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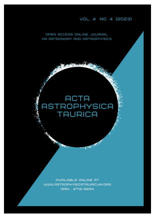

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Spectral features of the gaseous envelope of the Ae/Be Herbig Star HD 37806

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ABSTRACT

We analyze spectra of the Herbig Ae/Be star HD 37806 obtained from 2009 to 2019 in the region of the Hα, Hβ, He I λ 5876, Fe II λ 4923, and DNa I lines. Observations were carried out at two observatories: Crimean Astrophysical Observatory and OAN SPM (Mexico). Over 11 years we obtained 280 high-resolution spectra during 48 observational nights. From the whole variety of observed spectral variability, in this report we will focus on its three types:

1. Changes in the ratio of the maximum intensity of the violet (V) and red (R) emission peaks of the Hαprofile on the time scale months–years. An interpretation of this variability is proposed within a model of changes in the latitudinal wind distribution on both sides of the equatorial accretion disk.

2. Appearance of local absorption features on the violet emission component of the Hαline profile, shifting toward zero radial velocity with a characteristic time of a day. It is shown that such variability can be explained within the frame of a kinematic model of an outflowing stream rotating in the wind zone. We estimated the distance at which such a stream should cross the line of sight on various dates. They are in good agreement with the disk wind model in a region far from the star, where the outflow of matter forms in the decelerating disk wind.

3. Observation on certain dates of the so-called accretion episodes, when red absorption components appeared on the profiles of the Hβ, He I λ 5876 and Fe II λ 4923 lines, which are characteristic of accretion flows with velocities reaching 300–400 km/s. The duration of such episodes was several days, which exceeds the expected period of rotation of the star together with its hypothetical magnetosphere (about 1.5 days) and rules out rotational profile modulation as a possible cause of their changes. It is concluded that the observed phenomenon may be associated with local short-term changes of the accretion rate in the disk.

Key words: Herbig Ae/Be stars, spectroscopy, outflows, winds, accretion

1 Introduction

Herbig Ae/Be stars (HAEBEs) are conventionally regarded as pre-main-sequence (PMS) objects of intermediate mass (2 to 8 $M_\odot$) (Herbig, 1960; Finkenzeller and Mundt, 1984; The et al., 1994). They are surrounded by dust/gas accretion disks. Remote cold dust reveals itself in the form of a far-IR excess, and numerous emission lines originate in the circumstellar envelope. The envelope has a complex spatial structure and contains an equatorial disk and matter outflow in the form of a stellar/disk wind at higher latitudes. HD 37806 (MWC 120, B8e–A2e) was included in the list of Herbig Ae/Be stars after detection of the far-IR excess (Oudmaijer et al., 1992). Up to now, the spectrum of HD 37806 has been poorly studied. We can mark only the overview of the Hα profile types from 1995 to 2007 by Harrington and Kuhn (2009). We carried out our spectroscopic observations at two observatories: a) Crimean Astrophysical Observatory (2.6-m Shajn telescope, R is about 20 000), and b) OAN SPM observatory in Mexico (2.1-m telescope, R is about 17 000). More than 280 spectra have been obtained during 48 dates in 2009–2019. The temporal behavior of such lines as Hα, Hβ, Fe II 4923, He I λ 5876, and DNa I was investigated.

2 Results

The analysis of the results of our spectroscopic monitoring of HD 37806 revealed several types of spectral variations. The Hα line can transform its profile type from PCyg III to double emission and back again (Fig. 1). Variations of the V/R ratio of this emission profile from 2009 to 2019 are shown in Fig. 2. Such profile transformation can be associated with variations of the extent of latitudinal boundary of the wind zone. Figures 3a, 3b illustrate a zone of the flared wind accelerating up to velocity maximum $V_{\rm m}$ and than decelerating with the distance from the star. Such kinematics is typical of the magnetic centrifuge as a mechanism of wind driving. Three cases (A, B, and C) of the intersection of the wind zone by the line-of-sight are considered.

In case A, the star is screened by the wind completely, and the PCyg II line profile type is observed. In case B, the most high-velocity portion of the wind is too narrow in its latitu-

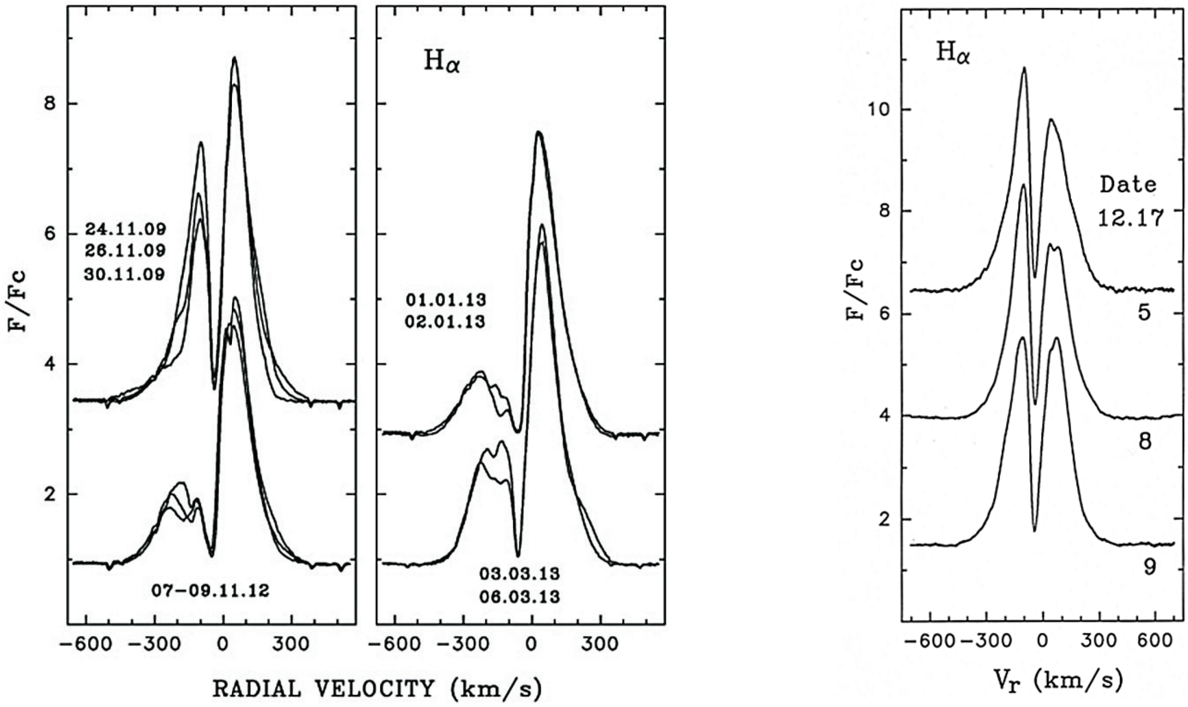

Fig. 1. Different types of the Hα profiles observed in the spectrum of HD 37806 on different dates. The plots on the left panel are reproduced from Pogodin et al. (2018).

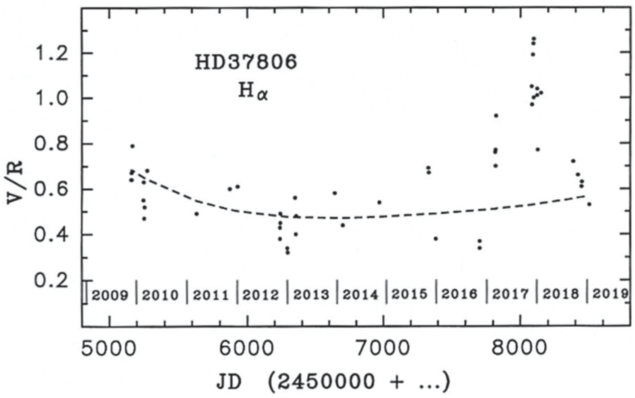

Fig. 2. Temporal behavior of the V/R ratio for the Hα profile of HD 37806 in 2009–2019.

dinal distribution and cannot screen the star. As a result, we observe the P Cyg III profile type. The case C corresponds to a very narrow wind zone, which screens the star and internal parts of the envelope only in the region of the slowest wind, and the observer can see a double emission line profile (see Fig. 3b). According to Bouvier et al. (2007), such latitudinal redistribution of the wind zone can result from variations of the magnetic field configuration in the region of interaction of the accretion disk with the magnetosphere stimulated by changing accretion rate in the disk.

The second type of variability of the Hα profile is an appearance of the local absorption component changing its velocity with a characteristic time of one day. Figure 4 illustrates these variations that were observed in November 7–11, 2012. The velocity of this local absorption component on November 7, 8, 9 was –175, –150, –135 km/s, respectively. Such phenomenon can be explained as rotation of the azimuthal inhomogeneity inside the wind zone. We consider

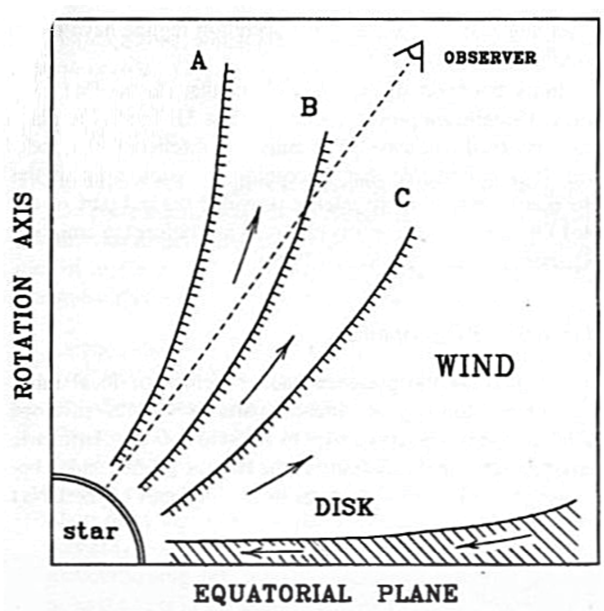

Fig. 3a. Schematic geometry of the envelope near a Herbig Ae star in the form of a meridional section through the rotation axis. The equatorial accretion disk and the high-latitude boundary of the wind zone in three positions A, B, and C are displayed. The cases A, B, and C correspond, respectively, to three types of the line profile, usually observed in HAEBEs: A – P Cyg II, B – P Cyg III, C – a double-peaked profile with narrow central absorption.

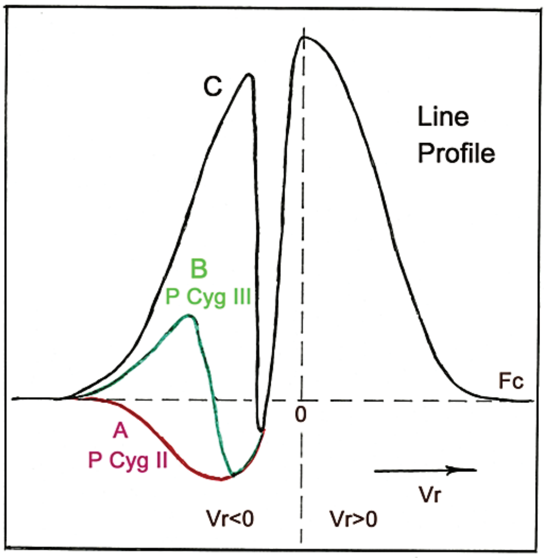

Fig. 3b. Illustration of three profile types A, B, and C.

the geometry and kinematics of the inhomogeneity in the form of an outflowing stream, illustrated in Fig. 5.

Additionally, we estimated the distance where this stream is formed. In different papers (Rucinski et al., 2010; Kreplin et al., 2018), the conclusion was made that HD 37806 is surrounded by the magnetosphere with a radius of 1.7–2.0 $R_{\odot}$, and the rotational period of the star with magnetosphere is P =1.3–1.5 days.

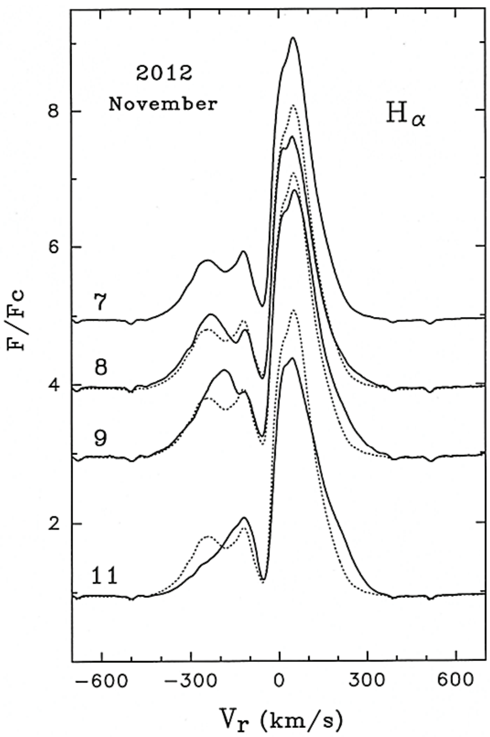

Fig. 4. Night-to-night positional variations of a local absorption feature in the PCyg type III Hα profile of HD 37806 in November 2012 (Pogodin et al., 2019).

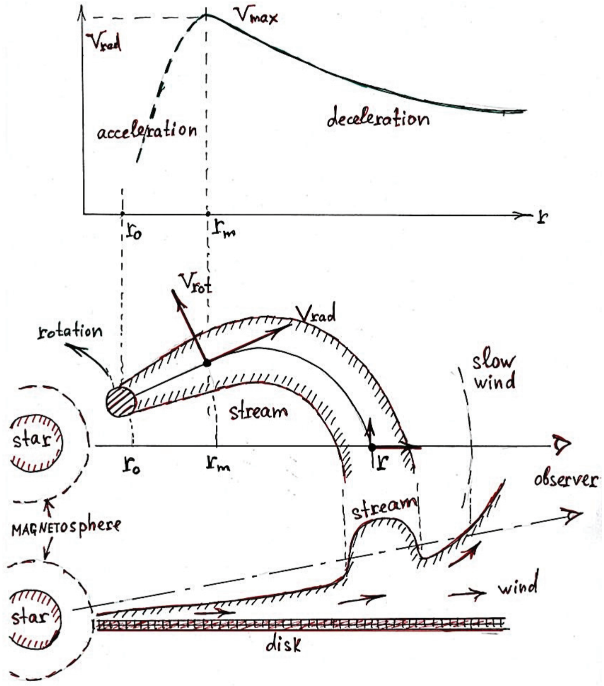

Fig. 5. Schematic geometry of the local stream-like azimuthal inhomogeneity rotating in the wind zone. The *upper* plot illustrates the radial velocity law $V_{\rm rad}(r)$ in the wind zone. The picture is shown in projection on the equatorial plane (*middle*) and the plane of the meridional section through the rotation axis (*bottom*).

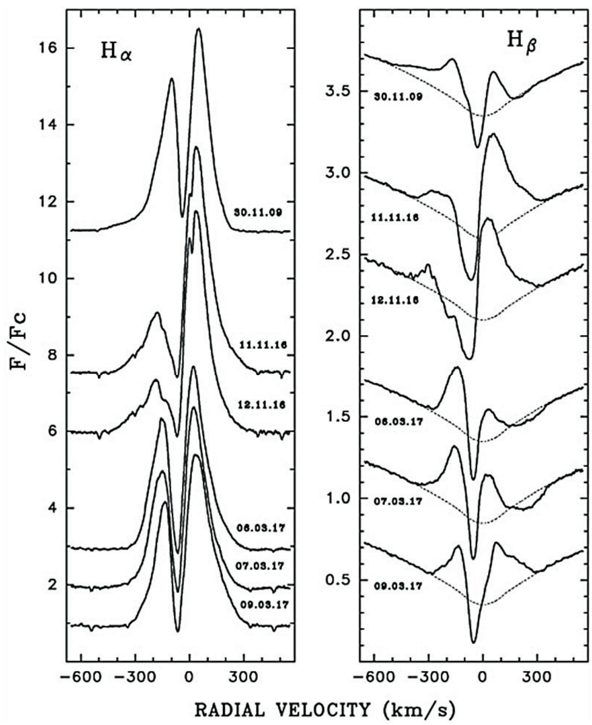

Fig. 6. Appearance of the accretion signatures in the Hβ line profile on the nights when the Hα line profile was double-peaked (Pogodin et al., 2018).

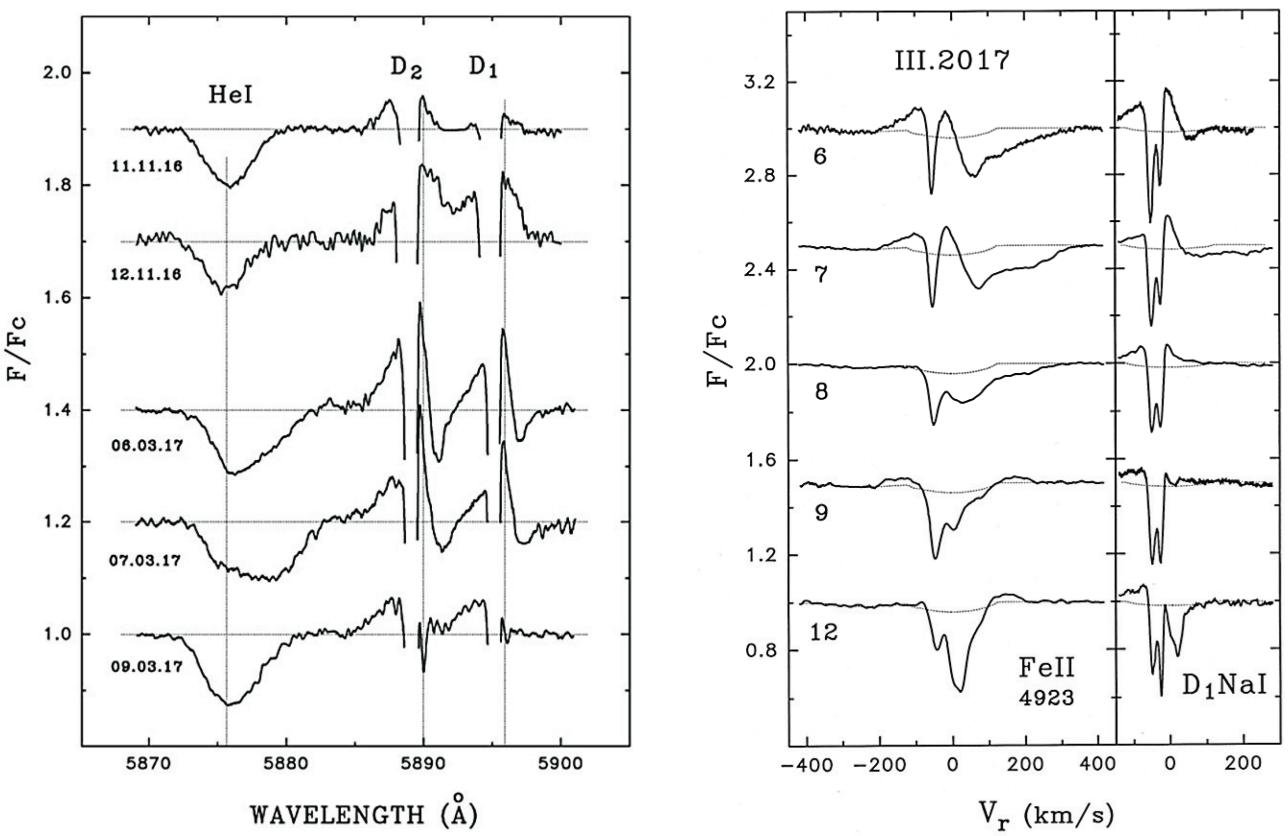

Fig. 7. The same as Fig. 6, but for the He I λ 5876, Fe II λ 4923, and DNa I line profiles. The left panel is reproduced from Pogodin et al. (2018)

Our hypothetical stream intersects the line-of-sight only once during 4 days; therefore, its rotational period has to be more than 4 days. Such a stream can be formed only in the disk with differential rotation at distance $r > 1.85(4/1.4)^{2/3} = 3.7\,R_\odot$.

Our conclusion is as follows: variable local features in the blue part of the emission Hα profile can be explained within the model of outflowing stream formed in the decelerating disk wind.

On some dates the signatures of accretion onto the star appear in the profiles of Hβ, He I λ 5876, Fe II λ 4923 and DNa I lines, with the lifetime of an order of several days (Figs. 6, 7). This phenomenon was observed only on the dates when the Hα line profile was double-peaked. We assume that it can be associated with an increase in the disk accretion rate, which can stimulate the concentration of the outflowing matter inside the wind zone toward the equatorial disk, making the latitudinal distribution of the zone more narrow.

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