



BeppoSAX OBSERVATIONS OF AN ORBITAL CYCLE OF THE X-RAY BINARY PULSAR GX 301-2

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ABSTRACT

We present preliminary results on our campaign of observations of the X-ray binary pulsar GX301-2. *BeppoSAX* observed this source six times in January/February 1998: at the periastron and apostron, and at other four, intermediate, orbital phases. We present preliminary results on the GX 301-2 spectral and temporal behaviour as a function of orbital phase. © 2000 COSPAR. Published by Elsevier Science Ltd.

1 INTRODUCTION

The X-ray binary pulsar GX 301-2 (4U 1223-62) is a ~ 700 s pulsator orbiting the B2 Iae supergiant Wray 977 every 41.5 days along the most eccentric orbit among X-ray binary pulsars (Sato *et al.* 1986; Koh *et al.* 1997). It exhibits a flaring activity that shows its maximum ~ 1.4 days before the periastron passage. This anticipation with respect to the phase of closest approach to Wray 977 has been explained as due to the crossing of the neutron star through a circumstellar disk around the supergiant (Pravdo *et al.* 1995). Recent observations by BATSE (Pravdo *et al.* 1995) have revealed the presence of a second flare occurring near the apostron, at orbital phase 0.45.

The overall power-law X-ray spectrum of GX 301-2 is characterized by a strong soft excess below 4 keV. Because pulsation was not detected in this band, the partial covering model has been ruled out as possible origin of this excess. ASCA observations revealed the presence of two soft components: a *scattering* component, between 2 and 4 keV, due to the gas stream from the supergiant to the neutron star, and a *ultrasoft* component, below 2 keV, described with thermal emission from a plasma at ~ 0.8 keV (Saraswat *et al.* 1996). A strong narrow iron emission line and an absorption edge are also present. The emission line is the result of fluorescence in the cooler circumstellar material, while the absorption edge is due to the same material when it crosses the line of sight and absorbs the X-rays coming from the neutron star. At high ($E > 10$ keV) energies, the power law spectrum is modified by a high energy cutoff. A possible cyclotron resonance feature at ~ 40 keV has been claimed (Makishima and Mihara 1992).

2 OBSERVATIONS

GX 301-2 was the target of a campaign of observations with the Italian-Dutch satellite *BeppoSAX* (Boella *et al.* 1997). The source was observed at six different orbital phases (see Table 1), in order to monitor its spectral and timing behaviour along the orbit. All four Narrow Field Instruments aboard *BeppoSAX* worked nominally during all the observations, namely the LECS (0.1-10 keV), MECS (1.5-10 keV), HPGSPC (3-120 keV), and PDS (15-200 keV).

The source displayed its maximum intensity not at the periastron observation OP3428/9 but at orbital phase 0.85 (OP3373). The net count rate in this observation was about four times that detected at the periastron. We confirmed the increase in the intensity near the apostron.

OP #	Start Time (UT)	Length (sec)	$\langle I \rangle$ (C/s)				Orbital Phase ^a
			LECS	MECS	HPGSPC	PDS	
3275	07/1/98 14:46:40	96582	1.331 ± 0.007	3.871 ± 0.010	19.78 ± 0.07	16.24 ± 0.05	0.5837–0.6106
3373	17/1/98 22:18:43	85375	5.581 ± 0.016	14.54 ± 0.020	100.1 ± 0.10	70.34 ± 0.07	0.8322–0.8560
3428	23/1/98 13:02:57	126695	0.397 ± 0.003	2.724 ± 0.007	61.89 ± 0.15	36.24 ± 0.05	0.9674–0.0027
3503	30/1/98 07:19:12	15211	0.249 ± 0.004	0.668 ± 0.004	7.394 ± 0.08	6.273 ± 0.05	0.1303–0.1346
3514	30/1/98 18:29:37	61811					
3588	05/2/98 17:23:39	98063	0.503 ± 0.005	1.312 ± 0.005	11.94 ± 0.07	10.54 ± 0.05	0.2850–0.3123
3650	12/2/98 19:50:07	60749	1.777 ± 0.012	4.692 ± 0.014	27.43 ± 0.09	23.09 ± 0.06	0.4561–0.4730

^a Ephemeris from Sato *et al.* (1986)

Table 1: Log of the observations of GX 301–2 performed by *BeppoSAX*. Observations 3503 and 3514 have been summed together.

2.1 Spectral Analysis

The spectral analysis of the *BeppoSAX* observations is very preliminary (we did not use HPGSPC data). The pulse averaged spectrum is very complex and rich in features. We show in Fig. 1 some of the best-fit parameters relative to the fit to the pulse averaged spectra of all the six observations with the *scattering* model by Saraswat *et al.* (1996), defined in terms of two absorbed power laws, with the same index but different absorptions and normalizations. The stronger absorption affects the pulsating, hard (above 4 keV) component, while the softer absorption is thought to arise because of scattering. We added an Iron line at ~ 6.4 keV, but we found systematic deviations at ~ 20 and ~ 40 keV. While the latter might be attributable to a cyclotron resonance, the correspondence of the cyclotron energy with the cutoff energy for the former makes, at this stage of the analysis an identification with a cyclotron resonance difficult.

2.2 Timing Analysis

We folded the light curves of all the observations with the apparent pulse period obtained by an epoch folding search. In this preliminary analysis arrival times were not corrected to the solar system barycenter nor for orbital motion. The background subtracted pulse profiles as a function of energy for the most intense observation are shown in Fig. 2. In this particular observation we were also able to detect pulsation below 2 keV and in the 60–100 keV range. Note the evolution of the four sub-peaks in the main peak. The modulation index, defined as $1 - I_{\min}/I_{\max}$, where I_{\min} and I_{\max} are the minimum and maximum count rate observed in the pulse profile, shows a monotonic increase with energy without any deviation at the suspected cyclotron resonance features (Frontera and Dal Fiume 1989).

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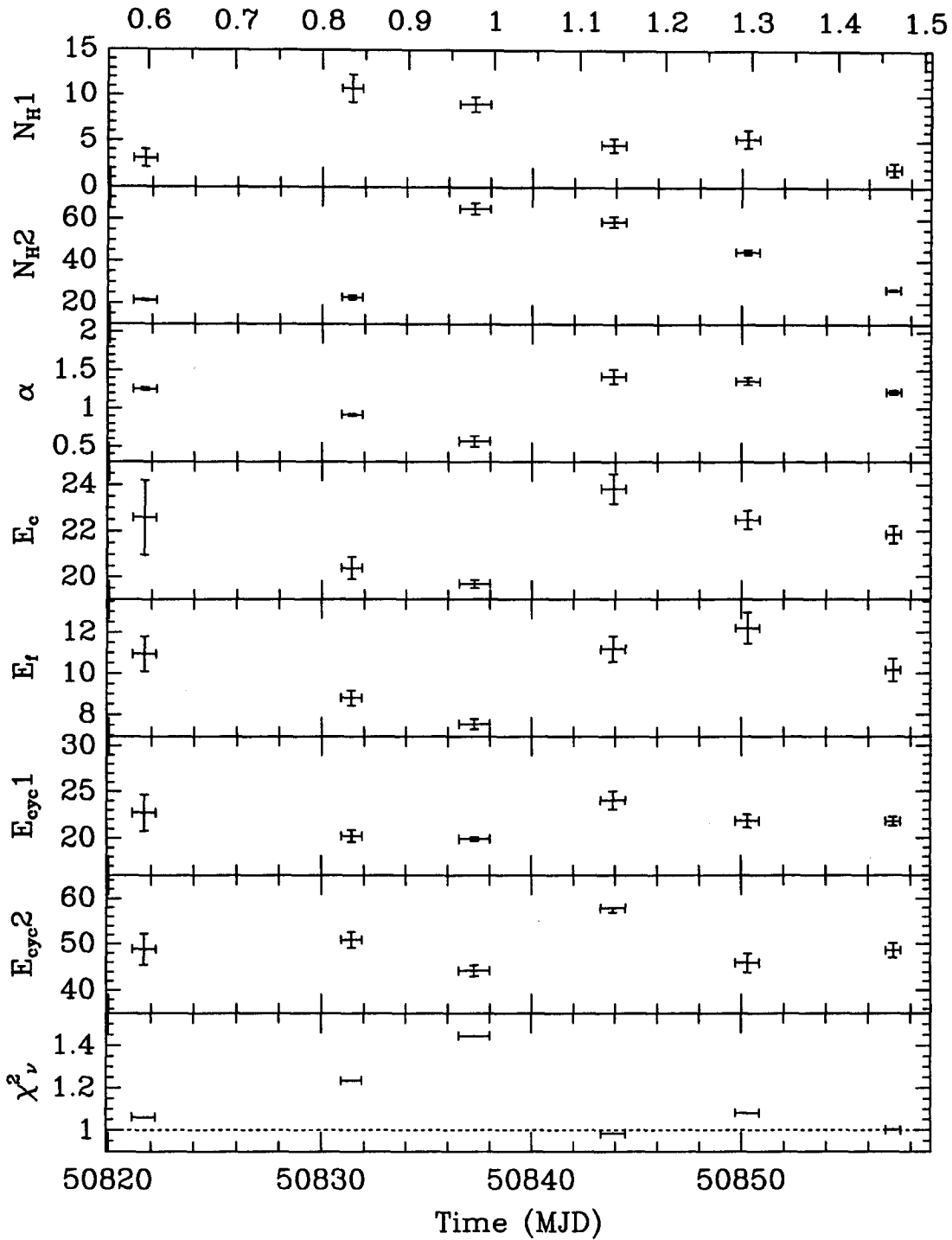


Figure 1: Best-fit parameters obtained by fitting two absorbed power laws with the same index (scattering model in Saraswat et al. (1996)), modified by a high energy cutoff, plus a gaussian iron line and 2 cyclotron resonance features. N_{H1} and N_{H2} are in units of 10^{22} cm^{-2} , while the energies are in keV. The upper scale refers to the orbital phase from the ephemeris given by Sato et al. (1996).

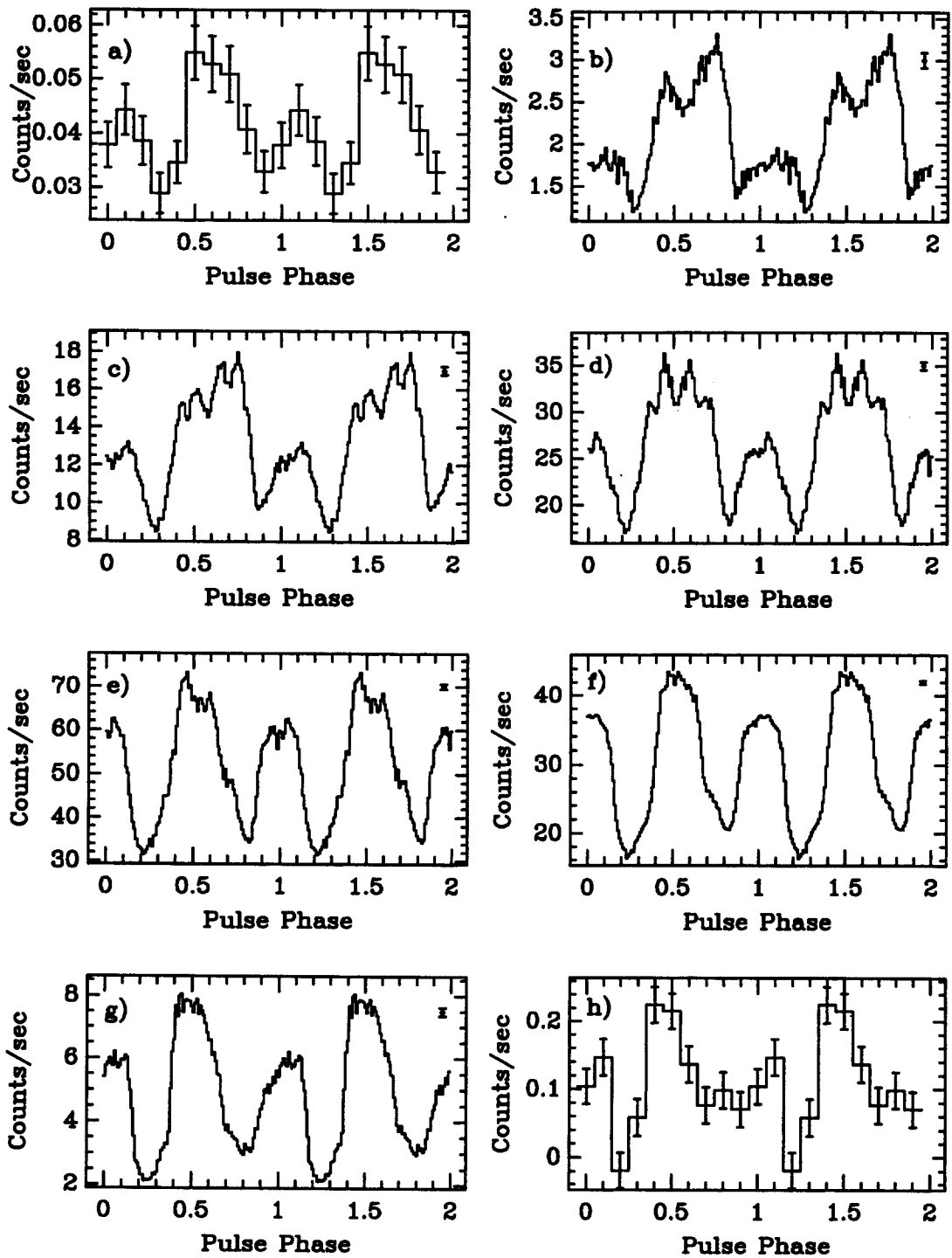


Figure 2: GX 301-2 background subtracted pulse profiles as a function of energy for OP3373, the most intense among all the observations: a) 0.2-2 keV (LECS); b) 1.5-4 keV (MECS); c) 4-10 keV (MECS); d) 4-10 keV (HPGSPC); e) 10-20 keV (HPGSPC); f) 15-30 keV (PDS); g) 30-60 keV (PDS); h) 60-100 keV (PDS).