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# SEVEN NEW PERIOD-CHANGE ECLIPSING BINARY STARS

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In the course of surveying eclipse timing difference (or O−C) plots for a series of papers on period change (Nelson et al. 2014a,b,c), several overcontact systems came to light—not previously noted in the literature—which showed strong evidence of period change. The eclipse timing (ET) data were well modelled by quadratic functions. However, the time interval over which the quadratic relation was evident was short, typically around a decade. Because subsequent data can often prove a relationship wrong, these systems were not included in the main group of 60 to be discussed in detail. Rather, they were simply added as notes at the end of Paper 3. Therefore it was deemed useful to describe the relationships more fully here.

## EG CVn

The variability of EG CVn (GSC 3026-1046, ROTSE1 J133726.05+373458.4) was discovered as part of the Robotic Optical Transient Search Experiment I (ROTSE-1, Akerlof et al. 2000). It was identified as EW-type with a period of 0.34927(2) days. Blättler & Diethelm (2002) presented new eclipse timings and an unfiltered CCD light curve. Since then, there have been a number of eclipse timings reported, but no period analysis. As far as is known, there has been no light curve analysis for this system.

In Figure 1, the ET differences from the 32 eclipse timings from 1999 to 2012 are plotted. (The abscissa is the cycle number; the ordinate is the eclipse timing difference (O−C value) in days. Legend: squares—photographic; triangles—visual; open (red) circles—photoelectric; solid circles—CCD timings). The least squares best-fit quadratic curve is shown; its parameters yield the rate of period change as $\mathrm{d}P/\mathrm{d}t = 5.9(4) \cdot 10^{-7}$ days/year. The coefficient of correlation (cc) is 0.992; thus the rate of period change is fairly constant. The first set of timings near cycle 0—showing a large scatter—were given a weight 0.1; the others, 1.

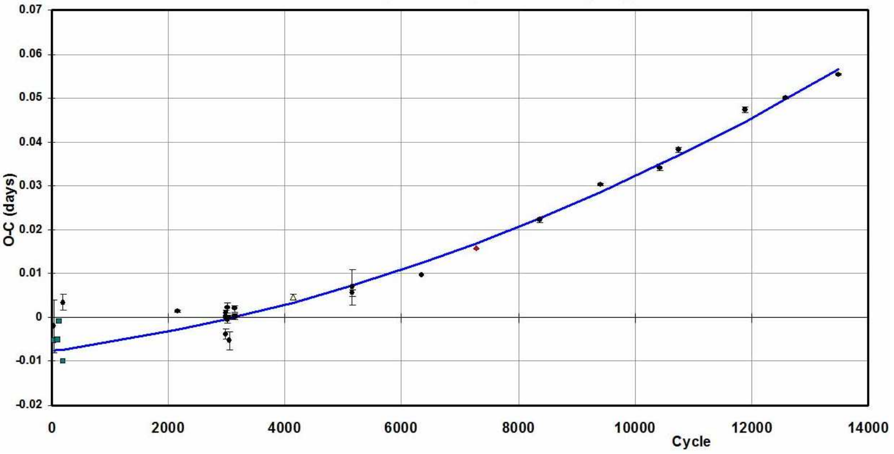

**Figure 1.** EG CVn: Eclipse timing differences (O−C) using Min I (hel) = 2451246.7820 + 0.349271 E.

## V2240 Cyg

The variability of V2240 Cyg (GSC 2684-1255) was discovered by Safár (1999) who presented elements (epoch, period of 0.404194(68) days), six CCD eclipse timings, and an unfiltered light curve. From the shape of the light curve, he identified it as a W UMa variable. Since then, there have been numerous eclipse timings reported in the literature, but no period analysis. As far as is known, there has been no light curve analysis for this system.

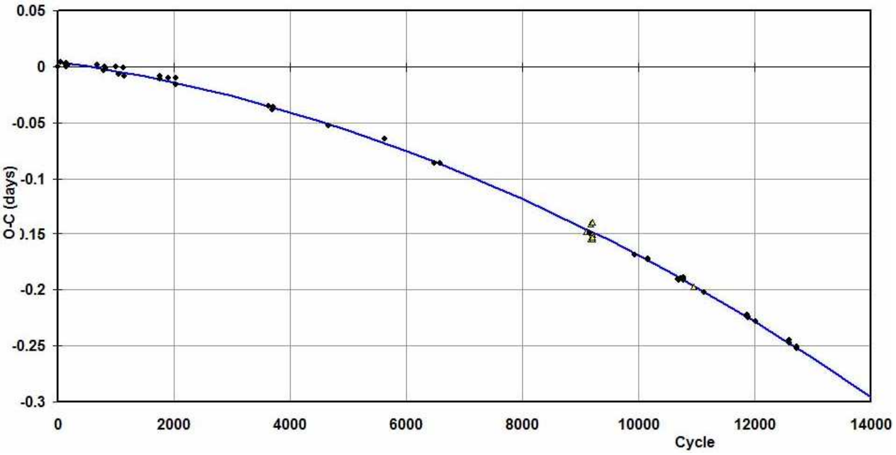

**Figure 2.** V2240 Cyg: Eclipse timing differences (O−C) using Min I (hel) = 2451375.4523 + 0.404194 E.

In Figure 2, the ET differences from the 63 eclipse timings from 1999 to 2013 are plotted (for the legend, see Section 1). The least squares best-fit quadratic curve is shown; its parameters yield the rate of period change as $\mathrm{d}P/\mathrm{d}t = -1.84(4) \cdot 10^{-6}$ days/year. This is one of the higher rates of period change amongst overcontact binaries. The coefficient of correlation (cc) is 0.999; thus the quadratic equation is a very good fit and the rate of period change very constant in the range.

## MS Her

The variability of MS Her (GSC 2101-0313, ROTSE1 J181653.46+273945.4) was discovered by Hoffmeister (1949). The reference is from the CGVS4, but the work is not available. The next reference is the ROTSE-I paper, Akerlof et al. (2000) which lists coordinates and a period of 0.86793(28) days. Since then, there have been numerous eclipse timings reported, but no period analysis. Strangely, the GCVS4 lists the period of this system incorrectly as 0.6052626 days. As far as is known, there has been no light curve analysis for this system.

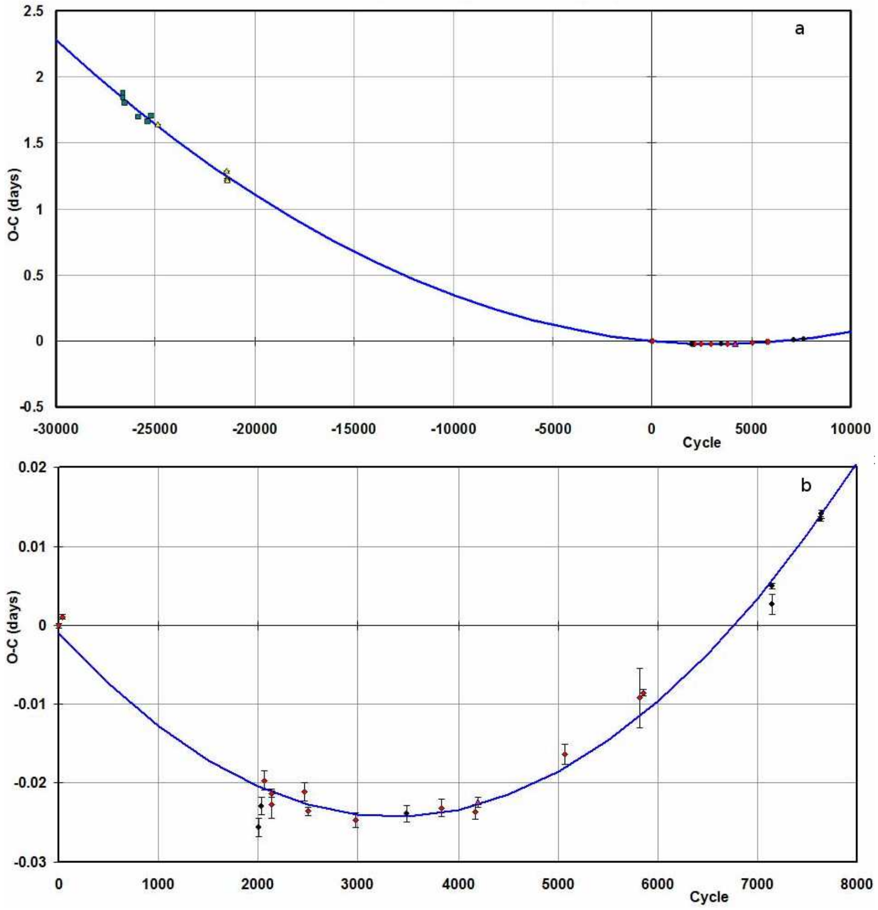

**Figure 3.** Top: MS Her: eclipse timing differences (O$-$C) using Min I (hel) = 2449534.4903 + 0.8680423 E. Bottom: eclipse timing differences (O$-$C) using Min I (hel) = 49534.4903 + 0.8680423 E.

In Figure 3a, the ET differences from the 33 photographic, visual, photoelectric and CCD timings from 1931 to 2012 are plotted. In Figure 3b, the same data and fit are plotted, but for the restricted range cycle 0 (1994) to cycle 7463 (2012). The fact that the quadratic fit—which uses parameters optimized for all the data—fits the restricted range well gives one confidence that the cycle reassignments necessary for Figure 3a are correct.

Weighted least squares fitting for all the data yields a value of $\mathrm{d}P/\mathrm{d}t = 1.74(2) \cdot 10^{-6}$ days/year with a cc of 0.999. Using only the data from cycle 0 or later yields a value of $\mathrm{d}P/\mathrm{d}t = 1.77(7) \cdot 10^{-6}$ days/year with a cc of 0.989. It seems clear that the rate of period change has been constant for the 80 years that timings have been made.

## V400 Lyr

This variability of V400 Lyr (GSC 3121-1799, VV 223) was discovered by Miller (1969) who classified it as RRab and supplied a period of 0.3201645 days. Blättler & Diethelm (2000b) presented unfiltered CCD light curves showing the system to be of type EW. They also supplied an updated pair of elements (epoch, period); the latter being 0.2534306(8) days. Marino (2011) obtained CCD light curves and—using PHOEBE software (Prsa & Zwitter 2005)—obtained a Wilson-Devinney fit for BVRI pass bands (Wilson & Devinney 1971). Marino (2011) also displayed an ET difference plot which showed a secular period decrease but did not determine a quadratic fit.

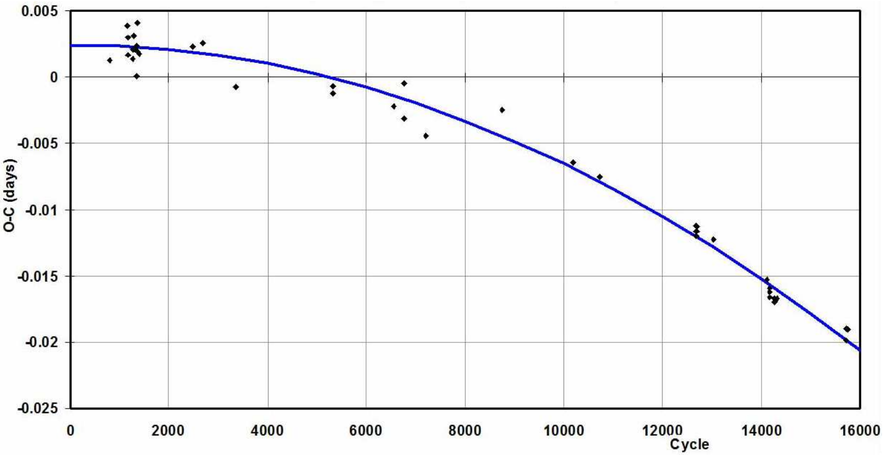

**Figure 4.** V400 Lyr: Eclipse timing differences (O−C) using Min I (hel) = 2451801.3651 + 0.2534274 E.

In Figure 4, the (all CCD) ET differences from the 43 eclipse timings from 2001 to 2011 are plotted, yielding a value $\mathrm{d}P/\mathrm{d}t = -2.61(23) \cdot 10^{-7}$ days/year with a coefficient of correlation (cc) of 0.992.

## V406 Lyr

The variability of V406 Lyr was discovered by Parenago (1946). Meinunger (1970) obtained the first period, 1.51130 days and published a photographic light curve. Agerer et al. (1994) presented new photographic and CCD eclipse timings, and determined that the above period was an alias of the true one, $P = 0.86078384(9)$ days. They also obtained a new light curve with two distinctly unequal minima. Since then, there have been many eclipse timings published but no period analysis.

In Figure 5, the (all CCD) ET differences are plotted for the time interval 1993-2013; the earlier photographic and visual timings are not plotted because the gaps impose an uncertainty as to the correct cycle count. Plotted are 29 points yielding a value $\mathrm{d}P/\mathrm{d}t = 8.35(29) \cdot 10^{-7}$ days/year with a coefficient of correlation (cc) of 0.989. As far as is known, there has been no light curve analysis for this system.

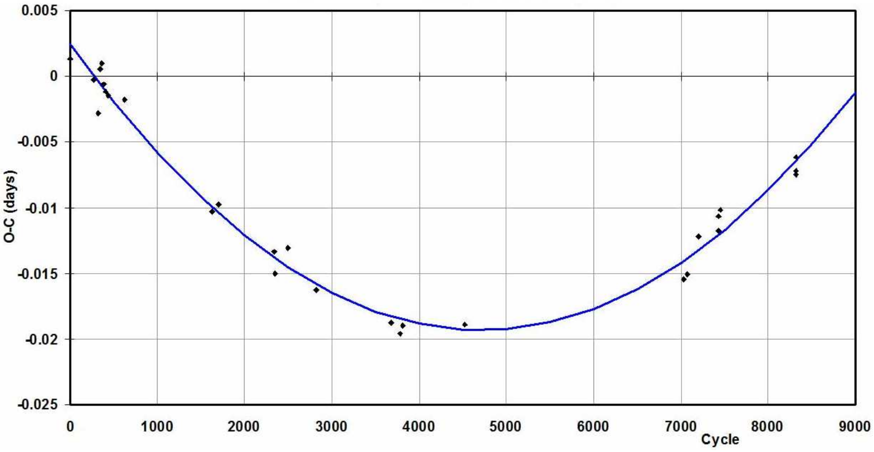

**Figure 5.** V406 Lyr: Eclipse timing differences (O−C) using Min I (hel) = 2449250.4582 + 0.8607838 E.

# V579 Lyr

The variability of V579 Lyr (GSC 3131-0476) was discovered by Akerlof et al. (2000) in the ROTSE-1 all-sky survey for variable stars. Blättler & Diethelm (2000a) presented unfiltered CCD light curves showing the system to be of type EW. They also supplied an updated pair of elements (epoch, period); the latter being 0.2429100(25) days. Since then, there have been many eclipse timings published but no period analysis.

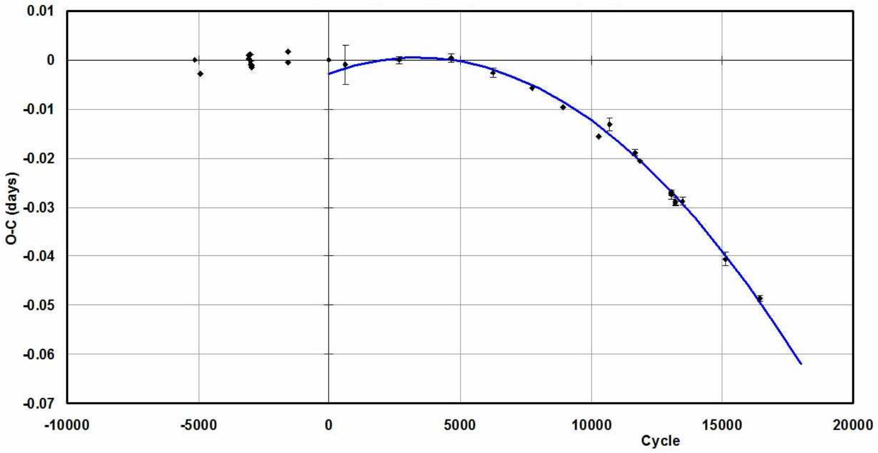

**Figure 6.** V579 Lyr: Eclipse timing differences (O−C) using Min I (hel) = 2452500.0623 + 0.2429093 E.

In Figure 6, the (all photometric-CCD) ET differences are plotted for the time interval 1999-2013, but only the eclipse timings since cycle 0 (2002) were used to compute the period change, $\mathrm{d}P/\mathrm{d}t = -8.78(48)\cdot 10^{-7}$ days/year with a cc = 0.998. The timings before cycle 0 represent a discrepancy to the quadratic fit. It is possible that the period change is caused by the light time effect from the orbit of a companion (rather than—say—mass interchange), in which case the relationship would be a good deal more complex. In any case, future eclipse timings over several decades are required to establish the true relationship. As far as is known, there has been no light curve analysis for this system.

## KN Vul

The variability of KN Vul (GSC 2148-3403) was discovered by Wachmann (1966) in a survey of the southern stars in Cygnus. Kreiner (2004) provided a set of elements (epoch, period). Since then, there have been a number of eclipse timings published, but no period analysis.

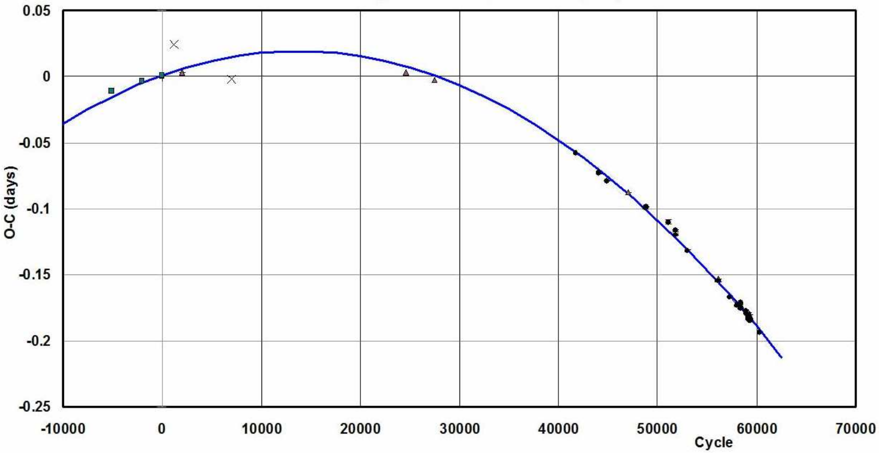

**Figure 7.** KN Vul: Eclipse timing differences (O−C) using Min I (hel) = 2434634.2821 + 0.3573325 E.

In Figure 7, the ET differences from the 85 eclipse timings from 1948 to 2012 are plotted. The rate of period change is $\mathrm{d}P/\mathrm{d}t = 2.00(2) \cdot 10^{-7}$ days/year with a cc of 0.999. As far as is known, there has been no light curve analysis for this system.

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References:

Agerer, F., Kleikamp, W. & Moschner, W., 1994, *IBVS* No. 4132
Akerlof, C., et al., 2000, *AJ*, **119**, 1901
Blättler, E. & Diethelm, R., 2000a, *IBVS*, No. 4982
Blättler, E. & Diethelm, R., 2000b, *IBVS*, No. 4995
Blättler, E. & Diethelm, R., 2002, *IBVS*, No. 5269
GCVS4, General Catalogue of Variable Stars, http://www.sai.msu.su/gcvs/
Hoffmeister, C., 1949, *Veröff. Sternw. Sonneberg*, **1**, N3
Kreiner, J. M., 2004, *AcA*, **54**, 207
Marino, G., 2011, *IBVS*, No. 6002
Meinunger, L., 1970, *Mitt. Ver. Sterne*, **5**, 128

Miller, W. J., 1969, *Ricerche Astronomiche*, **7**, 459
Nelson, R. H., Terrell, D. & Milone, E.F., 2014a, *New Astr. Rev.*, **59**, 1 (Paper 1)
Nelson, R. H., Terrell, D. & Milone, E.F., 2014b, *New Astr. Rev.*, (Paper 2), submitted
Nelson, R. H., Terrell, D. & Milone, E.F., 2014c, *New Astr. Rev.*, (Paper 3), in preparation
Parenago, P., 1946, *Perem. Zvezdy*, **6**, 25
Prsa, A. & Zwitter, T., 2005, *ApJ*, **628**, 426
Safár, J., 1999, *IBVS*, No. 4818
Wachmann, A. A., 1966, *Astron. Abh. Hamburg. Sternw.*, **6**, 281
Wilson, R. E. & Devinney, E.J., 1971, *ApJ*, **166**, 605