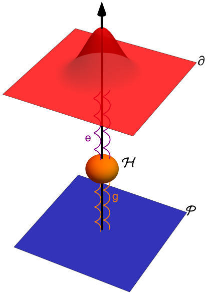
Violating weak cosmic censorship in AdS_4

Jorge E. Santos
NBI Current Themes in High Energy Physics and Cosmology



In collaboration with
T. Crisford, G. T. Horowitz, N. Iqbal, B. Way

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Weak cosmic censorship (Penrose 69 - page 1162 and 1164):

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Weak cosmic censorship (executive summary):

Is it possible to **form a region of arbitrarily large** curvature that is visible to **distant observers**?

Operationalising 2/2:

Weak cosmic censorship (Geroch and Horowitz 79):

Let (Σ, h_{ab}, K_{ab}) be a geodesically complete, **asymptotically flat**, initial data set. Let the matter fields obey second order **quasi-linear hyperbolic** equations and satisfy the **dominant energy condition**. Then, generically, the maximal development of this initial data is an asymptotically flat spacetime (in particular $\mathcal{I}^+$ **is complete**) that is strongly asymptotically predictable.

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Claims to fame - Gregory Laflamme type - $d \geq 5$:

Lehner, Pretorius '10 - Black String

Figueras, Kunesch, and Tunyasuvunakool '16 - Black Rings

Figueras, Kunesch, Lehner, and Tunyasuvunakool '17 - Myers-Perry

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Wish list:

Remain in **4D**, and start in the **vacuum of the theory**.

1 Setup

2 Adiabatic approximation: $\mathcal{A}(t) = \mathcal{A}$

3 The Conjecture

4 Violation of the Weak Cosmic Censorship Conjecture

5 Results

6 Conclusion & Outlook

The bulk theory we study is governed by the action

$$S = \frac{1}{16\pi G} \int \mathrm{d}^4x \, \sqrt{-g} \left[R - F^{ab} F_{ab} + \frac{6}{L^2} \right] ,$$

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- At $T=0$, moduli space of solutions is **1D**: $a_0(t) \equiv \mathcal{A}(t)\sigma$.

Adiabatic approximation: $\mathcal{A}(t) = \mathcal{A}$

G. T. Horowitz, N. Iqbal, JES, B. Way '14

M. Blake, A. Donos, D. Tong '14

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A simple criterion:

$\alpha < 1$: impurity destroys the IR, *i.e.* is relevant.
$\alpha = 1$: impurity marginally deforms the IR.
$\alpha > 1$: impurity should be irrelevant in the IR.

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  - In simple examples one can show that $G = 0 \Leftrightarrow G^H = 0$.

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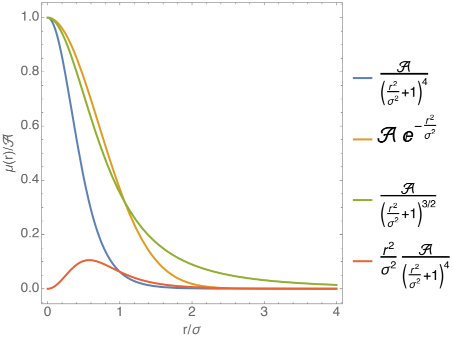
    - In practice, trust ellipticity: solution locally unique.
    - Equations of motion solve for gauge defined by $\xi = 0$.

The irrelevant case 1/5

We have considered many distinct profiles for the irrelevant case, *e.g.*:



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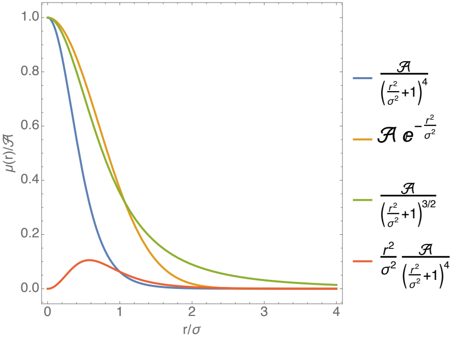

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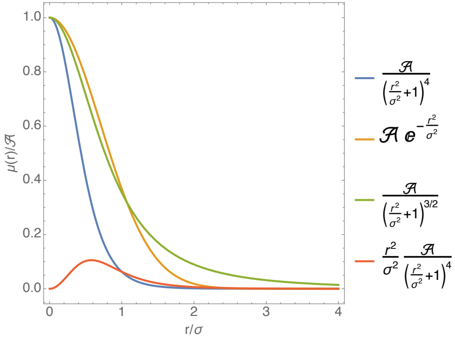

- For all of the profiles above, we find that there is a maximum value for $a \equiv \mathcal{A}\sigma$ ($a_{\max}$) beyond which we cannot find a regular solution.
- In all cases, the IR geometry is always AdS_4 - irrelevant.

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Static orbits:

We searched for locus in our manifold where

$$U^a \nabla_a U_b = \frac{q}{m} F_{ba} U^a \quad \text{with} \quad U_a U^a = -1\,,$$

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- If the minimum is absolute, the solution should play a role even at finite N, *i.e.* not a large N artefact.

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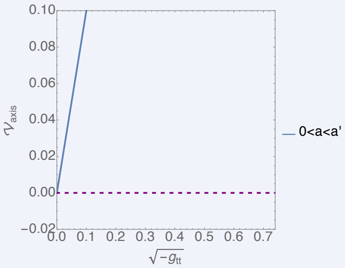

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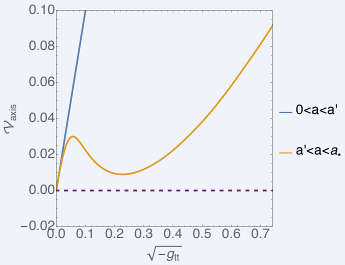

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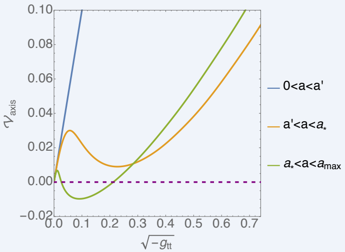

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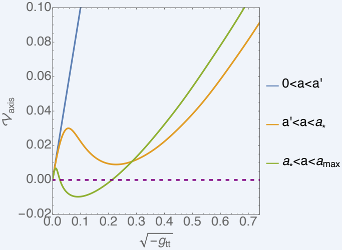

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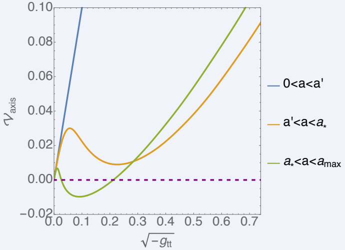

Can we go beyond the probe approximation and construct the solutions where the extremal hole hovers the Poincaré horizon?

The irrelevant case 4/5

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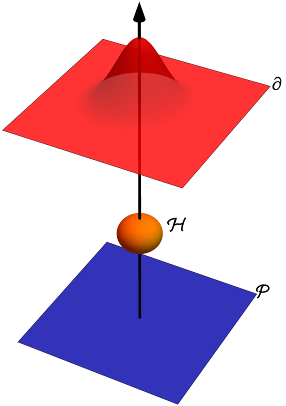

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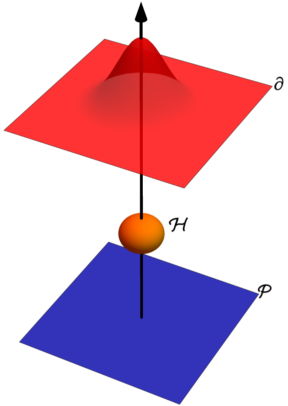
- Why do they exist in the first place?



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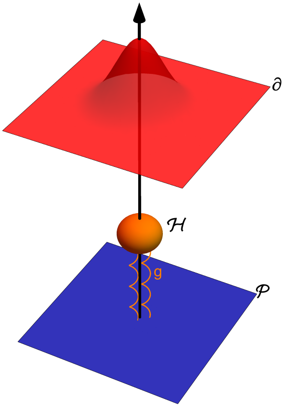

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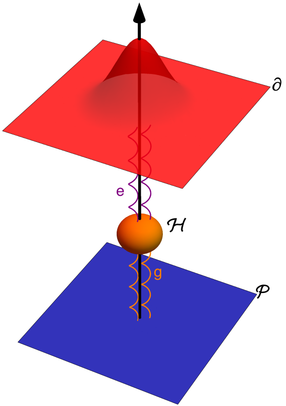

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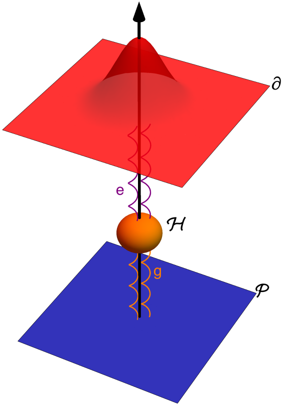

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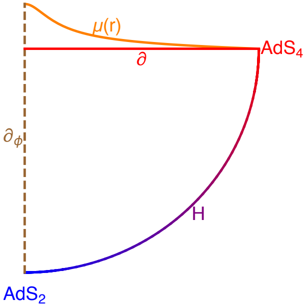

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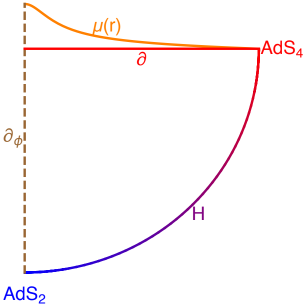

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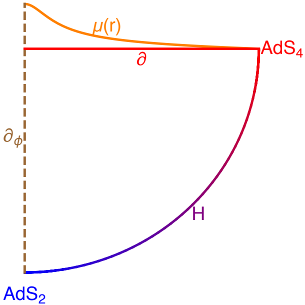

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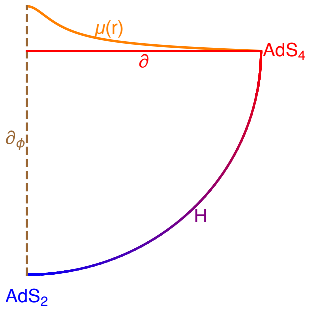
- Also have a maximum amplitude $a_{\max}$ which can be computed analytically.



The conjecture

G. T. Horowitz, JES, B. Way '16

The conjecture 1/2

- Impose **boundary electric profile** (with $\alpha \geq 1$):

$$f = \frac{a(t)\, r\, \alpha}{\sigma^2 \left(1 + \frac{r^2}{\sigma^2}\right)^{\frac{\alpha}{2}+1}} \mathrm{d}t \wedge \mathrm{d}r \,.$$

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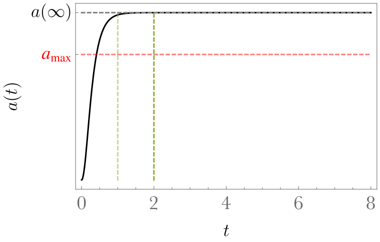

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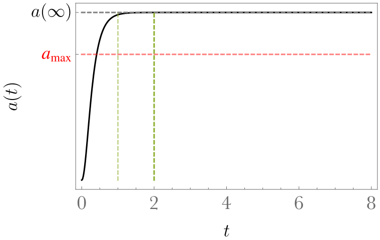

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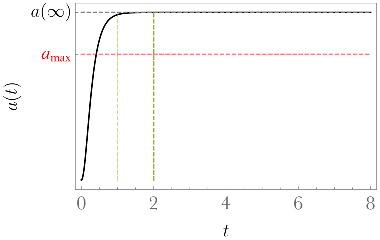

- Smallest $a_{\mathrm{max}} \approx 0.678$ occurs for $\alpha = 1$.

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Possible outcomes:

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Conjecture - G. T. Horowitz, JES, B. Way '16:

For $a(\infty) > a_{\max}$, the resulting time evolution leads to **arbitrarily large curvatures** at late times, which are visible to boundary observers: **weak cosmic censorship is violated**.

Violation of the Weak Cosmic Censorship Conjecture

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Easier said, than done! Thankfully (or foolishly),

Toby Crisford was ready to embrace this!

Back to basics - 1/2:

$$\mathrm{d}s^2 = \frac{L^2}{z^2}\left[-\left(1-\frac{z^3}{z_+^3}\right)\mathrm{d}t^2 + \frac{\mathrm{d}z^2}{1-\frac{z^3}{z_+^3}} + \mathrm{d}r^2 + r^2\mathrm{d}\varphi^2\right].$$

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5. The **intersection of the horizon** with a partial Cauchy surface with $v = \mathrm{const.}$ is uniquely parametrised by (r, φ).

Back to basics - 2/2:

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5. r is a **bad** coordinate on the **intersection of the horizon** with a partial Cauchy surface with $v = \mathrm{const.}$, since $g_{rr} \to 0$ as $z \to +\infty$.

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Change coordinates:

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1. $\rho = 0$ is $\mathcal{H}^+$, and θ is a **good coordinate** on the horizon!
2. However, it is a **bad time coordinate** at the boundary: characteristics **all intersect** at $\rho = \infty$!

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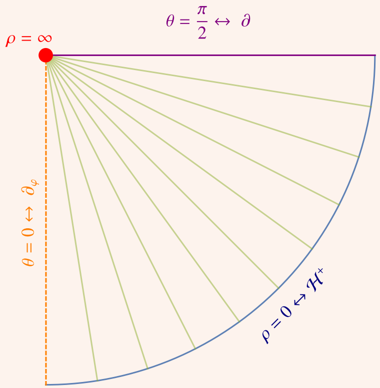

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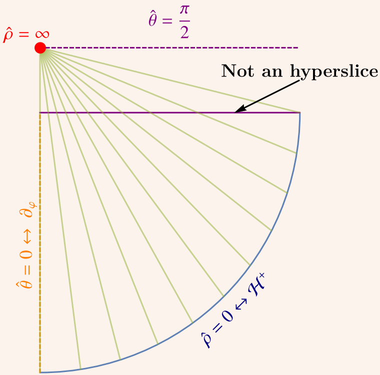

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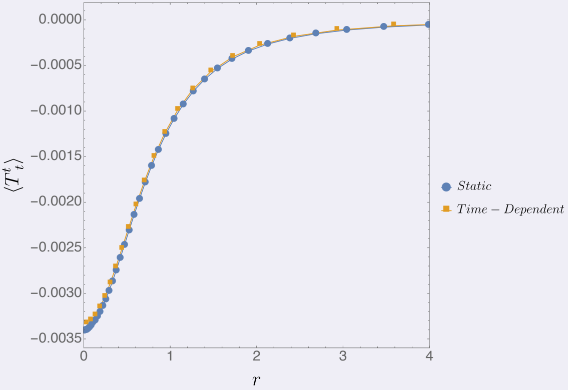
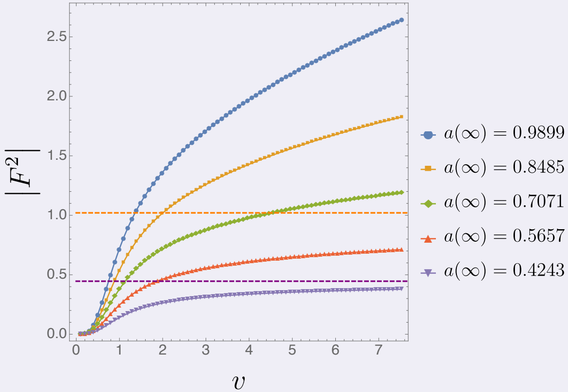


Matching old results with a time-dependent code!

Results 2/2: $a > a_{\text{max}}$:



F^2 is measured at the apparent horizon, and along the axis of symmetry.

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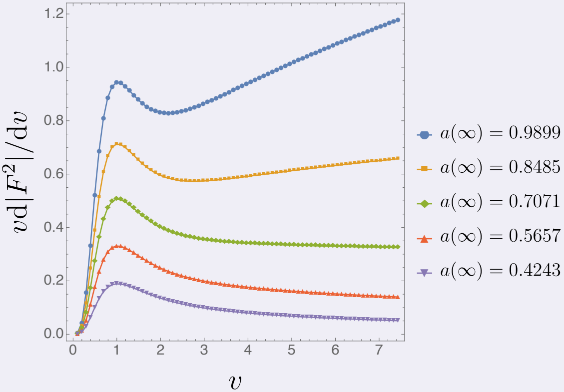

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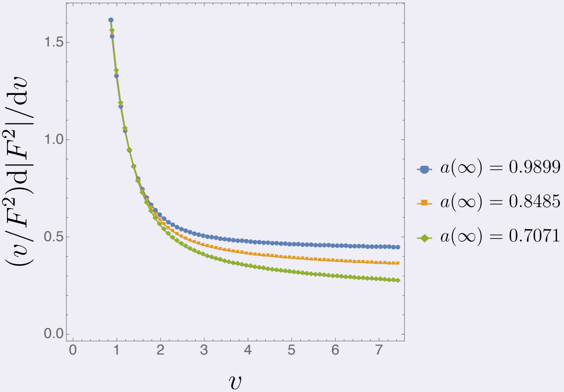

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4. At $t = 0$ **vacuum state of the theory**: inject finite energy.

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Outlook:

- What is the field theory interpretation of this phenomenon?

Preliminary results - Crisford, Horowitz and Santos:

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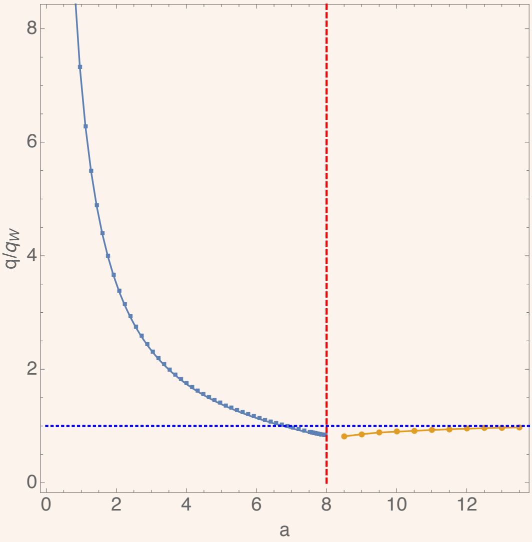

Thank You!