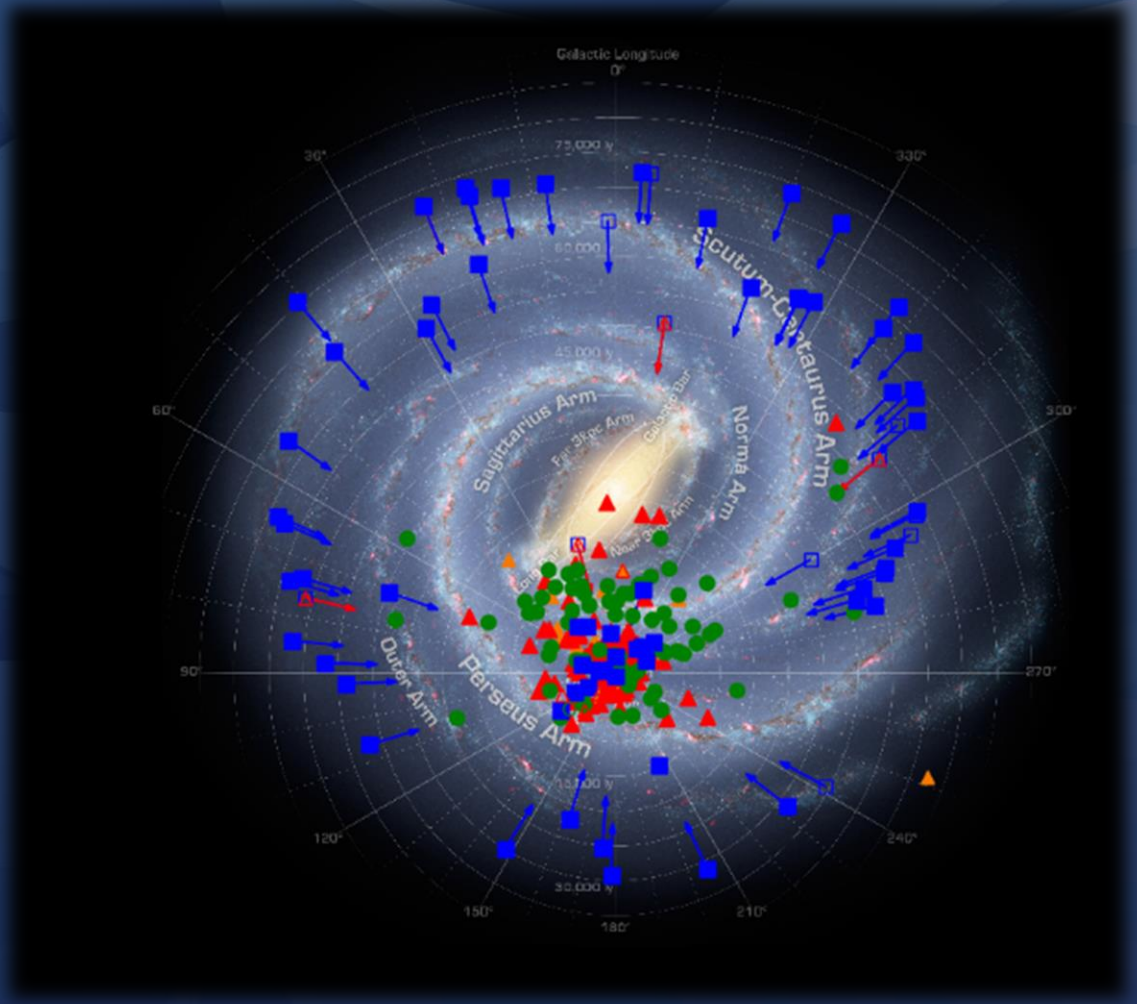
U.S. NAVAL RESEARCH LABORATORY

The *Third* Fermi-LAT Pulsar Catalog

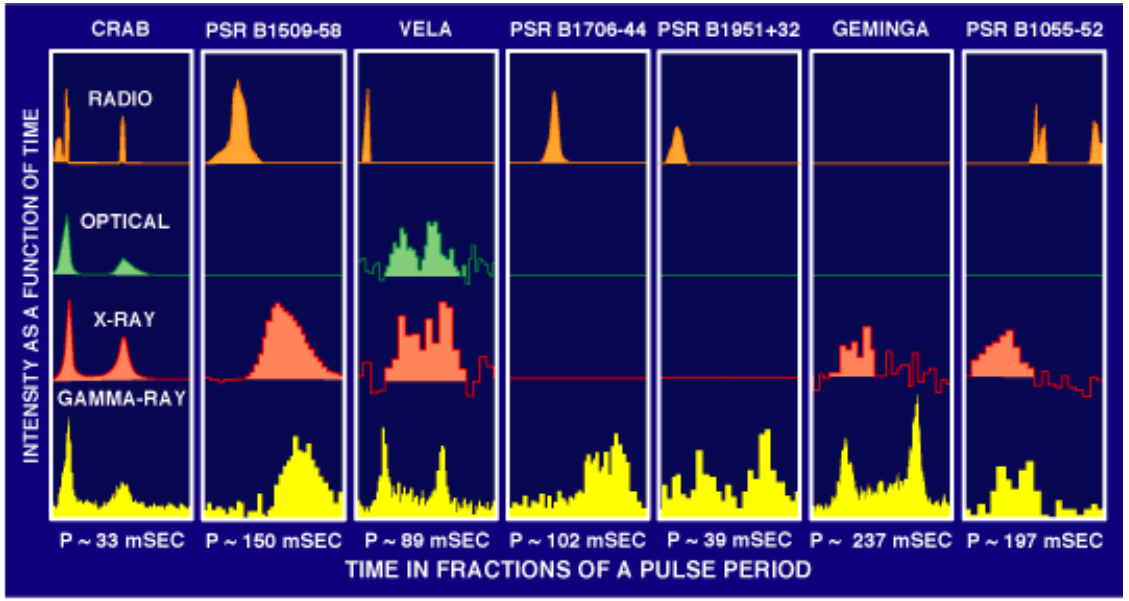
On behalf of *many*, including the Fermi-LAT Collaboration!



April 16, 2021 / Ninth International Fermi Symposium
Matthew Kerr, U.S. Naval Research Laboratory

A Brief History of Gamma-ray Pulsar Catalogs

The “Thompson” plot: despite a very successful CGRO mission, most of what we knew (observationally) about high-energy pulsar emission could fit on a postcard!



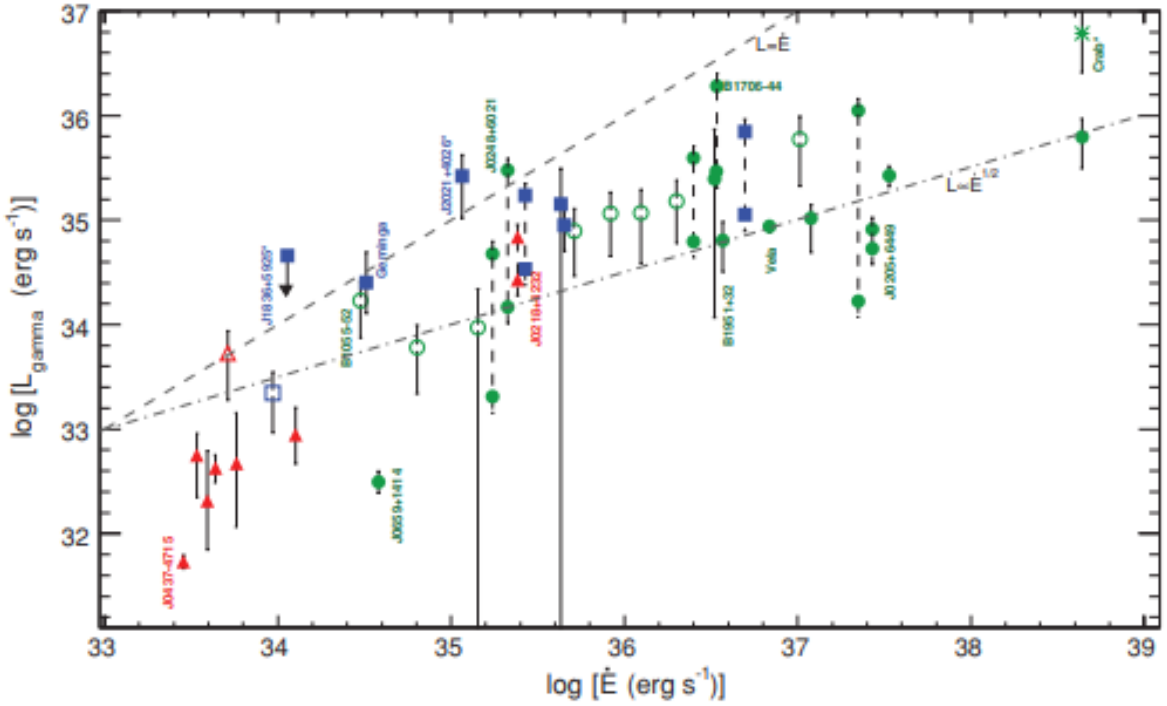
A Brief History of Gamma-ray Pulsar Catalogs

Fermi-LAT changes this with the detection of populations of millisecond pulsars (MSPs), radio-quiet gamma-ray pulsars, and radio-loud young pulsars.

The **First** LAT Pulsar catalog (1PC) contains **46** pulsars and is based on **6 months** of LAT data.

One of the main results from any of these pulsar catalogs is the distribution of gamma-ray luminosities vs "Edot", which ties the observational aspects of the pulsar populations to their physical properties.

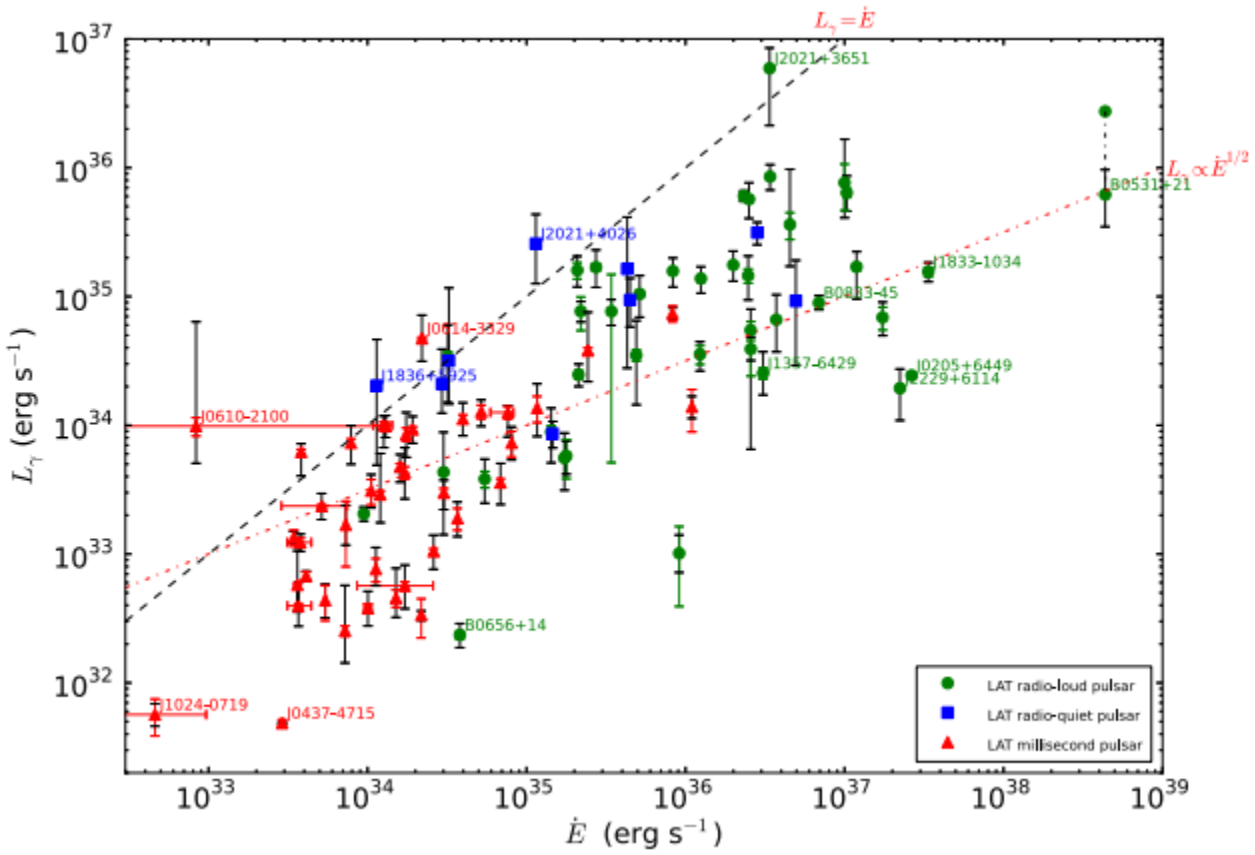
Also one of the most difficult – distances are hard to estimate, Edot may be biased, selection effects…



A Brief History of Gamma-ray Pulsar Catalogs

The **Second** LAT Pulsar catalog (2PC) contains **117** pulsars and is based on **3 years** of LAT data.

It includes many more MSPs, found through successful efforts by the Pulsar Search Consortium.

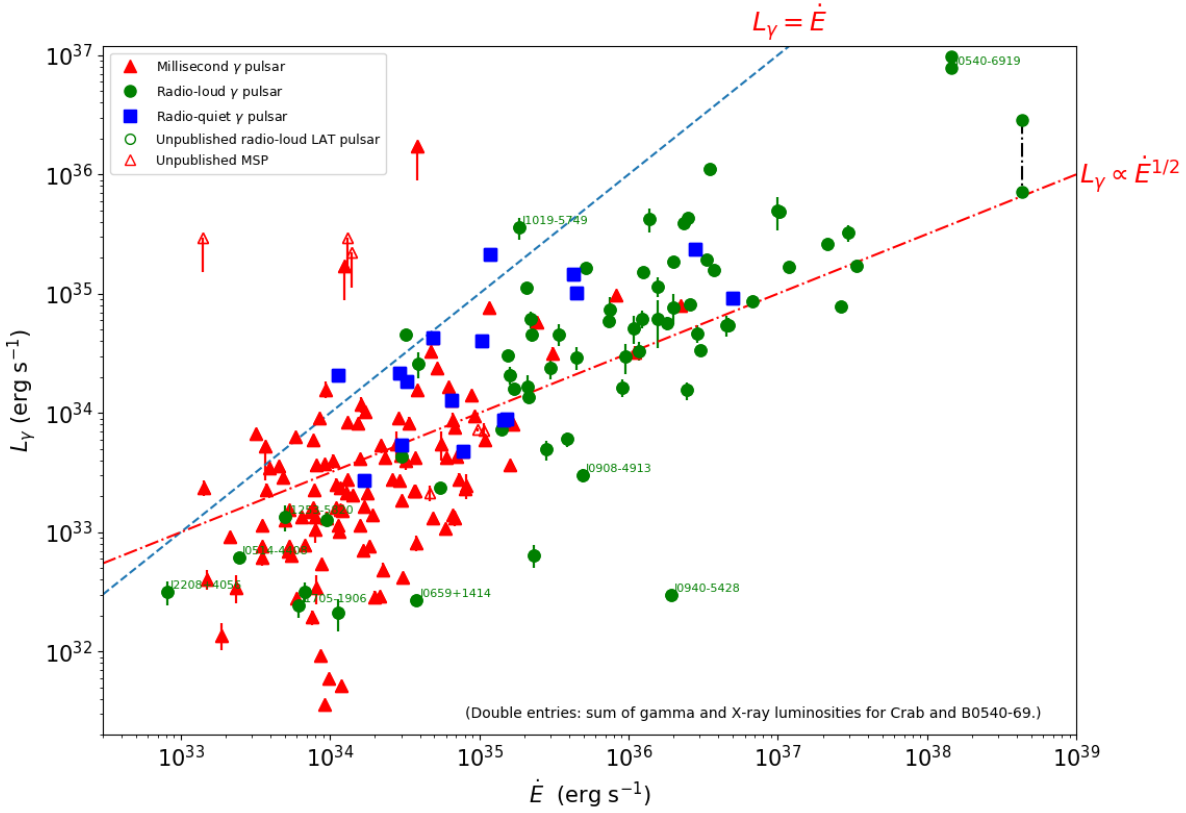


The Future History of Gamma-ray Pulsar Catalogs

The **Third** LAT Pulsar catalog (3PC) contains **270 (300)** pulsars and is based on **>9 years** of LAT data.

It has grown through substantial contributions from:

- improved blind search techniques
- searches of ~1000 radio pulsars down to low Edots
- more MSP discoveries by the PSC
- discoveries of compact binaries (spiders) through constrained blind searches



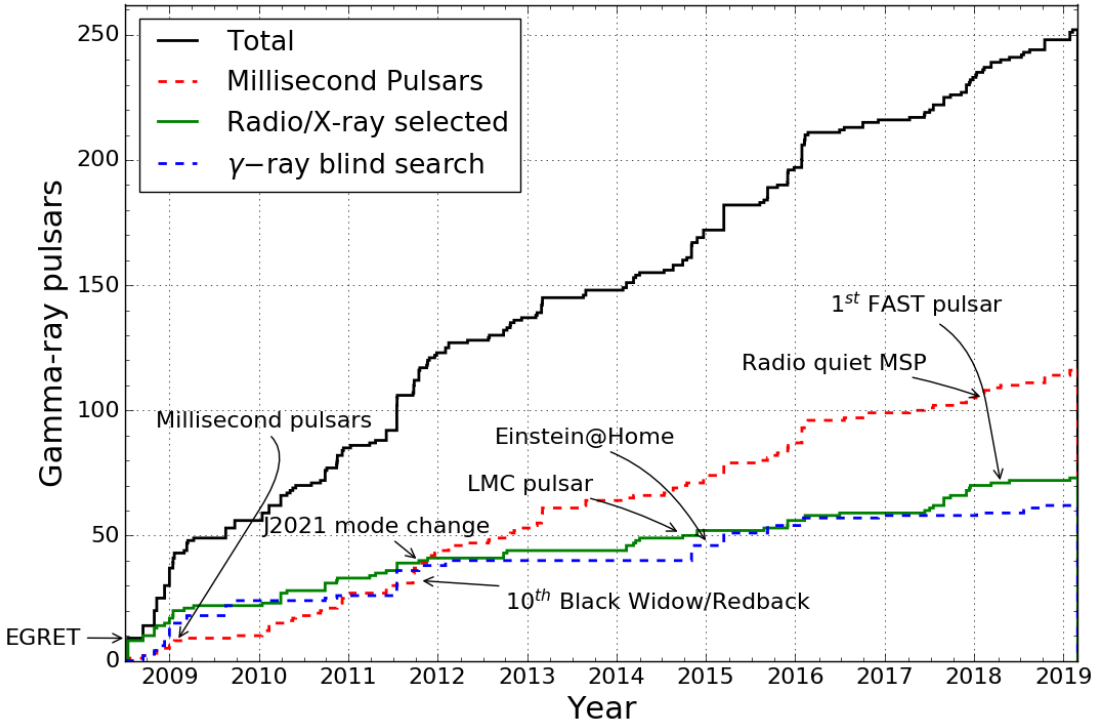
*30 MSPs have been discovered by radio observations of Fermi sources, but we don't yet have timing solutions to confirm gamma-ray pulsations

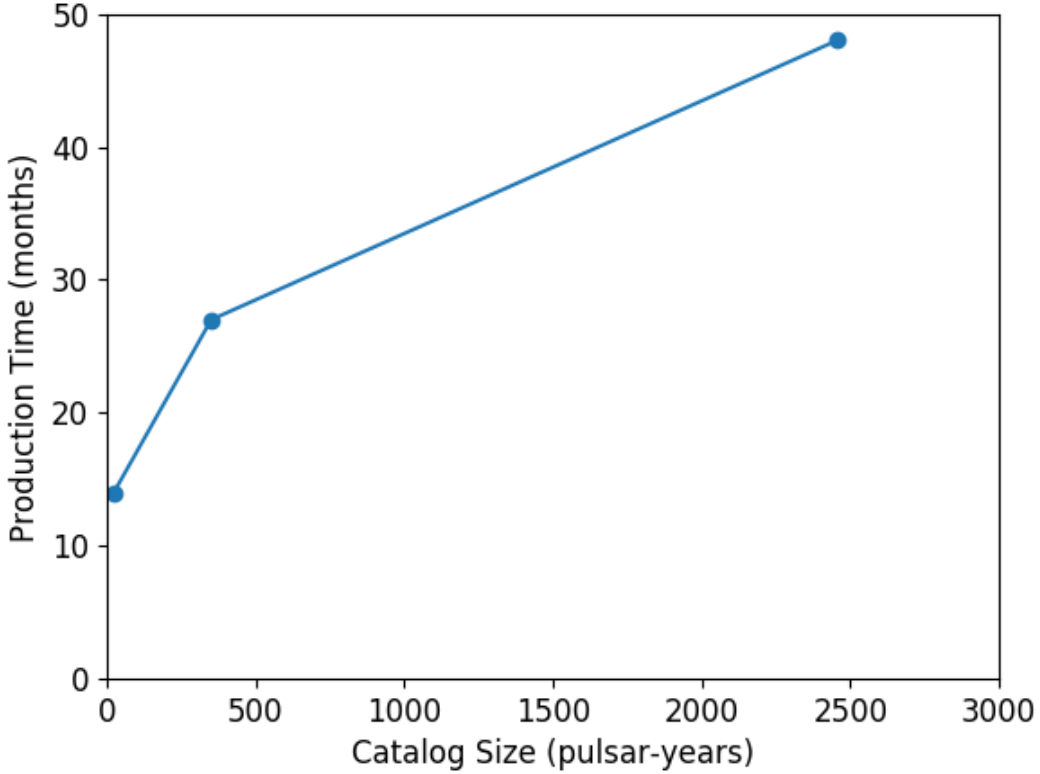
A Note on Timelines

1PC was published Apr 2010: 0.5 years of data, 46 pulsars → 14 month production time

2PC was published Oct 2013: 3.0 years of data, 117 pulsars → 27 month production time

3PC: 9.1 years of data, 270 pulsars → 48 month (?) production time





The 3PC Sample

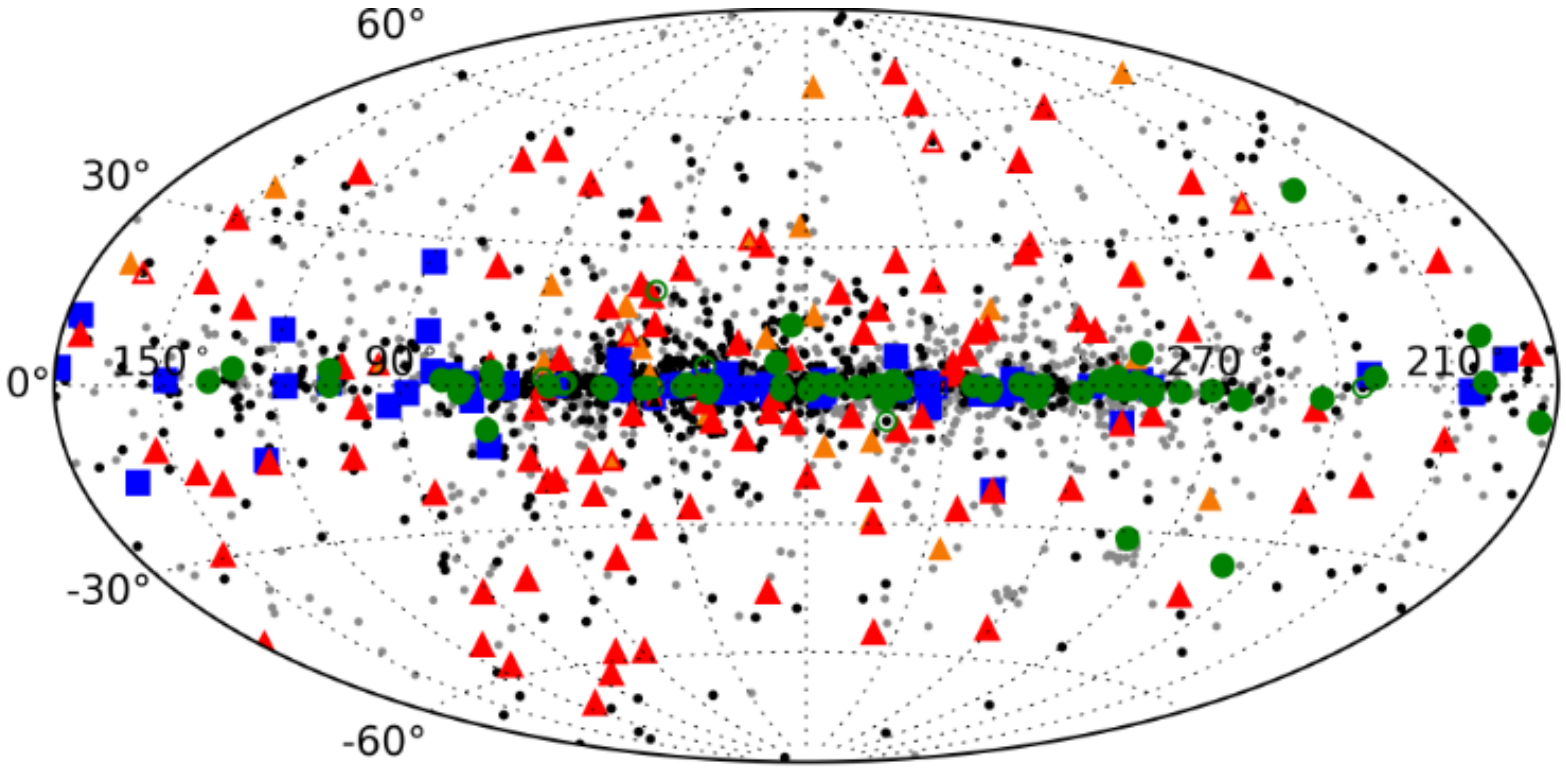
270 (+30 “MSPs”) = 300

144 young/middle-aged

- 76 radio loud (29%)
- 68 radio quiet (25%)

126 millisecond pulsars (47%)

- 29 isolated
- 97 binary
  - 30 black widows
  - 9 redbacks
  - 2 tMSPs



What's in 3PC?

Timing solution through >= MJD 58,000

- Advanced techniques to handle timing noise, orbital period variations, …

Light curves (gamma-ray and radio)

- analytic models and analytics (number of peaks, peak separation, radio-gamma lag…)

Astrometry

- population studies and Shklovskii correction (critical for MSP efficiency!)

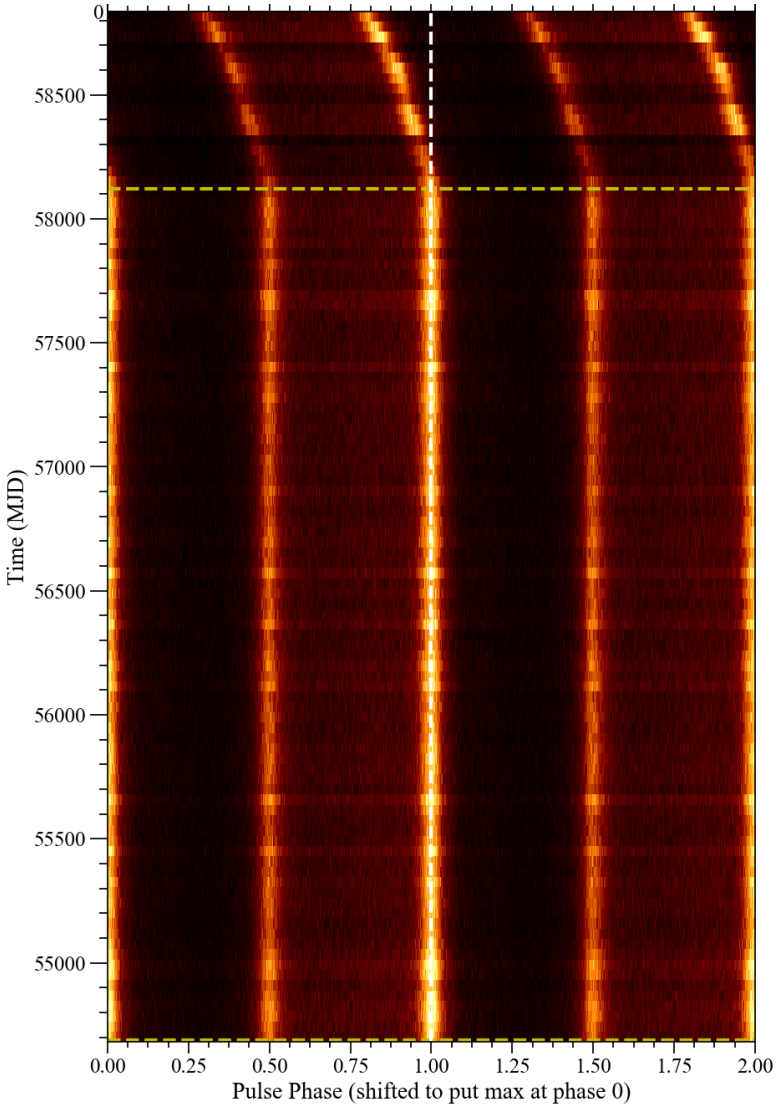
Distances

- critical for luminosity, population studies, efficiencies, diffuse contributions

Radio fluxes: radio-gamma connection, population synthesis

Spectra

Sensitivity & Selection effects (kindof)



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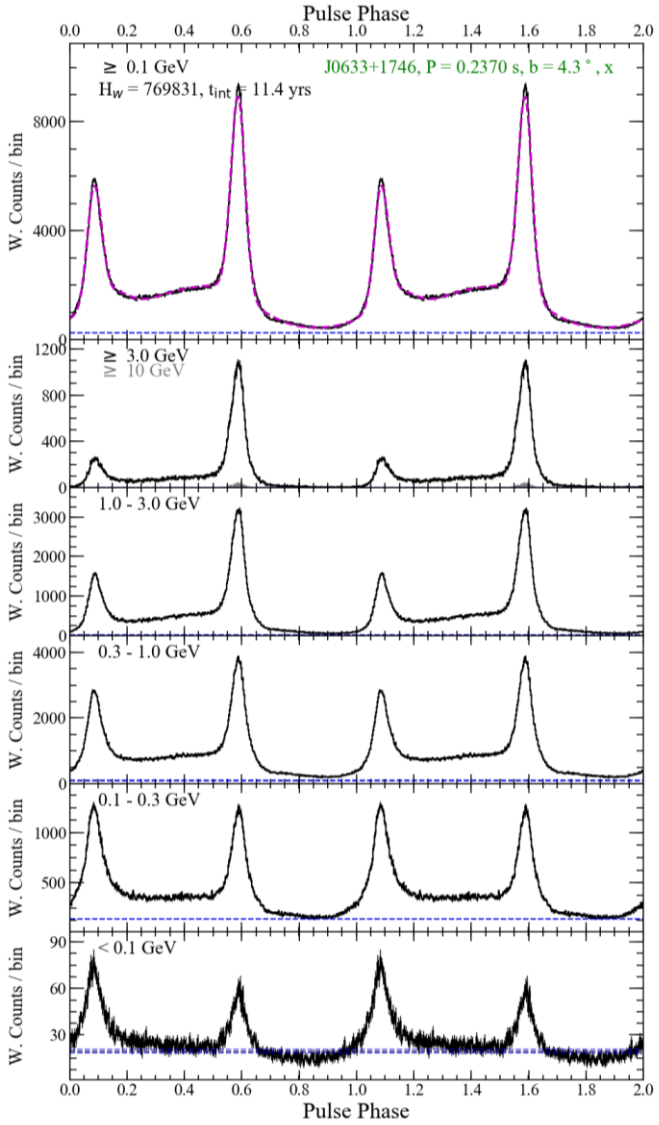

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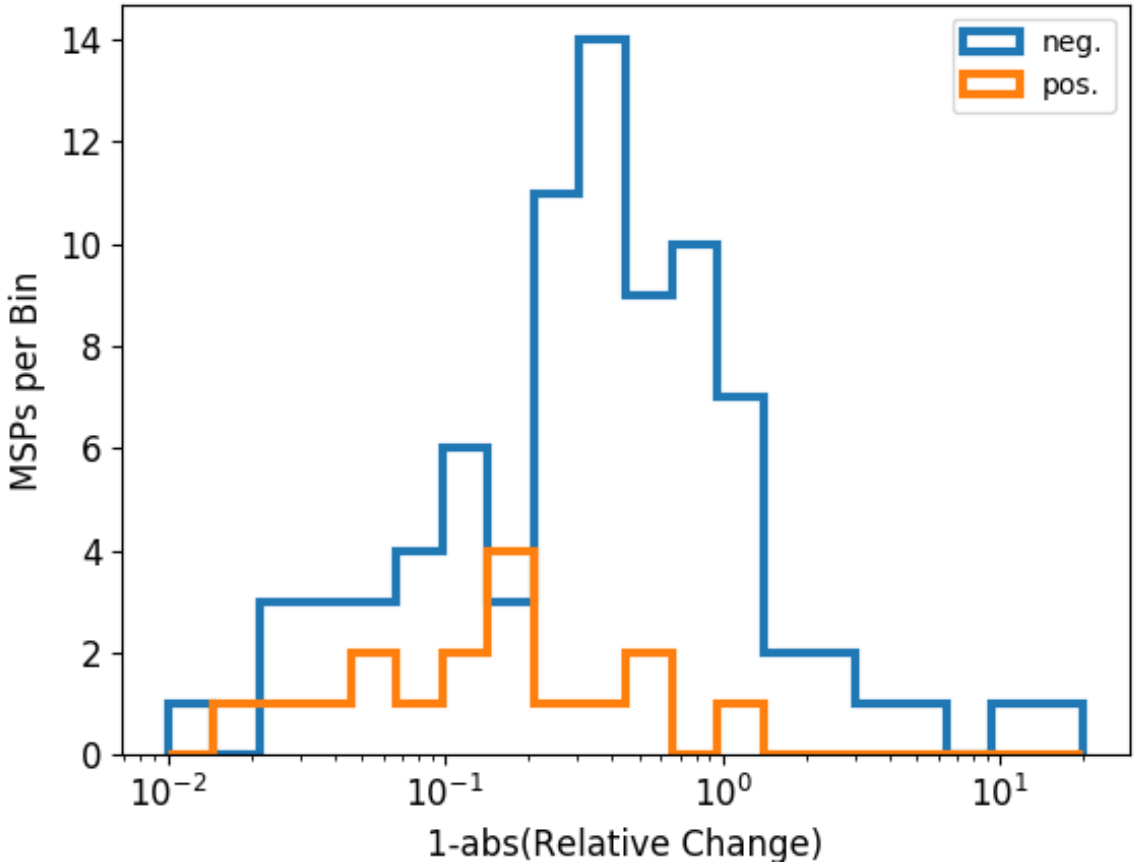

How Edot changes with Shklovskii and Galactic potential corrections. X=1 ←→ 100% change in Edot.

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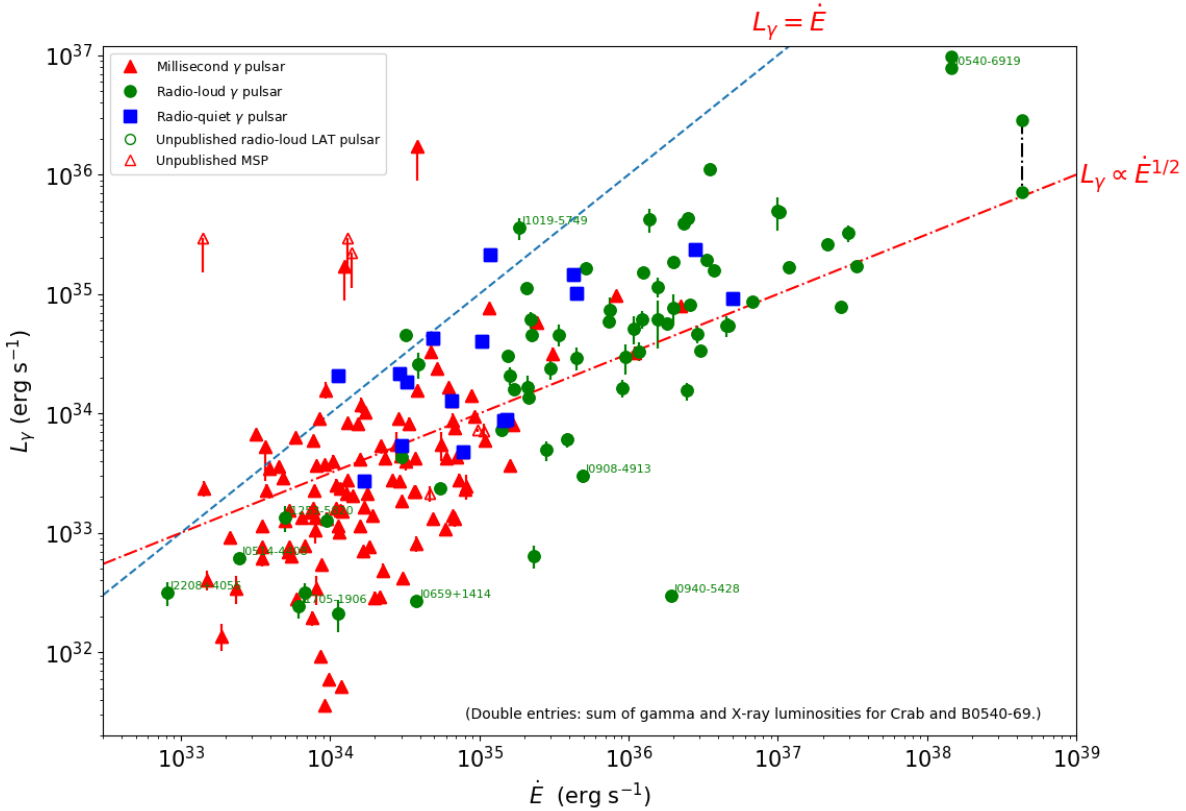

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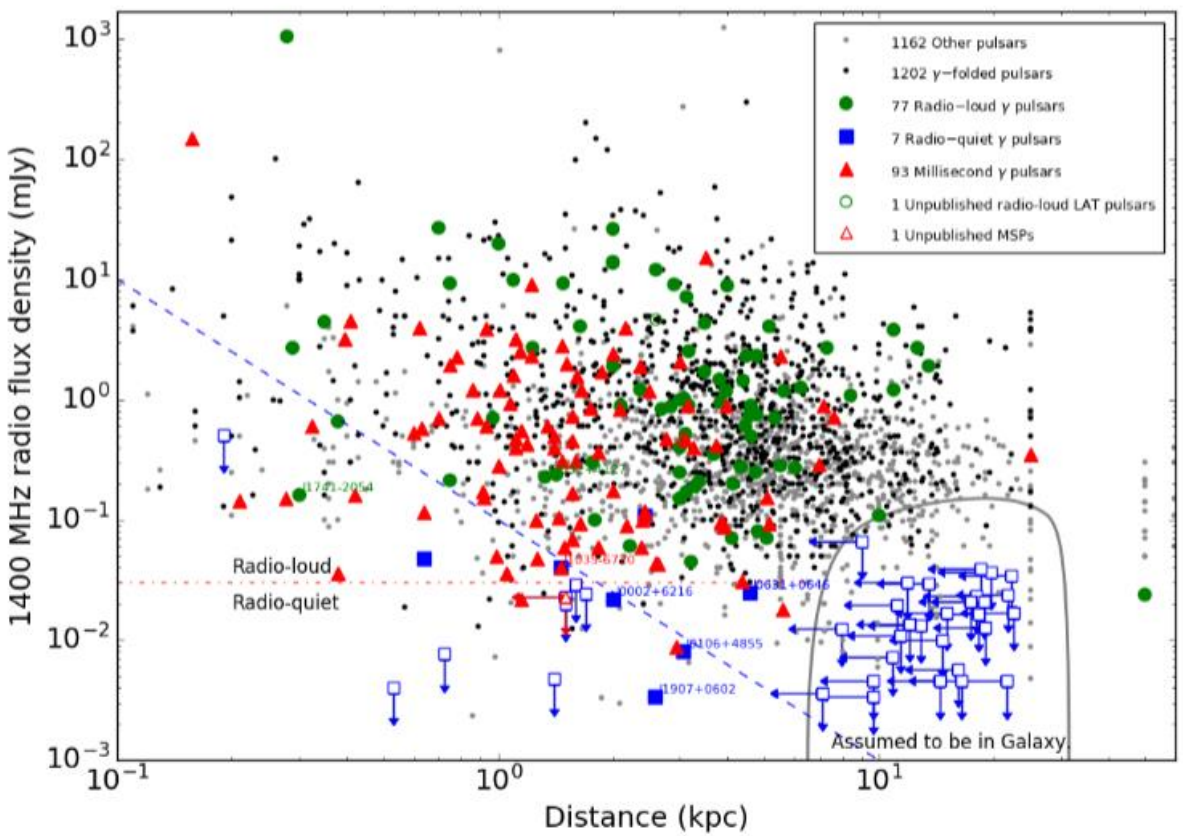

Lack of gamma-ray/radio flux correlation continues

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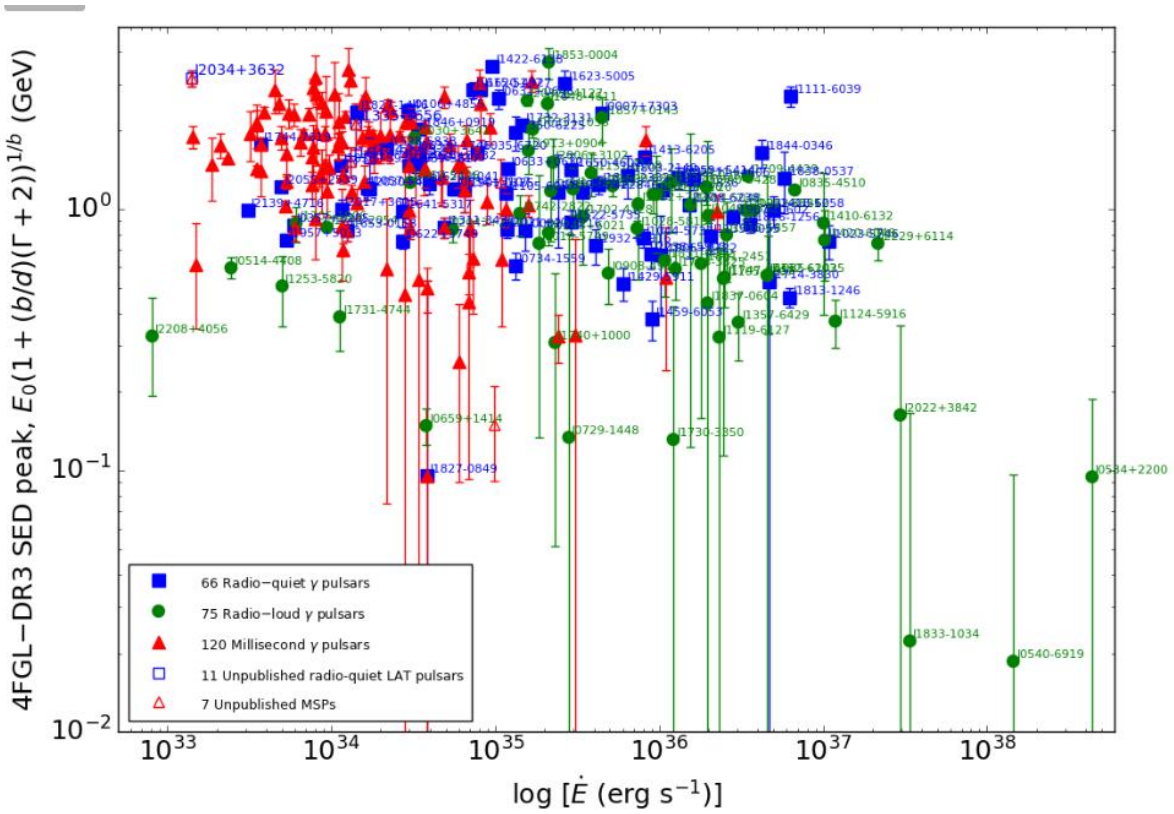

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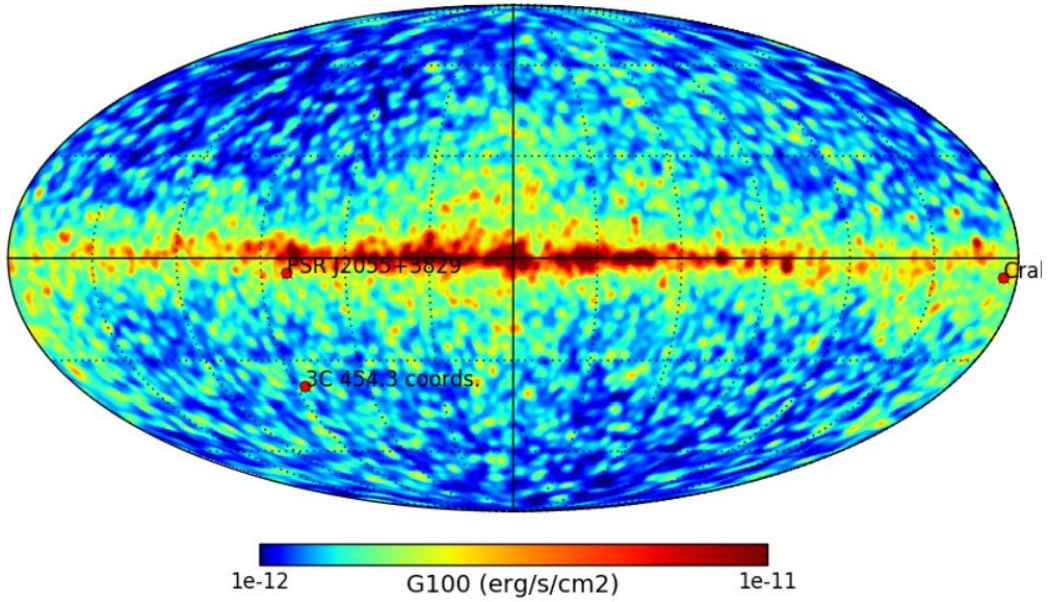


Sensitivity for point sources; discussion of extensive search for low-Edot radio pulsars; discussion of missing high-Edot radio pulsars; discussion of blind search selection effects.

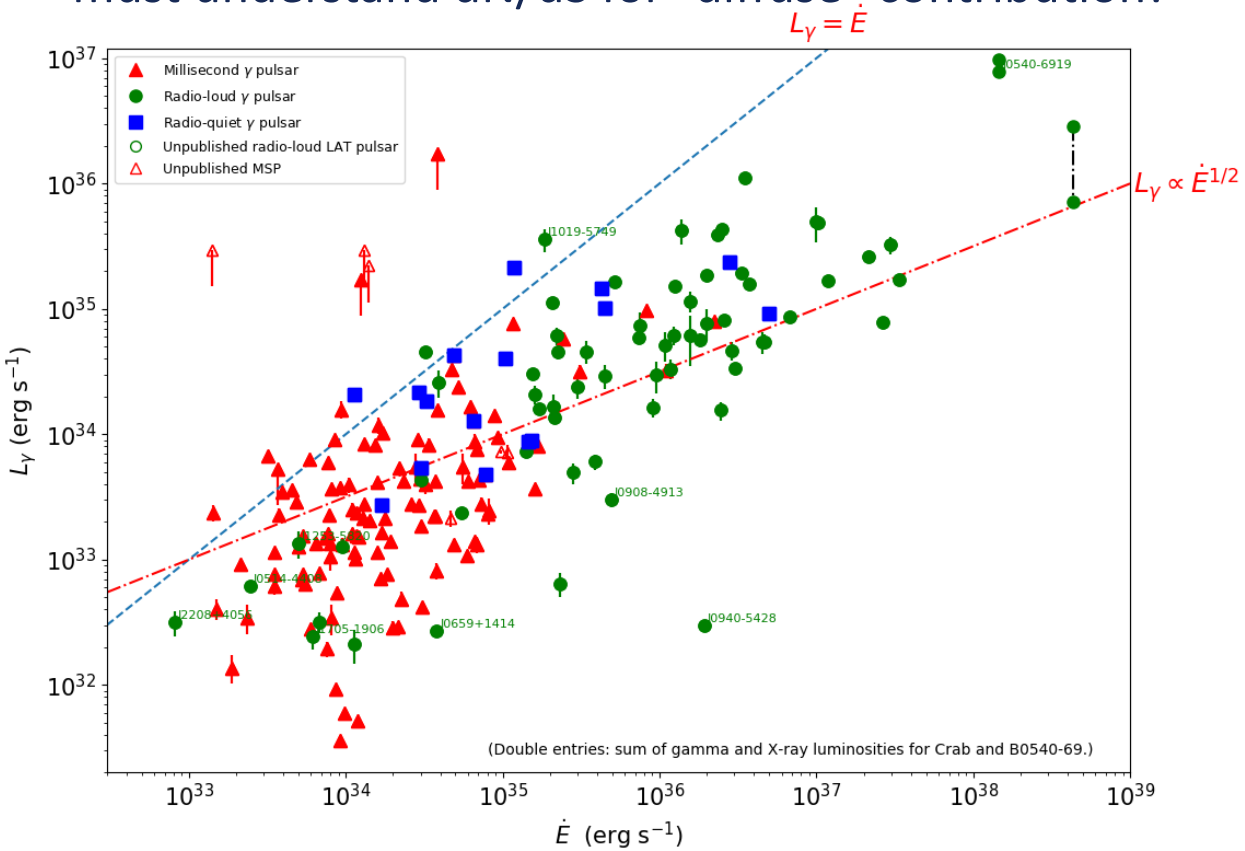
Complicated…

Science with populations: Energetics and Death Lines

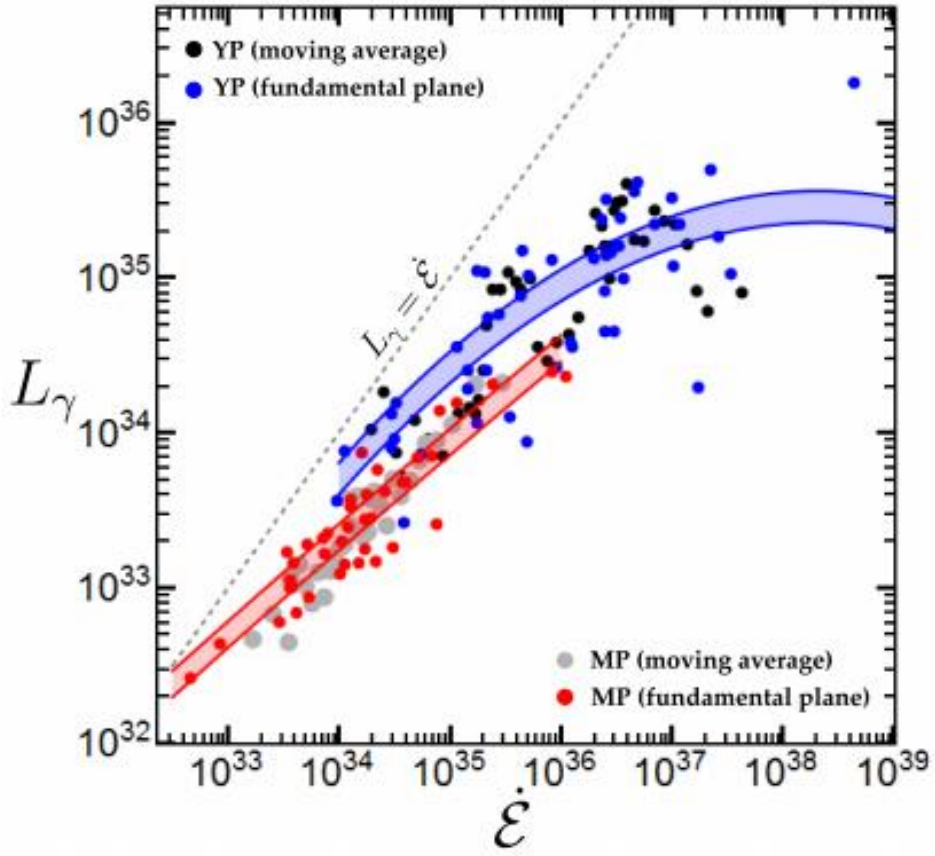
2PC made great strides in understanding young pulsars (delta/Delta + theoretical developments cement outer magnetosphere picture)

3PC will extend to middle-aged pulsars and MSPs:

must understand dN/dS for "diffuse" contribution!



Kalapotharakos et al., 2019



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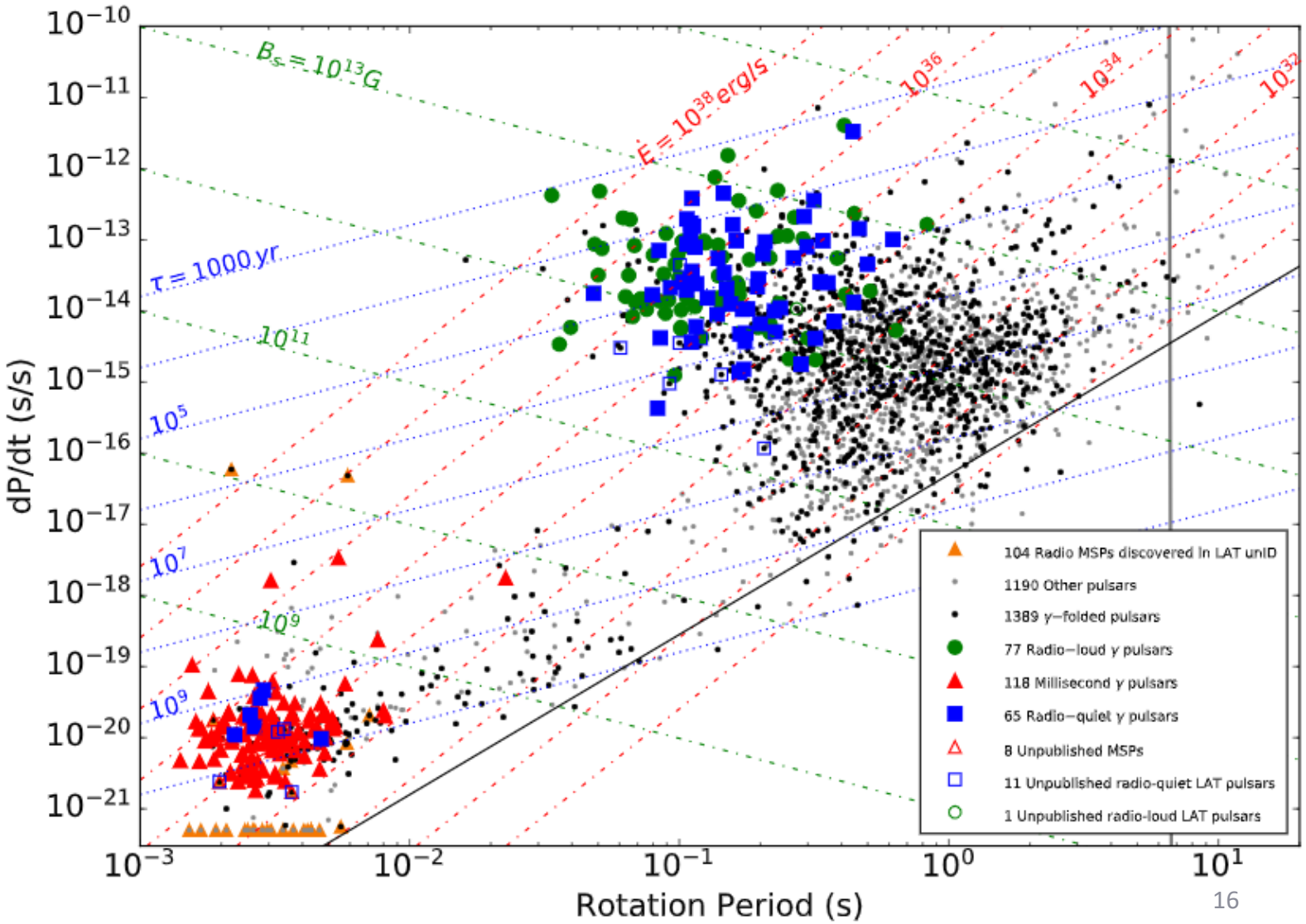

Summary and Looking Forward

3PC has all of the goodies of 1PC and 2PC, but with a much larger, more diverse data set.

Many more MSPs, especially in compact orbits.

It is enhanced with the fruits of ancillary studies helping to understand selection effects: how many radio pulsars have we searched? What is the real beaming fraction of young pulsars?

It is a huge amount of effort… but it is progressing and we expect a (2021) reference.

Theorists/observers/everyone: It is not tooooooo late to request a piece of analysis for the catalog. But please hurry :)