Dark Matter in the Time of Primordial Black Holes

Based on:
NB & Óscar Zapata
arXiv:2010.09725, 2011.02510, 2011.12306

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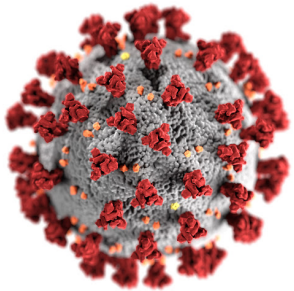
UAN UNIVERSIDAD ANTONIO NARIÑO

5th COMHEP
November 30 - December 4, 2020

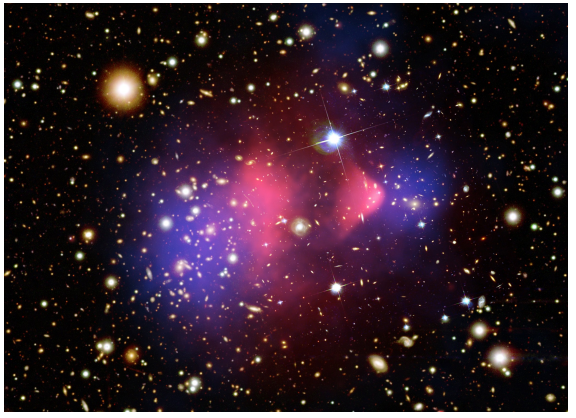


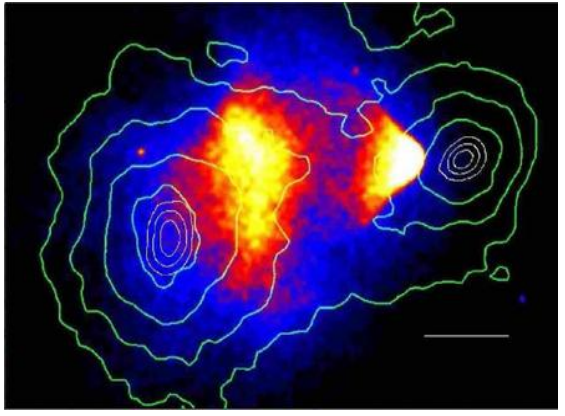
El conocimiento es de todos
Minciencias

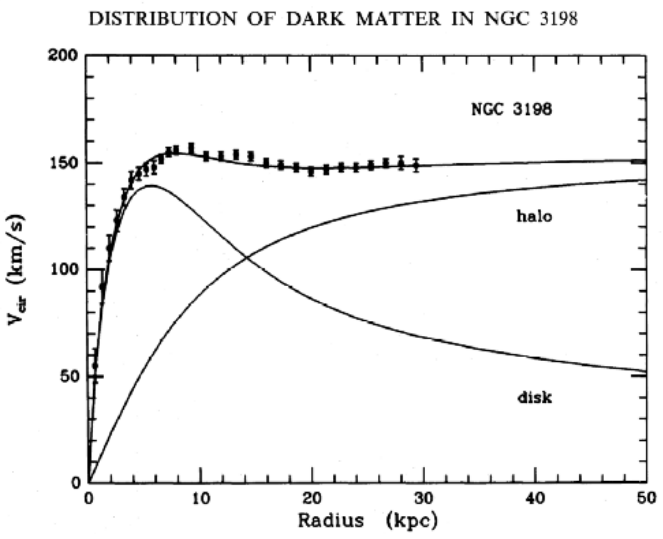
Evidences for Dark Matter

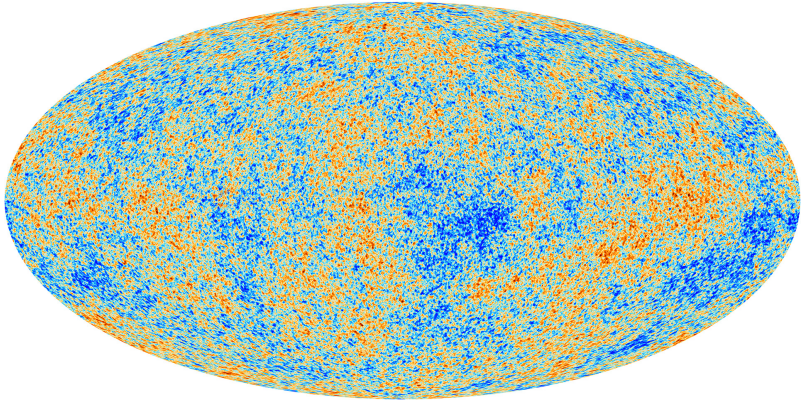
Several observations indicate the existence of non-luminous Dark Matter (missing *gravitational* force) at very different scales!

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





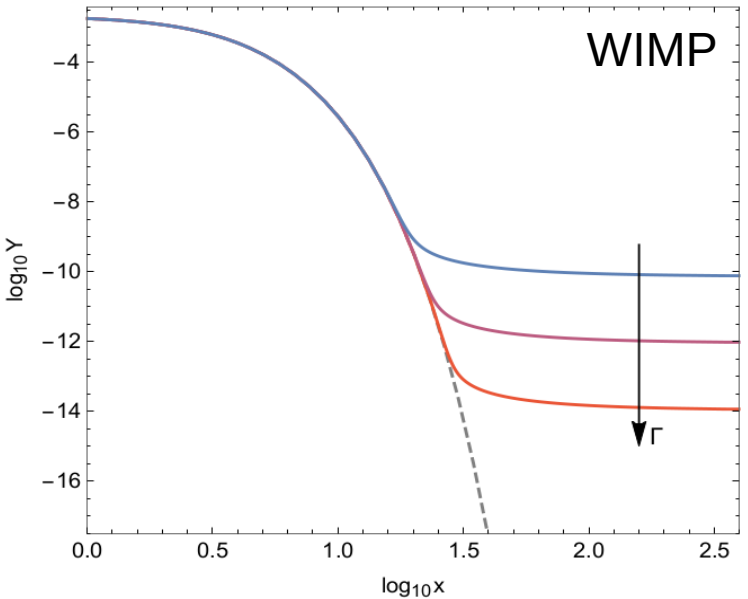


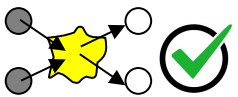


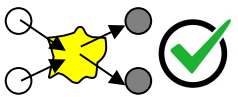
Dark Matter: WIMP

$$\frac{dn_\chi}{dt} + 3\,H\,n_\chi = -\langle v\sigma_\chi\rangle\left[n_\chi^2 - (n_\chi^{\rm eq})^2\right]$$

Talks by:
Roberto,
Óscar,
Amalia...







Dark Matter: WIMP vs FIMP

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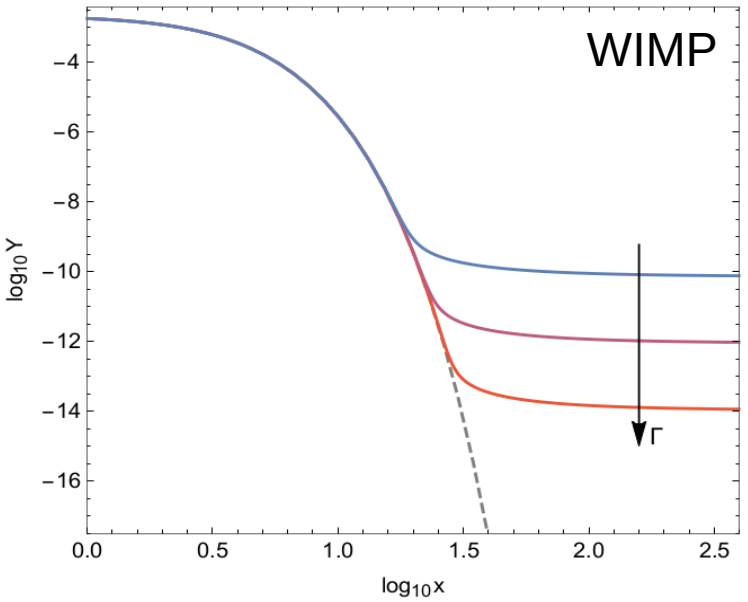
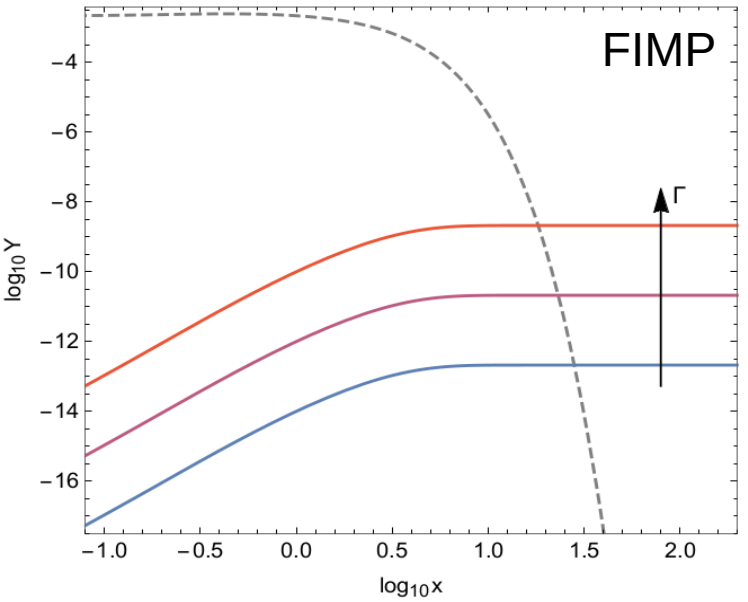
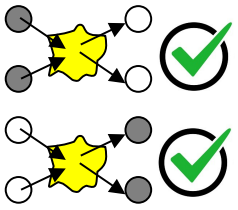
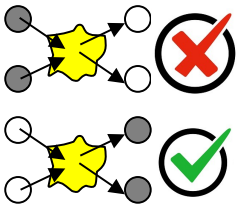




Talk by Basabendu





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

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DM is *unavoidably* produced by PBH Hawking evaporation!

Primordial Black Holes

Talk by J. Lu N. Fernández

* Density fluctuations can collapse into a PBH in the early universe
* Lose mass by emitting *all* particles via Hawking evaporation
  → PBH have a ~black body spectrum, with temperature $T_{BH} \sim 1/M_{BH}$
  → PBHs unavoidable radiate DM!
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Effective theory: <u>Two free parameters</u>

* A single PBH characterized by its mass at formation $\boldsymbol{M_{in}}$
  (or equivalently, by the SM temperature T_{in} at formation)

* Initial PBH energy density $\boldsymbol{\beta} = \rho_{BH}/\rho_{SM}$

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!

$$N_j = \frac{15\,\zeta(3)}{\pi^4}\frac{g_j\,\mathcal{C}_n}{g_\star(T_{\rm BH})}\begin{cases}\left(\frac{M_{\rm in}}{M_P}\right)^2 & \text{for} \quad m_j \leq T_{\rm BH}^{\rm in} \\ \left(\frac{M_P}{m_j}\right)^2 & \text{for} \quad m_j \geq T_{\rm BH}^{\rm in}\end{cases}$$

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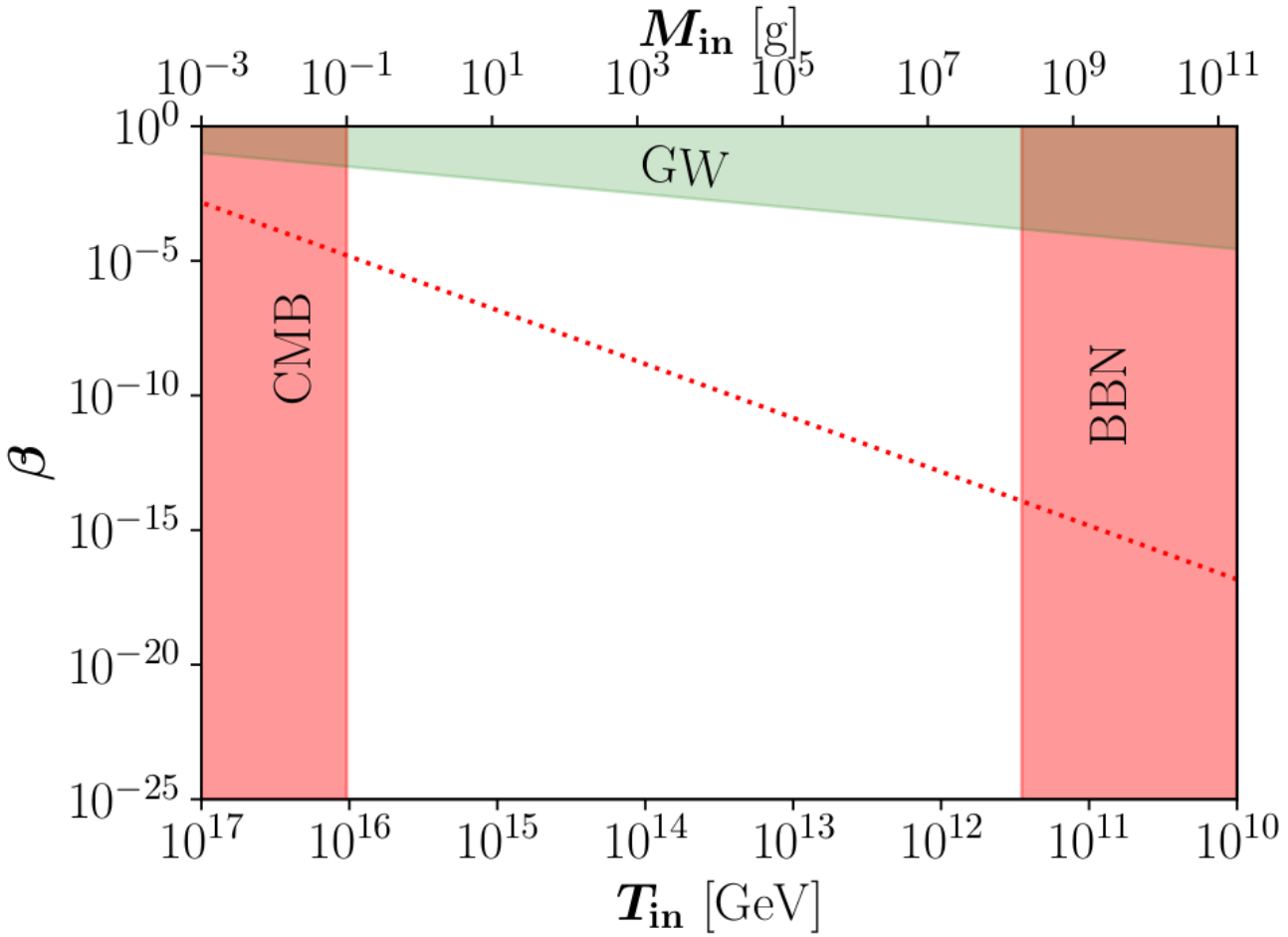
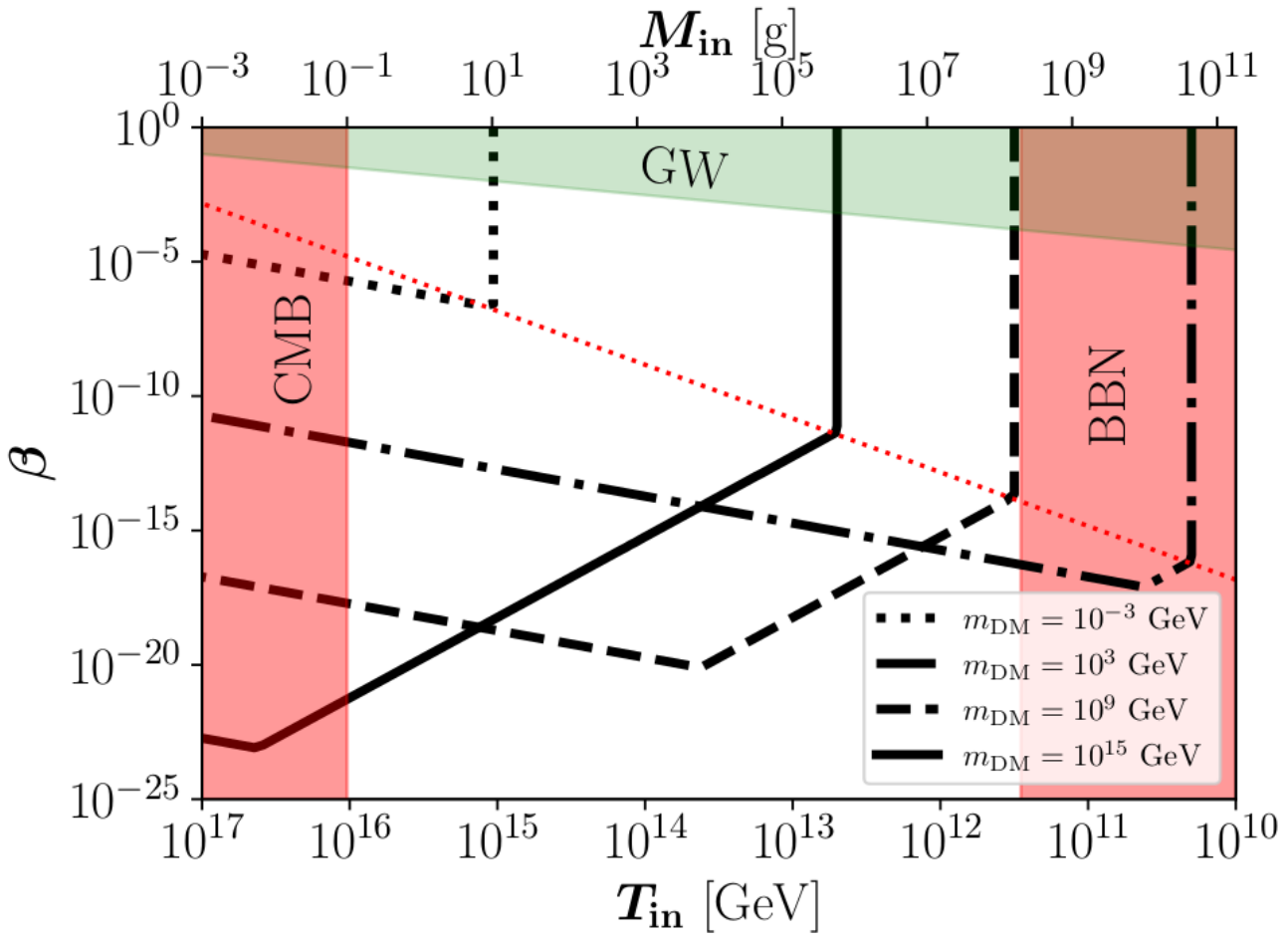
As PBH scale like non-relativistic matter,
they can dominate the total energy density of the universe

→ Nonstandard expansion!

DM from PBHs


$M_{\rm in}$ [g]
10^{-3}
10^{-1}
10^{1}
10^{3}
10^{5}
10^{7}
10^{9}
10^{11}
10^{0}
10^{-5}
10^{-10}
10^{-15}
10^{-20}
10^{-25}
β
GW
CMB
BBN
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
$T_{\rm in}$ [GeV]

DM from PBHs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β
GW
CMB
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$m_{\rm DM} = 10^{-3}$ GeV
$m_{\rm DM} = 10^{3}$ GeV
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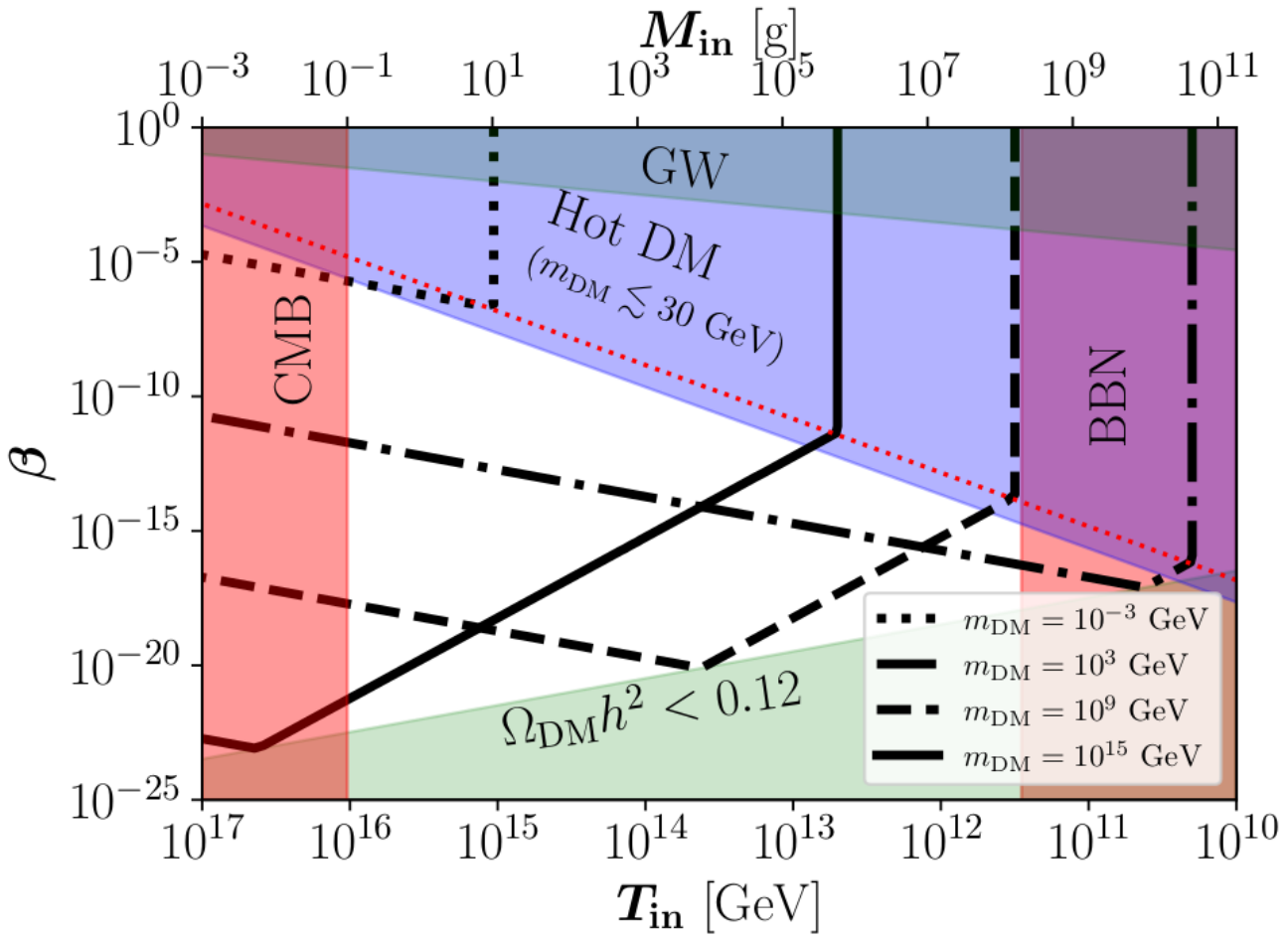
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
$T_{\rm in}$ [GeV]

DM from PBHs


$M_{\rm in}$ [g]
10^{-3}
10^{-1}
10^{1}
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10^{5}
10^{7}
10^{9}
10^{11}
10^{0}
10^{-5}
10^{-10}
10^{-15}
10^{-20}
10^{-25}
β
GW
Hot DM
($m_{\rm DM} \lesssim 30$ GeV)
CMB
BBN
$\Omega_{\rm DM}h^2 < 0.12$
$m_{\rm DM} = 10^{-3}$ GeV
$m_{\rm DM} = 10^{3}$ GeV
$m_{\rm DM} = 10^{9}$ GeV
$m_{\rm DM} = 10^{15}$ GeV
10^{17}
10^{16}
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10^{13}
10^{12}
10^{11}
10^{10}
$T_{\rm in}$ [GeV]

Self-interacting DM from PBHs

- If DM possess sizable self-interactions:
  - → DM thermalizes
  - → Number-changing interactions: $2 \leftrightarrow 3$, $2 \leftrightarrow 4$...

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* What is the DM temperature? (kinetic equilibrium)
* What is DM equilibrium number density? (chemical equilibrium)

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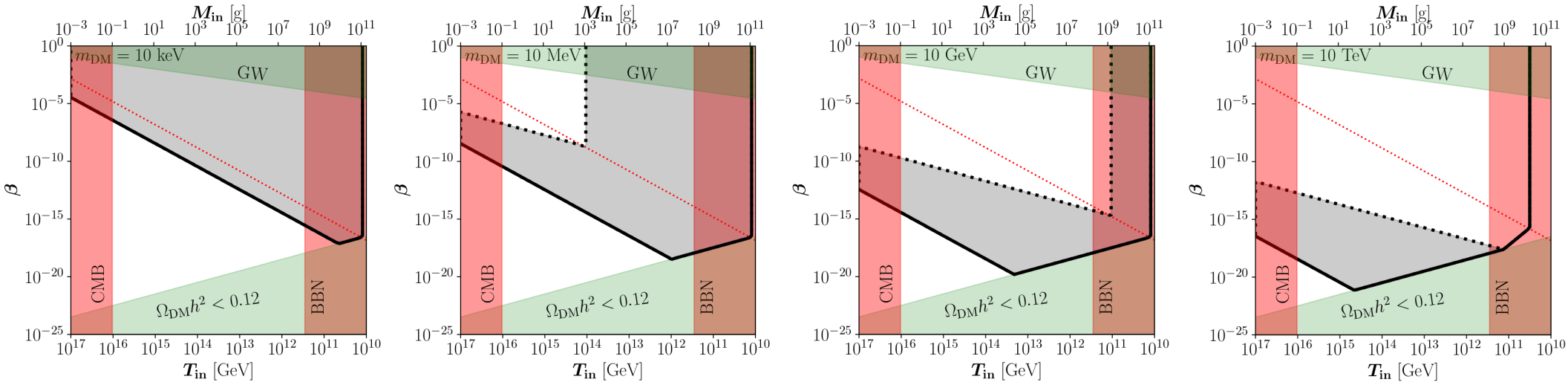
* What is DM equilibrium number density? (chemical equilibrium)

Self-interactions:

- → Increase the DM density
- → Decrease the mean DM kinetic energy

Self-interacting DM from PBHs



* DM production more efficient → smaller β could be explored

* DM cools down → keV DM becomes viable

* Model independent result

Conclusions

- PBHs formed in the early universe
- 0.1 g < M_{in} < 10^9 g evaporate before BBN
- PBH could Hawing radiate the *whole* DM density
- DM masses: 1 MeV < m_{DM} < 10^{18} GeV
- DM self-interactions:
  → boost DM density
  Boost factors of several order of magnitude
  can be computed in a *model independent* way!
  → cools down DM
  keV DM becomes viable

¡Muchas gracias!

Next week!

December 7-9, 2020

by videoconference

INVITED SPEAKERS

Xiaoyong Chu (HEPHY, Austria)
Miguel Escudero (TUM, Germany)
Nicolás Fernández (Illinois U., Urbana, USA)
Camilo Garcia-Cely (DESY, Germany)
Hyun Min Lee (Chung-Ang U., Korea)
Roberto Lineros (Católica del Norte U., Chile)
Laura López-Honorez (Brussels U., Belgium)
Gopolang Mohlabeng (Brookhaven Natl. Lab., USA)
Sergio Palomares-Ruiz (IFIC, Spain)
Carlos Pires (Paraiba U., Brazil)
Diego Restrepo (Antioquia U., Colombia)
James Unwin (Illinois U., Chicago, USA)
Hardi Veermäe (NICPB, Tallinn, Estonia)
Tomer Volansky (Tel Aviv U., Israel)
Hai-bo Yu (UC, Riverside, USA)
Tien-Tien Yu (Oregon U., USA)

The goal of the workshop is to bring together theorists and experimentalists to discuss searches, theories, results, opportunities, and, in general, new ideas for sub-GeV dark matter. It will focus on models and regions in parameter space that are overlooked by the standard WIMP studies, and that may open a new window into the dark sector. If the WIMP paradigm turns out to be wrong, new theoretical and experimental directions may prove to be of outmost importance. This workshop aims at developing such ideas, paving the way for the discovery of dark matter.

There is no registration fee and due to COVID-19 the workshop will be held online.

Registration deadline:
November 29, 2020
Online registration and more information:
http://ictp-saifr.org/ntdm2020/