Discovery of a 1.69 ms radio pulsar associated with the X-ray binary XSS J12270-4859

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Abstract

XSS J12270-4859 is an X-ray binary associated with the Fermi LAT gamma-ray source 1FGL J1227.9-4852 (Hill et al. 2011). In 2012 December, the source underwent a transition where the X-ray and optical luminosity dropped suddenly and spectral signatures of an accretion disk disappeared (Bassa et al. 2014). We report the discovery of a 1.69 millisecond pulsar using the Giant Metrewave Radio Telescope (GMRT) at 607 MHz associated with this source, confirming that system is now an active radio millisecond pulsar. We report on radio timing observations of the source with the GMRT and Parkes Telescope that allow determination of the orbital parameters and study of the radio eclipses and variability.

History

The LMXB XSS J12270-4859 is an INTEGRAL source and is the only LMXB associated with a Fermi/LAT gamma-ray source (1FGL J1227.9-4852; Hill et al. 2011):

• The LAT source has a pulsar-like spectrum
• X-ray source studied with Swift, RXTE, XMM and more
• Associated compact flat-spectrum radio source seen with ATCA
• Source searched many times for radio pulsations by Fermi Pulsar Search Consortium
• Hill et al. noted similarities with PSR J1023+0038, the archetypal redback in the Galactic plane

State Transition (Bassa et al. 2014)

• Transition occurred between 2012 November 14 and December 21
• Optical flux decreased by 1.5–2 magnitudes
• Previous emission lines disappeared
• X-ray flux dropped by an order of magnitude
• Fermi LAT flux dropped significantly
• Suggested transition from X-ray binary to a radio millisecond pulsar state

Results

• We have discovered PSR J1227–4853, a 1.69 ms pulsar in the X-ray binary XSS J12270–4859 (and the 7th fastest pulsar known!)
• This demonstrates that this LMXB is indeed a redback system like J1023+0038 (which also has a period of 1.69 ms), but here we observed the LMXB→MSP transition instead of the reverse as seen in J1023.
• Orbit parameters require a minimum companion mass of 0.216 Msolar and a most probable mass of 0.25 Msolar, for an assumed pulsar mass of 1.4 Msolar. The most probable mass goes up to 0.32 Msolar if the pulsar has a mass of 2.0 Msolar.
• Another one of the last few bright LAT unassociated sources is resolved! Only 3 sources out of Romani’s selection of 249 bright LAT sources (Romani 2012) are still unidentified. One of those (2FGL J1653.5–0158) was reported to be another black widow/reddback last week (Romani et al. 2014)! The two remaining are 2FGL J1702.5–5654 and 2FGL J1906.5+0720.
• DM of 43.5 pc cm$^{-3}$ gives NE2001 distance of 1.4 kpc (consistent with earlier optical estimates of 1.4–3.6 kpc)
• Continued timing on GMRT ongoing, trying to get phase-connected solution for LAT pulsation detection

Pulsar Timing Status

Since the discovery, we have been timing PSR J1227–4853. We have 127 TOAs spanning a total of 137 days, but are not able to get a fully phase-connected timing solution yet, probably because of orbital period variations in this redback pulsar system (similar to J1023+0038; Archibald et al. 2013)

Our initial circular orbital fit has a period of 0.28789 days (=6.90936 hours), and an a sin i of 0.668 lt.s.

Timing will be continued at the GMRT with a goal of getting a phase-connected solution that allows us to search for gamma-ray pulsations in the LAT data.

References

Bassa, C. et al. 2014 MNRAS 441, 1825
Hill, A. et al. 2011 MNRAS 415, 235
Roy, J., Bhattacharyya, B., Ray, P. S. 2014 ATel #5890

Pulsion Discovery Plot

Flux Variations and Profile Evolution

The figure above left shows the orbital phases of our radio observations (green = Parkes 1400 MHz, red = GMRT 607 MHz, magenta = GMRT 327 MHz). Thick lines indicated detections, while thin lines represent observations. We never detect the pulsar between inferior conjunction and even near inferior conjunction there are frequent intervals (sometimes very short) of non-detections.

The figure above right shows the pulse profile variations at three frequency bands. The phase alignment is arbitrary.

Optical Orbital Modulation

Bassa et al. reported an orbital period of 6.913(2) hours based on optical photometry.