

Fundamentality and Levels in Everettian Quantum Mechanics

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Warsaw Spacetime Colloquium – 17th December 2021

1. Introduction

Background: Everettian quantum mechanics (EQM) of the contemporary ‘decoherence-based’ variety, in which quantum theory is understood along scientific realist lines without any collapse of the wavefunction. Everettians including Simon Saunders (1993) and David Wallace (2003, 2010) have exploited techniques from decoherence theory (see Crull 2022) to argue that a space of approximately classical histories can be identified within a unitarily evolving, universal quantum state. EQM combines a determinate fundamental reality (the universal wavefunction) with an indeterminate emergent reality (decoherent worlds).

The fundamental/derivative distinction plays some crucial roles in decoherence-based EQM:

- Justifying the use of decoherence theory in modelling quantum measurement.
- Defusing demands for precise individuation criteria for worlds.
- Rendering Everett worlds a standard instance of higher-level ontology, like tigers or clouds (Saunders (2010) calls this Wallace’s ‘killer observation’).

Aim: explore how the Everettian appeal to fundamentality and emergence can be understood within existing metaphysical frameworks, and then characterize a system of explanatory levels suited to EQM.

2. Frameworks for fundamentality in Everettian quantum theory

Wallace has offered an account of the emergent multiverse in terms of Dennett’s notion of *real patterns* (Wallace 2003, 2010; Dennett 1991). In their application to EQM real patterns are embedded within the distinctive metaphysical view of science called *ontic structural realism* (OSR) which Wallace favours (see also Ladyman and Ross (2007)). But OSR is controversial. Are there other options for understanding EQM?

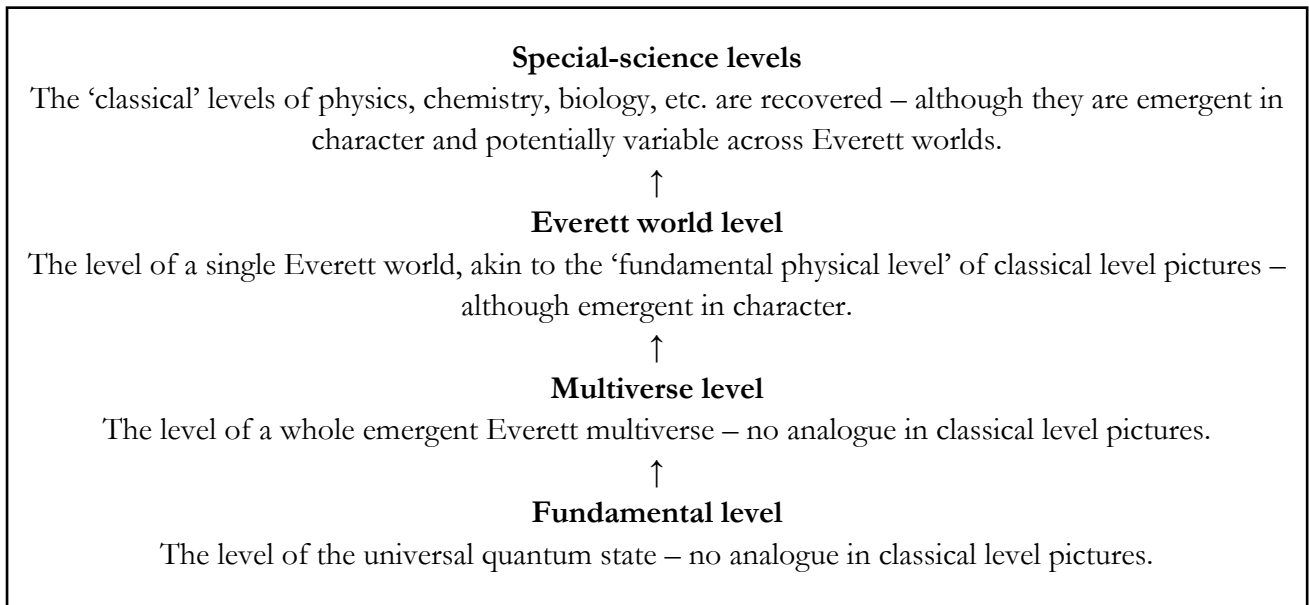
Supervenience is modal correlation: the A-facts supervene on the B-facts iff there can be no change in the A-facts without some difference in the B-facts. While this relationship can hold symmetrically, we can easily define a one-way notion: *A one-way supervenes on B* iff A supervenes on B and B does not supervene on A. A general objection: insufficiently explanatory. An EQM-specific objection: see section 5.

Grounding is a currently popular notion of explanatory metaphysical determination, with an appeal which largely stems from its perceived theory-neutrality and topic-neutrality: this feature will be exploited in section 3 to relate the very metaphysically heterogeneous kinds of levels which are combined into the decoherence-based EQM picture. We will not need to tweak any of the standard logical properties of ground for the Everettian application, although in section 3 I will argue that Everettians would do well to adopt a slightly non-standard approach to the distinction between partial and full grounds.

Concept fundamentality is Ted Sider’s generalization (Sider 2011, 2020) of Lewisian naturalness (Lewis 1983). Like grounding, concept fundamentality is well suited to EQM. Not only properties and relations can correspond to fundamental concepts, but items of all grammatical categories. So we have the prospect of Ψ – the fundamental quantum state – being a perfectly fundamental concept, and of an account of the higher-level structure of Everett worlds and laws thereof in terms of a Sider-style *metaphysical semantics*.

3. Explanatory levels in Everettian quantum theory

Applying grounding or concept fundamentality *semi-conservatively extends* a ‘classical’ levels structure.



- The transition from the fundamental level to the multiverse level introduces *indeterminacy*. Everett multiverses are (correlatedly) indeterminate with respect to world number and to world nature.

The fundamental state is a single object, and multiplicity of Everett worlds is only found at the derivative level. Unlike typical level relationships in higher-level sciences, there are no interesting mereological relations between lower-level elements as parts and higher-level elements as wholes.

This observation rules out the application of some influential accounts of interlevel relationships which rely on mereological relations, such as that of Oppenheim and Putnam (1958). However, the flexibility of the two approaches which we have adopted allows them to be applied to the emergence of the emergent multiverse.

- The transition from the multiverse level to the Everett world level introduces *indexicality*: a perspective centred within a world.

Grounding can handle the relation between the multiverse and Everett world levels in a distinctive way, if we acknowledge the possibility of partial grounds which cannot be completed into any set of full grounds. The perspectival fact about the outcome of a quantum process is partially grounded in the multiverse, of course – the multiverse determines what the possible outcomes of that process are. But the perspectival fact also includes a self-locating element which is not grounded in the multiverse. Which world is ours is, in grounding terms, a brute fact.

Concept fundamentality, and the associated metaphysical semantics, can also be brought to bear. Some of our concepts – not the wholly fundamental ones, but still relatively fundamental ones, through which we view all of the contingent goings-on that are the regular subject-matter of the sciences – are essentially self-locating/indexical in character.

- The transition from the Everett world level to the special-science levels adds no new ingredients.

Not all the features of the classical level structure are retained in the emergent levels of EQM however: in particular, there is likely to be physical contingency in the levels structure, with very different higher-level phenomena playing out in Everett worlds in different regions of the multiverse. This hypothesis is supported by the apparent extreme sensitivity of physical phenomena in our current cosmological epoch to the exact value of certain ‘fine-tuned’ cosmological parameters. If – as seems quite plausible – even one of these parameters takes its value as the result of a quantum-mechanical process, then there will be Everett worlds in which the parameter took on a different value, and in those Everett worlds there will be very different physical processes ordered into different sorts of levels structures.

4. Levels of laws in Everettian quantum theory

In A. Wilson (2020a), I offer a unified account of the fundamental and non-fundamental laws at work in the Everettian picture, making use of the notion of *modally strong generalization*.

Laws of individual Everett worlds are generalizations which hold across instances not only in the actual Everett world but also in other Everett worlds. We can further distinguish fundamental laws of individual worlds (e.g. energy conservation) from derivative laws of individual worlds (e.g. Mendel’s laws).

Fundamental laws are generalizations which hold true of the fundamental quantum state; they are degenerately modally strong, since there is only one fundamental quantum state.

The Schrödinger equation itself will not appear in the laws of individual Everett worlds; that law holds only of physical reality as a whole. Likewise, the initial quantum state of physical reality is not amongst the laws of any individual Everett world, even the fundamental laws of that world. The Schrödinger equation and the initial quantum state may of course still be used by actual physicists to predict and explain actual events – on my proposal, not only laws of the actual world can play that predictive and explanatory role.

5. Novel features of Everettian levels

To make the case for going beyond supervenience in modelling fundamentality in EQM, I will need to introduce some further assumptions about EQM – assumptions not shared by all Everettians.

The core principles of quantum modal realism (A. Wilson 2020a):

Alignment: to be a metaphysically possible world is to be an Everett world. (p.22)

Indexicality-of-actuality: Each Everett world is actual according to its own inhabitants, and only according to its own inhabitants. (p.22)

Everett worlds then represent alternative possibilities – different ways things physically could turn out – rather than representing different parts of one single, complicated, possibility.

Quantum modal realism renders supervenience hopeless as an account of interlevel dependence within EQM itself. If contingency is a matter of variation across the multiverse, then the fundamental quantum state itself is non-contingent. If the emergent multiverse supervenes on the fundamental state, then there is no possible difference in the emergent multiverse without some possible difference in the fundamental. Since a non-contingent fundamental quantum state cannot be different, nor can the emergent multiverse. And so we lose the one-way nature of the dependence relationship: the fundamental quantum state supervenes on the emergent multiverse and vice versa.

What is needed for EQM is an interlevel relation which can hold compatibly with one-way supervenience – and which entails one-way supervenience in cases where there is any modal variation at all – but which can also hold non-trivially in the absence of modal variation. It is also desirable that this relation should be an explanatory relation: we want to be able to explain the higher levels, including the emergence of a multiverse, on the underlying fundamental quantum level. Grounding and concept fundamentality both fit this job description. In each case, the holding of the relevant grounding relation (or the relevant portion of the metaphysical semantics) explains why any corresponding relation of one-way supervenience holds.

6. Conclusions

- An Everettian approach to quantum theory invokes a levels structure which extends previous conceptions of levels by including a level below the fundamental level of previous systems of laws.
- Grounding and Siderian concept fundamentality both offer potential metaphysical frameworks which can accommodate an Everettian level structure.
- EQM invokes an additional fundamental level, not present in the classical levels picture, and a novel potential role for self-location in interlevel metaphysics.
- When given a modal realist interpretation, EQM also makes trouble for supervenience-based approaches to levels.

References¹

- Crull, E. (2022). “Decoherence”, in *The Routledge Companion to the Philosophy of Physics*, eds. E. Knox and A. Wilson. New York: Routledge.
- Dennett, D. (1991). “Real Patterns”, *Journal of Philosophy* 88(1): 27-51.
- Ladyman, J. & Ross, D. (2007). *Every Thing Must Go: Metaphysics Naturalized*. New York: Oxford University Press.
- Lewis, D. (1983b). “New Work for a Theory of Universals”, *Australasian Journal of Philosophy* 61(4): 343-377.
- Lipman, M. (2015). “On Fine’s Fragmentalism”, *Philosophical Studies* 172(12): 3119-3133.
- Oppenheim, P & Putnam, H. (1958). “The Unity of Science as a Working Hypothesis”, *Minnesota Studies in the Philosophy of Science* 2: 3-36. Minneapolis: University of Minnesota Press.
- Saunders, S. (1993). “Decoherence, Relative States, and Evolutionary Adaptation”, *Foundations of Physics* 23(12): 1553-1585
- (2010). “Many Worlds: An Introduction”, in *Everett, Quantum Theory, & Reality*, eds. S. Saunders, J. Barrett, A. Kent, and D. Wallace. Oxford: Oxford University Press.
- Sider, T. (2011). *Writing the Book of the World*. Oxford: Oxford University Press.
- (2020). *The Tools of Metaphysics and the Metaphysics of Science*. Oxford: Oxford University Press.
- Wallace, D. (2003). “Everett and Structure”, *Studies in History and Philosophy of Science B* 34(1): 87–105.
- (2010). “Decoherence and Ontology”, in S. Saunders, J. Barrett, A. Kent and D. Wallace (eds.), *Many Worlds? Everett, Quantum Theory, and Reality*. Oxford: Oxford University Press.
- Wilson, A. (2020a). *The Nature of Contingency: Quantum Physics as Modal Realism*. Oxford: Oxford University Press.

¹ This work forms part of the project A Framework for Metaphysical Explanation in Physics (FraMEPhys), which received funding from the European Research Council (ERC) under the European Union’s Horizon 2020 research and innovation programme (grant agreement no. 757295). Funding was also provided by the Australian Research Council (grant agreement no. DP180100105). I am grateful for feedback to an audience in Geneva, and especially to Baptiste Le Bihan and Valia Allori.