



SORBONNE
UNIVERSITÉ

UNIVERSITÉ
FRANCO
ITALIENNE

UNIVERSITÀ
ITALO
FRANCESE



INTEGRAL X-RAY CONSTRAINTS ON SUB-GEV DARK MATTER

Speaker: Elena Pinetti

PPC2021, 19th May 2021

INTEGRAL X-ray constraints on sub-GeV Dark Matter

Marco Cirelli ^a, Nicolao Fornengo ^b,
Bradley J. Kavanagh ^c, Elena Pinetti ^{a,b}

^a *Laboratoire de Physique Théorique et Hautes Energies (LPTHE),
UMR 7589 CNRS & UPMC, 4 Place Jussieu, F-75252, Paris, France*

^b *Dipartimento di Fisica, Università di Torino & INFN, Sezione di Torino,
via P. Giuria 1, I-10125 Torino, Italy*

^c *Instituto de Física de Cantabria, (IFCA, UC-CSIC),
Av. de Los Castros s/n, 39005 Santander, Spain*

INTEGRAL X-ray constraints on sub-GeV Dark Matter

Marco Cirelli ^a, Nicolao Fornengo ^b,
Bradley J. Kavanagh ^c, Elena Pinetti ^{a,b}


$$1 \text{ MeV} \leq m_\chi \leq 5 \text{ GeV}$$

*Laboratoire de Physique Théorique et Hautes Energies (LPTHE),
UMR 7589 CNRS & UPMC, 4 Place Jussieu, F-75252, Paris, France*

*^b Dipartimento di Fisica, Università di Torino & INFN, Sezione di Torino,
via P. Giuria 1, I-10125 Torino, Italy*

*^c Instituto de Física de Cantabria, (IFCA, UC-CSIC),
Av. de Los Castros s/n, 39005 Santander, Spain*

Photon searches

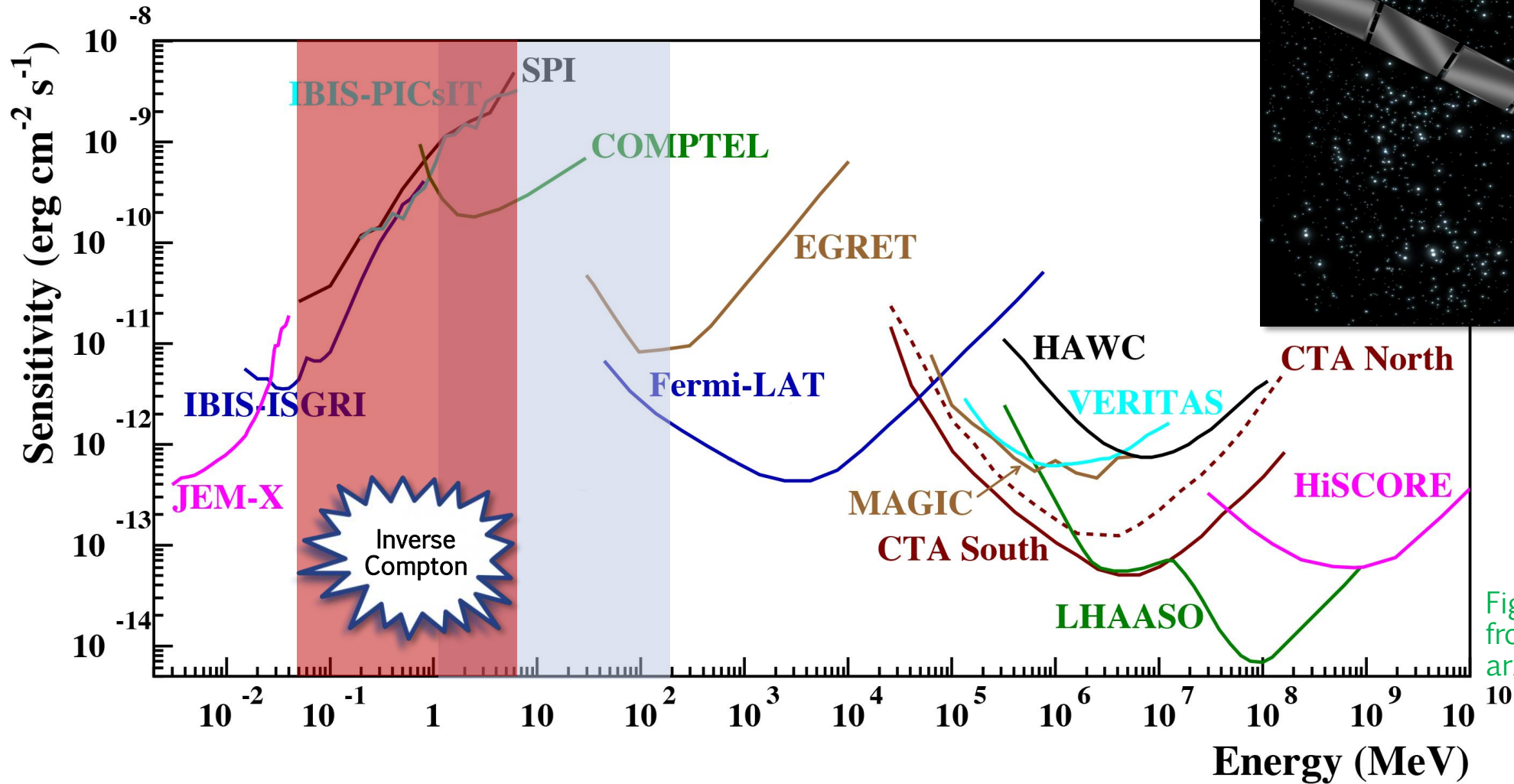


Figure adapted from Tatischeff+ arxiv:1805.06435

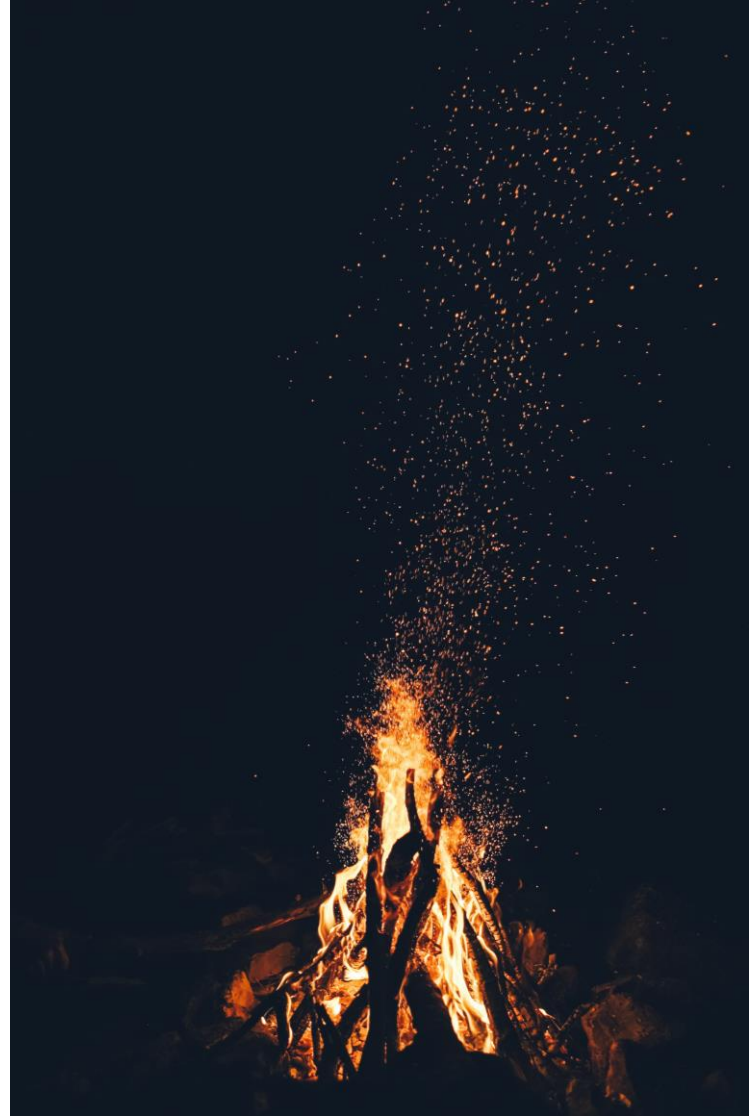
Annihilation channels

3 annihilation channels: $\chi\chi \rightarrow e^+e^-$

$$\chi\chi \rightarrow \mu^+\mu^-$$

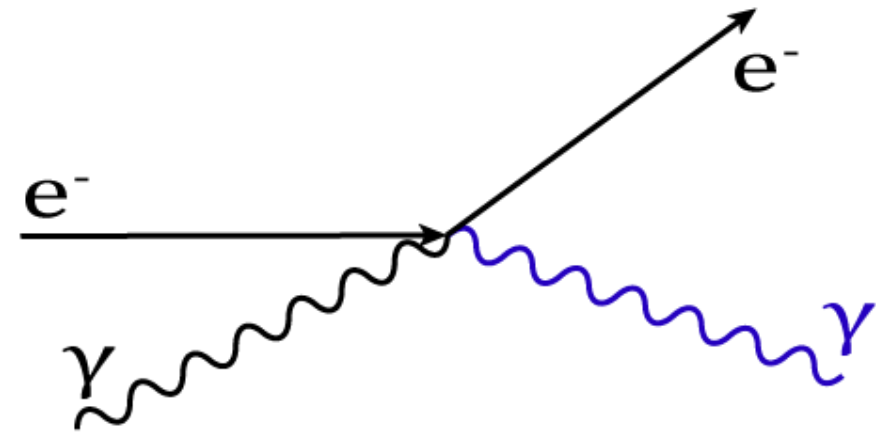
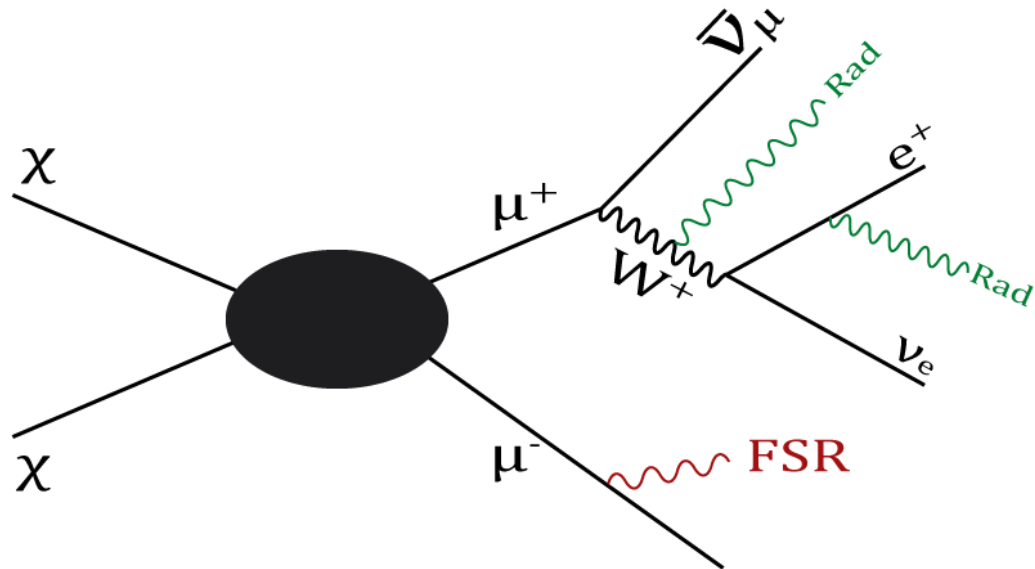
$$\chi\chi \rightarrow \pi^+\pi^-$$

Kinematically open: $m_\chi > m_i \quad i = e, \mu, \pi$



Total Flux

$$\Phi_{TOT} = \Phi_{FSR} + \Phi_{Rad} + \Phi_{ICS}$$



Inverse Compton Scattering

$$\chi\chi \rightarrow \mu^+\mu^-\gamma \quad \text{FSR}$$

$$\chi\chi \rightarrow \mu^+\mu^- \quad \text{Rad}$$

$$\begin{matrix} \text{L} \\ \text{└} \end{matrix} \rightarrow e^+\nu_e\bar{\nu}_\mu\gamma$$

$$\chi\chi \rightarrow (\dots) \rightarrow e^+e^-$$

$$e^- + \gamma \rightarrow e^- + \gamma$$

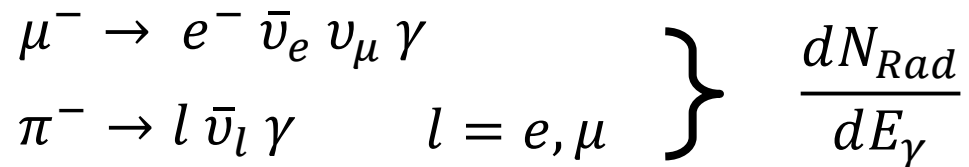
Final State Radiation

$$\frac{d\phi_{FSR}}{dE_\gamma d\Omega}(E_\gamma, \theta) = \frac{1}{4\pi} \frac{\langle \sigma_{ann} v \rangle}{2m_{DM}^2} \frac{dN_{FSR}}{dE_\gamma} J(\theta)$$

Particle
Properties

Energy spectrum per
annihilation event

Radiative Decay:



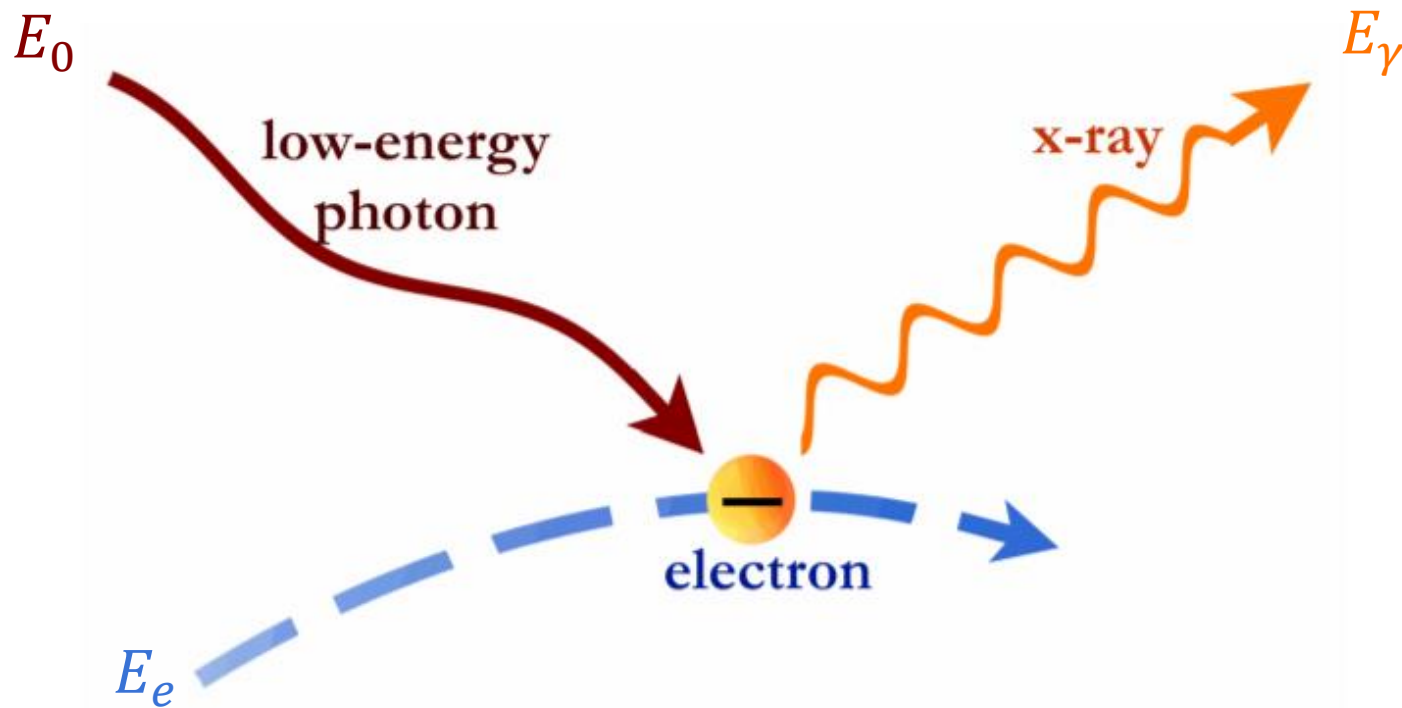
Angle in the sky DM density

$$J(\theta) = \int_{l.o.s} \rho^2(r(s, \theta)) ds$$

Line of sight

Inverse Compton Scattering

$$\chi\chi \rightarrow (\dots) \rightarrow e^+ e^-$$



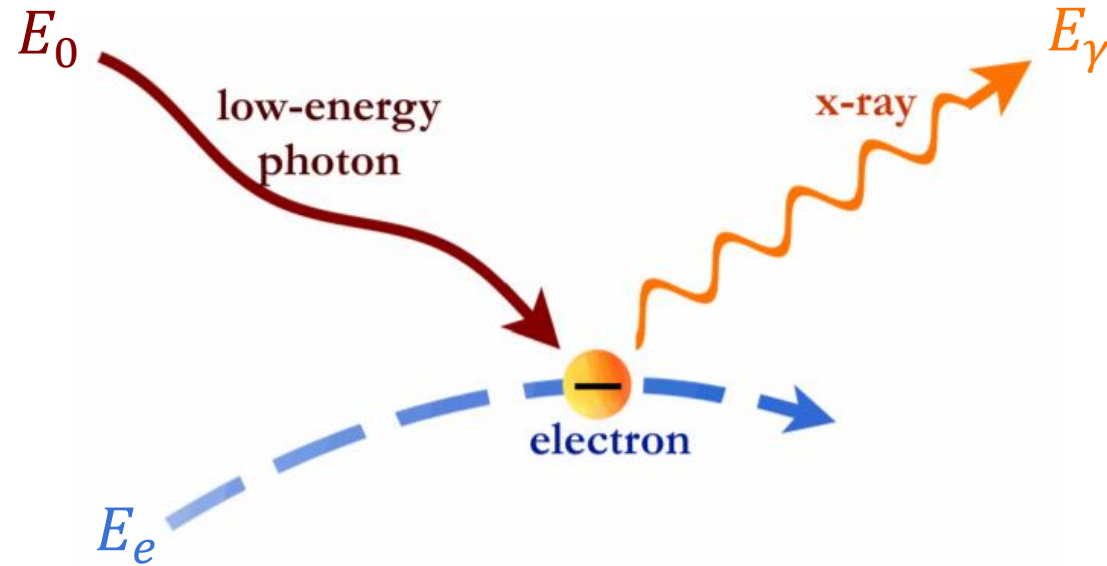
3 kinds of photons:

- CMB
- IR (dust)
- Optical (starlight)

X rays

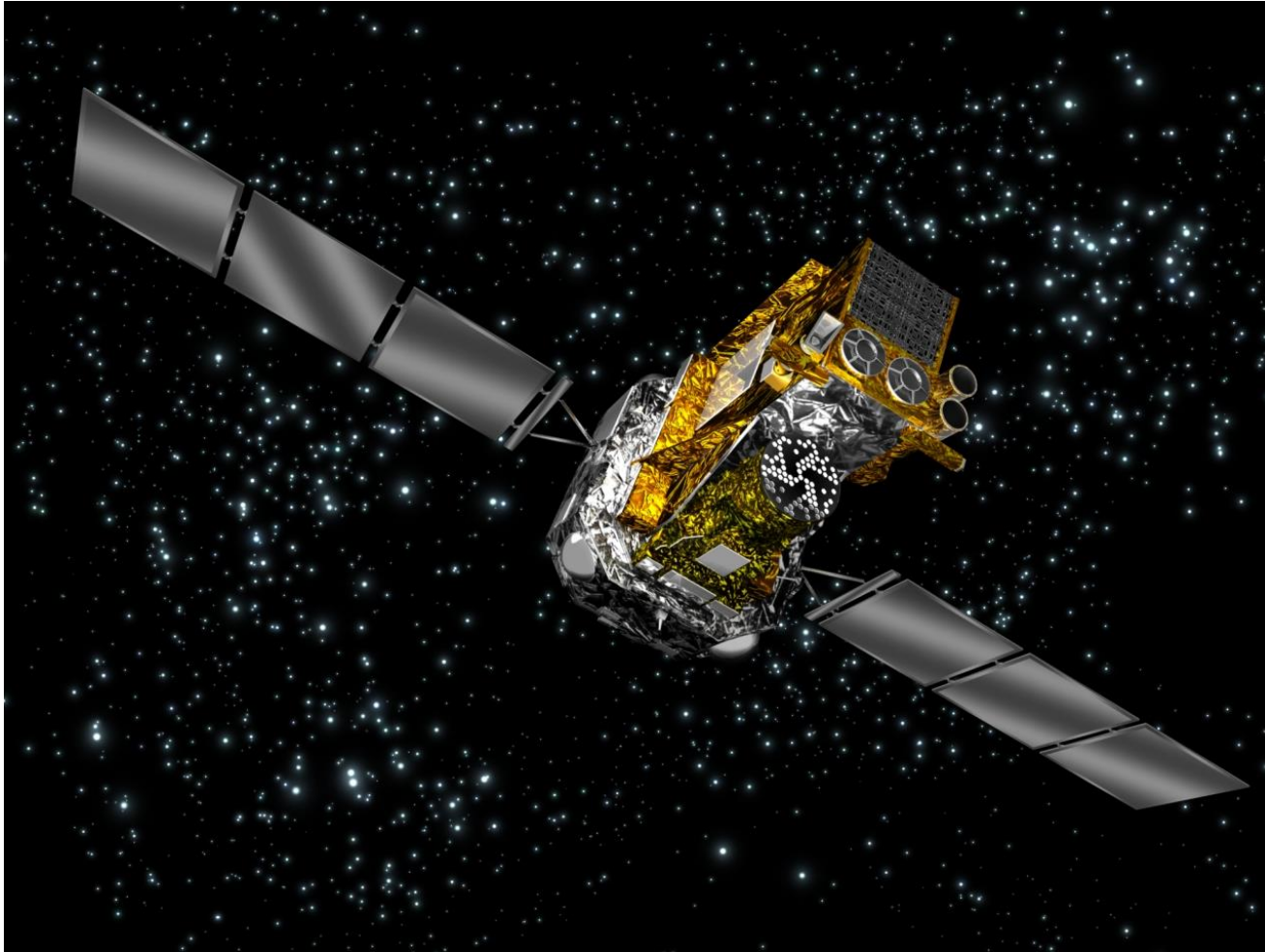
$$\gamma = \frac{E_e}{m_e}$$

$$E_\gamma \approx 4\gamma^2 E_0$$



Type	E_0 [eV]	E_e [GeV]	E_γ [keV]
CMB	10^{-4}	5	40
IR	10^{-2}	0.5	40
Opt	10	0.05	400

} X rays



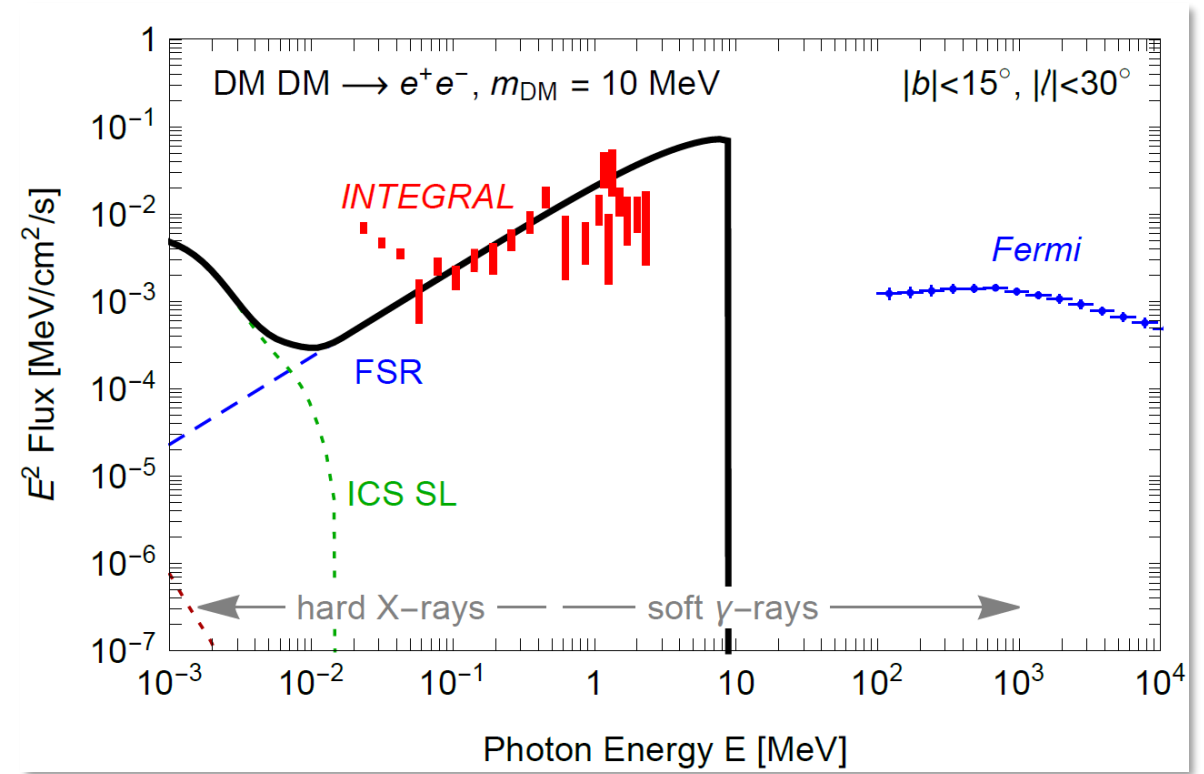
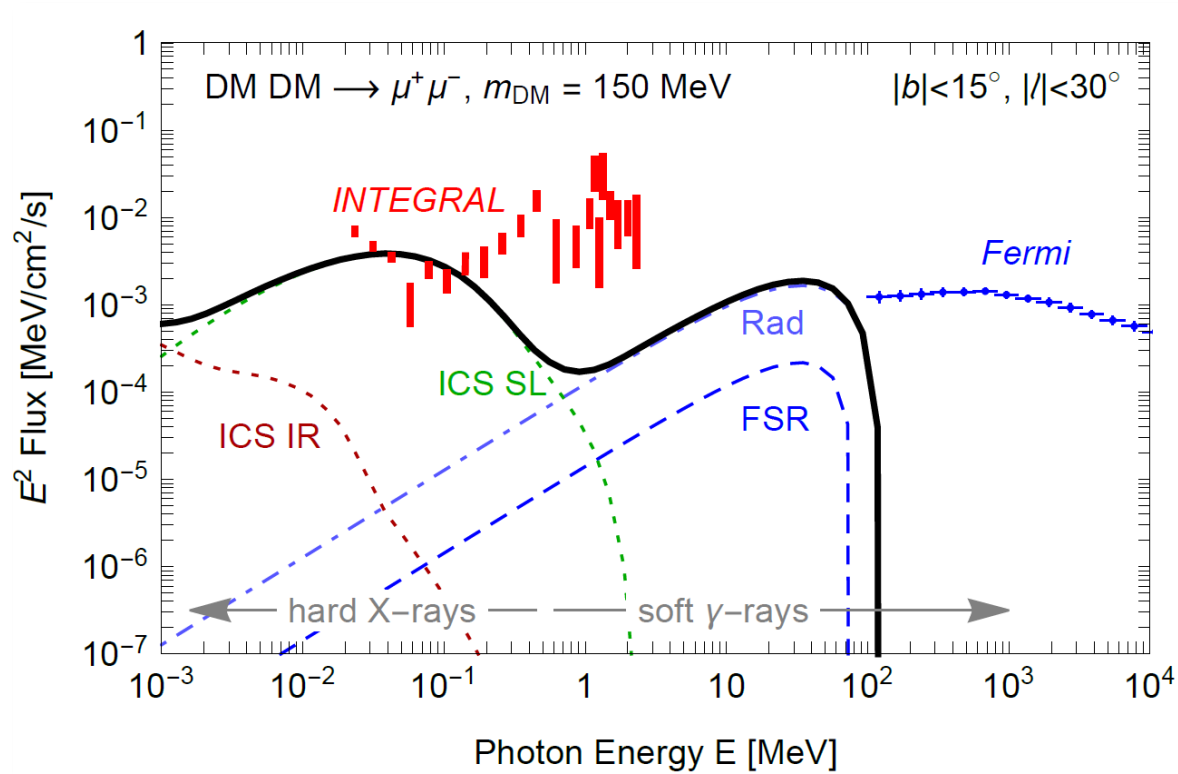
Data taking: 2003-2009

Photons in the energy range:
20 keV ~ 8 MeV

- Hard X rays
- Soft gamma rays

INTEGRAL:
INTErnational Gamma-Ray Astrophysics Laboratory

Photon Spectra



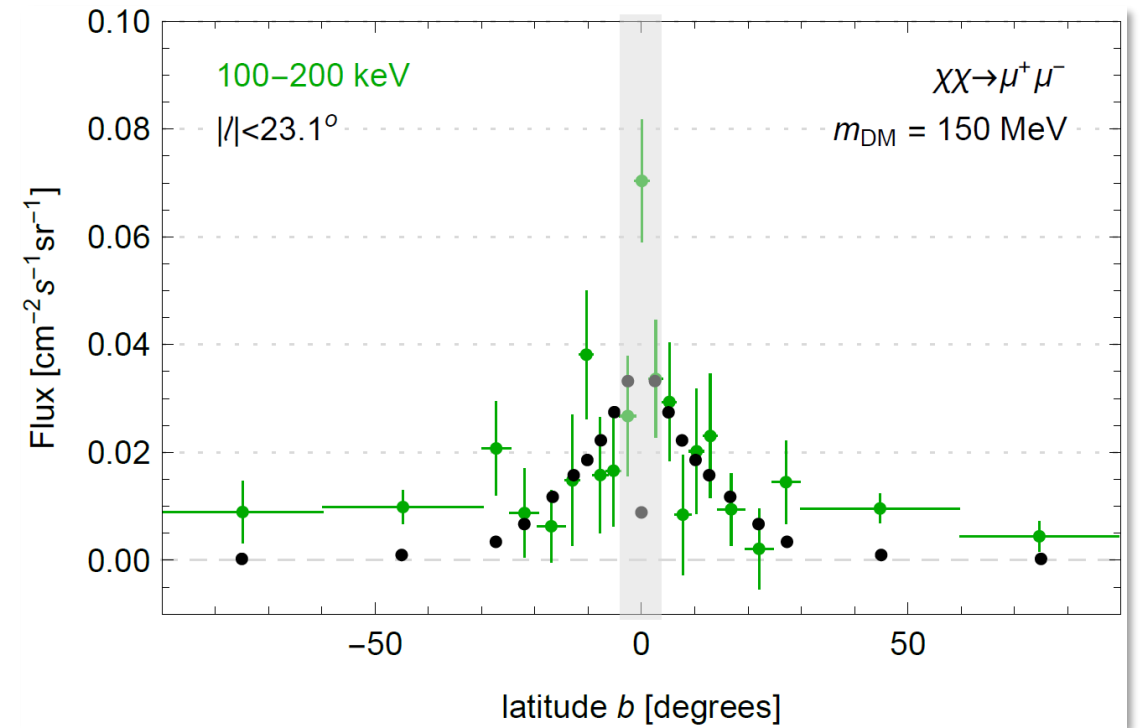
Data set

5 energy bands:

- 27-49 keV
- 49-90 keV
- 100-200 keV
- 200-600 keV
- 600-1800 keV

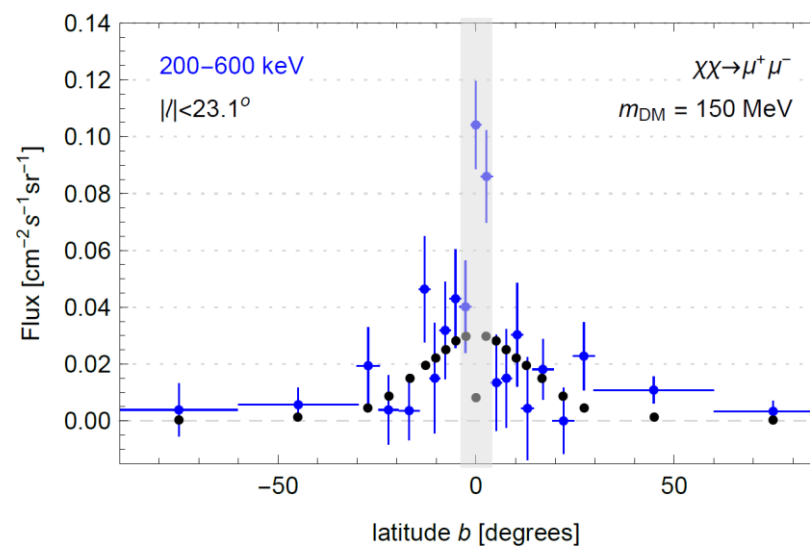
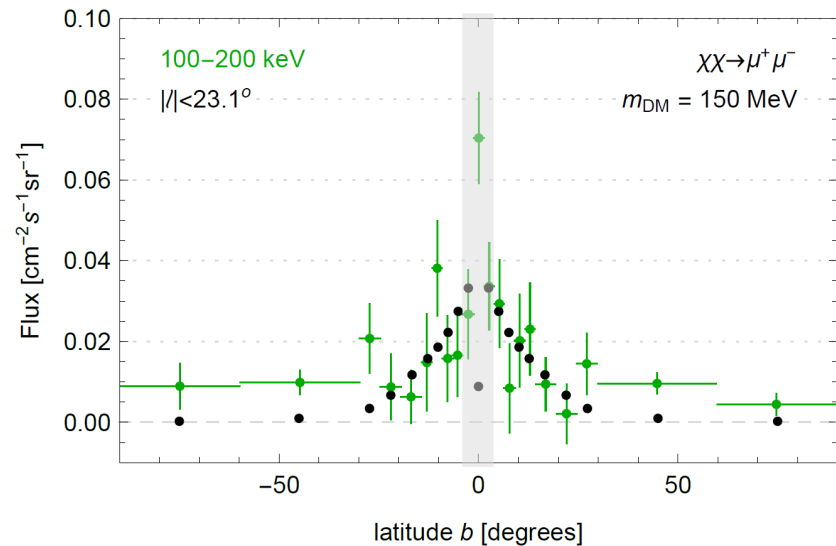
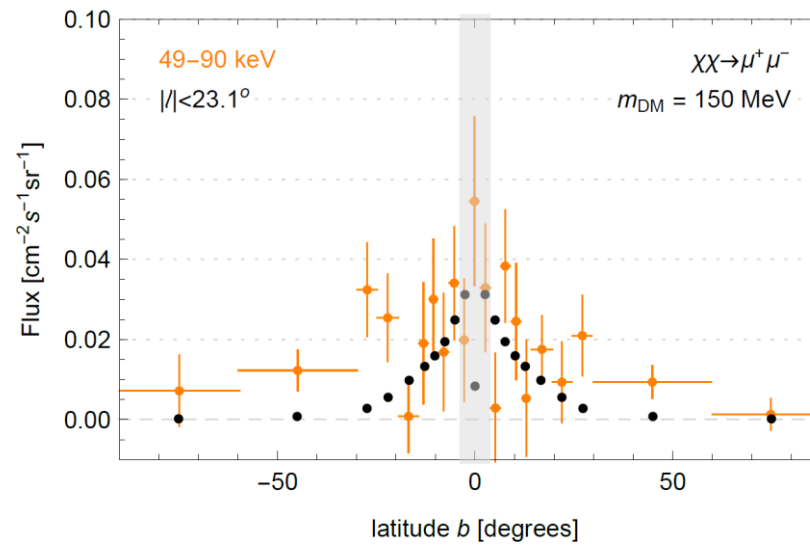
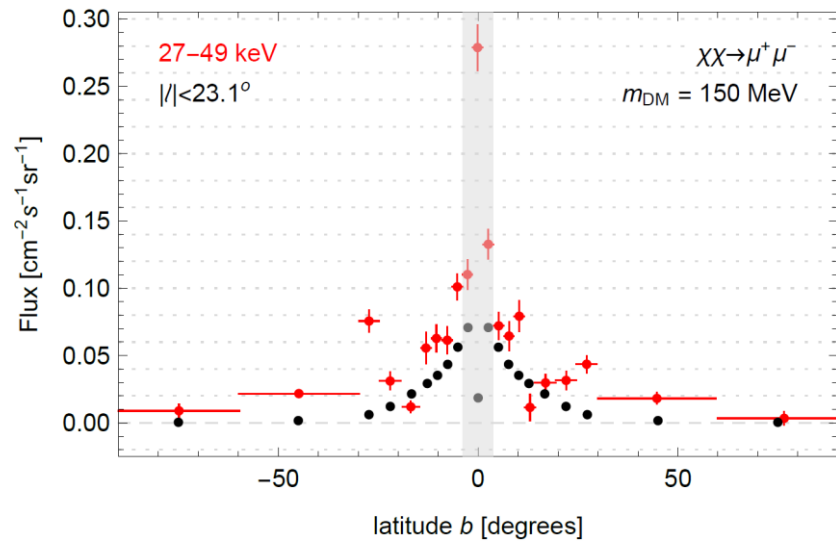
21 bins in latitude (15 for the fifth band)

$-23.1^\circ < l < 23.1^\circ$ ($|l| < 60^\circ$ for the fifth band)

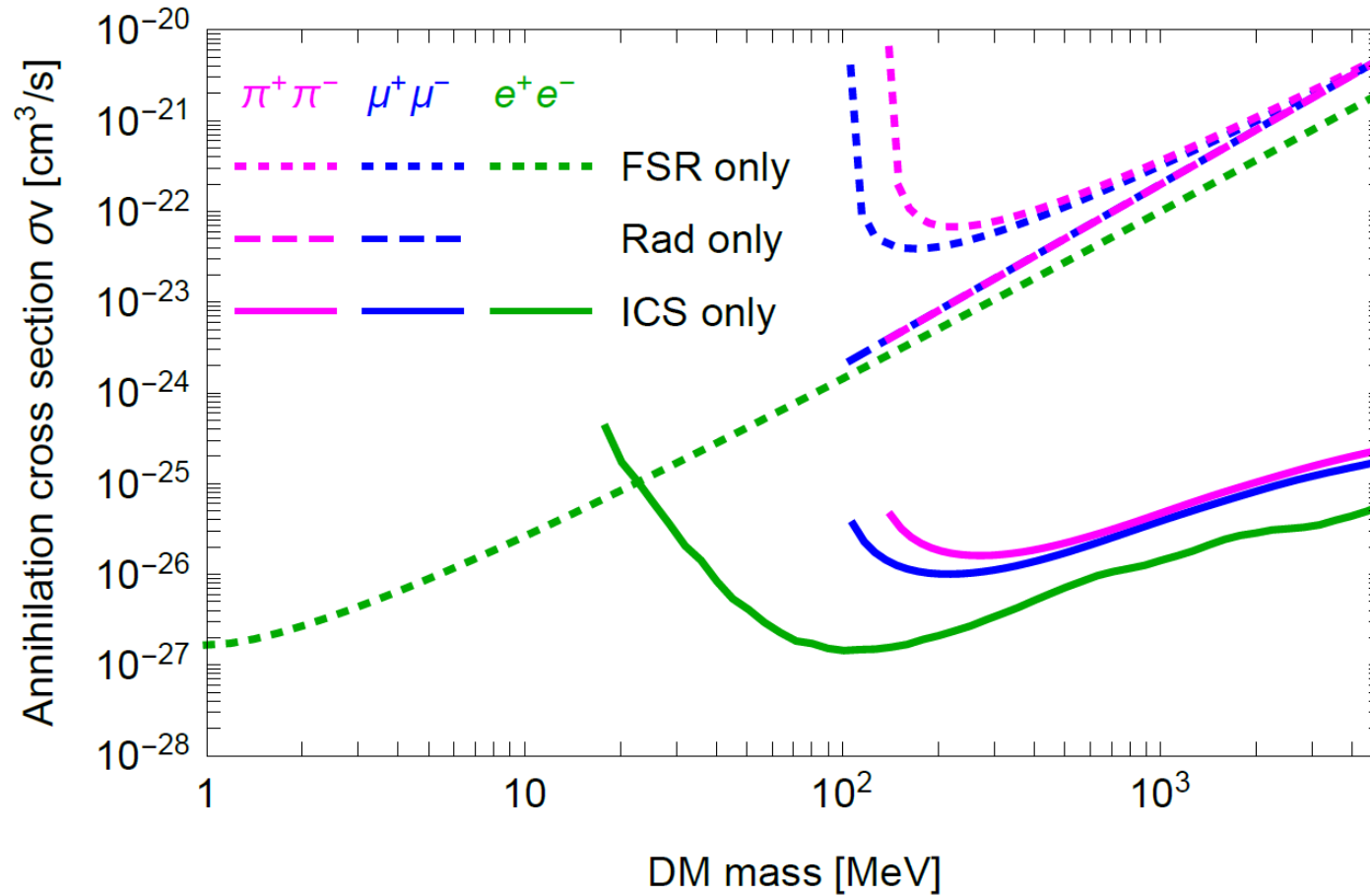


INTEGRAL data (green points)
Bouchet et al. (2011)

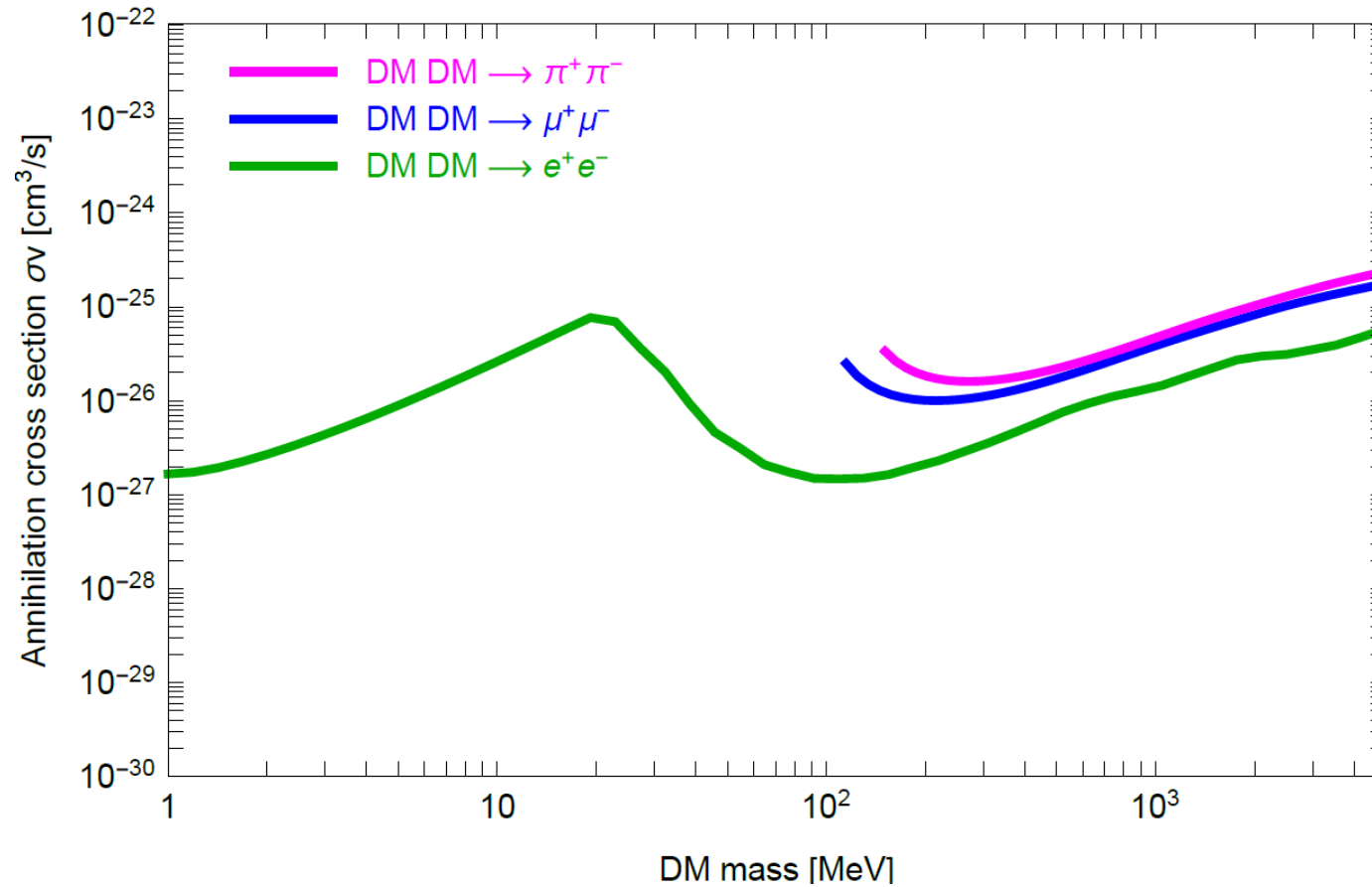
Angular profile



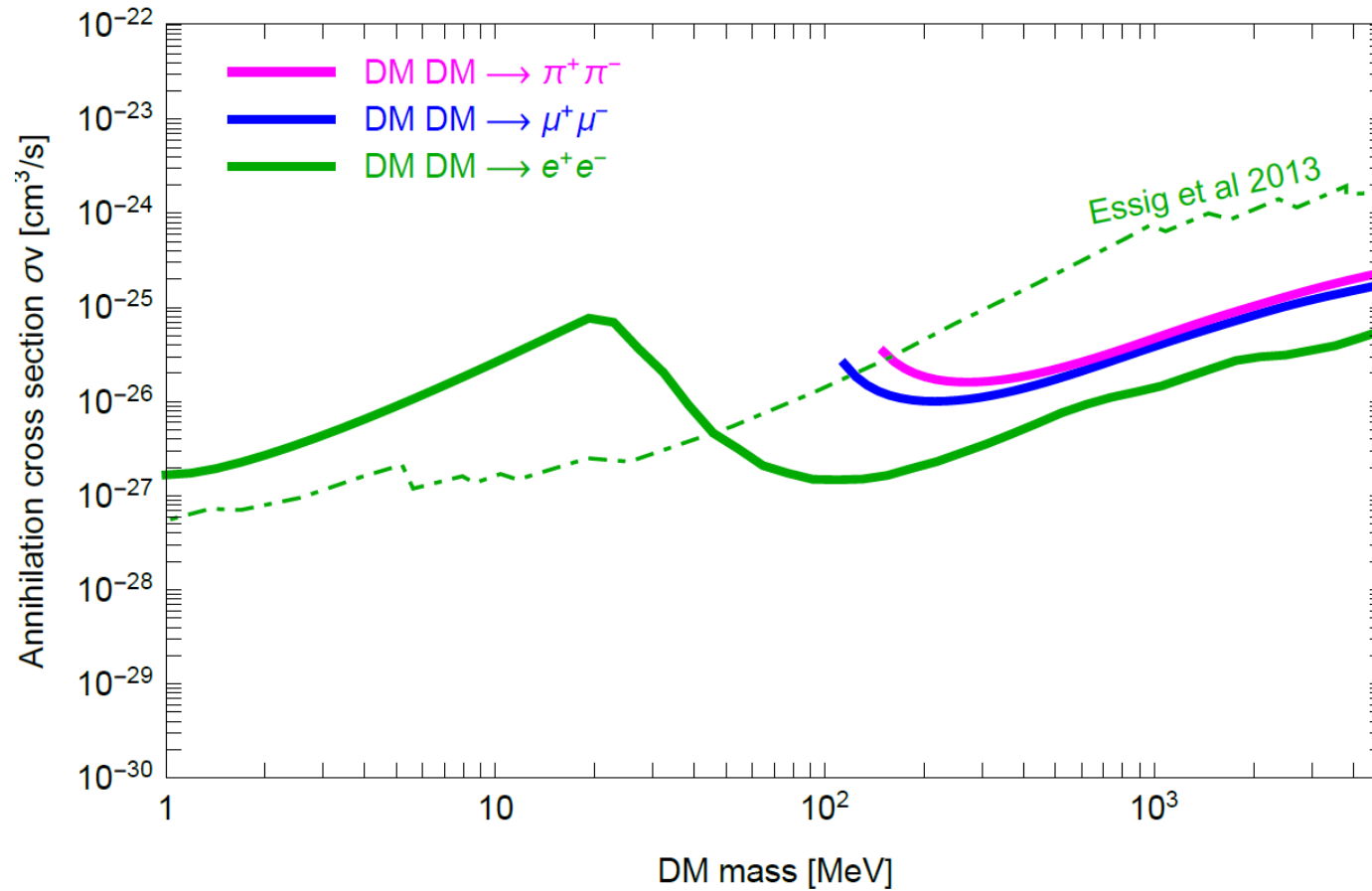
Bounds from FSR, Rad, ICS



Constraints on sub-GeV Dark Matter

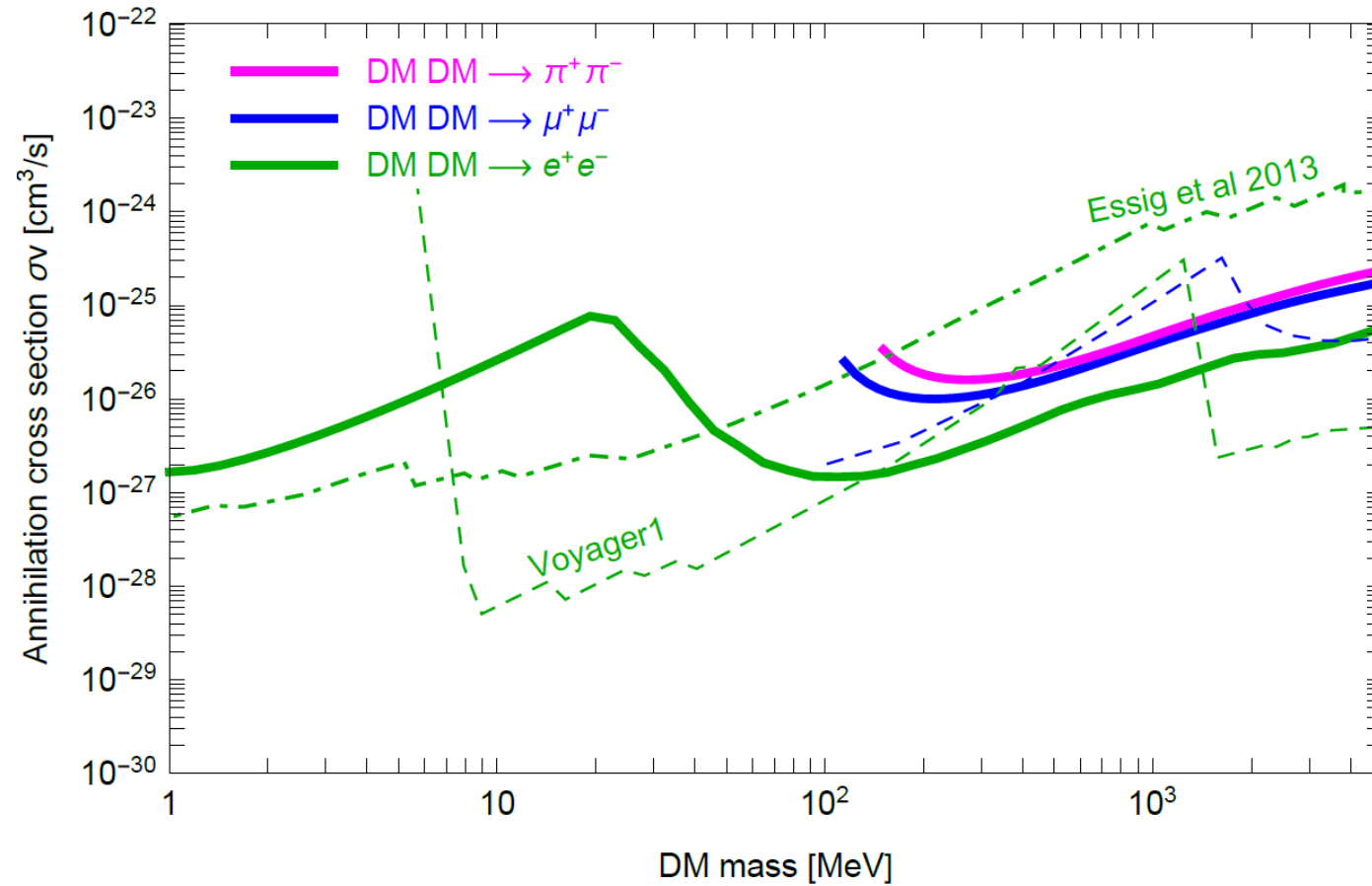


Constraints on sub-GeV Dark Matter



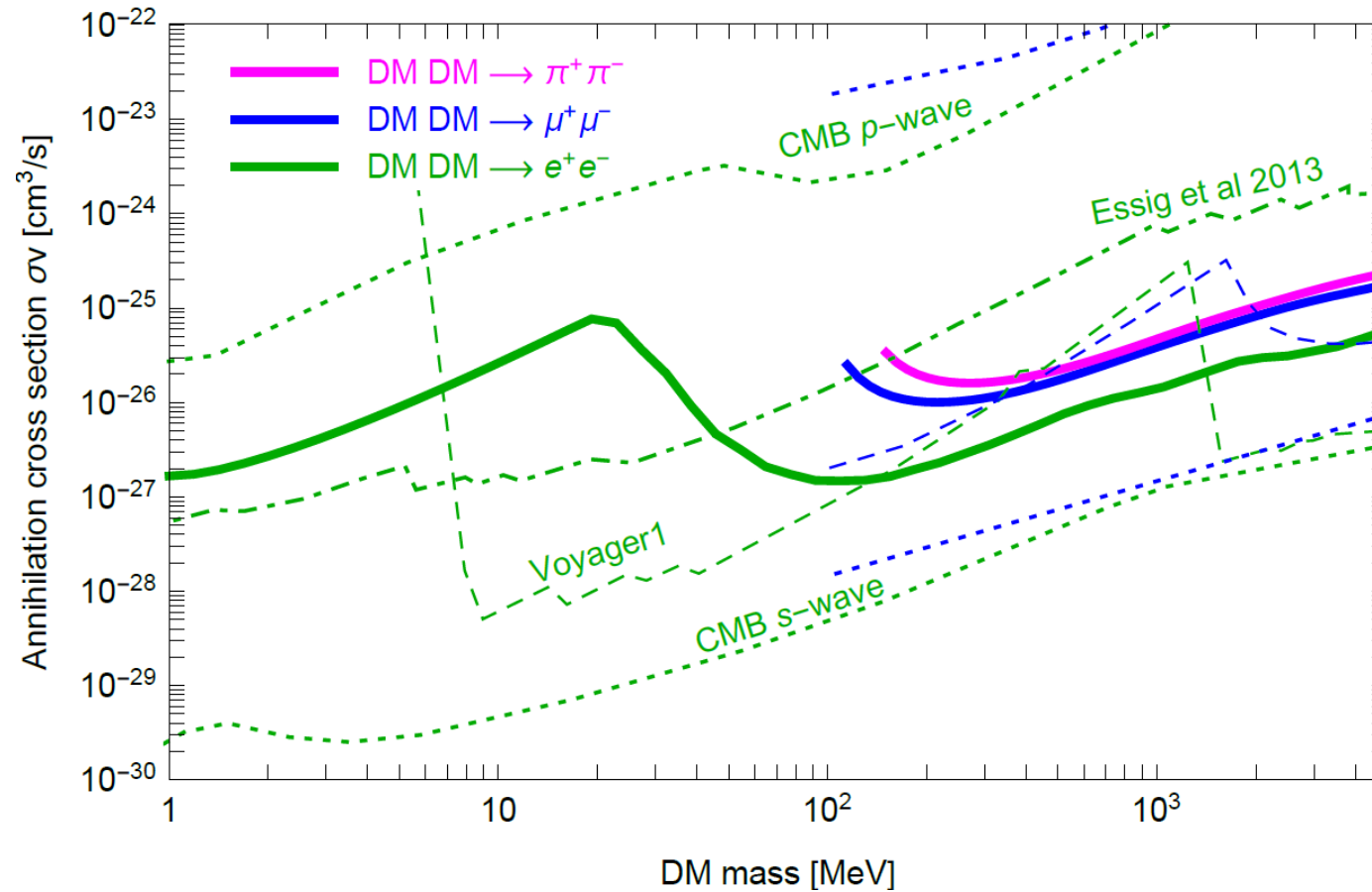
Essig et al., JHEP 11 (2013) 193

Constraints on sub-GeV Dark Matter



Boudaud et al., Phys. Rev. Lett. 119 (2017) 021103

Constraints on sub-GeV Dark Matter



Slatyer, Phys. Rev. D 93 (2016) 023527

Lopez-Honorez et al., JCAP 07 (2013) 046

Diamanti et al., JCAP 02 (2014) 017

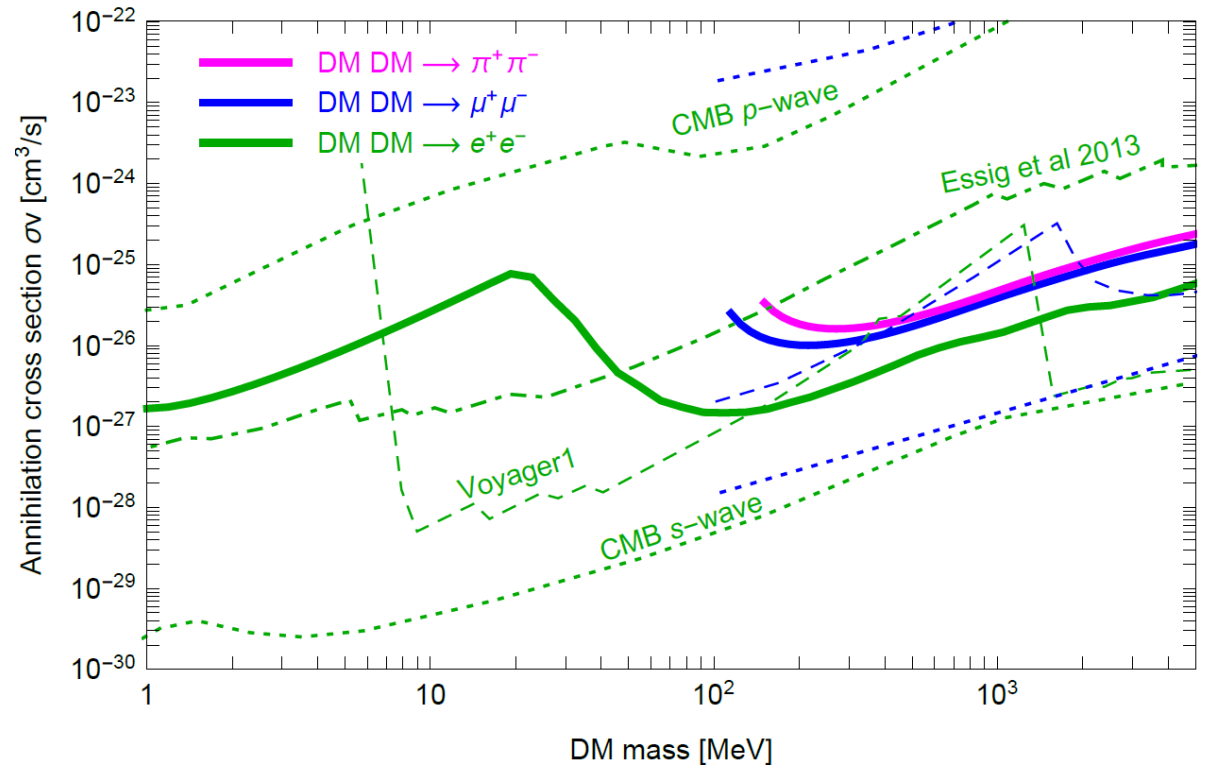
Liu et al., arXiv:2008.01084

Conclusions

- $1 \text{ MeV} \leq m_\chi \leq 5 \text{ GeV}$
- Include Inverse Compton Scattering
- X-ray data from INTEGRAL telescope

Strongest bound (if p-wave):

$$150 \text{ MeV} \leq m_\chi \leq 1.5 \text{ GeV}$$

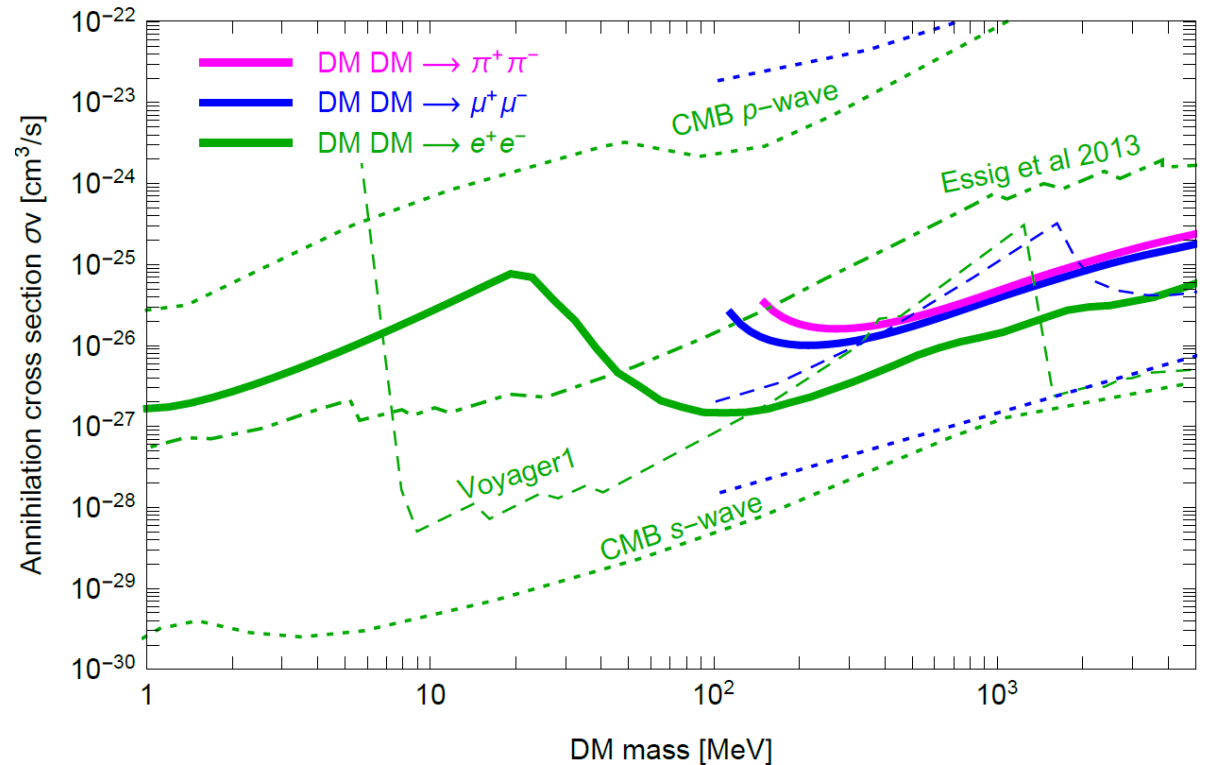


Conclusions

- $1 \text{ MeV} \leq m_\chi \leq 5 \text{ GeV}$
- Include Inverse Compton Scattering
- X-ray data from INTEGRAL telescope

Strongest bound (if p-wave):

$$150 \text{ MeV} \leq m_\chi \leq 1.5 \text{ GeV}$$



Thank you for your attention!