Philosophica 90 (2015) pp.23-60

THE CURRENT STATE OF THE METAPHYSICS OF SCIENCE DEBATE

Cristian Soto

ABSTRACT

I examine the current state of the debate on the metaphysics of science (MS for short). In 1, I identify some of the main questions belonging to the MS, looking into the relationship between science and metaphysics. In 2, I expound the rise of the old wave in the MS, which endorses the belief that metaphysics is a guide to, or a heuristic for, science and outlines the stronger idea that metaphysics makes science possible. In 3, I examine the maximalist MS. This is a contemporary revival of the old wave, reformulating the claim that metaphysics makes science possible. In 4, I look into the new wave in the MS, which argues that science is a guide to metaphysics and, more radically, that metaphysics is to be motivated by, and restricted to, science. In 5, I briefly introduce my own minimalist MS, which contends that science sets the epistemic, methodological and ontological criteria which should work as desiderata of the MS. I close this chapter in 6 with some concluding remarks.

1 Science and Metaphysics Intertwined[1]

The current debate on the metaphysics of science (MS, for short)[2] promotes a style of metaphysical research that seeks to work hand in hand with scientific endeavour. Those who work on the viability of the MS argue that if metaphysics is worth pursuing as part of the search for knowledge of reality, its procedures should be reconceived in several respects in order to make them akin to those of science.

The rise of this specific understanding of the MS can at least be dated back to the end of the 19th century to the works of Peirce on scientific metaphysics.[3] On the negative side, Peirce's philosophical stance emerged as a rebuttal of some extreme forms of non-scientifically motivated metaphysics, which were inspired at the time by, among others, Hegel's absolute idealism. This, nevertheless, shall not concern us here. On the positive side, the founder of pragmatism developed a form of metaphysical research that was properly engaged in current best science. His evolutionary metaphysics is an instance of such an approach. Peirce was aware of the intertwining of science and metaphysics. He claims: "[f]ind a scientific man who proposes to get along without any metaphysics ... and you have found one whose

[1] Some of the ideas in this Chapter have grown as a development of previously published work (see Soto 2013, 2014 and 2015). My hope is that, in its present shape, this work succeeds in offering a more accurate account of the current state of the MS debate.

[2] What I call MS has also been called by others scientific metaphysics. See, for instance, Ross et al. eds. (2013) and Ross (2012). In what follows, I shall use these expressions interchangeably, as referring to a form of science-based metaphysical research. Overall, I will consistently employ the former, unless the context or other stylistic considerations suggest the latter.

[3] For a detailed analysis of this point, see Reynolds' (2002) systematic account of Peirce's scientific metaphysics.

doctrines are thoroughly vitiated by the crude and uncriticised metaphysics with which they are packed" (CP, 1.129).[4] Accordingly, he dealt in his manuscripts with many of the philosophical issues that currently concern metaphysicians of science, such as causation, space and time, laws of nature, and the thesis of realism.

Over the last decades, the MS has become a prominent sub-discipline within the philosophy of science. In a series of lectures, the physicist and philosopher Redhead gathered substantial evidence for the claim that "physics and metaphysics blend into a seamless whole, each enriching the other" (Redhead 1985, p. 87). He goes as far as to claim that "in very truth neither can progress without the other" (ibid. p. 87). More recently, Papineau distinguished between the epistemology of science, which deals with the justification of claims of scientific knowledge, and the MS, which investigates philosophical problems resulting from our scientific view of reality. Among the problems of the second branch Papineau (1996, p. 1) identifies those of causation, laws of nature, quantum indeterminacy and natural selection, which overall deal with ontological concerns. Later on, in a slightly different vein, Sankey characterised the MS as "the extremely fruitful interaction currently underway between metaphysics and philosophy of science," (Sankey 1999, p. xvi) emphasizing that it "represents one of the most vital and promising areas of contemporary philosophical research" (ibid. p. xvi). The number of volumes and papers tackling questions in the MS has experienced an exponential increase, so much so that Ellis et al. have recently observed that "the project of a realistic metaphysics of science is surely well advanced" (2012, p. 8).[5]

[4] Nubiola (2012) examines some peculiarities of the expression scientific metaphysics attributed to Peirce in the volume 8 of Peirce (CP).

[5] The collections of papers published in the volumes *Scientific Metaphysics* (Ross et al. eds., 2012), *Properties, Powers and Structures: Issues in the Metaphysics of Realism* (Bird et al.

The MS investigates the *intertwining* of science and metaphysics, which takes place in various ways through the mutual contribution between these disciplines in view of their aims. Science can contribute to metaphysics by means of suggesting genuine metaphysical concerns and settling questions about the boundaries of empirical knowledge and reality. Likewise, metaphysics can contribute to scientific practice examining issues related to the elaboration of a scientific view of reality and looking into the sources and boundaries of scientific ontology.

Evidence for the intertwining of science and metaphysics is provided by examples of the reciprocal contribution of these disciplines at different stages of history. Indeed, historical evidence demonstrates that metaphysics has to some extent stimulated scientific progress. Aristotle's views on substance, causation and movement are one example, since they fruitfully triggered early modern scientific conceptions of similar issues. Likewise, the Leibniz-Clarke discussion on relational and substantival views of space and time presents a remarkable case of metaphysical debate engaged in scientific research. Other cases worth mentioning are the philosophical enquiry into atomism, which partook in the development of mechanical natural philosophy, and the Cartesian distinction between the material and immaterial substances, which was translated into different research programmes in both empirical psychology and cognitive science. Lastly, early modern teleology arguably set an influential regulatory research framework for the emergence of scientific taxonomies in some branches of modern biology and evolutionary theory.

If we look at the contribution of science to metaphysics, we find that it has had both a negative and a positive impact. As to the former, it can be argued that an important part of the history of modern science can

---

eds., 2012) and *Metaphysics and Science* (Mumford et al. eds., 2013) reflect the various trends of the current debate.

largely be read as the continuous rejection and refutation of certain non-scientifically motivated metaphysical views. This appears to be an undeniable fact that shows that science has in part purged metaphysics of its ghosts on more than a few occasions throughout history. Scientists' critical appraisals of metaphysics abound in the literature. Feynman, for one, in addressing the question of the character of physical laws and the philosophers' attempts to investigate the laws of nature, claims that "we have learned from much experience that all philosophical intuitions about what nature is going to do fail" (1965, p. 53), whereas Weinberg maintains that the insights of non-scientifically informed philosophers are "murky and inconsequential compared with the dazzling successes of physics and mathematics" (1993, p. 133).

As to the positive impact, those who work in the MS need to demonstrate that there is yet room for arguing that science can positively contribute to metaphysical research. From this perspective, some of the questions which philosophers in this field face are as follows: Does scientific practice set certain restrictions on how to carry out metaphysical research, especially when it comes to the MS? What is the positive job that we expect the MS to accomplish? How can metaphysical theories genuinely contribute to the epistemic success of science? And, how can metaphysical theories be assessed – let alone subject to rigorous testing – in order to guarantee their positive epistemic contribution to scientific knowledge? Likewise, if metaphysics is somehow to be conceived of as complementary to science, is the MS possible only insofar as the current best scientific view of reality remains incomplete? And if that is so, do we have to assume that metaphysical assumptions currently involved in scientific theories are to be replaced or eliminated by new findings in future scientific research? As I shall argue below, we find various answers to these questions in the literature and some of them are radically incompatible with each other.

In its general outlook, the MS examines the interplay between science and metaphysics, and whether some forms of such interplay are more fruitful than others. I shall not attempt to establish a normative understanding prescribing *the* appropriate relationship that *must* hold between these two disciplines. By contrast, this relationship, I submit, is just as it has happened to take place throughout recent history. In my argument, I pay close attention to the fact that over the last four decades or so, metaphysicians of science have ingeniously investigated different scenarios of such interaction. Indeed, looking into the main proposals available in the field, I find the following ways of conceiving the *intertwining* (for short, *I*) of science and metaphysics:

> Section 2 addresses the old wave in the MS, which broadly maintains that *(I1)* metaphysics works as a guide to, or heuristic for, science, and even more that *(I2)* metaphysics makes science possible.
>
> Section 3 examines the maximalist MS, which is the contemporary trend in the current debate that advances a revival of the old wave, putting forward a new defence of the idea that *(I2*)* metaphysics makes science possible.
>
> And section 4 looks into the new wave in the MS, which is a broadly naturalistic approach advocating the idea that *(I3)* science is a guide to, or heuristic for, metaphysics; and in a stronger fashion, that *(I4)* metaphysics is to be motivated by, and restricted to, science.
>
> Lastly, in section 5 I shall introduce a first outline of the minimalist approach. Such outline will constitute *(I5)*, which is the tenet that science sets the epistemic, methodological and ontological criteria that should operate as desiderata of the MS.

Those interested in the prospects of this programme ask: Is the MS *metaphysics enough*? Here I have in mind Quine (1953, p. 446), who claims that philosophy of science is philosophy enough. Throughout my argument, this concern takes the following form: apart from the MS, do

we need any other form of non-scientifically motivated metaphysics? My answer will be that the MS is metaphysics enough, where this entails that if we are interested in accounting for our scientific view of reality, we surely do not need alternative forms of non-scientifically motivated metaphysics. Along with science, some form or another of the MS should suffice for our theoretical purposes.

2 The Old Wave in the MS

Wartofsky (1967) and Agassi (1975 and 1996) systematically addressed questions about the intertwining of science and metaphysics. They represent the rise of the old wave in the MS as a sub-discipline within the philosophy of science. Noticeably, this tradition attributes a relevant role to metaphysics in its contribution to scientific research. We can state its main tenet in both a weak and a strong version:

> ***(I1)*** *Weak version*: Metaphysics works as a guide to, or heuristic for, science.
>
> ***(I2)*** *Strong version*: Metaphysics makes science possible.

Both Wartofsky and Agassi defend these claims. On the one hand, in line with *(I2)*, Wartofsky (1967, p. 123) maintains that metaphysics is not only a heuristic for scientific research and theory formation, but also that it articulates the conceptual framework within which science is possible. On the other hand, even though Agassi (1975, p. 210) seems to agree with Wartofsky on this, he stresses *(I1)*, maintaining that metaphysics helps science decide what scientific problems are worth investigating (Agassi 1975, p. 208). In Agassi's view, metaphysics leads to the development of new scientific theories and discoveries, unifying

science and generating its agenda (Agassi 1975, p. 229; see also, Agassi 1996, p. 498).[6]

Wartofsky's (1967, pp. 129-130) elaboration illuminates some of the issues involved in the relationship between science and metaphysics. In his view, there are four possible ways in which this takes place:

i. Metaphysical theories may have no heuristic value at all either in metaphysics or in science;

ii. Metaphysical theories may have heuristic value, but this value lies outside the domain of science proper;

iii. Metaphysical theories may have heuristic value within the domain of science, but they are to be distinguished from proper scientific theories; and,

iv. Metaphysical theories are not distinguishable in any clear way (i.e., neither heuristically nor ontologically) from scientific theories.

The distinction between *heuristic* and *ontological* claims is of crucial importance here. Scientific theories are thought to standardly express ontological claims about the nature of reality, such as the specification of the electric charge, mass and spin of electrons, positrons and the like. By contrast, heuristic claims are those which are not intended to inform us about the nature of things, but only to deliver a better understanding of ontological claims. Whereas the ontological character of most scientific claims can be taken for granted, what is called into question is

[6] More recently, Dilworth (2007 (1996), pp. 53-57) has advocated the strong version of the main tenet, defending the view that metaphysics sets some fundamental ontological presuppositions that make science possible, viz.: the principles of uniformity of nature, substance and causality. For a similar approach, see also Maxwell (2005).

whether metaphysical claims are restricted to only playing a heuristic role, if any, or whether they can have purported ontological content as well.

Although metaphysical practice is usually understood as involving a variety of ontological claims, the question Wartofsky raises is whether metaphysical and scientific claims are on a par in their ontological content. If they are not, one alternative is to maintain that metaphysical claims only play a heuristic role in relation to the ontological claims we find in science. In this regard, alternative *i* represents the sceptical position, viz., metaphysics plays neither a heuristic nor an ontological role. By contrast, alternative *ii* takes metaphysics to be a non-scientific way of knowledge, which aims at pedagogical or psychological explanations of science by means of heuristics or interpretations that can eventually contribute to our overall understanding of the scientific worldview.

Consequently, alternatives *iii* and *iv* should represent the strategy to be endorsed and developed by those who are interested in the prospects of the MS. According to *iii*, metaphysics can be considered as a heuristic for science; whereas according to *iv*, metaphysics is a proper part of science that makes both heuristic and ontological claims. On the one hand, as per *(I1)*, within the perspective of the old wave, alternative *iii* suffices for a form of metaphysics that contributes to scientific research. Thus conceived, the MS would play a heuristic role in the quest for objective knowledge of reality and yet would still be distinguished from proper scientific theorising. In other words, even though metaphysics cannot account for independent ontological claims, it can serve as a guide to scientific research.

On the other hand, if we look into the details of *iv*, we find two possible readings, both of which make this alternative appear problematic. The first is this: *iv* leaves room for taking metaphysics to independently contribute genuine ontological claims about reality *as if it were an autonomous discipline with respect to science*. Interpreted in this

way, it would constitute an example of what I shall call *maximalist MS*,[7] which suggests a form of non-scientifically motivated metaphysical investigation. Yet, a second reading of *iv* is possible: if metaphysical terms are not distinguishable from scientific terms in any clear way – for instance, regarding their epistemic and ontological scope –, this would mean that we can expect metaphysics to work along with science, employing experimental procedures and mathematical techniques. In short, metaphysics would then become a science proper.[8]

My understanding is that the old wave in the MS is at least prepared to endorse *iii* in accordance with *(I1)*. However, this view ambiguously moves between the first and the second reading of *iv*. The question is relevant since this would determine the extent to which the old wave supports *(I2)*. What is clear thus far is that the adoption of the first reading of *iv* entails that the MS merges into a non-scientifically motivated form of metaphysics, and hence it has to be rejected; by contrast, the adoption of the second reading of *iv* promotes the view that the MS is to be properly understood as a particular science, and the question emerges as to whether it still can be distinguished from the sciences proper.

Note that the old wave raises the following general concern: Is the MS to be understood as a particular science? I am pessimistic about the prospects of a positive response to this question. As shall become clear throughout the argument, the best scenario for the MS seems to be one in which metaphysics is carried out hand in hand with the sciences, advancing scientifically informed metaphysical theories which have the

[7] See section 3 below.

[8] Bunge (1972, p. 507) adopts the second reading of *iv*. He advocates the idea that scientific metaphysics, as he dubs it, is to be distinguished from plain metaphysics insofar as the former, but not the latter, is informed by scientific theories. He argues that theories of scientific metaphysics are to be formulated in mathematical terms in accordance with our best science. For the latter claim see Bunge (1972, p. 518).

epistemic power of contributing to scientific research (as stated in claim *iii* above). Accordingly, what has been argued so far should not be taken to imply that the MS is a particular science (as the second reading of option *iv* suggests). Instead, it is a philosophical endeavour that attempts to be properly engaged in current scientific practice. Ross (2012) examines this issue in his exercise in scientific metaphysics. As I understand his views, he suggests that we need not expect metaphysics to bring about independently well-grounded philosophical theories of reality without the sciences being taken seriously into consideration. In the same spirit, being scientifically informed, the MS is in the service of the sciences. Metaphysicians should not regret this, since as a matter of fact scientific research has at present succeeded in delivering the best account we have of reality and constitutes our basic source of information about the way reality is.

In sum, although not always acknowledged, Wartofsky and Agassi set the terms of the discussion on the MS articulating the central questions which repeatedly appear throughout the literature: Does metaphysics work as a guide to science? Does it make science possible? Do metaphysical claims purport to play a heuristic role only? Or, do they have ontological content?

3 Maximalism in the MS: a Revival of the Old Wave

The contemporary trend in the maximalist MS brings back to the recent debate the spirit of the old wave, since in line with *(I2)* it emphasises the idea that metaphysics makes science possible. The works of Chakravartty (2010, 2013), Mumford (2012) and Mumford and Tugby (2013), among others, represent in different respects this programme. Let us state the main tenet of the maximalist approach as follows:

> ***(I2*)*** Metaphysics not only is a guide to or heuristic for science, but it also makes scientific research possible.[9]

I examine three arguments in favour of this view. The first is Chakravartty's contention that science is unavoidably metaphysical so long as it pursues investigation of unobservable entities (3.1). The second is Mumford and Tugby's argument for the view that metaphysics makes science possible (3.2). Lastly, the third is Chakravartty's argument for the metaphysical slippery slope of science (3.3).

3.1 Argument 1: Science is Unavoidably Metaphysical

Chakravartty outlines the general argumentative strategy adopted by the maximalist approach. In particular, he emphasises the idea that science inevitably involves some metaphysics. In arguing for this, science is conceived of as having a significant a priori aspect, insofar as it aims at delivering explanations of observable phenomena by means of accounting for unobservable realities. Metaphysical theorising about unobservables, it is argued, is found in science as much as it is found in standard metaphysics. He goes further, maintaining that "*[p]rima facie*, the sciences are plainly metaphysical, insofar as they appear to take a very strong interest in phenomena underlying the observable [i.e., the unobservables]" (Chakravartty 2010, p. 62). Furthermore, he claims that among the methods for uncovering unobservable realities are those of conceptual analysis, intuitions and explanatory power. Both metaphysicians and scientists would employ these methods –

[9] One referee for *Philosophica* (Ghent University) has pointed out to me that *(I2*)* is the conjunction of *(I1) and (I2)*. I find no problem with this reading. Nevertheless, in what follows I set myself the task of demonstrating that the recent defence of *(I2*)* involves specific argumentative strategies that make it different from the old wave.

sometimes in an a priori manner – in the investigation of the unobservable dimension of reality (ibid. p. 62). The conclusion, in brief, is twofold: on the one hand, science appears to be unavoidably metaphysical, whereas on the other hand, given its interest in unobservable phenomena, science is (at least partly) a priori in character (ibid. p. 66).

A problem with this view is that it mixes up sound experimental and mathematical sciences with a priori metaphysical speculation. As a first critical remark, note the ambiguity in the use of the expression *unobservable phenomena*, which is supposed to refer to the metaphysical dimension of reality investigated by both metaphysics and science. In the philosophy of science literature, standard unobservable entities are those of electrons, Higgs bosons, dark matter, and the like. They are not observable by means of the unaided senses. However, this does not entail the claim that they make up the metaphysical dimension of reality nor does it mean that scientists discover such entities by exercising non-scientifically motivated metaphysical speculation.

Quite to the contrary, scientists develop intricate experimental techniques and laboratory designs for actually gaining access to such unobservable entities. In some relevant cases, achieving indirect knowledge of unobservable realities is possible by means of experiments, application of mathematics to data-gathering processes, and construction and manipulation of models and theories, but not by means of a priori metaphysical speculation. The point is this: equating the unobservables of science with the unobservables of metaphysics seems to be gratuitous. Likewise, confounding the epistemic tools employed in metaphysical speculation with the epistemic tools employed in experimental and mathematical sciences is misleading. Overall, this poses serious problems to the claim that science is unavoidably metaphysical.

3.2 Argument 2: Metaphysics Makes Science Possible

Let us look into the details of Mumford and Tugby's (2013) elaboration of the maximalist MS. They explicitly address the question of what the MS is. However, the answer they offer faces some serious challenges, especially when it comes to demarcating the goals of the MS from those of other forms of non-scientifically motivated metaphysics (which they call armchair metaphysics).

To begin with, Mumford and Tugby do not provide a clear story about the different forms that the MS can take or has actually taken over the last four decades or so. Even though they mention the neo-Humean empiricist movement against metaphysics and alternative developments of armchair metaphysics, their remarks do not unmistakeably situate their approach within the current debate. Instead, they commence their defence of the MS by outlining a definition of the discipline, which we can adequately classify as an exemplar of maximalism:

> *MS def.:* "The metaphysical study of the aspects of reality, such as kindhood, lawhood, causal powers, and causation, which impose order on the world and make our scientific disciplines possible (that is, disciplines which are able to provide predictions – often novel – and offer explanations for new facts and anomalies within their given domain)" (Mumford and Tugby 2013, p. 14).

Such a definition exemplifies an exercise in *(I2*)*. They further explain their view arguing that there are some "metaphysical-cum-scientific concepts with which metaphysicians of science are concerned: natural kinds, laws, causation, and causal powers" (2013, p. 6). A common feature of these metaphysical-cum-scientific concepts is that they are "at the heart of all the sciences" (2013, p. 9). This feature leads them to the main claim of *(I2*)*, viz. without such concepts

"science as we know it would not even be possible" (ibid. p. 9). Here is the argument again: "without kindhood, lawhood, and causation, neither systematic scientific predictions nor explanations would be possible" (ibid. p. 9).

There are various challenges to this position, some of which I briefly outline. The first is this: What truly makes science possible? Rather than metaphysics, what makes science possible is the organised application of complex processes of experimentation, the construction and manipulation of scientific models and theories, the employment of highly refined mathematical notation and operation rules, measurements, computer simulations of various kinds, and the processing of data through statistical techniques, among other scientific procedures. The institutional organisation of science and the implementation of these methodologies can indeed be considered responsible for scientific practice and its empirical successes in many domains. At first glance, none of them relies on the claim that metaphysics makes science possible.

We can enunciate the second problem as follows: What issues belong to the MS? Mumford and Tugby try to demarcate the MS from other forms of armchair metaphysics. As to the question of what issues do not belong to the MS, they claim: sub-disciplines like the metaphysics of particulars, properties, time, space, composition, identity, parthood, persistence, numbers, and propositions are "independent of questions relating to the metaphysical nature of the world-order" (2013, pp. 14–15), and hence they are not part of the MS.

In view of this, one wonders whether the metaphysical nature of the world-order is a robust criterion for determining what problems are suitable for metaphysical investigation. Perhaps, it can be shown that such criterion does not work in practice. As a first step, we can accept that questions about parthood, persistence, particulars and propositions can in general be set aside as merely belonging to armchair metaphysics. This, however, does not seem to be the case with

ontological concerns such as the nature of time, space and properties. But if we assume for the moment that there is a world-order, we should expect that it reflects the way in which reality is structured and constituted. In this respect, questions about space, time and properties should depend upon what the order of reality is like – regardless of whether such order is metaphysical or otherwise.

This argument remains nevertheless problematic. Mumford and Tugby (2013, p. 9) would reply that time, space and properties are issues that do not belong to the MS, given that they are not at the heart of all the sciences. However, both scientific and metaphysical practices speak against this maximalist move. Think of the notions of space and time as they appear in general relativity, which in fact makes strong claims about ontological and mathematical features of the four-dimensional space-time and enables scientists to explain and predict a range of other observable phenomena. Philosophers of physics have noticed this, offering insightful examinations of the ontological and epistemic conundrums raised by the four-dimensional space-time of general relativity (Maudlin 2012). Hence, scientific and metaphysical practices rebut the maximalist move, showing that if there is any ground for the notion of space and time – and for the scientific posit of a four-dimensional space-time – it should be the way reality is *according to current scientific practice.*

A third problem is this: Is there a world-order after all? It is *prima facie* problematic to appeal to the world-order as a criterion for demarcating issues belonging to the MS from those that belong to armchair metaphysics. The thesis itself that there is a metaphysical world-order is not straightforwardly suggested by science and requires, by contrast, a good deal of speculation which already finds its rationale in some form or another of metaphysics. I do not claim here that there is no order in reality as it is described by current best science; I do not hold either the controversial view that scientific laws (equations, principles, symmetries, etc.) fail to account for empirical

regularities that hold in a variety of contexts across well-specified physical domains. However, it appears evident that we cannot take the thesis of the world-order both as a metaphysical condition that makes science possible and as a criterion for drawing the boundaries between the MS and armchair metaphysics. First of all, to believe that science attempts to discover the *metaphysical world-order* cannot be endorsed as a scientifically grounded idea, but only as an expression of metaphysical belief. It is undeniable that scientists not only assume that nature can always surprise us, thereby breaking what we may want to think of as the world-order, but they also try to make this happen in various cases. And second, for all we know, nothing prohibits in principle that the fundamental structure of reality be inherently stochastic as quantum mechanics demonstrates, case in which scientific theories and laws would be restricted to express the best physical generalisations about those regularities which scientists have come to find out so far. To our best knowledge, this does not require *per se* any further assumption as to a deeper, metaphysical world-order.

Furthermore, adopting an empiricist vein, philosophers can wisely ask why reality should have an order at all for our science to discover. This appears to be a genuine concern: What exactly is the metaphysical nature of the world-order? At first sight, if there is a metaphysical world-order, given that it is metaphysical and not physical, we should not expect to uncover it by means of employing scientific methodologies (experimentation, model- and theory-construction processes, application of statistics and mathematics, computer simulation, and so forth). In this scenario, metaphysicians in the maximalist trend face some not-so-easy-to-answer questions, such as, how do philosophers determine what concerns about objective features of reality belong to the metaphysical nature of the world-order? Do they perform this job by merely exercising non-scientifically motivated metaphysical speculation? Do they identify sub-disciplines belonging to the metaphysics of the world-order by looking, for

example, at standard disciplinary divisions in metaphysical schools or at instances of metaphysics as it is presented in metaphysical textbooks? Or, do they actually find out about this by looking into our current best scientific account of reality?

There is a philosophical agenda beneath this understanding of the aim and scope of the MS. Mumford has made it explicit in previous work consistently favouring the development of *(I2*)* and blurring the distinction between the maximalist MS and armchair metaphysics. Among other things, he maintains that armchair metaphysicians believe that metaphysical theorising goes deeper than any other science in the knowledge of reality by exercising a priori reasoning. This is, however, exactly what his MS appears to assume – metaphysics makes science possible by means of postulating a fundamental metaphysical dimension of reality. In a similar vein, he claims that armchair philosophers address problems such as the nature of "substances, properties, changes, causes, possibilities, time, personal identity, nothingness, and emergence" (Mumford 2012, p. 1). He further develops his view by claiming that philosophy has a distinctive approach to knowledge of reality and it should not defer to science questions as to what exists (Mumford 2004, pp. xiv and 4-8).

3.3 Argument 3: the Metaphysical Slippery Slope of Science

In an interesting move, Chakravartty advances an argument, which he calls the metaphysical slippery slope of science. It can be summarised as follows: when looking into philosophical problems resulting from the examination of science, philosophers are inescapably led to the postulation of metaphysical underpinnings of scientific theorising.

If this argument is correct, it would work in favour of the maximalist MS, perhaps not supporting in particular the claim that metaphysics makes science possible, but at least advocating the view that science

entails metaphysical baggage. One example Chakravartty (2013, p. 38) mentions is the metaphysical speculation about the causal powers involved in gene transcription processes as described by cell and tissue biology. In this view, *causal powers* would count as the metaphysical posits that help explain the working of scientific posits such as *genes*. Hence, Chakravartty (2013, p. 39) points out that there is no reasonable determination of where to stop when outlining the metaphysical foundations of science.

Overall, this argument raises a powerful reason in favour of the maximalist MS and poses a challenge to the viability of more minimalist approaches. In arguing that there is no definite stopping-point when working out the metaphysical underpinnings of science, this view stresses the difficulty of demarcating armchair metaphysics from the MS by appealing to proximity to scientific context. How do we measure such proximity? The proximity criterion, Chakravartty contends, is "intuitively compelling but largely empty" (2013, p. 30).

Some current exercises in the MS support the slippery slope argument. In this section, I want to examine two. The first has to do with the discussion of properties and laws in Ellis, Armstrong and Bird, whereas the second is related to the defence of realism about mathematical ontology recently put forward by Psillos.

a) Properties and laws. In a recent debate,[10] Armstrong, Bird and Ellis compared their metaphysical views on properties and laws, which they claim are motivated by current best science. Armstrong proposes the first view, which holds that all properties are categorical in nature. This entails the claim that there are no dispositional properties. Nomic connections between states of affairs can be formulated as follows: φ1's being F and having R to φ2 causes φ2's being G, which means that

[10] See Bird et al. eds. (2012, Chapters 1-3)

something's being F and having the (perhaps spatial) relation R to some further thing causes that further thing to be G. This leads Armstrong (2012, p. 30) to the conclusion that "laws of nature are relations holding between states of affairs types," where all the possibly involved properties must only be categorical in nature. Contrary to this, Bird (2012, p. 36) advances a second view, maintaining that all the properties of things are dispositional in nature. This entails the idea that there are no categorical powers. Hence, laws of nature supervene on the necessary relations that dispositional properties have according to their essences. Yet, Ellis rounds out the discussion advancing a third view which proposes a mixed account of properties, including both dispositional properties and categorical structures. In this account, "laws of nature, including all of the laws of action of the causal powers, describe the relation that must hold between the basic dimensions of things" (Ellis 2012, p. 17). That is, both categorical structures (first view) and dispositional causal powers (second view) ground the reality of laws of nature.

We need not go into the detail of these positions in order to have a glimpse of the slippery slope in each of them. By interpreting current best scientific theories, metaphysicians of science elaborate several conceptual frameworks for explaining the nature of scientific posits and the lawful connections between them. In so doing, metaphysical theorising goes beyond what we find in current best scientific theories; for instance, whereas scientific theories refer to the mass, charge and spin of electrons, metaphysical theories add an extra layer of theorising claiming that such mass, charge and spin can be conceived of in terms of categorical properties, dispositional properties or a mixture of them. Accordingly, if what Armstrong, Bird and Ellis do is representative of the MS, Chakravartty's concern regarding the metaphysical slippery slope is confirmed, i.e., philosophers postulate a metaphysical dimension of reality in accounting for a scientific worldview.

Against the metaphysical slippery slope argument, a meta-philosophical concern immediately arises. Even though it is claimed that the three metaphysics of properties and laws outlined above are inspired by current best science, they differ in such a radical way one from each other that the question emerges: How can these science-inspired MS so evidently vary in their conceptions of the ultimate nature of properties and laws? And more to the point, what are the criteria for evaluating these proposals in order to choose the one that can be considered the best?

Armstrong acknowledges this situation and outlines an answer to our questions. He firstly maintains that the three views above agree that "it is up to empirical science to tell us just what these universal properties and relations are" (Armstrong 2012, p. 27). Secondly, he claims that "if there are more than two competing metaphysical theories, one should try, if possible, to indicate which theory one would retreat to if your view turned out to be incorrect" (Armstrong 2012, p. 28). Importantly, to acknowledge this involves the bankruptcy of *(I2*)*: metaphysics does not make science possible, but quite to the contrary, the viability of metaphysical views ultimately depend upon our current best scientific understanding of reality. Metaphysics ceases thus to be a science-independent research on certain fundamental metaphysical dimension of reality and it has to defer to science questions about what exists (whether properties, laws, and else).

Therefore, here is the question to be asked while going down the slippery slope: What is the legitimate scope of metaphysical speculation if we expect it to be properly engaged in science? *Legitimate* means in this context *scientifically motivated,* but such motivation remains a concept void of any content if it is not applied to specific cases of metaphysical theorising inspired in science. In the present scenario, it seems evident that philosophical speculation about the metaphysical underpinnings of science cannot decide what properties and laws there are. Instead, metaphysicians are recommended to

restrict their investigation to what the nature of properties should be if current best scientific theories were correct – where such scientific theories, and not the metaphysical ones, would be the ultimate account of both properties and laws.

b) Mathematical ontology. A second remarkable example of the metaphysical slippery slope is the examination of the ontological status of abstract mathematical entities. In this regard, anti-realism about mathematical ontology entails commitment to the causal inertness, the epistemic indispensability and the ontological dispensability of abstract mathematical objects (Psillos 2012, p. 79).[11] By contrast, realism about mathematical ontology appeals to some form or another of indispensability argument, which basically proposes that "the existence of abstract entities follows from the truth of scientific realism" (ibid. p. 64).

The metaphysical slippery slope in this argument is at work as follows:

> *Mathematical ontology:* If we acknowledge the epistemic success of science and adopt scientific realism, then given that scientific theories quantify over both physical scientific posits and abstract mathematical entities, *we should accept the reality of the latter* just as we standardly accept the reality of the former.

Note that in the eyes of those who are not naturally inclined to endorse the standard defence of realism, scientific practice might give us reason for believing in the reality of many of the physical posits involved in scientific theories, while remaining widely neutral about the question of the reality of mathematical entities. In order to defend

[11] Others, like Field (1980), would still want to defend the epistemic dispensability of mathematics in science.

the reality of mathematicalia, philosophers require a battery of metaphysical arguments to determine what exists and what does not. Psillos has nicely put forward one elaboration of such approach, arguing that realism about mathematical ontology involves the following three claims: first, abstract mathematical objects form part of the fabric of reality; second, there are bottom-level mixed physico-mathematical facts; and third, the assumption of bottom-level mixed physico-mathematical facts best explains the theoretical indispensability of mathematics.

This argument goes down the metaphysical slippery slope, since in terms of explanatory considerations, it suggests adding an ontology of abstract mathematical entities to our scientific ontology. The move is this: the best way to explain the compatibility between scientific realism and mathematical realism is to postulate by inference to the best explanation the existence of bottom-level mixed physico-mathematical facts, that is, "facts that are constituted by a combination of concrete and abstract objects" (Psillos 2012, p. 77).

The point I want to make is this: going down the metaphysical slippery slope of science raises a series of problems that metaphysicians have to deal with. Some of these problems do not naturally stem from scientific ontology, but from the metaphysical exercise of positing new layers of reality. In the present case, the ontology of bottom-level mixed physico-mathematical facts suggests the question. One concern is this: How can we explain the unity between the abstract and the concrete that makes up a physico-mathematical fact? Psillos thinks that this is not a causal unity and that we presumably are "cognitively closed to this kind of aspect of reality" (2012, p. 80). Yet, another problem is: if abstract mathematical entities are to be granted ontological status on a par with physical entities, what exactly is their nature? Does the abstract dimension of such entities shape their physical counterpart? And if so, is this relation of *shaping* a causal one? At first sight, it should not be causal, granted that abstract mathematical entities are

acausal. We can still go further down the metaphysical slippery slope. Otherwise, we can restrict the MS to our current best scientific view of reality. That is to say, we can still look into the sources and boundaries of scientific ontology without adding metaphysical ontology.

4 The New Wave in the MS: the Naturalistic Turn

The new wave in the contemporary MS adopts a naturalistic approach. In its various forms, this view emphasises that science is the best way we have to achieve knowledge of reality.[12] In this the new wave radically differs from maximalism, especially since a basic assumption that its advocates widely adopt is some form or another of Quinean naturalism, which contends that "it is within science itself, and not in some prior philosophy, that reality is to be identified and described" (Quine 1981, p. 21). In brief, the challenge that this poses to philosophers is that if metaphysics is to contribute to our knowledge of reality, it has to be engaged in scientific research proper.

Let us formulate the main tenet of the new wave in the MS in both a weak and a strong version:

> ***(I3)*** *Weak version:* Science is a guide to, or heuristic for, metaphysics.
>
> ***(I4)*** *Strong version:* Metaphysics is to be motivated by, and restricted to, current best science.

[12] The works of Hawley (2006), Esfeld (2006 and 2007), Ladyman (2007, 2011, 2012), Maudlin (2007), Ladyman et al. (2007), Ross (2012), Ney (2012), and Ladyman and Ross (2013), among others, are representative of this approach.

On the one hand, according to *(I3)*, in order to decide among different metaphysical views on a particular realm of reality, we should consider their theoretical proximity to and coherence with our best available scientific theories. Likewise, concerning particular metaphysical statements, if they do not appear plausible in the light of current best science, they should be discarded for this sole reason as failing to represent a live line of research, which is worth pursuing from a scientific point of view. On the other hand, if we grant *(I4)*, there is no room for science-independent metaphysics. That is to say, interesting metaphysical theories and problems are those that stem from the examination of our current best scientific view of reality and are restricted to it.

It should be noted at this point that neither the weak nor the strong formulation of the main tenet recommends the adoption of a sceptical stance on the viability of metaphysics. Contrary to this, it only imposes restrictions on the way it should be practiced. The new wave in the MS is thus optimistic about the possibility of elaborating a metaphysics that genuinely contributes to scientific research.

Allow me to further illustrate the spirit of the new wave by examining Hawley's analysis of different alternatives for assessing the involvement of metaphysical claims in scientific theorising. She maintains that our attitudes towards the interaction between science and metaphysics can vary from optimism to radical pessimism:

i. *Optimism*: There actually are cases in which the involvement of a metaphysical claim in an empirically successful scientific theory provides some reason to think that the claim is true;

ii. *Moderate Pessimism*: There is a kind of involvement in theory which, were a metaphysical claim to achieve this involvement, would provide some reason to think that the claim is true, though there are no such cases; and,

iii. *Radical Pessimism*: The involvement of a metaphysical claim in an empirically successful scientific theory can never provide any reason to think that the claim is true. (See Hawley 2006, p. 456)

Interestingly, none of these alternatives are committed to non-scientifically motivated forms of metaphysics. In this Hawley is right. Such an alternative would be some form of *radical optimism*, i.e., the view that metaphysical theories are to be accepted regardless of their involvement in scientific theorising. Such a position would call for an outright rejection, granted that the MS is to be properly engaged with current *bona fide* science.

Metaphysicians of science have to make a decision about adopting *i, ii* or *iii*. Such a decision can be made on the basis of studying particular cases of the interplay between science and metaphysics throughout history. Let us put to one side option *iii* and focus instead on *i* and *ii*. There may be some instances in favour of *i*, according to which metaphysical terms are positively involved in empirically successful scientific theories, and some other cases in favour of *ii*, where such involvement is possible, but not actual according to our best knowledge.

In the rest of this section, I look into two examples, which have recently been elaborated in the new wave in the MS literature. I shall particularly be interested in whether they support alternatives *i* and *ii*. The first is Esfeld's examination of the viability of the tenseless versus tensed theories of time and existence in the light of special relativity, whereas the second is Ladyman and Ross' ontic structural realism interpreted as a metaphysics for quantum mechanics.

a) Esfeld's example: special relativity and the discussion of tensed vs. tenseless theories of time and existence. Esfeld holds the view that there is a mutual dependence between metaphysics and science. Metaphysics "needs science to know about what there is in the real world, and science needs philosophy in the sense of epistemology" (Esfeld 2007, p. 200). The first

part of the conjunction is of our interest here: when it comes to ontological claims, metaphysics depends on science.[13]

One of the examples that Esfeld sets forth is the metaphysical discussion between advocates of tensed vs. tenseless theories of time and existence. The former view proposes that existence is relative to a time, claiming for instance that only what is present exists. The latter, by contrast, proposes that there are no objective modes of time (past, present and future), and accordingly existence is not relative to time considerations. After examining the structure of the main arguments in favour of these views, Esfeld maintains that the discussion can be settled by taking science into account. For instance, special theory of relativity postulates that there is no objective simultaneity; instead, references to past, present and future are relative to specific space-time frameworks. Hence, time considerations are not inherently relevant to existence claims. In this sense, it is argued, we can make a case for tenseless theories of time and existence by taking into account special relativity, which broadly means to maintain on scientific grounds that "there is no basis in the physical world for upholding a tensed theory of time or existence" (Esfeld 2007, p. 205).[14]

Going back to Hawley's distinctions, there is the question: Does this example demonstrate that metaphysical theories of time and existence are involved in scientific theorising? The analysis leaves room for

[13] One referee for *Philosophica* (Ghent University) has noted the ambiguity in the shifting from *metaphysics* to *philosophy* in this quote. She correctly points out that as far as metaphysics and science are concerned, in Esfeld's view the former depends on the latter. Things might work differently when it comes to philosophy and science regarding matters epistemological. In what follows, I shall restrict my comments to the first claim only, leaving aside philosophical analyses of the epistemology of science. See also Esfeld (2006, p. 90).

[14] For a different analysis of philosophical theories of time in the light of special and general relativity, see Ladyman (2007, pp. 187-191).

claiming that – employing Hawley's terminology – the tenseless theory of time and existence is better involved in (or more closely agrees with) special relativity, whereas the tensed view appears to simply contradict current best science. Nevertheless, Esfeld does not seem to be concerned with whether the involvement of a metaphysical claim in scientific theorising amounts to evidence for accepting the former. This might be a by-product of the argument. By contrast, what his example shows is a case in which a metaphysical dispute can actually be settled by looking at current science, thus confirming the more general tenet that metaphysical claims about ontology depend on scientific ontology.

b) Ladyman and Ross' example: ontic structural realism and the metaphysics of quantum mechanics. In a recent contribution, Ladyman and Ross reinforce the claim that "if metaphysics is to be part of the pursuit of objective knowledge, it must be integrated with science" (2013, p. 109). The example I am interested in is the ontic structural realist interpretation of quantum mechanics, which proposes a strong ontological view of reality as being irreducibly stochastic. This proposal intends to meet metaphysical challenges currently resulting from the examination of this branch of science. The authors suggest that there are two ways for metaphysicians to address ontological problems, namely: first, answering the question of which entities scientists should be construed as really believing in; and second, investigating the fundamental structure of the world. Holding the idea that quantum mechanics is the only mature part of science which is reasonably intended to restrict all possible measurement values in the universe at all scales (Ladyman and Ross 2013, pp. 131–132), the MS of ontic structural realism is designed to deal with problems about the fundamental constitution of reality. In particular, it addresses quantum mechanical conundrums such as systems in superposition with respect to observables and the measurement problem.

Regarding Hawley's distinctions above, we can ask: Does the involvement of the structural realist MS in quantum mechanics give us

reason to think that the pursuit of the former contributes to the development of the latter? Leaving aside Hawley's commitment to approximate truth,[15] the example under consideration does indeed speak in favour of option *i*: metaphysical theorising is properly involved in scientific theorising, and this appears to give evidence for the adequacy of the metaphysical theory in question.

Here is the case. The ontic structural realist MS is inspired by Peirce's ideas on hypothesis, laws of nature and psychophysics (Ladyman and Ross 2013, pp. 142-148). Peirce's notion of hypothesis is interpreted as a procedure that yields explanation and qualitative amplification of knowledge. More specifically, the notion of hypothesis is conceived of as a generalisation worthy of further investigation because it structures ontologies of sample-generating processes of which scientists can then compute frequency distribution of variables that they want to predict or control. As to the second element, laws of nature are understood in Peirce's view as part of a permanent structural change underway in reality. Insofar as laws of nature evolve from chance, their constants of reference are not fixed, but evolving. Indeed, the access we have to them is in relevant cases statistical and reveals the stochastic character of reality. Lastly, with respect to the third element, Peirce's interest in psychophysics encouraged him to reinterpret properties of frequencies not as second-order properties of judgments, but instead as basic properties of reality that constitute its structure.

In short, the Peircean framework, along with an up-to-date scientific and philosophical knowledge of quantum mechanics, allows Ladyman

[15] Whereas Hawley examines whether the involvement of a metaphysical theory in a scientific theory can yield evidence for the truth of the former, I remain neutral on this point. For reasons I do not discuss here, it can still be possible for a metaphysical theory to be properly engaged in scientific practice without this being a reason for claiming that such metaphysical theory is true.

and Ross to put forward their view of reality as irreducibly stochastic. This case successfully illustrates an example of a metaphysical theory which is properly involved in scientific theorising. In one of their formulations, they maintain that the world is the totality of non-redundant statistical data, namely the endless wave of patterns that science will go on uncovering for as long as scientific research is pursued (Ladyman and Ross, 2013, p. 148). It is the close interplay with current scientific theorising what makes ontic structural realism a live option in the MS debate when it comes to quantum mechanics.

5 First Outline of the Minimalist MS

In this section, I restrict my comments to a brief outline of the minimalist approach in view of the background discussion presented in the previous sections. To start with, note that the minimalist MS opposes non-scientifically motivated forms of metaphysics. In this, metaphysical minimalism finds various advocates throughout the current debate. Kincaid, for one, maintains that analytic metaphysics is considered "a questionable enterprise because of its lack of scientific standing" (2013, p. 1), while in a similar vein Melnyk goes straight to the point claiming that non-naturalized metaphysics "has been pursued for a very long time without yielding results at all comparable with those achieved by mathematics and logic" (2013, pp. 80–81). Metaphysical minimalism agrees with such assessments of the misfortunes of non-scientifically motivated metaphysics, and this gives its point of departure to the minimalist approach.

In general, the development of the minimalist MS deals with a variety of programmatic questions. Some of them are epistemic, such as: Is there any proper metaphysical knowledge? And in particular, is there genuine metaphysical knowledge that is epistemically on a par

with scientific knowledge? Regarding methodological concerns, the main question is this: Does metaphysics have a specific methodology? And again more precisely, does metaphysical research have methodological procedures which are akin to, or compatible with, the methods employed in science? Lastly, some ontological concerns are to be addressed: Is there an independent metaphysical dimension of reality for metaphysicians to investigate? Or, is metaphysics instead in the business of uncovering features of the physical reality investigated by the sciences? These questions, I argue, are related to the epistemic, methodological and ontological dimensions of the MS respectively, and they help us outline the following formulation of the main tenet of this view:

> ***(I5)*** Scientific practice exemplifies and provisionally establishes epistemic, methodological and ontological criteria, which should work as desiderata in the pursuit of metaphysics, thereby constraining metaphysical practice.

In short, these criteria illustrate one way in which science can actually contribute to the pursuit of metaphysical research. Given, first, that science and metaphysics aim at delivering knowledge of reality, and granted, second, that current scientific practice comparatively emerges as a more successful enterprise than metaphysics when it comes to accomplishing such task, the epistemic, methodological and ontological criteria operating in science can be now read as desiderata for the development of the respective dimensions of the minimalist approach. We can define the three desiderata in question in the following terms:

> *Epistemic desideratum*: The minimalist MS acknowledges the epistemic success of science and contends that scientific knowledge is the best account we have of reality. It sets the bar

> for other epistemic endeavours. Metaphysical knowledge should not neglect knowledge available in current best science.
>
> *Methodological desideratum*: The minimalist MS embraces the methodological success of science, which proceeds, for instance, by constructing mathematical models and idealizations, empirical testing, statistical analysis of data, and so forth. Metaphysical methods should be in agreement with such procedures, and the outcomes of metaphysical methods should not violate those of science.
>
> *Ontological desideratum*: The minimalist MS contends that both metaphysics and science aim at finding out about the nature and structure of the physical reality. It denies, in short, that there is an independent metaphysical dimension of reality for metaphysicians to investigate.

One dilemma that emerges at this point is that, whereas we propose to reject science-independent forms of metaphysics, an argument is needed to explain how the minimalist MS can still contribute to our scientific view of reality *if metaphysics has to be thoroughly restricted to science.* I do not pretend to have an answer for such problem here. I am rather inclined to believe that there is not a single, all-encompassing answer to this question. The strategy, it seems to me, is to proceed by assessing several case studies in which the MS can both be properly engaged in science and contribute to scientific progress.

I do not claim either to have a knockdown argument in favour of the minimalist approach. For the time being, we are nevertheless in a position to point out some recent developments that draw our attention in this direction. Here are two examples by Roberts and Woodward, who have finely illustrated a cutting-edge exercise in the minimalist view of laws. Roberts, on the one hand, seeks to vindicate the idea that the counterfactual robustness of laws is both real and objective

"without relying on any particular assumption about ontology or metaphysics" (2013, p. 29). In particular, he proposes a measurement account of laws: "what it is to be a law of nature is to be one of the general truths that follow from the reliability of the legitimate measurement methods" (Roberts 2013, p. 34). To put it differently, the measurement account of laws aims to explain the counterfactual reliability of laws by appealing to the counterfactual resilience of measurement methods. In this regard, in any particular epistemic context, scientific laws are the generalisations resulting from legitimate measurement procedures.

On the other hand, Woodward claims that "it is possible to say interesting things about how 'cause' and 'law' figure in scientific practice without providing a full-blown metaphysics of science" (2013, p. 48). Against Lewis' best system approach and the postulate of a Humean supervenience base, Woodward investigates how laws appear in science, that is, not as laws in nature, but as "generalizations representing relationships in nature" (2013, p. 59). Of particular interest is his distinction between initial conditions and laws: the latter, but not the former, bear enough invariance or stability for scientific purposes. Lawfulness, in particular, is mere *de facto* invariance, where invariance is stability under a range of both initial conditions and background conditions (Woodward 2013, p. 65).

6 Concluding Remarks

I am aware of the many arguments I have referred to throughout my analysis, and that they can for other purposes be examined in further detail. However, my hope is that what I have said so far has shown that the MS represents a live debate in the philosophy arena. As argued above from several perspectives, the goal of the MS is to examine the

way in which science and metaphysics interact in the pursuit of knowledge of reality. This debate poses many open questions that are still to be answered by new findings in both scientific and metaphysical research.

The intertwining of science and metaphysics was originally extensively examined by what I have called the old wave in the MS, position which is amply optimistic about the contribution of metaphysics to science. In its various forms, the old wave argues that metaphysics is a guide to scientific research, or moreover, that metaphysics makes science possible, according to *(I1)* and *(I2)* respectively. Nevertheless, the old wave clearly stands in the need of further developments. For instance, it needs to make clear whether it proposes a full-blown defence of the claim that metaphysics makes science possible, or whether it entails a form of metaphysics which stands on a par with the sciences – a form of metaphysics whose claims are independent of scientific knowledge.

Over the recent years, the maximalist MS has set forth a revival of the old wave, putting forward various arguments for a newly reformulated version of the claim that metaphysics makes science possible. This is what I called *(I2*)*. The maximalist approach is at least committed to the idea that science is unavoidably metaphysical. If that is the case, some form of metaphysical dimension of reality is added to scientific ontology. Recall Mumford and Tugby's (2013) argument: the metaphysical investigation of laws, natural kinds and causal powers makes possible scientific explanations and predictions of various sorts.

Contrary to both the old wave and the maximalist approach, the new wave in the MS proposes a thoroughly naturalistic understanding of the relationship between science and metaphysics. It claims, in brief, that science is a guide to metaphysics, or in other words, that metaphysics is to be motivated by, and restricted to, current best science, as per *(I3)* and *(I4)* respectively. In this view, metaphysics is expected to work hand in hand with the sciences. This brings up a series of consequences. One

is that metaphysical problems are suggested by our current best scientific picture of reality; another is that our best metaphysical account of reality depends on what the world is like according to the sciences; and yet another is that there is no room for science-independent metaphysical knowledge.

The discussion remains open with many questions yet to be settled. Some such questions have to do with whether metaphysics and science are epistemically, methodologically and ontologically on a par, as per *(I5)*. This view needs yet to be further developed, and I do so elsewhere (Soto forthcoming), arguing that the minimalist MS is designed to address three main tasks, namely: first, to defend the scientistic stance; second, to elaborate the epistemic, methodological and ontological desiderata of the MS; and third, to examine the sources and boundaries of scientific ontology.

Area de Logica, Epistemologia y Filosofia de la Ciencia
Departamento de Filosofía
Universidad de Chile
School of Historical and Philosophical Studies
University of Melbourne
Email: cssotto@gmail.com

REFERENCES

Agassi, J. 1975. *Science in Flux*. Dordrecht and Boston, D. Reidel Publishing Company.

_____ 1996. "The Place of Metaphysics in the Historiography of Science", *Foundations of Physics*, Vol. 26, No. 4, pp. 483-499.

Armstrong, D. 2012. "Defending Categoricalism", in Bird et al. eds., 2012, pp. 27-33.

Bird, A. 2012. "Monistic Dispositional Essentialism", in Bird et al. eds., 2012, pp. 35-41.

Bird, A., B. Ellis, and H. Sankey eds. (Bird et al. Eds.) 2012. *Properties, Powers, and Structures. Issues in the Metaphysics of Realism*. New York and London, Routledge.

Bunge, M. 1972. "Is Scientific Metaphysics Possible?", *The Journal of Philosophy*, Vol. 78, No. 17, pp. 507-520.

Chakravartty, A. 2010. "Metaphysics between the Sciences and Philosophies of Science", in Magnus et al. eds., 2010, pp. 59-77.

_____ 2013. "On the Prospects of Naturalized Metaphysics", in Ross et al. eds., 2013, pp. 27-50.

Cohen, R. and M. Wartofsky eds. (Cohen et al. eds.). 1967. *Boston Studies in the Philosophy of Science, Vol. III*. Dordrecht, D. Reidel Publishing Company.

Dilworth, C. 2007 (1996). *The Metaphysics of Science. An Account of Modern Science in Terms of Principles, Laws and Theories*. Second Edition. Dordrecht, Springer.

Ellis, B. 2012. "The Categorical Dimension of the Causal Powers", in Bird et al. eds., 2012, pp. 11-26

Ellis, B., H. Sankey and A. Bird (Ellis et al.). 2012. "Introduction", in Bird et al. eds., 2012, pp. 1-6.

Esfeld, M. 2006. "The Impact of Science on Metaphysics and Its Limits", *Abstracta*, Vol. 2, No. 2, pp. 86-101.

_____ 2007. "Metaphysics of Science between Metaphysics and Science", *Grazer Philosophische Studien*, 74, pp. 199-213.

Feynman, R. 1965. *The Character of a Physical Law*. London, Penguin Books.

Field, H. 1980. *Science without Numbers. A Defence of Nominalism.* Princeton, Princeton University Press.

Hawley, K. 2006. "Science as a Guide to Metaphysics?", *Synthese*, 149, pp. 451-470.

Kincaid, H. 2013. "Introduction: Pursuing a Naturalist Metaphysics", in Ross et al. eds., 2013, pp. 1-26.

Ladyman, J. 2007. "Does Physics Answer Metaphysical Questions?", *Royal Institute of Philosophy Supplement*, Vol. 61, pp. 179-201.

_____ 2011. "The Scientistic Stance: the Empirical and the Materialist Stances Reconciled", *Synthese*, 178, pp. 87-98.

_____ 2012. "Science, Metaphysics and Method", *Philosophical Studies*, Vol. 160, Issue 1, pp. 31-51.

Ladyman, J. and D. Ross, with D. Spurrett and J. Collier (Ladyman et al. eds.). 2007. *Every Thing Must Go. Metaphysics Naturalized*. Oxford, Oxford University Press.

Ladyman, J. and D. Ross. 2013 "The World in the Data", in Ross et al., eds., 2013, pp. 108-150.

Magnus, P. D. and J. Busch eds. (Magnus et al eds.) 2010. *New Waves in Philosophy of Science*. London, Palgrave MacMillan.

Maudlin, T. 2007. *The Metaphysics within Physics*. Oxford, Oxford University Press.

_____ 2012. *Philosophy of Physics. Space and Time*. Princeton, Princeton University Press.

Maxwell, N. 2005. "Scientific Metaphysics", *PhilScience Archive*, http://philsci-archive.pitt.edy/1674/

Melnyk, A. 2013. "Can Metaphysics Be Naturalized? And If So, How?", in Ross et al. eds., 2013, pp. 79-95.

Mumford, S. 2004. *Laws in Nature*. London and New York, Routledge.

_____ 2012. *Metaphysics: A Very Short Introduction*. Oxford, Oxford University Press.

Mumford, S. and M. Tugby (2013), "What is the Metaphysics of Science?", in Mumford et al. eds., 2013, pp. 3-26.

Mumford. S. and M. Tugby eds. (Mumford et al. eds.) 2013. *Metaphysics and Science*. Oxford, Oxford University Press.

Ney, A. 2012. "Neo-Positivist Metaphysics", *Philosophical Studies*, 160, pp. 53-78.

Nubiola, J. 2012. "What a Scientific Metaphysics Really Is (According to C. S. Peirce)", *First European Pragmatism Conference*, http://www.nordprag.org/papers/epc1/Nubiola.pdf

Papineau, D. ed. 1996. *The Philosophy of Science*. Oxford, Oxford University Press.

_____1996. "Introduction", in Papineau ed., 1996, pp. 1-20.

Peirce, C. S. (CP) 1931-1958. *Collected Papers of Charles Sanders Peirce*, Volumes 1-6, C. Harshorne and P. Weiss eds., and Volumes 7-8, A. Burks ed. Cambridge, MA., Harvard University Press.

Psillos, S. 2012. "Anti-Nominalistic Scientific Realism: a Defence", in Bird et al. eds., 2012, pp. 63-80.

Quine, W. v. O. 1953. "Mr. Strawson on Logical Theory", *Mind*, Vol. 62, No. 248, pp. 433-451.

_____ 1981. *Theories and Things*. Cambridge, MA., Harvard University Press.

Redhead, M. 1995. *From Physics to Metaphysics*. Cambridge, Cambridge University Press.

Reynolds, A. 2002. *Peirce's Scientific Metaphysics: The Philosophy of Chance, Law, and Evolution*. Nashville, TN, Vanderblit University Press.

Roberts, J. 2013. "Measurements, Laws, and Counterfactuals", in Mumford et al. eds. 2013, pp. 29-47.

Ross, D. 2012. "Will Scientific Metaphysics Still Be Philosophy?", *Academia.edu* http://www.academia.edu/948847/Will_scientific_philosophy_still_be_philosophy

Ross, D., J. Ladyman, and H. Kincaid, eds. (Ross et al. Eds.) 2013. *Scientific Metaphysics*. Oxford, Oxford University Press.

Sankey, H. ed. 1999. *Causation and Laws of Nature*. Dordrecht, Boston, London, Kluwer Academic Publishers.

Sankey, H. 1999. "Introduction", in Sankey ed., 1999, pp. xi-xvi.

Soto, C. 2013. "Looking for a Realist Metaphysics of Science", *Metascience* 22, pp. 289-292.

_____ 2014. "The Aim and Scope of Scientific Metaphysics", *Metascience* 23, pp. 117-123.

_____ 2015. "Metaphysics, Laws, and Natural Kinds: Minimalist Approaches", *Metascience* 24, pp. 321-331.

_____ Forthcoming. *Issues in the Minimalist Metaphysics of Science*. Doctoral Dissertation, University of Melbourne.

Wartofsky, M. 1967. "Metaphysics as Heuristic for Science", in Cohen et al. eds., 1967, pp. 123-172.

Weinberg, S. 1993. *Dreams of a Final Theory*. London, Vintage.

Woodward, J. 2013. "Laws, Causes, and Invariance", in Mumford et al. eds., 2013, pp. 48-72.