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How to understand empirical adequacy as an aim of science

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Abstract: Constructive empiricists consider the aim of constructing empirically adequate theories (roughly, theories that save the phenomena) to be the primary aim of science. This paper addresses the question of how to understand this aim in such a way that it can fruitfully guide scientific practice. My answer comes in two parts. First, there is the issue of how to understand the notion of empirical adequacy, specifically when it comes to the nature of the phenomena to be saved by a theory. I argue that an empirically adequate theory should be understood as a theory that saves the observed phenomena (past, present, and future). This view contrasts with the constructive empiricist view that an empirically adequate theory must save the observable phenomena (regardless of whether such phenomena have been or will ever be observed). Second, there is the issue of the primacy of the aim of constructing empirically adequate theories. I argue for a pluralist empiricism, according to which this aim is just one among many empiricist aims, none of which is primary. This view contrasts with the constructive empiricist view that constructing empirically adequate theories is the primary aim of science.

Keywords: empirical adequacy, constructive empiricism, manifest adequacy, manifestationalism, pluralism

1. Introduction

Empiricist philosophers of science face a challenge. As philosophers of science, their aim is to provide a philosophical understanding of science as a rational activity. As empiricists, they tend to be suspicious of commitments to such things as entities that we cannot directly observe. The challenge that they face arises from cases in which it seems that rational scientists embrace such commitments. The molecules, atoms, subatomic particles, and fields that populate our best theories are entities that cannot be directly observed. The challenge for empiricist philosophers of science is to make rational sense of these aspects of scientific practice in a way that is consistent with their empiricist commitments.

In this paper, I focus on an empiricist response to this challenge which van Fraassen has developed within the context of his constructive empiricism, and the sort of empiricism on which I focus will be van Fraassen's style of empiricism. According to van Fraassen (1980, p. 203): "To develop an empiricist account of science is to depict it as involving a search for truth only about the empirical world, about what is actual and observable." His constructive empiricism is based on the idea that science aims primarily to give us theories that are empirically adequate, which very roughly means that those theories need only be true of the empirical world. i.e., they need only save the phenomena. For any case in which it seems that scientists go beyond what is actual and observable, van Fraassen's goal is to provide a plausible interpretation of that case according

to which we can understand those scientists' activities as furthering the aim of constructing empirically adequate theories.

My goal in this paper is to motivate a different sort of empiricist position. This position shares with constructive empiricism the idea that science aims to provide us with empirically adequate theories. It differs from constructive empiricism in two significant ways. First, I argue for an understanding of empirical adequacy according to which an empirically adequate theory is, to a first approximation, merely true of the observed phenomena (whether observed in the past, present, or future). This understanding of empirical adequacy is referred to as 'manifest adequacy' (Asay & Bordner, 2015). It contrasts with van Fraassen's understanding of empirical adequacy, which, to a first approximation, requires a theory to be true of all of the actual observable phenomena (regardless of whether they are ever actually observed). Arguing in favor of manifest adequacy is significant because this understanding of empirical adequacy is typically taken to be too weak for an empiricist philosophy of science,[1] mainly due to an objection from Rosen (1994), which I will discuss later.

The second way in which this position differs from constructive empiricism concerns the issue regarding whether science has a primary aim. According to constructive empiricism, the aim of constructing empirically adequate theories is the primary aim of science, and all other aims are secondary to this aim. In contrast, I motivate a pluralist empiricism, according to which the aim of constructing empirically adequate theories is one important empiricist aim among many others, none of which is primary. This second difference is related to the first. Rosen may be correct that manifest adequacy is too weak if taken to be the primary aim of science. However, I'll argue that it is not too weak if we take the aim of constructing manifestly adequate theories as one aim among others, none of which is primary. To put the point another way, constructive empiricists attempt to understand all of science in terms of one primary aim, and so they must pack everything that is important for understanding science into a single aim. In contrast, I'll argue that it is more reasonable for empiricists to understand science by distinguishing separate (empiricist) aims of science, none of which is primary.

In short, my central question in what follows is: How should we understand the aim of constructing empirically adequate theories in such a way that it can fruitfully guide scientific practice? And my answer comes in two parts. First, we should understand empirical adequacy as manifest adequacy. Second, we should understand the aim of constructing manifestly empirically adequate theories, not as the primary aim of science, but as one among many important aims of science.

In order to develop and defend this way of answering the central question, the remainder of the paper is organized as follows. Since I'll motivate my empiricist position by contrasting it with constructive empiricism, I'll begin with a discussion of constructive empiricism and van Fraassen's notion of empirical adequacy in section 2. In section 3, I'll discuss manifest adequacy. In section 4, I'll argue that, from the standpoint of scientific practice, we ought to prefer manifest adequacy to van Fraassen's notion of empirical adequacy. In section 5, I'll consider Rosen's (1994) objection to manifest adequacy as the primary aim of science. The typical response to this objection is to reject manifest adequacy in favor of a stronger notion of

[1] An exception is Asay and Bordner's (2015) modest defense of manifest adequacy as the primary aim of science.

empirical adequacy. In contrast to the typical response, I'll argue that we should instead reject the idea that science has a primary aim. I'll then demonstrate how a pluralist empiricism, which admits many (empiricist) aims of science, none of which is primary, can avoid Rosen's objection while understanding empirical adequacy as manifest adequacy. Finally, in section 6, I conclude.

2. Constructive empiricism

2.1 The basic idea

Van Fraassen characterizes constructive empiricism in terms of the aim of science and in terms of what sort of belief is involved when accepting a scientific theory:

> Science aims to give us theories which are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate. (van Fraassen, 1980, p. 12)

Constructive empiricism is an anti-realist philosophy of science insofar as it contrasts with scientific realism, which van Fraassen characterizes in similar terms:

> Science aims to give us, in its theories, a literally true story of what the world is like; and acceptance of a scientific theory involves the belief that it is true. (1980, p. 8)

Few scientific realists today would accept this characterization of realism in terms of the aim of science. But the focus on truth (nowadays approximate truth) remains important, and van Fraassen's characterization of realism provides a contrast that is useful for understanding constructive empiricism.

It's clear that empirical adequacy plays an essential role in constructive empiricism. Van Fraassen's "preliminary explication" of this notion is that "a theory is empirically adequate exactly if what it says about the observable things and events in this world, is true—exactly if it 'saves the phenomena'" (1980, p. 12). According to van Fraassen's terminology, phenomena are always observable, so 'observable phenomena' is redundant (van Fraassen, 2008, p. 8). Importantly, empirical adequacy differs from truth. While a completely true theory would also be empirically adequate (i.e., true of observables), a theory could be merely empirically adequate without being completely true (i.e., true of both observables and unobservables). Constructive empiricism is an anti-realist position insofar as it characterizes the aim of science and acceptance of a theory in terms of something that falls short of truth, namely, empirical adequacy.[2] I'll discuss van Fraassen's all-things-considered definition of empirical adequacy in section 2.2. His preliminary explication will suffice for presenting the basic idea of constructive empiricism in this section.

Both van Fraassen's preliminary explication of empirical adequacy and his all-things-considered definition of it depend on a distinction between what is observable and what is

[2] Nowadays, van Fraassen's constructive empiricism is perhaps the main representative of empiricist philosophy of science in the anti-realist tradition. However, it is not representative of empiricist philosophy of science in general, which also includes forms of empiricism that are compatible with realism (e.g., the positions developed by Cartwright (2000) and Sober (1990)).

unobservable. There is much to be said about the way in which van Fraassen draws this distinction. To keep the discussion brief, the following three features can be singled out as perhaps the most important features of his distinction. First, van Fraassen applies his observable-unobservable distinction to "putative entities (entities which may or may not exist)" (1980, p. 15). So, for example, the moons of Jupiter are observable, while electrons are not. Observable entities are basically the same as phenomena for van Fraassen. Second, for van Fraassen, science, not philosophy, is our best guide when it comes to answering the question of what is observable (1980, pp. 17, 56-59). There is a fact of the matter regarding what human beings can observe, and our best guide regarding that fact comes from our best science. Third, in order to distinguish between observable and unobservable entities, van Fraassen (1980, p. 16) uses the following "as a rough guide to the avoidance of fallacies":

> X is observable if there are circumstances which are such that, if X is present to us under those circumstances, we observe it.

In order for this rough guide to be useful, we must first make clear what it means to observe something, and for van Fraassen, "[s]eeing with the unaided eye" is the clearest case of observation (1980, p. 16). For the purposes of this paper, I'll assume that there is a workable observable-unobservable distinction very roughly along the lines of what van Fraassen proposes. More specifically, I'll assume that there is a way of using science, along with something like van Fraassen's rough guide, to distinguish between observable and unobservable entities.

I realize this may seem to be a big assumption given that van Fraassen's way of drawing the distinction has been criticized extensively. Most recently, it has faced two strong challenges. One concerns whether the notion of observability, which van Fraassen seems to characterize in terms of a counterfactual conditional in his "rough guide," presupposes a form of modality that conflicts with his commitment to modal nominalism (Ladyman, 2000, 2004; Monton & van Fraassen, 2003; Hanna, 2004; Muller, 2005; Dicken, 2007; Ladyman & Ross, 2007). The other concerns whether van Fraassen can use scientific theories (which he accepts as, at most, empirically adequate, i.e., true about observables) to tell him what is unobservable (Musgrave, 1985; Muller, 2004; Dicken & Lipton, 2006; Muller & van Fraassen, 2008; Dicken, 2009).

I won't weigh in on these difficult issues here. For the most part, I take it that these sorts of objections, if successful, identify some sort of incoherence in van Fraassen's overall position (cf. Muller, 2004, p. 638). I take it that they do not demonstrate that his distinction, when considered apart from constructive empiricism as a whole, is unworkable. Moreover, if there is no workable observable-unobservable distinction, that would be bad news, not just for constructive empiricism, but for philosophy of science more generally. The notions of observation, observability, and empirical adequacy are important notions when it comes to understanding science. So, regardless of whether one is a constructive empiricist, philosophers of science need some sort of observable-unobservable distinction.

Constructive empiricism can be seen as van Fraassen's answer to the question of how to be an empiricist philosopher of science. Since this position is sometimes misunderstood, it's important to be clear about what constructive empiricists are committed to. Van Fraassen never claims that it is irrational to believe that unobservable entities exist (1985, p. 252). He is not an

atheistic sort of anti-realist who denies that such entities exist, but rather an agnostic sort who refrains from believing that they exist. His point is not that scientific realism is irrational, but rather that we are not rationally compelled to be realists. Realists claim that understanding science requires a commitment to the unobservable entities posited by our best theories. Van Fraassen sees such a commitment as both unnecessary for understanding science and inconsistent with empiricism. In order to create the logical space necessary for constructive empiricism, he argues that we needn't be realists in order to make sense of science. We can make sense of science without attributing an aim to science that goes beyond empirical adequacy and without believing in anything that goes beyond what is, in principle, observable.

2.2. Van Fraassen's definition of empirical adequacy

Van Fraassen (1980, p. 64) presents his all-things-considered definition of empirical adequacy in terms of the so-called semantic view of theories. The semantic view contrasts with the syntactic or 'received' view of the logical positivists, which identifies a theory with a set of sentences in a first-order language. In contrast, the semantic view identifies a theory with a class of models. For example, proponents of the syntactic view would take a theory like Newtonian mechanics and formulate the theory in a first-order language. In contrast, proponents of the semantic view focus on what they call *theoretical models*, each of which contains a domain of objects and some additional elements that describe how those objects are related to one another and how they behave over time. So, for Newtonian mechanics, each model would include a number of bodies, perhaps of different sizes and masses, located in different parts of space, along with some other elements that describe the forces acting on those bodies, the ways in which they move, and so on. All of the theoretical models taken collectively provide all of the possible ways that the world could be according to the theory (van Fraassen, 1989, p. 226). This is why proponents of the semantic view identify a theory with the class of theoretical models.

In what follows, I'll make use of this general idea of a theoretical model in order to characterize van Fraassen's notion of empirical adequacy and also the notion of manifest adequacy. There are various ways to formalize this general idea.[3] However, since the informal idea sketched above will suffice for my purposes, I'll proceed rather informally in what follows. Moreover, I want to acknowledge from the outset that the difference between the syntactic and semantic views may be quite minimal given that the models need to be described in some sort of language. Lutz (2017) reviews the debate regarding these two views and concludes that the difference is illusory. The idea that I will make use of in what follows is just the idea of a theoretical model as a way that the world could possibly be according to the theory, rather than a full-blown commitment to the semantic view as distinct from, and superior to, the syntactic view.

Shortly after providing his preliminary explication of empirical adequacy, van Fraassen gives a more precise account of what it takes for a theory to be empirically adequate: "such a theory has at least one model that all the actual phenomena fit inside" (1980, p. 12). While this more precise account is still not van Fraassen's all-things-considered definition, it is useful for introducing that definition, which, in turn, requires introducing some additional terminology.

[3] To take one example, Bueno (1997) uses the partial structures approach to characterize the theoretical models as partial structures.

First, there is the notion of the *empirical substructures* of a theoretical model. Recall that each model can be understood as a way the world could possibly be according to the theory. As such, the objects in the model include both observables and unobservables. The model as a whole describes how all of these objects behave and are related to one another. The empirical substructures are the parts of the model that tell us about observable objects only, their behavior, and their relationships to each other. These parts of the model, as van Fraassen (1980, p. 64) puts it, are "candidates for the direct representation of observable phenomena." In short, the empirical substructures of the theoretical models tell us all the possible ways that the observable phenomena could appear to us according to the theory.

Second, there is what van Fraassen calls *appearances*. Van Fraassen describes the appearances as "[t]he structures which can be described in experimental and measurement reports" (1980, p. 64) and more recently as "the contents of observation or measurement outcomes" (2008, p. 8). Appearances are separate from theoretical models. In short, they are models of the data that scientists collect via observation, measurement, and experimentation. Importantly, these models, like the empirical substructures, are restricted to what is observable since they concern the sorts of things that scientists can observe and measure.

Finally, we can introduce van Fraassen's all-things-considered definition of empirical adequacy:

> To present a theory is to specify a family of structures, its *models*; and secondly, to specify certain parts of those models (the *empirical substructures*) as candidates for the direct representation of observable phenomena. The structures which can be described in experimental and measurement reports we can call *appearances*: the theory is empirically adequate if it has some model such that all appearances are isomorphic to empirical substructures of that model. (1980, p. 64; emphasis in original)

As van Fraassen sometimes puts it, a theory is empirically adequate if all of the appearances can be "embedded" in one of the theory's models (1980, p. 66). This way of understanding empirical adequacy is one way of capturing the idea that an empirically adequate theory is a theory that can accommodate the data that scientists collect.

Van Fraassen (1980, pp. 44-45) uses the example of Newtonian mechanics to illustrate these notions. Appearances in this case include data regarding the apparent motions of bodies that we observe from our perspective. For example, we may observe the apparent motion of some planet relative to the moving earth. The true motion of the planet is not something that we can observe directly. However, we can represent apparent motions within the models of Newton's theory as differences between true motions of bodies. These parts of the models, which we can distinguish in terms of differences between absolute times and absolute locations, are the empirical substructures of the models. Finally, for Newtonian mechanics to be empirically adequate, all appearances (e.g., apparent motions) would need to be isomorphic to empirical substructures (e.g., differences between true motions) of at least one of the models of Newtonian mechanics.

More recently, van Fraassen has changed his view by distinguishing more carefully among data, phenomena, and appearances. He acknowledges that he did not previously distinguish between phenomena and appearances carefully enough, especially with regard to the example of Newtonian mechanics discussed above (2008, n. 24, pp. 391-392). In his previous discussion of that example (1980, pp. 44-45), phenomena and appearances are often treated as the same thing. According to his more recent and more careful discussion of these issues, phenomena are "observable entities (objects, properties, events, […]) of any sort" (2008, p. 283), while appearances are "the contents of measurement outcomes" (2008, p. 283). He provides a bit more detail in the following passage:

> "Appearance" I reserve strictly for the contents of (possible) measurement outcomes. Phenomena are observable, but their appearance, that is to say, *what they look like in given measurement or observation set-ups*, is to be distinguished from them as much as any person's appearance is to be distinguished from that person. (2008, pp. 284-285; emphasis in original)

Partially under the influence of Bogen and Woodward (1988), van Fraassen uses the term 'data' to refer to the results obtained in these measurement outcomes (2008, p. 166, n. 14, p. 376). These data are then summarized by data models (2008, pp. 166-167) which represent the appearances (2008, p. 252). It is these data models that are potentially embeddable in a theoretical model.

For the purposes of this paper, the most important feature of van Fraassen's definition of empirical adequacy concerns the appearances that a theory would need to capture in order to be empirically adequate. Regarding the appearances that a model of Newtonian mechanics would have to capture, van Fraassen (1980, p. 45) emphasizes: "This refers of course to all actual appearances throughout the history of the universe, and whether in fact observed or not."[4] With regard to the preliminary explication of empirical adequacy as 'saving the phenomena,' van Fraassen similarly "emphasize[s] that this refers to *all* the phenomena; these are not exhausted by those actually observed, nor even by those observed at some time, whether past, present, or future" (van Fraassen, 1980, p. 12; emphasis in original). And shortly after introducing his all-things-considered definition of empirical adequacy, he writes:

> empirical adequacy goes far beyond what we can know at any given time. (All the results of measurement are not in; they will never all be in; and in any case, we won't measure everything that can be measured.) (1980, p. 69)

To understand van Fraassen's view, suppose we take all of the actual observable phenomena throughout the history of the universe. Most of those phenomena will never be observed or measured. But in order to be empirically adequate, a theory would have to accommodate the observations and measurements (appearances) of those phenomena.

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[4] This quotation is a good example of van Fraassen's earlier tendency to treat appearances and phenomena as the same thing. On his later view, data are not observed (2008, n. 14, p. 376), and so appearances, i.e., the content of measurement outcomes, are not observed either. Hence, the issue here is not about whether the appearances are observed, but about whether there are any measurement outcomes.

As a result, van Fraassen's notion of empirical adequacy is quite strong, though it is obviously weaker than truth. It is also weaker than what is known as modal empirical adequacy, which was discussed by Giere (1985, p. 83) and developed more recently by Ruyant (2021). Whereas van Fraassen's notion requires saving all of the actual phenomena, a modally empirically adequate theory would have to save all of the possible phenomena, including non-actual possibilities. So, for example, a modally empirically adequate theory would have to capture possible but non-actual apparent motions of bodies. I'll set modal empirical adequacy aside in what follows, and will focus instead on van Fraassen's notion and on the weaker notion of manifest adequacy, which I will discuss in section 3.

2.3 Constructive empiricism and traditional forms of empiricism

My goal in this paper is to motivate an empiricist position that is somewhat similar to constructive empiricism. Constructive empiricism differs from traditional forms of empiricism, and the empiricist position that I will motivate inherits these differences.

There is an objection that arises as a result of these differences, and I will now address that objection.[5] The objection concerns the use of the term 'empiricism' to label positions like van Fraassen's position and the position that I will motivate. Traditional forms of empiricism tend to treat individual experience, particularly what we experience via our senses, as the only empirical input. However, for van Fraassen, observation and measurement outcomes are often read off from our instruments and presented using the language of scientific theories. This sort of practice does not pose a problem for pragmatists, but it may pose a problem for empiricists. Empiricists may require a bridge that takes us from the content of sensory experience to reports of observations and measurements presented in theoretical language. Without such a bridge, empiricists may need to rely on a pragmatic view of observation that may conflict with traditional empiricism and lead ultimately to a pragmatist position. In that case, perhaps neither van Fraassen's position nor the position that I will motivate are really empiricist positions. Since this objection concerns features that my position shares with constructive empiricism, I will address this objection now.

In short, my response is that a pragmatic view of observation does not require abandoning empiricism in favor of pragmatism. Van Fraassen's view admits experience as the sole empirical input, but it rejects the need for a bridge and involves a view of observation that may be fairly labeled as a 'pragmatic' view. According to van Fraassen: "All our language is thoroughly theory-infected. … Hygienic reconstructions of language such as the positivists envisaged are simply not on" (1980, p. 14). Moreover, he denies that there are such things as sense data (1980, p. 72). As a result, we have no choice but to describe what we experience, observe, and measure in theory-laden terms. Importantly, though, the fact that we use theoretical language doesn't entail that we believe that those theories truly describe an unobservable reality (1980, p. 14). It's fair to label van Fraassen's view of observation a 'pragmatic' view since it concerns the *use* of theories to describe what we experience, observe, and measure. However, commitment to such a pragmatic view does not require abandoning empiricism in favor of pragmatism. Insofar as van Fraassen's view admits experience as the sole empirical input, it's appropriate to label his view an 'empiricist' view even if it incorporates some views that

[5] I owe this objection to an anonymous reviewer.

pragmatists may also be committed to. The same goes for the view that I will motivate later in the paper, which inherits these features from van Fraassen's constructive empiricism.

3. Manifest adequacy

At this point, I will discuss a kind of empirical adequacy that is weaker than van Fraassen's notion, namely, manifest adequacy. I'll begin with Asay and Bordner's (2015) recent characterization of manifest adequacy. According to them, "[t]heories are manifestly adequate when they correctly capture not all phenomena, but only the *observed* phenomena" (2015, p. 149; emphasis in original). The most defensible form of manifest adequacy concerns, not merely the phenomena observed so far, but also any phenomena that will be observed at any time in the future. Asay and Bordner call this notion "a comprehensive notion of manifest adequacy," and they characterize it as follows: "A comprehensively manifestly adequate theory is one which captures all truths about *all* the observed phenomena, whether past, present, or future" (2015, p. 149; emphasis in original). When I use the term 'manifest adequacy' in what follows, I mean this notion of comprehensive manifest adequacy.

Since I want to compare manifest adequacy with van Fraassen's all-things-considered definition of empirical adequacy, I will put manifest adequacy in a form similar to the form that van Fraassen puts his definition. What Asay and Bordner give us is closer to van Fraassen's preliminary explication of empirical adequacy rather than his all-things-considered definition. For the purposes of characterizing manifest adequacy, we can treat the notions of a theoretical model, the empirical substructures, and appearances exactly as van Fraassen does. Recall that, on van Fraassen's definition, a "theory is empirically adequate if it has some model such that all appearances are isomorphic to empirical substructures of that model" (1980, p. 64). For van Fraassen, "all appearances" means all appearances regarding actual, observ*able* phenomena, whether or not such phenomena are ever actually observed. The crucial difference between van Fraassen's notion and manifest adequacy is that, for manifest adequacy, "all appearances" means all appearances regarding actually observ*ed* phenomena, whether observed in the past, present, or future.

The view that manifest adequacy is the aim of science is known as manifestationalism or manifest empiricism (Railton, 1989; Rosen, 1994; Alspector-Kelly, 2001, 2006; Monton & van Fraassen, 2003; Ladyman, 2004; Ladyman & Ross, 2007; Asay & Bordner, 2015; Gava, 2019; Ruyant, 2021). Basically, it is the view that we get by substituting manifest adequacy for van Fraassen's definition of empirical adequacy in the characterization of constructive empiricism. Apart from a modest defense by Asay and Bordner (2015), manifestationalism is usually considered to be an absurd position. This is due in large part to an objection from Rosen (1994) that suggests that manifestationalism cannot accommodate some central aspects of scientific practice. In section 5, I'll consider Rosen's objection in more detail. Although manifestationalism may be an absurd position, I'll argue for a way of understanding manifest adequacy as an aim of science while avoiding Rosen's objection. But first, I'll argue that, from the standpoint of scientific practice, we ought to replace the aim of constructing empirically adequate theories, in van Fraassen's sense of empirical adequacy, with the aim of constructing manifestly adequate theories. I now turn to this argument.

4. In defense of manifest adequacy

In order to argue for manifest adequacy and against van Fraassen's notion of empirical adequacy, I'll begin with a question: How should we understand empirical adequacy in such a way that the aim of constructing empirically adequate theories can fruitfully guide scientific practice?

The question requires some clarification, specifically regarding what it would mean for an aim to fruitfully guide scientific practice. In order to clarify the question, I'll make use of Chang's (2022) notion of operational coherence. On my view, an aim fruitfully guides scientific practice if the activity of attempting to achieve that aim is operationally coherent in Chang's sense. In that case, the aim of constructing empirically adequate theories fruitfully guides scientific practice if the activity of attempting to construct such theories is operationally coherent.

Chang (2022, p. 4) provides a first approximation of the notion of operational coherence as follows: "Very roughly, operational coherence is a matter of making elements of our activities fit together harmoniously so that our aims may be achieved." He goes on to provide a couple of illustrative examples. The first concerns the ways in which various actions and movements are coordinated with one another when one rides a bicycle. The second concerns the ways in which various theories and technologies are coordinated in the global positioning system (GPS). Chang's all-things-considered account of operational coherence is as follows:

> In short, operational coherence consists in aim-oriented coordination. A coherent activity is one that is well designed for the achievement of its aim, even though it cannot be expected to be successful in each and every instance. Operational coherence is based on pragmatic understanding; it consists in doing what *makes sense* to do in specific situations of purposive action. (Chang, 2022, p. 40; emphasis in original)

In order to evaluate whether an activity is coherent in this sense, we must first determine what the aim of the activity is. We must then investigate the extent to which the elements of the activity are coordinated in such a way as to bring about that aim. Chang (2022, pp. 41-42) also makes it clear that operational coherence is a matter of degree rather than an all-or-nothing notion. Activities can be more or less coherent to the extent that they can be more or less well designed and more or less coordinated.

How should we understand empirical adequacy in such a way that the activity of constructing empirically adequate theories is an activity with a high degree of operational coherence? So far, I've focused mostly on the notion of empirical adequacy rather than on the activity of constructing empirically adequate theories. So, it will be necessary to briefly describe this activity in order to evaluate it in terms of Chang's notion of operational coherence. Oftentimes, scientists are already working with at least one theory when they do their experimental work. They collect data via observation and experiment, and they often create a model of the data rather than comparing the theory with the raw data. They consider the extent to which the theory fits the data. When the fit is not exact enough, they may revise the theory, develop it further, or consider an alternative theory. The ultimate aim of this activity is to construct an empirically adequate theory, and so that is the aim that we must keep in mind when

evaluating this activity. However, regardless of whether we understand empirical adequacy as manifest adequacy or in the way that van Fraassen proposes, there is a sense in which the aim is practically unachievable. At any stage in the process described above, the best we can hope for is that we arrive at a theory that has *not* been shown to be empirically *in*adequate. Regardless of which sort of empirical adequacy we aim at, we have the same starting point: the data that we've collected up until that point in time. At most, we can only show that a theory fits the data collected so far.

There is an issue here about whether some form of inductive reasoning may justify the claim that a particular theory that fits the data so far will fit future data and is therefore empirically adequate. Could there be an inductively strong inference from a theory's ability to fit the data so far to the conclusion that it will fit all future data? Here I can only note my skepticism. If we adopt something like Norton's (2021) material theory of induction, for example, it's not clear to me what sort of fact could warrant this inference. Moreover, since I'm making use of van Fraassen's and Chang's ideas in this paper, perhaps it's appropriate to follow their inductive skepticism here. In response to Cartwright (2007), van Fraassen writes: "I do not think that there is such a thing as Induction, in any form, and I would also express this in more or less her words: *there is no purely epistemic warrant for going beyond our evidence*" (van Fraassen, 2007, p. 343; emphasis in original). More recently, Chang (2022, p. 250) has made a similar point: "in practice, 'ampliative inference' is a lazy notion: if only, somehow, just by thinking, we can get stronger conclusions than apparently warranted by the evidence we put into the thinking […]" I'll follow van Fraassen and Chang, and I'll argue that there is a way to make sense of the activity of constructing empirically adequate theories even for an inductive skeptic.

If it is practically impossible to achieve the aim of this activity of constructing empirically adequate theories, does this activity therefore have a low degree of operational coherence? Not necessarily. In order to see why, I will make use of another idea from Chang's work, namely, the idea of an "operational ideal" (2022, p. 2). Chang observes that "[i]deals are of course hardly ever achievable, but in order to serve a useful function an ideal needs to be something that has an effect of making us think and behave differently" (2022, p. 2). Such ideals are operational ideals, and Chang's examples include such things as creating a test for a virus that has no false negatives. Although we may not reach the ideal, by aiming for it, we can come closer to it. Chang's main example of an ideal that is not operational is the aim of absolute truth. Chang has in mind here the idea of absolute truth as correspondence to a mind-independent external world (2022, p. 69), an idea that, as a pragmatist, he rejects. As Chang (2022, p. 2) puts it, "there is nothing we can actually do in order to approach that ideal."

Since my argument in this section makes use of Chang's views regarding operational ideals, there is a sense in which my argument presupposes some sort of pragmatist view. More specifically, my argument turns on the pragmatist idea that it is problematic to talk about correspondence (or fit, when it comes to theoretical models) when one of the two things in the relation of correspondence (or fit) is completely inaccessible to us. While traditional scientific realists may find this pragmatist idea objectionable, it is consistent with a broadly empiricist view. That is the important point for my purposes since my main goal in this paper is to motivate a new position for empiricists rather than to persuade traditional realists to become empiricists.

The next question is: Even if empirical adequacy is practically unachievable as an aim, how can we understand such an aim as an operational ideal? My answer, in short, is that we should understand it as manifest adequacy rather than in the way that van Fraassen proposes.

Empirical adequacy, understood as manifest adequacy, is an operational ideal. It is an ideal in the sense that, at any stage in the process of science, there will be further observations that scientists haven't yet made,[6] and so we cannot demonstrate that we have achieved the aim. However, it is an ideal that we can approach by constructing theories that fit more and more of the observations that we have made and continue to make. We have methods for constructing theories that fit the data we have collected so far. And the methods for constructing theories that fit future data are basically the methods for constructing theories that predict what we will observe in the future and testing whether those predictions are true. Hence, this ideal does have an effect on the way in which scientists think and behave, and it is therefore an operational ideal. As a result, even if the aim of constructing a manifestly adequate theory is an aim that we will never achieve in practice, the activity of attempting to construct such theories is an activity with a high degree of operational coherence.

Now we can consider empirical adequacy understood in the way that van Fraassen defines this notion. The main difference between van Fraassen's notion and manifest adequacy is that van Fraassen's notion requires fitting actual observable phenomena that will never be observed. Van Fraassen (2008, p. 247) acknowledges that these sorts of cases that involve fitting "[p]henomena far outside experience" pose a challenge to empiricism. The challenge he considers is that "we have to understand how a phenomenon somewhere and somewhen, which is not encountered in human experience or targeted in actual measurements or observations, can be said to 'fit' a theoretical model" (2008, p. 246). The specific example of a forever unobserved phenomenon that van Fraassen considers is "the actual number of bacteria in a certain colony located in Antarctica in a certain interval of 12 hours several million years before humanity emerged on earth" (2008, p. 248). After asking whether the growth of the colony during this interval fits one of the models under consideration and what that could mean, van Fraassen provides the following answer:

> At the beginning of those 12 hours there was a certain number $N'(0)$ of bacteria in the colony and at each time $t = \tau, 2\tau, [\ldots]$ within those hours a number $N'(\tau)$. Is the function N' actually one of the empirical substructures of one of those models? Yes or no? If yes, then the phenomena fit that model, and hence the theory, in the sense required. (2008, p. 248)

Generalizing from this specific example, the core of van Fraassen's response to the challenge is to note that there is some fact of the matter regarding phenomena that, due to being too distant in space or time, we will never observe. If the phenomenon in question is as the empirical

[6] There is an exception that is relevant to manifest adequacy, namely, the point at which our epistemic community makes its very last observations. I'll ignore this exception because I don't think this sort of extreme circumstance is representative of scientific practice more generally.

substructures of some theoretical model characterize it, then the model fits the phenomenon; and if not, then it does not.[7]

Van Fraassen's response to this challenge brings out the sense in which his notion of empirical adequacy is not an operational ideal, at least to the extent that his notion goes beyond manifest adequacy. This way of understanding how a theoretical model could fit observable but forever unobserved phenomena certainly looks similar to the idea of absolute truth as correspondence to a mind-independent external reality. In both cases, one of the things that stands in the relation of fit or correspondence is completely inaccessible to us. Like absolute truth, the ideal of constructing a theoretical model that fits phenomena that scientists will never observe is not the sort of ideal that scientists could approach. Hence, we have another example of an ideal that is not operational.

That said, it's important to acknowledge that van Fraassen's notion of empirical adequacy, considered as an ideal, is operational to the extent that it overlaps with manifest adequacy. Like manifest adequacy, the aim of empirical adequacy, in van Fraassen's sense, encourages scientists to construct theories that fit the currently available data and accurately predict what we will observe in the future. To that extent, it is an operational ideal. And to that extent, the activity of constructing empirically adequate theories in van Fraassen's sense can be seen as an operationally coherent activity. However, to the extent that it goes beyond manifest adequacy, it becomes an ideal that is not operational. As a result, the activity of constructing empirically adequate theories, in the sense that goes beyond manifest adequacy, has a low degree of operational coherence.

To the extent that van Fraassen's notion includes the weaker notion of manifest adequacy, the ideal is just as operational as manifest adequacy; and to the extent that it goes beyond manifest adequacy, the ideal is not operational. As a result, when considering the operational coherence of the activity of constructing empirically adequate theories, van Fraassen's notion of empirical adequacy does not give us anything that we cannot get from manifest adequacy. So, we ought to understand empirical adequacy as manifest adequacy rather than in the way that van Fraassen proposes.

However, a full defense of understanding empirical adequacy as manifest adequacy requires addressing Rosen's (1994) objection to understanding manifest adequacy as the aim of science. I now turn to that objection, and my response to it, which involves introducing a pluralist empiricism which differs from constructive empiricism.

5. Towards a pluralist empiricism

Rosen (1994, pp. 161-162) raises the following objection to manifestationalism, which is the idea that the primary aim of science is to construct theories that are manifestly adequate. Suppose that

[7] In responding to this challenge, van Fraassen is concerned with some issues that are not relevant for my purposes, and his response to the challenge involves exploring some subtleties that I will ignore here. Very briefly, he is concerned with refuting the idea that, in order to fit the model, the phenomenon and the model must have some kind of shared structure in a sense that implies the objective existence of something like universals, which would presumably be problematic for an empiricist. See van Fraassen (2008, pp. 247-250).

science aims primarily at manifest adequacy. Suppose further that we have a theory that fits our observations so far. If we continue to make observations, we risk making an observation that does not fit with that theory. Should we continue to make observations? If we stop making observations then, since the theory fits the past observations, and since there are no future observations, the theory would be manifestly adequate. In that case, the primary aim of science would be achieved. Hence, in order to achieve the primary aim of science in this case, we should stop making observations. And that, of course, goes against one of the most fundamental aspects of scientific practice, which is to make new observations. Rosen (1994, p. 162) illustrates the objection in terms of an example. Suppose an archaeologist has a theory that fits all of the observations so far regarding Etruscan urns. Suppose further that there is only one site in the world that may contain some additional Etruscan urns, and that this archaeologist can decide whether to dig or destroy the site. Rosen's point is that, if the primary aim is a manifestly adequate theory, the archaeologist ought to destroy the site. Since manifestationalism conflicts with scientific practice, we therefore ought to reject it. Except for one modest defense of manifestationalism against Rosen's objection (Asay & Bordner, 2015), there is some consensus among philosophers who have considered the issue that manifestationalism is an absurd position (Railton, 1989; Rosen, 1994; Alspector-Kelly, 2001, 2006; Monton & van Fraassen, 2003; Ladyman, 2004; Ladyman & Ross, 2007; Gava, 2019; Ruyant, 2021).

In Rosen's (1994, p. 162) view, constructive empiricism is the weakest empiricist position that has any chance of accommodating scientific practice. If scientists stop making new observations in the sort of scenario described above, the result may be a manifestly adequate theory. But such a theory would not be an empirically adequate theory in van Fraassen's sense because such a theory needs to fit, not just the observed phenomena, but rather all actual observable phenomena. Hence, according to constructive empiricism, it makes sense why scientists would continue to make new observations, and why the archaeologist would dig rather than destroy the site.

However, constructive empiricism may be susceptible to a modified version of Rosen's objection (Ladyman & Ross, 2007, pp. 109-110; Ruyant, 2021, p. 106). Suppose that scientists have a theory that has not yet been shown to be empirically inadequate, and that predicts that, under certain experimental conditions, it is possible to create an observable phenomenon that would not exist otherwise. Suppose further that the scientists are able to perform this experiment and test the prediction. The risk is that, by performing the experiment, the theory may be shown to be empirically inadequate, thus making it more difficult to achieve the aim of constructing empirically adequate theories. However, if scientists refrain from performing the experiment, there will be no chance that the hypothesized phenomenon becomes actualized. Empirical adequacy, in van Fraassen's sense, doesn't require fitting possible but non-actual phenomena. By refraining from performing the experiment, scientists thereby make it easier to achieve the aim of constructing empirically adequate theories. Hence, according to constructive empiricism, the scientists should not perform the experiment. And that conclusion goes against the scientific practice of creating new types of phenomena when possible.

Since I've already argued, in section 4, that we have independent reason to reject van Fraassen's notion of empirical adequacy in favor of manifest adequacy, the most important task at this point is to respond to Rosen's objection to manifestationalism. That said, as I will discuss

later, a modified version of my response to Rosen's objection may provide a way to address the above objection to constructive empiricism. However, these responses will leave neither manifestationalism nor constructive empiricism intact.

The point that I want to make now is that there are two ways to take the upshot of Rosen's objection to manifestationalism. In short, Rosen's objection is that manifestationalism is an absurd position because it conflicts with scientific practice. Recall that manifestationalism is the view that the primary aim of science is manifest adequacy. The standard way to understand the upshot of Rosen's objection is to conclude that the primary aim of science is something stronger than manifest adequacy, for example, empirical adequacy as van Fraassen understands it. However, there is another way to understand the upshot. We could retain the idea that science aims at manifest adequacy while rejecting the idea that this aim is the primary aim of science. This latter idea is the idea that I will explore in what follows.

I'd like to propose a pluralist empiricism according to which science does not have one primary aim, but rather has a number of aims, none of which is primary, but all of which are important. Moreover, these aims should be empiricist aims in the sense that they do not involve the sorts of problematic metaphysics that empiricists reject and do not go far beyond what we can experience. One important empiricist aim is the aim of making new observations, where observations may be new in the sense that they involve unexplored parts of nature or types of experiments that have not yet been performed. Another important empiricist aim is the aim of producing new kinds of observable phenomena, especially those that may not exist if scientists do not create them. In contrast, correctly describing the properties and behavior of unobservable entities (a traditional realist aim of science) and capturing the objective modal structure of reality (a structural realist aim of science) are not empiricist aims. Pluralist empiricism is the view that we can make sense of scientific practice without going beyond the empiricist aims of science, where none of these aims is the primary aim of science.

By proposing that empiricists ought to understand science as having multiple aims, I'm once again taking a cue from Chang's work. One of the themes of his work is pluralism, and Chang (2018, p. 177) comments that "the most basic source of pluralism is the plurality of the aims of science." Among the aims that he discusses are "description and understanding" as well as "the production of new phenomena" (2018, p. 177), which is an aim that will play an especially important role in my response to Rosen's objection. Chang also explicitly considers van Fraassen's view that empirical adequacy is the primary aim of science. Van Fraassen originally framed his position in terms of the aim of science in order to characterize what would count as success when it comes to the activity of science (1980, p. 8). In contrast, Chang argues that we ought to understand the empirical success of science across multiple dimensions rather than solely in terms of empirical adequacy.

My main goal in this paper is to defend a particular way of understanding empirical adequacy as an aim of science. And my main reason for proposing this sort of pluralist empiricism is connected to this goal. In order to defend the view that empirical adequacy ought to be understood as manifest adequacy, I need a framework for attributing to science the aim of constructing manifestly adequate theories while avoiding Rosen's objection. Pluralist empiricism is that framework. It squares with scientific practice because, unlike manifestationalism, pluralist

empiricism does not entail that scientists should refrain from making new observations or producing new phenomena. This is because these aims are separate aims of science, distinct from the aim of constructing manifestly adequate theories. If we have a theory that fits all of the observations so far, these separate aims ensure that we continue to make new observations and produce new phenomena. Pursuing the aim of constructing manifestly adequate theories then requires that we examine whether our theory can accommodate these new observations and new phenomena. It may be that our theory cannot accommodate them. In that case, the aim of manifest adequacy ensures that we continue the process of constructing manifestly adequate theories that fit the new observations and new phenomena. To put the point in terms of Rosen's example, pluralist empiricism makes it clear that the archaeologist should dig rather than destroy the site.

Although these aims of constructing manifestly adequate theories, of making new observations, and of producing new phenomena are separate aims, they are related to one another in various ways. One important kind of activity in which these aims are interrelated is the activity of theory testing. Theories are tested in terms of whether their predictions align with what scientists observe and what phenomena scientists produce in experimental settings. Scientists are independently motivated to make new observations and produce new phenomena, given that these are separate aims of science. These aims will, in turn, shape how scientists conceive of the aim of constructing manifestly adequate theories. Given these aims, scientists anticipate that their colleagues and successors will make new observations and produce new phenomena. As a result, they aim to construct theories that anticipate those new observations and new phenomena, i.e., theories that will pass future tests. Moreover, the observations and phenomena that typically matter most for theory testing are the ones that are new in the senses described above, i.e., the senses of involving unexplored parts of nature, new types of experiments, and new types of phenomena. However, scientists aim for this sort of novelty, not merely for the sake of testing the manifest adequacy of theories, but for its own sake. In that case, these aims of making new observations and producing new phenomena are still separate from the aim of constructing manifestly adequate theories. And since novelty is part of these aims regarding observations and phenomena, scientists would not be motivated to make the same observations or produce the same phenomena over and over again, especially after such results have been replicated enough times to demonstrate their reliability.

Pluralist empiricism also provides the resources for responding to the modified version of Rosen's objection that applies to constructive empiricism. Since producing new observable phenomena is a separate aim of science, pluralist empiricism fits with the standard scientific practice of creating new types of phenomena. Some empiricist philosophers of science may prefer van Fraassen's notion of empirical adequacy. They could offer more-or-less the same response that I developed above while replacing the aim of constructing manifestly adequate theories with the aim of constructing theories that are empirically adequate in van Fraassen's sense. That said, for the reasons discussed in section 4, the version of pluralist empiricism that I defend here maintains the aim of constructing theories that are merely manifestly adequate.

Pluralist empiricism, as I've introduced it here, is more of a general framework for an empiricist philosophy of science rather than a completely spelled-out position. This is another way in which it contrasts with constructive empiricism, which is more completely spelled out.

Van Fraassen clearly states his position by specifying the primary aim of science. In contrast, I've introduced pluralist empiricism as the idea that science has many empiricist aims, none of which is primary, and all of which are important. But I haven't specified what all of those aims are. Here I've only specified three of those aims: constructing manifestly adequate theories, making new observations, and producing new phenomena. I focus on these aims mainly because of my concern with how an empiricist should understand empirical adequacy, and because of my goal of defending an understanding of empirical adequacy as manifest adequacy, especially in light of Rosen's objection. It's possible that science has other empiricist aims, and we may need to appeal to other such aims in order to account for other aspects of scientific practice. As a result, I won't commit to the claim that the three aims I've focused on here are the only empiricist aims of science. I regard it as a topic for future research to develop the general framework of pluralist empiricism in more detail and investigate whether other empiricist aims are needed to account for other aspects of scientific practice.

A final question that should be addressed concerns the relationship between pluralist empiricism and scientific practice. In particular, is pluralist empiricism supposed to be descriptive or revisionary? Philosophers of science who are engaged in descriptive projects believe that scientific practice is typically rational, and they seek to offer a philosophy of science that fits with how science is actually practiced. As I understand van Fraassen's position, his constructive empiricism is part of such a descriptive project, where the "positive argument for constructive empiricism" is that "it makes better sense of science, and of scientific activity, than realism does and does so without inflationary metaphysics" (1980, p. 73). In contrast, philosophers of science who are engaged in revisionary projects believe that scientific practice could be better, and they seek to offer a philosophy of science that can change and improve scientific practice. A good example of this sort of project is the normative position that Chang has developed, which advocates the proliferation of alternative systems of scientific practice (2012, pp. 284-285). The challenge for empiricist philosophers of science with which I began the paper is a descriptive challenge insofar as it involves making rational sense of actual scientific practice from an empiricist perspective. I've proposed pluralist empiricism as a way of addressing that challenge, and so, pluralist empiricism, as I've developed it here, is a descriptive project. To be sure, it's possible for the general framework of pluralist empiricism to be developed in a revisionary way, perhaps based on the idea that scientific practice should be more empiricist than it actually is. That said, my goal in this paper has been to develop pluralist empiricism as a descriptive project.

6. Conclusion

I've considered three positions in this paper: constructive empiricism, manifestationalism, and pluralist empiricism.

Constructive empiricism, as perhaps the most well-developed empiricist philosophy of science in the anti-realist tradition, is, in many ways, a worthwhile position. Any empiricist successor to constructive empiricism would have to preserve the many strengths of this position. However, the position also has its weaknesses. The two that I have focused on concern van Fraassen's notion of empirical adequacy and his idea of characterizing science in terms of one primary aim. Regarding his notion of empirical adequacy, I've argued that we ought to prefer

manifest adequacy to van Fraassen's notion on the grounds of operational coherence. And regarding the aim(s) of science, I've suggested that we ought to be pluralists rather than monists.

Manifestationalism is generally viewed as an absurd position, but I've argued that there is something valuable here that should not be rejected with manifestationalism, namely, the notion of manifest adequacy. I agree with the consensus that Rosen's objection provides a solid ground for rejecting manifestationalism. But I've also argued that we ought to understand empirical adequacy as manifest adequacy, again on the grounds of operational coherence. While the standard way of understanding the upshot of Rosen's objection is that the primary aim of science is something stronger than manifest adequacy, I understand the upshot as the idea that manifest adequacy is not the primary aim of science, though it is still an aim of science.

Pluralist empiricism is the framework that I've proposed for incorporating the strengths of these two positions while avoiding their weaknesses. I've defended it mainly on the grounds that it offers a way of understanding empirical adequacy as manifest adequacy while avoiding Rosen's objection to manifestationalism. In doing so, I've focused on the aims of constructing manifestly adequate theories, making new observations, and producing new phenomena. I take it that these are most likely not the only empiricist aims of science. Further development of pluralist empiricism may identify other aims and show how empiricists can use these multiple aims of science in order to make sense of scientific practice.

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