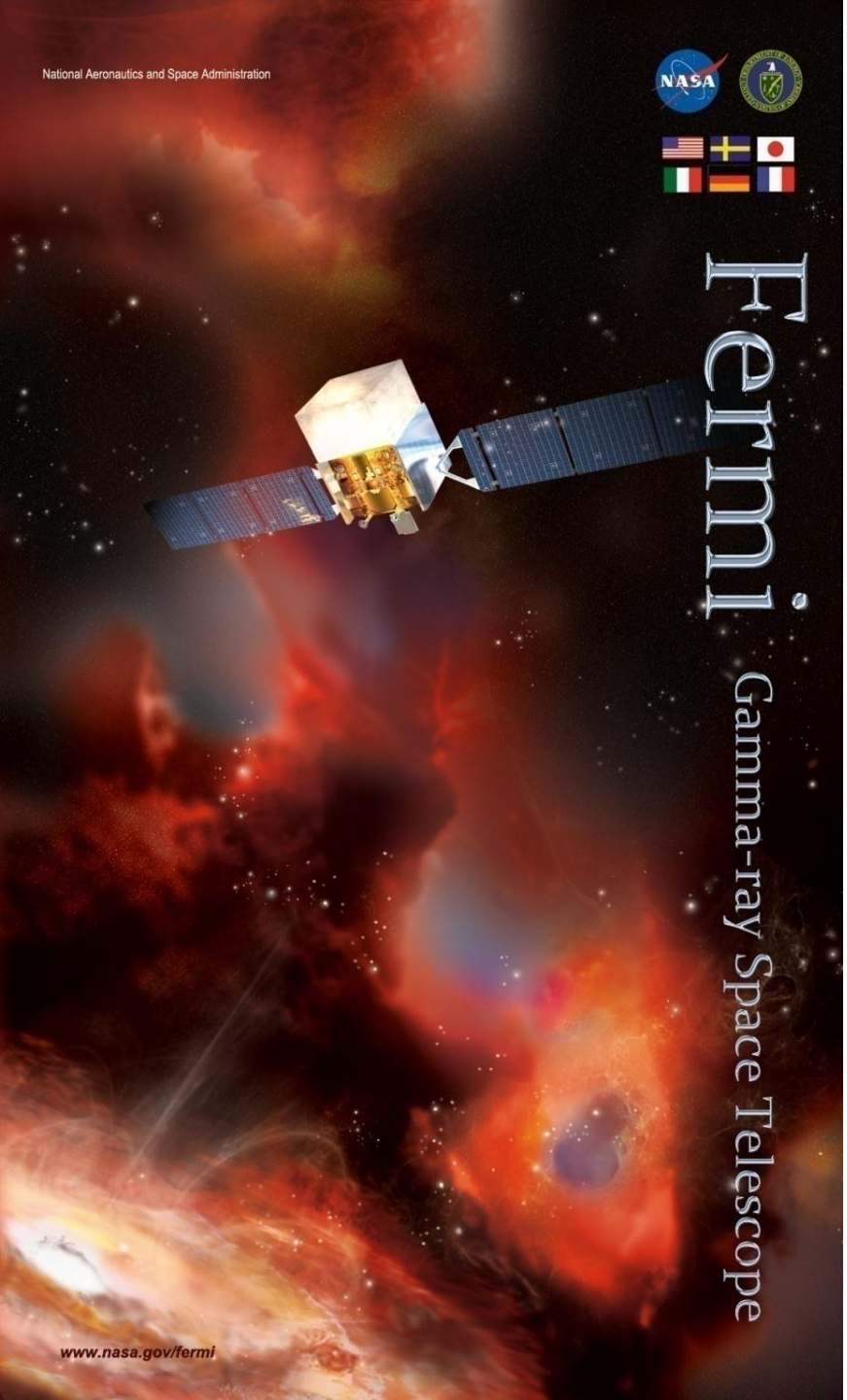


Fermi Gamma-ray Space Telescope

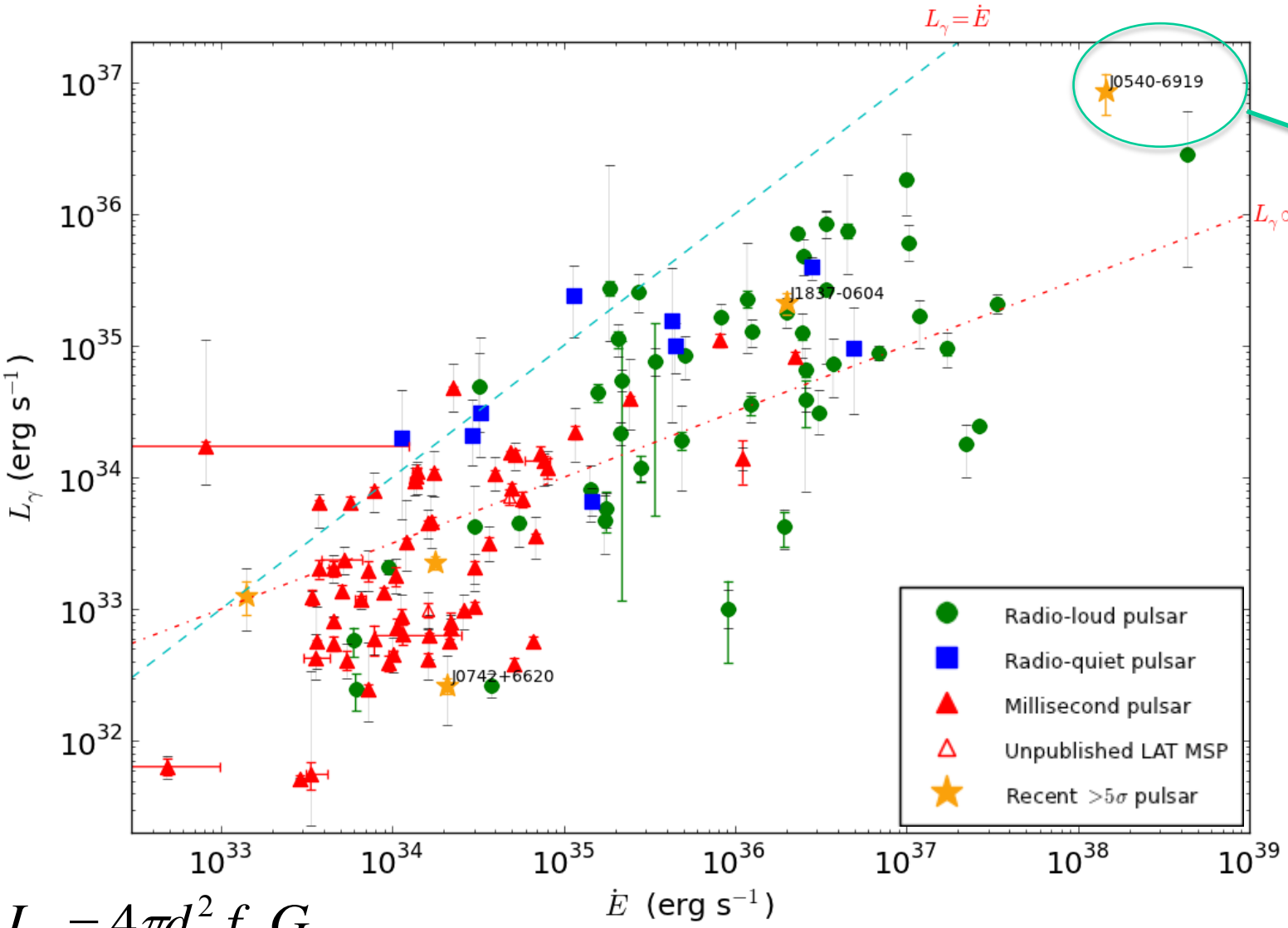
New pulsars detected in gamma-rays with the Fermi-LAT

H. Laffon, L. Guillemot, D. A. Smith, on behalf of the Fermi-LAT collaboration

Outline

- Which pulsars do we see?
- Pass 8 performance and application to pulsars
- New gamma-ray detections
  - Young energetic pulsars
  - Millisecond pulsars (MSPs)
- More MSPs than expected
  - Shklovskii correction
- Conclusions

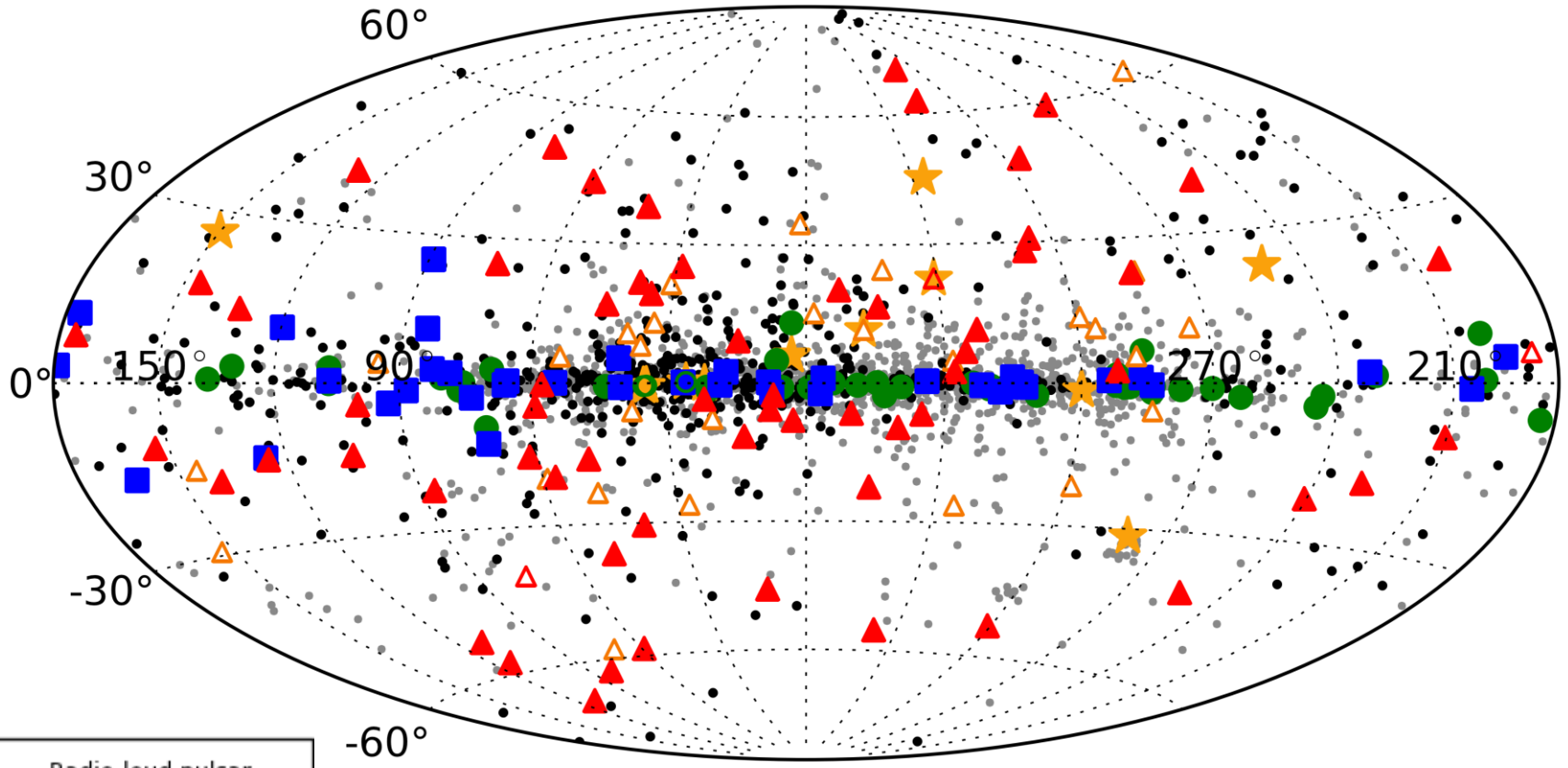
Which pulsars do we see?



See talk on LMC by P.Martin

$$L_\gamma = 4\pi d^2 f_\Omega G_{100}$$

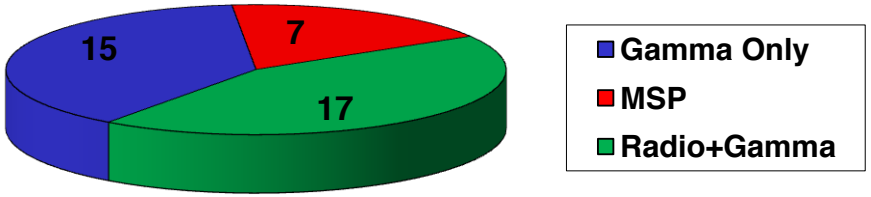
Where are they?



- Radio-loud pulsar
- Radio-quiet pulsar
- Millisecond pulsar
- Unpublished LAT MSP
- Recent $>5\sigma$ pulsar

The millisecond revolution

2009, R. Romani (AAS conf.)



The millisecond revolution

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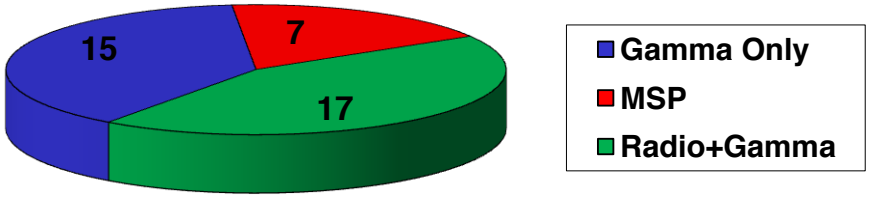
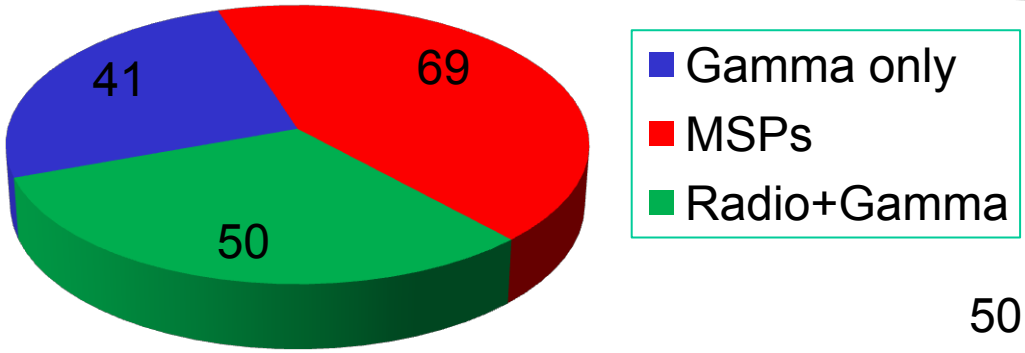
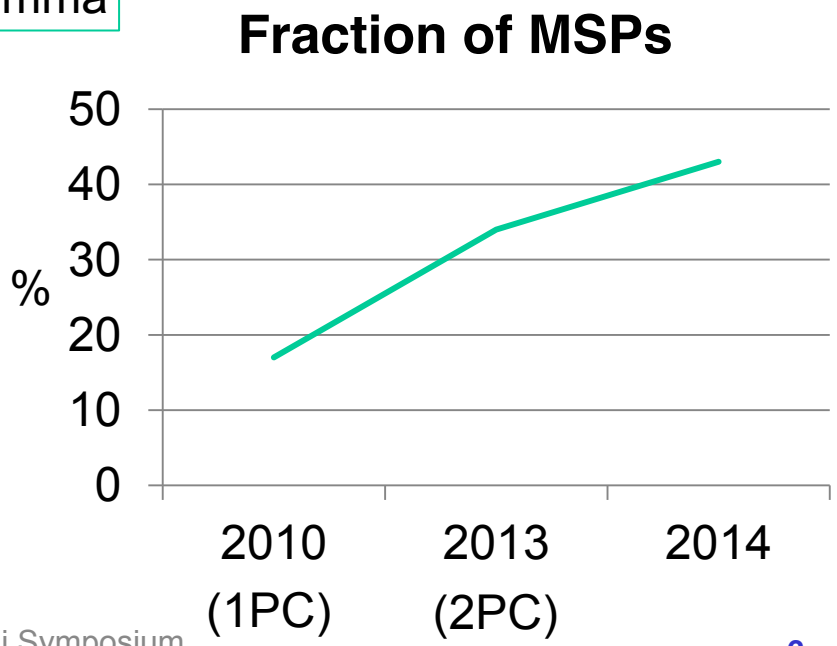


2014



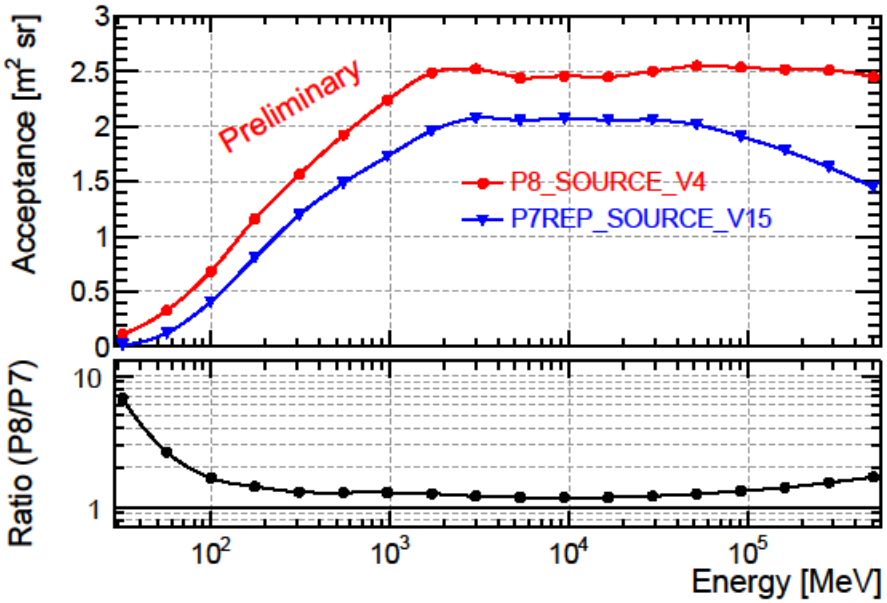


➢ Growing fraction of millisecond pulsars (MSPs): **43%** of gamma-ray pulsars at present

https://confluence.slac.stanford.edu/display/GLAMCOG/Public+List+of+LAT-Detected+Gamma-Ray+Pulsars

Pass 8 performance

- **New event selection and reconstruction strategy (see talk by P. Bruel on Wednesday, analysis session)**

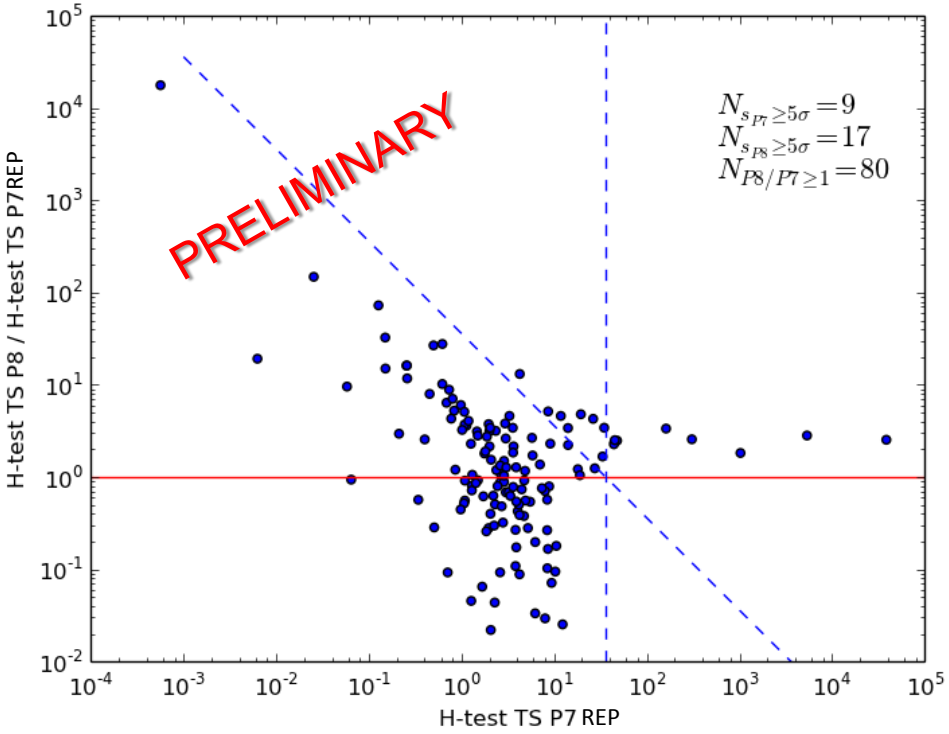


- Better acceptance and sensitivity at low energy (≤100MeV)
- Most of pulsars have spectra that cut off around few GeV
- Energy flux density contained between MeV and GeV range
- Pass 8 is good for pulsar studies

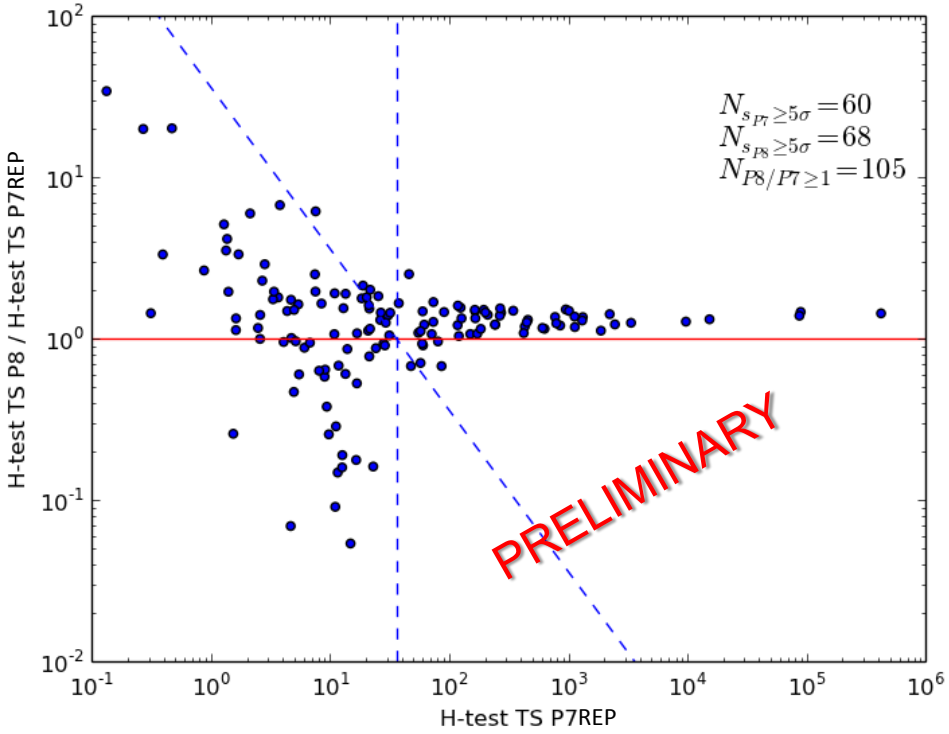
Pass 8 applied to pulsars

- **141 pulsars detected with Fermi, 2 years of data**

E<100 MeV



E>100 MeV



- **E<100 MeV: increased H-test TS in 57% of cases, twice more pulsars >5σ**
- **E>100 MeV: increased H-test TS in 75% of cases, 13% more pulsars >5σ**

The still-to-be-detected

- **Location-limited:**
  - **Large distance**
- **Background-limited:**
  - **Crowded region (galactic plane)**
- **Object features-limited:**
  - **Intrinsically faint**
  - **Low energy cutoff (<1 GeV)**
  - **Wide gamma-ray peaks**
  - **Where the beam is sampled (f_Ω)**
- **Pass 8 increased acceptance will help to discover new objects**

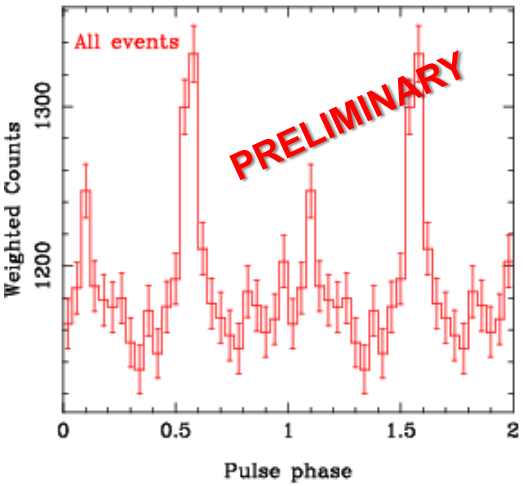
See Hou et al. A&A, 570, A44 (2014) for more information about faint gamma-ray pulsars

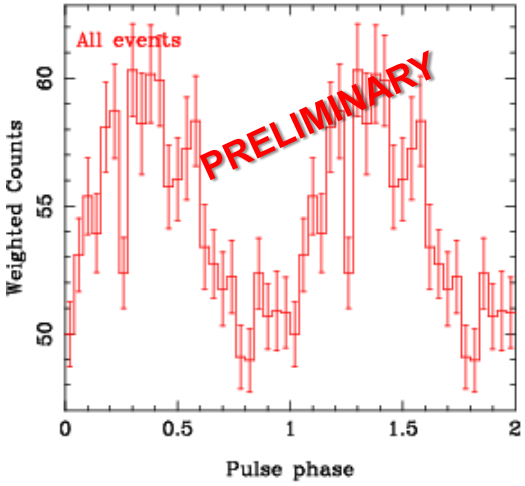
The new detections

- **Thanks to the collaboration with radio telescopes providing up-to-date ephemerides we phase-fold the gamma-ray data and detect pulsations with the Fermi-LAT**
- **Pass 8 improvement allows new detections:**
  - **5 young pulsars**
    - **PSR J1856+0113**
    - **PSR J1857+0143**
    - **PSR J1831-0952**
    - **PSR J1837-0604**
    - **PSR J1224-6407**
  - **4 MSPs**
    - **PSR J0742+6620**
    - **PSR J1455-3330**
    - **PSR J1730-2304**
    - **PSR J0931-1902**

New young pulsars

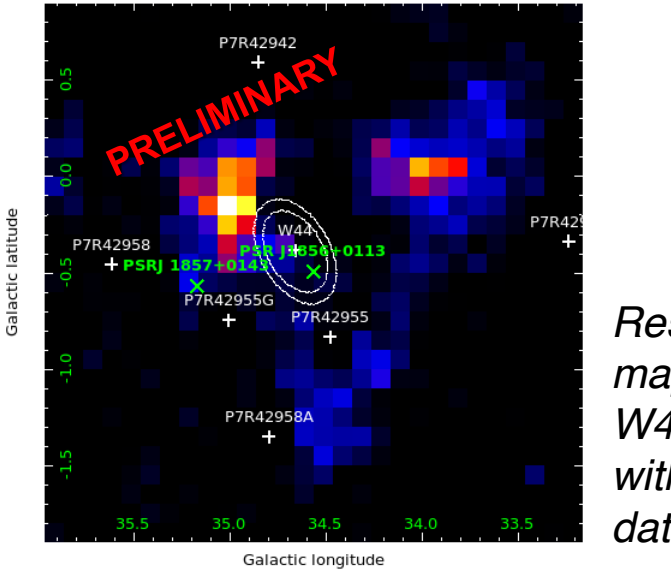
PSR J1856+0113
Latitude = -0.497°
Ė= 4.3 x10^{35} erg/s
Period = 267 ms
Distance= 3.3 kpc





PSR J1857+0143
Latitude = -0.571°
Ė= 4.5 x10^{35} erg/s
Period = 140 ms
Distance= 5.7 kpc

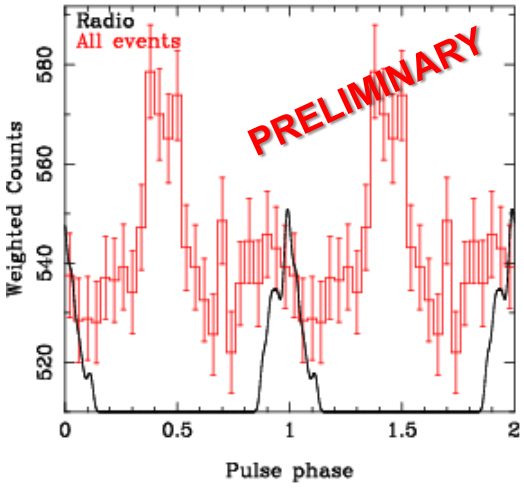
- **PSR J1856+0113 is the central object of SNR W44**
- **First detection of both the SNR and its associated pulsar in gamma-rays**



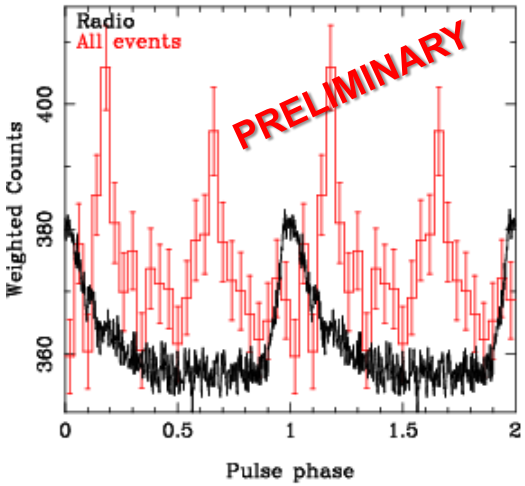
Residual TS map of the W44 region with Pass 8 data

New young pulsars

PSR J1831-0952
Latitude = -0.128°
Ė= 1.08 x10^{36} erg/s
Period = 67 ms
Distance= 4.0 kpc



JBO ephemeris

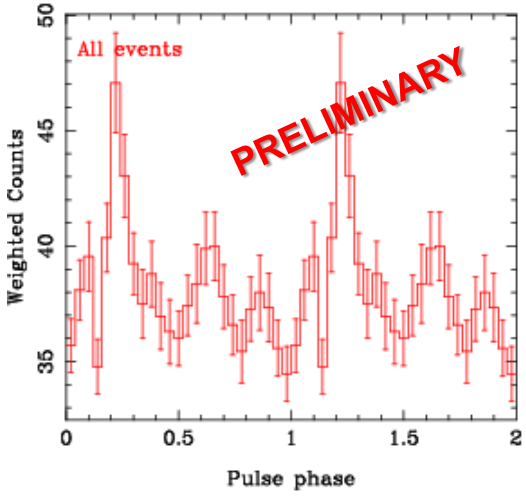


Parkes ephemeris

PSR J1837-0604
Latitude = 0.265°
Ė= 2 x10^{36} erg/s
Period = 96 ms
Distance= 6.4 kpc

→ **See dedicated poster on high spin-down powered pulsars (7.06)**

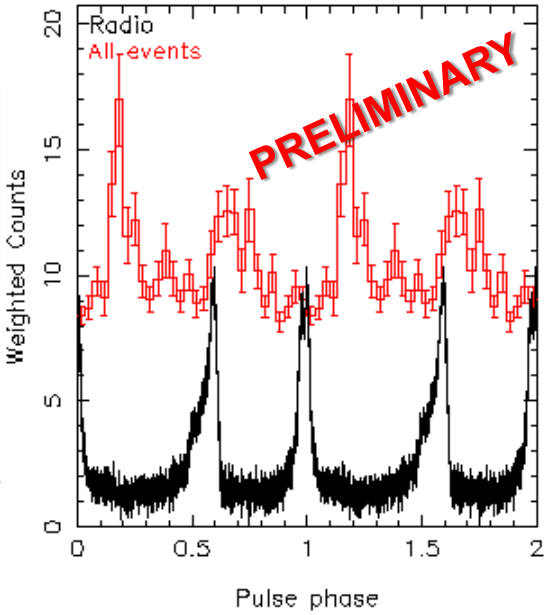
PSR J1224-6407
Latitude = -1.415°
Ė= 1.9 x10^{34} erg/s
Period = 216 ms
Distance= 4.0 kpc

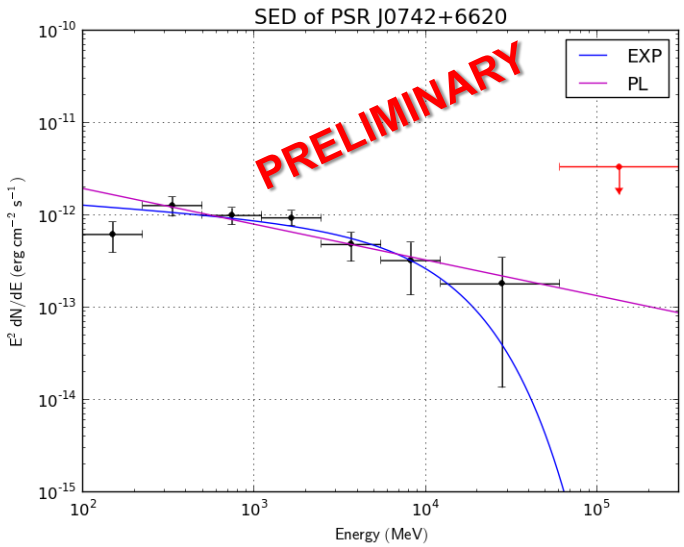


New MSPs

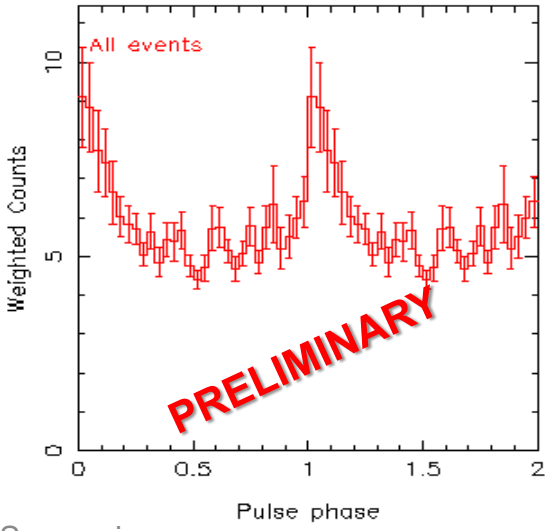
PSR J0742+6620
Latitude = 29.6°
$\dot{E}$= 2 x10^{34} erg/s
Period = 2.9 ms
Dist = 0.7 kpc

Nançay ephemeris





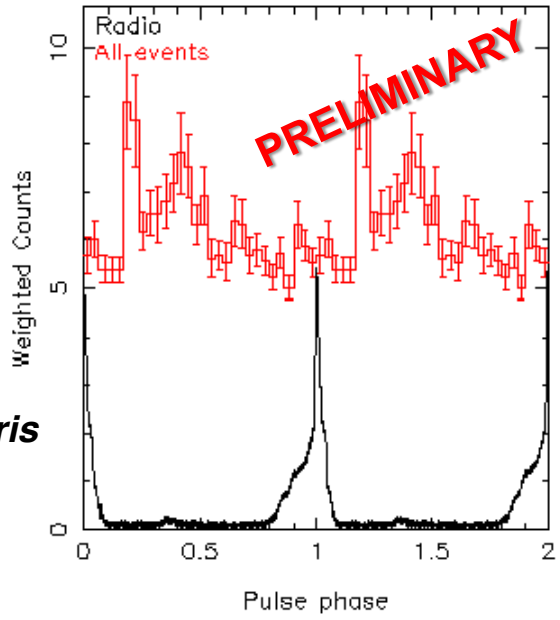
PSR J0931-1902
Latitude = 23.05°
$\dot{E}$ = 1.4 x10^{33} erg/s
Period = 4.6 ms
Dist = 1.9 kpc



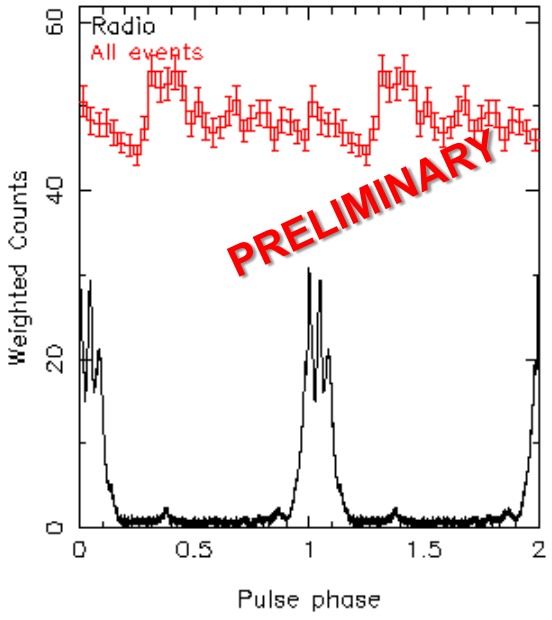
New MSPs

PSR J1455-3330
Latitude = 22.6°
$\dot{E}$= 1.9 x10^{33} erg/s
Period = 8 ms
Dist = 0.5 kpc

PSR J1730-2304
Latitude = 6.0°
$\dot{E}$= 1.5 x10^{33} erg/s
Period = 8 ms
Dist = 0.5 kpc

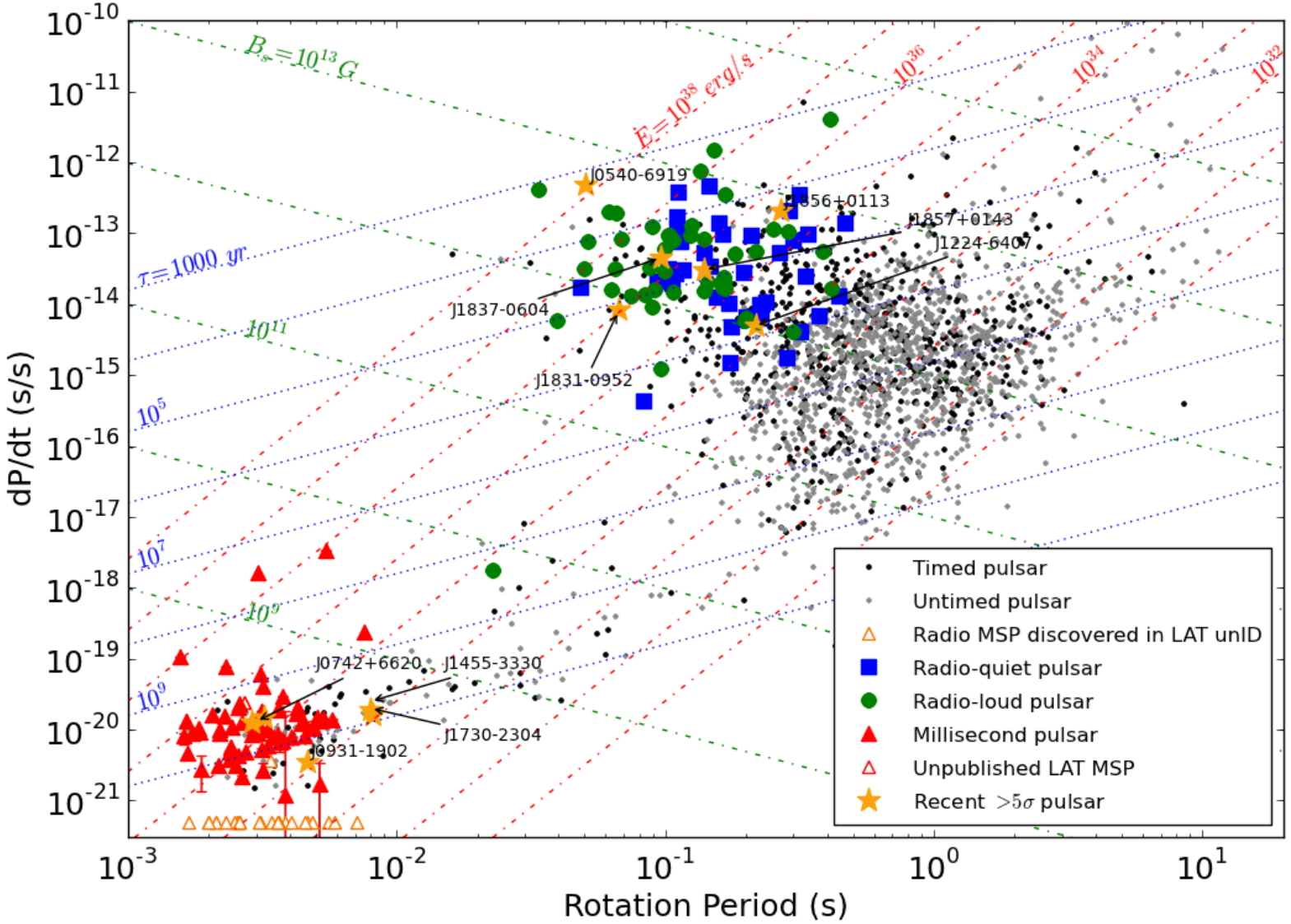


Nançay ephemeris



Nançay ephemeris

New detections



Shklovskii correction

- **Shklovskii effect: artificial increase of the apparent $\dot{P}$ value over the intrinsic one due to the pulsar's transverse motion**

$$\dot{P}_{true} = \dot{P}_{obs} - \Delta\dot{P}_{Shk}$$

$$\Delta\dot{P}_{\rm Shk} \simeq 2.43 \times 10^{-21} \left(\frac{\mu_T}{\rm mas\ yr^{-1}}\right)^2 \left(\frac{d}{\rm kpc}\right) \left(\frac{P}{\rm s}\right)$$

- **Radio monitoring : proper motion measurements to correct for this effect**
  - **Spin-down power correction**
  - **Gamma-ray efficiency correction**
- **Ongoing study @ Nançay on the new MSPs and others**

Conclusions

- Pass 8 allowed the detection of 10 more pulsars and even more are expected
- To detect new pulsars we need radio timing – A big thanks!
  - Fold them all : up-to-date ephemerides
  - Find them all : look at UNID Fermi sources
    (see poster 7.02 by E. Ferrara)
- The fraction of MSPs among the gamma-ray pulsars keeps on growing
- With long-term monitoring we can measure proper motions and correct for the Shklovskii effect
- Better understanding of these objects
- Theoretical aspects will be discussed by M. Kerr on Wednesday