

Observational phenomena on black hole with dark matter dress

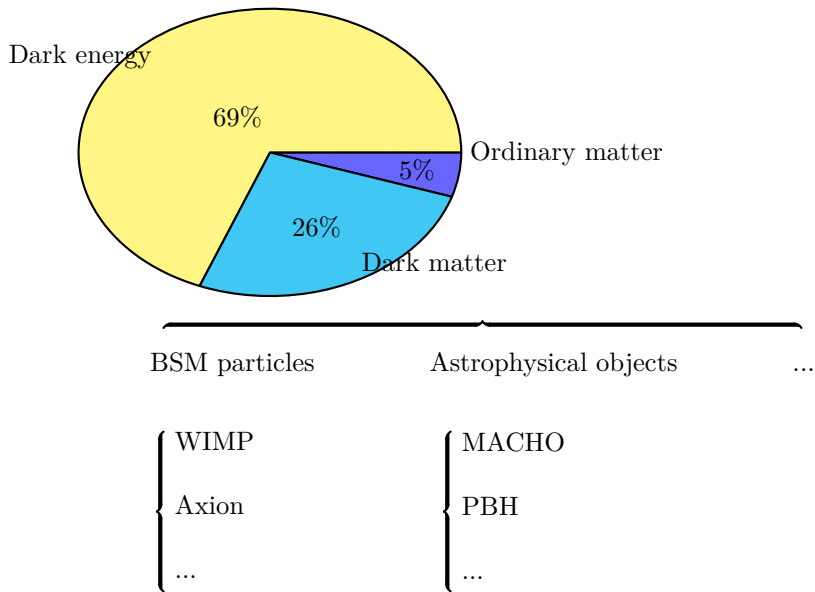
Xing-Yu Yang (杨星宇)



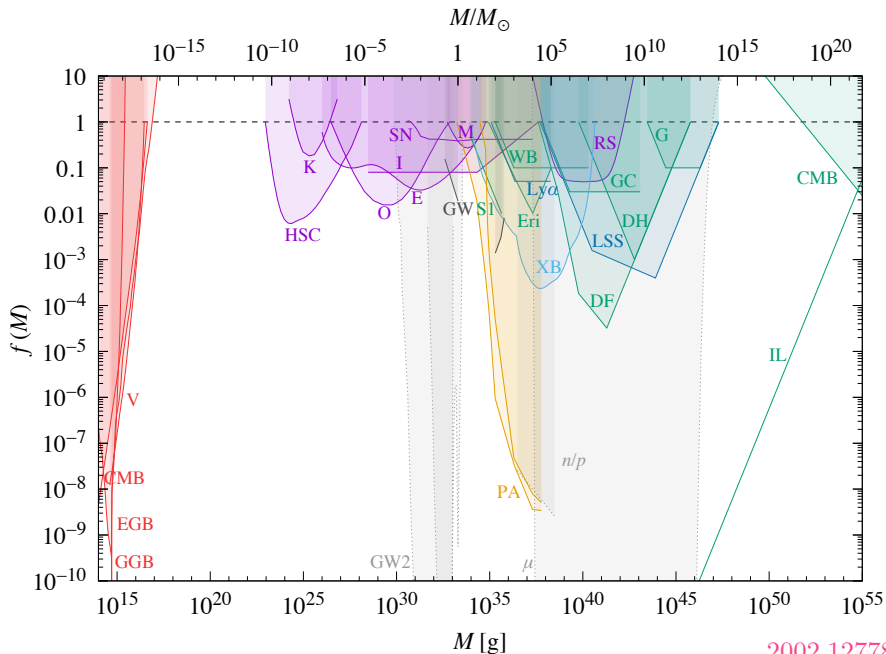
2023-06-15 @ PPC2023

[2007.11804] JCAP 03 (2021) 057

[2210.02078] JCAP 03 (2023) 043

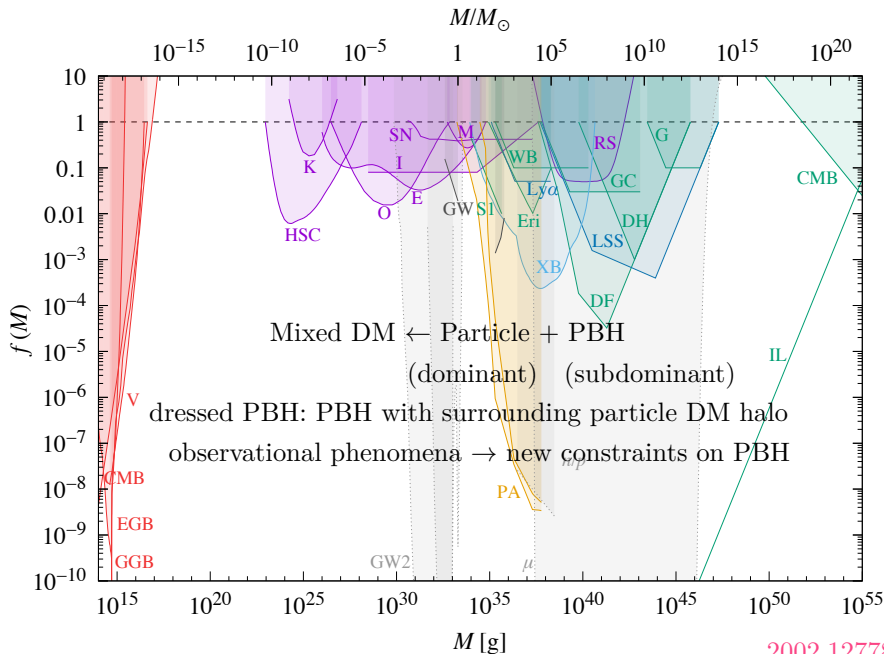


Constraints on PBH abundance

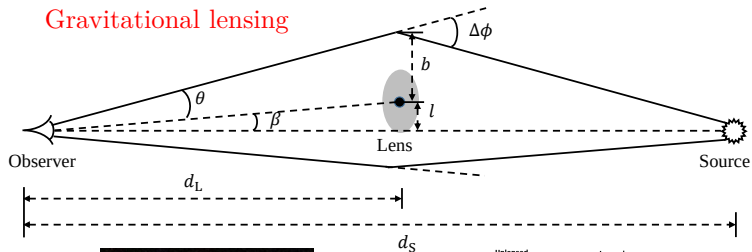


2002.12778

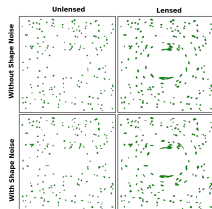
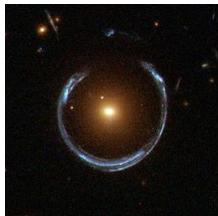
Constraints on PBH abundance



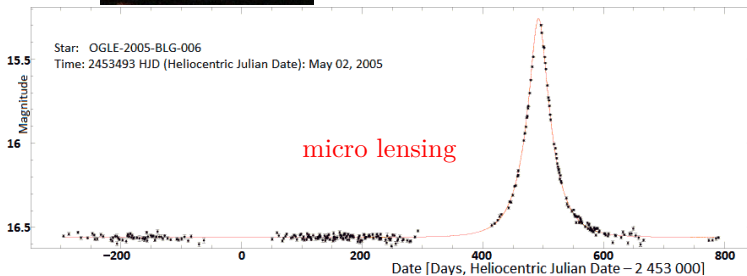
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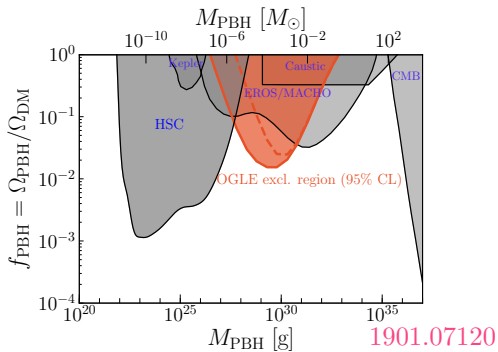
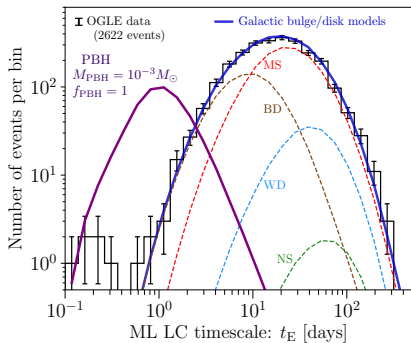


strong lensing



weak lensing



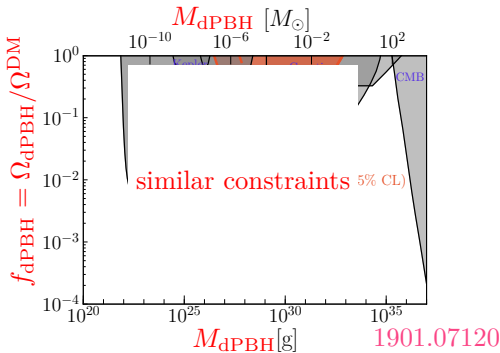
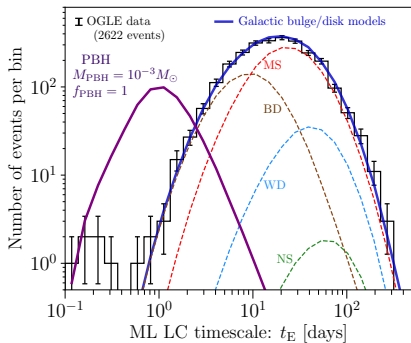


PBH as lens

$$N_{\text{event}} (\text{Galactic}) + N_{\text{event}} (\text{PBH}) \lesssim N_{\text{event}} (\text{Observed})$$

$$N_{\text{event}} (\text{PBH}) \leftarrow f_{\text{PBH}} + M_{\text{PBH}}$$

1901.07120



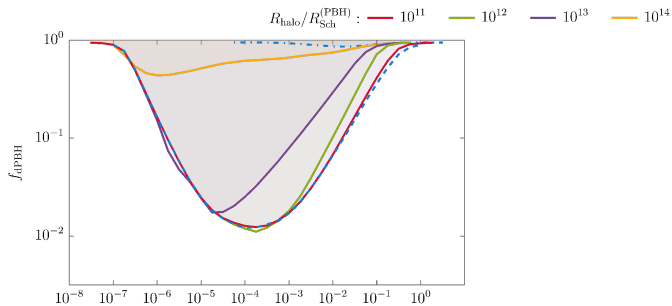
dPBH as lens

$$N_{\text{event}} (\text{Galactic}) + N_{\text{event}} (\text{dPBH}) \lesssim N_{\text{event}} (\text{Observed})$$

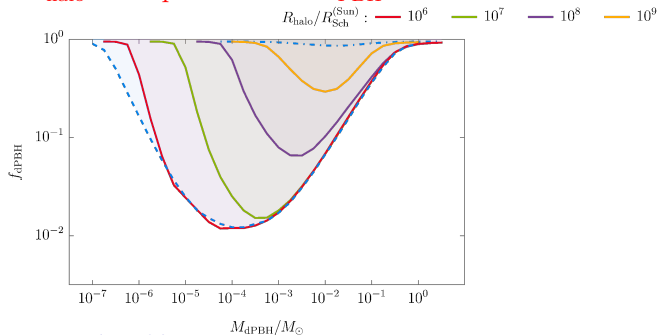
$$N_{\text{event}} (\text{dPBH}) \leftarrow f_{\text{dPBH}} + M_{\text{dPBH}} + R_{\text{halo}}$$

$$M_{\text{dPBH}} = M_{\text{PBH}} + M_{\text{halo}}$$

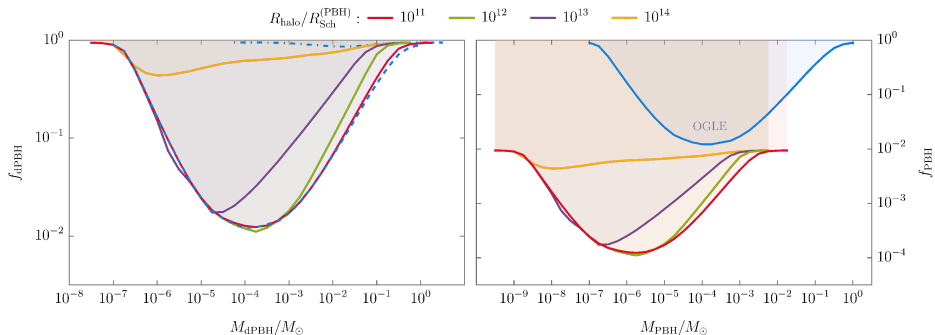
$$R_{\text{halo}} \propto M_{\text{PBH}} \quad M_{\text{halo}} = 100 M_{\text{PBH}},$$



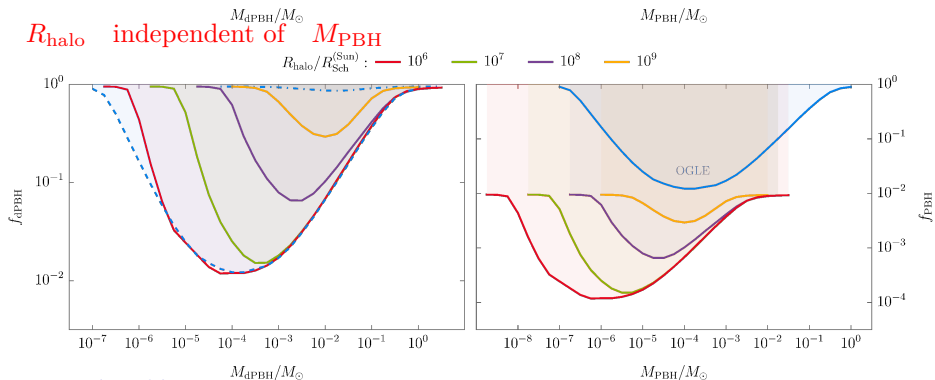
R_{halo} independent of M_{PBH}

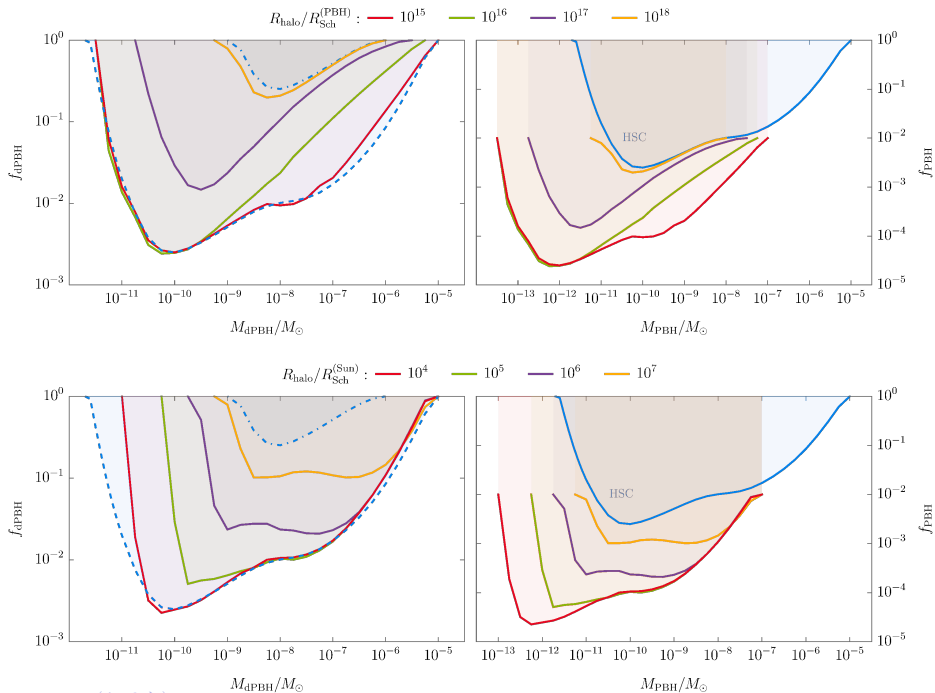


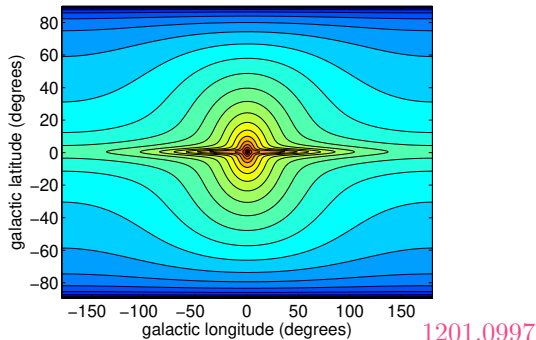
$$R_{\text{halo}} \propto M_{\text{PBH}} \quad M_{\text{halo}} = 100 M_{\text{PBH}},$$



$$R_{\text{halo}} \text{ independent of } M_{\text{PBH}}$$





511 keV γ -ray intensity distribution

- 511 keV γ -ray excess

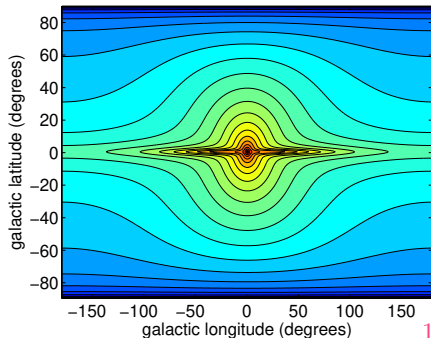
- $\gamma \leftarrow e^+ + e^-$

- puzzling morphology: flux ratio of bulge-to-disk $\sim O(1)$

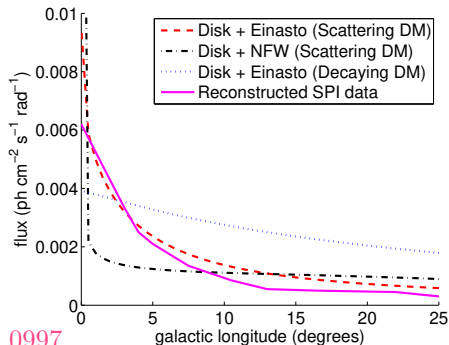
- ? origin of low-energy e^+

- * astrophysical explanation: low-mass X-ray binaries, neutron star mergers, ...

- * DM

511 keV γ -ray intensity distribution

1201.0997



- scattering DM

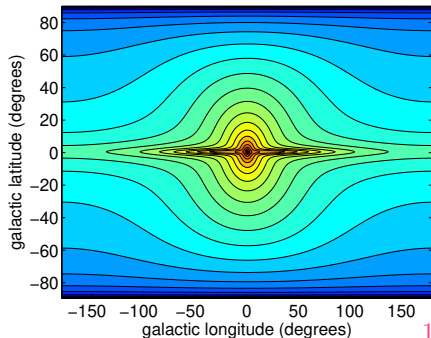
- $\chi + \chi \rightarrow e^+ + \dots$

- $I(l, b) \sim \rho^2(\mathbf{r})$

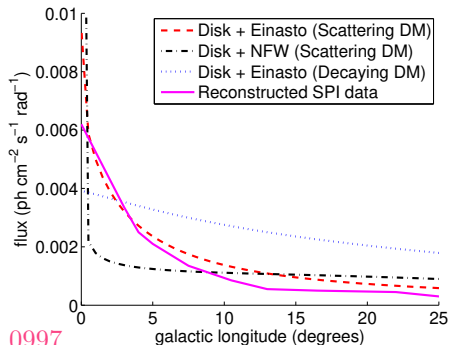
- decaying DM

- $\chi \rightarrow e^+ + \dots$

- $I(l, b) \sim \rho(\mathbf{r})$

511 keV γ -ray intensity distribution

1201.0997



- scattering DM

- $\chi + \chi \rightarrow e^+ + \dots$

- $I(l, b) \sim \rho^2(\mathbf{r})$

gives upper bound



$$\text{Mixed DM} = \text{Scattering DM} + \text{Decaying DM}$$

- decaying DM

- $\chi \rightarrow e^+ + \dots$

- $I(l, b) \sim \rho(\mathbf{r})$

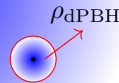
Self-annihilating particles + PBHs

Self-annihilating

$$\rho(\mathbf{r}) I_{\text{unbounded}}(l, b) \propto \int_{\text{l.o.s}} \frac{1}{2} \frac{\langle \sigma v \rangle}{m_\chi^2} (1 - f_{\text{PBH}})^2 \overset{C_A}{\boxed{\rho^2(\mathbf{r})}} ds$$

$$I_{\text{dPBH}}(l, b) \propto \int_{\text{l.o.s}} \overset{C_D}{\boxed{\frac{\Gamma_{\text{PBH}}}{M_{\text{PBH}}} f_{\text{PBH}}}} \rho(\mathbf{r}) ds$$

$$\Gamma_{\text{PBH}} = \int dr^3 \frac{1}{2} \frac{\langle \sigma v \rangle}{m_\chi^2} \rho_{\text{dPBH}}^2$$



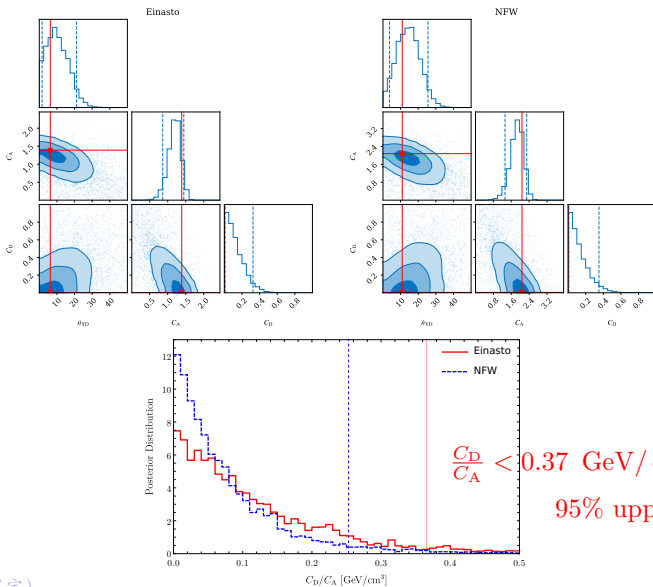
dPBH $\sim$ Decaying DM

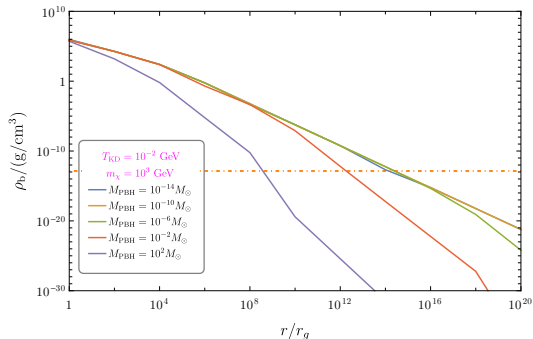
$$\frac{f_{\text{PBH}}}{(1 - f_{\text{PBH}})^2} = \frac{2M_{\text{PBH}}}{\int dr^3 \rho_{\text{dPBH}}^2} \frac{C_D}{C_A}.$$

- Morphology of 511 keV gamma-ray observations $\Rightarrow$ upper bound on C_D/C_A
- Theoretical calculation $\Rightarrow \rho_{\text{dPBH}}$

Fit to INTEGRAL/SPI data

$$I(l, b) = I_{\text{unbounded}}(l, b) + I_{\text{dPBH}}(l, b) + I_{\text{disk}}(l, b)$$





- Maximum possible density at present time by

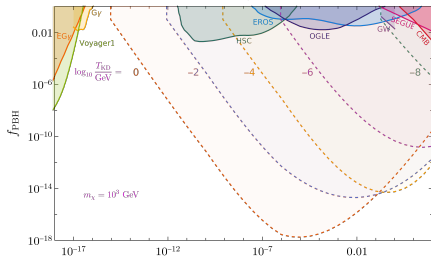
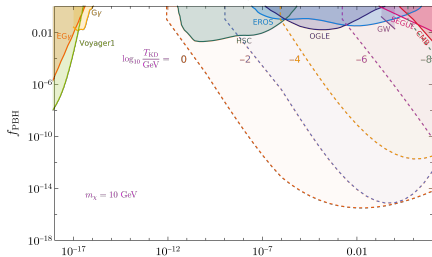
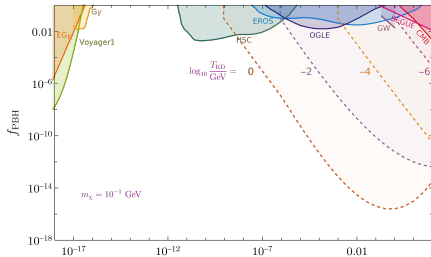
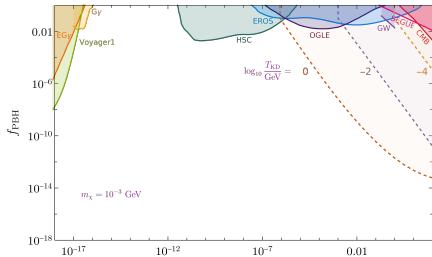
$$\rho_{\max} = \frac{m_{\chi}}{\langle \sigma v \rangle_a t_0},$$

where $t_0 \approx 4.3 \times 10^{17} \text{s}$, and $\langle \sigma v \rangle_a \sim 3 \times 10^{-26} \text{ cm}^3 \text{s}^{-1}$.

•

$$\rho_{\text{dPBH}}(r) = \min[\rho_{\max}, \rho_b(r)]$$

$$\frac{f_{\text{PBH}}}{(1 - f_{\text{PBH}})^2} = \frac{2M_{\text{PBH}}}{\int dr^3 \rho_{\text{dPBH}}} \frac{C_{\text{D}}}{C_{\text{A}}} < \frac{3M_{\text{PBH}}}{2\pi \rho_{\text{max}}^2 r_c^3} \times 0.37 \text{ GeV/cm}^3$$



$M_{\text{PBH}}/M_{\odot}$

$M_{\text{PBH}}/M_{\odot}$

- When DM contains subdominant PBHs, the accretion of DM around PBHs could lead to the formation of surrounding minihalos, which gives characteristic observational phenomena compared with single-component DM.
- Using the data of OGLE and HSC observations, the existence of DM minihalos surrounding PBHs can strengthen the constraints on PBH abundance by several orders and can shift the constraints to the well-known asteroid-mass window where PBHs can constitute all the DM.
- The DM explanation for the 511 keV gamma-ray background can give much more stringent constraints on PBH abundance.