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# Explanatory power: Factive vs. pragmatic dimension

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This chapter identifies two dimensions of explanatory power: one *'factive'*, having to do with how explanations relate to mind-independent reality, and one *'pragmatic'*, having to do with how explanations relate to us (as epistemic agents who use explanations to gain understanding). It argues that keeping these two dimensions in mind helps to better understand the explanatory role of idealisations and mathematics; the factivity of understanding; explanations' realist commitments; and how 'explanatory power' is best construed.

## 1 Introduction

As science advances it provides better explanations of natural phenomena. Today we have good explanatory understanding of various phenomena that were understood only vaguely or not at all just a couple of decades ago. So, as science improves, its explanatory capacity increases: it provides better understanding through theories and models that have more *explanatory power*. I will explore how this notion of explanatory power cuts across philosophical issues of current interest concerning the explanatory role of idealisations and mathematics; the factivity of understanding; explanations' realist commitments; and how 'explanatory power' is best construed.

I will begin by identifying in abstract terms two central dimensions of explanatory power. One is *'factive'*, having to do with how explanations relate to mind-independent reality. The other is *'pragmatic'*, having to do with how explanations relate to us as epistemic agents who use explanations to gain understanding. Although more fine-grained distinctions between different dimensions of explanatory power can be made in the context of specific philosophical accounts of explanation, the two-pronged coarse-grained distinction will prove useful in thinking about various issues at the intersection of explanation, understanding, and representation.

In the first half of the paper I will frame my discussion around two natural intuitions regarding explanatory power. Each is prima facie plausible in its own right, but together they seemingly give rise to a tension (Section 2). We can alleviate this tension by drawing a broad conceptual distinction between factive and pragmatic dimensions of explanatory power (Section 3) that can be made more precise in terms of specific ideas regarding scientific explanation and understanding (Section 4). In the second half of the paper I will first look at a number of benefits of demarcating between these two dimensions of explanatory power, focusing on understanding's factivity (Section 6) and its growth (Section 7).

## 2 Two intuitions concerning explanatory power

The following two intuitions concerning explanatory power are prima facie very plausible. (1) *Increasing explanatory power is due to representing the world better.* (2) *More powerful explanations provide better understanding.*

The first is supported by intuitions regarding the factivity of actual (as opposed to merely potential) explanations. If an explanatory law statement or a model is changed so that it represents the world less well, how could that yield a better explanation? It could of course yield a *lovelier* explanation in Peter Lipton's (2004) sense: an explanation that would be better *if it were true.* But, as Lipton argues, when science aims at providing deeper or more powerful explanations, loveliness is at best a means to achieving that aim. (Conspiracy theories tend to furnish rather lovely explanations, for example.) It seems intuitively epistemically misguided to *mis*represent the world in effort to boost an explanation's explanatory virtues: e.g., its scope, precision, mechanistic detail, unifying power, simplicity. For instance, if an explanation of some phenomenon $P$ is "improved" by incorporating an abstract mathematical framework that unifies it with a disparate phenomenon $P^*$, it is not clear what has been explanatorily gained if the unification is entirely spurious and only pertains to our formal representation of $P$ and $P^*$. Or, if an explanatory model of $P$ is "improved" so that it represents $P$ in a more fine-grained way by incorporating mechanistic details that misrepresent the actual mechanism behind $P$, it is natural to think that we have ended up with a merely potential explanation. Similarly, radically idealised explanatory models, such as the Schelling model of social segregation, can furnish great potential or 'how-possibly' explanations (Reutlinger et al., 2018), but it seems wrong to regard them as powerful explanations of why there actually is social segregation (Sullivan and Khalifa, 2019). These intuitions are contestable, of course, but they provide prima facie support for (1).

Turning now to (2), it is straightforwardly supported with reference to the epistemic role of explanations: what explanations are *for*. We care about explanations because they provide understanding. An explanation that doesn't provide any understanding seems to lack the epistemic value that we place on explanations. We value science in part because as it advances it provides better and better understanding of the world. This central aspect of scientific progress is naturally captured by saying that science provides better, more powerful, explanations. It seems oxymoronic to say that explanation $E$ is more powerful than explanation $E'$, but that $E$ provides no more understanding than $E'$ does. This intuition provides prima facie support for (2).

Within a broadly realist framework these two intuitions about explanatory power could even be regarded as platitudes. More powerful explanations provide better understanding, since that's what explanations are *for*. And increasing explanatory power is due to representing the world better, since *actual* explanations are factive.[1] So far, so good, but (1) and (2) may also seem to be in tension. Taking them at face value, in conjunction, may suggests that *increasing scientific understanding is a matter of scientific theories and models representing the world better and better*. This seemingly intuitive implication is often implicitly endorsed in philosophy, lying behind various explanation centered arguments.[2] But we know that this implication is false! We know that increasing scientific understanding is not just a matter of representing the world better. This can be clearly seen by paying attention to the explanatory use of idealisations, 'theories emeritus', non-factive 'explanatory perspectives', and explanatory approximation schemes. The relevant aspects of science are well-known and discussed at length in the literature.[3]

Given the plentiful evidence against the idea that increasing scientific understanding is just a matter of representational improvement, we can ask how the two prima facie plausible intuitions (1) and (2) are best understood, so that they don't suggest something we know to be false.

## 3 Two dimensions of explanatory power

In thinking about (1) and (2) it is worth distinguishing between two dimensions of explanatory power. This enables us to account for the extent to which (1) and (2) *pull in different directions*, while nevertheless being platitudes in their own right.

On the one hand, we can continue regarding (actual) explanations as factive by associating explanatory power in connection with (1) with the amount of true explanatory information contained in or captured by an explanation. Exactly what kind of informa-

[1]Not everyone accepts such a realist framework. For example, these connections between explanation, understanding, and representation can be severed from a thoroughly pragmatist perspective like that of van Fraassen (1980).

[2]For relevant discussion of explanatory indispensability arguments and explanationist argument in the scientific realism debate, see Saatsi (2016a, 2018).

[3]For example, Potochnik (2020) and Rice (2021b,a) discuss the indispensable role of idealisations in providing understanding. Bokulich (2016, 2008a,b) and de Regt and Gijsbers (2016) discuss the role of 'theories emeritus' (e.g., Newtonian gravity) in explanatory contexts, and Saatsi (2019) discusses the role of non-factive explanatory perspectives (e.g., ether-theoretic conception of light).

tion is regarded as explanatory depends on our theory of explanation, of course. According to some philosophers explanatory information is information about difference-makers (Strevens, 2008); according to others it is information answering what-if-things-had-been-different (*what-if*) questions (Woodward, 2003); and so on. Whatever it is, we can maintain that explanatory information is factive — viz. information that can be expressed with true propositions — and that the more such information an explanation provides, the better the explanation, ceteris paribus. This is the *factive* dimension of explanatory power. It is a feature that an explanation has in relation to its explanandum.

On the other hand, we also need to recognise that explanatory *understanding* is not a feature of an explanation in and of itself, but rather something that *we* stand to gain from it. We can take into account this relationship between explanations and ourselves (as cognitive agents whose understanding is at stake) by associating explanatory power with an explanation's capacity to provide us understanding. It is a feature that an explanation has in relation to its users. An explanation's capacity to provide understanding is not just a matter of how much explanatory information is contained or captured by an explanation; what matters also is how that explanatory information is (re)presented, so that it has the capacity to provide understanding to us. Exactly what we take this capacity to amount to depends on our theory of understanding, of course, but whatever it is, it is a feature of an explanation that is dependent not only on its informational content, but critically also on how we can use it to gain understanding. This is the *pragmatic* dimension of explanatory power.

With these two dimensions of explanatory power in mind we can disambiguate between the instances of "explanatory power" in the two platitudes above: (1) Increasing **explanatory power** is due to representing the world better. (2) **More powerful explanations** provide better understanding. The first instance of "explanatory power" refers to a quality of explanations that is independent from us: the amount of factive explanatory information contained in an explanation. The second refers to a quality of explanations that depends on us: how much understanding we can gain from an explanation. This disambiguation allows us to see why (1) and (2) do not imply that increasing scientific understanding is (just) a matter of scientific theories representing the world better and better. The two instances of "explanatory power" refer to the two different dimensions, each of which can be to an extent increased (or decreased) independently from the other. On the one hand, a theory or model that represents the world better can contain or capture more explanatory information, thus increasing explanatory power along the factive dimensions, without increasing its capacity to provide us understanding. On the other hand, by misrepresenting the world in suitable respects, and thus losing out on the factive dimension of explanatory power, a model can nevertheless enhance its capacity to provide us understanding if it renders its remaining factive explanatory information more usable to us.

Distinguishing between the two dimensions of explanatory power enables us to schematically see why (1) and (2) do not give rise to a problematic tension. I will next flesh this out by indicating how prominent conceptions of scientific explanation and understanding coherently fit this two-dimensional conception of explanatory power.

## 4 Explanation and understanding

What could factive explanatory information be, first of all? I am sympathetic to the idea that explanations provide information about how an explanandum (variable) counterfactually depends on an explanans (variable). This idea is at the heart of a prominent counterfactual-dependence account of causal explanation (Woodward, 2003), which can arguably be extended to also cover various non-causal explanations (Jansson and Saatsi, 2019; French and Saatsi, 2018; Reutlinger, 2018; Woodward, 2018). With this conception of explanation in mind, the factive dimension of explanatory power can be simply identified with the amount of appropriate counterfactual information that an explanation contains. An explanation that provides (approximately) true answers to a broader range *what-if* questions regarding the explanans variable is more powerful, ceteris paribus (Hitchcock and Woodward, 2003).

Extant analyses of explanatory power in the context of the counterfactual-dependence account fill in the details. These analyses are more fine-grained than the two-fold distinction that I made above. For example, Hitchcock and Woodward (2003) identify six different ways in which the degree of invariance of an explanatory generalisation can vary — that is, there are six ways in which explanations can differ in the range of *what-if* questions they cover. Relatedly, but carving the matter at different joints, Ylikoski and Kuorikoski (2010) count five dimensions of explanatory power. These analyses assume that explanatory information is factive, and also that there are always pragmatic and contextual factors in play in the assessments of explanatory power. My two-fold distinction focuses on highlighting the difference between explanatory power as a feature of explanations due to their representational relationship to mind-independent reality, and explanatory power as a feature of explanations due to their relationship to us.

Moving on to understanding, what could this be? It is commonplace to associate understanding with some kind of "grasping" of an explanation. This notion of grasping is often left somewhat unarticulated (see Belkoniene 2021). A prominent thought — one that I am very sympathetic with — is that 'grasping' is best construed as an ability. In the context of the counterfactual-dependence account of explanation it is natural to identify it with an agent's ability to correctly perform counterfactual *what-if* inferences to extract counterfactual-dependence information contained in an explanatory theory or model (Kuorikoski and Ylikoski, 2015; Ylikoski and Kuorikoski, 2010). Obtaining understanding in this sense obviously requires that there actually is true modal information contained in the explanation to begin with, i.e. that the explanation is sufficiently powerful in the factive sense. At the same time understanding in this sense is also unavoidably dependent on the cognitive salience and extractability of the relevant modal information relative to an agent equipped with appropriate reasoning skills. An explanation can render relevant modal information more or less readily available to an agent, depending on the latter's training, skills, cognitive limitations, and other such contextual factors (de Regt, 2017; Kuorikoski and Ylikoski, 2015; Ylikoski and Kuorikoski, 2010).

These prominent conceptions of explanation and understanding serve to flesh out the two dimensions of explanatory power in a coherent way.

## 5 Benefits

Distinguishing between pragmatic and factive dimensions of explanatory power can help throw light on various issues at the confluence of explanation, understanding, and representation. I will briefly review some potential benefits in this section before delving deeper into the question of understanding's factivity (Section 6) and its growth (Section 7).

**Explanatory role of idealisations and fictional presuppositions.** Let's first look at the role of different intentional misrepresentations in the context of explanatory modelling. According to some philosophers such falsehoods sometimes play an essential role in explanations (e.g., Batterman 2005a, 2009, 2001; Bokulich 2009, 2008b,a, 2012). This contrasts with the more commonly held view that the false parts or aspects of explanatory models always correspond to explanatorily irrelevant features of the systems being represented (e.g., Strevens 2008). Let's focus on Bokulich (2017), who acknowledges as "counterintuitive" the notion that "the idealizations or [fictional] falsehoods themselves do real explanatory work," while nevertheless maintaining that "sometimes it is in part because of their falsehoods — not despite them — that models explain." (111) According to Bokulich (2009) "some fictions can give us genuine insight into the way the world is, and hence be genuinely explanatory and yield real understanding" (94).

Lumping together "genuine physical insight", "genuine explanatoriness", and "real understanding" in this way cries out for unpacking and articulating what each of these notions refers to. In fairness to Bokulich, she has explicitly associated the explanatoriness of what she calls "structural model explanations" with how they correctly capture patterns of structural dependencies in the world (Bokulich, 2008a). This chimes well with the counterfactual-dependence account of explanation. But, as I indicated above, the latter account can be regarded as factive in the sense that explanatory power can be identified with true counterfactual information contained in an explanation, so it is not very clear how the non-veridical aspects of explanatory models can then do "real explanatory work," or yield "physical insight".

Distinguishing between factive and pragmatic dimensions of explanatory power helps by allowing us to precisify Bokulich's position by locating the contribution of idealisations and fictional presuppositions on the pragmatic side of the equation: such falsehoods improve explanatory models simply by rendering them more user-friendly, allowing cognitive agents to extract (more easily) factive explanatory information. If understanding is furthermore construed as an ability to make correct counterfactual inferences on the basis of a model, we can more clearly see how falsehoods can be conducive to increasing explanatory understanding by contributing solely to the pragmatic dimension of explanatory power. And while Bokulich's references to 'real physical insight' and 'real explanatory work' are ambiguous and potentially misleading, I am very sympathetic overall to her analysis of, e.g., semiclassical mechanics as a discipline in which "reasoning with fictional classical structures [...] can yield explanatory insight and *deepen our understanding*." (Bokulich 2008a, 20, my emphasis) In the light of the factive/pragmatic distinction I would, however, insist on explicitly associating the explanatory role of idealisations and fictions firmly with the pragmatic dimension of explanatory power.[4]

**The explanatory role of mathematics.** The distinction between pragmatic and factive dimensions of explanatory power can similarly help in analysing mathematical explana-

[4]This is broadly aligned with Sullivan and Khalifa (2019, §4).

tions in science.[5] Mathematics' indispensability to scientific explanations is undeniable: mathematics-laden models often furnish better, more powerful explanations than those expressed by purely nominalistic means. Although mathematics arguably often has a merely representational function in explanatory models, there is a lively debate around examples in which mathematics is purportedly 'distinctively' explanatory (e.g., Baker 2009; Lange 2013; Baker 2017; Baron 2020; Barrantes 2020).[6] This debate is multifaceted and I cannot do justice to its nuances here, but let's focus on a contrarian viewpoint according to which there actually are *no* mathematical explanations of empirical phenomena (Kuorikoski, 2021). How can such a claim be maintained in the face of the abundant evidence that by appealing to mathematical theories we end up with more powerful explanations?

Our two-fold distinction can help answering this question. When one looks more closely at the explanatory virtues of mathematical explanations in contrast to their nominalistic counterparts, it can be argued that their explanatory virtues often pertains specifically to explanations' *degree of integration* and *cognitive salience* (Knowles and Saatsi, 2021). The former is a matter of an explanation's connectedness to other theoretical frameworks, and its importance lies in enhancing one's inferential ability with respect to counterfactual *what-if* questions (Ylikoski and Kuorikoski, 2010). The latter relates to an explanation's pragmatic virtue of making explanatory reasoning more easily followed, rendering explanatory implications and scope cognitively transparent and more easily evaluated, and so on (*ibid.*, 215). All these explanatory virtues to which mathematics can contribute point along the pragmatic dimension of explanatory power in a way that is entirely compatible with the denial that mathematical truths/facts/entities in and of themselves are explanatory (Saatsi, 2016b). For example and more specifically, Knowles and Saatsi (2021) study mathematics' contribution to the virtue of explanatory generality. They

[5] There is clearly potential overlap between explanations' mathematical presuppositions and explanatory fictions; a mathematical fictionalist might indeed identify the two.

[6] Prominent, well-worn examples involve Königsberg's bridges and cicada life cycles.

argue in the context of the counterfactual dependence account that even with respect to the so-called 'distinctly' mathematical explanations mathematics increases explanatory generality only relative to our limited cognitive powers, maximising explanations' cognitive salience in particular.

Kuorikoski (2021) goes further to articulate a notion of "formal understanding" that pertains to understanding, not of empirical phenomena, but of our systems of reasoning and representation:

> Such understanding is constituted by the abilities in making correct what-if inferences about systems of reasoning. It is formal in that the relevant abilities concern the form of the inferences. What would follow from special relativity if the symmetry group of space-time was de Sitter rather than Poincaré? What would the properties of a competitive equilibrium be if preferences were nonhomothetic? These kinds of questions concern primarily our systems of reasoning and representation, not directly what we are representing and reasoning about (i.e., space-time or specific markets). The answers are nevertheless fully objective and ontic in that they are grounded on the objective features of our representational systems—what could justifiably be inferred from given assumptions if the properties of the system of reasoning were different.

Kuorikoski is explicit in drawing "a sharp distinction between this formal understanding and explanation proper", where the latter involves "explanatory relationships [that] do not hold between representations, concepts, or descriptions but between the things in the world being represented, conceptualized, and described." (191) Information about such worldly explanatory relationships is factive in the sense associated with the factive dimension of explanatory power. By contrast, "formal understanding" involves directly our systems of reasoning, not the phenomenon being reasoned about — hence, it's akin to "the distinction between understanding a model and understanding with a model" (*ibid.*, 207). So, although there are objective (e.g. mathematical) facts about these systems of reasoning, in so far as increase in formal understanding is conducive to increasing understanding of some *empirical phenomenon*, this is still measured by explanatory power purely along the pragmatic dimension.

**Explanatory autonomy of non-fundamental theories.** Can non-fundamental sciences provide explanations that are more powerful than those provided by fundamental physics? Are there contexts in which the ideal gas law, for example, can furnish an explanation more powerful than those furnished by statistical mechanics? Many philosophers have argued that the answer to both of these questions is yes, thus defending the (intuitively plausible) explanatory autonomy of non-fundamental sciences (e.g., Garfinkel 1981; Jackson and Pettit 1992; Woodward 2003). Weslake (2010) criticises various extant analyses of such explanatory autonomy, and he puts forward his own account of "explanatory depth" that is meant to track the explanatory value of non-fundamental theories and explain their explanatory autonomy. According to Weslake it is the *abstractness* of a higher-level explanation, in the sense of it applying to a wider range of counter-nomically possible systems, that can render it 'deeper' (viz., more powerful) in some contexts. For example, Weslake notes that "the ideal gas law is independent of whether the underlying mechanics is Newtonian or quantum mechanical", which "means that there are physically impossible systems to which the macroscopic explanation applies but to which the microscopic explanation does not." (287)

The distinction between factive and pragmatic dimensions of explanatory power provides an alternative (and in my view preferable) perspective on explanatory autonomy. The latter can be simply explained in terms of higher-level theories offering more powerful explanations (ceteris paribus) along the pragmatic dimension. There is no reason to think that the explanatory autonomy is a feature of explanatory theories or models independent of cognitive agents who use scientific theories to explain and understand.

For a quick illustration, consider the well-worn example of Putnam's peg. Why doesn't a square peg of 1 inch side go through a hole of 1 inch diameter? A mundane geometrical explanation answers this question in a way that not only provides information about the factive explanatory dependencies (e.g. what if the relative sizes/shapes were different thus and so?), but does that in a way that renders those explanatory dependencies cognitively salient so as to maximise (in a typical context) the explanatory power along the pragmatic dimension. Although a detailed microphysical account of the two bodies' solid physical composition, shapes, and motions would contain all the same information, it would be render this information cognitive opaque and hidden in the mass of other, explanatorily irrelevant information. This points to a simple analysis of the explanatory power of high-level, non-fundamental theories. This account can be contrasted with Weslake's analysis, according to which the geometrical explanation is 'deeper' by virtue of being multiply realisable with respect to microphysical laws alternative to the actual world. This analysis of explanatory depth is problematic in that it isn't at all clear how such nomological possibilities are connected to the way we appeal to and appreciate the explanatory power of the geometrical explanation.

## 6 Is understanding factive?

A lot has been written about the issue of factivity of understanding (Khalifa, 2017; Strevens et al., 2017; Elgin, 2017; Mizrahi, 2012; Lawler, 2021; Potochnik, 2017). The ongoing debate around this issue is motivated by a clash between a prima facie intuition that understanding is factive, and the fact that scientific understanding can be facilitated by falsehoods. Insa Lawler (2021) explains:

> Prima facie, understanding is factive: its content can only contain true propositions (or at least approximations to the truth). If I seem to understand a phenomenon but it turns out that my account of the phenomenon contains

> false propositions, one would say that it looked as if I understood it, but I actually did not. Yet, science is replete with falsehoods that are considered to foster or facilitate understanding rather than prevent it. (2)

One of the benefits of drawing the distinction between factive and pragmatic dimensions of explanatory power is that it goes a long way to resolve this tension. The intuition that understanding is factive reflects the factive dimension of explanatory power. If I claim to have explanatory understanding of some phenomenon, the level of my understanding is bound by the amount of true explanatory information contained in my account of the phenomenon. In other words, it is the truth-content of my account that underwrites the maximum degree of understanding that I can have on the basis of this account.[7] This basic factivity intuition notwithstanding we should also recognise that it is not enough for an account of a phenomenon to contain true explanatory information, for that information also needs to be suitably accessible to human beings who are trying to understand it. Therefore, if you have two accounts that both contain the same explanatory information, one can be more or less powerful than the other in the pragmatic sense of providing us more or less understanding, and the falsehoods that science is replete with sometimes have the function of enhancing theories' capacity to provide us more understanding, as required by our cognitive needs and limitations.

This schematic resolution of the tension can be fleshed out with reference to more specific ideas regarding explanation and understanding. Let's again identify the former with information that correctly answers counterfactual change-relating *what-if* questions, and the latter with an *ability* to reliably make the relevant counterfactual inferences (see Section 4). With these philosophical theories in mind, understanding can be regarded as 'factive' in the sense that it can only be had through an explanatory theory or model that contains true counterfactual information, but at the same time understanding is clearly

[7] The way Lawler captures the factivity intuition in the quote above requires too much from understanding, I think. Do we want to say that Newton didn't have understanding of the tides, for example, when it turned out that his account contained various false (not even approximately true) propositions?

not 'factive' in the sense that this ability to make correct counterfactual inferences could well be increased by non-veridical aspects of our theory or model. There can thus be a tradeoff between (i) representing explanatory dependences in a less veridical way that increases our ability to make correct counterfactual inferences (the pragmatic dimensions of explanatory power), and (ii) representing these dependencies in a more veridical way (along the factive dimension) that reduces our inferential ability. (See also Kuorikoski and Ylikoski 2015; Ylikoski and Kuorikoski 2010.)

This perspective saves the basic factivist intuition about explanation. It complements existing defences of factivism regarding understanding. Consider Lawler (2021), for instance, whose strategy is to distinguish between the 'content' of understanding as the *product* of scientific reasoning or modelling, and the *process* of obtaining it. According to Lawler idealisations and other such "felicitous legitimate falsehoods" merely play an epistemic enabling role for "extracting" from theories and models (approximate) truths that comprise the content of understanding. "These falsehoods can play an epistemic enabling role in the process of obtaining understanding but are not elements of the explanations or analyses that constitute the content of understanding." (*ibid.*, 6860) This allows Lawler to defend the view that "understanding is factive: its content can only contain true propositions (or at least approximations to the truth)." (*ibid.*)

This view is kindred to mine, but Lawler doesn't take sides on the debate on the nature understanding or explanation, only suggesting that "one might say that a subject understands a phenomenon only if they grasp an explanation or analysis of it." (*ibid.*, 6859) What is being grasped, the explanation, is the "content" of understanding. (*ibid.*) That being so, she is committed to the claim that (genuine) explanations are (approximately) true. Whatever role the falsehoods play, these are somehow connected to the "production" of explanations, while not being 'part' of explanations themselves.

When it comes to figuring out whether a given mathematical feature or idealisation (e.g. the thermodynamic limit or renormalisation group fixed points) is a 'part' of a scientific explanation. I prefer to operate in the context of a *specific theory of explanation*. With a theory of explanation in hand, one can look at the explanatory role of different theoretical posits, and argue that mathematics, idealisations, and fictional posits play a broadly representational or instrumental role in procuring factive information that is doing the explanatory heavy lifting (e.g., Saatsi 2016b; Reutlinger and Saatsi 2018). Demarcating between different kinds of explanatory roles in this fashion can furthermore be connected to the two dimensions of explanatory power, as indicated in Section 4. In my analysis, in comparison to Lawler, such demarcation is dependent on a more substantive view on what it is to explain and what understanding consists of.

## 7 The growth of scientific understanding

Another benefit of the distinction between factive and pragmatic dimensions of explanatory power comes in relation to capturing the growth of scientific understanding. This aspect of scientific progress involves an epistemic achievement of steadily improving scientific explanations. Our account of explanatory power should make sense of this progress in terms of the interrelationships of the theories and models that contribute to it. Paradigmatic examples of explanatory progress include, for instance, increasing understanding of tidal phenomena, and increasing understanding of the rainbow, glory, and other related optical phenomena. Arguably a naturalistic philosopher ought to regard these as examples of lasting epistemic achievements regardless of her stance on scientific (anti-)realism, for there is an accepted scientific narrative of the development of relevant theoretical explanations from early modern science to the current day. Importantly, despite radical shifts in the relevant theories' conceptual frameworks and ontological commitments — shifting from Newtonian gravitational force to curved spacetime, for example, and from Newtonian light corpuscles to ether waves and electromagnetic waves — there is also a cumulative growth of scientific understanding.

In Saatsi (2019) I explore in some detail the interplay between the accumulation of understanding as a lasting epistemic achievement, on the one hand, and the varying theoretical perspectives on the phenomena being understood (e.g. gravity, or light), on the other. My analysis sees value in these shifting "explanatory perspectives" even when they don't form a lasting epistemic achievement by themselves, but rather function as a cognitive scaffolding for scientists operating in a particular theoretical context that involves specific ways of thinking about and representing the phenomenon at stake mathematically and metaphysically. Such explanatory perspectives can contribute to understanding broadly along the lines of de Regt's (2017) account, by enhancing theories' and models' intelligibility. According to de Regt "a phenomenon $P$ is understood scientifically if and only if there is an explanation of $P$ that is based on an intelligible theory $T$ and conforms to the basic epistemic values of empirical adequacy and internal consistency." (92)

The way I think of it, the various features of $T$ that enhance its intelligibility increase $T$'s explanatory power along the pragmatic dimension (in the relevant context). This is only half the story, however, as it doesn't account for the *epistemic achievement* of understanding that accumulates over potentially radical theory-shifts as science advances.[8] The key to capturing this epistemic progress is to also pay attention to the factive dimension of explanatory power that tracks the human-independent sense in which theories latch better and better onto explanatory features reality. (E.g., the electromagnetic theory of light contains more explanatory information than the ether theory, and general theory of relativity contains more explanatory information than Newtonian gravity.) To the extent these factive explanatory features are 'grasped' by cognitive agents we gain more and more understanding. For example, this allows us to make sense of the way in which Descartes and Newton managed to contribute to the accumulating scientific understanding of rainbows: despite operating in the context of explanatory perspectives that were idiosyncratic and misguided from our current theoretical vantage point, Descartes' and Newton's theorising provided them the ability to correctly answer critical *what-if*

[8]In my view this accumulation isn't well captured by de Regt's account, but I won't argue for this here.

questions involving explanatory variables that carry over to contemporary explanatory models of the rainbow (see Saatsi 2019 for more detailed discussion).

In addition to helping us capture large-scale historical trends of epistemic progress in science, the factive-pragmatic distinction is useful also with respect to more fine-grained aspects of scientific understanding that involves mutually incompatible explanatory perspectives. In the context of contemporary theories of the rainbow, for example, one can consider the epistemic achievement of the semi-classical Complex Angular Momentum (CAM) method as furnishing a ray-theoretic perspective that clashes with what is regarded as complete and fundamental wave theoretic account of rainbow scattering, viz. the Lorentz-Mie theory. The latter is a model of Maxwell's electromagnetic theory representing an "ideal" rainbow (comprising plane waves and perfectly spherical raindrops), all the optical properties of which it deductively entails. This model maximises the factive dimension of explanatory power, as it contains all the answers to different *what-if* questions about the (ideal) rainbow. The CAM method, which occupies the theoretical borderland between geometrical ray theory and the wave theory, goes beyond this fundamental explanatory framework by increasing explanatory power along the pragmatic dimension: it allows us to represent key features of the dynamics of electromagnetic radiation in a way that makes them transparent to us. This is nicely expressed by the main architect behind CAM, Herch Nussenzveig (1992):

> A vast amount of information on the diffraction effects that we want to study lies buried within the Mie solution. In order to understand and to obtain physical insight into these effects ... it is necessary to extract this information in a "sufficiently simple form." (45)

This simplicity, Nussenzveig goes on to emphasise, lies "to some extent ... in the eye of the beholder" (*ibid.*, 210). I think all this is nicely captured by the distinction between the factive and pragmatic dimensions of explanatory power, which thus helps to throw light on how studying an approximation scheme (CAM method), in relation to the complete and fundamental theory (Lorentz-Mie theory) that provides an exact solution, can make a substantial epistemic contribution to understanding. In essence, the issue with the fundamental theory is its lack of cognitive salience. As Nussenzveig (quoting Eugene Wigner) poetically puts it: “It is nice to know that the computer understands the problem, but I would like to understand it too.” (*ibid.*) footnoteFor more detailed philosophical discussion of the explanatory use of semi–classical optics, see Pincock (2011) and Saatsi (2019), as well as Batterman (2005b) and Belot (2005). For a review of the CAM method, see Adam (2002) and Nussenzveig (1992).

## 8 Conclusion

Many philosophers begin with the assumption that actual explanations are factive. If genuine understanding is just a matter of “grasping” an actual explanation, this basic factivity assumption can suggest that increasing scientific understanding is a matter of scientific theories and models representing the world better and better. This is problematic since genuine understanding can be increased in ways that involve idealisations, approximations, and other kinds theoretical presuppositions that essentially incorporate falsehoods, or are not regarded as representational by the scientists. We can alleviate this tension by drawing a distinction between pragmatic and factive dimensions of explanatory power. This distinction allows us to hang on to the basic factivity assumption regarding explanations’ relationship to reality, as well as to the natural idea that explanations’ primary function is to give us understanding, and that better explanations provide more understanding.

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