Impact of UV Photons from Dark Matter Annihilation on Cosmic Recombination and First Galaxies

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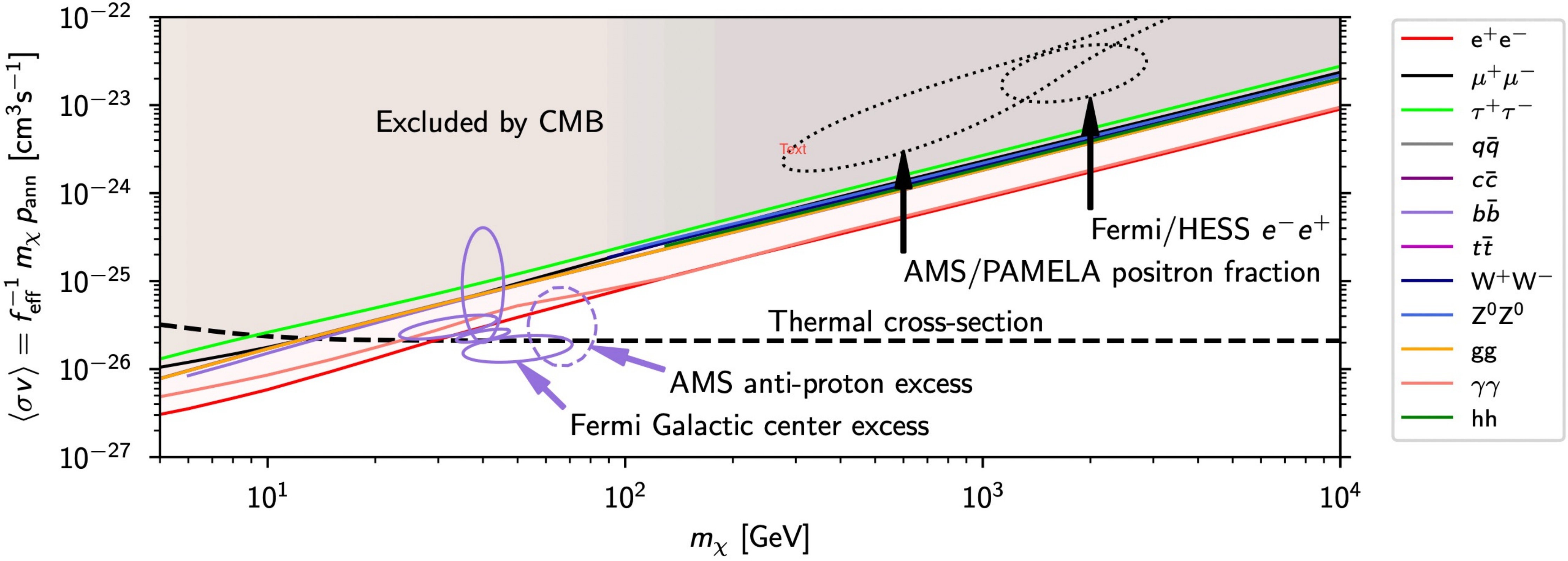
Outline

- Cosmology as a probe for particle physics
- Sensitivity of Cosmological probes to UV photons
- Dark matter model
- Recombination problem
- Results
- Future work

Cosmology as a probe for particle physics

- Cosmological probes provide powerful tools to observe impact of dark matter (DM) interactions (21 cm, CMB, BBN, Lyman-α forest etc.).
- They are sensitive to different ranges of energy/particle injection by DM annihilation at different redshifts.
- For example, Planck satellite can detect perturbations up to a sub percent level in Recombination history.



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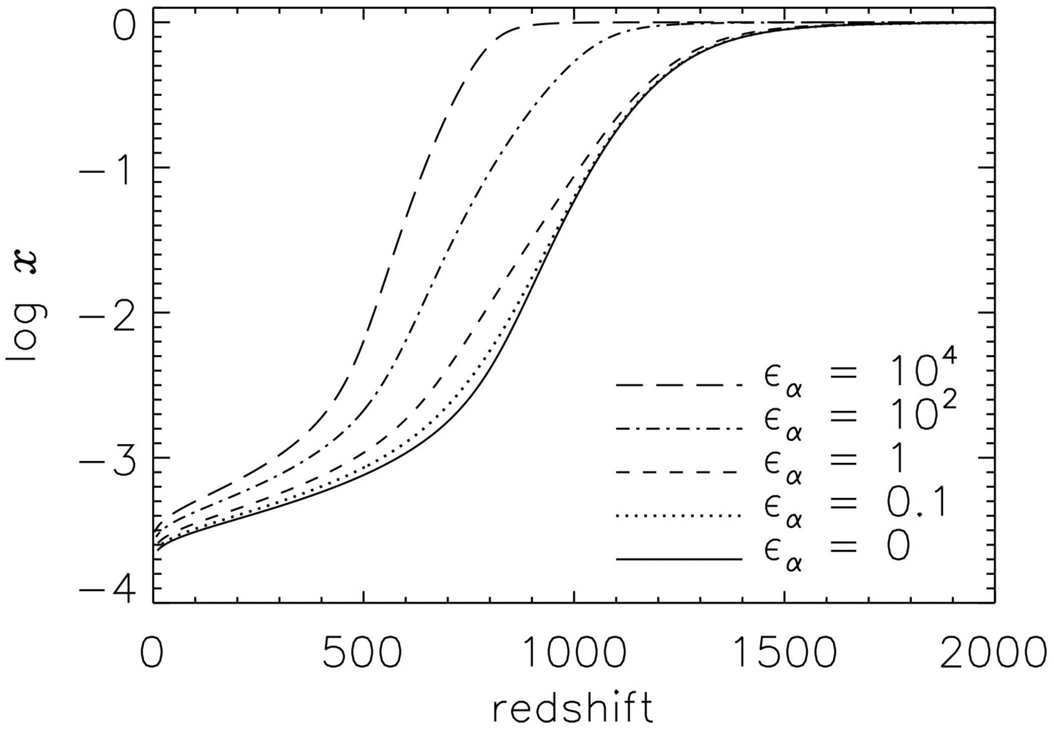
Sensitivity of Cosmological probes to UV photons

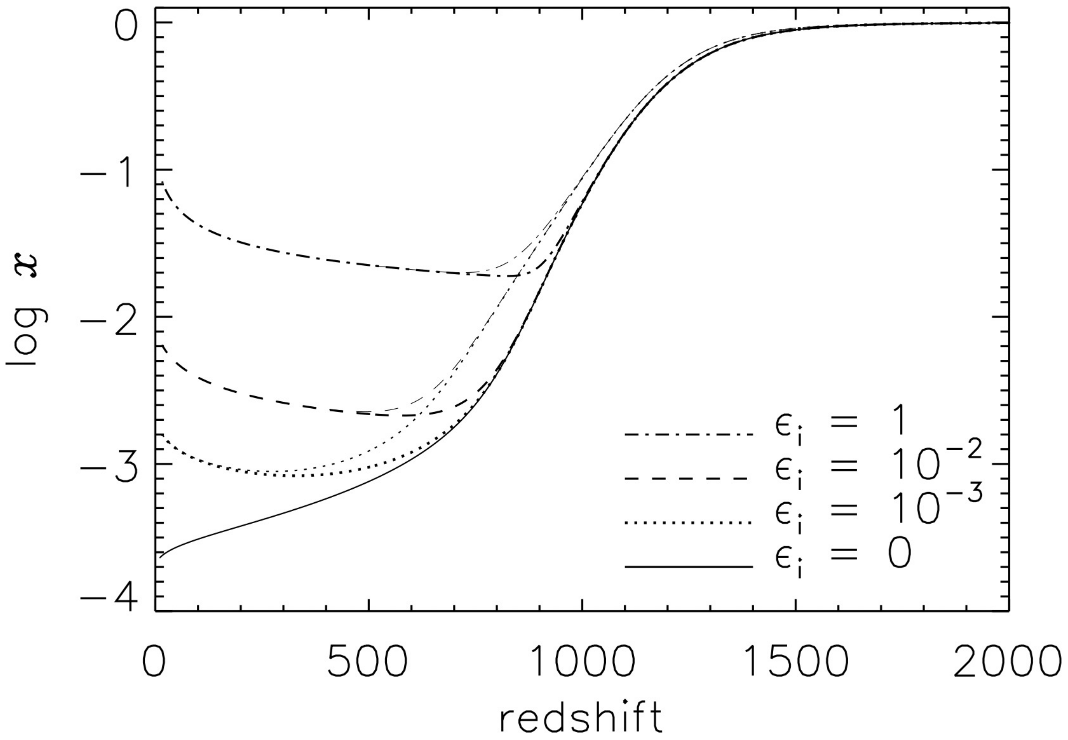
- Photons produced in the UV, ~ O(10 eV), have some of the strongest consequences on cosmological history as they:
  - Readily ionize atoms
  - Dissociate molecular structure
  - Excite atomic lines
- Presence of additional UV photons can show up in 21 cm, Lyman-α forest, CMB data, and structure of first galaxies.

Perturbations to Cosmic Recombination through addition of UV photons

Additional Lyman-α photons
(Peebles et. al. 2000)

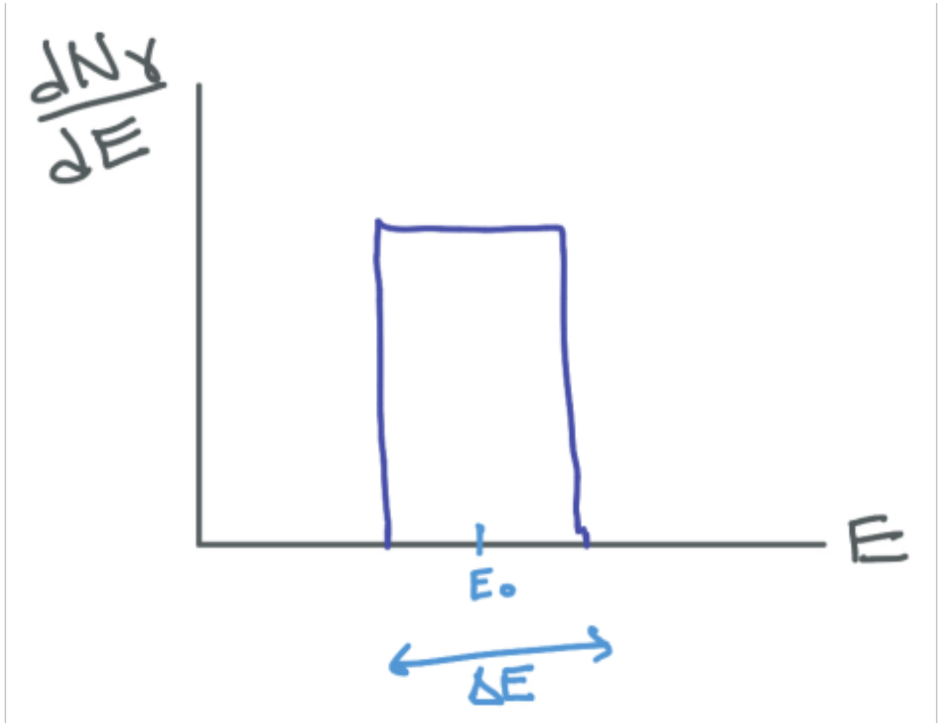


Additional H-ionizing photons
(Peebles et. al. 2000)



Dark Matter

- A large class of thermal relic DM models comprises interactions in both the hidden sector and in the standard model (SM).
- In these models, there is a segment wherein DM particles annihilate to many SM soft products.
- A good way to probe these models is to ask what if DM annihilates primarily to UV photons.



- To construct the pipeline, we start with a simple box spectrum localized around Lyman limit.
- A fiducial model with m_χ ~100 GeV and $\langle\sigma v\rangle \sim 3 \times 10^{-26}$ cm^3/s produces ~ 10^9 photons at each resonant line with each annihilation!

Recombination problem

- Cosmological Recombination then requires us to solve following set of coupled differential equations.
- Rate equation:

$$(1+z)H(z)\frac{dn_i(z)}{dz} - 3H(z)n_i(z) = n_e(z)n_c(z)P_{ci} - n_i(z)P_{ic} + \Sigma_{j=1}^{N}\Delta R_{ji}$$

- Temperature equation:

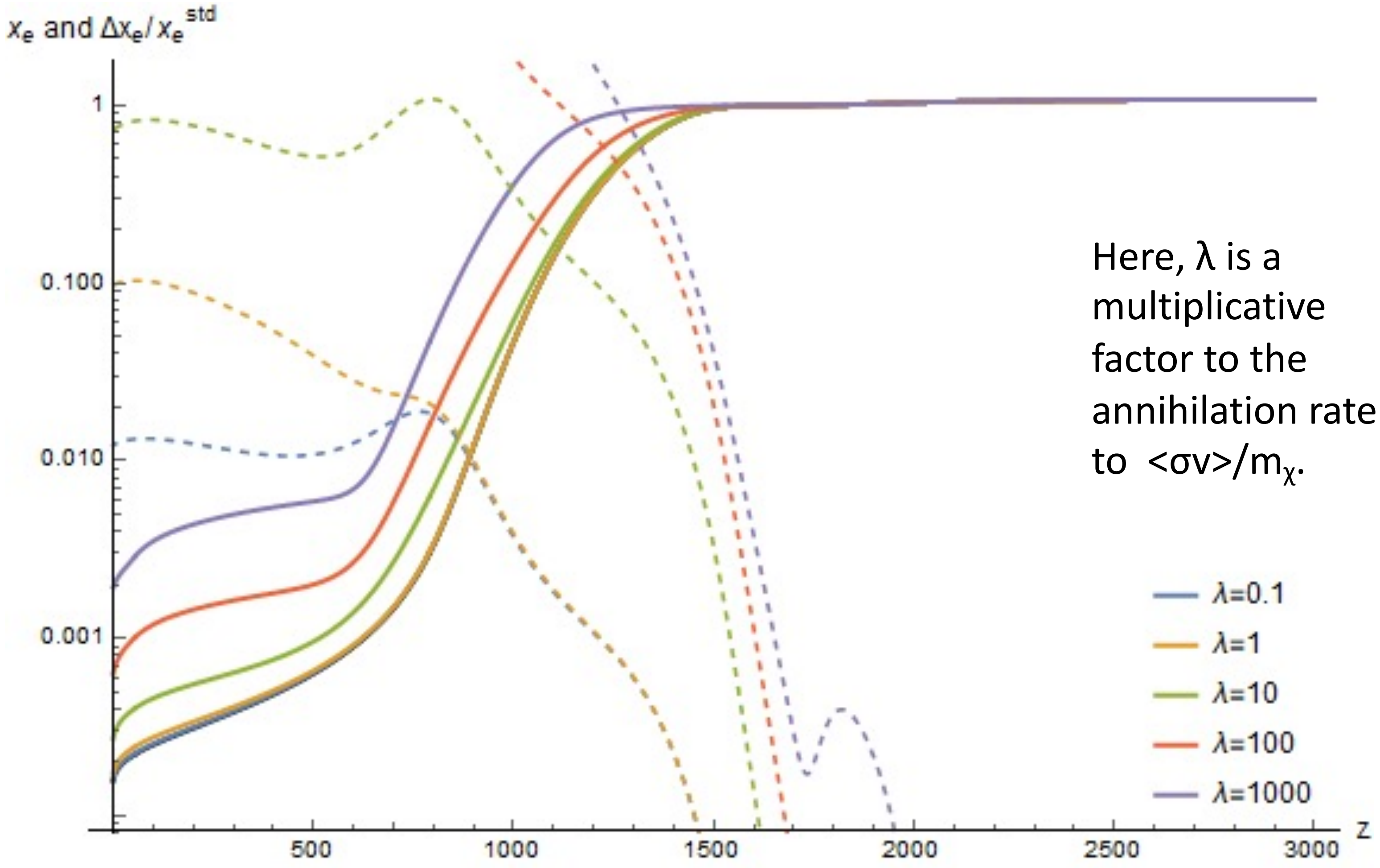
$$(1+z)H(z)\frac{dT_M}{dz} - 2H(z)T_M = \frac{8\sigma_T U(J_\nu, z)}{3m_e c}\frac{n_e}{n_e + n_H + n_{He}}(T_M - T_R) - \frac{2\{\Sigma\Lambda_{int}\}}{3k_B n_{tot}}$$

- Radiative Transfer equation:

$$(1+z)H(z)\frac{dJ(\nu,z)}{dz} - 3H(z)J(\nu,z) = \kappa(\nu,z)J(\nu,z) - j(\nu,z)$$

Results

Preliminary results. *Solid lines:* Recombination history with DM annihilation. *Dashed lines:* perturbations to cosmic recombination normalized to Planck's data



Here, λ is a multiplicative factor to the annihilation rate or to <σv>/m_χ.

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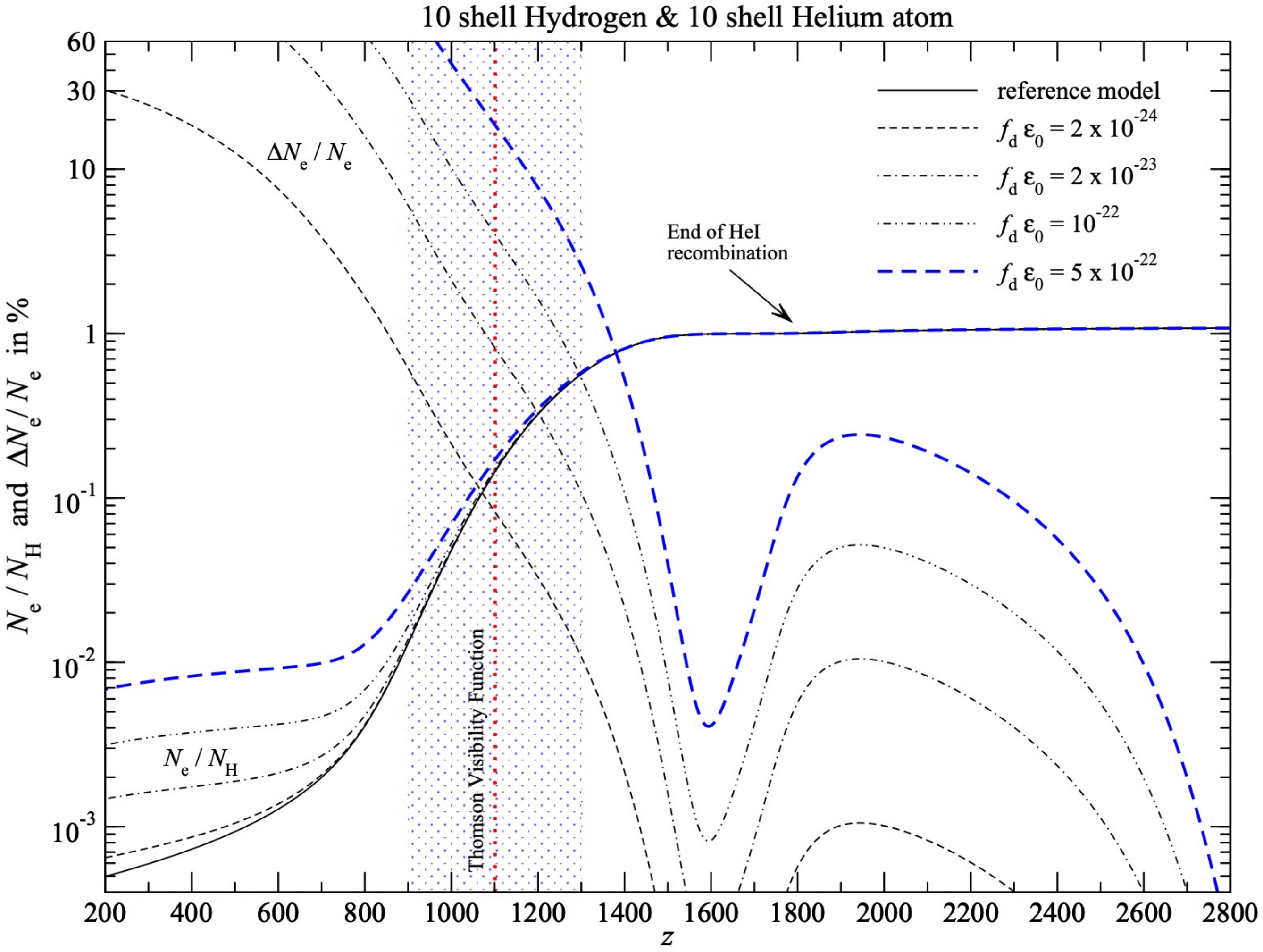
Comparison to general fitting function used for DM annihilation

(Chluba 2009)



Future Work

- UV photons can alter the spin temperature that can alter the 21 cm signal during cosmic dawn.
- ~10^6 solar mass halos around z ~ 25 are thought to be site for formation of first POP III stars in the universe.
- UV radiation may remove H_2 from these sites, a necessary coolant for star formation, and halt the process.
- Research shows that these sites void of coolant may also become seeds early supermassive blackholes.

Thank You!