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# Realismo Ontológico e a (In)Dependência das Entidades Científicas

## *Ontological Realism and the (In)Dependence of Scientific Entities*

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## Resumo

O realismo ontológico defende que as entidades científicas são independentes das práticas científicas. Este artigo apresenta a importância do realismo ontológico para a compreensão da crença na existência das entidades científicas. Em seguida discute outra concepção: a dependência das entidades científicas à prática científica. Por fim argumenta-se que as duas teses não são excludentes.

**Palavras-chave:** realismo ontológico; entidades científicas; prática científica.

## Abstract

*Ontological realism argues that scientific entities are independent of scientific practices. This paper introduces the significance of ontological realism for understanding the belief in the existence of scientific entities. It then discusses another concept: the dependence of scientific entities over scientific practice. Finally, it is argued that the two theses are not excluding between themselves.*

**Keywords:** *ontological realism; scientific entities; scientific practice.*

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## INTRODUCTION

Broadly characterized, scientific realism is the doctrine that scientific theories always refer to real objects and, in referring to these objects, produce knowledge about the world (Psillos, 1999, p. 3).

Because it is a complex doctrine, this characterization evidently does not cover the entire variety of definitions of scientific realism. There are several ways to characterize scientific realism, but the following dimensions are usually presented: i) ontological realism: scientific entities are independent of the theories in which these entities are located; ii) epistemological realism: there are good reasons to believe in the truth of a successful theory; iii) semantic realism: the sentences that make up a theory must be considered either true or false; iv) Explanatory realism: although truth plays a prominent role in the evaluation of scientific theories, the main virtue, for a realist, is the explanatory capacity of a theory[1].

Despite the fact that these four dimensions are, conceptually speaking, distinct, they can relate to each other; and, in fact, this usually occurs. The distinction therefore serves, in most cases, merely an organizing role in the discussion – since, as the discussion itself progresses, it is difficult (though not impossible) for a debater to focus on only one of the dimensions of realism.

This article deals with ontological realism[2], which, as we have already seen, argues that scientific entities are independent of the theories in which the entities are located.

The thesis of the independence of scientific entities in relation to the knowledge we possess of them means that our knowledge is not a property of these entities. Furthermore, the reality of such entities is affirmed precisely in function of such independence; For the realist, if entities were dependent on our knowledge, this would mean subtracting or adding something to the entities that would not be part of the entities themselves.

One of the virtues of ontological realism's argument is the image of science that flows from the thesis of the independence of scientific entities in relation to the knowledge we possess about them: the truths of science are *discovered* as a function of scientific methodology; science deals

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[1] There are at least five other forms of realism: representational realism, common-sense realism, metaphysical realism, axiological realism, and structural realism. The first three are very similar to (although not completely identical to) ontological realism. Axiological realism complements epistemological realism and states that the goal of scientists is the pursuit of truth. Structural realism argues that, in some cases of conceptual change, the mathematical structure of theories remains unchanged.

[2] But, as already noted, it will inevitably end up touching, albeit tangentially, on epistemological, semantic, and explanatory issues.

with the real world and in a reliable way. However, there is another image of science, stemming from another thesis: science deals with the real world and in a reliable way, but this occurs as a function of the intervention of scientific practice, through instruments, materials, and methods.

Apparently, then, we are facing a debate: either the entities are independent or they depend on scientific practice. The objective of this article is to show that the philosophical objectives of ontological realism and of the defenders of the idea that entities emerge through scientific practice are completely different and, therefore, there would not, strictly speaking, be a philosophical debate on the subject; instead, there would be a certain complementarity between the two theses and the two images of science.

The first section of this article presents the thesis of the independence of scientific entities in relation to the knowledge we possess about them. The second section deals with the emergence of entities within scientific practices. The conclusion shows that the two theses are not mutually exclusive.

## 1. An Introduction to Ontological Realism

As established in the introduction, we will work here with the realist conception of the independence of scientific entities in relation to our knowledge of such entities. Therefore, the realism addressed here is ontological realism, and not epistemological, semantic, or explicative realism.

An excellent characterization of the ontological dimension of realism can be found in *Realism and Truth*, by Michael Devitt: a scientific entity is not "constituted by our knowledge, by our epistemic values, by our capacity to refer [to an entity], by the synthesizing power of the mind, by our imposition of concepts, theories or language" (Devitt, 1997, p. 15). Thus, a scientific entity exists independently of scientific and mental resources.

The ontological dimension of scientific realism, in the style of Devitt, is highly plausible. Firstly, it is natural. A scientist, when dealing with entities in their scientific activity, does not consider them as constituted by anything from Devitt's list above – they employ them as part of the real world, without any problematization regarding their existence[3] (Franklin, 1996, p. 132).

[3] This does not mean, however, that at certain points in the history of science there have not been (and will not be again) controversies regarding the existence of certain scientific entities. The thesis that scientists do not question the existence of an entity only applies to entities that are already accepted and established within a scientific discipline.

Secondly, it is more reasonable than a contrary position (which will not be defended in this article), which can be presented as follows: entities only exist due to our knowledge, values, etc. It is not sensible to maintain that an entity only exists as a function of knowledge and values; For example, while it is true that the values of Victorian society in Charles Darwin's time did not present obstacles to understanding reality in terms of a (Darwinian) concept such as “struggle for survival” (Lewens, 2005, p. 568), it is also true that the concept actually denotes a real process[4]: the dispute between organisms for the same natural resources; conversely, the fact that the context of research on heredity in Darwin's time authorized him to defend the existence of entities such as “gemmules” (Bowler, 1989) did not legitimize the existence of such an entity.

Despite such virtues, ontological realism may give the impression of having a weak relationship with scientific knowledge, since its philosophical basis is the thesis that objects only possess properties that we can observe; thus, considering the functioning of our sensory perception, it would be tempting to confuse the ontological realism presented here with the representative realism defended by John Locke[5]. But this is not the case. Ontological realism provides a particularly interesting conceptual starting point for the notion of causality in the natural sciences. Accepting that a phenomenon has a cause, and that, if the cause is removed, the effect does not occur, it can be affirmed that the cause exists (independent of our knowledge). A conception close to this can be found in Nancy Cartwright's *How the Laws of Physics Lie* and Ian Hacking's *Representing and Intervening*. For Cartwright, scientific laws accommodate phenomena in an organized way within an explanatory scheme (Cartwright, 1983, pp. 76-77), but only the causes are real[6] – and the causes are, precisely, the scientific entities (Cartwright, 1983, pp. 76-77). For Hacking, in a well-known passage, if electrons have effects then they possess causal powers and, therefore, electrons are real (Hacking, 1983, pp. 24). Thus, ontological realism is definitely not committed only to what we directly observe.

A second negative impression regarding ontological realism that needs to be avoided is that of exaggerating the independence of scientific entities in relation to scientific theories and scientific activity itself. An ontological realist would not be naive enough to believe that complex entities such as gravity, electrons, genes, etc., emerged from a simplified inspection of nature. Human intervention was absolutely necessary: the affirmation of the reality of

[4] By "process" we mean something related to the notion of entity.

[5] According to representative realism, entities are inferred from experience. For discussions on Locke's representative realism, see: Mandelbaum (1964, p. 01; p. 53) and Devitt (1997, p. 67; p. 76).

[6] For Cartwright, only causes are real; scientific laws, due to their complexity, are neither true nor false.

electrons effectively depended on a profound theoretical involvement (instrumentation, theorizing, etc.) (Psillos, 1999, p. 256). What the ontological realist defends is that the theoretical apparatus revealed a reality presupposed by an investigator (Hacking, 1983, p. 265; Devitt, 1997, pp. 108-109; p. 143). Thus, postulated electrons (and subsequently, for science, real electrons) ontologically precede the theorizing about real electrons.

Having presented these considerations, the argumentative structure of ontological realism seems clear:

i) there exists a reality independent of the mind; ii) within this broad reality, it is postulated that specific entities such as electrons exist; iii) following the scientific methodology, electrons are revealed to be real. Note that steps (i-iii) do not make electrons dependent on theories in terms of their existence, but only dependent in relation to the knowledge we possess about them (epistemological realism), to the sentences that will employ the term "electron" (semantic realism), and to the explanations provided by theories that employ electrons (explanatory realism).

Thus, Devitt's previously cited assertion — that a scientific entity is not constituted by our knowledge — now becomes absolutely clear. Whatever a theory successfully asserts about electrons, this increases the success of the electron theory (Devitt, 1997, p. 115) and adds reliability to theories (Devitt, 1997, p. 115); however, what interests the ontological realist (although, in Devitt's case, he does not deny the importance of theoretical considerations in his defense of ontological realism (Devitt, 1997, p. 109)), is the existence of the electron, which is not constituted by our knowledge. Our scientific action has only unveiled the existence of the electron—but our scientific action *has not created* electrons.

However, it could be objected here that scientific research, so to speak, is what made it possible for electrons to enter the scientific world; that is to say: without scientific intervention we would not be talking about electrons. Electrons, therefore, would not be entities independent of our knowledge (and our intervention). Three answers can be offered to this objection: i) a pragmatic answer; ii) an answer based on a realistic philosophical conception of what scientific activity means; iii) an answer based on scientific activity itself.

The philosophical answer would be that the presupposition of the existence of electrons has proven more effective than the opposite presupposition (their non-existence)[7]. This answer is

[7] An argument along these lines – though not as a defense of ontological realism – can be found in Peter Lipton's explicative realism (2010, p. 319).

similar to rebuttals to traditional skeptical arguments, such as the claim that our sensory experience is merely an illusion; in short, the rebuttals return the objections to the skeptic, arguing that, for example, believing in the existence of a non-illusory world is more reasonable than believing that our sensory experience is an illusion.

The answer from a realist philosophical conception regarding what scientific activity means can be found in realist philosophers who defend the importance of prior knowledge already consolidated in the literature. A scientific entity is not postulated in a cognitive vacuum – in some way, it is embedded in an already existing cognitive framework, and therefore it relates to some reliable prior knowledge (Lipton, 2010, p. 322; Bird, 1999, p. 34; Bird, 2014, p. 378; Boyd, 1985, pp. 06-07; Psillos, 2000, p. 47). Thus, it is not by mere whim that the existence of electrons was postulated; in some sense, the postulated electrons were, in light of established knowledge, reasonable and plausible (and were subsequently incorporated into the cognitive heritage of science).

The answer from the perspective of scientific activity needs to be illustrated by an example from the history of science. It is not an easy task to see, in nature, a struggle for survival in the Darwinian sense; However, since the scarcity of natural resources is accepted as a fact (Darwin, 1859, p. 62), and since it is also accepted as a fact that the reproduction of organisms can occur at a rate that makes natural coexistence unpleasant (or almost impossible) (Darwin, 1859, p. 63), it is not at all implausible to suppose the existence of a struggle for survival.

However, it remains to mention, albeit briefly, at least one more objection to ontological realism. Ontological realists defend the existence of a world independent of the mind both at the observable level (everyday objects, or those easily detectable by means of scientific instruments) and at the unobservable level (an unobservable entity such as an electron[8]). Empiricist philosophers often challenge ontological realism by stating that the thesis of the independence of entities would only apply to observable entities, but not to unobservable ones. This, however, has been constantly refuted by realist philosophers (and not only by ontological realists), showing that the difference between observables and unobservables is only a difference of degree (Devitt, 1997, p. 142; Psillos, 1999, p. 195). If a person perceives a glass falling from a table, and if a scientist "sees" electrons, both are organizing their mental

[8] It is important not to confuse "unobservable entities" with "abstract entities." The former are constituents of the natural sciences; abstract entities are entities of logic, mathematics, geometry – such as numbers, classes, etc.

framework of the experiences that affect them. According to realists, there would be no dividing line between the two perceptual processes.

But we might insist: why incorporate unobservable entities into the patrimony of science?

A first and relatively trivial answer is that, without such entities, scientific knowledge would not have the scope it possesses. A second reason is that they make experience more intelligible (Psillos, 1999, pp. 19-20). Thirdly, unobservable entities provide reasons for believing in the truth of scientific explanations (Psillos, 1999, p. 28)[9]. Thus we perceive the relevance of the appeal to unobservable entities on the part of ontological realists. And, being so relevant, we also begin to delve into another fundamental point of the realist argument: for, just as the postulation of observable entities helps us to organize experimentation and formulate scientific explanations, this also occurs with the postulation of unobservable entities. Thus, there would be no reason for the existence of a boundary between observable and unobservable entities.

Furthermore, one of the great achievements of scientists (and consequently of science itself) occurs precisely when a new entity is presented; after all, the, let's say, “portfolio” of science consists of its products: gravity, the DNA double helix, electrons, the Higgs boson, etc. And such entities – directly or indirectly confirmed – are both part of everyday scientific life (Franklin, 1996, p. 132) and are effectively real. Ontological realism, therefore, captures an important dimension of science.

Up to this point, we have been trying to keep ontological realism immune to the idea that the existence of entities is due to intervention (mental, scientific). More than that: we are operating on the disjunctive logical-conceptual platform offered by the ontological realist: either there is intervention or there is no intervention. Evidently, as we have seen, the ontological realist believes that existence is not due to any intervention – and that intervention, in fact, only serves to confirm existence. Thus, broadly speaking, the conceptual scheme of ontological realism can be summarized as follows: existence without intervention (or independent existence). And from

[9] An interesting example (of a now-abandoned concept) is provided by Peter Bowler. Until the emergence of evolutionary concepts in the 19th century, biology had what is called "natural theology": an attempt to explain biological phenomena by taking into account (scientifically) an ordering of nature given by a creator and orderer: God. One of the great biological problems of this tradition of natural theology was explaining heredity. An 18th-century naturalist, Charles Bonnet, situated the problem in the conception that "all organisms grow from miniatures or 'germs' created by God at the beginning of the universe, stored one inside the other like a series of Russian dolls. The first woman, Eve, literally contained within her ovaries the rest of humanity, generation after generation of miniatures compacted one inside the other, waiting for an act of fertilization to give them the chance to grow" (Bowler, 1989, p. 29). In other words: God, an unobservable entity, was included in Bonnet's explanation. Why did Bonnet offer this type of explanation? Was it because he was religious? Perhaps. But that is not the main point here. Bonnet, with his idea of Eve containing the rest of humanity in her ovaries, was trying to offer an order where an ordered explanation did not yet exist (Bowler, 1989, p. 29).

this follows an image of science: science deals with the real world in a reliable way. This is clear in the quotations below.

> Scientific theories postulate various (...) entities and employ theoretical terms – for example, 'electron', 'proton', 'electromagnetic field', 'DNA molecules', etc. How should this theoretical discourse be understood? (...) The realist tradition (...) aims to show that a complete and in-depth explanation of theoretical discourse in science requires commitment to the existence of these (...) entities (Psillos, 1999, p. 03).
>
> The Earth of the ancients is the Earth on which we live (Devitt, 1997, p. 160).
>
> Perhaps most of the postulates introduced by our ancestors are entities that we no longer approve of, but, as time passes, we discover that increasingly the postulates of theoretical sciences endure within contemporary science (Kitcher, 1993, p. 136).

All three quotes share the same focus: scientific entities. They also share the same objective: they must exist. Finally: these entities exist independently of our knowledge, of our theorizing.

Of the three quotes, the last one (from Kitcher) is the one that is most relevant to this article. It is a historical fact (obviously admitted by realists, as Kitcher's own quote reveals) that certain supposed entities are no longer accepted, as the classic examples of phlogiston (from the phlogiston paradigm) and gemmules (from Charles Darwin's theory of heredity) reveal. This is not a problem for realists: *our cognitive world* has changed and revealed the non-existence of phlogiston and gemmules; *the real world*, however, is the same. The scientists were wrong – but reality continues to be what it always was. Or, as Devitt states: "Merely asserting that 'entities exist' does not ontologically commit us to entities. Commitment depends on the truth conditions of the statements we accept" (Devitt, 1997, p. 50). And, as we know, we no longer have this commitment to phlogiston and gemmules. Devitt continues (1997, p. 160): "a has reference only if the descriptions normally associated with it apply to one and only one object. If the descriptions do not apply, then it has no reference (...) and the object referred to by it does not exist."

In other words: our epistemology may be misguided, but our ontology points the way to the correct representations of reality.

From both a philosophical and a historical perspective, there is nothing to criticize in this idea. Affected by real bacteria, we defend ourselves with antibiotics that contain real chemical properties and, if the treatment is successful, we are truly cured. Thus, there are regularities that actually occur and in which we truly believe. In fact, according to Devitt, this image is even "trivial" (Devitt, 1997, p. 114). And to those who question (or disqualify) this triviality, we leave the question: would our culture have the scientific order (with all its consequences for human beings) that it has without a robust sense of reality and, therefore, of realism? Do we want a science that says “a bacterium is a unicellular organism” or one that says “we have defined for decades that bacteria are unicellular beings, but, since we are not absolutely certain about this, we are unable to suggest that drugs be produced based on this definition of bacteria”?

Except for skeptical challenges, we do not believe that what has been presented so far in this text can (or even should) be questioned. But we also do not believe that another conception cannot be presented.

## 2. Scientific Entities Within Scientific Practices

The realistic image presented in the previous section is limited to situations in which the scientific order is already established, either through the acceptance of current real entities or through the rejection of conceptual systems (with their corresponding entities) that have already been abandoned; that is, ontological realism (and realism in general) is directed towards scientific products. Ontological realism departs from the discussion about the production of scientific knowledge, and here the aforementioned triviality (in its benign sense) of ontological realism mentioned at the end of the last section of the previous chapter disappears, since we enter what is called “scientific practice”.

When a scientist encounters a phenomenon that needs to be explained – an explanation that will reveal knowledge about a part of the natural world – he needs to master the appropriate practices to deal with this phenomenon: a plausible methodology, precise instrumentation, a standardized language, etc. Thus, between the scientist and the desired knowledge there is a practice that needs to be mastered so that the knowledge itself can emerge. These practices, in turn, are standardized within specific institutionally established communities and guide the scientists of these communities in the production of their knowledge. In short, there is a “right way” (contextually characterized, of course) to practice science: it is not possible to practice science without the telescope, the microscope, the DNA synthesizer, etc.

It is tempting, here, to identify the notion of practice with something like a “condition of possibility for the production of scientific knowledge”: if there is no microscope, then there is no chromosome identification, etc. Thus, in this view, scientific practice is a condition for the emergence of knowledge – but a separate part of knowledge itself[10].

[10] It is even possible to infer that for the realist, scientific practice would not even be considered knowledge; in a way, this is Baird's conclusion (2004, p. 1). A specific discussion of whether scientific practice is merely a condition of possibility for scientific knowledge is beyond the scope of this article.

The problem with this conception is not so much the devaluation of scientific practice; there is an even deeper problem with this view, which arises if the idea that knowledge emerges alongside practice is accepted (Latour and Woolgar, 1997, p. 61): “phenomena depend on the material; they are entirely constituted by the instruments used in the laboratory.”

When evaluating a cognitive novelty, scientists also need to know how the novelty emerged, because only then will they be in a position to assess such novelty and be able to repeat the procedures used by the proponent of the novelty in order to check whether the novelty actually reveals genuine knowledge.

Scientific practice stabilizes communication within scientific communities; obviously, scientists disagree with each other, but such disagreement occurs on a common platform; it would be like someone saying that 2+2=5 and hearing that they are wrong because, after all, 2+2=4. How, however, can one disagree with someone who says that 2+2=green? The categorical error in 2+2=green prevents any recourse to the axiomatics of mathematics, the theory of mathematical induction, etc. It is scientific practice that is responsible for giving the rules to a scientific field and preventing a statement like 2+2=green.

Returning to the theme of ontological realism, one of the ways in which scientific practice consolidates an entity is through replication: after the discovery of an entity, a scientist describes the experimental situation that led to the entity: their methods, instruments, and materials. The more times and in more places the original experimental situation is replicated, and obtains the same original result, the more consolidated the entity will be. The problem, argues Harry Collins in his *Changing Order*, is that replication is not always desirable for those who replicate – although, of course, it is desirable for the pioneering scientist. According to Collins, the scientific community values the pioneer more than those who confirm that the pioneer is right (Collins, 1985, p. 19), so replication is more of an “axiom than a practical matter” (Collins, 1985, p. 19).

However, Collins continues, it is a decisive axiom for science: replication is fundamental; and, the author argues, the axiom functions more as a statement that something is replicable than as a statement that something will actually be replicated; that is: whoever claims that a new entity emerged due to the methods, instruments, and materials mentioned is saying the following: “replicate using the same methods, instruments, and materials and you will obtain the same results"[11]. This statement, according to Collins, is the beginning of the community agreement regarding the existence of the entity (Collins, 1985, pp. 19-120). It is possible that there will be no replication; but the pioneer's statement regarding openness to replication is fundamental.

And it is clear that such a statement is not made in the manner presented above ("replicate using the same methods, instruments and materials and you will obtain the same results"). The "statement" will be contained in the article precisely through literary clarity regarding the methods, instruments and materials)[12].

It turns out that obtaining the same entity using exactly the same methods, instruments, and materials will not increase *the power of confirmation* of the entity's existence. Gradual changes – but ones that encompass the maximum possible variation of methods, instruments, and materials, *and that still obtain exactly the same entity* – are what will increase the confirmation that the entity actually exists (Collins, 1985, p. 34). And, Collins continues: if, at the end of several rounds with the maximum possible variation mentioned, a scientist who initially did not believe in the entity becomes convinced that he was wrong, then the ontological assertion of the pioneer will be even more confirmed (Collins, 1985, p. 34).

Up to this point, this scheme has, strictly speaking, nothing new; in fact, it even refers to the old metamethodological prescriptions of Francis Bacon (experimentation, repetition, variation of experimental conditions). But Collins goes a little further and it is worthwhile, in the context of this article's discussion, to follow the author (albeit with other conceptual contributions from other authors), since he deals with the complexities of the replication scheme.

One of these problems is the problem of *selecting* what is relevant for the development of research. This is a problem in itself, since science has limited resources and not everything can be the object of investigation. How then to decide what deserves scrutiny? The philosophy of science offers several approaches to understanding how selection occurs: i) paradigms: paradigms determine what can be investigated (Kuhn, 1996); ii) funding allocation: research that does not fit into what is of interest to funding agencies tends to be left aside (Stanford, 2015); iii) Institutionalization of scientific disciplines: scientific disciplines determine the relevance of research and thus exclude lines of investigation that do not promote the

[11] In other words, using Bruno Latour's terms, the pioneer needs to show that what happened in his laboratory is "independent" (Latour, 2001, p. 144) of his will: if others replicate the experiment, the result will be the same.

[12] It is therefore not surprising that one of the complaints of several scientists against Louis Pasteur when he presented his rabies vaccine was that he did not make clear his methodology for obtaining the vaccine (Geison, 2002, part III (but see especially page 262).

development of the disciplines themselves (Lenoir, 2003); iv) Laboratories: they define the cultural activity of science; it is within laboratories that knowledge is generated through the production of scientific objects (Knorr-Cetina, 1992). Let us consider, as an example, the case of laboratories.

According to Karen Knorr-Cetina, it is in the laboratory that the production of scientific objects occurs, which in turn happens through the dissemination of literary products (scientific articles) and the political alliances that scientists make so that their scientific interests are met (Knorr-Cetina, 1992, p. 115). It is also in the laboratory that knowledge validation processes occur, this validation being understood as a decision-making and community process that takes place during scientific production (and not at the end of a production) (Knorr-Cetina, 1981, p. 8). In short, the laboratory is dynamic in relation to knowledge production. Thus, it is not simply a matter of postulating an entity, but of postulating an entity in relation to certain circumstances.

Thus, the reality of entities seems to be shrouded in more complex circumstances than the realistic scheme of "proposition/acceptance (or rejection) of the entity." And it is here that we begin to understand the meaning of the term "interest" when applied to scientific research and when inserted within scientific practices. Generally, the term is understood pejoratively – as if it signified an obstacle to research (although this can sometimes happen). But this usage does not correspond to scientific practice.

Scientific interests are involved in much broader situations than the mere detection of entities. When receiving the Nobel Prize in Physiology or Medicine in 1934, Thomas Hunt Morgan treated the gene not only as a real entity, but also in terms of its applications to practical problems (medicine, paternity claims, and agriculture) (Morgan, 1934, pp. 327-328). According to Collins (who did not address this example, but others similar to it), the more "external" a scientific document is, the greater the *interest* of other scientists in the disciplinary field (Collins, 1985, p. 137). Furthermore – and this would not clash with ontological realism – the greater the confirmation of the existence of the postulated entity.

Let's look at a brief example. Gravitational waves (GWs) were predicted by Einstein's Theory of Relativity in 1916 (Collins, 1981, p. 35). In layman's terms, GWs are ripples resulting from celestial collisions that interfere with spacetime; these waves, of course, reach Earth, but until recently the instrumentation was insufficient for their detection. This began to change in the 1970s, when several research groups began building GW detectors. One of these groups was coordinated by physicist Joseph Weber at the University of Maryland.

The signals from gravitational waves (GWs) are weak on Earth, but Weber claimed to have detected them. The problem is that the evidence produced by Weber did not allow him to distinguish between GWs and “vibrations (...) produced by other forces” (Collins and Pinch, 2000, p. 133); in fact, what Weber's equipment could detect were only vibrations (and therefore not necessarily GWs). Given this, the scientific community did not accept his results, arguing, among other things, that the data were not compatible with the consolidated knowledge of cosmology (Collins, 1981, p. 36), and thus did not constitute strong evidence of a GW traversing our planet. Therefore, Weber failed to establish the existence of GWs.

However, partly due to Weber's pioneering efforts, the research continued (Collins and Pinch, 2004, p. 135; Collins, 1981, p. 37); and thus other laboratories began to develop more sophisticated detector antennas than Weber's (Weiss, 2017, p. 74). A major event in these developments was the founding, at *Caltech* (California), in 1992, of a laboratory dedicated solely to the detection of gravitational waves (GW), LIGO: *Laser Interferometer Gravitational-Wave Observatory*. Thus we see that, starting with Weber's work and continuing through subsequent scientific developments, research within LIGO became strongly institutionalized. Since we are not interested in the story as a whole here, it is only necessary to conclude this historical segment: in 2016, LIGO's research finally confirmed the existence of the GW entity, and scientists Kip Thorne, Rainer Weiss, and Barry Barish shared the Nobel Prize in Physics in 2017.

The point that interests us here is that the GW story does not disqualify Weber's efforts, even though he could not have detected GW. It is important to emphasize the reliability of Weber's methods, which were never abandoned, but rather refined to the point that other scientists later managed to actually detect GW. Evidently, what matters *in the end* is GW itself: GW exists or it doesn't, it passes through the Earth or it doesn't, etc. But the reliability of Weber's general methodology was fundamental to the end of the story, since LIGO stems, in part, from Weber's work.

What is interesting is that another story would also be possible. Why didn't scientists accept Weber's (false) ontological claim that GW existed and subsequently try, so to speak, to “refine” the entity? In other words: why not accept the unobservable entity GW in Weber's version and, as we have already said, work on the entity so that it would manifest itself with greater ontological power?

This did not occur because, in science, while the detection of entities is fundamental, increasingly reliable methods and instrumentation are equally important. Thus, scientific beliefs are not considered true solely due to evidence, but also to the reliability of the processes that lead to beliefs (Lewens, 2005, p. 567; Goldman, 1992, p. 434; Moser, Mulder and Trout, 1998, pp. 89-90)[13].

Applied to Weber, this philosophical thesis produces the following historical result: Weber detects "something," but his instruments and methods fail to establish whether this "something" is what he wished to detect. It is therefore not an ontological question; or, if it is, it is also a question related to scientific practice.

## CONCLUSION

As Bruno Latour has already argued, consolidated scientific products resulting from disputes and controversies do not deserve contestation regarding their legitimacy; therefore, consolidated scientific entities also do not deserve contestation. In Latour's words: "If there is no longer disagreement among scientists regarding the state of the facts, it will be useless to continue talking about interpretation, representation, preconceived or distorted views of the world (...). Nature speaks clearly, facts are facts. End of story" (Latour, 2000, p. 166).

That is to say: gravitational waves did not exist scientifically while Weber was conducting the research, but they came to exist scientifically with the research carried out inside LIGO, etc. However, note that we are talking about completed processes. But, conversely, while the controversies surrounding gravitational waves have not been resolved, it cannot yet be said that gravitational waves exist. It is in this sense that, as already stated in this article, the realistic image of science is circumscribed to situations in which the scientific order is already established.

Ontological realism is a notable contribution to the philosophical understanding of science. What we intended to point out was that this school leaves aside aspects that are equally relevant. However, mentioning such aspects does not necessarily mean opening a controversy with

[13] Reliabilism is the doctrine that a belief is justified if the believer judges the mechanisms of belief production to be reliable (Goldman, 1992, p. 434; Moser, Mulder, and Trout, 1988, pp. 89-90). As Lewens (2005, p. 595) argues: "The reliabilist asserts that the justification or warrant of a belief depends on whether the belief is constituted by a reliable mechanism." In a reliabilist approach, evidence (though not disregarded, of course) carries less weight than the reliability of the method employed to explain the evidence. A classic example of instrumental reliability is provided by Davis Baird. In order to demonstrate a phenomenon known as electromagnetic rotations, the physicist Michael Faraday, in the 1820s, built an instrument called the "electromagnetic motor," which was readily accepted as reliable by the scientific community, despite theoretical controversies about the results obtained by the equipment (Baird, 2004, pp. 1-2). In other words, a practice was being characterized as reliable and as determining a way of conducting scientific activity, even if beliefs might vary (Rouse, 2003, p. 108); moreover, as Baird reminds us, instruments are not beliefs (Baird, 2004, p. 4).

ontological realism. Apparently, the two conceptions presented here do not rival each other, since they deal with different aspects of science.

Thus, there is a perspective that agrees with the ontological realism's assumption that entities are independent. However, our means of accessing and confirming the existence of such entities need to be created for the entity to exist scientifically – and this is not the same as saying that the entities are created.

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