Hiding a collapse mechanism inside the Standard Model

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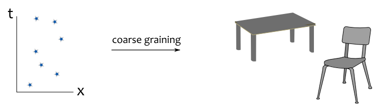
Ontological content of collapse models

Stochastic Schrödinger equation

$$\partial_t |\psi_t\rangle = -iH|\psi_t\rangle + f_\xi(|\psi\rangle)$$

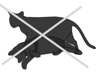
- Non linear
- Random
- Jump or diffusive
- Markovian or not

Local beables (field or flashes)



Weak constraints:

- Macroscopic stuff well localized



Averaging over the noise

Define:

$$\rho = \mathbb{E}_\xi[|\psi_t\rangle\langle\psi_t|]$$

Stochastic unraveling

Find $|\psi_t\rangle$ such that:

$$\rho = \mathbb{E}_\xi[|\psi_t\rangle\langle\psi_t|]$$

and $|\psi_t\rangle$ collapses in some basis

- Non-unique
- **Always** doable

Lesson

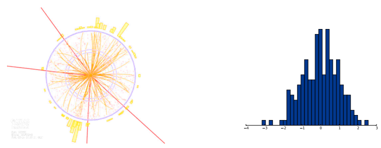
Thanks to the universal stochastic unraveling method, collapse models can be constructed starting from the right instead of from the left. One just needs to find a legitimate open system evolution.

Empirical content of collapse models

Master equation

$$\rho_t = \Phi_t \cdot \rho_0$$

Probabilities for outcomes of experiments



Strong constraints:

- No faster than light signaling
- Born rule still valid

Φ_t has to be **linear** (and CPTP)

Question

How to construct nice open system evolutions?

Answer

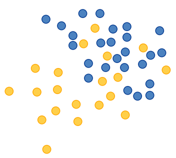
Use existing interacting quantum field theories!

Interacting Quantum Field Theory

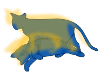
for fermions and bosons

$$\mathscr{L} = \mathscr{L}_{\text{bosons}} + \mathscr{L}_{\text{fermions}} + \mathscr{L}_{\text{int}}$$

e.g. QED, Yukawa, etc.



- Has macroscopic superpositions (linear)



Tracing out bosons

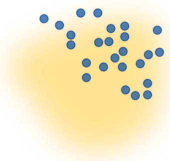
$$\rho_f = \text{tr}_b[\rho_{\text{tot}}]$$

Open Quantum Field Theory

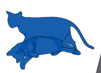
for fermions

$$\rho_t = \Phi_t \cdot \rho_0$$

à la Feynman-Vernon or Keldysh



- Has macroscopic superpositions (still linear)



Stochastic unraveling

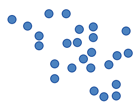
$$\rho_f \to |\psi(\xi)\rangle_f$$

Collapse model

for fermions

$$\partial_t |\psi_t\rangle_f = -iH|\psi_t\rangle_f + f_\xi(|\psi\rangle_f)$$

Stochastic field ξ as local beable



- Has no macroscopic superposition

Empirically equivalent

because all measurements can be recast into position measurements for the fermions in detectors

Consequences

It's great for collapse models!

- Collapse models can easily be made relativistic.

- Their empirical content can be trivial to compute (= QFT).

- Collapse models can provide a great **interpretation** of quantum field theory.

- A sound basis for a rigorous construction of interacting QFT?

It's a tragedy for collapse models!

- Collapse models are flexible enough that they can be hidden in any interacting QFT if the Markovian assumption is dropped.

- If collapse models are naturally hidden in the SM, it makes little sense to test less symmetric ones that deviate from it.

- Collapse models may provide only a **reformulation** of QFT (just like Bohmian mechanics).

References

For the details of the proposal:
- arXiv:1702.06325

On general stochastic unraveling:
- Diósi, Gisin & Strunz, (1998) *Phys Rev. A*, **58**(3), 1699
- Gambetta & Wiseman, (2002) *Phys. Rev. A*, **66**(1), 012108
- Diósi & Ferialdi (2014) *Phys. Rev. Lett.*, **113**(20), 200403

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