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SOUTHERN ECLIPSING BINARY MINIMA AND LIGHT ELEMENTS IN 2018

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Abstract: We present 142 minima estimates of 62 southern eclipsing binaries obtained in 2018 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 142 times of minima of 62 southern hemisphere eclipsing binary stars acquired in 2018 (and a few earlier). These observations were acquired and analyzed by the authors who are members of the Southern Eclipsing Binary group of Variable Stars South (VSS) (http://www.variablestarssouth.org). For six of the systems we have derived light elements and present those as well as O-C values for our zero epochs as calculated from the original light elements in the literature.

This paper is the fourth in a series, following (Richards *et al*. 2016, 2017, 2018).

2 Observations

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.

All observers using PERANSO employed polynomial fitting for minima estimation; Canopus uses the Hertzsprung method (Hertzsprung 1928, described in Henden & Kaitchuck, 1982). Minima25 takes the weighted mean and standard deviation of the means of six methods: parabolic fit, tracing paper, bisectors of chords, Kwee-van Woerden (Kwee & Van Woerden 1956), Fourier fit, and sliding integrations.

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Table 1. Observers, equipment and software. See the References section of this paper for the software mentioned in this table.

Observer	Instrument	Imaging	Calibration	Photometry	Minima
TR	41 cm R-C + SBIG STXL-6303e	MaxIm	Muniwin	Muniwin	Minima25 (multiple methods), PERANSO
MB (DSLR)	Canon 600D & 1100D DSLRs*	MaxIm	MaxIm	MaxIm	PERANSO
MB (CCD)	35-cm R-C + SBIG STT-3200	TheSkyX Professional	MaxIm	MaxIm	PERANSO
NB	Canon 550D	Canon EOS utility	AIP4Win	AIP4Win	PERANSO
GC	28cm SCT + SBIG STT8300	MaxIm	MaxIm	Canopus	Canopus
RJ	25 cm Newtonian + QSI-583 CCD.	MaxIm	MaxIm	MaxIm	Minima25

*Both cameras used at prime focus of an Orion ED80T refractor; the 1100D also used with a 200mm telephoto lens.

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.

3 Results

Table 2 lists the minima estimates. Columns 1 and 2 list the GCVS designation and GCVS variability type of the target stars in lexical order of constellation abbreviation, as listed in (Samus et al., 2017). In some cases, more recent work may propose different variability types. Columns 3 and 4 record the heliocentric Julian dates of minima and the uncertainty (in days) as reported by the algorithm used in the photometry software. Column 5 lists the minimum type, primary (P) or secondary (S). We define the primary minimum as the deeper one in our observations where that can be determined, otherwise we assume the epoch recorded in the AAVSO Variable Star Index (Watson, Henden & Price, 2006) – hereafter referred to as VSX – is of a primary minimum. Column 6 gives the filter used: B and V are Johnson *B* and *V*, or the transformed equivalent in the case of DSLR colour sensors; C is clear or unfiltered. R is Cousins *R*, and r' and i' are Sloan *r'* and *i'*. G is the green plane image from a tri-colour DSLR camera. Column 7 gives the initials of the observer.

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Table 2. Minima estimates.

ID	Type	HJD of min	error	Min	Filter	Obs
S Ant	EC	2458197.1293	0.0017	P	V	MB
MR Aps	EB	2458279.9325	0.0040	S	V	TR
MR Aps	EB	2458280.1943	0.0014	P	V	TR
R Ara	EA	2458312.07584	0.00040	P	V	MB
V0610 Ara	EW	2458276.1012	0.0036	S	V	NB
V0610 Ara	EW	2458291.0363	0.0031	P	V	NB
V0878 Ara	EW:	2458347.9372	0.0041	P	V	NB
V0454 Car	EB	2458158.15108	0.00036	P	V	MB
V0454 Car	EB	2458192.95595	0.00059	S	V	MB
V0462 Car	EB	2458191.9807	0.0042	P	G	NB
V0625 Car	EW	2458192.947616	0.000069	P	V	MB
V0625 Car	EW	2458193.086356	0.000075	S	V	MB
V0625 Car	EW	2458195.025136	0.000088	P	V	MB
V0625 Car	EW	2458195.163376	0.000071	S	V	MB
V0625 Car	EW	2458195.99417	0.00030	S	V	MB
V0625 Car	EW	2458196.132804	0.000090	P	V	MB
V0625 Car	EW	2458215.93464	0.00013	S	V	MB
V0625 Car	EW	2458216.07271	0.00032	P	V	MB
BH Cen	EB/KE	2458216.987905	0.000082	P	V	MB
BH Cen	EB/KE	2458218.17440	0.00022	S	V	MB
BH Cen	EB/KE	2458224.112125	0.000073	P	V	MB
V0701 Cen	EB/KE	2458253.9288	0.0019	P	G	NB
V0701 Cen	EB/KE	2458272.0238	0.0028	S	G	NB
V0752 Cen	EW/KW	2458217.01773	0.00016	P	V	MB
V0752 Cen	EW/KW	2458217.9427	0.0011	S	V	MB
V0752 Cen	EW/KW	2458224.05299	0.00017	P	V	MB
V0757 Cen	EW/KW	2458220.04904	0.00010	S	V	MB
V0757 Cen	EW/KW	2458220.21897	0.00023	S	V	MB
V0757 Cen	EW/KW	2458225.02446	0.00020	P	V	MB
V0757 Cen	EW/KW	2458225.19648	0.00016	P	G	NB
V0757 Cen	EW/KW	2458277.0164	0.0015	P	V	MB
V0759 Cen	EW/RS	2458235.0571	0.0032	P	G	NB
V0759 Cen	EW/RS	2458270.1334	0.0047	P	G	NB
V0901 Cen	EW	2458199.96908	0.00013	P	r'	TR
V1129 Cen	EB+UG	2458260.0814	0.0073	S	V	MB
Z Cha	UGSU+EA	2458124.02222	0.00025	P	C	MB
Z Cha	UGSU+EA	2458124.09691	0.00050	P	C	MB
Z Cha	UGSU+EA	2458127.00244	0.00037	P	C	MB
Z Cha	UGSU+EA	2458127.07672	0.00026	P	C	MB

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ID	Type	HJD of min	error	Min	Filter	Obs
Z Cha	UGSU+EA	2458127.15129	0.00031	P	C	MB
RW Dor	EW/KW	2458156.9700	0.0024	P	V	GC
RW Dor	EW/KW	2458158.1120	0.0093	P	V	GC
RW Dor	EW/KW	2458159.9678	0.0029	S	V	GC
RW Dor	EW/KW	2458164.9629	0.0014	P	V	GC
RW Dor	EW/KW	2458457.99191	0.00080	S	r'	TR
RW Dor	EW/KW	2458458.13407	0.00060	P	r'	TR
YY Eri	EW/KW	2458462.16282	0.00010	P	R	MB
YY Eri	EW/KW	2458480.005289	0.000051	S	R	MB
RV Gru	EW/KW	2458358.04820	0.00070	P	r'	TR
RV Gru	EW/KW	2458358.17770	0.00080	S	r'	TR
V Gru	EW/KW	2458362.9813	0.0038	P	G	NB
V Gru	EW/KW	2458376.9984	0.0026	P	G	NB
YY Gru	EW	2458374.94320	0.00052	P	r'	TR
YY Gru	EW	2458375.09066	0.00059	S	r'	TR
YY Gru	EW	2458375.23590	0.00043	P	r'	TR
SZ Hor	EW/KW	2458136.088870	0.000050	P	V	RJ
SZ Hor	EW/KW	2458141.089220	0.000040	P	V	RJ
SZ Hor	EW/KW	2458142.028250	0.000020	S	V	RJ
SZ Hor	EW/KW	2458441.1354	0.0013	P	V	TR
NSV 1000 Hyi	EW	2458076.0191	0.0022	P	i'	TR
NSV 1000 Hyi	EW	2458076.1874	0.0019	S	i'	TR
NSV 1000 Hyi	EW	2458421.0135	0.0011	P	r'	TR
NSV 1000 Hyi	EW	2458421.18190	0.00089	S	r'	TR
CO Ind	EB/KE	2458359.05072	0.00090	P	r'	TR
CR Ind	EW	2458366.0007	0.0010	S	r'	TR
CT Ind	EA	2458359.99830	0.00080	P	r'	TR
ST Ind	EW/KW	2458355.98083	0.00090	S	r'	TR
ST Ind	EW/KW	2458356.1838	0.0015	P	r'	TR
GG Lup	EA	2458319.0524	0.0022	S	I	MB
GG Lup	EA	2458321.998571	0.000063	P	I	MB
NSV 2569 Men	EB	2458159.98791	0.00058	P	C	MB
NSV 2569 Men	EB	2458166.0582	0.0020	S	C	MB
TY Men	EW/K	2458160.0211	0.0015	P	V	MB
DI Mic	EW	2458321.9636	0.0020	S	r'	TR
DI Mic	EW	2458322.1054	0.0020	P	r'	TR
DI Mic	EW	2458322.2492	0.0020	S	r'	TR
BS Mus	EB/KE	2458180.0380	0.0060	S	r'	TR
BS Mus	EB/KE	2458183.11167	0.000050	S	V	RJ
BS Mus	EB/KE	2458188.09221	0.00027	P	V	RJ
BS Mus	EB/KE	2458204.22829	0.00020	P	r'	TR

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ID	Type	HJD of min	error	Min	Filter	Obs
BS Mus	EB/KE	2458221.12957	0.00020	P	V	TR
BS Mus	EB/KE	2458226.13560	0.00060	S	V	TR
BS Mus	EB/KE	2458228.04311	0.00019	P	V	RJ
BS Mus	EB/KE	2458231.11474	0.00014	P	V	RJ
BS Mus	EB/KE	2458236.12267	0.00030	S	V	TR
eta Mus	EA	2458178.0659	0.0033	P	V	MB
TU Mus	EB/KE	2458214.07098	0.00023	P	V	MB
TU Mus	EB/KE	2458221.00734	0.00023	P	V	MB
TV Mus	EW/KW	2458177.12444	0.00030	S	r'	TR
TV Mus	EW/KW	2458216.11552	0.00010	P	r'	TR
TW Mus	EW/KW	2458238.15690	0.00020	S	r'	TR
TW Mus	EW/KW	2458238.99270	0.00040	S	r'	TR
TW Mus	EW/KW	2458239.20004	0.00014	P	r'	TR
EZ Oct	EW/KW	2458264.12608	0.00014	S	r'	TR
EZ Oct	EW/KW	2458264.26916	0.00016	P	r'	TR
VV Ori	EA/KE	2458478.1029	0.0060	S	V	MB
VV Ori	EA/KE	2458481.0817	0.0054	S	V	MB
IY Pav	EA/SD	2458365.11980	0.00070	S	r'	TR
V0401 Pav	EW	2458271.05445	0.00020	P	r'	TR
V0401 Pav	EW	2458271.21763	0.00020	S	r'	TR
V0401 Pav	EW	2458317.99460	0.00050	S	r'	TR
AD Phe	EW/KW	2458435.125147	0.000059	P	R	MB
AD Phe	EW/KW	2458436.0751	0.0018	S	R	MB
AD Phe	EW/KW	2458440.06392	0.00080	P	r'	TR
AU Phe	EW	2458441.03821	0.00080	P	r'	TR
BL Phe	EB	2458423.14994	0.00022	P	I	MB
BM Phe	EW	2458401.1400	0.0018	P	V	MB
BM Phe	EW	2458422.02752	0.00010	S	V	MB
BQ Phe	EW	2458126.027800	0.000010	S	V	RJ
BQ Phe	EW	2458375.013310	0.000010	S	V	RJ
NSV 455 Phe	EW	2458434.12941	0.00025	P	R	MB
NSV 455 Phe	EW	2458435.08889	0.00020	P	R	MB
GZ Pup	EW/KW	2458143.065070	0.000050	S	V	TR
GZ Pup	EW/KW	2458146.106820	0.000050	P	V	TR
GZ Pup	EW/KW	2458147.06716	0.00025	P	V	TR
GZ Pup	EW/KW	2458484.1427	0.0014	P	V	TR
HI Pup	EW/KW	2458136.176070	0.000060	P	V	TR
HI Pup	EW/KW	2458150.01873	0.00010	P	V	TR
HI Pup	EW/KW	2458175.976170	0.000090	P	V	TR
HI Pup	EW/KW	2458176.1905	0.0010	S	V	TR
V0621 Pup	EB/KW	2458157.13459	0.00090	S	V	MB

ID	Type	HJD of min	error	Min	Filter	Obs
V0621 Pup	EB/KW	2458158.11071	0.00063	P	V	MB
V0621 Pup	EB/KW	2458178.02014	0.00046	P	V	MB
NSV 1389 Ret	EB	2458439.1414	0.0019	P	r'	TR
UX Ret	EW	2458479.0602	0.0012	S	V	MB
CP Scl	EB	2458438.9952	0.0070	S	r'	TR
V0954 Sco	EB	2458272.9835	0.0045	P	V	NB
V1055 Sco	EW	2458349.9755	0.0028	P	V	NB
VY Sex	EB/KE	2458364.0105	0.0066	P	V	MB
VY Sex	EB/KE	2458333.9457	0.0005	P	V	MB
V2509 Sgr	EB/KE	2458335.0693	0.0045	P	G	NB
V3792 Sgr	EB/DM	2458344.06139	0.00067	S	I	MB
V3792 Sgr	EB/DM	2458215.09320	0.00029	P	I	MB
V3792 Sgr	EB/DM	2458215.97977	0.00025	P	I	MB
QW Tel	EW	2458349.0184	0.0040	P	G	NB
AQ Tuc	EW	2458352.079730	0.000070	P	V	RJ
AQ Tuc	EW	2458372.007310	0.000020	S	V	RJ
AQ Tuc	EW	2458383.0116	0.0022	P	r'	TR
DX Tuc	EW	2458424.06597	0.00046	S	R	MB
DX Tuc	EW	2458434.0560	0.0019	P	R	MB
V0362 Vel	EW	2458161.0646	0.0022	P	G	NB
V0362 Vel	EW	2458234.0679	0.0036	P	G	NB

4 Analysis

Binaries with a primary minimum in Table 2 for which we have derived three or more primary minima in earlier years (Richards *et al* 2016, 2017, 2018) are listed in Table 3, together with the ephemerides (aka light elements: period and one epoch of minimum) we have derived from those minima by linear regression. (Binaries with light elements reported in earlier papers in this series are excluded.)

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 P and its standard error Perr derived by the regression. Column 6 lists the number N of minima estimates used in the regression, and column 7 is the interval Int in days over which the minima observations were obtained. Columns 8-10 record the O-C (Observed minus Calculated) value of our (regressed) E0 in days, the O-C error and its cycle count, calculated using VSX light elements as at April 2019.

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

ID	E0	E0 error	P	P error	N	Int	O-C	O-C err	Cycle
RW Dor	2457679.104230	0.000070	0.285463447	0.000000053	9	779	-0.002761	0.000070	14757
SZ Hor	2458094.20735	0.00012	0.62509556	0.00000053	6	347	-0.02114	0.00012	6046
GG Lup	2456058.09070	0.00056	1.84959871	0.00000078	8	2264	-0.0133	0.0019	11638
AD Phe	2455130.98663	0.00091	0.37991699	0.00000014	6	3309	-0.00428	0.00091	8495
HI Pup	2457385.16138	0.00083	0.43261707	0.00000030	6	1105	-0.00362	0.00083	12622
UX Ret	2457346.1746	0.0012	0.4901078	0.0000011	5	754	0.0075	0.0012	18049

5 Conclusions and further work

Of the 62 eclipsing binaries for which we have provided minima estimates occurring in 2018, six have sufficient (four or more) primary minima estimates in our 2018 and earlier data to derive linear light elements.

In this paper no account has been taken of other minima estimates that may be available in the literature. A proper inclusion of such third-party data, its analysis and assessment, is a large task best left to papers on the individual binaries – which we intend to develop.

To improve our light elements and lower their errors it is necessary to obtain longer series of minima estimates, which we are pursuing. Longer series and better ephemerides will also strengthen evidence for period change.

We are continuing with the following work on the stars covered in this paper as appropriate, as well as on others: (1) monitoring 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 estimate tables in further papers in this series.

Acknowledgements

This research has made much use of the International Variable Star Index (VSX) database, operated at AAVSO, Cambridge, Massachusetts, USA (Watson et al. 2006).

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MaxIm DL: http://www.cyanogen.com

Minima25 http://www.variablestarssouth.org

Muniwin: http://c-munipack.sourceforge.net

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