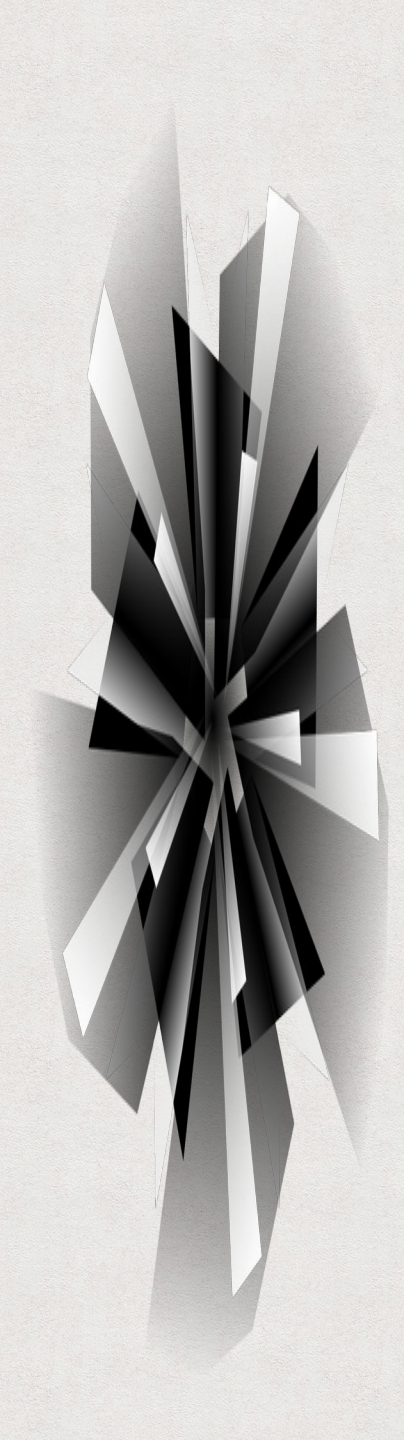


Regular PBH constraint from isotropic γ-ray background

Marco Calzà.

University of Trento.

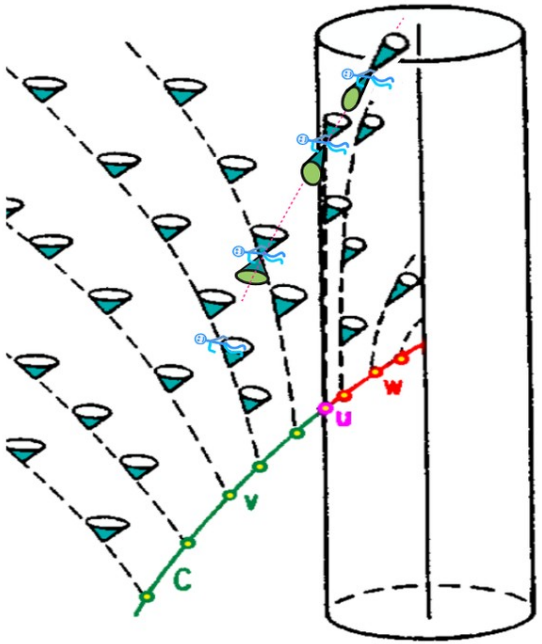
In collaboration with Sunny Vagnozzi & Davide Pedrotti.

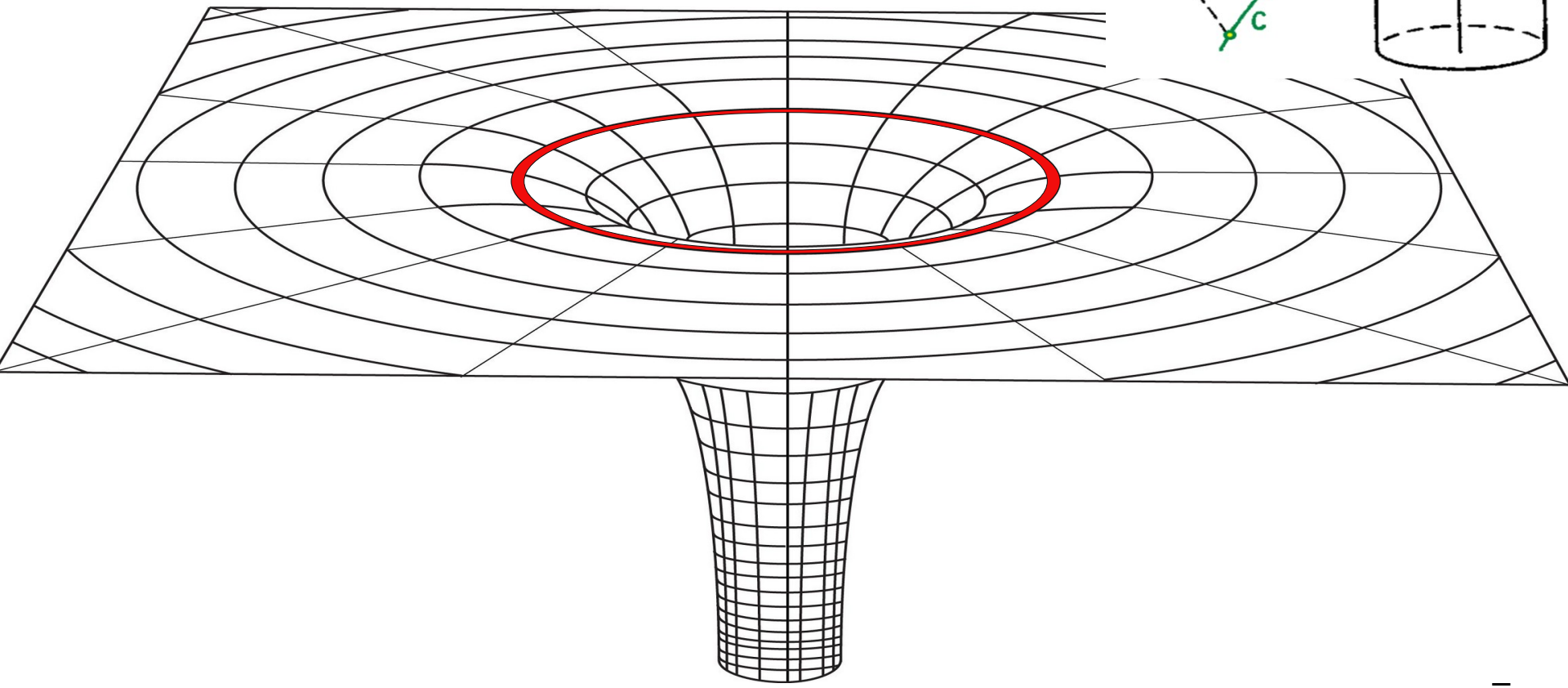
$$ds^2 = -f(r)dt^2 + f(r)^{-1}dr^2 + r^2\left(d\theta^2 + \sin^2(\theta)d\phi^2\right)$$

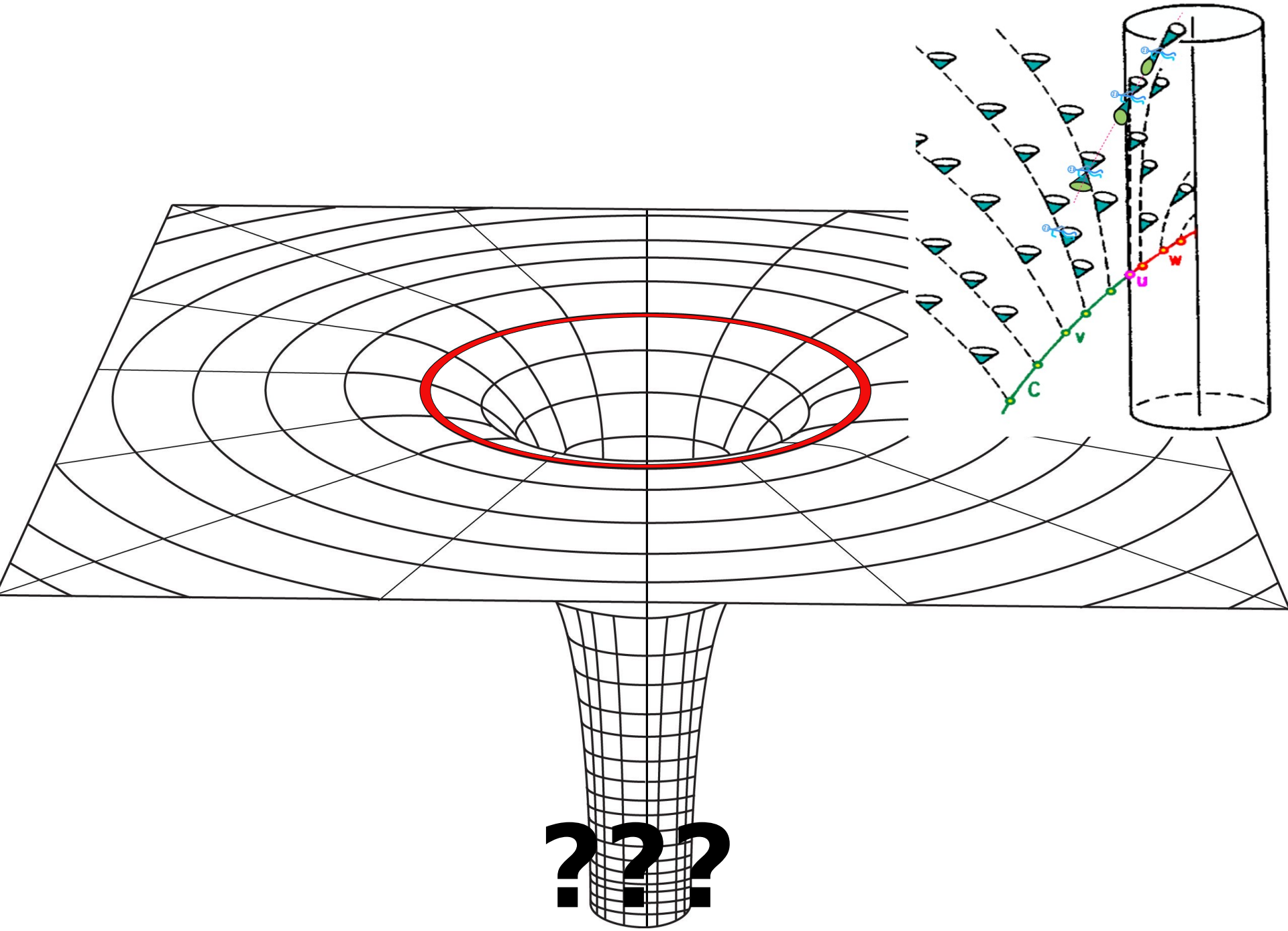
$$\exists\ r_H \in \mathbb{R}_{++} \ : \ f(r_H)=0 \ \wedge \ f'(r_H)>0$$

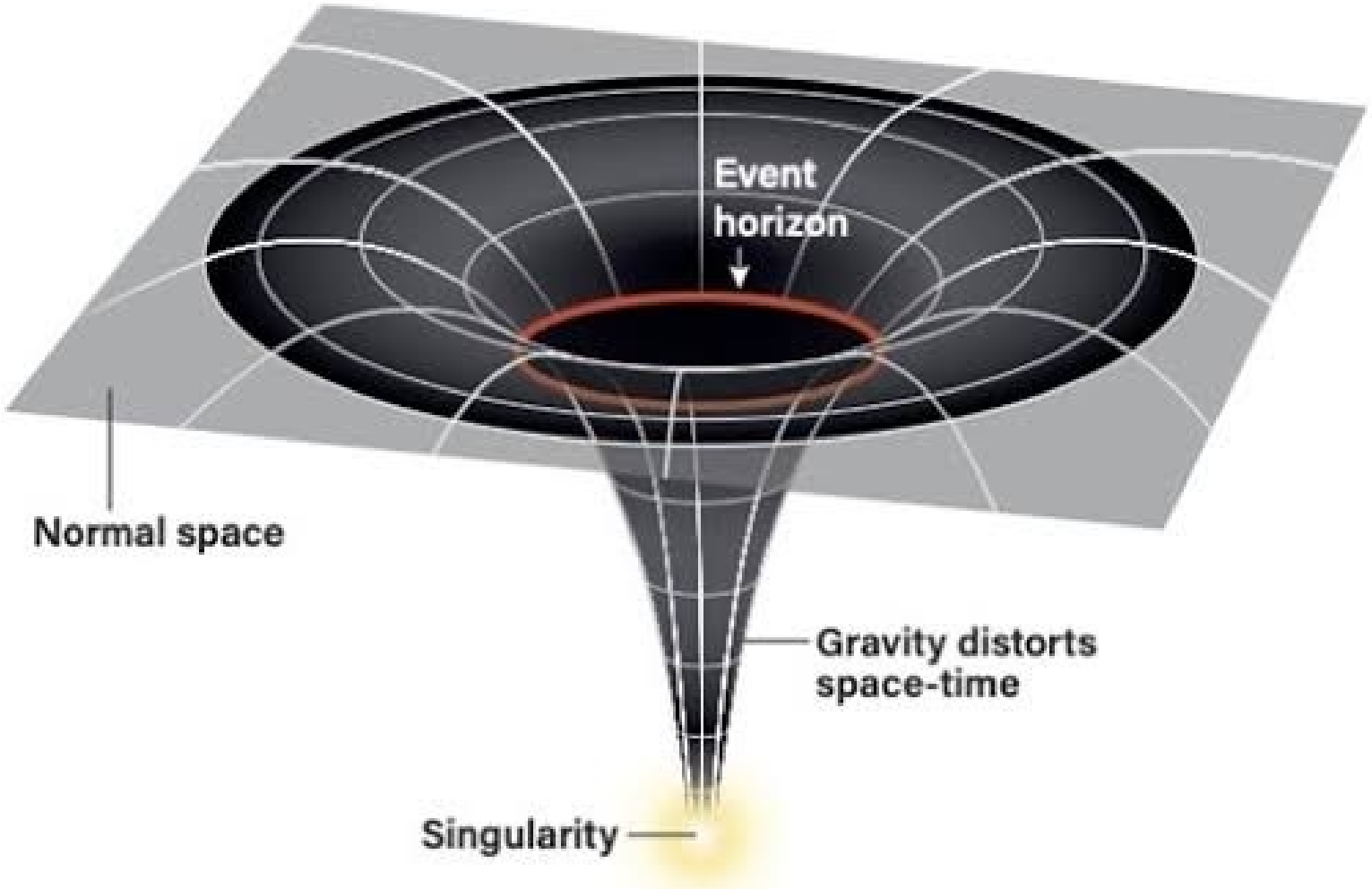
Locate a Horizon

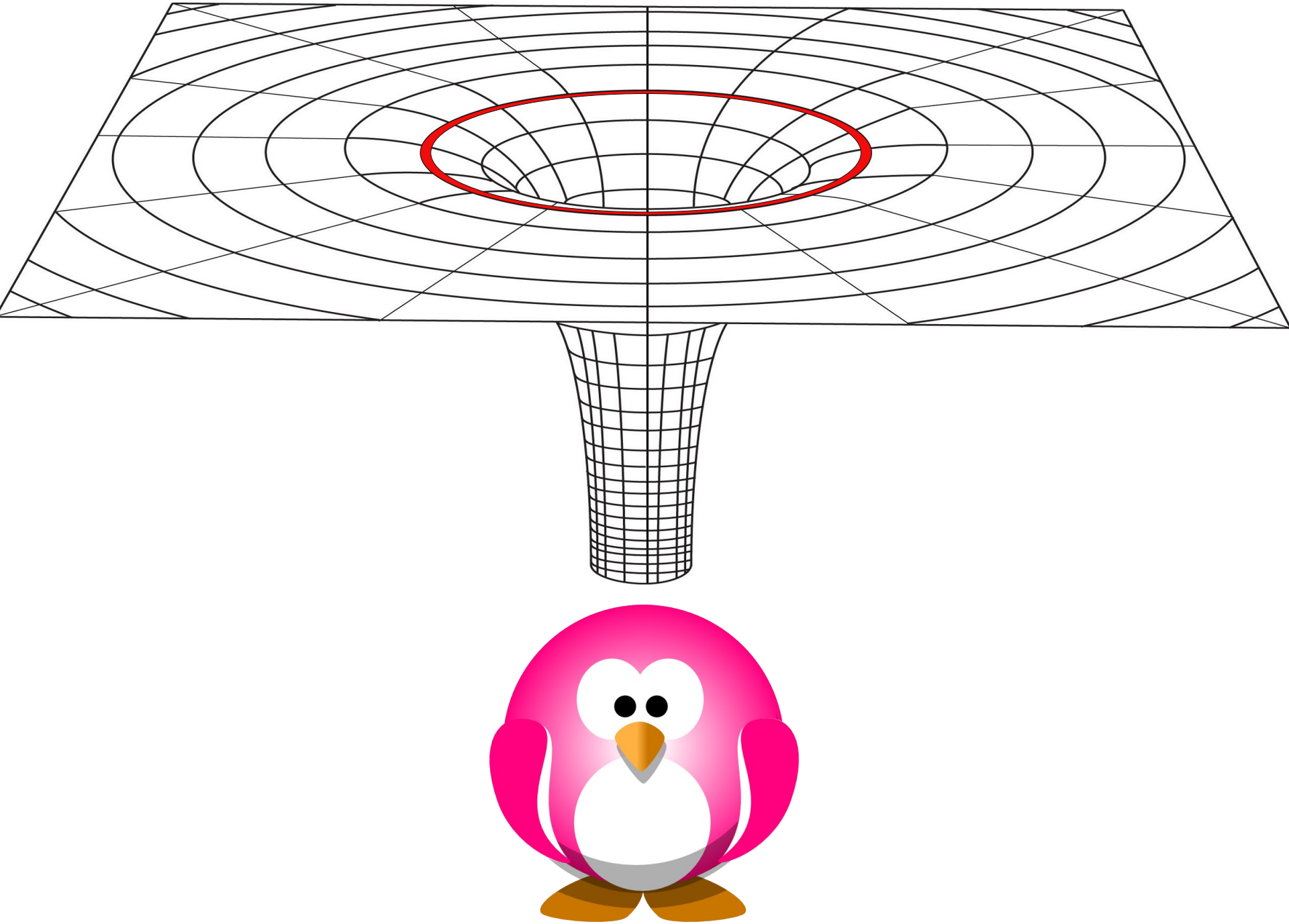
$$T = \frac{\kappa}{2\pi} = \frac{f'(r)}{4\pi}|_{r_H}$$

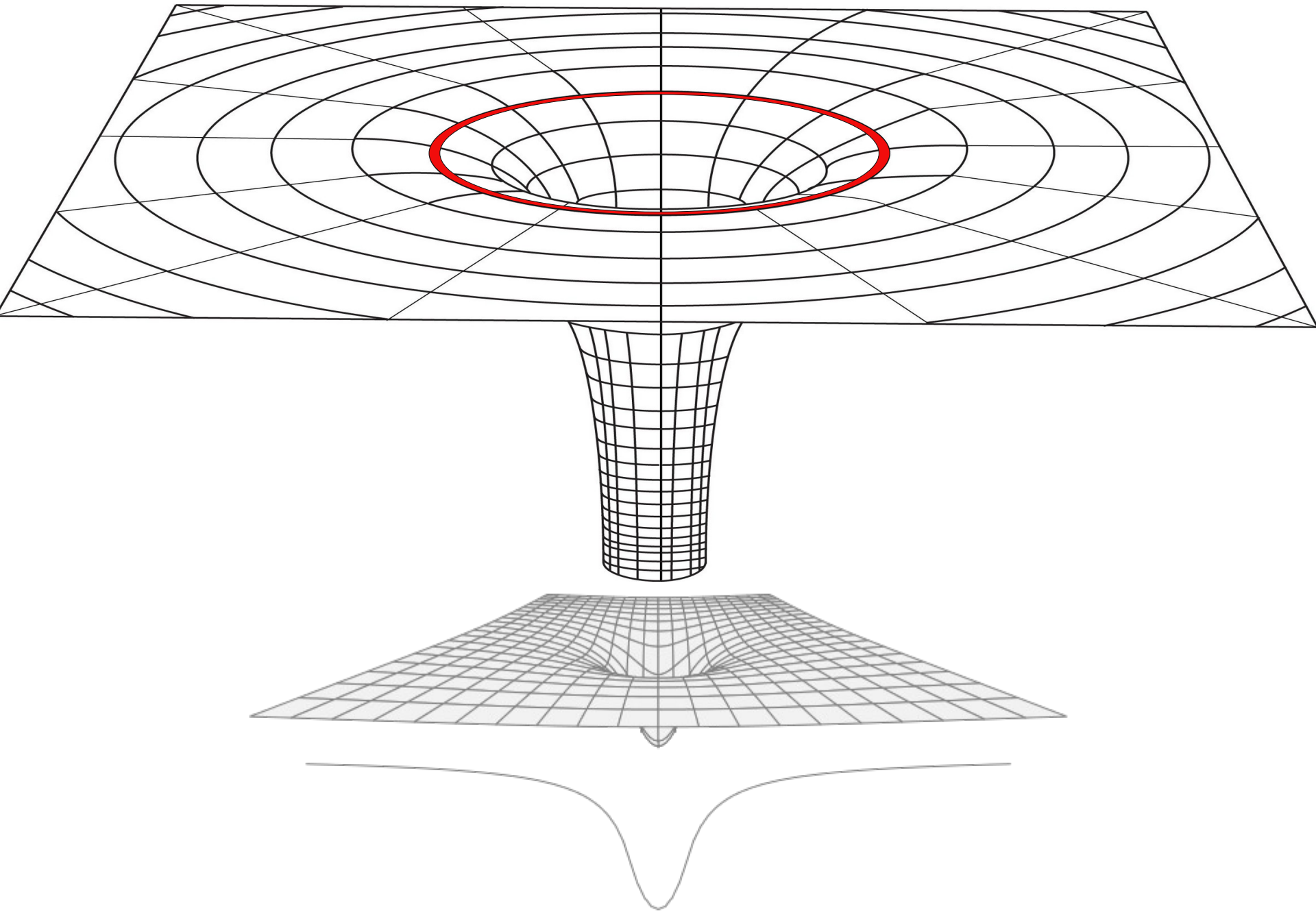





C
v
u
w
???


Event
horizon
Normal space
Gravity distorts
space-time
Singularity





Regular BH

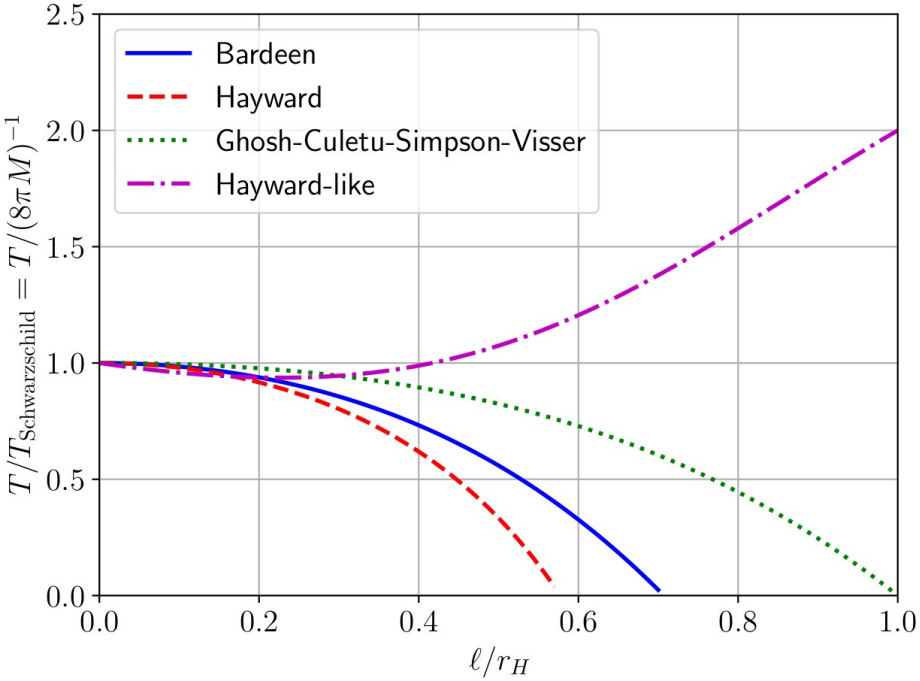
$$R \equiv g^{\mu\nu} R_{\mu\nu} \qquad R_{\mu\nu} R^{\mu\nu} \qquad \mathcal{K} \equiv R_{\mu\nu\rho\sigma} R^{\mu\nu\rho\sigma}$$

$$f_{\mathrm{B}}(r) = 1 - \frac{2Mr^2}{(r^2+\ell^2)^{3/2}}$$

$$f_{\mathrm{H}}(r) = 1 - \frac{2Mr^2}{r^3+2M\ell^2}$$

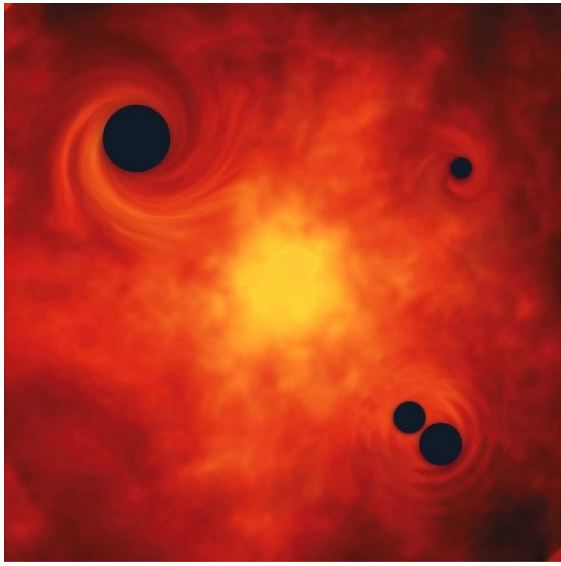
$$f_{\mathrm{GCSV}}(r) = 1 - \frac{2M}{r}\exp\left(-\frac{\ell}{r}\right)$$

$$f_{\text{H-l}}(r) = 1 - \frac{2Mr^2}{r^3+\ell\,(1-\ell r)}$$

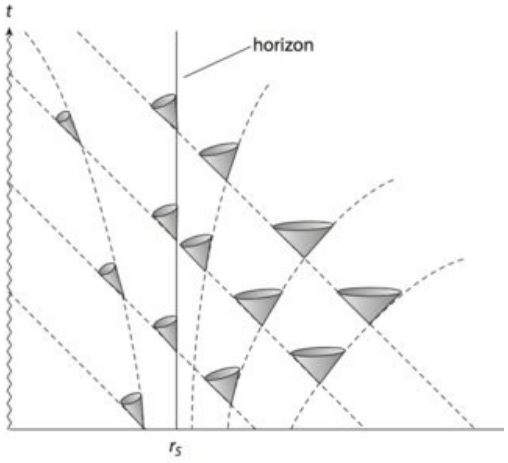


Primordial BH

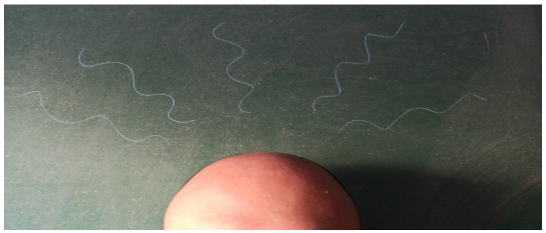
- PBHs are BHs formed in the **early Universe**
- Through the gravitational collapse of **overdensities** in the **cosmic plasma**
- **Masses** can be several orders of magnitude **below** the **solar mass**



So what? Why?



$$M,\ a = J/M^2,\ \cancel{Q}$$



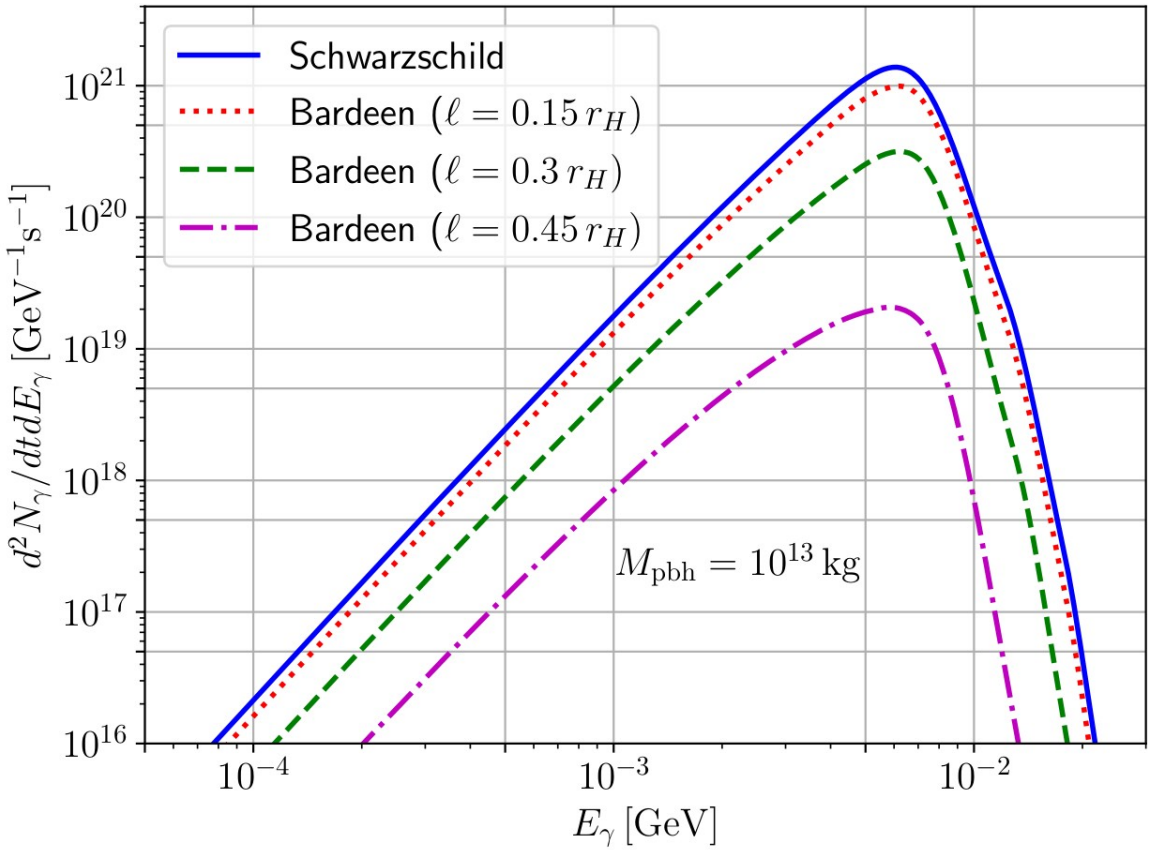
BHs evaporate

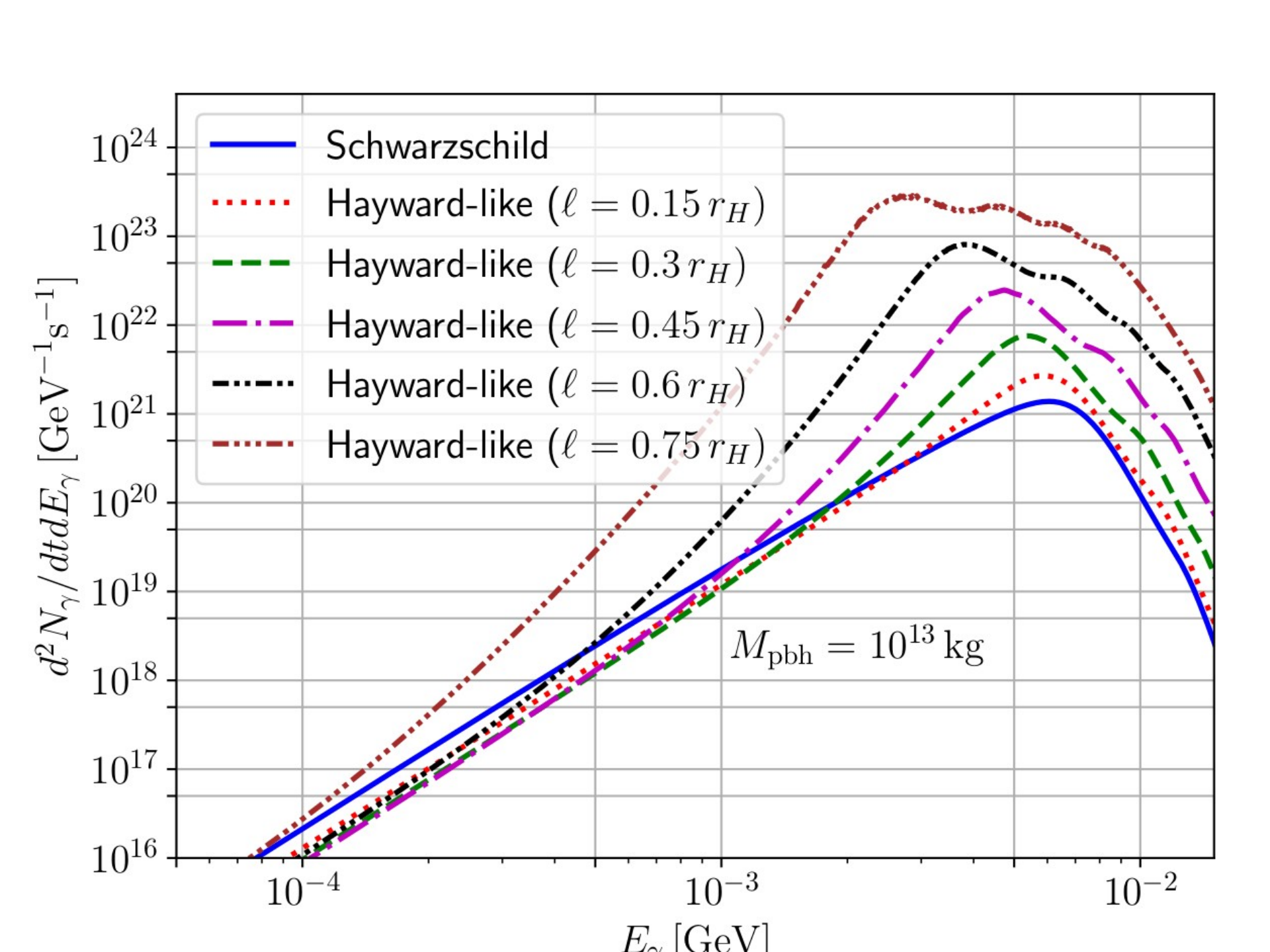
GR

QFT

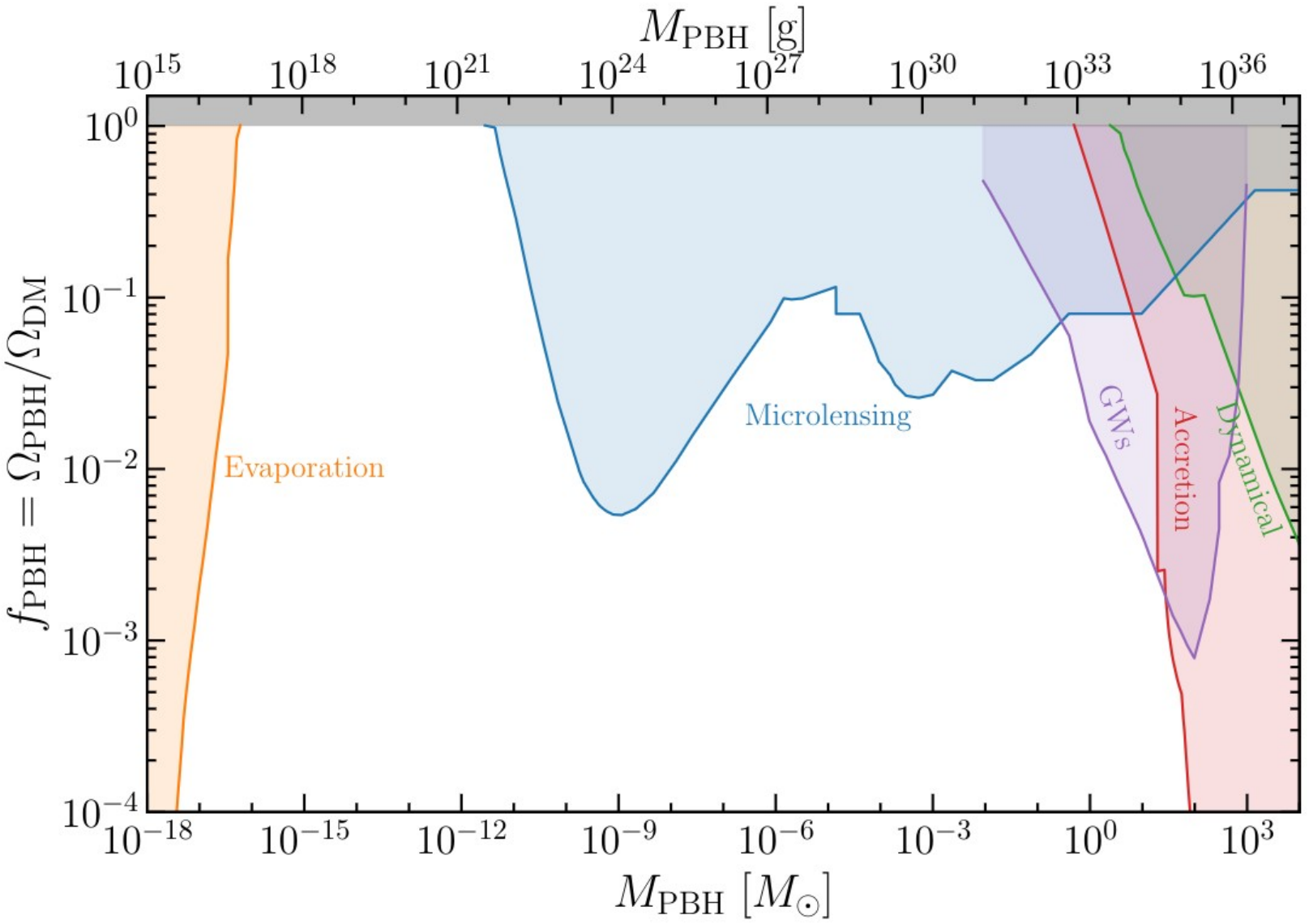
$$\frac{d^2 N_{P,i}}{dt dE_i} = \frac{1}{2\pi} \sum_{l,m} \frac{\Gamma^s_{l,m}(\omega)}{e^{\omega/T} \pm 1}$$

$M\downarrow$ & $T_H\uparrow$




Schwarzschild
Hayward-like ($\ell = 0.15\, r_H$)
Hayward-like ($\ell = 0.3\, r_H$)
Hayward-like ($\ell = 0.45\, r_H$)
Hayward-like ($\ell = 0.6\, r_H$)
Hayward-like ($\ell = 0.75\, r_H$)
$M_{\rm pbh} = 10^{13}\,{\rm kg}$
$d^2 N_\gamma / dt dE_\gamma\ [{\rm GeV}^{-1}{\rm s}^{-1}]$
$E_\gamma\ [{\rm GeV}]$
10^{24}
10^{23}
10^{22}
10^{21}
10^{20}
10^{19}
10^{18}
10^{17}
10^{16}
10^{-4}
10^{-3}
10^{-2}

PBH as DM fraction

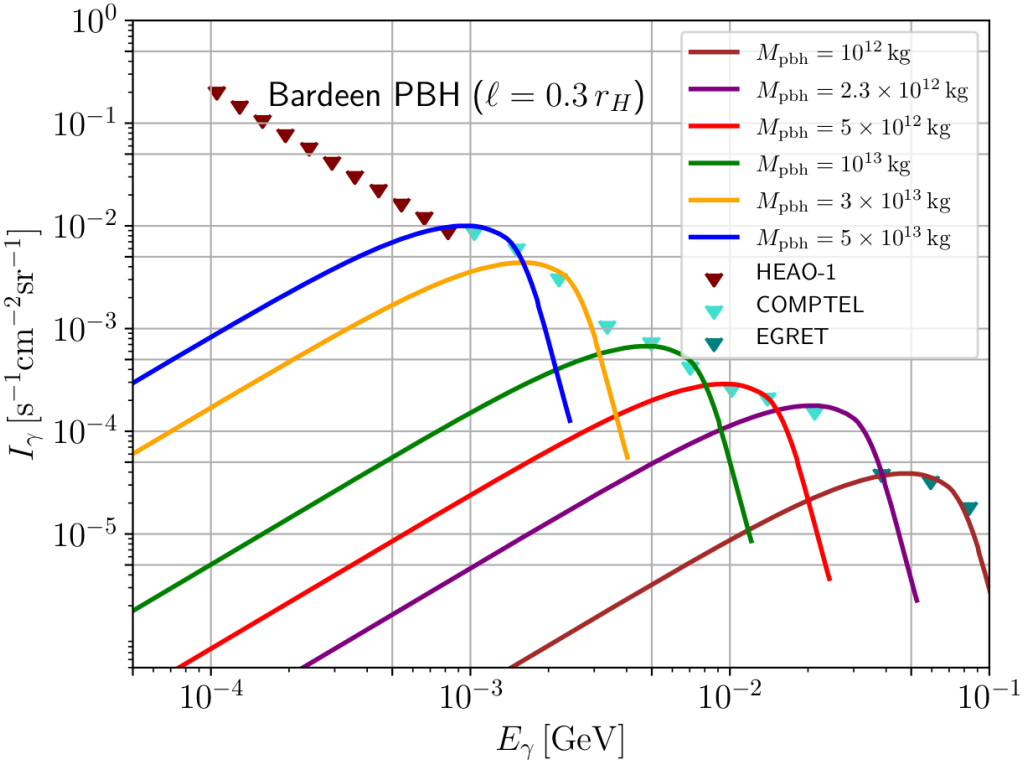


Evaporational constraint

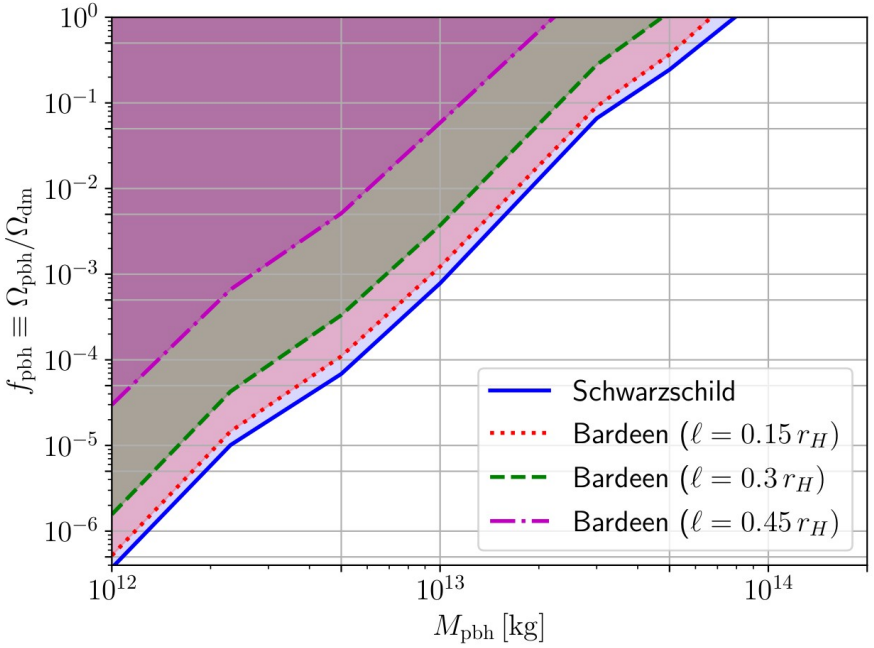
$$\frac{\mathrm{d}n_\gamma}{\mathrm{d}t}(E_\gamma, t) \simeq n_{\mathrm{PBH}}(t)\, E_\gamma\, \frac{\mathrm{d}\dot{N}_\gamma}{\mathrm{d}E_\gamma}(M(t), E_\gamma)\,,$$

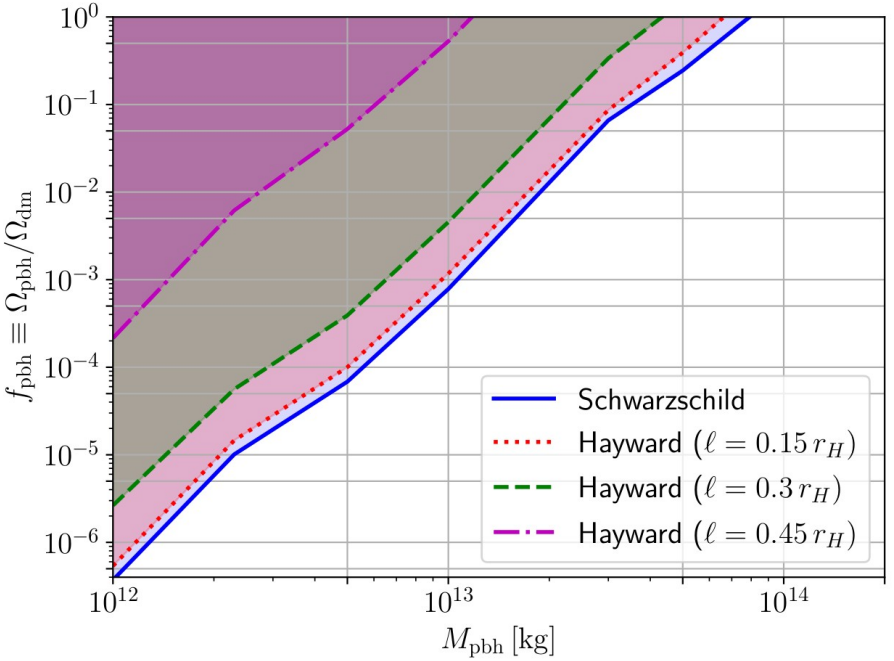
$$n_{\gamma 0}(E_{\gamma 0}) = n_{\mathrm{PBH}0}\, E_{\gamma 0} \int_{t_{\min}}^{\min(t_0,\tau)} \mathrm{d}t\, (1+z)\, \frac{\mathrm{d}\dot{N}_\gamma}{\mathrm{d}E_\gamma}(M(t), (1+z)\, E_{\gamma 0})\,,$$

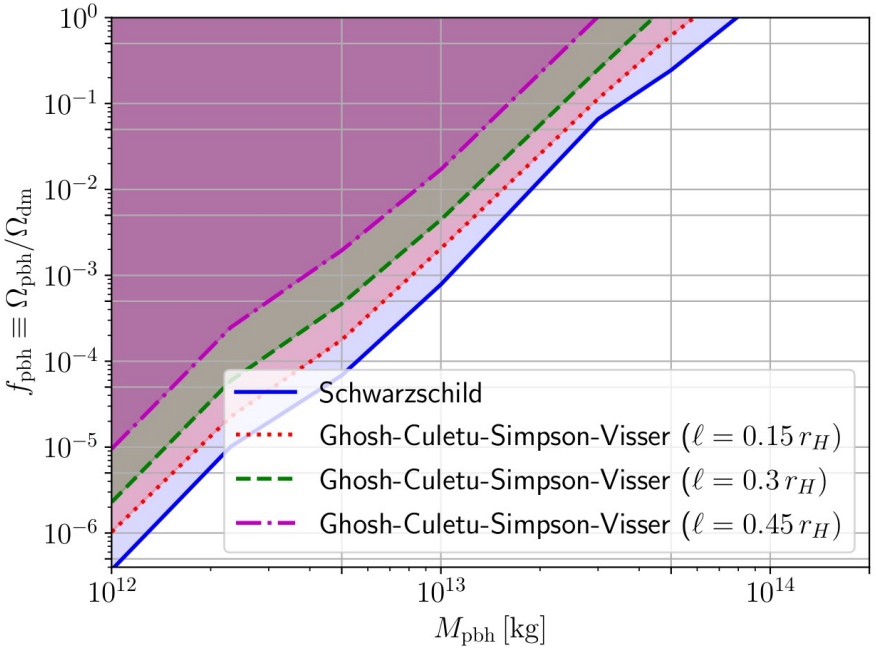
$$I \equiv \frac{c}{4\pi}\, n_{\gamma 0}\,.$$



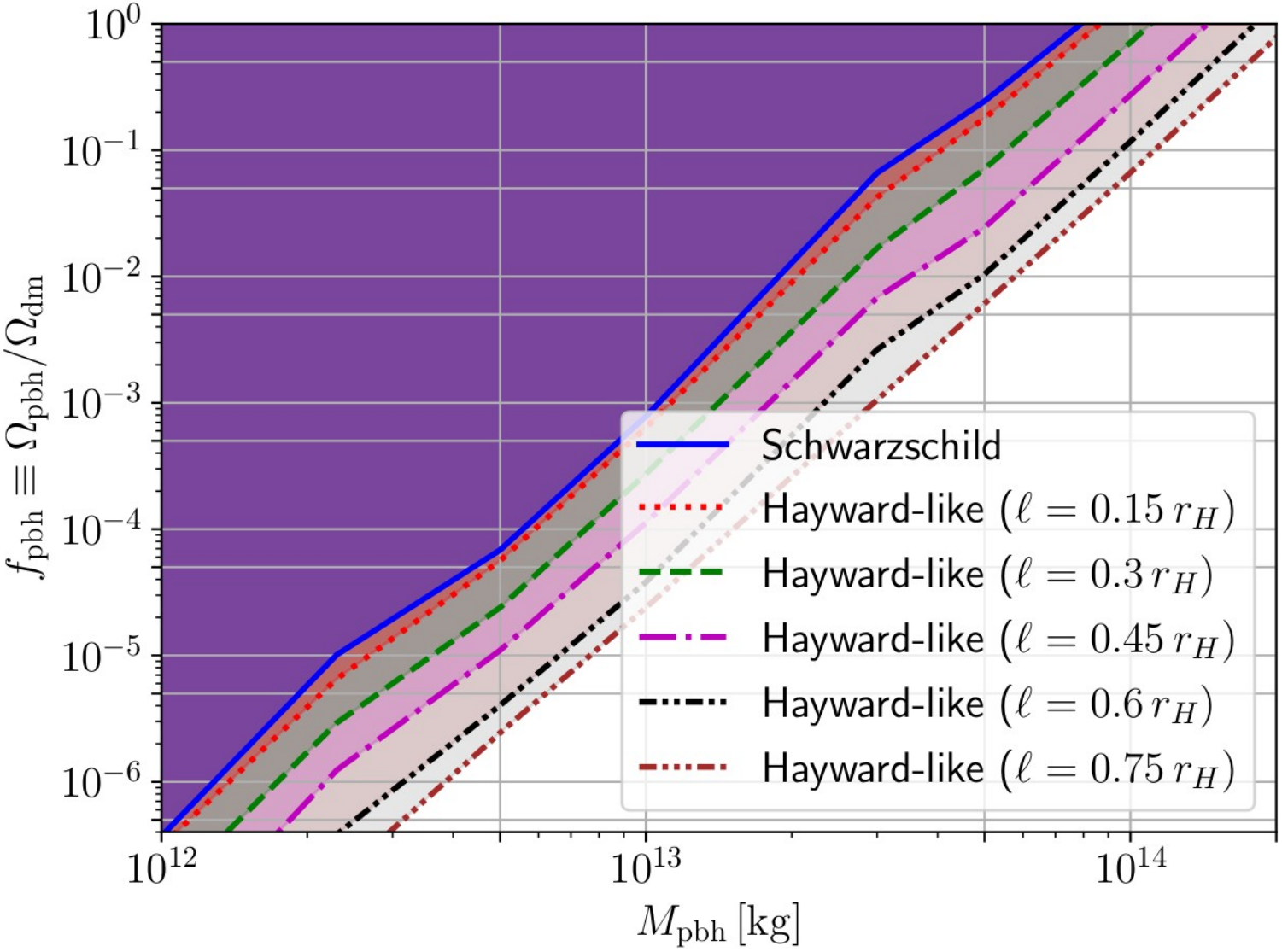
Results


$f_{\rm pbh} \equiv \Omega_{\rm pbh}/\Omega_{\rm dm}$
$M_{\rm pbh}$ [kg]
Schwarzschild
Bardeen ($\ell = 0.15\, r_H$)
Bardeen ($\ell = 0.3\, r_H$)
Bardeen ($\ell = 0.45\, r_H$)


$f_{\rm pbh} \equiv \Omega_{\rm pbh}/\Omega_{\rm dm}$
$M_{\rm pbh}$ [kg]
Schwarzschild
Hayward ($\ell = 0.15\, r_H$)
Hayward ($\ell = 0.3\, r_H$)
Hayward ($\ell = 0.45\, r_H$)


$f_{\rm pbh} \equiv \Omega_{\rm pbh}/\Omega_{\rm dm}$
$M_{\rm pbh}$ [kg]
Schwarzschild
Ghosh-Culetu-Simpson-Visser ($\ell = 0.15\, r_H$)
Ghosh-Culetu-Simpson-Visser ($\ell = 0.3\, r_H$)
Ghosh-Culetu-Simpson-Visser ($\ell = 0.45\, r_H$)

Results


10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
$f_{\rm pbh} \equiv \Omega_{\rm pbh}/\Omega_{\rm dm}$
10^{12}
10^{13}
10^{14}
$M_{\rm pbh}$ [kg]
Schwarzschild
Hayward-like ($\ell = 0.15\, r_H$)
Hayward-like ($\ell = 0.3\, r_H$)
Hayward-like ($\ell = 0.45\, r_H$)
Hayward-like ($\ell = 0.6\, r_H$)
Hayward-like ($\ell = 0.75\, r_H$)

Conclusion

New Physics = New Constraint

Worth studying since it provides
a rich phenomenology!!!

Thanks for your attention!!!

Thanks for your attention!!!