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## Henrietta Leavitt's key role in the development of the period-luminosity relation in astronomy<sup>+</sup>\*

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### Abstract

*This argument draws from the pillars of Science Teaching, History, Philosophy, and Sociology of Science, as well as the gender issue in the scientific world, argued that a contextualized approach to the teaching of science through the discussion of a historical event in which a woman plays a central role can contribute to the engagement of women in specific fields. A stand-out example of that is that of Henrietta Leavitt (1868-1921), a computer at the Harvard College Observatory, who, in this capacity, formulated the Period-Luminosity Relation (PLR), a tool which would later be essential for the development of methods for estimating large distances in space. One of the people who continued to study the PLR was Harlow Shapley (1885-1972), whose research was much more frequently quoted by his peers than that of Leavitt's. Considering the gender dynamics that marked Leavitt's life, especially in the process of establishing the PLR, this study aims to clarify the role historically attributed to her in that specific research context through documentary investigation. The analysis of the social and gender relations therein is founded on Bruno Latour's Actor-Network Theory*

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<sup>+</sup> O protagonismo de Henrietta Leavitt na elaboração da relação período-luminosidade da astronomia

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*and Londa Schiebinger's Feminist Epistemology. The results indicate that, in addition to his in-depth research, one of the reasons for Harlow Shapley's prominence among astronomers of the time might have been his academic influence. The findings also reveal that the underrepresentation of Henrietta Leavitt's role has been gradually decreasing over time, thanks to studies of the history in which she played a significant part.*

**Keywords:** *Variable Stars; Astronomy Teaching; Actor-Network Theory; Women in Science.*

## **I. Introduction**

A widely known fact to those who study history is that the so-called Western Civilization is ruled by patriarchy, and that women have been denied or heavily restricted in their right to study science or to be recognized for their studies. This distancing from women still persists in the Exact Sciences despite the struggle for equality (CARVALHO; RABAY, 2013; LOMBARDI, 2005). Fewer women enroll in university courses related to these areas than men, and more women quit them than their male counterparts (AGRELLO; GARG, 2009). In line with this trend, the field of Astronomy is also predominantly male, despite the increasing number of women in it, and the struggle against female invisibility. Women have been responsible for great advances in Astronomy (VIEGAS, 2014) in Brazil and in other countries. Despite this growth, the number of women in the area is still much lower than that of men. For example, among countries with more than 100 members in the International Astronomical Union, Brazil ranks sixth in percentage of women's participation, at only 24% (IAU, 2021).

In the educational context, there is a noticeable deficiency in the approach of Astronomy-related subjects, both due to the lack of didactic materials and the absence of properly trained teachers. However, according to Pires and Peduzzi (2021), "through the didactic use of History and Philosophy of Science, it is possible not only to demonstrate the scientific results, but also to identify the context in which this knowledge was constructed"<sup>2</sup> (p. 159). This would therefore be a way to increase the interest and the participation of women in the area, beginning with an understanding of the minority context. As for the History of Astronomy, it is no exception to the possibility of addressing the problem of the scarce presence of women in the scientific field.

Although its numbers still reflect gross inequality, Astronomy has always been more welcoming to the participation of women. For several centuries, women have been present in

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<sup>2</sup> Translated from: "por meio da utilização didática da História e Filosofia da Ciência é possível não somente demonstrar os resultados científicos, mas também identificar o contexto de construção destes conhecimentos".

observations of the sky, especially since the early 1800s. Not rarely, they collaborated with male family members (fathers, brothers or husbands), which contributed to their work being labelled as not exactly original (DOBSON; BRACHER, 1992). By the late nineteenth and early twentieth centuries, more women were able to enter Astronomy, and among them the “Harvard Computers” stand out. These were women who worked on the cataloging of stars and astronomical objects at the Harvard College Observatory. Hired by the director Edward C. Pickering (1846-1919), these women helped the Observatory to become the world’s leading reference in astronomical photometry studies.

The works performed by them were monotonous and tedious, which did not appeal to men. In addition, the salary received by the women was lower than that offered to men when they were hired to the Observatory (JOHNSON, 2005). One of these computers was Henrietta S. Leavitt, who, among other contributions, was the first to observe and present the Period-Luminosity Relation (PLR), which is the relation between the period of variation and the luminosity of Cepheid variable stars, i.e., stars whose luminosity varies with time in a cyclic pattern (SOBEL, 2016). Harlow Shapley (1885-1972) was an American astronomer who studied RR Lyrae stars whose luminosity also varies periodically. He was well known for his measurements of the Milky Way, but also for his studies of the PLR and the presentation of the Luminosity-Period Curve (LPC), a continuation of Leavitt’s work.

Taking these studies developed by Henrietta Leavitt and Harlow Shapley as a starting point, this work employs a documentary analysis about Leavitt’s history and the development of the PLR. As a theoretical-methodological framework to approach the social issues in Astronomy, it applies the scientific studies summarized in the Actor-Network Theory. In essence, according to Latour, the word “actor” serves to identify anyone who acts on the studied process, “network” defines elements that can be traced along the translations carried out by these actors, and “translation” correspond to the transport or transformations that occur in the network. The network is not a concept, but rather a tool that helps us describe an event while it was still in progress (RICHARD; BADER, 2009; SITKO, 2019).

Given the focus of this study on the story of a woman, another epistemology that supported this analysis stems from the feminist epistemologies, more specifically the one proposed by Londa Schiebinger, which also presents science as a collective construction. Schiebinger (2001) highlights the work done by women, seeking to understand how they did/do science and why they would be seen differently in the scientific environment. Thus, the historical analysis of a specific episode was conducted, investigating Henrietta Leavitt’s participation and prominence in the development of the PLR and listing possible reasons for her lack of recognition, in order to address gender-related difficulties<sup>3</sup> that women scientists

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<sup>3</sup> Following the definition of Londa Schiebinger (2001), “gender should be regarded as the multidimensional and dynamic understanding of what it means to be man or a woman within specific social contexts” (p.14) (Translated from: “*gênero deve ser entendido como a compreensão multidimensional e dinâmica do que significa ser homem ou mulher dentro de contextos sociais específicos*”).

deal with throughout their education, as well as the influence that a certain historical, social and political context characterized by the participation of women can have on science.

Recent studies (SILVA; ARANTES, 2017; SILVA, 2019) show how a curriculum that disregards gender issues in science can impact the number of young girls who wish to follow a scientific career. Thus, this work sought to highlight that science is a collective construct, of which women are part, and that a teaching approach that addresses issues such as these is fundamental for the critical development of young girls, encouraging them to participate in the construction of science (CHASSOT, 2019). In this sense, this paper presents a documentary analysis of articles, news from newspapers and diaries of the period between the hiring of Leavitt and the complete establishment of the PLR, in order to show how the astronomer figures in the Network of which she was part. In addition, we highlight the intersection between the ideas of Bruno Latour and Londa Schiebinger as a theoretical-methodological framework, as a different way to understand the power relations linked to gender which were so ingrained in the social, professional, and academic environment at that time.

## **II. Science as a construct of society**

The theoretical foundations employed here aim to present an epistemological reflection on gender and the History of Science, along with the challenges, needs, and possibilities of discussing the contributions of women throughout the History of Science. This shows that science is a male-dominated institution that has consistently rendered women invisible across time. It is worth mentioning that, despite the obstacles created by this social organization, some women have managed to assert themselves and could not be overlooked by History, as is the case of Marie Curie. However, it is important to point out that these are exceptions, i.e., the vast majority of women who have worked in science have gone unrecognized by the general public because they have been made invisible. This does not imply the absence of other women in the sciences, but rather highlights their invisibility, in spite of their contributions. It is therefore the responsibility of science historians precisely to find these women and to narrate (and interpret) their stories.

### **II.1 The circulation of information in Bruno Latour's Network**

It is very common, when dealing with the History of Sciences, to speak of “a science contextualized to its historical moment”. Bruno Latour’s scientific studies are presented as something that completely surpasses this notion of contextualization. Drawing an analogy, one could argue that a traditional view of the History of Science persists which treats the sciences as an aspect of society enclosed within a bubble. This bubble, in turn, is immersed in a scene, which, in other words, means that science is immersed in a context that can be social,

political, economic, cultural... Through Latour's Actor-Network Theory (ANT<sup>4</sup>), this paper attempts to overcome the paradigm that regards the "History of Science" and the "History of Society" as parallel fields by approaching both as one single entity. According to him, science and politics, culture and nature, the social and the technical go together—none contextualized by the other, but all united in a network. Revisiting the analogy, within the ANT framework, there is no bubble: science is an integral part of that network. A network is formed by several threads, each one of which represents a certain aspect that leads to the circulation of a piece of information (LATOURE, 2012; 2017). In other words, this information travels through a thread that can correspond to science, politics, economics, or human relations. This thread is interconnected through nodes, or links, to other ones, resulting in a network of interactions through which the information can circulate.

This enables the identification of aspects not typically perceived as integral to science, but still fundamental for scientific production, such as funding, political interests associated with the continuation of specific research, and cultural and religious influences. It also facilitates the methodological execution of the analysis. In short, all through history, science has not been a closed and compartmentalized box where only scientific and technical knowledge prevails, but rather a construction carried out in the "open" by countless groups of people, things, ideas and cultures. This explains why research delving into the realms of History, Philosophy and Sociology of Science is so necessary and should be articulated with teaching. Considering that the main focus of this work is to understand how a **woman** participated, and was seen, in a historical episode, it was necessary to take into account all the factors associated with the engagement of women in the sciences, whether they be social, economic, cultural or political.

Neither an object nor the social itself has an inhuman aspect to it; everything is shaped by those who produce it, and there is no "outside world" to the sciences. What exists are sciences in the form of "collective experimentation" that humans and non-humans<sup>5</sup> sustain and build together. Latour rejects the idea of dividing History into two parts, arguing that, at one point, the construction of a fact or concept occurs due to scientific development; at another, due to social, economic, or political relations; and at yet another by both. When these situations occur, a network of connections of the fact or concept is built. In this way, scientific studies trace the connections "when they exist" (LATOURE, 2000; 2017).

Through the analysis of the historical episode under consideration, this work seeks to show that there are no two distinct domains in a given study; there is no correspondence or gap. What does exist is what Latour (2017) defines as a circulating reference. That is, a set of

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<sup>4</sup> Acronym of Actor-Network Theory. The acronym "ANT" is a reference to the insect, which Latour uses as an analogy for the scientific work; he proposes that one should look at the "ant work" in a study.

<sup>5</sup> According to the Actor-Network Theory, not only people can participate in the construction of the event, but also non-humans, whether these be instruments, laws, objects of study, etc. As an example, Latour (2017) delves into a long discussion about the relationship between Pasteur and the microbes: Pasteur was the human who acted in the "discovery of microbes", but the microbes themselves also acted as non-humans in this event.

innumerable practices that lead to an articulation of propositions, or even to a chain formed by several elements that produce and enable a series of transformations on the area. The entire network, regardless of its size, is summarized as a single “black box”<sup>6</sup>. A historical analysis can allow us to observe the closure of a black box and see the various parts that constitute it, each with its relatively independent function and purpose.

The network is integrated by events and actors (human and non-human) that act upon it. The term “actor” refers to a moving set of entities around the concept. An actor is never alone, and its action is displaced and translated. Network is a tool that helps to describe the event, which occurs with the succession of translations<sup>7</sup>. Actor-Network, therefore, means considering, at the same time, both the actor and the network in which it finds itself (LATOUR, 2012). Scientific studies describe types of activities linked to the scientific discipline, instruments, colleagues, allies, public and links or nodes. All these nourish each other, as illustrated by Latour through the circulatory system or the circulating reference of activities linked to the scientific practice.

This system integrates five interconnected elements: Mobilization of the world (instruments); Autonomization (colleagues); Alliances (allies); Public representation; and Links and nodes. Each of these elements makes scientific work mobile, carries information, and makes the world and itself susceptible to argumentation. The circulating reference does not stop with data; it continues to flow and in search of convincing colleagues. For scientists, the circulation is not interrupted in any of the circuits. It is the alliances that “constitute what makes this blood flow faster and with a higher rate of pulsation” (LATOUR, 2017, p. 124). For science, it is necessary that there be associations of different entities in the collective. The more associations the concept has, the more connected, transformed and embodied it is, the more real it seems and the more tightly closed the black box becomes (SITKO, 2019).

For a historical analysis based on ANT, one should question which actors were involved, what actions were significant in the formation of groups (if such groups occurred) and what possible paths could be traced or followed in this formation (RICHARD; BADER, 2009). Human actors extend social relationships to other actors by exchanging various properties and forming collectives (LATOUR, 2017). Discussing this “unified world” presents a highly vascularized society of scientists, instruments, and institutions. When one deals with science education, this reflection makes it possible to demonstrate the articulation of the uncertainties and contradictions through which scientific knowledge passes,

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<sup>6</sup> Black box, for Bruno Latour (2004), corresponds to the concept or object that is already well established in its circle of interest. A black box is an expression adopted in the computational area to define the part of a code that is irrelevant, focusing only on what enters or exits it. It would be like a dogma, something about whose construction and involved actors one does not intend to learn. It is only necessary to know how to use the concept or object to which it corresponds.

<sup>7</sup> Translations refer to the displacements, transports or transformations between actors that are indispensable for the occurrence of some action. They are the works through which actors modify and displace according to their interests (RICHARD; BADER, 2009; LATOUR, 2017).

recognizing the social process that are intrinsic to the network. This contributes to a comprehensive understanding and learning of science, encompassing not only its concepts (RICHARD; BADER, 2009).

## II.2 Reading information based on Londa Schiebinger

The analysis of the information that circulates through the network can be allied to other epistemologies. The option here is to use the feminist epistemology proposed by Londa Schiebinger (2001). The exclusion of women from science is undeniable, and attributing the domestic space to women has only pushed them further away from the scientific world. There is a sharp dichotomy between the social roles assigned to men and women, a dichotomy that extends itself to differences between reason and emotion, objectivity and subjectivity, mind and body, power and subjugation (KELLER, 2006). To understand the development of the Period-Luminosity Relation (PLR), the guiding actors chosen for this study are Henrietta Leavitt, the first to present the concept, and Harlow Shapley, director of the Harvard College Observatory and successor of Edward Pickering, one of the main astronomers responsible for further deepening studies in the area.

The first point that can be raised in a discussion such as this is the gender issue, since what is under consideration is the primacy between a man and a woman. It is common to think that science is devoid of any kind of inequality; that it is neutral. However, social problems also affect it, given that there is a relationship between the production system and patriarchy, through the sexual division of labor, which refers to the designation of men to the productive sphere and women to the reproductive sphere. In other words, science – which falls within the productive sphere – is produced by intertwining knowledge and power and propagating the idea that scientific production is disconnected from the social and political world, i.e., the dominant science is the subjective science. It is designed for and by men and, precisely for this reason, works developed by men gain greater relevance and those produced by women are overlooked (DORLIN, 2009).

Regarding gender differences, Helen Longino *et al.* (2021) argues that “feminism is about gender and gender differences, and not about women” (p. 333)<sup>8</sup>. Like Schiebinger, she defends “the subject of the feminist theory as being the issue of gender difference. That is, the ways in which perceptions of gender, or perceptions of gender difference, are used to establish several forms of differences” (p. 334)<sup>9</sup>. In this epistemology, epistemic norms should be sought that either make gender visible or do not make it disappear from analysis.

Thus, the epistemology presented by Londa Schiebinger (2001) defends the idea that the insertion of women in the sciences enables the emergence of a new science, not

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<sup>8</sup> Translated from: “*feminismo é sobre gênero e as diferenças de gênero, e não sobre a mulher*”.

<sup>9</sup> Translated from: “*o sujeito da teoria feminista como sendo o tema da diferença de gênero. Ou seja, as maneiras pelas quais percepções de gênero, ou percepções da diferença de gênero, são usadas para estabelecer diversas formas de diferenças*”.



necessarily different from the one created by men, but more diverse; a science that includes more points of view, more efficient methods and more means of exploring research objects. She emphasizes that women do not do differently because they are women, but because they bring with them the diversity that the sciences need. According to her, women are able to look differently at the same event that a man observes. She argues that, by using the same methods that a man would use, but giving greater attention to objects, situations and data ignored or neglected by men, women could reach new results. For Schiebinger, this insertion of diversity in science can change what scientists study. However, for that change to occur, a shift in the structural order of culture and, consequently, in the institutionalization of the sciences is necessary. The cataloging of stars, for example, was a process that had been carried out for a long time by many people, long before Henrietta Leavitt, but it was only she who, at the beginning of the twentieth century, noticed the relationship between the brightness of variable stars and their periods of variation.

Another important point that should not be ignored is highlighted by historian Margaret Rossiter (1978; 1980; 1993): the so-called “women’s work in science”, which includes the teams of anonymous women who served as support for a central man. This is the case with the Harvard computers, who carried out the repetitive and tedious work of stellar cataloging, under the direction of Edward Pickering and Harlow Shapley at the College Observatory. Rossiter (1993) points out the existence of a “territorial segregation” which demarcates the spaces most often occupied by women. In academia, this is exemplified by the female majority in the areas of Humanities and Social Sciences at the expense of Exact Sciences and Engineering. Additionally, she exposes the existence of a “hierarchical segregation”, referring to the predominantly subordinate hierarchical positions occupied by women, as evidenced by the Harvard computers, who were more focused on assisting men than on managing research. This is also reflected in wages, since, in the first decade of the twentieth century, women received, on average, 55% less than men with similar positions (US, 1905).

The images we associate with science also reveal power relations: an image can project a message, defining what is conduct, what is morality, who is a scientist or what is science. The image of a scientist as a middle-aged or elderly, sloppy-looking white man, neglectful of physical, emotional, and social matters, always secluded in a laboratory, has persisted for quite a long time. In that image, one rarely envisions a woman or any non-white person. To be seen as a successful woman, one must assimilate the “male honor codes”. Edwin Hubble, for example, went as far as to state “that the outstanding astrophysicist Cecilia Payne-Gaposchkin was ‘the best man at Harvard’” (SCHIEBINGER, 2001, p. 154)<sup>10</sup>. This goes to show that gender can never dissociate itself from scientific practices. Despite her being a woman, Hubble decided to describe Payne as “the best man” in order to acknowledge

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<sup>10</sup> Translated from: “*que a destacada astrofísica Cecilia Payne-Gaposchkin era ‘o melhor homem em Harvard’*”.

her contributions. If he had said that she was “the best woman”, he would not have done her work justice, given that women “were just assistants and computers”. However, he also did not choose to say that Cecilia Payne was “the best person at Harvard”, as doing good science was linked to being an excellent *male* professional.

Despite comments like Hubble’s, “Science is a human activity; it must serve everyone, including women” (SCHIEBINGER, 2001, p. 334)<sup>11</sup>. Change happens in different ways: through the cooperation of researchers, feminists, and the government; the collaboration of researchers with different ideals; or even the efforts of feminist researchers themselves. Some measures that could foster the development of women in the sciences, especially in Exact Sciences, include affirmative actions<sup>12</sup>; increased representation of women in various fields; incorporation of biographical materials into course curricula; and the integration of gender studies to other departments, so as to enable the perception of gender biases throughout the training of new researchers. Aligned with this, this work aims to add to the efforts towards the encouragement of girls and women in science by highlighting an important female contribution to the development of Modern Astronomy.

### III. Research methodology

Memory is limited; therefore, it is impossible to accurately record the whole process of an event. That is why it is important to produce documents that serve as a record and help to remember facts without distorting them (CELLARD, 2008). Menga Lüdke and Marli André (1986) state that documents “represent a ‘natural’ source of information” (p. 39)<sup>13</sup> that can persist over time in a stable way, that is, they are contextualized records that provide information about the same context in which they were recorded.

A study that relies on documents extracts its analysis from them, organizing and interpreting them according to its research objectives. Documentary research is a process of “prospecting”. According to Alessandra Pimentel (2001), the first stage of documentary research is to find the sources or documents, without worrying about analysis, only with obtaining the information contained in them, not being necessary to opt for only one type of document. After the general documents have been found, the type of document that will be

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<sup>11</sup> Translated from: “*A ciência é uma atividade humana; ela deve servir a todos, inclusive mulheres*”.

<sup>12</sup> An example of affirmative action is the Programa Futuras Cientistas of the Centro de Tecnologias Estratégicas do Nordeste (Cetene). The program aims to “stimulate the interest and promote the participation of women teachers and high school students, in the areas of Science and technology, through their approach to technological centers and educational and research institutions” (More information on can be found at: <https://bitly.com/wnWCz>). Another is the Programa L’Oréal-Unesco-ABC para Mulheres na Ciência, promoted by the Academia Brasileira de Ciências, in partnership with L’Oréal and UNESCO, which, since 2006, have been annually awarding young Brazilian women doctors who develop high-merit scientific projects in national institutions with a 12-month long Bolsa Auxílio Grant (More information about it can be accessed at: <https://bitly.com/MDzJ45>).

<sup>13</sup> Translated from: “*representam uma fonte ‘natural’ de informação*”.

analyzed is determined: official (decrees, opinions, etc.), technical (report, article, etc.) or personal (letter, autobiography, etc.) to then begin the analyses presented below (LÜDKE; ANDRÉ, 1986).

Whatever the document may be, it should not be altered or completed: “one must accept it as it is presented, as incomplete, partial or inaccurate as it may be” (CELLARD, 2008, p. 299)<sup>14</sup>. However, it remains important to analyze even the “poorest” documents if they are the only ones available. In this case, its credibility and representativeness must be verified. The meaning expressed in the content of the document should be interpreted as adequately as possible. Regarding that, there are five dimensions to observe: the context, the author, the authenticity, the nature and the internal logic of the text. After observing all these points, the process of interpreting the document begins. The way it is interpreted depends on the initial question of the research, but throughout the analysis new questions may arise that modify or enrich the original inquiry. The role of documentary analysis is to reconstruct a certain fact or episode, that is, to discover links between each situation found and the research question (CELLARD, 2008).

Here, the analysis of the historical period is conducted using the social and cultural theories proposed by Bruno Latour and the feminist epistemology proposed by Londa Schiebinger. All the documents used in this research are archived in public or private libraries, namely: the newspaper news collected on the Cambridge Public Library website; the academic works were located through searches on the Google Scholar platform, with determined keywords; the letters and diary excerpts were found in the books of George Johnson (2005) and Dava Sobel (2016), as well as in the digitized archives of the Harvard Library.

#### **IV. Opening the black box of the period-luminosity relation**

Henrietta Swan Leavitt was born on July 4, 1868, in Lancaster, Pennsylvania. In 1887, she began her studies at the Society for the Collegiate Instruction of Women, later Radcliffe College, in Cambridge, United States, one of the first institutions of higher education for women. She graduated in 1892 and joined the Harvard College Observatory the following year as a volunteer assistant in order to learn more about Astronomy. However, she was hired at the place in 1895, under the direction of Edward Pickering, to act as a computer, cataloging and classifying stars, mainly variable stars. She died on December 12, 1921, in Cambridge, Massachusetts.

Edward Pickering was someone who sought funding very intensively, both for the people who worked at the Observatory and for the research site itself, as well as for the construction of new instruments. It was he who mobilized sponsors to enable the construction

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<sup>14</sup> Translated from: “*é preciso aceitá-lo tal como ele se apresenta, tão incompleto, parcial ou impreciso que seja*”.

of instruments, sought alliances among observatories and promoted numerous activities for the public of the city, so that the population knew the work done by them and valued them. It is evident that Pickering understood the circulation of the system and the importance of world mobilization, autonomization, alliances and public representation (LATOIR, 2017). One of his greatest legacies was the construction of the Harvard Observatory in Arequipa, Peru, which operated from 1890 to 1927. This is where the Bruce Telescope was built, named after its benefactor Catherine Wolfe Bruce<sup>15</sup> (1816-1900). This allowed Harvard University to have observatories photographing the sky both in the Northern and Southern Hemispheres, resulting in a substantial volume of data for analysis.

Because of this, between the end of 1880 and the beginning of 1890, the director decided to hire several women to work at the Observatory in the capacity of computers, for the cataloging of stars through the analysis of photographic plates made with the telescopes.

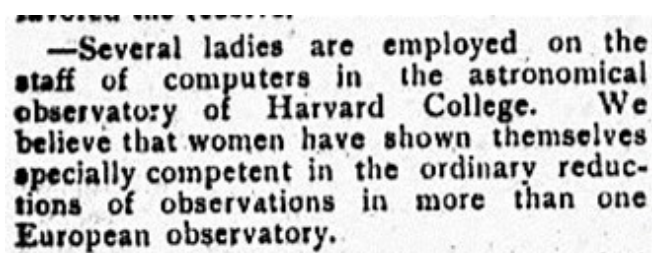


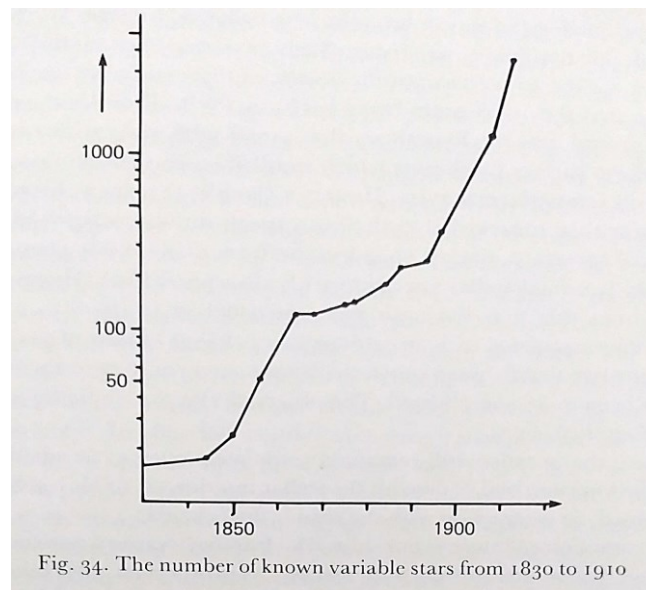
Figure 1 – News coverage in the Cambridge Chronicle about regarding the hiring of women as computers at the Observatory (THE CAMBRIDGE CHRONICLE, 1882).

Henrietta Leavitt was one of them. In Figure 1, to the left, there is a clipping from a newspaper that reads: “Several ladies are employed on the staff of computers in the astronomical observatory of Harvard College. We believe that women have shown themselves especially competent in the ordinary reductions of observations in more than one European observatory”.

Here, a clear portrait of what could be described as a “female science” can be seen, since the newspaper itself implies that women would perform a “differentiated” work, corroborating the notion that women are seen as more observant and persistent. However, according to Londa Schiebinger (2001), this would be a simplistic view, which reduces women to certain characteristics linked to the cultural understanding of gender, and ignores that, like men, women are able to follow scientific rigor and perform the necessary tasks in an observatory, using the same methods as they do.

Regardless of how they were viewed by their peers or represented in the media, these women were responsible for the biggest breakthrough in the accumulation of information about stars in history. An example of this is illustrated in the following graph in Figure 2, which presents the number of variable star discoveries just before the turn of 1900.

<sup>15</sup> Catherine Wolfe Bruce was a patron of the arts and Astronomy. She defrayed various activities and equipment of the Observatory. At the end of her life, she created the Bruce Medal, an award for "citizens of any country, persons and both sexes" for contributions to astronomy.



*Figure 2 – Graph showing discoveries of variable stars in the period from 1830 to 1910 (HERRMANN, 1984).*

Specifically regarding the work of the women at the Observatory, according to Helen Reed (1892), they were divided into three functions: informatics, that is, a more mechanical work of carrying out the calculations that would later be used by other astronomers; analysis of photographic plates and star cataloging by the students; and the group of small surveys, in which the women who defined spectra of stars identified new ones and characterized them. This was the group of which Henrietta Leavitt was part.

The hiring of women was not exclusively due to the fact that they received a lower salary than men, but also because they were paid per hour worked. So, they could reconcile domestic and professional life without any of the parties worrying about delays, being able to harmonize the two spheres (public/university and private/domestic) that had been separated until then. Reed also comments that some men have done the same work, but not in as organized a way as women, once again emphasizing the idea that there are attributes considered feminine – care and strict attention – that would be more developed in women and, therefore, would allow them to perform a different science. In addition, the integration of these women into the environment was a great advance for that time and they did not go unnoticed by the eyes of the general population, since they were constantly featured in newspapers. To the right, in Figure 3, we can see an example of a news article from December 3, 1904, announcing an Astronomy class about the Milky Way and the Nebular Hypothesis, scheduled for the following Monday after the publication of the newspaper, to be taught by Henrietta Leavitt.

Receiving 25 cents per hour – which, according to Johnson (2005), was 10 cents more than what cotton plantation workers earned at the time – and working seven hours a day,

six days a week, the hired people received \$10.50 per week, being entitled to one month of vacation.

The work of cataloging stars was something monotonous and tedious, which did not appeal to men and was then left to women. Williamina Fleming (1857-1911) was a maid in Pickering's house and was one of the first to be hired by the Observatory for the computer work.

She mentioned that Pickering always claimed that she received an above-average salary for women, but regarding this, she wrote:

*If he would only take some step to find out how much he is mistaken in regard to this he would learn a few facts that would open his eyes and let him thinking. Sometimes I feel tempted to give up and let him try some one else or some of the men to do my work, in order to have him find out what he is getting for \$1,500 a year from me compared with \$2,500 from some of the other assistants. Does he ever think that I have a home to keep and a family to take care of as well as the men? But I suppose a woman has no claim to such comforts. And this is considered an enlightened age! [...] The Director expects me to work from 9 a.m. until 6 p.m., although my time called for is 7 hours a day, and I feel almost on the verge of breaking down* (FLEMING, 1900, p. 18-9).

The salary issue was an agenda even among the men and Pickering himself, since at the time there was no government support for this type of research: they depended entirely on philanthropic actions and funding from rich people, so that no one "was there for the money" (JOHNSON, 2005). In the excerpt transcribed above, the wage gap based on gender is exposed, in addition to confirming, once again, that with respect to men working at the university, it is assumed that there is always a woman at home doing the housework, which in most cases was true, while the women who were at the institution did not share the same situation: there was no one doing the housework while they worked.

As mentioned, the work they carried out in locating and cataloging stars was considered the simplest and most tedious: it was not their responsibility to perform subsequent calculations on those objects, since this was reserved for men, something that was questioned by several women. Antonia Maury (1866-1952) once wrote: "I always wanted to learn the calculus, but Professor Pickering did not wish it" (JOHNSON, 2005, p. 87).

In her diary, Williamina Fleming also expressed her frustration:

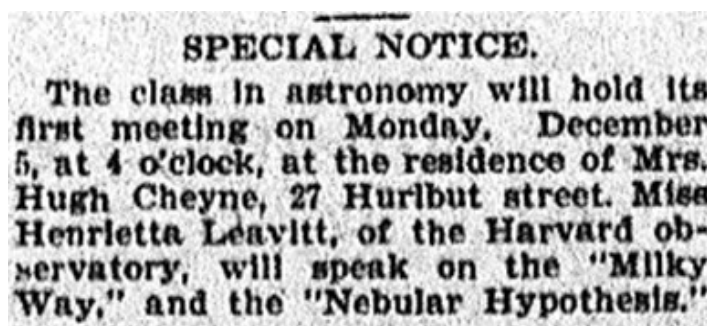


Figure 3 – Special Notice in the Cambridge Chronicle (THE CAMBRIDGE CHRONICLE, 1904).

*If one could only go on and on with original work, looking to new stars, variables, classifying spectra and studying their peculiarities and changes, life would be a most beautiful dream; but you come down to its realities when you have to put all that is most interesting to you aside, in order to use most of your available time preparing the work of others for publication (p. 87).*

When Cecilia Payne (1900-1979) arrived at the Observatory, she also commented that “Pickering chose his people to work, not to think” (p. 88). The director’s goal, when he took over the Observatory, was to discover and accumulate information about the stars, that is, under his leadership, it was not a priority for any of the employees to develop theories about celestial bodies, and this dynamic becomes even clearer through the story of Henrietta Leavitt.

All these reports are clear indications of what Margaret Rossiter (1978; 1980; 1993) describes as hierarchical and territorial segregation. This becomes evident when women do not achieve a higher academic title, when Maury states that she wanted to learn the calculus but could not, and when Fleming talks about having to let others publish<sup>16</sup>. As for Henrietta Leavitt herself, she did not leave any impressions of her own about the work she did. She also left no diaries, memoirs, personal letters, or anything personal to help us understand her thoughts about the work. All that remains are small notes, diaries of other people and her published works.

While still a volunteer, Leavitt began searching for variable stars. She was not expected to find out the reasons why the stars varied, only which ones did. In Astronomy, until that moment, this variation was observed through photographic plates, by comparing the size of the star with other fixed ones close to it. This size corresponds to the apparent magnitude, or luminosity, of the star. Variable stars, as the name suggests, are stars that have a brightness, or luminosity, that varies over time, such as novae and supernovae. On May 13, 1902, Henrietta wrote a letter to Edward Pickering (Figure 4) apologizing for having left the work incomplete for so long. She also mentioned an ear problem that, according to the doctor, prevented her from working in the cold or at night. In view of this, and her excellent work, in the response letter, dated May 16, Pickering offers her a full-time job with a salary of 30 cents per hour (5 cents more than the other computers) and the possibility of working from home.

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<sup>16</sup> This last case opens up the possibility of further discussing the Matilda Effect, also presented by Rossiter. The author herself briefly deals with the case of the Harvard Computers in the article “‘Women’s Work’ in Science, 1880-1910” (1980). As the purpose of this work is to discuss Henrietta Leavitt’s key role, it will not delve into the issue of the other computers.



ack. May 16, 1902.  
1263 Chapin St.  
Beloit, Wisconsin,  
May 13<sup>th</sup>, 1902.  
My dear Professor Pickering,-  
Two years  
ago last winter you gave  
me some of the manu-  
script of my work in  
Harvard Observatory, that  
I might make certain cor-  
rections before the final dis-  
cussion of measurements.  
You were to send the

Figure 4 – Fragment of a letter from Henrietta Leavitt to Edward Pickering (HARVARD UNIVERSITY, 1902).

These letters reveal how Pickering simultaneously cared for Leavitt and felt concerned about her health, while also insisting on the continuity of the work. He gave her the possibility of conducting her duties at the Observatory, at her home in Cambridge, or any other place with milder temperatures. What did not seem to be an option for him was allowing the work to remain suspended for an extended period of time. She accepted his offer to receive even a higher salary to work regardless of where she was, provided she was producing. That is, for the director, she was important and indispensable to the Observatory, despite any adversity that her hiring might have faced.

Around 1905, Leavitt began the process of analyzing the two Magellanic Clouds, discovering more than 900 new variable stars within the first few months. This large number of variables caught the attention of both the astronomical community and the general public, as Leavitt's discoveries prompted news articles that described her with adjectives and explanations such as "who has won much fame through her discovery of many of the variable stars" (THE CAMBRIDGE CHRONICLE, 1910a), or "famous for her discovery of hundreds of variable stars" (THE CAMBRIDGE CHRONICLE, 1910b). These news pieces, along with pro-suffrage coverage (THE CAMBRIDGE TRIBUNE, 1897; 1894), demonstrate that the city as a whole appeared to be receptive to the advancement of women's rights, labor and



voting. Londa Schiebinger (2001) states that it is not only necessary for women to enter the sciences on their own, but that this space to be receptive to them. If society plays the role of supporting social rights, university institutions must also follow the same path in order to welcome them as scientists and researchers.

Henrietta Leavitt cataloged thousands of these stars. One of her published works was “1777 variables in the Magellanic Clouds”, from 1908, in which she presented data such as minimum and maximum magnitudes and location of variable stars in the Small and Large Magellanic Clouds. At the end of the text, she presents a hypothesis about the periods of variation of the stars, writing that “the brighter variables have the longer periods” (LEAVITT, 1908, p. 107). Since this seemed to be something important, more measurements should be made to confirm the statement. Starting from this hypothesis, Leavitt produced a second work, entitled “Period of 25 variables in the Small Magellanic Cloud” in 1912, published in Circular 173 under the name of Edward Pickering<sup>17</sup>. In this text, she further analyzed these periods of brightness variations, produced graphs of period vs. magnitude and found that there was indeed a logarithmic relationship between the variables, i.e., the greater the brightness of a variable star, the greater its period of variation.

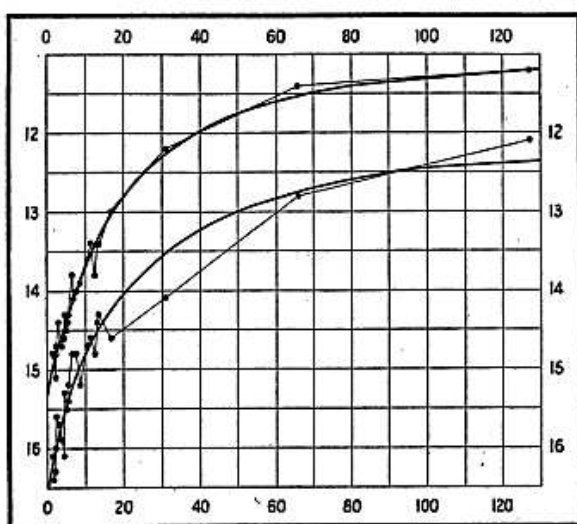


FIG. 1.

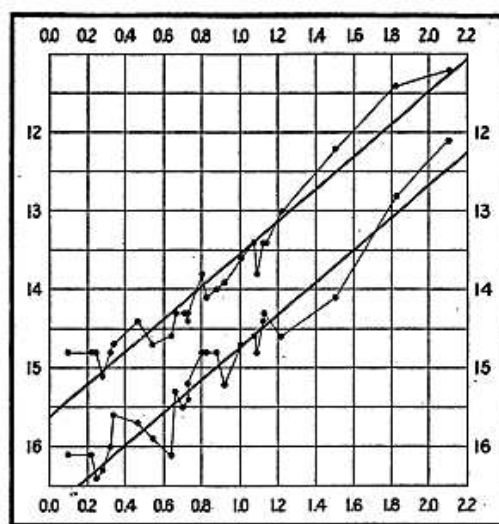


FIG. 2.

Figure 5 – Graphs produced by Henrietta Leavitt (LEAVITT; PICKERING, 1912).

In that work, she also wrote: “A remarkable relation between the brightness of these variables and the length of their periods will be noticed [...] Since the variables are probably at nearly the same distance from the Earth, their periods are apparently associated with their actual emission of light” (LEAVITT; PICKERING, 1912, p. 1-3). Unfortunately, Henrietta

<sup>17</sup> Edward Pickering was the director who instituted the Circulars, which contained works published by the Observatory itself, and for this reason he always signed at the end of each publication. However, he makes it explicit right from the first lines that the work had been done by someone else – Henrietta Leavitt in this case. For this reason, the chosen reference format here is Leavitt; Pickering, 1912, as opposed to only his or her name.

Leavitt did not continue her studies on the relationship between period and luminosity of Cepheid variables because director Pickering kept her in other projects. He believed that “the best service he could render to astronomy was the accumulation of facts” (JOHNSON, 2005, p. 56) and that her work in the Clouds was already over (MARCHI, 2011).

Her work directly allowed to determine how much farther one star was than another, but not the real distance of the stars. This calibration of the relationship would be the next step. At this point, the Period-Luminosity Relation (PLR) assumes the character of a non-human, gains space and becomes something well established: to deal with PLR is also to deal with Henrietta Leavitt. This moment is marked by the occurrence of a translation (Latour, 2016) with respect to Leavitt. Prior to this, she was seen as a person, a computer, and an important woman for the city and the Observatory; with the PLR, however, she becomes someone different: an astronomer, a precursor to the understanding of the relations of distance in the universe. *This is how she should figure (or should have figured) in History*. It is possible to notice a change in the network, one that is also influenced by gender issues: Leavitt would not only experience a translation in regard to herself and her research, but also her “hierarchical position”. While presenting data (accumulating information), she was only seen as a computer, but from the moment she introduced a new concept, something revolutionary for Astronomy, she became an astronomer<sup>18</sup>.

Measurements of distance in space began in Antiquity with the parallax<sup>19</sup> made between two distant points on Earth. Using this technique, it was possible to determine the distances of the planets in the Solar System. Then, distance measurements began to be carried out with the parallax between the two most distant points of Earth’s translational orbit. This method made it possible to determine the distance of the nearest stars. It was only much later, with the relationship discovered by Leavitt, that it became possible to determine greater distances.

The same way one can see the movements of the planets, a sufficiently long observation would also reveal the movement of the entire celestial sphere, for just as the Earth moves, so does the Sun (and the entire Solar System). Ejnar Hertzsprung (1873-1967) was the first to use this movement – noticeable only when comparing ancient data with current ones alongside the PLR – to find out the distance of the Small Magellanic Cloud. He calculated it at 30,000 lightyears, while Henry Norris Russell (1877-1957) found the value of 80,000

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<sup>18</sup> Here the relationships between Actor-Network Theory and gender issues in the sciences are explicit. When Bruno Latour (2016) proposed his ideas within the framework of social studies of the sciences, he did not cover the issue related to women. Other sociologists seek to approximate these parallels, such as Donna Haraway, Anne Fausto Sterling, and Nelly Oudshoorn (Citeli, 2000). However, the link established here is between the feminist epistemology presented by Londa Schiebinger and Bruno Latour’s Theory.

<sup>19</sup> Parallax is a method of measuring distance based on triangulation, which can be geocentric – involving the use of different positions on the Earth’s surface to measure the distance from an external object, such as the Moon –, or heliocentric – which entails measuring the distance from closer stars starting from their apparent position in relation to more distant stars when observed from opposite positions on the ellipse formed by the Earth’s translation around the Sun (OLIVEIRA FILHO; SARAIVA, 2017).

lightyears<sup>20</sup>. Concerning this disparity, Henry Russell wrote in a letter addressed to Hertzsprung: “I had not thought of making the very pretty use you make of Miss Leavitt’s discovery about the relation between period and absolute brightness” (JOHNSON, 2005, p. 45).

After the introduction of the PLR by Henrietta Leavitt, several astronomers wrote about the relationships between period and other characteristics of variable stars, including their luminosity. In addition to Ejnar Hertzsprung and Henry Russell, notable figures in this field include Harlow Shapley (1885-1972), Edwin Hubble (1889-1953), and others. These are the main actors in the network.

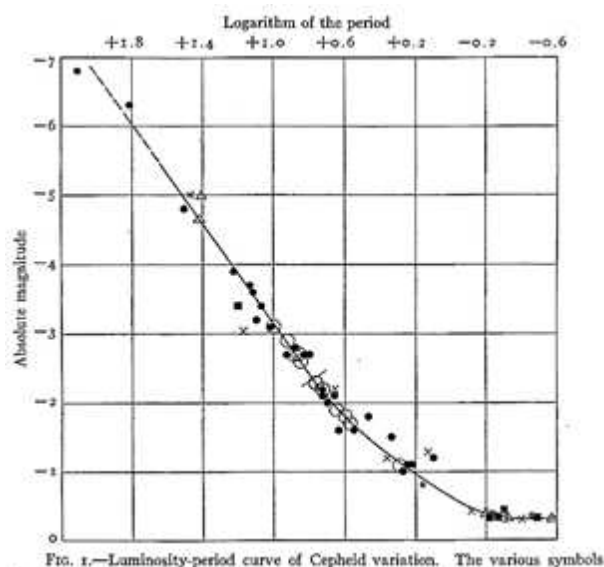


Figure 6 – Luminosity-Period Curve of Cepheid variation (SHAPLEY, 1917).

During the 1910s, Harlow Shapley worked at the Mount Wilson Observatory, during which period he began to study the “globular clusters,” which could, according to him, reveal the skeleton of the Galaxy. To be able to define the distances of these clusters, he used the Cepheid variables, with which he was already familiar because of his doctoral research, developed under the supervision of Henry Norris Russell. With the Cepheid variables, Harlow Shapley (1917) introduced the “luminosity-period curve” (LPC), a graph that, as the name suggests, presents a curve that establishes a relation between the period and the luminosity of variable stars (Figure 6), similarly to Leavitt’s previously presented Figure 1 and 2 (Figure 5). The difference, however, is that Russell used the absolute magnitude of the stars, as opposed to their maximum and minimum apparent magnitudes (JOHNSON, 2005).

Concerning this, it is imperative to recall that Leavitt herself wrote that the periods of the Cepheids “are apparently associated with their actual emission of light” (LEAVITT; PICKERING, 1912, p. 3). Therefore, this event exposes Shapley’s veiled usurpation of

<sup>20</sup> The currently accepted distance is 199,000 lightyears.

Leavitt's idea, as he fails to mention her observation from five years earlier when he presents the LPC. One could also say that this is an example of what has come to be known as the Matilda Effect, which is when a man appropriates or becomes known for something previously presented by a woman (ROSSITER, 1993). This event from 1917 can only be confirmed through the works of other astronomers using the PLR and the LPC. It is also worth noting that the LPC is also known as the "Shapley's curve."

The variable stars he found in the globular clusters were of shorter periods than those found by Leavitt in the Clouds: while hers varied in days or weeks, his varied in hours<sup>21</sup>. Shapley always believed that Henrietta's discovery was very important for observational astronomy, so much so that he wrote several letters to the Observatory seeking advice from her (JOHNSON, 2005). These letters show that, like Pickering in 1902, Shapley is insistent about Leavitt's work. For **him** to make progress in his research, it was necessary that **she** performed cataloging and calculations upon the data he had. In other words, even after **she** introduced a new concept so valuable to **him** and to astronomy itself, even after **he** use **her** proposal to present another graph (one might say that the LPC is a continuation of her work on the PLR), Shapley still reached out to Leavitt at times when he needed data. Even though he recognized her importance, he seemed to see her only as a computer, as someone who should provide information for him to continue his research. Shapley cites several subjects that would benefit from her work, but they are all subjects with which he was directly connected, i.e., the benefit would be his own. This exchange of letters could be regarded as a formed alliance (LATOIR, 2017), but it is inevitable to think of the power relationship that characterizes this gender difference: Shapley does not see Leavitt as an ally, but rather as a computer, someone who must provide data. On one hand, there is a Shapley who values Leavitt's work, seeks and offers her advice on how to continue with their respective studies, and emphasizes the importance not only of the work, but of herself; in short, a person within the network who acknowledges her. On the other hand, there is a man looking for reliable, well-defined data, treated with sound methods that, apparently, only one person could offer at that moment: Shapley had no one to turn to but Leavitt. These two sides of the same relationship suggest that Shapley may not have deliberately sought to make Leavitt invisible and claim her work as his own. This was rather the result of a set of factors not necessarily influenced by him. Shapley was a man of great prominence in the area and he may not have acted so that Henrietta was not as prominent as he was. However, he also did not act in her favor, did not quote her on every occasion he should have, did not treat her as an astronomer of the same hierarchical position as him. Harlow Shapley may have been just one actor in this

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<sup>21</sup> Walter Baade (1893-1960) classified the different types of Cepheids: he labeled one group as Population I (the ones discovered by Leavitt) and another as Population II (the ones discovered by Shapley). Each type follows its own Period-Luminosity Relation. In light of this, during Shapley's era, measurements taken from the Cepheids belonging to Population II indicated that astronomical objects were twice as distant and twice as large (JOHNSON, 2005).

network, just one person in a science built by and for men, but his actions contributed to an epistemic injustice in this historic episode.

The events narrated here took place shortly before Shapley assumed the direction of the Observatory, on March 28, 1921. That same year, Henrietta distanced herself even further from work, this time due to stomach cancer, a disease that would eventually lead to her death on December 12, 1921.

On February 23, 1925, the Harvard College Observatory received a letter from the mathematician Magnus Gösta Mittag-Leffler (1846-1927) (HARVARD UNIVERSITY, 1925), who was then one of the consultants for the Nobel Prize. The letter was addressed to Henrietta Leavitt and expressed his keen interest in her work. He mentioned that she could be nominated for the Physics prize for her discovery of the relationship between the period and luminosity of Cepheids. The sender was a strong advocate for the recognition of women in science. In the letter itself, he cites the mathematician Sonja Kowalewsky. Additionally, he was responsible for the pushing for the inclusion of Marie Curie in the nomination for the Nobel Prize of 1903 (PUGLIESE, 2009). The author was not yet aware of Henrietta Leavitt's death. So, in March 1925, who received and replied to the letter was the director of the Observatory, Harlow Shapley. In his response, Shapley expressed gratitude for Mittag-Leffler's acknowledgement of Leavitt, affirming that her work was indeed very important and that it had allowed him to carry out various other studies (HARVARD UNIVERSITY, 1925).

It is evident that Shapley recognized the importance of Leavitt's work, having stated that, had it not been for the health problems she faced throughout her studies, she would have done much more. However, his response also reveals that he tended to attribute the primacy of the matter to himself. He mentioned that Leavitt discovered the relationship between period and apparent magnitude, and that this provided the community with a new measuring tool. Nevertheless, he also suggests that what truly enabled progress in the field were his interpretations, namely, the Luminosity-Period Curve – which, again, he owes to her groundbreaking work. As previously mentioned, she herself had already pointed out the existence of a relationship between period and actual magnitude, reinforcing the possibility that the Matilda Effect occurred here (ROSSITER, 1993).

Shapley further comments that she would have offered more brilliant contributions if she had had more time to dedicate to science. It is known that she did not have this time, not only because she was affected by several episodes of illness, but also, and especially, because director Edward Pickering did not see the need to advance more specific studies. Shapley does not take this into account when lamenting Leavitt's "small" contribution. There is a certain "euphemism" in the working relationship between the director and the assistant: Shapley attributes to Leavitt's health a situation that was beyond her control, since decisions were made based on the existing hierarchy. Leavitt held a position as an assistant supervised by Williamina Fleming, but she was also an assistant to the director, that is, the power to decide what to study was not in the hands of either woman—only the man's. Henrietta Leavitt

had an undergraduate degree and possessed as much scientific knowledge as any of the male assistants of the Observatory. However, it was her position as a woman that did not allow her to continue a specific study. From the perspective of man who naively views science as impartial (GIL-PÉREZ *et al.*, 2001) through the lens of his time, Shapley does not perceive this gender-based difference in treatment, nor does he notice that the science built at the Observatory also stems from this fundamental principle of society (SCHIEBINGER, 2001; DORLIN, 2009).

Despite the way Harlow Shapley treats Leavitt's PLR, it is undeniable that he did play a major role in the development of the area. Thanks to his studies and the LPC, he was widely cited as an academic reference in the area. Understanding this dynamic of publications and citations demanded the analysis of numerous works performed by him and other authors and published between the decades of 1910 and 1950. This analysis focused on publications that discussed the works of Henrietta Leavitt or Harlow Shapley, seeking to determine whether there was a divergence in the primacy of the PLR between them. The objective, therefore, was to ascertain if the primacy is attributed to Leavitt, for presenting the concept, or Shapley, for developing it in more depth.

The papers analyzed, in chronological order of publication, were: *Über die räumliche Verteilung der Veränderlichen vom delta Cephei-Typus* (HERTZSPRUNG, 1913); Sixth paper: on the determination of distances of globular clusters (SHAPLEY, 1917); Globular clusters and the structure of the galactic system (SHAPLEY, 1918a); Notes bearing on the distances of clusters (SHAPLEY, 1918b); N.G.C. 6822, a remote stellar system (HUBBLE, 1925a); Cepheids in spiral nebulae (HUBBLE, 1925b); On the relation between period and form of light-curve of variable stars of the delta Cephei type (HERTZSPRUNG, 1926); On the nature of stellar variability (PERRINE, 1926); On the relations between period, luminosity, and spectrum among Cepheids (RUSSELL, 1927); Distances of the Galactic Cepheids, Magellanic Clouds, and Globular Clusters (PERRINE, 1927); *Étoiles doubles* (DANJON, 1928); *Revue annuelle d'Astronomie* (ALLIAUME, 1928); A spiral nebula as a stellar system, Messier 31 (HUBBLE, 1929); Star Clusters (SHAPLEY, 1930); *Recherches statistiques sur les céphéides* (LI, 1933); *Sur la théorie des oscillations radiales d'une étoile* (LEDOUX, 1940); *Une nouvelle méthode pour déterminer le diamètre linéaire et la magnitude absolue des céphéides* (VON HOOFF, 1943); Magellanic clouds, VI. Revised distances and luminosities (SHAPLEY, 1953).

The analysis revealed that the only work that cites Leavitt exclusively is the first, by Hertzsprung (1913), which can be explained by the fact that Shapley had not yet published anything about the matter. After he published, all the subsequent works cite him, but not all of them cite Leavitt. In this dispute for alliances (LATOUR, 2017), Shapley remained predominant for a long time among the astronomical community, being considered responsible for the PLR. Even though Henrietta Leavitt introduced the idea of a relationship between the luminosity and the logarithm of the period, even though she cataloged 1777

variable stars in the Clouds to establish this relationship, and even though she was part of one of the largest observatories in the world, she, as a woman, was not “able” to overcome the relevance that he, a man, held among his peers.

Another crucial point to consider is the passage of time: Leavitt does not figure more prominently at the beginning than she does the end of this chronological line, or vice versa. Thus, it is not determined whether she gained prominence or remained overlooked as debates on women’s rights gained momentum in the world. What can be determined, however, is that, within the French academic community, Leavitt exerted more influence, perhaps because of the debate around the figure of Marie Curie.

In the network that formed around the development of the PLR, this work has highlighted the existence of numerous human actors, such as Henrietta Leavitt, Edward Pickering, Catherine Bruce, Harlow Shapley, Ejnar Hertzsprung, Edwin Hubble, Gösta Mittag-Leffler etc., along with non-humans, such as the PLR itself, feminist movements, local newspapers, the infrastructure of the Harvard College Observatory, etc. Each of these acted on the network so as to create a translation on the Leavitt-PLR set, where, at times, the woman stood out, while in other instances, the PLR gained more significance, and the woman was omitted. None of the individual actors had the sole power to omit Leavitt or render her invisible. As Latour (2017) asserts, only the collective has this power. However, what becomes evident throughout this episode and the analyzes conducted under the viewpoint of Latour’s ideas from a feminist perspective is that men such as Pickering, Edwin Hubble, and especially Harlow Shapley have a profound effect on the collective and on the network. While some would work to highlight Leavitt, others would contribute to rendering her invisible by not quoting her, either deliberately or not.

What can also be noticed is that the collective figured in different contexts. The first one comprises the period from 1900 to 1940 in the United States, characterized simultaneously by pronounced segregation and vibrant feminist discussions. At this time, some actors deemed Leavitt as the “discoverer of hundreds of variable stars” and the proposer of the PLR, while others viewed her as a mere computer, assuming the PLR was already a “well-known and studied” instrument. This dichotomy demonstrates how fickle society is and how it is in constant construction and reconstruction due to movements against gender inequalities, for example. While Pickering and Shapley sought financial and institutional support in favor of the women assistants of the Observatory, they also ignored the women’s additional workload represented by domestic chores. The dichotomy is also present in the way Pickering and Shapley approach Leavitt, because although they seem to consider her as someone indispensable to the point of adapting the work to her needs and asking her for advice, they also view her as someone who should provide data, similar to a computer. The second context is that of the 1920s in France, where Marie Curie was already a prominent figure on account of (and also despite) being a woman. This led to Henrietta Leavitt receiving different recognition than she did in the United States at the same time. Lastly, the third

context encompasses the period from 1950 until the end of the twentieth century. During this time, feminist struggles gained strength, resulting in women attaining high-level positions. At the same time, however, Henrietta was omitted from her own history.

By analyzing these last two moments and considering the significant influence that science produced in the United States had on the rest of the world during the latter half of the twentieth century, it becomes apparent that the phenomenon previously described arose as a consequence of the prevailing dominance of the first context. This can also be attributed to the fact that, as Attico Chassot (2019) suggests, science is masculine, or as Londa Schiebinger (2001) adds, science is made by men and for men, and if women did not insist on occupying and changing this space, it would continue to be so.

Henrietta Leavitt was omitted from her history because the most important actor – the collective – contributed to this. Following a series of translations in the Leavitt-PLR set, the collective composed by men and women from the twentieth century in the United States acknowledged only the Period-Luminosity Relation (or Law), but not its creator. To draw a direct comparison between Henrietta Leavitt and Harlow Shapley's primacy over the PLR is, at the very least, to perpetrate an injustice. Shapley, as a man and a recognized astronomer who was then the director of a large observatory, could move unrestrictedly within the network, among colleagues and the public, whereas Leavitt was hired as a computer. Despite her contributions, her responsibility at the observatory was to accumulate data, as required of her by Pickering (and as requested by Shapley through letters). In other words, she lacked the freedom of movement to pursue the studies she deemed necessary. Fortunately, contemporary discussions about gender and science are leading to more comprehensive analyses, gradually rectifying the historical marginalization of women in this field.

Nonetheless, there are still very few works about Henrietta Leavitt and the Harvard Computers, which underscores the significant importance of discussing the pivotal roles that these women played, since each of them made essential contributions to the development of Modern Astronomy. Without their efforts, we would not know that the universe is expanding. In contrast, the number of articles, books, and film productions on this subject, particularly those featuring men associated with them, is countless. In order to reinforce the importance that women have in doing science, this work delves specifically into the historical episode in which Henrietta Leavitt was the protagonist, aiming to highlight her relevance as a woman who reshaped a field previously conducted exclusively by men and from the male perspective (SCHIEBINGER, 2001).

## **V. Teaching with history and philosophy of sciences and the gender issue**

The contextualization of Science Education through the discussion of a historical episode centered around a woman is aimed at assisting in the better development of women in the field, as well as to advance a less naive image of science, which disregards women participants in its production. There seems to be a consensus that science teaching in schools



is not satisfactory (TURNER, 2008). At the same time, numerous initiatives using History of Science are being created and applied to change this scenario<sup>22</sup>. Three main points are raised in this sense: the need to consider students' point of view; the effort to cultivate a scientific culture for all, so that students themselves can engage in debates; and the promotion of critical thinking (RICHARD; BADER, 2009).

The aim here was to present a new initiative based on Bruno Latour's Actor-Network Theory and Londa Schiebinger's Feminist Epistemology, seeking to provide teachers with insights into new ways of crafting curricula and approaching research in teaching. It does so by incorporating themes that combine social studies on the sciences with gender issues. Moreover, this work sought to contribute to democratize the sciences through a teaching approach where they are contextualized within their social construction. Many students have the impression that science is produced in a few steps, without controversies and disputes, as if following an unbreakable sequence. Reflecting on the disruption of this perception also involves considering the concept of the Nature of Science and the distorted image of science (BEJARANO; ADÚRIZ-BRAVO; BONFIM, 2019; GIL-PÉREZ *et al.*, 2001). "In science education, this reflexive openness entails articulating and explicating the uncertainties that are central to scientific knowledge; it is also contingent upon the recognition of the social processes operating in research" (CALLON; LATOUR, 1991, p. 05). This proposal does not aim to introduce "a certain side of the discussion", but to employ the Actor-Network Theory to present the Nature of Science in the classroom in a non-distorted or reductionist way, explaining the discussions and controversies that exist in the scientific practices (RICHARD; BADER, 2009).

Focusing on the theme "Henrietta Leavitt and the Period-Luminosity Relationship", two examples of approaches that deal with the History and Philosophy of Science and the Nature of Science can be mentioned. The first involves a simulated jury, wherein students engage in a debate about the question: "Who owns the Period-Luminosity Relationship?". In this activity, students are divided into two groups, one defending Henrietta Leavitt's primacy over the PLR and the other defending Harlow Shapley's primacy. Supporting materials are provided to aid in the construction of arguments and counterarguments. It is expected that, though this discussion, the class will understand the importance of viewing science as a collective construction, of which women are also part (SILVÉRIO; SANTOS; SITKO, 2023, in press). The second proposal consists of a didactic activity about the development of the PLR, which deals with the creation of a "time network," in which the class itself inserts cards in order to practice history analysis. Unlike a traditional timeline, students are expected to

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<sup>22</sup> These initiatives, which have been growing markedly since the early 2000s, are present in several Brazilian journals, such as *Ciência & Educação*, *Caderno Brasileiro de Ensino de Física*, *Revista Brasileira de História da Ciência*, *Investigações no Ensino de Ciências*, *Revista Brasileira de Pesquisa em Ensino de Ciências*, *Experiências em Ensino de Ciências*, among many others. At the international level, it is worth mentioning, for example, *Enseñanza de las Ciencias*, *Science & Education*, *International Journal of Science Education*, *Science Education*, and *Research in Science Education*.

realize that the information contained in the cards forms a completely interconnected network. This network also exemplifies Bruno Latour's Actor-Network Theory, as it presents the actors of history, human and non-human, the instruments, the public representation and the links and nodes (SILVÉRIO; SITKO; FIGUEIRÔA, 2022).

The historical approach focused on a female character presents different nuances that allow new possibilities of approach to Science Teaching, and history itself becomes material to guide the activities. The distancing of science and science classes from social issues reinforces stereotypes that marginalize diversity. If the school changes, the classes change and, accordingly, the science also changes. "Science (re)constructed by diversity is essential for its own development as it will provide knowledge from the perspective of multiple perspectives" (SILVA *et al.*, 2021, p. 2)<sup>23</sup>.

In this context, the field of History and Philosophy of Women in the Sciences has been growing. With diverse theoretical, political and methodological perspectives, this area includes four main approaches: (1) the history of women scientists; (2) the status of women as professionals in the sciences; (3) the inclusion of women as an object of study within the biological and medical sciences; (4) the critique of the androcentric bias of scientific theories and methods (CITELI, 2000). The present work aligns with the first approach. During the first half of the twentieth century, it is notable that both the History of Sciences and the Philosophy of Sciences did not take gender markers into account in their discussions, "so that the legacy of women in sciences and technologies was neglected by the conventional History, Philosophy and Sociology of Sciences" (p. 96). If the History of Women is consolidated through the male norm, it corroborates the vision of a woman scientist as an exceptionality, contributing little to changing gender policy guidelines in the sciences (SEPULVEDA; SILVA, 2021).

The work presented by Silva *et al.* (2021) shows that, in the classroom, symbolic associations are observed in the teaching materials that present science: the exact sciences are associated with the male image, endowed with moral and objective vigor, whereas the biological and social sciences are associated with women, who are allegedly more fickle and sentimental. That is, the exact sciences, industrial technologies and, therefore, what common sense sees as the generation of wealth presents an intimate link with masculinity. In scientific and academic institutions, there is a high growth in female participation, which, however, does not reach the leading positions.

Fernandes, Noronha and Fraga (2017) point out three perspectives for the inclusion of gender issues in science curricula: through the presentation of the stories and productions of women in the scientific field; by discussing the different paths and difficulties faced by men and women in these professions; and by studying how this androcentric hegemony is reproduced in curricula, so that alternatives are found to promote the identification and

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<sup>23</sup> Translated from: "ciência (re)construída pela diversidade é essencial para o seu próprio desenvolvimento à medida que proporcionará conhecimentos pela perspectiva de múltiplos olhares".

engagement of women in the sciences. Silva *et al.* (2021) warn that this incorporation of gender issues into curricula must be done in a critical way, so as not to reproduce or reinforce processes of subordination, binary conceptions and gender stereotypes.

## VI. Conclusion

In addition to demanding and creating spaces for the inclusion of women in the sciences, feminism also enabled the integration and/or alteration of various aspects within the scientific work. These include the academic sphere (sometimes more open, sometimes more closed); the instruments of gender analysis; the analysis of primacies and results (funding, etc.); the analysis of objects of study; the analysis of institutional arrangements (prestige and reception of women); the decoding of language and iconographic representations (images represent power); the reevaluation of the definitions of science; government actions; society and culture (how society is organized and what it deems to be true can impact scientific practices, regardless of its appropriateness for women) (SCHIEBINGER, 2001).

In the history of the PLR, this happens to Henrietta Leavitt: when the Observatory hired women, a great advance in the cataloging of stars happened and, even with certain reservations in the way of conducting the work, the search for specific financial assistance for women by director Pickering and, later, by Harlow Shapley himself was essential for women in Astronomy in the United States. The constant reference to these computers in the media of the time demonstrates support for female participation outside the domestic sphere.

Throughout the analysis carried out here, it was noted that just like society, science is socially constructed (LATOUR, 2017). Social relations between humans and non-humans, who are actors in history, exchange properties and form collectives. And, precisely because there is no external world to science, there was a silent dispute of primacy between Henrietta Leavitt and Harlow Shapley concerning the Period-Luminosity Relationship, for as Londa Schiebinger (2001) explains, science is built upon gender power relations. Perhaps not a silent dispute, but a silencing one on Shapley's part towards Leavitt. By combining the ideas of Bruno Latour and Londa Schiebinger, the "collective" finally gains a "palpable" meaning: it is what unites us to a single network of interactions. Through these ideas, it becomes evident that there are no two separate powers in the sciences, the indisputable and impartial nature, and the debatable and foreign politic. What does exist are two different tasks in the same collective.

For Science Education, reflections such as these open doors to explanations and discussions about the uncertainties that are essential to scientific knowledge, as well as the relationships that exist between men and women or between managers/directors and employees. In turn, that creates space for recognizing the social processes that are integral and equally essential to any research.

But after all, why was Henrietta Leavitt omitted from her own contribution? This work points out some hypotheses, focusing mainly on the gender issue and the power

imbalance that existed between Henrietta Leavitt and Edward Pickering, as well as between her and Harlow Shapley. However, based on the information available, it is not possible to determine what actually happened in the first decades of the twentieth century; it remains uncertain whether astronomers such as Edwin Hubble or Henry Norris Russell omitted Leavitt's work and name because they did not know her or because they did not consider her important; and it cannot be ascertained that Harlow Shapley actively tried to take credit for the development of the Period-Luminosity Relation. The sole conviction is that her exclusion can be attributed to her being a "computer" rather than an "astronomer," which in turn is due to the fact that she was a woman, and not a man. The analysis of works written by these men, especially their bibliographic references, suggests that it is unlikely that they did not know about Henrietta Leavitt. Similarly, the analysis of the correspondences between Harlow Shapley and Gösta Mittag-Leffler also seem to indicate that Shapley did try to secure for himself the primacy over the PLR studies. All of this converges so that an instance of the Matilda Effect can be pointed out in the Luminosity-Period Curve development process.

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