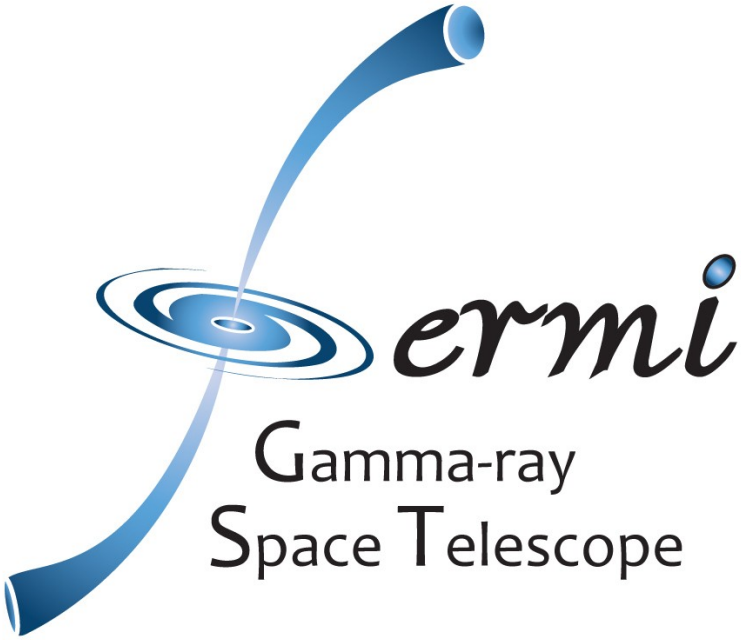


Fermi LAT timing database and expectations from MSPs

Workshop « Pulsars, Théories et Observations »

25 November 2008

L. Guillemot

What's new since May 2007

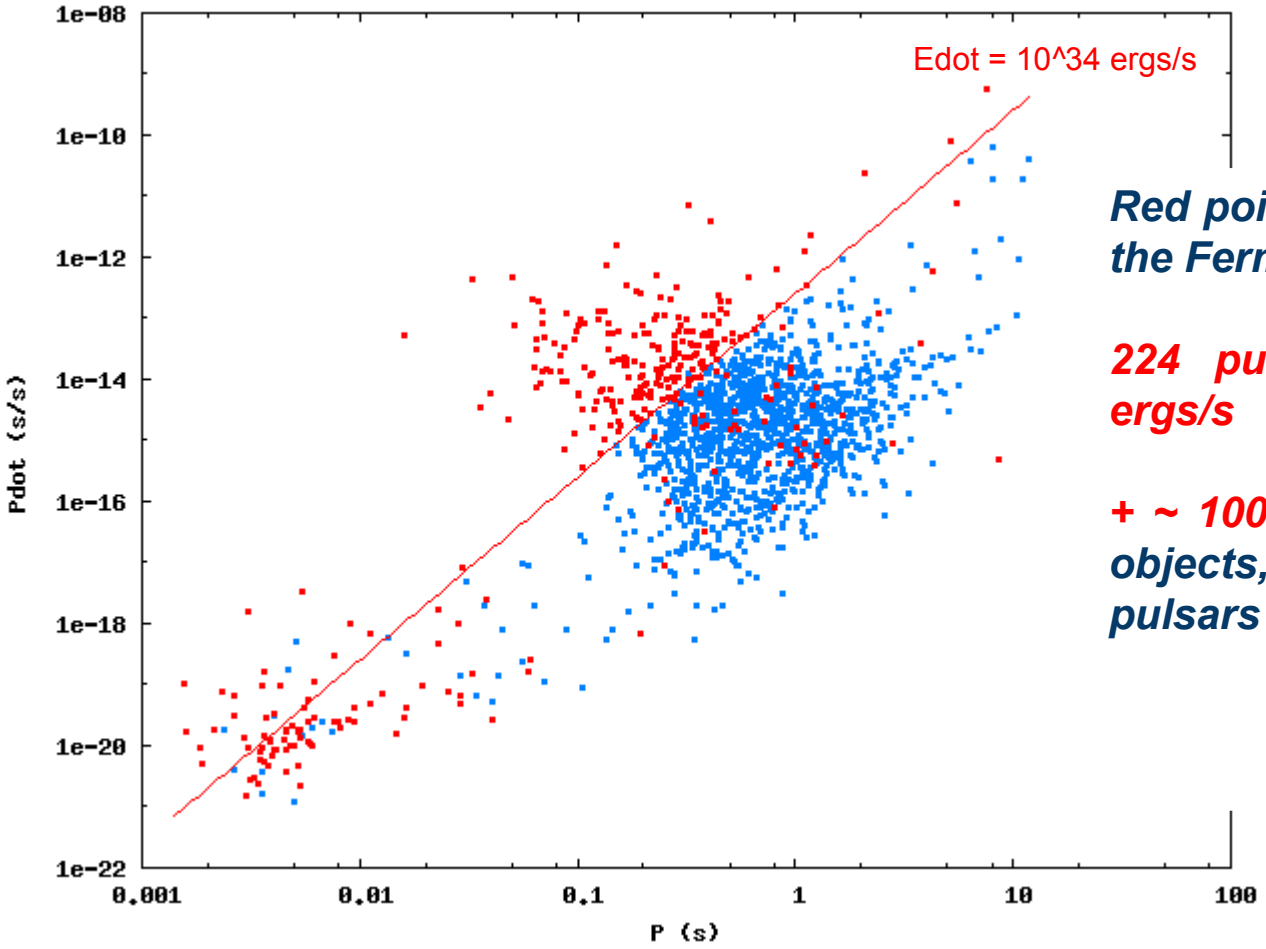
At the time of the previous workshop (~1 yr before the launch):

- *The extensive pulsar observation campaign: not yet begun*
- *We were thinking about analyzing the Nançay data automatically*
- *We were willing to verify the LAT pulsar analysis tools*

What's new ?

- *The telescope has been launched !*
- *> 300 pulsars are monitored*
- *The timing tools are validated*

Followed pulsars



Red points = pulsars monitored for the Fermi LAT.

224 pulsars with Edot > 10^34 ergs/s

+ ~ 100 interesting sources (close objects, millisecond pulsars, pulsars in globular clusters, ...)

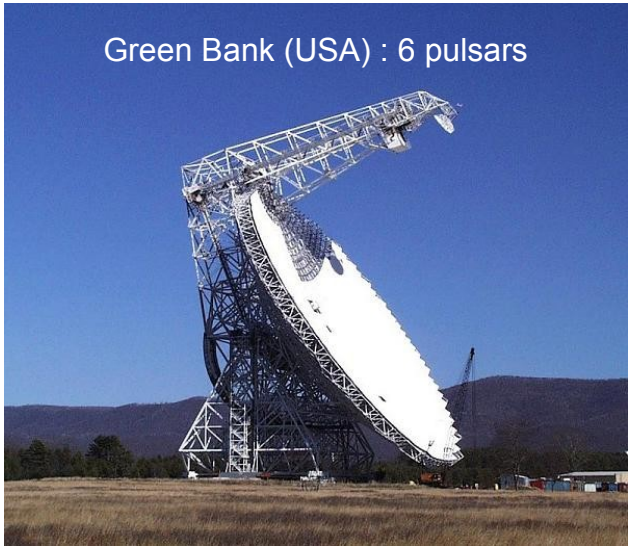
Who's involved ?

Jodrell Bank (England) : 102 pulsars

Parkes (Australia) : 205 pulsars

RXTE (space) : 5 pulsars

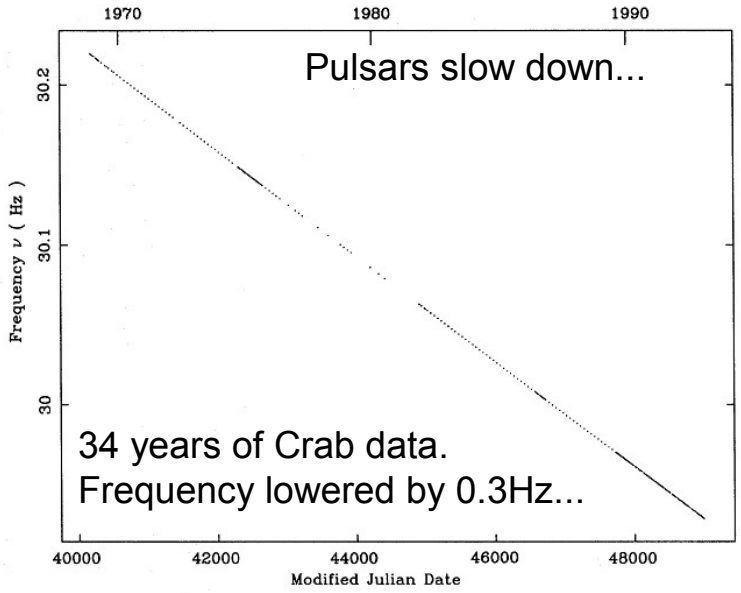
Nançay : 156 pulsars



+ other contributions.

Notably : Arecibo (Porto Rico) : 1 pulsar, Urumqi (China) : 36 pulsars

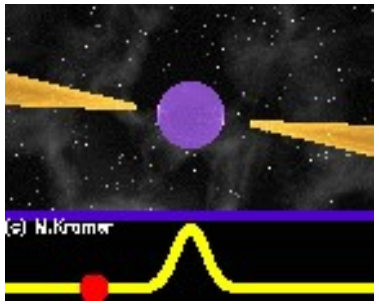
Ephemerides



Pulsar ephemeris = pulsar phase as a function of time

$$\Phi(t) = f(\underbrace{\text{Position, Frequency, Orbit}}_{\text{Fit}})$$

For Nançay: done automatically



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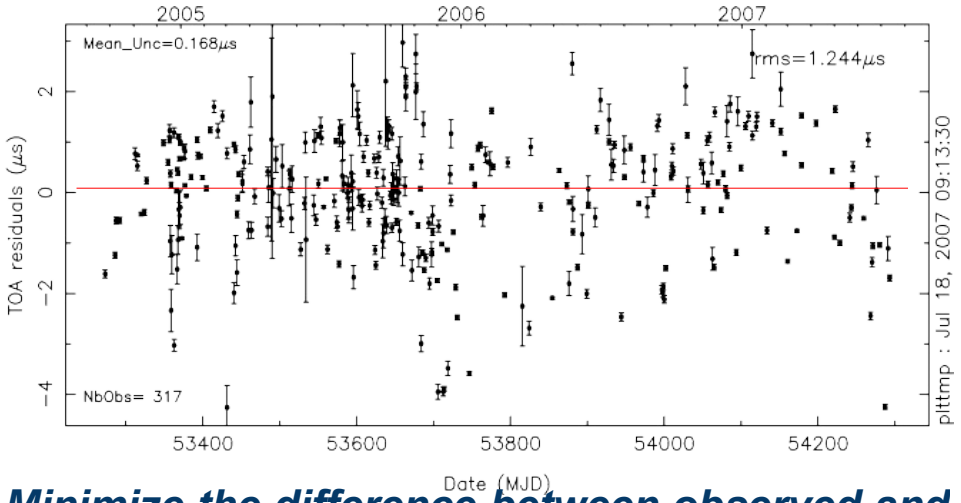
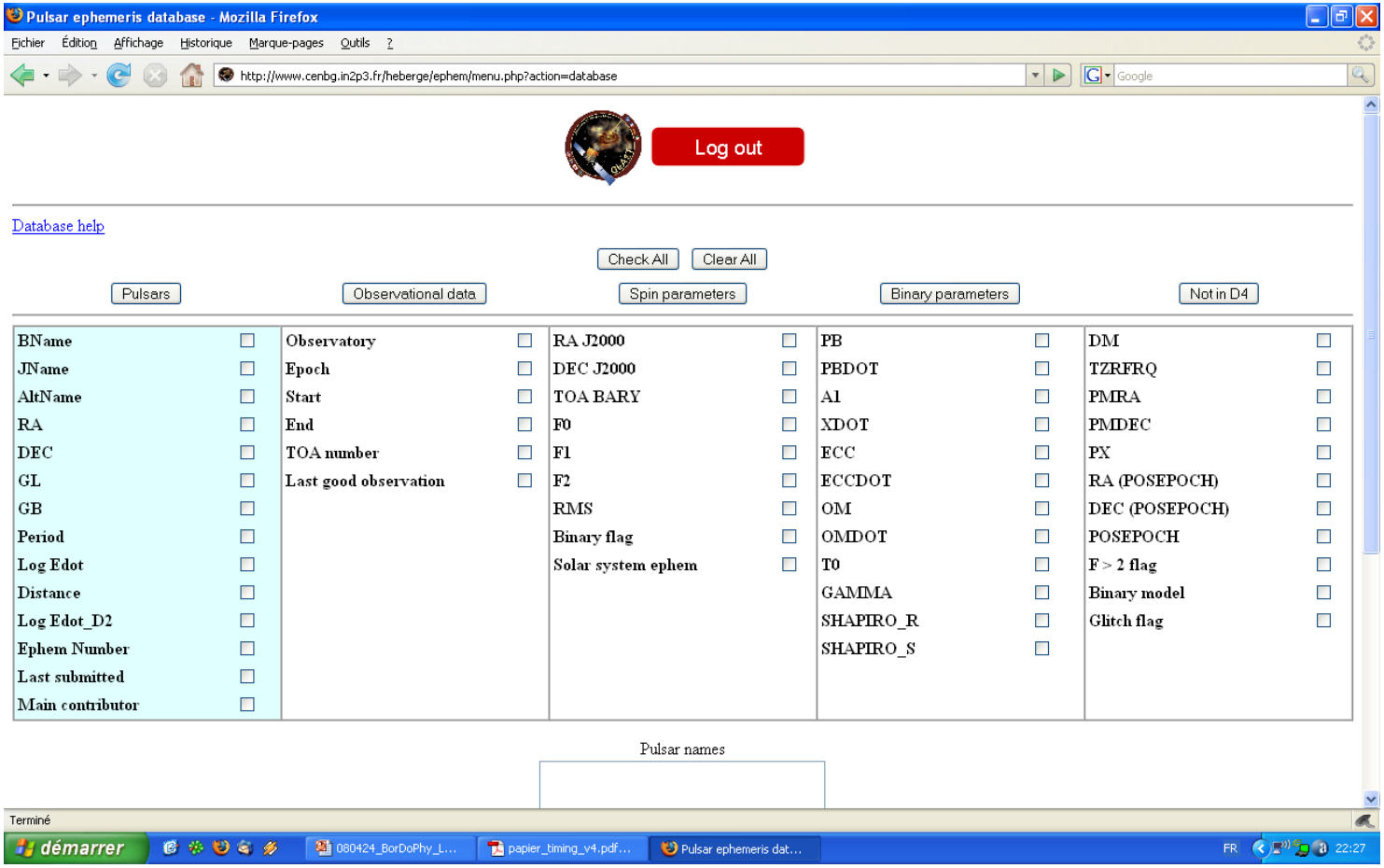


Minimize the difference between observed and predicted pulses.

Web pulsar timing database

Radio and X-ray timing solutions => gathered at the CENBG.

A website provides timing solutions suitable for LAT data analysis.



Tests of the timing software (1/2)

We've performed tests of the LAT pulsar tools using real data.

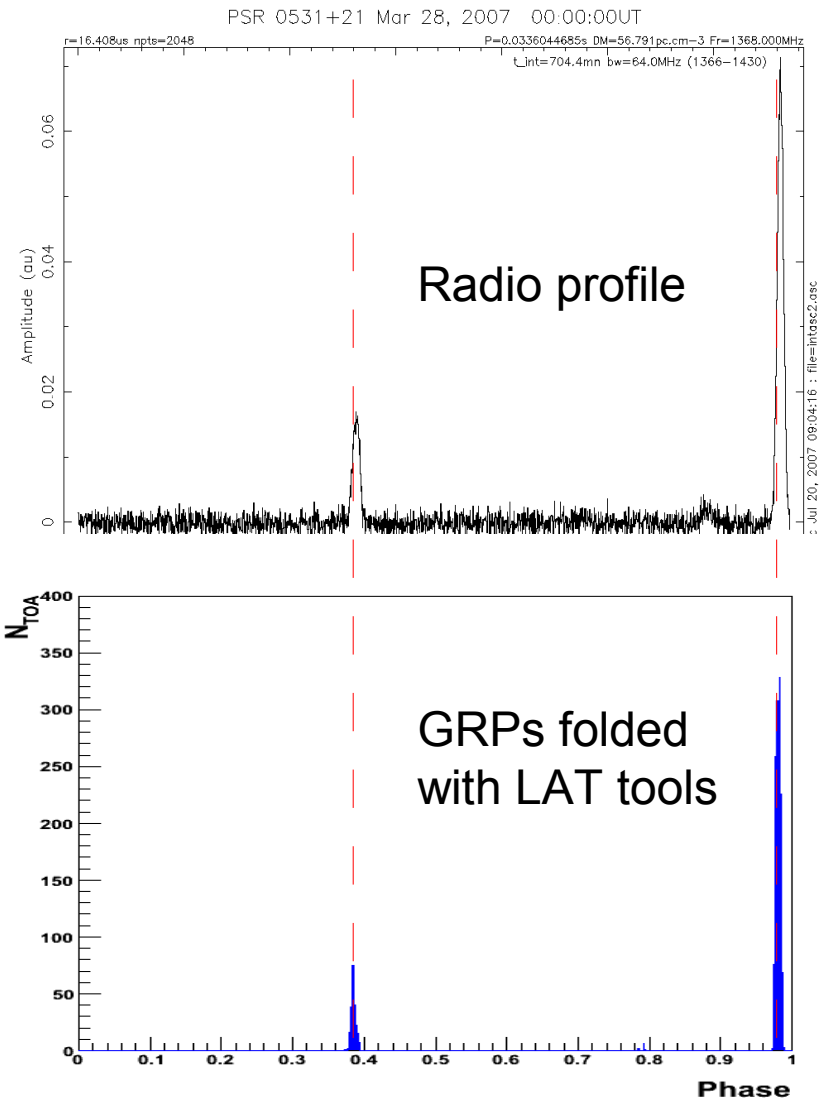
We could validate:

- barycentering
- phase-folding
- orbital demodulation (if any)

Here: Giant radio pulses from the Crab, recorded at Nançay over 8 months.

The radio GRPs analyzed with our tools is aligned with the normal radio emission.

Here: validation at a few tens of µs.



Tests of the timing software (2/2)

Other tests:

- ***Giant radio pulses from B1937+21 (millisecond pulsar) recorded at Nançay***
- ***X-ray data from J0218+4232 (millisecond pulsar in binary orbit) observed by XMM***
- ***Simulated radio TOAs from J0437-4715 (millisecond pulsar in binary orbit)***

The timing software is validated at the µs level.

Those tests and the timing campaign are described in:

Pulsar Timing for the *Fermi* Gamma-ray Space Telescope

D. A. Smith[1,2], L. Guillemot[1,2], F. Camilo[3], I. Cognard[4,5], D. Dumora[1,2], C. Espinoza[6], P. C. C. Freire[7], E. V. Gotthelf[3], A. K. Harding[8], G. B. Hobbs[9], S. Johnston[9], V. M. Kaspi[10], M. Kramer[6], M. A. Livingstone[10], A. G. Lyne[6], R. N. Manchester[9], F. E. Marshall[8], M. A. McLaughlin[11], A. Noutsos[6], S. M. Ransom[12], M. S. E. Roberts[13], R. W. Romani[14], B. W. Stappers[6], G. Theureau[4,5], D. J. Thompson[8], S. E. Thorsett[15], N. Wang[16], and P. Weltevrede[9]

(Astronomy & Astrophysics, accepted)

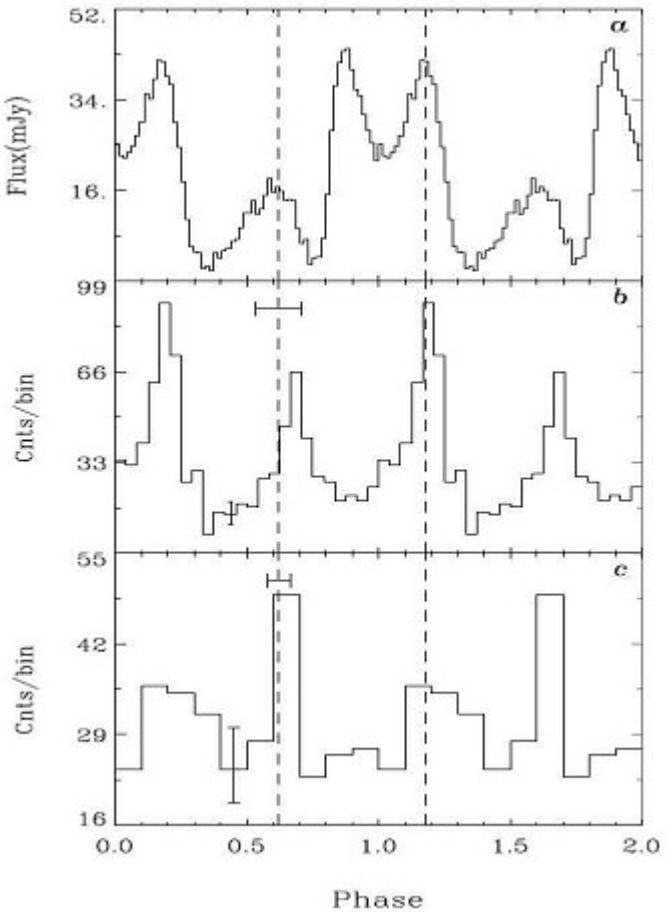
J0218+4232

Discovered at radio wavelengths by Navarro et al. (1995) at Westerbork.

J0218+4232 turned out to be a 2.3 ms pulsar, orbiting a 0.2 Msun white dwarf companion.

It was also observed in the X-ray band using ROSAT, BeppoSAX, Chandra and XMM (Kuiper et al 1998, Mineo et al 2000, Kuiper et al 2002, Webb et al 2004).

Kuiper et al. (2000) reported a 3.5 sigma detection with EGRET, later strengthened to the 4.9 sigma level (Kuiper et al 2002) after the improvement of the X-ray phase histogram.



Top: radio profile at 610 MHz. Middle: X-ray 0.8-10 keV profile, with Chandra. Bottom: 0.1-1 GeV EGRET phase histogram (from Kuiper et al 2002).

MSPs and Fermi (1/2)

MSPs with Edot > 10^34 ergs/s, sorted by sqrt(Edot) / d^2.
In this list: 3 have larger Edot. 9 have larger sqrt(Edot) / d^2 !

Red arrows: searched in EGRET data with ephemerides (Fierro et al 1995). No detections.

Jname	GL	GB	P0 (s)	EDOT	sqrt(Edot)/ d2	
0437-4715	253,39	-41,96	0,005757	1,19E+34	4,26E+18	←
1741+1354	37,8	21,7	0,004000	2,29E+34	6,05E+17	
0034-0534	111,49	-68,07	0,001877	2,96E+34	5,90E+17	←
0613-0200	210,41	-9,31	0,003062	1,32E+34	4,99E+17	←
1300+1240	311,31	75,41	0,006219	1,88E+34	2,31E+17	
1909-3744	359,73	-19,6	0,002947	2,16E+34	1,13E+17	
1843-1113	22,06	-3,4	0,001846	6,02E+34	8,59E+16	
2129-5721	338,01	-43,57	0,003726	2,27E+34	8,15E+16	
1911-1114	25,14	-9,58	0,003626	1,17E+34	7,27E+16	
0218+4232	139,51	-17,53	0,002323	2,44E+35	6,93E+16	
1959+2048	59,2	-4,7	0,001607	1,60E+35	6,45E+16	
1824-2452	7,8	-5,58	0,003054	2,24E+36	6,23E+16	←
1623-2631	350,98	15,96	0,011076	1,95E+34	2,89E+16	←
1939+2134	57,51	-0,29	0,001558	1,10E+36	1,51E+16	←
0537-6910	279,56	-31,75	0,016122	4,88E+38	9,05E+15	
1841+0130	33,12	2,94	0,029773	1,22E+34	8,57E+15	

Low conf. EGRET detection

(Kuiper et al 2000)

MSPs and Fermi (2/2)

Northern MSPs (observed by Nançay) with Edot < 10^34 ergs/s.

All these 16 pulsars have higher sqrt(Edot) / d^2

Provided J0218+4232 is a true detection: many candidate MSPs for gamma emission.

Jname	GL	GB	P0 (s)	EDOT	sqrt(Edot)/ d2	
2124-3358	10,93	-45,44	0,004931	6,78E+33	1,32E+18	
0737-3039A	245,24	-4,51	0,022699	5,94E+33	7,08E+17	
0030+0451	113,14	-57,61	0,004865	3,48E+33	6,55E+17	
1012+5307	160,35	50,86	0,005256	4,66E+33	4,06E+17	
1744-1134	14,79	9,18	0,004075	5,21E+33	3,13E+17	
1024-0719	251,7	40,52	0,005162	5,32E+33	2,60E+17	
0751+1807	202,73	21,09	0,003479	7,30E+33	2,22E+17	
1455-3330	330,72	22,56	0,007987	1,88E+33	1,54E+17	
1730-2304	3,14	6,02	0,008123	1,49E+33	1,37E+17	←
0900-3144	256,16	9,49	0,011110	1,41E+33	1,29E+17	
1022+1001	231,8	51,1	0,016453	3,84E+32	1,22E+17	
2322+2057	96,52	-37,31	0,004808	3,44E+33	9,16E+16	←
1857+0943	42,29	3,06	0,005362	4,53E+33	8,13E+16	←
1804-2717	3,51	-2,74	0,009343	1,98E+33	7,31E+16	
1751-2857	0,65	-1,12	0,003915	7,41E+33	7,11E+16	
2317+1439	91,36	-42,36	0,003445	2,34E+33	7,02E+16	←

Fermi Gamma-ray Space Telescope

Summary

- *In the context of the timing campaign, > 300 pulsars are observed.*
- *Contributing observatories: GBT, Jodrell Bank, Parkes, RXTE, etc. and Nançay !*
- *For Nançay: timing solutions for 150 pulsars are produced automatically.*
- *LAT pulsar tools = validated at the μs level.*
- *Furthermore: the LAT clocks have proven accurate (cf. Vela paper, submitted)*

- *MSPs with Edot > 10^34 ergs/s, close MSPs and some MSPs in globular clusters are being searched for gamma-ray pulsations. Many candidates !*
- *One of the main question being: will the LAT confirm the detection of J0218+4232 ?*