Primordial Black Holes as laboratories for Physics beyond the standard scenarios

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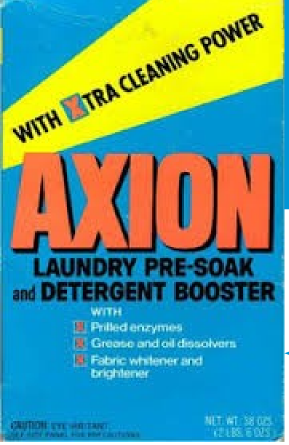
Beyond what?

BSM

A new way to probe the total number of ALPs with m < few MeV through the spin distribution of PBHs that are evaporating today!

BGR

A way to probe the beyond the horizon structure through the dynamics of evaporation (M, a, T) of BHs!



Ingredients

Scalar field with a shift symmetry in **4D**

No mass terms by perturbative effects

Mass is generated by **non-perturbative** effects

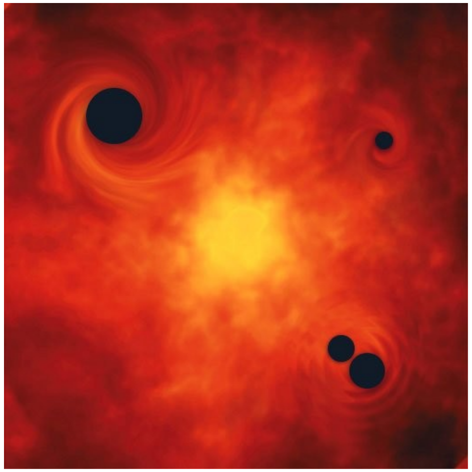
String theory compactification:

6 extra d + many ways to compactify => ($N_a \sim [100\text{-}10^5]$)

PBHs are BHs formed in the **early Universe**

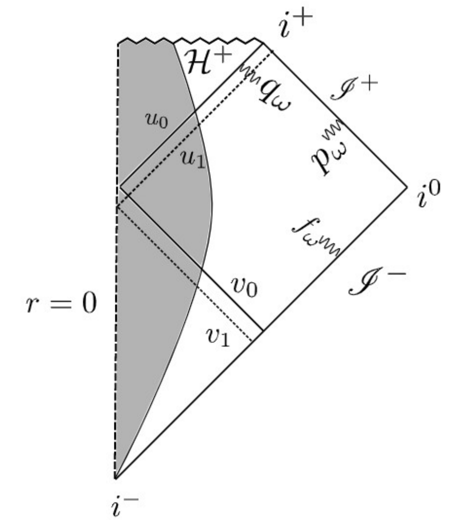
Through the gravitational collapse of **overdensities** in the **cosmic plasma**

Masses can be several orders of magnitude **below** the **solar mass**



$M \sim 10^{12}$ kg evaporates enough to show changes in a_* in presence of many scalars. ($T >$ few MeV)

BH evaporation



Spacetime before and after the formation of an horizon

(Hawking 1975) $n_\omega = \frac{1}{\left(e^{\frac{2\omega\pi}{\kappa}} - 1\right)}$, $T_H = \frac{\kappa}{2\pi}$

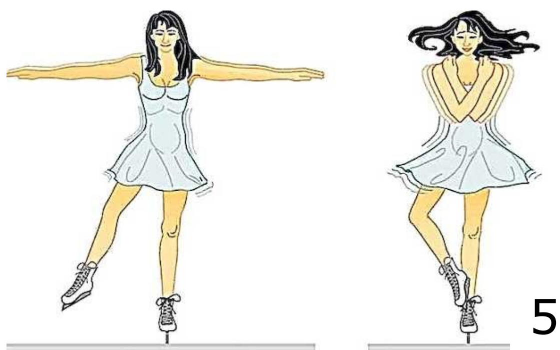
$$\Delta^{-s}\frac{d}{dr}\left(\Delta^{s+1}\frac{dR}{dr}\right) + \left(\frac{K^2 - 2is(r-M)K}{\Delta} + 4is\omega r - \lambda\right)R = 0 \quad \ldots$$

Evaporating BH: **M↓** & **T_H↑** → emitted particle **set changes**!!!

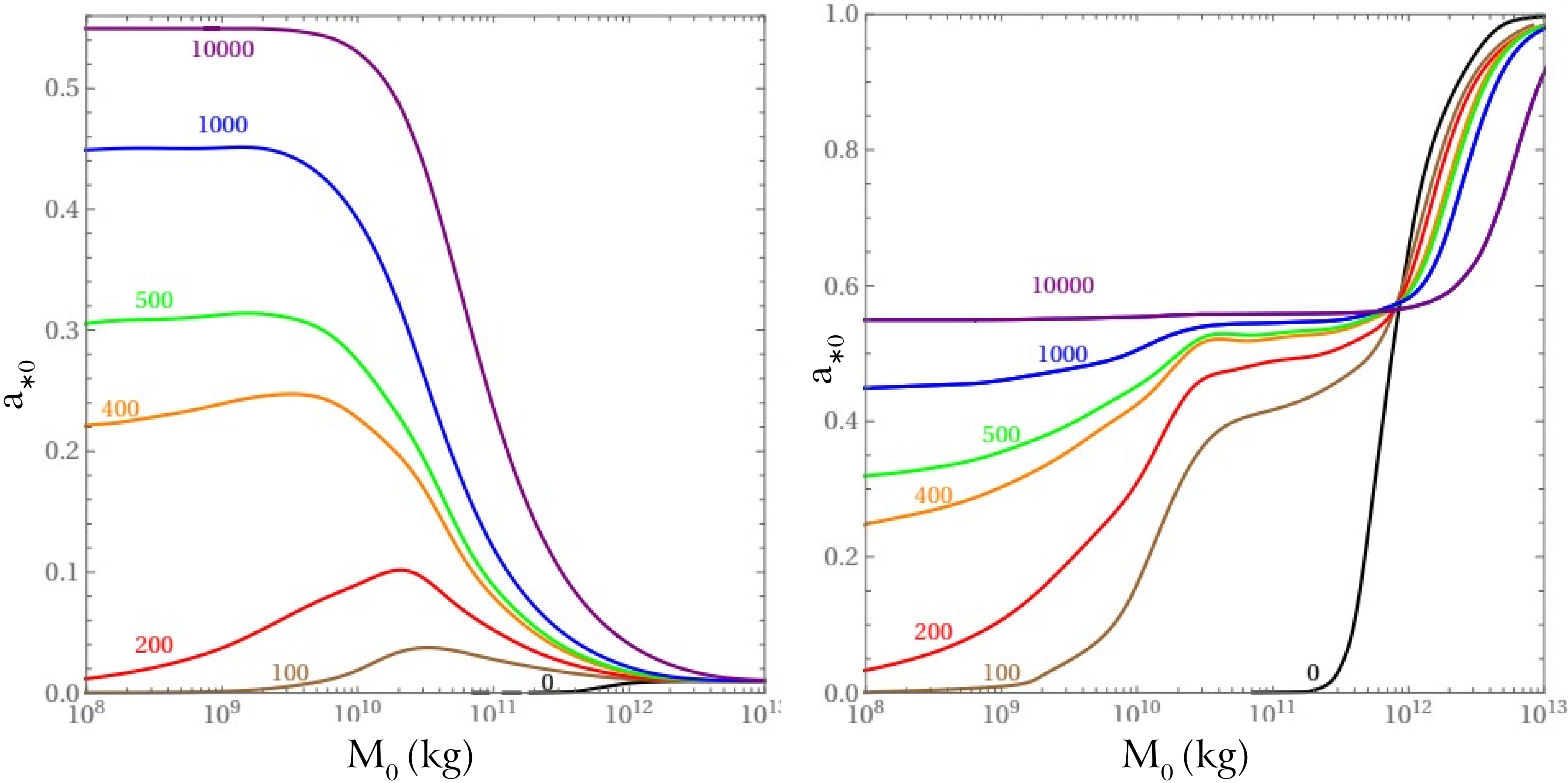
Particles emission with **m > T_H** is exponentially **suppressed**

Approximation: particles are considered **massless** for **m < T_H** and are **otherwise absent** from the emission spectrum.

ALPs → s=0 leading mode l=m=0 → $J/M^2 = a^*$↑



Axiverse fingerprint in PBHs evaporation



Present PBH spin, a_{*0}, as a function of their present mass, M_0, for an initial population with spin $a_* = 0.01, 0.99$ and varying mass. Curves labeled by number of light ALPs.

Why is this so interesting?

ALPs → **cosmological** and **astrophysical effects** → **signatures** of **individual** axions (mass ranges), **not** of the **whole** 'string **axiverse**'.

The **PBH spin distribution** from **evaporation** process in the presence of **many light scalar** fields **cannot**, to our knowledge, be **mimicked** by other processes → **unique signature** of an **underlying theory** with a large number of light scalars.

How to go Beyond GR?

$$\nabla^{\mu}\nabla_{\mu}\Phi=0 \quad \Rightarrow \quad \frac{1}{\sqrt{-g}}\partial^{\mu}\left(\sqrt{-g}\,g_{\mu\nu}\partial^{\nu}\right)\Phi=0 \quad \Rightarrow \quad \cdots$$

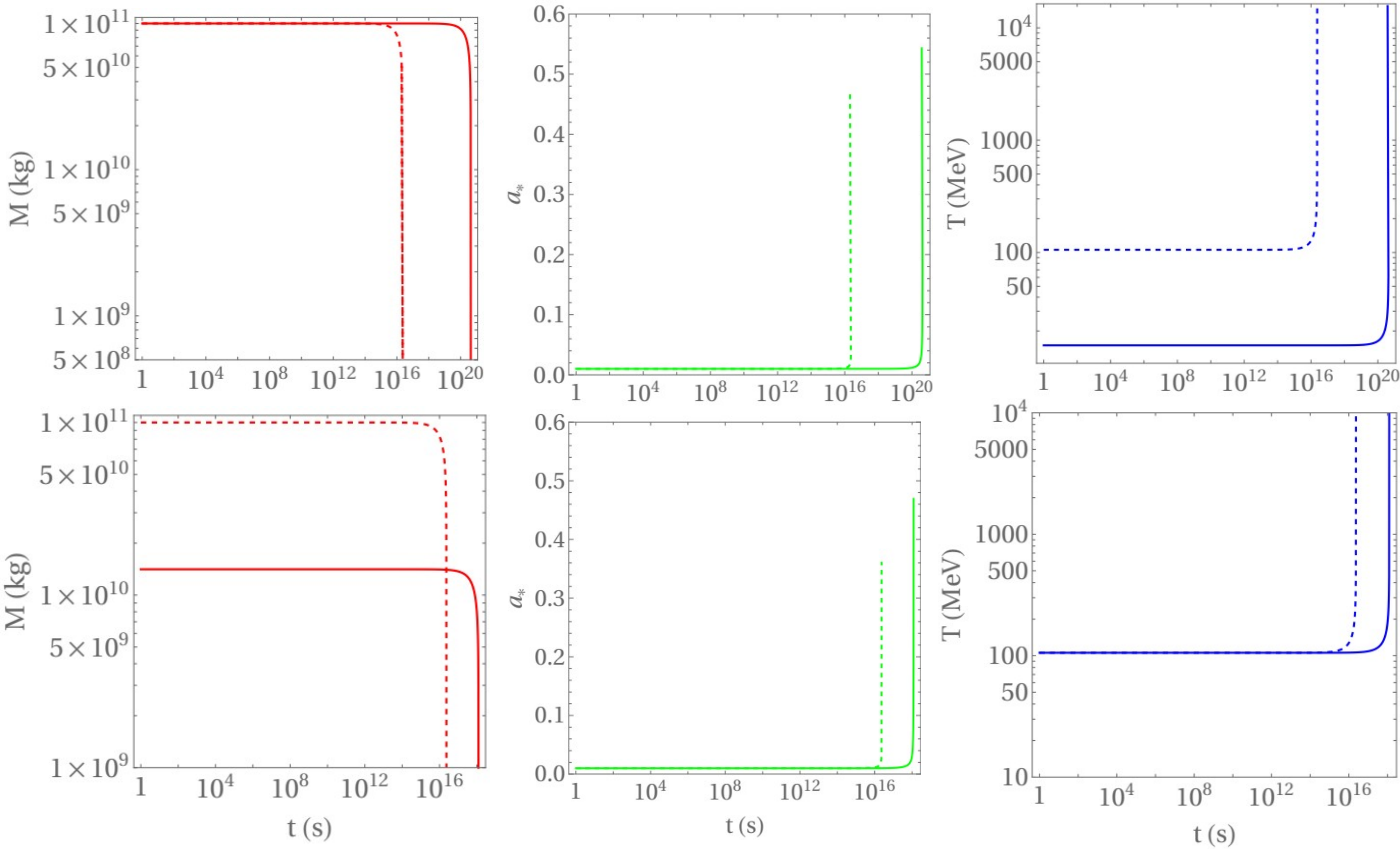
Take a metric not vacuum solution of GR

Kerr-black-bounce: $r=\sqrt{\tilde{r}^2+\ell^2}$

$$ds^2 = -\left(1-\frac{2Mr^2}{\Sigma}\right)dt^2 + \frac{\Sigma}{\delta\Delta}dr^2 + \Sigma d\theta^2 + \frac{A\sin^2\theta}{\Sigma}d\phi^2 - \frac{4Mar\sin^2\theta}{\Sigma}dtd\phi,$$

$$\Sigma = r^2+a^2\cos^2\theta, \qquad \Delta = r^2+a^2-2Mr, \qquad A=(r^2+a^2)^2-\Delta a^2\sin^2\theta, \qquad \delta = 1-\frac{\ell^2}{r^2}$$

Same M and T evolutions

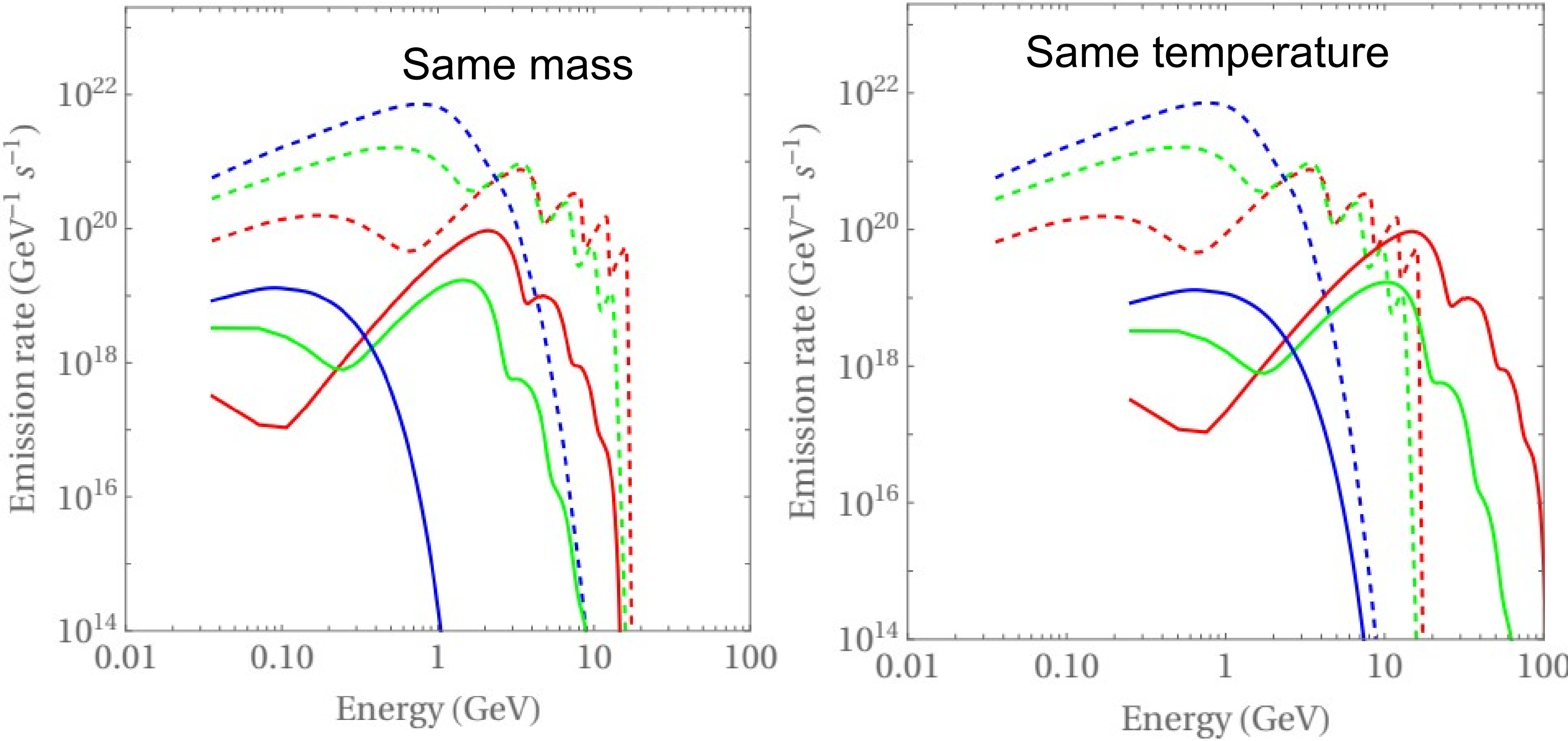


Solid Kerr BH Dashed Kerr-b-b BH

Primary scalar emission

$$\frac{d^2 N}{dtdE} = \frac{1}{2\pi} \sum_{l,m} \frac{T_{l,m}(\omega)}{e^{2\pi k/\kappa} - 1} .$$

$$\kappa = \sqrt{\frac{r_H^2}{r_H^2 + \ell^2}} \sqrt{1 - a_*^2} / 2r_+$$



Why is this so interesting?

BH structure → Event Horizon → differences in the Hawking emission.

No information is coming from inside the EH but in a certain sense you can look inside with out looking inside!!!

References

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"Evaporation of a Kerr-black-bounce by emission of scalar particles",
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Thanks for your attention!!!