On The Prospects of an Effective Metaphysics

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1 Introduction

Few books have generated as much discussion in philosophy over the last decade as Ladyman and Ross's *Every Thing Must Go* (2007). While a central purpose of the book was to defend ontic structural realism (OSR) – the doctrine that the structure is ontologically fundamental – two further themes were central to it. The first was that contemporary analytic metaphysics is in a sorry state – in large part, because it is conducted as though the world were still regarded as fundamentally classical in character and hence as though quantum mechanics had never happened.[1] The second was that non-fundamental *qua* 'effective ontology' ought to be embraced as ontologically robust and real. Unlike OSR itself, perhaps, these latter two themes enjoy a broad base of support within philosophy of physics generally. But given that classical physics is the paradigm of 'effective physics' it seems, to my mind at least, that we might regard them as in a state of some tension. For one might wonder whether many of the same metaphysical projects that were condemned for their pretense that the world is fundamentally classical could be recast as more modest but nevertheless worthwhile attempts to metaphysically interpret that portion of the world that *is* classical, effectively speaking. In analogy to effective physics – an approach to theorizing in which we regard the non-fundamental in non-fundamental terms,

[1]As they write, 'Metaphysicians surely know that contemporary physics is hugely more complicated and less intuitively comprehensible than either classical physics or toy worlds based on features of classical physics. Most, however, resist the obvious lesson that any attempt to learn about the deep structure of reality from thought experiments involving domesticated physics is forlorn. If it really doesn't matter that classical physics is false then we might as well do our metaphysical theorizing on the basis of Aristotelian or Cartesian physics' (Ladyman et al, 2007 p. 26). See also pages 19, 26, 44, 132, 155 and 172 for similar statements that suggest that it is an over-reliance on concepts associated with classical physics that is partly responsible for the irrelevancy of much current metaphysics. It may be worth noting that in a later work summarizing the themes of *Every Thing Must Go*, Ladyman largely drops the mention of reliance on classical physics as the problem with contemporary metaphysics, suggesting that the problem is the reliance on 'common sense and intuition' (Ladyman 2017). But since the earlier work also claims that 'the "common sense" of many contemporary philosophers is shaped and supplemented by ideas from classical physics' (Ladyman and Ross *op. cit.* p. 10), and talks of 'the familiar categories from classical physics that derive from the common-sense world of macroscopic objects' (ibid. p. 172), it isn't clear that this represents any disavowal of (what seems to be) the earlier view.

and thus not in those of fundamental physics – such a project would metaphysically interpret non-fundamental ontology conceived of in its own terms and thus independently of the more fundamental. Call it the project of 'effective metaphysics'.[2]

The question mediated upon in this paper concerns the prospects for an effective metaphysics. Let us say that 'effective metaphysics has prospects' iff (i) there are metaphysical truths about non-fundamental ontology out there to be discovered, and (ii) these facts can be accessed prior to the emergence of a more fundamental theory. If those conditions are fulfilled there are grounds for hope that, at least for many questions and projects, analytic metaphysicians may continue to view the world as approximately classical and still generate insight into the nature of reality without eliciting protests from metaphysicians of science. However if, like me, one *is* a metaphysician of science, then the question of the prospects for an effective metaphysics is a pressing one independently of whatever trends may happen to be afoot in the contemporary literature and whatever charges may have been leveled against our more armchair counterparts. For the question of the prospects for an effective metaphysics asks us whether we can hope to access metaphysical facts concerning the ontology of non-fundamental sciences prior to our acquaintance with a scientific theory that we can regard as truly fundamental; seeing as we do not yet take ourselves to possess a such a theory, *we are all effective metaphysicians*. Should effective metaphysics turn out to be a hopeless enterprise, the very legitimacy of metaphysics of science will be thrown into question until we have in our possession a truly fundamental scientific theory – an event which could be a very long time in coming, assuming it ever happens at all.

It is therefore clear that we metaphysicians of science – ontic structural realists as much as anyone else – need to think carefully about whether there are prospects for an effective metaphysics. Another thing that seems clear is that we are all, at some level, at least under the impression that there are, for as much seems implicit performatively in the very fact that we do what we do. Nevertheless, I will here argue that we should in fact be deeply sceptical about the value of engaging in metaphysics of science prior to the emergence of a fundamental theory: sceptical certainly about the idea that we can discover metaphysical facts about non-fundamental reality, and perhaps even as to whether there are any out there to be discovered at all. And while the argument, at this stage at least, remains rather schematic I hope at the very least to persuade metaphysicians that the success of effective physics does not unproblematically imply that its attendant metaphysics may be taken to be successful as well.

The structure will be as follows. In Section 2, I outline what is meant by an 'effective metaphysics' in a little more detail, introducing the analogous 'physics question' of whether there are prospects for an effective physics. In Section 3, I reconstruct how philosophers of physics take themselves to have shown that the physics question can be answered affirmatively. In Section 4, I discuss why the strategy taken to secure the prospects of effective physics will not

[2]So to be clear, there is both a methodological and an extensional component to effective metaphysics: it is about effective ontology, and is conducted independently of considerations of fundamental ontology. I note also that what I call 'effective metaphysics' seems to be similar, if not identical, with what Baptiste Le Bihan calls 'scale fragmentalism' about metaphysics (see Le Bihan 2020, p. 17). His assessment of the prospects of scale fragmentalism seem to be as pessimistic as mine, though for different reasons (see Le Bihan *op. cit.*, Section 7.)

in general succeed in securing those of effective metaphysics, and indeed may undermine that there are any strategies that do. In Section 5, I conclude.

A few points of clarification should be made before we embark on all that however. First, by ‘non-fundamental’ I mean to denote those portions of the world that are *determined* by what is more fundamental, in some suitably ontological sense; the fundamental, by contrast, is that which is not determined by anything (or at least anything distinct from itself). Depending on one’s philosophical predilections, this determination may be understood in purely modal terms, such as supervenience, or (more plausibly) a more demanding conception such as grounding.[3] For my purposes it doesn’t really matter which: all that will matter is that (1) we are happy that there is some meaning to be attached to talk of more and less fundamental reality, that (2) the classical is properly regarded as less fundamental than the quantum mechanical, and that (3) the non-fundamental must at least supervene on the more fundamental. All of that, I take it, is uncontroversial. Secondly, I have noted that we cannot claim at present to possess a truly fundamental framework for physics. But we do have a framework that has good claim to being more fundamental than any other that we have, namely *quantum field theory*. For ease of presentation, I am for the most part going to pretend that this is a truly fundamental framework. Nothing will hang on this fiction, for all that will matter for our purposes is how transitions between more and less fundamental levels work, not whether we know what the fundamental level is. And of course, when we remind ourselves that QFT is not fundamental, we remind ourselves that my sceptical conclusion applies equally to ourselves. Thirdly, I will discuss the non-fundamental in terms of that which is described in non-fundamental physics specifically. While there are of course other sciences that describe the non-fundamental, it is in physics that the notion of effective ontology is most familiar and arguably that in which inter-theory relations are the most codified; it is also the chief locus of the major metaphysical debates I will focus on here. A more circumspect title would therefore be ‘on the prospects for an effective metaphysics of physics’ in particular; but I will mostly drop this qualification throughout. (Of course, if the metaphysics of other sciences turns out to be unlike that of physics in respect of problems caused by theory change, and so immune from the challenges I mount here, then that would be a significant discovery.)

2 The Question of Effective Metaphysics

The question at hand is whether metaphysics pursued antecedent to the emergence of a fundamental theory has any hope of delivering metaphysical knowledge. Let us call this the ‘metaphysics question’.

> **The metaphysics question:** Is it possible for us to attain metaphysical knowledge of the non-fundamental, antecedent to the emergence of a theory of reality at its most fundamental?

[3] See however McKenzie (forthcoming a) for reasons to think that the relation of grounding, as standardly understood, does not relate the ‘’levels’ described in effective theories.

What we want to know is whether such theorizing is acceptable by the lights of the naturalistic metaphysician – that is, the metaphysician who takes science as their starting point and engages closely with science throughout the course of their theorizing. Again, the science we are focusing on here is physics. As such, a positive answer to the metaphysics question presupposes a positive answer to the corresponding 'physics question':

> **The physics question:** Is it possible for us to attain scientific knowledge of the non-fundamental, antecedent to the emergence of a theory of reality at its most fundamental?

We of course have two questions here only to the extent that metaphysics and physics may be distinguished from one another. While I will not here attempt the fool's errand of drawing a clean demarcation between the two, let us at least say this.[4] It seems that *scientific* knowledge consists, at least in part, of knowledge of (i) what *kinds* of objects exist, and hence of the determinate natural properties, fundamental or otherwise, that identify them; (ii) what *sort* of objects they are, in the sense of their being particles, fields, etc., and (iii) the *laws of nature* that those objects evolve in accordance with. By contrast, let us say that *metaphysical* knowledge consists of, well, knowledge of the answers to the questions that metaphysicians of science centrally concern themselves with.[5] As such, and among other things, metaphysical knowledge consists of knowledge of the answers to such questions as whether the properties identified in (i) above are *intrinsic or extrinsic*, *categorical or essentially dispositional*, or *particulars or universals*; of whether the entities referred to in (ii) are *individuals or non-individuals*, and *prior to or secondary to* the nexus of relations in which they stand; and of whether the laws identified in (iii) above are *fundamental or non-fundamental* elements of reality, and *necessary or contingent*. While I make no claim that those questions exhaust the questions that metaphysicians – even metaphysicians of science – ask, I take it that it is uncontroversial that these are questions that are apt to be characterized as 'metaphysical', and moreover regarded as of central import.

While different, each question concerns our knowledge of non-fundamental ontology, and here we understand the 'non-fundamental' as conceptualized in physics (naturalistic metaphysics being *about* physics after all). In metaphysics the term usually elicits thoughts of mereological composition, but although those entities (such as atoms and nuclei) that may, without too much violence, be regarded as 'mereological composites' will usually be considered non-fundamental by physicists, this is not a sufficiently general characterization of relative fundamentality for our purposes. The right starting point for thinking about ontological priority, as with all metaphysics of physics, is with physical theories and the relations in which they stand, using those relations as our guide to the relations between the ontologies that feature in

[4]The distinction here is close to what Anjan Chakravartty refers to as the distinction between 'small-m' and big-M' metaphysics (Chakravartty 2017). Stating in rather philosophically unvarnished terms what the referents of the terms of a scientific theory constitutes 'small-m metaphysics', and so in that sense merely being a scientific realist incurs small-m metaphysical commitments. By contrast, one trades in 'big-M' metaphysics when that scientific ontology is categorized and characterized in the sorts of overtly metaphysical terms exemplified above. While there may be a sliding scale between the two, it is that I am concerned with here.

[5]This is (obviously) not supposed to be an analysis: but no such analysis is needed here. All that is needed is that we can agree that these are paradigms of metaphysical questions.

them. In keeping with a perfectly standard characterization, we will say that a physical theory T_n is less fundamental than a physical theory T_f iff T_n may be derived, in some approximation, from T_f using bridge laws if necessary.[6] With a suitable liberal interpretation of 'theory', this will accommodate the 'building block' model beloved of metaphysicians, insofar as (for example) the hydrogen atom and its dynamics may be derived from the Schrödinger equation featuring an electron and proton in the circumstance that they form a bound state.[7] But it will also accommodate the relations between the grand *frameworks* of physics, such as classical and quantum mechanics, and non-relativistic and relativistic theories. These transitions are of particular interest to us, as these constitute some of the major 'paradigm shifts' – changes that are arguably regarded as revolutionary precisely because they incur shifts in our overall metaphysical *gestalt*. It is thus these that will serve as our focus here.

In an obvious notation, and in highly schematic fashion, we may represent the relation between classical mechanics, quantum mechanics, and quantum field theory as in Figure 1. Theories nearer the top of the pyramid are less fundamental because derivable, in some approximation, from those nearer the bottom. As such, they are applicable in more restricted set of circumstances, and provide less accurate descriptions, than the more fundamental. There is no implication here that the form of derivation – that is, the parameters varied, and in which way – will be the same in each case: indeed that is not so. Further, the hard boundaries between each theory are of course not to be taken seriously. Nevertheless, the values of the parameters concerned will pick out a physical regime in which the less fundamental theory may be, with little practical loss, applied.

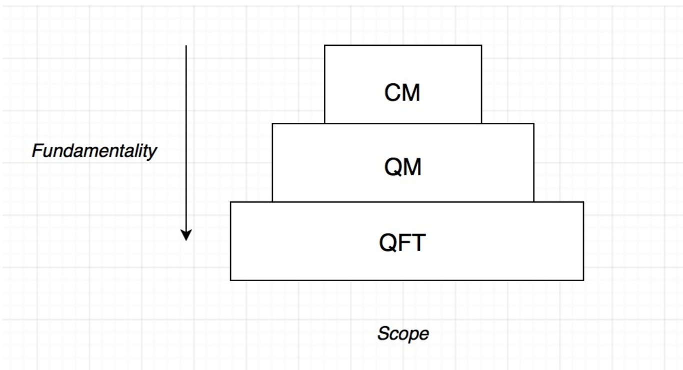

Figure 1: Schematic representation of more and less fundamental theories

That this description tracks the use of relative fundamentality talk in physics as applied to theories seems obvious and uncontroversial. But everything we have said so far about the

[6]This is the 'generalized Nagel-Schaffer' model defended in eg. Dizadji-Bahmani et al. 2010.

[7]And of course, the success here is taken to indicate that more complex atoms and molecules may similarly be built up in principle, even if the calculations exceed us: cf. Hoefer 2003.

non-fundamental concerns their conditions of application, and is neutral on whether these theories may be realistically interpreted. However, for an effective physics, and hence an effective metaphysics, to have prospects it is necessary that these non-fundamental theories furnish a description corresponding to something that is out there in the world. That this is so however is far from obvious. As we know from the attacks on 'convergent realism' marshaled by Laudan and others, developments in theory have a nasty habit of displacing the ontological commitments of previous theories, even if they continue to be useful or even indispensible tools for predicting experience. But at the core of the embrace of effective physics by philosophers of physics is the conviction that, in some crucial cases at least, less fundamental theories may indeed be said to describe, with considerable accuracy, the ontology of the domain in which the theory proved successful (a domain characterized by the values of appropriate parameters).[8] Undergirding this claim is the fact that the ontological description provided by the *successor* theory, in that domain, *closely approximates* the ontological description furnished by the previous theory. Next on the order of business, then is to see how this works in the transitions of interest schematically represented above by surveying some key moves made in these derivations. While the results are encouraging as regards the prospects of effective physics, I will go on to argue that there is no obvious inference from that fact to the existence of analogous prospects for an effective metaphysics.

3 The Prospects for an Effective Physics

As noted, a positive answer to the physics question requires some answer to Laudan's challenge and a restitution of convergent realism. Given the present context was prompted by Ladyman and Ross's accusation of the overtly classical character of much contemporary metaphysics, we have extra motivation to try to show, in particular, that 'classical and modern physics stood to one another in the manner in which the convergent realist... imagines they do'.[9] Our aim, then, is to place non-relativistic quantum mechanics and the classical theory of matter into a structure sufficiently nested for us to be able to say that some approximation of the ontology of the latter is recoverable from that which features in the former; following that, we will try to derive non-relativistic quantum mechanics, and by implication classical physics, from its relativistic extension, quantum field theory.[10] And while (needless to say) questions still remain as to many of the details, there are plenty of philosophers of physics who would claim that the 'bulk' of this work deriving classical from quantum ontology has already been done, thanks to the resources provided by *quantum decoherence theory*.[11] Since it has been

[8] The implications of this for structural realism, which has traditionally been sceptical about our knowledge of ontology, needs a fuller discussion than I can give it here.

[9] Laudan 1981, p. 42.

[10] Recall that we are pretending for now that this is a truly fundamental theory.

[11] This claim will be met by the objection that the derivation is overly formalistic, since we cannot even talk about the ontology of quantum theory until a 'primitive ontology' has been specified. The approach taken here assumes the truth of Rosaler's claim that 'the bulk of technical analysis needed to recover classical behavior from quantum theory is largely independent of the precise features of the collapse mechanism and ontology of the quantum state. The analysis [...] demonstrates that concerns about wave function collapse and

expanded in detail in numerous places elsewhere, here I will only give the broadest outlines of how the story goes.[12]

The task is to recover classical ontology from the underlying ontology of non-relativistic quantum mechanics – namely, that of *wavefunctions* evolving in accordance with the *Schrödinger equation*. The recovery of approximately classical ontology – of 'effectively classical systems' – is taken to require the recovery of entities satisfying the following kinematical and dynamical criteria:

- **Kinematical requirements:**
  - The system possesses determinate or approximately determinate values for both position and momentum, and moreover does so simultaneously.
  - The state of a system exhibiting classical behaviour should be determined by the states of its individual subsystems.
- **Dynamical requirements:**
  - The trajectories of the system must approximate the solutions to classical equations of motion.

The basic challenge facing the convergent realist is that the ontology of quantum physics seems to be absolutely nothing like this. For one thing, the quantum systems generically exist in superpositions of states – superpositions of (e.g.) position states that prevent us from attributing to them any one determinate position. Such states, given the unitary nature of the Schrödinger equation, will moreover be completely generic. The fact that the states of complex systems likewise superpose also means (it can be shown) that the states of complex systems are not in general determined by the states of their subsystems. Further, the complementarity embedded in quantum theory means that systems cannot have precise positions and momenta simultaneously, making the attribution of a trajectory to quantum systems seemingly impossible. And if quantum systems do not even have trajectories, it seems the question of how they can be said to have *classical* trajectories becomes moot. To that extent, Laudan is absolutely right to suggest that wavefunctions are in no sense 'approximations' to classical ontology.

However, and despite the sheer scale of these challenges, philosophers of physics believe they can be met. And they are met not simply by staring at the properties of wavefunctions in the abstract, but by thinking about the phenomena that emerge over time from wavefunctions interacting in realistic situations. It is the concept of *environmentally induced decoherence* that is thought to provide the key.

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ontology can be addressed as a coda – albeit a necessary one – to the account of classical behavior suggested by decoherence theory, so that one need not start anew in the recovery of classical behavior with each new interpretation of quantum theory that is considered' (Rosaler 2016, 55). Those who dispute that will at least I hope agree that however classical-like physics is derived from more fundamental physics, the derivation will involve the taking of limits, and whatever is derived will only be an approximation to classical physics strictly speaking. That is all my argument requires.

[12] For much more detail, see Rosaler 2016; Wallace 2010; Wallace 2012.

To see this, begin with a paradigmatic QM phenomenon: the double slit experiment. Here we start with a particle incident upon a barrier with two apertures. As it goes through the barrier, its state is described by

$$|\Psi(x)\rangle = \frac{1}{\sqrt{2}}(|\psi_l(x)\rangle + |\psi_r(x)\rangle)$$

with $|\psi_l(x)\rangle$ that component that has gone through the left slit and $|\psi_l(x)\rangle$ that which has traversed the right. Famously, what we obtain is an interference pattern on the screen recording the final position of the particle. The probability density $\rho(x)$ corresponding to detections made in the plane of the screen is given by

$$\rho(x) = |\langle\Psi(x)|\Psi(x)\rangle|^2 = \frac{1}{2}|\psi_l(x)|^2 + \frac{1}{2}|\psi_r(x)|^2 + Re\{\psi_l(x)\psi_r(x)^*\}. \tag{1}$$

Since the probability density corresponding to a set-up in which particles determinately go through one slit or the other is given by

$$\rho(x) = |\langle\Psi(x)|\Psi(x)\rangle|^2 = \frac{1}{2}|\psi_l(x)|^2 + \frac{1}{2}|\psi_r(x)|^2, \tag{2}$$

it is the presence of the 'interference term' $Re\{\psi_l(x)\psi_r(x)^*\}$ that obstructs an 'ignorance interpretation' of a particle with a determinate if unknown position. This term encodes the extent of the *coherence* characteristic of quantum systems that prevents them from being straightforwardly viewed as an ensemble of classical states.

However, now consider that we never encounter particles in a vacuum: we only ever encounter them in an *environment*, whether that be the Earth's atmosphere or the cosmic microwave background. Since we are taking non-relativistic quantum mechanics to be the true description of matter (we will think about how it stands to QFT momentarily), it should be the case that this environment itself can be modeled quantum mechanically. So let us build that in as follows:

$$|\Psi(x)\rangle|E_0\rangle = \frac{1}{\sqrt{2}}(|\psi_l(x)\rangle + |\psi_r(x)\rangle|E_0\rangle)$$

Running this through the Schrödinger equation, this quickly becomes

$$|\Psi(x)\rangle|E_0\rangle \to \frac{1}{\sqrt{2}}(|\psi_l(x)\rangle|E_l\rangle + |\psi_r(x)\rangle|E_r\rangle) \tag{3}$$

The state of the particle, considered now as a subsystem of the particle-environment composite, is obtained by 'tracing out' the environmental degrees of freedom $|E_l\rangle$ and $|E_r\rangle$ to obtain its density operator. It may easily be shown that this operator has interference terms proportional to $\langle E_l|E_r\rangle$, which measure the coherence between its position states. But what one can show is that, if either (a) the interaction between the environment is strong, or (b) there are sufficiently many weak interactions, then $\langle E_l|E_r\rangle$ will *very quickly* tend to *very close to zero*. Moreover, those conditions on the strength of interactions are satisfied by all realistic situations, so that we can generically expect $\langle E_l | E_r \rangle \approx 0$ in very short order. Indeed, it is by now well known that, in realistic situations, coherence is in practice lost *extremely* quickly – in general much more quickly that other relevant timescales for the system.[13] For example, Schrödinger's cat will persist in a coherent superposition for a mere 10^{-35} seconds before the coherence of its state is lost. Even a dust particle of a micron diameter will be decohered by sunlight in a vanishingly short amount of time.[14] As such, as a result of its surrounding environment, the interference terms that prevent us from interpreting the particle as possessing a determinate state very quickly all but disappear. Rather, we have a situation which we can interpret, *formally* at least, as an ensemble of classical states, or one in which the particle is in some one determinate state and yet we do not know which.[15]

We can already see, then, that there is a sense in which decoherence recovers a world bearing at least a formal resemblance to the classical world. But there is much more yet to be had. First of all, one can show that the states of the particle that result from decoherence are *approximately sharply peaked in both position and momentum*.[16] Moreover, one can show that if one does have an approximately sharply-peaked state – that is, if its spatial spread is small in comparison with the length scales characteristic of the interaction the particle is participating in – then the trajectory in phase space traced out by each state is 'overwhelmingly likely' to be *approximately Newtonian*: that is, Newton's second law of motion is very likely to be satisfied to a high degree of approximation.[17] The degree of deviation from the Newtonian trajectory will vary as the spread of the state; the continued impact of the environment, however, will be to keep it tightly peaked, and the fit with classical predictions extremely close.

In sum, then, what we have deduced is the existence of systems that approximate classical systems in that they (1) have only a small spread in their position and momentum coordinates, (2) evolve approximately classically, and (3) are separable in the sense that the worlds that they evolve in are specified by a product of the particle and environment states. As Wallace puts it,

> [I]f we.. look at the concrete models (mathematical models and computer simulations) to which decoherence has been applied, and if, in those models, we make the sort of system/environment split that fits our natural notion of environment (so that we take the environment, as suggested previously, to be – say – the microwave background radiation, or the residual degrees of freedom of a fluid once its bulk degrees of freedom have been factored out), then we find two things. First: The basis picked out by decoherence is approximately a coherent state basis: that is,

[13] Such as, for example, the 'relaxation' timescale in which the system comes into thermal equilibrium with its surroundings.

[14] See Wallace 2012, pp. 80-81.

[15] Whether one takes the first route, and hence the many-world interpretation, or another interpretation that consistent with the second, depends on considerations orthogonal to those here. But as Rosaler argues, what interpretation one takes is something that comes *after* the decoherence analysis.

[16] Rosaler op cit. p. 62.

[17] Rosaler op cit, 60.

> it is a basis of wavepackets approximately localized in both position and momentum. And second: The dynamics is quasiclassical not just in [a] rather abstract, bloodless sense... but in the sense that the behaviour of those wavepackets approximates the behaviour predicted by classical mechanics... Structurally speaking, the dynamical behaviour of each wavepacket is the same as the behaviour of a macroscopic classical system. (Wallace 2010, pp. 62-3.).

In that sense, then, we may claim to have genuinely recovered an *approximation of classical ontology* from the wavefunctions of non-relativistic quantum mechanics. And all this has been deduced by appeal to highly (though not wholly) generic but also realistic models of the underlying quantum dynamics.[18] As such, while there is no such thing as a once-and-for-all reduction of 'classical mechanics' to 'quantum mechanics', we may claim to have shown that there exists an *ontological reduction of paradigmatic classical systems to highly generic quantum systems*.

The above showed that we can take classical ontology to exist on the assumption that wavefunctions do. For these reasons, we may claim that that 'convergent realism' is justified with respect to the transition between classical and quantum mechanics, and that Laudan's charge has been rebutted with respect to this transition at least. And since classical mechanics was obviously developed long in advance of any knowledge of quantum theory, it seems that the *physics question* has been answered in the affirmative with respect to classical ontology: it *is* the case that we managed to say true things about classical ontology in advance of a more fundamental theory, so long as we permit the bit of latitude inherent in the notion of *approximate* truth. However, we are moving too fast here, for that claim only works if quantum mechanics itself and its associated ontology can be regarded as in good standing. However, as noted, non-relativistic quantum theory is not the most fundamental theory – not even the most fundamental that we have managed to produce to date, for that mantle belongs to *quantum field theory*. As such, we should think about how wavefunctions fare from the point of view of that.

The first thing to say is that quantum fields are not quantum wavefunctions: for one thing, quantum fields permit states with indeterminate numbers of particles. As such, work needs to be done in deriving wavefunctions from fields. While I will go into even less detail here, suffice to say that work by Myrvold (2015) has shown in detail how to derive wavefunctions – quantum states of fixed and definite particle number satisfying the Schrödinger equation – from quantum fields in the non-relativistic approximation. This is the approximation in which the relativity of simultaneity may be regarded as negligible, which will be the case if 'we are not dealing with processes that are spread out too far in space [...], and the temporal resolution with which we are concerned is not too small'.[19] If those conditions are satisfied, the dynamics of quantum fields may be approximated by the Schrödinger equation, and states with a well-defined numbers of quanta emerge as a 'reasonable approximation'. As such, entities whose properties approximate the properties of *wavefunctions* emerge, and thus the same sort of story

[18] Chaotic systems, for example, bring with them issues that need separate treatment, although decoherence has been argued to resolve long-standing problems involved in the reduction of classically chaotic systems (see Rosaler op cit. Section 6.3 for references).

[19] Myrvold op cit. p. 3263.

repeats itself for this transition.

For these reasons, in what follows I will take it that classical ontology is derivable from the fundamental theory through two successive limiting procedures:

$$\textbf{QFT} \longrightarrow \textbf{QM} \longrightarrow \textbf{CM}.$$

Although the procedures involved differ, in each case we 'see' non-fundamental ontology emerge from more fundamental ontology by *limiting our measurements* to a *certain finite resolution* – by *not looking too closely* at the ontology of the more fundamental theory. Thus we can find entities with the properties of the wavefunctions described in non-relativistic quantum theory by making measurements of relativistic fields, so long as we refrain from measuring the latter with clocks that are too accurate. From these we may in turn find entities with the properties of classical ontology, so long as we don't study the behaviour of the system under too short a timescale, and don't go out of our way to pick up the tiny interference effects that remain present after decoherence. In this sense, we move from more to less fundamental ontology by looking at it through 'blurry glasses'.[20] And while *more* may be involved than that, all that is required for present purposes that some kind of limiting of the resolution on the devices we use to measure is essentially involved in extracing less from more fundamental ontology – something that is certainly the case in the two pivotal transitions discussed here.[21]

On account of this recovery of classical ontology from what is *prima facie* radically unlike it, we may say, from the perspective of the most fundamental theory that we have, that 'the objects of which classical physics speaks are real, even if they aren't exactly as imagined in classical physics'.[22] In this sense, we may say that convergence has been sustained with respect to the ontology of the central physics theories. This gives us every reason to hope that the pattern will continue right down to a truly fundamental theory. If that is right, the claims we have made so far will not be contradicted by those of a more fundamental theory, and we will be able to state that the answer to the physics question is *yes*. Crucially, what makes a positive answer possible in this case is the fact that from the ontology of the more fundamental theory we are able to deduce, in an appropriate limit, *approximations* to that of the less fundamental theory.

[20]While this is a metaphor often used in the context of effective quantum field theories (see for example Zee 2003, p. 361), it can't be taken too literally here. For one thing, the temporal resolution permitted in the QM-CM transition may be even finer than in the QFT-QM case. For another, recovering QM from QFT requires that we not look at processes spread out too *far* in space, rather than too confined.

[21]If one is sceptical about the idea that e.g. classical ontology can be genuinely be recovered from more fundamental theories, the ensuing argument can be read as a conditional: *even if* we could have an effective physics in this sense, it's still unclear that we could have an effective metaphysics.

[22]According to Wallace's Dennettian criterion for non-fundamental ontology, these probably come to the same thing. But we needn't take a stand on this here.

4 The Prospects for an Effective Metaphysics

With the physics question behind us, let us now turn to our central concern – namely, the metaphysics question:

> **The metaphysics question:** Is it possible for us to attain metaphysical knowledge of the non-fundamental, antecedent to the emergence of a theory of reality at its most fundamental?

Given that we already engage in metaphysics although still absent a final theory, we will surely want to assure ourselves that the metaphysics question can be answered with a 'yes'. Now, recall also that the sort of metaphysics we are primarily concerned with here is metaphysics of science: metaphysics that *interprets* the deliverances of science in some way. And it was said above that what metaphysicians typically do is take the objects, properties, and laws discovered by science and argue as to how they ought to be categorized with respect to some schema of metaphysical categories deemed appropriate to them – that is, it asked whether they should be categorized as *individuals or non-individuals*, *intrinsic or extrinsic*, *abstract or concrete*, *contingent or necessary*, and so on. In that sense metaphysics, whether fundamental or non-fundamental, is *about* the relevant portion of physics. And as noted, if effective metaphysics is to have prospects then there had better be metaphysical facts located at non-fundamental levels for these interpretations to be right or wrong about; moreover, they had better be accessible prior to the discovery of a fundamental theory. Thus at some sufficiently course level of abstraction, the picture of the relation between fundamental and non-fundamental physical facts, that between the metaphysical facts that correspond to each level of physical facts, and that between the physical and metaphysical facts is something like that depicted here:

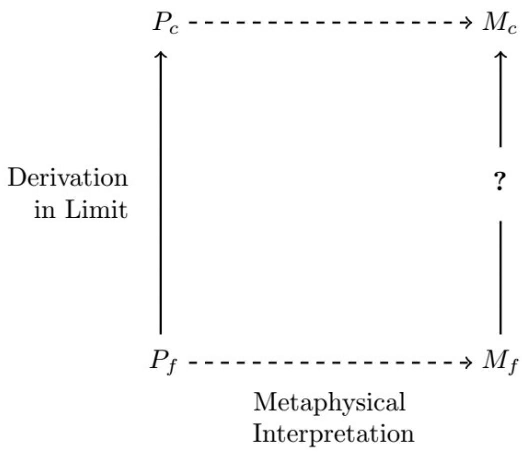

Figure 2: Relations between fundamental and non-fundamental physical facts, and metaphysical and physical facts; relation between metaphysical facts left unspecified.

with M_f signifying the metaphysical facts at the most fundamental level, M_c the metaphysical facts at a non-fundamental level, such as in particular the *classical* level, and P_f and P_c the corresponding physical facts. As we have seen, the facts at P_c include that there exists approximately classical ontology in the sense alluded to in Section 3. Recall that the limiting relation that takes us from the fundamental to non-fundamental physical domains crucially involves limiting the resolution at which the latter is measured: we 'see' the non-fundamental only when we agree to put on 'blurry glasses'. The inclusion of the 'unspecified' relation between M_f and M_c invites us to consider what if any relation the two presumed sets of metaphysical facts bear to one another; this will be a focus below.

What the metaphysics question asks us is whether we have any hope of identifying these metaphysical facts about non-fundamental physical ontology in advance of a final theory – that is, whether we have a hope of identifying the correct *metaphysics of non-fundamental physics* on the basis of the non-fundamental physics that we have identified while still on the path to a 'theory of everything'. Now to be sure, many believe that metaphysical questions are by their very nature incapable of being settled, so that while there may be metaphysical facts out there we will never be in a position to identify them. For example, it is widely held that metaphysics is in principle 'underdetermined' by the relevant physics, so that knowing the latter cannot identify the relevant metaphysical facts: indeed, French's approach to OSR has historically placed this consideration front and centre.[23] Furthermore, the epistemic standing of the supra-empirical features frequently cited by metaphysicians as guides to theory choice (explanatory power and so forth) are (and quite rightly) regarded as controversial. While some of this will be relevant to the ensuing, note that these criticisms are taken to be completely general and as such directed to all metaphysical knowledge whatsoever. The argument here, by contrast, directs itself to non-fundamental metaphysical facts in particular, and as such presents a challenge even to those who believe (as I take it metaphysicians must) that the above challenges can be dealt with. To get a better purchase on the nature of the problem, it will be useful to illustrate what is going on by looking at a concrete example. Since [some identifying information removed], I will here focus on the case of the metaphysics of modality.This is appropriate in a discussion of structuralist metaphysics not only since it is pertinent to scientific realism more generally, but also because leading structuralists have often characterized the kind of structure they are concerned with as inherently 'modal'.[24] With the structure of that debate clearly in sight, we will be better positioned to think about whether we there is any hope to doing metaphysics in advance of a final theory.

[23] See e.g. French and Krause 2006, 189-97.

[24] See e.g. French 2014, 123; Ladyman and Ross op cit., 123.

5 A concrete example: the metaphysics of laws, properties, and modality

Let's begin by considering what I have elsewhere (and artlessly) called the 'canonical' debate over laws, properties and modality.[25] This is a debate primarily between three main camps: a Humean camp, an anti-Humean camp, and a position sometimes known as 'semi-Humean'. These are, respectively, the positions associated with the

- 'Best system' analysis, associated with Lewis, Ramsey, and Mill; the
- 'Dispositional Essentialist' analysis: Bird, Chakravartty, Ellis and others; and the
- 'Contingent Necessitation' (or 'governing' conception, or 'DTA' analysis), created by Dretske, Tooley, and Armstrong.

These are, I take it, the canonical positions in the debates over laws of nature.

These canonical positions differ over three things: (1) the *modal* aspect of the properties defining natural kinds, and the interpretation of laws with respect to (2) their *ontological priority* relative to kinds and (3) their associated *modality*. With regard to (1), they differ over whether natural properties are *categorical* or *essentially dispositional*. While 'categorical' is a rather difficult concept to define, let us here settle for a standard characterization of categorical property as one with 'no essential or other non-trivial modal character'.[26] Essentially dispositional properties, by contrast, involve modal operators in their definition and are thus a species of non-categorical properties. With regard to (2), the positions differ over whether laws are to be regarded as secondary to, and hence (at the least) *supervenient* upon, the properties instantiated in worlds in which the laws operate, or whether they too are fundamental ingredients of reality.[27] With regard to (3), the positions differ over whether the laws are necessary or contingent, disputed in terms of whether the kinds that exist in a world could accord in other worlds with laws that differ from those that they actually accord with. The various positions with respect to these questions may be summarized as follows.

> **Humeanism**: laws *supervene* on a basis of *intrinsic categorical properties*; as such, laws describing a given set of kinds are *ontologically secondary* and *modally contingent*; there is no *primitive modality* in the picture.
>
> **Dispositional essentialism**: laws *supervene* on a basis of *intrinsic* and *essentially dispositional* properties, standardly defined in terms of a necessary and subjunctive relationship between stimulus and manifestation conditions; as such, laws describing a given set of kinds are *ontologically secondary* and *modally necessary*; there is *primitive modality* in the picture, specifically in the definition of properties themselves.

[25] McKenzie 2014.

[26] Bird 2007, 67.

[27] While they agree *that* laws supervene, the dispositional essentialist view and the Humean will differ over *what* they supervene on: for the former all that one needs in order to know the laws is what the kind properties are, whereas for the latter one must also know their distribution in spacetime.

DTA theory: laws involve primitive relations of 'contingent necessitation' between *categorical properties*: as such, laws are *ontologically fundamental*, in the sense that they do not supervene upon the properties related in the laws, and *modally contingent*; there is *primitive modality* in the picture, this time in the laws themselves and the primitive necessitation relation involved.[28]

We may summarize these positions as follows:

	Humean BSA	Disp. Ess.	DTA
Laws Necessary	✗	✓	✗
Laws Secondary	✓	✓	✗
Primitive Modality	✗	✓	✓

As I have argued elsewhere, this 'canonical debate' is by and large conducted over classical laws, such as Coulomb's law, and as such is by and large a debate about *non-fundamental* metaphysics.[29] Furthermore, it is almost exclusively conducted without input from more fundamental physics, making it an example of *effective* metaphysics. And while one could certainly complain that many of the protagonists in this debate are guilty of false advertising – since they often explicitly claim it is a debate over fundamental laws and then use classical electrostatics or gravitation as their examples – what we want to consider is whether this debate could be more modestly reconceptualized as a debate over non-fundamental metaphysics. If this debate has any hope of arriving at the truth of whether laws are contingent or necessary, of whether the properties involved categorical or essentially dispositional, and so on, then there will be reason to think that the metaphysics question may be answered in the affirmative. Again, the issue is not whether familiar epistemological problems of metaphysics relating to underdetermination may be gotten around. The question is how non-fundamental metaphysics such as this fares given that there is a more fundamental metaphysics underlying it: can the non-metaphysical facts – in this case, modal facts pertaining to the classical domain – by identified without presupposing knowledge of the more fundamental physics?

What is clear is that for that to be the case, there must of course *be* some such facts, and since the canonical positions above each contradict one another at most one of them can be true. Let the metaphysical facts that hold at the classical level, with respect to the above questions, be denoted M_c. Let us furthermore suppose that the three positions above exhaust the possible combinations that are motivated by classical physics considered independently of more fundamental theory. (Certainly, if there is another position, it is not one that seems to have struck very many philosophers as being as compelling as these three.)[30] The question we are asking is whether there is any hope of us determining M_c in advance of a fundamental

[28]Handfield (2005), 258 calls the nomic necessitation relation as an 'über-disposition'.

[29]See McKenzie 2016.

[30]I am not sure, but I think Maudlin's 'primitivist' interpretation (Maudlin 2007) would check the same boxes above as the DTA theory. But in any case, the assumption just made is not strictly required: all that is required is that the facts at this level with respect to these questions are sufficiently distinct from those at lower levels as to not reasonably be regarded as 'approximations' of one another – something that I will argue below seems right.

theory, which, given our assumptions, is at the very least to ask whether M_c is expressed by any of the positions above. So let us consider how those facts look, given the perspective of more fundamental metaphysics – namely, the metaphysics of quantum field theory (QFT).

What, then, is that metaphysics? In the same paper alluded to above, I argued that the modal metaphysics that seems most suitable in QFT's most fundamental regimes differs radically from all of those outlined above. In particular, I argued for a kind of *Humean necessitarianism* that has no analogue in any of the above views. For one thing, the fundamental laws of QFT should plausibly be regarded as *fundamental constituents of reality*, or at least, as more fundamental than objects – the reason being that even 'fundamental particles' can decay, meaning that we do not have a good purchase on what makes an object fundamental independently of its featuring in fundamental laws. The latter, by contrast, may be independently defined, in terms of their behaviour in the infinite-energy limit (the range appropriate to fundamental laws in QFT).[31] Secondly, the laws ought to be regarded as *necessary*, at least in the sense that it isn't possible for the laws pertaining to a given set of fundamental particles to differ structurally from those they accord with in the actual world.[32] However – and most significantly – this necessity may be seen as compatible with Humean strictures, insofar as what is doing the work in arguing for their necessity is mere *consistency* constraints on a theory if it is to be valid in the infinite-energy limit. To cut a long story short, finding an equation that is consistent both with the principles of relativity and of quantum mechanics *and* that gives well-defined empirical predictions in a limit as demanding as that is an extremely big ask mathematically, and there is reason to think that for any one set of particles there is only one way to do it. As such, what is driving the claim that laws are necessary is mere logico-mathematical necessity, given the assumption that the entities involved are quantum fields.[33] But since such necessities are traditionally regarded as kosher for Humeans, there is arguably no problematic *primitive* modality in the picture here.

Let the position on fundamental laws in QFT just argued for be $fQFT$. Now to be sure, the metaphysics of QFT in general remains underdeveloped at present, and I am neither so naïve nor so sociopathic as to claim that the position that I happen to have argued for is the only sane position on the menu. But all that will matter for my purposes is that it is at least *plausible* that the true metaphysics of laws and properties in fundamental regimes – ie that which expresses M_f – may be very different to that we find in classical regimes. And given how radically metaphysical views regarding locality, determinism, etc have had to change since even non-relativistic quantum theory came along, that should not be a big pill to swallow: much of

[31] Something like this position may be found in Heisenberg (see e.g. 1957).

[32] This will be a qualified form of necessitarianism if the coupling constants featuring in the laws are allowed to vary. But in fact the renormalization group will constrain the value of these constants at any particular scale; I cannot discuss this further here however.

[33] Does that assumption beg the question, assuming that quantum fields are entities that accord with the basic postulates of QFT? I don't think so – or not unless every form of Humeanism does similarly. For every system of metaphysics, including Lewisian metaphysics, sets out assuming a schema of categories of some sort at least together with certain *a priori* rules on how they behave (see e.g. MacBride 2001). In that sense, there is no fully reductive theory of modality. But the Humean may nevertheless hope to reduce, and so render true, the claim that the laws are necessary from more primitive assumptions, and that is precisely what happens here.

the motivation for naturalistic metaphysics after all stems from the fact that metaphysics can change radically as science does. As such, whether the position to be outlined below turns out to be the right one or not – or more perspicuously, *would* be right if QFT were a fundamental theory – turns out not to be so critical; all that matters is that M_f could well be very different from M_c, in something like the way that $fQFT$ differs. But that at least seems very plausible.[34] Let then $fQFT$ serve as our model of a plausible fundamental metaphysics, and explicitly contrast it to the canonical positions as follows:

	Humean BSA	Disp. Ess	DTA	fQFT
Laws Necessary	✗	✓	✗	✓
Laws Secondary	✓	✓	✗	✗
Primitive Modality	✗	✓	✓	✗

Clearly, the modal landscape looks very different at the fundamental than at classical levels: with respect to the metaphysical issues we have chosen to focus on, each of the classical positions agrees in only one place with the $fQFT$ view. As such, it seems none of the classical positions can in any sense be said to be 'approximations' to it. With this case study behind us, then, how does the canonical debate over classical laws inform us with regards to the prospects for an effective metaphysics? Supposing (as we are for argument's sake) that $fQFT$ expresses the fundamental metaphysical facts M_f, are we to do something analogous to Laudan and say that, since the metaphysical positions arrived at in the case of classical ontology are so profoundly different from that of the successor ontology, they cannot be regarded as approximately true and hence are ruled out as objects of realist belief?

At this point, the response I at least reflexively want to give is: *of course not!* And the reason is that, so far at least, we have no grounds to infer that $fQFT$ is actually in conflict with whichever of the canonical position expresses M_c. The reason, of course, is that each metaphysics applies *to different levels* of the world than the other: M_c describing the classical level, $fQFT$ the fundamental. As such, there is no more contradiction here than in saying, for example, that the building is cold on the ground floor and warm on the top. Properties that are incompatible with each other can of course be simultaneously true *of different things*.

However, for all that that seems to be a natural resolution to the problem, I don't think we should move so fast here. To see the issue, suppose that someone confronted with Laudan's historical challenge had made essentially the same move in the face of it. That is, suppose that they responded by saying something like the following: 'Classical and quantum ontologies both exist, but they exist at different *levels* – the classical at less fundamental levels and the quantum at more. Hence there is no more contradiction in taking both classical and quantum objects to populate the world than there is in saying that a road is straight at one point and bent at another'. Now of course, the convergent realist does make precisely this claim, but we take it that they had to *argue* for it. In particular, we take it that it had to be *shown* that approximately classical ontology exists *by the lights of our best theories* if they were to make such a claim.

[34] Points supportive of this will follow below.

In the case of physics, then, one cannot simply say that radically different facts are true at different 'levels': one has to *show* that the non-fundamental facts are determined by the (vastly different) fundamental ones, such that they approximately match at the relevant boundaries. But given that we are concerned with metaphysics, what are the implications of these observations about the levels structure in physics for the issue at hand? It seems that there are two ways to go. Either we require that metaphysical facts stand in relations of determination in a manner at least analogous to what we require of physical facts, or we do not require any such thing. *That* much at least is clear. But I will argue first that if the metaphysical facts obtaining at non-fundamental levels are distinct from those that lie beneath, then they are not determined by them. This means that if there are metaphysical facts at that level then they themselves qualify as 'fundamental'. A corollary will be that whatever metaphysical facts there are at non-fundamental levels cannot be accessed prior to a truly fundamental theory.

To see how all this works, let us start by supposing that metaphysical facts stand in relations of determination analogous to those in which physical facts do. Thus remembering that we are taking the relations between more and less fundamental facts to be relations of determination at least as strong as supervenience, we begin by supposing that M_c supervenes on M_f. For this to be the case, we require that given that the fundamental metaphysical facts M_f are as they are then the metaphysical facts at the classical level could not be other than M_c. What else can we say about this relation between the two sets of facts? Recall that M_c and M_f are both facts *about* certain physical ontologies – classical and quantum field theoretic respectively. As such, whatever relation takes us between M_f and M_c must somewhow *involve*, must somehow *be a function of*, the relation between P_f to P_c. For if that is not the case, then how do we get from M_f to M_c and not the metaphysical facts concerning some *other* domain of physics (say that of non-relativistic quantum mechanics)? While it seems clear that we can at least say that, it has as a consequence that the relation between M_f to M_c cannot be *identical* with the relation between P_f and P_c: that is, it cannot be that some *approximation* to M_c may be *derived* from M_f in the *limit of low resolution*.

To see this, consider what we did when we advanced our metaphysical interpretation of QFT. We took things that we find in physics – fundamental laws and properties – and then argued that they should be filtered into certain metaphysical categories. But categories are not like laws and physical properties – at least not like properties in physics, which of course admit of *magnitudes*. One consequence of this is that, while we can talk of laws and properties *approximating* other laws and properties, we cannot likewise speak of the metaphysical categories they are filtered into doing so. For example, suppose we say (contra structuralists) that the property of being 5g is an intrinsic property. Then while we might be entitled to say (in a given context) that *being 5g* approximates *being 5.05g*, we cannot similarly say that the second order property of *being intrinsic* 'approximates' anything else. After all, the only property that being intrinsic is contrasted with is is that of being *extrinsic*, and it seems that there is no middle ground in between.[35] After all, what would it mean to say that a property was just a *little* extrinsic? Would its possession require only the existence of a distinct but somehow insignificant object, or that the object concerned was at a barely perceptible distance away?

[35] See McKenzie 2020.

But saying that is just to say that it is extrinsic *simpliciter*: its possession requires the existence of something distinct from itself. Things are similar with *being categorical*. There is no sense to saying that a property needs *just a dash* of primitive modality in order to define it: if recourse to modal concepts must be made in any aspect of its definition then the property is not categorical, *period*. But just as with intrinsic and extrinsic properties, categorical and essentially dispositional properties are standardly defined dichotomously. Bird, for example -– surely one of the most subtle of thinkers on the topic of dispositional essentialism — takes it that 'to say that a property is categorical is to deny that it is essentially dispositional', and similarly Mumford uses 'categorical' and 'non-dispositional' interchangeably.[36] Things are similar again with the issue of *being ontologically secondary*. If what laws are is not something that can be analyzed, exhaustively and without remainder, in terms of entities whose definitions do not themselves refer to laws, then laws are not ontologically secondary to those entities, and if they can, then they are. Again, there doesn't seem to be any room for a middle ground here. And finally, with the standard definition of 'necessary' being 'true at all possible worlds', and 'contingent' as 'true in some but not all possible worlds', it seems that the same holds true for these categories, so crucial to modal metaphysics, also. For this reason, we might say that *metaphysical categories are 'clunky'*: one simply belongs in the category, or doesn't belong, and there is no middle ground in between. Thus we cannot sensibly talk of one metaphysical picture 'approximating' another: they are simply different or the same in certain respects. The central implication in this context of this receptivity to quantification further is that we cannot talk about a metaphysical theory being 'derived' from another in the sorts of limits that are relevant here. For as we have seen, these limits crucially involve placing restrictions on the subtlety of the phenomena we are interested in and hence decreasing the sensitivity of the measurements we require: we obtain classical processes from quantum processes if, for example, we pay no attention to processes that take too short a period of time. But there is no sense in placing metaphysical theories into this sort of relation. Partly this is of course because we do not measure them at all, and so limits on the accuracy we demand of our measurements is not something that applies in this context. But even if (in some sense) we did measure metaphysical phenomena, there would be no sense to saying that we only measure them up to a certain level of 'grain' on account of their clunky character.

In sum, M_f and M_c are not the sort of things that can stand in the relation that P_f and P_c stand in. As such, the relation between them cannot be as it is in Fig 3. In fact, since the limiting relation is so inapplicable to metaphysical facts themselves, it seems that whatever relation there is between M_f and M_c, it must proceed in *separate steps*. For we know that the limiting relation between P_f and P_c must be involved; and yet we know that that relation cannot itself relate metaphysical facts. Hence, it seems, the relation between M_f and M_c must somehow be analyzable as a *conjunction* of relations, one of which relates their physical subject matters. As such, the relation between M_f and M_c must be rather more indirect than it looks in Fig 3, and in fact must look something like it does in Fig 4.

[36]Bird 2007, 66-67; Mumford 2006, 477.

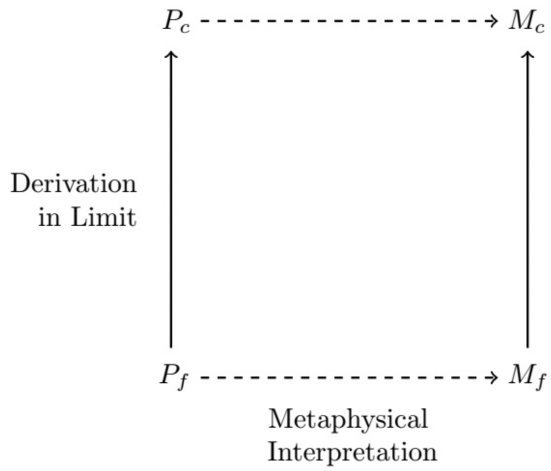

Figure 3: M_f and M_c directly related by limiting relations

In this picture, M_f determines M_c in a way 'mediated' by the relation from P_f to P_c. We start with M_f, 'zoom out' from its physical subject matter until we reach P_c, and from there M_c is determined. Given the clunkyness of the categories involved, it seems there is no other way for this determination to succeed.

However, there are several reasons to think that there can be no such determination of M_c by M_f via this route *if M_c is a metaphysics accessible to us prior to the emergence of a fundamental theory*. One obvious worry stems from the *underdetermination of metaphysics by physics*: for if that obtains, it is clear that a relation with this structure cannot be a relation of metaphysical determination at all. For if P_c does not determine M_c – which, we have already noted, it standardly assumed to be the case – then nor does M_f by this route.[37] In that case then, while we know that limiting relations between P_f to P_c must be involved in the relations between M_f to M_c, we cannot see any way for the determination to work. Suppose for now, however, that we simply choose to ignore this worry: we have already noted above that this is an old objection to the purposiveness of metaphysics in general, and my intention here is to mount a new one.[38] The problem now is that even in the absence of metaphysical underdetermination, the metaphysics that will be determined through this route is *not the metaphysics of classical physics*. The reason is that the physics P_c that is determined, in the limiting relation, by P_f is strictly speaking *at best an approximation* of the theory we knew antecedent to a more fundamental physics; however, metaphysical claims

[37]Note that underdetermination of metaphysics by physics is arguably most plausible for non-fundamental theories, which for present purposes is the only place that the problem need arise.

[38]I think it is worth noting here that the generic underdetermination of metaphysics by physics seems to be simply assumed, rather than argued for. It may be that it is time for this piece of 'common knowledge' to be scrutinized more carefully, as has been the case recently regarding familiar Quinean assertions that scientific theories are inevitably and a priori underdetermined. I discuss this rather more in McKenzie (forthcoming b).

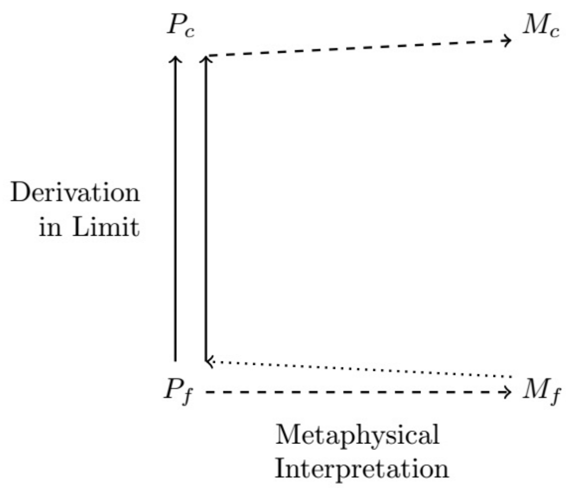

Figure 4: M_f and M_c indirectly related by limiting relations

are generically highly unstable under approximations of this sort. To put it another way, *the metaphysics of approximately classical physics is not an approximation to the metaphysics of classical physics*.[39]

While this claim asks for much further elaboration and defence, a few examples should suffice to make it plausible. Consider the metaphysics of diachronic identity and its behaviour in classical and quantum settings. Classically it is generally thought that trans-temporal identity may straightforwardly be ascribed to particles, and in reductive terms; for the existence of continuous non-overlapping trajectories unambiguously establishes the identity of a given particle at any time given its identity at some other. Famously, however, quantum mechanically this is not the case: the textbook theory does not permit a continuous sequence of position eigenvalues, and any two wavefunctions initially in widely-separated eigenstates will quickly overlap. This has the consequence that any sequence of discrete position measurements cannot be unambiguously attributed to one rather than another.[40] Thus even if it may be vastly more probable that a particle initially at x_1 goes through one sequence of positions that a particle that sets out from x_2, this is not good enough for the purposes of an *identity* which requires nothing less than the satisfaction of conditions stated in 'if and only if' terms. This means that the diachronic identity of quantum particles in the classical limit cannot be defined in spa-

[39] Since the bulk of this paper was written, Rasmus Jaksland has pointed out to me that the idea that metaphysical theories cannot be approximated is arguably already present in the work of Karen Barad. See Rasmus 2022, Chapter 7 for the details.

[40] Of course, if we supplement the formalism with hidden variables, *à la* Bohm, then this does not go through. Given the non-contextuality of the required hidden variables, arguably the metaphysical bump in the carpet for the Bohmian will simply go up somewhere else. Here my purpose however is simply to show how the transition from classical to quantum mechanics has been taken to give rise to radical metaphysical changes: not everyone will agree on the interpretation that gives rise to any such change.

tiotemporal terms; hence either it is taken as primitive or we infer instead that there is no such thing, effectively eliminating the category of objects and replacing it with that of events.[41] Either way, we have a sharp discontinuity between the metaphysics of identity appropriate to classical and quantum physics, and this *even though* the classical trajectory is, in a perfectly straightforward sense, a good approximation *physically* speaking to that implied by quantum mechanics.

The above argument concerning identity may also be readily adapted to the metaphysics of determinism. Since quantum mechanics supplies an approximation to classical laws, there is a clear sense in which they may be said to be 'approximately deterministic' in the sense that the probability of a position outcome close to the Newtonian prediction is close to 1.[42] Nevertheless, for some metaphysical projects, there is a world of difference between a metaphysics that is fully deterministic and one that is *almost* so. The *principle of sufficient reason* was after all taken to mean that 'nothing occurs for which it would be impossible for someone who has enough knowledge of things to give a reason adequate to determine why the thing is as it is and not otherwise' (Leibniz 1989 (1714), p. 639). This principle was at the heart of the metaphysical systems of both Leibniz and Spinoza, and was used to motivate such doctrines as the principle of the identity of indiscernibles and the existence of only a single possible world. That there is only 'approximate' determinism is no more coherent in these systems than would be the idea that there were *only a few* blades of grass that were exactly alike. For this reason, any departure from full and strict determinism was regarded as 'unthinkable' in these systems (d'Espagnat 2006 p. 320-1), even if with respect to the business of physics it represents continuity with business as usual (cf. Born 1956).

A second example concerns the fate of presentism in the move from pre-relativistic physics to special relativity. While not the first to do so, Putnam made an influential formal argument that relativity contradicts the metaphysical thesis of presentism: the idea that all and only that which exists *now* is real. At the root of the argument is the relativity of simultaneity – an innovation of relativity induced by the finiteness of the speed of light, c; given this finitude, a transitive relation may be defined forcing us to reify either the whole of the spacetime continuum or just a single point (the latter being completely implausible). Note, here, that it is not the specific finite value of c that has this transformative effect: rather it is simply the fact that it is *some finite number or other*. Now, as is well known, the equations of special relativistic kinematics reduce to their Galilean counterparts in the limit in which $v/c \to 0$ – formally the limit in which the speed of light may be regarded as infinite – which largely constitutes the sense in which Galilean physics is still viewed as 'approximately true'.[43] However, since the metaphysics of presentism (at least if Putnam is right) follows should c take *any* finite value, anything short of the strict truth of Galilean physics incurs a radically new metaphysics.[44] As

[41]The latter was Schrödinger's interpretation: see Bitbol 2007, p. 88.

[42]See Rosaler 2016 for more detail.

[43]As Fletcher 2019 points out, this cannot be taken to be sufficient for the reduction of Galilean to relativistic physics: for example, reduction to the non-relativistic Euler equation requires not just that the relative velocity of the fluid is small, but also that its pressure and internal energy are sufficiently small. But that this is even part of the reason is enough to ground the point made here.

[44]I am assuming here, for argument's sake, that eternalist metaphysics is considerably less plausible in pre-

such, while Galilean physics may be 'approximately true' insofar as v/c may be so small as to for c to be 'effectively' infinite, that approximate truth does not percolate up to what we are apt to call its metaphysics.

The most pressing case study for our purposes, however, is modal metaphysics and how it behaves as the theories it is grounded in are demoted to mere approximations. The metaphysics of modality is such an expansive enterprise, involving so many elements of our theorizing, that I cannot hope to do this issue full justice here. However, to at least make plausible that an analogous situation may be expected to recur in this context I will briefly gesture at two reasons why Humeanism may be expected to fare poorly under the transition from non-relativistic quantum theory to quantum field theory *even if* it can survive the transition from classical to non-relativistic QM. (Of course, this implies that there is no derivation of M_c from what we are assuming is M_f.) But to see why, it will be nevertheless helpful to first recap how Humeans have attempted to adapt their metaphysics to the classical–QM transition.

The most popular form of contemporary Humeanism is the 'Humean supervenience' (HS) chiefly associated with David Lewis. According to this view, reality fundamentally consists of a mosaic of intrinsic local qualities. But Lewis was explicitly operating with a classical framework, and as is by now well-known correlations arising as a result of quantum entanglement threaten the locality of the theory. In order to render quantum mechanics consistent with HS locality must be restored, a popular way to do so is to shift the fundamental space of the theory from spacetime to the associated configuration space.[45]. This is a space of enormously high dimensionality, with the number of dimensions determined by the number of particles in the theory. As such, this represents an extreme move – but one that devout Humeans are willing to make.[46] However, when we consider that quantum mechanics is a limit of its relativistic extension, quantum field theory, it is entirely unclear that such a move is either available or successful in restoring the features Humeans need. For one thing, in the QFT context some of the properties that feature in the Humean mosaic, now defined on configuration space, are associated with the couplings of quantum field theory – most obviously, mass and charge. But quantum field theory tells us that the value these properties take at any given energy scale is a function of the full field content of the theory. (For example, the mass of a quantum of the electron field at any scale is a function of how many flavours of fermion inhabit the theory alongside the electron.) This is because in QFT couplings 'run' with the energy in a way described by the renormalization group equation, and the way that they run is generically a function of every other coupling in the theory. As such, while non-relativistic quantum mechanics can be a valid approximation at a low energy scale, it is still a limit of a more fundamental theory, and moreover one that implies that the properties *at that low-energy scale* are functions of the full particle content of the theory. As such, it is hard to see how the Humean mosaic consists of 'intrinsic local qualities' in configuration space or anywhere else.

relativistic settings. This isn't an assumption I will defend. To repeat, however, unless metaphysics may be expected to change with physical theory it's hard to motivate being a naturalist at all.

[45]See for example Loewer 1996, p. 104

[46]As Maudlin puts it, 'This move constitutes the ultimate elevation of Separability as a regulative principle, rather than an empirical theory, and urges even more strongly the question of motivation'. (Maudlin 2007, p. 61.)

A second argument against the view that moving to configuration space salvages HS in quantum mechanics emerges when we remember that the states of the more fundamental theory generically do not consist of states of definite particle number. Rather, in quantum field theory the generic state is a *superposition* of states of definite particle number. The states needed to define configuration space, then, must be thought of as a very special sector of the state space appropriate to the more fundamental theory. While that itself is not necessarily a problem – non-relativistic states are a special case of the states of any relativistic theory – the problem that is posed is that once we think of states in this way the value of a wavefunction at a point in configuration space arguably cannot be regarded as a 'local beable'.[47] The reason is that once we conceive of these special states of N particles in the terms of the more fundamental theory, we do so in a context in which we are thereby committed to the claim that there do not exist regions containing $N' \neq N$ particles in anywhere in the space housing that special state. A non-zero value to the wavefunction for N particles at any point x in the space in that sense carries implications for regions disjoint from x, and as such is arguably not a local beable. Thus while it is true that one can find states of well-defined particle number in a quantum field theory – namely, as special cases – the very fact that they *are* special cases deprives them of their locality.[48]

The moral, then, is this. When we speak of 'the classical level', P_c, in physics, we understand it to be at best an approximation to classical physics strictly speaking. Insofar as there is a classical level of the world, it is thus only an approximation to what we were theoretically acquainted with prior to later developments. The metaphysics of any given theory however, seems highly unstable under its relegation to a mere approximation. As such, we can expect that the metaphysical 'facts' known antecedent to a fundamental theory are not facts at all, but gross misrepresentations of the metaphysics at any given level of the world. Thus, even if there are metaphysical facts at that level, we should not expect these facts to be known or knowable antecedent to the emergence of a fundamental theory. Condition (ii) on a prospectful effective metaphysics is therefore violated.

While there is a sense in which we can stop there, I think it is worth trying to try to say a little more about the nature of these facts themselves. Physicists (and philosophers of physics) are by now accustomed to thinking of ontology in 'FAPP' terms – that is, 'for all practical purposes' – in which a ballparky characterization of the underlying physics is explicitly embraced as good enough most of the time. The argument that has been given above suggests that this emphatically not the case when it comes to the metaphysics of that physics.[49] Since there is no sense to regarding paradigm claims of metaphysics as 'approximately true', those claims must be exactly true if true at all. Moreover, the truth value of those claims is highly

[47] This is argued in Myrvold *op cit*. Note that Ney 2021 criticizes Myrvold's argument. However, the debate over the meaning, the extent, and the significance of quantum nonlocality is such a large one that I will not attempt to adjudicate on it here.

[48] Note that one finds this phenomenon even in non-relativistic field theory. Relativistic considerations however – in particular the phenomenon of particle production – seem to force a field theory upon us.

[49] Of course, one might say that there is a sense in which by merely describing the ontology of FAPP physics we engage in a kind of metaphysics. But this is more like 'small-m' metaphysics, not the 'big-M' metaphysics that I am interested in here (see footnote 4 above).

unstable under small perturbations of the underlying subject matter. If we want to make true claims in metaphysics, then, we must regard the ontology we are giving an interpretation of in 'strictly speaking' terms: terms in which it is regarded just as an instance of the ontology described in a more fundamental theory. Partly on account of this, there is no obvious reason to expect the metaphysics of non-fundamental levels to be *distinct* in any relevant way from the metaphysics of the fundamental. For the ontologies in either case belong to the same 'paradigm', and as such we can expect the metaphysics to be relevantly similar. This of course comports with the observation that has already been made regarding how hard it is to think of metaphysics 'changing' as we change levels: for metaphysical categories are not functions of the parameters that define those levels. For all these reasons, then, it seems that we should think not only that the metaphysical facts at a given level cannot be known prior to a fundamental theory, but that those facts are, in a relevant sense, just *instances* of the fundamental metaphysical facts. That is, whether what they are about is fundamental or not, *metaphysical facts are always themselves fundamental*.

Something about that last claim strikes me as right, and indicative of a profound difference between metaphysics and physics. (The irony is that the claim as stated is somehow 'not quite right'.) But it is beyond question that the nature of the claim just made needs a good deal more fleshing out. For now, then, let the take-home message be the less ambitious one – namely, that whatever the facts at a non-fundamental physical level are, they cannot be known antecedent to a fundamental theory. That is enough to ground the claim that effective metaphysics does not have prospects, and thus the value of reflecting on the metaphysics of physics before the 'end of inquiry' is far more obscure than it was before. It seems, then, that the problem of theory change that originally motivated epistemic structuralists is back to bite their ontic counterparts.

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