This is a preprint of a chapter to appear in *Open Systems: Physics, Metaphysics, and Methodology*, eds. Cuffaro, Michael E. and Stephan Hartmann, Oxford University Press, 2026.

Open Systems as Metaphysically Fundamental: Some Questions

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9th August 2024

Abstract: If open systems are metaphysically fundamental, as Cuffaro and Hartmann (2024) have proposed, then what is the fate of the system that corresponds to the entire physical universe? One option is that the universe exists but is non-fundamental. This amounts to *priority pluralism*, the converse of Schaffer's *priority monism* (2009). Monism itself has often been defended by appeal to quantum physics. We first ask how Cuffaro and Hartmann's proposal manages to avoid existing argument from quantum physics to priority monism, then raise some worries about their own argument from quantum physics to the open system view. In any case, a real but derivative universe remains puzzling. We suggest an alternative metaphysics for the open systems view which lacks a complete cosmos altogether. Metaphysical realists about the content of physical theories typically assume that there is such a thing as the totality of physical reality: a well-defined physical entity on which the fundamental laws of nature operate holistically. We explore some potential consequences for the metaphysics of physics of dropping this assumption and embracing a picture of physical reality as *indefinitely extensible*.

1. Introduction

If open systems are fundamental, as Cuffaro and Hartmann (2024) have proposed, then what is the fate of the closed system that corresponds to the entire physical universe?

One option is that the physical universe exists but is non-fundamental. This view has been discussed in the metaphysics literature under the name *priority pluralism*; it is the converse of Jonathan Schaffer's *priority monism* (2009). Priority monism itself has often been (including by Schaffer) motivated through appeal to quantum theory; arguments from entanglement to monism/holism can be traced back at least to Teller (1986). Nevertheless, Cuffaro and Hartmann aim to draw support for the open systems view from quantum theory, directly contrary to these monist arguments.

After a review in section 2 of the different fundamentality claims at issue, we look in section 3 at how Cuffaro and Hartmann's proposal handles existing arguments from quantum theory to monism/holism. We then turn in section 4 to the positive case that Cuffaro and Hartmann offer, based on quantum theory, for the open systems view. We raise the objection that their argument involves moving from a premise about epistemic possibility to a conclusion about objective possibility.

Even if the idea of a real but derivative cosmos can be made coherent through a suitable treatment of entanglement, such a cosmos remains puzzling. In section 5 we suggest an alternative metaphysics for the open systems view which lacks a complete cosmos altogether. Metaphysical realists about the content of physical theories typically assume that there is such a thing as the totality of physical reality. We explore the potential consequences for the metaphysics of physics of dropping this assumption. Perhaps the open system theorist who wants to commit to the fundamentality of open systems ought to deny that there is any such thing as the totality of physical reality: for any candidate for physical reality, we can always characterise a more expansive reality relative to which our initial candidate is a mere subsystem. This is reminiscent of the indefinite extensibility view in the philosophy of mathematics, associated in particular with Michael Dummett (1963) and also – in dialetheic form – with Graham Priest (2013). Indefinite extensibility has largely been studied to date in the context of logical and metaphysical ontologies – as an account of sets, for instance, or as an account of nested alethic modalities. We instead explore the application of the notion of indefinite extensibility to physics. We conclude that, while interesting and worth pursuing further, the indefinite extensibility view of the physical universe remains a challenging project likely to incur controversial philosophical commitments.

2. Which Fundamentality?

In "The Open Systems View" (Cuffaro and Hartmann 2024), the authors make a sustained case that the framework of theorizing about physical systems interacting with their environment, rather than about closed systems including all relevant environment, should be taken as fundamental. The purpose of this section is to explain what this means and why it might be believed.

Cuffaro and Hartmann distinguish three different kinds of fundamentality: ontic fundamentality, epistemic fundamentality and explanatory fundamentality. Our concern here will be with ontic and explanatory fundamentality. Given a broadly explanationist / abductivist approach to metaphysics, and given that fundamentality is typically regarded as closely related to explanatory reductions between theories, these two notions are closely intertwined. It is worth unpacking these connections a bit. For explanationists about metaphysics, the ontological claims made by metaphysics are justified, in general, by their role in our best overall explanatory account of the phenomena. We should recognize the existence of those things which do explanatory work in our best theories. This explanatory work may be causal or non-causal in character.

It is uncontroversial that fundamental-level entities/quantities stand in explanatory relations – not necessarily as causes and effects in any simple way, but still as playing some functional role in explanations mediated by the true underlying physical theory of our universe. Although there is a debate over whether this kind of explanation qualifies as causal, we can set this aside here, since that debate primarily concerns the specificity of the relationship to time that is built into the concept of causation. The explanations involved are generally agreed to be causal in the more general sense of being mediated by some law of nature (see Wilson 2020 for further discussion of that criterion).

In addition, a popular conception of ontological fundamentality links it to metaphysical explanation: the facts at the fundamental level are the facts which metaphysically explain all other facts. As with causal explanations, the conception of interlevel explanations as explanatory tends to establish a connection between ontological fundamentality and explanatory fundamentality. Insofar then as ontologically fundamental entities are those which appear in our most fundamental explanations, we should expect that explanatory fundamentality and ontological fundamentality will tend to align. Given the background methodological considerations favouring keeping ontological and explanatory questions as aligned, we will be working in this chapter with a unified notion of fundamentality which combines both ontological and explanatory elements. We will refer to the resultant notion of fundamentality as *metaphysical fundamentality*.

We are assuming, then, that ontological fundamentality and explanatory fundamentality will coincide in all cases of interest. We take it that this is in line with Cuffaro & Hartmann's general approach, since in their discussion of explanatory fundamentality they are mainly concerned to deny that any notion of explanatory fundamentality over and above ontological fundamentality has clear relevance to the present debate. On that point we agree, and so we will remain neutral on how the issues we discuss will play out if ontological dependence is conceived as not essentially connected to explanatory dependence – as it is for example in Cameron (2022).

Cuffaro and Hartmann do not talk, as is customary in contemporary discussions of fundamentality in physics, in terms of relative fundamentality of different kinds of physical fact. Instead their main focus is a notion of fundamentality which attaches to theoretical frameworks: roughly, the idea is that one framework is more fundamental than another if and only if the structures essential to the first framework determine the structures essential to the second framework in all relevant models. Here is Cuffaro and Hartmann's official statement of the relevant part of their main thesis, as applied to fundamentality of objects:

> (OntFund-O) Let O_F and O_P be any two objects of a given theoretical framework, F. O_F is ontologically more fundamental than O_P with respect to F iff whenever an instance of O_P appears in any model of any theory that can be formulated in F , some instance of O_F can be understood to determine O_P in that model. Furthermore, O_F is ontologically fundamental in F iff nothing is more fundamental than O_F in F.
> (Cuffaro and Hartmann 2024, 16)

And here is their view, as applied to fundamentality of theoretical frameworks:

> (OntFund-2) Let F_F and F_P be two theoretical frameworks, and let $\{O_F\}$ and $\{O_P\}$ be their corresponding fundamental objects (in the sense, say, of OntFund-O). Furthermore let F_F and F_P be motivated by two distinct metaphysical positions, M_F and M_P, respectively, in regard to their little-o objects. F_F is ontologically more fundamental than F_P iff the way that the $\{O_P\}$ actually represent their little-o objects corresponds not to M_P but to M_F. Furthermore, F_F is ontologically fundamental iff there is no theoretical framework more fundamental than F_F.
> (Cuffaro and Hartmann 2024, 21)

In these definitions, an object *O* is of a framework *F* iff matters "are representable in terms of *O* in every model of every theory that can be formulated in *F*". These are the abstract concepts used by that framework to represent the physical systems in a given model (the 'little-o objects').

OntFund-2 says, then, that a framework is more fundamental than another if and only if the less fundamental framework represents physical reality in a way which 'corresponds to' the metaphysical picture motivating the more fundamental framework. It is a little difficult to decipher what is meant by this idea of a correspondence between a way some physical models represent the world and a metaphysical view of the world. However, it seems open to interpret this in a straightforwardly realist kind of way: the fundamental physical framework is the one which is formulated in terms of the fundamental metaphysics of the world.

A peculiarity of this definition is that it does not seem to distinguish theories in terms of fundamentality if neither of them corresponds to the fundamental metaphysics of the world. Perhaps Cuffaro and Hartmann intend all such theories to be equally non-fundamental. But it is natural to think that something more can be said here to enable relative judgments of fundamentality even amongst non-fundamental frameworks. That feature was had by their first-pass definition of fundamentality, OntFund-1:

> OntFund-1: Let FF and FP be two theoretical frameworks, and let OP be any one of the fundamental objects (in the sense of OntFund-O) of FP. FF is ontologically more fundamental than FP iff FF always re-describes any instance of OP as effectively determined given an instance of some other object, OF, that is more fundamental in FF. Furthermore, FF is ontologically fundamental iff there is no theoretical framework more fundamental than FF.
> (Cuffaro and Hartmann 2024, 16)

OntFund-1 can give rise to multi-layer orderings, such that FF (the most fundamental theory) is more fundamental than both FP and FQ, with FP being more fundamental than FQ. A toy example might be general relativity (GR) → special relativity (SR) → classical mechanics (CM). However, it seems that OntFund-2 can only give us a two-layer ordering, with GR → SR and GR → CM but not SR → CM. (The underlying problem seems to be that the notion of correspondence between a framework's way of representing and a metaphysical framework is not comparative, so does not form transitive chains.) It is not clear that this flattening effect is intentional: perhaps either a return to OntFund-1, or a move to a third formulation which allows for compound orderings, would better suit Cuffaro and Hartmann's intentions.

For present purposes, we take Cuffaro and Hartmann's core idea to be that fundamentality of a framework is linked to how the success of a framework is explained. If one framework's application to the phenomena is only explainable in terms of another framework, then the latter framework is more fundamental than the former. This seems very similar to saying that a framework is more fundamental than another when there is an explanatory reduction of the latter to the former: that is, when the former framework furnishes all the needed explanatory resources for an explanation of the core features of the latter framework. This sort of move from reduction to relative fundamentality is familiar from the effective scientific realist tradition: see, e.g., Robertson and Wilson (2026).

Recall that Cuffaro and Hartmann distinguish the kind of fundamentality they have in mind from the sense in which fundamental particles might be fundamental: "the question of whether one theory or theoretical framework is more fundamental than another is not like the question of whether quarks are more fundamental than protons in particle physics". However, we would still expect there to be a close connection between the fundamentality of a framework and the fundamentality of its little-o objects: if the little-o objects featuring in OntFund-2 are non-fundamental, then how these non-fundamental little-o objects are 'actually represented' by the fundamental objects of a given framework would offer little guidance as to the fundamentality of the framework. For instance, if only the universe as a whole is fundamental, then how a given framework 'actually represents' the non-fundamental subsystems of the universe has little bearing on the fundamentality of that framework.

Accordingly, we will proceed on the assumption that the fundamentality of a theoretical framework relative to another framework typically goes hand-in-hand with the fundamentality of the first framework's characteristic entities relative to the second framework's characteristic entities (staying neutral on what the explanation for that correlation might be). This will allow us to sidestep much of the complication around the definition of a framework and its relation to a set of models, and focus directly on the claim that open systems themselves – those real things out there – are more metaphysically fundamental than closed systems.

In the next two sections we turn to one particular physical system – the universe – and look at how extant metaphysical approaches classify it with respect to metaphysical fundamentality. We will first explore how Cuffaro and Hartmann resist arguments from quantum theory to monism, before turning to their own argument from quantum theory to pluralism, which we call the *open question argument*. We will then show how priority monists can respond to the open question argument, before exploring the metaphysical implications of priority pluralism in a bit more detail.

3. From Quantum Theory to Priority Monism

Quantum theory is a key battleground for the debate between priority monism and priority pluralism. Schaffer and other 'quantum holists' take quantum theory to support monism, whereas Cuffaro and Hartmann take it instead to support pluralism. This section and the next will attempt to get to the bottom of this situation, by identifying the different background assumptions which enable these authors to draw support from quantum theory for their preferred view.

Bringing fundamentality into the metaphysics of totality is a move with ancient roots, although it has recently revived in popularity – partly thanks to Jonathan Schaffer (Schaffer 2010, 2013), who defends a monism characterised in terms of fundamentality. Many monists – including the most influential monist views of the 20th century – have denied the existence of anything except the universe – a view which Schaffer calls 'existence monism'. Schaffer endorses instead:

Priority monism: the universe is fundamental, and parts of the universe are less fundamental.

Cuffaro and Hartmann, on our reading, cannot avoid denying priority monism. The open systems view entails that if there is a closed system corresponding to the totality of everything then that system is non-fundamental. And the totality of everything – call it the cosmos for short – is invariably conceived in the literature (including in Schaffer's discussion) as being a closed system. But perhaps this argument might be blocked, if the totality of physical existence itself were to be regarded as an open system. At times this option is suggested by Cuffaro and Hartmann's discussion. But what would it mean for the cosmos to be an open system, despite having no environment? One answer is simply that it be correctly described by a non-unitarily evolving state vector. However, it is not clear to us that this technical sense of 'open' should trump the traditional criterion for a system being open, as stated in terms of systems and subsystems. According to that traditional criterion, a complete cosmos is a paradigm closed system.

Cuffaro and Hartmann recognise this difficulty, but deflect it using the idea that "the ontological distinction between open and closed systems (at least when it pertains to the cosmos) breaks down in GT" (op. cit.: 19). They remark in this connection that metaphysical categories should not be imposed a priori upon physics, a claim with which we agree. Still, our point remains. Insofar as Cuffaro and Hartmann's proposal can be conceptualised in terms of existing categories (such that open systems but not closed systems have environments), it disfavours priority monism and favours:

Priority pluralism: parts of the universe are more fundamental than the universe itself.

Priority pluralism is a very respectable view within contemporary metaphysics – indeed, it is probably the orthodox view amongst those who accept the notions of fundamentality used to frame the debate. Cuffaro and Hartmann position the metaphysical view behind the open systems framework as a departure from orthodoxy, and within philosophy of physics that may well be the case – but it is interesting to note that in general metaphysics there is already wide support for a position very like the one they endorse, albeit motivated by very different (usually a priori) considerations. Priority pluralism is for example endorsed, implicitly or explicitly, by Lewis (1986), Armstrong (1989, 1997), and Sider (2011). Philosophers in this camp tend to make an a priori case for metaphysical principles concerning the modal freedom of the fundamental entities – typically principles of recombination which permit any configuration of the fundamental entities within certain bounds – and the a priori case made for these principles tends to presuppose priority pluralism.

To the extent that philosophers of physics over recent decades have engaged with the monism/pluralism debate, the tendency has been to take physics – especially quantum physics – to support monism. For example, Howard (1989) and Schaffer (2010) argue directly from quantum theory to forms of monism (though Howard talks of 'ontological holism' rather than 'monism', his arguments can also be taken to support a monist view, cf. Ney, 2021), while Schaffer (2013) widens the scope of the argument to the claim that the underlying structure of both classical and quantum physics supports his priority monism. Cuffaro and Hartmann are going against the grain by defending a view more in the spirit of priority pluralism. As well as making a positive case for the open systems view, they accordingly owe us a response to these familiar pro-monist arguments which tend to favour the closed systems view.

The argument from entanglement, at its core, is that the intrinsic state of a whole entangled system contains all the information necessary to determine the intrinsic states of the parts – the entangled subsystems – but not vice versa. In Ismael and Schaffer (2020), the argument from entanglement is put in the form of an inference to the best explanation. The best explanation of the correlation between the individual subsystems of an entangled system is that they have a common ground: there is one underlying state, the state of the composite system, which both explains the states of the individual subsystems and their modal connection. This common ground is taken to be more fundamental than the entities it grounds. Moreover, Ismael and Schaffer argue such a common ground explanation would not face the same difficulties with Bell's Theorem as faced by attempts at a common cause explanation. As far as we can see, Cuffaro and Hartmann have not offered a response to this style of argument from entanglement, and from our perspective it remains an important consideration which favours the closed systems view.

The argument from entanglement is not the only physics-based argument for priority monism that has been made out in recent years. In what he calls the argument from nomic integrity, Schaffer argues (Schaffer 2013), drawing on Bigelow, Ellis and Lierse (1992) and Maudlin (2007), that the fundamental laws of physics – in both classical and quantum settings – apply directly to the totality of everything and only indirectly to subsystems of the universe. Bigelow, Ellis and Lierse mention relativity principles, conservation laws, and symmetry principles as principles of physics which are fundamental and also global – in the sense that these principles "neither ascribe properties to things within the world, nor describe correlations between things in the world" (384). Of these three kinds of principle, Schaffer focuses on conservation laws. Conservation laws in general only hold true at the global level: for any given open system, there is always the possibility of interaction with the environment which could lead to a change in the level of some (putatively) conserved quantity. Only considering the physical universe as a whole can be guaranteed to avoid this prospect completely. Therefore conservation laws apply to the universe as a whole. If any conservation laws are fundamental, then the system to which they apply – the whole universe – is equally fundamental. Or so Schaffer reasons. (Note that this argument applies equally to quantum and classical physics.)

We think that the most natural response for Cuffaro and Hartmann to Schaffer's argument from conservation laws is to deny that conservation laws are fundamental. Here Cuffaro and Hartmann may point to Noether's theorems, which on their most widespread physical interpretation (Lange 2007 provides evidence) are taken to show that conservation laws are non-fundamental in the sense that the holding of a conservation principle is explained by the holding of the corresponding symmetry principle. It is *because* of the symmetry of physical interactions under rotations that the quantity of angular momentum is globally preserved. So, on the assumption that physical laws which are wholly explained by other physical principles are non-fundamental, we get the conclusion that conservation laws are non-fundamental. Does this response simply move the bump in the carpet, from the conservation laws to the symmetry principles? If symmetry principles are essentially global, then we still have prospects for an argument from the fundamentality of symmetry principles to the fundamentality of the universe as a whole. Bigelow, Ellis and Lierse do claim that symmetry principles are global, in the sense of applying to everything. Relatedly, the kind of symmetries in question (those to which Noether's theorem applies) are in physics usually called global symmetries, in the sense that they act the same way at every point. However, none of this makes the symmetry laws global in the sense relevant to Schaffer's argument – which is that they can only be understood as functions acting on the universe as a whole. And in a clear sense global symmetries do not apply essentially to the whole in this way: they apply individually at points (albeit in a globally uniform way) and the interactions which exhibit the relevant symmetries may themselves be locally defined.

This is all quite consonant with the open systems view so far as we can see. Entanglement is a threat to the locality of these interactions, of course; but then we are back to the argument from entanglement, and we have not yet identified a distinct argument from nomic integrity. Accordingly we would recommend that defenders of the open system view adopt an interpretation of Noether's theorem according to which conservation laws are non-fundamental and explained in some way by symmetry principles, where those symmetries are understood as local constraints on the behaviour of physical interactions, rather than being essentially global in character.

The upshot of this discussion is that Cuffaro and Hartmann have a good response available to the more general argument from nomic integrity, but there remains an apparent explanatory gap in their proposal with respect to the argument from entanglement, at least as posed by Schaffer and Ismael (2020). Of course, even if the open systems view does have an explanatory disadvantage over the closed systems view with respect to explaining the modal connection between subsystems of an entangled system, this disadvantage may be outweighed by other considerations. Accordingly we next turn to considering arguments in favour of the open systems view.

4. From Quantum Theory to the Open Systems View

We have discussed arguments from quantum theory to the closed systems view; now we turn to the potential for a converse case to be made, from quantum theory to the open systems view.

Cuffaro and Hartmann's main argument for the open systems view takes the form of an open question argument. First, they note that most (or even all) physical systems are represented as open systems even on the framework motivated by the closed systems view. As such, these physical systems could equally well be represented by the fundamental objects of the framework motivated by the open systems view. However, unlike the open systems view, the closed systems view is not able to make physical sense of dynamical evolutions of these (open) systems described by not completely positive maps (we grant Cuffaro and Hartmann this claim, though it is deniable). As it is currently an open theoretical question whether not completely positive maps have essential application in physics, we should pre-emptively endorse the open systems view in order to properly allow for this possibility. Here is how they state the argument:

> "… we think there is every reason to at least take the former possibility—the idea that the universe's evolution takes the form of the evolution of an open system—

> completely seriously in fundamental physics; i.e., as a live option that any theoretical framework should allow us to make sense of. And if we do this then there is every reason to embrace GT, rather than ST, as our preferred theoretical framework for quantum theory, given that the former is the only framework that actually permits us to model the dynamics of the universe fundamentally in these terms."
> (Cuffaro and Hartmann 2024, 20)

It is not only committed priority monists who should want to resist this type of inferential move within the metaphysics of physics. From our perspective, this argument for the open systems view amounts to a tempting but mistaken inference from open epistemic possibility to metaphysical possibility. If whether the open systems view is correct is a non-contingent matter (as Cuffaro and Hartmann appear to think) then that argument fails.

In general, we cannot infer from the fact that it is unknown whether p to the conclusion that p is a possibility in any non-epistemic sense. The open question argument for the open systems view may be compared to an open question argument for the truth of Goldbach's conjecture. (Assume realism about mathematical truth for the sake of the comparison.) It is currently an open question in mathematics whether Goldbach's conjecture is true or false. So we should take its truth as a live option. So we should adopt a framework for representing mathematical possibility according to which it is possible. But, since mathematical truths are non-contingent, if it is possible then it is true. So Goldbach's conjecture is true.

We take the lesson here to be simple: we cannot generate knowledge of genuine possibility out of ignorance, even principled ignorance. If the closed systems view is in fact correct, and non-contingently so, then the current live theoretical possibility that the open systems view is correct is now like the possibility our ancestors once entertained, that everything be made of water. We do not have to make room for the all-water scenario in our contemporary account of the different possibilities for matter just because that scenario was once a live possibility (see Wilson 2021 for a more extended version of this argument). The same, for all Cuffaro and Hartmann say, may go for the open systems view.

Perhaps this objection can be defused by regarding frameworks as not epistemically assessable – but instead as pragmatically adopted on grounds of fruitfulness. Still, the open epistemic possibility of fruitfulness does not entail the objective possibility of fruitfulness any more than open epistemic possibility of truth entails objective possibility of truth; and if questions about fruitfulness are not themselves epistemically assessable, we are dealing with a very radical kind of pragmatism.

Of course, none of this shows that the closed systems view is correct; in this section we have aimed only to undercut Cuffaro and Hartmann's positive argument for the open systems view.

5. Doing Without the Universe

Set aside, now, whatever reasons we might have for or against the open systems view, and explore its implications in a little more detail. If open systems are fundamental, what is the fate of the whole physical universe?

Cuffaro and Hartmann appreciate the pull of the idea that there is such a thing as the physical universe. Their official view leaves it open that closed systems, including the universe, might exist.

> "As we have mentioned already, the open systems view does not deny that closed systems exist. It merely denies that only closed systems exist, and also that a closed system must exist, and represents all systems as, in general, open." (op. cit.: 14)

A question immediately arises about the modal status of the open systems view in light of these claims. If it is not the case that closed systems must exist, then is the cosmos a contingent existent? – or should we instead say that the cosmos is only contingently a closed system? But we set this question aside here. Our current question is about what it could mean for the totality of physical reality to be an open system. Cuffaro and Hartmann think that this latter question may have no good answer, because the concept of 'open system' might not apply in all cases:

> "We must not presume that every such concept that arises in a scientific theory will conform, when interpreted ontologically, to our pre-theoretic concepts or even to the concepts of our predecessor theories."
> (Cuffaro and Hartmann 2024, 22)

Accordingly they suggest reframing the question in terms of representation:

> "What, then, can it mean to represent the cosmos as a non-unitarily evolving density operator?"
> (Cuffaro and Hartmann 2024, 22)

The options they consider are that we should imagine the non-unitary evolution of the universe construed as an open system as either resulting from non-physical external influence (perhaps from an interventionist deity) or as being a brute fact with no further explanation, at least none at the level of our current physics (Cuffaro and Hartmann 2024, 22). Neither of these options strike us – or indeed strike Cuffaro and Hartmann – as satisfactory. We would like to instead explore a different possible response, which is to deny that there is any such thing as the universe. Perhaps physical reality is *indefinitely extensible*, in the sense that any given physical system is a subsystem of a larger physical system.

The prospect of an indefinitely extensible material reality has been considered in contemporary metaphysics, but it is regarded as decidedly outré. Such hypothetical universes are sometimes referred to as *junky* (such that every object in them is a proper part of something – see Schaffer 2010), and they have attracted most attention in virtue of their role as a potential counterexample to mereological universalism. This attention has often been critical: Schaffer, for example, says that '[o]nly the most radical views of mereological composition, contravening both intuition and science, could refuse the cosmos." (Schaffer 2013: 74). This dismissive attitude is supported elsewhere by considerations of the nature of a possible world: "No world—provided that worlds are understood as possible concrete cosmoi—could contain worldless junk because a world that contained junk would be an entity not a proper part of another entity at that world. A world would top-off the junk." (Schaffer 2010: 65). Of course, one might think that worlds in the relevant sense are representations of concrete cosmoi rather than concrete cosmoi, and thereby avoid this objection. Be that as it may, it strikes us that the indefinite extensibility picture may be the most natural way to do justice to the intended metaphysical picture behind the open systems view, and in the space that remains to us we will explore this picture in a bit more detail.

A first point to note here is that indefinite extensibility of the cosmos does not necessarily mean indefinite extensibility in physical or temporal extent. Indeed an indefinitely extensible universe might in principle be finite in both space and time, so long as there were infinite complexity in the physical interactions within that finite spacetime. To take a toy model, consider a description in terms of non-relativistic n-particle quantum theory of an infinite number of non-interacting particles (imagine them to be bosons, such that spatiotemporal colocation is possible) moving freely in a finite closed spacetime. Such a universe might be indefinitely extensible in the sense that for any multi-particle composite system one can consider, there is still a further particle system with which the composite system could be combined. Since there would then be no totality of all the particles, nor would there be there any physical system – open or closed – corresponding to the combined system of all the particles.

Can we simply collect together in thought all the systems in an infinitely extensible physical universe, and then introduce a term for the composite of them all taken together? According to the current proposal, such a procedure would not succeed in referring to any physical system, if indeed it succeeds in referring to anything at all. Since the collection cannot be picked out in any direct way – for example by enumerating a series of increasingly inclusive systems – we would have to introduce it by impredicative description. And, as is familiar from the study of such impredicative definitions, they may fail – most notoriously, in the paradoxical description 'the set of all sets'.

Of course, if it were impossible to refer to the most inclusive physical system, this impossibility would not be as not a result of any logical paradox, as it is in the case of set-theoretic indefinite extensibility. However, the impossibility of successful reference might – so far as we can see – simply be attributed to the nature of physical reality on the open system view: it is not such as to form any totality, and hence attempts to refer to the cosmos as the collection of all physical systems taken together do not succeed. Either such attempts do not refer at all, or they succeed in referring to something which is not itself a physical system.

Indefinite extensibility for the physical universe naturally goes along with other forms of indefinite extensibility, for example with respect to the notion of a set. Since it is plausible that for any physical object there is a set containing that object, then indefinite extensibility for physical reality seems directly to generate indefinite extensibility for set-theoretic reality. Likewise, since every physical system, no matter how large, will instantiate some new physical property (as represented by a density operator), the concept of physical property will also be indefinitely extensible.

An indefinitely extensible cosmos doesn't prevent us from doing cosmology as a science, but it may require some alterations in cosmologists' conception of their object of study. Cosmology becomes, on this picture, a matter of exploring physical reality on the very largest scales rather than a matter of exploring the universe as a whole. Thus cosmology becomes more open-ended: there could in principle be always more to say as we expand our horizons indefinitely. Yet cosmology does not have to be infinite in content under the open systems view: it could happen that from certain scales upwards there is nothing more interesting to say, in that certain patterns may repeat in the series of larger and larger systems one can consider. For example, a material universe isolated in an infinitely extensible empty spacetime would be one compatible with the open systems view, but one about which cosmology would eventually run out of interesting things to say.

6. Conclusion

The picture of physical reality as indefinitely extensible is extremely unfamiliar, and may strike many readers as bizarre. Nonetheless, we think it is a plausible way to make sense of the positive commitments of the open system view, and to take at face value the idea that all physical systems are open. While we have questioned some of the positive arguments Cuffaro and Hartmann have marshalled in support of the open systems view, we hope to have highlighted how many interesting questions at the intersection of philosophy of physics and metaphysics arise from exploring its implications.

Acknowledgments

We are grateful to Michael Cuffaro and Stephan Hartmann for the opportunity to contribute to this volume and for encouraging and helpful editorial feedback throughout, and to two referees for their constructive comments. The chapter benefited from feedback from audiences at the Workshop on the Metaphysics of Quantities in Birmingham and the Annual Conference of the British Society for the Philosophy of Science in York, both in July 2024. We would in particular like to thank Sam Fletcher, Nick Huggett, Kerry McKenzie, Zee Perry, Jer Steeger and Karim Thébault.

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