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Research Note

The 1584 day period in the Be Star LSI +61°303

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Abstract. The Be star LSI +61°303 shows the 1584 d period in its X-ray emission. The difference in the 1584 d period phases of the peak X-ray and radio emissions and the Hα emission is explained as being due to the time taken by the density enhancement, emitted by the Be star, and which is responsible for the increased emissions, to reach the periastron of the orbit of the binary companion.

Key words. X-ray: binaries – stars: binaries: general stars: LSI +61°303 – stars: emission libre: Be

1. Introduction

The radio source GT 0236+610 (Gregory & Taylor 1978) was identified with the optical object LSI +61°303. X-ray emission (Bignami et al. 1981) as well as gamma ray emission (van Dijk et al. 1996) was observed from the object. This led to the suggestion that the system is a binary containing a compact object accreting matter from the Be star disk. A binary period of 26.5 days was found in the radio emission (Taylor & Gregory 1982) and subsequently in the X-ray and Hα emissions. The binary orbit was found to have an eccentricity of ∼0.6 (Hutchings & Crampton 1981). The radio emission was also found to have a quasi periodicity of ∼4 yr (Gregory et al. 1989; Gregory 1999). Subsequently this long period was refined to be about 1584 d.

The X-ray emission shows a peak emission at a phase 0.5 of the 26.5 day period (Taylor et al. 1996; Harrison et al. 2000). This is suggested to be due to the encounter of the compact object, in its eccentric motion, with the denser portion of the Be star disk. The radio emission also shows a peak, but the 26.5 day period phase of the peak occurs later than 0.5, sometimes as late as 0.9 (see Paredes et al. 1991; Ray et al. 1997), the stronger radio bursts peaking at an earlier phase. This delay in phase is explained as being due to the time taken by the "plasmon" containing the high energy electrons responsible for the radio emission, to expand in the Be star "hot" wind to a size when it becomes optically thin to the radio emission (Taylor & Gregory 1984; Apparao 1999).

Recently, Zamanov & Marti (2000) have compiled the data on radio and Hα emission from the object and established the 1584 d period. They fitted a sinusoidal function to the data and obtained the phases of the peak emission. The found that there is a difference of ∼0.25 between the two phases. They also found that the separation of the peaks in the Hα emission and the onset of the radio emission also shows a dependence on the phase of the 1584 d period.

The 1584 d period has been suggested as being due to precession of relativistic jets as well as to periodic variability of the Be star gas disk (Paredes 1987; Gregory et al. 1989; Apparao 1999). The existence of the 1584 d period in the Hα emission suggests that the Be star disk variation is the likely cause of the period. The existence of the Hα emission at some level throughout the 1584 d period suggests that there is a permanent gas disk around the Be star which is density bound to the ionising radiation of the star. Emission of density enhancements from the Be star leads to further absorption of the ionising radiation of the Be star and increase in the Hα emission.

Zamanov & Marti (2000) have attempted to explain the phase relation of the peak radio emission and the onset time, but have not tried to give the reason for the phase (1584 d) difference between the peak radio emission and Hα emission.

In this note we examine first whether the 1584 d period is seen in X-ray emission and then discuss the origin of the 1584 d period and the relative phase variations of the emissions.

2. The 1584 d period variation of X-ray emission

The object LSI +61°303 was observed by the X-ray satellites EINSTEIN (Bignami et al. 1981), ROSAT (Goldoni & Mereghetti 1995; Taylor et al. 1996), ASCA (Leahy et al. 1997) and RXTE (Harrison et al. 2000). The energy range of the X-ray observations are however different for the diffrent satellites; EINSTEIN 0.2–5 keV, ROSAT

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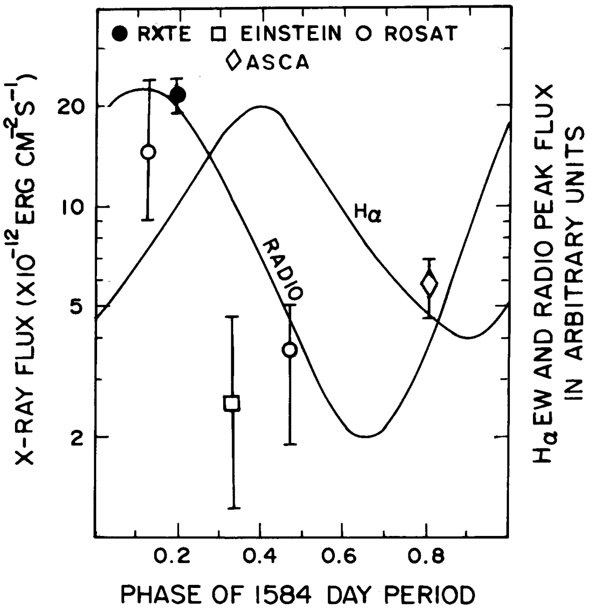

Fig. 1. The X-ray emission from LSI +61°303 observed by various satellites plotted against the phase of the 1584 d period. The curves correspond to radio and Hα emission from the object as obtained by Zamanov & Marti (2000). The errors on the EINSTEIN and ROSAT points are estimated (see text)

(Goldoni & Mereghetti 1995) 0.1–2.4 keV, ROSAT (Taylor et al. 1996) 0.07–2.48 keV, ASCA 2–10 keV, and RXTE 2–10 keV. In order to compare the fluxes, we have reduced the fluxes from the EINSTEIN and ROSAT observations to the range 2–10 keV by using a power law for the photon spectrum, with an index 1.1 (Goldoni & Mereghetti 1995). The observed fluxes as well as the corrected fluxes are given in Table 1. These derived fluxes can have an error up to a factor of 2, if for example the errors on the power law index found by Goldoni & Mereghetti (1995) are taken into account. The errors for the ASCA and RXTE values are less than twenty percent.

Table 1 gives the Julian day of the various X-ray observations. The phases of the 1584 d variation and the 26.4917 d orbital variations for the different observations are obtained using JD 2 443 366.75 as the time of zero phase (Gregory et al. 1999). These phases are given in Table 1. The X-ray intensity varies with the orbital period and a correction has to be made to obtain the maximum flux in a given orbit. In order to normalise the observed flux to the maximum flux (phase 0.5), we used the X-ray light curves given by Taylor et al. (1996) and Harrison et al. (2000). A template of X-ray intensity versus the orbital phase is made. It turns out that the normalised fluxes in the two cases agree to about ten percent in the phase range 0.4–0.6. In any case, the orbital phases of the observations are close to the maximum intensity phase and the corrections are small. The corrected fluxes are given in Table 1.

The values of the corrected fluxes from different observations are plotted against the phase of the 1584 d period in Fig. 1. Also plotted are the variation of the Hα and radio peak variations as a function of the 1584 d phase, as obtained by Zamanov & Marti (2000).

The X-ray emission from LSI +61°303 seems to show, though there are only a few observations, the 1584 d varaiation. The X-ray flux from the EINSTEIN satellite is low. It is seen, however, both from the radio peak and Hα fluxes (Zamanov & Marti 2000), that the parameter value at a given time can fluctuate and differ significantly from the average value. The X-ray flux variation seems to be more consistent with the phase variation of the radio peak than the Hα phase variation.

3. Phase correlations

The detection of Hα emission throughout the 1584 d period indicates that the gas disk around the Be star exists throughout. The enhancement of Hα emission is then due to the increase in the density of the gas in the disk and further absorption of the Be star ionising radiation. We suggest that the density enhancement starts at the Be star and expands outwards. Near the star this density enhancement can be optically thick to Hα radiation (Apparao & Tarafdar 1997). As the disk expands, the optical depth for Hα radiation becomes less and the intensity of the Hα emisssion increases. The maximum Hα emisssion is reached when the gas in the disk becomes optically thin to Hα radiation. The gas subsequently becomes density bound to the Lyman radiation from the Be star, and the Hα emission decreases.

Enhanced peak X-ray emission takes place when the density enhancement reaches the periastron and encounters the compact object leading to accretion onto it. It is likely that the maximum particle acceleration takes place at this time, leading to the maximum peak radio emission. In this picture the maximum of peak radio emission in the 1584 d period occurs after the Hα maximum. The 1584 d phase diference between the Hα maximum and the peak radio emission is then ∼0.7 and not ∼0.25, as given by Zamanov & Marti (2000). This diffrence in phase of ∼0.7 corresponds to ∼1100 d. The distance of the periastron of the secondary orbit from the Be star is $\sim 3\ 10^{12}$ cm, and using the phase difference between the Hα and radio peaks, the velocity with which the enhancement travels outwards is ~ 0.3 km s^{-1}.

At the time of the zero phase of the 1584 d period, the gas is near the Be star and the velocity in the direction of rotation $v_{\rm r}$ of the gas is larger than at subsequent times and the peak separation in th Hα emission profile is largest. On the other hand, when the enhancemant expands, and the Hα emission is no longer self- absorbed and reaches its highest value, the emitting gas of enhanced density has moved away from the Be star. The velocity $v_{\rm r}$ of the gas in this region is smaller than earlier and the separation of the peaks in the Hα profile is smaller. The above mechanism accounts for the behavior of the Hα peak separation (ΔV) with the 1584 d period phase as given by Zamanov & Marti (2000). As the density enhancement dissipates and the gas becomes density

Table 1. X-ray observations of LSI 61°+303 and their orbital and 1584 d phases

Observers	Time of Obs. JD 2400000+	1584 d phase	Orbital phase	Obs. energy range	Obs. flux	Flux corrected to 2–10 keV	Flux corrected for orb. phase
Bignami et al. 1981	43908	0.34	0.42	0.2-5	0.21	0.18	0.24
Goldoni & Mereghetti 1995	48308.5	0.12	0.54	0.1–2.4	0.43	1.26 -	1.4
Taylor et al. 1996	48864	0.47	0.51	0.07–2.48	0.34	0.36	0.38
Leahy et al. 1997	49492	0.8	0.43	2–10	0.43	0.43	0.55
Harrison et al. 2000	50161.5	0.29	0.48	2–10	2	2	2.1

All fluxes in units of 10^{-11} erg cm^{-2} s^{-1}.

bound, the separation of the peaks corresponding to the permanent residual gas disk is restored and the next cycle begins.

The nature of the radio spectrum during the early stages of the radio flares indicates that the plasmon responsible for the radio emission is optically thick to the radio emission (Taylor & Gregory 1984; Apparao 1999). The radio emission onset occurs when the plasmon begins to get optically thinner. Apparao (1999) has shown that the radio peak 26.5 d phase delay can be explained as the time it takes for the plasmon to expand in the hot wind of the Be star to become optically thin. The stronger the radio emission, the earlier the phase of the peak (Taylor & Gregory 1984; Ray et al. 1997). The onset of the radio emission will also occur earlier for the stronger radio emissions, as the high energy electron density and the consequent pressure will be larger in the plasmon for the stronger radio emissions leading to a faster expansion and becoming optically thin.

4. Discussion

We have suggested a picture in which density enhancement in the gas disk around the Be star occurs every ∼1584 days. The density enhancement starts from the Be stars, expands and dissipates, leading to the increase and decrease of the Hα emission. The delay in the enhanced X-ray and radio emission is due to the time taken for the density enhancement to reach the periastron, where the high energy radio electrons are produced. The velocity of travel of the enhancement was found to be ~ 0.3 km s^{-1}; this is nearly the same as the initial velocity of the cold "wind" in the disk found for ψ Per by Marlborough et al. (1997), but smaller than ~ 5 km s^{-1} (Pockert & Marlborough 1978, 1979) suggested for γ Cas.

Further X-ray observations will be of interest to establish the 1584 d variation indicated by Fig. 1.

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