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H_α AND RADIO OBSERVATIONS OF LSI+61°303

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Abstract. Quasi simultaneous H_α and radio observations of LSI+61°303 during August-September 1993 are presented. The radio data show that during the studied epoch the outburst has peaked at radio phase $\sim$ 0.6, at a level $\geq$ 100 mJy. No significant variations in the H_α profile at phases 0.5 to 0.65 have been detected. A remarkable increase of the EW and FWHM of the H_α blue peak is observed at radio phase $\sim$ 0.23. Possible reasons are considered.

1. Introduction

The Be X-ray binary LSI+61°303 is the optical counterpart of the variable radio source GT0236+610. This object exhibits strong radio outbursts with a period of $26^{d}.496$ (Gregory and Taylor, 1978; Taylor and Gregory, 1982, 1984). Usually, the radio outbursts peak around phases 0.6 to 0.8 (Paredes *et al.*, 1990). The spectroscopic observations of Hutchings and Crampton (1981) are consistent with a binary system with the same period, an eccentric orbit and a secondary with a mass $\leq 1.5M_\odot$. These observations indicate that the primary is a main sequence B0-B0.5 star ($10M_\odot$) with an equatorial disk and mass loss.

$\mathbf{H_\alpha}$ observations of LSI+61°303 have been discussed by Gregory *et al.* (1979), Hutchings and Crampton (1981) and Paredes *et al.* (1994). These observations revealed clear variations in the line profile. In particular, Paredes *et al.* (1994) found a noticeably variability of the red hump of $\mathbf{H_\alpha}$ at or close to the radio maximum. In the present study we show that similar variations exist in the blue hump of the line too, but at the opposite location of the orbit (at radio phase $\sim$ 0.25). First of all quasi simultaneous H_α and radio observations at radio outbursts are performed. Our data do not indicate considerable changes in H_α close to the radio maximum.

2. Observations and Data Reduction

Between August 25 and September 9, 1993 six spectra were obtained with the Coudé spectrograph of the 2m RCC telescope at the Bulgarian National Astronomical Observatory. ISTA-CCD with 400 × 580 pixels of 22μ was used as a detector. The total spectrum coverage is about 60Å with a resolution of about 0.1Å/px. S/N ratio of 15–20 is only reached. The CCD frames are corrected for bias, flat field

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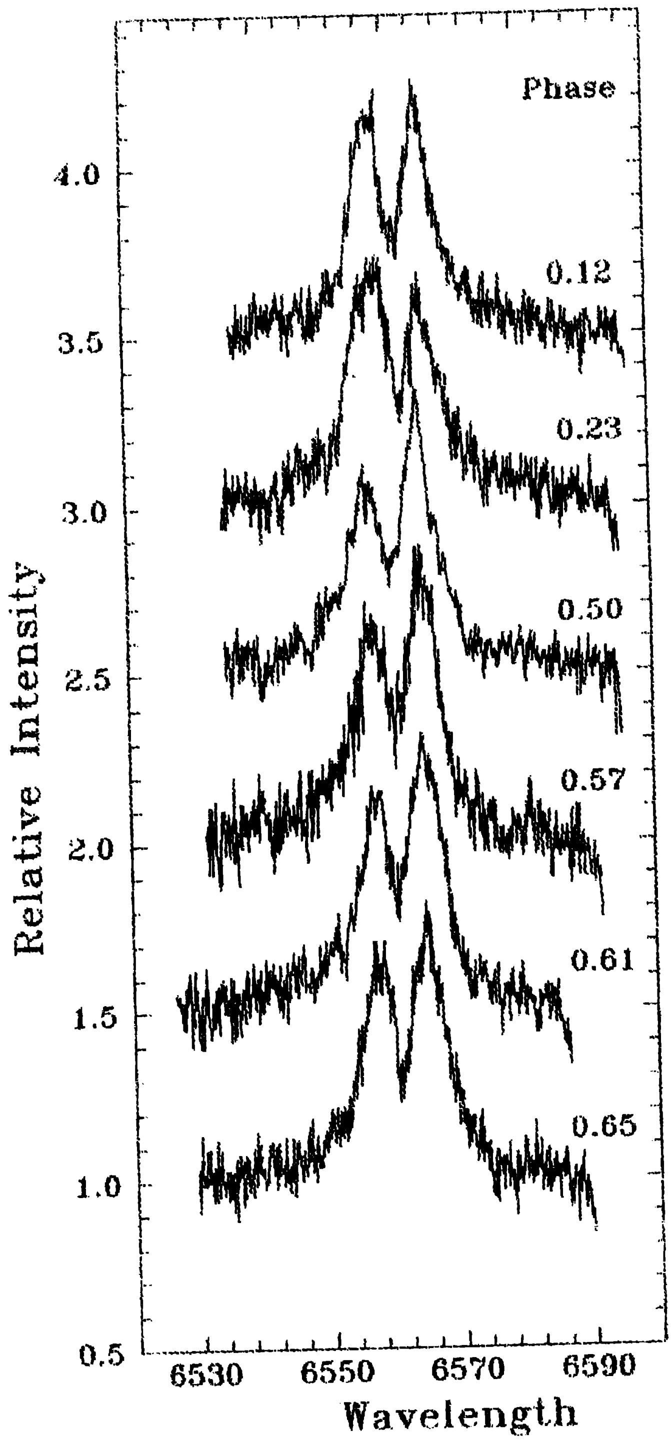

Fig. 1. Normalized H_α profiles of LSI+61°303. The radio phase is indicated. The plots are separated by adding different constants to each one.

and cosmic ray hits using *pcIPS* software package of Smirnov *et al.* (1992). The obtained H_α records are normalized to the continuum intensity equal to unity.

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TABLE I

H_α line parameters of LSI+61°303 observed during August-September 1993

Date	Radio Phase	V_r(B) (km s^{-1})	V_r(R) km s^{-1})	FWHM(B) (Å)	FWHM(R) (Å)	B/R	EW (Å)	EW_R/EW_B
Aug 25	0.12	–203	132	5.43	5.75	0.96	9.2	1.07
Aug 29	0.23	–192	139	7.47	5.76	1.04	10.4	0.74
Sep 05	0.50	–258	101	5.85	6.27	0.87	9.8	1.14
Sep 07	0.57	–229	127	6.02	5.86	0.91	10.5	1.04
Sep 08	0.61	–228	117	5.61	6.17	0.92	10.0	1.22
Sep 09	0.65	–220	109	5.82	6.09	0.95	9.9	1.09

In the course of our spectroscopic observations, the level of the radio emission of LSI+61°303 was also monitored in two occasions: at 6 cm wavelength, with the VLA interferometer of NRAO,* and at 3.6 cm wavelength using the 70 m antenna at the Madrid Deep Space Communication Complex (INTA-NASA). The VLA data were reduced using the standard AIPS package. They will be discussed in detail by Peracaula *et al.* (1997). The single dish observations were reduced using the software packages available at the telescope site (Rius *et al.*, 1988).

3. Results and Discussion

The H_α profiles normalized to the continuum intensity are shown in Figure 1. Line parameters measured on each profile are summarized in Table I. The radio phase is computed on the base of a 26.496 day period and phase zero set at JD 2443366.775 (Taylor and Gregory, 1982, 1984). The heliocentric radial velocity of the blue and red peaks is estimated with an error of about 5 km s^{-1}. The FWHM of the blue and red humps are derived employing a gaussian fitting. The other parameters are measured directly. It is necessary to note that the H_α Full Width Zero Intensity is about 3100 km s^{-1} (Hutchings and Crampton, 1981) and so, a part of the wings lies out of the spectral range covered. This probably leads to an underestimation of the H_α EW. The error in the equivalent width ratio of the blue and red humps as well as in other parameters is insignificant.

The results of the radio monitoring are given in Table II. The first 3.6 cm radio observation is a 3σ upper limit due to bad weather conditions. The obtained data allow us to suppose that the radio outburst in September 1993 probably peaked around radio phase 0.6, at a level of $\sim$ 100 mJy or higher. This fact is consistent with LSI+61°303 being rising from the low state of the long term ($\sim$ 4 yr) modulation

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TABLE II
Radio monitoring of LSI+61°303

Date	Radio Phase	$S_{6\ cm}$ (mJy)	$S_{3.6\ cm}$ (mJy)
1993 Sep 06	0.57	–	< 67
09	0.66	103.5 ± 0.6	–
11	0.74	–	35 ± 5
13	0.81	55.5 ± 0.3	–

of the radio outburst peak flux density (Gregory *et al.*, 1989; Paredes *et al.*, 1990), as expected from the latest modulation period determination by Martí (1993).

According to Paredes *et al.* (1994) several H_α emission line parameters change strongly around radio phase 0.75. Taking into account the fact that radio outbursts typically peak around phases 0.6 to 0.8 (Paredes *et al.*, 1990) they conclude that the variations in the H_α EW and the width of its red hump take place at or close to radio maximum. Our spectroscopic observations, however, do not show any significant variations in the H_α profile at phases 0.5 to 0.65, i.e. before and at the radio maximum in September 1993. Therefore, the correlation between the H_α line profile variability and the radio maximum of LSI+61°303 – if it exists – appears to be not constant in time.

At the same time the H_α profile obtained on August 25, 1993 (radio phase 0.23) is obviously different. The EW and the FWHM of its blue hump are considerably higher than those measured in the other profiles of the sample. Taking into account that the FWHM(B) = 7.14 Å at radio phase 0.4 (Paredes *et al.*, 1994), we can suppose that this parameter probably reaches its maximum at radio phase 0.25 to 0.35. Hence, it appears that the maximums of FWHM of the red and the blue humps occur at opposite locations of the orbit.

A problem in the interpretation of the H_α variability is the uncertainty in the orbital elements of LSI+61°303. Few solutions have been proposed by Hutchings and Crampton (1981) on the base of different spectral lines. As average value we can accept $e = 0.6$, $\omega = 20°$ and periastron passage at radio phase ~ 0.2. New orbital solutions, based on the near infrared light curve, have been derived by Martí and Paredes (1995). Assuming an edge-on orbital plane, their average solutions seems to indicate $e \cong 0.8$ and periastron passage at phase around 0.54, with ω being in the range $50 - 80°$.

Let us assume that most of the H_α emission is formed in the outflowing disk around the primary. The presence of a neutron star moving in an eccentric orbit, however, will cause distortion, and so, the disk will be probably non-axisymmetric. According to Paredes *et al.* (1994) $R_{out}/R_{in} = 9.2$, where R_{out} and R_{in} are the

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outer and the inner radius of the envelope of the primary. Adopting $R_{in} \geq R_*$ and $R_* = 10R_\odot$ (Howarth, 1983) we estimate $R_{out} \geq 90R_\odot$. Therefore, as a result of the eccentricity of the orbit, we conclude that the maximal distance between the components of LSI+61°303 is about $150R_\odot$. Hence, at the apastron the neutron star will probably lie out of the disk where H_α emission forms. So, when the companion is around the apastron the H_α profile must be similar to the unperturbed profile. From simple geometrical considerations it appears that an emission line profile forming in an outflowing and rotating disk will have more intensive red peak. It is just what we have observed at phases $0.5 - 0.65$ (Fig. 1).

When the compact object moves through the circumstellar envelope it will capture matter from the stellar wind of the primary. This will lead to an increase of the density in those part of the outflowing disk where the secondary is, and will probably enhance the H_α emission from this region. Such scenario was proposed by Telting *et al.* (1993) for γ Cas. Following the orbital solution of Hutchings and Crampton (1981) we can expect an increase and/or broadening of the blue peak of H_α around phase 0.2, when the neutron star moves to the observer.

Recently Zamanov (1995) have proposed an Ejector – Propeller model for the neutron star in LSI+61°303. In view of this model the enhancement of the H_α blue peak at phase ~ 0.23 can be due to the Propeller action as well.

Paredes *et al.* (1994) have discussed the possibility the broadening of the humps to be a result of the non-axisymmetric perturbation in the outer edge of the disk. In view of the orbital solution by Martí and Paredes (1995) the observed increase of the FWHM of the humps at radio phases ~ 0.3 and 0.75 will coincide with the moments when the secondary crosses the outer edge of the circumstellar disk, if the disk radius is $R_{out} \sim 100R_\odot$.

Finally, we would like to note that theoretical investigation of the influence of the compact object onto the Be star disk are needed to explain in detail the behavior of the H_α emission line of LSI+61°303. In our opinion the phase interval $0.1 - 0.5$ deserves more attention from the observers.

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