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X-ray periodicity in the supersoft X-ray sources CAL 83 and SMC 13

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Abstract. The discovery of X-ray modulations in CAL 83 with a period of ∼67 s is reported. Its long-term presence suggests it may be the spin period of a highly spun-up white dwarf; however, this is still under investigation. SMC 13 has an orbital period of ∼4.1 h, and has been reported in the literature to exhibit orbital modulation in its ROSAT X-ray flux. This orbital modulation is confirmed from 3 *Chandra* observations, each providing continuous coverage of ∼2.7 orbital cycles.

Key words. X-rays: binaries – Stars: individual: CAL 83 – Stars: oscillations – Stars: individual: SMC 13 – binaries: eclipsing

1. Introduction

Supersoft X-ray sources (SSS) form a highly luminous ($\sim 10^{36}-10^{38}$ erg s^{-1}) class of objects that emit $\gtrsim$90% of their energy below 0.5 keV. Van den Heuvel et al. (1992) showed that this can be explained by the nuclear burning of hydrogen on the surface of a white dwarf (WD) accreting at a very high rate ($\sim 10^{-7} M_{\odot}$ yr^{-1}) from a companion star.

2. CAL 83 in the LMC

To date, the binary SSS CAL 83 has been observed 24 times by XMM-Newton. These archival observations were calibrated, and barycentric corrections performed, with SAS v. 12.0.1. A Lomb-Scargle (LS) periodogram was created from each light curve with the Starlink PERIOD package v. 5.0-2.

A peak near 15 mHz (∼67 s) was discovered at a 6.3σ significance level in the periodogram of the PN detector (the most sensitive of the X-ray detectors) of observation 0506531501, and at a lower significance level in 6 other PN data sets. In 3 of these 7 observations, one of the MOS light curves also exhibited a weak peak at ∼67 s (see Table 1). The periodogram and light curve for observation 0506531501 are shown in Fig. 1.

The long-term presence of the oscillation leads to its interpretation as the WD spin period. However, the ∼2 s variation from the mean in the period, not associated with the orbital motion, complicates this straightforward interpretation, and is still being investigated.

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Table 1. Results of Lomb-Scargle analysis of CAL 83 XMM-Newton light curves.

Obs ID	Start date	Period (s)	σ
0123510101PN	23-04-2000	68.63 ± 0.06	–[1]
0500860301MOS2	06-07-2007	66.1 ± 0.2	1.5
0500860301PN		67.5 ± 0.2	2.1
0500860501PN	05-10-2007	70.6 ± 0.2	–[1]
0500860601PN	24-11-2007	67.7 ± 0.1	2.5
0506530501PN	16-04-2008	66.8 ± 0.5	1.0
0506531501MOS2	12-08-2008	66.8 ± 0.3	2.8
0506531501PN		66.9 ± 0.3	6.3
0506531701MOS1	30-05-2009	67.29 ± 0.05	2.8
0506531701PN		65.17 ± 0.05	4.3

[1]Faintly visible, but statistically insignificant peak.

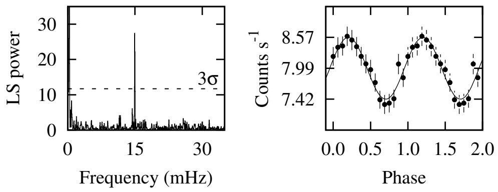

Fig. 1. Left: LS periodogram of data set 0506531501 PN. Right: Folded light curve. A sine curve with a period of 66.9 s is overplotted.

Table 2. *Chandra* observations of SMC 13.

Obs ID	Instrument	Start date	Exposure (s)
4535	ACIS-S3	2005-01-30	40140
7456	HRC-S+LETG	2007-02-12	40190
8519	HRC-S+LETG	2007-02-18	42670

3. SMC 13 in the SMC

Kahabka (1996) reported the discovery of orbital modulation with a period of 4.123 h in the ROSAT X-ray light curve of the binary SSS SMC 13. According to Van Teeseling et al. (1998), the orbital period is 4.126 h.

Timing analysis was performed on 3 archival *Chandra X-ray Observatory* observations of SMC 13 (see Table 2), each constituting an uninterrupted observation of ~11 h. Calibrated light curves were obtained with CIAO v. 4.3, and an LS periodogram was created for each. The orbital modulation was evident, and the periodograms exhibited substantial power in the region of 4.123 h. All 3 observations were then combined to obtain a periodogram with a higher period resolution. Aliasing effects made it difficult to decide which peak represents the true orbital period, so the period of Van Teeseling et al. (1998) was used to choose the most appropriate peak, yielding $P_{\rm orb} = 4.1378 \pm 0.0005$ h.

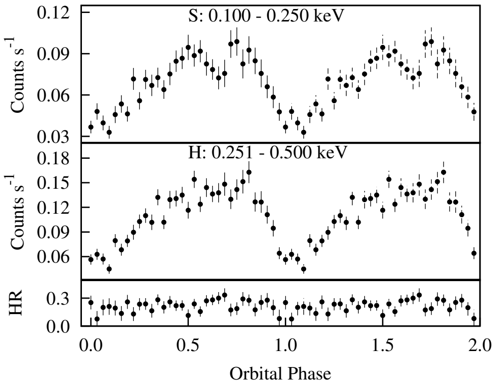

Fig. 2. *Chandra* ACIS light curves of SMC 13, folded on $P_{\rm orb}$ = 4.1378 h with respect to third minimum of data set. HR=(H-S)/(H+S).

The intrinsic energy resolution of ACIS-S was used to create soft, hard and hardness ratio (HR) light curves (Fig. 2). Comparison with the ROSAT light curve of Kahabka (1996) shows remarkable stability over more than a decade. The form of the light curves may be due to SMC 13 being an eclipsing system, where the observed X-ray emission is modulated by the accretion disc edge. The X-ray eclipse is not total, indicating that we are observing the modulation of an extended region.

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