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 line core asymmetries on the red side mainly (so-called knife-like profiles) and reaches 8–12 km s⁻¹ in 2003 with a subsequent decrease to 1.5–2 km s⁻¹. We interpret a 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

Detection of an 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 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 a secondary variable absorption in the Hα line cores, while short-period ones exhibit a smoother, so called knife-like shape. Besides that, a slight change in the RV of the Hα line core with pulsational phase compared to that determined from the metallic 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 metallic lines and Hα (in some cases Hβ) line cores and to estimate visually the shape of the latter ones.

2. Observations

Observations of Polaris Aa have been obtained using the following facilities:

1. 1 m telescope of the Ritter Observatory, University of Toledo (Ohio, 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 done using IRAF and MIDAS software packages, all the RV measurements 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 derived from the metallic lines, Hα, and Hβ, respectively.

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

As seen in Table 1 and Fig. 1, the difference between the measurements obtained from the metallic lines and
Table 1: Radial velocity data of Polaris Aa in 1994–2010

| Spectrum run ID | RV | NL | RV | RV |
|-----------------|----|----|----|----|
| 490609          | -14.21 | 1.24 | 116 | -14.53 |
| 490908          | -13.35 | 0.93 | 152 | -14.34 |
| 491012          | -14.97 | 1.05 | 132 | -16.69 |
| 491023          | -14.38 | 1.07 | 130 | -15.53 |
| 229033          | -18.26 | 2.81 | 302 | -19.58 |
| 229036          | -16.51 | 2.36 | 317 | -16.48 |
| 224008          | -14.53 | 2.68 | 275 | -15.33 |
| 011009          | 0.81  | 0.81 | 281 | -19.23 |
| 020522          | -16.88 | 1.17 | 138 | -18.18 |
| 020523          | -17.67 | 1.45 | 145 | -19.35 |
| 020527          | -18.75 | 1.32 | 109 | -19.46 |
| 020601          | -18.18 | 1.28 | 121 | -20.39 |
| 020602          | -17.35 | 3.06 | 119 | -18.33 |
| 020610          | -16.53 | 1.18 | 142 | -19.19 |
| 020615          | -16.78 | 1.08 | 112 | -20.35 |
| 36713           | -20.39 | 0.92 | 270 | -22.54 |
| 36614           | -15.33 | 0.66 | 366 | -17.77 |
| 340008          | -16.62 | 0.60 | 374 | -16.41 |
| 303103          | -21.64 | 1.30 | 93  | -14.25 |
| 303107          | -21.59 | 6.07 | 104 | -17.13 |
| 303109          | -22.37 | 4.00 | 111 | -15.07 |
| 304010          | -17.76 | 0.73 | 279 | -20.47 |
| 304019          | -17.75 | 0.79 | 251 | -20.25 |
| 304029          | -16.62 | 0.76 | 247 | -19.08 |
| 314029          | -16.38 | 0.89 | 384 | -15.76 |
| 303121          | -19.19 | 1.37 | 90  | -7.46  |
| 303122          | -18.48 | 1.89 | 125 | -10.53 |
| 304101          | -17.86 | 1.67 | 107 | -9.31  |
| 304106          | -16.50 | 1.13 | 141 | -8.17  |
| 304206          | -17.79 | 0.88 | 279 | -19.91 |
| 304202          | -17.82 | 0.88 | 266 | -19.22 |
| 304203          | -17.81 | 0.64 | 251 | -20.09 |
| 304207          | -18.02 | 0.77 | 291 | -20.17 |
| 304241          | -17.52 | 0.80 | 278 | -19.69 |
| 304522          | -18.21 | 0.98 | 549 | -18.40 |
| 304332          | -16.50 | 0.73 | 281 | -19.22 |
| 304332          | -17.08 | 0.85 | 304 | -19.06 |
| 304427          | -20.51 | 3.84 | 261 | -23.39 |
| 304523          | -16.08 | 1.05 | 108 | -17.54 |
| 304528          | -15.82 | 0.66 | 616 | -16.48 |
| 304531          | -18.24 | 1.20 | 589 | -18.60 |
| 304562          | -17.80 | 1.13 | 566 | -17.50 |
| 304582          | -17.82 | 1.06 | 550 | -17.34 |
| 304592          | -17.93 | 1.06 | 549 | -17.21 |
| 304602          | -16.83 | 1.21 | 581 | -16.72 |
| 304602          | -18.78 | 1.55 | 933 | -19.43 |
| 304692          | -17.87 | 1.09 | 506 | -17.21 |
| 304700          | -17.40 | 1.29 | 569 | -17.20 |
| 304801          | -18.43 | 1.15 | 579 | -18.88 |
| 304852          | -17.58 | 1.21 | 406 | -17.27 |
| 304858          | -18.09 | 1.09 | 415 | -20.09 |
| 304907          | -18.92 | 1.25 | 592 | -18.59 |
| 304910          | -19.41 | 1.04 | 464 | -18.47 |
| 305100          | -16.65 | 1.19 | 603 | -16.26 |
| 305434          | -17.19 | 1.10 | 573 | -17.23 |
| 305437          | -17.19 | 1.10 | 573 | -17.23 |

1. As seen from the results in 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 1990’s.
3. During 2003 the difference between the metallic line RV and those from the Hα line core reaches 8–12 km s⁻¹. This event is accompanied by the pronounced asymmetries of the Hα core on the red side as well as on the blue side.
4. Since 2004 the Hα line core asymmetries are observed on the red side only and nearly disappear after 2005, when the RV amplitude grows to a new minimum.
5. Hα core asymmetries (so-called a knife-like profile) in the atmosphere of Polaris Aa 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 Polaris Aa.

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Figure 2: The H$_\alpha$ line core profiles of Polaris Aa in 1994–1999. The intensity ($R$) is shown in the units of the underlying continuum, the wavelengths are shown in Angströms.
Figure 3: The $\text{H}_\alpha$ line core profiles of Polaris Aa in 2003.

Figure 4: The $\text{H}_\alpha$ line core profiles of Polaris Aa in 2004.
Figure 5: The H$_\alpha$ line core profiles of Polaris Aa in 2005–2006.

Figure 6: The H$_\alpha$ line core profiles of Polaris Aa in 2008–2010.