Contribution of Dark Matter annihilations to the low-redshift metagalactic ionization rate

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Overview

1. Introduction
2. Connection between Lyman-α forest and DM annihilation
3. Non-thermal p-wave annihilation

Cookbook for discovering DM

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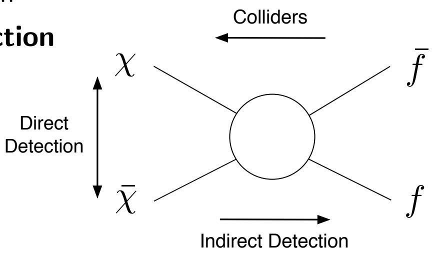

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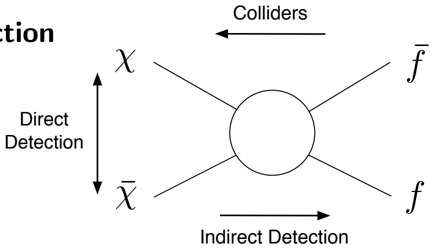

This talk will be about an indirect^2 detection method.

[2] No, it is not a footnote. I really mean squared.

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- ✓ Looking forward to 21-cm cosmology ($50 \lesssim z \lesssim 200$) and CMB spectral distortions ($10^3 \lesssim z \lesssim 10^5$)!
- ✓ At the low-redshift end, Lyman-α forest has dirty astrophysics. But the background characterization is improving (Haardt & Madau, 2012).

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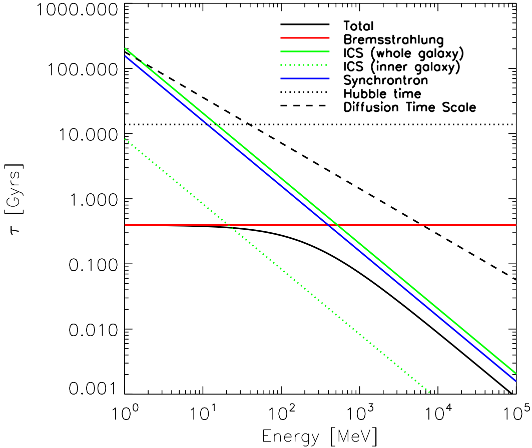

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- ✓ Resulting UV and X-ray photons can potentially contribute to the ionization state of the IGM.

Injection spectrum

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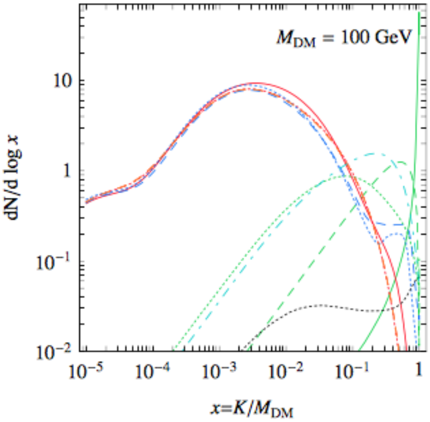
e^-/e^+ multiplicity (green) peaks at $\sim 0.01 M_\chi$ in hadronic annihilations channels and $\sim 0.1 M_\chi$ in leptonic channels (Cirelli et al. 2012).



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✓ DM annihilation emissivity is given by,

$$j(\vec{r}, z, E_e) \equiv E_e^2 \frac{\mathrm{d}N}{\mathrm{d}V\,\mathrm{d}t\,\mathrm{d}E_e}(\vec{r}, z, E_e) = \times E_e^2 \frac{\mathrm{d}N_{ann}}{\mathrm{d}E_e} \times \langle \sigma v \rangle_{\vec{v}} \times n^2(\vec{r}, z)$$

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✓ After DM particles start clustering the spatially averaged signal is averaged over a collection of halos,

$$\langle j(z, E_e) \rangle_{\vec{r}} \approx \langle j \rangle_{\mathrm{halos}}(z, E_e) = \int \mathrm{d}M \, \frac{\mathrm{d}N}{\mathrm{d}M} \int_{V_{vir}} \mathrm{d}^3\vec{r}\, j(r, z, E_e).$$

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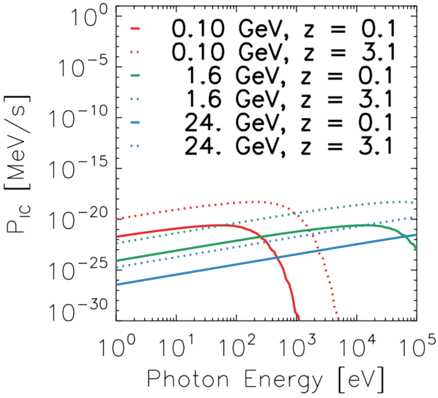

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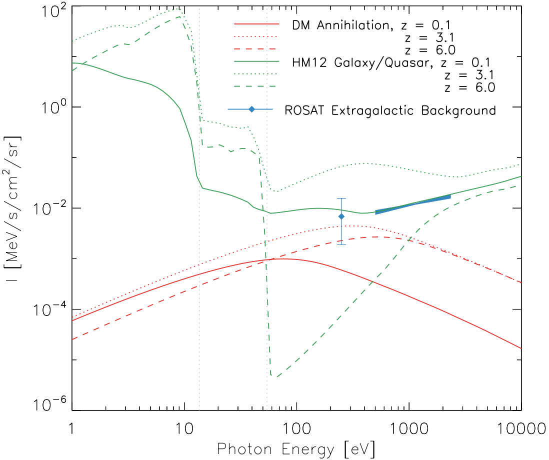

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- ✓ The mass of the WIMP should be low ($M_\chi \approx 10 - 100$ GeV).
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- ✓ Change the production history of the WIMP?

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- ✓ Similarly gamma-rays from stacked dwarf galaxies constrain thermal production to $M_\chi \gtrsim 100$ GeV (Fermi-LAT and DES collaborations, 2015).

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- ✓ However boosting the s-wave annihilation cross section violates the constraints!

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- ✓ Given the DM velocity variance during the freeze-out, $\langle v_f^2 \rangle \approx 0.1$, and the observed velocity variance in galaxy clusters, $\langle v_c^2 \rangle \approx \times 10^{-5}$, a p-wave velocity suppression of 10^{-4} is more than compensated by a non-thermal production boost of $T_f / T_r \sim 10^5$.

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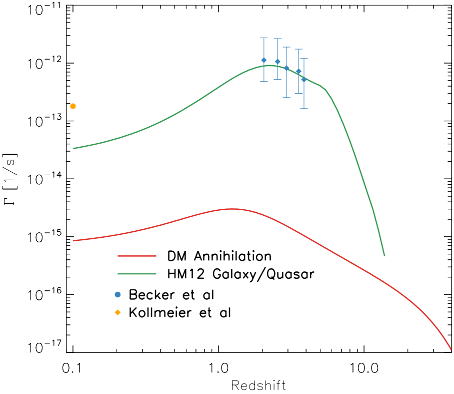

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Conclusion

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- ✓ p-wave annihilations of non-thermally produced DM can do better, avoiding CMB anisotropy constraints.
- ✓ This scenario was initially motivated by the gamma-ray excess in the inner galaxy (Goodenough and Hooper, 2009).
- ✓ However this is no longer the case if DM is non-thermally produced and is predominantly annihilating in the p-wave. (See Stephen's talk on Tuesday for the other reason.)