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Theological roots of scientific realism and its persistence in contemporary physics

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Abstract

The attitude of a large majority of the physicists is realistic: They believe that their successful models describe approximately the actual structure of the world. This attitude is rooted in the theological and philosophical movement that gave birth to modern science. But the fact is that the current philosophical climate is very different from the climate that reigned at the beginning of modern physics. So the question arises of whether scientific realism can now rely on other theoretical bases, or we should rather expect the evolution of physics towards a non realistic science. In this presentation are reviewed the mentioned points; it is furthermore discussed how a non realistic physics might look like, and finally some recent cases are addressed that may indicate this new impulse toward a non realistic physics.

Keywords: Realism, costructivism, theological framework, experimental data, quantum gravity, neutrino sources

CONTENTS

1 INTRODUCTION

As I hope this text will prove, through a sufficient number of examples, most physicists adopt a realistic interpretation of scientific activity[1]. In other words, physicists tend to consider their successful models, not just as useful constructions, but as descriptions of the actual structure of the world. What is the reason for this position? Is it inseparable from scientific activity, or perhaps the situation could change over time, making way for other ways to interpret the products of that activity?

In the following pages I will first refer to the widely recognized fact that the realistic attitude is rooted in the theological and philosophical movement that gave birth to modern science. The trust in the power of the human mind to discover the real structure of the world was derived, by the founders of modern physics, from their conception of man as *imago dei*.

However, the current philosophical climate is very different from that reigning at the beginning of modern physics. As we shall see, scientific realism seems today dominant primarily by inertia. The question then arises whether we can expect a long-term survival of scientific realism, assuming the thought-keys dominant in our day endure; or if we should rather expect an evolution towards a non-realistic science. I will then outline how this alternative physics, not based on realism, could be. And I will point out briefly that a mutation of such scope in scientific activity would turn science into something very different from what it has come to be, since the sixteenth and seventeenth century onwards.

2 THE THEOLOGICAL ORIGIN OF SCIENTIFIC REALISM

Scientific realism is the belief that good scientific theories, those that are able to explain in detail the known phenomena, and successfully predict new phenomena, are not simply instrumental constructions, or useful fictions in some sense, but true (though approximate) representations of the real structure of the physical world.

Scientific realism is the most widespread attitude among physicists, to the point that we could say that it is their "natural attitude", which tends to be held by those who do not spend much time thinking on philosophical discussions about science.

Moreover, scientific realism is not simply the natural attitude of the current physicists, but it was, in the first place, the conscious and militant position adopted by the pioneers of the first generations of modern physics. In this section I will first propose an example in which this fact is seen clearly, and then will point to the theological origin of that position.

2.1 One example: The realism of Copernicus and his school

If one browses through the book which marks the beginning of the modern cosmology—"De Revolutionibus" by Copernicus—including the anonymous introduction added by Andreas Osiander to the first edition (1543) of this work, one finds, separated only by a few pages, two radically different views about the meaning of the mathematical models of physics: the realistic and the anti-realistic view.

The anti-realistic view—represented by Osiander's preface—states that the Copernican Model is merely a calculation scheme that can describe the loops of the planets in the sky properly, but has no ontological significance. In his words:

> For it is the duty of an astronomer to compose the history of the celestial motions through careful and expert study. Then he must conceive and devise the causes of these motions or hypotheses about them. Since he cannot in any way attain to the true causes, he will adopt whatever suppositions enable the motions to be computed correctly from the principles of geometry for the future as well as for the past. [...] For these hypotheses need not be true or even probable. On the contrary, if they provide a calculus consistent with the observations, that alone is enough. [...] So far as hypotheses are concerned, let no one expect anything certain from astronomy, which cannot furnish it, lest he accept as the truth ideas conceived for another purpose, and depart from this study a greater fool than when he entered it.[2]

Copernicus himself had a very different opinion. He defended the realistic view that a good description of the phenomena can only be successful if the model characterizes the real structure of the world (more or less) correctly. Copernicus therefore argued that the problems of the Ptolemaic Astronomy arose from some incorrect assumptions about the structure of the world. And the inscription of his book (addressed to Pope Paul III) includes the following lines:

> Nor could they elicit or deduce from the eccentrics the principal consideration, that is, the structure of the universe and the true symmetry of its parts. On the contrary, their experience was just like someone taking from various places hands, feet, a head, and other pieces, very well depicted, it may be, but not for the representation of a single person; since these fragments would not belong to one another at all, a monster rather than a man

> would be put together from them. Hence in the process of demonstration or "method", as it is called, those who employed eccentrics are found either to have omitted something essential or to have admitted something extraneous and wholly irrelevant. This would not have happened to them, had they followed sound principles. For if the hypotheses assumed by them were not false, everything which follows from their hypotheses would be confirmed beyond any doubt.[3]

The difference between the two interpretations of the Copernican Model is so radical, that the rejection and even irritated reaction of the friends of Copernicus to the preface of Osiander is not surprising:

> The Copernicus circles reacted to Osiander's anonymous preface with anger and horror. [...] Even later supporters [of the Copernican views] (such as Johannes Kepler) understood this as a treacherous falsification of the Copernican intentions. (Carrier, 2001: 131)[4]

This group of Copernican realists was later joined by Galileo:

> What unites Galileo and Kepler is an unambiguous realistic view of science. He wanted not only to save appearances, but to make true statements about physical bodies. Therefore, he did not maintain the Copernican doctrine *ex suppositione*, following the example of Osiander and as Cardinal Bellarmine recommended, but in full knowledge of the semantic function of factual hypotheses with a real referent, as a representation of reality [...]. (Kanitscheider, 2002: 113)[5]

Of course, such a dispute about interpretation does not arise only in the aforementioned example of the Copernican model. In any other physical model we may also wonder whether we have a useful fiction in some sense, or rather an authentic description of the universe.

Must we then interpret physical models in a realistic way, or not? In other words, can we trust that physics gives us (approximate) descriptions of the true structure and dynamics of nature? Or should physical models be taken as mere calculation tools that project a fictitious order, and no less fictitious links, between a number of known phenomena and data, thus allowing us to refer to them in a synthetic form?

As we have seen in the above example, the answer given by the founders of modern physics (Copernicus, Galileo, Kepler, etc.) was clearly realistic. The models that really work and are really useful, work and are useful because they describe (although approximately) the actual structure of the world. And they are useful and work just to the extent that the proposed description is correct.

Now, where did this belief come from?

2.2 The theological framework of the realism of the founders of modern physics

The realism of the first physicists stands on theological grounds. It is well known that those physicists who launched modern science were deeply religious people. In fact, the study of their biographies shows that were usually more linked to religion, and more interested in theology, than the average of their contemporaries. And this happened in an age where religion performed an important role in society[6].

From religion and Christian theology, these authors derived three convictions whose conjunction laid the foundation for the scientific activity they were undertaking. They are the following:

(1) Nature is completely rational.

(2) Man as "*imago dei*" is qualified to discover the rationality introduced by God in creation.

(3) God could choose between different rational world orders, so that only a careful observation of nature allows us to discover which was the actually chosen order[7].

Despite all the initial difficulties, these three beliefs made possible the design and development of a program to research nature, combining in a balanced way the element of theoretical-mathematical speculation with the element of observation and experimentation. The scientific realism of the pioneers of modern physics was derived precisely from points (1) and (2): reality has a rational structure, an objective order given by God. And man, as the image of God, can discover that order through scientific work.

This is how Kepler explained it in the seventeenth century:

> God, who based everything in the world according to the norm of quantity, has also endowed humanity with a mind that can understand these rules… These laws are reachable by the human mind. God wanted to be recognized by creating us in his image, so that we could share his thoughts. Only fools fear that this will make humanity equal to God; for the divine mind is impenetrable, but his material creation is not. (Kepler, 1599).

Another text by Kepler, taken from his magnum opus "Astronomia Nova", allows us to see in action this realistic attitude, derived from his theological confidence in his ability to discover the true order of the world:

> As for us, since God's goodness gave us the painstaking observer Tycho Brahe, from whose observations have made it possible to prove the eight

> minutes error of this Ptolemaic calculation, we should recognize and gratefully honor this goodness of God. So let us do our best to investigate the true form of celestial movements [...]. I myself will show, in the pages that follow, a certain way of my own. Because, if I thought that the eight minutes in length were negligible, I would have corrected sufficiently the hypothesis contained in Chapter XVI [...]. But as they cannot be neglected, these simple eight minutes force us to reform the entire astronomy. (Kepler, 2005: 234)

It is well known that Kepler would invest nearly ten years of his life in pursuit of "the true form of celestial movements", until he finally discovered the laws that have made him famous. Throughout this long period of sustained effort, his confidence in the rationality of creation, and the accessibility of the divine design of the world to the efforts of the human mind, fueled his hope to find this "true form" of planetary movements.

The following words by Copernicus, for instance, written in the sixteenth century, are related to the same conception:

> Reflecting for a long time on this uncertainty of the mathematics transmitted to calculate the movements of the spheres in the world, I began to get angry because philosophers, who in other subjects have studied so carefully the most minute things of that world, are aware of no safe calculation about the movements of the world machine, built for us by the best and most consistent artificer of all.[8]

Throughout this period, nature is not only conceived as a global order (a cosmos), but that order is also the means (or one of the means) through which one intelligence (the Creator) makes himself manifest to other intelligences (human beings). This is the reason for the correctness of the Galilean metaphor of nature as a book, an image that captures the essence of such interplay of relations. And so, the passage of the Epistle to the Romans where Paul says about divinity that "his invisible qualities—his eternal power and his divinity—become visible to the eyes of intelligence through his works, since the creation of the world" (Rom 1:20) became one of the biblical quotations most used by the physicists of the seventeenth, the eighteenth and even the nineteenth century.

3 INERTIA OF SCIENTIFIC REALISM AND CHANGE IN THE PHILOSOPHICAL CLIMATE

I do not think that we need to emphasize further the fact that the philosophical climate where we find ourselves today is very different from that around the scientists of the first generations. It can be said without exaggeration that we are living in a period of apogee of the materialistic thinking. We find ourselves in a situation where the approaches of the great atheistic thinkers of modernity, especially those of the nineteenth century, have achieved the status of a standard worldview in the academic environments of the old continent. Therefore, any fact that does not fit well in this world view (such as, to name a concrete case, the biophile fine tuning of the laws of physics) is obscured, ignored or reinterpreted at any price (even if the price is so expensive as postulating the existence of an infinity of real unobservable universes). This is why any scientific theory is always amalgamated with a materialistic gloss, even though that gloss is not the only possible one, or even if that gloss is unnatural or problematic in central aspects.

We can often hear voices that consider the development of science as the main engine of this great change in the Western world view. But if we descend to a detailed study of the way of thinking of the leading physicists of the nineteenth century, it is difficult to support this view. For example, it is striking to notice that the proportion of believers and atheists among the most prominent physicists of that century virtually reverses the same proportion among philosophers. Among physicists, the group of believers (among which we must count signal figures like Volta, Faraday, Maxwell, Hertz, Planck, etc.) predominates widely against atheists or agnostics, while among the philosophers the nineteenth century is primarily the time of Marx, Comte, Feuerbach, Schopenhauer, Nietzsche, etc., whose efforts to build an atheistic worldview have given rise to the most popular ideas in today's academic world. Considering these data, it can be concluded that scientists, or at least physicists, not only were not the vanguard of the nineteenth century change in world view, but rather represented a collective resistant to such change, possibly due to the origins of the research program of modern physics, so close to theology.

Perhaps this explains the inertia towards scientific realism maintained among physicists until today, despite such a radical change of the philosophical framework, a realism that would be strained against that framework. In Torretti words:

> The founders of modern physics took Plato's metaphor [of the laws of nature] quite literally, and set out to find the articles of nature's legal code. In the writings of these Christian authors the word "law" does not signify the universal scope of the prescribed regularities, but rather the legislative authority of their divine source.
>
> […] Today few would countenance basing physics on our knowledge

> of God. However, one implication of seventeenth-century theological commitments has lingered on as a source of confusion. Like the smile of the Cheshire cat, the idea of a ready-made world continues to haunt a philosophical tradition from which the idea of it Maker has long vanished. [...] the dream persists of a final theory of everything representing the true mathematical structure of the universe. (Torretti, 1999: 406; 432-433)

In the next subsections I will present several examples of the realistic attitude in modern physics, so as to get an idea of how far this inertia towards scientific realism continues in our time.

3.1 Weinberg vs. Pickering

Can we do science without presupposing, as the founders of physics did (influenced by theology) an objective rational order whose discovery is largely accessible to man?

Philosophers of science and sociologists are exploring, especially from the seventies in the twentieth century, an interpretation of scientific activity which responds to this question affirmatively. This is the proposal of the so-called "social constructivism". According to constructivists, scientific theories are nothing more than cultural constructs that emerge from negotiations between various academic groups (e.g. the different currents of theoretical and experimental physicists), and do not describe anything resembling a "real structure" of the world.

In the opinion of the authors who support this approach[9], experiments can neither confirm nor refute theories, since the experimental results themselves must first be evaluated, and that evaluation involves subjective judgments by scientists. The best way to understand the process of confirmation or refutation of a theory would be achieved, therefore, by analyzing the process from a sociological point of view. It is not the rational arguments based on experience, but the interests at stake (the prestige of the various groups, economic benefit, the prospects of opening a field that will benefit the development of their own lines of work, etc.) that determine the evolution of science. Thus, the dangerous idea—because it is religious—of a knowable natural order, disappears completely from the horizon, and science becomes an activity without reference to anything beyond the human.

It is instructive to study the reaction of scientists, and especially physicists, to the constructivist approach. Since this is an approach clearly designed to eliminate the theological basis of science, one might expect that those members of the scientific community with a way of thinking more attuned to materialism would welcome it willingly. Actually the opposite has happened. As soon as the constructivist interpretations of scientific activity were detailed, all scientists, whether theistic or atheist, reacted strongly against social constructivism, which led to a series of disputes between the faculties of sciences and those of humanities; disputes which lasted for more than a decade, especially in the Anglo-Saxon academia, and have been christened with the name of "science wars". As a representative example of the position taken by scientists in this episode, we can mention the following passage from one of today's physicists most committed to the materialist philosophy, Steven Weinberg:

> It is simply a logical fallacy to go from the observation that science is a social process to the conclusion that the final product, our scientific theories, is what it is because of the social and historical forces acting in this process. A party of mountain climbers may argue over the best path to the peak, and these arguments may be conditioned by the history and social structure of the expedition, but in the end either they find a good path to the peak or they do not, and when they get there they know it. (No one would give a book about mountain climbing the title Constructing Everest.) I cannot prove that science is like this, but everything in my experience as a scientist convinces me that it is. The "negotiations" over changes in scientific theory go on and on, with scientists changing their minds again and again in response to calculations and experiments, until finally one view or another bears an unmistakable mark of objective success. It certainly feels to me that we are discovering something real in physics, something that is what it is without any regard to the social or historical conditions that allowed us to discover it. (Weinberg, 1992: chap. 7)

This quote is taken from a chapter by Weinberg bearing the significant title "Against Philosophy", where constructivist philosophers of science and sociologists are the target against whom the dart is going. The suggestion that a book titled "Constructing Everest" would be meaningless alludes to the most important work so far produced by current social constructivism in the field of physics, the book "Constructing Quarks", by Andrew Pickering[10]. Regardless of such details, what I want to emphasize is Weinberg's commitment with the existence of an objective rational order in nature that physicists can discover through their research activity. This is just the theologically rooted conception that moved the first physicists, which once this root has been removed becomes baseless, suspended in the air. And yet, Steven Weinberg is a declared atheist.

On what basis does he base his realism? Weinberg confesses that he cannot prove it, but that "everything in my experience as a scientist convinces me that it is". In some ways, the approach of authors like Weinberg, Smolin and other atheists of our generation, who cling to the idea of an objective physical natural order while attacking its theological basis, reminds the situation of someone who is trying to cut the base of a tree while being perched in its crown.

3.2 Examples of current realistic developments in particle astrophysics

Be that as it may, the fact is that the position of most physicists today remains realistic[11]; we could say instinctively realistic. And this realistic position (with respect to the rational order of nature and the possibility of discover this order) results, among other things, again and again, in the rejection of very promising theoretical proposals, because the results of experiments do not support them sufficiently, according to very strict control criteria; or, again and again, in a declaration of failure for experiments and devices whose implementation has mobilized great human and material resources.

And we must keep in mind that the experimental physics of our time is dealing with increasing frequency with phenomena which are only detectable in situations where the background noise can only be separated from the signal by means of complicated processes of data analysis. In other words, if the realism of experimental physicists were not as strict as in fact it is, on many occasions it would not be too difficult to agree on a satisfactory result. Of course, I am not speaking about a gross fraud, but about something much more subtle: getting along with results with some statistical relevance—which could correspond to a signal confirming an important hypothesis—, but that in actual practice are rejected for lack of sharpness, because they do not reach the high level of certainty required to support a certain interpretation of the data, ultimately by the realistic zeal of physicists[12].

The best way to see how far current physicists consider themselves bound to a realistic interpretation of their activity, is analyzing the dynamics of those fields in physics in full development, those handling data sources are accessible only through very complicated devices, after a very complicated process of data extraction from background noise. One of these disciplines is, for example, astroparticle physics.

Astroparticle physics aims to study highly energetic particles that reach Earth from space sources such as stars, active galactic nuclei, nebulae, etc. Its goal is trying to understand the properties of sources that can emit such objects. The interesting thing about this discipline, on the issue of scientific realism, is that research here has all the characteristics that would favor a constructivist evolution of the same:

(1) the need of using expensive devices and complex theoretical models of the devices;
(2) the need of performing an extremely difficult analysis of the data;
(3) the possibility of promoting, with the discovery of these or those results, the progress of certain lines of theoretical physics, such as research on dark matter, quantum gravity, particle physics beyond the standard model, etc.; and finally
(4) a great number of academic and economic interests at stake.

However, despite all the above, in recent years particle astrophysicists have missed, again and again, chances to motivate interesting developments and responding to expectations placed on them by theoretical physicists. And they have done this because of mere realistic scruple. I will outline in this subsection two concrete examples that help to understand the inertia of scientific realism in current research. The first is the no confirmation of a result anticipated by theorists who are trying to formulate a theory of quantum gravity. The second example concerns the failure of a large scientific collaboration to achieve its objectives. Let us see in what sense scientific realism has to do with both.

3.3 *Lorentz's invariance*

Many theoretical physicists of our time assume that quantum physics is behind all natural phenomena, without exception. However, while the electromagnetic, weak and strong forces seem well described from that framework, the same is not a fact with gravity: no line of research in the field called "quantum gravity" has yet achieved any empirical support, although this program has been investing for decades a huge theoretical and economical effort. Moreover, it has barely managed to make a concrete prediction, testable in principle, either in cosmology or in any other field of physics.

The most significant exception to a complete absence of predictability is the fact that many models of quantum gravity involve a violation of the so-called "Lorentz invariance"[13]. In other words, they imply that the speed of light in a vacuum depends on the energy of the photons. Usually, what these models are proposing is that the most energetic photons move in a vacuum at a slower rate than less energetic photons. If any of the overabundant preliminary versions of the theory of quantum gravity would manage to make a precise quantitative estimate of this effect, and if later observations would confirm it, we would have, for the first time, a real basis to build a unified quantum picture of natural phenomena.

But we are still far from that. In 2008 the MAGIC scientific group, which currently manages the largest gamma-ray telescopes, announced what could be the first signs of a possible violation of Lorentz invariance (Albert et al., 2008). They were based on the analysis of data obtained during the flare that took place in 2005 in the active galactic nucleus Markarian 501. This analysis encouraged confidence in the possibility that, after decades of searching, we were peering at last at an effect of the quantum nature of space-time.

However, the delay effect of the most energetic photons was not subsequently confirmed by other scientific groups with access to equipment capable of observing similar phenomena (particularly the HESS and FERMI groups), through the analysis of the flares of other active galactic nuclei, or in events such as gamma-ray bursts (GRB). There is a broad consensus today among specialists that the announcement made by the MAGIC group was a mistake.

However, if we analyze the instruments and procedures for collecting and analyzing data underlying the MAGIC article where the possible effect is proposed, together with the articles written to reject it, we can see that we are dealing with a complex exploration of data, hidden in a background noise thousands of times more intense than the desired signal, so that only a laborious process of reduction and analysis of the raw data collected by the detectors makes it possible to draw the desired conclusions. Thus we have here a situation where the four points mentioned earlier in this subsection as possible predisposing factors for constructivist dynamics (expensive equipment, complicated analysis, possibility of promoting theoretical developments, and economic and academic interests) are applicable. And yet, the result favored by theoretical physicists that would have been the most advantageous for everybody involved in the research process, has not been confirmed, despite the initial inklings provided by MAGIC which show that an honest analysis in the confirmatory direction was possible. This outcome is perfectly understandable if the dynamics underlying the process of data analysis is realistic, but is much less explicable from constructivism.

However, from a realistic point of view, this example contains a disturbing element that we should not ignore: the fact that the initial analysis of the data by the MAGIC group favored precisely the conclusions desired by theoretical physicists, which later were proven invalid. If these findings did not finally prevail, it was due to the control exercised by other independent scientific groups using different instruments. This leads to the question of what can be expected in a situation with no independent groups able to control the results of another one. In the next example we show that even under these extreme circumstances there are results suggesting that scientific realism still prevails.

3.4 The success for scientific realism in the AMANDA failure

The AMANDA Collaboration, which incorporated over 100 scientists from nineteen research institutions in America and Europe[14] in 2004, pursued two goals:

(1) The first goal was acquiring the necessary technical expertise for building a neutrino telescope in the Antarctic ice, with a volume of $1\,km^3$ at a later stage. (2) The second goal was testing different theoretical models, according to which some sources of cosmic neutrinos should be detectable with the help of a detector with an effective area of $10^4\,m^2$. The AMANDA Detector would reach, and even exceed such surface[15].

The AMANDA Detector was built at the South Pole (close to the current location of the "IceCube") between 1993 and 2000. The idea of a system of strings with optical modules which would be sunk in the ice was first realized by AMANDA. This was a large scientific collaboration funded with several million dollars.

AMANDA provided data until 11 May 2009. Although the detector was still functional, it was shut down to save energy. During its eight years of operation, the data from AMANDA led to strict upper limits for possible neutrino flux from different cosmic sources. No significant source has been observed in all this time.

But in 1996—when the first four strings of the AMANDA-B Detector had been placed at a depth between 1545 and 1978m—we find the following reference to very ambitious goals in an article by Francis Halzen (for the AMANDA Collaboration):

> Speculations that the highest energy photons and protons are produced by cosmic accelerators powered by the supermassive black holes at the center of active galaxies can be used to estimate the required effective volume of a neutrino telescope. The answer is $1\,km^3$. [...] Model building suggests that the detection of these accelerators may be within reach of much smaller detectors with effective area of order $10^4\,m^2$. The AMANDA collaboration is ready to complete such an instrument within the next few months (Halzen, 1996: 1)

And in the same paper Halzen also points out that even the indirect detection of WIMPs ("Weakly Interacting Massive Particles") is to be expected. Because in most theoretical scenarios the neutrino flux associated with the annihilation or decay of WIMPs should lie within the observable range of the AMANDA Detector.

Such optimistic expectations can be found in all the papers of the AMANDA Collaboration.

> "Who knows what secrets will be uncovered as the wealth of data from AMANDA-II is processed and analyzed?"[16]

This sentence can still be found on the web page of AMANDA-II. And although one of the goals of such formulations is to draw public attention to one's own work, it can easily be imagined what high expectations the participating scientists had for the experiment. However, in the meantime everything points to the fact that the expected great discoveries the AMANDA Detector was hoped to make are missing. Instead, the results achieved after a decade of data acquisition and data analysis can be summarized as follows:

> Results from AMANDA-II [...]:
>
> 1. A search using AMANDA-II established a flux limit for point sources.
>
> 2. There is no evidence for any neutrino point sources, although some interesting, but low-statistics, possibilities bear further investigation.
>
> 3. AMANDA-II has provided an extremely useful test module for the much larger IceCube [...]. (Boyd, 2008: 82)

In other words, none of the expected neutrino and other signal sources were detected: no AGNs, GRBs, WIMPs or exotic particles. After a thorough data analysis, the members of the AMANDA Collaboration were only able to set upper limits for the neutrino flux from these sources. And these limits imply that the neutrino flux should be much lower than predicted by established theoretical models in the 90s.

However, keep in mind that in the case of AMANDA, if a constructivist development had taken place, all the factors to be taken into account to analyze the dynamics of the research process would have conspired for the achievement of a positive result. This is because we are facing the situation of a large scientific collaboration using an expensive device; that had to extract the relevant data by means of an extraordinarily complicated analysis (due to both the very weak interaction of the neutrinos with the detector, and to the fact that it had to discard atmospheric neutrinos); that had the opportunity to promote significant (and highly anticipated) theoretical developments with clear economic and academic interests... and that possessed the only detector in the world with such characteristics. The fact that in such circumstances no spectacular discovery was finally announce is, in my view, a very significant indication of the extent in which current physicists are still attached to the rigor of scientific realism.

At this point we could continue accumulating examples of realistic dynamics, both in particle astrophysics as in other border areas of the physical research of our time, but I think that the above is sufficient. Therefore we can move to the last block of questions I would like to address in this article, which can be summarized as follows: Can we expect a long-term preservation of scientific realism in the current philosophical context? And if not, how could be the non-realistic physics in the future? We will address these issues in the next section.

4 TOWARDS A NEO-ALEXANDRIAN PHYSICS?

Can we expect that scientific realism will survive in the long-term in the current philosophical context? This question is not easy to answer. On the one hand, if we consider that the atheism-prone philosophical climate is widespread in Western academia since the nineteenth century, and that realistic belief in a natural order is still the default attitude of most of the physicists in the twenty-first century, it must be recognized that the inertia towards realism is very remarkable among the specialists in this discipline. However, on the other hand, one could argue that the survival of realism may be due, at least in part, to the fact that philosophers and sociologists of science have still not offered to the physicists alternative interpretations of their activity that can be considered minimally acceptable.

For example, during the famous episode, mentioned above, the “science wars”, the sociologists of science —Pickering, Latour, etc.— applied to the scientific activity mainly categories such as “trade”, “negotiations”, “advantages”, “benefits”, “profitable” etc. And so, for example, referring to the discovery of *neutral currents*, which resulted in the confirmation of the electroweak theory, Pickering wrote this:

> Quite simply, particle physicists accepted the existence of the neutral current because they could ply their trade more profitably in a world in which the neutral current was real. (Pickering, 1984: 87)

This approach was considered by physicists as something so alien to their real motivations, that the angry response from many of them was not surprising.

Meanwhile, much more refined constructivist analyses of science are being developed. Perhaps the author who has advanced most in the formulation of a non-realistic alternative to the understanding of scientific activity has been Harry Collins. A very interesting book about his way of looking at that activity is "Gravity's Ghost. Scientific Discovery in the Twenty-First Century"[17], which describes and analyzes the research work carried out by the international collaboration LIGO, dedicated to search gravitational waves, especially during the period between 2007 and 2009.

Commenting towards the end of the book the reluctance of the physicists in this group to publish tentative results (announcing them as such), Collins writes, for example, the following:

> One of the senior scientists in LIGO is quoted above as saying that to offer only gradualist and tentative results in the search for gravitational waves would "abrogate our responsibility as scientists". He was reflecting a very widespread view among the collaboration's members at the beginning of 2009. From the sociological and political perspective offered here, the opposite is the case. Scientist' responsibility lies in making the best possible technical judgments, not in *revealing* the truth. To represent every judgment as a calculated certainty is to abrogate *social* responsibility. To be a producer of certainties is, at best, to consign oneself to the nonexemplary sciences—the corner of scientific world that has dominated, and distorted, Western thought with examples of what it claims to be a perfect and, worse, *attainable* mode of knowledge-making. (Collins, 2011: 161)

In short, against the scientific realism still dominant among the members of the LIGO collaboration, as in general among physicists, Collins conceives scientific activity as a research investigation that does not aim to "revealing the truth", but simply to make the best possible technical judgment from the data available at a given time. In other words, the question is to find the most convincing possible way to model the available data, or, more typically, to "save the phenomena".

Therefore, the realistic conception of nature and science, and the alternative "post-realistic" conception proposed by Collins, could be summarized in a table like the following:

Model of realistic physics		Model of constructivistic physics	
Nature	Science	Nature	Science
Order; real structures	description; theories reflect real structure	Set of raw data	construction; theories reproduce data; save phenomena

Anyone who knows the history of science will recognize in this proposal a new version of the old instrumentalist approaches of the Alexandrian astronomy, strongly rejected by Copernicus and the other founders of modern physics.

Certainly, this "new" conception of science is far from being common among physicists, as Collins is witness. But, if the current intellectual pressure from the faculties of humanities continues, especially from philosophy and sociology, who can guarantee that the ideal of the discovery of the natural order will not give way, in more or less time, to an idea of science as consensus building, whose aim is adjusting reasonably the models to the phenomena?

If such thing happened, there would still be physicists, chemists and biologists, of course! Science faculties, specialized publications, and everything else would still exist. But scientific activity would have changed radically. After abandoning their faith in a rational, simple and beautiful order of the cosmos, which reflects the rationality of its Creator, scientists would tend to settle with a simple adjustment of the data in the Alexandrian mode, and science would have become a mere technique for the rational management of information, without hoping to find a beautiful and simple structure hidden behind the appearances. The new science would fall far short of the tradition begun by Copernicus, Galileo and Kepler, as much as the current enterprise-oriented university is very far from the medieval assembly of students and teachers gathered to seek the knowledge of truth about the world and about God.

Is this the fate of science in the twenty-first century?

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NOTES

1. An extensive study of the realistic attitude prevalent today among physicists, obtained from a detailed analysis of the dynamics of research in a particular field of this discipline, can be found in (Soler Gil, 2012).
2. Available at: http://www.webexhibits.org/calendars/year-text-Copernicus.html XIX.
3. Available at: http://www.webexhibits.org/calendars/year-text-Copernicus.html XXI
4. My translation.
5. My translation.
6. On the religious attitude of scientists in general see e.g. (Fernández-Rañada, 2002), where numerous quotations and biographical details of the physicists of the first generations are included; also a very important study, although primarily focused on figures of the eighteenth century, is (Arana, 1999).
7. As a complement to what has been said above, I would draw attention to the fact that, while the belief in the rationality of nature and the power of human mind to discover the rational order, were thesis shared by some of the Greek

philosophers, this does not apply to point (3) in this list: accepting the existence of different possible cosmic orders and the consequent need for experimentation to determine which order in fact exists, is an original contribution of medieval Christian theological thought.

The historical context of this contribution was the process of analysis and discussion of Aristotle's philosophy in the medieval universities (especially in Paris) since the thirteenth century. Its starting point was initially the fear that the freedom of God, and the created character of the world, could be challenged by the influx of Aristotelian physics and cosmology, recently rediscovered in the West.

Aristotle does not seem to have made a distinction between rational order and logical necessity—and this is a typical feature of Greek philosophical thought—, therefore his physics and cosmology are deductive, starting from first principles considered self-evident. This meant that the character of the cosmos was necessary, that God could not have done things in a different way, at least in the essential aspects of the cosmic structure. Put in another way, God would have had not much choice—perhaps none—, for the Aristotelian cosmos was imposed by its own logic.

The rejection provoked by this approach in spirits oriented towards Christian theology exacerbated the tension between the Faculty of Arts and the Faculty of Theology at the University of Paris. This growing tension would result in the crash that led to what has been called "the Great Damnation" of 219 theses supported by arts teachers, promulgated by Stephen Tempier, the bishop of Paris, on March 7, 1277. From that point, any philosopher or Christian theologian who considered the orthodoxy of his thought important, would adopt a strongly critical position about those doctrines by Aristotle that question the divine omnipotence, understood as the ability to create different cosmic orders. Among the theses condemned for these reasons were some very significant for cosmology, such as these: that just one world is possible [prop. 27]; that the heavenly bodies cannot move with a rectilinear motion [prop.66]; etc. Denying their validity implied the immediate opening of a range of structural possibilities that highlighted the contingent nature of the universe, its rightful character as a creature. The universe embodies a certain order, but it could have been very different; its essential features are the result of a particular free choice by God. Then how can we find out which was the divine choice? Only the observation of nature will allow us to discover the actual world order. And thus, since the fourteenth and fifteenth centuries, all the theoretical assumptions needed for modern science to develop were already in circulation.

8. Source: http://de.wikisource.org/wiki/Nicolaus_Coppernicus_aus_Thorn_%C3%BCber_die_Kreisbewegungen_der_Weltk%C3%B6rper/Vorwort_Coppernicus
9. The reader interested in the constructivist approach to science can consult, for instance, (Collins - Pinch, 1998), and (Pickering, 1984).
10. (Pickering, 1984).
11. I have dealt at length with the issue of realism in current experimental physics

in my study (Soler Gil, 2012). The various points mentioned in this subsection are treated in detail there.

12. The reader interested in studying more closely a possible science built following constructivist guidelines—a science built on "indicazioni", i.e. experimental results that "suggest" something—can consult Collins proposals in line with his description of the dynamics of research on the subject of gravitational waves (Collins, 2011). I will return to this important work at the end of this paper.
13. Shao, Xiao y Ma mention, for instance, the following versions of quantum gravity that require violation of Lorentz invariance: "spacetime foam, loop gravity, torsion in general gravity, vacuum condensate of antisymmetric tensor fields in string theory, and the so called double special relativity" (Shao, Xiao y Ma, 2010).
14. See: http://www.amanda.uci.edu/collaboration.html
15. The effective area of the AMANDA II detector is 3×10^4 m^2.
16. Source: http://www.amanda.uci.edu/public_info.html
17. (Collins, 2011).
