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ARTICLE

Subatomic Particles, Epistemic Stances, and Kantian Antinomies

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Abstract
In *Scientific Ontology*, Chakravartty diagnoses a "dramatic conflict" between empiricism and metaphysics and aims to overcome that conflict by opting for a modern-day variant of Pyrrhonism, i.e. by appreciating the equal strength (*isostheneia*) of the arguments for and against the empiricist and metaphysical positions, and by achieving tranquility (*ataraxia*) by suspending judgment or remaining speechless in the face of that *isostheneia*. In this paper, I want to argue that instead of remaining speechless in the face of the *isostheneia* of the arguments for and against the empiricist and metaphysical positions, we should adopt a position that remains underrated in Chakravartty's analysis: a position that amounts to a modern-day variant of the Kantian combination of transcendental idealism and empirical realism, and that like the original Kantian combination, is capable of solving many instances of the dramatic conflict between empiricism and metaphysics and, in particular, a conflict that is the talk of the town in philosophy of science these days—the conflict between ontic-structural realism and Lewisian metaphysics.

Keywords Metaphysics · Empiricism · Neo-Kantianism · Fundamental physics · Epistemic stances

1 Introduction

In *Scientific Ontology*, Chakravartty argues that a scientific domain of entities cannot be clearly separated from an ontological one: the sciences always incorporate philosophical thinking, and philosophical investigations of ontology typically depart from scientific-empirical explorations of the world. The sciences always incorporate philosophical thinking because for scientists, the world is "carved up" in terms of objects, events, processes and properties, and because carving up the world in this way is a basic requirement for coordinated action in scientific practice. Philosophical investigations depart from scientific-empirical explorations in order to reduce "epistemic risk".

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The problem is that scientific practice and empirical investigation underdetermine scientific ontology (the way in which the world is carved up), and that consequently, scientific ontology results from metaphysical inference. Metaphysical inference involves considerable epistemic risk, and philosophers traditionally disagree about the possibilities of reducing that risk: while empiricists put emphasis on the "empirical vulnerability" of the inference, other philosophers rely on what they perceive to be the explanatory power of metaphysical inference. Chakravartty rightly points out that the power of explanatory power to reduce epistemic risk is contested, and that assessments of how to weigh empirical vulnerability and explanatory power are "ineluctably in the eye of the beholder" (Chakravartty 2017, 111).

Adopting a notion introduced by van Fraassen (2002), Chakravartty identifies the eye of the beholder with that of proponents of "epistemic stances": of stances that relate to the production of knowledge, and that their various proponents adopt in accordance with a broadly pragmatic standard of rationality (with rationality in the sense of internal coherence). Chakravartty distinguishes a deflationary, an empiricist and a metaphysical epistemic stance. But of the deflationary stance he says that he mentions it "primarily so as to set it aside" (Chakravartty 2017, 140); and he decides to turn his attention to the "dramatic conflict" between the empiricist and metaphysical stances of which he says that it "lies at the heart of many of the epic, perennial battles of philosophy down through the ages" (Chakravartty 2017, 32).

It is this dramatic conflict that Chakravartty aims to overcome by opting for Pyrrhonism, which he characterizes as the ability to appreciate the equal strength (*isostheneia*) of the arguments that empiricists and metaphysicians develop to support their claims, and to attain *ataraxia*, i.e. peace of mind or "freedom from worry in the face of previously pressing questions" (Chakravartty 2017, 163), by practicing *aphasia*, i.e. by remaining speechless or suspending judgment about the truth or falsity of the claims of empiricists and metaphysicians in the face of the *isostheneia* of the arguments that they develop in support of their claims.

Scientific Ontology is an inspiring and elegantly written work; and I am very much convinced by the majority of Chakravartty's arguments and positions. In this paper, however, I want to draw attention to the epistemic stance that Chakravartty chooses to set aside. I want to argue that we should adopt a specific variant of the deflationist stance, if we are able to appreciate the *isostheneia* of the arguments that empiricists and metaphysicians develop to support their claims. The variant of the deflationist stance that I think we should adopt is a modern-day variant of the Kantian combination of transcendental idealism and empirical realism. What that variant has in common with Pyrrhonism is that it is capable of overcoming the "dramatic conflict" between the empiricist and metaphysical stances. But it is also preferable to Pyrrhonism because unlike Pyrrhonism, it allows us to continue to speak, i.e. to pass a judgment about the truth or falsity of the claims of empiricists and metaphysicians.

I will begin by providing a somewhat more detailed summary of Chakravartty's book (Sect. 2). I will then discuss an episode of the epic, perennial battles between empiricists and metaphysicians—an episode that is the talk of the town in philosophy of science these days: the conflict between ontic-structural realism and Lewisian metaphysics (Sect. 3). Next, I will emphasize some of the similarities between this conflict and the Kantian antinomies (Sect. 4). I will finally suggest that the ability of neo-Kantianism to solve that conflict strictly parallels the ability of the original combination of transcendental idealism and empirical realism to solve the Kantian antinomies (Sect. 5).

2 Chakravartty on Scientific Ontology and Epistemic Stances

Science is concerned with what there is, and so is ontology, as a branch of philosophy. Is there a way to clearly separate a scientific domain of entities from an ontological one? One might think that the answer is positive, since scientific and philosophical explorations of questions of existence appear so entirely different. Chakravartty, however, argues that the answer is negative; he argues, in particular, for two claims. The first claim is that "the sciences have always incorporated philosophical thinking"; the second that "philosophical investigations of ontology that are wholly disconnected from scientific investigations ignore arguably the best possible starting point for ontological theorizing" (Chakravartty 2017, vi).

Much of *Scientific Ontology* can be regarded as an elaboration of these two claims. In support of his first claim, Chakravartty argues that "one inevitably views the outputs of scientific work through a philosophical lens, whether self-consciously or, as is often the case (especially among those who have never studied philosophy), inadvertently" (Chakravartty 2017, 5). One inevitably views the outputs of science through a philosophical lens because science underdetermines ontology: because "theories and models are often compatible with contrary readings of the ontologies one may describe with them, and they do not themselves indicate which of these readings, if any, is 'correct'" (Chakravartty 2017, 5).

Since science or scientific practice underdetermines scientific ontology, scientific ontology results from "metaphysical inference". By "metaphysical inference", Chakravartty understands a priori reasoning "in metaphysics from data to conclusions" (Chakravartty 2017, 23). He says that typically, the goal of metaphysical inference is to explain observable phenomena in terms of some underlying, unobservable thing, and that the criteria most commonly cited in evaluating the quality of an explanation include simplicity, internal and external consistency, and scope (Chakravartty 2017, 23). Perhaps one may add that given the multitude of these criteria, the quality of an explanation resulting from a metaphysical inference is difficult to assess.

Chakravartty's claim that one inevitably views the outputs of science through a philosophical lens conflicts with the self-perception of many scientists and empiricists who believe to be avoiding metaphysics altogether. But with respect to scientists Chakravartty points out that they often make judgments about the nature or quality (or force) of evidential observations, and that when making such judgments, "one inevitably makes use of a multitude of categories and classifications of objects, events, processes and properties" (Chakravartty 2017, 38). For scientists, the world is carved up in terms of these objects, events, processes and properties; and "[c]arving up the world in this way is a basic requirement for coordinated action in scientific practice and otherwise, not least, for example, in the form of successful communication between scientists and others about the content of empirical science" (Chakravartty 2017, 38). With respect to empiricists, Chakravartty suggests that the verifiability criterion of meaning of the logical empiricists probably qualifies as a piece of metaphysics (Chakravartty 2017, 26), and that many Humean views and denials result from metaphysical inference (Chakravartty 2017, 35).

In support of his second claim, Chakravartty argues that "almost everyone interested in scientific ontology" follows the "norm of naturalized metaphysics", where the norm of naturalized metaphysics is not to be understood narrowly in the Quinean sense or in the sense of ontic-structural realism (which I will be concerned with in Sect. 3), but widely in the sense of "the principle that scientific ontology is properly delimited by

metaphysical inferences and propositions that are sufficiently informed by or sensitive to scientific-empirical investigation" (Chakravartty 2017, 44).

According to Chakravartty, the rationale for this principle is the desire to reduce "epistemic risk". He says that epistemic risk "is a feature of propositions (and the inferences generating them, as conclusions) that determines how confidently one is able to judge whether they are true or false" (Chakravartty 2017, 56). He also says that epistemic risk is inversely proportional to "empirical vulnerability" and explanatory power. While empirical vulnerability "concerns how susceptible a proposition is to empirical testing" (Chakravartty 2017, 56), explanatory power measures "how well a metaphysical inference or resulting proposition satisfies the criteria typically associated with good explanations" (Chakravartty 2017, 57-8).

Chakravartty argues that the determination of epistemic risk "yields an answer to the question of how far a given exercise in ontology is from the ground of empirical inquiry and, in turn, the question of whether the norm of naturalized metaphysics has been satisfied" (Chakravartty 2017, 16). He also points out, however, that "epistemic risk is determined by weighing the contributions of empirical vulnerability and explanatory power" (Chakravartty 2017, 58). And the problem with weighing these contributions is that "the power of explanatory power to affect epistemic risk is hugely contested" (Chakravartty 2017, 58).

Chakravartty asks readers to "imagine a spectrum of metaphysical inferences ranging from smallest 'm' at one end to the largest 'M' at the other" (Chakravartty 2017, 35). He suggests that scientists and philosophers typically agree that "a line should be drawn between small 'm' and big 'M' metaphysics, or magnitudes of metaphysical inference that are conducive to knowledge and those that are so large as to suggest a suspension of belief instead" (Chakravartty 2017, 111). But given the contested nature of the power of explanatory power to affect epistemic risk, the problem is that "assessments of where (if anywhere) a line should be drawn […] are ultimately and ineluctably in the eye of the beholder" (Chakravartty 2017, 111).

Chakravartty argues that assessments of where a line should be drawn depend on "epistemic stances, viz. stances regarding the production of knowledge" (Chakravartty 2017, 31). Unlike propositions or claims about matters of fact, epistemic stances "are not subject to belief, disbelief, or agnosticism" (Chakravartty 2017, 137); they represent "collections of attitudes, commitments, and strategies which determine how one goes about producing ontological claims" (Chakravartty 2017, 137); they "reflect different degrees of epistemic risk one associates with ontological claims" (Chakravartty 2017, 137); and they incorporate "a guideline—like a set of instructions, or policies—for how to behave, epistemically" (Chakravartty 2017, 138).

Chakravartty distinguishes, in particular, three epistemic stances: the deflationary, the empiricist, and the metaphysical (epistemic) stance (Chakravartty 2017, 138). The deflationary stance is that of philosophers who "approach the idea of scientific ontology with a certain amount of wariness" and deflate "literal interpretations of ontological claims in favor of a different conception of them which recasts them in other terms" (Chakravartty 2017, 138). Among these philosophers, Chakravartty includes historicist philosophers, sociologists of science, and pragmatists. He summarizes the "core epistemic policies" of the deflationary stance as follows: "D1 Reject traditional philosophical (i.e. realist) understandings of scientific ontology. D2 *A fortiori*, reject any analyses of truth and reference with which they are typically explicated" (Chakravartty 2017, 139). It is worth noting that what Chakravartty has in mind when speaking of "realist" understandings of scientific ontology is what Putnam calls "metaphysical realism" or what Kant calls "transcendental

realism" (the sort of realism that standard scientific realists, Humeans and anti-Humeans subscribe to, and that even constructive empiricists endorse, as long as observable objects are concerned).

The empiricist stance, by contrast, is "widely emblematic of empiricist thinking about scientific ontology" and "comprises a cluster of attitudes representing a cautious approach to ontological theorizing, in which the limits of reasonable caution are drawn at the boundary of what we can detect using our unaided senses" (Chakravartty 2017, 140). It reflects an intuition that ontological claims beyond the realm of the observable "incur too much epistemic risk to be believed, owing to their insufficient vulnerability to empirical investigation, and the uncompelling nature of the idea that the explanatory power which one may associate with these posits amounts to a form of epistemic warrant" (Chakravartty 2017, 140). Chakravartty summarizes "the core epistemic policies" of that stance as follows: "E1 Reject demands for explanation in terms of things underlying the observable. E2 *A fortiori*, reject attempts to answer these demands by theorizing about the unobservable."

Finally, the metaphysical stance is that of philosophers "with more expansive ontological ambitions" (Chakravartty 2017, 141). Philosophers moved by such ambitions "see the empiricist stance as precluding at least some knowledge of the world which they not only seek to possess, but think is within our grasp" (Chakravartty 2017, 141). These philosophers "are interested in the pursuit of explanatory investigations which aim to furnish descriptions of, among other things, unobservable objects, events, processes, and properties"; and "they take explanatory power seriously as having evidential force in the assessment of hypotheses concerning these entities, and seek to understand things that are too small, or too large, or too distant from us in space and time to be detected using human sensory modalities alone." Chakravartty summarizes "the core epistemic policies" of this stance as follows: "M1 Accept demands for explanation in terms of things underlying the observable. M2 Attempt to answer these demands by theorizing about the unobservable" (Chakravartty 2017, 141).

Chakravartty issues a warning about his distinction of the three stances: he says that each of them "admits of more complex and nuanced formulations in the actual thinking of specific individuals", that "it may be that no two people think about (if they do) or apply these guidelines (knowingly or tacitly) in exactly the same ways", and that there might be "inevitable variation even among those sharing […] a given stance" (Chakravartty 2017, 138). The point of this warning will become evident in the next section, when I will try to disentangle the epistemic stances underlying ontic-structural realism and Lewisian metaphysics. But I also think that Chakravartty is right when saying that "it is possible to consider the kernel of each of these approaches to scientific ontology which is broadly shared by its subscribers" (Chakravartty 2017, 138).

His distinction of the three stances raises the question of how they are adopted and assessed against each other. He argues that these stances are adopted on the basis of two criteria. The first criterion is rationality, where rationality "is understood in a broadly pragmatic way as internal coherence" (Chakravartty 2017, 32). Chakravartty points out that the criterion is adopted from van Fraassen who understands the "defining hallmark" of irrationality as "self-sabotage by one's own lights" (Chakravartty 2017, 32). According to that criterion, people behave or think rationally, as long as they succeed "by their own lights in doing what they set out to do, or at the very least, have no cause for concern that their stances are promoting epistemic inquiries that are doomed to failure" (Chakravartty 2017, 33).

The second criterion "is one's values, in the sense that one may value certain kinds of information and forms of explanation, for example, informed by one's sense of the

importance of these things and the likelihood of success in acquiring them" (Chakravartty 2017, 33). If rationality is understood in this broadly pragmatic way, then rationality will be "very permissive" in the sense that it will allow "different and mutually incompatible stances" to be rational (Chakravartty 2017, 33), and then differences in epistemic stances will reflect differences in values. Philosophers adopting the empiricist and metaphysical stances, for instance, have incompatible values, but are not engaged in self-sabotage by their own lights.

In a move that is less clear to me (and I will comment on below), Chakravartty decides to set aside the deflationary stance: "having paid it due attention and respect, I mention it here primarily so as to set it aside" (Chakravartty 2017, 140). Focusing on the empiricist and metaphysical stances exclusively, he states, on the one hand, that they do not "hold mutually contradictory beliefs regarding matters of putative fact" (Chakravartty 2017, 33), and on the other, that a "dramatic conflict" between them "lies at the heart of many of the epic, perennial battles of philosophy down through the ages" (Chakravartty 2017, 32). Both statements do not necessarily conflict if the first is taken to refer to constructive empiricism, which professes to remain agnostic about non-observable entities, and the second to less radical variants of the empiricist stance (e.g. to Humeanism).

It is this dramatic conflict between (the less radical variants of) the empiricist stance and the metaphysical stance that Chakravartty aims to overcome by opting for Pyrrhonism. Following Sextus Empiricus, he characterizes Pyrrhonism as the ability to appreciate the equal strength (*isostheneia*) of arguments for and against a proposition and to remain speechless or suspend judgment about the truth of the proposition in the face of that *isostheneia*, where speechlessness or suspension of judgment (*aphasia*) are said to result in *ataraxia*, i.e. peace of mind or "freedom from worry in the face of previously pressing questions" (Chakravartty 2017, 163).

I want to argue in the remaining three sections that a specific variant of the deflationist stance is preferable to Pyrrhonism if we are able to appreciate the *isostheneia* of the arguments that empiricists and metaphysicians develop to support their claims. The variant of the deflationist stance that I think is preferable is a modern-day variant of the Kantian combination of transcendental idealism and empirical realism. Like Pyrrhonism (and like the original Kantian combination), the modern-day variant brings peace in the sense that it is capable of overcoming the "dramatic conflict" between the empiricist and metaphysical stances. But unlike Pyrrhonism (and like the original Kantian combination), the modern-day variant allows us to continue to speak, i.e. to solve many of the episodes of the epic, perennial battles between empiricists and metaphysicians by assigning truth-values to their claims.

3 Ontic-Structural Realism and Lewisian Metaphysics

One of these episodes is the conflict between ontic-structural realism and Lewisian metaphysics. Ladyman and Ross (2007, 130) characterize ontic-structural realism (OSR) as the view that "the world has an objective modal structure that is ontologically fundamental, in the sense of not supervening on the intrinsic properties of a set of individuals", and that "even the identity and individuality of objects depends on the relational structure of the world".[1] They point out that OSR contradicts the assumptions of a position that they refer

[1] Earlier statements of the view can be found in Ladyman (1998) and French and Ladyman (2003). Regrettably, limited space does not allow me to discuss the variant of OSR defended by French (2014). I therefore

to as "standard metaphysics" (Ladyman and Ross 2007, 140–151), that coincides with the empiricist or Humean position that David Lewis endorses, and that I will refer to as "Lewisian metaphysics" or "LM" in order to avoid a confusion of the abbreviations for "standard model" and "standard metaphysics". According to Ladyman and Ross, LM relies on the following four assumptions (Ladyman and Ross 2007, 151):

1. There are individuals in spacetime whose existence is independent of each other and of their relations to each other.
2. Each individual has some properties that are intrinsic to it.
3. The relations between individuals other than their spatio-temporal relations supervene on the intrinsic properties of the relata.
4. There are some properties (perhaps including spatio-temporal properties) that distinguish each thing from every other thing, and the identity and individuality of physical objects can be accounted for in terms of these properties.

A property is intrinsic to an individual if it has that property in virtue of what it is in itself; a property is, by contrast, extrinsic to an individual if it has that property only in virtue of its relations to other individuals. Examples of intrinsic properties include the property of being a cuboid or the (relational) property of having longer fingers than toes. Examples of extrinsic properties include the property of being the sister of someone and the property of being a node or edge in a graph. By supervenience, Ladyman and Ross understand Humean supervenience: the doctrine that "all there is to the world is a vast mosaic of local matters of particular fact", and that "all else supervenes on that", i.e. cannot be different without there being a difference in local matters of particular fact (cf. Lewis 1986, x).

Ladyman and Ross argue that OSR contradicts LM with respect to (1)–(3) and possibly with respect to (4) (Ladyman and Ross 2007, 149–151). To their mind, the fundamental entities in spacetime are relations between individuals, not individuals themselves. These individuals do not exist independently of each other or of the relations to each other because they ontologically depend on their relations to each other. Permutation symmetry rules out that there are intrinsic properties, and that relations between individuals supervene on the intrinsic properties of these individuals. With respect to (4), Ladyman and Ross point out that identity and individuality might be "a primitive feature of the structure as a whole that is not accounted for by any other facts about it" (Ladyman and Ross 2007, 151).

Since OSR and LM contradict each other, we may wonder whether we should endorse OSR or LM. I want to argue in this section that this is impossible to tell because the arguments that can be provided in support of or against OSR and LM have equal strength (*isostheneia*). An argument that can be provided in support of OSR is the no-miracles argument (NMA): an inductive (or abductive) argument, according to which (standard) scientific realism is the only explanation for the empirical success of science, where empirical success is usually taken to be predictive, explanatory, or confirmatory success or successful novel prediction (the criterion favored by Ladyman and Ross), and where science is typically understood as our most mature science, which in our time is a combination of quantum mechanics (QM) and the theory of general relativity (GR).

Footnote 1 (continued)
want to emphasize that in the present paper, my criticism of OSR does not necessarily pertain to the variant defended by French.

NMA can be provided in support of OSR because in QM, subatomic particles are not the billiard-ball type of objects that interact by bouncing off of one another. They are rather modes of excitation of quantum fields: placeholders for whatever has the properties associated with them by the theory (mass, charge, spin). They, moreover, exhibit a kind of permutation symmetry: exchanging (or "permuting") particles of the same type leaves the relevant measurement outcomes unchanged and does not result in a new physical arrangement. Accordingly, subatomic particles do not seem to qualify as individuals with intrinsic properties.

Nor do they seem to be independent of each other or of their relations to each other. Their relations to each other obtain between particles that form so-called 'symmetry groups'. Symmetry groups are sets of particles the properties of which are described mathematically in terms of certain quantities that are invariant under certain (so-called 'symmetry group') transformations, such as translations (through space, time, and spacetime) and rotations. Quantities that are unchanged under the action of these transformations are identified with properties such as mass, charge, and spin. The relations that obtain between particles forming symmetry groups do not depend on any intrinsic properties of these particles. It seems, on the contrary, that the identity and individuality of these particles depends on these relations.

But an argument that can be provided against OSR is the pessimistic meta-induction (PMI): an inductive argument departing from the premise that the history of science is full of empirically successful theories which have subsequently been rejected and whose theoretical terms do not refer according to our best current theories, and proceeding to the conclusion that the same fate awaits our best current theories: that GR and QM will turn out to be false even though we presently believe them to be (approximately) true, and that their central terms will turn out to be non-referring.

Many philosophers believe that the scientific realism debate has reached an impasse because NMA and PMI have equal strength. Some philosophers think that the impasse can be broken if realism is restricted to those parts of theories which play an essential role in the derivation of subsequently observed (novel) predictions. If realism is restricted in this way, the terms of past theories, which are now regarded as non-referring, can be regarded as non-essential for the derivation of subsequently observed (novel) predictions. A type of realism that is restricted in this way is "structural realism": a view that emphasizes the mathematical or structural content of our theories, and not the physical (or metaphysical) content that (standard) scientific realists take to describe the nature of things (cf. Worrall 1989).

I want to emphasize, however, that OSR wants substantially more than structural realism. While structural realism emphasizes the mathematical or structural content of our theories, Ladyman and Ross endorse a variant of standard scientific realism. Ladyman and Ross nowhere explicitly endorse the (approximate) truth of GR and QM, but they distinguish formal structures and material structures (Ladyman and Ross 2007, 119), and identify the ontology of the world according to GR with what the apparatus of differential geometry and the field equations describe (Ladyman and Ross 2007, 159). They also claim that "science can discover fundamental structures of reality that are in no way constructions of our own cognitive dispositions" (Ladyman and Ross 2007, 300). One may accordingly say OSR qualifies as a variant of standard scientific realism that is metaphysical, semantic and epistemological in the sense that it assumes that material structures exist independently of our own cognitive dispositions, that the apparatus of differential geometry and the field equations of GR represent these structures, and that we can come to discover these structures (or know that they exist).

But in order to defend that variant of (standard) scientific realism, proponents of OSR need to be able to tip the balance between NMA and PMI in favor of NMA, and it is questionable whether they are able to do so. Ladyman and Ross discuss four well-known objections that have been raised to NMA (Ladyman and Ross 2007, section 2.1.2), and at least one of their responses is inadequate. Since NMA is an inductive (or abductive) argument, its conclusion should be interpreted as saying that the conditional probability of the (approximate) truth of a scientific theory and of the genuine reference of its central terms, given the empirical success of that theory, is high. But Howson (2000, 45) is right when objecting that computing that conditional probability requires knowledge of an outcome space, a probability distribution and so on, and that it is impossible to tell whether there is anything like a well-defined outcome space, probability distribution and so on. Ladyman and Ross (2007, 74) respond that they "suppose that the no-miracles argument is an important consideration in the thinking of many scientists who say they find antirealism unsatisfactory of their aims." But they fail to account for the many scientists who either find antirealism satisfactory of their aims or would find Howson's objection convincing if they were given the chance to consider or entertain it.

It goes without saying that the balance between NMA and PMI cannot be tipped in favor of PMI either. Like NMA, PMI is an inductive argument. Its conclusion should accordingly be read as saying that the conditional probability of the (approximate) truth of a scientific theory and of the genuine reference of its central terms, given the empirical success of that theory, is low. But computing that conditional probability requires a thorough survey of past theories, true and false, successful and unsuccessful, referring and non-referring; and Lewis (2001, 379) is right when objecting that a "moment's reflection on the difficulties of such a survey perhaps indicates why nothing like it has been attempted".

A conclusion to be drawn states that the inductive strength of NMA and PMI is not really assessable, and that it is ultimately impossible to tell whether they are exactly balanced. Chakravartty nicely explains that impossibility when discussing several case studies of the late eighteenth, early nineteenth century theory of caloric: of a theory that posited caloric as a substance to account for phenomena like heating and cooling, and that was later supplanted by the kinetic theory of heat (Chakravartty 2017, 17–18). He cites Psillos as defending the view that the leading scientists who were involved in the development of the theory (Black, Laplace, Lavoisier and so on) did not believe that the theory was true, or that caloric was a material substance. But Chakravartty also cites Chang and Stanford who claim that at the time the leading scientists did indeed believe that the theory was true, and that caloric was a material substance. What these case studies suggest is that realists and antirealists might disagree over whether or not a single theory from the history of science qualifies as a positive instance of the type of theories that figure in the premise of PMI.

Another conclusion to be drawn states that Ladyman and Ross should suspend judgment about the reality of material structures (and the genuine reference of the mathematical models of GR and QM). They say about "the actual world occupied by all observers" that it "is *either* truly tensed, or else merely seems to us to be so given the measurements we can obtain, but is in fact a block universe"; and they say about their metaphysics that it "should avoid presupposing either side of this disjunction" (Ladyman and Ross 2007, 246). They should pass a similar verdict on the disjunction of OSR and its negation. There is no such thing as a scientific consensus about the reality of material structures (not to mention its fundamentality), or about the genuine reference of the central terms of GR and QM.

An argument that can be provided in support of LM says that the special sciences deal with lots of individual objects (atoms, molecules, organisms, agents, social groups,

ecosystems, planets and so on), and that on the face of it, it seems that these objects have intrinsic properties, that their relations to each other supervene on their intrinsic properties, that their intrinsic properties determine their individuality and identity, and that they exist independently of each other and of their relations to each other. Begin with atoms. Their properties—e.g. that of having a certain number of protons and neutrons—are seemingly intrinsic properties; the relations in which they stand to other atoms—especially relations formed by chemical bonding—appear to supervene on their intrinsic properties; their intrinsic properties seem to determine their individuality and identity; and they appear to exist independently of each other and of their relations to each other. But an argument that can be provided against LM says that it fails to do justice to QM: that QM has obtained a degree of confirmation that is "unprecedented" (Ladyman and Ross 2007, 149), that permutation symmetry is an important feature in QM, and that permutation symmetry raises intriguing questions about the identity and individuality of subatomic particles.

It is worth emphasizing that unlike proponents of LM, who fail to account for the adequacy of LM in fundamental physics, Ladyman and Ross come up with a non ad-hoc account of the adequacy of OSR in the special sciences. The account that they come up with is called "rainforest realism" (RR). They choose that name in order to distinguish their account from an account of scientific ontology that is even more parsimonious: from an account that Quine (1978, 162) defends, and of which he says that it is "an open space in the tropical jungle, created by clearing tropes away".

According to RR, "[t]o be is to be a real pattern" (Ladyman and Ross 2007, 233). A pattern (expressed as '$x \rightarrow y$') is the material counterpart of a "projection" $x_L \rightarrow y_L$, i.e. of a computation that is effected by a physically possible computer, and that yields y_L as output when given x_L as input (while x and y are 'materialist-mode' entities, x_L and y_L are 'formal-mode' entities). A pattern is real if and only if two conditions are satisfied (Ladyman and Ross 2007, 233). The first condition requires that $x \rightarrow y$ be "projectible", i.e. that there be a physically possible computer M that could perform the projection $x_L \rightarrow y_L$ given some resolution R on dimensionality D, and that there be at least one other projection $x_L \rightarrow z_L$ that M can perform without changing its program (Ladyman and Ross remark that the second requirement is needed to avoid trivialization of projectibility by reference to an M that simply implements the one-step inference rule 'given x_L, compute y_L''). The second condition requires that $x \rightarrow y$ have a (structural) model "that carries information about at least one pattern P in an encoding that has logical depth less than the bit-map encoding of P, and where P is not projectible by a physically possible device computing information about another real pattern of lower logical depth than $x \rightarrow y$" (Ladyman and Ross 2007, 233).

Logical depth is said to be "a property of structural models of real patterns", "a normalized quantitative index of the execution time required to generate the model of the real pattern in question 'by a near-incompressible universal computer program […]'" (Ladyman and Ross 2007, 220). As such, logical depth is similar to thermodynamic depth, i.e. "the minimum amount of entropy that must be produced during a state's evolution" (Ladyman and Ross 2007, 218). But while the second law of thermodynamics holds for real patterns at the level of many special sciences, we do not know whether it holds at the level of fundamental physics because we ultimately do not know whether the universe is a physical (tensed) process or a block universe. Therefore, Ladyman and Ross prefer to define real patterns in terms of logical depth: in terms of a notion that is more general than that of thermodynamic depth.

RR accounts for the apparent adequacy of QM in the special sciences because it involves ontological scale relativity: the relativity of specific selections of spacetime regions to the specific scales to which scientific disciplines are dedicated. Individual objects (atoms, molecules, organisms, agents, social groups, ecosystems, planets and so on) and the (e.g. causal) relations in which they stand are real patterns, but the reality of these patterns is relative to the scale to which the respective discipline (chemistry, biology, psychology, sociology and so on) is dedicated, and this scale is "to a very great extent, a function of practical human concerns" (Ladyman and Ross 2007, 239).

Because this scale is a function of practical human concerns, the reality of individual objects is only second best to that of objective modal structure. Ladyman and Ross sometimes suggest that the reality of individual objects has always been and will always remain second best: that individual objects are "book-keeping devices" (Ladyman and Ross 2007, 241), "constructs built for second-best tracking of real patterns" (Ladyman and Ross 2007, 242), or "second-order real patterns with respect to some other real patterns" (Ladyman and Ross 2007, 243), and that "no individuals are extra-representational real patterns" (Ladyman and Ross 2007, 243). But in other passages they seem to allow for the possibility that we currently do not know whether there are individual objects, of which the reality is not only second best: for the possibility that at one point, we will be able to develop a (structural) model that carries information about an individual object in an encoding that has the logical depth of QM. Currently, in any case, the only first-order or extra-representational pattern that we know of is objective modal structure.

RR is a sophisticated non ad-hoc account of the adequacy of OSR in the special sciences. But the realism, the adequacy of which it accounts for, is again a variant of standard scientific realism: to say that objective modal structure is the only first-order or extra-representational pattern that we (currently) know of is to say that objective modal structure exists independently of our cognitive dispositions or practical concerns (metaphysical realism), that we can discover objective modal structure (or come to know that it exists) (epistemic realism), and that objective modal structure is represented by the models of QM and GR (semantic realism).

If rationality reduces to a broadly pragmatic criterion, then proponents of OSR and LM succeed "by their own lights in doing what they set out to do", and then the adoption of their respective positions ultimately depends on incompatible epistemic stances. It seems to be clear, however, that the stances underlying LM and OSR do not exactly coincide with the metaphysical and empiricist stances that Chakravartty summarizes when stating epistemic policies M1 and M2 and epistemic policies E1 and E2, respectively. While both stances are metaphysical in the sense that they apply policies M1 and M2, none of them is empiricist in the sense that they apply policies E1 or E2 (i.e. in the sense of the stance underlying constructive empiricism).

The stances underlying OSR and LM may in fact be regarded as different variants of the materialist stance, which van Fraassen (2002, 59) characterizes as a cluster of attitudes that include "strong deference to the current content of science in matters of opinion about what there is" and "an inclination […] to accept (approximative) completeness claims for science as actually constituted at any given time". While the materialist stance underlying OSR represents a cluster of attitudes that include strong deference to the content of QM, the materialist stance underlying LM represents a cluster of attitudes that include strong deference to the current content of the special sciences (and, of course, to predicate logic and everyday experience).

Ladyman and Ross (2007, 64) claim that the stance underlying OSR is a synthesis of the stance underlying constructive empiricism and the materialist stance. It is worth emphasizing, however, that the two stances are incompatible.[2] The entities in terms of which the world is "carved up" (objective modal structure according to OSR, individual objects with intrinsic properties according to LM) are non-observable. As constructive empiricists, Ladyman and Ross should declare themselves agnostic with respect to these entities. But as the materialists that they are, they say that they know that the world is carved up in terms of objective modal structure. It is true that on occasion, van Fraassen talks as if he thought that he knew that the world of our immediate experience is "carved up" in terms of individual objects (cf. Ladyman and Ross 2007, 102). But these statements are lapses and do not necessarily indicate that the empiricist stance underlying constructive empiricism should be (or is capable of being) synthesized with the materialist stance underlying LM (or any materialist stance).

The stances underlying OSR and LM may also be regarded as empiricist in a more Kantian sense (cf. Sect. 4). They then qualify as less radical variants of the empiricist stance, i.e. as stances that are empiricist in the sense that they follow the "norm of naturalized metaphysics" (cf. Sect. 2 above): while OSR is sufficiently informed by QM, LM is sufficiently informed by the special sciences. When regarding them as less radical variants of the empiricist stance, one may also understand them as playing specific roles in the "dramatic conflict" that "lies at the heart of many of the epic, perennial battles of philosophy". Because of the unprecedented degree of precision, with which QM has been confirmed, the stance underlying OSR is arguably more empiricist and less metaphysical than the stance underlying LM. One may accordingly (if somewhat arbitrarily) say that in the dramatic conflict, OSR plays the part of empiricism and LM the part of metaphysics.

Chakravartty argues in Sect. 4 of chapter 5 of *Scientific Ontology* that OSR leads into absurdities: that OSR is either eliminative or non-eliminative, that it is eliminative (non-eliminative) if it assumes that particles do not exist at all (depend ontologically on structures), and that both eliminative and non-eliminative OSR are compelled to stipulate the existence of entities that are ontologically problematic (relations-in-themselves in the case of eliminative and intrinsically-extrinsic properties in the case of non-eliminative OSR). If OSR leads into absurdities, then its adoption cannot be said to be rational even in the broadly pragmatic sense (then proponents of OSR cannot be said to succeed "by their own lights in doing what they set out to do"). I do not think, however, that OSR leads into absurdities. In line with RR, Ladyman and Ross (2007, 254) maintain that it is "an empirical question for any particular common-sense object whether it is a genuine real pattern", and that "eliminativism […] cannot be ruled out a priori". But no matter whether experience tells them to be eliminativists or non-eliminativists: they do not need to stipulate the existence of entities that are ontologically problematic (i.e. of relations-in-themselves or intrinsically-extrinsic properties) because, as they point out, "[a] core aspect of the claim that relations are logically prior to relata is that the relata of a given relation always turn out to be relational structures themselves on further analysis" (Ladyman and Ross 2007, 155).

[2] Van Fraassen views them as incompatible, and Ladyman and Ross know that he views them as incompatible. Nonetheless, they wish to endorse a position that they say relies on a synthesis of the two. Their (ironic?) evocation of Hegelianism (cf. Ladyman and Ross 2007, 62–63) is unhelpful in this context.

4 Kant on Antinomies and Their Solutions

I pointed out toward the end of Sect. 2 that according to Chakravartty, we should suspend judgment or remain speechless in the face of the *isostheneia* of the arguments that can be provided for or against the propositions favored by the empiricist and metaphysical stances, and that our suspension of judgment or speechlessness will result in *ataraxia*. In the present and in the following section, I want to argue that we should not suspend judgment or remain speechless in the face of the *isostheneia* of these arguments: that an alternative stance (a contemporary variant of the Kantian combination of transcendental idealism and empirical realism) should be adopted, and that this alternative stance will allow us to assign truth-values to the respective propositions. I will refer to the conflict between OSR and LM to illustrate that argument.

In the present section, I will argue, in particular, that the conflict between OSR and LM resembles a Kantian antinomy. According to Kant an antinomy is a pair of propositions (thesis and antithesis) that contradict each other and result from a synthetic regression that departs from an appearance (or object of experience) and proceeds to the totality of its conditions (Kant 1781/1787, A411/B438). The regression is synthetic (or non-deductive) because its counterpart, a progression from the totality of the conditions of an appearance to the appearance, as the conditioned of that totality, would be analytic (or deductive) (Kant 1781/1787, A307-308/B364). Kant distinguishes four kinds of synthetic regressions: one departing from the spatio-temporal form (or quantity) of an appearance, one departing from the matter (or quality) of an appearance, one departing from the relation in which an appearance stands to another appearance that causes the former, and one departing from the contingency (or more generally, the modality) of an appearance (Kant 1781/1787, A413-415/B440-442).

For Kant, it is no coincidence that there are exactly four kinds of synthetic regressions. He thinks that there are exactly four groups of pure concepts of the understanding: categories of quantity, quality, relation, and modality. He accordingly believes that there are exactly four antinomies (cf. Kant 1783, §51): (1) *The world has, as to space and time, a beginning* (thesis) vs. *The world is, as to space and time, infinite* (antithesis). (2) *Everything in the world is constituted out of the simple* (thesis) vs. *There is nothing simple, but everything is composite* (antithesis). (3) *There exist in the world causes through freedom* (thesis) versus *There is no freedom but everything is nature* (antithesis). (4) *In the series of causes in the world there is a necessary being* (thesis) versus *There is nothing necessary in this series, but in it everything is contingent* (antithesis).

Thesis and antithesis contradict each other in all four antinomies because the synthetic regression is finite in all four cases of the thesis and infinite in all four cases of the antithesis: in the case of the first antinomy, thesis and antithesis say that spatio-temporal regions occupied by matter are finite and infinite, respectively; in the case of the second antinomy, they say that the divisibility of matter is finite and infinite, respectively; in the case of the third, they say that the chain of causes of an appearance is finite (and interrupted by freedom) and infinite, respectively; and in the case of the fourth, they say that the contingency of an appearance is finite and infinite (that there is and isn't a necessary being), respectively. Kant points out that reason alone cannot decide whether the totality of the conditions of an appearance is finite or infinite, and that consequently, proponents of the thesis (antithesis) cannot solve the antinomies by trying to demonstrate to the proponents of the antithesis (thesis) that the antithesis (thesis) is false.

Kant also believes, however, that reason can become aware of its inherent dialectic and solve the antinomies by adopting a position that combines empirical realism and transcendental idealism. Empirical realism is the position that we cannot decide whether a proposition is true or false unless the object that the proposition relates to is an appearance (or object of experience) (Kant 1781/1787, A371). Transcendental idealism, by contrast, is the position that a priori intuition and thought coordinate experience (Kant 1781/1787, A491-497/B519-525), where "a priori intuition" refers to the pure intuitions of space and time, and "a priori thought" to the pure concepts of the understanding (or categories) and to the pure principles of the understanding (which for Kant, coincide with the axioms of intuition, the anticipations of perception, the analogies of experience, and the postulates of empirical thought in general). These a priori intuitions, concepts and principles coordinate experience in the sense that they represent transcendental conditions of experience or necessary conditions of the possibility of experience, as Kant also likes to say.

Transcendental idealism needs to complement empirical realism because without transcendental idealism, empirical realism would remain agnostic about the necessary conditions of the possibility of experience: about the "objective validity" or "objective reality" of the categories of substance and causality, for instance. But on the other hand, empirical realism needs to complement transcendental idealism because without empirical realism, transcendental idealism would remain a free-floating metaphysical enterprise like dogmatism (the position endorsed by the proponents of the theses) or empiricism (the position endorsed by the proponents of the antitheses). It is this combination with empirical realism that puts transcendental idealism ahead of dogmatism and empiricism. Like Kant, dogmatists and empiricists depart from appearances. But unlike Kant, they proceed to finite and infinite totalities of the conditions of these appearances; and unlike Kant's a priori intuitions, concepts and principles, these totalities fail to qualify as necessary conditions of the possibility of experience.

Adopting a position that combines empirical realism and transcendental idealism solves the antinomies because it allows for assignments of truth-values. Adopting that position allows, more specifically, for the conclusion that the theses and antitheses of the first and second antinomies are false, and that the theses and antitheses of the third and fourth antinomies are true (Kant 1781/1787, A531-2/B559-60). The theses and antitheses of the first and second antinomies are false because it is false to say of an indefinite synthetic regression that it will proceed *ad finitum* or *infinitum* when departing from the quality or quantity of an appearance (1783, §52). The theses and antitheses of the third and fourth antinomies are true because they hold for different "worlds": for the world of morality in the case of the theses, and for the world of appearances (or nature) in the case of the antitheses of the third and fourth antinomies. The theses of the third and fourth antinomies are true for the moral realm because (Kant believes that) freedom and a necessary being can be shown to represent transcendental conditions of the determination of the human will by the moral law (Kant 1788, A219-240). The antitheses of the third and fourth antinomies are true for the world of appearances because (Kant believes that) there would be no greatest systematic unity in experience if it were impossible to proceed ad infinitum when departing from a causal relation or the modality of an appearance (Kant 1781/1787, A672/B700).

In order to argue that the conflict between OSR and LM resembles a Kantian antinomy, I want to suggest that synthetic regressions that depart from appearances and proceed to totalities of conditions of these appearances represent special cases of what Chakravartty calls "metaphysical inference". Remember that according to Chakravartty, metaphysical inference is reasoning in metaphysics from data to conclusions: reasoning that is fueled primarily by non-empirical considerations and aims to explain observable phenomena in

terms of, non-observable phenomena. If synthetic regressions that depart from appearances and proceed to totalities of conditions of these appearances represent special cases of metaphysical inference, there will be no need to insist that antinomies represent pairs of propositions that result from synthetic regressions; they may likewise be understood as pairs of propositions that result from metaphysical inferences more generally.

If antinomies are understood as pairs of propositions that result from metaphysical inferences more generally, it will also be unnecessary to insist that there are exactly four of them. I indeed believe that "many of the epic, perennial battles of philosophy down through the ages" are fought between philosophers who conduct inferences that depart from data (appearances or objects of experience) and proceed to propositions that contradict each other and refer to underlying, non-observable phenomena that are meant to be explanatory of data (or appearances) in some way. I accordingly believe that in addition to the four Kantian antinomies there is an antinomy consisting of the proposition that there are dispositional properties and the proposition that dispositions reduce to categorical properties; an antinomy consisting of the proposition that laws of nature represent relations of necessitation between universals and the proposition that laws of nature represent regularities; an antinomy between OSR and LM and so on.

The antinomy between OSR and LM resembles the second of the Kantian antinomies because like the second of the Kantian antinomies, it represents a pair of propositions that contradict each other and result from metaphysical inferences that depart from the matter of appearances. It will turn out in the following section, however, that with respect to truth-values, the antinomy between OSR and LM resembles the third or fourth of the Kantian antinomies: that as long as experience in fundamental physics and the special sciences is not required to have greatest systematic unity, both OSR and LM may be true.

I also want to suggest that the finiteness and infinity of the synthetic regressions in the cases of the theses and antitheses, respectively, reflect different epistemic stances. Kant refers to the proponents of the theses as "dogmatists" and to the proponents of the antitheses as "empiricists" (Kant 1781/1787, A466/B494). One might accordingly think that the different epistemic stances should be referred to as "dogmatist" and "empiricist", respectively. There are, however, two provisos that need to be kept in mind. The first is that the Kantian distinction between dogmatists and empiricists is not very clear-cut. Note, for instance, that Hume (2009, 25)—the empiricist *par excellence*—endorses the thesis and not the antithesis of the second antinomy when saying that units are not real unless they are "perfectly indivisible, and incapable of being resolv'd into any lesser unity". The second proviso is that the distinction between a dogmatist and empiricist stance does not coincide with Chakravartty's distinction between a metaphysical and empiricist stance unless in Chakravartty's distinction, the empiricist stance is identified with a stance that is less radical than that of the constructive empiricist.

I finally want to suggest that what Kant calls "logical use of reason" roughly coincides with rationality in the broadly pragmatic sense favored by Chakravartty and van Fraassen. For Kant, the logical use of reason is the use of reason to conduct non-immediate (deductive as well as non-deductive) inference (Kant 1781/1787, A303-304/B360-361), and a special case of non-immediate inference is a synthetic (or non-deductive) regression that departs from appearances and proceeds to totalities of conditions of these appearances. The logical use of reason roughly coincides with rationality in the broadly pragmatic sense because someone who conducts non-immediate inference when proceeding from arbitrarily chosen premises to conclusions can be said to succeed by her own lights in doing what she set out to do (or not to be engaged in self-sabotage by her own light). It is important to understand, however, that for Kant, the logical use of reason is not the only use of reason,

and that another important use is the critical one (Kant 1781/1787, A516/B544). For Kant, that is, rationality does not reduce to rationality in the broadly pragmatic sense but incorporates the ability of reason to become aware of its inherent dialectic and to solve the antinomies by adopting a position that combines empirical realism and transcendental idealism.

It goes without saying that the original Kantian combination of empirical realism and transcendental idealism cannot solve the antinomy of OSR and LM. The reason is that the a priori intuitions of space and time and the pure concepts and principles of the understanding are meant to represent necessary conditions of our experience of the macro-objects of Newtonian mechanics, and that Newtonian mechanics has been replaced with a new scientific paradigm: GR and QM. That the original Kantian combination cannot solve the antinomy of OSR and LM is not supposed to mean, however, that the Kantian project of naturalizing metaphysics by identifying the transcendental conditions of experience is dead. It means, on the contrary, that the Kantian project will continue to live if the a priori intuitions of space and time and the pure concepts and principles of the understanding are either replaced or supplemented with the transcendental conditions of experimental observation in GR and QM. They require replacement if experience in fundamental physics and the special sciences is supposed to have greatest systematic unity, but supplementation will do if that experience is not required to have greatest systematic unity.

Replacing the a priori intuitions and pure concepts and principles of the understanding with the transcendental conditions of experimental observation in GR and QM has, of course, always been part of the program of neo-Kantian philosophers like Reichenbach. According to Reichenbach, the meaning of "a priori" in "a priori intuitions, concepts, and principles" is twofold: it means (1) "necessary" or "strictly valid for all times", on the one hand, and (2) "constitutive" of the objects of experience, on the other. Reichenbach (1920, 243f.) believes that there are so-called "coordinating principles", which are crucial to any physical theory, and that these coordinating principles are constitutive of the objects of that theory. Reichenbach also believes, however, that one of the lessons of the advent of GR is that the first meaning of "a priori" needs to be abolished: that unlike the intuitions of space and time and the concepts and principles of the understanding, coordinating principles are not a priori in the sense of "necessary" or "strictly valid for all times".

More recently, Friedman (2001) has taken up and developed Reichenbach's program. He argues that Newton's three laws of motion implicitly define gravitational changes of momentum relative to space and time; that as implicit definitions, they represent transcendental conditions that make the theory (or law) of universal gravitation possible as a properly empirical statement; and that something similar happens in GR: that Einstein's 'kinematical' definition of simultaneity in terms of the constancy and invariance of the speed of light implicitly defines the relativistic (Lorentzian) inertial frames, and that as implicit definition, it represents a transcendental condition that makes Maxwell's equations possible as a properly empirical statement; that Einstein's principle of equivalence implicitly defines the state of 'freely falling' motion, and that as an implicit definition, it represents a transcendental condition of the empirical significance of the mathematical geodesics of the variably curved space–time geometry of GR; and so on.

Neo-Kantian philosophers like Reichenbach and Friedman are primarily concerned with experimental observation and its transcendental conditions in fundamental physics. They accordingly call for a replacement of the a priori intuitions and pure concepts and principles of the understanding with the transcendental conditions of experimental observation in GR and QM: for a replacement of these intuitions, concepts and principles with Einstein's 'kinematical' definition of simultaneity, Einstein's principle of equivalence, and so

on.[3] The conjunction of the transcendental conditions of experimental observation in GR and QM can be referred to as "structure", but then structure must not be misinterpreted as a thing-in-itself or object that exists independently of current scientific practice.

But the a priori intuitions and pure concepts and principles of the understanding only need to be supplemented with structure if experience in fundamental physics and the special sciences is not required to have greatest systematic unity. If that requirement is dropped, then at least some of the conditions that Kant identifies with the transcendental conditions of experience can be retained as coordinating principles for the special sciences. The category of substance, for instance, can be retained as a coordinating principle because according to Kant, it makes possible our experience of individual objects with (intrinsic) properties. There accordingly seems to be a sense in which structure and the category of substance (and possibly a bunch of other principles) can be said to supplement each other, if experience in fundamental physics and the special sciences is not required to have greatest systematic unity.

5 Neo-Kantianism

It is the continuing life of the Kantian project that motivates my claim that a modern-day variant of the Kantian combination of transcendental idealism and empirical realism is capable of solving the antinomy of OSR and LM. In the present and final section, I want to substantiate that claim by first explaining what I understand by that modern-day variant; by then explaining why the epistemic stance underlying that modern-day variant represents a variant of the deflationary stance that Chakravartty chooses to set aside; by then distinguishing the two senses in which that modern-day variant can be said to solve the antinomy between OSR and LM; and by finally emphasizing some of the major differences between that variant and OSR.

I refer to the modern-day variant of the Kantian combination of transcendental idealism and empirical realism as "neo-Kantianism". By "neo-Kantianism" I understand the position that

(NK1) scientific experience is supposed to have greatest systematic unity, and that structure (i.e. the conjunction of Einstein's 'kinematical' definition of simultaneity, Einstein's principle of equivalence, and so on) represents a necessary condition of the possibility (or transcendental condition) of that experience; or (alternatively) the position that

(NK2) scientific experience is not required to have greatest systematic unity, and that structure represents a transcendental condition of experimental observation in GR and QM, while the category of substance and possibly a bunch of other principles represent transcendental conditions of experience in the special sciences.

The presentation of an exhaustive list of transcendental conditions of experimental observation in GR and QM and of experience in the special sciences would be the objective of an extensive research project. In the present context, I just want to remark that the

[3] Other neo-Kantian philosophers have added Riemann's geometry, Noether's theorems, Feynman's path integrals, and non-commutative geometry (cf. Bitbol et al., 2009, 22–25).

transcendental conditions of experience in the special sciences are likely to include the category of substance and possibly a bunch of additional principles.[4] I also want to remark that the conjunction of the transcendental conditions of experimental observation in GR and QM can be referred to as "structure" if structure is understood as the conjunction of mathematical models from GR and QM, and not as material or objective modal structure.

In the present context, "transcendental condition" means roughly the same as "coordinating principle", but by "coordinating principle" I do not necessarily mean what Reichenbach has in mind, but rather what Chakravartty has in mind when speaking of "a multitude of categories and classifications of objects, events, processes and properties" that scientists make us of when making judgments about the nature or quality (or force) of evidential observations (Chakravartty 2017, 38). These "categories and classifications" (or "coordinating principles") determine how the world is "carved up"; and Chakravartty remarks that "[c]arving up the world in this way is a basic requirement for coordinated action in scientific practice and otherwise, not least, for example, in the form of successful communication between scientists and others about the content of empirical science" (Chakravartty 2017, 38).

Positions (NK1) and (NK2) represent modern-day variants of transcendental idealism that combine with some sort of realism about observable entities to form contemporary variants of Kant's original combination of transcendental idealism and empirical realism. The realism in question can be thought of as constructive empiricism minus its refusal to explain observable entities in terms of underlying, unobservable entities, i.e. as metaphysical, semantic and epistemic realism about observable entities. But the neo-Kantian is more likely to endorse a position, according to which observable entities do not exist independently of scientific practice because observations (laboratory measurements and manipulations) are paradigm-dependent. That position may be understood as realist in the minimal sense of implying that underlying our scientific discourse about observable entities is the principle that the world contains these entities.

It seems to me that the stance underlying neo-Kantianism is a variant of the epistemic stance that Chakravartty refers to as "deflationary". Proponents of neo-Kantianism reject a transcendentally realist understanding of coordinating principles like Einstein's 'kinematical' definition of simultaneity, Einstein's principle of equivalence, the category of substance and so on; and they refuse to analyze the truth of these coordinating principles as the truth of principles that refer to entities that exist independently of scientific practice and experience ("things-in-themselves"). As a deflationary stance, the stance underlying neo-Kantianism in fact comes closest to the pragmatic variant of the deflationary stance.

Remember from Sect. 2 that Chakravartty decides to set aside the deflationary stance and to be concerned with the empiricist and metaphysical stances exclusively. I now want to argue that this decision is unfortunate because in the shape of the stance underlying neo-Kantianism, the deflationary stance gives rise to a position that is capable of solving antinomies and, in particular, the antinomy of OSR and LM. If rationality does not reduce to a broadly pragmatic criterion, but includes the ability of reason to become aware of its inherent dialectic (or the ability to appreciate the *isostheneia* of the arguments that empiricists and metaphysicians develop to support their positions), then the deflationary stance is preferable to the empiricist stance and the metaphysical stance.

[4] If causality does not supervene on individual objects with intrinsic properties, the category of causality will figure among the transcendental principles of experience in the special sciences.

I pointed out in Sect. 3 that arguments that can be provided for or against OSR and LM have equal strength (*isostheneia*), and that it is accordingly impossible to decide which of them is true. This point no longer obtains, once OSR and LM are interpreted as statements assigning a property—fundamentality—to objects of which we do not know whether they exist independently of current scientific practice: to the objective counterpart of structure in the case of OSR, and to substances in the case of LM. Once OSR and LM are interpreted in this way, there are two senses in which the antinomy of OSR and LM can be said to be solved: either both OSR and LM are true, or OSR is true, while LM is false.

Both OSR and LM are true if scientific experience is not required to have greatest systematic unity. If scientific experience is not required to have greatest systematic unity, then both the objective counterpart of structure and substances (and possibly a bunch of other entities) may be fundamental. To say that both are fundamental is not contradictory because structure coordinates (or is a transcendental condition of) experimental observation in GR and QM, while the category of substance coordinates (or is a transcendental condition of) experience in the special sciences. But if scientific experience is supposed to have greatest systematic unity, then structure coordinates scientific experience in general: then OSR is true, while LM is false.

Why does structure, and why does not the category of substance coordinate scientific experience in general? The reason is that the indefinite synthetic regression that proceeds from scientific experience (the matter of appearance) to the totality of its conditions currently ends with the objective counterpart of structure, and not with the objective counterpart of the category of substance. It is perhaps worth mentioning that the regression is not to be misunderstood as a reduction in the sense of any of the reductionist programs that Ladyman and Ross (2007, Section 1.5) criticize, and that it must not be confused with the analytical procedure that RR makes reference to: with the procedure of developing computational models that carry information about patterns in encodings that have logical depth less than the bit-map encoding of the patterns. The indefinite synthetic regression is rather a generalization of the synthetic inverse of that procedure.[5]

When interpreting OSR and LM as statements assigning the property of fundamentality to objects of which we do not know whether they exist independently of current scientific practice, neo-Kantians believe in the truth of OSR or LM with a degree that is not particularly high. That degree corresponds roughly to the degree with which Kant believes in the truth of the theses and antitheses of the third and fourth antinomies, once they have been solved. Unlike transcendental principles (like the analogies of experience), these theses and antitheses do not express a priori knowledge, but pragmatic beliefs (Kant 1781/1787, A824-5/B852-3). Unlike beliefs in the truth of the theses or antitheses of the unsolved antinomies, pragmatic beliefs are not doctrinal beliefs (Kant 1781/1787, A825/B853). But unlike beliefs expressed by the transcendental principles, pragmatic beliefs do not result from transcendental proofs, but only from pragmatic arguments, i.e. from arguments that proceed from premises that we do not know and either desire or not desire to be true. For Kant, pragmatic beliefs have accordingly a lower epistemic status than beliefs in the truth of the transcendental principles.

The premise, from which the pragmatic argument in favor of the truth of OSR or LM proceeds, is the same as the premise from which Kant's pragmatic argument in favor of

[5] Ladyman and Ross suggest that there is a generalization of the analytical procedure when arguing that RR can be explicated in statistical terms (cf. Ladyman and Ross 2013) or dynamical terms (cf. Ladyman, 2017), and not only in information-theoretic terms.

the antitheses of the third and fourth of the antinomies proceeds: the premise that scientific experience has greatest systematic unity. There is no fact of the matter as to whether that premise is true. While scientists and philosophers with unitary leanings may desire it to be true, special scientists who find it absurd to think that the patterns they are investigating have only second-order reality, or philosophers who reject the idea of unity in science, may desire it to be false. The degree with which they believe in the truth of that premise should, in any case, be that of a pragmatic belief; and that degree is of course passed on to beliefs in the truth of OSR or LM.

The claim that there is no fact of the matter as to whether that premise is true is, of course, a claim that Cartwright and Dupré defend (Ladyman and Ross discuss their respective positions on pp. 5–6 of *Every Thing Must Go*). It is worth emphasizing that Ladyman and Ross do not deny the claim: the degree with which they believe in the truth of the premise that scientific experience has greatest systematic unity is that of a pragmatic belief. But the degree with which they believe in that premise is *not* passed on to their belief in the truth of OSR. They, in short, endorse a variant of scientific realism that is unwarranted given the pragmatism of their belief in the premise that scientific experience has greatest systematic unity.

The type of pragmatism that Ladyman and Ross (2007, 27) say they endorse is the "broadly Peircean verificationism" embodied in the "principle of naturalistic closure" (PNC), according to which "[a]ny […] metaphysical claim that is to be taken seriously […] should be motivated by […] the service it would perform, if true, in showing how two or more specific scientific hypotheses, at least one of which is drawn from fundamental physics, jointly explain more than the sum of what is explained by the two hypotheses taken separately" (Ladyman and Ross 2007, 37). An important principle that figures in PNC is the "primacy of physics constraint" (PPC), which says that "[s]pecial science hypotheses that conflict with fundamental physics […] should be rejected", and that "[f]undamental physics hypotheses are not symmetrically hostage to the conclusions of the special sciences" (Ladyman and Ross 2007, 44). It is because of PPC that of the two or more specific scientific hypotheses mentioned in PNC, at least one needs to be drawn from fundamental physics.

Ladyman and Ross (2007, 43) point out that two inductive arguments from the history of science speak in favor of PPC: that scientific hypotheses reducing physical outcomes to non-physical entities or processes have failed, and that processes in living systems have come to be largely or entirely understood in terms of physical entities or processes. Ladyman and Ross (2007, 44) also claim that PPC is "a regulatory principle in current science" that "should be respected by naturalistic metaphysicians". Note, however, that PNC cannot "motivate" any metaphysical claims, if "motivate" is to mean as much as "justify". What PNC (with PPC as an essential ingredient) motivates is the claim that structure coordinates scientific experience in general. It does not (and cannot) motivate the claim that there is objective modal structure, that the apparatus of differential geometry and the field equations of GR represent material structures (Ladyman and Ross 2007, 119, 159), that there are "fundamental structures of reality" that we can discover, and that are "in no way constructions of our own cognitive dispositions" (Ladyman and Ross 2007, 300), and so on. The variant of scientific realism that Ladyman and Ross endorse is, in other words, unwarranted given the type of pragmatism they endorse.

In Sect. 3, I characterized the variant of scientific realism that Ladyman and Ross endorse as a variant of standard scientific realism. Ladyman and Ross do not subscribe to all tenets of standard scientific realism. They say, for instance, that their metaphysics "is the best metaphysics we can have at *t*": that their metaphysics is "probably not true", but

"at least motivated by out most careful science at time *t*" (Ladyman and Ross 2007, 2). There is the question of whether they can afford to reject some of the tenets of standard scientific realism: of whether their variant of scientific realism does not simply collapse into the full-blown version of standard scientific realism.[6] I will not be able to decide this question in the present paper. But I want to insist that OSR is sufficiently different from neo-Kantianism to qualify as a variant of standard scientific realism.

By way of conclusion, I would like to re-emphasize the most decisive difference between OSR and neo-Kantianism. While OSR amounts to a variant of standard scientific realism about the entities, in terms of which the world is carved up (about objective modal structure), neo-Kantianism maintains that what carves up the world are transcendental conditions of scientific experience. These transcendental conditions may have a counterpart in reality, but we must not be realists about that counterpart because we do not know whether that counterpart exists independently of current scientific experience, or whether it is in fact fundamental. The decisive difference between OSR and neo-Kantianism is accordingly that OSR is a position about the fundamentality of an entity (objective modal structure) that is believed to exist independently of current scientific practice, while neo-Kantianism is a position about an entity of which we do not know whether it is ontologically fundamental, or whether it exists independently of current scientific experience. I take it that Ladyman and Ross agree that this difference is decisive when comparing their position with the Kantian position in a section titled "Why this isn't Kant": "Unlike Kant, we insist that science can discover fundamental structures of reality that are in no way constructions of our own cognitive dispositions" (Ladyman and Ross 2007, 300).

I argued in Sect. 3 that together with LM, OSR forms an antinomy, and that like LM, OSR expresses a belief that is only doctrinal. But I also argued in the present section that neo-Kantianism is capable of solving that antinomy. The capability of solving antinomies is what puts neo-Kantianism (or the deflationist stance underlying it) ahead of the empiricist and metaphysical stances, but also ahead of Pyrrhonism, if rationality does not reduce to a broadly pragmatic criterion, but includes the ability to appreciate the equal strength of the argument that empiricists and metaphysicians develop to support their positions (i.e. the ability of reason to become aware of its inherent dialectic). *Scientific Ontology* is a wonderful book. I just felt that I needed to say something in favor of the epistemic stance that Chakravartty chooses to set aside.

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[6] Note in this context that Ladyman and Ross (2007, 156–157) deal with the objection that structural realism collapses into standard scientific realism. Remember from Sect. 3, however, that OSR wants substantially more than structural realism: that OSR is concerned with material structures, while structural realism only deals with formal structures. Ladyman and Ross argue (successfully, to my mind) that structural realism does not collapse into standard scientific realism. But they fail to consider the objection that OSR collapses into standard scientific realism.

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