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

I. A. Usenko1,2, V. V. Kovtyukh1, A. S. Miroshnichenko3, S. Danford3
1 Astronomical Observatory, Odessa National University, Shevchenko Park, Odessa 65014, Ukraine, ukovtyukh@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 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 \(T_{\text{eff}}\) = 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 \(T_{\text{eff}}\) = 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\(^3\) 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 \(T_{\text{eff}}\) 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 (\(\gamma – \text{velocity}\)) is equal to \(-12.50\pm1.48\) km s\(^{-1}\).

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

\[
RV_{\text{min}} = HJD 2457685.737 + 3.96192 \times E \quad (1)
\]

\(^3\)http://www.shelyak.com
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 larger (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.

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.

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).

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