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LITHIUM-RICH CLASSICAL CEPHEID V1033 CYG: EVOLUTIONARY STATUS

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ABSTRACT. We investigate evolutional status of cepheid V1033 Cyg in this work, its period of light variation consists $4^d.94$ and the star is a real candidate on first crossing of instability stripe (IS) (as well as α of UMi). At first crossing of instability stripe, that lasts all close 1000 years, cepheids demonstrate the rapid increase of period, sometimes is a presence of strong line of lithium 6707 Å. Such objects knows only four in our Galaxy, one of them - V1033 Cyg. During included in a instability stripe amplitude of pulsations headily grows from a zero to some permanent size, and on leaving from (IS) - again falls to a zero. For verification this phenomenon in the Astronomical observatory of Odesa National University (Ukraine) on the 48-cm telescope AZT-3, equipped by CCD photometer with the optical sensor Sony ICX429ALL, a 1864 measuring of light V1033 Cyg were done in the filter of V and 713 in the filter R, that are partly presented in the Table. 1 and Fig. 2, and fully accessible to address http://cdsarc.ustrasbg.fr/viz-bin/cat. Considerable change of amplitude it is not got by us. The position of cepheid is certain by us in the (IS) - it appeared that star is near her center. In this phase evolutional to development and it must not be observed considerable change of amplitude (color index). The light curves, effective temperature and luminosity of V1033 Cyg are consistent with fundamental mode pulsation for a classical Cepheid on the center of the instability strip.

АНОТАЦІЯ. У даній роботі ми досліджуємо еволюційний статус цефеїди V1033 Cyg, період зміни блиску якої становить $4^d.94$, і яка є реальним кандидатом на перше перетинання смуги нестабільності (як і α UMi). При першому перетину смуги нестабільності (СН), який триває всього близько 1000 років, цефеїди демонструють швидке зростання періоду, інколи – наявність сильної лінії літія 6707 Å. Таких об'єктів відомо лише 4 у нашій Галактиці, одна з них – V1033 Cyg. Під час входу у смугу нестабільності амплітуда пульсацій стрімко зростає від нуля до якоїсь сталої величини, а при виході зі СН – знову падає до нуля. Для перевірки цього явища в Астрономічній обсерваторії Одеського національного університету (Україна) на 48-см телескопі АЗТ-3, оснащеному фотометром з ПЗЗ-матрицею Sony ICX429ALL, були зроблені 1864 вимірювання блиску V1033 Cyg в фільтрі V, і 713 вимірювань у фільтрі R, які частково наведені в табл. 1 та на рис. 2, а повністю доступні за адресою http://cdsarc.ustrasbg.fr/viz-bin/cat. Значної зміни амплітуди нами не отримано. Нами визначено положення цефеїди у смузі нестабільності – виявилося що вона знаходиться біля її центру. У цій фазі еволюційного розвитку і не повинно спостерігатися значної зміни амплітуди (показників кольору). Криві блиску, ефективна температура і світність V1033 Cyg відповідають стадії фундаментальних пульсацій класичних цефеїд у центрі смуги нестабільності.

Keywords: Stars: variables: Cepheids – V1033 Cyg

1. Introduction

V1033 Cyg (GSC 2674.03107), ($\alpha_{J2000.0} = 20^h05^m20.66^s$; $\delta_{J2000.0} = +32°39'32.5''$) is the classical cepheid variable star (GCVS) with amplitude $14.^m4 - 15.^m.5$ (pg) and period $4.^d937512$ (Samus' et al., 2011).

The variability of the star was found by Miller (1965), using the moments of brightness on 88 photographic plates, it has defined elements of light variation and has noted, that the period of cepheid quickly changes. The star was thoroughly investigated by L. Berdnikov (1987, 1992), L. Berdnikov et al. (2019), as the cepheid that crosses the instability strip for the first time. It was reported as a Cepheid with Li over-abundance by Luck & Lambert (2011).

2. Observations

The photometric CCD observations of V1033 Cyg were obtained at the Astronomical station near Odesa during the observation seasons in 2013-15 years, in V filter, later on, in 2017 year the observations were performed in V and R filters. We were using the 48 cm reflector AZT-3 of Astronomical observatory of Odesa National University, equipped with CCD photometer and Peltier cooler (Sony optical sensor ICX429ALL, ~600x800 pixels) in the f/4.5 Newtonian focus (Udovichenko, 2012).

The datasets consists of 1864 V-band and 713 R-band data points obtained from over 60 nights of observations. Two stars were chosen as comparison and check stars as close as possible in B-V color to variable. Comparison star is USNO-A 1200-14402731, $B_{comp} = 14.^{m}285$, $V_{comp} = 13.^{m}399$ (APASS, 2010), $R_{comp} = 12.^{m}800$ (NOMAD, 2005); check star is USNO-A 1200-14401158).

The standard reduction of the CCD frames were carried out by using the MUNIPACK (Motl, http://sourceforge.net/projects/c-munipack) software. The procedures for an aperture photometry is composed of the dark-level and flat-field corrections, determination of the instrumental magnitudes and precision. The photometry was transformed to the standard VRc Johnson-Cousins system by means of the differential photometry method (Benson 1998). The transformation coefficient was determined from observations of standard stars (Udovichenko 2012). The finding chart with market-out variable, comparison and check stars is shown in Fig. 1. The errors in individual data points vary from $0^{m}.005$ to $0^{m}.02$.

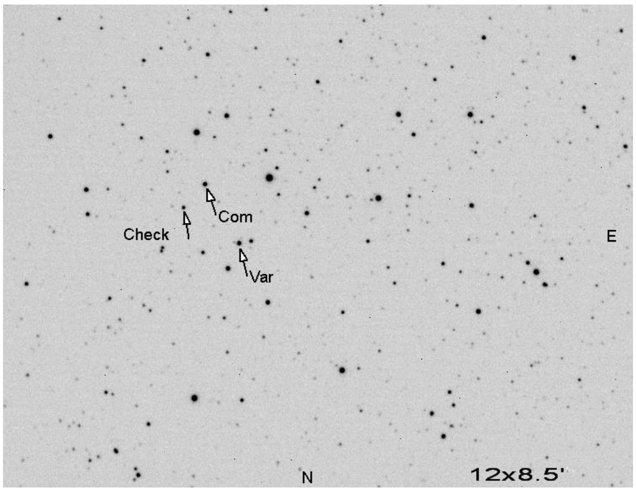

Figure 1: The finding chart V1033 Cyg with the comparison and check stars marked.

3. Results

Period. Using only the photoelectric moments of maximum from paper by Berdnikov et al (2019), current quadratic light elements of V1033 Cyg are obtained:

$$\text{MaxHJD} = 2452701.6164 + 4.9494727\ \text{E} + \\ +0.14237\ 10^{-5}\ \text{E}^2,$$

the phases calculated for these elements are given in Table 1. The phase curve V1033 Cyg from our observations and quadratic light elements is presented in Fig. 2.

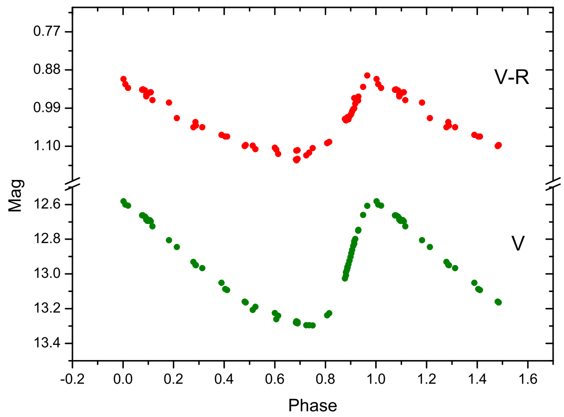

Figure 2: The phase curve in V-band and V-R color variations V1033 Cyg with quadratic light elements.

The O–C diagram covering more than 100 years indicates a rapid increase of the period of 18.2 s/yr, in agreement with a first crossing of the instability strip for this star (Berdnikov et al. 2019).

Amplitude. The Fourier decomposition was applied to Berdnikov's photoelectric and our CCD observations of V1033 Cyg. For the V-amplitude obtained values A_V= 0.724 mag (Berdnikov) and A_V=0.718 mag (our observations). Thus, there are no rapid evolutionary changes in the amplitude of V1033 Cyg.

Temperature. Using the $T_{\rm eff}$ vs (B–V) calibrations from the papers by Kovtyukh (2007) and Kovtyukh et al (2008), effective temperatures ($T_{\rm eff}$) for the Cepheid were obtained, its are shown in Fig. 3. The average effective temperature for V1033 Cyg is $<T_{\rm eff}> = 5864 \pm 45$ K (phases = 0.288 and 0.846).

Hertzsprung-Russell diagram. The absolute magnitude M_V=–3.13 is found using the "absolute magnitude–pulsational period" relation of Gieren et al. (1998). The loci of V1033 Cyg on the H-R diagram are shown in Fig. 4. Evolutionary tracks from Salasnich et al (2000) for Z=0.019 and [α/Fe]=0 are shown for reference. These models do not develop long blue loops for stars with 2–5 $M_\odot$, and hence they do not cross the instability strip. On the other hand, stars with 5–7 $M_\odot$ do show blue loops that cross the lower part of the cepheid instability strip.

In Figure 4 also shown the location of yellow

Table 1: V1033 Cyg. Observational list.

JDhel 2450000+	phase	V mag	$V-R$ mag	JDhel 2450000+	phase	V mag	$V-R$ mag	JDhel 2450000+	phase	V mag	$V-R$ mag
8335.4033	0.887	12.960	1.019	8341.3018	0.079	12.662	0.936	8365.3242	0.929	12.751	0.968
8335.4219	0.891	12.943	1.022	8342.3057	0.281	12.962	1.054	8365.4268	0.949	12.660	0.929
8335.4395	0.895	12.923	1.014	8342.3271	0.285	12.964	1.059	8366.2520	0.116	12.726	0.967
8335.4580	0.899	12.902	1.010	8343.2939	0.481	13.159	1.099	8374.2744	0.736	13.295	1.118
8335.4766	0.902	12.880	1.006	8343.3164	0.485	13.164	1.096	8375.2354	0.930	12.746	0.957
8335.4941	0.906	12.861	0.999	8344.3057	0.685	13.273	1.112	8379.2949	0.750	13.296	1.105
8335.5137	0.910	12.839	0.993	8344.3281	0.690	13.276	1.111	8380.3623	0.965	12.608	0.896
8335.5332	0.914	12.826	0.991	8345.2754	0.881	12.990	1.020	8381.4365	0.182	12.805	0.974
8335.5527	0.918	12.798	0.977	8345.2939	0.885	12.976	1.019	8382.4619	0.389	13.051	1.067
8336.4141	0.092	12.687	0.951	8345.3115	0.888	12.963	1.016	8383.5078	0.600	13.225	1.104
8336.4287	0.095	12.685	0.947	8346.2979	0.087	12.669	0.939	8390.4492	0.002	12.581	0.906
8336.4424	0.097	12.695	0.949	8346.3193	0.092	12.679	0.956	8397.3916	0.404	13.087	1.072
8337.3340	0.278	12.930	1.045	8347.2793	0.286	12.947	1.030	8398.3965	0.606	13.260	1.109
8337.3525	0.281	12.957	1.048	8347.2930	0.288	12.950	1.040	8399.3877	0.807	13.238	1.091
8337.3701	0.285	12.953	1.035	8348.4072	0.513	13.207	1.098	8400.3916	0.009	12.601	0.921
8339.3428	0.683	13.280	1.138	8351.3438	0.106	12.690	0.945	8401.4004	0.213	12.845	1.019
8339.3604	0.686	13.282	1.140	8351.3623	0.110	12.697	0.944	8402.3809	0.411	13.092	1.072
8339.3760	0.690	13.284	1.136	8362.2725	0.313	12.966	1.045	8403.3799	0.613	13.240	1.122
8340.3037	0.877	13.026	1.021	8363.3115	0.523	13.189	1.108	8404.3818	0.815	13.226	1.087
8340.3213	0.881	13.008	1.025	8364.3105	0.724	13.295	1.126	8405.3955	0.020	12.606	0.932
8341.2842	0.075	12.662	0.937	8365.2510	0.914	12.811	0.961				

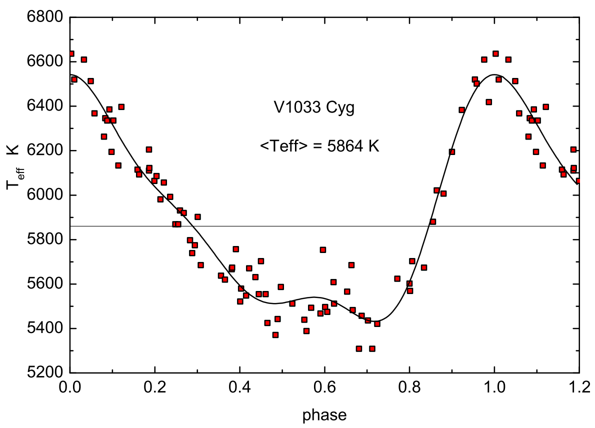

Figure 3: Variation of $T_{\rm eff}$ of V1033 Cyg with phase.

supergiants and classical Cepheids in the H-R diagram (Kovtyukh et al 2010). First, we find that the Z = 0.019 tracks do a good job of predicting the positions of the blue loops and yellow supergiants for $M_V > -5$. The most luminous yellow supergiants in our sample have $M_V \sim -8$, consistent with the evolutionary tracks.

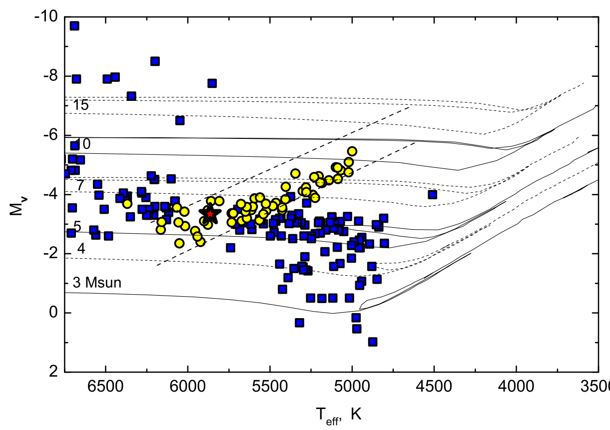

Figure 4: The H-R diagram constructed using our parameters. Classical Cepheids are plotted as open circles, supergiants as filled squares. Lines indicate evolutionary tracks by Salasnich et al (2000) for 15, 10, 7, 5, 4, and 3 $M_\odot$ (top to bottom) for z=0.019 and [α/Fe]=0. Dashed lines indicate IS for classical Cepheids. V1033 Cyg is shown as asteric.

Conclusion

Our own analysis of V1033 Cyg, covering more than 100 years indicates a rapid increase of the period of 18.19±0.08 s/yr, in agreement with a first crossing of the instability strip for this star (this paper and Berdnikov et al 2019).

It was found that the V-amplitude does not change rapidly. This is naturally explained by the position of the star in the center of the instability strip.

The results are consistent with fundamental mode pulsation in V1033 Cyg, as well as with a first crossing of the instability strip.

References

APASS, Star catalog: 2010, *http://www.aavso.org.*

Benson P.J.: 1998, *Intern. Amateur-Professional Photoel. Photom. Communic.*, **72**, 42.

Berdnikov L.N.: 1987, *Perem. Zvezdy*, **22**, 530.

Berdnikov L.N et al.: 2019, *Astronomy Letters*, **45**, 4, 227.

Berdnikov L.N.: 1992, *Astron. Astrophys. Trans.*, **2**, 1.

Gieren W.P., Fouqué P., Gómez M.: 1998, *ApJ*, **496**, 17.

Henden A.A.: 1996, *Astron. J.*, **111**, 902.

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

Kovtyukh V.V., Soubiran C., Luck R.E., Turner D.G., Belik S.I., Andrievsky S.M., Chekhonadskikh F.A.: 2008, *MNRAS*, **389**, 1336.

Kovtyukh V. V., Chekhonadskikh F. A., Luck R. E., Soubiran C., Yasinskaya M. P., Belik S. I.: 2010, *MNRAS* **408**, 1568.

Luck R.E. & Lambert D.L.: 2011, *AJ*, **142**, 136.

Motl D.: 2009-17 *http://sourceforge.net/projects/c-munipack*

Salasnich B., Girardi L., Weiss A., Chiosi C.: 2000, *A&A*, **361**, 1023.

Samus N.N., Durlevich O.V., Kazarovets E.V., Kireeva N.N., Pastukhova E.N., Zharova A.V. et al.: 2011, *General Catalogue of Variable Stars* (GCVS database, Version 2011Jan).

Udovichenko S.N.: 2012, *Odessa Astron. Publ.*, **25**, 32.

Zacharias N. et al.: 2005, VizieR Online Data Catalog: NOMAD Catalog (Zacharias+2005), 1297.