Scientific Realism and Empirical Confirmation: a Puzzle

Simon Allzén*

Department of Philosophy, Stockholm University

Abstract

Scientific realism driven by inference to the best explanation (IBE) take the empirically confirmed objects in science to exist, independent, *pace* empiricism, of whether the objects are observable or not. This kind of realism, it has been claimed, does not need probabilistic reasoning with respect to the claim that these objects exist and are real. In this paper, I show that there are scientific contexts in which a non-probabilistic IBE-driven realism leads to a puzzle. Since there is no reason why IBE could not be applied in scientific contexts in which empirical confirmation has not yet been reached, this implies that realists are forced to be committed to the existence of empirically unconfirmed objects. As a consequence of such commitments, because they lack probabilistic features, the possible empirical confirmation of those objects are epistemically redundant with respect to realism.

1 Introduction

The explanationist version of scientific realism typically invokes inference to the best explanation (IBE) as a means to justify realism regarding unobservable objects which are indispensable for the predictive success of a theory.[1] The existence of those indispensable unobservables, it claims, is the best explanation for the theory's predictive success. The idea is to safeguard the connection between explanation and truth from the anti-realist meta-inductive argument that many predictively successful theories have turned out to be false, providing reason to doubt the truth of currently held predictively successful theories. This IBE-driven realism has typically been applied to contexts in which the unobservable objects of dispute enjoys some degree of empirical confirmation. Based on this confirmation, the realist argue that we should epistemically commit to these objects because they constitute the best explanation of the predictive success, while anti-realist say that we should not. In this paper I argue that there

*Email: simon.allzen@philosophy.su.se

[1] Take predictive success to mean *novel* predictive success.

is no reason internal to the realist programme as to why the mechanics of IBE should be restricted to the domain of empirically confirmed objects. As I aim to show, IBE can just as easily be applied to predictively successful theories the central objects of which has not been empirically confirmed. As a case study, I use the theory of dark matter. The theory of dark matter ticks all the realist boxes: it's sufficiently mature, it's predictively successful, it has explanatory breadth and depth, and it satisfies the theoretical virtues of IBE. Consequently, the realist is forced to commit to the existence of dark matter despite the fact that dark matter has never been empirically confirmed. This shows that the epistemic commitments of IBE-driven realism reaches beyond the boundary of empirical confirmation. This consequence might on its own merit caution given the constitutive theses of scientific realism, but there is a far more serious implication of this fact: the eventual empirical confirmation of dark matter in the future would have no epistemic effect on the realist commitment. This is a direct consequence of the non-probabilistic nature of IBE used by some realists. Since this reading of IBE does not offer any way to grade belief, it is forced to output the (approximate) truth of the theory of dark matter, as opposed to an increase in its probability of being true, in response to dark matter's explanatory virtues. The somewhat rhetorical question is then what difference it makes to realism if we empirically confirm dark matter or not. I argue that these considerations provide good reason for realists to look at probabilistic versions of explanatory reasoning, an end to which I offer a tentative suggestion in the form of meta-empirical confirmation.

2 The epistemology of scientific realism

Psillos (1999, 2009) defines one of the three central theses of scientific realism in the following way:

> 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 2009, 4)

The claim is that the epistemic reach of science goes beyond the observable world such that knowledge about unobservables is not just possible, but actual. The version of realism that seeks to provide a rationale for this claim, and the one I will focus on in this paper, has been most forcefully articulated by Psillos (1999, 2000, 2007, 2009).[2] Psillos' realism narrows the scope of theoretical truth that can be reached by using indispensability and predictive success. The idea is that we ought to be realists only about the parts of a theory (and the entities posited therein) that are indispensable for the predictive success of the theory. This maneuver achieves two things: it localizes the retained parts of previous theories that were empirically successful but false (thus mitigating the

[2] See also Kitcher (1995).

force of Laudan's (1981) pessimistic meta-induction), and it attempts to connect unobservables to empirical data via indispensability. The inference that licenses us to go from 'x is indispensable for the predictive success of h' to 'x is real' is IBE: the best explanation for the fact that an object is indispensable for the predictive success of a theory is that it really exists. It is easy to see then, that IBE is a key element in this realist position. Given that it is an ampliative inference, the legitimacy of reasoning in accordance with IBE has been heavily criticized (van Fraassen 1989, Fine 1991), but also vigorously defended (Douven 2002, Bird 2006, Lipton 2003, Psillos 2007, 2009). Psillos takes IBE to be an inference that operates with 'epistemic standards' or explanatory virtues in order to rank hypothesis on the base of which we are warranted to make our inferences. If a hypothesis H is ranked to be the best explanation among its competitors with respect to the relevant background knowledge, we should infer that it is true. He even suggests that it is the inference that best captures the abstract concept of the scientific method:

> IBE can emerge as the general specification of scientific method which promises to solve in the best way its central philosophical problem. (Psillos 2009, 194)

Psillos' characterization of IBE as *the* scientific method is a result of comparing it to hypothetico-deductivism and enumerative induction as a way to balance epistemic warrant with epistemic risk. Be that as it may, for the purposes of this paper, it makes more sense to take a closer look at Psillos' view of the relationship between IBE and Bayesianism.

2.1 IBE and Bayesianism

In confirmation theory, most philosophers agree that Bayesianism in some form is our best option. While many philosophers have suggested that Bayesianism and IBE are compatible and can be supplemented in a number of interesting ways, Psillos has argued against this:[3]

> Bayesian reasoning does not have rules of acceptance. On a strict Bayesian approach, we can never detach the probability of the conclusion of a probabilistic argument, no matter how high this probability might be. So, strictly speaking, we are never licensed to accept a hypothesis on the basis of the evidence. (Psillos 2009, 195)

One can clearly see how there is a tension between the project of providing epistemic criteria for accepting a theory as being true via IBE and the "naked" probabilistic conclusions given by Bayesianism. Psillos (2004, 2007, 2009) considers various ways to combine IBE and Bayesianism but ultimately argues against it. According to Psillos, the most plausible way of combining them -

[3]See Lipton (2003) Niiniluoto (2004), Henderson (2013) and Weisberg (2009) for different versions of compatibilist approaches to IBE and Bayesianism.

letting explanatory considerations guide prior probabilities - suffers from two problems. If we incorporate explanatory considerations in subjective Bayesianism it trivializes the epistemic role played by explanation because priors wash out anyway. The upshot of subjective Bayesianism is that almost any method for determining priors works because continually updating on evidence makes posteriors converge over time. If we let explanatory power be a normative constraint on priors, thereby switching to an objective Bayesianism, it calls for a radical conceptual modification of Bayesianism that many would not accept. This is because the received view on confirmation in Bayesianism is subjectivism, and objectivists have their own normative rational constraints to begin with. This 'dilemma', Psillos argues, is best handled by friends of IBE by simply rejecting compatibilism all together. In earlier work, however, Psillos considers the merits of the Bayesian feature of degrees of belief:

> [A]lthough a hypothesis might be reasonably accepted as the most plausible hypothesis based on explanatory considerations (abduction), the degree of confidence in this hypothesis is tied to its degree of subsequent confirmation. (Psillos 2000, 67)

Psillos' abandonment of compatibilism is motivated by the fact that it forces IBE to work in the context of discovery rather than in the context of justification. Best explanations are only tentative prior to a Bayesian treatment and do not confer any warrant. In this sense, IBE does not contribute epistemically to the justification of the hypothesis, which is precisely the opposite of what Psillos argues that IBE is supposed to do. Psillos' approach to IBE then, is then entirely decoupled with Bayesianism.

Taking stock, we have a realism at the core of which is a non-probabilistic version of IBE that operates with explanatory virtues to output (approximately) true theories.

2.2 IBE and empirical confirmation

Scientific realists take empirical confirmation of some kind to be a prerequisite of realist commitment. It is no different in Psillos (and Kitcher's) case:

> Kitcher and I draw the line between the 'good' and the 'bad' parts of successful theories differently, but we both agree that confirmation is selective and that the theoretical constituents that are confirmed are those that essentially contributed to the success of a theory. (Psillos 2009, 96-7)

Selective confirmation is supposed to stand in contrast to the Quinean confirmational holism, broadly construed. That is, if a theory is empirically tested and its (novel) predictions are correct, the parts of the theory that are indispensable for those predictions are confirmed, as opposed to the whole theory. Based on this confirmation, we can input those parts, together with any competing explanations, in IBE which ranks them according to explanatory virtues and return a truth-statement. In this sense, IBE-driven realism makes itself dependent on the first-order evidence provided by science that constitutes empirical confirmation. It's only after the scientists' have announced the discovery of some object, say a particle, that the realist apply IBE and epistemically commit to the existence of that particle. This is particularly telling when reviewing the realism/anti-realism debate: the disagreement is usually centered around the observable/unobservable distinction with respect to objects in science that have been empirically detected. IBE-driven realism about unobservables is, however, not *necessarily* connected to the empirical confirmation of those objects. As I show in the following section, the selective confirmation of Psillos and Kitcher can sometimes lead to realism about empirically *unconfirmed* objects. This is particularly worrisome because the non-probabilistic nature of IBE forces the realist to accept two things: 1) that realism extends to unconfirmed objects, and; 2) that the eventual empirical confirmation of those objects is epistemically impotent with respect to realist commitments. As a case study, I use the theory of dark matter.

3 Dark matter

Roughly, one may view the dark matter hypothesis as the theoretical paradigm invested in the idea that there is a kind of non-baryonic matter that interacts gravitationally but not electromagnetically.[4] The term 'dark matter' is commonly attributed to the Swiss astronomer Fritz Zwicky's speculative explanation of the discrepancy between the observed velocity dispersion and the calculated gravitational potential of the luminous mass in the Coma Cluster. The extra gravitational potential, he thought, must be due to some unseen 'dunkle materie'. At the time, he didn't constrain his speculation to non-baryonic matter, but the general idea that additional low-luminous matter could explain the observed dynamics as well as the coining of the phrase was enough to retrospectively treat Zwicky's work as the start of the modern history of dark matter. Although several hypotheses were entertained as explanations of the observed discrepancy in the mid 20th century, in the 1970's the dark matter hypothesis emerged as the most plausible candidate to explain the observed mass-to-light discrepancy in galaxy clusters. (de Swart et al. 2017) Part of the scientific community's growing acceptance of the dark matter hypothesis in the 1970's was due to the fact that it could explain galaxy cluster dynamics as well as the newly observed phenomena of flat rotation curves in galaxies by Rubin and Ford Jr (1970).[5] The rotation curve of a galaxy is roughly the plotted orbital speed of stars and gas as a function of their distance from the galactic center. In smaller systems, such as our solar system, the orbital speed declines with

[4]I'm not considering here the recent proposal by Bird et al. (2016) that dark matter could consist of primordial black holes.

[5]The synthesis of taking these two different phenomena to be the cause of additional mass was first made by Ostriker et al. (1974) and Einasto et al. (1974). See de Swart et al. (2017) and de Swart (2020) for an in depth analysis of the role that the development of modern cosmology had in this process.

distance so that planets close to the sun orbit faster than planets further away. When analyzing the rotation curve of the Andromeda however, Rubin and Ford obtained a 'flat' rotation curve, meaning that the orbital speed of the stars and gas in it did not decline with increasing distance from the galaxy center. The flat rotation curve is taken to be evidence for the presence of additional mass in the form of a halo surrounding galaxies.

Since the 1970's, a range of phenomena has been discovered that is taken to support the dark matter hypothesis: gravitational lensing, the decoupling of mass and gravitational potential in the Bullet Cluster, the formation of the large scale structure of the universe et.c.[6] The dark matter hypothesis has displayed remarkable explanatory breadth and depth with respect to a range of different phenomena and enjoyed predictive success by being indispensable for the ΛCDM model's prediction of the large scale distribution of mass (as confirmed by the Sloan Digital Sky Survey). It also performs well with respect to the epistemic standards, or explanatory virtues, set up by (Psillos 1999, 184-5). Just to exemplify two of them:

> *Consilience*: Suppose there are two potentially explanatory hypotheses H_1 and H_2 but the relevant background knowledge favours H_1 over H_2. Unless there are specific reasons to challenge the background knowledge, H_1 should be accepted as the best explanation.
>
> *Unification*: Suppose we have two composite explanatory hypotheses H_k and H_j a body of data $e_1, ..., e_n$. Suppose that for every piece of data e_i (i = 1, . . . , n) to be explained H_j introduces an explanatory assumption H_j^i such that H_j^i explains e_i. H_k, on the other hand, subsumes the explanation of all data under a few hypotheses, and hence it unifies the explananda. Then H_k is a better explanation than H_j.

If we take the relevant background knowledge to be general relativity, then dark matter is the best explanation that connects the background theory to the evidence, thereby displaying *Consilience*. With respect to *Unification*, dark matter has subsumed a substantial amount of data under a single postulate, compared to the rival explanations.[7] The dark matter hypothesis displays all the salient explanatory and predictive features that realists are looking for, which means that it merits realist commitment. The problem, of course, is that dark matter is paradigmatically unconfirmed:

> Not only has dark matter never been observed in accelerators, it has also not been seen in direct detection experiments (in which the recoil energy of a nucleus impacted by a dark matter particle is observed) or in indirect detection experiments (in which the debris

[6]See Bertone and Hooper (2018) for an excellent review of the conceptual and evidential history of dark matter.

[7]The only rival to dark matter that is currently somewhat seriously considered in cosmology and astronomy is Modified Newtonian Gravity, or MOND for short.

> from dark matter annihilations in space are observed). (Dodelson 2011, 2)

IBE-driven realism thus implies realism about dark matter, a postulated entity that has yet to be empirically confirmed in any way. The way one judges this consequence is dependent on the attitude one takes towards keeping realism empirically grounded. Realists may claim that their selective confirmation strategy in the dark matter case works precisely as intended - dark matter is an indispensable part of the predictive success of ΛCDM model, and so it is, as it should be, confirmed by virtue of this fact. Others might find the confirmation-by-indispensability strategy somewhat disconnected from a proper theory of confirmation. No respectable scientist would agree that the existence of dark matter is confirmed in the strong sense that follows from the non-probabilistic nature of IBE. I am not implying here that philosophy of science should always appeal to scientific authority with respect to confirmation-theory, but the discrepancy between empirical confirmation by observation or detection and confirmation by indispensability conflates having theoretical and explanatory reasons for believing that dark matter exist with confirming that it exists by detecting it. This is precisely why the dark matter case is interesting to analyze from a realist perspective - the empirical confirmation of the central objects of a theory is usually already in place before the philosophical discussion with respect to realism kicks in, but in the case of dark matter, it is not, exposing a vulnerability in the realist project. In fact, taking the selective confirmation by indispensability approach is extra vulnerable because as it turns out, it is inconsistent with empirical confirmation by detection within a non-probabilistic IBE-realism.

4 The epistemic relevance of empirical confirmation

Given what I've just argued, IBE-driven realism is forced to commit to the existence of dark matter despite the fact that it has eluded every attempt at empirical detection, thereby extending realism beyond the domain of empirically confirmed objects. Even though some realists could bite the bullet and say that this is all in good order, the bullet might be bigger than expected. The reason why is that approaching selective confirmation via indispensability has a direct impact on the relevance of empirical confirmation by detection. In the context of dark matter, selective confirmation via indispensability and the application of IBE generates a truth-statement about dark matter, effectively implying that the eventual empirical confirmation of dark matter contributes nothing, epistemically speaking, to the belief that dark matter is real.[8] Cosmologists and astronomers usually talk about the confirmation of dark matter as a Nobel prize

[8]It also suggests that realists should recommend the abandonment of alternative research-paradigms to dark matter. See Dellsén (2019) for arguments concerning scientific realism and theoretical conservatism.

worthy achievement, but I'm not convinced that the Nobel committee will settle for confirmation by indispensability. The core of the problem is this: if we should already believe that dark matter is real and exists, what possible epistemic addition to this belief could empirical confirmation have? Again, if IBE operated probabilistically, the evidence coupled with the explanatory power and predictive success of dark matter would impact the probability that the dark matter hypothesis is true, but not to the level where empirical discovery would be made redundant. But as we have seen, some realists have argued against the compatibilist view. What could such realists say against the charge that their view makes empirical confirmation redundant?

4.1 Existential quantifier realism?

One way for the realist to attribute epistemic relevance to empirical confirmation is to highlight the distinction between being realist with respect to the claim that there is an entity to which dark matter refers, and being realist with respect to the nature and properties of that entity:

> [I]t is one thing to assert that *there is* an entity to which a term t refers, quite another matter to find out the exact nature of this entity, and hence to specify the correct description to associate with the term t used to refer to this putative entity. (Psillos 1999, 283)

While there are some constraints imposed on the class of possible dark matter particle candidates given by the astrophysical and cosmological evidence as well as from unsuccessful direct detection experiments, there is still a large number of different theoretical possibilities left, ranging from supersymmetric particles, extra dimensions, weak neutrinos, hidden sector self-interacting dark matter, and so on. Given the rather large class of dark matter candidates, the realist can point to a very important and significant way in which empirical confirmation by way of discovery can impact the epistemic status of dark matter - it tells us about the nature and properties of dark matter. There is no reason to be realist about anything more specific than the existential statement that there is some x such that it causes the phenomena we observe. Embracing confirmation via indispensability and IBE is sufficient for realism about the existential claim about some object, while empirical confirmation is necessary for establishing the *nature* of that object.

This partition of confirmation where indispensability operates to retrieve justification about the existence of dark matter and detection or discovery operates to retrieve justification about the nature of it is a neat solution to the present challenge. Unfortunately, it suffers from two problems: i) it requires a theory of reference which makes referential success trivial, and; ii) it depends on the existence of a class of alternative theories about the nature of dark matter.

4.2 Referential success

One of the problems facing realism is how theoretical terms can be taken to successfully refer in light of substantial theory change. The realist project is premised on a connection between empirical success and truth, and since the successful reference of theoretical terms to ontologically robust objects is a natural consequence of this connection, successful reference in theory change is a vulnerable point in the realist framework. The argument against realism is that there are theoretical terms in past theories which, despite being empirically successful, were nevertheless not referring to anything at all. Laudan (1981) has perhaps most forcefully pushed this point against realists, arguing that past successful theoretical terms such as "luminiferous aether" are now abandoned and considered non-referring.[9] As a response to Laudan's argument, realists adopted a causal theory of reference that they thought could strengthen referential success in cases where a term was successful but still abandoned.[10] According to causal models of reference, references are fixed existentially, usually by simple ostension (Psillos 1999). Given that ostension is a poor way to fix references to unobservable objects, we may substitute it for the assumption that the cause of some observed phenomena is associated with, in Psillos' terms, a 'physical magnitude'. Given that we observe some phenomena with an unknown cause, we can associate a physical magnitude to the cause with a term t. This moment is then taken to be the introduction of the term t which refers to the physical magnitude responsible for causing the phenomena. We now have a causal theory of reference that seem to fix the *existential* reference of the term 'dark matter' as being introduced in order to explain the cause of galaxy cluster dynamics. We may say then that this condition states that there is a physical magnitude, an object or a structure, to which 'dark matter' refers. The nature and properties of that physical magnitude, however, can remain unspecified or be updated once theoretical or empirical work has been done. For instance, in the early 1900's, the use of 'dark matter' picked out a particular class of objects:

> [A]stronomers at the time [1930's] were open to the possibility that large amounts of dark matter might be present in astrophysical systems, in the form of "extinguished stars, dark clouds, meteors, comets, and so on", as Lundmark writes in 1930." (Bertone and Hooper 2018, 18)

It is clear that there is no overlap between what scientists in the early 20th century thought dark matter to be, and what scientists today think that dark matter is. On a purely causal account of reference, however, there is no tension between the early and the later use of the term since they both satisfy the same causal role played by the term - exerting gravitational influence. The causal account, however, makes successful reference too easy to get. The early use of 'dark matter' referred to low-luminous macroscopic objects made of ordinary (baryonic) matter and the modern use refers to non-luminous, microscopic

[9]See also Lyons (2006), Stanford (2003), and Elsamahi (2005).

[10]See Hardin and Rosenberg (1982) and Laudan (1984) for exchanges in this debate.

non-baryonic matter. Given that the two descriptions of dark matter share no salient content with respect to the properties of the object, the continuing referential success of 'dark matter' in terms of fixing the reference existentially is inconspicuous. Laudan (1984) argues against the causal account of reference on precisely those grounds - if reference is fixed purely as an existence claim of an object as the cause of some phenomena, then the success of that reference is guaranteed despite the fact that theoretical changes over time attribute radically different properties to the object. Referential success then becomes a trivial matter because the causal theory of reference is tailor made to succeed. Further problems with the causal theory of reference is that it separates what a scientist *is* talking about from what she *thinks* she is talking about:

> Aristotle or Newton could be said to be referring to geodesic motion in a curved spacetime when, respectively, they talked about the natural motion of material objects, and the fall of a body under the effect of the gravitational force. Ladyman (2020)

Ladyman's argument in this context implies that it would mean that Zwicky, Poincaré and others who used the term 'dark matter' in the first half of the 20th century were actually referring to non-baryonic non-luminous particles all along, which is clearly false. A purely causal account of reference will simply not do. Psillos, well aware of the issues related to such an account, adds a descriptive component to his theory of reference:

1. A term t refers to an entity x if and only if x satisfies the core causal description associated with t.
2. Two terms t' and t denote the same entity if and only if (a) their putative referents play the same causal role with respect to a network of phenomena; and (b) the core causal description of t' takes up the kind-constitutive properties of the core causal description associated with t. (Psillos 1999, 296)

The descriptive addition specifies that there must be some properties attributed to the object such that it can play its stipulated causal role. But the kind-constitutive properties associated with the core causal description of dark matter must necessarily be informed by theory, and therefore go beyond the mere existential claim that dark matter exists. The existential claim is therefore coupled with the purely causal theory of reference which, by realists own admission, is insufficient to handle problems associated with theory change. Furthermore, one may worry about how to assess the core causal description of dark matter in the first place, and whether there is some overlap in the kind-constitutive properties assigned to such descriptions between the theorizing of its nature in the early 20th century and current hypotheses.

4.3 Dependence on alternatives

The realist solution that empirical confirmation finds a function in the context of justification with respect to the nature of dark matter is only valid in situations which contains formulated alternative theories. The solution cannot in principle maintain the partition in order to keep IBE-driven realism from resulting in a full fledged realism about the existence *and* nature of some objects in contexts without empirical confirmation. This becomes apparent once one reflects on the fact that whether or not there are alternative theories to any given theory is contingent. If there is only one formulated theory, the proposed existential quantifier realism collapses into full blown realism regarding that theory. Suppose that all currently formulated theories about the nature of dark matter except for Axions are ruled out. In such a case, the moderate realism about the existence of dark matter collapses into realism about the nature of dark matter. Not because Axions have been experimentally or observationally determined to be dark matter, but because of how IBE operates in that environment. This shows why there is a *principled* tension between empirical confirmation and IBE-driven realism that amounts to an inconsistency between the two.[11]

One may think that the set up of this problem, that the realist partition of confirmation breaks down in situations where there is only one theory, is highly unlikely, so makes no practical difference. That would be wrong. While such situations may not be common, they are not unknown to science.

4.3.1 Isomers

At the turn of the last century, the scientific community were debating the epistemic credentials of the theory of scientific atomism.[12] Critics of atomism argued, amongst other things, that the principled divide between the observable and the unobservable rendered atomism a theory that could never be conclusively confirmed, given that its core postulates were microphysical. Atomism, according to this line of criticism, was a speculative theory with instrumental value at best. Exponents of atomism claimed that its predictive success and explanatory power should amount to significant epistemic support for the theory. One, for our purposes, particularly interesting argument in favor of atomism comes from late 19th century chemistry - the explanation of isomers.

Isomers are chemical compounds that consist of the same elements in equal proportions but that nevertheless differ in their chemical properties. This peculiar phenomenon in chemistry needed to be explained, and attempts at doing so came from an atomist perspective. Both Le Bel (1874) and Van't Hoff (1874) theorized that if atoms were differently spaced in the molecular bonds in the different isomers, this would explain the difference in chemical behavior. Interestingly, the phenomenon of isomers appeared to only be explained by atomism:

> First, in the absence of spatial positioning there seemed to be no degree of freedom available at all to represent differences between substances that consisted of the same elements with same proportions.

[11] A realist solution to this problem could refer to the possible existence of unconceived alternatives, but that would mean revisiting the problem of unconceived alternatives by Stanford (2003, 2006).

[12] I refer to Dawid (2020) for a full case analysis of the situation with respect to the confirmational aspects of scientific atomism.

> Second, as had been observed by Louis Pasteur, different isomers of salts of tartaric acid rotated the polarization axis of polarized light in different ways. Given that light polarization was understood to be a spatial phenomenon, it seemed difficult to imagine any physical representation of the effect of isomers on polarization that was not based on spatial characteristics of the differences between the isomers themselves. (Dawid 2020, 8)

Here, there was only one theoretical option on the table, the central objects of which had not yet been empirically confirmed. For realists, had they been around at the time, the situation would have merited full realist commitment without empirical confirmation, meaning that the later empirical detection of atoms would have contributed nothing to realism about atomism so long as new properties were not discovered. The case of isomers shows that a context in which theoretical alternatives are restricted to a single theory is a very live possibility in science.[13] Presented with such situations, the realist epistemology will treat the indispensability and explanatory virtues of a theory (or parts thereof) as sufficient for conclusive confirmation of that theory with respect to the existence of its central objects and their properties. It becomes clear then, that the principled tension between confirmation by indispensability and confirmation by empirical detection is not merely a pragmatic issue, but very much an epistemic one.

5 Probabilistic IBE

The core of the challenge I have presented is that IBE generates truth-statements in contexts with insufficient empirical confirmation, thereby eliminating the epistemic force of the detection or discovery of the central objects of a theory. While epistemic optimism was one of the promises that IBE-driven realism aimed at delivering, this epistemology is a little bit too optimistic. In the kind of situations I have described, the fact that Psillos worried about - that Bayesianism does not have rules of acceptance - is a good thing. It is not reasonable to accept a theory as true in these contexts, and having an epistemology that forces you to do so is unwise. The crux, as I have argued so far, is that IBE is taken to deliver the (approximate) truth of a hypothesis instead of a statement with respect to the probability of the hypothesis being true. If explanatory considerations could instead act as grounds to increase the probability of a hypothesis, the epistemic force of empirical confirmation by detection would not be made redundant. There are a number of ways that realists could incorporate probabilistic reasoning in their IBE-driven framework. Lipton (2003) provides a compatibilist model in which explanatory reasoning is central to the heuristics of conditionalization. Weisberg (2009) have suggested that due to inconsistencies

[13] There are many contenders for theories that are considered "the only game in town", for example the theory of evolution, the big bang theory, and string theory.

in the subjective compatibilist project explanatory virtues ought to constrain prior probabilities in a version of objective Bayesianism:

> Forced to choose between IBE and subjective Bayesianism, I hope that compatibilists will reject subjectivism and pursue a Bayesian IBE with a more objectivist flavor.

This means that two hypotheses, H_1 and H_2 are assigned different probabilities depending on how well they perform with respect to some set of explanatory virtues (or epistemic standards). The effect of this is that, once the Bayesian machinery gets going, the posterior probability of the best explanation vis-à-vis the explanatory virtues is higher than its rival, given that $P(E|H_1) = P(E|H_2)$. Henderson (2013) argues that IBE can plausibly be thought to emerge from Bayesian reasoning, thus offering a compatibilist view in which explanatory considerations do not constrain priors, but are instead part and parcel in the Bayesian machinery. There are clearly options on the table for the realist: subjectivist, objectivist, and emergent versions of compatibilism can all be explored to deal with the situation.

As we have seen, Psillos has indeed entertained the idea that a hypothesis could be accepted as the most plausible based on explanatory grounds where the degree of confidence in the hypothesis was coupled with later empirical confirmation. However, Psillos' aversion against compatibilist approaches ultimately led him to abandon the idea of compatibilism altogether. Compatibilist approaches did not attribute the level of epistemic significance to explanatory reasoning as desired, either in the sense of explanatory power being washed out as a prior in subjectivist accounts, or in the sense of merely operating in the context of discovery in objectivist accounts. Is there any route to a probabilistic framework that respects explanatory reasoning in the way Psillos claims it should? I want to suggest a kind of probabilistic framework of confirmation that attributes epistemic relevance to explanatory considerations precisely in the kind of contexts that I have been discussing, i.e. in cases where there are no alternatives and non-probabilistic IBE-driven realism collapse.

5.1 Meta-empirical theory confirmation

Even though dark matter has not been detected, most cosmologists and astronomers display a high level of trust in the viability of the hypothesis that there exist some form of non-luminous non-baryonic matter. A different, but not completely dissimilar, situation can be found in the context of String theory - string physicists have a high degree of trust in their theory despite the (in)famous lack of empirical confirmation. In order to understand why, Dawid (2013, 2015, 2016) developed an account of non-empirical theory assessment that addresses precisely the situations in which the data needed to evaluate a theory empirically is lacking. In such situations Dawid argues that we can nonetheless assess the theory's viability by analyzing its non-empirical features. In this framework, there are three distinct ways that non-empirical facts can bear on the confirmation of a theory: the no-alternatives argument, the argument of unexpected explanatory interconnections, and the meta-inductive argument. I will follow Dawid and refer to the application of one or a combination of these as an instance of meta-empirical confirmation (MEC). One reason for realists to take interest in the framework is that a central feature of MEC is that it principally respects the distinction between empirical and non-empirical confirmation:

> [T]he distinction between MEC [Meta-Empirical Confirmation] and empirical confirmation remains of crucial importance today because it indicates a substantial difference in confirmation strength. Empirical confirmation remains the only path to conclusive confirmation. (Dawid 2020, 15-16)

MEC is able to uphold this distinction precisely because it takes a probabilistic approach to confirmation. Intuitively, explanatory considerations plays an important epistemic role in all three modes of MEC, making it attractive for realist purposes. As a proof of concept I will focus on the no-alternatives argument in conjunction with the meta-inductive argument.

5.2 The no-alternatives argument

As we have seen, scientists sometimes find themselves in contexts in which they have a theory that can explain a range of phenomena but where that theory has not yet been empirically confirmed. When such a situation is also coupled with the fact that the theory has no alternatives, the IBE-driven realist is forced to epistemically commit to that theory, lock stock and barrel, making empirical confirmation redundant. The no-alternatives argument (NAA) offers a way to retain the idea that explanatory considerations have epistemic force without sacrificing the epistemic role of empirical confirmation. The general idea of NAA is to limit underdetermination by examining the explanations for the scarcity of theoretical alternatives:

> Scientists have looked intensely and for a considerable time for alternatives to a known theory H that can solve a given scientific problem but haven't found any. This observation is taken as an indication of the viability of theory H. (Dawid 2017, 17)[14]

There might be a number of explanations for why there are no formulated alternatives - perhaps scientists are not clever enough; it might be a particularly difficult problem; the computational resources might not yet be available, et.c. - but the best explanation can be taken to be that there is, in fact, few alternatives. This explanation of the fact that there are no formulated alternatives can be assessed probabilistically in the following way.[15]

[14] Even though Dawid is using MEC to evaluate the viability of a theory, realists are free to substitute it for truth without structural loss.

[15] For proofs and a thorough Bayesian analysis of the no-alternatives argument, see Dawid et al. (2015).

Let $Y_k = \{Y = k\}$ be the expression that there are k number of alternatives that satisfy the following conditions: fulfill a set of theoretical constraints $\mathcal{C}$, explain existing data $\mathcal{D}$, and give predictions for future experimental outcomes $\mathcal{E}$. If we assume that Y takes a value in the natural numbers, and that F_A expresses the fact that no alternative H' satisfying $\mathcal{C}$, $\mathcal{D}$, and $\mathcal{E}$, has been found, then: $P(H|F_A) > P(H)$. That is, F_A confirms H. The degree to which F_A confirms H depends mainly on the number of alternatives. If the number of alternatives is low, confirmation is stronger, if it is high, confirmation is weaker. The prior assigned to the value of Y_k can be determined by applying the meta-inductive argument, providing reason to think that existing alternative explanations to why scientists haven't found an alternative theory, for instance that scientists are not clever enough, are improbable:

> [I]f scientists have been so successful in finding viable theories in the past, it seems less plausible to assert that they are not clever enough for doing the same this time. (Dawid 2016, 14)

Again, the application of the meta-inductive argument serves to bolster the explanation of theoretical scarcity to the fact that there are no alternatives. Additionally, the three conditions $\mathcal{C}$, $\mathcal{D}$, and $\mathcal{E}$ are not so different from the internal ranking-conditions of IBE:

> 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)

One can see how MEC in a way echoes the explanatory virtues of IBE. In this framework, they contribute to the confirmation of the theory, thereby operating in the context of justification. In short, there is plenty of room in MEC for explanatory considerations to make an epistemic difference in the context of confirmation and justification, not just in the context of discovery, without having to sacrifice the epistemic credentials of what is arguably the golden standard of confirmation and justification in science - empirical confirmation.

6 Conclusion

In this paper I have argued that explanationist versions of selective scientific realism in some cases imply realism about empirically unconfirmed objects and that a consequence of this implication is the rejection of the epistemic significance of empirical confirmation. I argued that the realist, faced with this problem, should turn to probabilistic frameworks for solutions. Given the realist aversion to more classical compatibilist approaches to merge probabilistic reasoning and explanatory reasoning, I suggested they instead look to the theory of meta-empirical confirmation. Tentatively, this theory could safeguard the epistemic value of explanations while still avoiding the implication that empirical confirmation is redundant.

Acknowledgements: I am very grateful to Richard Dawid, Casey McCoy, Siska de Baerdemaeker, Karim Thébault, and Ylwa Sjölin Wirling for valuable feedback and written comments on the draft manuscript, and also to the audience at the open minds XIV conference in Manchester.

References

Bertone, G. and Hooper, D.: 2018, History of dark matter, *Reviews of Modern Physics* **90**(4), 045002.

Bird, A.: 2006, *Philosophy of science*, Routledge.

Bird, S., Cholis, I., Muñoz, J. B., Ali-Haïmoud, Y., Kamionkowski, M., Kovetz, E. D., Raccanelli, A. and Riess, A. G.: 2016, Did ligo detect dark matter?, *Phys. Rev. Lett.* **116**, 201301.
URL: *https://link.aps.org/doi/10.1103/PhysRevLett.116.201301*

Dawid, R.: 2013, *String theory and the scientific method*, Cambridge University Press.

Dawid, R.: 2016, Modelling non-empirical confirmation, *Models and inferences in science*, Springer, pp. 191–205.

Dawid, R.: 2017, The significance of non-empirical confirmation in fundamental physics, *Why Trust a Theory*, Cambridge University Press, p. 99–119.

Dawid, R.: 2020, The role of meta-empirical theory assessment in the acceptance of atomism.
URL: *http://philsci-archive.pitt.edu/18163/*

Dawid, R., Hartmann, S. and Sprenger, J.: 2015, The no alternatives argument, *The British Journal for the Philosophy of Science* **66**(1), 213–234.

de Swart, J.: 2020, Closing in on the Cosmos: Cosmology's Rebirth and the Rise of the Dark Matter Problem, *in* A. Blum, R. Lalli and J. Renn (eds), *The Renaissance of General Relativity in Context. Einstein Studies, vol 16*, Birkhäuser, Cham, pp. 257–284.
URL: *http://link.springer.com/10.1007/978-3-030-50754-1_8*

de Swart, J., Bertone, G. and van Dongen, J.: 2017, How dark matter came to matter, *Nature Astronomy* **1**(3), 1–9.

Dellsén, F.: 2019, Should scientific realists embrace theoretical conservatism?, *Studies in History and Philosophy of Science Part A* **76**, 30–38.

Dodelson, S.: 2011, The real problem with mond, *International Journal of Modern Physics D* **20**(14), 2749–2753.
URL: *http://dx.doi.org/10.1142/S0218271811020561*

Douven, I.: 2002, Testing inference to the best explanation, *Synthese* **130**(3), 355–377.

Einasto, J., Kaasik, A. and Saar, E.: 1974, Dynamic evidence on massive coronas of galaxies, *Nature* **250**(5464), 309.

Elsamahi, M.: 2005, A critique of localized realism, *Philosophy of Science* **72**(5), 1350–1360.

Fine, A.: 1991, Piecemeal realism, *Philosophical Studies* **61**(1), 79–96.

Hardin, C. L. and Rosenberg, A.: 1982, In defense of convergent realism, *Philosophy of Science* **49**(4), 604–615.

Henderson, L.: 2013, Bayesianism and inference to the best explanation, *The British Journal for the Philosophy of Science* **65**(4), 687–715.

Kitcher, P.: 1995, *The advancement of science: Science without legend, objectivity without illusions*, Oxford University Press on Demand.

Ladyman, J.: 2020, Structural Realism, *in* E. N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy*, winter 2020 edn, Metaphysics Research Lab, Stanford University.

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

Laudan, L.: 1984, Realism without the real, *Philosophy of Science* **51**(1), 156–162.

Le Bel, J. A.: 1874, Sur les relations qui existent entre les formules atomiques des corps organiques et le pouvoir rotatoire de leurs dissolutions, *Bull. Soc. Chim. Fr* **22**, 337–347.

Lipton, P.: 2003, *Inference to the best explanation*, Routledge.

Lyons, T. D.: 2006, Scientific realism and the stratagema de divide et impera, *The British Journal for the Philosophy of Science* **57**(3), 537–560.

Niiniluoto, I.: 2004, Truth-seeking by abduction, *Induction and deduction in the sciences*, Springer, pp. 57–82.

Ostriker, J., Peebles, P. and Yahil, A.: 1974, The size and mass of galaxies and the mass of the universe.

Psillos, S.: 1999, *Scientific realism: How science tracks truth*, Routledge.

Psillos, S.: 2000, Abduction: Between conceptual richness and computational complexity, *Abduction and induction*, Springer, pp. 59–74.

Psillos, S.: 2004, Inference to the best explanation and bayesianism, *in* S. F. (ed.), *Induction and Deduction in the Sciences. Vienna Circle Institute Yearbook (Institut 'Wiener Kreis' Society for the Advancement of the Scientific World Conception)*, Springer, Dordrecht.

Psillos, S.: 2007, The fine structure of inference to the best explanation, *Philosophy and Phenomenological Research* **74**(2), 441–448.

Psillos, S.: 2009, *Knowing the structure of nature: Essays on realism and explanation*, Palgrave Macmillan, Basingstoke.

Rubin, V. C. and Ford Jr, W. K.: 1970, Rotation of the andromeda nebula from a spectroscopic survey of emission regions, *The Astrophysical Journal* **159**, 379.

Stanford, P. K.: 2003, No refuge for realism: Selective confirmation and the history of science, *Philosophy of Science* **70**(5), 913–925.

Stanford, P. K.: 2006, *Exceeding our grasp: Science, history, and the problem of unconceived alternatives*, Vol. 1, Oxford University Press.

van Fraassen, B. C.: 1989, *Laws and Symmetry*, Oxford University Press.

Van't Hoff, J.: 1874, Sur les formules de structure dans l'espace [about spacial structural formulas], *Archives Néerlandaises des Sciences Exactes en Naturelles* **9**, 445–454.

Weisberg, J.: 2009, Locating ibe in the bayesian framework, *Synthese* **167**(1), 125–143.