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New RRC variables with an additional non-radial pulsation

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We present a new study of 14 known RR Lyrae variable stars from the Catalina surveys periodic variable star catalog. We analyzed all observations available for these stars in the Catalina Surveys online public archives using the period-search software developed by Dr. V.P. Goranskij for Windows environment. According to these data, the stars are RRC variables with an additional non-radial pulsation.

1 Introduction

There exist a number of RRC stars (first-overtone pulsators) that also have one simultaneously detected additional non-radial mode. Some authors consider stars of this variability type as RRC variables with the Blazhko effect, as the Blazhko effect in RRAB stars (fundamental-mode pulsators) can usually be described with a superposition of an additional non-radial mode.

RRC stars with a single non-radial pulsation whose frequency is close to that of the first overtone were first discovered by Olech et al. (1999) in the globular cluster M55 (three variables). Alcock et al. (2000) identified 24 such stars among variables in the Large Magellanic Cloud (the MACHO project; the variability type designated RR1-ν1). A star of this kind, TYC 6556 00609 1, is known in the galactic field (Antipin & Jurcsik 2005). Later, I detected two variables of this type: GSC 2493-00118 and USNO-A2.0 0900-20281750 (Khruslov 2012).

The P_1/P_N period ratios for stars of this type (assuming $P_1 < P_N$, although it is possible that $P_1 > P_N$) are within 0.9–0.999. The amplitude of the non-radial oscillation can be considerably lower than the amplitude of the main one, but these amplitudes can also be virtually the same.

In this article, I present a discovery of 14 new cases of RRC stars with a single excited additional non-radial mode. These stars were found in the our search for RR Lyrae variables with two radial pulsations, F/1O (Khruslov 2014, 2015ab). The variability of all these variables was announced by Drake et al. (2014) in the Catalina Surveys Periodic Variable Star Catalog. One variable (No. 2) was classified as a double-mode RR Lyrae star, type RR(B) in GCVS classification (Samus et al. 2007–2015); 13 other variables were classified as single-mode first-overtone RR Lyrae star (type RRC). There are two cases of wrong periods announced in the Catalina surveys periodic variable star catalog: Nos. 5 and 10, with periods being one-day aliases of the real first overtone period.

2 Results

All results were obtained on the base of Catalina sky survey (CSS) data (Drake et al. 2009). For the star No. 4, our data analysis additionally used 1SWASP data (Butters et al. 2010). For the star No. 5, we analyzed combined data of the CSS and SSS (Siding Springs Survey).

Information on the studied stars is presented in Tables 1 and 2. Finding charts and data are available online in the html version of this paper as a zip-archive. The light curves of all the stars displayed in Figs. 1 and 2.

The star designations are from the USNO-B1.0 catalog (Monet et al. 2003). The tabulated coordinates of the variables were drawn either from the GSC2.3 (Lasker et al. 2008) or from the 2MASS (Skrutskie et al. 2006) catalogs.

Table 1 contains, for each star, its equatorial coordinates (J2000); number from the USNO-B1.0 catalog; magnitudes in maximum and minimum in the Catalina surveys photometric system; period previously known for the star, according to the Catalina surveys periodic variable star catalog.

Table 1. Positions, magnitudes and first CSS periods

No.	Coordinates (J2000)	USNO-B1.0	Magn.	$P_{css\ cat}$, days
1	$02^h34^m39\overset{s}{.}44$ $+04°55'28\overset{''}{.}4$	0949-0024801	$13\overset{m}{.}84$–$14\overset{m}{.}26$	0.281675
2	08 25 19.75 +37 48 25.0	1278-0205991	15.12–15.45	0.2563464
3	10 19 59.98 +30 17 54.6	1202-0180839	17.6 –18.3	0.3093978
4	10 24 22.39 +36 55 24.3	1269-0201347	13.95–14.37	0.3066193
5	12 11 43.61 –16 45 00.8	0732-0287960	15.79–16.39	0.3678677
6	12 32 04.84 +18 20 09.7	1083-0224291	15.82–16.29	0.263563
7	14 11 13.47 +06 40 13.7	0966-0241897	15.84–16.25	0.2772159
8	14 16 04.81 +29 59 08.3	1199-0219251	15.76–16.11	0.2940443
9	14 34 29.84 +26 57 28.0	1169-0257343	16.11–16.48	0.2696107
10	15 07 36.04 +10 05 02.6	1000-0239484	17.03–17.76	0.4735085
11	16 31 59.91 +33 51 35.3	1238-0254586	16.65–17.30	0.2744261
12	17 40 16.19 +31 59 50.5	1219-0309843	15.65–16.14	0.3475867
13	23 18 25.66 +24 25 51.8	1144-0564929	15.31–15.87	0.3054350
14	23 57 56.77 +29 17 34.0	1192-0600617	16.55–17.26	0.299204

Table 2 presents light elements and amplitudes of two oscillations: the first-overtone period P_1; the non-radial-mode period P_N; the first-overtone and non-radial mode epochs of maxima (expressed as JD – 2455000); period ratio P_1/P_N; beat period (or Blazhko effect period); semi-amplitudes of first-overtone (A_1) and non-radial-mode (A_N) oscillations. Additional information about some of the stars is collected in Remarks.

Table 2. Light elements and amplitudes

No.	P_1, d	P_N, d	Epoch_1	Epoch_N	P_1/P_N	P_{Blazh}	A_1	A_N
1	0.2816745	0.2820182	0.267	0.197	0.9988	231	0.093	0.068
2	0.2563447	0.2534778	0.167	0.087	1.0113	22.7	0.074	0.062
3	0.3094036	0.3056288	0.078	0.271	1.0124	25	0.123	0.120
4	0.306622	0.313789	0.188	0.210	0.9772	13.4	0.150	0.042
5	0.2687390	0.2691307	0.043	0.172	0.9985	185	0.141	0.050
6	0.2635594	0.2687276	0.078	0.234	0.9808	13.7	0.100	0.062
7	0.2772165	0.2702020	0.041	0.115	1.0260	10.7	0.101	0.062
8	0.2940444	0.2909421	0.042	0.227	1.0107	27.6	0.096	0.037
9	0.2696078	0.2645555	0.160	0.080	1.0191	14.1	0.079	0.061
10	0.321350	0.324200	0.118	0.317	0.9912	36.6	0.139	0.113
11	0.2744265	0.2737529	0.244	0.172	1.0025	112	0.142	0.059
12	0.347583	0.340686	0.283	0.140	1.0202	17.2	0.110	0.068
13	0.3054374	0.3122540	0.226	0.115	0.9782	14.0	0.143	0.045
14	0.299201	0.310512	0.201	0.075	0.9636	8.2	0.172	0.072

Remarks:

1. GSC 0049–00915.

4. GSC 2517–00730. The SWASP data were additionally used. From 1SWASP data, $13\overset{\mathrm{m}}{.}6$–$14\overset{\mathrm{m}}{.}37$, $A_1 = 0\overset{\mathrm{m}}{.}092$, $A_N = 0\overset{\mathrm{m}}{.}030$.

11. Two entries with identical coordinates in the Catalina surveys periodic variable star catalog (Drake et al. 2014). The period $P = 0\overset{\mathrm{d}}{.}2744256$ is given for the second entry.

12. The star has a faint close red companion 2MASS 17401606+3159476, $d = 3''$. The variable is much brighter than the red companion in the B band; the components are of comparable brightness in the POSS IR band.

13. There is a possible second non-radial pulsation, with the period $P_{N2} = 0\overset{\mathrm{d}}{.}321512$ and amplitude $A_{N2} = 0\overset{\mathrm{m}}{.}026$.

3 Conclusions

The periods of dominant oscillations (first overtone, P_1) for all our stars are within 0.256–0.348 days. As for periods of the non-radial modes, the $P_1 > P_N$ and $P_1 < P_N$ cases are equally frequent. The P_1/P_N period ratios for these stars are within 0.964–0.999 and 1.003–1.026. The beat periods (Blazhko effect periods) are from 8.2 to 231 days. The amplitude ratios A_1/A_N are within 1.03–3.57.

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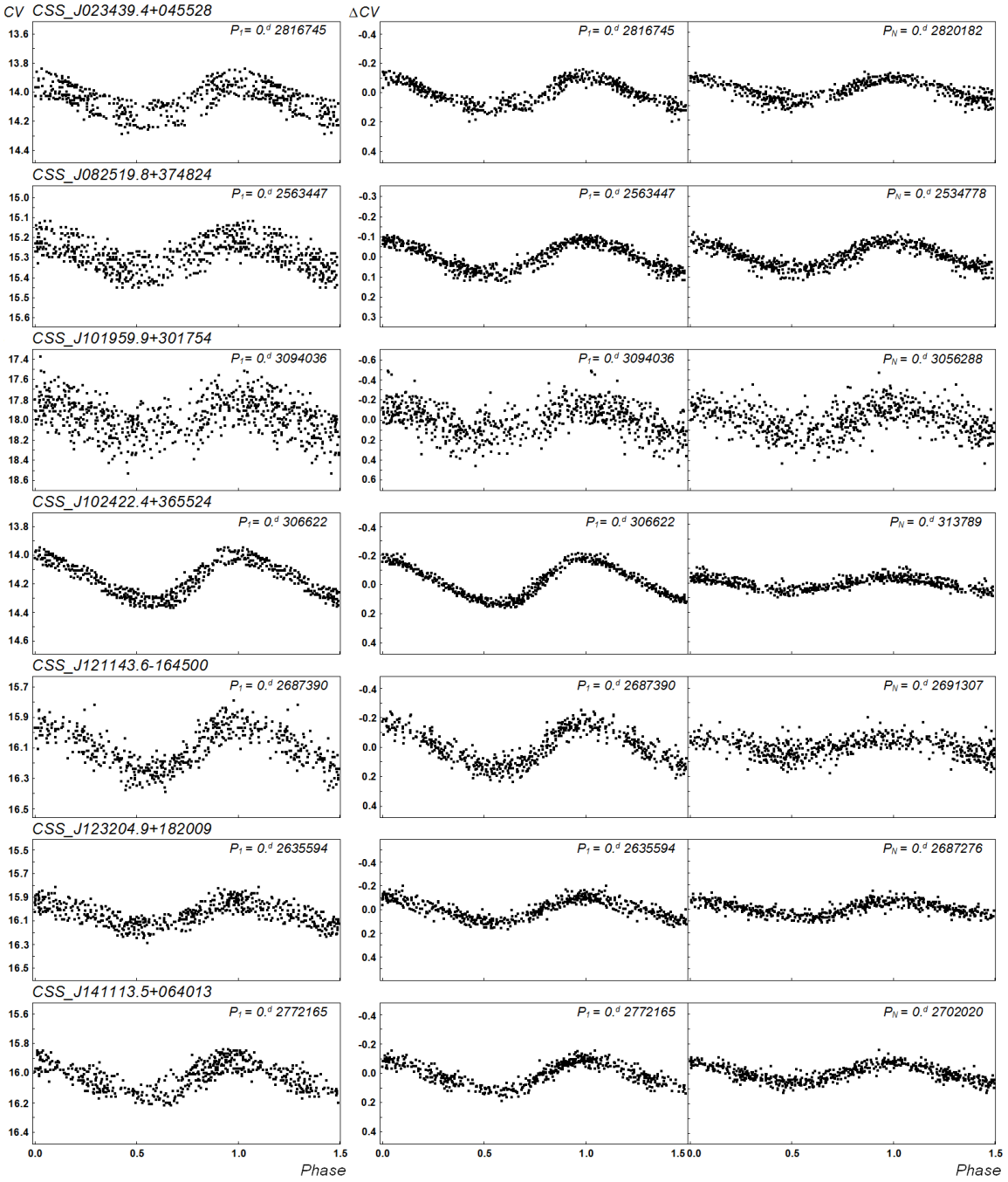

Figure 1.

The light curves of the stars Nos. 1–7. The left panel present data folded with the first overtone periods. The central and right panels show the same curves after prewhitening the other oscillation (frequencies f_1 and f_N).

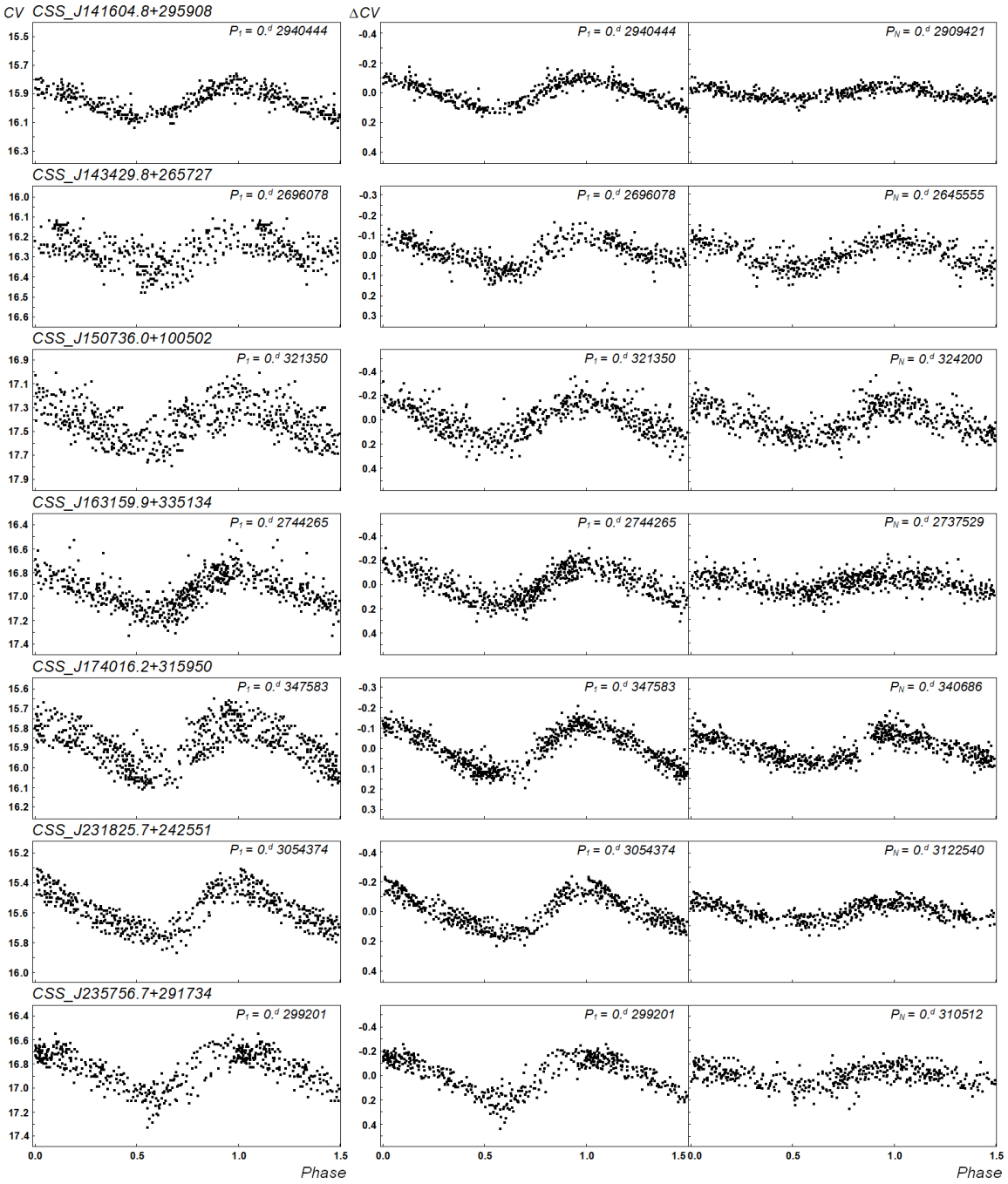

Figure 2.
The light curves of the stars Nos. 8–14.