Causal fermion systems as an effective collapse theory

- joint work with J. Kleiner and C. Paganini, arXiv:2405.19254 [math-ph]

General message

- causal fermion systems naturally involve a *stochastic background field*
- the causal action principle is *nonlinear*
- Combined, one gets a dynamical collapse theory
- Similar to *CSL model*, but with a few important differences

---

The stochastic background field

- Dynamics of *causal action principle in Minkowski space* can be described in terms of a *nonlocal Dirac equation*

$$(i\partial\!\!\!/ + \mathscr{B} - m)\psi = 0\,.$$

Here $\mathscr{B}$ is nonlocal, i.e. an integral operator

$$\big(\mathscr{B}\psi\big)(x) = \int_M \mathscr{B}(x,y)\,\psi(y)\,d^4y\,.$$

- The integral kernel has a specific form:

$$\mathscr{B}(x,y) = \sum_{a=1}^N \gamma_j\,A_a^j\Big(\frac{x+y}{2}\Big)\,L_a(y-x)$$

- Thus not just one potential, but a *multitude* of them!

The stochastic background field

- The kernels $L_a(y-x)$ are nonlocal on the scale $\ell_{\min}$ with

$$\ell_{\text{Planck}} \ll \ell_{\min} \ll \ell_{\text{macro}}$$

- The number N of fields scales like

$$N \simeq \frac{\ell_{\min}}{\varepsilon}$$

- All potentials A_a^j satisfy the homogeneous wave equation $\Box A_a^j = 0$.

The effective collapse model

- Two important features:
  - The stochastic field is *nonlocal* also *in time*
  - Conservation laws (probability conservation, energy conservation) formualted via *surface layer integrals*, also nonlocal in time.
- Working this out systematically gives
  - Effective *collapse model*
  - More recently: *Energy* of the probe is *conserved*!
