Dark Matter Production from Two Evaporating PBH Distributions

XXVI BLED WORKHOP
"WHAT COMES BEYOND THE STANDARD MODEL

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Contents

- PBH mass distribution
- Various components of the universe
- Role of PBH and relic contours
- 2PBH scenario - Formalism and results

PBH Mass Distribution

In simple terms it is the number density of PBHs within a mass range.

- Monochromatic
- Non-Monochromatic

Various Components of Universe

- $P_j(t) = \omega_j \rho_j(t)$
- Standard Components:

A. Relativistic Radiation: $\omega_j = \frac{1}{3};\ \rho_j(a) \propto a^{-4}$

B. Non-relativistic Matter: $\omega_j = 0;\ \rho_j(a) \propto a^{-3}$

C. Vacuum Energy: $\omega_j = -1;\ \rho_j(a) \propto const$

Role of PBH

- Production of Dark Matter through Hawking radiation of PBH
- Entropy injection through Hawking radiation
- Modification of the Hubble parameter dependence:

$$H(a) = \sqrt{\frac{\rho_{Rad}(a) + \rho_{PBH}(a)}{3M_{PL}^2}}$$

Ingredients of DM Production from PBH Evaporation

- Important Parameters:
  1. PBH initial mass (M_{in})
  2. Dark matter mass
  3. $\beta = \dfrac{\rho_{PBH}^{ini}}{\rho_{Rad}^{ini} + \rho_{PBH}^{ini}}$

$$\frac{d\rho_{BH}}{dt} + 3H\rho_{BH} = \frac{\rho_{BH}}{M}\frac{dM}{dt},$$

$$\frac{d\rho_R}{dt} + 4H\rho_R = -\frac{\varepsilon_{SM}(M)}{\varepsilon(M)}\frac{1}{M}\frac{dM}{dt}\rho_{BH}$$

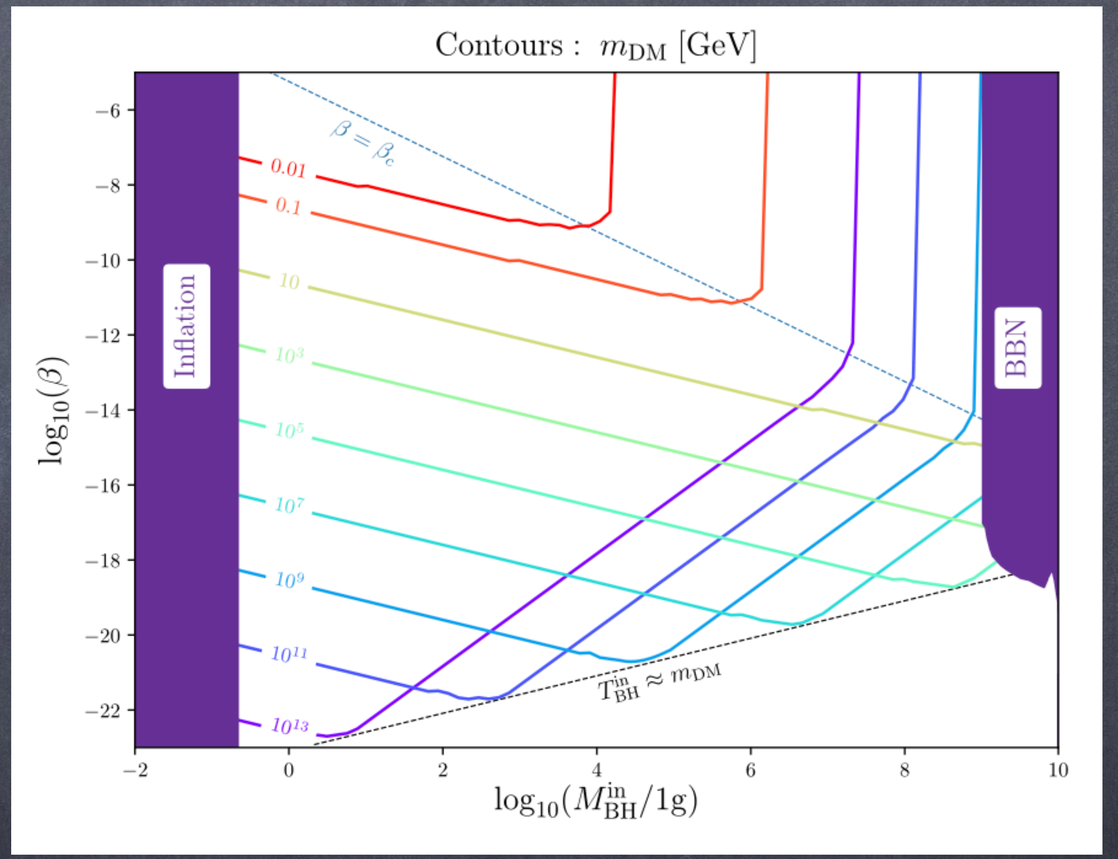
$$\frac{dn_{DM}}{dt} + 3Hn_{DM} = \frac{\rho_{BH}}{M_{BH}}\frac{dN_{DM}}{dt}$$

$$\beta_c = \gamma^{-\frac{1}{2}}\left(\frac{\mathcal{G}g_{\star,H}(T_{BH})}{10640\pi}\right)^{\frac{1}{2}}\frac{M_{Pl}}{M},$$

- Constraints from Big Bang Nucleosynthesis, Inflation and Gravitational Waves observations

Relic Contours : Single PBH Distribution

DM of mass range $1 - 10^9$ GeV produced from evaporation of a monochromatic PBH can not satisfy DM relic in the PBH dominated region of parameter space due to the BBN bounds



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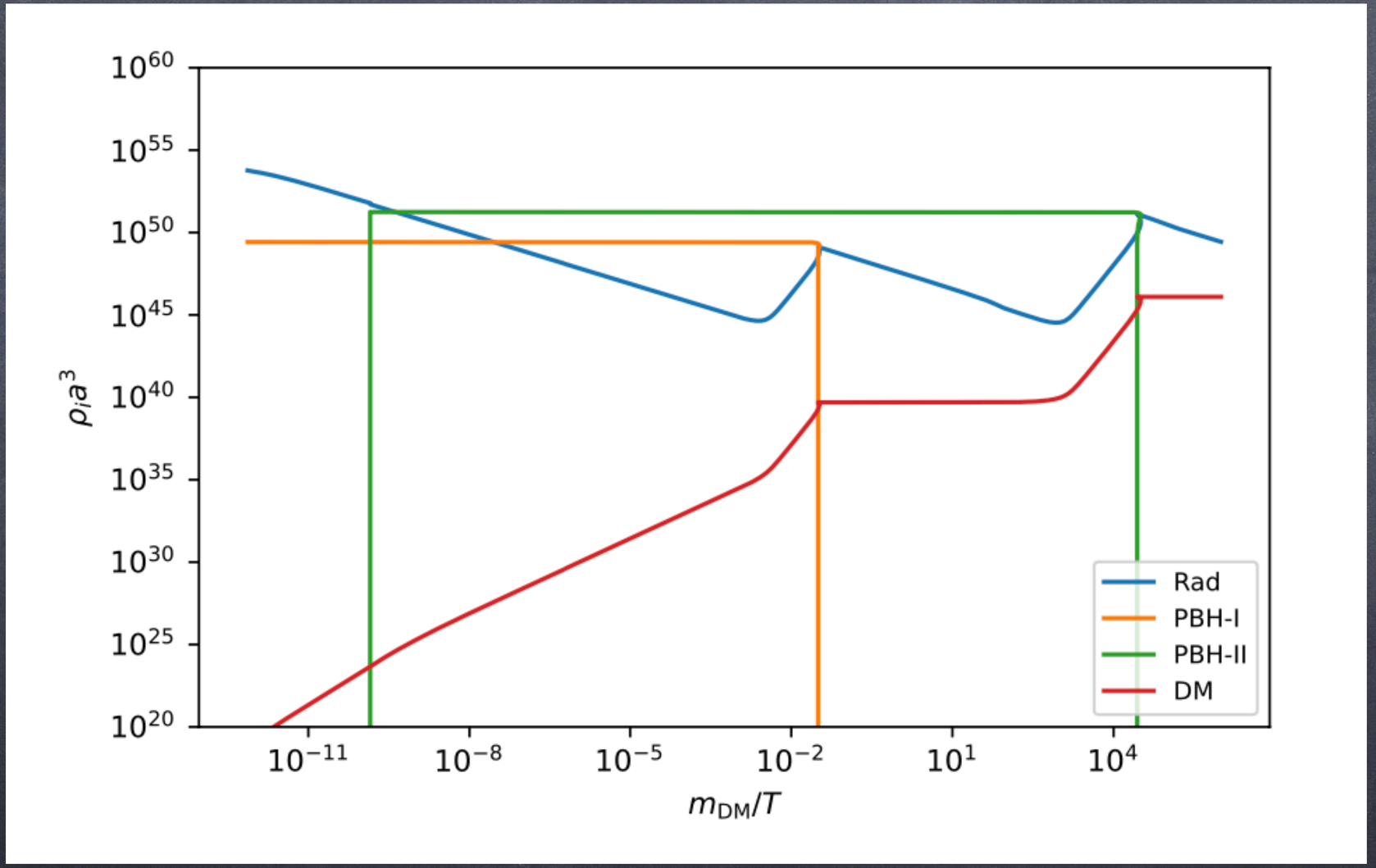
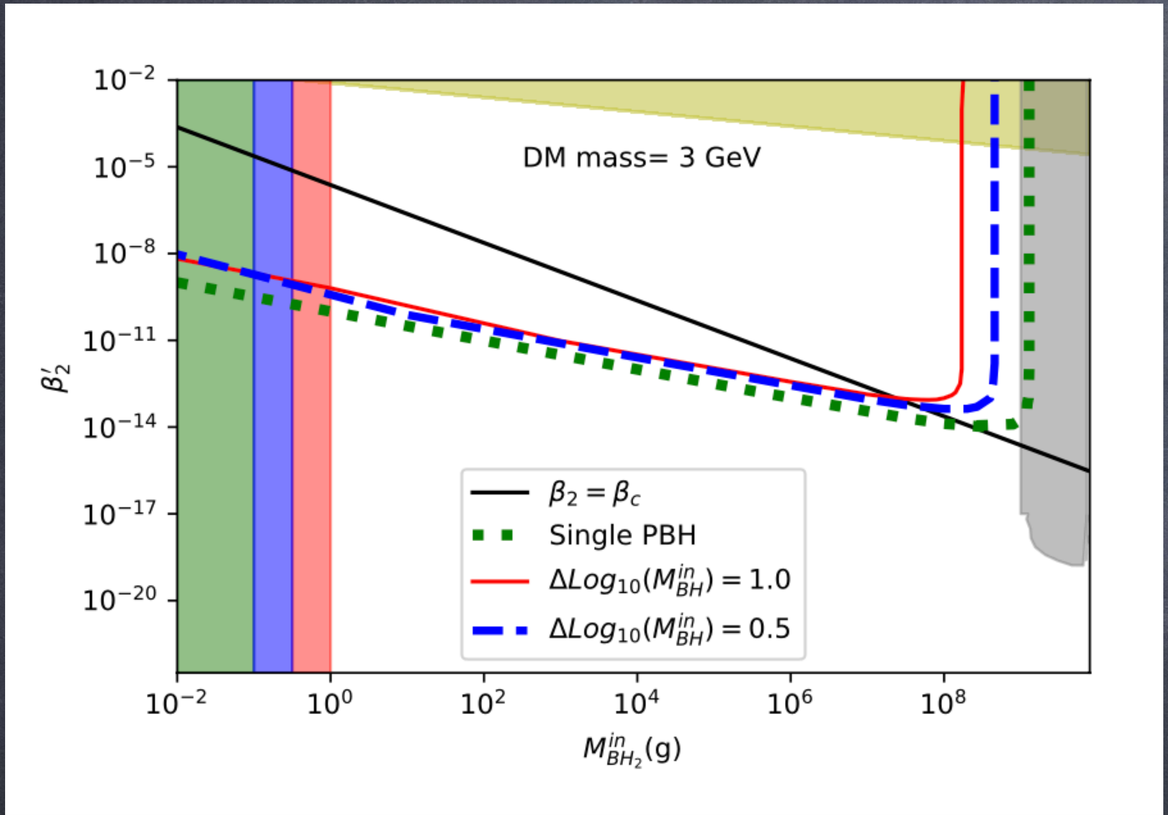
Formalism

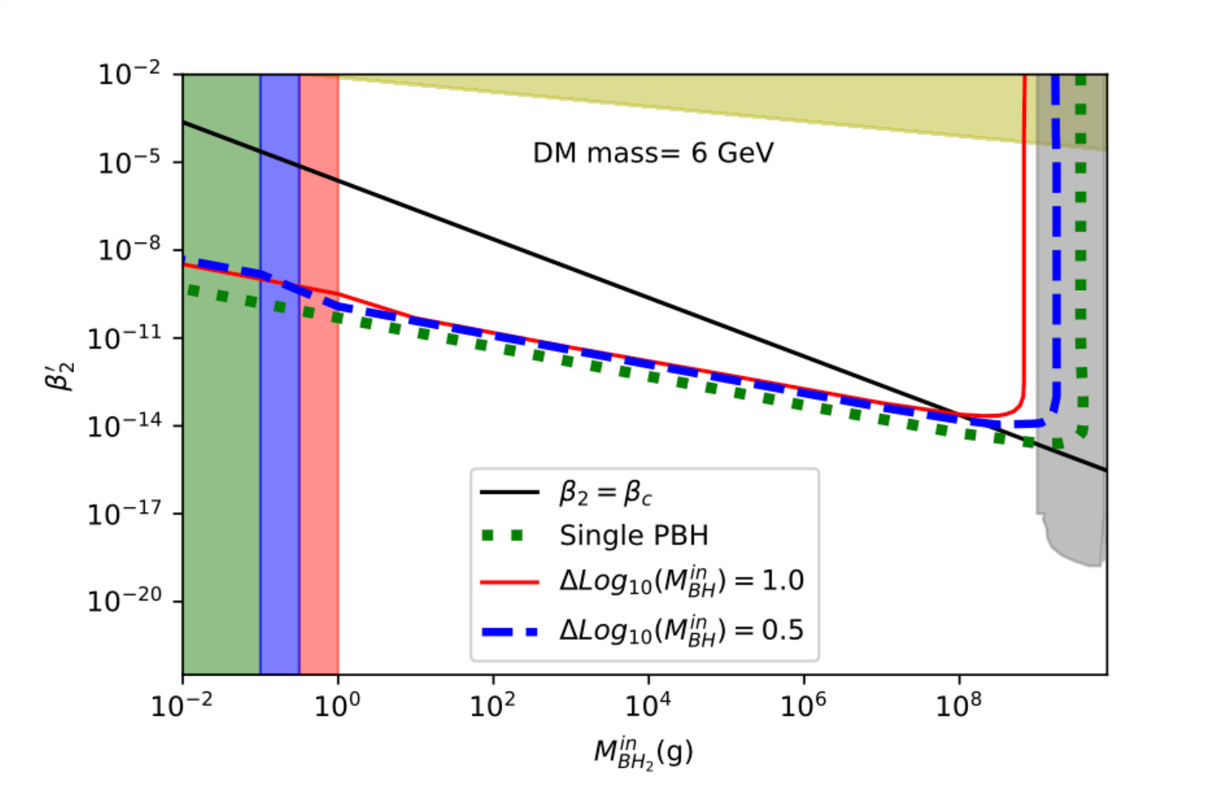
- Temporally separated formation of two monochromatic PBH distributions
- $T_1 > T_2$ and hence, $M^{in}_{BH_1} < M^{in}_{BH_2}$
- The one-PBH case is compared to the second PBH of two-PBH scenario
- $\beta_1 = \dfrac{\rho_{BH_1}(T_1)}{\rho_{BH_1}(T_1) + \rho_{Rad}(T_1)}$, $\beta_2 = \dfrac{\rho_{BH_1}(T_2) + \rho_{BH_2}(T_2)}{\rho_{BH_1}(T_2) + \rho_{BH_2}(T_2) + \rho_{Rad}(T_2)}$

Evolution of Components of the Universe

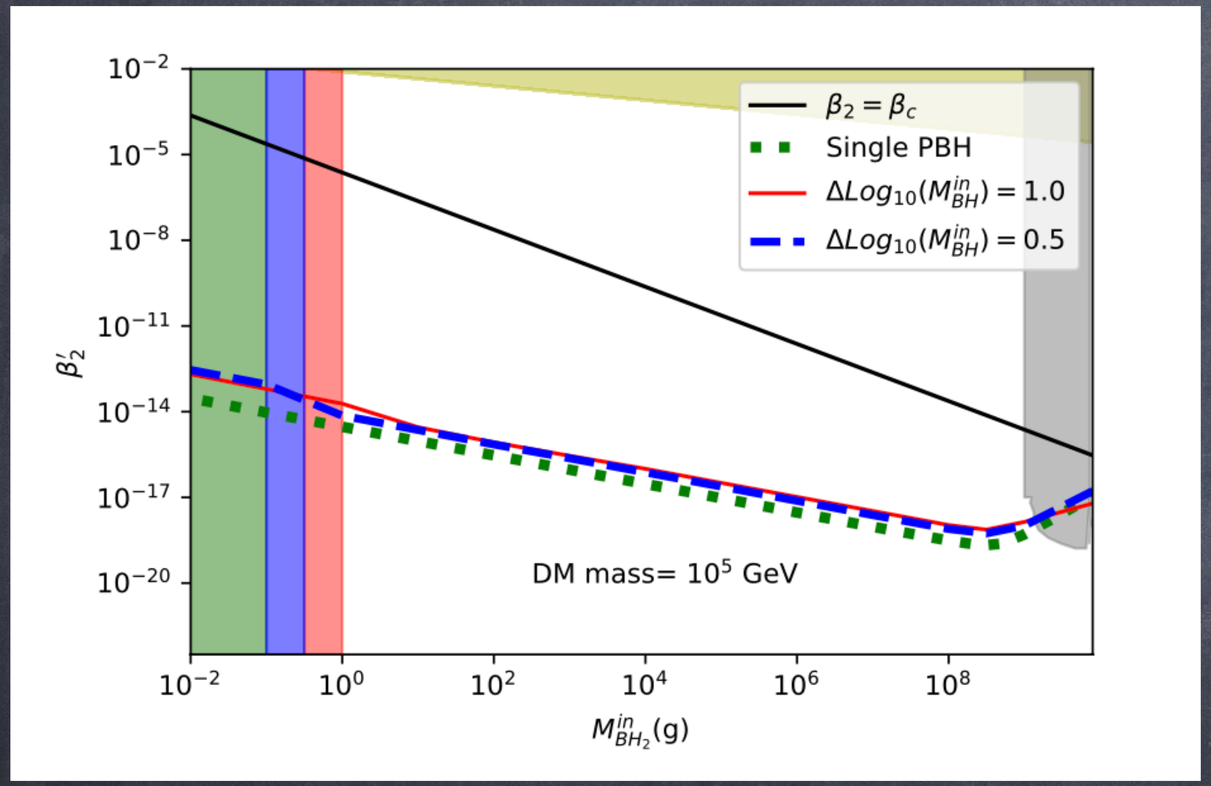


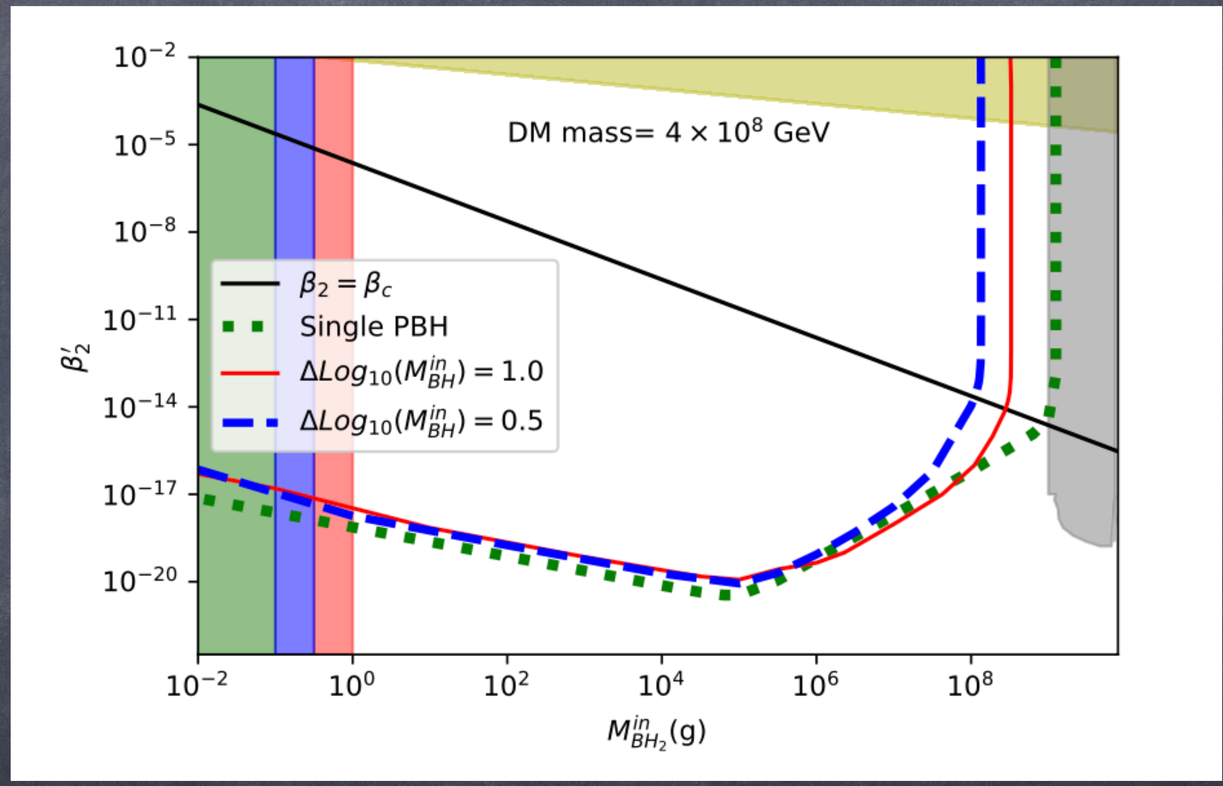
Relic Contours : Two PBH





Relic Contours : Two PBH

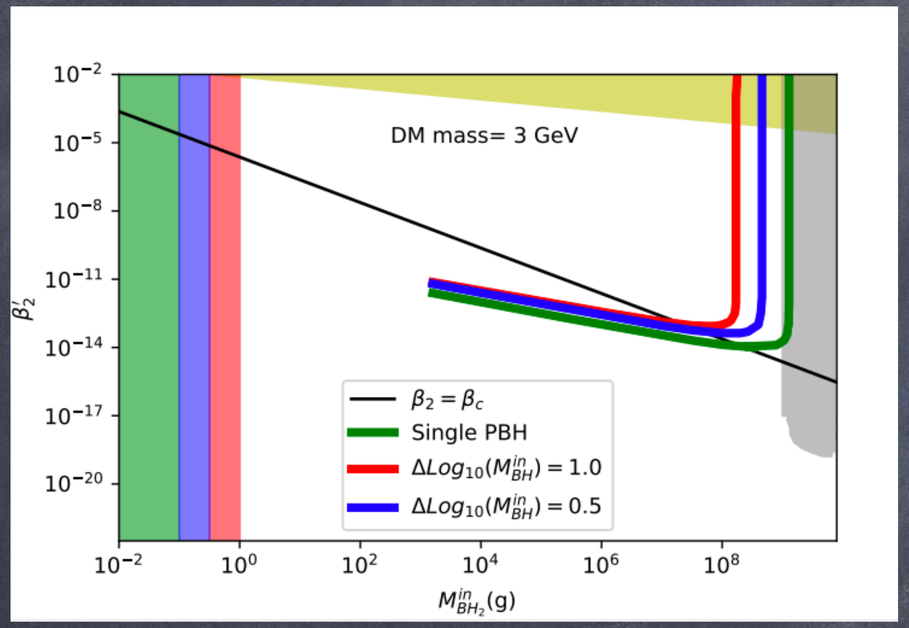


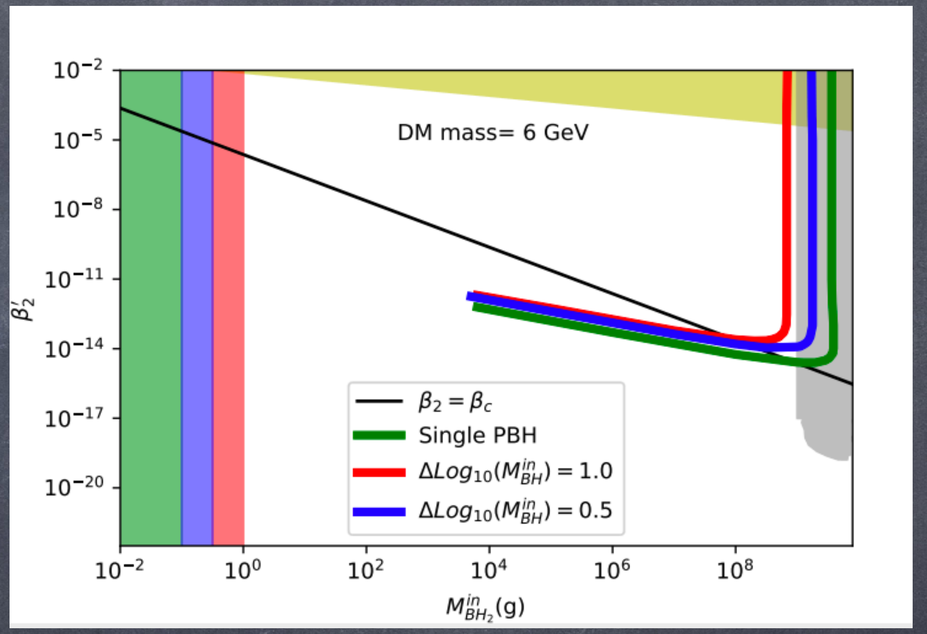


Warm Dark Matter Constraints

The more massive DM masses are immune to WDM constraints. However the low DM masses are disallowed irrespective of the single or double monochromatic PBH distributions.

WDM constraints...





The "Disallowed" Region is shown for the lower massed DM

Exact Window of relaxation

We wanted to squeeze the disallowed region..

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- For a $\Delta Log_{10}(M_{BH}^{in}) = 1.0$ (in grams) the allowed DM mass range is $(7.24 - 8.91 \times 10^7)$ Gev.

- For a $\Delta Log_{10}(M_{BH}^{in}) = 0.5$ (in grams) the allowed DM mass range is $5.56 - 2.67 \times 10^7$ Gev.

Conclusion

- With the inclusion of an extra PBH distribution, some part of PBH dominated region opens up which was almost completely disallowed
- More parameter space opens up even in the radiation dominated region in this two-PBH scenario compared to one-PBH scenario
- Relative mass difference of the two PBH distributions plays a crucial role

Acknowledgement

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Thank you