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SOUTHERN ECLIPSING BINARY MINIMA AND LIGHT ELEMENTS, 2015

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Abstract: We present 113 minima estimates of 27 southern eclipsing binaries obtained by members of the Southern Eclipsing Binary group of Variable Stars South using DSLR and CCD detectors. Where sufficient minima estimates of a target are obtained, we report the light elements derived from those minima, together with O-C comparisons with light elements in the literature.

1 Introduction

We present 113 times of minima of 27 southern hemisphere eclipsing binary stars acquired in 2015 and earlier. These observations were acquired and analyzed by the authors who are members of the Southern Eclipsing Binary group of Variable Stars South (http://www.variablestarssouth.org). For twelve of the stars, we have derived light elements and present those as well as O-C values for our zero epochs derived from the original light elements in the literature.

2 Observations and Analysis

Equipment and software used are set out in Table 1. Observer initials abbreviate the name of an author of this paper, surname last. Instrument refers to the telescope and objective diameter in cm, or to the DSLR camera used. Remaining columns refer to the software used for the purposes listed. Software references are AIP4Win, (Berry & Burnell 2005); MaxIm, (http://www.cyanogen.com); Muniwin, (http://c-munipack.sourceforge.net); PERANSO, (http://www.peranso.com), BackyardEOS (http://www.otelescope.com) and VStar, (www.aavso.org/vstar-overview).

Table 1. Observers, equipment and software.

Observer	Instrument	Imaging	Calibration	Photometry	Minima
TR	41 cm R-C + Apogee U9 CCD	MaxIm	Muniwin	Muniwin	PERANSO
MB	Various Canon DSLRs	BackyardEOS, MaxIm	MaxIm	MaxIm	PERANSO
NB	Canon 550D	BackyardEOS	AIP4Win	AIP4Win	PERANSO
PE	25 cm SCT + SBIG ST9XE CCD	MaxIm	Muniwin	Muniwin	PERANSO
RJ	25 cm Newtonian + QSI-583 CCD.	MaxIm	MaxIm	MaxIm	VStar

CCD or DSLR image sets were obtained in hours-long runs. Each observer analysed their own image sets as follows:

1. Calibrated them using bias frames, dark frames and flat field frames.
2. Executed differential aperture photometric measurements on the calibrated sets.
3. Performed minima estimation on the photometric data using polynomial fitting.

3 Results

Table 2 lists the minima estimates. Columns 1 and 2 list the GCVS designation and variability type (Samus *et al*, 2007-2015) of the target stars in constellation order. Columns 3 and 4 record the heliocentric Julian dates of minima and the uncertainty (in days) as reported by the software. Column 5 lists the minimum type, Primary or Secondary. We define the primary minimum as the deeper one in our observations where that can be determined, otherwise we assume the epoch in the original light elements is of a primary minimum. (The sources of the original light elements are recorded at the end of this section.) Column 6 gives the filter used: V is Johnson V, or the transformed equivalent in the case of DSLR colour sensors; C is Clear or unfiltered. Column 7 gives the initials of the observer.

Table 2. Minima estimates.

ID	Type	HJD	error	Min	Filter	Obs
MR Aps	EB	2457159.012	0.002	P	V	TR
MR Aps	EB	2457167.986	0.001	P	V	TR
MR Aps	EB	2457184.083	0.005	S	V	RJ
MR Aps	EB	2457223.1460	0.0006	S	V	RJ
NT Aps	EW	2457207.988	0.001	S	V	MB
NT Aps	EW	2457208.135	0.001	P	V	MB
V0535 Ara	EW	2456869.972	0.001	P	V	MB
V0535 Ara	EW	2456875.007	0.001	P	V	MB
V0535 Ara	EW	2456875.951	0.001	S	V	MB
V0878 Ara	EW:	2457235.011	0.005	S	V	NB
V0878 Ara	EW:	2457236.931	0.004	P	V	NB
V0454 Car	EB:	2456709.093	0.003	P	V	MB
V0454 Car	EB:	2456713.019	0.003	P	V	MB
V0454 Car	EB:	2456714.000	0.003	P	V	MB
RR Cen	EW/KE:	2456792.063	0.002	S	V	MB
RR Cen	EW/KE:	2456825.072	0.002	P	V	MB
RR Cen	EW/KE:	2456826.890	0.002	P	V	MB
RR Cen	EW/KE:	2457140.937	0.003	S	V	MB
RR Cen	EW/KE:	2457141.237	0.002	P	V	MB
RR Cen	EW/KE:	2457182.121	0.002	S	V	MB
V0676 Cen	EW/KW	2457128.7904	0.0007	P	C	PE
V0676 Cen	EW/KW	2457128.9367	0.0008	S	C	PE
V0676 Cen	EW/KW	2457129.814	0.001	S	C	PE
V0676 Cen	EW/KW	2457129.961	0.001	P	C	PE

V0676 Cen	EW/KW	2457130.1059	0.0009	S	C	PE
V0676 Cen	EW/KW	2457140.7787	0.0007	P	C	PE
V0676 Cen	EW/KW	2457140.925	0.001	S	C	PE
V0676 Cen	EW/KW	2457141.0709	0.0008	P	C	PE
V0676 Cen	EW/KW	2457141.802	0.001	S	C	PE
V0676 Cen	EW/KW	2457141.9488	0.0009	P	C	PE
V0676 Cen	EW/KW	2457142.095	0.001	S	C	PE
V0676 Cen	EW/KW	2457143.119	0.001	P	V	TR
V0676 Cen	EW/KW	2457143.997	0.001	P	V	TR
V0676 Cen	EW/KW	2457146.043	0.001	P	V	TR
V0676 Cen	EW/KW	2457153.790	0.001	S	C	PE
V0676 Cen	EW/KW	2457153.935	0.001	P	C	PE
V0676 Cen	EW/KW	2457154.0828	0.0006	S	C	PE
V0676 Cen	EW/KW	2457155.8138	0.0006	S	C	PE
V0831 Cen	ELL:	2456010.116	0.004	P:	V	MB
V0831 Cen	ELL:	2456071.159	0.004	P:	V	MB
V0831 Cen	ELL:	2456749.987	0.004	S:	V	MB
V0831 Cen	ELL:	2457166.024	0.003	P:	V	MB
eps CrA	EW	2457285.027	0.004	S	V	NB
YY Gru	EB:	2456907.1577	0.0009	S	V	TR
YY Gru	EB:	2456908.035	0.001	S	V	TR
YY Gru	EB:	2456962.7603	0.0008	S	C	PE
YY Gru	EB:	2456962.9074	0.0009	P	C	PE
CN Hyi	EW	2456869.288	0.003	P	V	MB
CN Hyi	EW	2456870.202	0.003	P	V	MB
CN Hyi	EW	2456872.252	0.003	S	V	MB
CN Hyi	EW	2456875.217	0.003	P	V	MB
NSV 1000 Hyi	E	2456973.046	0.001	P	V	TR
NSV 1000 Hyi	E	2456973.215	0.001	S	V	TR
NSV 1000 Hyi	E	2457005.021	0.002	P	V	TR
NSV 1000 Hyi	E	2457012.089	0.002	P	V	TR
NSV 1000 Hyi	E	2457351.025	0.002	P	V	TR
NSV1000 Hyi	E	2457351.196	0.002	S	V	TR
NSV 1000 Hyi	E	2457353.047	0.002	P	V	TR
NSV 1000 Hyi	E	2457369.035	0.001	S	V	TR
BO Ind	EW	2457243.249	0.003	P	V	MB
BO Ind	EW	2457245.072	0.003	S	V	MB
BO Ind	EW	2457245.271	0.004	P	V	MB
BO Ind	EW	2457246.082	0.003	P	V	MB
BO Ind	EW	2457246.285	0.003	S	V	MB
BO Ind	EW	2457275.041	0.003	S	V	MB
BO Ind	EW	2457277.068	0.003	S	V	MB
DE Mic	EW	2457249.118	0.002	P	V	NB
DE Mic	EW	2457281.973	0.002	P	V	NB
DI Mic	EW	2456883.919	0.002	S	V	TR
DI Mic	EW	2456884.062	0.002	P	V	TR
DI Mic	EW	2456884.205	0.002	S	V	TR

DI Mic	EW	2456892.090	0.003	P	V	TR
DI Mic	EW	2456892.232	0.002	S	V	TR
VV Ori	EA/KE:	2456686.0003	0.0020	S	V	MB
MW Pav	EW	2457248.175	0.003	P	V	MB
MW Pav	EW	2457273.222	0.005	S	V	MB
V0386 Pav	nil	2457279.147	0.006	S	V	MB
V0386 Pav	nil	2457281.076	0.005	P	V	MB
AD Phe	EW/KW	2455130.9873	0.0008	S	V	TR
AD Phe	EW/KW	2456948.128	0.002	S	V	TR
AD Phe	EW/KW	2456950.978	0.001	P	V	TR
AD Phe	EW/KW	2456992.008	0.001	P	V	TR
AD Phe	EW/KW	2457279.038	0.004	S	V	TR
AD Phe	EW/KW	2457313.989	0.002	S	V	TR
AD Phe	EW/KW	2457314.183	0.002	P	V	TR
GZ Pup	EW/KW	2457019.102	0.001	P	V	TR
GZ Pup	EW/KW	2457374.112	0.001	P	V	TR
GZ Pup	EW/KW	2457380.036	0.001	S	V	TR
GZ Pup	EW/KW	2457380.196	0.001	P	V	TR
GZ Pup	EW/KW	2457386.122	0.001	S	V	TR
UX Ret	EW	2457346.176	0.002	P	V	NB
UX Ret	EW	2457362.105	0.002	S	V	NB
V0505 Sgr	EA/SD	2456538.039	0.004	S	V	MB
V0505 Sgr	EA/SD	2456846.169	0.001	P	V	MB
V0883 Sco	EB/KE	2457268.935	0.007	S	V	NB
V0883 Sco	EB/KE	2457283.916	0.007	P	V	NB
V0954 Sco	EB/KE	2457207.999	0.006	S	V	NB
V0954 Sco	EB/KE	2457220.045	0.005	P	V	NB
CP Scl	EW	2456921.987	0.001	P	V	TR
CP Scl	EW	2456922.145	0.002	S	V	TR
CP Scl	EW	2456923.085	0.002	S	V	TR
CP Scl	EW	2456923.242	0.001	P	V	TR
CP Scl	EW	2457315.002	0.003	P	V	TR
CP Scl	EW	2457322.997	0.002	S	V	TR
CP Scl	EW	2457323.155	0.002	P	V	TR
CP Scl	EW	2457324.095	0.001	P	V	TR
BU Vel	EW	2456712.157	0.002	P	V	TR
BU Vel	EW	2457034.065	0.000	S	V	TR
BU Vel	EW	2457064.013	0.003	S	V	TR
BU Vel	EW	2457073.045	0.002	P	V	TR
BU Vel	EW	2457381.013	0.004	S	V	TR
BU Vel	EW	2457384.110	0.002	S	V	TR
W Vol	EA/AR:	2456698.061	0.002	P	V	TR

In the case of V0831 Cen, there is uncertainty about which is the primary minimum and which is the secondary. They are separated by ~0.01 mag. We are acquiring further data to settle this issue. In the case of AD Phe, the last two minima were recorded in the same observing run, revealing that the second of them was 0.12 mag fainter than the other and hence was the primary. This is at odds with the original light elements, on which that last minimum occurred at phase ~0.5. The minima types recorded for AD Phe in Table 2 accord with our determination of primary/secondary, not with the original elements. The same reversal of primary and secondary eclipses occurs with GZ Pup: the two minima at HJD 2457380 are in the same observing run, and the second minimum is 0.066 mag fainter than the first, and occurs at phase ~0.5 on the original elements.

With the exception of V0831 Cen, where four or more minima were determined for a binary we derived light elements from them in Microsoft Excel using linear regression, as recorded in Table 3. Column 1 shows the GCVS ID of the star. Columns 2 and 3 show the heliocentric Julian date and its standard error of our zero epoch E0 derived by the regression, using the regressed value of an observed primary minimum. Columns 4 and 5 list the period and its standard error derived by the regression. Column 6 lists the number of minima estimates used in the regression, and column 7 is the interval in days over which the minima observations were obtained. Columns 8-10 record the O-C value of our E0 in days, the O-C error and its cycle count, using the original light elements.

Table 3. VSS light elements of binaries with four or more VSS minima estimates.

Star	E0	E0 error	P [d]	P error [d]	N	Int	O-C [d]	Cycle
MR Aps	2457159.0122	0.0003	0.527851	0.000004	4	64	0.0070	8789
RR Cen	2456826.8890	0.0005	0.605681	0.000001	6	390	-0.0377	53816
V0676 Cen	2457128.7908	0.0003	0.292399	0.000005	18	27	0.0707	77645
YY Gru	2456962.9070	0.0004	0.292649	0.000003	4	55	0.0054	17400
CN Hyi	2456869.2888	0.0009	0.4560	0.0001	4	6	0.0864	18349
NSV 1000	2456973.0460	0.0005	0.3365815	0.0000007	8	396	-0.0054	15164
BO Ind	2457245.2728	0.0006	0.40502	0.00002	7	34	0.0296	21589
DI Mic	2456884.0620	0.0004	0.28669	0.00002	5	9	-0.0463	13919
AD Phe	2456950.9779	0.0009	0.3799168	0.0000005	7	2184	0.0504	33428.5
GZ Pup	2457374.1116	0.0002	0.3202612	0.0000005	5	367	0.0185	71737.5
CP Scl	2456921.9874	0.0006	0.3136572	0.000001	8	403	0.016	16112
BU Vel	2456712.158	0.001	0.516291	0.000001	6	672	0.076	30407

The O-C error is just the E0 error in column 3, since in no case do the original light elements include uncertainties. Consequently the error value is significantly too small, especially where the cycle count is large. The original light elements from which the O-C values of our light elements were derived are from the GCVS, except for the following which do not have GCVS light elements. YY Gru, NSV 1000 and BO Ind are from the AAVSO VSX (VSX 2016); CN Hyi from the O-C Gateway (Paschke & Brát 2006), and DI Mic from (Otero *et al* 2005).

4 Conclusion and further work

We have reported minima estimates for 27 southern eclipsing binaries. We have reported light elements (zero epochs and periods, with uncertainties) for twelve of them for which we obtained four or more minima. We have provided O-C values of those zero epochs, calculated from the original light elements in the literature.

In Table 3 there are cases where the O-C value of our E0 exceeds the O-C error by a large factor, indicating the possibility of period change. But in the absence of uncertainty values for the original light elements such an indication is not firm, especially where the cycle count is large. A study of period change in these systems requires the inclusion of other minima values (with uncertainties) that can be found in the literature, as well as more minima estimates by us in the future. Such investigations warrant separate papers and lie outside the scope of this report.

We plan to do the following future work on these stars as appropriate, as well as add others to our observing list. (1) continue to monitor minima, to improve the light elements derived from our data; (2) investigate period change; (3) obtain full phased light curves in two or three bandpasses, to carry out photometric modelling of the systems.

We intend to publish future minima estimates and (updated) light elements in papers like the present one.

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