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VARIATION OF THE Hα LINE PROFILE IN THE SPECTRUM OF THE SUPERGIANT STAR HD 207260 (A2 Iae)

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ABSTRACT. We present the results of a detailed spectroscopic investigation of the supergiant HD 207260 (A2 Iae), based on high-resolution echelle spectra obtained in 2018 with the 2-meter telescope at the Shamakhi Astrophysical Observatory. The focus is on the variability of the Hα line, which exhibits a complex and variable profile, consisting of both an absorption and an emission component. The intensity of the emission component and its radial velocity were found to vary significantly across different epochs. These changes were accompanied by synchronous variations in the radial velocity of the absorption and in the equivalent width of the line. Such behavior suggests a dynamical origin for the emission component, possibly related to instabilities in the upper atmosphere or episodic mass loss processes.

Fourier analysis of the radial velocity variations reveals with an approximate of 35–40 days. This periodicity is consistent with the presence of radial or non-radial pulsations, which may drive structured outflows in the upper layers of the stellar atmosphere.

It is assumed that the change in the Hα line profile, the change in the radial velocity and the equivalent width of the absorption and emission components of the Hα line profile occur as a result of the interaction of the stellar atmosphere with the circumstellar envelope as a result of the pulsation of the star.

Keywords: supergiant stars, Hα line profile, radial velocity, spectral variability, stellar pulsations.

АНОТАЦІЯ. Ми представляємо результати детального спектроскопічного дослідження надгіганта HD 207260 (A2 Iae), що базується на високодисперсних ешель-спектрах, отриманих у 2018 році за допомогою 2-метрового телескопа Шамахинської астрофізичної обсерваторії. Основна увага приділяється варіабельності лінії Hα, яка демонструє складний і змінний профіль, що складається як з абсорбційного ядра, так і з емісійної компоненти. Було встановлено, що інтенсивність емісії та її променева швидкість значно змінюються в різні епохи. Ці зміни супроводжувалися синхронними варіаціями радіальної швидкості та еквівалентної ширини поглинальної складової лінії. Така поведінка свідчить про динамічне походження емісійної компоненти, можливо повязане з нестабільностями у верхніх шарах атмосфери або з епізодичними процесами втрати маси.

Фур'є-аналіз радіальної швидкості показує приблизний період у 35–40 днів. Ця періодичність узгоджується з наявністю радіальних або нерадіальних пульсацій, які можуть спричиняти структуровані потоки у верхніх шарах зоряної атмосфери.

Передбачається, що зміна профілю лінії Hα, зміна радіальної швидкості та еквівалентної ширини поглинальної та емісійної складових профілю лінії Hα відбуваються в результаті взаємодії зоряної атмосфери з навколозоряною оболонкою внаслідок пульсації зірки.

Ключові слова: надгіганти, профіль лінії Hα, радіальна швидкість, спектральна варіабельність, зоряні пульсації.

1. Introduction

B- and A-type supergiant stars represent the brightest stellar population in both spiral and irregular galaxies that are undergoing active star formation. These stars are young and predominantly located within the galactic plane. Due to their high luminosity, they can be observed at large distances, providing a unique opportunity to study the distribution of chemical elements and to trace the chemical evolution of the Milky Way as well as other galaxies. Furthermore, these stars are extensively used to investigate the spiral structure of galaxies and to determine their morphological parameters.

HD 207260 (A2 Iae), as a typical representative of this class of supergiants, is therefore of particular interest for studies related to stellar evolution. To this end, high-resolution spectra of HD 207260 were obtained with the 2-meter telescope at the Shamakhi Astrophysical Observatory. Based on these observations, the variability of the Hα line profile was analyzed, including measurements of its characteristic parameters and changes in the profile shape over time.

The supergiant star ν Cep (HD 207260 = HR 8334) has a visual magnitude of V=4.29 (Ducati, 2002) and a spectral type of A2 Iae (Gray & Garrison, 1987). In the Galactic coordinate system, its position is l=102°.3, b=+5°.93 (Pan et al., 2004), and its distance is 2083 pc (π=0.00048; Van Leeuwen, 2007).

In the work by Samedov et al. (Samedov et al., 2020) investigated the supergiant HD 207260. Atmospheric parameters were determined: T_{eff} =9200±200K; logg = 1.4

± 0.2; ξt = 6.0±0.5 km/s; logε(Fe)=7.55±0.1; [Fe/H]=0.08. Chemical composition analysis has revealed that the carbon abundance in ν Cep is lower than the solar value, while nitrogen is overabundant. The abundances of Sc, Ti, V, Cr, Fe, Ni, Sr, Zr, and Ba are close to solar values. These results indicate that ν Cep and the Sun formed from material with similar overall chemical composition, and evolutionary processes have modified the initial carbon and nitrogen abundances while other elements relatively unchanged. The observed chemical abundances are consistent with stellar evolution theory (Hajiyeva, 2020).

2. Magnetic Field in the Supergiant Star HD 207260

Between 1975 and 1979, Scholz and Gerth (1980) conducted observations of νCep at the Karl Schwarzschild Observatory (Tautenburg, Germany) in the 4000–4600 Å spectral range, obtaining 55 Zeeman spectra. Based on these observations, they investigated the star's magnetic field and the line profiles of the hydrogen Balmer series, specifically Hβ and Hδ, as well as the radial velocity variations.

The magnetic field was found to vary weakly between several hundred gauss during 1975–1978, but in 1978 it increased sharply to approximately +2000 gauss. Radial velocity variations exhibited both slow and rapid changes similar to the magnetic field. A quasi-periodicity of 39.9 days in radial velocity was detected, which the authors attributed to stellar rotation. Differences in radial velocity between H_β, H_γ, and H_δ lines were explained by the presence of an extended circumstellar envelope. Additionally, various neutral and ionized spectral lines showed radial velocity variations in the range of 1–4 km s^{-1}. During 1975–1976, radial velocities displayed inconsistent and contradictory values ranging from ~−18 to ~25 km s^{-1}. Scholz and Gerth suggested that ν Cep might be a binary system (Scholz & Gerth, 1980).

Previous studies provide some information on the spectral and photometric parameters characterizing HD 207260. However, details regarding non-stationary processes in the stellar atmosphere and the spectral lines that trace these phenomena remain largely unexplored. Therefore, investigating the Hα line of hydrogen and other lines that characterize atmospheric non-stationary processes is timely and of significant importance.

3. Observations, data reduction, and discussion

Spectroscopic observations of HD 207260 were carried out between 2015 and 2019 using the 2-m telescope at the Shamakhi Astrophysical Observatory named after N. Tusi. Until 2016, spectra were obtained in the Cassegrain focus with the UAGS spectrograph equipped with a 530×580-pixel CCD camera at a spectral resolution of R=14000, covering the 3960–6600 Å spectral range (Mikaillov et al., 2005).

After 2016, spectra were acquired using the fiber-fed Cassegrain echelle spectrograph with a 4000×4000-pixel CCD camera at spectral resolutions of R=28000 and R=56000, spectral region are 3700-8500 ÅÅ. Daytime sky spectra were used for dispersion curve calibration. Typically, 2–3 spectra of the star were obtained per night. Since no significant short-term variability was observed within a single night, these spectra were averaged to improve the signal-to-noise ratio.

The obtained spectra were reduced using the IRAF software package (Hasanova & Rustamova, 2023; Hasanova, 2024). It should be noted that the spectra of HD 207260 had previously been processed using the DECH software packages (DECH-20, DECH-20T, and DECH-30T) developed by Galazutdinov (1992). In the present study, the spectra were reprocessed with IRAF, and the results are in good agreement with those obtained using DECH, confirming the reliability of the reduction and analysis procedures. The uncertainty in the measurement of equivalent widths does not exceed 5%, while the error in radial velocity determinations is less than 1 km s^{-1}. A detailed description of the observational material and the data reduction methodology is provided in our previous works (Hasanova & Rustamova, 2023; Hasanova, 2024).

A total of 25 high-resolution spectra of the HD 207260 star were obtained during the 2016–2019 observational campaigns. In this study, we used the spectra obtained in 2018. A comparative analysis of the emission and absorption components of the Hα line profiles reveals that both the shape and structure of the profile, as well as the spectral parameters characterizing it, exhibit significant variability.

The Hα line profiles are observed in the following forms (Figure 1):

a) Fully absorption profile;

b) Normal P Cyg-type profile – absorption with emission component in the red wing.

The Hα line profiles observed in the spectrum of the hypergiant star HD 207260 at different epochs were constructed (Figure 1). As seen in Figure 1, both the shape of the Hα line profile and its spectral parameters vary over a time interval of seven days or less. The intensity of the emission component observed in the red wing of the Hα line changes with time; occasionally, the Hα line exhibits a P Cyg-type profile. At other times, the emission component completely disappears, resulting in a fully absorption profile.

For instance, on 16 August 2018, the emission component in the red wing of the Hα line in the spectrum of HD 207260 was almost entirely absent. During this epoch, the equivalent width of the absorption component increased abruptly ($\Delta W \approx 540$ mÅ), reaching a maximum value of W = 1662 mÅ. No significant variations in the radial velocity of the emission component were detected.

Based on the performed measurements, a plot showing the temporal variations of the radial velocities of the absorption and emission components of the Hα line, as well as the equivalent width of the absorption component, was constructed (Figure 2).

The plot demonstrates that both the radial velocities of the absorption and emission components and the equivalent width of the absorption component vary with a period of approximately 35–40 days.

An increase in the absolute value of the radial velocity of the absorption component is observed simultaneously with a decrease in both the equivalent width and the intensity of the emission component. In other words, these variations occur synchronously. It is suggested that these changes occur as a result from pulsations of the star, leading to interactions between the stellar atmosphere and the circumstellar envelope.

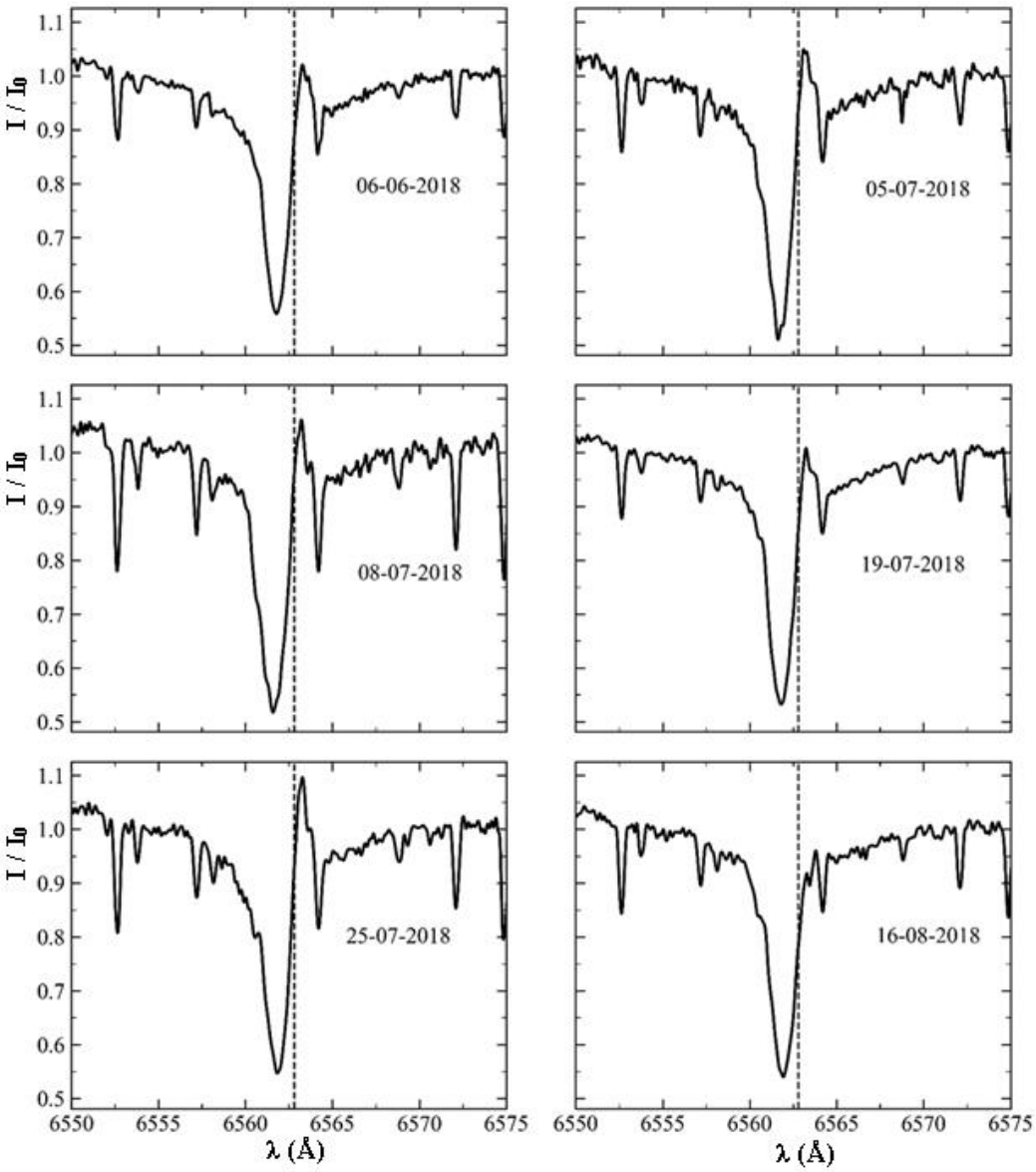

Figure 1: Profiles of the Hα line observed at different epochs in the spectrum of the HD 207260 supergiant star. The dashed line corresponds to the wavelength λ(Hα) = 6562.816 Å.

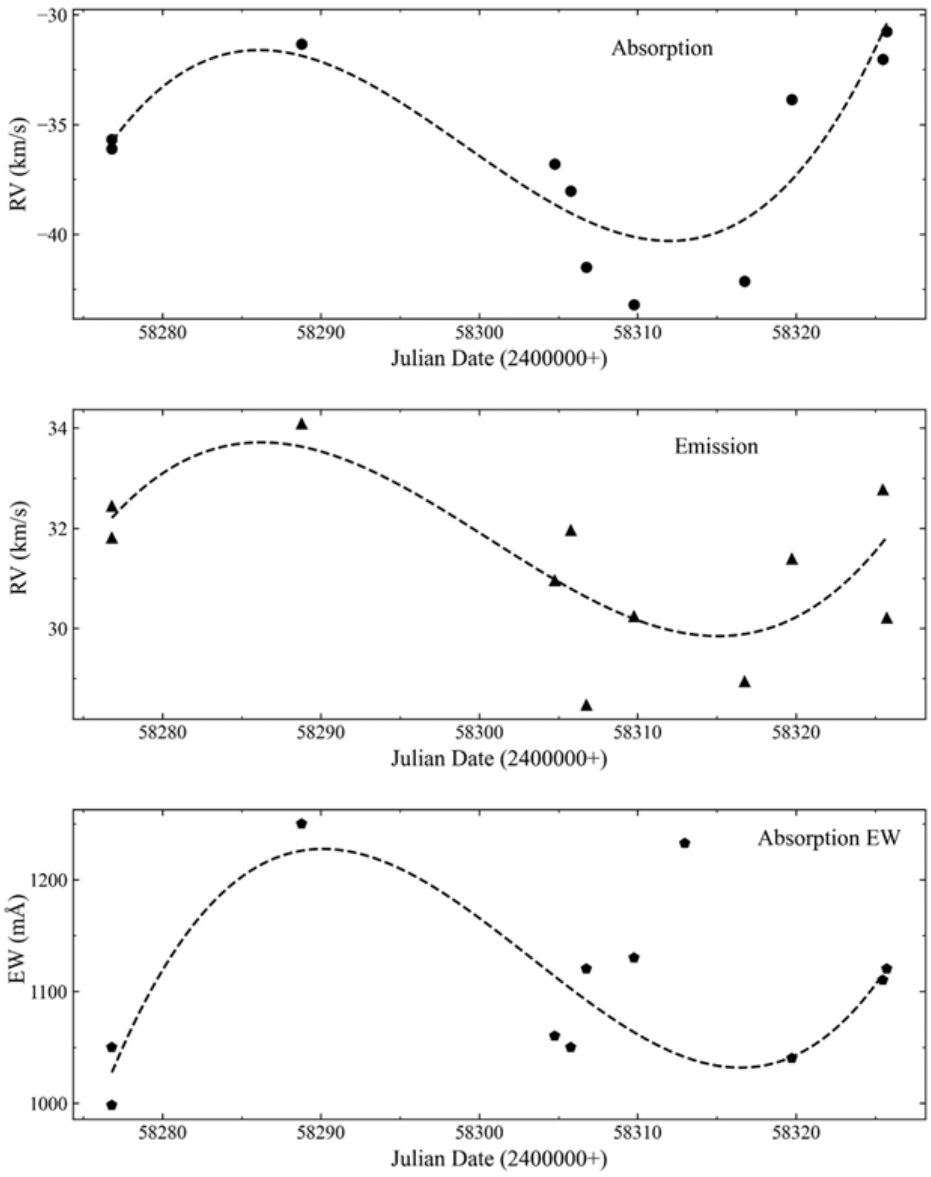

Figure 2: Temporal variations of the radial velocities of the absorption and emission components of the Hα line profile, as well as the equivalent width of the absorption component, observed in the spectrum of the HD 207260 supergiant star.

4. Conclusions

Based on the comparative study of the Hα line profiles in the spectra of the supergiant star HD 207260 obtained in 2018, the following conclusions can be drawn:

The analysis of the Hα line profiles revealed that they generally exhibit a P Cyg-type profile, consisting of an absorption component and an emission component in the red wing. The radial velocities of these components, as well as the equivalent width of the absorption component, vary over time.

It was found that the radial velocities of the absorption and emission components, together with the equivalent width of the absorption component, vary synchronously (Figure 2). These variations occur with a period of approximately 35–40 days.

These results can be utilized in constructing a theoretical model of the star.

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