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CCD MINIMA FOR SELECTED ECLIPSING BINARIES IN 2020

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Abstract: A total of 212 CCD determinations of times of minima for selected eclipsing binaries occurring in 2020 are presented. These were obtained at either Mountain Ash Observatory in Prince George, BC, Canada or Desert Blooms Observatory in Benson, AZ, USA.

1 Introduction

This is the 23rd report of CCD eclipse minima timings by this observer. All but one of the previous reports were in the (sadly) defunct *Information Bulletin on Variable Stars*, culminating in Nelson (2019a). The 22nd report was Nelson (2020a). In this report, a total of 212 minima timings of 156 eclipsing binaries acquired in the calendar year 2020 is presented.

2 Observations, Data Reduction and Analysis

Selection of targets was made possible by software *EB_Min* (available at Nelson 2013). This software makes use of the data in EB_Elements5c.xls (also available at the same website) which lists parameters from some 8853 eclipsing systems (at last count) based on a database of some 5472 O-C files available at Nelson (2019b, 2020b). *EB_Min* generates a customized nightly ephemeris taking into account the observer's local horizon and user-defined obstructions. Choices were made to maximize the scientific value of the timings based on an inspection of the latest O-C files.

- Observatory and Telescope:
    1. Mountain Ash Observatory (mao), 53°54'41.52" N, 122°47'23.82" W, elev 606 m.; 33 cm f/4.5 Newtonian on Paramount ME (German equatorial) mount
    2. Desert Blooms Observatory (DBO), 31°56'27.96" N, 110°15'25.14" W, elev. 1095 m; 40 cm f/6.8 Meade SCT telescope on Paramount Taurus 400 (fork) mount
- Detector and Filters (all provided a choice of B, V, Rc, Ic, clear filters):
    1. mao: SBIG ST-10XME camera, 2184 x 1472 pixels, each 6.8 µm, FOV 34.4' x 23.2'
    2. DBO: QSI 683 camera, 3326 x 2504 pixels, each 5.4 µm (binned 2x2), FOV 22.3' x 16.8'
- Method of data reduction: Differential photometry using MIRA by Mirametrics Inc.
- Method of minimum determination: A choice of six methods as implemented in software *Minima* available at Nelson (2020a). Among those available, and used here are: digital tracing paper method, Kwee and van Woerden (1956), five-term Fourier fit, and sliding integrations.

3 Data analysis

As mentioned above, up to four methods were used to extract times of minima from light curves surrounding each minimum. Every effort was made to include at least the inflection points in the light

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curve (and more if possible). This involved runs of typically three hours or more in duration, as shorter runs that capture only the bottom of the curve produce inaccurate results. In some publications in the literature, errors as high as ±0.002 days or worse have been quoted for entire CCD datasets. One wonders if this poor peformance might have resulted from this deficiency in procedure, as accuracies an order of magnitude better than ±0.002 should usually be attainable. On the other hand, because of unseen systematic errors (such as differential extinction, starspots, etc.), accuracies of better than ±0.0001 day are rarely if ever attainable and are not quoted here. Occasionally some of the errors quoted below in Table 1 are of the order of ±0.002 days or worse. In those cases, the low precision was due to poor sky conditions, not a deficiency in procedure. Poor as they were, it was decided to report these timings (accompanied by appropriately large error estimates), as they can still often be useful.

For the data presented here, the assignment of errors took advantage of the fact that multiple determinations for each timing (i.e., by using the different algorithms) were available. The sample standard deviation of the values provides a starting point for the error estimate. However, it should be remembered that it represents only the statistical error, and it can be shown that the systematic error is at least as large. Therefore, for this observer, it is standard procedure to adopt double the sample standard deviation (or perhaps slightly larger) for the error estimate.

4 Results

Table 1 lists the minima estimates. Column 1 lists the (usually) GCVS star name (the GSC designation is shortened to "G" to save space); column 2 lists the GCVS eclipsing type, columns 3 and 4 list the heliocentric minimum times and errors respectively; column 5 lists the minimum type (I signifies a primary minimum while II signifies a secondary); and column 6 lists the filter(s) used. In the case that multiple filters are listed for a detemination (e.g., BVRI in the third line), that signifies that the data were to be part of a full light curve acquisition; hence it would have been clearly seen whether the minimum was a primary or secondary one. (In other cases, the assignment (of I or II) was based on the best available eclipse elements--epoch and period--and may or may not be correct.) Again with the case of multiple filters listed, the differences in times between filters were deemed negligible and a single mean value was quoted. In the case of two systems, GN Boo and GS Cep, the differences between filters were not negligible and separate values were quoted. Lest there be a suggestion that *all* times of minima from the different filters should be listed separately, it is worthwhile pointing out the purpose of all these minima determinations is to understand the period variation in each system. Multiple equal or near-equal values for the same minimum that one sees in the literature are basically a nuisance, as they do not further the understanding of period variation, and lead to longer tables with much duplication. Further, variations of minima between different filters will often be of interest only to observers gathering their own full light curve data, and they will have numerous examples of their own.

Table 1: Times of minima of eclipsing binaries

Star	GCVS	Time of Min.	Error	Ecl.	Filter	Obser-
name	Type	HJD-2400000	(days)	Type	used	vatory
AB And	EW/KW	59139.6917	0.0002	II	V	mao
EP And	EW/DW	59186.6105	0.0001	II	c	mao

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LO And	EW/KW	59137.6241	0.0003	II	R	mao
V0404 And	EA/RS	59122.743	0.001	I	c	mao
V0801 And	EW	59119.8148	0.0003	II	c	mao
V1426 Aql	EA	59010.9023	0.0005	II	BVI	DBO
V1426 Aql	EA	59020.8899	0.0006	I	BVI	DBO
V1426 Aql	EA	59026.765	0.002	I	BVI	DBO
DD Aqr	EB/KE:	59134.7263	0.0003	I	BVI	DBO
DD Aqr	EB/KE:	59173.6606	0.0004	I	BVI	DBO
BM Ari	EW	59164.7091	0.0003	II	c	mao
G1772-0674*	EC	59147.6954	0.0001	I	c	mao
HL Aur	EB/SD	59164.8172	0.0003	II	c	mao
KU Aur	EA/SD	59163.9678	0.0003	I	BVI	DBO
KU Aur	EA/SD	59169.9087	0.0004	II	I	DBO
KU Aur	EA/SD	59175.8444	0.0002	I	BVI	DBO
V0410 Aur	EW	59161.8537	0.0003	I	V	mao
V0585 Aur	EB	59147.8036	0.0004	I	0	mao
V0826 Aur	EW	59184.7420	0.0002	II	c	mao
V0845 Aur	EB	59122.8948	0.0002	II	c	mao
TY Boo	EW/KW	58945.7337	0.0002	II	c	mao
TZ Boo	EW/KW	58924.8051	0.0002	II	V	mao
CK Boo	EW/KW	58967.7590	0.0005	II	V	mao
EL Boo	EW	58979.7534	0.0004	I	R	mao
GH Boo	EW	58950.7354	0.0006	II	c	mao
GN Boo	EW	58947.9044	0.0004	II	VRI	DBO
GN Boo	EW	58949.8652	0.0002	I	VRI	DBO
GN Boo	EW	58951.9764	0.0002	I	VRI	DBO
GN Boo	EW	58953.7861	0.0002	I	VRI	DBO
GN Boo	EW	58955.8972	0.0002	I	BVRI	DBO
GN Boo	EW	58965.8505	0.0002	I	BVRI	DBO
GN Boo	EW	58967.8108	0.0003	II	BVRI	DBO
GN Boo	EW	58973.8426	0.0004	II	BVRI	DBO
GN Boo	EW	58981.6842	0.0002	II	I	DBO
GN Boo	EW	58981.6845	0.0002	II	R	DBO
GN Boo	EW	58981.6846	0.0002	II	V	DBO
GN Boo	EW	58981.6848	0.0002	II	B	DBO
GT Boo	EB	58916.8250	0.0004	I	c	mao
KP Boo	EB	58933.8111	0.0005	I	c	mao
PU Boo	EW	58978.7828	0.0005	II	c	mao
V0389 Boo	EB	58940.7895	0.0004	II	c	mao
FN Cam	EW	58909.6992	0.0003	II	V	mao
V0335 Cam	EA	59209.6135	0.0006	I	R	DBO
V0366 Cam	EW	59146.7724	0.0003	II	c	mao
V0403 Cam	EW	59119.941	0.001	I	c	mao
V0516 Cam	EA	58952.7326	0.0005	I	R	mao

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V0584 Cam	EW	59162.775	0.001	I	c	mao
V1049 Cas	EA	59124.7599	0.0003	I	c	mao
V1337 Cas	EW	59146.6628	0.0002	I	R	mao
GS Cep	EB/KE	59155.7961	0.0003	II	BVI	DBO
GS Cep	EB/KE	59169.7764	0.0008	I	BVI	DBO
GS Cep	EB/KE	59203.6241	0.0002	I	BVI	DBO
GS Cep	EB/KE	59189.6403	0.0001	II	B	DBO
GS Cep	EB/KE	59189.6406	0.0001	II	V	DBO
GS Cep	EB/KE	59189.6412	0.0001	II	I	DBO
CZ CMi	EW	59161.9529	0.0004	II	R	mao
EK CMi	EB	58902.6912	0.0008	I	c	mao
EH Cnc	EW	59184.0029	0.0003	II	V	DBO
TX Cnc	EW/KW	59186.8907	0.0004	II	c	mao
CC Com	EW/KW	58922.7159	0.0003	II	c	mao
CC Com	EW/KW	58977.6664	0.0003	II	BVI	DBO
CC Com	EW/KW	58977.7761	0.0002	I	BVI	DBO
LQ Com	EW	58933.7078	0.0004	II	c	mao
PU Com	EB / EW	58947.7359	0.0003	I	c	mao
SS Com	EW/KW	58985.7692	0.0003	II	BVI	DBO
SS Com	EW/KW	58989.6910	0.0006	I	BVI	DBO
TW CrB	EB/KE	58982.7417	0.0002	II	c	mao
YY CrB	EW	58955.8595	0.0002	I	V	mao
AS CrB	EW	58926.9517	0.0002	II	c	mao
AW CrB	EW	58923.7898	0.0004	II	c	mao
AW CrB	EW	58980.8193	0.0003	II	c	mao
BI CVn	EW/KW	59020.7058	0.0002	II	V	DBO
BO CVn	EW	58928.7856	0.0003	II	c	mao
DF CVn	EW	58909.8138	0.0003	II	c	mao
DR CVn	EW	58907.0195	0.0005	II	VRI	DBO
DR CVn	EW	58924.9603	0.0006	II	BVI	DBO
DR CVn	EW	58961.8157	0.0007	I	BVRI	DBO
DR CVn	EW	58969.7120	0.0004	I	B	DBO
DR CVn	EW	58936.8060	0.0006	II	BVRI	DBO
DR CVn	EW	58936.9680	0.0012	I	BVRI	DBO
DR CVn	EW	58938.7800	0.0012	II	BVRI	DBO
DR CVn	EW	58938.9423	0.0008	I	BVRI	DBO
DR CVn	EW	58941.7424	0.0006	I	BVRI	DBO
DR CVn	EW	58941.9036	0.0004	II	BVRI	DBO
DX CVn	EW	58917.7406	0.0003	II	c	mao
EL CVn	EA	58959.7624	0.0003	I	V	mao
FV CVn	EW	58944.8371	0.0003	II	c	mao
GM CVn	EW	58944.7273	0.0003	II	c	mao
GN CVn	EW	58926.8364	0.0002	II	c	mao
HN CVn	EW	58916.709	0.001	I	c	mao

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V0401 Cyg	EW/KE	58952.9129	0.0010	I	c	mao
V0753 Cyg	EA	58942.9397	0.0002	I	c	mao
V0859 Cyg	EW/KW	58970.8674	0.0003	II	c	mao
V2197 Cyg	E	58983.8894	0.0001	I	c	mao
V2364 Cyg	EW	58944.9368	0.0004	I	c	mao
BL Dra	EW	58977.9163	0.0002	I	c	mao
BV Dra	EW/KW	58941.7396	0.0003	II	V	mao
BW Dra	EW/KW	58941.7906	0.0003	I	V	mao
BX Dra	EB	58943.9377	0.0003	II	c	mao
CV Dra	EW	58916.0028	0.0002	II	R	mao
EF Dra	EW	58934.8314	0.0005	II	c	mao
FU Dra	EW	58917.9306	0.0003	I	c	mao
MY Dra	EA	58951.7266	0.0003	I	c	mao
OX Dra	EA	58922.8002	0.0002	I	c	mao
V0353 Dra	EB	58916.9384	0.0002	I	c	mao
V0388 Dra	EB/KE	58924.9244	0.0005	II	c	mao
V0471 Dra	EW	58909.8992	0.0006	I	c	mao
V0518 Dra	EB	58975.9389	0.0005	II	V	DBO
V0550 Dra	EW	58915.8795	0.0005	II	c	mao
V0550 Dra	EW	58951.8114	0.0004	II	V	mao
V0551 Dra	EW	58943.8069	0.0003	I	c	mao
V0556 Dra	EA	58977.7328	0.0002	I	c	mao
WW Gem	EB/KE	59181.7601	0.0006	II	B	DBO
V0404 Gem	EW	59184.8296	0.0003	I	c	mao
V0405 Gem	EW	59184.8296	0.0007	I	c	mao
V0437 Gem	EW	59146.9235	0.0001	I	c	mao
TU Her	EA/SD	59018.8585	0.0001	I	BVI	DBO
CC Her	EA/SD	58943.8924	0.0002	I	BVI	DBO
CC Her	EA/SD	58989.8456	0.0006	II	BVI	DBO
CC Her	EA/SD	58963.834	0.001	II	BVI	DBO
CC Her	EA/SD	58969.9037	0.0002	II	BVI	DBO
G2093-1156*	EW	58981.929	0.002	II	c	mao
G2093-1156*	EW	58982.908	0.002	I	c	mao
G2093-1156*	EW	58983.8879	0.0008	I	BVI	DBO
G2093-1156*	EW	58991.886	0.001	II	BVI	DBO
V0829 Her	EW/KW	58928.8884	0.0002	II	R	mao
V0842 Her	EW	58970.7498	0.0004	II	R	mao
V0857 Her	EW	58899.0119	0.0005	II	c	mao
V1033 Her	EW	58932.9055	0.0002	II	R	DBO
V1038 Her	EW	58958.8506	0.0002	I	c	mao
V1042 Her	EB	58929.9525	0.0003	I	c	mao
V1071 Her	EB	58996.8155	0.0004	I	c	mao
V1097 Her	EW	58959.9522	0.0003	II	c	mao
V1119 Her	EB	58971.8052	0.0005	II	V	DBO

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V1143 Her	EA	58922.9177	0.0002	I	c	mao
V1148 Her	EW	58917.8335	0.0003	II	c	mao
V1173 Her	EW	58952.8291	0.0003	I	R	mao
V1181 Her	EW	58960.7729	0.0003	II	c	mao
V1187 Her	EW	58898.029	0.006	II	V	DBO
V1223 Her	EW	58950.8693	0.0003	II	R	mao
V1261 Her	EW	58909.9811	0.0003	I	c	mao
V1289 Her	EW	58981.7779	0.0001	I	c	mao
V1306 Her	EW	58940.9426	0.0001	II	c	mao
V1454 Her	EW	58959.8682	0.0004	I	c	mao
V1527 Her	EB	58981.8814	0.0001	I	c	mao
AV Hya	EB/KE	58967.6756	0.0008	II	BVI	DBO
EU Hya	EA/DW	58896.6840	0.0004	I	BVI	DBO
EU Hya	EA/DW	59209.916	0.003	II	BVI	DBO
XY Leo	EW/KW	58924.6871	0.0002	II	V	mao
AL Leo	EA/D	58906.6951	0.0002	II	BVRI	DBO
AL Leo	EA/D	58926.7633	0.0005	I	BVI	DBO
AL Leo	EA/D	58930.7768	0.0004	II	BVRI	DBO
CE Leo	EW/KW	58934.7532	0.0002	I	c	mao
DU Leo	EA/SD	58896.9006	0.0002	I	BVI	DBO
G1965-0735*	EB:	58923.7071	0.0004	I	R	mao
MW Leo	EA	58932.7029	0.0002	I	R	mao
XY LMi	EW	58928.7002	0.0004	II	c	mao
CW Lyn	EW	59181.944	0.004	I	BVI	DBO
CW Lyn	EW:	59205.910	0.002	II	BVI	DBO
KO Lyn	EW	58888.7272	0.0003	II	V	DBO
KO Lyn	EW	59205.7613	0.0004	II	c	mao
G3104-1085*	EW?	58977.8232	0.0008	I	c	mao
V0653 Lyr	EW	58923.941	0.001	II	c	mao
V0658 Lyr	EW	58933.9239	0.0001	II	c	mao
V0740 Lyr	EA	58951.9648	0.0003	I	c	mao
V0958 Mon	EW/KW	58898.6543	0.0003	II	c	DBO
V1008 Mon	EW	58892.7244	0.0003	I	c	DBO
V0508 Oph	EW/KW	58979.8804	0.0001	II	c	mao
V2713 Oph	EB	59024.7096	0.0002	I	R	DBO
ES Ori	EA/DM	59144.9234	0.0004	I	BVI	DBO
ET Ori	EA/SD	59165.860	0.002	II	BVI	DBO
ET Ori	EA/SD	59173.9441	0.0004	I	BVI	DBO
V1363 Ori	EW	59183.8804	0.0003	II	R	DBO
DK Peg	EA/DM	59167.6903	0.0004	I	BVRI	DBO
DK Peg	EA/DM	59185.638	0.001	I	BVRI	DBO
V0596 Peg	EW	59114.6879	0.0005	I	BVI	DBO
V0740 Per	EW	59186.7398	0.0001	I	c	mao
V0881 Per	EW/KW	59171.7286	0.0003	II	c	DBO

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V0887 Per	EA	59136.848	0.002	II	BVI	DBO
V0887 Per	EA	59116.9000	0.0002	II	BVI	DBO
V1052 Per	EB	59161.7307	0.0003	I	c	mao
V1092 Per	EW	59184.6181	0.0002	II	R	mao
VZ Psc	EW/KW	59175.6789	0.0005	II	BVRI	DBO
VZ Psc	EW/KW	59179.5976	0.0007	II	BVI	DBO
VZ Psc	EW/KW	59181.688	0.001	II	BVI	DBO
VZ Psc	EW/KW	59165.615	0.001	I	BVRI	DBO
VZ Psc	EW/KW	59165.751	0.001	II	BVRI	DBO
CP Psc	EB:	59119.7042	0.0004	I	c	mao
AU Ser	EW/KW:	58942.8566	0.0001	I	R	mao
Y Sex	EW/KW	58898.8065	0.0003	II	c	mao
DL Sge	EA/SD	58978.9043	0.0002	I	c	mao
GN Sge	EB/KE	58977.892	0.002	I	BVRI	DBO
GN Sge	EB/KE	58987.956	0.001	I	BVI	DBO
GN Sge	EB/KE	59118.778	0.002	I	BVRI	DBO
RS Tri	EA/DM	59187.709	0.004	II	I	DBO
AK Tri	EW	59199.7829	0.0008	I	c	DBO
XY UMa	EB/DW/RS	58899.7173	0.0005	II	R	mao
AA UMa	EW/KW	58937.7751	0.0005	I	c	DBO
BH UMa	EW/KE	58926.7174	0.0008	II	c	mao
G3452-0720*	E	58899.810	0.001	II	c	mao
HN UMa	EW:	58915.7304	0.0003	II	c	mao
HV UMa	EW	58943.7024	0.0004	II	V	mao
MQ UMa	EW	58929.6989	0.0002	II	c	mao
V0354 UMa	EW	58921.842	0.005	I	c	mao
V0385 UMa	EW	58898.830	0.002	I	c	DBO
V0441 UMa	EA	58898.7083	0.0005	II	c	mao
VY UMi	EW	58929.8414	0.0001	II	c	mao
AH Vir	EW/KW	58991.6798	0.0002	II	BVRI	DBO
BT Vul	EA	58983.9425	0.0004	I	c	mao
V0496 Vul	EW	58973.9331	0.0001	I	R	DBO
V0499 Vul	EA	58980.9199	0.0001	I	c	mao

*To save space, the usual designation GSC ... has been shortened to only G.

Three stars listed above do not have elements (epoch, period) listed in VSX. The elements are presented in Table 2.

Readers are encouraged to make use of the O-C database at Nelson (2019b, 2020b) which contains over 5400 Excel files for the latest elements, many of which will supersede those at VSX. Efforts are planned to reconcile any differences in elements between the two databases.

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Table 2. Eclipse elements for stars not listed in VSX.

Star	Constell	epoch	period
G2093-1156	Her	58991.8860	0.3264645
G3104-1085	Lyr	58977.8249	0.4336593
G3452-0720	UMa	58899.7047	0.2130907

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This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France

The construction of the O-C database (Nelson 2019b, 2020b) has benefited from, in part, the databases of Kreiner (2012), Kundera (2012) and Paschke & Brát (2012) whose long-time dedication is gratefully acknowledged.

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