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

I.A. Usenko,[1], A.S. Miroshnichenko,[2], V.G. Klochkova,[3], N.S. Tavolzhanskaya,[3]

[1] Astronomical Observatory, Odessa National University
T.G.Shevchenko Park, Odessa 65014 Ukraine, *igus@deneb1.odessa.ua*
[2] Dpt of Physics and Astronomy, University of North Carolina
Greensboro, NC 27402-6170, USA *a_mirosh@uncg.com*
[3] Special Astrophysical Observatory, Russian Academy of Sciences
Nizhnij Arkhyz, Karachaevo-Cherkessia, 369167 Russia *valenta@sao.ru; panch@sao.ru*

ABSTRACT. We present the results of the radial velocity (RV) measurements of metallic lines as well as H_α (H_β) 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 H_α 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 H_α line core as dynamical changes in the envelope around Polaris Aa.

Key words: - Stars: Cepheids - Stars: radial velocities - Stars: H_α 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 H_α 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 H_α cores, thereas short-period ones be noted by more smoothed, so called knifelike form. Besides, a slight change in the RV of the H_α 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 H_α (in some cases H_β) 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 ($\lambda\lambda$ 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 ($\lambda\lambda$ 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 ($\lambda\lambda$ 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, H_α and H_β, respectively.

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

As seen in Table 1 and Fig. 1, originally the difference between the measurements obtained from metal lines and H_α (and one H_β) for each spectrum does not exceed 1.5 km/s in 1994. As seen from Fig. 2, the H_α core does not demonstrate any visible asymmetries.

Table 1: Radial velocity data of Polaris Aa in 1994–2010

Spec-trum	HJD 2400000+	Tele-scope	Metallic lines *RV*	σ	NL	H_α *RV*	H_β *RV*
940609	49512.615	1	-13.28	1.23	126	-14.78	-
940815	49579.824	1	-14.21	1.21	116	-15.53	-
940908	49603.853	1	-13.35	0.93	152	-	-14.34
941012	49637.792	1	-14.97	1.05	132	-16.69	-
941023	49648.810	1	-14.38	1.07	130	-15.53	-
s22923	51240.612	3	-18.26	2.81	302	-19.98	-
s23908	51360.538	3	-16.51	2.36	317	-16.48	-
s24008	51361.536	3	-14.53	2.68	275	-15.33	-16.82
011009	52192.858	2	-16.88	0.81	281	-19.23	-
020522	52416.655	1	-16.53	1.17	138	-18.18	-
020523	52417.616	1	-17.67	1.45	145	-19.35	-
020527	52421.679	1	-17.85	1.32	109	-19.46	-
020601	52426.667	1	-18.18	1.28	121	-20.39	-
020602	52427.650	1	-17.35	3.06	119	-18.33	-
020610	52435.634	1	-16.53	1.18	142	-19.19	-
020616	52441.673	1	-16.78	1.08	112	-20.35	-
s36713	52514.575	3	-20.39	0.92	270	-22.54	-
s36814	52515.588	3	-15.33	0.86	396	-	-15.77
s40008	52782.543	3	-16.62	0.60	374	-	-16.41
031013	52833.741	1	-21.64	1.30	93	-14.25	-
031017	52837.678	1	-21.59	6.07	104	-17.13	-
031019	52839.746	1	-23.97	4.00	111	-15.07	-
s40410	52861.560	3	-17.76	0.73	279	-20.47	-
s40819	52867.562	3	-17.75	0.79	251	-20.25	-
s40921	52869.570	3	-16.62	0.76	247	-19.08	-
s41209	52891.600	3	-16.38	0.89	384	-	-15.76
031109	52952.700	1	-19.19	1.37	90	-7.46	-
0312131	52986.692	1	-18.48	1.89	125	-10.53	-
0312132	52986.709	1	-17.86	1.67	107	-9.31	-
040101	53005.595	1	-16.50	1.13	141	-8.17	-
s42006	53015.167	3	-17.79	0.88	279	-19.81	-
s42202	53019.108	3	-17.28	0.82	266	-19.22	-
s42302	53072.165	3	-17.81	0.64	251	-20.09	-
s42327	53072.631	3	-18.02	0.77	291	-20.17	-
s42421	53073.622	3	-17.52	0.80	278	-19.69	-
s42502	53131.194	3	-18.21	0.98	549	-18.40	-
s43302	53246.192	3	-16.50	0.73	281	-19.22	-
s43812	53285.167	3	-17.08	0.85	304	-19.06	-
041227	53367.091	2	-20.51	3.84	261	-23.39	-
s45233	53686.647	3	-17.68	1.05	198	-	-17.54
s45328	53687.637	3	-15.82:	1.00	616	-	-16.48
s45531	53689.649	3	-18.24	1.20	589	-18.60	-
s45602	53690.111	3	-17.80	1.13	566	-17.50	-
s45821	53691.635	3	-17.82	1.06	550	-17.34	-
s45902	53693.124	3	-17.93	1.06	549	-18.41	-
s463002	53751.123	3	-16.83	1.21	581	-	-16.72
s466002	53808.277	3	-18.78	1.55	933	-	-19.43
s469012	53904.348	3	-17.87	1.09	506	-	-17.21
s478030	53980.588	3	-17.40	1.29	569	-17.20	-
s482001	54073.591	3	-18.43	1.15	579	-17.88	-
s485029	54077.653	3	-17.58	1.21	406	-	-17.27
s494030	54169.639	3	-19.18	1.09	415	-	-20.09
s497012	54225.226	3	-18.92	1.25	592	-18.59	-
s504049	54344.551	3	-19.41	1.04	464	-18.47	-
s510001	54426.185	3	-16.65	1.19	603	-16.26	-
s532015	54934.587	3	-17.19	1.10	573	-16.61	-

1 - 1m Ritter Observatory;

2 - 2.1m McDonald Observatory;

3 - 6m Special Astrophysical Observatory, Russian Academy of Sciences.

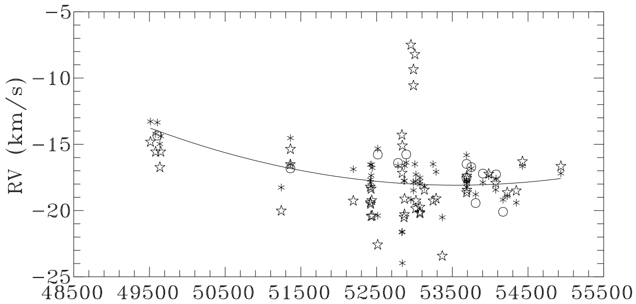

Figure 1: Radial velocity estimates of Polaris Aa during 1994–2010. Six-point stars, - estimates from metal lines, open five-point stars, - from H_α line, open circles, - from H_α line. A square polynomial approximation is drawn for the metal lines.

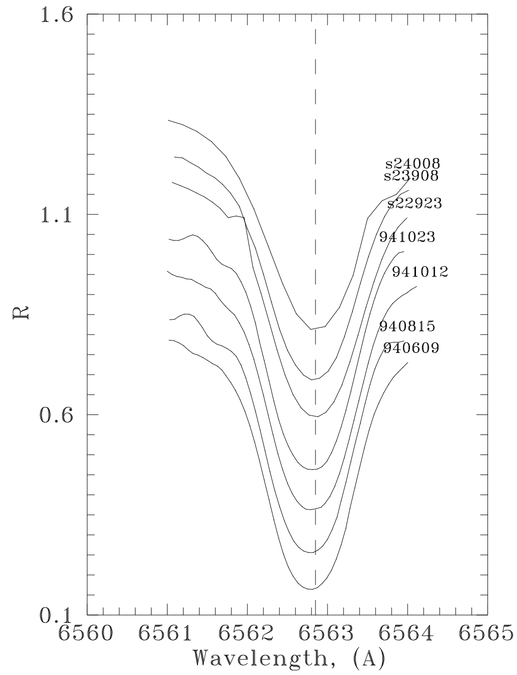

Figure 2: H_α line core profiles of Polaris Aa during 1994–1999.

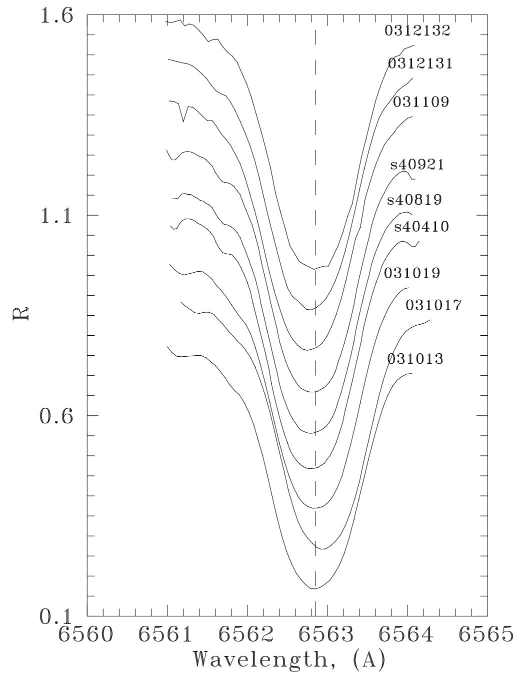

Figure 3: H_α line core profiles of Polaris Aa during 2003

Since 1999 (HJD 2451240–2451361), this difference begins to increase (Fig. 1) and a slight asymmetry on the red side of the H_α 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

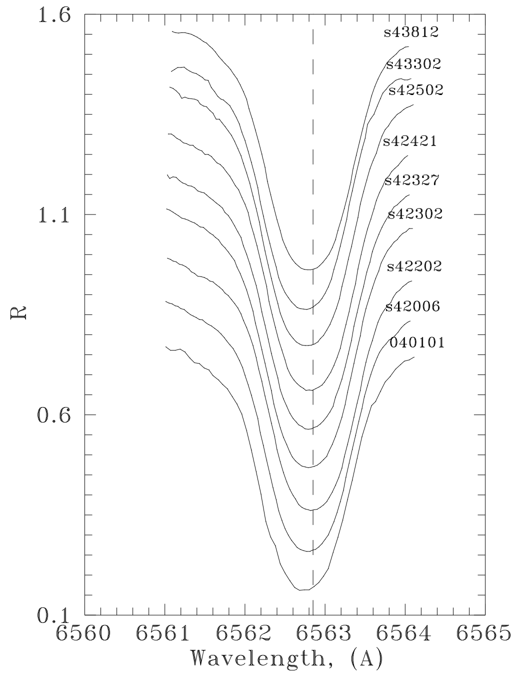

Figure 4: H_α line core profiles of Polaris Aa during 2004

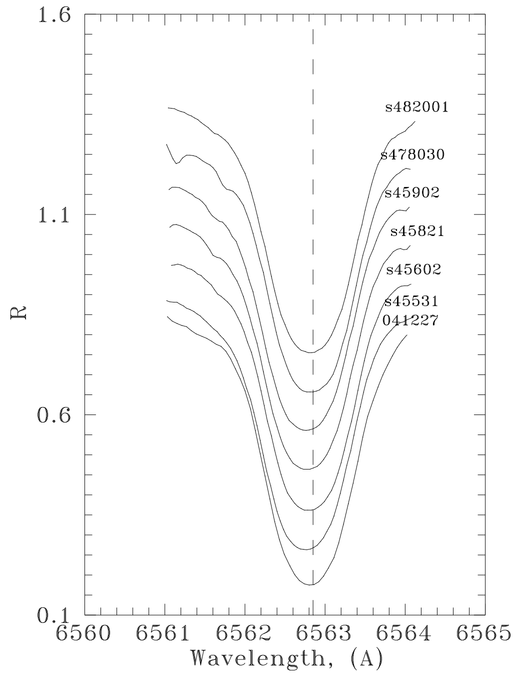

Figure 5: H_α line core profiles of Polaris Aa during 2005–2006

the core get quite visible (Fig. 3) during two years (2001–2002).

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 H_α core shows asymmetries on the red side as well as on the blue side (see Fig. 4).

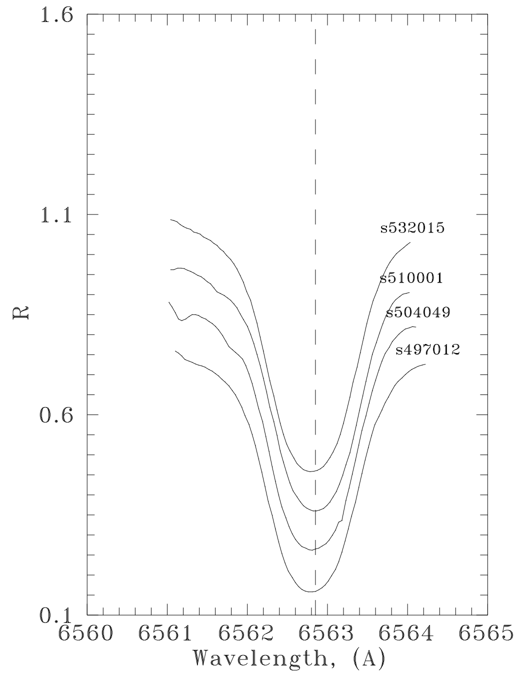

Figure 6: H_α line core profiles of Polaris Aa during 2008–2010

Since 2004 this difference decreases to 2–2.5 km/s (HJD 2453015–2453367), and the H_α 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 H_α and H_β 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 H_α and H_β are very small and close to those determined from the metallic lines.

2. First H_α 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 H_α core reaches 8–12 km/s. This event is accompanied by

the pronounced asymmetries of the H_α core on the red side as well as on the blue side.

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

5. H_α 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_α core during 2003 could be explained by dynamical changes in the envelope around of Polaris Aa.

Acknowledgments. This study was financially supported by the SCOPES Swiss National Science Foundation (project no. IZ73Z0152485).

References

Galazutdinov G.A.: 1992, *Preprint SAO RAS*, **No.92**, 1.
McCarthy J.K., Sandiford B.A., Boyd D., Booth J.: 1993, *PASP*, **105**, 881.
Mérand A., Kervella P., Coudé du Foresto V., Perrin G. et al.: 2006, *A&A*, **453**, 155.
Panchuk V.E., Klochkova V.G., Galazutdinov G.A., Radchenko V.P., Chentsov E.L.: 1993, *AstL*, **19**, 431.
Panchuk V.E., Najdenov I.D., Klochkova V.G., Ivanchik A.B., Yermakov S.V., Murzin V.A.: 1997, *Bull. SAO RAS*, **44**, 127.
Panchuk V.E., Klochkova V.G., Nadenov I.D., Yushkin M.V.: 2006, *The Ultraviolet Universe: Stars from Birth to Death, 26th Meeting of the IAU, Joint Discussion 4, 16-17 Aug. 2006, Prague, Czech Republic*, **D04**, 14.
Usenko I.A., Kniazev A.Yu., Berdnikov L.N., Kravtsov V.V., Fokin A.B.: 2013, *AstL*, **39**, 432.
Usenko I.A., Kniazev A.Yu., Berdnikov L.N., Fokin A.B., Kravtsov V.V.: 2014a, *AstL*, **40**, 435.
Usenko I.A., Kniazev A.Yu., Berdnikov L.N., Kravtsov V.V.: 2013b, *AstL*, **40**, 800.
Usenko I.A., Klochkova V.G.: 2015 *AstL*, **41**, 351.