Revisiting the C^0-formulation of the strong cosmic censorship conjecture

Alexander Y. Yosifov

Huawei Hong Kong Research Center, 2012 Labs

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Outline

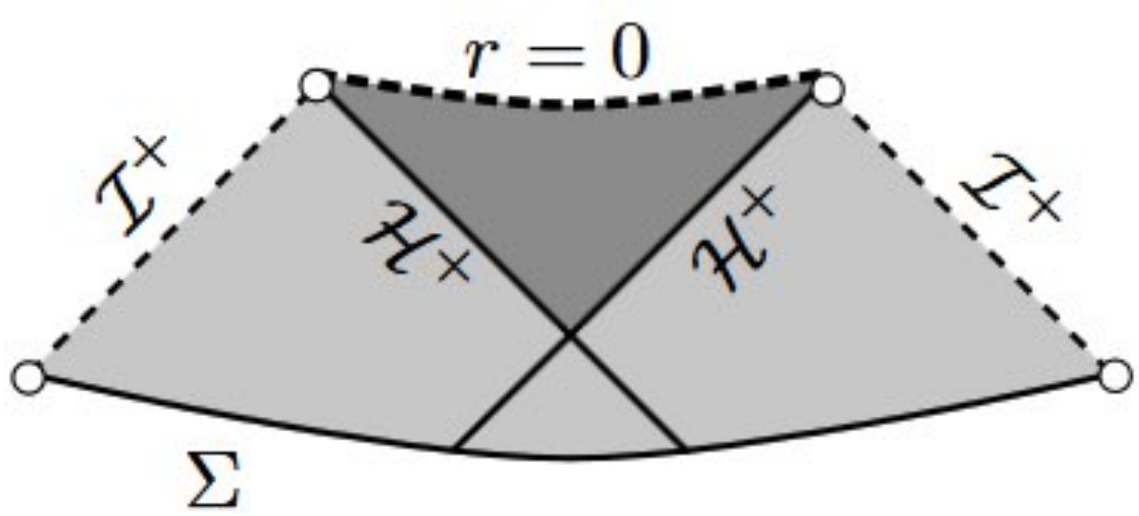
1. Schwarzschild as a future Cauchy development

2. Kerr as a (maximum) future Cauchy development

3. C^0-form of the censorship conjecture

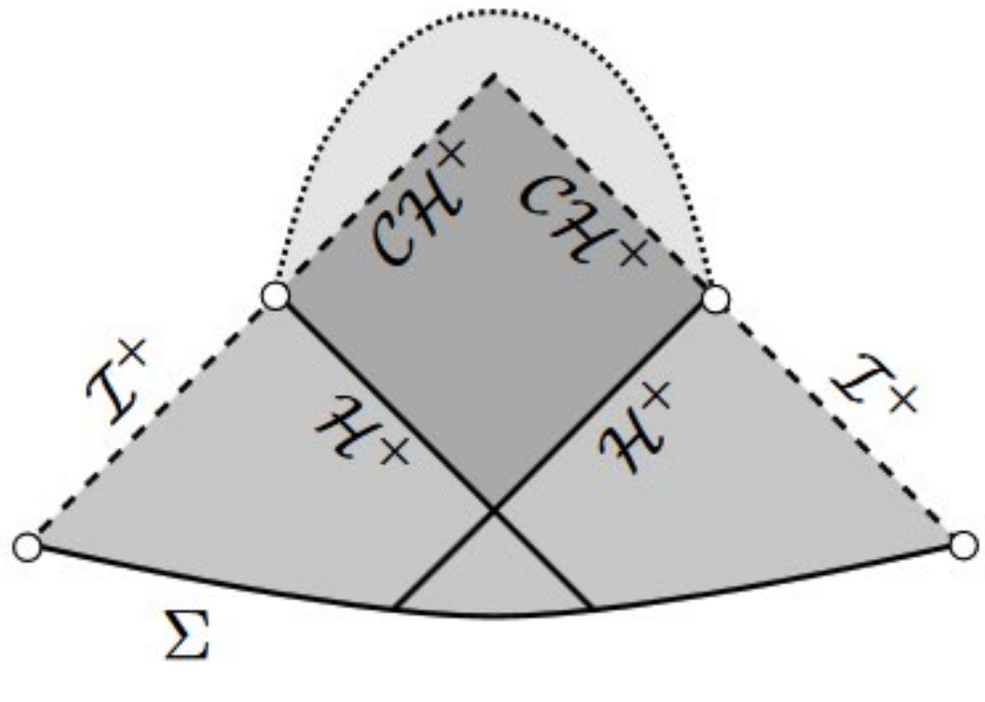
4. Complexity-theoretic approach

Schwarzschild



- Spacetime is inextendible across $r = 0$
- Timelike geodesics γ are incomplete (the future is uniquely determined)
- Future null infinity $\mathscr{I}^+$ is complete, Penrose 1969

Kerr



- Maximal Cauchy development in $\mathscr{M}\backslash J^-(\mathscr{I}^+)$ is **non-uniquely** extendable
- Breakdown of global hyperbolicity (lack of future determinism)
- Σ is no longer the Cauchy surface

C^0-form of the censorship conjecture

Global non-hyperbolicity in general relativity is pathological.

Strong cosmic censorship: Initial data uniquely determines the future (Penrose, 1972).

A statement of uniqueness & determinism.

Conjecture (C^0-form of strong cosmic censorship): The maximal Cauchy evolution of generic asymptotically flat vacuum initial data is **inextendable** to a larger C^0 Lorentzian manifold $\mathscr{M}$ across the Cauchy horizon $C\mathscr{H}^+$.

C^0-form of the censorship conjecture

Theorem (Dafermos-Luk, 2017): Consider general vacuum initial data corresponding to the expected induced geometry of a dynamical black hole settling down to Kerr (with parameters $0 < |a| < M$) on a suitable spacelike hypersurface Σ in the black hole interior. Then the maximal future development of the spacetime $(\mathscr{M}, g)$ corresponding to Σ is globally covered by a double null foliation and has a non-trivial Cauchy horizon $C\mathscr{H}^+$ across which the metric is **continuously extendable**.

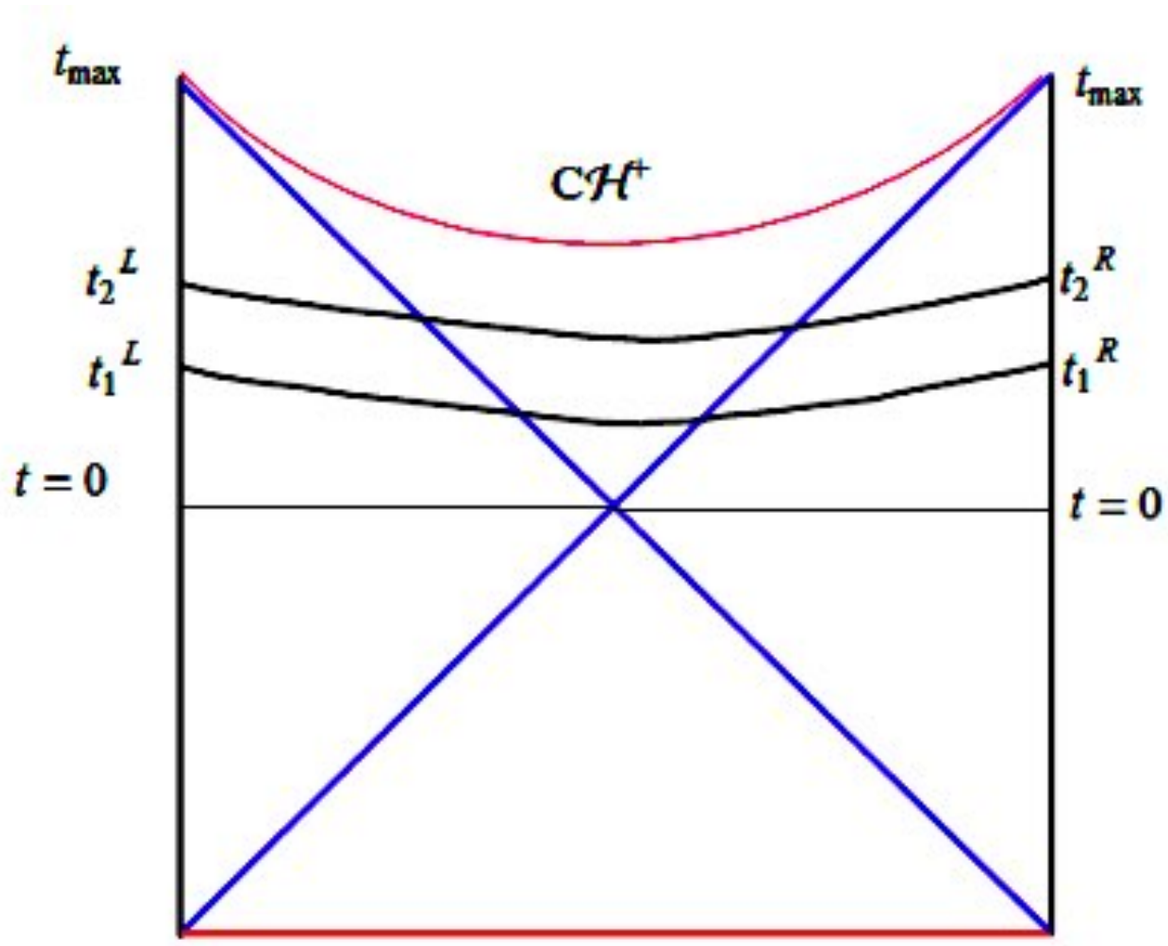
The C^0 SCC is false!

More C^0-stability results: Dafermos 2003, Moortel 2018, Chesler 2019.

Quantum complexity-theoretic approach

What would a hypothetical validity of the C^0 SCC conjecture mean from a quantum complexity-theoretic perspective?

- ❑ Cauchy evolution is spacelike
- ❑ Timelike geodesics γ cannot reach $\tilde{\mathcal{M}} \setminus \mathcal{M}$



Low-temperature hyperbolic black hole

Consider a $d+1$ hyperbolic AdS black hole with $\mathbb{R}^2 \times \mathrm{S}^{d-1}$ topology

$$ds^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + \frac{r^2}{l^2}d\Sigma_{d-1}^2 \quad , \quad f(r) = -1 + \frac{r^2}{l^2} - \frac{M}{r^{d-2}}$$

The volume of the maximal $r = const.$ spacelike hypersurface is given by $r^{d-1}\sqrt{|f(r)|}$.

In the interior, $f(r)$ takes the form $r^{d-1}\sqrt{\left|1 - r^2 + \frac{M_{\min}}{r^{d-2}}\right|}$ and maximizes at $\rho_v \in (r_-, r_s)$.

The C^0 SCC conjecture violates the CV-duality for low-temperature hyperbolic black hole solutions in AdS_{d+1}/CFT_{d-1}

Thank you!