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# NEW CCD TIMES OF MINIMA

# OF ECCENTRIC ECLIPSING BINARY SYSTEMS IN 2017-2019

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**Abstract:** We present 88 times of minima for 56 eccentric eclipsing binary systems determined from photometric observations at the Sobaeksan Optical Astronomical Observatory (SOAO) in Republic of Korea from February 2017 to December 2019.

## 1 Introduction

The observed period changes of eclipsing binary (EB) stars have been studied with their eclipse timing diagrams (ETDs, commonly referred to as O-C diagrams) formed from observed times of minimum light (O), minus those calculated from an ephemeris (C), plotted against the number of revolutions. The period of an EB system with deep and well defined eclipses can be determined to an accuracy of one part in  $10^{-9}$  d or less (Batten, 1973). The period change of the EB star with such favorable circumstances can be easily detected to several parts of  $10^{-8}$  d in its ETD over a significantly long time baseline. The observed period change can be used as direct clues in understanding astrophysically interesting topics, such as: apsidal motion (AM) in eccentric EBs (EEB), light time effects (LITE) induced by a third body orbiting an EB pair, mass transfer from one component to the other, mass loss from one (or both) component(s), magnetic activities of the stars, and so on. In this respect, it is highly needed to constantly monitor times of minima of EB stars.

In recent years, Kim et al. (2018) compiled a comprehensive catalogue of galactic EEB stars based on ETD. The catalogue lists 623 EEB stars and the AM parameters of 170 EEB stars showing AM. While editing the catalogue, they published a lot of times of minima of EEB stars in the catalogue (Ogłoza et al., 2017; Kim et al., 2017). This paper continues the publication of times of minima for several dozens of the EEB systems determined from new photometric observations. Information on the observations and the data processing are summarized in Section 2. The observed times of minima are listed in Section 3.

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# 2 Observation and Data Reduction

In order to systematically obtain times of minimum light for EEB systems in the catalogue of Kim et al. (2018), we first predicted the eclipse timings of each system in advance by using the AM parameters of each system given in the catalogue. Then, based on the predicted eclipse timing schedule of each system, photometric observations at the SOAO from February 2017 to December 2019 were performed. A 61-cm reflecting telescope was used with a FIL 4K CCD system and a standard BVR filter set. To increase the time resolution between observations, most observations were done only with the R filter. The CCD system, with a  $15.2' \times 15.2'$  field of view, was electronically cooled during the observations. By using the IRAF/CCDPROC package, all raw images were preprocessed and corrected with bias, dark, and flat-field images, and then aperture photometry in the IRAF/DAOPHOT package was performed for the postprocessing of the data. More details of the data reduction procedure were described in Kim et al. (2014).

Differential photometry was adopted to ensure high precision with our current equipment and techniques. Photometric information on the observed EEB stars and their comparison stars is listed in Tab. 1 where most of the V magnitude and B-V color index were extracted from the SIMBAD database, while the V magnitude and B-V color index of some systems marked with '\*' and '\*\*' in the first or the sixth columns were excerpted from the UCAC4 (Zacharias et al., 2012) and GSC2.3 (Lasker et al., 2008) catalogues, respectively. Individual differential measurements of each system are available as a machine-readable format. Fig. 7 shows a sample of the eclipse light curves. All eclipse light curves of the observed EEB stars are also available in the Appendix.

## 3 Observed Times of Minimum Light

As shown in the Appendix, a total of 88 eclipse light curves for 56 EEB systems were secured from our observations. To determine the times of minima from our observations, we basically used the method of Kwee & van Woerden (1956, KW). Before calculating the times of minima, first we scrutinized each of all eclipse light curves, and found that 33 eclipse light curves have a big difference in length between the descending and ascending branches of eclipse and two have a significant gap during eclipse. The timing determined by applying only the KW method to such data can be unrealistic. To avoid the risk, in addition to the KW method, we adopted two different methods of Fourier fit and sliding integration (Nelson, 2001) of which the computing programs are provided by Bob Nelson<sup>a</sup>. A time of minimum light for the data in question was calculated by each of the three methods, and then the average of them and its standard deviation were finally adopted as the time of minimum light and its error, respectively. We think that the average timing is less risky than a timing determined with only one method. For the rest 53 eclipse light curves, a single time of minimum light from each of them was determined by only the method of Kwee & van Woerden (1956). The epochs of minimum light determined separately from multi-bandpass observations were then averaged to yield a weighted mean

<sup>&</sup>lt;sup>a</sup>https://www.variablestarssouth.org/software-by-bob-nelson/

Table 1: Information of the program stars

| Star Name                | To                 | Р           | V      | B = V | Star Name                               | V      | B <sub>-</sub> V |
|--------------------------|--------------------|-------------|--------|-------|---|--------|------------------|
| (Variable)               | (HJD 2400000+)     | (day)       | (mag)  | (mag) | (Comparison)                            | (mag)  | (mag)            |
| (1411411)                | (100 - 1000000 + ) | (44)        | (8)    | (8)   | ( • • • • • • • • • • • • • • • • • • • | (8)    | (8)              |
| V871 Aql*                | 38637.16579        | 2.95266654  | 12.535 | 0.967 | 2MASS J18424480-0307558*                | 12.765 | 0.843            |
| AG Ari                   | 54033.32590        | 1.96312799  | 8.18   | 0.10  | 2MASS J02263288+1257222                 | 10.75  | 0.69             |
| AL Ari                   | 51112.82099        | 3.74746230  | 9.23   | 0.46  | 2MASS J02421749+1250459                 | 8.62   | 0.53             |
| CG Aur                   | 27148.86801        | 1.80485871  | 11.43  | 0.43  | 2MASS J05035856+2915521*                | 1.355  | 10.217           |
| EQ Boo*                  | 47931.50209        | 5.43535535  | 8.937  | 0.701 | 2MASS J14522065+1746527                 | 7.87   | 1.52             |
| WW Cam                   | 39403.55462        | 2.27436274  | 10.09  | 0.52  | 2MASS 04312305+6420115*                 | 12.451 | 1.591            |
| AS Cam                   | 40204.40430        | 3.43096730  | 8.60   | -0.01 | 2MASS J05300699+6930562                 | 11.69  | 1.35             |
| DT Cam                   | 48501.60621        | 7.06625452  | 8.13   | 0.20  | 2MASS J05151122+5622301                 | 11.23  | 1.29             |
| V399 Cam                 | 51508.62330        | 2.59762137  | 9.74   | 0.56  | 2MASS J05375639+6118381                 | 10.43  | 1.03             |
| V534 Cam*                | 51497.16948        | 3.01423674  | 13.555 | 1.087 | 2MASS J03565756+5316184*                | 14.658 | 1.782            |
| LT CMa                   | 48388.54124        | 1.75952345  | 7.44   | -0.10 | 2MASS J07040342-1217491*                | 10.559 | 1.307            |
| IT Cas                   | 28762.52450        | 3.89664878  | 11.23  | 0.34  | 2MASS J23413825+5141416                 | 11.43  | 0.68             |
| OX Cas                   | 46733.76386        | 2.48934850  | 9.9    | 0.3   | 2MASS J01093315+6123089                 | 9.34   | 0.25             |
| V381 Cas                 | 44546.28271        | 1.74594337  | 10.22  | -0.11 | 2MASS J00332653+4919037                 | 12.21  | 0.71             |
| V744 Cas                 | 48277.12244        | 4.78170067  | 8.43   | 0.07  | 2MASS J00224217+5336199                 | 9.09   | 0.06             |
| V785 Cas                 | 48502.37348        | 2.70251432  | 9.28   | 0.38  | 2MASS J02101321+6450236                 | 9.70   | 0.33             |
| V799 Cas                 | 48500.39266        | 7.70293311  | 8.82   | 0.14  | 2MASS J03052520+6137583                 | 9.77   | 0.21             |
| V821 Cas                 | 51767.34797        | 1.76973848  | 8.260  | 0.110 | 2MASS J23594522+5343533                 | 9.69   | 0.01             |
| V1018 Cas                | 51601.48815        | 4.12775943  | 10.12  | 0.74  | 2MASS 03015366+6035162*                 | 12.159 | 0.734            |
| CW Cep                   | 41669.57245        | 2.72913959  | 7.6    | 0.4   | 2MASS J23031266+6322245                 | 10.00  | 1.10             |
| V397 Cep                 | 48501.26846        | 2.08682365  | 7.40   | 0.14  | 2MASS J00013014+7318294                 | 8.98   | 0.41             |
| V839 Cep                 | 51448.69498        | 9.96336239  | 9.64   | 0.40  | 2MASS J21025482+5926450                 | 10.43  | 0.57             |
| V898 Cep                 | 51366.38105        | 2.87476369  | 11.66  | 0.73  | 2MASS 22374157+6727219*                 | 10.999 | 0.599            |
| V919 Cep                 | 51295.78131        | 1.85198163  | 10.48  | 0.45  | 2MASS J22593447+6509106                 | 10.89  | 0.35             |
| V957 Cep                 | 51504.73017        | 1.98873400  | 11.26  | 0.27  | 2MASS J23463044+7127361**               | 12.43  | 0.98             |
| V961 Cep                 | 51442.65503        | 7.03846879  | 10.16  | 0.47  | 2MASS J23574090+6737268                 | 11.88  | 0.39             |
| Y Cyg                    | 46308.31071        | 2.99633139  | 7.32   | -0.09 | 2MASS J20521115+3447086                 | 9.69   | 1.29             |
| V796 Cyg                 | 37997.09900        | 1.48086983  | 10.95  | 0.06  | 2MASS J19333549+4718196                 | 11.73  | 0.96             |
| V2647 Cyg                | 53670.77670        | 5.85530790  | 11.05  | 0.46  | 2MASS J21471417+5000565                 | 12.11  | 0.25             |
| CM Dra                   | 42893.93243        | 1.26838996  | 12.87  | 1.63  | 2MASS 16342460+5708270*                 | 14.369 | 1.014            |
| V425 Dra                 | 51397.90706        | 9.33540795  | 10.59  | 0.57  | 2MASS J19435022+8147579                 | 11.13  | 1.59             |
| OZ Hya*                  | 51983.94270        | 2.04876589  | 9.505  | 0.305 | 2MASS J10015462-1942350                 | 11.87  | 0.26             |
| RW Lac                   | 18657.40081        | 10.36921020 | 10.81  | 0.42  | 2MASS 22445911+4940012**                | 11.34  | 1.28             |
| CO Lac                   | 27534.07560        | 1.54220722  | 10.4   | 0.06  | 2MASS J22465613+5647154                 | 11.41  | 0.38             |
| GX Lac                   | 46009.30697        | 6.35524092  | 10.18  | 0.17  | 2MASS J22461077+5652105                 | 12.32  | 0.27             |
| MZ Lac                   | 38264.54643        | 3.15878972  | 11.45  | 0.54  | 2MASS J22280824+5340231*                | 13.017 | 0.717            |
| V401 Lac                 | 48501.87924        | 1.95009212  | 8.01   | -0.02 | 2MASS J22073463+4920435                 | 10.03  | 0.29             |
| CF Mon*                  | 51165.34324        | 2.61047343  | 13.588 | 0.540 | 2MASS J06492062-0024060*                | 14.044 | 0.463            |
| V498 Mon                 | 33221.74701        | 2.47277003  | 10.10  | 0.35  | 2MASS J06400009+0150517                 | 10.26  | 0.07             |
| V521 Mon                 | 33008.40334        | 2.97067068  | 10.19  | 0.04  | 2MASS 06560122-0014036*                 | 12.373 | 1.144            |
| V578 Mon                 | 54469.07927        | 2.40848583  | 8.55   | 0.17  | 2MASS J06320613+0452153                 | 9.71   | 0.13             |
| V684 Mon                 | 54153.53767        | 1.85142071  | 8.44   | -0.13 | 2MASS J06402475+0946082                 | 10.12  | 0.43             |
| FT Ori                   | 41349.01924        | 3.15039304  | 9.29   | 0.03  | 2MASS J06140472+2125078                 | 9.90   | 0.99             |
| IM Per                   | 33541.37916        | 2.25422648  | 11.28  | 0.70  | 2MASS J03113496+5213065**               | 13.76  | 1.16             |
| IQ Per                   | 44290.36399        | 1.74356232  | 7.73   | 0.04  | 2MASS J03594494+4808255                 | 9.28   | 0.2              |
| V871 Per                 | 51421.56011        | 3.02388343  | 10.89  | 0.48  | 2MASS J02440066+5640222                 | 9.89   | 0.18             |
| V495 Vul                 | 54651.50017        | 1.63513233  | 9.60   | 0.03  | 2MASS J19535496+2029483                 | 11.34  | 0.91             |
| 2MASS J03314391+3631523  | 52503.09005        | 3.64747393  | 11.37  | 0.59  | 2MASS J03314334+3626490*                | 11.373 | 1.566            |
| 2MASS J03520066+4003477* | 52501.15398        | 4.45685045  | 13.609 | 0.698 | 2MASS J03520345+4005035*                | 14.319 | 1.481            |
| 2MASS J04370204+4205520  | 52500.94594        | 1.45471874  | 10.64  | 0.33  | 2MASS J04365524+4205196*                | 11.111 | 1.293            |
| 2MASS J05421802+2003391  | 52500.08049        | 5.11588406  | 11.38  | 0.57  | 2MASS J05421802+2003391                 | 11.38  | 0.57             |
| 2MASS J06194134-1107556  | 52602.39001        | 2.58916977  | 10.86  | 0.49  | 2MASS J06194547-1108405                 | 11.36  | 0.51             |
| 2MASS J07412319+0253210  | 52501.71738        | 8.59928037  | 11.21  | 0.47  | 2MASS J07410271+0254227                 | 10.93  | 0.28             |
| 2MASS J07505239+0048040  | 52500.47816        | 2.05432730  | 9.39   | -0.03 | 2MASS J07505822+0049588*                | 12.245 | 0.523            |
| 2MASS J18432690+0841321  | 53147.33615        | 2.13920808  | 10.12  | 0.14  | 2MASS J18433868+0841582                 | 11.18  | 0.71             |
| 2MASS J19033272+3941003  | 52500.31520        | 2.18910463  | 10.83  | 0.12  | 2MASS J19033643+3939158*                | 12.235 | 0.723            |

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Figure 1: 15 eclipse light curves of 6 EEB systems. The gray dots indicate the individual measurements, and the red dot lines refer to the minimum times determined from the measurements. An extended version of this sample figure is available in the Appendix.

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time of minimum for each eclipse. Tab. 2 lists the observed times of minima. In Tab. 2, the second column contains the category classified by Kim et al. (2018); the fourth, the HJD time of minimum light in the UTC time scale; the sixth, the eclipse type: I= primary eclipse, II= secondary eclipse; the seventh, the method to determine each of timings: 'KW'= the KW method, 'Av'= average of timings determined by each of the methods of the KW, Fourier fit, and sliding integration; the eighth, the remark: 'd' denotes the duration time of the flat-bottom at primary or secondary eclipses in minutes. 'C' indicates that a visual companion is very close to the system. All the timings in Tab. 2 were archived into the database of TIDAK (TIming DAtabase at Krakow; Kreiner, 2004; see also the web page: http://www.as.up.krakow.pl/ephem).

The second 'category' column contains three categories (D, A, and A+III) based on the O-C behaviours of the primary and secondary times of minima in each of the ETDs: 'D' systems showing just constantly displaced secondary minima relative to primary ones, 'A' systems displaying the AM effect alone, and 'A+III' systems exhibiting a combined form of AM and LITE due to a third body orbiting the system (For more details, refer to Kim et al. (2018)). In the categorisation, systems with less well established AMs or LITEs are indicated with ':'. Systems with 'D' or ':' need a continuous monitoring of their times of minima to detect the AM effect or to determine more reliable AM and/or LITE parameters in a longer time base, respectively.

| Star<br>Name | Category | Filter | Time of Min.<br>(HJD 2400000+) | Error   | Eclipse<br>Type | Met. | Remark       |
|--------------|----------|--------|--------------------------------|---------|-----------------|------|--------------|
|              |          |        |                                |         |                 |      |              |
| V871 Aql     | А        | R      | 58628.16770                    | 0.00016 | II              | KW   |              |
| AG Ari       | A:       | V      | 58095.97976                    | 0.00153 | II              | Av   |              |
| AG Ari       | A:       | R      | 58403.29016                    | 0.00082 | Ι               | KW   |              |
| AG Ari       | A:       | R      | 58409.18026                    | 0.00028 | Ι               | Av   |              |
| AL Ari       | A+III:   | R      | 58409.10572                    | 0.00014 | Ι               | KW   |              |
| AL Ari       | A+III:   | R      | 58500.95543                    | 0.00540 | II              | Av   | $d\simeq 68$ |
| CG Aur       | A+III    | R      | 58463.13318                    | 0.00022 | Ι               | KW   |              |
| CG Aur       | A+III    | R      | 58473.11903                    | 0.00037 | II              | KW   |              |
| CG Aur       | A+III    | R      | 58501.03693                    | 0.00021 | Ι               | KW   |              |
| CG Aur       | A+III    | R      | 58510.05928                    | 0.00027 | Ι               | KW   |              |
| CG Aur       | A+III    | R      | 58777.18583                    | 0.00015 | Ι               | KW   |              |
| CG Aur       | A+III    | R      | 58796.19734                    | 0.00020 | II              | KW   |              |
| EQ Boo       | D        | R      | 58574.21798                    | 0.00031 | Ι               | KW   |              |
| WW Cam       | А        | R      | 58093.12362                    | 0.00032 | II              | KW   |              |
| WW Cam       | А        | R      | 58442.25205                    | 0.00003 | Ι               | KW   |              |
| AS Cam       | A+III:   | V      | 58066.10799                    | 0.00034 | Ι               | KW   |              |
| AS Cam       | A+III:   | BVR    | 58445.05799                    | 0.00039 | II              | KW   | $d\simeq 57$ |
| AS Cam       | A+III:   | R      | 58536.15611                    | 0.00057 | Ι               | Av   | $d\simeq 56$ |
| AS Cam       | A+III:   | R      | 58838.07740                    | 0.00032 | Ι               | KW   | $d\simeq 56$ |
| DT Cam       | D        | R      | 58832.23169                    | 0.00013 | Ι               | KW   |              |
| V399 Cam     | D        | R      | 58569.01291                    | 0.00081 | Ι               | KW   |              |
| V534 Cam     | A:       | R      | 58451.05010                    | 0.00072 | Ι               | KW   |              |
| LT CMa       | A:       | R      | 58466.21641                    | 0.00016 | II              | Av   |              |

Table 2: Observed Times of Minimum Light

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| Star<br>Name | Category | Filter | Time of Min.<br>(HID 2400000+)    | Error   | Eclipse  | Met.          | Remark        |
|--------------|----------|--------|-----------------------------------|---------|----------|---------------|---------------|
|              | Δ.       | D      | (115E) 2100000 ( )<br>59419 09979 | 0.00008 | т        | UW            |               |
| II Cas       | A:       | R<br>D | 58412.02272                       | 0.00008 | I<br>II  | KW            |               |
| II Cas       | A:       | n<br>D | 00400.10021<br>59451 15500        | 0.00017 | 11<br>T  | KW            |               |
| OX Cas       | A+111:   | R<br>D | 58451.15590                       | 0.00013 | 1        | KW            |               |
| V281 Car     | A+111:   | R<br>D | 58705.99033<br>58745 10900        | 0.00035 | 11<br>11 | K W           |               |
| V381 Cas     | A        | R<br>D | 58745.16306                       | 0.00040 | 11<br>11 | AV            |               |
| V744 Cas     | D        | R<br>D | 58827.99422                       | 0.00007 | 11<br>11 | AV            |               |
| V 785 Cas    | A        | R      | 58438.12228                       | 0.00087 | 11       | AV            |               |
| V785 Cas     | A        | R      | 58465.14890                       | 0.00046 | 11       | KW            |               |
| V785 Cas     | A        | R      | 58475.96001                       | 0.00073 | 11<br>T  | Av            |               |
| V785 Cas     | A        | R      | 58796.29254                       | 0.00053 | l<br>TT  | Av            |               |
| V799 Cas     | A        | V      | 58009.22964                       | 0.00020 | 11       | KW            |               |
| V799 Cas     | A        | V      | 58099.01784                       | 0.00037 | 1        | KW            |               |
| V821 Cas     | A        | R      | 58411.01913                       | 0.00014 | 1        | KW            |               |
| V1018 Cas    | A:       | R      | 58063.28650                       | 0.00084 | 11       | KW            |               |
| V1018 Cas    | A:       | R      | 58509.08876                       | 0.00071 | II       | KW            |               |
| CW Cep       | А        | R      | 58466.03636                       | 0.00008 | II       | Av            |               |
| V397 Cep     | А        | R      | 58403.21252                       | 0.00018 | Ι        | KW            |               |
| V397 Cep     | А        | R      | 58448.15179                       | 0.00035 | II       | KW            |               |
| V839 Cep     | D        | R      | 58657.25601                       | 0.00035 | II       | Av            |               |
| V898 Cep     | A:       | R      | 58628.29182                       | 0.00033 | Ι        | Av            |               |
| V919 Cep     | А        | R      | 58462.94586                       | 0.00038 | Ι        | Av            |               |
| V957 Cep     | А        | R      | 58508.96911                       | 0.00015 | Ι        | $\mathbf{KW}$ |               |
| V961 Cep     | A:       | R      | 58453.06054                       | 0.00014 | Ι        | Av            |               |
| V961 Cep     | A:       | R      | 58745.02735                       | 0.00188 | II       | Av            |               |
| Y Cyg        | А        | R      | 58412.12370                       | 0.00062 | II       | $\mathbf{KW}$ |               |
| V796 Cyg     | А        | VR     | 58273.20397                       | 0.00042 | Ι        | $\mathbf{KW}$ |               |
| V796 Cyg     | А        | R      | 58592.26261                       | 0.00057 | II       | Av            |               |
| V2647 Cyg    | А        | R      | 58777.07256                       | 0.00028 | Ι        | $\mathbf{KW}$ | $d\simeq 29$  |
| CM Dra       | D        | R      | 57888.20294                       | 0.00003 | II       | KW            |               |
| V425 Dra     | D        | R      | 58809.98610                       | 0.00018 | Ι        | KW            |               |
| OZ Hya       | A:       | R      | 58508.23111                       | 0.00030 | II       | Av            |               |
| RW Lac       | A+III    | R      | 58646.23542                       | 0.00010 | II       | KW            | $d\simeq 36$  |
| CO Lac       | А        | R      | 58496.98312                       | 0.00019 | Ι        | KW            |               |
| GX Lac       | A:       | R      | 58776.99320                       | 0.00021 | Ι        | KW            |               |
| MZ Lac       | А        | R      | 58446.04493                       | 0.00013 | Ι        | KW            |               |
| MZ Lac       | А        | R      | 58765.08619                       | 0.00012 | Ι        | KW            |               |
| MZ Lac       | А        | R      | 58776.15876                       | 0.00054 | II       | KW            |               |
| V401 Lac     | А        | V      | 58064.09678                       | 0.00357 | II       | Av            | $d \simeq 76$ |
| V401 Lac     | А        | R      | 58463.00493                       | 0.00071 | Ι        | Av            |               |
| CF Mon       | D        | R      | 58532.08882                       | 0.00006 | Ι        | Av            |               |
| V498 Mon     | А        | R      | 58511.95770                       | 0.00044 | II       | Av            |               |
| V521 Mon     | A+III    | R      | 58437.19593                       | 0.00337 | Ι        | Av            | $d \simeq 69$ |
| V578 Mon     | Å        | R      | 58496.10866                       | 0.00133 | Ι        | Av            |               |
| V684 Mon     | A        | R      | 57798.99754                       | 0.00127 | Ι        | KW            |               |
| V684 Mon     | A        | BVR    | 58445.14992                       | 0.00347 | I        | Av            |               |
| FT Ori       | A        | R      | 58449.15824                       | 0.00002 | I        | KW            | $d\simeq 20$  |
| FT Ori       | А        | R      | 58808.30649                       | 0.00003 | Ι        | KW            | $d \simeq 19$ |
| IM Per       | А        | R      | 58465.22002                       | 0.00021 | II       | Av            | -             |

### Table 2 – (Continued)

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| Star<br>Name              | Category | Filter | Time of Min.<br>(HJD 2400000+) | Error   | Eclipse<br>Type | Met.          | Remark       |
|---------------------------|----------|--------|--------------------------------|---------|-----------------|---------------|--------------|
| IM Per                    | А        | R      | 58508.05241                    | 0.00067 | II              | Av            |              |
| IQ Per                    | А        | V      | 58066.28853                    | 0.00012 | Ι               | $\mathbf{KW}$ | $d\simeq 72$ |
| IQ Per                    | А        | R      | 58502.97702                    | 0.00002 | II              | Av            | $d\simeq 75$ |
| IQ Per                    | А        | R      | 58828.22493                    | 0.00013 | Ι               | KW            | $d\simeq 72$ |
| V871 Per                  | А        | R      | 58830.17518                    | 0.00021 | Ι               | KW            | $d\simeq 37$ |
| V495 Vul                  | А        | R      | 58745.07741                    | 0.00072 | II              | KW            |              |
| V495 Vul                  | А        | R      | 58650.24254                    | 0.00017 | II              | Av            |              |
| 2MASS J03314391 + 3631523 | D        | R      | 58804.07624                    | 0.00163 | II              | Av            | C            |
| 2MASS J03520066 + 4003477 | D        | R      | 58765.17217                    | 0.00052 | II              | Av            |              |
| 2MASS J04370204 + 4205520 | A:       | R      | 58767.15828                    | 0.00015 | II              | KW            |              |
| 2MASS J04370204 + 4205520 | A:       | R      | 58802.07143                    | 0.00041 | II              | KW            |              |
| 2MASS J05421802 + 2003391 | D        | R      | 58532.01437                    | 0.00222 | Ι               | Av            |              |
| 2MASS J06194134-1107556   | D        | R      | 58537.95243                    | 0.00098 | II              | Av            |              |
| 2MASS J07412319 + 0253210 | D        | R      | 58538.08906                    | 0.00037 | Ι               | KW            |              |
| 2MASS J07505239 + 0048040 | D        | R      | 58566.96793                    | 0.00033 | Ι               | Av            |              |
| 2MASS J18432690 + 0841321 | D        | R      | 58764.96851                    | 0.00008 | Ι               | $\mathbf{KW}$ |              |
| 2MASS J19033272+3941003   | A:       | R      | 58647.14920                    | 0.00028 | Ι               | Av            |              |

Table 2 - (Continued)

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## References

- Batten, A. H. 1973, Binary and Multiple Systems of Stars (New York, Pergamon), p. 77, <u>1973bmss.book.....B</u>
- Kim, C. -H., Kim, H. -W., Park, J. -H., et al. 2017, *IBVS*, 6202, 1, <u>2017IBVS.6202...1K</u>
- Kim, C. -H., Kreiner, J. M., Zakrzewski, B., Ogłoza, W., Kim, H. -W. & Jeong, M. -J. 2018, *ApJS*, **235**, 41, 2018ApJS..235...41K
- Kim, C. -H., Song, M. -H., Yoon, J. -N., Han, W. & Jeong, M. -J., 2014, ApJ, 788, 134, 2014ApJ...788..134K

Kreiner, J. M. 2004, AcA, 54, 207, <u>2004AcA....54..207K</u>

Kwee, K. K., & van Woerden, H., 1956, Bull. Astron. Inst. Neth., **12**, 327, <u>1956BAN....12..327K</u>

Lasker, B. M., Lattanzi, M. G., McLean, B. J., et. al., 2008, *AJ*, **136**, 735, 2008AJ....136..735L

Nelson, R. H. 2001, IBVS, 5040, 1 2001IBVS.5040....1N

Ogłoza, W., Dróżdż, M., Kreiner, J. M., et al. 2017, IBVS, 6193, 1, 2017IBVS.6193....10

Zacharias, N., Finch, C. T., Girard, T. M., et al. 2012, VizieR Online Data Catalog, I/322A, 2012yCat.1322....0Z

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Figure 2: 15 eclipse light curves of 6 EEB systems. The gray dots indicate the individual measurements, and the red dot lines refer to the minimum times determined from the measurements.

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Figure 3: 15 eclipse light curves of 8 EEB systems. The gray dots indicate the individual measurements, and the red dot lines refer to the minimum times determined from the measurements.

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Figure 4: 15 eclipse light curves of 8 EEB systems. The gray dots indicate the individual measurements, and the red dot lines refer to the minimum times determined from the measurements.

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Figure 5: 15 eclipse light curves of 6 EEB systems. The gray dots indicate the individual measurements, and the red dot lines refer to the minimum times determined from the measurements.

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Figure 6: 15 eclipse light curves of 12 EEB systems. The gray dots indicate the individual measurements, and the red dot lines refer to the minimum times determined from the measurements.

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Figure 7: 15 eclipse light curves of 8 EEB systems. The gray dots indicate the individual measurements, and the red dot lines refer to the minimum times determined from the measurements.

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Figure 8: 15 eclipse light curves of 9 EEB systems. The gray dots indicate the individual measurements, and the red dot lines refer to the minimum times determined from the measurements.

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Figure 9: 3 eclipse light curves of 3 EEB systems. The gray dots indicate the individual measurements, and the red dot lines refer to the minimum times determined from the measurements.