

Constraining Unresolved Point Source Contributions to the GeV Excess with Probabilistic Catalogues

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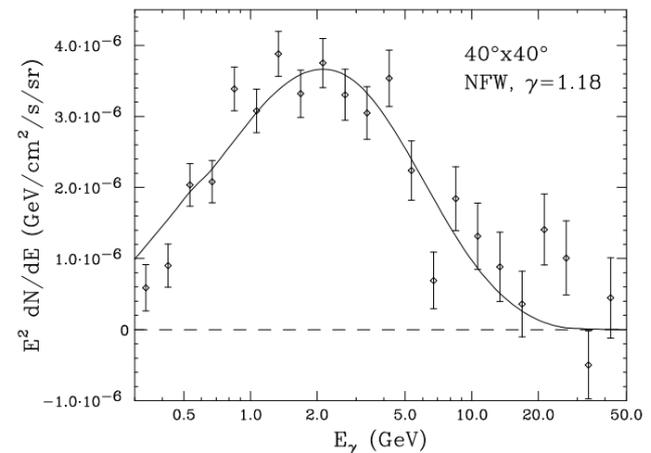
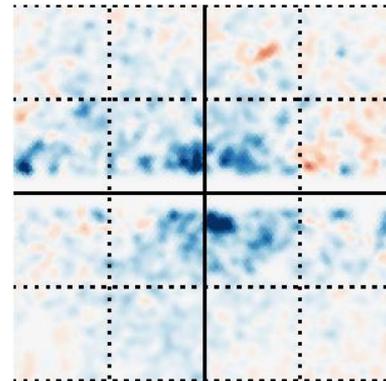
with Tansu DAYLAN and Douglas P FINKBEINER

3 August 2015, APS DPF Ann Arbor



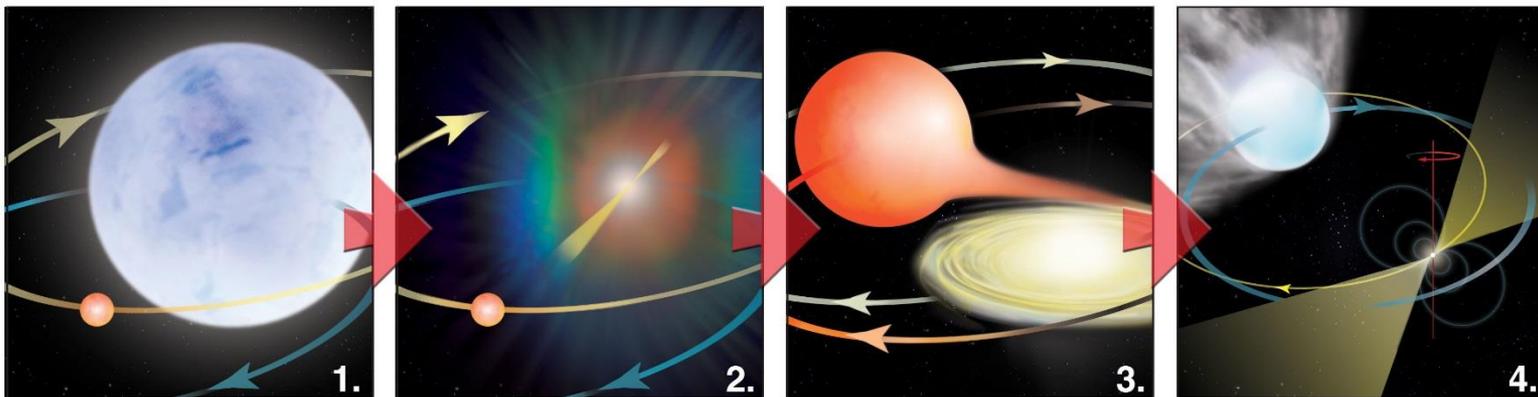
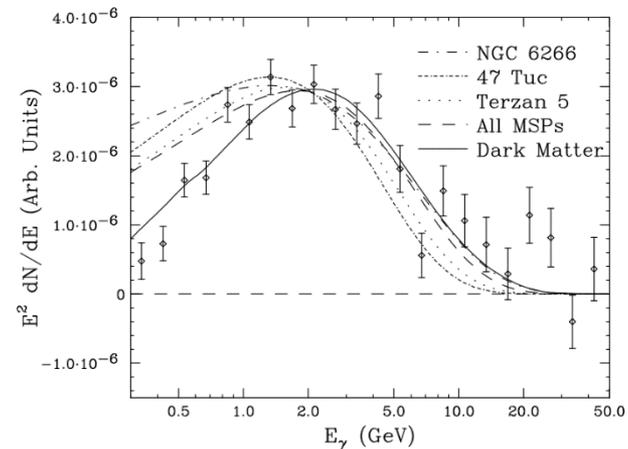
GeV Excess

- ▶ Found by analyses of *Fermi* LAT gamma-ray data
- ▶ Spherical emission about Galactic Centre
- ▶ Radial profile $\propto r^{-2.4}$
- ▶ Extends at least 10° (1.4 kpc)
- ▶ Spectrum peaks at 1-3 GeV
- ▶ Consistent with WIMP annihilation among many other DM interpretations



Millisecond Pulsars (MSPs)

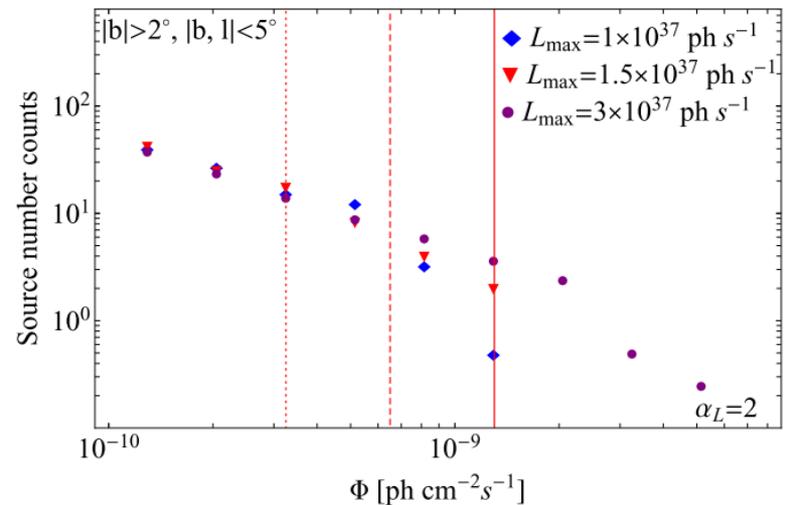
- ▶ Similar spectrum to GeV Excess
- ▶ Formed in stellar binaries where primary becomes pulsar
- ▶ Formation rates and gamma-ray emission mechanisms are active research topics



MSP Interpretation

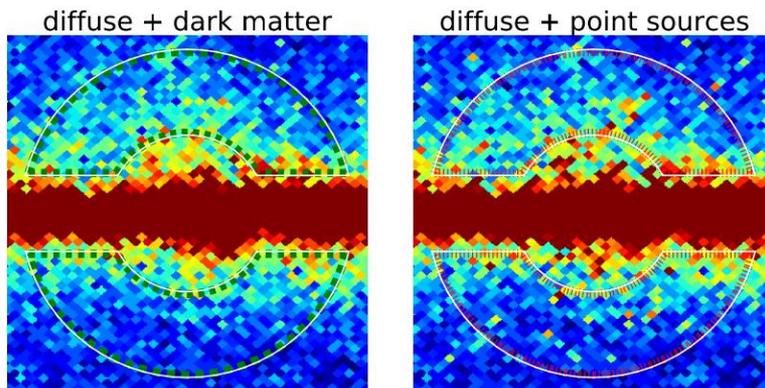
- ▶ A central population of thousands of MSPs
 - ▶ Mechanism distributing them to match Excess morphology
 - ▶ Possibly harder spectrum than local MSPs to better match excess spectrum
- ▶ But no MSP has been detected in the Inner Galaxy

- ▶ Unclear how many should already be detected:
 - ▶ MSP luminosity function
 - ▶ *Fermi* LAT sensitivity

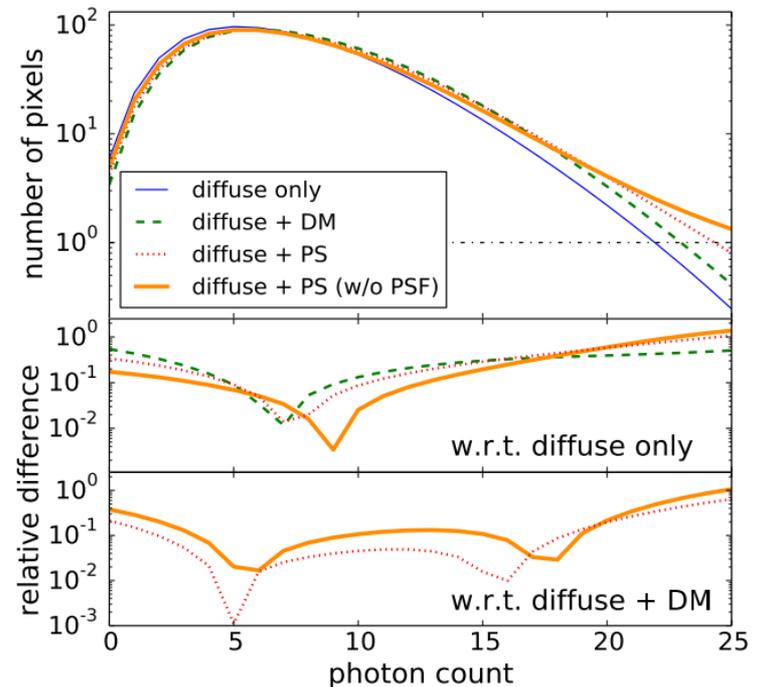


Point Sources vs. Diffuse Source

- ▶ Unresolved point source emission looks different than diffuse emission, even without sensitivity to detect individual sources

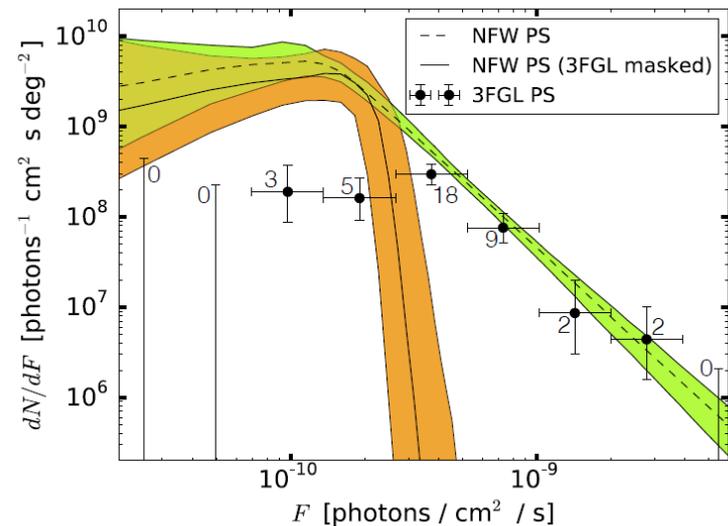


- ▶ Unresolved point source emission overdispersed Poisson photon statistics



Evidence for Point Sources

- ▶ Lee et al. 2015 favour interpretation of entire GeV Excess as unresolved point source emission
- ▶ Inferred luminosity function peaks just below *Fermi* LAT detection threshold
- ▶ **How else can we distinguish unresolved point sources from diffuse emission?**



Probabilistic Catalogues

- ▶ Lee et al. 2015 find the point source luminosity function and number of point sources preferred by the data

$$P(N, \beta | D)$$

- ▶ (Deterministic) catalogue is a set of sources that are almost certainly present and measurements of their properties, given the data

$$D \rightarrow N, \beta, \{\ell_i, b_i, F_i\}_{i=1}^N$$

- ▶ Probabilistic catalogue is the distribution of sets of sources and their properties that are consistent with the data

$$P(N, \beta, \{\ell_i, b_i, F_i\}_{i=1}^N | D)$$

Sampling the Probabilistic Catalogue

$$P(\theta = N, \beta, \{\ell_i, b_i, F_i\}_{i=1}^N | D) = P(\theta)P(D|\theta)$$

- ▶ **Prior:** sources independently drawn from separable spatial distribution and flux function

$$P(\theta) = P(\beta)P(N, \beta) \prod_{i=1}^N P(\ell_i, b_i)P(F_i)$$

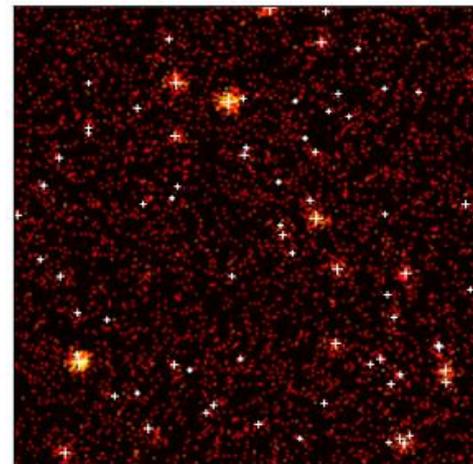
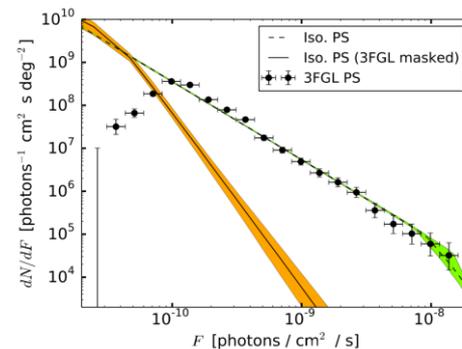
- ▶ **Likelihood:** Poisson distribution given catalogue expected counts in each pixel

$$P(\theta|D) = \prod_{j=1}^{N_{pix}} f_{Poisson}(k_j, \mu_j(\theta))$$

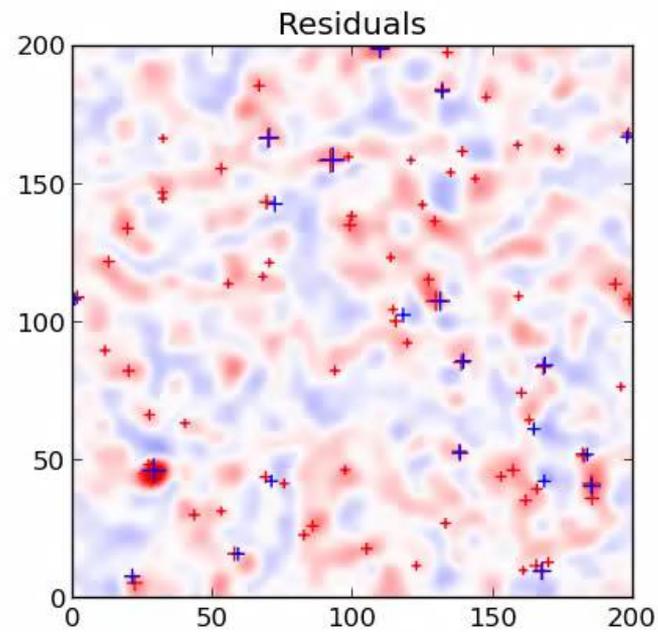
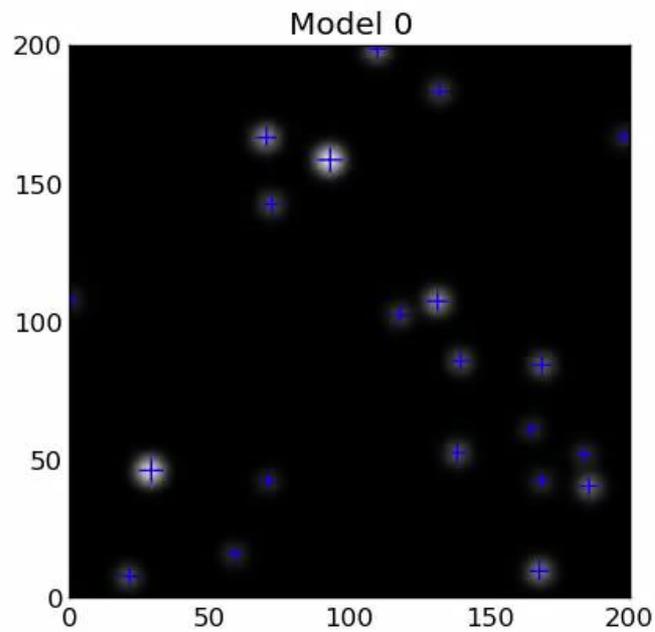
- ▶ We use DNest3+RJObject to sample this difficult posterior

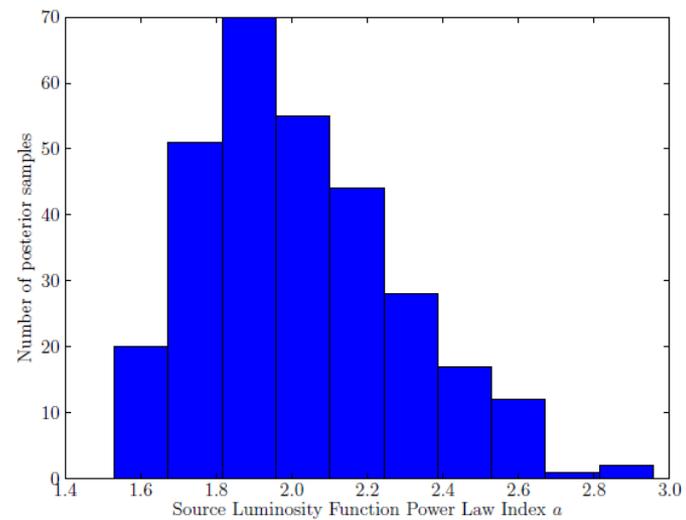
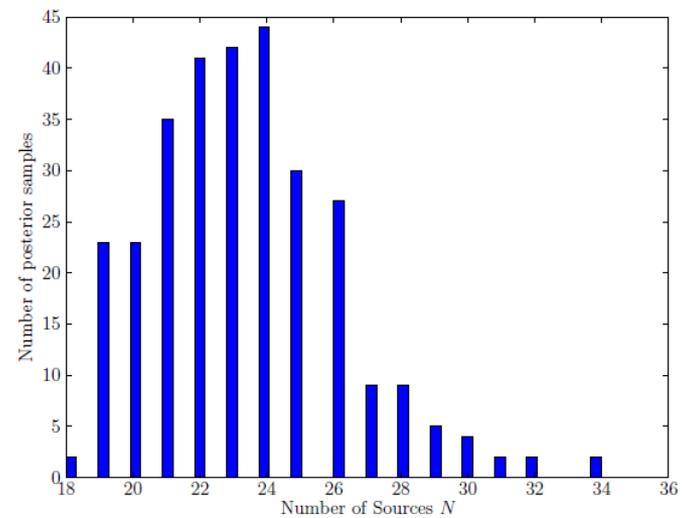
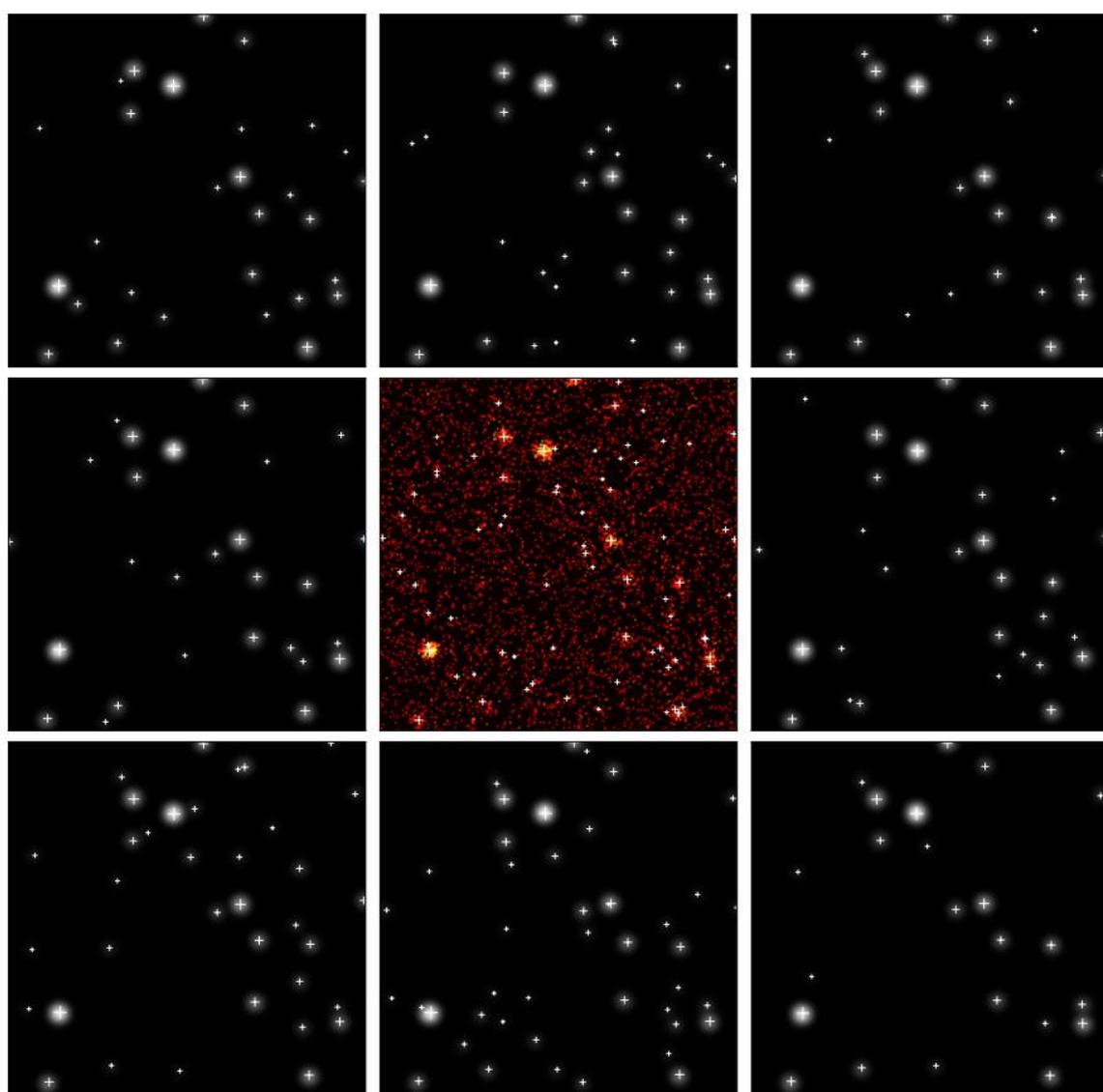
First Steps

- ▶ Start with high latitude:
 - ▶ Galactic emission is weak so background is isotropic extragalactic emission
 - ▶ Active galaxies are point sources
- ▶ Create mock data set based on Lee et al. 2015 high latitude result
- ▶ Usable results for a $20^\circ \times 20^\circ$ patch of sky in an hour with 8 threads



Video: Posterior Samples





Conclusion

- ▶ GeV Excess compelling DM annihilation candidate
- ▶ Population of MSPs also plausible interpretation
- ▶ Point source emission can be distinguished from diffuse emission, even if sources unresolved
- ▶ Lee et al. 2015 claim that GeV Excess prefers point sources, and find their luminosity function
- ▶ Probabilistic catalogues may be feasible to probe this possible point source population in more detail