Spectral activity episode of the Be-shell star Pleione in 2013-2018

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Abstract. Pleione is well known as a prototype of a group of similar Be-stars, among the vast diversity of active B type stars. Its transitions between cyclic decades-long periods of having a spectrum with intense emission lines or a spectrum with sharp absorption lines is traced already for more than a century. In the present study we report an episode of Hα emission activity in the spectrum of the Be-shell star Pleione in 2016. It was documented with high resolution spectral observations carried out at VLT (ESO). The outburst of Hα emission was superimposed onto a gradual spectral changes during the development of a shell spectral phase of Pleione. The Hα outburst was accompanied by synchronized activity in the Hβ line.
Key words: stars: emission-line: Be - stars: shell - stars: variable - stars: individual : Pleione

1 Introduction

Classical Be stars are considered as fast rotating, main-sequence B-type stars, embraced by gaseous, ionized, self-ejected, circumstellar disk-shaped envelope (Porter & Rivinius 2003; Klement et al. 2022, and references therein). One typical example of this interesting class of active variable stars is Pleione (28 Tau, BU Tau, HR 1180, HD 23862, Gaia EDR3 66529975427235712). The star is also a member of the Pleiades (M 45, MWSC (KPS2012) 0305) open cluster and is classified as B8Vne spectral type. Pleione is well known for its periodic transitions between different activity cycles (Hirata, 1995). Over a period of more than 130 years the star exhibited remarkable spectral changes. The spectrum of the star evolved through periods with strong double-picked emission of the hydrogen lines (Be phase), lines with strong absorption cores (shell phase) and pure absorption spectrum (normal B-type or diskless phase) (Marr et al. 2022; Iliev 2017; Nemravova et al. 2010). After entering in July 2004 its consecutive spectral phase (Iliev 2015, 2019), Pleione gradually developed spectral features typical for the shell phases of all classical Be stars. Katahira et al. (1996) found that Pleione is probably a binary system with a period of 218 days. Later Nemravova et al. (2010) confirmed the period.

2 Observations, processing of data, measurements

Observations used in the present study were retrieved from the observational data archives of European Southern Observatory (http://eso.org). These observations were accessed using searching resources of International Virtual Observatory Alliance (http://ivoa.net). Altogether, 12 high resolution spectral observations of Pleione were found available. The set of high quality spectroscopic observations includes 8 observations obtained in October 2016 - January

2017. There were also observations from 2013, 2014 and 2018. Observations were obtained at VLT Unit 2 telescope with different instruments. All but the last two observations were obtained with X-Shooter spectrograph. The last two observations from 2018 were obtained with the UVES spectrograph. Information about the observations used in the present study can be found in Table 1. All observations were wavelength calibrated. Normalization to the continuum of the spectra was performed with the set of software tools of IVOA. Before performing positional and other measurements over the spectra, transition to the dynamical local standard of rest was performed by means of the software tools used.

Table 1. Log of VLT observations used. Time is in Heliocentric Julian Days (HJD)

HJD 2400000+	VLT instrument	sp.range [nm]
56507.41251	XShooter	299-556
56507.41258	XShooter	534-1020
56862.40824	XShooter	299-556
56862.40830	XShooter	534-1020
57667.37286	XShooter	299-556
57667.37292	XShooter	534-1020
57687.16081	XShooter	299-556
57687.16088	XShooter	534-1020
57689.31637	XShooter	299-556
57689.31643	XShooter	534-1020
57702.34382	XShooter	299-556
57702.34388	XShooter	534-1020
57724.05820	XShooter	299-556
57724.05826	XShooter	534-1020
57744.18436	XShooter	299-556
57744.18442	XShooter	534-1020
57746.05294	XShooter	299-556
57746.05271	XShooter	534-1020
57773.04265	XShooter	299-556
57773.04271	XShooter	534-1020
58448.25642	UVES	473-684
58449.21256	UVES	473-684

3 Spectral activity of Pleione in the period 2013 - 2018

3.1 Activity in the Hα line

Inspection of VLT spectral observations of Pleione demonstrates that the emission strength in Hα in general increased during the period 2013-2018 (Fig. 1). There were however significant variations of the spectral profile imposed over this general trend. Observations from October 2016 to January 2017 allow tracing in more detail the event tracing gradual increase of Hα emission of Pleione followed by a gradual decrease. The spectrum from December 2, 2016 (Fig. 2a) reveals the strongest emission of V and R emission components that reached respectively values of 2.944 and 3.106 in relative intensity. Thus this moment (JD 2457724) could be accepted as a maximum of the Hα emission outburst episode. At this particular moment, not only the emission strength reached local maximum, but the central absorption core was above the continuum level (Fig. 2b). This was not typical for the current shell spectral phase of Pleione. In fact, this is quite typical for the emission spectral phase of Be stars. Checking in the extremely rich and well organized BeSS database of spectral observations of Be stars (http://basebe.obspm.fr/basebe/) confirmed the existence of the Hα emission outburst of Pleione with its maximum in December 2016. Similar in time scale and intensity range activity episodes were reported by Labadie-Bartz et al. (2018). They found that many stars from a sample of 160 Galactic classical Be stars had undergone similar periods of activity, that they call outbursts. In their work, Labadie-Bartz et al. (2018) commented that this type of activity of classical Be stars is probably caused by processes of circumstellar disk build up or disappearance.

The V/R ratio of the Hα emission components also changed during the period covered by the VLT observations. In the spectrum from 2014 (Table 2) it can be seen that the V/R ratio was less than unity. The same was true in the beginning of the October 2016 - January 2017 period of Hα outburst. In December 2016, the V/R ratio was already > 1. The same is also observed in November 2018 (Table 2).

3.2 Activity in the Hβ line

High quality spectral observations allow the registration of prominent variations of the Hβ line profile of Pleione (Fig. 3). Variations in the Hβ profile were synchronized with and resembled the ones observed in Hα but at smaller intensity levels. Observations from 2013 and 2014 showed that the V and R emission components of Hβ line of Pleione were nearly equal (Fig.4a). During the outburst, the V/R ratio was < 1 at the beginning. After the emission reached its maximum, the V/R ratio reversed to < 1. Observations from 2018 show that the V/R ratio is again > 1 (Table 2). The central absorption core of the Hβ profile reached its highest level in relative intensity at the moment of maximal intensity of the Hα central absorption core (about HJD 2457724) (Fig.4b). During the outburst, the V component of Hβ developed in a slightly different way than the V component of Hα. During the outburst, it stayed with little variations, while the R component became more intensive.

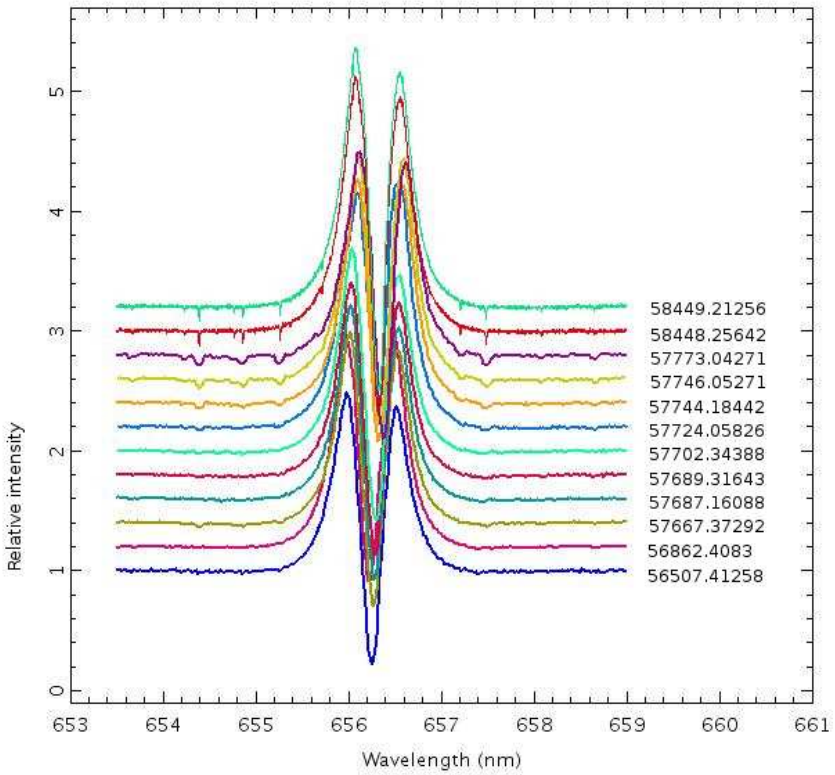
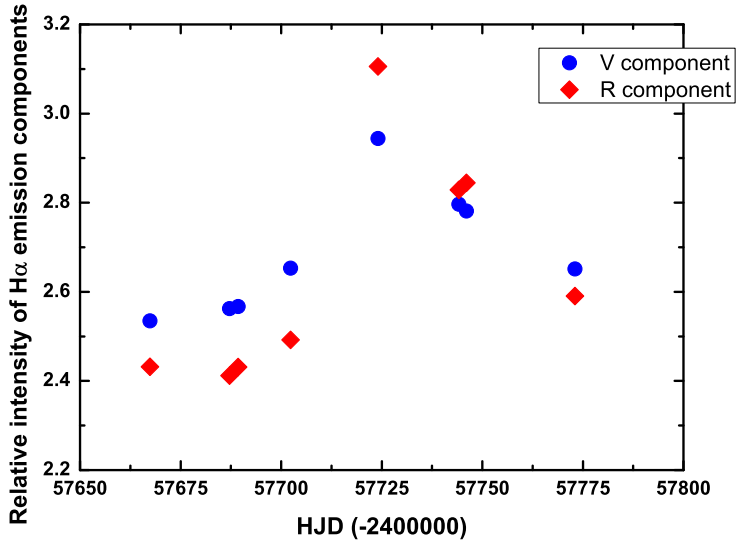
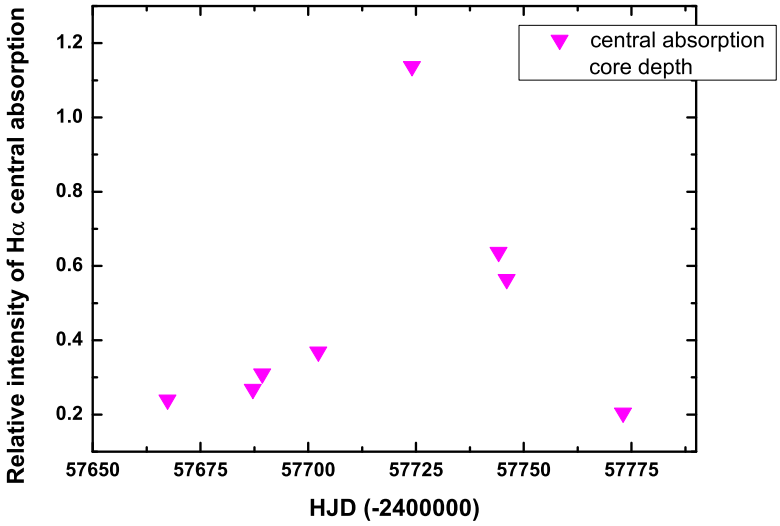


Fig. 1. Hα profiles of Pleione in 2013-2018 period based on VLT observations. Time is in HJD -2400000.



(a)



(b)

Fig. 2. (a) Changes of Hα emission components during October 2016 - January 2017 Hα-emission outburst of Pleione. Time is in Heliocentric Julian Dates (HJD). (b) Variations of central absorption core depth of Hα during the outburst.

Table 2. Results from Hα and Hβ measurements of emission profiles details.

Date	sp. line	V emiss. component	R emiss. component	mean emiss.	centr. abs. component
2013.5889	Hα	2.447	2.357	2.402	0.166
2013.5889	Hβ	0.875	0.847	0.861	0.026
2014.5607	Hα	2.741	2.779	2.760	0.673
2014.5607	Hβ	0.875	0.872	0.873	0.054
2016.7641	Hα	2.535	2.431	2.483	0.240
2016.7641	Hβ	0.830	0.802	0.816	0.076
2016.8181	Hα	2.562	2.412	2.487	0.268
2016.8181	Hβ	0.830	0.808	0.819	0.093
2016.8235	Hα	2.567	2.431	2.499	0.310
2016.8235	Hβ	0.838	0.813	0.825	0.082
2016.8599	Hα	2.653	2.492	2.573	0.369
2016.8599	Hβ	0.838	0.816	0.827	0.079
2016.9266	Hα	2.944	3.106	3.025	1.138
2016.9266	Hβ	0.836	0.897	0.866	0.144
2016.9745	Hα	2.796	2.829	2.812	0.637
2016.9745	Hβ	0.846	0.873	0.860	0.089
2016.9799	Hα	2.781	2.844	2.813	0.564
2016.9799	Hβ	0.844	0.878	0.861	0.083
2017.0540	Hα	2.651	2.591	2.621	0.205
2017.0540	Hβ	0.834	0.843	0.839	0.075
2018.9031	Hα	3.058	2.923	2.990	0.248
2018.9031	Hβ	0.899	0.970	0.934	0.010
2018.9058	Hα	3.099	2.937	3.018	0.255
2018.9058	Hβ	0.912	0.974	0.943	0.002

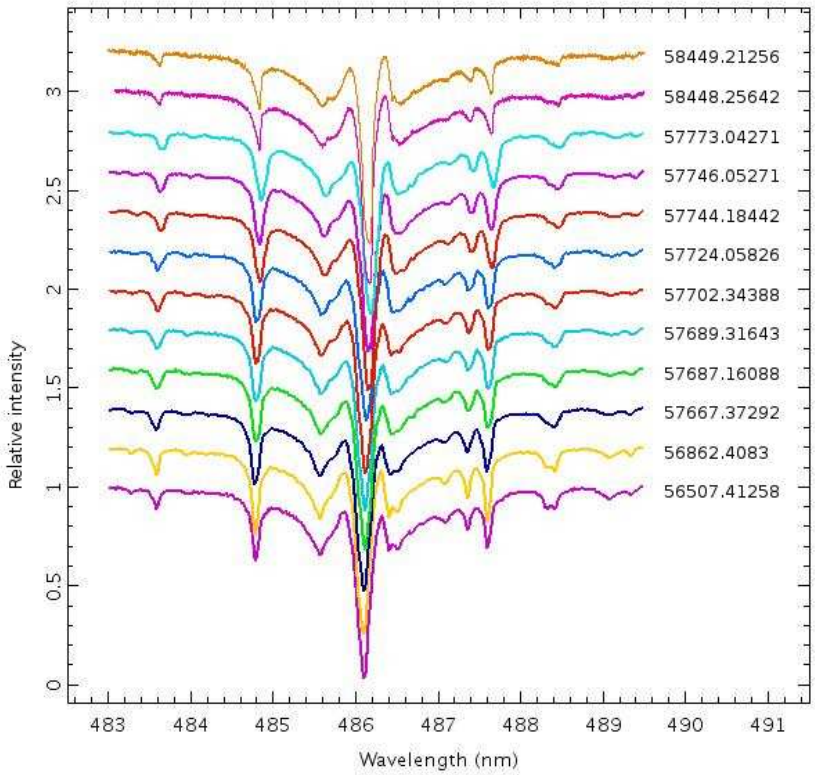
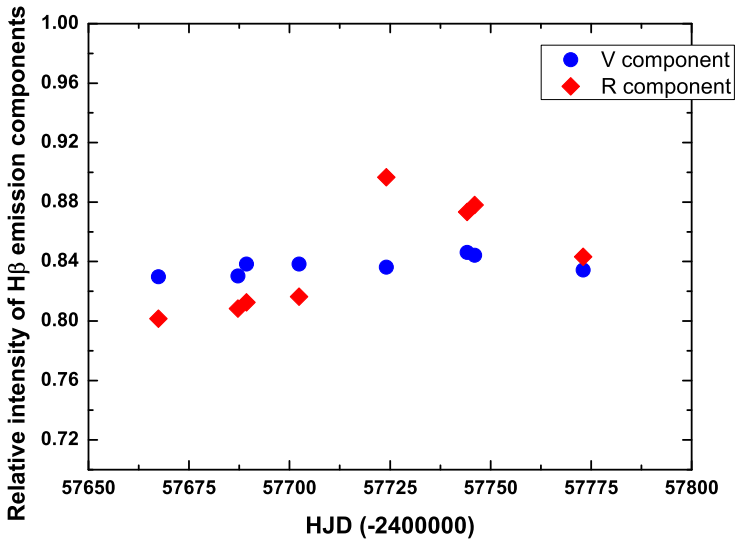
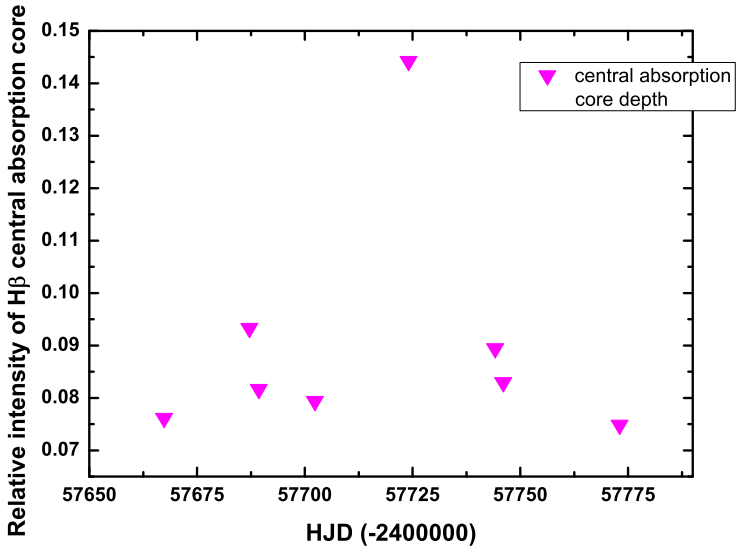


Fig. 3. Hβ profiles of Pleione in 2013-2018 period based on VLT observations. Time is in HJD -2400000.



(a)



(b)

Fig. 4. (a) Changes of Hβ emission line components during October 2016 - January 2017 Hα-emission outburst of Pleione. Time is in Heliocentric Julian Dates (HJD). (b) Variations of central absorption core depth of Hβ during the outburst.

4 Conclusion

Even preliminary analysis of high quality VLT spectral observations of Pleione shows that during the period covered by the observations there was an episode of Hα emission increase and consequent decrease. It was imposed over gradual changes that occur in the course of the current spectral phase development of the star. Observed Hα variations of Pleione in 2016-17 resemble spectral outbursts, described by Labadie-Bartz et al. (2018) for a sample of Galactic classical Be stars. This outburst of Pleione is similar in terms of the intensity scale and time interval of spectral variations to the described in the work of Labadie-Bartz et al. (2018). Spectral activity in the Hα line was accompanied by a corresponding variability in Hβ and possibly in other emission lines in the spectra of Pleione. Moments of maximal intensity of the central absorption core of the emission profiles coincided, although the variation of emission components of different lines followed different scenarios. More comprehensive and detailed studies are needed in order to better understand the observational manifestations of the spectral phase transitions and interactions in the fascinating Pleione system.

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