Spacetime Emergence: Revolution or Footnote?

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- These approaches put under pressure spacetime structure in different ways: in LQG, by quantizing spacetime, in GFT, by introducing non-spatiotemporal atoms, in holography, by showing the equivalence between gravity and a non-gravitational CFT; and many more!
- These approaches suggest that different properties we usually associate to spacetime in some sense disappears in QG.

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- Or perhaps just a catchy slogan to secure grants.
- **We argue to the contrary.**
- We distinguish between different senses in which spacetime disappears and emerges, and discuss what each means for physics and philosophy.

Terminology Explained

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- **Epistemology**: the theory of knowledge, and more generally, considerations on knowledge.

Spacetime, Space, Time — What Are We Talking About?

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- What exactly is denied fundamentality when it is said that spacetime is not fundamental? In other words: what are the defining features of spacetime?
- Methodological issue: where is the threshold between *revision* and *elimination*?

Spacetime as a Structure

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- Raises the question: is spacetime more—or less—than the sum of space + time?
- Difficult to reply, as there is no consensus on what spacetime is supposed to be (Baron and Le Bihan, 2022b) and whether it is necessarily tied to GR (e.g., Newton-Cartan spacetime).

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- Relation to change and motion.

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- As such spacetime emergence can be more or less radical. Usually, GQ goes further than GR in denying core properties of space and time, and possibly spacetime.

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- Then, we'll discuss broader implications for the "big questions" outside of physics.

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- Examples: GFT, string theory, holography

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- But one of the methodology might be more promising in latching onto the physical structure of reality.
- Call this the claim that one methodology is **factive**, unlike the other. The methodological success would reflect a **fact** about the physics.

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- Replacement, on the other hand, requires more than limits, since we do not start from GR spacetime.
- For example, in holography we do not simply take a semiclassical limit to recover spacetime: we also have to go through the duality map, for example using tools such as entanglement wedge reconstruction.

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- Non-fundamentality shapes and justifies specific QG methodologies.

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- Leads to a natural and elegant view of spacetime emergence, where spacetime emergence is mediated by the same limiting relations familiar from other areas of physics.
- More conservative approach: spacetime emergence is analogous to more mundane kinds of emergence.
- The emergence of the classical gravitational field, i.e. spacetime, from its quantum counterpart is analogous to the emergence of the classical electromagnetic field from its quantum counterpart.

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- Holography: GR spacetime is treated as equivalent to a CFT, which is then quantized to produce a QG theory. Here too, we first replace GR spacetime with something else, and then work on that.

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- This is especially clear on the metaphysics side of things, we suggest: it is replacement that sanctions many of the more revisionary claims that can be derived from spacetime emergence.

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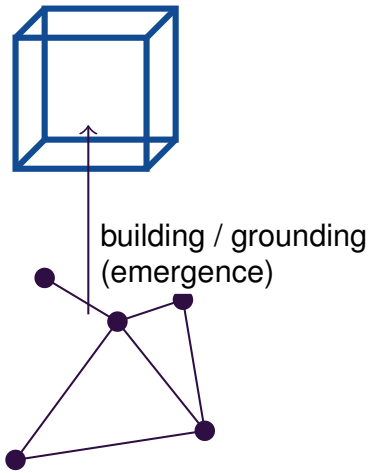
- **Full-Blow Realism**: spacetime exists and does not differ significantly from what we ordinarily think it is (Baron and Le Bihan, 2022a).

F-Eliminativism



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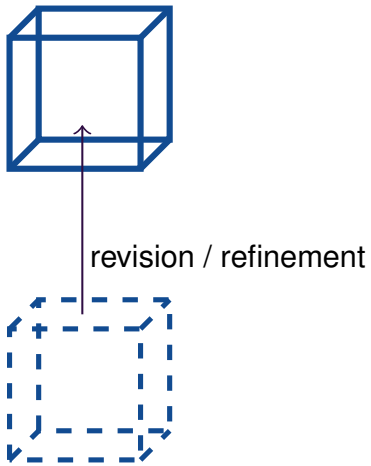
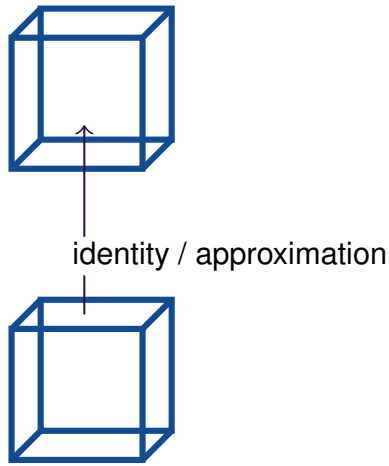


Full-blown Realism



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- In other words: at the **derivative level** one might be a **derivative revisionist** or a **derivative eliminativist** (but not a derivative full-blown realist, since full-blown realism collapses the need for levels). Call them D-eliminativism and D-revisionism.

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- If there really are two distinct structures, the fundamental and the derivative, then these might be connected via different kinds of 'building relations' (composition, grounding, functional realisation).

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- If replacement is factive, then F-Eliminativism obtains. We could still revise spacetime at the derivative level, but we accept that spacetime is nowhere to be found at the more fundamental level of description.

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- But what about **F-Revisionism**? Does it mean that spacetime emergence, once downgraded to mere revisionism, becomes a footnote rather than a revolution?
- For physics: an insightful and *surprising* discovery about the structure of reality. For metaphysics: it depends on exactly which spacetime features we revise.

Metaphysical Outlook

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- For F-Revisionism, metaphysical implications have to examined on a case-by-case basis: the devil lies in the details.
- Overall, we believe that F-Eliminativism entails *drastic* consequences, whereas F-Revisionism remains more conservative and offers weaker motivation to pursue metaphysical conclusions.

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  - *Dualities:* T-duality swaps large/small radii; AdS/CFT pairs a 5D bulk with a 4D boundary CFT while preserving empirical content.

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  - *Perspectival dimensionality:* different duals fix different "dimension gauges" of one underlying structure.
- **UpShot.** Ask "how many dimensions?" only *at the effective level* you're working with; at the fundamental level, dimensionality may be undefined—or not a property at all.

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- **String theory (ST):**
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  - Option 2 — reification of solutions at an emergent level, but solutions connected at a more fundamental level via a non-spatiotemporal structure (perhaps via moduli fields).

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- Spacetime emergence supports *non-spatiotemporal monism*: no need for fundamentally mental substances; the live options are monist (physicalism, neutral monism, panpsychism) rather than dualism (Le Bihan, forthcoming).

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- **Asymmetry.** Platonism is unaffected by what the physical base is (spatiotemporal or not); nominalism is sensitive to it.

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- **2. Non-spatiotemporal nominalism.** Redefine nominalism. Revise the reduction base: reduce maths to *non-spatiotemporal* physical posits rather than to spacetime entities.
- F-revisionism and full-blown realism will not, in general, raise such issues, since there are still fundamental physical constructs.

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- Although often dismissed (for familiar "incredulous stare" reasons), Pythagoreanism can be motivated by a simple thought: once the link between concreteness and fundamental spatiotemporality is severed, our grip on concreteness itself may dissolve.

Conclusion

- Spacetime emergence could redefine discussions both in physics and metaphysics.

Conclusion

- Spacetime emergence could redefine discussions both in physics and metaphysics.
- A revolution is not certain — but the potential is high.