

One decade of pulsar studies with Fermi

Pablo Saz Parkinson

for the Fermi LAT Collaboration

Department of Physics & Laboratory for Space Research

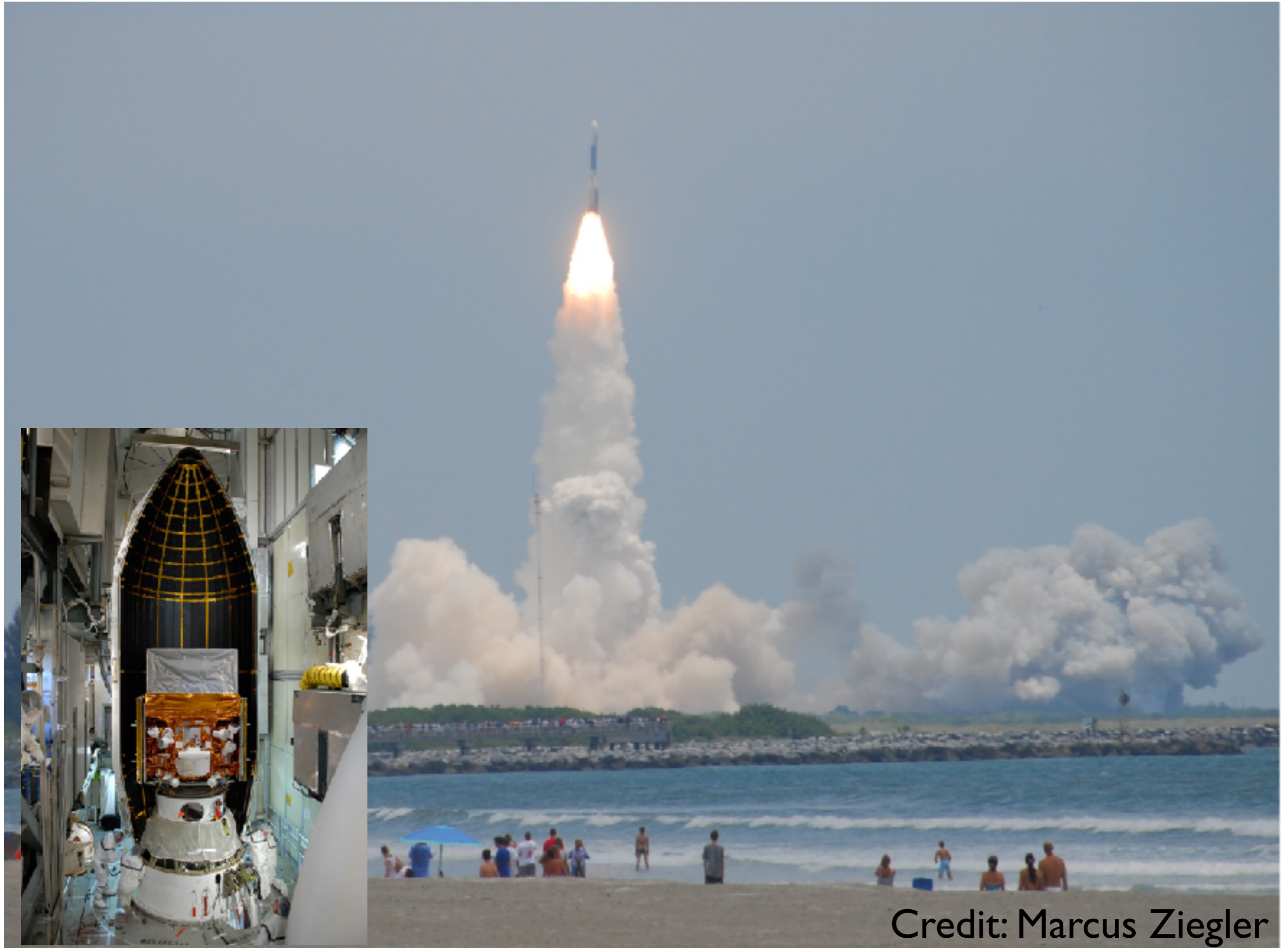
The University of Hong Kong

Santa Cruz Institute for Particle Physics, UCSC



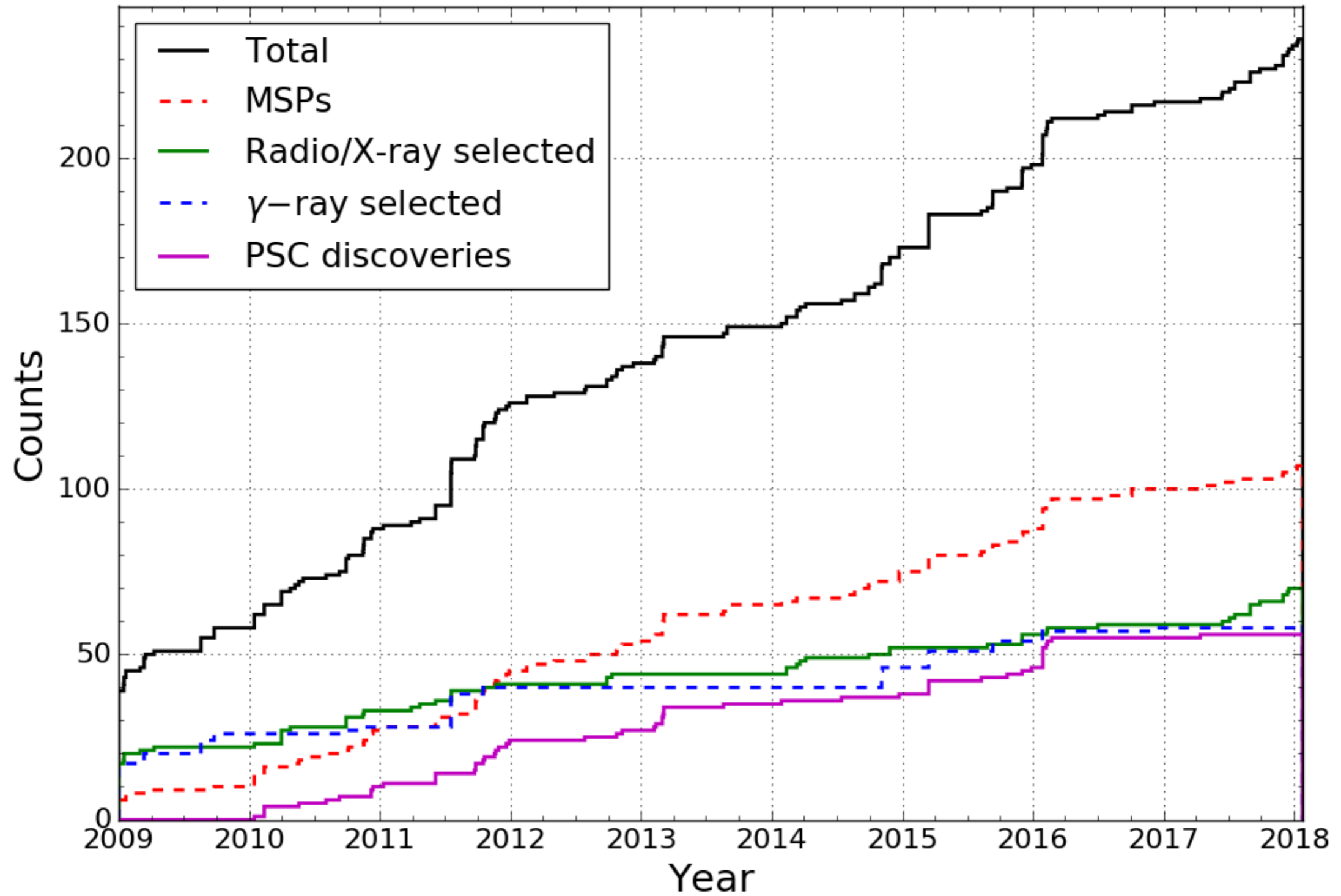
UNIVERSITY OF CALIFORNIA
SANTA CRUZ

11 June 2008



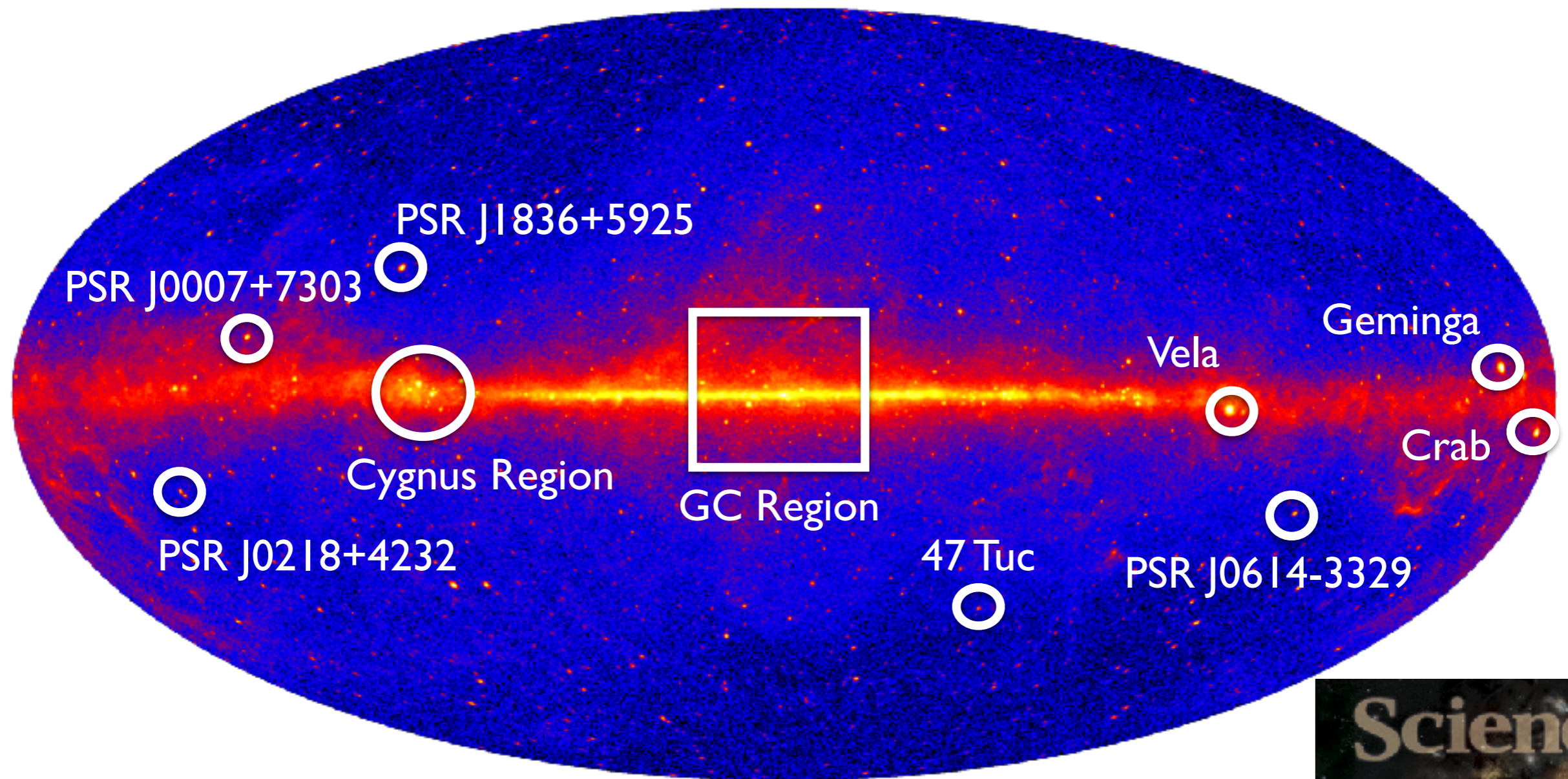
Credit: Marcus Ziegler

Fermi LAT Pulsar Discoveries



<http://tinyurl.com/fermipulsars>

Early pulsar *Science* with Fermi



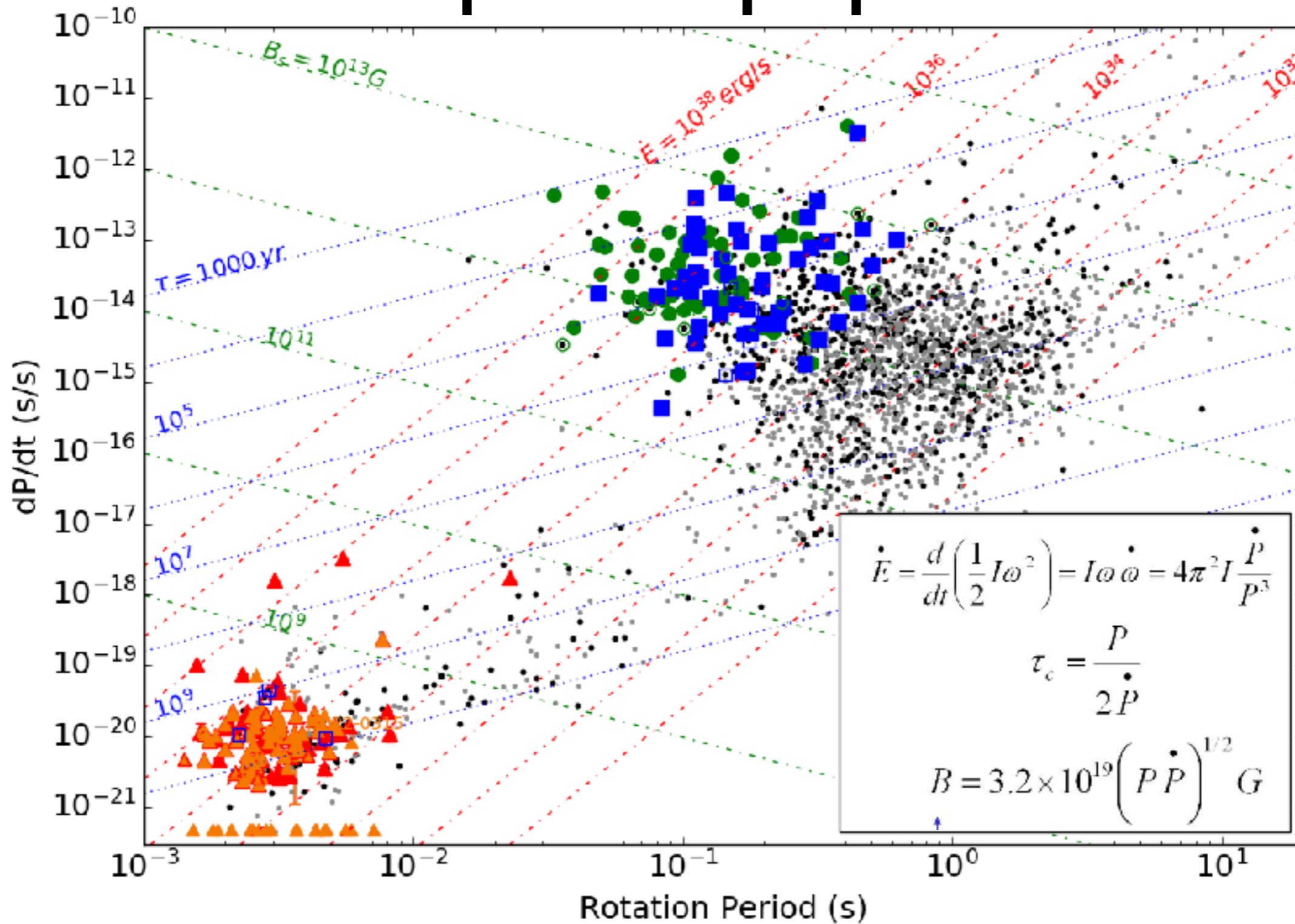
Abdo et al., *Science*, **325**, 840 (2009): Gemingas

Abdo et al., *Science*, **325**, 845 (2009): Globular Clusters

Abdo et al., *Science*, **325**, 848 (2009): MSPs



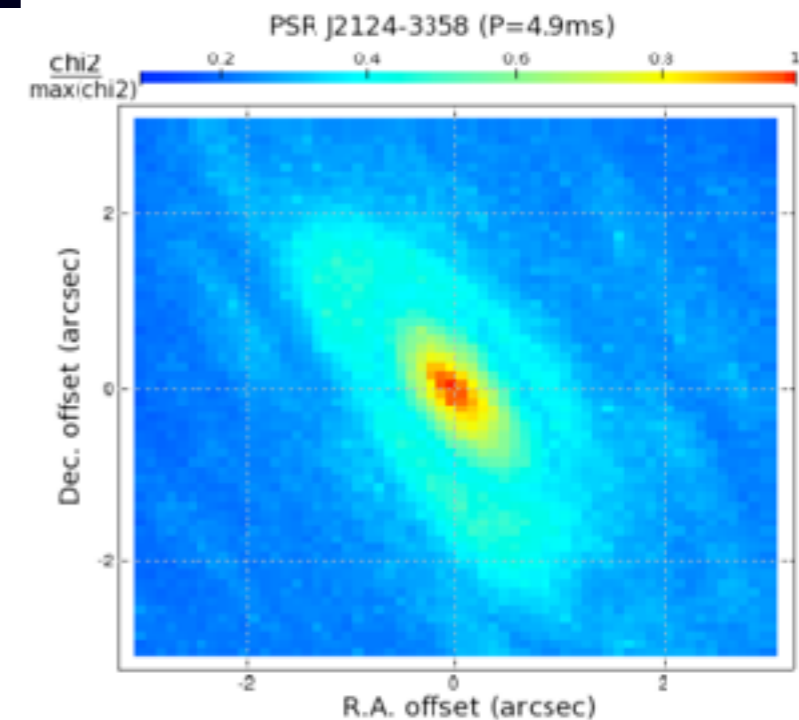
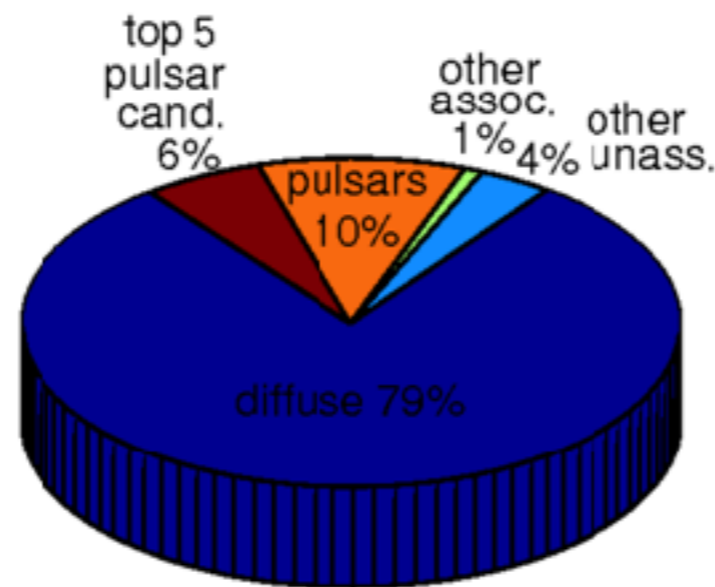
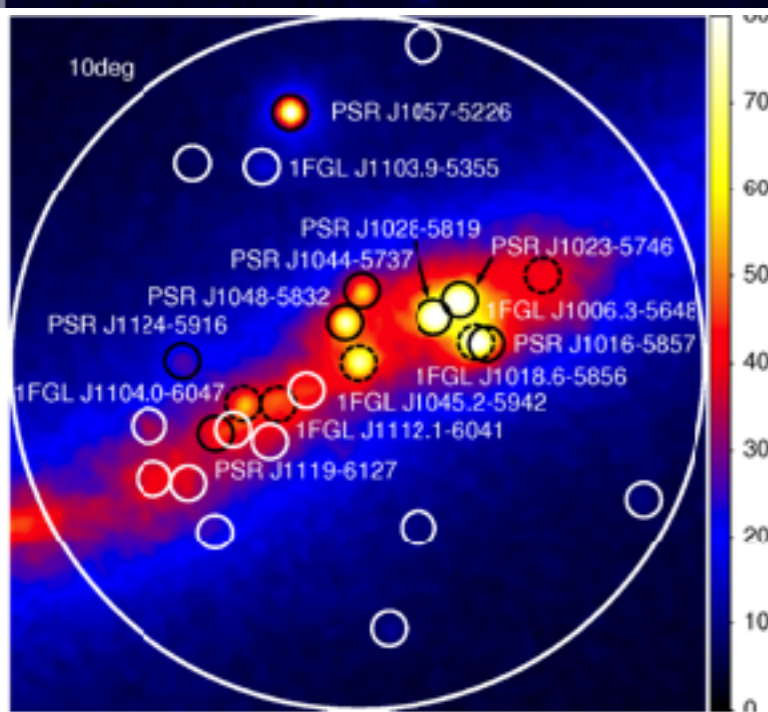
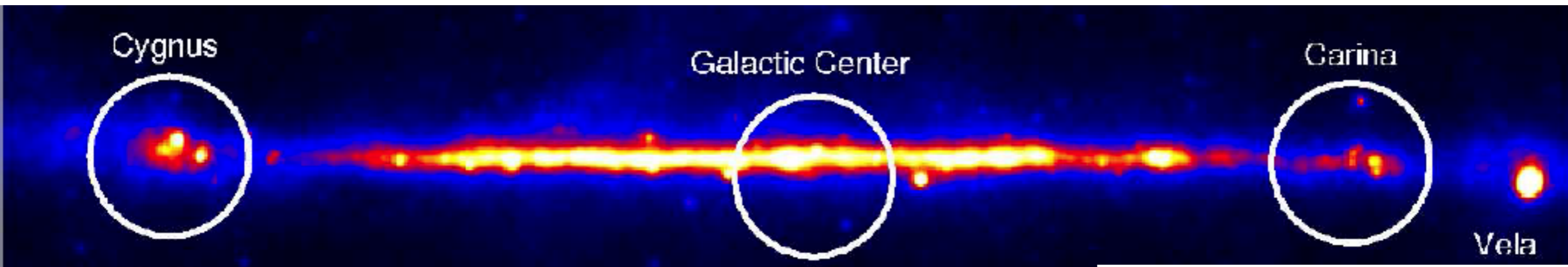
The pulsar population



<http://tinyurl.com/fermipulsars>

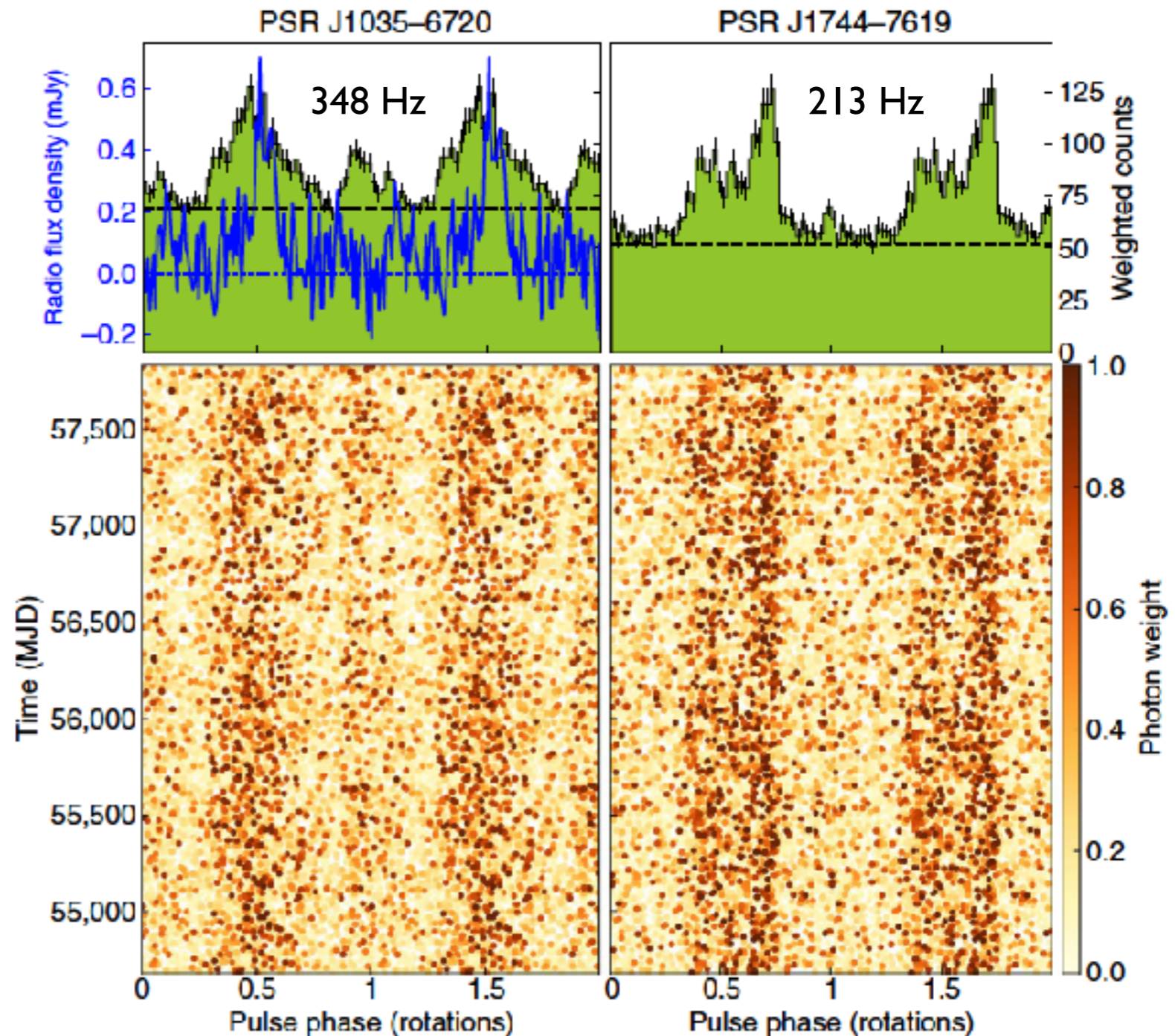
Searches for gamma-ray pulsars

- The PSF of a gamma-ray instrument is broad (\sim deg)
- Pulsars are often in the Galactic plane, where there are many sources and a strong diffuse background
- Very accurate position is needed



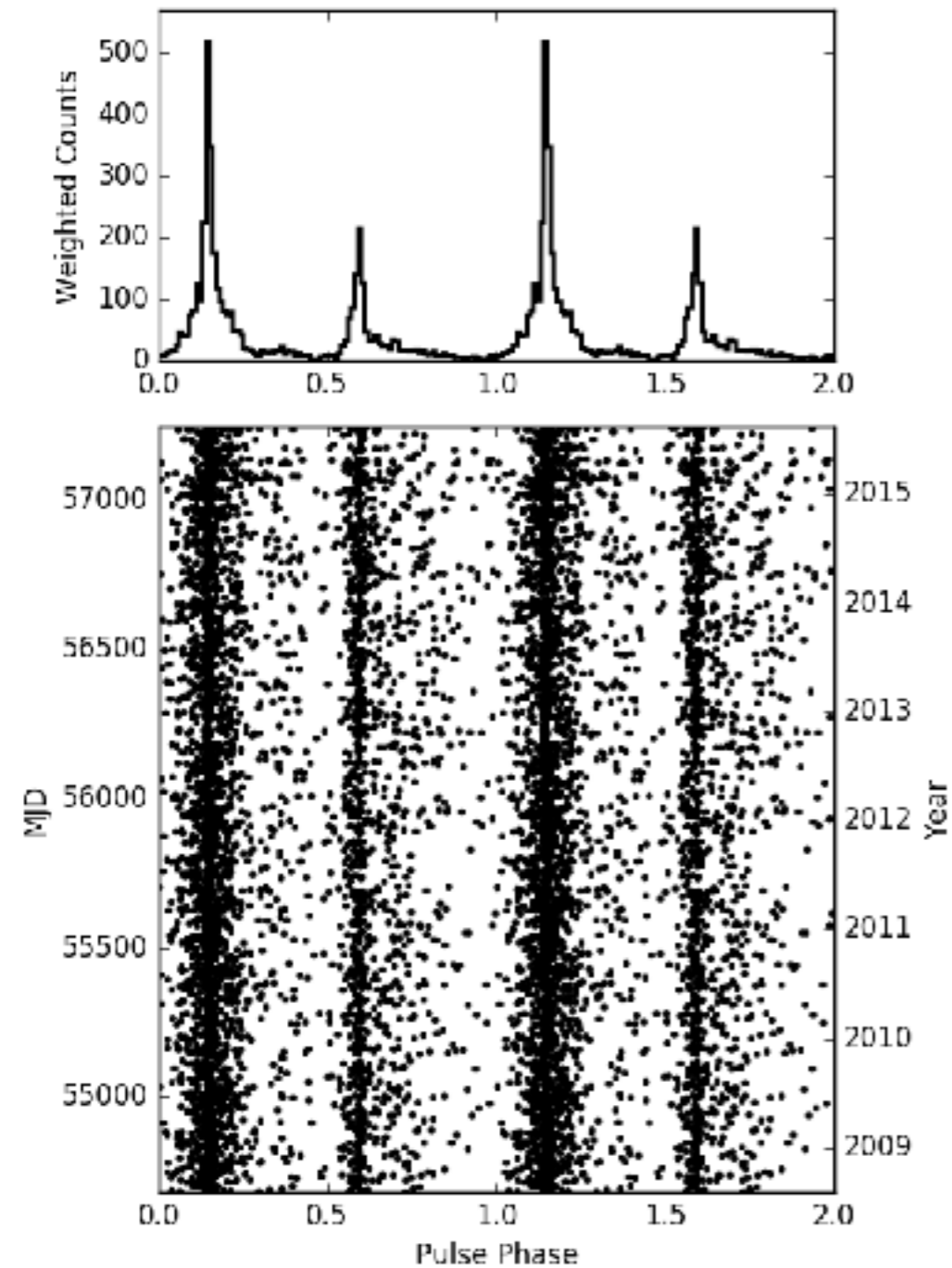
The first radio-quiet MSP

- Discovered using Einstein@Home (>10,000 CPU yr)
- First MSP not detected in radio
- Searched with Parkes ~10 times
- Could be only the tip of the iceberg

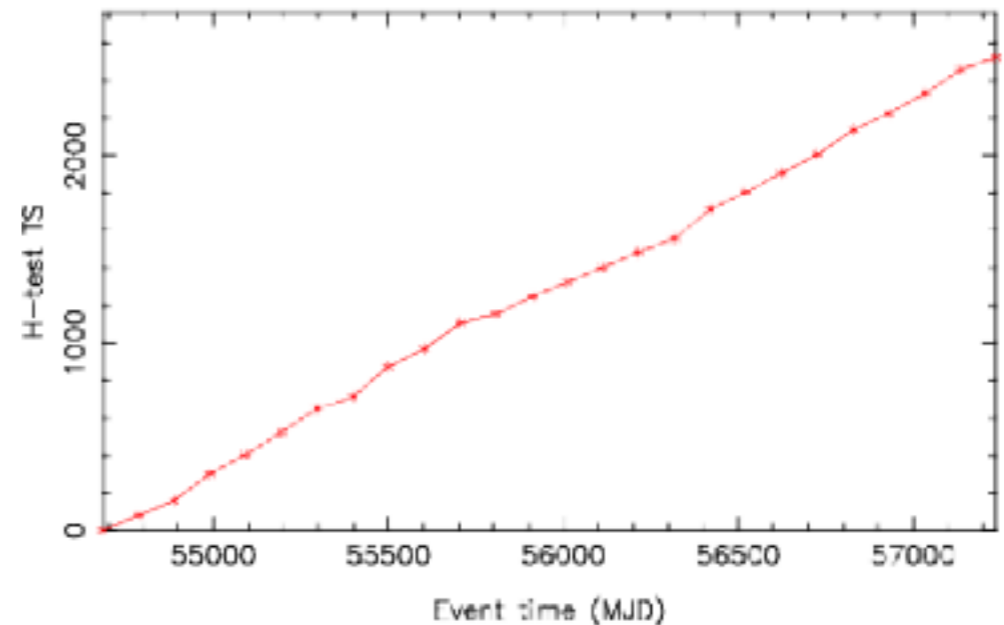
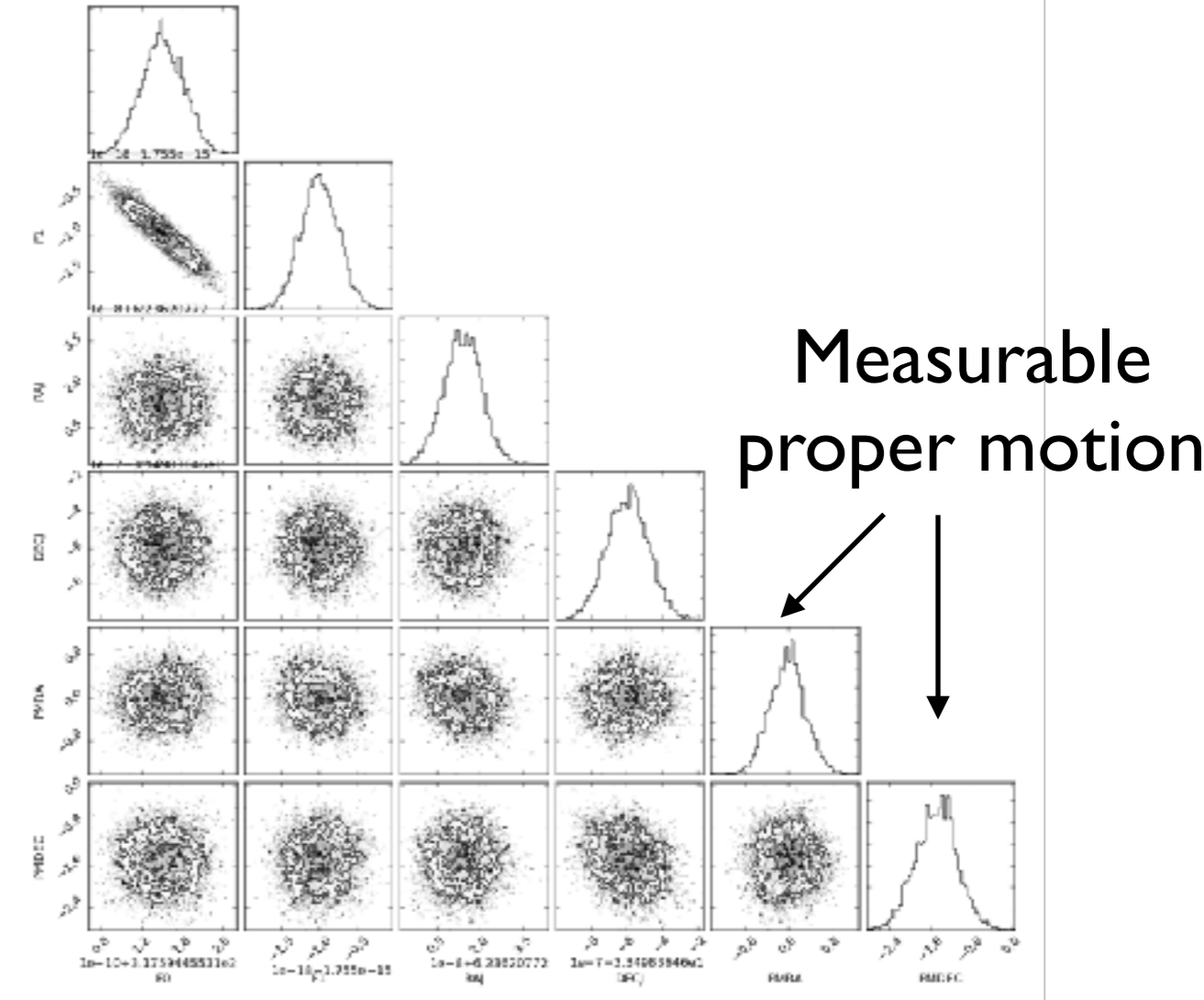


Clark et al. 2018

Long term pulsar timing



~3000 days
> 80 billion rotations
< 20,000 photons
~ 1 photon every 5 million rotations

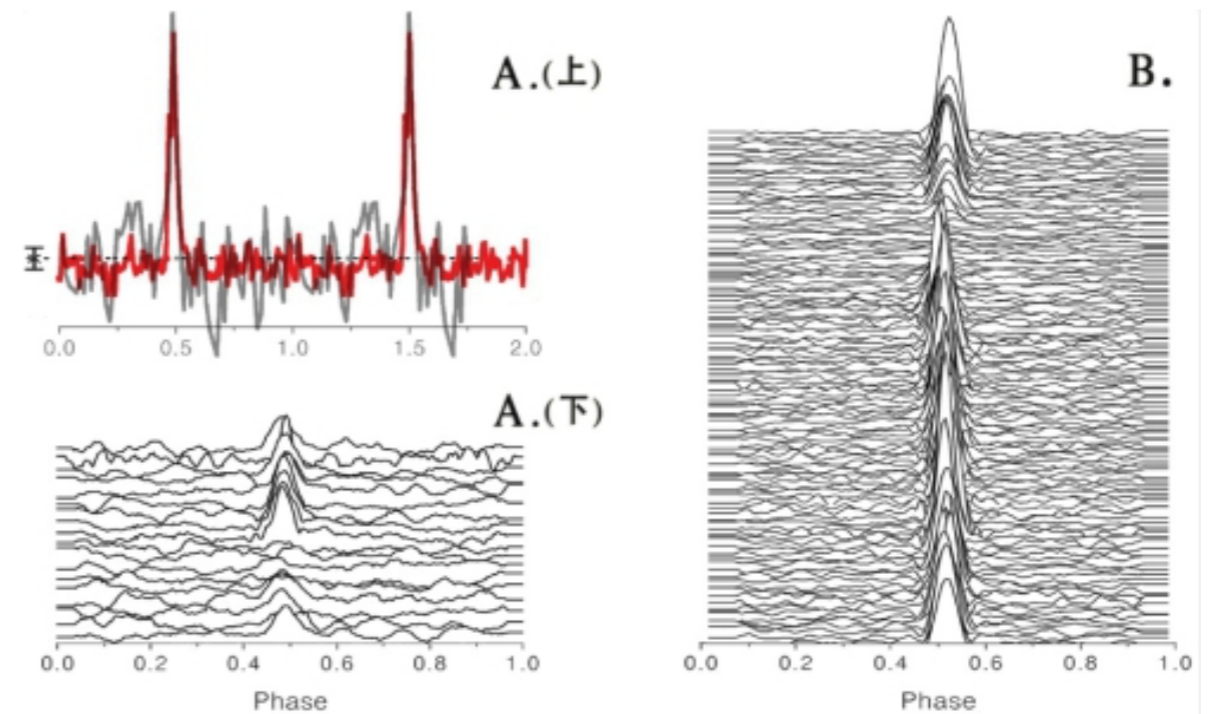


The Pulsar Search Consortium



Formed in 2009 between LAT pulsar searchers and radio astronomers (Ray et al. 2012: arXiv: 1205.3089)

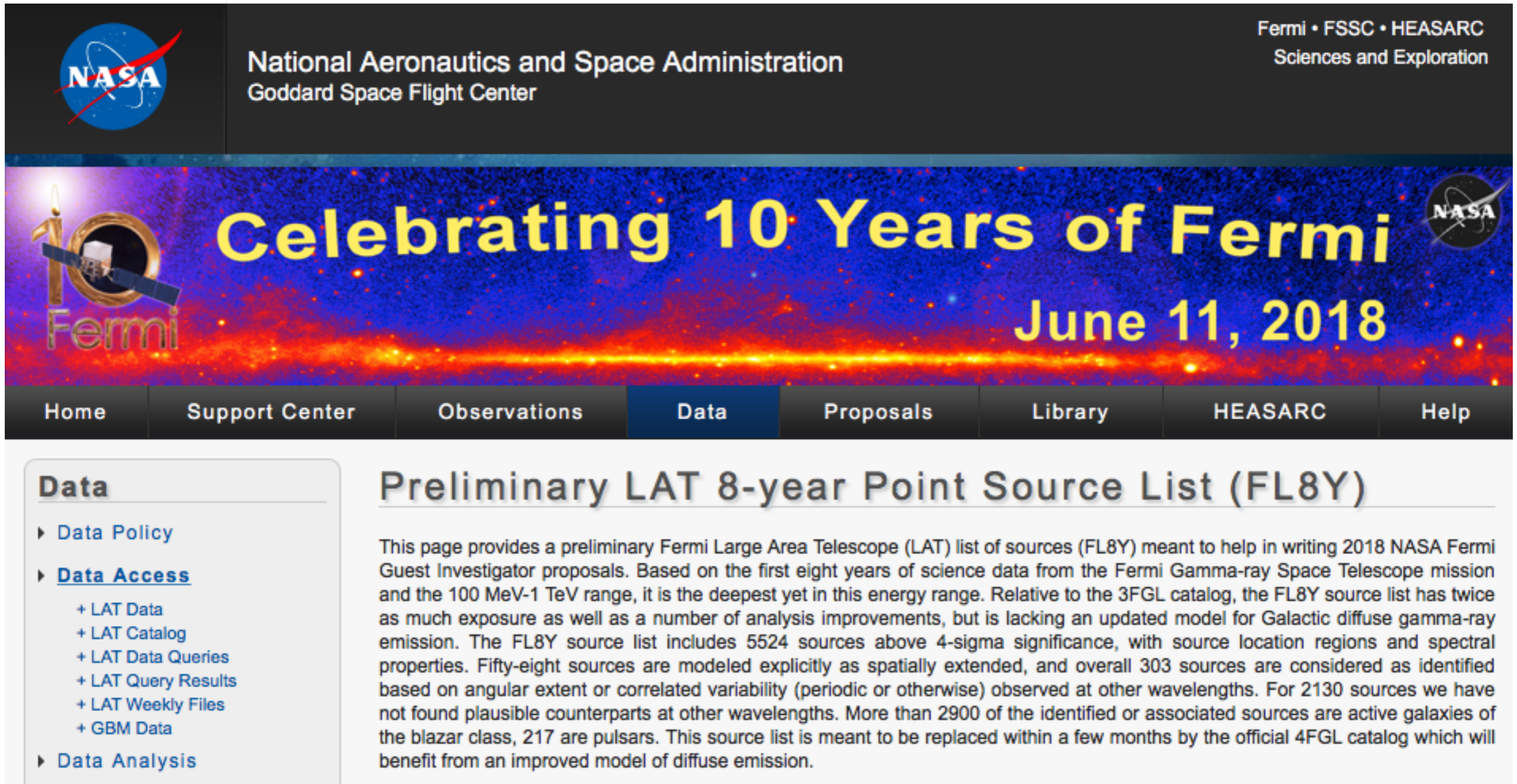
FAST joins the PSC!



<http://crafts.bao.ac.cn/pulsar/>

- FAST and Fermi recently signed an MOU
- Fermi GI and NSFC proposals submitted (2018)
- Searches for new pulsars in LAT sources and radio pulsations from radio-quiet gamma-ray pulsars are ongoing ...

4FGL catalog in preparation ...



The screenshot shows the NASA Fermi website interface. At the top left is the NASA logo. To its right, the text reads "National Aeronautics and Space Administration" and "Goddard Space Flight Center". In the top right corner, it says "Fermi • FSSC • HEASARC" and "Sciences and Exploration". A large banner across the middle of the page reads "Celebrating 10 Years of Fermi" in yellow text, with "June 11, 2018" below it. The banner features a background of a starry sky with a bright orange and red streak. Below the banner is a navigation menu with links: Home, Support Center, Observations, Data (highlighted), Proposals, Library, HEASARC, and Help. On the left side, there is a "Data" sidebar menu with sub-links: Data Policy, Data Access (with sub-links for LAT Data, LAT Catalog, LAT Data Queries, LAT Query Results, LAT Weekly Files, and GBM Data), and Data Analysis. The main content area displays the title "Preliminary LAT 8-year Point Source List (FL8Y)" and a paragraph of text describing the catalog's scope and content.

NASA
National Aeronautics and Space Administration
Goddard Space Flight Center

Fermi • FSSC • HEASARC
Sciences and Exploration

Celebrating 10 Years of Fermi
June 11, 2018

Home Support Center Observations **Data** Proposals Library HEASARC Help

Data

- ▶ Data Policy
- ▶ **Data Access**
 - + LAT Data
 - + LAT Catalog
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- ▶ Data Analysis

Preliminary LAT 8-year Point Source List (FL8Y)

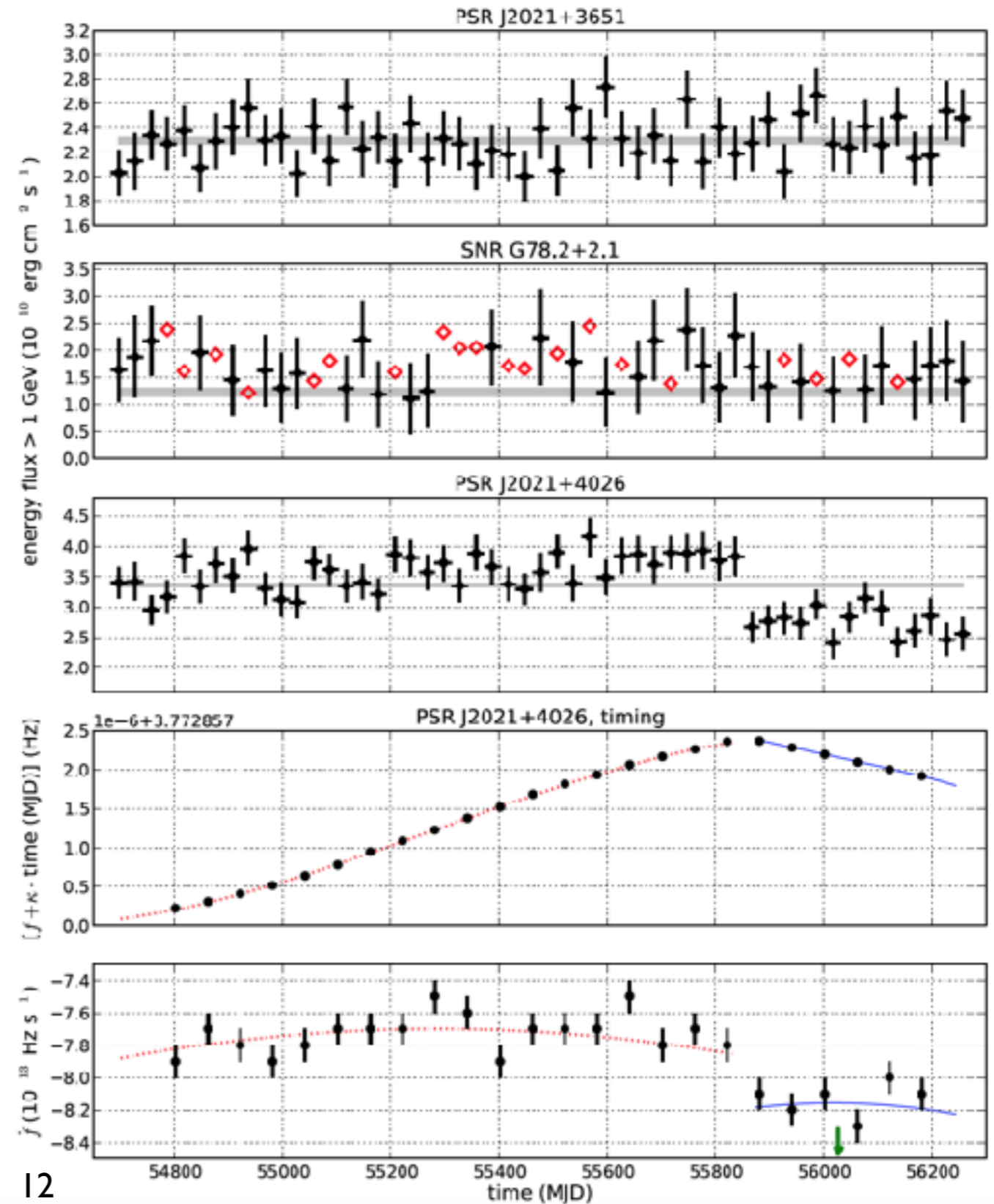
This page provides a preliminary Fermi Large Area Telescope (LAT) list of sources (FL8Y) meant to help in writing 2018 NASA Fermi Guest Investigator proposals. Based on the first eight years of science data from the Fermi Gamma-ray Space Telescope mission and the 100 MeV-1 TeV range, it is the deepest yet in this energy range. Relative to the 3FGL catalog, the FL8Y source list has twice as much exposure as well as a number of analysis improvements, but is lacking an updated model for Galactic diffuse gamma-ray emission. The FL8Y source list includes 5524 sources above 4-sigma significance, with source location regions and spectral properties. Fifty-eight sources are modeled explicitly as spatially extended, and overall 303 sources are considered as identified based on angular extent or correlated variability (periodic or otherwise) observed at other wavelengths. For 2130 sources we have not found plausible counterparts at other wavelengths. More than 2900 of the identified or associated sources are active galaxies of the blazar class, 217 are pulsars. This source list is meant to be replaced within a few months by the official 4FGL catalog which will benefit from an improved model of diffuse emission.

2900 AGN, 217 pulsars, 2130 unassociated

PSR J2021+4026:

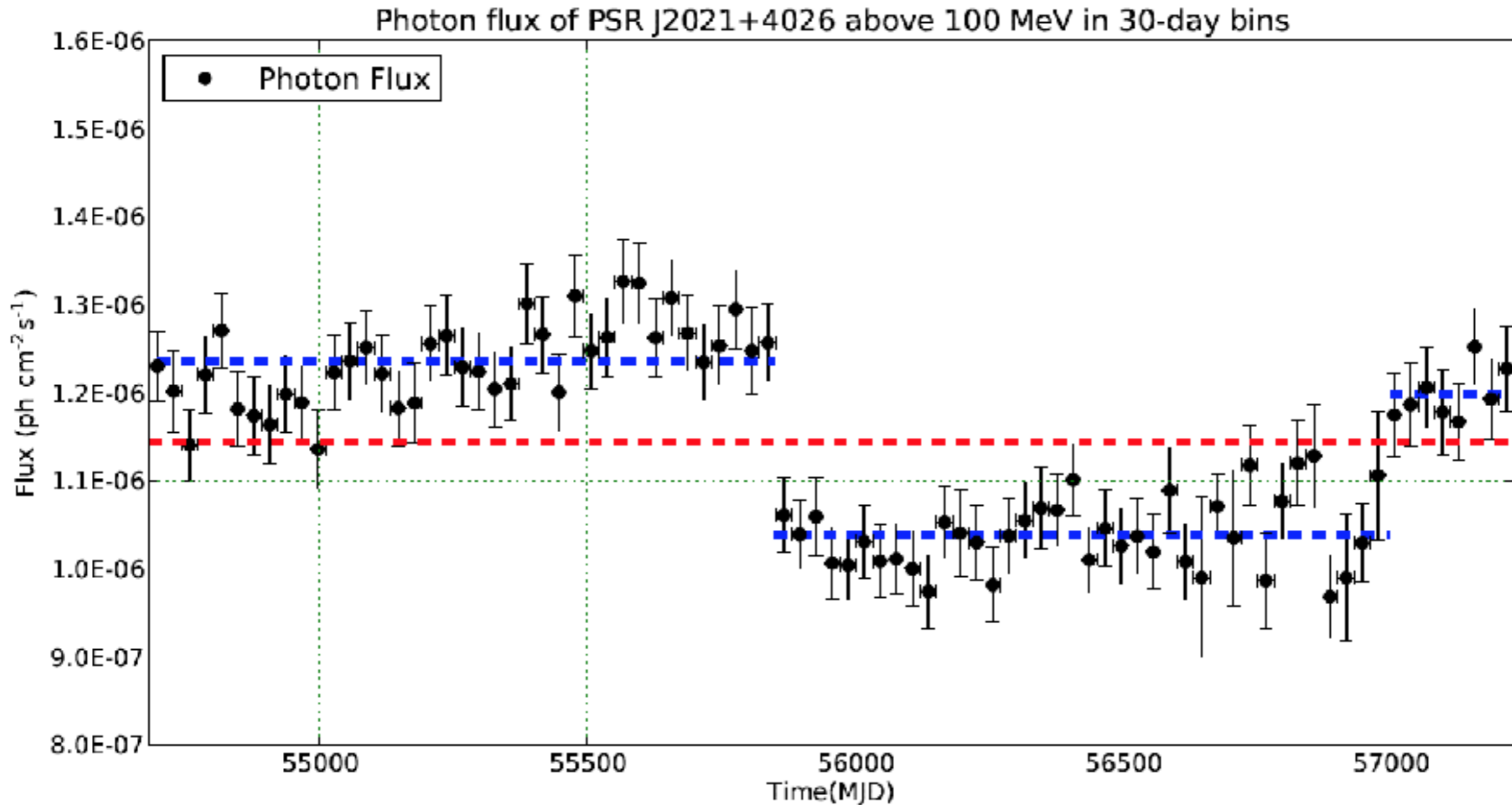
The first variable gamma-ray pulsar

- ~20% drop in flux
- Increase in spin down rate
- Changes in pulse profile
- First case of mode changes observed in gamma-ray pulsars



Allafort et al. 2013

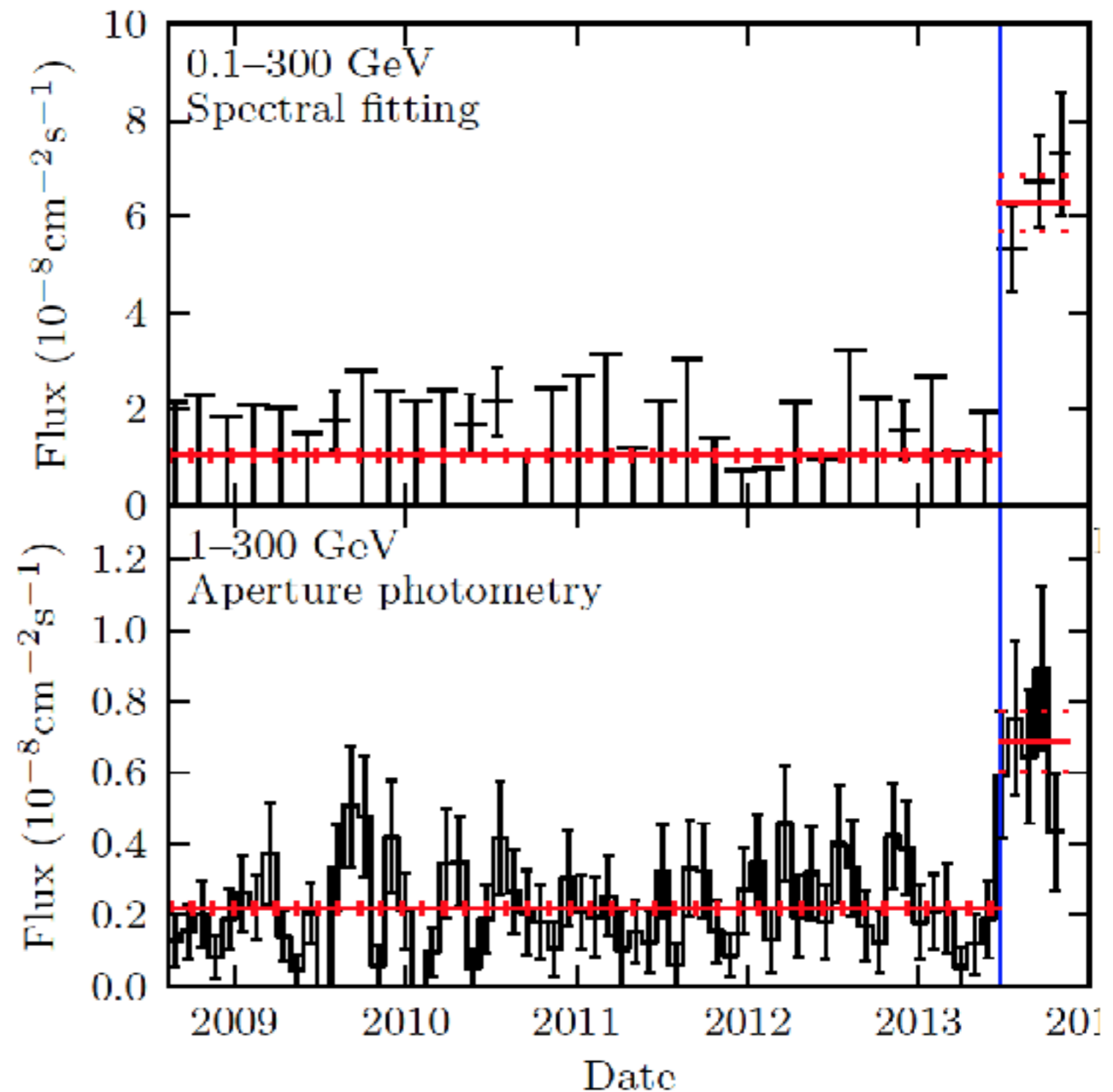
The first variable gamma-ray pulsar



Ng et al. 2016

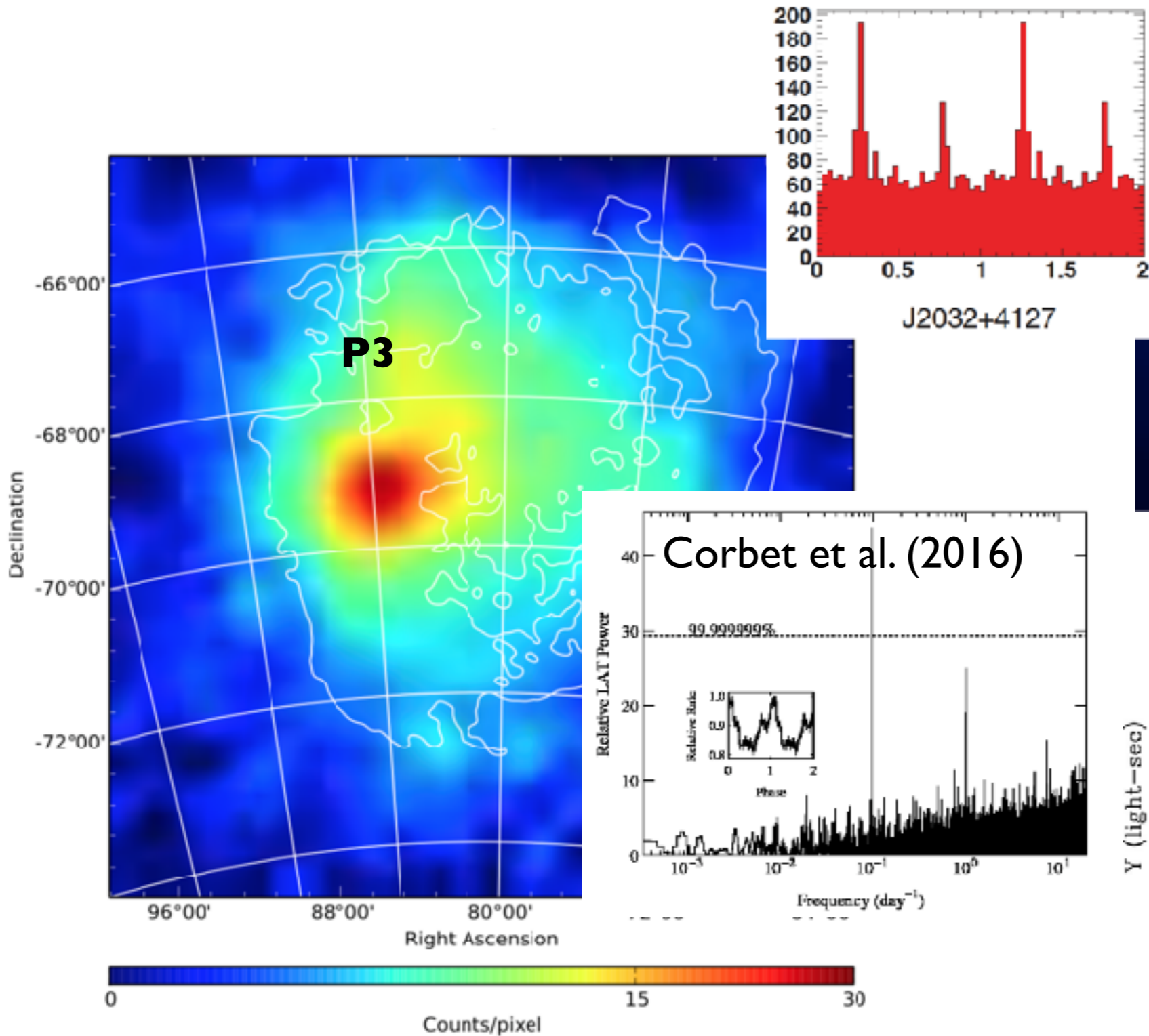
A state change in J1023+0038

- Known as the “missing link”: RPP MSP in 2009. Previously in LMXB state
- Radio pulsar disappearance coinciding with five-fold increase in gamma-ray flux
- Transition from MSP state back to qLMXB
- Radio pulsar mechanism probably still active but radio pulsations obscured
- Appears to swing between states every several years

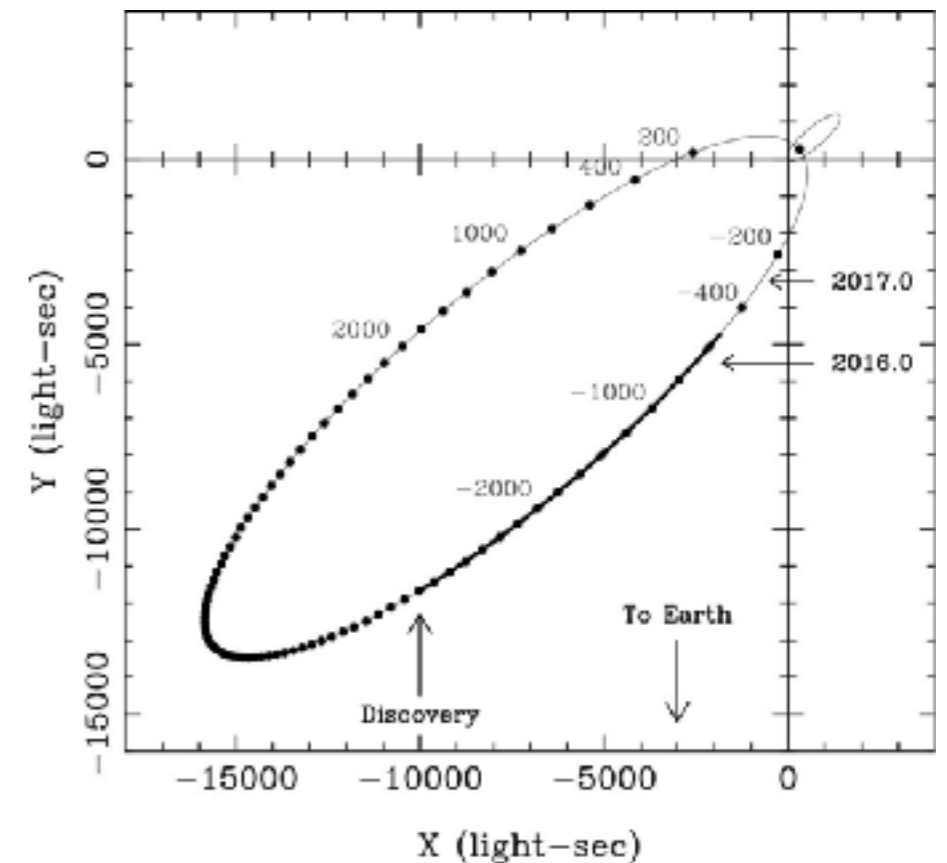
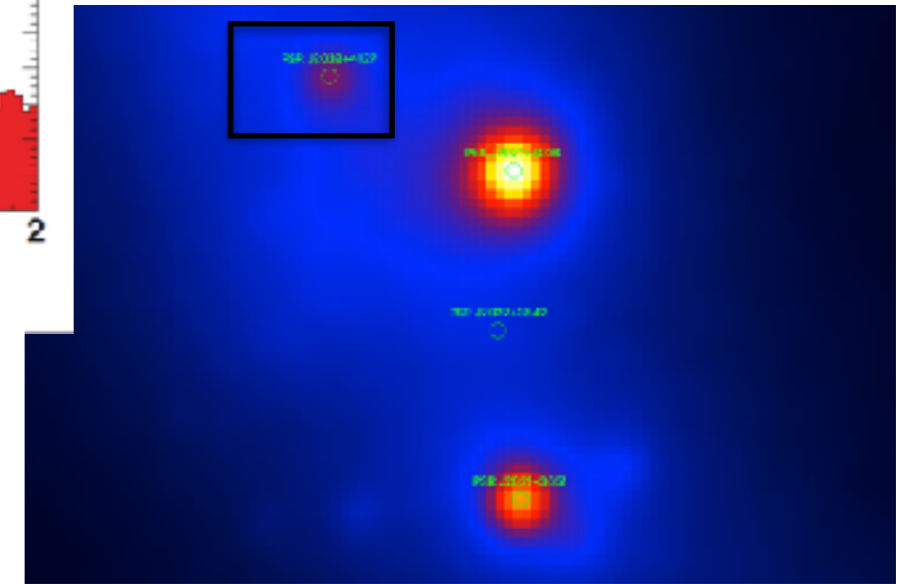


Stappers et al. 2014

Latest gamma-ray binaries

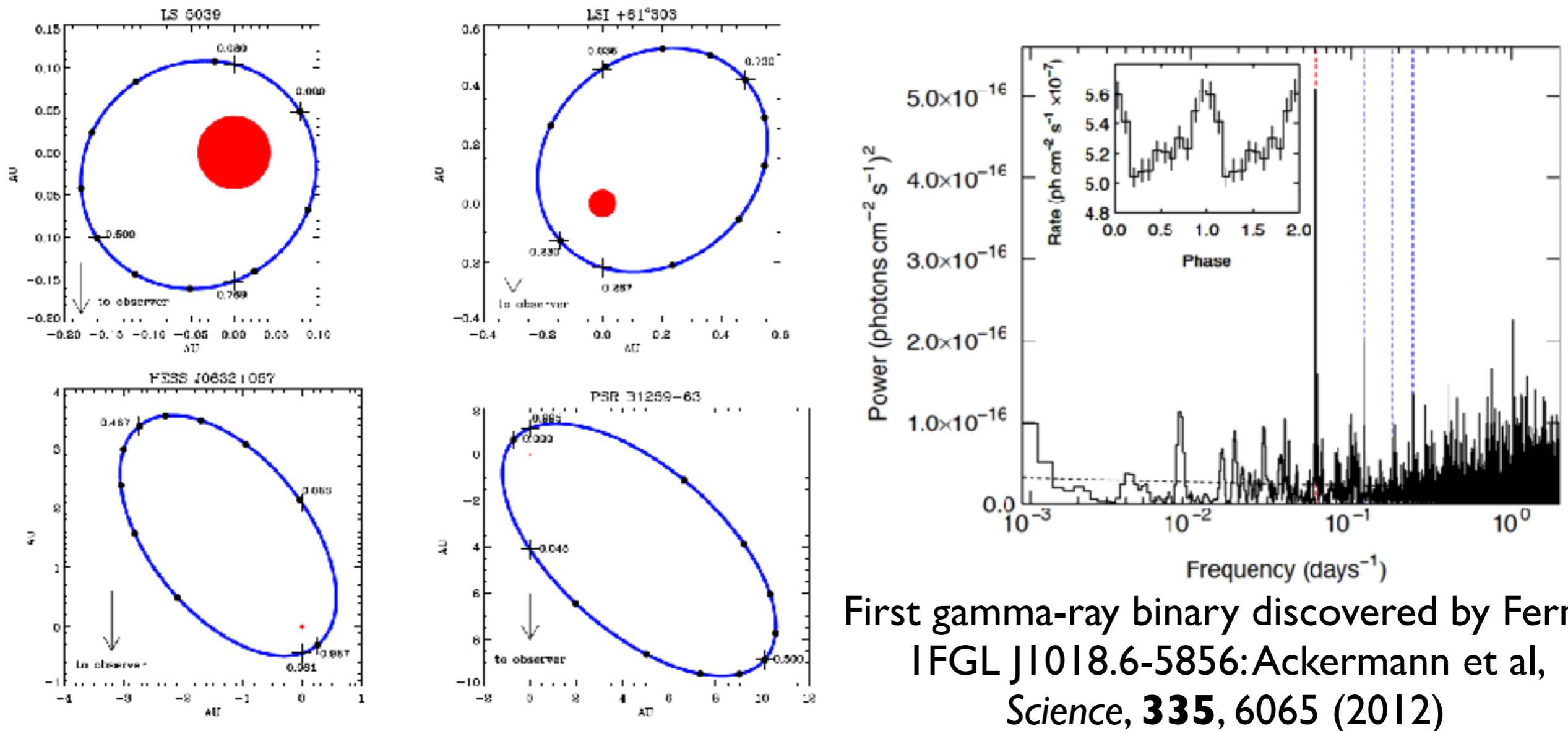


Ackermann et al. 2015



Lyne et al. 2015

Young gamma-ray binary pulsars?

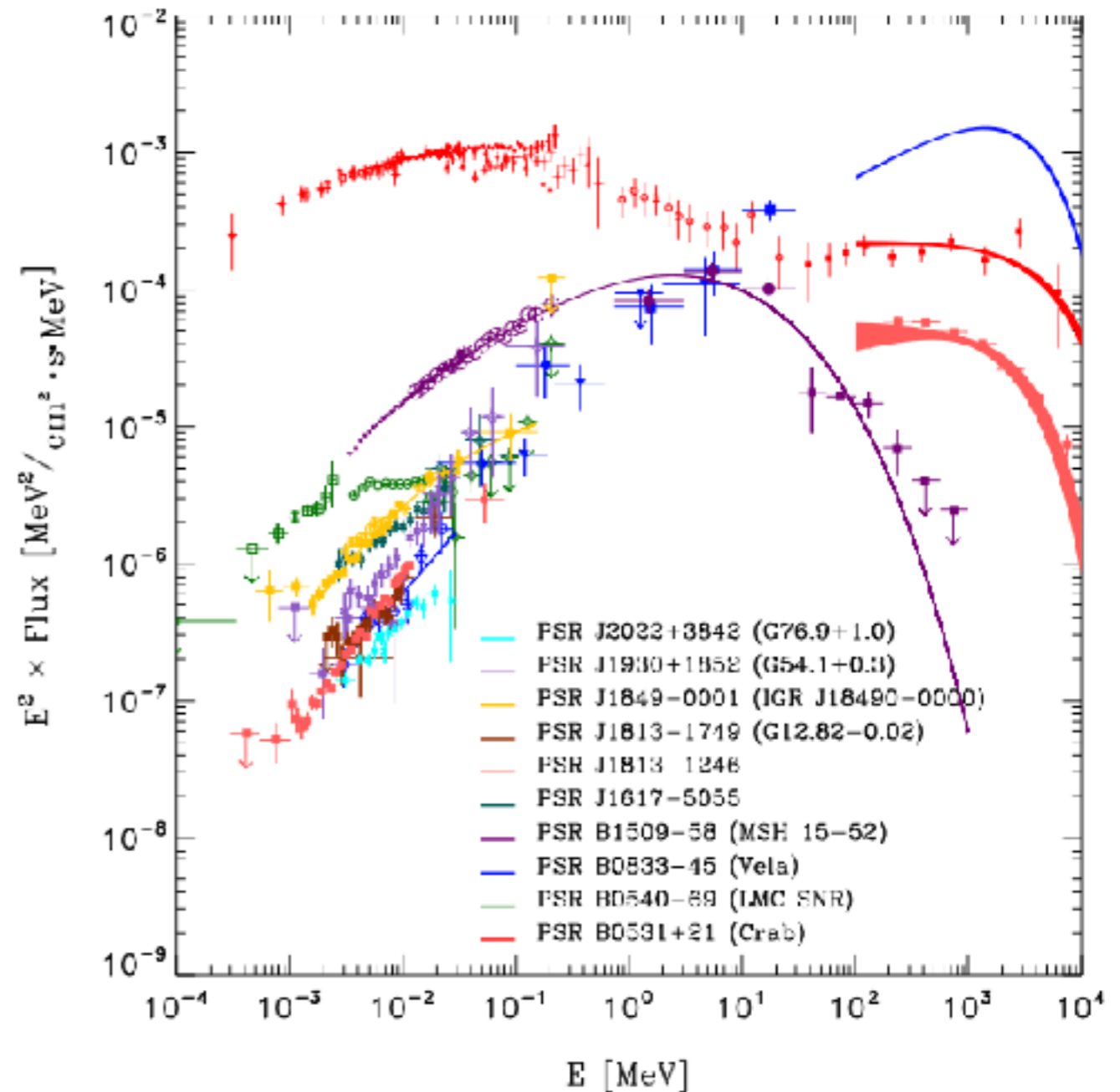


Credit: Dubus et al. 2017

Gamma-ray binaries: typically consist of a massive star in orbit with a compact object, characterized by a broad non-thermal emission peaking at \sim MeV energies.

Soft gamma-ray pulsars: a missing population

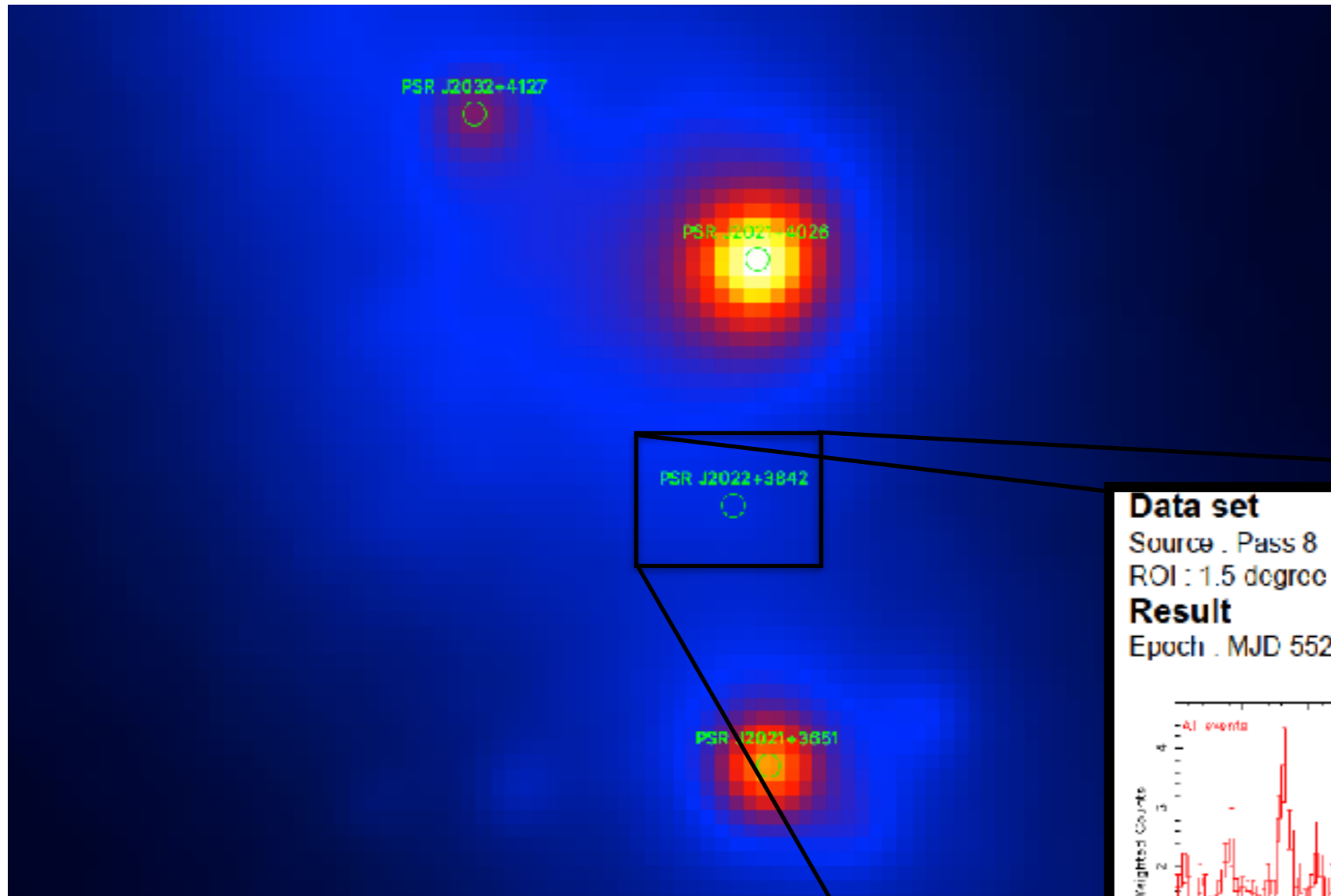
- Peak of emission below 100 MeV
- Typically young and very energetic, high B-field
- Often associated with SNRs, TeV sources
- Very few detected by Fermi LAT



Kuiper & Hermsen (2015)

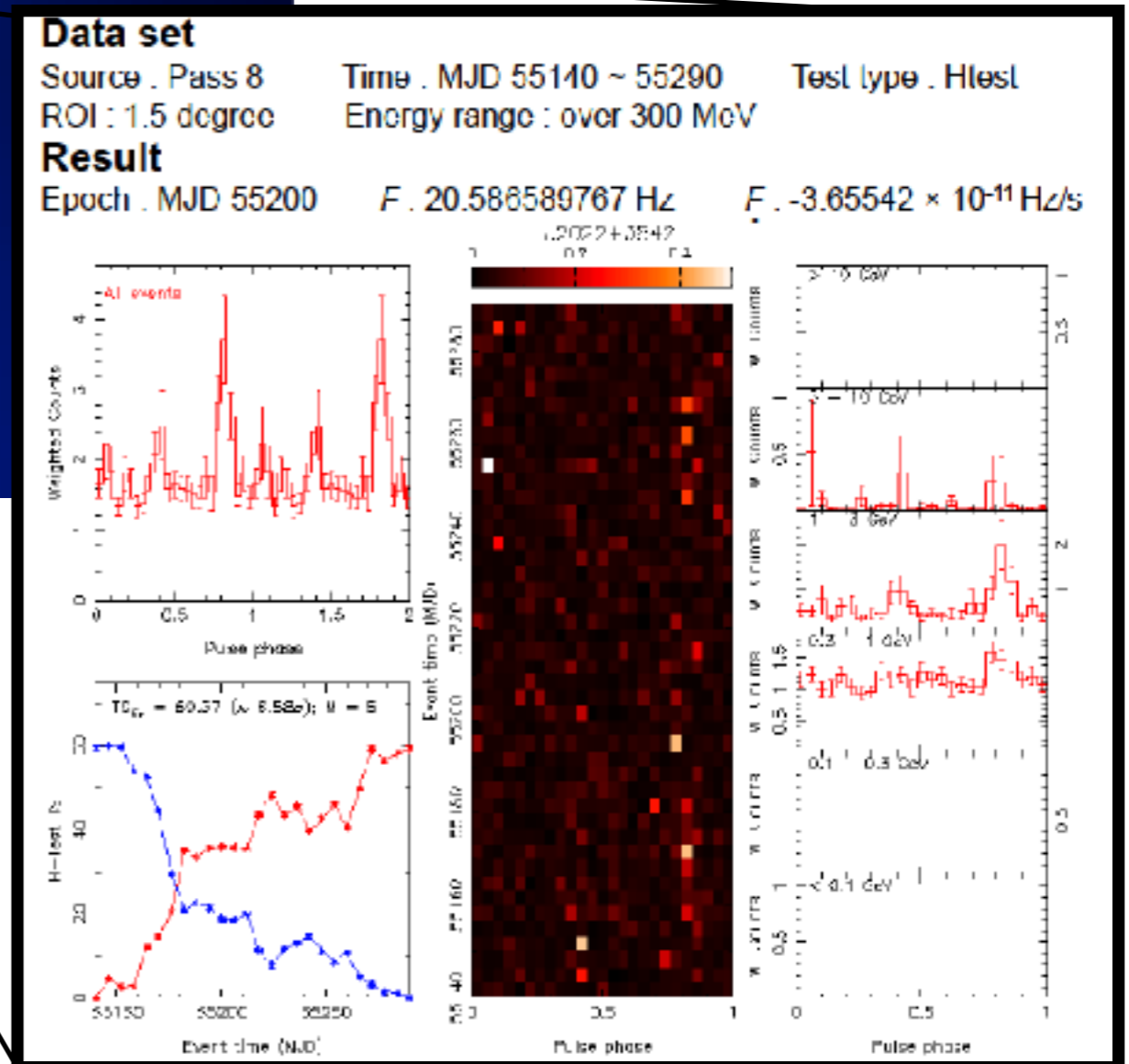
See poster by Brent Limyansky

PSR J2022+3842: soft gamma-ray pulsar?



Ohuchi et al. 2015
(Fermi Symposium)

One of the most energetic pulsars ($3E37$ erg/s), seen in X-rays and radio
Associated with SNR G76.9+1.0
Arzoumanian et al. (2011)



Summary

- Fermi is a highly efficient pulsar-finding machine, revealing energetic pulsars of (almost) all types, young, recycled, radio-loud, radio-quiet, etc.
- Long-term observations will uncover more and likely new classes of pulsars and behaviors ...
- Multi-wavelength observations are crucial: radio, soft and hard X-rays, MeV, TeV, etc ... the recent addition of FAST to the PSC will have a big impact!

Extra slides

Finding soft gamma-ray pulsars is hard

