Emergent Spacetime and Empirical (In)coherence

Nick Huggett and Christian Wüthrich[1]

December 1, 2012

[1]Work on this project has been supported in part by a Collaborative Research Fellowship by the American Council of Learned Societies.

1.1 - Local Beables and Empirical Incoherence

- Tim Maudlin (2007, 3157): *local beables do not merely exist: they exist somewhere.*
- A beable is local if the degrees of freedom describing it are associated with an open region of spacetime.

1.1 - Local Beables and Empirical Incoherence

- Tim Maudlin (2007, 3157): *local beables do not merely exist: they exist somewhere.*
- A beable is local if the degrees of freedom describing it are associated with an open region of spacetime.
- Following Jeff Barrett (1999, §4.5.2): *A theory is empirically incoherent in case the truth of the theory undermines our empirical justification for believing it to be true.*
- Thus, a theory without fundamental spatiotemporal ‘furniture’ is empirically incoherent unless it is possible to derive local beables from it.

1.1 - Local Beables and Empirical Incoherence

- Tim Maudlin (2007, 3157): *local beables do not merely exist: they exist somewhere.*
- A beable is local if the degrees of freedom describing it are associated with an open region of spacetime.
- Following Jeff Barrett (1999, §4.5.2): *A theory is empirically incoherent in case the truth of the theory undermines our empirical justification for believing it to be true.*
- Thus, a theory without fundamental spatiotemporal 'furniture' is empirically incoherent unless it is possible to derive local beables from it.
- What about quantum theories of gravity, which put pressure on classical spacetime?

1.1 - Local Beables and Empirical Incoherence

- Tim Maudlin (2007, 3157): *local beables do not merely exist: they exist somewhere.*
- A beable is local if the degrees of freedom describing it are associated with an open region of spacetime.
- Following Jeff Barrett (1999, §4.5.2): *A theory is empirically incoherent in case the truth of the theory undermines our empirical justification for believing it to be true.*
- Thus, a theory without fundamental spatiotemporal 'furniture' is empirically incoherent unless it is possible to derive local beables from it.
- What about quantum theories of gravity, which put pressure on classical spacetime?

At bottom, what is the nature and significance of derivations of local beables in quantum gravity?

1.2 - Questions

- Are there quantum theories of gravity without (fundamental) spatiotemporal furniture?

- If so, are there formal derivations of local beables? What are they?

- Is a purely formal solution to the problem of local beables adequate?

1.2 - Questions

- Are there quantum theories of gravity without (fundamental) spatiotemporal furniture?
- Yes – but there are degrees of conceptual distance from classical notions.
- If so, are there formal derivations of local beables? What are they?
- Is a purely formal solution to the problem of local beables adequate?

1.2 - Questions

- Are there quantum theories of gravity without (fundamental) spatiotemporal furniture?
- Yes – but there are degrees of conceptual distance from classical notions.
- If so, are there formal derivations of local beables? What are they?
- Yes – but the ease of derivation does not correlate with degree of conceptual distance from classical notions.
- Is a purely formal solution to the problem of local beables adequate?

1.2 - Questions

- Are there quantum theories of gravity without (fundamental) spatiotemporal furniture?
- Yes – but there are degrees of conceptual distance from classical notions.
- If so, are there formal derivations of local beables? What are they?
- Yes – but the ease of derivation does not correlate with degree of conceptual distance from classical notions.
- Is a purely formal solution to the problem of local beables adequate?
- It can be – such a derivation can illuminate the 'physical significance' of a theory without spacetime.

1.2 - Questions

- Are there quantum theories of gravity without (fundamental) spatiotemporal furniture?
- Yes – but there are degrees of conceptual distance from classical notions.
- If so, are there formal derivations of local beables? What are they?
- Yes – but the ease of derivation does not correlate with degree of conceptual distance from classical notions.
- Is a purely formal solution to the problem of local beables adequate?
- It can be – such a derivation can illuminate the 'physical significance' of a theory without spacetime.

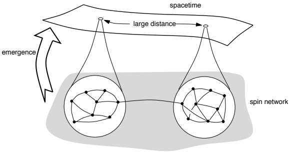
First: why bother considering such partial theories?

2.1 - Spacetime Lattices

- Discrete metrical spacetimes – by itself no more causes problem for local beables than the atomic theory does for apparently continuous material bodies.
- Non-metrical lattices, with primitive 'causal' relations. 'Derivations' of spacetimes done via embedding – the dynamical principles that lead to classical spacetimes are unknown. Empirical coherence is not established (CW: redefine local beables in causal terms?)

2.2 - Loop Quantum Gravity

- States as quantum superpositions of spin networks – 'spin foam'.
- Superposition means locality 'indeterminate'.
- Adjacency of nodes does not entail 'closeness' in the derived metric – the path from nodes to locality is not straight-forward.



2.3 - String Theory

- Strings look like local beables – they live in a background spacetime.
- But . . . dualities suggest/show that the background spacetime is geometrically indeterminate (metrically or topologically) in ways phenomenal spacetime is not – hence they are not the same thing.
- Taking dual theories as different representations of the same physical world, one of the representations matches ours – a technical solution to the problem of local beables.

2.4 - Non-Commutative Field Theory

- *Algebraic* commutative geometry:
  - (Roughly) $[x, y] = 0$ characterizes the differential geometry of the plane.
  - Geroch: Einstein algebras characterize models of GTR (Earman).
  - Of course, these algebras have a *representation* in terms of scalar fields polynomial in x and y – fields in classical space(time).

2.4 - Non-Commutative Field Theory

- *Algebraic* commutative geometry:
  - (Roughly) $[x, y] = 0$ characterizes the differential geometry of the plane.
  - Geroch: Einstein algebras characterize models of GTR (Earman).
  - Of course, these algebras have a *representation* in terms of scalar fields polynomial in x and y – fields in classical space(time).
- Non-Commutative Geometry:
  - Deform the algebra of polynomials in x and y to $[x, y] = \theta$.
  - The usual apparatus of field theory (action, fibre bundles etc) can be formulated algebraically.
  - A representation in terms of polynomial fields in the plane, but w.r.t. non-commutative, 'Moyal-$\star$' multiplication – physics is blind to the commutative nature of the plane.

2.4 - Non-Commutative Field Theory

- *Algebraic* commutative geometry:
  - (Roughly) $[x, y] = 0$ characterizes the differential geometry of the plane.
  - Geroch: Einstein algebras characterize models of GTR (Earman).
  - Of course, these algebras have a *representation* in terms of scalar fields polynomial in x and y – fields in classical space(time).
- Non-Commutative Geometry:
  - Deform the algebra of polynomials in x and y to $[x, y] = \theta$.
  - The usual apparatus of field theory (action, fibre bundles etc) can be formulated algebraically.
  - A representation in terms of polynomial fields in the plane, but w.r.t. non-commutative, 'Moyal-$\star$' multiplication – physics is blind to the commutative nature of the plane.

The algebraic – space(time) free – representation is fundamental: no fundamental meaning to point values.

3.1 - Maudlin's Challenge

> *But one might also try instead to derive a physical structure with the form of local beables from a basic ontology that does not postulate them. This would allow the theory to make contact with evidence still at the level of local beables, but would also insist that, at a fundamental level, the local structure is not itself primitive. . . . This approach turns critically on what such a derivation of something isomorphic to local structure would look like,* **where the derived structure deserves to be regarded as physically salient** *(rather than merely mathematically definable). Until we know how to identify physically serious derivative structure, it is not clear how to implement this strategy.*

(Maudlin 2007, 3161, emphasis added)

3.2 - The Upwards Path

- To complain that a derivation is not physically salient as understood by current theory is question begging.
- So how do we learn what is physically salient? It's part of a new theory and supported by the empirical evidence for the theory – consider the Cartesians and Newtonians on action at a distance.
- So developing a new account of what derivations are physically salient is part of developing a theory of quantum gravity – conceptual analysis and development.
- Lesson for theory: a place for philosophy.

3.2 - The Upwards Path

- To complain that a derivation is not physically salient as understood by current theory is question begging.
- So how do we learn what is physically salient? It's part of a new theory and supported by the empirical evidence for the theory – consider the Cartesians and Newtonians on action at a distance.
- So developing a new account of what derivations are physically salient is part of developing a theory of quantum gravity – conceptual analysis and development.
- Lesson for theory: a place for philosophy.

3.3 - The Downwards Path

- Maudlin has things backwards – don't decide what physical salience is and then validate derivations, rather our best guide to physical salience is successful derivations.
- A sketch of the analytic program: for existing theory fragments, study the 'partial' interpretations given by the statement that 'under such-and-such approximations (etc) the t-terms and o-terms are related thusly'.
- In philosophical terms, a program of empirical analysis of theoretical concepts.
- Lesson for philosophy: work top-down to maintain a controlled examination.

3.3 - The Downwards Path

- Maudlin has things backwards – don't decide what physical salience is and then validate derivations, rather our best guide to physical salience is successful derivations.
- A sketch of the analytic program: for existing theory fragments, study the 'partial' interpretations given by the statement that 'under such-and-such approximations (etc) the t-terms and o-terms are related thusly'.
- In philosophical terms, a program of empirical analysis of theoretical concepts.
- Lesson for philosophy: work top-down to maintain a controlled examination.