ВАК 2024 MODERN ASTRONOMY:
FROM THE EARLY UNIVERSE TO EXOPLANETS AND BLACK HOLES
300 years Russian Academy of Sciences

Spectral and photometrical peculiarities of the unusual Herbig Ae star HD 179218

N. Ismailov[1], M. Pogodin[2], A. Kholtygin[3], H. Adigozalzade[1], U. Bashirova[1], O. Kozlova[4], and A. Ivanova[3]

[1] Shamakha Astrophysical Observatory, Shamakha, AZ-5626 Azerbaijan
ismailovnshao@gmail.com,
[2] Central Astronomical Observatory of the Russian Academy of Sciences at Pulkovo, 65 Pulkovskoye Shosse, St. Petersburg, 196140 Russia
[3] Saint-Petersburg University, 7-9 University Emb., St. Petersburg, 199034 Russia
[4] Crimean astrophysical observatory of the Russian Academy of Sciences, Nauchny, 298409 Russia

Abstract. We present the results of the spectroscopic monitoring of the Herbig Ae star HD 179218 carried out at the Shamakha Astronomical Observatory from 2015 to 2021 and the $UBVRI$ photometry at the Crimean Astronomical Observatory, covering the period 2007–2021. This object has a unique orientation of its rotation axis close to "pole-on". The Hβ line profiles are a single emission profile overlapped by blue and red absorption features living about several days. The 17 dates of 77 the Hβ and the He I λ5876 line profiles demonstrated the inverse P Cyg-type profile with the variable velocity of the red edge of the absorption component up to 400 km/s. The period of the variations $P = 1.341 \pm 0.002$ days determined by Lafler–Kinman method is in accordance with the expected rotation period of the star. This observational fact can be a signature of the magnetospheric character of accretion in HD 179218. The inclination angle of the rotation axis is estimated as $i = 23° \pm 3°$. The observed phenomena can be connected with a specificity of stellar magnetism of HD 179218. Additionally, it has been shown that equivalent widths of the Hα and Hβ lines as well as the photometric $UBVRI$ parameters of HD 179218 demonstrate cyclic variability with several periods falling in the range from 19 days to 737 days. A possible interpretation of these phenomena can be a result of presence near HD 179218 of a low-mass binary component or exoplanets. A sudden drop of circumstellar extinction took place in October of 2011, possible interpretations of this phenomenon are considered.

Keywords: stars: variables: Herbig Ae/Be, circumstellar matter; accretion; individual: HD 179218

DOI: 10.26119/VAK2024.061

1 Introduction

Herbig Ae/Be stars are conventionally regarded as pre-main sequence (PMS) objects of intermediate mass (2–10 $M_\odot$) (Herbig 1960; Finkenzeller & Mundt 1984; The et al. 1994). They are surrounded by circumstellar (CS) envelopes containing the equatorial accretion disk and a matter outflow (wind) zone at higher latitudes. The Herbig Ae star HD 179218 demonstrates a “pole-on” orientation relative to the line of sight. According to Leinert et al. (2004) its inclination angle i is near 20°. We present here the results of our investigation of this object.

2 Observations

We carried out spectroscopic monitoring of HD 179218 from 2015 to 2021 with echelle-spectrometer installed at the 2-m telescope of the Shamakha Astrophysical Observatory of the Azerbaijan National Academy of Sciences. In total, 86 spectra have been obtained. Additionally, we used in our investigation the results of $UBVRI$ photometry of the object, performed at the Crimean Astrophysical Observatory of the Russian Academy of Sciences between 2007 and 2021 (76 observing dates).

3 Short-term spectral variability

We used temporal behavior of the Hβ profile in spectra of HD 179218 to investigate structural and kinematic properties of its CS gas in the region near the line of sight between the star and the observer. This object demonstrates a wide variety of Hβ profile types observed on different dates: simple single emission profiles, the P Cyg-type and the inverse P Cyg-type profiles, and, at last, multi-component emission profiles with blue as well as red absorption features as it is seen in Fig. 1. Among profiles with the inverse P Cyg-feature, the velocity of the red boundary of the absorption component varied from 235 km/s to 390 km/s on different dates (17 dates). On these dates profiles of another emission line He I λ7876 also demonstrate the inverse P Cyg-type structure with the velocity of the red edge of the absorption component from 50 km/s to 450 km/s. Using the Lafler & Kinman (1965) method we have found the period of the line profile variability for both lines Hβ and He I λ5876. The corresponding periodograms are presented in Fig. 2.

The mean value of the revealed period and its error is $P = 1.341 \pm 0.002$ days with the use of four independent estimations (P and doubled P for both lines seen in periodograms). This value is in correspondence with the expected rotation period of HD 179218. This result can be estimated as a signature of magnetospheric accretion in HD 178218. The values of the rotation period allows us to estimate the inclination

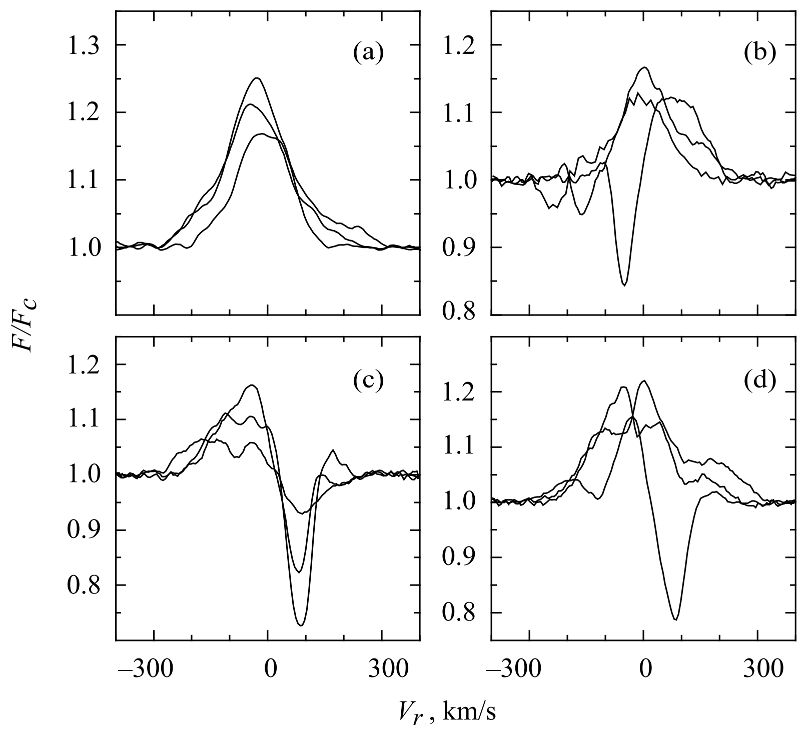

Fig. 1. Normalized to the continuum level Hβ line profiles observed at different dates in the spectrum of HD 179218 after subtracting the stellar atmospheric component: single emission profiles (a); P Cyg-type profiles (b); inverse P Cyg-type profiles (c); multi-component profiles (d).

angle of the rotation axis $i = 23° \pm 3°$, which is in a good accordance with Leinert et al. (2004).

Besides the periodic variations of the Hβ line profile, some other types of variability were registered in the spectra of HD 179218. The most commonly occurring one is an appearance of the local blue or red local absorption features overlapping a single emission profile with the lifetime of several days and stable velocity positions. Examples of such phenomenon are illustrated in Fig. 3. Such temporal behavior excludes rotational modulation of the line profiles as a result of eclipsing of the star by azimuthal CS inhomogeneities, since the rotation period of the star is only 1.34 days. We are forced to accept that at the present time we are unable to propose a single certain interpretation of this phenomenon. We assume that it can be connected with a specificity of stellar magnetism of HD 179218.

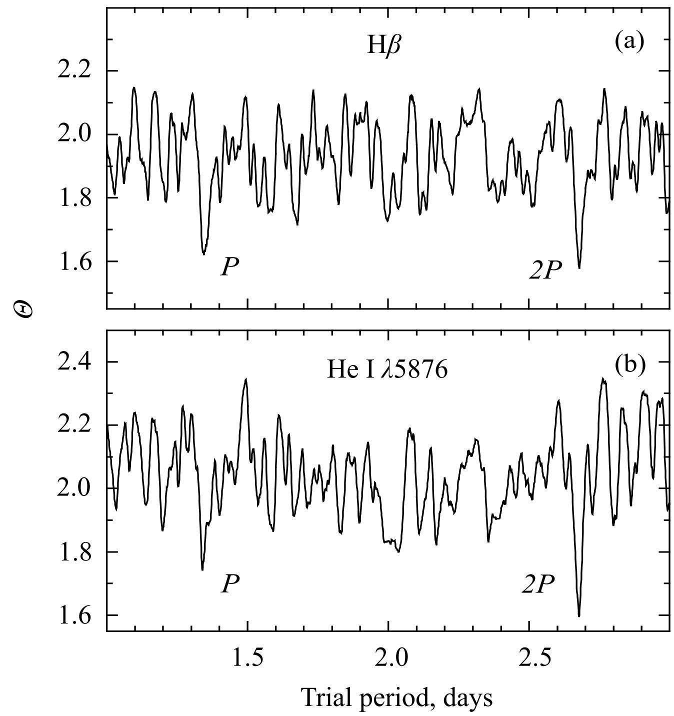

Fig. 2. The the Lafler–Kinman periodogram for $V_{\rm red}$ values for Hβ line (a) and He I λ5876 (b).

4 Long-term photometric variability

To analyze the variability we used photometric data obtained in five bands of the $UBVRI$ system in 2007–2021 at the AZT-11 telescope in Crimean Astrophysical Observatory with the 5-channel Piirola photometer-polarimeter. Besides the cyclic variability, a remarkable abrupt brightness jump was observed in October 2011 in all $UBVRI$ photometric bands. The maximum rise in brightness was in U-band, then its magnitude decreased from U to V. It became almost unnoticeable in the R band, and in the I band the brightness, on the contrary, suddenly decreased. The UVI light curves, illustrating this phenomenon, are shown in Fig. 4a. Dependencies between stellar magnitudes in the UVI bands on V are given in Fig. 4b. We assume that the phenomenon can be connected with a sudden disappearance of dust from the CS region between the star and the observer. This has to lead to a reduction of CS extinction and, consequently, to a rise of brightness in the visual spectral range. But such reduction of amount of CS dust, responsible for the near-IR excess, can result in a fall of the emission in the I band, where this excess starts to be observed.

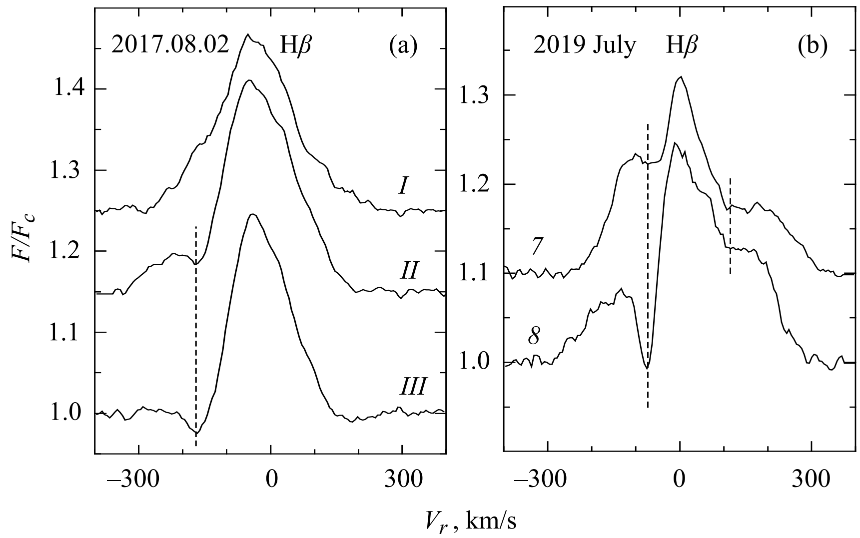

Fig. 3. Profiles of the Hβ line obtained on 29/30.07.2017 with the interval of time of 10 hours (I and II) and 02.08.2017 (III) (a). The vertical dashed line marks are not displaced during three days absorption feature. Profiles of the Hβ line obtained on July 7 and 8, 2019 (b). Two local absorption features at -75 km/s and $+115$ km/s are seen.

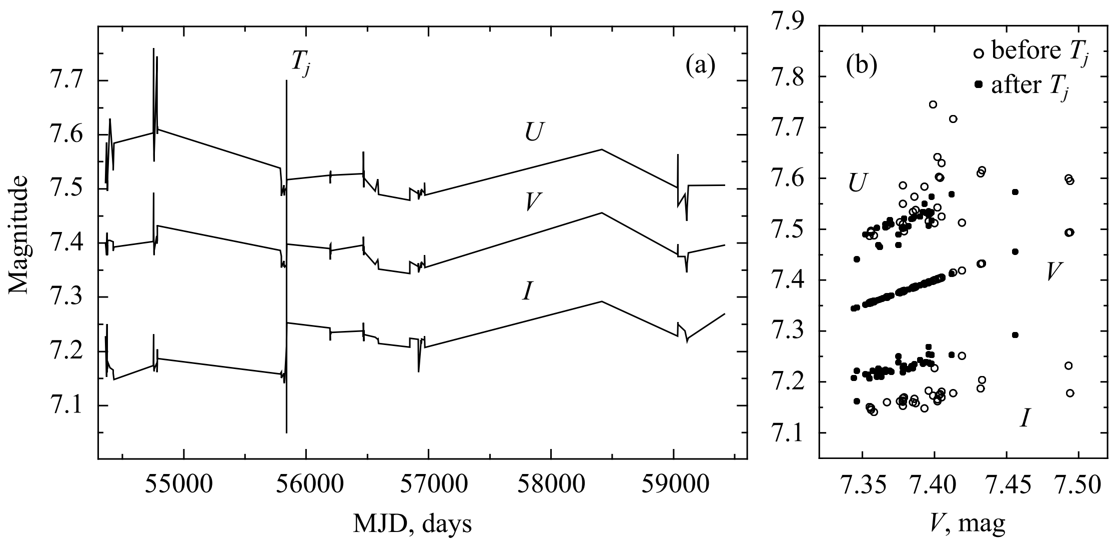

Fig. 4. Time dependencies of the stellar magnitudes of HD 179218 in the U, V, and I bands before and after the jump time T_j (a). Dependence U, V, and I magnitudes on V (b).

Also, we can speculate, that all active phenomena, observed in HD 179218 at the time scales of order of years can be connected with:

a) existence in the CS disk of dense local bodies (protoplanets), rotating at different distances from the star;

b) formation in the disk of azimuthally inhomogeneous (spiral-like) structures (Boccaletti et al. 2020);

c) presence of small-mass components of the main A0e object.

5 Conclusion

In the present paper we continue the study of a very rare subgroup of young Herbig Ae/Be stars: class A stars with an orientation of the rotation axis relative to the observer close to the pole. It is from this angle one can observe the circumpolar regions of the circumstellar envelope, where the gas has the least studied structure and kinematics.

A cyclic variability of the red boundary of the absorption component $V_{\rm red}$ of the Hβ and He I λ5876 line profiles with a period $P = 1.34$ days, corresponding to the expected rotation period of the star, was discovered. The maximum values of the parameter $V_{\rm red}$ reach 350–400 km/s, which is possible only with the magnetospheric nature of accretion. The angle of inclination of the stellar rotation axis to the line of sight is estimated to be $i = 23^\circ \pm 3^\circ$.

The analysis of the Hα and Hβ line profiles in the HD 179218 spectra and photometric data in the $UBVRI$ bands carried out in this work showed the presence of regular spectral and photometric variability with long periods. Such variability may be associated with changes in the accretion rate and precession of the accretion disk. Regular variability over long periods of time may indicate the presence of a distant satellite and, possibly, a distant exoplanet/exoplanets.

Analysis of the dependencies of the stellar brightness in the I band and the V–I color index on the magnitude in the V filter indicates an increase in the absorption of the stellar radiation in the I band in the period from September 20, 2011 to October 3, 2011. This increase in absorption continued through 2021.

References

Boccaletti A., Di Folco E., Pantin E., et al., 2020, Astronomy & Astrophysics, 637, id. L5
Finkenzeller U. and Mundt R., 1984, Astronomy and Astrophysics Supplement Series, 55, p. 109
Herbig G.H., 1960, Astrophysical Journal Supplement, 4, p. 337
Lafler J. and Kinman T.D., 1965, Astrophysical Journal Supplement, 11, p. 216
Leinert C., van Boekel R., Waters L.B.F.M., et al. 2004, Astronomy & Astrophysics, 423, p. 537
The P.S., de Winter D., Perez M.R., 1994, Astronomy and Astrophysics Supplement, 104, p. 315