Can MSPs account for the gamma-ray excess in the inner Milky Way?

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Overview

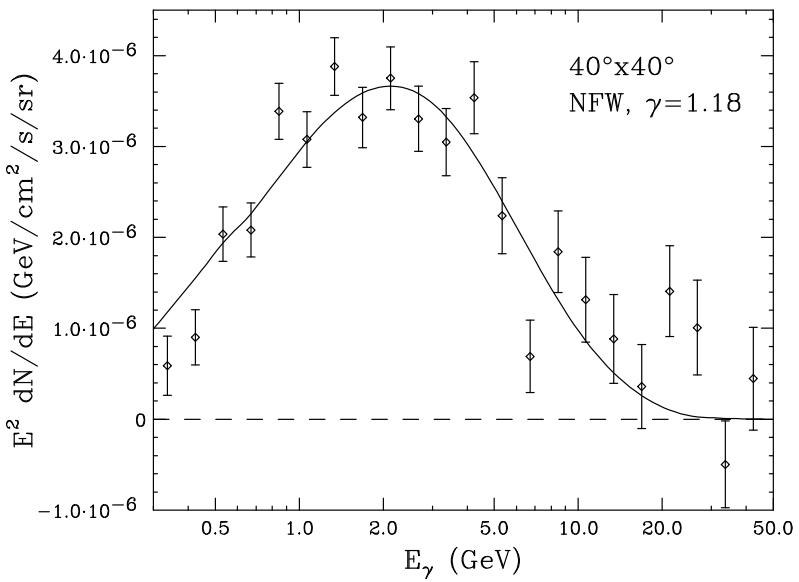
1. Gamma-ray excess in the inner Milky Way
2. Distinguishing between interpretations
3. Gamma-ray time variability of the ROI

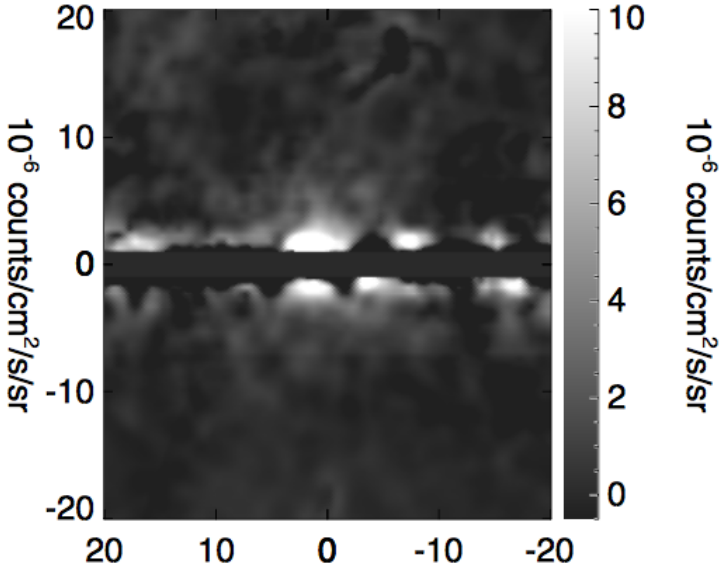
Gamma-ray excess in the inner Milky Way

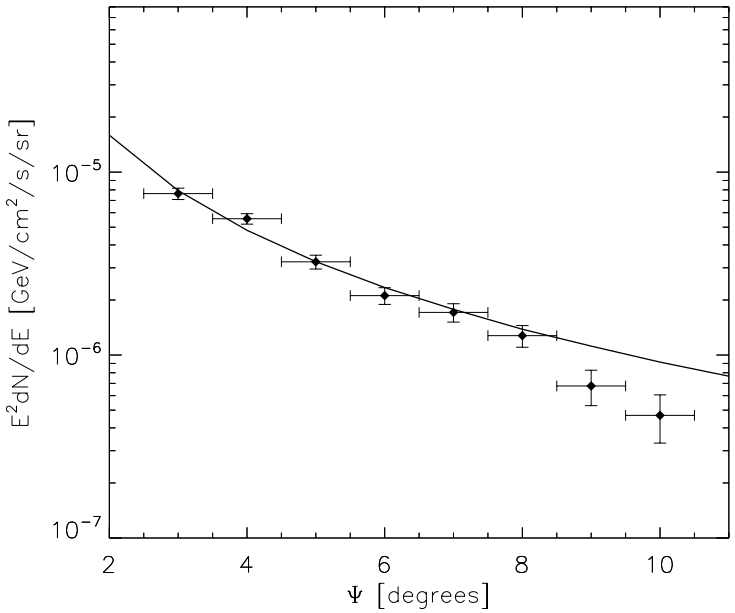
A template-based Poisson regression of the Fermi-LAT data reveals a residual emission in the inner galaxy (Goodenough & Hooper 2009) that:

- ✓ has a spectrum that peaks at $\sim$ 1-3 GeV,
- ✓ is extended out to $\sim 10^{\circ}$ from the galactic center,
- ✓ falls off away from the galactic center as an inverse power law with index ~ 2.5.

Gamma-ray excess in the inner Milky Way







Perspectives on the excess

Does the excess *really* exist?

- ✓ Background systematics, i.e., missing Inverse Compton emission
- ✓ Oversubtraction along the galactic plane

If so, what is its origin?

- ✓ Prompt or secondary photons from dark matter annihilation
- ✓ Series of past hadronic or leptonic cosmic ray outbursts from the SMBH at the galactic center
- ✓ **Unresolved millisecond pulsars with a steep radial profile (This talk)**

Diffuse or point source emission?

- ✓ The morphologies of the gamma-ray signal from an unresolved population of MSPs and dark matter annihilation are similar.
- ✓ However their photon statistics are different, i.e., diffuse emission is equivalent to emission from a collection of "1-photon" emitters.
- ✓ In general, there are n_m "m-photon" emitters in an unresolved MSP population, which is itself Poisson distributed with mean x_m

$$p_{n_m} \sim \mathrm{Po}(n_m; x_m) = \frac{x_m^{n_m}}{n_m!} e^{-x_m}.$$

Diffuse or point source emission?

- ✓ The PDF of observing k photons from a pixel that has n_m m-photon sources is no longer Poisson distributed

$$p_k^m = \begin{cases} p_{n_m} & \text{if } k = mn_m \\ 0 & \text{o/w} \end{cases}.$$

- ✓ Summing p_k^m over all m (or rather taking the product of the relevant distribution functions), the level of non-Poissonity can be exploited to determine the nature of the excess (Malyshev & Hogg 2011, Lee et al. 2014, Lee et al. 2015).

Diffuse or point source emission: time perspective

- ✓ The members of the new population of MSPs required to fit the excess should be dim, possibly due to state transitions.
- ✓ Assuming that some fraction of them are transitional, spatially incoherent month/year-scale time variations could potentially be observed in the excess emission.
- ✓ Since there should be ~ 1000 MSPs with random transitional periods and phase shifts (if periodic at all), the time variation should be very weak, but possibly detectable away from the galactic plane, where backgrounds are dimmer and there are fewer members of the population.
- ✓ This exploits the fact that diffuse backgrounds do not vary over human time scales.

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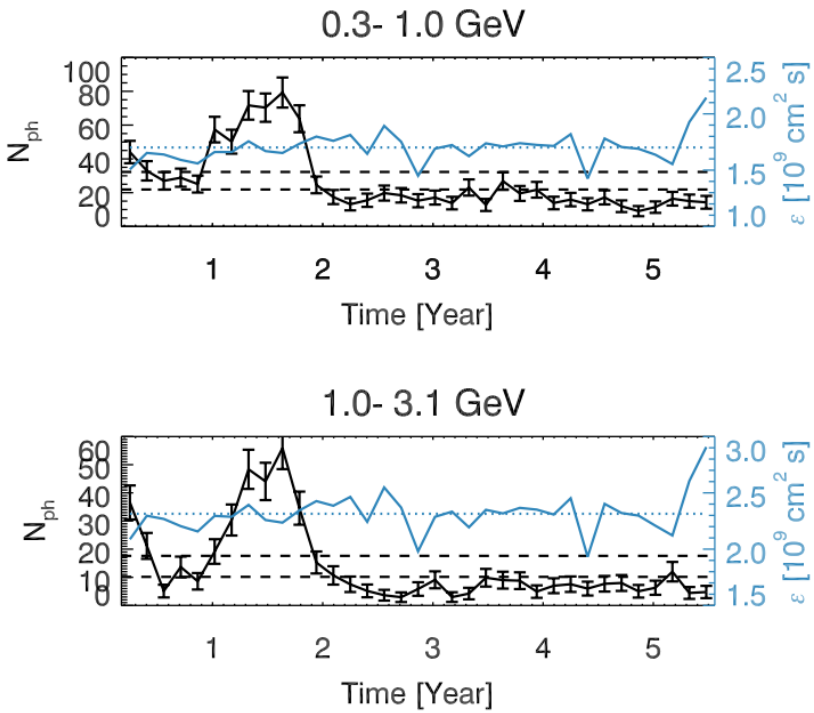

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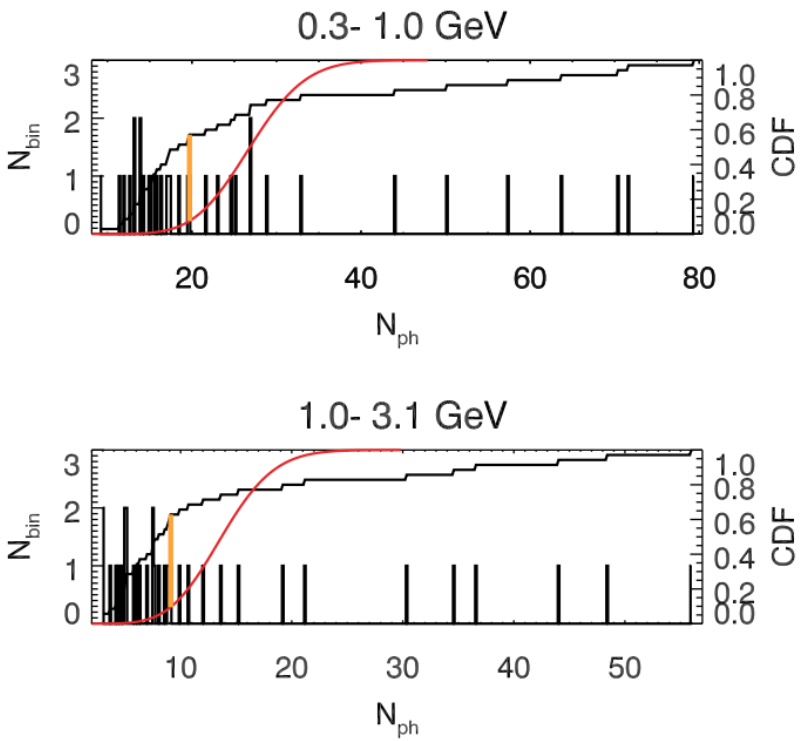
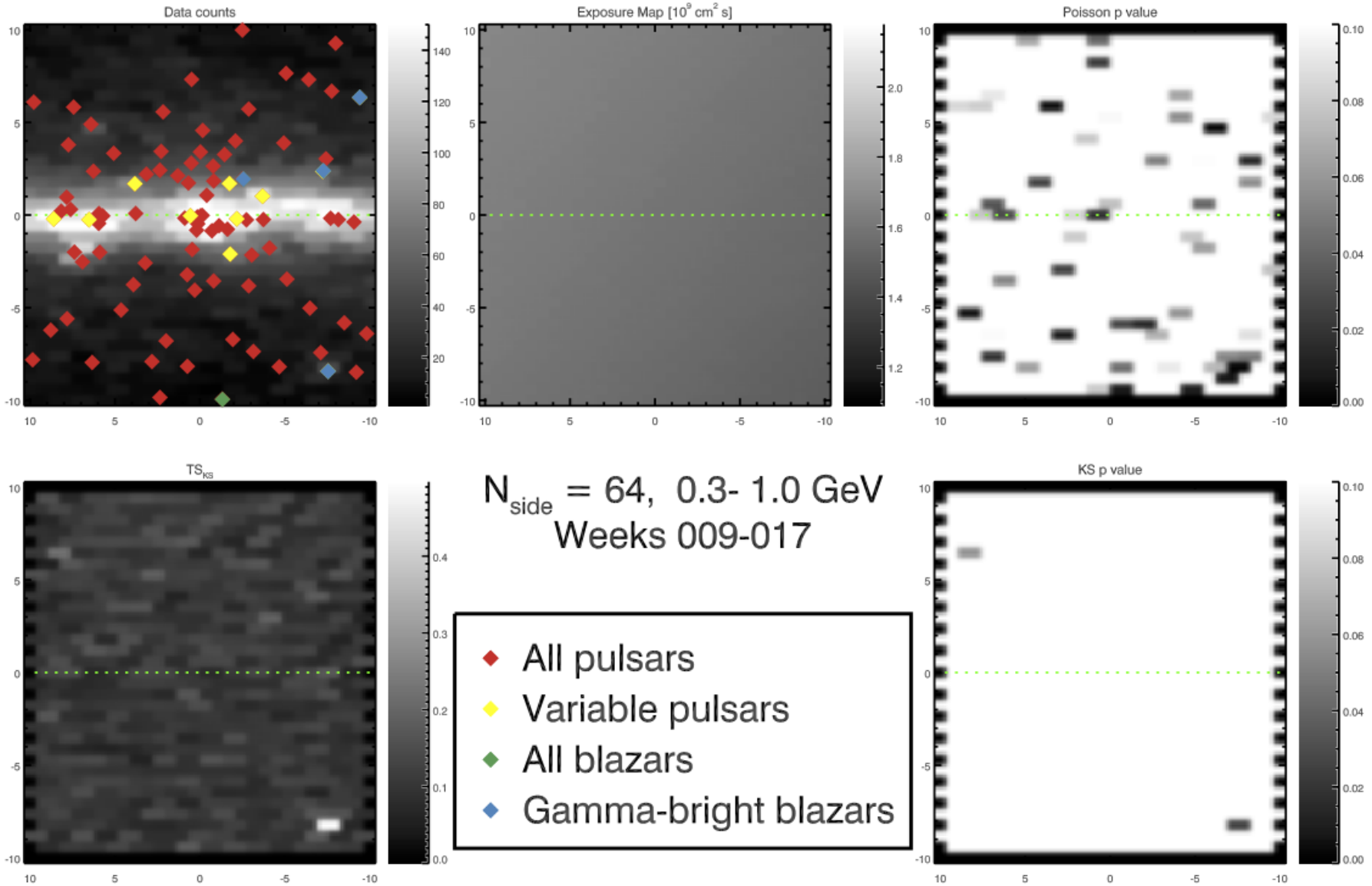


Constraining time variation



Outlook

- ✓ There is no statistically significant (>90% C.L.), time variation in the inner galaxy.
- ✓ Previous analyses exploiting the non-Poissonity of the point source emission have fixed the number of sources, i.e., the model dimensionality, making the Bayesian evidence comparison between different models in the limit of large number of MSPs computationally expensive.
- ✓ A trans-dimensional approach to the luminosity function inference problem is needed (work in progress).