A Probabilistic Catalogue of Unresolved High Latitude *Fermi* LAT Sources

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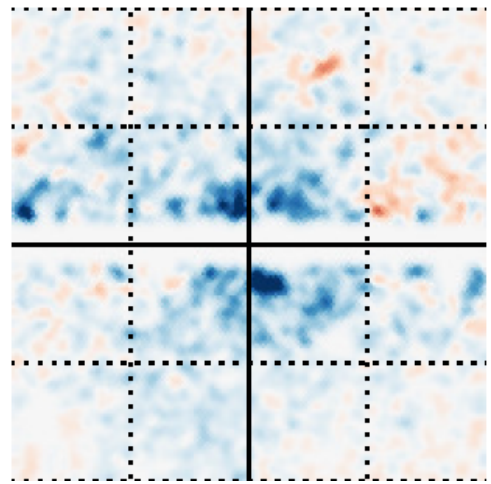
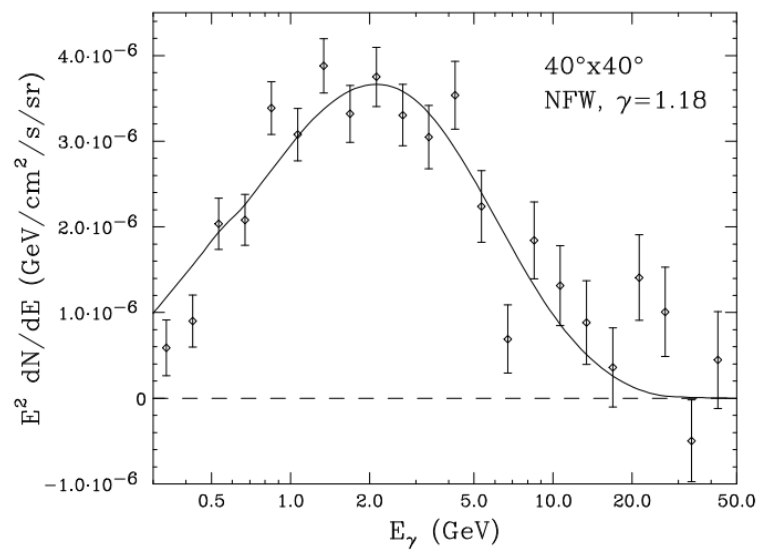
11 November 2015
Fermi Symposium VI, Washington DC

GeV Excess Interpretations

- Excess about Galactic Centre in *Fermi* LAT data
- Morphology, intensity, and spectrum compatible with dark matter interpretations
- May also be interpreted as a new population of faint point sources





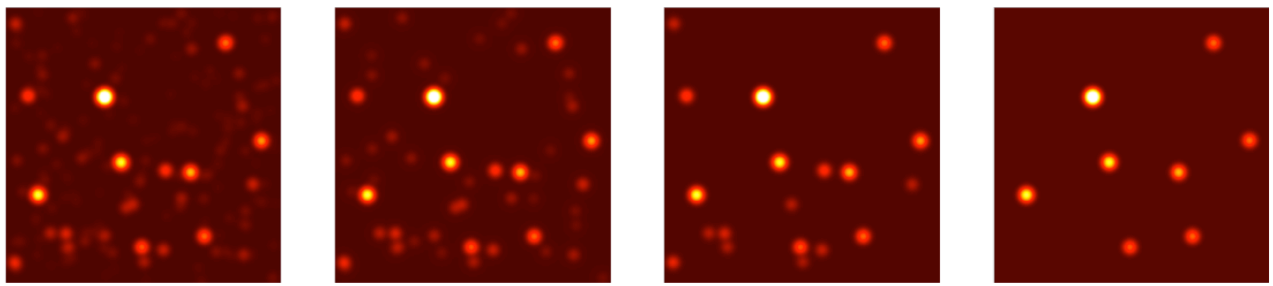
F. Calore, I. Cholis, and C. Weniger, JCAP 3, 38 (2015)
T. Daylan et al., arXiv:1402.6703 (2014)

Point Source Populations vs Diffuse Sources

increasing F_{min} , I_{iso}
constant $\int I \, d\Omega$

infinite counts

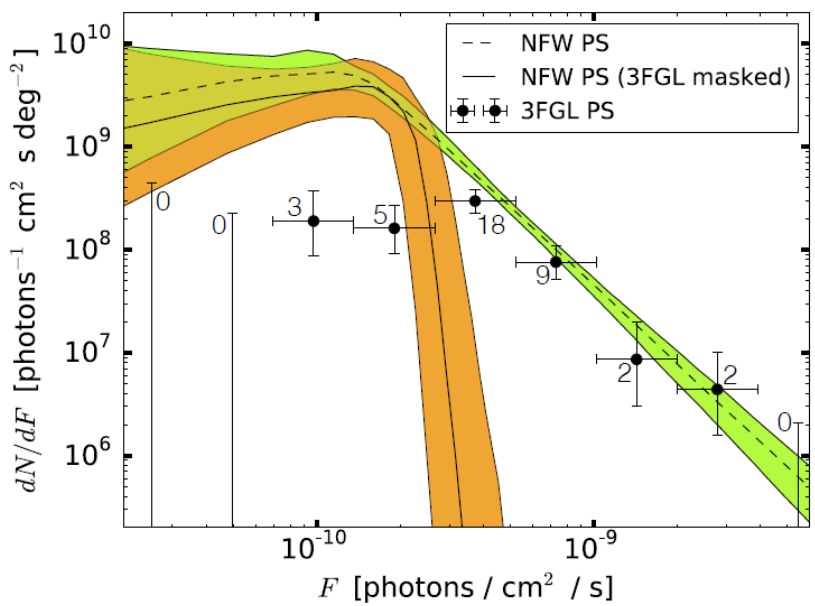
finite counts



Counting statistics introduce a point source detection threshold
But even sources fainter than this threshold can affect image

Non-Poissonian Template Fitting

- A point source population with a given spatial distribution can be treated as a diffuse source with non-Poissonian statistics
- Greatly favours a point source interpretation of the GeV Excess
- Inferred population's luminosity function peaks just below *Fermi* LAT detection threshold



NFW template point sources
NFW template point sources minus 3FGL

S. K. Lee, et al., arXiv:1506.05124 (2015)

(Deterministic) Catalogues

- A (deterministic) catalogue is a list of point source candidates above some inclusion threshold F_{incl}
  $Data, F_{incl} \rightarrow \{\ell_i \pm \sigma_{\ell_i}, b_i \pm \sigma_{b_i}, F_i \pm \sigma_{F_i}\}_{i=1}^{N}$

- **Inclusion threshold = detection threshold:**
  Almost all catalogue sources are true sources
  But faint true sources are not in the catalogue

- **Inclusion threshold < detection threshold:**
  More faint true sources are included in the catalogue
  But many catalogue sources are not true sources
  The data is overfitted

Probabilistic Catalogues

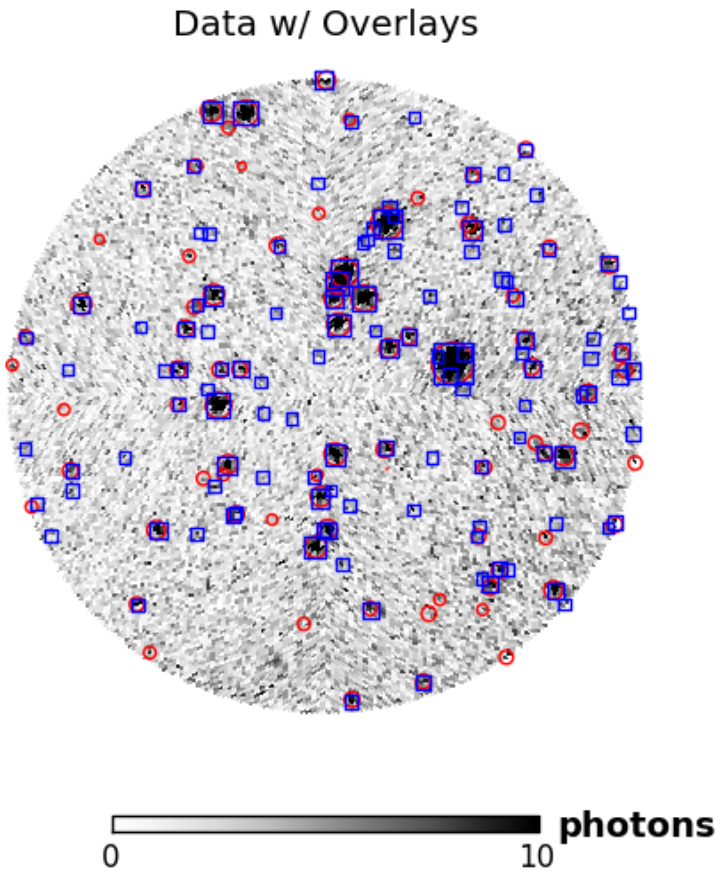
- A probabilistic catalogue is a probability distribution over the space of lists of point source candidates $P\{\ell_i, b_i, F_i\}_{i=1}^{N} \mid Data$
- Sampling the probabilistic catalogue provides an ensemble of catalogues consistent with the data
- This ensemble captures the degeneracies of point source identification
- The reality of a single faint point source candidate will be very uncertain, but the properties of a faint population are constrained
- We currently use Brendon BREWER's DNest3+RJObject to sample; see Tansu DAYLAN's poster for more details
- This technique is a different approach to the GeV Excess that retains more information than non-Poissonian template fitting

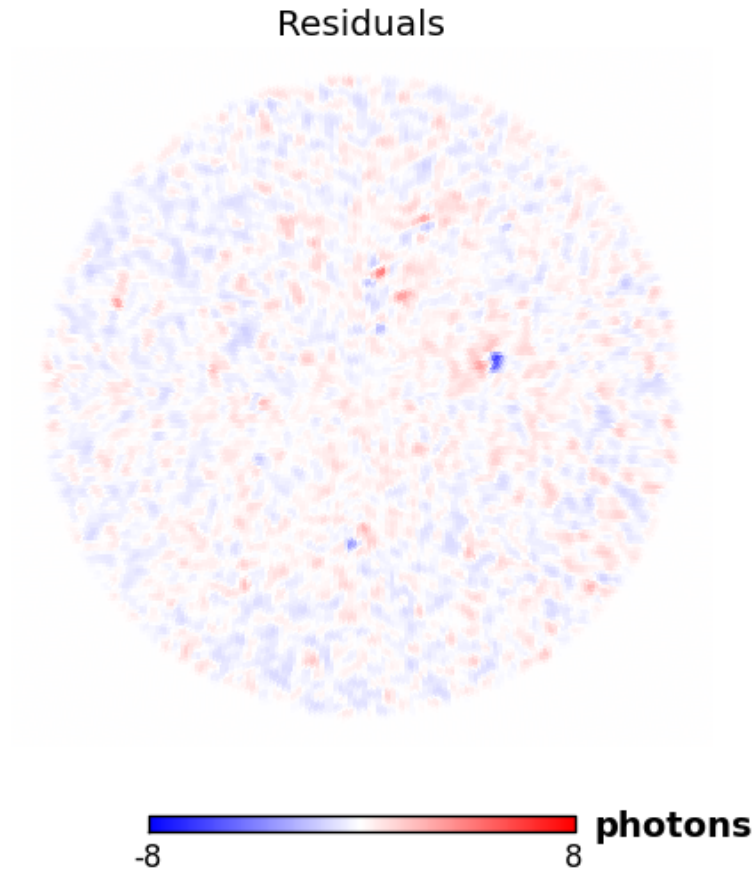
B. Brewer, L. B. Pártay, and G. Csányi, arXiv:0912.2380 (2009)
B. Brewer, arXiv:1411.3921(2014)

Validation at High Latitude

- North Galactic Pole $b>70°$ ($N_{pix}=23\,544$)
- Region includes 84 3FGL sources
- Run with ~400 core-hours
- Diffuse sources:
  - Galactic diffuse emission
  - Isotropic emission
- Point source population:
  - Mostly distant active galaxies
  - Assumed to be isotropically distributed
  - Unknown flux distribution parameterized as power law

Probabilistic Catalogue Samples

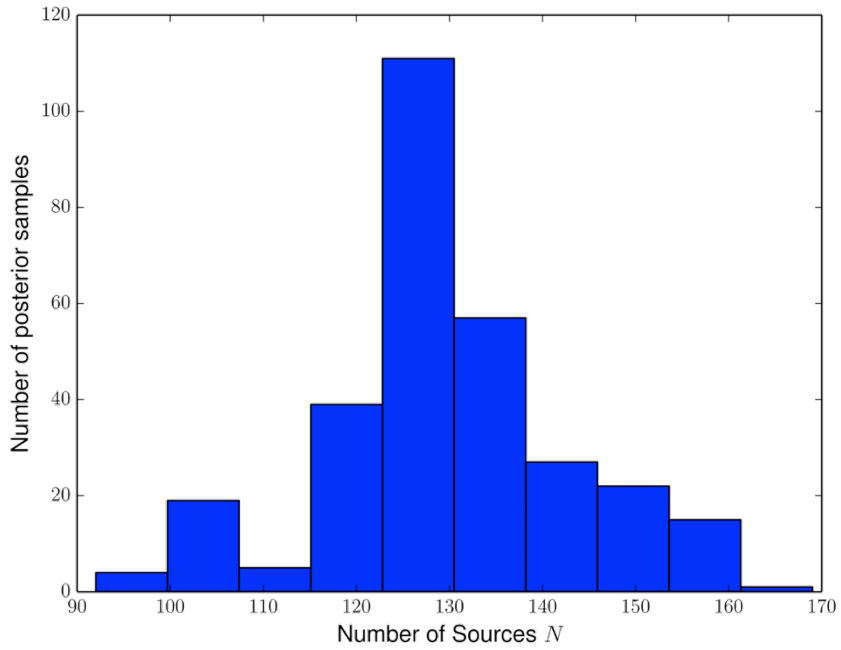


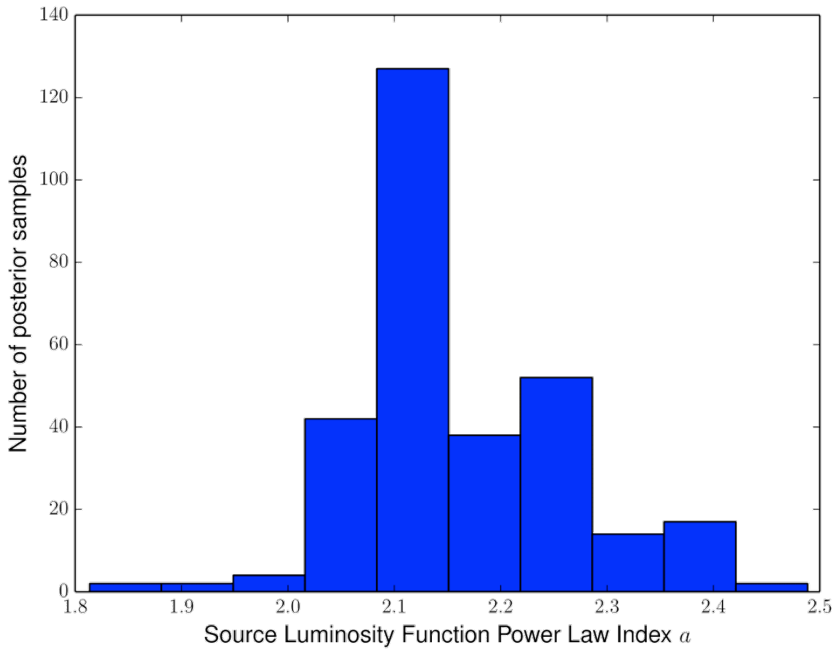


red circles – 3FGL point sources
blue squares – point source candidates

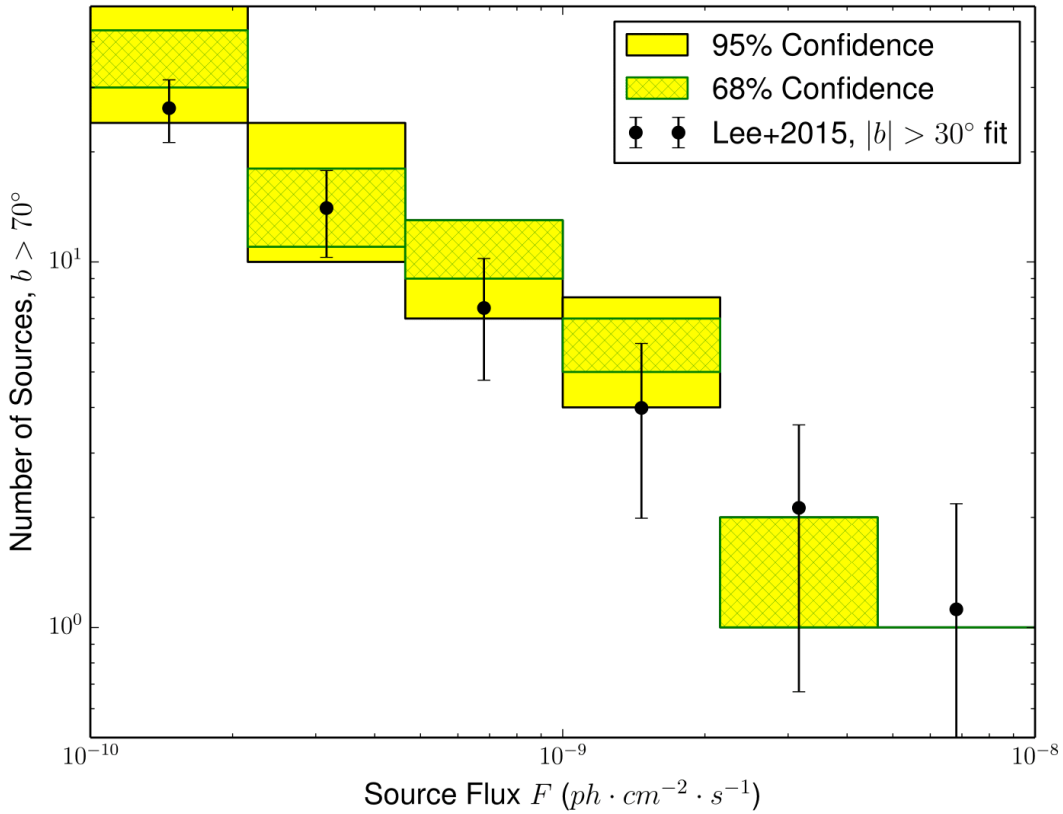
Pass 8 SOURCE
1-3 GeV
Weeks 9-217

Point Source Population Constraints





Comparison



Pass 8 ULTRACLEANVETO PSF3
1.893-11.943 GeV
Weeks 9-365

Conclusion

- Constraining the point source contribution to the GeV Excess essential to its interpretation
- A point source population can be distinguished from a diffuse source, even if the individual sources are below the detection threshold
- Probabilistic catalogues capture the degeneracies of point source identification
- We have constructed a probabilistic catalogue for high latitude *Fermi* LAT sources in reasonable agreement with the 3FGL and non-Poissonian template fitting
- Stay tuned for Galactic Centre results…