DOI: http://dx.doi.org/10.18524/1810-4215.2017.30.114382

PULSATIONAL ACTIVITY OF THE SMALL–AMPLITUDE CEPHEID POLARIS (α UMi) IN 2016-2017

I. A. Usenko[1,2], V. V. Kovtyukh[1], A. S. Miroshnichenko[3], S. Danford[3]

[1] Astronomical Observatory, Odessa National University, Shevchenko Park, Odessa 65014, Ukraine, *vkovtyukh@ukr.net*

[2] Mykolaiv Astronomical Observatory, Obsevatorna 1, Mykolaiv 54030, Ukraine, *igus99@ukr.net*

[3] Dept. of Physics and Astronomy, University of North Carolina at Greensboro, P.O. Box 26170, Greensboro, NC 27402, USA, *a_mirosh@uncg.edu; danford@uncg.edu*

ABSTRACT. We present the results of an analysis of 49 spectra of α UMi (Polaris) obtained during August – December 2016 and January – March 2017. Frequency analysis displays an unexpected decrease of the pulsational period up to 17.3 min in comparison to the 2015 observational set. The radial velocity amplitude was reduced to 3.43 km s^{-1} in 2016 and to 3.31 km s^{-1} in the beginning of 2017 in comparison with 4.16 km s^{-1} in 2015. This result is also unexpected, because during the last decade a gradual amplitude growth has been observed. The average T_{eff} = 6021 K determined from the 2016–2017 data is close to the values determined for the 2001–2015 set.

Key words: Stars: radial velocities; Cepheids: effective temperatures; Cepheids: α UMi

1. Introduction

In our previous papers (Usenko et al., 2016; Usenko et al., 2017) we found that in 2015 the pulsational period and radial velocity amplitude of Polaris had increased. The former was 8.6 min longer compared to the 2007 data, and the latter became 4.16 km s^{-1} (twice the one of 2007 data). The average T_{eff} = 6017 K, and it is close to the value determined for the 2001–2004 set. These facts allow us to make a conclusion about the Cepheid movement to the red edge of the Cepheids instability strip (CIS). Since Polaris is a peculiar Cepheid demonstrating an increase of its pulsational activity after a long-term decrease, it needs high-quality continuous observations with both photometry and spectroscopy.

2. Observations and frequency analysis

Thirty seven spectra were taken in August–December 2016 and twelve in January – March 2017 with the 0.81 m telescope of the Three College Observatory (TCO), located in central North Carolina, USA. They were obtained with an échelle spectrograph manufactured by Shelyak Instruments[1] in a spectral range from 4250 to 7800 Å with a spectral resolving power of $R \sim 12000$ and no gaps between the spectral orders. The data were reduced using the *échelle* package in IRAF.

DECH30 package (Galazutdinov, 2007) allows to measure the line depths and radial velocities using spectra in FITS format. Lines depths were used to determine the effective temperature (a method based on the spectroscopic criteria, Kovtyukh, 2007).

Derived values of T_{eff} and radial velocity for each spectrum are given in Table 1.

In the next step, we used the PERIOD04 program (Lenz & Breger, 2005), which employs the Fourier and Fast Fourier Transform analysis and minimizes the residuals of sinusoidal fits to the data.

A Fourier amplitude spectrum was obtained over a frequency range of 0–1 d^{-1} with a resolution of 0.00002 d^{-1}. The highest amplitude of 1.97 corresponds to a frequency of 0.252403 ± 0.000255 d^{-1}, or a period of 3.96192 ± 0.004 days, respectively. This period is 17.3 minutes shorter compared to that of 3.97394 days determined from the 2015 data set. The systemic velocity (γ – velocity) is equal to -12.50 ± 1.48 km s^{-1}.

The following ephemeris has been computed based on the radial velocity values:

$$RV_{\min} = HJD\,2457685.737 + 3.96192 \times E \quad (1)$$

[1] http://www.shelyak.com

Table 1: Observational data of α UMi

HJD	T_{eff}	σ	Phase	RV (km s^{-1})					
2450000+	K	K		Metals	σ	NL	H_α	H_β	H_γ
7623.5721	6016	17	0.309	–12.52	1.31	165	–11.72	–12.34	–11.80
7627.5674	6003	19	0.318	–12.47	1.60	154	–12.56	–13.09	–12.24
7636.6104	6035	18	0.600	–13.28	1.40	173	–11.36	–11.64	–11.72
7637.6578	6075	23	0.865	–15.43	1.78	170	–14.57	–15.06	–15.21
7638.6128	6039	22	0.106	–15.04	1.52	151	–14.37	–14.15	–15.30
7640.5840	6046	25	0.603	–11.86	1.63	155	–10.62	–11.89	–12.73
7646.6272	6064	23	0.129	–13.66	1.67	167	–14.39	–14.29	–14.89
7656.5042	6039	16	0.622	–12.30	1.86	152	–11.70	–11.80	–12.27
7663.5326	5981	17	0.396	–11.33	1.52	151	–11.45	–11.94	–11.67
7666.5895	6058	20	0.167	–12.71	1.42	166	–14.23	–14.03	–13.95
7671.6202	6021	16	0.437	–10.97	1.37	143	–10.70	–11.38	–12.13
7672.5231	6054	17	0.665	–12.15	1.51	146	–12.49	–11.68	–11.78
7679.6214	5992	17	0.456	–11.38	1.70	165	–10.02	–10.81	–12.77
7684.5583	6017	15	0.703	–11.95	1.58	159	–12.27	–11.76	–12.44
7685.5899	6035	17	0.963	–14.60	1.65	164	–15.62	–15.05	–14.84
7686.5955	5998	15	0.217	–13.29	1.33	161	–13.02	–13.34	–13.76
7687.6101	6040	17	0.473	–10.92	1.52	165	–10.25	–10.54	–10.91
7690.6666	6020	19	0.244	–12.79	1.27	159	–13.16	–12.89	–13.75
7695.5187	5935	20	0.469	–11.06	1.37	168	–10.79	–10.27	–12.08
7697.5328	6017	15	0.977	–14.50	1.34	158	–14.20	–14.31	–14.05
7699.5794	6004	17	0.494	–10.39	1.43	169	–10.06	–10.64	–11.71
7703.5998	6011	18	0.509	–10.53	1.51	159	–9.71	–10.60	–10.71
7705.5479	6028	15	0.000	–14.72	1.43	164	–14.44	–14.70	–14.92
7708.6107	6079	19	0.773	–12.55	1.36	163	–12.80	–12.40	–13.18
7709.6391	6042	18	0.033	–14.46	1.44	158	–14.76	–14.48	–15.60
7710.6093	5966	14	0.278	–12.58	1.55	164	–12.41	–12.83	–13.83
7713.5625	6049	13	0.023	–14.40	1.33	167	–14.36	–14.20	–14.18
7714.5859	5997	14	0.282	–12.00	1.12	157	–11.64	–11.95	–11.32
7715.5773	5990	20	0.532	–10.55	1.53	159	–10.01	–10.47	–10.20
7719.5312	5984	17	0.530	–10.59	1.52	155	–9.94	–10.19	–10.88
7724.5379	6034	22	0.794	–12.85	1.39	163	–12.11	–13.02	–12.39
7725.6085	6024	19	0.064	–14.52	1.40	169	–14.20	–13.85	–13.55
7731.5661	6017	19	0.567	–10.66	1.58	164	–10.21	–10.42	–9.30
7732.5298	6045	17	0.811	–13.28	1.46	155	–13.47	–13.25	–14.03
7738.6107	5990	21	0.346	–11.97	1.23	169	–11.72	–11.79	–12.40
7743.5390	6016	21	0.589	–9.74	1.36	151	–9.79	–10.78	–9.87
7744.6051	6015	16	0.859	–12.37	1.32	163	–11.64	–11.95	–11.32
7772.5311	6031	16	0.907	–13.40	1.18	159	–13.07	–13.20	–13.05
7780.5681	6014	23	0.936	–13.41	1.28	164	–13.53	–12.99	–12.14
7782.5585	5995	19	0.438	–10.77	1.16	167	–10.41	–11.18	–10.44
7789.5451	6024	16	0.202	–12.69	1.34	159	–13.05	–12.80	–13.10
7794.5778	5997	21	0.472	–10.27	1.27	168	–9.92	–10.18	–10.59
7798.5661	5969	23	0.478	–10.34	1.25	165	–10.17	–11.54	–12.36
7802.5420	5995	13	0.482	–10.15	1.35	169	–9.75	–10.73	–10.51
7804.5477	6086	15	0.988	–12.90	1.39	158	–12.77	–13.16	–12.04
7808.6782	6058	20	0.031	–13.09	1.33	158	–14.09	–13.58	–13.96
7810.6837	5993	18	0.537	–10.11	1.23	168	–9.85	–10.06	–10.34
7815.6644	6040	13	0.794	–11.33	1.33	159	–11.43	–10.89	–8.42
7816.7154	6080	16	0.059	–13.19	1.13	164	–13.28	–13.25	–13.90

The effective temperature and radial velocity data for each spectrum along with the pulsational period phases are shown in Table 1.

Figure 1 represents phase curves of the Polaris radial velocity (lower panel) and effective temperature (upper panel) variations between August 2016 and March 2017. As seen in this Figure, the 2016 data have a lager (within an uncertainty of 1.48 km s^{-1}) amplitude compared to the 2017 data. In case of the data approximations by sinusoidal curves, the mean amplitudes of the radial velocity curves are 3.43 km s^{-1} and 3.31 km s^{-1}, respectively.

The effective temperature variations show no significant changes, and the average values are 6021±18 K and 6024±18 K for the 2016 and 2017 data, respectively. These values are close to 6017 K derived for the 2015 and for the 2001 – 2004 set.

Figure 2 demonstrates the radial velocity amplitude variations in the last ∼125 years. As seen in this Figure, the 2016/2017 data are below that of 2015, but the amplitude growth tendency still remains.

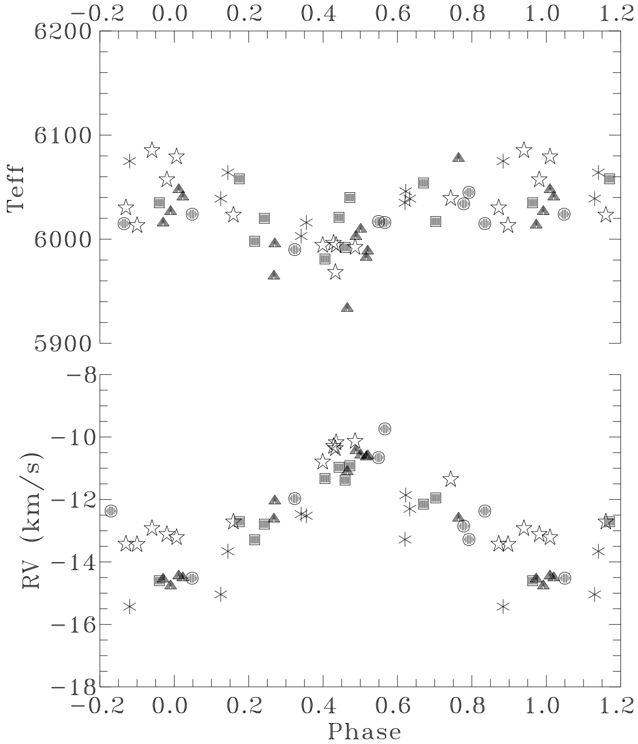

Figure 1: The effective temperature and radial velocity variations of Polaris during its pulsational period. Symbols of the data are: six-pointed stars - August–September 2016, squares - October 2016, triangles – November 2016, circles – December 2016, five-pointed stars – January–March 2017.

3. Summary

1. As seen from the results of our observations, the pulsational period of Polaris shows an abrupt decrease in comparison with the measurements obtained in 2015. This fact is very unusual and needs a careful verification. The last such a rapid pulsational period change took place in 1956 (Turner et al., 2005). Therefore in order to confirm this result, spectroscopic monitoring has to continue to obtain as many radial velocity measurements as possible.

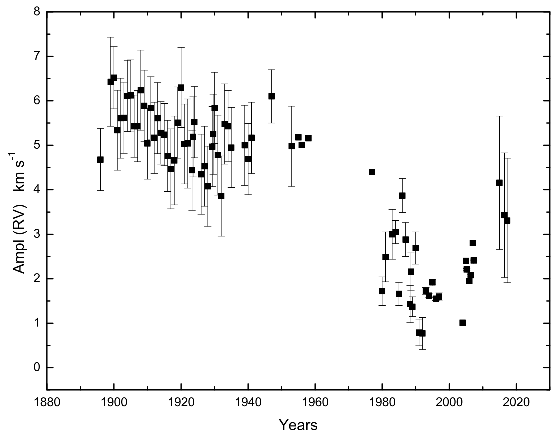

Figure 2: Radial velocity amplitude variations of Polaris over the last ∼125 years.

2. The mean amplitude of the radial velocity in 2016 – 2017 decreased by nearly 0.8 – 0.9 km s^{-1} compared to the 2015 data. Nevertheless, the pulsational amplitude growth tendency still remains.

3. The mean effective temperature of Polaris for this data set averages at 6017 – 6024 K. This value is close to 6015 – 6017 K determined for the set of 2001–2004 and 2015 data (Usenko et al., 2005; Usenko et al., 2016; Usenko et al., 2017).

References

Galazutdinov G.A.: 2007, *http://gazinur.com/DECH-software.html.*

Kovtuykh, V.V.: 2007, *MNRAS* **378**, 617

Lenz P. & Breger M.: 2005, *Commun. Astroseismology*, **146**, 53.

Turner D.G., Savoy J., Derrah J., Sabour M.A., Berdnikov L.N.: 2005, *AJ*, **117**, 207.

Usenko I.A., Miroshnichenko A.S., Klochkova V.G., Yushkin M.V.: 2005, *MNRAS*, **362**, 1219.

Usenko I.A., Kovtyukh V.V., Miroshnichenko A.S., Danford S.: 2016, *Odessa Astron. Publ.*, **29**, 100.

Usenko I.A., Kovtyukh V.V., Miroshnichenko A.S., Danford S.: 2017, *Nauka Innov.*, **13(1)**, 109.