Constraints from Extragalactic Background Light Models on Dark Matter Decay

Barbara Skrzypek[1], Carlos Argüelles[1], Marco Chianese[2]
[1] *Harvard University*
[2] *U. Amsterdam, GRAPPA*

Abstract

Among the questions at the center of multimessenger astronomy is the nature of dark matter. Various methods for indirect detection of dark matter have been employed, taking from phenomenological models that predict possible dark matter annihilation and decay channels into Standard Model particles. In the case of dark matter decay, measurements of gamma-rays by Fermi-LAT were combined with IceCube neutrino data to obtain constraints of dark matter mass and lifetime for various models and channels. However, tensions existing between these measurements suggest that gamma rays become heavily suppressed below energies of around 50 TeV. A reason for this could be that properties of the traversed medium, which consists of extragalactic background light (EBL), the cosmic microwave background (CMB), and the intergalactic magnetic field, significantly alter the final gamma-ray spectrum that reaches telescopes on Earth. The existence of competing models for the EBL, moreover, complicates estimates of these dark matter constraints. My research aims to address these questions and to improve measurement techniques in order to understand the impact that the EBL has on indirect measurements of dark matter decay. I present my predictions for gamma-ray spectra undergoing attenuation by different EBL models, and I show how optical depth varies across these models, as well as its dependence on injected energy and redshift.

Background

Gamma rays originating from dark matter decay can be expressed in terms of their Galactic and Extragalactic contributions:

$$\phi_\chi = \phi_G + \phi_{EG} \tag{1}$$

As these photons propagate to Earth, a portion of them scatter off of CMB and EBL photons, giving rise to attenuated spectra and secondary cascades. This effect becomes significant particularly at low energies for the Extragalactic component. The final spectrum perceived at redshift z can be written as

$$\frac{d\phi_\gamma}{dE_\gamma} = c\frac{1}{E_\gamma}\int_z^\infty dz' \frac{1}{H(z')(1+z')}\left(\frac{1+z}{1+z'}\right)^3 \times j_{EG}(E'_\gamma, z')e^{-\tau(E_\gamma,z,z')}, \tag{2}$$

where τ is the optical depth for pair production in an isotropic radiation field and j_{EG} is the emissivity, which can be separated into two components:

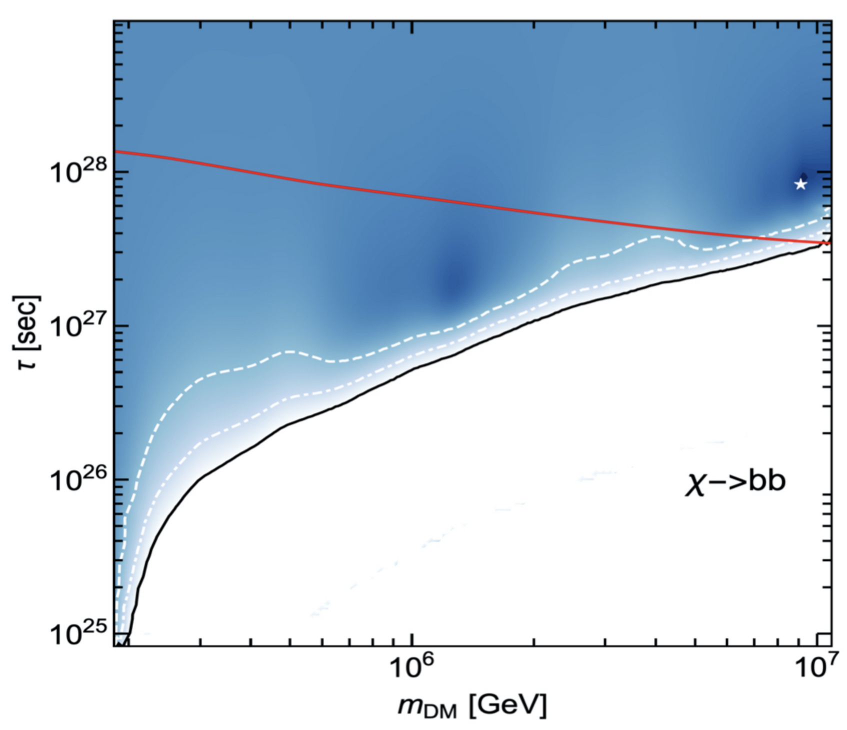
Prompt: Photons created at the source can be described using

$$j_{EG}(E'_\gamma, z') = E'_\gamma \frac{\rho_0(1+z')^3}{m_{DM}}\sum_f \Gamma_f \frac{dN^f_\gamma}{dE_\gamma}(E'_\gamma) \tag{3}$$

Secondary: Lepton pairs produced from collisions with background radiation inverse Compton Scatter (ICS) with radiation photons, producing secondary gamma rays, for which

$$j_{EG} = 2\int_{m_e}^{m_{DM}/2} dE_e \frac{\mathcal{P}_{IC}}{b_{IC}}\int_{E_e}^{m_{DM}/2} d\tilde{E}_e \times \frac{dN_e}{d\tilde{E}_e}\frac{\rho_0(1+z')^3}{m_{DM}}\sum_f \Gamma_f \tag{4}$$

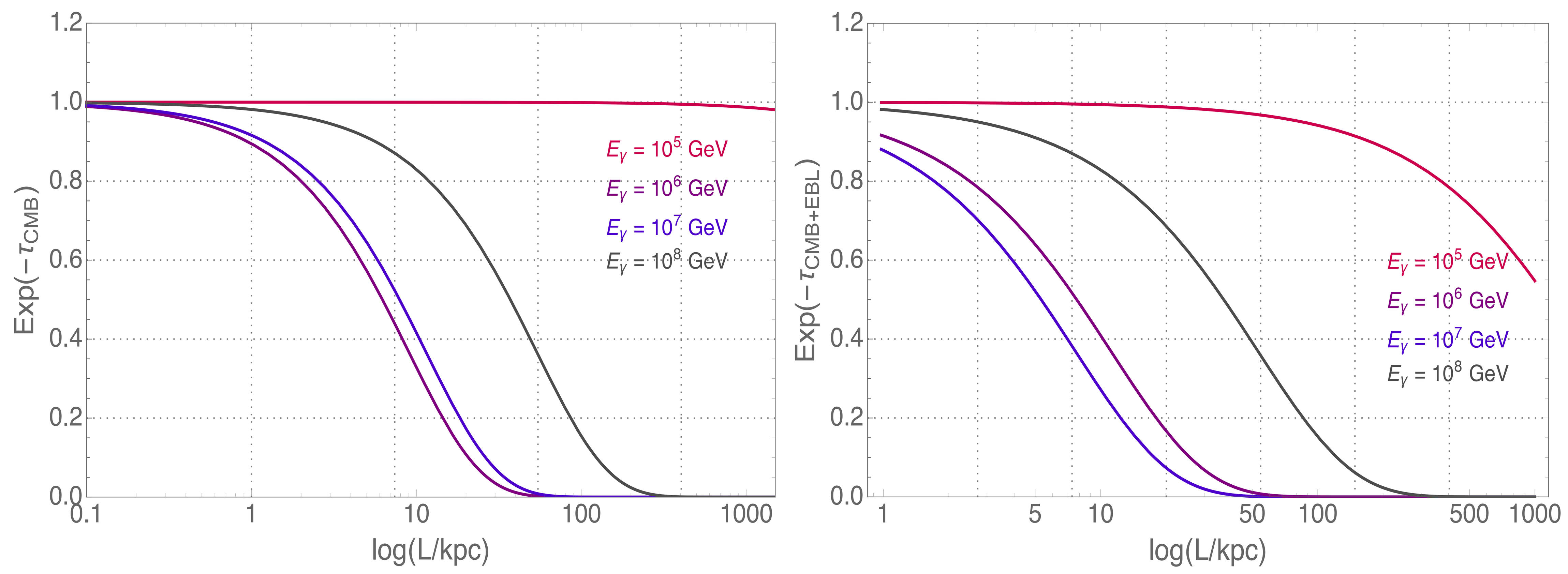
Both $\mathcal{P}_{IC}$ and b_{IC} depend on the radiation field in question and so will differ with different EBL models.



Here we show a result obtained from [1] showing exclusion regions from Fermi-LAT (red) and HESE (blue) under a two-power law assumption.

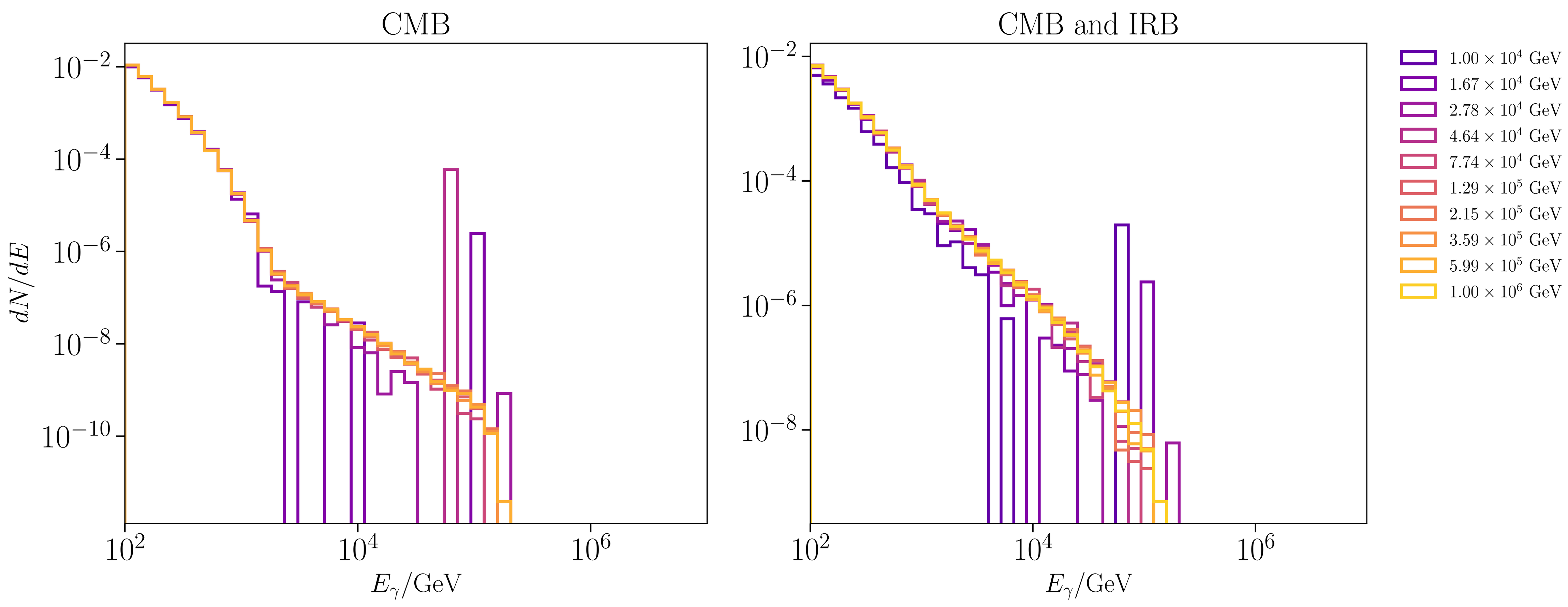
Optical Depths

Below we show CMB and EBL optical depths, where we use the EBL model from [2]:

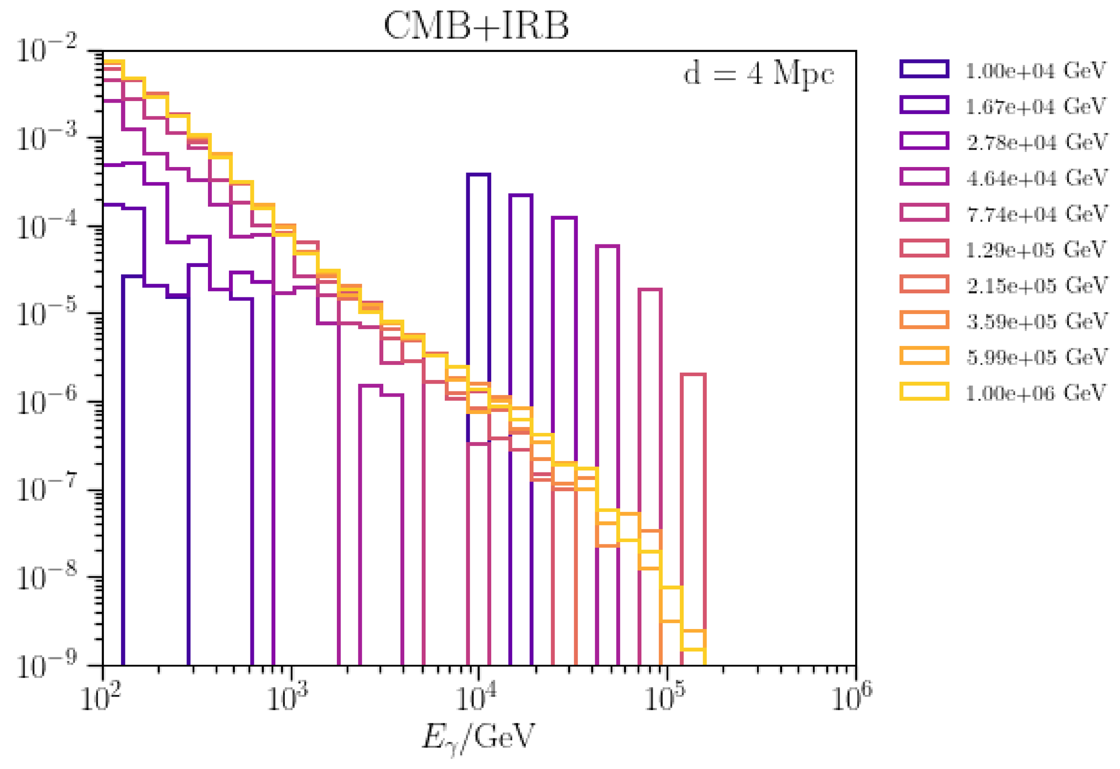


Spectra from CMB and EBL & Next Steps

We use GCascade [3] and CRPropa [4] to propagate photons and obtain final spectra for different initial energy distributions from a distance of 4 Mpc:



On the top right, we show the attenuation due to one EBL model [2], while directly to the right, we show the attenuation due to another, different EBL model [5]. Going forward, we will obtain fluxes for gamma ray spectra from decaying dark matter, propagated using different EBL models. From there, we plan to extract the uncertainty associated with EBL so that we could apply these uncertainties to current constraints on dark matter. These results, along with a paper, are in preparation.



References

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