photographic image, the greater sensitivity of the camera compared to the human eye, and the ability to perform precision measurements. Thanks to all this, astronomical photography could be used in the study of solar physics, in the discovery of new celestial bodies, and in the determination of stellar parallaxes (di Florio, 2021).

The ROA participated in the Sky Map Project since 1887 proposed in Paris by Mouchez (1821–1892). The Paris Academy of Sciences sponsored the meeting and extended invitations to various scientific societies and the directors of the most important observatories of the time, who attended the first meeting in Paris in 1887, constituting the International Astrophotographic Congress or Paris Conference of Astronomists. The entire work plan was organized and implemented in subsequent meetings. Its objective was to observe ten million stars up to magnitude 14 and catalog the coordinates of objects brighter than magnitude 11. The project was defined down to the last detail with a common proposal for all observatories, including the type of telescope, lens aperture, focal length, the size, and information to be contained in the photographic plates, and the observation and data reduction strategy – all the ingredients of a modern-day observing consortium. Many countries, including Spain, had to make significant investments to begin taking the first plates in 1892. Today, in the field of Astrometry, the Gaia Project has taken up the mantle, sending information to ESA stations at a rate of 40 Gbytes per day since its launch in 2013. Our observatory completed the project. And today it preserves all the instruments, plates, and photographs. About the ROA's participation in the Sky Map, we can summarize it as follows (González, 1989; González, 2024): the director of the ROA in that time, Cecilio Pujazón, attended the International Astrophotographic Congress in Paris in 1887, so it was one of the observatories to participate in the Sky Map from the beginning. In 1888, the ROA commissioned Gautier to design the Equatorial Photographic Telescope, the dome, and a plate-measuring machine. A dome, photographic laboratories, and calculation offices were built. In 1889, Cecilio Pujazón attended the International Permanent Committee Meeting in Paris, where the work plan for the 18 observatories was established. After a year of testing, the final work began in 1891, but Cecilio Pujazón dies. However, the next director of the ROA and the astronomers continue the project. San Fernando was assigned the declination zone between -3° and -9°, and they must produce 1,260 plates. In 1894, the ROA completed the 1,260 plates for the Catalog. In 1919, the first women were hired at the ROA to perform the calculations. In 1923, the ROA completed the Map at the same time as Oxford and Greenwich. New calculations and adjustments continued to be made with the plates until 1975. The Gautier astrograph was used for other projects until 2008, measuring satellite positions. In 2001–2020, three women (Yolanda Muñoz Rey, Belen Vicente, and Gabriella di Florio) recover the memory of the Sky Map: museology, restoration, new calculations.

The ROA currently houses many materials related to astrophotography in its heritage collections: astrophotographic instruments and accessories, glass plates, and plate holders, etching matrices, and printed material from the Sky Map: the Gautier astrograph, built in Paris in 1889, two plate measuring machines produced in the same

workshop in 1892 and 1906 respectively, as well as numerous accessories. The Archive houses both the collection of glass plates corresponding to the observations in the Astrophotographic Catalogue and the Sky Map, as well as another 287 boxes (with an average of 12 plates each) from other observation programs carried out with the Gautier astrograph until the early 1980s. The ROA also houses a complete collection of the 720 printed sheets corresponding to the observation area assigned to it in the project, in addition to several thousand sheets corresponding to the areas assigned to other observatories. In addition to all this scientific and cultural heritage, we must add the 403 copper plates prepared in Paris to be used as engraving matrices for the Chart sheets. These plates were rescued relatively recently, at the end of 2015, from a warehouse where they had remained forgotten for several decades.

Women Astronomers in the World and in Spain.

We know that in historical times, the presence of women in science has been anecdotical due to the prevailing social organization and way of thinking based on patriarchy, in which women were relegated to the domestic sphere and legally subject to men. We must wait until the 19th century, during the Industrial Revolution and the fall of the Ancient Régime in European countries, for a truly feminist activist movement emerging, fighting for equality and breaking old patterns. Among these was the need to allow and normalize the presence of women in scientific fields, universities, and research.

In the case of astronomy, from ancient times, we have records of En'Heduana (2353 BC) in Babylon, Aglaonike (2nd century) in Greece, and Hypatia (4th century) in Alexandria. In Europe during the Middle Ages and the early modern period, there were also occasional and anecdotical women who were interested in astronomy and made observations, studies, and writings, most of them daughters of male astronomers. In all cases, their presence was relegated to auxiliary duties, and their significant contributions, when they existed, were silenced, hidden, or appropriated by their male entourages (fathers, brothers, or husbands). Their dedication to these activities was always difficult, socially challenged, and hampered, even impeded, by their domestic and family obligations.

In the case of Spain, we only find historical references to a Spanish woman, Fátima De Madrid (10th century), from the time of the Caliphate of Córdoba. Fátima was the daughter of the Andalusian astronomer, mathematician, and philosopher Abul Qasim Maslama ibn Ahmad al-Mayrity, with whom she learned and collaborated. Notable among her works is *The Corrections of Fátima*, in which she presented an updated review of the astronomical knowledge existing at the time.

Already in the 19th century, in the new society and with the support of feminist movements, the female presence in the field of astronomy increased (Ling et al., 2015). In Europe and the United States, some women managed to complete university studies in astronomy and even obtain doctorates, contributing important discoveries with their research. Henrietta S. Leavitt (1868–1921), Williamina Fleming (1857–1911), and Cecilia Payne-Gaposhkin (1900–1979) are some of the pioneers.

In the case at hand, the Sky Map, many of the participating observatories implemented the strategy invented by Pickering (1846–1919) at Harvard from 1877 (Smith, 2021): hiring women to do the tedious work of measuring and calculating photographic plates, since this required many hours of work and hiring women was cheaper and submissive than hiring men, especially if they were hired not as astronomers but as assistants with different titles. Later, other observatories such as Paris, Melbourne and the Vatican did the same.

They identified thousands of stars in glass photographic negatives by comparing them with published catalogs, measured stellar magnitudes, classified spectra, and detected new objects of interest such as nebulae, variables, and rare star types. They spent their days performing mathematical calculations for the male astronomers who worked the telescopes at night. The female calculators took the astronomers observation notebooks and reduced the data recorded in them, averaging numbers and correcting for refraction, parallax, and the inherent error of different instruments to record an object's absolute position in the sky. Previously, these calculation tasks have been performed by children from vocational schools or orphanages or by young men aspiring to be astronomers (these were promised a rising career, but no women). The tedious, long-hour calculations took their toll on the women working at the Harvard Observatory, both mentally and physically, resulting in everything from stress to illness and muscle problems. The salary was low; they earned 30% less than men in the same position and it was barely enough for them to survive. In many cases, the women hired were relatives of the men working at the observatory. They were often not even recorded in the institutions' administrative documentation and often worked on a voluntary basis. But in some ways, Pickering acted as a supporter of female astronomy education, helping female astronomy professors establish observatories, training female students in the use of physics laboratories, and writing about the potential for women to make influential discoveries in astronomy. At other observatories studied, the circumstances were similar. At the Melbourne Observatory (Stevenson, 2023), separate workrooms and toilets were built for them, they were given an entrance exam, and their work was closely monitored and supervised.

In Spain, one, of the pioneers women in Astronomy, was Antonia Ferrín Moreiras (1914–2009) (Núñez, 2020; Ling, 2014) who, in the first half of the 20th century, obtained several degrees and was the first Spanish woman to earn a doctorate in Mathematics (in Astronomy). Another legendary figure in Spanish astronomy was Asunción Catalá i Poch (1925–2009), the first professional astronomer to obtain a teaching position at a Spanish university (Masegosa, 2009).

Nowadays, although the trend is upward, there are still few women in scientific university programs, pursuing doctorates, and holding positions in scientific institutions as researchers and in management positions. The representation of Spanish women (compared to Spanish men) in the IAU (International Astronomical Union) is 23% (2010). The “glass ceiling,” work-life balance issues, and the attitudinal, administrative, and educational micro-sexisms that still exist in the system continue to hinder progress toward equality (Pérez & Kiczkowsky, 2010).

Today, the Spanish government and the CSIC (Higher Council for Scientific Research in Spain) have promoted studies on current and historical Spanish astronomers. Among the activities carried out to commemorate the 2009 International Year of Astronomy, the pillar project "She is an Astronomer" was carried out, with the main objective of illustrating to what extent women astronomers throughout history have participated in the great discoveries that have led us to our current knowledge of the Universe (UNED, CSIC & Sociedad Española de Astronomía, 2009). This project showcased the contributions of 139 Spanish astronomers from the last 100 years. Also, "AstrónomAs" in 2021 (Ling, 2022; CSIC, 2021) is a virtual exhibition focusing on women dedicated to the study of astronomy and astrophysics. Hosted on the website www.astronomas.org, it includes information on more than three hundred astronomers who work or have worked in one or more of the fourteen themes that comprise the exhibition. It reflects a wide variety of ethnicities, geographical areas, professional categories, and functional diversity. It has been founded by *Fundación Española para la Ciencia y la Tecnología* from *Ministerio de Ciencia e Innovación and Sociedad Española de Astronomía (SEA)*. It is complemented by various educational and informative materials. Its nature is based on the success of the previous museum exhibition, "With an A for Astronomers," in 2009, which toured numerous venues for twelve years. Also, we can see the "11defebrero" project (Valdés-Solis, 2009; Castro, 2022), which aims to highlight the work of women scientists. Also, "Henrietta Levitt's Secret Diary" is an outreach project of the Institute of Astrophysics of Andalusia and the CSIC, which, in video-blog format, discusses astronomy and Harvard calculators (CSIC, 2023).

2025 marks the "Centennial of Stellar Atmospheres, Cecilia Payne-Gaposchkin's Groundbreaking PhD Dissertation" (Harvard University, 2024), the first astronomy PhD awarded by Harvard, and a foundational text in astrophysics. For her research, Payne-Gaposchkin drew on more than forty years of glass plate astronomical data from the Harvard College Observatory. Her work built upon and was enabled by a pioneering group of women astronomers who created, studied, and preserved this glass plate collection, initially funded by Anna Palmer Draper. The "PHaEDRA" project (Harvard University, 2025) seeks to recover the names of all the women who worked at Harvard by tracing the notes they left on envelopes and documents of their calculations. Whether these individuals spent time at the Harvard Observatory as volunteers, computers, astronomers, researchers, or students, the glass plate collection was recognized as a space for women, a refuge filled with numbers and stars.

These types of actions always aim to empower what has already been achieved and what is in progress, to make it visible to value it, and to foster new vocations.

Women at ROA.

There is just research on women hired to perform calculations for the Sky Map project at other observatories around the world, such as Harvard, Greenwich, Paris, Melbourne, and the Vatican.

We know that in the beginning at San Fernando, this work was carried out by the observatory's astronomers. There is no record of women being hired for this until 1919. After the Gautier Astrographer took each photograph (three photos per exposure), they went through a laborious process of measurement, matching, and transfer from glass plates to bronze plates and paper. All of this had to be done with a Gautier measuring and calculating machine, which required many hours and was a very mechanical and not very complicated process.

It is very important to understand that feminism in Spain lagged due to the country's tortuous political evolution in the 19th century. Then also, in the 20th century, we must add the Civil War and Franco's dictatorship, which marked a reversal of the little that had been achieved.

Furthermore, the ROA is a military institution, and its scientists are military staff, which makes it even more difficult for women to work there. Women's access to the Spanish army has been anecdotical in historical times, impossible during Franco's dictatorship, and only really began with the arrival of democracy, especially after 1990.

In the ROA's Historical Archive, there is a box dedicated to the Sky Map, and it hasn´t documentation referring to these women (Historical Archive of the Royal Observatory of the Navy, 1887–1985, Box 144). Pujazón (1890a; 1890b) published two articles on the work of the Sky Map. One of them, in the journal *Naturaleza*, provides no information on the presence of women computers at observatories, although they already existed by that time. But at last, in the article in the *Revista General de Marina*, he points out that:

"…a certain number of observers (men) cooperating in the photographic work, although willing to carry out the two series of plates necessary for the chart and for a catalog, are refraining from promising their participation in the latter, believing that, as some claim, it is a work of many years, and will entail considerable expenses" (p. 204).

And in a letter written in 1789 Pujazón mentions that women have been hired in other observatories (box 144, Historical Archive of the ROA, section 4.1.2. Astrophotography).

In addition, García published a small, very detailed and precise manual on how to perform the calculations for the work on the Sky Map, first in manuscript (1921a) and later printed (1921b), in which he lists the astronomers and assistants who participated in these calculations, but does not mention any women. He does point out that "...the lack of personnel [in 1892] and the difficulty of finding non-professionals with the aptitude for measurement, caused a great delay in being able to employ it" (1921b, p. 48).

In all the documentation preserved in the ROA Historical Archive, only in box 1781 (section 4.1.2. Astrophotography) a woman named Pilar is mentioned, in a document consisting of loose pages that appear to be a draft, handwritten routine diary. This document is neither dated nor signed but based on its characteristics and the context of the other accompanying documents, which are dated 1973, we can place it around this time. It seems to have been written by the chief astronomer and narrates, in a personal style, the measurement and calculation operations performed on

astrophotographic plates. He recounts that they carried out this work from 9:00 a.m. to 6:00 p.m., with an hour and a half break. He mentions that *Pilar* takes measurements while two other male workers record them. Or that *Pilar* stays behind taking measurements while he goes to a meeting or talks with someone. He also mentions that she and he take the same measurements, secondhand. He mentions her frequently; it is a collaborative effort. It recounts the problems they encounter and the mistakes they make. Comparing this with the data table (see Appendix) obtained from the research in the Master Book, we deduce that it must have been María del Pilar Rodríguez Sáenz de Urraca, because we see that in 1977, she was still working, having received a promotion that year, while the only other woman named *Pilar* was dismissed in 1959 for getting married. I transcribe the mentions about *Pilar* in mentioned document:

"Then I took over and measured Nesta, which Pilar then did. The system was the same as for the stars, but... The result was...". "I start by measuring Mars using both methods. Then Pilar measures the entire plate, with Azcona and De Pablo taking notes... At a quarter to one, when I return to the machine, Pilar has just finished, and I measure the 15 stars...". "...while Pilar was measuring and a technical engineer was taking notes, I had interviews...". "...we went to visit the observatory of...while Pilar stayed behind taking measurements, and on this occasion, De Pablo measured plate 41, which is second-hand." "When it's Pilar's turn, she does the same operation as me on star number 6." (Historical Archive ROA, box 1781, 1973).

Apart from this, the only data about women in ROA we find is in the ROA's Master Books, which contain a complete list of all the people employed by the ROA from the mid-19th century to the present. These books detail the bureaucratic or administrative processes of their working lives: promotions, dismissals, recognitions, contracts, leaves, etc. As there are so few of them, we have analyzed not only the women astronomical computers, but also all the women registered in these books.

The results of this research were as follows (You can see a table with all the data in the Appendix). A total of 30 women were hired between 1919 and 1967. There are two periods when several hiring coincides: in 1919–1920 and 1943–1956. The hiring age is around 20 years old, but some of the hired workers were 14 years old. Many of them were sisters or cousins among them. Although women were hired as *private maids* or *cleaners*, the case at hand (astronomical computer) is that of women hired under the following titles: *typist, 2nd-class operator, astrophotographic plate measuring assistant, administrative assistant, calculation assistant*, and *3rd-class official*. Those hired for this purpose had no astronomy training or even basic education. Many of them earned their high school certificates while they were working at the ROA. Neither of them ever completed university studies. Their work was only on calculators, so they did not conduct astronomy research. Improvements in their contracts and promotions resulted from having been employed for many years, and several of them reached the rank of *1st-class Analyst*. Particularly relevant is the reason for dismissal: two due to death, two due to individual choice, one due to incapacity for work by illness, five due to retirement, but seven due to marriage, as the laws during Franco's dictatorship prohibited women from working if they were married.

Apart from the Astronomical Computer: in 1961, María de la Concepción Herrero Valdés, a highly specialized and trained woman was hired for the first time to manage the Library and the Historical Archive; in 2001, Yolanda Muñoz Rey designed the museological program for the ROA's collection of historical scientific instruments with a research grant from Alvargonzález Fundation; from 2004 till 2016, Astronomer Belén Vicente, an expert in stellar astrometry and specialized in the characterization and kinematics of star clusters, analyzed the Sky Map data collected by the ROA more than 100 years ago; and in 2021, Italian restorer Gabriella di Florio restored the Sky Map plates with a contract after having conducted research on the subject for his Master's Thesis. In addition to conducting a historical study of photography in the ROA and its historical photographic collection, it is designing a preventive conservation project in four phases.

Gender Analysis and Conclusions.

In recent decades, gender studies have increased, confirming that despite everything, there is still inequality in the numerical presence of women in the field of science (training, research, and work). From a qualitative perspective, women are invisibilized, and there is even a presence of micro-sexisms and situations of undervaluation and access to opportunities. There are discrimination and harassment. Within the academic sphere itself, there are pernicious lines of thought such as relying on future improvement through natural evolution rather than conscious and active action, as well as avoiding conflict, failing to recognize micro-sexisms, and thinking that inequality is something of the past, or of previous generations and already overcome. When a woman scientist is mentioned in the press (this already happened in the 19th century, but it still happens today), the headline focuses on the fact that “she's a woman” and not on the scientific achievement itself as a person.

Currently, some gender studies have been conducted regarding the hiring of female calculators at astronomical observatories. The Harvard case is particularly striking, as it has also been cited in the literature under the unfortunate title “Pickering's Harem,” a term that alludes to sexual ownership, objectification, and domination over women. It is also noteworthy how the authors of these contracts falsely argued that “women have greater qualities for detailed and meticulous work,” rather than the real argument that they were cheaper and more submissive (the latter due to education, social imperative, and economic necessity). They were not hired as astronomers but with auxiliary titles, and their work was silenced: their names did not appear in documents, reports, results, or publicity. The ROA Historical Archive contains a large amount of documentation about the Sky Map, and in all of it there is no mention of the women hired.

This study has achieved to make visible, empower, and analyze the historical presence of Women Astronomical Computer during the history of ROA from a gender perspective. In this regard, we would like to highlight the following points. We must understand that these types of mechanical and office jobs were a safe place for many women in Spain during this time of repression (Angulo, Guijarro & Garrido, 2025),

when women were not allowed access to work (Franco's dictatorship). They were in auxiliary, submissive positions where they were controlled, but it allowed them to earn a salary, as women who had no other normal means of subsistence at this time and in this context of repression, namely, marriage or support from others family members. These jobs were few, and it is noteworthy that most were fired upon marriage. Their career prospects were limited and invisible in the documentation and in public knowledge. However, they contributed the fact of their presence there and the fact that a 100% male military institution accepted the presence of women, which opened the door to future hiring once democracy arrived. We have managed to locate and identify the names of 30 previously invisible women, thereby empowering them. Based on the data obtained, we have been able to confirm gender discrimination and their employment circumstances, which are identical to those found in other observatories conducting similar studies. The methodology used has made this possible.

This study is still in its initial phase, and I would like to continue taking the following steps: identify the calculation documents generated by them and other internal documents to determine if they are named, so do their names appear in the notes and documents of the calculations they performed? Is there a bias toward making them invisible compared to the same type of documentation generated by men? find data on the salaries they received in case they were lower than those of their male colleagues, and were there men hired for the same job? why them? Did they have family or similar relationships with other ROA workers? In this sense, one of the last hired, Agustina Panellés Lazaga, we know that her brother was a Navy Captain and we have seen some surname coincidences in astronomers or other military positions in years prior to the presence of some hired women; locate photographs of them working at the ROA, which has not been possible until now; conduct newspaper research to locate press releases about them (if any) and identify gender biases; we don't know anything about the work environment they experienced, or whether they suffered discrimination in their work context; identify the criteria that existed to determine which workers lived within the ROA premises and which ones outside, and whether they were affected by any gender discrimination in this matter.

Some of the gender-based outreach efforts we should be doing in the future with this case include: rename them fairly from a gender perspective and in accordance with other international studies on the same case; integrate their work into the historical narrative of Spanish women astronomers include their story in guided tours; promote gender studies at the ROA; and establish a network with other national and international projects on this topic, launch a project like PHaEDRA in the ROA.

Although the case of the Women Astronomical Computers was an entry-level solution for women in astronomy, the discriminatory circumstances in which they worked are evidence of the gender inequality that existed at that time in the world of science, which even today, despite the progress made, continues to sustain unequal tendencies that require further work.

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Appendix

Table 1. List of the 30 women hired by the ROA between 1919 and 1967. Source: Historical Archive of the Royal Naval Observatory of San Fernando. (1899–1995). Master Books. (nº 1–7). San Fernando, Spain. (Authors' source).

Name	Date of birth	It comes from another unit	Hiring date	Workstation	Promotion 1	Promotion 2	Promotion 3	Promotion 4	Contract end date	Reason for termination of contract
Moreno Jiménez, Angustias	1914	Naval Military Academy from 1939	06/21/1943	Typist	04/18/1945 3rd grade Administrative Assistant (typist)	11/16/1948 2nd grade administrative assistant (typist)				
Espín Peña, Manuela	1894		06/16/1919	Temporary Typographic Operator	1932 Corps of Technical Services Assistants of Arsenals	10/06/1944 1st Section of the Navy Arsenal. 2nd Class Operator	03/06/1945 First-class operator (typesetter)		1958	Retirement
Cruz Belizón, Concepción	1889		1919	Temporary Typographic Operator	1933 2nd Section Technical Services of the Navy	10/06/1944. 1st Section of the Workshop. 2nd Class Operator	03/06/1945 First-class operator		1954	Death
Espín Peña, Isabel	1900		1919	Temporary Typographic Operator	08/07/1933 2nd Section of the Navy's	10/06/1944. 1st Section of the	06/03/1945 First-class operator		1960	Retirement due to physical

Name	Date of birth	It comes from another unit	Hiring date	Workstation	Promotion 1	Promotion 2	Promotion 3	Promotion 4	Contract end date	Reason for termination of contract
					Technical Services	Workshop. 2nd Class Operator				disability (loss of vision)
Romero Márquez, Regla María	1893		1919	Temporary Typographic Operator	1933. 2nd Technical Services Section of the Navy	03/06/1945. First-class operator (typesetter)			1958	Retirement
Carmona Peña, Manuela	1906		09/07/1920	Temporary Typographic Operator	1933. 2nd Technical Services Section of the Navy					
Gómez Lagóstena, Carmen		San Carlos Naval Hospital	07/20/1943	Operator 2nd Section C.A.S.T.A. as a package seller	1944. Naval Workshop. 3rd Section. Second Class Worker	1948. First-class worker			1953	Retirement
Rivero Romero, María de la Oliva	1931		08/25/1951	Measurement of astrophotographic plates					06/30/1957	Marriage
Rivero Romero, María Teresa	1934		1959	Administrative Assistant					1960	Marriage
Rodríguez Sáenz de Urraca, María del Pilar	1930		08/25/1951	Measurement of astrophotographic plates	1957 Administrative Assistant	1961 Second Class Administrative Officer	1971. 2nd Class Analyst	1977. Analyst 1st		
Rodríguez Sáenz de Urraca, María del Carmen	1924		05/30/1956	She is hired as an administrative assistant to provide services as a calculation assistant	1961. Second Class Administrative Officer	1971. 2nd Class Analyst	1977. Analyst 1st			
Ristori Fernández, Amalia	1907		08/30/1951	Measurement of astrophotographic plates	1957. Administrative Assistant	1961. Second Class Administrative Officer	1971. 2nd Class Analyst		1974	Voluntary resignation
Valverde Peralta, María del Carmen	1933		08/25/1951	Measurement of astrophotographic plates	1957. Administrative Assistant	1961. Second Class Administrative Officer			1961	Marriage
Valverde Quintana, María del Pilar	1937		05/30/1952	Private maid. Profession: typographer.	1959. Administrative Assistant				1959	Marriage
Jiménez Castañeda, Josefa	1935		08/06/1954	Private maid					1958	
Quintana Pizarro, Carmen	1936		08/06/1954	Private maid					1961	Marriage
Sánchez Hidalgo, Mercedes	1925		08/06/1954	Private maid	1963. Third Officer					
Serrano Cano, Carmen	1939		08/06/1954	Private maid	1963. Third Officer					
Serrano Cano, Úrsula	1943		1958	Private maid					1963	
Aceytuno García, María del Rosario	1929		1960	Measurement and calculation of astrophotographic plates. Second-level administrative officer					1964	Marriage
Espino Pineda, María del Carmen	1905		12/10/1955	Administrative Assistant of 2nd Workshop					1970	Retirement
Herrero Valdés, María de la Concepción			03/27/1961	Official of the 8th category of the Faculty Corps of Archives, Libraries and Archaeologists						
Navarro González, María del Carmen	1931		05/22/1956	Calculation Assistant	1961. Second Class Administrative Officer	1971 Second-level Analyst	1977 Analyst 1st		1995	Early retirement
Lazaga González, Consuelo	1938		1962	Second Class Administrative Officer					1967	Marriage
Panelles Lazaga, Agustina	1939		1964	Second administrative officer, for measuring astrophotographic plates and calculation	1971. 2nd Class Analyst				1975	Death
Ramírez Rubio, Natividad			1967	Cleaner					1977	Voluntary resignation

Name	Date of birth	It comes from another unit	Hiring date	Workstation	Promotion 1	Promotion 2	Promotion 3	Promotion 4	Contract end date	Reason for termination of contract
Romero Sánchez, Marina	1923		1967	Cleaner					1979	Work incapacity
Sánchez López, Josefa			1967	Cleaner					1980	
Sánchez Hidalgo, Mercedes			1967	Third-class typesetter at the printing press						
Serrano Gamo, Carmen			1967	Third-class typesetter at the printing press						

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Жінки-обчислювачки у військовій астрономічній обсерваторії Іспанії

Анотація. *Королівська астрономічна обсерваторія Військово-морських сил у Сан-Фернандо є однією з найстаріших і найважливіших наукових установ Іспанії. Під керівництвом директора Сесіліо Пухасона вона брала активну участь у міжнародному астрономічному проєкті «Карта неба» (Carte du Ciel), започаткованому в Парижі у 1887 р. на Конференції астрономів за ініціативою Муше. Як військова установа, обсерваторія тривалий час залишалася практично недоступною для жінок, що додатково ускладнювало й без того обмежений доступ жінок до наукової діяльності. Проте, подібно до інших астрономічних обсерваторій, обсерваторія Сан-Фернандо залучала жінок для виконання вимірювань і розрахунків, пов'язаних з обробкою астрофотографічних пластин, – надзвичайно кропіткої роботи, що потребувала багатьох годин праці. Така практика пояснювалася тим, що праця жінок була дешевшою, а самі вони вважалися більш слухняними виконавицями. У цьому дослідженні, заснованому на методах бібліографічного та документального аналізу із залученням матеріалів історичного архіву обсерваторії Сан-Фернандо (передусім реєстраційних книг персоналу), зроблено спробу виявити, висвітлити та переосмислити присутність цих жінок крізь призму гендерного підходу. Було встановлено відомості про 30 жінок, які працювали в обсерваторії у 1919–1967 рр. Цей період збігся з одним із найскладніших політичних і соціальних етапів в історії Іспанії для жіноцтва. Жінок приймали на роботу лише на нижчі посади, а після одруження вони підлягали звільненню. Незважаючи на те, що їхня праця залишалася майже непомітною, а службові функції були підпорядкованими, сама їхня присутність у військовій установі, де традиційно домінували чоловіки, відкривала можливості для подальшого залучення жінок до роботи в подібних закладах. Проведений аналіз показує, що як у цій, так і в інших обсерваторіях, дискримінаційні умови праці жінок відображали стійку гендерну нерівність у науковому середовищі. Це дослідження долучається до низки аналогічних проєктів, які вже здійснюються в обсерваторіях світу (Гарвардській, Мельбурнській, Паризькій, Ватиканській), де жінки також працювали за подібних обставин. Усі ці дослідження мають на меті повернути цих жінок із*

забуття та розвивати гендерні студії в історії науки. На міжнародному рівні досягнуто домовленості використовувати щодо них назву «жінки астрономічні обчислювачки» (Women Astronomical Computers), а перспективою подальших досліджень є створення спільного банку оцифрованих документів, що висвітлюють їхню професійну діяльність.

Ключові слова: *Королівська астрономічна обсерваторія Військово-морських сил у Сан-Фернандо; жінки астрономічні обчислювачки; історія науки; гендерні дослідження*

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