Neutrinos from Dark Matter scatterings around blazars

Jacopo Nava, U. Bologna and INFN

Dark Matter and Neutrinos, IHP Paris, 5-23 May 2025

Exploring Sub-GeV Dark Matter

- WIMP paradigm in tension: Need to explore other mass ranges

- Detection of sub-GeV DM challenging due to very low recoil energy to nuclei

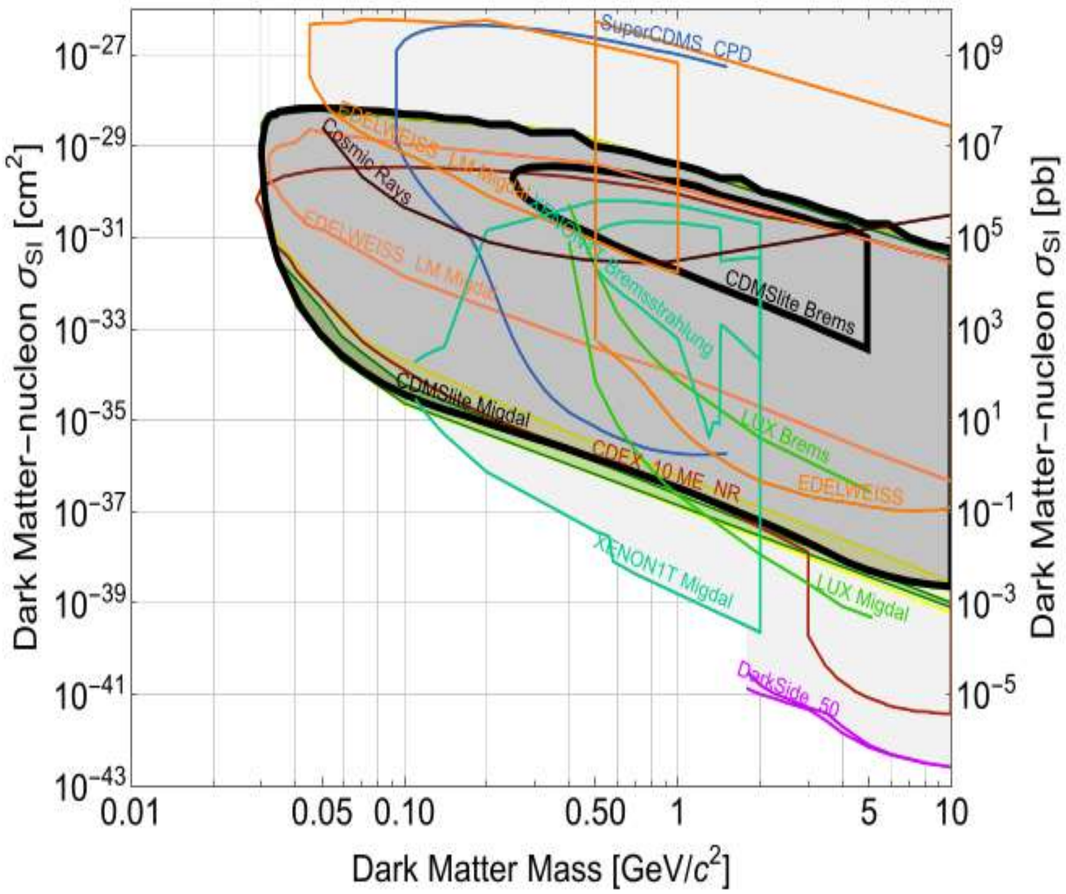
- Experimental effort: lower the threshold (e.g. Migdal effect, phonons)

Pheno effort: look for DM-nucleon upscatterings

(CR upscattered DM: Bringmann Pospelov 1810.10543

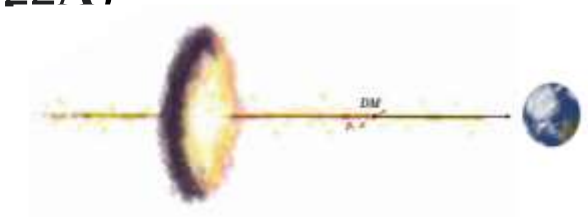
Ema, Sala, Sato, 1811.00520…)

arXiv 2302.091151



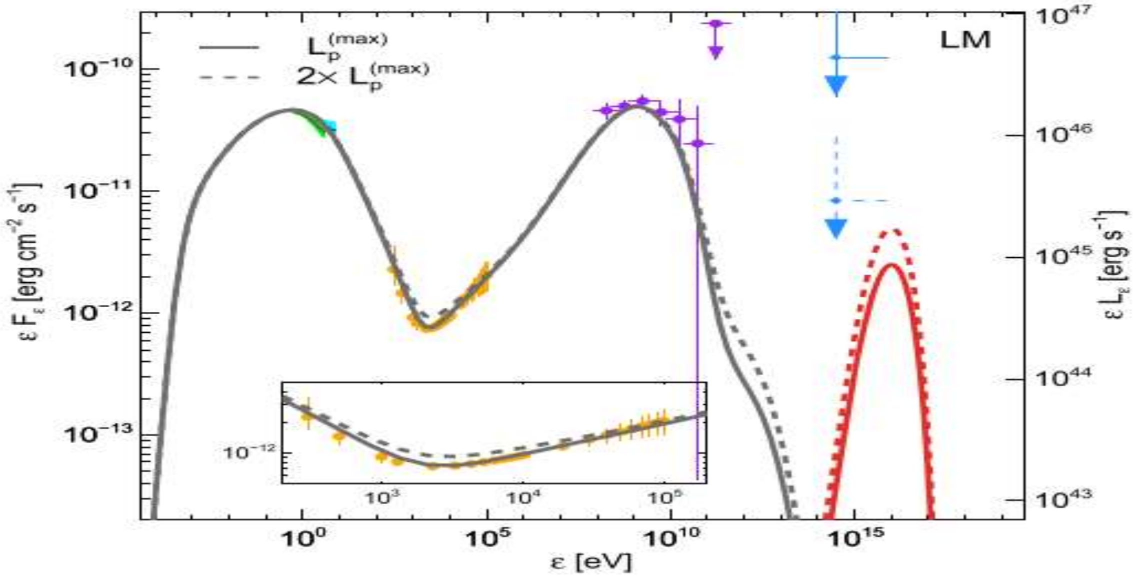
Dark Matter signals from Blazars

- Framework: Blazar Jet model, focus on TXS 0506+056 (**IceCube-170922A)**



Lepto-Hadronic model for the jet, but too few neutrinos!

$$\frac{d\Gamma'_j}{dE'_j d\Omega'} = \frac{1}{4\pi} c_j \left(\frac{E'_j}{m_j}\right)^{-\alpha_j}$$



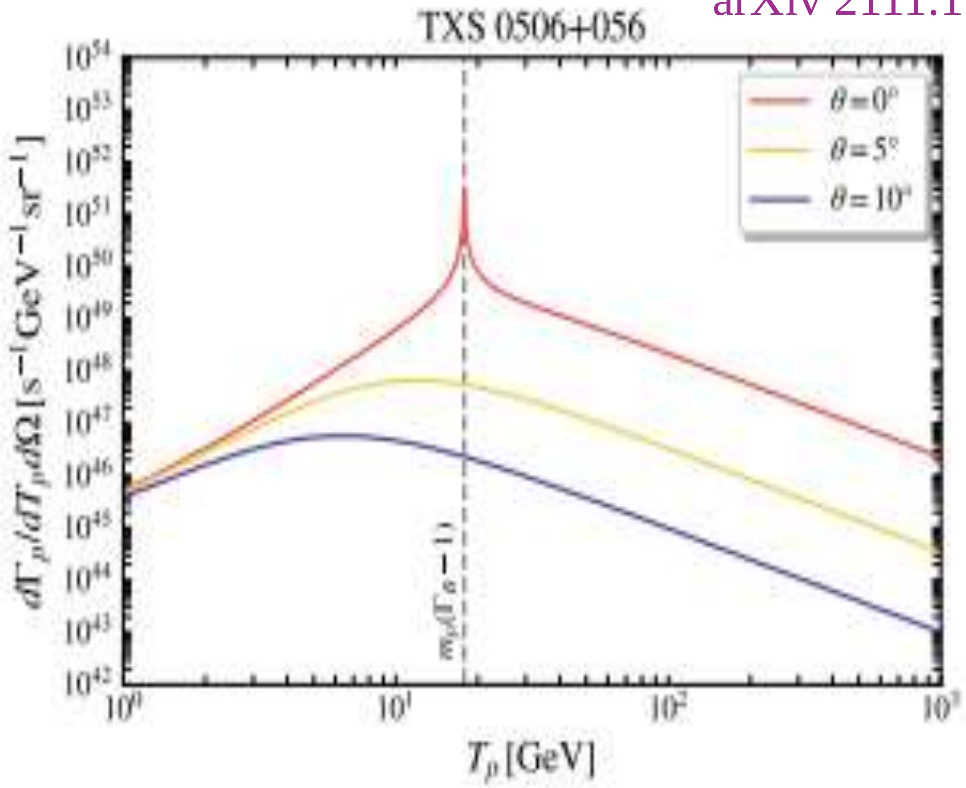
TXS 0506+056 Keivani et al.

What we study: DM spike around the BH, look at signal produced by DM-proton interactions

Blazar jet Proton spectrum

arXiv 2111.13644

- Proton energy spectrum peaks at O (10 GeV), dependance on the jet boost factor



- Relevant blazar parameters obtained by fitting the photon spectral energy distribution (SED)

We use one-zone model Lepto-hadronic blazar fits (Keivani et al. arXiv 1807.04537, Rodrigues et al, 2307.13024) as input for calculations of DM induced signals

Could DM IceCube neutrino from TXS be due to DM?

$$\chi + p \to \chi + X \to \chi + \text{hadronic showers} + \gamma\text{-rays} + \text{neutrinos.}$$

- Why looking at neutrinos is promising : BSM (production)+SM (detection)

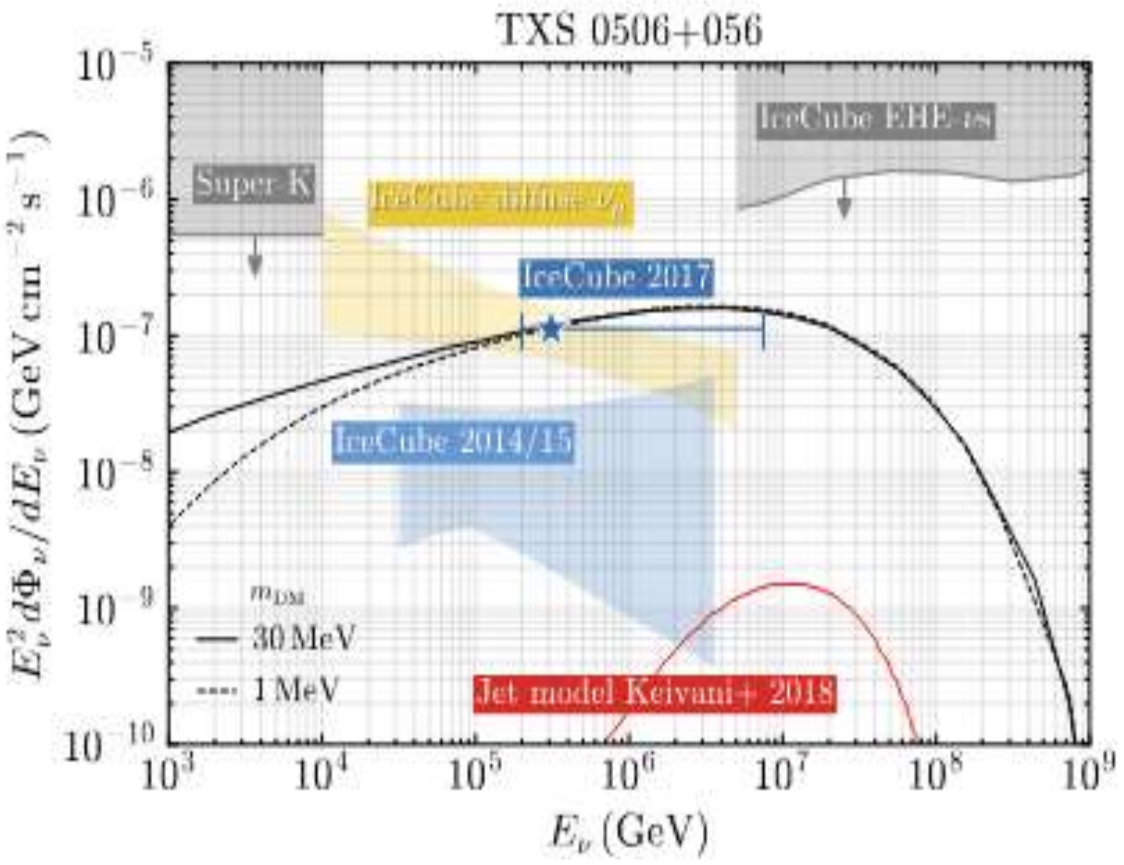
- MadGraph + Pythia to compute neutrino flux, use realistic DM models (Vector mediator)

$$\mathcal{L}_{\chi q V} = g_{\chi V}\bar{\chi}\gamma^{\mu}\chi V_{\mu} + g_{qV}\bar{q}\gamma^{\mu}q V_{\mu}$$

- We did not include baryon resonances, conservative result!

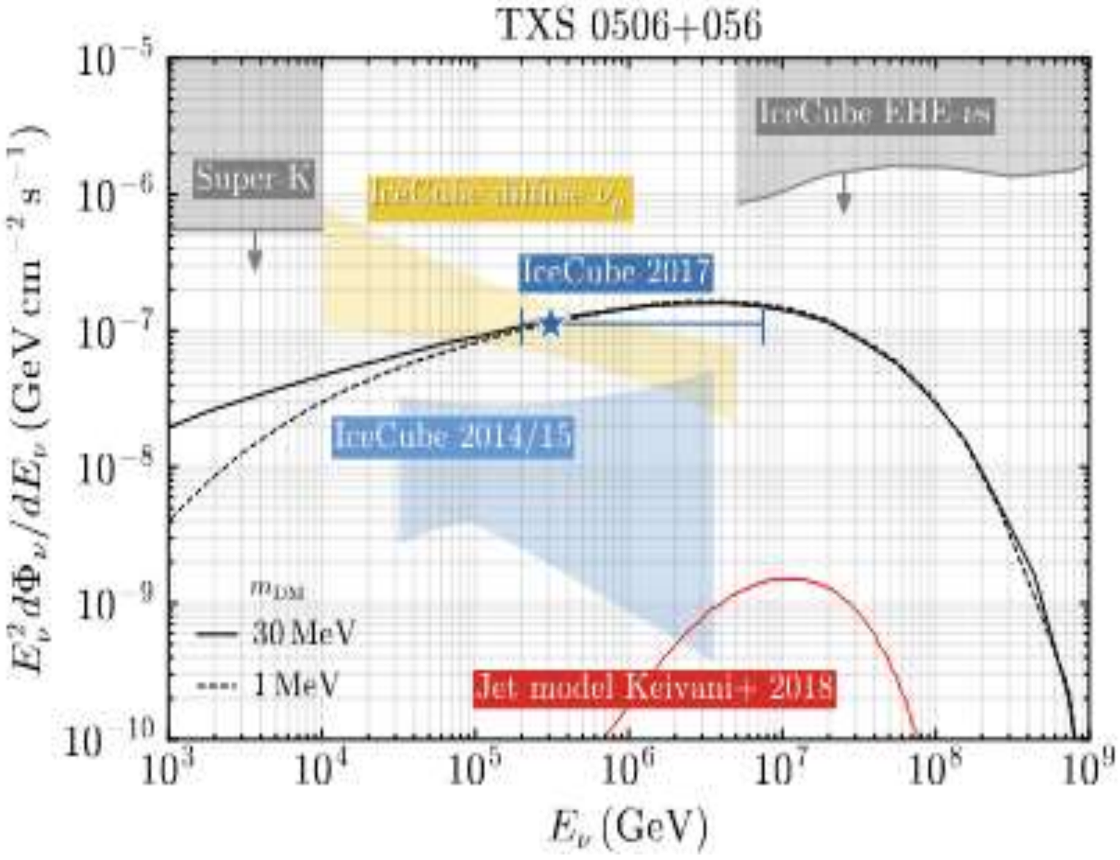
YES!!!

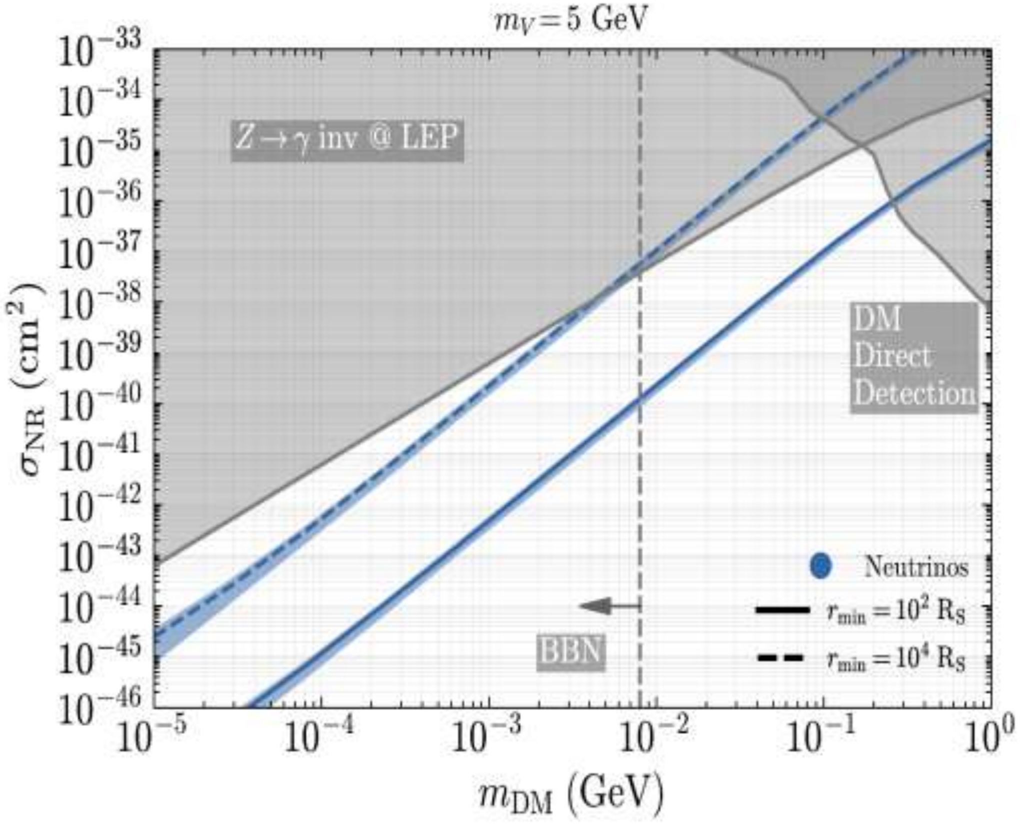
(2412.07861, A. De Marchi, A.Granelli, JN, F.Sala)



YES!! Compatibly with experimental constraints

(2412.07861, A. De Marchi, A.Granelli, JN, F.Sala)

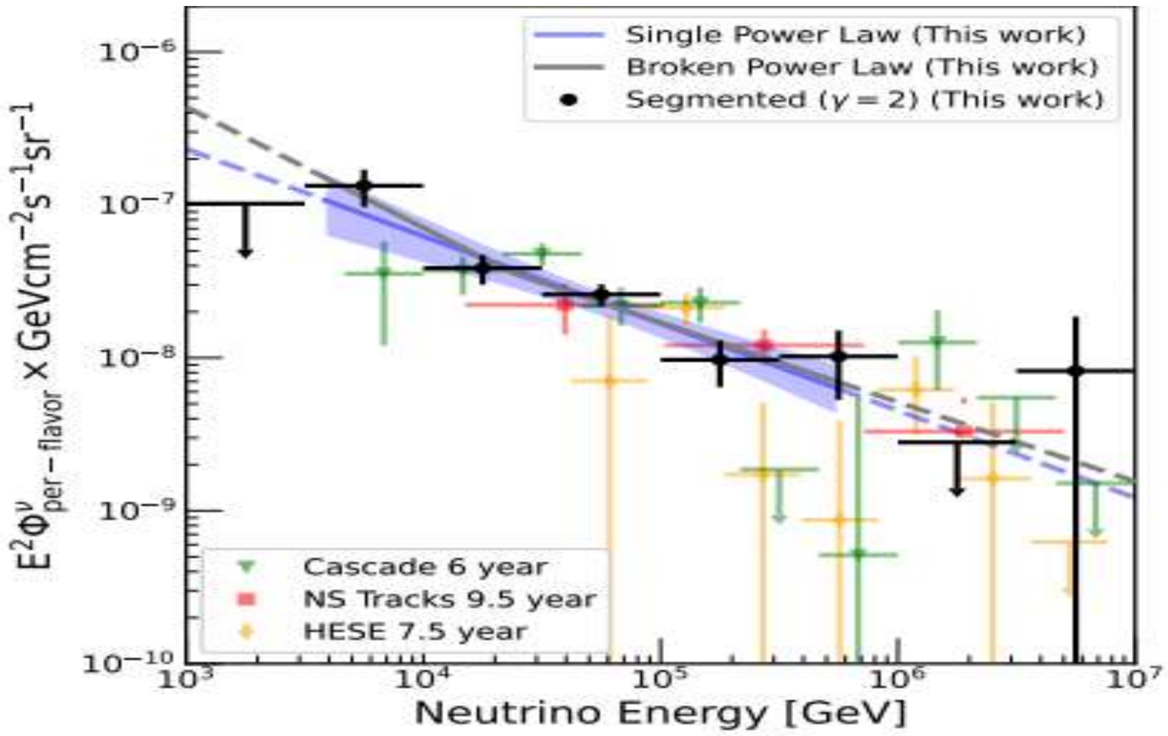




DM as the origin of diffuse neutrino flux?

How do we explain Icecube neutrinos?

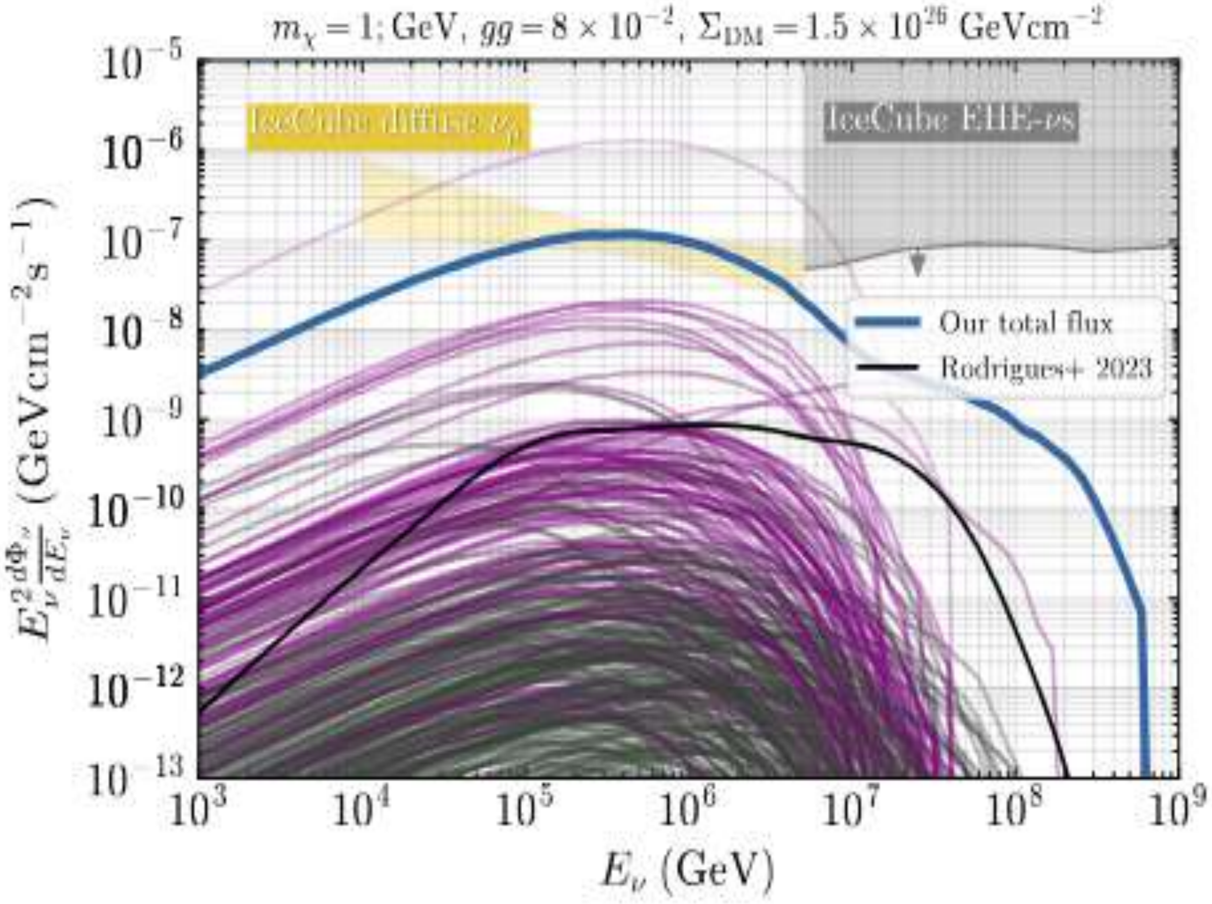
(2402.18026, IceCube)



DM as the origin of diffuse neutrino flux?

- We study a sample of 324 blazars (Rodrigues et al, 2307.13024)

- This mechanism can saturate the diffuse astrophysical neutrino flux observed by IceCube! New work appearing soon! (2506.xxxxx A. De Marchi, A.Granelli, JN, F.Sala)

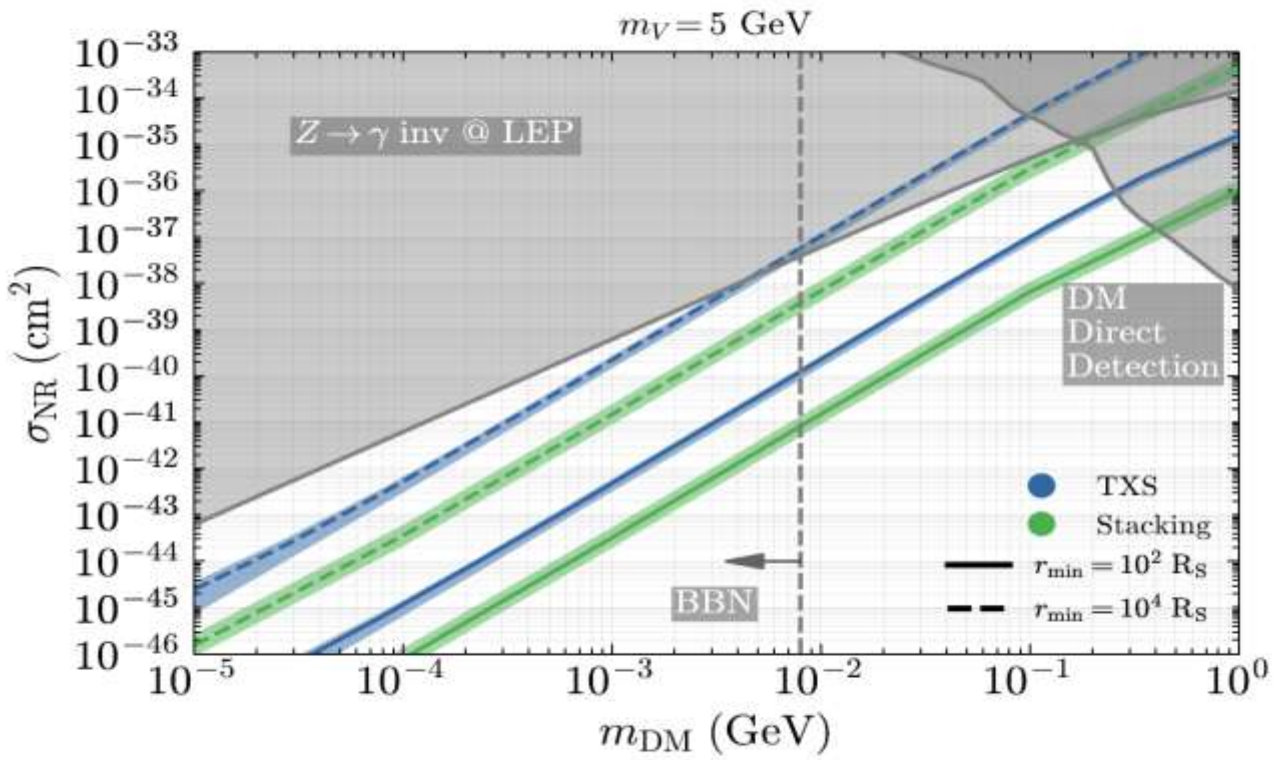


YES!! Compatibly with experimental constraints

KEY RESULT : DM origin of

i) TXS 2017 neutrino
ii) IceCube diffuse neutrino flux

Compatible with experimental constraints for several DM models



BUT…from the same DM interactions we expect other DM-induced signals !

(2506.xxxxx A. De Marchi, A.Granelli, JN, F.Sala)

Boosted DM vs Neutrinos from blazars

Blazar boosted DM (BBDM): look for nuclear recoils from DM-proton scattering at XENON1T (Wang, Granelli, Ullio, 2111.13644)

i) Neutrinos: strong dependence on the signal on the proton spectral index

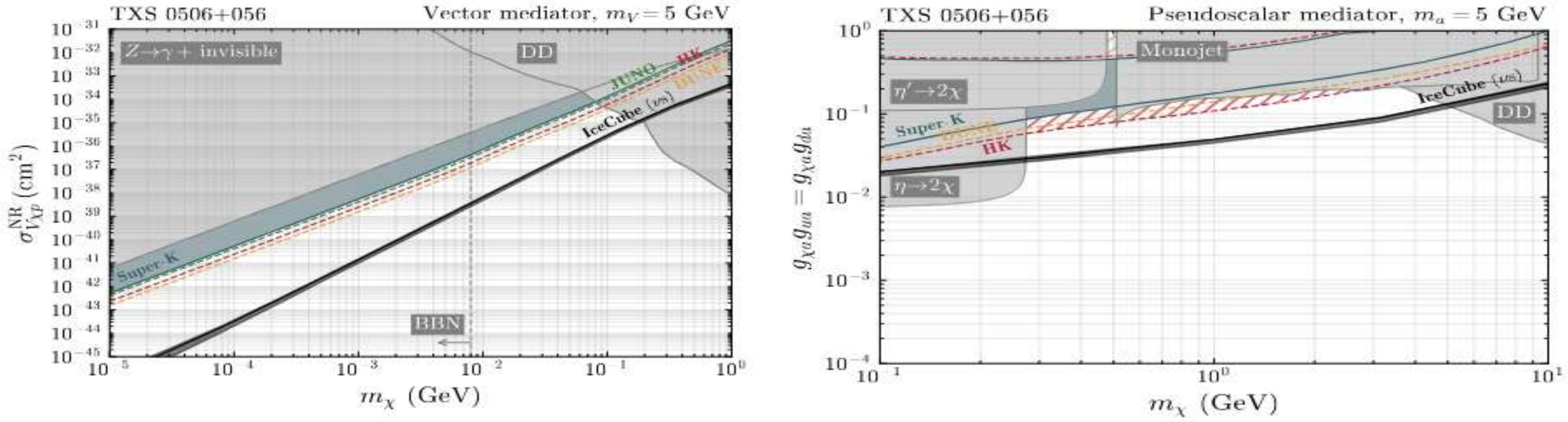
ii) BBDM: dominant parameter is the proton luminosity of the jet

Neutrinos:
$E_p \sim TeV - PeV$

BBDM:
$E_p \sim GeV$

Best messenger depends on source, fit, and the parameters of DM models

Neutrino signal survives Boosted DM!



Look for signals at neutrino detectors

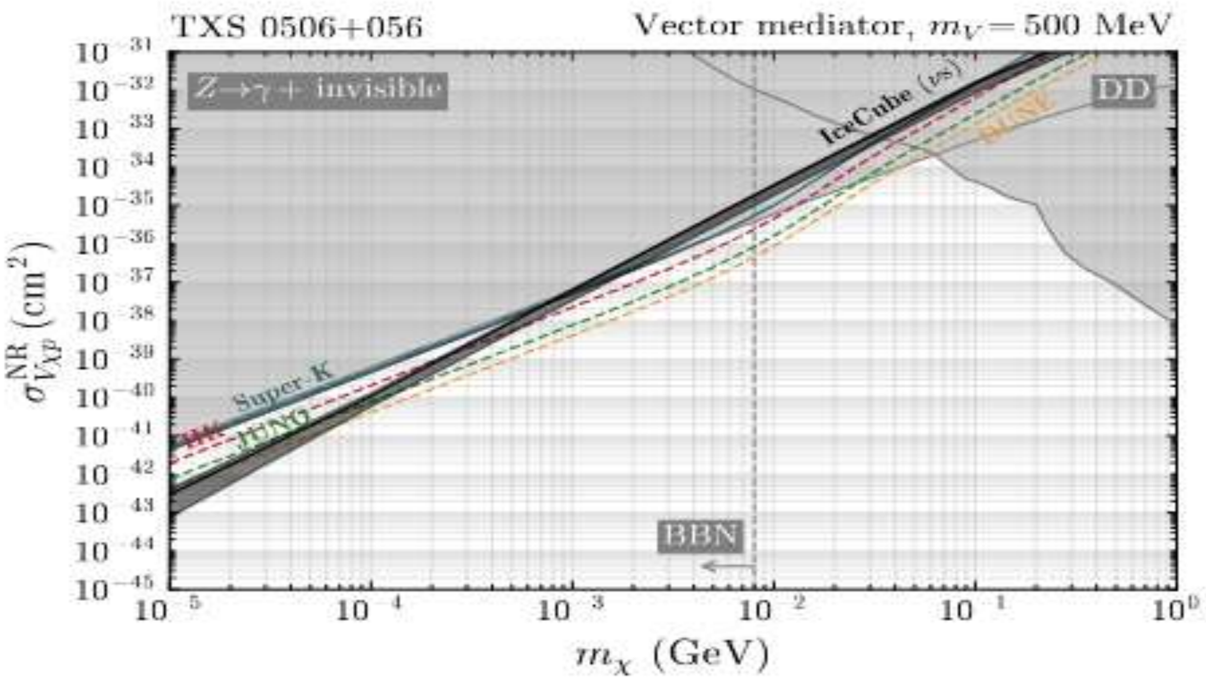
i) Larger Volume

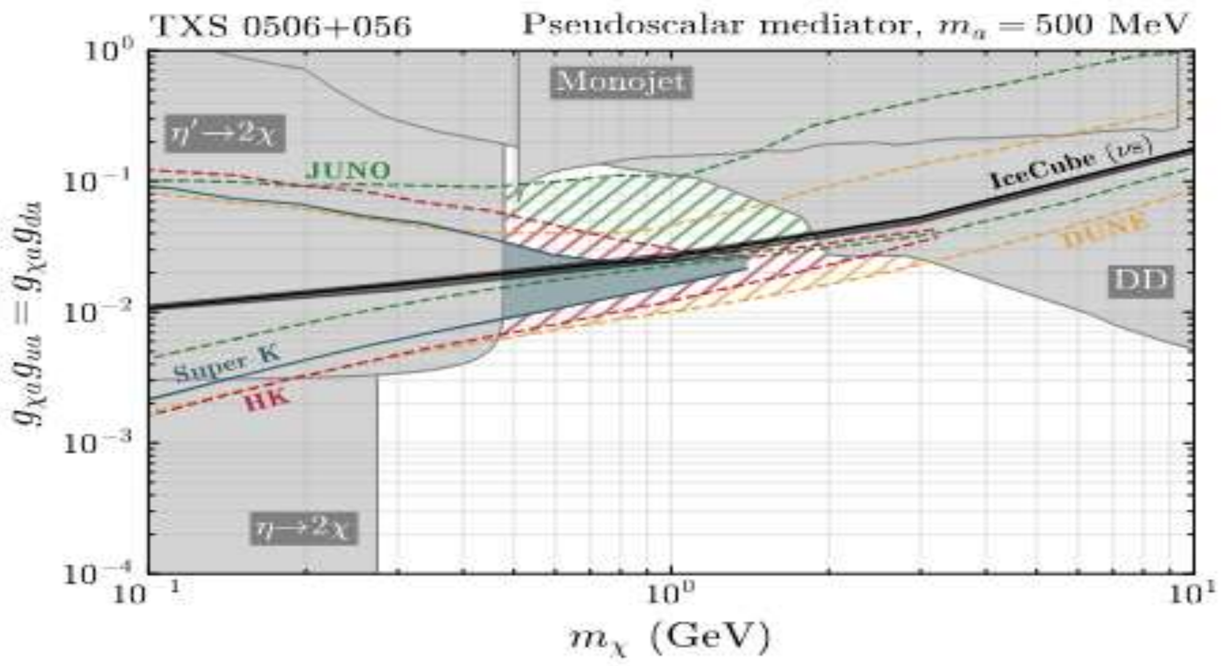
ii) Energy range sensitivity

New work appearing soon! (2506.xxxxx A. De Marchi, A.Granelli, JN, F.Sala)

BBDM signal does not rule out DM origin of astrophysical neutrinos

Neutrino signal survives Boosted DM!





Changing the mass of the mediator has sizable impact on BBDM-neutrino signal interplay

Conclusions and Prospects

We find that sub-GeV DM around blazars can explain:

i) TXS 0506+056 neutrino detected by IceCube in 2017

ii) The diffuse astrophysical neutrino flux measured by IceCube

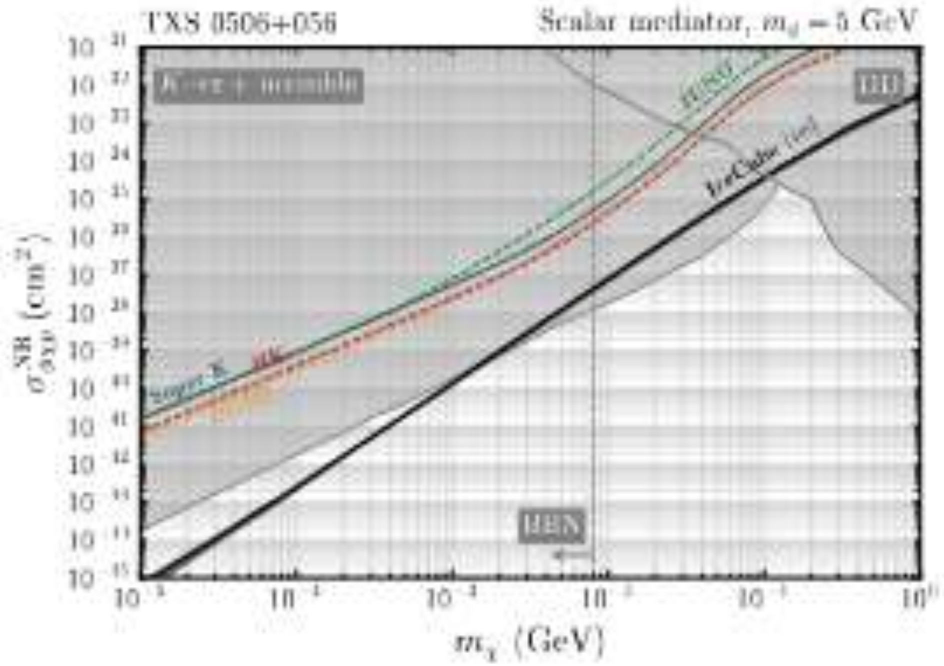
We highlight the importance of analyzing realistic DM models, including inelastic interactions.

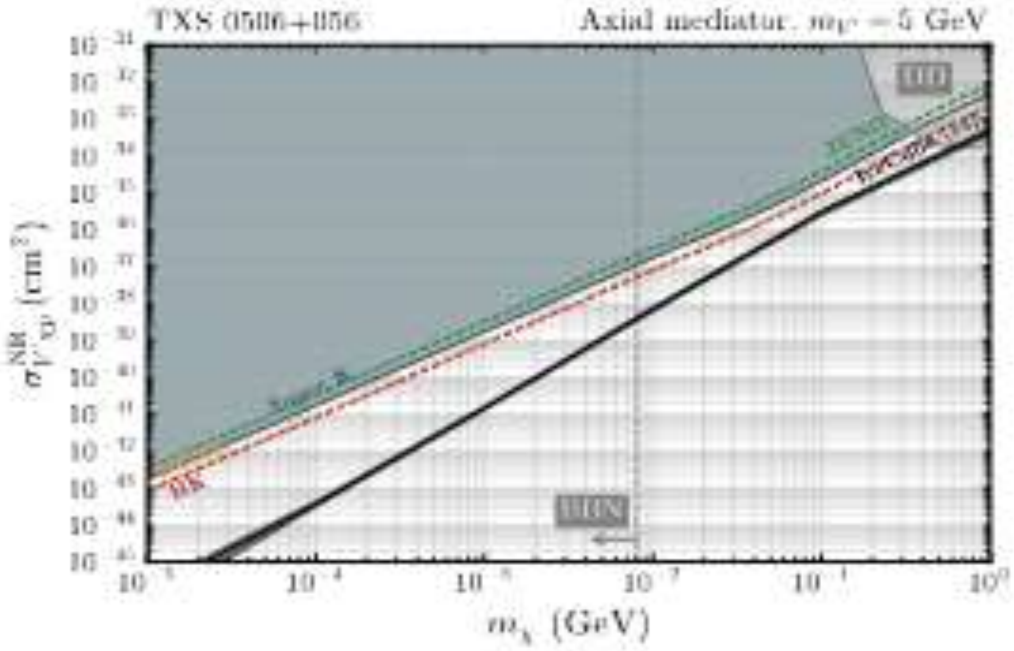
For the future: Need to include DM in blazar fits (How will the photon spectrum be affected? Can we lower the proton luminosity below Eddington limit?)

Thank you for your attention!

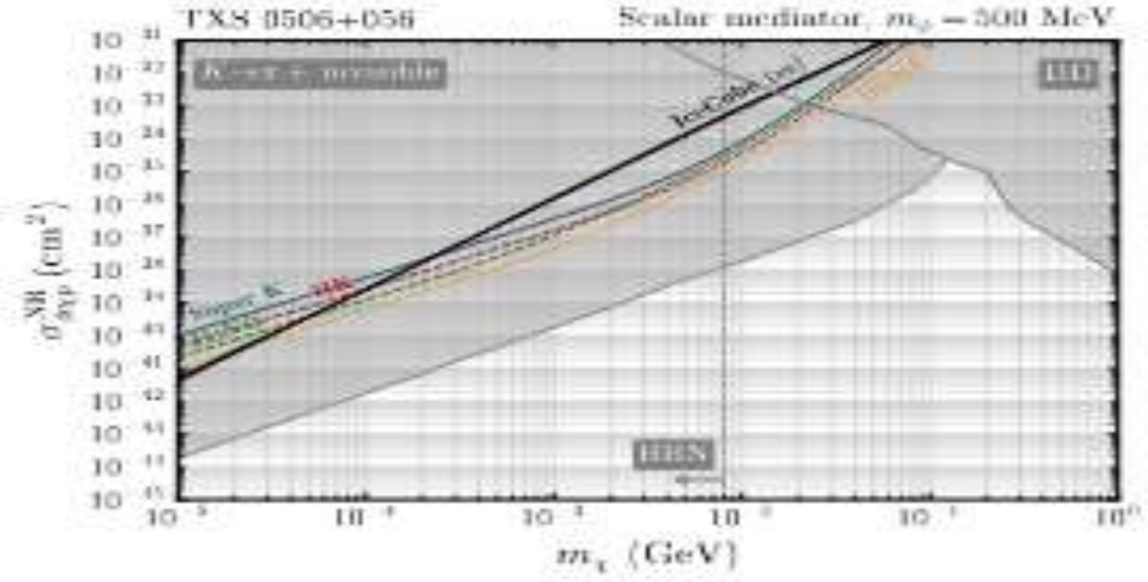
Backup Slides

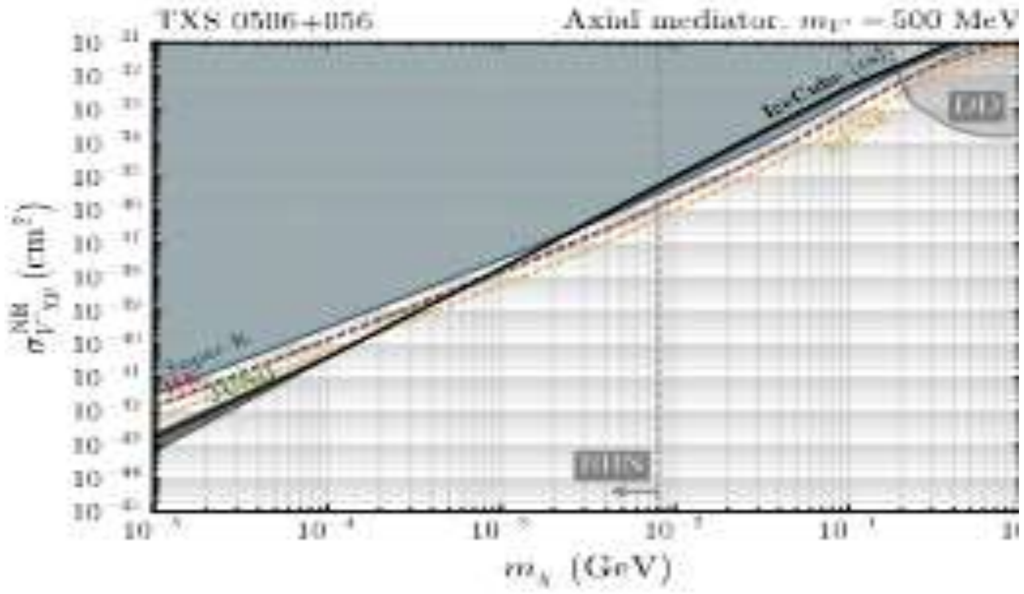
Results for other DM models





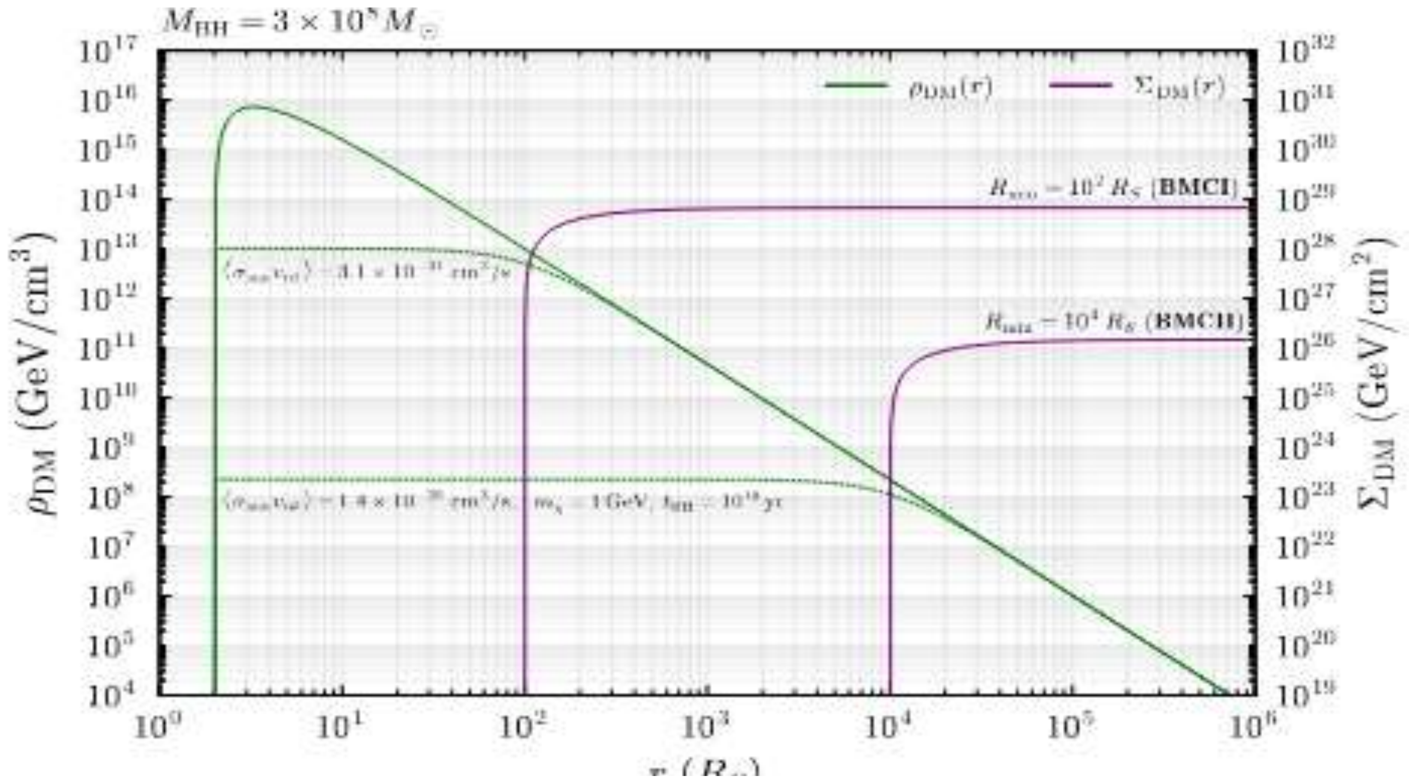
Results for other DM models



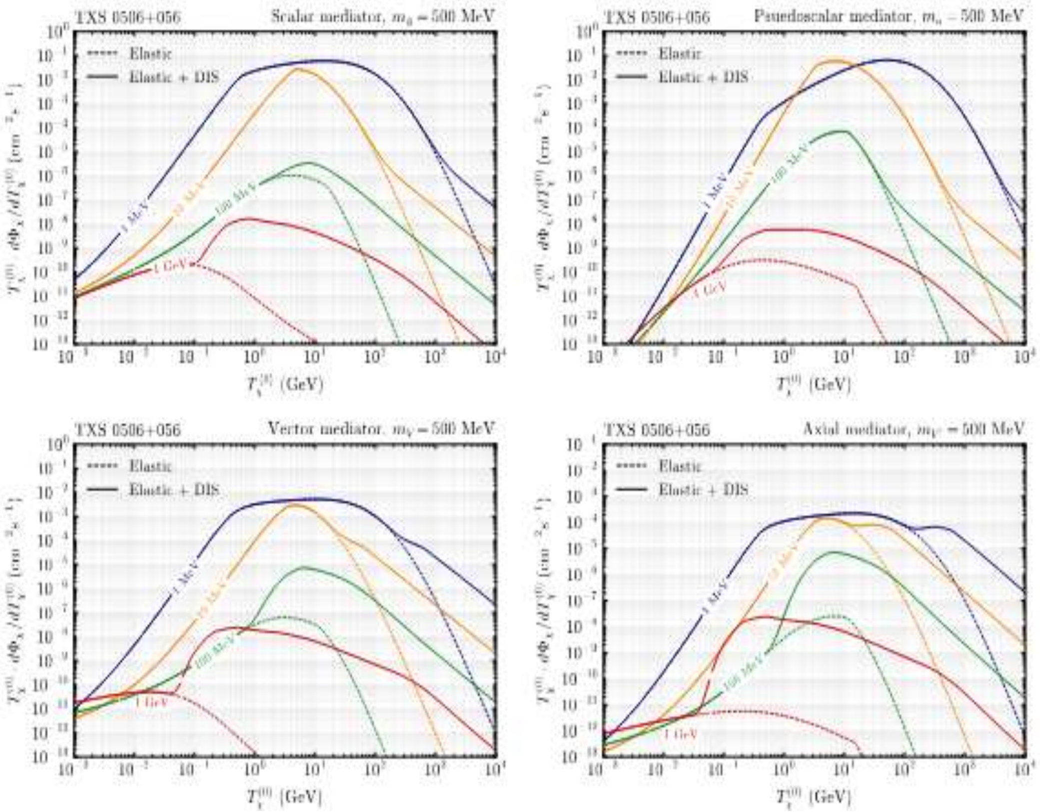


Dark Matter profile around the Black Hole

$$\int_{4R_S}^{10^5 R_S} 4\pi r^2 \rho'(r) dr \simeq M_{\mathrm{BH}} \qquad \Sigma_{\mathrm{DM}}(r) \equiv \int_{r_{\min}}^{r} \rho_{\mathrm{DM}}(r')\, dr'$$



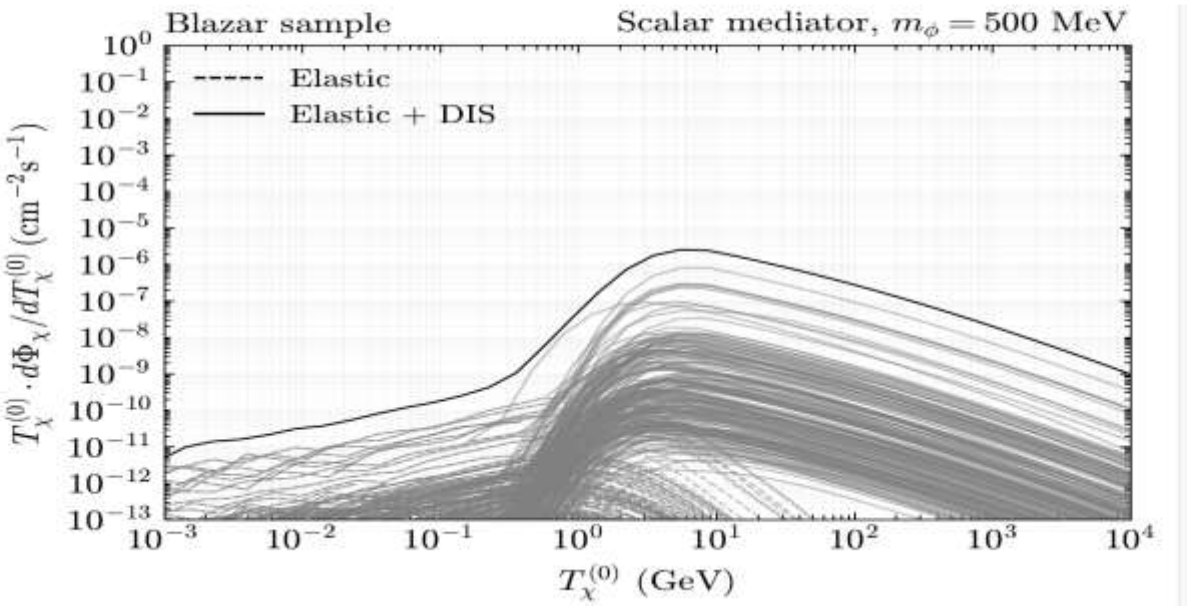
Blazar boosted DM flux



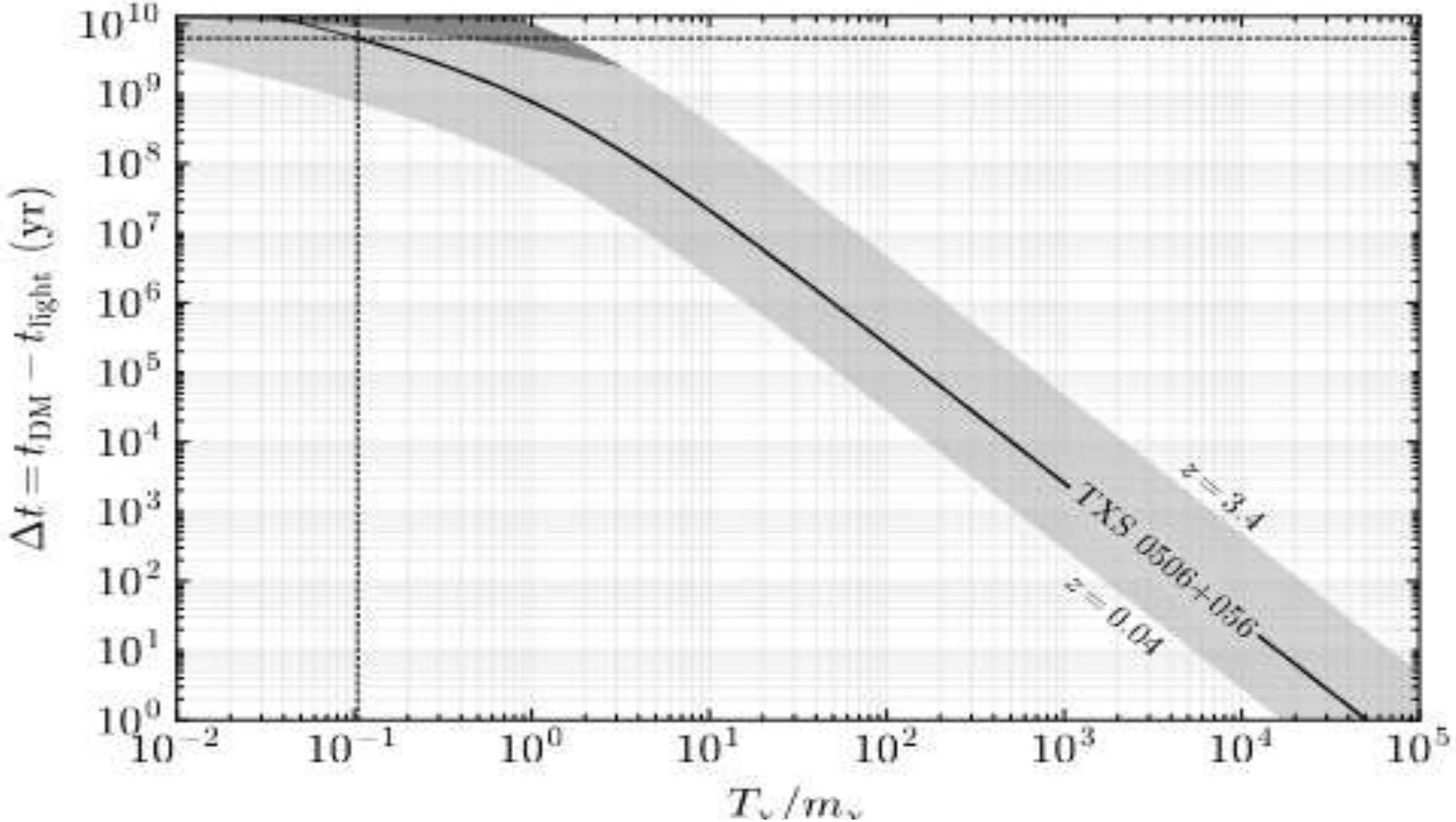
$$\frac{d\Phi_\chi}{dT_\chi} = \frac{\Sigma_{\rm DM}^{\rm tot}}{2\pi m_\chi d_L^2} \int_0^{2\pi} d\phi_s \int_{\gamma_p^{\rm kin}(T_\chi)}^{\gamma_p^{\rm upper}} d\gamma_p \int d\mu_s \frac{d\Gamma_p}{d\gamma_p d\Omega} \frac{d\sigma_{\chi p}^{\rm EL+DIS}}{dT_\chi d\mu_s},$$

- Peak of the BBDM flux controlled by the proton energy spectrum

- Effect of inelastic interactions important for DM mass of O (GeV) and vector+axial mediator. Relative strength dependence also on the blazar fit



Dark Matter-photons delay



Blazar parameters

Lepto-Hadronic Model Parameters		
Parameter (units)	TXS 0506+056 [27]	Blazars sample [46]
z	0.337	$[0.04, 3.41]$
d_L (Mpc)	1765	$[171, 30.2 \times 10^3]$
$M_{\rm BH}(M_\odot)$	3×10^8	$[10^8, 10^9]$
R_S (pc)	3×10^{-5}	$[10^{-5}, 10^{-4}]$
Γ_B	24.2	$[3.4, 31.5]$
$\theta_{\rm LOS}(^\circ)$	2.37	$[1.81, 16.95]$
α_p	2	1
$\gamma'_{\min_p}$	1	100
$\gamma'_{\max_p}$	1.6×10^7	$[10^6, 3.1 \times 10^7]$
L_p (erg/s)	1.85×10^{50}	$[2.2 \times 10^{44}, 3.1 \times 10^{50}]$
$\kappa_p\,(\mathrm{s}^{-1}\mathrm{sr}^{-1})$	1.27×10^{49}	$[3.1 \times 10^{37}, 1.3 \times 10^{46}]$

BBDM with constant cross section

(Wang, Granelli, Ullio, 2111.13644)