Anisotropies in the Gamma-Ray Sky from Millisecond Pulsars

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Goal

- Disentangle the components of diffuse gamma ray background
- Find millisecond pulsar (MSP) contribution to intensity and anisotropy of high latitude emission
- Look for anisotropy signatures of MSPs

Approach

- 10 Monte Carlo Realizations of the Milky Way MSP population
- Make HEALPix maps of the gamma-ray emission
- Calculate the mean intensity and anisotropy properties from the sky maps
- Show constraint method for possible number of MSPs
- Estimate detectability with Fermi of MSPs via anisotropy

MSP Model

MSP2_Base Model from Faucher-Giguere & Loeb (2010)

- Height

$$N(z) \propto e^{-|z|/<|z|>}$$

$$<|z|> = 1\,kpc$$

- Radial

$$\rho(r) \propto e^{-r^2/2\sigma^2}$$

$$0 < r < \infty$$

- Period

$$N(P) \propto P^{m-1}$$

$$m = 1.5$$

- Magnetic Field

$$N(\log B) \propto e^{[-(\log B - <\log B>)^2/2\sigma^2_{\log B}]}$$

$$<\log B> = 8 \qquad \sigma_{\log B} = 0.2$$

$$B = 3.2\times10^{19}(P\dot{P})^{1/2}\,G$$

$$L_\gamma^{ph} \equiv K \min\{C\dot{P}^{1/2}P^{-3/2}, f_\gamma^{\max}\dot{E}\}$$

$$\frac{dN}{dEdAdt} \propto E^{-\Gamma} e^{-E/E_{cutoff}}$$

Fermi

$$\Gamma \sim 1.522 \pm 0.199$$

$$E_{cutoff} \sim 1.88 \pm 0.54$$

Abdo et al (2010)

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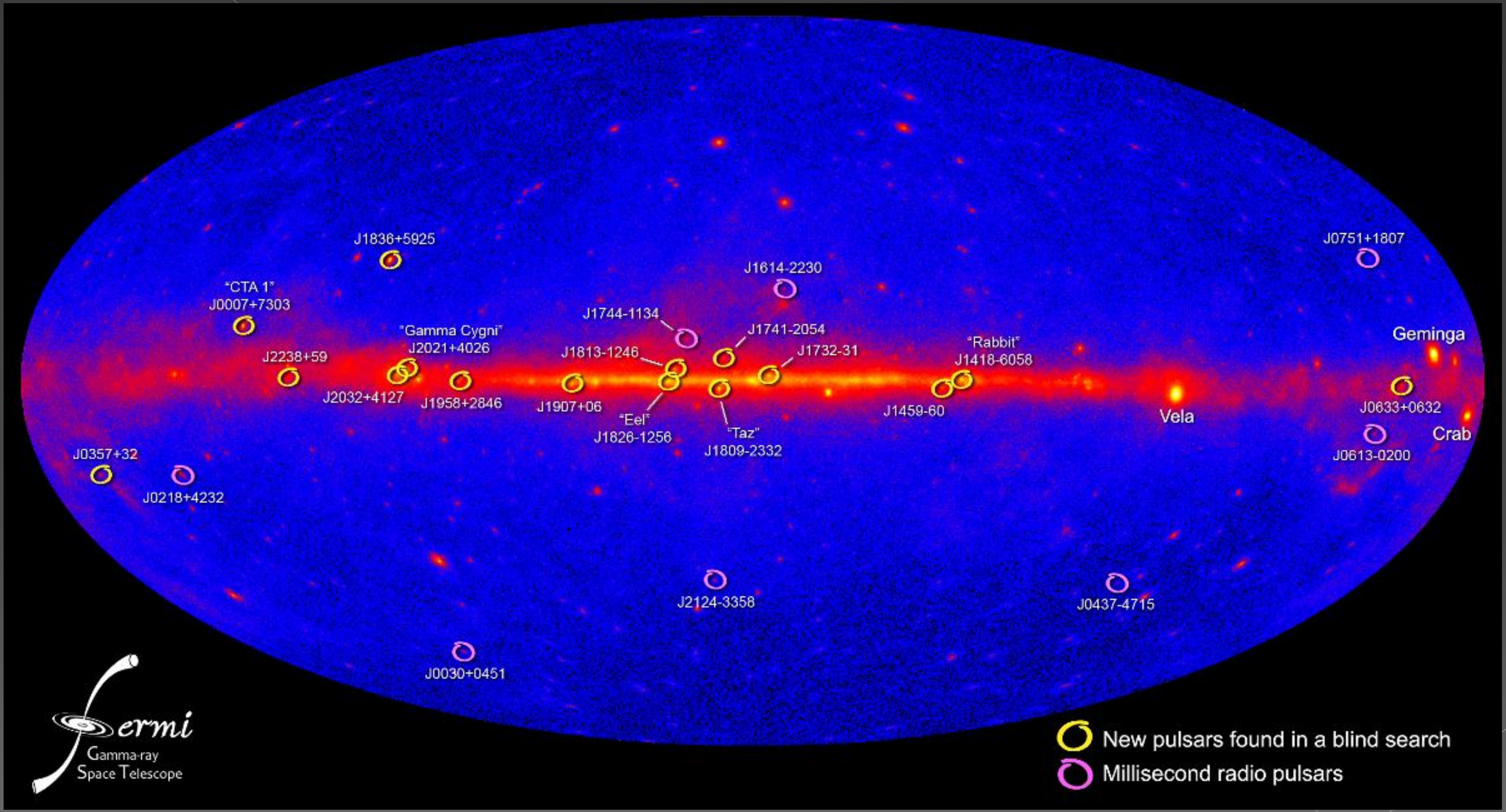
Fermi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J2238+59
"Gamma Cygni"
J2021+4026
J2032+4127
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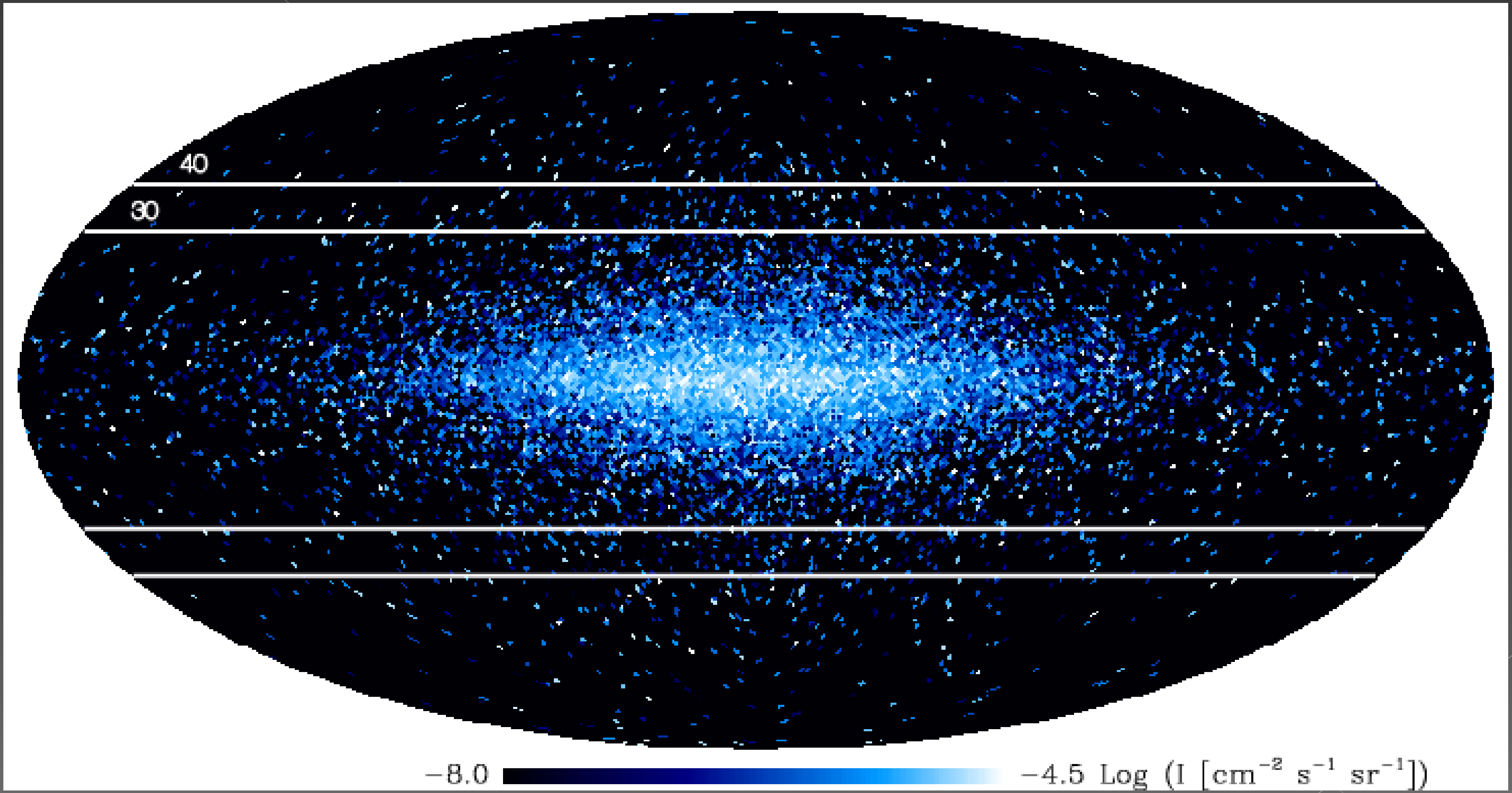
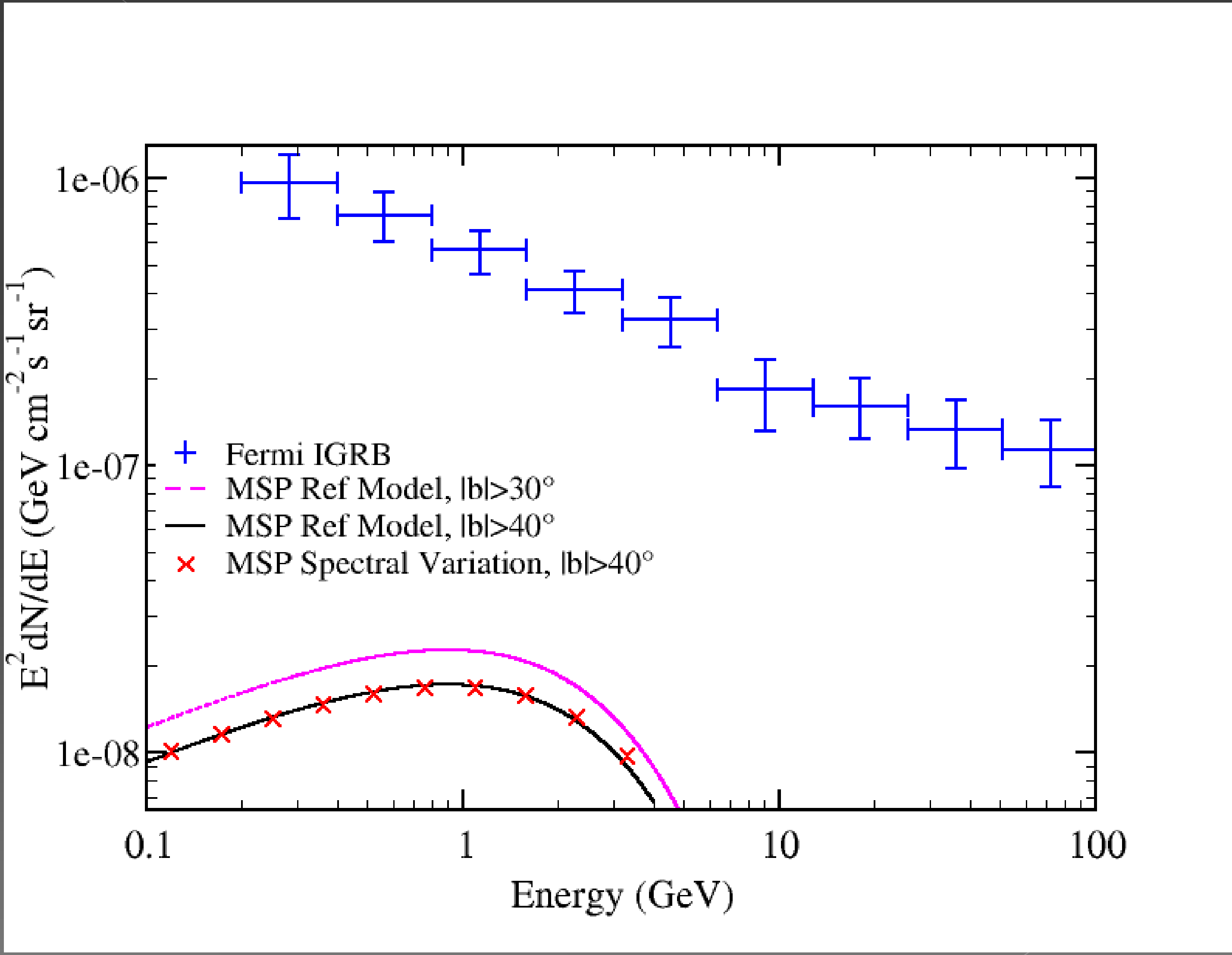
J1813-1246
J1744-1134
J1614-2230
J1741-2054
J1732-31
"Eel"
J1826-1256
"Taz"
J1809-2332
"Rabbit"
J1418-6058
J1459-60
Vela
Geminga
J0751+1807
J0633+0632
J0613-0200
Crab
J0357+32
J0218+4232
J2124-3358
J0437-4715
J0030+0451
fermi
Gamma-ray
Space Telescope
New pulsars found in a blind search
Millisecond radio pulsars

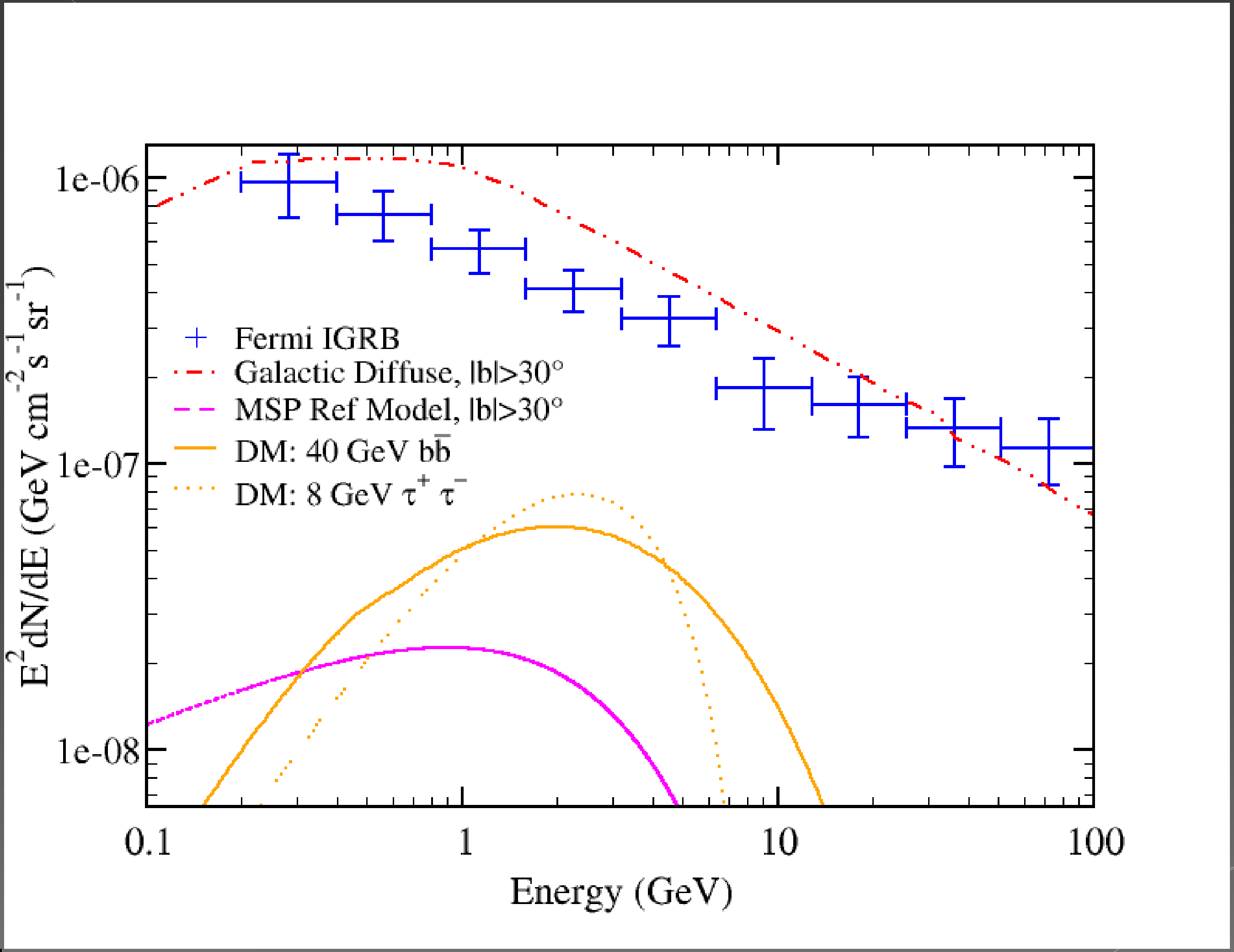
Intensity Map



Intensity Spectra – 2 Models



Intensity Spectra



Angular Power Spectrum of Intensity Fluctuations

$$\delta I = \frac{I - \langle I \rangle}{\langle I \rangle}$$

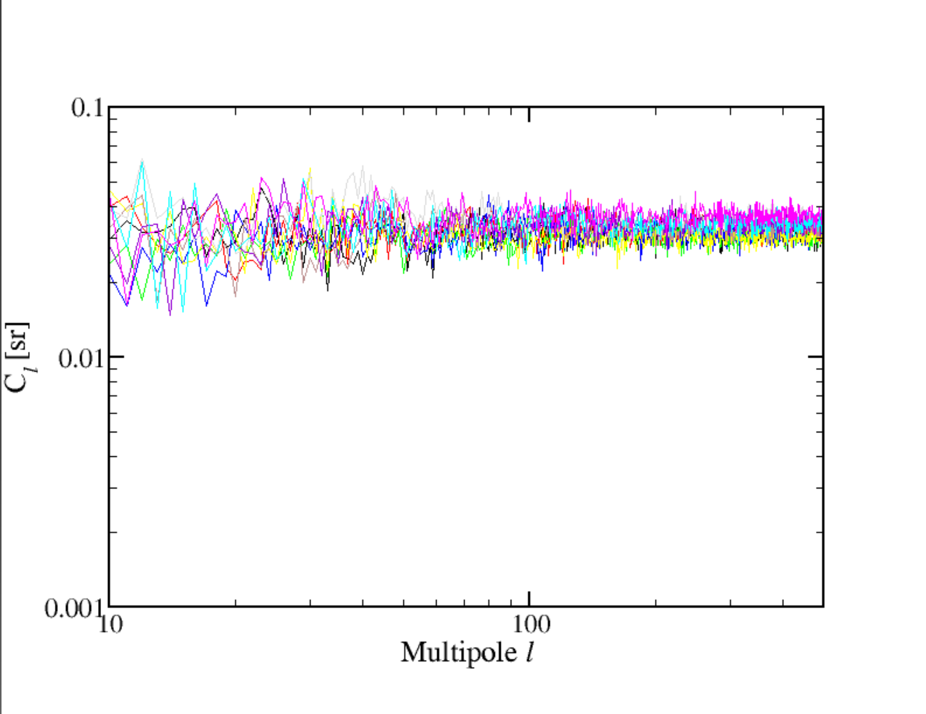
Expand δI in spherical harmonics:

$$\delta I = \sum_{l,m} a_{l,m} Y_{l,m}$$

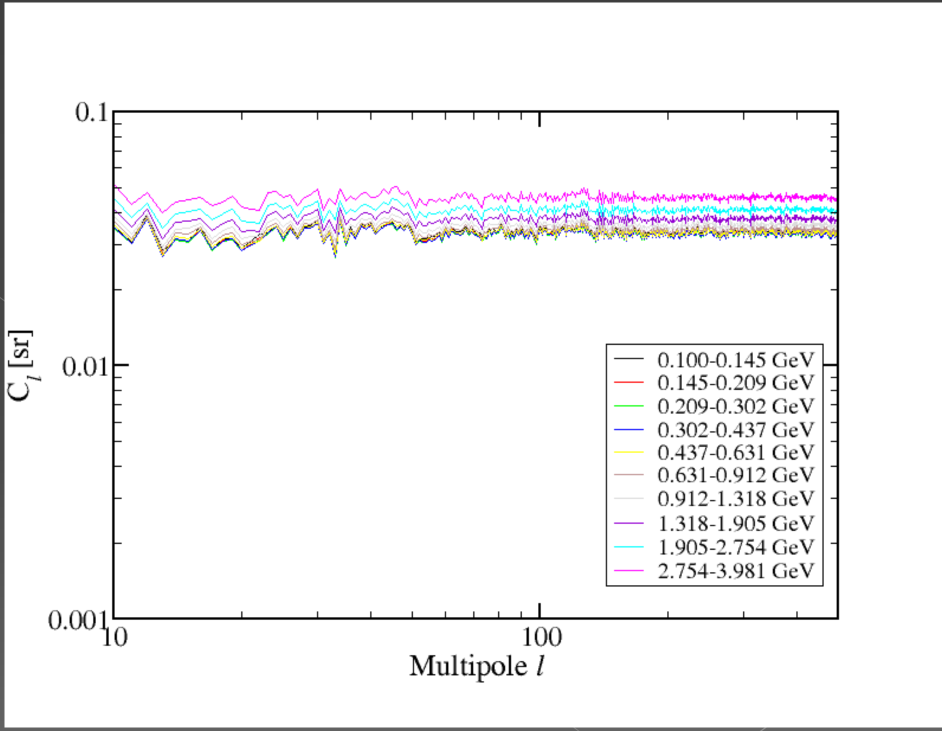
Then

$$C_l = \langle |a_{l,m}|^2 \rangle$$

Angular Power Spectrum

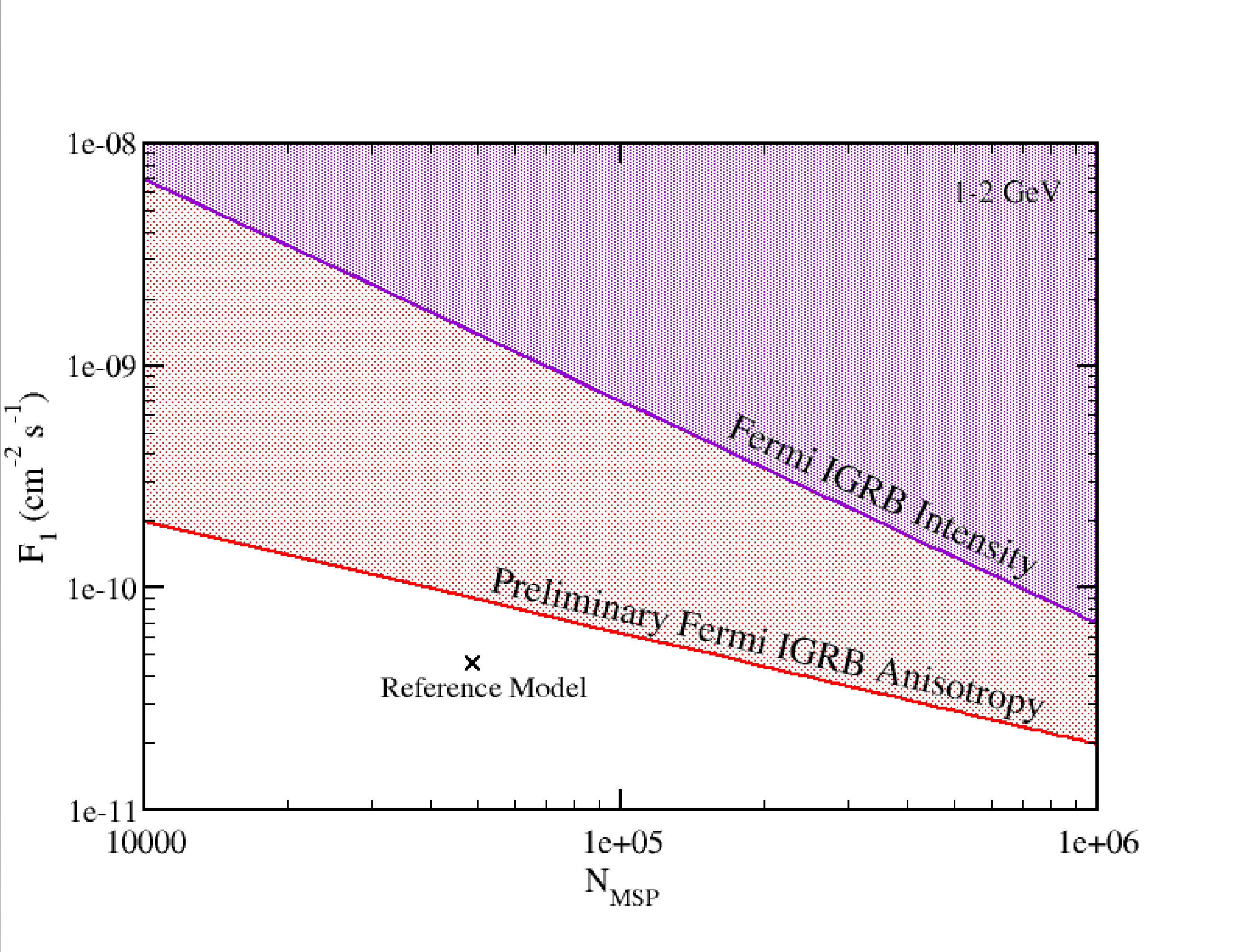


Reference Model



Spectral Variation Model

Anisotropy vs. Intensity Constraints



Conclusion

- Anisotropy can be a stronger constraint than intensity
- The MSP intensity spectrum is likely to cutoff at a few GeV
- Fermi anisotropy spectrum contains information on millisecond pulsars