NEW ELEMENTS FOR SOME ECLIPSING BINARY STARS

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For eight years a number of AAVSO observers have been actively pursuing the timing of eclipsing binary minima. The large pool of data now on hand has made it possible to examine the behavior of several of these stars in sufficient detail to determine where there exist appreciable deviations from applicable elements listed in the 1969 General Catalogue of Variable Stars.

We review here a few of the most important findings that have been made to date. In the case of each of the nine stars examined a new initial epoch and a new period has been determined based upon available data from AAVSO observers and/or data by the Swiss observing group, BBSAG, working under the leadership of Kurt Locher. Both the linear elements from the GCVS and the revised elements are given. Also shown in diagram form (Figures 1 through 9) are the epochs and O-C residuals for all minima. All residuals and epochs are based upon elements of the 1969 GCVS. A "best fit" straight line has been entered upon each diagram. This line represents the revised elements. On one diagram (Fig. 1) additional detail is given to illustrate how measurements are made to establish the revised period.

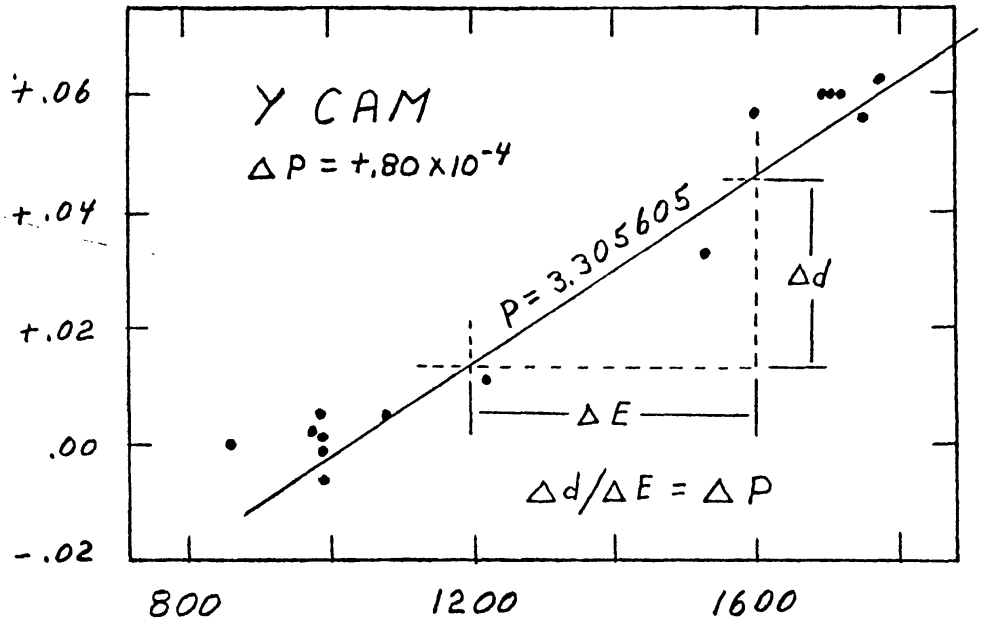
Listings of the minima upon which the O-C diagrams are based are available from the writer upon request. However, reproduction capability is seriously limited and, therefore, only materials which will actually be put to use should be requested. AAVSO minima timings used in the preparation of this paper are currently being prepared for publication and will appear as rapidly as their preparation can be completed.

STARS EVALUATED

Y Cam (072776) GCVS elements; JD 2435904.537 + 3.305525E
Revised elements; JD 2439477.815 + 3.305605E

Insufficient observations were obtained, particularly during 1968 and 1969, to fully define this star's deviation from the GCVS elements. However, simple straight line projection back to the zero residual line representing the old elements suggests that the change in period may have taken place in mid-1966. Some explanation of the method used to establish the revised elements is perhaps in order. The explanation which follows and its diagrammatical representation on the O-C diagram is provided only in the case of this star. It may be assumed that the same method was applied in all other cases unless otherwise specified. On the O-C diagram (Fig. 1) an arbitrarily chosen incremental number of cycles, ΔE, the corresponding incremental change in the O-C residual, Δd, and the equation defining their relationship to the incremental change of period, ΔP, are shown. The change of period is calculated at +0.000080 day. Adding this

to the GCVS period used in construction of the O-C diagram results in the determination of the revised period. Choosing an initial epoch lying on the "best fit" line completes the revision of the elements.



ΔE = 400 cycles ΔP = +0.032/400 P_o = 3^d.305525
Δd = +0.032 day = +0.000080 ΔP = +.000080
P = 3.305605

Figure 1. Y Cam, O-C Residuals, showing derivation of ΔP.

U Cep (005381) GCVS elements: JD 2438291.502 + 2.493041E
Revised elements: JD 2441562.397 + 2.493095E

Construction of the O-C curve from 105 minima observed by AAVSO and BBSAG observers reveals a major change of period centered near JD 2439800. In the case of this star minima timings were considered too numerous to obtain the best depiction of the O-C curve by plotting them independently. Mean data points have been plotted instead, with the size of the point indicating confidence level. Measurement of the straight line best representing the latter portion of the plotted data gives a correction to the GCVS period amounting to +0.000054 day. This correction combined with Kurt Locher's minimum of JD 2441562 forms the basis for the revised elements established here. U Cep has a long history of major changes of period, so any similar future behavior should come as no surprise. Visual minima timings of high quality made at any time are of considerable value for detection of these changes and for generally describing the characteristics of the O-C curve.

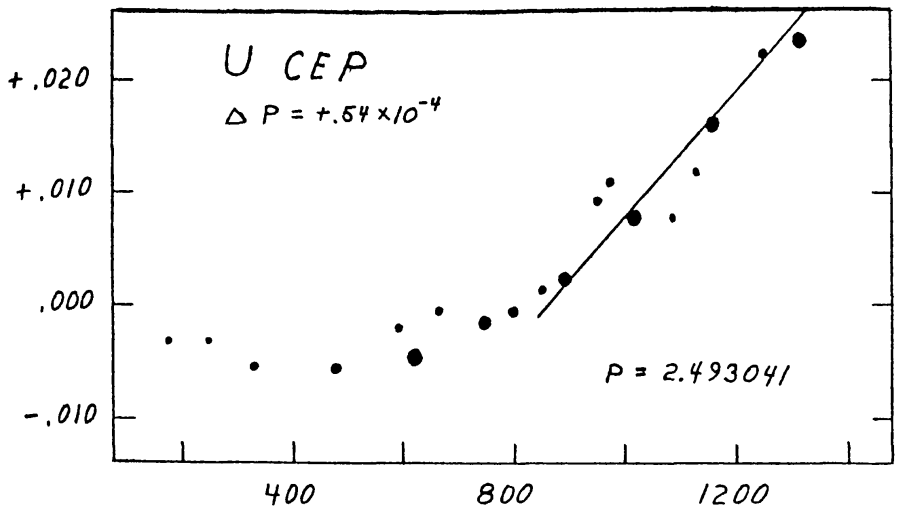


Figure 2. U Cep, O-C Residuals.

TT Del (203108) GCVS elements: JD 2438258.482 + 2.871085E
Revised elements: JD 2441201.361 + 2.871053E

Only four minima were available for this evaluation. However, they are reasonably well spaced and provide a fairly good basis for determining a new period for this star. In 500 cycles the measured O-C deviation is -0.016 day. This yields a deviation from the old period of -0.000032 day. Adjusting Roger Diethelm's minimum of JD 2441201 to match the point on the mean linear O-C line for that date, the revised elements are established. Although all minima show this star eclipsing later than predicted by the GCVS elements, the period, quite surprisingly and in direct opposition to what should be expected, appears to be much shorter than that given in the GCVS. It would appear that at some time in the past the period was appreciably longer than that given in the GCVS.

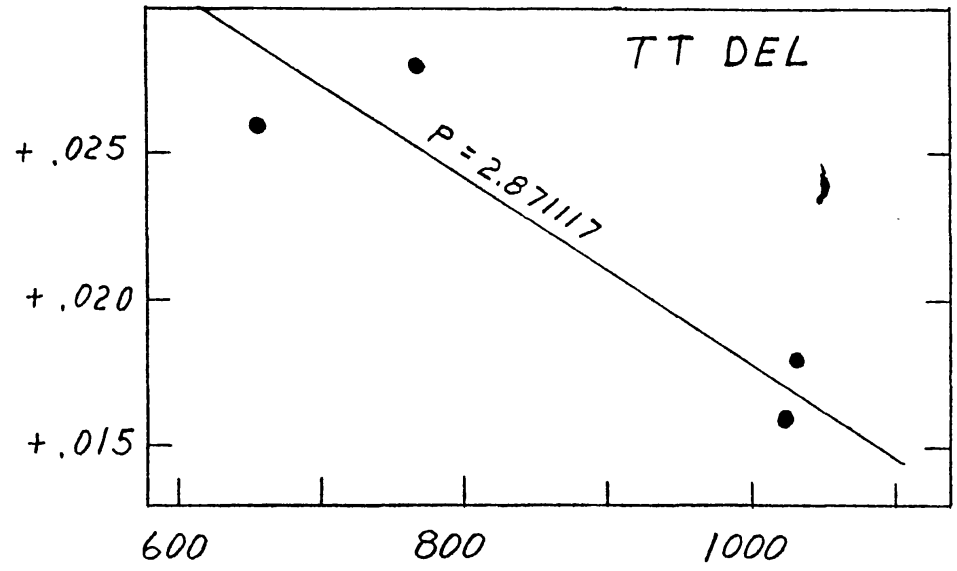


Figure 3. TT Del, O-C Residuals

TW Dra (153264) GCVS elements: JD 2433888.452 + 2.806870E
Revised elements: JD 2441562.411 + 2.806828E

The O-C diagram showing each of the 20 minima timed by observers of the AAVSO and the BBSAG during the past five years results in an evenly distributed pattern with a period significantly shorter than that given in the GCVS. Five years ago TW Dra seemed to be in phase with the GCVS elements, but minima now arrive about three-quarters of an hour early. The period has shortened by about 3.6 seconds, requiring the period adjustment of -0.000042 day. The data shown here are not sufficient to define the point in time where the period shortened. An examination of earlier data is undoubtedly required to accomplish this.

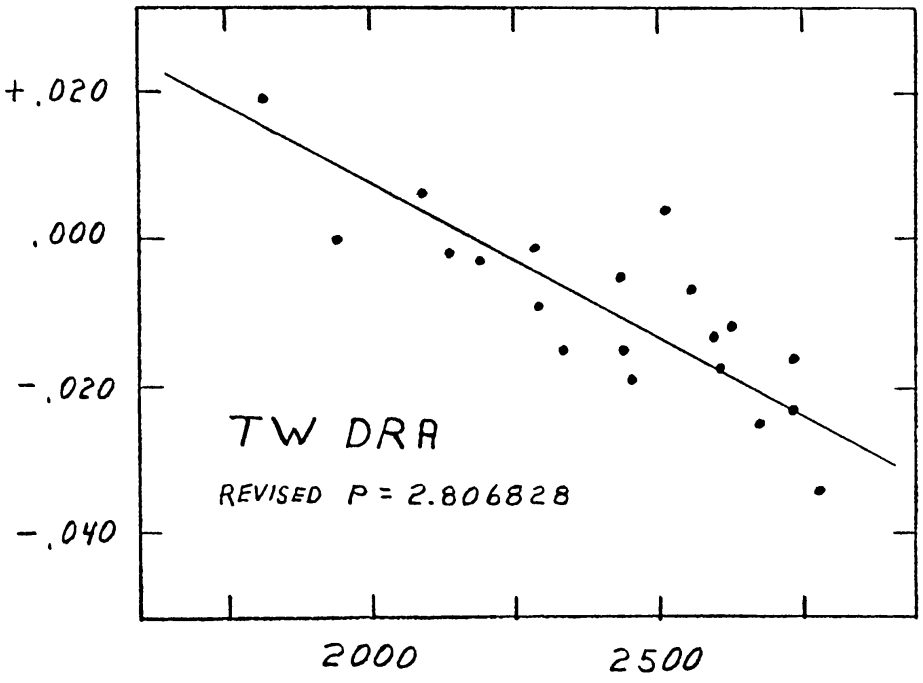


Figure 4. TW Dra O-C Residuals

FL Ori (050202) GCVS elements: JD 2427452.271 + 1.550971E
Revised elements: JD 2439495.641 + 1.550978E

Although we are tentatively able to establish these revised elements from the available data, much more data are needed to adequately define the shape of the O-C curve. We have only five observed minima. Two were observed in the winter of 1966-1967 and three in 1970-1971. Scatter in the later data is somewhat larger than in the earlier data and does not provide us with the best results. We can be certain that this star is reaching minimum later than the GCVS elements indicate by more than two hours. The revision of the period, however, remains less certain until such time as more minima timings of good quality are accomplished.

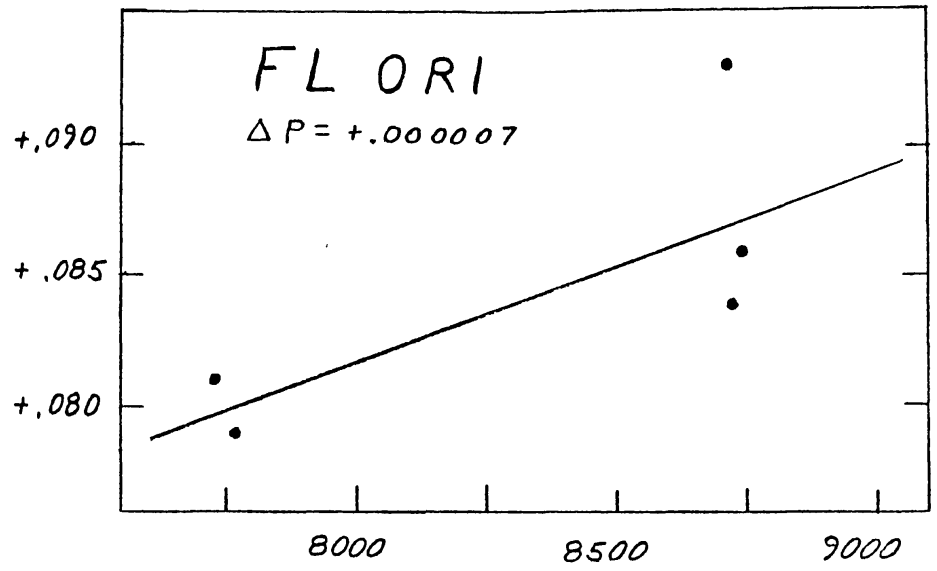


Figure 5. FL Ori, O-C Residuals.

Z Per (023341) GCVS elements: JD 2438669.457 +3.05630E
Revised elements: JD 2439769.724 +3.056335E

Minor scatter of the data points on the O-C diagram causes the current period for this star to be somewhat inconclusive, but it is clear that there is an increase of period as compared to the GCVS elements. The measured deviation from the GCVS elements equals +0.0000353 day and is rounded more realistically to six decimal places. The revised elements are completed using Lawrence Hazel's minimum of JD 2439769 after adjustment to fit the mean linear O-C curve. It is possible Z Per may now be undergoing a decrease of period, but the minima timings are neither frequent enough nor sufficiently accurate to confirm this.

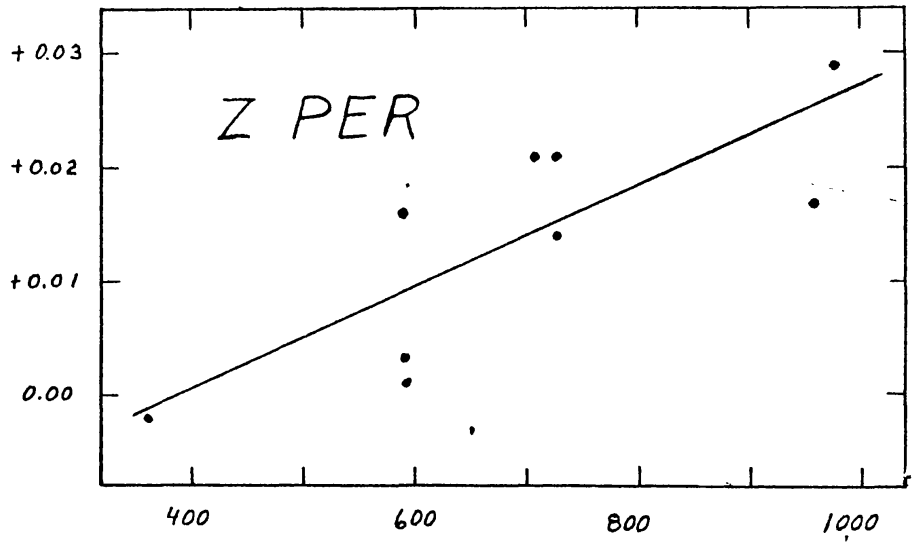


Figure 6. Z Per, O-C Residuals.

RT Per (031646) GCVS elements: JD 2424553.250 + 0.84940710E
Revised elements: JD 2439886.713 + 0.8493994E

Residuals of fifty-two minima obtained by the AAVSO and BBSAG during the period 1964-1972 are plotted. Although there is some scattering of data, a decrease in the length of the period is unmistakable. The annual means of the O-C's fit well the revised linear elements listed above. The measured deviation from the GCVS elements was found to be -0.031 day in 4000 cycles. This equated to a period correction factor of approximately -0.0000077 day per cycle. The revised elements are established when this correction factor is applied to the GCVS period and the writer's minimum of JD 2439886 is used as the initial epoch.

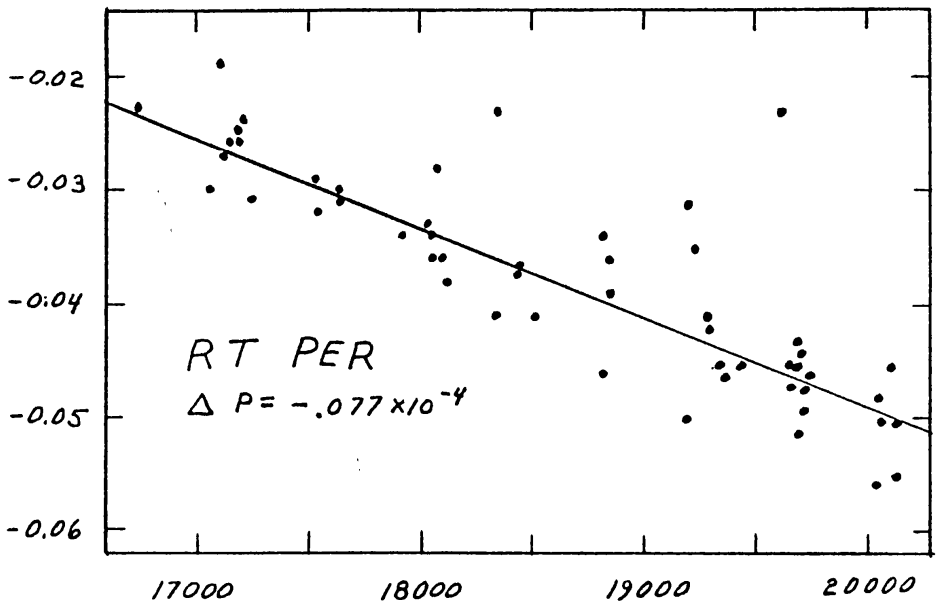


Figure 7. RT Per, O-C Residuals.

Y Psc (232907) GCVS elements: JD 2435030.681 + 3.765766E
Revised elements: JD 2441225.473 + 3.765859E

From the O-C diagram both a large deviation from the predicted times of minimum and a major deviation from the established period are evident. Minima are now arriving some three hours later than predicted by the GCVS elements. The current period is such as to suggest that a period change took place at about cycle 600. This assumes that the GCVS elements were valid until 1961, and it assumes a change at that time to a new period valid to the present. Lengthening the GCVS period by about eight seconds and adjusting Hermann Peter's minimum of JD 2441225 to match the mean linear O-C curve provides the basis for the revised elements listed above. It should be noted that minima timings recently received indicate this star may be experiencing a further increase in period.

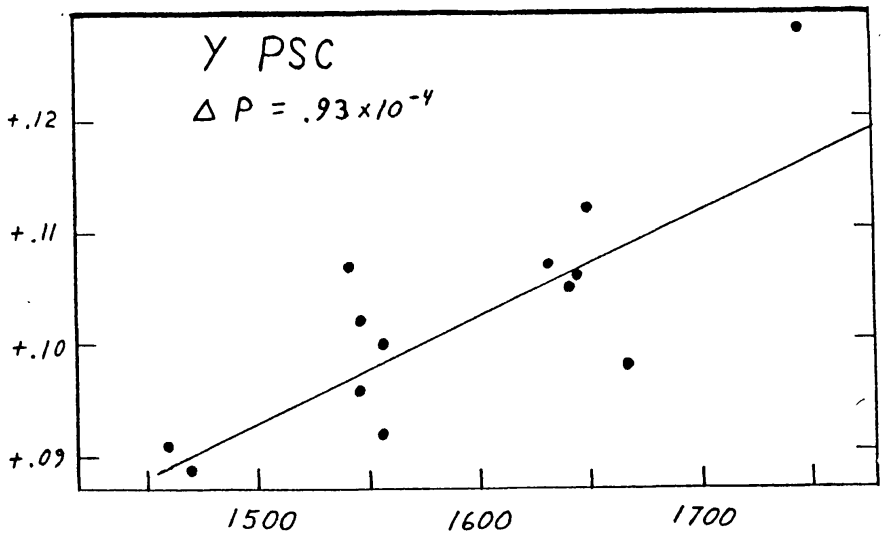


Figure 8. Y Psc, O-C Residuals.

XZ UMa (092449) GCVS elements: JD 2426385.344 + 1.222314E
Revised elements: JD 2440319.669 + 1.222310E

Scatter in the plotted O-C values is pronounced, however, this does not prevent the establishment of a new period, because sufficient data are available to lend a fair degree of confidence to the results. The period is shorter than listed in the GCVS by some 0.35 second. Revising the period accordingly, and using John Bortle's minimum of JD 2440319 for the initial epoch gives us the basis for the revised elements. Although the measured deviation from the GCVS period is small, the cumulative O-C has approached a minus value of one and one-half hours. It is interesting to note that the GCVS initial epoch for this star is more than 40 years old, and when our revised elements are projected back they intersect the GCVS elements very near that initial epoch. Whether our current data represent a change of period or simply an improvement over the GCVS period can be determined only when the data upon which the GCVS elements are based, and possibly the intervening data, have been re-examined.

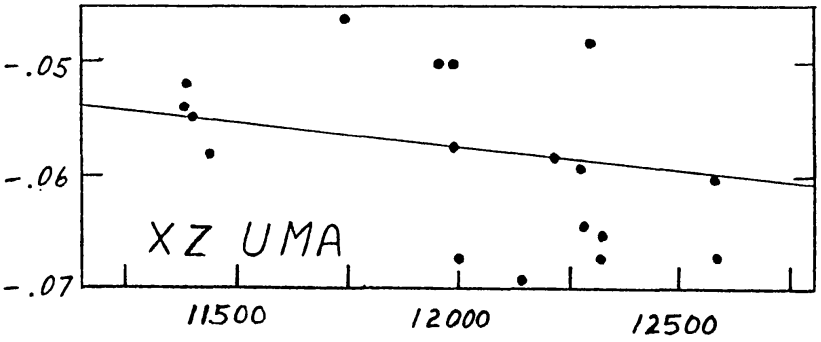


Figure 9. XZ UMa, O-C Residuals.

REFERENCES

Kukarkin, B. V., et al,, 1969, General Catalog of Variable Stars, Moscow.
Locher, K. and Diethelm, R. (1970-1972) BBSAG Bulletin, 1-8.