

# Gravitational Dark Matter: Primordial Black Holes and UV Freeze-in

Based on:

NB, Maíra Dutra, Yann Mambrini, Keith Olive, Marco Peloso & Mathias Pierre - arXiv:1803.01866  
NB & Óscar Zapata - arXiv:2010.09725, [2011.02510](#), 2011.12306

**Nicolás BERNAL**

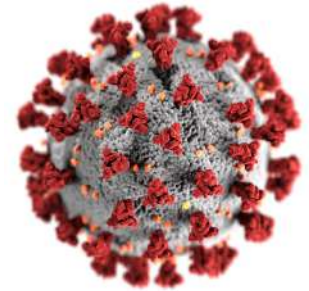


3<sup>rd</sup> South American Dark Matter Workshop  
December 2-4, 2020



El conocimiento  
es de todos

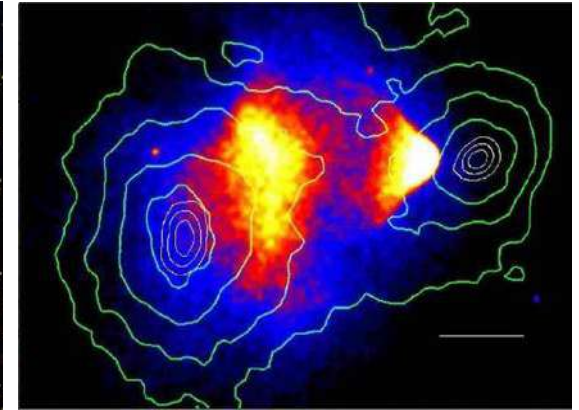
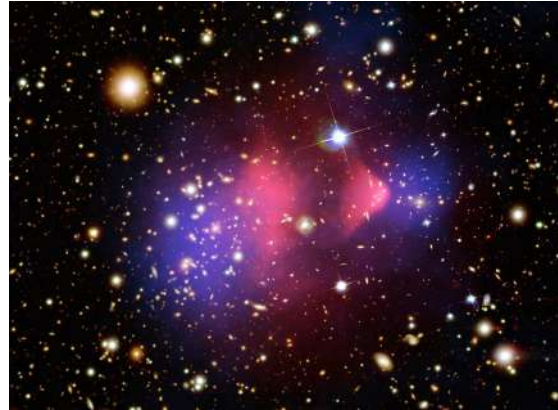
Minciencias



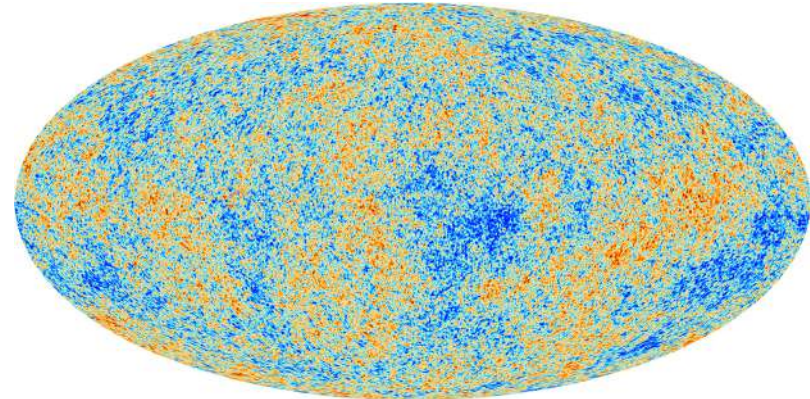
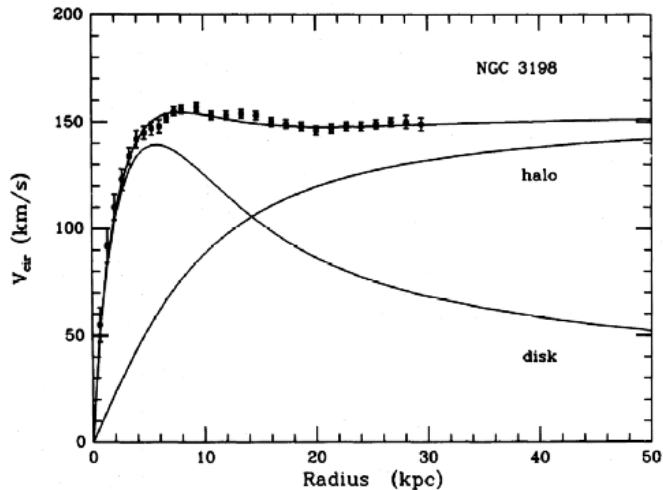
# Evidences for Dark Matter

Several observations indicate the existence of non-luminous Dark Matter (missing *gravitational* force) at very different scales!

- \* Galactic rotation curves
- \* RC in Clusters of galaxies
- \* Clusters of galaxies
- \* CMB anisotropies



DISTRIBUTION OF DARK MATTER IN NGC 3198





**What if DM *only* couples to the SM  
via *gravitational* interactions?**



**What if DM *only* couples to the SM  
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**DM is *unavoidably* produced  
by PBH Hawking evaporation!**



# Primordial Black Holes

- \* Density fluctuations can collapse into a PBH in the early universe
- \* Lose mass by emitting *all* particles via Hawking evaporation
  - have a  $\sim$ black body spectrum, with temperature  $T_{\text{BH}} \sim 1/M_{\text{BH}}$
  - unavoidable radiate DM!
- \* If  $M_{\text{in}} < 10^9$  g, PBHs completely evaporate before BBN
  - poorly constrain

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Effective theory: Two free parameters

- \* A single PBH characterized by its mass at formation  $M_{\text{in}}$   
(or equivalently, by the SM temperature  $T_{\text{in}}$  at formation)
- \* Initial PBH energy density  $\beta = \rho_{\text{BH}}/\rho_{\text{SM}}$

# DM from PBHs

**DM density = PBH density x # DM emitted per PBH**

Number of DM particles radiated per PBH.

→ Only depends on initial PBH mass!

$$N_j = \frac{15 \zeta(3)}{\pi^4} \frac{g_j C_n}{g_*(T_{\text{BH}})} \begin{cases} \left(\frac{M_{\text{in}}}{M_P}\right)^2 & \text{for } m_j \leq T_{\text{BH}}^{\text{in}} \\ \left(\frac{M_P}{m_j}\right)^2 & \text{for } m_j \geq T_{\text{BH}}^{\text{in}} \end{cases}$$

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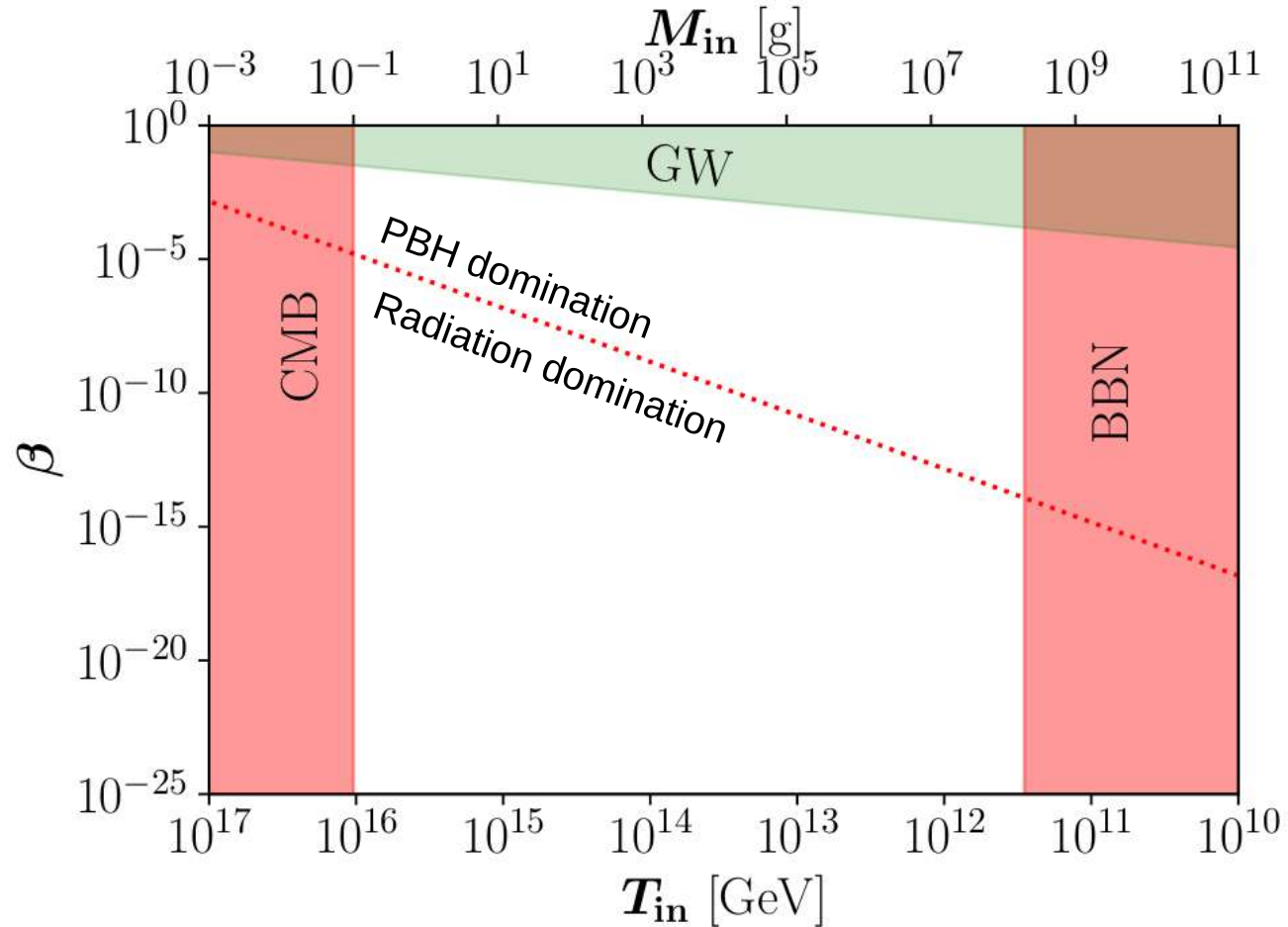
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As PBH scale like non-relativistic matter,  
they can dominate the total energy density of the universe

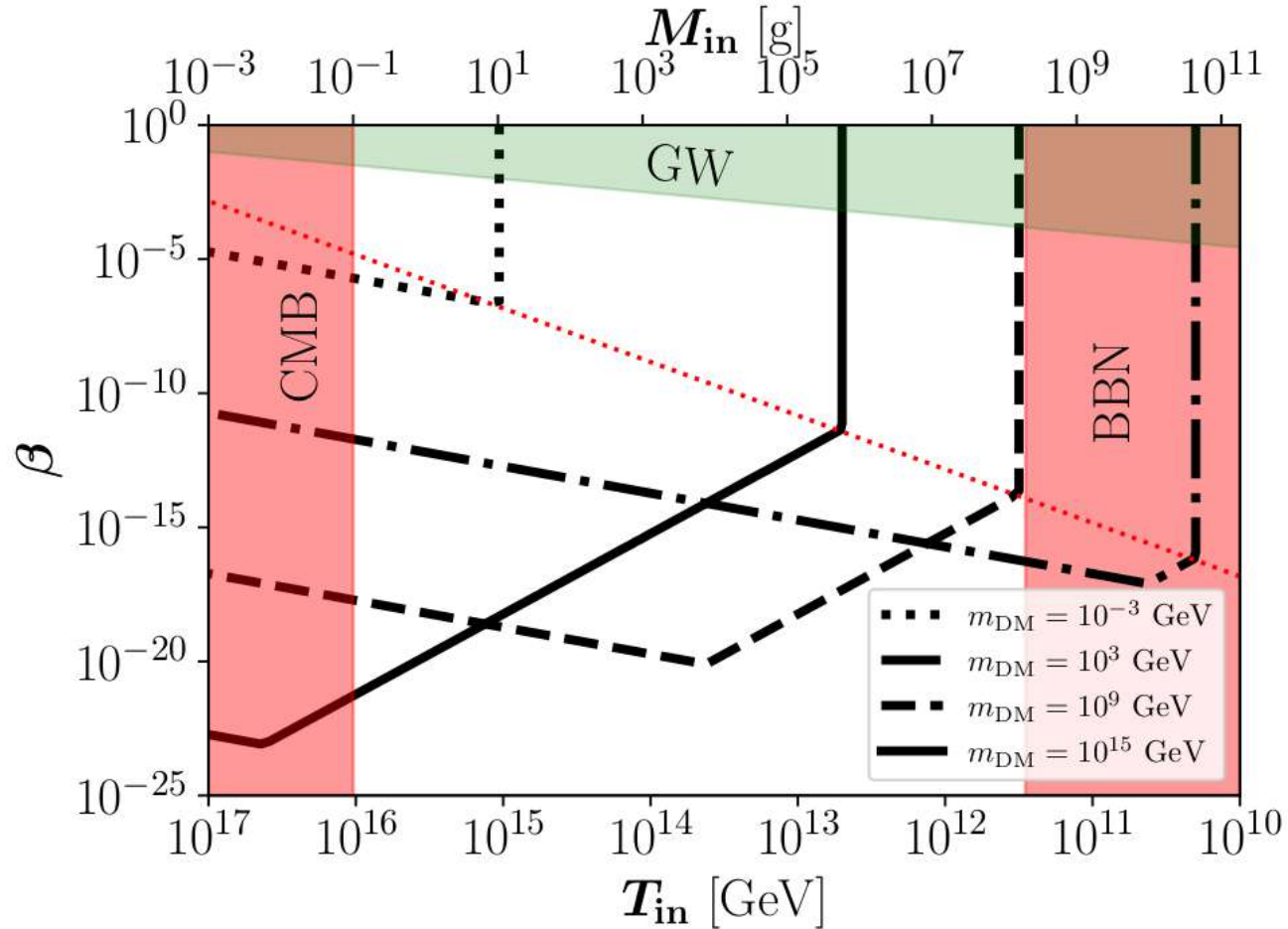
→ Nonstandard expansion!



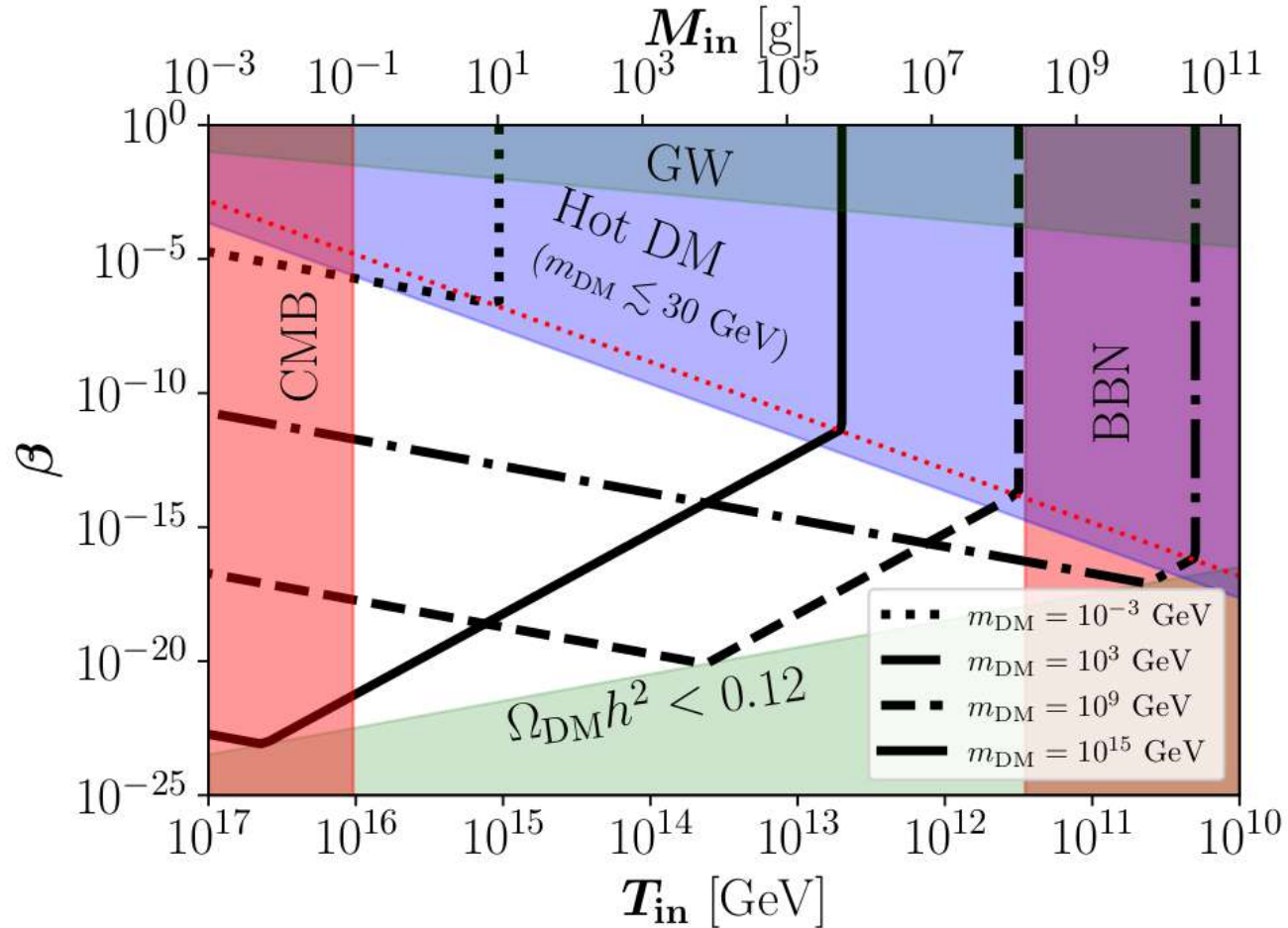
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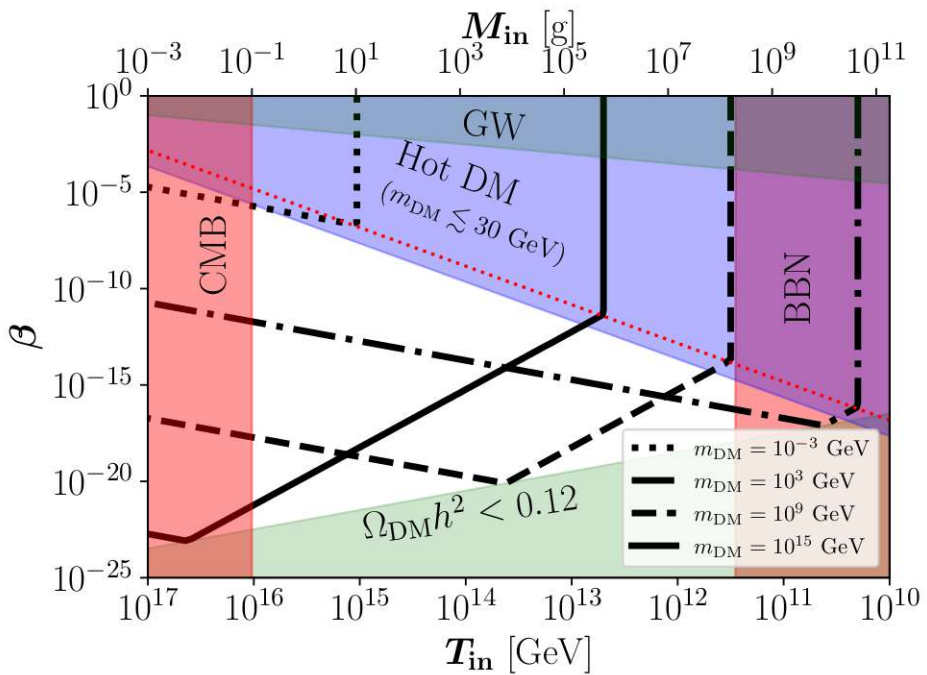
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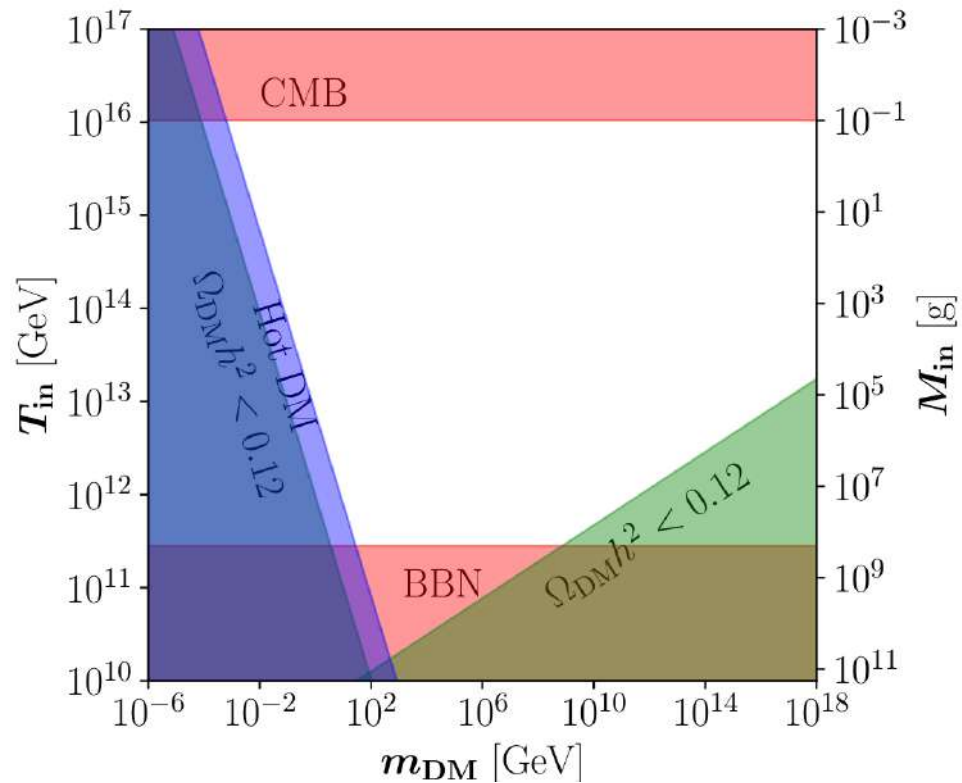
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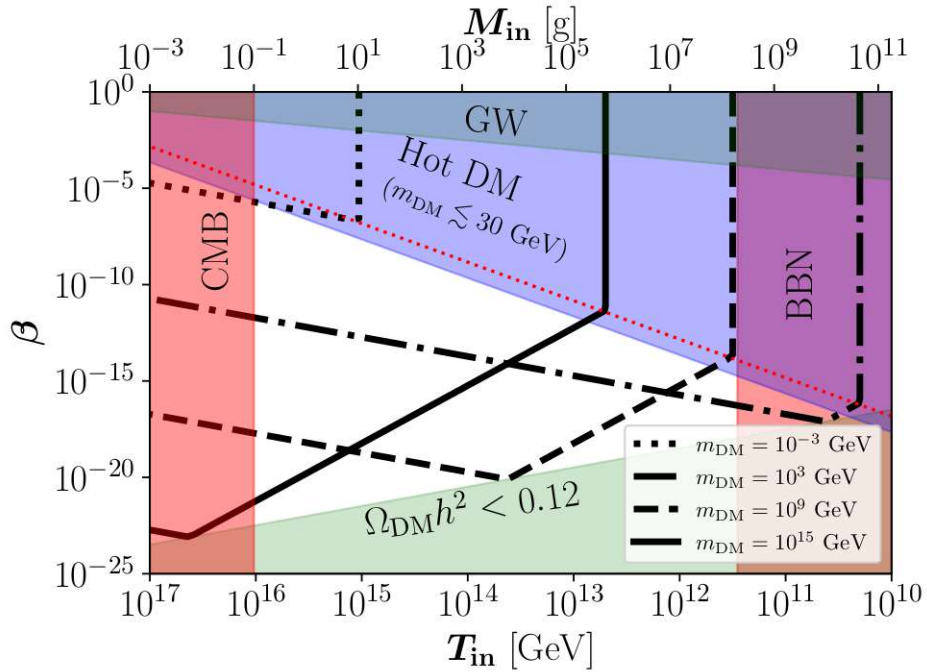
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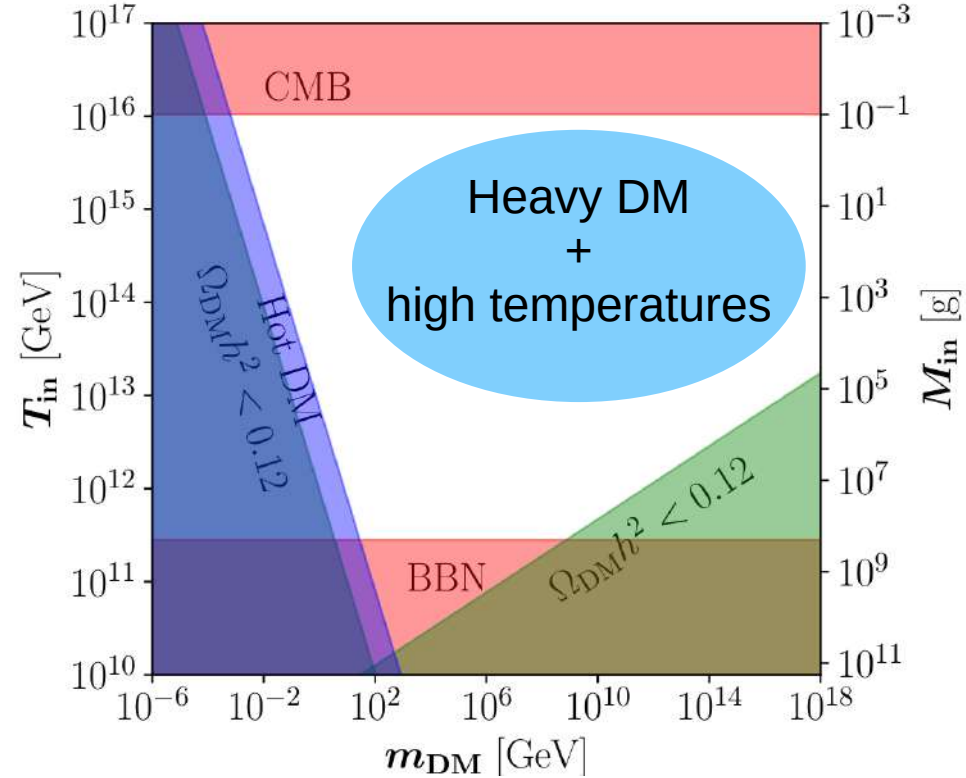
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**DM is *unavoidably* produced  
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and gravitational UV freeze-in!**

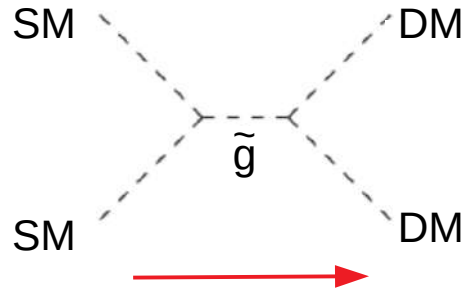


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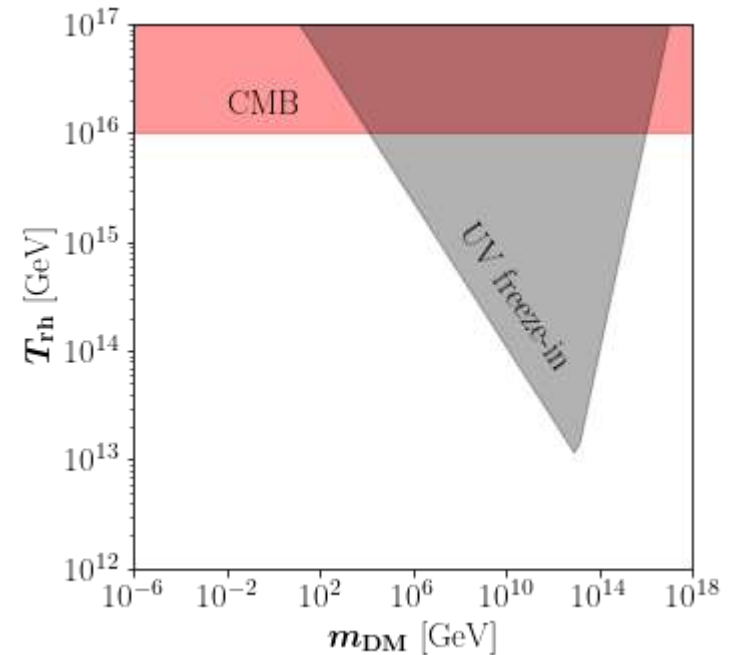
# Gravitational UV Freeze-in

An example of UV FIMP, mediated by massless SM gravitons



Depends on:

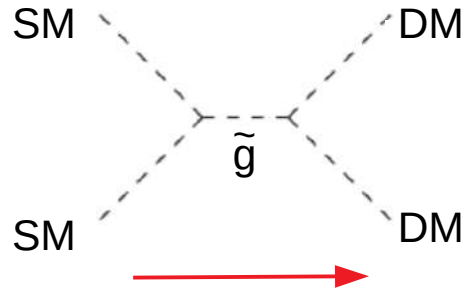
- \* DM mass and spin
  - \* Reheating temperature  $T_{\text{rh}}$
- No free couplings:  $M_P$
- $$\Omega h^2 \sim m (T_{\text{rh}}/M_P)^3$$





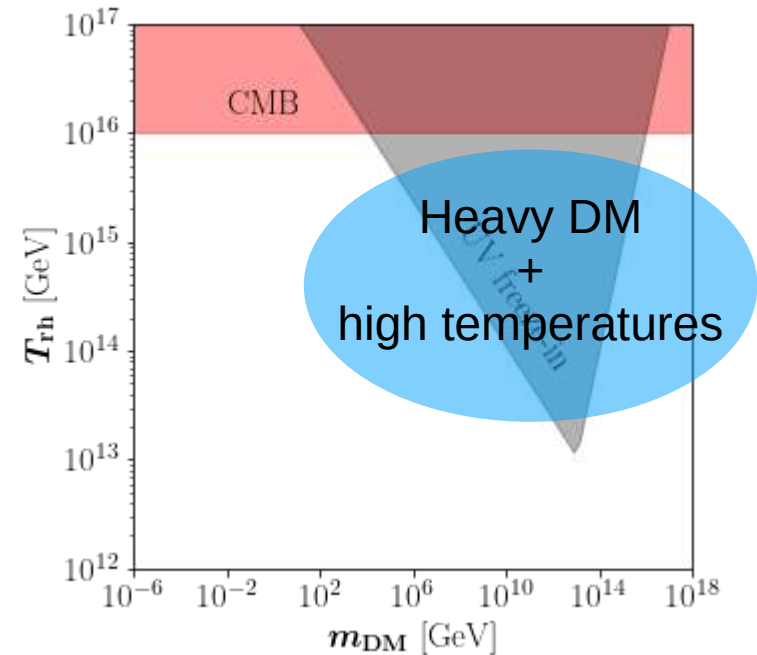
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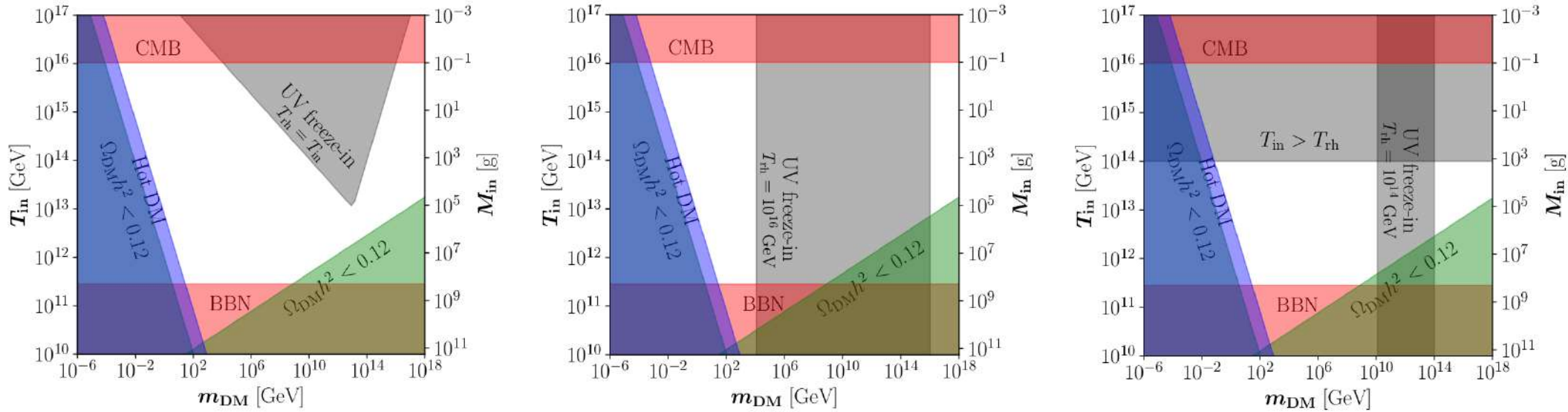


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# Gravitational DM: PBHs & UV Freeze-in



Gravitational UV freeze-in strongly constrains super heavy DM radiated by PBHs!

# Conclusions

- It's possible that DM *only* features *gravitational* interactions
- PBH could Hawking radiate the *whole* DM density
- PBHs formed in the early universe
- $0.1 \text{ g} < M_{\text{in}} < 10^9 \text{ g}$  evaporate before BBN
- DM masses:  $1 \text{ MeV} < m_{\text{DM}} < 10^{18} \text{ GeV}$   
SM temperature at formation:  $10^{12} \text{ GeV} < T_{\text{in}} < 10^{16} \text{ GeV}$
- Gravitational UV freeze-in is effective in the same ballpark
- **Interplay between PBH and UV freeze-in production sets strong bounds to super heavy DM**
- **Gravitational DM production is unavoidable!**
- Test: baryogenesis, isocurvature, gravitational waves, non-Gaussianity...

Talks by: M. Fairbairn, C. Unal, B. Kavanagh

**¡Muchas  
gracias!**

Nicolás BERNAL @ UAN

