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Optical Variability of HBC 379 and HBC 426 during 1990–1995

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Abstract—The new *BVR* observations of two T Tauri stars which were obtained between 1990 and 1995 are presented. Changes in the maximum brightness, amplitude, and shape of the light curves are discussed.

INTRODUCTION

The third catalog of young, pre-main-sequence emission-line stars includes 742 objects (Herbig and Bell 1988). Herbig and Bell classified about fifty objects from this catalog as weak-line T Tauri stars (WTTS). Objects from X-ray surveys of several star-forming regions and from a survey of stars with CaII H and K line emission were categorized as WTTS. These stars exhibit a weak, narrow Hα line [W(Hα) < 10 Å], a strong LiI absorption line (6707 Å) with W(LiI) > 0.1 Å, and a substantial CaII H and K line emission.

Photoelectric *UBVR* observations of these stars revealed periodic light variations in most WTTS (Grankin 1992, 1993, 1996; Bouvier *et al.* 1993, 1995; Vrba *et al.* 1993). The detected photometric periods were explained in terms of rotational modulation of the stellar emission by extended spotted regions in the photospheres of these stars. Unfortunately, most of the photometric programs of observations of WTTS have been carried out episodically, in an interval from one to three months.

Systematic photoelectric *(U)BVR* observations for thirty WTTS in the Taurus–Auriga star-forming region began in 1990 at the Maidanak Observatory (Astronomical Institute of the Academy of Sciences of Uzbekistan) (Grankin *et al.* 1995). Presently, the photometric program includes about twenty objects, for some of which fairly detailed light curves have been obtained in six or more years (Grankin 1997).

In this paper, we present the six-year-long observations of two WTTS from the catalog of Herbig and Bell: HBC 379 and HBC 426. The two objects belong to the Taurus–Auriga star-forming region (the radial velocities of HBC 379 and HBC 426 are 16 and 14 km s^{-1}, respectively), have similar spectral types (K7V and K0V), are fairly slow rotators ($v\sin i$ = 10 and 19 km s^{-1}), and have roughly the same age [log (t) = 5.5 and 6.1]. Nevertheless, they differ greatly in photometric behavior on a time scale of six years.

OBSERVATIONS

We performed all observations using a pulse-counting *UBVR* photometer attached to a 0.48-cm telescope with a 28″ aperture. The comparison stars were secondary standards: BD+28°643 ($V = 9\overset{m}{.}452$, $U-B = 1\overset{m}{.}503$, $B-V = 1\overset{m}{.}576$, $V-R = 1\overset{m}{.}306$) for HBC 379 and BD+30°742 ($V = 7\overset{m}{.}607$, $U-B = 0\overset{m}{.}123$, $B-V = 0\overset{m}{.}109$, $V-R = 0\overset{m}{.}127$) for HBC 426. The instrumentation and observing and reduction techniques are described in Grankin *et al.* (1995). The integration time in each band ranged from 60 to 120 s. The observations were carried out on moonless nights, when possible. The error of a single measurement in *B*, *V*, and *R* was no greater than $0\overset{m}{.}04$, $0\overset{m}{.}03$, and $0\overset{m}{.}02$, respectively. We performed the observations in September/October and/or November/December of each season.

LONG-TERM VARIABILITY

The main parameters of the long-term photometric variability of the stars are given in the table; its columns give (1) the star name, (2) the observing season, (3) the number of observations in *V*, (4) the maximum *V* brightness, (5) the amplitude of the *V* light variations, (6) the mean *V* magnitude, (7) the mean *B–V* color, and (8) the mean *V–R* color.

The *V* light curves of HBC 379 and HBC 426 spanning six years of observations are shown in Fig. 1. Over the entire period of these observations, the maximum brightness $V_{\max}$ and mean $\bar{V}$ magnitude of HBC 379 were essentially constant. In contrast, the variations in $V_{\max}$ and $\bar{V}$ of HBC 426 exhibited a noticeable slow component (see the table and Fig. 1). We can assume that the long-term light variations in HBC 426 are cyclic or even periodic in nature. However, further long-term observations are needed for this conclusion to be confirmed.

These stars have a common feature in their long-term photometric behavior—a season-to-season change in the maximum amplitude of the V light variations (ΔV). The amplitude of the seasonal light variations varied from $V = 0^{m}.37$ to $0^{m}.62V$ in HBC 379 and from $V = 0^{m}.05$ to $0^{m}.15V$ in HBC 426. At the same time, the mean color indices $\overline{B-V}$ and $\overline{V-R}$ of the two objects remained essentially constant over the six years of observations. The seasonal light variations in these stars are periodic in nature and are attributable to rotational modulation by spots.

PERIODIC VARIABILITY

HBC 379 and HBC 426 were detected during a search for stars with CaII H and K line emission and were designated as Lk Ca7 and Lk Ca19 (Herbig *et al.* 1986). Later, Walter *et al.* (1988) identified these emission-line stars with the X-ray sources TAP 29 and TAP 56, respectively. Several independent photometric programs revealed periodic light variations in HBC 379 and HBC 426 with periods of 5.66 and 2.24 days, respectively (Grankin 1992, 1993; Bouvier *et al.* 1993; Vrba *et al.* 1993). Subsequently, Grankin (1994) refined these periods using the 1990–1993 observations. The photometric periods of HBC 379 and HBC 426 were found to be $5^{d}.6638$ and $2^{d}.236$, respectively. The most interesting result of the study of short-term periodic light variations in these and other WTTS was the detection of stability of the photometric periods and their initial epochs on a time scale from two to four years. This circumstance has spurred us to continue the long-term photometric observations of the selected WTTS (Grankin 1997).

The phase light curves for HBC 379 and HBC 426 that we constructed using our observations during 1990–1995 are shown in Figs. 2 and 3, respectively (the elements of the light curves are shown in the figures). We see from Fig. 2 that the initial phase of the photometric period for HBC 379 is preserved over six observing seasons. Only small changes in the shape of the phase curve and substantial season-to-season changes in the total amplitude of the periodicity are observed (see also the table). Similar behavior of the photometric phase light curve was reported only for V410 Tau [see Petrov *et al.* (1994) and the references therein]. The situation with HBC 426 is different. We see from Fig. 3 that the initial phase of the periodicity is preserved only in 1990–1993. Over this period, the amplitude of the periodicity decreased. In 1994, the periodicity disappeared completely. In a year, it reappeared, but its initial phase changed greatly and did not correspond to the previous initial phase.

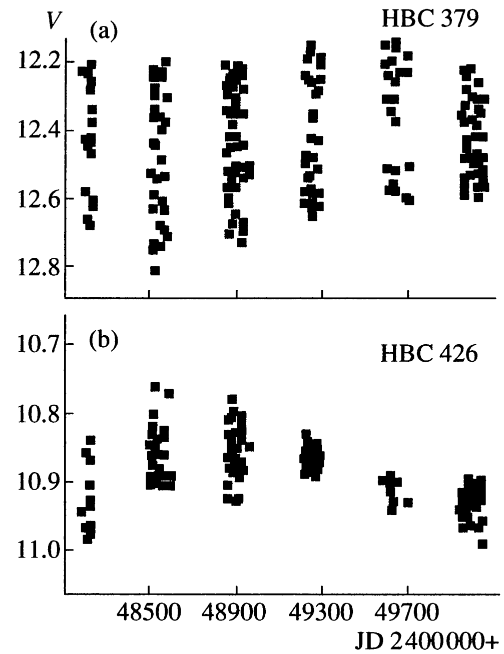

Fig. 1. The photometric behavior of (a) HBC 379 and (b) HBC 426 during 1990–1995.

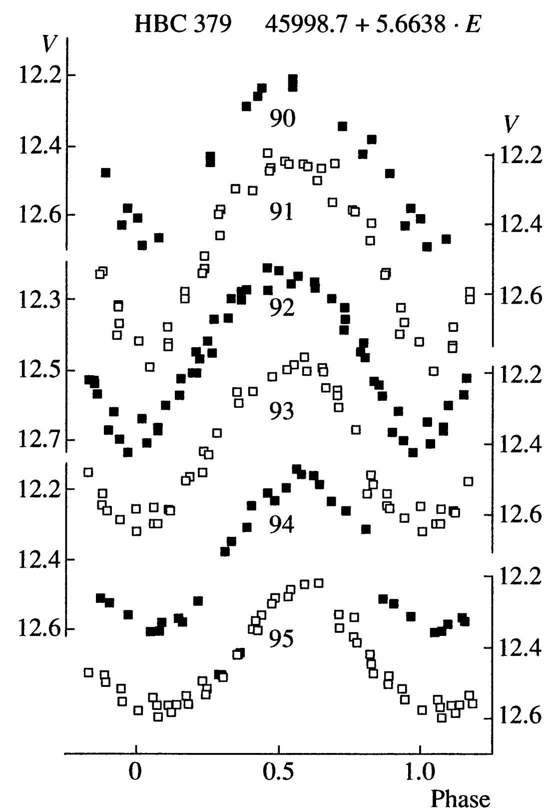

Fig. 2. The phase V light curve of HBC 379 for each season separately.

Photometric behavior during 1990–1995

Star	Season	N_{obs}	V_{max}	ΔV	$\bar{V}$	$\overline{B-V}$	$\overline{V-R}$
HBC 379	1990	17	12.21	0.47	12.43	1.35	1.33
	1991	36	12.20	0.62	12.45	1.36	1.35
	1992	46	12.21	0.52	12.45	1.35	1.35
	1993	37	12.16	0.50	12.42	1.35	1.34
	1994	23	12.14	0.46	12.37	1.35	1.32
	1995	44	12.22	0.37	12.43	1.35	1.34
HBC 426	1990	17	10.84	0.15	10.92	1.02	0.90
	1991	32	10.76	0.15	10.85	1.01	0.87
	1992	47	10.78	0.15	10.85	1.02	0.87
	1993	28	10.83	0.06	10.86	1.03	0.88
	1994	17	10.89	0.05	10.91	1.03	0.91
	1995	37	10.89	0.10	10.93	1.03	0.90

ROTATIONAL MODULATION BY SPOTS

The most natural explanation for the periodicity in the photometric behavior of these objects and other WTTS is generally believed to be the presence of extended spotted regions in the photospheres of these stars. The pattern of variations in the $B-V$ and $V-R$ colors with V brightness provides circumstantial evidence of the presence of these regions. The method of determining the parameters of spotted regions from the $(B-V)-V$ and $(V-R)-V$ relations can be found in Petrov *et al.* (1994) and Grankin *et al.* (1995). The V, $V-R$ diagrams for HBC 379 and HBC 426 are shown in Figs. 4a and 4b, respectively. According to various independent estimates obtained for HBC 379 and HBC 426, the spotted regions are cooler than the photosphere by 800–1500 K and cover from 9 to 24% of the visible stellar hemisphere (Bouvier *et al.* 1993; Vrba *et al.* 1993; Grankin *et al.* 1995).

The appearance, disappearance, and migration of individual spots or their groups within an active region cause the shape, amplitude, and phase of the photometric light curve of HBC 426 to change. The long-term stability of the main parameters of the photometric light curve for HBC 379 is attributable to the stable positions of active regions at certain longitudes of the stellar surface. The stable positions of active regions over many years do not rule out the appearance and disappearance of large individual spots or their groups within these regions on shorter time scales. This is indicated by the season-to-season change in the shape and amplitude of the photometric light curve of HBC 379.

CONCLUSION

The six-year-long photometric observations of the two WTTS suggest that there is a long-term periodic

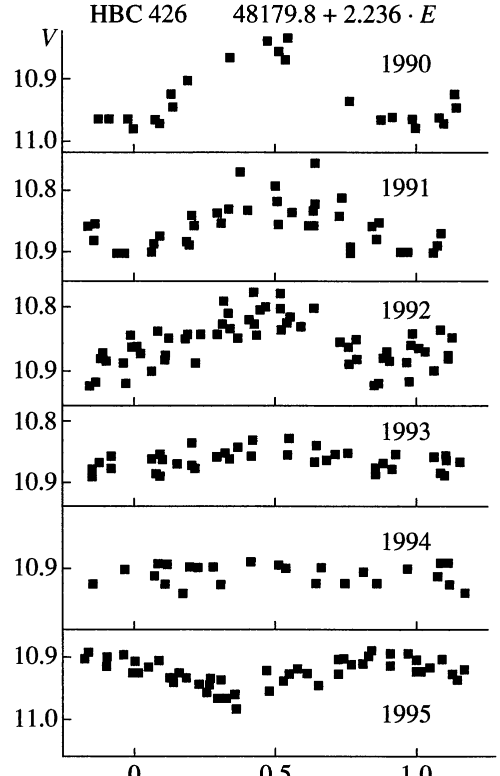

Fig. 3. Same as Fig. 2 for HBC 426.

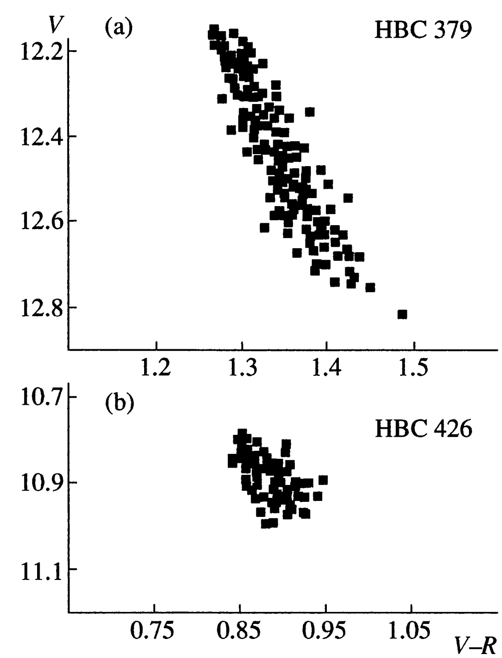

Fig. 4. The V, $V-R$ diagrams for (a) HBC 379 and (b) HBC 426.

component in the photometric behavior of HBC 426 and confirm that the initial phase of the light curve of HBC 379 is stable over the entire period of observations. We will subsequently use our photometric data to study the evolution of the main parameters of extended spotted regions with time. A continuation of the photometric observations of these objects will help estimate the lifetime of active regions and make progress in our understanding of the phenomenon of stellar and, accordingly, solar activity.

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