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

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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 $10^\circ (1.4 \text{ kpc})$
- 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

Bill Saxton, NRAO
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

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

Unresolved point source emission overdisperses Poisson photon statistics.

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?

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

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

- 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°x20° 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 feasible to probe this possible point source population in more detail