COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5776

Konkoly Observatory
Budapest
1 June 2007

HU ISSN 0374 – 0676

Hα OBSERVATIONS OF THE GALACTIC MICROQUASAR LSI+61°303

ZAMANOV, R.K.; STOYANOV, K.A.; TOMOV, N.A.

Institute of Astronomy, Bulgarian Academy of Sciences, Tsarigradsko shosse Blvd. 72, 1784 Sofia, Bulgaria
e-mail: rkz@astro.bas.bg; kstoyanov@astro.bas.bg

LSI+61°303 (V615 Cas, GT0236+610) is a Be/X-ray binary star at a distance of 2.3 kpc (Steele et al., 1998) and with radio outbursts every 26.496 d (Gregory, 2002, and references therein) which is assumed to be the orbital period. The variable radio counterpart of the system was resolved at milliarcsecond scales as a rapidly processing relativistic compact jet (Massi et al., 2004), so LSI+61°303 joined the group of Galactic microquasars. It is also a variable γ-ray source (Albert et al., 2006). The compact object is probably a black hole orbiting around a Be star in a highly eccentric orbit (Casares et al., 2005). Spectral observations show that the Hα emission is variable on time scales days-years (see Grundstrom et al., 2007, and references therein). Here we present the results of our Hα spectroscopy during the period January 2000–April 2007.

We have secured 53 spectra with the Coudé spectrograph of the 2-m RCC telescope at the Bulgarian National Astronomical Observatory Rozhen and Photometrics AT200 CCD. The wavelength coverage is from 6500 Å to about 6700 Å at resolution 0.2 Å/pixel. For each spectrum, we have measured the equivalent width (EW) of the Hα emission line and the separation between the blue and red humps (ΔV). The measured quantities are given in Table 1. The typical error of our measurements is $\pm 10\%$ in EW, and ± 10 km s^{-1} in ΔV.

In Fig. 1 (left panel) we show a few examples of the Hα line. From up to down are plotted our spectra 20000127, 20000820, and 20000623. In all our spectra the Hα line is in emission with two peaks and EW(Hα) is always > 8 Å. We have not observed a third peak in the emission, as visible in the September 2001 observations of Liu & Yan (2005), nor very weak emission in Hα as detected by Grundstrom et al. (2007) at JD2451468.

In Fig. 1 (right panels) we plot the long-term variability of EW(Hα) and ΔV. We also use data from Paredes et al. (1991), Zamanov et al. (1999, 2001), Liu & Yan (2005), and Grundstrom et al. (2007). EW(Hα) achieved values ≈ 18 Å during the two prominent maxima at JD2448800 and at JD2450000. It seems that there are three minima of EW(Hα) at about JD2449200, JD2451200, and JD2453270, when EW(Hα) was ~ 7 Å. During the last 2000 days, there is not a prominent maximum. After JD2451000, the EW(Hα) is always < 14 Å. We see a clear minimum in ΔV at JD2451900, when ΔV dropped to $\Delta V \leq 280$ km s^{-1}, values similar to those observed during the maximum of EW(Hα) at JD2450000.

The distance between the blue and red peak (ΔV) is connected with the outer size of the Hα emitting disk: $\Delta V/(2v \sin i) = (R_{\rm out}/R_*)^{-1/2}$ for a Keplerian disk (Huang, 1972).

Adopting for a typical B0 star radius $R_* = 10\ R_\odot$, and $v \sin i = 360$ km s^{-1} (Hutchings & Crampton, 1981), we obtain that $R_{\rm out}$ varies from 3.7 R_* (37 $R_\odot$) to 7.7 R_* (77 $R_\odot$). These values are in the range 1.2–100 R_* as derived by Hanuschik et al. (1988) in other Be stars.

It deserves noting that the sudden drop on 1 week scale of the EW(Hα) observed by Grundstrom et al. (2007) at JD2451468 is not accompanied with dramatic changes in ΔV, indicating that the disk size does not change on such time scale.

Using the PDM method (Stellingwerf, 1978), we did not detect a clear periodicity in Hα line parameters in the interval 200–3000 days. However, when we plot the data folded with the radio period $P = 1667$ days (Gregory, 2002) we see that the modulation is clearly visible (Fig. 2). All of the data (and the subsets of data when EW < 12 Å and EW ≥ 12 Å) show signs of the 1667 day modulation in EW(Hα) and ΔV. The maximum of EW(Hα) and the minimum of ΔV are at phase 0.25 ± 0.10. At the minimum $\Delta V \approx 260$ km s^{-1}, and at phase 0.75 it achieves ~ 370 km s^{-1}.

Table 1. Parameters of the Hα line in the spectrum of LSI+61°303

date yyyymmdd	JD 2400000+	EW(Hα) [Å]	ΔV [km s^{-1}]	date yyyymmdd	JD 2400000+	EW(Hα) [Å]	ΔV [km s^{-1}]
20000127	51571.29	13.1	351	20010206	51947.40	8.8	307
20000621	51717.48	8.6	325	20010207	51948.29	9.7	307
20000621	51717.51	8.3	338	20010208	51949.29	10.3	299
20000621	51717.52	10.0	313	20010317	51986.23	9.7	281
20000623	51718.50	7.8	325	20010317	51986.24	10.2	294
20000623	51718.51	8.8	401	20010407	52007.24	10.5	319
20000623	51718.52	9.6	338	20010709	52100.57	11.8	345
20000623	51719.48	8.1	313	20010727	52118.53	10.8	256
20000623	51719.50	8.5	363	20010903	52156.44	13.4	332
20000623	51719.51	9.5	338	20010904	52157.36	12.4	332
20000817	51774.38	9.4	313	20011003	52186.55	12.0	331
20000817	51774.39	9.0	300	20020123	52298.34	9.2	280
20000818	51775.39	9.4	275	20020622	52448.54	8.6	332
20000818	51775.40	9.5	288	20020624	52450.55	9.7	357
20000819	51776.39	10.4	325	20021020	52568.46	11.0	332
20000820	51777.39	10.3	325	20021112	52591.45	10.3	306
20000820	51777.40	12.3	300	20030717	52838.58	9.3	390
20000821	51778.35	9.8	300	20030718	52838.58	11.8	362
20000821	51778.36	10.2	325	20031205	52979.46	11.4	312
20000822	51779.35	10.3	338	20031208	52982.39	12.4	349
20000822	51779.36	11.0	338	20031208	52982.40	12.8	375
20000917	51805.50	10.1	338	20041001	53280.50	10.6	300
20000917	51805.52	10.5	351	20060116	53752.40	12.4	361
20001205	51884.43	11.4	332	20061202	54072.46	10.0	300
20001206	51885.48	11.8	299	20070401	54192.25	10.6	337
20001208	51887.43	10.2	281	20070402	54493.24	9.5	340
20010204	51945.32	12.0	332				

Possible origins of 4.5 year modulation are:

- (1) precessing relativistic jet (Gregory et al., 1989);
- (2) quasi-cyclic Be star envelope variations (Gregory et al., 1989);
- (3) precession of the Be star (Lipunov & Nazin, 1994);
- (4) outward-moving density enhancement in the equatorial disk (Gregory & Neish, 2002);
- (5) variability of the Be star mass loss;

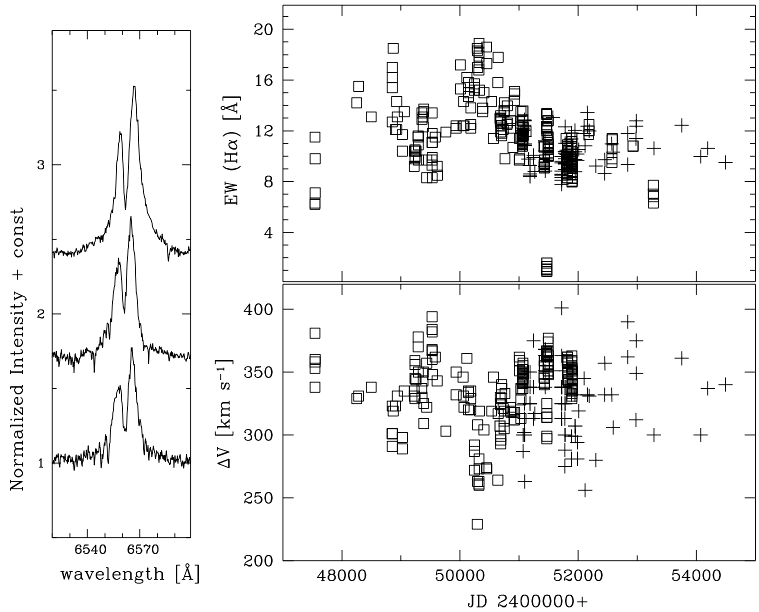

Figure 1. Profiles of the Hα emission line in the spectrum of LSI+61°303 (left panel). Long-term variability of the EW(Hα) and ΔV (right panels). Squares indicate the previous data, and crosses indicate our new observations

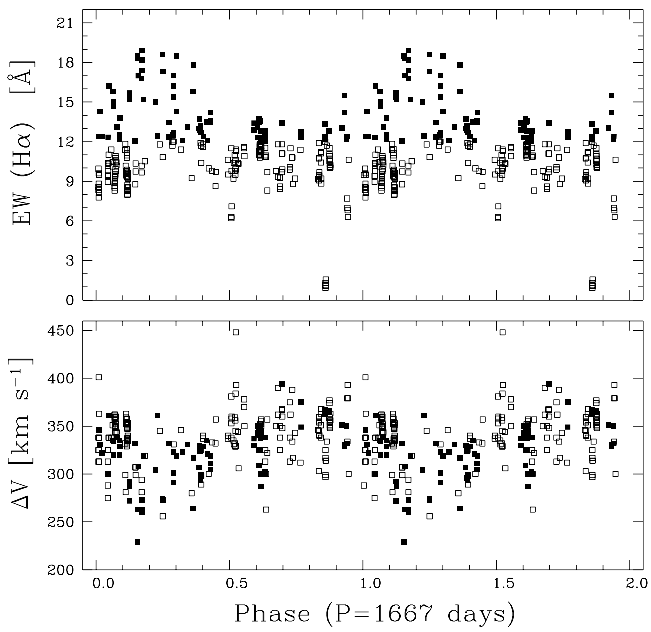

Figure 2. Variability of the EW(Hα) and ΔV folded with period $P = 1667$ days. Filled squares indicate EW(Hα) ≥ 12 Å, open squares indicate EW(Hα) < 12 Å

- (6) variability of the size of the circumstellar disk.

The circumstellar disks in Be/X-ray binaries are truncated by the gravitational influence of the compact object (Okazaki & Negueruela, 2001). Very likely in LSI+61°303 a precession of the Be star leads to variations of the truncation radius, which combined with variable mass-loss rate of the Be star, creates the 4.5 year modulation in Hα and radio emission.

To conclude, the main results of our spectral observations of the Be/X-ray binary and galactic microquasar LSI+61°303 are:

- **(i)** In our observations the equivalent width of the Hα emission line varied from 8 Å to 14 Å.
- **(ii)** The separation of the Hα peaks varied from 250 to 400 km s^{-1}.
- **(iii)** The signs of 1667 day modulation are visible in the Hα parameters, even during the time of lower EW(Hα).

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