Revised Light Elements of 78 Southern Eclipsing Binary Systems

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Abstract Since 2011, members of Variable Stars South have undertaken intensive time series observations and analysis of eclipsing binary systems, most of which are south of declination –40°. Many of them have not been observed in detail since their discovery 50 to 80 years ago. New or revised light elements are presented here for 60 systems and revised O–C values for a further 18 systems. A pulsating component has been discovered in four of the binary systems: RZ Mic, V632 Sco, V638 Sco, and LT Her.

1. Introduction

The Southern Eclipsing Binaries Programme of Variable Stars South (VSS) is a multi-purpose and ongoing campaign to observe and analyze bright eclipsing binary stars accessible to Southern Hemisphere observers. Despite their importance and ease of observation, many of them have not been observed in detail since their discovery, and others require follow-up work to check and extend existing studies (Richards 2013). When we began this study, many ephemerides were so far out of date that eclipses were not observed at the times predicted by the GCVS elements. It was necessary, therefore, to obtain accurate eclipse timings and update ephemeris elements. We present here new or revised light elements for 60 of the 150 targets selected for study and revised O–C values for a further 18 systems.

2. Observations and Analysis

The data reported here are based on observations from early in 2011 to the end of 2013. Time-series photometry was performed with the instruments given in Table 1. Each observer used NTP software such as DIMENSION 4 (Thinking Man Software 1992–2014) to synchronize their computer's clock to UTC. A fast cadence was used in acquiring the photometric data to ensure good coverage for accurate determination of the eclipse times of minima. Eclipses were observed over a period of several hours to cover both descent and ascent around the minimum.

All CCD imaging was done with Johnson V filters unless otherwise indicated. Bright targets were observed with DSLR cameras and the procedures described by Blackford and Schrader (2011) were used to convert magnitudes to the standard BVR_c system. All images were reduced using aperture photometry and the resulting magnitude data are all untransformed unless otherwise indicated. Times of minima were determined using the Kwee and van Woerden algorithm or the Polynomial fit in PERANSO (Vanmunster 2013). Where three or more times of primary minima were accurately determined for any target, a linear regression analysis was applied using the Linest function in MICROSOFT EXCEL to obtain improved light elements. Although more than three primary eclipse measurements are preferable for a regression analysis, the results are an improvement on previously published data. One exception to this was AS Mon, for which only secondary eclipses were used for the regression analysis.

To further refine the light elements, VSS data were combined with ASAS observations (Pojmański 1997) as follows.

The ASAS data were phase-folded using a period which, by eye, achieved a minimum corresponding to the VSS epoch calculated from the Linest function. For these phase-folded data an "ASAS pseudo time of minimum" and associated uncertainty were determined close to the median time for the ASAS data. A weighted regression analysis was then performed using the combined VSS and ASAS times of minima and associated uncertainties.

The magnitudes of the eclipses are given here as an observational aid, rather than as a definitive assessment of eclipse depths. Although determined from aperture photometry, the CCD data are untransformed and therefore subject to instrumental differences between observers. Nevertheless, for several targets our results give a more realistic indication of the depth of the eclipses compared to those determined from photographic plates or survey telescopes such as ASAS. Additionally, for some targets, the elimination of instrumental variations by using data sets from the same observer permitted discrimination between primary and secondary eclipses where their depths were very similar. This led to further investigation and reassessment of the period.

We also report the maximum magnitude of the uneclipsed portion of the light curve. Where we have no relevant data for this, we give an approximate average magnitude assessed from ASAS data. Again the latter are included solely as an observational aid.

For many of the targets we observed, the predictions for times of minima were quite inadequate, either because the period and/or epoch had not been updated since discovery or the prediction methods used by others were insufficiently robust. To improve predictions, one of us (Byron) developed a routine to find the period giving the minimum value to a "scatter" parameter of the phase-folded ASAS data. This revised period

Table 1. Equipment used by the different observers.

Observer	*Initials This Paper*	*AAVSO Initials*	*Telescope*	*Camera*
Streamer	MS	SFU	200 mm Meade Schmidt-Cassegrain	SBIG ST402 CCD
Streamer			350 mm Meade Schmidt-Cassegrain	SBIG ST8XME CCD
Allen	WA	AWH	410 mm Cassegrain f/15	SBIG STL 1001E
Axelsen	RA	ARX	230 mm Celestron C9.25 Schmidt-Cassegrain	Canon EOS 500D DSLR
Bohlsen	TB	BHQ	200 mm Vixen VC200L Cassegrain	SBIG ST10XME CCD
Herald	DH	—	400 mm Meade Schmidt-Cassegrain	SBIG STL-6303 CCD
Kerr	SK	KSH	80 mm William Optics Refractor	Meade DSI Pro II
Ogmen	YO	OYE	356 mm Meade LX200R (ACF)	SBIG ST8XME CCD
Moriarty	DM	MDJA	280 mm Celestron Schmidt-Cassegrain	SBIG ST8XME CCD
Moriarty			356 mm Celestron Edge HD 1400 aplanatic Schmidt-Cassegrain	Moravian G3-6303 CCD
Powles	JP	PJOC	254 mm Meade Schmidt-Cassegrain	Atik 383L+
Richards	TR	RIX	410 mm RCOS Ritchey-Chrétien	Apogee U9 CCD
Starr	PS	SPET	508 mm Planewave CDK	SBIG STL 6303

was used to determine a nominal epoch, corresponding to a calculated minimum, close to the mid-value of the HJD of the ASAS data. This combination of epoch and period provided an improved prediction of current times of minima compared to previously published elements.

3. Results and discussion

3.1. Revised epochs and periods

Epochs and periods have been revised for 25 eclipsing binaries for which we obtained sufficiently high quality primary eclipse data for regression analysis on the times of minima (Table 2). For most targets, a weighted regression analysis using the combined VSS and ASAS data resulted in little change in period or epoch, within the appropriate error limits, compared to the Linest determination using VSS data alone. These values are also recorded in Table 2 under VSS+ASAS (Wtd). It must be emphasized, however, that these values are only valid if there has been no change in period of the target during the years from when ASAS data and VSS data were taken. However, note that the Linest function tends to underestimate the uncertainties in the final results, whereas the weighted regression procedure is more conservative.

We determined new periods, or clarified discrepancies in the literature, for the following binary systems.

TZ Cru has a period of 2.091154 days, which is double that given in the *General Catalogue of Variable Stars* (GCVS; Kholopov *et al.* 1985) and used in the ASAS light curve. In the discovery paper, Bruna (1930) suggested that the period should probably be doubled. Our results clearly show primary eclipses at V magnitude 13.1 and secondary eclipses at V magnitude 13.0. There was no indication of a secondary eclipse occurring at or about phase 0.5 using the shorter period.

AS Mon. GCVS gives a period of 1.836486 days, which is that used by Alfonso-Garzon *et al.* (2012). Using these predictions we observed four eclipses. However, we now conclude that the period is double this and that we had observed three secondary (V magnitude 11.2) and one primary (V magnitude 11.3) eclipses. Our weighted regression analysis of only the secondary eclipses results in a period of 3.673106 days, close to that given by Diethelm (2012) and Pojmański with ASAS data.

V632 Sco. There is confusion in the literature concerning its period. Our period of 1.610156 days is similar to that reported by Malkov *et al.* (2006) and that used originally in the GCVS catalogue (1.610168 days). Dvorak (2004) reported a period of 3.2204 days. We confirmed the shorter period by identifying a shallow secondary minimum with V magnitude 11.2 which occurs at phase 0.5.

V5552 Sgr has a period of 1.347670 days, which is half that reported by Otero (2003) and that used for the ASAS light curve. A small secondary eclipse was also identified close to the time predicted with the shorter period. Although requiring confirmation, the latter may not occur at exactly 0.5 phase, thus suggesting apsidal motion in this system.

V536 Ara, GM Nor, and CT Phe. Even after a weighted regression analysis, our results for these three targets remained poorly aligned with ASAS data. The results determined from VSS data alone are given in Table 3. There are several possibilities to explain this mismatch of data. For example, there could be a small period change; a third body may be causing a small deviation in the period; there could be slight apsidal motion in the system. Further observations on these targets are required to confirm and clarify our results.

The individual times of minima for each target in Tables 2 and 3 are given in Table 4.

3.2. Improved epochs

For some targets there were insufficient numbers of observed minima for a linear regression analysis, but the epochs of the minima we observed permitted revisions that are an improvement on data previously available. These results are given in Table 5. The observed times of minima for some targets differed by several hours from predictions using the old epochs, some of which had not been updated since discovery. Multiple observations of these targets were sometimes needed before an eclipse was finally detected. For each target, a single current epoch is presented equal to the time of minimum derived from the best data set.

Even though we have limited data for the targets given in Table 5, some of them show interesting features and are highlighted below.

TZ CMa. We used the longer period as given by Kreiner (2004) although the latter has the primary and secondary eclipses incorrectly assigned. The eclipses are of almost equal depth (V magnitude, p = 10.6, s = 10.5). We found that the secondary eclipse occurs at phase 0.515 rather than 0.5, indicating an eccentric orbit for this system.

CZ Mic. Otero (2003) reported a period double that previously published (1.00944 days). We assessed ASAS data using both periods and believe the shorter period to be more appropriate and we give an updated epoch for the primary eclipse. We have recently identified the shallow secondary eclipse based on the shorter period.

EF Vel showed deep primary eclipses of V magnitude 15.4. Both the *International Variable Star Index* (VSX; Watson *et al.* 2014) and ASAS data plots give the primary eclipse depth as magnitude 13.7. We conclude the differences are due to the limitations of the equipment used by other observers.

3.3. O–C results from reliable predictions

For several targets, the published light elements provided reliable predictions for times of minima; these are listed in Table 6. We used the original GCVS periods and epochs to calculate O–C values unless otherwise indicated.

V339 Ara is worth noting. This binary system has shown virtually no change in period since the original GCVS light elements were published. However, the magnitudes reported for the system vary considerably. Our observations showed an out-of-eclipse V magnitude of 11.6, falling to 13.1 during primary eclipse. VSX gives the range from 10.2 to 10.8, as does the GCVS. ASAS data show the magnitude range from 11.0 to 11.7. These discrepancies are difficult to explain.

AR CMa, V526 Sgr, and AO Vel have eccentric orbits and show apsidal motion, and the times of minima for these are included in Table 6 as a resource for others studying these systems.

Table 2. Light elements revised by regression analysis of VSS eclipses using Linest and matched to ASAS data using a weighted (Wtd) regression analysis.

Target	*# p*	*# s*	*Observers*	*Observation Span*	*Mag. Max.*	*Mag. p*	*Mag. s*	*Revised Period (days)*		*Revised Epoch (HJD)*	
								VSS data (Linest)	*VSS + ASAS (Wtd)*	*VSS data (Linest)*	*VSS + ASAS (Wtd)*
XY Ant	3	1	MS	2012-03-2013-05	9.0*	10.7	10.6	2.1803412 ±0.0000014	2.1803419 ±0.0000005	2456438.9951 ±0.0002	2456438.9952 ±0.0005
V881 Ara	3	1	MS	2012-05-2013-07	10.1	10.7	10.6	2.4188846 ±0.0000014	2.4188894 ±0.0000005	2456064.1238 ±0.0001	2456064.1237 ±0.0002
DI Cen	3	—	MS, PS	2012-04-2012-05	11.6*	12.4	—	3.549563 ±0.000057	3.5495684 ±0.0000015	2456045.9981 ±0.0003	2456045.9980 ±0.0004
V775 Cen	4	3	DM	2011-08-2013-06	9.7	10.3	9.9	0.6636414 ±0.0000009	0.6636413 ±0.0000001	2455808.8962 ±0.0005	2455808.8963 ±0.0005
V777 Cen	3	—	MS, TR	2012-05-2013-02	10.9	11.8	—	1.7759917 ±0.0000053	1.7759942 ±0.0000006	2456313.0666 ±0.0005	2456313.0666 ±0.0005
SZ Cru	5	2	DM, TR	2011-06-2013-05	11.2	12.3	11.5	1.9743162 ±0.0000015	1.9743156 ±0.0000006	2456430.0678 ±0.0003	2456430.0678 ±0.0005
TZ Cru	8	5	DM, MS, TR	2012-03-2013-06	12.4	13.1	13.0	2.0911644 ±0.0000046	2.0911536 ±0.0000006	2456057.9998 ±0.0005	2456058.0008 ±0.0005
AA Cru	4	2	DM, MS	2011-06-2013-04	11.0	11.5	11.4	3.7876324 ±0.0000036	3.7876337 ±0.0000007	2456070.0280 ±0.0003	2456070.0279 ±0.0009
BE Cru	4	3	DM, TR	2011-06-2013-05	12.7	13.5	12.7	2.2210130 ±0.0000032	2.2210076 ±0.0000017	2456084.0376 ±0.0002	2456084.0378 ±0.0004
RU Gru	4	1	DM, MS	2011-08-2013-10	11.1	11.8	11.1	1.8932001 ±0.0000018	1.8931963 ±0.0000009	2455805.1032 ±0.0005	2455805.1040 ±0.0007
TT Hor	6	2	DM, MS, TR	2011-11-2013-12	10.9	11.6	11.0	2.6082143 ±0.0000033	2.6082123 ±0.0000017	2456267.0788 ±0.0003	2456267.0789 ±0.0014
KZ Lib	3	—	MS	2012-05-2012-07	11.2	13.0	—	1.2387368 ±0.0000001	1.2387368 ±0.0000008	2456086.1355 ±0.0001	2456086.1355 ±0.0003
RZ Mic	3	1	MS	2011-10-2013-09	11.3*	12.3	11.6	3.9830610 ±0.0000048	3.9830361 ±0.0000029	2456543.9738 ±0.0005	2456543.9738 ±0.0005
CY Mic	3	—	MS, PS	2012-05-2012-08	11.7	12.4	—	1.6287250 ±0.0000037	1.6287358 ±0.0000007	2456153.0395 ±0.0001	2456153.0397 ±0.0005
AS Mon	1	3	MS	2011-12-2013-01	10.6	11.3	11.2	3.6731149 ±0.0000012	3.6731059 ±0.0000017	2456308.1235 ±0.0001	2456308.1227 ±0.0006
HM Pup	3	—	DM, MS	2012-03-2013-12	10.8	14.3	10.9	2.5897029 ±0.0000029	2.5897006 ±0.0000018	2456306.9982 ±0.0003	2456306.9982 ±0.0004
V849 Sgr	4	—	MS, TR	2011-09-2013-08	12.6	13.7	—	2.9506535 ±0.0000001	2.9506519 ±0.0000019	2455818.9621 ±0.0001	2455818.9623 ±0.0014
V5552 Sgr	4	1	DM, MS	2012-07-2013-06	12.9	13.6	13.0	1.3476614 ±0.0000060	1.3476697 ±0.0000014	2456152.0751 ±0.0007	2456152.0752 ±0.0010
V490 Sco	3	3	DM, MS	2012-07-2013-08	11.9	12.3	12.3	3.003763 ±0.000054	3.0037555 ±0.0000023	2456128.9342 ±0.0003	2456128.9341 ±0.0005
V626 Sco	5	—	DM, MS, TR	2012-06-2012-08	11.3	12.1	11.6	1.0336825 ±0.0000010	1.0336847 ±0.0000004	2456510.9553 ±0.0002	2456510.9555 ±0.0007
V632 Sco	4	—	TB, DM, MS	2012-07-2013-09	11.1	11.9	11.2	1.610148 ±0.000015	1.6101555 ±0.0000011	2456476.8968 ±0.0004	2456476.8965 ±0.0011
V634 Sco	4	1	DM, MS	2011-07-2013-06	11.6*	12.1	12.0	1.2240290 ±0.0000010	1.2240290 ±0.0000007	2455769.9765 ±0.0001	2455769.9763 ±0.0003
V638 Sco	3	—	DM, MS	2011-08-2013-08	10.8	11.7	—	2.3582339 ±0.0000085	2.3582243 ±0.0000014	2456114.1140 ±0.0011	2456114.1153 ±0.0013
LU Tel	3	1	DM	2012-06-2013-09	12.4	14.0	12.5	1.5717378 ±0.0000020	1.5717431 ±0.0000010	2456096.1639 ±0.0004	2456096.1637 ±0.0006
AW Vel	6	2	DM, MS, TR	2012-05-2013-03	10.7	12.2	10.8	1.992458 ±0.000038	1.9924771 ±0.0000005	2456274.1503 ±0.0003	2456274.1502 ±0.0003

** ASAS data*

Table 3. Light elements revised by regression analysis of VSS eclipses using Linest with a poor match to ASAS data.

Target	*# p*	*# s*	*Observers*	*Observation Span*	*Mag. Max.*	*Mag. p*	*Mag. s*	*Revised Period (days)*	*Revised Epoch (HJD)*
V536 Ara	3	—	MS	2012-05–2013-07	11.7*	13.2	—	2.3740622 ±0.0000016	2456062.1003 ±0.0002
GM Nor	3	—	TB, DM, DH	2011-07–2013-04	10.6	11.1	—	1.8846063 ±0.0000017	2456112.0091 ±0.0002
CT Phe	3	—	WA, TB, MS, TR	2011-09–2013-11	11.3	11.8	—	1.2608260 ±0.0000025	2456195.0750 ±0.0005

** ASAS data*

Table 4. Times of minima observed for targets listed in Tables 2 and 3.

Target	*Eclipse Type**	*Observers*	*Time of Minimum (HJD)*	*Error (day)*
XY Ant	p	MS	2456016.0090	0.0001
	p	MS	2456087.9600	0.0001
	p	MS	2456438.9951	0.0001
	s	MS	2456437.9050	0.0001
V536 Ara	p	MS	2456062.1004	0.0001
	p	MS	2456138.0701	0.0001
	p	MS	2456487.0574	0.0001
V881 Ara	p	MS	2456064.1238	0.0004
	p	MS	2456139.1093	0.0003
	p	MS	2456172.9736	0.0003
	s	MS	2456478.9625	0.0001
DI Cen	p	MS	2456045.9983	0.0001
	p	PS	2456053.0969	0.0001
	p	MS	2456077.9442	0.0001
V775 Cen	p	DM	2455798.9418	0.0019
	p	DM	2455808.8956	0.0017
	p	DM	2456075.0171	0.0014
	s	DM	2456458.9343	0.0030
	p	DM	2456459.9282	0.0009
V777 Cen	p	MS	2456051.9958	0.0010
	p	MS	2456313.0671	0.0007
	p	TR	2456329.0501	0.0001
SZ Cru	p	DM	2455748.9281	0.0026
	p	DM	2455750.9035	0.0001
	p (R_c)	TR	2456355.0435	0.0004
	s (R_c)	TR	2456356.0203	0.0070
	p (R_c)	TR	2456422.1709	0.0001
	p	DM	2456430.0675	0.0017
	s	DM	2456431.0349	0.0014
TZ Cru	p	DM	2455988.9895	0.0030
	p	MS	2456055.9094	0.0012
	s	MS	2456056.9546	0.0015
	p	DM	2456058.0005	0.0001
	s	DM	2456059.0453	0.0021
	p	MS	2456078.9121	0.0012
	s	DM	2456100.8696	0.0002
	s	DM	2456123.8726	0.0017
	p (R_c)	TR	2456354.9457	0.0016
	s (R_c)	TR	2456355.9899	0.0019
	p (R_c)	TR	2456357.0371	0.0016
	p	MS	2456377.9478	0.0017
	p	MS	2456446.9553	0.0014
	s	MS	2456448.0006	0.0016
AA Cru	p	DM	2455732.9282	0.0002
	p	DM	2455767.0177	0.0004
	s	MS	2455996.1702	0.0001
	p	DM	2456070.0282	0.0001
	s	DM	2456124.9488	0.0001
	p	DM	2456410.9147	0.0001
BE Cru	p	DM	2456084.0372	0.0001
	p	DM	2456092.9221	0.0004
	p	DM	2456112.9108	0.0001
	s	DM	2456384.9907	0.0022
	s	DM	2456404.9534	0.0126
	p	DM	2456406.0845	0.0003
	s	DM	2456416.1055	0.0004
RU Gru	p	MS	2455805.1025	0.0012
	p	MS	2455858.1135	0.0016
	p	DM	2456533.9854	0.0013
	p	DM	2456586.9947	0.0015
TT Hor	p	MS	2456267.0793	0.0031
	p	MS	2456280.1201	0.0027
	p	TR	2456280.1193	0.0025
	p	MS	2456567.0232	0.0035
	p	MS	2456580.0651	0.0035
	p	MS	2456627.0122	0.0049
KZ Lib	p	MS	2456074.9868	0.0006
	p	MS	2456086.1355	0.0005
	p	MS	2456131.9687	0.0005
RZ Mic	p	MS	2455846.9381	0.0050
	s	MS	2456537.9960	0.0100
	p	MS	2456539.9903	0.0002
	p	MS	2456543.9743	0.0001
CY Mic	p	PS	2456055.3161	0.0001
	p	MS	2456153.0397	0.0008
	p	MS	2456170.9554	0.0001
AS Mon	s	MS	2455904.0808	0.0001
	p	MS	2455949.9946	0.0001
	s	MS	2455995.9088	0.0001
	s	MS	2456308.1235	0.0014
GM Nor	p	DM	2456112.0093	0.0001
	p (UF)	DH	2456128.9704	0.0004
	p	TB	2456406.0077	0.0003
CT Phe	p	MS	2456195.0745	0.0003
	p	MS	2456205.1621	0.0002
	p	TR	2456601.0608	0.0015
HM Pup	p	MS	2455991.0542	0.0005
	p	MS	2456306.9986	0.0005
	p	MS	2456628.1211	0.0002
V849 Sgr	p	MS	2455818.9621	0.0025
	p	MS	2456116.9781	0.0026
	p (R_c)	TR	2456465.1552	0.0036
	p	MS	2456530.0696	0.0028
V5552 Sgr	p	MS	2456152.0752	0.0016
	p	MS	2456174.9864	0.0014
	p	MS	2456201.9374	0.0028
	s	MS	2456203.9666	0.0057
	p	DM	2456466.0804	0.0032
V490 Sco	p	DM	2456128.9343	0.0001
	p	MS	2456140.9489	0.0001
	p	MS	2456158.9719	0.0015
	s	DM	2456508.9095	0.0001
	s	DM	2456520.9256	0.0002
	s	DM	2456535.9399	0.0001
V626 Sco	p	MS	2456115.0549	0.0011
	p	TR	2456484.0796	0.0013
	p	DM	2456509.9212	0.0014
	p	DM	2456510.9554	0.0013
	p	DM	2456513.0230	0.0016
V632 Sco	p	MS	2456476.8964	0.0020
	p	DM	2456484.9479	0.0026
	p	DM	2456542.9124	0.0017
	p	TB	2456542.9133	0.0020
V634 Sco	p	DM	2455769.9766	0.0008
	p	MS	2456124.9447	0.0002
	p	MS	2456146.9772	0.0002
	p	MS	2456452.9845	0.0004
	s	MS	2456460.9402	0.0003
V638 Sco	p	DM	2456114.1139	0.0021
	p	MS	2456481.9993	0.0018
	p	MS	2456515.0130	0.0033
LU Tel	p	DM	2455773.9577	0.0012
	p	DM	2456096.1644	0.0009
	s	DM	2456537.0117	0.0032
	p	DM	2456540.9654	0.0011
AW Vel	p	MS	2456274.1502	0.0005
	p	MS	2456282.1202	0.0006
	p	DM	2456292.0821	0.0009
	p	TR	2456292.0827	0.0007
	p	MS	2456296.0669	0.0006
	p	TR	2456296.0677	0.0006

**(R_c) indicates minima observed with Cousins R filter; (UF) are unfiltered observations.*

Table 5. Current epochs of targets with limited eclipse data.

Target	*Eclipse Type***	*Observers*	*Magnitude Uneclipsed*	*Mag. p*	*Mag. s*	*Ref. Period (days)*	*Current Epoch (HJD)*	*Error (day)*
TZ CMa	p	MS, TR	10.1	10.6	—	3.822884	2456299.0585	0.0013
TZ CMa	s	MS, TR	10.1	—	10.5	3.822884	2456299.1085	0.0013
DO Car	p	DM, TR	9.0	9.3	—	3.85194	2456066.9614	0.0003
GP Car	s	MS	11.4*	—	11.9	2.464172	2456327.0850	0.0003
V594 Car	p	TB, DM	10.1	10.8	—	3.165830	2456402.8984	0.0025
ST Cen	s	DM	10.5	—	11.2	1.22339	2456435.9265	0.0011
V471 CrA	p	MS, TR	12.8	13.2	—	2.486044	2456532.9969	0.0028
AF Cru	p	DM, MS, TR	9.8	10.6	9.9	1.895685	2456099.0083	0.0002
W Gru	p	SK, MS	8.9*	9.5	—	2.968535	2456181.0712	0.0001
LT Her	p (UF)	YO	10.6	11.0	—	1.084033	2455752.3186	0.0004
GK Lib	p	PS, TR	12.4*	14.5	12.7	2.116458	2456058.0799	0.0001
FV Lup	p	DM, MS	10.2*	11.2	—	4.103084	2456462.0946	0.0001
RR Men	p	DM	11.4*	12.9	—	2.599540	2456290.9499	0.0002
CZ Mic	p	MS, TR	12.7	13.3	—	1.00944	2456470.0727	0.0001
VX Nor	p	DM, MS	11.4	12.0	—	2.082440	2456129.1177	0.0002
V384 Nor	p	DM	10.1*	10.7	—	3.97413	2456109.0133	0.0003
RV Pic	p	DM	9.6*	11.9	—	3.97178	2455887.0659	0.0003
AH Pup	p	MS, TR	11.6*	12.6	—	2.02485	2456250.1528	0.0005
KX Pup	p	MS	12.3	12.7	—	2.146777	2456302.0876	0.0025
SV Pyx	p	MS, TR	10.7*	11.4	—	1.446429	2456061.8969	0.0005
V789 Sgr	p	MS, TR	12.4*	12.7	—	2.55234	2456463.1385	0.0005
V2351 Sgr	p	MS	10.1*	10.7	—	3.748819	2456143.07195	0.0030
V606 Sco	p	MS	11.7	12.5	—	2.6857	2456165.9949	0.0001
V1226 Sco	p	MS	10.6	10.8	—	2.08355	2456458.9573	0.0007
V1270 Sco	p	MS	9.2*	9.7	—	4.243190	2456179.937	0.001
V356 Sct	p	MS	11.8*	12.4	—	2.1229	2455798.9312	0.0001
EQ TrA	p	SK, DM, MS	8.4*	9.1	—	2.709149	2456067.9472	0.0001
RV Vel	p	DM	9.9*	10.5	—	4.82105	2456060.9268	0.0004
AR Vel	p	MS	12.3*	12.9	—	3.212764	2456063.9098	0.0024
EF Vel	p	MS	13.2*	15.4	—	3.0696	2456077.0065	0.0022
EL Vel	p (R_c)	TR	11.3*	12.4	—	2.758338	2456340.0922	0.0002
ET Vel	p	TR	11.1*	11.9	—	3.080858	2456323.0803	0.0003
FV Vel	p	TB, MS	10.9	12.0	—	1.521131	2455962.1014	0.0001

** ASAS data. **(R_c) indicates minima observed with Cousins R filter. (UF) are unfiltered observations.*

Zasche (2012) revised the period for AR CMa to double that previously reported and showed that the system had an apsidal motion of a period of 44 years.

Oosterhoff and van Houten (1949) reported that AO Vel has an orbital eccentricity of 0.12 with the line of apsides moving with a period of about 50 years. It has since been reported as a quadruple system formed by two double-lined spectroscopic binaries (Gonzalez *et al.* 2006). Our data, obtained over a six-month time span, showed the secondary eclipse at phase 0.698 using GCVS elements.

V526 Sgr has an orbital eccentricity of 0.22 and apsidal period of about 156 years. We used the original GCVS elements for O–C values.

4. New pulsating systems

We announce the discovery of four new systems that exhibit δ Scuti-type pulsations in their light curves. These are RZ Mic, V632 Sco, V638 Sco, and LT Her. The light curves of Ebbighausen and Penegor (1974) clearly showed the presence of pulsations for LT Her but they did not comment on their nature.

Of the 78 eclipsing binary systems that we report in this paper, we have now found seven that contain a pulsating component. Our preliminary characterization of AW Vel, HM Pup, and TT Hor has already been published (Moriarty *et al.* 2013). We shall be presenting our data on the four new systems in another paper.

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References

Alfonso-Garzon, J., Domingo, A., Mas-Hesse, J. M., and Gimenez, A. 2012, *Astron. Astrophys.*, **548A**, 79.

Blackford, M. G., and Schrader, G. 2011, *Variable Stars South Newsletter,* **2**, 8.

Bruna, P. P. 1930, *Bull. Astron. Inst. Netherlands*, **6**, 45.

Chen, K-Y. 1975, *Acta Astron.*, **25**,89.

Table 6. Times of minima and O–C values from observed eclipses.

Target	*Eclipse Type**	*Observers*	*Cycle*	*Time of Minimum (HJD)*	*Error*	*O–C (day)*	*Ref. Period (days)*	*Ref. Epoch (HJD)*	*Eclipse Mag.*
V339 Ara	p	MS	11242	2456115.9705	0.0013	0.0001	2.438853	2428698.385	13.1
	p	MS	11267	2456176.9411	0.0015	–0.0007			13.1
TU CMa	p	MS	25700	2455961.9999	0.0001	–0.0104	1.1278041	2426977.445	10.4
	s	TR	26017.5	2456320.0804	0.0007	–0.0078	—	—	10.0
AR CMa	p	MS	1391[a]	2455893.0072	0.001	0.0106	2.3322242	2452648.8727	11.6
	p	MS	1436[a]	2455997.9547	0.002	0.0081	—	—	11.6
DQ Car	s	MS	1882.5[a]	2456088.9324	0.0009	–0.0001	1.733678	2452825.284	11.6
	p	MS	1841[a]	2456016.9853	0.0006	0.0001	—	—	11.7
	s	MS	2009.5[a]	2456309.1068	0.0008	–0.0031	—	—	11.6
	s	MS	2047.5[a]	2456374.9863	0.0008	–0.0034	—	—	11.6
	p	MS	2085[a]	2456439.9985	0.0007	–0.0042	—	—	11.7
V762 Cen	p	MS	1076	2456069.0078	0.0001	–0.0042	3.367895	2452445.157	12.4
	p	DM	1084	2456095.9517	0.0001	–0.0035	—	—	12.4
CW Eri	p	SK	5329[b]	2455807.1603	0.0002	–0.0027	2.728371	2441267.6756	8.9
	s	MS	5478.5[b]	2456215.0591	0.0004	0.0046	—	—	8.7
VZ Hya	p	MS	402	2456033.9261	0.0001	–0.0006	2.904301	2454866.3976	9.5
FZ Lup	p	SK, MS	791[c]	2456086.9599	0.0001	–0.0085	4.534625	2452500.08	10.7
AN Mon	p	MS	1433[c]	2456006.9913	0.0003	–0.0031	2.4458	2452502.163	12.9
	s	MS	1576.5[c]	2456357.9660	0.0005	–0.0007	—	—	12.1
AQ Mon	p	JP, MS	1618[c]	2456620.1341	0.0001	0.0010	2.545551	2452501.431	11.3
V648 Ori	p	TR	5068[c]	2456622.1442	0.0011	–0.0002	0.8132364	2452500.6623	12.4
	p	TR	5074[c]	2456627.0225	0.0007	–0.0013	—	—	12.4
	p	JP	5090[c]	2456640.0351	0.0003	–0.0005	—	—	12.4
LT Pup	p	MS	18030	2455979.9606	0.0001	–0.0069	1.642681	2426362.429	13.1
V526 Sgr	p	MS	17769	2456160.0188	0.0012	–0.0826	1.919411	2422054.0856	10.3
	s	MS	17782.5	2456186.1006	0.0014	0.0872	—	—	10.0
V457 Sco	p	DM, MS	14420	2456129.0399	0.0001	–0.0097	2.00738	2427182.63	11.3
V569 Sco	p	MS	2983[a]	2455797.0394	0.0001	0.0020	1.04724351	2452673.11	11.5
	s	MS	3350.5[a]	2456181.9007	0.0003	0.0013	—	—	11.4
	p	MS	3301[a]	2456130.0628	0.0003	0.0020	—	—	11.5
	p (Tfd)	RA	3659[a]	2456504.9766	0.0013	0.0026	—	—	11.5
	p (Tfd)	RA	3660[a]	2456506.0237	0.0014	0.0024	—	—	11.5
	p	MS	3660[a]	2456506.0233	0.0006	0.0020	—	—	11.5
CE Scl	p	SK, MS	3174	2455865.0515	0.0001	0.0070	2.277687	2448635.666	9.9
	p	SK, MS	3318	2456193.0372	0.0001	0.0057	—	—	9.9
AO Vel	p	MS	19946	2455876.0319	0.0002	0.2812	1.5845993	2424269.333	9.8
	p	MS	20189	2456261.0868	0.0001	0.2786	—	—	9.8
	s (R_c)	TR	20239.5	2456341.1439	0.0002	0.3134	—	—	9.8
	s	MS	20261.5	2456376.0067	0.0001	0.3150	—	—	9.7
	s	MS	20273.5	2456395.0206	0.0001	0.3137	—	—	9.7
BC Vel	p	MS	2991[c]	2456011.0128	0.0013	–0.0068	1.173598	2452500.788	11.6
	p	MS	3216[c]	2456275.0716	0.0021	–0.0076	—	—	11.6
	p (R_c)	TR	3268[c]	2456336.0982	0.0018	–0.0081	—	—	11.7
	p	MS	3308[c]	2456383.0434	0.0014	0.0067	—	—	11.6

Notes: a, Zasche (2012) light elements; b, Chen (1975) light elements; c, Kreiner (2004) light elements.
**(R_c) indicates minima observed with Cousins R filter; (Tfd) indicates transformed data obtained with DSLR camera.*

Diethelm, R. 2012, *Inf. Bull. Var. Stars*, No. 6029, 1.

Dvorak, S.W. 2004, *Inf. Bull. Var. Stars*, No. 5542, 1.

Ebbighausen, E. G., and Penegor, G. 1974, *Publ. Astron. Soc. Pacific*, **86**, 203.

Gonzalez, J. F., Hubrig, S., Nesvacil, N., and North, P. 2006, *Astron. Astrophys.*, **449**, 327.

Kholopov, P. N., *et al.* 1985, *General Catalogue of Variable Stars*, 4th Ed., Moscow.

Kreiner, J. M. 2004, *Acta Astron.*, **54**, 207.

Malkov, O. Y., Oblak, E., Snegireva, E. A., and Torra, J. 2006, *Astron. Astrophys.*, **446**, 785.

Moriarty, D. J. W., Bohlsen, T., Heathcote, B., Richards, T., and Streamer, M. 2013, *J. Amer. Assoc. Var. Star Obs*, **41**, 182.

Oosterhoff, P. Th., and van Houten, C. J. 1949, *Bull. Astron. Inst. Netherlands*, **11**, 63.

Otero, S. A. 2003, *Inf. Bull. Var. Stars*, No. 5480, 1.

Pojmański, G. 1997, *Acta Astron.*, **47**, 467.

Richards, T. 2013, Southern eclipsing binaries programme of the Variable Stars South group (http://www.variablestarssouth.org/research/variable-types/eclipsing-binaries).

Thinking Man Software. 1992–2014, DIMENSION 4 software (http://www.thinkman.com/dimension4/).

Vanmunster, T. 2013, Light Curve and Period Analysis Software, PERANSO v.2.50 (http://www.peranso.com/).

Watson, C., Henden, A. A., and Price, C. A. 2014, AAVSO International Variable Star Index VSX (Watson+, 2006–2014; http://www.aavso.org/vsx).

Zasche, P. 2012, *Acta Astron.*, **62**, 97.