



Fundamentality Metaphysics and Spacetime Emergence

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About me

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Structure

1. Introduction:
Aims & Scope

2. Functional
Realization

3. Mereological
Composition

4. The Grounding
Approach



Research Question

Many Quantum Gravity (QG) approaches hold that spacetime (or space and/or time) does not exist **fundamentally**. Instead, it **emerges** from a non-spatiotemporal ontology which is prior to the spatiotemporal ontology.

How do we understand, metaphysically speaking, the notions of priority and emergence?



Easy and Hard Problems

- The physics and metaphysics of QG is a work-in-progress domain of inquiry. Le Bihan (2018a,b) has distinguished four easy and hard problems of spacetime emergence.
1. **Scientific problem:** How do we formally bridge General Relativity and Quantum Theory?
 2. **Conceptual problem:** How do we account for the apparent explanatory gap between spatiotemporal and non-spatiotemporal notions?
 3. **Ontological problem: What is the nature and ontological status of emergent spacetime?**
 4. **Empirical Coherence Problem:** How can we rely on using spatiotemporal scientific evidence to justify the claim that spacetime is not fundamental?

Why bother?

- An answer to the ontological problem of emergent spacetime clears the way to an answer to the conceptual problem.
- Answering the ontological problem demands an elucidation of foundational issues surrounding the relationship between spacetime and non-spatiotemporal ontology.
- Physicists and philosophers of physics are generally unbothered about analysing ‘fundamentality’ and ‘emergence’. Recent developments in fundamentality metaphysics prompt us to investigate whether certain notions in the metaphysician’s toolkit could improve our understanding of foundational aspects of QG.

Aims

How should we understand, metaphysically speaking, the thesis that spacetime emerges from a more fundamental non-spatiotemporal ontology?

- 3 views: **functional realization**, **mereological composition**, and the **grounding** approach
- **My objective:** I aim to establish that the grounding approach is preferable to both the functional realization view and the mereological composition view. However, it commits us to a non-standard view of grounding or a primitively distinct kind of grounding in addition to its more familiar version. It is unclear whether the grounding approach wins the day.

Assumptions and remarks

- My goal is to evaluate certain metaphysical interpretations of the **thesis**. It is not to assess their scientific correctness.
- I will be concerned with the emergence of spacetime as a claim about an ontic element or elements (a substance, properties, facts) rather than a claim about concepts or truths or representations (cf. Yates 2021, Chalmers 2021).

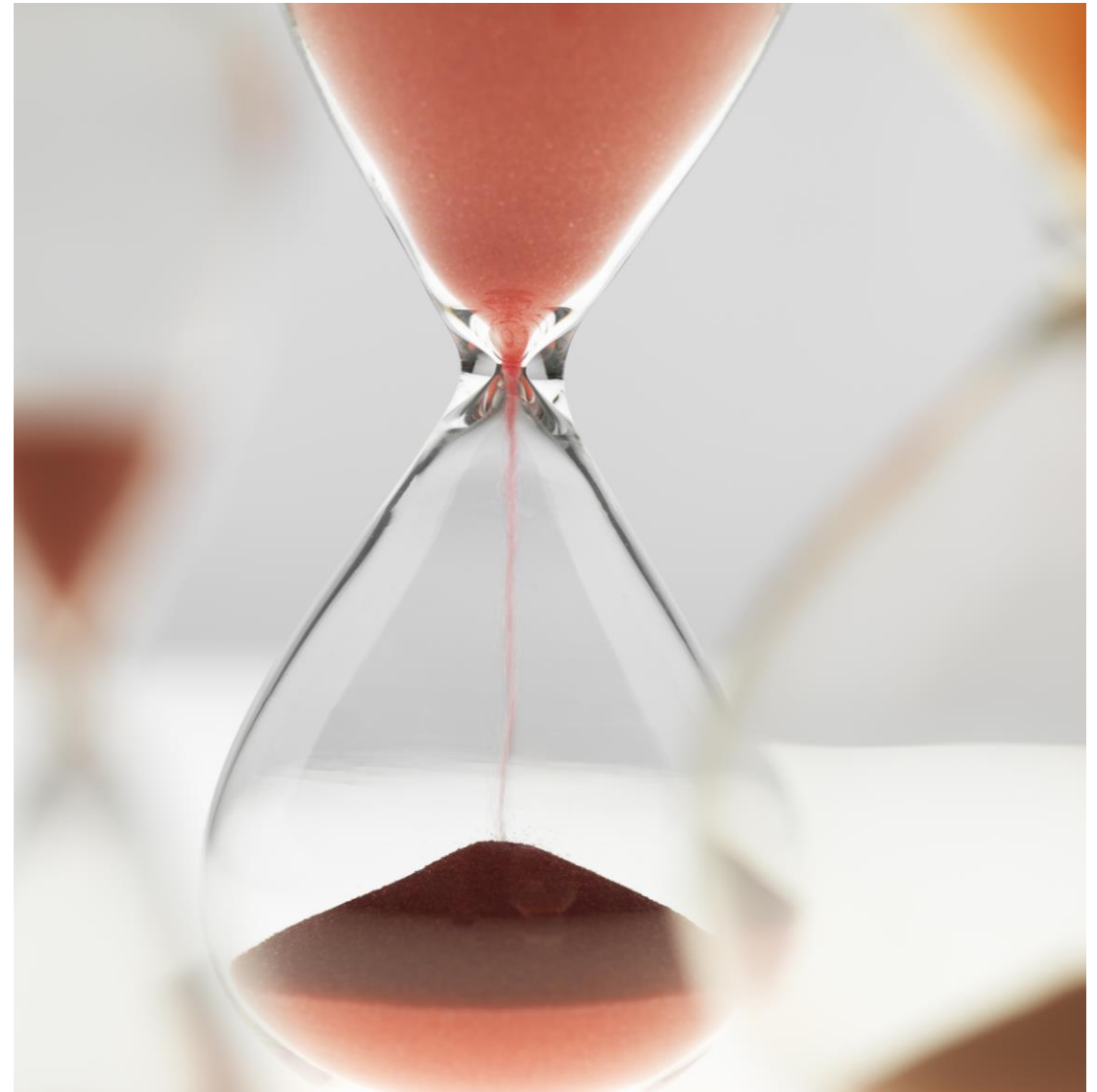
Popular QG approaches

- QG is motivated by the need to explain phenomena that display both quantum and relativistic features (black holes, early stages of the Universe). QG is currently a diverse family of research programmes.
- **String Theory:** fundamental one-dimensional entities and branes. Fundamental spacetime has 10 rather than 4 dimensions.
- **Loop QG:** general relativity first approach that attempts to recover gravity. The fundamental ontology is a structure of spin network states or, alternatively, spin foams. It is hard to identify spacetime with this structure.
- **Causal Set Theory:** spacetime emerges from the collective discrete structure of causal sets and partial ordering relations between these elements.

Evaluation Criteria

A good metaphysical interpretation should capture the **reality** and yet **derivativeness** of spacetime

A good metaphysical interpretation should preserve the **priority** and **fundamentality** of the non-spatiotemporal ontology over spacetime



Functional Realization

- **To be spacetime or spatiotemporal is to have a specific behaviour or function.**
- Spacetime functionalism holds that spacetime is emergent from non-spatiotemporal ontology in the sense that the functional roles of space is realized by the latter.
- What is the functional role of spacetime? To be spacetime is to be whatever element of reality it is that determines inertial motion of matter (cf. Knox 2014, 2018).

Problems with functionalism about spacetime (1/2)

- On certain interpretations, functional realisation implies a kind of (functional) reduction between the realizers and what is realized (cf. the philosophy of mind). If this view is correct, then it is unclear whether we preserve the **derivativeness** of spacetime.
- If spacetime is functionally realized by non-spatiotemporal ontological items, it can be functionally identified with the spatiotemporal ontology. **Plausibly, spacetime is real but it is unclear whether it is derivative due to functional identification.** (There are views that identity-like relations are compatible with priority. These are controversial.)
- If spacetime roles are functionally realized, then one is committed to the existence of both roles and realizers (Le Bihan 2021). However, does the spacetime role functionalism protect the non-fundamentality of spacetime?

Problems with functionalism about spacetime (2/2)

Spacetime is functionally reduced to its roles (cf. Huggett & Wutrich 2018, Gomes & Butterfield 2020). The roles themselves are played by non-spatiotemporal items.

1. It is not obvious what the metaphysics of spatiotemporal roles is. Worry of odd ontological commitment or underspecified metaphysics.
2. It is not obvious that the roles themselves are derivative. (restricted/unrestricted priority)

Mereological Composition

- **Spacetime or spatiotemporal relationships are mereologically constituted by non-spatiotemporal items.**
- Baron & Le Bihan (2022a): ‘Dependent spacetime is literally composed of non-spatiotemporal building blocks just as, say, a gas is composed of atoms in motion. These non-spatiotemporal building blocks constitute proper parts of a spacetime.’ (cf. Le Bihan 2018a,b, Baron 2020, Baron & Le Bihan 2022b).
- The composition relation is the good old mereological composition, but it might require us to abandon some principles, such as the harmony between parts and locations.

Problems with Mereological Composition

- The direction of priority of the composition relation is unfixed (cf. J. Wilson forthcoming; cf. David Lewis letters).
- **Le Bihan 2017:** ‘There is no necessary connection between logical mereology and the view that the proper parts of a whole are more fundamental than what they compose’.
- If mereology is topic neutral (cf. Baron & Le Bihan 2022), the composition view does not automatically ensure that the non-spatiotemporal proper parts are more fundamental than what they compose, namely spacetime (cf. priority monism).
- **The view must be supplemented with some extra metaphysical support for linking parthood and priority.**

Summing up

Functional realization and mereological composition views do not automatically secure the derivativeness of spacetime

The determinative relation of grounding is constitutively linked with priority. Thus it offers an initially more promising approach to spacetime emergence



Grounding approach

- **Spacetime is grounded in non-spatiotemporal ontology.**
- Explicating or systematising a form of ontological priority of some items over others is one of grounding main theoretical roles (cf. Schaffer 2009, Rosen 2010, Audi 2010, Raven 2012, Schnieder 2020; deRosset 2023, McKenzie 2023, Bliss 2024; cf. Mendez & Giannotti forthcoming).
- **Relative Fundamentality:** if F grounds G, then F is more fundamental than G.

Problems with the grounding approach

- Grounding secures the non-fundamentality of spacetime, unlike the functionalist view and the mereological composition view. And if grounding is factive, it ensures that derivative spacetime is real.
- However, in addition to general objections against grounding, this approach faces specific challenges.
 1. It is theoretically costly (Le Bihan 2018a, 82 – 84)
 2. **It clashes with the standard view of grounding (Wilson 2021)**
 3. QG dissipates the distinction between grounding and causation (Le Bihan & Vieser ms, cf. Yates 2021, 147-150)

Modal problem

- A. Wilson (2021, 189): the following four claims cannot be true together
 1. Spacetime is grounded in a superposition of spin foams.
 2. **The grounding of spacetime is metaphysically non-contingent.**
 3. Newtonian spacetime is metaphysically possible.
 4. Newtonian spacetime is not grounded in a superposition of spin foams.
- Proponents of grounding must reject 2 or 3. However, without independent reasons, ‘the moves just look ad hoc’ (Wilson 2021,190)

Tentative grounding solutions

- **Contingent grounding:** the orthodox view is that grounding connections hold with metaphysical necessity (e.g., Rosen 2010). However, there are contingentist views about grounding. One could draw support from them and argue the grounding of spacetime is contingent (cf. Leuenberger 2014, Skiles 2015, 2020, Chilovi 2020, Baron-Schmitt 2021, Richardson 2021).
- **Natural grounding:** the grounding of spacetime could be naturally but not metaphysically necessary (cf, Fine 2012, 40; Giannotti ms).

Open problems

Issue with contingentism

1. Superficial distinction between contingentism and necessitarianism about grounding (e.g., Cohen 2020).
2. Arguments for contingentism about grounding are controversial.

Issues with natural grounding

1. If natural grounding is irreducible to metaphysical grounding, this approach commits us to an unfamiliar primitive notion of grounding (cf. Giannotti ms)
2. This strategy disunifies the theory of grounding. (cf Wilson 2021)

Upshot

The grounding approach can solve the problems identified by Le Bihan and A. Wilson.

However, plausible solutions strongly suggest that the grounding approach commits its proponents to a distinct and not well understood variety of grounding.



Thank you

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