Cosmological gravitational particle production and primordial black holes

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Objectives and motivations

- Dark matter that interacts only with gravity!

- Study the interplay among two different **gravitational** production mechanisms:

Primordial Black Holes (PBHs)

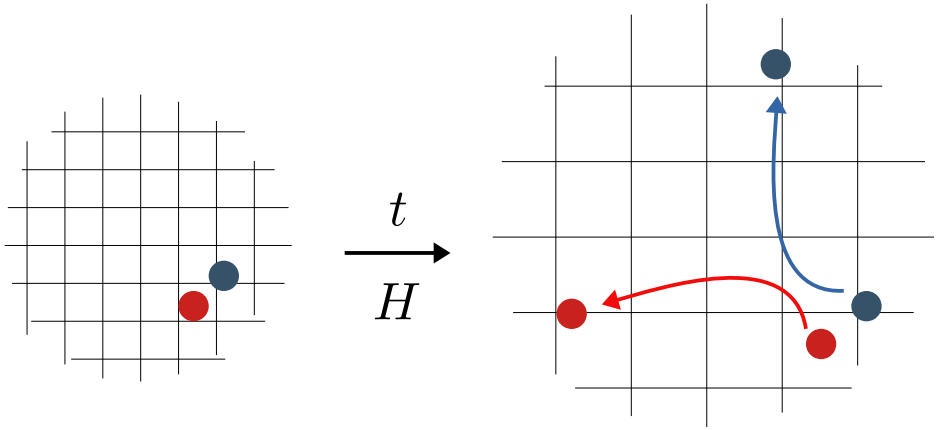
+

Cosmological Gravitational Particle Production (CGPP)

[Parker, 1968, 1969, 1971]
[Ford, 2021]
[Kolb, Long, 2023]

CGPP

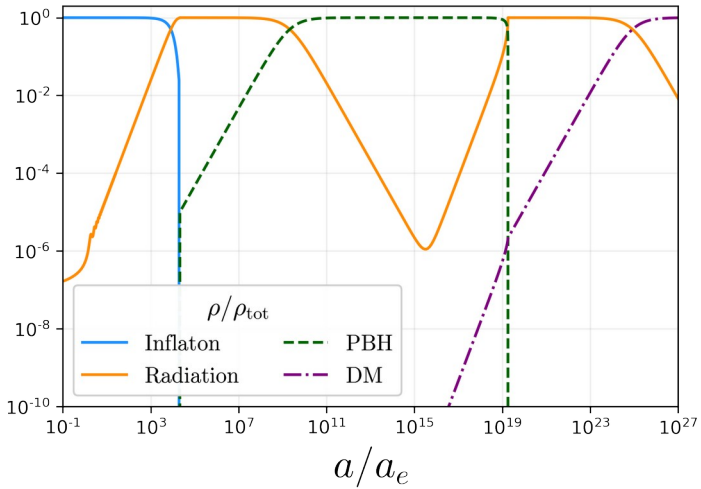
- Particles that are produced by the expansion of the universe:



FLRW space-time

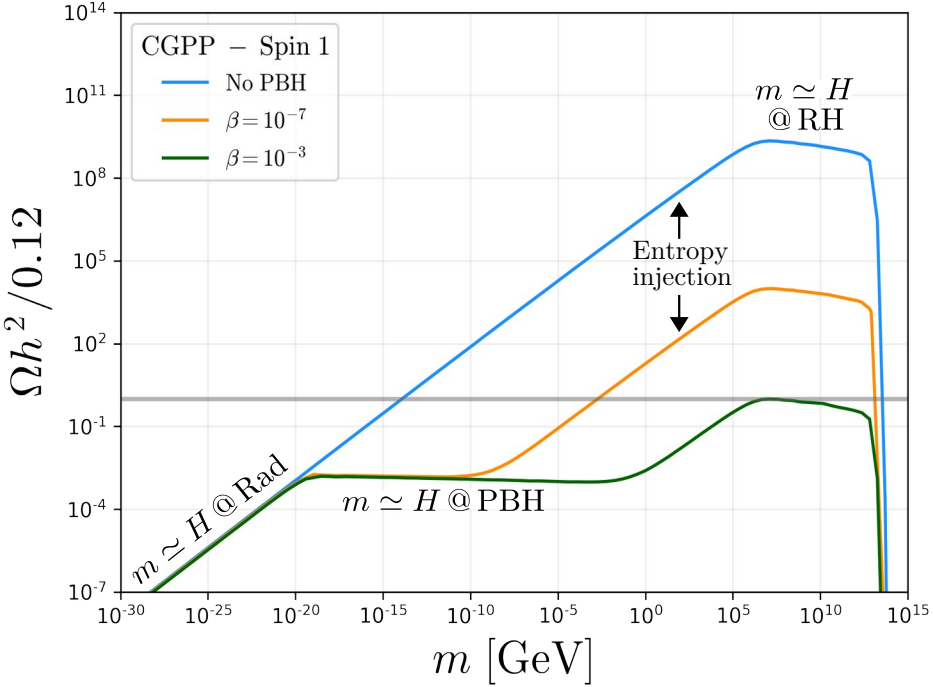
PBHs

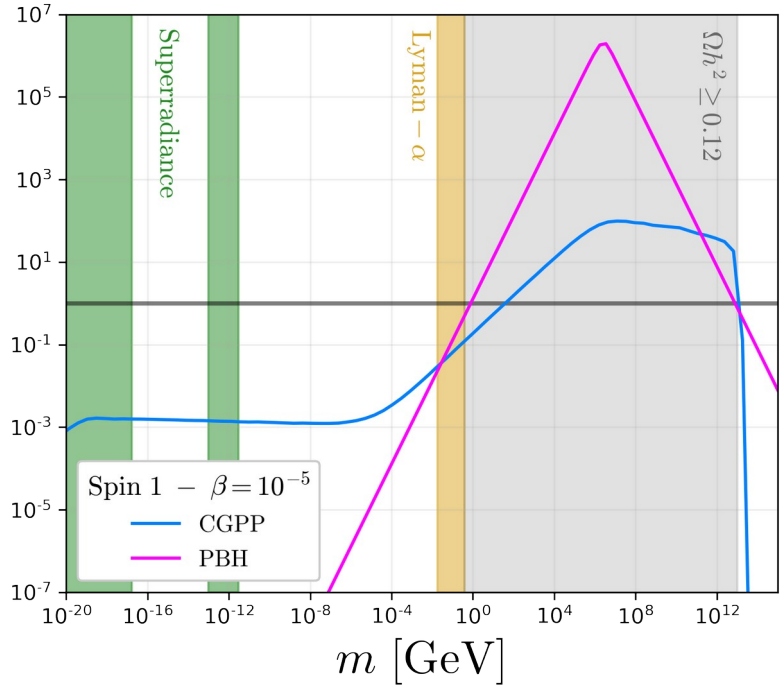
- Black Holes from the early universe;
- Affect the cosmological evolution in many ways:



Results – Spin-1 DM

- CGPP and PBHs cannot be disantangled!

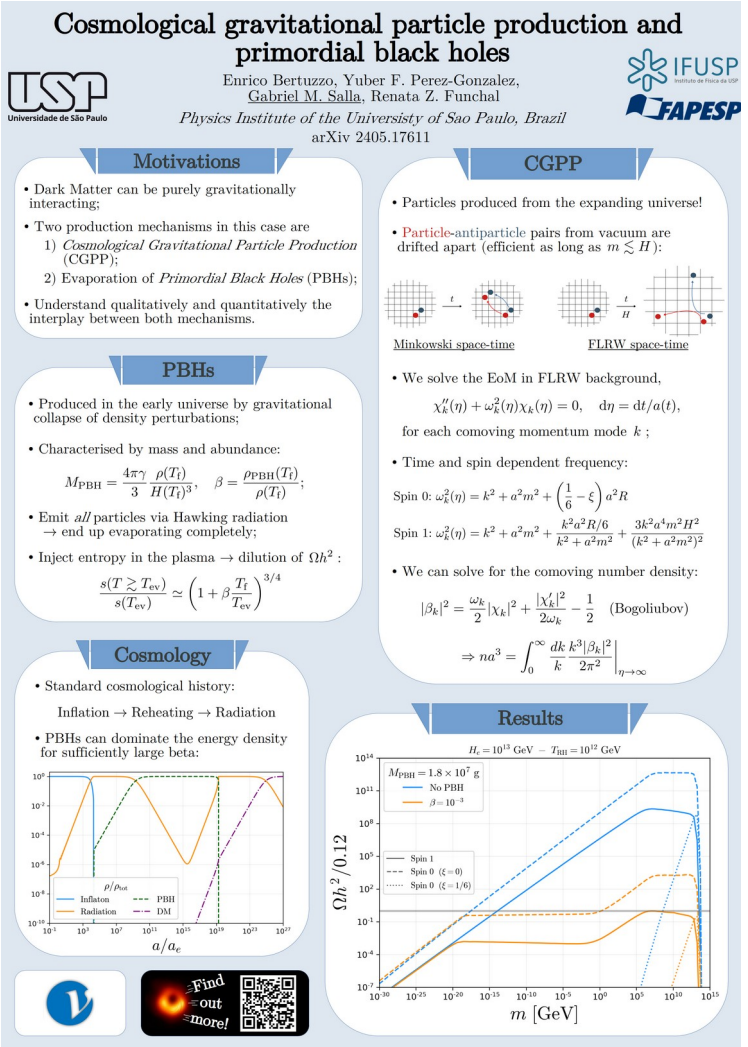




Conclusions

- PBHs can affect CGPP in an interesting and non-trivial way;
- This interplay deeply impacts the final DM abundance.

Thank you!
(and don't forget to check the poster!)



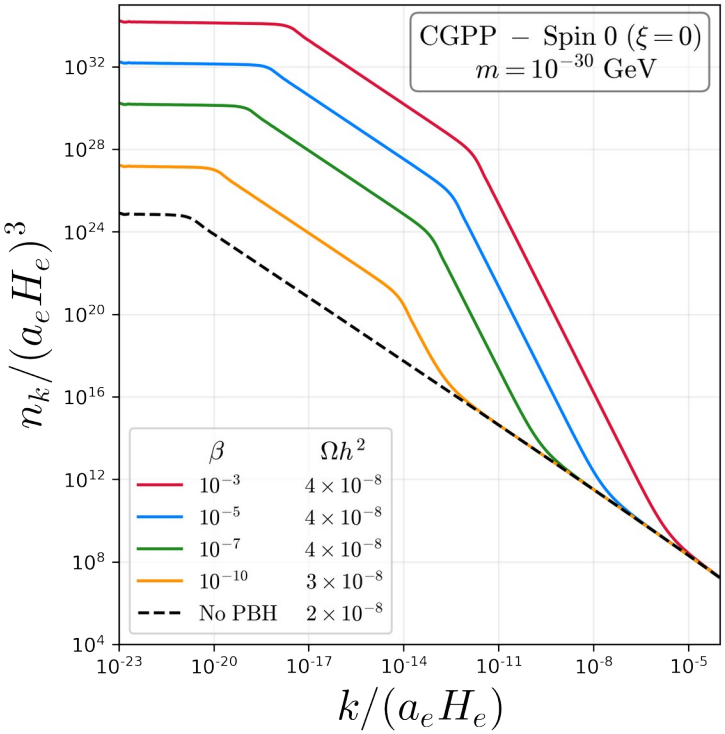
Backup - CGPP

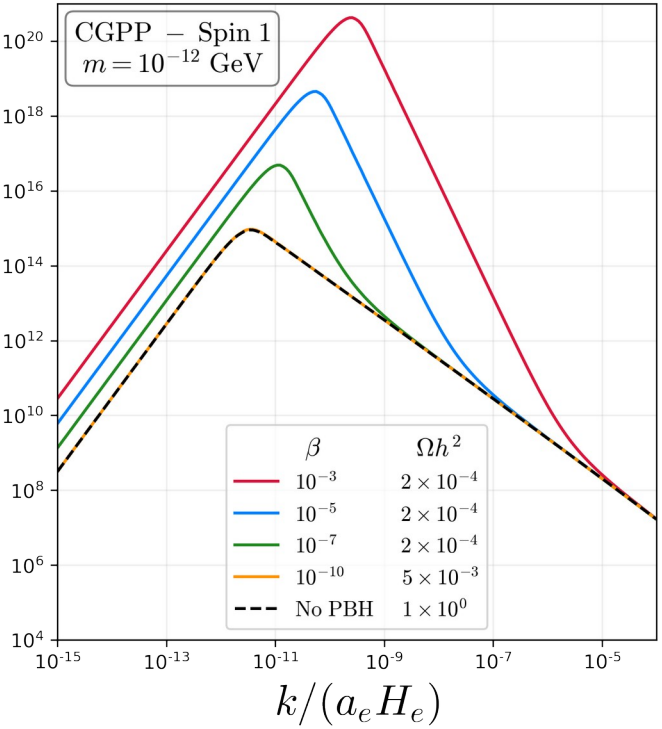
- Equations of motion: $\chi_k''(\eta) + \omega_k^2(\eta)\chi_k(\eta) = 0$

- Spin 0: $\omega_k^2(\eta) = k^2 + a^2 m^2 + \left(\frac{1}{6} - \xi\right) a^2 R$
  - $\xi = 0$ is minimal coupling
  - $\xi = 1/6$ is conformal coupling

- Spin 1: $\omega_k^2(\eta) = k^2 + a^2 m^2 + \frac{k^2 a^2 R/6}{k^2 + a^2 m^2} + \frac{3k^2 a^4 m^2 H^2}{(k^2 + a^2 m^2)^2}$

Backup - Results – Momentum spectrum



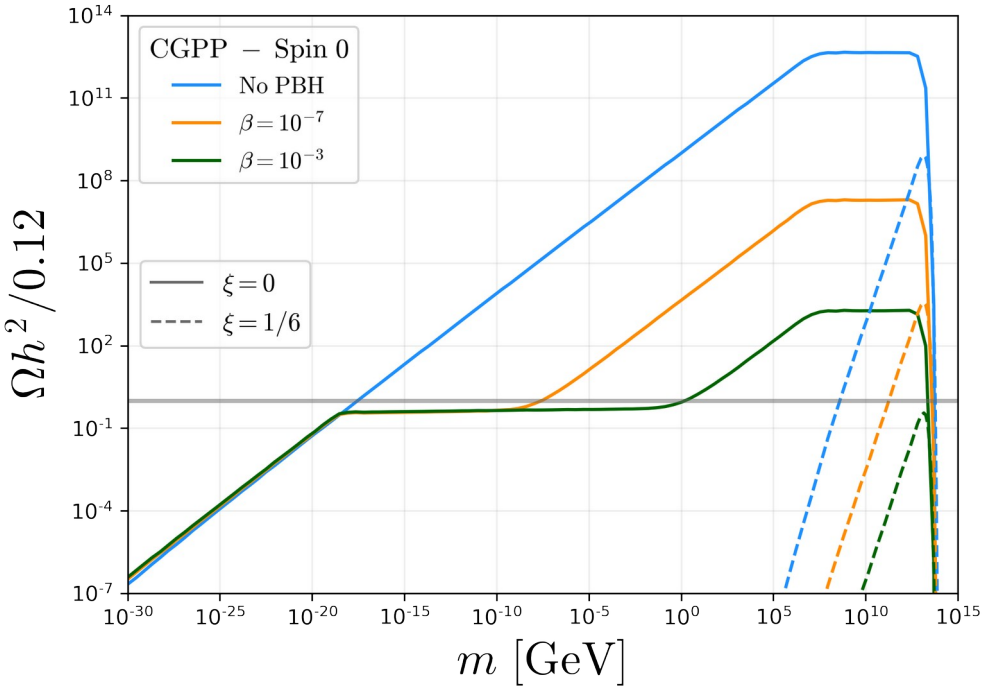


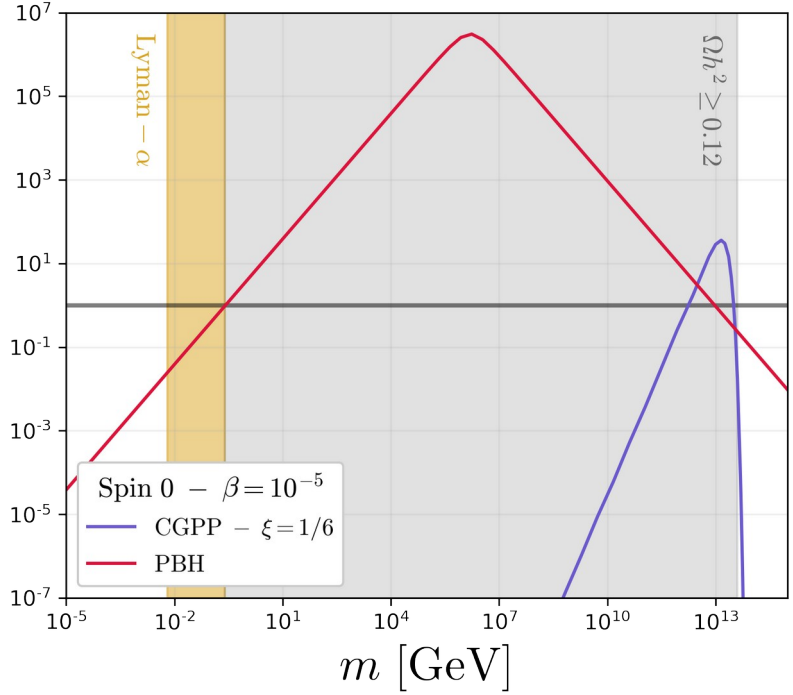
- Number per comoving momentum:

$$n_k = \frac{k^3}{2\pi^2} \times \left[\frac{\omega_k}{2} |\chi_k|^2 + \frac{|\chi_k'|^2}{2\omega_k} - \frac{1}{2} \right]$$

Backup - Results – Spin 0

- Minimally coupled strongly constrained by isocurvature





Backup - PBH production

- PBHs generated by ultra-slow roll of inflaton field:

$$V(\Phi) \to V(\Phi)(1+\epsilon(\Phi)), \qquad \epsilon(\Phi) = A \exp\left[-\frac{(\Phi-\Phi_0)^2}{\sigma^2}\right]$$

- Only mild effect in the reheating plateu: