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# Hard X-ray spectra of some X-ray binaries from balloon-borne observations

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**Abstract.** We have studied X-ray binaries 4U1907 + 09, GX1 + 4 and Cygnus X-1 in the energy range 20-100 keV, using balloon-borne xenon-filled multi-layer proportional counters flown from Hyderabad, India. Results of these observations are reported in this paper. X-ray binary 4U1907 + 09 was observed in 1985 and 1991. During 1985 the source was detected above 20 keV at a significance level of 13$\sigma$ and was only marginally detected in 1991, indicating that the flux was four times lower than that on the first occasion. Energy spectrum between 20-100 keV obtained in 1985 was fitted with power-law with photon index –1.4. GX1 + 4 was observed in December 1991 and April 1992. The source showed a factor of two decrease in flux during the two observations. Hard X-ray spectra obtained on two occasions are found to be consistent with spectrum obtained from HEXE experiment on board Kvant module. Cygnus X-1 was observed on several occasions from 1984 to 1992. There is an indication of QPO in April 1992 Cygnus X-1 observations as seen by SIGMA on board GRANAT and BATSE on board GRO.

*Key words* : X-ray binaries

## 1. Introduction

Several classes of cosmic X-ray sources like X-ray binaries, Seyferts, quasars exhibit hard X-ray spectra. A study of the energy spectra of these sources is of great astrophysical interest to understand the physical processes responsible for producing X-rays in them. X-ray spectra of some of the sources e.g. Her X-1, 4U0115 + 63 show cyclotron line feature in hard X-ray region. In order to study these features it is necessary to observe them with detectors having high sensitivity and good spectral resolution. Also, investigation of pulsation characteristics of X-ray pulsars in hard X-ray region is necessary to understand accretion processes. We have been studying temporal and spectral characteristics of several X-ray sources using X-ray telescope consisting of xenon-filled multi-anode proportional counters (XMPC). This instrument is built in TIFR and we have carried out several balloon flights of this instrument since 1984, from Hyderabad.

## 2. Instrument details

The balloon-borne payload consists of a detector system along with event selection logic and other subsystems mounted on an orientable platform. Detector system consists of two xenon-filled multi-anode proportional counters each with an effective area of 1200 $cm^2$. The detectors have an average detection efficiency of ~ 50% between 20 and 80 keV. A mechanical graded slat collimator made of tin and copper defines the detector field of view to 5° × 5° FWHM. For details of the X-ray telescope refer to Rao *et al.* (1987, 1991).

The payload is servo stabilized with respect to the earth's magnetic field by using a flux gate magnetometer. The orientation of the flux gate magnetometer with respect to the payload is varied by using a geared motor and in this way the azimuthal angle of the telescope is controlled. The zenith angle of the detectors, mounted on a platform, is controlled by using another geared motor. Two 12 bit shaft encoders are used to measure the azimuth and the zenith angles. The target X-ray sources and the corresponding nearby source-free background regions are tracked alternately throughout the flight. For this purpose, predetermined source and background region coordinates are stored in memory in an on-board programmer. The stored values are compared with the shaft encoder outputs and the zenith and azimuth angles are updated automatically every minute. The data are transmitted by a 50 kHz Pulse Code Modulated (PCM) telemetry system.

## 3. Observations and results

Several balloon flights of this payload were carried out from Hyderabad during 1984 to 1992. A sample light curve of Cygnus X-1 from detector A obtained during the flight carried out on 6th April 1992 is shown in figure 1. Effect of change in air mass can be seen as decrease in count rate from the source away from the meridian transit. Aspect calibration is visible as a triangular count rate profile as detector points slowly away from the source.

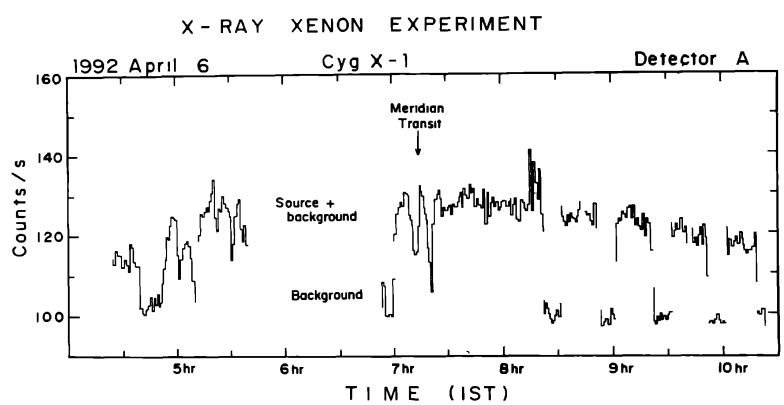


**Figure 1.** Light curve of Cygnus X-1 from detector A obtained during April 1992 balloon flight is shown. Effects of change in air mass and aspect calibration can be seen.

### 3.1. *4U1907 + 09*

This X-ray binary was discovered by UHURU satellite (Giacconi *et al.* 1978). X-ray pulsations at period of 437.5 s were detected by *Tenma* satellite from this source. The 2-30 keV spectrum obtained by *Tenma* was best fitted with power-law with photon index −1.5 (Makishima *et al.* 1984).

The source was observed by XMPC on 18th April 1985 and 5th March 1991. It was detected above 20 keV at a significance level of 13$\sigma$ in 1985 and marginally detected in 1991. The energy spectrum over 20-100 keV obtained during 1985 April observation was fitted with power-law with photon index $-1.4^{+0.4}_{-0.6}$ giving minimum $\chi^2$ of 5 for 7 degree of freedom. The 20-100 keV flux was estimated to be $7.2 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$. Using power-law photon index of –1.4, the 20-100 keV flux was estimated to be $1.76 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$ for 1991 March observation. For details refer to Chitnis *et al.* (1993).

### 3.2. *GX1 + 4*

This X-ray binary was discovered by a balloon borne experiment in 1970 as a source with pulsation period ~ 135 s (Lewin *et al.* 1971). In 1970s source was in high luminosity state and was spinning up (Elsner *et al.* 1985). In 1980s it entered the low luminosity state and is found spinning down (Sakao *et al.* 1990; Mony *et al.* 1991; Sunyaev *et al.* 1991). Energy spectrum in hard X-rays is fitted with power-law with photon index ~ –2.2. (Mony *et al.* 1991). Spectral shape did not change between the era of high luminosity spin-up and the present era of low luminosity spin-down (Money *et al.* 1991).

This X-ray binary was observed with XMPC on 11th December 1991 and 6th April 1992. The source was detected above 20 keV at a significance level of 4$\sigma$ in 1991 December and 5$\sigma$ in 1992 April. The energy spectrum obtained on these two occasions is fitted with power-law with photon index $-(2.3 \pm 0.9)$ and $-(2.7 \pm 0.9)$ respectively. The 20-100 keV flux is estimated to be $1.07 \times 10^{-9}$ and $6.96 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$ respectively. The deconvolved spectrum obtained on these two occasions is shown in figure 2 along with the best fit power-law spectrum. Global spectrum is shown in figure 3.

### 3.3. *Cygnus X-1*

Cygnus X-1 is a well-known black hole candidate showing aperiodic fluctuations of the X-ray flux on time scales of minutes, seconds and fractions of seconds which can be explained

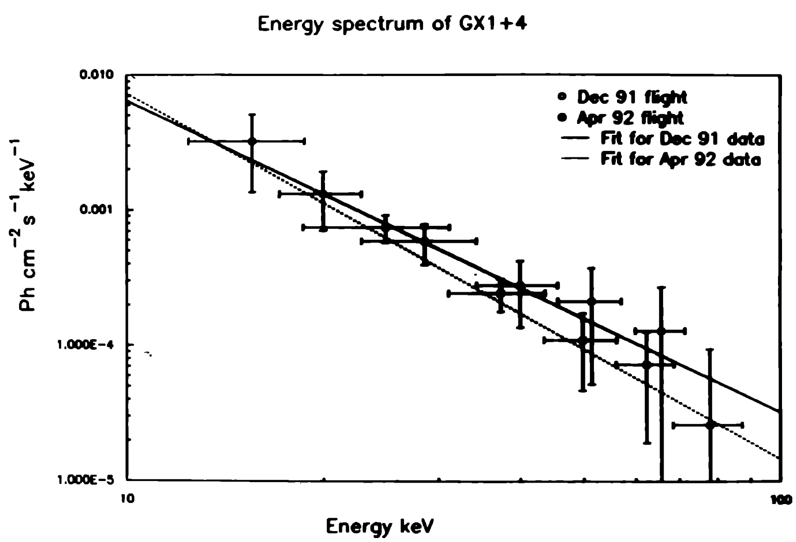


**Figure 2.** The deconvolved spectrum of GX1 + 4 obtained with XMPC in December 1991 and April 1992 is shown along with best fit powerlaw spectra obtained on both the occasions.

in terms of instabilities of accretion flow in disk. Recently SIGMA on board GRANAT and BATSE on board GRO have detected QPO centered at 0.04 Hz (Vikhlinin *et al.* 1992; Kouvêliotou *et al.* 1992).

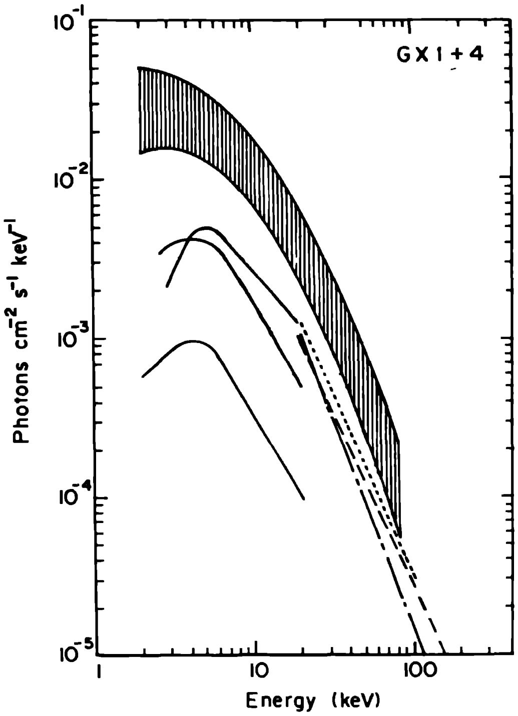


**Figure 3.** The best fit energy spectra obtained from XMPC in December 1991 (small dash) and April 1992 (long dash followed by small dash). The shaded region in the figure corresponds to the bright phase (1970-1980). Three spectra shown in solid line are the observations made by Ginga satellite at different epochs. The dashed line represents the best fit spectrum for HEXE observations on board Kvant module.

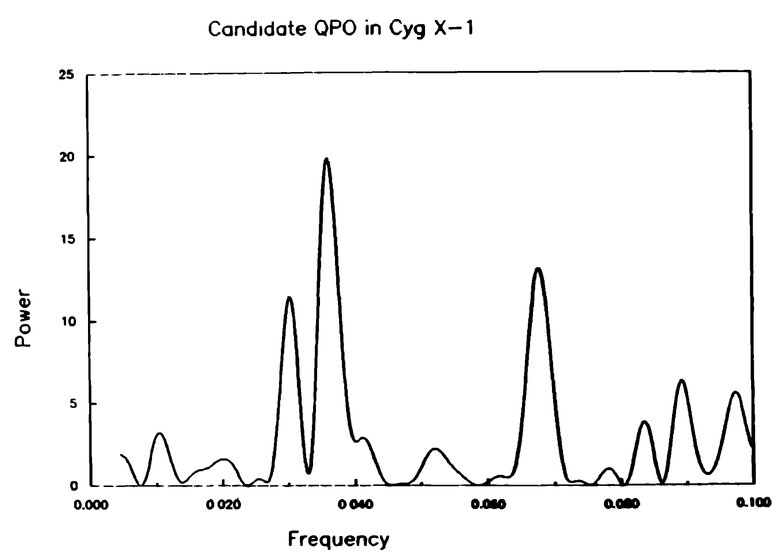


**Figure 4.** The periodogram of autocorrelation function of Cygnus X-1 data obtained during April 1992 flight. Candidate QPO is seen centered at 0.035 Hz.

This source was tracked continuously for one hour on 6th April 1992 by XMPC. Periodogram of autocorrelation function of the data obtained by detector A is shown in figure 4. Candidate QPO is seen centered at 0.035 Hz. Further analysis to detect QPO combining data from both the detectors is in progress. During the flight carried out on 5th March 1991 variations in intensity over time scale of minutes were observed from this source. The source has been observed in several balloon flights from 1984 to 1992 and study of variation in spectral parameters during these flights is in progress.

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