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Constitutive elements through perspectival lenses

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Abstract

Recent debates in philosophy of science have witnessed the rise of two major proposals. On the one hand, regarding the conceptual structure of scientific theories, some believe that they exhibit constitutive elements. The constitutive elements of a theory are the components that play the role of laying the foundations of empirical meaningfulness, and whose acceptance is prior to empirical research. On the other hand, as for the nature of scientific knowledge and its relation to nature, perspectival realism has pursued a middle ground in classic debates between realism and antirealism, by assuming that although knowledge is always situated both historically and culturally, scientific statements have truth values and constitute genuine claims about a mind-independent world. In this paper, I argue that these two lines of research are not only compatible but complement each other, and provide a common view of science. I contend that a theoretical perspective is a set of constitutive elements where models and representations may develop, and stress that both constitutivism and perspectivism have numerous shared characteristics, such as their vindication of the historicity of scientific knowledge, their recognition of human epistemic limits, and a very similar conception of truth.

Keywords Perspectival realism · Perspectivism · Relative a priori · Constitutive a priori · Scientific realism · Michael Friedman · Hans Reichenbach · Ronald Giere · Michela Massimi

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1 Introduction

It is widely accepted among scholars that scientific theories exhibit constitutive elements (Friedman 2001, 2010; Richardson 2002; Massimi 2005; Chang 2008; Bitbol et al. 2009; Stump 2015).[1] Those who claim that scientific theories have constitutive features believe that their diverse identifiable parts — a formal language for mathematical calculus, fundamental principles, kind terms, empirical statements and the like — are of unequal conceptual importance within the theory involved, so that some foundational elements are taken as conceptual conditions that must be met by all subsequent empirical statements. A classic example is provided by Newtonian mechanics, where it is impossible to make any sense of universal gravitation or simple harmonic motion without already presupposing the applicability of the Newtonian laws of motion. Since the meaning of all possible empirical statements is conditioned by prior commitment to a theoretical background that functions as a condition for the possibility of the entire theory's meaningfulness, it is said that the elements that form this background are a kind of relativized a priori (Reichenbach 1920; Friedman 1999, 59).

In a parallel effort, in the context of the undying realism-antirealism debate, a new face of realism has been added to its many guises in recent years. I refer here to *perspectivism* or *perspectival realism*, principally developed by Giere (2006) and Massimi (2017, 2018; see also Massimi and McCoy 2019). This "new face" is distinguished from previous ones since it does not emerge as an argument against antirealism, but rather aims to overcome the terms of an irresolvable dispute.[2] Perspectivists recognize the epistemic limits of human cognition by assuming that knowledge is always situated both historically and culturally (Massimi 2017), but nonetheless contend that scientific statements have truth values and constitute genuine claims about the world.[3] Thus, perspectivism does not attempt to counter classical antirealist arguments with realist counterarguments, but rather to amalgamate what seems correct about both sides of the debate.

This paper is motivated by a striking fact: fairly frequently, the former account pays no attention to the eventual consequences that the presence of constitutive elements might have in the context of realism.[4] Given this issue, I will here seek to demonstrate that there are strong affinities between the view that scientific theories present constitutive elements and perspectival realism. Roughly stated, the goal to be pursued is to argue that scientific theoretical perspectives are always committed to a set of constitutive elements taken as necessary presuppositions. My goal, however, is not to identify theoretical perspectives with constitutive elements. Instead, I claim that every theoretical perspective first requires a set of constitutive elements to be in place, so that those constitutive elements will determine how that perspective addresses reality. It is my aim to show that perspectivists and constitutivists share similar views of science; but while constitutivists have focused on the conceptual structure of scientific theories, perspectivists have paid attention to the nature of scientific

[1] Particularly, but not only physics. See Sober (2011), Díez and Lorenzano (2015) and Luchetti (2018) for examples extracted from biology. See Friedman (2011) for its application to the history of astronomy.

[2] The idea that the dispute cannot be solved because both realism and antirealism are flawed is usually attributed to Fine (1986, ch. 7 & 8). Whether the debate is resolvable or not, and what perspectival realism has to say to that effect, will be addressed in section 3.

[3] "And not merely claims about beliefs about the world", Giere (2013, 53) says.

[4] There are some exceptions to this general trend. As pointed out by an anonymous referee, van Fraassen (2008) constitutes one blatant case.

knowledge and its relation to nature. Also, I ought to highlight that both lines of research are not only compatible but also complement each other and provide a common view of science. It will be claimed that both constitutivists and perspectivists have many shared characteristics, such as vindicating the historicity of scientific knowledge, recognizing human epistemic limits and a very similar conception of truth.

The paper is structured as follows. In section 2, I will trace the evolution of the constitutive and relative a priori, from the inchoate interpretation of Reichenbach (1920) to the contemporary pragmatic reading (Chang 2008; Stump 2015). This "pragmatic turn" will prove to be relevant since substantial similarities between pragmatism and perspectivism have recently been advanced by Chang (2019). Moreover, although I will assert that it is possible to identify constitutive elements in physical theories, I will also offer some criticism of the idea that the liberalization of the "a priori" remains on the pathway of any legitimate Kantianism. After defining "constitutive element" in section 3, I will present an overview of perspectival realism and discuss how it can be made compatible with the relative a priori. Once these common grounds have been established, in section 4 I will examine Massimi's concept of perspectival truth (2018) as overcoming some difficulties of perspectivism. To conclude, in section 5 I will summarize the reasons offered to view the constitutive elements of scientific theories through perspectival lenses.

2 From the dynamics to the pragmatics of reason

My goal in this section will be to define "constitutive element" in a way that makes it compatible with perspectival realism. I will argue, however, that we cannot regard constitutive principles as a priori in any proper Kantian sense.

2.1 Constitution as coordination: Reichenbach's account

Since Friedman (1999, 2001) popularized Reichenbach's typology of the a priori, it has received significant attention (de Boer 2011; Padovani 2011; Darrigol 2018). The heart of Reichenbach's work is the replacement of Kant's "contribution of reason" to knowledge by a far more modest notion of constitution capable of addressing conceptual changes in physical theories. He carries this out by separating two meanings of a priori: "a priori" as "necessarily and transcendentally true", and "a priori" as "constitutive of experience" (Reichenbach 1920, 48–50). While the Kantian conception encompasses both senses, Reichenbach only keeps the latter. An immediate consequence is that a priori statements are not defined by timelessness: "a priori", asserts Reichenbach, "means 'before knowledge', but not 'for all time' and not 'independent of experience'" (1920, 105). Therefore, scientific principles have an eminently historical character. In light of these remarks, what happened with the emergence of the theory of relativity was not the refutation of Kant's "doctrine of the a priori", but only its transformation "into the theory that the logical construction of knowledge is determined by a special class of principles, […] the significance of which has nothing to do with the manner of its discovery and the duration of its validity" (1920, 94). Reichenbach called the principles responsible for the constitution of experience "axioms of coordination" or "coordinating principles".

A Kantian driving force certainly propels Reichenbach's early ideas on constitution. He claimed that "if perceptual data are to be ordered to result in knowledge, there must exist principles defining this coordination more precisely" (1920, 56), that is, principles that stipulate the conditions of applicability of physical laws. In Reichenbach's early work, axioms of coordination comprise a wide variety of principles, ranging from specific scientific principles — such as absolute time in the context of Newtonian mechanics — to much more general principles that mediate our epistemic engagement with reality, such as the principle of normal induction, the principle of probability, and the principle of genidentity. As Padovani has lucidly expressed, "many of these coordinating principles are *de facto* preconditions for the individuation and the determination of physical magnitudes" (Padovani 2017, 54). These principles or axioms of coordination define "the individual thing in the 'continuum' of reality" or "the individual elements of reality", and in this sense, they "constitute the real object" (Reichenbach 1920, 50–53). Hence, Reichenbach's axioms of coordination and Kant's synthetic a priori statements share the characteristic of being constitutive of experience (Reichenbach 1920, 47).

There is a more profound sense in which the similarities between Kant's and Reichenbach's views of scientific principles can be understood. As van Fraassen (2008, ch. 5) and — more explicitly — Padovani (2017) have shown, coordination does not merely proceed top-down; rather there is a crucial bottom-up sense in which coordination takes place. That is, in essence, what distances Reichenbach's account from conventionalism. Axioms of coordination are not definitions, and its presupposition does not merely determine the constitution of experience, but rather "the existence of reality is expressed in this mutuality of coordination" (Reichenbach 1920, 42). In the words of van Fraassen, the physical object is "not defined independently of that coordination, but defined *in* the coordination" (2008, 123; emphasis added). Here we taste an account of a noticeable Kantian flavour: the interpretation of physical objects does not emerge from the unidirectional application of conceptual apparatuses to reality, but rather in the very confluence of abstract concepts — such as those of mathematics — and experience.

This is indeed a very Kantian idea of constitution. However, as Darrigol (2018) has shown, it is also very heterogeneous and "obscure". Among the criticism raised by Darrigol, we find two significant remarks. Firstly, he notes that "it is not clear how the coordination between the mathematical formalism and empirical reality is effectively done" (2018, 12). In effect, Reichenbach disclaimed a transcendental conception of sensibility in order to reconcile his Neo-Kantian epistemology with the theory of general relativity; but without any alternative to sensible intuition, the process of coordination between "thought" and "experience" remains unexplained. And secondly, "it is not clear how the principles of coordination should be chosen." Darrigol argues that these difficulties led Reichenbach to opt for a Poincaresian conventionalist approach to geometrical principles by the end of the 1920s. This is only partly true, however. Reichenbach was certainly encouraged by Schlick's criticism to move towards conventionalism.[5] But this does not make Reichenbach's conventionalism equal to Poincaré's. According to Poincaré, the principles of geometry are hypotheses that are conventionally chosen and applied to experience. Even if our choice is "guided

[5] See Coffa (1991, 201–204).

by experimental facts" and therefore not utterly arbitrary, "it remains free" which set of conventions should be chosen (Poincaré 1905, 50). As de Boer (2011, 516) has pointed out, Reichenbach shares with Poincaré — and obviously, with Kant — the belief that "physics must rely on principles that bridge the gap between pure thought, now basically exemplified by mathematics, and experience." They also concur that this choice is made attending to simplicity.[6] Nevertheless, Reichenbach had little trust in the "arbitrariness" that Poincaré assigns to the choice of geometrical principles:

> Although the statement about the geometry is based upon certain arbitrary definitions, the statement itself does not become arbitrary: once the definitions have been formulated, it is determined through objective reality alone which is the actual geometry. […] The description of nature is not stripped of arbitrariness. (Reichenbach 1928, 37).

It is not my intention to emphasize Reichenbach's philosophical continuity from 1920 to 1928 — although I think it could be cautiously defended (see note 11) — but rather to point out where Reichenbach's and Poincaré's conventionalism part ways. Reichenbach's axioms of coordination cannot be regarded as Poincaresian conventions, because they are determined by "objective reality" while naive conventionalism, in Reichenbach's eyes, "overlooks the possibility of making objective statements about the real space" (Reichenbach 1928, 36). One might freely create alternative geometries — as long as these are consistent — but their application to physical space is not subject to the same kind of freedom. It depends, instead, on the very structure of the world.

Reichenbach's idea of coordination is ultimately much more demanding than that of convention — "coordination attests to what is real", says Reichenbach (1920, 42). What Reichenbach manifests is a much more realist attitude towards scientific principles than Poincaré, since the former engages with the possibility of attaining an objective description of reality even in the presence of constitutive a priori elements, whilst the latter adopts a standpoint closer to instrumentalism.[7] Reichenbach's account is therefore relevant for the aim of this paper, as it demonstrates that realism does not conflict with the presence of constitutive elements in science.

I want to make one last remark on Reichenbach's account. According to van Fraassen, "the rules or principles of coordination that can be introduced to define particular sorts of measurement cannot even be formulated except in a context where some forms of measurement are already accepted and in place" (2008, 137). Here van Fraassen underscores the idea that scientific development never happens in the absence of a set of constitutive elements, and that is something that is relevant in Reichenbach's work. This point is not explicitly stressed by Reichenbach (1920), and although

[6] Although they did not agree in their approach to simplicity. For Poincaré, Euclidean geometry was simpler because it fits better with the psychological way we inhabit the world. In contrast, Reichenbach thought that simplicity was related not to intuition but to calculus and measurement.

[7] Padovani (2011) has given another argument against a naive reading of Reichenbach's turn towards conventionalism. She raises serious doubts about whether this shift was in any sense fully completed, for even in his later stages, Reichenbach displayed commitment to the constitutive status of some very fundamental principles.

Padovani (2017) has raised some objections to it, it succinctly helps us to see some initial affinities between perspectival realism and the presence of constitutive elements. "There is no presuppositionless starting point for coordination", as van Fraassen puts it; nor is there for knowledge, perspectivists will claim.

2.2 Constitution as a necessary presupposition: Friedman's account

Reichenbach's account of the relative a priori allowed for a Neo-Kantian dynamical description of theory change, which materialized in Friedman's "historicized version of transcendental philosophy" (Friedman 2008, 112). I will not delve into Friedman's conceptual analysis of Newtonian and relativistic mechanics, for there is already a vast literature on this.[8] Nor will I address his recent attempt to "attribute some kind of transcendental significance to particular sets of constitutive principles" via exhaustive historical research, in order to amend his "overly simplified 'formalistic'" initial account (Friedman 2010, 698). My focus will instead be on what is modified and preserved from Reichenbach's work. I will argue that Friedman's account of scientific development is inappropriate, because it lays the burden of proof on the ostensibly ambiguous concept of "philosophical metaparadigms", but I will nevertheless argue that his notion of "constitution" as "necessary presupposition" is still of great value and exhibits considerable similarities with perspectival realism.

As we have seen, Reichenbach distinguished between axioms of coordination and empirical statements, and he thought that sets of axioms of coordination characterize scientific theories. Friedman (2001, 45–46) does not identify two different conceptual strata but three: (i) empirical statements facing "the tribunal of experience" via "empirical testing"; (ii) constitutive a priori principles, consisting of the theory's fundamental laws and mathematical structure (Friedman 2001, 74); and (iii) philosophical metaparadigms, which tacitly conduct scientific research when constitutive principles are threatened in times of Kuhnian crisis, in such a way that they provide a source of "new ideas", "alternative programs" and "expanded possibilities" (Friedman 2001, 17).[9] He also articulates a slightly different idea of constitution. Friedman holds that "to say that A is a constitutive condition of B rather means that A is a necessary condition, not simply of the truth of B, but of B's meaningfulness or possession of a truth value. It means […] that A is a *presupposition* of B" (Friedman 2001, 74). So, while Reichenbach put forward a phenomenical notion of constitution, Friedman provides a semantic one: "to be constitutive of" means to be a condition for the possibility of all further meaning, a necessary presupposition that must be satisfied by all potential empirical statements, and without which the theory does not hold. According to Friedman (2001, 72), Euclidean geometry and Newton's three laws of motion are constitutive of Newtonian mechanics; and the principle of equivalence, the constancy of light speed, the geometry of Minkowski space-time and the Riemannian theory of manifolds are constitutive of Einsteinian relativity.

[8] Apart from criticism (see note 15), see Ryckman (2005), DiSalle (2006), Domski and Dickson (2010) and Suárez (2012).

[9] The idea that only the emergence of new constitutive principles might challenge those that are already accepted is anticipated in Putnam's conception of the contextual a priori. See Tsou (2010) for a revision.

In his *Dynamics of Reason*, Friedman asserts that the acceptance of a set of constitutive principles resembles the preconditional status of Kuhn's paradigms as "relatively stable sets of rules of the game" (2001, 45). But this analogy is wholly problematic. Kuhn argued that "the existence of a paradigm need not even imply that any full set of rules exists" (1962, 44) because a significant portion of scientists' knowledge takes the form of tacit knowledge, and therefore is not explicitly defined in terms of rules and principles; not to mention that this tacit dimension includes non-propositional knowledge. So, although paradigms and constitutive principles might be constitutive in some sense, they do not share the same notion of constitution. Paradigms are constitutive of experience while Friedman's a priori principles are constitutive of meaning.

In a recent paper, Friedman (2012) has addressed this concern by claiming that our (frequently unstated) scientific ideals — such as universal communicability and the demand for rigorous proof — which he likens to Kant's regulative ideals of reason, capture the intersubjective, social and historical character of scientific knowledge. Still, I am inclined to say that Friedman's idea of constitutive principles is better connected with Giere's approach to fundamental laws than with Kuhnian paradigms. Giere suggests that some especially relevant laws — such as Newton's laws of motion — function like "recipes for constructing models *more* than like general statements" (1994, 293; emphasis added). He classifies Newtonian mechanics in five hierarchical levels of models, ranging from those that only satisfy Newton's laws of motion (level I) to much more specialized models such as pendulums and elliptical orbits (level V). What Giere and Friedman share here is a genuinely kindred idea of constitution: each level is a necessary presupposition for the meaningfulness of all subsequent levels. Level I is a necessary presupposition for levels II-V; level II is likewise for levels III-V, and so forth. It goes without saying that Friedman does not have in mind the model-based account of scientific theories that Giere does — this issue will be addressed in section 3.1 — but both support the existence of conceptual hierarchies within the components of a theory. This can be taken as a sign of the resemblance between the presence of constitutive elements in science and perspectival realism, although it will be in the next section that this intuition is comprehensively developed.

One last difference between Reichenbach's and Friedman's takes on constitutive elements concerns the issue of theory change. Friedman provided a convergent, progressive and cumulative account of scientific development in which philosophy has an indispensable task. In his schema, philosophy has the function of "mediating the transmission of rationality across revolutionary paradigm shifts" in a way that "reflection on the distinctively philosophical […] level helps us to define, during the revolutionary transition in question, what we now mean by a natural" and "reasonable" theory change (Friedman 2001, 105). Here Friedman aims to avoid the troubling issue of incommensurability. Philosophical resources help in the transition from one set of constitutive elements to another, so trans-theoretical communication and rationality are assured by the existence of philosophy as a transcendental activity underlying science.[10]

Sceptics might reasonably ask why we should accept such an account of the interaction between science and philosophy. And indeed, as Shaffer (2011) has shown,

[10] This latter point is conspicuously articulated in Friedman (2002).

Friedman cannot offer any proper epistemic justification for constitutive principles unless he first provides some such justification for meta-philosophical paradigms.[11] Nevertheless, I would like to suggest a different line of criticism.[12] Friedman perceives his work as part of an established Kantian tradition that regards the constitution of scientific knowledge aprioristically. However, does he have any right to place himself in this Kantian tradition, in light of his own idea of constitution? After all, his *Dynamics* tends to reduce the "Kantian spirit" to the detection of principles that function as condition for the possibility of empirical meaning; but that is definitely a trivialization of what Kant meant by a priori knowledge. Also, contrary to Reichenbach, Friedman's idea of constitution is not forged "in the mutuality of coordination", but has a conspicuous top-down appearance. This way of constituting meaning is clearly far from Kant's original project.

This modest objection would not strike Friedman as breaking news. In his recent aforementioned paper, he states that his previous notion of constitutive principles "is too thin, in so far as it does not attribute to what is given in sensibility a sufficiently rich and sufficiently independent a priori structure" (2012, 48). There he aims to replace Kant's faculty of sensibility with Friedman's "physical frames of reference […] within which empirical phenomena are to be observed, described, and measured." I do not have space here to evaluate this novel reconfiguration, but its mere presence manifestly reveals the need to get "Kant's wheels" back on track.[13]

2.3 The new pragmatist framework for constitutive elements

One shortcoming of Friedman's account is his omission of the literature on pragmatism.[14] This oversight must have been intentional since, by the time of the publication of *Dynamic of Reason*, several proposals were at his disposal. Only 3 years after Reichenbach's *Theory of Relativity*, Lewis (1923) presented his now well-known pragmatic conception of the a priori. And during the 1940s, Pap (1946) put forward the view that the components of some physical sciences are functionally a priori, although they might be substituted for pragmatic reasons. Lewis's paper goes unnoticed in Friedman's *Dynamics*, while Pap's work is briskly discussed in a footnote. Although

[11] There are many other problematic aspects of his dynamical conception of scientific theories. Some critics have argued that Friedman's dynamic of reason does not solve incommensurability but instead constitutes a pretty solid argument for it (Korkut 2011). This need not be regarded as a negative outcome as such, but it is for Friedman's purposes. Massimi (2005, 20) has stressed that Friedman's account makes science an individual endeavour, dependent on some crucial decisions that are conventionally taken. Others have attacked the transcendentalist description he ought to undertake. Van Dyck (2009) defends the view that Friedman's convergentism is not inferable from the need for philosophical frameworks. And Dimitrakos (2018) has critically pointed out Friedman's "minimal idealist thesis" as well. Finally, others such as Everett (2015) have criticized the putative applicability of Friedman's model to the history of science.

[12] I would like to thank an anonymous referee for pressing me on this point.

[13] See (Lipton 2003) on this expression. However, one might claim, there is another important *locus* of Kantianism in Friedman's proposal: the idea that scientific development is driven by the presence of the regulative power exercised by constitutive principles towards a "final ideal community of inquiry" (Friedman 2001, 64). However, in that case, Friedman should be considered a Kantian because of his views on scientific development, and not because of his account of constitution. Convergentism is what could keep Friedman on Kant's path. Richardson (2002, 2010) has thoroughly attacked this view, holding that Friedman's dynamics engage with Hegel's views on the development of reason rather than Kant's.

[14] Mormann (2012) has underscored this claim.

Friedman does not discuss Lewis's and Pap's characterizations, they have recently been vindicated by Chang (2008) and Stump (2015) respectively, who have each emphasized the importance of paying attention to pragmatism while addressing constitutive elements in science. Their accounts, however, are entirely dissimilar. Chang suggests that some epistemic activities necessarily presume certain metaphysical assumptions — i.e. counting implies discreteness, assertion implies non-contradiction, empathy implies other minds, prediction implies uniform consequence. Stump posits that some principles in physics play the role of being functionally a priori and are chosen pragmatically. Since, on the one hand, my purpose is to give a perspectival account of the constitutive elements in science, and, on the other, given that Friedman did not convincingly attain an account of theory change, I will focus on the work of Stump (2015).

Stump (2015, 8) considers three cases in which we may talk of constitutive elements: "formerly empirical statements which are turned into criteria", "necessary preconditions that function as tools needed to start inquiry" and "presuppositions about what the physical world is like". To this effect, his views are not too far from Friedman's. The key point is that "being constitutive" is regarded as a temporary function that some statements play within a theory, and which varies when a scientific revolution happens. A consequence that Stump infers from his functional approach is that assuming that some principles function as conditions for the possibility of empirical meaning entails no Neo-Kantian affiliation. Therefore, Stump claims, his account remains closer to philosophical naturalism. And within a naturalistic approach, we can regard theory change in terms of pragmatic preferences.

I endorse Stump's vindication of the centrality of pragmatic considerations regarding theory change, but I heartily believe that what he means by pragmatism should be slightly clarified. For the purposes of this paper, I take Chang's (2019) definition of pragmatism to be quite accurate. According to him, the core of pragmatism lies in recognizing that "knowledge is created and used by intelligent beings who engage in actions in order to live better in the material and social world" (2019, 11). This is nothing more — and nothing less — than what scientists as epistemic agents do. In Stump's view, a theory is a hierarchical statement-based structure erected over functionally a priori principles, which aims to provide a more or less detailed description of reality. In this sense, a theory can be successful or not. Successfulness will ultimately be dependent on the interests, demands and problems to be solved by the scientific community at stake. If these variables are not satisfied, scientific communities might start looking for alternatives. So, when theory change takes place, the motivations of that episode are likely to be related to pragmatic considerations, whatever these might be.

Once different approaches towards constitutive principles have been disclosed, I would like to suggest some clarifications. As I see it, there are two kinds of constitutive elements that have been treated indiscriminately in the relevant literature: those that are constitutive of scientific practice, and those that are constitutive of theoretical perspectives. Among the first, we find some very general principles that are simultaneously presupposed by several scientific fields — induction, genidentity probability and causality, to name but a few. Measurement procedures, as well as Chang's contingent metaphysical assumptions, belong to this group too. It is characteristic of such constitutive elements that they are not necessarily replaced during theory change, for they do not exclusively pertain to any single theory. This does not imply that they are irrefutable or present in every scientific theory. But constitutive elements of scientific practice are shared by scientists of the most unrelated branches of science, so they are not constitutive of theories, but rather of the practice of science in its broadest sense. Simply put, epistemic activities possess some *first-order* constitutive elements as presumptions, while, at the same time, a set of *second-order* constitutive principles — namely, those constitutive of theoretical perspectives — further determines exclusive conditions for the possibility of a specific theoretical perspective.

Thus, constitutive elements of theoretical perspectives are the components of any theory that play the role of laying the foundations of empirical meaningfulness, and whose acceptance is prior to empirical research. Frequently these components will take the form of fundamental laws, for their refutation implies the dismissal or substantial modification of the theory at stake. These elements are also characterized by their relative/historical status — that is, they change over time — and their specificity — they are only constitutive of one particular theory. Scientific change, in this context, may be understood as the replacement of the constitutive elements that identify two different theories, and the occurrence of such episodes is due to the contextual and pragmatic necessities of the communities in competition. In what follows, I will only focus on the constitutive elements of theoretical perspectives.

This definition aims to make a double move. First, it dismisses an unattainable conception of dynamic rationality *à la* Friedman, without abandoning the view that scientific theories possess constitutive elements. This might prompt an objection of incommensurability: since constitutive elements are dropped in revolutionary episodes, and new theories bring along new elements, communication between different sides might be threatened. As will be shown in section 4, there is nothing to fear once a new definition of truth *from within* is provided. Second, and more importantly, thanks to the addition of the pragmatic clause, the definition nicely captures some commonalities between the presence of constitutive elements and perspectival realism. Following the paper by Chang (2019) mentioned above, pragmatism and perspectivism coincide in that both understand knowledge — scientific knowledge included — as a human activity, always finite, located in a certain context and dependent upon it. Giere would likely be pleased with Chang's affirmation, as he claims that one key feature of perspectivism is the view that scientific claims "are not unconditional, but relative to a set of humanly constructed concepts" (Giere 2013, 53). He also maintains that his philosophical standpoint embraces "some aspects of pragmatism" (Giere 2006, 13). As I said, I think that accounting for the presence of constitutive elements in science shares this attitude as well, and that is so for two reasons. First, accentuating the presence of non-definitive — thus changeable — constitutive elements marks their historical character just as much as perspectivism does. And second, the above definition highlights the fact that scientific communities are engaged with some set of principles that demarcates all possible research in the absence of alternatives, and therefore denotes a vantage point from which the world is assessed.

3 Constitutive elements through perspectival lenses

In everyday language, a "perspective" is a way of regarding things from a certain point of view. This is how common parlance captures the subjective and interpretative nature of experience. This naive intuition underlies the non-trivial claim that representations (broadly understood), experiments and models are perspectival (van Fraassen 2008). Neither representations, experiments or models capture, nor do they aim to capture, the totality of what is represented, experimented or modelled, as such epistemic strategies include idealizations, abstractions, ceteris paribus clauses and the like. Perspectivism, broadly understood, refers to the fact that there are numerous factors that come into play in the process of gaining knowledge and thus influence the final outcome, so we end up knowing only a portion of the object. These perspectives, however, are "intersubjectively objective" representations of a given phenomenon (Giere 2006), insofar as different knowers will eventually come to similar conclusions under similar circumstances. As Giere (2006) has pointed out, colour vision is a prominent example of this kind of perspectivism. In the remainder, I will focus on a more concrete form of perspectivism that might be dubbed "theoretical perspectivism". Theoretical perspectivism points at the fact that sets of theoretical elements determine the standpoint from which reality is assessed. My concern in what follows is that on numerous occasions (Giere 2006; Massimi 2018; Teller 2019), perspectivism has been defended as a cutting-edge position to bear in mind in the context of scientific realism.

Perspectivism is indeed one of the latest faces of realism, but its goal is to overcome an impasse reached in the classic debate between realists and antirealists.[15] Here I take realism and antirealism to be opposing attitudes towards the aims of science.[16] So, while realists understand that scientific theories aim to represent a mind-independent world in both its observable and unobservable aspects, antirealists argue that scientific theories are artifices, instrumentally optimal in terms of empirical adequacy, which do not aim to represent a mind-independent world, but only to successfully intervene in it. Both parties have their own argumentative strategies. Realists endorse Putnam's (1975, 73) no-miracle argument,[17] now reformulated as an inference to the best explanation. Conversely, antirealists support Laudan's pessimistic meta-induction (Laudan 1981): an argument that has recently been updated via Stanford's unconceived alternatives (2006). Independently of the strategy to follow, this dispute is usually reduced to one of the previous arguments. The discussion is still ongoing, but it is disputable whether any synthetic outcome is to be expected, or whether this debate instead suffers some sort of meta-incommensurability between realists' and anti-realists' assumptions.[18] It is not even clear whether the cornerstones of the debate have been "clearly posed", in which case the very foundations of this issue should be reconsidered.[19]

In any case, the attitude of realists is frequently translated into an objectivist characterization of scientific knowledge, that is, the thesis that science emits claims about mind-independent states of affairs. Antirealists, however, tend to emphasize scientific knowledge's local status, claiming that we never reach a God's-eye position from which objectivity can be inferred. In the middle of this arena, perspectivists believe that it is possible to achieve a consensual solution that combines both claims.

[15] For brevity, I assume here some familiarity with the issue at stake, although I will briefly address it. See Psillos (1999) and Wray (2018) for an overview of the main arguments for and against each position.
[16] And, as Teller (2019) has argued, perspectival realism is also an attitude itself.
[17] See also van Fraassen's "definitive argument" (1980, §7).
[18] This idea has been put forward by Oberheim and Hoyningen-Huene (1997).
[19] See Blackburn (2002).

Perspectival realism ought to do justice to the idea that scientific knowledge has an intrinsic historical and cultural component (Massimi 2017, 164), and nonetheless is epistemically valuable. For this enterprise, traditional ideas of objectivism and truth as correspondence have to be substantially modified (Giere 2006), so instead of statements, models and representations are put at the core of the analysis. Giere uses the metaphor of a map to illustrate the epistemic value of scientific representations. Maps, Giere (2006, 72–73) asserts, have three relevant features: they are partial, inasmuch as they only represent some aspects of the reality at issue, they have limited adequacy, inasmuch as their target is not to provide a perfect representation, and they are not mere linguistic entities. The analogy Giere establishes is that the representational function carried out by maps in everyday life is performed by models in science. According to Giere (1999, 73), scientific representation does not take place "directly between statements and the world, but between models and the world." I will return later to this model-based approach to scientific theories, but for now it is important to highlight that Giere's turn towards models involves a new notion of truth. Statements can be true or false. Models, instead, show gradual signs of adjustment or similarity with what they aim to represent. So, as long as scientific theories employ models, Giere infers that it is an appropriate move to substitute a traditional account of truth with ideas of fitness and similarity (1999, 5–6). Now, how can this view be made compatible with the presence of constitutive elements in science?

3.1 Hints and prospects of a combined program

Throughout Giere's career, significant grounds for optimism are settled:

> The sorts of general principles operative in some sciences provide a perspective within which particular models may be constructed. (Giere 1999, 241)

> The grand principles objectivists cite as universal laws of nature are better understood as defining highly generalized models that characterize a theoretical perspective. Thus, Newton's laws characterize the classical mechanical perspective; Maxwell's laws characterize the classical electromagnetic perspective; the Schrödinger Equation characterizes a quantum mechanical perspective; the principles of natural selection characterize an evolutionary perspective, and so on. (Giere 2006, 14–15)

> Models are constructed according to explicitly formulated principles. (Giere 2006, 61)

And more explicitly:

> Michael Friedman has invoked Reichenbach's distinction between two understandings of Kant's synthetic a priori. [...] I would assimilate a relativized, thus contingent, set of constitutive principles as defining a theoretical perspective within which one could formulate potentially true statements. This is a version of perspectivism. (Giere 2013, 54)

In the light of these passages, it is natural to picture a view in which perspectival realism and a constitutivist account of scientific theories go hand by hand. What Giere defines as "general principles", "grand principles objectivists cite as universal laws" or "explicitly formulated principles" are indeed what have been defined as constitutive elements: those necessary presuppositions of the theory that have to be met by all the theory's components. Constitutive elements are not perspectives, but *allow for* perspectives. In the same vein, Massimi (2015) has tried to tease out some possible ways of understanding Giere's (2013) notion of a scientific perspective:

> Scientific perspectives incorporate relativized constitutive principles, qua *conditions of possibility of our experience* of the world. Constitutive a priori principles (say, Newton's three laws of motion in Newtonian mechanics) provide the conditions of possibility of what we can (truly or falsely) assert about objects in motion within this scientific perspective. (Massimi 2015, 141)

Although Massimi's aim is not to stress the points in common between perspectivism and constitutivism — nor does she subscribe to this reading — her research brings about the possibility of arguing for such an account. As I see it, constitutive elements could be built into Giere's view (1994), in the sense that they establish conceptual "systems of coordinates" through which the representational capacities of the theory can be developed. A set of constitutive elements has a perspectival character, as it fixes the standards for the truth and meaningfulness of both the statements and models of the theory at issue. Furthermore, perspectivism also emphasizes the relative status of these constitutive elements, not only because they change over time, but also because they only provide a perspective from which reality is assessed. To take up Giere's metaphor: constitutive elements are the map's legend and scale.

One potentially challenging concern arises from the fact that Giere's perspectivism stems from a model-based account of scientific theories, while Reichenbach, Friedman and Stump understand scientific theories as collections of statements. A difficulty arises, as both conceptions are usually regarded as mutually exclusive: theories are principally characterized either by their statements or by their models. The task here is to harmonize these ideas. To my mind, it is possible to defeat the objection via the premise stated in section 1, according to which, for constitutivists, some elements of knowledge are more fundamental than others. Accordingly, to claim that theoretical models play a crucial role for scientific representations would not be in competition with the claim that what constitutes the framework in which these models operate is a set of constitutive elements of more considerable conceptual weight. This is precisely what Giere seems to be suggesting in the foregoing extracts. A perspective is something much broader than a theoretical model, and both are components of a theory's conceptual structure. Since both Friedman and Giere, as representatives of constitutivist and perspectival accounts respectively, are connected by their explicitly acknowledged Kuhnian parentage, a Kuhnian analogy seems appropriate: the relation between a theoretical perspective delimited by constitutive elements and the models operating within it is analogous to the relation that holds between a disciplinary matrix and its exemplars (Kuhn 1974).[20] What I would like to underline is the fact that models and statements are both elements that are present in scientific theories. A scientific theory is much more than a set of statements, but it is also far more than a set of models. Both components should be borne in mind, and no incompatibilities between them should arise, as long as the conceptual role played by each component is successfully identified. However, I see a major tension not in connection with perspectival realism and the presence of constitutive elements, but within perspectival realism itself.

4 Truth from a vantage point

There is an evident tension between declaring that "truth claims are always relative to a perspective" (Giere 2006, 81), and aspiring to describe how science provides true claims about the world. The seed of "relativism of one form of another" is sown if all perspectivism amounts to is to the claim that "perspectival facts are all that can be known" (Chakravartty 2010). A realist position must be capable of providing criteria to demarcate claims that are true of the world beyond the evaluation of particular theoretical perspectives. But how perspectival knowledge might be true in a trans-perspectival sense is unclear. How can empirical statements be dependent upon perspectives and simultaneously make claims about a mind-independent world? "Can our scientific knowledge claims be perspectival, while also being claims about the world as it is?" (Massimi 2018, 342). I will attempt to shed some light on this, although my take on this issue will be rather programmatic.

One plausible solution involves reformulating what we understand by "truth". Massimi (2017, 2018) has provided a compelling account. Standardly, from Psillos (1999, xvii) to Massimi herself (2017), scientific realism is believed to satisfy a tripartite-tenet structure:

(i) A metaphysical tenet about a mind-independent world.
(ii) A semantic tenet about the truthfulness of scientific language.
(iii) An epistemic tenet whereby if a theory is accepted, then it is believed to be true of the world.

Scientific realism has traditionally seen truth from a God's-eye point of view: a scientific utterance U is said to be true *iff* the content of the utterance corresponds to a state of affairs in an objective, replicable and permanent way. In other words, it has classically been thought that truth-conditions (tenet ii) can be settled once and for all and applied to particular claims. Truth, in this context, points to a one-way relation

[20] Of course, this analogy has its limits, for a disciplinary matrix comprises methodological and non-propositional elements and, as we saw in section 2.2, that is not Friedman's account of constitutive principles. The point is that Kuhn recognized the complexity of scientific theories, identifying not only the different conceptual levels that compose them but also their relation in terms of integration. This last point is the one I am trying to highlight.

between knowledge and nature (tenet iii). This being the case, perspectivism looks to be barely reconcilable with tenets (ii) and (iii). But instead of addressing truth *from above*, perspectivists have tried to address truth *from within*. The main idea is that once scientific historicity is acknowledged, we come to the conclusion that the truth of scientific claims is always evaluated from a perspective, regardless of which perspective the evaluated claim belongs to. And even if our judgements are always indexed to a context, we can still pronounce on "truth across scientific perspectives". According to Massimi, theoretical perspectives function as both *contexts of use* and *contexts of assessment*. "Qua context of use", Massimi says, "scientific perspectives lay out truth-conditions intended as standards of performance-adequacy for their own scientific knowledge claims."[21] And as "qua contexts of assessments", she continues, "scientific perspectives offer standpoints from which knowledge claims of other scientific perspectives can be evaluated" (Massimi 2018, 356–357).

To be true *within a perspective* is to satisfy the standards of performance adequacy that a scientific claim is meant to satisfy. I go one step further than Massimi, for I take this to be connected to scientific explanation: a claim is true when it provides a successful explanation for a phenomenon that a perspective considers problematic. So, Newton's law of universal gravitation is true within a Newtonian perspective, as it solves the problem of gravitation; the postulation of phlogiston-based reactions is true within a phlogiston perspective, as it solves the problem of combustion, and so on. This is how perspectives as "contexts of use" determine which claims are true of the world. However, it might be argued that as contexts of use, perspectives do not go beyond Kuhn's paradigms and the already-stated fear of relativism. Scientific realism cannot be content with the idea that the evaluation of truth is always dependent upon the theoretical perspective from which the claim at stake is assessed. The task for the perspectivist here is to explain how to evaluate truth in a cross-perspectival sense without invoking a "Nagelian view from nowhere". Thus, to be *true across perspectives* is to continue to satisfy the standards of performance adequacy, as set by the original perspective, as we move from one perspective to the next one. "Insofar as knowledge claims", Massimi says, "continue to be found — from the point of view of a new scientific perspective — as still performing adequately, such knowledge claims can be said to be true" (2018, 357). Massimi's conception is subtle and interesting, for it points not only at how knowledge relates to nature, but also to the ways in which different perspectives relate to each other.

The standards of performance adequacy are not settled once and for all, since they are concomitantly historical. So, to keep performing adequately might happen diachronically, when a perspective comes to replace another. Even if the Einsteinian perspective has replaced the Newtonian one, Newton's laws of motion can still solve the problem of uniform acceleration — something they were supposed to do in the native perspective — in some limiting cases of Einsteinian mechanics, and are routinely used in contemporary scientific practice (Chang 2012, 266). This might also happen with synchronic perspectives. Both thermodynamics and statistical mechanics aim to solve heat transfer: the former from a macroscopic point of view, the latter from a microscopic one. Therefore, they provide successful explanations for phenomena that each perspective considers problematic. Why, then, assign truth content exclusively to one half of the equation, when they both match some "worldly state of affairs" in a reproducible way? They rather each provide a different *perspective* on the analysis of

[21] The terminology "standards of performance adequacy" is borrowed from Rosenberg (2002).

temperature. So as long as the claims they respectively hold adequately perform their explanatory functions, we can regard them as true. The desire to reach absolute knowledge of nature was abandoned a long time ago, so the perspectival account of truth looks promising. As Massimi (2018, 358) puts it, “we simply do not possess a God’s eye view to do that otherwise.”

5 Final remarks

Regarding truth as applying to claims that remain performatively adequate across perspectives can also be considered a way of overcoming Friedman’s transcendentalism. There is no need to commit to Friedman’s convergent account of scientific rationality. If theoretical perspectives are considered as sets of constitutive elements where models and representations develop, within which one could formulate potentially true statements, then the transmission of performance-adequacy also occurs from one set of constitutive elements to another. This entails, as discussed at the end of section 2.3, that there is no threat to inter-perspectival communication. Naturally, constitutive elements play an important role in establishing the standards of performance-adequacy as necessary presuppositions that every scientific explanation must meet. They are, in this sense, what Massimi has called “contexts of use”. But scientific explanations originated within different frameworks are also to be regarded as true or false. So as long as models and statements developed within one theoretical perspective keep providing a successful scientific explanation in another perspective that is composed of an alternative set of constitutive elements, there is no reason not to consider those pieces of knowledge as true. Sets of constitutive elements are “contexts of evaluation” as well. Knowledge is always viewed through a theoretical perspective, just as a set of constitutive elements is always in place before any scientific claim can be made. As van Fraassen (2008) puts it, there is simply no view from nowhere.

In this paper, I have argued that the presence of constitutive elements and perspectival realism are proposals that complement each other and together provide a better understanding of scientific theories. They focus on different areas of research: while constitutivists are concerned with the conceptual structure of scientific theories, perspectival realists focus on the nature of scientific knowledge and its relation to nature. Nevertheless, these views are nothing but two sides of the same coin, for theoretical perspectives can be seen as sets of constitutive elements. Here I have also stressed some conspicuous similarities they share: the historical nature of scientific knowledge, the recognition of humans’ epistemic limits, a familiarity with pragmatism, a displeasure with relativism, and a kindred approach to truth are among them. But most significantly, they embrace a common view of science that locates it between the boundaries of every human epistemic activity and the aim of achieving a non-relativistic description of reality.

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References

Bitbol, M., Kerszberg, P., & Petitot, J. (2009). *Constituting objectivity. Transcendental perspectives on modern physics*. Dordrecht: Springer.

Blackburn, S. (2002). Realism. Deconstructing the debate. *Ratio, 15*(2), 111–133.

Chakravartty, A. (2010). Perspectivism, inconsistent models and contrastative explanation. *Studies in History and Philosophy of Science, 41*, 205–212.

Chang, H. (2008). Contingent transcendental arguments for metaphysical principles. In M. Massimi (Ed.), *Kant and the philosophy of science today* (pp. 113–133). Cambridge: Cambridge University Press.

Chang, H. (2012). *Is water H_2O? Evidence, realism and pluralism*. Dordrecht: Springer.

Chang, H. (2019). Pragmatism, perspectivism and the history of science In M. Massimi & C. D. McCoy (Eds.), *Understanding perspectivism. Scientific challenges and methodological prospects* (pp. 10–27). New York and London: Routledge.

Coffa, J. A. (1991). *The semantic tradition from Kant to Carnap*. Cambridge: Cambridge University Press.

Darrigol, O. (2020). Constitutive principles versus comprehensibility conditions in post-Kantian physics. *Synthese, 197*, 4571–4616.

de Boer, K. (2011) Kant, Reichenbach, and the fate of a priori principles. *European Journal of Philosophy, 19*(4), 507–531

Díez, J., & Lorenzano, P. (2015). Are natural selection explanatory models a priori? *Biology and Philosophy, 30*(6), 787–809.

Dimitrakos, T. (2018). Scientific mind and objective world: Thomas Kuhn between naturalism and apriorism. *Erkenntis, 85*, 1–30.

DiSalle, R. (2006). *Understanding space-time. The philosophical development of physics from Newton to Einstein*. Cambridge: Cambridge University Press.

Domski, M., & Dickson, M. (Eds.). (2010). *Discourse on a new method. Reinvigorating the marriage of history and philosophy of science.* Chicago and La Salle: Open Court.

Everett, J. (2015). The constitutive a priori and the distinction between mathematical and physical possibility. *Studies in History and Philosophy of Modern Physics, 52*, 139–152.

Fine, A. (1986). *The shaky game. Einstein, realism and the quantum theory*. Chicago and London: The University of Chicago Press.

Friedman, M. (1999). *Reconsidering logical positivism*. Cambridge: Cambridge University Press.

Friedman, M. (2001). *Dynamics of reason*. Stanford: CSLI Publications.

Friedman, M. (2002). Kant, Kuhn and the rationality of science. *Philosophy of Science, 69*, 171–190.

Friedman, M. (2008). Einstein, Kant and the a priori. In M. Massimi (Ed.), *Kant and philosophy of science today* (pp. 95–112). Cambridge: Cambridge University Press.

Friedman, M. (2010). Synthetic history reconsidered. In M. Domski, & M. Dickson (Eds.). *Discourse on a new method. Reinvigorating the marriage of history and philosophy of science* (pp. 571–801). Chicago: Open Court.

Friedman, M. (2011). Extending the dynamics of reason. *Erkenntis, 75*, 431–444.

Friedman, M. (2012). Reconsidering the dynamics of reason: Response to Ferrari, Mormann, Nordmann and Uebel. *Studies in History and Philosophy of Science Part A, 43*, 47–53.

Giere, R. (1994). The cognitive structure of scientific theories. *Philosophy of Science, 61*(2), 276–296.

Giere, R. (1999). *Science without laws*. Chicago: The University of Chicago Press.

Giere, R. (2006). *Scientific perspectivism*. Chicago: The University of Chicago Press.

Giere, R. (2013). Kuhn as perspectival realist. *Topoi, 32*, 53–57.

Korkut, B. (2011). The real virtue of Friedman's neo-Kantian philosophy of science. *Philosophy of Science, 78*, 1–15.

Kuhn, T. S. (1962). *The Structure of Scientific Revolutions*. Chicago: The University of Chicago Press [3rd Edition 1996].

Kuhn, T. S. (1974). Second thoughts on paradigms. In F. Suppe (Ed.), *The structure of scientific theories* (pp. 459–482). Urbana: University of Illinois Press.

Laudan, L. (1981). A confutation of convergent realism. *Philosophy of Science, 48*(1), 19–49.

Lewis, C. I. (1923). A pragmatic conception of the a priori. *Journal of Philosophy, 20*(7), 169–177.

Lipton, P. (2003). Kant on wheels. *Social Epistemology, 17*(2–3), 215–219.

Luchetti, M. (2018). Constitutive elements in science beyond physics: The case of the hardy–Weinberg principle. *Synthese*, 1–25.

Massimi, M. (2005). *Pauli's exclusion principle. The origin and validation of a scientific principle*. Cambridge: Cambridge University Press.

Massimi, M. (2015). Walking the line: Kuhn between realism and relativism. In W. J. Delvin & A. Bokulich (Eds.), *Kuhn's structure of scientific revolutions – 50 years on* (pp. 135–152). Dordrecht: Springer.

Massimi, M. (2017). Perspectivism. In J. Saatsi (Ed.), *The Routledge handbook for scientific realism* (pp. 164–175). New York: Routledge.

Massimi, M. (2018). Four kinds of perspectival truth. *Philosophy and Phenomenological Research, 96*(2), 342–359.

Massimi, M., & McCoy, C. D. (Eds.). (2019). *Understanding perspectivism. Scientific challenges and methodological prospects*. New York and London: Routledge.

Mormann, T. (2012). A place for pragmatism in the dynamics of reason? *Studies in History and Philosophy of Science Part A, 43,* 27–37.

Oberheim, E., & Hoyningen-Huene, P. (1997). Incommensurability, realism and meta-incommensurability. *Theoria, 12*(3), 447–465.

Padovani, F. (2011). Relativizing the relativized a priori. Reichenbach's axioms of coordination divided. *Synthese, 181*, 41–62.

Padovani, F. (2017). Coordination and measurement: What we get wrong about what Reichenbach got right. In M. Massimi, J-W. Romeijn, & G. Schurz (Eds.), *EPSA 15 Selected Papers* (pp. 49–60). Springer.

Pap, A. (1946). *The a priori in physical theory*. New York: Russel & Russel.

Poincaré, H. (1905). *Science and hypothesis*. New York: The Science Press.

Psillos, S. (1999). *Scientific realism. How science tracks truth*. London and New York: Routledge.

Putnam, H. (1975). What is mathematical truth? In *Mathematics, matter and method* (pp. 60–78). Cambridge: Cambridge University Press.

Reichenbach, H. (1920). *The theory of relativity and a priori knowledge*. Berkeley & Los Angeles: Cambridge University Press.

Reichenbach, H. (1928). *The philosophy of space and time*. New York: Dover Publications.

Richardson, A. (2002). Narrating the history of reason itself. *Perspectives on Science, 10*(3), 253–274.

Richardson, A. (2010). Ernst Cassirer and Michael Friedman: Kantian or Hegelian dynamics of reason? In M. Domski, & M. Dickson (Eds.). Discourse on a new method. Reinvigorating the marriage of history and philosophy of science (pp. 279–294). Chicago: Open Court.

Rosenberg, J. F. (2002). *Thinking about knowing*. Oxford: Oxford University Press.

Ryckman, T. (2005). *The reign of relativity. Philosophy in Physics 1915-1925.* Oxford: Oxford University Press.

Shaffer, M. J. (2011). The constitutive a priori and epistemic justification. In M. J. Shaffer & M. L. Veber (Eds.), *What place for the A Priori?* (pp. 193–210). Chicago: Open Court

Sober, E. (2011). A priori causal models of natural selection. *Australasian Journal of Philosophy, 89*, 1–19.

Stanford, K. P. (2006). *Exceeding our grasp. Science, History, and the problem of unconceived alternatives*. Oxford: Oxford University Press.

Stump, D. J. (2015). *Conceptual change and the philosophy of science*. New York: Routledge.

Suárez, M. (Ed.). (2012). Reconsidering the dynamics of reason: A symposium in honour of Michael Friedman. *Studies in the History and Philosophy of Science Part A.* [Special Issue].

Teller, P. (2019). What is perspectivism, and does it count as realism? In: M. Massimi & C. D. McCoy (Eds.), *Understanding perspectivism. Scientific challenges and methodological prospects* (pp. 49–64). New York and London: Routledge.

Tsou, J. Y. (2010). Putnam's account of apriority and scientific change: Its historical and contemporary interest. *Synthese, 176*(3), 429–445.

Van Dyck, M. (2009). Dynamics of reason and the Kantian project. *Philosophy of Science, 76*, 689–700.

van Fraassen, B. C. (1980). *The scientific image*. Oxford: Clarendon Press.

van Fraassen, B. C. (2008). *Scientific Representation. Paradoxes of perspective*. Oxford: Clarendon Press.

Wray, B. K. (2018). *Resisting scientific realism*. Cambridge: Cambridge University Press.