

DOI:<http://dx.doi.org/10.18524/1810-4215.2019.32.182238>

PULSATIONAL ACTIVITY OF THE SMALL-AMPLITUDE CEPHEID POLARIS (α UMi) IN 2018-2019

I. A. Usenko^{1,2}, A. S. Miroschnichenko^{3,4,5}, S. Danford³, V. V. Kovtyukh¹

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 261170, Greensboro, NC 27402, USA, a_mirosh@uncg.edu; danford@uncg.edu

⁴ Main Astronomical Observatory of the Russian Academy of Sciences,
Pulkovskoe shosse 65-1, Saint-Petersburg, 196140, Russia

⁵ Fesenkov Astrophysical Institute, Observatory 23, Almaty, 50020, Kazakhstan

ABSTRACT. We present the results of an analysis of 20 spectra of α UMi (Polaris) obtained in September 2018 – January 2019 using 0.81 m telescope of the Three College Observatory (TCO), North Carolina, USA. Frequency analysis displays an increase of the pulsational period up to 3.68 min in comparison to the August - December 2017 - January - May 2018 observational sets, and it come to 3.973216 days. The systemic velocity (γ – velocity) is equal to -11.75 km s^{-1} . The radial velocity amplitude rose to 3.50 km s^{-1} and actually returned to the previous values of 3.43 , 3.31 , and 3.81 km s^{-1} , respectively, found from the August - December 2016, January - March 2017 and August - December 2017 sets. The radial velocity's amplitude growth tendency still remains. The average $T_{\text{eff}} = 6051 \pm 22$ K shows a growth toward the value found from the 2005 – 2007 observational sets and probably has a tendency toward the T_{eff} growth. The joint TCO and *Hermes* radial velocity measurements during the last four years show the changes of Polaris' pulsational amplitude.

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

АНОТАЦІЯ. Ми презентуємо результати аналізу 20 спектрів α UMi (Полярної), які були отримані на протязі вересня - грудня 2018 та січня 2019 років за допомогою 0.81 м телескопу Обсерваторії Трьох Колледжів (Three Colledge Observatory, TCO) штат Північна Кароліна, США. Частотний аналіз виявив зріст періода пульсації на 3.68 хв у порівнянні з спостережними сетами серпня - грудня 2017 та січня - травня 2018 років та рівний 3.973216 днів. Швидкість системи, або (γ – velocity) виявилася

рівною -11.75 km s^{-1} . Амплітуда радіальної швидкості досягла 3.50 km s^{-1} , та повернулася приблизно на рівень попередніх оцінок у 3.43 , 3.31 , and 3.81 km s^{-1} , відповідно, які були встановлені для сетів серпня - грудня 2016, січня - березня 2017 та серпня - грудня 2017 років. Тенденція зростання амплітуди радіальної швидкості все ще зберігається. Середня $T_{\text{eff}} = 6051 \pm 22$ K, та вона показує зріст до результатів сетів 2005 – 2007 років, та, вірогідно, має тенденцію до зростання. Сумісні оцінки радіальних швидкостей, отриманих на TCO та *Hermes* за останні чотири роки показують зміни пульсаційної амплітуди Полярної.

Ключові слова: Зорі: радіальні швидкості; цефеїди: ефективні температури; цефеїди: пульсаційні періоди; цефеїди: α UMi

1. Introduction

In our previous papers (Usenko et al. 2016, 2017, 2018) we found that the pulsational period and radial velocity amplitude of Polaris had increased in 2015–2018.

The former was up 8.6 minutes in comparison to the data from 2007, and the latter became 4.16 km s^{-1} (twice the one of the 2007 data). The average $T_{\text{eff}} = 6017$ K is close to the value determined from the 2001–2004 set. During August – December 2016 (37 spectra) and January – March 2017 (12 spectra) the pulsation period decreased by 17.3 min in comparison with the 2015 data. The radial velocity amplitude decreased to 3.43 km s^{-1} in 2016 and to 3.31 km s^{-1} in the beginning of 2017. The average T_{eff} was 6021

Table 1: Observational data of α UMi during September - December 2018 and January 2019

Date	HJD	T_{eff}	σ	Phase	Metals	σ	RV (km s ⁻¹)	H_{α}	H_{β}	H_{γ}
YY/MM/DD	2450000+	K	K				NL			
180906	8368.5931	6058	21	0.934	-14.49	1.70	176	-14.45	-14.84	-14.67
181019	8411.4928	6057	20	0.731	-11.50	1.77	159	-12.23	-9.93	-8.58
181021	8413.5843	6055	19	0.258	-11.68	1.68	189	-12.23	-8.92	-10.96
181024	8416.5683	6073	23	0.009	-13.01	1.61	173	-13.42	-7.80	-11.84
181029	8421.6551	5984	18	0.289	-11.19	1.78	166	-11.20	-7.53	-10.24
181030	8422.6439	5969	21	0.538	-9.95	1.86	157	-9.47	-4.03	-8.90
181116	8439.6274	6038	22	0.812	-12.35	1.69	147	-12.07	-9.87	-11.31
181117	8440.6117	6086	21	0.060	-13.20	1.91	155	-13.40	-10.75	-12.20
181119	8442.6074	6050	21	0.562	-10.69	1.86	163	-10.18	-6.94	-8.58
181120	8443.6292	6117	23	0.819	-12.37	1.60	153	-13.25	-8.88	-11.26
181205	8458.6511	6074	21	0.600	-10.72	1.48	158	-11.30	-8.21	-8.81
181216	8469.5308	6007	21	0.338	-11.29	1.47	159	-10.92	-8.52	-9.70
181217	8470.5557	6083	25	0.596	-10.63	1.59	164	-10.74	-6.97	-9.46
181222	8475.5715	6095	24	0.859	-13.30	1.20	161	-14.05	-9.15	-11.57
181224	8477.5626	5948	20	0.360	-11.40	1.34	159	-10.33	-8.56	-9.44
181226	8479.5699	6102	22	0.865	-13.09	1.45	170	-13.39	-10.70	-12.34
190105	8489.5582	6041	20	0.379	-11.07	1.51	164	-10.38	-7.44	-9.77
190115	8499.5614	6090	22	0.897	-11.85	1.37	160	-11.89	-8.81	-10.80
190125	8509.5801	6050	22	0.418	-10.21	1.46	171	-10.12	-7.02	-8.83
190130	8514.6088	6042	27	0.684	-11.03	1.63	170	-11.47	-9.57	-9.53

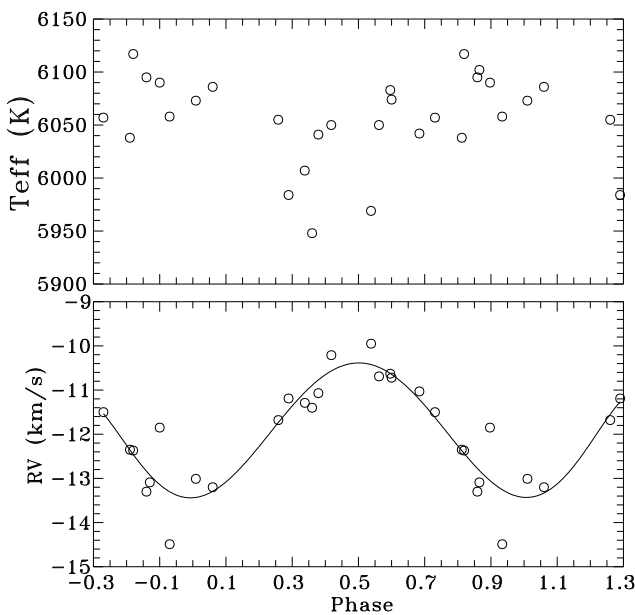


Figure 1: The effective temperature and radial velocity variations of Polaris folded with its pulsational period for the September – December 2018 and January 2019 set.

K with amplitudes of 54 K and 70 K, respectively. Instead during August–December 2017 (29 spectra) and January–May 2018 (38 spectra) the pulsational period increased to 3.^d970662 but was still less than 3.^d979872 observed in 2015. The mean radial velocity amplitudes in these sets were 3.81 km s⁻¹ and 2.80 km s⁻¹ respectively, i.e. a new amplitude decrease was obvious. The average values of T_{eff} were found to be 6017 K and 6039 K, respectively, but the T_{eff} amplitude has increased despite the decrease in the radial velocity amplitude. Therefore we have to continue our investigation to study this unusual behavior of Polaris.

2. Observations and frequency analysis

Sixteen spectra were taken in September–December 2018 and four in January 2019 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 Instruments¹ 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). The 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 corresponds to a frequency of 0.251685 ± 0.000255 d⁻¹ or 3.973216 ± 0.004 days, respectively. This period is larger by 3.68 minutes compared to that of 3.970662 days determined from the August – December 2017 and January – May 2018 observational set. The systemic velocity (γ – velocity) is equal to -11.75 km s⁻¹.

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

$$RV_{\min} = HJD\ 2458440.3736 + 3.973216 \times E \quad (1)$$

Figure 1 represents phase curves of the Polaris radial velocity (lower panel) and effective temperature (upper panel) variations during our observational set.

¹<http://www.shelyak.com>

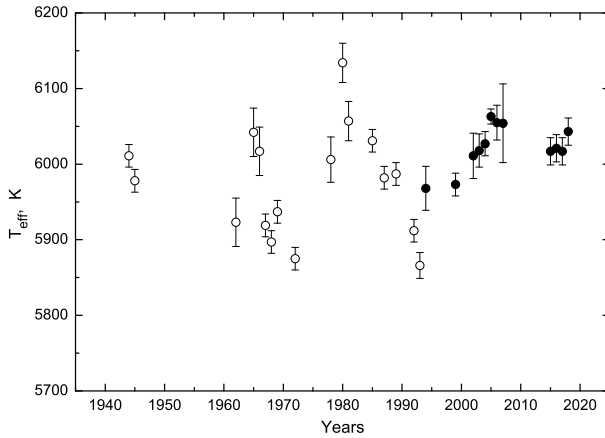


Figure 2: Variations of the mean effective temperature of Polaris during the last 75 years. Open circles show values from the $(B - V)$ vs. T_{eff} relationship by Gray (1992), filled circles show values from the line depth ratios (Kovyukh 2007).

As seen in Figure 1, in case of the data approximations by sinusoidal curves, the mean amplitudes of the radial velocity curves are 3.50 km s^{-1} , and it is somewhat larger compared to the January – May 2018 result ($A_{RV} = 2.80 \text{ km s}^{-1}$). However, it is comparable with our previous results (August - December 2016, January - March 2017 and August - December 2017 with $A_{RV} = 3.43, 3.31, \text{ and } 3.81 \text{ km s}^{-1}$, respectively).

The effective temperature variations show remarkable changes – their mean and maximum values have increased in comparison to those from previous sets with the average value of $6051 \pm 22 \text{ K}$. This value is close to the result derived from the 2005–2007 sets (Usenko et al. 2018), and probably has a tendency toward the T_{eff} growth. Figure 2 shows the variations of the mean T_{eff} of Polaris during the last 75 years, while Figure 3 demonstrates the radial velocity amplitude variations in the last ~ 125 years. As seen in Figure 3, the amplitude growth tendency still remains.

It would be interesting to compare our TCO 2015 – 2019 radial velocity measurements with those obtained by Anderson (2019) taken with the *Hermes* spectrograph. As seen in Figure 4, there is a good agreement between the TCO and *Hermes* data, therefore we can observe their positional relationship and changes of the pulsational amplitude during the last four years.

3. Summary

1. As seen from the results of our observations, the pulsational period of Polaris shows an increase by 3.68 minutes in comparison with the data obtained during the August - December 2017 and January - May 2018 observational set.

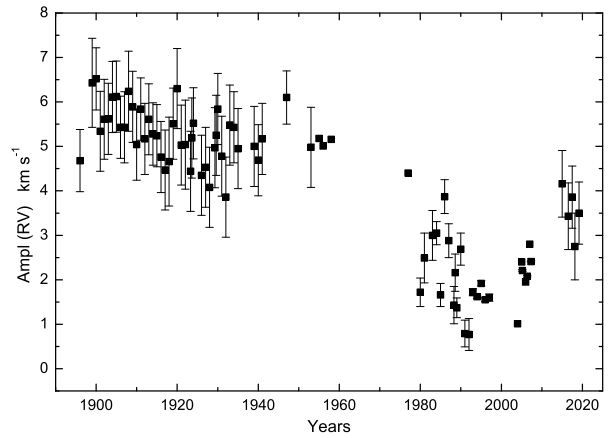


Figure 3: Radial velocity amplitude variations of Polaris over the last ~ 125 years.

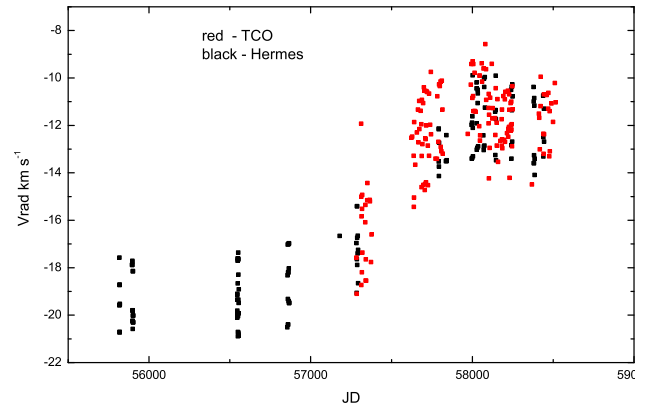


Figure 4: Radial velocity variations of Polaris over the last ten years. Red squares - TCO data, black squares - *Hermes* data.

2. The mean amplitude of the radial velocity during this observational set 3.50 km s^{-1} has returned to that of the previous sets of August - December 2016, January - March 2017 and August - December 2017. Nevertheless the pulsational amplitude growth tendency still remains.
3. The mean effective temperature of Polaris for this data set was found to be $6051 \pm 22 \text{ K}$. This value is close to those determined for the 2005–2007 sets (Usenko et al. 2018).
4. All the TCO radial velocity measurements during 2015 – 2019 have a good agreement with those measured from *Hermes* data. The joint data show the changes of Polaris' pulsational amplitude.

References

- Anderson R.I.: 2019, *A&A*, **623**, 146.
- Galazutdinov G.A.: 2007, <http://gazinur.com/DECH-software.html>.
- Gray D.: 1992, *Observation and Analysis of Stellar Atmospheres*, 2nd edn. Cambridge Univ. Press, Cambridge.
- Kovtuykh V.V.: 2007, *MNRAS*, **378**, 617.
- Lenz P. & Breger M.: 2005, *Commun. Astroseismology*, **146**, 53.
- Usenko I.A., Kovtuykh V.V., Miroshnichenko A.S., Danford S.: 2016, *Odessa Astron. Publ.*, **29**, 100.
- Usenko I.A., Kovtuykh V.V., Miroshnichenko A.S., Danford S.: 2017, *Nauka Innov.*, **13(1)**, 109.
- Usenko I.A., Kovtuykh V.V., Miroshnichenko A.S., Danford S., Prendergast P.: 2018, *MNRAS*, **481**, L115.