Peremennye Zvezdy (*Variable Stars*) **37**, No. 3, 2017

Received 28 September; accepted 12 October.

A photometric study of GSC 01374–01131, a HADS variable star with an eclipsing component

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We present the results of our new observations of GSC 01374–01131, a recently discovered high-amplitude δ Scuti (HADS) star for which, in 2013, we detected an eclipsing component of the light curve in the Catalina Surveys data. We acquired new CCD photometry in Johnson's B, V, and R bands for this star, improved the periods of the eclipses ($P_{\rm e} = 5\overset{\rm d}{.}96857$) and of the pulsation ($P_{\rm p} = 0\overset{\rm d}{.}08494573$) and other parameters of the light curves. GSC 01374–01131 is an eclipsing binary of the Algol type (EA); one of its components is a pulsating HADS star. Currently, GSC 01374–01131 has the lowest depth of the main eclipse ($A_{\rm e} = 0\overset{\rm m}{.}13$) among all known HADS stars in eclipsing binary systems, comparable to the observed pulsation amplitude.

1 Introduction

The variability of GSC 01374–01131 = VSX J074722.4+220414 (RA = $07^{\rm h}47^{\rm m}22\overset{\rm s}{.}470$, Dec = $+22^\circ04'13\overset{''}{.}95$, J2000) was discovered in 2011 by Santiago Roland, Nadia Martinez, and Sebastian Bruzzone (announcement of November 19, 2011 in the AAVSO Variable Star Index, VSX[1]). The variable was classified as a high-amplitude δ Scuti star, HADS type in the AAVSO database, from a single night of observations (January 15, 2009). The light elements were:

$$\mathrm{HJD(max)} = 2454846.73 + 0\overset{\rm d}{.}08 \times E.$$

In 2013, one of the authors of the present paper (A.V. Khruslov) reinvestigated the star using the publicly available data of the Catalina Surveys[2] (Drake et al. 2009). According to his publication (Khruslov 2013), the variable is a HADS star with an eclipsing component (EA or EB type). The light elements of the pulsating and eclipsing components of the light variations are the following:

$$\mathrm{HJD(max)} = 2454846.734 + 0\overset{\rm d}{.}0849458 \times E \quad \text{(pulsations)};$$

$$\mathrm{HJD(min)} = 2455004.25 + 5\overset{\rm d}{.}9688 \times E \quad \text{(eclipses)}.$$

[1] http://www.aavso.org/vsx/

[2] http://nunuku.caltech.edu/cgi-bin/getcssconedb_release_img.cgi

2 Observations and data reductions

We acquired new photometry of GSC 01374–01131. Our CCD observations in the standard Johnson B, V, and R bands were performed at the Tien Shan Astronomical Observatory of the V.G. Fesenkov Astrophysical Institute, at the altitude of 2750 m above the sea level. The time span of the observations is JD 2456366 – 2456782 (March 14, 2013 – May 4, 2014).

Our observations were performed with one of the two observatory's Zeiss 1000-mm reflectors, the "eastern Zeiss" (the focal length of the system was $f = 13380$ mm before JD 2456500 and 6650 mm after this date; the detector was an Apogee U9000 D9 CCD camera).

The finding chart (Fig. 1) identifies the variable star, comparison star, and check star. Information on the comparison star and check star used in our CCD photometry is presented in Table 1. The magnitudes of the comparison star are from the AAVSO Photometric All-Sky Survey (APASS[3]) catalog. The R-band observations could be presented only as magnitude differences with respect to the comparison star ($\Delta R = m_{\rm var} - m_{\rm comp}$).

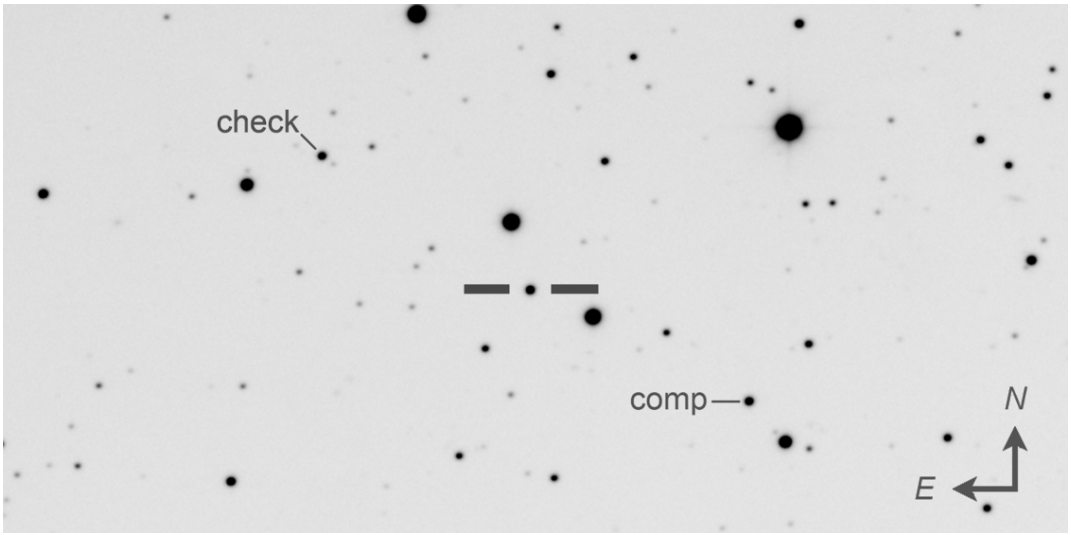

Figure 1. The finding chart of GSC 01374–01131 (V band, $7' \times 14'$).

Table 1. Comparison and check stars

Comparison star	Name	GSC 01374–01123
	Coordinates, J2000.0	$07^{\rm h}47^{\rm m}09\overset{\rm s}{.}98$ $+22°02'45\overset{''}{.}6$
	V, mag	$14\overset{\rm m}{.}067$
	B, mag	$14\overset{\rm m}{.}925$
Check star	Name	GSC 01374–01674
	Coordinates, J2000.0	$07^{\rm h}47^{\rm m}34\overset{\rm s}{.}35$ $+22°06'00\overset{''}{.}2$

Reductions were performed using the MaxIm DL Version 5.23 aperture photometry package. We analyzed the time series using two methods implemented in the WinEfk code[4] written by V.P. Goranskij: the Deeming method (Deeming 1975) for the pulsating component and the Lafler–Kinman method (Lafler & Kinman 1965) for the eclipsing

[3] http://www.aavso.org/download-apass-data
[4] http://www.vgoranskij.net/software/

component. The Deeming method is used for data analysis in the case of sinusoidal light curves and search for multiperiodic variability. The Lafler–Kinman method is much more suitable for data analysis in the case of variables with strongly asymmetrical light curves (for example, RRab stars and eclipsing binaries, especially Algol-type variables).

Our observations are provided online in the html version of this paper.

In addition, we used new Catalina Surveys data, recently made available to users, to improve the light elements.

3 Results

We improved the periods of eclipses and pulsations and other parameters of the light curves. GSC 01374–01131 is an eclipsing binary of the Algol type (EA); one of its components is a pulsating HADS star (DSCT+EA according to classification of the General Catalogue of Variable stars, GCVS[5], Samus et al. 2017). The new light elements of the pulsating and eclipsing components of the light variations are the following:

$$\mathrm{HJD(max)} = 2456669.3296 + 0^{\mathrm{d}}.08494573 \times E \quad \text{(pulsations)};$$

$$\mathrm{HJD(min)} = 2456669.480 + 5^{\mathrm{d}}.96857 \times E \quad \text{(eclipses)}.$$

The light curves of GSC 01374–01131 from raw CCD data with the two periods are displayed in Fig. 2. The light curves with the eclipsing variations pre-whitened, folded with the pulsation period, are presented in Fig. 3. The light curves with the pulsations pre-whitened, folded with the eclipsing period, are shown in Fig. 4. All light curves are given in the Johnson B, V, and R bands. The primary minimum (with the pulsations pre-whitened) is displayed in Fig. 5.

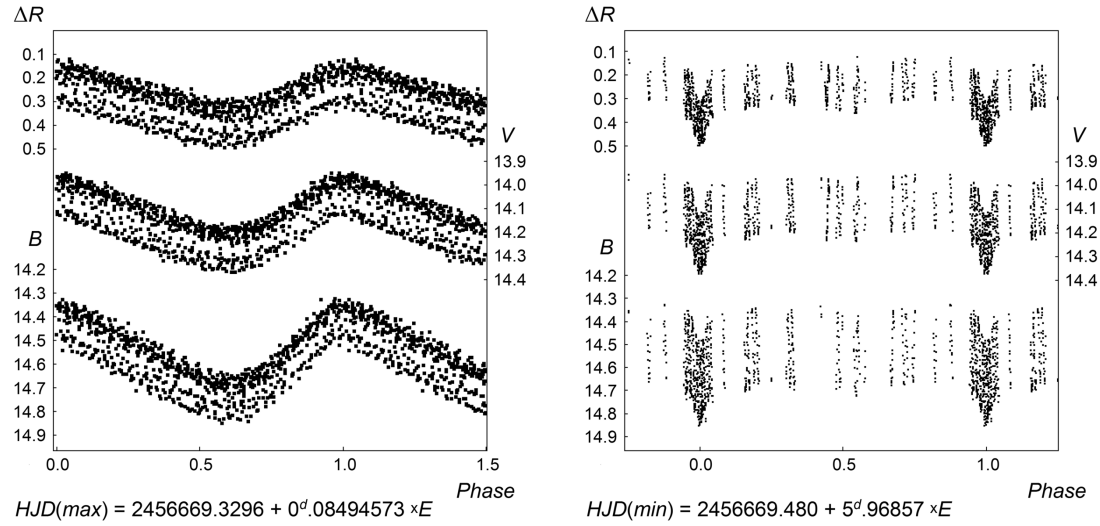

Figure 2. The light curves of GSC 01374–01131 from raw CCD data, folded with the periods of pulsations (left) and eclipses (right).

[5]http://www.sai.msu.su/gcvs/gcvs/

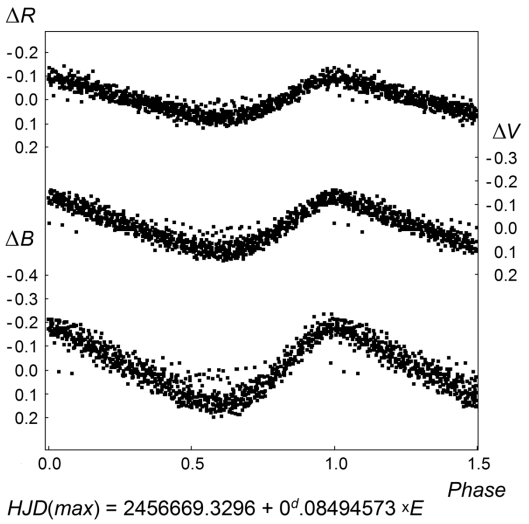

Figure 3. The light curves of GSC 01374–01131 with the eclipsing variations pre-whitened, folded with the pulsation period.

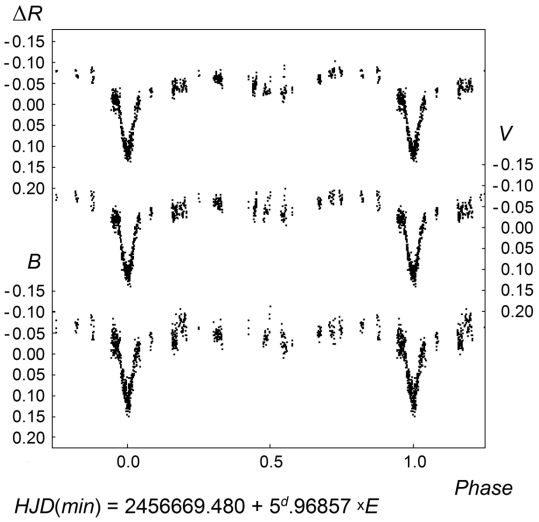

Figure 4. The light curves of GSC 01374–01131 with the pulsations pre-whitened, folded with the eclipsing period.

We derived new light elements taking into account the newly available CSS data (time interval JD 2453469 – 2457495). The light curves of GSC 01374–01131 with the other variation pre-whitened, from Catalina Surveys data (CSS), are presented in Fig. 6.

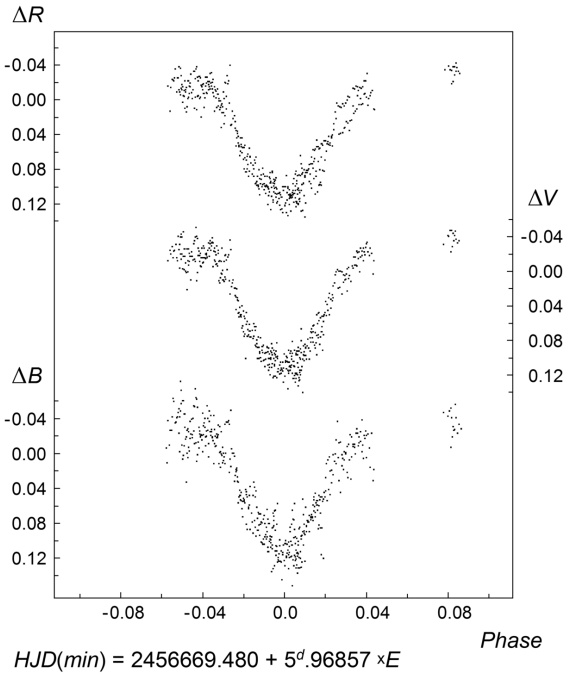

Figure 5. The close-up of the primary eclipse.

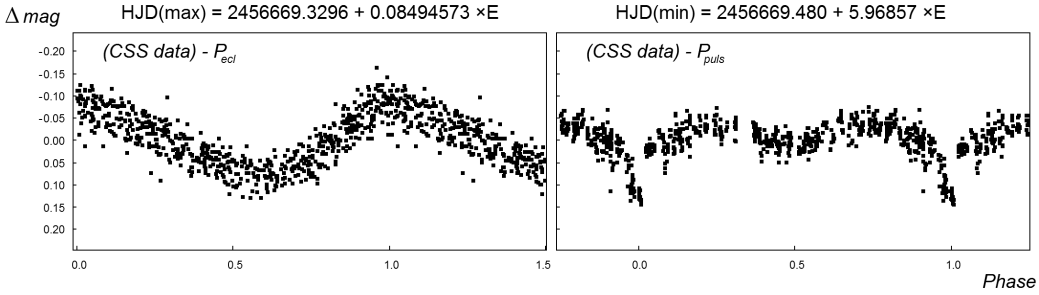

Figure 6. The light curves of GSC 01374–01131 from CSS data folded with the pulsation period (left) and eclipsing period (right), with the other variation pre-whitened.

The light curve shape of the eclipsing variation component is of the Algol type. The duration of primary eclipse is $D = 0\overset{\mathrm{P}}{.}07$. The depth of the primary eclipse is the same in all photometric bands. There is a slight decrease in the brightness level at the phase 0.5 (secondary minimum). The brightness level outside the eclipses varies a little (most noticeably, in the R band), a kind of O'Connell effect. The amplitude (depth) of the primary eclipse is comparable to the amplitude of pulsations. Among all currently known HADS stars in Algol-type eclipsing binary systems (HADS+EA in the AAVSO classification), GSC 01374–01131 has the lowest amplitude of the eclipse.

In observations of a binary system, we measure total (combined) light from a point source; actually, the full amplitude of light variations of the pulsating component should be significantly larger, in full accordance with the HADS type. The asymmetry parameter of the pulsation light curve is $M - m = 0\overset{\mathrm{P}}{.}40$.

The amplitudes of pulsations and eclipses, depths of the primary minimum, and ranges of light variations for the Johnson B, V, and R bands and for the Catalina Surveys CV

band are presented in Table 2.

Table 2. The variation amplitudes and ranges of GSC 01374–01131

Band	Semi-amplitude, pulsations, mag.	Full amplitude, eclipses, mag.	Depth of Min I	mag
B	0.1489	0.17	0.14	$14\overset{m}{.}33 - 14\overset{m}{.}85$
V	0.1052	0.18	0.14	$13\overset{m}{.}95 - 14\overset{m}{.}37$
R	0.0771	0.19	0.13	$0\overset{m}{.}38^*$
CV	0.0760	0.18	0.12	$13\overset{m}{.}88 - 14\overset{m}{.}26$

* For the R band, the total variability amplitude is given.

Acknowledgments: The authors are grateful to Dr. V.P. Goranskij for providing light-curve analysis software. Thanks are due to Dr. N.N. Samus for helpful discussions. We wish to thank M.A. Krugov, N.V. Lichkanovsky, and I.V. Rudakov for their assistance during the observations. This study was supported by the Basic Research Program P–7 of the Presidium of Russian Academy of Sciences and by the Science Committee of the Science and Education Ministry of Kazakhstan (project No. 0075/GF4).

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