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QUASI-PERIODIC OSCILLATIONS IN CYG X-2

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I. INTRODUCTION

The European Space Agency's X-ray observatory EXOSAT (Taylor et al. 1981) is particularly well suited to carry out detailed time variability studies of cosmic X-ray sources, because of (a) its ~ 90 hour eccentric orbit, which allows uninterrupted observations up to ~ 80 hours, (b) the large effective area of the Medium Energy (ME) proportional counter array (~ 1500 cm^2) and (c) the real time analysis system by means of which it is possible to optimise the configuration of the instruments and of the on-board computer.

A great deal of interest in bright galactic bulge and globular cluster X-ray sources has been recently raised in connection with the discovery of a Quasi-Periodic Oscillations (QPO) with frequencies ranging from ~ 5 Hz to ~ 50 Hz in the X-ray flux of GX5-1 (van der Klis et al. 1985a), Sco X-1 (Middleditch and Priedhorsky 1985 and 1986; Priedhorsky et al. 1986; van der Klis et al. 1985b and 1986) and Cyg X-2 (Hasinger et al. 1986a; Norris and Wood 1985). QPO provide a new (and unexpected) tool to investigate the physics of accretion onto collapsed stars and, in turn, to help determining the nature of this conspicuous and poorly understood class of bright galactic X-ray sources (see also van der Klis and Jansen 1986).

Sco X-1 and Cyg X-2 are known to be binary systems containing a collapsed object (probably a neutron star, although the presence of a black hole cannot be excluded) and a low mass companion star. Due to the rapid frequency changes observed, QPO cannot directly reflect the rotation of a neutron star. For GX5-1 and Cyg X-2 a strong correlation exists between QPO frequency and source intensity. In the case of Sco X-1, instead, depending on the source state, the QPO frequency can be correlated, anticorrelated or even uncorrelated with the source intensity. The presence of QPO is accompanied by a substantial Low Frequency Noise (LFN), whose strength is comparable to the QPO strength in GX5-1 and Cyg X-2. The LFN strength in Sco X-1 is instead lower than the QPO strength, when these are detected. It has, therefore, become clear that the QPO phenomenology is complex, and varies from source to source and that an individual source can also change from a QPO active mode to another (or even to a QPO inactive mode).

Several models for QPO have been proposed, which include: (i) a modulation of the mass accretion rate at the difference frequency between the Keplerian frequency and the neutron star rotation frequency at the magnetospheric boundary of a weakly ($\sim 10^9$ Gauss) magnetised neutron star rotating with a period of a few milliseconds (the so-called beat frequency model; Alpar and Shaham 1985, Lamb et al. 1985; Berman and Stollman 1986; cf. also Morfill and Trümper 1985); (ii) inhomogenieties in a strongly differentially rotating boundary layer at the surface of an unmagnetised slowly rotating neutron star (Hameury, King and Lasota 1985); (iii) scattering in an oscillating accretion disk corona (Boyle, Fabian and Guilbert 1986); (iv) obscuration of a central X-ray source by an oscillating accretion disk rim (van der Klis 1986; Stella 1986). QPO models involving a weakly magnetised fast rotating neutron star are appealing because they might provide a link with the millisecond binary radio pulsars.

This field of research is rapidly developing. By the end of September 1985 five more sources were found to display QPO with frequencies $\gtrsim$ 1 Hz, namely GX17+2 (Stella, Parmar and White 1985), GX349+2 (Lewin et al. 1985; Cooke, Stella and Ponman 1985), the Rapid Burster (MXB 1730-335) (Tawara et al. 1982; Stella et al. 1985), 4U1820-30 (Stella, White and Priedhorsky 1985) and GX3+1 (Lewin et al. 1986).

We report here on the analysis of the high time resolution ME data from a series of EXOSAT observations of Cyg X-2 in September 1983.

II. OBSERVATIONS AND RESULTS

Cyg X-2 was observed with EXOSAT at five different phases in a single orbital cycle (P = 9.8 days; Cowley et al. 1979) in 1983 September 13-22. A journal of the observations is given in Table 1, together with the corresponding orbital phases. The source energy spectra obtained from the ME experiment were fitted to a two component spectral model consisting of the sum of a thermal bremsstrahlung and a blackbody spectrum (Chiappetti et al. 1986). The

1-16 keV source luminosities obtained from these fits are also given in Table 1. It is apparent that observation 3 corresponds to a source intensity state about 30 % lower than the other observations. Except for two pronounced dips during observation 2, the source flux varied by about 10 % on timescales of minutes within each observation.

High time resolution data from the ME detectors were also obtained during all the observations with accumulation intervals of 7.8125 ms and no spectral information. Following the discovery of 5-50 Hz QPO in the X-ray flux of Cyg X-2 (Hasinger et al. 1986a; Norris and Wood 1985) these data were analysed to further investigate the very short term activity of this source. The source power spectrum for each observation was calculated by summing the power spectra obtained for each 256 s interval. The frequency range which can be explored extends to 64 Hz. In all five observations a very significant excess power above the counting statistics noise was observed. The power increased towards the low frequency end of the power spectra (LFN) and was modelled with a simple power law. The power law slope obtained for each observation is given in Table 1, together with a direct evaluation of the source RMS fractional variation in the frequency range 0.03-20 Hz.

Only in one case (observation 3) a broad peak revealing the presence of QPO was detected (see Fig. 1). The frequency, FWHM and RMS fractional variation obtained by fitting a Lorentzian to the peak were respectively 28.3±0.4 Hz, 2.7±1.5 Hz and 2.0±0.5 %. The QPO frequency is consistent with the one found by Hasinger et al. (1986) for their lowest intensity interval, although in our observation 3 the RMS variability associated to the QPO is a factor of ~ 2 lower. A second peak is also visible in Fig. 1 at a frequency of 60±3 Hz (with a chance probability of 0.01), which could be due to the second harmonic of the 28 Hz QPO being also excited. The upper limits to the QPO strength during the other observations were ~ 1 % RMS. No evidence for QPO was found during the two intensity dips of observation 2. QPO were therefore observed only during the observation with the lowest source intensity.

From Table 1 it is also apparent that the LFN strength was larger during observations 3, 4 and 5. The source intensity of observations 4 and 5 was, however, similar to that of observations 1 and 2, such that the change of the short-term variability properties of Cyg X-2 did not correspond to a change of the source luminosity. In this context it is interesting to note that during the observations in which the LFN strength was higher (i.e. observations 3, 4 and 5) the source spectrum was considerably harder (with blackbody and thermal bremsstrahlung temperatures of $T_{bb} \simeq 1.3$-1.4 keV and $T_{th} \simeq 7$-8 keV) than that observed when the LFN strength was lower (i.e. observations 1 and

TABLE 1

N	Epoch (days of 1983)	Phase	Luminosity (1-16 keV) 10^{37} erg/s	LFN slope	LFN RMS fractional variation (%)
1	256 23:03-01:08	0.86	12.0	-1.2±0.3	1.6 ± 0.2
2	258 18:40-22:09	0.05	11.9	-0.55±0.15	2.5 ± 0.5
3	261 16:05-19:13	0.33	8.6	-0.52±0.03	5.5 ± 0.2
4	263 23:22-01:36	0.55	11.9	-0.75±0.03	4.3 ± 0.2
5	265 15:51-19:09	0.75	12.5	-0.75±0.03	4.2 ± 0.1

Note: the high time resolution data for observation 1 include data from both the argon (1-16 keV) and xenon (5-35 keV) ME detectors. All other observations include the argon data only.

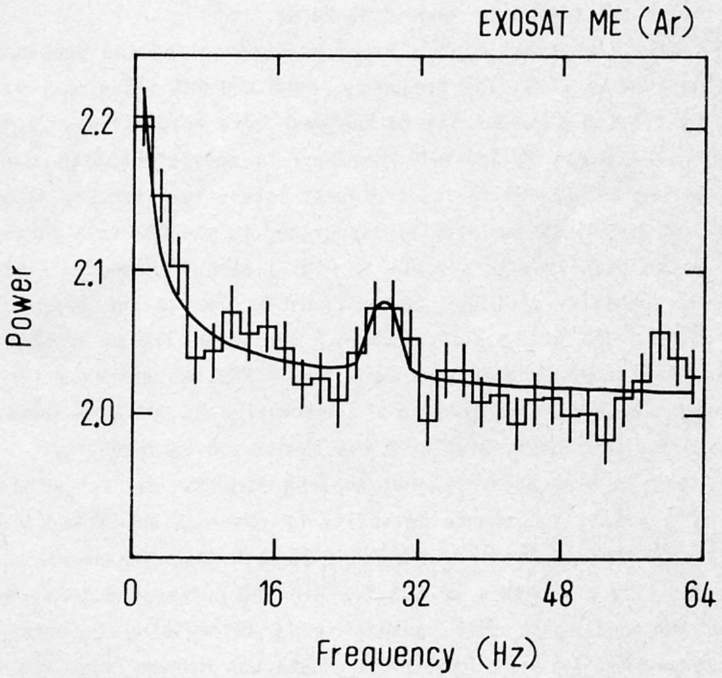

Figure 1: Power Spectrum of Cyg X-2 during observation 3 (1983 day 261). The counting statistics noise corresponds to a level of 2.

2, for which $T_{bb} \simeq 1.1$ keV and $T_{th} \simeq 5$ keV). This result confirms that, as first pointed out by Hasinger et al. (1986b), the short term activity of Cyg X-2 is different for different spectral states of the source.

III. CONCLUSION

The analysis of the Cyg X-2 observations reported here confirms the presence of ~ 28 Hz QPO in the X-ray flux of Cyg X-2 and provides some evidence that the second harmonic of the QPO (at ~ 60 Hz) could also be excited. In four out of five observations QPO were not detected and various levels of LFN strength were found to be associated to different source spectral states. A correlation of the QPO properties with the source spectral hardness has been recently discovered by Hasinger et al. (1986). Our results emphasise that, like Sco X-1, Cyg X-2 displays different short term activity modes which are associated to different source intensity levels (QPO were detected only in the observation with the lowest intensity) and/or spectral states (the LFN strength increased with the spectral temperatures).

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