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Variability of emission lines in the optical spectra of the Herbig Be binary system HD 200775

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Abstract In our previous papers we have improved the value of the orbital period of the binary Herbig Be star HD 200775 and showed that the [O I] and Si II 6347 and 6371 Å emission lines displayed variations which correlate with the orbital period. In this paper we provide evidences that other broad emission lines of metals in the spectra of HD 200775 also exhibit variability, which is probably related to the orbital cycle of the binary. Analysis was performed based on the high-resolution spectral data collected over a time span of 6 years at the Kourovka Astronomical Observatory of the Ural Federal University (Russia) and the Three College Observatory of the University of North Carolina at Greensboro (USA) as well as archival spectral data compiled since 1994. We report new data points in the radial velocity curve of the He I 5876 Å line near the extremal values of the radial velocity.

Key words: techniques: spectroscopic — stars: variables: T Tauri, Herbig Ae/Be — stars: individual: HD 200775

1 CONTEXT

The star HD 200775 (V380 Cep, MWC 361) is a Herbig Be binary system surrounded by a circumbinary disk (Monnier et al. 2009 and Okamoto et al. 2009). There are indications of the existence of an accretion disk around the primary (more massive) component of the system (Monnier et al. 2009 and Benisty et al. 2013) but no clear evidences of any circumstellar material around the secondary component. The orbital period of the system is well-known from several investigations (see our previous work Bisyarina et al. 2015 and references therein). In the previous paper, we have shown that the photospheric line of He I 5876 Å in the spectra consists of a broad component from the primary star of the system and a narrow component of the secondary one, and used radial velocity curves to improve the value of the orbital period. All the orbital phases used in the current paper were calculated assuming this value of the period ($P = 1361.3\,\mathrm{d}$).

Radial velocity measurements at orbital phases $\sim$0.9 allow determining the amplitudes of the radial velocity curve and, consequently, $M \cdot \sin^3 i$ for the components of the binary system. In this paper, we added six new data points at relevant phases from our continued monitoring of HD 200775 obtained in 2015. These new data show that the amplitude of the radial velocity curve for the secondary component of the binary system probably has a value of about $15\,\mathrm{km\,s^{-1}}$.

There are several indications that the variations of some emission lines in the optical spectrum correlate with orbital phases. Thus, the periodically active phases of the Hα line are characterized by large values of the equivalent width and additional components in the line profiles (Miroshnichenko et al. 1998). The [O I] 6300 Å and 6363 Å lines, as well as the Si II 6347 Å and 6371 Å lines, show significant variations but with the same profiles in close orbital phases at different epochs (Bisyarina et al. 2017a; Bisyarina et al. 2017b; Ismailov et al. 2017). Now we report the variations of other broad emission lines in

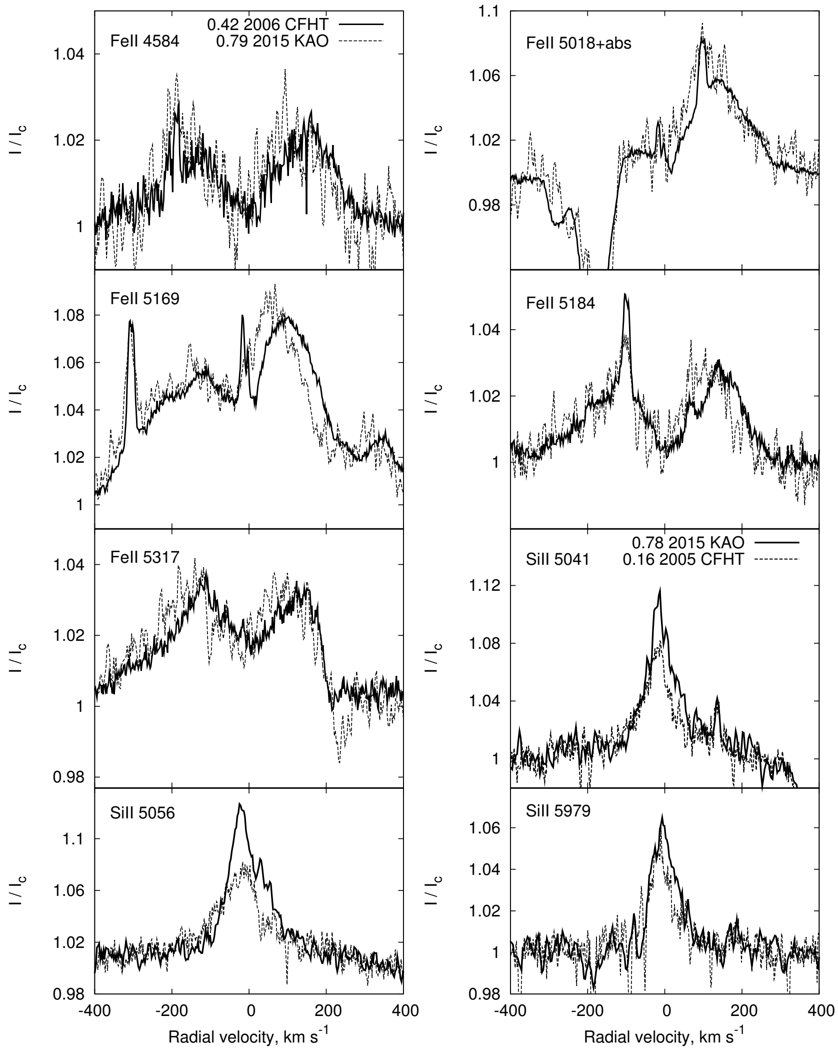

Fig. 1 Profile variations of the examined broad emission lines from the optical spectra of HD 200775. All presented iron profiles are taken from the spectra obtained in June, 2006 with CFHT and in April, 2015 at KAO. Corresponding orbital phases are 0.42 and 0.79 respectively. The epochs for the silicon lines are March, 2015 (the orbital phase is 0.78) and June, 2005 (the phase is 0.16). The presented KAO data are smoothed by a three point average.

the optical spectra which are probably related to accretion disk emission.

2 OBSERVATIONS AND DATA REDUCTION

The optical spectral monitoring of HD 200775 has been conducted since 2012.05.02 using the high-resolution spectrograph ($R \sim 30\,000$, Panchuk et al. 2011; Krushinsky et al. 2014) installed at the 1.2-m telescope at the Kourovka Astronomical Observatory (KAO) which is operated by the Ural Federal University. This range included five KAO spectra (from 2015.01.29 to 2015.04.02; orbital phases about 0.74–0.79). Contemporaneous monitoring of the star has been conducted with the échelle spectrograph[1] ($R \sim 12\,000$) at the 0.81-m telescope of Three College Observatory (North Carolina, USA) since 2012.

We also analyzed other available spectroscopic data obtained since 1994 from ELODIE (Baranne et al. 1996) and SOPHIE (Perruchot et al. 2008) spectrometers of the Observatoire de Haute-Provence (OHP), the ESPaDOnS spectropolarimeter at the Canada-France-Hawaii Telescope (CFHT) and the NES spectrometer (Panchuk et al. 2009) at the Special Astrophysical Observatory of the Russian Academy of Science (SAO RAS). Data reduction was conducted using DECH (SAO RAS, Galazutdinov 1992) and IRAF software. All the radial velocities presented in the paper are heliocentric.

[1] eShel manufactured by Shelyak Instruments

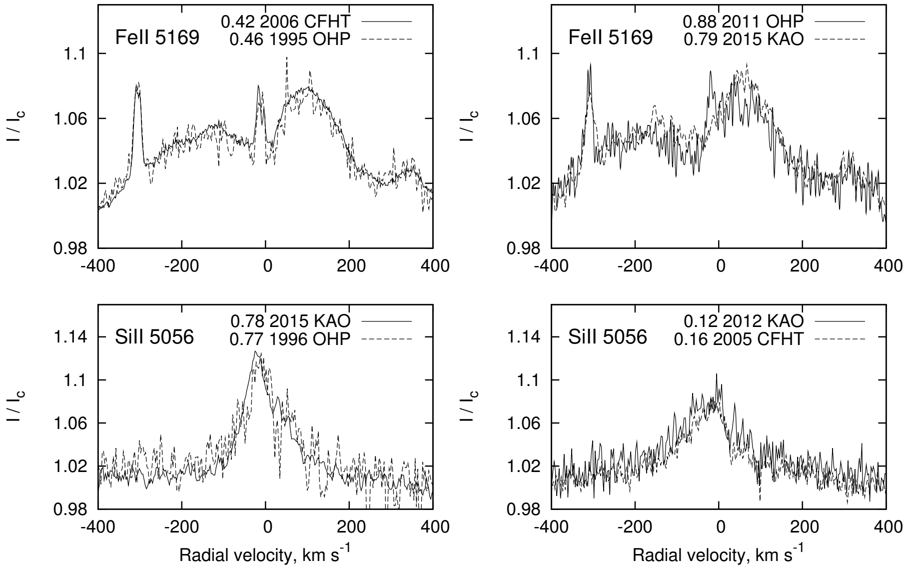

Fig. 2 Profiles of the Fe II 5169 Å and Si II 5056 Å lines (which are the most intense among the examined lines). Both right and left panels for the same line represent the data for close orbital phases but different epochs. The presented orbital phases are close to those from Fig. 1.

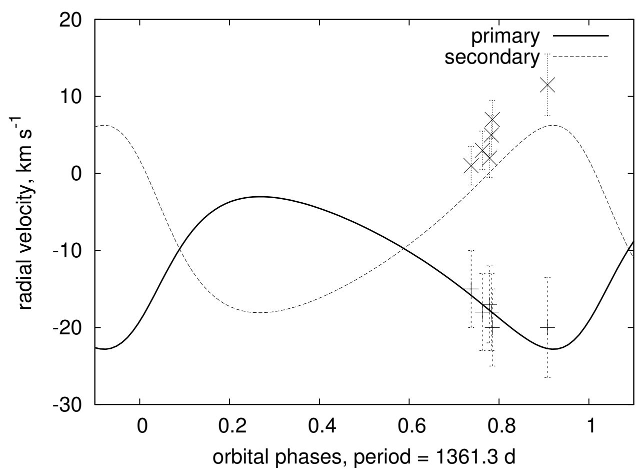

Fig. 3 Radial velocities of two components of the He I 5876 Å line. The pluses and crosses represent new data points obtained in the 0.7–1.0 orbital phases range (for the primary and secondary components of the system respectively). The lines show the model radial velocity curves from Bisyarina et al. (2015) obtained based on 20 years of observational data.

Radial velocities of the components of the He I 5876 Å line were measured by fitting the observed line profilies with synthetic spectra calculated with the Synspec 48 software (Hubeny & Lanz 1992). Parameters of the synthetic spectra were taken from Bisyarina et al. (2015).

3 RESULTS AND DISCUSSION

We examined the profiles of broad emission lines (with wing extent of more than 70 km s^{-1}) with sufficient peak intensity ($I/I_c > 1.015$). In addition to the hydrogen Balmer emission lines and previously published data for the [O I] and Si II 6347 and 6371 Å lines, there are the Fe II 4584, 5018, 5169, 5184, 5317 Å and Si II 5041, 5056, 5979 Å lines in the spectra. We found variations in all of the mentioned lines, however they are generally not as significant as those of the Balmer, [O I] and Si II 6347 and 6371 Å lines. The variability is expressed in the changes of line profiles. The most significant changes for the lines of singly ionized iron are seen in the profile of the Fe II 5169 Å line, near the radial velocities of about 35 km s^{-1} and $170\,km\,s^{-1}$; and for the silicon lines – in the profile of the Si II 5056 Å line, near the velocities -20 and $50\,km\,s^{-1}$ (see Fig. 1). As before, we found that the line profiles obtained at different epochs with close orbital phases are similar (e.g., Fig. 2). Therefore, the variations of the broad emission lines are related to binarity.

As was mentioned in Section 1, we obtained new data in the radial velocity curve close to its extremum. We measured radial velocities of the two components of the He I 5876 Å line from our new observational data obtained at the 0.7–1.0 orbital phases. This range included five KAO spectra (from 2015.01.29 to 2015.04.02; orbital phases about 0.74–0.79) and one TCO spectrum obtained on 2015.09.17 at the orbital phase 0.9 (the closest to the extremum). The results are in general agreement with our model radial velocity curve from Bisyarina et al. (2015) (Fig. 3). There is an indication that the radial velocity amplitude is slightly higher than its previous estimate ($K \approx 15\,km\,s^{-1}$ rather than $K \approx 12\,km\,s^{-1}$ for the secondary component). In order to obtain a better estimate, we need more observational data around orbital phase 0.9.

4 SUMMARY

Optical spectral monitoring of the Herbig Be binary star HD 200775 has been conducted at KAO and TCO. New data basically confirm our previous results (Bisyarina et al. 2015). Based on these and archival data, we examined the variability of emission lines probably formed in the accretion disk. In addition to previously published results for the [O I] 6300, 6363 Å and Si II 6347, 6371 Å lines, we found that the variation of other broad emission lines in the optical spectra of HD 200775 (the Fe II 4584, 5018, 5169, 5184, 5317 Å and Si II 5041, 5056, 5979 Å lines) also correlates with the orbital phases of the binary system.

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