Hα LINE AS AN INDICATOR OF ENVELOPE PRESENCE AROUND THE CEPHEID POLARIS Aa (α UMi)

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ABSTRACT. We present the results of the radial velocity (RV) measurements of metallic lines as well as Hα (Hβ) obtained in 55 high-resolution spectra of the Cepheid α UMi (Polaris Aa) in 1994–2010. While the RV amplitudes of these lines are roughly equal, their mean RV begin to differ essentially with growth of the Polaris Aa pulsational activity. This difference is accompanied by the Hα core asymmetries on the red side mainly (so-called knifelike profiles) and reaches the value of 8–12 km/s in 2003 with subsequent decrease to 1.5–2 km/s. We interpret so unusual behaviour of the Hα line core as dynamical changes in the envelope around Polaris Aa.

Key words: - Stars: Cepheids - Stars: radial velocities - Stars: Hα absorption line - Stars: envelopes - Stars: individual - α UMi (Polaris A)

1. Introduction

Detecting the extended envelope around the Cepheid Polaris (hereafter Polaris Aa) using a near-infrared interferometer (Mérand et al. 2006) suggested an idea to check its presence spectroscopically. Usenko et al. (2013, 2014ab), Usenko and Klochkova (2015) revealed that the Hα absorption line could be used as an indicator of the envelope presence not only in long-period Cepheids but also in short-period ones. As a rule, Cepheids with pulsational periods longer than 7–10 d demonstrate a pronounced appearance of the secondary variable absorption in the Hα cores, thereas short-period ones be noted by more smoothed, so called knifelike form. Besides, a slight change in the RV of the Hα core with pulsational phase compared to that determined from the metal lines is another indicator of the envelope presence in Cepheids.

Hence the main goal of this work is to measure the RVs of Polaris Aa in different pulsational phases using the metal lines and Hα (in some cases Hβ) line cores and to estimate visually the form of the latter ones.

2. Observations

Observations of Polaris Aa have been obtained using:

1. 1 m telescope of the Ritter Observatory, University of Toledo (Toledo, OH, USA) - fiberfed echelle spectrograph 1150×1150 pixel CCD (λλ 5800–6800 Å).
2. 2.1 m Otto Struve telescope of the McDonald Observatory (Texas, USA) - SANDIFORD spectrograph (McCarthy et al. 1993) 1200×400 pixel CCD (λλ 5500–7000 Å).
3. 6 m telescope BTA - SAO RAS (Russia) - LYNX (Panchuk et al. 1993), PFES (Panchuk et al. 1997), NES (Panchuk et al. 2006) spectrometers (λλ 4470–7100 Å.)

The data reduction was made using IRAF and MIDAS software packages, all measurements of the RV were done using the DECH20 software (Galazutdinov 1992). In Table 1 we present these RV data from the spectra obtained in 2005–2010. This table contains the measurements determined from the metal lines, Hα and Hβ, respectively.

2. Radial velocity measurement analysis and the Hα line cores behaviour

As seen in Table 1 and Fig. 1, originally the difference between the measurements obtained from metal lines and Hα (and one Hβ) for each spectrum does not exceed 1.5 km/s in 1994. As seen from Fig. 2, the Hα core does not demonstrate any visible asymmetries.
Table 1: Radial velocity data of Polaris Aa in 1994–2010

| Spectra | HJD Tele-scope | Metallic lines | \( H_\alpha \) | \( H_\beta \) | \( RV \) | \( \sigma \) | \( NL \) | \( RV \) | \( RV \) |
|---------|----------------|----------------|------------|-------------|--------|----------|--------|--------|--------|
| 940606  | 49712.853      | 1              | -11.35     | 126         | -16.32 | 1.29     | -16.69 | -15.53 |
| 940815  | 49759.824      | 1              | -11.35     | 126         | -16.32 | 1.29     | -16.69 | -15.53 |
| 940906  | 49703.853      | 1              | -14.21     | 116         | -16.32 | 1.29     | -16.69 | -15.53 |
| 941012  | 49737.892      | 1              | -14.21     | 116         | -16.32 | 1.29     | -16.69 | -15.53 |
| 942923  | 51240.612      | 3              | -18.26     | 302         | -19.98 | 1.56     | -19.35 | -18.82 |
| 943008  | 51360.538      | 3              | -18.26     | 302         | -19.98 | 1.56     | -19.35 | -18.82 |
| 943110  | 51361.536      | 3              | -18.26     | 302         | -19.98 | 1.56     | -19.35 | -18.82 |
| 020522  | 52416.655      | 1              | -16.53     | 119         | -18.18 | 1.17     | -17.65 | -17.15 |
| 020523  | 52417.616      | 1              | -18.18     | 119         | -18.18 | 1.17     | -17.65 | -17.15 |
| 020527  | 52421.679      | 1              | -17.35     | 3.06        | -20.35 | 1.08     | -19.82 | -19.31 |
| 020601  | 52426.667      | 1              | -17.35     | 3.06        | -20.35 | 1.08     | -19.82 | -19.31 |
| 020610  | 52435.634      | 1              | -17.35     | 3.06        | -20.35 | 1.08     | -19.82 | -19.31 |
| 020616  | 52441.673      | 1              | -17.35     | 3.06        | -20.35 | 1.08     | -19.82 | -19.31 |

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Figure 1: Radial velocity estimates of Polaris Aa during 1994–2010. Six-point stars, - estimates from metal lines, open five-point stars, - from \( H_\alpha \) line, open circles, - from \( H_\beta \) line. A square polynomial approximation is drawn for the metal lines.

Figure 2: \( H_\alpha \) line core profiles of Polaris Aa during 1994–1999.

Figure 3: \( H_\alpha \) line core profiles of Polaris Aa during 2003.

Since 1999 (HJD 2451240–2451361), this difference begins to increase (Fig. 1) and a slight asymmetry on the red side of the \( H_\alpha \) core are visible (Fig. 2). Two years later this difference becomes larger (from 1 km/s to 2 km/s), and the asymmetries on the red side of
During 2003 we can see the most interesting event when the difference between the measurements reaches 8–12 km/s (see Table 1 and Fig. 1) and the Hα core shows asymmetries on the red side as well as on the blue side (see Fig. 4).

Since 2004 this difference decreases to 2–2.5 km/s (HJD 2453015–2453367), and the Hα core exhibits asymmetries on the red side only (see Fig. 1 and 5).

During 2005–2006 (HJD 245689–2454073) the difference is less than 1 km/s and the asymmetries are less visible (Fig. 6). The same one can see in other results obtained during 2008–2010 (HJD 2454077–2454934) (Fig. 7). It should be noted that the differences between the Hα and Hβ measurements are negligible.

3. Conclusions

We can summarize the results of our investigations as follows.

1. As seen from the results of Table 1 and Fig. 1, amplitudes of the RV curve from Hα and Hβ are very small and close to those determined from the metallic lines.

2. First Hα line core asymmetries on the red side arise with an increase of the RV curve amplitude after the historical minimum of the Polaris Aa pulsational activity in the beginning of the 1990s.

3. During 2003 the difference between the RV estimates obtained from metal lines and the Hα core reaches 8–12 km/s. This event is accompanied by...
the pronounced asymmetries of the $H\alpha$ core on the red side as well as on the blue side.

4. Since 2004, the $H\alpha$ core asymmetries are observed on the red side only and nearly disappear after 2005, when $RV$ amplitude grows to the new minimum.

5. $H\alpha$ core asymmetries (so-called knifelike profile) in the Polaris Aa atmosphere show that this absorption line could be an indicator of the envelope presence in yellow pulsating supergiants with short periods and small amplitudes.

6. So unusual behaviour of the $H\alpha$ core during 2003 could be explained by dynamical changes in the envelope around of Polaris Aa.

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