The Einstein@Home Gamma-ray Pulsar Survey

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Blind Search Problem

Assign rotation phases to photons and calculate Fourier power:

$$\phi(t) = 2\pi f(t - t_0) + \pi \dot{f}(t - t_0)^2 \longrightarrow \mathcal{P}_n = \frac{1}{\kappa^2} \left| \sum_{j=1}^{N} w_j \, e^{-in\phi(t_j)} \right|^2$$

Search parameter space is 4D: $\left\{ f, \dot{f}, \alpha, \delta \right\}$

O(10^{22}) trials required per source for a coherent search!

Similar to Atwood et al. (2006), only sum coherently up to T, and combine power incoherently:

$$S_1 = \sum_{j,k}^{N} w_j w_k \, e^{-i[\phi(t_j) - \phi(t_k)]} \, \hat{W}_T^{\mathrm{rect}}(\tau_{jk}) \qquad \hat{W}_T^{\mathrm{rect}}(\tau) = \begin{cases} 1, & |\tau| \leq T/2 \\ 0, & \mathrm{otherwise}\,. \end{cases}$$

Optimising a Blind Search

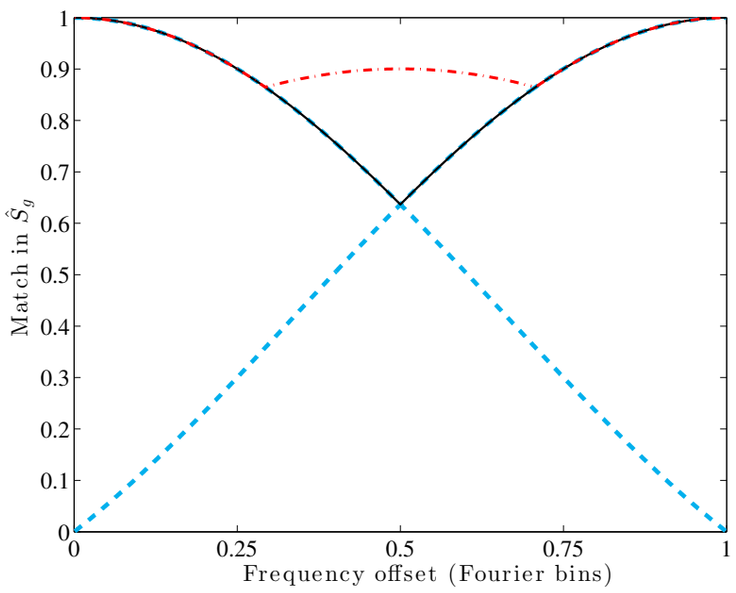
Pletsch, H. J. & Clark C. J., 2014, ApJ 795, 75

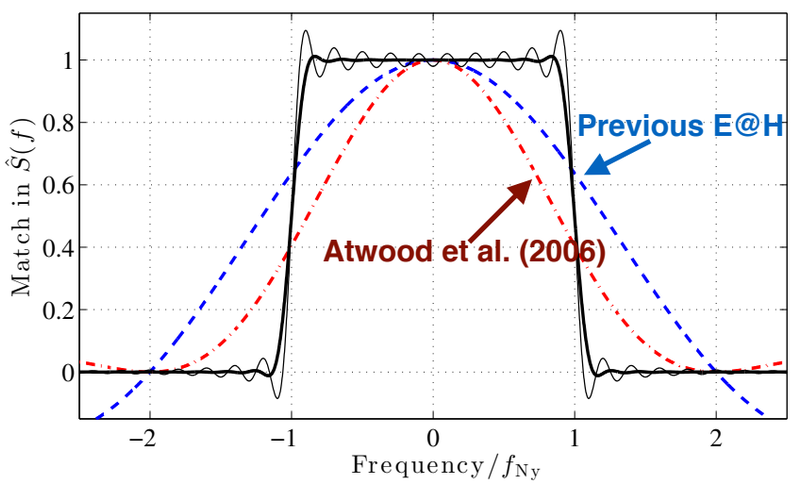
Maximise search sensitivity at a fixed computing cost

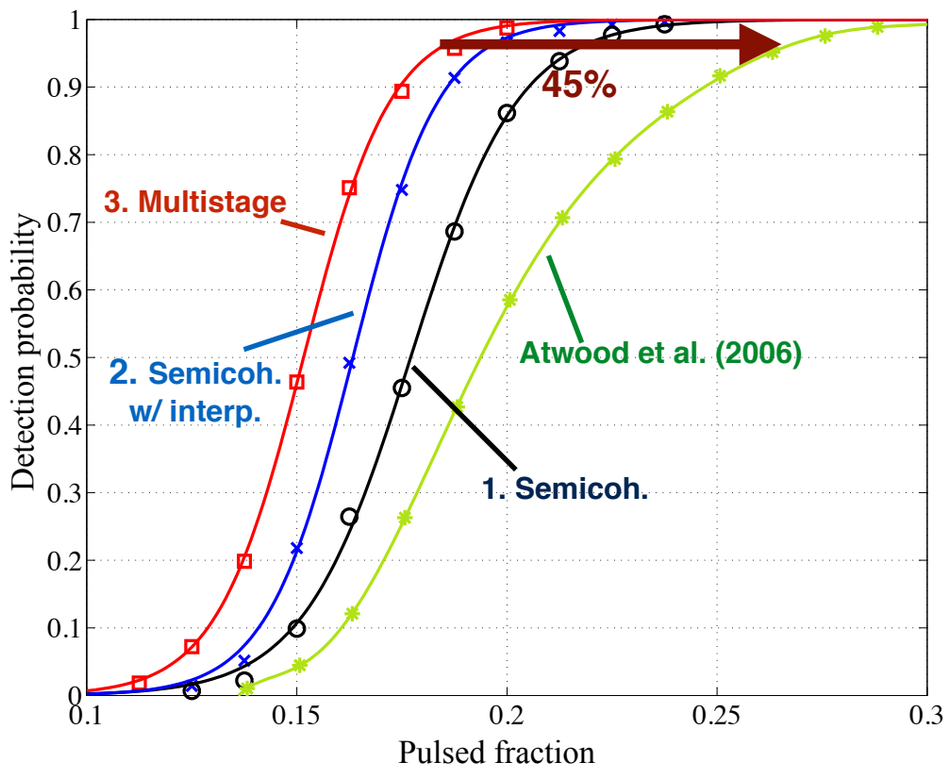
1. Optimal spacing of grid points throughout parameter space

2. Lag- and frequency-domain interpolation to reduce losses

3. Refinement and follow-up stages







Einstein@Home

A volunteer supercomputer

- Unused computing cycles from 75,000 active computers
- **~2 PFlop/s** sustained computing power

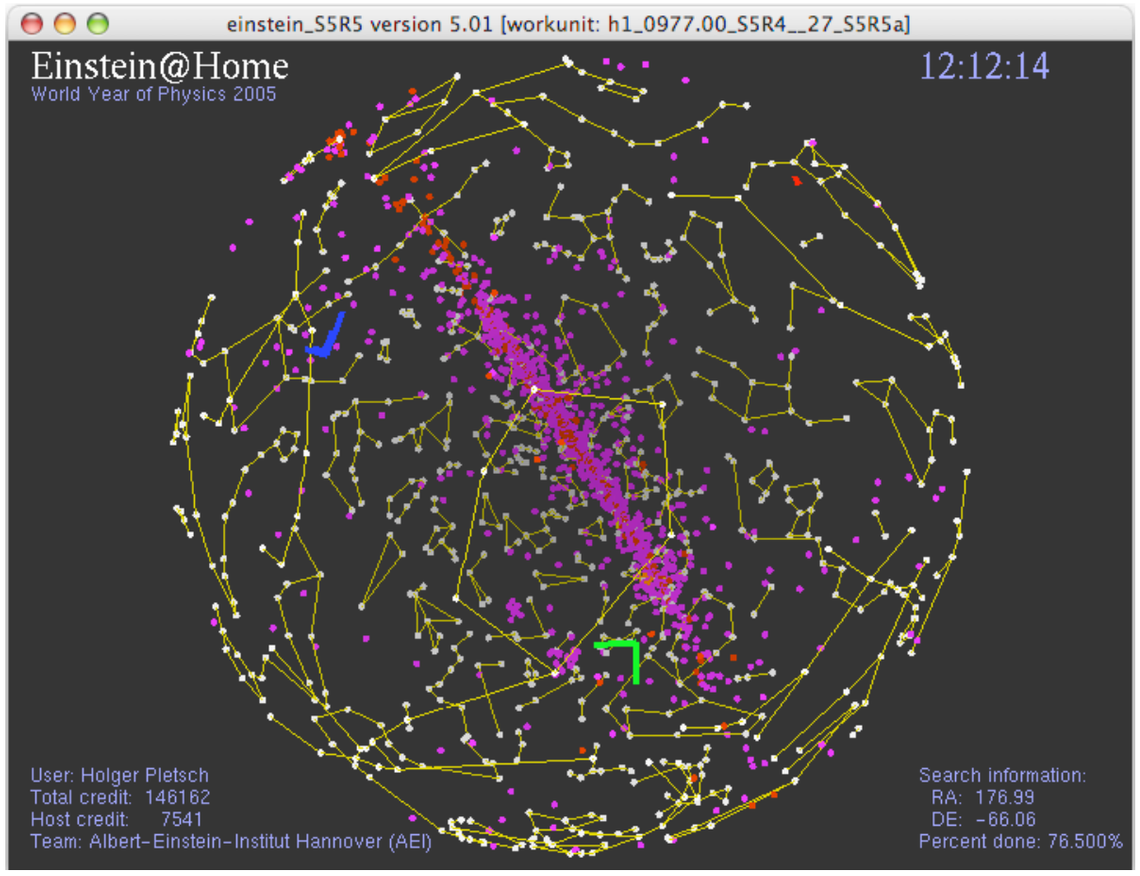
GW, Radio & Gamma-ray searches

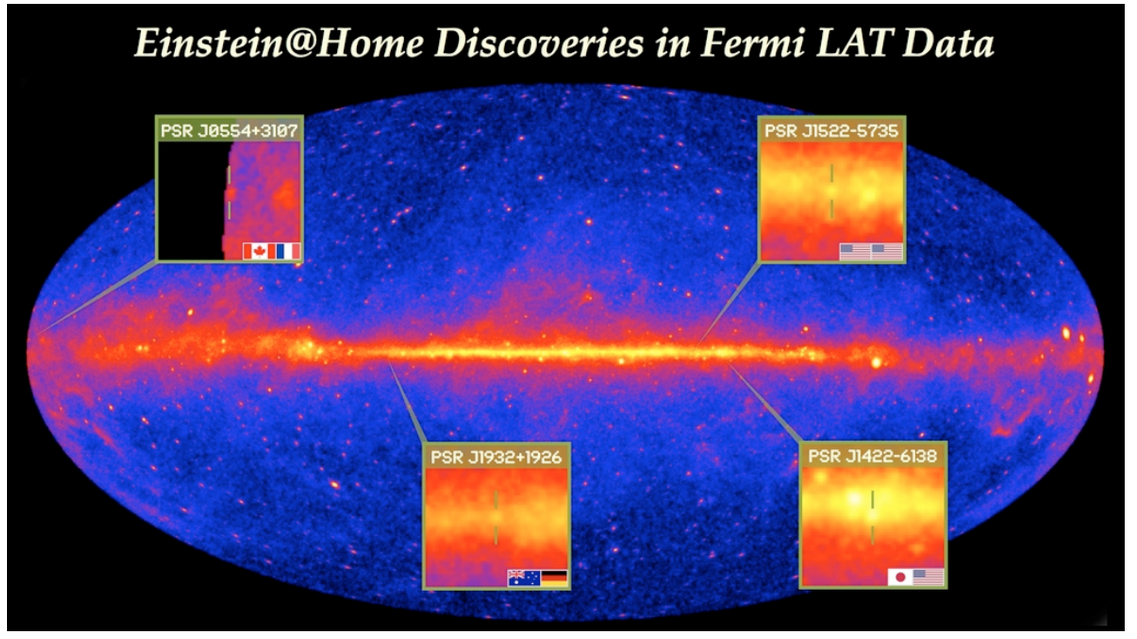
- 54 new radio pulsars

Previous Hannover discoveries

- 11 new gamma-ray pulsars
- Another 4 after moving to E@H

http://einsteinathome.org/





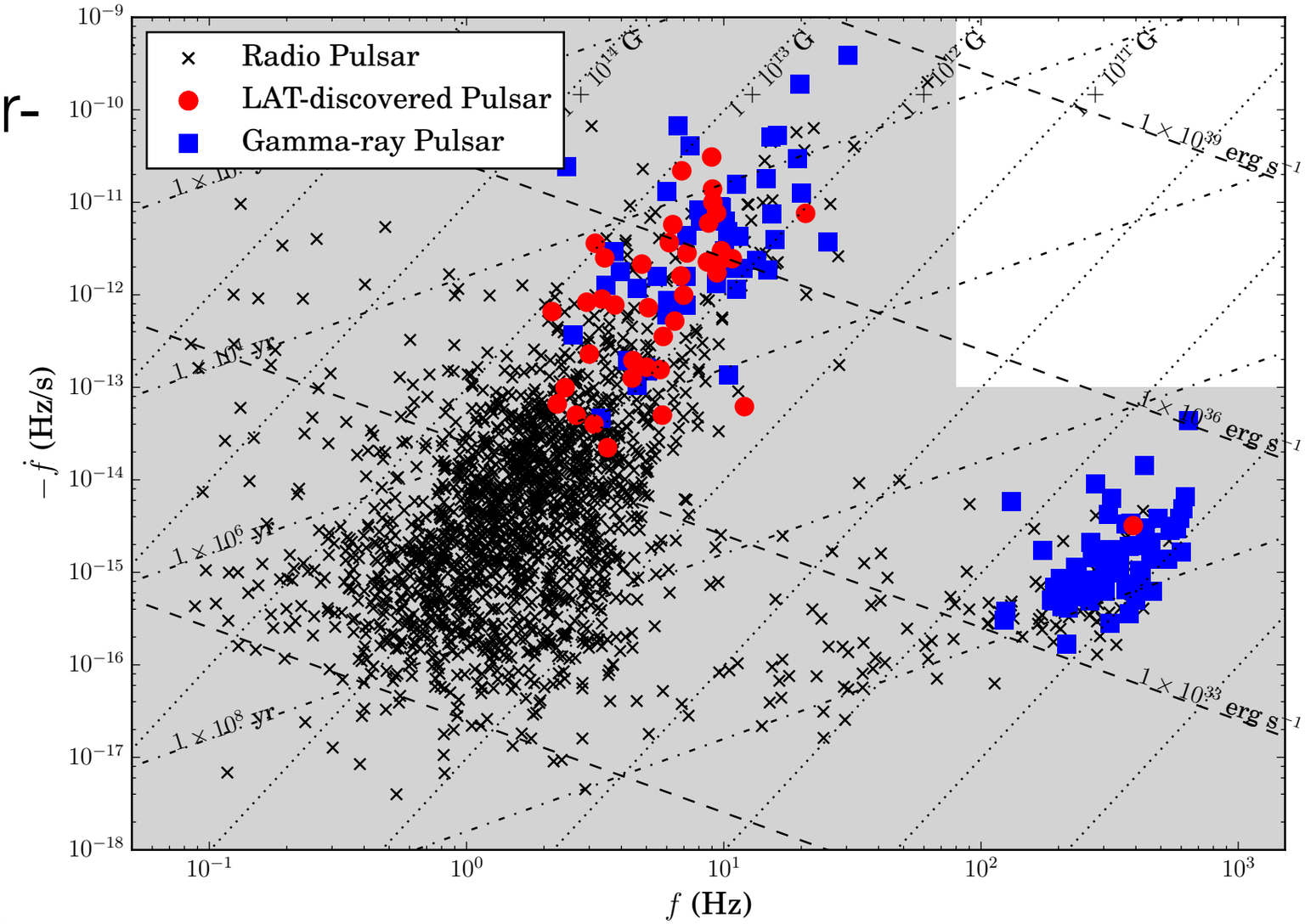
Survey Setup

Latest E@H Search:

- 118 unidentified pulsar-like 3FGL sources
- Early Pass 8 data until Apr./Oct. 2014
- Relocalised source positions

See poster from J. Wu for details!

- Using newly-improved search methods



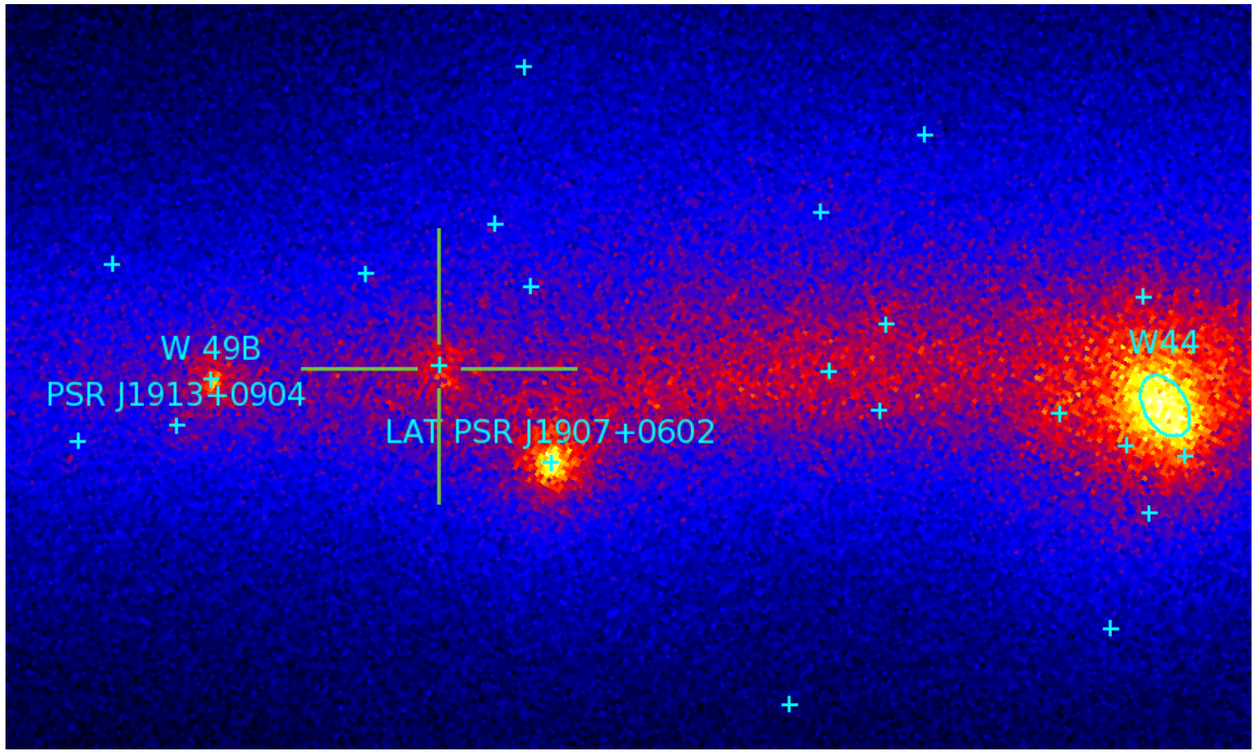
10^4 - 10^6 work units per source
11,991,296 total — O(10,000) CPU years!

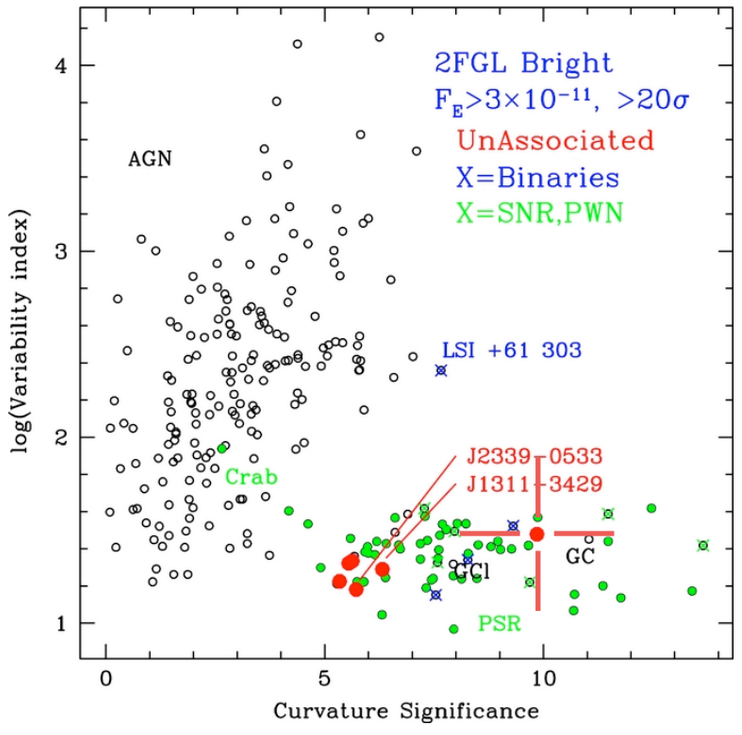
3FGL J1906.6+0720

- Most significant remaining unassociated 2FGL source
- Among top 10 unidentified 3FGL sources
- Highest ranking pulsar candidate source in 2FGL

  Lee, K. J. et al. 2012, MNRAS, 424, 2832
- No pulsations detected in radio or gamma-ray searches

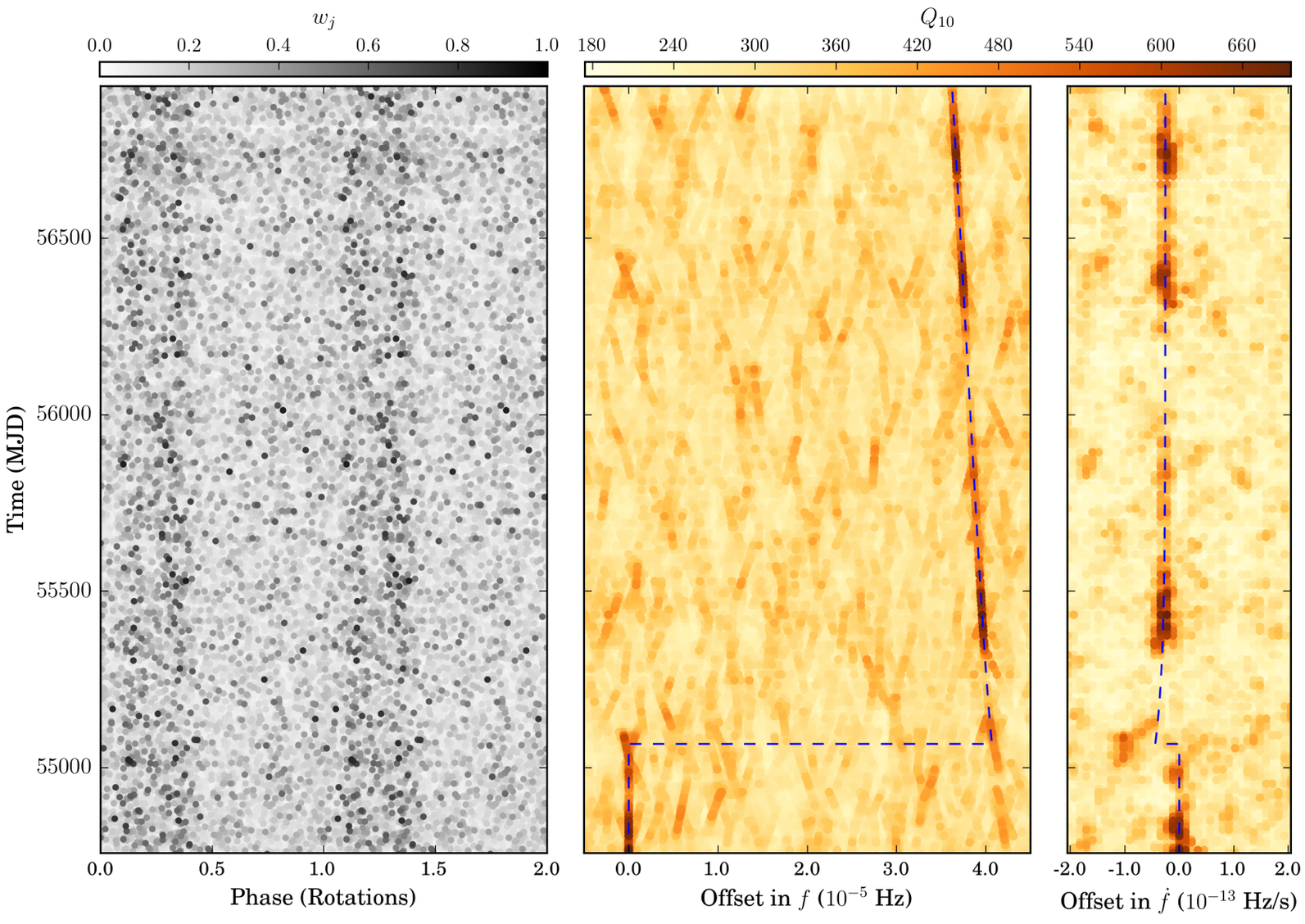
  Xing, Y., & Wang, Z. 2014, PASJ, 66
  Barr, E. D. et al. 2013, MNRAS, 429, 1633



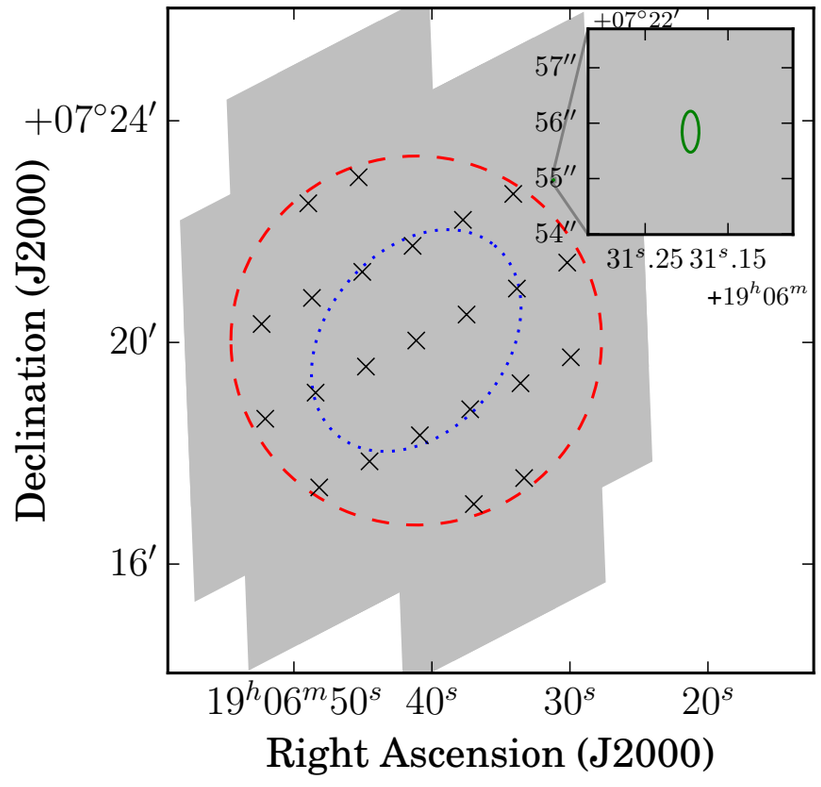


Romani, R. W. 2012, ApJ 754, L25

PSR J1906+0722 - Complications



Clark, C. J., Pletsch, H. J., Wu, J., et al. 2015, ApJL, 809, L2

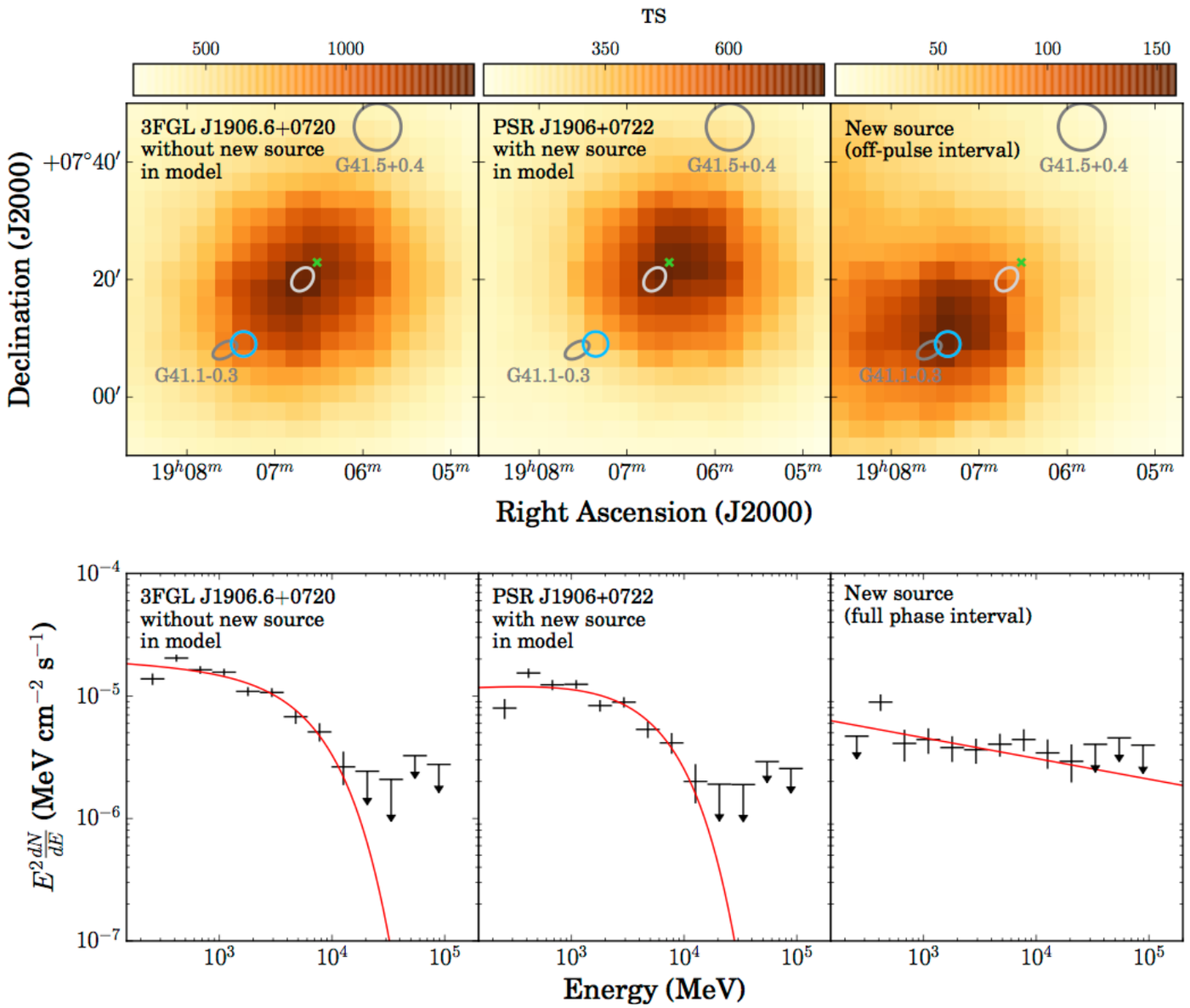


One of the largest glitches detected from a gamma-ray pulsar

$$\Delta f / f \approx 4.5 \times 10^{-6}$$

Large angular offset between pulsar and 3FGL source

Off-pulse Analysis



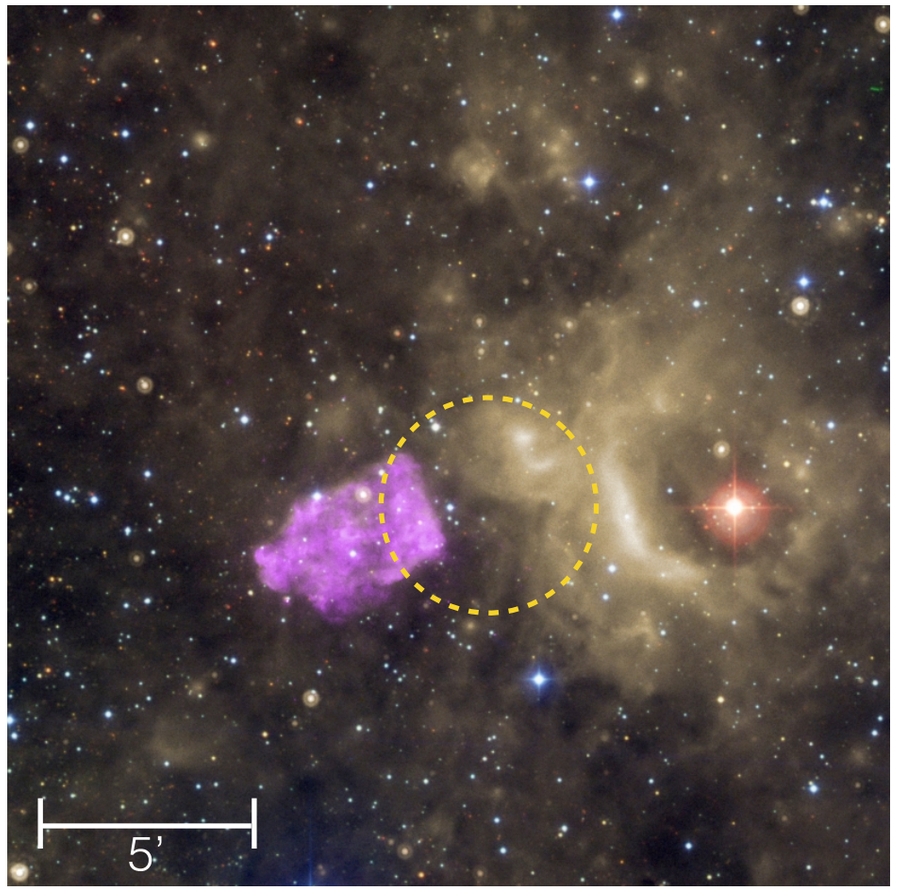
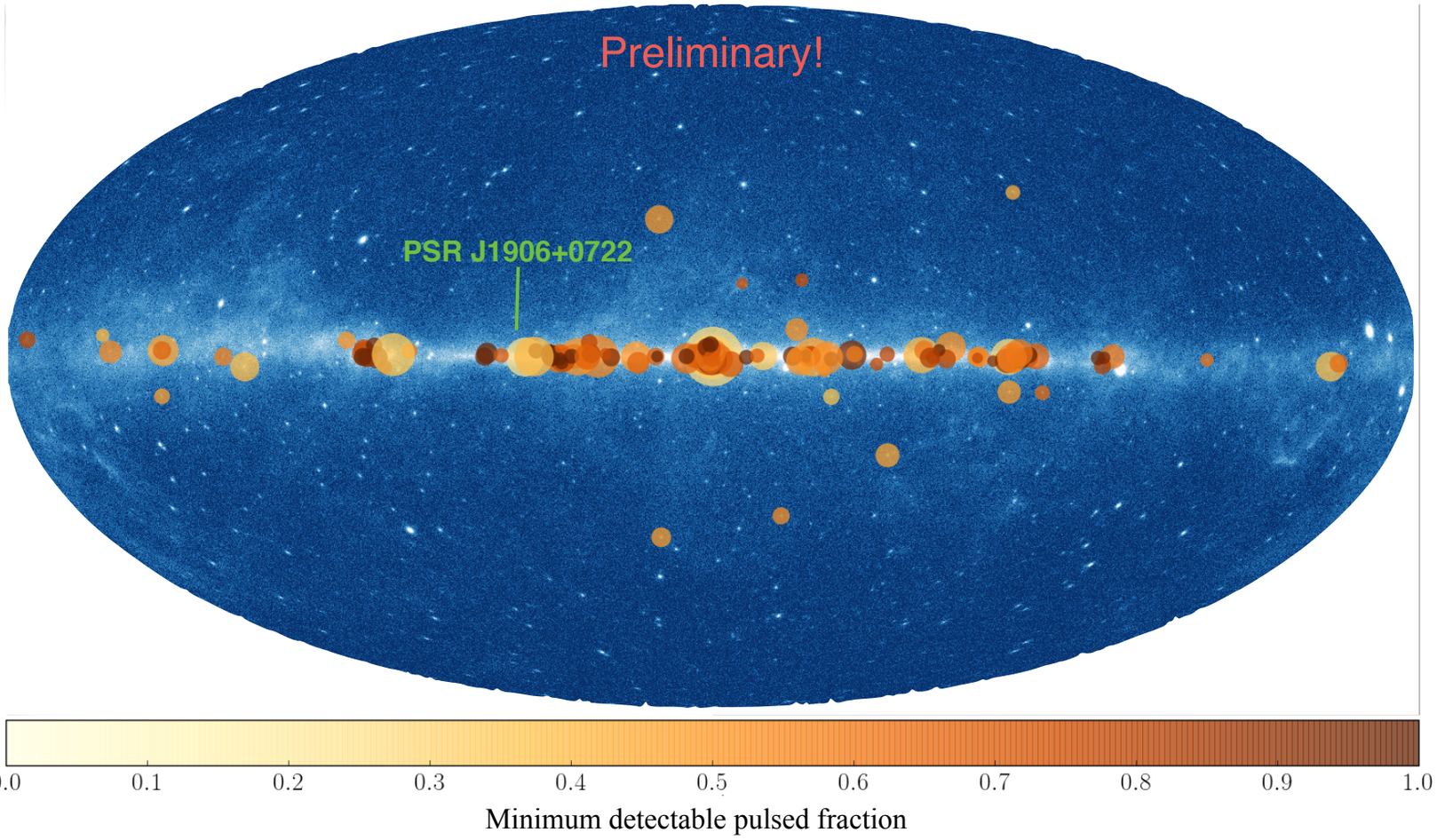


Image credit: X-ray: NASA/CXC/Univ of Manitoba/S.Safi-Harb et al, Optical: DSS, Infrared: NASA/JPL-Caltech

Off-pulse analysis revealed a new source ~0.3 deg away from timing position.

Possible interaction between SNR (3C 397) and molecular cloud?

Outlook



- First set of 118 sources almost complete, adding more with the latest Pass 8 data
- Searches for gamma-ray pulsars in binary systems in development

Thank you for listening!