CCD Minima for Selected Eclipsing Binaries in 2019

Robert H. Nelson
Mountain Ash Observatory, 1393 Garvin Street, Prince George, BC V2M 3Z1, Canada; bob.nelson@shaw.ca

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Abstract 204 CCD-based times of minima of eclipsing binary stars are presented.

1. Introduction

This is a continuation of a series of 21 papers published in the (sadly) now-defunct *Information Bulletin on Variable Stars* (IBVS), the latest being Nelson (2019a).

Eclipse timings are very important in tracking changes in the period of eclipsing binaries. The eclipse timing difference (O–C) plot is, as is well known, an important tool in detecting small changes in orbital periods and outlining their long-term trends. There are many reasons as to why the period of a given eclipsing binary might change. One of the most commonly made assumptions—in the case of overcontact binaries (and others)—is that the period change is due to the transfer of mass (most often, but not always) from the star of lesser mass to its companion. In the latter case there will be a steady period increase, detectable as data fitting an upward-facing parabola in the O–C plot. Unfortunately, there have been many papers in the literature where authors blithely assume that any steady period change must be due to mass transfer. The equations work even if the use of them might be invalid.

This is one of the reasons why my colleagues and I undertook a series of papers reviewing the period-change literature with a view to establishing a reliable case for mass exchange in selected overcontact binaries (Nelson *et al.* 2014, 2015, 2016, 2020). In them we sorted out some of the unfortunate mistakes in period change papers, as well as period change conclusions no longer supported by subsequent timing data. One of the most glaring lapses in period change analyses is the neglect of the light time effect (LiTE) due to a seen or unseen companion to the eclipsing pair. This defect was highlighted in a paper by Hill *et al.* (1989) in a study of 44 Boo in which the authors pointed out that all previous analyses had neglected the effect of the known (brighter) star A in the A-BC configuration (where BC is the eclipsing pair) and were therefore invalid. The fact that at least 42 ± 5% of overcontact binaries brighter than $V_{max} = 10$ have a gravitationally bound companion was established by Pribulla and Ruciński (2006), thus stressing the need for taking LiTE into account. The light time effect (LiTE) can be dealt with by equations due to Irwin (1952, 1959), and numerous authors have employed these routines in their analyses of period change as has the present author.

Other causes of period variation are magnetic cycles due to the Applegate effect (Applegate 1989, 1992), mass loss through the Lagrangian L_2 point, and angular momentum loss through a stellar wind (Kallrath and Milone, 1999; Linial and Sari 2017).

Thus, the acquisition of eclipse timings is important. However, not all systems are equally meriting of attention. There are some systems for which the period is closely constant; they therefore require timings only every three to five years or longer; in that case yearly timings would be a waste of precious clear-sky time. On the other hand, there are systems for which there have been no timings for many years, as well as those whose periods are changing rapidly and unpredictably, therefore requiring close attention. Observers are encouraged to visit the database containing EXCEL files for over 5,000 eclipsing binaries at Nelson (2019b, 2020) in order to make good choices of observing targets that will be of maximum benefit to the astronomical community. In addition, some of the files, (for example AB And), contain formulas using the LiTE equations; readers are encouraged to explore the capabilities of the analysis.

The eclipse timings reported below were all selected with these principles in mind.

2. The equipment

a) Mountain Ash Observatory (MAO)
Location: 53° 54' 41.7" N, 122° 47' 22.8" W,
Prince George, BC, Canada
Mount: Paramount ME (German Equatorial)
OTA: 33 cm f/4 Newtonian
Detector: SBIG-10 XME (2184 x 1472 pixels, each 6.8 microns)
Filters: B, V, Rc, Ic, clear
Flats: Light box
Software: THESKY6 + CCDSOFT5

b) Desert Blooms Observatory (DBO)
Location: 30° 24' 54.7" N, 110° 15' 27" W,
Benson, Arizona
Mount: Paramount Taurus 400 (Fork)
OTA: 40 cm f/6.8 Meade LX-200
Detector: OSI 683 (1663 × 1252 pixels, each 10.8 microns)
Filters: B, V, R_c, I_c, clear, r'
Flats: Illuminated screen
Software: THESKYX + IMAGER

3. Data reduction

All data were reduced in the usual way (bias, darks, flats), followed by aperture photometry using MIRA UE (Mirametrics 2020), usually using one comparison (C) and one check (K) star. When the C–K plot was found to be not flat, a second (or sometimes third) check star was employed to sort out the situation. Occasionally, new variable stars have been discovered.

Table 1. Sample of first ten times of minima for 204 eclipsing binaries.

Star Name	*Time of Min. HJD–2400000*	*Error (days)*	*Type*	*Filter*	*O–C (days)*	*Observatory*
AB And	58774.6124	0.0008	II	BVI	0.0008	DBO
AB And	58774.7781	0.0006	I	BVI	0.0006	DBO
AB And	58801.6610	0.0004	I	BVI	0.0004	DBO
AB And	58819.5830	0.0003	I	BVI	0.0003	DBO
AB And	58837.6715	0.0008	II	BVI	0.0008	DBO
QX And	58786.6839	–0.0001	II	c	–0.0001	MAO
V0363 And	58788.7220	–0.0015	II	c	–0.0015	MAO
V0404 And	58781.6826	–0.0056	II	BRVI	–0.0056	DBO
V0404 And	58847.5982	–0.0033	I	BVRI	–0.0033	DBO
V0527 And	58725.7539	0.0019	I	c	0.0019	MAO

Remarks: To save space, in Table 1 GSC star names have been shortened to a leading "G" only but with the constellation in the filename. Times of minimum are heliocentric Julian dates with the leading 24 removed. O–C values were computed using elements computed from the O–C database listed in the references (Nelson, 2019b, 2020). The remote observatory, Desert Blooms (DBO), in Benson, Arizona, is described in Nelson (2002). Readers wishing original data are welcome to write to the author. The full table is available through the AAVSO ftp site at ftp://ftp.aavso.org/public/datasets/nelson482-ccdminima.txt (if necessary, copy and paste link into the address bar of a web browser).

Minimum time determinations were performed using MINIMA v27 (Nelson 2013). In it, six methods for minimum determination are available: Parabolic fit, Digital tracing paper, Bisector of chords, Kwee and van Woerden (Kwee and van Woerden 1956), Five-term Fourier fit, and Sliding Integrations (Ghedini 1982). Generally speaking, the two most reliable methods are Kwee and van Worden and Fourier fitting (roughly equivalent), but the other methods are useful as well. With very good data, precisions approaching ±0.0001 day (as determined from the sample standard deviation of the output values) are possible; however, with poor quality data, standard errors of up to ±0.001 day or worse have been encountered. A rule of thumb, employed by this observer, is to take the sample standard error and double it. The reason for this is that unseen systematic factors can distort the measured times (sky transparency gradients for example); experience with many O–C files has supported this practice. Whenever possible, all observing runs were long enough to cover both points of inflection (maximum slope) of the light curve; however, problems with the weather and other factors occasionally prevented this from happening. In each of those cases, the estimated error was increased correspondingly.

4. The data

For each star, Table 1 gives time of minimum, error, type (primary or secondary), O–C value, and the observatory at which the data were obtained.

5. Acknowledgements

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

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