On the gamma-ray emission from the core of the Sagittarius dwarf galaxy

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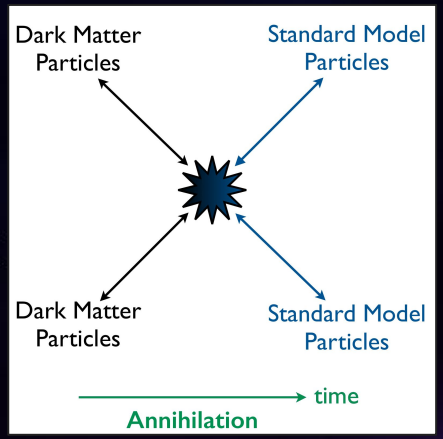
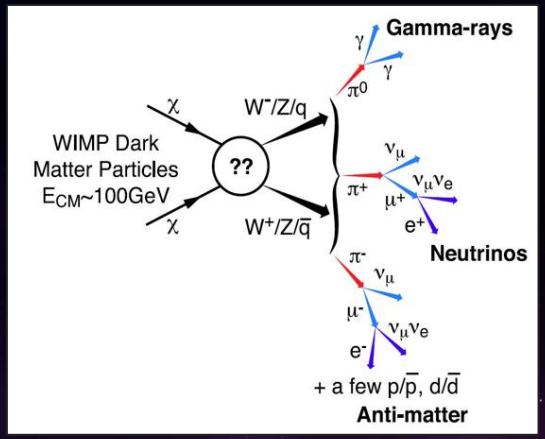
Astrophysical probes of dark matter: annihilation products

Assuming dark matter is a WIMP that self-annihilates:





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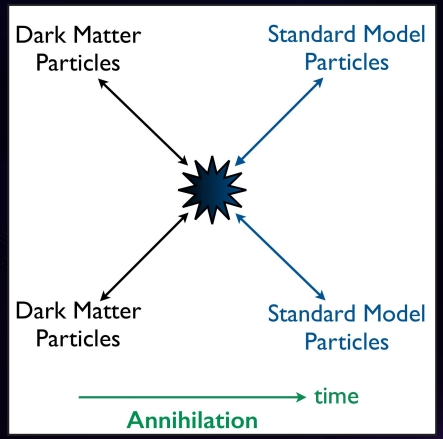
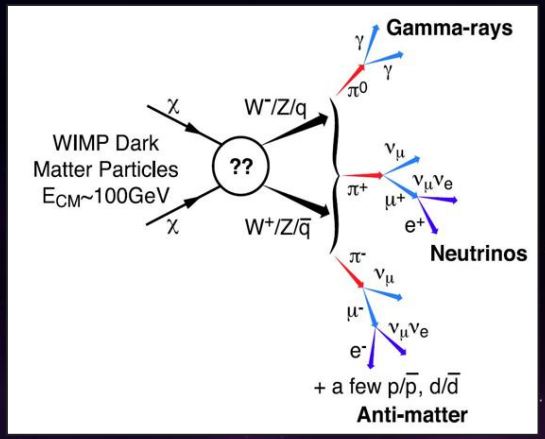




The goal is to find high-energy Standard Model particles <u>that cannot be attributed to other astrophysical sources.</u>

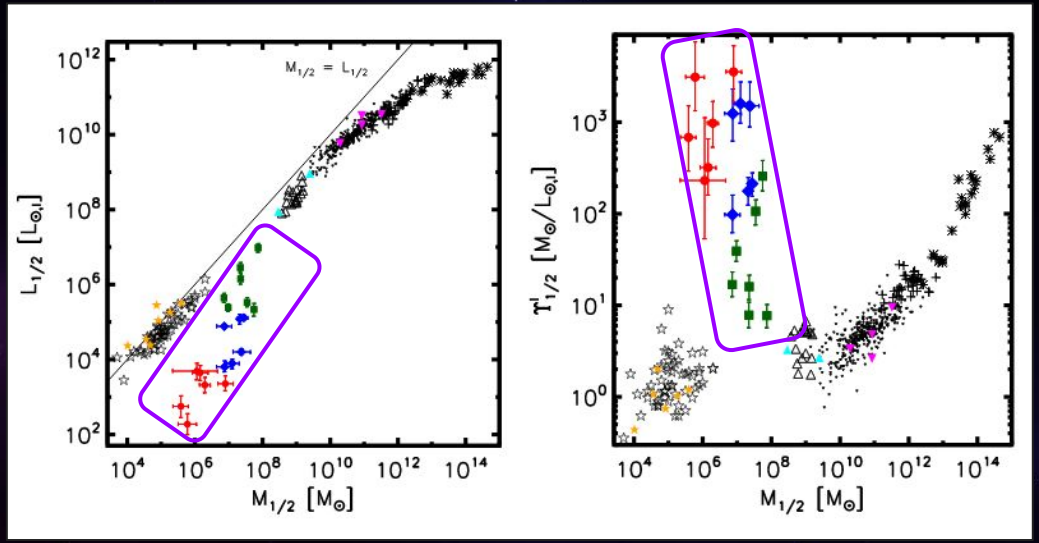
Indirect detection with dwarf galaxies

Dwarf galaxies: the most dark matter dominated galaxies in the Universe

→ Very high mass to light ratios

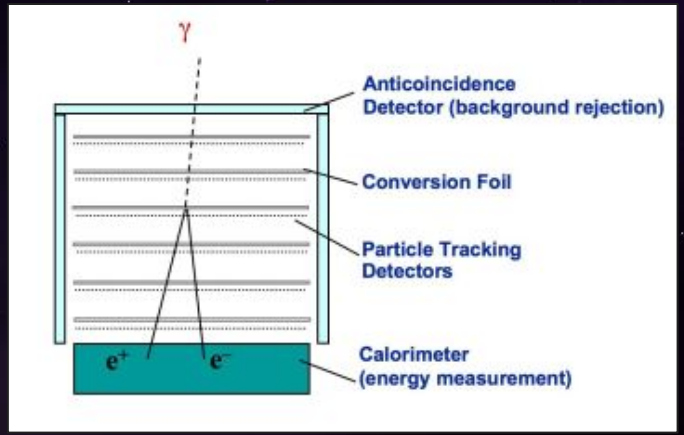
→ Fewer astrophysical gamma-ray sources

→ A great place to go looking for dark matter annihilation products!



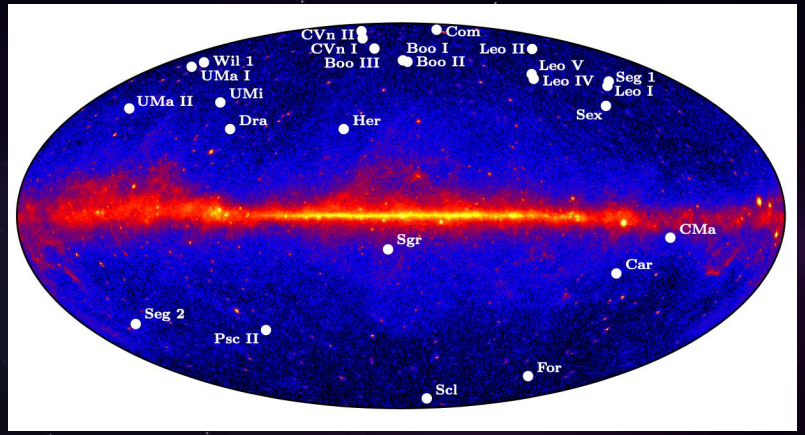
The Fermi Large Area Telescope

→ The Fermi-LAT is a wide field-of-view high energy gamma-ray space telescope sensitive to the energy range of hundreds of MeV to thousands of GeV.

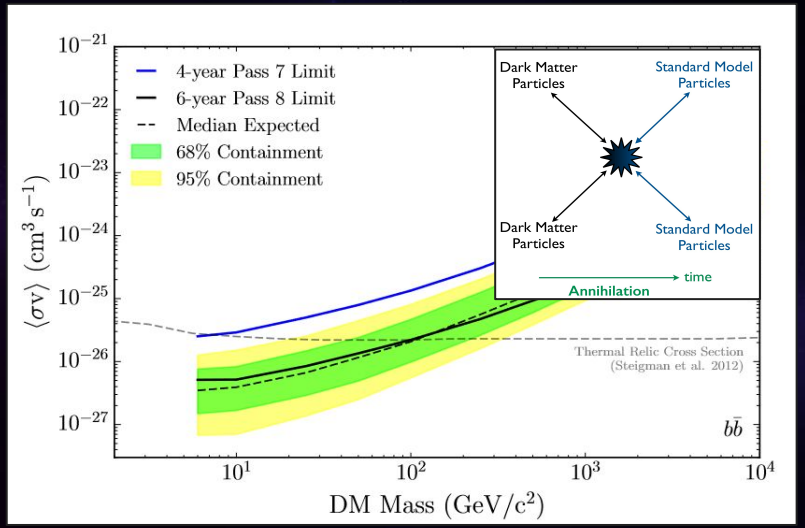


Fermi-LAT's search for dark matter

→ There have been many studies of dwarf galaxies with the Fermi-LAT



Drlica-Wagner, 2013

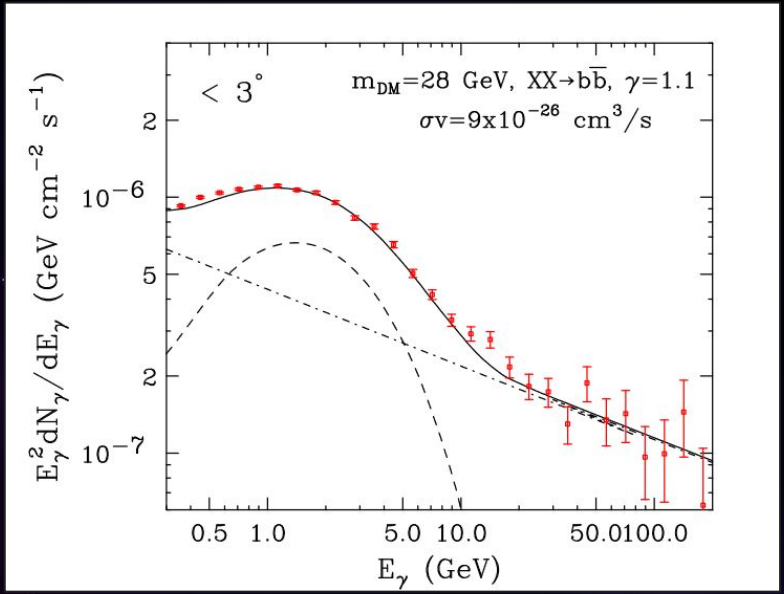


Fermi-LAT Collaboration, 2014

The GeV Excess at the Galactic Center

→ In 2009, Goodenough & Hooper discovered an excess of GeV emission from the Galactic Center consistent with annihilating dark matter.

→ The source is extended, spherically symmetric, and gives a mass and cross-section consistent with a thermal WIMP.



Goodenough & Hooper 2009

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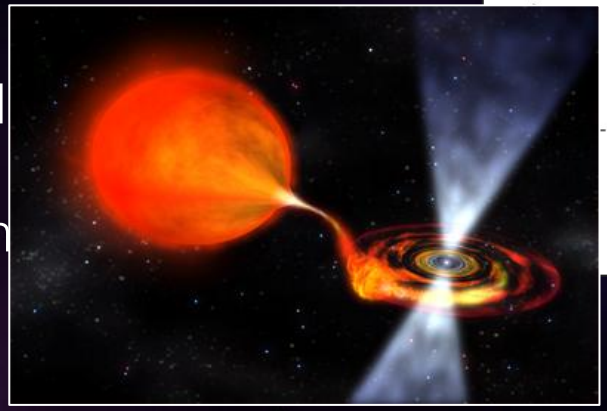
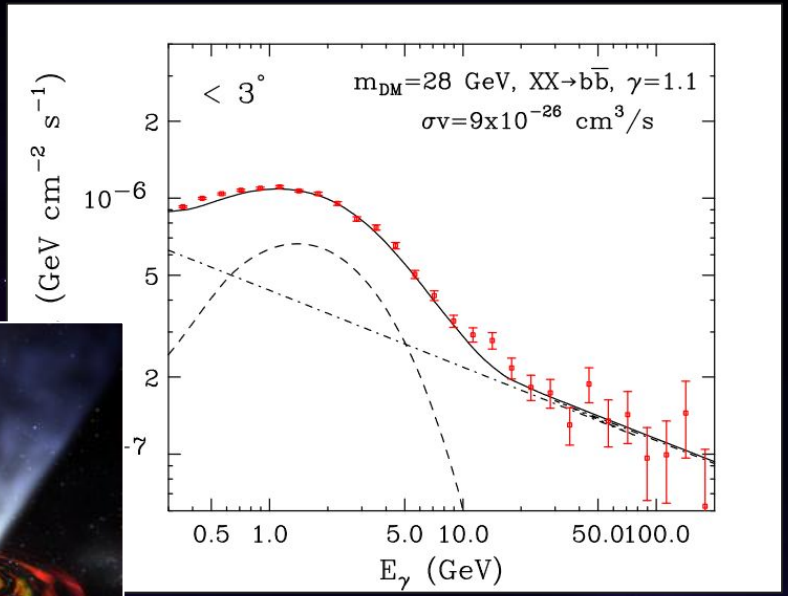




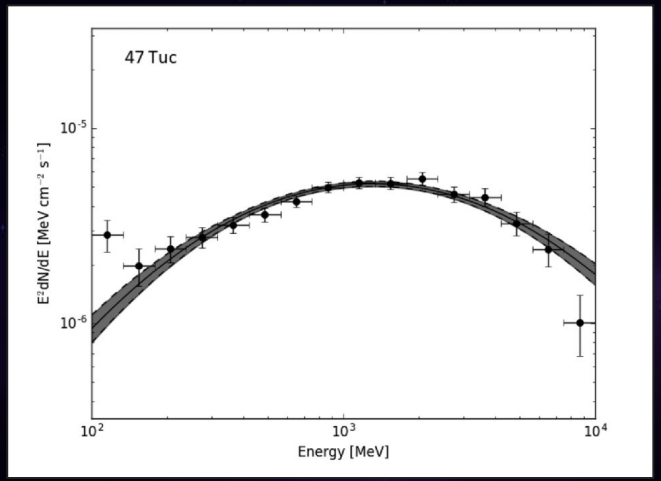
Goodenough & Hooper 2009

Could this be a population of millisecond pulsars instead?

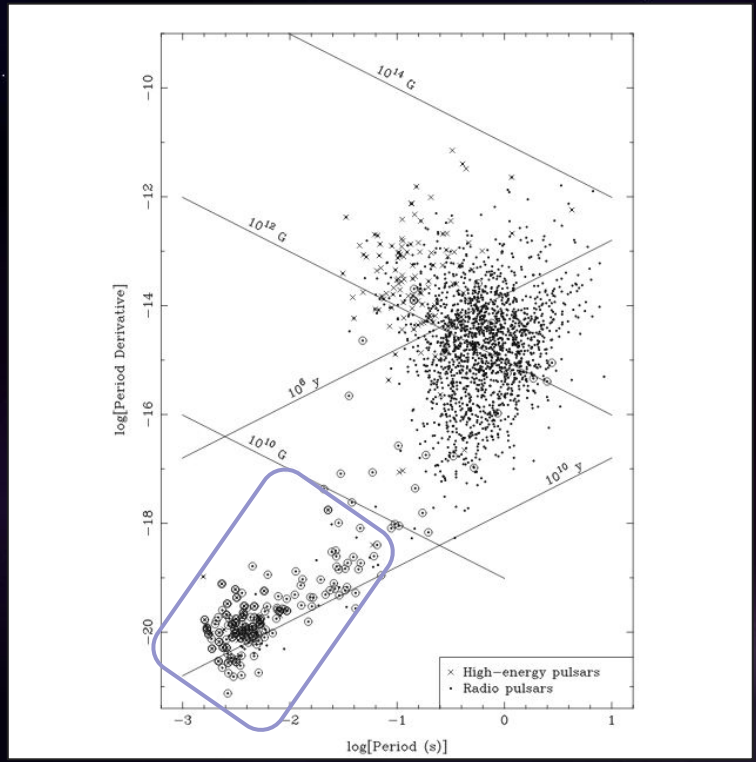
The gamma-ray emission of millisecond pulsars and globular clusters

→ Populations of recycled pulsars contribute to the total gamma-ray flux of globular clusters

→ Out of ~180 in the Galaxy, there are ~35 known gamma-ray bright globular clusters



S.J. Lloyd et al., 2018



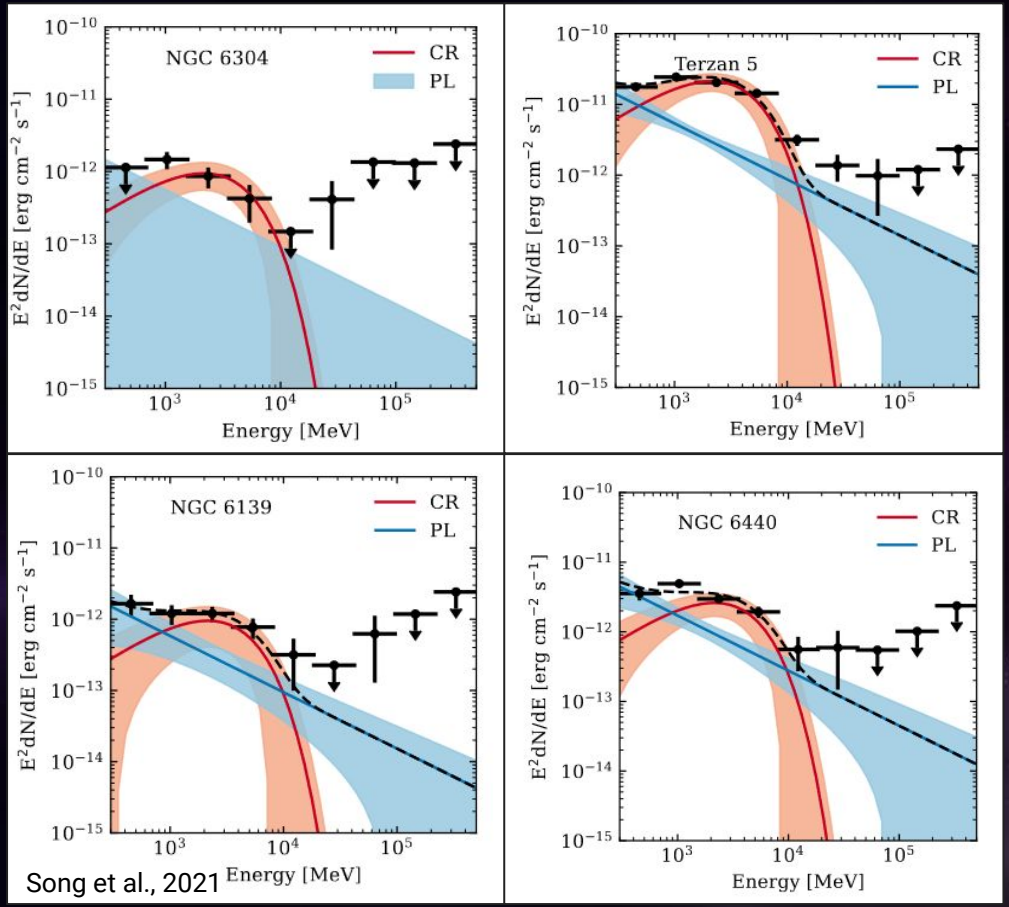
R.N. Manchester, 2017

The source of γ-ray emission in globular clusters

Two possible sources of emission:

1. Curvature or prompt radiation from millisecond pulsar magnetospheres (Harding et al., 2005)

2. Inverse Compton emission from leptons injected by millisecond pulsars into the surrounding environment (Bednarek & Sitarek, 2007)



Song et al., 2021

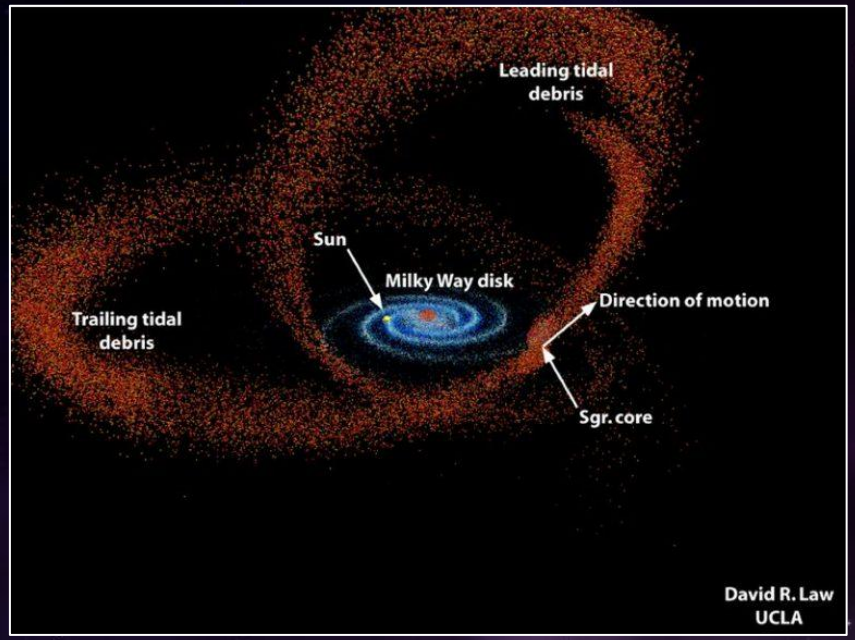
The Sagittarius dwarf spheroidal galaxy

→ Near the Galactic center & overlapping with structure in the Fermi bubbles

→ Undergoing tidal disruption

→ ~ 26 kpc away

→ Population of globular clusters, including recently identified ones (Minniti et al, 2022)



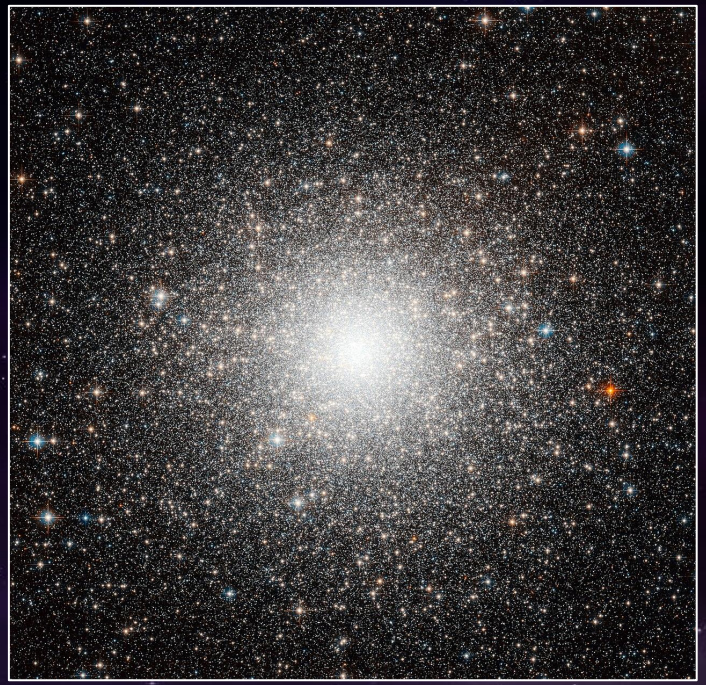
Fermi detections of the Sgr/M54 system

→ Recently detected by the Fermi Collaboration (4FGL-DR3)

→ Significance of ~ 5

→ At the core of Sagittarius

→ Coincident with the globular cluster M54



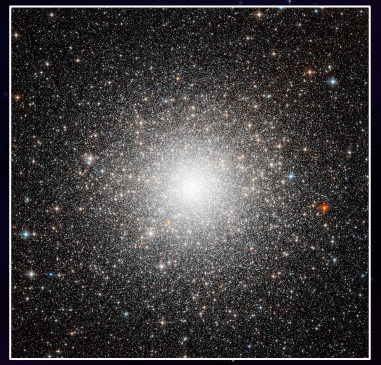
M54 (credit: Hubble/NASA)

Fermi-LAT Collaboration, 4FGL-DR3 2022

Possible sources of gamma-ray emission in Sgr

→ Point-like

a. Gamma-rays from millisecond pulsar population in M54 and other globular clusters
    i. Inverse compton scattering component to the flux?



M54 (Hubble/NASA)

→ Extended

a. Dark matter annihilation in the dense DM core of Sgr
b. Emission from an isotropically distributed population of millisecond pulsars

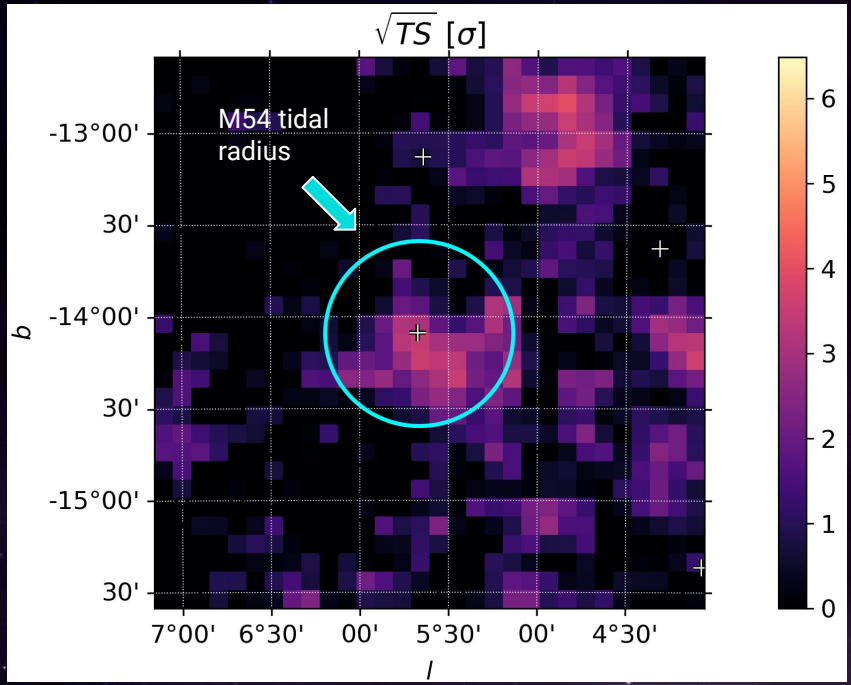
Dark matter substructure (Springel et al., 2008)

This work: the Sgr/M54 system in gamma-rays

→ We find point-like emission from the core of the Sgr galaxy, in agreement with the 4FGL-DR3 catalog

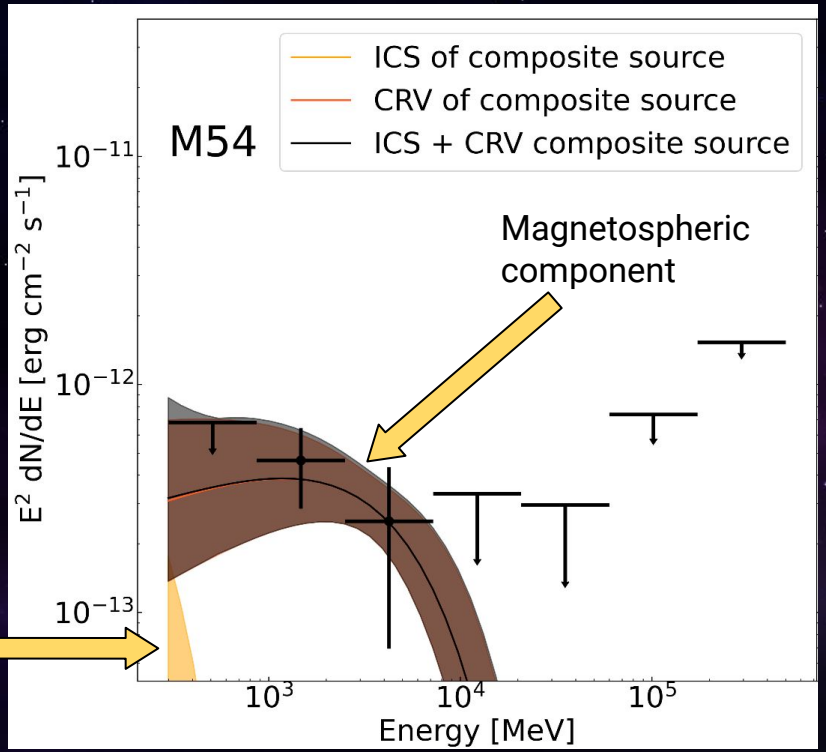
→ Source is spatially coincident with the M54 globular cluster and the core of Sgr

→ Significance of ~ 5



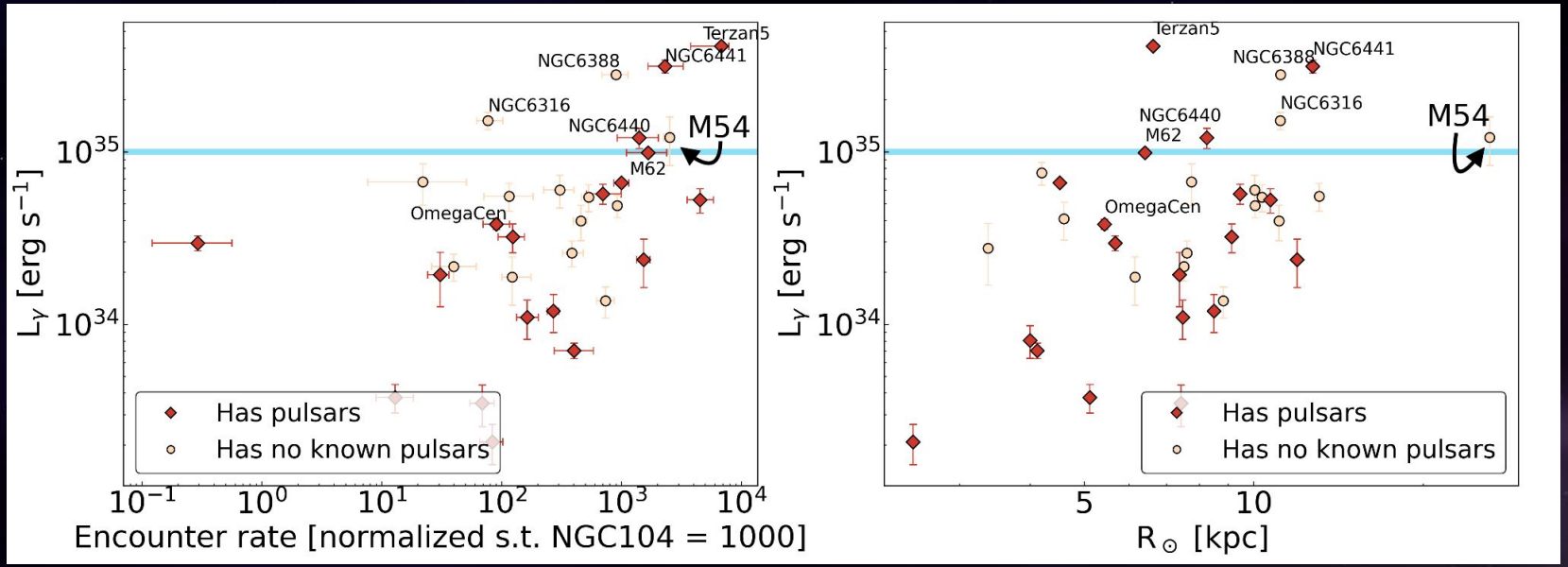
Globular cluster interpretation of the emission

→When using a two-component model, we find no evidence for a high-energy component with a negligible ICS flux compared to the magnetospheric flux



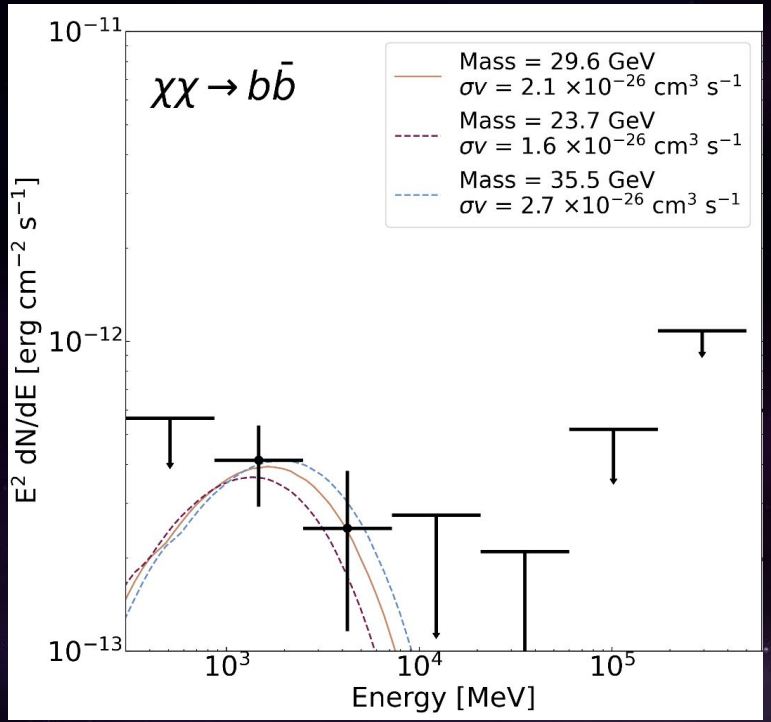
Globular cluster interpretation of the emission

→ The Sgr/M54 source shares similar properties to known Fermi-bright globular clusters



Dark matter interpretation of the emission

→ Assuming a dark matter scenario and annihilation via the bottom/antibottom channel, we derive a particle mass of ~ 30 GeV and annihilation cross-section of ~ 2 x 10^{-26} cm^3/s



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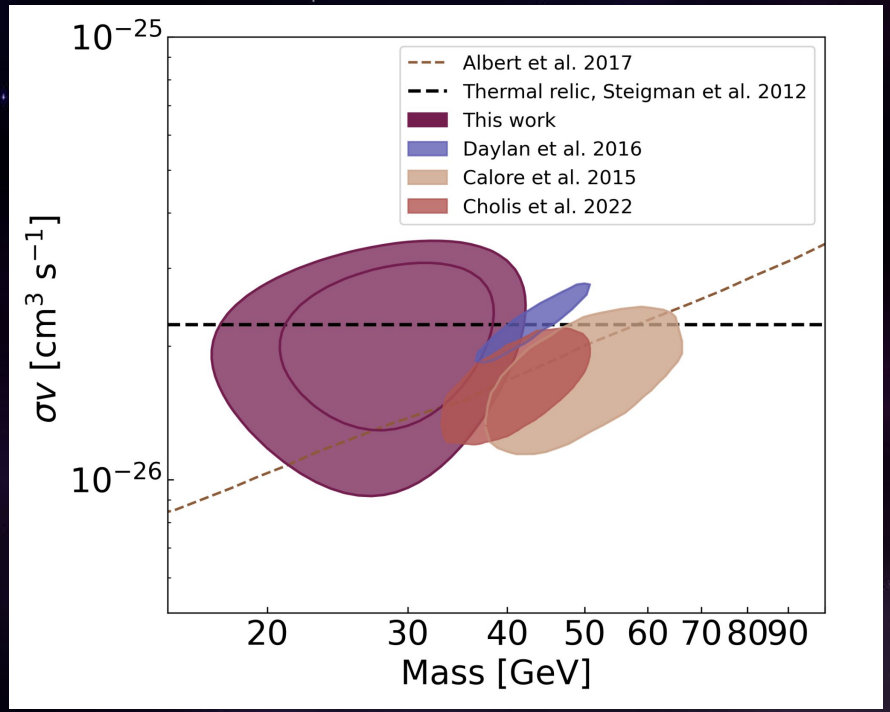

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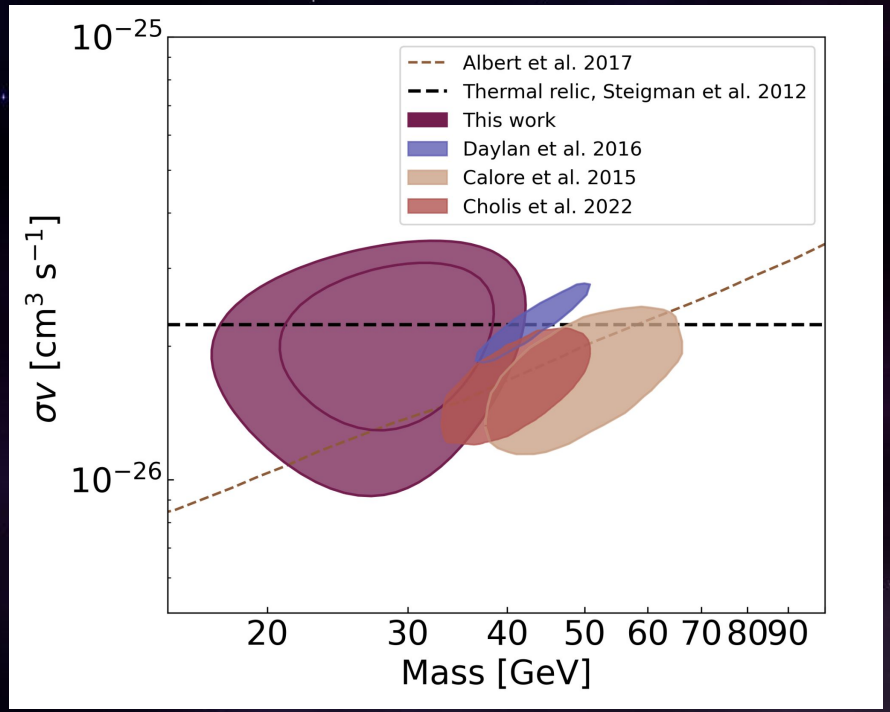
→ However, the source remains better fit by point-like emission



Summary

Stay in touch :)
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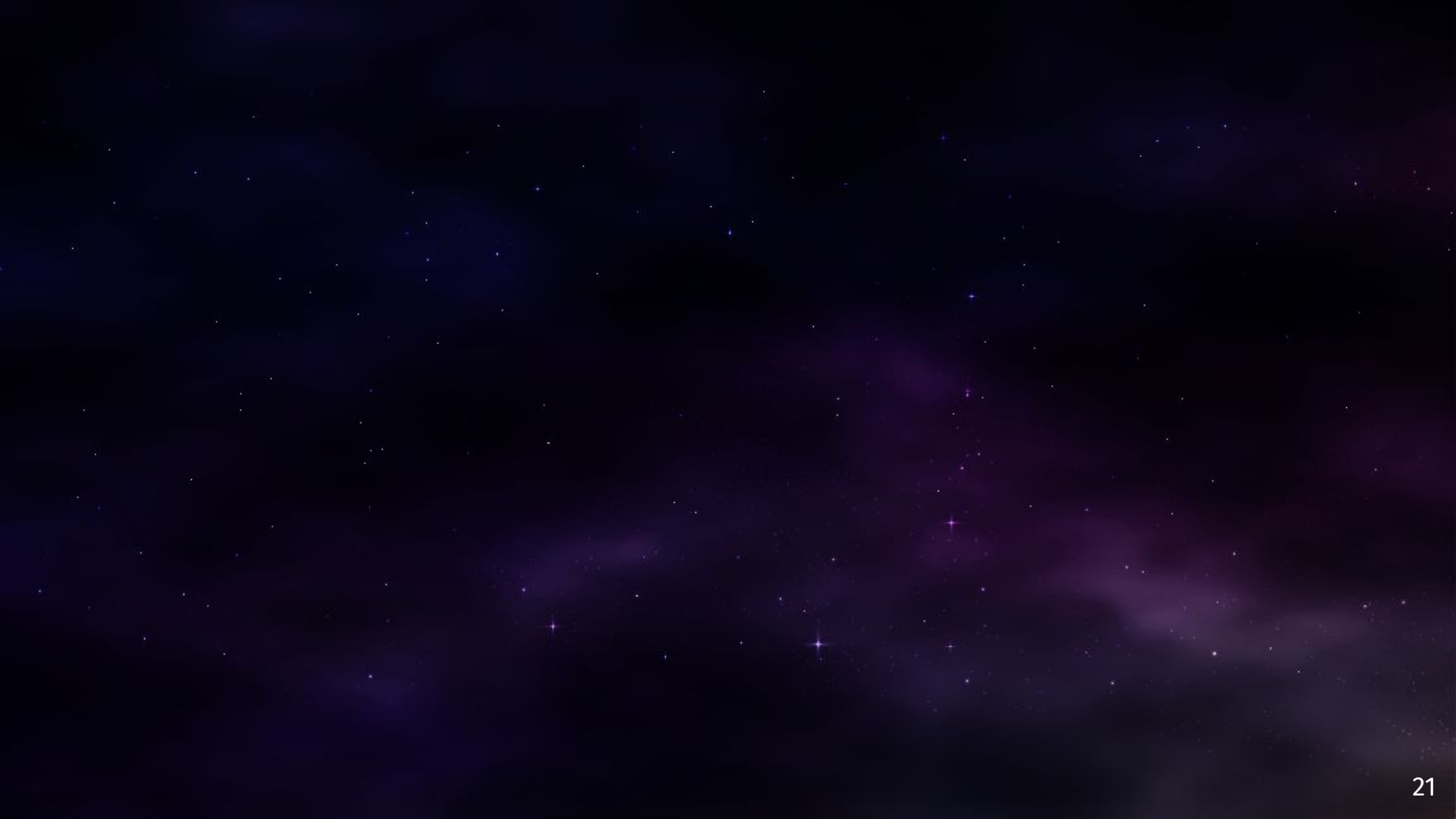
→ We search the Sgr/M54 system in Fermi data and find point-like emission associated with the core of the Sgr galaxy

→ This emission is possibly due to a millisecond pulsar population within the globular cluster M54

→ However, a dark matter interpretation is also possible

→ We find no evidence for high-energy emission from the catalog source, nor do we find any other sources possibly associated with Sgr

→ We find that the source is best-fit by a point-like model rather than an extended source for several choices of background models

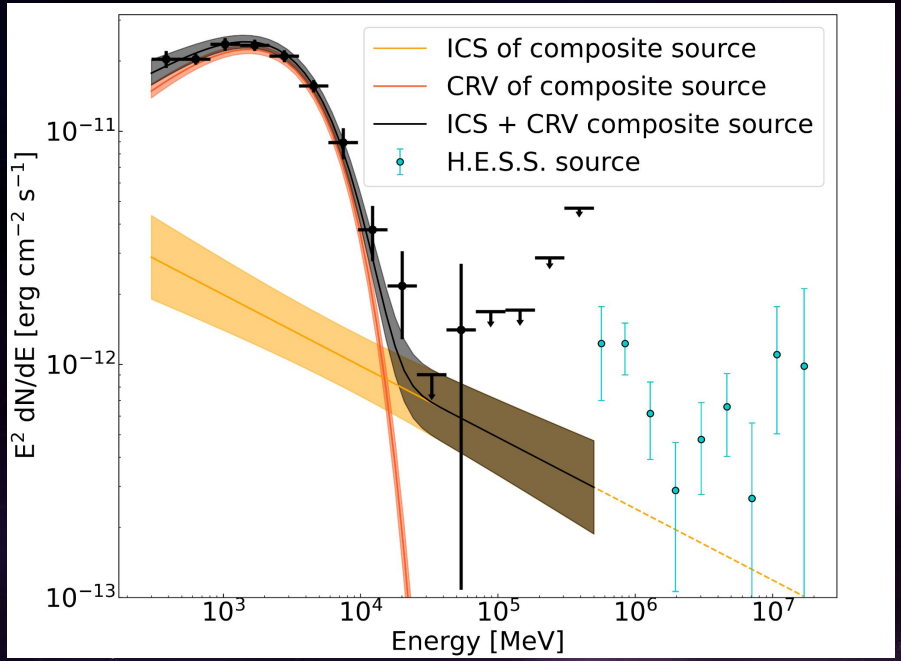


Extras

Future work: Disentangling astrophysical backgrounds from dark matter

→ Differentiating emission from a population of pulsars from that of annihilating dark matter is difficult at the Fermi-LAT's energy range

→ We can explore the spectra of MSPs and DM at higher energies in an attempt to disentangle them from each other



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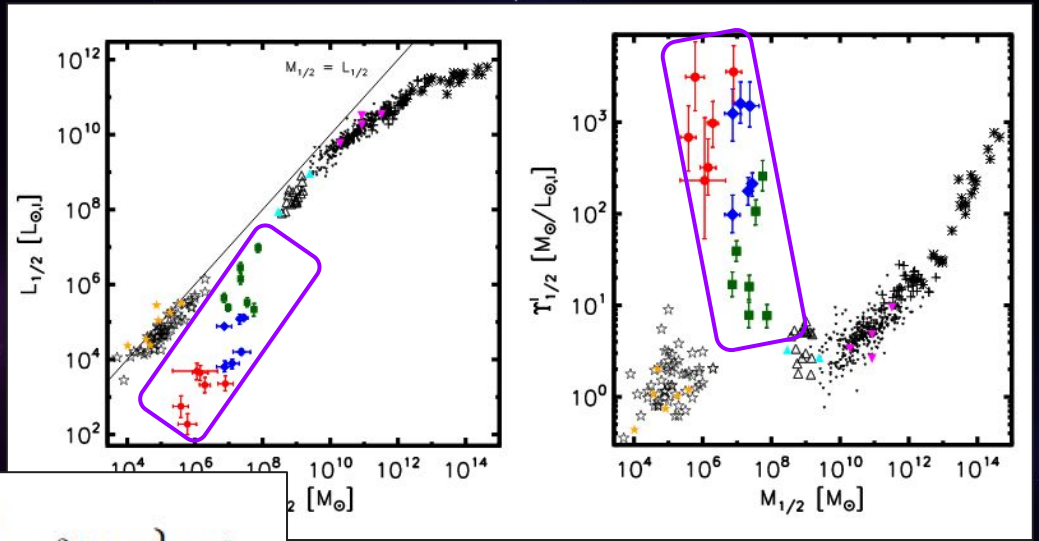
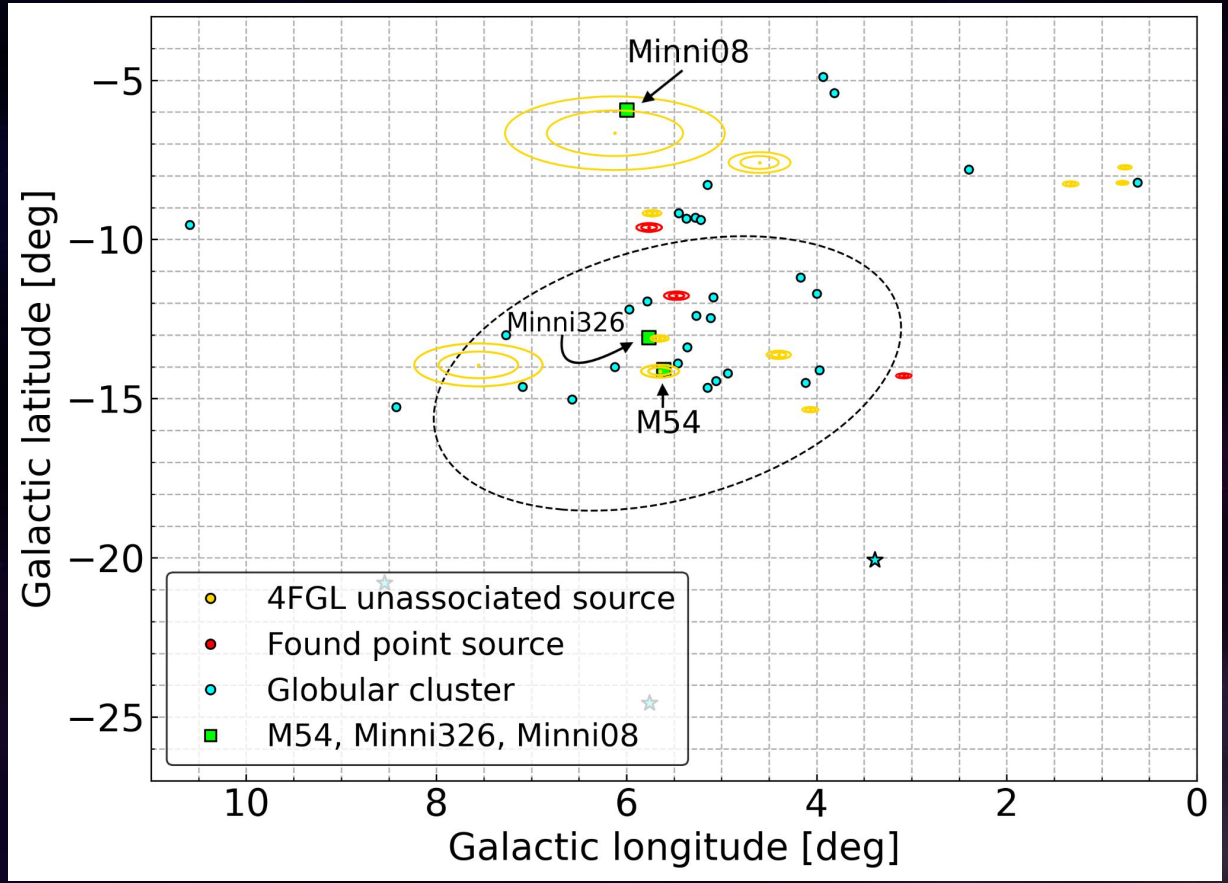


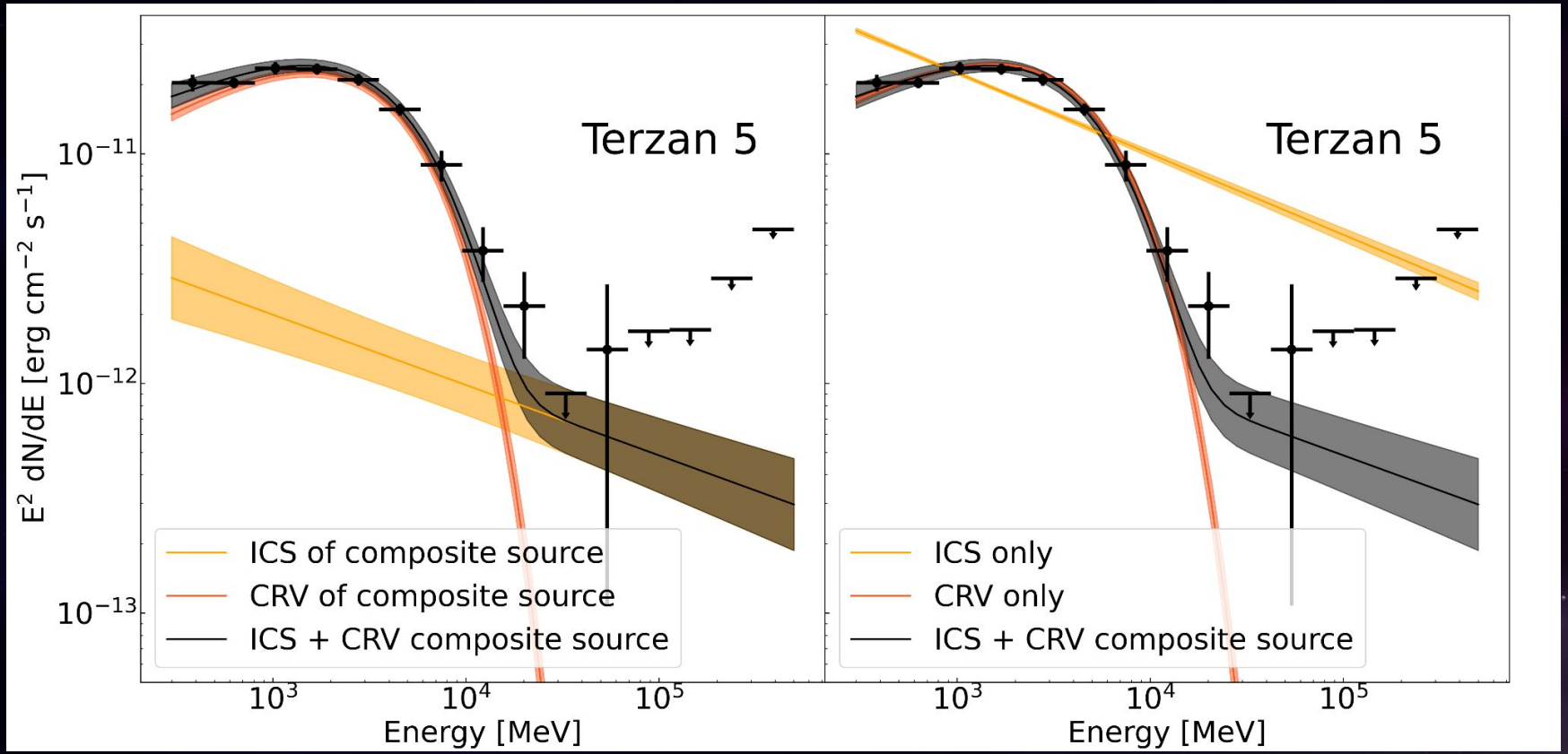
$$\phi_s(\Delta\Omega) = \underbrace{\frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_{\rm DM}^2}\int_{E_{\rm min}}^{E_{\rm max}}\frac{{\rm d}N_\gamma}{{\rm d}E_\gamma}{\rm d}E_\gamma}_{\Phi_{\rm PP}} \cdot \underbrace{\int_{\Delta\Omega}\left\{\int_{\rm l.o.s.}\rho^2(r){\rm d}l\right\}{\rm d}\Omega'}_{\text{J-factor}} .$$

The Sgr/M54 system in gamma-rays

→We search for other sources possibly associated with the Sgr/M54 system and find no substantial evidence for further sources



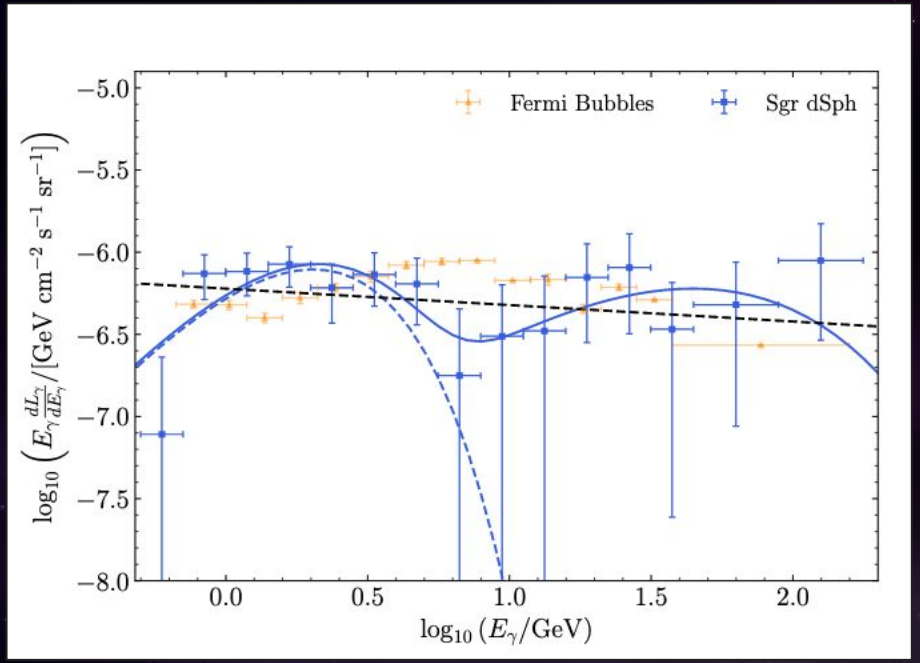
Two-component modeling of Terzan 5



The Sgr/M54 system in gamma-rays

→ Crocker et al. report a highly significant, extended source associated with Sgr

→ Attributed to the dwarf's millisecond pulsar population, with a high-energy component that is comparable to the low-energy component



Crocker et al., 2022