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The X-ray time variability of LSI+61^{o}303

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Abstract.

LSI+61^{o}303 was discovered in 1977 to be a strong, variable radio source and was proposed to be the counterpart of the COS-B γ–ray source 2CG0135+01. The radio light curve exhibits outbursts whose periodicity corresponds to the optical periodicity of the orbital motion. LSI+61^{o}303 has been also identified as an x-ray source and an MeV γ–ray source. Long-term continuous x-ray monitoring of LSI+61^{o}303 by the RXTE/All-Sky-Monitor has now been carried out for a period of 5 years. These data are analyzed and the resulting time variations are summarized. The results are compared to those from radio studies and from a previous x-ray study covering a period of ten months.

1 Introduction

LSI+61^{o}303 is one of a small but important group of radio emitting x-ray binary systems. Considerable interest has centered around LSI+61^{o}303 since 1977 when it was discovered to be a strong, variable radio source (Gregory and Taylor (1978)) and proposed to be the counterpart of the COS-B γ–ray source 2CG0135+01. It was then identified with its Be star optical counterpart (Gregory et al. (1979)). The radio light curve exhibits outbursts whose periodicity is consistent with the poorly-determined optical periodicity of the orbital motion (Hutchings and Crampton (1981)).

LSI+61^{o}303 has been also identified as an x-ray source (Bignami et al. (1981)). It was observed in x-rays by the ASCA satellite (Leahy et al. (1997)) and by ROSAT and RXTE (Harrison et al. (2000)). Long-term monitoring of LSI+61^{o}303 has been carried out by the All-Sky-Monitor (ASM) on board RXTE. Here are presented the results of the analysis of the x-ray time variability of LSI+61^{o}303 from the RXTE/ASM data.

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2 Data Analysis

The RXTE/ASM dwell data and dayly-average data were obtained from the ASM web site. The data reduction to obtain the count rates and errors from the satellite observations was carried out by ASM/RXTE team, and the procedures are described at the web site. The ASM count rates used here are for the full 2-10 keV band. The data covered the time period MJD50088.1 to MJD51969.2.

2.1 Power Spectrum Analysis

The power spectrum was created by averaging the dwell data into 0.05 day (1 hour 12 min) bins, subtracting the mean value of all inhabited bins from each inhabited bin, and taking an FFT. The resulting power in each frequency bin was divided by the average power over the whole frequency range. The chisquared distribution was used to assess the significance of any peaks in the power spectrum. The only significant frequency was at 0.00158946/hr, with a chance probability of 0.2 in 32676 trials. The corresponding period is 26.214 days, nearly the same as published values of the radio period (see below). The adjacent period at 26.426 days, also had significant power.

2.2 Epoch Folding Analysis

An epoch folding analysis was carried out, with the chisquared statistic used to assess the reality of variability at any given trial period. The dayly-average was folded into 24 bins for periods in the range of 20 days to 30 days, giving a maximum chisquared of 66.6 at a period of 26.448 days (see Fig.1).

The dwell data was also epoch folded giving a maximum chisquared of 101.2 at a period of 26.448 days (see Fig.2). The resulting folded light curve at this period is shown in Fig.3. The epoch folding results from the dwell data are more significant than from the dayly-average data. This is probably due to the effect of averaging over 1 day intervals. The period uncertainty for both day and dwell data is ± 0.05days.

The dwell data was also split into pieces and epoch folded.

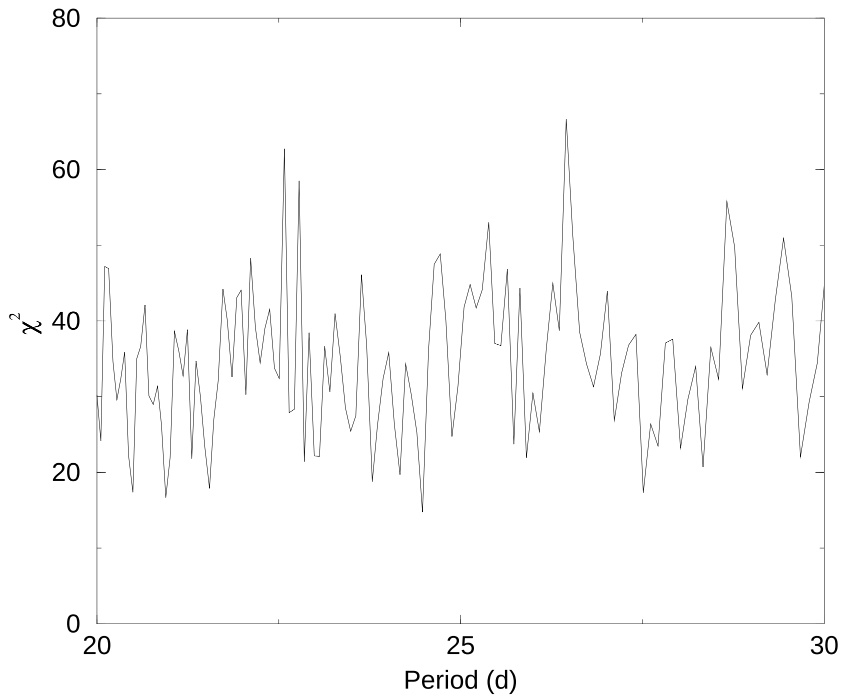

Fig. 1. chisquared vs. period for the ASM dayly-average data.

The individual pieces showed the same period as the whole data set. Thus we have no evidence for period variability over the whole time period. The first piece was chosen to be coincident with the time period used by Paredes et al. (1997). For that time period of 269 days, the dwell data was folded into 10 bins for period between 20 and 30 days. The peak chisquared was 70.74 at a period of 26.43 days, consistent within errors with the 26.45 day period found for the whole data set. The resulting light curve is shown in Fig. 4. The period uncertainty for the 269 day data set is ± 0.4day, so the 26.7 day period given by Paredes et al. (1997) is consistent with the constant period of 26.45 days.

2.3 Long-term Light Curve

The above analysis has determined that the periodicity in x-rays is a constant period of 26.45 days. In order to remove effects of this periodicity on the long-term light curve, the dwell data was binned into time bins of 26.45 days. The subsequent light curve had less variability as determined by the chisquared test, than light curves made using different bin sizes, demonstrating the success in removing the 26.45 day orbital variability. This long-term light curve still shows real variability: the mean RXTE/ASM count rate is 0.202 counts/s and the standard deviation is 0.123 counts/s. The best fit linear curve to the long-term light curve has a slope of $(4.9 \pm 2.7) \times 10^{-5}$ counts/s per day. However the chisquared test shows that the main variability is not accounted for in the linear fit. A sinusoidal plus constant model for the variability, with arbitrary phase and period for the sinusoid, provided a worse fit to the long term light curve than the linear fit.

3 Discussion

The RXTE/ASM data comprise the best long-term x-ray observations of LSI+61^{o}303. The period determined here of 26.45 days is the best determination of the orbital period of this system. The uncertainty is dominated by the limit of the time span of observations and is ± 0.05day. The radio period shows evidence of being variable (e.g. Ray et al. (1997)), which is likely due to the radio outbursts not being tightly coupled to the orbital period. The optical period is equal to the orbital period, but the only determination (Hutchings and Crampton (1981)) has a larger uncertainty than the x-ray data, of ± 0.1 days.

The x-ray light curve is probably produced by inverse compton emission of stellar photons on the relativistic electrons responsible for the radio synchrotron emission (e.g. see Leahy et al. (1997)). The peak of the x-ray emission should be consistently at periastron, unlike the radio emission peak which varies in phase. For the epoch folding analysis above, the reference for phase zero (T0x) was taken as JD2450088.1. Thus the peak of x-ray emission and periastron occurs at approximately phase 0.86.

The average phase for radio outburst was defined as 0 for the reference epoch of JD2449393.5($\pm$0.4) (Ray et al. (1997)). This translates to a phase of 0.26 with reference to T0x, and implies that the average radio outburst occurs 0.4 in orbital phase after periastron. This is consistent with what was found for two orbital cycles which have been sampled by observations with ROSAT and RXTE (Harrison et al. (2000)).

The resulting model for LSI+61^{o}303 system is as follows. Relativistic electrons are accelerated in the environement of a pulsar orbiting the primary Be star and emit inverse comp-

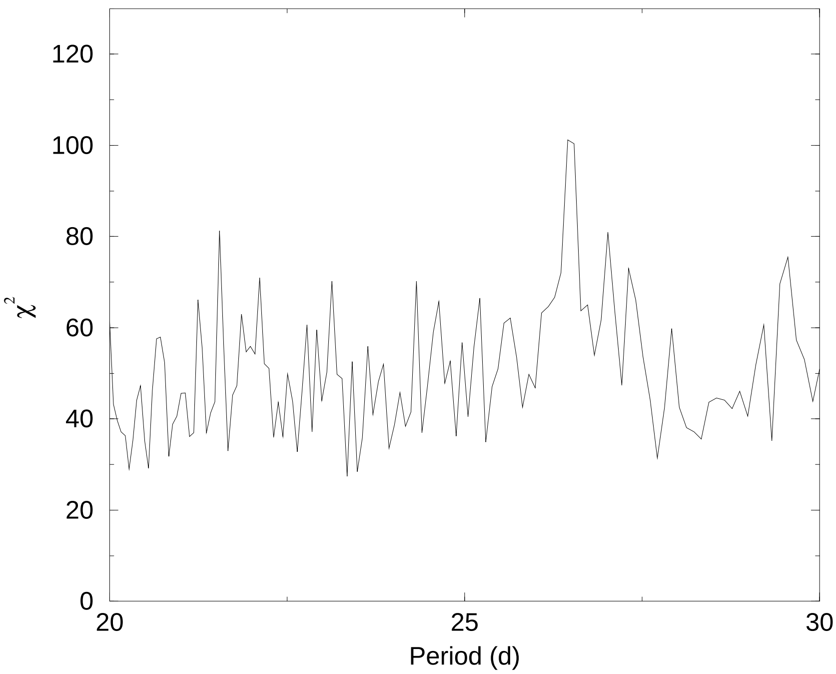

Fig. 2. chisquared vs. period for the ASM dwell data.

ton x-rays and gamma-rays, which peak at periastron due to the peak in photon flux at periastron. The radio outbursts occur 0.4 later in orbital phase when some fraction of the relativistic electrons around the pulsar escape the system. Detailed modelling of the radio outbursts is given in Peracaula (1997). A companion paper in these proceedings discusses the implications of the multiwavelength observations on the relativistic electron population.

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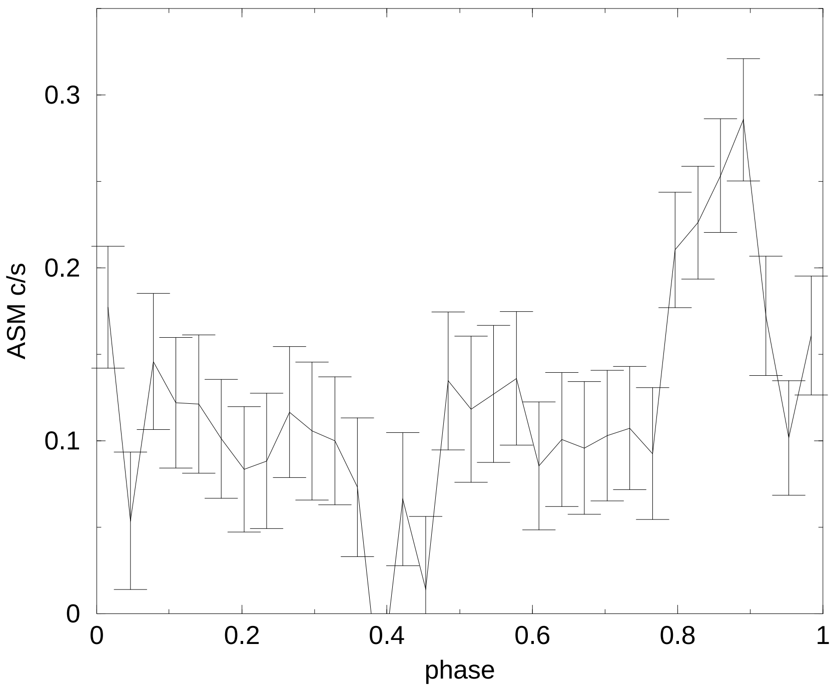

Fig. 3. Folded light curve at 26.448 days for the ASM dwell data.

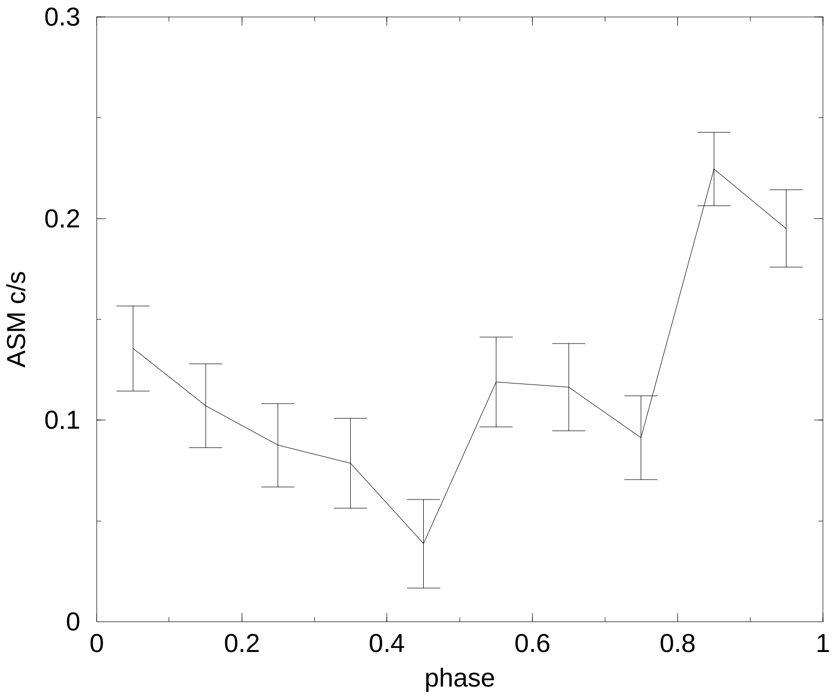

Fig. 4. Folded light curve at 26.43 days for the first 269 days of the ASM dwell data.