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BETWEEN RUPTURE AND CONTINUITY:
The Michelson-Morley Experiment in the Light of Gaston Bachelard's Epistemology

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Abstract:
In light of Gaston Bachelard's epistemological perspective, this paper analyzes the Michelson-Morley experiment (1887) to show that scientific theories do not arise solely from experiments, but are fundamental to the construction of knowledge and the historical conception of the luminiferous ether. Based on Bachelard's works, especially *The Formation of*

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the Scientific Mind (1938), the study discusses the epistemological obstacles involved in attempts to measure the speed of light and the motion of the Earth. It argues that, despite its negative result, the Michelson-Morley experiment represents epistemological progress, since, for Bachelard, error is part of scientific advancement and signals the overcoming of imprecise conceptions toward the scientific spirit.

Keywords: Bachelard; Michelson-Morley; Epistemology.

1. INTRODUCTION

"Error, you are not evil."[2]

From the epistemological perspective of Gaston Bachelard, present in works such as *The Formation of the Scientific Spirit* (1938 [1996]), *The Philosophy of No: Philosophy of the New Scientific Spirit* (1940 [1996]) and *The New Scientific Spirit* (1934 [1978]), we will analyze the experiment carried out by physicists Albert Michelson and Edward Morley in 1887, which aimed to detect the "wind of the ether". Considering that the Earth moved through this element, it was assumed that it would be possible to measure the speed of light in relation to the Earth and its variations.

In *The New Scientific Spirit* (1978), Bachelard states that science results from the restlessness between two divergent me-

[2] Bachelard, 1977, p. 298.

taphysics: realism and rationalism. The scientist, in this perspective, would be a rationalist, as he recognizes that every science depends on a theory, but also a realist, since he seeks to connect to the empirical reality he wants to know.

Thus, Bachelard (1978) understands science and the history of the rectifications of scientific concepts as expressions of rationality and it is through the history inherent to the development of the sciences that the philosopher will seek the foundations to constitute his new philosophy. The subject, in Bachelard's conception, is configured as an element in constant search for the process of rationalization, continuously rectifying himself. When the objective is materialized in the idea, the subject can only be conceived in becoming, transforming itself as a consequence of the objective rectification of scientific concepts.

However, the object cannot be given as an immediate objective, and an effective rupture between sensible and scientific knowledge is necessary. In view of this, this research will address one of the most important experiments – which even triggered the line of investigation that culminated in Albert Einstein's Theory of Special Relativity – carried out by Michelson and Morley. The experiment consisted of an interferometer with two arms of the same length, arranged perpendicularly and equipped with reflecting mirrors and a shield to observe the reflected beam of light, testing Fresnel's theory[3] of light propagation.

[3] Fresnel (1818) investigated the relationship between the motion of the Earth and light, developing theories about the ether and double refraction

The analysis will be conducted from the Bachelardian historical epistemology thesis, in which error is not a mere contingency, but an essential stage for scientific progress. Thus, even without obtaining the expected result, the Michelson-Morley experiment made a significant contribution to science.

2. THE EPISTEMOLOGY OF GASTON BACHELARD

> Philosophers who are rightly aware of the power of coordination of spiritual functions consider a meditation on this coordinated thought sufficient, without worrying too much about the pluralism and variety of facts [...] one is not a philosopher if one does not become aware, at a certain moment of reflection, of the coherence and unity of thought, if one does not formulate the conditions for the synthesis of knowledge. And it is always in function of this unity, of this synthesis, that the philosopher poses the general problem of knowledge[4].

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in crystals. Their wave surfaces influenced later experiments, such as the Michelson-Morley experiment. See: Bassalo, 1988, p.81.

[4] Bachelard, 1978, p. 3-4 (Preface).

The search for a basis from which science can be apprehended is what gives and maintains life to classical epistemology, made up of experimental and rational ideals. Thus, subject and object are only propellers of the epistemological problematic, in which science is made in the subject or in the object. This problem is now constructed with the weight of the new science: the detention of philosophy, the taking of science – in the name of philosophy – as an object of its own investigation, representing the modern epistemological image.

The epistemological philosopher who holds Bachelard's attention in his criticism is the one who, in the theory of knowledge, sticks to philosophical resolutions due to old questions of science, glimpsing the disposition of possibility in the face of the aspect of the endless. First, for this, we must encompass every category and epistemological arrangement that had been consolidated and bring to the fore, in order to express its uniqueness and real movement crossed by the scientific-epistemological classes. For the Frenchman, the repercussion of science comes from the fact that it is a philosophical action.

According to Fenati (1991, p.208), in the Modern Age, questioning science through philosophy meant an opposition between the concepts of *doxa* and *episteme*. Sometimes we are qualified to manifest the intelligence not suffered by constant transfiguration, sometimes we are not able to "go beyond" the field of opinion (*doxa*) – there is only a foundation in science as long as it is viable and refutable. From this point, we have two opposing biases to explore: empiricism and rationalism. Both are able to establish a philosophical-scientific foundation, and in both we reach the moving fuse of epistemology – which, for the empiricist, would be to expose the basis and power of perception.

We therefore need to prove that experience is a rational action, and the term *methodological reconstruction* allows us an empiricist observation. Therefore, the methodological reconstruction assesses the possibility of accessing the episteme, following all the necessary precautions. The progression of scientific knowledge is linked to obstacles, which Bachelard will deal with in *The Formation of the Scientific Spirit* (1996), being broken down into: first experience; general knowledge; verbal obstacle; substantialism; unitary and pragmatic knowledge; animistic obstacle; and obstacle to quantitative knowledge. The obstacles indicate the belief of the researcher and, in this way, scientific contemporaneity has to make use of the philosophy of science, intuiting the break with common sense and warring against subjectivity. In this regard, Bachelard (1996, p. 17) states that "when we look for the psychological conditions of the progress of the sciences, we arrive at the conviction that it is in terms of obstacles that the problem of scientific knowledge must be posed".

The first obstacle to be overcome in the construction of the scientific spirit, according to Bachelard (1996), is the *first experience* – carried out without criticism. This is based on empirical sensibilities and lust; therefore, every scientific spirit must oppose the usual datum, and science must not stick to images, because they are representations of comparison and similarity

– having said that, images refer to poetics, and concepts, to epistemology. The second obstacle is *generalized knowledge*, which, for Bachelard (1996), concerns the simulacrum of experience, whereby there is no ideal definition of things, only of words; thus, experience does not generate impulse, and generalizations only hinder thought. In the third obstacle, Bachelard refers to *unitary and pragmatic knowledge* as that which germinates an ideal of phenomenal similarity between elements that do not have similarities, generating numerous false questions, which requires a cautious scientific spirit for the projection of knowledge.

According to Bachelard (1996), the *verbal obstacle* is attributed to linguistic customs that cause problems to scientific evolution, either by the attribution of inappropriate words to express certain concepts, or by the simple absence of cohesion and coherence in the proposed terms. Another obstacle, according to Bachelard, would be *substantialism* – a tedious explanation about the notion of substance, that is, substantialism projects different qualities onto objects, hidden through a propensity of the subject to group divergent references in the same object, hindering the realization of research in the scientific sphere. Based on similarities between the animal, vegetable, and mineral kingdoms, Bachelard points out that the *animistic obstacle* refers to this, as well as to vital intuition, as a way of interpreting the phenomena of the natural plane. And, finally, regarding the *obstacle to quantitative knowledge*, Bachelard (1996) states that, when measuring objects accurately, a numerical disorientation is generated that makes the scientific process unfeasible. The whole idea presented by the philosopher, with regard to epistemological obstacles, is developed as something that causes an obstacle to scientific knowledge – the obstacle adheres to unquestioned knowledge.

According to Araújo (2017, p.20), one of the issues debated by Bachelard is knowledge as possessing a movement, a becoming, in which its concepts, processes, and theses are constantly updated, avoiding what, for the philosopher, would be the great mistake of science: immobilizing knowledge in a pattern of responses. Considering that the foundation of thought is transformed by the renewals that take place at the core of science, Bachelard (1996) states that each era has its respective means, procedures and problems, which agglomerate throughout history, allowing science an infinity of concepts that define various phenomena.

The philosopher reiterates that such coexistence of different concepts brings some apprehension, since there are words that, at the same time, bear their name and their explanation, deceiving us – their nomenclature is the same, but their description is different. We must immerse ourselves in this idea of an epistemological obstacle and understand the spiritual value conferred on the timeline of scientific thought, attentive to objectivity. Through this reflection, it will be possible to verify the epistemological validity and, then, scientific reasoning will be established as an obstacle overcome within the scientific culture.

In *The Formation of the Scientific Spirit* (1996), Bachelard states that the constancy of the dialectic of errors does not come from the objective field, but from the irreverent action of scientific thought in the face of the wise; in the same way that, since science is inventive, such creation must be founded. The treatise on the epistemological obstacle is, in its entirety, the animist obstacle of the physical sciences, as the philosopher describes in his work. This obstacle was almost overcome by the physics of the nineteenth century, but, as it had visibility in other centuries (seventeenth and eighteenth), one of the distinctive characters of the pre-scientific spirit will be configured according to classical physics, showing us the greatness of the obstacle at the same time in which it was overcome. Along with the notions of life and substance, other recognitions are inserted in physics that affect the real values of scientific thought, where Bachelard (1996) indicates psychoanalysis as the only way to free the scientific spirit from the so-called simulated values.

Rationalizing experience is not done only by linking a reason to a fact, since reason is a psychic action that seeks to analyze issues, diverge and interpose them, in order to germinate each other, inserted in a complex of plural reasons. For Bachelard (1978), discursive and hermetic rationalization presupposes the certainty of the knowledge that primarily aroused it.

Such rationalizations require verification, as they emerge from a pre-scientific context where the imaginary and affectivity (such as libido in artistic creation) still exert influence. However, through the psychoanalysis of objective knowledge, Bachelard shows that these initial intuitions cannot be taken as truths – only an epistemological rupture, mediated by new experiences and theoretical rectifications, allows such obstacles to be transcended and an effectively rational knowledge founded.

In the past, Bachelard (2000) also details the operational accident: when the expectation of a certain material action is not met, this does not harm the psychological greatness of the desires it represents. However, for the scientific spirit, a material failure is, immediately, an intellectual failure, since scientific empiricism shows itself to be inserted in a conglomerate of rational theses. An example of a particular point within a methodical generalization would be the experiment of physics in the context of science – in which case Bachelard (1972, 1996) cites the Michelson-Morley experiment.

2.1 The Michelson-Morley experiment

One of the main experimental applications in Einstein's relativistic kinematics was the Michelson-Morley experiment, conducted at the Case School of Applied Science in Cleveland, Ohio, in 1887. Physicist Albert Michelson, with the collaboration of chemist Edward Morley, carried out experiments seeking to understand the effect of the Earth's frame of reference, as an observer, on the measurement of the speed of light propagating in the ether. Such an effect was not detected, so Michelson and Morley began to seek the formulation of an electromagnetic theory more comprehensive than Maxwell'[5] s to explain several phenomena that were, until then, unproven. In this case, H.A. Lorentz was successful in postulating the theory of electrons in 1904, even presenting an explanation for the unsatisfactory results of the Michelson-Morley experiment in his thesis called the contraction hypothesis.

According to Stephen Hawking (2001), Michelson and Morley's experiment consisted of first creating an interferometer that captured the difference in the speed of light in the direction of the Earth's motion and in the opposite direction in order to compare the speed of light in two light beams that would meet at right angles.

> In the Michelson–Morley interferometer, light from a source is split into two beams by a semi-silver mirror. The two beams propagate in directions perpendicular to each other and are combined into a single beam when they fall back on the semi-silver mirror. A difference

[5] "The mathematician James Clerk Maxwell (1831-1879) brought together the discoveries of Ampère, Faraday, Lenz, and Gauss, who described electric and magnetic phenomena, and added their fundamental contribution: the hypothesis that the variation of an electric field could produce an induced magnetic field. In doing so, Maxwell synthesized the laws of magnetism into four equations that describe the relationships between electric and magnetic fields and their sources, forming the basis of classical electromagnetism" (Siqueira, 2021, p.2).

> in the speed of light propagating in both directions could cause the wave crests of one beam to arrive at the same time as the wave valleys of the other beam, canceling each other out (Hawking, 2001, p.7-8).

The configuration of the interferometer was based on the possibility of the Earth moving in relation to a stationary aether, and the equipment should identify a higher speed for light that propagated in the same direction as the Earth's motion and a lower speed when it propagated in the opposite direction. However, the result was negative, that is, it was not possible to detect the movement of the Earth in relation to the ether.

Physicists George FitzGerald and Hendrik Lorentz, in trying to explain the results of the Michelson-Morley experiment, proposed that bodies moving in the ether would undergo contraction and that clocks would be delayed – which would lead all observers to measure the same speed of light, regardless of its motion in relation to the ether. Although they reached the same conclusions, it is important to understand Lorentz's view of the phenomenon of contraction of bodies in motion, for whom the result was related to the very nature of matter (Hawking, 2001, p.8).

According to Martins (2023, p.255), unlike the concepts presented by Maxwell, who considered the effects on the spaces between particles and had electrically charged matter as its source, Lorentz argued that, if matter is composed of molecules, when a body starts moving, contraction occurs due to the change in forces, since two electrified particles interact through their fields. From this collaboration came the FitzGerald-Lorentz formula – FitzGerald's contribution was his statement about the contraction of material bodies in the direction of their motion in the ether, in a square-dependent proportion of the ratio between their velocities [v] and that of light [c] in a vacuum, while Lorentz, in addition to confirming the same result, developed his mathematical formulation.

Later, Morley and D.C. Miller repeated the experiments, but with different materials, one made of wood and the other made of steel (Martins, 2023, p.260). According to Lorentz's predictions, the results should be different, but the result remained the same; that said, interpretations of the Michelson-Morley experimental results were not fully understood at the time. It was only in 1905, with Albert Einstein, that it was possible to clearly understand both the Lorentz transformations and the Michelson-Morley results. In fact, Einstein (1999, p.47-48) mentions the experiment in *The Theory of Special and General Relativity*, stating:

> To this end, Michelson had found a method that seemed infallible. Let us imagine arranged on a rigid body two mirrors with their reflective faces facing each other. A ray of light needs a very definite time t to go from one mirror to the other and return to the first, if the

whole system is at rest with respect to the ether. But we find (by calculation) a somewhat different time for this process if the body, together with the mirrors, is in motion with respect to the ether. Moreover, the calculation indicates that, for a given velocity v in relation to the ether, time t' is different if the body moves perpendicular to the planes of the mirrors or if it moves parallel to these planes. Although the calculated difference between these two time intervals is small, Michelson and Morley introduced an interference experiment in which the difference should be clearly evidenced.

2.1.1 *The experience from the Bachelardian epistemological perspective*

The Michelson-Morley experiment is analyzed by Bachelardian philosophy through two parameters. First, considering its negative result, it is found that the experience, even though it is a concrete theory, does not depend on its predictions. Secondly, it is stated that *the no* is as valid as the *yes*, as it drives scientific evolution by seeking answers to unexpected a priori results. Therefore, the conclusion of the Michelson-Morley experiment demonstrates that the experience is self-sufficient in relation to the theoretical script and manifests the experience of an environment independent of the individual. It is worth mentioning that, for Bachelard, the real exists, but it is never accessed in its entirety.

However, specifically in this experiment, such an indication does not fully apply, because, in addition to requiring updates in physical theories, it also demanded a new thesis that encompassed the reality of the phenomena, since the basis proposed by FitzGerald-Lorentz was not able to sustain Einstein's theory on the contraction of bodies. The second parameter refers to the fact that the experiment required a new set of clarifications for its negative conclusion. In *The Philosophy of No* (1996), Bachelard presents an open philosophy – of scientific knowledge – as the understanding of a spirit that investigates the unknown in search of something real that refutes previous conclusions – it is essential to understand that the current experience denies the previous one; otherwise, a new non-experience is configured.

Thus, it is observed how the Michelson-Morley experience is incorporated by Bachelardian epistemology by abandoning the theoretical principles that guided it and proposing unprecedented conclusions about what was examined. A crucial aspect of the experiment is that it was conceived at a time when the existence of the ether was indisputable, but its definitive answer was only reached within the framework of the Theory of Special Relativity. Bachelard (1972, p. 121-122) complements by stating that, based on the

negative result of the experiment, physicists concluded that it was a negative experiment from the Newtonian perspective and positive from the Einsteinian perspective – for him, the result of the experiment is positive:

> This pseudo-negative experience would not open up about the mystery of things, about the unfathomable mystery of things. His 'mistake' would not carry an argument in irrationalism. This 'error' was not even a proof of the inadequacy of rationalism. Michelson's experience proceeded from an intelligent question, from a question that had to be thought about [...] thus, instead of a universal doubt, an intuitive doubt, a Cartesian doubt, technical science gives us a precise doubt, a discursive doubt, an instrumental doubt.

By intuiting scientific aggrandizement and fortification, the foundation of scientific inquiry becomes significant for his philosophy. For this reason, Bachelard (1977) attests that the rationalist does not prove himself as a unit, but guarantees confidence in his dialectic – given that such a rational experience is essential to express an experience in the object and in the individual, in a discursive-temporal way. The dialectic is situated between the rational and the experimental being.

Another inherent point would be the strengthening characteristic of previous theories and the updating of negative results, aiming at scientific growth, since, for the philosopher, knowledge is an inexhaustible source. The possible progress, in Bachelard's view, is also due to the fact that the result was not foreseen by experience, proving its autonomy and driving a scientific progression by demanding new answers to the theory of relativity, in this case.

Therefore, for Bachelard (1972, 1977), it is necessary to clarify that the perceptible real does not constitute a contributing factor to the emergence of the new, nor to the scientific triggering. Moreover, it was the "failure" of the Michelson-Morley experiment that made possible Einstein's "success" in postulating the Theory of Relativity – and this should not be seen as something negative, but rather as evidence that, for theoretical-scientific consolidation, an epistemological rupture is necessary. In short, as Velanes and Rocha (2020, p. 233) state, "it was Michelson's failed experiment on the possibility of calculating the speed of the Earth in relation to the ether that made it possible for physics to wake up from its 'dogmatic slumber', inspiring Einstein to compose the Theory of Special Relativity".

3. FINAL CONSIDERATIONS

> "This impression of the negativity of an experience must not be allowed to subsist. In a well-done experience, everything is positive"[6]

[6] Bachelard, 1972b, p. 121.

The idea of epistemological obstacle is understood, in addition to educational practice, in the historical course of scientific thought; It is necessary to insert oneself in a normative view, if there is the will to inquire into the efficiency of a thought. The epistemologist, since certain knowledge, even if true, ceases useful investigations prematurely, must select among the documents gathered by the historian and criticize them rationally.

Thus, the relationship between experience and reason, when analyzed in its same direction, will come across both danger and denouement. Being the only one that indicates scientific experience, only reason expands its studies beyond the knowledge of common sense. Therefore, rational and constructive dedication attentive to the epistemologist, differentiating him from the historian of science, who perceives notions as actions. For Bachelard (1996), a fact wrongly assimilated by a certain time, for the historian it remains as a fact; For the epistemologist, it becomes an obstacle, something to be overcome. Clearly, the verbal obstacle leads us to one of the most complex obstacles, substantialism. Thus, it is concluded that we must express that, for the physicist, realism is a null metaphysics, since it suspends investigation instead of motivating it.

When particle theory emerged, the notion of "ether" as 'action' was decimated, when in the nineteenth century the concept was resumed with the scientific intention of reinvestigating the primordial question. However, modern physics turned its gaze to the energetic interrelation of phenomena, in the matter of 'light', moving physicists since

Maxwell to aim for a mechanistic theory to explain electromagnetic emission in a vacuum – where the immovable electric charge would disorder the ether, refracting it by means of elastic vibrations, in a similar way to sound emission in a mechanical field.

Foreseeing that all optical experience on Earth related to aberration, reflection and refraction would culminate in no dimensional conclusion about the terrestrial motion in relation to the ether, Fresnel, in his thesis on the ether, justifies it by pointing out an omission of the effects in the medium – in his time, this theory was quite consistent. However, in 1867, Maxwell, by replicating this theory and ascertaining its origin through experiments, ends up reaffirming the null result postulated by Arago, referring to the terrestrial movement implying, through a prism, the luminous lapse – at the same time that Michelson began his research. In this period of history onwards, the entire course of the search for scientific knowledge developed, in this case, the measurement of the speed of light, of the Earth and the proof, or not, of the ether and its implications.

For Caruso and Oguri (2006), the interactions between space-time coordinates are no longer explained by Galileo transformations as a result of Lorentz transformations. In this way, in response to mutations between coordinated systems at different points of inertia that remain linear with each other, Einstein will admit the homogeneity and isotropy of space.

If, for Maxwell, the speed of light emission would represent the addition of the speed of light itself to the speed of its medium – the ether – then the speed of the ether directed to the Earth could be apprehended by the discrepancy between the time of emission of light in an east-west and north-south direction, aiming at the purpose of Michelson and Morley's experimental-scientific investigation. As a result, they created the interferometer and began their journey, which we call the Michelson-Morley experiment. Bachelard (1996, p. 87), when he states that "science instructs reason. Reason must obey science, the most evolved science, science in evolution", exposes his epistemological thought – where the dual scientific movement is through rationalism and empiricism.

In view of this, it is concluded in this research that the Michelson-Morley experiment, from the epistemological-Bachelardian perspective, can be considered scientifically positive – and its transformative and independent character in tests and results proves the universe of possibilities and how science is in constant search of knowledge, already postulated – unveiled – or not. In this way, all the updates of the hypotheses presented serve to confirm the essence of physics inherent in the new scientific spirit.

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