CARGESE SUMMER SCHOOL

Rekindling s-Wave Dark Matter Annihilation Below 10 GeV with Breit-Wigner Effects

arXiv:2503.08897

me

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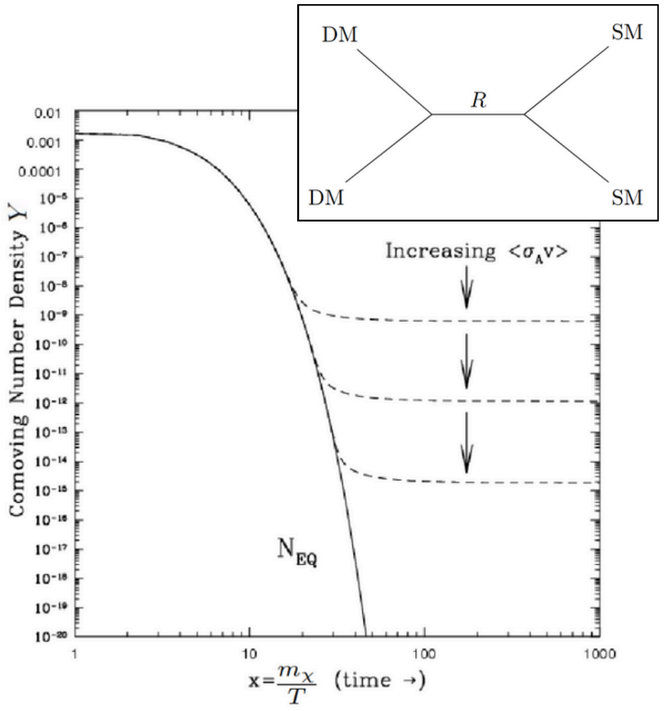


$\langle \sigma v \rangle$ must be high enough

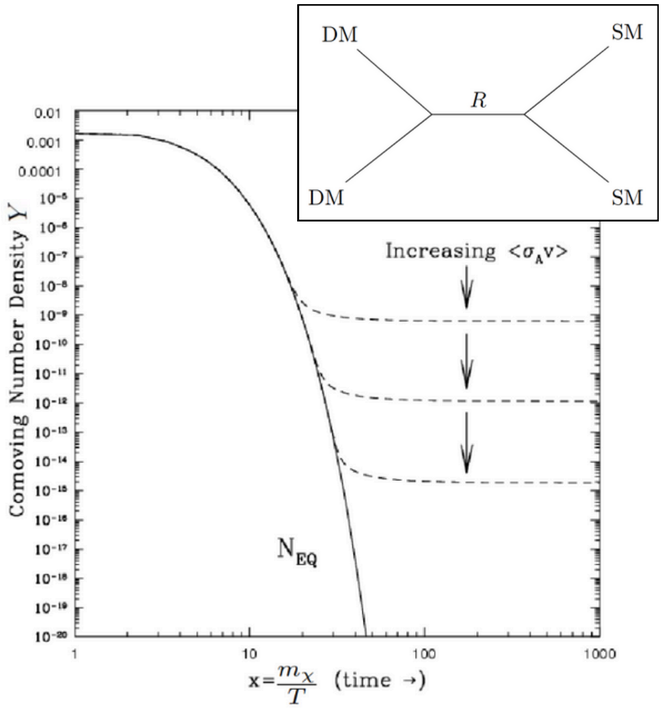
Freeze-out

0.01-100 MeV

CMB

0.4 eV

Universe Temperature



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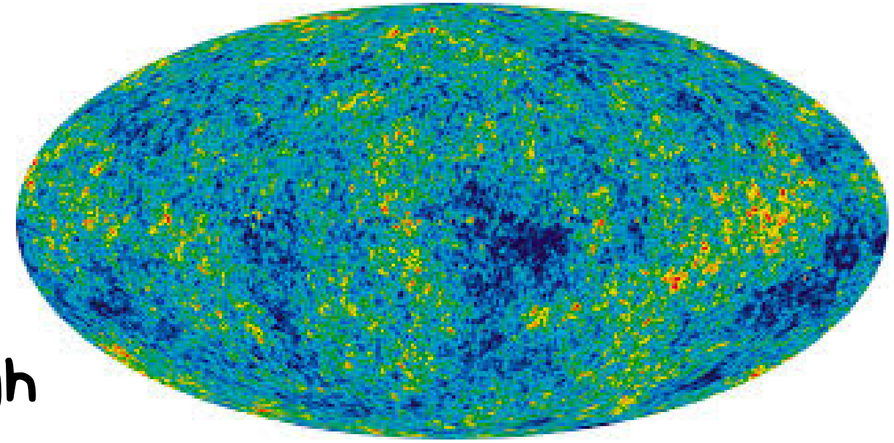

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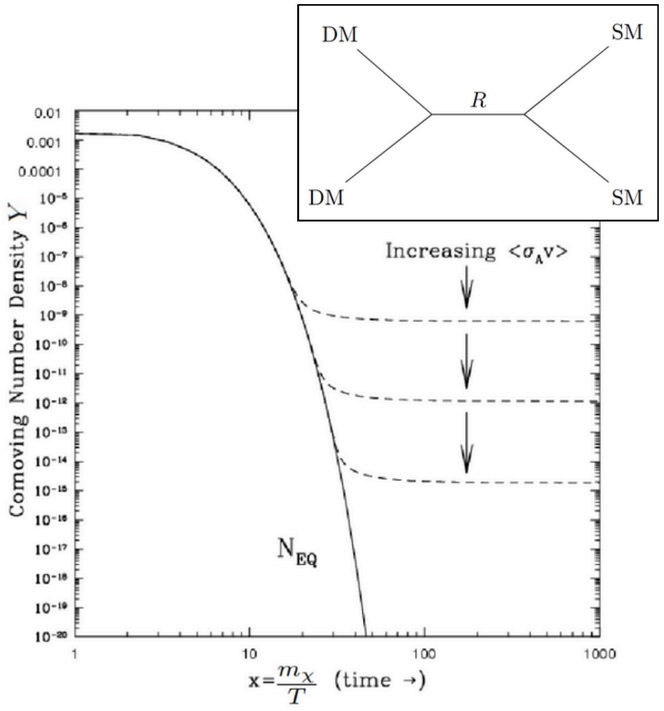

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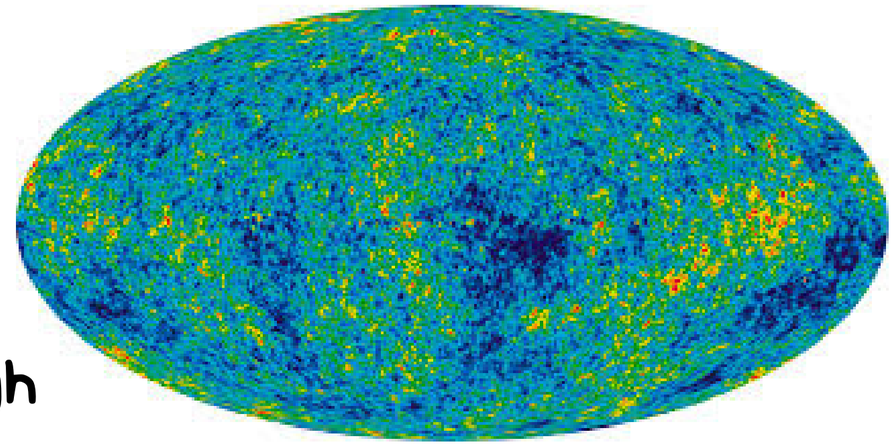

Freeze-out — **CMB**

0.01-100 MeV — **0.4 eV** — **Universe Temperature**

$\neq 0 \rightarrow$ s-wave

$$\langle \sigma v \rangle = c_0 + c_1 v^2 + c_2 v^4 + \ldots + c_n v^{2n}$$

velocity dispersion

$= 0 \rightarrow$ p-wave (or d-wave,...)

Breit-Wigner formalism:

$$\sigma_{\chi\chi\to f} = g_\chi g_{\mathrm{SM}} \frac{4\pi\omega}{p^2} B_\chi B_f \frac{m_R^2 \Gamma_R^2}{(s - m_R^2)^2 + m_R^2 \Gamma_R^2}$$

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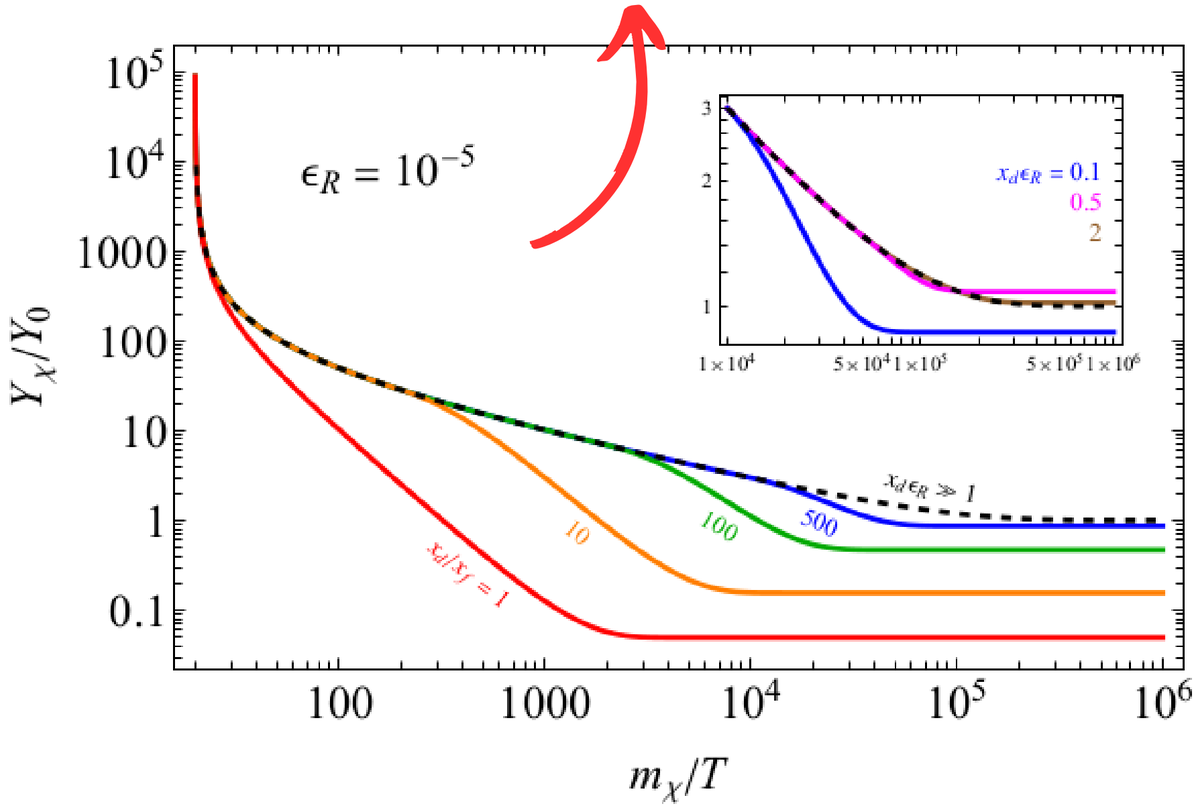
need lower couplings to reach observed relic density



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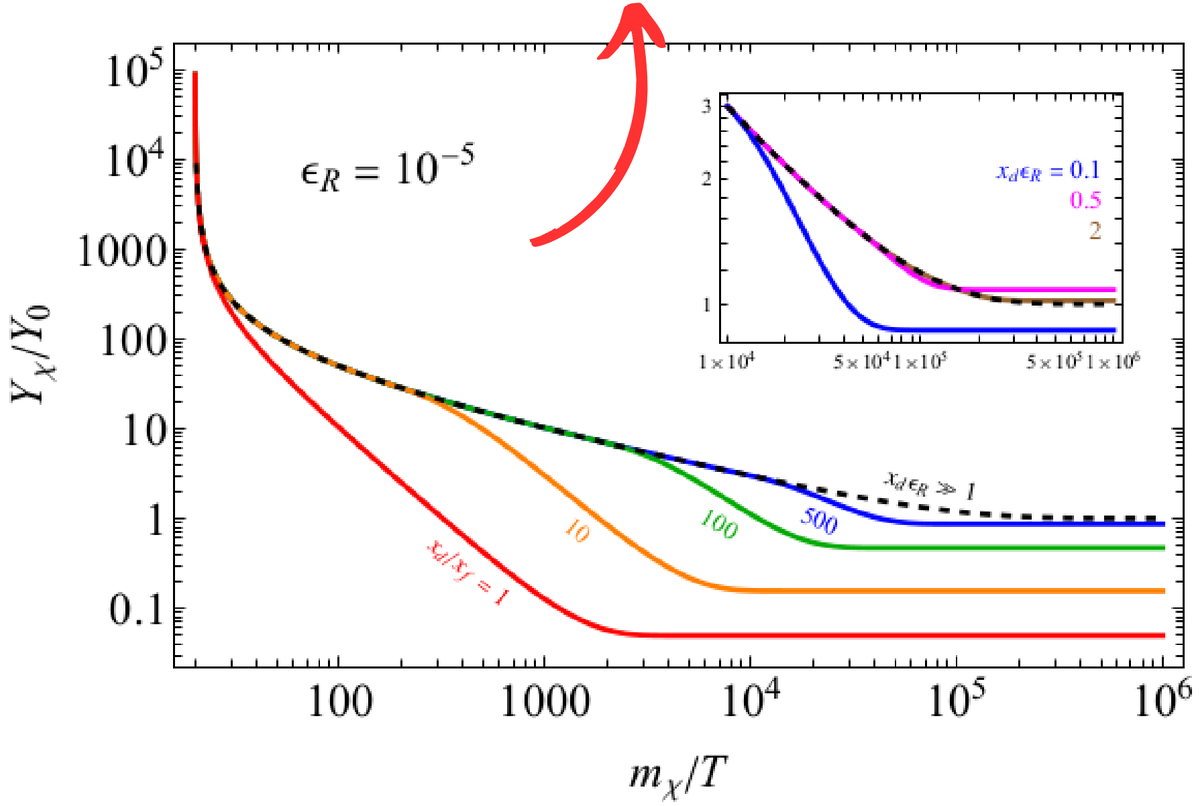
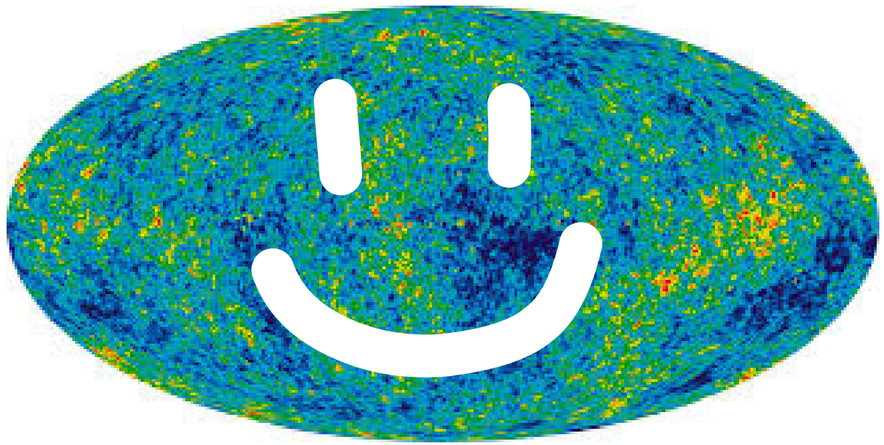
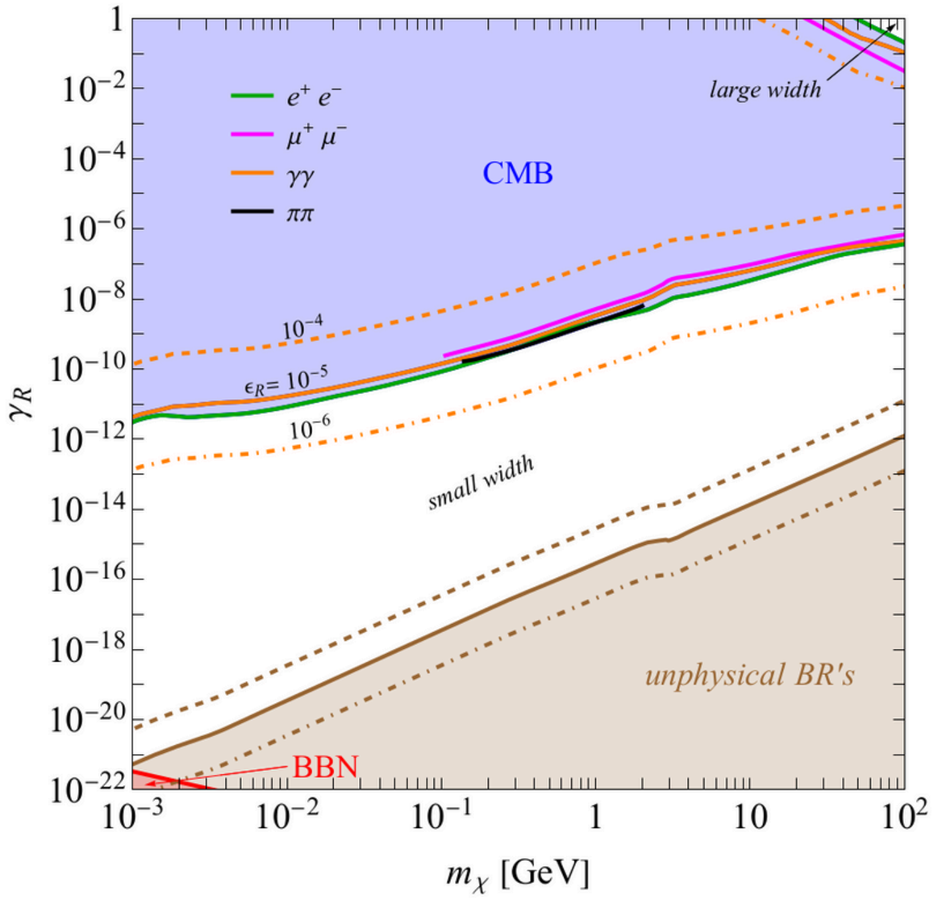


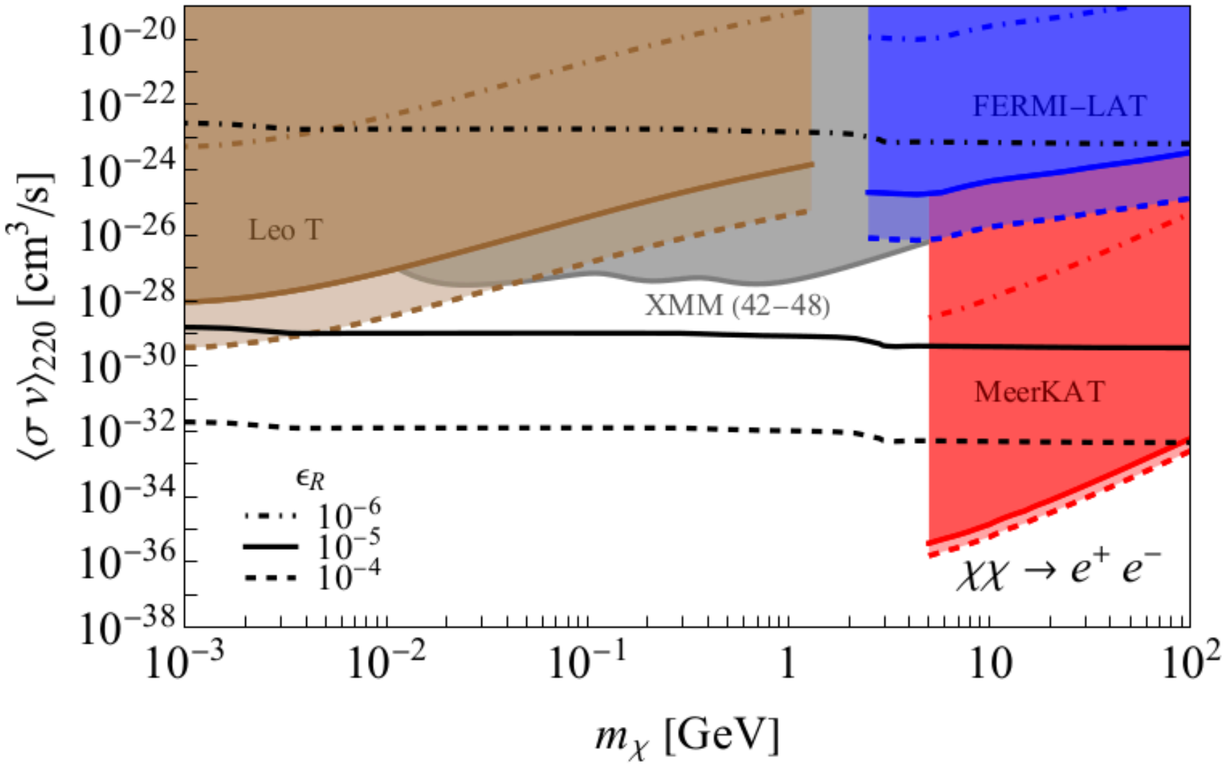
can escape CMB constraints

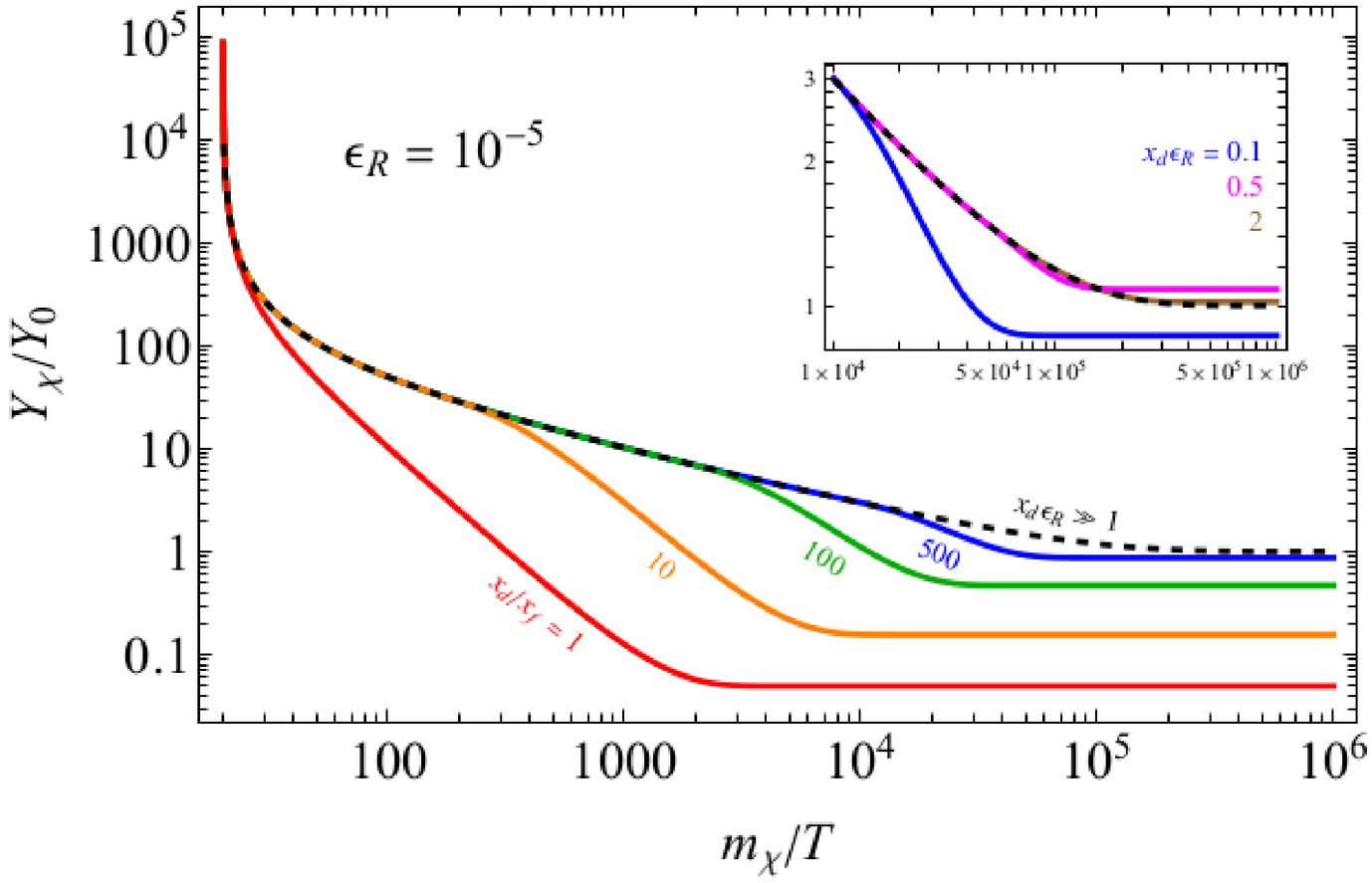


CMB constraints:



Indirect detection constraints:





Temperature of Dark Matter

$$T' = \left(\frac{h_{\rm eff}(T)}{h_{\rm eff}(T_d)}\right)^{2/3} \frac{T^2}{T_d}$$

$$k_{\rm dec} = \frac{\Omega_\chi}{\Omega_\chi^{\rm keq}} \simeq \sqrt{\pi x_d \epsilon_R}$$

Kinetic decoupling time →
Chemical decoupling time →

$$\left(\frac{x_d}{x_f}\right)^2 \equiv r_{df}^2 = \frac{H(T_f)}{H(T_d)} = \frac{n_\chi \langle\sigma_{\rm ann} v\rangle}{n_{\rm SM}\langle\sigma_{\rm scatt} v\rangle}$$

$$\gamma_R^c \equiv x_f^{3/2} e^{-x_f} \approx 1.8 \times 10^{-7} \qquad \Rightarrow r_{df} \simeq \begin{cases} \gamma_R/\gamma_R^c & \gamma_R > \gamma_R^c \\ 1 & \gamma_R \le \gamma_R^c \end{cases}$$

Thanks