Memory-burdened Primordial Black Holes (PBHs)

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Hawking radiation

Semiclassical computation: Black Holes (BHs) emit particles in the form of a gray-body spectrum.

PRIMARY EMISSION

Gray-body factor

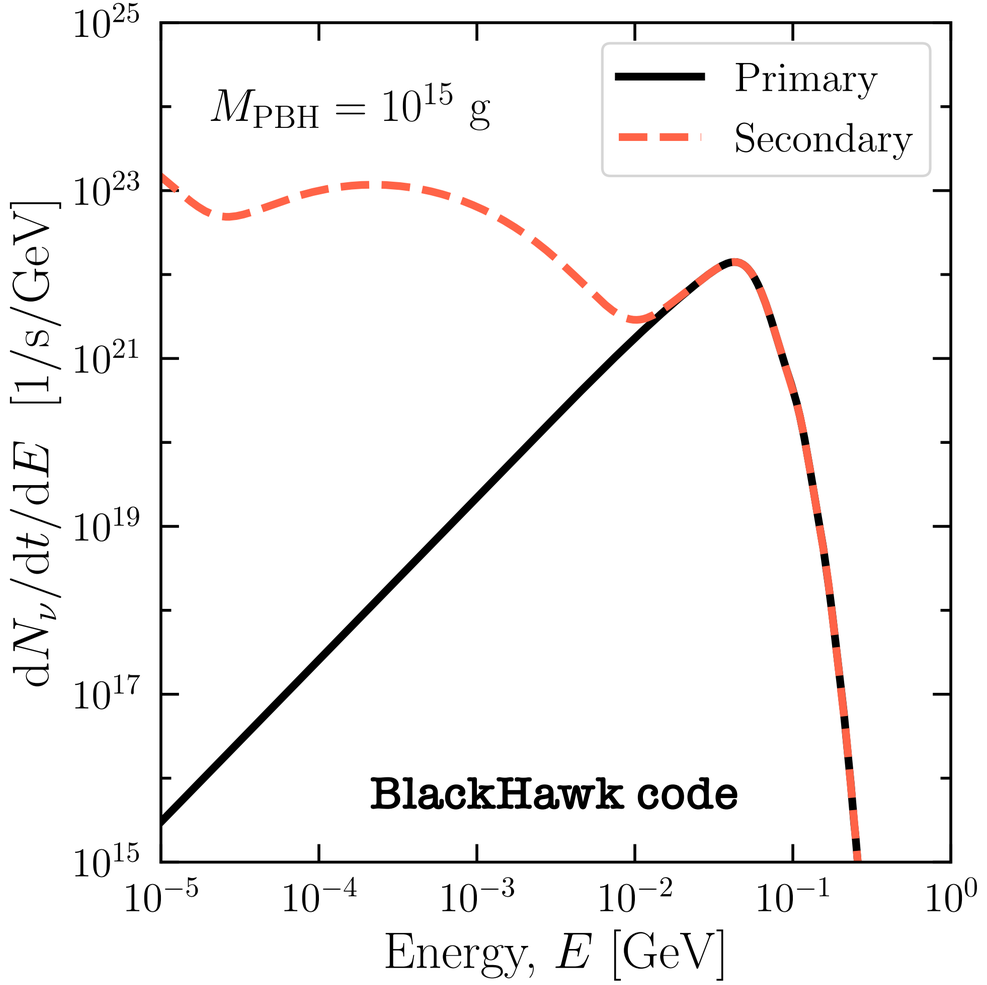
$$\frac{\mathrm{d}N}{\mathrm{d}t\,\mathrm{d}E} = \frac{g}{2\pi}\frac{\Gamma(E, T_{\rm PBH})}{\exp(E/T_{\rm PBH}) - (-1)^{2s}}$$

✦ Hawking temperature

$$T_{\rm PBH} \simeq 10\left(\frac{10^{15}\ \mathrm{g}}{M_{\rm PBH}}\right)\ \mathrm{MeV}$$

✦ Evaporation lifetime

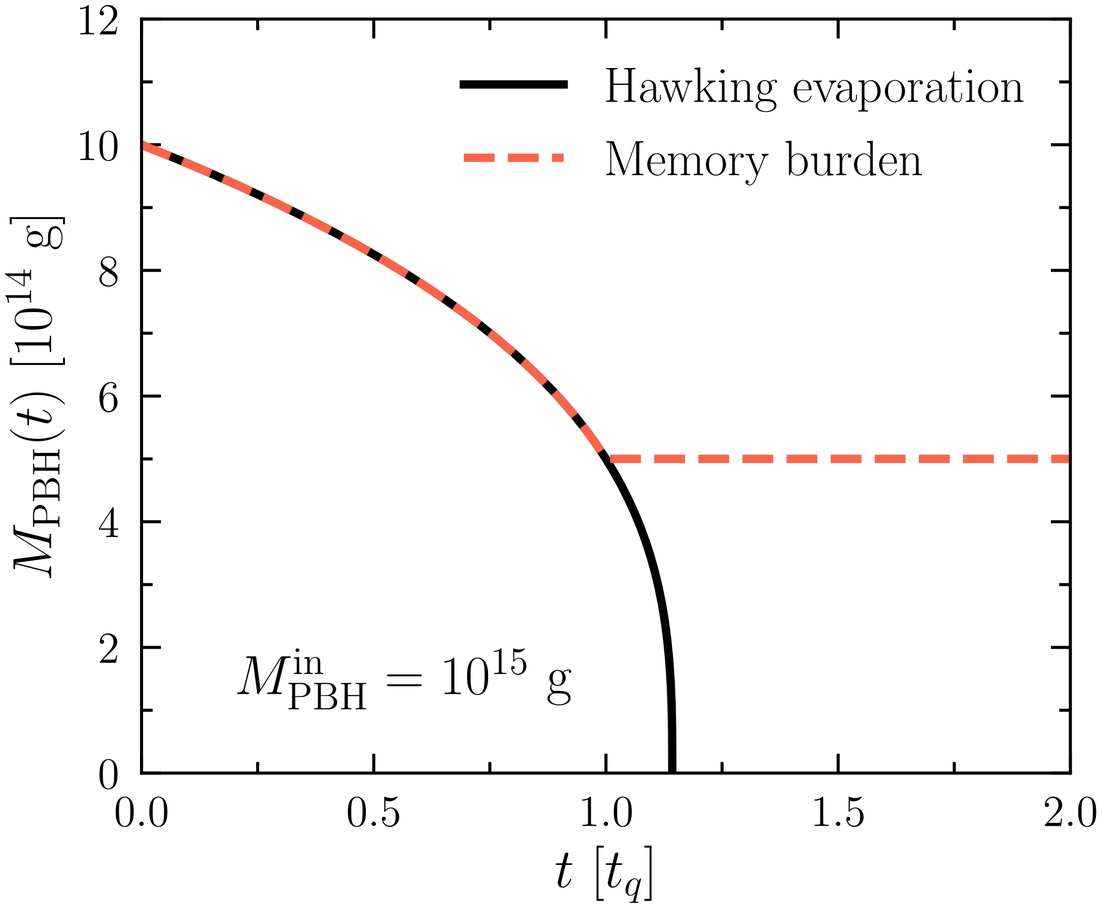
$$\tau_{\rm PBH} \simeq 4\times 10^{17}\left(\frac{M_{\rm PBH}}{10^{15}\ \mathrm{g}}\right)^3\ \mathrm{s}$$



*Hawking, **Nature** (1974); Hawking, **Comm.Math.Phys.** (1975);Carr, **ApJ** (1976); Page, **PRD** (1976)*

Memory-burdened evaporation

Universal memory-burden effect: an object is stabilized by its large quantum information capacity.



More stable and long-lived PBHs

✦ **Quantum application to black holes:** back-reaction might suppress the Hawking evaporation as

$$\left.\frac{\mathrm{d}N}{\mathrm{d}t\,\mathrm{d}E}\right|_{\rm mb} = \frac{1}{S\,(M_{\rm PBH})^k}\,\frac{\mathrm{d}N}{\mathrm{d}t\mathrm{d}E}$$

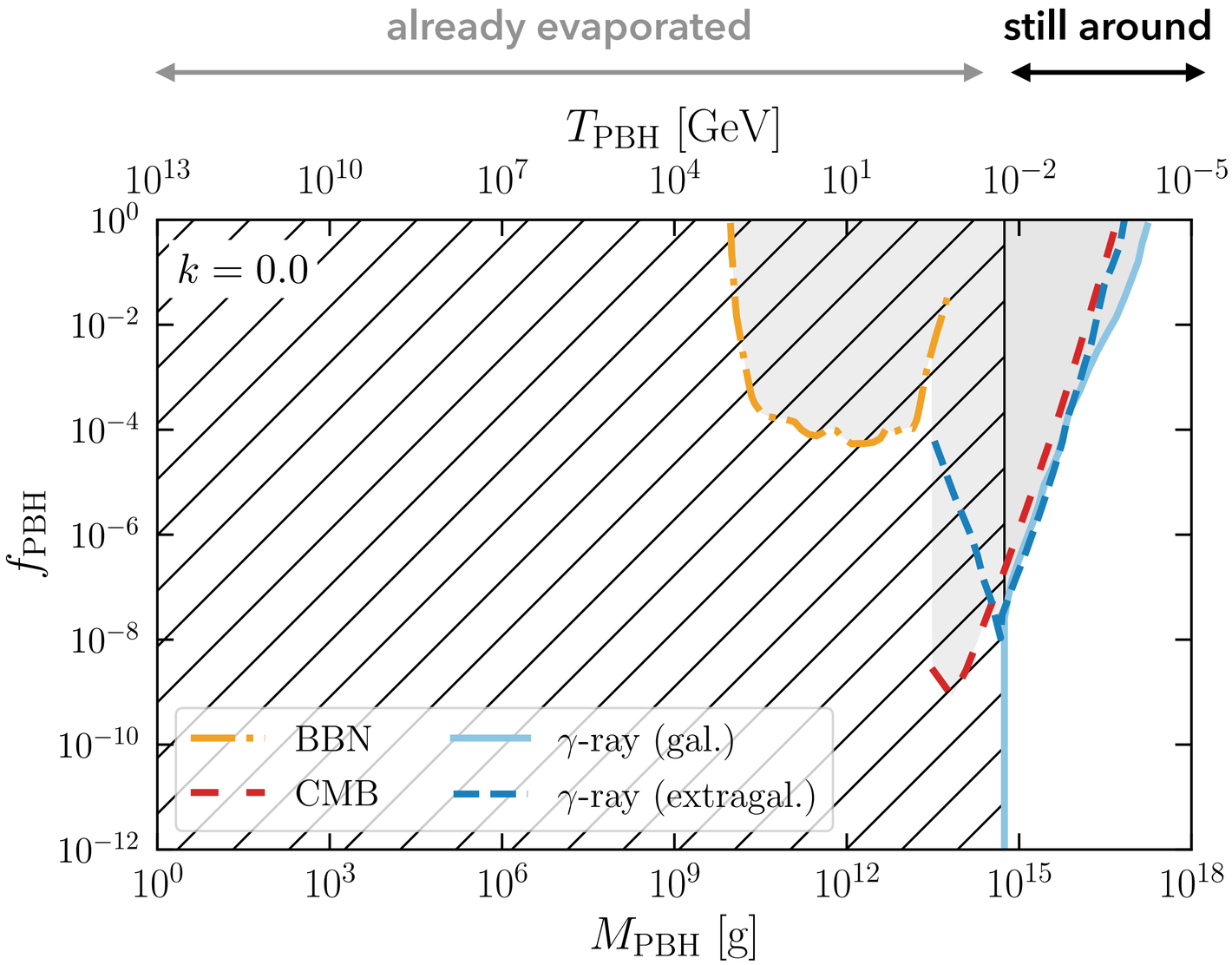
for $M_{\rm PBH} \leq q\,M^{in}_{\rm PBH}$ (with $q \simeq 0.5$)

✦ Suppression as a power k of the **BH's entropy**

$$S = 4\pi G M^2_{\rm PBH} \simeq 10^{10}\left(\frac{M_{\rm PBH}}{1\ \rm g}\right)^2$$

Dvali, 1810.02336; Dvali+, PRD 102 (2020); Dvali+, PRD 110 (2024)

PBHs constraints: *standard picture*



Plot adapted from Thoss+, MNRAS 532 (2024)

PBHs as DM candidates

- Viable DM (*asteroid*) window:

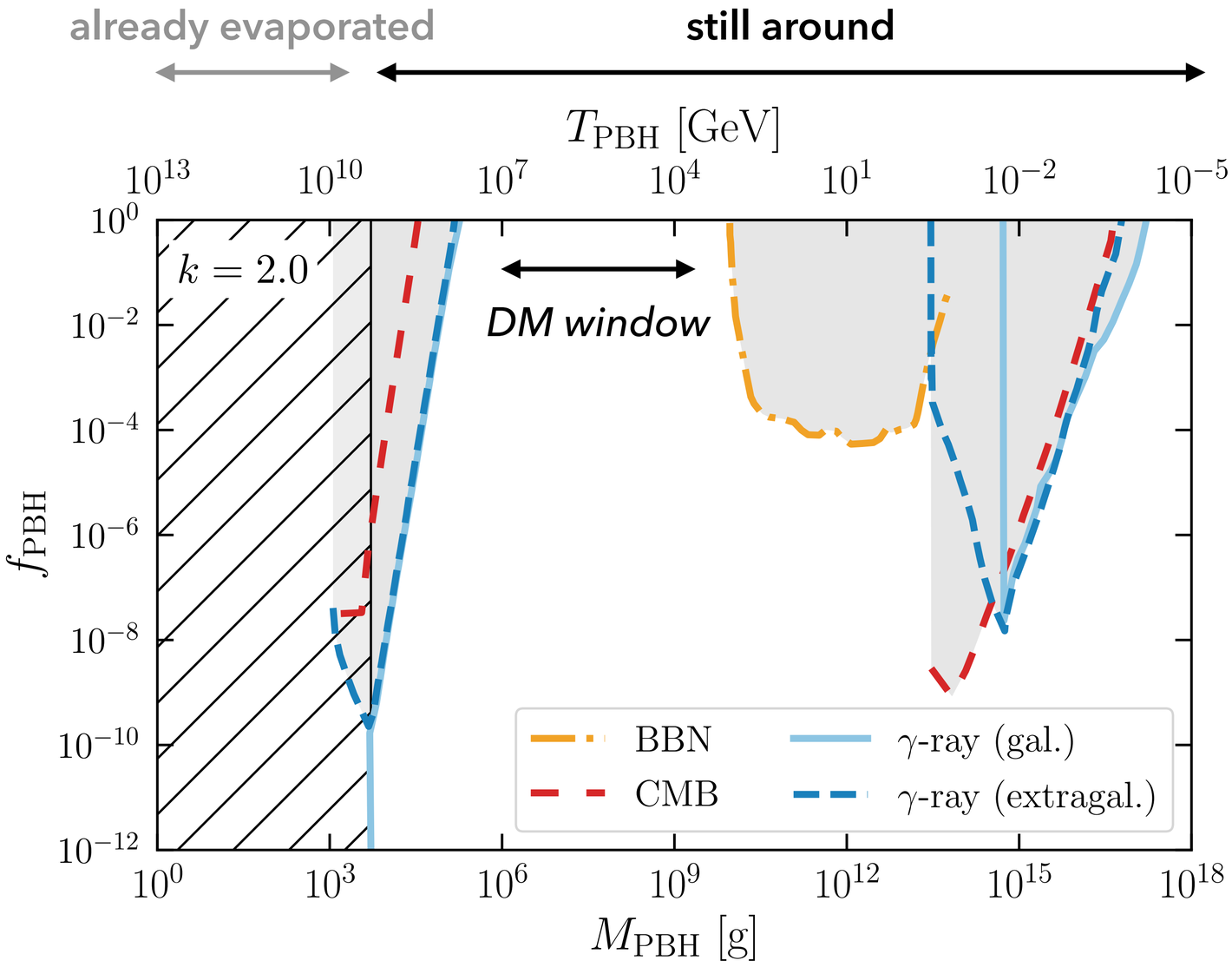
$$10^{17}\ \mathrm{g} \lesssim M_{\rm PBH} \lesssim 10^{22}\ \mathrm{g}$$

- Astrophysical signatures at sub-GeV energies

Cosmological PBHs

- Sourcing heavy particles with masses up to 10^{15} GeV
- Early matter-dominated epochs

PBHs constraints: *memory-burden picture*



Plot adapted from Thoss+, MNRAS 532 (2024)

PBHs as DM candidates

- New DM mass window:

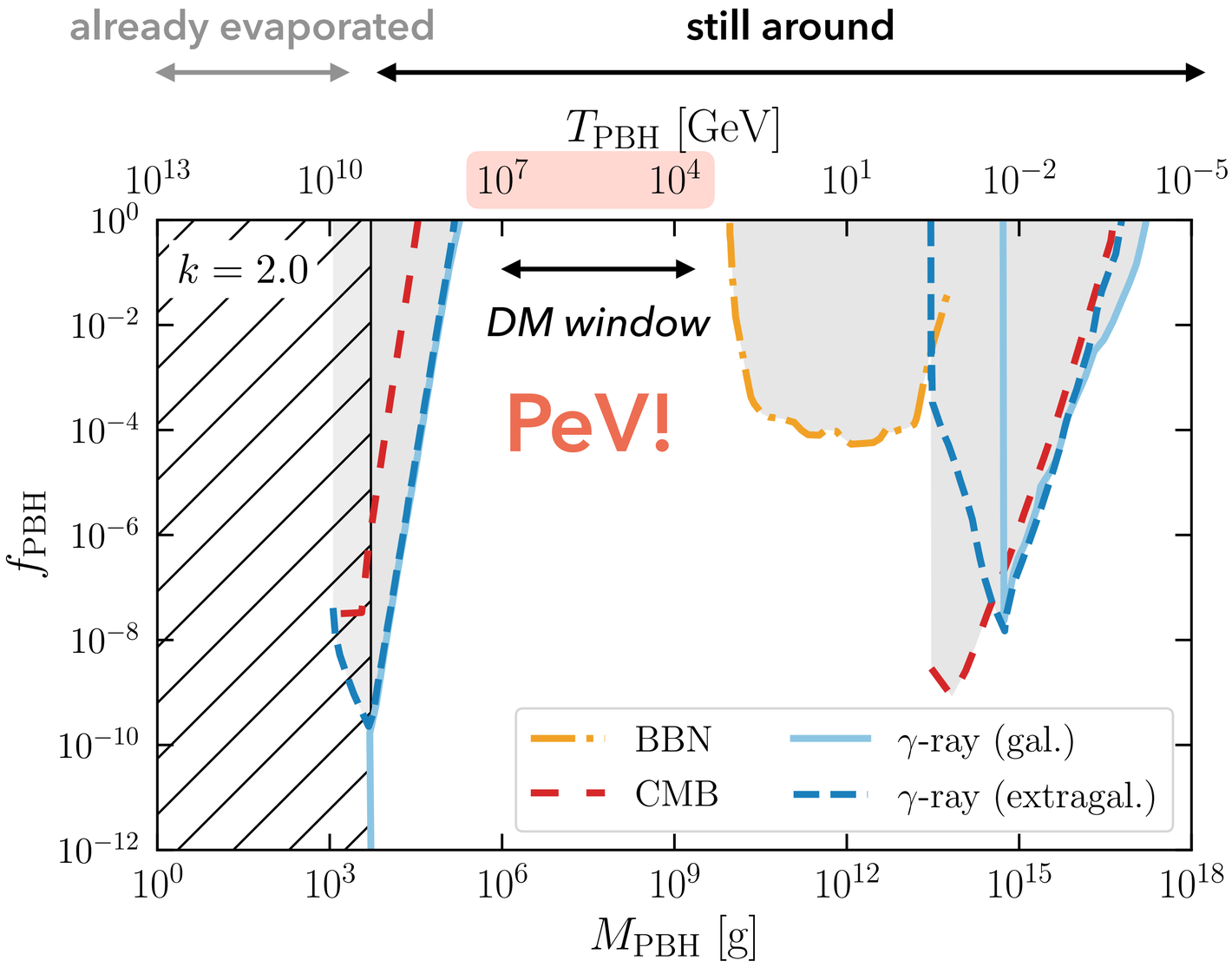
$$M_{\rm PBH} \lesssim 10^{10}\ {\rm g}$$

- Astrophysical signatures at *very high energies*!

Cosmological PBHs

- Sourcing heavy particles with less efficiency
- *Longer* early matter-dominated epochs

PBHs constraints: *memory-burden picture*



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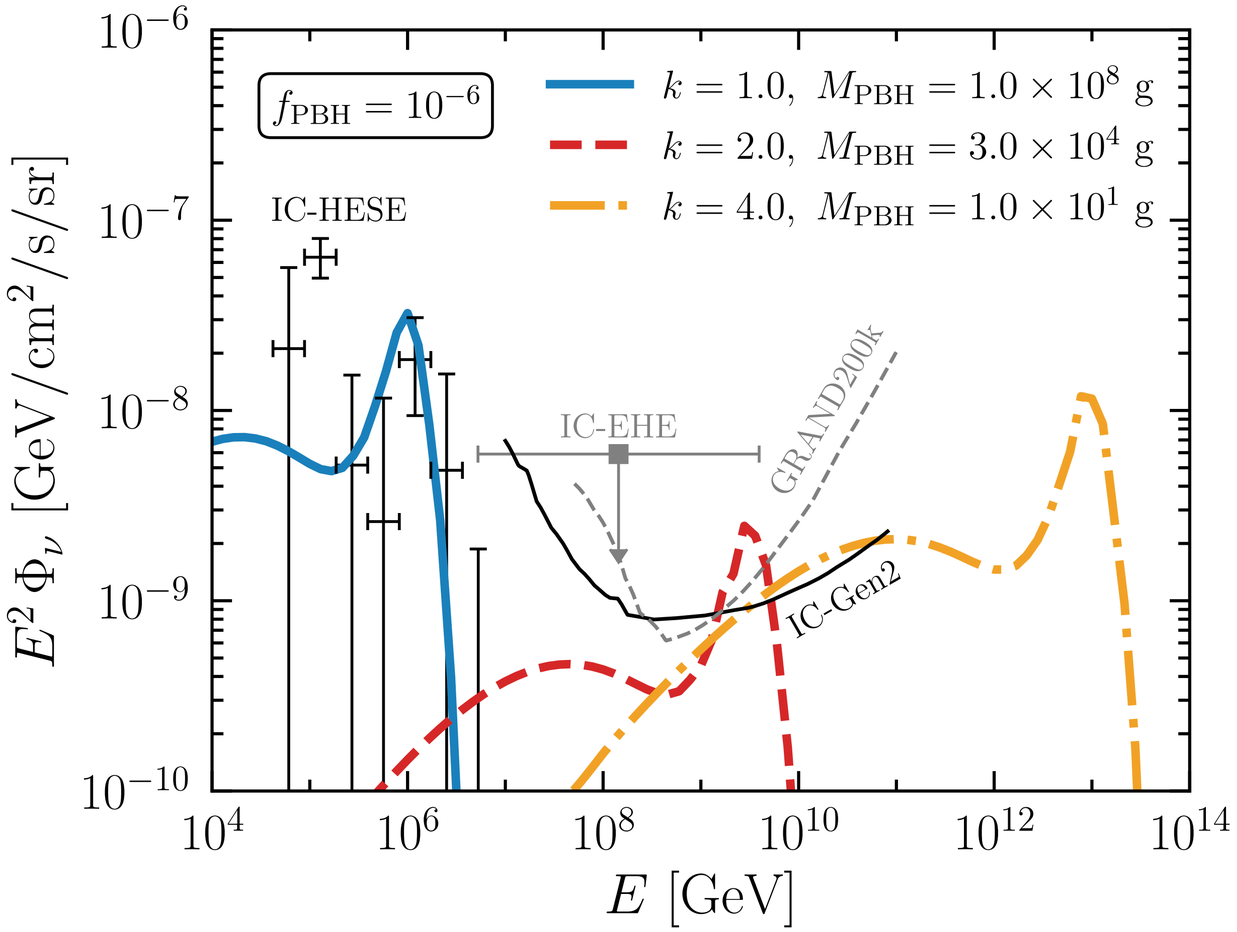
High-energy neutrino emission

MC, Boccia, Iocco, Miele, Saviano, ***arXiv:2410.07604***



- High-energy neutrino flux from a monochromatic population of galactic and extragalactic DM-PBHs
- Competitive and complementary bounds on PBHs with current and future neutrino data
- High-energy neutrinos as a crucial probe of the memory burden effect!

Take-home messages

- PBHs provide a rich phenomenology in connection with Hawking radiation, *e.g.* dark matter candidates and non-standard cosmology.

- PBHs might be stabilized by the memory-burden effect: light PBHs in the present Universe and Hawking emission at ultra-high energies.

- **Let us think more on the phenomenological implications!**

Let’s now discuss!

Novel bounds

MC, Boccia, Iocco, Miele, Saviano, ***arXiv:2410.07604***