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Study of HMXB 4U0115+63 by RXTE Satellite.

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ABSTRACT:

Luminous X-ray binaries are classified as Low Mass X-ray Binary (LMXBs) and High Mass X-ray Binary (HMXB) systems depending on the mass of the donor star. Periodic X-ray pulsations with periods ranging from 0.069 to 1455 s are present in a large no of (~35) of HMXBs). In 4U0115+634 for soft energy range, the profile is double peaked. As the energy increases, the second peak disappears and the profile becomes single peaked. It supports the hypothesis that high energy X-rays are emitted by accretion disc inner edge close to NS at high temperature and low energy X-rays far from the edge at low temperature.

KEY WORDS : X-ray binary, accretion disc, pulse profile

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INTRODUCTION:

Depending on the mass of the donor star, X-ray binaries (Luminosity 10^{35}erg/s) are often classified as Low Mass X-ray Binary (LMXBs) and High Mass X-ray Binary (HMXBs) systems . While this classification leaves unspecified nature of the accreting collapsed object (which indeed can be either a NS or a black hole), allowing to distinguish the phenomenology of the X-ray sources and their optical counterpart in a natural way.

Periodic X-ray pulsations with periods ranging from 0.069s to 1455s are present in a large number (~ 35) of HMXBs. This signal originates from the beamed radiation which is produced close to the magnetic poles of the young accreting neutron star with a surface field of ~10^{12}G. Due to the misalignment of the magnetic and rotational axes, the neutron star rotation modulates the X-ray intensity in a light-house fashion. Period or phase changes introduced by the binary motion, allow to measure some of the orbital parameters of these systems. The measurements together with the duration of the X-ray eclipse (which is present in several HMXBs) Doppler velocity and photometric modulation of the optical star, provide the absolute orbital solution and the masses of the two components. Secular spin period changes arise because of the torque exerted on the neutron star magnetosphere by the accreting matter. X-ray pulsations from luminous X-ray binaries provide an incontrovertible signature of accretion onto a magnetized neutron star.

After the discovery of first X-ray pulsar, it is well known that accretion disk is important for the evolution of accretion-powered X-ray Binary Pulsars (AXBPs). The accretion rates from the surrounding disk determines the instantaneous luminosity and spin rates, which have been investigated for 4U0115+634 in this paper.

SOURCE

4U0115+634 is a Be/X-ray binary system presumably comprising of a orbiting neutron star around a orbiting Be star in a eccentric orbit. It is defined as an early luminosity class 3-5 Be/X-ray star[1]. 4U0115+634 Be/X-ray binary shows emission in Balmer series lines, with excess infrared. The companion neutron star 4U0115+634 is hard X-ray transient pulsar and its behavior is attributed to the accretion disc of circumsteller material on to it which is not continuous, but present periodic X-ray outburst occurring at the time of periastron passage of compact object 4U0115+634 around central Be star. However, it is referred as centrifugal inhibition of accretion matter.

HEAO-1 Satellite observed X-ray spectrum of 4U0115+63 and Rose[2] fitted power law model with large changes in the index across the pulse and broad iron line at 6.6 keV.

Rappaport[3], used SAS 3, timing observations to derive the orbital parameters P_{orb} ~24.3 d ; e ~ 0.34 ; $a_x$sini ~ 140 light second, together with the orbital period yielding the mass function of ~ 5 M_{odot} and evidences for spin-up states of 4U0115+634[4].

Nagase[5] & Tamura[6] detected X-ray burst in 1990, February for the 4U0115+634 pulsar in the energy range upto 37 kev and two cyclotron resonance absorption at 12 & 23 kev confirming the earlier results of White[7].

Whitlock[8], observed four small burst in the Vela 5B data between 1969, August and 1971, January with 180 days periodic behaviour until a major outburst takes place in 1974, January. Lutovinov[9] studied the 2004 outburst with IBIS and JEM-X telescopes.

Nakajima[10] reported RXTE pointed observations of 4U0115+63 covering an outburst of March, 1999. They observed double harmonic cyclotron resonance absorption feature at ~ 11 keV and ~22 keV. They also reported that with the decrease in luminosity, the second cyclotron resonance absorption feature disappeared and the fundamental resonance energy increased unto ~16 keV and confirmed the result obtained by Mihara[11] using GINGA.

Soong & Swank[12] reported a broad 0.062 Hz QPO in HEAO 1 Observation of 4U0115+634 which did not fit into beat frequency model.

BeppoSAX observations of the transient X-ray pulsar was studied by Campana[13] close to its periastron passage. Ariel 6 X-ray instrument observed 4U0115+634 during December, 1980 and during the observation the pulse period was declining[14].

OBSERVATION AND DATA REDUCTION

To perform high resolution time variability studies of the emission from X-ray sources, the RXTE (Rossi X-ray Timing Explorer) satellite was launched on 30 December 1995. In this paper, the data obtained with the Proportional Counter Array (PCA) instrument are used comprising of data from five identical co-aligned gas filled proportional modulus (for details see chapter 2). These units give a collecting area of ~ 6500 cm^2, having an energy resolution of < 18 percent at 6 keV and a time resolution of 1 micro second. There are two volumes in each PCU, the main Xenon volume, the propane veta volume. To prevent the detection of photons with energies lower than 2 keV, each PCU is covered with a thin window of aluminized mylar. There is also a collimator in each PCU for providing the same field of view for all the PCUs (~1^o). A detailed description of the proportional counter array instrument can be found in Glasser, Odell & Senfert[15]. The All Sky Monitor (ASM) on board the Rossi X-ray Timing Explorer satellite consists of three wide-angle Scanning Shadow Cameras (SSCs). These cameras are mounted on a rotating drive assembly, which covers ~ 70% of the sky every 1.5 h[16].

In RXTE satellite, data can be packed in up to seven different modes, each mode suitable for a particular purpose. We use standard 1 mode, which provides binned data with a time resolution of 0.125 s but no energy resolution, as all 256 channels are combined into one, to calculate light curve, hardness ratios, pulse periods and pulse profiles[17].

Data reduction was carried out using FTOOLS whereas data analysis was done using the XRONOS and XSPEC packages[18] .

The observations of the source 4U0115+634 were taken from NASA's High Energy Astrophysics Science Archive Research Center (HEASARC) browse site ``heasarc.gsfc.nasa.gov''. The data of the source reported here were made during March,04 - April,14, 1999 with the pointed mode instruments of the RXTE satellite .

RESULTS :

OUTBURST

The RXTE satellite carries a continuously scanning all sky monitor (ASM). The full RXTE-ASM light curve of 4U0115+634 is shown in figure 1. There are three prominent X-ray bursts of 1999, 2000 and 2004. X-ray burst of 1999 was chosen for timing analysis using total 31 observations of high resolution (0.125 second) for the present work. It is lasting for about 60 days and spreads over the two and half orbital period of NS with 3.5 times photon flux as compared to ID 40051-05-02-00 flux.

LIGHT CURVE

From all the 31 observations, Barycenter corrected light curves were extracted with a bin size of 0.125 sec. The background count rates were simulated and subtracted from the Standard-1 light curves. All the individual light curves showed the pulses. The intensity of combined background light curve binned at the pulse period of ~3.61 s increases and then decreases.

PULSE PROFILE

A pulse period of 3.6140 s±.0001 within 90 percent confidence interval is found by pulse folding and χ^2 maximization method. ID 40051-05-04-00 has been used to show a plot of pulse period of X-ray pulsar 4U0115+634. Figure 2 shows the pulse period variability under 0.01% accuracy of measurements of RXTE. The variation of 0.1% in pulse is substantial and indicates that NS, while entering into circumstellar matter during passage close to periastron position in orbit of Be/X-ray binary, experiences a torque due to in falling matter under gravity with angular momentum of companion star. however, it spins up but while going out of circumstellar matter. it again spins down. this happens in one complete orbital period of 46.2 days. the estimated $\dot{P}$/P=2.5X10^{-2} yr^{-1} or 6.9X10^{-5} day^{-1} is consistent with earlier results[4]. All the energy resolved background subtracted light curve were folded with the pulse period of 3.61 s and the resultant pulse profiles in different energy bands 2-5 keV, 5-10 keV, 10-15 keV, 15-20 keV, 20-25 keV, 25-30 keV, 30-35 keV, 35-40 keV, 40-45 keV, 45-50 keV, 50-55 keV and 55-60 keV are shown in figure 3 and figure 4 for observation ID 40051-05-04-00. In soft energy range, the profile is double peaked. With the increase in energy, the second peak disappears and the profile becomes single peaked above ~ 25 keV. It could be due to pencil beam model followed at high energy range whereas fan-beam model is obeyed at low energy. It supports the hypothesis that high energy X-rays are emitted by accretion disk inner edge close to NS at high temperature and low energy X-rays for from the edge at low temperature.

The pulse fraction which is defined as (maximum - minimum)/maximum or the ratio of pulse flux to the total flux gradually increasing from 43% at 3 keV to ~ 67% at 17 keV. It is consisted with the enhanced softness of low X-ray flux from the accreting disk. Then the pulse fraction decreases upto 41% in the energy band of 55-60 keV. Hardness of high energy X-ray flux is related to flux emitted from the middle column of accretion disk near to surface of the NS and mostly blocked by dense accretion disk. Above 45 keV, due to low signal to noise ratio and low detection efficiency, the pulsations in the pulse profiles are not clearly detectable with the PCA. These findings are similar to that previously observed by Rose[2].

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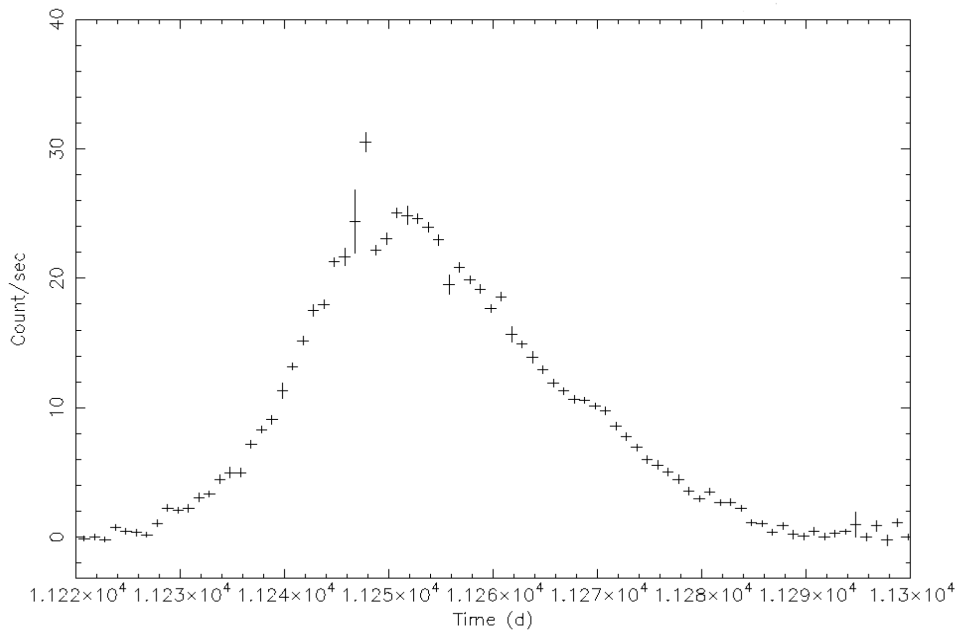

Fig. 1 RXTE-ASM long term light curve of 4U0115+634 for X-ray outburst observed in 1999 with binning of 1 day

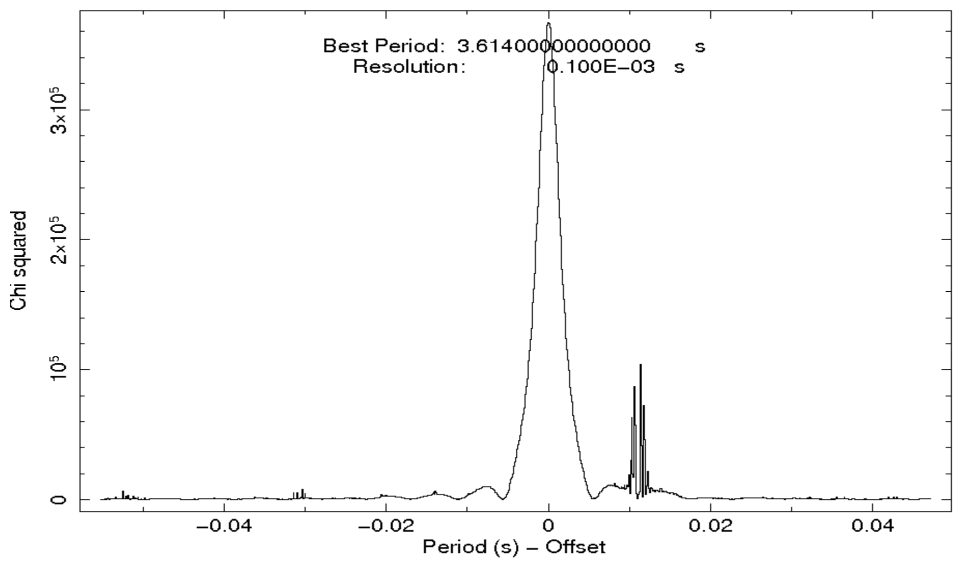

Fig. 2: Plot of pulse period for one of the observations of 4U0115+634

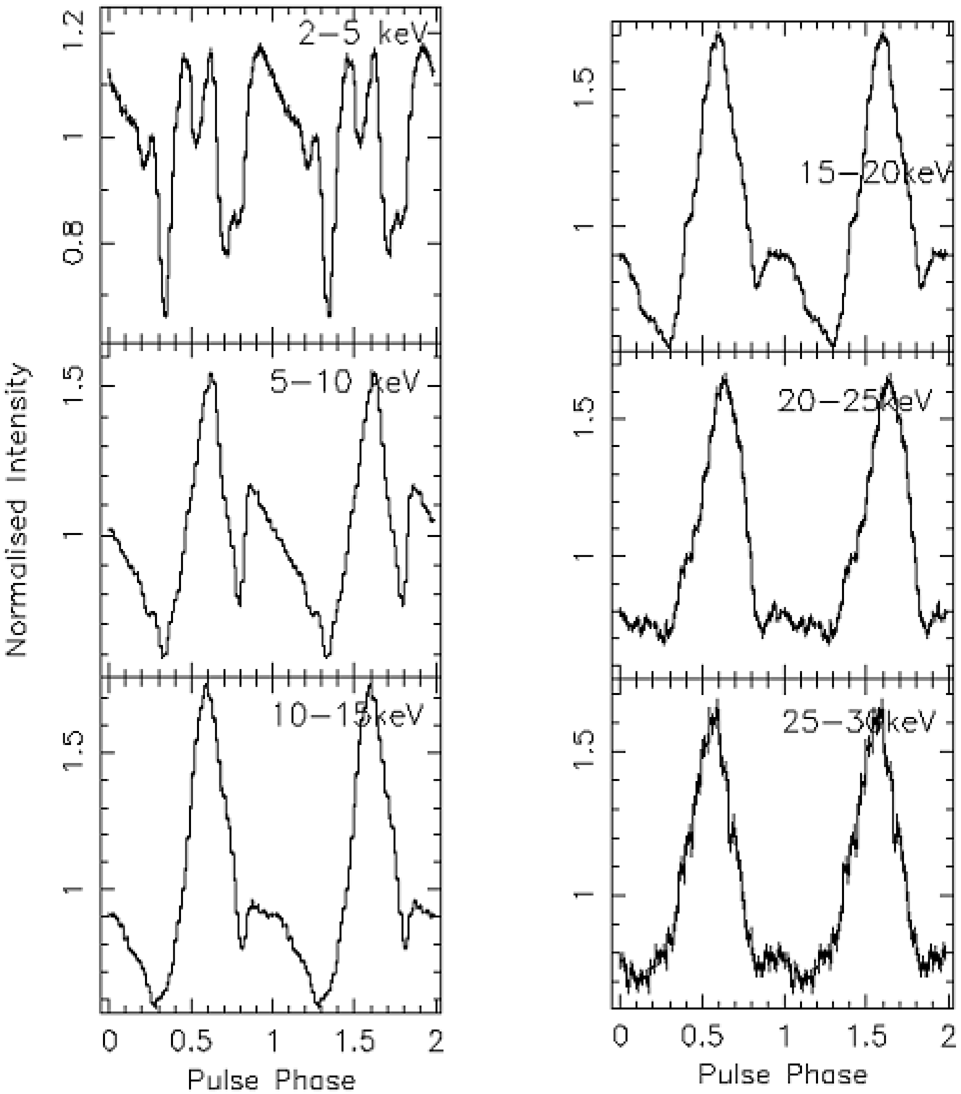

Fig. 3 : The nearly sinusoidal pulse profiles of 4U0115+634 folded at a period of 3.6140 s are shown (left, from the top) for 2-5 keV(first panel), 5-10 keV(second panel), 10-15 keV (third panel). In the right for 15-20 keV(top panel), 20-25 keV(second panel), 25-30 keV(third panel)

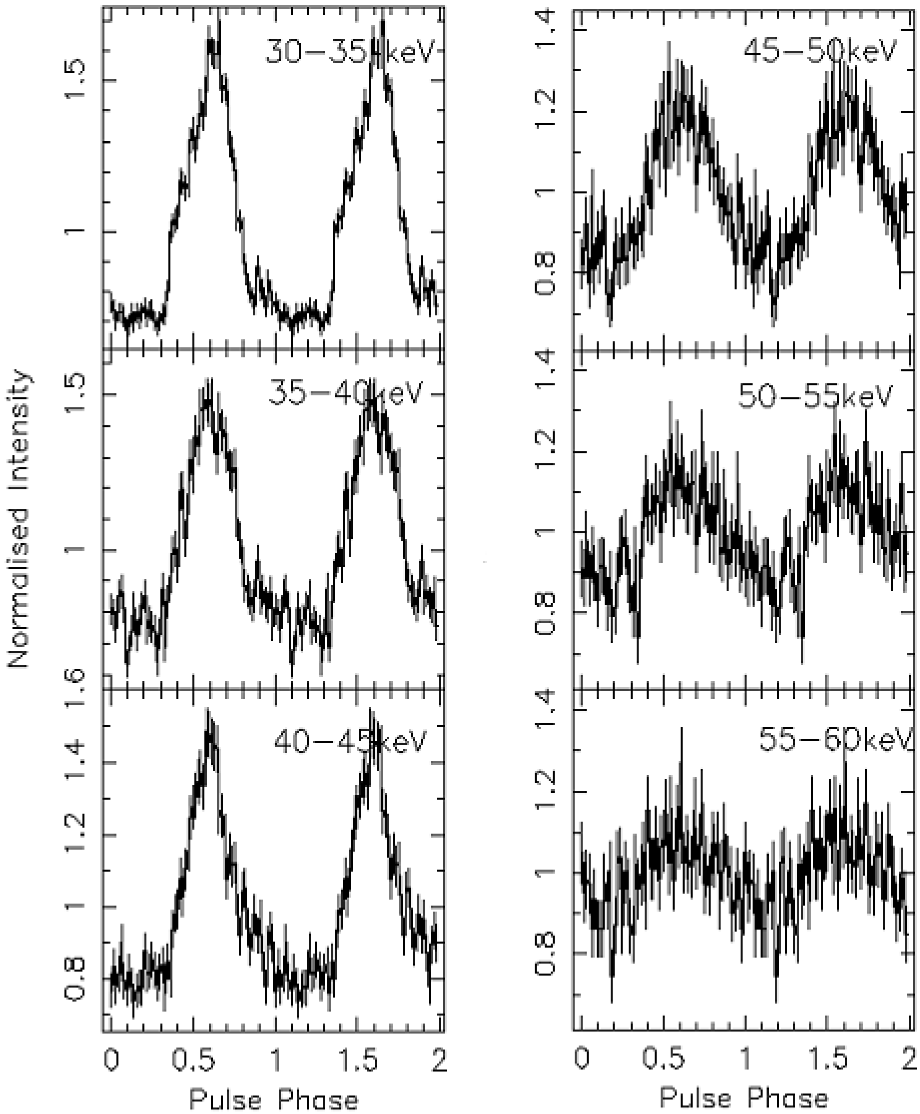

Fig.4: The nearly sinusoidal pulse profiles of 4U0115+634 folded at a period of 3.6140 s are shown (left, from the top) for 30-35 keV(first panel), 35-40 keV(second panel), 40-45 keV(third panel). In the right for 45-50 keV(top panel), 50-55 keV(second panel), 55-60 keV(third panel)

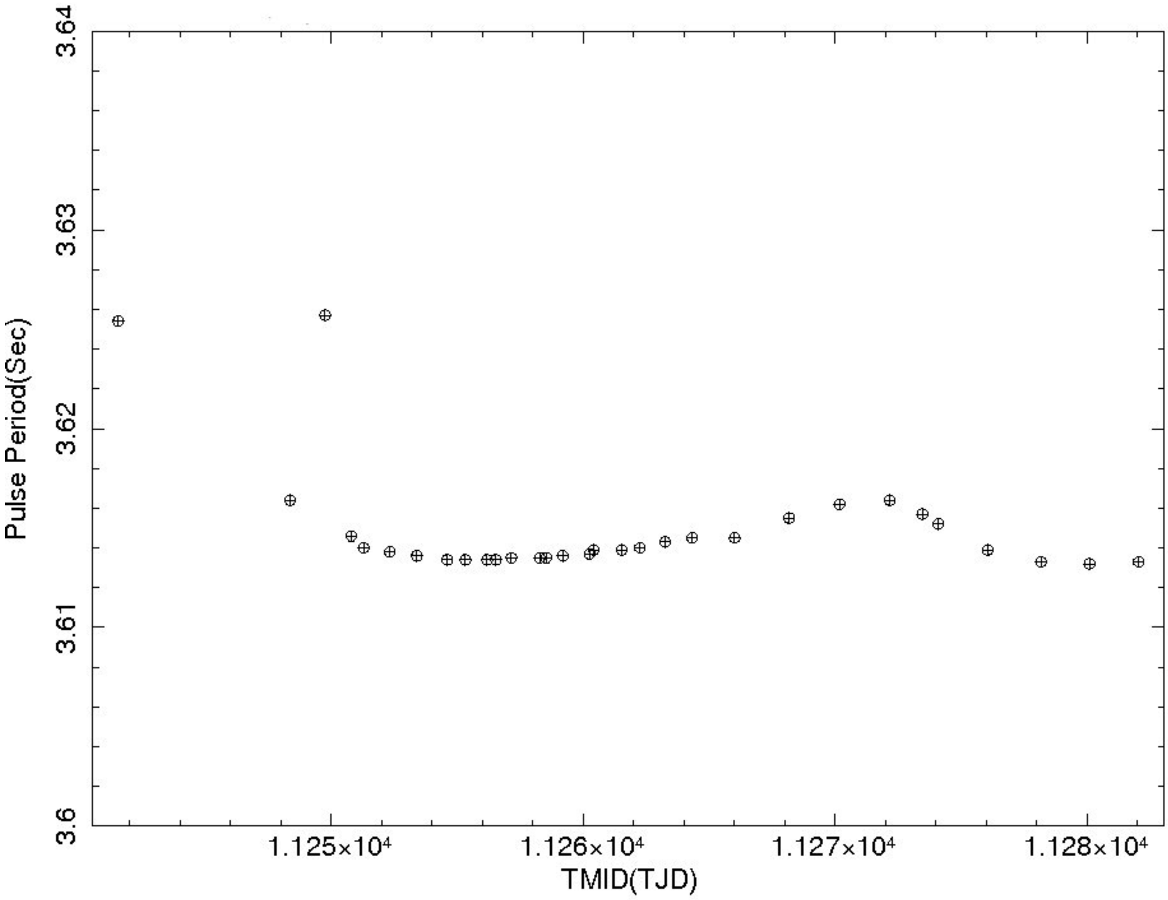

Fig 5 : Plot of pulse period as a function TMID(TJD)