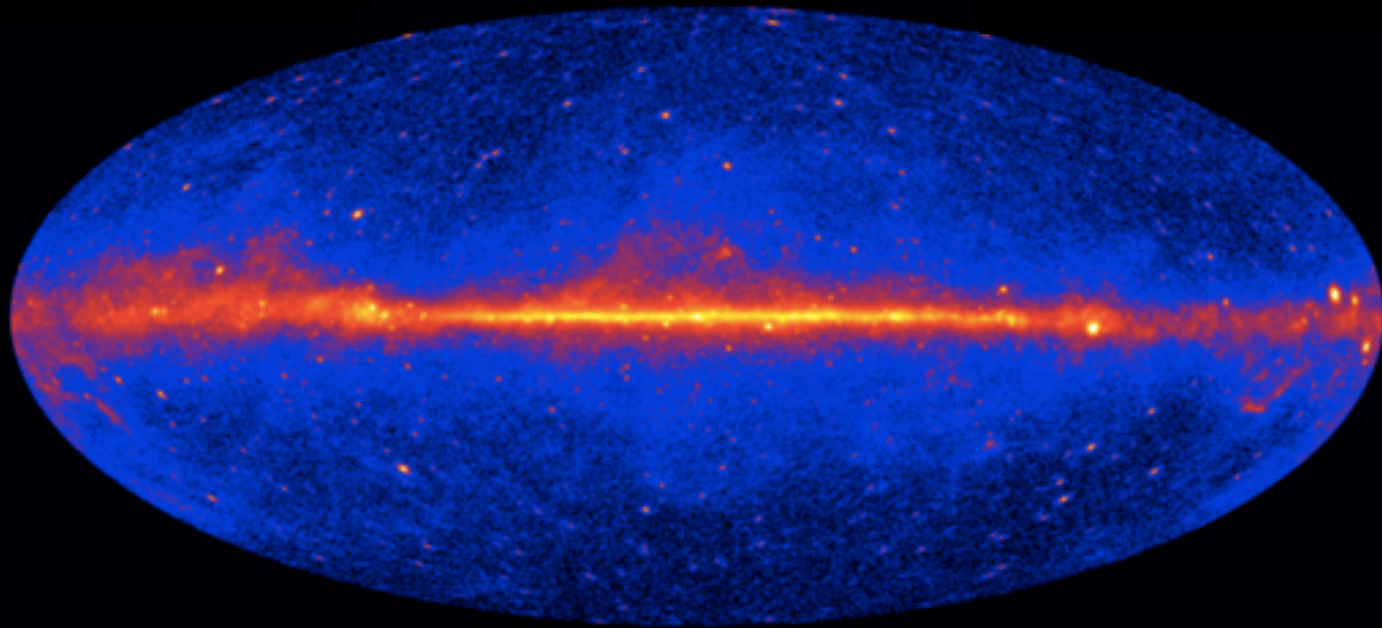


Is the Galactic bulge shining in gamma rays?

Chris Gordon
University of Canterbury (NZ)



- Macias O., Gordon C., Crocker R., Coleman B., Paterson D., Horiuchi S. and Pohl M., Nature Astronomy.
- Ploeg H., Gordon C., Crocker R. and Macias O., Journal of Cosmology and Astroparticle Physics 2017.

Fermi Gamma-ray Space Telescope (2008 – present)

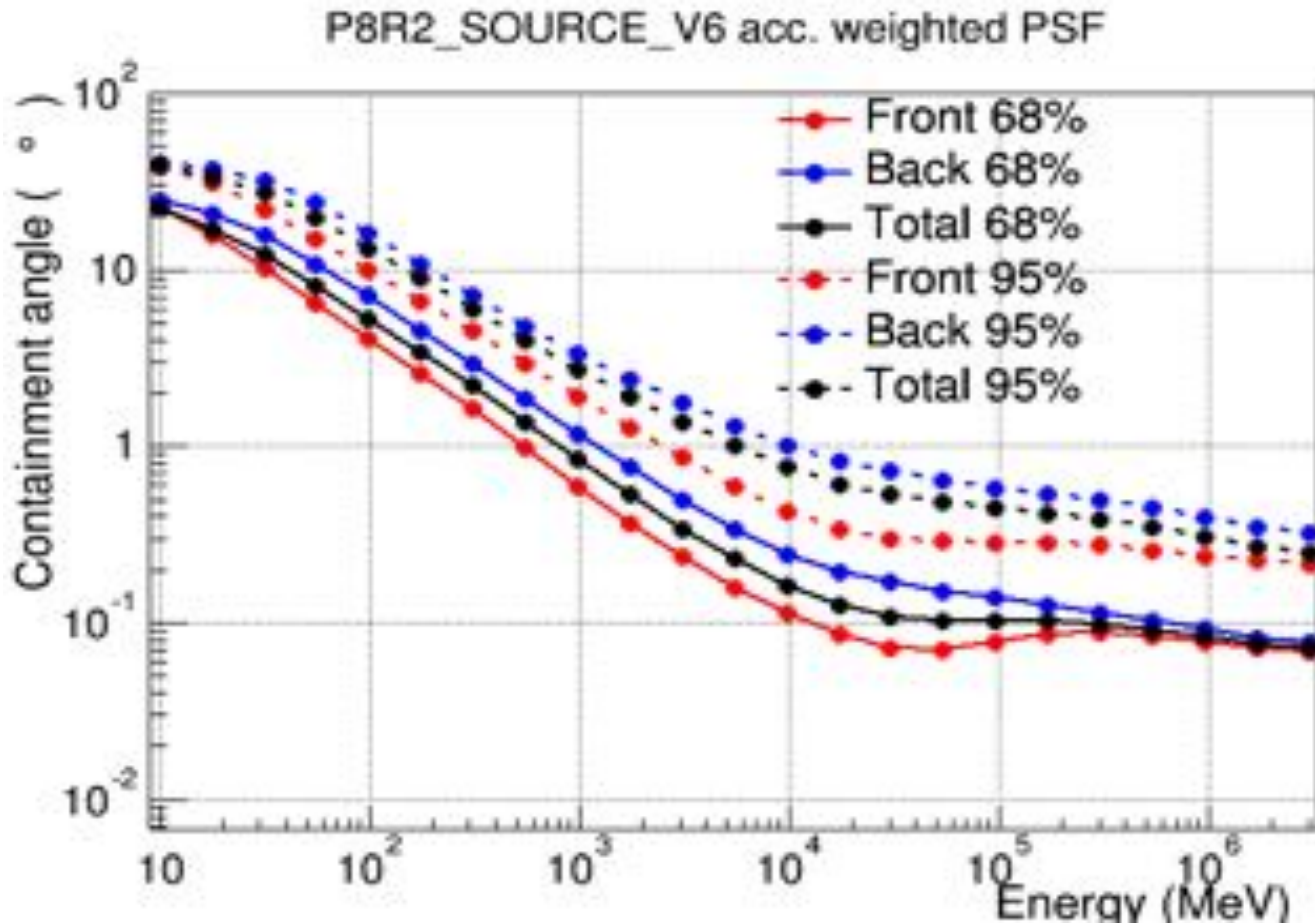
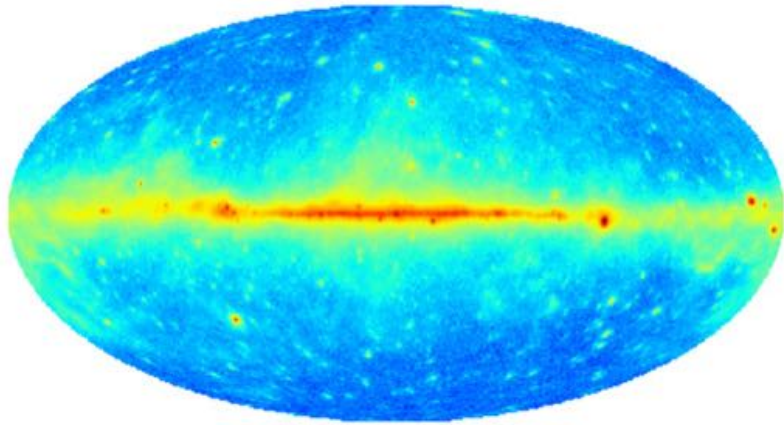


Image Credit:

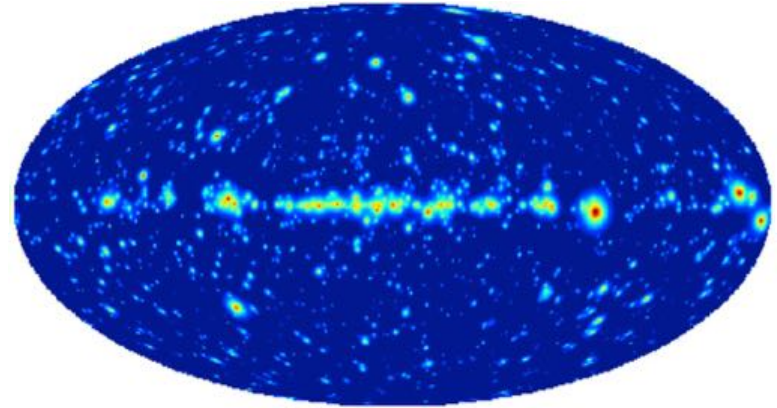
https://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.html

Gamma-ray Sky



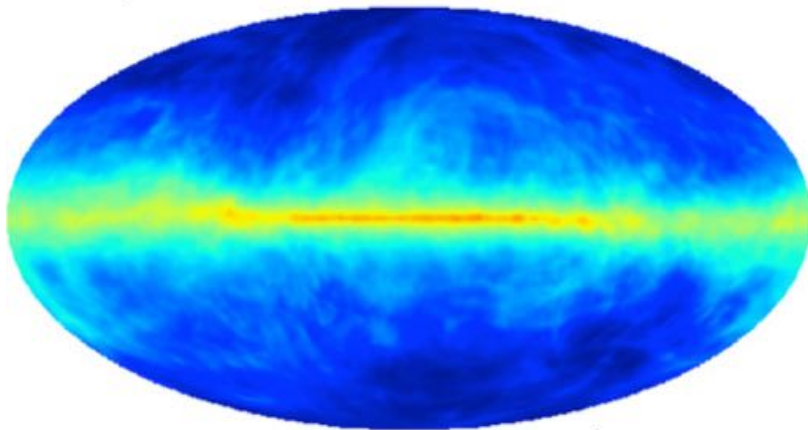
Data

=



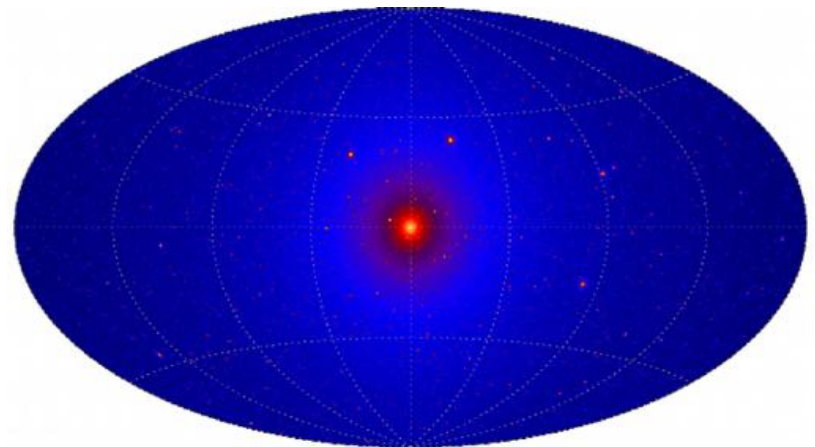
Point sources

+



Galactic Diffuse

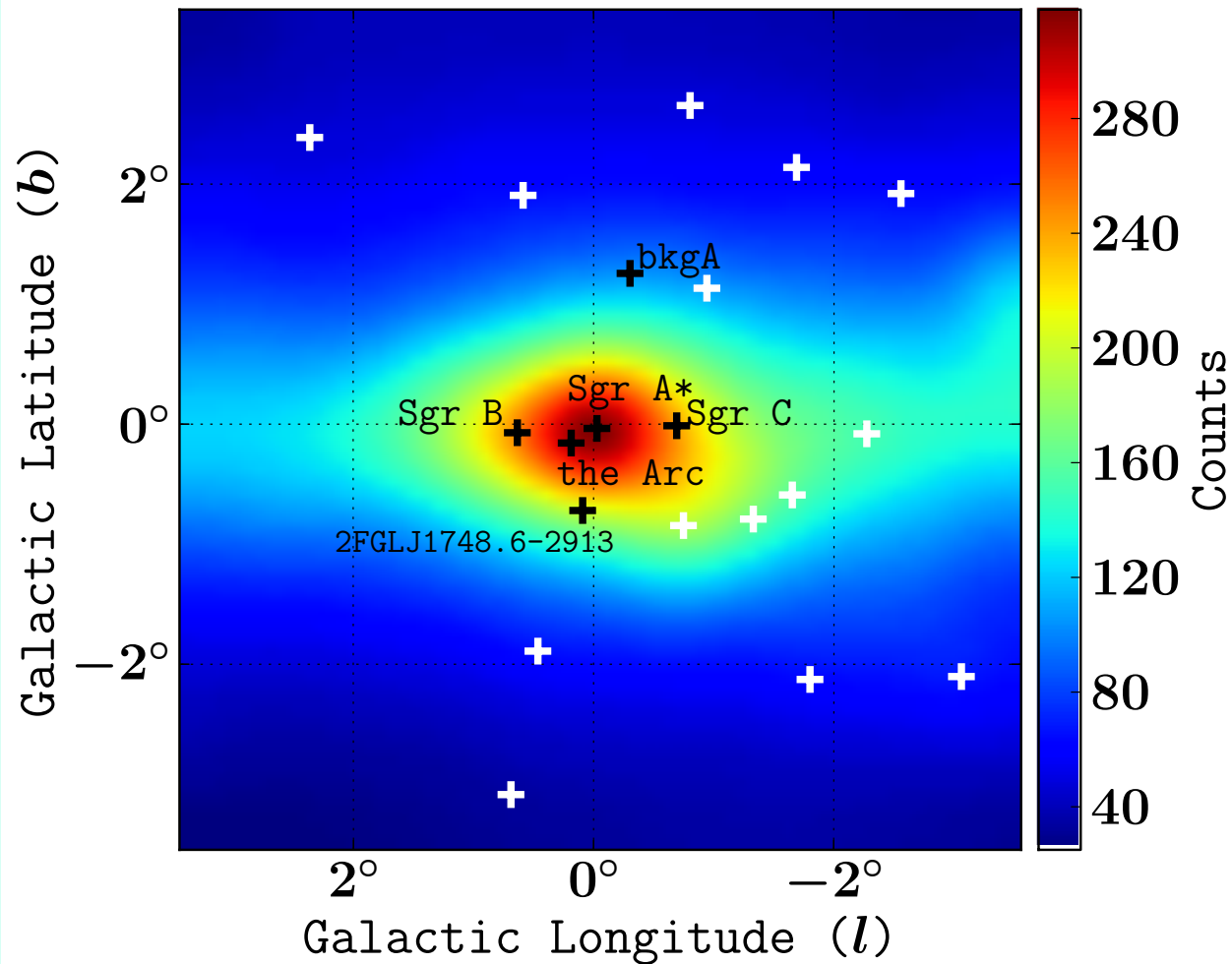
+

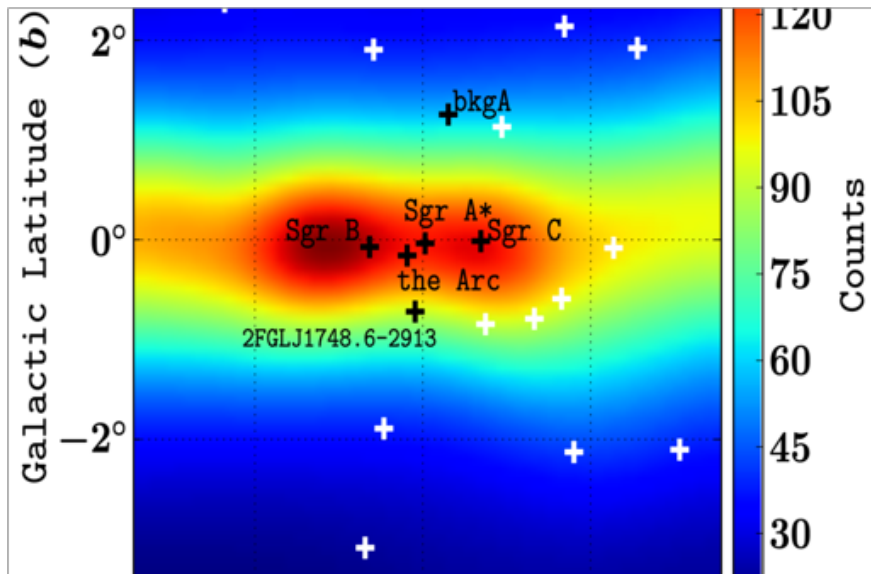


Dark Matter?

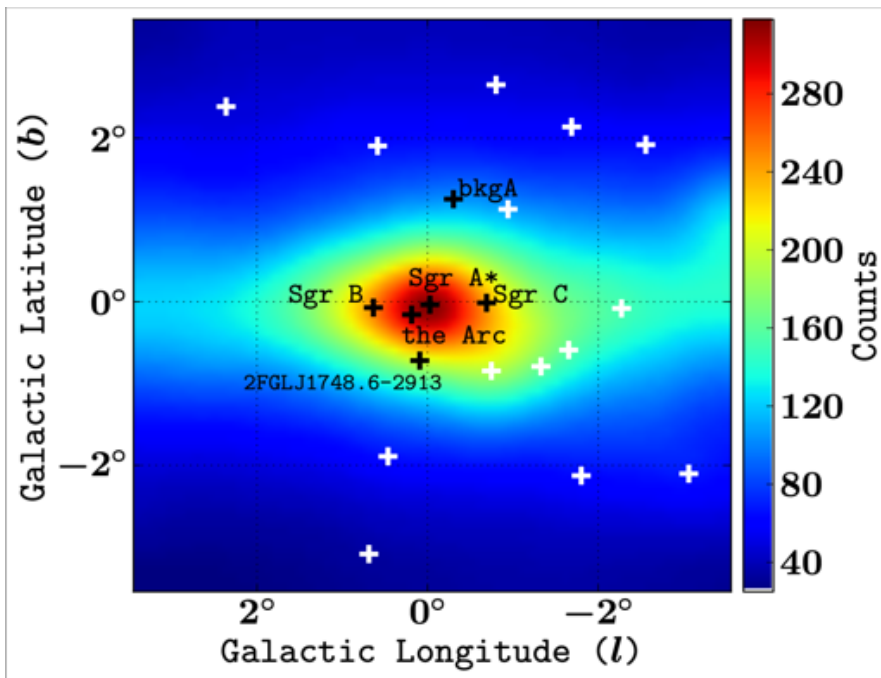
Excess Emission from Galactic Center

- Hooper and Goodenough (2009)
- Confirmed by several groups including CG&Macias (2013, 2014) and by the Fermi team (2016).



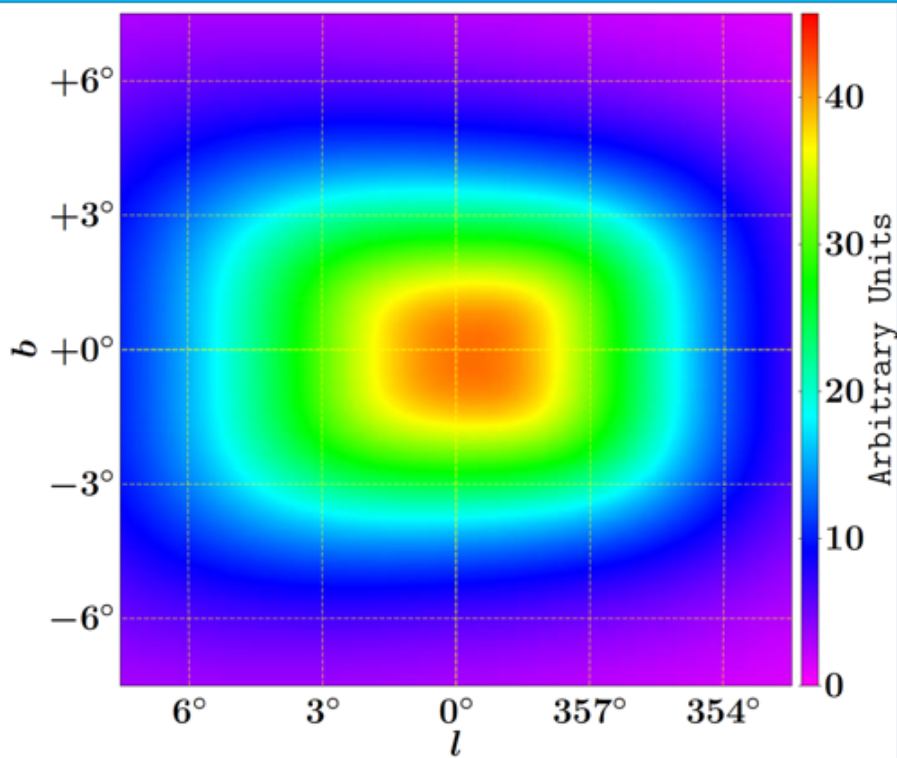


Diffuse Galactic
Emission

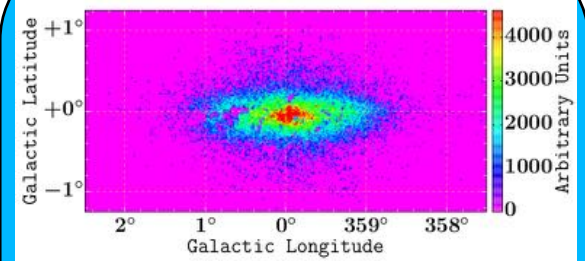


Fermi
gamma-ray
data

Best Fit Model



Galactic Bulge
(Freudenreich, 1998)



Nuclear Bulge
(Nishiyama et al.,
2013)

Millisecond Pulsars (MSPs)

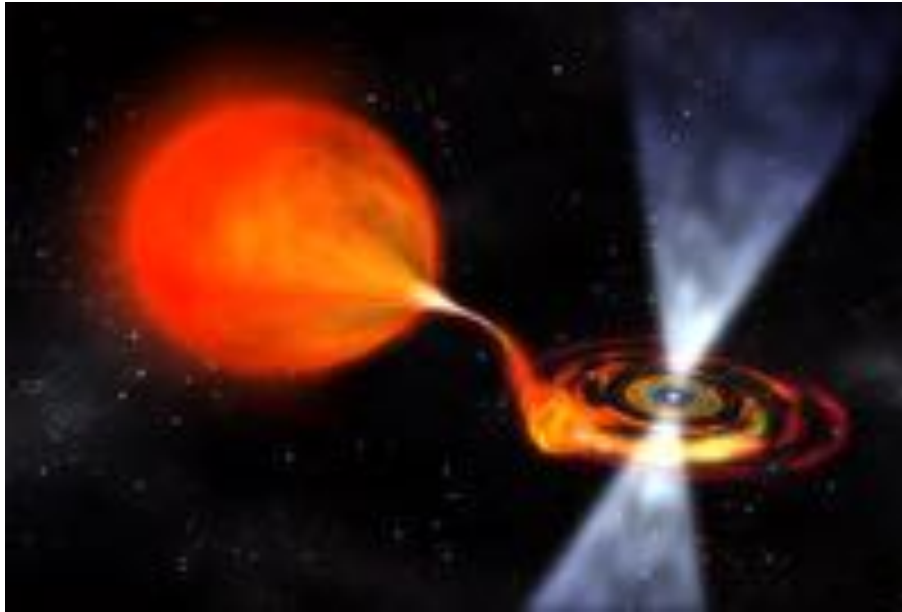


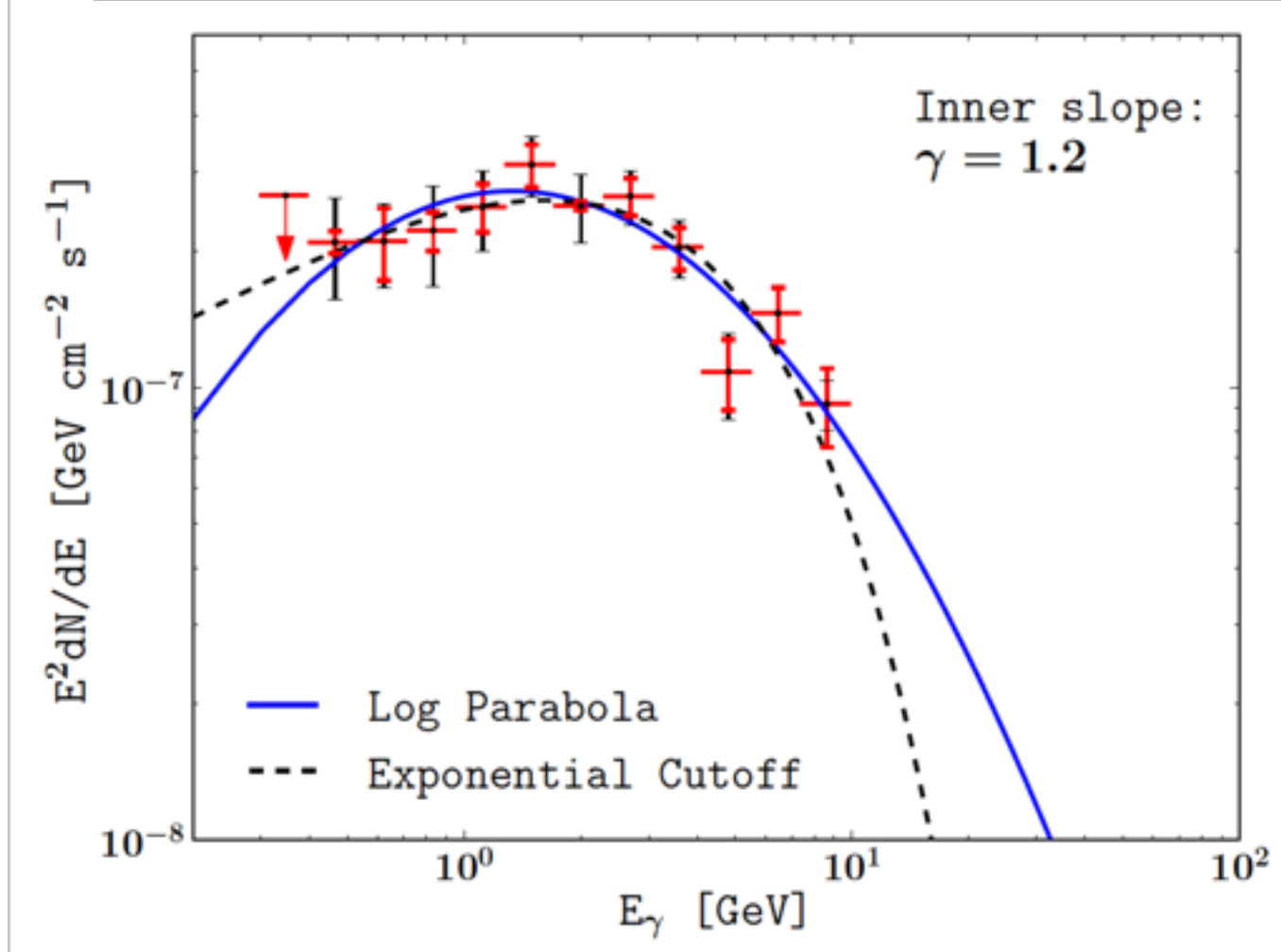
Image: NASA/Dana Berry.



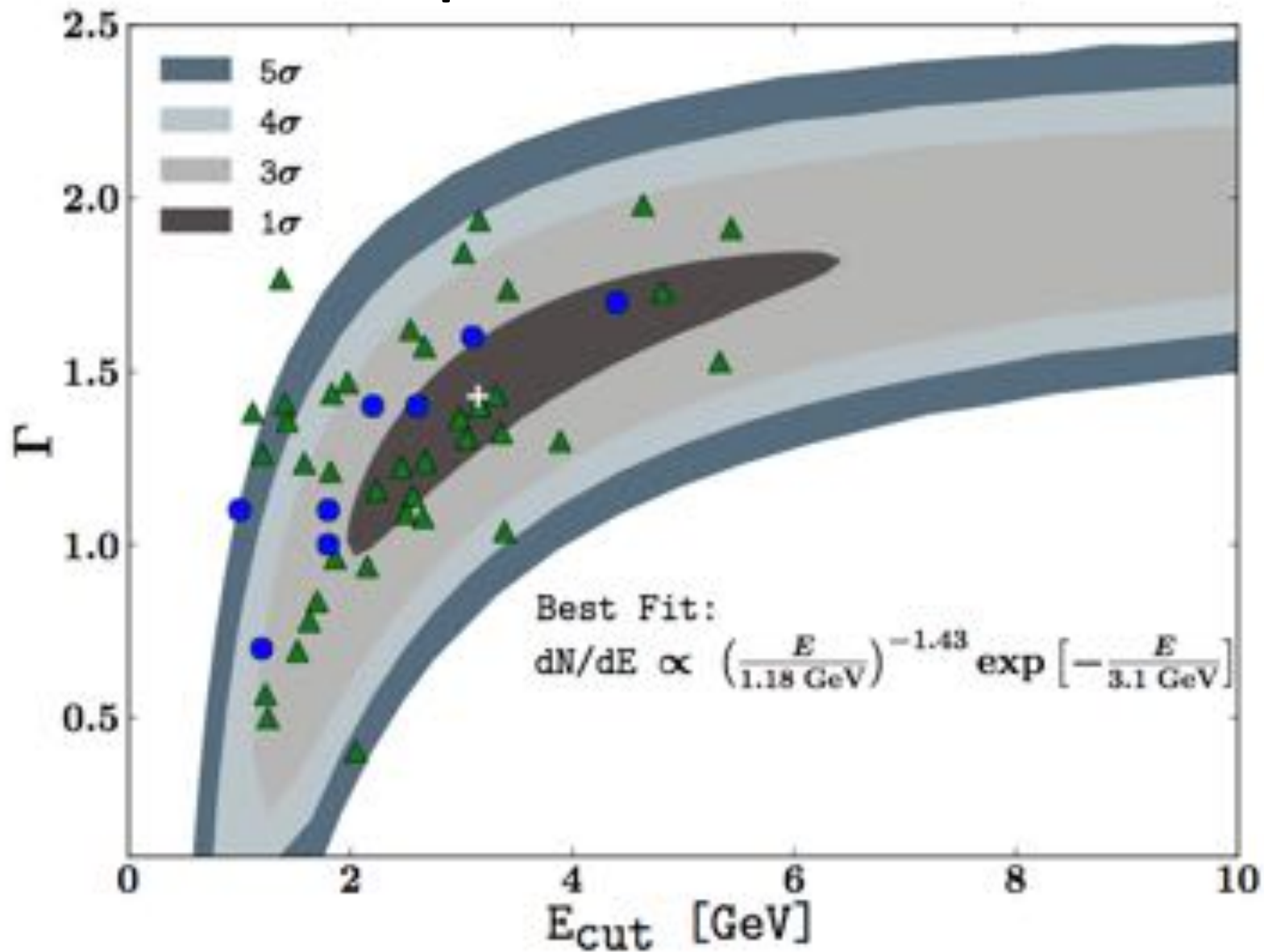
ESO image of Globular cluster Terzan 5 which hosts about 100 MSPs.

Spectral Fit

$$dN/dE \propto E^{-\Gamma} \exp(-E/E_c)$$

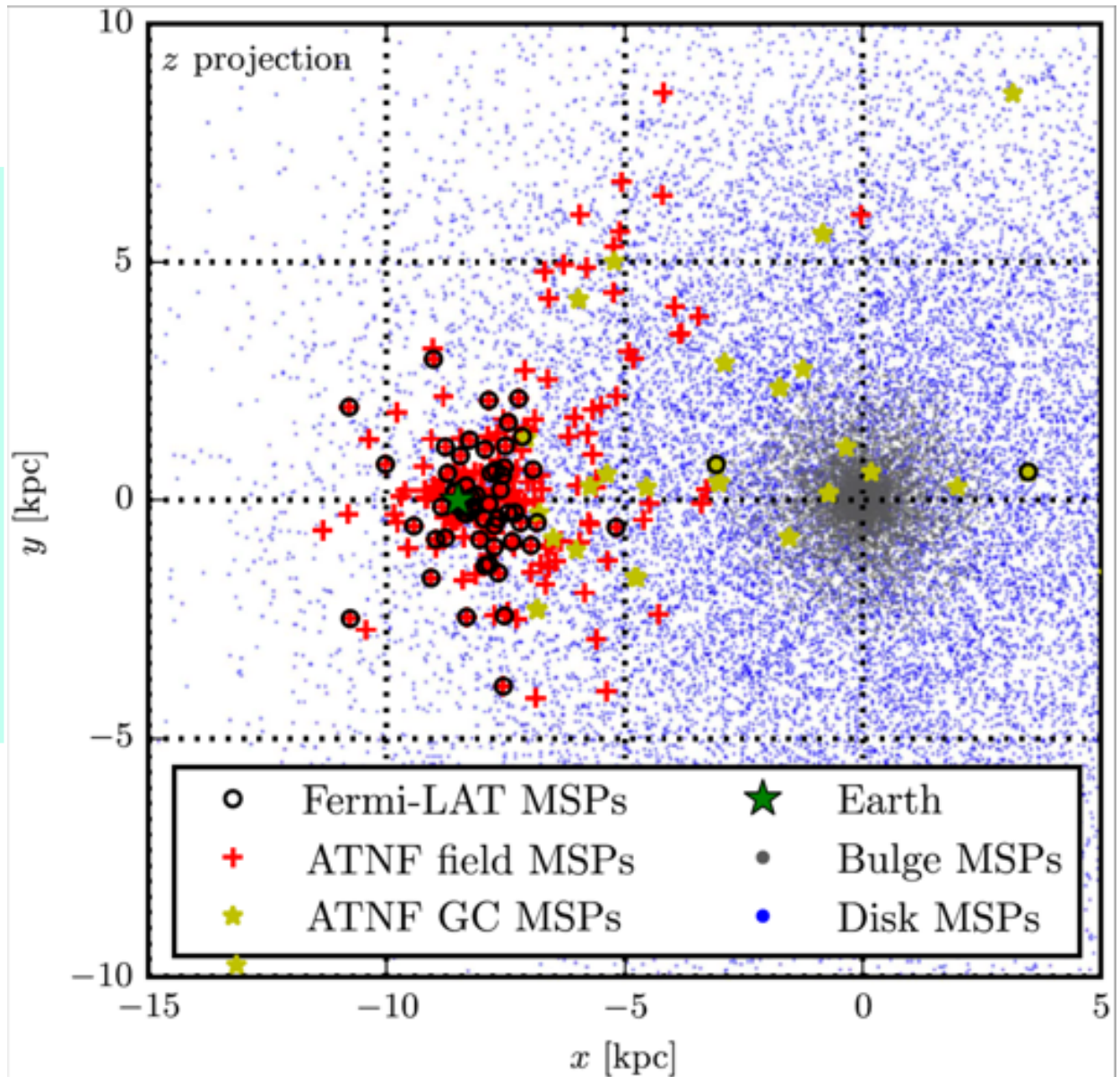


Spectral Fit



Predicted Spatial Distribution of MSPs

- ATNF=Australian Telescope National Facility.
- GC=Globular Cluster
- Image credit: Calore et al. APJ 827:143(2016).



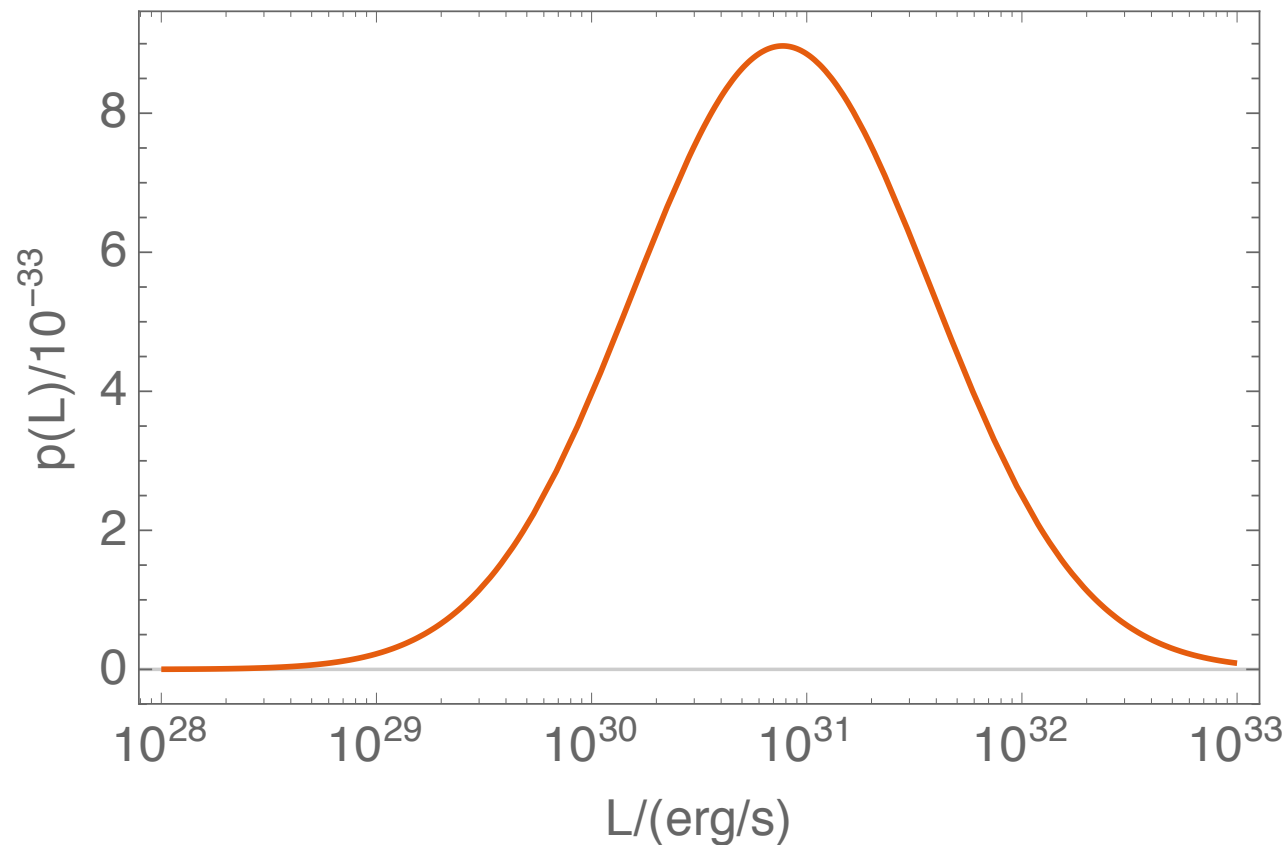
MSP Luminosity Function

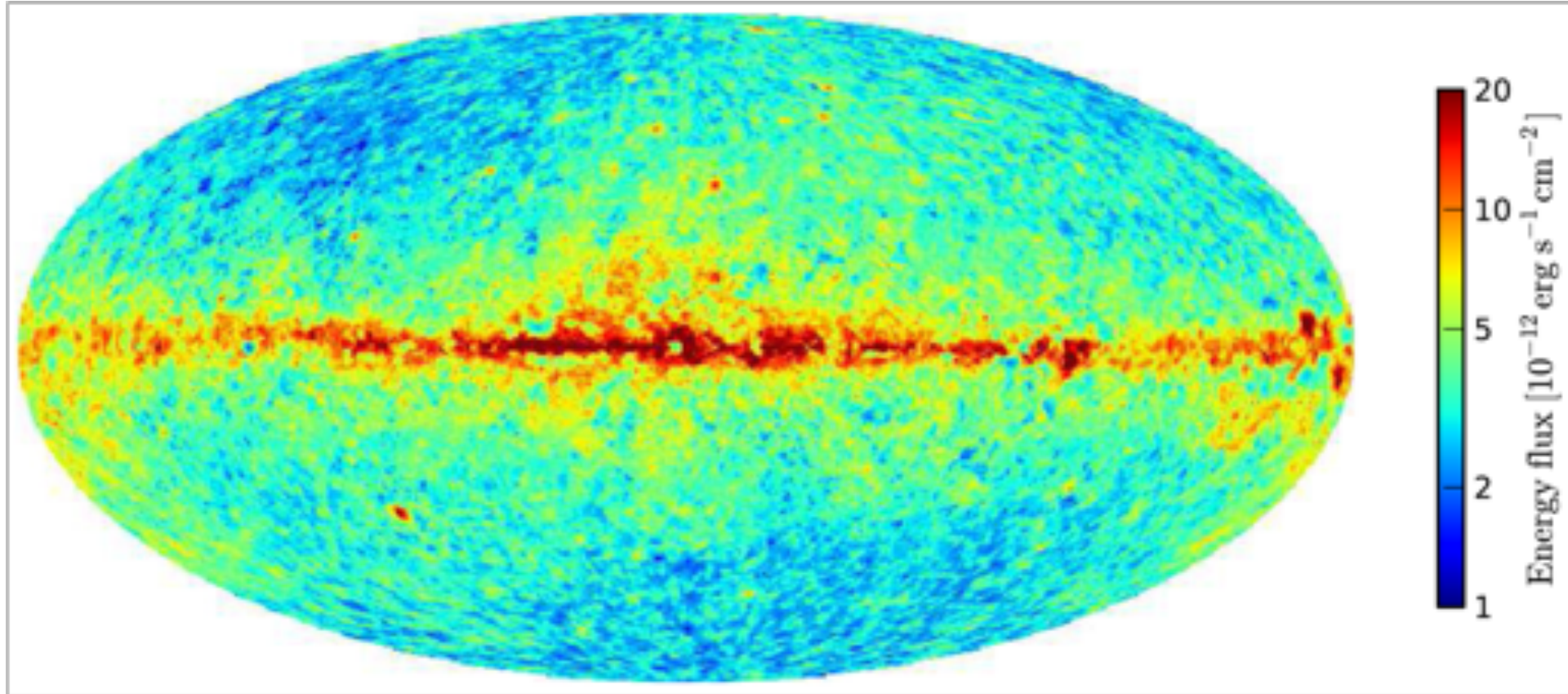
$$p(L) = \frac{1}{\sigma_L L \sqrt{2\pi}} \exp \left[\frac{-(\ln(L) - \ln(L_{\text{med}}))^2}{2\sigma_L^2} \right]$$

Luminosity

Probability
distribution
function

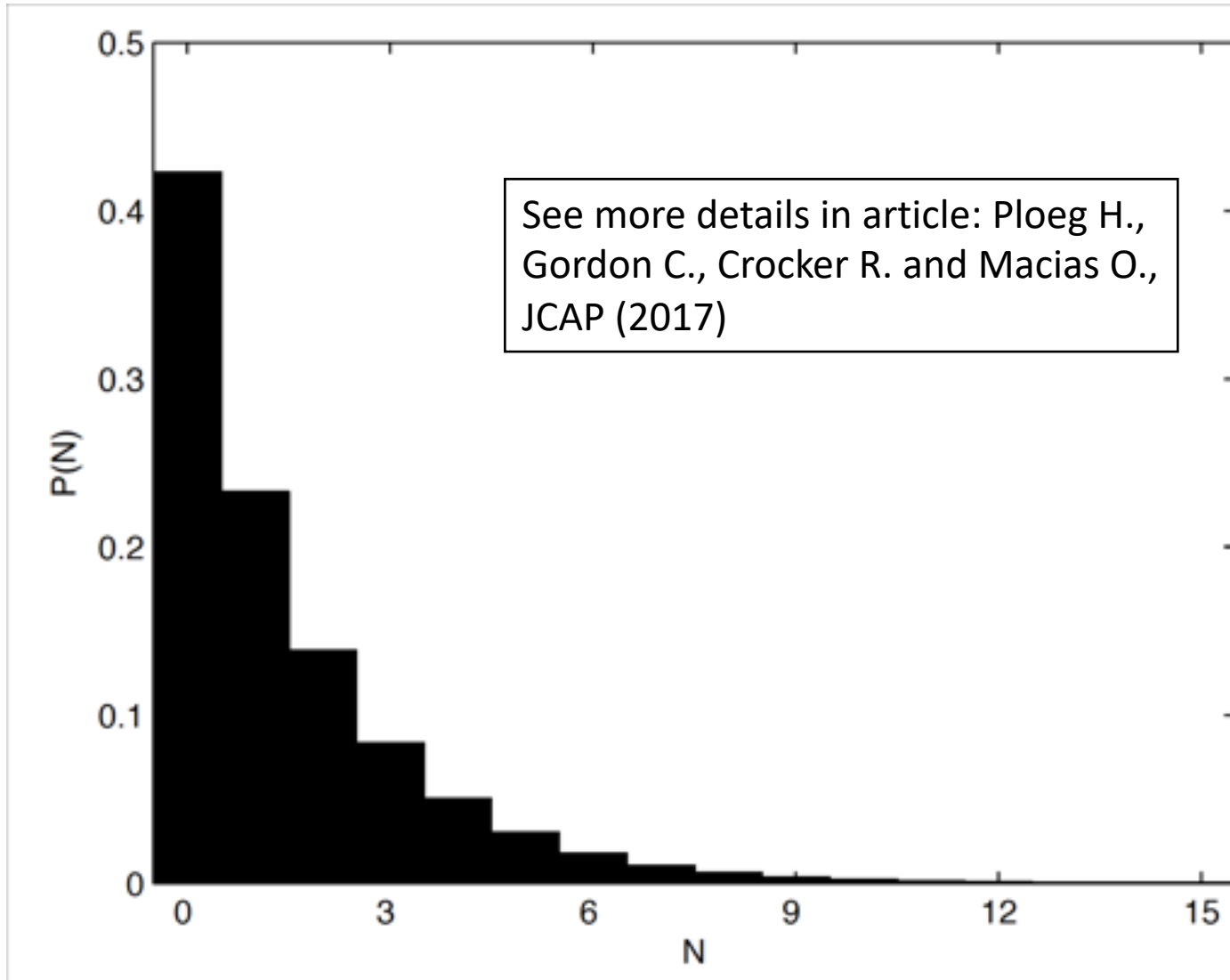
Parameters to be fit





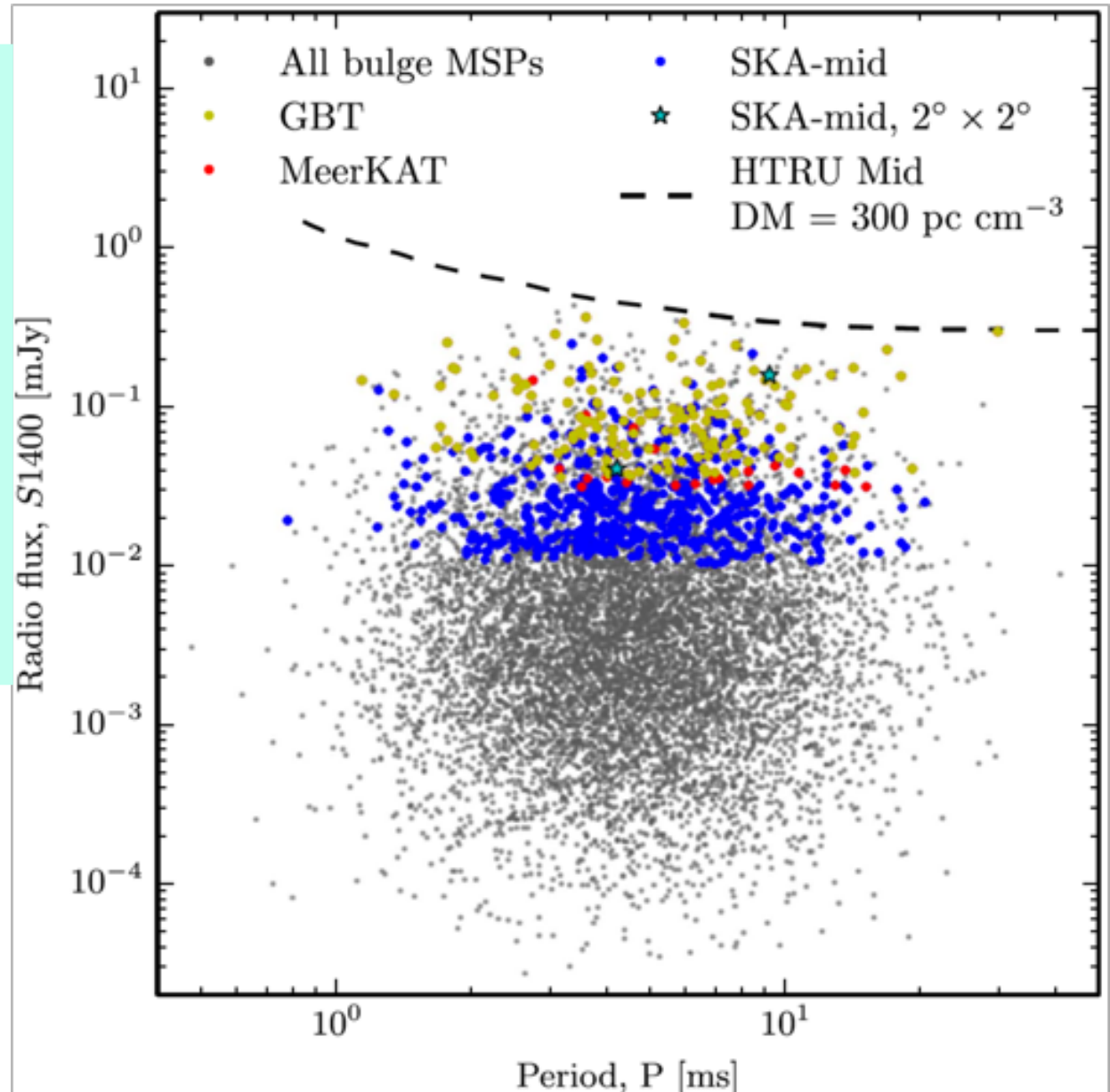
Hammer–Aitoff projection of the LAT three-year sky-survey **energy flux sensitivity** above 100 MeV, assuming a pulsar-like exponentially cutoff power law energy spectrum. Image credit: Abdo et al., ApJ 208:17, 2013.

Predicted Number of Resolved Bulge Pulsars



Forecasts for MSP Radio Surveys

- Image credit: Calore et al. APJ 827:143(2016).
- Sensitivities for the future MeerKAT and SKA-mid are based on the SKA Phase 1 System Baseline Design report.



Dependence on Stellar Mass

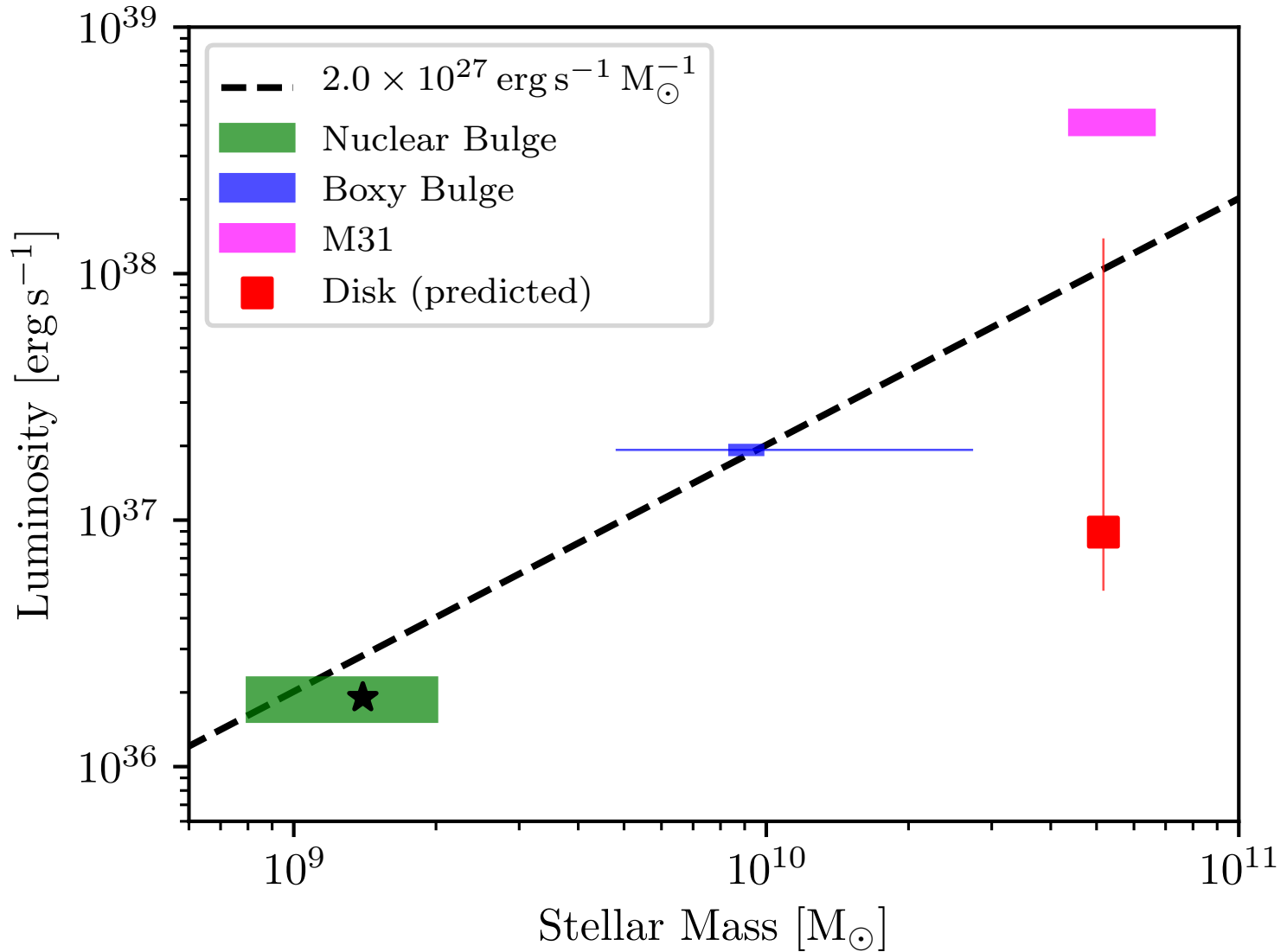


Image Credit: Bartels et al. (2018).

Conclusions

- Galactic Center Excess traces Galactic Bulge stars thus favoring the MSP over annihilating dark matter explanation.
- Found a similar number of bulge MSPs to disk MSPs could provide a good fit.
- SKA-mid observations may be needed to eventually better constrain the millisecond pulsar explanation.

