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TIME-RESOLVED Hα MONITORING OF THE HERBIG Ae/Be STAR HD 200775

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Many Herbig Ae/Be stars demonstrate strong variability in the structure of their spectral-line profiles that can be interpreted as resulting from disk accretion and variable stellar wind. According to different studies, these variations are caused by longitudinal stratification of the star-wind zones, i.e. by the presence of inhomogeneous dense fragments of clouds in the circumstellar environment, interacting with the star's shell (Beskrovnaya et al., 1994; Grinin and Rastopchina, 1996; Pogodin et al., 2000). Thus, we can expect to observe rapid variations of the spectrum and brightness for such stars. In this paper, we present the results of our time-resolved spectral variability monitoring of the Herbig Ae/Be star HD 200775 = V380 Cep.

Our observations used the echelle spectrometer in the Cassegrain focus of the 2 m telescope with a 580×530-pixel CCD. In 1998–2003, this system was in use in the Coude focus (Aliyev and Ismailov, 2000), and then it was adapted, on the base of a UAGS spectrograph, for the Cassegrain focus (Mikailov et al., 2005). The spectral range was $\lambda\lambda 4400 - 6800$ ÅÅ, the spectral resolution was $R = 14000$. We selected 38 orders from orders 70–140, each of them about 100 Å wide, with linear dispersions between 11 and 6 Å/mm. The readout and reductions of the spectra were performed using software developed at the Special Astrophysical Observatory of the Russian Academy of Sciences (Galazutdinov, 1992). The observations we report on here were acquired in June – August, 2004. Each night, the variable star was continuously observed for 1.5–2.5 hours, with short intervals between exposures. For the signal-to-noise ratio $S/N = 150 - 200$, the average exposure time was $5 - 7$ minutes. The observing nights are summarized in Table 1, where the Julian dates correspond to the middles of each observing period. A total of about 150 spectrograms were obtained for the variable and the standard stars. The mean uncertainty of our radial-velocity measurements for standard stars was within 2 km/s, that for the equivalent widths was about 4-5%, and that for the central residual intensities, 0.6%.

The H_α line in the spectrum of HD 200775 is known to have a double-peaked emission structure with small absorption at the centre of the line. We measured the line parameters using the method described by us earlier (Ismailov, 2003). To remove the influence of the terrestrial-atmosphere water lines, we used the standard software option of dividing the observed spectrum by the spectrum of an early-type standard star. After such a procedure, we used the rectified spectra to derive equivalent widths and relative intensities. The following parameters of the line have been measured: Va, the radial velocity of the central absorption; $V1$ and $V2$, respectively the radial velocities of the blue and red emission components of the line; W(Å), the emission's full equivalent width; and $W1$ and

$W2$, the equivalent widths respectively of the blue and red components. Besides, the line's profile variations were looked for during all the series as well as for individual observing dates. Our observations during 9 nights revealed no obvious changes of the measured H_α parameters within any of the nightly series. Significant differences of the line parameters were found from night to night. These variations are summarized in Table 2.

Table 1. The spectroscopic observations of HD 200775

Night No.	JD 2453000+	Series duration (minutes)	No. of spectrograms	Mean exposure (minutes)
1	202.348	70	12	5
2	203.342	90	22	5
3	216.325	20	4	5
4	217.342	81	12	5
5	220.315	25	5	5
6	233.279	72	7	8
7	236.367	126	15	7
8	238.307	105	18	5
9	239.297	65	8	7

Table 2. Nightly-mean $H\alpha$ radial velocities and equivalent widths

No.	$V1$, km/s	Va, km/s	$V2$, km/s	$W1$, Å	$W2$, Å	W, Å
1	−55.1	−2.8	59.7	31.9	27.7	58.4
2	−52.9	−2.6	57.8	30.0	26.8	56.8
3	−54.3	−16.6	48.2	26.5	22.1	48.6
4	−53.5	−19.0	45.7	31.7	26.2	58.0
5	−53.6	−19.4	41.7	30.5	24.8	55.3
6	−57.8	−18.3	44.6	48.5	44.6	93.1
7	−65.2	−23.8	35.5	32.5	28.8	61.1
8	−47.2	−4.3	55.0	34.3	30.3	64.5
9	−46.6	−4.5	53.6	34.7	31.1	65.7

Figure 1 (top panel) displays radial velocities of the H_α components in the spectra for each observing series. Each data point is for one of the series listed in Table 1. The relative equivalent widths, $W1/W2$, for each series, are presented in the bottom panel. This graph makes it possible to follow the displacements of individual line components. It appears from Fig. 1 that, beginning with series 3, a displacement of the line components to the blue is observed on JD 2453216–JD2453236 (series 3–7). The largest displacement, almost 20 km/s for all the components, was observed for series 7 on JD2453236. Besides, there is an increase of the equivalent width of the H_α emission's violet component compared to that of the red one; as a result, the relative equivalent widths of the line's emission components also increase synchronously with the radial velocities. Some of the emission components changed their equivalent widths by more than 20%. Figure 1 shows that the radial velocities of the individual components vary from night to night. While the velocities of the absorption component (Va) and of the red emission component ($V2$) vary almost synchronously, the velocity of the blue component ($V1$) changes irregularly. The difference between displacements of the components can be as high as 10 km/s for the series 3–6, in a significant variance with the series 1 and 2, when all the components showed nearly equal shifts. The displacements of the red and blue emission components become practically the same in the series 7 and then do not vary with respect of each other. The series 7 also reveals an interesting abrupt increase of the full and relative equivalent widths of the emission components, due to the increased strength of the red component. In the series 8 and 9, the absorption is redshifted by +10 km/s, whereas both emission components show identical, almost zero, relative displacements. This figure clearly shows the presence of considerable dynamic variations in the circumstellar environment and in the star's atmosphere during approximately 20 days.

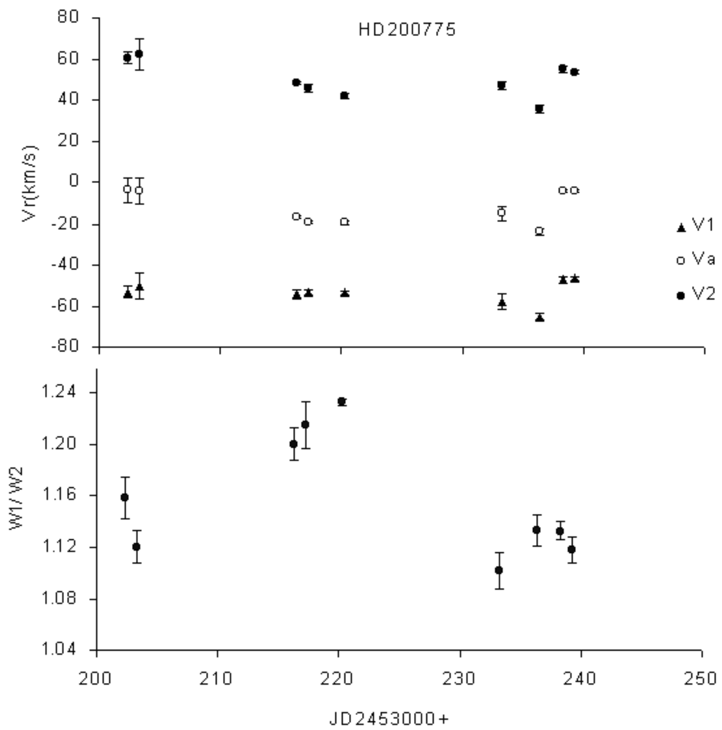

Figure 1. Variations of the H_α-line parameters for HD 200775. Top: Radial velocities of individual line components. Triangles: $V1$; filled circles: $V2$; open circles: Va. Each data point corresponds to one of the series listed in Table 1. Bottom: Relative equivalent widths, $W1/W2$, for each series.

Figure 2 shows the H_α profiles from three different nights. The general structure of the lines does not appear to change from night to night.

Thus, our study is the first one to present time-resolved monitoring of the structure and main details of the H_α emission profile. It allows to follow displacements of the individual emission components and the central absorption, continuously for times from one hour to several days. Our observations span about 2 months. Within 1–2.5 hours, we find no rapid changes in the structure or in the parameters of the H_α line. However, there is significant variability from night to night, especially on JD 2453216–2453236. During this time interval, approximately for 20 days, systematic displacements to the blue, up to 10–20 km/s, were observed for individual components of the H_α line.

The star's rotational velocity is $v \sin i = 103$ km/s (Ruusalepp, 1987) or 40 km/s (Bohm & Catala, 1995). From Watt et al. (1986), the star's orbital inclination is $i = 70°$. For the spectral type B3IV (Altamore et al., 1980) and radius $R_* = 4.5\ R_\odot$, the primary component's longest possible axial-rotation period is $5^{\rm d}\!.4$. This period is nearly 4 times shorter than the H_α activity time scale found by us. Thus, the systematic change we have observed in the H_α line cannot be explained by the existence of relatively stable local inhomogeneous clouds in the atmosphere, observable because of modulation by the star's axial rotation. Ismailov (2003) found the star to be a spectroscopic binary, with the orbital period $P = 1180^{\rm d}$. Later, Pogodin et al. (2004) confirmed the system's binarity and derived the orbital period $P = 1341^{\rm d}$. The orbital phases for the dates of observations from our study computed with the elements from Ismailov (2003) are $0^{\rm P}\!.88$–$0^{\rm P}\!.92$, the phases with the elements from Pogodin et al. (2004) are $0^{\rm P}\!.02$–$0^{\rm P}\!.03$, so we observed the very minimum of the binary's radial velocity curves. The two radial velocity curves in the cited papers, based on independent data, show that a radial-velocity change just of the size we have found is possible at these phases. Thus, the observed variations of the H_α line can be partially due to the system's orbital motion.

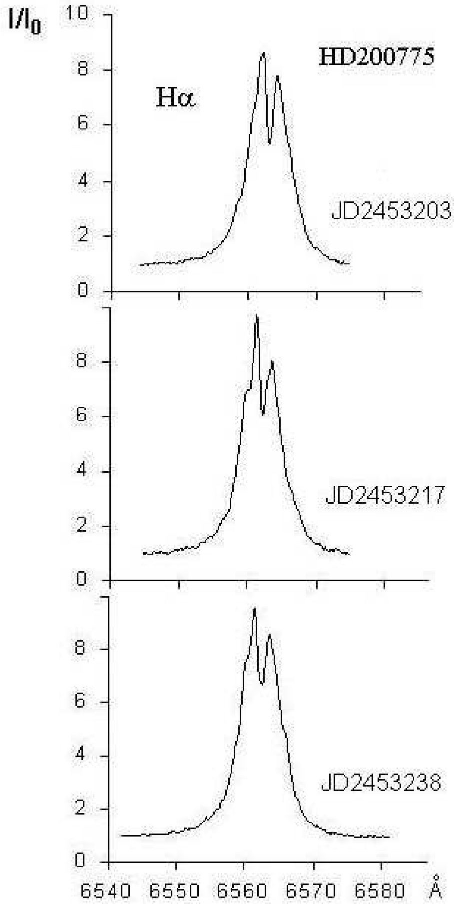

Figure 2. H_α profiles for three individual nights.

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