OBSERVED PERIOD CHANGES IN DETACHED BINARY SYSTEMS

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A comprehensive study of period changes in eclipsing binaries is being carried out at the University of Oklahoma. The survey of available information is supplemented by observations obtained at the University Observatory, at Kitt Peak and Cerro Tololo observatories, and, as part of a cooperative program, at Ankara University. The present review reports the behaviour of 20 systems classified as detached, some of which do show noticeable variations of the period.

We would not expect detached systems of binary stars to show appreciable variations of the period, apart from geometric effects such as apsidal motion or light-time shifts. But are their periods really constant?

This question was first systematically investigated by Plavec, Pěkný and Smetanová [1960], and the present survey is a direct-line continuation and extension of that study. It became obvious very soon, however disappointing, that the main obstacle in 1960, the lack of suitable observations (regular timings of minima) remains the same today. Observers of detached systems are more interested in orbital parameters; time and again, complete and accurate light curves are observed and used for many years of orbit calculation. In the meantime, the O-C curve of the minimum epochs is reduced to hardly more than a few isolated points. Further, since the minima are usually not as deep as primary minima of semi-detached systems, much of the earlier visual or photographic observations is of limited usefulness.

Nonetheless, a new comprehensive study of the literature, with some additional observations, is needed if we want eventually to reach a clearer understanding of how detached pairs behave. Twenty systems have been selected with which to begin this study:

RT And, V805 Agl, RX Ari, WW Aur, AR Aur, β Aur, SS Cam, AW Cam, RS Cha, RX Her, TX Her, VZ Hya, YY Gem, CM Lac, UV Leo, U Oph, WZ Oph, V451 Oph, EE Peg, and RS Sgr.

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The following discussion, hardly more than an extended abstract, offers a progress report of this investigation.

Two problems present somewhat unexpected difficulties:

1. In quite a number of cases the nature of the binary system (detached or semi-detached) is not easy to decide upon; also, several systems considered detached are now reclassified as semi-detached. For these reasons ZZ Cyg, MR Cyg, DI Peg and a few other binaries have not been included; moreover, the classification of one object or other on the above list remains in contention.

2. In some cases the O-C time residuals may be rendered spurious or, at least, markedly influenced by distortions in the light curve, notably by asymmetries of the minima. If the eclipsed component has, for instance, a large asymmetrically placed starspot on its surface turned toward the earth, the time of minimum light will not necessarily coincide with the moment of inferior conjunction. A discussion of the system XY UMa by Geyer [1977] is very instructive; clearly, this problem deserves much careful attention. I am convinced that we can decide upon the reality of the O-C values and hence the period changes, provided the photometric observations are accurate enough and the individual data points are made accessible. Available evidence seems to indicate that the majority of the observed time residuals are not spurious.

A good fraction, about one-third, of the stars in our list show no sign of period variations. This finding, however, is based on observations so few in number or encompassing such a short time span that the constancy of the period cannot be definitely established as yet. In three further cases, constant periods appear to be far better documented, for time intervals of 30-60 years; these systems are: β Aur, VZ Hya and CM Lac.

Ten systems out of the twenty show period variations or, at least, are suspected of period changes. In this latter group of suspected "period variables" we find WW Aur, AR Aur, UV Leo, WZ Oph and EE Peg; some of these belong to the well-behaved systems which supply us with the best data on masses and radii. The evidence is in the form of a few, more or less isolated, minimum epochs which show deviations (usually of the order of 0.01-0.02 days) from linear ephemeris formulae. When backed by photoelectric observations, these O-C values are certainly significant. On the other hand, the linear ephemeris formulae themselves are sometimes unreliable; at any rate, the fragmentary O-C diagrams do not even indicate the mode of the period variations.

Two of the systems, YY Gem and V451 Oph, had earlier been expected to show apsidal rotation; recent data seem to, if not prove, at least support this hypothesis. The case of the late dwarf binary YY Gem (Castor C) may prove particularly interesting. The light curve exhibits, however, quite conspicuous distortions, thus, if anywhere,

here is a cautious treatment of possibly spurious residuals advisable. The apparently opposite shift of primary and secondary minimum rests entirely with recent observations made by Leung and Schroeder [1978] and by Budding [1975]. If real, this shift would indicate an apsidal period of some 200 years or possibly much longer. The corresponding apsidal motion coefficient would be close to the lowest values found: $\log k \lesssim -2.6$, as crude estimates indicate.

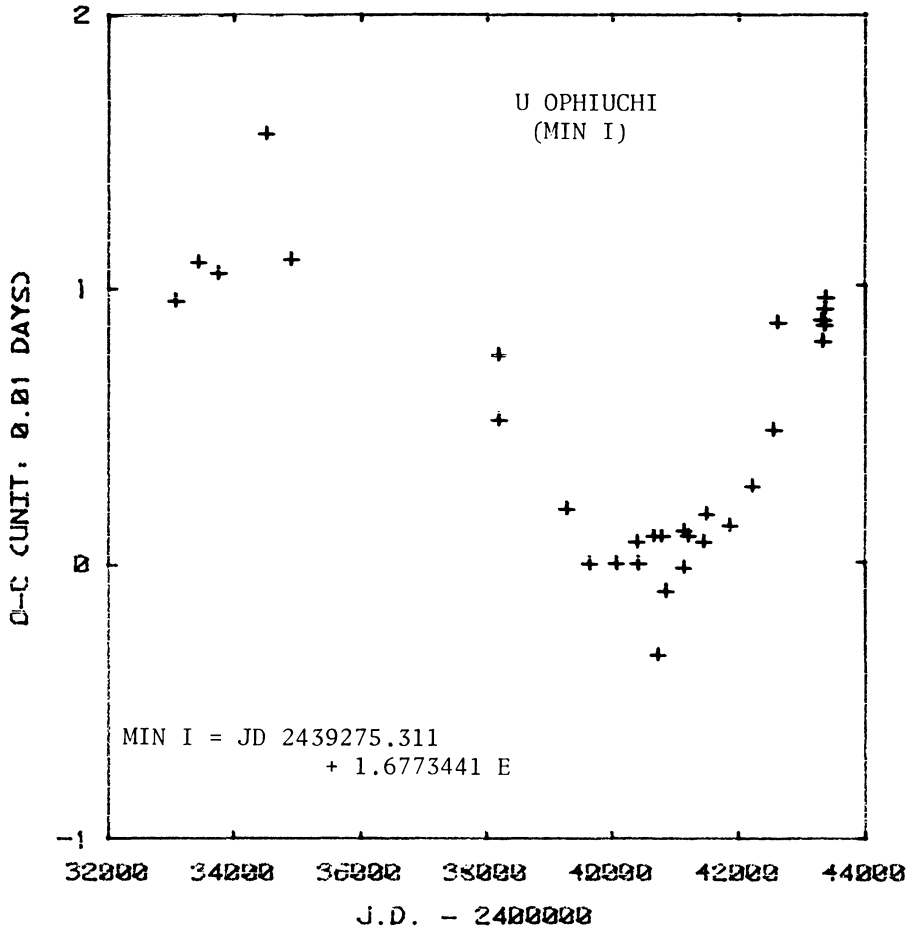
Finally, three systems show marked changes of the period: RT And, TX Her and U Oph. In the case of RT And the time residuals grow to rather substantial values (well over 1 hour) and, quite significantly, the period variations seem to be discontinuous, similar to those shown by many Algol-type semi-detached systems [Williamon, 1974]. Here the fact of a variable period is demonstrated beyond doubt, yet the detached nature of the system is sometimes questioned. It appears, however, that a recent photometry of RT And by Dean [1974] demonstrated that the primary eclipse is a transit; also, "both stars are well within their contact surfaces."

TX Her is the only system among those considered where the time residuals may indicate a light-time effect in a triple system [Vetešnik and Papoušek, 1973]. Between 1972 and 1976, eleven additional photoelectric minima have been observed and later published; they do not contradict the periodic representation of the paper quoted, although the residuals turn out predominantly negative.

U Oph is another very interesting case. The system consists of two early-type stars and has the relatively short period of 1.677 days. Yet U Oph is certainly a detached system, although a very close one with fractional radii $r_1+r_2 \approx 0.52$. The period is known to vary and attempts have been made to represent the observed O-C values by a periodic curve, see recent discussions of the period by Frieboes-Conde and Herczeg [1973] and by Koch and Koegler [1977]. A periodic representation of the residuals, however, remains somewhat unconvincing, apparently due to the inacceptably low accuracy of the early measurements but also to conflicting recent data [Batten and Scarfe, 1977].

This star is not neglected by photoelectric observers and a glance at the diagram of the photoelectrically determined O-C values for primary minima reveals immediately that the system very probably exhibits irregular changes of the period (Fig. 1). Secondary minima are in good agreement with this O-C diagram. The period increased steadily since about 1963 and its present value is 1.677355 days. Just before 1963 it underwent a sharp decrease, by about 1.0 sec; prior to this decrease, the period was for years apparently constant, at 1.677344 days.

One has to point out the possibility of an alternate interpretation: A short period sine curve (approx. 28 years) would fit most of these data equally well; the decision depends entirely on which of two conflicting early photoelectric determinations (near 2434500) is more accurate.



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References

Batten, A.H., Scarfe, C.D. 1977: Rev. Mex. Astron. Astrofis. 3, 21
Budding, E. 1975: Tokyo Obs. Bull. 2nd Ser. No. 240
Dean, C.A. 1974: PASP 86, 912
Frieboes-Conde, H., Herczeg, T. 1973: Ast. Aph. Suppl. 12, 1
Geyer, E.H. 1977: Ap.Sp.Sc. 48, 137
Koch, R.H., Koegler, C.A. 1977: Ap J 214, 423
Leung, K.C., Schroeder, D.P. 1978: AJ 83, 618
Plavec, M., Pěkný, Z., Smetanová, M. 1960: BAC 11, 180
Vetešnik, M., Papoušek, J. 1973: BAC 24, 57
Williamon, R.M. 1974: PASP 86, 924

DISCUSSION FOLLOWING HERCZEG

Smak: What is the percentage of detached binaries with a third body?

Herczeg: Surprisingly low, if we consider only the information from period changes, the light-time effect. I do not know of a single case where the existence of a third body in the system was discovered in this way, although it was occasionally demonstrated later, for instance in the case of Algol, after the spectroscopic or astronomic discovery, by observing the time resuduals. Counting the few uncertain cases, I would estimate the percentage values at 1 or perhaps 2 but this certainly reflects mainly an unfavorable observational selection.

Budding: I have a couple of remarks to make about RT And. Daniel Jassur and I have been looking carefully at the system recently. In some work which we hope to publish soon we should show good reasons why the system can be taken to be detached. But the other point I would like to make is that the system does exhibit fairly substantial irregular photometric fluctuations. In view of what you said already about the effects of this on apparent period variation, how reliably would you say a genuine period variation has been shown for this system?

Herczeg: Obviously RT And is still comewhat controversial; I have based in classifying it a detached system on the papers of Gordon and Dean. As to the O-C curve of RT And in particular, its type suggests that the period changes are not spurious: the period is constant for years then suddenly changes, to a new value; this is typical also for Algol-type stars or W UMa systems. It is difficult to imagine that a certain deformation stays unchanged for such a long time and goes unnoticed. Available evidence, for instance with YY Gem, suggests that the effect of light curve variations is rather an increased scatter of data in the O-C diagram.

Andersen: RS Cha figures in your list. In a paper in press by J.V. Clausen and B. Nordström discussing new light curves of it, there is no indication of period change. But it contains at least one δ Scu star, so here is another source of scatter in the times of minimum (though hardly any systematic variation over longer periods).

Herczeg: Yes, RS Cha is one of those cases in my list where presently we cannot say more than this period seems to be constant, at least for the relatively short time interval of reliable observation.