Detection of the high spin-down powered pulsars PSR J1837-0604 and PSR J1831-0952 with the Fermi-LAT

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Two pulsars with spin-down power greater than 10^{36} erg/s, PSR J1837-0604 and PSR J1831-0952, are now detected with the Fermi Large Area Telescope thanks to Pass 8, the new reconstruction strategy developed by the Fermi-LAT collaboration. We show their light curves and spectral properties as well as other promising high spindown-powered pulsars not yet seen in gamma-rays.

Abstract

More than 50% of the known pulsars with spin-down power greater than 10^{36} erg/s show pulsations in gamma rays, as seen with the Fermi Large Area Telescope. Many non detections are thought to be a consequence of a high background level reducing the signal to noise ratio or a large distance leading to a flux below the sensitivity limit of the instrument. Pass 8 is a new reconstruction and event selection strategy developed by the Fermi-LAT collaboration. Thanks to improved acceptance at low energy, the new Pass 8 data now allows the detection of gamma ray pulsations from two of these faint high spin-down pulsars, PSR J1837-0604 and PSR J1831-0952. We report on their gamma-ray light curves as well as their spectral properties.

Detection of pulsars with known ephemerides

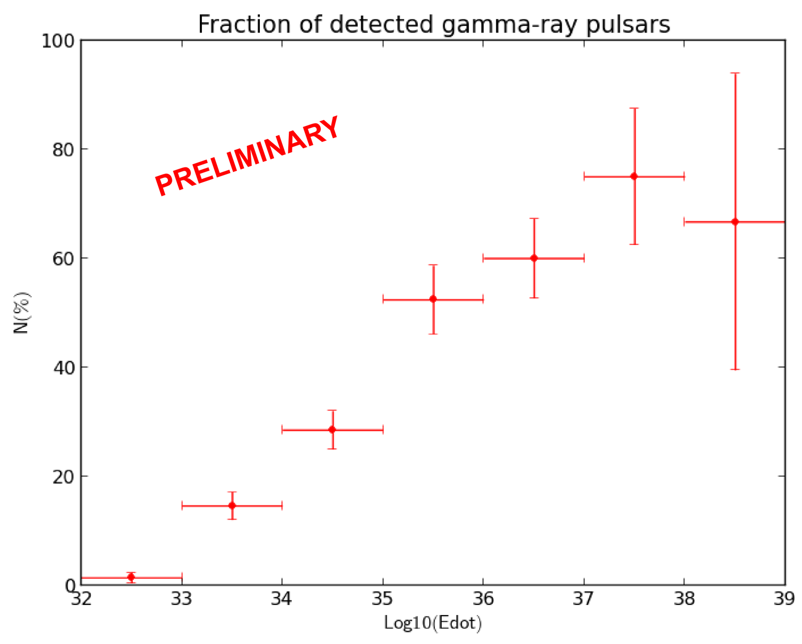


Fig 1. Fraction of detected gamma-ray pulsars among the objects timed with the Fermi-LAT using radio ephemerides, versus spin-down power ($\dot{E}$)

Thanks to radio timing, ~60% of the pulsars with a spin-down power between 10^{36} and 10^{37} erg/s are detected in gamma-rays.

What about the other ~40%? Many reasons can explain a non-detection and can be sorted in two categories:

1) The location of the pulsar:
   - Large distance
   - Very crowded region such as the galactic plane
2) The characteristics of the object:
   - Intrinsically faint (low gamma-ray luminosity)
   - Low cutoff energy due to high magnetic field
   - Wide gamma-ray peaks
   - Beam sampling (f_Ω)

See [1] for further discussion of faint gamma-ray pulsars, as well as presentation by H. Laffon « New pulsars detected in gamma-rays with the Fermi-LAT ».

Pass 8

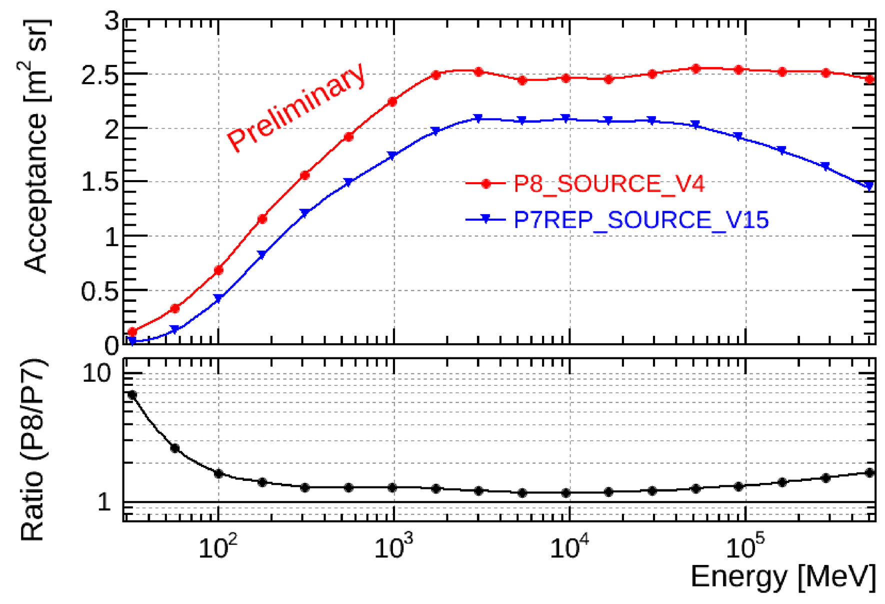


Fig 2. Comparison of the acceptance as a function of energy for P7REP_SOURCE_V15 and P8_SOURCE_V4 response functions.

Pass 8 is a new reconstruction and event selection strategy developed by the Fermi-LAT collaboration. It allows better acceptance and sensitivity at low energies (≲100 MeV) compared to reprocessed Pass 7 data. Most of pulsars have spectra that cut off around few GeV(s) and therefore have most of their flux at these low energies.

➢ **We expect more pulsar detections with Pass8**

PSR J1831-0952

Pulsar's features:
Latitude = -0.128°
$\dot{E}$= 1.1 x10^{36} erg/s
Period = 67.3 ms
Distance = 4.0 kpc

This pulsar was discovered during the Parkes Multibeam Pulsar Survey [2]. The gamma-ray pulsations were detected thanks to radio timing provided by the Jodrell Bank Observatory (JBO). Strong radio polarization is measured [3]. This pulsar is a potential counterpart to the TeV source HESS J1831-098 [4]. The latter could be a pulsar wind nebula powered by this energetic pulsar. The gamma-ray energy flux measured for this pulsar is 1×10^{-11} erg cm^{-2} s^{-1} , which is among the lowest measured in [5].

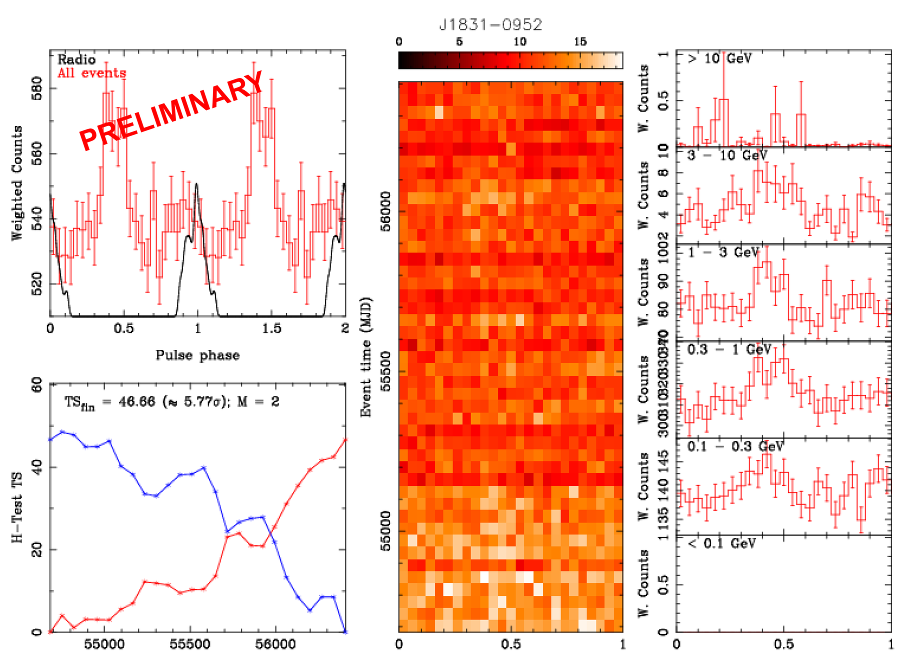
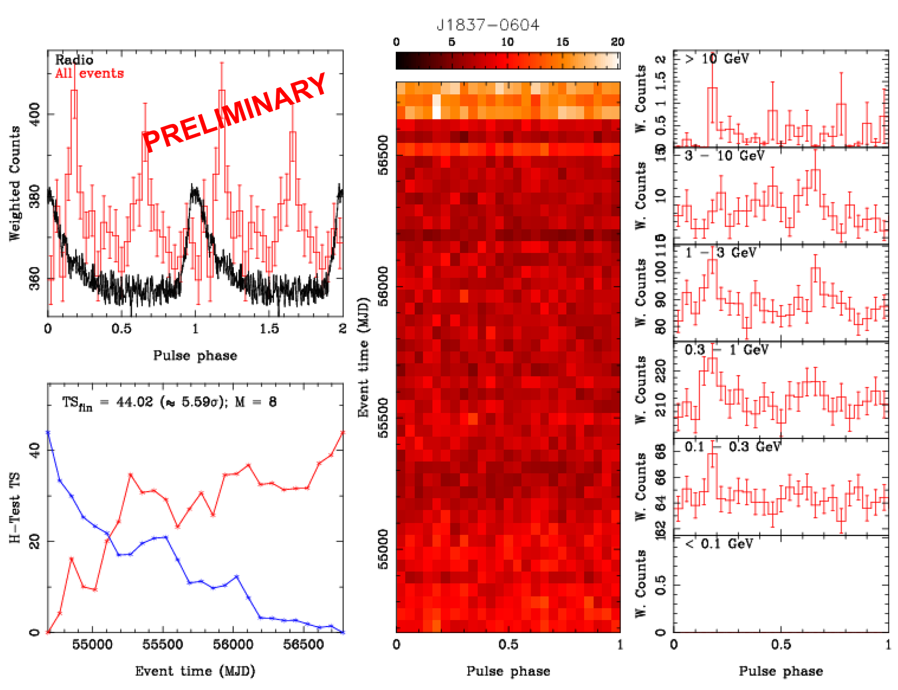


Fig 3. Top left: The red line represents the weighted phase-folded light curve of PSR J1831-0952 using the source model of the field of view and the point spread function to derive the photons' probability of coming from the pulsar. The black line is the radio light-curve obtained by JBO. Bottom Left: H-test Test Statistic (TS) evolution of pulsation detection over time. Middle: Pulse phase evolution over time. Right: weighted light-curves in different energy bands.

PSR J1837-0604

Pulsar's features:
Latitude = 0.265°
$\dot{E}$= 2 x10^{36} erg/s
Period = 96 ms
Distance = 6.4 kpc

Fig 4. Weighted light-curves of PSR J1837-0604 using the same conventions as Fig. 3. The black line in the top left denotes the light curve obtained by the Parkes telescope.⟶



This pulsar was also discovered during the Parkes Multibeam Pulsar Survey [6]. The gamma-ray pulsations were detected using radio timing provided by the Parkes telescope (PKS). Strong radio polarization is measured at 3000 MHz [3].
Its position is compatible with the EGRET source 3EG J1837-0606 [7] but its low gamma-ray energy flux of 4×10^{-11} erg cm^{-2} s^{-1} seems to show that the pulsar is only one contribution to the EGRET source in this complicated region.

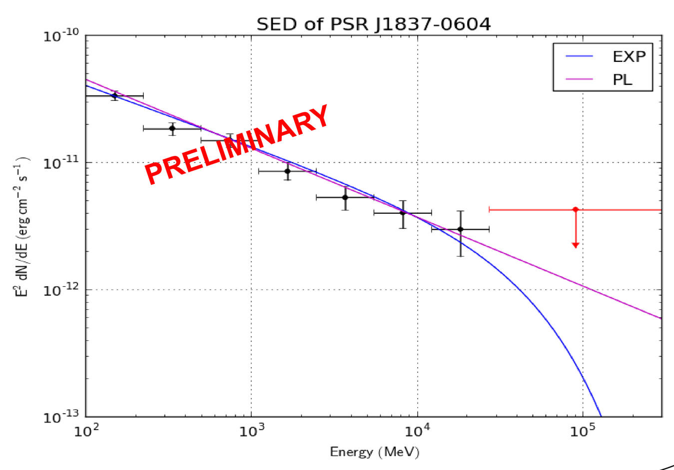


Fig 5. Spectral energy distribution of PSR J1837-0604 with power-law and exponential cutoff models overlaid.⟶

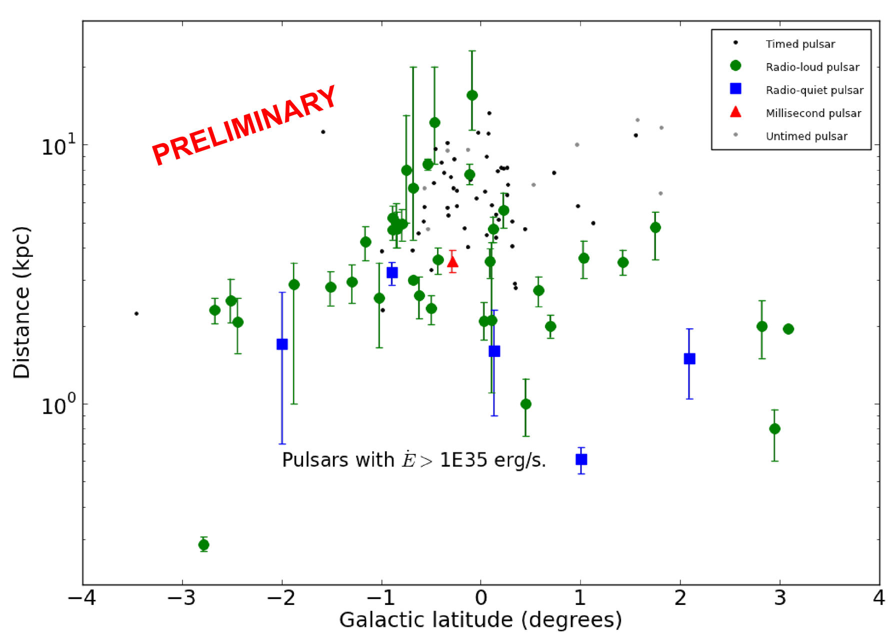


Fig 6. Distance distribution of pulsars with spin-down power greater than 10^{35} erg/s as a function of their galactic latitude.

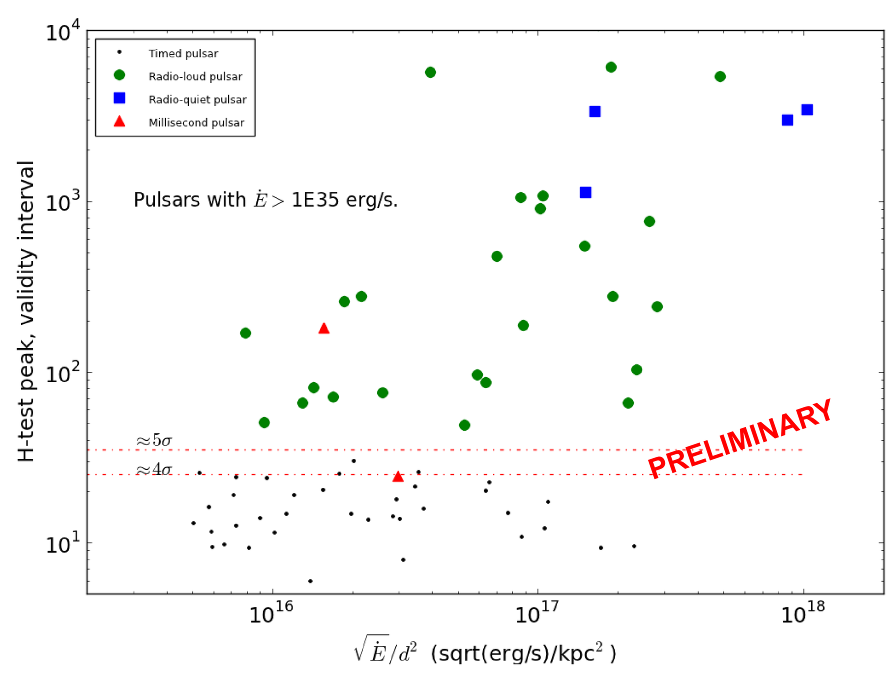


Fig 7. Preliminary H-test of timed pulsars with spin-down power greater than 10^{35} erg/s as a function of heuristic luminosity. The H-test value shown here corresponds to the maximum obtained over the ephemeris validity interval for a rough study of 5 years of Pass 8 data for a list of timed pulsars.

Young pulsars with high spin-down power show more erratic behavior than the stable millisecond pulsars. As a consequence, proper up-to-date radio timing is required to detect gamma-ray pulsations. The pulsar timing consortium agreement with the radio telescopes JBO, PKS and Nançay allows regular monitoring of hundreds of pulsars [8]. Thanks to this collaboration, we are able to detect new pulsars with the Fermi-LAT.
Most of the energetic pulsars not yet detected in gamma-rays are located along the galactic plane and quite far away as shown in Fig. 6. Their detection is therefore challenging but the increasing exposure over time and the improvement brought by Pass 8 on the signal-to-noise ratio could make it possible.
Fig 7 shows that new promising candidates are indeed close to detection (see Table 1). However those results need to be improved by doing spectral analysis of each gamma-ray pulsar candidate, to allow photon probability weighting [9].

Promising candidates

Name	Galactic latitude (deg)	Period (ms)	Distance (kpc)	$\dot{E}$(erg/s)
PSR J0117+5914	-3.457	101	2.2	2.2x10^{35}
PSR J1739-3023	0.336	114	2.9	3.0x10^{35}
PSR J1828-1101	0.042	72	6.63	1.6x10^{36}
PSR J1856+0113	-0.497	267	3.3	4.3x10^{35}
PSR J1857+0143	-0.571	140	5.75	4.5x10^{35}

Table 1. Promising candidates for gamma-ray pulsation detection among the pulsars with spin-down power> 10^{35} erg/s with available ephemerides based on distance consideration and preliminary H-test TS values.

References

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