Probing Asymmetric Dark Matter with the CMB

AsymDM (coming soon…)

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The University of Manchester

Asymmetric Dark Matter (ADM)

Setting the scene…

What is ADM?

- WIMP Dark Matter (DM) candidate → $\eta = Y_X - Y_{\overline{X}}$

Motivation

- Baryonic matter asymmetry → DM asymmetry?

Why use the CMB?

- Indirect probe → DM annihilation → $X + \overline{X} \rightarrow \gamma + \gamma$
- CMB anisotropies are very ‘responsive’ to a source of energy injection
- Energy injection → Energy deposition → Modifies ionization history → CMB anisotropies
- CMB anisotropies are measured to extremely high precision → Constrain DM annihilation

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How is the CMB used to constrain DM annihilation?

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- CMB anisotropies are measured to extremely high precision → Constrain DM annihilation

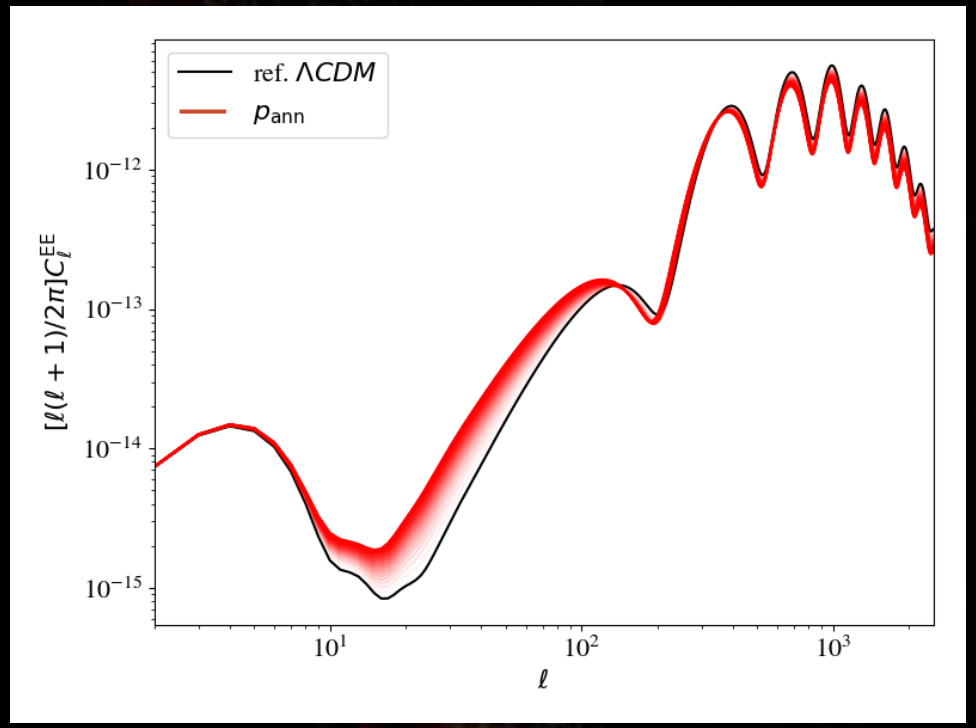
Annihilation Parameter, $p_{\rm ann}$ *(Planck TT+TE+EE+lensing)*

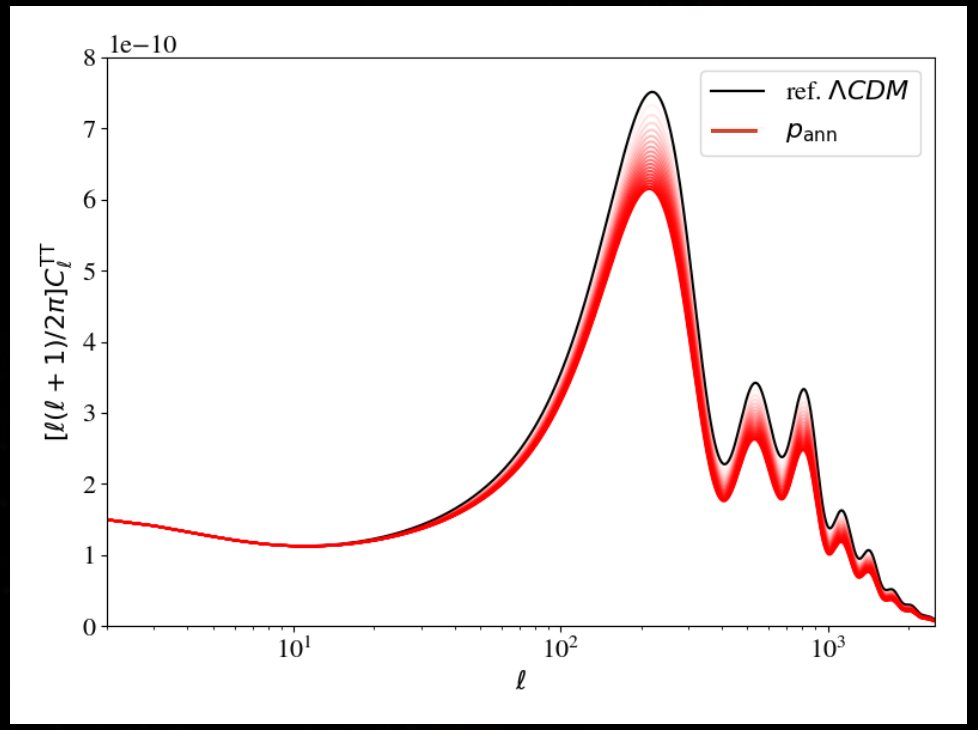
What is $p_{\rm ann}$?

- Defines the particle dependant terms in energy deposition equations from DM annihilation

$$\frac{\mathrm{d}E_d}{\mathrm{d}z} = f_{\rm eff}\frac{\mathrm{d}E}{\mathrm{d}z} = \frac{1}{2} f_{\rm eff}\frac{\langle\sigma v\rangle^{\rm CMB}}{M_X}\Omega_X\Omega_{\overline{X}}\rho_c^2(1+z)^6 \qquad p_{\rm ann} \equiv f_{\rm eff}\frac{\langle\sigma v\rangle^{\rm CMB}}{M_X}$$

- DM annihilation → Change in Polarization (EE) and (TT) CMB anisotropies from LCDM





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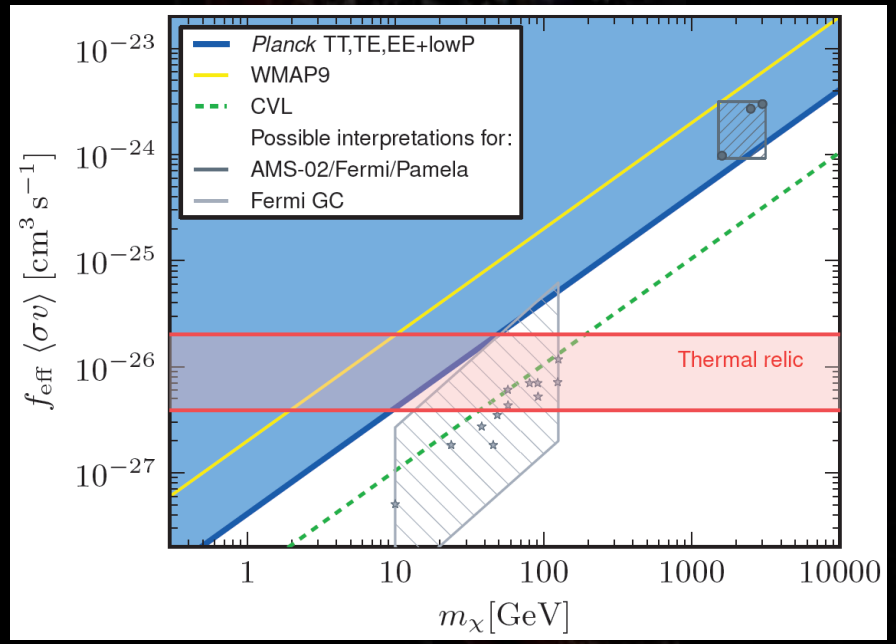
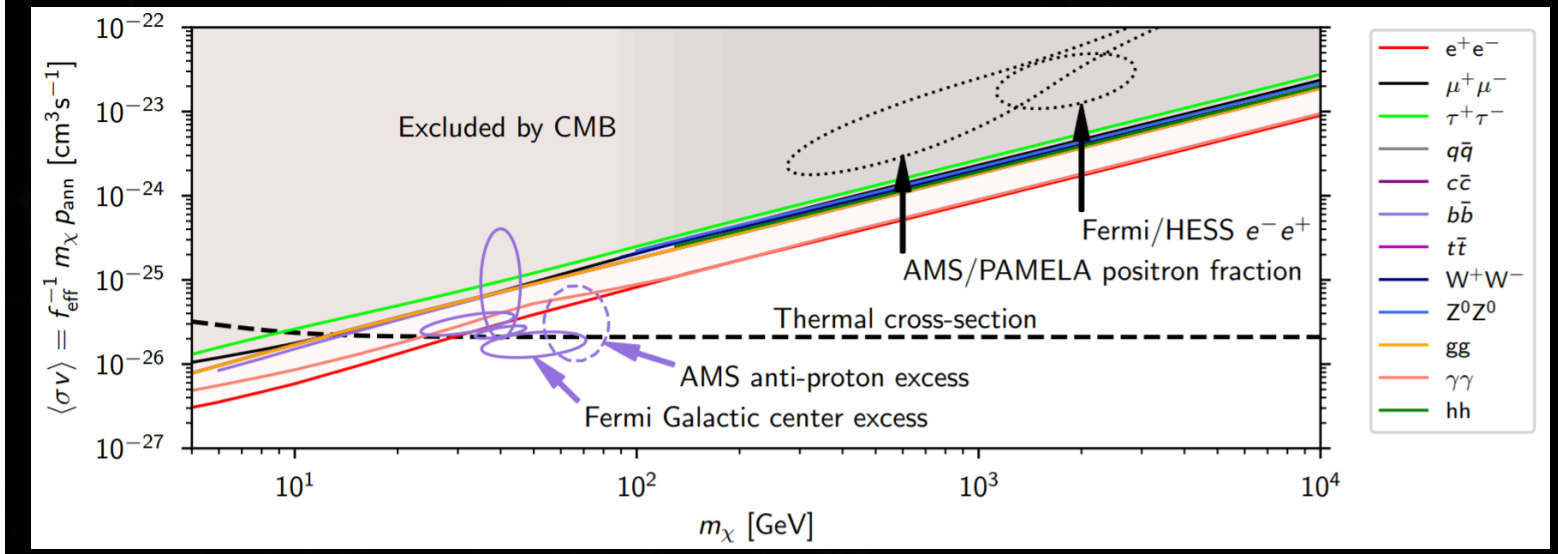
Current constraints

- WIMP DM annihilation with zero asymmetry

  (See Planck Collaboration 2015, Planck Collaboration 2018, Steigman et. al, 2015)

$$p^{\rm Pl}_{\rm ann} = \frac{f_{\rm eff}\langle\sigma v\rangle^{\rm CMB}_{\rm planck}}{M_X} < 3.2\times10^{-28}\frac{\rm cm^3}{\rm s}\rm GeV^{-1}$$





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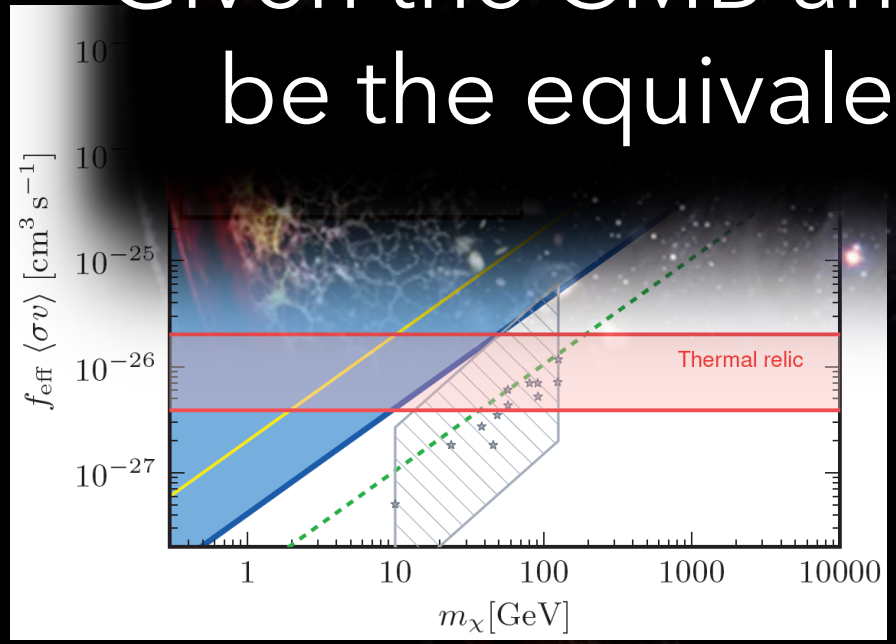
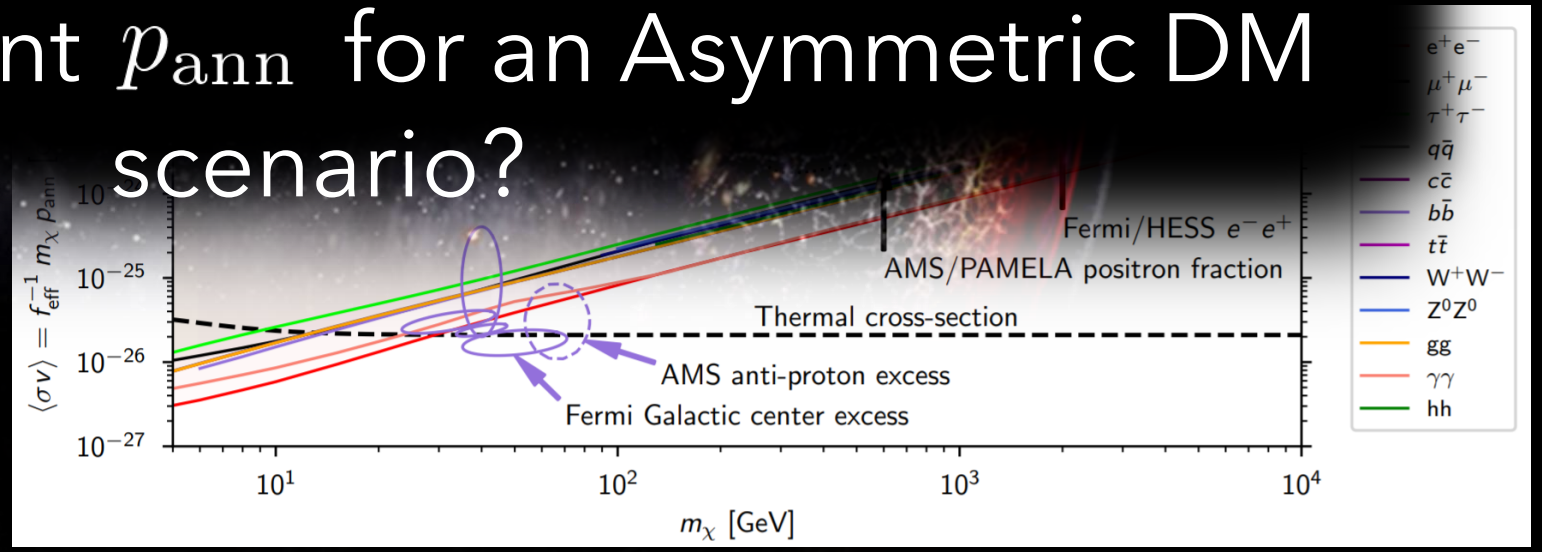
$$\mathrm{cm}^3\,\mathrm{GeV}^{-1}$$

(Se[illegible]

Given the CMB anisotropies we detect, what would be the equivalent $p_{\rm ann}$ for an Asymmetric DM scenario?





Updated Planck Constraints

Methodology (very briefly!) NEW code AsymDM

1. DM evolution equations
2. Freezeout yield of DM
3. Cross-section from Relic Abundance

$$\Omega_{\rm DM}h^2 = 0.1200 \pm 0.0012 \ (Planck)$$

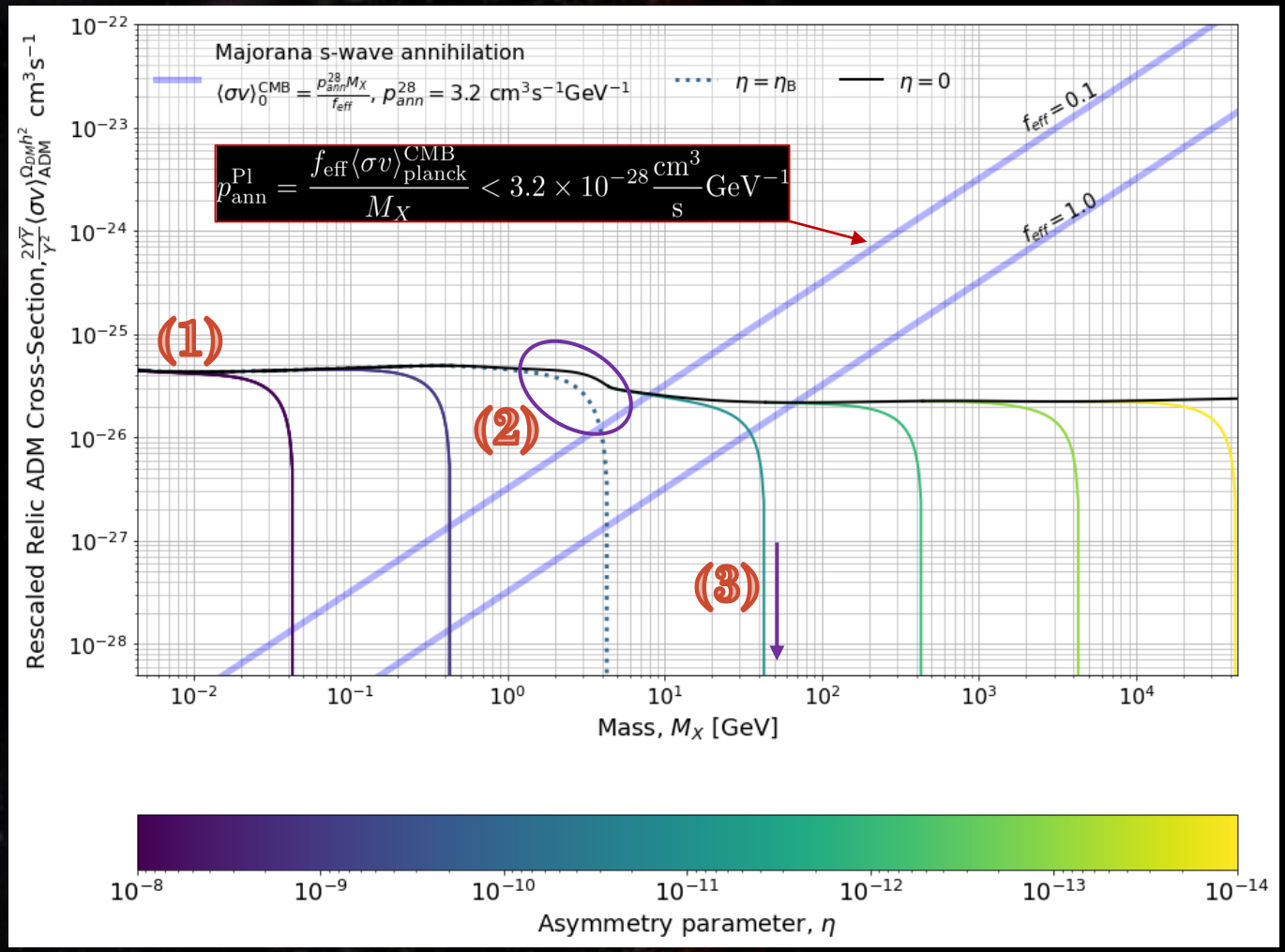
$$Y_\infty = 4.38 \times 10^{-10} \left[\frac{\Omega_{\rm DM}h^2}{0.12}\right] \left[\frac{s_0}{2891.24\ {\rm cm}^3}\right] \left[\frac{\rm GeV}{M_X}\right]$$

4. Effective cross-sections

$$2\frac{Y_\infty \overline{Y}_\infty}{Y_\infty^2}\langle\sigma v\rangle_{\rm ADM}^{\Omega_{\rm DM}h^2} < \langle\sigma v\rangle_{\rm planck}^{\rm CMB}$$

5. ADM parameter space
6. Scaling function for energy injection

$$\eta = Y_X - Y_{\overline{X}}$$



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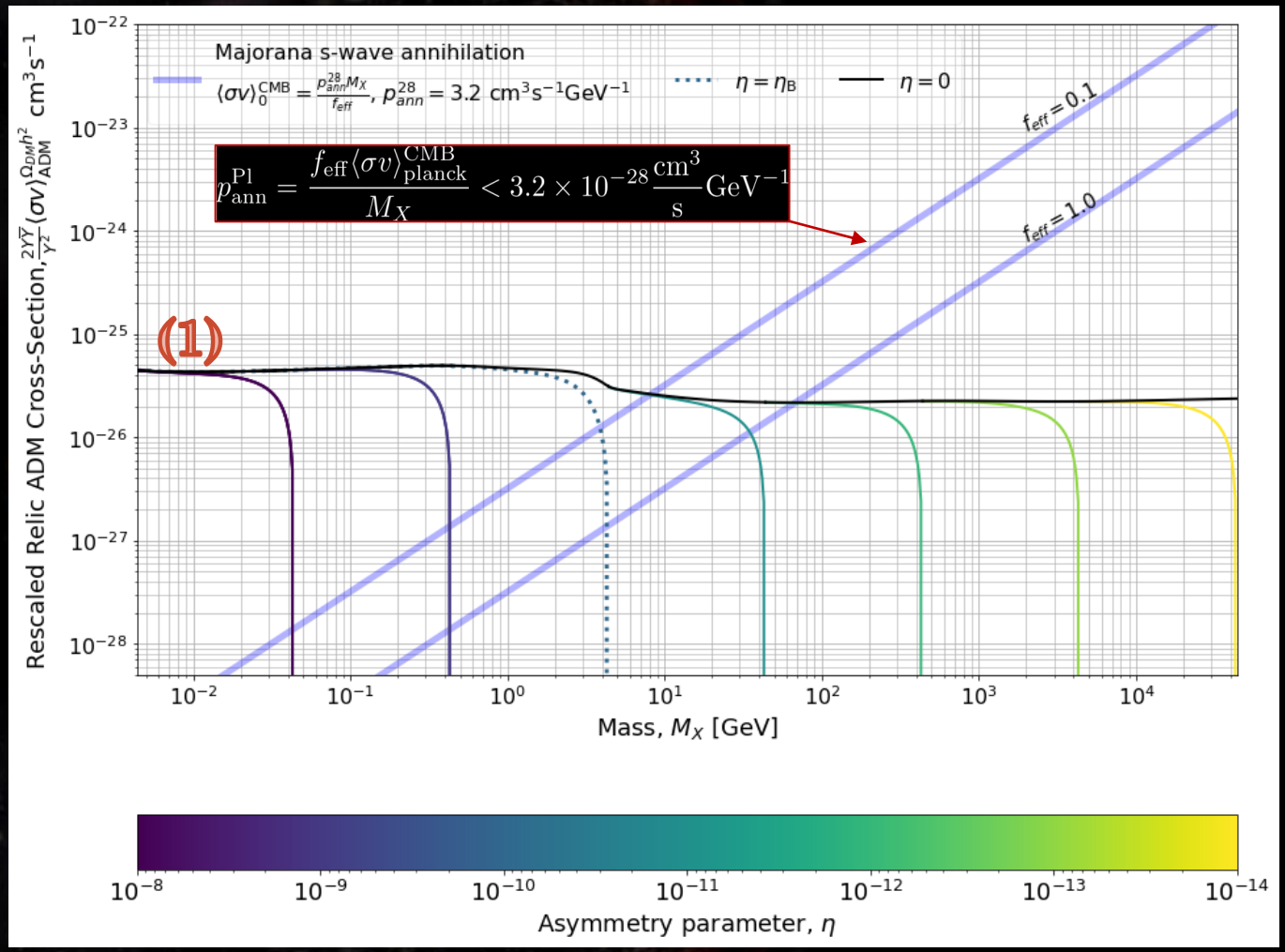

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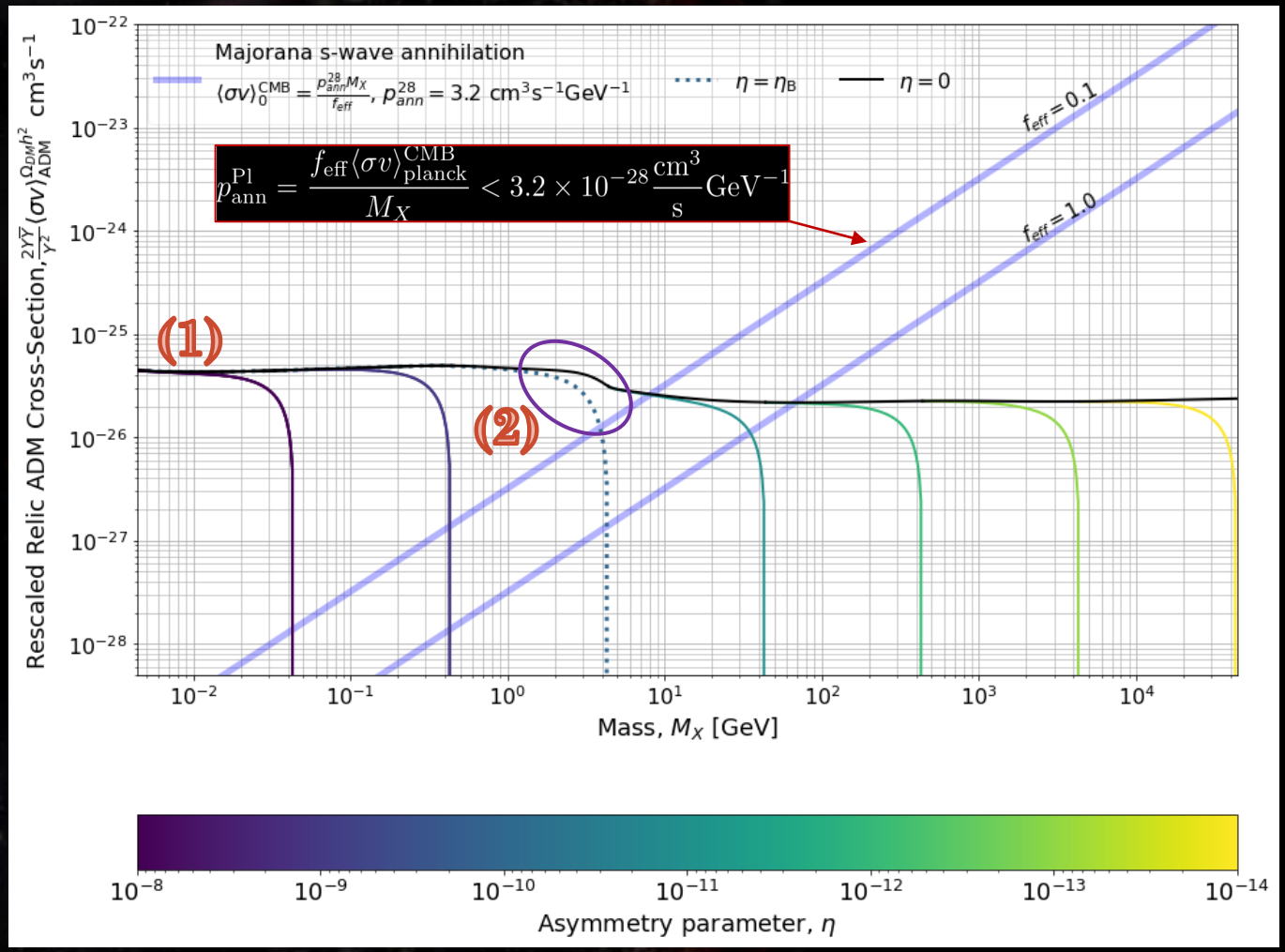

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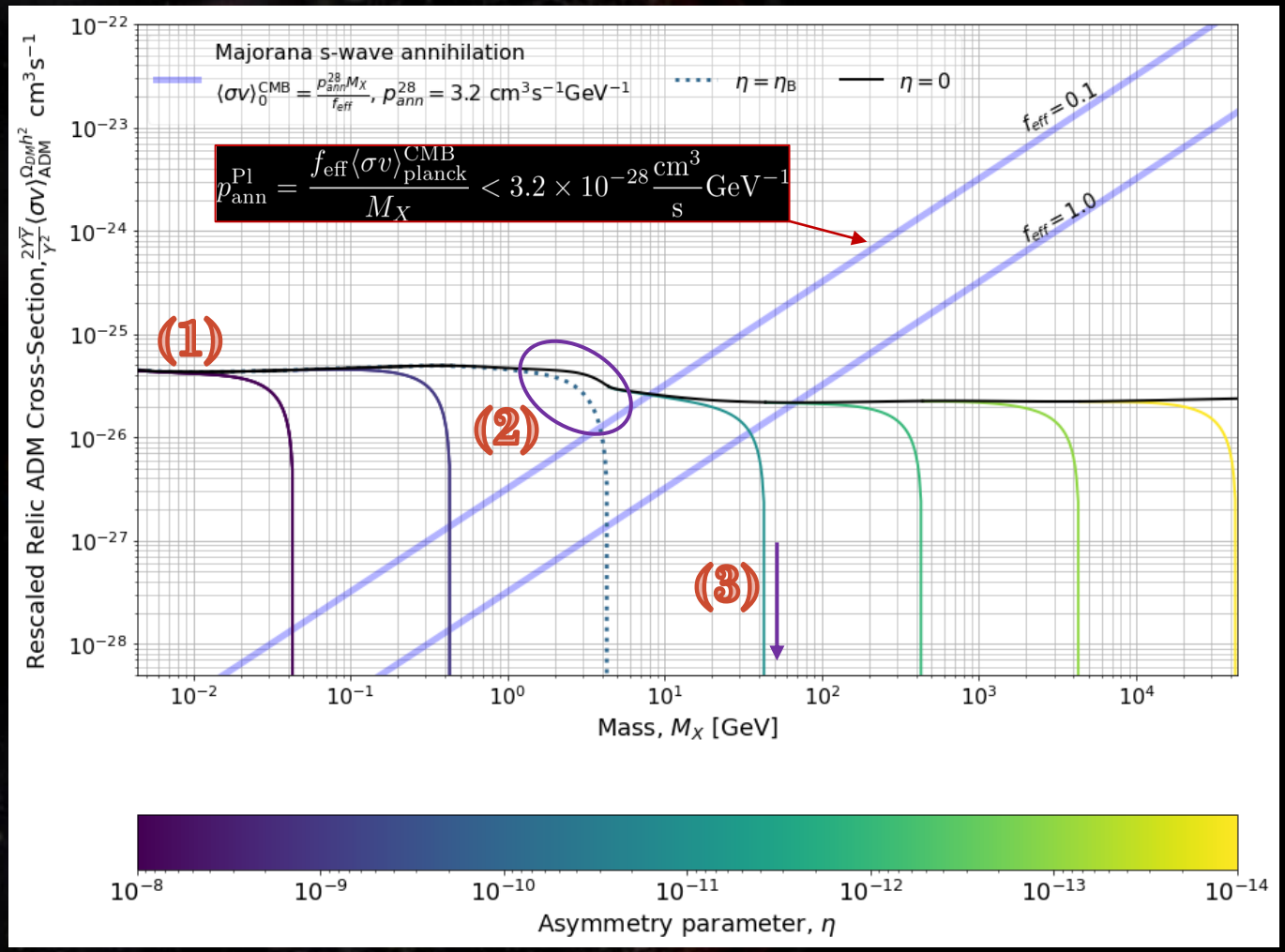

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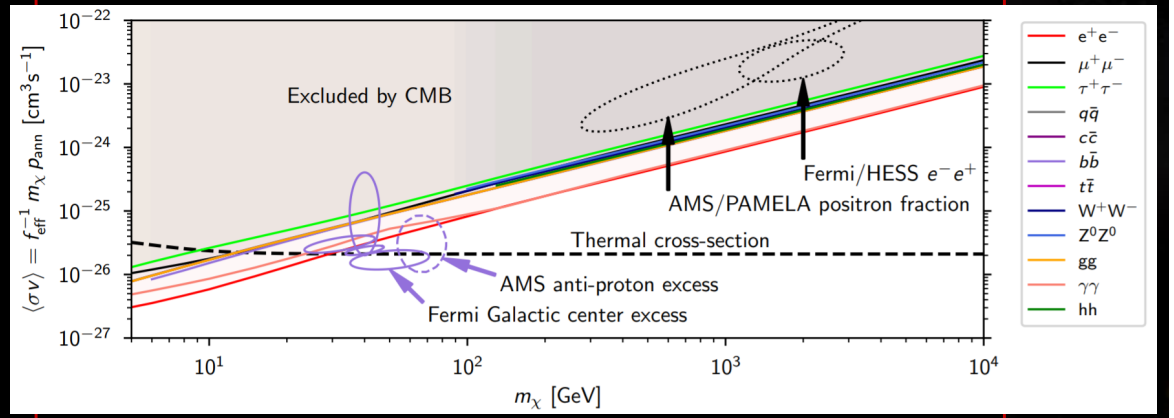

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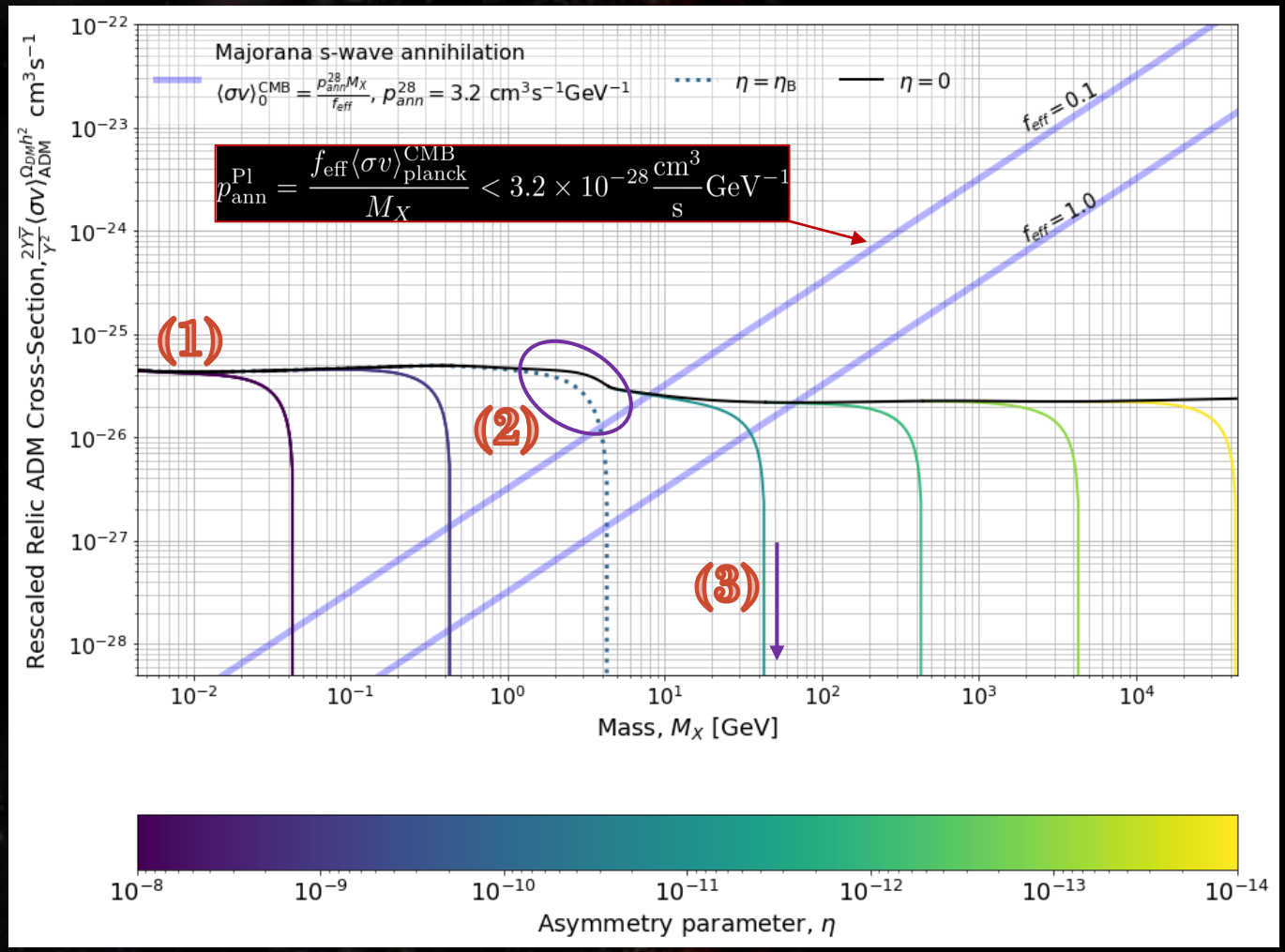

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Conclusions *To be continued…*

- Summarised the CMB as an in-direct probe of DM
- Update CMB constraints → ADM scenario → $p_{\rm ann}(\langle\sigma v\rangle, M_X) \to p_{\rm ann}^{\rm ADM}(\langle\sigma v\rangle, M_X, \eta, \Omega_{\rm DM}h^2)$
- Push CMB bounds to lower masses → New parameter space (η, M_X) → Critical parameters
- Reproduce results for $\eta = 0$

Future Work

- Spectral Distortion constraints

$$\mu = 1.401 \int_0^\infty \frac{\dot{Q}}{(1+z)\mathcal{H}} \frac{\mathrm{d}z}{\rho_\gamma} \mathcal{J}_\mu(z) \qquad y = \frac{1}{4} \int_0^\infty \frac{\dot{Q}}{(1+z)\mathcal{H}} \frac{\mathrm{d}z}{\rho_\gamma} \mathcal{J}_y(z)$$

- Release AsymDM to GitHub → Apply and replicate our results!

Thank you for listening

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