Discussion Note: Massimi's Modal Account of Exploratory Models

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Abstract

Michela Massimi (2018; 2019) claims to have identified two novel kinds of exploratory modeling practices that are both characterized by their epistemic function: they deliver possibility knowledge. In this note we argue that the epistemic claim is unclear and insufficiently supported, and that this threatens to undermine the claim to novelty. The upshot is a challenge to provide a modal epistemology of exploratory models.

Introduction

In two recent papers in this journal, Michela Massimi (2018; 2019) has drawn attention to a family of *exploratory* modeling practices that are characterized by delivering "genuine modal knowledge (about how things *might be in nature*)" (2019, 871).[1] Massimi offers a number of case studies to show the prevalence of these practices, but claims that philosophy of science neither has payed much attention to them, nor is able to account for them with current accounts of scientific modeling.[2]

We very much sympathize with Massimi's claims that philosophy of science should pay more attention to *modal* modeling practices (reference omitted) and needs to adjust its existing theories of scientific modeling in order to account for them. However, we argue that (a) Massimi's claim that exploratory models deliver modal knowledge is underdeveloped and currently lacks adequate support; and (b) failure to deliver on (a) threatens to collapse Massimi's distinction between different kinds of exploratory models.

1. Massimi's modal account of exploratory modeling

Massimi provides excellent discussions of several modeling practices in physics and uses them to illustrates what she takes to be two distinct kinds of exploratory modeling: hypothetical modeling (2018; 2019), and fictional modeling (2019).[3]

Hypothetical modeling models entities that are "possible, neither known to be actual nor known to be fictional" (2018, 349). At the hand of the ATLAS collaboration's search for sub-atomic particles, and the CMS experiment's exploration of possible production scenarios of the neutralino, Massimi shows how scientists model *possible* ways in which such particles could exist or be produced. These are neither models of data, nor phenomenological models of actual phenomena, nor theoretical models, as they explicitly seek to bracket as many assumptions about the Standard Model as possible in order to not limit the search for particles unnecessarily. Instead, they are "a genuine exercise in modeling physically conceivable states for supersymmetric particles (within experimental and nomological boundaries) as a guide to what might be objectively possible in nature" (2018, 353).

Fictional exploratory modeling differs from hypothetical modeling by having a target that is fictional – by which Massimi means known to be non-existent. However, by imputing properties from the fictional model to the target, conclusions can be drawn about what is

[1] All references without name are to these papers.

[2] Massimi (2018) also offers her account of "perspectival models", as a solution to the *problem of inconsistent models* for scientific realists. We do not address that part of her argument here.

[3] Massimi (2019) calls her earlier concept (2018) of perspectival modeling 'hypothetical modeling'. We follow that practice.

causally possible for actual phenomena. The construction of the fiction is guided by analogies to models with actual targets. Massimi illustrates this with Maxwell's ether model. Maxwell constructed it in analogy with Helmholtz's equations of fluid dynamics, and he was aware that such an ether did not exist, calling it a "collection of imaginary properties". Obeying laws analogous to those of hydrodynamics, Massimi claims, licensed Maxwell's ether-model to provide modal knowledge. From the ether model, Maxwell acquired "a particular kind of modal knowledge (…) of what is *causally possible*" (2019, 871) for electromagnetic induction.

Based on her analyses, Massimi makes two claims: the modeling practices she identifies are novel types of exploratory modeling, and they provide possibility knowledge. Both relate to Massimi's *modal account* of these modeling practices.

1.1. Massimi's Novelty Thesis

Axel Gelfert (2016) has recently done important work on different types of *exploratory* modeling, adding to philosophy of science's rich catalogue of types of modeling practices. Massimi claims that the two types of exploratory modeling she identifies are distinct from those already discussed by Gelfert and others. This *Novelty thesis* has two parts:

The first concerns representation. Hypothetical models have a *sui generis* mode of representational content, as compared to standard representationalism according to which models successfully represent by establishing a "one-to-one mapping between relevant (partial) features of the model and relevant (partial) – actual or fictional – states of affairs" (2018, 342). But hypothetical models represent neither actual nor fictional states of affairs; they have representational content by virtue of "being about possibilities" (2018, 349).

The second concerns exploratory function. As Massimi notes, Gelfert distinguishes four different functions of exploratory models. They may serve (1) as a *starting point* for future inquiry; (2) as *proof-of-principle* demonstrations; (3) as generating *potential explanations* of observed phenomena; or (4) as leading to assessments of the *suitability of the target*. Massimi explicitly claims to be *adding* functions to this list, namely "(5) delivering knowledge of causal possibilities and (6) delivering knowledge of objective possibilities for hypothetical entities" (2019, fn. 1). Although she notes some further differences between Gelfert's four kinds and hers (2018, 339), the key distinction of both kinds is their ability to deliver some kind of modal knowledge.

1.2. Massimi's Epistemic Thesis

Massimi claims to have delineated a novel family of exploratory models, characterized by providing possibility knowledge. We read her as suggesting that these modeling practices substantially contribute to the acquisition of modal knowledge in the following two senses: First, modeling *affects* scientists' beliefs about what is possible. Second, modal knowledge requires justification, and we take Massimi to mean that the modeling practices provide *justification* for believing certain modal claims to be true. Jointly these make up what we call Massimi's *Epistemic thesis*.

Massimi argues that hypothetical and fictional modeling can perform their respective epistemic functions by inviting model users to imagine non-veridical scenarios about the hypothetical or fictional target. She defines the relevant type of restricted imagination –which she calls *physical conceivability* – as follows:

> *p* is physically conceivable for an epistemic subject S (or an epistemic community C) if S's (or C's) imagining that *p* not only complies with the state of knowledge and conceptual resources of S (or C) but it is also consistent with the laws of nature known by S (or C) (2019, 872).

According to Massimi, hypothetical and fictional exploratory modeling rely on physical conceivability in different ways, and therefore deliver slightly different types of modal knowledge.

Hypothetical modeling delivers knowledge of what is "objectively possible", e.g. about whether a hypothetical target system might exist. It involves, Massimi avers, "imagining something ... with the goal of facilitating inferences about its very existence" (2019, 875). One is justified in concluding that a hypothetical entity z can possibly exist in a certain way (e.g. with properties P_i) only if attribution of P_i to z complies with the state of knowledge and is consistent with the laws of nature, i.e. only if $P_i z$ is physically conceivable. This is what Massimi calls *law-bounded physical conceivability*.

Fictional modeling, in contrast, facilitates knowledge of what is "causally possible". It concerns possible causes of actual phenomena rather than possible existence of hypothetical entities: the "goal is to identify a possible causal mechanism behind a given phenomenon that the fictional target system is a proxy for" (2019, 872). This type of modeling involves what Massimi calls *law-driven physical conceivability*. Somewhat different from law-bounded conceivability, it provides a connection between fictional systems and actual phenomena by way of analogy.

The analogical reasoning proceeds in two steps: First, analogy drives construction of the model, which is guided both by laws that govern the phenomenon of interest, but also those in other domains. For instance, Maxwell's model was physically conceivable not just in the sense of being consistent with the known relation between strength of magnetic field and displacement of electric current (i.e. Faraday's law), but also with Helmholtz's equations for fluid dynamics. "Maxwell (…) came up with an intentionally fictional honeycomb model of the ether, whereby Faraday's lines of magnetic force could be thought of as analogous with lines of fluid motion; and electric displacement as analogous with rotation in fluid" (2019, 873). Second, properties attributed to the fictional system during its construction and analysis, are "via suitable keying (…) translated into essential properties and relations (…) imputed to the phenomenon" (2019, 874). This in turn allows drawing conclusions about how the actual phenomenon of interest might possibly be caused. This imputation is presumably also justified by analogy, but Massimi is not very clear here. Thus, conceivability *and* imputation together constitute the basis for Maxwell's knowledge of a causal possibility about electromagnetic induction.

In sum, Massimi's notion of physical conceivability bolsters her epistemic thesis: *because* these models are compliant and consistent with the state of knowledge and with laws of nature, they provide modal knowledge. Note also that the tenability of the Epistemic thesis is crucial to the tenability of at least one part of the Novelty thesis, since the distinctiveness of these modeling types lie in their particular epistemic function of providing modal knowledge.

2. Discussion

We now raise some worries about both the Novelty and the Epistemic thesis. At heart, they all relate to questions regarding the relevant notion(s) of possibility.

Massimi claims that exploratory models help "carve out a space of genuine – causal, epistemic, or objective – possibilities" (2018, 339). On a standard understanding, to say that *p* is epistemically possible, is roughly to say that for all we know, *p* might be true of the actual world. Epistemic possibilities are "genuine" merely in the sense of being candidates for actual truth, *as far as we know*. Objective (sometimes 'alethic') possibilities are normally understood as "genuine" in a quite different sense. There are more and less restricted notions of objective possibility – the least restricted one of interest to science is probably nomological possibility (i.e. compatibility with laws of nature), but holding fixed further facts generates other, more

restricted notions. But any objectively possible *p* is a "genuine" possibility in the sense that *p* is possible regardless of whether or not *p* actually obtains, and the truth of these possibilities is not dependent on our knowledge.

It's fine to be inclusive about the sorts of possibility claims models can support (see e.g. Verreault-Julien's 2019 approach to how-possibly explanation), as long as it is clear, for every case, which sort is at issue. We argue that Massimi is not clear on this. In particular, her account uncomfortably oscillates between objective and epistemic modality.

2.1 The Novelty thesis

Massimi's Novelty thesis has two parts. We raise one worry about each.

According to the first part, hypothetical models have a *sui generis* mode of representation that does not satisfy the representation-as-mapping principle. They have representational content, but "their being about X is being about possibilities (as opposed to actual or fictional states of affairs)" (2018, 349). First, we have some reservations about the claim that representation-as-mapping holds for models of fictional systems.[4] If we grant that it does, however, we fail to see why hypothetical model representation could not be described as mapping relevant model properties onto a possible system. Second, Massimi's tripartite distinction makes sense only if the possibilities are epistemic: known to be actual, known to be non-actual, and epistemically possible. But hypothetical models are supposed to be about *objective* (nomological) possibilities. This spells trouble for the distinction. All actual states of affairs are objectively possible, since actuality implies objective possibility, and many fictional (i.e. non-actual) states of affairs are objective possible (that is, things could be different from what they are). Since these possibilities are not clearly distinct from actual and fictional states of affairs, hypothetical models cannot be distinguished from other models based on their mode of representation in terms of objective possibilities.

According to the second part of the Novelty thesis, fictional models differ from *other* exploratory models by virtue of providing modal knowledge.[5] One of the already documented functions of exploratory models is to provide potential explanations of an observed phenomenon (Gelfert 2016, 87). Indeed, Gelfert uses Maxwell's honeycomb model to illustrate this functional kind (see also Massimi 2018, 339). Yet in her (2019), Massimi claims that her fictional modeling account of Maxwell's honeycomb model describes a novel function – delivering knowledge of causal possibilities – *besides* that of potential explanation. This makes us wonder what the distinction between these two functions really is. Note that the problem is not with having one model illustrate different functions – that's fine – but with making good on the claim that she is really adding "two further functions to this list" (2019, fn. 1). Are we not just being offered a more extensive explication of the potential explanation function of Maxwell's model? Massimi does not address this. But we can think of two related ways to make good on this part of the Novelty claim:

First, the most straightforward way to understand "potential explanation" of some x is presumably as identifying an *epistemically possible* explanation of x. A distinct function would be to identify that so-and-so is an *objective possibility* for a target system. It is not clear whether "causal possibility" is epistemic or objective, but to us it seems reasonable to understand it as a restricted form of objective possibility. Indeed, talk of "modal knowledge" is generally taken to concern objective (as opposed to epistemic) modal matters, so Massimi's insistence on that term in describing the function supports our reading. Second, the idea might be that Massimi is identifying an *epistemic* function of fictional models, in contrast to the (let's assume) merely heuristic function of potential explanations. That is, her exploratory models provide *knowledge*

[4] For this claim, see Massimi (2018, 343)

[5] The Novelty thesis also claims this for hypothetical modelling, but our worry here centers on fictional modelling.

that so-and-so is a possible cause of some actual phenomenon, while others merely suggest avenues worthy of further pursuit. In fact, this may coincide with a distinction in terms of epistemic vs. objective possibility. To show that *p* is epistemically possible, it suffices to show that *p* is not ruled out by current knowledge. This is compatible with knowing very little about matters relevant to *p*. Justifying a claim of objective possibility, in contrast, requires marshalling actual evidence in support of the suggestion that so-and-so is genuinely a way that the world could be. Thus, fictional modelling really would satisfy a novel function only if it justified objective possibility.

Reflection on both parts of the Novelty thesis thus casts into bold relief the need for Massimi to specify more clearly the kind(s) of possibility that she considers relevant to the distinctive function of exploratory modal modeling. Moreover, as the Novelty thesis appears to turn very centrally on the claim that some exploratory modeling practices deliver knowledge of objective possibility, it is of great importance that such a version of the Epistemic thesis can be sufficiently supported.

2.2. The Epistemic thesis

While we take the first part of the epistemic thesis – that exploratory modeling *affects* scientists' beliefs about possibilities – to be convincingly supported by Massimi's cases, we have some worries about the second, normative part, concerning *justification*.

That Massimi wants to defend such a normative claim is evidenced not only by her repeated assertion that exploratory modeling provides modal knowledge. It is further evidenced by her claim that hypothetical modeling contributes to the "realist quest" of "producing scientific theories (qua families of models) that are approximately true" (2018, 349). Evidently, she sees these modeling endeavors not merely causing the production of theories, but as contributing to the justification of claims about these theories' truth.

Her notion of physical conceivability is central to how these exploratory models can perform the epistemic function. For *p* to be physically conceivable for an epistemic subject S, it must satisfy two necessary conditions: (i) *p* must comply with S's state of knowledge and S's conceptual resources, and (ii) *p* must be consistent with the laws of nature known by S. The definition specifies the conditions under which models are good epistemic guides to possibility: that the proposition *p*, which describes what the model represents, is physically conceivable, is a reason to regard *p* as possible.

In order to evaluate this, we must have a clear view of the relevant notion of possibility. In particular, claims that so-and-so is epistemically and objectively possible, respectively, need to be justified in different ways. On the one hand, not all current knowledge is relevant to whether *p* is objectively possible, since many objective possibilities are counterfactual. On the other hand, being justified in taking *p* as epistemically possible (i.e. not being known to not obtain)[6] is perfectly compatible with knowing very little of relevance to whether *p*. In contrast justifying the claim that *p* is objectively possible requires marshalling evidence or arguments really speaking to the genuine possibility of *p*. That current knowledge (which may well be scarce in some domains) does not include that not-*p,* is not sufficient for that purpose. In light of this, Massimi's definition of physical conceivability is both too *restrictive* and too *weak* to be a guide to objective possibility. It is too *restrictive*, because its insistence on compatibility with *all* current knowledge (i.e. (i)) excludes many distinctively modal modeling practices. First, most models include idealizations: assumptions known or suspected not to be true about the target. This also holds for hypothetical models, as Massimi admits. When physicists build simplified models to search for neutralino production, for example, they not only explore what

[6] This kind of negative definition of epistemic possibility is standard in the literature. This particular formulation is from Weatherson and Egan (2011, 1).

they do not know, they also simplify and hence idealize what they know (Massimi 2018, 354). Such models do not comply with the state of knowledge and are thus excluded by (i).[7]

Furthermore, in some disciplines, modelers are interested in counterfactual objective possibilities. For example, researchers have synthesized XNA and explored its functional properties. Some scientists conclude on the basis of this research that such alternative systems *could have* existed – the evolution of life could have been based on some XNA, instead of or in addition to RNA/DNA. But they know full well that *in fact* evolution of life was based on RNA/DNA. Because of (i), such a model is not physically conceivable, as it does not comply with modelers' state of knowledge. More generally, physical conceivability is supposed to deliver knowledge of objective possibilities, but although many scenarios known to be non-actual are objectively possible, no such scenario would be physically conceivable.

It might therefore seem wise to just drop (i) and define physical conceivability solely in terms of (ii). That would allow counterfactual scenarios.[8] Alternatively, perhaps Massimi just intends physical conceivability to be a tailor-made guide to a restricted set of objective possibilities: those that might be actualized, for all we know, hence (i). One may as well drop (ii) then, since satisfying (i) implies satisfying (ii).

However this might be resolved, all alternatives face another issue, namely that of being too *weak*. In Massimi's notion of physical conceivability, *compliance* with current knowledge (which we interpret as "being consistent with") suffices to establish that *p* is epistemically possible. But justifying the claim that *p* is objectively possible requires more than not knowing that not-*p* (or not knowing whether *p* is precluded by the laws) – it requires actual support for *p*'s possibility. Of course, when one *can* provide such support one will be drawing on current knowledge. But the definition does not ensure that a physically conceivable model provides this – if S's state of knowledge is poor, many systems will be physically conceivable.

While we don't deny that exploratory models *can* provide justification for objective possibility claims, including Massimi's notions of "objective" and "causal" possibility, our above worries place a substantial burden on the models in question. Can these models really deliver on this? This is all the more pressing in light of our conclusion in 2.1 that Massimi's Novelty claim depends on it.

It is interesting to note Massimi's own ambiguity here. Despite the fact that her Novelty thesis to a large extent turns on her ability to make good on the justification-part of the Epistemic claim, in some passages she sounds much more guarded with respect to the epistemic nature of the function she identifies for these exploratory models. For instance, she writes that exploring possibilities is an "important *heuristic* task for [hypothetical] modeling" (2018, 355, our emphasis); and that models' "*heuristic* success ... depends on their ability to explore and carve out the space of possibilities" (2018, 349, our emphasis). With fictional modeling, the modal knowledge derived allows one to "see how far the analogy (…) could lead" (2019, 875).'Heuristic' in general use typically refers to a means of discovering and in philosophy of science is thus often contrasted to a means of justifying a claim. More specifically, heuristics are fallible and systematically biased means that might be pragmatically successful in some contexts (Wimsatt 2007), but do not by themselves provide epistemic justifications.

But insofar as the distinctive function of Massimi's exploratory modeling practices is their ability to produce "modal knowledge", their conclusions about possibilities must be assessed with respect to the epistemic justification provided by the modeling. Any pragmatic

[7] This is analogous to a problem that Betz (2015) raises for (epistemic) possibilistic interpretations of climate models, and while it may not be unresolvable, it adds another level of complexity to the idea of modeling epistemic possibilities that should not be ignored.

[8] It would still leave physical conceivability irrelevant for capturing modeling practices in fields where laws are scarce (many domains of biology) or entirely absent (as is arguably the case in economics), despite the fact that objective modal modeling has been documented for both (Koskinen 2017; reference omitted).

consideration (e.g. "how far it could lead") will be secondary, and at best relevant to functions already identified by Gelfert or others). If, to the contrary, there is no epistemic justification of the produced possibility claims, and the modeling can be assessed and justified only through pragmatic criteria, this undermines the claim that these models deliver modal knowledge, and thereby the Epistemic thesis. But it also undermines the Novelty thesis, since the distinctiveness of these modeling practices was supposed to be tied to their epistemic function.

3. Conclusion

Massimi claims novel and epistemically stronger functions for exploratory models than those presented in the extant literature, and elucidates them in terms of *possibilities*. We think modal modeling is an important topic, but find Massimi's account wanting in certain respects. The upshot is a *challenge* for Massimi (and others) to elucidate more clearly how these modeling practices successfully represent and justify claims of (objective) possibility by way of (some improved notion of) physical conceivability. If this Epistemic thesis cannot be sustained, the Novelty thesis is also undermined.

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