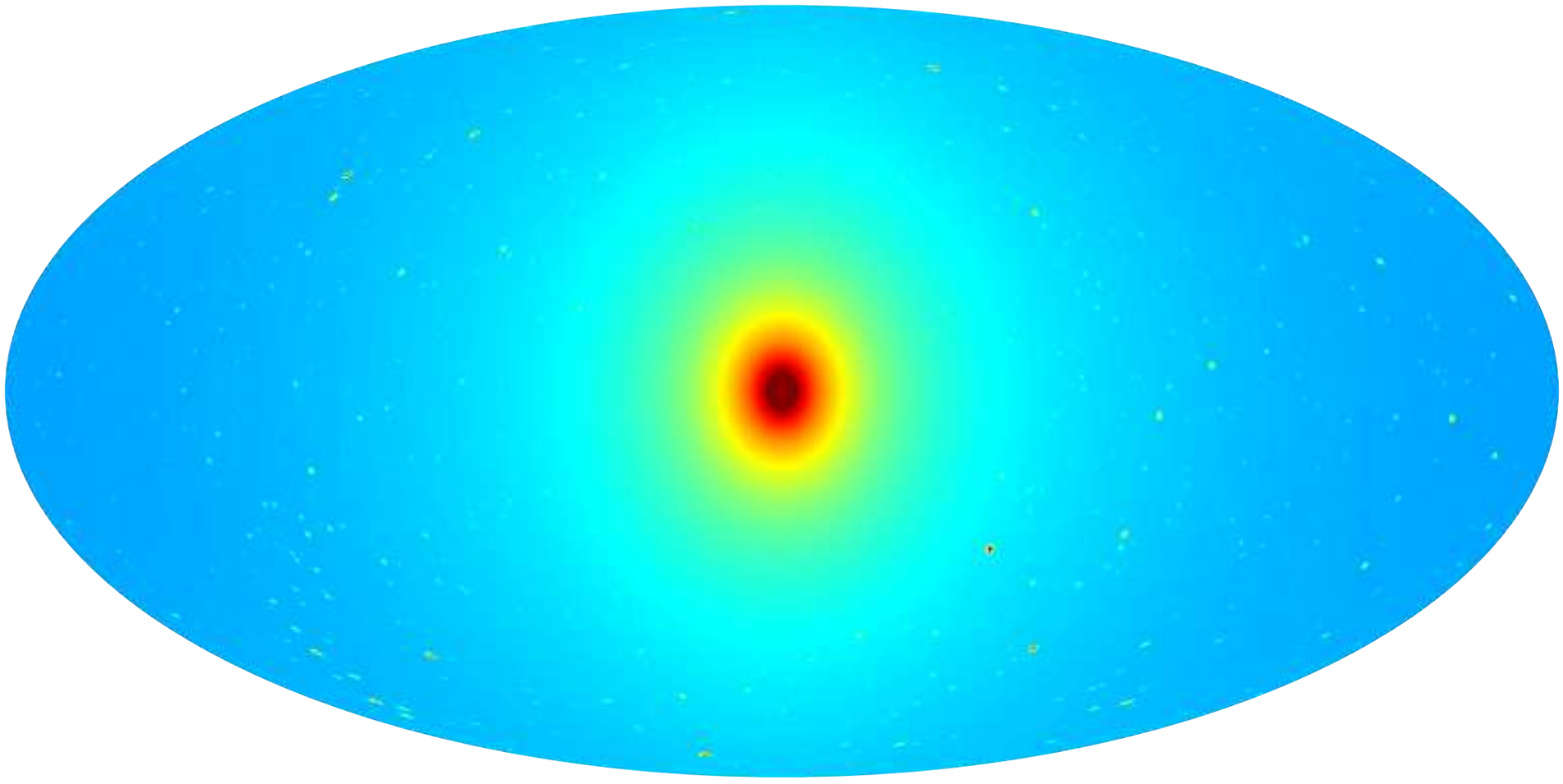
Image Credit: Springel et al. 2008

Indirect dark matter detection and the Galactic Center GeV Excess

Jennifer Siegal-Gaskins
Caltech

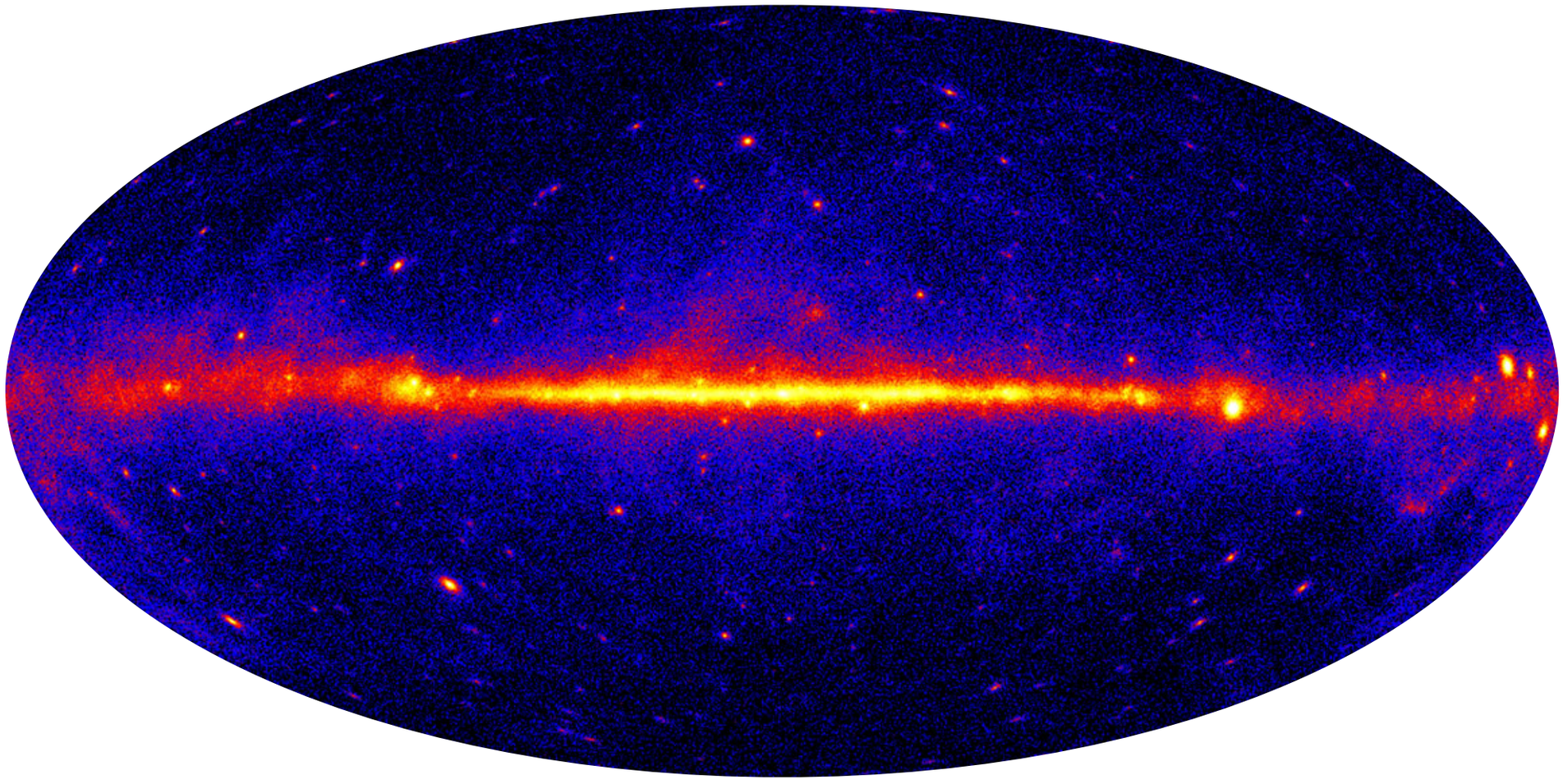
Image Credit: Springel et al. 2008



Jennifer Siegal-Gaskins

Caltech

Image Credit: NASA/DOE/International LAT Team



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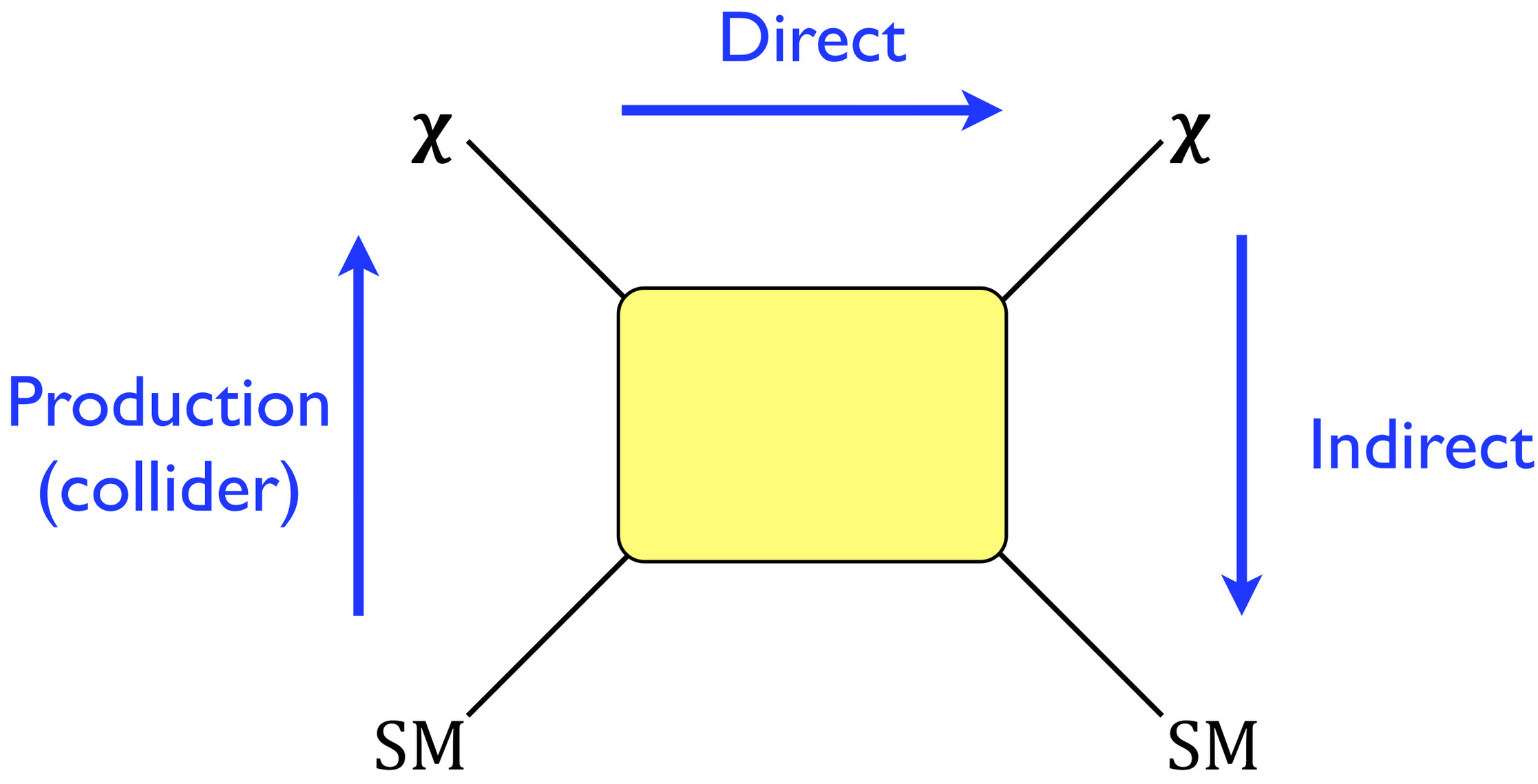
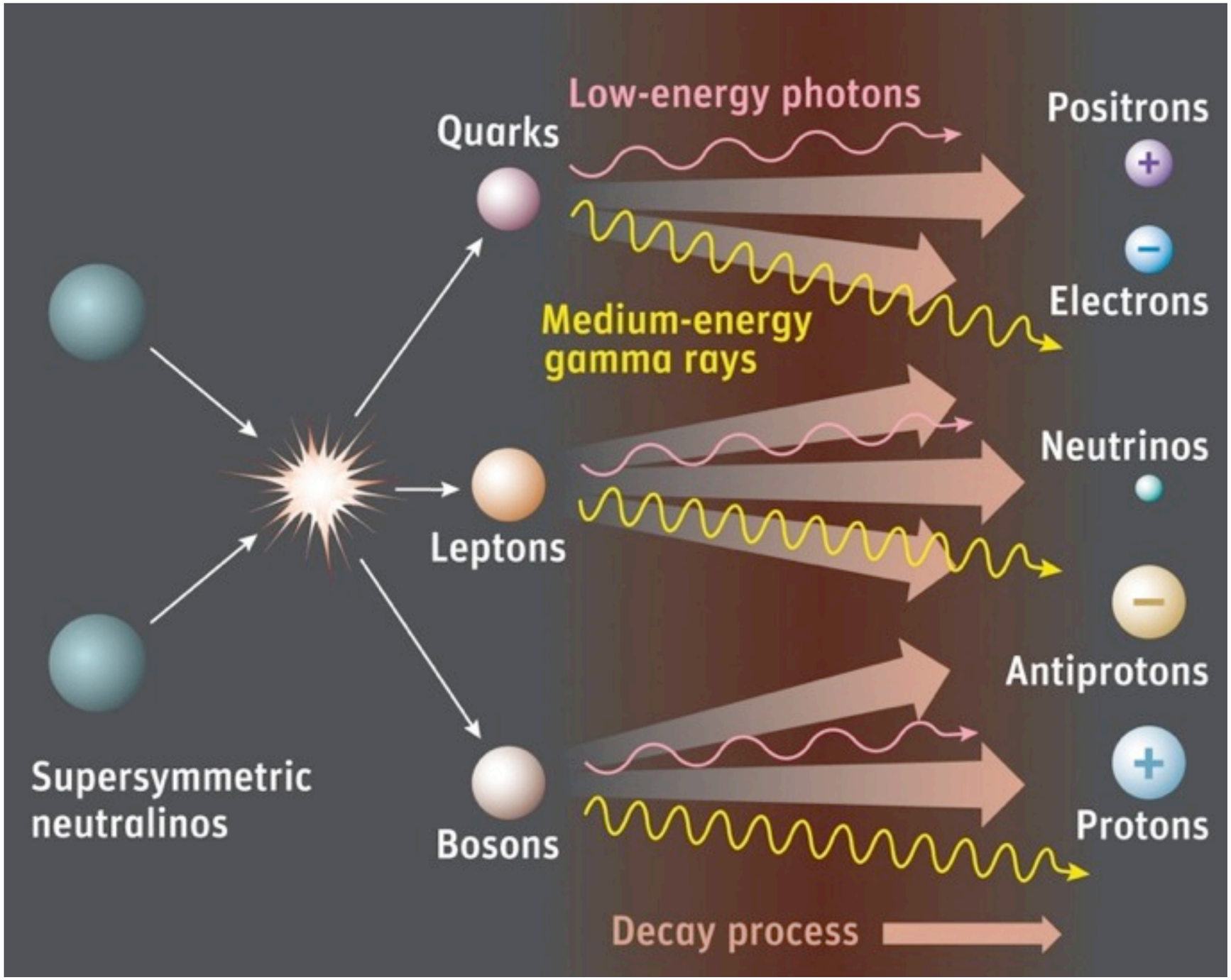
Caltech

How to detect particle dark matter?



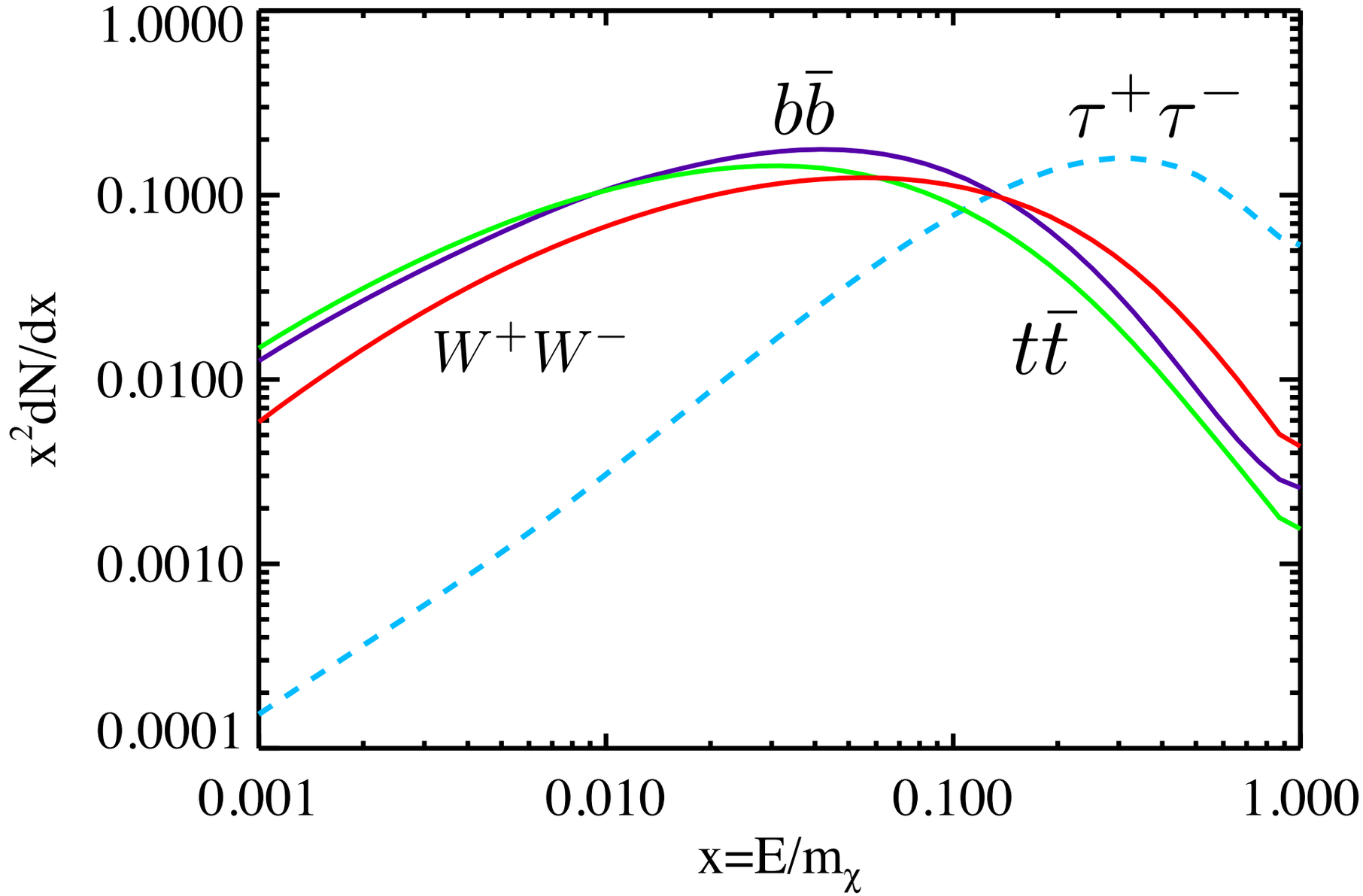
Indirect dark matter signals



Credit: Sky & Telescope / Gregg Dinderman

Dark matter photon spectra

- "soft" channels = quarks, W, z
- "hard" channels = charged leptons (e, μ, τ)
- direct annihilation to photons = line emission (γγ, Zγ)



Spectra calculated with PPPC 4 DM ID [Cirelli et al. 2010]

The dark matter annihilation signal

intensity = particle physics term "K" • astrophysics term "J"

$$K_{\rm ann} = \frac{{\rm d}N}{{\rm d}E}\frac{\langle\sigma v\rangle}{2m_\chi^2} \qquad J_{\rm ann}(\psi) = \frac{1}{4\pi}\int_{los} {\rm d}s\ \rho^2(s,\psi)$$

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spectrum of particles produced

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dark matter particle mass

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average of pair annihilation cross section times relative velocity

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dark matter density

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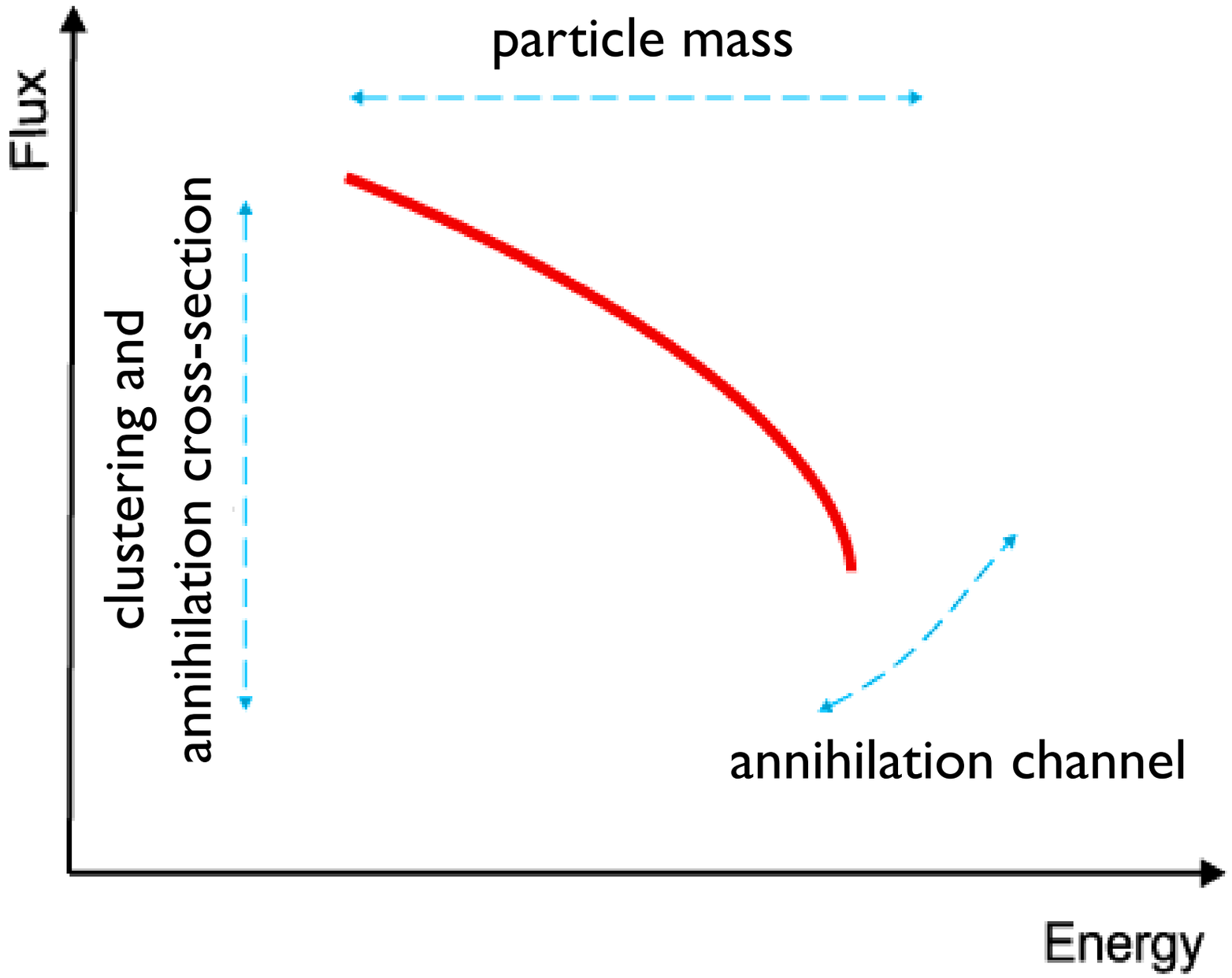


Bertone 2007

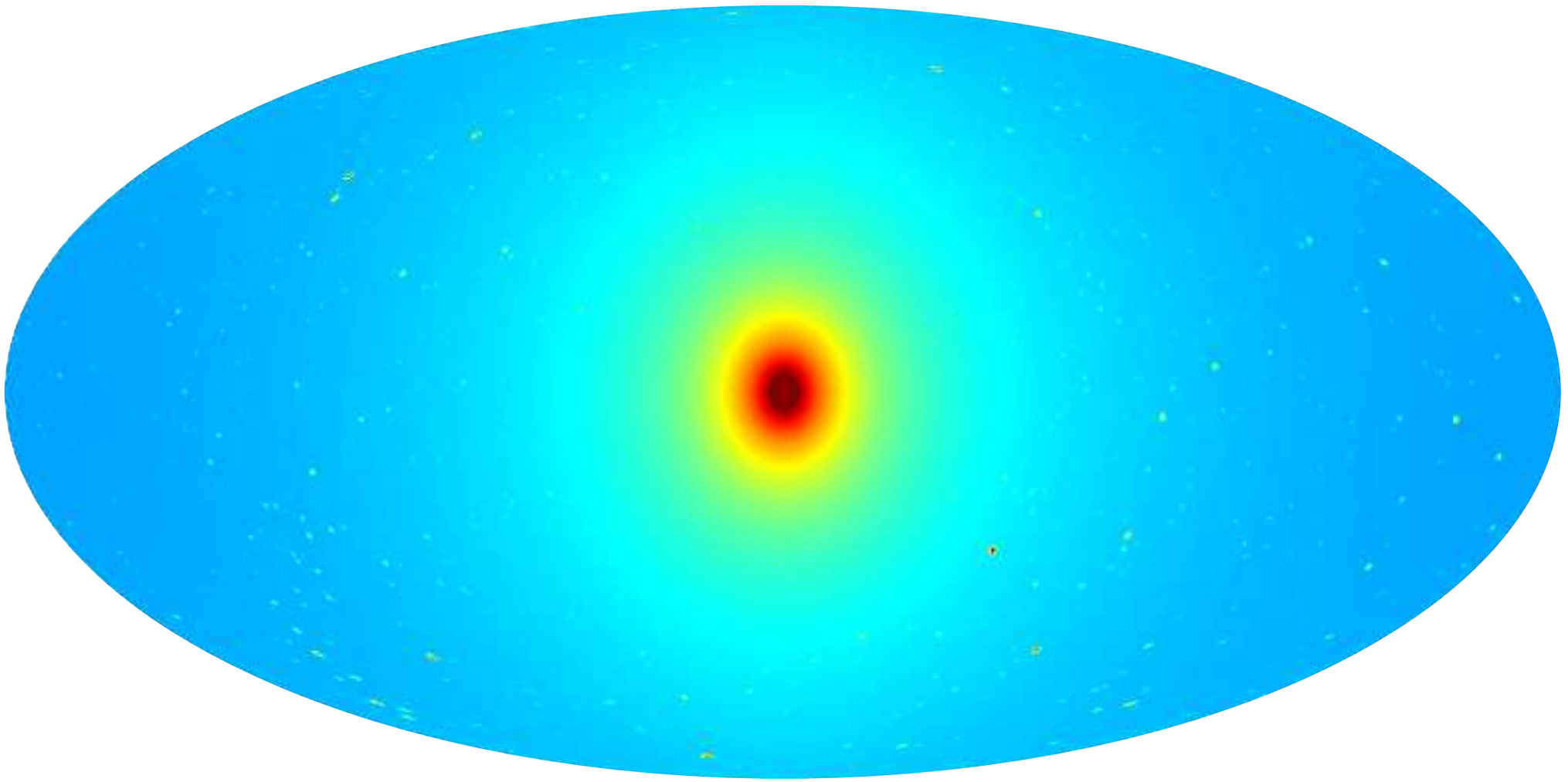
The Fermi Large Area Telescope (LAT)

- launched June 2008
- 20 MeV to > 300 GeV
- angular resolution:
  - ~ 0.1 deg above 10 GeV
  - ~ 1 deg at 1 GeV
- primarily sky-scanning mode for first ~ 5 years, enhanced Galactic Center observation mode began in December 2013

Fermi data and analysis tools are public!

Credit: NASA/General Dynamics

Dark matter annihilation signal



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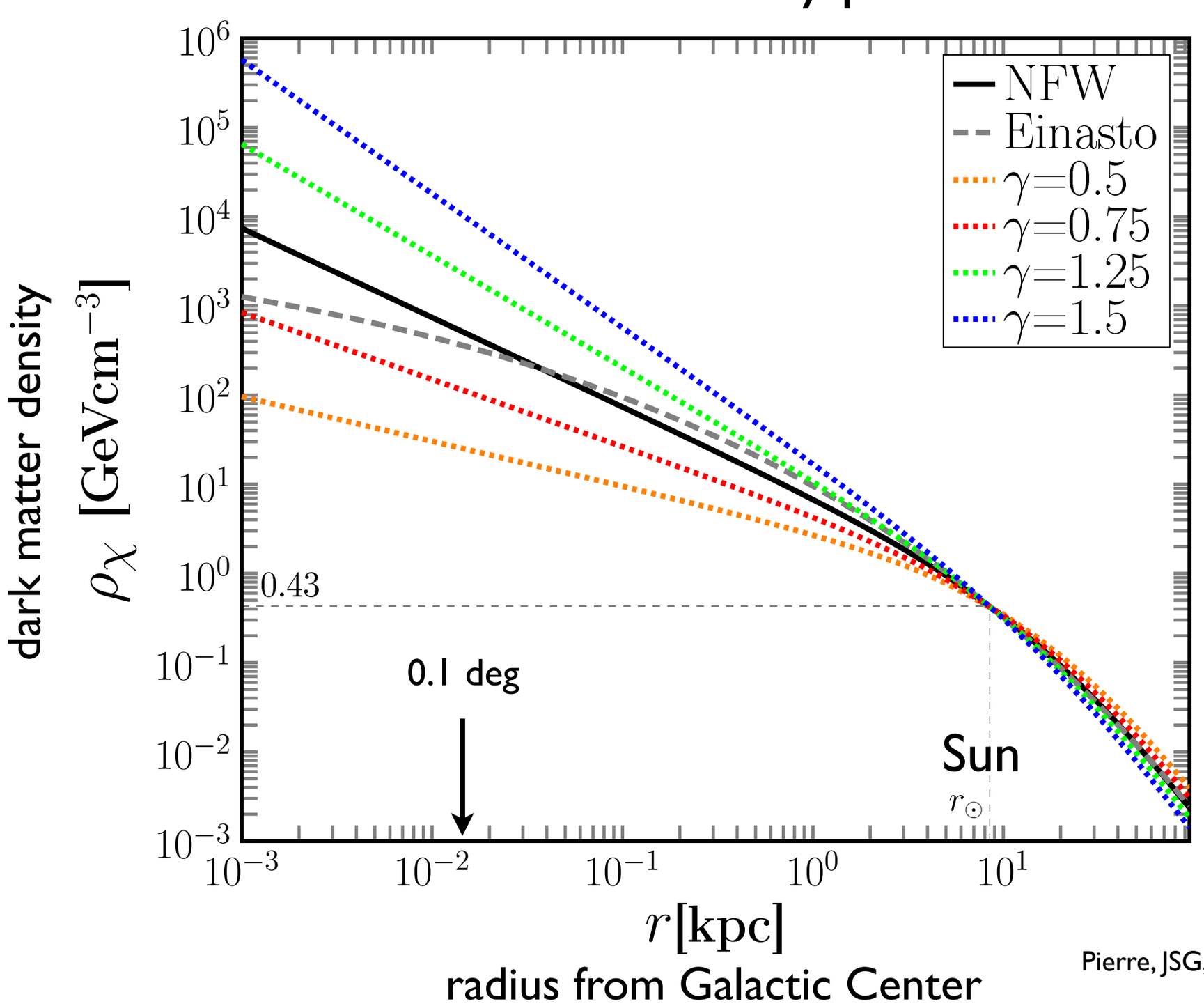
Dark matter signals from the Inner Galaxy



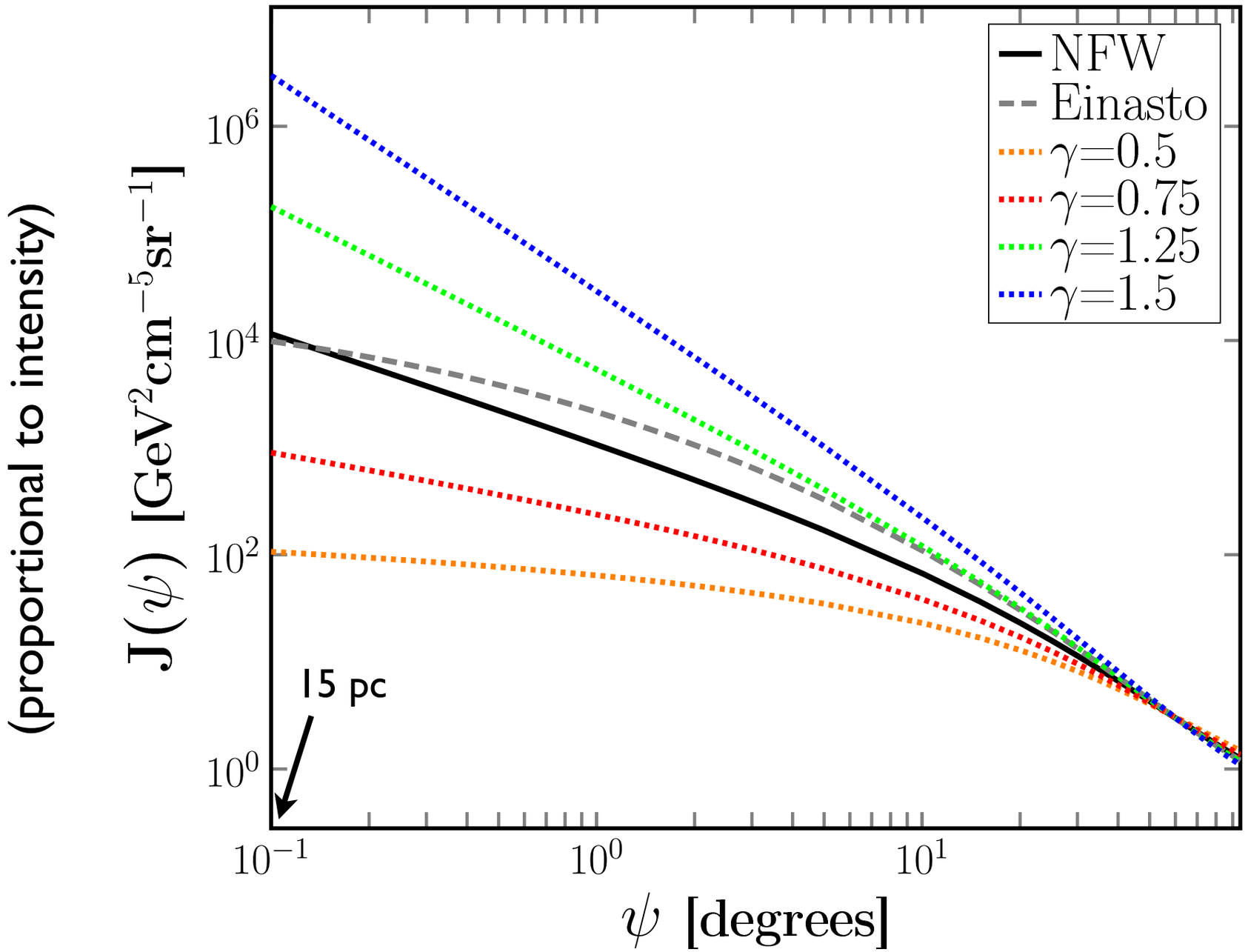
inner regions:

$$\rho(r) \propto r^{-\gamma}$$

Pierre, JSG, & Scott, 2014

Dark matter signals from the Inner Galaxy

angular dependence of dark matter intensity



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see: Hooper & Goodenough 2011, Abazajian & Kaplinghat 2012, Hooper & Slatyer 2013, Gordon & Macías 2013, Abazajian et al. 2014, Daylan et al. 2014, and others

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- Using Fermi LAT data, multiple groups have claimed an excess at a few GeV from the Galactic Center and higher Galactic latitudes. The excess has been interpreted as emission from dark matter (DM) annihilation and/or unresolved millisecond pulsars (MSPs).

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  - would require a few thousand MSPs, which seems plausible

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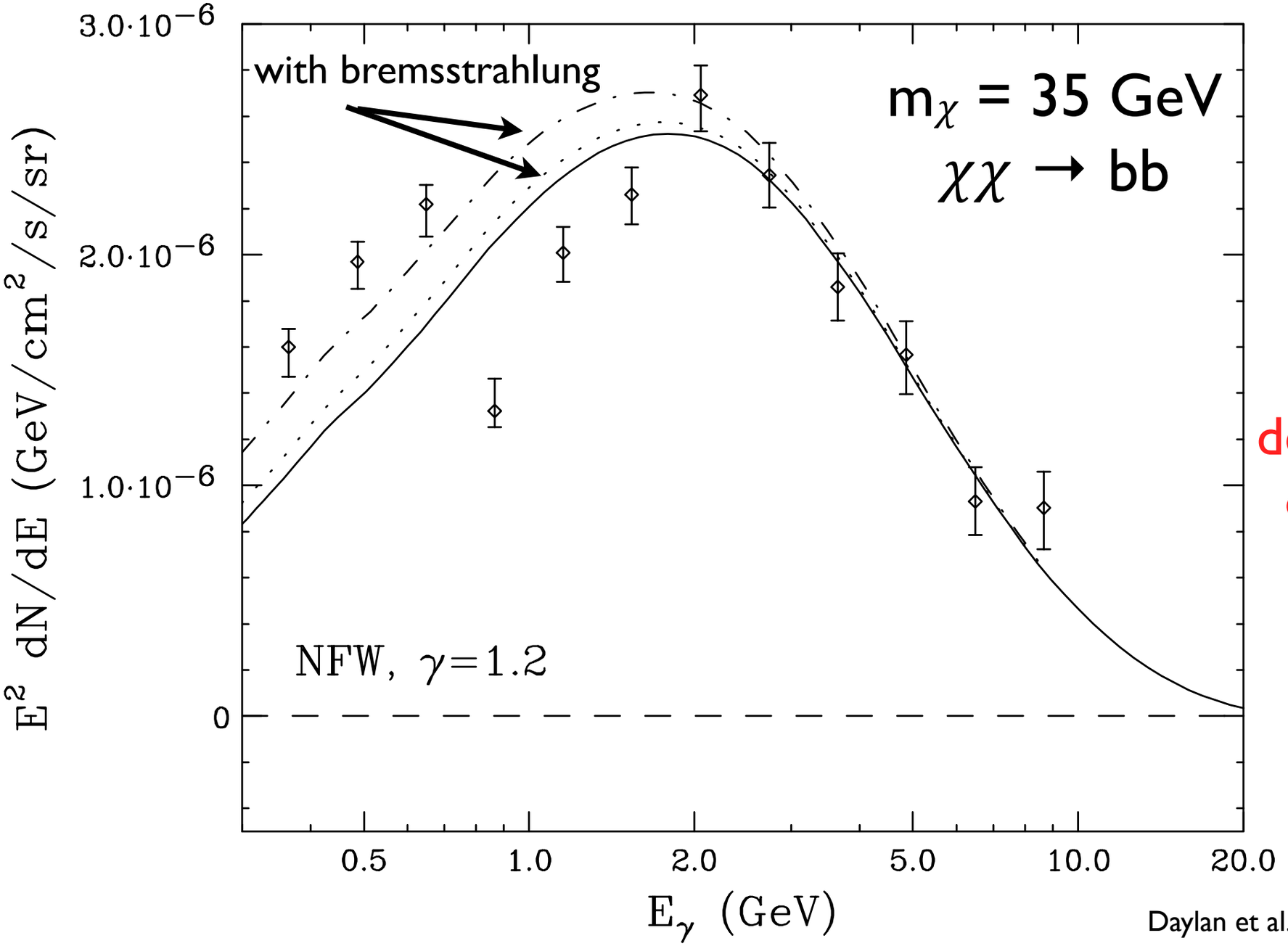
A dark matter signal in the Inner Galaxy?

Energy spectrum of excess in Galactic Center



Daylan et al. 2014

NB: Abazajian et al (2014) find strong dependence of spectrum of excess on details of background model

A dark matter signal in the Inner Galaxy?

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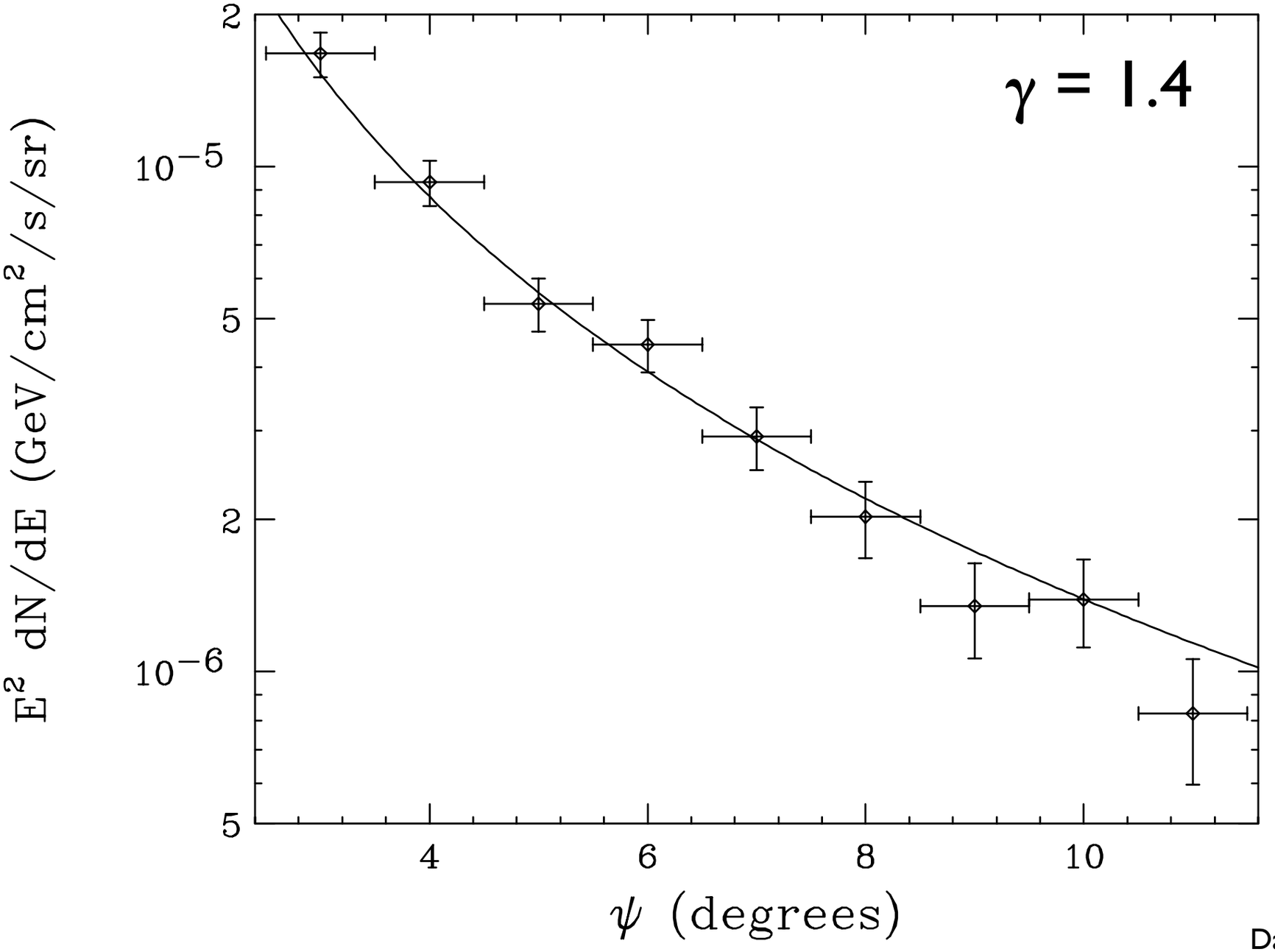


Daylan et al. 2014

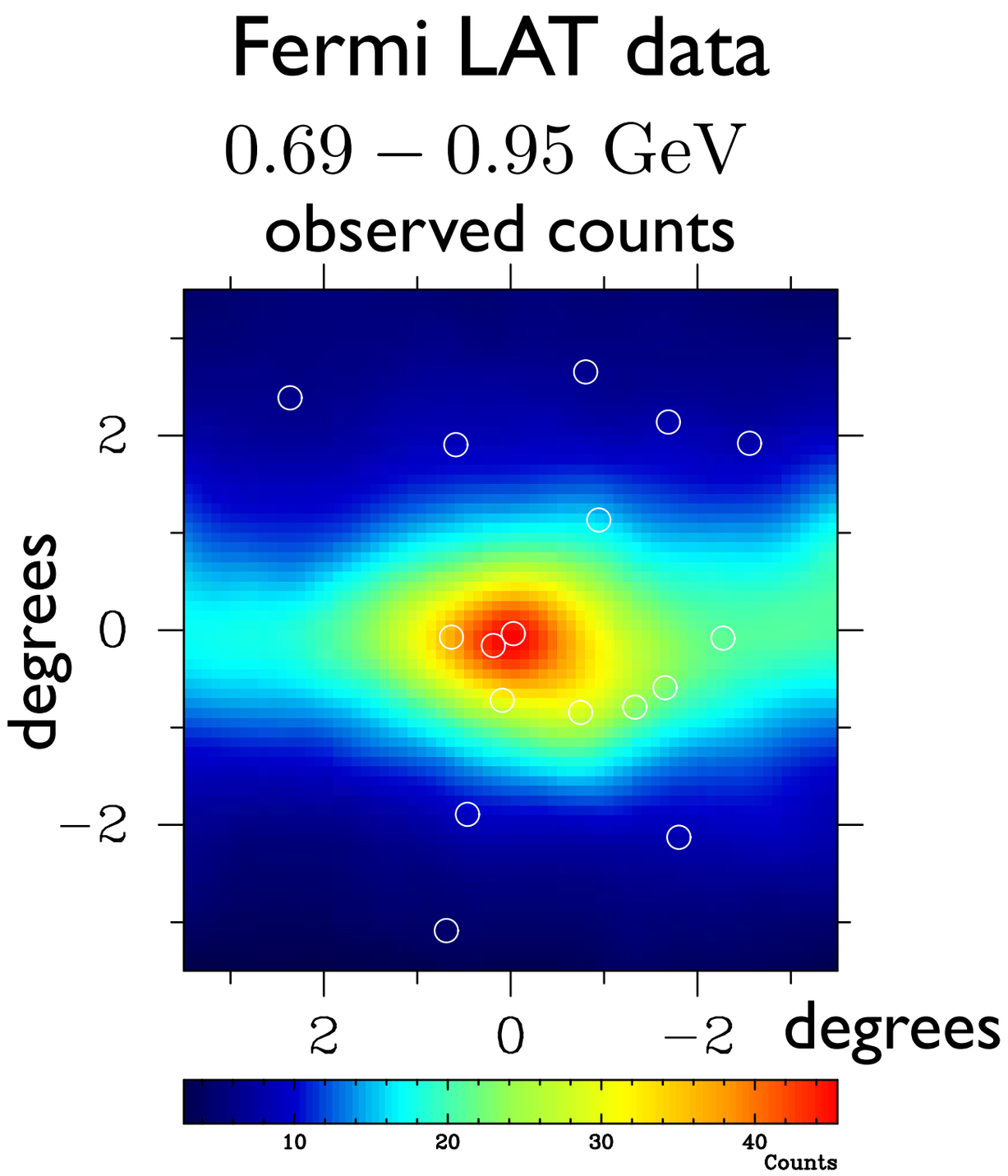
Excess over what?

What's in the model:

- Galactic diffuse emission associated with cosmic-ray interactions (sum of many processes)
- isotropic gamma-ray background (measured)
- detected gamma-ray sources (e.g., pulsars, supernova remnants)

What's not in the model:

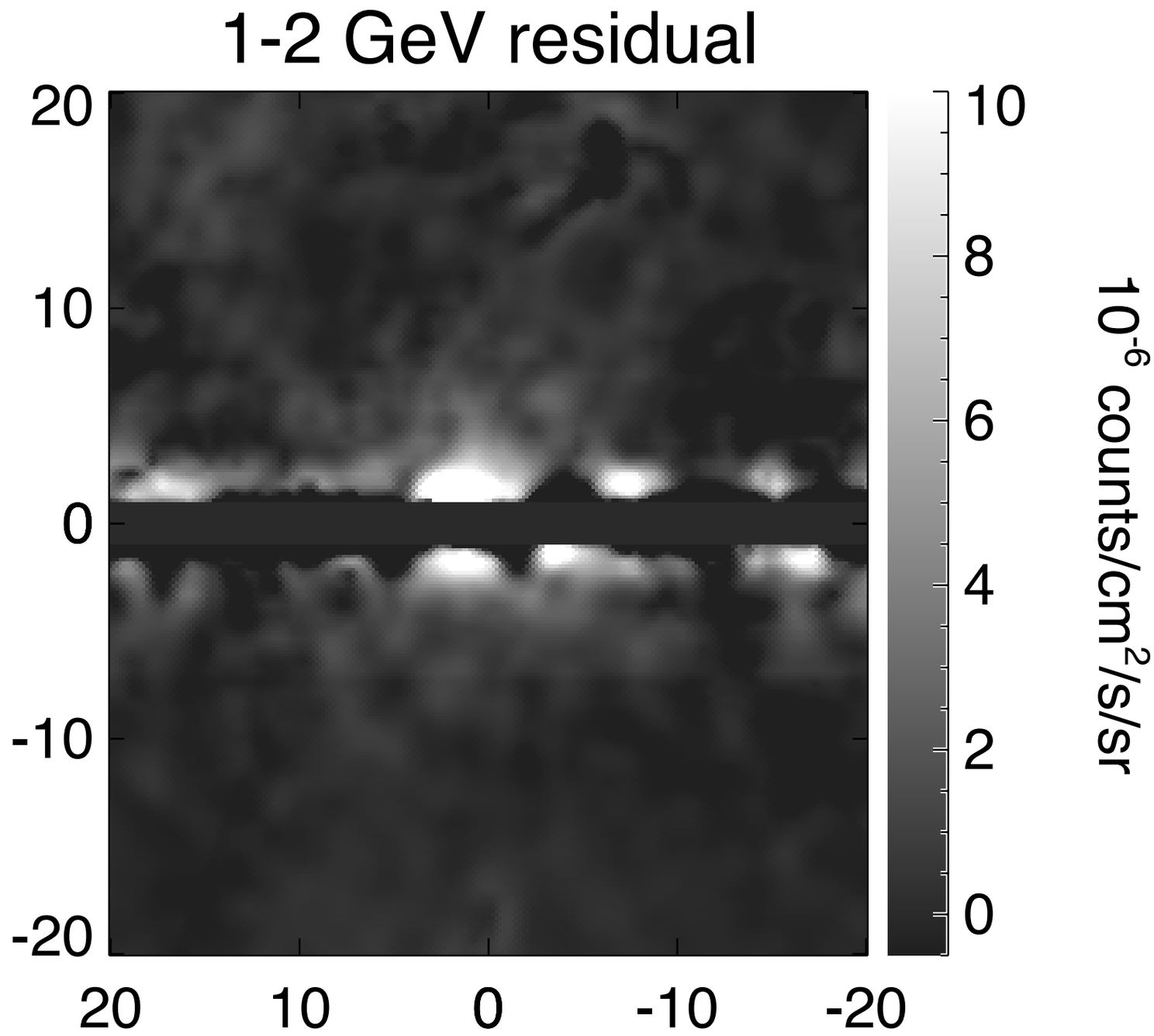
- unresolved gamma-ray sources
- dark matter



Abazajian & Kaplinghat 2012

Residuals

(for best-fit model w/o dark matter component)



Daylan et al. 2014

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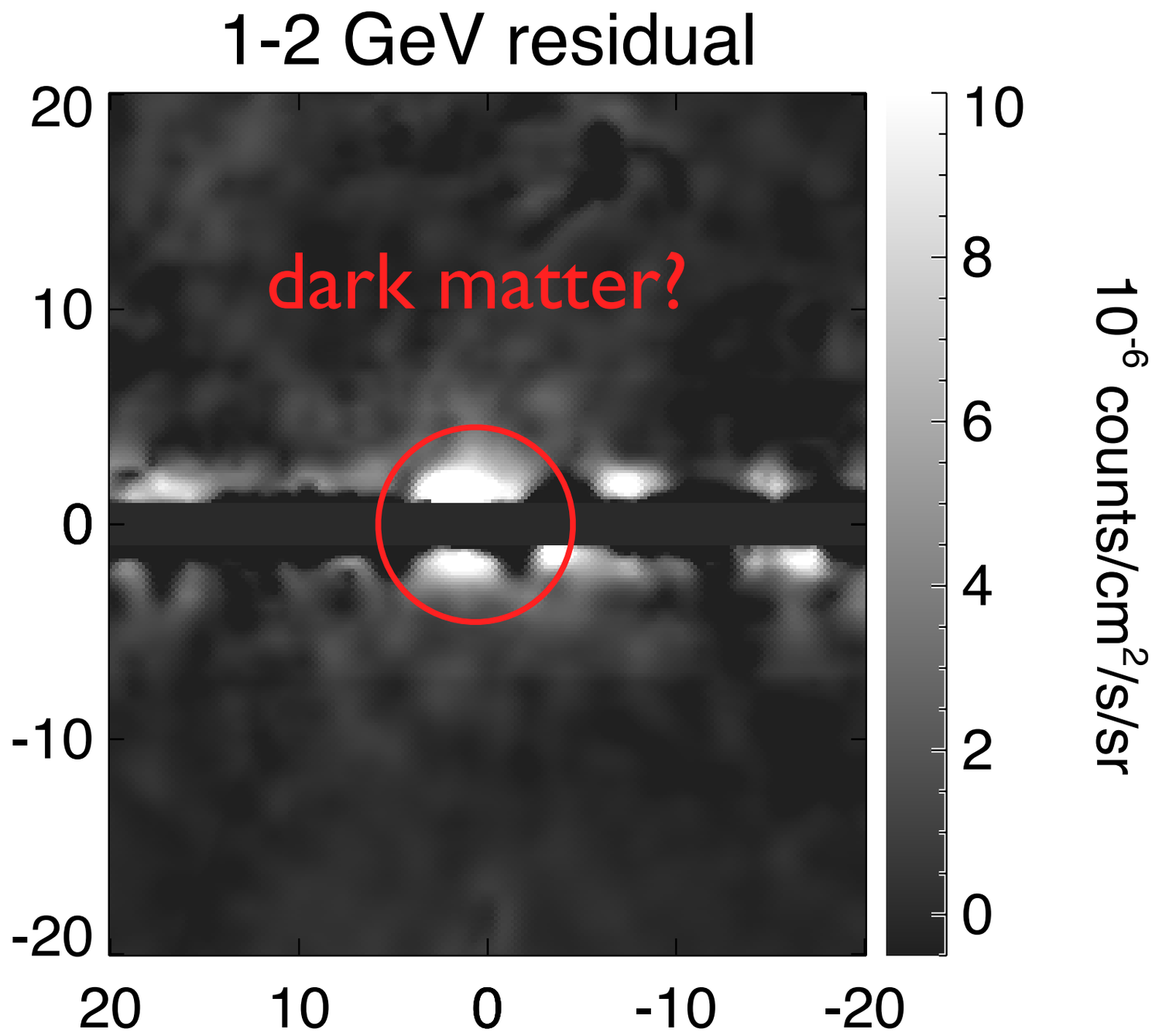

Daylan et al. 2014

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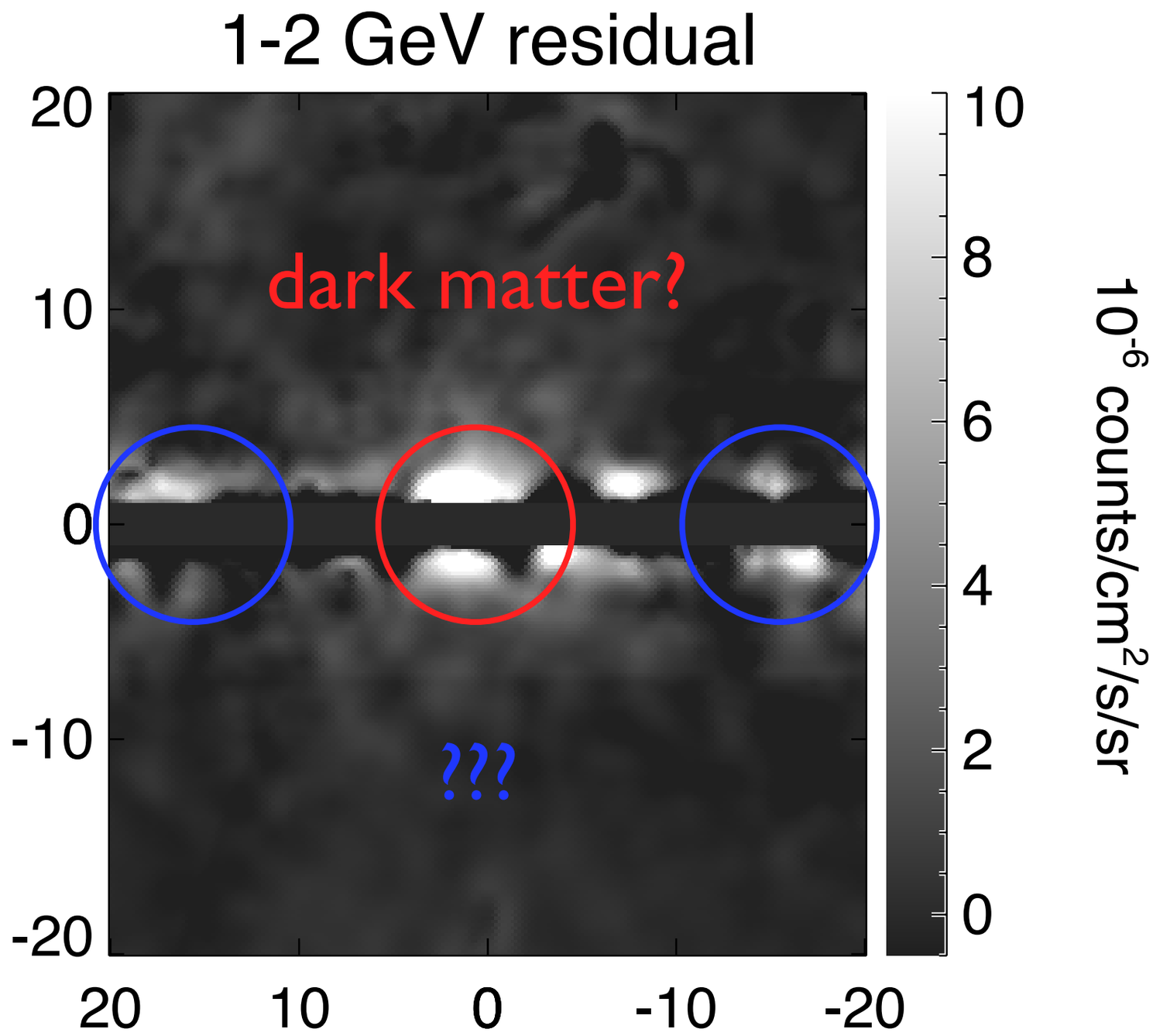
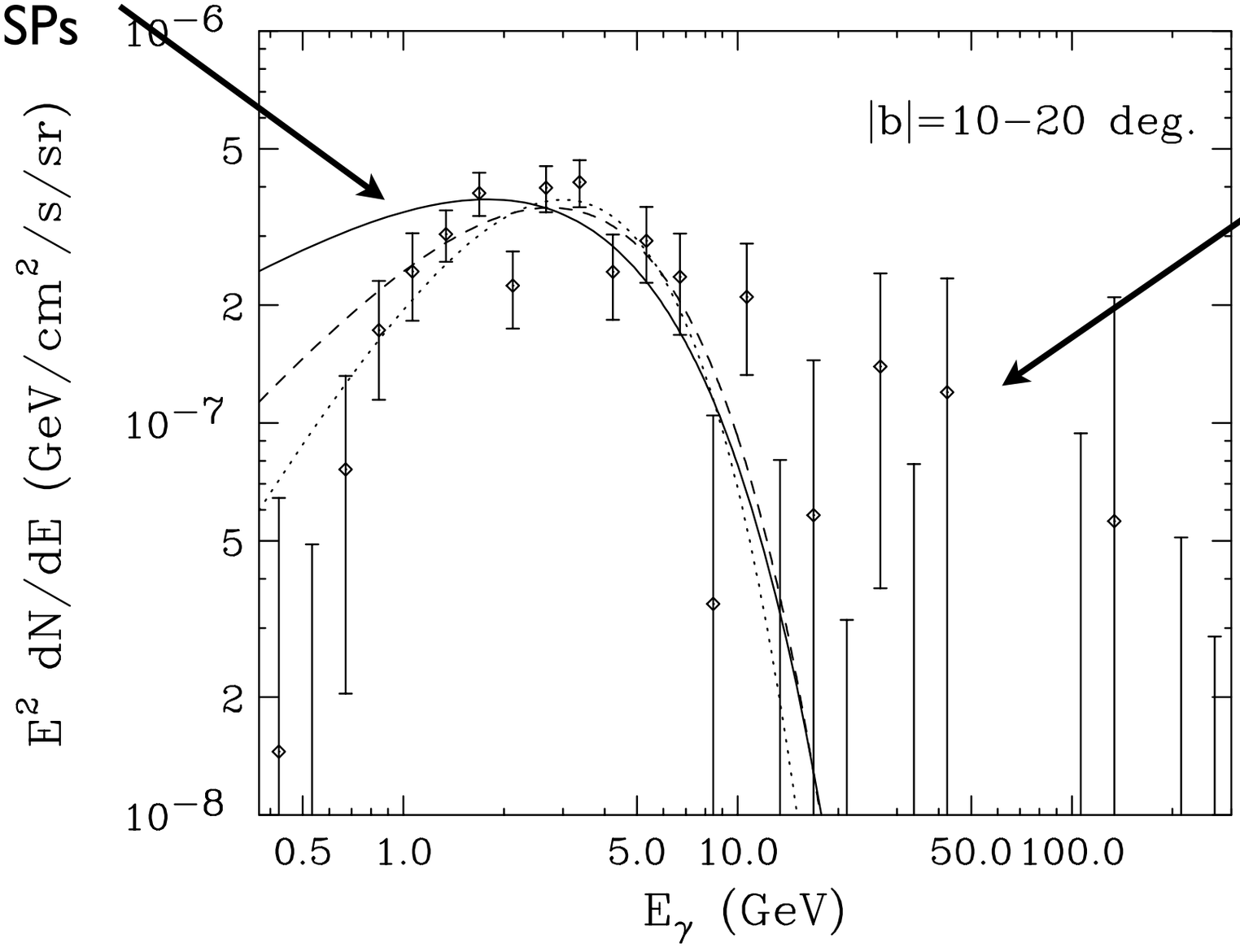


Daylan et al. 2014

Can the GeV excess be millisecond pulsars?

best-fit to Fermi-detected MSPs

spectral comparison



GeV excess at high latitudes (data points)

Hooper, Cholis, Linden, JSG, Slatyer 2013

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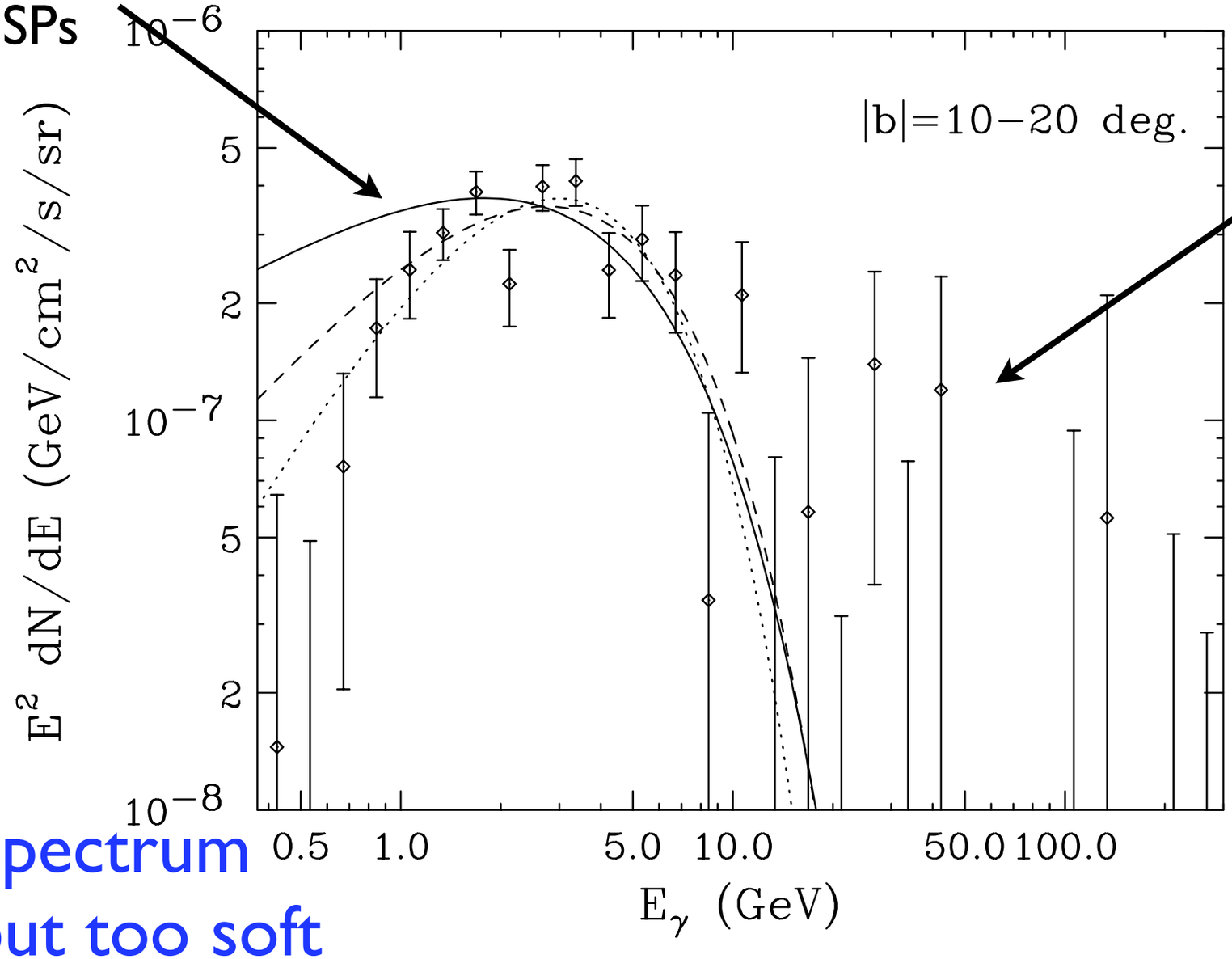


GeV excess at high latitudes (data points)

MSP spectrum similar but too soft at low energies

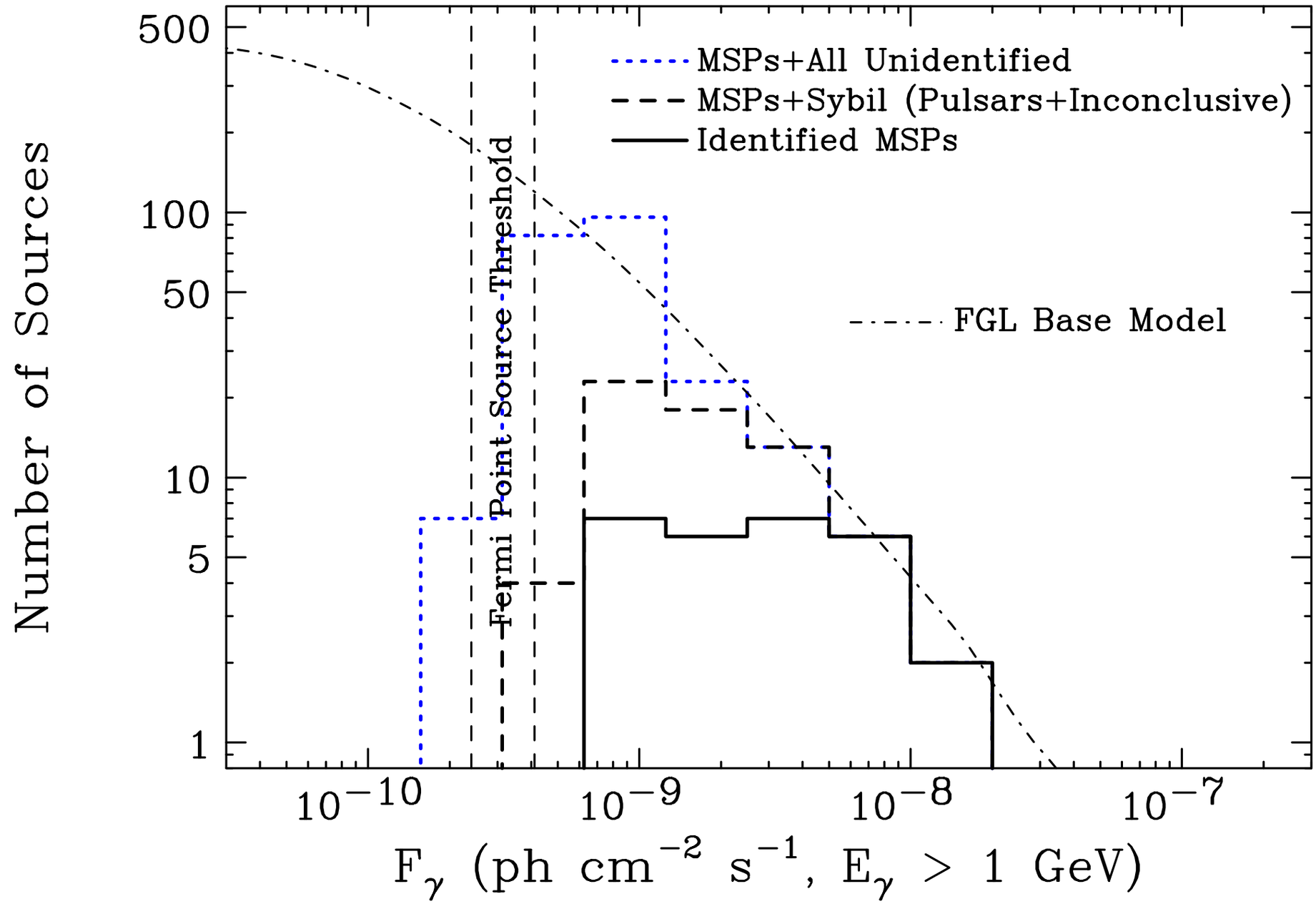
Hooper, Cholis, Linden, JSG, Slatyer 2013

Can the GeV excess be millisecond pulsars?

- adopt a spatial model and luminosity function for the MSPs, calibrated to detections in radio

- base model can roughly account for the amplitude of Inner Galaxy excess, but strongly overpredicts number of Fermi-detected MSPs

source count distribution (|b|>10 deg)



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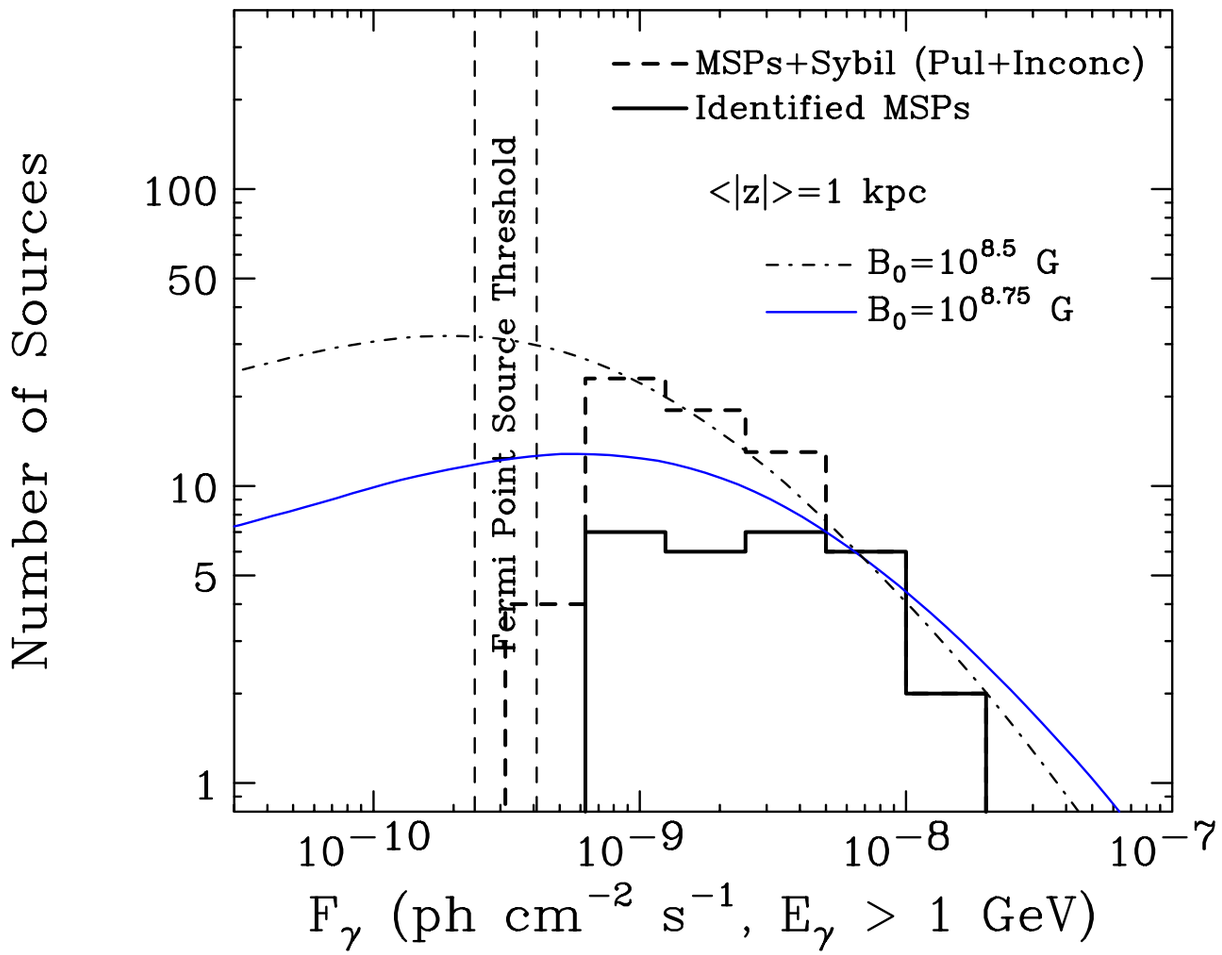
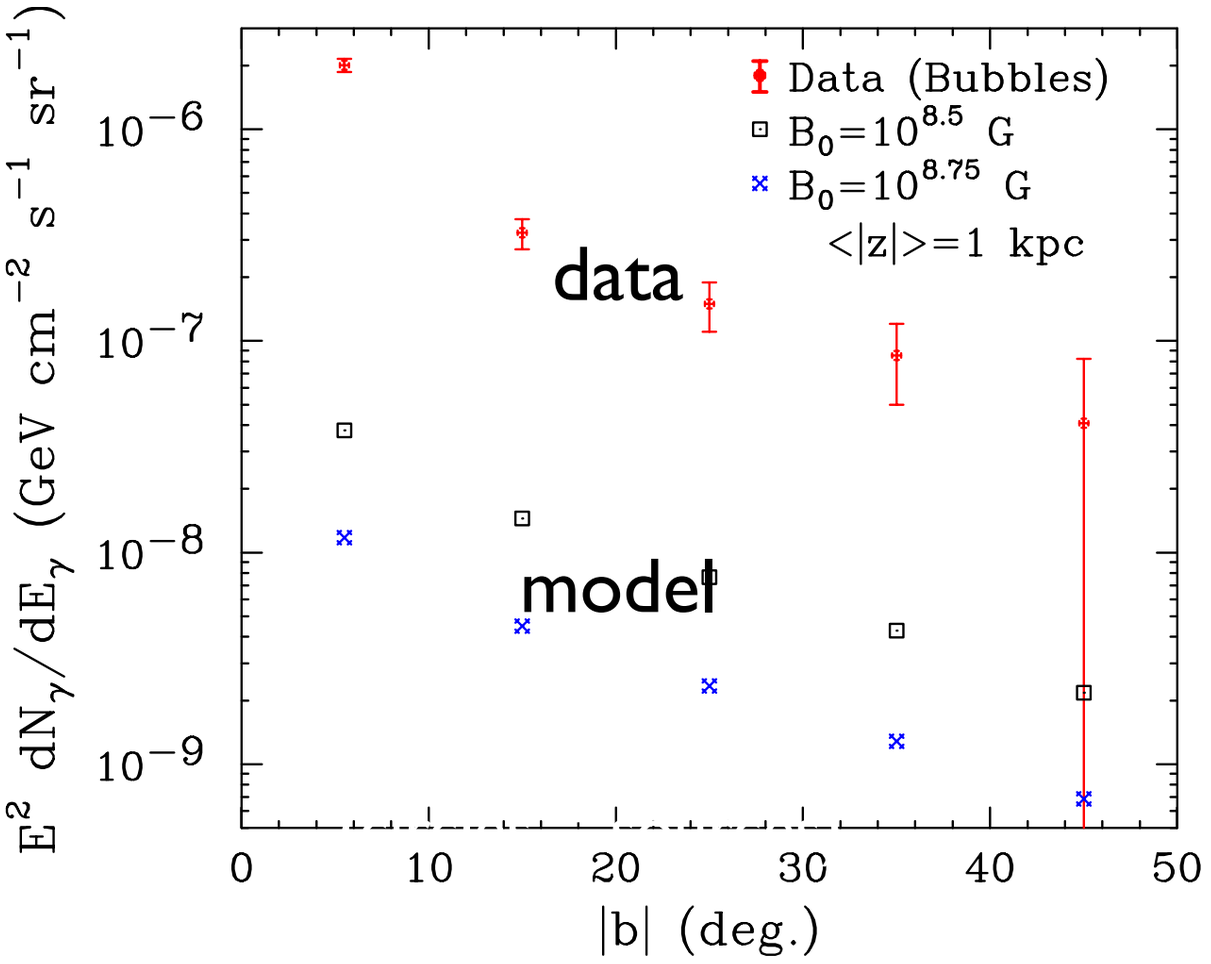


Latitude dependence of excess



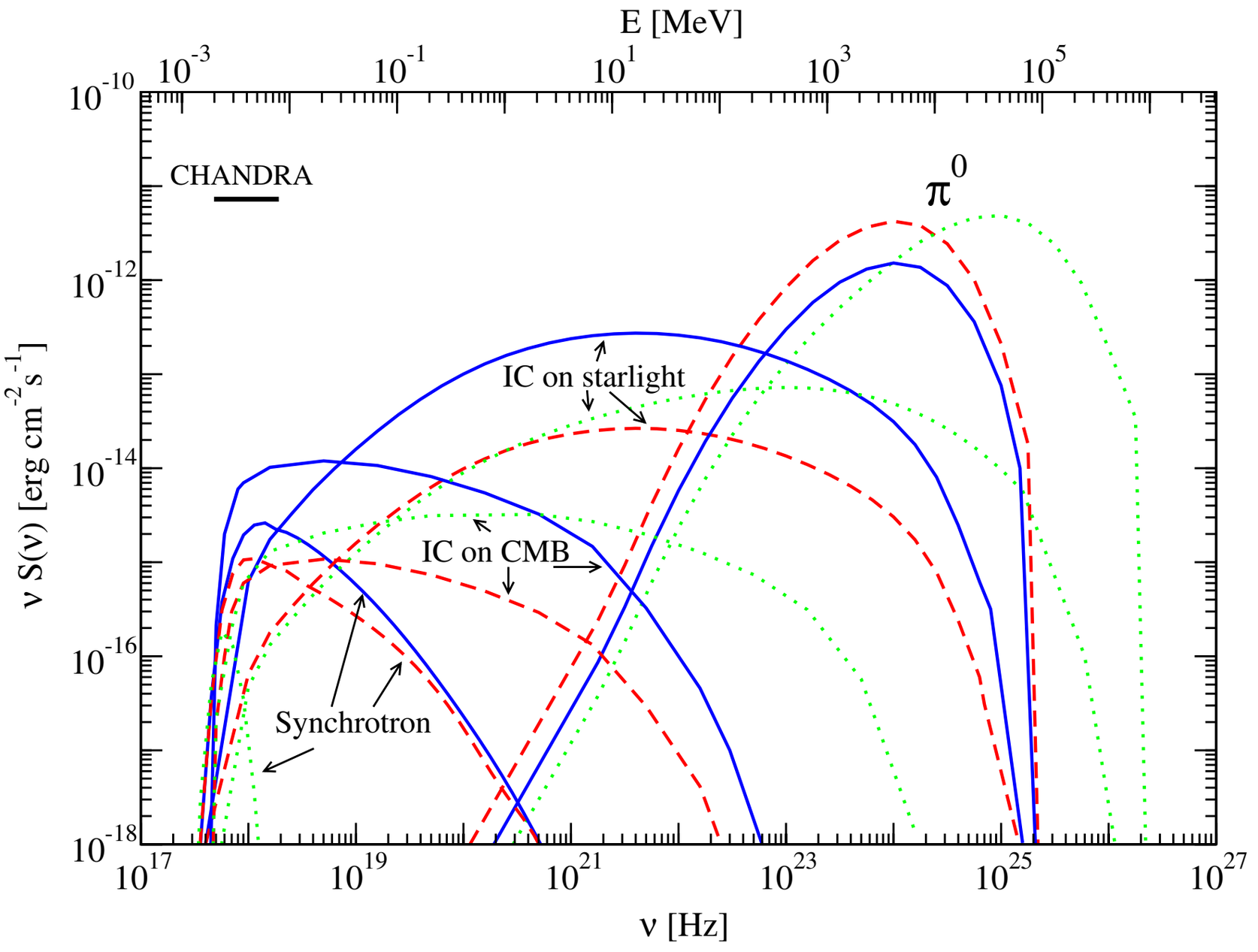
adjusting MSP model parameters to better reproduce the observed source counts leads to models that cannot explain the *amplitude* of the observed excess

Hooper, Cholis, Linden, JSG, Slatyer 2013

Multi-wavelength dark matter photon spectra

- secondary photon emission associated with charged particle final states:
  - bremsstrahlung
  - inverse Compton scattering of starlight, CMB
  - synchrotron due to magnetic fields

DM spectrum from the Galactic Center



Regis & Ullio 2008

Bed of Procrustes

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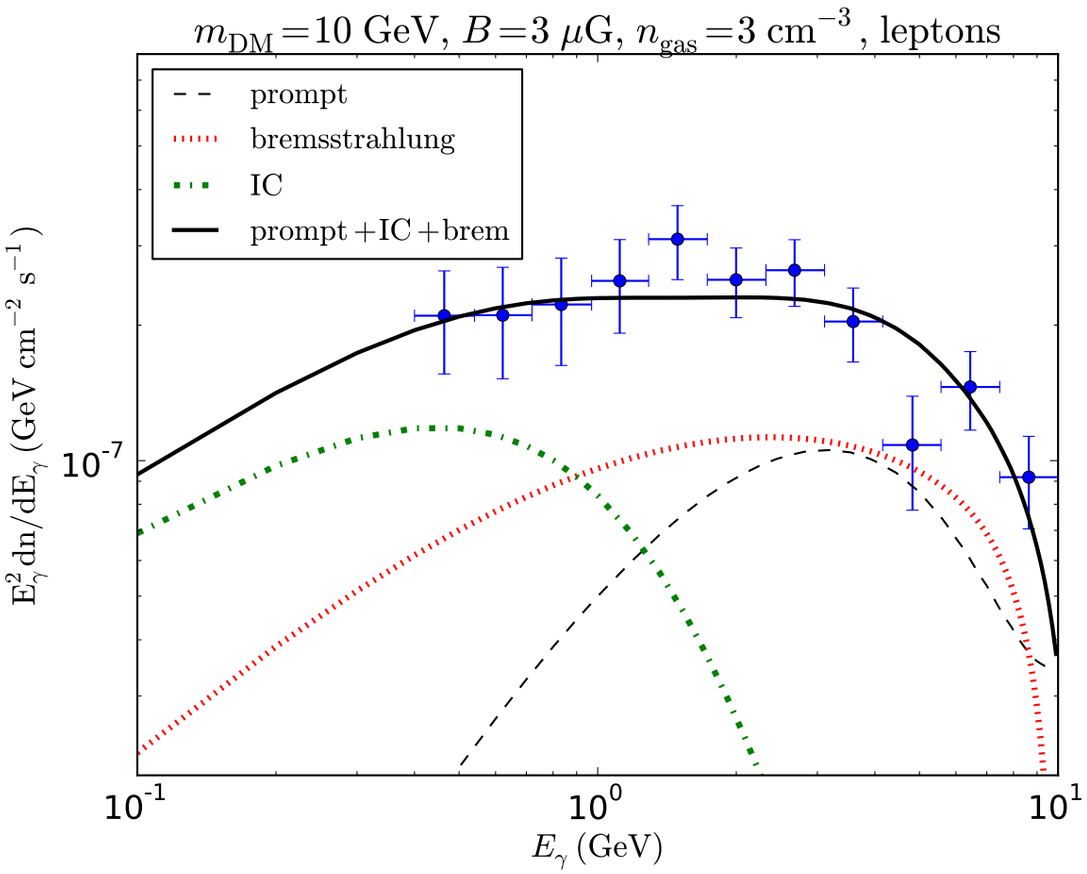

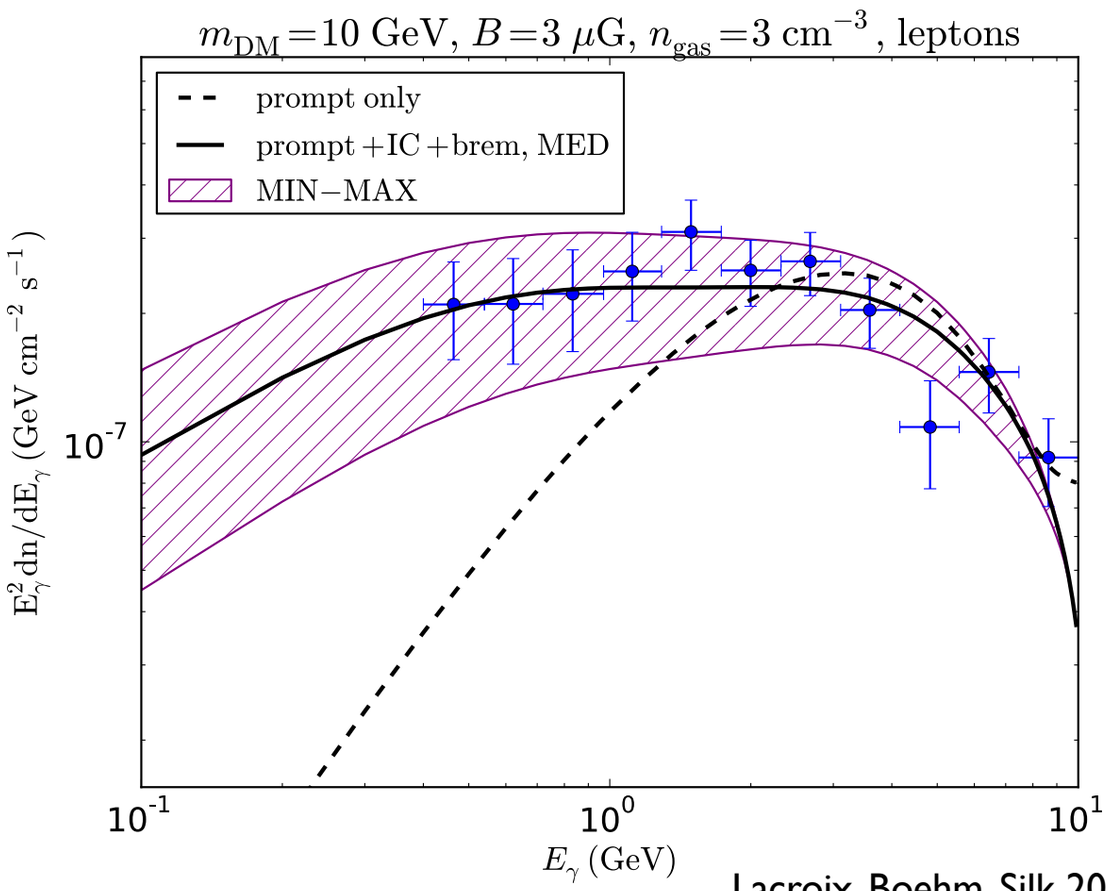

Lacroix, Boehm, Silk 2014

- Lacroix et al. point out importance of:
  - inverse Compton
  - propagation model
  - diffusion (and latitude dependence of secondary emission)

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- Systematics? (Not statistics-limited!)