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New Variable Stars Discovered Using the Tzec Maun Observatory Telescopes II

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#	Name	Other	Coord (J2000)	Type	Max	Min	System	Period	Epoch (JD)	type	Sp	Comment	L.Curve	Find.Chart	Data
1		USNO-B1.0 1034-0068308	05 30 07.91, +13 24 24.4	EW	18.3	18.8	R	0.23106	2454741.9517	min			pks0528_R_1155.png	pks0528_R_1155_chart.png	pks0528_R_1155_hjd.dat
2		USNO-B1.0 1035-0062360	05 30 20.54, +13 35 41.7	EW	17.45	17.9	R	0.37311	2454742.9646	min		Comm. 2	pks0528_R_0422.png	pks0528_R_0422_chart.png	pks0528_R_0422_hjd.dat
3		USNO-B1.0 1416-0177809	05 57 35.24, +51 38 17.2	DSCT	13.53	13.63	R	0.062268	2454866.7478	max		Comm. 3	5_cr_01677.png	5_cr_01677_chart.png	5_cr_1677_hjd.dat
4		USNO-B1.0 1415-0175241	05 58 10.71, +51 33 36.7	EW	16.05	16.40	R	0.3067	2454866.7292	min		Comm. 4	5_cr_01170.png	5_cr_01170_chart.png	5_cr_1170_hjd.dat
5		USNO-B1.0 1415-0175561	05 59 16.43, +51 34 45.1	EW	17.0	17.5	R	0.2839	2454860.7900	min		Comm. 5	5_cr_01305.png	5_cr_01305_chart.png	5_cr_1305_hjd.dat
6		USNO-B1.0 1278-0239703	10 59 57.18, +37 50 20.5	RR(B)	15.5	16.5	V	0.35269	2454848.0016	max		Comm. 6	mrk421_cv_03454.png	mrk421_cv_03454_chart.png	mrk421_cv_03454_hjd.dat
7		GSC 2521-00245, USNO-B1.0 1260-0187504	11 00 21.54, +36 03 19.9	RRC	14.4	15.0	V	0.31409	2454876.9789	max			mrk421_cv_03064.png	mrk421_cv_03064_chart.png	mrk421_cv_03064_hjd.dat
8		USNO-B1.0 1264-0188140	11 03 08.38, +36 24 02.0	RRAB	15.8	17.0	V	0.6278	2454876.9329	max			mrk421_cv_12144.png	mrk421_cv_12144_chart.png	mrk421_cv_12144_hjd.dat
9		GSC 3010-02260, USNO-B1.0 1277-0237737	11 03 08.87, +37 47 49.0	RRC:	13.6	13.8	V	0.21756	2454846.8843	max		Comm. 9	mrk421_cv_02542.png	mrk421_cv_02542_chart.png	mrk421_cv_02542_hjd.dat
10		GSC 2521-00840, USNO-B1.0 1263-0189512	11 03 30.05, +36 22 47.6	EW	12.23	13.37	V	0.36784	2454847.8718	min		Comm. 10	mrk421_cv_02183.png	mrk421_cv_02183_chart.png	mrk421_cv_02183_hjd.dat
11		USNO-B1.0 1284-0212125	11 04 29.18, +38 29 20.4	EW	15.65	16.2	V	0.25676	2454847.8694	min		Comm. 11	mrk421_cv_02260.png	mrk421_cv_02260_chart.png	mrk421_cv_02260_hjd.dat
12		GSC 2521-00328, USNO-B1.0 1262-0188469	11 05 45.89, +36 15 55.3	EW	13.6	14.0	V	0.28265	2454856.9317	min		Comm. 12	mrk421_cv_01506.png	mrk421_cv_01506_chart.png	mrk421_cv_01506_hjd.dat
13		USNO-B1.0 1257-0189164	11 10 21.81, +35 46 50.6	RR(B)	15.2	16.1	V	0.35051	2454851.7556	max			mrk421_cv_00310.png	mrk421_cv_00310_chart.png	mrk421_cv_00310_hjd.dat

Comments:

2. MinII = 17.85.

3. Two pulsation frequencies can be identified: 16.05974 +/-0.00049 c/d, half-amplitude 0.025 +/-0.001 mag, and 14.40987 +/-0.00057 c/d, half-amplitude 0.022 +/-0.001 mag. Light elements: HJDmax(TT) = 2454866.7478 + 0.062268 x E and HJDmax(TT) = 2454874.7290 + 0.069397 x E.

4. MinII = 16.25. Unequal minima (not typical for EW eclipsing binaries) may be a result of high starspot activity.

5. MinII = 17.35.

6. 2MASS 10595715+3750203 (J = 15.385 +/-0.042, H = 15.320 +/-0.087, Ks = 15.215 +/-0.133 measured on JD 2450912.8110), infrared colors are consistent with spectral type A, typical of RR Lyrae variable stars. This is a double-mode RR Lyrae variable star with the fundamental frequency 2.10743 +/-0.00020 c/d, half-amplitude 0.161 +/-0.007 mag, and first overtone frequency 2.83538 +/-0.00014 c/d, half-amplitude 0.229 +/-0.006 mag. The first overtone to fundamental mode period ratio is 0.743. Light elements for the fundamental mode pulsation: HJDmax(TT) = 2454876.9243 + 0.47451 x E; for the first overtone: HJDmax(TT) = 2454848.0016 + 0.35269 x E.

9. 2MASS 11030886+3747491 (J = 12.604 +/-0.022, H = 12.342 +/-0.023, Ks = 12.315 +/-0.020 measured on JD 2450912.8387), infrared colors are consistent with F spectral type (Bessell & Brett 1988). Classification as an EW eclipsing binary with the light elements HJDmin(TT) = 2454875.7161 + 0.43511 x E is also possible.

10. MinII = 12.33.

11. MinII = 16.05.

12. MinII = 13.95. 13. Case A-F 716, an A-F spectral type star according to low-dispersion spectroscopy by Pesch & Sanduleak (1989) which is in agreement with 2MASS colors: 2MASS 11102180+3546502 J = 14.934 +/-0.038, H = 14.864 +/-0.059, Ks = 14.567 +/-0.093. The star is a double-mode RR Lyrae variable with the fundamental frequency 2.12227 +/-0.00016 c/d, half-amplitude 0.141 +/-0.006 mag, and the first overtone frequency 2.85296 +/-0.00011 c/d, half-amplitude 0.213 +/-0.006 mag. The first overtone to fundamental mode period ratio is 0.744, typical of double-mode RR Lyrae stars (see e.g. Wils 2009). Light elements for the fundamental mode: HJDmax(TT) = 2454847.9552 + 0.47119 x E; for the first overtone: HJDmax(TT) = 2454851.7556 + 0.35051 x E.

Remarks:

We present a list of variable stars discovered using remotely controlled telescopes of the Tzec Maun observatory. The telescope parameters are presented in Table 1. Table 2 presents the observation log.

Table 1. Telescopes used for observations

Telescope	D (mm)	F (mm)	CCD camera	Location
Maksutov-Newton	350	1330	SBIG ST-10E	Mayhill, New Mexico, USA
Takahashi FSQ 106	106	530	SBIG STL-11000M	Mayhill, New Mexico, USA
Takahashi TOA-150	150	1100	SBIG STL-6303	Pingelly, Western Australia

Table 2. Observation log

USNO-B1.0	Telescope	Filter	Dates	N	Calibration
1034-0068308	Maksutov-Newton	R	2454740 - 2454856	97	a
1035-0062360	Maksutov-Newton	R	2454740 - 2454858	106	a
1416-0177809	Maksutov-Newton	clear	2454853 - 2454907	277	b
1415-0175241	Maksutov-Newton	clear	2454853 - 2454907	286	b
1415-0175561	Maksutov-Newton	clear	2454853 - 2454907	284	b
1278-0239703	FSQ 106	clear	2454846 - 2454952	679	c
1260-0187504	FSQ 106	clear	2454846 - 2454926	662	c
1264-0188140	FSQ 106	clear	2454846 - 2454921	347	c
1277-0237737	FSQ 106	clear	2454843 - 2454926	741	c
1263-0189512	FSQ 106	clear	2454843 - 2454926	718	c
1284-0212125	FSQ 106	clear	2454843 - 2454926	638	c
1262-0188469	FSQ 106	clear	2454843 - 2454926	735	c
1257-0189164	FSQ 106,TOA-150	clear	2454846 - 2454946	814	c

Magnitude scale was calibrated using:
(a) R magnitudes of comparison stars in the field of PKS 0528+135 (González-Pérez et al. 2001);
(b) assuming R = 15.0 for the comparison star USNO-B1.0 1415-0175230 (05:58:08.45 +51:33:34.8, J2000; R1 = 14.77, R2 = 15.27, Monet et al. 2003);
(c) V magnitudes of the comparison stars in the field of Mrk 421 (Villata et al. 1998).

The VaST software (Sokolovsky & Lebedev 2005) was used for the preliminary data reduction and detection of variable stars. Our final lightcurve analysis was conducted using two different methods. First, all lightcurves were analyzed using the Lafler-Kinman method which has the advantage that it does not assume any particular shape of a phased lightcurve. For three variable stars which show multi-periodic behavior, the final analysis was conducted using the Discrete Fourier Transform (DFT) method implemented in the Period04 software developed by Lenz & Breger (2005). For those three stars, the lightcurve approximation with a superposition of two sine waves seems to be reasonable. The errors in frequencies and amplitudes derived from the DFT analysis were estimated with Monte Carlo simulation.

Identification with the 2MASS catalog (Skrutskie et al. 2006) is provided whenever the simultaneous infrared photometric data from this catalog may improve the variability type classification. All coordinates in this paper were taken from the USNO-B1.0 catalog (Monet et al. 2003). The finding charts are made from POSS-II red images.

It was a surprise to find two double-mode RR Lyrae variables among five RR Lyrae stars identified in a single 234' x 156' field-of-view.

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