Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 7; April-June, 2015 pp. 520-524

http://www.krishisanskriti.org/jbaer.html

Study of Twin Quasi-Periodic Oscillations in the NS-LMXB 4U1608-52

Yogita Trivedi[1] and Santvana Bapna[2]

[1]Research Scholer Mewar University Chittorghar
[2]B.N. Girls' College Rajsamand
E-mail: [1]shrimaliyogita@yahoo.in, [2]santvanabapna@gmail.com

Abstract—*We present results from study of timing properties and a report on the detection of twin quasi-periodic oscillation (QPO) of frequencies 0.203 Hz and 0.26 Hz in the transient NS-LMXBs 4U1608-52 using RXTE/PCA observations. The observations used in the present work were carried out during the X-ray outbursts in 2003 (March-April -September-October). However QPO were never detected during other outbursts of the pulsar, detected the first time in this pulsar in order of mHz. Pulse profiles of different energy ranges [2-60 keV] are also plotted in this paper for two different observations, one in which QPO is detected and other in which QPO is not detected. The results of our analysis of RXTE data during outburst of the pulsar are presented in the paper.*

1. INTRODUCTION

A low mass X-ray binary (LMXB) is a binary star system comprising a neutron star (NS-LMXB) or a black hole (BH-LMXB) with a late type companion star. NS-LMXBs are known to emit X-rays erratically and exhibit certain physical states by their emission behavior, which is complicated owing to the different natures of the sources [12]. Soft X-ray transients (SXTs) are a group of X-ray binary systems that occasionally exhibit bright outbursts in a soft X-ray band. They are mostly identified as a low-mass X-ray binary (LMXB) containing either a neutron-star (NS-LMXB) or a black hole (BH-LMXB) [9]. An NS-LMXB is generally accompanied by an old neutron star with a weak magnetic field. Thus, the behavior of an NS-LMXB is similar to that of a BH-LMXB in variability and state transitions; however, the existence of a rigid surface and an intrinsic magnetic field as well as smaller gravitational forces in NS-LMXB differentiates from BH-LMXBs.

The power law photon energy spectra often observed in LMXB's suggests that the dominant radioactive mechanism in these systems is Compton up-scattering of soft photons in a hot plasma [20], [14]. The temporal behavior of such models has been studied in a variety of circumstances, [24], [5], [4]. For QPO in particular, both the fractional amplitude vs. energy and the relative time lag vs. energy can be predicted based upon models where a hot, uniform plasma is illuminated by soft black body photons, accounting for the system's response to variations in either the soft photons or the plasma,[24], [9] . The variability of the NS-LMXB intensities reveals both quasi-periodic oscillations (QPOs) of various periods in addition to erratic variation and coherent mills-second pulsations for some NS-LMXBs, [10] , [2] . However, the pulsation behavior differs from that of ordinary X-ray binary pulsars which are generally binary systems consisting of a younger neutron star and an early type star.

Soon after the launch of the Rossi X-ray Timing Explorer (RXTE), rapid (300–1300 Hz), nearly periodic variability in the X-ray light curves of low mass X-ray binary systems (LMXB's) was discovered [19], [14] .These oscillations, referred to as kilohertz QPO (quasi-periodic oscillations), have now been observed in over two dozen neutron star bearing LMXB's (see van der Klis 2000 for a review). They are distinguished by high frequencies and high quality factors (Q=FWHM/frequency), and tend to be seen in pairs, with nearly constant frequency separation between the lower and higher frequency peaks (also called the lower and upper QPO). The high frequencies of kilohertz QPO are thought to tie them to phenomena taking place in the inner regions of accretion disks surrounding neutron stars. In the present work, we have investigated the timing properties of the transient NS-LMXB 4U1608−52 from March 2003 to October 2003 using observations made with the RXTE and report the detection of QPO features detected during X-ray outbursts in 2003. The results obtained from the timing analysis of the RXTE/PCA observation are presented in this paper. We also present pulse profile for this source in this paper. The low mass X-ray binary 4U1608−52 was first observed in 1971 [21]. It is the same source as the Norma bursts, from which the first X-ray bursts were discovered [3] independent from the X-ray burst discovered by Grindlay etal. (1976) from 4U 1820−30. 4U1608−52 is a soft X-ray transient, which shows outbursts at intervals varying between 100 days and several years [11].

4U1608−52 is famous transient NS-LMXBs, where Type I X-ray bursts have also been detected in so 4U1608−52 [13]. The outbursts typically show a sharp rise and an exponential decay. 4U1608−52 sometimes occurs outbursts with a symmetric evolution between the rise and the decay. The periodicity of the outbursts has been reported in 4U 1608−52. Neutron star spin period to be 1.61 ms . Its distance is estimated to be 3.6 kpc from observations of flux-saturated type-I X-ray bursts [13]. The behavior in the soft state of 4U1608−52 is investigated in detail by Takahashi, Sakurai & Makishima Hasinger and Van der Klis (1989) classified 4U1608−52 as an atoll source, based on the correlated X-ray spectral variability and less than 10 Hz noise in the X-ray intensity that is characteristic for this class of objects. There are several models to define QPOs. According to Beat Frequency Model (BFM), QPOs arise from the modulation of accretion flow onto a weakly magnetized, rapidly rotating neutron star.

2. OBSERVATION AND DATA ANALYSIS

The timing study of celestial X-ray sources was main objective. It made great contributions to our understanding of high energy astrophysics by means of its unrivaled timing resolution. Almost all the X-ray sources in the sky are variable i.e. their intensity changes with time. The intensity changes can be highly periodic, quasi periodic or sometimes totally aperiodic. Time scale of such variation ranges from few mile-seconds to tens of year's .The plot of the power of individual component as a function of frequency is known as Power Density spectrum.

Data will be analyzed by using appropriate operating system software heasoft and different models. First the standard step for methodology to quantify variability is to compute the power spectrum that is the amplitude squared of the Fourier transform of the light curve. The power spectra is expected to give information about characteristic frequencies of the system which might show up either as spectral breaks or as near Gaussian peaks, i.e. Quasi-Periodic oscillations (QPO).

A QPO is identified by performing a power spectrum of the time series of the X-rays. A periodic pulsation appears in the power spectrum as a peak of power at exactly one frequency or more than one frequency. The QPO phenomenon promises to help astronomers understand the innermost regions of accretion disks and the masses, radii and spin periods of white dwarfs, neutron stars and black holes. Data will be sampled by analyzing the ASM (All Sky Monitor) light curve. If this curve has outburst then it will appropriate for timing and spectral studies. In any outburst, accreting matter is very large so we can obtain a sharp peak in ASM light curve, which gives many physical parameters. Data will be collected by different satellites. These satellites collect data from different sources, which are available at the NASA's site. In our investigation we collect data by RXTE.

ASM was sensitive in 1.5-12 keV energy range [17]. The PCA, which was consisting of five Xenon filled proportional counter detectors, was sensitive in 2-60 keV energy range. The effective area, energy resolution and time resolution of PCA at 6 keV, 18 % at 6 keV and 1 s, respectively. A detailed description of the PCA instrument can be found in paper by Jahoda [6]. The third instrument, HEXTE was operating in 15-250 keV energy range [17]. We used standard 1 mode data, which provided binned data with a time resolution of 0.125 s to calculate the light curve and pulse periods. Fig. 1 represents the full RXTE-ASM curve from the beginning of the RXTE mission in 1996 to 2012.

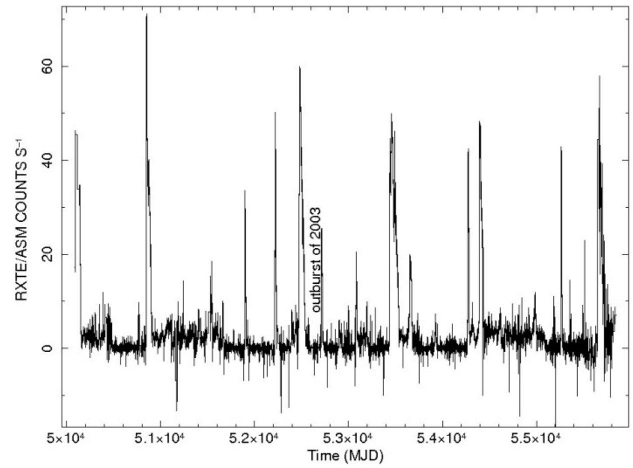


Fig. 1: ASM one-day averaged light curve of the transient NS-LMXB 4U 1608−52 from 1996 February 2 (MJD 50133) to 2012 January 01 (MJD 55927). During entire observing period of RXTE many major outbursts were detected in the ASM light curve. RXTE/PCA observations during 2003 outburst were analyzed to investigate the QPO features in the pulsar.

We used data from all the PCA observations for our timing analysis during the 2003 outbursts (as marked in Fig. 1). There were a total of 49 RXTE/PCA observations during 2003 outburst. Standard 1 mode data with a time resolution of 0.125 s were used in the present analysis. Data reduction was carried out by using the software package FTOOLS whereas data analysis was done by using the Heasoft package (version 6.11).

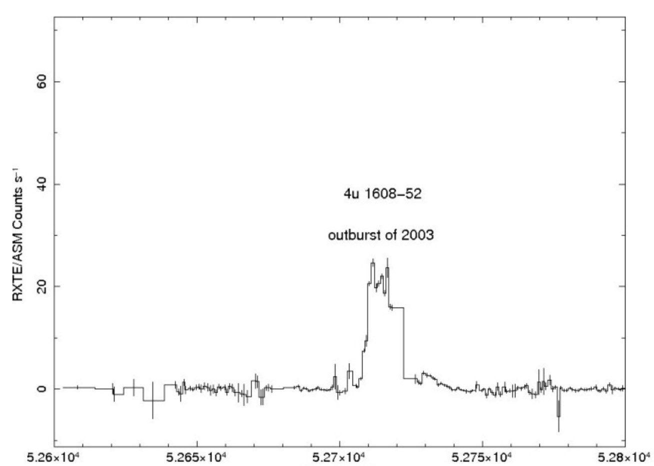


Fig. 2: One day averaged RXTE/ASM light curve of the transient NS-LMXB 4U1608−52 during 2003 outburst.

Observation detail with date, Modified Julian Days (MJD), duration of observation, exposure of observation, the PCUs ON during the observation and averaged light curve counts with error are shown in table 1 & 2 Using the standard 1 mode PCA data, we extracted light curves with a time resolution of 0.125 s from all the RXTE pointed observations during the 2003 outburst.

One-day averaged 1.5-12.0 keV RXTE/ASM light curves of the pulsar during the 2003 outburst are shown in Fig. 2.

We generated power-density spectrum (PDS) from each of the light curves by using the FTOOLs package. We found that the1.61ms regular pulsations of the pulsar and its harmonics were present in the PDS obtained for all the PCA observations. Apart from these pulsations and corresponding harmonics, the PDS from some RXTE/PCA observations during the outburst of the pulsar.

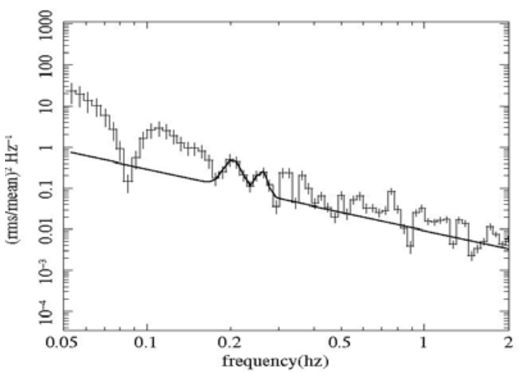


Fig. 3; Representative PDS showing QPO for observation ID 80406-01-04-08 (MJD 52727, 2003) March 2.

Table 1: Log of observations during 2003

Obs id	Obs date	Pcu on	Av count	Mjd	Exposur	Duration
80406-01-01-00	13/03/03	1,2,3	3058.25±6	52711	1301	1789
80406-01-02-00	16/03/03	0,1,2,3	3326.94±6	52714	1865	2352
80406-01-02-01	16/03/03	0,2,3,4	3511.53±5	52714	1385	1837
80406-01-02-02	17/03/03	0,2,3,4	2436.87±3	52715	2888	6072
80406-01-02-03	18/03/03	0,2,3	2275.98±4	52716	1466	1767
80406-01-02-04	19/03/03	0,2,3,4	1961.42±3	52717	1925	2531
80406-01-03-00	21/03/03	0,2,3,4	2105.95±3	52719	2706	4418
80406-01-03-01	22/03/03	0,2,3,4	1292.74±3	52720	1895	3721
80406-01-03-02	23/03/03	0,2,3,4	850.99±3	52721	1634	4366
80406-01-03-03	24/03/03	0,2,3,4	177.04±1	52722	1325	2128
80406-01-03-06	27/03/03	0,2	147.52±2	52725	1472	1859
80406-01-04-00	29/03/03	0,2,3	195.56±2	52727	1350	2905
80406-01-04-01	29/03/03	0,2,3	210.41±2	52727	1862	2486
80406-01-04-02	30/03/03	0,2,3	246.83±1	52728	2224	3390
80406-01-04-04	01/04/03	0,2,4	343.83±1	52730	1979	2567
80406-01-04-05	02/04/03	0,2,3	364.93±1	52731	1731	4020
80406-01-04-06	03/04/03	0,1,2	294.23±2	52732	1941	2520
80406-01-04-07	29/03/03	0,2,3	202.38±2	52727	1241	2318
80406-01-04-08	29/03/03	0,2,3	318.42±5	52727	985	1740
80406-01-05-00	04/04/03	0,2,3	482.46±2	52733	2119	2619
80406-01-05-01	08/04/03	0,2,3,4	329.23±4	52737	904	2036
80406-01-06-00	24/09/03	0,2,3	304.98±4	52906	1646	2014
80406-01-06-01	24/09/03	0,2	326.76±1	52906	558	910

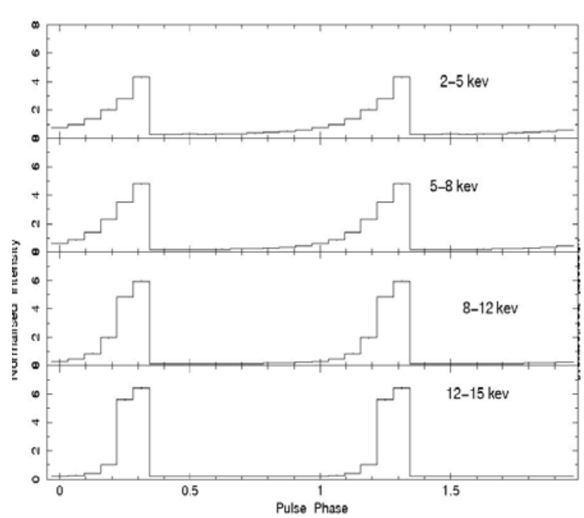
Out of a total of 49 RXTE observations, we found the presence of QPOs in only one observation (as shown in table no. 3). The log of observation is given in Table 1, 2, 3. Fig. 3 show the representative PDS for the outburst of observation ID 80406-01-04-08 (MJD 52727, 2003) March 2.

Table 2: Log of observations during 2003

Obs id	Obs date	Pcu on	Av count	Mjd	Exposur	Duration
80406-01-06-02	24/09/03	0,2	146.4732	52906	1267	1681
80406-01-06-04	24/09/03	0,2	306.78±4	52906	1745	2307
80406-01-06-05	24/09/03	0,2	290.72±4	52906	1032	1395
80406-01-06-06	25/09/03	0,2	277.55±3	52907	927	1960
80406-01-07-00	26/09/03	0,2,3	329.77±1	52908	1960	2280
80406-01-07-01	27/09/03	0,2,3	363.19±2	52909	1997	2642
80406-01-07-02	28/09/03	0,2,3,4	563.83±1	52910	1609	2330
80406-01-07-03	28/09/03	0,2,3,4	577.60±4	52910	551	1200
80406-01-07-04	29/09/03	0,2,3,4	790.62±6	52911	610	2569
80406-01-07-05	30/09/03	0,1,2,3	658.27±1	52912	2510	5013
80406-01-07-06	01/10/03	0,2,3,4	579.35±2	52913	2057	5027
80406-01-07-07	02/10/03	0,1,2,3	453.73±2	52914	1624	1931
80406-01-08-00	03/10/03	0,2,3	295.36±2	52915	1076	2243
80406-01-08-01	04/10/03	0,2,3	259.74±2	52916	977	2140
80406-01-08-02	05/10/03	0,2,3	247.66±1	52917	2150	2798
80406-01-08-04	07/10/03	0,2,3	438.13±2	52919	1204	3406
80406-01-08-05	08/10/03	0,2,3	349.21±2	52920	855	3001
80406-01-08-06	08/10/03	0,2,3	339.86±2	52920	974	3331
80406-01-09-00	12/10/03	0,2,3,4	197.1±1	52924	878	2211
80406-01-09-01	14/10/03	0,1,2,3	241.91±2	52926	1098	2322
80406-01-09-02	15/10/03	0,1,2,3	193.72±1	52927	1192	3342
80406-01-09-03	16/10/03	0,2	100.61±1	52928	1400	3033
80406-01-10-00	17/10/03	0,2,3	109.29±.6	52929	1343	2460
80406-01-10-01	20/10/03	0,2,3	91.04±1	52932	2001	3242
80406-01-10-02	21/10/03	0,2,3	92.26±1	52933	1466	2941
80406-01-10-03	23/10/03	0,2,3	196.32±2	52935	903	1560

3. PULSE PROFILE FOR DIFFERENT ENERGY RANGE

Pulse profiles represent the normalised intensity as the function of the pulse phase (0-2). All the energy resolved background subtracted light curve were folded with the above mentioned pulse period and the resultant pulse profiles in different energy ranges 2-5 keV, 5-8 keV, 8-12 keV, 12-15 keV, 15-25 keV, 25-35 keV, 35-45 keV, 45-60 keV are shown in fig below. In plotting pulse profiles we use standard 2f data and bin size used is 16.



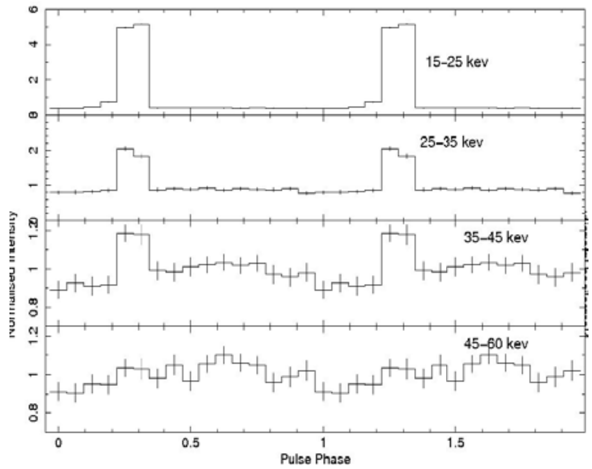


Fig. 4: Representative PDS showing pulse profile for energy range 2-5 keV, 5-8 keV, 8-12 keV, 12-15 keV, 15-25 keV, 35-45 keV, 45-60 keV for observation Id 80406-01-04-08 in which QPO is detected.

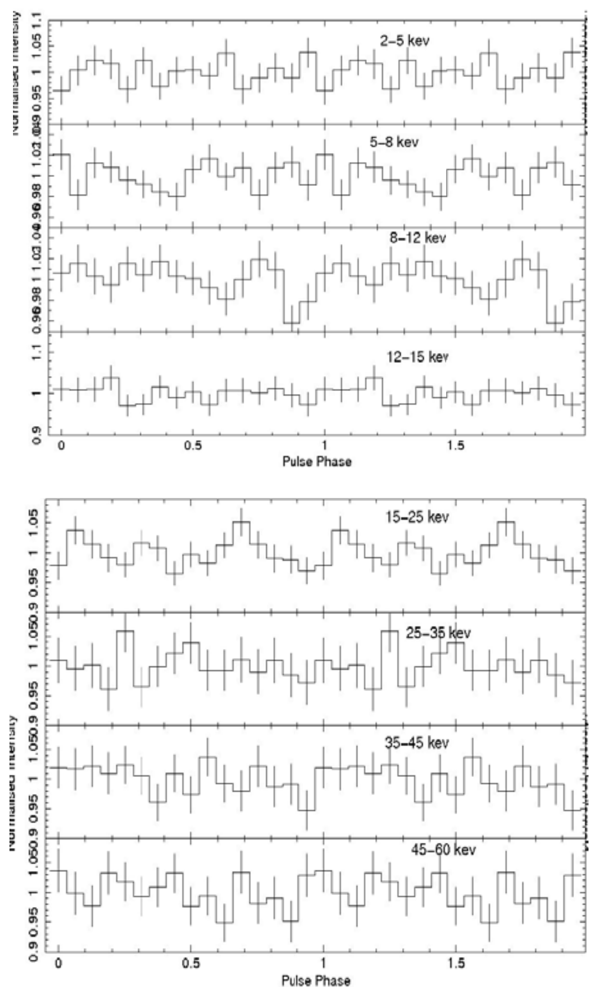


Fig. 5: Representative PDS showing pulse profile for energy range 2-5 keV, 5-8 keV, 8-12 keV, 12-15 keV, 15-25 keV, 35-45 keV, and 45-60 keV for observation Id 80406-01-09-03 in which QPO is not detected.

Fig 4 shows pulse profiles for id 80406-01-04-08 in which QPO is detected and fig 5 shows pulse profiles for id 80406-01-09-03 in which QPO is not detected. Both are very different. In first, pulse become sinusoidal at higher range (above 45 keV) where as in second, pulse is sinusoidal at lower range (below 25 keV).

Usually the pulse height variation for the mono-energetic incident radiation of the energy arises due

to the excitation of the gas molecules instead of ionization in the proportional counter. Hence the Pulse height is proportional to the square root of the energy whereas the energy resolution is inversely proportional to the square root of energy [16]. The pulse fraction is defined as (maximum – minimum)/ maximum or the ratio of pulse flux to the total flux. In the timing analysis it is worthwhile to measure the % Pulse – fraction, by the following equation as:

Δ = (Pulse height / total height) × 100

Pulse fraction is varying from 9 to 97% for this source.

4. DISCUSSIONS

In the inner part of the accretion disk, due to the motion of the inhomogeneously distributed matter, gives raise evolution of QPOs in accretion powered X-ray binary pulsars. Best useful information on the radius of the inner accretion disk and the interaction between the neutron star accretion disk can be found from detection of QPOs. According to Psaltis [15] the QPO frequency detected in accretion powered X-ray pulsars falls in the range of 1 MHz to 40 Hz. QPO features are detected more in transient sources compared to the persistent ones.

In 4U1608-52, the QPO features were detected only in one RXTE observation during 2003 outburst (present work). The QPO features in the accretion powered X-ray pulsars have been explained using several models as: (i) Beat frequency model (BFM) (ii) Keplerian-frequency model (KFM) and third one (iii) magnetic disk precession model (MDPM). According to the magnetospheric BFM model, the observed QPO frequency represent the beat between the coherent spin frequency of the pulsar and the Keplerian frequency at the inner disk radius at the magnetospheric boundary of the pulsar[[1][8].

In the KFM model the modulation of the X-rays by inhomogeniously distributed matter in the inner accretion disk at the Keplerian frequency gives rise to QPOs [23]. When the spin frequency of the pulsar exceeds the Keplerian frequency, mass accretion on to the neutron star is stopped at the magnetospheric boundary by centrifugal inhibition of accretion [18]. This results in the onset of propeller effect.

The predictions of both models are in good agreement with the measured values. It is not possible to exclude either of the two models due to the evident is based on the QPOs frequency. The interaction between the magnetosphere and the inner accretion disk regions modulates the accretion rate at the QPOs frequency. In principle most of the gravitational energy released at the neutron star surface is available to generate the QPOs signal [8].

5. CONCLUSIONS

In this paper, we have performed timing analysis using the RXTE observation of the star NS-LMXB 4U1608-52during the outbursts of 2003.

Using Gaussian model to fit and analyze the PDS of X-ray pulsars and investigation, we have discovered twin QPOs between ~0.203 Hz & 0.26 Hz of centroid frequency are in excellent agreement with the predictions of the BFM. These results provide the first quantitative confirmation of the BFM and show that the model can work in the presence of an accretion disk interacting with a rotating neutron star magnetosphere. As the source show QPO of kHz frequencies but in our investigation we observe lower frequency QPO in order of mili Hz. Pulse profiles of different energy range are also plotted for this data. There is a significant deference between curves for observations in which QPO is detected and in which QPO is not detect .The pulse curves are sinusoidal in higher energy range for later and for former it is sinusoidal in lower energy range.

6. ACKNOWLEDGEMENTS

Trivedi and Bapna gratefully acknowledge the use of computing facilities at Astronomy & Astrophysics Laboratory, Department of Physics, Mohanlal Sukhadia University, Udaipur, India and IUCAA Resource Centre (IRC), Udaipur, India to carry out the present work. The authors would like to thank all the members of the RXTE for their contributions in the instrument preparation, spacecraft operation, software development, and in-orbit instrumental calibration. This research has made use of data obtained through HEASARC Online Service, provided by the NASA/GSFC, in support of NASA High Energy Astrophysics Programs.

REFERENCES

[1] Alpar, A., & Shaham, J., Nature, 316, 239, 1985
[2] Archibald, A. M., et al. 2009, Science, 324, 1411
[3] Belian R.D, Conner J.P. and Evans W.D,1976, ApJ 206, L135
[4] Bottcher, M. & Liang, E.P. 1999, ApJ, 511, L37
[5] Hua, X., Kazanas, D. & Titarchuk, L. 1997, ApJ, 482, L57
[6] Jahoda, K., Swank, J. H., Giles, A. B., et al., Proc. SPIE, EUV,X-ray and gamma ray instrumentation for Astronomy VII, 2808, 59, 1996
[7] Klu_zniak, W., & Abramowicz. M. 2000, Phys. Rev. Lett., submitted (astro-ph/0105057) . 2001, Acta Phys. Polonica B, 32, 3605
[8] Lamb, F.K., Shibazaki, N., Alpar, A., Shaham,J., Nature, 317, 681, 1985
[9] Lee, H.C. & Miller, G.S. 1998, MNRAS, 299, 479
[10] Levine, A.M., Bradt, H., Cui, W., Jernigan, J.G., Morgan, E.H., Remillard, R., ApJ, 469, L33, 1996
[11] Lochner J.D., Roussel-Dupr´e D., 1994, ApJ 435, 840
[12] Masaru Matsuoka,1 and Kazumi Asai 1 1MAXI team, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198 matsuoka.masaru@riken.jp (Received 2012 March 5; accepted 2012 October 9) PASJ: Publ. Astron. Soc. Japan, 1–? 2013 April 15 c 2012. Astronomical Society of Japan
[13] Nakamura, N., et al, 1989, PASJ, 41, 617
[14] Podznyakov, L. A., Sobol, I. M., & Sunyaev, R. A. 1983,
[15] Psaltis, D., Astro.ph. 10536, 2004
[16] Ramsey, B.D.; Agrawal, P.C. “Gas mixtures for X-ray proportional counters”, 1988, SPIE , bf 982 , 258
[17] Rothschild, R. E., et al., ApJ, 496, 538, 1998
[18] Stella, L., White, N. E. & Rosner, R., ApJ, 208, 669, 1986
[19] Strohmayer, T. E., Zhang, W., Swank, J. H., Smale, A.,Titarchuk, L., Day, C. & Lee, U. 1996, ApJ, 496, L9
[20] Sunyaev, R. A. & Titartchuk, L. G. 1980, °a, 86, 121
[21] Tananbaum H., Chaisson L.J., Forman W., Jones C., Matilsky T.A. 1976, ApJ 209, L215
[22] van der Klis, M., Swank, J. H., Zhang, W., Jahoda, K.,Morgan, E. H., Lewin, W. H. G., Vaughan, B. & van Paradijs, J.1996, ApJ, 496, L1
[23] van der Klis, M., Stella, L., White, N., Jansen, F., Parmar, A. N., ApJ, 316, 411, 1987
[24] Wijers, R. A. M. J., van Paradijs, J., & Lewin, W. H. G. 1987, MNRAS, 228, 17P