

Spectral and photometrical evidences of activity in the circumstellar envelopes of typical Be stars

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In the present work we performed review of the development of our present day knowledge about Be stars by means of general gnoseologic theory. On the basis of T. Kuhn (1962) conception about the structure of scientific revolutions it could be concluded that the temporal knowledge about Be phenomenon is at preparadigm stage of development. As a consequence of this conclusion logically follows the increasing importance of establishing new factological frontiers and enhancement of accuracy of our knowledge about typical individual Be stars and about Be phenomenon as a whole. Following this general aim we performed spectroscopical and photometrical study of a sample of typical representatives of the group of Be stars.

The case of Pleione

We present results from high resolution spectroscopical monitoring in the visual spectral range of Pleione, a Be star well known for its cyclic transitions between different spectral phases.

1. From our early spectral observations of Pleione it was found that Balmer decrement in the spectrum of the star changed significantly just before the shell phase end at 1987 - 1988 (Iliev et al., (1988)).
2. Overall strength of the emission was found to vary gradually during the Be-phase reaching its maximum in January 2003. After that the strength of the emission gradually decreased with the course of the phase.
3. We were able to trace gradual decrease of the dimensions of the emitting regions in Pleione's envelope. In the course of last Be phase of the star, dimensions of emitting in $H\alpha$ region of the envelope decreased from $63R_*$ in 1998 to $32R_*$ in 2005, while for $H\beta$ emitting region dimensions decreased from $26.3R_*$ in 2002 to $13.46R_*$ in the winter of 2005 (Iliev et al., (2007)).
4. High resolution spectral observation obtained at Rozhen coude-spectrograph allowed to register double peak emission at V and R components in the profile of $H\alpha$. This was observed for the first time for Pleione.

Other Be stars

Other typical Be stars were also included in the present study.

1. EW Lacertae is known for its strong shell-type spectrum. Our observations proved that V/R ratios in the $H\alpha$ and $H\beta$ lines have always

the same sign in contrast with the stars from the group of stable shell stars. For a first time for that star changes in the Balmer progression were revealed in the period of V/R activity as defined by Mon et al., 2013. Balmer progression was found to change both in sign and value of gradient.

2. V923 Aquilae is an example of Be star that was proved to be a member of a binary system (Koubský et al., (1988)). Period dependent change of the asymmetry of shell spectrum lines was found for a first time for the star (Iliev, (1993)). Orbital phase connected variations of the line strength of most populated multiplets of Fe II 27, Fe II 36 and Fe II 37 were also discovered. It was shown as well that Balmer decrement variations in the spectrum of V923 Aql are probably not connected with the orbital phase of the binary.
3. Our high resolution spectral observations of 2 stable shell stars, HD 179343 and 1 Delphini, proved that they are in fact small scale spectral variables (Iliev & Kubát, (2010, 2013)). It was found that the overall emission strength in H α and H β lines varies by several percents. V/R ratio of H α and H β also was found to vary from <1 to >1 and vice versa. Our observations show that at some moments V/R ratio for H α and H β lines has different sign. Thus it was proven that the group of Stable Shell Stars defined by Gulliver (1981) contains actually small scale spectroscopically variable stars as the vast majority of other Be stars are.

IR spectroscopy of Be stars

High resolution spectral observations in the near IR region ($\lambda < 10000 \text{ \AA}$) could provide valuable additional information concerning different regions of circumstellar envelopes of Be stars.

1. Spectral observations of Pleione in the near IR region during transition between Be and shell phases reveal considerable differences with results from observations in visual region (Iliev, (2015)). During last stages of Be phase of Pleione, all observable lines from the Paschen series of hydrogen were in emission up to P16 and P17. No photospheric absorption component of these lines was present. After the Be phase end (approximately in 2004) all observable lines of Paschen series were in pure absorption.
2. Spectral line of O I 8446 $\text{\AA}$ prove to be a sensitive instrument for studies of the Be stars circumstellar envelope changes. For Pleione estimations of dimensions of emitting in O I 8446 region in its envelope were carried out. The outer radius of this region was found to decrease from $18 R_*$ in period 2001 - 2002 to $5 R_*$ in 2007. After Pleione's entering a new spectral phase, the dimensions of emitting region gradually decreased.
3. O I 8446 $\text{\AA}$ spectral line was present in emission in 3 of 4 stars defined by Gulliver (1981) as Stable Shell Stars. In the spectrum of 1 Delphini this line was in pure absorption.
4. Estimation of dimensions of emitting in O I 8446 circumstellar envelopes of HD 179343, HD 192954 and HD 193182 resulted respectively to: $6.55 R_*$, $7.85 R_*$ and $5.33 R_*$. These values are close to the estimation of

Pleione's emitting region at the moment of its minima during its phase transition.

Photometry of Be stars

Photometrical behavior of some of the stars of our target list was studied in more detail.

1. For the Be star Pleione for the first time photometrical behavior during the last Be phase was traced. It was found that during this Be phase maximal levels of Pleione's brightness were reached in the period January-February 2004.
2. Values reached were $5^m.002$ in Johnson V filter, $4^m.77$ in Johnson B filter and $4^m.46$ in Johnson U filter.
3. After reaching maximum Pleione's brightness gradually declined by $0^m.3$ in V, $0^m.45$ in B and $0^m.55$ in U filter. Minimal brightness Pleione reached around JD 2454940 (April 18, 2009). This corresponds well with the observed diminishing of the strength of Balmer emission in the spectrum of Pleione (Iliev et al., (2007)).

Analysis of Rozhen homogenous set of photometrical observations of Be/shell star EW Lacertae proved that the star underwent multiperiodic variability (Iliev et al., (1984), Stagg et al., (1988)).

1. Evidences for cyclic variability with periods found by Stagg et al. (1988) were confirmed. Additional cyclic variability with characteristic frequency 2.2248 d^{-1} was found.
2. During the local photometrical minimum at JD 2445624 small scale variations were found with characteristic time of $23^{min}.49317$ and amplitude of $0^m.014$.

Analysis of the photometrical behavior of stable shell star 1 Delphini was based on set of more than 610 individual observations.

1. By means of Fourier analysis it was found that there are evidences for cyclic periodicity with characteristic time of $0^d.831414$ and amplitude of $0^m.1$.
2. Separate analysis of the data from different observing seasons gave evidences about cyclic periodicity in year 2002 season with characteristic time of $0^d.161778$ and amplitude of $0^m.085$.
3. All photometrical multiperiodic variabilities of 1 Del were found to be with variable amplitude, as in case of EW Lac.

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