Enhancing Searches for Pulsars around the Galactic Center with *Fermi*-LAT

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Understanding the gamma-ray emission from the Galactic Center (GC) is challenging and interpretations can be controversial. This region likely contains thousands of pulsars, but their radio detection is hampered by the large amount of interstellar scattering, while in gamma rays the detections are limited by the low fluxes and high levels of diffuse emission. In addition, many pulsars suffer from severe timing irregularities, limiting the maximum time span of the data set that can be effectively searched. Sensitivity of LAT searches for gamma-ray pulsars in this region could be improved in a number of ways, but the biggest improvement would come from a modified observing strategy to point at the GC, whenever possible, while continuing to perform a less sensitive all-sky survey when the GC is occulted.

Introduction

Claims that gamma-ray emission from the GC (Figure 1) may be due to dark matter (Hooper & Goodenough 2011, Weniger 2012) should be measured against conventional explanations, such as a possible pulsar origin. The LAT has been very successful at discovering pulsars (e.g. Abdo et al. 2009, Saz Parkinson et al. 2010). Blind searches for gamma-ray pulsars around the GC are affected by low fluxes (due to the large distance), and high levels of diffuse emission. Although most LAT pulsars are likely nearby (~few kpc), the LAT *has* detected a pulsars as far as 8.4 kpc away (MSP J1823-3021A, in the globular cluster NGC 6624), which is roughly the distance to the GC. Furthermore, it is possible to estimate the distance limit for blind searches with the LAT data by scaling the gamma-ray flux of the Crab (several thousand times brighter than the faintest gamma-ray pulsar discovered in a blind search). Thus, we conclude that it is possible to discover a Crab-like (young, bright, and energetic) gamma-ray pulsar in LAT blind searches out to at least ~15 kpc.

The Inner Galaxy (including GC), as seen by the LAT

As a site of massive star formation, the GC likely contains many young pulsars, but their radio detection is hampered by the large amount of interstellar scattering. A few pulsars have been found fairly close to the GC, and predictions for the number of pulsars associated with the GC range in the thousands (Deneva et al. 2009). It is possible that some are radio quiet, like the majority of young pulsars found in LAT blind searches (e.g. PSR J1732-3131, seen in Figure 1). The bright gamma-ray source at the GC (2FGL J1745.6-2858) has properties similar to many known gamma-ray pulsars (non-variable, with a curved spectrum), but blind searches have so far failed to uncover a pulsar.

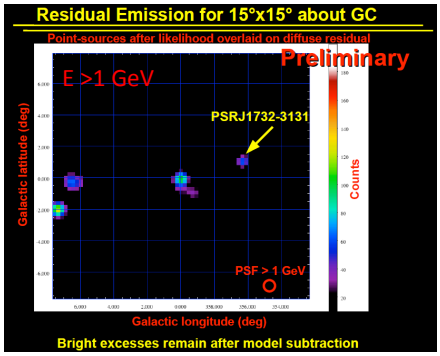

Figure 1: *LAT view of the GC (Porter, 2011 Fermi Symposium). The source at the GC is 2FGL J1745.6-2858.*

Searching for gamma-ray pulsars with Fermi-LAT

Perhaps some of the hardest pulsars to find around the GC may be young, pulsars prone to *timing noise* (random, rotational irregularities) and glitches. The loss of coherence limits the amount of data that can be effectively searched (see Figure 2). While it is possible to time these pulsars, a good timing model often requires many frequency derivatives and other whitening terms. Regardless of how much LAT data are available, it may only be possible to search several months at a time. Thus, the sensitivity of such searches may only improve significantly with major enhancements in the reconstruction (e.g. Pass 8, see poster by L. Baldini) or an increase in exposure by changing the observing mode.

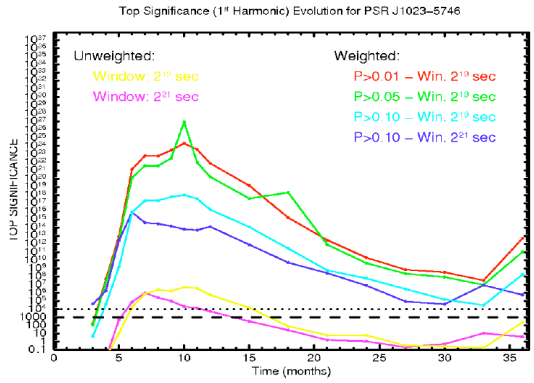

Figure 2: *Blind-search significance (1/P, where P=Prob. of a random fluctuation) of PSR J1023-5745, as a function of cumulative observing time. This radio-quiet pulsar is young, very energetic and "noisy", and has already suffered at least one glitch since its discovery by the LAT. Note that after 7-10 months, the significance decreases with addition of more data, so the discovery of this pulsar in several years of data would be very difficult.*

A modified observing profile

For the first four years of its mission, *Fermi* has operated mostly in survey mode. This has many advantages for most of the scientific goals of the mission, including pulsar searches (and timing). Modifying the observing profile, however, could enhance the sensitivity to detection of faint signals (both from pulsars and/or dark matter) from the GC. Figure 3 shows the relative gain in exposure (compared to survey mode) with a modified mode in which the LAT points to a location slightly offset from the GC. Whenever the GC is occulted, the LAT could go back into survey mode, thus maintaining a level of exposure over the whole sky.

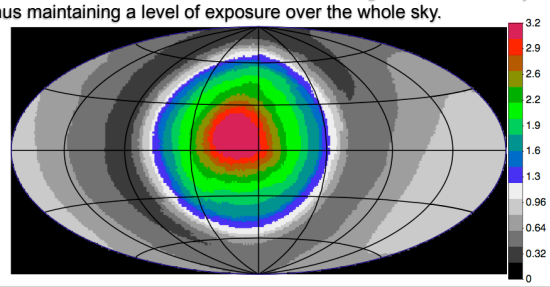

Figure 3: *Simulation, with gtorbsim[1] [see poster by Razzano], of the relative exposure (vs survey mode) for a LAT viewing strategy favoring the GC. The gain is a factor of ~3, while the exposure for other parts of the sky decreases to ~ one third, in the worst case.*
[1]http://fermi.gsfc.nasa.gov/ssc/

Conclusions

The NASA Senior Review recently recommended that *Fermi* operations continue through 2016. *Fermi* could continue operating far longer. As the LAT accumulates more data, it will continue to detect gamma-ray pulsations from ever fainter radio-loud pulsars. Blind searches of LAT data are increasingly computationally intensive. Perhaps more limiting to the potential discovery of new LAT pulsars (in particular around the Galactic Center) is the loss of coherence of the signal in young, energetic pulsars over a period of months. A modified observing profile enhancing the exposure to the GC could play a crucial role in discovering such pulsars.

References

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