

Science, Metaphysics, and Scientific Realism

Jerzy Gołosz

Jagiellonian University in Kraków

Abstract. The paper can be logically divided into two parts. In the first part I distinguish two kinds of metaphysics: basic metaphysics, which affects scientific theories, and a second kind, which is an effect of interpretations of these theories. I try to show the strong mutual relations between metaphysics and science and to point out that the basic metaphysics of science is based on realistic assumptions. In the second part of my paper I suggest that we should consider the basic metaphysics of science and its realistic foundations in order to better understand scientific realism and to properly resolve the debate around it. The methodology of Imre Lakatos is applied in the paper.

Introduction

In recent years much time and energy has been devoted to the problem of how science influences our knowledge of reality. We consider, for example, what the General Theory of Relativity (GTR) tells us about space-time and its relation to matter; what the same theory tells us about the past, the present, the future, and the flow of time; and what quantum mechanics reveals to us about the identity and individuation of elementary objects of our world. We also ponder on the referents of the theoretical terms featured in our theories and the role played by the structures discovered by these theories. It is surprising that, at the same time, we pay so little attention to the problem of how our conjectures about reality affect science—surprising, that is, because our theories are not handed to us from somewhere outside in a finite, perfect form and free of any assumptions, but rather the opposite is the case: they are created (or discovered) by us as solutions to problems which at a given time seem to be crucial to us, being grounded on some basic assumptions. Revealing these foundations, no matter how self-evident they can seem, can help us to see the limitations of our theories and, perhaps, to see also how best to develop them. This effort, therefore, lies at the heart of science. Such an analysis can also help us answer some of the questions mentioned earlier. While investigations of the consequences of some theories and possible additional postulates are logically much easier

to undertake than research on the methods which led to these theories, this should not dissuade us from undertaking the latter kind of exploration.¹

I do not claim, of course, that the problem is new; indeed, some philosophers have already written about how metaphysics can affect science.² What I want to do is to strengthen the thesis about the importance of metaphysics to science, and to distinguish between metaphysics that affects science and metaphysics that *is* affected *by* science. First, however, some remarks on the metaphysics which interest me seem in order.

2. Metaphysics, but of what sort?

I intend to confine myself to the kind of metaphysics that is interested in the physical world and wants to stay in touch with science. I start with a very general qualification of metaphysics. Traditionally, we distinguish between metaphysics, which is concerned with reality as a whole, and epistemology, which is a theory of our knowledge. On the other hand, what dominates instead in the philosophy of science is the qualification of metaphysics stemming from Hume and Kant, where metaphysics is defined as something unempirical. If we accept this feature as an important characteristic of metaphysics, together with the first requirement, that metaphysics is interested in referring to the physical world, two conditions can be used to characterize metaphysical statements. The first condition, which I will call **P** and which is imposed on the statements themselves, demands that they should not be empirical and, of course, not analytic:

P A statement is metaphysical *P* iff (if and only if) it is not empirical and not analytic.³

The second condition, which I will call **R**, requires that statements aspire to refer to the physical world (rather than to our knowledge):

R A statement is metaphysical *R* iff it refers to the physical world.

Sometimes, in speaking about the ontology of some empirical theory,⁴ we use statements that satisfy condition **R**. Condition **P** was widely exploited

¹ This kind of research has been included in the context of discovery and has been qualified as irrational and belonging to the domain of psychology, but it seems rather that it is this qualification and the aversion to this kind of research that should be explained psychologically. I will not pursue this question.

² See e.g. Popper (1959, 1983), Lakatos (1970, 1971), Watkins (1958, 1975), Agassi (1964), Sklar (1981), Redhead (1995), Belot, Earman (1999). Redhead, Belot and Earman write about the two-way interactions between metaphysics and science.

³ This first condition imposed on metaphysical statements is assumed following Watkins (1958, p. 345). I introduced two independent conditions in order to be able to distinguish between those statements that satisfy only one of the conditions, and those that satisfy both.

by logical positivists. It seems, however, that when we consider metaphysics, we think mainly about statements that satisfy both of these conditions, **P** and **R**. Unless indicated otherwise, I use the term “metaphysical” in such a sense. What I want to show in the next part of my paper is that metaphysical statements understood in this manner are of particular importance for empirical sciences.

Two kinds of metaphysics are closely related to science: basic metaphysics, which can affect science, and interpretative metaphysics, which may be seen as an effect of the attempts to interpret scientific theories. What distinguishes these two kinds of metaphysics is their relation to scientific theories and the way their use is justified. The first actually affects science—it tries to grasp the general properties of the world, and its reliability can be justified on the basis of its fruitfulness for the creation, assessment, and development of scientific theories.⁵ The second concerns our interpretation of scientific theories and is justified mainly by its explanatory worth. This division, of course, is not a dichotomy: statements that form the metaphysical basis of some theory can be—and often are—part of its interpretative metaphysics. The distinction, however, is drawn for three reasons. Firstly, a metaphysical interpretation of scientific theories can be—and indeed sometimes is—made on the ground of somewhat different metaphysical assumptions than those taken for granted in their metaphysical basis. Secondly, basic metaphysics refers to a broader class of phenomena than interpretative metaphysics does, and can be somehow ‘deeper’, as in the case of the metaphysical assumption about a uniform order of the world. And thirdly, some new basic metaphysical ideas and new notions for science might not ever be considered before we actually start to look for a new theory. If somebody forgets about the metaphysical basis of science, they will only see a one-way impact of science on metaphysics.⁶

2.1 BASIC METAPHYSICS

The attitude toward metaphysics and its relation to science in the 20th century evolved from denying it as meaningless in the early positivist “narcotic” conception of metaphysics, to treating it as “influential” by Popper, to considering metaphysics as a rightful part of science with

⁴ I treat ontology as a branch of metaphysics which talks about what exists. We can speak, for example, about the ontology of a particular theory as the set of things whose existence is acknowledged by this theory.

⁵ Such a role of metaphysics was emphasized, for example, by Popper (1983), Watkins (1958), Agassi (1964) and Lakatos (1970).

⁶ Such a one-way impact of science on metaphysics is considered, for example, by Hawley (2006).

Lakatos.⁷ It is just this continual struggle of both logical positivists and their critics with the concept of metaphysics that has revealed how metaphysics can be interesting and important even for those of us inclined to treat scientific methods as the best available for humankind.

A new attitude toward metaphysics was made possible when Lakatos adopted a novel approach to the rationality of science, together with the assumption, which seems to be quite natural, that events and factors that influence science *in a rational way* should be included in science and treated as internal to it. This criterion for differentiating between internal or external factors was complemented by Lakatos with a second meta-methodological criterion, that of appraisal of methodology. If one methodology, involving a certain theory of scientific rationality, allows us to treat as internal something that another methodology treats as external, then that is an argument for the superiority of the first methodology.⁸ What Lakatos showed that is particularly important for the topic of this paper is that scientific research programmes advance not by induction or falsification, but as a development of the metaphysical doctrines that become part of the hard cores of such programmes.⁹

It is not hard to find examples of such doctrines. We can point out several metaphysical ideas that were born in Greece and should be mentioned here because of their importance for science. The whole of science can be treated as grounded on two metaphysical assumptions that we owe to the Presocratics. The first one speaks of the rationality of the world treated as something exterior to and independent of us: *there is a uniform order in the world that is subject to a principle or law available to our understanding*.¹⁰ The second one boils this principle down to numbers. Both of these assumptions are necessary for science: only someone who believes there is order in the world will look for it and will be able to find

⁷ See e.g. Popper (1959, 1983), Lakatos (1970, 1971), Watkins (1958, 1975). A substantially longer and somewhat different history of metaphysics in the 20th century can be found in Zimmerman (2004, Prologue).

⁸ The meta-methodological criterion was used by Lakatos to show the superiority of his own methodology of scientific research programmes over competing methodologies (see Lakatos (1971) p. 99; Watkins (1975) p. 94). I am later going to use Lakatos' meta-theoretical criterion to assess different metaphysical views concerning the relations between science and reality.

⁹ The title of this section should be read in the spirit of Lakatos and not Popper; I am discussing metaphysics that permanently affects science, and not Popperian (1933-34) metaphysics, which influenced science only in its infancy. Following Lakatos, we can include basic metaphysics (but not always interpretative metaphysics) into scientific research programmes.

¹⁰ This metaphysical assumption seems to be the most fundamental metaphysical assumption we take for granted in our cognition, and is also assumed in this paper as a primary principle. It might be recalled here that the Greek word "kosmos" means order.

regularities. In particular, a numerical order can be found only by somebody who is looking for numbers and not only for properties in the world—that is, a numerical order can be found only by somebody who is trying to describe the world in terms of numbers. And the third metaphysical doctrine of great consequence—atomism—has been very influential through the centuries. For instance, it made possible the development of the corpuscular theory of light, it led Boltzman's research into the possible reduction of thermodynamics to mechanical laws, it inspired Planck when he was looking for a formula for black-body radiation consistent with observations, and at present it motivates the attempts to find a quantum theory of space-time.¹¹

Even these simple examples of three metaphysical doctrines and their history can reveal some important regularities. The Pythagoreans first looked to find the rationality of the world in integers, but after the discovery of incommensurable magnitudes (irrational numbers, as we call them now) they began to see geometrical objects as the fundamental entities of the world. This shows that in fact we do not work on one single metaphysical assumption, but rather on a set of assumptions that have different levels of generality.¹² In case of difficulties with the realization of a certain metaphysical principle, we can refer to a principle at a higher level (e.g., about the rationality of the world) either to replace it or to modify the initial idea. Greek mathematicians also made an attempt to resolve their problem in another way: Eudoxus' theory of proportions made it possible to deal with incommensurable magnitudes and—as we know at present—it could be used to change the concept of number by embracing irrational magnitudes within it.¹³ The history of atomism also allows us to see how the original metaphysical idea was modified: formulated with success for the elementary components of matter, the doctrine was next implemented for energy, and is now used in the attempts to formulate a new theory of space-time. Such a broadening of the original idea is nothing more than an attempt to implement a more general metaphysical idea of the uniformity (or simplicity) and rationality of the world.

¹¹ See e.g. Smolin (2001).

¹² See e.g. Waerden (1954) for the origins of the Pythagoreans' geometric algebra. Their conversion from belief in integers to belief in geometric magnitudes also resulted in Plato's geometry-based metaphysics in the *Timaeus*. It seems that, contrary to what Popper (1952) maintains, Plato was influenced by the Pythagoreans' new attitude toward geometry rather than the other way round. See Heath (1981, pp. 150-154) and Waerden (1954, pp. 125-126) who claim that according to the reliable report of Eudemus, it was particularly the Pythagoreans who laid the foundations of geometric algebra.

¹³ For similarities and differences between Eudoxus' theory of proportions and Dedekind's theory of cuts see, for example, Bourbaki (1969).

Twentieth century physics also shows that metaphysical ideas which are not implemented in a physical theory can be used to criticize it and to inspire the formulation of a new theory to overcome the shortcomings of the first; this, for example, is the case with determinism and quantum mechanics.¹⁴ Such a discussion is possible because we have differing metaphysical ideas, such as determinism and indeterminism, atomism and the principle of continuity (Leibniz), or the principles of action at a distance (Newton) and of action at vanishing distances (Descartes), which are incompatible and can therefore be employed to criticize one another.

It is obvious that metaphysical doctrines do not determine the scientific theories we are searching for; what they do is point out general properties of the world and of the theories we are looking for. Unlike scientific laws, they do not describe particular properties or structures of the world, but only inspire us in our research by showing the direction it should take. This is why they are not empirical; they are too general to be verified directly and can only be evaluated on the basis of their fruitfulness in the formulation, assessment, and development of scientific theories. For example, metaphysical doctrines can maintain that all there is in the world are continuous fields, postulating that every phenomenon should be explained in terms of continuous fields (the metaphysical program of Faraday, Maxwell and Einstein), but without actually specifying particular kinds of fields or their properties (or structure). Success in searching for a particular theory does not prove, of course, that our metaphysical doctrine *is* true, but rather that it *can* be true—after all, our theories are only hypotheses and are applicable only to some restricted types of phenomena, whereas metaphysical doctrines want to be as universal as possible. Similarly, failure in our hunt for a new theory with the required features does not prove that our metaphysical assumptions are false, only that our search did not succeed (maybe it was not deep enough). Not being provable or falsifiable, our metaphysical doctrines are still—or rather, should be—open to criticism; they can be—and sometimes should be—refuted, modified, or simply made more precise.

Finding a new scientific theory requires not only luck, but first and foremost the creativity to make our metaphysical assumptions more precise. For instance, if we believe in the rationality of the world, we should decide what this rationality consists of: numbers or ideal geometrical constructions (e.g., Pythagorean circles and spheres), deterministic or perhaps indeterministic laws. If we decide on numbers, we have to decide which numbers we want to employ to describe the world. It follows from this, as has already been mentioned, that we do not use single, isolated

¹⁴ See e.g. Einstein (1949, pp. 81-89).

metaphysical claims, but rather a collection of claims that can form a hierarchy.

Well-known cases of accidental discoveries could be cited to dispute such a claim, but I would nevertheless still maintain that our search is always driven by some metaphysical assumptions.¹⁵ Without denying room for accidents and simple luck, I would insist that there are no purely accidental discoveries—purely, that is, in the sense that such discoveries lack metaphysical assumptions. As Kuhn remarked, an unexpected discovery—originating from some anomaly—emerges only for the man who, “knowing with precision what he should expect, is able to recognize that something has gone wrong.”¹⁶ It can also be added that such a discovery is only possible for the man who believes in the rationality of the world—that it is uniform or homogenous, without room for contradictions and exceptions from the rules that are available to our cognition, and that whatever happens can and should be confronted and explained by our knowledge. What distinguishes “accidental” discoveries from “non-accidental” ones is that the former are based on more general or deeper metaphysical assumptions.

From a philosophical point of view, a fundamental problem is that of justifying the methodological rules and values we use in science. There is also the essential question concerning the relations, if there are any, between these rules and values on the one hand and metaphysical claims on the other—for example, between the rule “search for the simplest and most general theories” and the metaphysical claim “the organization (or the constitution) of the world is simple and homogeneous,” or the rule “look for general laws describing the world in numbers” and the claim “the structure of the world is based on numbers” (or “numbers are the principle of the world”). The scientific status of methodological rules has always seemed firm and has never been doubted. Contrary to this, metaphysical statements were often treated as non-scientific and were mistrusted. Even Popper, one of the co-authors of the new attitude toward metaphysics, in the beginning (1933-34) treated metaphysical statements as hypostases of methodological rules.¹⁷ However, many of the most important methodological values that we impose on our theories and the methodological rules that guide our

¹⁵ See, e.g., Kuhn (1996, pp. 57-58) for the discovery of X-rays by Roentgen.

¹⁶ Kuhn (1996, p. 64). This way Kuhn tried to resolve the following problem: “why normal science, a pursuit not directed to novelties and tending at first to suppress them, should nevertheless be so effective in causing them to arise.”

¹⁷ It is not quite clear how Lakatos saw this problem. In (1970) he repeated after Popper that methodological rules are primary and they may be formulated as metaphysical principles (1970, pp. 132, 136) while in (1971) he did not derive metaphysical principles from methodological rules and seemed to treat them as of equal rank.

research have their roots in statements that are metaphysical. We can ask: why do we appreciate such values as simplicity and generality, depth, coherence, richness of content, precision and exactness of predictions, and intersubjective validity, and assume methodological rules that demand that we search for these values? Why are we still trying to describe the world in a language of numbers and causal relations? The answer to these questions seems to be simple. We look for some lost object in our home because we are convinced that it is there. In the same way, we look for simple and general theories with rich content because we are convinced, as were the Greeks, that the constitution or structure of the world is simple and uniform, and that the theories that we regard as general and “deep” have a chance of revealing their fundamental (or deep) structure. We require coherence because we believe in the ontological law of contradiction, and demand intersubjective validity of our theories because we believe that the world is independent of us and the same for all of us. We try to describe the world in numbers because we are convinced that its structure is mathematical; we appreciate precise and exact predictions and want to see causal relations in the world because we do not want to see our world as ruled by accident. In all these cases, our metaphysical convictions (i.e., they refer to the world and are unempirical because of their generality) are motives or reasons for accepting methodological values and rules.¹⁸ Alternative attempts to answer the above questions by pragmatic efficacy do not seem to be attractive. They do not explain why we so insistently pursue more and more general theories, why we treat simplicity as such an important methodological value, and why we think of old theories as false.¹⁹

For a philosopher, the difference between epistemological (referring to our knowledge) and metaphysical (referring to the world) statements is elementary, but, setting this aside, one could maintain that there is no real difference between, for instance, the heuristic rule “astronomical models describe (or should describe) motions of heavenly bodies as combinations of uniform motions in the circular orbits” and the claim “heavenly bodies are uniformly moving in circular orbits,” which formed the metaphysical program for astronomy from the Pythagoreans until Copernicus, or “our fundamental theories are (or should be) as simple and general as possible” and “the constitution of the world (or its structure) is simple and homogenous.” However, this is not the case. To show this, I could simply recall that, for example, astronomers from the Greeks until now have been

¹⁸ My use of the words “motive” and “reason” is not accidental; as noted by Watkins (1958, pp. 356-357), there is a logical gap between statements and prescriptions illustrated by the fact that someone may reject a certain doctrine in its fact-stating form while subscribing to the prescriptive version of it.

¹⁹ Similar arguments were used by Popper (1983, pp. 113-117) in his critique of instrumentalism.

trying to describe the motion of celestial bodies treated as real; Newton regarded space as a substance; Huygens, Mach, and Einstein wanted to deal with spatiotemporal structure as something determined by relations between real bodies and so on. Instead, I would like to demonstrate something more, that is, that we *have* to rely in science on metaphysical (*P* and *R*) claims.

The best argument for this viewpoint comes from meta-theoretical considerations that are required in science whenever we want to compare or to unify two different theories. To show this, I would like to consider the following questions: why do we demand, as Einstein did, that different theories, for example mechanics and electrodynamics, *must have* the same spatiotemporal symmetries, and, more generally, why do we use the *same* entities with the same properties in different theories? Why do we use the same charged particles (e.g., the electrons) in theories of electricity and magnetism? Why do the same entities appear in electrodynamics and in the theory of weak interactions? Why do we use the same spatiotemporal characterizations for certain objects when we describe them in mechanics and in electrodynamics, or in mechanics and the theory of gravity? It seems that the only plausible answer is that all these theories tell us about the *same* objects or the *same* structures. In such cases, our judgments are based on two assumptions that are metaphysical (*P* and *R*): “there are objects—e.g., elementary particles—independent of us that form the bases of all physical phenomena” and “there is a spatiotemporal structure independent of us that forms the physical base—the same for all physical phenomena.”²⁰

Two essential remarks should be made at this point. Firstly, our cognition is aimed, as can be seen in these and other examples, both at observable (e.g., heavenly bodies) and unobservable objects (e.g., electrons, current density, electromagnetic fields, or space-time structure and its symmetries). It is not that we want only to describe and explain the behavior of observable objects and indications of measuring instruments and therefore we introduce such theoretical entities as, for example, electrons, space-time symmetries, and electromagnetic and gravitational fields. On the contrary, since the Greeks we have always aimed mainly at gaining knowledge of the unobservable constitution of the world, its

²⁰ Although I am of the opinion that non-eliminative ontological structuralism is the best response to Laudan’s (1981) pessimistic meta-induction, in the very general considerations of this paper I do not want to prejudge which form of structural realism is best. Similarly, in speaking about the same entities and the same objects, I do not want to prejudge what is their nature and which metaphysics of structures should be implemented. For a different kind of structuralism see Worrall (1989) and Ladyman (1998, 2007), and for a critical analysis of structuralism from the realistic point of view see Psillos (1995). The argument formulated above in the main text can be seen as a reversal of the pessimistic meta-induction, so it could be called *the optimistic meta-abduction*.

general laws and fundamental principles, as well as its elementary components, their properties and interactions. The indications of measuring instruments are always for us nothing more than simply means to this end.²¹

Secondly, much of our research about the world seems to be aimed at its various structures. Of course, we want to gain knowledge about the components, both elementary and compound, but we are also interested in the structure (or constitution) of the world: causal structure, space-time structure, the structure of matter distribution, and, perhaps most importantly, the structure that we think of when we consider the fundamental physical laws and relations between them. Of this last structure, we say that the more unified and more general the theories are, the simpler and deeper the structure of the world that they reveal. Our efforts, which have been continuing ever since the early Greeks, to discover the fundamental principle or the fundamental laws of the world considered as independent of us are aimed at this very structure and are led by the general metaphysical assumption mentioned before: "There is a uniform order in the world that is subject to a principle or law available to our understanding."

I would like to emphasize that I do not claim that we are guided only by metaphysical doctrines in our scientific research. I claim, rather, that science in principle tries to refer to the world and what we do is make an effort to obtain knowledge about it, both in its observable and unobservable parts. Of course, we also use heuristic principles and rules, like, for example, "our knowledge is uncertain" or "be critical of your knowledge," which are weakly connected with metaphysical doctrines. Again, however, even if we consider our knowledge and its properties, a better part of this knowledge refers, or at least aspires to refer, to the world and is based on metaphysical (*P* and *R*) conjectures about this world.

2.2 INTERPRETATIVE METAPHYSICS

I have tried to show that science is aimed at the world and makes an effort to acquire knowledge of its observable and unobservable entities, and that scientific theories are based on metaphysical assumptions (those which are unempirical and refer to the world). Having formulated a scientific theory, we can try to interpret it metaphysically and, among other things, check whether it really embodies the intended metaphysics. Rather than fully discuss the broad subject of interpretative metaphysics, I offer some general remarks about it.

²¹ This naturally connects with the scientific realism debate. I return to this problem below.

Historical cases show us that the basic metaphysics is not always, as a whole, embodied in the theory. Newton was convinced that space and time are absolute in the sense of being independent of physical bodies and in the sense of the existence of a distinguished reference frame, and he wanted to refer motion in his dynamics to an absolute space understood in the second way. As we know at present, only this first metaphysical assumption is embodied in his theory. Einstein, on the contrary, was led by his anti-absolutist metaphysical assumptions while working on GTR. He was convinced that if an inertial structure of space-time affects the motion of physical bodies, it should be affected by them as well or, in other words, it should be a dynamic element of the new theory. He also wanted to embody the relational metaphysical ideas expressed by Mach's principle into GTR. Again, as we know at present, and contrary to Einstein's first assessment of GTR, only this first metaphysical assumption is included in his theory.²²

Such cases, as well as Laudan's instances of mistakes in interpretative metaphysics consisting in a discontinuity of ontological interpretation of scientific theories, or the possibility of different formulations of the same theory, show us that we should be cautious and open to criticism when doing a metaphysical interpretation of some theory.²³ But should we, completely or partially (regarding theoretical terms), abandon the realistic interpretation of scientific theories for this reason? I do not think so. We do not claim, after all, that all our metaphysical claims have to be necessarily true. Mistakes are quite normal if we take into account the fact that our knowledge, metaphysical as well as scientific, is hypothetical in character, and it is usually not so difficult to correct such mistakes. In some cases, such as Newton's assumption about the existence of a distinguished reference frame or Einstein's conviction about the validity of Mach's principle, we can simply reject the false assumptions. A more sophisticated and more universal resolution of the difficulties mentioned above was proposed by Worral (1989), following Poincare. His structural realism boils down to the claim that what scientific theories really tell us about the world are structural relations between phenomena and not the nature of these phenomena. Such a line of attack regarding the problem of metaphysical discontinuity seems to be additionally justified by the fact that, as pointed out above, an important part of our cognition seems to be aimed at the different structures of the world.

²² See, e.g., Earman (1989).

²³ Laudan (1989) pointed out that many entities posited by empirically successful theories, such as phlogiston, caloric or ether, were abandoned in the history of science. We know also many examples of different ways of expressing the same physical theory; for example, for Newtonian mechanics we can use a standard formulation (with an action at a distance), or the Lagrangian and Hamiltonian approach, or a formulation in terms of curved space. See, e.g., Jones (1991).

An alternative approach to the problem of mistakes and difficulties in the metaphysical interpretation of scientific theories in the form of a partial (with respect to unobservable entities) or complete cutting off of the realistic roots of such theories (carried out usually by philosophers) consists in trying to interpret them in an anti-realistic way, e.g., instrumentally. Such an approach, however, seems to be just as rational as denying science itself by virtue of its mistakes, such as the phlogiston theory of combustion or the theory of ether. What is more, such an attitude toward science gives us much less than it promises. What it really does is produce an exchange of metaphysical assumptions. The assumptions about the reference of scientific theories and their theoretical terms to the world are substituted by other—likewise empirically unjustified—metaphysical (*P*) claims, such as, for example, that scientific theories (or at least their theoretical terms) are *only* instruments for predictions, or that the *only* aim of scientific theories is empirical adequacy and that knowledge of unobservable phenomena is impossible.²⁴

I have tried to show that we cannot simply deduce metaphysics from a scientific theory: we can interpret it metaphysically only if we assume some additional metaphysical (at least in the sense of being metaphysical *P*) assumptions in both the realist and the anti-realist approaches.²⁵ In the case of the realistic approach, which seems to be more interesting, the more extended the metaphysics we desire, the more developed set of metaphysical assumptions we need. So, for example, it does not follow from scientific realism that this realism must have a structuralist form, it does not follow from structural realism either that it must have an ontic or an epistemic form, and it does not follow from ontic structural realism that it should take an eliminative form (regarding individuals) rather than applying a structural theory of identity for individuals.²⁶ In a similar way, it does not follow from space-time substantivalism whether space-time should be identified with a bare differential manifold or maybe with a pair consisting of a manifold and a metric tensor, and it does not follow from this second option whether we should accept primitive thisness for space-

²⁴ The last two statements are a crude exposition of van Fraassen's (1980) constructive empiricism.

²⁵ For example, Sklar noticed: "one cannot simply 'read off' simple metaphysical conclusions from the relativistic theory. Rather, the metaphysical stance one ought to adopt follows only from the adoption of a number of fundamentally philosophical postulates" (1985, p. 289). However, sometimes in his conclusions, he seems to go too far: "one can extract only so much metaphysics from a physical theory as one puts in" (1985, p. 292). After all, he also claims that some metaphysical options have more plausibility than others. I try to show in my paper that we have the methodological tools, both in basic and interpretative metaphysics, to compare and assess different metaphysical doctrines.

²⁶ See Ladyman (1998, 2009).

time points or rather a structural theory of identity.²⁷ In each case, we have to make additional metaphysical assumptions to receive the metaphysical interpretation of the theory. The explanatory value of such an interpretation is the only justification for the theory.

It should be emphasized that the task of interpretative metaphysics is twofold: together with the interpreted scientific theory, of course, it should not only describe and explain physical phenomena and in this way provide us with the truth about the world, but it should also explain why we understand and use this theory in a certain way (or propose an alternative way that is equally effective) and why we should treat successive changes in a series of theories as rational. Given that we have a metaphysical interpretation that satisfies these two conditions better than other interpretations, we can treat the former as better—again according to Lakatos' criterion applied to the interpretative metaphysics in my meta-theoretical analysis. In this way we can, for example, consider structural interpretative metaphysics (or, strictly speaking, the methodology equipped with structural interpretative metaphysics) as better than non-structural or anti-realistic metaphysics. It is not only compatible with the earlier mentioned aim of science, which at least partially consists in getting knowledge about the structural properties of the world, but also allows us to explain some theory changes as continuous and rational. In the special case of space-time, a structural interpretative metaphysics can explain to us why we can think of GTR as at the same time substantival and deterministic; it also explains the practice of identifying space-time with the pair (M, g) , generally accepted by physicists, and does not lead to inconsistency in the appraisal of the determinism of Newton's kinematics in the classical and the generally covariant versions.²⁸

One might have the following objection to the reasoning which I used to justify basic and interpretative metaphysics: if someone takes for granted some assumptions in her reasoning, she cannot at the same time justify them without falling into *petitio principii*. In fact, this would be a misguided objection. We do not deduce scientific theories from basic metaphysical assumptions. What we do is look in a creative way for new theories that can satisfy these assumptions. If we are successful, we can acknowledge these metaphysical assumptions as fruitful and probably true. In a similar way, we look for metaphysical assumptions that can help us interpret scientific theories, phenomena described by them, and changes in theories in a rational way, and if we find such assumptions, we can appreciate them as providing satisfactory explanation and being probably true.

²⁷ See Earman (1989) for a view which identifies space-time with a bare manifold and Gołosz (2005) for an opposite view.

²⁸ See Gołosz (2005).

In any case, our appraisal of assumed metaphysics is more plausible if we also try to apply opposite or alternative assumptions—if such trials fail, our evaluation is more credible. Good examples of what I am talking about can be found both in history of science and in recent philosophical discussions. Newton took it for granted that there is (ontologically) absolute space and time and his mechanics refers motion to their inertial structure. Attempts to build alternative relational theories of motion and relational theories of space and time on the basis of Leibniz's, Huygens', and Mach's ideas as taken up by Einstein and, more recently, by Barbour have come to nothing.²⁹ In the case of interpretative metaphysics, the above comparison of structural scientific realism on the one hand, and non-structural realism or anti-realism on the other, seems to be an example of how different metaphysical assumptions can affect our assessment of the continuity and rationality of the development of science.

It is interesting to note that sometimes the metaphysical statements that we receive as a result of the interpretation of some theory can be used as a metaphysical basis for a new theory. For example, J. Stachel (2005) proposes that the future theory of quantum gravity that we are looking for should satisfy the *principle of maximal permutability*, requiring the theory to be formulated in such a way that the physical results are invariant under all possible permutations of basic entities of the same kind. In the form of a metaphysical statement, this principle says that whatever the ultimate nature of the fundamental entities according to the quantum gravity theory turns out to be, they should not possess inherent individuality, because it is absent, according to Stachel, at the level of both general relativity and quantum theory.³⁰

3. Science, Metaphysics and Scientific Realism

The scientific realism debate is a debate among different metaphysical views concerning the relations between scientific theories and reality; it concerns the problem of whether we can take scientific theories at face

²⁹ See, e.g., Barbour (1974) and Earman (1989) for an assessment of these trials.

³⁰ See Stachel (2005, p. 9). Although the proposed principle is interesting and worth remembering, it is hard to accept the way Stachel uses the term "haecceity"; he seems to use it as a term which is supposed to mean something like giving "final individuality" and he distinguishes between "inherent haecceity" (pp. 57-59), which means inherent individuality, and a non-inherent haecceity, which, for example, in the case of points of space-time is gained only "from the properties they inherit from the metrical or other physical relations imposed on them" (2005, p. 57). The point is that haecceity is a non-qualitative property that cannot be shared by different individuals, which can happen in the case of a symmetrical metrical field and other symmetrical physical relations.

value, i.e., whether there are theory-independent phenomena which our theories talk about. In particular, it relates to the theoretical terms that appear in our theories and about which we cannot be sure whether they really refer to mind-independent entities. The anti-realist claims that theoretical terms and constructions are only a kind of auxiliary scaffolding that we can get rid of as soon as we reach predictions about observables.

The debate concerns the problem of how we can interpret our scientific theories and their theoretical constructions and methods. This means—and this is especially striking in this debate—that we are not paying enough attention to the metaphysical basis of science, that is, to the realistic roots of science. This is convenient for the anti-realist because it is obvious that once we cut off these realistic roots, there appear possibilities of interpreting scientific theories in almost any way we want, and the arguments needed to grow these roots again lose much of their persuasive force. In such a situation, interpreting theoretical constructions in terms of artificial auxiliary scaffolding can seem plausible and more cautious than the realistic view. What follows from previous considerations and what I would like to maintain is that the realist should rather return the discussion to more familiar ground: she should insist on taking into account the metaphysical—that is, the realistic—basis of science. Thus, instead of claiming that we can explain the amazing success of science only if we assume realism, she should rather maintain that science is first and foremost aimed at the real world, trying to gain knowledge about it, including knowledge of both observable and unobservable phenomena, and that this task is being performed as well as it can be. Unobservable entities such as the basic components of physical objects, their properties and interactions; the ideal order of moving celestial bodies, which astronomers until Copernicus stubbornly constructed from circles and uniform motions, notwithstanding what they saw in the sky; numbers which we try to see everywhere; space-time and causal structure; the large-scale structure of universe and the amazing properties of the vacuum; the relations between space and time and physical bodies—these are the primary targets of our cognition, and the corresponding theoretical terms are not just artificial crutches or instruments for predictions. Much of our research is aimed at discovering structures (space-time structure, causal structure, or simply those that are described by our physical theories). And one of our fundamental metaphysical claims demands simplicity of these structures.

I referred above to scientific practice, but I would also like to recall here the arguments I used previously in section (2.1): we can develop science only because we rely on metaphysical—i.e., realistic in my use of the term—conjectures about the world. I tried to show that many of the most important methodological values that we impose on our theories and the methodological rules that guide our research have their roots in statements

that are metaphysical in nature. We appreciate such values as, for example, simplicity and generality, depth, coherence, richness of content, precision and exactness of predictions, and intersubjective validity. And we assume methodological rules that require us to search for these values because we are convinced that the constitution of the world is simple and uniform and the theories that we regard as general and “deep” have a chance of revealing their fundamental (or deep) structure; we require coherence because we believe in the ontological law of contradiction, and we demand that our theories be intersubjectively valid because we believe that the world is independent of us and the same for all of us; we try to describe the world in numbers because we are convinced that its structure is mathematical; we appreciate precise and exact predictions and want to see causal relations in the world because we do not want to see our world as ruled by accident. In all these cases, our convictions, which are clearly metaphysical in nature (i.e., they refer to the world), become the motives or reasons behind the acceptance of methodological values and rules.

At least one of these metaphysical assumptions, as I have tried to demonstrate, is indispensable: we *have* to refer to mind-independent entities when we want to compare or unify two different theories. There is no other *plausible* basis for the appearance in different theories of the same entities, such as, for example, electromagnetic waves in optics and in electromagnetic theory, the same entities in electrodynamics and in the theory of weak interactions, or the same spatiotemporal structure in different theories, than the actual existence of these entities, together with their properties, in the world. The anti-realist view cannot provide us with a plausible basis for, or an explanation of, the entities we should identify; it cannot give us any foundation for our claim that some entities, such as the above-mentioned space-time structure in different theories (for example, in Maxwell’s theory and in mechanics), not only *can* have the same properties, but that they *must* have them.

It should be emphasized that the argument formulated above is not simply a new version of the no-miracles argument.³¹ I do not claim simply that the success of science would be inexplicable if scientific theories were not at least an approximately true description of the world. I rather try to show, by analyzing *basic* and not interpretative metaphysics, that science in its deepest foundations refers to the real world and that this is a *necessary* condition for its development.

Of course, I do not claim that the above considerations can prove (in the sense in which we use this term in mathematics) the claims of the scientific realist. What I claim is that science tries to refer to the world (to both observable and unobservable entities that make it up) or, in other words,

³¹ See, e.g., Worral (1989, p. 101).

that science relies on metaphysical claims, and that scientific realism is a metaphysical position that describes and develops this scientific interest in the real world from a philosophical point of view. Although metaphysics aspires to say something about the world, we as humans are unable to look at this world from the point of view of God and say simply that this metaphysics is certainly true or false; we rather assume that metaphysical views consist of hypothetical claims that are justified by their fruitfulness and explanatory worth for science and for our knowledge in general, and—as I have tried to show—scientific realism best satisfies both of these criteria. The contrary view, although it can be vindicated as one of the possible interpretations of scientific theories, completely fails when we try to make use of it to understand the realistic attitude of science. In the anti-realist's claims, which are highly theoretical and by no means instrumental or intended to be any kind of auxiliary scaffolding, the authors are forced to treat the realistic attitude of scientists toward unobservable entities and structures as merely a kind of illusion. The true merit of anti-realism consists rather in the fact that it is a valuable source of criticism for scientific realism, making it possible to see some of the latter's weaknesses and enabling us to improve our understanding of the relations between scientific theories and the world.

4. Final Remarks

Science is developing through an ongoing dialogue with metaphysics. In this dialogue, metaphysics alternately changes its role from a cautious guide to a careful interpreter, while at all times remaining open to critical remarks from the other side. Its role consists in formulating general ideas—primarily about the world, with us as part of it, and secondarily about our knowledge of it. Science can then develop and verify these ideas. Both sides of this dialogue need each other because giving up this dialogical relation would lead to the ossification of our knowledge.

Both science and metaphysics are aimed at the real world, both work toward gaining knowledge about it. Unobservable entities, such as the elementary components and physical structures of the world, have not been—from ancient Greece until now—just an ordinary part of our research, they need to be the principal target of it. The mistakes that we make in both metaphysics and science should not discourage us from looking for the truth, but should rather encourage us to be more critical and more cautious.

References

- Agassi, J. (1964). The Nature of Scientific Problems and their Roots in Metaphysics. In M. Bunge, (Ed.), *The Critical Approach to Science and Philosophy* (pp. 189-211). New York: Free Press.
- Bourbaki, N. (1969). *Elements d'histoire des mathematiques*. Paris: Hermann.
- Barbour, J. B. (1974). Relative-Distance Machian Theories. *Nature*, 249, 328-329, erratum *Nature*, 250, 606.
- Belot, G., & Earman, J. (1999). From Metaphysics to Physics. In J. Butterfield, & C. Pagonis, (Eds.), *From Physics to Philosophy*. Cambridge: Cambridge University Press.
- Earman, J. (1989). *World Enough and Space-Time*. Cambridge, MA: MIT Press.
- Einstein, A. (1949). Autobiographical Notes. In P. A. Schilpp, (Ed.), *Albert Einstein, Philosopher Scientist*. New York: Harper & Brothers Publishers.
- Einstein, A. (1961). *Relativity. The special and General Theory*. New York: Crown Publishers.
- Gołosz, J. (2005). Structural Essentialism and Determinism. *Erkenntnis*, 63, 73-100.
- Hawley, K. (2006). Science as a Guide to Metaphysics? *Synthese*, 149, 451-470.
- Heath, T. (1981). *A History of Greek Mathematics*. New York: Dover.
- Jones, R. (1991). Realism about What. *Philosophy of Science*, 58, 185-202.
- Kuhn, T. (1996). *The Structure of Scientific Revolution*. Chicago: University of Chicago Press.
- Ladyman, J. (1998). What is Structural Realism. *Studies in History and Philosophy of Science*, 29, 409-424.
- Ladyman, J. (2009). Structural Realism. *The Stanford Encyclopedia of Philosophy (Summer 2009 Edition)*, E. N. Zalta, (Ed.), URL = <<http://plato.stanford.edu/archives/sum2009/entries/structural-realism/>>.
- Lakatos, I. (1970). Falsification and the Methodology of Scientific Research Programmes. In I. Lakatos, & A. Musgrave, (Eds.), *Criticism and the Growth of Knowledge* (pp. 91-195). Cambridge: Cambridge University Press.
- Lakatos, I. (1971). History of Science and its Rational Reconstruction. In R. C. Buck, & R. S. Cohen, (Eds.), *Boston Studies in the Philosophy of Science*, 8, 91-136.
- Laudan, L. (1981). A Confutation of Convergent Realism. *Philosophy of Science*, 48, 19-49.
- Popper, K. R. (1952). The Nature of Philosophical Problems and their Roots in Science. *British Journal for the Philosophy of Science*, 10, 124-156.

- Popper, K. R. (1959). *The Logic of Scientific Discovery*. London: Hutchinson.
- Popper, K.R. (1983). *Realism and the Aim of Science*. London: Hutchinson.
- Psillos, S.L. (1995). Is Structural Realism the Best of Both Worlds? *Dialectica*, 49, 15-46.
- Redhead, M. (1995). *From Physics to Metaphysics*. Cambridge: Cambridge University Press.
- Sklar, L. (1981). Time, Reality, and Relativity. In R. Healy, (Ed.), *Reduction, Time, and Reality*. Cambridge: Cambridge University Press. Reprinted in Sklar, 1985.
- Sklar, L. (1985). *Philosophy and Spacetime Physics*. Berkeley: University of California Press.
- Smolin, L. (2001). *Three Roads to Quantum Gravity*. New York: Basic Books.
- Stachel, J. (2006). Structure, Individuality and Quantum Gravity. In D. P. Rickles, S. R. D. French, & J. Saatsi, (Eds.), *Structural Foundations of Quantum Gravity* (pp. 53-82). Oxford University Press.
- Van Fraassen, B. (1980). *Scientific Image*. Oxford: Oxford University Press.
- Waerden, van der B. L.(1954). *Science Awakening*. Groningen: P. Noordhoff Ltd.
- Watkins, J. W. N. (1958). Confirmable and Influential Metaphysics. *Mind*, 67, 344-365.
- Watkins, J. W. N. (1975). Metaphysics and the Advancement of Science. *British Journal for the Philosophy of Science*, 26, 91-121.
- Worrall, J. (1989). Structural Realism: The Best of Both World? *Dialectica*, 43, 99-124.
- Zimmerman, D. W. (2004). Prologue: Metaphysics after the Twentieth Century. In D. W. Zimmerman, (Ed.), *Oxford Studies in Metaphysics*, Vol. 1, Oxford: Oxford University Press.