Search for Young, Gamma-quiet Pulsars

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Introduction: GeV gamma-ray pulsations from 77 pulsars have been seen using the Large Area Telescope (LAT) on NASA's *Fermi* satellite [1], and more show possible signals approaching detection threshold as the all-sky survey continues. Radio ephemerides enabled 52 of the detections, the rest were discovered in blind period searches. Of the 214 pulsars with spin-down power Ė > 1E34 erg/s targeted for sustained timing before launch [2], *we see 22 of the top 50 pulsars, ranked by* $\sqrt{\dot{E}}/d^2$, a simple but effective figure-of-merit for gamma-detectability [2].

Why don't we see them all? This poster explores 3 possible reasons:

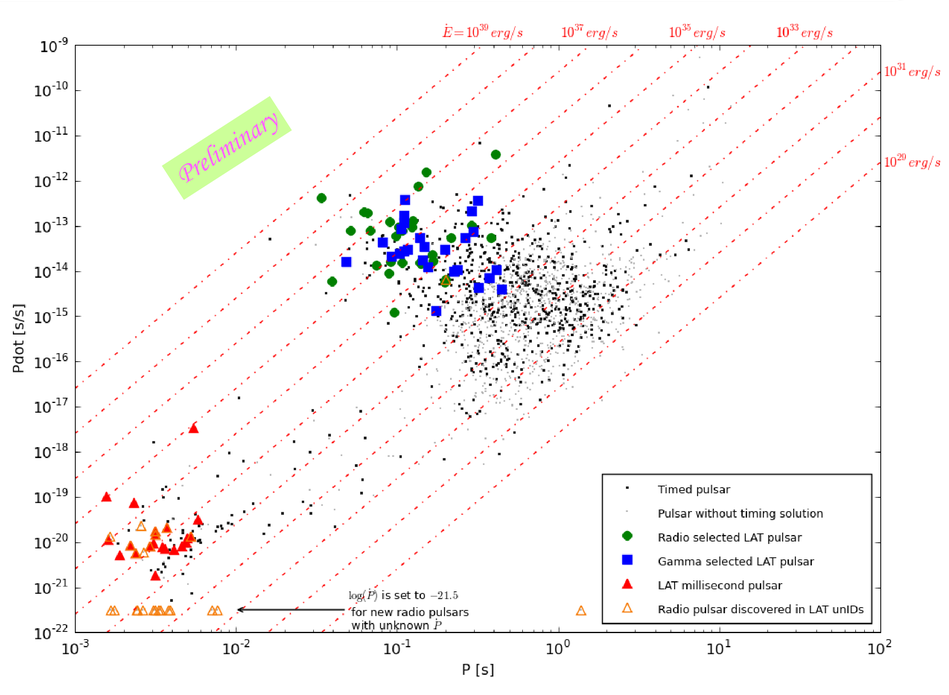
1. Low S/N -- the distance *d* may be underestimated, and/or low galactic latitude leads to high diffuse gamma-ray backgrounds ;
2. Difficulties with the timing ephemerides ;
3. Beam geometry! We can test emission models by studying pulsars for which the radio beam sweeps the Earth, but the gamma-ray beam does not.

What are the high Ė black & gray dots?

The Pdot-P diagram at right shows (colored points) all the gamma-ray pulsars detected with the *Fermi* LAT to date, as well as 14 radio pulsars discovered in deep searches of unidentified *Fermi* sources for which gamma pulsations have not (yet?) been seen. Even at the highest Ė's (red diagonals), uncolored dots persist.

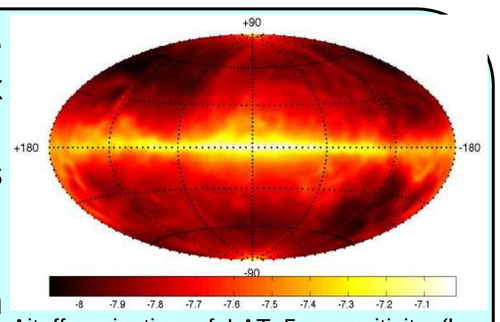
The two **black dots** with Ė>1E38 erg/s are in the LMC, presumably too far to be easily seen. For 1E37<Ė<1E38, three dots are black (we have ephemerides), but these, J1437-5959, J1747-2809, and J1930+1852 are apparently far and at very low latitude where the diffuse gamma background is intense. Two other dots are gray: J1617-5055 has a weak radio signal and terrible timing noise, while J1813-1749 can only be timed in X-rays.

Tracking down nearby large Ė pulsars unseen in gamma-rays a) makes sure our gamma-searches are effective and b) may identify "gamma-quiet" radio pulsars to test emission model predictions [5].



#1 Low signal-to-noise? $\sqrt{\dot{E}}/d^2$ is sensitive to often unreliable distances, *d*. VLBI parallax studies are underway for all LAT pulsars [4]. Improved Galactic electron distribution models would also be welcome.

Also, LAT sensitivity varies widely, mainly with galactic latitude. We will improve the $\sqrt{\dot{E}}/d^2$ Figure-of-Merit by including the modeled diffuse emission at all pulsar positions.



Aitoff projection of LAT 5σ sensitivity (log photon flux, ph /cm²/s) for 6 months of sky-survey, for pulsar spectra with typical differential photon indices and exponential cutoff energies. (This is Figure 9 from [1].)

High Ė, near-ish pulsars without clear LAT detections

Rank by $\sqrt{\dot{E}}/d^2$ for ATNF [7] pulsars with Ė>3E33 & P0 > 10 ms. Those unseen, with Ė>1E35, from the Top Fifty.

J1357 & J1617 are hard to time. J1811 & J1846 are timed with RXTE. J1302 is an eclipsing binary (HMXB). None have a radio interpulse. J1803 and J1809 have two peaks $\Delta\phi$~0.15 apart.

Rank	PSRJ	Edot (erg/s)	Dist1 (kpc)	|b| (deg)
14	J1740+1000	2.3E35	1.2	20.3
16	J1357-6429	3.1E36	2.5	-2.5
19	J1524-5625	3.2E36	2.8	0.35
23	J0940-5428	1.9E36	2.9	-1.3
24	J1930+1852	1.2E37	5.0	0.27
25	J1302-6350	8.2E35	2.8	-0.99
29	J1846-0258	8.1E36	5.1	-0.24
31	J1826-1334	2.8E36	3.9	-0.69
32	J1809-1917	1.8E36	3.5	0.08
34	J1811-1925	6.4E36	5.0	-0.35
36	J1803-2137	2.2E36	3.8	0.15
38	J0117+5914	2.2E35	2.2	-3.5
43	J1617-5055	1.6E37	6.8	-0.28
47	J1913+1011	2.9E36	4.8	-0.17
49	J1739-3023	3.0E35	2.9	0.34
50	J1831-0952	1.1E36	4.0	-0.13

#2 Good pulsar timing? X-ray and radio timing for *Fermi* has been very productive. Nevertheless, a few pulsars with strong timing noise could benefit from additional observations, for example PSR J1617-5055 in a HESS TeV PWN.

#3 – Physics! (beam geometry)

A piece of (α,ζ) space is near the magnetic axis: you see the radio beam, but only weak or zero γ emission at such high magnetic latitude.

Watters & Romani's recent paper [5] says that as pulsars age and Ė decreases, the outer gap grows and γ emission is increasingly equatorial. The narrower γ beam can make them RLGQ.

Comparing tallies of *predicted* vs *observed* radio-loud gamma-quiet ("RLGQ") pulsars is thus a good test of emission models, and thus of population syntheses.

RLGQ's tend to not have radio interpulses, so polarization constrains (α,ζ) weakly. We'll try anyway to explore the geometry of the high FoM pulsars that have reliable *d* and good .par's, but no LAT signal, hoping to stress models (e.g. via predictions of f_Ω.)

PSR J1740+1000 has a single peak with strong polarization, and is far off the plane. PSRJ1524-5625 has a close-double radio peak, both with large $\sqrt{\dot{E}}/d^2$. Candidates?

Conclusions: We list 16 young, nearby pulsars with Ė>1E35 erg/s that do not show clear GeV gamma-ray pulsations in *Fermi* LAT data at this time. Timing difficulties may explain two. J1302-6350 should "turn on" (unpulsed?) at periastron in mid-December. Three indicate weak pulsations, and another overlays a steady LAT source: these may be confirmed as the LAT accumulates data. A signal from most of the remaining 10 may simply be overwhelmed by diffuse emission, although J1357-6429 & J0117+5914 are ≥2.5° off the plane. All but two have single radio pulses and polarization data will not easily constrain the magnetic and rotation inclinations. We will thus continue this search to lower Ė and/or farther distances to attempt to identify truly "gamma quiet" pulsars.

[1] 46 detections are described in the "First Fermi Catalog of Gamma-ray Pulsars", Abdo et al 2010, ApJ Suppl **187**, 460. Eight additional blind-search pulsars are described in Saz Parkinson et al, Ap J accepted. The remaining 22 pulsars have either been published recently, or are in preparation.
[2] "Pulsar Timing for Fermi", Smith, Guillemot, et al (2008) A & A **492**, 923.
[3] Ransom et al, ApJ accepted. Cognard et al ApJ submitted. Keith et al MNRAS to be submitted. Roberts et al, in prep. Kerr et al, in prep.
[4] Cycle 3 *Fermi* Guest Investigator proposal: S. Chatterjee et al.
[5] "Galactic Population of Young Gamma-ray Pulsars", Watters & Romani (2010) ApJ submitted.
[6] "Precise Gamma-ray Timing and Radio Observations of 17 Fermi Pulsars", Ray et al., ApJ to be submitted
[7] http://www.atnf.csiro.au/research/pulsar/psrcat/expert.html and Manchester et al., AJ, 129, 1993-2006 (2005)

Radio pulsars:
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