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My research interests

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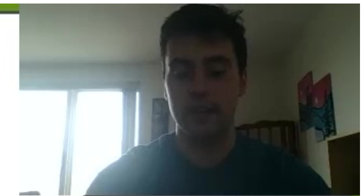
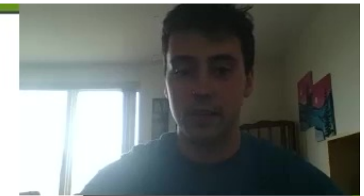
UCL (PhD) $\rightarrow$ PI (Quantum foundations group)

Postdoc welcome event 2021

Studying the interaction between quantum matter and classical things



- Long debate and no-go theorems concerning consistent classical quantum couplings (Feynman 1957 Chapman Hill, Eppley-Hannah 1977 and many others) known to be circumvented (Blanchard-Jadczyk 1993, Diosi 1995 and many others) if one adds noise to the system.
- Define a classical-quantum state $\rho(z)$ as a subnormalized density matrix at each point in phase space $z = (q, p)$. $Tr[\rho(z)] = p(z)$ and $\int dz \rho(z) = \rho_Q$. Normalization $\int dz Tr[\rho(z)] = 1$.
- Consistent classical-quantum dynamics acts linearly on the CQ states, preserves classical-quantum split, is CP on the quantum system and preserves probabilities.



In fact, can do better, we now know the most general form of map defining consistent classical-quantum dynamics (Poulin 2017, Oppenheim 2018).

CQ

Dynamics: $\varrho(z,t) = \int dz' \Lambda^{\mu\nu}(z \mid z', t) L_\mu \varrho(z', 0) L_\nu^\dagger$
Normalization: $\int dz \sum_{\mu\nu} \Lambda^{\mu\nu}(z \mid z', t) L_\nu^\dagger L_\mu = \mathbb{I}$
Positivity: $\Lambda^{\mu\nu}(z|z',t)$ positive matrix for each z, z'

natural generalization of the classical and quantum cases

Classical

Dynamics: $p(z,t) = \int dz' P(z \mid z', t) p(z', 0)$
Normalization: $\int dz P(z \mid z') = 1$
Positivity: $P(z|z')$ positive for each z, z'

Quantum

Dynamics: $\sigma(t) = \sum_\mu \lambda^{\mu\nu} L_\mu \sigma(0) L_\nu^\dagger$
Normalization: $\sum_\mu \lambda^{\mu\nu} L_\nu^\dagger L_\mu = \mathbb{I}$
Positivity: $\lambda^{\mu\nu}$ positive matrix

And when the dynamics is Markovian, the most general form of master equation

CQ

Master Equation:

$$\frac{\partial \varrho}{\partial t} = \int dz' W^{\mu\nu}\left(z \mid z'\right) L_\mu \varrho\left(z'\right) L_\nu^\dagger - \frac{1}{2}\left\{\int dz' W^{\mu\nu}\left(z' \mid z\right) L_\nu^\dagger L_\mu, \varrho(z)\right\}$$

Positivity: $\Lambda^{\mu\nu}\left(z \mid z', \delta t\right) = \begin{bmatrix} \delta\left(z, z'\right) + \delta t W^{00}\left(z \mid z'\right) & \delta t W^{0\beta}\left(z \mid z'\right) \\ \delta t W^{\alpha 0}\left(z \mid z'\right) & \delta t W^{\alpha\beta}\left(z \mid z'\right) \end{bmatrix}$

a positive matrix

Classical

Master equation: $\frac{\partial p}{\partial t} = \int dz' W\left(z \mid z'\right) p\left(z'\right) - \int dz' W\left(z' \mid z\right) p(z)$

Positivity: $\delta(z, z') + \delta t W(z|z')$ positive

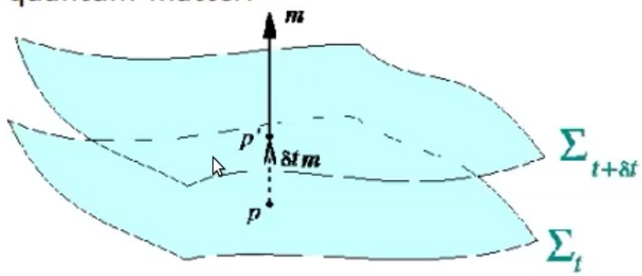
Quantum

Master equation: $\frac{\partial \sigma}{\partial t} = -i[H, \sigma] + h^{\alpha\beta} L_\alpha \sigma L_\beta^\dagger - \frac{1}{2}\left\{h^{\alpha\beta} L_\beta^\dagger L_\alpha, \sigma\right\}$

Positivity: $h^{\alpha\beta}$ positive matrix

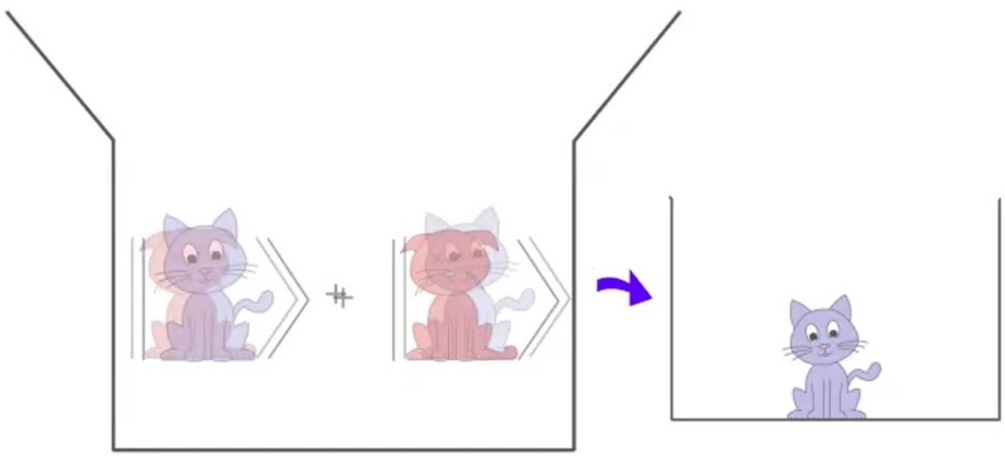
Some research questions

- Try and apply to gravity: taking the phase space degrees of freedom to be g_{ab}, π^{ab} one can propose a consistent theory of classical gravity interacting with quantum matter.



- In the gravitational context the theory could be treated as effective, or fundamental. As such, we can revisit the question of whether we need to quantize gravity, or, can we show in a concrete framework that theories which treat gravity as fundamentally classical are experimentally ruled out?

- If gravity is classical, then its dynamics should be Markovian and described by a classical-quantum master equation. Can we use these general properties of the dynamics to get experimental predictions of treating the gravitational field as being fundamentally classical (and perhaps experimentally rule it out within a concrete framework)




Thank
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