Revisiting Cosmological Constraints on Supersymmetric SuperWIMPs

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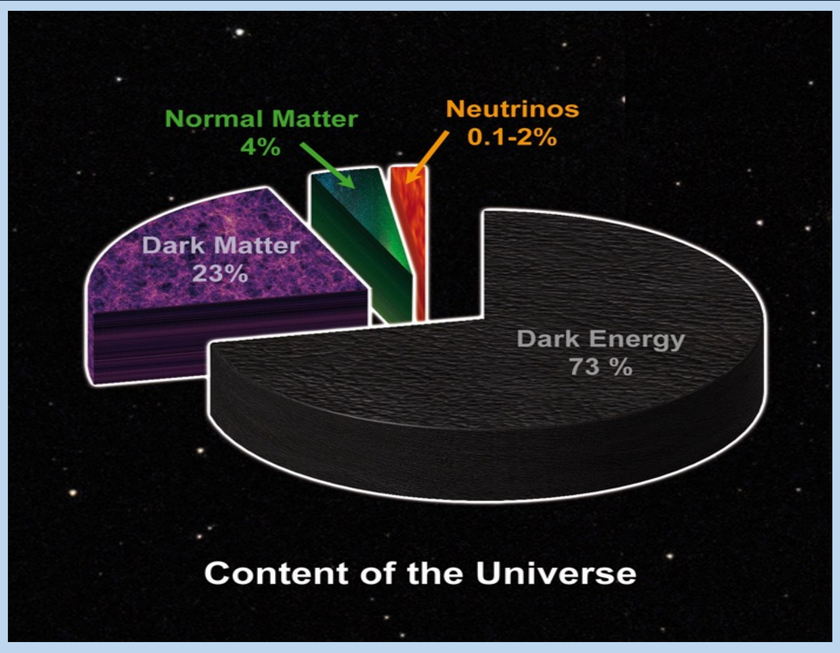
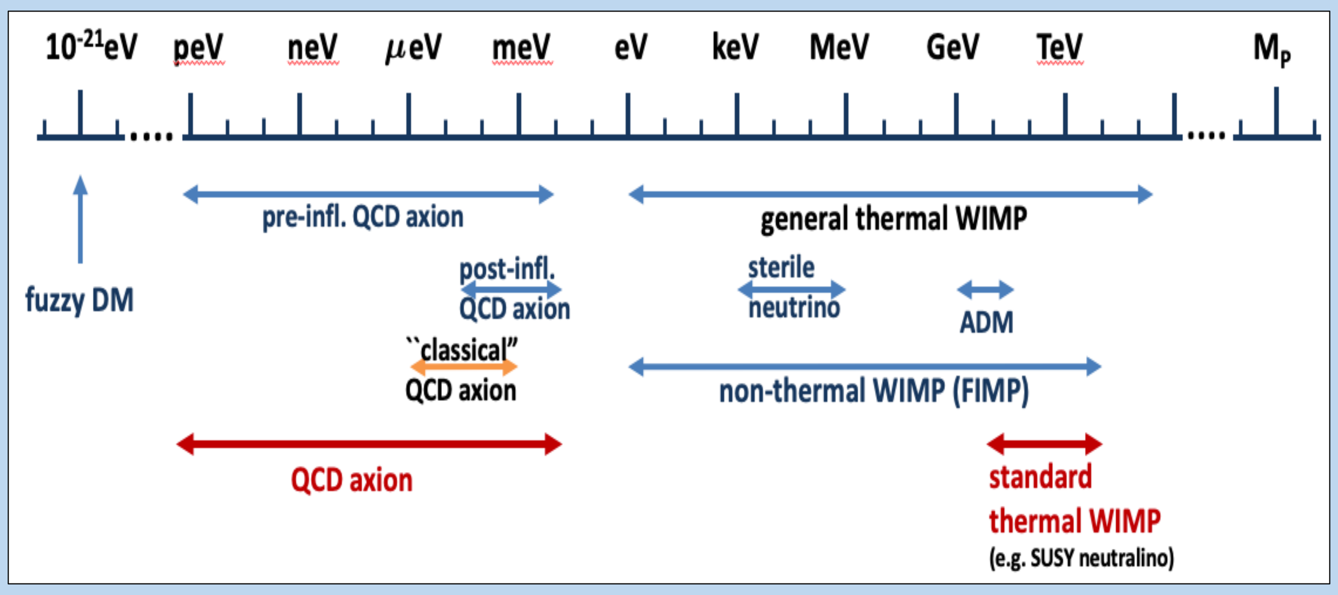
SuperWIMP Dark Matter

Motivation

- Observational evidence suggests 23% of *matter content in the Universe is invisible*
- There are a ***multitude of Dark Matter candidates*** and production ways

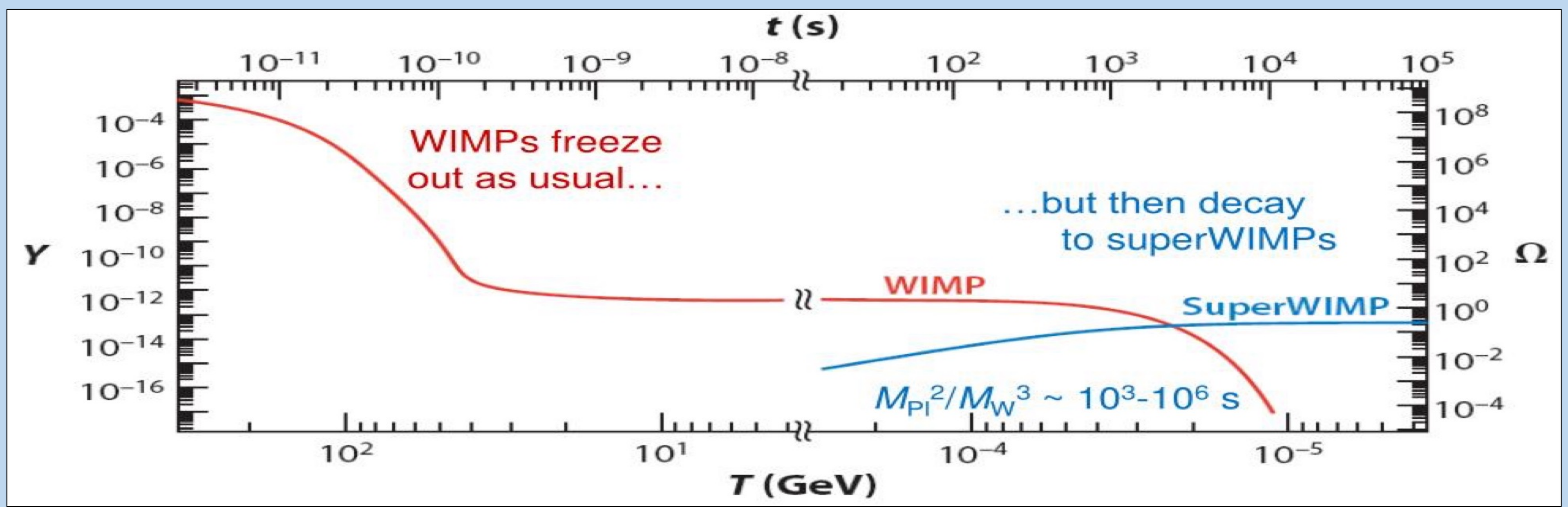


❑ **Weakly Interacting Massive Particles** (*WIMPs*): well-motivated candidates to account for observed relic density with a thermal freeze-out process

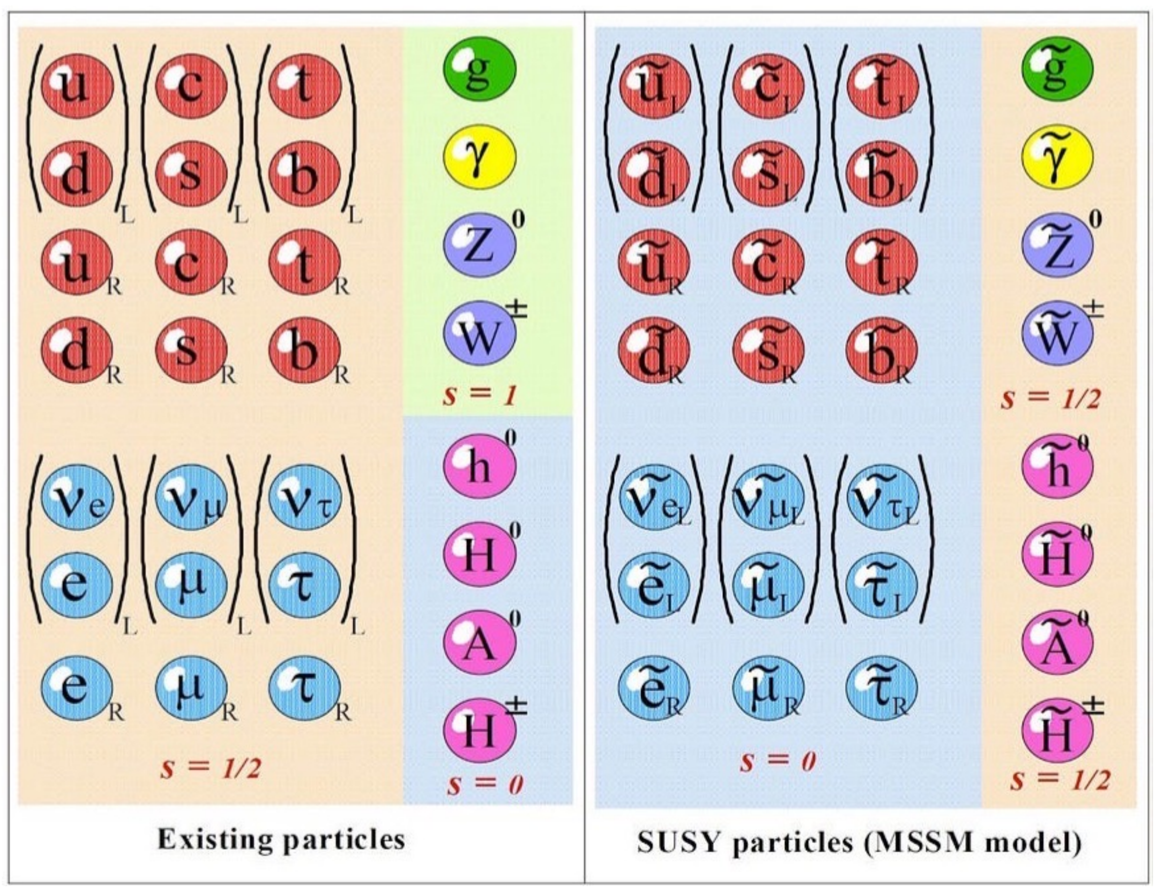


SuperWIMPs:

- product of *decay of frozen-out WIMPs* (if they are not the lightest particles)
- characterized by *extremely weak interactions* and tiny couplings



Mechanism and Candidates in Supersymmetry



❑ **Neutralinos**: gauge eigen-states of the neutral gaugino sector

- lightest stable particle (LSP) in SUSY, but not in SuperGravity scenarios
- with right annihilation, can freeze-out and account for all dark matter in the Universe
- can be next-to-LSP and decay late to lighter states with long lifetimes

➡ Within Supersymmetry (SUSY), *two well-motivated SWIMP candidates:*

❑ **Gravitinos**: Super Partner of the Graviton

- can be also produced in early universe through thermal scattering

$$\Gamma(\chi_1^0 \to \tilde{G}\gamma) = \frac{m_{\chi_1^0}^5 \cos^2\theta_W}{48\pi m_{Pl}^2 m_{\tilde{G}}^2}\left(1-\frac{m_{\tilde{G}}^2}{m_{\chi_1^0}^2}\right)^3\left(1+3\frac{m_{\tilde{G}}^2}{m_{\chi_1^0}^2}\right)$$

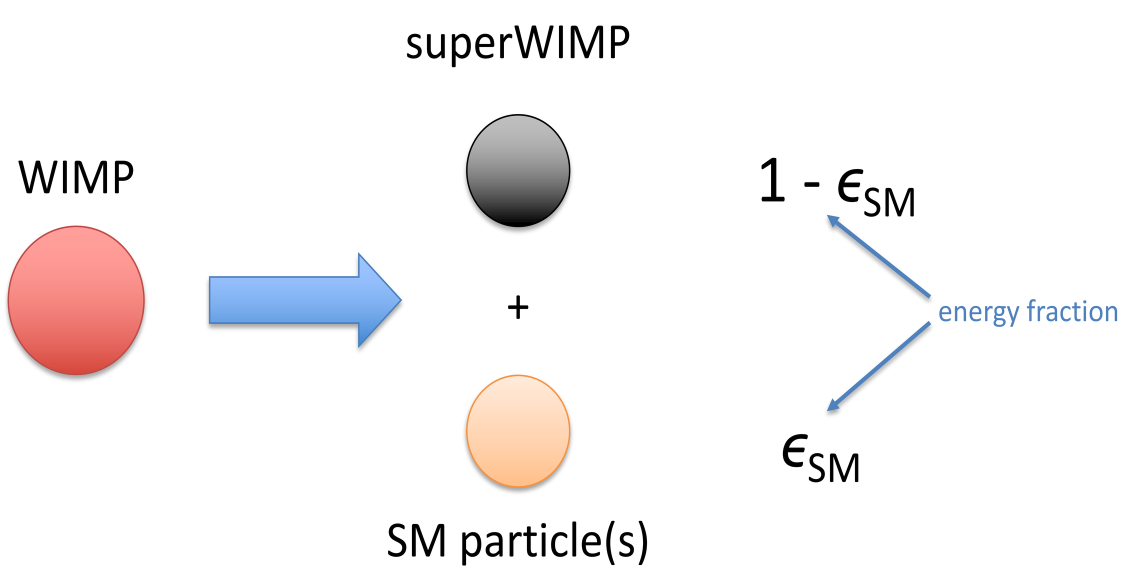
$$L = c\tau \simeq 1.4\times 10^{22}\ \mathrm{m}\ \frac{1-2\epsilon_{em}}{\epsilon_{em}^3(2-3\epsilon_{em})}\left(\frac{\mathrm{GeV}}{m_{\chi_1^0}}\right) \qquad \epsilon_{em} \equiv \frac{E_\gamma}{m_{\chi_1^0}} = \frac{m_{\chi_1^0}^2 - m_{\tilde{G}}^2}{2m_{\chi_1^0}^2}$$

❑ **Axinos**: Super Partner of the Axion

$$\Gamma\left(\chi_1^0 \to \tilde{a}\gamma\right) = \left(\frac{\alpha^2}{4\pi}\right) C_{aYY}^2 \frac{m_{\chi_1^0}^3}{4\pi^2 f_a'^2 \cos^2\theta_W}\epsilon_{em}^3$$

$$L = c\tau \simeq 14.15\ \mathrm{m}\ \epsilon_{em}^{-3}\left(\frac{f_a'}{10^8\ \mathrm{GeV}}\right)^2\left(\frac{100\ \mathrm{GeV}}{\mathrm{m}_{\chi_1^0}}\right)^3$$

Cosmological Constraints on the SuperWIMP parameter space



❑ **Big Bang Nucleosynthesis:** 1. Photo-dissociation of Nuclei due to energy injection.
2. Changes of primordial abundances of H, He-3, He-4

❑ **CMB Spectral Distortion:** 1. Energy injection between $10^6 - 10^{13}$ s
2. The blackbody spectrum is distorted.

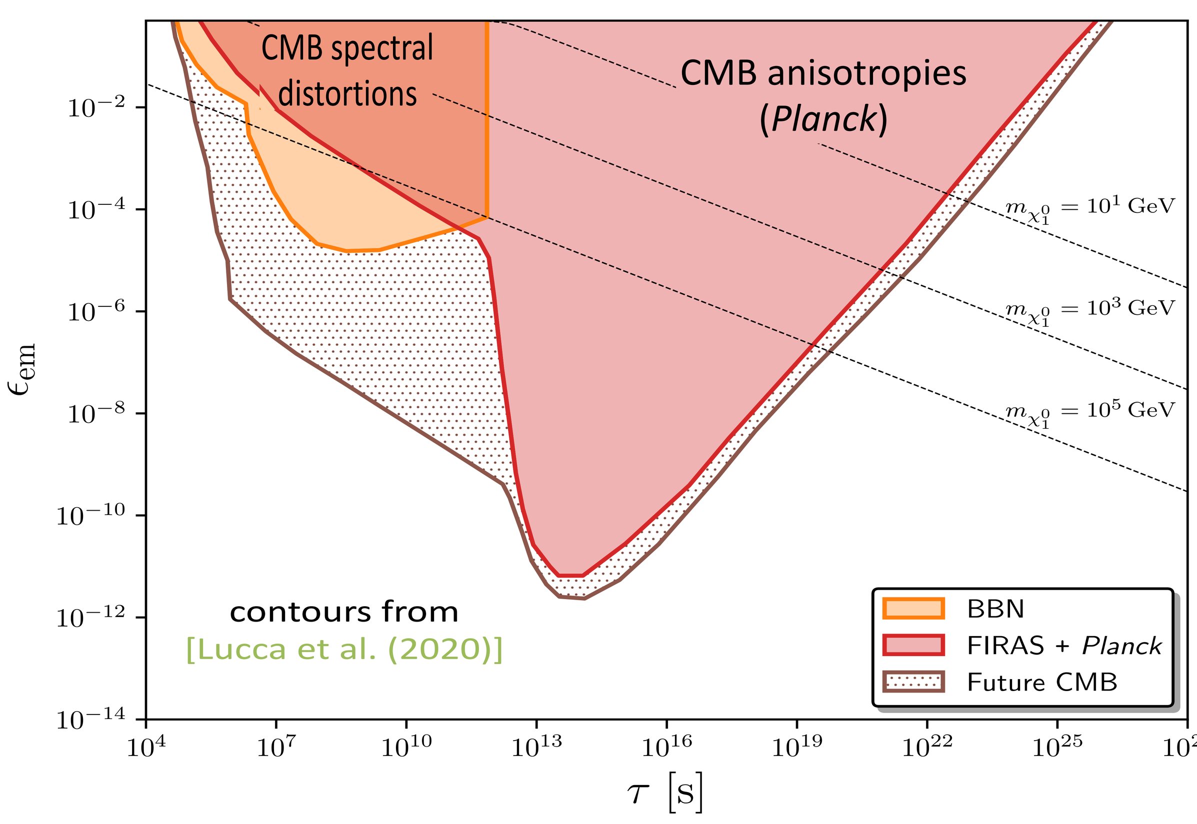
❑ **CMB Anisotropies:** 1. Energy injections for lifetimes > 10^{13} s affect temperature and polarization
2. Ionizes neutral hydrogen.
3. Increases free electron fraction
4. Changes acoustic peak patterns in the CMB angular spectrum.

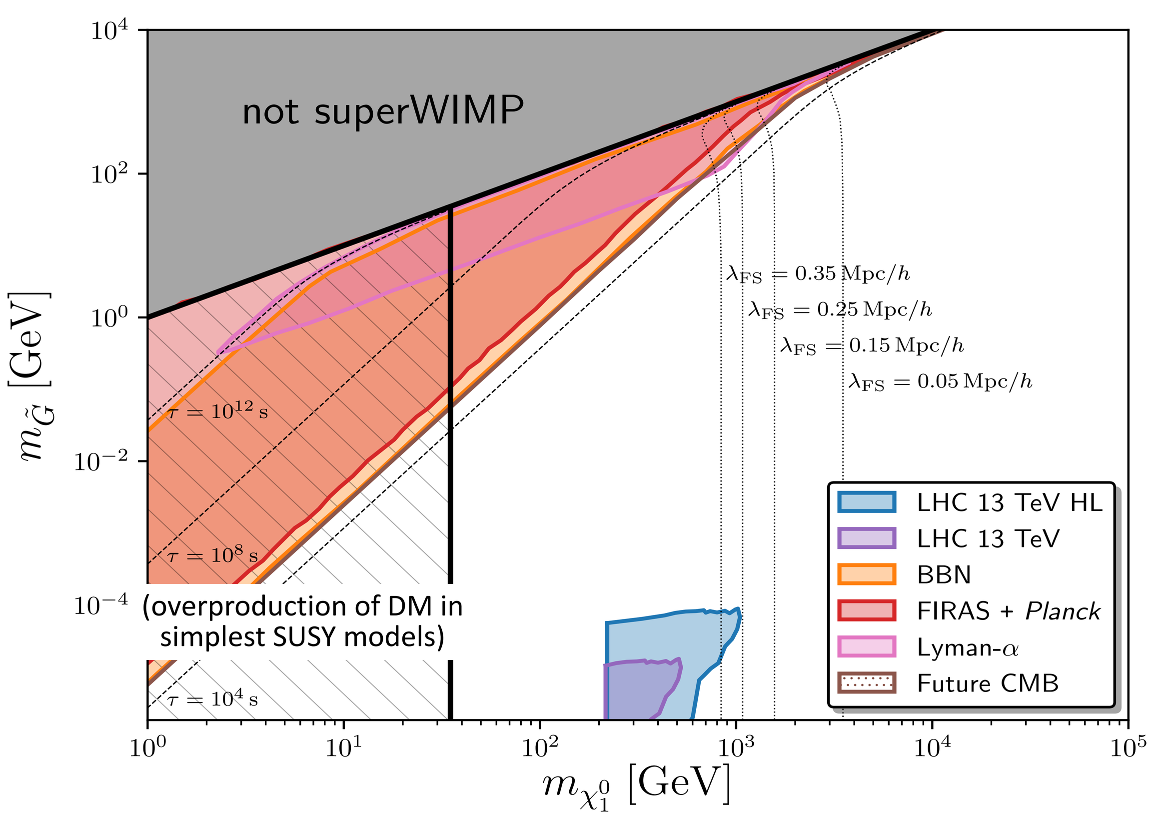
❑ **Lyman-alpha forest:** 1. Quasar spectra show Ly-a spectrum along the line of sight.
2. Probe of small-scale fluctuations
3. SuperWIMPS with non-zero velocity dispersion, suppression of power spectrum.

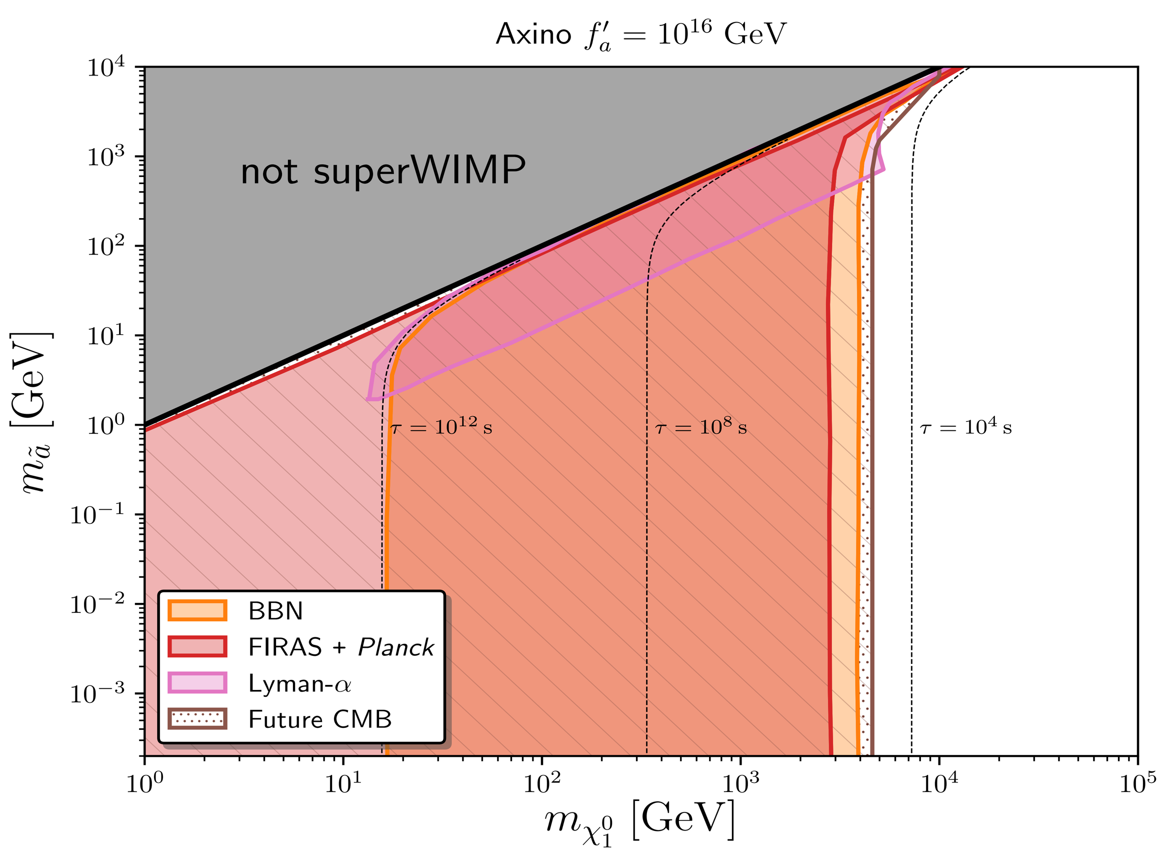
❑ **Relic Abundance:** 1. Collider limits force neutralinos to masses above 34 GeV to satisfy relic abundance.
2. s-wave annihilation with perturbative couplings limit it to below 100 TeV.

❑ **Collider Constraints:** Long-lived particle searches at the LHC and fixed target experiments.

Results







❑ Gravitino SuperWIMPS are extremely constrained from Cosmology $0.8 \lesssim m_{\tilde{G}}/\mathrm{GeV} \lesssim 99.998$ for neutralino masses of 100 GeV

❑ Axinos with decay constants ~ $f_a = 10^{14}$ GeV or above also have very strong constraints $m_{\chi_1^0} = 2.7$ TeV $: 0 \lesssim m_{\tilde{a}}/\mathrm{GeV} \lesssim 2699.990$ $f_a' = 10^{16}$ GeV

❑ Collider constraints are sub-dominant and model dependent

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