Reassessing Realism

On the Ontology of the Unobservable

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Abstract

It is widely believed that science is in the business of finding out what the world is *really* like. The philosophical version of this belief is *scientific realism* -- a doctrine about science that tells us that we ought to believe that the best theories in science are true, and that the world is occupied with the objects that those theories contain. If scientific realism was not correct, the argument goes, the incredible success of science would be a miracle. The best explanation for the success of science however, is not that it is a miracle, but that scientific theories are true. This argument is an instance of inference to the best explanation, or IBE. Skeptics have questioned why scientific success must imply its truth given that there are so many abandoned, false scientific theories in the history of science that were nevertheless successful. One of the controversies in the debate between scientific realists and anti-realists surrounds the legitimacy of reasoning in accordance with IBE. Realists need IBE to be a justified and reliable guide to truth. In this compilation thesis, I address various questions related to IBE and scientific realism. Paper 1 argues that scientific realism without IBE loses too much of its epistemic optimism, and that it in some contexts even becomes more pessimistic than the most prominent rival philosophical doctrine about science -- constructive empiricism. To avoid deflating realism, I argue, a defense of IBE is necessary. Paper 2 addresses whether methodological similarities between science and metaphysics force scientific realists to also be realists with respect to metaphysics. If IBE is legitimate, it should not only be valid in science, but also in metaphysics, effectively inflating the ontology that scientific realists are rationally bound to accept. I argue against this conclusion. Paper 3 offers a proof of concept regarding a novel way to justify inferences to unobservable objects. Paper 4 establishes a novel critique of non-probabilistic versions of IBE in scientific realism.

Keywords: *Scientific Realism, Inference to the best explanation, Scientific Method.*

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Cover image: The Carina Nebula - a star forming Nebula in the Milky Way.
Image credit: NASA, ESA, CSA, and STScI.

To my family and
friends, for unwavering
support. Thank you.

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1. Introduction

1.1 The project

The central theme discussed in this thesis is *scientific realism*. As a rough definition, scientific realism is a philosophical doctrine that says that we, under certain specified conditions, ought to believe that our best scientific theories are true or approximately true, that their terms successfully refer, and that we are justified in believing that the entities described by successful scientific theories exist.[1] For many, myself included, science has an intuitive appeal, given the central role it has in society and how much we rely on it for our everyday lives to function. Providing a rigorous philosophical defense of scientific realism, especially regarding the 'certain specified conditions' under which it applies, has proven to be a difficult task. One of the largest conceptual and empirical obstacles for scientific realism has been how to account for past scientific theories which we now believe were wrong. Given that many such theories can be found in the history of science, and assuming that we have no reason to believe that we are located in an especially truth-conducive part of history, we have no reason to believe that our current best scientific theories are any different in that respect

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[1]I will not engage in the conceptually alternative definition of scientific realism as a doctrine about the *aim* of science, as offered by van Fraassen (1980) and Lyons (2005), although some of their criticism against scientific realism will be addressed.

from our past theories. Another issue which is coupled with the historical challenge is that most defenses of scientific realism depend on the legitimacy of explanatory reasoning, specifically an inference where explanation is taken to be a guide to truth. If it should turn out that explanatory reasoning of the relevant kind can be argued to be irrational, this would undermine the rationale for scientific realism.

This introduction to the thesis provides a rough explication of scientific realism, and its main supporting argument – the no-miracles argument. It also outlines one of the main objections to realism – the pessimistic meta-induction – and how realists have responded to it. Given that the most optimistic of those responses still depend on the legitimacy of explanatory reasoning, a section devoted to the explication of a particular instance of explanatory reasoning – inference to the best explanation (IBE) – is provided. Lastly, the introduction offers a set of salient objections to this particular inference rule.

Given that the most optimistic realist project of the different propositions is sensitive to the fate of explanatory reasoning, the first paper explores a view that relies less on explanatory reasoning and more on causation. I offer an analysis of the consequences for realism that this view entails by studying the case of the cosmic event horizon. Ultimately, I reject this version of realism because it turns out that in some ways, it is *less* epistemically optimistic than anti-realism, but more liberal than realism in terms of metaphysical influence on physics.

If one, as I do, takes this less explanatory realism to be in a sore state, one must face the challenges coupled with defending inference to the best explanation. Papers 2 and 3 attempt to deal with these challenges. One challenge is to decouple the use and justification of IBE in metaphysics from the use of IBE in science and realism so as not to conflate the epistemic grounds for believing in the posits of science with our epistemic grounds for believing in the posits of metaphysics. An argument to this effect is presented in paper 2. Paper 3 aims to provide some

additional substance to paper 2 by means of a case study of the discovery of radium. This case study is meant to convince you that IBE with respect to entities considered unobservables can in some cases be confirmed observationally, giving us a proof of concept for the justification of IBE with respect to objects considered unobservable. The usual problems facing a scientific realism dependent on explanatory reasoning, I argue, can thus be mitigated. The last paper is devoted to a novel way in which non-probabilistic versions of IBE spell trouble for realism – the problem of undermining empirical confirmation in contexts where IBE nevertheless is applicable.

The overarching argument in the thesis can be summarized as something like the following: realists do not need to abandon IBE for fear of being epistemically on a par with, or accidentally justifying, metaphysics; nor need they abandon IBE because it is unjustified with respect to unobservables. What they *do* need to worry about, and pay more attention to, is how IBE operates in theoretical contexts where it is applicable despite the fact that the central objects of the theory are not yet empirically confirmed. These contexts show that non-probabilistic IBE is in principled conflict with canonical ideas of empirical confirmation, which is a conflict that realists will have, not with metaphysicians or constructive empiricists, but with scientists and confirmation theorists.

1.2   What is scientific realism?

There are many ways to express the idea or view that our scientific theories correctly describe the world we live in:

> To a very rough, first approximation, realism is the view that our best scientific theories correctly describe both observable and unobservable parts of the world. (Chakravartty, 2007, preface)

> [...] scientific realism is the view that we ought to believe that our best current scientific theories are approximately

true, and that their central theoretical terms successfully refer to the unobservable entities they posit. (Ladyman et al., 2007, 68)

Different formulations of this idea come in as many varieties as philosophers who engage with it, but common for all of the formulations is a positive epistemic attitude towards the conclusions and results offered by scientific practice.[2] We have *good reason* to believe that the world works according to well established and confirmed scientific theories and that it is populated with the entities posited therein. The core in all the different versions of the claim is that science produces *knowledge* in the philosophical sense. To further unpack and clarify what scientific realists mean when they claim that science produces knowledge, it is customary to distinguish between the different philosophical commitments that facilitate the claim.

1.2.1 Three central theses

In comparison to the history of philosophy, the history of philosophy of science is relatively short.[3] Despite its 'short' history the core claims central in the debate about the topic of scientific realism have evolved and changed substantially more than once. Though it may be an imprecise and perhaps even anachronistic perspective, I think it is fair and instructive to say that its historical morphology can be viewed by distinguishing the differences in emphasis it has placed on what Psillos (1999; 2009) refers to as the three central theses of scientific realism: the epistemic thesis, the semantic thesis, and the metaphysical thesis:

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[2]See for example Maxwell (1962); Putnam (1975); Boyd (1980); Hacking (1983); Harré (1986); Worrall (1989); Kitcher (1995); Psillos (1999); Vickers (2013) for different formulations of scientific realism.

[3]Here, I'm taking 'science' to refer to the systematic and modern approach characterized by theory construction, prediction, and experimentation.

> *The Metaphysical Thesis*: The world has a definite and mind-independent structure.
>
> *The Semantic Thesis*: Scientific theories should be taken at face value. They are truth-conditioned descriptions of their intended domain, both observable and unobservable. Hence, they are capable of being true or false. The theoretical terms featuring in theories have putative factual reference. So, if scientific theories are true, the unobservable entities they posit populate the world.
>
> *The Epistemic Thesis*: Mature and predictively successful scientific theories are well confirmed and approximately true of the world. So, the entities posited by them, or, at any rate, entities very similar to those posited, inhabit the world. (Psillos, 1999, xix), (Psillos, 2009, 4)

Although the first thesis is accepted by realists, it is not *only* accepted by realists. One contrasting view with respect to the acceptance of the metaphysical thesis would be *idealism* – the idea that reality is a construction or collection of ideas generated by the mind. According to this view, the world is dependent on the mind, and does not have an existence external to it. In the modern context of philosophy of science, however, idealism has no lasting offspring despite being a historically important view, so will not be further addressed here.[4]

Acceptance of the second thesis is supposed to facilitate the idea that we can take the claims that scientists make with respect to the world literally. The realist interpretation of claims in science, for example 'the electron has a negative charge' is that is has a definite truth-value, whether it is true or false. This means that realists take electrons to actually exist and that they actually have a negative electric charge. One contrasting view, in the sense of denying the semantic thesis, is *instrumentalism*. Most instrumentalists hold that scientific descriptions of entities which can not be observed are meaningless,

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[4]One may also view logical empiricism – the idea that the mind-independent structure of the world is a meaningless statement – as a doctrine that rejects the metaphysical thesis.

or devoid of semantic content, beyond the mere pragmatic use of them to create predictive systems with respect to observable phenomena.[5] For instrumentalists, the interpretation of 'the electron has a negative charge' is just to say that if we treat the world *as if* it contained things like electrons with negative charge, we can create systems that allow us to predict behavior at the observational level. There is no need, strictly speaking, to interpret scientific claims literally in order to make those predictive systems work. Historically, instrumentalism is connected to philosophy of science at the turn of the last century, especially to the philosophy of Duhem (1991) and Mach (1907), but it has also been considered in more contemporary debates, then by Rowbottom (2011) and Dion (2013).

Accepting the third thesis is a matter of accepting some version of the claim that the claims made by scientists are justified. The epistemic thesis is a license to be optimistic about the idea that science is in the business of generating knowledge about the world, and that it is successful in this endeavor. The acceptance of this thesis leads to a full scientific realist view: scientific theories are about the mind-independent world, the claims within those theories can be true or false, and we are justified in believing that those claims are true, even when it is theoretical truth such that those claims are about unobservable objects. In contrast to the full fledged scientific realism which is the result of accepting these three theses, there are positions which accept the metaphysical and the semantic theses, but which deny the epistemic one. One set of views which denies that we are, or will ever be, in possession of knowledge of theoretical truth is *agnostic empiricism*. These views take it that there is a mind-independent structure to the world, that scientific claims are to be taken literally, but that the only statements we can be in a position to know are true or false are observational state-

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[5]Some instrumentalists may be exempted from this general implication. A Ramsay sentence may be interpreted as instrumental, in which case theories are on par with their empirical content in terms of being meaningful.

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ments. The agnostic part of such views consists of the fact that scientific theories may contain true statements about the mind-independent world, but that we have no safe epistemic route to checking if this is so. By far, the dominant view in this spirit is the constructive empiricism developed and championed by van Fraassen (1980; 1985; 1989; 2001).

Generally speaking, early scientific realists tended to put more emphasis on the semantic thesis given the questions concerning the meaningfulness and reference of theoretical terms asked by the logical positivist movement. Later realists have instead given more attention to the epistemic thesis and the ability of science to generate knowledge about the unobservable parts of our world. Despite putting different amounts of effort on defending the different theses realists subscribe to some form of all of them. Given that realism can be conceptually understood as accepting these theses, what reasons do realists offer in support of that acceptance?

1.2.2 The No-Miracles Argument

Historically speaking, the no-miracles argument (NMA) is probably the most influential one in favor of scientific realism. The argument was first formulated by Putnam (1975) and can be stated as follows:

1. Our best scientific theories are predictively successful.

2. The hypothesis that our best scientific theories are true (or approximately true) is the best explanation of the predictive success.

3. Therefore: Our best scientific theories are true (or approximately true).

The argument is taken to establish the (approximate) truth of our best theories because the denial of that conclusion entails

the acceptance of the claim that the astonishing level of predictive success in science comes about by chance, or, by a *miracle.* If we must choose between a miracle and the truth of our best scientific theories in order to account for the predictive success of science, realists argue, we should pick the latter.[6] Since its conception, NMA has, in some form, been the dominant argument for realism. We may already at this point take note of the fact that the inference at play in various NMA type arguments is inference to the best explanation. IBE is a form of inference that takes explanation and truth to be connected such that a sufficiently good explanation of some phenomena can be taken to be true. The nature and justification of IBE will in some sense function as a recurring thread throughout this thesis, and will therefore be addressed in detail in the individual papers, but it also plays an important role in the history of the development of realism. The reason why is that if NMA is to succeed as an argument for realism, two things need to be the case: (i) there must be a clear explanatory connection between predictive success and truth, and; (ii) IBE must be a reliable form of inference. Realizing this, anti-realist arguments against realism have traditionally focused on objecting against (i) or (ii) or both. One argument that seeks to deny (i) is the so called pessimistic meta-induction (PMI).

1.2.3 The Pessimistic Meta-Induction

If NMA is the strongest argument for realism, then PMI is the strongest argument against it. PMI is an argument that targets the claim in NMA that there is an explanatory connection between predictive success and truth. First introduced by Laudan (1981), PMI takes the explanatory claim in NMA to involve a prediction with respect to the history of science – if predictive

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[6]An earlier version of the same argument can be found in Smart (1963), and subsequent versions have been defended by Boyd (1983), Lipton (2003), and Psillos (1999).

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success is linked to truth, then we will not find any instances of predictive success in abandoned scientific theories. This, as Laudan shows, is not the case:

> [...] what the history of science offers us is a plethora of theories which were both successful and (so far as we can judge) non-referential with respect to many of their central explanatory concepts. (Laudan, 1981, 33)

The use of 'non-reference' here is to say that the objects corresponding to central terms in many predictively successful theories in the past were ontologically empty. This means that we cannot assert the truth of theories which are empirically predictively successful, and we cannot take their central objects to exist. Laudan proceeds to give a list of scientific theories which were once predictively successful but nevertheless false:

– the crystalline spheres of ancient and medieval astronomy;
– the humoral theory of medicine;
– the effluvial theory of static electricity;
– 'catastrophist' geology, with its commitment to a universal (Noachian) deluge;
– the phlogiston theory of chemistry;
– the caloric theory of heat;
– the vibratory theory of heat;
– the vital force theories of physiology;
– the electromagnetic aether;
– the optical aether;
– the theory of circular inertia;
– theories of spontaneous gene (Ibid, p. 33)

The efficacy of the argument is easy to see – success and truth cannot be connected in the way realists need it to be on pain of being realist about abandoned scientific theories like the ones mentioned above. This shows that the semantic thesis of scientific realism – that the theoretical terms in successful scientific theories, which we can take to be true on account of their success, must populate the world – cannot be correct. This is

because the putative entities which, for example, phlogiston, was supposed to refer to did not exist. If we take Laudan's argument seriously, we ought to revise our doxastic attitudes towards current predictively successful theories from believing that they are true to agnosticism about their truth. It prompts a suspension of belief, but it does not require us to believe that current predictively successful theories are false. This historical gambit can, however, also be used in a stronger argument against realism. The stronger argument uses the false theories in the history of science as an inductive base for the evaluation of our current theories. In doing so it becomes clear that the appropriate doxastic attitude to have with respect to current scientific theories is *pessimism*, in the sense of being skeptical towards their truth, hence the name of the argument. The reason for this is that given that most of our predictively successful theories in the history of science have turned out to be false, and if we have no reason to believe that our current position is in some way privileged, then we have reason to believe that our current scientific theories are likely to turn out to be false as well.

PMI has proven to be a powerful argument against the realist, causing different proponents of realism to adopt different strategies to combat its rather stark conclusion. Below, I will sketch some of the salient modifications to the realist view that have been made in response to PMI.

1.3   Realism Fragmented

Most realists who have aimed to tackle PMI have opted for a reduction of the domain where realism is attainable. This reduction can, as we shall see, be approached in various ways. One approach is to make a distinction between being realist in the sense of claiming that a theory is true, and being realist about the existence of some of the objects or entities that a theory uses, or contains. This view is embodied by *entity real-*

ism, and restricts the domain of realism to entities, instead of theories. Another approach is to take the appropriate domain of realism to be structure, meaning that the internal structure of scientific theories represents actual structures in the world. This approach is aptly named *structural realism* and bans entities from realism. Realists who are uncomfortable with these revisions to the domain of realism may instead wish to include both theory and entities, but instead introduce restrictions on exactly which entities and which parts of a theory one may be realist about. This approach is known as the *'Divide et impera'* view, courtesy of Psillos (1999).

Common to these three versions of restricted realism is that they respond to PMI by becoming selective in their realism. Below, I will briefly describe the core claims for each type of selective realism.

1.3.1   Entity realism

The core of entity realism is, not surprisingly, a realist commitment to scientific *entities* only, as opposed to entities *and* theoretical truth. The ambition to obtain theoretical truth is, entity realists argue, a goal set too high. While the corpuscles present in the cathode ray tubes of J.J. Thomson in the late 19th century and the electrons used in electron microscopes today are claimed to be the same kind of entity, the theories that describe the nature of the electron have seen a number of changes during this time. These changes make it hard to assert the *truth* of theoretical statements concerning the nature of the electron, given the inconsistent descriptions found in the different theories. It is epistemic humility, in light of the PMI, that drives the omission of theoretical truth, narrowing the scope of realism to just the entities. How, then, are the conditions for realism about entities spelled out? Hacking (1983), one of the founders of, and primary advocates for, entity realism, suggests taking the *manipulation* of entities to be central to realist

commitment:

> Experimenting on an entity does not commit you to be-
> lieving that it exists. Only manipulating an entity, in
> order to experiment on something else, need do that.
> (Hacking, 1983, 263)

In order to manipulate an entity, scientists must first establish
a certain level of causal connection to it. The causal connec-
tion enables scientists to extract some of the causal properties
of the entity in order to build devices that can manipulate it.
The core premise for realism outlined by Hacking offers a sig-
nificantly smaller but epistemically safer scope of things to be
realist about: we may not be licensed to believe in the truth of
the standard model of particle physics or the theory of electro-
magnetism, but we are licensed to believe in the reality of the
electron and some of its causal properties. Hacking is in a sense
employing a methodological approach to realism: since experi-
mentation by manipulation of electrons does not require a full
theory of the nature of the electron, philosophers can take a leaf
from the experimentalists' book and be realist with respect to
entities which functions, to us, as tools.

Another philosopher who embraces the existence of theoret-
ical entities (meaning unobservable entities) is Cartwright:

> I think that van Fraassen and Duhem eliminate more
> than they should. It is apparent from earlier essays that
> I share their anti-realism about theoretical laws. On the
> other hand, I believe in theoretical entities, and that is
> my main topic in this essay. (Cartwright, 1983, 89)

Like Hacking, Cartwright puts emphasis on the role played by
causality in homing in on what she considers to be the proper
objects of realism: the entities. For her, however, the connection
between causation and realism is not modeled on the manipula-
tion of entities by experimentalists. Instead, *causal explanation*
is the epistemic route to realism. Causal explanations, she ar-
gues, only make sense if we take the causes described by the

explanations to be real. That is, if we want to take the causal explanations offered by science seriously, we have to believe in the entities to which they refer. Or as Cartwright herself puts it: "In causal explanations truth is essential to explanatory success." (1983, 10)

Both Hacking and Cartwright restrict realism to entities because they are worried about the consequences brought about when accepting theoretical truth, as demonstrated by PMI. Realism about theories may only be achievable if we are at the 'end of science' in some sense. That is, given the supposition that science converges to truth, theoretical truth can only be asserted once we have a final theory of everything. Even if we arrive at such a point, threats of underdetermination may still hold theoretical realism hostage given that there are alternatives to the final theory in logical space. For entities, however, things may not be so bleak. The entities manipulated today, to take Hacking's example, may very well be the same as those described by whatever final theory we end up with. The entities we can manipulate are stable during the discontinuous nature of theory change and this is why realism about them is attainable, *pace* PMI.

1.3.2 Structural realism

The acceptance of radical theoretical discontinuity is shared by structural realists, but instead of identifying the manipulable entities as the stable elements during theory change, they identify the core mathematical structure of scientific theories as the appropriate and stable objects for realism. The move is to suggest that there is a way for theoretical continuity to be broken while structural continuity obtains. Worrall (1989), commonly associated with the introduction of structural realism as a remedy for realism in response to radical theory-change, takes it to be supported by the fact that the mathematical structure – i.e. the equations – found in Fresnel's theory of light is retained

in the succeeding theory of light by Maxwell. This strategy, as Worrall notes in his (1989) abstract, has deep roots, starting with Henri Poincaré:[7]

> It cannot be said that this is reducing physical theories to simple practical recipes; these equations express relations, and if the equations remain true, it is because the relations they express preserve their reality. They teach us now, as they did then, that there is such and such a relation between this and that; only that something which we called motion, we now call electric current. But these are merely names of the images we substitute for the real objects which Nature will hide from our eyes. The true relations between these real objects are the only reality we can attain [...] Poincaré (1905, 179)

The idea of structural stability in theory change thus has some pedigree and can be backed with cases beyond the retention of equations from Fresnel to Maxwell:

> Simon Saunders (1993a) discusses the structural continuities between classical and quantum mechanics and also shows how much structure Ptolemaic and Copernican astronomy have in common. Harvey Brown (1993) explains the correspondence between Special Relativity and classical mechanics. Jonathan Bain and John Norton (2001) discuss the structural continuity in descriptions of the electron, as does Angelo Cei (2004). Votsis (2011) considers examples of continuity and discontinuity in physics. Ladyman (2020)

Noting that the structure of theories survives radical theory change leaves open questions concerning what, exactly, structural realists are realists about. If the *relations* are the things we are supposed to be realists about, and we are eliminativist with respect to entities, we are what Ladyman (1997) refers

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[7]Arguments to the effect that Poincaré was a structural realist (of the epistemic kind) can be found in Psillos (1999, 149-51) and Frigg and Votsis (2011, 20).

to as ontic structural realists. Epistemic structural realism, in contrast, can be taken to be the view that accepts that we can have knowledge with respect to the relations between entities, but that we have no knowledge about the entities themselves. In this sense, ontic structural realism says that structure is *all there is*, while epistemic structural realism says that structure is *all we know*. The version put forward in Worrall's (1989) account of structural realism can be taken to be ontic, given its explicit aim as a response to PMI where ontological content is in focus. If one takes the focus on ontological content in PMI as an indicative feature of the fact that scientific theories were false, as opposed to an intrinsic one, Worrall's realism may not so apparently be classified as ontic instead of epistemic. The classical interpretation of ontic structural realism has, however, been contested due to issues arising from having relations without relata.

1.3.3 Divide et Impera Realism

The response that arguably seeks to save the most content from the original realist claim – that science can deliver knowledge about both theory and unobservable entities – is the 'Divide et impera' approach developed by Psillos (1999). The basic idea is to argue that much of the content in the abandoned theories from the history of science has, *pace* PMI, been retained in succeeding scientific theories. This strategy is reminiscent of the previous two realist strategies in terms of arguing for partial continuity during theory-change, but Psillos introduces a framework specifically designed for the identification of retained content during theory change that is invariant with respect to entities, structure or theory. This enables Psillos to concede Laudan's argument – that empirically successful theories have been abandoned – while simultaneously making the claim that *parts* of those theories, as well as their entities and structure, have been retained in succeeding theories. It is those

parts, Psillos claims, that we can be realist about. The heart of the 'Divide et impera' approach to dealing with PMI is that its piecemeal realism with respect to scientific theories is a way of maintaining that there is, in fact, an explanatory connection between predictive success and truth. The parts of a theory that are retained are also the parts responsible for the predictive success of its precursor. The best explanation of *this* fact is that those parts are true. There is, so to speak, a red thread of truth running through the history of predictively successful theories.

There are three reasons for presenting these particular three varieties of realism. The first reason is that they, taken together, by and large make up the bulk of contemporary approaches to scientific realism. The second reason is that they all serve a dialectical purpose given that they offer explicit solutions to the PMI. The third reason is that two of these views – entity realism and selective explanatory realism – will be discussed in more detail in the upcoming papers.

At this point, we may notice that the response to the PMI that depends the most on the efficacy of explanatory reasoning (although in some sense, all responses may so depend), is the 'Divide et impera' approach. The next section will offer an explication of what explanatory reasoning, in terms of IBE, has been taken to be.

1.4 Inference to Best Explanation

The core idea of IBE is that one can infer that the best explanation of some fact is true. This inference, under the current moniker, is attributed to Harman (1965):[8]

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[8]The philosopher credited with the first analytic treatment of this form of reasoning, under the label 'abduction', is Charles Sanders Peirce in the early 20th century. His work on abduction has, however, been argued to have its place in the scientific context of discovery, not justification (Douven

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> In making this inference one infers, from the fact that a certain hypothesis would explain the evidence, to the truth of that hypothesis. In general, there will be several hypotheses which might explain the evidence, so one must be able to reject all such alternative hypotheses before one is warranted in making the inference. Thus one infers, from the premise that a given hypothesis would provide a "better" explanation for the evidence than would any other hypothesis, to the conclusion that the given hypothesis is true. (Harman, 1965, 89)

Harman, originally arguing that enumerative induction is merely a species of IBE, is trying to explicate and make clear the workings of a particular way of reasoning already known under several other names.[9] In doing so, he provides a strong case for IBE given the numerous contexts in which this particular way of reasoning is successfully used: scientists use explanatory reasoning to infer causes of phenomena; detectives use it to draw conclusions about suspects; doctors use it as a method in medical diagnostics. Following Josephson (1996, 5), one may express IBE more formally in the following way:

> D is a collection of data (facts, observations, givens).
> H explains D (H would, if true, explain D).
> No other hypothesis can explain D as well as H does.
>
> Therefore, H is probably true

That IBE should be a kind of inference different from induction is contested (for example by Harman himself), but one can at

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2021). The mode of reasoning that we today recognize as IBE is thought to be an inference in the scientific context of justification. Roughly, Perice thought of abductive reasoning as a pragmatic tool, while Harman thought of it as an epistemic one.

[9] "'The inference to the best explanation' corresponds approximately to what others have called 'abduction,' 'the method of hypothesis,' 'hypothetic inference,' 'the method of elimination,' 'eliminative induction,' and 'theoretical inference.'" (Harman, 1965, 88-9)

least distinguish it from deductive reasoning on account of IBE being an *ampliative* mode of reasoning.

1.4.1   Ampliation and Epistemic Warrant

For an inference to be ampliative just means that it outputs conclusions which are logically stronger than the premises it uses as input. The most commonly known ampliative inference is of course regular enumerative induction, where the amplification is purely quantitative. Science, being an empirical endeavor, regularly deals with generalizations and universal laws and contains theories which infer causes beyond the observational evidence. These are practices to which ampliative inferences lend themselves well. There is, however, a downside to ampliation. The content-increasing nature of amplification means that its conclusions are susceptible to being false. Taking the realist's perspective, scientists' are not (that) interested in universal laws if they are false or in postulated entities which are not real. While strictly false theories like Newtonian mechanics have their rightful place in the history of science, and can be seen as important stepping stones to a complete picture of reality, they are no longer contenders for being true. Given that science is not in the business of aiming at false theories, it simply isn't enough for an inference to be ampliative, it also needs to be epistemically probative. Psillos, a defender of IBE as a rational epistemic tool of science and a defender of scientific realism, argues that ampliation and epistemic warrant are two desiderata in the definition of the abstract characterization of the scientific method:[10]

> Any attempt to characterise the abstract structure of scientific method should make the method satisfy two general and intuitively compelling desiderata: it should be

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[10]Other defenses of IBE as a rational methodological tool in science and scientific realism include Harré (1986), Lipton (1994; 2003), Kitcher (2001), and Bird (2006).

> ampliative and epistemically probative. Ampliation is necessary if the method is to deliver informative hypotheses and theories, namely, hypotheses and theories that exceed in content the observations, data, experimental results and, in general, the experiences which prompt them. This 'content-increasing' aspect of scientific method is indispensable, if science is seen, at least prima facie, as an activity which purports to extend our knowledge (and our understanding) beyond what is observed by means of the senses. But this ampliation would be merely illusory, qua increase of content, if the method was not epistemically probative: if it did not convey epistemic warrant to the excess content produced thus (viz., hypotheses and theories). To say that the method produces – as its output – more information than what there is in its input is one thing. To say that this extra information can reasonably be held to be warranted is quite another. (Psillos, 2009, 173-4)

The need for ampliation is simply necessary if science is supposed to go beyond what we already know based on ordinary sensory experience. The extra content is precisely what epistemic warrant is needed for. In his (2009), Psillos provides an analysis of how enumerative induction and the hypothetico-deductive method fare with respect to the two desiderata. Enumerative induction is argued to satisfy epistemic warrant, but only in a quantitative way. If all observed A's are B's, then we may infer that the amplified conclusion that all A's are B's is epistemically warranted. While ampliation is clearly involved, it may be characterized as 'horizontal', meaning that the content that is being increased is restricted to the entity which one already have observed, so one is not able to infer anything beyond what is observable. It is not able to introduce new ontology, for example, and so is not ampliative in that particular sense. The H-D method is argued to be compatible with both 'vertical' ampliation and epistemic warrant, but is, according to Psillos, too epistemically permissive: it has no discriminatory

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function vis-á-vis two (or more) hypotheses which deductively entail the empirical data. The consequence is that the application of the H-D method selects both (or all) hypotheses which deductively entail the empirical data, leading to an underdetermination problem. In Psillos's terminology, enumerative induction is minimally ampliative and maximally epistemically probative, while the H-D method is maximally ampliative but minimally epistemically probative. The analysis of the methods with respect to the desiderata highlights the dynamic between ampliation and epistemic warrant:

> [A]mpliation is inversely proportional to epistemic warrant. This is clearly not accidental, since ampliation amounts to risk and the more the risk taken, the less the epistemic security it enjoys. (Psillos, 2009, 182)

What is needed is a healthy balance between sufficient ampliative strength and sufficiently robust epistemic warrant. It should come as no surprise that Psillos argues that IBE strikes precisely this balance.

1.4.2 IBE and epistemic warrant

The problem with the H-D method – that it can't discriminate between multiple hypotheses from which the empirical data could be derived – is precisely the issue Psillos argues that IBE has the resources to deal with. This evaluative function is grounded in the comparison of hypotheses with respect to a number of explanatory virtues:

> Those hypotheses are ranked higher which a) explain all the facts that led to the search for hypotheses; b) are licensed by the existing background beliefs; c) are, as far as possible, simple; d) have unifying power, e) are more testable, and especially, are such that entail novel predictions. (Psillos, 2000, 65)

That IBE can discriminate between hypotheses by selecting for their explanatory virtues does of course not itself imply that

the explanation that ranks highest is epistemically warranted. In order to achieve epistemic warrant, Psillos uses elimination of doubt with respect to the best explanation. That is, he uses the absence of defeaters to provide prima facie epistemic warrant for the best explanation. The two kinds of defeaters in play are *rebutting* and *undercutting* defeaters. A rebutting defeater may simply be an observation that refutes the hypothesis in question[11], and an undercutting defeater can be that several other hypotheses can derive the evidence, making the probability that the considered hypothesis is true significantly lower. With respect to rebutting defeaters, Psillos claims that since IBE, unlike the H-D method, is not an inference where the evidence must be entailed by the hypothesis, one may attribute the inconsistency between observation and hypothesis to one of the auxiliaries. While this may seem like gerrymandering, Psillos claims that unless there is some other reason for abandoning the best explanation (perhaps the new observation renders an alternative hypothesis the best explanation, or perhaps there are reasons to think that new explanations will supersede the currently best one), it is still rational to stick with the best explanation. With respect to undercutting defeaters, it is a problem which only marginally affects IBE. Not every hypothesis that can derive the evidence offers any explanation of it, so only the hypotheses which entails *and* explains the evidence will survive an initial screening. The ones that do will be evaluated with respect to the above explanatory virtues. We may then have a set of alternative hypotheses which explain the evidence worse, in which case their existence cannot be seen as epistemically undercutting the best explanation.

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[11]In this sense, rebutting looks very much like ordinary falsification.

1.5 Arguments Against IBE

Given that scientific realism is tightly knit to the epistemic credentials of IBE, it makes sense for critics of realism to scrutinize IBE. What, then, are some of the salient arguments against the legitimacy of reasoning in accordance with IBE? Given that one of the reasons why philosophers have taken IBE to be rational is its success in science (and elsewhere), one may attempt to undermine the specific use of IBE in the defense of scientific realism by eliminating IBE in science, or reducing apparent instances of IBE to inductive or deductive reasoning. This *eliminativist* approach would, if successful, undermine the argument that scientific realism, by using IBE in NMA, employs rational scientific reasoning. A second attempt to undermine realism via attacking IBE is to point out that NMA actually defends the claim that IBE works in science by using IBE, thereby manifesting a circularity – IBE cannot be defended without assuming that IBE works. This argument focuses on the claim that such a defense would be *viciously circular*. A third attempt is to concede the logical mechanics of IBE – that IBE can select a true explanation among a set of available explanations – while arguing that we have no reason to expect that the true explanation should be an element in the set of explanations available. If the true explanation is one we have not yet considered, it will not be present in the set of available ones and the mechanics of IBE will select the *best of a bad lot*.

1.5.1 Eliminativism

According to many philosophers, IBE is at work in much of our ordinary and scientific reasoning:

> The sleuth infers that the butler did it, since this is the best explanation of the evidence before him. The doctor infers that his patient has the measles, since this is the best explanation of the symptoms. The astronomer infers

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> the existence and motion of Neptune, since that is the best explanation of the observed pertubations of Uranus. Chomsky infers that our language faculty has a particular structure because this provides the best explanation of the way we learn to speak. (Lipton, 2003, 56)

It is one thing to point out that IBE permeates different contexts of reasoning, but it is quite another to say that it is rational to employ IBE, or that one ought to do so. For friends of IBE, however, this further normative claim is never far away: "The abductive methodology is the best science provides, and we should use it." (Williamson, 2017, 15)[12] The descriptive and normative claim taken together offer something like a firewall with respect to criticism of realism via IBE: if IBE is rationally undermined, it would not only undermine scientific realism but also all the contexts in which it is used. If one thinks that undermining IBE in this way risks throwing the baby out with the bathwater, one viable approach to circumvent this problem is to eliminate IBE, or reduce it to other forms of reasoning, in the contexts one thinks are worth saving.

Fumerton (1980) offers an argument in which the canonical illustration of reasoning in accordance with IBE – that when we see the presence of footsteps in the sand we infer that a human walked there – can be reduced to a case of general inductive reasoning with premises derived from observation, thus eliminating the presence of IBE from the inferential schema entirely:

> I want to cast doubt on the claim that there is a legitimate process of reasoning to the best explanation which can serve as an alternative to either straightforward inductive reasoning or a combination of inductive and deductive reasoning. (Fumerton, 1980, 590)

He goes on to dismount this "locus classicus" of explanatory

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[12]For additional claims that IBE is (and ought to be) indispensable for scientific reasoning see Boyd (1980; 1983), Harré (1986), McMullin (2013).

reasoning and suggests that IBE is indeed dispensable in our rational practices. If Fumerton's argument can be generalized, it would decouple IBE used in rational contexts from IBE used in the defense of scientific realism, thereby undermining the rationality of NMA. The prospect of generalizing this argument is, however, bleak. To eliminate IBE from scientific contexts would be to eliminate all type of inferences to unobservable objects. If only inductive reasoning can be rationally used, science would simply not have sufficient resources to infer unobservable causes and processes, for a reason we have already encountered: induction is only ampliative *horizontally*, quantifying over observed objects. Perhaps a subset of scientific cases of IBE can be reduced to induction and deduction from observables, but not all, and especially not inferences to unobservables. (Weintraub, 2017, 191)

1.5.2 Vicious circularity

Following Putnam's canonical description of NMA, Boyd (1980; 1983) sets out to refine NMA in order provide an a posteriori defense for the reliability of IBE in science. He starts by asking why it is the case that the methodology that scientists use when conducting experiments is so successful in terms of generating accurate predictions. The methodology – consisting of experimental design, models of ruling out confounding effects, data analysis and so on – is, according to Boyd, heavily dependent on background and auxiliary theories. The best explanation for the reliability of the methodology is the fact that the background and auxiliary theories used in the methodology are approximately true:

> No scientifically plausible explanation of the instrumental reliability of actual scientific methods is possible which does not portray those methods as reliable for the acquisition of theoretical knowledge as well. Moreover, the reliability (instrumental or theoretical) of scientific meth-

> ods at a given time will typically be explicable only on
> the assumption that the existing theoretical beliefs which
> form the background for its operation are (in relevant re-
> spects) approximately true. (Boyd, 1980, 617-8)

Boyd can be taken to aim at a naturalistic defense of an epis-
temology of science, an epistemology that includes concrete in-
stances of explanatory reasoning. So far, however, the realism
we get from Boyd's approach is coupled to whatever theories
scientists rely on when instrumental reliability is a fact, and the
predictions are correct. That is, we get particular instances of
explanatory reasoning in science, and we get particular theories
that are involved in instrumental reliability. NMA is a far more
general argument for scientific realism, but gets strengthened by
Boyd's argument in two ways: (i) the fact that explanatory rea-
soning is reliable in science reinforces NMA because it is itself
an instance of such reasoning. In this sense, NMA can be taken
to involve a mode of inference that is part and parcel of the
naturalized epistemology of science. (ii) Boyd's argument can
be used to support the claim that theoretical truth is possible,
thereby supporting the claim in NMA that seeks to establish
the achievability of theoretical truth. (Psillos, 1999, 79)

To use the instrumental reliability (including explanatory rea-
soning) in science in order to defend an explanatory defense of
scientific realism has been accused of being viciously circular
since it uses IBE in order to defend IBE:

> [T]he issue under discussion in judging realism in this
> debate is precisely whether explanatory success provides
> grounds for belief in the truth of the explanatory story.
> To use explanatory success to ground belief in realism,
> as the explanationist defense does, is to employ the very
> type of argument whose cogency is the question under
> discussion. In this light the explanationist defense seems
> a paradigm case of begging the question, involving a cir-
> cularity so small as to make its viciousness apparent.

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(Fine, 1991, 82)

We might break down the argument against a defense of IBE in the following way. Presumably, there are inferential rules or practices which we are rationally permitted to use – modus tollens, IBE, induction – and ones we are not rationally permitted to use – inference to the worst explanation, affirming the consequent. The distinction between these groups of inferential rules by rational allowance must be justified somehow. That is, we need to have justification for why some inferential rules are rational and some not. (Boghossian, 2007; Enoch and Schechter, 2008) What Fine argues that Boyd's defense amounts to is the attempt to justify IBE as a rational inference rule by referring to the fact that IBE is a rational inference rule. The move against scientific realism is to argue against the very possibility of a justification for IBE. The argument, in its epistemic form, can be framed as follows:

> 1. We cannot justify our use of IBE with a justification that relies upon IBE (or otherwise assumes its privileged epistemic status), since such a justification would be objectionably circular.
>
> 2. We cannot justify our use of IBE by appealing to other belief-forming methods, since IBE is a basic rule.
>
> 3. Thus, there is nothing in virtue of which we are justified in using IBE. (Carter and Pritchard, 2017, 134)

One may of course argue that what's good for the goose is good for the gander – if the above argument applies to IBE then it also applies to other, supposedly more legitimate, inference rules. Are we prepared to say that it is irrational to employ modus tollens as well?[13] Even if we are not, we must admit that a circular justification of any inference rule, as in Boyd's case, must amount to an epistemically illegitimate way to approach

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[13]As Carroll argues in his (in)famous (1895), deductive inferences are not intrinsically justified, but only work if assumed.

the issue. This question will be discussed in more detail in papers two and three.

1.5.3 Best of a bad lot

One way to restrict the practical utility of IBE is to concede that while the best explanation does track true theories, this can only happen if the true theory is among the set of alternatives that we apply IBE to. That is, it can be conceded that if the true theory is a theory that scientists have conceived and is among the alternatives that we consider when applying IBE, it will be selected. The problem is that we have no idea if the true theory is, in fact, conceived of and among the alternatives:

> The argument of the bad lot purports to show that, even if it were in general the case that the best explanation of the evidence is true (or highly probable), that would not suffice by itself to make IBE acceptable as a rule of inference. For, evidently, the potential explanations between which we can choose are the ones we have actually come up with. So to conclude that the best of these is true an additional premise is required, viz., that none of the possible explanations we have failed to come up with is as good as the best of the ones we have. (Ladyman et al., 1997, 306)

Only if we know that the true theory is in the set of alternatives can we rely on IBE to select it, but, so the argument goes, we don't, so we can't. This, skeptics say, shows that IBE is unjustified as an inferential rule.

One way in which proponents of IBE have responded to the argument from the bad lot has been to point out that the concession of explanatory power as a guide to truth still means that one can reformulate IBE as a comparative inference. This means that one states that, given the set of alternatives $H_1, ..., H_n$ and some evidence E, if H_1 explains E better than any alternative, H_1 is closer to the truth than any alternative in the set. Douven

(2021) As Douven points out, this requires a theory of closeness to truth, but such theories are on offer.[14] One way to strengthen the comparative version of IBE is to limit underdetermination, i.e. to provide arguments that support the claim that there are few (or no) alternative hypotheses to the currently accepted one. Arguments of this kind have been pursued in cases where empirical confirmation of a theory is not likely to appear, for example in string theory.[15] If one could persuasively argue that the number of alternative theories that are consistent with the known data, make testable predictions and fulfill a set of theoretical constraints is low, or even null, the comparative version of IBE would be as strong as the original version. The consequences of this move are examined in more detail in paper four.

1.6 Concluding remarks

As we have seen, contemporary versions of scientific realism are defined by their various responses to the pessimistic meta-induction. Acceptance of the pessimistic conclusion generated a variety of restrictions to the realist ontology, either to entities or to structures. More optimistic realists tried to maintain as much of the spirit of realism as possible by imposing restrictions on indispensable contributions to predictive success. This approach relied heavily on the prospects of justifying a form of IBE that can secure an epistemology of unobservables. Consequently, anti-realists amassed a number of arguments aimed at undermining or defeating the justification of IBE as a rational and legitimate inference. The question guiding the four individual papers in this thesis is whether the pessimistic approach

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[14]See, for example, Niiniluoto (1998). See (Lipton, 2003, 61) for an alternative which does not require a theory of truth-proximity.

[15]See Dawid (2013); Dawid et al. (2015); Dawid (2016, 2017a,b) for a rigorous treatment of limitations to underdetermination and meta-empirical confirmation.

restricting realist ontology is sufficient for a plausible and robust scientific realism, or if the optimistic approach relying on IBE is the way to go.

1.7 Paper summaries

The format of this thesis is known as a compilation thesis, which means that it consists of a number of papers accompanied by an introductory text. Below I provide short summaries of the four included papers together with information about their publication status.

1.7.1 Paper I: Modest Scientific Realism and Belief in Astronomical Entities

The first paper examines the status of a version of realism which relies on causality, or detection, as the hallmark of realist epistemology, thereby removing itself from the contested epistemic status of explanatory reasoning. The paper raises a challenge to detectionists – calling on them to clarify how their view addresses astronomical objects, properties, and entities. I use a case-study of astronomical objects passing beyond the cosmic event horizon in order to mount this challenge.

A version of this paper is accepted at the Philosophy of Science Association's biannual conference in Pittsburgh 2022.

1.7.2 Paper II: Against Methodological Continuity and Metaphysical Knowledge

Paper two argues against the so called methodological continuation argument which claims that (some) metaphysics is methodologically continuous with the sciences, on the grounds that both rely on inference to the best explanation. I raise two major grounds for concern: (1) that the justification of IBE

is domain-specific and does not transfer to metaphysics, and (2): that metaphysicians are unable to specify particular results about which we ought to be realist.

This paper is under review at the European Journal for Philosophy of Science.

1.7.3   Paper III: Scientific Realism and the Discovery of Radium

The debate between scientific realists and anti-realists concerns the epistemic status of our claims about unobservable entities. It has been assumed by both parties to the debate that there is a fixed distinction between observables and unobservables, although some authors have dissented from this opinion. Building on work from the dissenters, I argue that what counts as unobservable can change over time, due to theoretical and empirical discoveries. These changes are then brought to bear on the justification of IBE with respect to unobservables. The claim is illustrated by giving a detailed account of the discovery of radium.

This paper is published in *Journal for General Philosophy of Science.* See Allzén, S. From Unobservable to Observable: Scientific Realism and the Discovery of Radium. *J Gen Philos Sci* (2022).

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1.7.4   Paper IV: Scientific Realism and Empirical Confirmation: a Puzzle

The last paper argues that a principled issue arises when non-probabilistic IBE is applied in theoretical contexts lacking canonical empirical confirmation. More specifically, I argue that the

application of non-probabilistic IBE in the case of dark matter may undermine the role of empirical confirmation as a significant epistemic arbiter for realism. I consider how probabilistic accounts of confirmation may mitigate the situation for the realist without infringing on the core epistemic values of explanation.

This paper is published in *Studies in History and Philosophy of Science Part A*. See Allzén, S., 2021, Scientific Realism and Empirical Confirmation: A Puzzle, *Studies in History and Philosophy of Science Part A*, 90, pp. 153–159.

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1.8 Swedish summary

Många anser att vetenskapens huvudsakliga mål är att ta reda på hur världen *egentligen* är beskaffad, utöver det begränsade perspektiv om verkligheten som människan har tillgång till. Den filosofiska doktrinen kopplad till denna föreställning går under namnet 'vetenskaplig realism' och vidhåller att vi har goda skäl att tro att våra bästa vetenskapliga teorier är sanna och att världen innehåller de entiteter som dessa teorier beskriver. Det främsta filosofiska argumentet för denna doktrin menar att den enda rimliga förklaringen till vetenskapliga teoriers otroliga förmåga att förutsäga och förklara världen är att de är sanna. Vore de inte sanna, menar man, så skulle det vara ett mirakel att dessa teorier fungerar så bra. Detta argument *för* vetenskaplig realism kallas därför ofta för 'inga-mirakel argumentet' ('the no-miracles argument' på engelska) och använder sig av en särskild slags slutledning: slutledning till bästa förklaringen ('inference to the best explanation' på engelska). Idén bakom denna slutledningsmetod är relativt enkel (och väl använd) – den hypotes som bäst förklarar relevant evidens (av en mängd alternativa hypoteser) är den sanna, eller åtminstone mest san-

nolika. Vetenskapliga teoriers framgång är ett empiriskt faktum som behöver förklaras, och vetenskapliga teoriers sanning är hypotesen som bäst förklarar detta faktum. Sundheten i vetenskaplig realism är alltså till viss del beroende av legitimiteten i användandet av denna slutledning. Detta beroende har utnyttjats av anti-realister som menar att det inte existerar något samband mellan en teoris förklaringskraft och dess sanningshalt. Att detta samband existerar är någonting som går att falsifiera (även om det inte går att verifiera). Teorier vars förklaringskraft vi har tagit som en indikation på deras sanningshalt bör, om sambandet finns, vara exakt de teorier som också har överlevt vetenskapens progression. Detta, menar anti-realisterna, är inte fallet.

Många vetenskapliga teorier, till exempel teorin om Flogiston – ett hypotetiskt ämne som förklarade förbränningsprocesser – användes framgångsrikt för att göra förutsägelser om olika kemiska reaktioner. Teorin om Flogiston vederlades dock när Antoine Lavoisier upptäckte syre och ersattes då med Caloric-hypotesen som i sin tur senare ersattes med termodynamiken. Om de flesta teorier i den vetenskapliga hisorien är som Flogiston, d.v.s empiriskt framgångsrika men falska, så menar anti-realisterna att vi istället har goda skäl att tro att våra nuvarande teorier kommer att möta samma öde. Inte nog med att vi *inte* har goda skäl att tro att våra mest framgångsrika teorier är sanna, vi har nu även goda skäl att tro att de är falska. Detta argument går under det passande namnet 'den pessimistiska meta-induktionen' (PMI).

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Det är i dispyten mellan dessa två positioner som denna avhandlar tar avstamp i. För att överkomma PMI så behöver vetenskapsrealisten visa att slutledning till den bästa förklaringen är en slutledning som är pålitlig, alltså en slutledning som oftast (men inte alltid) genererar korrekta slutsatser. Ett sätt att argumentera för detta är att försöka visa att de aspekter av historiskt verderlagda, men empiriskt framgångrika, teorier som låg bakom den empiriska framgången som oftast överfördes in i de nyare teorierna. Detta argument, framfört av framförallt Psillos (1999), kallas ibland för 'divide et impera', eller 'söndra och härska' argumentet. Den grundläggande idén är helt enkelt att vi inte ska ta vetenskapliga teorier i sin helhet när vi bedömer deras sanningshalt, utan dess delar. När vi gör det märker vi att många av de delar som var ansvariga för empirisk framgång också är de delar som behölls i efterföljande teorier. Länken mellan empirisk framgång och sanningshalt upprättas alltså igen och slutledning till den bästa förklaringen får stöd av historien.

Det finns dock andra sätt att invända mot denna slutledning. En särskild typ av anti-realister – konstruktiva empirister – menar bland annat att skiljelinjen mellan vad vi kan veta och inte bör dras vid våra observationsförmågor, eller sinneserfarenheter. Kom ihåg att vetenskapsrealistens mål är att övertyga oss om att vetenskapen ger oss en sann bild av hur världen är beskaffad även *bortom* våra sinneserfarenheter. Dessa empirister utmanar alltså vetenskapsrealisterna att visa hur, utan logiska felslut, slutledning till den bästa förklaringen är en pålitlig slutledning bortom denna sinneserfarenhetens gräns. Hur vet vi att den fungerar utan att anta att den fungerar? Här tar artiklarna i denna avhandling vid.

ARTIKEL I

Den första artikeln utgår ifrån en vetenskapsrealism som medger att förklaringskraft är en dålig utgångspunkt för att bedöma vad vi ska vara realister om. Denna form av realism tar istället kausalitet som realismens signum. Artikeln argumenterar för

att denna realism är för fjättrad vid exempel från 1900-talets partikelfysik och därför blir en alldeles för begränsad form av realism. I kontexter som t.ex. kosmologi blir konsekvenserna av detta att vi bör vara anti-realister med avseende på astronomiska objekt som vi kan observera, men som vid observationsögonblicket $t =_{nu}$ är så långt borta att hastigheten med vilket det astronomiska objektet rör sig bort från oss är större än ljusets hastighet (på grund utav universums expansion så blir $V_{rec} > c$) och därför ligger bortom den så kallade kosmologiska händelsehorisonten. Detta innebär alltså att vi i princip kan observera objekt som vi inte längre kan komma i kausal kontakt med, givet att ljusets hastighet också är vår kausala gräns. I detta fallet är vetenskapsrealisten alltså *mer* anti-realistisk än de kontruktivistiska empiristerna. Ett försvar av slutledning till den bästa förklaringen är alltså fortsatt ett alternativ väl värt att utforska.

ARTIKEL II

Den andra artikeln utgår ifrån en annan disputs gällande slutledning till den bästa förklaringen, denna gång mellan vetenskapsrealister och metafysiker. En del menar att metafysikens epistemologi är berättigad i den mån dess metodologi är berättigad. Då man inom metafysiken använder sig av slutledning till den bästa förklaringen, så borde vetenskapsrealister inte kunna förneka att dess applikation inom metafysiken inte fungerar. Detta argument menar alltså att vetenskapsrealister som tänker sig att såtillvida slutledning till den bästa förklaringen är en pålitlig inferens, så bör dess pålitlighet inte vara begränsad till den vetenskapliga kontexten, utan bör accepteras även inom metafysiken. Artikeln argumenterar för att det finns skäl att tro att sådana slutledningar är pålitliga i en vetenskaplig kontext, och att de skälen *är* begränsade till just den vetenskapliga kontexten. Vetenskapsrealister kan acceptera slutledning till den bästa förklaringen utan att förbinda sig till att metoden är berättigad inom metafysik. De behöver därmed

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inte heller acceptera de slutsatser som metafysiken innehåller.

ARTIKEL IV

Samma manöver som vetenskapsrealisten kan använda sig av, gällande i vilka kontexter som slutledning till bästa förklaringen är giltig i, kan användas av konstruktiva empirister för att argumentera mot vetenskapsrealister. Det är upp till vetenskapsrealister att påvisa slutledningens legitimitet, men då empiristerna enbart godtar sinnesintryck som epistemiskt relevanta så är slutledningens legitimitet begränsad till den observerbara delen av världen. Pålitligheten i slutledning till bästa förklaringen är alltså inte påvisbar bortom sinnesintryckens domän. Den tredje artikeln argumenterar för att det, i princip, är möjligt att påvisa motsatsen. Argumentet tar som fallstudie Marie Curies upptäckt av radium. Curie drog slutsatsen att det existerade ett nytt och oupptäckt radioaktivt grundämne baserat på att det bäst förklarade utfallet av ett experiment hon utförde tillsammans med sin make och kollega Pierre Curie. Denna slutsats skulle de sedan mödosamt visa stämde, genom att extrahera en observerbar mängd radium i saltform. Argumentet för att detta fall skulle stödja slutsatsen till den bästa förklaringen i en *icke-observerbar* kontext är att det vid tiden inte fanns någon indikation för huruvida radium var observerbart eller inte. Radiums kritiska massa hade kunnat vara bortom gränsen för observerbarhet, men Curies slutsats hade varit lika legitim ändå, vilket visar att observerbarhet inte har med slutsatsens giltighetsdomän att göra.

ARTIKEL V

Den fjärde och sista artikeln behandlar ett fall där slutsatsen till bästa förklaringen trots allt får besvärliga konsekvenser för vetenskapsrealisten. En av de mest populära alternativen till slutsats till bästa förklaringen är Bayesianism, en gren av sannolikhetslära som menar att vi som bäst kan veta till vilken grad viss evidens stödjer en teori eller en hypotes. För vetenskapsre-

alisten är detta bekymmersamt på grund av att de vill att vi ska acceptera vissa teorier som sanna. Artikeln tar som fokus en av den moderna fysikens största öppna frågor: mörk materias existens. Applikationen av realisternas föredragna slutsats till den bästa förklaringen på hypotesen om mörk materia visar att de bör vara rationellt bundna till att mörk materia existerar. Problemet blir att det i så fall verkar vara epistemiskt överflödigt att upptäcka mörk materia experimentellt. Varför bygga stora och dyra experiment för att påvisa mörk materias existens om vi redan bör tro på att den finns?

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