Detection of a luminous gamma-ray pulsar in a Globular Cluster with the Fermi-LAT

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Millisecond pulsars (MSPs) have recently been confirmed by the Fermi Large Area Telescope as a class of pulsed γ-ray emitters. They have been observed individually contributing to the population of high-latitude γ-ray sources and collective emission from a population of MSPs has been suggested to be the source of γ-ray emission from globular clusters. We report the Fermi Large Area Telescope high significance (7 sigma) detection of γ-ray pulsations above 100 MeV from pulsar J1823-3021A in the globular cluster NGC 6624. The number of MSPs in NGC 6624 was previously estimated at ~100, based on its high γ-ray flux. We find instead that most of it originates in this single pulsar, whose γ-ray luminosity L = 8.4E34 erg/s is among the highest observed for any MSP. We find no detectable γ-ray emission from the direction of the cluster in the off-pulse phase of J1823-3021A, implying that the number of MSPs in this cluster is much smaller than previous estimates and ruling out several competing mechanisms as the dominant contributors to its γ-ray emission.

PSR J1823-3021A in NGC 6624

Discovered by Biggs et al. (1990) using the Lovell Telescope at Jodrell Bank Observatory in the globular cluster (GC) NGC 6624, PSR J1823-3021A is one of the youngest (26 Myr) and most energetic MSPs known (Edot = 8.3 x 10^{35} erg/s). Its observed period derivative is one to two orders of magnitude larger than that of other MSPs. However, the pulsar is very near the center of the core-collapsed cluster. This could induce a large acceleration which would increase the period-derivative, and affect the characteristic age, the rotational energy loss, and the inferred surface dipole magnetic field of the pulsar.

What about NGC 6624 ?

- Discovered in 1784 by Herschel
- Diameter: 20.6 arc min
- Distance: 8.4 ± 0.6 kpc
- Age ~ 14 Gyr
- 6 known radio pulsars *
- Detected in γ-rays (Tam et al. 2011)

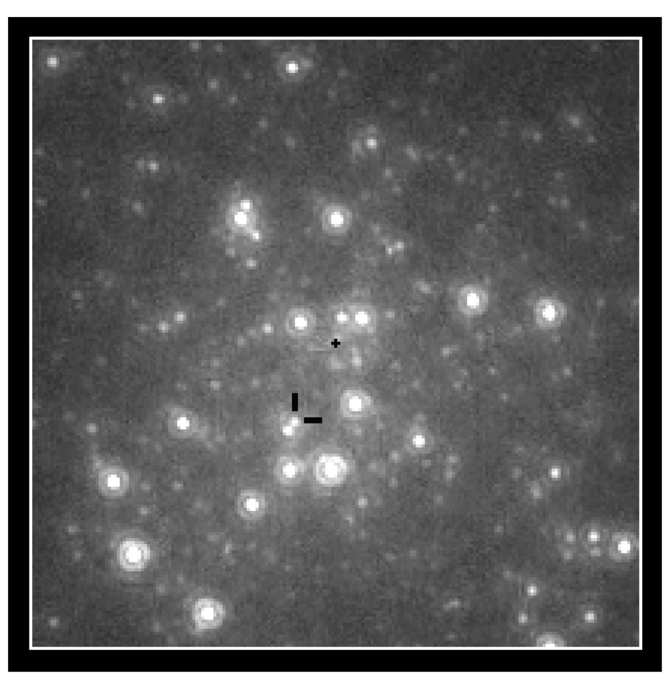


Fig 1. Hubble Space Telescope image of the globular cluster NGC 6624.

* http://www.naic.edu/~pfreire/GCpsr.html

Gamma-ray discovery

The figure (Fig. 2) shows the phase-aligned radio and γ-ray profiles for PSR J1823−3021A (Freire et al. 2011). Radio and γ-ray data were obtained with the Nancay (France) and Jodrell Bank telescopes, and the Fermi-LAT respectively. The γ-ray background for the 0.1 GeV light curve is indicated by the dashed horizontal line in the top panel. The highlighted areas show the on-pulse region.

The significance of the pulsed γ-ray signal above 0.1 GeV (top panel) is 7 sigma. This is the first firm detection of gamma-ray pulsations from an MSP in a globular cluster.

Radio and gamma-ray peaks are aligned within statistical uncertainties, suggesting co-located emission regions. Until now such alignment has only been observed for the Crab pulsar and three, energetic MSPs.

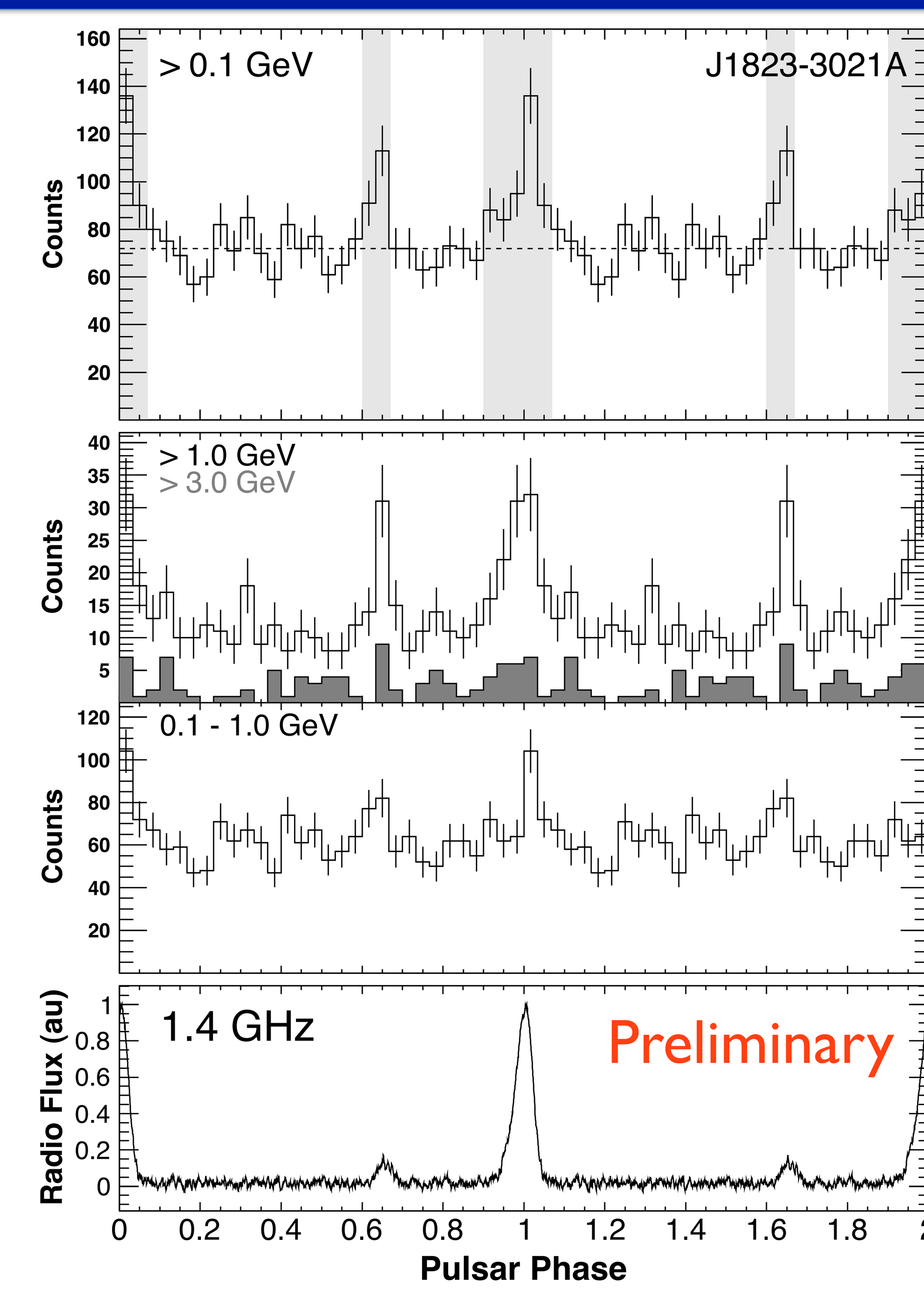


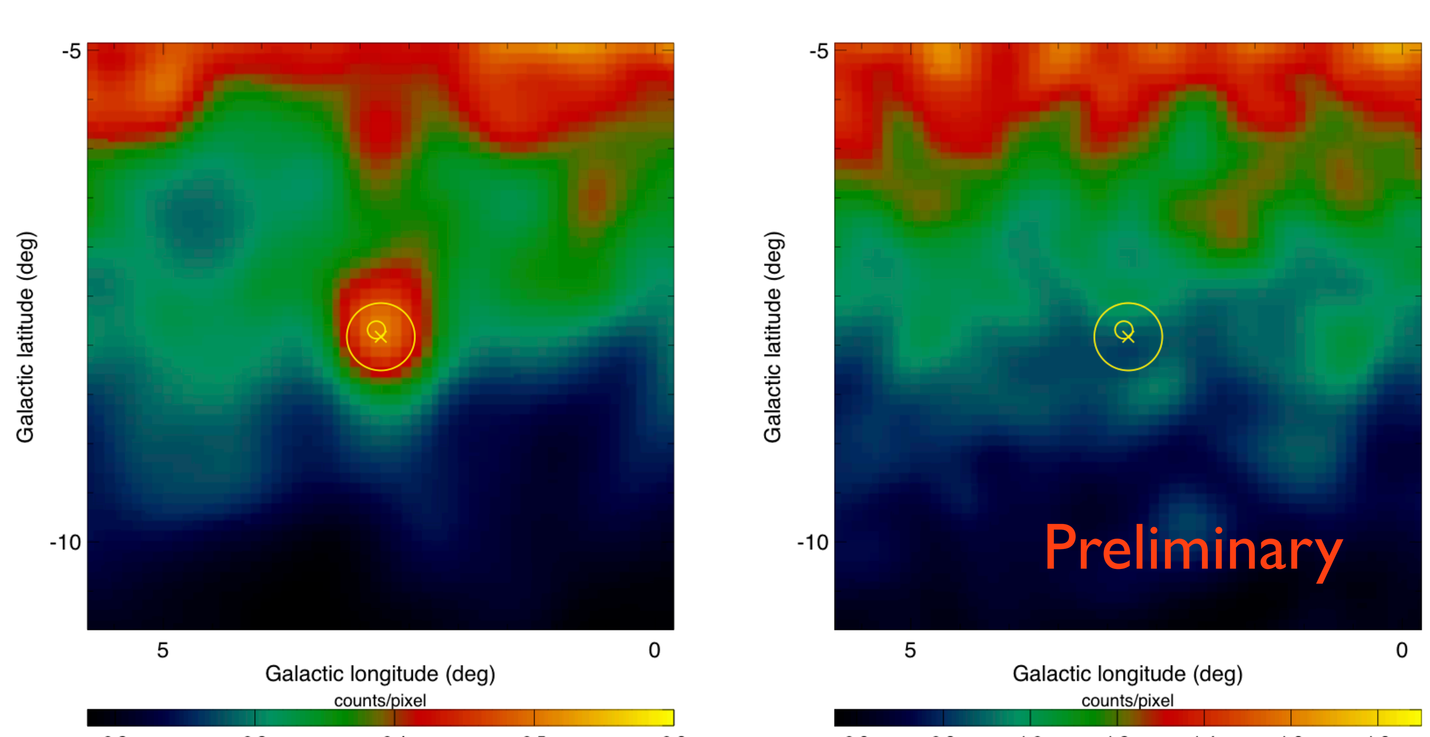
Fig 2. Radio and γ-ray light curves for J1823-3021A

A luminous gamma-ray pulsar

The power emitted above 0.1 GeV is $L_\gamma = (8.4 \pm 1.6) \times 10^{34}$ erg/s making this pulsar the most luminous γ-ray MSP to date (Abdo et al. 2010). Its γ-ray efficiency is ~10%, similar to what has been observed for other MSPs. This suggests that a large fraction of its observed spin-down is intrinsic and this has important implications on its formation mechanism.

No significant emission from the cluster was detected in the off-pulse region of the pulsar. This means that the number of γ-ray emitting MSPs (N_{MSP}) is skewed by the presence of this single pulsar. Our upper off-pulse flux limit implies that $N_{MSP} < 32$. This result also rules out several competing mechanisms as the dominant contributors to the cluster γ-ray emission (e.g. inverse Compton scattering between relativistic electrons/positrons in MSP wind and background soft photons).

Fig 3. Fermi LAT γ-ray count map above 0.1 GeV for J1823−3021A during the ON (left panel) and OFF (right panel) pulse regions (see Figure 2). The 6 x 6 degree region is centered on the pulsar position (cross). The map was adaptively smoothed by imposing a minimum signal-to-noise ratio of 13 and 16 for the ON and OFF pulse regions, respectively. The large circle indicates the tidal radius of NGC 6624. The small circle shows the 99% confidence region for the location of the γ-ray source.



Light curve modeling

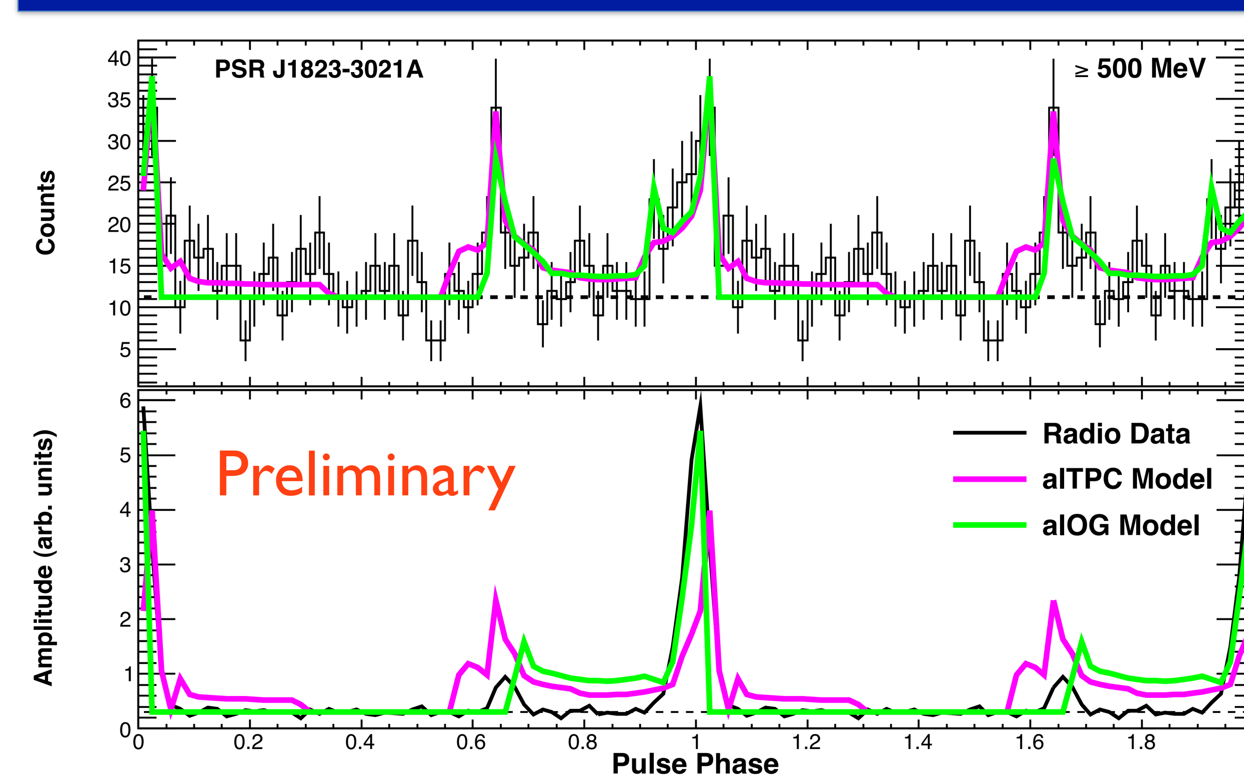


Fig 4. The figure shows the observed and best-fit γ-ray (top) and radio (bottom) light curves for PSR J1823-3021A using the altitude-limited Two-Pole Caustic (alTPC) and Outer Gap (alOG) models (Johnson et al. 2011).

The best fit constrains the magnetic inclination angle α to ~50° and 70° (for alTPC and alOG respectively) and the viewing angle ζ to ~68° for both models.

Conclusions

- First detection of γ-ray pulsations from an individual globular cluster MSP (PSR J1823-3021A)
- Whose γ-ray luminosity is among the highest observed for any MSP.
- The pulsar dominates the total emission of the cluster. This rules out several competing mechanisms as the dominant contributors to the cluster γ-ray emission and skews the γ-ray emitting MSP number estimate.

References

A. A. Abdo et al., Astrophys. J. Supp. 187, 460 (2010) (Pulsar Cat)
J. D. Biggs et al., Mon. Not. R. Astron. Soc. 267, 125 (1994)
P. Freire et al. (2011), Submitted in Science
T. J. Johnson et al. (2011) - Poster on Modeling and Likelihood Fitting of gamma-ray and radio MSP Light Curves (2011 Fermi Symposium)
Tam et al., ApJ, 729, 90 (2011)

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