Blazar constraints on the DM–ν cross section

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F. F., G. Herrera, & A. Ibarra, arXiv:2209.06339

DM interactions with SM particles

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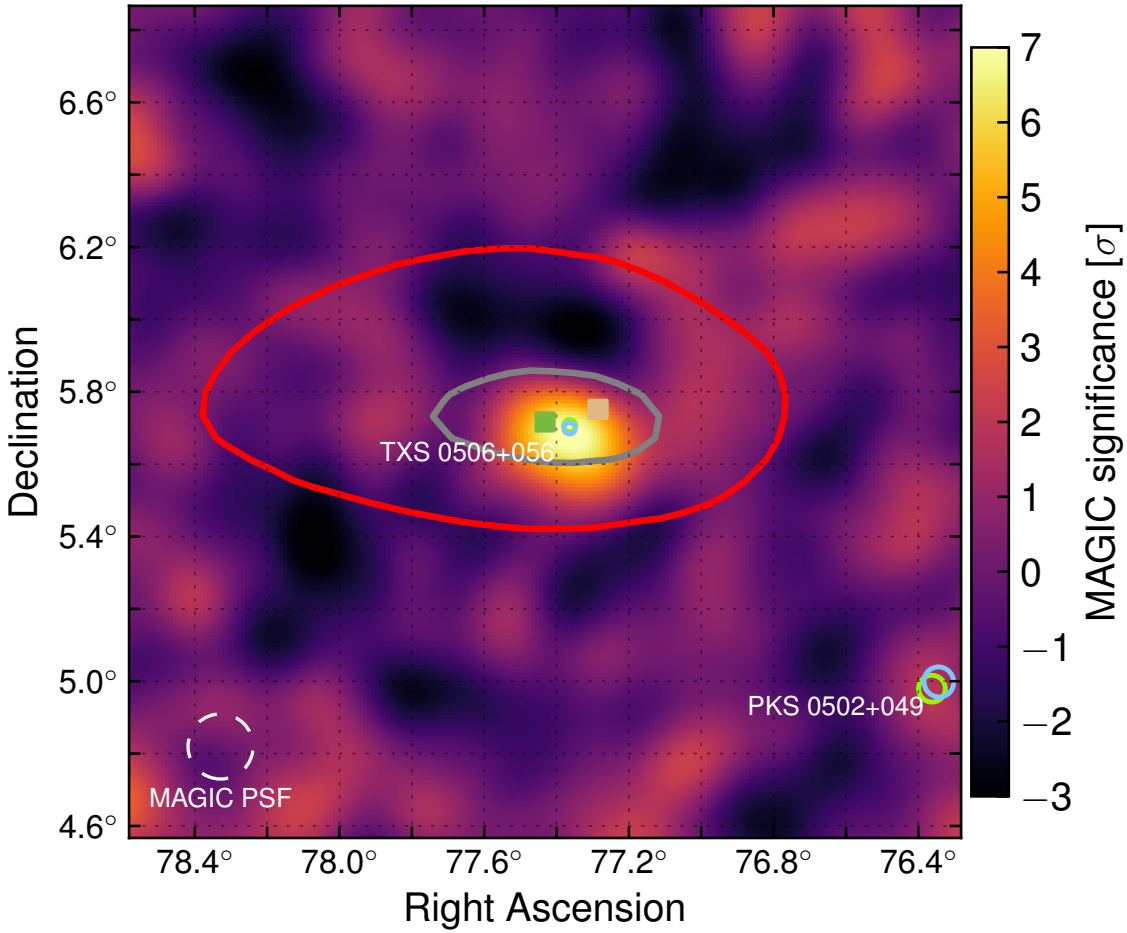
These additional couplings can be beneficial. Self interactions and/or interactions with SM particles (baryons, neutrinos) can help with:

- Cusp vs core
- Satellite problem
- Too much structure at small scales

TXS 0506+056



IceCube, Fermi-LAT, MAGIC, et al, *Science* (2018)

The first high-energy neutrino source at a distance of 1421 Mpc.

Flux attenuation

The observation of ν's from TXS 0506+056 can be used to set constraints on their interaction strength with DM particles from the requirement that the flux is not significantly attenuated due to interactions with the dark matter in the intergalactic medium and in the MW.

K-Y Choi, J Kim $ C Rott, 1903.03302; K Kelly & P Machado, 1808.02889; JBG Alvey & M Fairbairn 1902.1450; C Argüelles, A Kheirandish & AC Vincent, 1703.00451

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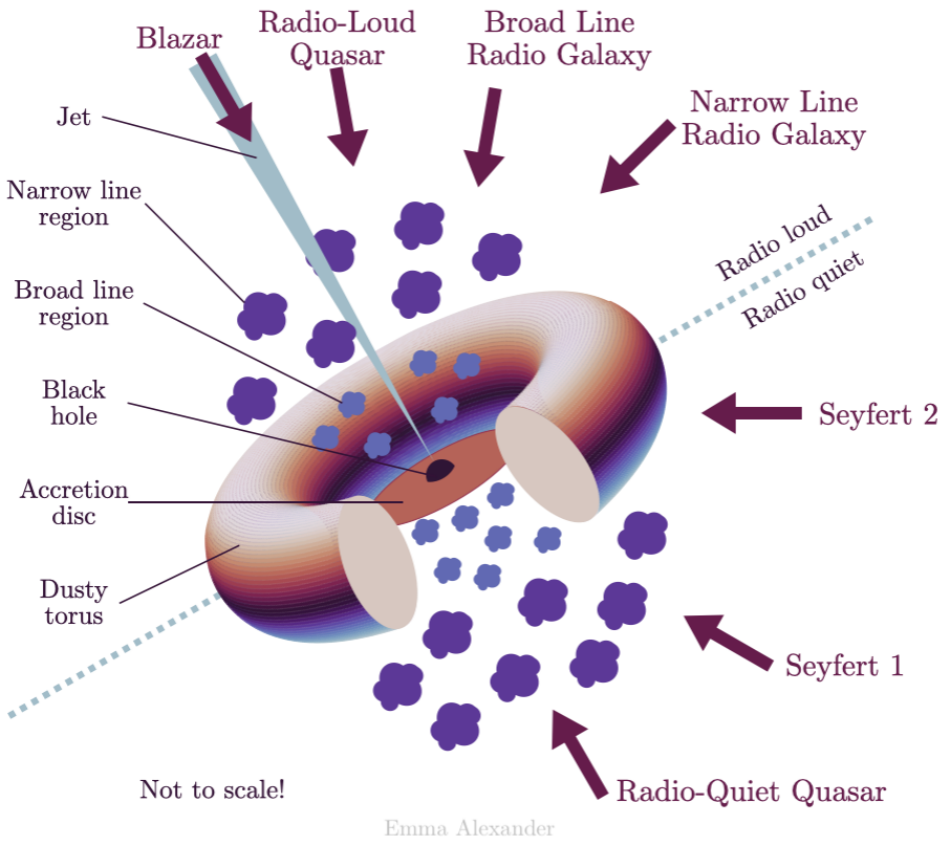
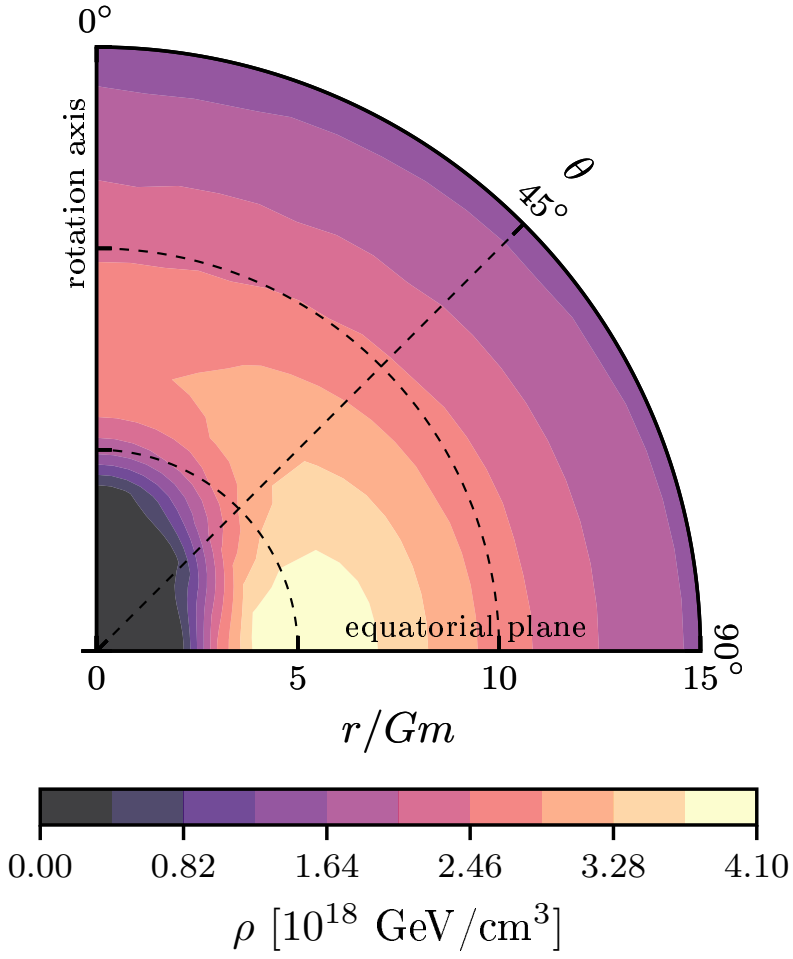
We will consider the attenuation of the neutrino flux *within* the host galaxy of TXS-506+056. Similar considerations will allow us to put bounds on the interaction strength between dark matter particles and photons. (See also J Cline et al, 2209.02713.)

The Broad Line Region



ν's and γ's are emited from $R_{\mathrm{BLR}} \sim 0.021$ pc.

DM around the supermassive BH



P Gondolo & J Silk, astro-ph/9906391; L Sadeghian, FF & C M Will, 1305.2619; FF, A Medeiros & C M Will, 1707.06302

The DM spike

The supermassive black hole at the center seeds the formation of a DM spike that extends from $\sim 10^{-4}$ pc to ~ 1 pc, where the density of dark matter particles is substantially larger than the one expected from a naive extrapolation of the galactic density profile. *The Broad Line Region lies within the DM spike*[1].

$$\rho_{\rm sp}(r) \approx \rho_R \left(1 - \frac{4R_{\rm s}}{r}\right) \left(\frac{R_{\rm sp}}{r}\right)^{7/3},$$

with $R_{\rm s} \approx 3 \times 10^{-5}$ pc for $M_{\rm BH} \approx 3 \times 10^8 M_\odot$.

P Padovani et al 1901.06998

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If the DM self-annihilates, the spike saturates at $\rho_{\rm sat} = m_{\rm DM}/ < \sigma v > t_{\rm BH}$.

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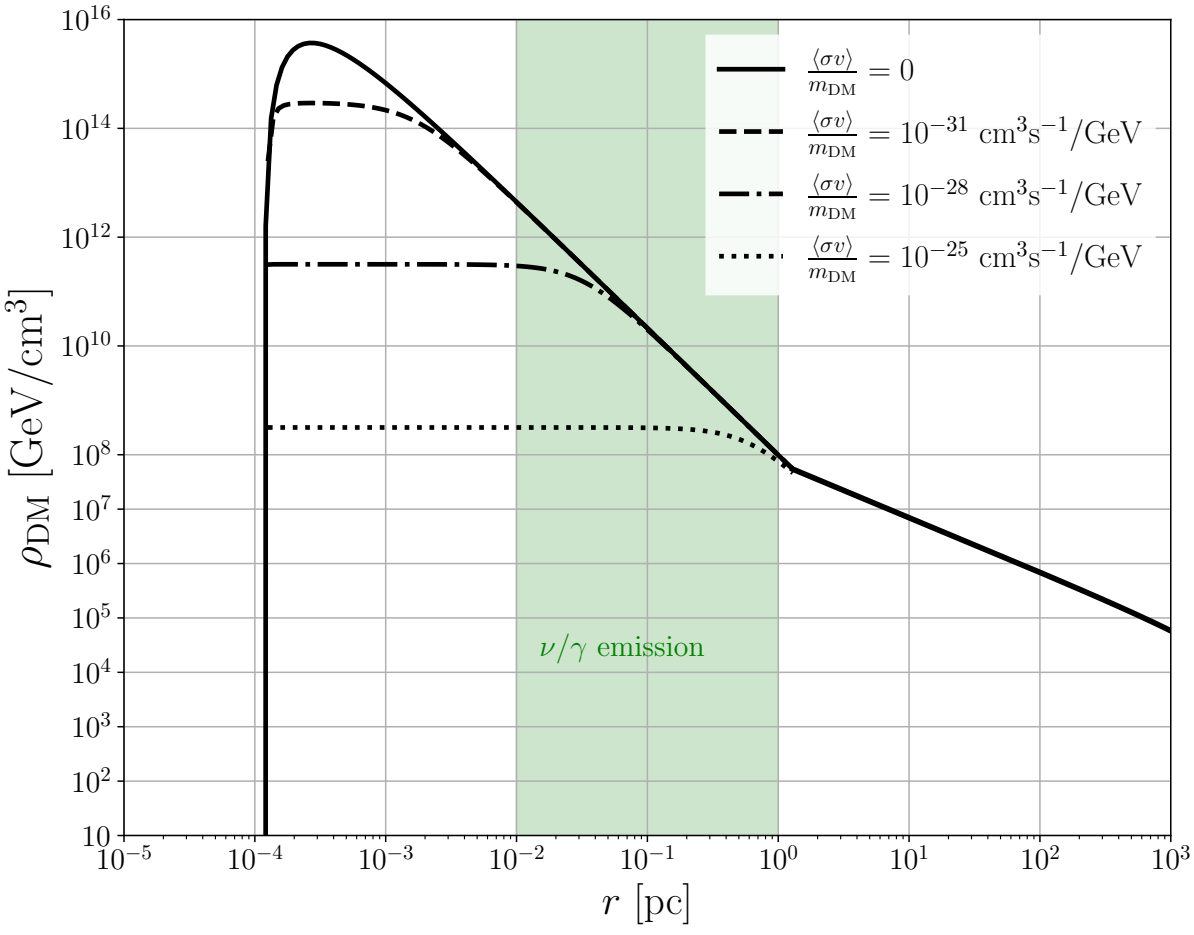
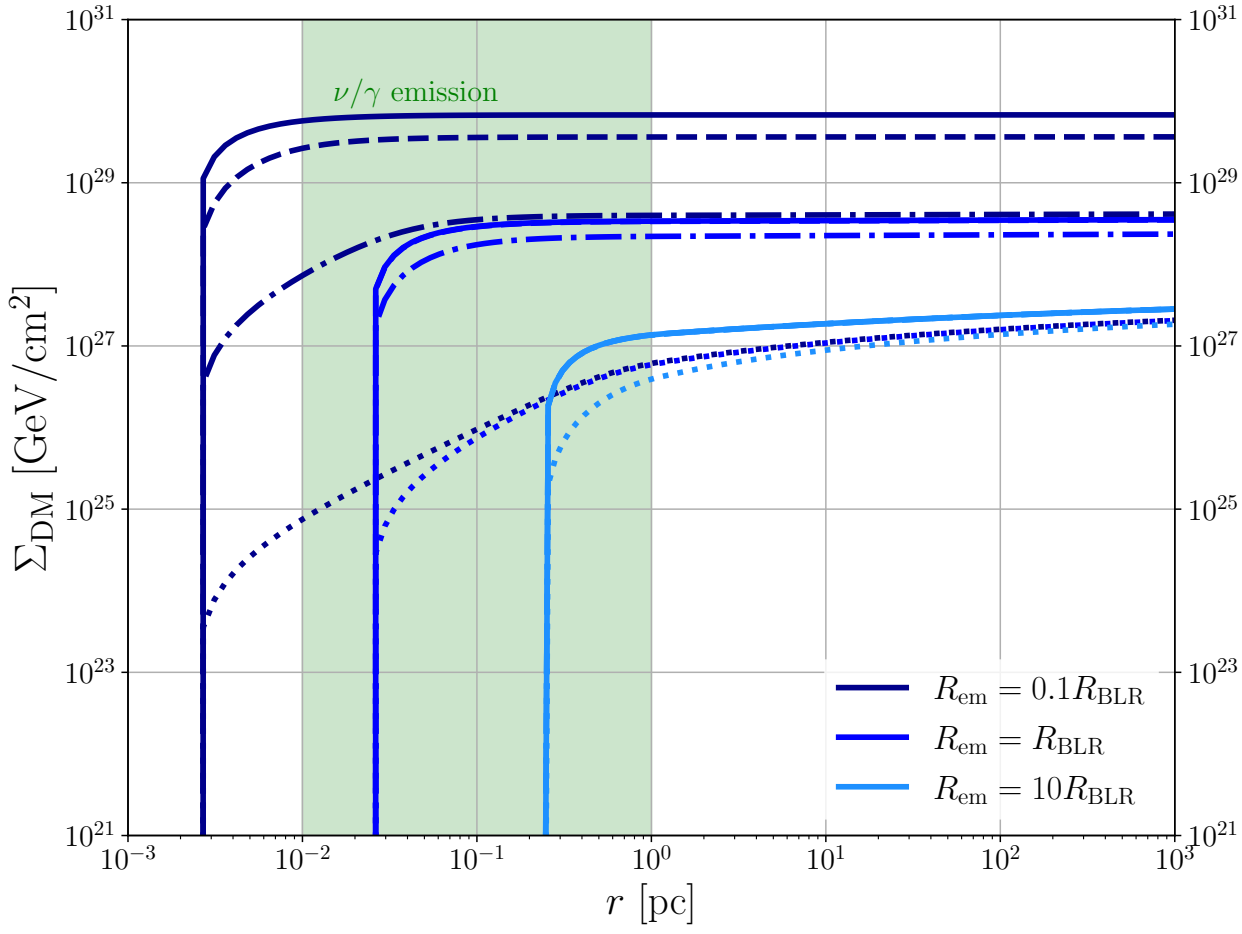
Distribution around the black hole



Total DM mass



Flux attenuation

The flux of neutrinos and photons gets attenuated due to interactions on their way to the Earth:

$$\frac{\Phi_i^{\rm obs}}{\Phi_i^{\rm em}} = e^{-\mu_i},$$

where the attenuation due to dark matter is:

$$\mu_i\big|_{\rm DM} = \frac{\sigma_{\rm DM-i}}{m_{\rm DM}}\Sigma_{\rm DM},$$

and

$$\Sigma_{\rm DM} = \int_{\rm path} dr\,\rho(r) \simeq \Sigma_{\rm DM}\Big|_{\rm spike} + \Sigma_{\rm DM}\Big|_{\rm host}$$

is the column density of dark matter particles along the path.

Constraints

We impose that the attenuation due to DM-ν interactions is less than 10%, which translates into $\mu_\nu|_{\rm DM} \lesssim 2.3$. For photons, which interact more strongly with SM particles in the medium, we require that the flux depletion is less than 1%.

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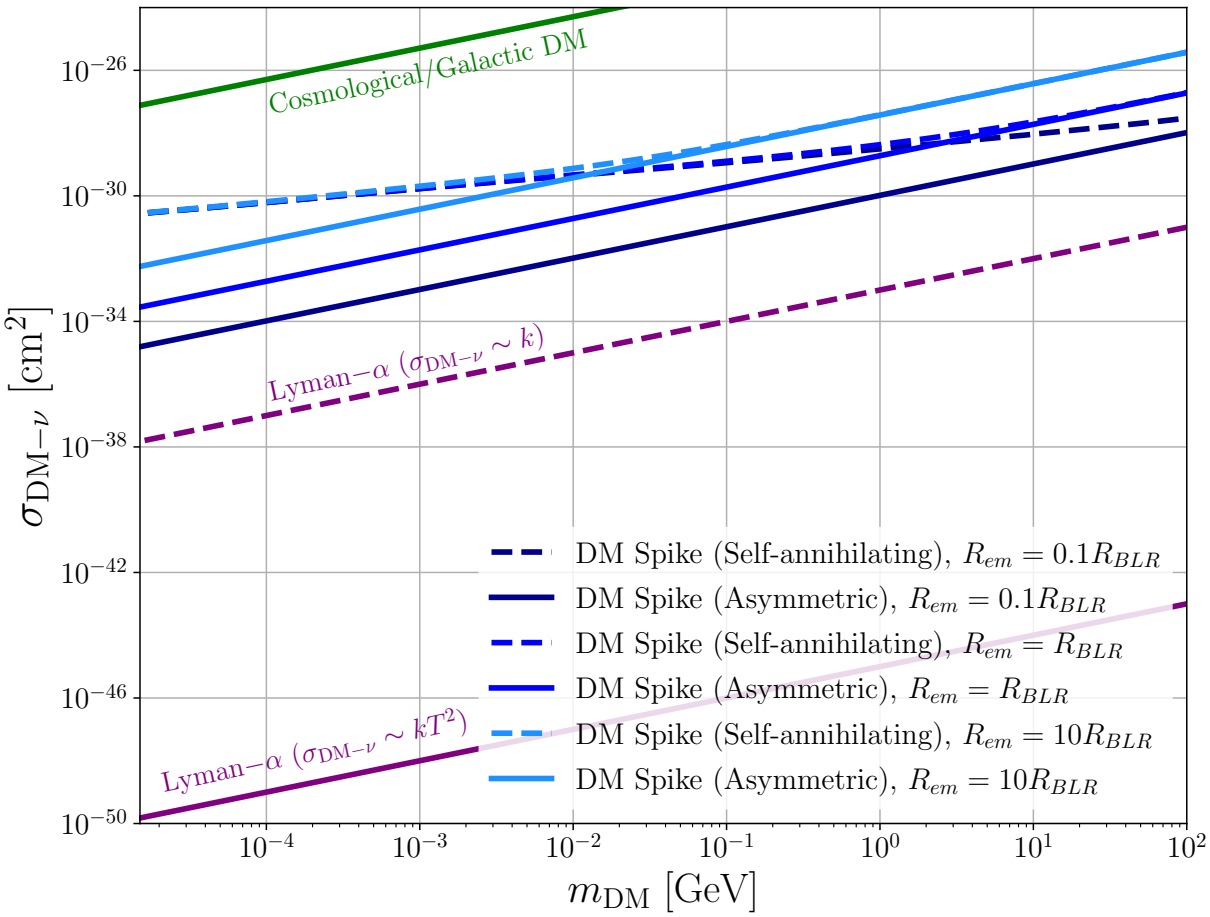
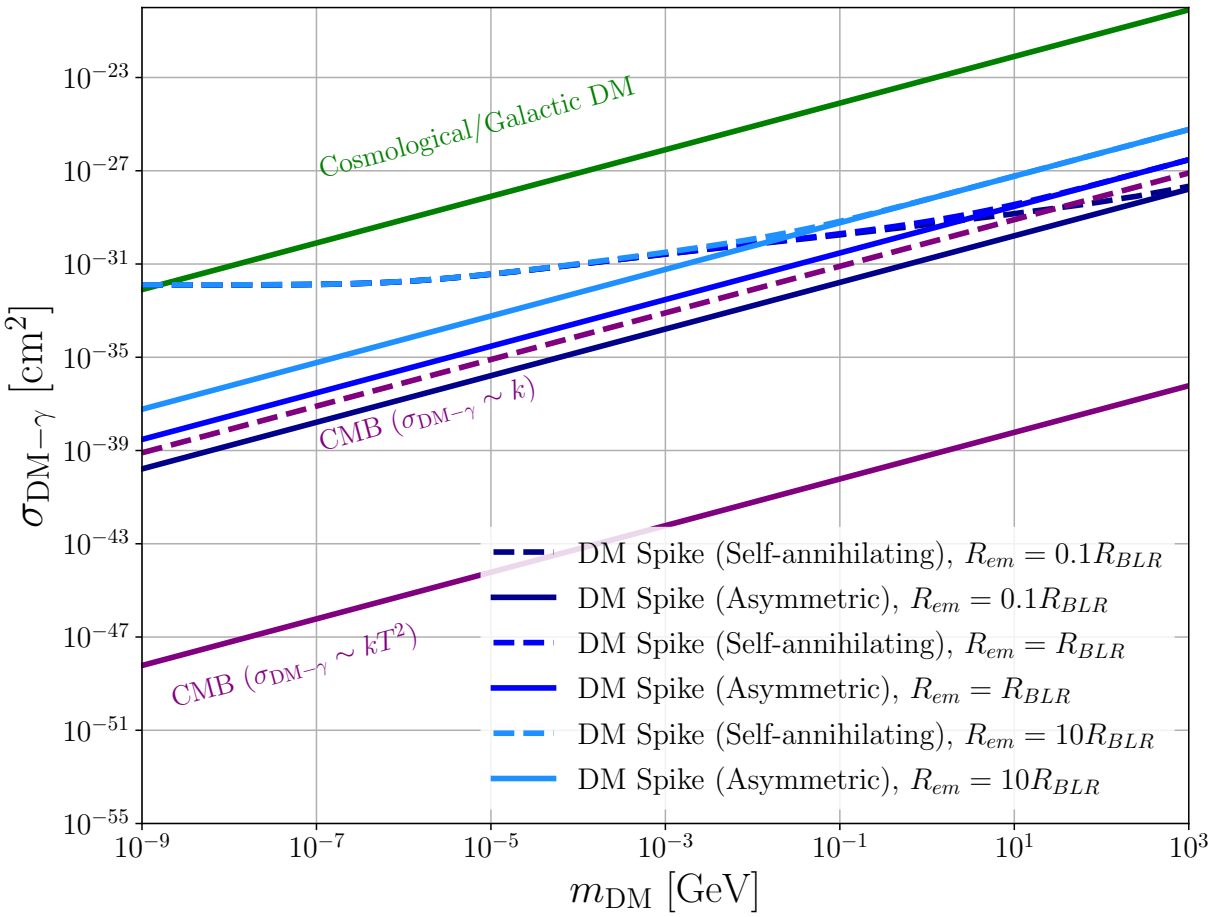
Assuming the cross-section is energy independent and $< \sigma v >= 0$, we find the upper limits:

$$\frac{\sigma_{\rm DM-\nu}}{m_{\rm DM}} \leq 2.0\times10^{-29}{\rm cm}^2/{\rm GeV} \qquad \frac{\sigma_{\rm DM-\gamma}}{m_{\rm DM}} \leq 4.1\times10^{-29}{\rm cm}^2/{\rm GeV}$$

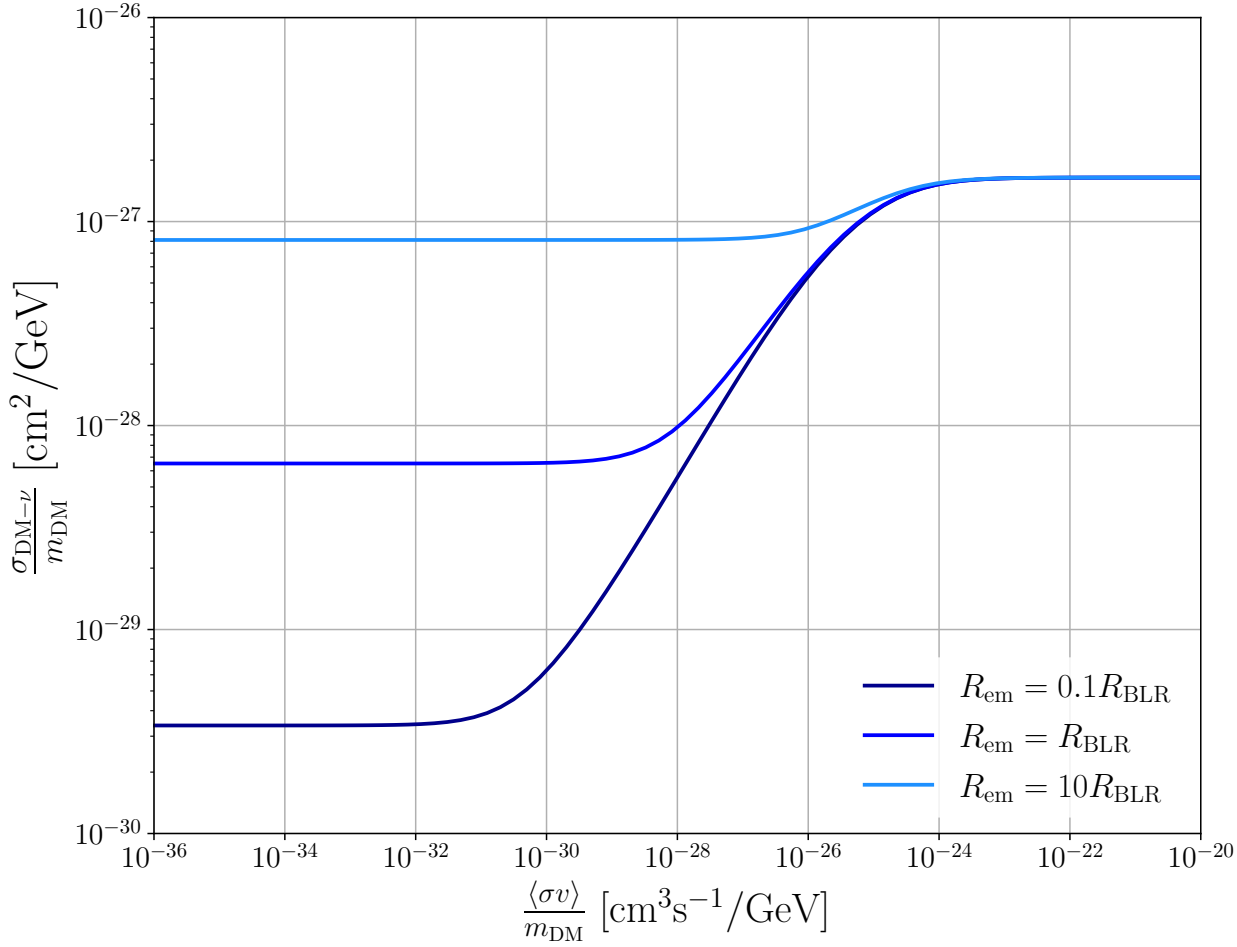
DM - ν constraints



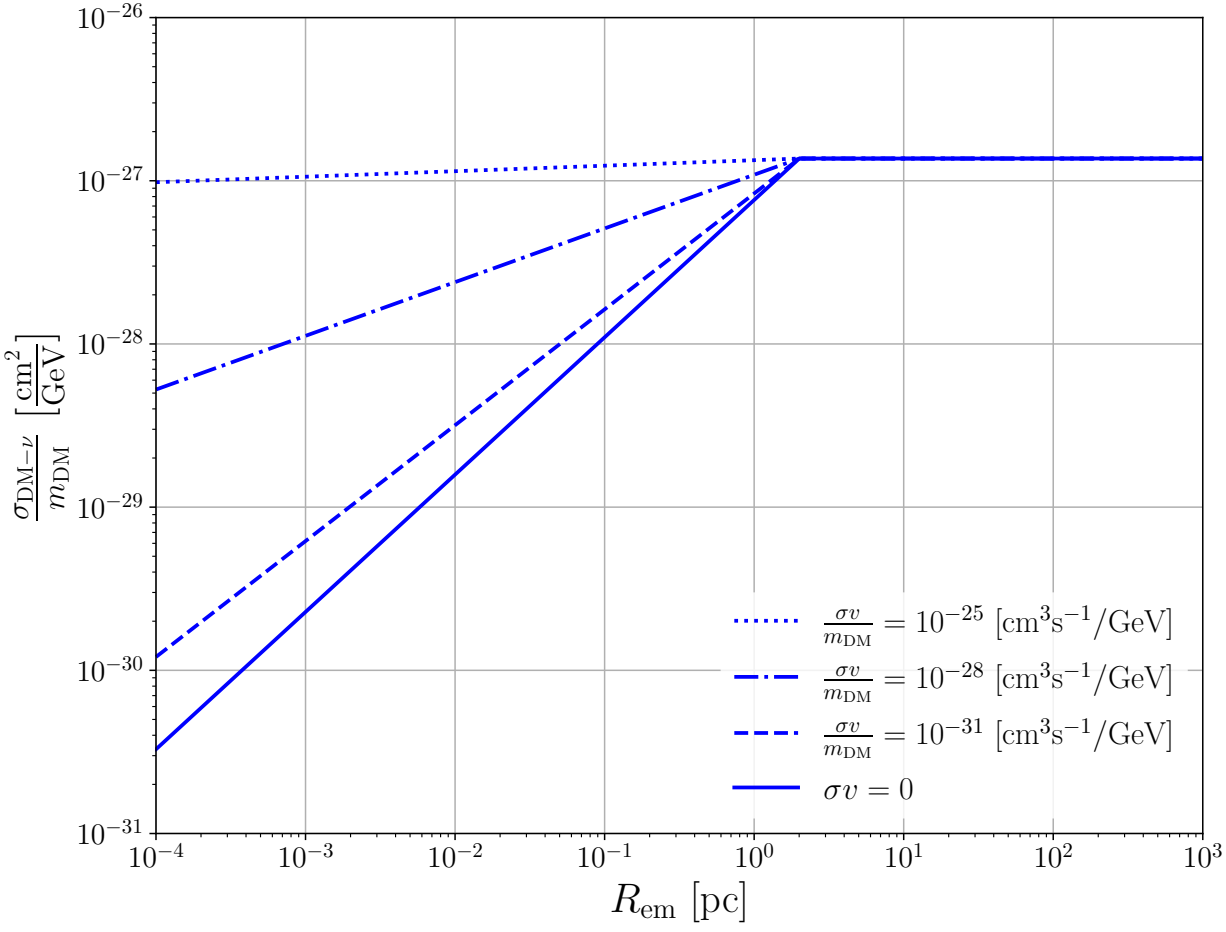
DM - γ constraints



Dependence on $< \sigma v >$



Dependence on the emission region

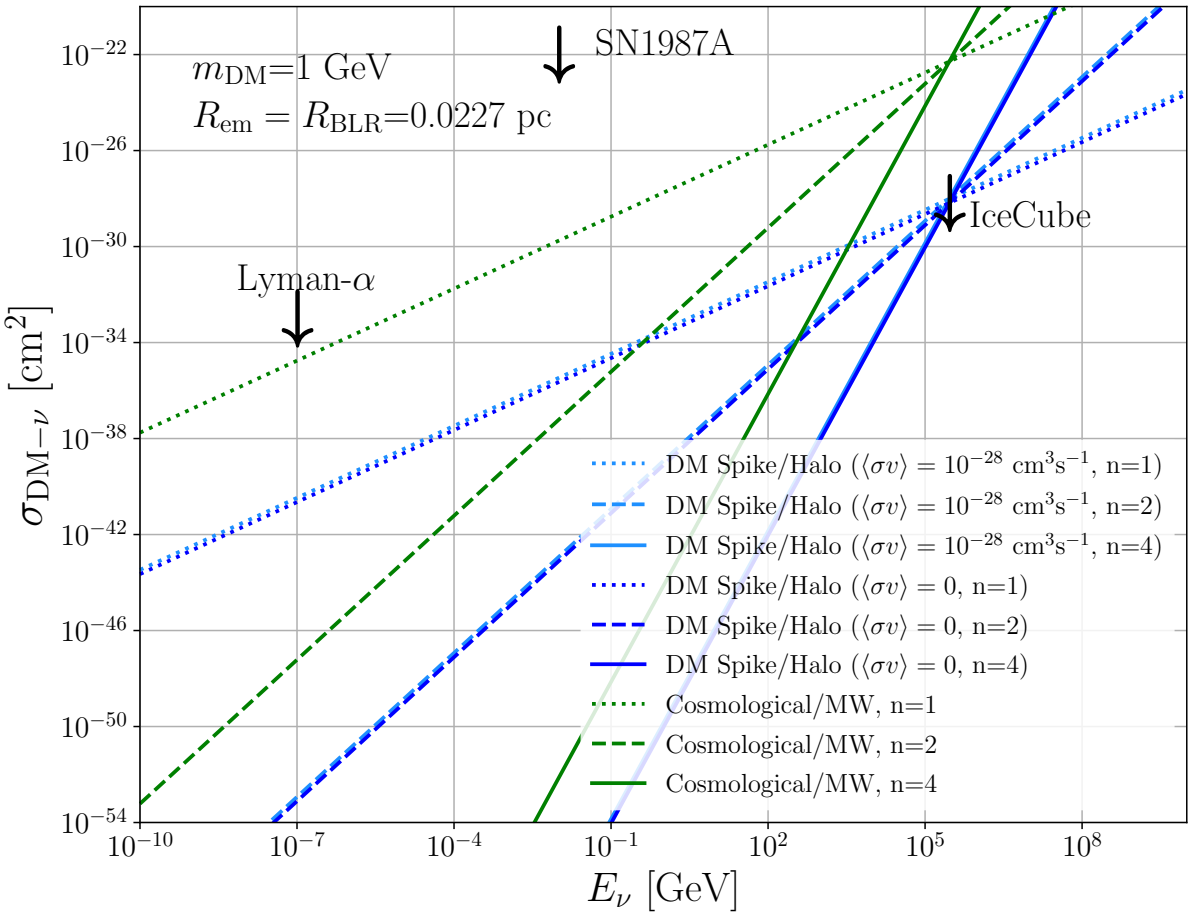


- Varying the slope of the halo profile $\gamma = 0.7 - 1.4$ changes the limits by a factor of at most ~ 2.
- The attenuation due to the propagation through the IGM and the MW is orders of magnitude smaller.
- Constraints from the suppression of primordial density fluctuations, which affect the CMB and Lyman-α, are orders of magnitude stronger. However, in a realistic model the interaction depends on the neutrino energy,

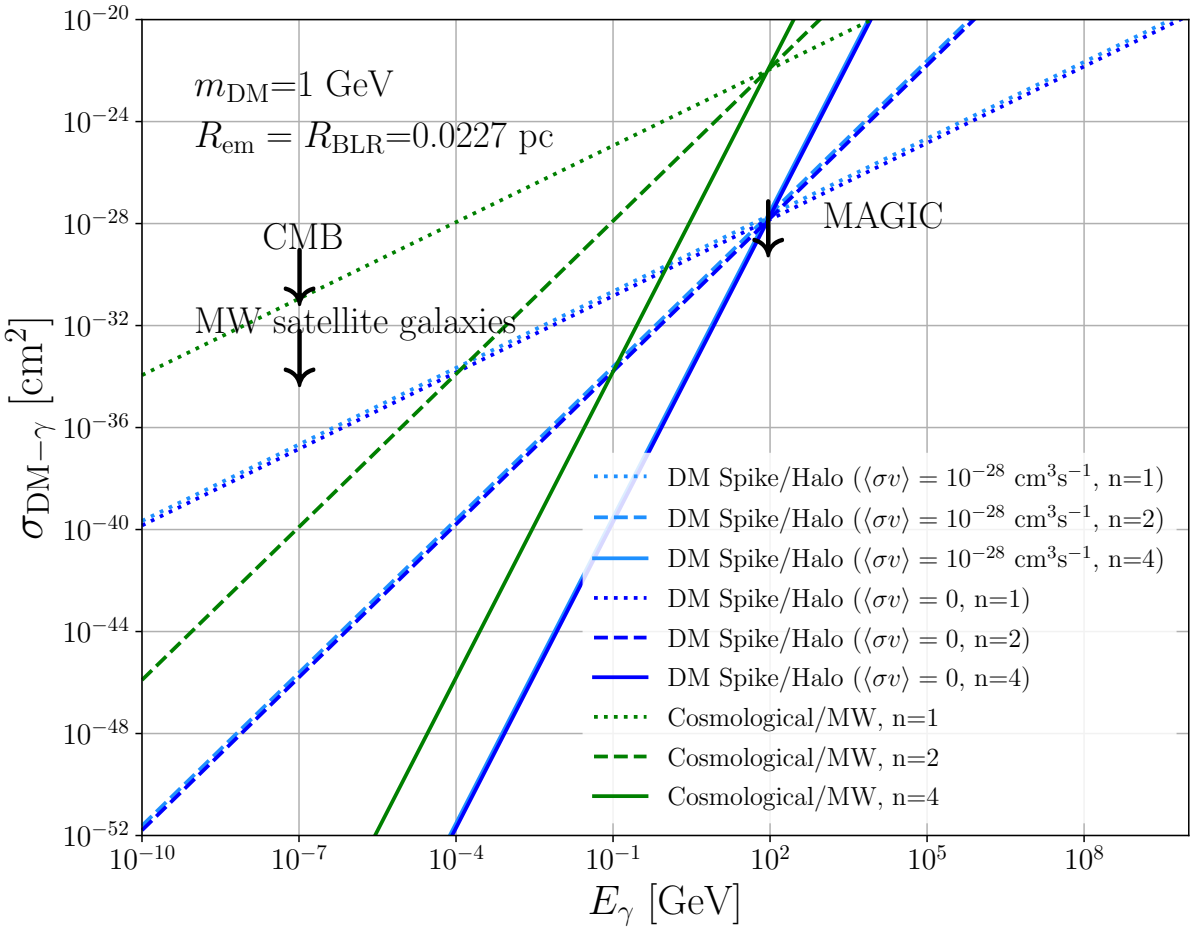
$$\sigma_{\mathrm{DM}-\nu} = \sigma_0 \left(\frac{E_\nu}{\mathrm{GeV}} \right)^n .$$

and blazar neutrinos ($E_\nu \sim 290$ TeV) are significantly more energetic than the Lyman-α (~ 100 eV).

Dependence on energy



Dependence on energy



Conclusions

- Constraints due to the DM around the BH are orders of magnitude stronger than those from the attenuation in the IGM and MW halo.
- Constraints from the CMB are 5 orders of magnitude stronger than ours if the cross-section is independent of the energy. If the cross-section increases with energy, attenuation constraints are *more stringent*.
- The recent identification of high-energy neutrino sources provides a powerful probe of dark matter interactions.