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The dark Universe for women: Gender and Science in Vera Rubin's career in Astronomy+*

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Abstract

The recurring absence of women scientists in the "naiver" narratives of the History of Science reinforces a widely held view that intellectual production is the result of the efforts of primarily male scientists. To circumvent this scenario, Gender and Science studies suggest approaching historical narratives that focus on the contributions and trajectories of women scientists. In science education, recognizing the identities of those characters who have played leading roles in the construction of science enables teachers and students understand the contribution of a diversity of people in the scientific enterprise. In this sense, this article seeks to expose aspects of gender relations manifested in the academic career of the American astronomer Vera Rubin, recognized for her studies on galaxies that provided evidence for the existence of dark matter in the Universe. The biographical research is based on primary literature, such as autobiographical essays and interviews, as well as secondary literature, including biographies about the scientist. The main reference for discussions on Gender and Science is the studies of historian Londa Schiebinger. Based on a critical analysis of women's structural difficulties in maintaining their position in the academic and scientific world, paths are outlined for reversing this scenario.

+O Universo escuro para as mulheres: Gênero e Ciência na trajetória de Vera Rubin na Astronomia

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I. Introduction

In the traditional historiography of science, developed from an androcentric[2] and eurocentric[3] view, reports on women's contributions and trajectories are still rarely present (Chassot, 2004). As a historical-cultural construct, the world of science has been structured predominantly from a male perspective, through discourses and practices of exclusion or denial of women's contributions to scientific work (Silva, 2012). The mechanisms for excluding this over time consisted, above all, of

> *[...] formal processes that prevented women from accessing universities through laws or regulations, through scientific discourses that, by "naturalizing" the differences between men and women, determined the social places that subjects should occupy according to their biological characteristics, or even through cultural processes that made women scientists invisible* (Silva, 2012, p. 20).

Although there are different levels of representation in some fields, it is imperative to recognize that women actively participated in the History of Science. According to Margaret W. Rossiter (1982, p. 15), "women's historically subordinate 'place' in science (and thus their invisibility to even experienced historians of science) was not a coincidence and was not due to any lack of merit on their part". However, science is still influenced by gender stereotypes, as evidenced by the widely held view that intellectual production results from the efforts of only male scientists (Chassot, 2004).

Studies on the history of women in science became more frequent throughout the 1970s (Schiebinger, 2001). These historiographical studies provided reports on the challenges women faced in securing a prominent place in the History of Science, thereby expanding the body of knowledge about their contributions to the scientific enterprise. The inclusion of women in the historical debate took place "in the midst of a maturing women's movement and at a time when more and more feminists were assuming positions of power in history and science" (Schiebinger, 2001, p. 58). Therefore, feminist studies were decisive in making it possible to modify the traditional conception of the History of Science.

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[2] Androcentrism, characteristic of patriarchal society, is the "stance according to which all studies, analyses, investigations, narratives, and proposals are focused from a solely male perspective, and taken as valid for most humans, both men and women" (Oliveira, 2004, p. 43).

[3] Eurocentrism corresponds to "the hegemony of a way of thinking based on Greek and Latin and the six European and imperial languages of modernity; that is, modernity/coloniality" (Mignolo, 2008, p. 301), in other words, it "thinks and organizes the totality of time and space for all humanity from the point of view of its own [European] experience, placing its historical-cultural specificity as a superior and universal reference standard" (Lander, 2005, p. 13).

According to Londa Schiebinger (2001), the history of women in science shows that scientific institutions, formed over the centuries, can either encourage or hinder women's participation. The success of female researchers is affected by interdependent factors, including available study opportunities and historical, political, and economic circumstances; and highlights that the process by which women became part of the History of Science was marked by cycles of advancement and retreat, influenced by the social conditions and thinking of each era.

In the 18th and 19th centuries, when women were largely denied education, scientists such as Caroline Herschel and Sophie Germain became renowned for their self-education. By the end of the 19th century, universities in the United States and Europe began to admit women to their courses, albeit with significant restrictions, such as limited course enrollment, restricted access to certain buildings like libraries, and the inability to obtain a diploma despite completing the coursework (Schiebinger, 2001). In the first half of the 20th century, marked by two world wars, opportunities for women in scientific research and industry increased. However, they were still rarely in leadership positions and often performed secondary roles as assistants and technicians - functions that were undervalued at the time but crucial to major advances in scientific research. The post-war period of second half of the 20th century was marked by the civil rights movement in the United States, which led to the prohibition of gender discrimination in federally funded educational programs, thus expanding women's access to scientific education (Schiebinger, 2008). It is noted that up until that point, there was a struggle to even minimal access for women. Although there was excitement about the progress, it was still insufficient. In the 1980s and 1990s, scientific institutions and universities initiated programs and policies aimed at increasing women's participation in science (Schiebinger, 2001). Conditions for women's retention in these predominantly male-dominated fields began to improve, providing a necessary condition for their survival in the profession.

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In Brazil, the debate about women in science began in the 1970s, a period that marked the start of the Brazilian feminist movement and the increased access to higher education for women, and it remains relevant today. According to the World Economic Forum (WEF) "Global Gender Index Gap", which annually evaluates and compares the state and evolution of gender inequality across economy, education, health, and politics, Brazil ranks 70th among the 146 countries (WEF, 2024). It corresponds to a worsening compared to the previous year (in 2023 the country was ranked in 57th). Among 22 Latin American and Caribbean countries evaluated, Brazil is 16th, indicating one of the lowest equality indices (WEF, 2024). Data also show that female students represent only 36.64% (WEF, 2024) of those in undergraduate in STEM fields (Science, Technology, Engineering, and Mathematics) in Brazil, compared to the global average of 35% (UNESCO, 2024). Seeking to understand the set of statistics on women in science and how this relates to the disadvantages women have gone through in the area, Rossiter (1982) proposed the concept of "territorial segregation" to explain the unequal distribution of gender across different fields of knowledge, which helps elucidate the low female representation in STEM areas.

Women are also underrepresented in the national scenario of teaching and research in the STEM field. According to the study "Diversity in Brazilian Science" (GEMAA, 2023), women make up 42% of professors in master's and doctoral programs. In engineering graduate courses, the proportion of permanent female professors is around 23%, while in fields such as Physics, Astronomy, Computer Science, and Mathematics, it is even lower. The Gender Inclusion Quotient in Graduate Studies (QIGPG) for female PhD holders compared to female professors in graduate programs, measured from 2017 to 2020, was 0.785 This quotient (meaning equivalence between the presence of female PhD holders and female professors), being less than 1, indicates a barrier in the transition from a PhD to teaching position. Therefore, to explain the lower female presence as the prestige of the positions increases, Rossiter (1982) coined the concept of "hierarchical segregation". This hierarchical disparity is associated with the exclusion of women from advancing in academic positions. Additionally, the data expose the "scissors effect", a phenomenon characterized by the systematic decreased in the proportion of women as one progresses in an academic career. In other words, there is a reduction in female representation between the master's and doctoral levels and further from the doctorate to tenured teaching position (Menezes, 2017).

Therefore, despite improvements in access to higher education, there remain a significant distance to achieving gender parity in academic careers, particularly in STEM field. Despite the data presented above, indicators of gender relations in STEM areas are still insufficient (Aquino, 2006; Sarti, 2004; Schiebinger, 2008). Including information on race, class, and other demographic categories in statistics could foster more refined discussions about the more diverse representation of our country's population in scientific research. Among the resistance of researchers to the adoption of gender studies in science, one can mention opinions based on idealizations about the universality, neutrality, and objectivity of science (Schiebinger, 2008).

In contrast, the Gender and Science relations direct research toward the dynamics of gender oppression that exist in scientific practices, environments, and results. The gender category not only allows us "understand the science and history of a given female scientist, but it is also a useful tool to escape anecdotal and hagiographic writings" (Santana, 2021, p. 64) about women. The authors Marta I.G. García and Eulalia P. Sedeño[4] (2002, p. 4) emphasize that this approach avoids disseminating the idea that only "exceptional" and "brilliant" women

[4] The authors draw attention to the "Curie Effect", a phenomenon that takes the example of the famous Curie family, holders of the largest number of Nobel Prizes – 5 members were awarded – to explain that historical studies must consider the family, social, and economic circumstances that enabled the rise of women in science (García; Sedeño, 2002). So that the characters are not burdened with the weight of the label of unattainable geniuses, it is important to highlight that many of them had extraordinary opportunities, something inaccessible to most women in their time. Many were daughters and wives of scientists, belonged to the upper class and had a series of other factors that facilitated their involvement in scientific activities.

can pursue scientific careers. Therefore, it is essential to highlight that "social, economic, institutional, cultural, and political" factors (Schiebinger, 2001, p. 96) determine the opportunities and possibilities for overcoming barriers and restrictions for women in each era. Thus, historical narratives must highlight the significant roles of women in science and examine how gender relations, as power dynamics, influenced their experiences, the development of the scientific field, and the conceptualization of science as a body of knowledge (Santana, 2021).

Consequently, studies "developed around the problem of how to increase the number of women working in science" (Schiebinger, 2001, p. 40). The disparity between the number of men and women in Physics and other scientific fields contributes to a lack of female representation in scientific research (Cordeiro, 2017). Making explicit the roots of the problem of gender disparity in contemporary science disciplines is essential to sustaining female interest and understanding the social obligations implicit in the area.

In this sense, knowing the history of women who contributed significantly to scientific disciplines, as well as showing the adversities to which they were subjected, is a crucial way of bringing women closer to science. By recognizing their contributions and fostering a sense of belonging, we can stimulate greater female interest in being part of the scientific community. The History of Science, there are several examples of women scientists, particularly astronomers, who played significant roles in the advancement of their fields of study.

Michael R. Matthews (1995) argues in favor of incorporating topics such as feminism in the teaching of the History and Philosophy of Science, aiming at a greater understanding of the Nature of Science, which in turn enhances science teaching. This is particularly important because, traditionally, the contributions of feminism and gender studies face considerable resistance in science, given that the its contents are mostly presented as the production of the "civilized white-heterosexual-First-World" individual, excluding all those who do not fit this reference model. Likewise, male practices are more valued and hierarchized compared to female ones" (Rago, 1998, p. 4). This perception is related to a historical process that disregards the collaborative contribution of women, Latinos, Africans, Asians, and others to scientific and technological development, which can lead to distancing these groups from pursuing scientific careers (Lima, 2015). Given this framework, it is crucial to develop the humanization of science, so that scientists are no longer viewed as geniuses.

In science education, adopting historical narratives that reinforce the identities of characters constitutes an important tool for helping teachers and students recognize science content as a product of the efforts of the diversity of people who have been involved in it over time (Sepulveda; Silva, 2021). In other words, "science can be considered as a language constructed by men and women to explain our natural world" (Chassot, 2002, p. 91). In line with recent research in Physics and Astronomy teaching (Lima, 2015; Maia filho; Silva, 2019; Pires, 2019, 2022; Santana; Pereira, 2021; Vieira; Massoni; Alves-Brito, 2021) that brings to light stories of women in scientific fields and discuss situations of sexism, discrimination, difficulties, and obstacles experienced by female scientists, this article aims to expose aspects of gender relations in the academic trajectory of the American astronomer Vera Rubin.

Vera Rubin's story is distinguished by her pivotal role in one of the most important episodes in Astronomy over the last century: the discovery of dark matter. Furthermore, she has always remained firm in her activism for women's equality in science. In one of her essays, Rubin (1996, p. 176) wrote, "there are enormously diverse styles of doing science, and the variety will increase as science becomes more egalitarian". Therefore, the focus of this theoretical research is: "What discussions about the challenges faced by women in the academic and scientific environment can be raised based on aspects of Vera Rubin's trajectory in Astronomy?"

Regarding the methodological premises, the text was written based on primary literature, including an autobiographical essay collection (Rubin, 1996) and transcribed interviews, and on secondary literature, consisting of two biographies of the astronomer (Mitton; Mitton, 2021; Yeager, 2021). By presenting aspects of Rubin's academic trajectory, an interpretative analysis was conducted to discussions the manifestation of gender relations in science. The main reference source for the analysis of gender relations is historian Londa Schiebinger (2001, 2008). The choice of studies in the field of Gender and Science from this author's perspective is motivated by her framework, which analyzes theory and practice in the North American scientific context to develop mechanisms for women's equality. To this end, three increasing levels of analysis are adopted: women's participation in science, gender in the cultures of science, and gender in the results of science (Schiebinger, 2008).

At the first level of analysis, using the disciplines of History and Sociology, the focus is on the increasing participation of women in science over time. Schiebinger (2008) explains that while women's participation has historically been encouraged through laws, gender equality incentives, and funding programs from development agencies, these efforts often serve merely as a "preparation" for women to be "successful" in male world. The second level of analysis raises questions about the cultures of science – made up of daily rituals, language, interaction, values, and practices – which have been predominantly developed by male professionals, as means of purported neutrality and objectivity. According to the author, this scientific culture is implicit in a set of assumptions, customs, and undeclared habits that have historically marginalized women. The third level of analysis, considered the most transformative by Schiebinger (2008), investigates how gender analysis in science, as it exposes its practices and structuring ideologies, can influence human knowledge. For the author, gender analyses should impact the content of science by contributing to the formulation of new questions and opening up new areas for research.

Furthermore, Schiebinger (2008) reflects on policies aimed at promoting gender equality in the scientific world in the United States and the challenges faced by feminist studies, based on the premise of understanding in depth how gender is expressed in science and society. Considering that the scientist Vera Rubin was American and was part of the context of scientific production in her country, it is appropriate to use the information gathered by the historian Schiebinger to specifically elucidate the situation of intellectual women contemporaneous to Rubin in the United States.

II. Brief biographical aspects of Vera Rubin

Vera Cooper Rubin (1928-2016) was born in Philadelphia, United States (Figure 1). She was a child curious about the Universe; at the age of 15, she built her own telescope and admired the astronomer Maria Mitchell[5] (Rubin, 1996). She attended Coolidge High School and pursued a career in Astronomy, obtaining her bachelor's degree from Vassar College[6] in 1948, a master's degree from Cornell University in 1951, and a doctorate from Georgetown University in 1954. In 1965, as a postdoctoral fellow, she joined the Department of Terrestrial Magnetism at the Carnegie Institution of Washington, where with her research colleagues, she investigated aspects of the Universe that resulted in surprising discoveries (Rubin, 1996).

In the same year, Rubin was the first woman to be authorized to conduct observations at the Palomar Observatory[7]. Throughout her scientific career, she served in several editorial and scientific boards and published almost 200 articles in the field of astronomy (Rubin, 1996). Vera Rubin is primarily recognized for her pioneering studies on the structure of galaxies, motions within galaxies, and large-scale motions in the Universe. Her remarkable findings helped convince astronomers that dark matter is an actual entity that makes up the Universe.

To situate the scientific status of the dark matter debate, throughout the 20th century, astronomers learned that the Universe is expanding and composed of galaxies that are moving apart from each other (Medeiros, 2024). In their quest to understand the new evidence, researchers began their investigations by asking questions about identifying the properties of galaxies, assuming that the findings would agree with classical physics. However, this idea was shaken by the divergence between the expected results for galaxies and those obtained observationally (Medeiros, 2024). As evidence accumulated from several studies over decades, the scientific community in Astronomy, Astrophysics, and Cosmology began to recognize that explaining this phenomenon required more matter in the Universe than previously thought.

[5] Maria Mitchell was the first professional astronomer in the United States. When Vassar Female College opened in 1865, Mitchell was the first female professor of astronomy and director of the observatory, even though she did not have a college degree. For Vera Rubin, Maria Mitchell's story was an exciting part of the tradition of her own country's scientific past, becoming a symbol of the emergence of women in the public world of science (Rubin, 1996).

[6] A women's college of education and liberal arts, located in Poughkeepsie near New York City.

[7] The Palomar Observatory is in San Diego and is part of the California Institute of Technology (Caltech). Rubin was the first woman legally authorized to carry out her observations at the site, which prohibited female scientists from carrying out their research on the grounds that it did not have adequate sanitary facilities for the presence of women (Rubin, 1996).

Fig. 1 – Vera Rubin at Vassar College in 2005 in front of a bust of Maria Mitchell. Source: Mitton; Mitton (2021, p. 295).

In honor of the scientists who studied this problem in the 1920s and 1930s, the extra matter was called "dark matter" (Medeiros, 2024). The first person to suggest the existence of dark matter to explain the dynamics of galaxies in clusters was astronomer Fritz Zwicky. Similar to Zwicky, around 1960, Rubin and her research collaborator, physicist and astronomer Kent Ford, began investigating the motion of stars and gas clouds rotating around the centers of galaxies (Medeiros, 2024).

The researchers' primary intention was not to provide evidence of dark matter's existence. However, their findings led to strong evidence that galaxies are immersed in halos of dark matter in a larger quantity[8] than all the ordinary matter particles in stars and gas clouds together (Rubin, 1996). The credibility of these observational results, and their implications, convinced even the most critical scientists regarding the possibility of the existence of this new type of matter, especially amid the advances in theoretical astrophysics and radio astronomy that were occurring at almost the same time (Rubin, 1986).

Rubin played a fundamental role in consolidating the existence of this new constituent of the Universe and in studies aimed to understand it. Her valuable contributions make her one of the leading figures in the scientific event of the dark matter discovery; therefore, it is essential to report her achievements. Although dark matter is currently undetectable by available instruments, it is known that its gravitational effects influence ordinary matter and it is one of the essential components for understanding the nature, origin, and evolution of the Universe (Rubin, 1996).

Important awards were given to the researcher in recognition of her contributions to science. Some of these were the Dickson Prize in Science from Carnegie Mellon University and the Weizmann Prize for Women and Science in 1994 and 1996, respectively, and the Gold Medal of the Royal Astronomical Society of London in 1996 (Rubin, 1996). In 1993, US

[8] It is now known that the Universe contains about nine times more dark matter than common/ordinary/visible/baryonic matter (Ferreras, 2019).

President Bill Clinton awarded her the National Medal of Science and appointed her to the honors committee two years later.

In addition, Vera Rubin's immense contributions to scientific knowledge, throughout her professional life, the scientist was also an activist for advancing the cause of women in science. In the words of astronomer Jocelyn Bell Burnell, "she was a trailblazer in two ways: detecting the presence of dark m6atter through the way galaxies rotate; and arguing for the recognition and inclusion of women in astronomy" (Burnell, 2021, p. 7).

III. Discussions on Gender and Science based on Rubin's academic trajectory

At a conference titled "The Recruitment and Retention of Women in Physics", sponsored by the American Association of Physics Teachers, the American Institute of Physics, and the American Physical Society in the 1990s, astronomer Vera Rubin was invited to give a lecture to the 148 physicists in attendance, only 19 of whom were women. The purpose of the event was to discuss issues related to the experience of women studying Physics at universities (Forman, 1991). Rubin shared three assumptions with the audience, who then offered their views on the topic:

> *There is no problem in science that can be solved by a man that cannot be solved by a woman; Worldwide, half of all brains are in women; and We all need permission to do science, but for reasons that are deeply ingrained in history, this permission is more often given to men than to women* (Rubin, 1996, p. 174).

Rubin explains that, for a person to advance in their professional career, they need support throughout their journey, whether from parents, teachers, academic staff, financial sponsors, mentors, and colleagues. Incentives for women to enter and remain in the scientific field involve, in addition to personal interest in science, the influences of those close to them, family values that favor education, and institutional support. The astronomer's perspective aligns with the second level of analysis proposed by Schiebinger, which addresses the gender dimension within scientific cultures. Female scientists encounter certain cultural expectations throughout their lives that may lead to their withdrawal from the scientific environment. As a result, "even women who have distinguished themselves in science sometimes suffer from a form of self-doubt" (Schiebinger, 2001, p. 124).

One of the areas in which Rubin was actively involved was highlighting gender disparity in professional environments. Like countless other women who were discouraged as students, Rubin was told by her physics teacher, "As long as you stay away from science, you should do okay" (Rubin, 1989). This comment can be examined within the second level of Schiebinger's framework. Its content reveals the consequence that "because they are subjected to close scrutiny, women develop extremely high standards as a prerequisite for entering and remaining in science, sometimes feeling that they must be more brilliant than men" (Schiebinger, 2001, p. 126).

On the other hand, considering the second level of analysis, it is important to recognize that, like men, women do not constitute a homogeneous or unified group (Sepulveda; Silva, 2021). By acknowledging this, the concept of intersectionality "considers that the categories of race, class, gender, sexual orientation, nationality, ability, ethnicity, and age group — among others — are interrelated and shape each other" (Collins; Bilge, 2020, p. 16). Intersectionality serves as an analytical tool for understanding and explaining the complex relationships shaped by the diversity of social factors that define a person's identity in society. Therefore, the oppressions experienced by one scientist cannot be generalized to all.

Therefore, using Rubin's example, her experiences can be contextualized by characterizing her as a cisgender, white, American, heterosexual woman belonging to a socioeconomic class that afforded her the material conditions necessary to access higher education at a time when few women could do so. However, despite her privileged position, Rubin's path to achieving her scientific goals was tortuous. Years later, when her professor discouraged her from pursuing a career in science as an astronomer while attempting to enter the graduate program at Princeton University, she received the response, "We do not admit women to graduate studies in Astronomy" (Rubin, 1996, p. 183). This university only began accepting women into its graduate program in Physics in 1971 and in Astronomy in 1975.

Since the Cold War, the United States has aimed to increase the participation of both men and women in science. Between the 1960s and 1970s, laws were enacted to promote women's equality, including the Equal Pay Act, the Equal Employment Opportunity Act, and efforts to apply Title IX – a federal law that protects individuals from gender discrimination in schools or educational programs funded by the federal government – to science, in order to increase the number of women and minorities in the field (Schiebinger, 2008). Following increased admissions to colleges and universities, a growing participation of women in science has been observed over the years, which serves as a strong motivation for investigating gender relations in this context and aligns with Schiebinger's first level of analysis.

In the 1960s, while studying galaxies at the Palomar Observatory, Rubin experienced firsthand the effects of gender discrimination. The dome of the telescope where she worked had only one bathroom designated exclusively for men. As a form of protest, Rubin drew a picture of a woman in a skirt and affixed it to the door of that bathroom[9] (Yeager, 2021). This incident, which aligns with the second level of analysis, marks the beginning of the events that culminated in the astronomer's activism for women's equality in Astronomy.

In 1964, Rubin was invited by the American Institute of Physics to visit schools as a way to convince young students that women could succeed in physics. Although she appeared at several schools to present her research on the Milky Way, she noted that on these occasions, "never been any contact with teachers or principals, or any discussion of science teaching, women in science, or the like" (Mitton; Mitton, 2021, p. 272). In the early 1970s, the American

[9] The drawing remained on the door for the four days she spent at the observatory, but when she returned a year later, it was gone.

Astronomical Society (AAS), based on a collection of gender indicators within the Society, identified the lowest percentage of women ever; no woman had ever held its presidency; only two women had served as vice presidents, compared to fifty-eight men; and the only award given to women was the Annie Jump Cannon Award[10], which was explicitly granted to women (Yeager, 2021).

The presence of women in scientific awards is a crucial indicator for examining the relationship between Gender and Science. In the History of Science, several notable women were recognized only belatedly, often decades after their achievements (Rossiter, 1982). Scientific recognition and awards confer power and prestige within the community, reflecting the hierarchical segregation and underrepresentation of women in scientific and technological fields (Santana, 2021). According to Schiebinger's third level of analysis, gender relations are embedded in the outcomes of science and highlight the need for an attitudinal shift within society and scientific institutions, which have long failed to properly recognize or provide adequate opportunities for women. This is because gender-based biases have shaped knowledge production for so long, thereby perpetuating the exclusion of women from scientific disciplines in different ways.

Although it is essential to have awards that recognize the merit of female scientists' research, which might otherwise be overlooked in awards open to both men and women, we must adopt a feminist perspective that does not reduce conventional stereotypes of men and women, as seen in difference feminism. Popularized in the 1980s, difference feminism posits that the inclusion of more women in research is justified because they approach science differently, with distinct values and ways of think thinking. This is an openly sexist idea, as it romanticizes the feminine qualities imposed on women (Schiebinger, 2001). If we truly aim to progress, such notions cannot form the epistemological foundation for a new theory and practice in science.

In 1972, Rubin was invited to lecture at the Philosophical Society of Washington — a science education organization that hosted events for researchers to share their recent work — held at the prestigious Cosmos Club[11]. At the venue, women were not permitted to enter through the front door, only through a side entrance (Yeager, 2021). Using the second level of analysis, this restriction highlights the exclusion of women from spaces of scientific knowledge dissemination solely because of their gender. Despite the indignation, Rubin presented her paper, "More than you ever wanted to know about the Andromeda Galaxy", to her peers. Reflecting on the incident later, she stated that she "no longer accept the discriminatory practice of being forced to use a special entrance" (Mitton; Mitton, 2021, p. 280). The club only began

[10] American astronomer Annie Jump Cannon (1863-1941) established the Harvard spectral classification system in 1912, classifying the spectra of more than 350 thousand stars and revolutionizing the way scientists categorized them (Lee, 2020).

[11] The "Cosmos Club", a private social club founded in 1878, served as a gathering place for the academic, professional, and political communities in the U.S. capital to exchange studies, engage in conversations, and share culture (Cosmos Club, 2022).

admitting women after the threat of legal action under Washington's 1988 Anti-Discrimination Act[12]. This experience led Rubin to take a public stand, frequently addressing sexism and the underrepresentation of women, particularly in science, through speeches and lectures.

In 1973, Rubin participated in the preparation of a report[13] by the AAS that presented detailed statistical data showing that "women astronomers face greater obstacles in almost all aspects [number of members in the AAS; positions and salaries; research productivity; presence in postgraduate courses] of their professional careers than their male counterparts" (Cowley *et al*., 1974, p. 422). It was also noted that female appointments to the teaching staff at the 28 universities investigated were considerably lower than those of men; the salaries of married women were lower; most women with doctorates in Astronomy occupied less prestigious and less stable positions compared to their male colleagues, likely reflecting gender discrimination in hiring. Additionally, there were differences in access to publishing in top journals, despite women having the same productivity as men, possibly because they felt discouraged from submitting or believed their studies were insufficiently relevant for acceptance.

Consequently, the AAS board acknowledged these results, accepting the report unanimously and publicly endorsing the view that "the astronomical community can only be enriched by the employment and acceptance of women as colleagues" (Cowley *et al*., 1974, p. 422). This is a significant achievement for women astronomers in this context. These results reinforce that the second level of analysis concerning gender in science cultures is also relevant to hiring and retention practices at universities and in academic careers (Schiebinger, 2008). Therefore, it is essential to promote academic cultures in which women can be active and assume prominent roles.

From this perspective, Rubin highlights that one of the obstacles women faces is the language used as a structuring discourse in science. In a letter[14] to the editor of Physics Today published in 1978, she wrote that although efforts to include women were increasing, the language used reflected that science was a field with clear gender demarcation (Rubin, 1978). She noted that language should be more inclusive to demonstrate that anyone, regardless of gender, could pursue a career in science. The scientist concluded that for a more inclusive scientific community, "changes in language may have to lead the way" (Rubin, 1978, p. 15). A few years later, Rubin critically commented on the article[15] "How to Address the American

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[12] The law, recognized and declared as a civil right, ensures that individuals are free from discrimination based on race, creed, color, national origin, sex, sexual orientation, or the presence of any disability (Washington State Legislature, 1988).

[13] The report titled "Report to the council of the AAS from the working group on the status of women in astronomy - 1973" can be accessed at the following link: <https://adsabs.harvard.edu/full/1974BAAS....6..412C>.

[14] The letter titled "Sexism in Science" published in Physics Today magazine in 1978 can be accessed at the following link: <https://pubs.aip.org/physicstoday/article-abstract/31/1/15/431745/Electron-beam-fusion?redirectedFrom=fulltext>.

[15] The aforementioned article, first published in 1951 and republished in 1961 and 1981, can be accessed at the following link: <https://users.physics.ox.ac.uk/~lvovsky/597/Darrow.pdf>.

Physical Society” authored by physicist Karl Darrow, which instructed researchers on how to give lectures, directing the instructions only to men. In response, Rubin expressed her discomfort by pointing out that when the feminine pronoun appears in the text, it explicitly refers to a ballet dancer falling face down on the floor:

> *Male world of Physics? I would hope that if Karl Darrow were addressing the APS today, he would recognize that not all physicists are male. After seven paragraphs of instructions to male speakers to a male audience, he finally introduces a female pronoun: ‘It may be instructive to see a dancer fall on her face, pick herself up, and resume her part in the ballet, but for practically everyone else it is acutely embarassing. In the male world of Physics of Darrow, presumably only females fall on their faces. And even the editorial comment accompanying the article calls his instructions ‘as appropriate today as they were when they were written.’. At least the falling dancer could have been male* (Rubin, 1982, p. 121).

In light of this, it is worth discussing how consumer culture in the United States values images that typically project societal expectations of what a scientist should look like. According to an iconographic survey conducted in the late 1990s, when students were asked to “draw a scientist”, 70% depicted men, around 16% depicted scientists clearly identified as women, and 14% created ambiguous drawings in terms of gender, with most scientists portrayed as Caucasian (Schiebinger, 2008). The unstated assumptions and values held by members of the scientific community, despite their claims of scientific objectivity and neutrality, are in fact expressions of gender within scientific cultures. These cultures, far from being neutral, carry traditions and practices that have developed over time without women’s participation and often in opposition to their inclusion (Schiebinger, 2008).

Thus, considering the power of images to project dreams, hopes, appearances, and behaviors, it is even more crucial to highlight the female scientists who made great contributions to Physics and are still invisible today. In our society, scientists are often envisioned with specific characteristics influenced by prevailing gender role conceptions. Traditionally, when asked to “draw a scientist”, the vast majority of students depict them as male (Finson, 2002; Knezz, 2019; Kosminsky; Giordan, 2002; Ribeiro; Silva, 2018). The author of the article, based on the pronouns chosen, also imagines a scientist as a man, while the individual who would supposedly fall face down on the floor is assumed to a woman — a notoriously sexist assumption.

In the early 1980s, the National Academy of Sciences (NAS) and the National Academy of Engineering (NAE) established programs aimed at advancing women’s careers in these fields by providing exceptional research grants (Schiebinger, 2008). Rubin’s influence grew significantly following her election to the NAS, where she became part of the small minority of female members in the most prestigious scientific organization in the United States. Invited to join panels, committees, and councils, Rubin amplified her efforts in advocating for gender equality (Mitton; Mitton, 2021).

Vera's concerns extended beyond Astronomy and touched upon science as a whole and its relationship with society. In 1981, the United States Congress passed a law requiring the National Science Foundation to submit a biennial statistical report on the participation of women and minorities in science and engineering. The Visiting Professorship for Women in Science and Engineering program was established as part of the agency's response to increasing political and social pressure. Rubin applied for this position and expressed that in, in addition to teaching, she would "also be available to provide advice, counsel, and mentorship for women at all levels" (Mitton; Mitton, 2021, p. 287). This action reflected a growing awareness within organizations that gender inequality was not only an issue for the individuals affected but a broader challenge for science itself.

In 1982, Rubin joined a large crowd of women in Lafayette Square, across from the White House, at a rally organized by the National Organization for Women. The demonstration called for ratification of the proposed 27th Amendment to the United States Constitution, known as the Equal Rights Amendment, which unequivocally declared that "equality of rights under the law shall not be denied or abridged by the United States or by any state on account of sex" (USA, 1972, p. 1523). At first glance, it was an urgent call for social justice. However, many feared the consequences of challenging established conventions, and as a result, the number of states ratifying the amendment fell short of the total needed to make it law (ERA, 2018). The AAS was one of several professional organizations that refused to hold meetings in states that had not ratified the proposal (Burbidge, 1978). Some critics argued that the organization was moving too far away from its focus on Astronomy and into political and social issues.

The creation of laws serves as an essential mechanism for promoting equality between men and women. Additionally, the allocation of extraordinary research funds by agencies specifically for women helps make them more competitive in the male-dominated scientific world (Schiebinger, 2008). This is particularly relevant since competitiveness is typically viewed as a trait more closely associated with men within the prevailing scientific culture, of which women are also part.

American institutions focused on advancing science were slow to equally the issues raised by women. Among them was the International Astronomical Union (IAU), whose Secretary General, Derek McNally, explicitly stated in 1990, "IAU regards itself as a body devoted to the promotion of astronomical science and to this extent has tried not to cross the line into matters of social concern" adding that the status of women in Astronomy was an "essentially social problem" (Mitton; Mitton, 2021, p. 288). The IAU's reluctance to abandon its conservative stance was likely a disappointment to Vera Rubin, who had been involved with the institution for many years, including chairing its Commission on Galaxies from 1982 to 1985. She also helped organize a special session titled "Women Worldwide in Astronomy" during the 1988 IAU General Assembly (Rubin, 1988).

Rubin's proposal was presented to the full IAU executive committee, with the requirement that "there be no interference between this 'specialized' session and any of the scientific meetings" (Mitton; Mitton, 2021, p. 288). The formal report of the session was not included in official IAU publications. However, Vera Rubin and the commission chair co-authored a report in the journal of the Astronomical Society of the Pacific. It documented that women continued to face several common problems, such as discrimination, which, though less overt than in the past, still persisted; their abilities, responsibilities, and contributions were consistently undervalued compared to their male colleagues; and societal prejudices continued to be perpetuated in both scientific and educational environments (Rubin, 1988). The report also highlighted the strong attendance and positive response from the organizers, as well as the possibility of holding a similar event at a future IAU General Assembly.

Given this scenario, it can be inferred that the justification provided by the IAU for not actively joining the fight for equality for women astronomers, considering it an agenda independent of the scientific field, is based on a naive positivist view of Western science, accepted by a significant portion of the population. This view attributes universality to science, often overlooking human cultural diversity, and is reflected in the widespread perception that scientists are neutrals individuals, independent of the socio-historical context in which they operate (Filho; Chaves, 2000). However, science is not a neutral and impartial activity; on the contrary, "gender inequalities constructed in scientific institutions influenced the knowledge produced within them" (Schiebinger, 2008, p. 174). Generally speaking, there is a certain difficulty in adhering to gender analysis in the physical sciences, which have resisted this approach. Several reasons contribute to this lack of interest. At first glance, the objects and processes in Physics do not seem to be explicitly influenced by gender, appearing to play no role in the discipline (Schiebinger, 2008). Still, to genuinely understand this, gender analysis must be integrated with scientific practices.

To this end, scientists can engage in a series of actions. It is essential for students and teachers to be trained to integrate gender analysis into their research from the planning stage, and that examples continue to be gathered on how such actions can transform theory and practice in subfields of science (Schiebinger, 2008).

Discussions about the role of women in Astronomy were long dismissed by the IAU, which argued that these were political issues rather than scientific ones. This effort to maintain apparently apolitical character for international scientific societies resulted in a disregard for actions that could protect the rights of female astronomers. At a General Assembly, challenging the IAU's position, Rubin, along with two other colleagues, stated: "We believe that measures which will increase the numbers of women in astronomy and increase their participation in astronomical activities worldwide are legitimate areas of concern for the IAU" (Mitton; Mitton, 2021, p. 289).

By the late 1980s, Vera Rubin was actively involved in campaigns to make women in science visible and influential at the highest levels of their careers. In 1989, Rubin was appointed as a member of the National Research Council (NRC) for Physics and Astronomy, the operational arm of the NAS. As the only female member, Rubin sent a letter to the board chair in which she enclosed an article citing data supported her argument that the all-male committees perpetuated low female participation and highlighted the consequences of the NAS's failure to address this issue (Mitton; Mitton, 2021). She urged the Physics and Astronomy Council to lead a change in behavior regarding the issue, but her intervention did not produce the expected results.

In this context, in the early 1990s in the United States, the Academies' Committee on Women in Science and Engineering (CWSE) collaborated with Congress and universities to formulate a policy aimed at supporting women's careers, increasing female representation in science, expanding funding for research led by women; and offering guidance for demanding fairer wages (Schiebinger, 2008). Political actions like this, advocating for female equality, gain importance when compared to real examples from the time, such as Rubin, who in 1990 again wrote a letter addressing the issue of low female participation and called on other female members of the NAS to do the same. The response she received was to forward the letter to the various councils, committees, and section presidents so that the topic could be placed on the agenda for discussion at the next meeting. Despite this, few changes have occurred. In protest against the indifference towards statistics on women's participation, in 1996, she declined an invitation to join the NAS committee entitled Women in Science and Engineering. Her opinion was that:

> *As long as the problems of "Women in …" are women's problems, I doubt that they will improve. It has to be everyone's problem. But on every committee on which I serve, it is only the woman who brings up the women's problems. So, if you can turn it into a NAS problem, which it surely is, headed by a man who really cares, some progress might be made* (Mitton; Mitton, 2021, p. 294).

More than a decade later, in 2007, when Vera Rubin was nearly 80 years old, the National Academies finally addressed the issue categorically by issuing a lengthy report from the Committee on Maximizing the Potential of Women in Academic Science and Engineering (National Academy of Sciences *et al*., 2007). Vera's conclusion regarding this achievement was that "Political changes are sustainable only if they created a 'new normal' a new way of doing things [...] The current situation is untenable and unacceptable" (Mitton; Mitton, 2021, p. 295). Some changes have indeed occurred; the percentage of new female members and associates at the Academy of Sciences increased to a record number in 2019, but it still has not reached gender parity.

Throughout Rubin's career in science, she consistently maintained an inquisitive stance towards the discriminatory situation that in women faced in the field. She also formulated alternatives with the resources available to her that other female scientists could exercise their potential under the same conditions as their male colleagues. Coupled with this was her indignation towards that reality, which kept her persistent and provided her a clear sense of purpose in her actions. The gratitude of those women who were directly impacted can be summed up by what astronomer Wendy Freedman wrote in a letter to Rubin in 1986: “Thanks for speaking out. I often get the feeling that if things are any easier for women like me, it’s because women like you have taken the time and energy to help make it so” (Mitton; Mitton, 2021, p. 296).

IV. Closing remarks

The scientific disciplines that constitute modern science originated simultaneously with the exclusion of women and minorities, who remain underrepresented in this field. Due to being rigorously and systematically marginalized from academic environments, they were unable to participate in what is seen as the public and institutionalized construction of science.

With this in mind, the culture in which we live goes beyond institutions, legal regulations, and documents, as it is full of assumptions and undeclared values, which influence ideas and behaviors. Western science’s methods, techniques, and epistemologies are often admired as a producers and holders of objective and universal knowledge, transcending these cultural precepts. However, science is clearly not a neutral value when it comes to gender relations, and a feminist perception guides recognize this aspect. Therefore, it is important to develop tools for gender analysis, especially in areas that have resisted and continue to resist, which requires substantial changes in cultural structures, methods, results, and scientific content.

In this sense, when addressing the insufficiency of materials in Physics that cover gender frameworks, Schiebinger (2001, p. 293) asks, “Does the fact that electrons do not have gender in the manner of certain objects of inquiry in the life and social sciences make Physics immune to feminist analysis?” To answer this question, one must understand that modern academic disciplines are arbitrary ways of selecting knowledge, historically created by humans and not inherently natural. Therefore, Physics is undoubtedly susceptible to feminist gender analysis. Creating space for participation and encouraging women to remain in science, aiming for full inclusion, can lead to significant changes in human knowledge (Schiebinger, 2008). Given this context, it can be inferred that historical narratives about women scientists, which are often underexplored in science-related disciplines, especially physics, can stimulate fruitful reflections.

As discussed in this article, examining the academic trajectory through a biographical study of the notable astronomer Vera Rubin allows us to highlight several aspects related to the practice, training, and work of scientists in this field. For example, from a feminist perspective, it was possible to underscore the consequences of the sexual division of scientific work, such as the neglect of women in science production environments, discrimination between men and women regarding recognition of their intellectual contributions; the need for support to enter and remain in academic institutions; the creation of public policies that encourage and promote research led by female scientists, among other issues.

Thus, the History of Science emerges as one of the pathways for focusing on the promotion of gender equality in science, in addition to being an alternative for repairing historical invisibility and breaking with the structure that perpetuates gender inequality. It is clear, then, how important it is to develop more work on the History of Science that connects the category of gender to the Nature of Science. Given the male and female researchers constitute groups of diverse people, as highlighted by intersectionality studies, it must be emphasized that gender relations permeate several social factors (Collins; Bilge, 2020; Sepulveda; Silva, 2021).

The specialized literature in the area of science education, both national and international, has been emphasized the importance of teachers and students not only learning and teaching the content of science but also developing an understanding of the nature of science (Ferreira; Custódio, 2022; Moura, 2014; Peduzzi; Raicik, 2020) given the persistent naive understanding of the process of constructing scientific knowledge. In this way, science is perceived as a product of human actions. Regarding the contributions of incorporating the History of Science into teaching, the following benefits stand out: humanizing science content, increasing interest and motivation, offering challenging and reflective science classes, stimulating critical thinking, and providing a comprehensive understanding of the content by mapping its development and improvement over time (Matthews, 1995). Recognizing the potential of historical approaches to humanizing science, writing about the past of scientists is a way to maintain plurality and diversity in science. This approach creates a more welcoming environment by making women feel represented, and demystifing the idea that scientific activity is exclusive to men. As a body of knowledge, science reflects social issues, including gender-based oppression. Therefore, it is crucial to emphasize the increasing discussions about gender and science being held in the educational field.

Given the importance of emphasizing the role of collaboration in science, the figure of Rubin emerges from the dark matter episode as an astronomer whose scientific career deserves visibility, especially in the field of science education. The biographical study of her life trajectory, from a feminist perspective, was able to reveal aspects of gender relations in participation, culture, and scientific outcomes. In order to deepen the discussions, reading the article highlights the opportunity to evaluate the environment in which Rubin worked – whether there were other female scientists, whether they were supported by colleagues, and what these personal relationships were like – as a way of incorporating gender analysis into the interactions that occur within scientific communities.

Beyond demanding a more significant female presence in science, we must recognize "Who are the great women scientists? What are their achievements? What are the experiences of women in universities, industries, and government laboratories?" (Schiebinger, 2008, p. 272). It is therefore evident the importance of works that are committed to highlighting the contributions of women in the History of Science and deepening the gender discussions that permeate the academic trajectories of these women. In Astronomy there are several other examples of notable female astronomers, such as Elisabeth Hevelius (1647-1693), Caroline Herschel (1750-1848), Annie Jump Cannon (1863-1941), and Cecilia Payne-Gaposchkin (1900-1979).

Finally, it is imperative to highlight those scientists who, like Rubin, contributed to supporting, assisting, and encouraging future generations of women in their research fields. Establishing a support network and acting as role models for inspiration are actions that help promote the retention and success of women in science. In a 1992 interview, when asked what **it would take to improve gender inequality in science**, Rubin responded, "it will take people who want to see it change. Or it will take a political climate that really believes in affirmative action, that really believes that opportunities should be made equally available to all" (Rubin, 1996, p. 161). Achieving this requires researchers, scientific policies makers, and science educators, particularly those in Physics, to reflect on the normalization of the scarce female presence in scientific careers and how it relates to societal expectations and interactions between men and women, revealing and formulating alternatives to the underlying causes of this phenomenon (Cordeiro, 2017).

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