Near infrared spectral lines of neutral oxygen as indicators of activity of the Be stars

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Abstract. For the classical Be stars there is established general correlation between observed spectral features in the visual and optical near IR spectral regions . However there is a lack of detailed studies of this correlation for typical representatives from different subgroups of the wide variety of Be stars. In the following work we present part of the results from an observational campaign carried out at Rozhen Observatory. The main goal of the campaign was time-domain study of spectral activity features of typical Be stars. Our intention was focused on the strongest lines of O I in the optical near infrared spectral region. For the first time beginning of 2008 is pointed as a period of maximal development of recent spectral phase of Pleione based on estimations of emitting volume of circumstellar envelope in near IR O I lines.
Key words: stars: emission-line: Be, stars: variable, stars: shell stars, stars: individual: BU Tau, 1 Del, LZ Del, HD 179343, HD 193182

1 Introduction

Be stars are widely known with their extreme fast rotation, leading to formation of diffusing gaseous dust-free Keplerian circumstellar disks (Rivinius et al., 2013). Processes of spinning up of the central star to nearly break-up rotation and formation of circumstellar envelope are still of unknown origin and are connected with obviously crucial moments of stellar evolution. Although main spectral features of the Be phenomenon were initially observed in the visual region, activities in infrared spectral region also were studied. Interesting results from medium and low resolution spectra in the near IR were presented by Andrillat et al. (1988). Torres et al. (1994) published results from observations of Fe II lines in the near IR region of a sample of Be stars and reported correlation between Fe II 9997Å emission line strength and intensity of Paschen δ line. More recently Granada et al. (2010) used observations in infrared K and L bands to estimate physical conditions in the circumstellar environment of Be stars. Mathew et al. (2012) analyzed O I lines of classical Be stars and proved that their intensities are connected with the fluorescence processes in UV region. Thus high resolution observations in the spectral region between visual and far IR can contribute significantly in filling the existing gap in our knowledge about Be stars and

to the comprehensive understanding of Be phenomenon. The aim of the present research is to trace the variations of chosen spectral lines in the optical near IR range and compare them with variations of most prominent spectral lines in visual range on the example of classical Be/shell star Pleione.

2 Observations

Our research activities were targeted mainly on active Be stars with intensive shell type spectra. One of the main targets of our program was Pleione (BU Tau, HD 23862, HR 1180, HIP 17851), a star with pronounced cyclic transitions between spectral phases: emission, emission plus shell and normal B-type (eg. Hirata & Kogure (1977), Iliev et al. (1988), Hirata, (1995), Sadakane et al. (2005)). With its quasi regular passes between different spectral appearances this star is a perfect testbed to compare results from observations in different spectral regions. Stars 1 Del, LZ Del, HD 179343 and HD 193182 that form the group of stars with stable shells (Gulliver, 1977) were also included in our observing campaign and results for these stars will be discussed in a forthcoming paper.

Observations included in the present research were carried out by the author with the coudé-spectrograph of Rozhen National Observatory 2m RCC telescope. Log of used observations is presented in Table 1. Details for the observing conditions and the spectrograph configuration could be found in, e.g., Iliev et al. (2012). O I lines in the near IR region were chosen as main target of our observing campaign as it was found that they are quite sensitive to the processes of Be star activity (Iliev, 2015).

3 Results and discussion

Pleione is widely known for its well defined cyclic transitions between phases of rotationally forced decretion followed by dissipation of circumstellar material. As is seen in Fig. 1, O I 7772-5 triplet in the spectrum of Pleione is presented in emission till the end of its last emission spectral phase. Emission in the triplet decreased to continuum level during the phase change. It happened approximately in the same time as the emission in the most prominent Hα line in the visual spectrum of Pleione reached minimal levels (see e.g. Iliev et al. 2007).

After the start of new spectral phase of Pleione, O I 7772-5 triplet absorption components gradually developed. They became of classical shell type after 2011, reaching core residual intensities of only 0.15 (Fig. 3 of present work). Emission of O I 8446 line represented classical for Be stars two-peak structure during the Be phase of Pleione as is shown in Fig. 2. After the phase transition of the star this line saved weak emission components in contrast with O I 7772-5 triplet were emission disappeared completely. The central absorption of O I 8446 gradually developed it's strength and in 2013 reached same values of residual intensity as O I 7772-5 triplet.

In Fig. 4 change of the separation between V and R emission peaks of O I 8446 is traced. This separation is connected with the volume and dimension of the emitting regions in the circumstellar disks around Be

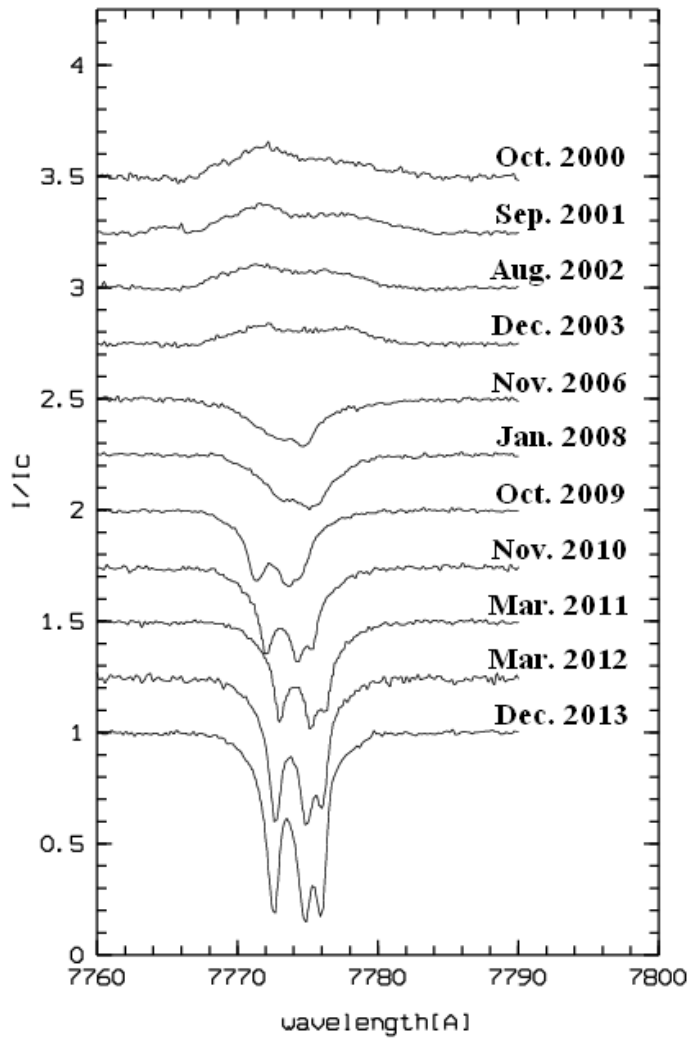

Fig. 1. Near IR O I 7772-5 triplet in the spectrum of active Be-shell star Pleione in the period of spectral phase transition.

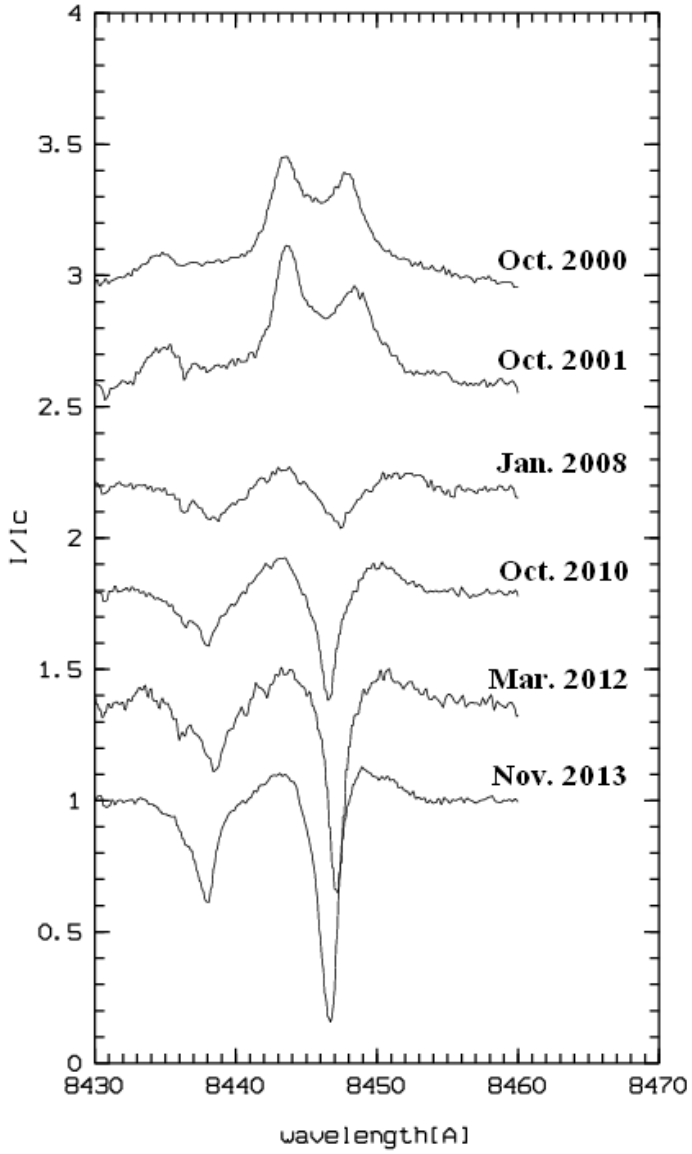

Fig. 2. The region of O I 8446 line in the spectrum of active Be-shell star Pleione in the period of spectral phase transition.

Table 1. Observing log for the sample of used spectra

eqiunox	heliocentric JD 2450000+	spectral region
2000.792	1834.568079	O I 8446
2001.753	2185.753189	O I 8446
2008.057	4487.448404	O I 8446
2010.882	5519.881517	O I 8446
2012.248	6018.295355	O I 8446
2013.893	6619.576182	O I 8446
2000.792	1834.577756	O I 7772-5
2001.753	2185.568079	O I 7772-5
2002.657	2515.547113	O I 7772-5
2003.925	2978.365606	O I 7772-5
2006.216	3815.440428	O I 7772-5
2008.057	4487.432466	O I 7772-5
2009.769	5113.552263	O I 7772-5
2010.876	5517.425939	O I 7772-5
2011.229	5646.321576	O I 7772-5
2012.253	6020.283877	O I 7772-5
2013.966	6646.460240	O I 7772-5

stars. Available observations generally cover the period of development of new envelope of Pleione. As can be seen from Fig. 4 maximal separation of the emission components of O I 8446 was reached in the beginning of 2008. This moment could be regarded as a turning point in the development of present Be/shell spectral phase of Pleione. It should be noted that in general O I 8446 line follows the behavior of strong lines of Balmer series of hydrogen in the spectrum of Pleione. In the same time observed changes of O I 7772-5 triplet resemble changes of Fe II lines characterized with weak emission components during emission spectral phase and pure absorption during shell phase.

4 Conclusions

Spectral lines of neutral oxygen in the near IR region proved to be sensitive indicators for the activity in the atmospheres and circumstellar environment of such complex active early-type stars like Be stars are. High resolution spectral observations of these lines could provide valuable information about fine details observed in spectral profiles. As can be seen on example of the classical Be/shell star Pleione such spectral monitoring could reveal information about important stages of stellar evolution like determining correct moments of spectral phase maximal developments and the transitions from one to another. Such observations could also supply information that will connect existing large databases of observations in visual spectral region and results from fast developing observational technologies in far-IR and other spectral regions. Further high resolution and high S/N spectral

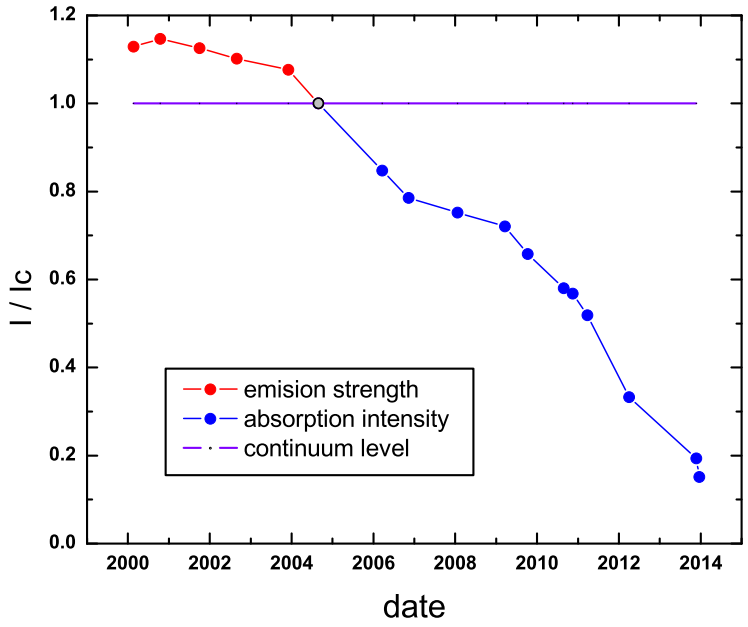

Fig. 3. Changes of the components of near-IR emission spectral triplet O I 7772-5 of BU Tau during recent phase transition.

observations of active Be stars in the near infrared spectral range are highly desirable.

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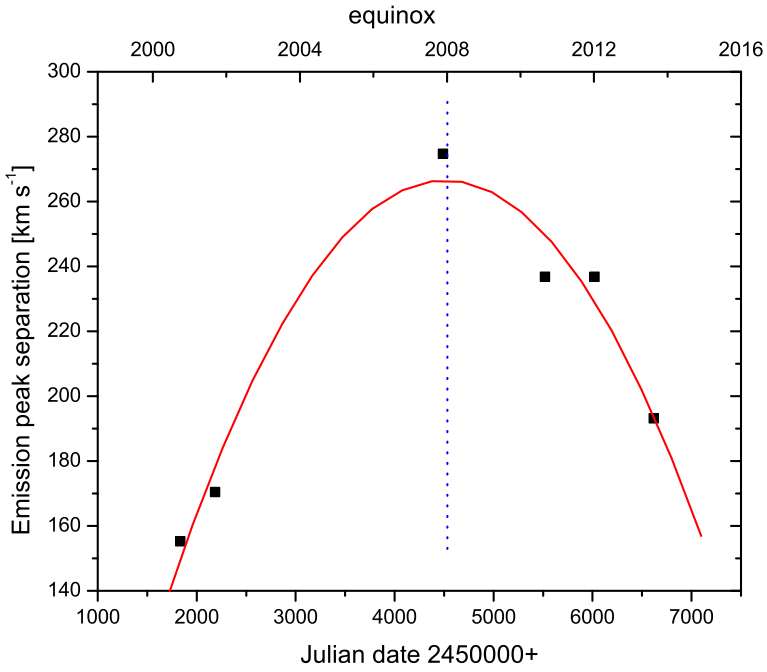

Fig. 4. Observed changes of separation between emission components of the near IR line O I 8446 in the spectrum of BU Tau in the period 2000-2013. Blue line marks the moment of maximal development of the emitting region.

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