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Primordial Black Holes as laboratories for Physics beyond the standard scenarios

Beyond what?

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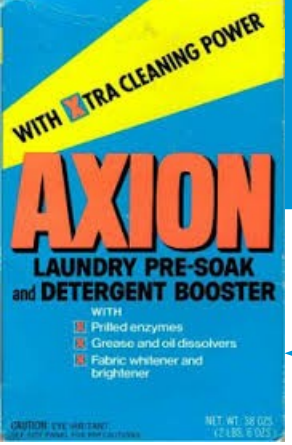
BSM

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

Detection & M, a* estimation

Ingredients



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

No mass terms by perturbative effects

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

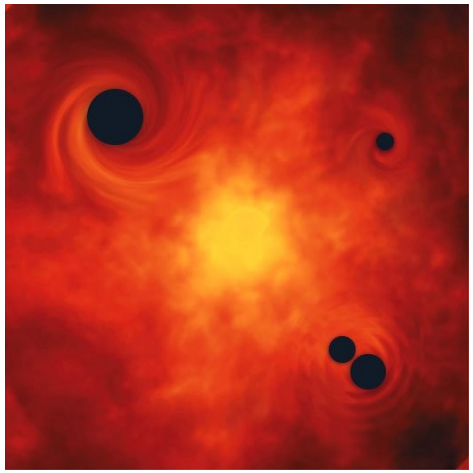
String theory compactification:

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

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

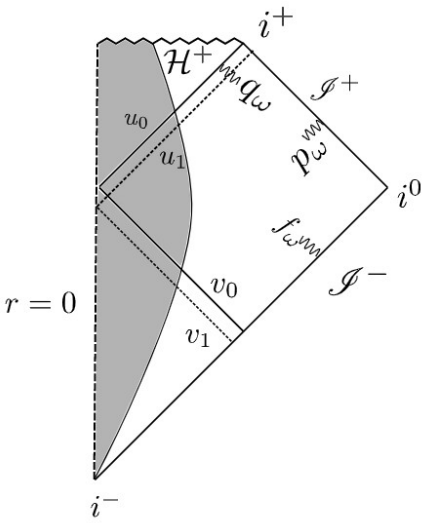
Through the gravitational collapse of **overdensities** in the **cosmic plasma**

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



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

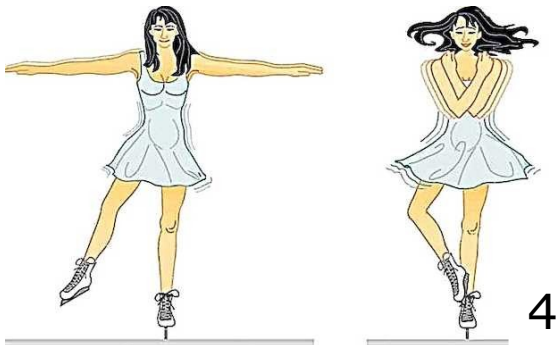
$$\Delta^{-s}\frac{d}{dr}\left(\Delta^{s+1}\frac{dR}{dr}\right) + \left(\frac{K^2 - 2is(r-M)K}{\Delta} + 4is\omega r - \lambda\right)R = 0 \quad \ldots$$

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

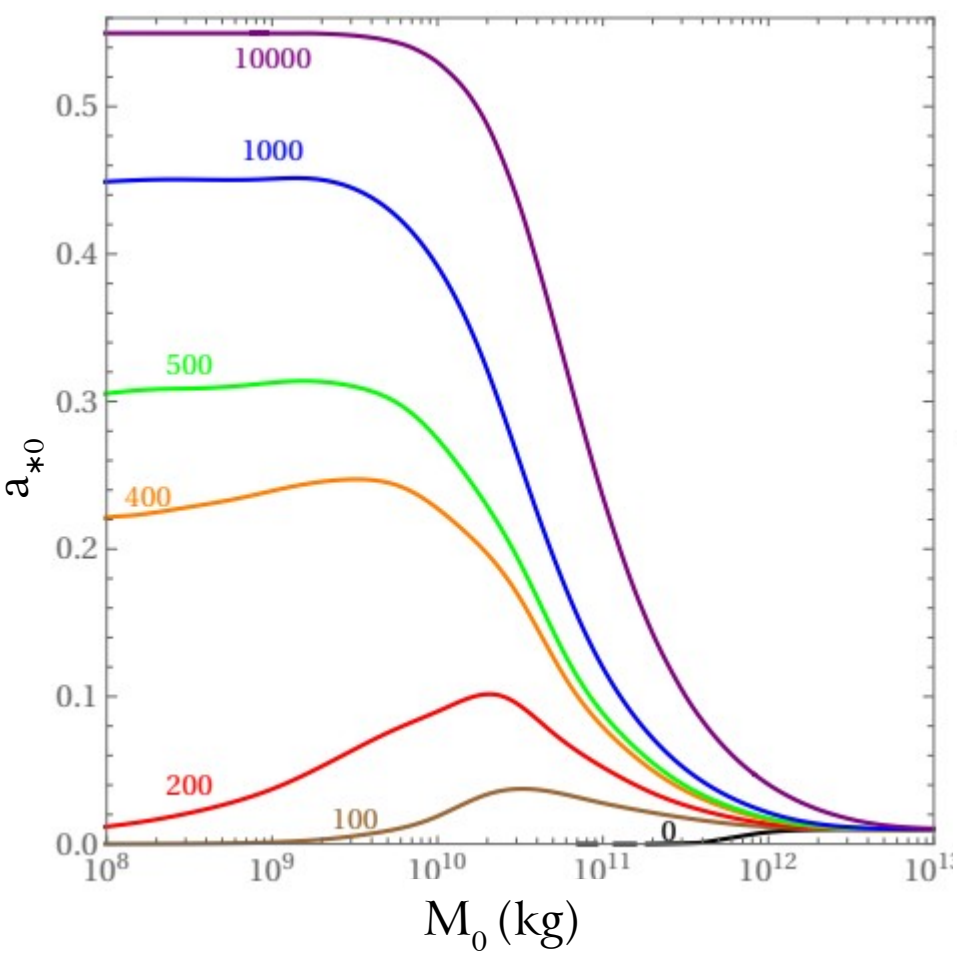
Particles emission with **m > T_H** is exponentially **suppressed**

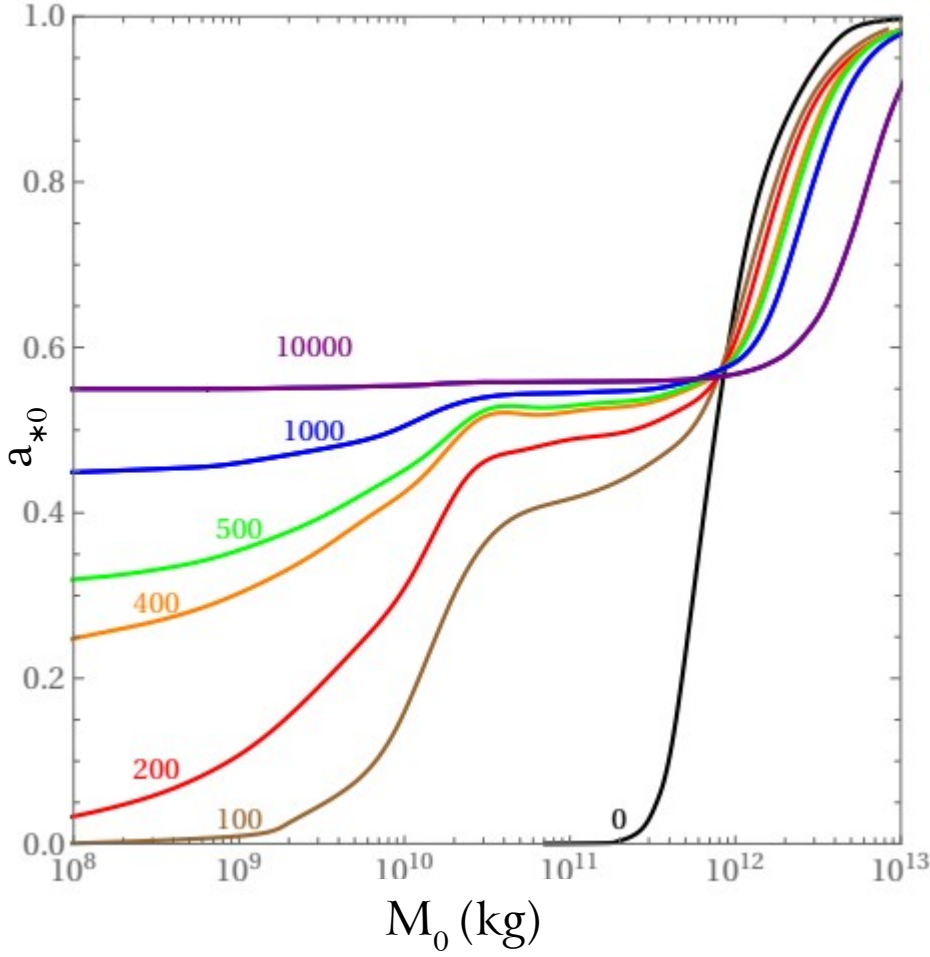
Approximation: particles are considered **massless** for **m < T_H** and are **otherwise absent** from the emission spectrum.

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?

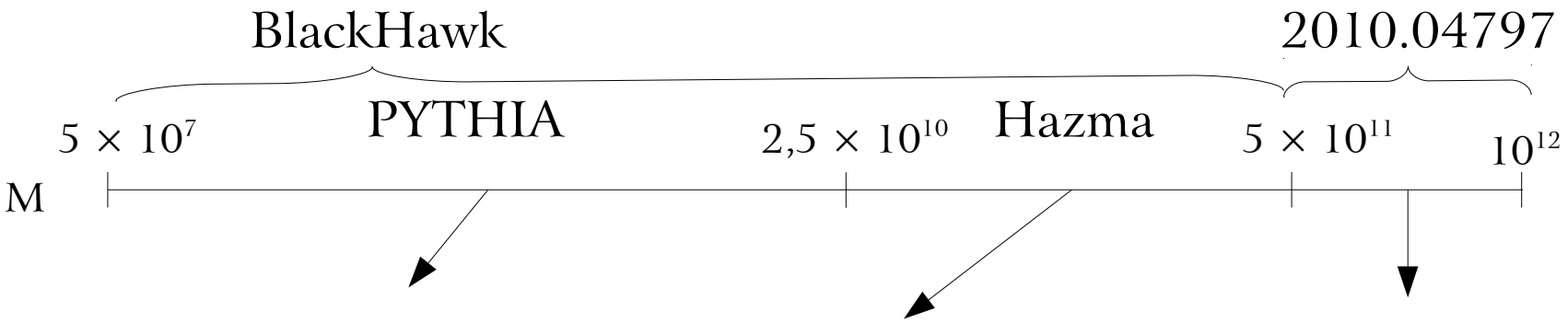
ALPs → cosmological and **astrophysical effects → signatures** of **individual** axions (mass ranges), **not** of the **whole** 'string **axiverse**'.

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 calculate the secondary γ emission?

$M \in [10^{12}, 5 \times 10^{7}]$ kg and $a^{*} \in [0, 0.5]$ ⇨ $T \in [10\ \text{MeV}, 200\ \text{GeV}]$.

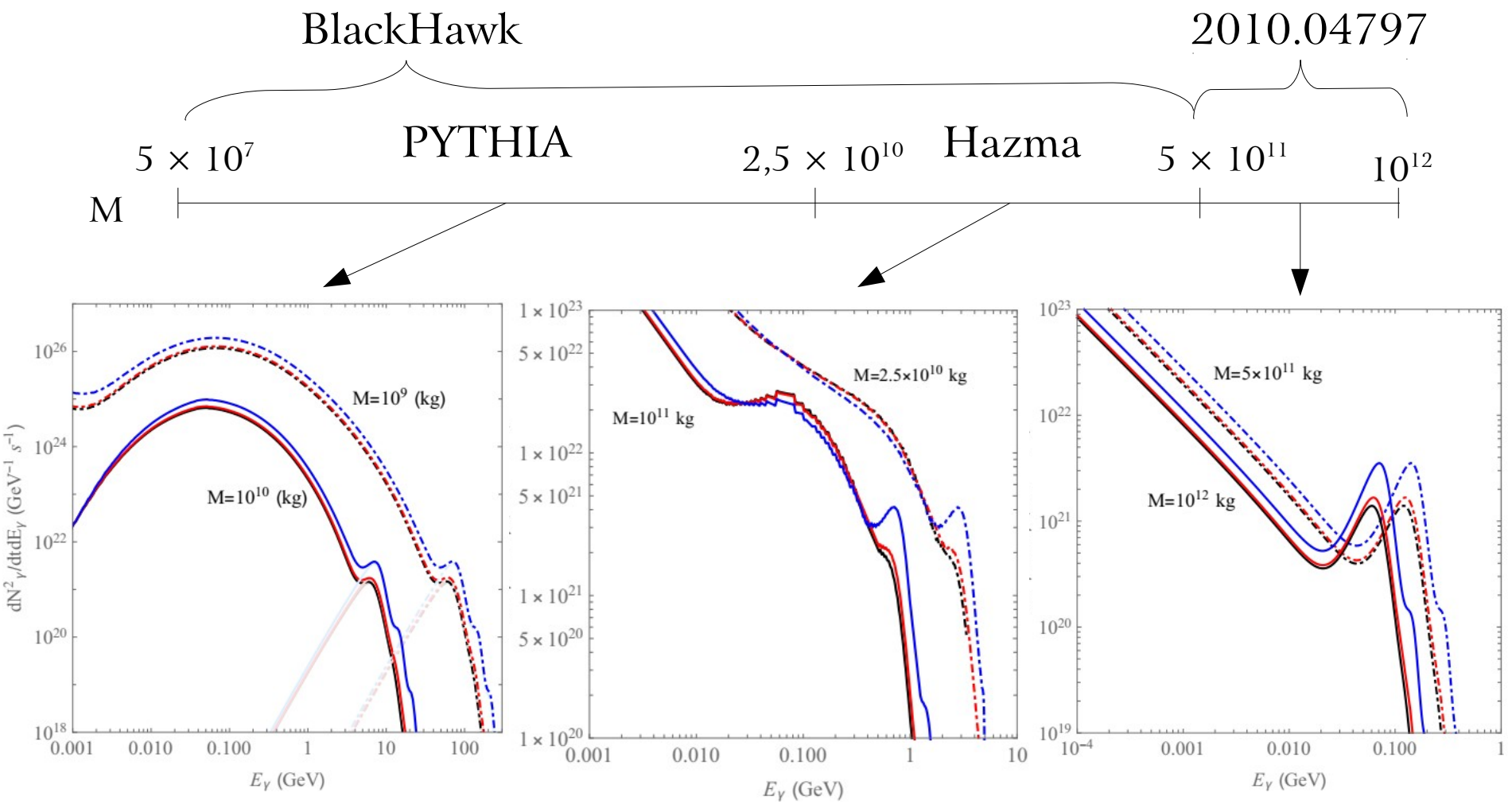
- $E > 10$ MeV → secondary component always present ($e^{\pm}$ FSR).
- $E < 200$ GeV → tested SM framework holds.
- There exist methods to calculate the secondary spectrum.



- Fully numerical.
- Relies on hadronizing tables (tabulated in certains range of energies).

- Semi-analytical.
- Next slides.

Distant independent meaurment of M and a*

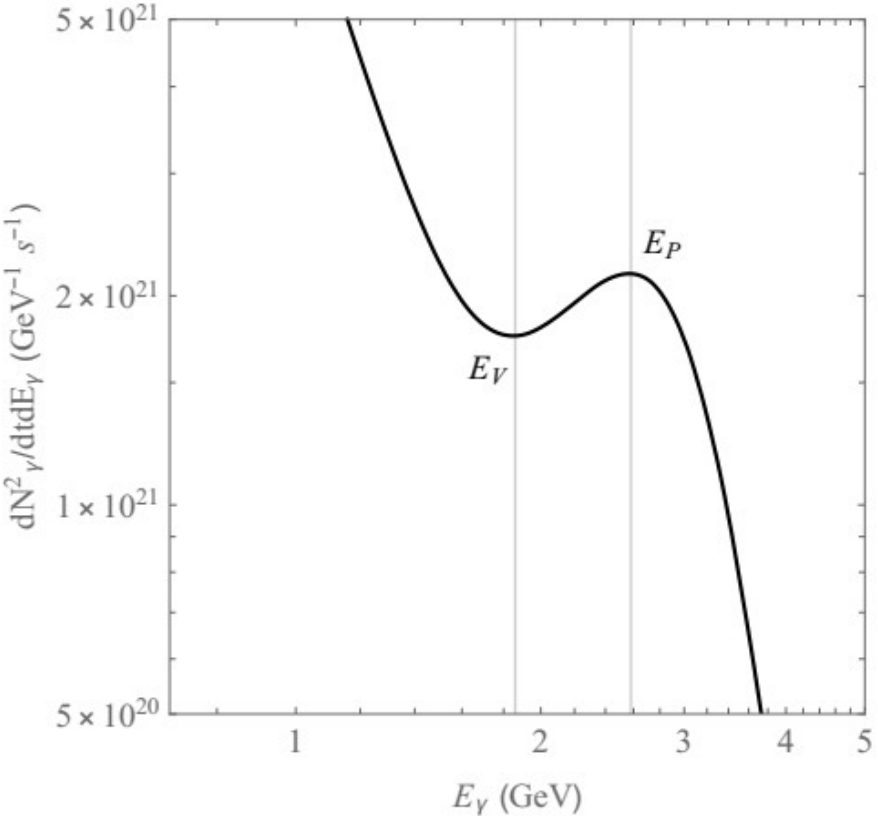


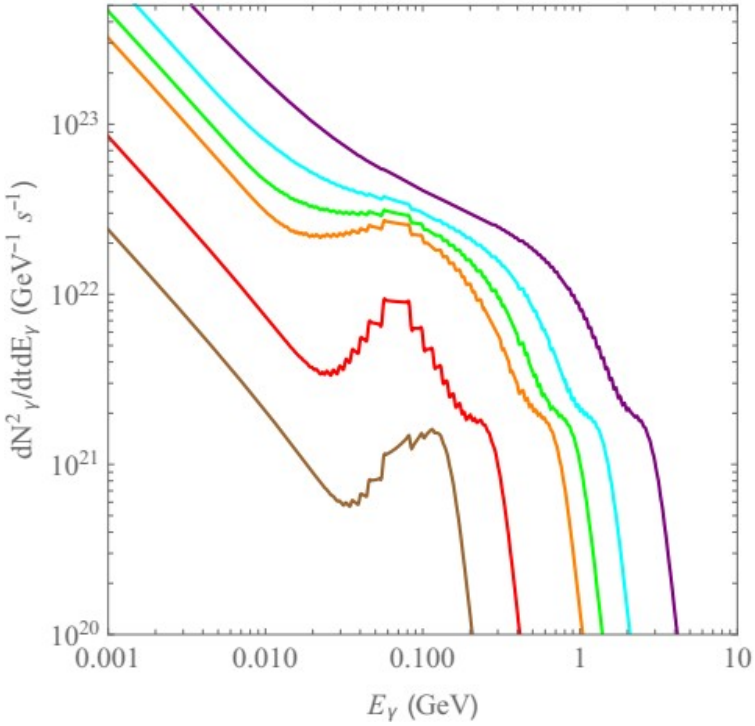
Distant independent meaurment of M and a*

2010.04797

5×10^7 PYTHIA $2{,}5 \times 10^{10}$ Hazma 5×10^{11} 10^{12}

M





$\pi \longrightarrow \gamma\,\gamma$

Distant independent meaurment of M and a*

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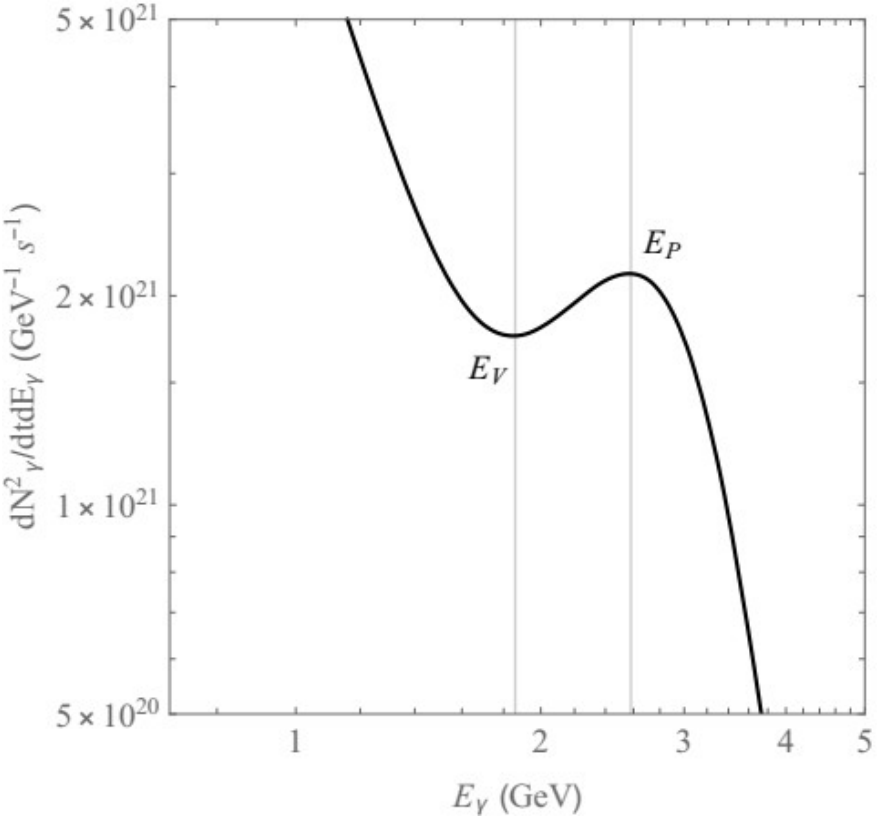
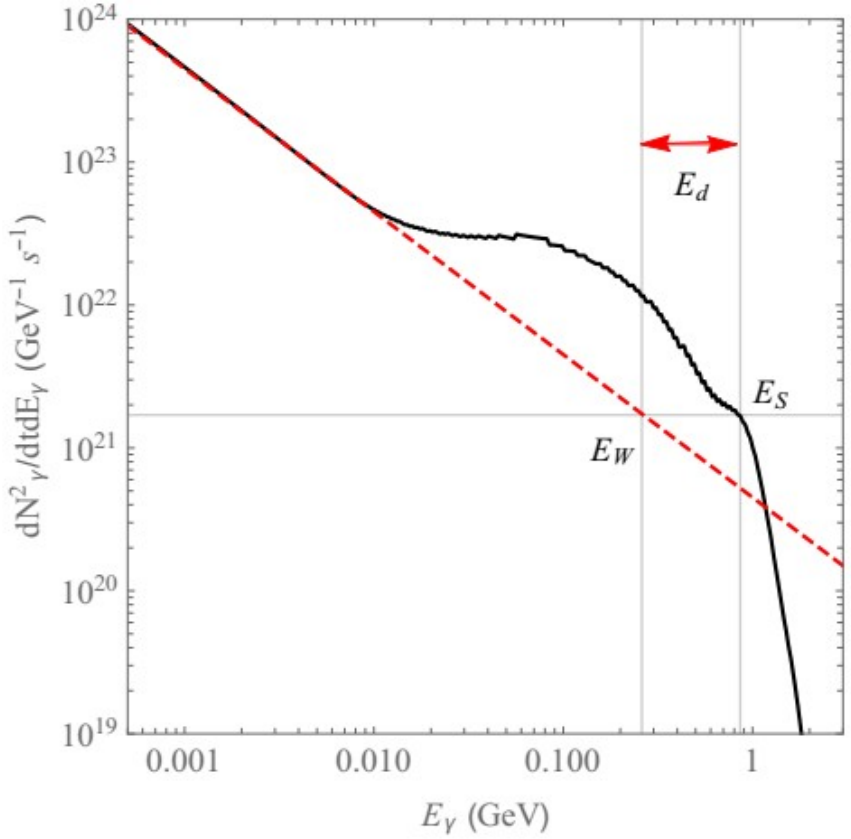




Results

5×10^7

PYTHIA

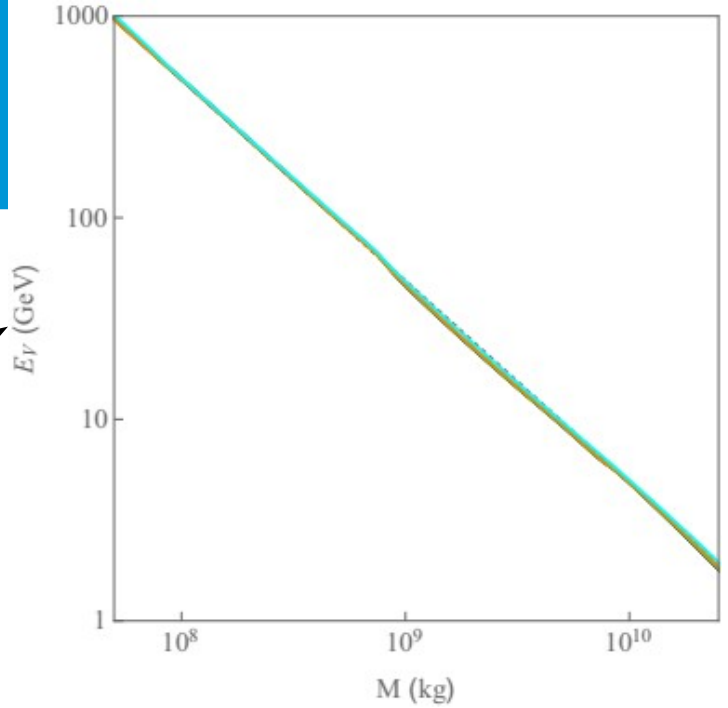
$2{,}5 \times 10^{10}$

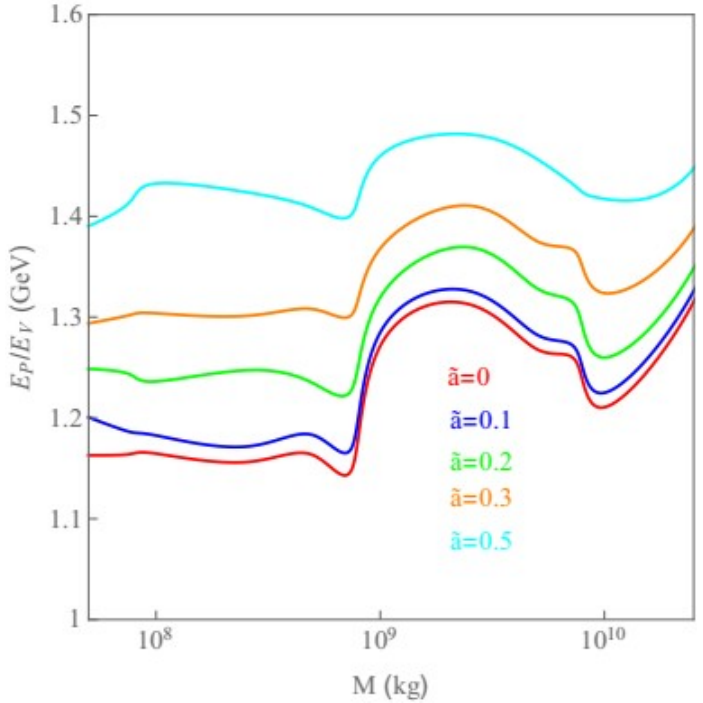
Hazma

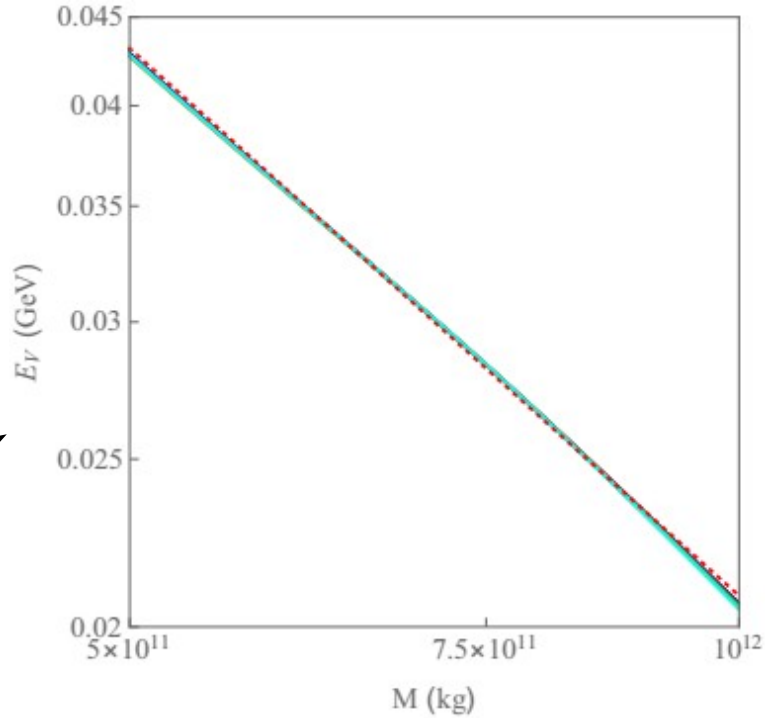
5×10^{11}

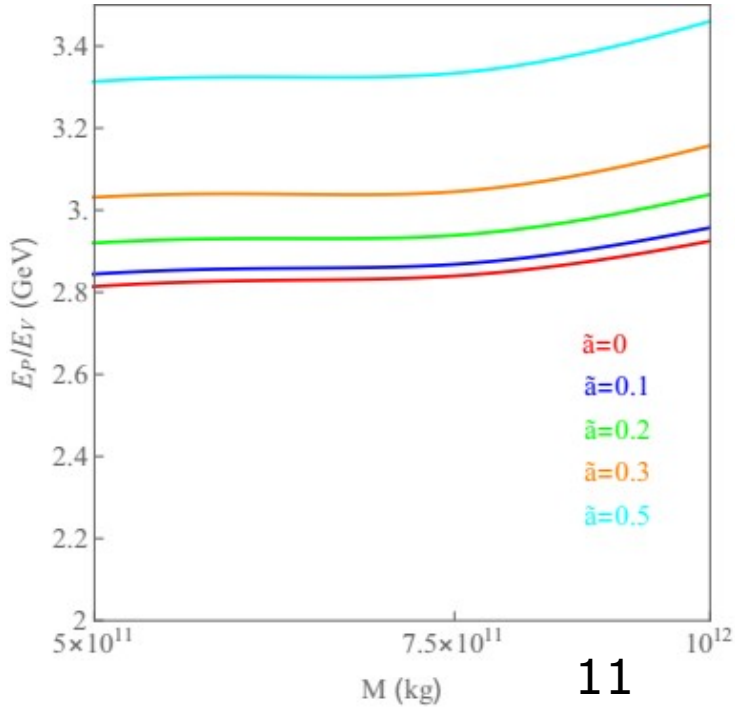
Profumo

10^{12}









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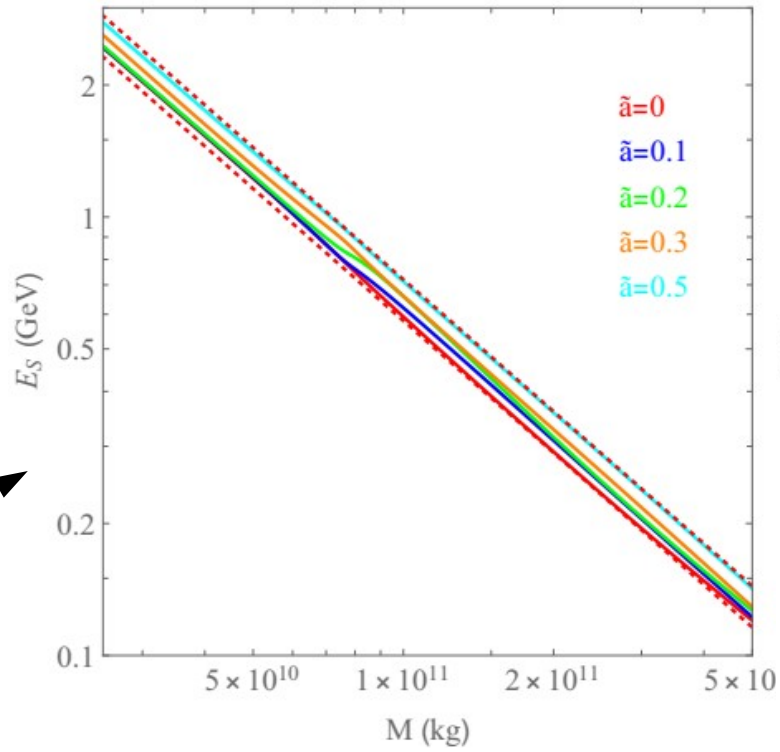
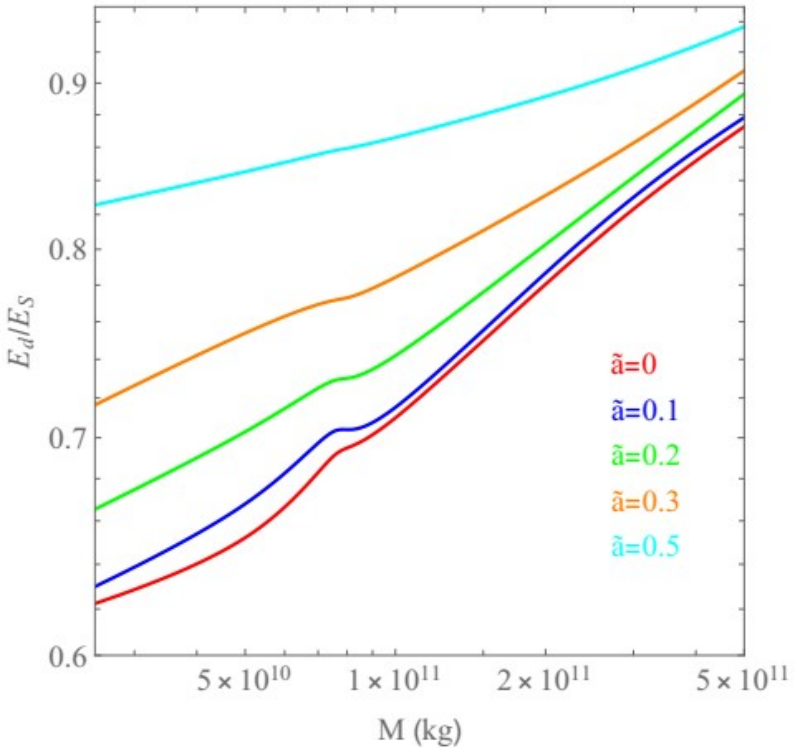
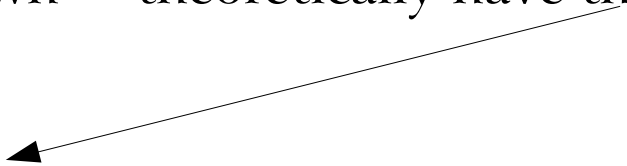




Why is this so interesting?

- ➔ EM radiation is the most probable source of information
- ➔ Knowing the distance of a PBH may be a difficult task
- ➔ M and a* are known → theoretically have the PBH photon-flux



Compare it with the experimental one → distance

Thanks for your attention!!!