Nature likes to hide

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ABSTRACT

Physics is usually regarded as a science capable of explaining any phenomenon in this World. However, Heraclitus had pointed out from ancient times that Nature remains beyond human grasp. Classical Physics was proven inadequate for the microcosm and replaced by Quantum Physics with extensive use of Mathematics, which sets aside the need for natural explanations, replacing physical quantities by functions and relations. Finally, in accordance with Heraclitus, the contemporary philosopher Ludwig Wittgenstein remarks that any language, scientific or mathematical, is not adequate to describe the World, giving just a picture of reality, leaving the real Nature beyond reach.

KEYWORDS

History of Physics, Physics and Mathematics, Classical and Quantum Physics, Heraclitus, Ludwig Wittgenstein

RÉSUMÉ

La Physique est généralement considérée comme une science capable d'expliquer n'importe quel phénomène dans ce Monde. Cependant, Héraclite avait déjà souligné depuis l'antiquité que la Nature reste hors de portée de l'homme. La Physique Classique s'est révélée inadéquate pour le microcosme et a été remplacée par la Physique Quantique, avec une utilisation extensive des Mathématiques, ce qui écarte le besoin d'explications naturelles, remplaçant les grandeurs physiques par des fonctions et des relations. Enfin, conformément à Héraclite, le philosophe contemporain Ludwig Wittgenstein note que tout langage, scientifique ou mathématique, n'est pas adéquat pour décrire le Monde, donnant juste une image de la réalité, laissant la vraie Nature hors de portée.

MOTS-CLÉS

Histoire de la Physique, Physique et Mathématiques, Physique Classique et Quantique, Héraclite, Ludwig Wittgenstein

INTRODUCTION

The realization that it is impossible to obtain complete knowledge of Nature made Heraclitus of Ephesus (c. 535-480 BC) claim that "*Nature likes to hide*" (fragment 123). Heraclitus, one of the Ionian philosophers who were seeking the ultimate element of everything, considered that "*the World was ever and is and shall be an everlasting fire*" (fragment 20). So, this World, although its inherent nature remains invariable, being a fire, changes continuously shape and position, impeding the human mind to grasp it (Bailey, 1928). Especially for those who study Nature, another philosopher, Empedocles of Akragas (495-435 BC), stated that: "*After seeing a small piece of life while they lived, very soon met death, rose like smoke and flew away, sure only of what each of them met crawling here and there, but they boast of having found the whole*" (Trépanier, 2017). Empedocles remarks that the shortness of human life combined with the inevitably limited knowledge obtained during it, does not usually prevent the deceptive arrogant belief that everything is known and understood.

Since ancient times, Physics, the effort to understand Nature, has given a constantly changing view of it. Various theories prevailed for a while, but sooner or later they were replaced by new ideas and speculations (Imanova, 2022). Even today Nature continues to remain hidden, as modern Physics, Quantum Mechanics, has become incomprehensible and departs from ordinary human experience and intuition, although it is extremely successful in explaining through Mathematics the microcosm with the highest precision. The introduction of Mathematics in the description of Nature is unavoidable but, in many cases, plays such a dominant role that it replaces Physics, ostracizing the need to find the causes of phenomena.

In this article, a few of the puzzling facts and the bold intuitions are reported, which overturned the prevailing picture of things. Finally, the question persists: after all, is it possible to find a way to understand and describe Nature, or will it remain inevitably hidden beyond human grasp?

THE INTERWEAVING OF MATHEMATICS WITH PHYSICS

According to Aristotle, Pythagoreans were the first who developed and studied Mathematics, considering its principles as the World's infrastructure. They imagined that idealized nonmaterial entities, called numbers, endow sensible objects with their existence and their distinctive characteristics. These ideas influenced Plato in the creation of his idealized world of Forms and Aristotle in his application of Geometry, where points have no dimensions and lines thickness, in Astronomy, Mechanics, Optics and Harmonics, the so-called "mixed sciences".

The connection between Physics and Mathematics in the mixed sciences was the main subject of analysis in the Middle Ages and continued beyond the Renaissance. Although Mathematics contains provable truths about its own structures concerning idealized objects, the relation of them to reality, as Physics requires, is not certain. Mathematics, apart from calculations, offered logical austerity, consistency, and reproducibility of conclusions, so in many cases it was considered not just the language of physics but coincident with it. Characteristically, Isaac Barrow (1630-1677) regarded Mathematics as identical to Physics, considering mathematical objects to be both intelligible and sensible in a different way as physical objects (Malet, 1997). With Newton, not only did the boundary between Mathematics and Physics become obscure, but a priority was given to Mathematics. According to him, "*although colours belong to Physics, nevertheless scientific knowledge of them must be considered mathematical…*" (Gingras, 2001). Newton believed that as Nature is exact, it can be understood through Mathematics, and any error comes from those who study it.

Over time, the gradual use of more and more complicated Mathematics made Physics inaccessible to many people who, although they continued to be interested in physical phenomena and theories, were not familiar with the mathematical formulation used. A characteristic example was Michael Faraday, who, writing to Clerk Maxwell, complained: "*When a mathematician engaged in investigating physical actions and results has arrived at his conclusions, may they be not expressed in common language as fully, clearly, and definitely as in mathematical formulae*?" (Gingras, 2001).

Another disadvantage of the extensive use of Mathematics in Physics is that it ignores the causes of the phenomena, failing to give explanations based on a mechanical or on a more generally accepted model of interaction expressed in common language. This proves that just Mathematics cannot convincingly give the image of what is happening in Nature. A characteristic example is Newton's *Principia*, which provides a purely mathematical aspect for forces acting at a distance, leaving obscure their physical cause. The French mathematician René Thom remarked: "*Descartes, with his vortices, his hooked atoms and the like, explained everything and calculated nothing: Newton, with his inverse square of gravitation, calculated everything and explained nothing*" (Gingras, 2001).

This disadvantage prompted efforts for a mechanical explanation of gravity via a material medium until the beginning of the twentieth century, without success. So, all these attempts were gradually abandoned for Newton's purely mathematical presentation of gravity attraction. Bertrand Russell remarked: "*Causes are useful to daily life and in the infancy of a science, but tend to be displaced by quite different laws as soon as a science is successful*". It seems as if the need to find the causes of phenomena wanes with the success of a theory replaced by more and more advanced and abstract mathematical representations (Cartwright, 1983).

MECHANISTIC AND ELECTROMAGNETIC VIEWS OF NATURE

The interweaving of Mathematics with Physics may tend to remove the need to penetrate into the causes of phenomena, but it is impossible to cease the influence of personal believes and preexisting generally accepted doctrines in innovative theories interpreting experimental results (Kuhn, 1962). Such an example is the electromagnetic view of Nature, popular in German-speaking countries, in which the ideas of Immanuel Kant were part of the education of young scientists (Wheaton, 1983). At the end of the nineteenth and the beginning of the twentieth century, Classical Physics based on Newton's Mechanics, Maxwell's Electrodynamics, and Thermodynamics appeared to have discovered all the important fundamental laws, making almost impossible the appearance of any new theory.

This perspective was very soon disproven. At that time the mechanistic view of Nature was generally adopted, according to which everything in physics had to be described by mechanical models based on force, mass, space, and time. However, J. J. Thomson in 1881 found experimentally that a moving sphere exhibits an additional resistance to any change of its velocity if it is electrically charged. A moving charged object is equivalent to an electric current, and this resistance comes from the tendency to conserve itself according to Lenz's law. Simultaneously, this moving body, because of its mechanical mass, tends to keep its velocity. So, in this object coexist two kinds of inertia, or equally mass, the electromagnetic and the mechanical, and as the first increases with velocity, though the latter remains constant, the entire mass of the charged sphere, and equivalently its matter, becomes variable.

This represents a decisive step towards a new perspective, the electromagnetic view of nature, which stands in opposition to the old mechanistic one, where mass and matter were considered constant everywhere and at any time. In the new theory Maxwell's ether had the role of a universal basic element, as even particles were considered concentrated ether, "*like minute crystals formed in a mother liquor*" (Lodge, 1883; Kragh, 2002). Matter was reduced to a structure of ether, a substance that exists beyond matter, so models of the old mechanistic view based on material particles or objects and generally the laws of nature had to be replaced by electromagnetic equivalents.

The mechanistic and the electromagnetic views offered different explanations of the same experimental results obtained by J. J. Thomson in 1897. In a glass tube with rarefied gas, the cathode rays, the electrons, considered charged particles, were reflected by a magnetic field according to the laws of magnetic deflection of macroscopic objects. From this reflection, the ratio of charge to mass was measured, and the mass of the electron was estimated. On the other hand, according to the electromagnetic view, cathode rays were structures of the electromagnetic ether, centers of electric force, and their magnetic reflection has been attributed to an abrupt alteration of the refractive index of the ether in the tube near the magnet due to the presence of the residual gas particles, which in their turn constitute other manifestations of this universal fluid (Wheaton, 1983). Finally, Philipp Lenard observed that the absorption of these rays was proportional to the density of the material they passed and they scattered even by some inches of air and so confirmed J. J. Thomson's idea that cathode rays were particles, not some sort of electromagnetic radiation.

INDICATION OF DISCONTINUITY IN RADIATION IONIZING A GAS

The ionization of a gas by electromagnetic radiation, supposed as spreading spherically through it, reveals two puzzling facts. The first is that only about 1 in 10^{12} gas molecules are ionized, as experiments have shown (Thomson & Rutherford, 1896).The second puzzling fact is that the energy of the expelled electron is equal to the whole energy of the wave, not the one associated with the tiny area of the wave surface corresponding to the gas molecule. So, it is natural to think that either the distribution of energy is not uniform over the wave surface or the atom is in a certain susceptive condition. As Maurice de Broglie remarked, "*The way by which the energy of frequency v is caught by the atom and leads to the ejection of a particle with energy hv remains absolutely mysterious. Specifically, we cannot understand if the energy of the particle came from the internal energy of the atom, how it would exhibit such a strict relationship with the frequency of the incident wave, as the latter would play only a role of activation. If we would accept, as it has been proposed sometimes we would be very near to a particle theory of light*" (De Broglie, 1922).

J.J. Thomson, after proposing several hypotheses to explain the very small number of atoms ionized by an electromagnetic radiation, returned to an older idea he had in 1893 that the "*tubes of force*" used by Faraday to explain electrostatic laws had a real existence. The radiation was regarded as the propagation of transverse tremors along tightly stretched discrete Faraday tubes embedded in ether, giving the latter a fibrous structure. J. J. Thomson, in a lecture given in 1903, describes the propagation of electromagnetic radiation, in this case light, by this picture: "*The front of the wave, instead of being, as it were, uniformly illuminated, will be represented by a series of bright specks on a dark ground, the bright specks corresponding to the places where the Faraday tubes cut the wave front*" (Thomson, 1908).

Likewise, G. I. Taylor remarks: "*Energy is distributed unevenly over the wave front. There are regions of maximum energy widely separated by large undisturbed areas. When the intensity of light is reduced these regions become more widely separated, but the amount of energy in any one of them does not change, that is, they are individual units*" (with energy hν). Taylor obtained interference fringes with such feeble light that only one of these individual units participated in the experiment at a time, showing the coexistence of granular and wave character of the electromagnetic radiation (Taylor, 1909). It is noticeable that from the end of the nineteenth and the beginning of the twentieth century, experimental results questioned the continuity of the wavefront of the electromagnetic radiation, taking the first steps to a particle-like image of it, where particles concentrated the entire energy of each radiation wave.

QUANTUM THEORY

In 1900, Max Planck, in order to fit the distribution of radiant heat energy from a body of a certain temperature among various wavelengths as it resulted from experiments, proposed the following theory: he accepted that the walls of the radiant body were covered with one-dimensional, simple-harmonic “oscillators”, each conceived as a damped, oscillating current that vibrated in a tuned response to the external stimulus, absorbing and emitting thermal radiation in discrete units, quanta, each with energy $\varepsilon = h\nu$, where ν is the natural frequency of the oscillator and h a universal constant, the Planck’s quantum of action.

Planck could not find any physical support for his theory, and the relation between ε and ν was “a purely formal assumption” to fit the experimental results. He says accordingly, “*It is true that we shall not thereby prove that this hypothesis represents the only possible or the most adequate expression of the elementary dynamical law of the vibration of oscillators…There is, however, no method of testing its admissibility except by the investigation of its consequences, and as long as no contradiction in itself or with experiment is discovered in it, and as long as no more adequate hypothesis can be advanced to replace it, it may justly claim a certain importance*” (Planck & Masius, 1914). In this way, Planck introduced the revolutionary idea that “*radiant heat is not a continuous flow and indefinitely divisible…It must be defined as a discontinuous mass, made up of units all of which are similar to one another*” in contrast to Maxwell’s theory (Planck’s obituary, 1947). This discontinuity was something that Planck himself and many others found difficult to accept for several years. However, in the following two decades, the belief that certain physical quantities can only assume discrete values will be generally established following the departure from Classical Physics.

In 1905 Einstein made the first use of Planck’s quantum hypothesis outside heat radiation to explain the photoelectric effect. He proposed that light is composed of discrete energy units, the light quanta (photons), each colliding with and being absorbed by one of the atomic electrons, giving all its energy to the latter so that the electron can be ejected if the energy is enough to overcome its atomic binding.

However, this explanation seems oversimplified; for example, it has been found that the temperature of the target surface affects the energy of the emitted electrons. In addition, experiments with polalized X – rays and with the gaseous form of the photoelectric effect showed that most of the electrons are ejected parallel to the electric vector of the polarized radiation, not along its propagation, indicating that photons are not like billiard balls. It seems that each “*quantum (photon) is a vector bundle of energy, for it explodes, so to speak, at right angles to its direction of motion*” (Bubb, 1924). These interwoven characteristics of particle/wave characteristics in electromagnetic radiation, in spite of the apparent incompatibility of them, made Einstein, in 1909, express the hope that “*The development of theoretical physics will bring us a theory of light that can be interpreted as a kind of fusion of the wave and the [particle] theory…[The] wave structure and [the] quantum structure…are not to be considered as mutually incompatible*” (Pais, 1991).

In 1909 the scattering of alpha particles from a gold foil made E. Rutherford regard the atom as a system where a massive, very small, positively charged nucleus was at the center with the electrons orbiting around at a distance, leaving most of the space empty. In 1913 Niels Bohr, based on Rutherford’s results, proposed an atomic model for hydrogen resembling our planetary system, where atomic electrons moved around the positive nucleus at certain orbits associated with fixed energy values without emitting electromagnetic radiation, although according to Maxwell’s theory they should. Electromagnetic energy is released or absorbed in discrete quantities (quantization) only when electrons “jump” from one orbit to another.

The behavior of electrons during the jumps puzzled scientists, especially Schrödinger, who always rejected the idea of jumps, replacing it with a different frequency of oscillation of the orbiting electron (considered as a wave) during the absorbing or emitting processes. No explanation was given why the atomic electrons had to move on these certain orbits and not in the space between them. A reason may be given by Louis de Broglie's quantum theory, according to which every particle is a small region (singularity) where almost all the mass-energy is concentrated, surrounded by an extended wave inseparably connected to the particle. Atomic electrons are associated with stationary waves, and the permitted orbits are those whose circumference is equal to an integer number of wavelengths correlated with each orbiting electron. However, the nature of these waves and the cause of their bending along the minute atomic orbits are obscure (Jones, 2008).

Starting from the original quantum theory of Planck and Bohr's model of the hydrogen atom, many eminent physicists, mathematicians, and philosophers tried to form a theory capable of describing and explaining the atomic and subatomic worlds. The traditional physics of Newton and Maxwell proved inadequate for the microcosm, although it seemed absolutely successful for the macrocosm. From the mid-1920s, Quantum Physics was developed, which was not free from notional defects but helped scientists to explain the atomic spectra, the chemical bonding, the electrical, magnetic, and thermal properties of matter, the nuclear structure and nuclear reactions, the evolution of stars, to predict the existence of antimatter, etc. (Davies & Brown, 1988). Quantum Physics, although spectacularly successful in describing the results of all known experiments, includes such an excessive mathematization that mathematical equations are considered sufficient explanations for the true view of Nature (Hossenfelder, 2018).

We see that although the world is one, there are two incompatible theories for it: Classical Physics for the macrocosm and Quantum Physics for the microcosm. Sheilla Jones remarks, "*The quantum world of the atom operates by rules that are physically impossible in our everyday world. It's a very strange notion that everything in the ordinary world is made up of "quantum staff", such as electrons, light waves and atoms, and yet there is no way to make the macroscopic and microscopic worlds operate under a single set of rules. Despite the best efforts of some of the greatest scientific thinkers of the time, the quantum revolution of the middle 1920s failed to produce a philosophical world view capable of combining the two disparate worlds into one sensible theory. If, after such a long time, all the smart men and all the smart women who work in physics have not been able to reconcile the two sets of rules for the universe, it is natural to wonder if one - or both - of the two sets might just be wrong. But suggesting that either of the two most successful, experimentally verified models of physics might be wrong is tantamount to goring a sacred cow*" (Jones, 2008).

HERACLITUS MEETS WITTGENSTEIN

Physical phenomena and experimental results are expected to be explained by theories, which are not self-evident truths imposed by Nature, but human inventions based on speculations, giving the wrong impression that they "*penetrate beneath the flux of phenomena to the real structure of Nature*" (Hesse, 1953). Ludwig Wittgenstein (1889-1951), who has been characterized as the most charismatic figure of 20th -century philosophy, in his book Tractatus Logico-Philosophicus written in 1921, takes up the problem to find the way in which language represents the World, remarks, "*The whole modern conception of the world is founded on the illusion that the so-called laws of nature are the explanations of natural phenomena. Thus people today stop at the laws of nature, treating them as something inviolable, just as God and Fate were treated in past ages*" (Simões, 2021). In brief, Wittgenstein expresses the following ideas: "*There is just one world that we want to describe and for this we have to use some language – scientific, mathematical or otherwise. There is a problem about whether what we say about the world corresponds to the way the world really is. We want to know the true nature of the correspondence between what we say and the way things are, but we can use only language itself to describe that correspondence. Words of a language can never express the desired correspondence…*" (Casti & DePauli, 2000).

In contrast to Newton, Wittgenstein doubts the ability of mathematical language to describe the way the World really is. He comments, "*But how remarkable: in the familiar theorems of mathematical physics there appear neither things nor functions nor relations nor any other logical forms of object! Instead of things what we have here is numbers, and the functions and relations are purely mathematical throughout*" (Simões, 2021). Therefore, the mathematical language is not suitable to express the real nature, as it is about something else, not actual things. According to Wittgenstein, there is always an unbridgeable gap between what can be expressed in any language, common, scientific, mathematical, or otherwise, and the real Nature, which remains elusive, beyond reach and hidden, in accordance with Heraclitus. We see that the contemporary philosopher Wittgenstein meets the ancient one!

According to Wittgenstein, every theory constitutes a description of Nature, offering just a picture of it, though the real Nature remains beyond access. Moreover, as physical theories are only descriptions of pictures of the World, it is possible for Natural Sciences to combine multiple models of explanation, making the notion of a privileged theory meaningless. If there is no privileged theory, there are certainly several possible ways of representing facts. One is not more correct than the others are, but one could be more appropriate to give a more detailed or helpful picture of that part of Nature that specific physical theory should describe (Simões, 2021). Notice Sheila Jones's bewilderment about the correctness of Classical and Quantum Physics, which, although incompatible, seem absolutely successful for the description and explanation of the macrocosm, the everyday world, and the microcosm, respectively.

In the words of Wittgenstein, *"(Newtonian) mechanics determines one form of description of the world by saying that all propositions used in the description of the world must be obtained in a given way from a given set of propositions-the axioms of mechanics. It thus supplies the bricks for building the edifice of science, and it says, "Any building that you want to erect, whatever it may be, must somehow be constructed with bricks, and with these alone". Similarly the possibility of describing the world by means of Newtonian mechanics tells us nothing about the world: but what does tell us is the precise way in which it is possible to describe it by these means"*, i.e. the propositions, the axioms of mechanics. According to Wittgenstein, "*the real achievement of a Copernicus or a Darwin was not the discovery of a true theory but of a fertile new point of view*" (Simões, 2021). This means that the two theories may be the motive for interesting speculations and ideas, but they miss the absolute, invariant truth hidden behind the flux of phenomena. After all, as it has happened to all theories so far, it is expected that they will be replaced by new approaches sooner or later.

The fact that theories are just pictures of reality becomes more evident when we consider older aspects of the world. Let's see two examples: Anaximenes of Miletus (c. 586-c. 526 BC) stated that the basic underlying material of all things is air. Its condensation by increasing density creates clouds, water, rocks, etc., though by rarefaction, which it was compared with felting, things returned eventually to air. Air, condensation, and rarefaction were the pieces of the puzzle making the picture of the entire world. In more recent times René Descartes tried to explain the construction and operation of the universe by atoms held together by hooks and eyes, though interlocking spinning vortices filling all space carried celestial bodies, determining their orbits and the rotation about their axis. Atoms endued with hooks and eyes, together with cosmic vortices, were the basic bricks of Descartes' cosmological picture. Obviously, neither Anaximenes nor Descartes caught the view of the real, one, eternal world, but at least their theories gave the opportunity for many remarkable ideas and intuitions to be set forth and become the basis of successive aspects of nature. Today, old theories may be considered outdated or even naive; however, they are the forerunners of contemporary science, and the persons who proposed them are honored as great intellectuals who opened new ways to apprehend the cosmos around us.

CONCLUSION

From ancient times the human mind tried to describe and explain Nature. Pythagoras and Plato considered an idealized World, though Ionian philosophers searched for the ultimate element underlying everything. Among them, Heraclitus was the first who emphasized the inability of the human mind to embrace and understand the true essence of Nature. The various theories and especially the practical applications inevitably interwove Mathematics with Physics, providing logical austerity, consistency, and reproducibility to the latter. This led in many cases, to the view that mathematical formulas represent elements of the World, excluding the need for natural explanations. In recent times, the philosopher Wittgenstein, approaching Heraclitus, claimed that any language, scientific, mathematical, or otherwise, cannot describe completely the World. So, a physical theory, e.g., Newtonian mechanics, tells nothing about the real World, but it just gives the ideas and propositions, i.e., the means to build a picture of it. However, apart from Wittgenstein's opinions, the fact of the endless coming and going of a plethora of theories about Nature through time proves that the efforts of innumerable physicists who, according to Empedocles, may have convinced themselves "of having found the whole", have been fruitless. Nature remains hidden, awaiting fresh ideas and propositions for the creation of a new picture screening the real essence of it.

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