How Many Angels Can Dance on the Head of a Black Hole?

Tom Banks (work with W.Fischler)

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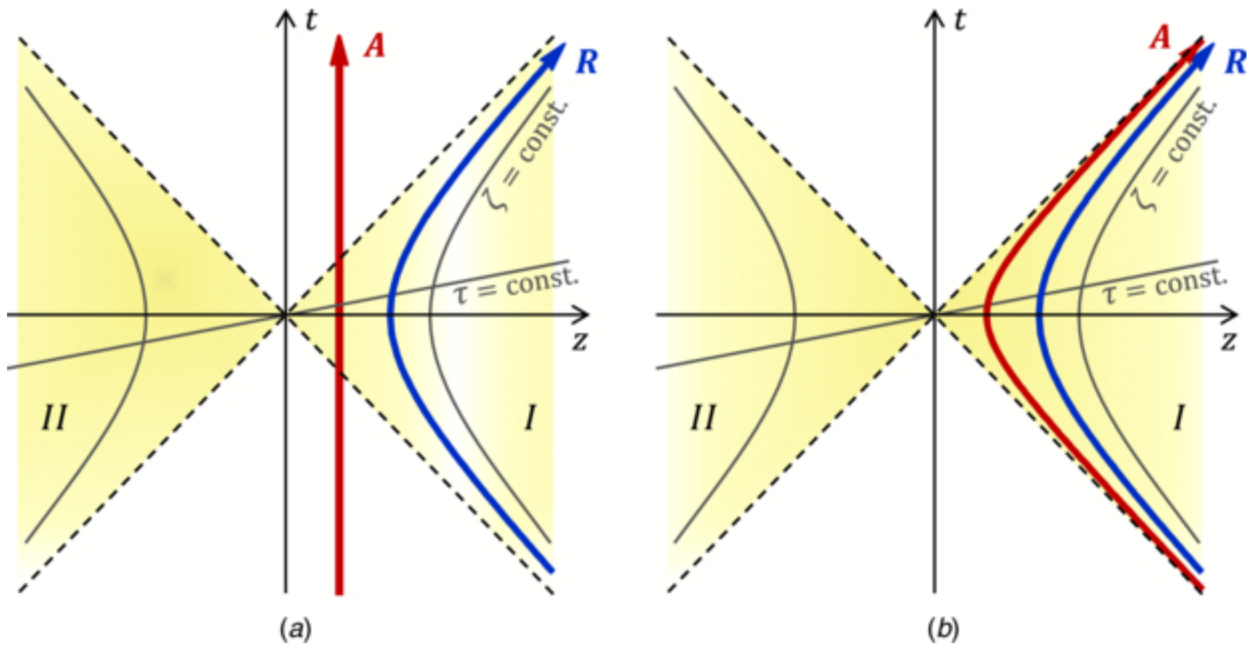
- Hawking uses QFT to demonstrate temp. and get the coefficient $S = A/4L_P^2$, $L_P^2 = G_N\hbar/c^3$.
- Geometric (but not quantum) understanding via Unruh, Gibbons and Hawking: GH show similar phenomenon for de Sitter horizon.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- Condition for no Black Hole formation $S \leq (R/L_P)^{3/2}$
- QFT/particle physics can't account for black hole entropy.

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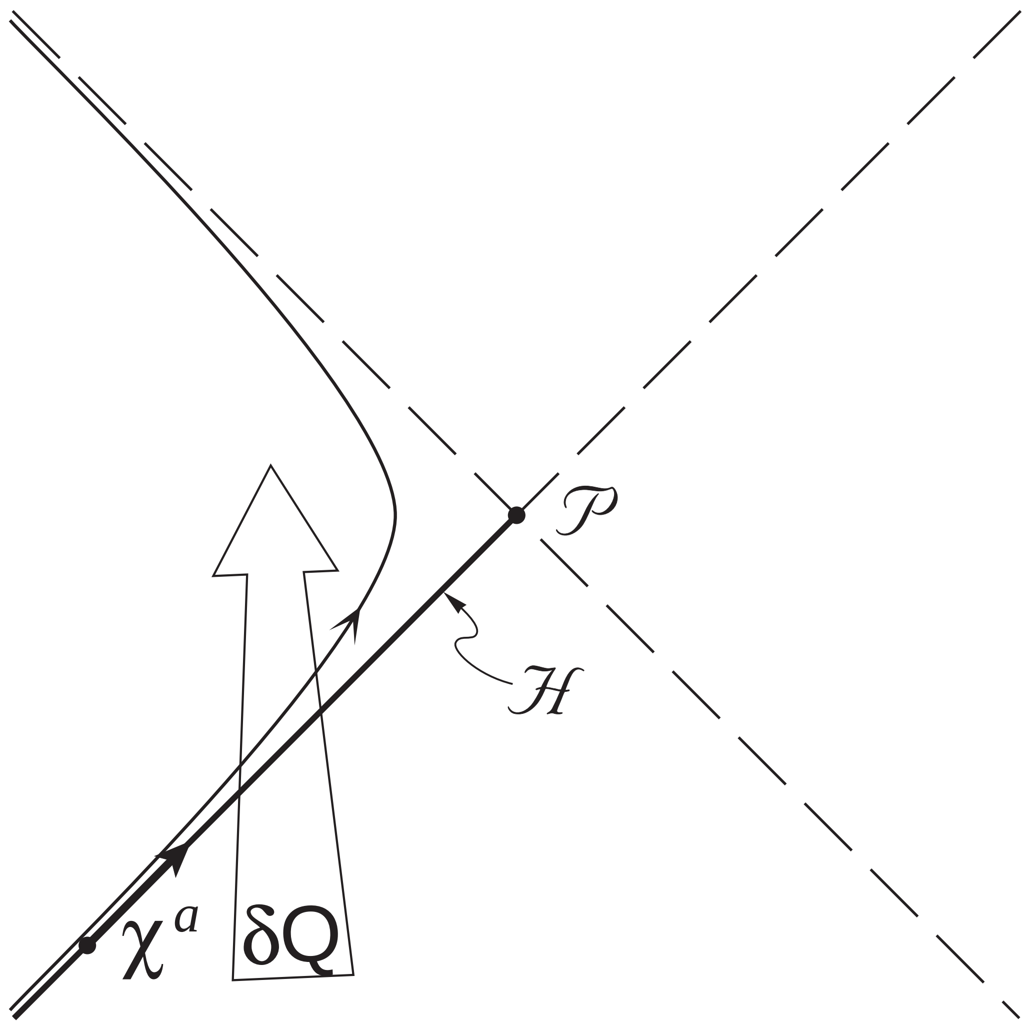
- That is *Einstein's Equations (with cosmological constant undetermined) are the hydrodynamics of any quantum system obeying the area law!*
- Implies QFT (in string theory we learn that all of QFT follows from the supersymmetric generalization of Einstein's equations in 11 dimensions) should only be quantized when discussing small fluctuations around the ground state.



$\mathcal{P}$
$\mathcal{H}$
χ^a
δQ

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- Bousso (also TB-Fischler): entropy must be interpreted as log of dimension of the Hilbert space of the diamond.
- Much of this was anticipated in Jacobson's paper.

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$$ds^2 = -(1 - \frac{R_S}{r} \pm \frac{r^2}{R^2})dt^2 + \frac{dr^2}{(1 - \frac{R_S}{r} \pm \frac{r^2}{R^2})} + r^2 d\Omega^2.$$

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- That is, Localized excitation *decreases* entropy of dS. Entropy deficit is Boltzmann's law $\Delta S = -\frac{Mc}{2\pi\hbar R}$, at GH temp.
- Leads to asymptotic energy conservation law in Minkowski ($R \to \infty$) limit.

Holographic Cosmology

- Principle that local excitations are constrained states of variables on the horizon, with a number of constraints $\sim N = R/L_P \ll N^2$ has profound implications for early universe cosmology. Explains Boltzmann-Penrose question of why the universe began in a low entropy state.

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- Leads to a finite, quantum mechanical theory of inflation, more constrained than QFT models, and with no conceptual ("trans-Planckian mode") problem.
- Holographic theory explains current data as well as QFT models, but gives different results for tensor (B mode) correlation functions. Unfortunately these are not yet measured and theory predicts them to be small.

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- Splitting in super multiplets $\sim \sqrt{m_{3/2} M_P} \sim a\ few\ \ TeV$.

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- Space-time is not a fluctuating quantum variable, but instead a representation of the hydrodynamics of the underlying quantum system.
- Localized excitations are constrained low entropy states of that system.
- Implications for the early universe, tensor fluctuations in the CMB, as well as TeV scale physics and supersymmetry.