

Near IR spectral observations of selected Be and shell stars

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Abstract. Observational program to study Be stars activities is carried out at the coude-spectrograph of Rozhen 2m telescope. The program comprises observations both in visual and near infrared spectral ranges. Spectral observations of Be stars in the near IR region can serve as conjunction between already existing extensive observational archives in visual region and new intensive studies in the far IR spectral region. Results and first estimations from near infrared spectral observations of selected Be and shell stars are presented.

Key words: stars: emission-line: Be - stars: shell stars - stars: variable - stars: individual: Pleione, HD 179343, HD 192954, HD 193182, HD 195325

1 Introduction

Classical Be stars for decades present unsolved challenges to the comprehensive understanding of general stellar evolution. They are very rapidly rotating active main sequence B type stars, which form diffusing gaseous dust-free Keplerian circumstellar disk (Rivinius et al., 2013). Features of complex variability including creation and complete dissipation of detached circumstellar envelopes as well as spinning up of the stars up to sometimes 100% of critical break-up rotational velocity are far from general understanding (Rivinius, 2013; Stee, 2011; Porter & Rivinius, 2003). The role of the fast rotation and the propagation of high values of angular momentum up in the atmospheres of Be stars is fundamental for understanding the Be phenomenon. Mechanisms of formation and dissipation of the circumstellar envelopes are still unknown and are connected with important moments of stellar evolution. Recent activities of Be stars observed in far IR spectral region (Granada et al., 2010), compared with observations in other spectral regions, contributed significantly to the understanding of Be phenomenon. New data about the geometry and physical conditions in the Be-star's circumstellar disks were obtained. The question about connection with the models that were built mostly based on previous observation in visual spectral region became relevant.

2 Observations

Our observational program has been focused on Be stars with intensive shell type spectra. The list of observed targets for the present work on the first place includes Pleione (BU Tau, HD 23862), a star with pronounced cyclic phase changes of dissipation and of creation of circumstellar envelope. Stars HD 179343, HD 192954 (LZ Del), HD 193182 and HD 195325 (1 Del) from the group of stable shell stars (Gulliver, 1977) were also included as targets.

All observations were done using the coude-spectrograph of Rozhen National Observatory 2m RCC telescope using 632 lines/mm Bausch & Lomb grating and Photometric AT200 (SiTe S1003AB 1024 x 1024) CCD camera. Dispersion obtained in the used configuration of the spectrograph is about 0.02 nm per pixel resulting in spectral resolution of about $R=21000$ at wavelength 8500 Å and dispersion of 8.5 Å/mm. The slit width was set at 0.83 arcsec, projected on the sky. O I line at 8446 Å was chosen as main target of the observing campaign as it was found to be very sensitive indicator for Be star activity. Lines of infrared Ca triplet and of the Paschen series were also observed. Nearly all spectra have S/N of more than 100. Details of the observing conditions and spectrograph's configurations could be found in, e.g., Iliev et al. (2012).

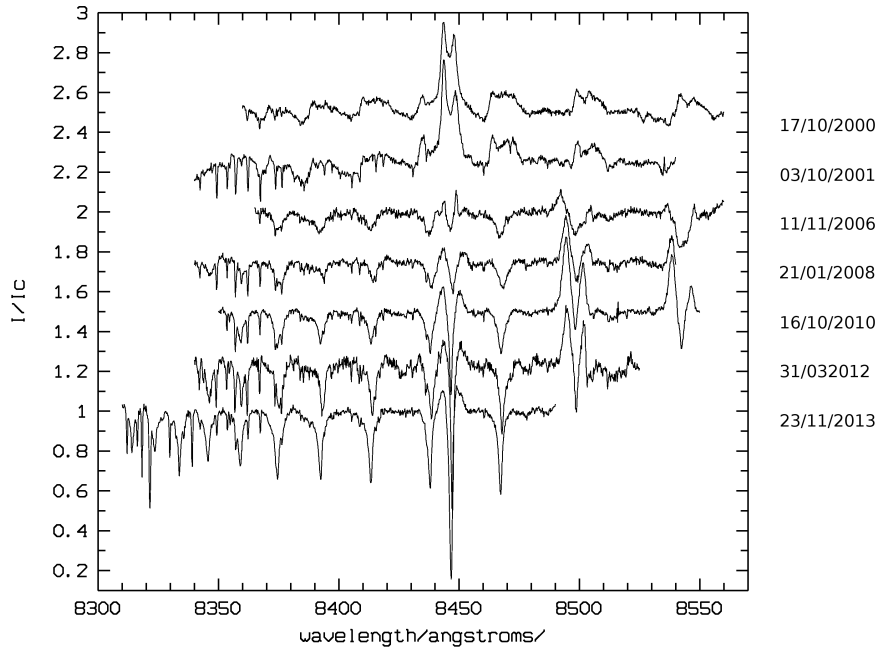


Fig. 1. Sample of near IR spectra of Be-shell star Pleione obtained during last spectral phase transition period.

3 General results from near-IR spectral observations

Pleione and the stable shell stars represent two complementary types of Be stars. While Pleione is well known with its regular deep spectral phase transitions, stable shell stars possess circumstellar gas disk envelopes that stay

steady for decades. As seen in Fig. 1, the spectrum of Pleione in the near-IR region changed drastically in the course of last spectral phase transition in 2005. In 2000 and 2001 in emission is not only O I 8446 line but also lines from the Paschen series of hydrogen as high as Pa 17 and Pa 18. Paschen emission is so intensive that fills entirely the corresponding photospheric component. It is worth to note that in the same time lines from the Balmer series of hydrogen higher than H α do not fill up their absorption cores (Iliev et al., 2007). Ca II IR triplet lines are weak or not present at all. After the end of the Be phase Paschen lines are presented only in absorption. In the same time during the development of new Be/shell phase Ca II IR triplet lines developed strong emission with $V/R > 1$ and intensive central absorption below the continuum level. Our observations show that O I 8446 line in the spectra of HD 179343, HD 192954 (LZ Del) and HD 193182 is in emission while the same line is in absorption in the spectra of 1 Del.

4 Case of Pleione

In the course of recent Be-to-Be/shell phase transition of Pleione, O I 8446 overall emission weakens until the "2005" turning point and strengthens after it (Fig. 2). During the same period central absorption core of O I 8446 line gradually developed. In November 2006 it is already below the level of continuum. Usually this is regarded as a criterion of the presence of cool circumstellar envelope. Thus the beginning of the new spectral phase could be determined to happen in the year 2005. Although the V/R ratio stays > 1 , the dimension of O I 8446 emitting region shrinks significantly (Fig. 3). The estimations of the outer limits of the emitting region gave about 20 stellar radii in 2000 and 2001. The dimension of near-IR emitting region reaches its minimum by decreasing about 4 times compared with the results from 2006. After that, with the development of the new spectral phase, IR emitting envelope of Pleione started to increase again reaching outer dimension of 8-10 stellar radii at the end of 2013.

5 O I 8446 line in the spectra of stable shell stars

Near-IR spectral observations of stable shell stars open the question about the homogeneity of the stable shell stars group. As seen in Fig. 4 while all HD 179343, HD 193182 and LZ Del show O I 8446 line in emission, in 1 Del there is no emission at all. However in the same time emission was presented in Balmer lines (Iliev & Kubat, 2012). In all 3 stars O I 8446 emission shows $V/R > 1$ and the dimensions of the IR emitting envelopes are: 6.53 stellar radii for HD 179343, 5.33 for HD 193182 and about 7.85 for HD 192954. Thus outer limits of the emitting region in IR line O I 8446 around stable shell stars are very close to the dimension of the O I 8446 emitting region of Pleione measured in the moment before new shell started to grow (Fig. 3).

6 Conclusions

Results from near-IR spectral observations of selected Be stars reveal that O I 8446 emission line is a sensitive indicator that can be used to estimate

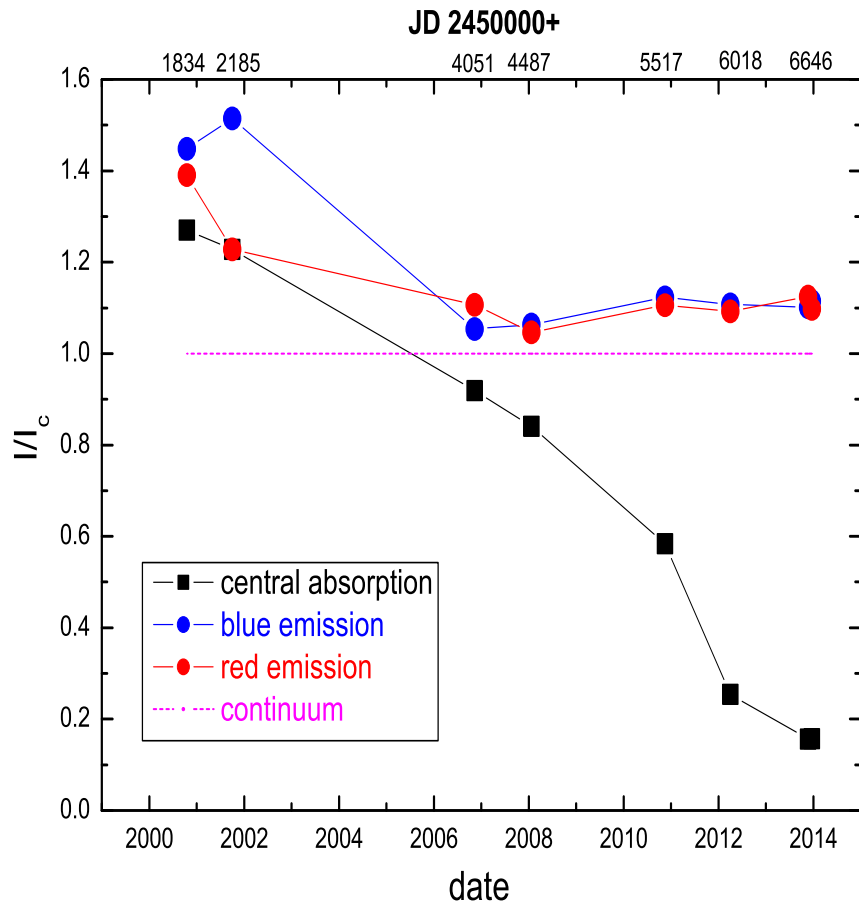


Fig. 2. Changes of the emission profile components of near-IR spectral line O I 8446 of Pleione.

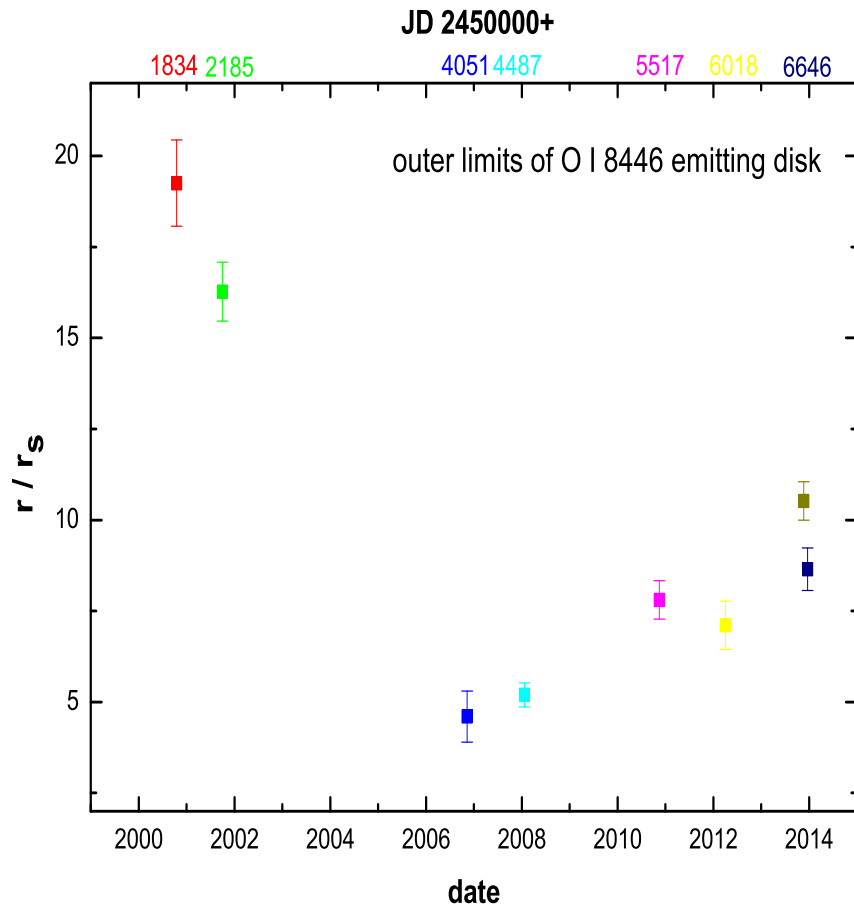


Fig. 3. Development of emitting gaseous disk around Pleione (BU Tau). Dimensions were calculated from O I 8446 emission profile elements. Error bars reflect intrinsic individual measurements standard deviation

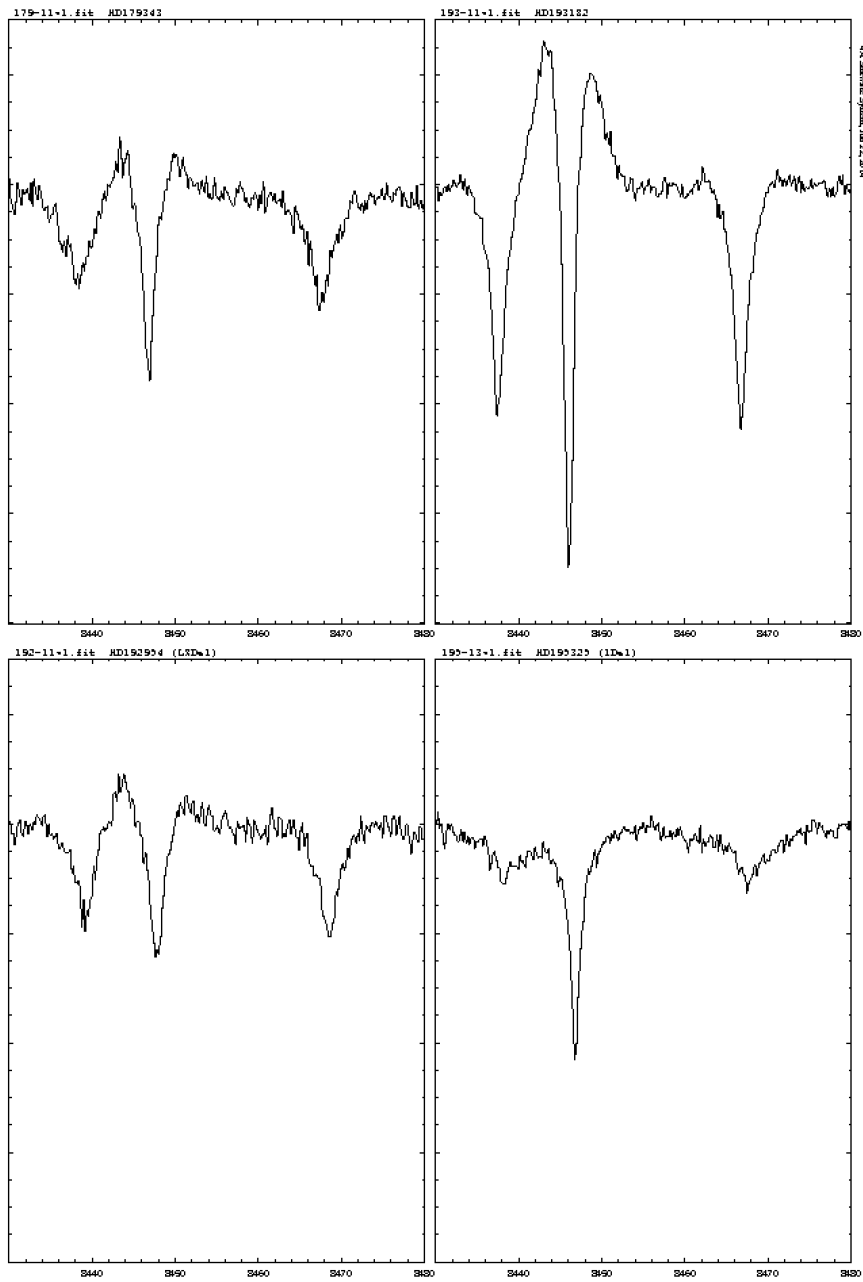


Fig. 4. The region of OI 8446 line in the spectra of stable shell stars HD 179343, HD 193182, LZ Del and 1 Del (from top left to bottom right)

the scale of Be/shell stars activities. All but 1 Del program stars show this line in emission. In the spectrum of Pleione O I 8446 emission was found to be variable. This variations are basically connected with Pleione's spectral phase transitions. For the first time for this star it was established that general trend of O I 8446 emission line variations follow the variations of H α emission observed during the same period (Iliev et al., 2007). Estimations of the dimensions of O I 8446 emitting envelope of Pleione show the same scale of variation as the ones based on H α profiles. The moments of minimal dimensions for emitting in H α and O I 8446 lines envelopes practically coincide.

It is particularly interesting to note that dimensions of emitting in O I 8446 envelopes of stable shell stars HD 179343, HD 192954 (LZ Del) and HD 193182 are all very close to the dimension of corresponding region of Pleione in the moment of maximal shrink of it's circumstellar envelope during the transition to a new spectral phase.

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