transversal
International Journal for the Historiography of Science

Transversal: International Journal for the Historiography of Science, 2025 (19): 1-11
ISSN 2526-2270
Belo Horizonte – MG / Brazil

Special Issue
Paul Feyerabend and the History and Philosophy of Science

"Anything Goes" Under the Sky: The Harvard Computers and Feyerabend's Epistemological Pluralism in Action

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Abstract:
The purpose of this article is to present the principles of Paul Feyerabend's epistemology, described in *Against Method*, through the scientific practice of Harvard computers – women who worked at the Harvard Observatory between the 19th and 20th centuries. Four key Feyerabendian concepts are highlighted for this discussion, namely: counter-induction, the proliferation of theories and methodological pluralism, supposed "irrationality" that can lead to scientific progress, and the use of "forbidden resources" (such as hypotheses *ad hoc*). Through the historical episodes involving the "computers", it is possible to show that astronomical knowledge has advanced through a diverse, creative and non-linear form of praxis. We conclude that the history of Harvard Computers embodies Feyerabend's thesis that scientific progress is a pluralistic enterprise, relying on the diversity of methods and the freedom to challenge established rules and consensus.

Keywords: Counter-induction; History of astronomy; Methodological pluralism; Scientific practice; Women in sciences

Received: August 30, 2025. Reviewed: November 18, 2025. Accepted: November 24, 2025.
DOI: http://dx.doi.org/10.24117/2526-2270.2025.i19.05

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Introduction

Paul Feyerabend's epistemological theory argues against a single, rigid scientific method, advocating counter-induction (advancing against established theories and facts), the proliferation of theories, methodological and ontological pluralism, the use of so-called forbidden resources, such as hypotheses *ad hoc* and experimentation by trial and error, and the use of methods sometimes labeled "irrational" (Feyerabend 1993). The history of the so-called Harvard Computers brilliantly illustrates how scientific practice differs from the formal, rationalistic image of science. Feyerabend shows that science does not follow a "single method", but is made up of improvisations, creative strategies, interpretations and even practices considered "irrational", and this is precisely how the Harvard computers worked.

Human computers were the people responsible for the mathematical-scientific calculations used to organize astronomical information, such as the position and movement of celestial objects, catalogs, and nautical and stellar charts. The first women hired by the Harvard Observatory in 1875 performed this work, doing computations based on observations conducted by other male astronomers. Each observation resulted in sets of photographic plates of the sky and/or spectra of the observed objects. These plates – recorded in light-sensitive glass emulsions – were carefully organized, cataloged and analyzed by this group, in practice, the women inspected the images with the aid of magnifying glasses and measuring microscopes, identified and compared the intensities of stellar brightness, and wrote down data regarding the position, magnitude, variations in luminosity of each visible object and, when available, information about the spectral lines, associating them with chemical elements. They also used measuring instruments such as micrometric rulers that allowed them to record precise coordinates on the plates, associating them with tables and mathematical formulas later transcribed into the catalogues (Zrull 2021).

According to Helen Reed (1892), the work of women at the Harvard Observatory was divided into three classes: calculation based on observations made by others; original investigations, such as the determination of longitudes and the preparation of catalogs; and, finally, large projects, such as the Henry Draper Catalogue and other similar initiatives, dedicated to the photographic and spectral analysis of stars, which resulted in important discoveries and classifications. The scope of their work expanded with the advancement of photometry and spectroscopy: in addition to calculating, they began to examine photographic plates, measure the brightness of stars in photometric studies, record their positions and organize the results in catalogues.

Although their work was initially associated with repetitive tasks, their function evolved into complex analyses that culminated in works such as that of the catalog, the creation of an international spectral classification system, the identification of the relationship between period and luminosity of Cepheid stars, the determination of solar composition, among other major astronomical milestones.

Thus, in this article, we draw on selected historical episodes about the development of knowledge in Astronomy at the Harvard Observatory, between the nineteenth and twentieth centuries to illustrate the main elements of the theory of Paul Feyerabend, based specifically on the work *Against Method* (1977 and 1993), showing how Harvard computers conducted their scientific practice, and how this resulted in the progress of science, in Feyerabendian terms.

Feyerabend's Epistemology Explained in Light of Examples of Harvard Computers Scientific Practice

The following sections present four topics that we understand to express the main elements defended by Feyerabend to describe the construction of Sciences and the execution of scientific practice, which are briefly explained and then discussed through examples that took place at the Harvard Observatory. These topics concern: (a) the counter-induction; (b) the proliferation of theories and methodological and ontological pluralism; (c) the "irrationality" within scientific practice, and; (d) the use of forbidden resources (hypotheses *ad hoc* and rial-and-error practices).

(a) Counter-Inductive Practice

Feyerabend seeks support in non-analytic philosophies and social thought to develop a more flexible and informal vision of scientific method. According to him (1977), science is a plural activity, more humane and conducive to progress than models guided by rigid rules and fixed order.

It is therefore valid to formulate hypotheses that contradict already consolidated theories or established experimental results, thereby enabling science to advance counter-inductively. The requirement that new hypotheses conform to old theories is unacceptable, since such a search for uniformity can deprive the critical spirit of science. Any concept, even if ancient, has the potential to refine knowledge, and it's up to science to take advantage of these ideas to refine its theories. We can illustrate this idea with the library analogy, described by Oliveira (2021): it is as if all our theories, in force or not, are books; those we accept, or that are acceptable, are on our table. However,

> It is normal and desirable that, once in a while, we check the books on the shelves, searching for new ideas, justifications, cosmologies, arguments, theories, insights, and answers which the books on our desk seem unable to provide. Maybe the answer is in the books on our desk, and we need a help from outside them to see it (Oliveira 2021, 446).

In this sense, it is crucial to overcome scientific chauvinism, which refuses to accept alternative views of established reality.

Contradictions between facts and theories can themselves indicate scientific progress (1977). This conflict represents the starting point for the identification of implicit principles contained in ordinary notions of observation. The Aristotelians, for example, used the tower argument to contest the motion of the Earth, relying on natural interpretations derived from observation. Galileo, however, identified and replaced such interpretations with others, creating a new and highly abstract language of observation.

The initial difficulties created by this change give new theories the necessary space to mature and indicate directions for future research. Galileo defended the Copernican theory based on telescopic observations, although he was promoting a refuted conception (Copernicanism) relying on another also contested (the fidelity of telescopic images). These "irrational" methods of justification were essential to the survival of the Copernican theory and other pillars of modern sciences, leaving reason in the background.

The existence of science demonstrates that reason cannot reign absolutely, but non-reason must not be excluded either (Moreira and Massoni 2011). This intrinsic characteristic of scientific practice therefore requires an epistemological pluralism.

Like the example of Galileo, who defended a conception already refuted, we can also think of the Harvard Computers, specifically in the case of the determination of solar composition, first identified by Cecilia Payne-Gaposchkin (1900-1979), which went against the prevailing belief that the Sun's composition resembled that of the Earth, showing that the Sun and the other stars were composed predominantly of lighter elements, such as hydrogen and helium.

In the 1920s, following solar spectroscopy, the theory, well established by the accepted science until then, believed that the composition of the Sun and stars was essentially the same as that of the Earth, with a similar abundance of heavy elements such as iron and silicon. Shortly after arriving in the United States, as a doctoral research fellow at Harvard University, Payne applied Meghnad Saha's new ionization theory to analyze stellar spectra (Vieira 2021). Her calculations led her to a hypothesis considered "heretical" at that time, in a similar sense held by the Galilean heliocentric ideas, in which the stars were composed predominantly of hydrogen and helium, light elements considered minor constituents until then (Payne 1925).

The eminent astronomer Henry Norris Russell (1877-1957), while praising her work, strongly discouraged her from publishing the conclusion regarding the predominance of light elements, considering it absurd and counter-inductive in relation to established knowledge. She partially conceded, adding in her thesis that the result was "almost certainly not real". Years later, Russell himself, through other methods, arrived at the same conclusion (Moore 2020). Payne's thesis, which began as a counter-inductive and "unreasonable" hypothesis, revolutionized Astrophysics and proved to be completely correct. She used what was "worth" (Saha's new theory) to challenge what was "accepted".

Even before the case of solar composition, another important example can be observed in the episode of the detection of the peculiar spectrum of ζ Puppis, identified by Williamina Fleming (1857-1911) in 1896. Fleming noticed a rhythmic sequence of spectral lines that did not fit the Balmer series, then considered the explanatory standard for hydrogen, while examining some photographic plates. Instead of dismissing the observations as an experimental error or product of defects in the plates, which would be the "inductively safe" path, Fleming recorded them and highlighted their regularity. Her decision to preserve the peculiar was essential for the phenomenon to become known, later called the Pickering series, in reference to the director of the Observatory, Edward C. Pickering (1846-1919), and later attributed to ionized helium (He^+) (Fleming 1896; McEachern and Friedrich 2025).

This decision not to eliminate the peculiar data, but to recognize them as potentially significant, illustrates a counter-inductive practice. From this "anomaly", in 1913, Bohr was able to expand his atomic model to encompass both the Balmer and Pickering series, validating the role of He^+ as empirical proof of the model. Like Galileo and Cecilia Payne, Fleming did not allow herself to be compelled to reject what did not fit into the current paradigms, allowing science, given its plural and non-linear nature, to advance through the irrational dimension of reason that Feyerabend argues to be the engine of progress.

(b) Proliferation of Theories and Methodological Pluralism

Feyerabend is a critic of rationalism and an advocate of pluralism of methods (1977), and, according to Oliveira (2021) highlights, an ontological pluralism, which involves methodologies, theories, ideas, and cultures. In this sense, it is important to note that the 3rd edition of his work was published in 1993, in which the author revises some conceptions, presenting a broader vision of pluralism, for example, no longer concerned only with methods and theories, but also with respect to ontologies and cosmologies (Feyerabend 1993). The presence of ontologies and cosmologies was deepened in his later work *The Conquest of Abundance* (1999).

Feyerabend opposes any single, absolute, unchanging principle of organization. Transposing this into the methodology, it is not a question of being against any procedure, but rather of opposing the imposition of a fixed set of universal rules, that claim to rigidly define what is or is not science.

It is necessary to be willing to examine any idea, admitting that behind the world described by science there may be a deeper reality, or that our perceptions can be arranged multiple ways. The choice of an organization that “corresponds to reality” will not necessarily be more “rational” or “objective” than another.

Feyerabend doesn’t just want to argue that all methodologies have limitations. He goes further and demonstrates in his book the “irrationality of rationalism” – his favorite hobby, as he says, is to disturb rationalists by finding solid reasons to substantiate doctrines considered absurd (1977). He shows how the rules of rationalism become self-destructive and conflict with their very foundations, when pushed to extremes (Regner 1996).

He is a major proponent of the use of alternative and conflicting theories, that is, of what he calls ontological incommensurability, in which theories are so different in concept, language, foundations, that they are incomparable, so that one cannot be said to be superior to the other (Feyerabend 1993). We need an external standard of criticism, a set of alternative assumptions. For him, the existence of a single dominant theory leads to scientific stagnation.

This can be illustrated with the case of Galileo, who defended the Copernican theory relying on other ideas considered irrational at the time (such as the law of inertia and the reliability of the telescope). Today, the heliocentric theory is the prevailing one, although the Galilean ideas were initially ridiculed by those who only trusted the reports of direct observation. This is a common case in sciences, in which theories only become “reasonable” and clear much later, when their incoherent parts are adjusted. This initial “irrational” condition is, for Feyerabend, inevitable for achieving scientific success.

Therefore, he advocates a pluralistic stance for the scientist, who must adapt their methods and practices to advance the understanding of the world (1977). The scientist must be free to do whatever is necessary to understand reality. Acting counter-inductively is Feyerabend’s first “counter-rule”, thus positioning himself against the essence of empiricism. He proposes that theories must be invented to predict phenomena that break expectations, instead of corroborating established facts. His goal is not to replace one set of rules with another of “counter-rules”, but rather to convince that all methodologies have limitations. The best way to grasp this is to expose the limits and irrationality of rules considered fundamental (Pantoja and Regiani 2020).

Feyerabend does not advocate for the substitution of one theory for another, but rather their divergent cosmological proliferation (Oliveira 2021). As he states (1977), unanimity is good for a church, but not for objective knowledge, which needs a variety of opinions to flourish.

He suggests that scientists adopt, among other things, a pluralistic methodology, comparing theories, and not just data. For him, the history of science is a rich source of alternative theories, which, according to the library analogy already mentioned earlier (Oliveira 2021), are archived in books on the library shelves, and which can be revisited at any time. For example, the idea that the Earth moves, proposed by the Pythagoreans, was considered ridiculous after Aristotle and Ptolemy, but it was later rescued by Copernicus and supported by Newton.

Feyerabend advocates the use of the history of sciences to remind that a theory accepted today can become a fairy tale in the future, just as a ridiculed myth can turn into a great scientific theory. There is a constant mixture between subjective and objective thinking. For him, no theory is in complete agreement with all the known facts in its domain, and that this lack of agreement is not a failure, but rather crucial evidence of progress.

For Harvard Computers, this becomes evident in the Henry Draper Catalogue. The work carried out by them was not homogeneous: different women specialized in different methods of classification and analysis, creating competing "theories" or systems for understanding stellar spectra.

Those computers played a decisive role in organizing thousands of stellar spectra into categories that not only followed, but often challenged, the prevailing astronomical logic of the nineteenth century. Williamina Fleming, for example, was responsible for one of the first major spectral classifications in the Catalogue, in which she organized stars into five types, based on the spectral lines recorded on photographic plates. More than a technical task, this work required identifying regularities in photographic records and recognizing patterns that were not predicted by theory. It was in this process that Fleming observed that stars of the so-called "third type" with bright lines of hydrogen were variable, something that contradicted expectations within the astronomical community and opened a new avenue for the identification of stellar variables (Pickering 1890; Reed 1892).

Antonia Maury (1866-1952), on the other hand, developed a much more detailed system, with twenty-two classes and subdivisions according to the sharpness of the spectral lines, prioritizing fidelity to raw data over simplicity. Although often described as complex, her proposal revealed crucial information. For example, her analysis of Beta Aurigae revealed it to be an extremely short-period binary system, a discovery considered unlikely at that time. In addition, this discovery became fundamental years later, when Ejnar Hertzsprung (1873-1967) demonstrated that its subdivisions distinguished giant stars from dwarfs. Later, director Edward Pickering himself acknowledged that Maury's detailing anticipated necessary solutions to problems that traditional classification did not solve (Maury 1898; Sobel 2016).

Annie Jump Cannon (1863-1941), in turn, simplified and consolidated the classification into a reduced sequence – O, B, A, F, G, K, M – which, due to its practicality, became the basis of the international system adopted (Sobel 2016). This proliferation of methods, far from being an obstacle, was essential, as it allowed the astronomical community to compare distinct approaches and test diverse hypotheses, rather than following a single "official method" from the beginning. The tension between Maury's refined precision and the practical utility of Cannon's simplification enriched the field and spurred new discoveries.

As shown in the article by Helen Reed (1892), there was no single "Harvard method", each computer was responsible for interpreting the photographic plates through different methods and worked out their own way of classifying, measuring and organizing the data. The Henry Draper Catalogue stands as a result of this pluralism of practices, as it not only gathered geometric data of stars and nebulae, but provided an index of their physical nature, the spectra. These practices complemented and reinforced each other, forming something far richer than a rigid methodology and exemplifying Feyerabend's defense of the multiplicity of paths in scientific progress.

(c) The "Irrationality" that Leads to Progress

The epistemological pluralism functions as a stance that strategically challenges rationalism. According to Feyerabend (1977), rationalism is "incorrect" because it cannot adequately explain scientific progress, and "undesirable" because it restricts a full existence. In addition, it is essential to understand the assumptions that underlie the author's epistemological perspective.

Feyerabend attributes rationalism to a Greek origin, in which contextualized concepts were replaced by a small number of abstracts, context-independent ideas (Feyerabend 1987). This gave rise to a second phase, based on proof or argument, supposedly derived from nature. As a consequence, knowledge came to be seen as singular, as if there were only one "truth", universal and based on arguments, independent of circumstances (Feyerabend 1977).

Therefore, the "reason" that Feyerabend questions is one that follows strict rules and inflexible standards, instituting and obeying a "method" with the following guidelines: (A) accept only hypotheses aligned with already validated or corroborated theories; and (B) reject those that do not correspond to consolidated facts.

Such rules synthesize the essence of empiricism and inductivism. The philosopher also disputes the effectiveness of acting on the basis of "reasons", that is, on what is claimed as the basis to justify our actions.

For Feyerabend (1977), the world is a vast reality to be explored, largely still unknown. Science is understood as a way of interpreting this reality, starting from the principle that the "object" and the "adequate representation" of this object constitute a continuous and inseparable process. He argues that there are no isolated facts, since they are all impregnated with historical-cultural influences and inserted in complex networks of interrelationships.

This is also illustrated by the work of the Harvard Computers. Stellar classification systems such as those of Williamina Fleming and Annie Jump Cannon were born out of an empirical practice, sustained by the recognition of patterns in thousands of stellar spectra, without a full physical explanation of what these patterns meant. Fleming grouped stars based on the presence and intensity of certain spectral lines; Cannon simplified this arrangement into a practical sequence that facilitated the handling of the large volume of data (Sobel 2016). At the time, however, there was still no understanding that these spectral differences were linked to stellar temperature and the degree of ionization, a connection that would only be established decades later, with the work of Meghnad Saha (1893-1956) and, above all, with the thesis of Cecilia Payne (1925).

Thus, when classifying stars, the computers were not deducing from "physical first principles" but engaging in a natural interpretation of the available data – something Feyerabend would describe as a form of methodological "fairy tale". These classifications, which might seem irrational or arbitrary, actually provided the indispensable empirical basis for later physical theories to develop. Just as Galileo defended a heliocentric system still surrounded by uncertainties and using instruments whose reliability was widely contested, Fleming, Cannon and their colleagues supported classification systems that did not correspond to a finished physical picture, but that created conditions for later scientific reason to advance. The "anything goes" attitude applied to data organization by these women, was a fundamental step in the construction of astronomical knowledge.

(d) The Use of "Forbidden Resources": Hypotheses *ad hoc* and Persistence

The case study of Galileo's defense of the Copernican system, analyzed by Feyerabend (1977), illustrates how the construction of scientific knowledge often depends on strategies that contradict rigid methodological rules, with emphasis on the crucial use of *ad hoc* hypotheses.

Before conflict with well-established theories and facts, the consolidation of the new cosmology required the replacement of sensory and conceptual patterns. This transition did not occur through direct confrontation with Aristotelian theory, but rather through the introduction of *ad hoc* hypotheses that made it possible to restructure the interpretation of experience and guide the search for favorable evidence.

Feyerabend (1977) argues that such *ad hoc* hypotheses, in conjunction with other forbidden means, such as propaganda and the temporary removal of contrary evidence, were not irrational, but rather necessary. They functioned as counter-rules that allowed a critical exploration of the evidence and, subsequently, proved to be corroborated by the scientific praxis. The case features an essential paradox that demonstrates that epistemological pluralism is necessary for the progress of science: artifices considered irrational by the rules of the method, such as adaptations *ad hoc*, were instrumental in ensuring the existence of a theory that proved rational and successful.

An example of an *ad hoc* hypothesis can be seen in the work of Henrietta Swan Leavitt (1868-1921), another of the computers. The function assigned to her of minutely measuring the brightness of variable stars on photographic plates was understood at the time as a repetitive, technical, and “minor” work, far from the formulation of great astronomical theories. However, it was from this “tedious” task that a decisive discovery emerged: the correlation between the pulsation period of Cepheid stars and their intrinsic brightness. Such a relationship did not arise from a logical deduction from a previous physical theory, but from an insight produced by the systematic observation of patterns in the data (Leavitt and Pickering 1912; Almeida Silvério, Sitko and Figueirôa 2023).

The period-luminosity relation, initially an *ad hoc* resource to make sense of Leavitt’s series of measurements, later became one of the most important tools in Astronomy, allowing us to calculate stellar distances with unprecedented precision. This methodological adjustment, born of a practice considered peripheral, provided the “tape measure of the Universe”, which made it possible for other astronomers, such as Edwin Hubble (1889-1953), to demonstrate the expansion of the cosmos. Leavitt’s case shows that what might seem “irrational” or “merely technical” in the eyes of a strict methodological view proved indispensable for the development of one of the most rational and successful theories in modern sciences.

This is also an example of the creative use of instruments by this group of women. The computers’ work was carried out from astronomical photographs on glass plates, a relatively new feature that greatly expanded the possibilities for recording the sky. The use of photometry and spectroscopy, however, was not without controversy. As Schaffer (1988) notes, there was a tension between relying on the “mechanical objectivity” of images and the tradition of the trained human eye, considered by many astronomers to be better able to perceive subtleties. Herrmann (1984) also suggests that in the case of spectroscopy, the classification criteria were still perceived as rather uncertain: the astronomer Angelo Secchi (1818-1878) had to revise his system several times, and Hermann Vogel (1841-1907), in 1874, constructed another classification based on then-current notions of stellar evolution. This methodological instability reveals that spectroscopy, although accepted as a technique, still lacked solid consensus on its application. That is, although the material was used by the computers rigorously and provided reliable results, the work of measuring and analyzing them was often considered secondary or “mechanical”, in contrast to the interpretive activities attributed to male astronomers.

In this sense, the creative use of the plates can be compared to Galileo’s employment of the telescope. Just as he used a new instrument, whose reliability was far from established, to support a worldview that challenged established conceptions, the Harvard women demonstrated that these images could be systematically explored and generate innovative interpretations. What initially might seem only a technical resource proved to be an indispensable path toward building new astronomical knowledge.

Final Conclusions

Many of the practices carried out at the Harvard Observatory by the "computers" were seen as "technical routine" and not as "real" science. However, despite their achievements being invisible at the time, and even today (although we fight in a movement in opposition to this erasure), the practices and achievements they carried out were fundamental to the progress (in Feyerabendian terms) of Astronomy.

What we can understand, therefore, is that it is precisely in the marginal ways, in the unofficial ways, that science actually occurs, through methodological pluralism and alternative ideas, which conflict with thought and theories accepted and established, what Kuhn would call the prevailing paradigm (Kuhn 1997); for many, what took place at the Observatory was only manual labor of cataloguing, calculating, and classifying, but it was there that progress really happened.

Feyerabend's theory describes very well the work of Harvard Computers, because they do not follow a stereotypical "scientific method" (perhaps even because they do not occupy the stereotypical posts of scientists and astronomers). Instead, they (a) practiced counter-induction, exemplified with the case in which Cecilia Payne challenged the consensus that stellar composition was similar to that of the Earth, demonstrating instead that hydrogen and helium were the predominant elements in stars – a conclusion initially rejected, but later confirmed; (b) proliferated theories and exercised methodological pluralism, using different classification systems, such as the initial scheme of Williamina Fleming, the detailing of Antonia Maury, and the practical simplification of Annie Jump, foundations for the consolidation of spectral classification; (c) advanced science through what might seem "irrationality", by producing empirical classifications from the photographic plates before fully understanding the underlying physics, classifications that later proved crucial to theories such as Saha's and Payne's; (d) used "forbidden resources" such as the considered tedious and painstaking work of measuring and cataloguing, exemplified by Henrietta Leavitt, whose examination of thousands of Cepheids led to the insight of the period-luminosity relation, providing the "tape measure of the Universe" that enabled the calculation of cosmic distances and consequently validate the expansion of the universe with Hubble.

The historical episodes presented here show that scientific progress is a human enterprise, complex, and much richer than any rigid set of rules could predict. We can say that Computers embody Feyerabend's argument that "chaos" and methodological diversity are not only possible, but necessary for progress. Thus, methodological and ontological pluralism are not only possible, but necessary for the internal progress of science and also for the development of our culture as a whole.

In this perspective, we argue that the Feyerabendian vision is an important lens to understand the challenges and opportunities of contemporary sciences, transcending the historiographical perspective. In a reality in which the complexity of problems increasingly demands interdisciplinarity and dialogue between different knowledges, Feyerabend's lessons on methodological pluralism and the refusal to a single method resonate significantly. What was presented in this work offers a counterpoint to the methodological reductionism often imposed by large research projects, which almost always "forget" irrationality or forbidden resources. Therefore, the recognition of the fundamental role of individuals and groups whose contributions were initially underestimated, marginalized or invisible, as in the case of the Harvard Computers, reinforces the importance of diversity in science, be it of gender, of approaches or of origins, and the potential of citizen sciences to enrich research. In light of this, we conclude that Feyerabend's theory, personified in the history of these women, should provoke questions about the norms established by/in science!

Acknowledgements

To CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) for financial support (funding 001). To FAPESB (Fundação de Amparo à Pesquisa do Estado da Bahia) for financial aid.

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