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Letter to the Editor

Evidence of X-ray periodicity in LSI+61°303

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Abstract. We have carried out a period analysis of 2-10 keV observations of the 26.5 d radio periodic X-ray binary LSI+61°303 retrieved from the quick-look results database provided by the ASM/RXTE team. After applying different period search methods, we find evidence that X-ray outbursts in LSI+61°303 are very likely to recur with the same radio outburst period. Our best estimate of the LSI+61°303 X-ray period is 26.7 $\pm$ 0.2 d. The folded X-ray light curve displays a fractional change in flux by a factor of $\sim$ 5 and its highest emission level overlaps with the active state of the radio emission.

Key words: Stars: LSI+61°303 – Radio continuum: stars – Stars: variables – X-rays: stars

1. Introduction

The radio emitting X-ray binary LSI+61°303 is a Be system well known for its periodic radio outbursts every 26.5 d (Taylor & Gregory 1982; 1984). Spectroscopic radial velocity observations also indicate a 26.5 d orbital period, and give support to the presence of a compact companion (Hutchings & Crampton 1981). The outbursts events are usually interpreted as non-thermal synchrotron radiation from relativistic electrons. The recent detection of linear polarization in LSI+61°303 gives observational support to this interpretation (Peracaula et al. 1997). The radio outburst pattern is usually rather complex and it is thought to be formed by series of smaller flaring events. In addition, there has been the recent report of microflares, with a short term period of 1.4 h and a few percent amplitude, superposed onto the general trend of the radio light curve (Peracaula et al. 1997). The outburst amplitude and shape appear to be modulated on a longterm $\sim$ 4 yr scale (Gregory et al. 1989; Paredes et al. 1990; Estalella et al. 1993). Periods close to the orbital 26.5 d radio period have been also found at other wavelengths in LSI+61°303. In the optical, Mendelson & Mazeh (1989; 1994) reported a 26.5 d photometric period. In the near infrared a similar 27.0 d was detected by Paredes et al. (1994).

The first X-ray detection of LSI+61°303 was due to EINSTEIN satellite (Bignami et al. 1981). More recently, Goldoni & Mereghetti (1995) found X-ray variability in a time scale of days in their ROSAT data. On the other hand, coordinated ROSAT X-ray and VLA radio observations of LSI+61°303 carried out over one orbital cycle by Taylor et al. (1996), revealed an X-ray outburst with a duration of $\sim$ 10 d. The unabsorbed X-ray luminosity that they derive was about a few times 10^{34} erg s^{-1} in the 0.1-2.4 keV range. At higher energies, LSI+61°303 has been proposed to be the counterpart of the COS B (>100 MeV) γ-ray source 2CG 135+1 (Gregory & Taylor 1978; Perotti et al. 1980). The association of LSI+61°303 with 2CG 135+1 is not yet firmly established but modern COMPTON GRO observations (Fichtel et al., 1994; Tavani et al. 1996; van Dijk et al. 1996) are consistent with a positional coincidence and indicate γ-ray luminosities of the order of 10^{36} erg s^{-1}.

The few days time scale variability and flaring behavior already seen in X-rays by ROSAT, clearly suggests the possibility that LSI+61°303 could also undergo periodic X-ray outbursts in connection with the periodic radio emission. In order to check this suspicion, a long term continuous X-ray monitoring of LSI+61°303 should be necessary beyond the few pointed observations so far available in the literature. In this context, the existence and public availability of quick-look results provided by the team of the All Sky Monitor (ASM) on board the Rossi X-Ray Timing Explorer (RXTE) appear as a plausible source of data to search for the suspected X-ray period of LSI+61°303. The sensitivity of LSI+61°303 data from the ASM/RXTE is not good enough to provide a detailed monitoring of individual X-ray outbursts from cycle to cycle. However, the huge amount of ASM data available is likely to compensate for the lack of sensitivity when folded and averaged on the correct X-ray period. Up to now, the ASM data for LSI+61°303 includes nearly ten months of daily monitoring and this is the only X-ray data from which a longterm period search can be envisaged up to

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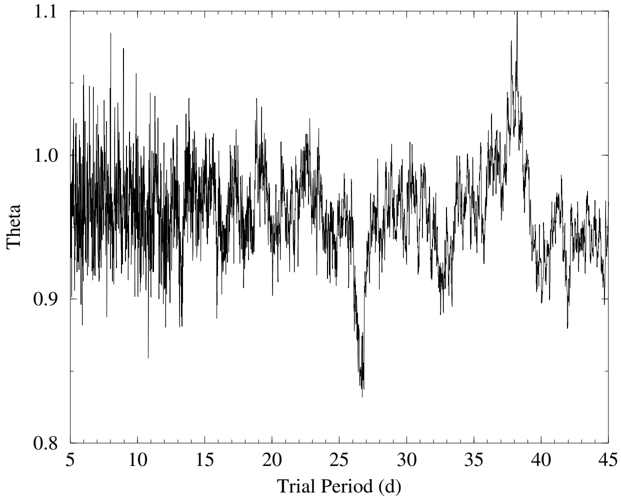

Fig. 1. Periodogram of the ASM/RXTE daily data for LSI+61°303 using the phase dispersion minimization technique (PDM). The period search has been carried out between 5 and 45 d, and the deepest minimum found corresponds to a period of 26.7 d.

now. This search appears to be successful and we report here in detail our period detection results.

2. X-ray period search using ASM/RXTE data

The ASM/RXTE consists of three wide-angle shadow cameras all of them equipped with proportional counters. The energy range is 2-10 KeV, with a total collecting area of 90 cm^2. The time resolution allows to cover 80% of the sky every 90 minutes. In our period analysis, we used the daily averaged ASM data of LSI+61°303, spanning from 1996 late February to early December and amounting to 269 flux measurements. Each data point represents the one-day average of the source fluxes of individual ASM dwells, typically 5-10 fluxes per day. The error value of the daily averages corresponds to the quadrature average of the estimated errors on the individual dwells of the day.

Two different methods were used to search for periodicities. The first method used was the phase dispersion minimization (PDM) technique (Stellingwerf 1978), consisting of assuming a trial period and constructing a phase diagram. The phase interval is divided into bins and the the variance of the data points is computed for each of them. The weighted mean of the variances is normalized with the total variance of the data. It can be shown that local minima of this function (Θ) corresponds to periods present in the data or to multiples of such periods. The error of each individual data point has been taken into account when computing the variances. A second independent search was performed using the CLEAN algorithm. This method, based on Hogbom's (1974) algorithm used in aperture synthesis imaging, was adapted to a time series analysis by Roberts et al. (1987). It consists of an iterative deconvolution method operating in the Fourier space.

In Fig. 1, we show the result of applying the PDM method to the ASM data in the period range 5-45 d. The most significant minimum was found at a period of 26.7 ± 0.2 d. This result is independently confirmed when using the CLEAN method. The CLEAN power spectrum, not shown here, displays a clear component power at a nearby but slightly larger period. The fact that a very similar period is found after applying two independent methods gives us confidence about reality of the X-ray period detection.

At this point, it is remarkable that our X-ray period of 26.7 ± 0.2 d is well consistent within error with the 26.496 ± 0.008 d radio period, as determined by Taylor & Gregory (1984) using more than a decade old observations. More recently, however, a different longer radio period of 26.69 ± 0.02 d has been reported based on daily monitoring with the Green Bank Interferometer from 1994 January to 1996 February (Ray et al. 1996). An independent analysis using the same radio data and the PDM technique yields 26.71 ± 0.05 d (Peracaula 1997). It is not clear at present time if these results represent a real increase related to orbital period change or some other effects are at work. The X-ray period detected by us is not accurate enough to support a longer radio period value, but it is certainly consistent too with any of the recent longer radio period estimates. Independently of any period evolution, the closeness within error of the LSI+61°303 X-ray and radio periods strongly suggests that they are actually the same.

Hereafter, and for practical computation purposes, we will fold the ASM data using our 26.7 d X-ray period value. Also, we will adopt always the same phase origin at JD 2443366.775, as originally set by Taylor & Gregory (1982).

The X-ray light curve, folded and averaged in bins of 0.1 phase, is shown in the bottom panel of Fig. 2. In the top panel of this same figure, we plot for comparison purposes an average radio light curve at 8.4 GHz. This radio light curve has been obtained by averaging three different radio outbursts taken from Tavani et al. (1996). This is the only well sampled LSI+61°303 radio data available close in time to the ASM measurements ($\sim$ 2 yr before). The data are plotted twice for better display.

The value assigned to each bin in the folded X-ray curve is the weighted average of about 25 ASM daily points. Given that this is a relatively high number, we regard the X-ray folded and averaged light curve as significant at least concerning its general shape, but possibly not the details. Representative error bars computed as the weighted error of the averaged bin mean are also indicated.

3. Discussion

The overall shape of the average X-ray light curve shown in Fig. 2 is noticeably different from that seen in the radio. X-ray emission is wider and spans longer than high radio emission, with a common overlap in the active state around phases 0.6-0.8. The X-ray emission level from LSI+61°303 appears to vary by a factor of ~ 5, with a broad active state that lasts for more than half an X-ray period and is centered around phase 0.5. A rather narrow X-ray minimum appears to be present at phases

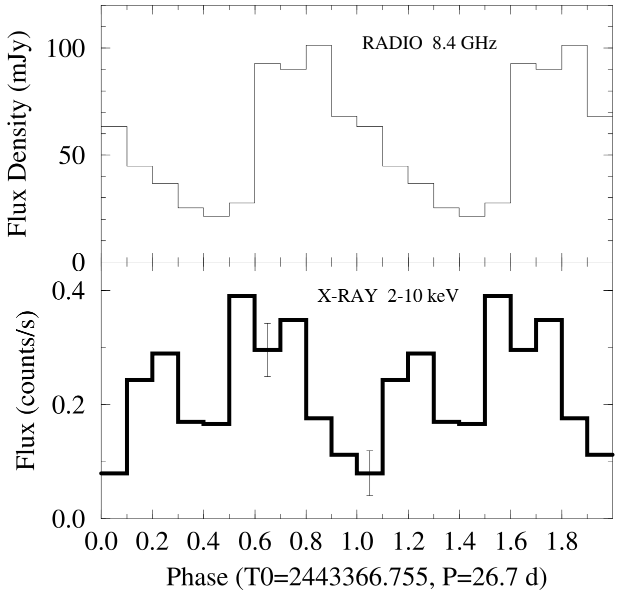

Fig. 2. Bottom: ASM/RXTE observations of LSI+61°303 in the 2-10 keV band folded on the 26.7 d period and averaged in bins of 0.1 phase. Representative error bars are shown. **Top:** Averaged radio light curve at 8.4 GHz folded on the same period as the X-ray data. The phase origin adopted corresponds to JD 2443366.775 in both panels and all data points are plotted twice.

0.9-0.1 and the X-ray light curve may also exhibit two maxima with different amplitude. This last point, however, should be confirmed from less noisy X-ray data.

Although we do not have spectral X-ray information, we can try to derive a rough estimate of the LSI+61°303 2-10 keV luminosity range knowing that the ASM Crab Nebula count rate in this energy band is ~75 ASM counts s^{-1}. From the LSI+61°303 count rate, the corresponding luminosity at a distance of 2.0 kpc (Frail & Hjellming 1991) is then found to vary within L_X(2-10 keV)$\sim 1\times10^{34}$ and $\sim 6\times10^{34}$ erg s^{-1}. This range is consistent in order of magnitude with the X-ray luminosities observed by other authors (e.g. Taylor et al. 1996). Our luminosity estimates are not corrected for absorption due to the atomic hydrogen column density. Frail & Hjellming (1991) HI observations yielded $N_H = 8.4\times10^{21}$ cm^{-2} for LSI+61°303. Therefore, the absorption correction should not be larger than about 10% in the ASM energy band.

Up to now, the only published full cycle simultaneous X-ray and radio observations of LSI+61°303 are those carried out by Taylor et al. (1995). These authors found that their X-ray and radio maxima occurred at well separated phases, and with the X-ray flux varying by a factor of $\sim$ 10. This fractional variability is higher but comparable to ours. In addition, our average light curves also display significant X-ray emission preceding the onset of the radio outburst.

Since both X-ray and radio emission appear to display the same periodicity, this implies that any model explaining the radio outbursts should also take into account, and be consistent with, the concurrent X-ray emission of the system. Current models proposed so far can be divided into two main broad categories, namely, accretion models and those based on a young non-accreting pulsar.

Accretion models initially proposed assumed that relativistic electrons were ejected and accelerated after super Eddington accretion events of mass from the Be star circumstellar envelope onto the neutron star companion surface (e.g., Taylor et al. 1992). This was supposed to occur during the periastron passage of a highly eccentric orbit. Recent X-ray observations by the ASCA satellite (Harrison et al. 1997) provide strong evidence that this scenario needs to be revised. In particular, the ASCA observations indicate a non-thermal power law spectrum together with an X-ray luminosity at least three orders of magnitude lower than predicted for super Eddington accretion. In addition, no X-ray pulsations nor Fe line features in the X-ray spectrum have been ever detected. A possible, but difficult, way to overcome this problem would be if the bulk of energy was emitted in the γ-rays rather than in the X-ray regime, possibly involving a photon shift towards higher energies due to inverse Compton emission. Another alternative is to consider that the accretion takes place over the magnetosphere of a rapidly rotating magnetized neutron star (Campana et al. 1995; Zamanov 1995).

On the other hand, non-accretion models involve a relatively young pulsar in a binary system. The radio outbursts are then originated from particles accelerated at the shock front produced at the interface between the dense Be star wind and the relativistic wind of the pulsar (Maraschi & Treves 1981; Tavani 1994). Synchrotron and inverse Compton emission of the same particles may also account for the X-ray emision of the system and perhaps γ-ray too. Both the X-ray and radio light curves are expected here to be modulated with the orbital period as the shock geometry changes along the orbit.

Concerning the origin of ASM X-rays, the fact that the highest X-ray and radio emission states take place roughly at the same orbital phases (0.6-0.8) could suggest that there is an important X-ray component produced by inverse Compton effect over the radio emitting electrons. Such production of non-thermal X-rays in the keV band is more naturally understood in the framework of non-accreting models since accretion X-rays would tend to produce a rather thermal spectrum.

Given the ASM sensitivity and the weak X-ray flux of LSI+61°303, the X-ray light results presented here have been necessarily based on averaging many orbital cycles of ASM data. Therefore, further coordinated radio and higher sensitivity X-ray observations of individual outbursts are needed in order to better understand the strong relationship between these two spectral domains, as suggested by the existence of a common period.

4. Conclusions

Based on ASM/RXTE quick look data, we find significative evidence of an X-ray period of 26.7 $\pm$ 0.2 d for the radio emitting X-ray binary LSI+61°303. The X-ray period appears to be the same as the radio/orbital period of the system. This fact gives support to the idea that the X-ray and radio emission of LSI+61°303 are strongly related.

An averaged X-ray light curve has been obtained that displays amplitude variations by a factor of ~ 5, with a broad active state whose highest emission level overlaps with the phases of strongest radio emission. This could be interpreted as inverse Compton effect playing an important role in the production of keV X-rays, as assumed in LSI+61°303 non-accreting models.

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