Exploring Cosmic Censorship in a Dual Collider

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September 5, Eurostrings 2024, Southampton

Based on upcoming work with *M. Aragonès Fontboté, D. Mateos, G. Pérez Martín and W. van der Schee*

Utrecht University

Motivation

General Relativity is an effective theory of gravity,

$$S = \frac{M_{\mathrm{P}}^2}{16\pi} \int \sqrt{-g}\, R$$

- It will break when curvature invariants become large,
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Nature, however, seems to hide these regions behind horizons (**Cosmic Censorship**).

Is there any system where curvature corrections become relevant?

Violations of Cosmic Censorship

In 4D, **critical collapse** [*Choptuik;* ***Phys. Rev. Lett. 70, 9***]

Initial overdensity

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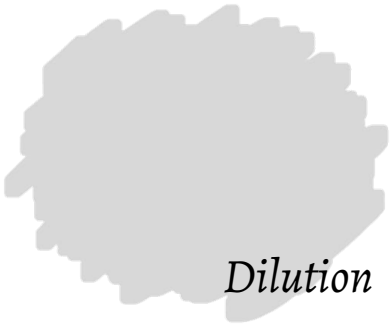
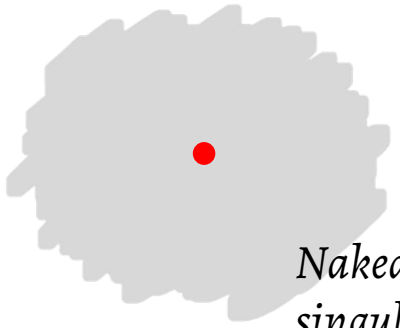
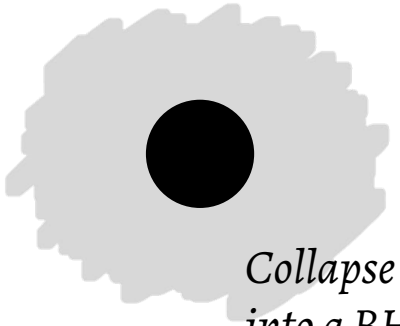


Dilution



Naked singularity



Collapse into a BH

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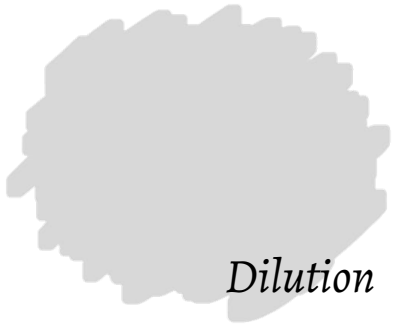

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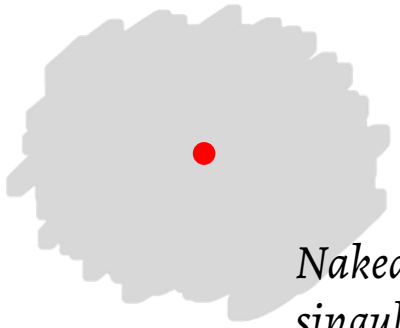

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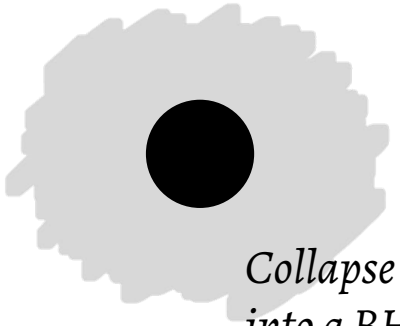
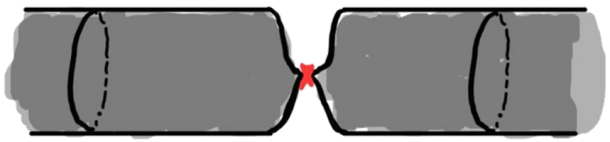


Collapse into a BH

In higher dimensions, Gregory-Laflamme instability

[*Gregory, Laflamme;* ***hep-th/9301052***], [*Lehner, Pretorius;* ***1006.5960***], [*Figueras, França, Gu;* ***2210.13501***]



Question:

Is there any situation where curvature invariants grow over
an extended region of spacetime, without fine-tuned initial conditions?

Yes, simple, robust.

See also [*Crisford, Horowitz, Santos;* **1709.07880**], [*Horowitz, Santos, Way;* **1709.07880**].

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Contents:

- The model,
- Dynamical evolution,
- Growth of curvatures at the horizon.

See also [*Crisford, Horowitz, Santos;* **1709.07880**], [*Horowitz, Santos, Way;* **1709.07880**].

The model

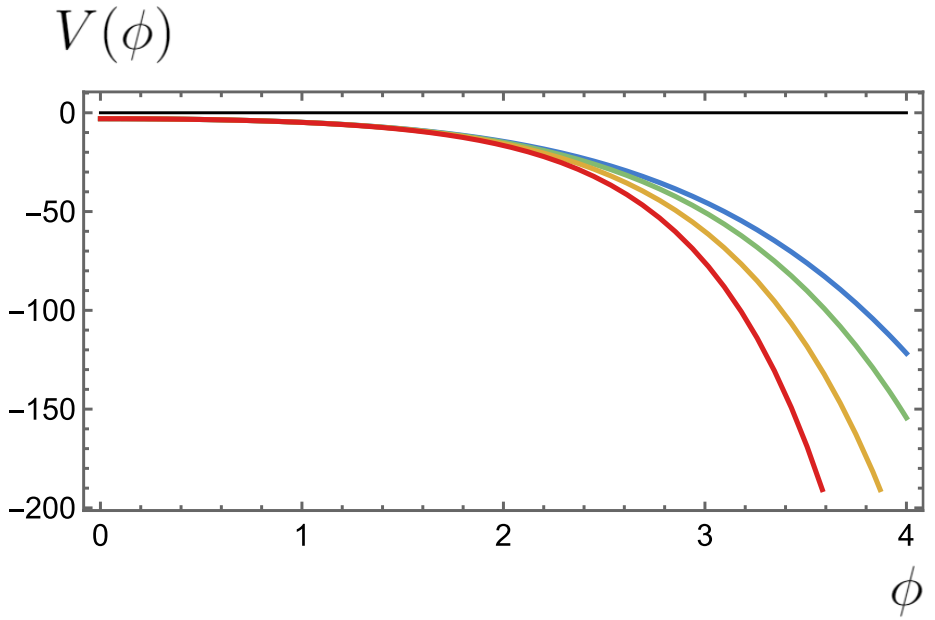
Consider

$$S = \frac{2}{\kappa_5^2}\int_{\mathrm{M}} \mathrm{d}^5x\sqrt{-G}\left(\frac{R}{4} - \frac{1}{2}\partial_M\phi\partial^M\phi - V(\phi)\right)$$

The potential is such that:

- Maximum at $\phi = 0$. **AdS** (dual UV CFT)
- $m^2 = -3/L^2$ (source Λ)
- Exponential fall-off

$$V(\phi) \propto -e^{4\gamma\phi}$$



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$$V(\phi) \propto \frac{1}{2}m^2\phi^2$$

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- **If you worry about how motivated this is:**
  This is generic in String Theory compactifications.

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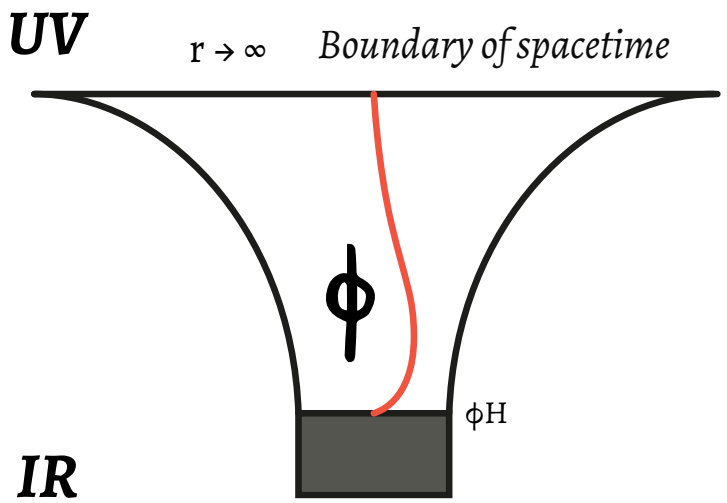
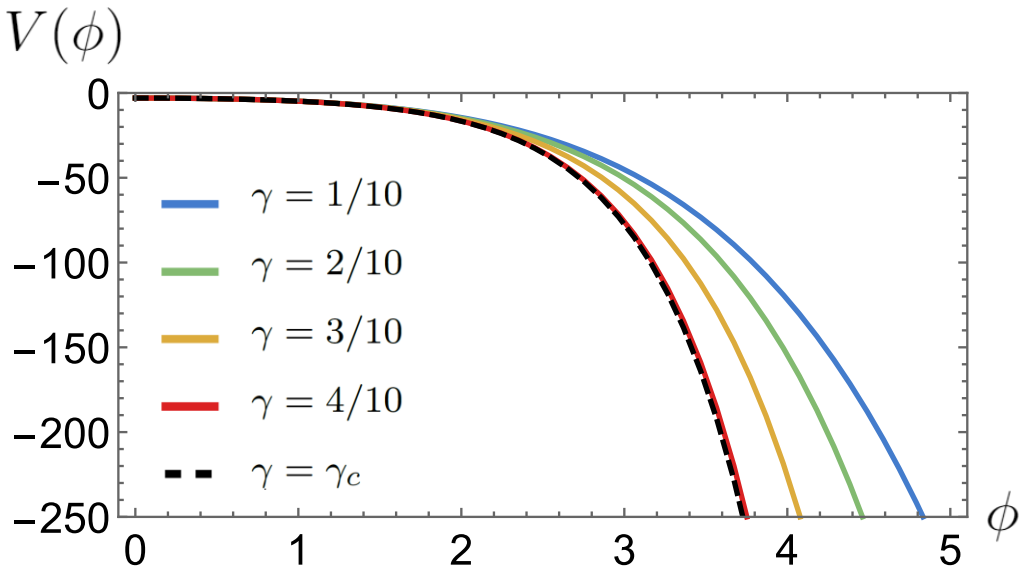
- **If you worry about positivity theorems:**
  The stability of the background is protected by SUSY.

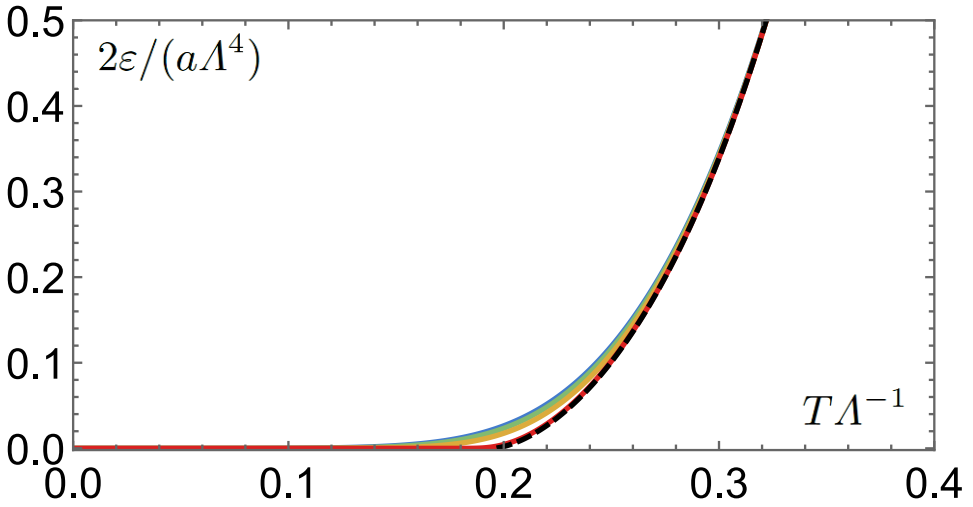
Thermodynamics





Related to properties of black brane solutions:

- horizon area ~ entropy (***s***),
- surface gravity ~ temperature (***T***) ,
- mass ~ energy (***ε***) ,
- on-shell action ~ pressure (***p***),



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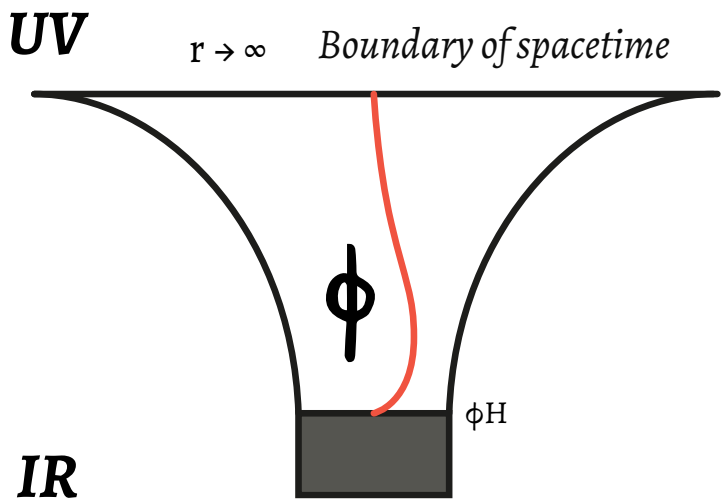

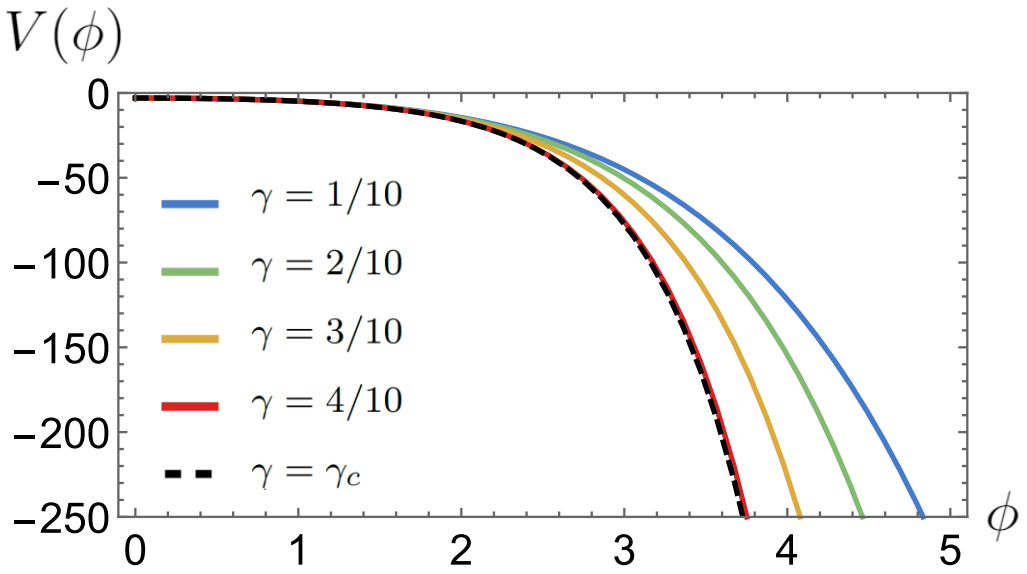

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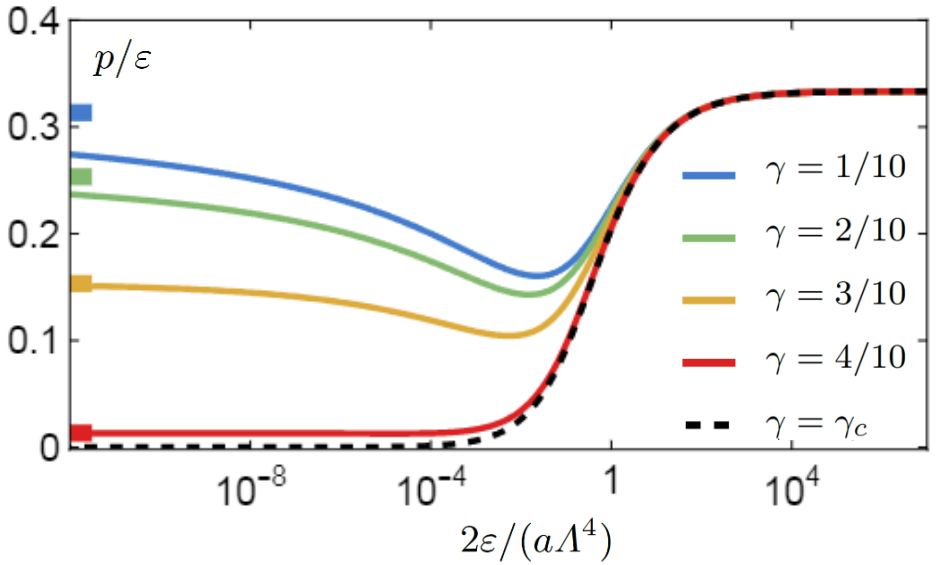

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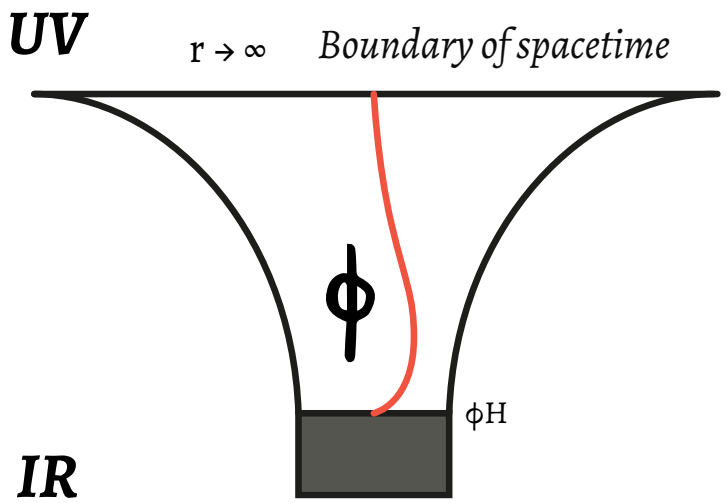
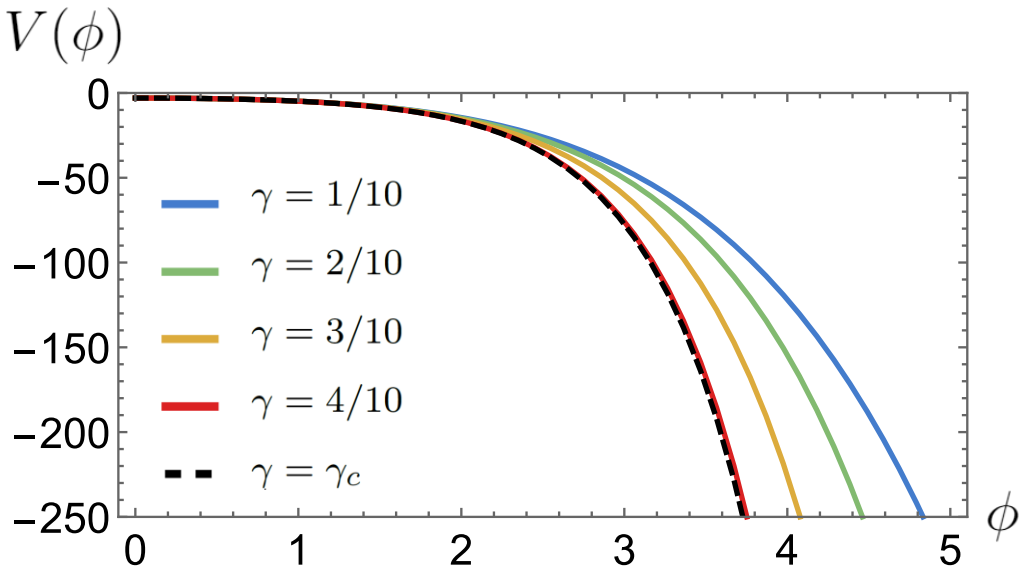
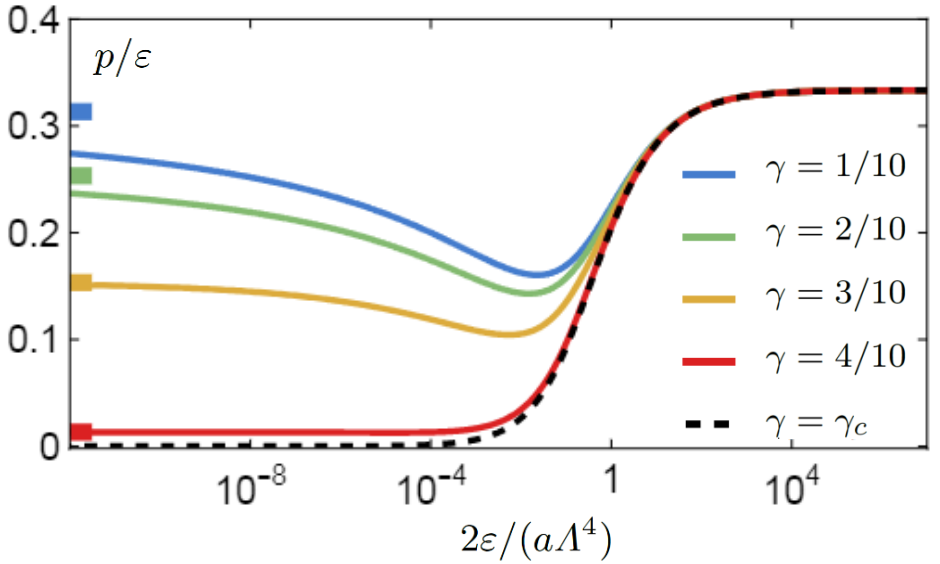




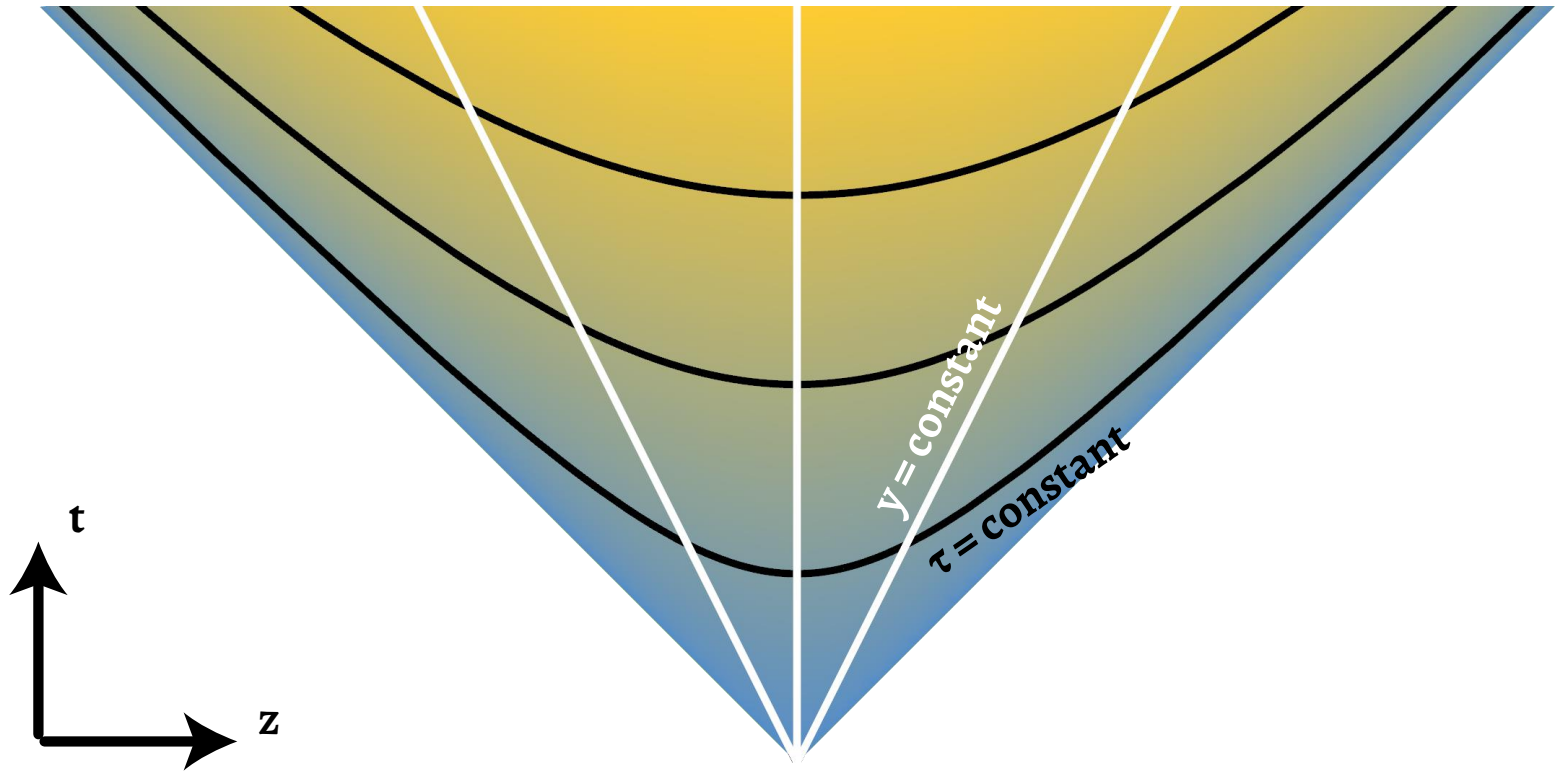
Low temperature solutions have growing curvatures at the horizon.

- Can we reach this region dynamically?



Boost-invariant dynamics

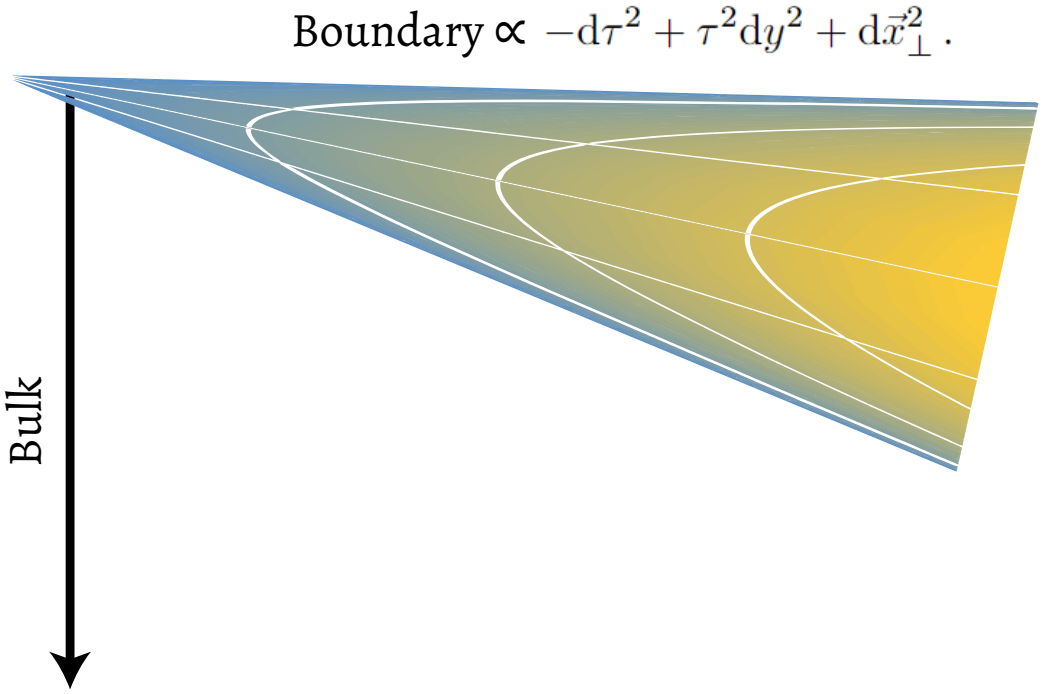
We can force the fluid to expand ➡ *Boost-invariant setup*.



Full dynamical evolution

We look for a 5D metric such that:

- It is asymptotically AdS,
- Asymptotically conformally flat and,
- Boost – invariant.



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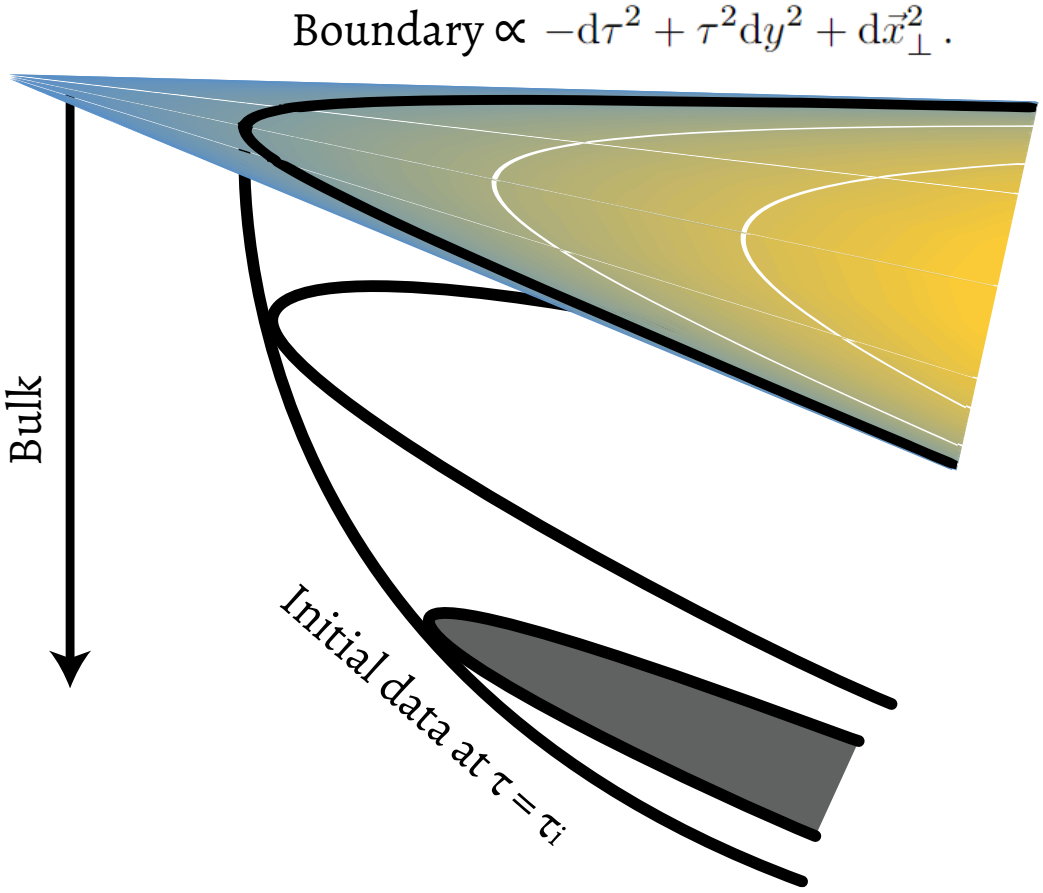

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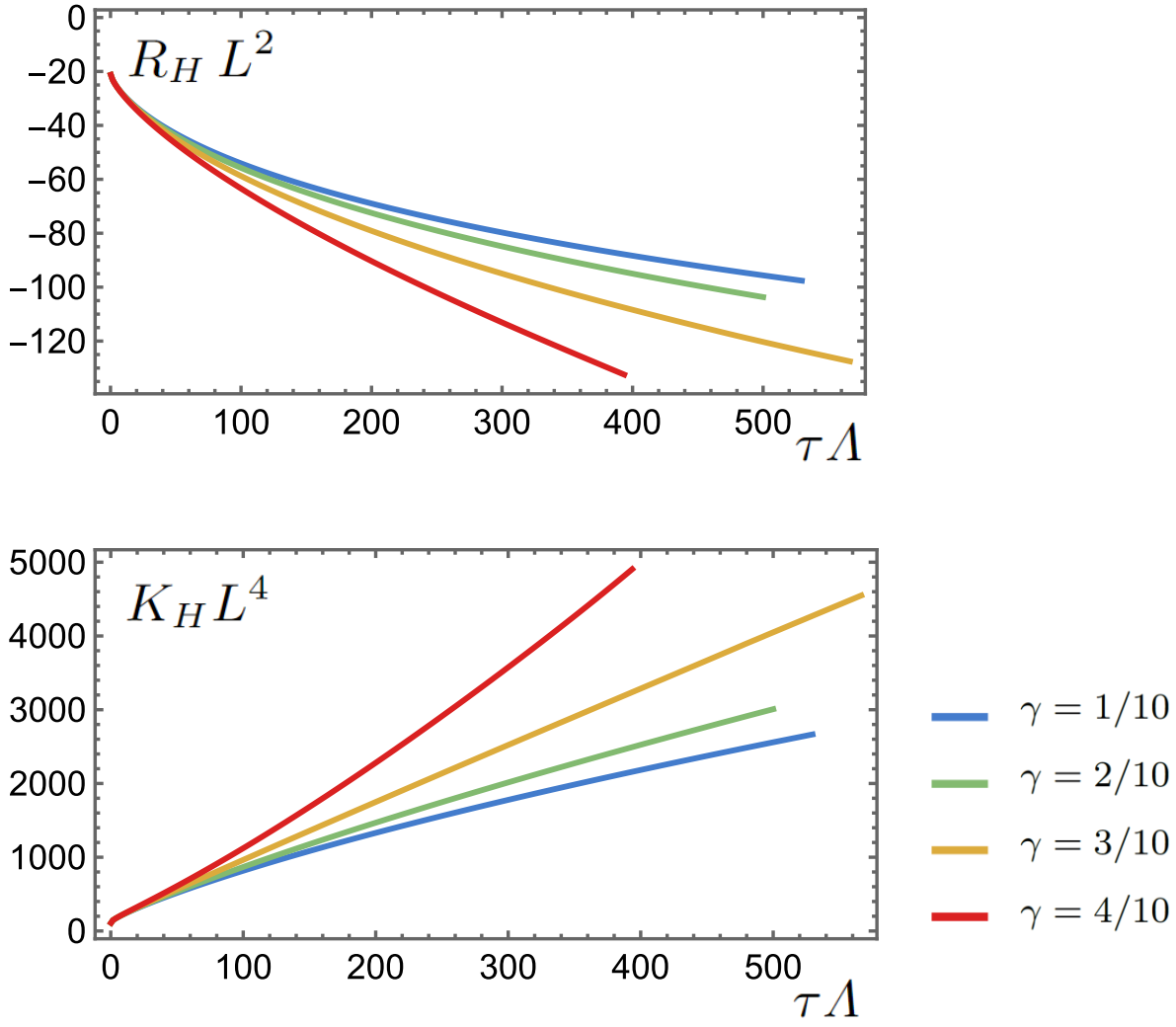
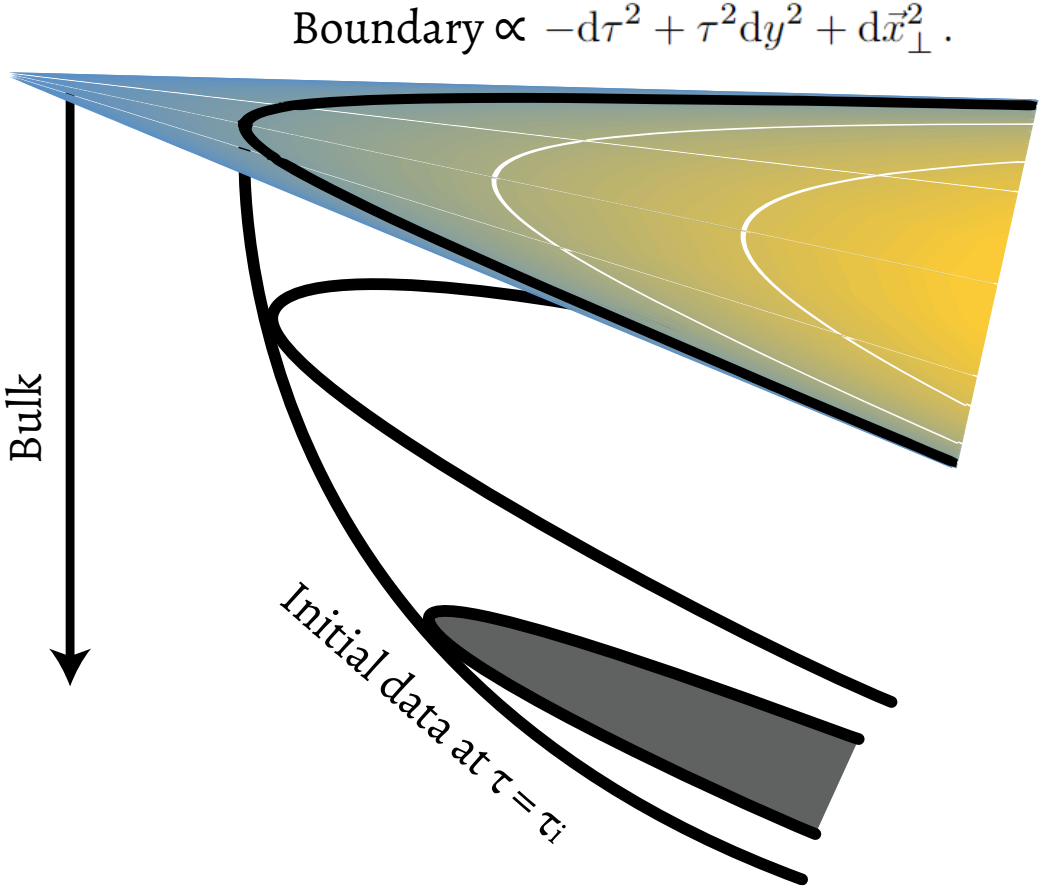
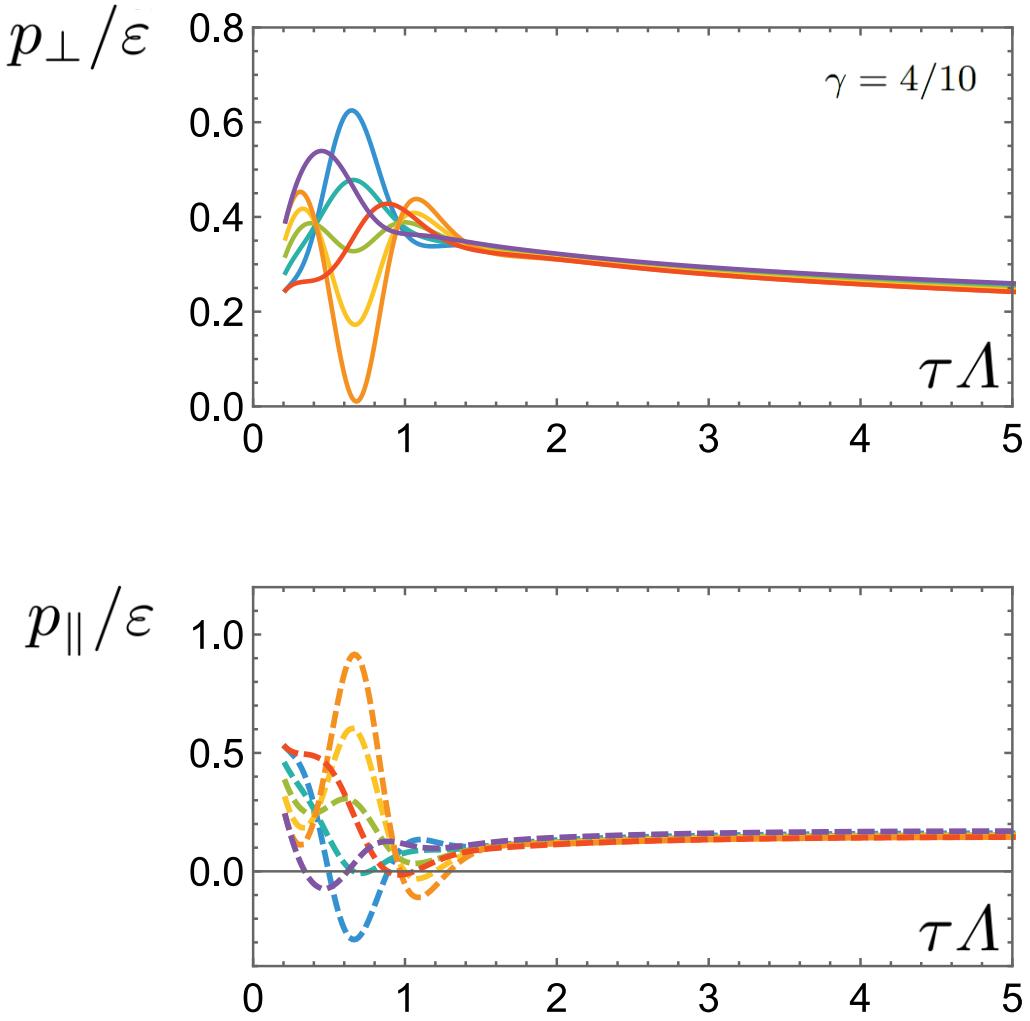
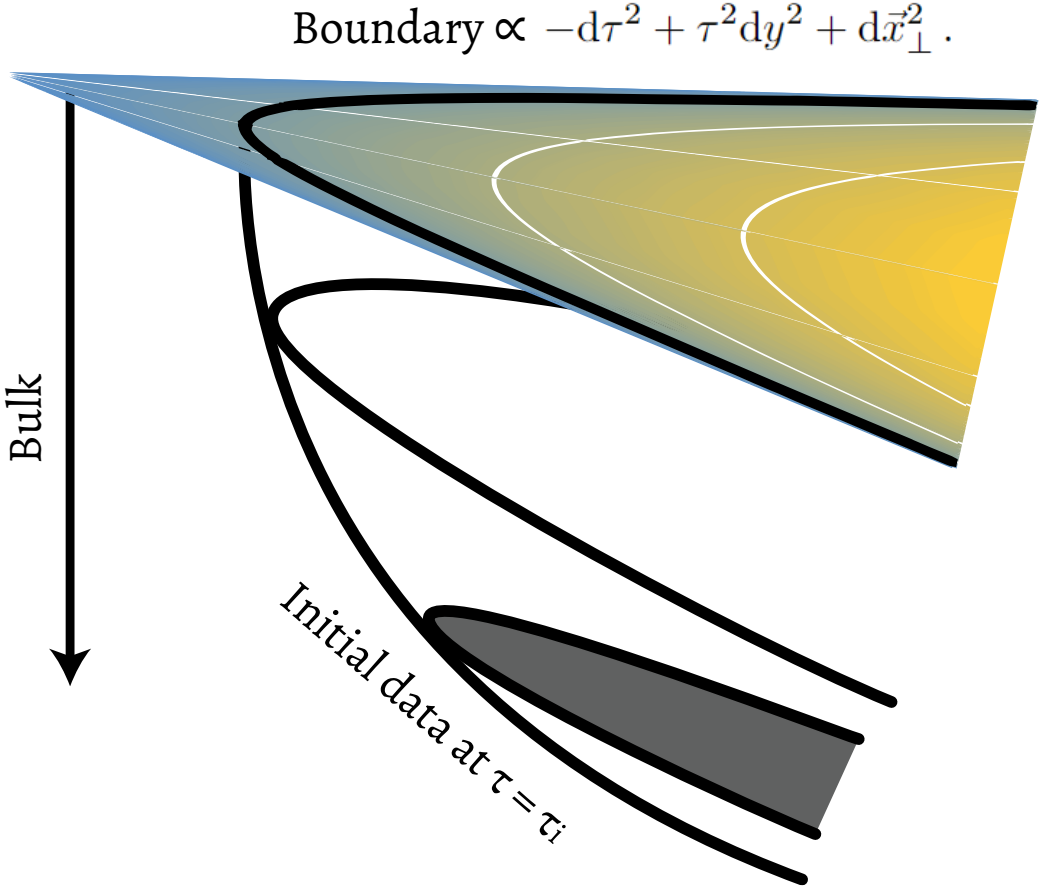




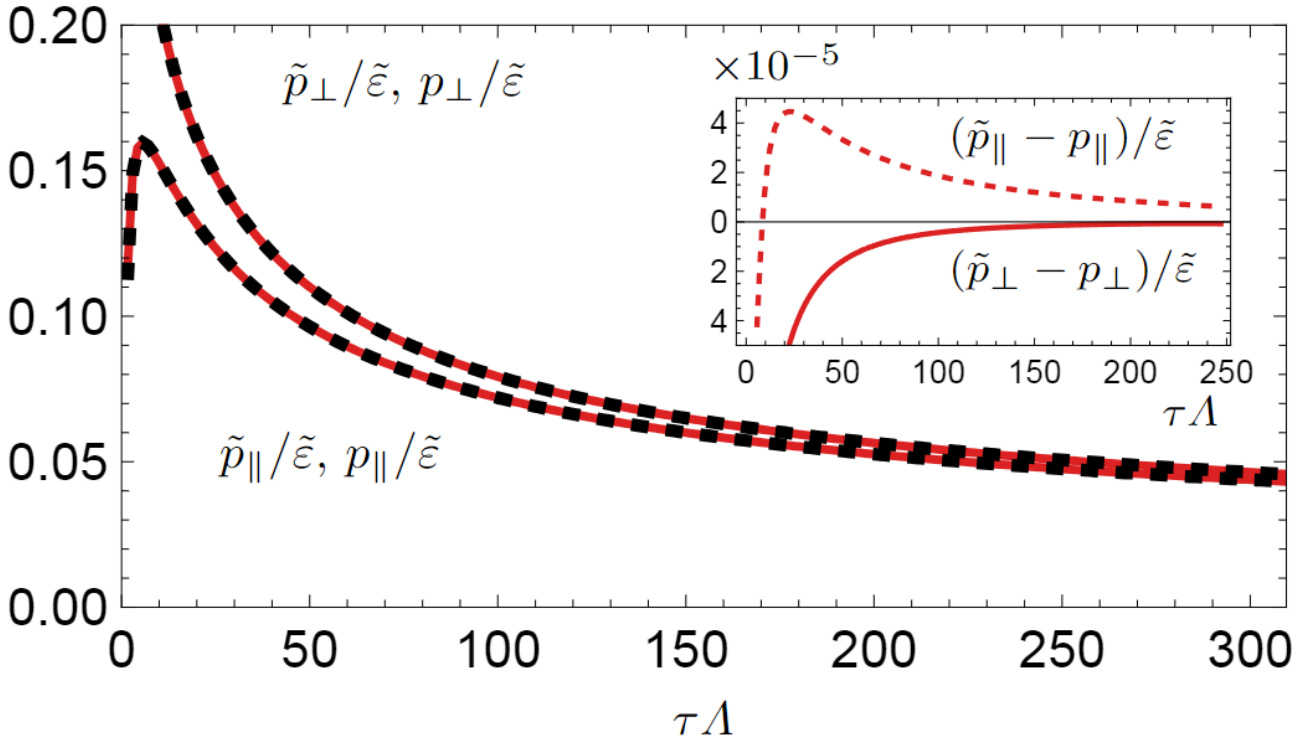
Independence of initial conditions

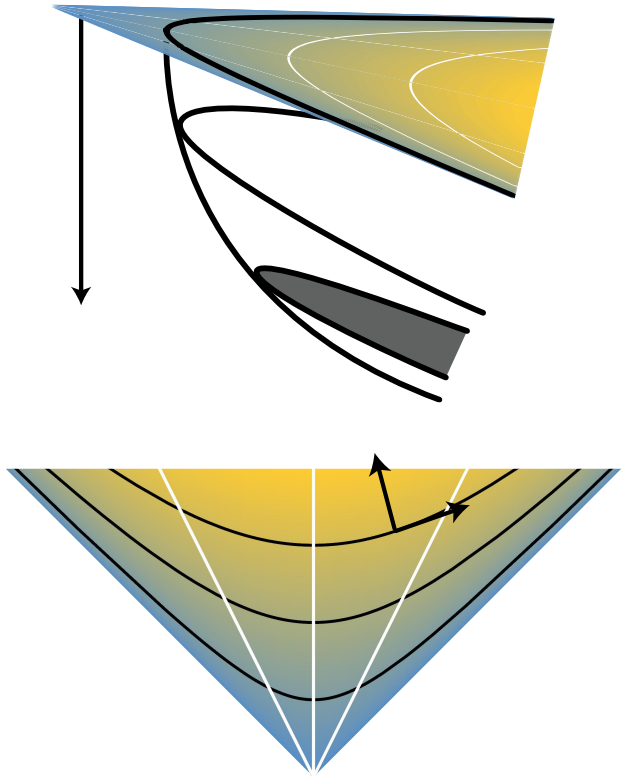




Comparison to the hydrodynamic approximation

The microscopic evolutions "*hydrodynamizes*" at very early times:



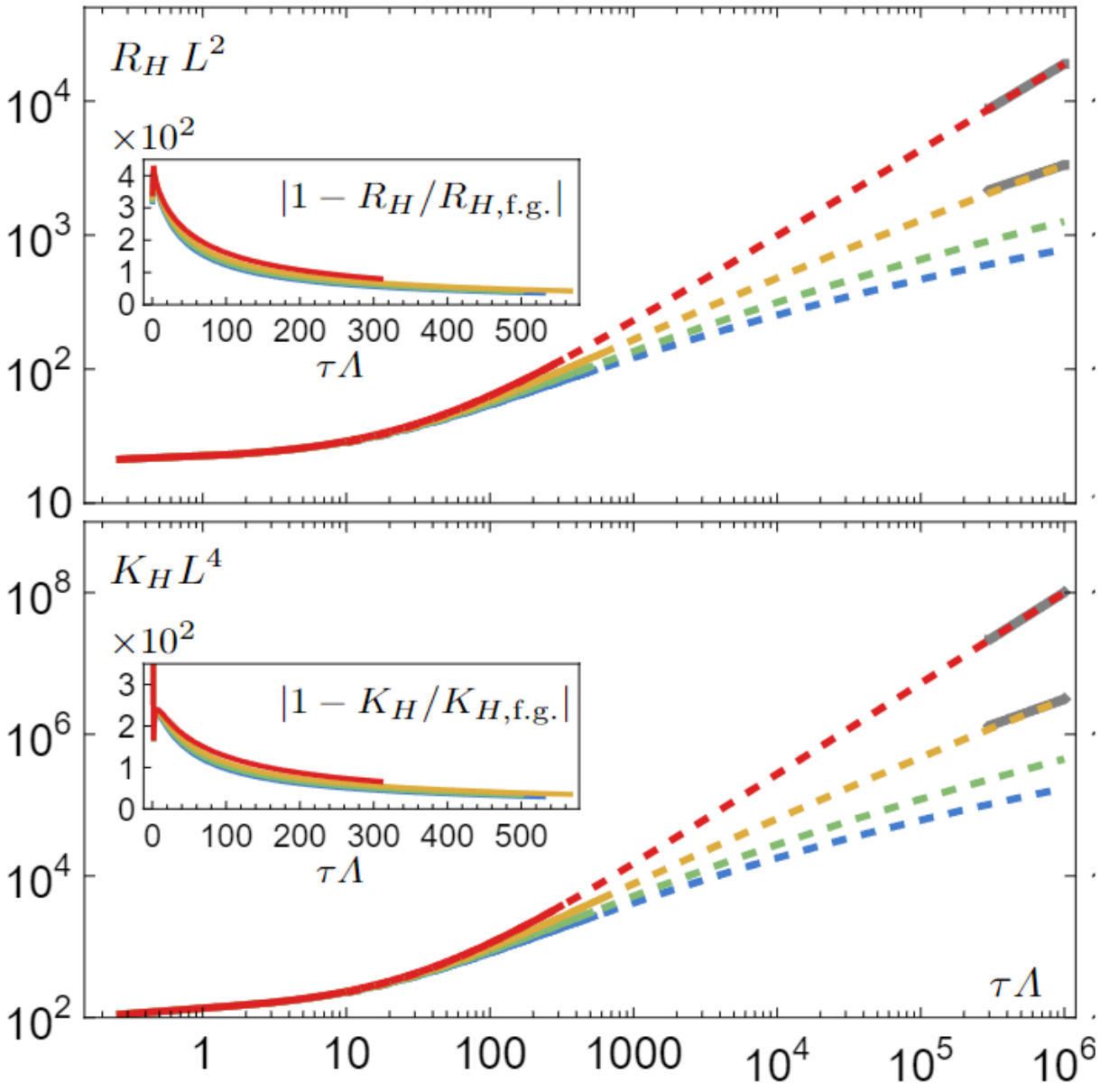


Then, the black brane solutions give a good approximation (*fluid/gravity*) at late times.

Cosmic censorship

We can extend the full evolution to arbitrary large times using fluid / gravity correspondence.

The late time, limiting behavior is recovered. [*Gursoy, Jarvinen, Policastro;* ***1507.08628***]

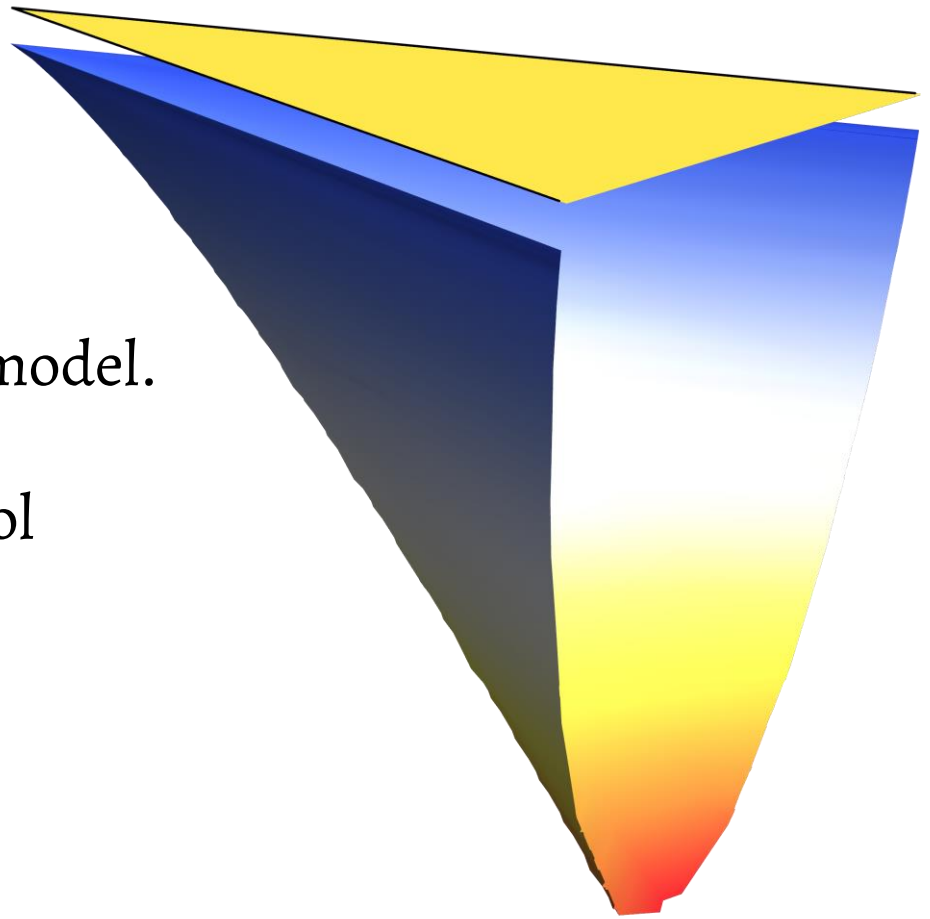


Conclusion

I presented a way to generate **dynamically** large curvatures in the bulk:

- **Robust, Generic**: mild assumptions on the model.

- **Simple, intuitive**: Relies on being able to cool down the system.



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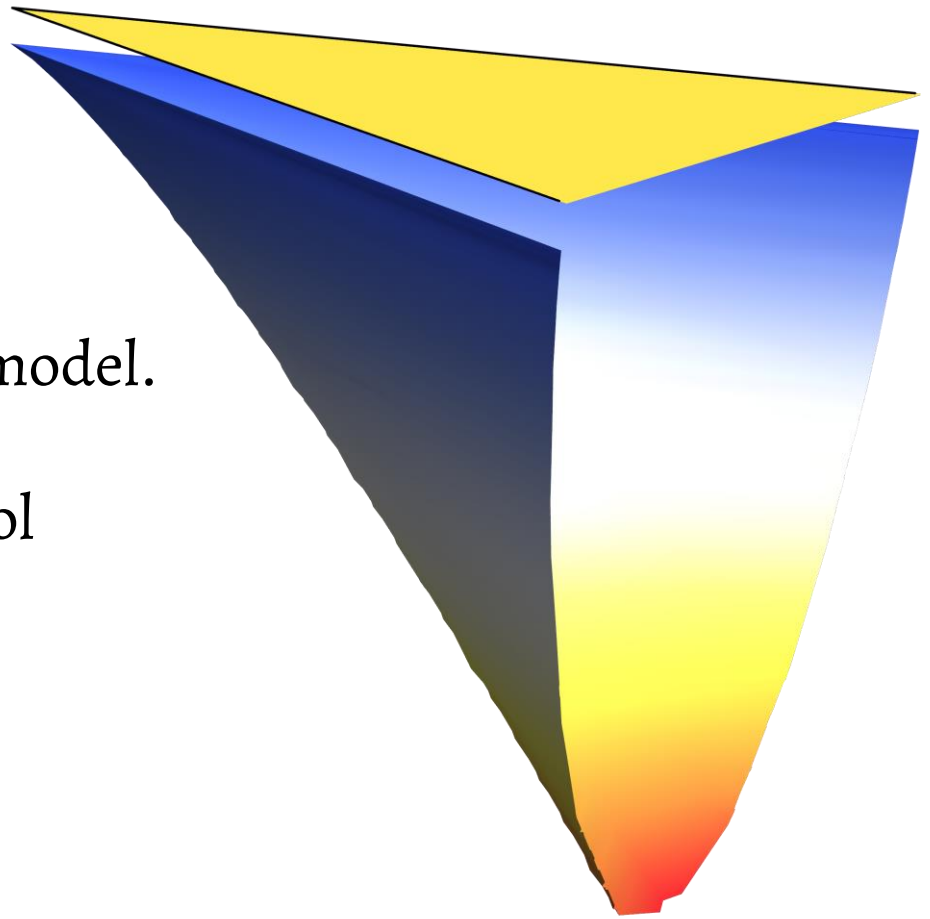

Outlook

Other expanding setups or ways to cool down the plasma?

Realization in String Theory.

Thanks.