Tracking Down the Highest Spindown Power Gamma-Ray Pulsars

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Abstract

Forty six gamma-ray pulsars were reported in the First *Fermi* Large Area Telescope (LAT) Catalog of Gamma-ray Pulsars [0]. Over forty more have been seen since then. A simple but effective figure-of-merit for gamma-detectability is $\sqrt{\dot{E}}/d^2$, where $\dot{E}$ is the pulsar spindown power and d the distance. We are tracking down the best gamma-ray candidates not yet seen. This poster presents the timing and spectral analysis results of some new high spindown power, nearby gamma-ray pulsars. We also update some population distribution plots in preparation for the 2nd *Fermi* LAT Pulsar Catalog.

New detection of young energetic gamma-ray pulsars

Figure 1 shows (colored points) the 88 gamma-ray pulsars (including the 7 previously-known CGRO gamma-ray pulsars) detected with the *Fermi* LAT to date. 55 were discovered using radio ephemerides and 26 by blind period searches. We are tracking down the best gamma-ray candidates not yet seen.

Ranked by $\sqrt{\dot{E}}/d^2$ for ATNF [1] pulsars with $\dot{E}$>3E33 & P0 > 10 ms, nine recently-detected young energetic radio-selected gamma-ray pulsars are listed in Table 1 along with the preliminary timing analysis results.

These gamma-ray detections made possible by sustained radio timing [2].

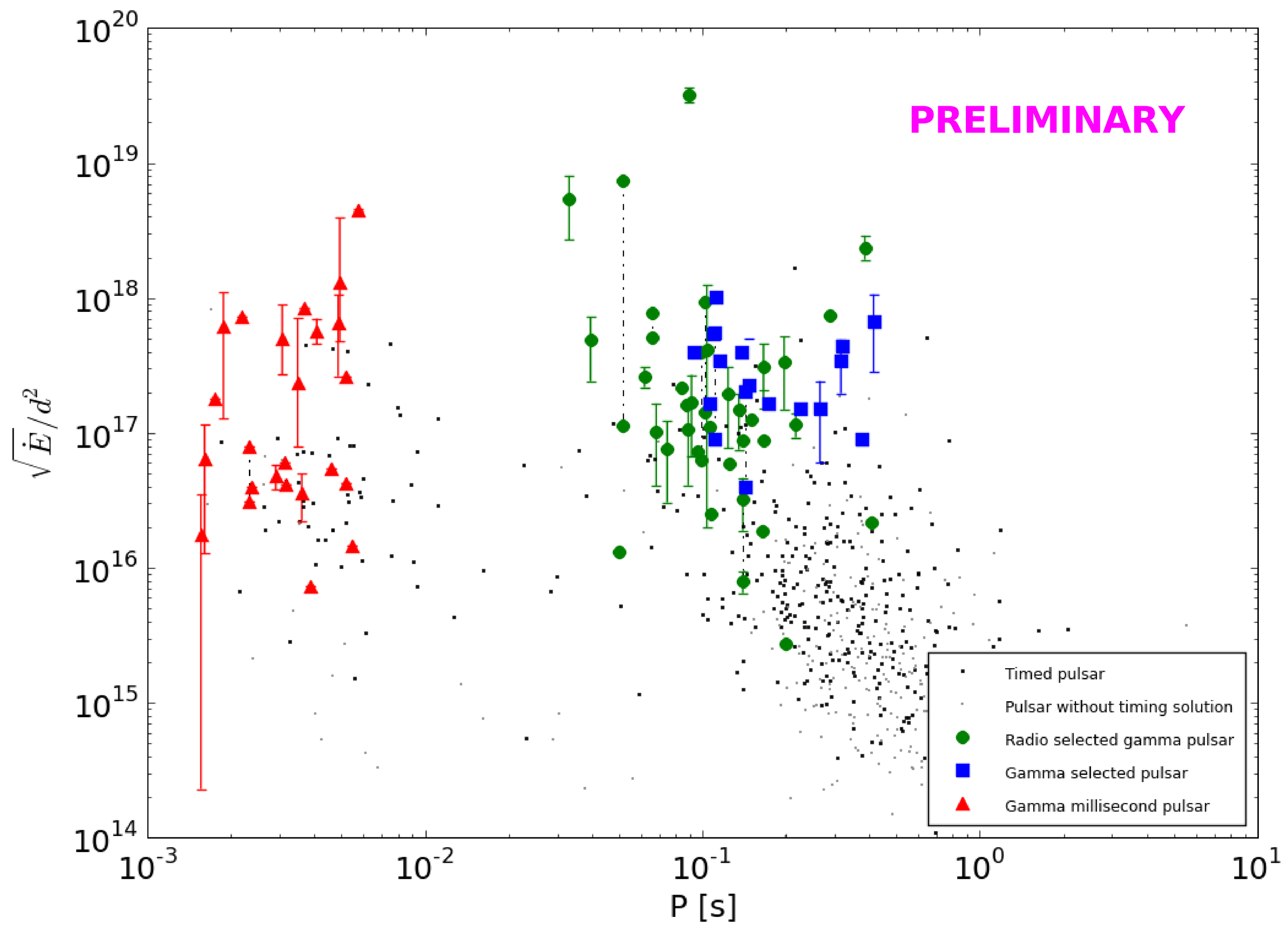

Figure 1: Pulsar "detectability" figure-of-merit $\sqrt{\dot{E}}/d^2$ vs spin period

Rank	PSRJ	P0 (s)	Edot (erg/s)	$\sqrt{\dot{E}}/d^2$ (erg/s/cm2)	Dist1 (kpc)	Gb (deg)	Npeak	Radio Lag δ	γ-ray peak sep. Δ
15	J1357-6429	0.1661	3.10E+36	2.82E+17	2.50	-2.51	1	0.38 ± 0.02	...
18	J1531-5610	0.0842	9.09E+35	2.18E+17	2.09	0.03	1	0.35 ± 0.02	...
23	J0940-5428	0.0875	1.93E+36	1.58E+17	2.95	-1.29	1	0.30 ± 0.01	...
28	J0908-4913	0.1068	4.92E+35	1.09E+17	2.53	-1.01	2	0.10 ± 0.01	0.50 ± 0.01
37	J1730-3350	0.1395	1.23E+36	8.74E+16	3.54	0.09	2	0.05 ± 0.01	0.45 ± 0.01
51	J1801-2451	0.1249	2.59E+36	5.92E+16	5.22	-0.88	2	0.10 ± 0.02	0.46 ± 0.02
87	J1016-5857	0.1074	2.58E+36	2.52E+16	8.0	-1.88	2	0.10 ± 0.01	0.50 ± 0.01
105	J1648-4611	0.1650	2.09E+35	1.86E+16	4.96	-0.79	1	0.53 ± 0.01	...
129	J1410-6132	0.0500	1.01E+37	1.30E+16	15.6	-0.09	2	0.03 ± 0.01	0.42 ± 0.01

Table 1: Nine recently-detected young energetic radio-selected gamma-ray pulsars.

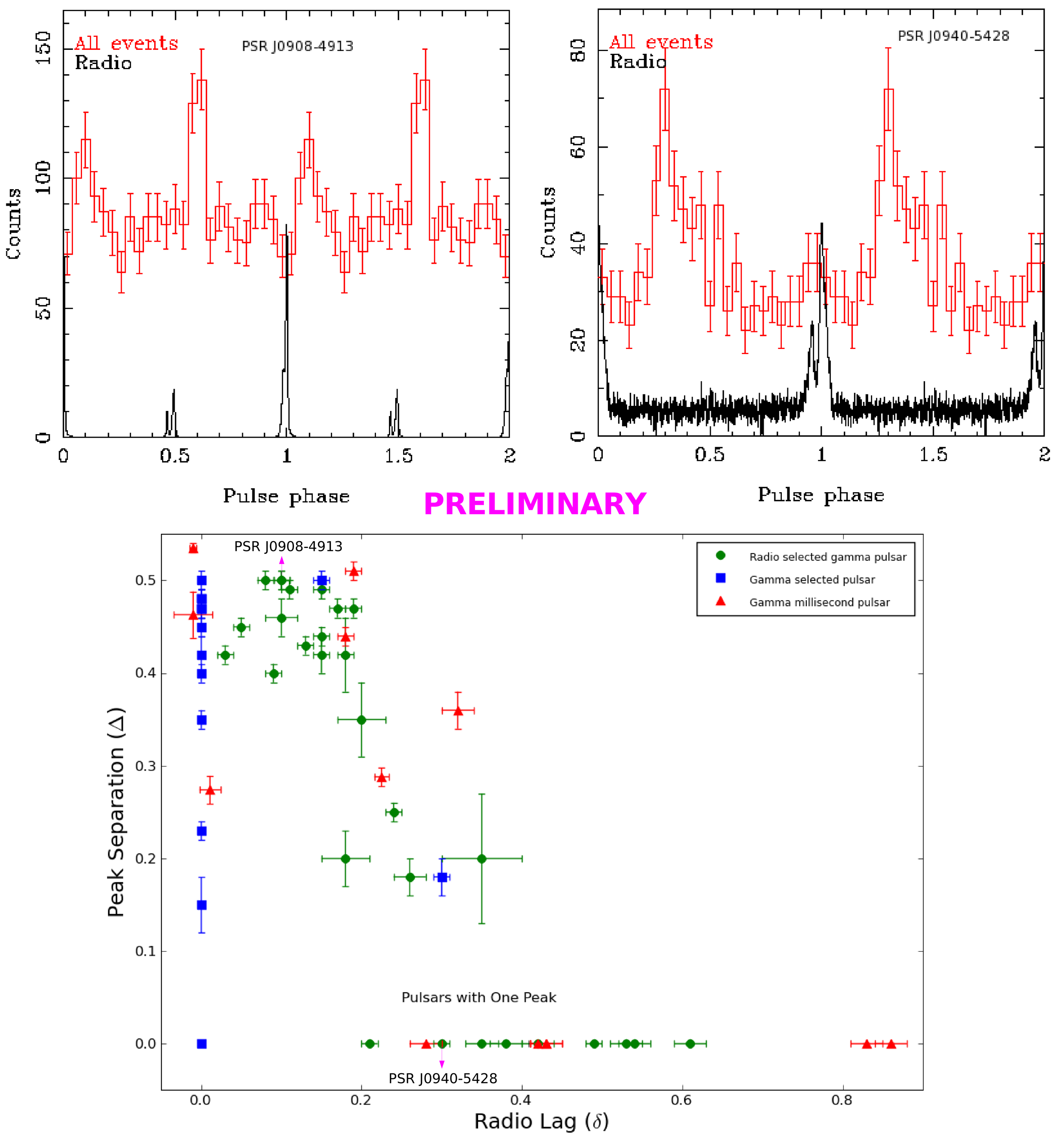

Figure 2: Examples of phase-aligned light curves (top panel) for two recently-detected young energetic gamma-ray pulsars along with the Δ-δ distribution (bottom panel).

Figure 2 shows the phase-aligned gamma-ray and radio profiles for two new gamma-ray pulsars, as well as the gamma peak separation - radio lag distribution. They have two narrow peaks or one single wide pulse, typical for gamma-ray pulsars. The Δ - δ distribution can be compared to predictions of e.g. TPC and OG models and help us probe details of the emission geometry. In particular, PSR J0908-4913 has been well determined as an orthogonal rotator with high-precision geometry studies in radio domain [3].

Why are some pulsars invisible in gamma-ray? As already been discussed by Dumora et al. [4]:

1. Distance & Galactic diffuse influence the signal-to-noise ratio. We see PSR J1410-6132 in spite of a very low $\sqrt{\dot{E}}/d^2$. Its large DM distance bears further investigation.

2. Timing model quality. PSR J1357-6428 discovered once we obtained a good radio ephemeris.

3. Physics (beam geometry): for those pulsars having reliable *d* and good timing models, exploration of geometry will help us constrain the emission models and improve the population syntheses [5].

Zoom in on PSR J1357-6429

Background: discovered during the Parkes multibeam survey of the Galactic plane [6], it is among the youngest and most energetic nearby pulsars known. It was in the top 2 "highest $\sqrt{\dot{E}}/d^2$ pulsars not yet seen with the LAT" [4] and might have become a candidate "sub-luminous pulsar" [5]. The absence of gamma-ray pulsation was due to the lack of a good radio timing model [8].

LAT Data Set: 29 months covering Aug 4, 2008 – Jan 15, 2011
Event Class: Pass 7 (V6) Source
IRFS: P7SOURCE_V6
Galactic Diffuse Model: ring_2year_P76_v0.fits
Extra-galactic Diffuse Model: isotrop_2year_P76_source_v0.txt

Analysis results:

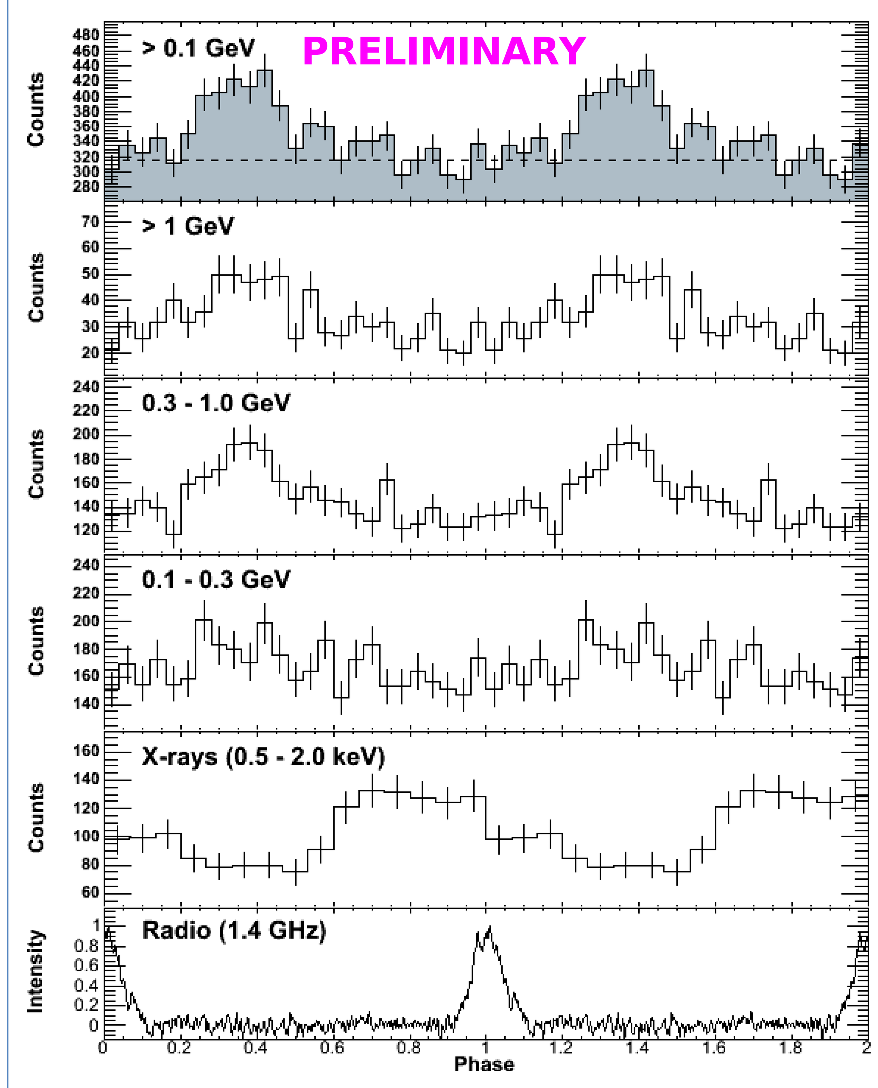

Figure 3: Phase-aligned multi-wavelength light curves [8]

Figure 3 shows the gamma-ray light curves at energy > 0.1GeV and within a ROI=0.8°, and taking into account the instrument performance to maximize the signal-to-noise ratio over a broad energy range. Phase-aligned X-ray (XMM-Newton 2009 data) and radio (1.4GHz from Parkes [7]) profiles are also presented. Confirmation of X-ray pulsations first suggested by Zavlin (2007).

The spectrum is best described by a power-law with a spectral index of 1.54 ± 0.31 ± 0.27 with an exponential cut-off at 0.8 ± 0.3 ± 0.3 GeV and an integral photon flux (> 100 MeV) of (6.46 ± 1.59 ± 2.34) x 10^{-8} cm^{-2} s^{-1}. The integral energy flux is (3.09 ± 0.37 ± 1.20) x 10^{-11} erg cm^{-2} s^{-1}. Assuming a distance of 2.4 kpc, the gamma-ray luminosity is L_γ = (2.13 ± 0.25 ± 0.83) x 10^{34} erg s^{-1}, consistent with a $L_\gamma \propto \sqrt{\dot{E}}$ relationship. The first error is statistical, while the second represents our estimate of systematic effects. Figure 4 shows the best fit spectrum as well as the 95% C.L. upper-limits on the gamma-ray emission from its potential PWN HESS J1356-645 [8].

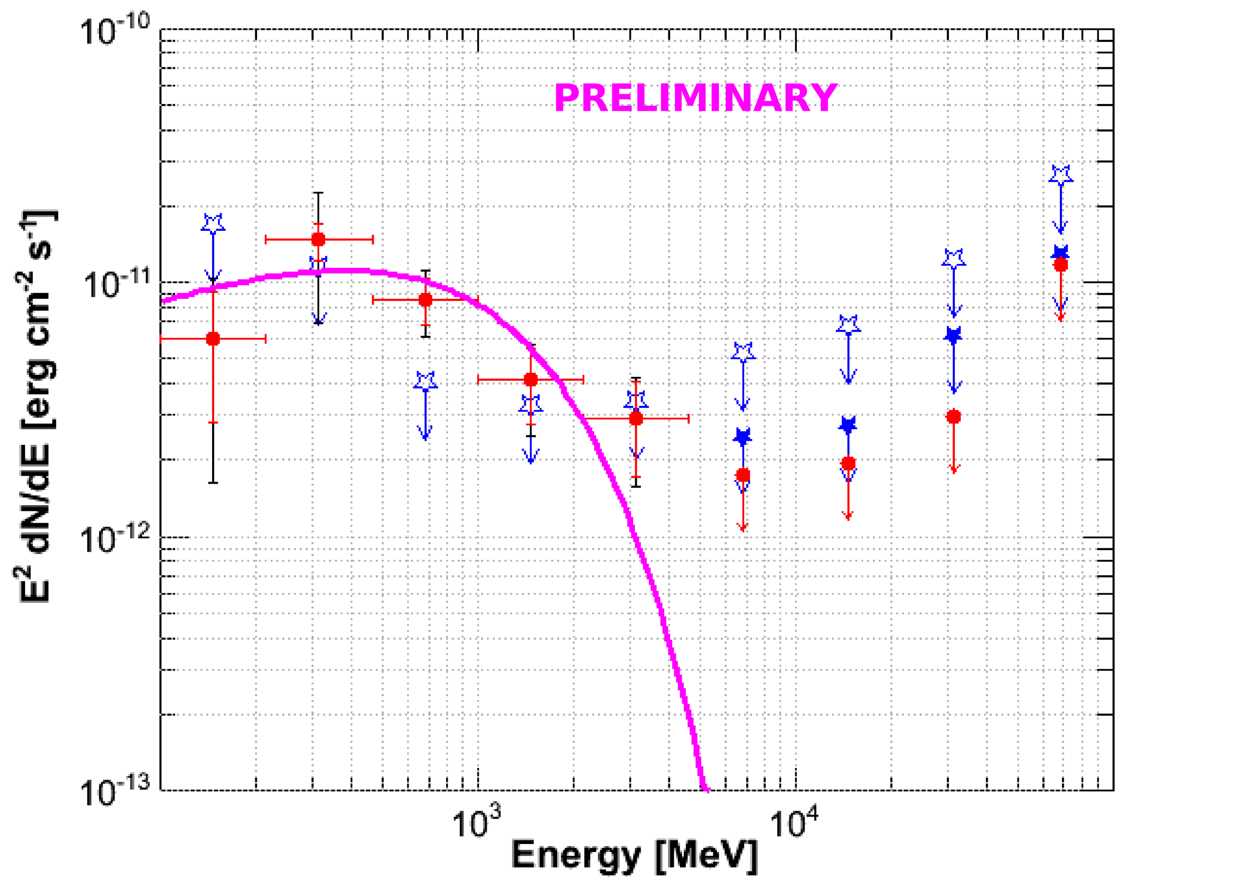

Figure 4: Pulsar spectrum & PWN upper-limits. Red dots: pulsar; full blue stars: PWN all phase 95% C.L. upper limits; open blue stars: PWN off-pulse 95% C.L. upper limits [8].

Conclusions

The number of gamma-ray pulsars has increased steadily since the launch of the *Fermi* Satellite in June 2008 and has reached 88 including the most recent detection of J0940-5428, the last piano key missing. We report 9 recently-detected young energetic radio-selected gamma-ray pulsars ranked by a figure-of-merit for gamma-detectability with some light curves and a preliminary update of the population distribution plots. Gamma-ray pulsar emission models will be better constrained by having a larger population, i.e. the 2nd *Fermi* LAT pulsar catalog. LAT data analysis for PSR J1357-6429 was illustrated as an example. The quality of timing models can influence or dominate gamma-ray detection.

References

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