PRIMORDIAL BLACK HOLE DARK MATTER EVAPORATING ON THE NEUTRINO FLOOR

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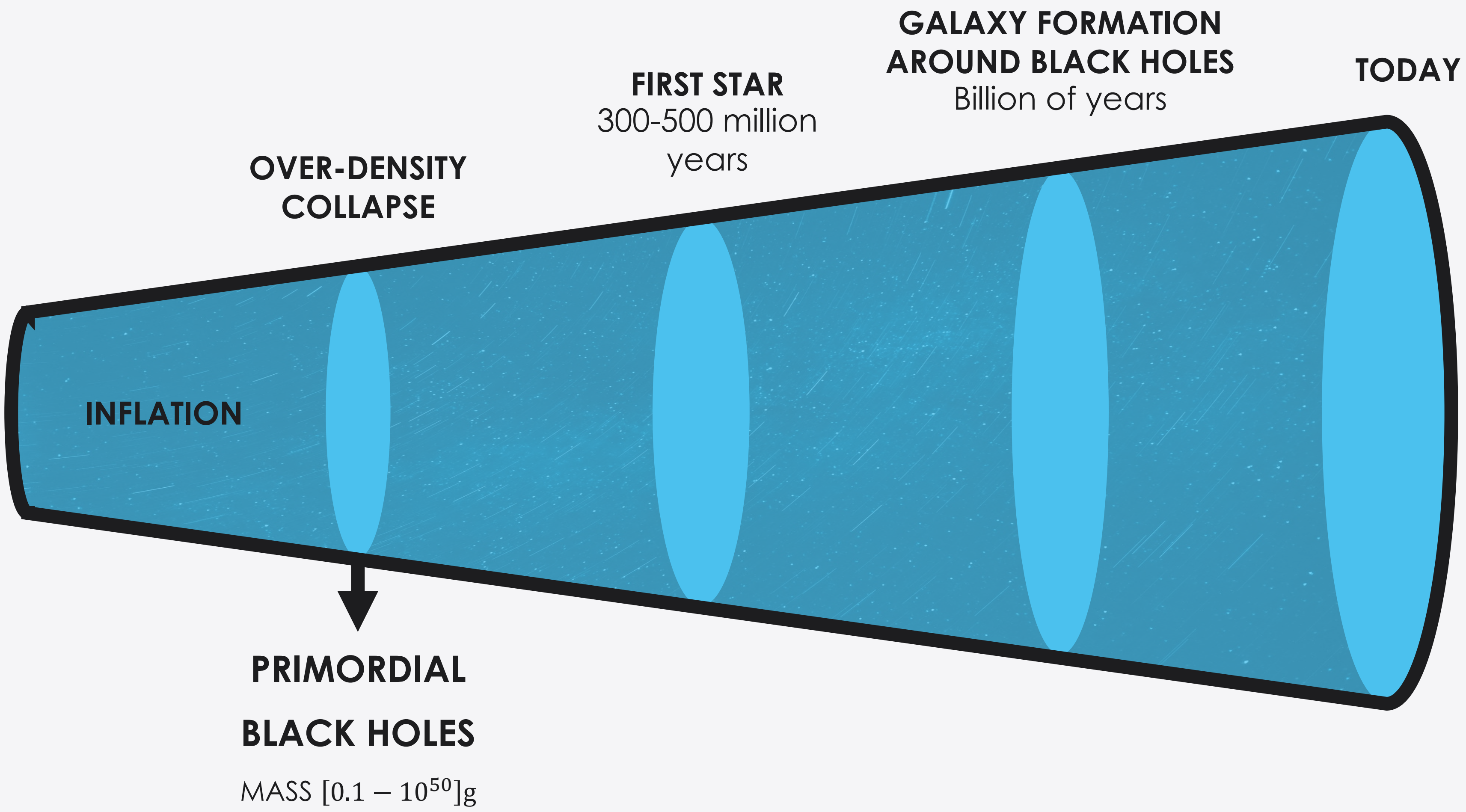
In collaboration with: D.F.G. Fiorillo, G. Miele, S. Morisi, A. Palazzo

Based on: Phys.Lett.B 829 (2022) 137050

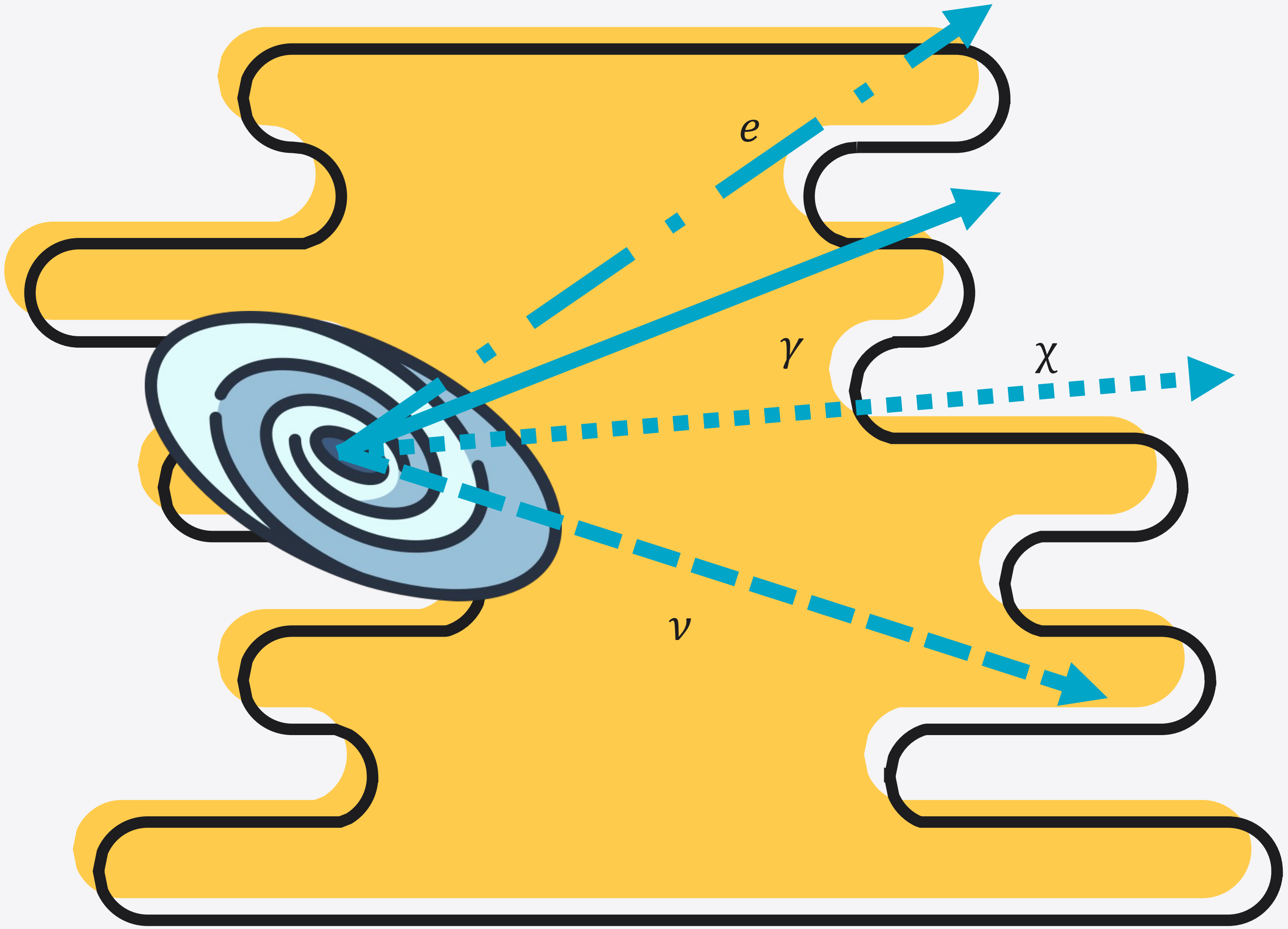
PRIMORDIAL BLACK HOLES

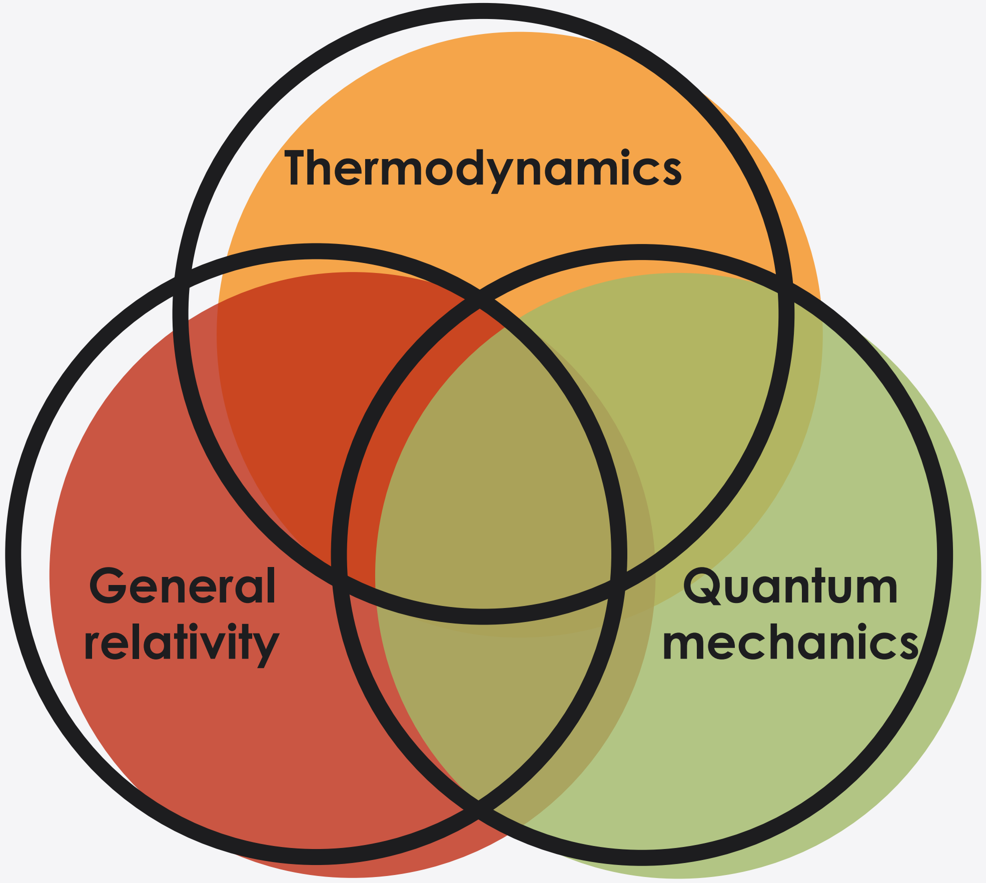


S. W. Hawking, *Commun.Math.Phys.* 43 (1975) 199-220
B. J. Carr, *Astrophys.J.* 201 (1975) 1-19
J. Auffinger, arXiv: 2206.02672

WHY PRIMORDIAL BLACK HOLES?

Primordial Black Holes represent an intrinsic link between three pillars of modern physics!

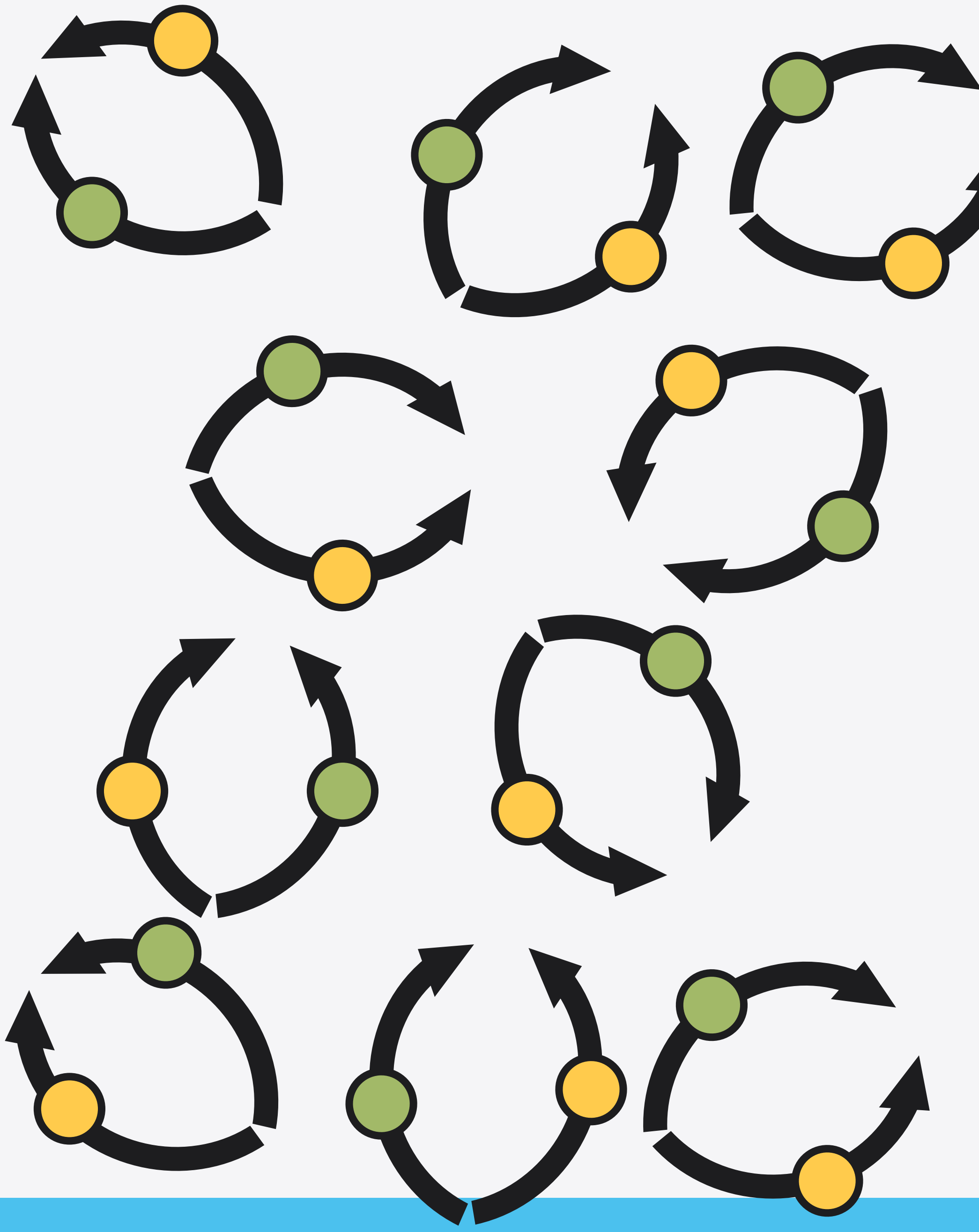




HAWKING RADIATION

Uncertainty principle → the vacuum is a medium in which particle and antiparticle pairs appear and disappear

$$E_p(\infty) + E_{\overline{p}}(\infty) = 0$$



S. W. Hawking, CMP 87 (1983) 577
G.W. Gibbons and S. W. Hawking, PRD 15 (1977)
H. J. Trashen, arXiv gr-qc/0010055

HAWKING RADIATION

Uncertainty principle → the vacuum is a medium in which particle and antiparticle pairs appear and disappear

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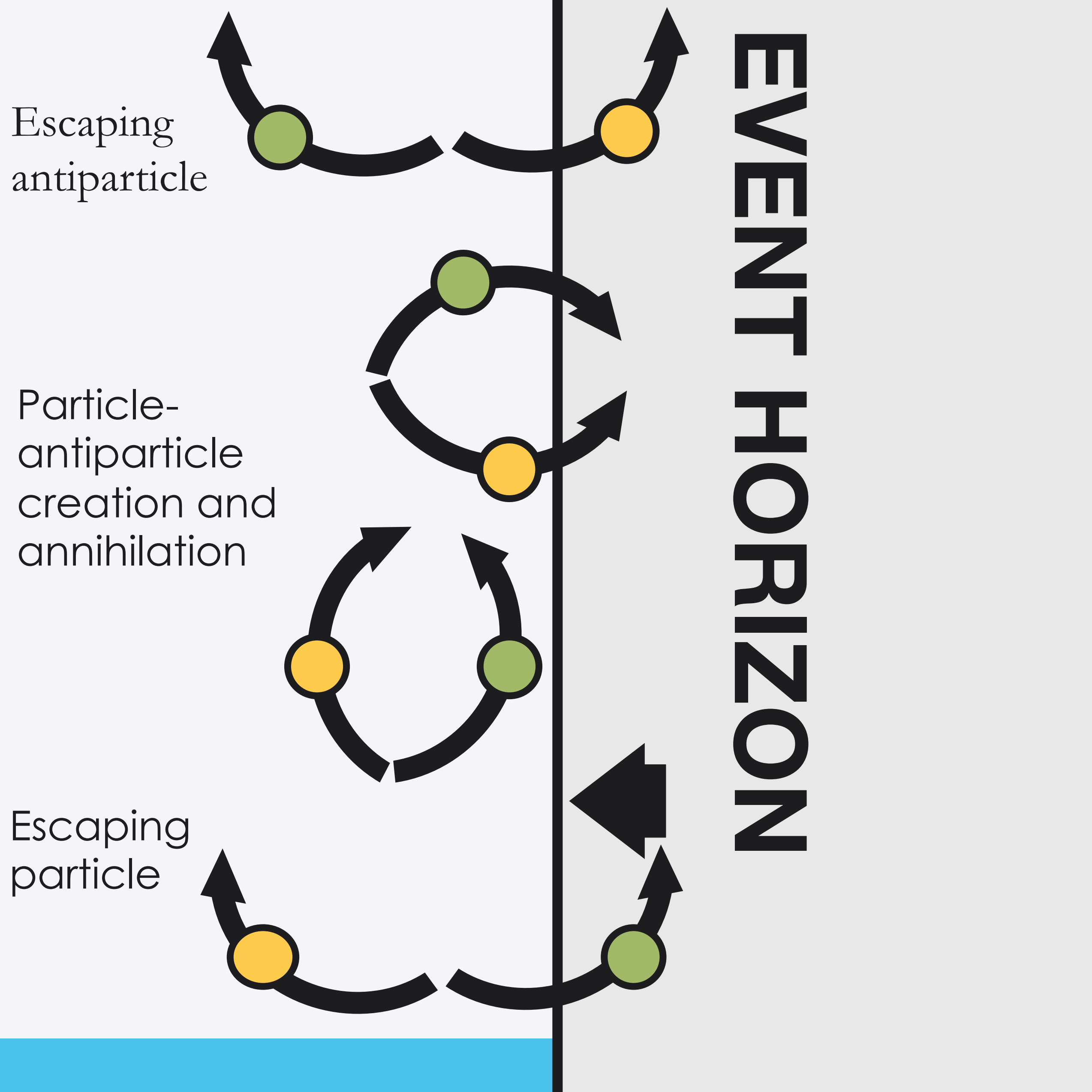
What happens near the event horizon?



S. W. Hawking, CMP 87 (1983) 577
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WHY PRIMORDIAL BLACK HOLES?

Dark Matter

(Candidate: B.J. Carr and S.W. Hawking, MNRAS 1974. Source: L. Morrison et al, JCAP 2019)

Early Universe

(A.M. Green, Fundam. Theor. Phys. 2015)

Baryogenesis & Leptogenesis

(S. W. Hawking, Nature 1974; Y. B. Zeldovich, Pisma Zh. Eksp. Teor. Fiz. 1976)

Seeds for Supermassive Black Holes

(B. J. Carr and M. J. Rees, MNRAS 1984)

Hawking Radiation

(S. W. Hawking, CMP 87 (1983) 577)

PARTICLE EMISSION

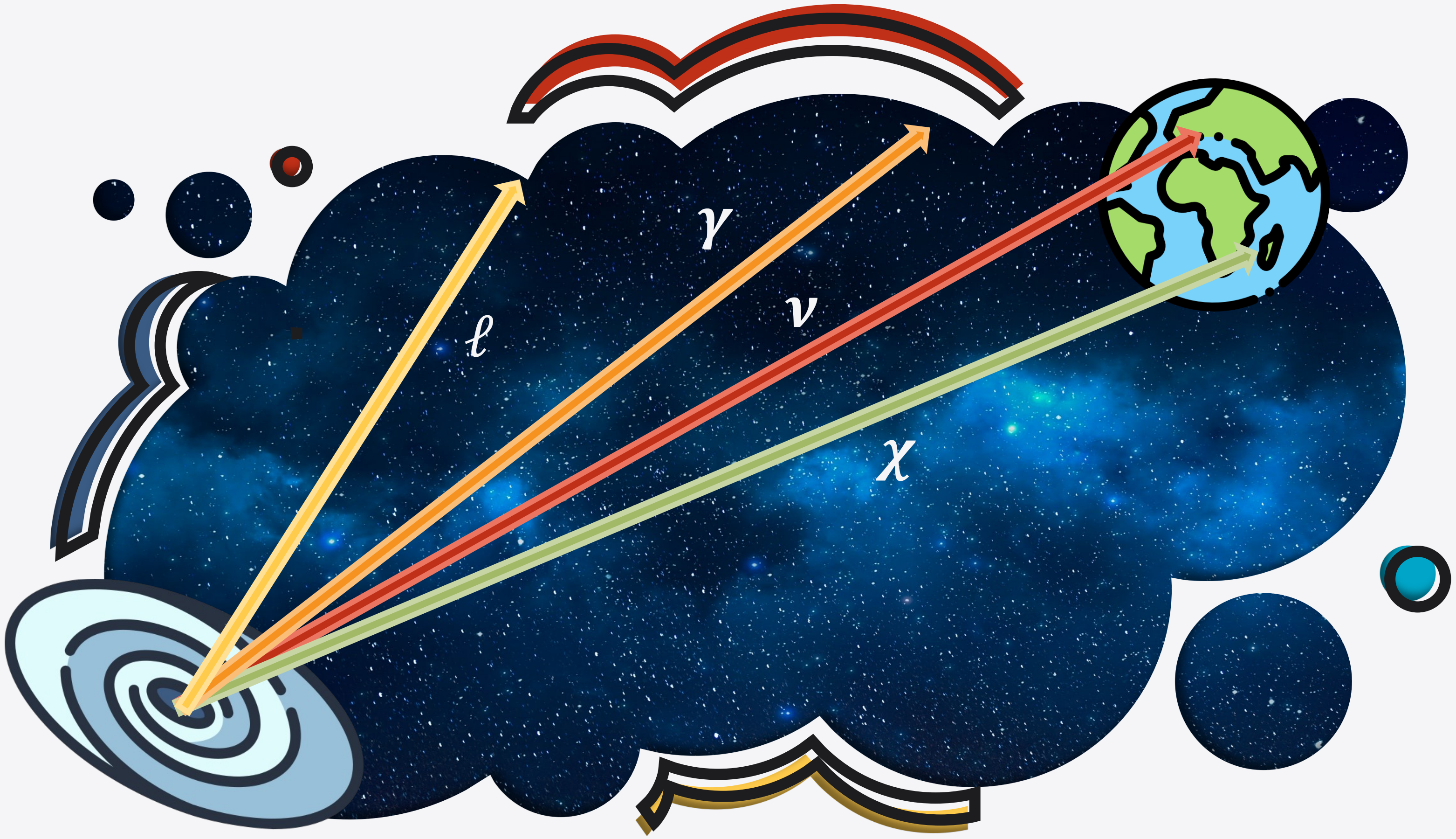
S. W. Hawking, CMP 87 (1983) 577
G.W. Gibbons and S. W. Hawking, PRD 15 (1977)
H. J. Trashen, arXiv gr-qc/0010055

The emission is black-body-like, with a temperature given by

$$T_{BH} = \frac{\kappa}{2\pi}$$

For a **neutral** and **non-rotating** Primordial Black Hole, the Hawking temperature is

$$T_{PBH} = \frac{\hbar c^3}{8\pi G k_B M_{PBH}}$$



PARTICLE EMISSION

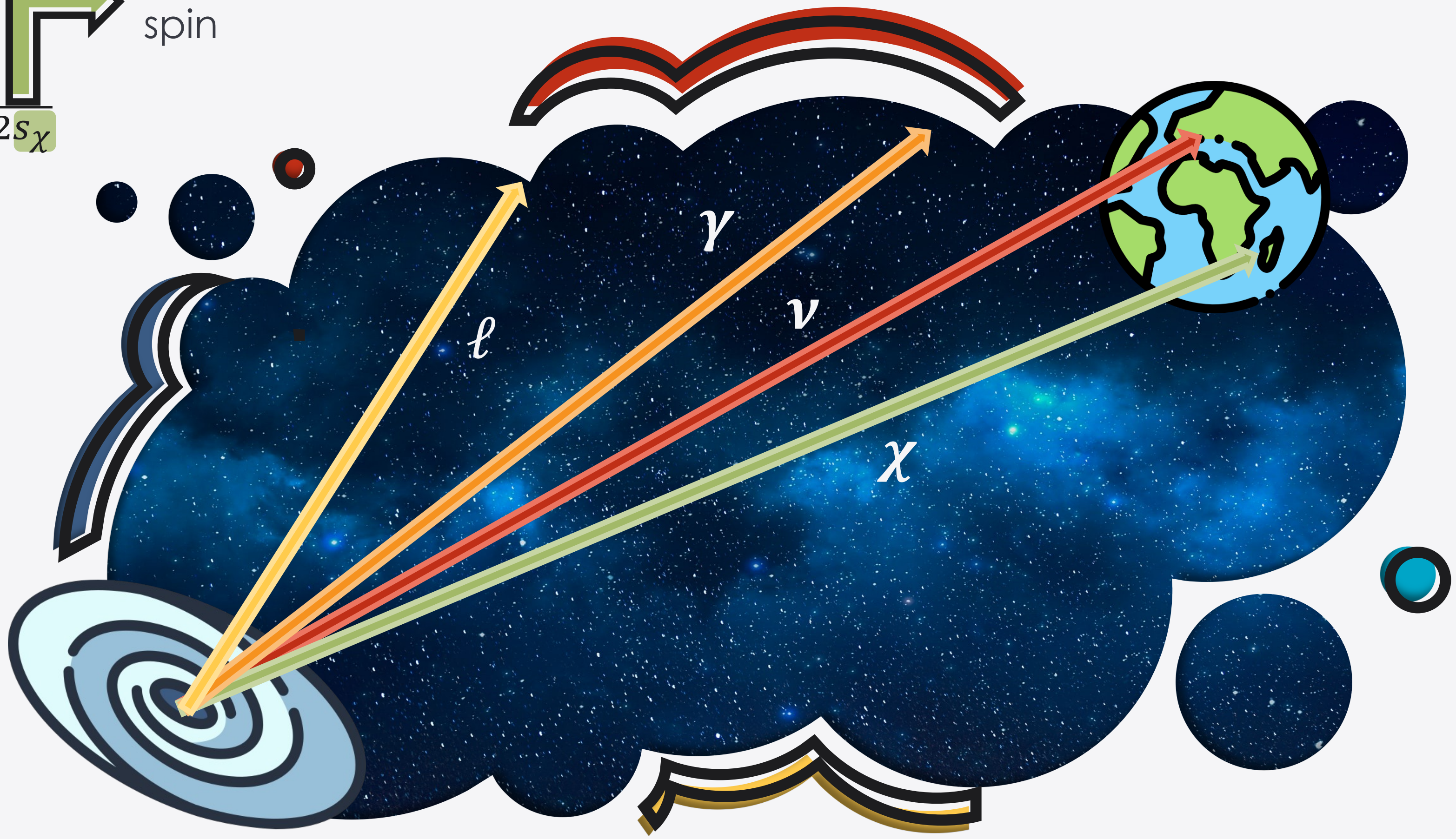
χ Degrees of freedom

Grey body factor

χ spin

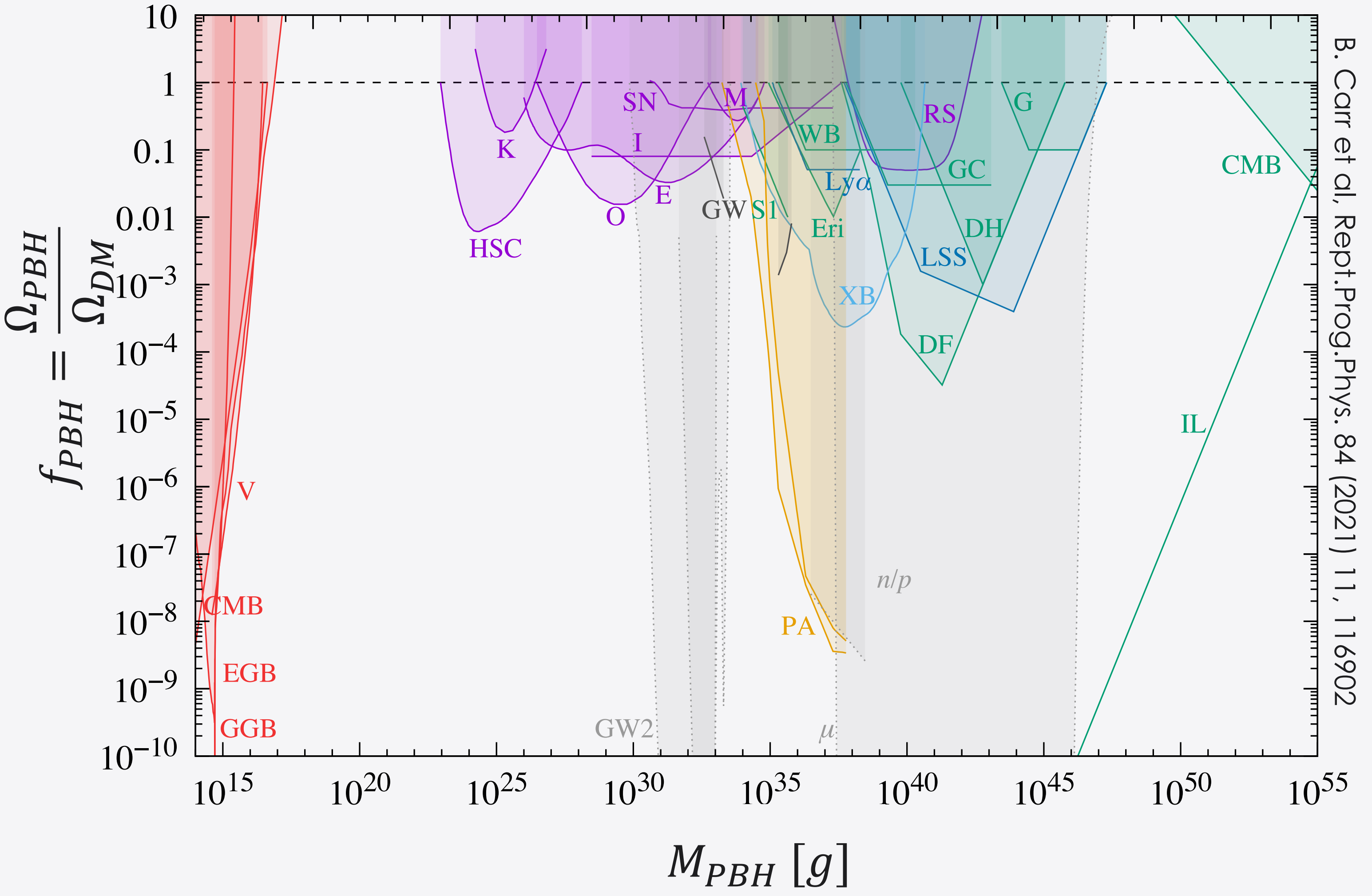
$$\frac{dN}{dt\,dE_\chi} = \frac{g_\chi}{2\pi}\,\frac{\Gamma^\chi(E_\chi, T_{PBH})}{\exp(E_\chi/T_{PBH}) - (-1)^{2s_\chi}}$$

χ Energy



BLACKHAWK (A. Arbey and J. Auffinger, Eur.Phys.J.C 79 (2019); A. Arbey and J. Auffinger, Eur.Phys.J.C 81 (2021); J. Auffinger, Eur.Phys.J.C 82 (2022))

EXISTING CONSTRAINTS



Lensing

Evaporation

CMB distortions

Dynamical effects

Accretion

Large Scale Structure (LSS)

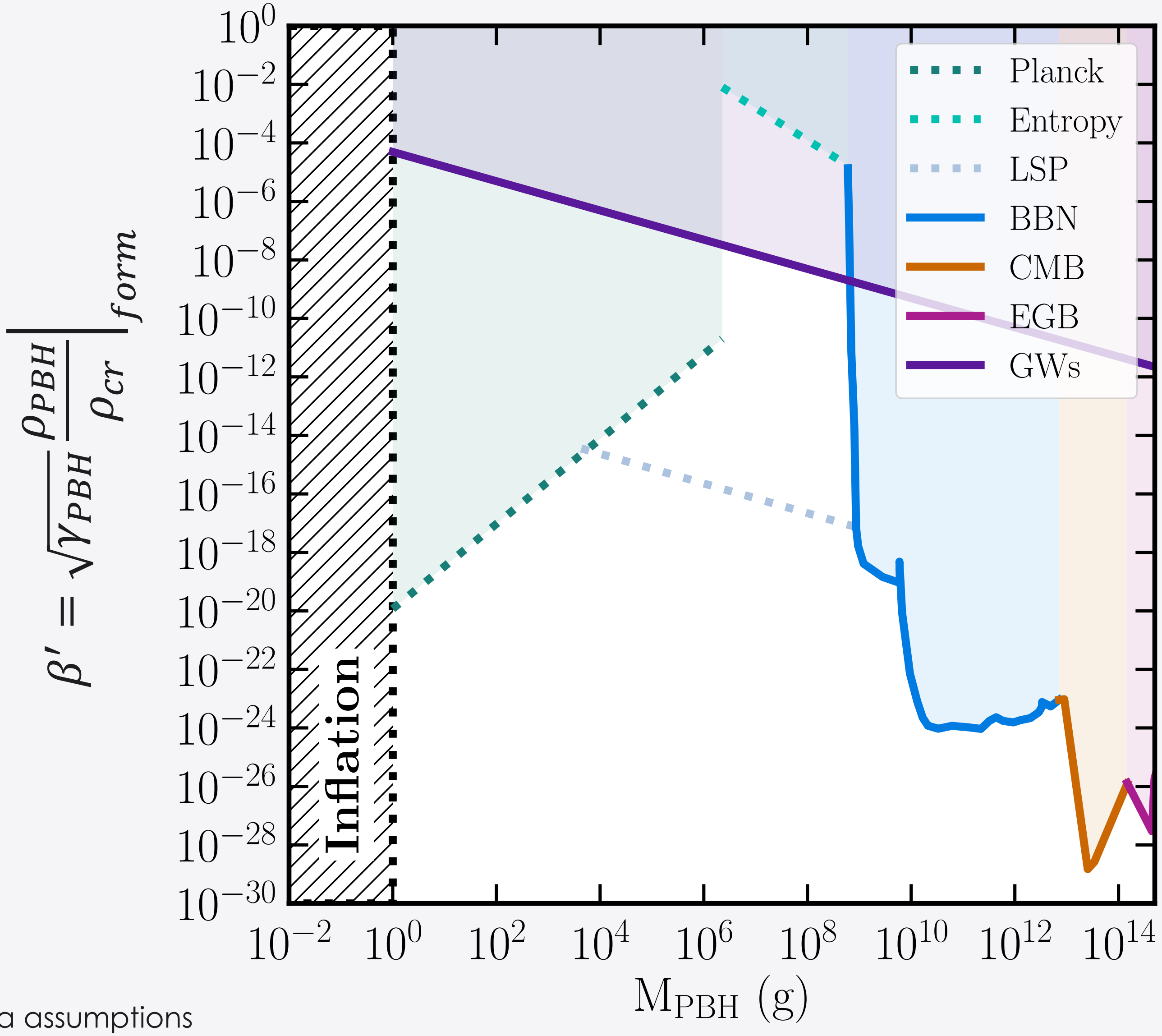
Gravitational Waves (GWs)

* dashed lines → not reliable

** dotted lines → rely on extra assumptions

EXISTING CONSTRAINTS

B. Carr et al, Rept.Prog.Phys. 84 (2021) 11, 116902
G. Domènech et al, JCAP 04 (2021) 062
A.M. Green et al, J.Phys.G 48 (2021) 4, 043001



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NEUTRINO FLUX

Secondary

Primary

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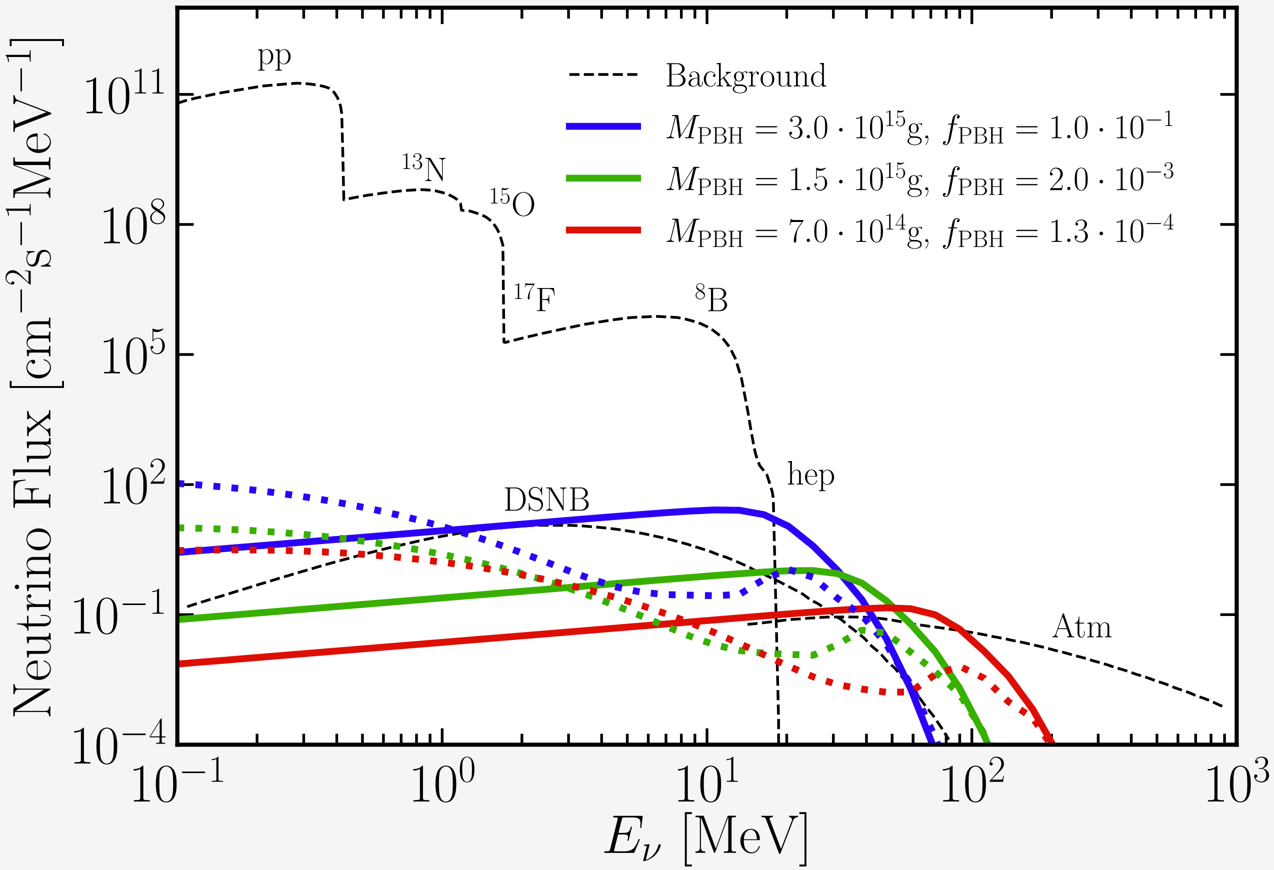

Hypothesis

- We consider **non-rotating** and **neutral** Primordial Black Holes with a **monochromatic mass distribution.**

We consider **Majorana** neutrinos.

CEνNS is **flavor blind :**

- no need to consider oscillation
- we consider all the active neutrinos.

NEUTRINO FLUX

$$\frac{d\phi_\nu^{EG}}{dE_\nu} = \int dt[1+z(t)]\,\frac{f_{PBH}\rho_{DM}}{M_{PBH}}\,\frac{dN}{dt\,d\widetilde{E_\nu}}\bigg|_{\widetilde{E_\nu}=E[1+z(t)]}$$

$$\frac{d\phi^{MW}}{dE_\nu} = \int \frac{d\Omega}{4\pi}\,\frac{dN}{dtdE_\nu}\int dl\,\frac{f_{PBH}\rho_{NFW}[r(l,\psi)]}{M_{PBH}}$$

$$\frac{d\phi}{dE_\nu} = \frac{d\phi_\nu^{EG}}{dE_\nu} + \frac{d\phi_\nu^{MW}}{dE_\nu} \propto f_{PBH} = \frac{\Omega_{PBH}}{\Omega_{DM}}$$

Secondary

Primary

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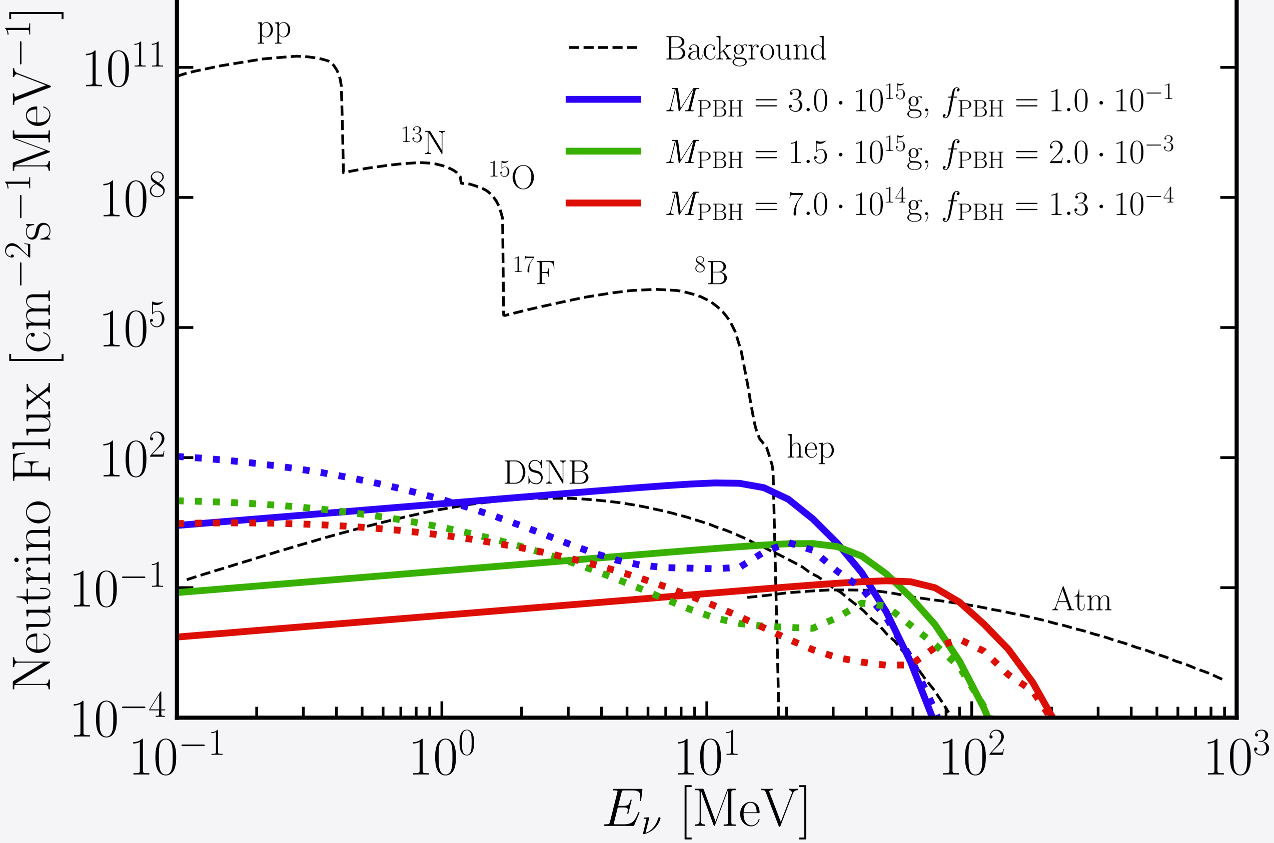

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Secondary Primary

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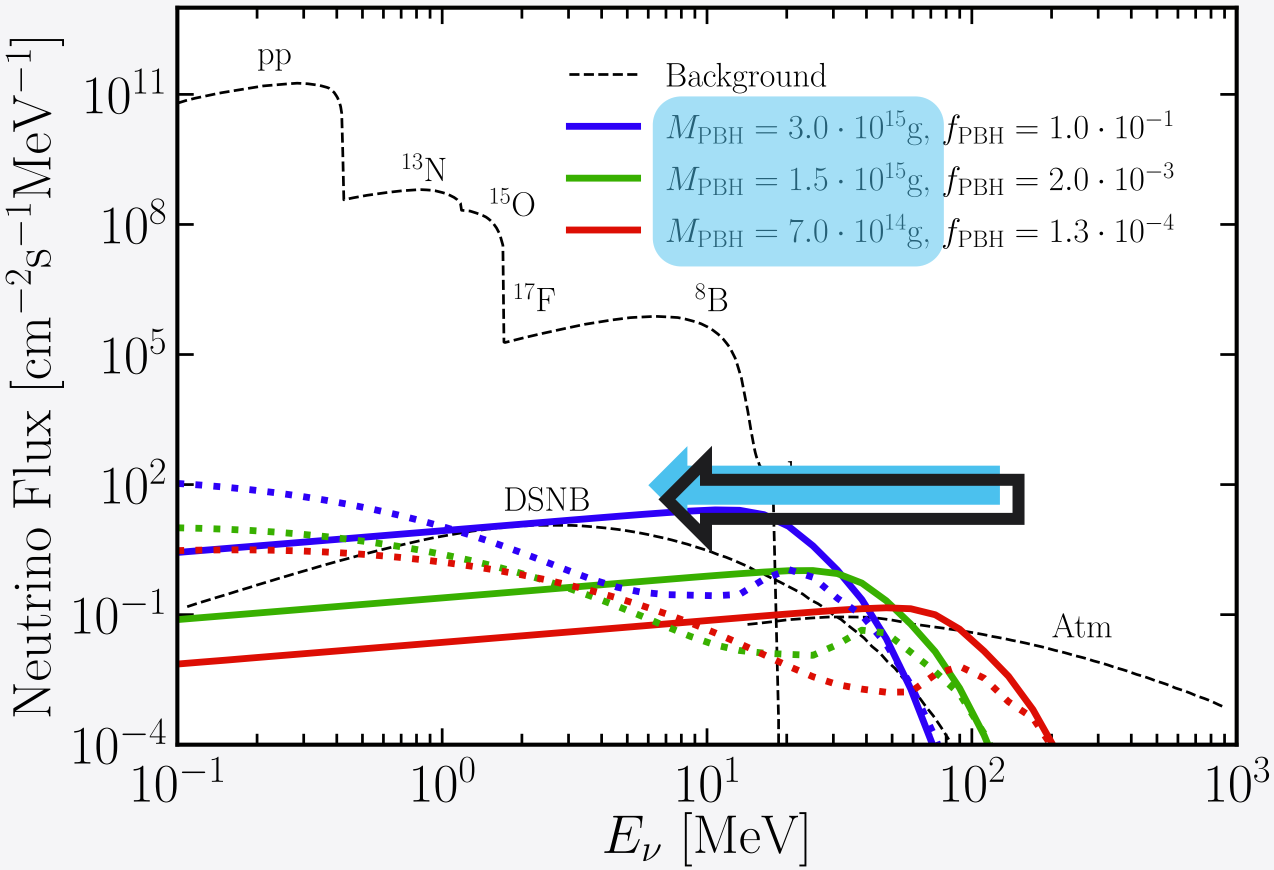

NEUTRINO FLUX

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Secondary

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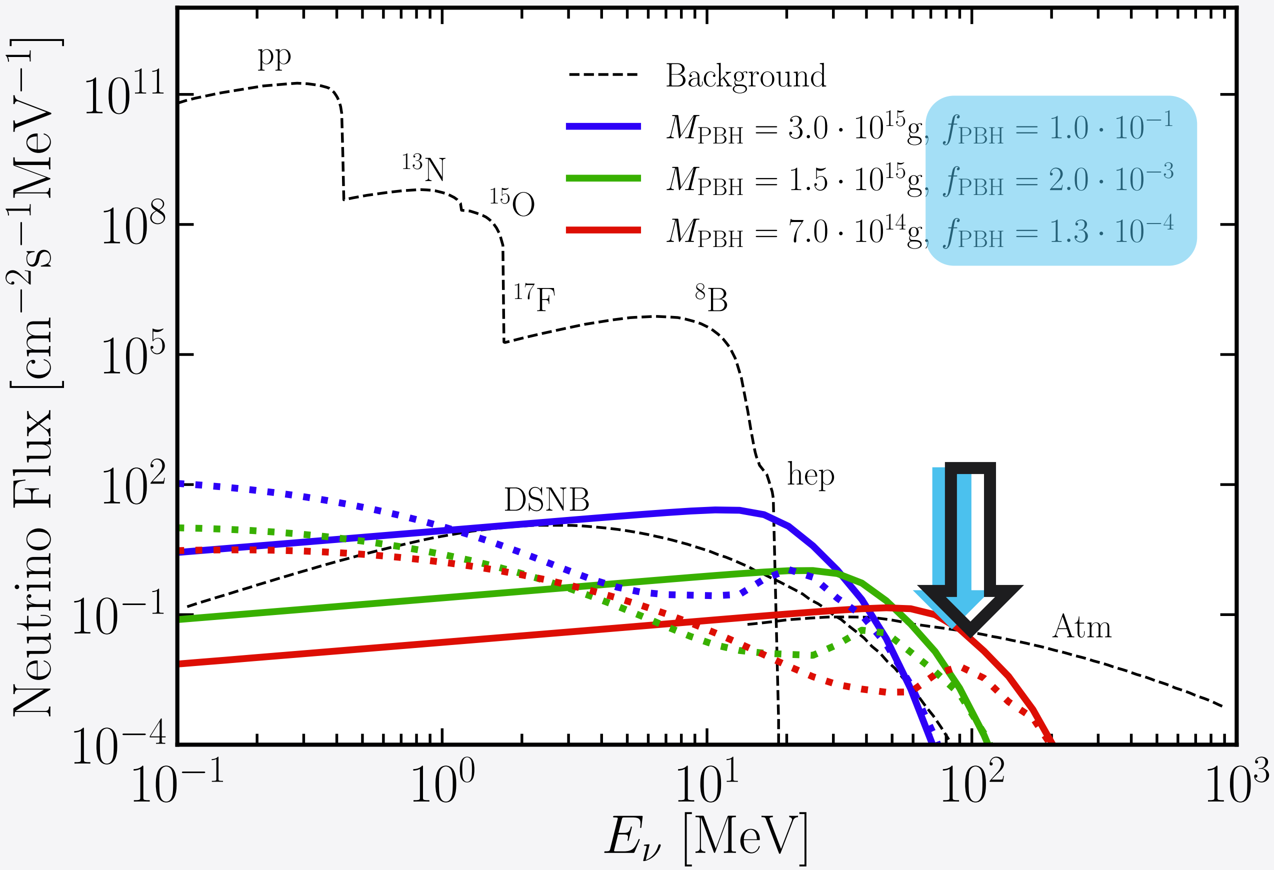

NEUTRINO FLUX

- ★ We can see that neutrinos from Primordial Black Holes are visible after the abrupt fall-off of the solar hep neutrinos
- ★ The background consists in Diffuse Supernova Neutrino Background **(DSNB)**, **hep** neutrinos and Atmospheric neutrinos **(Atm).**

Secondary

Primary

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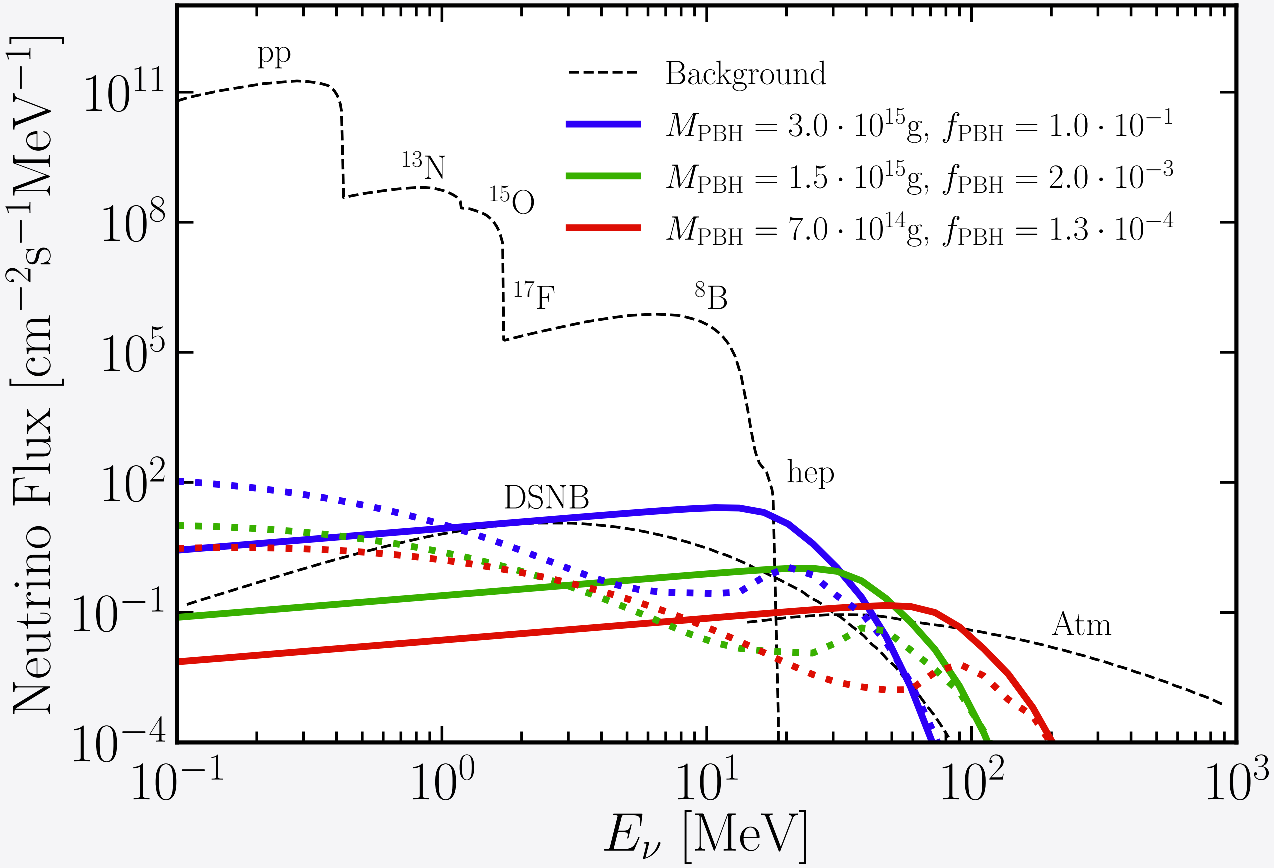
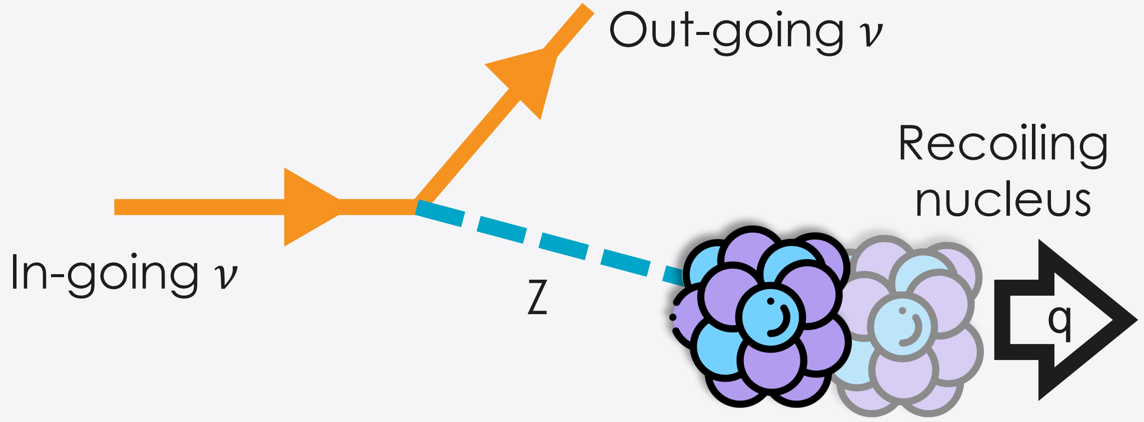


COHERENT ELASTIC NEUTRINO NUCLEUS SCATTERING

★ **Coherent Neutrino-Nucleus Scattering** (CEνNS) occurs between an active neutrino flavor and a nucleus

$$\frac{d\sigma}{dE_r} = \frac{G_F^2 m_T}{4\pi}[N - Z(1 - 4\sin^2\theta_W^2)]^2 \left(1 - \frac{m_T E_r}{2E_\nu^2}\right) F^2(\sqrt{2m_T E_r}).$$

Where $F(Q) = \frac{3j_1(QR_0)}{QR_0}\exp\left(-\frac{1}{2}s^2Q^2\right)$ is the form factor



CEνNS RATE IN DARWIN

The event rate from Coherent Elastic Neutrino-Nucleus Scattering is

$$\frac{2E_\nu^2}{m_T + 2E_\nu}$$

$$\frac{dR_{\nu \mathrm{N}}}{dE_r dt} = n_T \eta(E_r) \int dE_\nu \frac{d\sigma}{dE_r} \frac{d\phi}{dE_\nu} \Theta(E_r^{max} - E_r)$$

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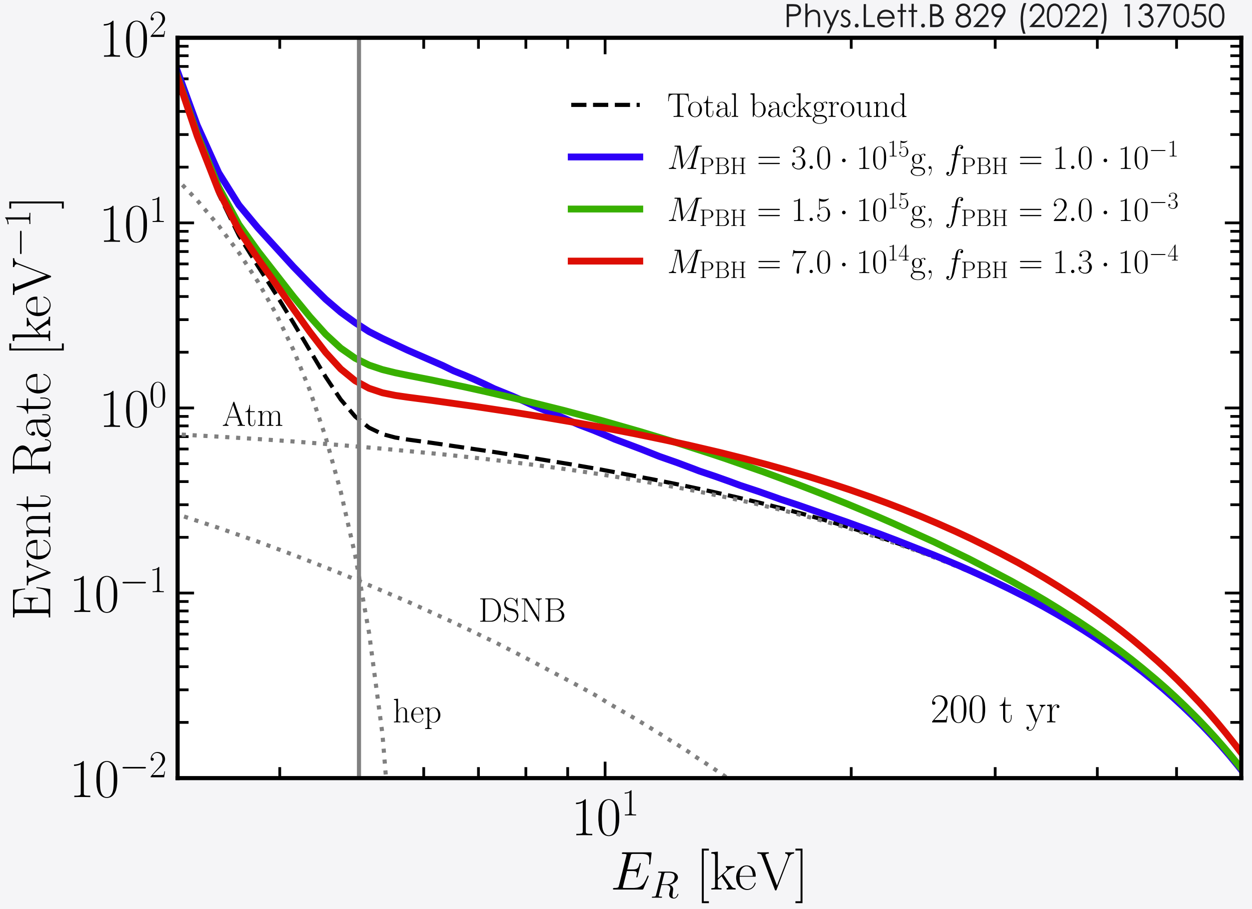

CEνNS RATE IN DARWIN

- ★ We calculated the event rate of $CE\nu NS$ In a multiton DM direct detection experiment **(DARWIN)**
- ★ The event spectrum of neutrinos from Primordial Black Holes depends on M_{PBH}:
  - ○ For higher masses it is similar to the background.
  - ○ For lower masses it is sensibly different.
- ★ We have employed a binned analysis to fully exploit the spectral information.

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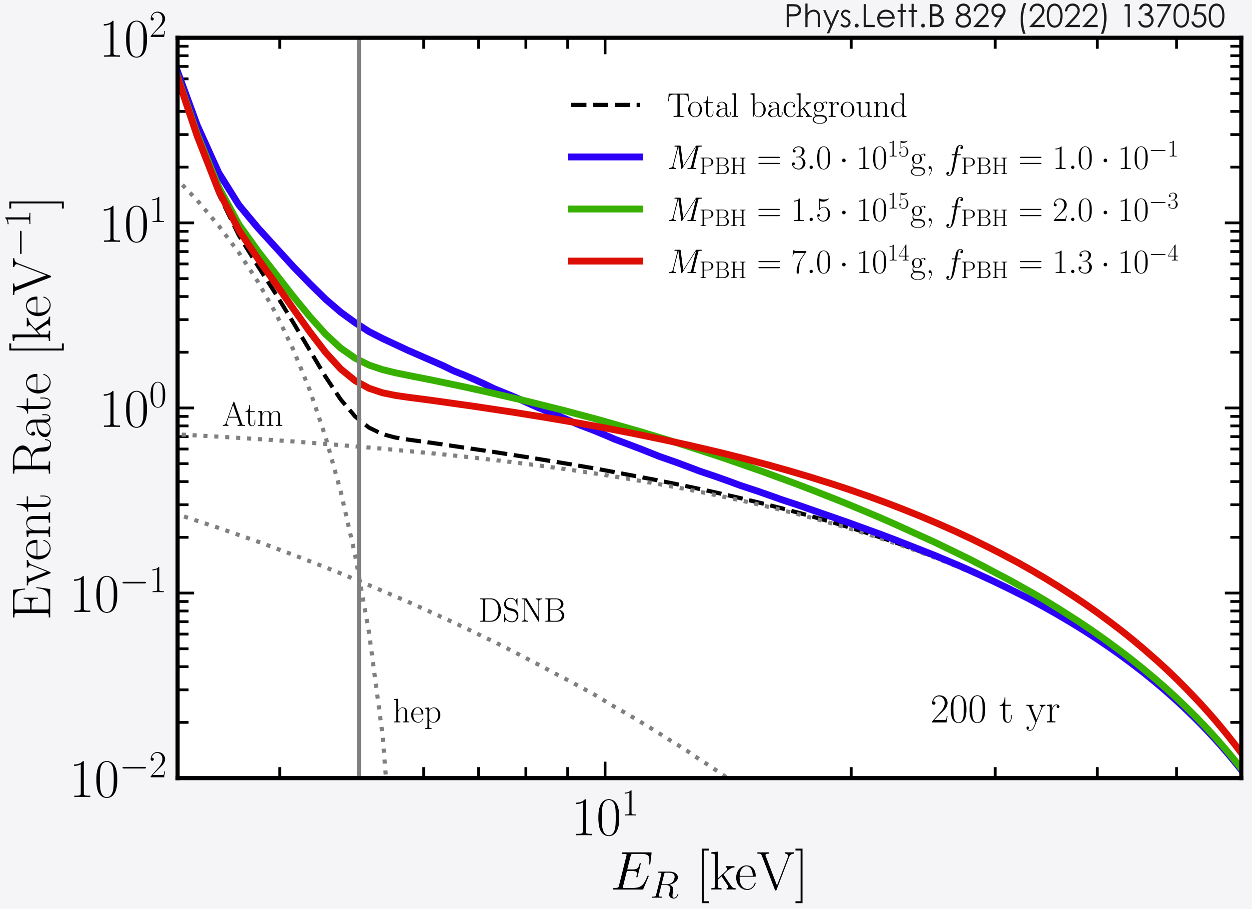

FORECAST CONSTRAINTS

- ★ CEνNS would allow us to improve the bounds derived from SuperKamiokande and extend it to lower Primordial Black Hole masses.
- ★ In the context of Primordial Black Hole searches Dark Matter direct detection facilities would rather operate as low-energy indirect observatories, complementary to the high-energy neutrino telescopes.

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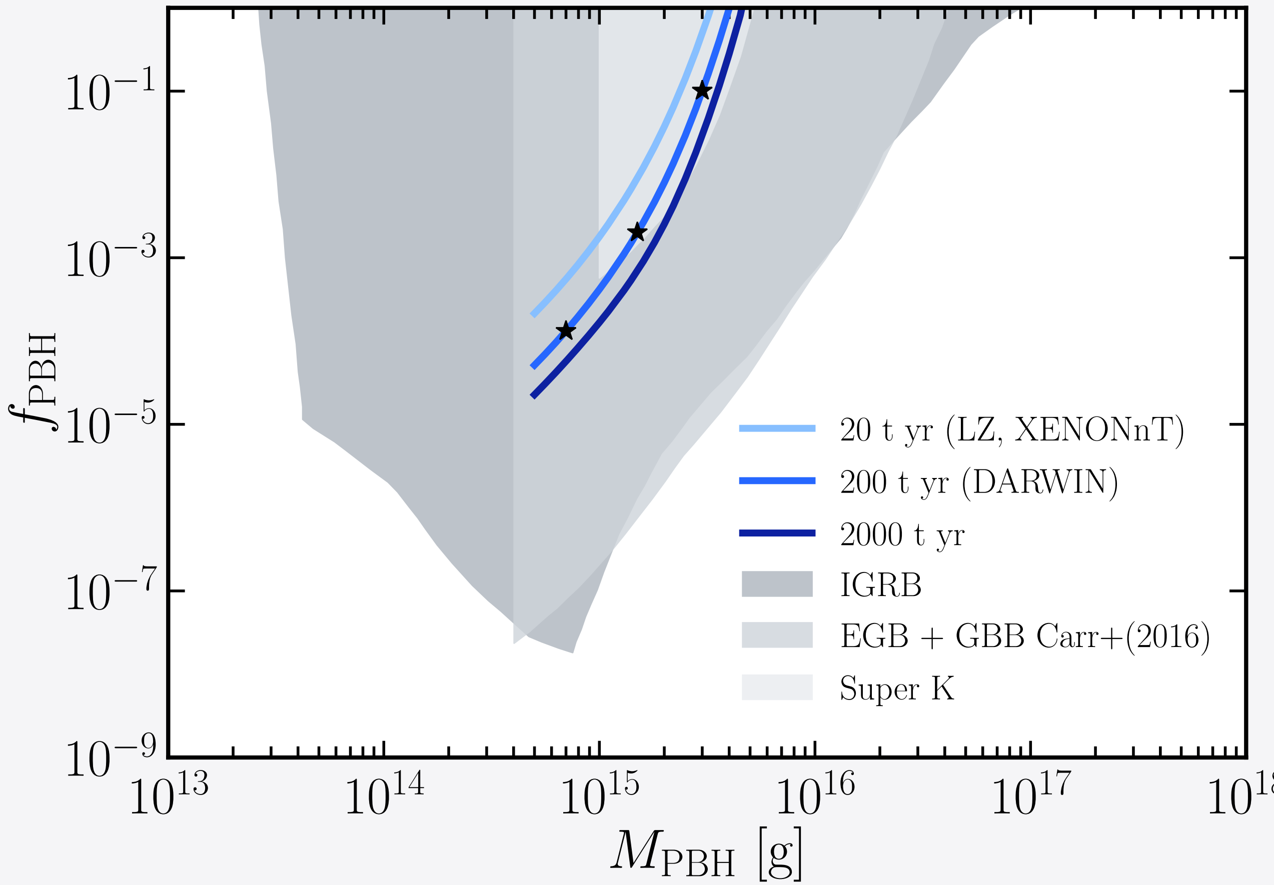

NEUTRINO FLOOR

★The solar, DSNB and atmospheric neutrinos constitute an irreducible background for the WIMPs searches.

★This background forms to the so-called "**neutrino floor**", an ultimate limitation to the discovery potential of the DM experiments.

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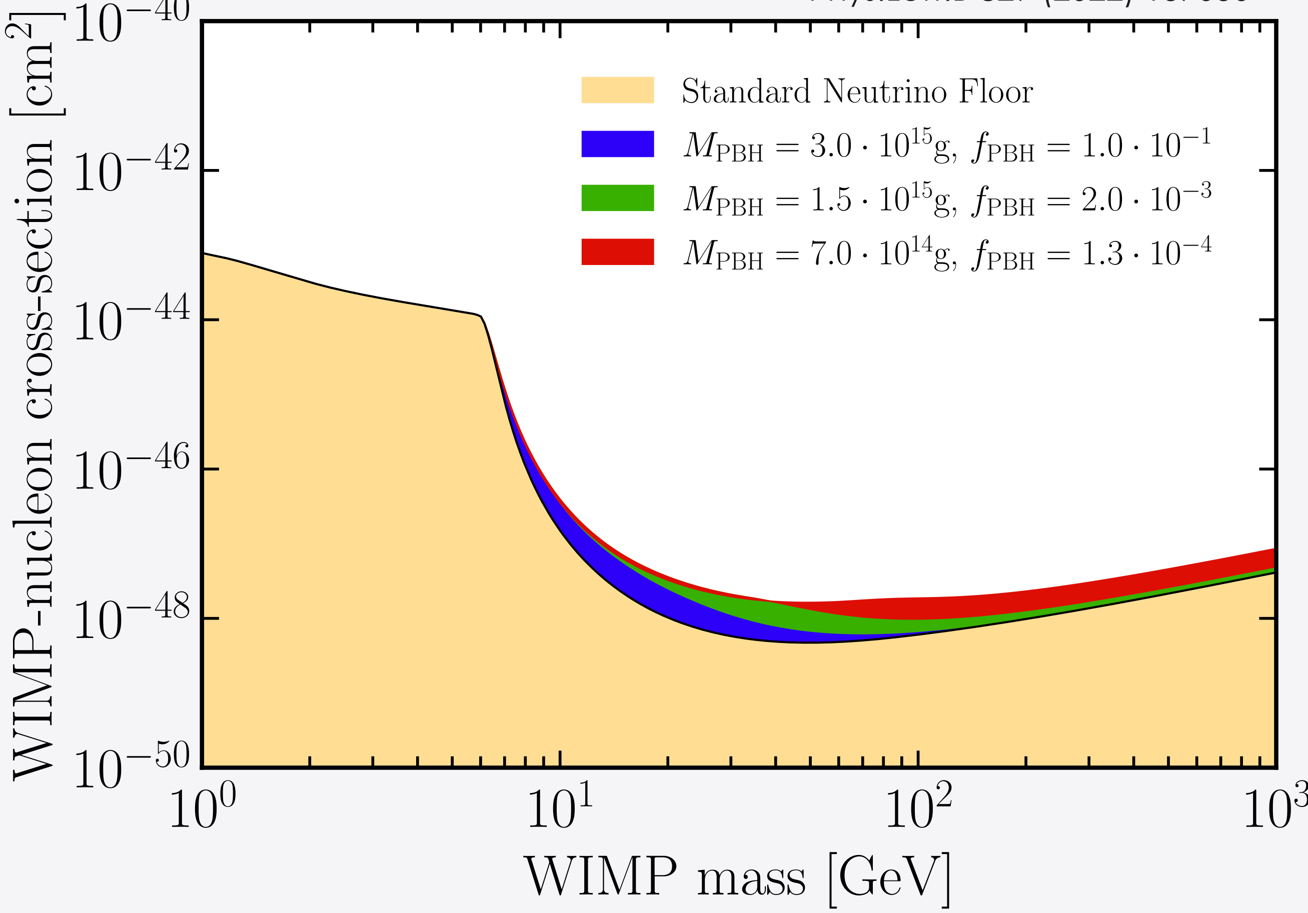

NEUTRINO FLOOR

- ★ Since Primordial Black Hole neutrinos lie on top of the "Standard" Background, the existence of a fraction of Primordial Black Hole in the Dark Matter content would modify the neutrino floor.
- ★ We have quantified how much a signal from PBHs would heighten the "**neutrino floor**"

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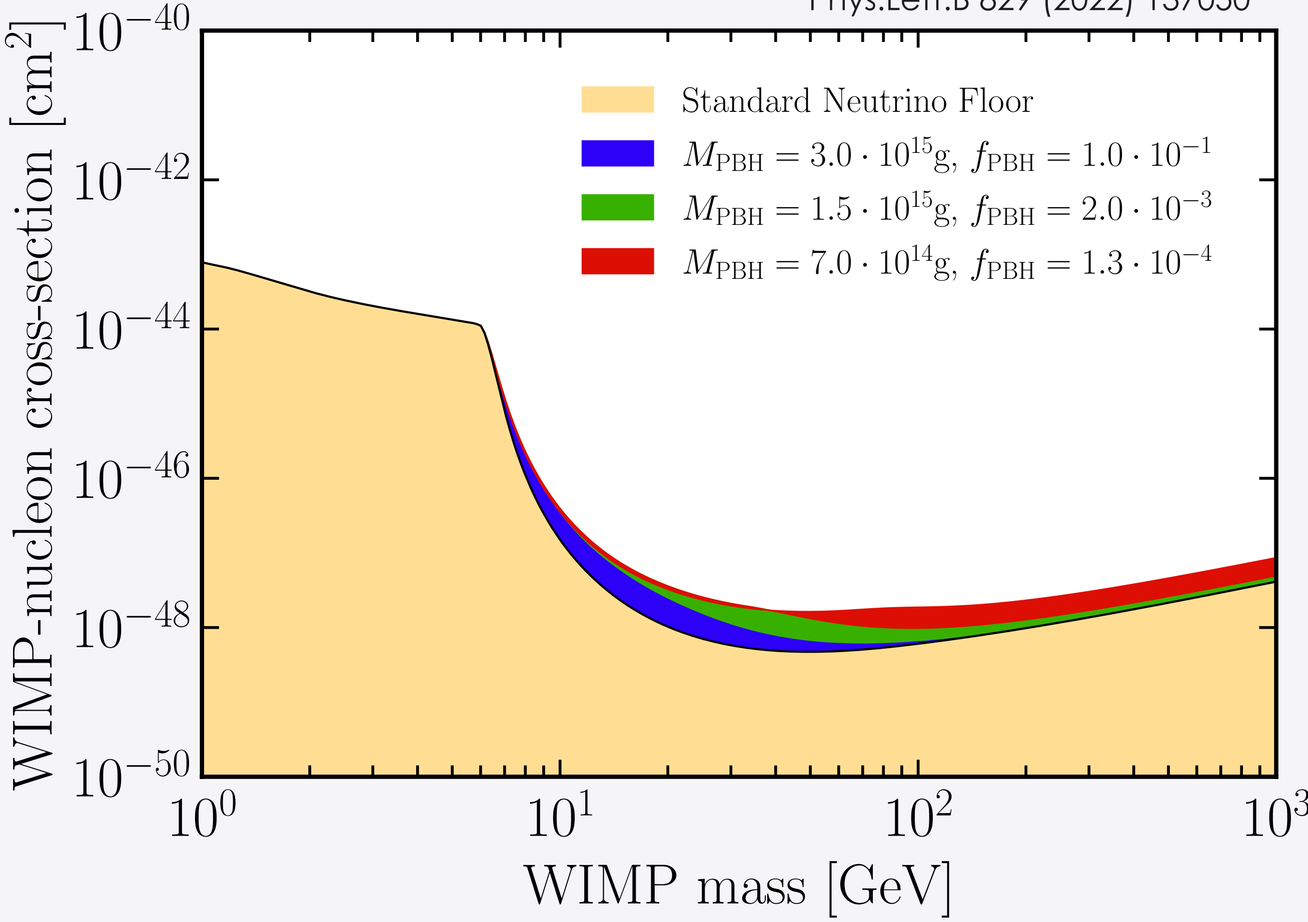

THANK YOU FOR THE ATTENTION

CONCLUSIONS

- The CEνNS would allow us to extend and improved Super-K constraints on PBH abundance.
- We used DM direct experiments as low-energy indirect observatories.
- We quantified how much the standard neutrino floor is affected by PBH neutrinos.