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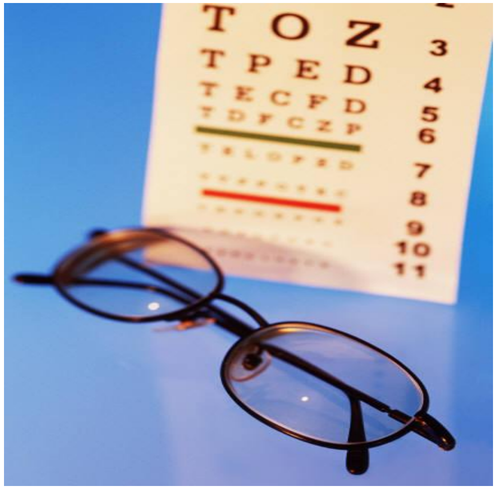
Moving in a Lonely Universe [speculative work in progress]

Central Argument

The Universe around us is - in a fairly primitive sense - what a self-observing particle in a single-particle Universe might potentially "see" as well

Key assumptions

- The particle is intrinsically "symmetric"
- The particle is free to observe its own "location" (to the extent that this is meaningful)
- Locations carry an ordering
- particle can repeatedly make (new) observations
- The generated spacetime (whether relational or container) supports an underlying "action"



Acknowledgments

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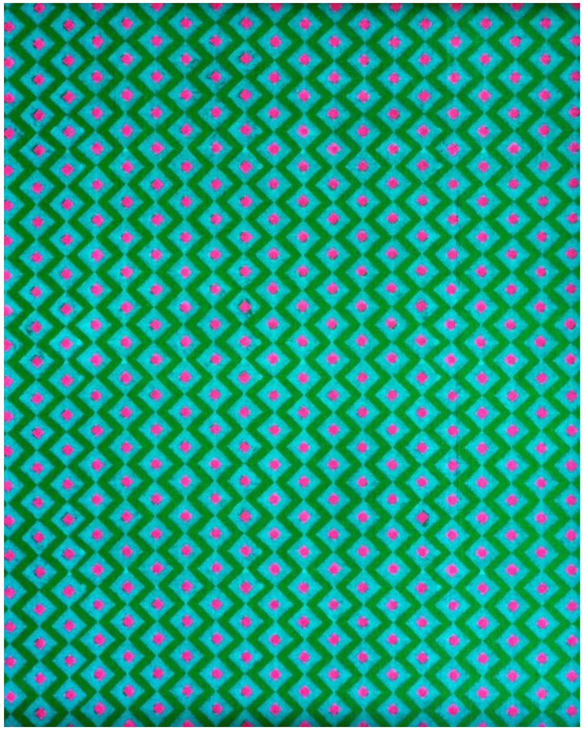
Resources

Köszönettel

- Useful conversations
  - Hajnal Andréka, Félix Costa, Fay Dowker, Judit Madarász, István Németi, Gergely Székely
- Useful article:
  - Fay Dowker (2005) Causal sets and the deep structure of spacetime. arXiv:gr-qc/0508109v1
- See also
  - Borchers & Sen (2006) Mathematical Implications of Einstein-Weyl Causality. *Lect. Notes Phys.* **709**, Springer.

Background papers

- M. Stannett (2009) The computational status of physics: A computable formulation of quantum theory. *Natural Computing*.
- Modelling Quantum Theoretical Trajectories within Geometric Relativistic Theories (2009) PIRT, Budapest.
- M. Stannett (2012) Computing the appearance of physical reality. *Applied Mathematics and Computation*.



Relationship to The Project

- Can we invent systems that are *observationally equivalent* to SpecRel (say) but which are "actually" more quantum theoretical in nature?
- How far can we push things?

Key observation

a particle is its **observed** worldline

- $w_m(b) = \{ (x,y,z,t) \mid W(m,b,x,y,z,t) \}$
  - This tells us where m **observes** b's worldline to be
  - It does ***not*** say that *b* **actually follows** this trajectory
- If two theoretical models generate the same observed worldlines, they cannot be distinguished at the level of **SpecRel**.

Our goal

- We are free to decide for ourselves what process creates the observed trajectories of particles.
- Find a model of particle motion that is
  - more quantum-ish
  - as simple as possible
  - removes as many assumptions as possible about interactions
  - produces outcomes that are observationally equivalent to those generated by "standard" theories.

Progress so far

- To devise a model of observation that generates QM-consistent worldlines:
  1. Continuity of motion is unnecessary (there exists an equivalent system in which all motion is discrete, symmetric and finitary) [mps, 2009]
  2. The appearance of motion can itself arise without being assumed [mps, 2012]
  3. You only need to consider self-observation of a single particle in an otherwise empty Universe [this talk]

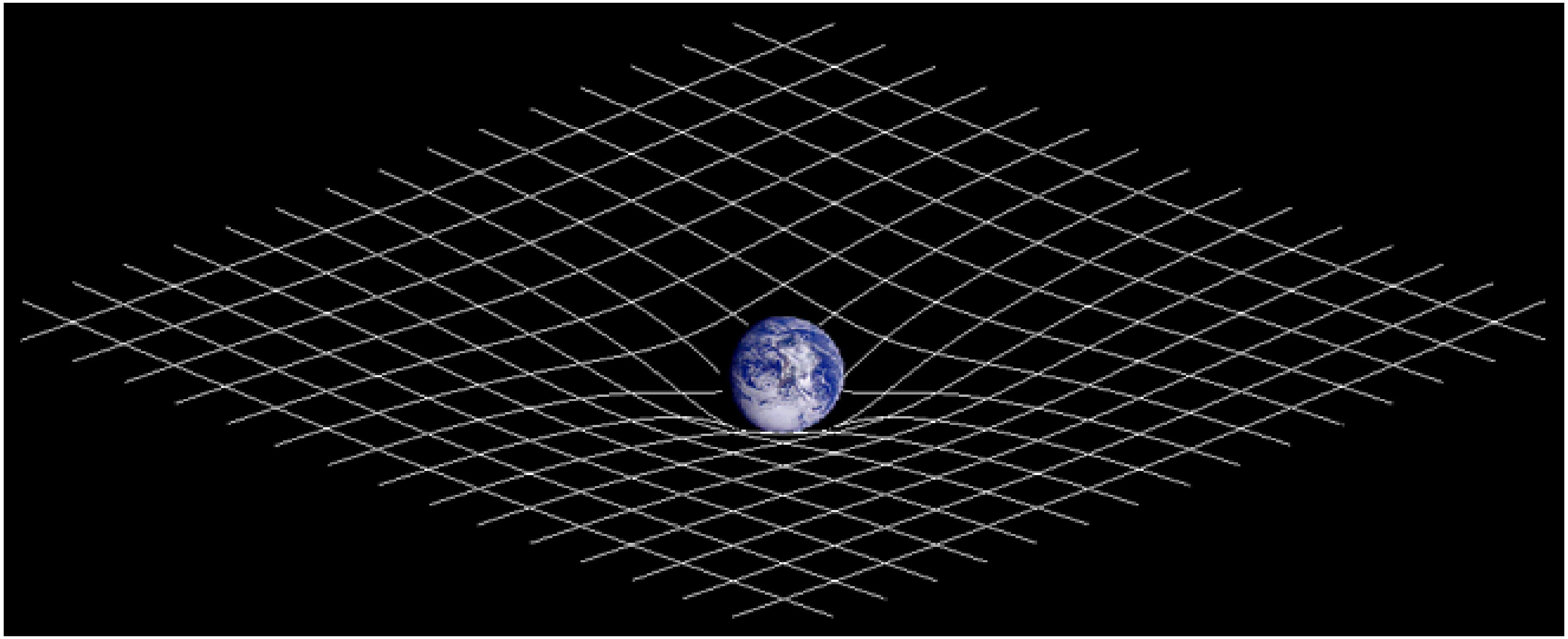
cf. Wheeler/Feynman

I received a telephone call one day from Professor Wheeler, in which he said, "Feynman, I know why all electrons have the same charge and the same mass" "Why?" "Because, they are all the same electron!" And, then he explained..., "suppose that the world lines ... were a tremendous knot, and then, when we cut through the knot ... we would see many, many world lines and that would represent many electrons..."

"But, Professor", I said, "there aren't as many positrons as electrons."

From Richard Feynman's Nobel Lecture, Dec 1965.

Single-Particle Universe



Consider a single self-observing particle, P
[NB. The notion of Universe may not be meaningful]

http://en.wikipedia.org/wiki/File:Spacetime_curvature.png

Self-observation

- *What* does the particle observe?
- *When* does it observe?
- How often?
- Are *different* self-observations *related* to one another?

What is observed?

The introduction of numbers as coordinates … is an act of violence (H. Weyl)

- No idea!
- Call them "locations" for convenience.
- We'll impose some structure on locations, just so we have something to talk about
- To the extent that this structure will be ordered, algebraic, etc, we can say it involves "numbers" or "coordinates" but this is just a convenient description for our own benefit.
- We're not suggesting that the particle understands numbers, geometry, etc!

When does P observe? How often?

- No idea, but let's suppose P can make "successive" observations **[Generalise this!]**
- In effect, P is equipped with a ticking clock
  - Tick? Make an observation!
  - Tick? Make an observation!
  - Tick? Make an observation!
  - Tick? Make an observation!

- Ticks are ordered, but there's no notion of "duration"

Internal clock

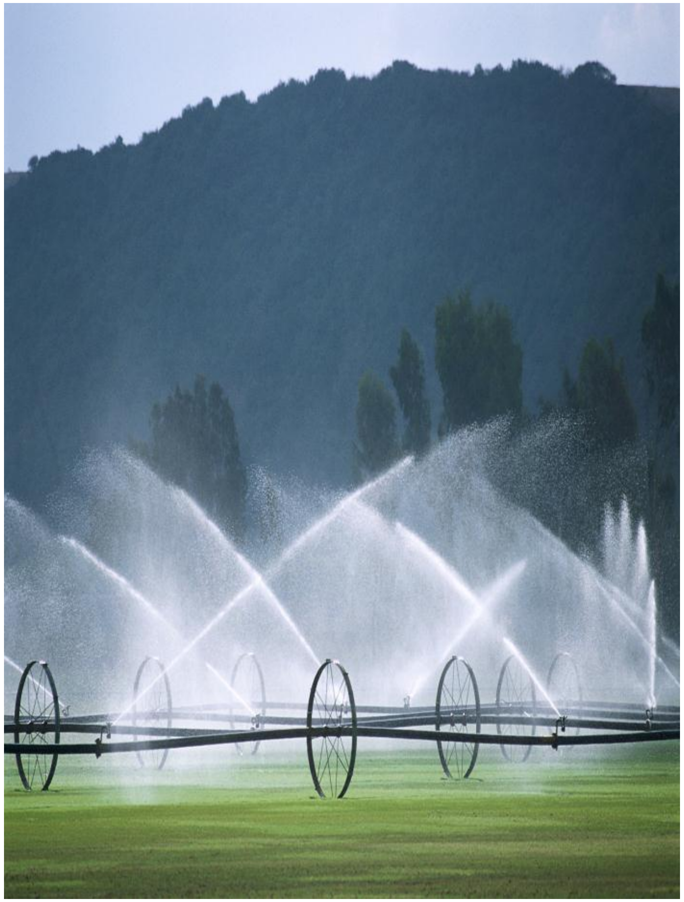
- Formally, we're assuming
  - a set L of *locations*
  - an *internal clock*, C = <0, 1, 2, ... >
  - a function at: C → L giving P's "coordinates" at each tick
- Notation
  - x@t means "x = at(t) "
  - "P coordinatizes itself to be at x on its t'th internal clock tick"

@

- What can we say about the at function?
- No idea?

@gain

- Suppose we wanted L to be something like a sequence of locations on a manifold M.
- How would we decide what M looks like?
- How should L be mapped to M?



Approximating L by M

- There is no reason for @ to embed L in M in any special way
- But **we** want L to be modelled reasonably accurately by M
- Need to say what it means for M to be a good enough approximation of L.

Random sprinkling

GEOMETRIC ANSWER
The symmetries of the L (embedded in M) can't differ significantly from those of M.

L should be randomly sprinkled in M

COMPARE:

- Feynman & Hibbs (1965) Quantum Mechanics and Path Integrals. New York: McGraw Hill.
- Dowker (2005) Causal sets and the deep structure of spacetime. arXiv:gr-qc/0508109v1
- Laskin (2008) Fractional Quantum Mechanics. arXiv:0811.1769v1 [math-ph]

Order embedding

- We generally want M to carry various orderings, so we have to assume that L also carries an ordering
- The sprinkling of L into M needs to respect this ordering
- Provided L is ordered, we can define a class of manifolds in which L can be discretely (or maybe densely) order-embedded

Choosing M

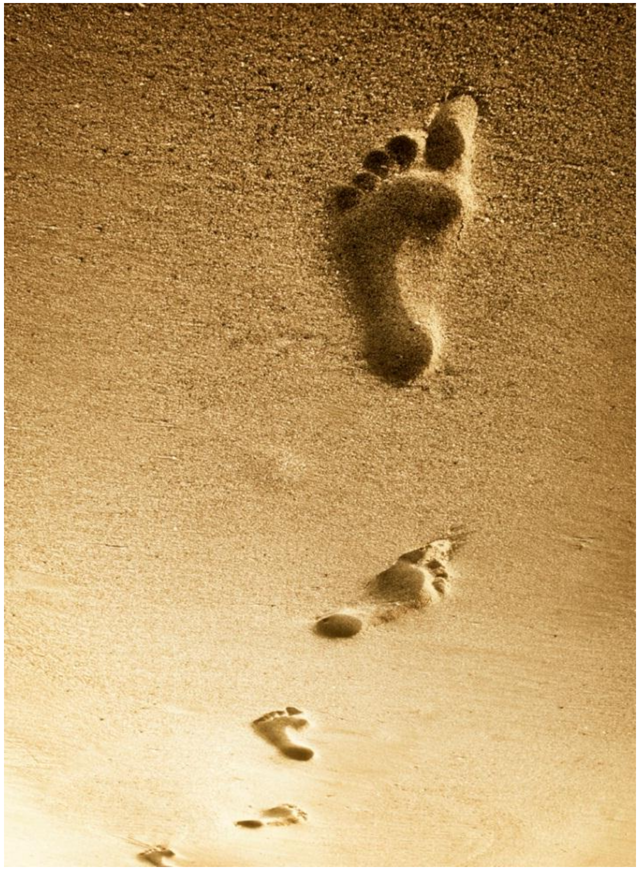
- cf. causal set theory
  - "a mass density is a good approximation if the atomic state could have arisen with relatively high probability from amongst the possible discretisations" [Dowker, 2005]
- how might we do it? **[still needs doing!]**
  - consider countable random samplings from M
  - define what it means for two samplings to be close together
  - look for M's in which L-like samplings that are "relatively likely"

Summary so far

- Single particle asserts own "locations" L
- Locations carry an ordering (causality)
- Identify manifolds M in which L can be order embedded with high probability
- Treat the embedding as a random walk of P in M

Continuity from randomness

- Having identified a suitable M, we now have what looks like a random walk followed by P.
- How do we get something that looks like a continuous worldline?



Finitary model [mps, 2009/2012]

- Assume motion occurs in random hops (w.r.t. both space and time), and that an action $s: M \times M \rightarrow R$ is defined where $s(x,y)$ gives
  - the classical action if P moves freely from x to y if y is later than x
  - the classical action for anti-P to move freely from y to x if x is later than y
- Treat s as the "hop-action", and regard paths as finite hop sequences
- Integrating over these finitary paths gives the same results as Feynman's path-integral formulation

Generating the hop-action

- Suppose P has mass
- Restrict choices of M to those in which any finite region of M contains finitely many points of L
- Approximate this by a mass density
- Think of a classical test-particle moving subject to the associated geometry/forces

Continuous motion of P in M

- The path apparently followed by P in M is identical to that predicted by the path-integral approach
- P experiences M in much the same way we would
- Example: reflection of light in a mirror

Summary: Lots to do & may fail!

- Clearly speculative - lots of assumptions!
- General idea is still being investigated
  - Embed locations randomly
  - Choose manifolds that approximate well
  - Define classical action
  - Generate hop-action
  - Determine finitary-path integrals
  - Determine probability P will be observed to travel from x to y via a path entirely in a region R
  - Identify apparent path followed by P in M.

Thanks for listening