HARD X-RAY OBSERVATION OF GALACTIC X-RAY SOURCES

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Abstract

Spectral and temporal measurements of three X-ray binary sources made in a series of baloon flights by using large area xenon filled proportional counter telescope from Hyderabad, India are described. The details of the spectra and pulsation light curves obtained in the 20-100 keV energy region for these sources are discussed.

1. Introduction

A large majority of the X-ray data obtained for 100 bright galactic X-ray sources, discovered so far; is confined to low energy region of 2-6 keV. In the case of about 40 X-ray sources, both galactic and extra-galactic, the observation have been extended upto 30 keV. In the energy region of 20-100 keV, the information is rather sparce due to lower fluxes and the fact that the experiments require very large area detectors and long integration time. A detailed study of the spectral characteristics of the hard X-ray emission from cosmic X-ray sources is of great importance from the point of view of understanding the physical mechanisms responsible for the production of X-rays. Hard X-ray emission from X-ray pulsars, the cyclotran line emission at hard X-ray energies as seen in the case of Her X-1 and the Crab Nebula and the quasi periodic behaviour in low mass X-ray binaries further emphasize the need of hard X-ray observations with better energy resolution. In this paper we describe the hard X-ray results obtained by a large area proportional counter telescope in a series of balloon flight between 1984 & 1986. The three X-ray sources observed during these flights were GX 1+4, 4U 1907+9 and Cyg X-3.

2. The Payload

The instrument consists of two identical multiwire Xenon filled proportional counters each having an effective area of 1200 cm^2, with a spectral resolution of 9% at 60 keV and an energy range of 20-100 keV. The detectors, complete with their high tension, electronics logic, on-board data analysis and calibration system are mutually independent and are mounted on an alta-azimuth platform. Source tracking and the corresponding background observations are made alternately during the flight and are controlled by an on-board programmer which is fed with a source trajectory data before the flight. Details of the design and the detector characteristics are described elsewhere (Rao et al., 1983).

3. Observation

The hard X-ray observations were made during three different balloon flights conducted on April 1984 (GX 1+4), April 1985 (4U 1907+9) and March 1986 (Cyg X-3). Apart from making short duration observations for the detector response calibration with the strongest hard X-ray source Cyg X-1, the entire ceiling duration in each flight was devoted to the detailed study of a single X-ray source. The pulse height analysed data from each detector were telemetered with a basic time resolution of 1.28 msec, while the other data modes like Quick-look data, PHA integrals and the Anti-counting rates were transmitted every 81.9 msec. The X-ray data were later analysed for spectral details, pulsar light curves and autocorrelation and fourier analysis for determination of the period.

4. Results and Discussion

a) GX 1+4

The hard X-ray observations of the X-ray pulsar (4 min period) were made on 7th April 1984 at 2200 UT. The source was detected at a signal level of 5 σ in 20-60 keV, which correspond to a source flux of $\sim$5.3 10^{-4} ph cm^{-2} s^{-1} keV^{-1}. The detected flux were a factor of $\sim$10 lower than that expected on the basis of the earlier observations. The optical counterpart of GX 1+4 binary is identified to be a symboitic star (Davidson et al, 1977) which does show the tendency of extended low. Optical observation made from the South Africa Astronomical Observatory on November 4, 1983 showed that source was in a low state, (Whitelock et al, 1983) which followed the earlier X-ray low state observations made on September 24/25, 1983 from the EXOSAT satellite (Hall et al, 1983) in which the source flux was observed to be 4UfU compared with 60 UfU seen normally. Later optical observations made on February 23/26, 1984 showed that the source activity was picking up again as was indicated by the presence of strong H_α line emission (Whitelock et al, 1983). The present observation of low X-ray intensity made two months later clearly indicate the delay in the onset of X-ray activity compared to the optical emission features. An autocorrelation analysis of our data indicated marginal detection of pulsation with a period of $\sim$ 234 sec, however the fourier analysis of the data did not show significant power corresponding to this or any other period. If this detection is real then a comparison with the earlier measured values (see Cutler et al, 1986) suggest a reversal of the spin-up trend of the pulsar.

b) 4U 1907+9

The hard X-ray observations of the source (orbital period 8.3 d) were made on April 17/18 1985 at 2210 UT. The X-ray pulsations from the source were clearly detected at a pulse period of 432.7 $\pm$ 1.6 s (figure 1). Using the period of 437.5 s as obtained during the earlier observations by Tenma Satellite (Makishima et al, 1984), a period derivative of 1 $\pm$ 0.3 x 10^{-7} s/s is obtained. This is the second highest spin-up rate for any X-ray pulsar after GX 1+4. To confirm this large period derivative, we have also analysed MPC data of the source taken from the Einstein observatory data bank. This analysis yeilded a period of 457 $\pm$ 15 s during 1979 and is consistent with the period derivative obtained by us (figure 2). The hard X-ray source is well

Fig. 1 . The X-ray pulse profile from Balloon observations in 20-80 keV band folded with pulsation period of 432.7 s. The average counting rate is shown by broken line while the background rate is shown as continuous curve

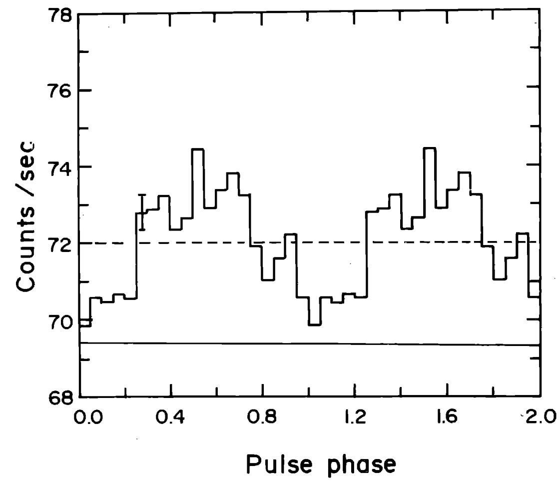


Fig. 2 . The pulsation period of 4U1907+09 vs Julian Day of observations. The best fit correspond to p/p = 1 ± 0.3 x 10^{-7} s/s

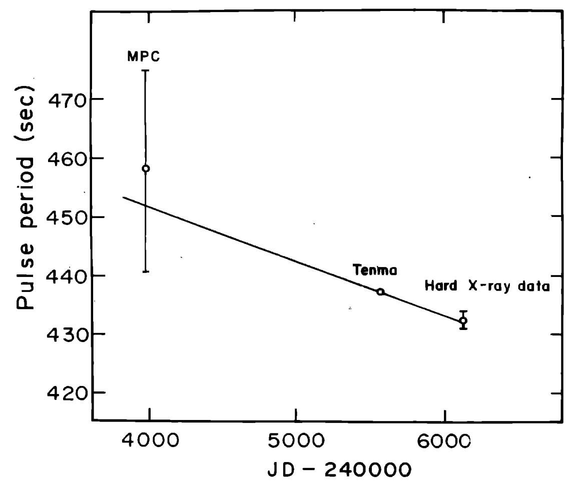
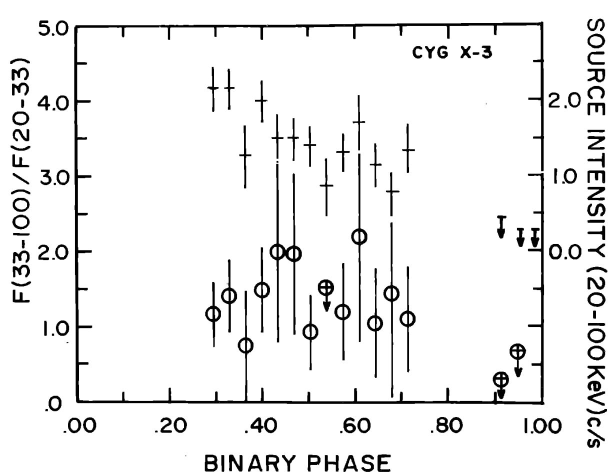


Fig. 3 . Binary light curve of Cyg X-3 (+) in the hard X-ray energy region 20-100 keV, the hardness ratio indicative of the spectral variation is also plotted



fitted by a power law with photon spectral index α - 1.2. The observed X-ray flux from the source is estimated to be $\sim 3 \times 10^{-10}$ erg cm^{-2} s^{-1} in the 20-80 keV energy band. For an assumed distance of 2 Kpc (Makshima et al, 1984) the hard X-ray luminosity is 2×10^{35} erg s^{-1}.

c) CYG X-3

A 4.8 hour period in Cyg X-3 was first discovered in the UHURU data (Parsignault et al, 1972). Majority of the later observations made for the study of binary light curve have been confined to the 2-10 keV band. The phase dependent study in the hard X-ray generally has been lacking due to low sensitivity of the previous detector systems. We made hard X-ray observations of the source between 20 -100 keV on March 18, 1986 at 0100 UT. Source was detected at a total significance of 20σ. The data were folded with a 4.8 hour binary period and the light curve is shown in the figure 3. The average spectrum of the source is well fitted with a power low index $\alpha \sim 1.5$. A thermal fit to the data give the best fit plasma temperature to be 35 keV. The hardness ratio H = F (>33 keV)/F (20-33) keV is plotted in figure 3. This ratio does suggest the double peaked structure with hard X-ray flux above 33 keV decreasing at phase 0.55. Similar feature is also present in the source intensity where the integral flux shows a dip at phase 0.55. Intensity fluctuations are also seen at phase 0.35 and 0.65. These changes can be interpreted in terms of extreme spectral changes of the source which appear to be uncorrelated with the phase. In a normal binary source a feature at 0.5 phase can be interpreted as due to geometrical effects arising due to precession of the accreting disc however Cyg X-3 is known to be a complex object with a class of its own since it exihibits a) 4.8 h variability which is always present in 2-10 keV b) the Extreme Spectral Changes c) the intense radio flares d) the sporadic high energy γ-ray emission upto PeV energies e) the bright infrared source which occasionally shows a weak 4.8 h modulation.

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