FOUNDATIONS OF PHYSICS: THE EMPIRICAL BLINDNESS

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INTRODUCTION

Physics has long been taken as the paradigm science. This was particularly the case under the logical empiricists. Physics was the only science that was worth discussing in epistemology. This is no more true and modern philosophy of science has to take all disciplines into account. Yet, it's true that biologists or sociologists don't wonder whether the objects they study are real. Their philosophy is a spontaneous realism which, in their mind, is not questionable. Physicists are the rare scientists wondering if scientific theories are about the world or about themselves. Physics remains the only empirical science that brings real new insights into philosophy and that is able to influence our philosophical conception of the world. Thus, the results of physics can't be ignored when discussing the status of reality or the validity of knowledge that science provides.

Among many others, these are questions that we can ask about physics:

1. Is physics describing the real world?
2. Is physics justifiable in any way?
3. Are the foundations of physics firm?

Of course these questions are linked. We'll try in the following to give some insight into possible answers.

1. REFUSING TWO OPPOSITE CONCEPTIONS

Traditional epistemology pits realism against idealism. It is generally assumed that refusing the existence of an independent reality which has a precise structure and definite properties leads necessarily to a position close to idealism. I will try in the following to show that the choice between realism and idealism is not compulsory. Both positions could be wrong or more precisely only partially true. Both stem from a philosophical framework that is perhaps too narrow. The main point is that the competition between realism and idealism is often materialized through some questions that are supposed to receive either a positive answer (and in this case, for example, realism wins) or a negative one (and in this case, idealism wins). This dualism generally comes from the fact that the negation of a proposition is thought to be obtained by asserting the main verb of the proposition in its negative form: “It is false that A has the property P” is understood as equivalent to “A has not the property P”, which is sometimes assumed to imply that “A has the property not-P”. However, modern physics shows that sometimes, this is not the case. If it is false that the spin along Oz of an electron is +1/2, that doesn't mean that this spin is –1/2, even if +1/2 and –1/2 are the only possibilities that could be obtained. When this sort of underdetermination arises for questions intended to decide between realism and idealism, neither the former nor the latter wins and the situation is more complex but also more interesting. I also want to focus attention on the necessity to avoid in this debate sentences like “something is real if one is compelled to somehow admit that it is different from nothing”[1]. The vagueness of this statement makes it both apparently true and in fact meaningless. But consequently, it can be used in many contexts, for example as an argument against idealism: “if thinking were not thinking of reality (understood as […] something which is different from nothing), it would be thinking of nothing and therefore no thinking at all”[2]. This type of argument clearly doesn't prove anything, but the dispute between realists and idealists often uses that sort of fuzzy (though apparently obvious) statement. Usually, the more these statements are obvious the more they are empty.

In the following I present arguments for and against realism and idealism and discuss them.

1.1. *Scientific Realism*

The scientific realist thinks that there exists an independent reality in which we are immerged and that this reality is literally and correctly described by scientific theories. Actually, scientific realism is made up of three assumptions. The first one is the thesis of metaphysical realism which claims that there exists an independent reality. The second one is the assumption that we can obtain some reliable knowledge of it. The third one states that scientific theories provide us with this knowledge.

Let's clarify some of these points. Metaphysical realism says that reality is independent because it would be essentially the same even if we were not existing, in particular it is a domain of mind-independent existence. Of course, it is perfectly possible to accept metaphysical realism and to deny the fact that independent reality is knowable. According to Kant, we can't have any knowledge of things as they are in themselves. But this is not what the scientific realist believes. For him, we can know something about independent reality and the most plausible way to get this knowledge is through natural science. Thus the scientific realism thesis goes well beyond metaphysical realism. According to it, scientific theories give an appropriate account of the features of what objectively exists in the independent reality. That means that the scientific realist is entitled to believe that the entities whose behaviour is described by science are real in much the same way as a chair or a bird are real and that they behave as the theory says they behave. Accepting a theory is therefore accepting the existence of its objects. Van Fraassen[3] says that according to scientific realism, science aims at providing us, through our theories, with a literally true story of what the world is. Thus, scientific theories are not to be thought of as metaphors but as expressing truths about the world. We must accept to the letter what they say. “To have good reason to accept a theory is to have good reason to believe that the entities it postulates are real” as Wilfrid Sellars[4] has expressed it. If a theory is about electrons and their behaviour then the theory says that electrons exist. As Rescher[5] puts it amusingly: “to accept a scientific theory about little green men on Mars is ipso facto to accept little green men on Mars”.

So, physics describes reality such as it is in itself. According to the most recent theories, the string theories[6], we live inside a ten-dimensional space-time. Six of these dimensions are curled up very tightly so we may never be aware of their existence. Moreover the various particle types are replaced by a single fundamental building block, a "string" which can be closed or open and can vibrate. Everything in the world is ultimately made with strings. If we take scientific realism seriously then we must believe that strings really exist in a ten-dimensional space-time exactly in the same way we think that chairs exist in our ordinary space. It is even worse than that because what physics actually shows is that the usual objects we are used to are not really existing. That's only the entities used in the theory that are existing. If we accept string theories then only strings exist. As Putnam[7] says realism reminds him of the seducer in the old-fashioned melodrama. "The seducer always promised various things to the innocent maiden which he failed to deliver when the time came". The maiden here is common sense which believes that chairs and ice cubes exist and which is frightened by idealism (and all the similar anti realist positions). So, common sense naturally goes with the realist. Then after a while, the realist reveals to the poor common sense that it is not the chairs and the ice cubes that exist but the objects that scientific theories use, no matter how far from usual experience they can be. Putnam conclusion is "Some will say that the lady has been had".

1.2. *Idealism*

For an idealist, the realist's claim that things exist independently of our thought is inconsistent since to say something, it's necessary to think about it. Thus simply by claiming that things are outside of our mind, these things are included in it. According to Berkeley "*esse est percepi*", only our perceptions are real. For him, the phenomena of sensations can all be explained without presupposing the reality of external material substances. Sensible objects exist only in the minds of those who perceive them. In its most extreme form, idealism leads to solipsism. The solipsist claims that only his thoughts exist. This position is not refutable but has the disadvantage to close the discussion. It was not Berkeley's position. For him, what is real exists in many minds, so it can continue to exist whether I perceive it or not because somebody else can see it.

But the problem is to account for the fact that the objects that I perceive now continue existing even when neither myself nor nobody else perceives them. For Berkeley, God plays that role. The mind of God serves as a permanent repository of the sensible objects that we perceive at some times and not at others. For Hegel and the German idealists this role was played by the Spirit, self-knowing, self-actualizing totality of all that is, obtained through dialectical reasoning as the synthesis of the thesis Idea and its antithesis Nature.

2. ARGUMENTS FOR REALISM

2.1. *Metaphysical realism*

Metaphysical realism seems a natural position directly based on the spontaneous knowledge of the world we acquire since early childhood. Believing in an external world in which we live and that doesn't depend on what we think or know is a natural attitude directly drawn from our everyday life. As Hume noticed, in general the reason why we think that something exists is based on the “cause effect relation”. If I hear a voice in the room next door, I think that there is somebody speaking. If I see a shape looking like a plateau with four legs, I think that there is a table in front of me. We assume that something exists that causes the effect we see and indeed, our experience shows that in many cases, this reasoning is correct (we'll see below how Hume refutes the validity of this argument). Another argument for metaphysical realism is the fact that people agree on what they see. Two persons watching a garden will agree saying that there are two trees, a clump of flowers and a dog on the grass. In general, people's observational reports are in agreement and why should it be so if the observations were not about something which really exists independently of the persons who observe? We'll call this argument the *inter subjective agreement*. Another reason for believing that something that doesn't depend on our theories or on our thoughts exists is the fact that we can't do what we want. Of course, it is clear that we can't fly but more than that, our scientific theories sometimes fail and are refuted by experiment. If there exists a reality that has a proper structure, we can't say anything and everything about it. There are propositions which will turn out to be false as they state what it is not[8]. D'Espagnat[9] says that “there is something that says no”. The fact that there are propositions in the scientific theories which turn out to be refuted through an adequate experimental device is an important clue that these propositions speak of reality. Thus, the three main reasons for metaphysical realism are the cause effect relation, the inter subjective agreement and the resistance of reality (something that says no).

The most elementary version of metaphysical realism is the layman’s spontaneous philosophy: independent reality is made up of objects such as chairs or cubes of ice (and perhaps also of waves and of forces for the most advanced ones). In this conception that d'Espagnat[10] calls “multitudinism”, the world is nothing more than a collection of entities with well defined properties, that exist independently of us and interact in a well defined way. Of course, much more sophisticated versions of metaphysical realism are possible. For example, Kant's transcendental idealism is compatible with a sophisticated metaphysical realism which asserts that we can't have any direct access to things as they are in themselves (noumena) and that the only access is through our experience (phenomena).

2.2. *Epistemic realism*

The very same reasons that make us believe that there exists an independent reality also lead us to think that we can know something about it. After all, we have learnt since the beginning of our life to use the objects around us, we know what is going to happen if we let a ball fall down, we wait for the daylight after the night and we drink water when we are thirsty. Thus, we know something, we even know many things. Common sense tells us that what we know is about reality. So reality is knowable. There is no reason to think that we can't know anything about reality since we do know a lot of things about it. Now, common sense and everyday life also tell us that many phenomena that we see are easy neither to understand nor to forecast. When will the next eclipse come? Why is the sky blue? How can we cure flu? These questions are not easily answered and that is where science becomes necessary. So science, being nothing else than the continuation of common sense by other ways as Bertrand Russell says, inherits the quality of common sense to speak about reality.

2.3. *Scientific realism*

It is then natural to adopt the position according to which the best way to get knowledge about reality is to ask science for it. It is difficult to deny that almost all scientists adopt a spontaneous realism. According to most of them (and this is all the more true as we move away from theoretical physics to biology and human sciences), their work aims at describing reality (or at least some part of it) and they believe that science can succeed in this objective. The most usual argument to defend scientific realism starts with the acknowledgement that scientific theories succeed in giving a correct description of the observed phenomena and in making it possible to forecast them at least within good approximation, what Boyd[11] calls the instrumental reliability of scientific theories. This success would be very surprising if science was not describing what reality is in itself. This is the "*no miracles*" argument of Putnam and the "*abductive argument*" of Boyd. This argument states that it is only by accepting the reality of approximate theoretical knowledge that we can adequately explain the uncontested instrumental reliability of scientific methods. The fact that there is an independent reality and that it is described by scientific theories is the best explanation of the fact that science is working. Put differently, this means that the explanation for the empirical success of a theory is simply that this theory is true. And if the theory is true then the entities that it deals with are real, exist and behave as the theory says they behave. An important consequence of this position is that we are entitled to believe also in the non-observable entities of the theory. For example, even if quantum chromodynamics tells us that it will never be possible to observe a free quark directly because of confinement[12], quarks are really existing in much the same way as atoms are.

3. CRITICISM OF THE ARGUMENTS FOR REALISM

3.1. *Metaphysical realism*

3.1.1.*Cause effect relation*

If I hear a voice in the room next door, I think that there is somebody speaking. If I see a shape looking like a plateau with four legs, I think that there is a table in front of me. The first sentence means that we infer from one perception (the voice in the room next door) another possible perception through a counter factual reasoning: if I went in the room next door, I would see somebody. The second one concerns the inference of the existence of something from a perception. These two inferences are not of the same type. Criticisms against both have been raised a long time ago. The first inference only concerns perceptions, it links two perceptions between them. Each time I hear a voice in the room next door, if I go into the room I'll see somebody. Hume criticises this inference which rests on the principle of induction that states that if such a link has been observed in the past it will remain valid in the future. Now induction principle is impossible to rationally justify. Thus nothing guarantees that two events that were linked in the past will remain linked in the future. So, from a purely rational point of view, we are not entitled to think that we'll find somebody when we hear a voice in the room next door. Induction is not a valid inference. We know that the solution given by Kant to this problem is to consider that induction must be understood as a synthetic a priori condition for empirical discourse. The second inference concerns the reality itself. It consists in assuming the existence of real entities as an explanation for our perceptions. Thus only this second formulation concerns directly metaphysical realism. Hume criticized it noticing that we have access to our perceptions only and not to reality. That things exist outside is thus not a conclusion that we should draw. According to him, it is only as a convenient way to organize our perceptions that we are led to assume that external objects exist. It is true that from a logical point of view we have no valid reason to fill the conceptual gap between the existence of our perceptions and the existence of an external world. After all, the objects that I perceive when I am dreaming are not external to my mind. Moreover, quantum mechanics gives good reasons to be prudent about conclusions such as "this thing exists". Thus, I will not consider cause-effect relation as a strong argument for metaphysical realism.

3.1.2. *Inter subjective agreement*

Inter subjectivity is an argument for the existence of things external to our mind based on the remark that pure idealism which states that there is nothing outside, has difficulty to explain why we agree about our perceptions. If Paul and Peter both agree on the fact that there are two glasses and a bottle of wine on the table, the simplest explanation is that there are really two glasses and a bottle of wine on the table. In some sense, this argument is an answer to the objection I raised above to the cause-effect argument: if I perceive a table, that could be an illusion (as in a dream). The table could exist only for me. On the other hand, if both Paul and Peter see the table, it becomes hard to say that they share the same illusion or, even if this is possible sometimes, it seems difficult to claim that all common perceptions are illusions. So, inter-subjectivity seems to be more a solid argument for metaphysical realism than cause-effect relation. And yet, quantum mechanics undermines this conclusion. This is not because Paul and Peter agree on the fact that the spin along Oz of one electron is +1/2 that this spin was equal to +1/2 before the measure. The intuitive explanation saying that if they both see that the result of the spin measurement is +1/2, this is because the spin was +1/2 before the measurement, is wrong and leads to false consequences. Quantum mechanics teaches us that the value of the spin was indefinite before the measurement and that it has become determined during the measurement process. In some sense, it is Paul and Peter's perception that is (partly) the cause of determination of this value. Quantum mechanics says that the very fact of measuring is, at least partly, the cause of what we perceive. This is particularly clear in the interpretation of the measurement process given through the decoherence theory[13]. Now, even if we contest the conclusion that if Paul and Peter have the same perception of a table this is an argument for the existence of this table, we have admitted till now that their perceptions were actually identical. But this is not mandatory and within the position that I have called "convivial solipsism"[14], I propose an interpretation of the measurement process where inter-subjectivity is apparently respected though perceptions are different. So, inter-subjectivity seems at the end not to be as strong an argument as it could appear intuitively.

3.1.3. *Resistance of reality*

If reality was only a human construction there would be no reason why our best theories be refuted by experiment. But the history of science attests that there has been an uninterrupted series of refutations. A lot of beautiful and powerful theories have been defeated by experimental results that were not in agreement with their predictions. So, as d'Espagnat puts it, “there is something that says no”. And according to him, this “something” can't be “us”. This argument implicitly assumes that a human construction will be its own yardstick and will be exempt of contradiction. But why should it be so? If we suppose that everything comes from us, that we invent the rules of the game, what we identify with reality is a human construction. Of course, it is very difficult to explicitly describe the nature of this construction and the way we use to build it. It is totally different from the formal way we build scientific theories. We start building it in our early childhood. Let's call it a perceptual construction. Scientific theories are then explicit, conscious and formal constructions intended to account for an unconscious perceptual construction. We know how difficult it is to show that a formal system is consistent as soon as it is complex enough. Gödel’s theorem proves that we can't demonstrate the consistency of a formal system by purely internal means (as soon as the system is powerful enough to contain arithmetic). So, building a consistent complex system is not an easy task, the more complex the more difficult. By extension[15] it is not so surprising that from time to time we discover some contradictions which manifest themselves through empirical discrepancies between our formal scientific constructions and the informal construction that we call reality. That means that we have some difficulties to build two different constructions (one formal giving scientific theories and one perceptual giving what we call reality) in such a way that these two constructions be simultaneously consistent. D'Espagnat[16] answers that, if everything is nothing but a construction coming from us, he doesn't understand why we generally choose to preserve the construction that represents reality against the theoretical construction. He says that we could as well choose to believe in a refuted theory and abandon our belief in reality. The reason why we don't do that is because the two constructions are not on an equal footing. Reality is much more epistemically entrenched than science, and confronted with the necessity of revising our beliefs we always choose to change those that are the less entrenched[17]. Science is by definition an empirical process and that means that confronted with a contradiction between data and theory we must give the priority to data.

3.2. *Scientific realism*

3.2.1. *Abductive argument of empirical success: no miracles*

As we have seen the abductive argument for scientific realism is often considered as the main argument for it. The empirical successes we get in applying our theories betoken their truth. This argument is also indirectly an argument for metaphysical realism since scientific realism rests on metaphysical realism and that assuming the truth of a theory without assuming a reality to refer to would be meaningless. Oversimplified this argument is nothing else than the old explanation that we see the grass green because grass is really green. It is well known since Locke's distinction between primary and secondary qualities that this is an explanation which raises many problems. Moreover, there has been an uninterrupted series of refutations of momentarily adequate theories during the history of science. That shows that it is difficult to believe that our current theories, even the best ones, are true because using a pessimistic inductive argument, we are led to think that they will be refuted in the future. The only possibility to save this argument is then to adopt (with Boyd[18] for instance) the concept of a gradual convergence of scientific progress. We'll show below that this is not acceptable. Another criticism can be given along the following line. Given a finite set of data (resulting from observations) it is in principle possible to build many theories accounting for them (as there is an infinity of curves going through a finite set of points). This is Quine's thesis of underdetermination of theory by evidence. So, there is no reason to be surprised that we can build adequate theories at a given time. The defenders of the argument admit this point and retort that it is not the description of known facts but the prediction of novel facts that would be miraculous if the theory were not reflecting something real. The most often quoted example is the discovery of Neptune through pure computation within Newton's mechanics. But, let's be cautious not to fall into the illusion of what can be called the horoscope effect which is the fact to remember only the successes and to forget the failures. The discovery of Neptune is of course a very remarkable prediction but the inexistence of Vulcan whose mass and position had been calculated to explain the correct value of the precession of the perihelion of Mercury is a memorable failure too! As Popper says, science is going on through conjectures and refutations. At each period of time, the stock of empirical data is finite. So it is in principle possible to account for it through many theories. Sometimes, scientists provide competing theories that need to be tested to know which is the best one. Some of these theories predict novel facts (a new planet or a new particle or a new physical effect). The best corroborated theory is kept but we must have in mind that other competitors, predicting other novel facts, have been refuted. To give a recent example, several theories were in competition with the Glashow-Weinberg-Salam model (now called "the standard model") to unify weak and electromagnetic interactions before the discovery in 1983 of the W and Z bosons predicted by the theory. Should these bosons have been inexistent, another theory would have survived. A posteriori, it seems a miracle that the winner predicted this novel fact but is it really surprising? When many theories compete, it is not strange that sometimes one of them be momentarily correct.

Besides that, one can wonder if it is really necessary for a theory to be true to provide good results. After all, nature could be error-tolerant and if the error has an impact that is below the threshold of the accuracy of today observations, then the theory will be confirmed. As Rescher[19] says:

> the success of the applications of our current science does not betoken its unqualified truth or ultimate adequacy. All it indicates is that those various ways (whatever they may be) in which it doubtless fails to be true are not damaging the achievement of these good results – that, in the context of those particular applications that are presently at issue, its error lie beneath the penalty level of actual failure.

So the empirical success argument doesn't seem really convincing. It is not necessary to assume any correspondence between a theory and reality to understand its empirical success. We'll see another reason not to accept this argument when we speak of scientific theories as compression algorithms.

3.2.2. *Non convergence of scientific theories*

In this view, scientific theories are becoming closer and closer to the truth and converge gradually towards an ultimate (perhaps forever out of reach) true theory. Though this conception may seem appealing it comes up against many difficulties. The first one is that we know since Popper's unsuccessful definition of verisimilitude that we have no satisfactory definition of approximate truth for a theory. What does it mean that a theory (which is known to be false) is closer to the truth that another one? In which respect is Newton's mechanics (which has been proved false after the discovery of special relativity) closer to the truth than thePtolemaic theory? There is one meaning of approximation which is unproblematic. This meaning is related to the numerical predictions made by the theory. If these numerical predictions are in general more accurate within one theory than within the other, we are entitled to say that the first one is numerically closer to the truth than the second one. And this is exactly what happened during the history of science. A theory empirically adequate at one time was replaced by a new one because its predictions were either in disagreement with experiment (that appeared through a numerical discrepancy) or less accurate than those given by the new one. Let's give as an example the successive replacement of the Ptolemaic system by Copernicus' circular trajectories then by Kepler's laws then by Newton's mechanics. At each step the predictions have been improved, which was necessary due to the improvement of observational means and of the accuracy of measures. Though empirically adequate at the time of the Greeks, Ptolemaic system is refuted by modern results of observation. Today we know that Newtonian mechanics (empirically adequate long after Newton's time) is refuted too. Its predictions are less and less good as speeds closer and closer to the speed of light are considered, and special relativity is the currently best theory in this case. Newton's theory is also refuted by the precession of the perihelion of Mercury which is only accurately predicted by general relativity. As computed inside Newton's theory, there is a discrepancy of 43 seconds of arc less per century. So, it is meaningful to say that as far as numerical predictions are concerned, Einstein's relativity is closer to the truth than Newton's mechanics which was closer to the truth than Kepler's laws which in turn were closer to the truth than the Ptolemaic system.

But this is not what realists have in mind when they say that a theory is closer to the truth than another one. They go further, meaning that what the better theory says about reality (the objects that the theory describes, the laws it uses, the structure of reality which is implicit in its mathematical structure) is reflecting more truly what is real. This is where we can't follow them. Literally speaking, the Ptolemaic system and Newton's theory are false. From the point of view of Einstein's relativity, there are no epicycles, there is no absolute time and there is no gravitational force acting at a distance. So, what could it mean that Newton's theory is closer to the truth than Ptolemaic system apart from the accuracy of numerical predictions? If the assumed truth is the description given by general relativity (which is the best theory for gravitation we have today and so, in this view, is supposed to be the closest description of the truth we ever had), is the image given by a flat space with an absolute time and a gravitational force closer to the truth than the image of epicycles? It is highly dubious. Actually, if we analyse the realist’s reasoning, it is very loose. It uses one fact and one hypothesis. The fact is that there is no doubt that the empirical adequacy of scientific theories is increasing as far as the accuracy of the predictions is concerned. The hypothesis is that an empirically adequate theory must be close to the truth (unless it is a miracle that it can give correct predictions). Truth means here that the structure of the theory closely reflects in every aspect the structure of reality and that the entities of the theory refer to real objects. Then from the fact that theories become closer and closer to numerical truth they infer that theories become closer and closer to the truth (truth taken in the above sense). This is clearly a wrong inference since it demands another assumption to be valid: the assumption according to which, having defined the concept of distance to the truth of a theory (let's call it f, so f(T) is the distance to the truth of the theory T), this function has the following property: if T' is numerically better that T then $f(T')<f(T)$. There are clearly two problems. The first one is that we don't know how to define this function f, the second one is that, even if this growth property of f seems intuitive, it is not obvious that it is not possible to define a distance to the truth violating it[20]. To summarize the argument: the empirical successes of a theory is supposed to betoken its truth. Faced with the objection that it can't be the case since many successful theories have been refuted and so were false, realists answer that these theories were not totally true but close to the truth. Thus, the argument has moved from “a successful theory is true” to “a

successful theory must be close to the truth”. But for lack of the definition for approximate truth, the only possibility for realists is to notice that theories are becoming more and more accurate and, under the implicit assumption that the more accurate the closer to the truth, to infer that theories are converging towards the ultimate true theory. This is not convincing since they are unable to define what they mean by close to the truth if this is not in the numerical sense.

There is also another reason why this argument is problematic. It is based on the hypothesis that there is an ideal (though perhaps out of reach) theory which is true. This theory is totally in agreement with reality which is supposed to be correctly described in all respects by it. But because of Quine's underdetermination of theory by evidence there is not a unique ultimate theory but presumably many that are empirically adequate whatever the stock of empirical data be. These theories could be incompatible or even contradictory in many ways. The famous example given by Putnam[21] is the one of two theories T and T' which are empirically equivalent but such as T entails that “there really are such things as spatial points” and T' entails that “there are arbitrarily small finite regions but not points”. In this case, which one is representing the truth? How is it possible for two contradictory theories to be true? Are there many truths? One hits a paradox that seems not easy to escape. Putnam’s internal realism enables us to say that both theories are true. But this is clearly because Putnam declines to assert a theory of truth and in particular denies that truth is captured by correct assertability[22]. For a traditional scientific realist this is clearly a problem.

3.3. *What is left in defence of realism?*

It is true that common sense exerts a very strong influence on the feeling that we live in an independent reality that frequently resists against what we want to do or that refutes what we could think a priori about things around us. It is also true that it appears that we do know something about reality, first through our everyday experience, second (in a more precise and efficient way) through our scientific theories. The proof is everywhere around us. We have invented planes which allow us to fly, rockets to go to the moon, satellites that allow us to communicate everywhere on the earth and even to find our location everywhere with a precision better that one meter, we are able to extract energy from atoms, etc. This list could be made much longer but this would not add anything to the argument. The force of what we see, what we hear, what we feel, what we experiment is extremely strong and leads us to become unable to envisage the possibility that there is no independent reality. Our feeling about its existence is shaped day by day since our childhood and is strengthened as we get older through the knowledge that we get from science. The process is the same for the child and the scientist. The abductive argument plays its role, and it is a very pervasive role! But, remember: we have this very strong feeling that we are at rest and yet the Earth is moving around the Sun at a speed of 28km/s; we think that a particle must have a definite position and quantum mechanics teaches us that this is not always the case; we feel that time goes everywhere the same way, but relativity theory shows that it is false; we believe that energy is a property of objects, and yet relativity theory shows that it is possible to transform energy into particles. All these strong feelings are extremely entrenched in our mind. Abandoning them is a very difficult task that many people refuse to accomplish (physicists excepted). Though these feelings mislead us. Can we think that our feeling that there is an independent reality is similarly a misleading feeling? We have given above good reasons for that and will propose in the following a conception that doesn't need this hypothesis.

4. ARGUMENTS FOR AND AGAINST IDEALISM

I will be much shorter as far as idealism is concerned. Berkeley's idealism was perfect for somebody wanting to defend religion and God against the dangers of science, materialism and atheism. His claim is that sensible objects cannot exist without being perceived. It is true that resorting to God for allowing things to exist even when no human being is perceiving them is both a means to answer the main criticism against idealism – it is very difficult to accept that this tree that I am the only one to see in the deep forest vanishes every time I close my eyes to reappear when I open them again – and a good argument in favour of the existence of God. The intellectual contortions of the German idealists to avoid to resort to God are not very satisfactory. The conception I will present below, although not realist, avoids these problems because it doesn't assume that everything comes from our mind.

I will now present some ingredient of my conception.

5. SCIENTIFIC THEORIES AS COMPRESSION ALGORITHMS

5.1. *The algorithmic theory of information*

The algorithmic theory of information has been simultaneously invented by Kolmogorov, Solomonoff and Chaitin. The algorithmic complexity of a string of bits is the smallest self-delimiting program to produce it. This measure is essentially concerned with the redundancy inside the string. If there is no redundancy, no regularity then the only way to produce the string is to give explicitly the string to the computer. We agree that the string "01010101010101010101" is simple because it can be described as a regular succession of "01". The string "01001100001100000111100101 01" seems on the contrary more complex because it is difficult to discern any pattern inside. A regular, ordered string will be made up of 0 and 1 that follow a simple rule. A string of one thousand "01" is easy to produce through a small program. This program is simply "write one thousand times "01" and stop". The important fact to notice is that in this case, it is possible to produce the string through a program that is significantly shorter than the string it produces. Typically the size of the program is roughly the logarithm of the size of the string. On the other hand, a string as "0100110000110000011110010101" will not be computed through a program using a simple rule, just because there is no simple rule to do the job. The shortest program to produce it will then be "write "0100110000110000011110010101" and stop". And the size of this program is roughly the same as the size of the string. The main lesson to remember is that when a string is ordered, when the succession of 0 and 1 follows a simple law, then it is possible to compute it through a short program, a program that is significantly smaller than the size of the string. On the other hand, when the string doesn't contain any regularity, when the succession is random then the only way to compute it is to give it explicitly to the program because no rule can compute it. Then the size of the program is the same as the size of the string[23].

5.2. *Scientific theories as algorithms*

Let's now view scientific theories as formal systems. Given one theory, the set of experimental data belonging to its domain is a set of statements inside the language of the theory. Now the theory will be empirically adequate if it can produce these statements, i.e. if these statements are provable inside the theory[24]. So the theory, if adequate, is a way to compute the empirical results. Thus, it becomes natural to see the theory as an algorithm to produce the set of empirical results. Let's take as an example, the series of experimental results from successive releases of a pebble in the vacuum starting from a height of one meter to a height of one hundred meters through one meter increments. The speed of the pebble when it lands is a one hundred numbers series. This series can be produced from a very simple algorithm given in Newtonian gravitation theory: the formula $v=(2gh)^{1/2}$. This simple example can be generalised to all predictions done by physical theories, even the most complex ones. Of course, all physical phenomena don't reduce to a series of numbers. Finding the good algorithm often needs to find good tools or new concepts to describe the phenomena that are studied. This is why, building a physical theory doesn't reduce to finding mathematical formulas. But, this doesn't change anything to the fact that, once the theory is built, it is an algorithm making it possible to generate the statements reporting experimental results. An empirically adequate theory must of course be able to produce all the experimental data coming from past experiments but it attempts also to predict the potentially infinite set of results of every future experiment. In this sense, the theory is really a way to compress the infinite number of data coming from all potential experiments that could be done inside a physical domain. As Chaitin[25] says:

> I think of a scientific theory as a binary computer program for calculating the observations which are also written in binary. And you have a law of nature if there is compression, if the experimental data is compressed into a computer program that has a smaller number of bits than are in the data it explains. The greater the degree of compression, the better the law, the more you understand the data. But if the experimental data cannot be compressed, if the smallest program for calculating it is just as large as it is […] then the data is lawless, unstructured, patternless, not amenable to scientific study, incomprehensible.

From this point of view, comprehension is compression. It is then possible to say that the domain of science is the set of all phenomena that are compressible. That's not the case for art for example. It is not possible to find an algorithm deciding if such a painting is better than another one from the aesthetic point of view. It is not possible to build an algorithm to produce grandiose symphonies. So there is no more reason to be surprised with Einstein that the world (the physical one) be understandable or to find extraordinary with Wigner that mathematics be so efficient. The reason why is that we apply science only where it is possible, that means in the domain of compressible phenomena. The only surprising thing is then that there are such phenomena!

5.3. *Induction revisited*

Hume's devastating criticism against induction shows indubitably that induction is not a valid reasoning. However, and contrary to Popper's claim, it is commonly used in scientific reasoning. In the light of scientific theories seen as compression algorithms the reason why it is so becomes clearer. Scientific process starts by building theories that explain (reproduce) past empirical results and then, use them to predict new results. If we think that scientific theories aim at compressing data, the best theories will make the best usage of the regularities that data contains. As we have seen, algorithmic complexity addresses the regularity that a string of 0 and 1 (or more generally a series of results) contains. If there is any regularity, the minimal program (program of the shortest length that computes the data) must certainly exploit it. For example, assume that the data you have gotten from your past experiments is a string of one million 1, representing the results of one million experiments. The minimal program to produce this string is certainly “write 1 one million times”. from our point of view of scientific theories as compression algorithms, this is not exactly what we would like to call a theory. The corresponding theory would be an algorithm giving you an answer when asked a question. In this (too) simple case, the question is “what is the result I'll get if I do an experiment” and the answer is “1” which is confirmed in every past experiment. Now, if we want to use this program for predicting new data, the simplest way to do it is to reproduce the same answer. The best theory under this point of view will be “all experiments give a result 1". Faced with a series of observations sharing common features (every morning the sun rises), given the fact that the smallest program that predicts this data is exploiting this regularity, the best theory will be the one that continues predicting the same features under the same conditions. So, the usual reason why we use induction, that is the belief that things that happened in the past will repeat identically in the future is replaced by the precept that, having built an algorithm which reproduces past experiments through the shortest way, we want to use it to build the simplest and shortest algorithm to predict the future. It happens simply that induction, i.e. reproducing past regularities, seems the right way to do that. Thus, that means no more that we must have confidence in the fact that future is similar to past, that means that following this particular rule for building scientific theories, we must believe that 1) minimal programs are the best theories and 2) using regularities is the best procedure to build minimal programs. So the induction justification shifts from a metaphysical problem to a pragmatic one.

6. THE EMPIRICAL BLINDNESS

6.1. *Empirical pertinence*

As is well known, the positivist demarcation between observational and theoretical statements has been questioned first by Hanson[26] then by Kuhn[27] and Feyerabend[28]. Observations and experiences have to be interpreted to be meaningful and that involves an inescapable theoretical dimension. That is what is called theory-ladenness. One consequence is that despite its harmless appearance, the fact to accept a theory as empirically adequate is less neutral than one could think. Accepting to recognize that a theory T has been, up to now, empirically adequate is already showing a certain commitment to T. As van Fraassen says[29], it is in particular accepting to use the conceptual framework of T to guide the look for new experiments and to interpret the observations. It is also accepting the fact that the set of observations made to test T, which have been guided by the research program induced by T, is relevant and significant compared to all the observations that could have been made to test T. T will be considered as empirically pertinent if the research program induced by T is relevant to guide the experiments made to test T. For example, a theory that would predict that every time there are clouds in the sky, a new moon will come within less than 28 days would be empirically adequate but not empirically pertinent. Accepting a theory as empirically adequate requires a preliminary commitment which is justified only if first, the structure of T is not too far from the dominant paradigm on good theories and second, T has some successes in its favour such as an explanation of a fact not understood in previous theories or the prediction of a novel fact[30]. There exists then a mutual support: the empirical successes got in the framework defined by the theory increase our confidence in the pertinence of the theory which in return confirms us in the fact that these successes are good evidence for the empirical pertinence of the theory. This is similar to the process described by Boyd[31]: “there is a dialectical relationship between current theory and the methodology for its improvement”. But unlike Boyd who interprets this as a possibility for a cumulative development of science, I think on the contrary, that it is a flaw weakening the status of empirical pertinence. Why? Because this process, once engaged in a false direction can maintain wrongly its own success.

6.2. *Empirical blindness: first aspect*

This mistaken process can happen through many different ways. The first one consists in providing predictions fuzzy enough for being confirmed whatever the experiments or in remembering only the observations that confirms the predictions. The best example of this kind of practice is astrology. Predicting to somebody who is a Libra that something concerning his family is going to happen during the week is not a very risky prediction since at any time almost everybody can refer to a familial event happened recently. Moreover, when asked about the quality of predictions made to him, a staunch supporter of astrology will remember only the successes and forget the failures. A second one consists in using ad hoc modifications to escape falsification. The famous example given by Popper is Marxism because its advocates preserved the theory from falsification by modifying it and because the only rationale for the modifications which were made to the original theory was to ensure that it evaded falsification. These two ways to ensure the success of a theory pose the problem to know how distinguishing a good scientific methodology. No definitive precise demarcation criterion is accepted yet. We have acquired a good intuition of what science is but this intuition is difficult to formalize. Nevertheless, we can think that this intuition is good enough to prevent us from falling into the traps just described. Yet, there is a more subtle possibility to maintain a wrong empirical success. This will be the case if the dominant theory provides a conceptual framework such that no experiment that could falsify it be launched. Here, Lubbock's famous quotation “what we see depends mostly on what we look for” is particularly appropriate. Let's use a voluntarily exaggerated example to show what we mean. Imagine as Putnam that there is a Twin Earth where the laws of nature are different. Let's call it Earth 2. On Earth 2, there is an absolute space and a universal time. There is no need neither for special nor for general relativity. The Newtonian mechanics (its local equivalent invented by Newton 2) is the dominant theory T and it works perfectly well. Roughly, Earth 2 is at the same scientific level than we were at Laplace's time. The main difference is that under the hypothesis we have adopted, no experiment (such as a discrepancy in the precession of the perihelion of Mercury) can falsify T predictions for macroscopic bodies. Assume moreover that the paradigmatical impact of T is such that all researches are focused on the behaviour of macroscopic bodies and that scientists are blind to other phenomena. On Earth 2, T works perfectly well to describe the behaviour of macroscopic bodies within the accuracy of the most precise experiments. The nature of light is not considered as a scientific problem and neither electricity nor magnetism have been discovered. In this case, T is empirically adequate since it is used only in a restricted domain where it works and only experiments about this domain are considered scientific. For Earth 2 realist physicists, T is true and reality is made up of objects like stones or planets following T laws. In this case, the empirical adequation of T comes from a bad empirical pertinence. The program of research induced by T has led physicists to be blind preventing them from launching experiments needed to refute T as for example making light waves interfere or study black body radiation. Of course, it is easy to raise objections against this too simple example. One could say that in a world where there is no need for relativity, the laws of Nature could well be as Earth 2 physicists think they are. I ask the reader to accept as a hypothesis the fact that it is possible that on Earth 2 everything is as it is on our Earth except for relativistic behaviours. The second, more serious, objection could be to criticize me on the basis that I have assumed what I wanted to prove in postulating that Earth 2 physicists don't care about the nature of light and that neither electricity nor magnetism have been discovered. My answer is that my example is certainly too simple but that I use it to show that the program induced by a theory can lead to forget about certain not obvious phenomena. Sometimes, having the idea to test something requires a long and difficult preliminary theoretical work. The Aspect's experiments that showed that locality is violated have been possible only after Bell's discovery of his inequalities. The non-separable property of space that follows comes from a very sophisticated experimental device built on a complex theoretical proof. This is not something that is just in front of our eyes. One proof is that neither Einstein nor Bohr during their hard discussions about EPR paradox have been able to imagine a real experiment to decide between their positions. So it is not absurd to think that for some theories, such complex phenomena, that could refute the theory if they were seen, stay hidden inside the framework of the theory. In this case, the theory, though false, will never be falsified. Something similar happened (admittedly during a short period of time) with mechanics when physicists at the beginning of the twentieth century were exclusively focused on integrable systems whereas we know now that non-integrable systems are the vast majority. Empirical blindness is then the fact to be blinded by a research program coming from a limited dominant theory that hinders from doing the experiments that could refute it. As this theory is not empirically pertinent, some phenomena remain then ignored and even can be left outside of scientific preoccupation.

6.3. *Empirical blindness: an inevitable disease*

There is another aspect of empirical blindness which is linked to indecidability. As is well known since Gödel, any complex enough formal system contains propositions that cannot be proved nor refuted inside it. These propositions are called indecidable. The consequence is that if some phenomena are expressed through such indecidable forms inside a theory, the theory will have nothing to say about them. Let's give an example. ZF is the Zermelo Fraenkel set theory. The totality of mathematics used in physics is inside ZF. Let's call T, a physical theory built by adding to ZF what is needed to get a good physical theory as for instance the M-theory we mentioned previously. Let's call ZFE, the theory ZF to which we add some large cardinals hypotheses[32]. The consistency of ZFE can't be proved inside itself and even less inside ZF and for some large cardinals hypotheses nobody has a reliable feeling about the fact that it is consistent or not. Now, it is perfectly possible to build a real Turing machine enumerating one by one all theorems of ZFE and stopping when it proves "1=2". Then, T will be dumb about the question whether the Turing machine will stop or not. This can seem strange but such a machine is a real physical system and no physical theory can predict its behaviour. This impossibility doesn't come from lack of knowledge of some laws or from quantum effects and would remain even in a classical world governed by pure mechanical laws. This is an example of a simple physical system whose behaviour is forever not predictable. The algorithmic power of scientific theories can't include the totality of empirical phenomena. This is another aspect of empirical blindness. Every theory will stay blind to some parts of the empirical reality and its formalism will stay dumb on the behaviour of these parts.

7. A THREE LEVELS STANCE

7.1. *The Realism of Phenomena*

Many positions (realist or not) assume that phenomena are explicitly given to us as if empirical reality was a big bag which we can get phenomena from or a stage where phenomena happen and can be looked at. This is what I call the realism of phenomena. It is, relative to phenomena, a position comparable to naïve realism which says that objects are really existing, are under our eyes and that it is the reason why we see them. This is a natural position for anybody accepting metaphysical realism. Oddly enough, it is sometimes admitted also by idealist thinkers who reject metaphysical realism. They refuse to accept the existence of objects in themselves but admit that we have a direct access to phenomena identified with our perceptions. For these thinkers, we content ourselves with watching passively what happens. This doesn't imply that we make no effort to observe phenomena but that these efforts are more like bending down to pick up a pebble than like creating something that would not exist otherwise.

Usually, two levels are considered. The first one is the level of phenomena (identified with our perceptions) and is called empirical reality. The second one, rejected by non-realists, is reality in itself. If realists admit that reality in itself exists beyond empirical reality, many non-realists admit that empirical reality exists in a sense that is very close. I don't agree with this position and I feel the need to introduce a distinction between what I'll call empirical reality (with a new meaning that I am going to precise) and the level of our perceptions that I call phenomenal reality. I will defend the following stance: our perceptions, interpreted, form the basis which we rely on. These perceptions are not to be considered as simple awareness of some pre-existing empirical reality. According to the realist image, phenomena exist outside, and we become aware of them through our perceptions. What I say is that no phenomenon exists outside and that we are responsible for our perceptions. In some way, we create phenomenal reality. But we are not free to create it as we want because many constraints are there. These constraints are what I call empirical reality. Empirical reality is what makes our perceptions possible while imposing constraints on them. That means that it is the framework for all the (physical and mental) acts that we use during the cognitive process. It is the set of all potentialities which, during their actualisation, give birth to our perceptions. Let's give an analogy from quantum mechanics. Perception and potentiality are in the same relationship as the result of a measurement (for example the value of the position of a particle) and the physical property that is measured (the position). It is through the measurement process that a value for position is determined (and that we become aware of it), but the position is not determined before and as such doesn't pre-exists as phenomenon but only as potentiality. Thus, a phenomenon is not something that pre-exists and that we observe passively, it is something that emerges from an act in which we play an essential role. Dummett[33] defends a similar position in mathematics and copying what he says and adapting it to physics, I would say: If we think that our perceptions come from outside (and I call phenomenal reality the set of all perceptions) we should think of a phenomenal reality that is not existing yet but that comes to birth along with our actions. Our tentative research gives birth to something that was not there before and what it gives birth to (phenomenal reality) is not coming exclusively from ourselves. Empirical reality is the framework that constrains our perceptions and makes them come from outside. In some way we build phenomenal reality from empirical reality. The first level is then the phenomenal reality and the second one the empirical reality. Now, this second level is very peculiar. It is not composed of objects or strengths or fields or anything else that is representable. It is the set of all potentialities that can be actualised. This actualisation can be effective only if it respects some constraints preventing us to create the phenomenal reality as we want. Empirical reality is then the set of all these potentialities and the associated constraints. Now we can understand why contradictory theories can be empirically adequate (what we should now call phenomenally adequate). It is because these theories respect the constraints imposed by empirical reality[34]. The reason why they are empirically adequate is neither the fact that the terms of the theories have a real referent in empirical reality (which is not composed of physical entities) nor the fact that the referent is in the phenomenal reality which is only composed of actualised perceptions. There is no more reality left to which physical theories can refer. Physical theories seen as algorithms are adequate if their algorithms are in adequation with the structural constraints imposed by empirical reality.

7.2. *The need for a third level*

Phenomenal reality is both conceptualizable and representable. Empirical reality is conceptualisable since we are able to build theories which reflect its structure but it is not representable. Its very nature (set of potentialities) is an obstacle to any representation since a representation is by definition actualised. Moreover, it is conceptualisable in many different ways because of underdetermination of theories. This means that it is only partially conceptualisable because it is impossible to gather all the different ways in a global conceptualisation. It remains beyond every exhaustive description. This is an analogue to quantum complementarity. In quantum physics, it is possible to measure the position of an electron or its momentum but not both simultaneously. Moreover measuring first position then momentum doesn't make it possible to know both values afterwards. Phenomenal reality is a sort of section of empirical reality, coming from many measures and giving a partial representation of it.

Each section is exclusive in the sense that it is impossible to rebuild a global view of empirical reality through different sections as is the case for example in architecture where 3D pictures are drawn from different 2D views. Thus, that empirical reality is not representable doesn't come from the fact that some of its parts are out of reach but from the fact that it is impossible to have a total and global knowledge of all these parts simultaneously.

One can wonder whether these two levels exhaust "the universe". It seems to me that it is naïve to think that "everything" is conceptualisable. Of course we must be very prudent here. If by "what is conceptualisable doesn't exhaust what is in the universe" we mean "there is something that is not conceptualisable" we fall immediately inside a trap of language. Let's remember Wittgenstein's famous sentence "*Whereof one cannot speak, thereof one must be silent"*. I am here going to try to show what I mean more than to describe it precisely. Empirical reality is the set of all actualisable potentialities and is a sort of asymptotical construction built from all the concepts that we use to describe and to predict phenomenal reality. Then in a way, it is linked to the capacities of the human brain. It is obvious that this empirical reality is totally out of reach for a dog or for a monkey. I pretend that our capacities of conceptualisation are limited and I refuse to consider that for example, some greater capacities are impossible. That means that for entities having these superior capacities, some things that are conceptualisable for them are not for us, exactly in the same way that what is conceptualisable for us is not for a dog. Thinking the contrary would mean that the human brain is the ultimate machine for conceptualising which seems a little bit pretentious. Then I will postulate that there are "entities" that are not conceptualisable. Language finds here its own limits because it is not possible to say anything about these "entities" which are not usual things. Let's only say that conceptualisable things are not everything and that there is something else which I'll call the third level. Thus there are three levels: the first one is the phenomenal reality that is representable and conceptualisable, the second one is the empirical reality that is conceptualisable but not representable and the third one (for which I give no name) is not conceptualisable.

CONCLUSION

This stance is compatible with the results of quantum mechanics and their interpretation that undermines traditional realism. It rejects metaphysical realism and epistemic realism but is not an idealist position. It also enables us to understand why apparently contradictory theories can be empirically adequate without being trapped in the false questions of the existence of a real referent of theoretical terms or of the wrong concept of approximate truth. Under-determination of theories becomes a natural consequence of the fact that theories are algorithms used to predict phenomenal reality. The "no miracle" argument vanishes in front of the fact that our theories work only inside the part of phenomenal reality that lends itself thereto. The success of these theories comes from the fact that they respect the structural constraints of empirical reality. Then the fact that "something says no" comes from the difficulty for our mental structures to work out a theoretical formal construction and a perceptual construction which are jointly consistent. Due to the empirical blindness features, it is certainly a sceptical epistemology but it doesn't refuse to recognize the possibility of obtaining some pragmatic knowledge about phenomenal reality.

This stance borrows some features from realism in that it refuses to say that everything comes from our mind but at the same time it doesn't admit the existence of an independent reality. Phenomenal reality and empirical reality exist only relatively to our perceptive capacities. Their existence is then of a different nature than the one postulated in traditional realism. The Human mind plays an essential role but is not the sole ingredient. As Putnam says[35]: "the mind and the world jointly build the mind and the world".

NOTES

[1] Agazzi, 1989, pages 91
[2] Agazzi, ibid.
[3] Van Fraassen, 1980.
[4] Wilfrid Sellars, 1963.

[5] Rescher, 1987, pages 2
[6] Actually, there are 5 different string theories which can be shown to be equivalent inside an eleven-dimensional M-theory.
[7] Putnam, 1987, pages 3
[8] Agazzi, 1989.
[9] D'Espagnat,1994.
[10] D'Espagnat 2002.
[11] Boyd, 1989.
[12] When two quarks become separated, as happens/occurs in collisions made in particle accelerators, a new quark/anti-quark pair emerges out of the vacuum. So instead of seeing the individual quarks, physicists see what they call "jets" of particles.
[13] Though this is still a controversial debate, see the analysis in d'Espagnat, 1994, 2002, Zwirn, 1997, 2000, to appear and Soler, 2006.
[14] I have no place to develop it here, (see Zwirn, 2000).
[15] I must admit that this is not a rigorous proof but rather a reasoning by analogy.
[16] D'Espagnat, 2002.
[17] Gardenfors, 1988.
[18] Boyd, 1989.
[19] Rescher 1987, pages 73
[20] In any case, in the absence of any plausible definition, this point is of little interest.
[21] Putnam, 1982.
[22] See in particular the discussion about the truth in realism in Newton-Smith, 1989.
[23] This is not totally correct because the program has to contain also the instruction "write" and the string needed to delimitate it, but the longer the string, the smaller the difference.
[24] Provided that suitable initial conditions are given.
[25] Chaitin, 2005, pages 53
[26] Hanson, 1958.
[27] Kuhn, 1962.
[28] Feyerabend, 1975.
[29] Van Fraassen, 1980.
[30] We have previously refused to count the prediction of a novel fact as an argument for scientific realism but we consider that such a prediction is an argument for the empirical pertinence of a theory because it proves that the theory is not a sterile construction limited to a description of recorded data.
[31] Boyd, 1989, pages 8
[32] For lack of place here, it is not possible to explain why it is necessary to use so/as complicated a theory than/as ZFE. For more details about it see Zwirn, 2000 where the detailed reasoning is drawn.
[33] Dummett, 1978.
[34] I have not place here to develop this point which is related to structural realism. See Zwirn, 2000.
[35] Putnam, 1981.

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