Summary

1. Overview of Parkes Timing of Young Pulsars
2. Ancillary Science: Planets & Precession!
3. New Gamma-ray Pulsars & Implications

From Gamma-rays to Precession

Latest Results from Parkes Pulsar Timing

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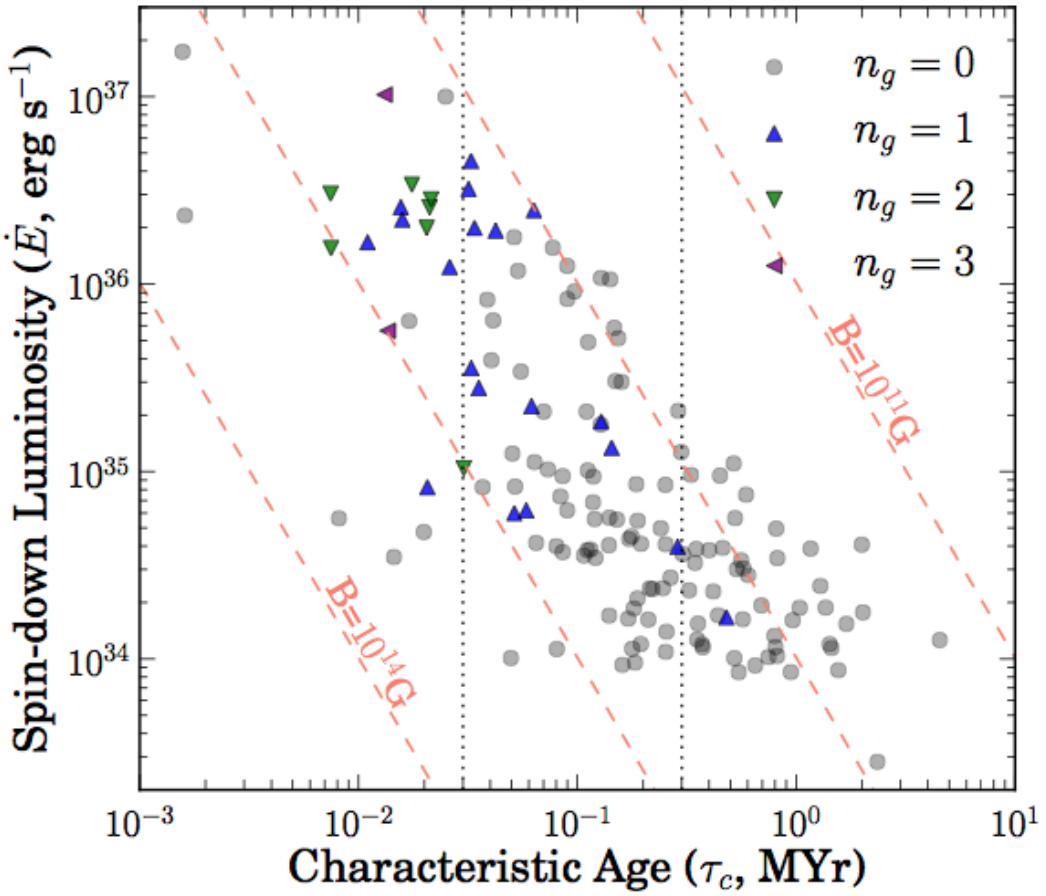
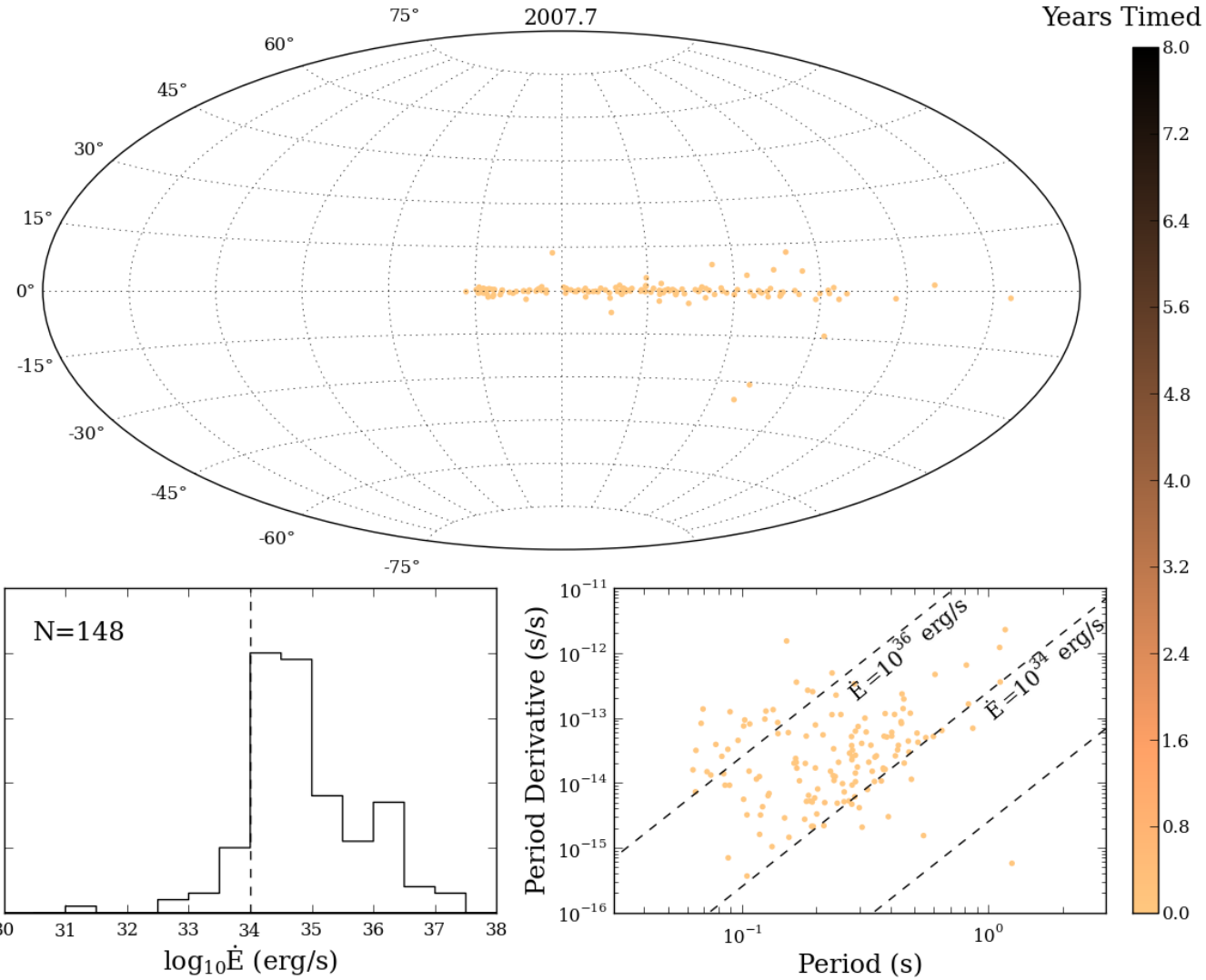
November, 2015 / Sixth Fermi Symposium

P574: Young Pulsar Timing with Parkes

- 2007: Time more than 150 pulsars to provide ephemerides for searching for pulsation in Fermi data.
- Because pulsar distances are unreliable, be guided by physics and choose ALL pulsars with spin-down luminosity > 10^{34} erg/s.
  - This is extremely useful, as it is a minimally biased sample.
- Now running for nearly eight years.
  - A rich data set full of pulsar glitches, multi-frequency data, timing noise…



An Ever-expanding Program



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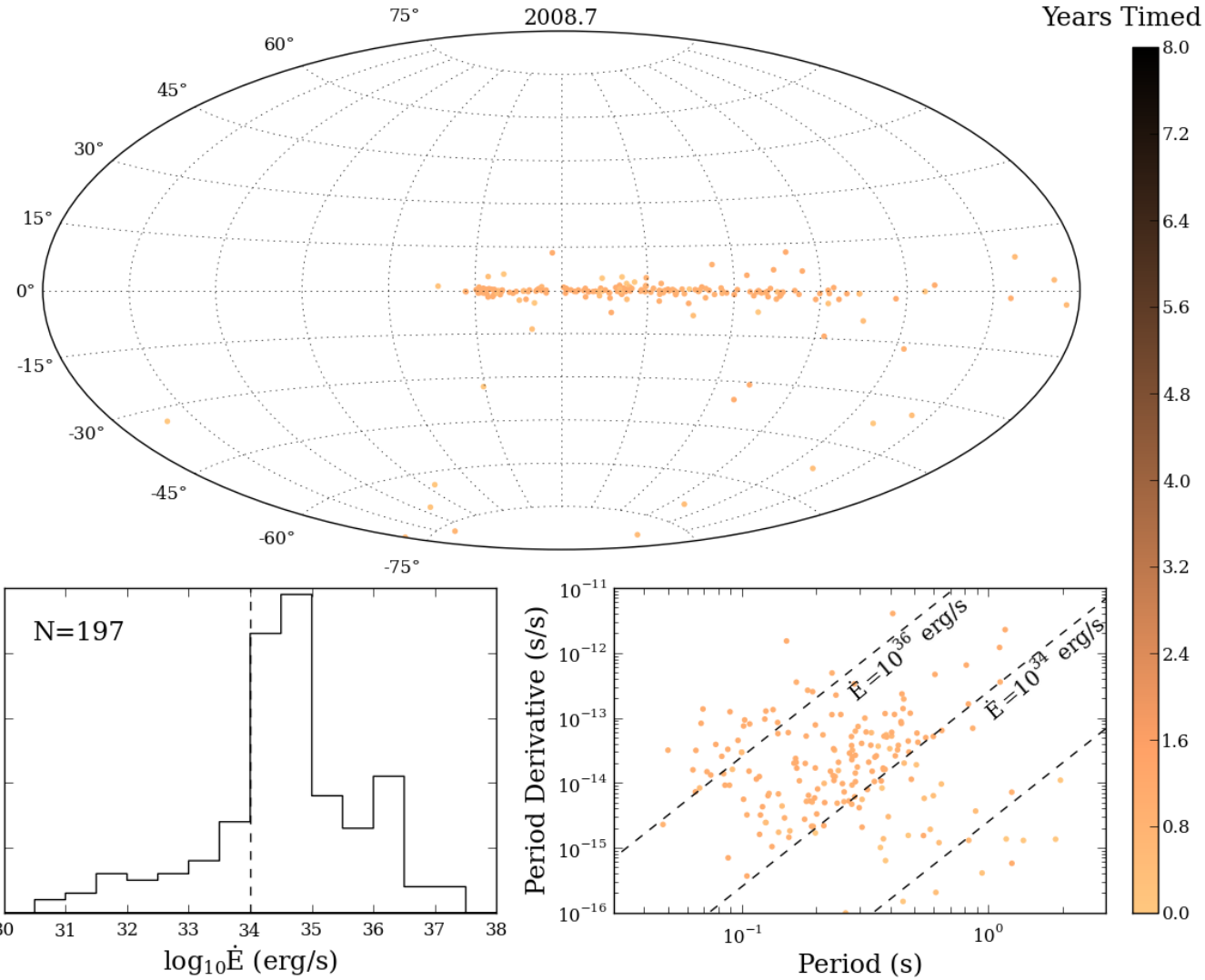

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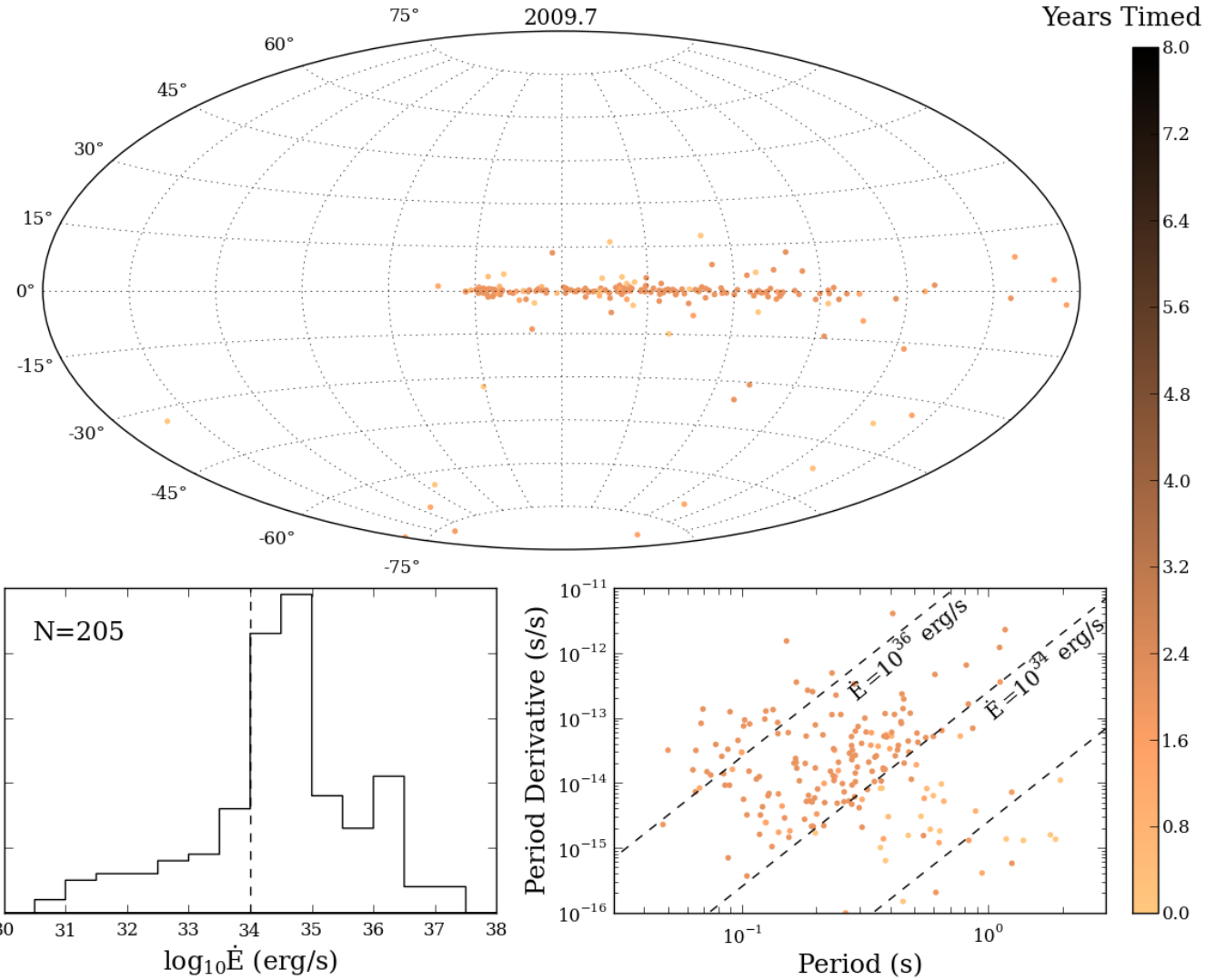

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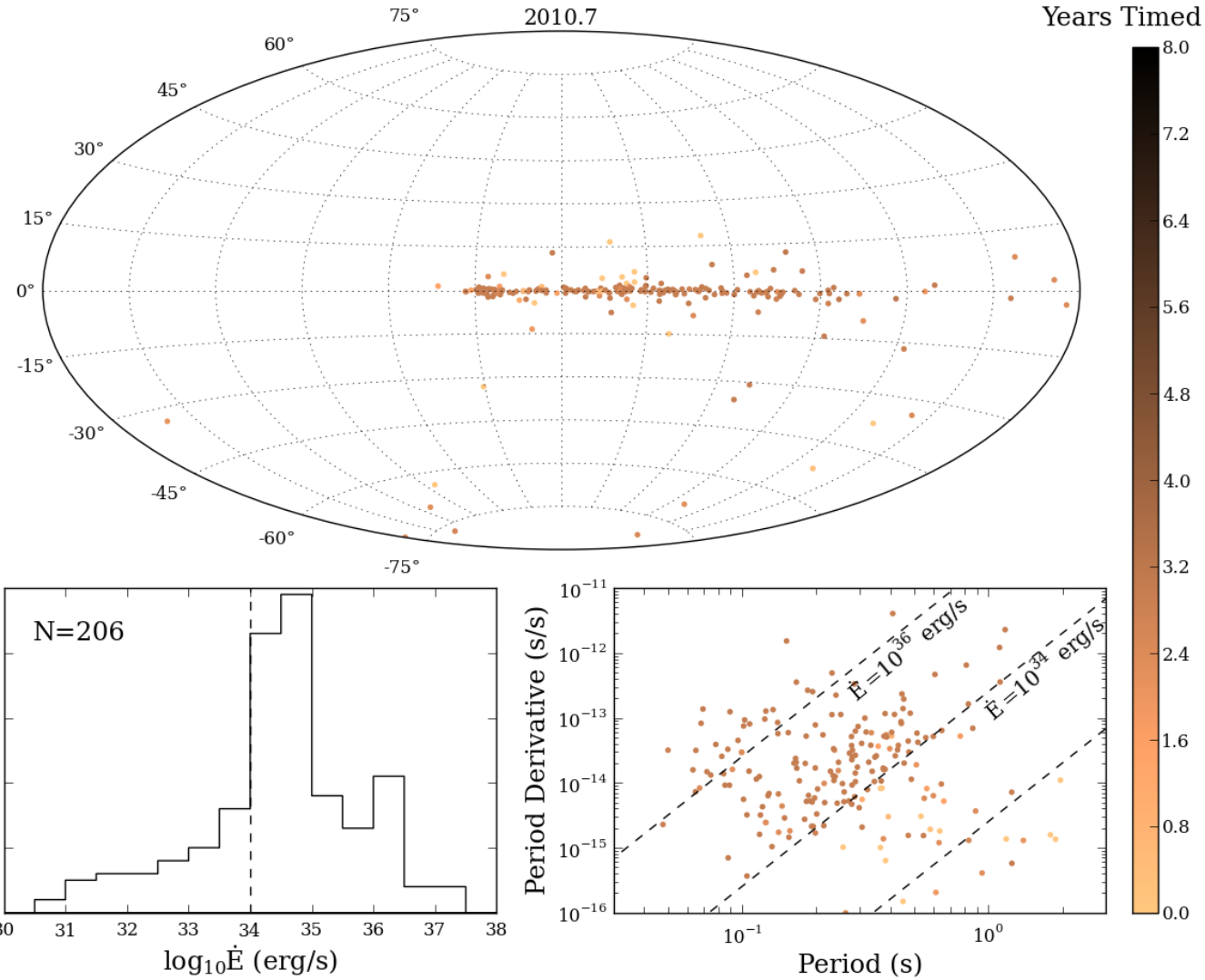

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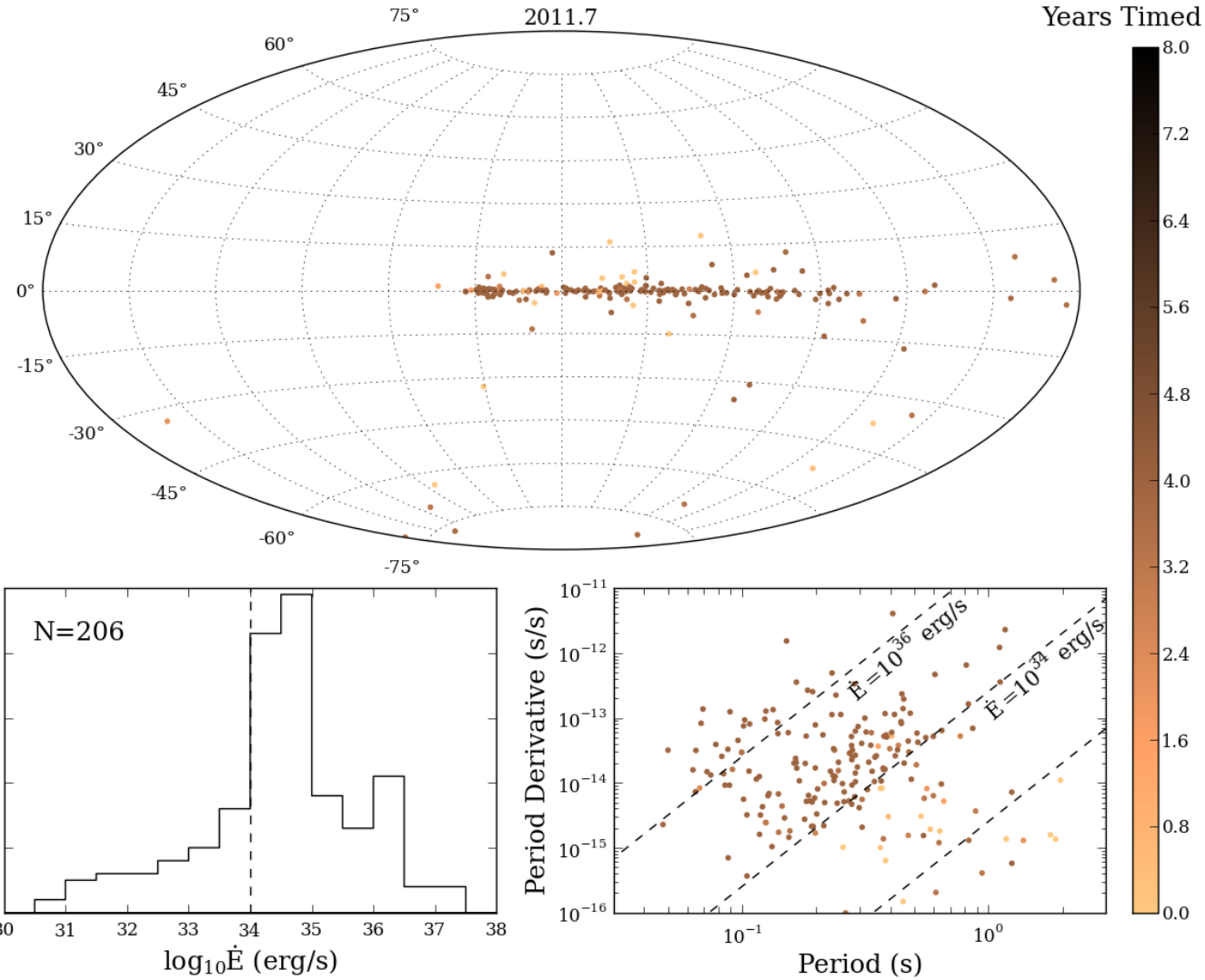

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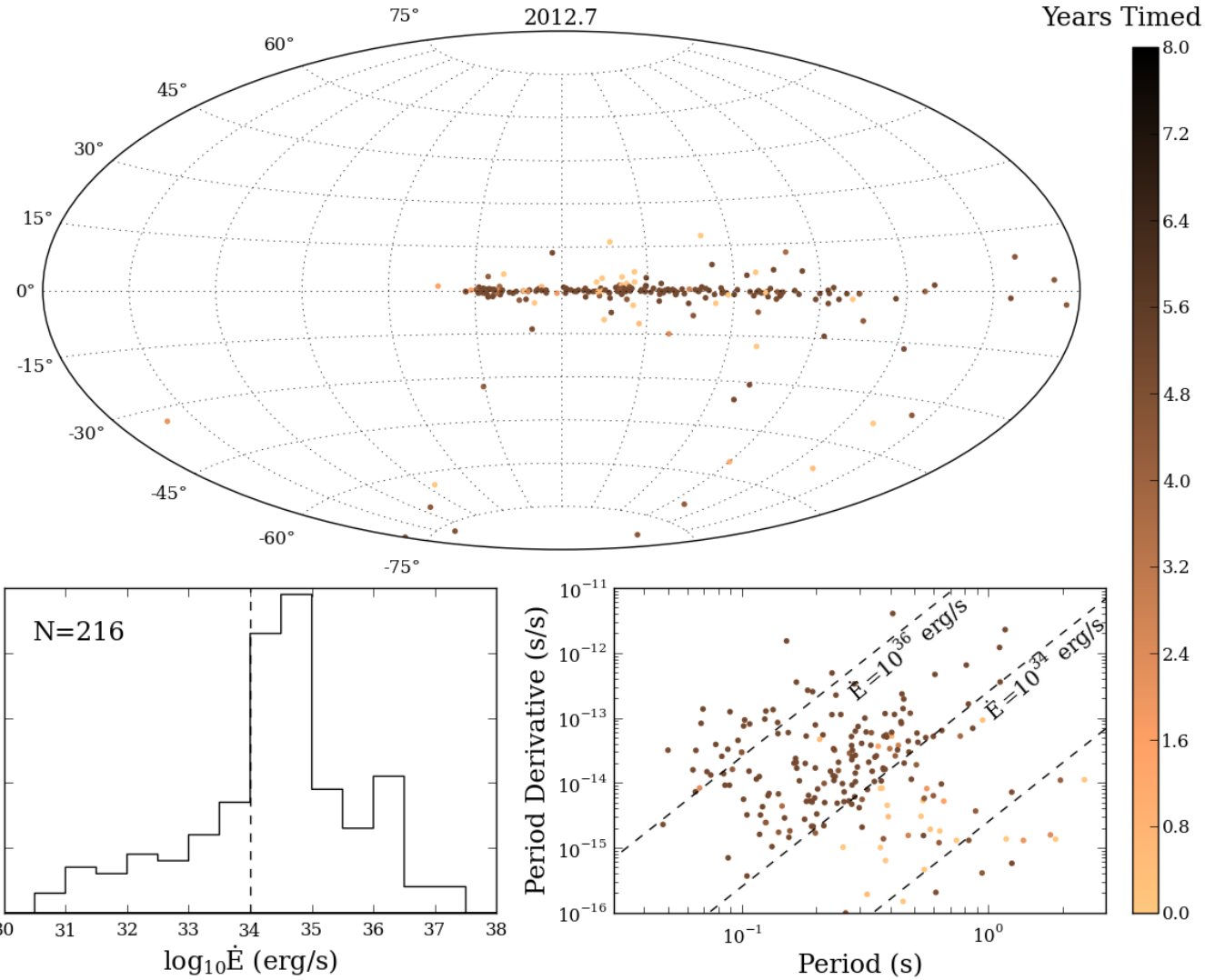

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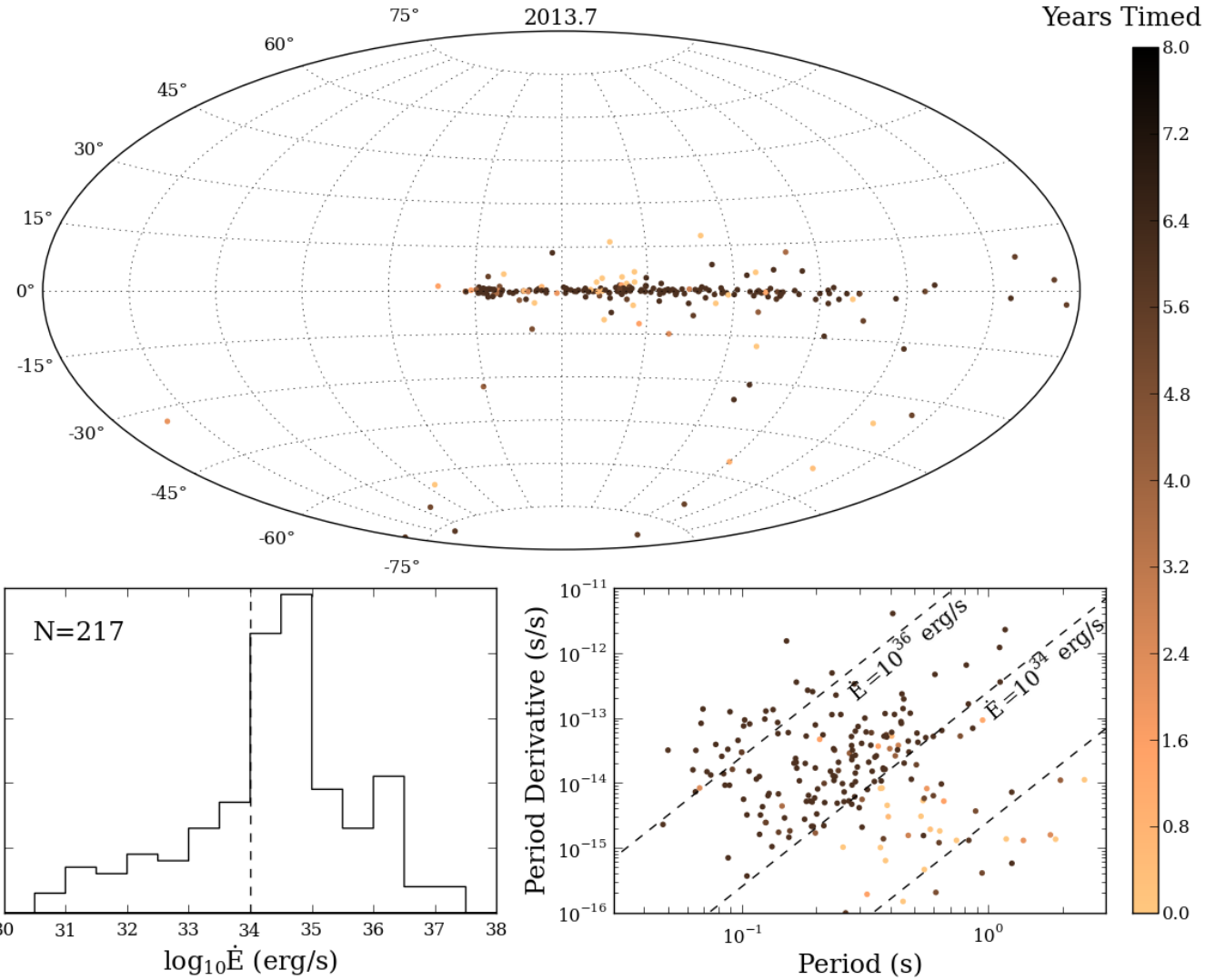

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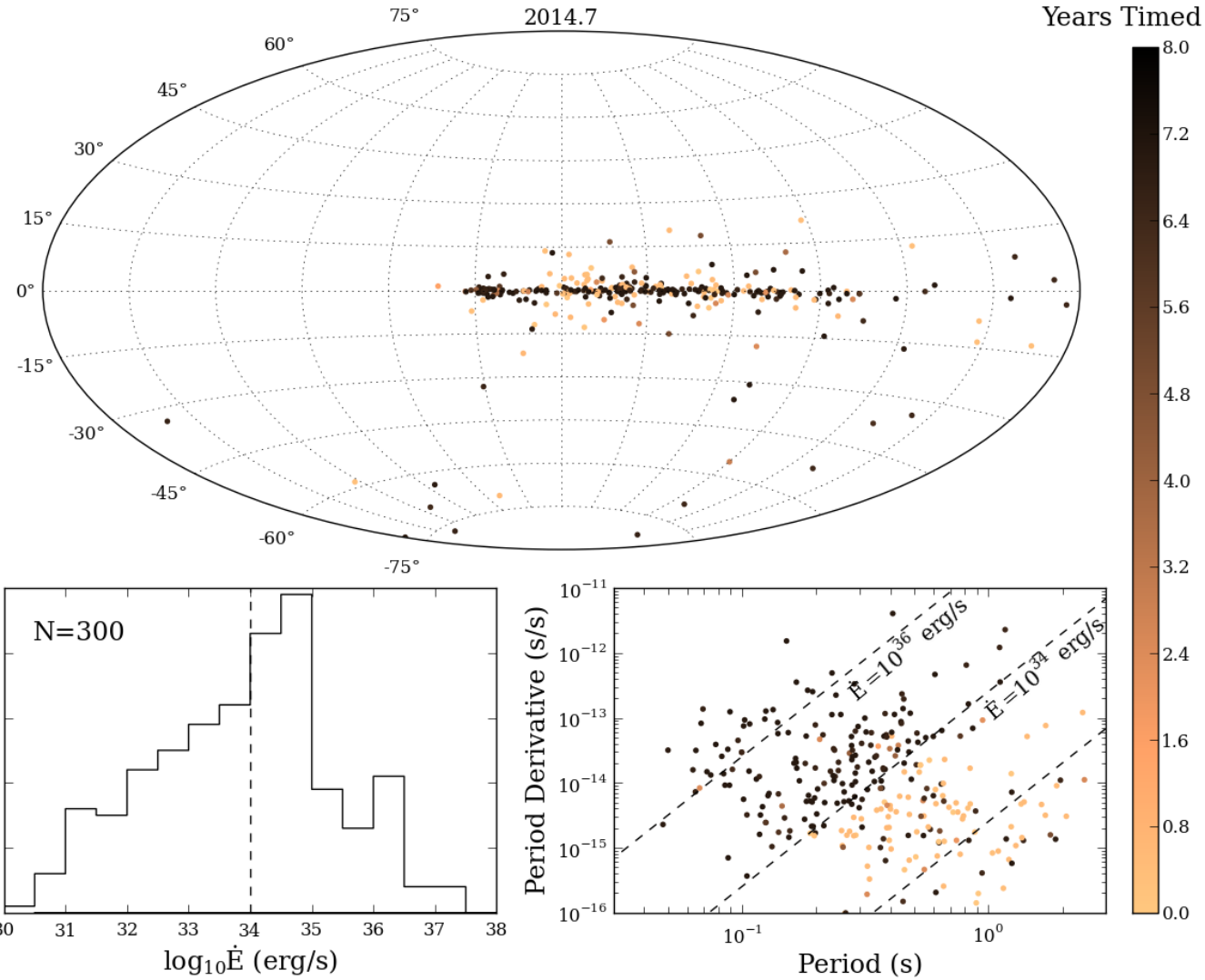

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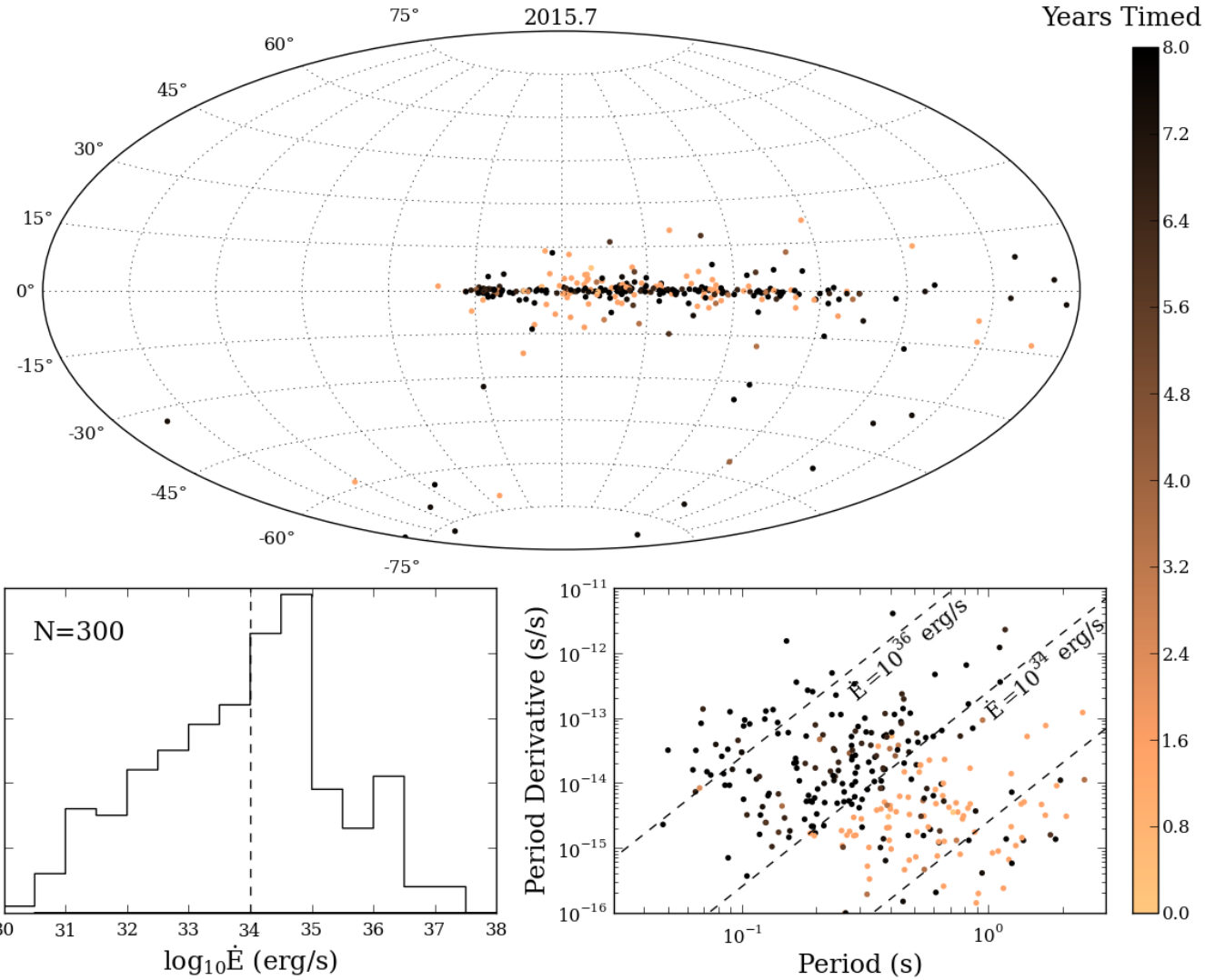
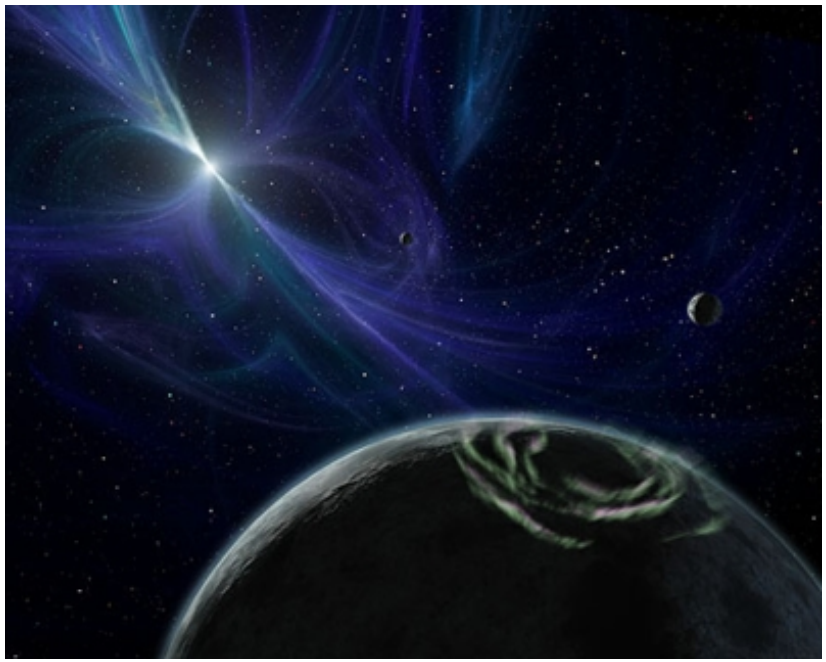
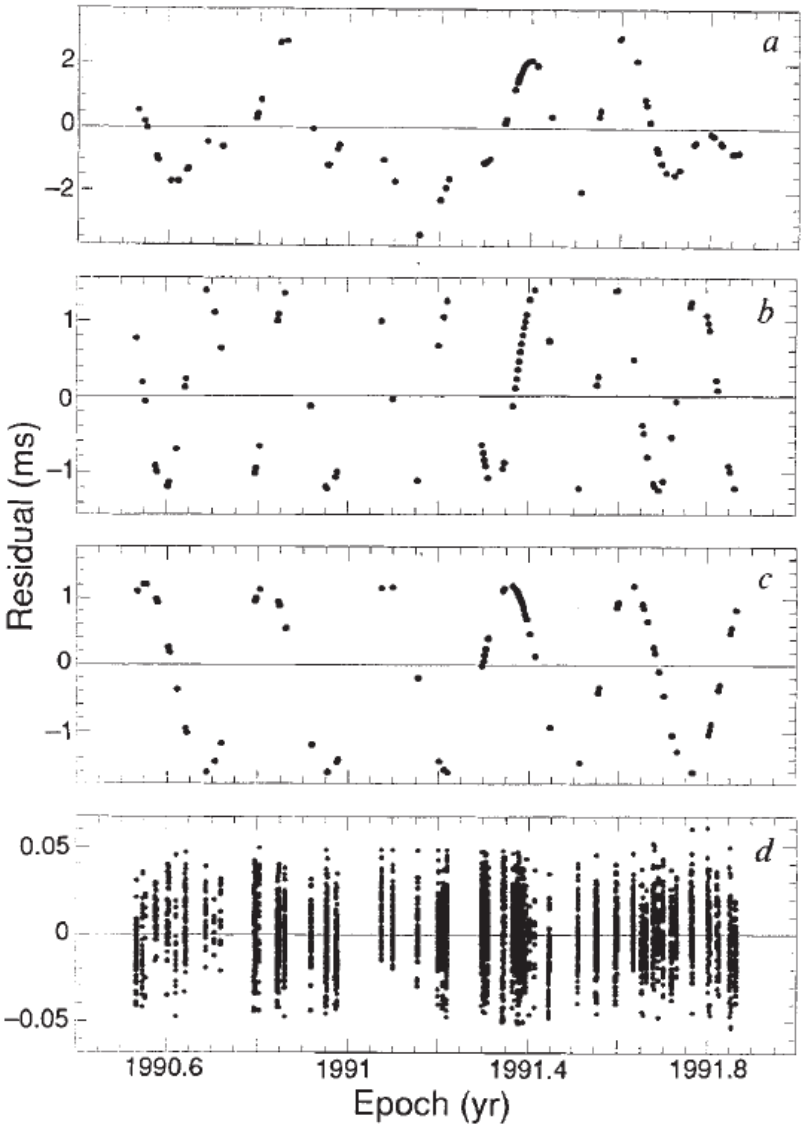


Highlights from Pulsar Timing: Exoplanets

- Two earth-mass planets discovered in orbit around MSP B1257+12.
- Nothing since! (in the field…)

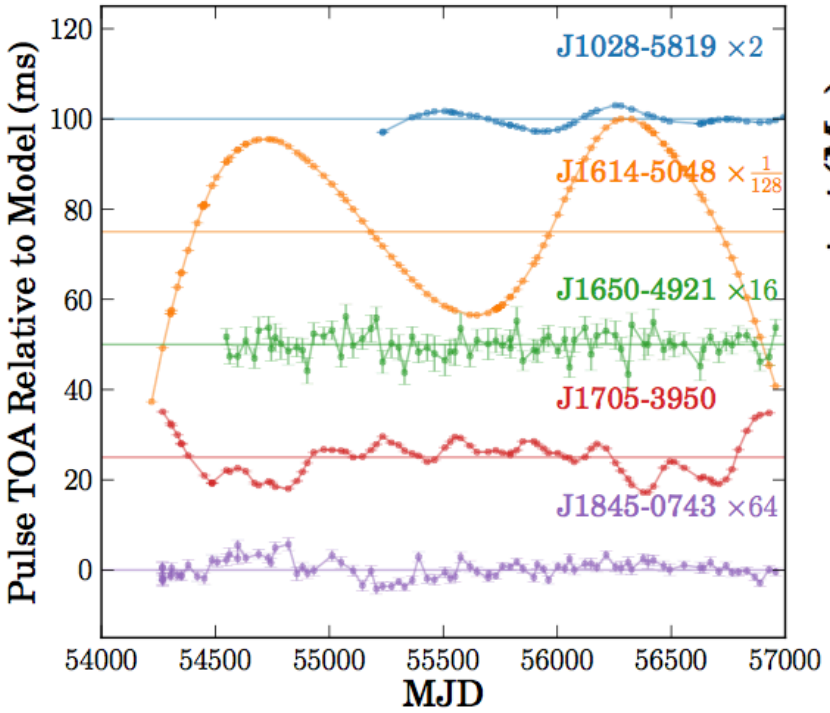


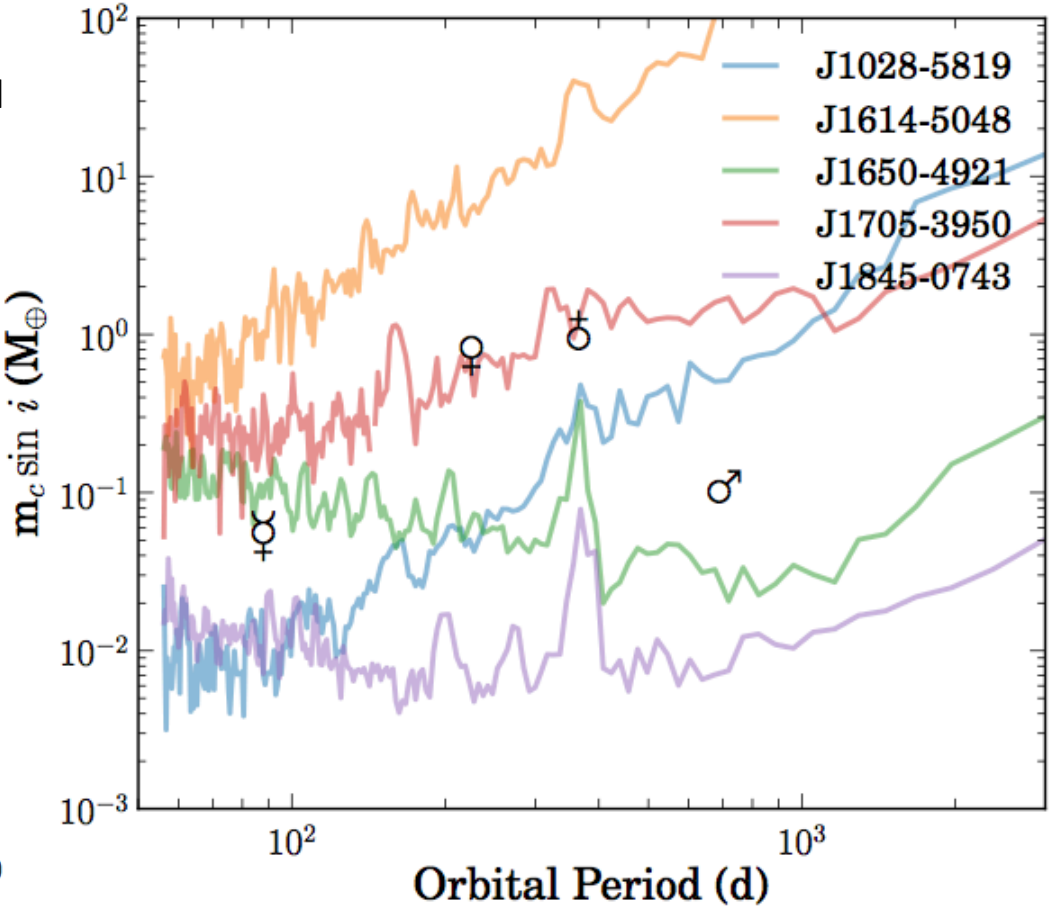
A. Wolszczan & D. A. Frail, *Nature*, 1992



Searching for Planets

Try elliptical orbits at variety of periods and see how big you you can make a companion before the signal is too large to be explained by timing noise.



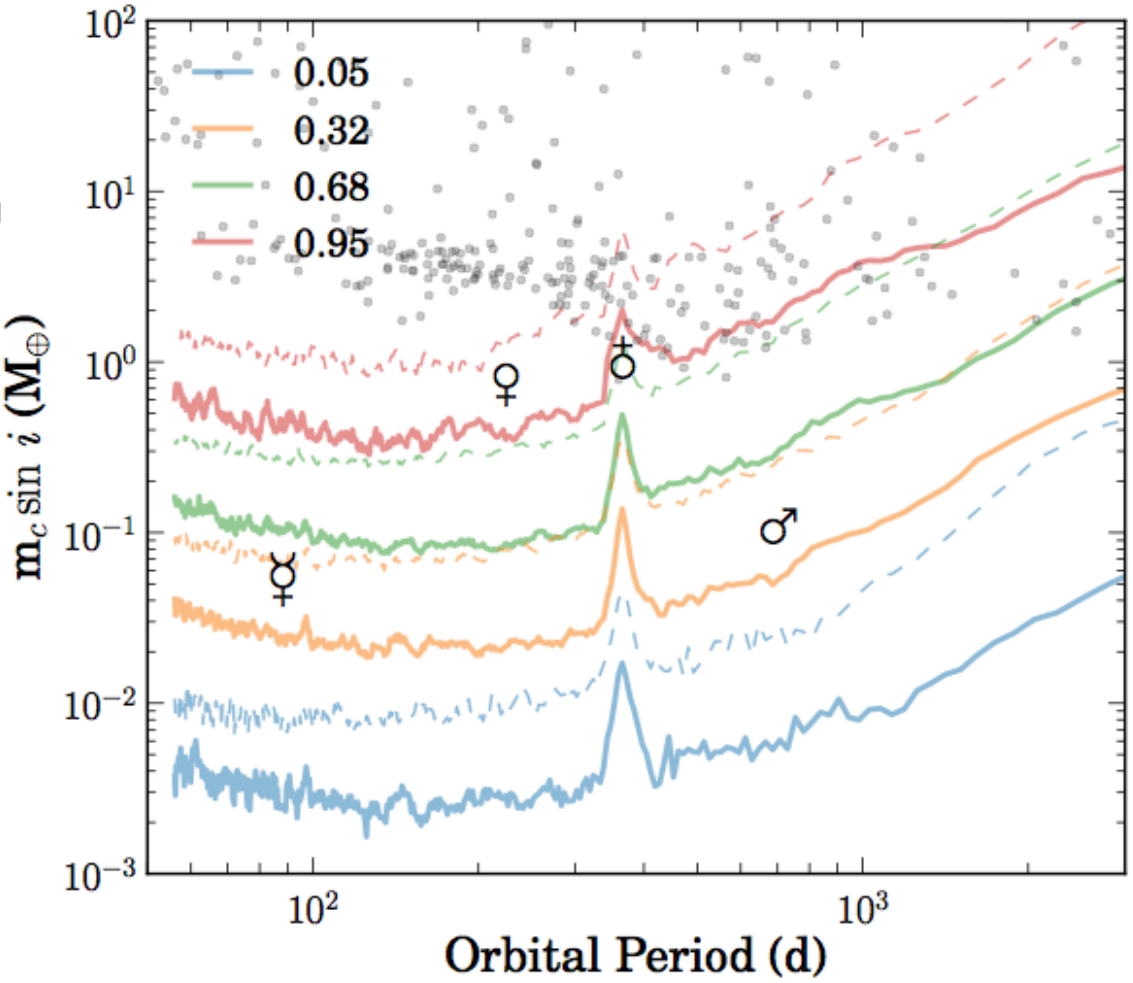


Kerr et al. 2015a

Planets Around Young Pulsars Are Rare

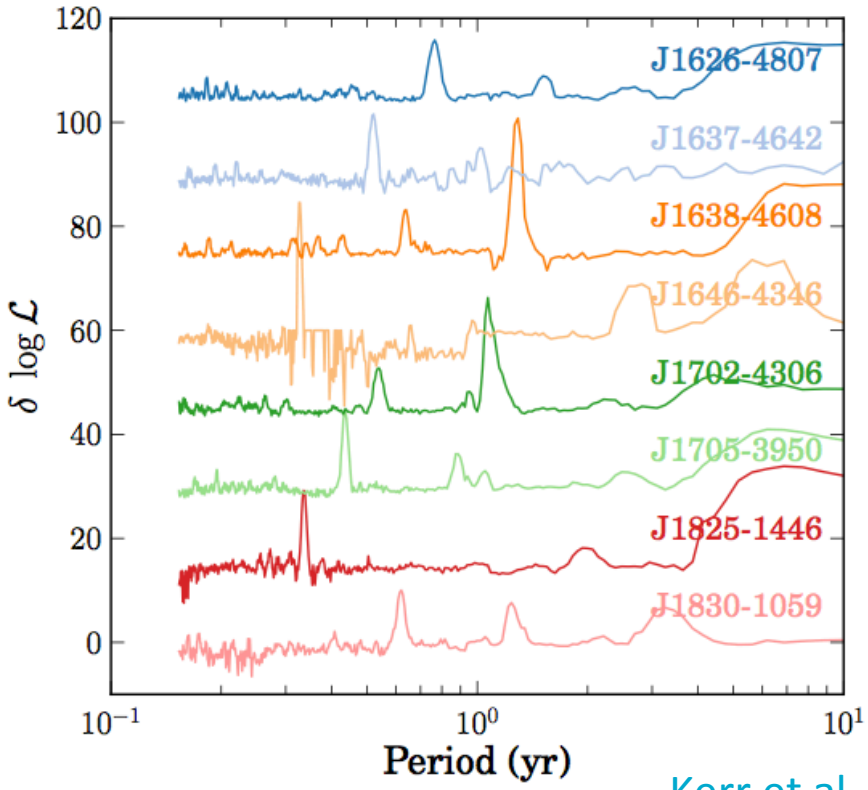
- No pulsar is special: combine upper limits on individual pulsars to place limits on the population.
- Divide pulsars up in to two age bins to be sensitive to delayed planet formation.

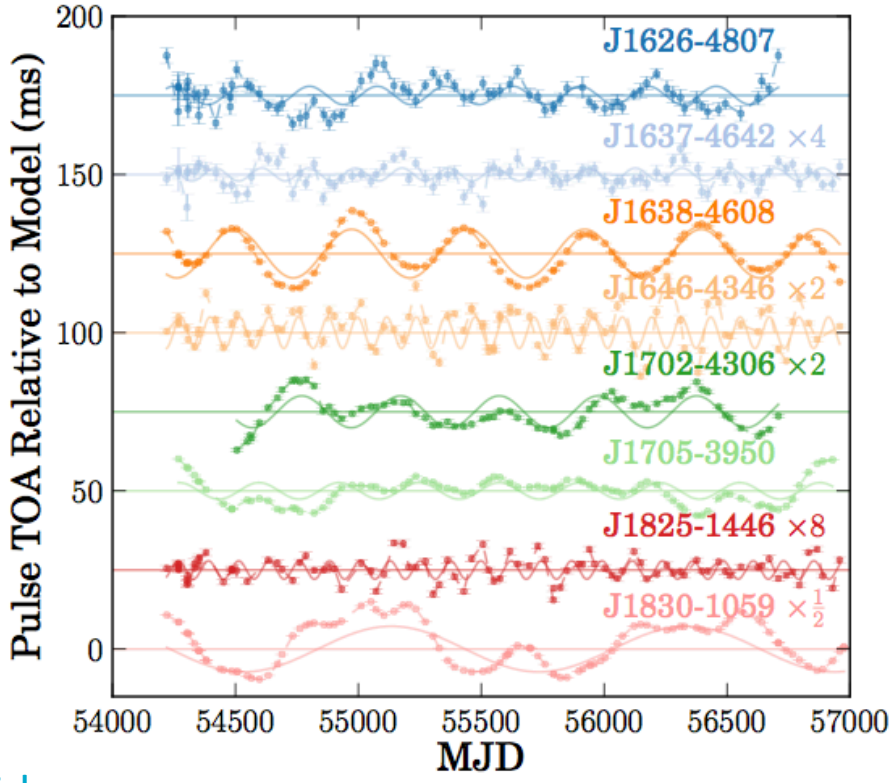
Kerr et al. 2015a



Seven Pulsars with Quasi-periodic Oscillations

- A closer look at the results from the planet study.
- Extensive simulations confirm very significant relative to timing noise.



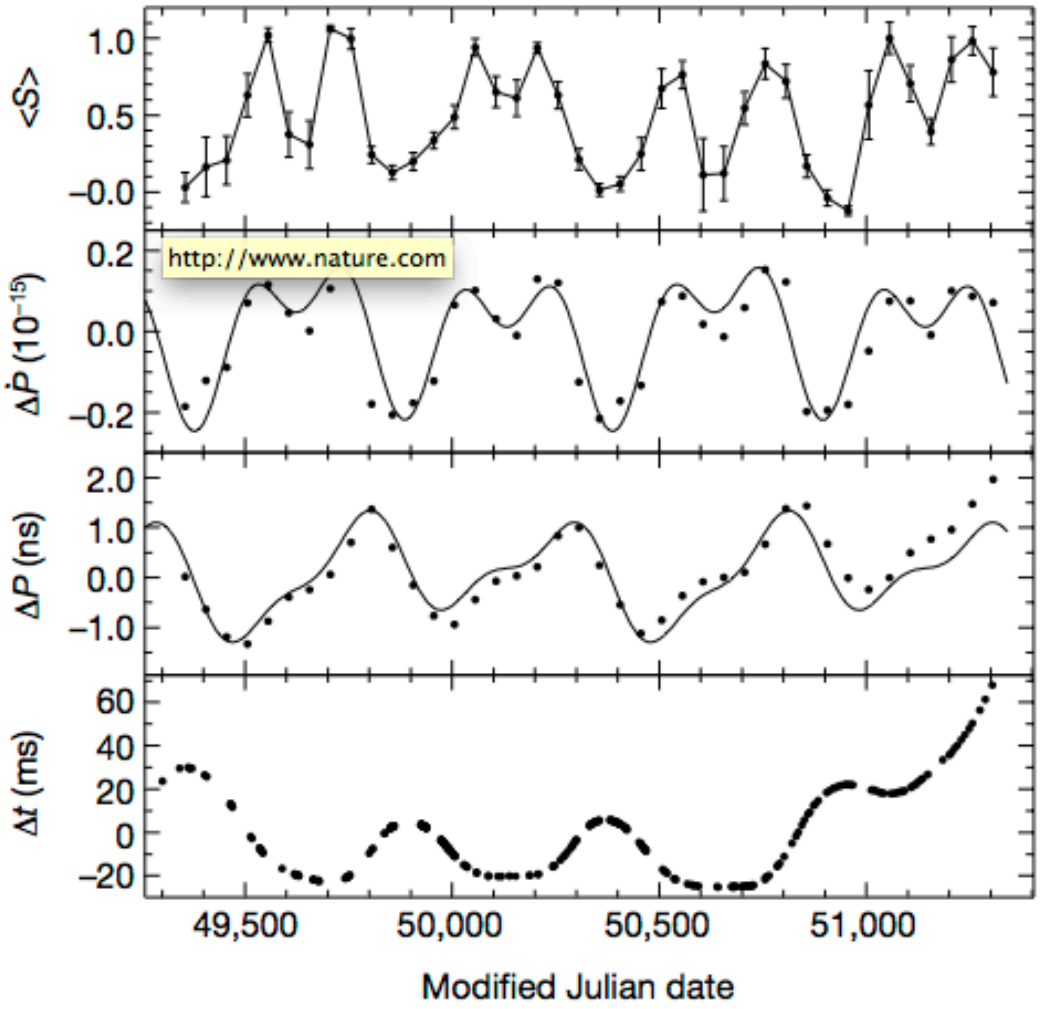


Kerr et al. 2015d

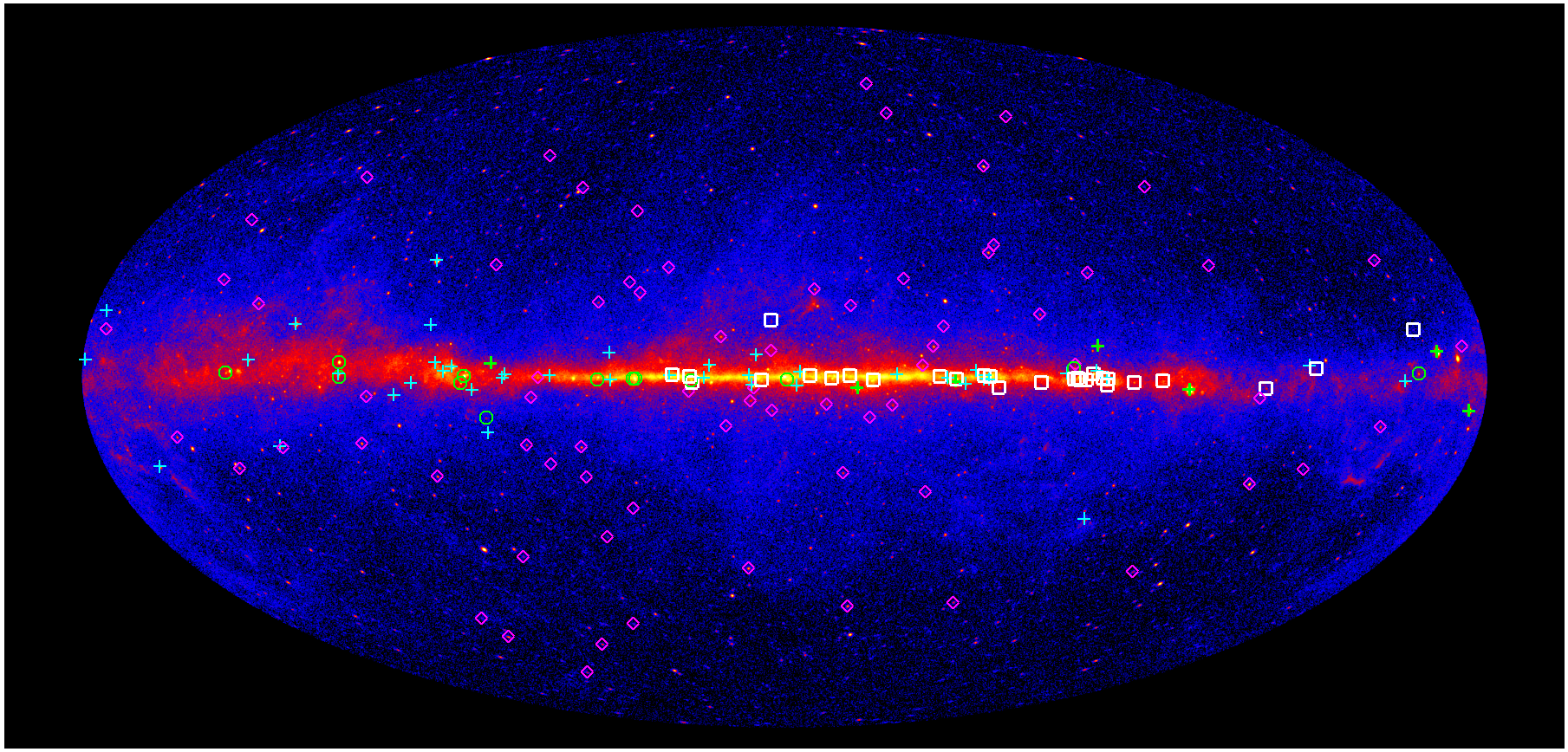
Could it be Precession?

Stairs et al., Nature, 2000

- Quasi-periodic pulse arrival time variation correlated with pulse shape changes.
- Naturally explained by a ("freely") precessing neutron star.
  - The angle between the spin axis and magnetic axis changes, changing the spin-down rate.
  - The "wobble angle" causes the observer to see different parts of the pulsar beam.



>160 Fermi Pulsars; 30 from Parkes timing



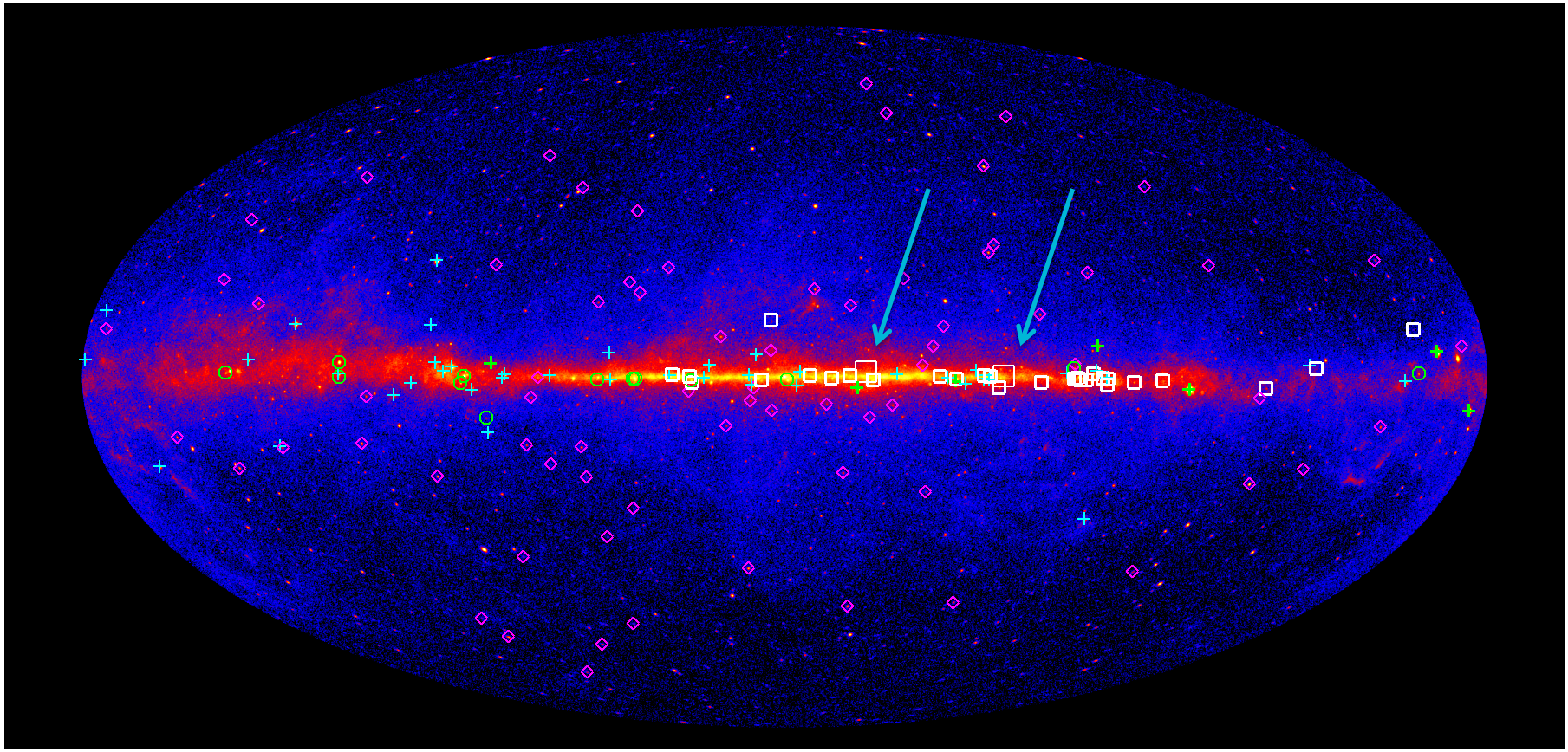
- White squares = Parkes
- Cyan crosses = other radio
- Green crosses = blind search
- Purple diamonds = MSPs

New Searches

- Updated timing solutions for 300 pulsars, spanning as much of the Fermi mission as possible (M. Kerr).
  - Low Edot pulsars expected to extrapolate back in time to some degree.
- Search using 7 years of Pass 8 data and tool to approximate photon "weights" (P. Bruel) to help separate background.
- Search over both full mission and ephemeris validity interval (L. Guillemot).

- Two new detections and a half-dozen promising candidates!

>160 Fermi Pulsars; ~~30~~ 32 from Parkes timing



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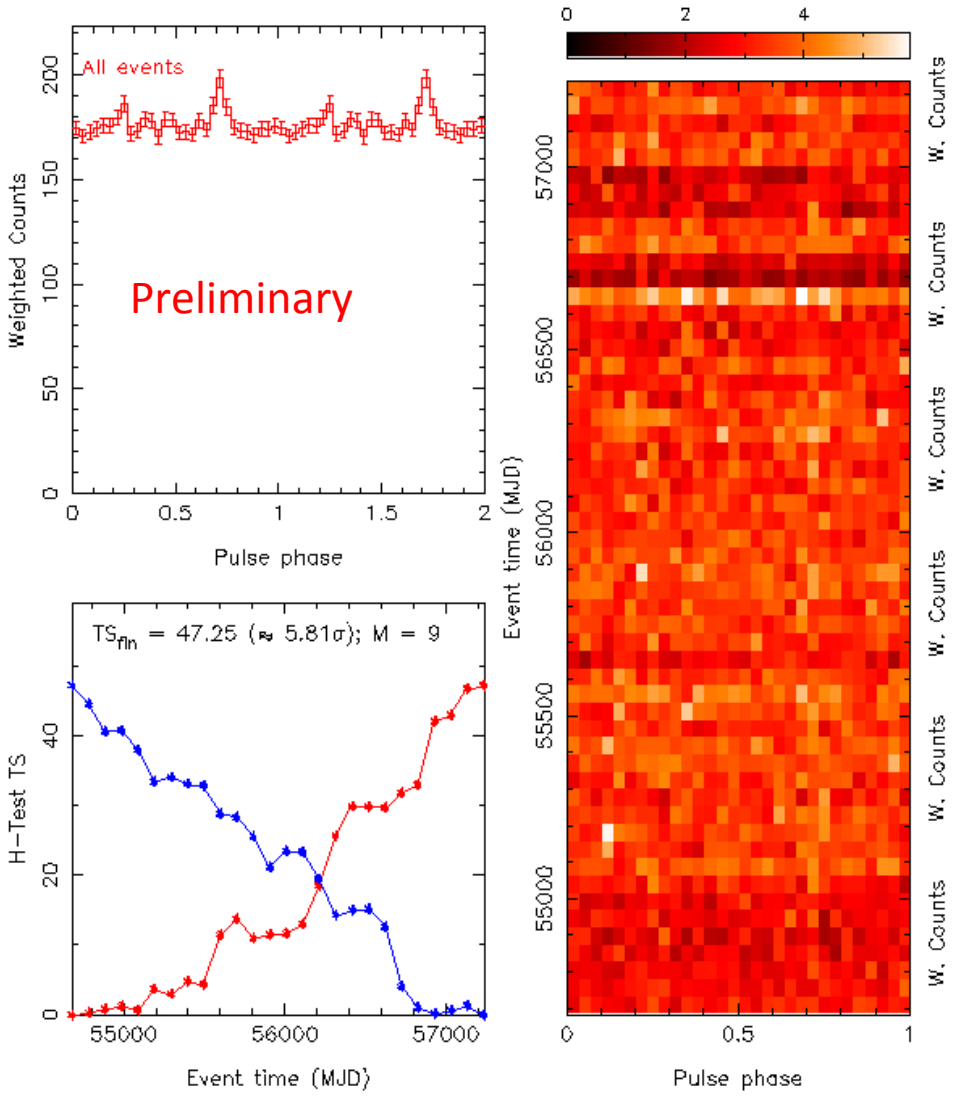
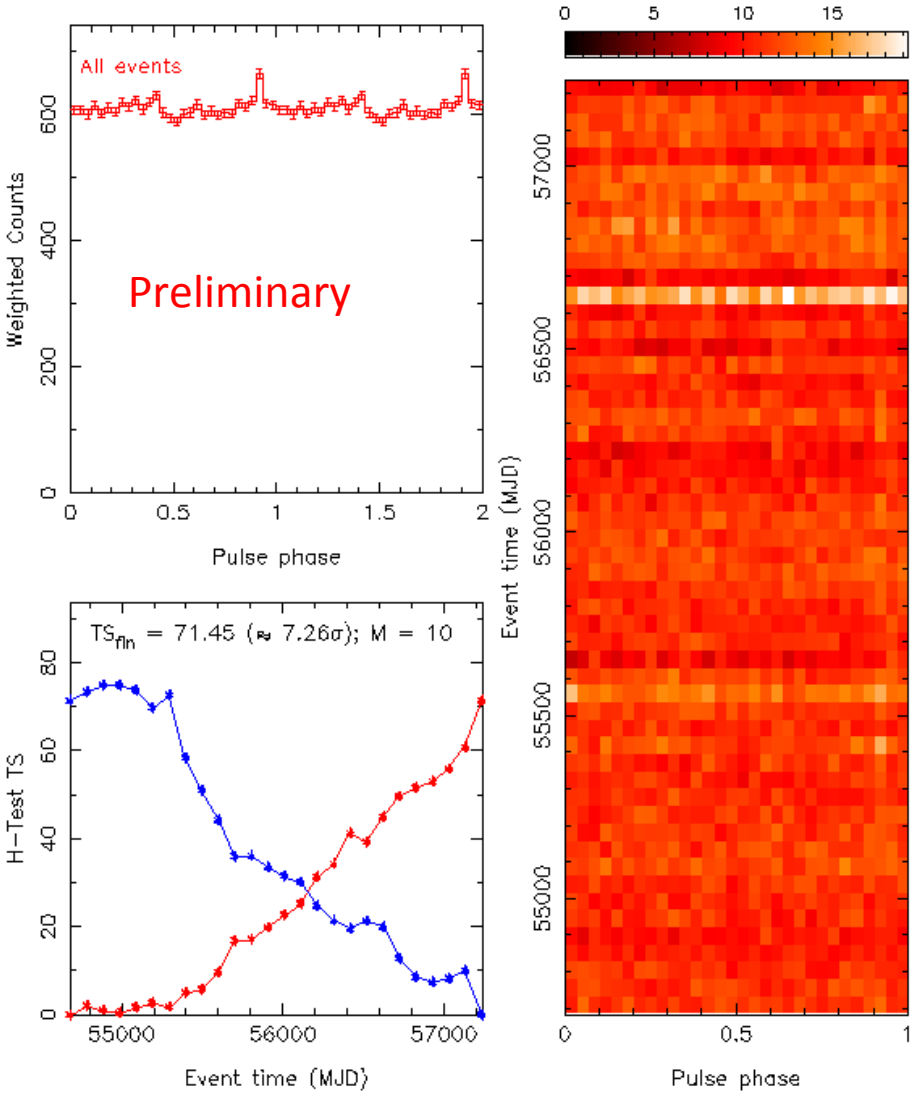
PSR J1341-6220

Associated with a Fermi source 0.1 deg away – confusion with SNR G308.8-0.1?



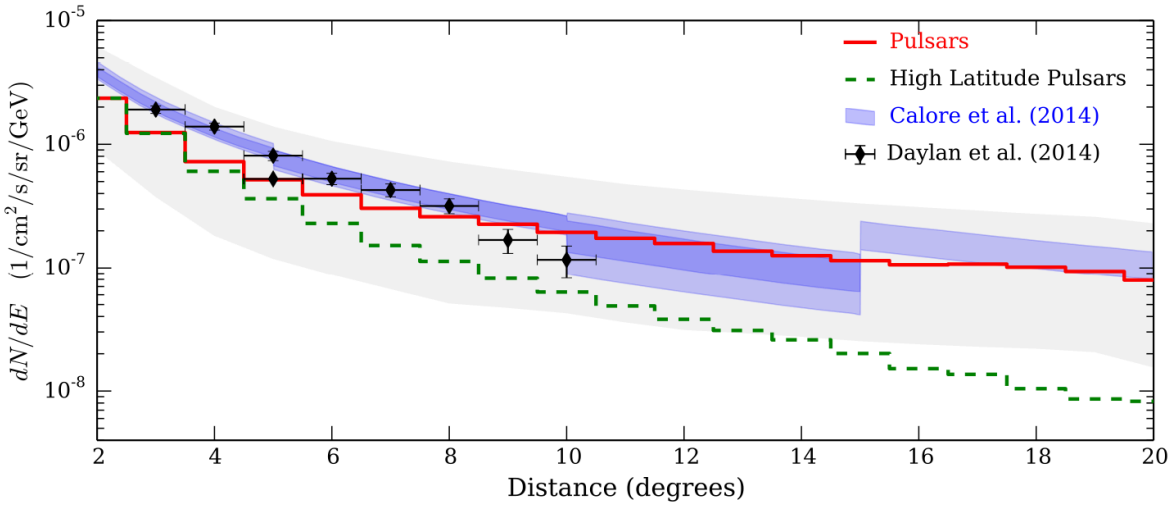
PSR J1646-4346

- No convincing LAT point source counterpart.
- Has a radio pulsar wind nebula.
- The radio TOAs show quasi-periodic modulation.



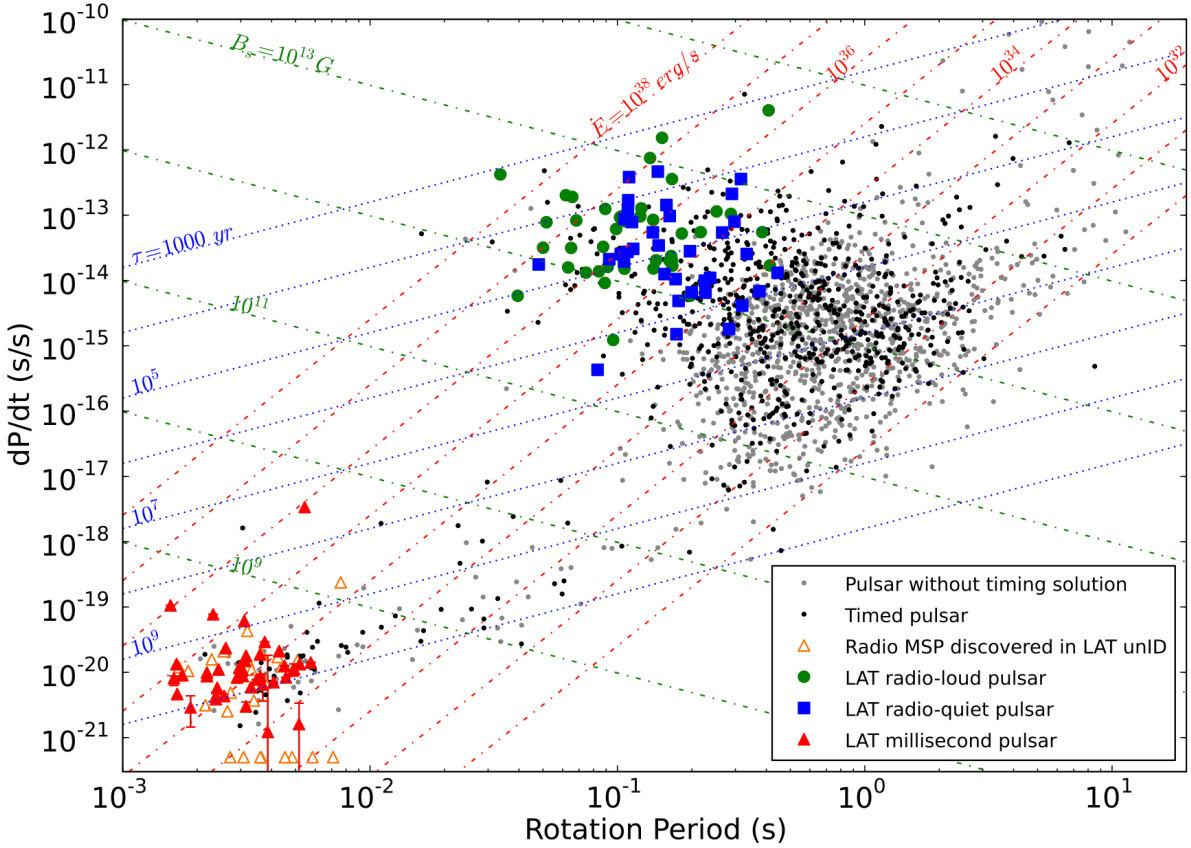
Implications for Galactic Plane Pulsars

- The contribution of near-threshold and unresolved pulsars is key to understanding the young pulsar population and could mimic other signals (e.g. annihilating dark matter).
  - See e.g. O'Leary et al. 2015, who posit a "kicked" population of young pulsars may contribute strongly to the GeV excess at the Galactic center.
- Neither candidate has a good point source counterpart!
  - Point source sensitivity may be a poorer proxy for pulsar upper limits than we had believed.
  - Blind searches may be hampered by poor / missing seeds.



Probing the Death Line

- The newly timed pulsars don't substantially complete the intermediate Edot (10^{32}—10^{34} erg/s) population.
  - But increase by >30% the *timed* population such pulsars.
  - Even one low Edot candidate can be informative for pulsar emission theory.
- Two low Edot candidates:
  - J1056-6258
    - Attempting to phase connect to earlier data to use entire Fermi mission.
  - J1749-3002



Conclusions

- Timing young radio pulsars yields heaps of science, both for Fermi and for neutron star and pulsar physics.

- Continued radio timing is key to detecting the faintest pulsars in the Galactic plane and understanding the contribution of unresolved pulsars to diffuse emission.

- Increased timing of less-energetic pulsars will probe the “death line” and shed light on the gamma-ray emission mechanism.