Protolocal Observables and Measurement

S. Giddings, D. Marolf, J. Hartle

Relational Observables in the QM of Closed Systems

- There are important global alternatives in cosmology that are not relational.
- But any protolocal observables are necessarily relational in diffeo invariant theory.
- Measurements involve protolocal observables:

Measurement Models

Measuring an operator A, eigenstates ψ_a

$$(\sum_a \psi_a(x))\Phi(Q) \underset{T}{\longrightarrow} \sum_a \psi_a(x)\Phi_a(Q)$$

- Separation of degrees of freedom in to those for measured subsystem (x) and apparatus (Q).
- Special uncorrelated initial state.
- Special kind of Hamiltonian that will produce a correlation between eigenstates and ``pointer states" in a definite time.
- Decoherence of histories of measurements, stable records, etc. etc.

Measurement Models in Diffeo Invariant Theories

- Measurement models can be contructed with protolocal observables, e.g.

$$S_{\rm int} = f \int d^4x \sqrt{-g} \mathcal{O}(\phi(x)) m(x)$$

where ϕ(x) acts on the field Hilbert space and m(x) acts on the apparatus Hilbert space.

- With suitable restriction on the state the usual measurement model is recovered approximately.

Limits of Protolocal Observables

- There are no local observables in a diffeo invariant theory.
- Protolocal observables are relational to other physical fields that carry energy.
- Constructing any kind of field configuration that can resolve spacetime distances of order $1/\Lambda$ and corresponding energies.
- In order that this energy not be in a black hole.

Excess Baggage?

- Should we seek a theory which only makes predictions about alternatives that can be exactly measured at least in principle?
- Cautions:
  - Measurement is an intrinsically approximate notion and not fundamental in modern QM.
  - Unmeasurable quantities useful (e.g gauge degrees of freedom, multiverses, other sides of horizons).
  - Instramentalism

But Maybe We Should Try it !