Inverse Compton emission from WIMP annihilation in the Galactic Centre

The Research Council of Norway

in collaboration
with Jim Hinton and
Brian Reville

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK HEIDELBERG

JULIA I. DJUVSLAND - UNIVERSITY OF BERGEN

https://doi.org/10.1016/j.dark.2022.101157

What’s the signal?

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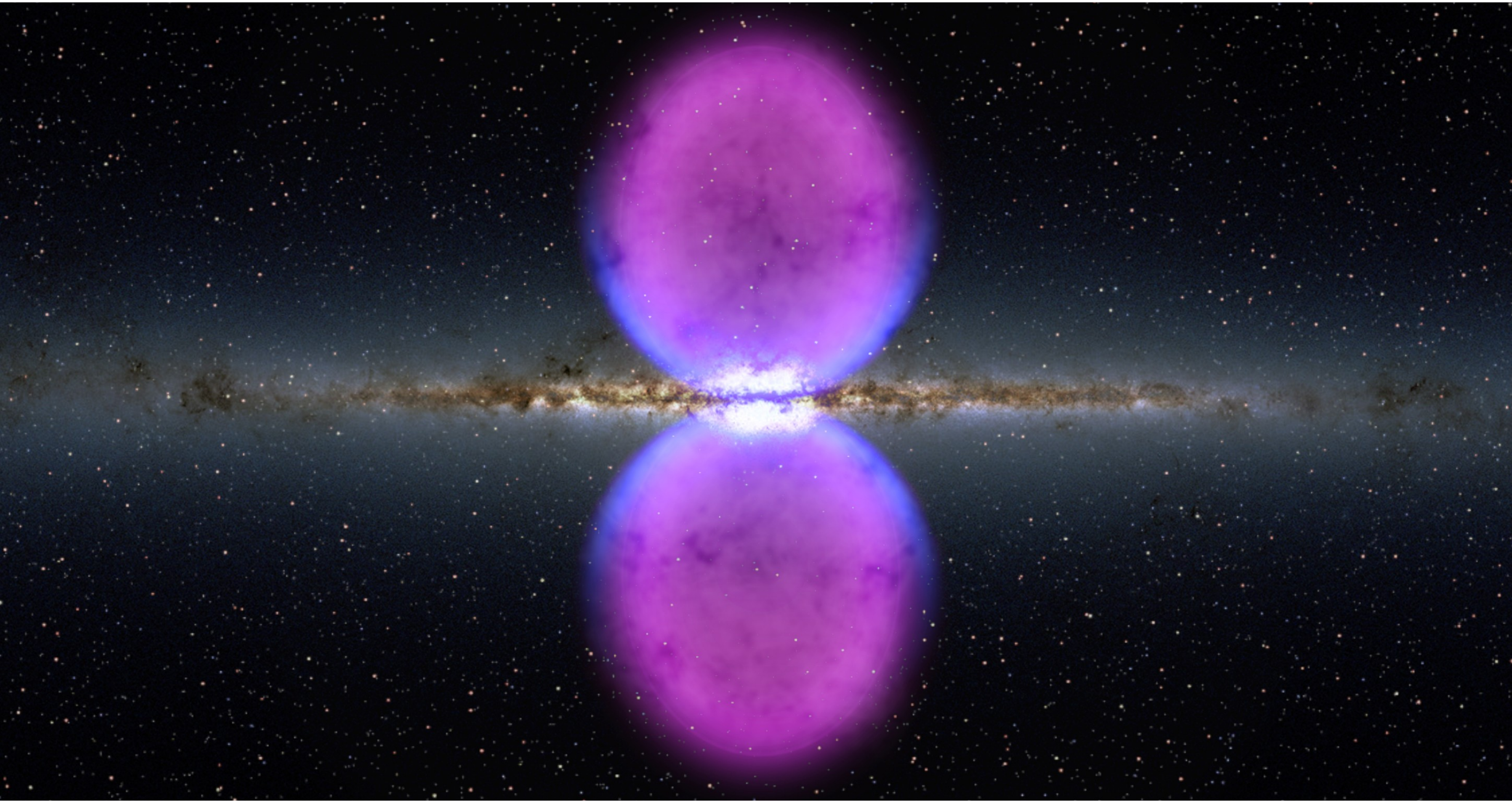
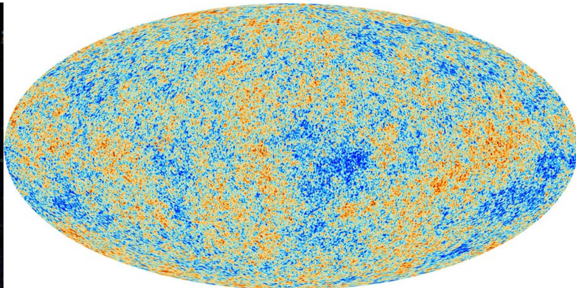
The Galactic Centre

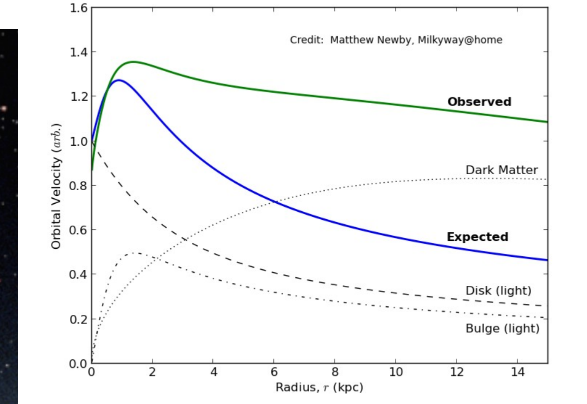


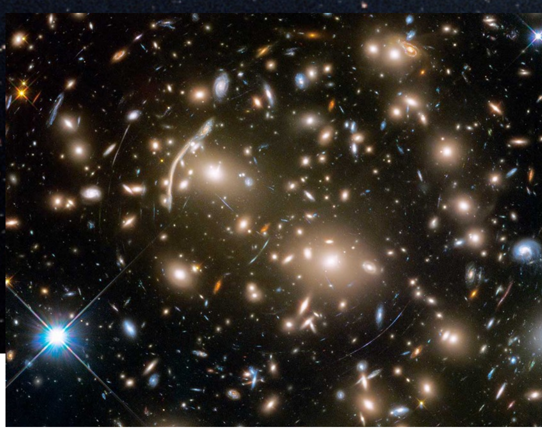
Evidence for Dark Matter

Cosmic Microwave Background

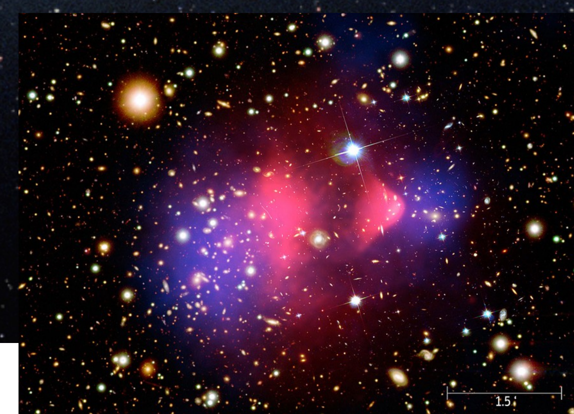


Galaxy Rotation Curves





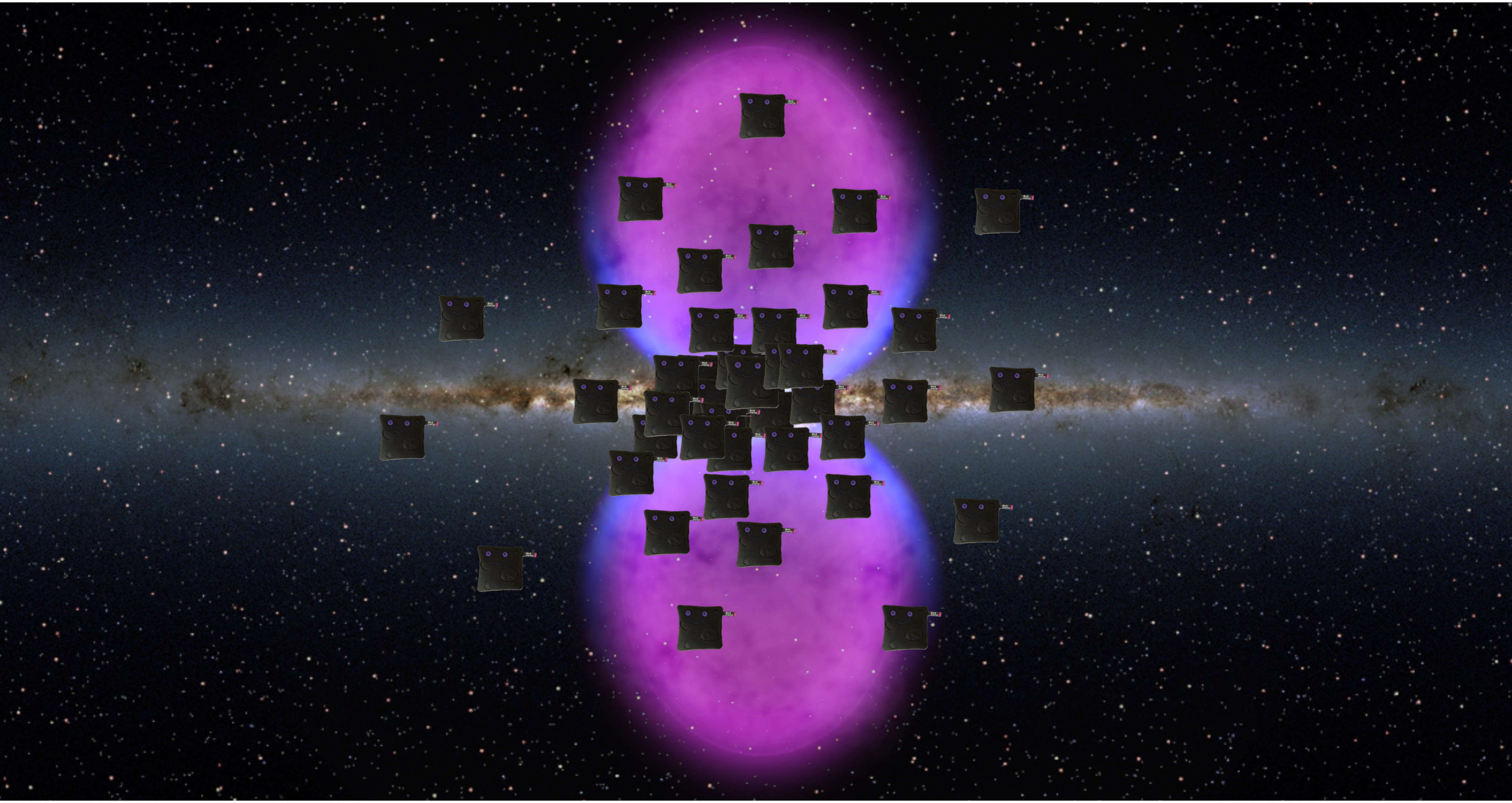
Gravitational lensing



Bullet Cluster

WIMPs in the Galactic Centre

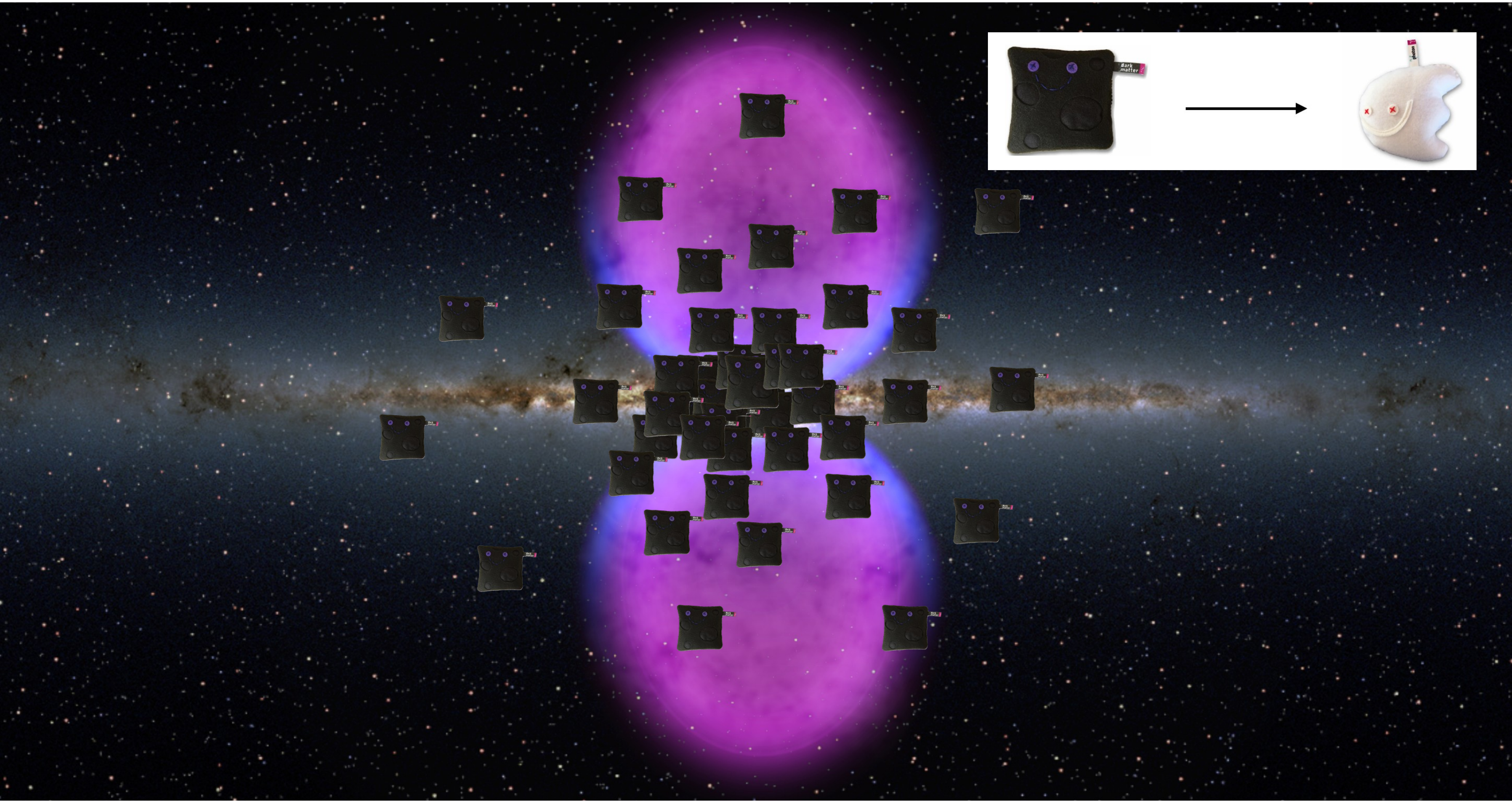
Weakly **I**nteracting (~O(EW scale)) **M**assive **P**article (m_{WIMP} ~O(GeV-TeV))



Easy extension of Standard Model – Correct relic density – Within experimental reach

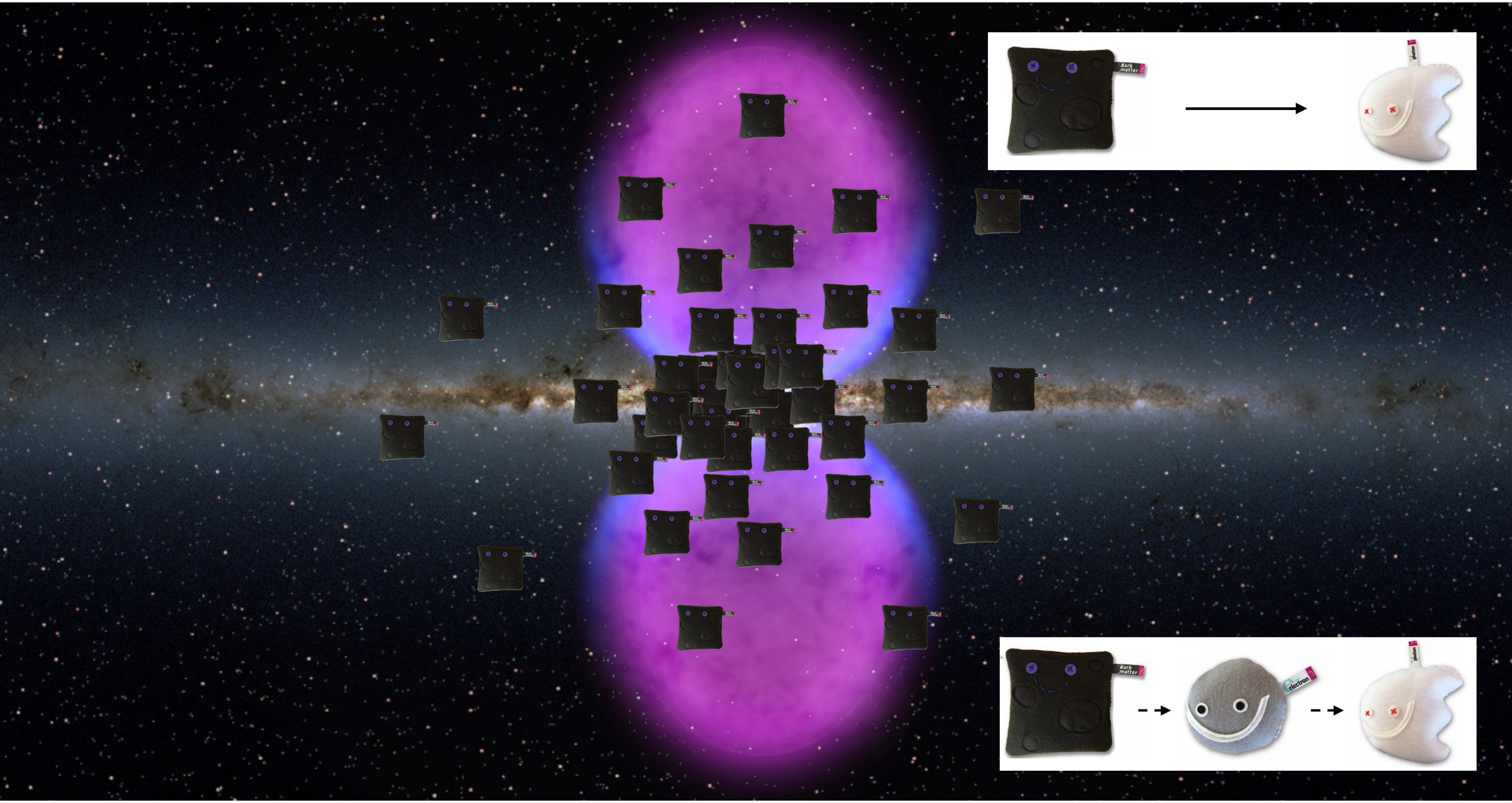
WIMP annihilation in the Galactic Centre

Direct photons



WIMP annihilation in the Galactic Centre

Direct photons

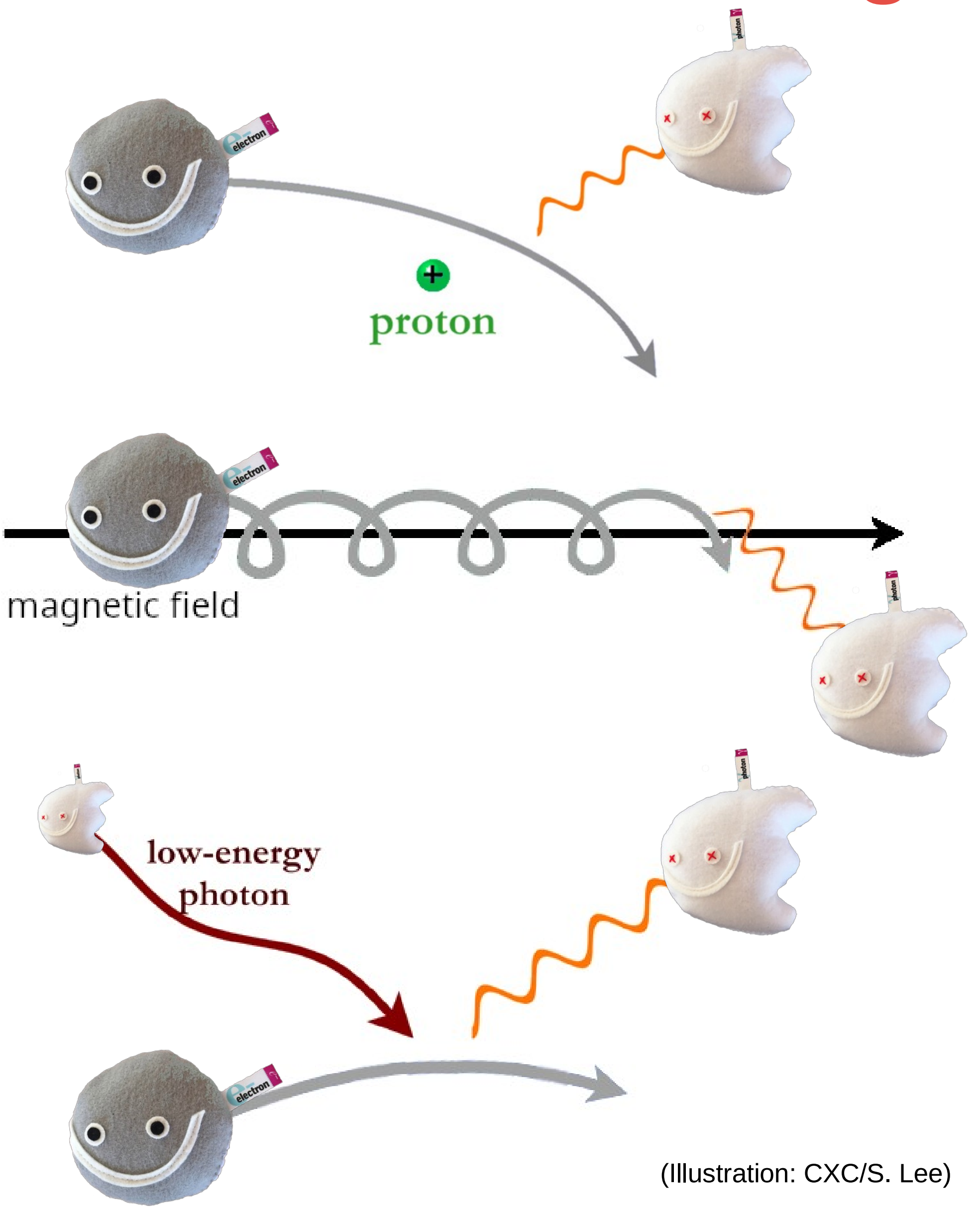


Indirect photons

Indirect Photons from Electron Cooling

Energy loss due to:

- Bremsstrahlung
- Synchrotron emission
- Inverse Compton (IC) scattering on CMB and background light



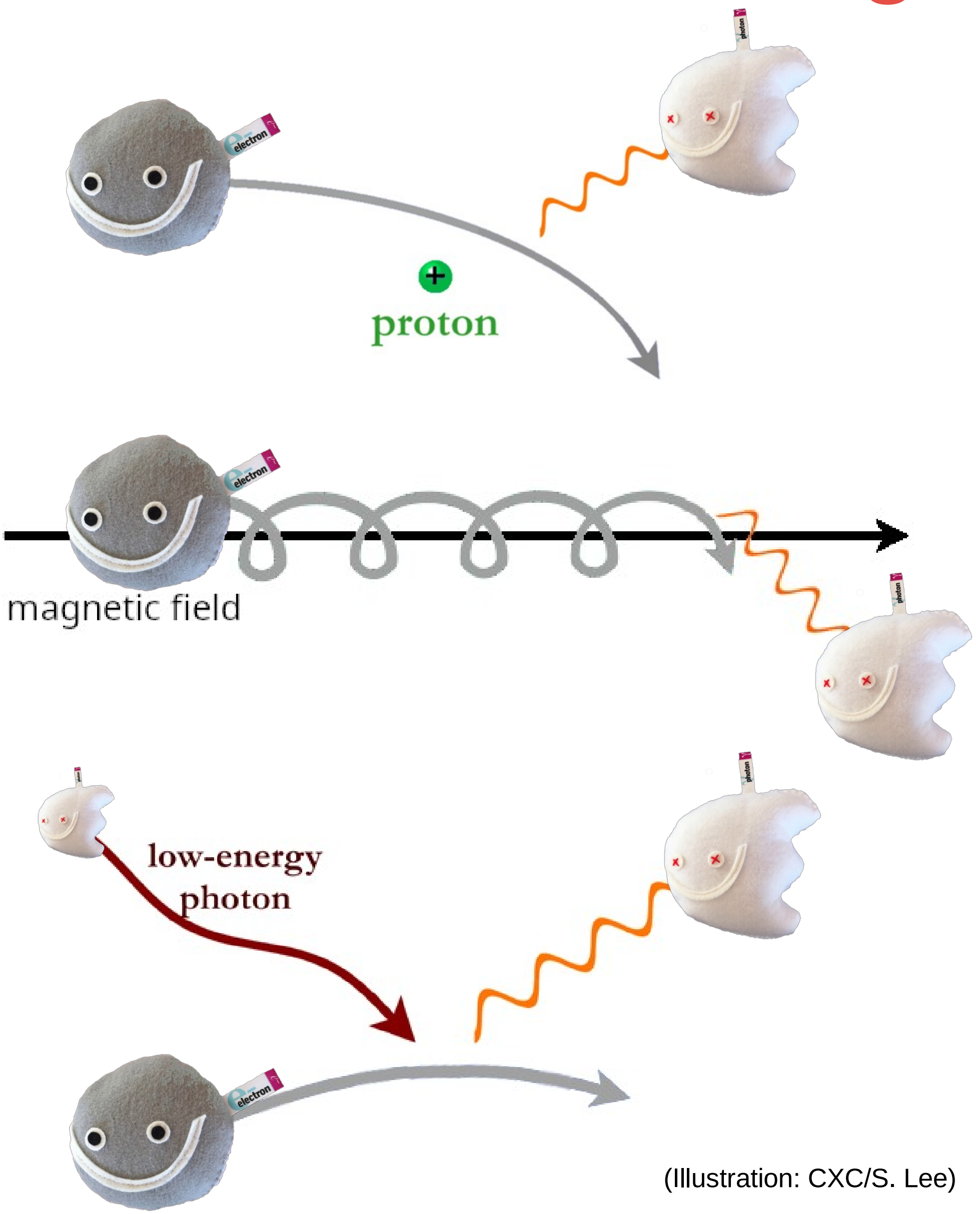
(Illustration: CXC/S. Lee)

Indirect Photons from Electron Cooling

Energy loss due to:

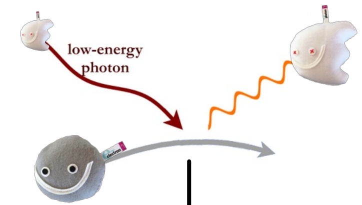
- Bremsstrahlung
- Synchrotron emission
- Inverse Compton (IC) scattering on CMB and background light

→ **How does this look like at the galactic centre?**



(Illustration: CXC/S. Lee)

Electron cooling in the GC

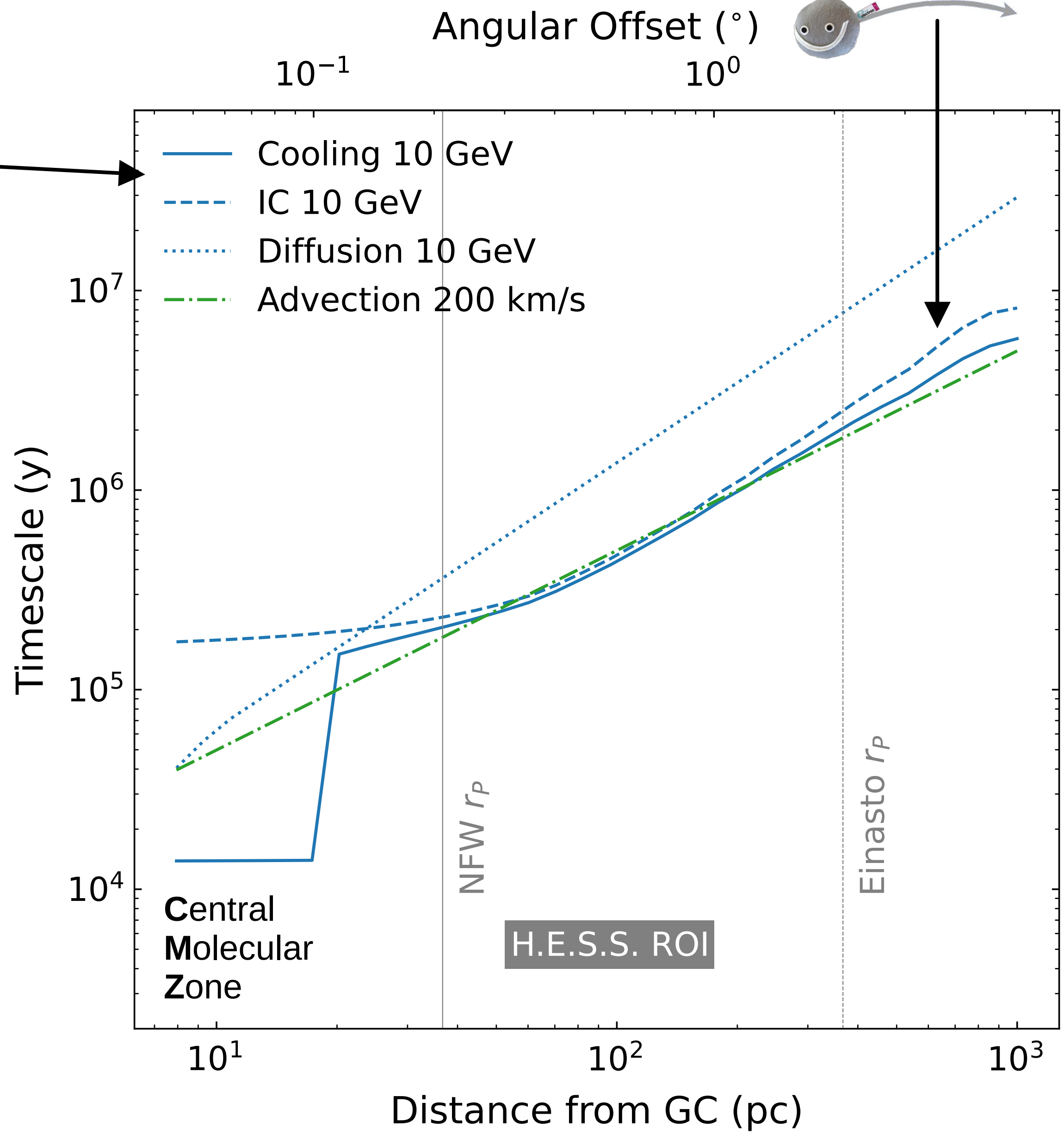


Computed with open source code GAMERA

Diffusion: much smaller than galactic average

$$D_{\parallel} \lesssim 10^{27} E_{\rm TeV}^{1/3} B_{10\mu{\rm G}}^{-1/3} L_{\rm pc}^{2/3}$$

Advection: winds from CMZ



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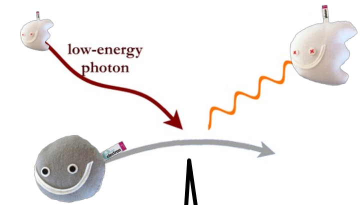

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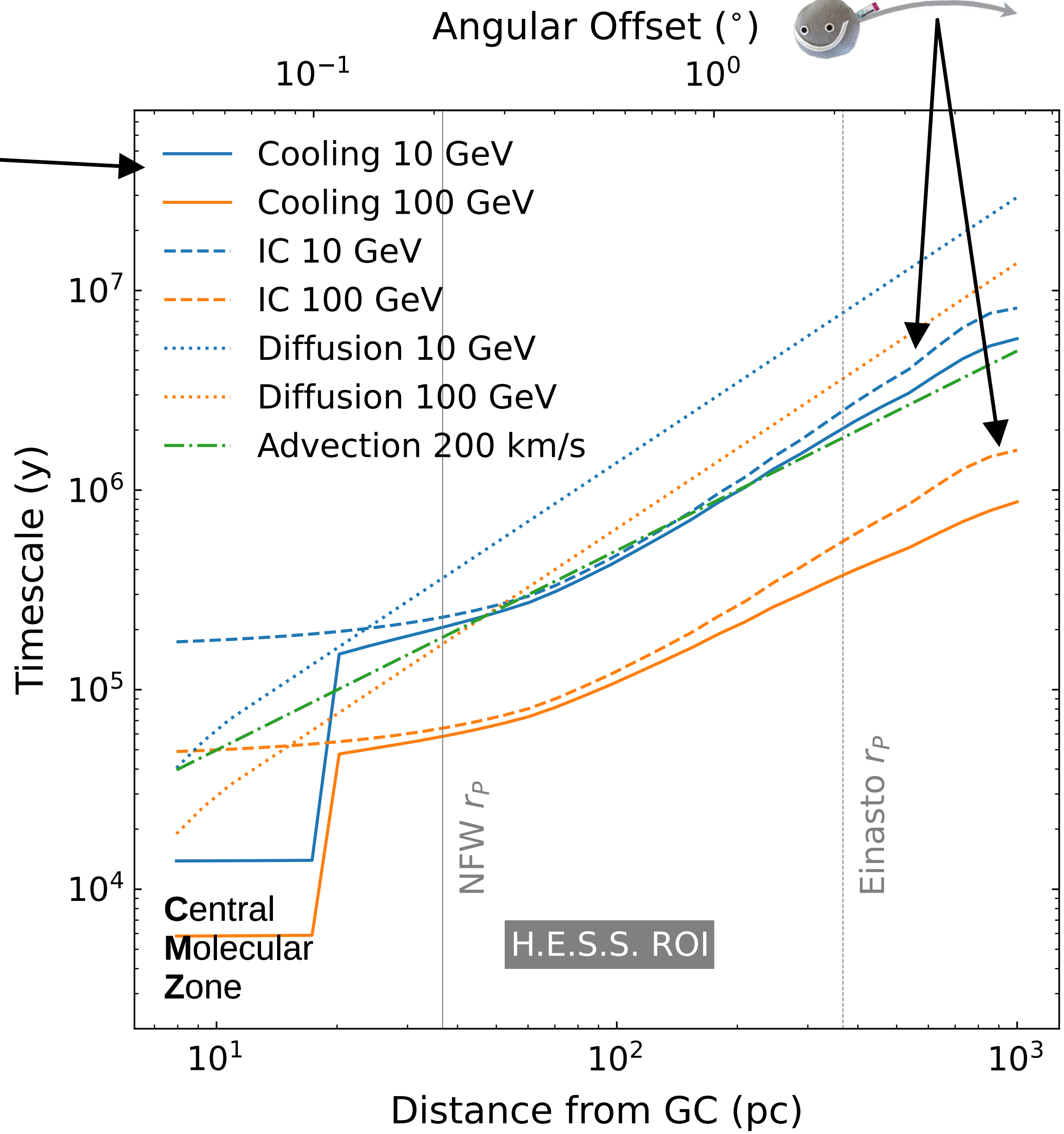

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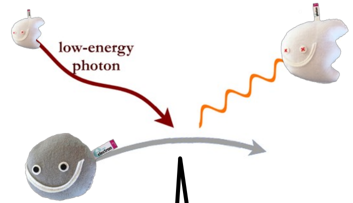

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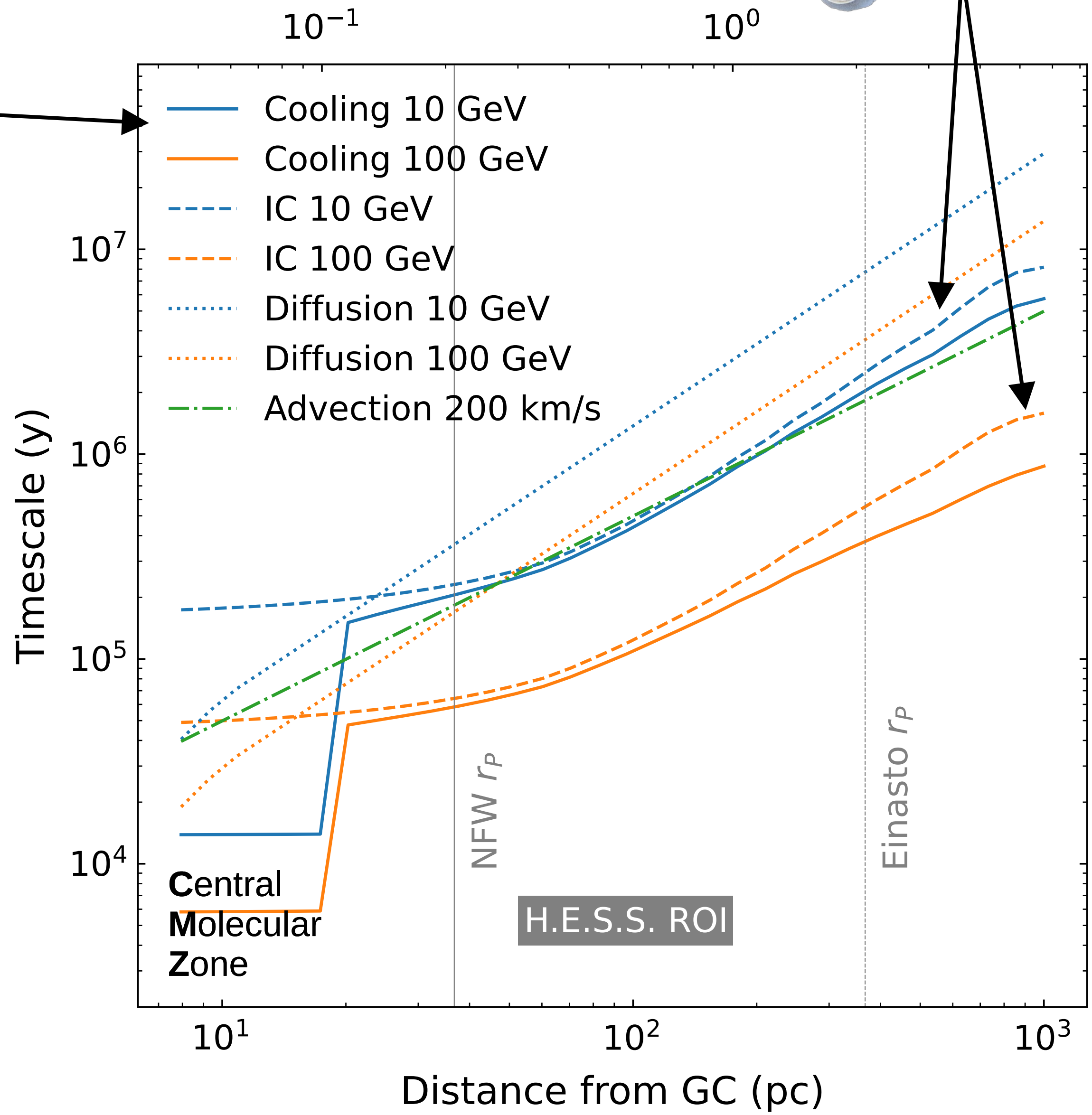
Advection: winds from CMZ

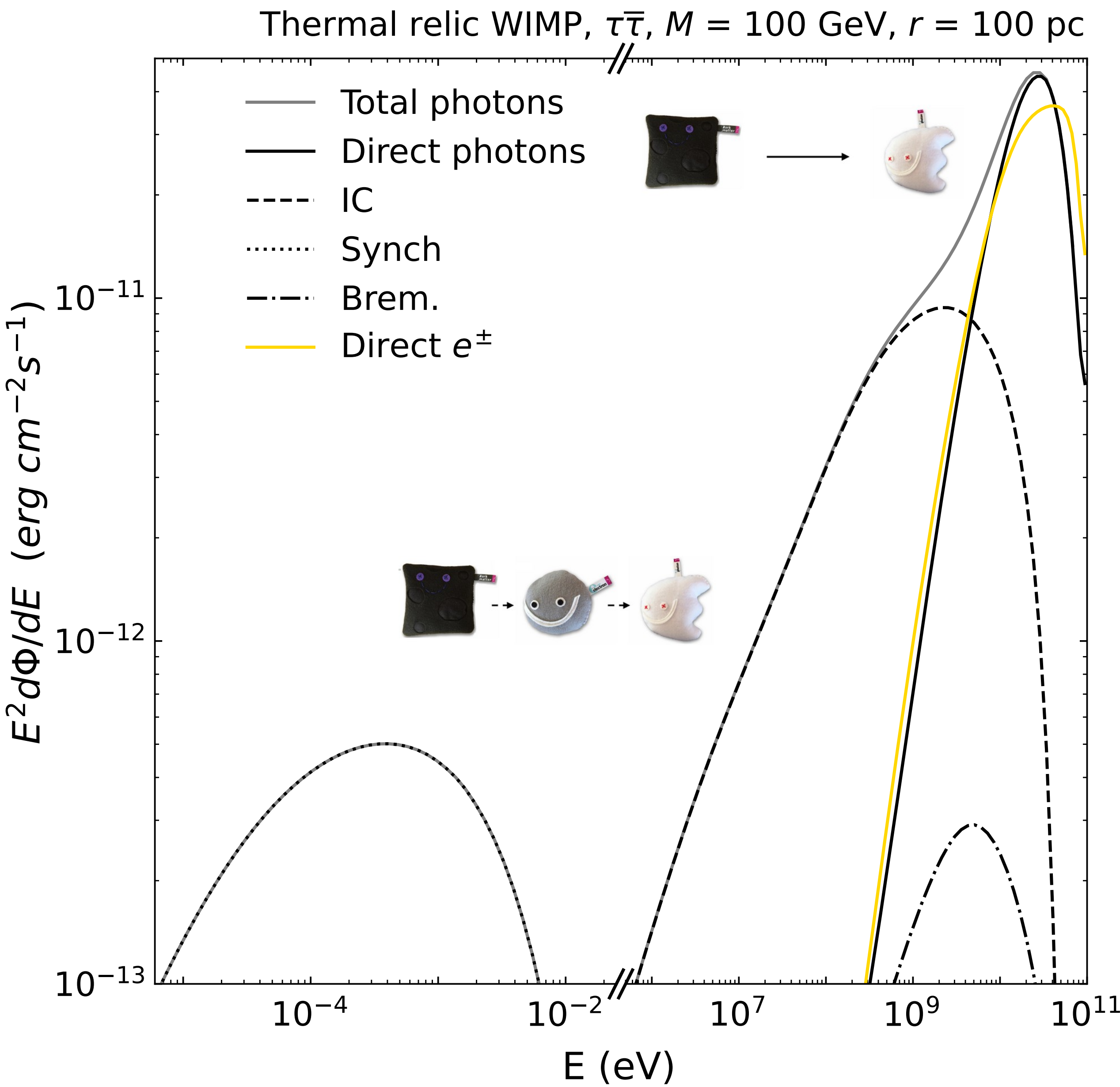
→ **Energetic GC electrons cool before leaving the region**



Photon emission from WIMPs

- Direct component from PPPC4DMID [1].
- Indirect component computed with GAMERA using B-field model by Jansson and Farrar [2] and radiation field model by Popescu et al. [3].

→ **Indirect photon emission adds low energy shoulder**



[1] Cirelli et al., DOI: 10.1088/1475-7516/2011/03/051 & 10.1088/1475-7516/2011/03/019

[2] DOI: 10.1088/0004-637X/757/1/14 & 10.1088/2041-8205/761/1/L11

[3] DOI: 10.1093/mnras/stx1282

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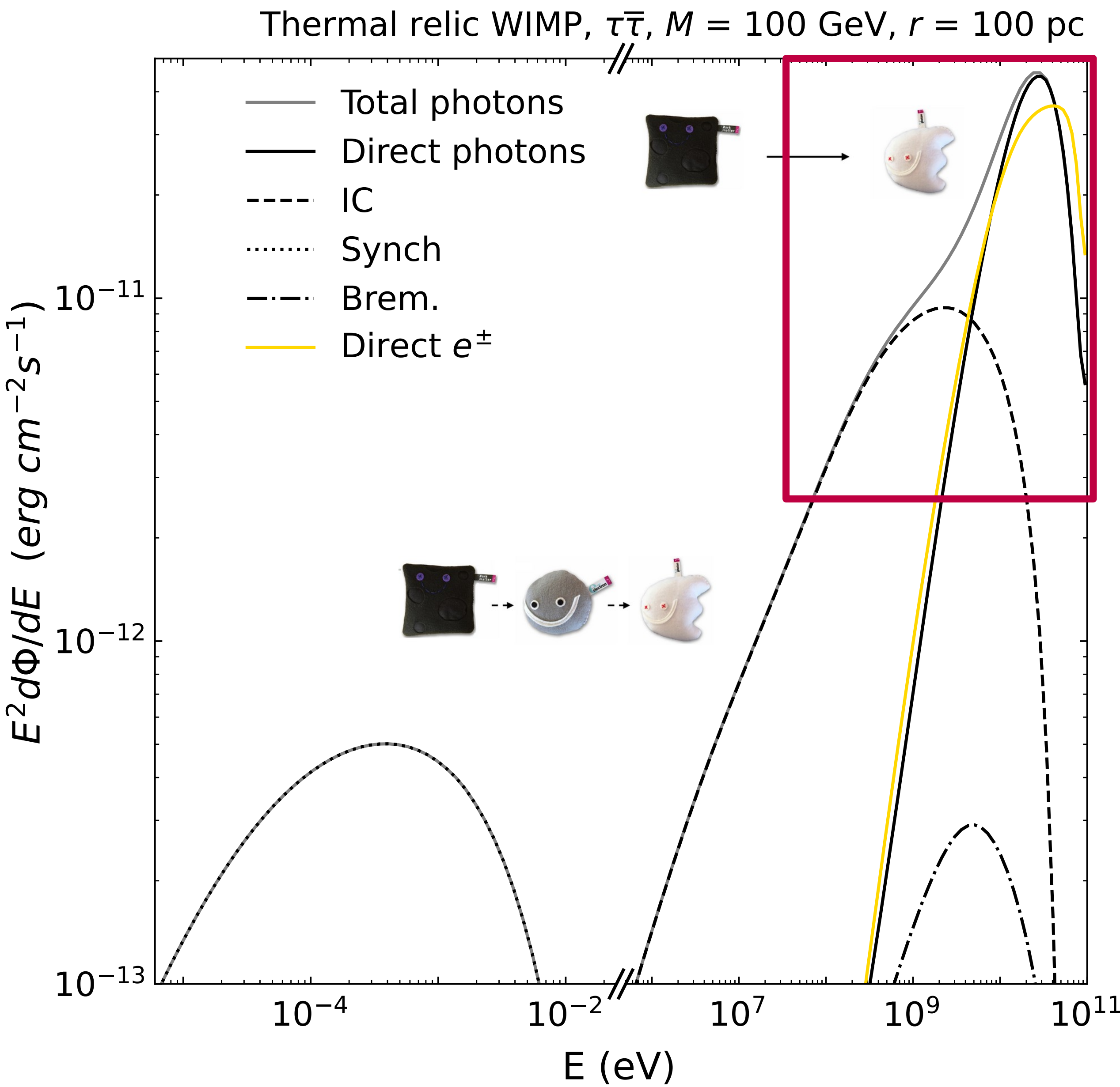

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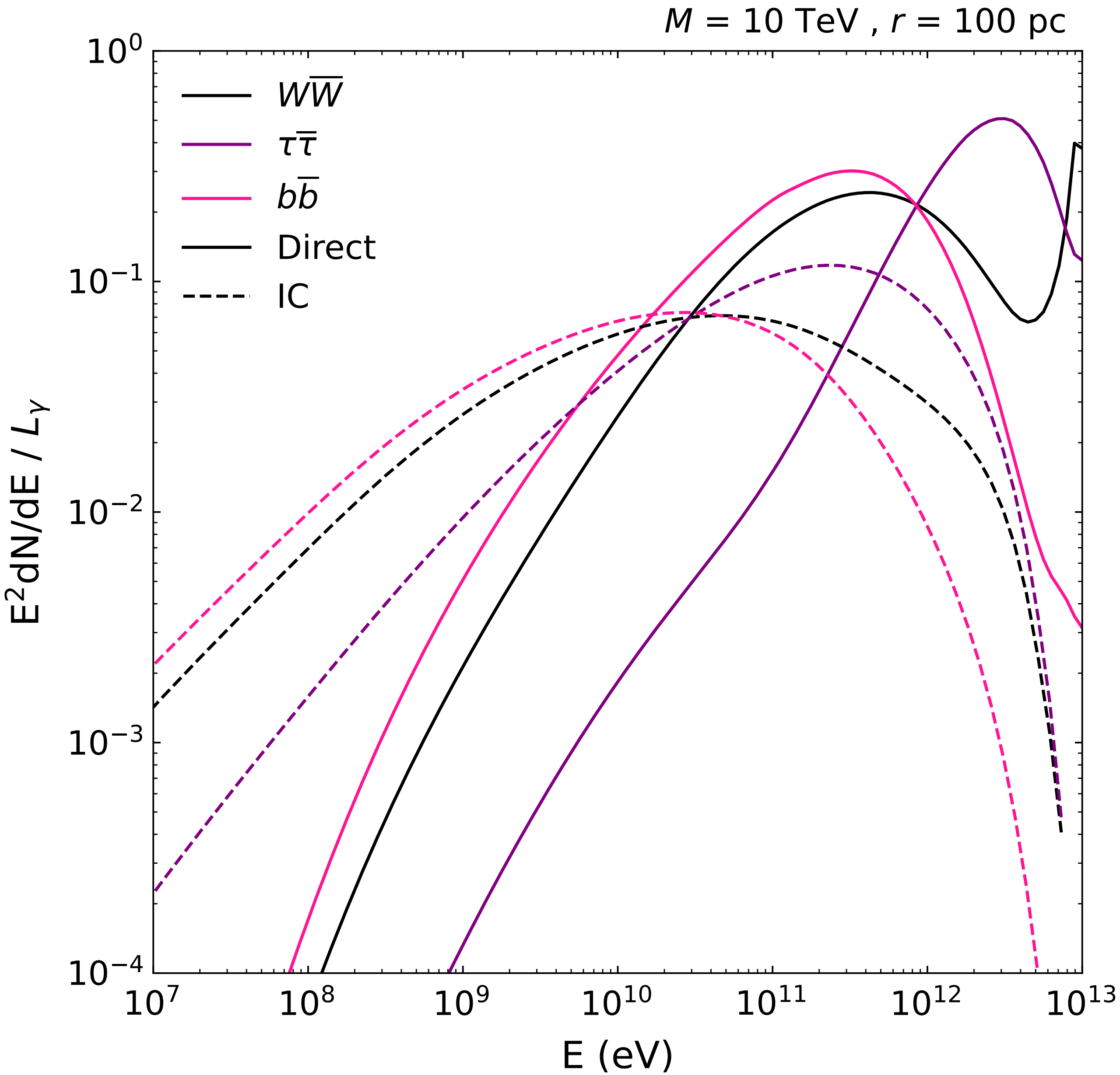
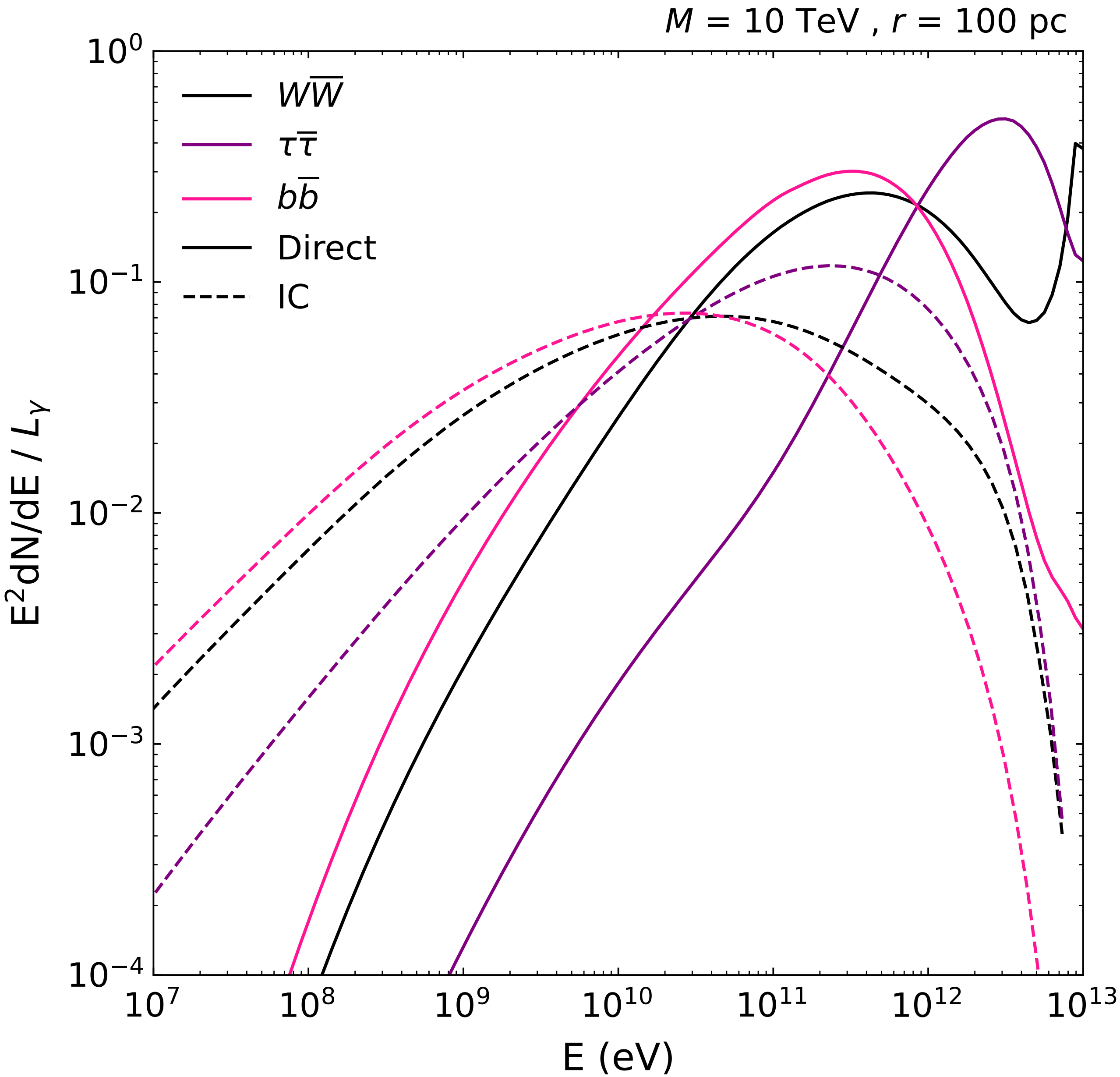
Implications of the IC component



Implications of the IC component

What does this mean for γ-ray telescopes?

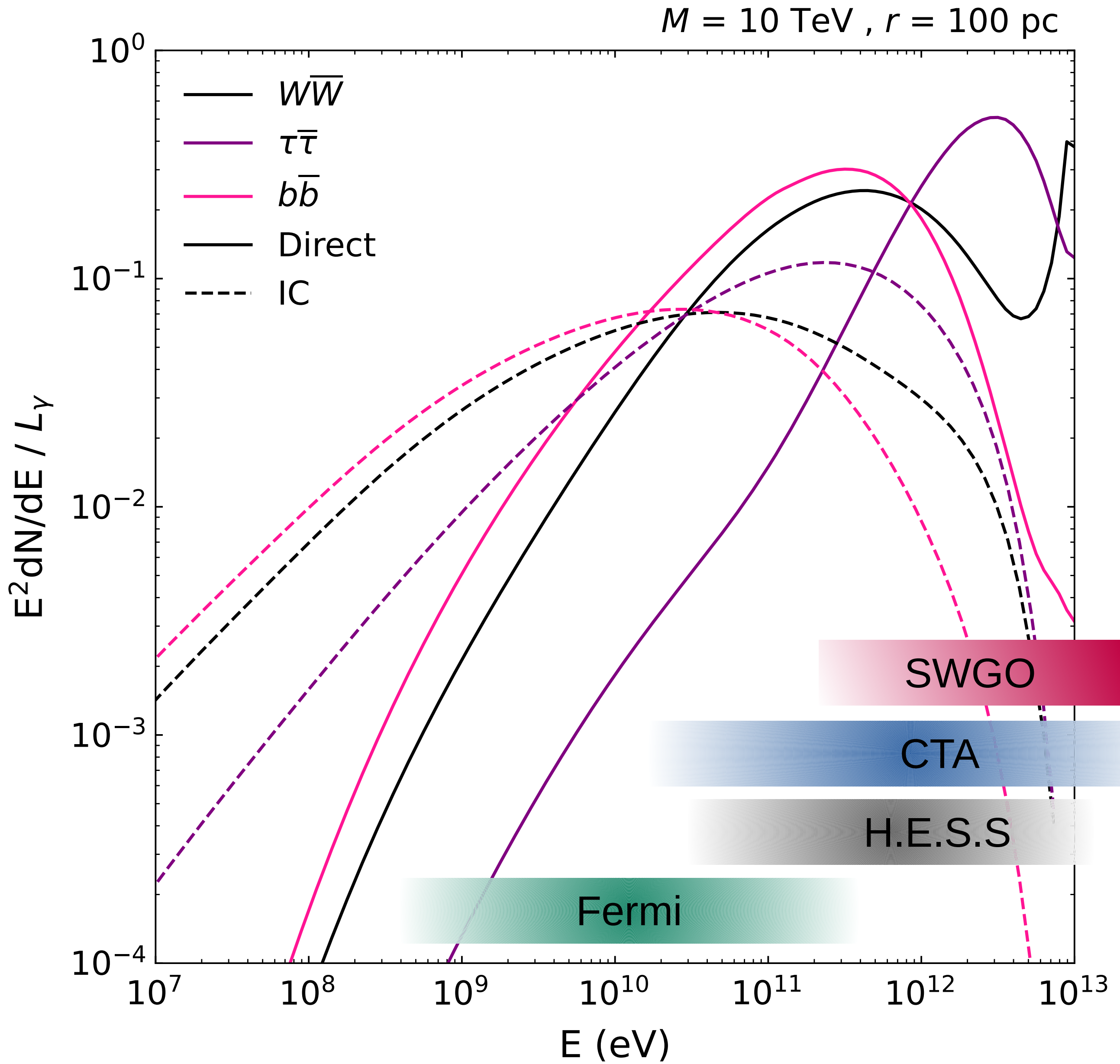


Implications of the IC component

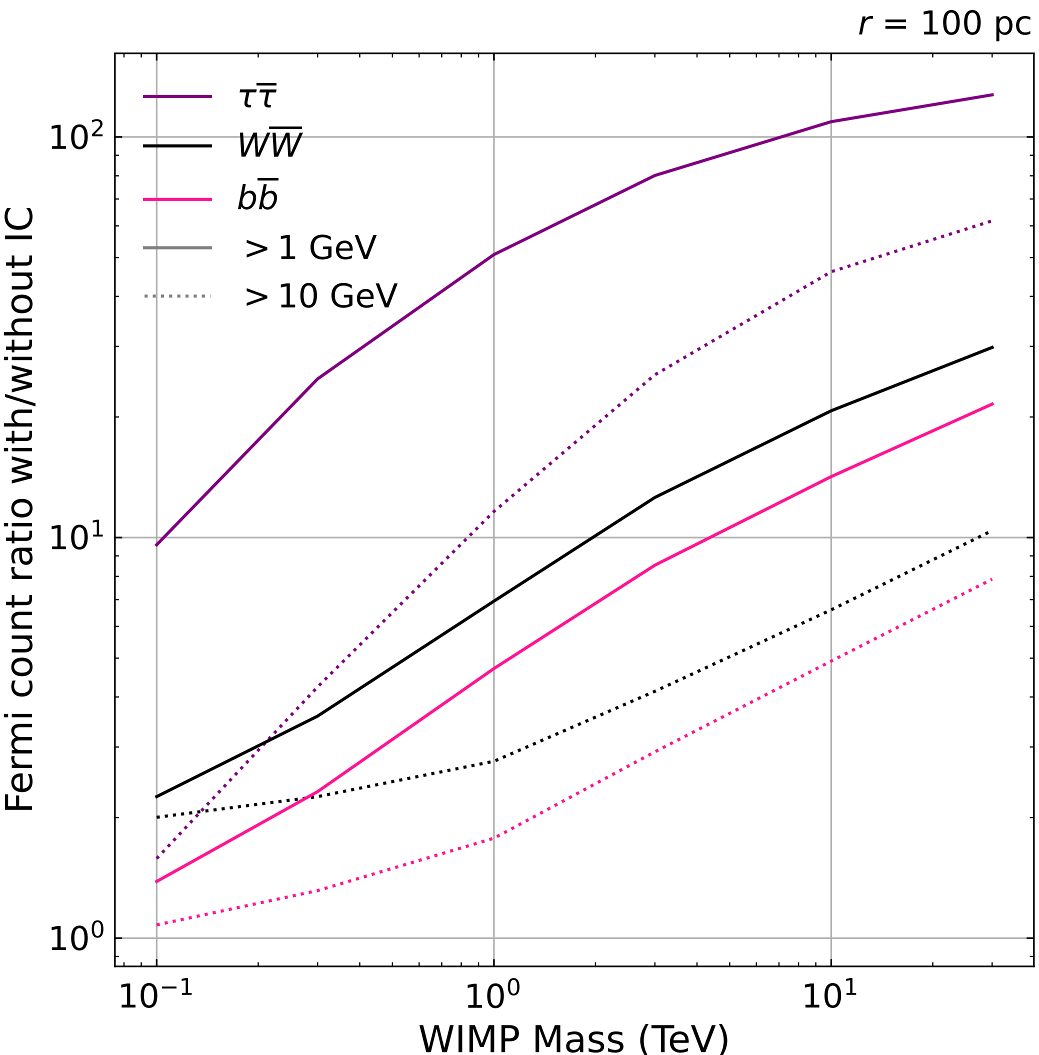
What does this mean for ɣ-ray telescopes?

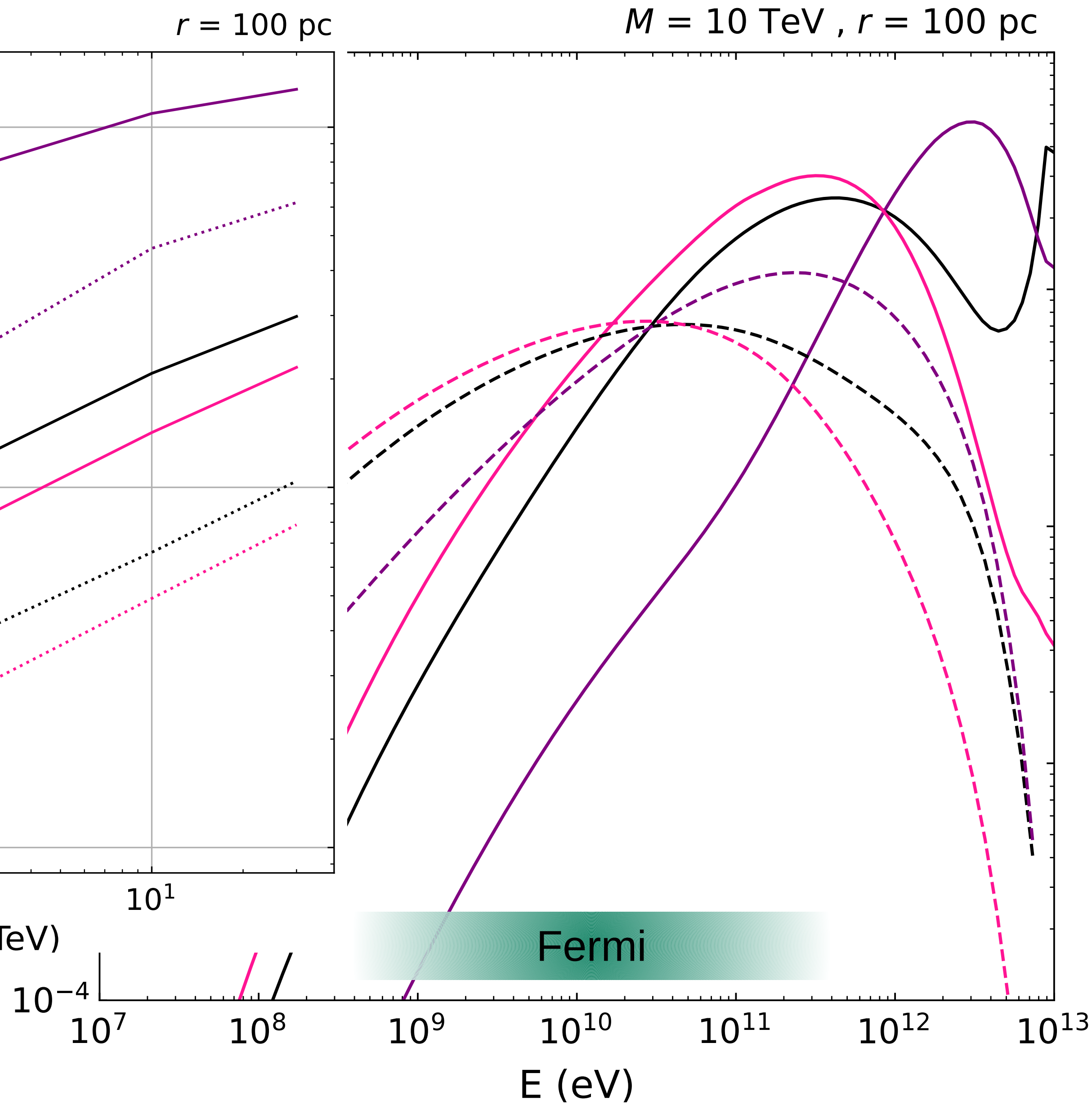
- Signal photons increase when taking IC component into account

  → IC component should not be neglected as common practise



Implications of the IC component





→ **highly increased signal count**

Summary

Studied the effect of secondary photon emission from WIMP annihilation in the Galactic centre

Indirect photon component of WIMP annihilation should not be neglected.

→ Experiments would underestimate their sensitivity to WIMP signal

→ If DM signal is observed this component can give additional insight

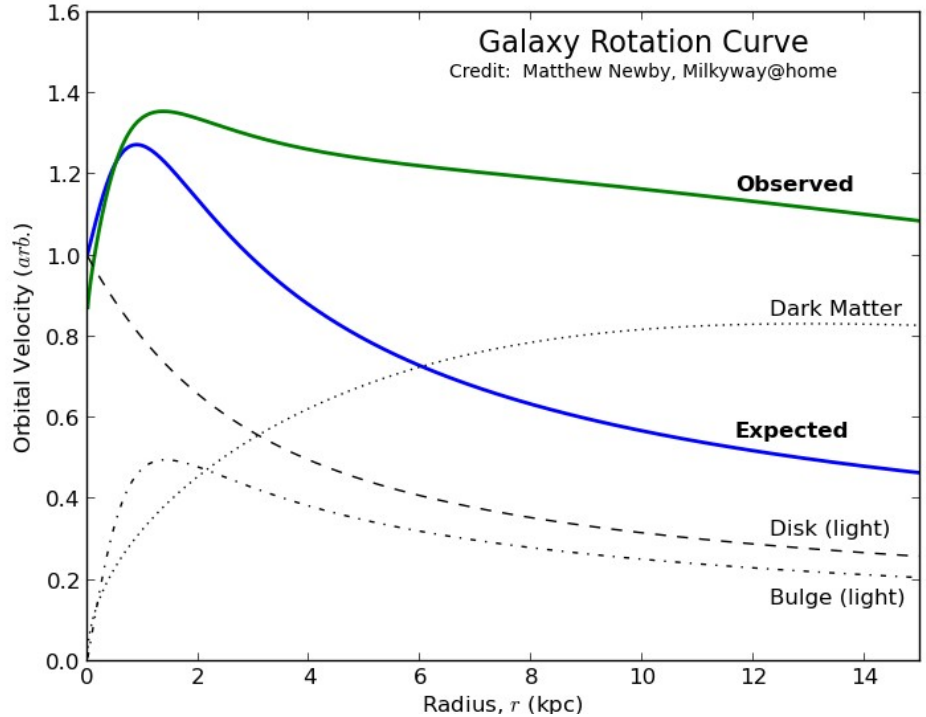
More information: https://doi.org/10.1016/j.dark.2022.101157

Thank you for your attention!

DM - It's there, but what is it?

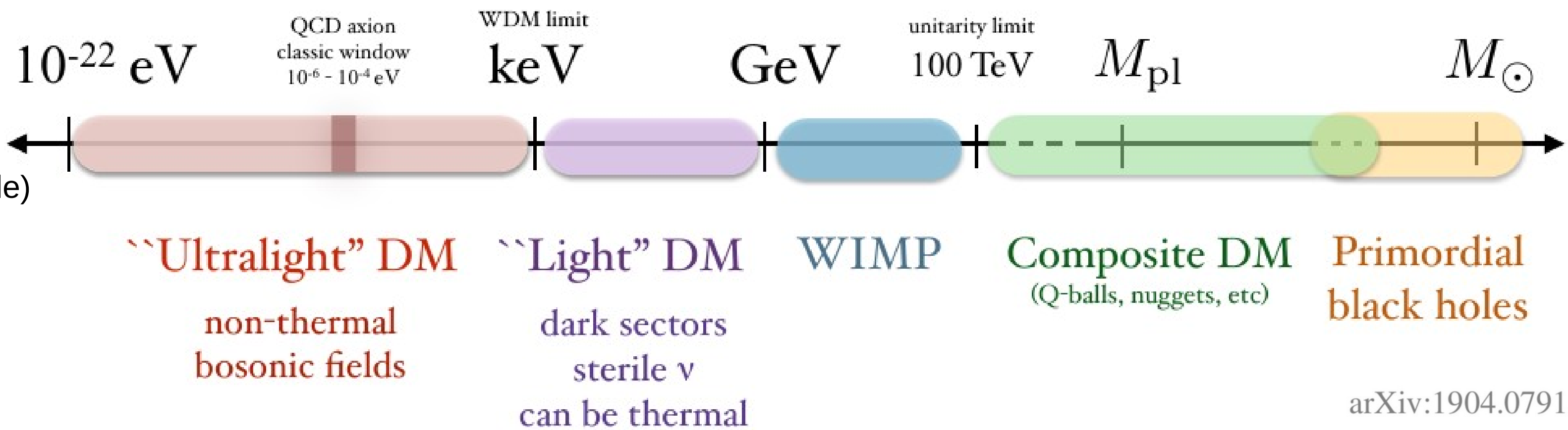
Ample experimental / gravitational evidence:

- Lensing
- CMB
- Rotation curves



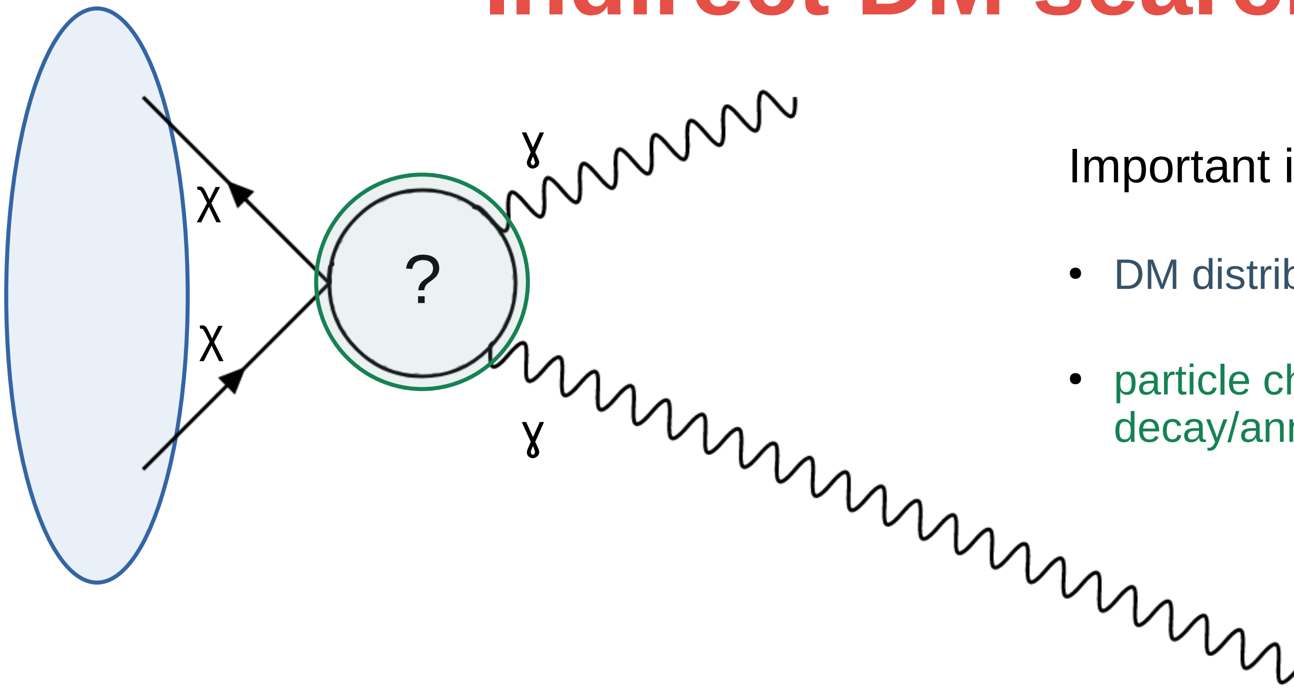
Even more theoretical models:

Mass
(not to scale)



arXiv:1904.07915

Indirect DM searches



Important ingredients:

- DM distribution
- particle characteristics: decay/annihilation, decay chains

Flux of annihilating DM:

$$\frac{d\Phi_\gamma}{d\Omega\, dE_\gamma} \sim \int_{\mathrm{l.o.s}} d\ell\, \rho_\chi^2(\mathbf{r}) \left(\frac{\langle \sigma v \rangle_{\mathrm{ann}}}{m_\chi^2} \sum_f B_f \frac{dN_\gamma^f}{dE_\gamma} \right)$$

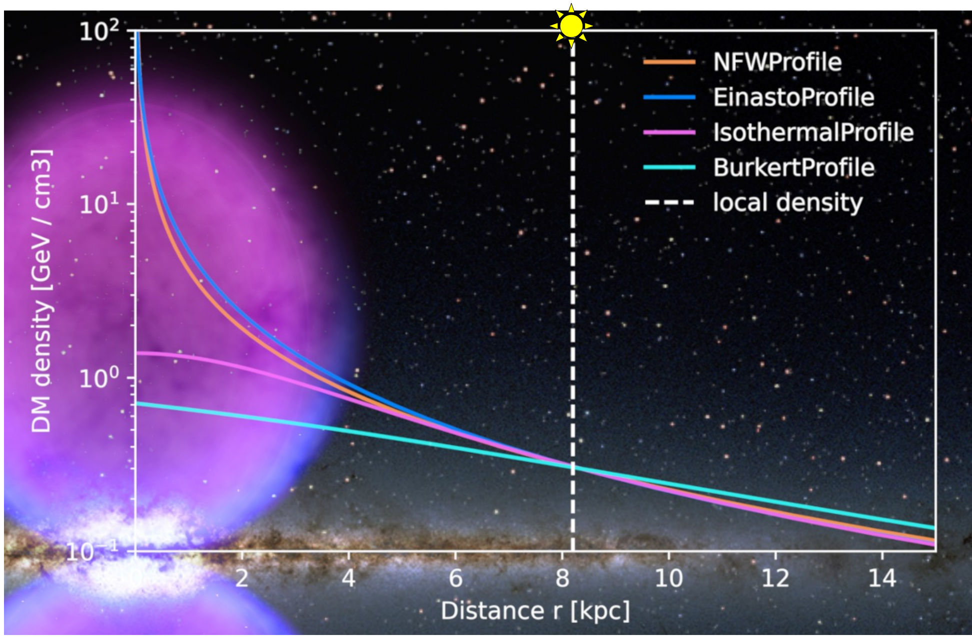
J-Factor　　Limits　　Decay specifics

The GC DM Distribution

- DM distribution profiles differ mainly in inner few kpc of the Galaxy
- Most popular profiles are rotational symmetric and have no substructure

  → too simplistic?

  → need to choose one in order to set limits



Einasto profile (used in CTA GC paper) with parameters:

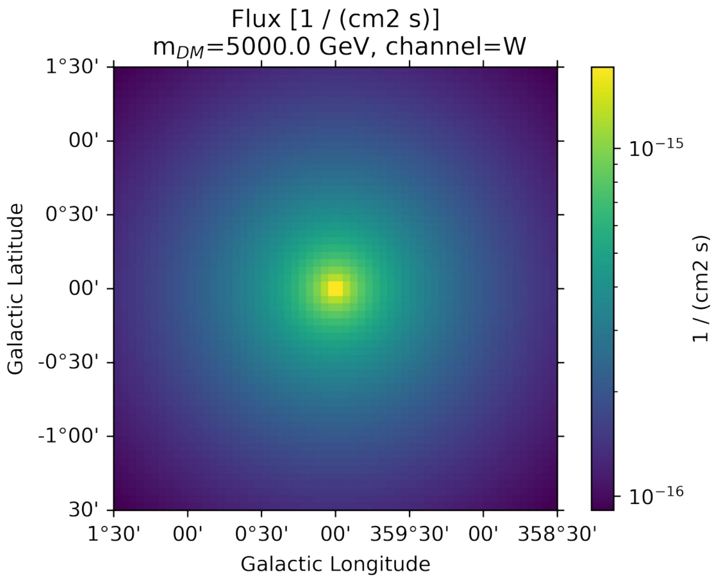
r_{Sun} = 8.2 kpc

ρ_{Sun} = 0.33 GeV/cm^3

α = 0.17

r_S = 20 kpc

$$\rho_{\mathrm{Einasto}}(r) = \rho_s \exp\left(-\frac{2}{\alpha}\left[\left(\frac{r}{r_s}\right)^{\alpha} - 1\right]\right)$$



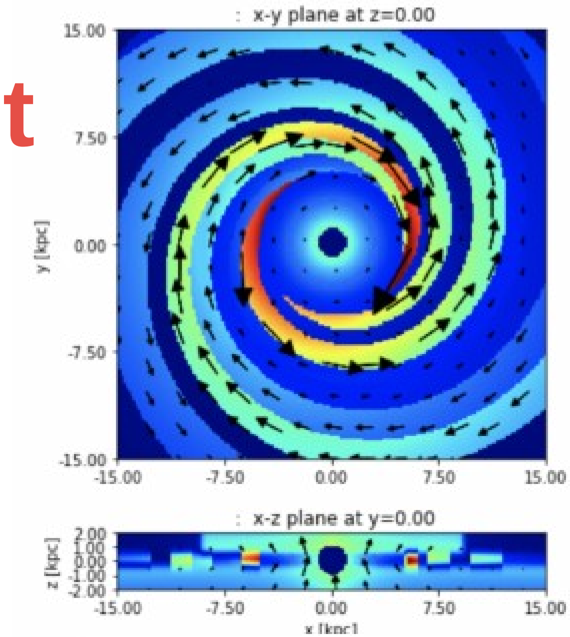
GC environment

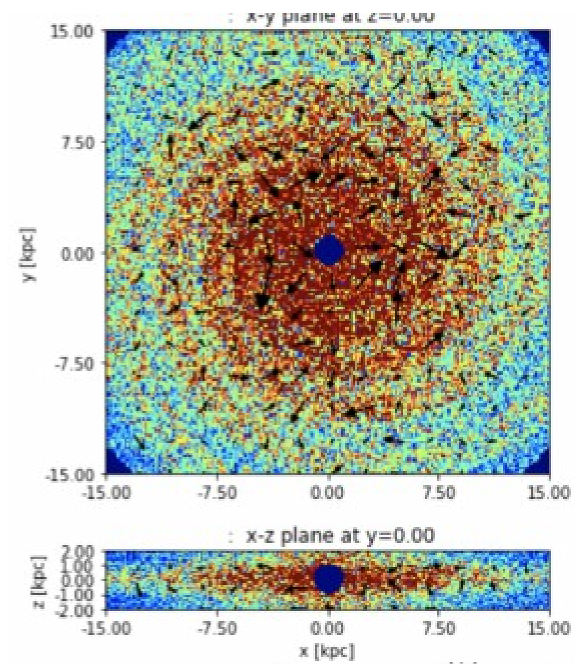
Magnetic field by Jansson & Farrar:

- large-scale regular fields, striated fields + small-scale random fields
- regular field: disk + extended halo with large, out-of-plane component
- striated component aligned with the regular field

Radiation field model by Popescu et al.:

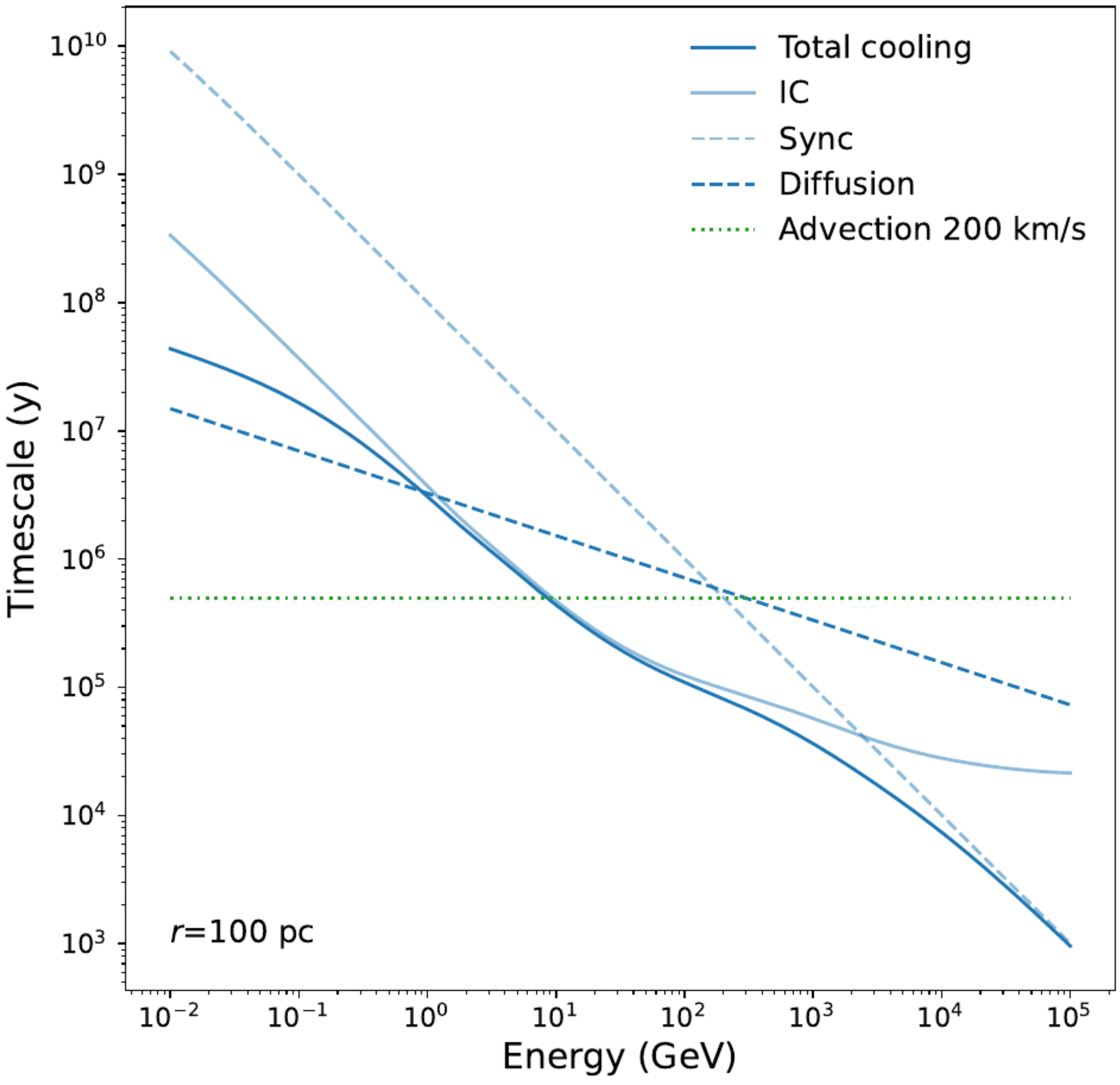
- self-consistent model of broad-band continuum emission
- derived from modelling maps of all-sky emission in infrared and submillimetre regime



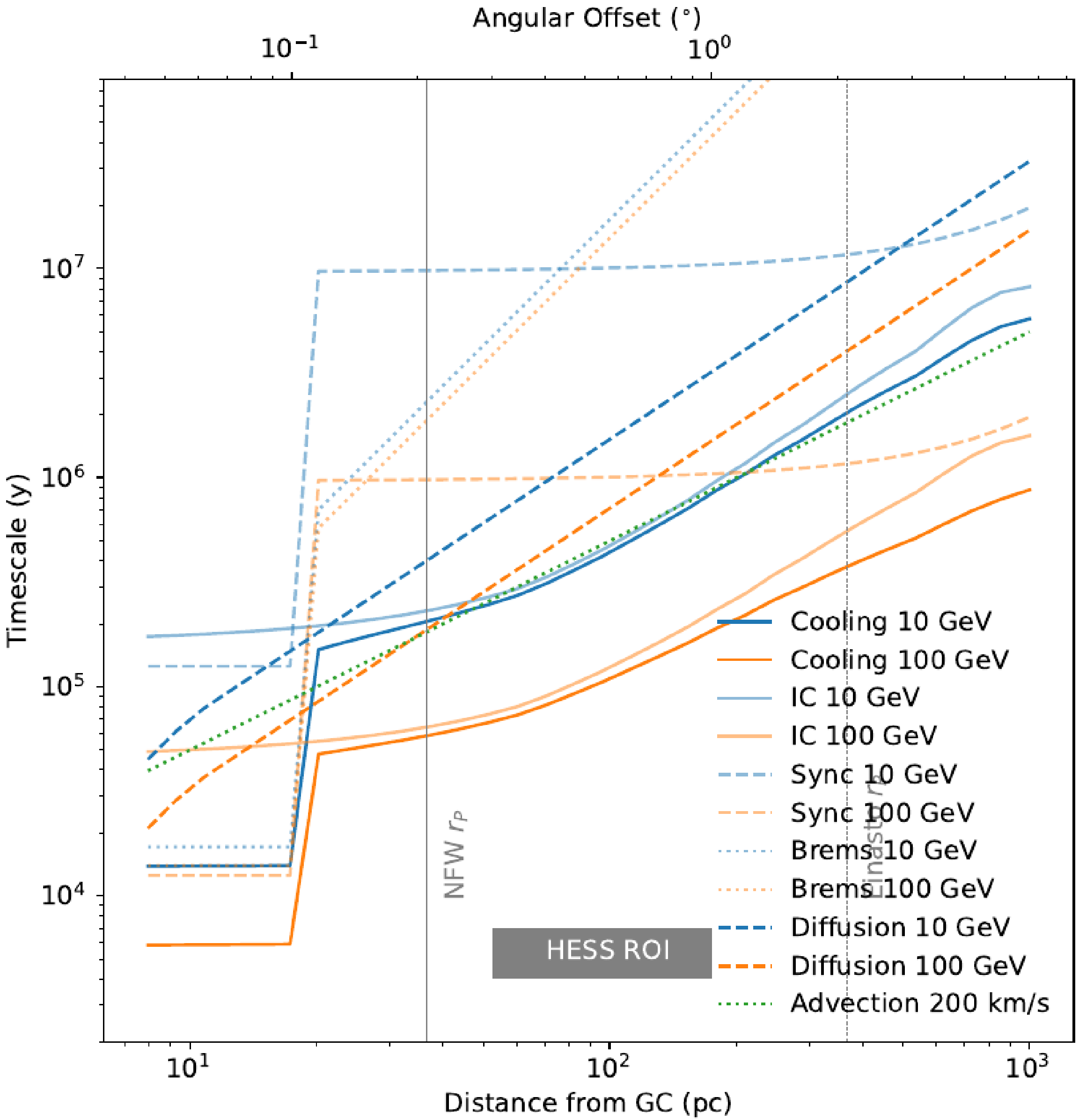


Jaffe, Galaxies, 2019

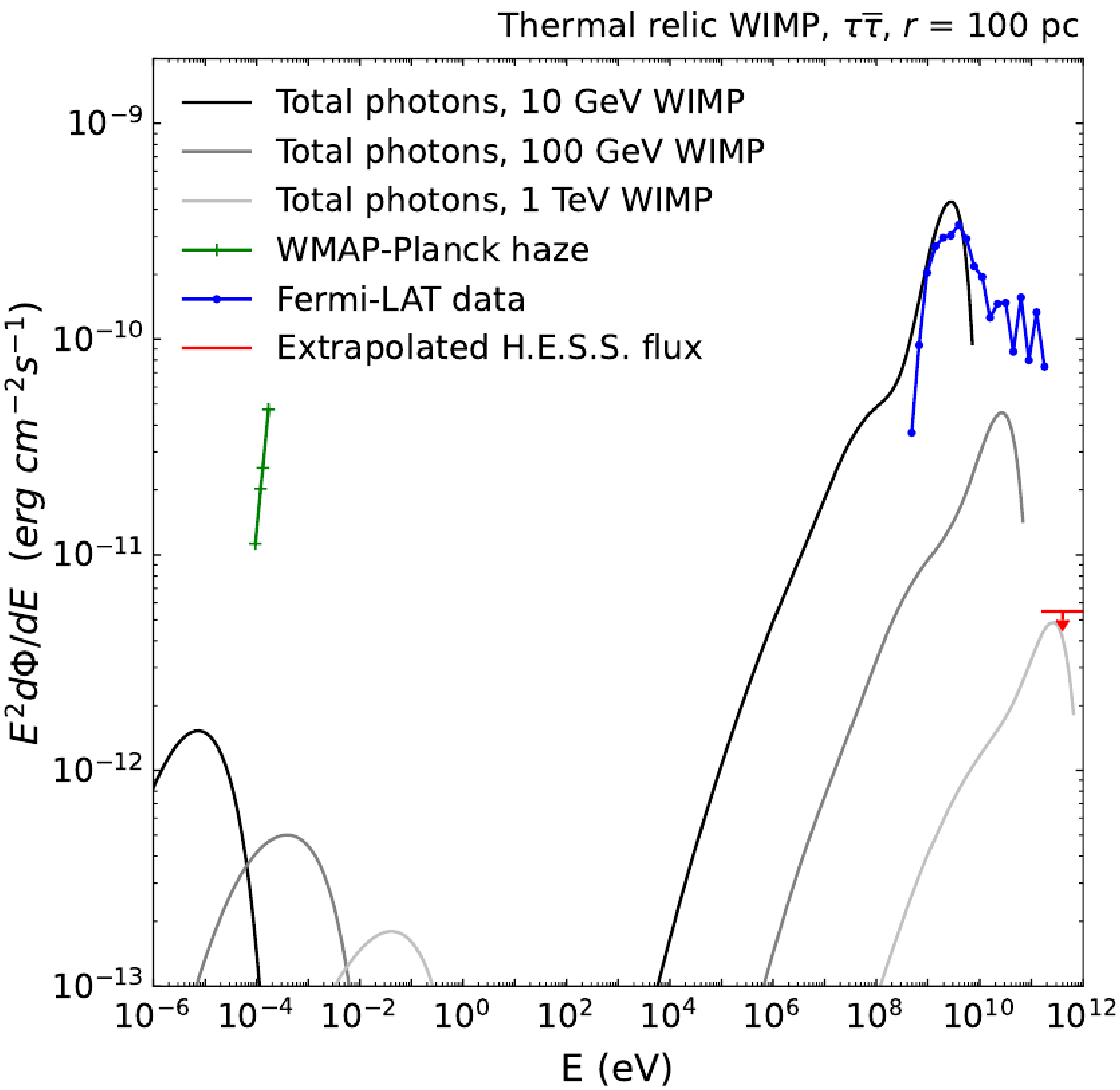
Electron Timescales



Electron Cooling Timescales

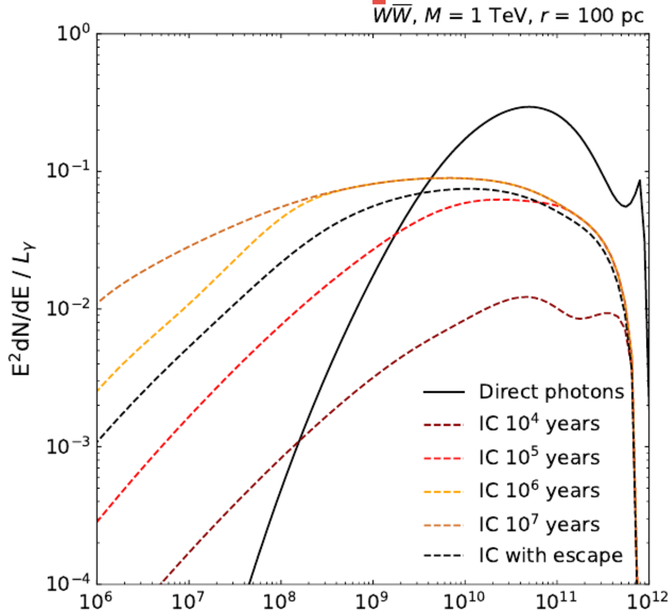


Indirect photon emission and data

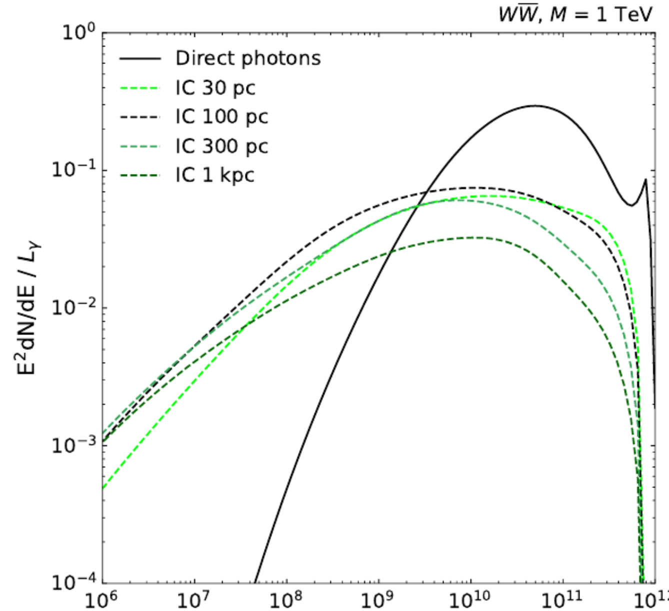


Inverse Compton emission from WIMPs

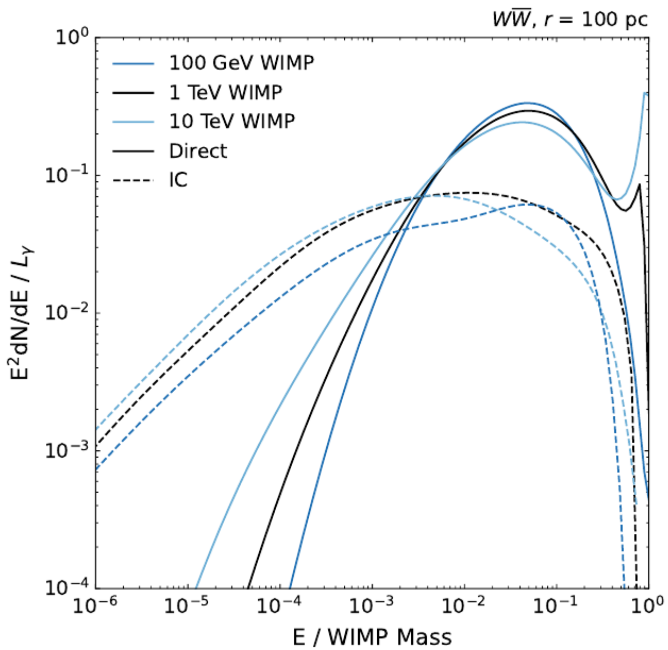
Time depen-dence



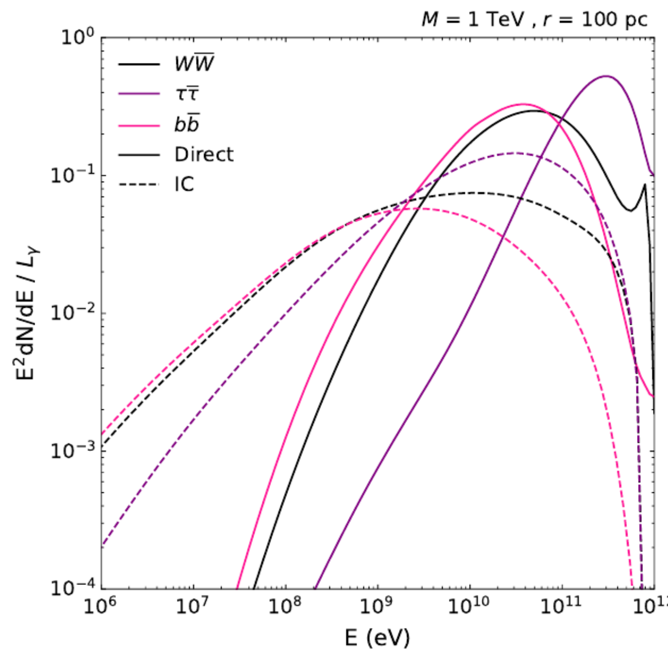
Distance depen-dence



WIMP mass depen-dence



Annihi-lation channel depen-dence



Inverse Compton emission from WIMPs

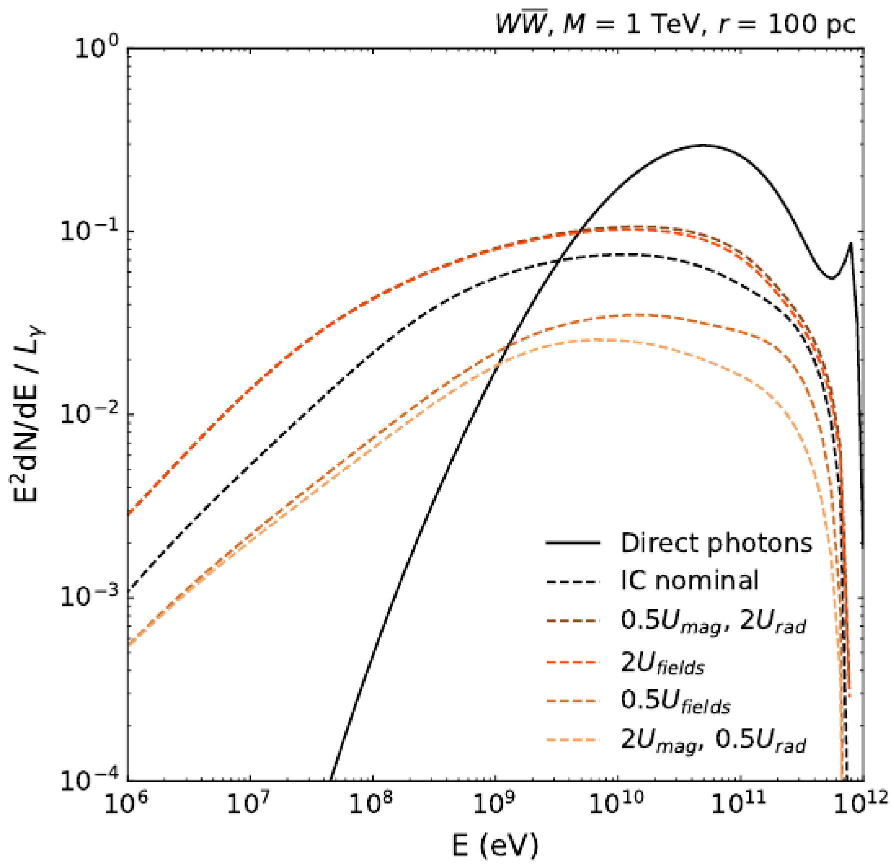
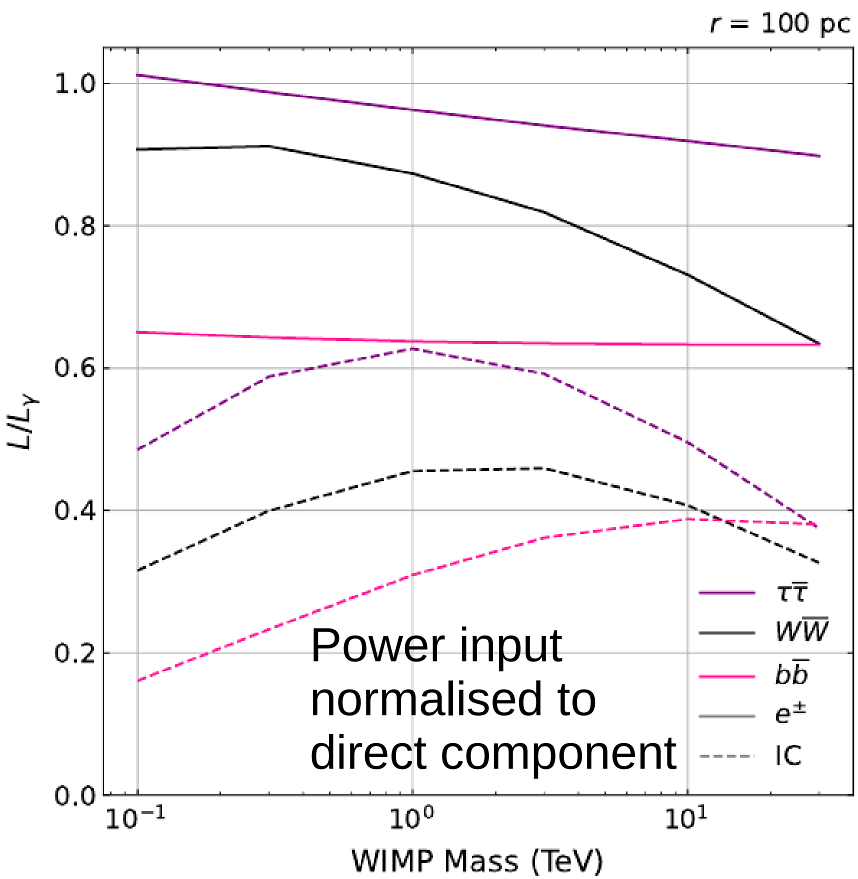
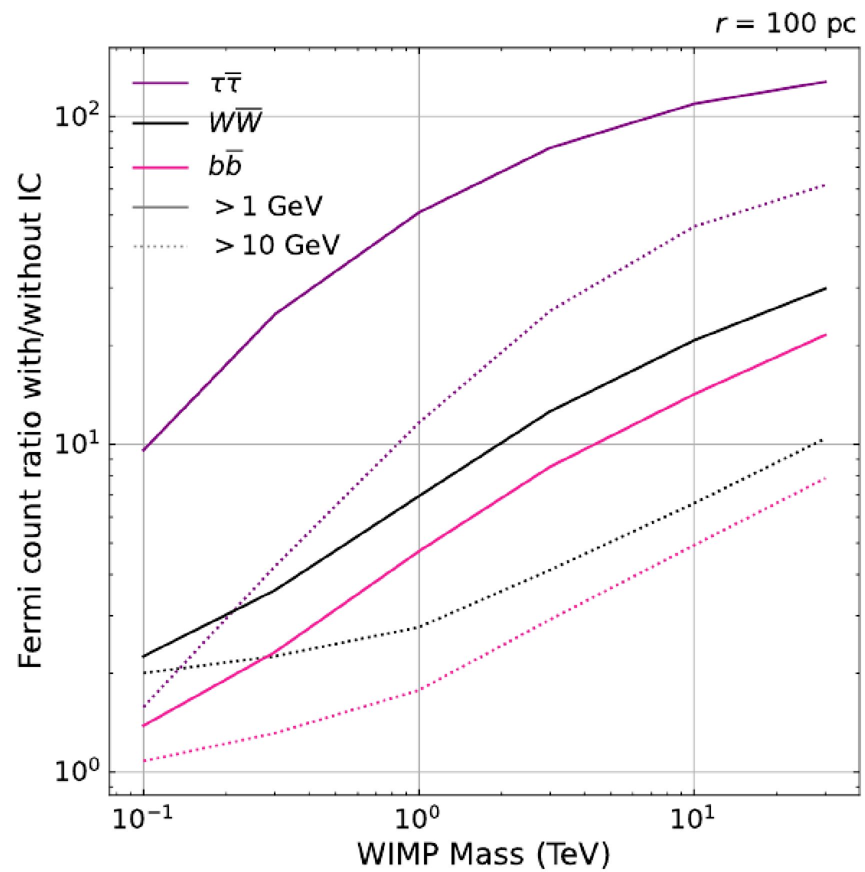


Figure 5: Photon spectrum from WIMP annihilation to W bosons in the GC normalised to the total luminosity of the direct photon component (solid line). The dashed lines show the IC component of the spectrum for a variation of the magnetic field strength and the radiation field of the model. The WIMP mass is set to 1 TeV and the model was evaluated at a distance of 100 pc from the GC and evolved for 10^6 years.

Implications of the IC component





- IC component is significant compared to the direct photon signal

  → signal photons increase when taking IC component into account

- Count rate for Fermi highly increased due to its particular sensitivity