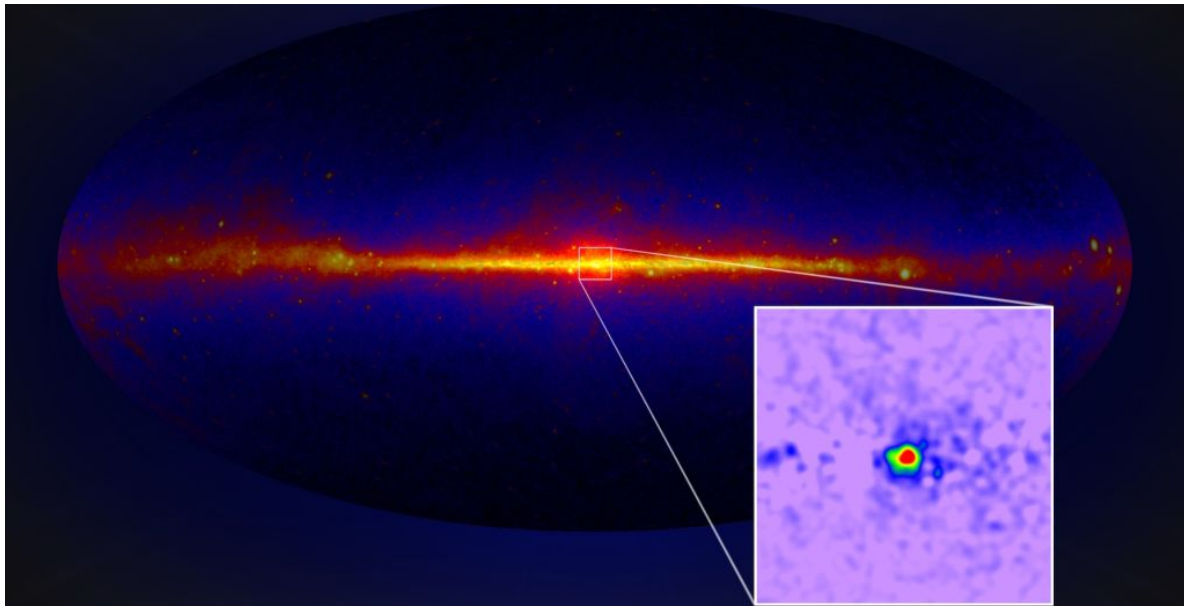
The gamma-ray mystery at the center of the Milky Way

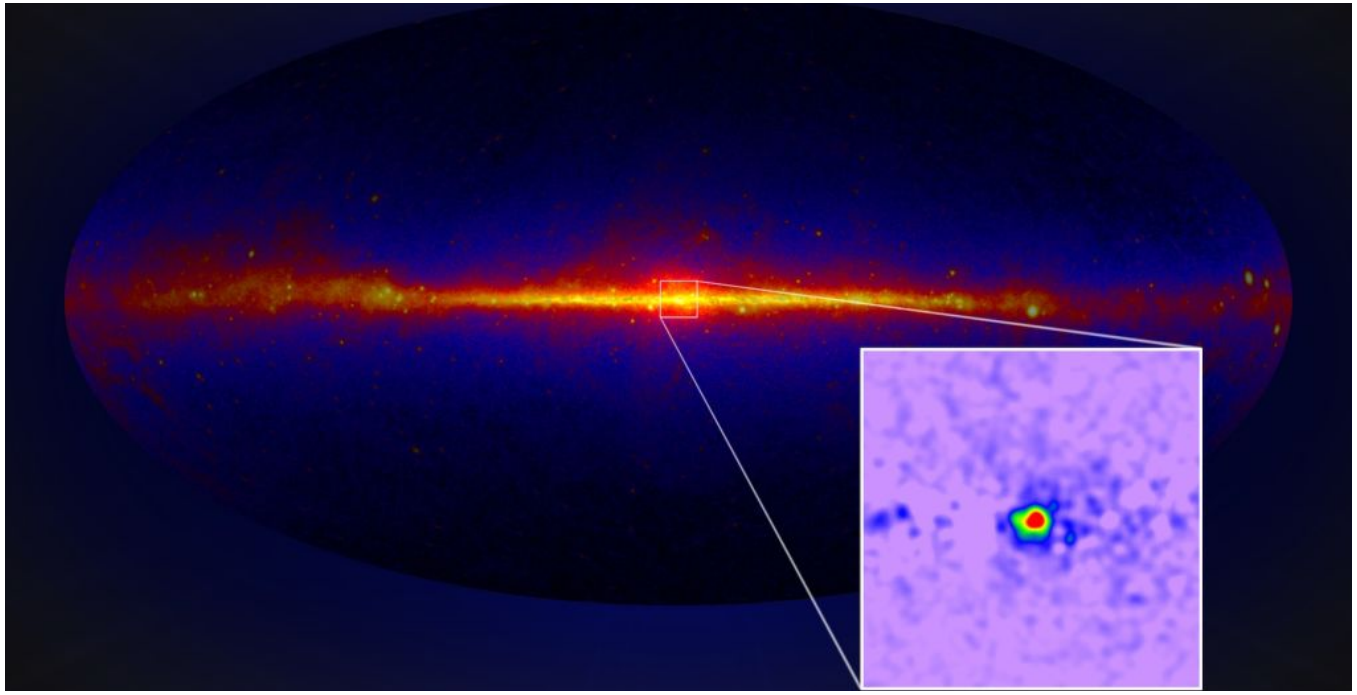


Ben Safdi
Massachusetts Institute of Technology

B.S., S. Lee, T. Linden, M. Lisanti, L. Necib, N. Rodd, S. Sharma, T. Slatyer, W. Xue

[JCAP 1505 (2015) , PRL 116 (2016), 1604.01026, 1606.04101]

Hints of dark matter annihilation in *Fermi* data?



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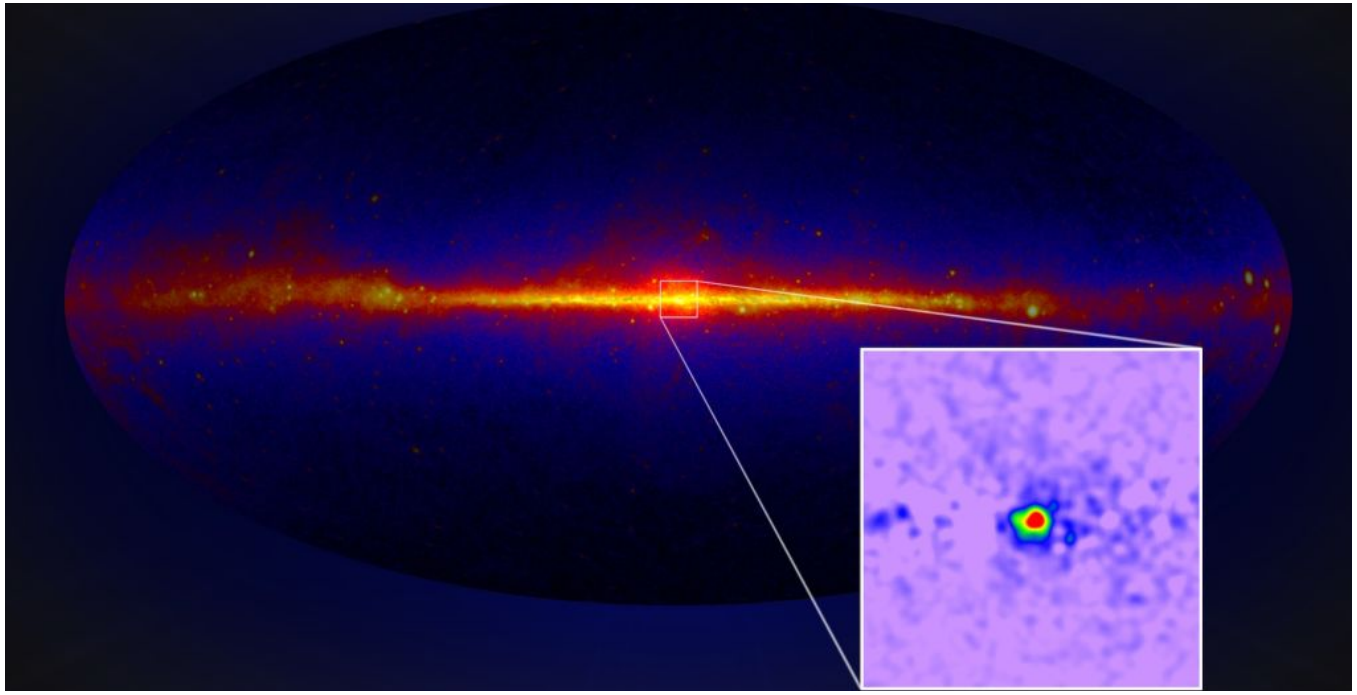

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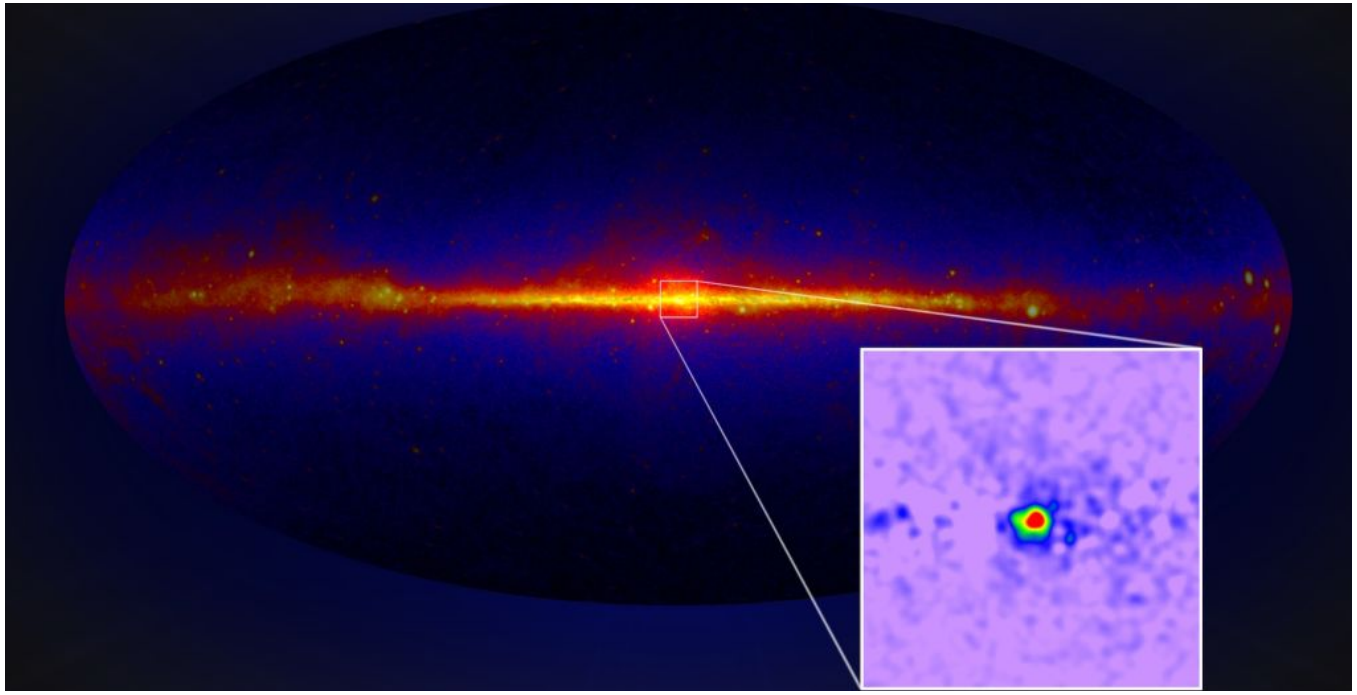

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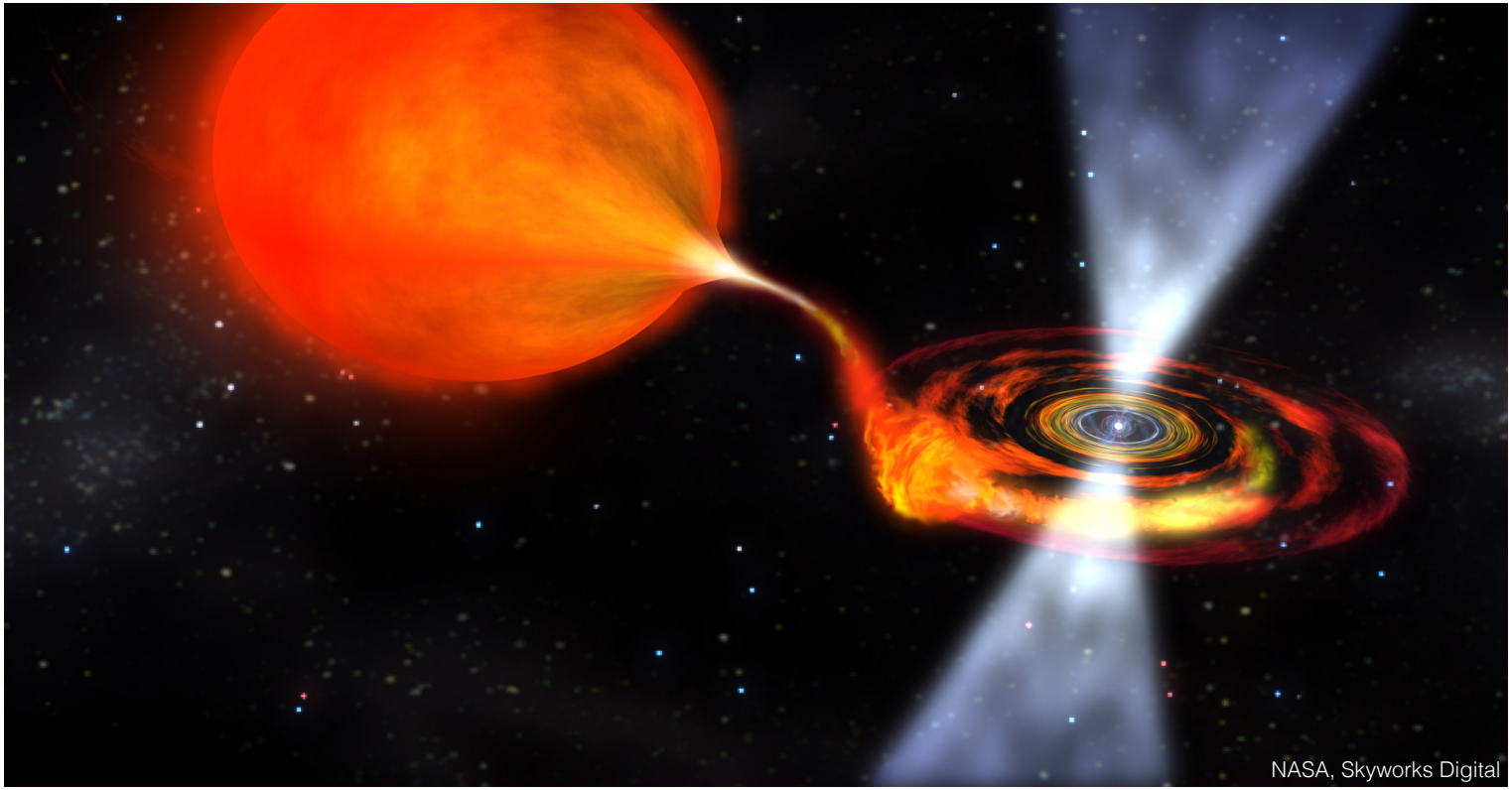
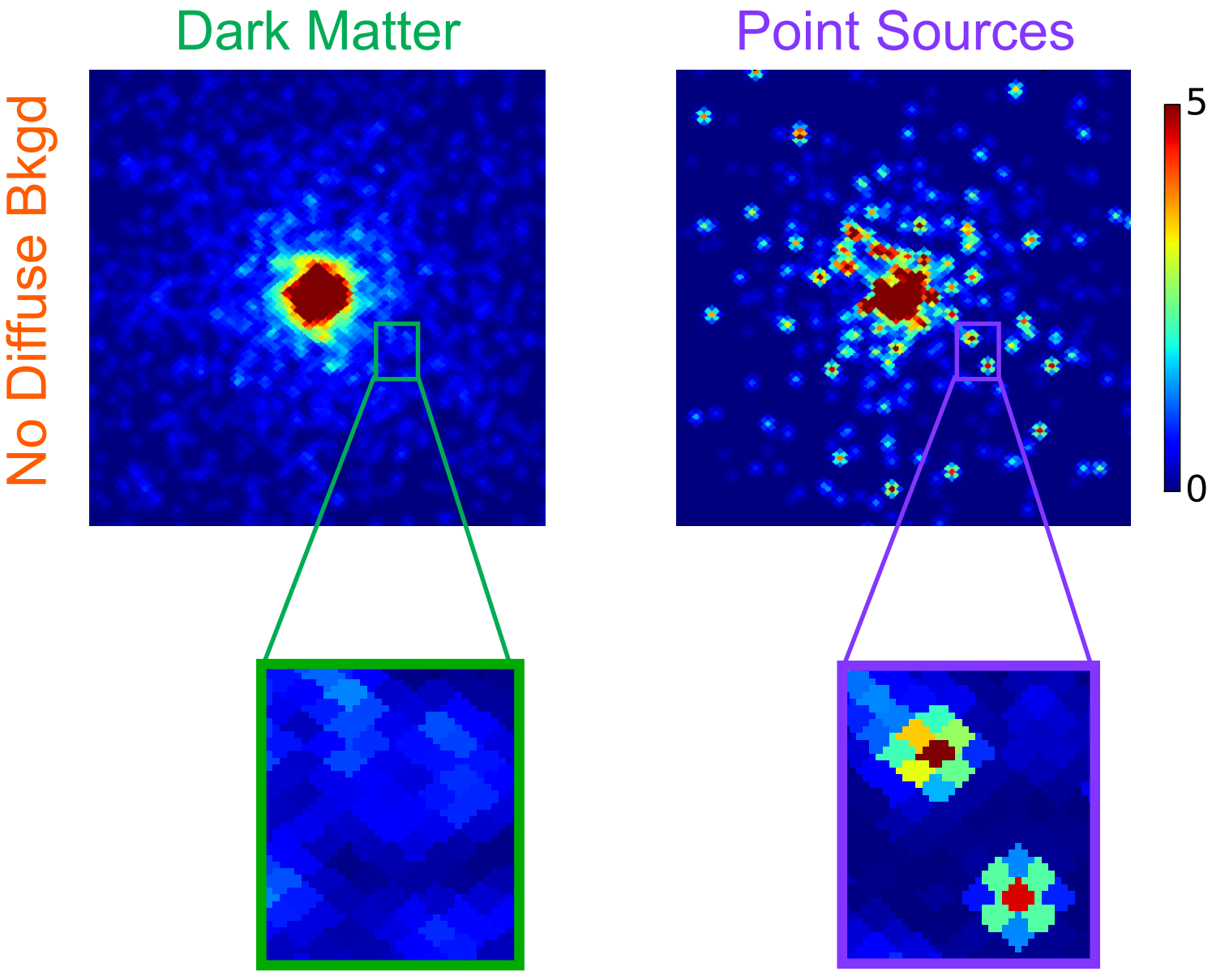
- Robust against mis-modeling cosmic-ray-induced emission (but see E. Carlson et. al. 2016)

Dark Matter or dim Point Sources?



- New method: Non Poissonian Template Fit (NPTF)
  - *JCAP* 2015: S. Lee, M. Lisanti, **B. S.**
  - *Phys. Rev. Lett.* 2016: S. Lee, M. Lisanti, **B. S.**, T. Slatyer, W. Xue
  - 1604.01026: T. Linden, N. Rodd, **B.S.**, T. Slatyer
  - many works in progress: **B.S.**, . . .

Photon Statistics: DM vs. Point Sources



P(D) distribution in X-ray astronomy; Malyshev and Hogg, 2011; Lee, Lisanti, **BS** 2014

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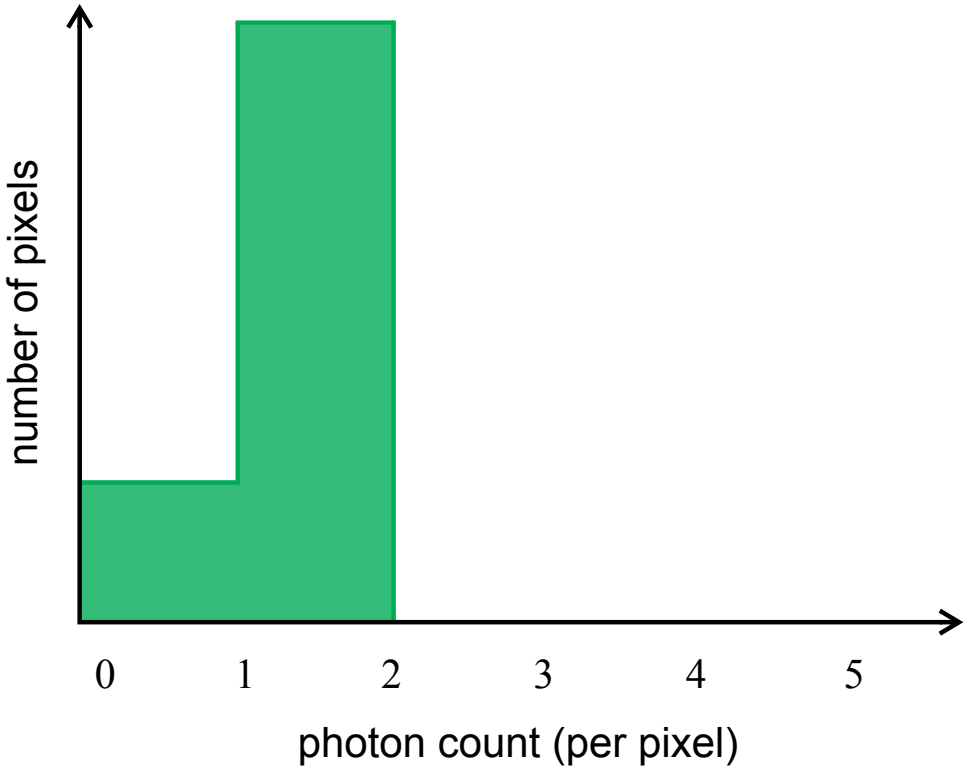
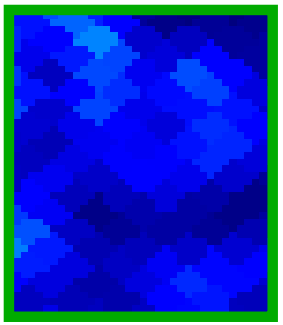


Dark Matter



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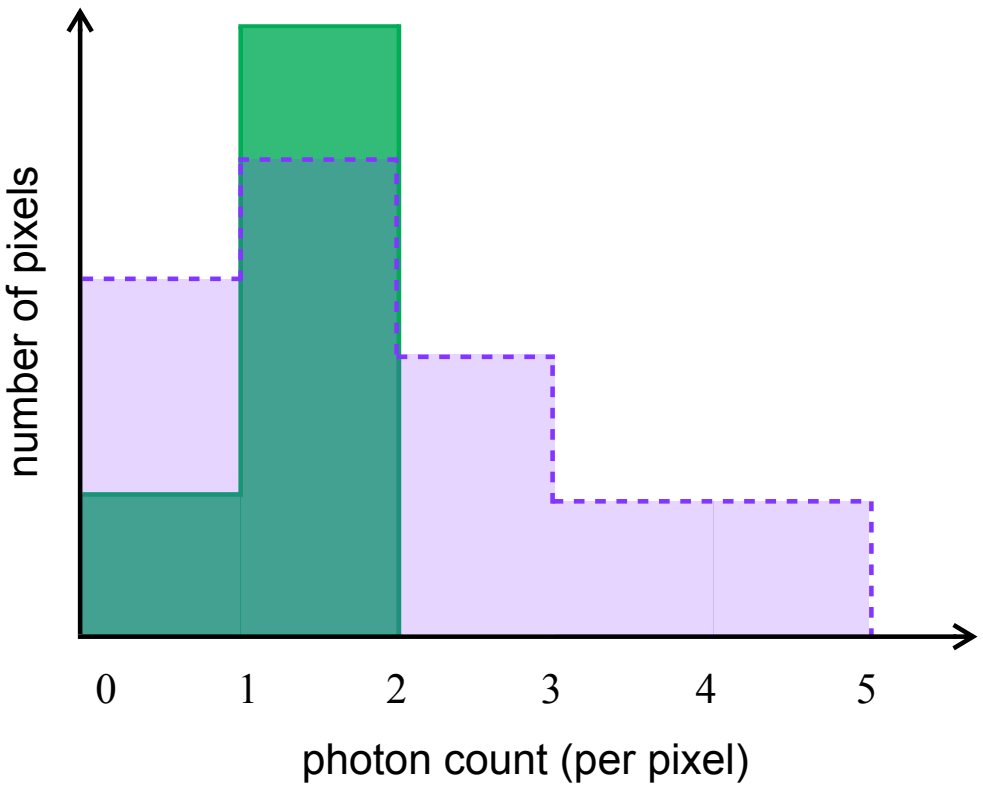

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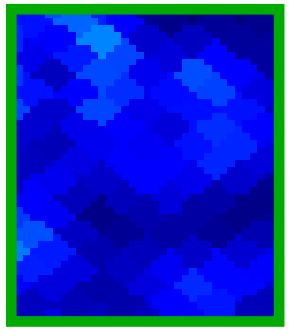
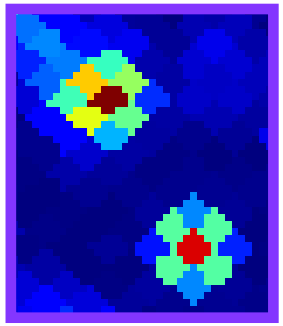


Point Sources



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Non-Poissonian template fit (NPTF)

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- model $\mathcal{M}$ with parameters θ
- The likelihood function:

$$p(d|\theta, \mathcal{M}) = \prod_{\text{pixels } p} p^{(p)}_{n_p}(\theta)$$

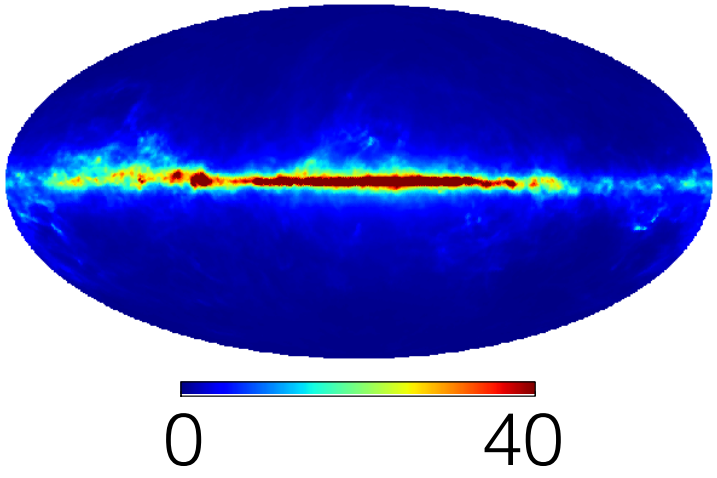
Thank you *Fermi* !

Fermi (NASA)

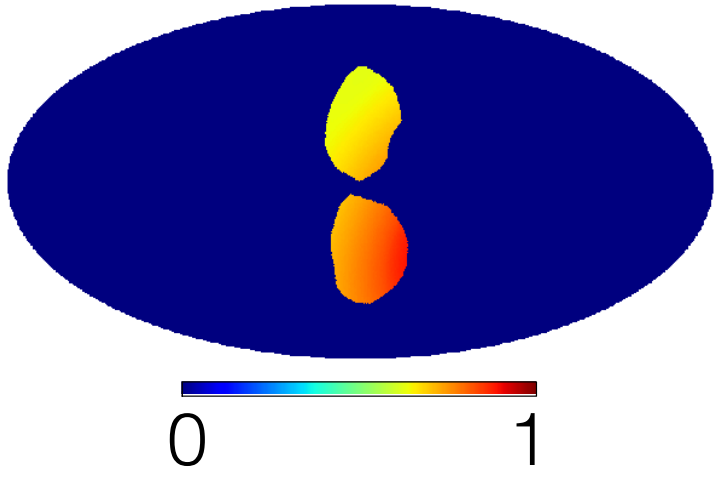
- Pass 8 data: *Ultracleanveto* class, top quartile by PSF (August 4, 2008—June 3, 2015)
- Energy range: $\sim$2–12 GeV

The models: Poissonian templates

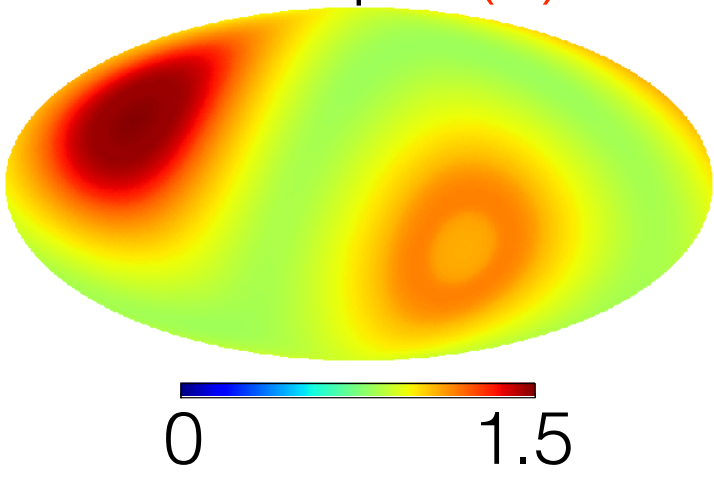
Fermi p6v11 diffuse (1)



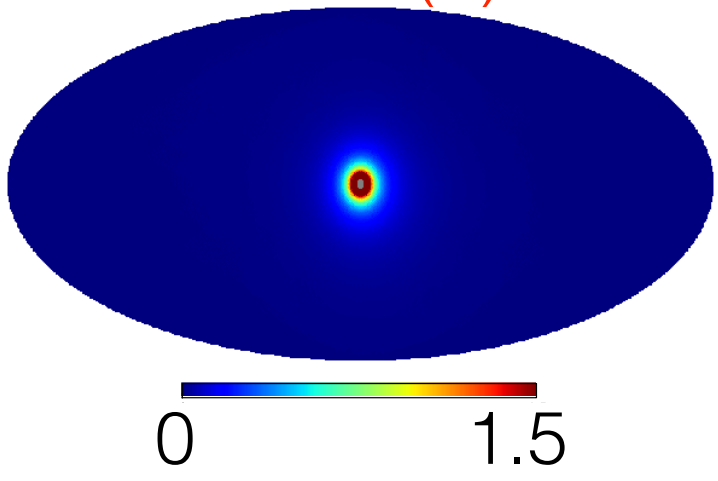
Fermi bubbles (1)



Isotropic (1)

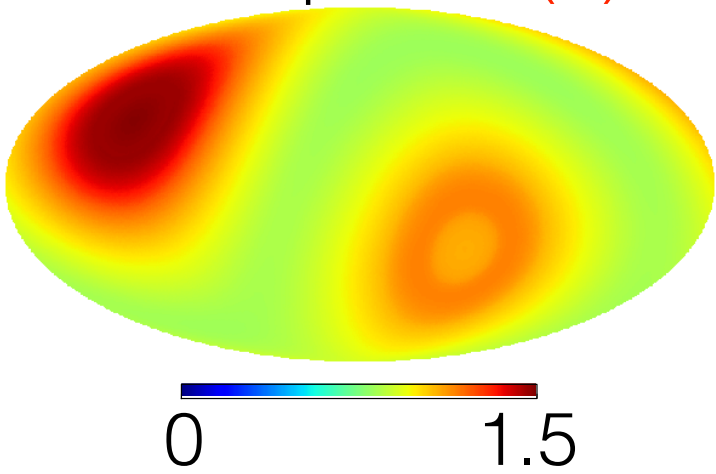


NFW (1)



The models: Non-Poissonian templates

Isotropic PS (4)



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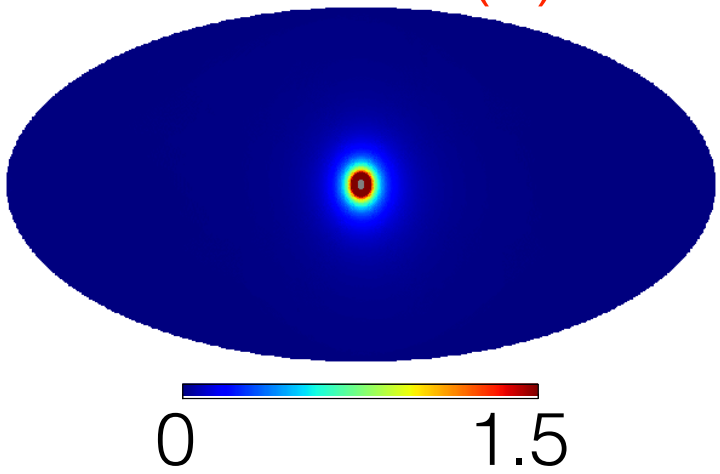
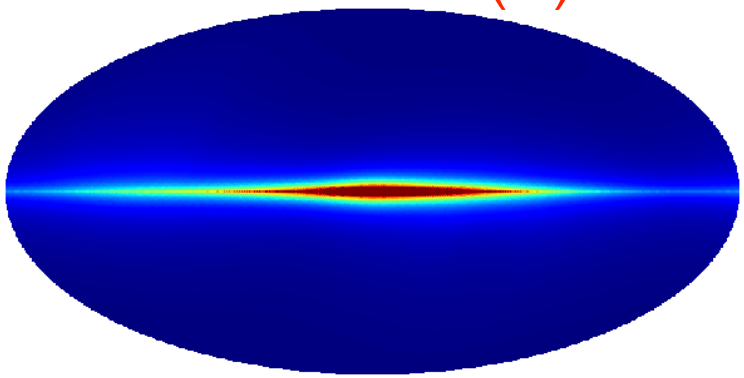


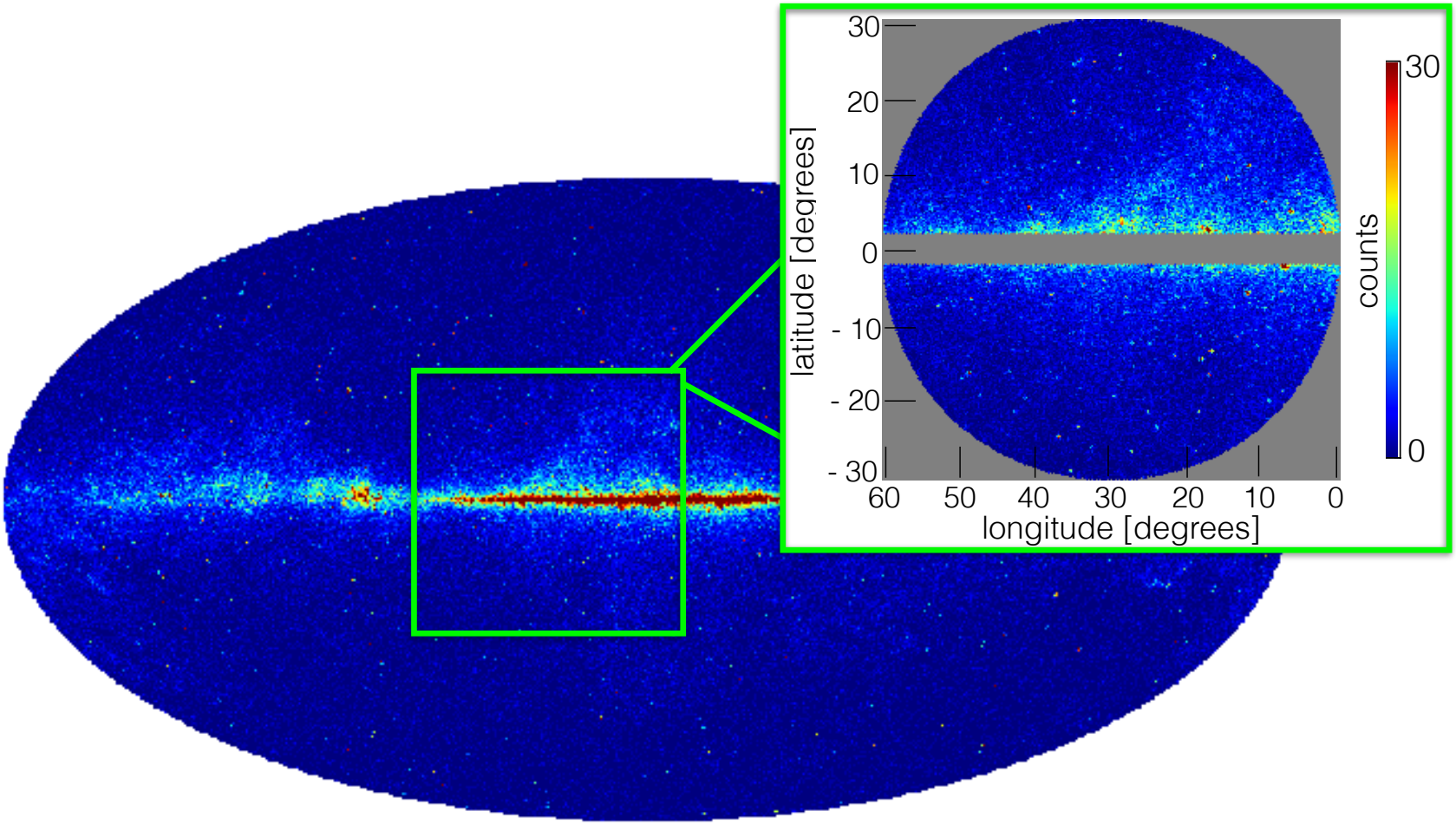
Disk PS (4)



- Disk: $n \propto \exp\left(-R/\,5 \text{ kpc}\right) \exp\left(-|z|/\,0.3 \text{ kpc}\right)$

Check 1: the $\ell = 30^\circ$ excess

Mask 4° around plane, out to 30° around $\ell = 30^\circ$



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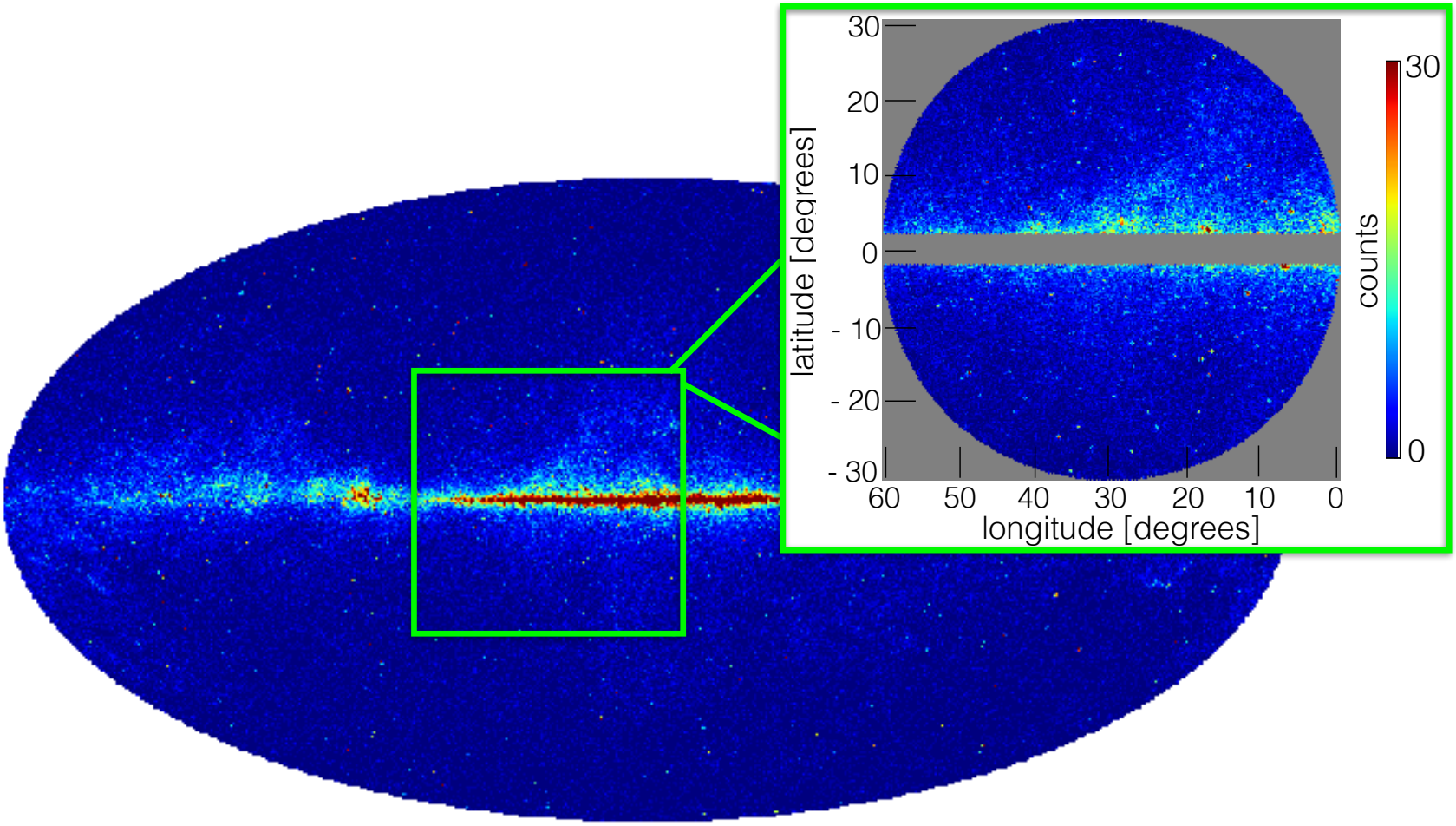

- Plots normalized for region within 10° of ROI center ($b \geq 4^\circ$).

The $\ell = 30^\circ$ excess: no evidence for spherical PSs

- NFW DM, NFW PS templates centered around $\ell = 30^\circ$
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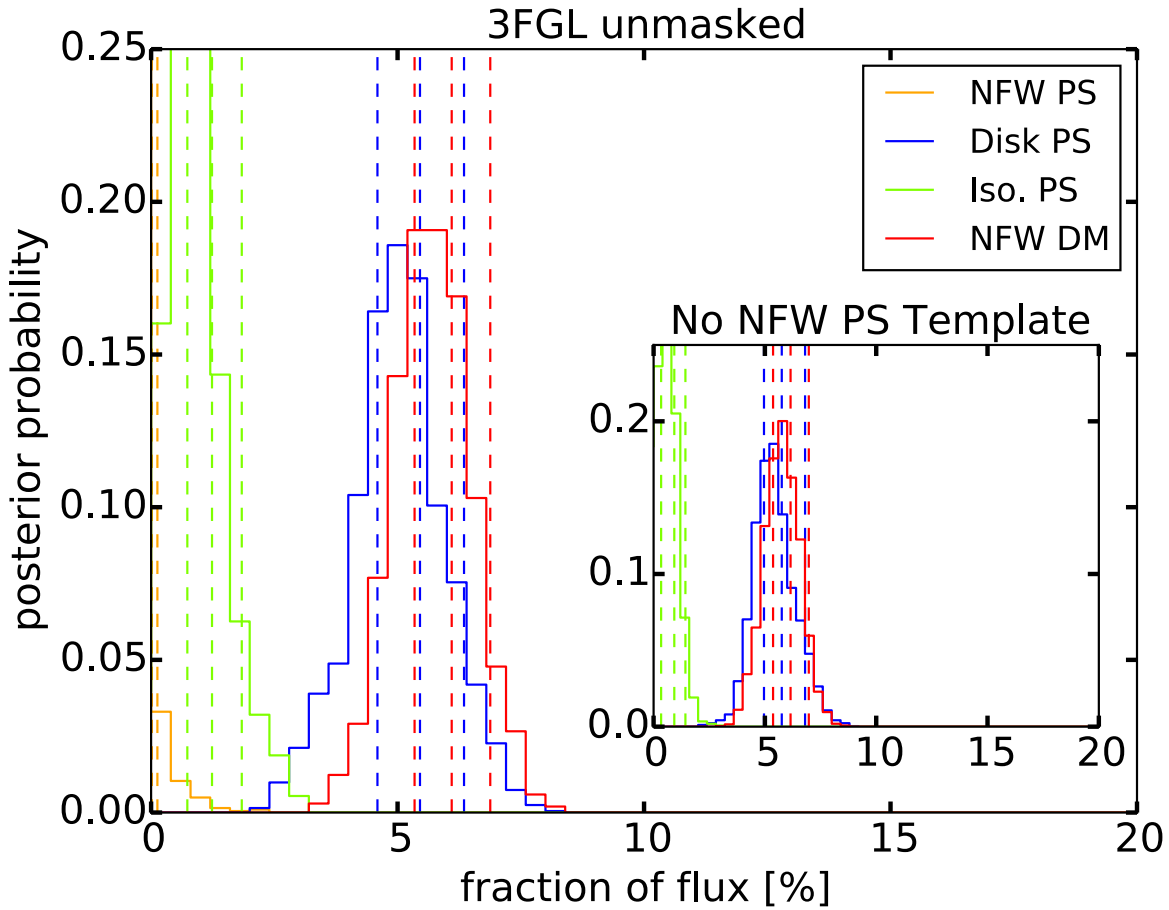

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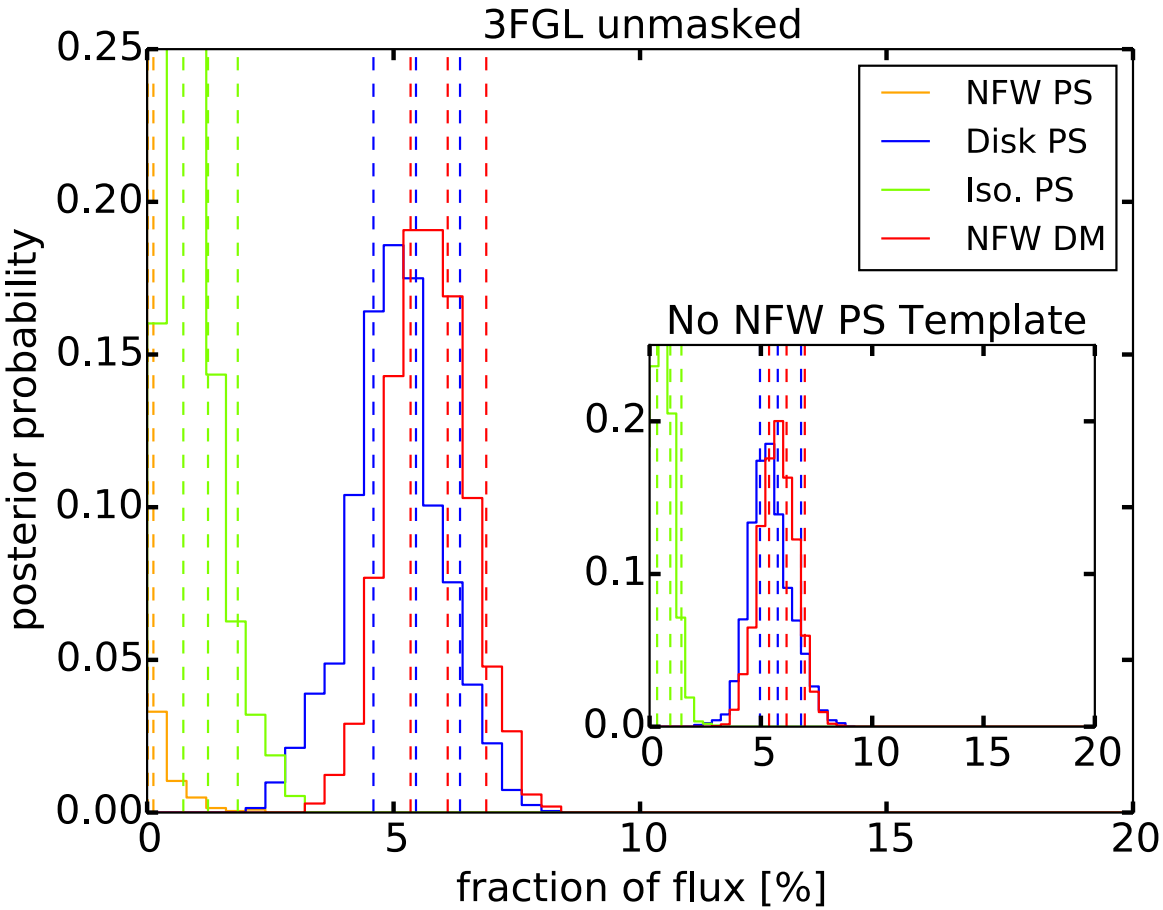

- Bayes factor ~ 0.1

ROI: the $\ell = 0^\circ$ excess

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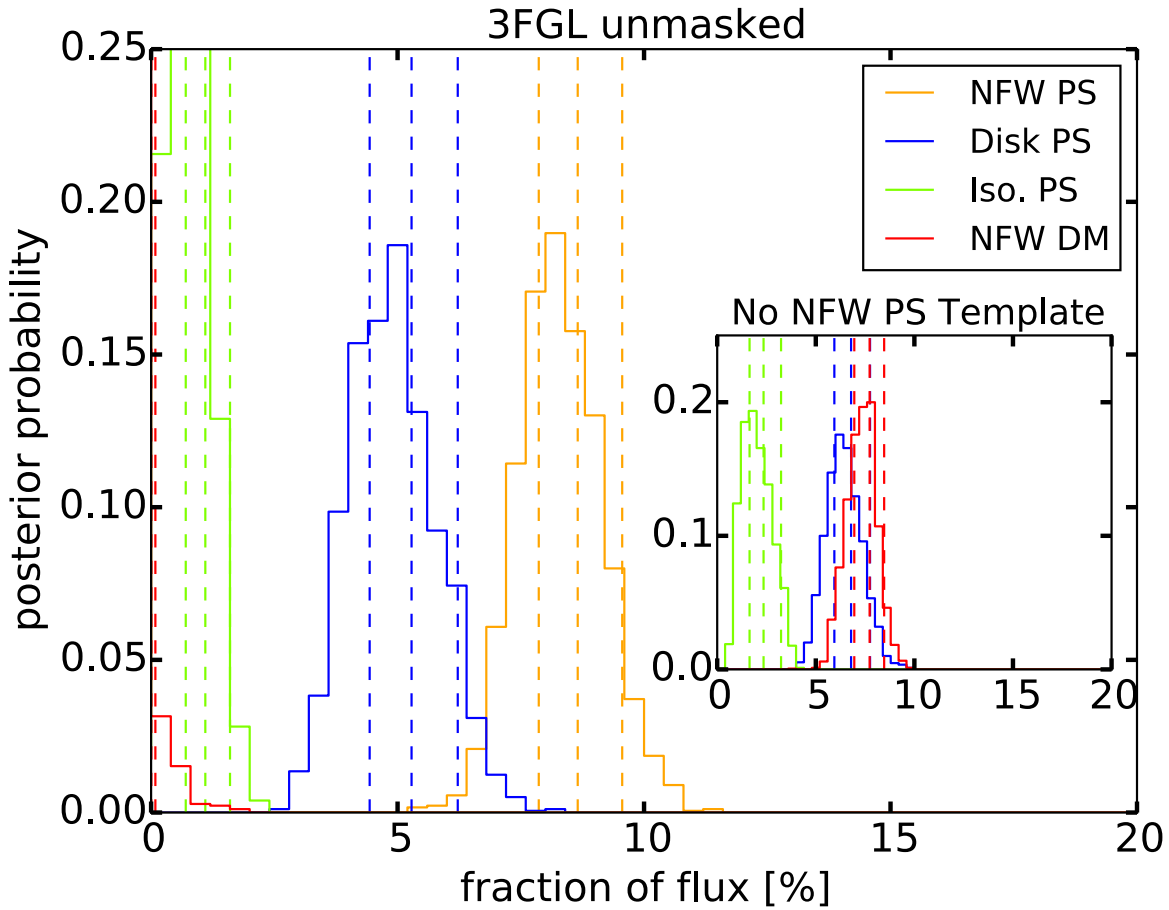

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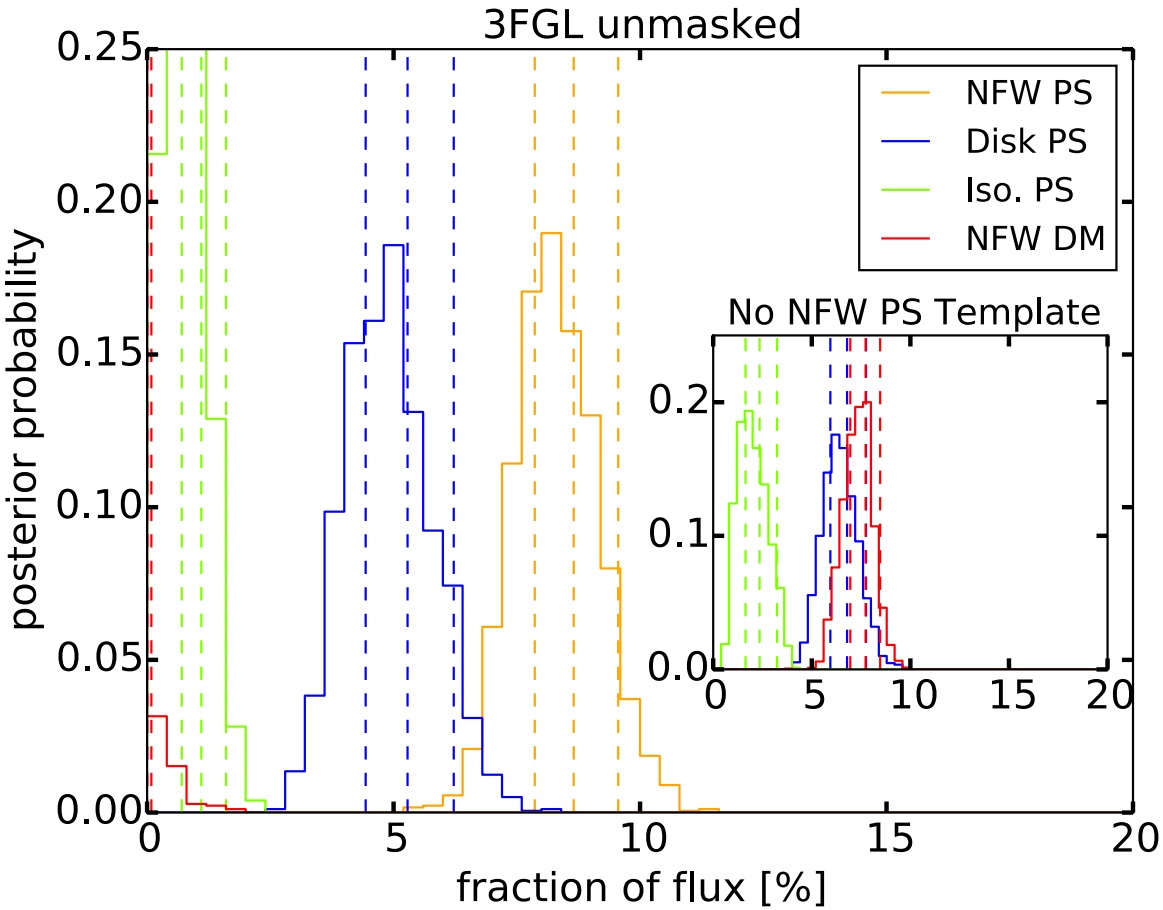
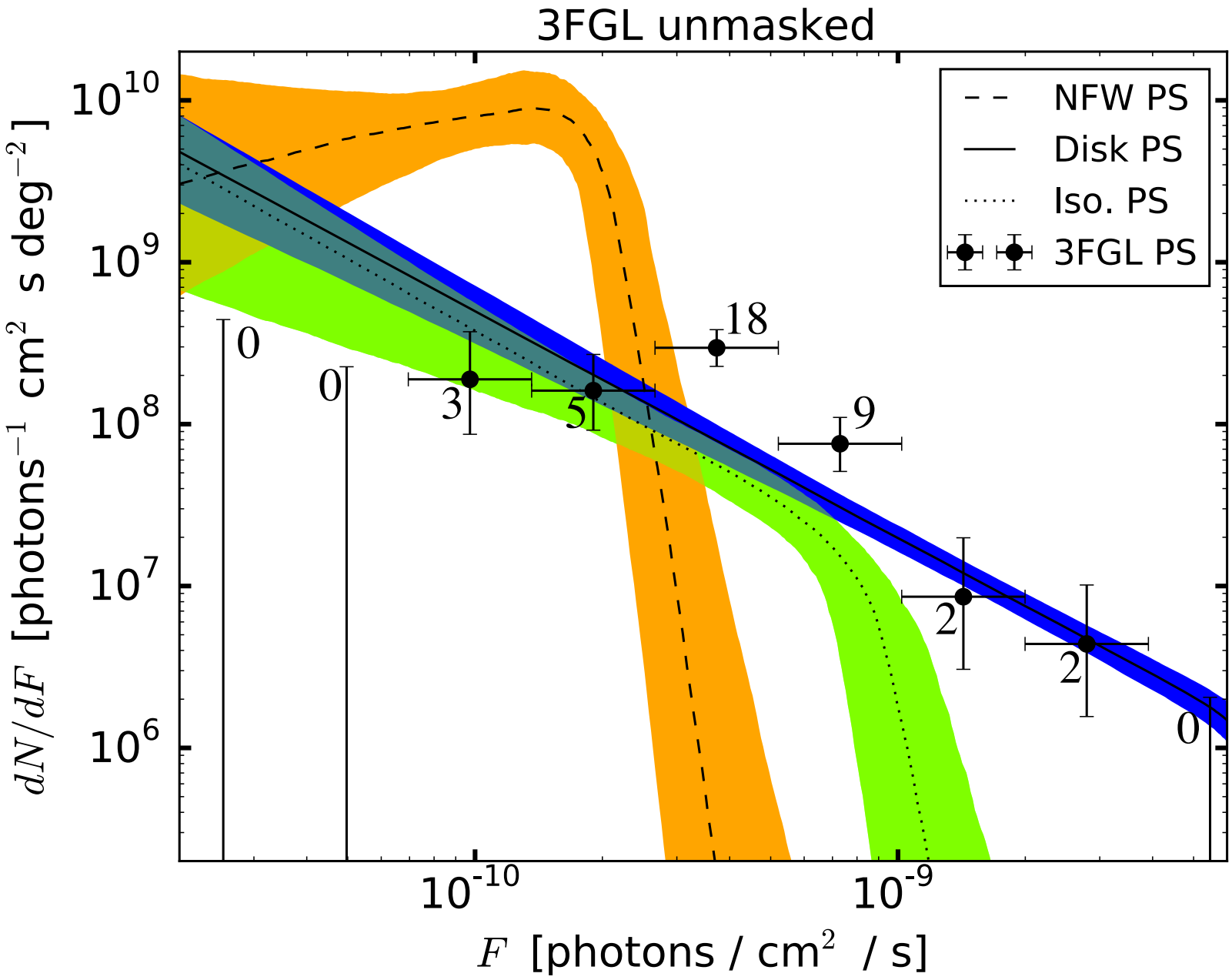
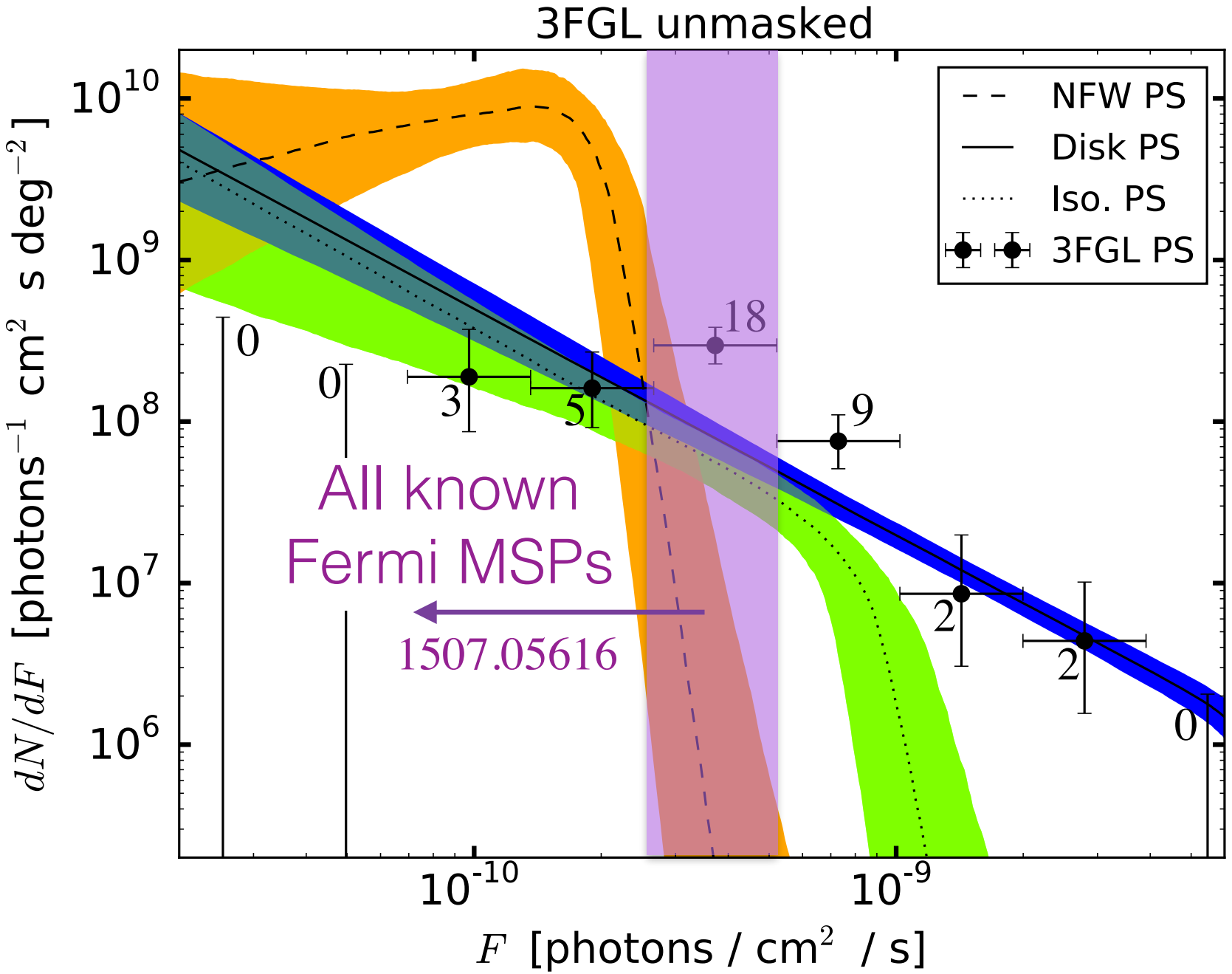


- Bayes factor $\sim 10^9$ (3FGL unmasked), 10^4 (3FGL masked)

The $\ell = 0^\circ$ excess: source-count function



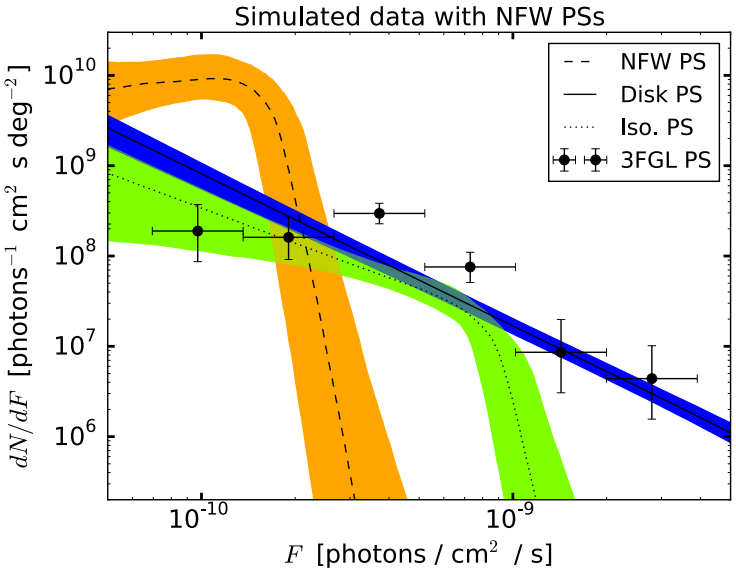
PSs consistent with MSP luminosity function?

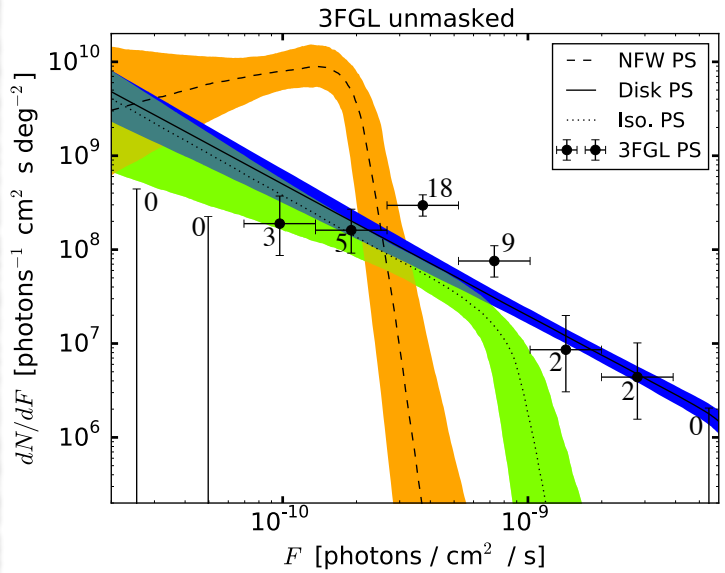


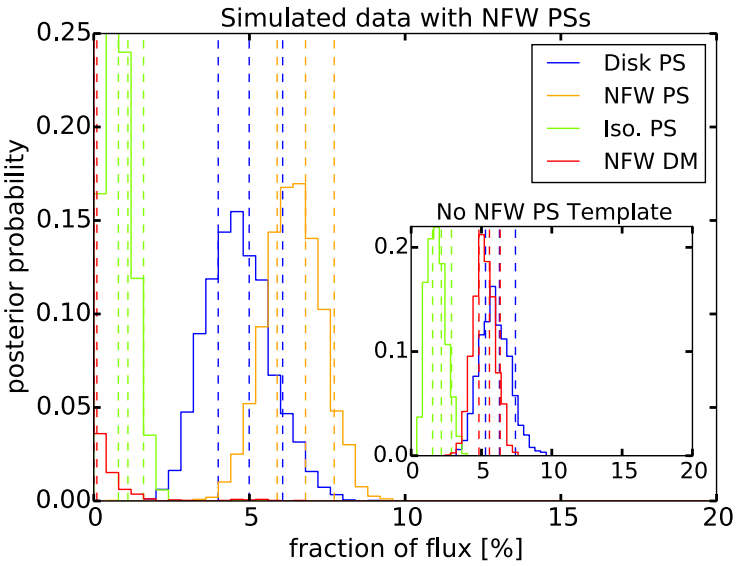
Check 2: Monte Carlo

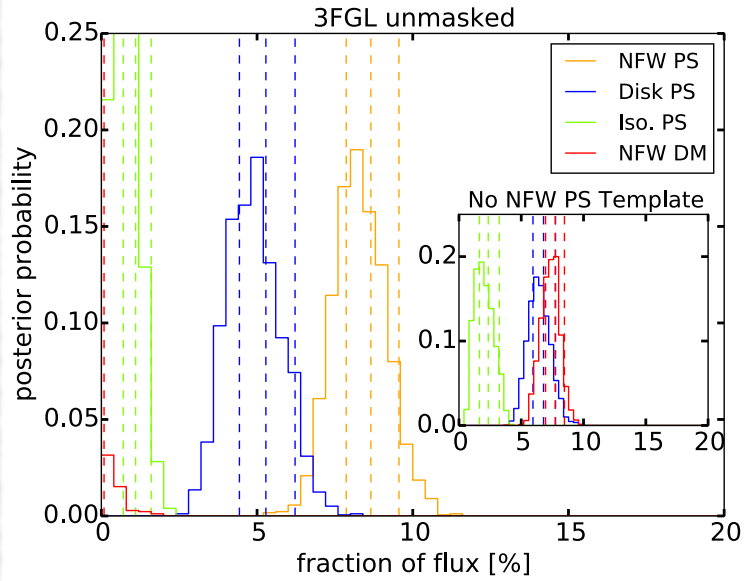
The $\ell = 0^\circ$ excess: Monte Carlo

Real data



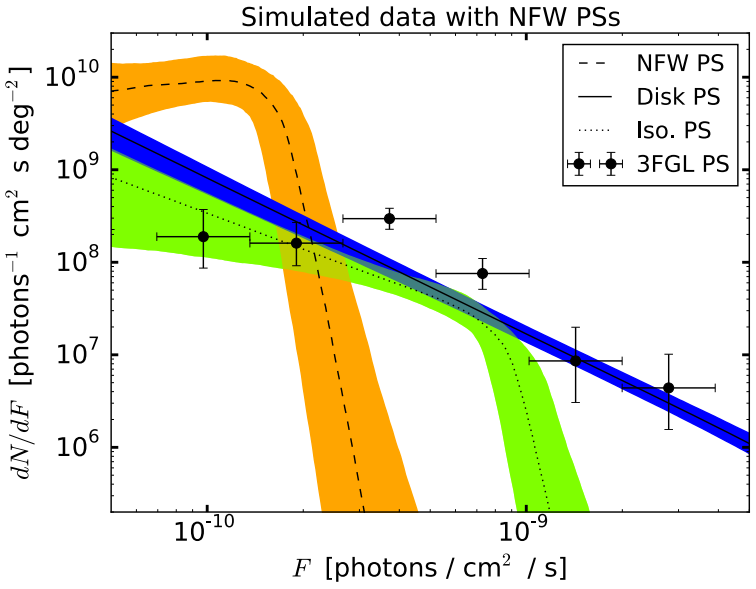


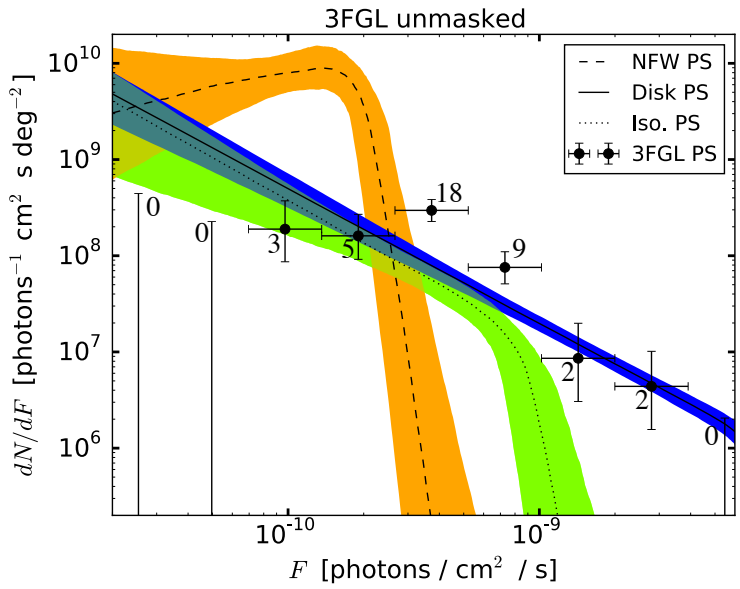


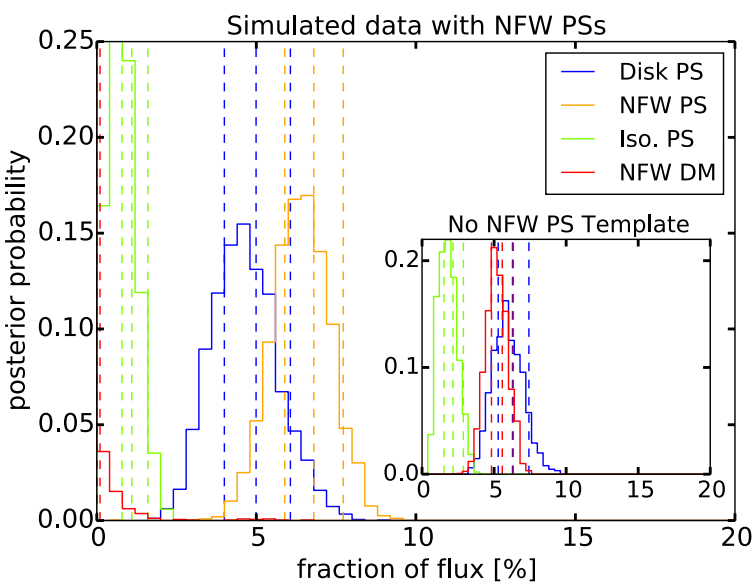


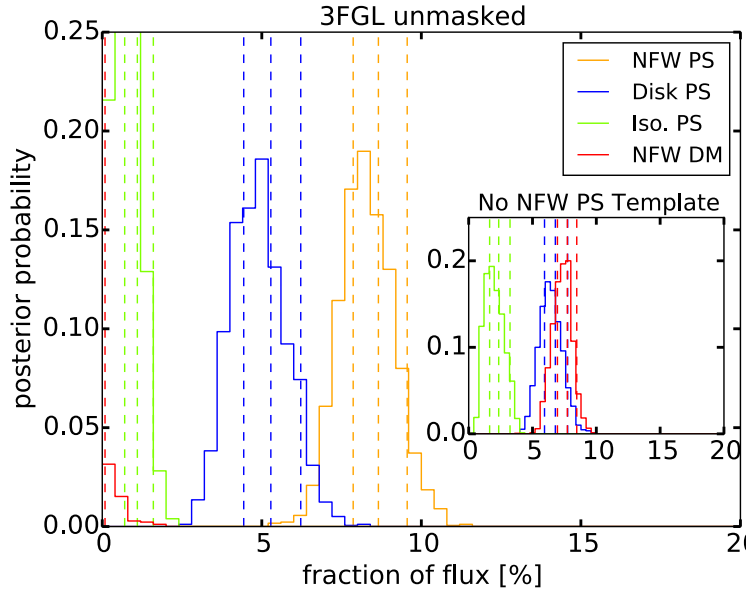
The $\ell = 0^\circ$ excess: Monte Carlo

Simulated data



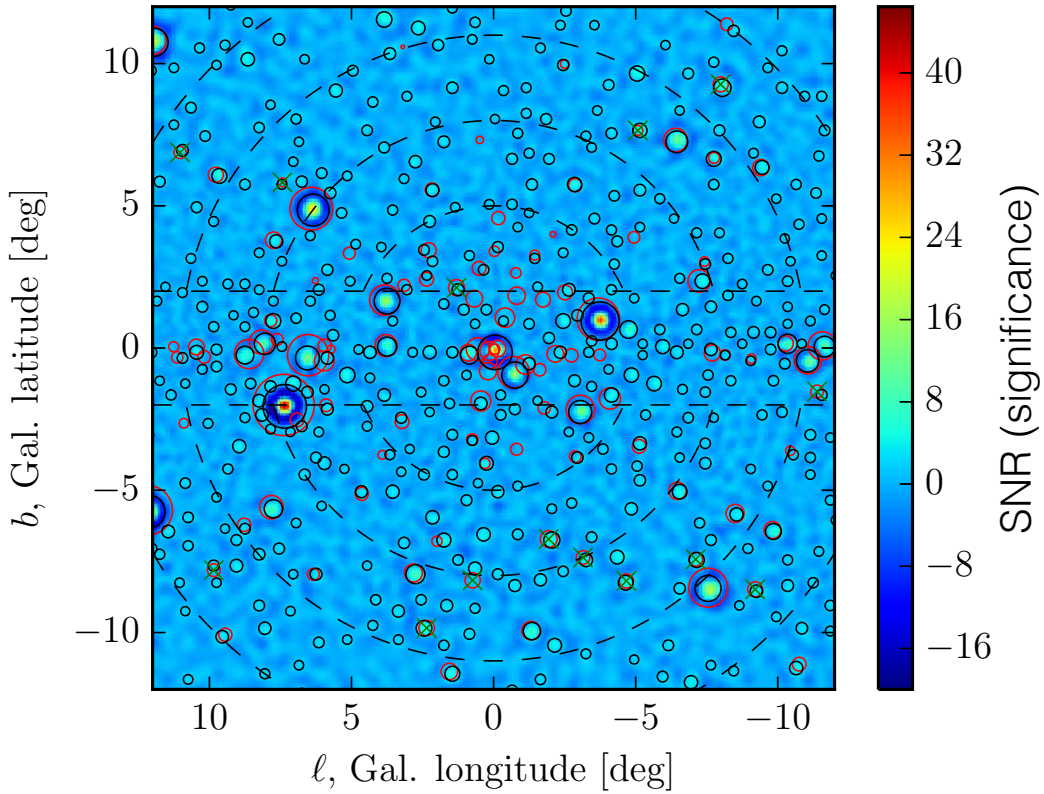






Wavelet approach comes to same conclusion

- Bartels, Krishnamurthy, Weniger (PRL 2016)
- Signal-to-noise ratio (SNR; S) of wavelet transform
- Filters out structure of specific size (PSF)



- red: 3FGL, black: $S > 2$

Radio followup survey

- Follow-up survey in radio (Green Bank, Parkes) for MSPs

- Submitted and submitting: proposals for Green Bank observing time

- Simulation results: $\sim$100 hours of observation time, find $\sim$5 MSPs in the bulge

Parkes (Australia)

Green Bank (West Virginia)

with T. Linden, S. Ransom, N. Rodd, P. Ray, J. Thaler, C. Weniger, . . . , *Fermi* members (E. Charles, M. Di Mauro)

Tentative conclusion: GeV excess better fit by point-source emission than smooth (DM) emission

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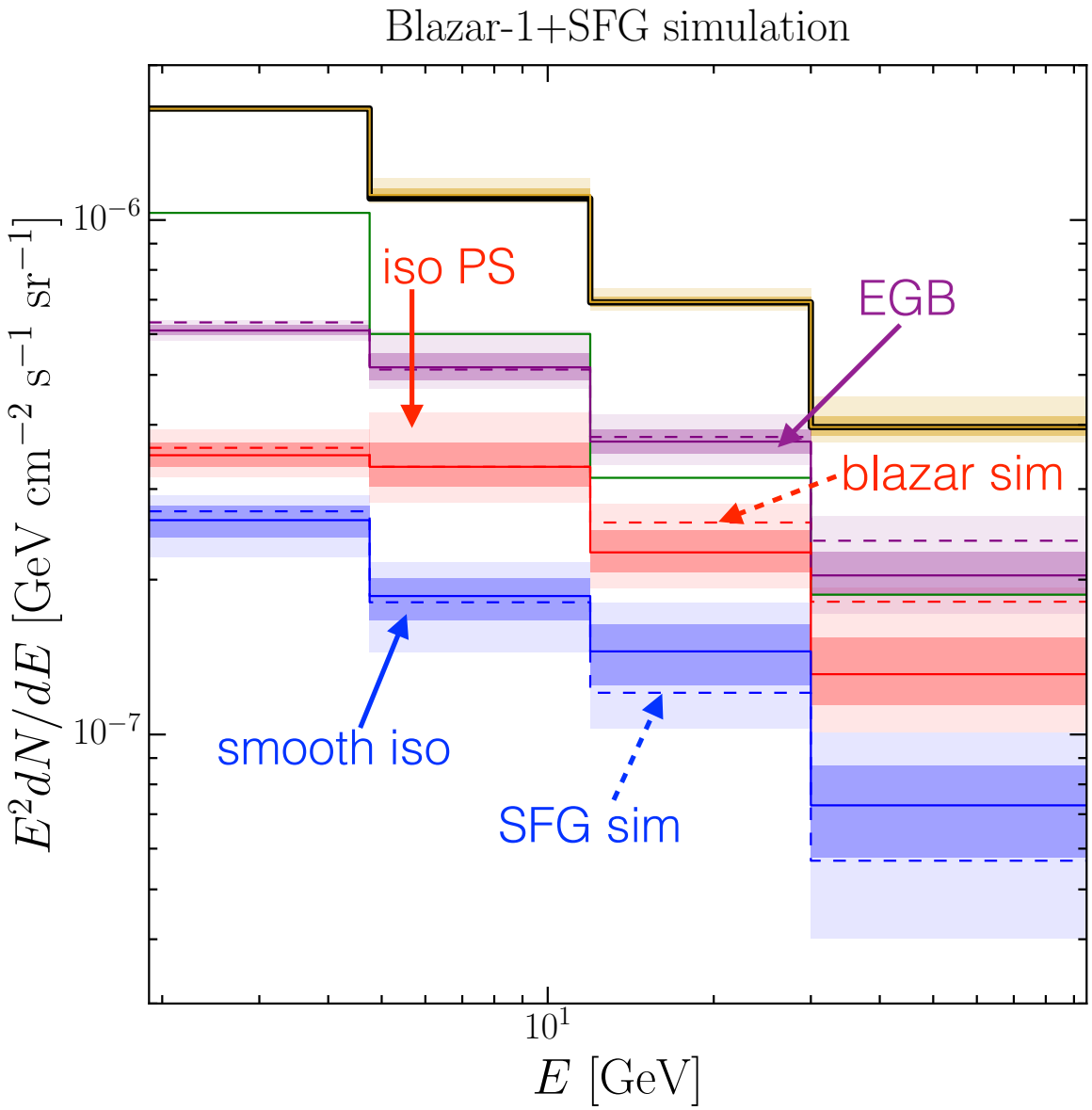
- L. Necib (MIT), N. Rodd (MIT), **B.S.**, Siddharth Sharma (Princeton)

NPTF at high-lat. constrains extragal. PSs (blazars)



1606.04101: M. Lisanti, S. Mishra-Sharma, L. Necib, **B.S.**

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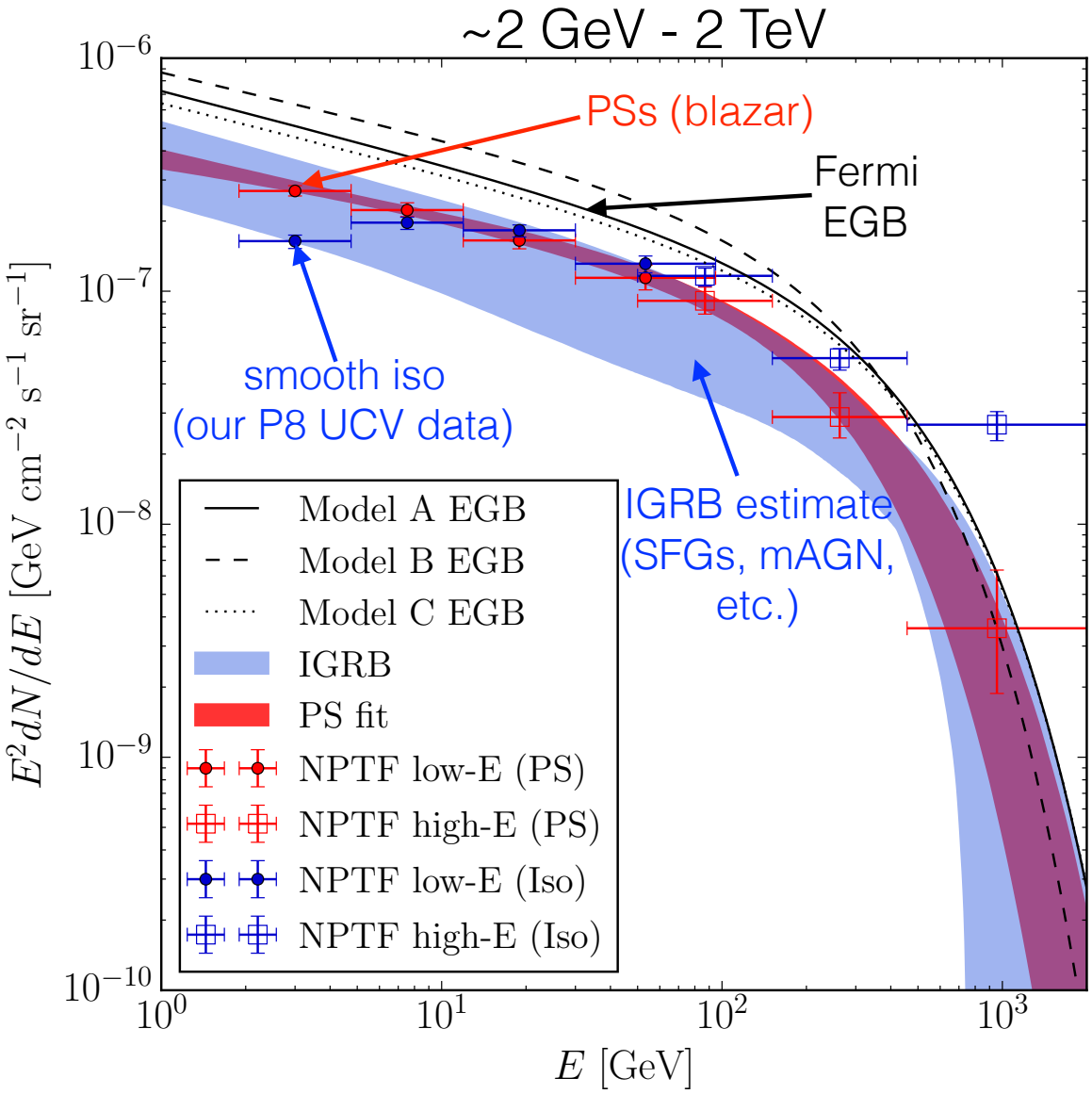

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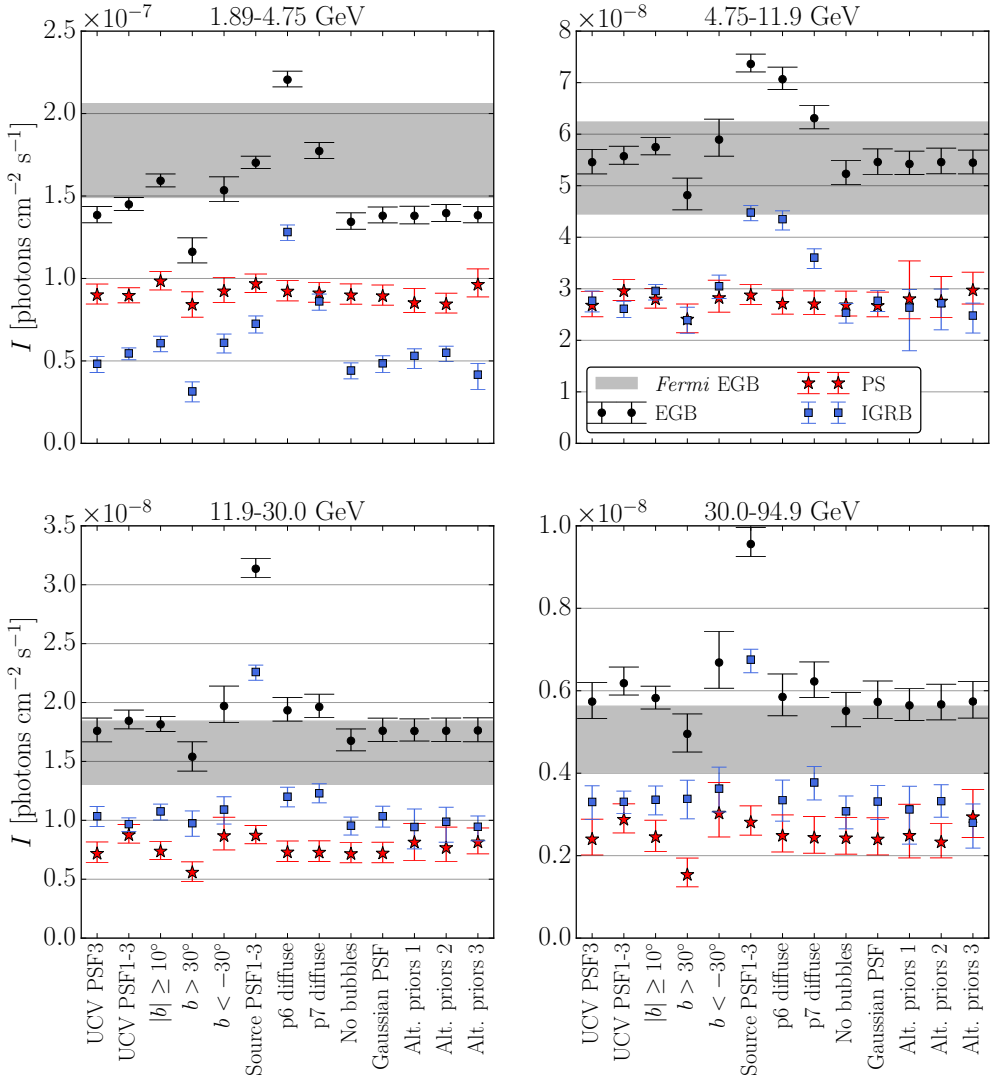

1606.04101: M. Lisanti, S. Mishra-Sharma, L. Necib, **B.S.**

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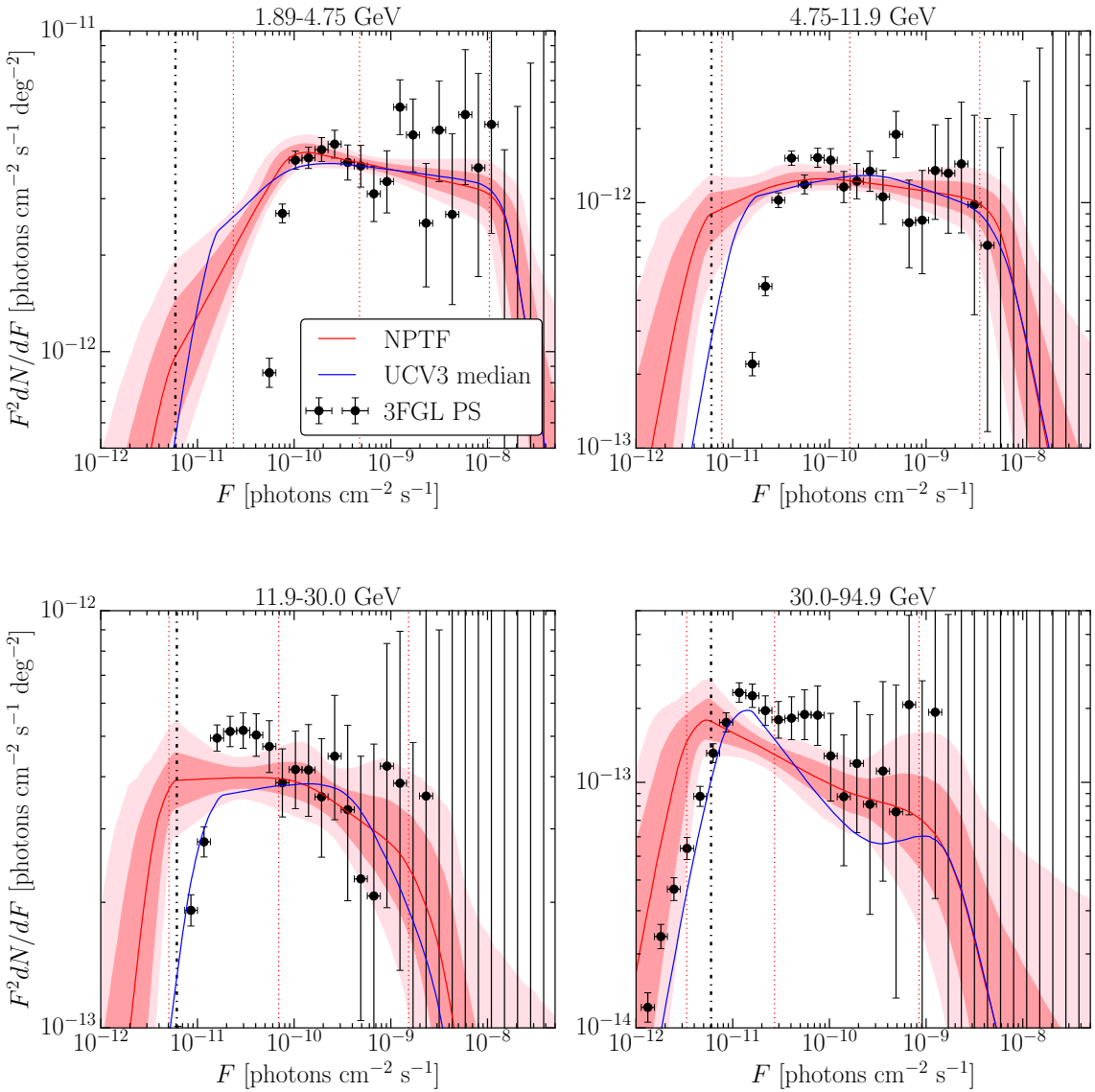
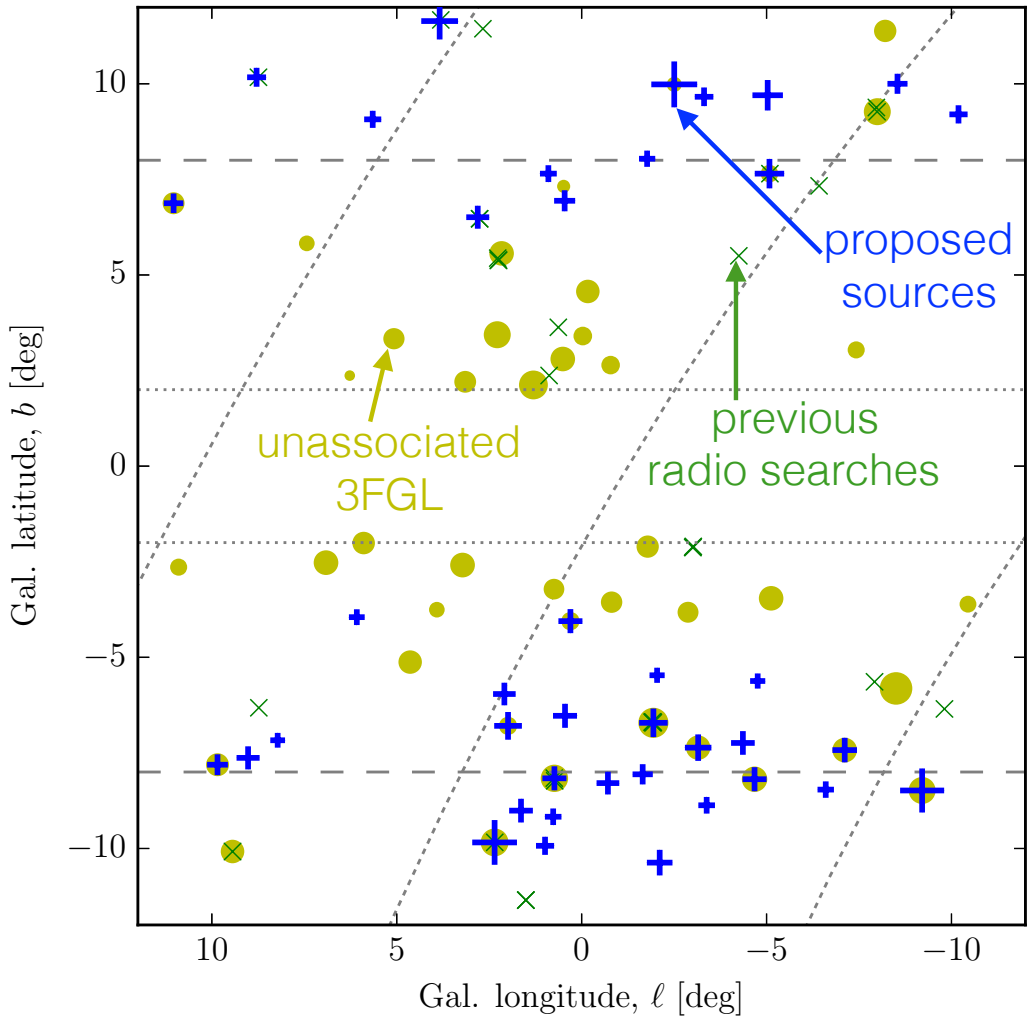


1606.04101: M. Lisanti, S. Mishra-Sharma, L. Necib, **B.S.**

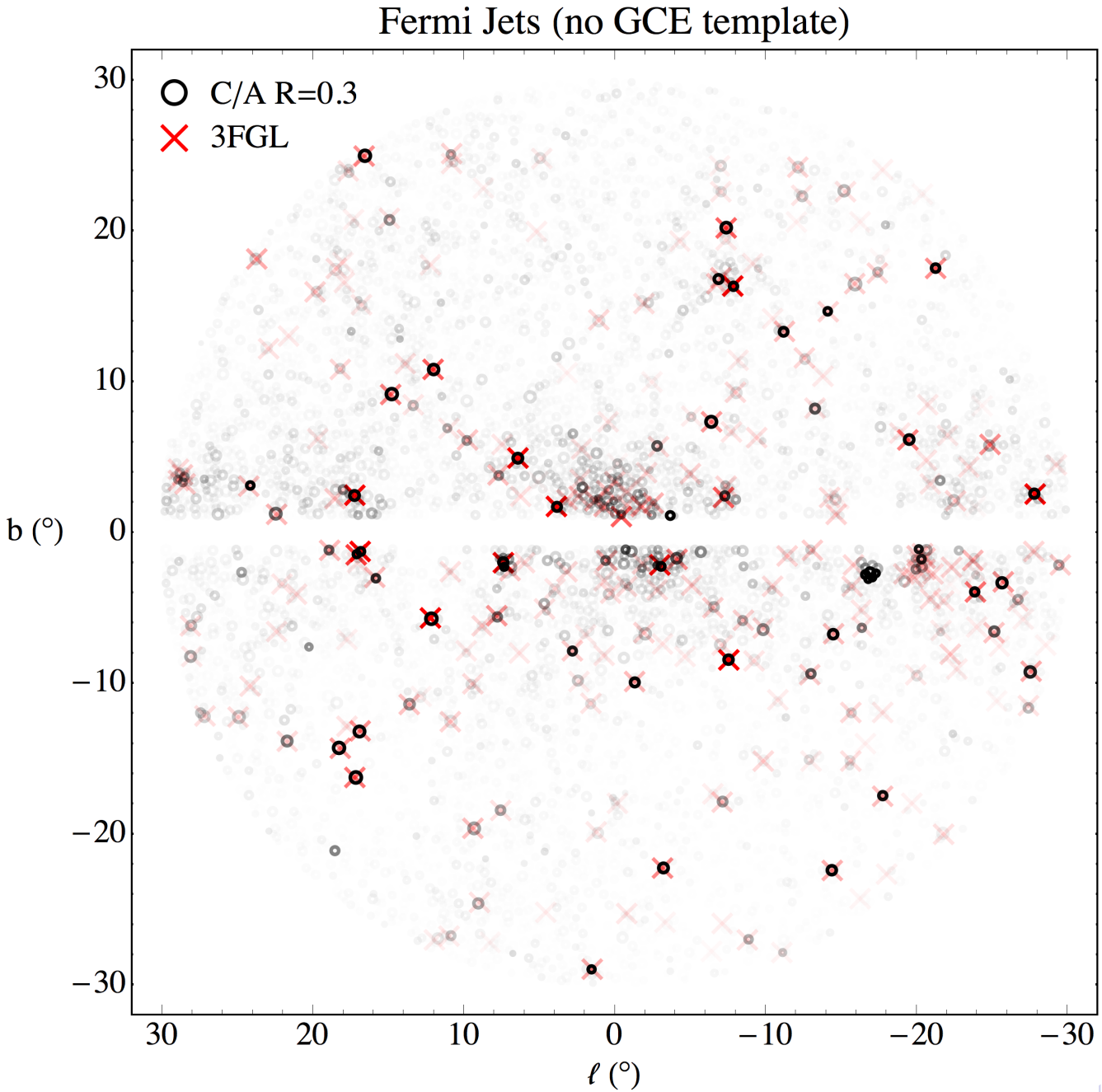
Questions?

Radio followup survey: where to look

- Candidates identified through wavelet analysis + modified jet clustering analysis (N. Rodd, **B.S.**,J. Thaler) of *Fermi* data



PS candidates from jet clustering



Statistics of PS candidates

- In each jet: $\epsilon^{(p)} \equiv 1 - \text{CDF}(\text{data; background model})$

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