Some ideas on thermal and out-of-time-order physics

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Simons Collaboration Meeting

December 8, 2016
Mixed state systems

- Dynamical open systems, low energy field theory (or gravity), subsystem evolution, ...

- Consider mixed state evolution
- Lorentzian dynamics (possibly far from stationary)
- Fluctuations, dissipation, apparent non-unitarity ('information loss'), ...
Out-of-time-order (OTO) correlators

- To approach such complications, consider contour-ordered correlators, e.g.,
  - 1 leg: Schwinger-Keldysh formalism
  - 2 legs: ‘chaos correlator’ [Maldacena-Shenker-Stanford,...]
  - $k$ legs: interesting ‘higher OTO physics’? [Roberts-Yoshida,...]

- Systematically explore symmetries of $k$-OTO contour, e.g.:

\[
\langle \mathcal{O}(t_1)\mathcal{O}(t_3)\mathcal{O}(t_4)\mathcal{O}(t_2) \rangle = \langle \mathcal{O}(t_1)\mathcal{O}(t_3)\mathcal{O}(t_2)\mathcal{O}(t_4) \rangle
\]

- Such identities are consequence of **unitarity**
  - Sounds rather basic, but turns out to be very constraining
Low-energy dynamics of thermal systems

- Gravity with horizons, black holes, fluids, ...

**Thermal equilibrium:**

- Euclidean time circle

Proposal for studying **perturbations, dissipation, etc.**:

- Universal $U(1)_T$ symmetry of ‘thermal diffeomorphisms’
- $U(1)_T$ charge = entropy

- ‘1-OTO $U(1)_T$ Ward identity’ $\Rightarrow$ 2nd law. $k$-OTO analogue?

- Connection with emergent time reparametrization symmetry in **SYK model**?
Also ask me about

- Constraints from entanglement inequalities in boundary and bulk
- Second law for non-stationary black holes in quantum gravity ‘toy models’
- Hydrodynamics, effective actions
- Kinematic space

Thank you!