IJASRM

International Journal of Advanced Scientific Research and Management, Volume 3 Issue 12, Dec 2018

www.ijasrm.com

ISSN 2455-6378

Pulse period study of few Anomalous X-ray Pulsars

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Abstract

Anomalous X-ray Pulsars are small class of pulsars which are highly magnetized and have spin period of several seconds. This paper present the calculation of spin period of seven AXPs using Japan's fifth X-ray astronomy satellite Suzaku observations.

Key word: *Neutron star*, AXPs, *pulse period.*

1. Introduction

Anomalous X-ray Pulsars (AXPs) are isolated young neutron stars having high order X-ray luminosity (~10^{34} ergs /s). They are called "anomalous" because they are neither rotation powered nor accretion powered X-ray pulsars. They are powered by a decaying ultra high magnetic field(~10^{13} -10^{15} gauss). AXPs have long spin period ranging from 5 -12 s. The X-ray luminosity of AXPs lies between 10^{33} to 10^{35} erg s^{-1}. Some of the AXPs also emit at optical and/or infrared wavelengths (Hulleman et al. 2000). The AXPs are also considered to be very young 10^{3} - 10^{5} years, some of which are associated with supernova remnants. There are currently 14 confirmed AXPs and 2 probable candidates {McGill SGR/AXP Online Catalogue}.

The survey of literature indicates that the first AXP discovered was 1E 2259+586 using the Einstein X-ray Observatory (Fahlman and Gregory 1981). It was initially thought as a low mass X-ray binaries. After few years, Seward et al. 1986, found ~ 6.44s pulsation in X-ray source 1E 1048.1-5937. Using the archival data of European X-ray Observatory, Isreal et al. (1994) discovered ~ 8.7s pulsation in 4U 0142 +61. All these three sources showed the lack of massive companion .

AXPs display different types of X-ray flux variability: from slow, moderate flux changes on timescale of months/years, to intense outbursts with short rise times (~ 1 day) lasting ~ 1 year. Some AXPs were found to undergo intense and drastic SGR like bursts activity on sub second time scales (XTE J 1810-197, 4U 0142+614, 1E 1048.1-5973, 1E 2259+586). The discovery of bursts from AXPs is strong evidence for their signature in favor of a common nature of AXPs and SGRs as young magnetars (Albano et al. 2010).

2.Observations

For the present work, we used public data from Suzaku observations of various AXPs. The details about observation ID, date of observation, RA, DEC etc. are given in the table 1 and 2. Suzaku is Japan's fifth X-ray astronomy satellite mission with important US contributed instruments under collaboration with Institute of Space and Astronautical Science (ISAS) and the Japan Aerospace Exploration Agency (JAXA) (Mitsuda, et al. 2007). It was launched on 2005 July 10. Its pre launched name was ASTRO-EII. It has a circular orbit at an altitude of 550 km with an inclination of 31^{o}. It covers the 0.2-600 keV energy range with three sets of instruments, X-ray imaging spectrometer (XIS) covering the soft X-rays in the energy range 0.2-12 keV, Hard X-ray detectors (HXD) covering the energy range 10-70 keV with PIN diodes and 40-600 keV with GSO scintillators and X-ray spectrometer (XRS) to measure the high resolution spectra of X-ray source. Due to the loss of cryogen, the XRS is no longer working from the August 2005.

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Table 1: Spatial parameters of AXPs

Name of Source	RA†	DEC†	Distance* (kpc)
CXOU J164710.2- 455216	$16^h 47^m 10.2^s$	45°52'16.9''	5
1E 1547.0 -5408	$15^h 50^m 54.11^s$	54°18'23.7''	3.9
1 RXS J 1708 -4009	$17^h 08^m 46.87^s$	-40°08'52.4''	~8
1E 1841 -045	$18^h 41^m 19.34^s$	-04°56'11.16''	~6.7
1E 1048.1-5937	$10^h 50^m 07.14^s$	-59°53'21.4''	2.7
4U 0142 +61	$01^h 46^m 22.44^s$	-61°45'03.3''	>2.5
1E 2259 +586	$23^h 01^m 08.29^s$	-58°52'44.4''	3.0

† McGill SGR/AXP Online Catalog * Özel et al. (2001)

Table 2: Observation details of AXPs used for present study

Source	ID	Date of observation	Exposure for XIS and PIN	Observation mode and window option of XIS
CXOUJ164710.2-455216	901002010	2006-09-23 10:44:58	38.68ks; 35.04ks	Pointing ; 1/8 i.e time resolution of 1s
1E1547.0 -5408	903006010	2009-01-28 21:34:12	10.69ks; 33.37ks	Pointing ; 1/4 i.e time resolution of 2s
1RXSJ 1708 - 4009	404080010	2009-08-23 10:25:08	50.91ks; 50.83ks	Pointing ; 1/4 i.e time resolution of 2s
1E 1841 -045	401100010	2006-04-19 10:51:40	96.97ks; 61.44ks	Pointing ; 1/8 i.e time resolution of 1s
1E 1048.1-5937	403005010	2008-11-30 23:02:01	85.02ks; 61.8ks	Pointing ; 0:off i.e
4U 0142 +61	404079010 402013010	2009-08-12 01:41:15 2007-08-13 04:04:13	82.66ks; 99.7ks 71.9ks; 10.1ks	Pointing ; 1/4 i.e time resolution of 2s Pointing ; 1/4 i.e time resolution of 2s
1E 2259 +586	404076010	2009-05-25 20:00:17	89.17ks; 10.25ks	Pointing ;1/4 i.e time resolution of 2s

3. Data analysis and result

The data obtained from NASA's archive are into FITS (Flexible Image Transport system) format. The software used for this work is FTOOLS which is part of HEAsoft, which is developed and maintained by High Energy Astrophysics Science Archive Research Center (HEASARC) at GSFC, NASA. It is independent of the detectors on board various satellites and can be utilized for timing analysis.

The intensity of X-ray sources are highly variable. The variation in time can vary from few milliseconds to years. Timing analysis is study of such variabilities of different sources. A light curve is the starting point of timing analysis. A light curve is the plot between intensity of the source and the time. In ftools there is task called *efsearch* which also searches for periodicity in the given data. It folds the light curves with a large number of trial periods. Each folded light curve is fitted with a constant and hence χ^2 is determined. If the trial period is correct then χ^2 will be high and if the trial period is not correct then χ^2 value will be small. Thus, the trial period corresponds to maximum χ^2 represents the correct period in the light curve.

For all the sources used for this study, the following timing analysis procedure were adopted. At first, the barycentric correction was applied to the cleaned XIS by use of *aebarycen*. To find the most reliable period, first light curve of minimum time resolution were obtained for all XIS. Then, all XIS light curves for each source were combined. As the XISs have very low backgrounds, background subtraction from the light curves was not done. We generated the lightcurve for XIS 0, 1 and 3. We combined these light curves using the ftool task "lcmath". Using the *efsearch*, we derive the pulse period using the combined XIS light curves by searching for the maximum in the χ^2 versus folding period. The plot of χ^2 with folded period is shown is figure 1 and figure 2.

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Magnetars are neutron stars having very high magnetic field and rotating very rapidly. They are around 20 km in diameter and much heavier than our sun. The magnetic field of the magnetars are of the order 10^{14} G where as, the magnetic field of earth is around ~0.6 G and the magnetic field of strong sunspots is ~ 4000G. The unique thing about them is that thet are not powered by nuclear fusion, rotation or accretion like other stars but rather they are powered by decay of the magnetic fields. Magnetars broadly classified into two: Anomalous X-ray pulsars (AXPs) and Soft Gamma-ray Repeaters (SGR). AS of know there are 29 known Magnetars out of which 14 belongs to Anomalous X-ray pulsars and 15 are Soft Gamma-ray Repeaters. {McGill SGR/AXP Online Catalog}.

In this work, I have used Suzaku x-ray satellite data to obtained their pulse(spin) period. The pulse period obtained for different AXPs are shown in the Table 3 . The pulse period so obtained were compared to period reported in the different literature. It is found that they are in good agreement.

4.Conclusion

In this work, I have used seven AXPs, out of 14 AXPs mentioned in McGill online Magnetar Catalogue in which twelve are confirmed AXPs and two are probable candidates. In future, I intend to find the pulse period of remaining AXPs using different observatories as Suzaku mission was ended in 2015. In addition to above, I intend to do pulse profile study and spectral study of AXPs and Soft Gamma-ray Repeaters (SGRs).

Acknowledgements

For the present work, I have use the data obtained from the High Energy Astrophysics Science Archive Center (HEASARC), provided by NASA's Goddard Space Flight Centre and McGill online Magnetar Catalogue . I also like to thank the entire team of Japan's x-ray astronomy satellite Suzaku.

Table 3: pulse(spin) period reported and obtained using Suzaku data.

Source	Spin period reported	Best period found
CXOU J 164710.2 -455216	10.6107s	10.61058 ± 0.0001s
1E 1547.0 -5408	2.069s	2.07404 ± 0.0001s
1 RXS J 1708 -4009	10.99s	11.00545 ± 0.0001s
1E 1841 -045	11.775s	11.78298 ± 0.000s
1E 1048.1-5937	6.452s	6.45985 ± 0.0001s
4U 0142 +61	8.688s	8.68893 ± 0.0001s
(Two observations)		8.68879 ± 0.0001s
1E 2259 +586	6.979s	6.97914 ± 0.0001s

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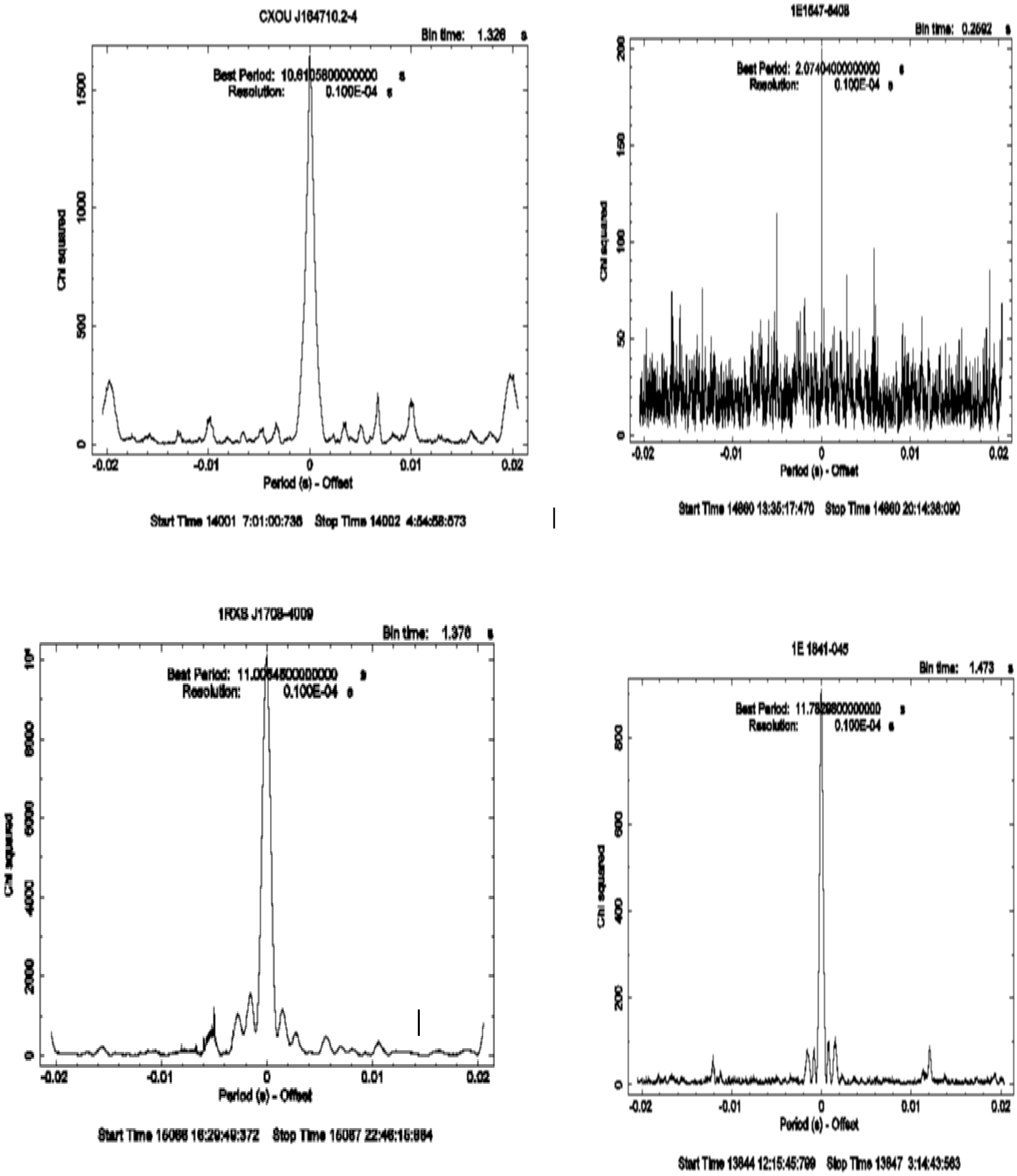

Figure 1: The plot of of χ^2 with folded period for AXPs CXOU J 164710.2 – 45, 1E 1547-5408, 1 RXS J 1708-4009 and 1E 1841-045 respectively.

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ISSN 2455-6378

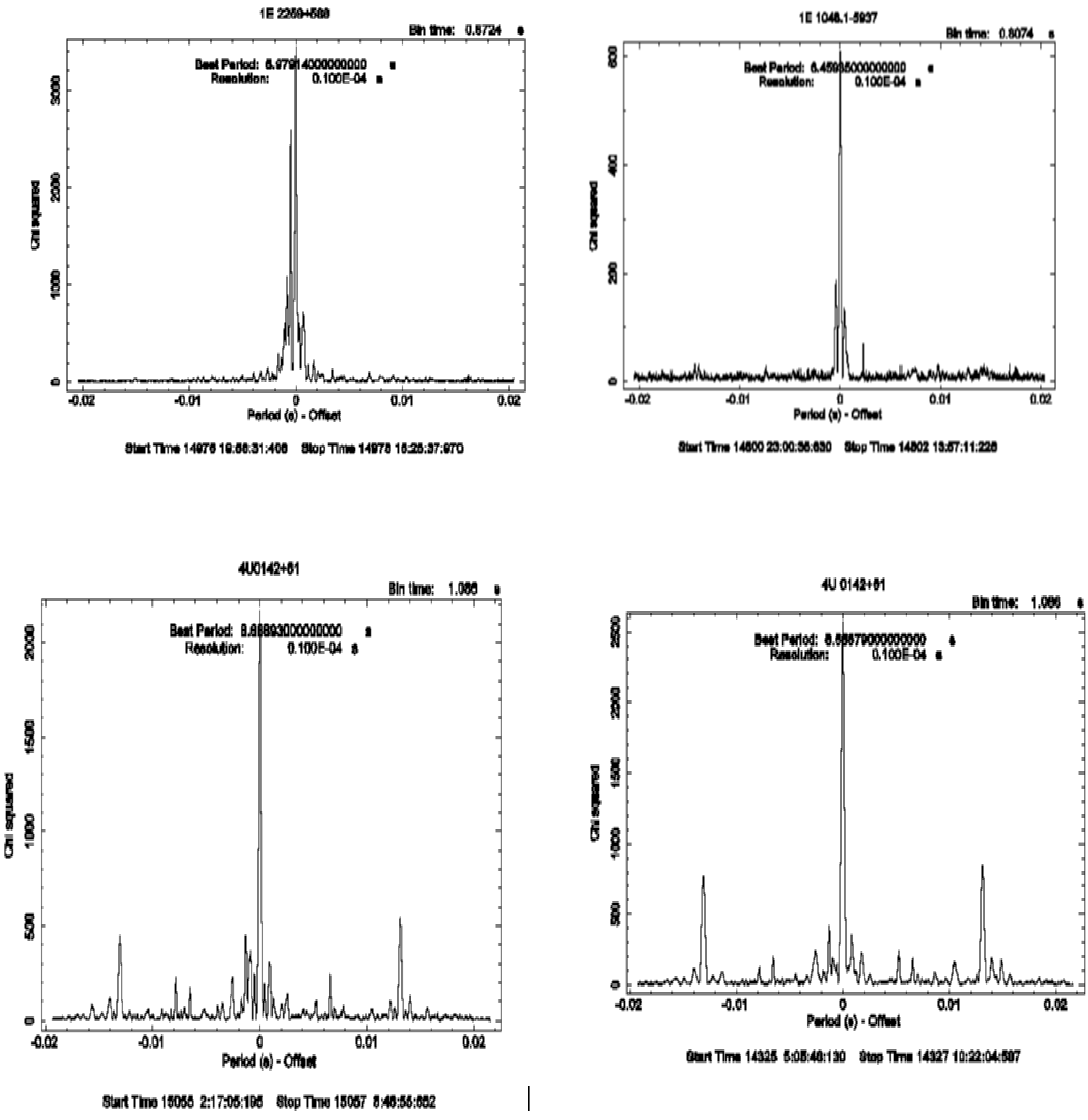

Figure 2 : The plot of of χ^2 with folded period for AXPs 1E 2259+588, AXP 1E 1048-593 and the AXP 4U 0142 + 61 for two observations(ID and 404079010 and 402013010).