Peremennye Zvezdy (*Variable Stars*) **33**, No. 4, 2013

Received 04 June; accepted 25 June.

New Eclipsing Variable Star with Delta Scuti Component

V. Solovyov[1], A. Samokhvalov[2,3], B. Satovskiy[3]

[1] Kazan Federal University, Russia, e-mail: solo.vya@gmail.com;

[2] Surgut, Russia, e-mail: sav@surgut.ru;

[3] Astrotel Observatory, Carachay-Cherkessiya, Russia; e-mail: bsatovski@gmail.com

We present our discovery a new variable star USNO-A2.0 1350-17086180 from observations at the Astrotel-Caucasus Observatory. The object shows Algol-type eclipses and, simultaneously, low-amplitude, short-period pulsations.

1 Introduction

During observations of a field in Cepheus, we discovered a new Algol-type variable star with a pulsating δ Scuti component: USNO-A2.0 1350-17086180 ($\alpha = 22^{\rm h}39^{\rm m}29\overset{\rm s}{.}02$, $\delta = +47^\circ04'51\overset{''}{.}8$, J2000, 2MASS), with the $13\overset{\rm m}{.}40 - 13\overset{\rm m}{.}67$ (R) variability range. For the finding chart of the star, see Fig. 1. Using an extensive series of observations, we determined parameters of the photometric behavior of the system.

2 Observations and data reduction

Our observations were carried out at the Astrotel-Caucasus observatory, located at the Astronomical station of the Kazan Federal University in the Northern Caucasus, using a 300-mm Ritchey–Chretien telescope equipped with an unfiltered Apogee Alta U9000 CCD camera. A total of 2058 images with 5-minute exposures were obtained during 45 nights between JD 2455828 and JD 2456219. The numbers of observations on each of the observing nights are presented in Table 1; the observations are attached to the html version of this paper.

For basic reductions for dark current, flat fields, bias and for removing cosmic rays hits, we used IRAF routines. For photometry of the new variable star, we applied VaST software by Sokolovsky and Lebedev (2005). The comparison star was USNO-A2.0 1350-17114431 = USNO-B1.0 1368-0511417 ($\alpha = 22^{\rm h}40^{\rm m}20\overset{\rm s}{.}93$, $\delta = +46^\circ50'33\overset{''}{.}3$, J2000, 2MASS; $R_1 = 13\overset{\rm m}{.}82$, $R_2 = 14\overset{\rm m}{.}20$, USNO-B1.0).

Unfiltered magnitudes were calibrated using the comparison star, assuming $R_{\rm comp} = 14\overset{\rm m}{.}01$.

All times in this paper are expressed in terrestrial time in accordance with IAU recommendations (resolution B1 XXIII IAU GA).

3 Analysis of observations

3.1 Eclipses

For analysis of our photometrical observations, we used the Lafler–Kinman method (Lafler and Kinman 1965) implemented in Peranso software (http://www.peranso.com). Using this method, we determined the eclipsing system's orbital period to be $2\overset{\mathrm{d}}{.}44962$. The depth of primary minima is $0\overset{\mathrm{m}}{.}27$ and that of secondary minima, $0\overset{\mathrm{m}}{.}20$. The three primary minima we observed are listed in Table 2; all these times were determined using the method described by Kwee and van Woerden (1956).

The light elements of the primary eclipses are:

$$\mathrm{Min\ HJD_{TT}} = 2455881.2869 + 2\overset{\mathrm{d}}{.}44962 \times E. \quad (1)$$

3.2 Pulsations

Using the prewhitening procedure of the Peranso software, we found the pulsation period of the δ Scuti component to be $0\overset{\mathrm{d}}{.}060193$. The variability amplitude is $0\overset{\mathrm{m}}{.}1$, rather typical of δ Scuti stars. During our observations, we detected 101 maxima of the pulsation light curve, collected in Table 3.

The light elements of the pulsations are:

$$\mathrm{Max\ HJD}_{TT} = 2455842.374 + 0\overset{\mathrm{d}}{.}060193 \times E. \quad (2)$$

Having 101 maxima observed on a time span of 392 days, corresponding to 6249 pulsation cycles, we can fully explore possible variation of the pulsation period of the δ Scuti component, starting with the light elements (2). We calculated pulsation maxima and

Table 1. Numbers of observations

Night No.	JD	No.of observations	Night No.	JD	No. of observations	Night No.	JD	No. of observations
1	2455828	11	16	2455925	40	31	2456185	48
2	2455833	50	17	2455926	20	32	2456186	48
3	2455842	50	18	2455930	38	33	2456188	28
4	2455843	60	19	2455956	28	34	2456189	52
5	2455873	72	20	2456109	7	35	2456190	51
6	2455879	75	21	2456115	19	36	2456195	44
7	2455880	95	22	2456116	5	37	2456196	45
8	2455881	72	23	2456153	21	38	2456197	2
9	2455883	85	24	2456173	2	39	2456200	44
10	2455884	55	25	2456174	40	40	2456201	48
11	2455888	29	26	2456175	42	41	2456202	52
12	2455895	35	27	2456177	40	42	2456216	95
13	2455900	73	28	2456182	53	43	2456217	72
14	2455901	75	29	2456183	45	44	2456218	70
15	2455902	12	30	2456184	44	45	2456219	24

Table 2. The observed primary minima

No.	$\mathrm{HJD_{TT}}$	±
1	2455881.2869	0.0006
2	2456187.4703	0.0004
3	2456219.3262	0.0004

determined $O-C$ residuals, also presented in the corresponding column of Table 3. The $O-C$ residuals suggest no variations of the pulsation period.

Using the light elements (1) and (2), we plotted the four light curves shown in Fig. 2. They illustrate the photometric behavior of the system.

Table 3. Observed maxima of pulsation light curve

No.	HJD_{TT}	±	E	$O-C$	No.	HJD_{TT}	±	E	$O-C$
1	2455842.374	0.001	0	0.000	52	2456175.426	0.003	5533	0.004
2	2455842.438	0.002	1	0.004	53	2456175.484	0.001	5534	0.002
3	2455842.499	0.002	2	0.005	54	2456177.412	0.002	5566	0.004
4	2455843.400	0.002	17	0.003	55	2456177.472	0.002	5567	0.004
5	2455843.464	0.003	18	0.007	56	2456182.345	0.005	5648	0.001
6	2455843.519	0.003	19	0.001	57	2456182.404	0.003	5649	0.000
7	2455873.193	0.003	512	0.000	58	2456182.468	0.003	5650	0.004
8	2455873.252	0.002	513	–0.001	59	2456183.427	0.002	5666	–0.001
9	2455873.314	0.002	514	0.001	60	2456183.489	0.002	5667	0.001
10	2455873.368	0.004	515	–0.005	61	2456184.393	0.004	5682	0.002
11	2455873.435	0.003	516	0.001	62	2456184.456	0.003	5683	0.005
12	2455879.277	0.002	613	0.005	63	2456185.416	0.002	5699	0.002
13	2455879.336	0.002	614	0.003	64	2456185.478	0.002	5700	0.004
14	2455879.400	0.002	615	0.007	65	2456186.384	0.002	5715	0.007
15	2455879.457	0.003	616	0.004	66	2456186.445	0.003	5716	0.008
16	2455880.171	0.003	628	–0.004	67	2456186.502	0.002	5717	0.005
17	2455880.237	0.002	629	0.002	68	2456188.483	0.002	5750	–0.001
18	2455880.295	0.002	630	–0.001	69	2456188.545	0.002	5751	0.001
19	2455880.357	0.002	631	0.001	70	2456189.384	0.002	5765	–0.003
20	2455880.418	0.003	632	0.002	71	2456189.451	0.002	5766	0.004
21	2455880.477	0.003	633	0.001	72	2456189.508	0.002	5767	0.001
22	2455881.377	0.002	648	–0.002	73	2456190.415	0.004	5782	0.005
23	2455881.442	0.003	649	0.003	74	2456190.472	0.005	5783	0.002
24	2455883.187	0.002	678	0.002	75	2456190.539	0.003	5784	0.009
25	2455883.250	0.002	679	0.005	76	2456195.406	0.002	5865	0.000
26	2455883.308	0.002	680	0.003	77	2456195.464	0.003	5866	–0.002
27	2455883.368	0.001	681	0.003	78	2456196.429	0.002	5882	0.000
28	2455883.435	0.002	682	0.009	79	2456196.488	0.002	5883	–0.001
29	2455884.274	0.002	696	0.006	80	2456200.412	0.002	5948	0.010
30	2455884.336	0.002	697	0.007	81	2456200.464	0.004	5949	0.002
31	2455884.389	0.004	698	0.000	82	2456200.524	0.003	5950	0.002
32	2455884.459	0.002	699	0.010	83	2456201.427	0.002	5965	0.002
33	2455888.242	0.002	762	0.001	84	2456201.549	0.001	5967	0.003
34	2455895.224	0.003	878	0.001	85	2456202.391	0.003	5981	0.003
35	2455895.284	0.002	879	0.000	86	2456202.453	0.003	5982	0.004
36	2455900.164	0.002	960	0.005	87	2456202.511	0.002	5983	0.002
37	2455900.216	0.002	961	–0.003	88	2456216.229	0.003	6211	–0.004
38	2455900.279	0.003	962	–0.001	89	2456216.296	0.003	6212	0.003
39	2455900.341	0.003	963	0.001	90	2456216.357	0.003	6213	0.004
40	2455900.398	0.003	964	–0.002	91	2456216.412	0.002	6214	–0.001
41	2455901.184	0.003	977	0.001	92	2456216.474	0.002	6215	0.001
42	2455901.242	0.004	978	–0.001	93	2456216.536	0.002	6216	0.002
43	2455901.303	0.003	979	0.000	94	2456217.317	0.002	6229	0.001
44	2455901.363	0.003	980	0.000	95	2456217.376	0.003	6230	0.000
45	2455901.422	0.003	981	–0.001	96	2456217.434	0.002	6231	–0.003
46	2455925.268	0.002	1377	0.008	97	2456217.498	0.002	6232	0.001
47	2455926.291	0.004	1394	0.008	98	2456218.342	0.002	6246	0.003
48	2455956.197	0.002	1891	–0.002	99	2456218.403	0.002	6247	0.003
49	2456153.397	0.002	5167	0.006	100	2456218.459	0.002	6248	–0.001
50	2456174.461	0.002	5517	0.002	101	2456218.521	0.002	6249	0.001
51	2456174.519	0.002	5518	0.000					

We hope that the present study will stimulate new observations of this interesting star.

Acknowledgements: We would like to thank S.V. Antipin and N.N. Samus for helpful discussions.

References:

Sokolovsky, K., Lebedev, A. 2005, in 12th Young Scientists' Conference on Astronomy and Space Physics, Kyiv, Ukraine, April 19–23, 2005, eds.: Simon, A.; Golovin, A., p.79

Kwee, K., van Woerden, H. 1956, Bulletin of the Astronomical Institutes of the Netherlands, 12, 464

Lafler, J., Kinman, T.D. 1965, Astrophys. J., Suppl. Ser., 11, 216

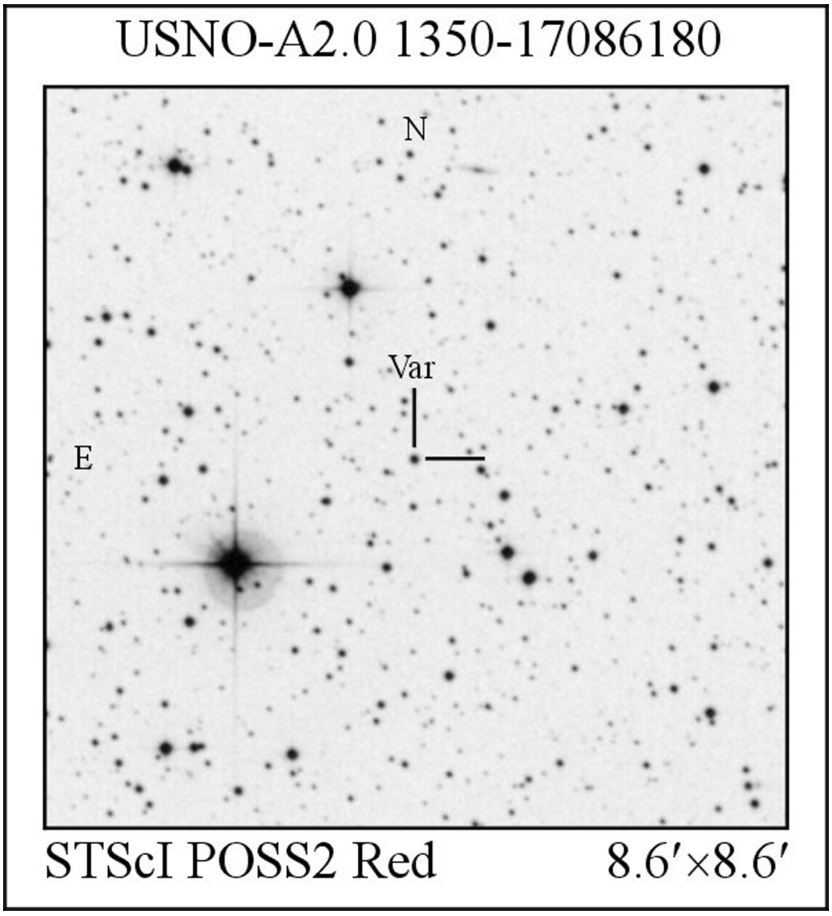

Figure 1. The finding chart of USNO-A2.0 1350-17086180.

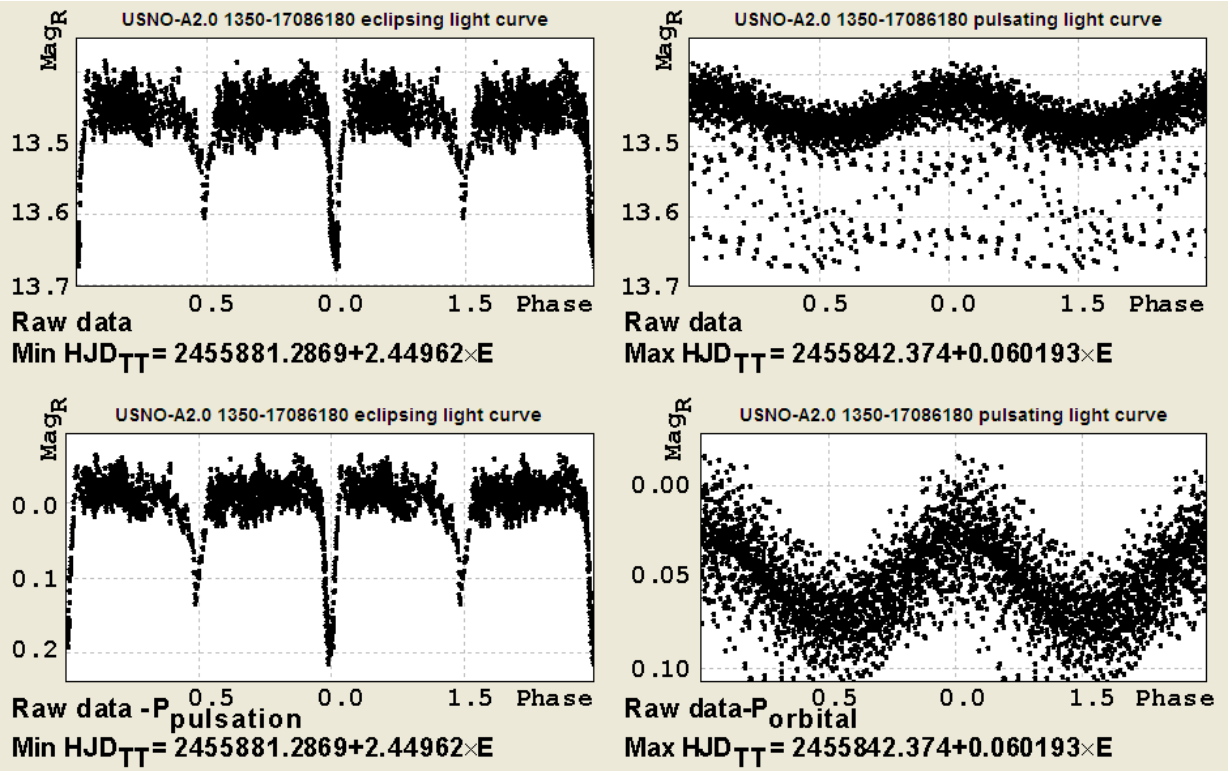

Figure 2. USNO-A2.0 1350-17086180 light curves. The upper left curve displays raw data with the orbital period; the upper right curve, raw data with the pulsation period; the bottom left curve, raw data with pulsations removed, folded with the orbital period; and the bottom right curve, raw data with eclipses removed, folded with the pulsation period.