EXOSAT OBSERVATIONS OF THE Be/X-RAY BINARIES
2S0114+65 and 4U2206+54

PRIYAMVADA SARASWAT
Indian Institute of Astrophysics, Bangalore, India

and

KRISHNA M.V.APPARAO
Tata Institute of Fundamental Research, Bombay, India

1. 2S0114+65

The X-ray source 2S0114+65 was identified as a Be star from its optical spectrum. The X-ray spectrum is hard and spectral fits indicate the presence of a large amount of circumstellar matter around the X-ray source. The source also undergoes transient X-ray outbursts as well as flaring activity is present. 2S0114+65 was observed with the EXOSAT satellite on four occasions: on 1983 July 28, 1985 December 29, 1986 January 1 and 2. We have carried out an analysis of the X-ray data on this star.

The X-ray source was detected in 1983 and in 1986, but not in the 1985 observation. The source showed strong variability in the X-ray intensity and several X-ray flares were seen. The flares vary in duration from about 2000s to 8000s. The time interval between the flares was about 3 hrs. The average 2–10 keV flux and the luminosities during each of these observations is given in table I. The X-ray source was in an 'off' state during 1985. The ratio of outburst flux (1986) to the quiescent flux (1985), $(L_X)_{max}/(L_X)_{min} \sim 32$.

The hardness ratio, that is, the ratio of the X-ray intensity in the (5.0–10.0) keV band to that in the (2.0–5.0) keV band was determined during each flare and was found to be variable. An inverse correlation between the 2–10 keV intensity and the hardness ratio is present.

Simple power law and thermal bremsstrahlung models along with absorption in the line of sight were used to fit the pulse–height data. The thermal bremsstrahlung model does not give acceptable fits. The best fit values of photon index α and N_H for each flare for the power law fits are given in table I. The spectrum was softer during the 1983 and the early 1986 January 2 observations with a higher hydrogen column density $\sim 10^{23}$ atoms cm^{-2}. In these two cases a positive excess near 6 keV was seen in the residuals. A significant reduction in χ^2 was obtained by the addition of a 6.4 keV iron fluorescence emission line to the continuum models. Using the parameters for the primary, given by Crampton *et al.* (1985) together with the

L. A. Balona et al. (eds.), Pulsation, Rotation and Mass Loss in Early-Type Stars, 208–210.

https://doi.org/10.1017/S0074180900214873 Published online by Cambridge University Press

TABLE I
Spectral characteristics of the flares observed by EXOSAT.

MJD– 2400000.5	Time UT (hrs)	Photon Index (α)	N_H 10^{22} cm^{-2}	Fe Line E (keV)	Fe Line E.W.(eV)	χ^2	Avg Flux
45543.5	0630–1422	1.60±0.60	8.2±4.5	6.9±1.4	527±400	1.10	0.7[a]
46431.5	0700–0858	1.25±0.17	2.1±0.7	—	—	1.35	14.0
46432.5	0050–0320	2.47±0.30	9.4±1.9	6.4±0.4	526±228	1.09	7.7
	0320–0552	1.01±0.16	1.8±0.9	—	—	0.95	
	0610–0800	0.93±0.07	1.2±0.5	—	—	1.00	16.0
	0800–0957	0.98±0.01	1.5±0.4	—	—	1.50	

[a] Average flux in the energy range 2–10 keV and in units of 10^{-11} ergs cm^{-2} s^{-1}.

flare durations of 2000–8000s, we can calculate the density of the gas in the envelope to be of the order of 2×10^{11} H–atoms cm^{-3}.

We have searched for coherent pulsations indicating the signature of a pulsar from the outburst data. We were unable to detect the 894s pulsations, seen in the Einstein data (Koenigsberger *et al.*, 1983). However, quasi–periodic oscillations were observed in the flare of 1986, January 2. The period was around 2000s.

2. 4U2206+54

The X-ray source 4U2206+54 has been generally ignored observationally since its discovery. Steiner *et al.* identified the optical counterpart with a Be star. No further observations have been reported on this source. The orbital period of the binary or the spin period of the compact companion are not known. Even the X-ray spectrum is poorly known. We decided to study the EXOSAT observations of this source in an effort to find an answer to some of these issues.

4U2206+54 was monitored by the EXOSAT satellite on 1983 August 8, 1984 December 7, and 1985 June 27. The source was active during the 1983 and the 1985 observations and several short duration flares were observed, but it was in quiescence during the 1984 observation. The occurrence times, durations, luminosities and the integrated flare luminosities in the 2–10 keV spectral band for each flare during 1983 are given table II. The 1985 observation broadly reveals the same features as seen in 1983.

The X-ray spectrum of 4U2206+54 was determined by analyzing the pulse–height data. Simple power law and thermal bremsstrahlung models

https://doi.org/10.1017/S0074180900214873 Published online by Cambridge University Press

TABLE II

Results of the Spectral Analysis of flares for 1983 August 8.

Fl.	Start Time (UT)	End Time (UT)	Δt (sec)	2–10 [a] keV flux	α [b]	N_H 10^{22} H cm^{-2}	L_X 10^{34} erg s^{-1}	E_{tot} 10^{36} erg	χ^2
E	18.75	18.94	700	20.277	$1.370^{+0.21}_{-0.20}$	$1.707^{+0.88}_{-0.61}$	14.333	100.331	1.162
B	17.21	17.36	550	19.092	$1.434^{+0.26}_{-0.24}$	$2.284^{+1.11}_{-0.99}$	13.495	74.224	0.975
C	17.36	17.78	1500	17.375	$1.643^{+0.17}_{-0.16}$	$2.239^{+0.65}_{-0.60}$	12.282	184.225	1.093
D	18.50	18.64	500	13.782	$1.690^{+0.37}_{-0.33}$	$3.141^{+1.62}_{-1.37}$	9.742	48.710	1.186
A	16.38	16.44	250	13.025	$1.673^{+0.56}_{-0.48}$	$3.096^{+2.75}_{-2.08}$	9.207	23.017	1.339

[a] In units of 10^{-11} ergs cm^{-2} s^{-1}.
[b] The errors in α and N_H are quoted at the 90% confidence level, that is, $\chi^2_{min} + 4.61$ for the two free parameters.

along with absorption in the line of sight give acceptable fits. There is a significant level of spectral variability in the source during the 1983 and the 1985 outburst. It was found that a simultaneous fit to the PH data from the different flares gave unacceptable values of χ^2. This implies that a single power law is not a good fit to the average spectrum of all the flares. The spectrum thus appears to vary from flare to flare. We examined the data for the evidence of line emission by adding to the continuum models, a Gaussian with a fixed width of 0.1 keV and a variable line energy. No improvement was found in the fits and we conclude that there is no evidence for the presence of a line in the spectrum. The upper limit to the iron K line equivalent width is 0.194 keV for 1983 and 0.103 keV for 1985 at the 90% confidence level.

To date nothing has been reported about the orbital period or the spin period of the compact object. We have searched for coherent pulsations indicating the signature of a pulsar from the two outburst data in a broad range in time. No periodicity was detected in the 50ms to 20s range at the 95% confidence level. Search for pulsations in the range 20s to 1000s resulted in a periodicity at 392.2s in the 1983 data and at 397.8s in the 1985 data. The above result, however, needs confirmation from further independent observations. If the spin period of the compact object is assumed to be 392s, a rough estimate of the orbital period of the binary can be made, using the P_{orb} vs. P_s relation of Corbet (1984); this gives P_{orb} between 150–250 days. It is strongly urged, that this source be monitored over a broad wavelength range to search for accurate pulse and orbital periods.

Saraswat,P. 1992, Ph.D. thesis and references therein
Apparao, K.M.V., Bisht, P., & Singh, K.P. 1991, ApJ **371**, 772
Saraswat, P. & Apparao, K.M.V. 1992, ApJ **401**, 678