Journal of İstanbul Kültür University
2005/2 pp. 41-51

DEĞİŞEN YILDIZLARIN MİNİMUM (veya maksimum) ZAMANI GÖZLEMLERİ

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Özet

Yıldızlarda her ışık değişiminin fiziksel bir nedeni vardır. Fiziksel nedeni anlayabilmek için öncelikle ışık değişiminin farklı filtrelerle duyarlı ve sistematik olarak eşzamanlı gözlemi gerekir. Diğer taraftan ışık değişiminin nedeni olan fiziksel mekanizmadaki değişimler minimum veya maksimum zamani gözlemlerinden saptanabilir.Bu gözlemler filitresiz bile olsa işe yararlar Örneğin manyetik çevrime sahip bir yıldızın dönmesinde ve manyetik çevrimdeki uzun süreli değişimler; pulsasyon yapan bir yıldızın puls döneminde uzun süreli değişimler; bu yıldızların çevresindeki madde dağılımı, hatta varsa çekim alanındaki başka yıldız veya gezegenlerle ilgili bilgiler; çift yıldız yörüngelerindeki uzun süreli değişimler ve bu değişimlerin fiziksel nedenleri; Güneş sistemi üyelerinin dönme hareketleri ve bu hareketlerdeki değişimler gözlemsel minimum veya maksimum gözlemlerinin analiziyle bulunur. Bu nedenle her türlü gök cismine ait minimum veya maksimum zamanını gözlemleri oldukça önemlidir. Ancak gözlemlerden söz konusu bilgilerin çıkarılabilmesi için gözlemlerin uzun zaman ölçeğine yayılmış düzenli duyarlı ve sistematik olmasi gerekmektedir. Amatör astronominin gözlemsel astronominin gelişimine en önemli katkılarından birisi bu bağlamda yapılan değişik gökcisimlerinin minimum veya maksimum zamanları gözlemleridir.

Abstract

The light changes in variable stars have certain physical causes behind. In order to understand the physical causes, the light changes have to be observed systematically and simultaneously in different filters. On the other hand, any change in the physical mechanism causing the light changes can be detected by the observations of minimum or maximum times. Even the unfiltered observations are usefull for this purpose. For example, the rotational changes or secular changes in the magnetic cycle of a magnetic star; the secular changes in the pulsation period of a pulsating variable; the mass distribution around a pulsating variable; information about other stars or planets in its gravitational field; the secular orbital period changes of binary stars and the physical causes of these changes; the changes in the rotational motions of the Solar System members can all be detected by the analysis of minimum or maximum observations. Therefore, the minimum or maximum observatins of any celestial object are very valuable. But, in order to extract information from such observations, they have to be systematic, accurate enough and distributed evenly in a long time base. One of the most important contributions of amator astronomers in the advances of observational astronomy must be the minimum or maximum observations of different celestial objects.

1. Introductıon

1.1 Determination of minima (or maxima) times

The photometric observations of minima (or maxima) of the light variations of different celestial objects are used in obtaining the minima (or maxima) times which in turn very valuable in studying the rotational and orbital motions of the celestial objects. The observed minima (or maxima) times of variable stars (single or binary) are determined very accurately and used effectively in measuring (phasing) the rotation periods, pulsation periods, and orbital periods of the respective systems.

The minima (or maxima) times are determined by using many different methods on the observations. The simplest one is graphical bisector method, sometimes called tracer paper technique. The best fit (parabola or polynomial) method and an analytical algorithm called Kwee and Van Woerden method based on defining the reflection axis are commonly used. The Kwee and Van Woerden method is explained here in more detail.

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1.1.1 The Kwee and Van Woerden method

The Kwee and Van Woerden method [1] defines an analytical algorithm for light minima evaluations. The importance of an analytical approach needs to be pointed out first. Objectiveness is one of the most important aims of the scientific method. Therefore the study of eclipsing binary systems and particularly of their period changes has benefited by the introduction of rigorous numerical approaches.

The Kwee and Van Woerden method (K.V.W.m.) is probably in the widest use by astronomers. It has replaced the old tracer paper technique which requires several graphic estimates. (2n+1) magnitudes, equally spaced by the same time interval ΔT . are required as input data. Because observations do not necessarily satisfy this hypothesis (odd number and equally spaced observations) they must often be linearly interpolated. Let (2n+1) be almost equal to N in order to avoid anomalous uses of observations. A preliminary rough estimate T, of the time of minimum should be chosen among the equidistant times. It defines a reflection axis for the interpolated magnitudes. Let Δm_k , k=1 ,2,.. ,n be the difference between the initial branch magnitudes and

the reflected magnitudes (fig. 1). The summation:

$$S(T_1) = \sum_{k=1}^{n} (\Delta m_k)^2 \tag{1}$$

is therefore an estimate of the degree of the branches superimposition for the reflection axis at t= T_1. The reflection axis is shifted successively to ($T_1+\frac{1}{2}\Delta T$) and to ($T_1-\frac{1}{2}\Delta T$) and the sums: $S(T_1+\frac{1}{2}\Delta T)$ and $S(T_1-\frac{1}{2}\Delta T)$ are computed. If T_1 has been properly chosen; $S(T_1) < S(T_1+\frac{1}{2}\Delta T)$ and

$S(T_1) < S(T_1-\frac{1}{2}\Delta T)$ If it is not the followirg, reflection axis has to be assumed:

a) if $S(T_1) > S(T_1-\frac{1}{2}\Delta T)$: refleclion axis: t= $T_1-\Delta T$

b) if $S(T_1) > S(T_1+\frac{1}{2}\Delta T)$: refleclion axis: t= $T_1+\Delta T$

This loop allows proper identification of a reflection axis which satisfies the above ment i oned cond it ions. Care should be taken that n is the same for all the summations

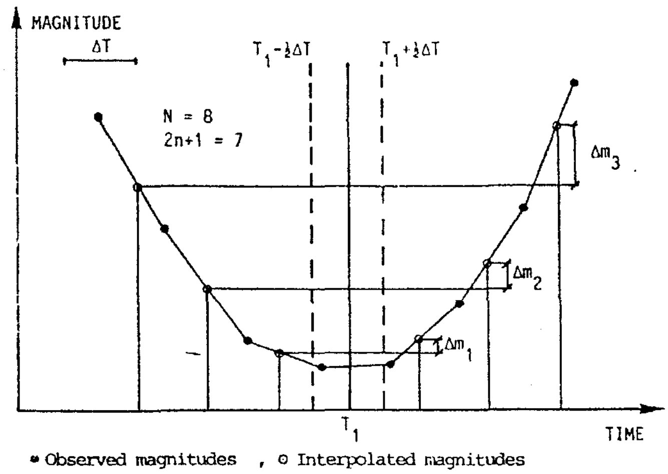


Fig 1 : Kwee and Van Woerden method. Reflecting axis and interpolated magnitude differences between the own and the reflected branches.

The function S(T) may be represented by the quadratic formula:

$$S(T) = a\,T^2 + b\,T + c, \tag{2}$$

where the coefficients a, b. c may be evaluated from the three summations (left, center, right) corresponding to the properly chosen reflection axis $t=T_r$:

$$\begin{aligned} S(T_r) &= a\,T_r^{\,2} + b\,T_r + c \\ S(T_r + ½T) &= a\,(T_r + ½\,T)^2 + b\,(T_r + ½T) + c \\ S(T_r - ½T) &= a\,(T_r - ½\,T)^2 + b\,(T_r - ½T) + c \end{aligned} \tag{3}$$

The parabole (2) has a minimum value

$$S(T_0) = c - \frac{b^2}{4a} \tag{4}$$

at the epoch of minimum:

$$T_0 = -\frac{b}{2a} \tag{5}$$

The mean error of the epoch To is given by:

$$\sigma^2{}_{T_0} = \frac{4ac - b^2}{4a^2(Z-1)} \tag{6}$$

where Z is the maximum number of independent magnitude pairs. In the recommended case of linear interpolation Z = N/4 . while if the observations were already equidistant in time Z = N/2.

The analytical approach of the K.V.W.m. is based on the assumption of the light curve symmetry (reflection axis = symmetry axis), but it may be conveniently used even if slight asynrnetries are present. In these cases the function S(T) is affected not only by the observation errors, but also by the asynluetry effects. Therefore equation (6) should be properly modified and the mean error will be greater.

This method identifies the reflection axis with a step organization slightly different from that initially proposed by Kwee and Van Woerden. The new axis differs from the preceding one of ΔT. When an inversion of the shift is found this difference becomes $\Delta T/2$ and only for one step. It is ΔT again if the. next step confirms the salile direction of shift (increment or decrement of time). This avoids mistakes in the identification of the reflection axis. The original step organization can assume a partial oscillation of one branch due to a light curve distotion. This problem becomes relevant whenever the observations are not symmetrically distributed around the predicted time of: minimum. In this case the algorithm needs a long time to reach a correct reflection axis and if there are oscillations it is possible a false estimate of the epoch of minimum or, even worse. the execution of a endless loop. The newly defined steps avoid this latter possibility and save execution time.

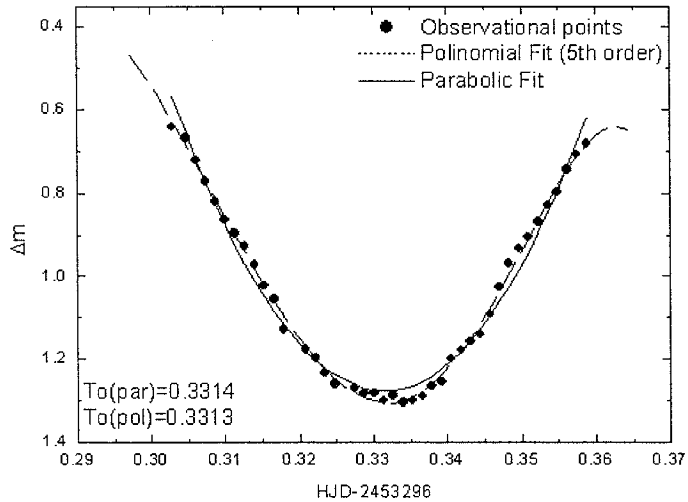


Fig 2 : The best fit ((a) parabola and (b) a polinomial of 5th order) to actual minimum observations and derived minimum times To from both fits.

1.2 Evaluation of the (0-C) Residuals

The O-C parameter indicates the time difference 'Observed Minus Calculated' between the minimum (or maximum) time of the observed periodic phenomenon and its prediction based on ephemeris. It allows one to check possible varia-tions of the period, which is useful in the study of the dynamic evo-lution of the observed star. Eclipsing binary systems are typical example of periodic phenomena in variable stars: in this case the analysis of the O-C variation allows the identification of possible causes of the period variation, which may be absidal motion, mass loss from the system, or mass exchanges between the two components, magnetic effect, or the presence of a third body. The expected phenomenon time T_e can be obtained by using the light (reference) elements P (period) and T_0 (initial reference time), as

$$T_e = T_0 + PE \tag{7}$$

where P is the period, T_0 the initial reference time and E the epoch number of cycles of the variable phenomena since the initial minimum (or maximum) time T_0. The epoch number E corresponding to each observed minimum (or maximum) time O is estimated by obtaining time difference O- T_0 in terms of the period P. There will be an E and C corresponding to each observed minimum (or maximum) time O. The O-C residuals, thus formed are not necessarily be zero; the subsequent values follow a trend which is called the O-C diagram.

1.3 Time – Phase Conversion

The observations of periodic phenomena in variable stars may be referred both to a time scale and to a phase scale. By using phase scale one can combine observations from different cycles and thus obtain a mean light curve of the variable star. For this the phase φ of each observational time must be established that is the time from the nearest preceding minimum (or maximum) and which is conveniently expressed as a fraction of a period P:

$$Q = (t - T_0) / P = E(t) + \varphi \tag{8}$$

Where Q has always an integer and fraction part as E(t) and φ, respectively. The E(t) describes the number of cycles of the variable phenomena since epoch T_0 , and φ is the phase of the observational time t.

1.4 Determination of the Light Elements T_0 and P

The determination of the elements of a periodic variable that is of the initial minimum (or maximum) T_0 and the period P can take place in the following manner given a number of observed maxima or minima. We write down the series of dates in a column, perhaps with a note of their probable reliability, and take the differences between consecutive values. All these differences are of the nature of nP (where n=I, 2, 3, ...). In long period variables like Mira stars we quite frequently find n=1, that is the period length, appearing directly in the differences. With rapidly-varying stars the determination of the correct period is more difficult, but we can succeed if we begin with the smallest differences. In the case of RR Lyrae stars we know that in the vast majority of objects the period lies between $0^d.3$ and $0^d.6$. The procedure is then to choose well-established, small differences, and to discover which reasonable value for the period will satisfy the observations in forming the least scattered light curve. If this gives too many possible values then further differences must be used and an effort made to determine which is the right value. In any case the aim is to obtain the best possible approximation of P, which can then be further refined, until to some extent it fits the whole series of epochs. For T_0 we may accept one of the well- determined minima (or maxima) times in the list. We thus obtain an approximate formula, with which we may calculate the appropriate value closest to each of the observed epochs. By taking the observed minus calculated (O-C) differences, and plotting these graphically as ordinates against the epoch number, we may use this to make further adjustments. The representation is called an O-C diagram.

2. Interpretation of the O-C diagrams

The O-C diagrams formed by the minimum (or maximum) times of the variable stars has an important role in stellar astronomy because it allows identification of errors in the light (reference) elements P (period) and T_0 (initial reference time) and the study of the rotational or orbital period changes of the observed stars.

Case a) The estimated residuals O-C's are lined along the time axis (fig. 3a): In this case there is no need to the corrections of the linear elements of this star. The period of the star is said to be constant during the considered time interval.The dispersion derives from the observational errors.

Case b) The estimated residuals are lined along a straight line parallel to the time axis at height A (fig. 3b): In this case the period P is correct, but not the reference initial time T_0. Therefore T_0 should be revised as follows:

$$(T_0)_{new} = (T_0)_{old} + A . \tag{9}$$

The investigated periodic phenomenon does not show any intrinsic variation, but only incorrect T_0.

Case c) The residuals are lined along a staight line crossing the origin, with positive slope (fig. 3c): In this case the period P is shorter than the true period and therefore each phenomenon occurs after the prediction. The difference between observations and predictions becomes greater as T - T_0 increases. The least squares method allows an evaluation of the slope B according lo the equation:

$$O\text{-}C = B\,E(\text{regression line}) \tag{10}$$

The new correct period P' may be evaluated then as:

$$(P)_{new} = (P)_{old} + B \tag{11}$$

In this case also, observations do not show any intrinsic variation of the periodic phenomenon, but only incorrect reference values.

Case d) Same as case c) but with a negative slope (fig. 3d): Then the period P is longer than the true period and it should be revised according to equation (11) with $B< 0$.

Case e) The residuals regression line is inclined and does not cross the origin (fig.3e): In this case both elements P and T_0 are different from the true values. The regression line to the O-C residuals will be as

$$O\text{-}C = B\,E + A \tag{12}$$

Therefore the reference elements must be revised according to equations (9) and (11).

When the elements T_0 and P have been revised the new 0-C diagram should be of the type shown in case a). Even if the regression line is inclined, in this case the observations do not reveal any intrinsic period variation, but only incorrect references.

Case f) The O-C residuals are lined along a parabola with a positive or negative concavity: This is one of the most interesting case: The star shows a continuous variation of the period. The light elements of the star are not linear, but may be expressed by a second order relationship of the type:

$$T_e = T_0 + PE + bE^2 \tag{13}$$

This equation derives from the continuous variation of the period: $P = P_0 + bE$, where P_0 is the period at time T_0. The coefficients of a second order regression polynomial for the 0-C residuals provide the elements of the periodic phenomenon and subsequent checks and revisions. If $b<0$ the residuals parabola is downward and the period decreases, while if $b>0$ the residuals parabola is upward and the period increases. The new element b is generally small when compared to the other two elements, and represents the rate of change of the period. A precise evaluation of b requires the observations of a great number of cycles.

Case g) The residuals curve is sinusoidal: The period changes, but not linearly. In this case the prediction formula must be written as follows:

$$T_e = T_0 + PE + cE\sin(\omega E+\varphi), \tag{14}$$

because the period P satisfies the equation: $P = P_0 + c\sin(\omega E+\varphi)$. where c is the wave amplitude, $\omega = 2\pi/T'$ (T'= period of the residuals sinusoid) is the angular frequency and φ the phase of the sinusoid. These clements may be conveniently estimated with a Fourier analysis. Generally it is necessary to observe many cycles in order to correctly estimate the sinusoidal elements of a variable star.

Case h) The residuals curve is more complex like an irregular shape. For axample, the O-C diagrams of many classical algols, and some RR Lyrae type stars are this kind. In this case the prediction formula may also be more complicated, and may include some high order polinomials and/or harmonic terms.

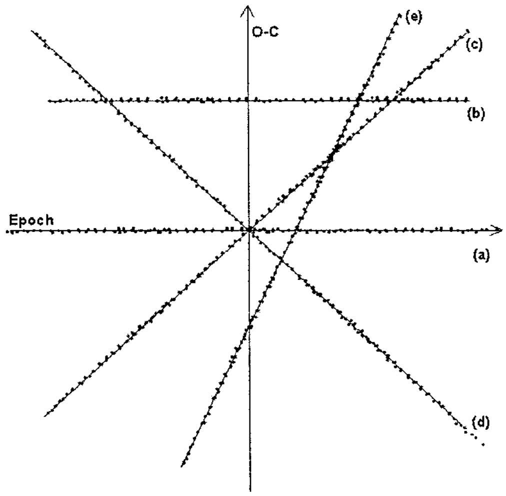


Fig 3 : The linear forms of the O-C diagram indicating errors in the light elements T_0 and P, or both (see cases a-e).

3. Observatıonal Complexıtıes In The O-C Dıagrams

Any intrinsic period variation requires nonlinearity in the O-C diagram. If a variable star display light curve changes caused by some physical phenomena, such as pulsation, magnetic activity or mass motions, then minimum(or maximum) times shifts. Such changes which are called Blazhko effect in RR Lyrae stars may result either as a scatter or slow variation in the O-C diagram, indicating period changes. At present, in favourable circumstances, the mean deviation of the minima times as small as 10 sec. for binaries with sharp eclipses may be detected. The minimum detectable variation on the (O-C) diagram depends on the time span of the variation. For example, a continuous P change as small as about 10^{-9} in systems with periods around 1 d would be observable over a timespan of a century. However, (i) the use of older visual and photographic data, (ii) uneven and inhomogenous distribution of data points, (iii) the use of normal points, (iv) large gaps in the data sets, and (v) insufficiently short time base of the data set reduce the accuracy and usefulness of the (O-C) diagrams so much that sometimes confusion results when deciding on the character of the variation: abrupt or continuous, linear or quadratic, cyclic or sinusoidal, ... etc. We see that in general if one has an (O-C) diagram with a time span of about 10 yr, the character of the diagram would seem to be linear. If the time span Δt becomes longer, say $10yr < \Delta t < 30yr$, then the character may usually appear to be parabolic. If $30yr < \Delta t < 50$ yr, then the character would be alternating; and if $\Delta t > 50$ yr then the character seems more complicated. A part of a sinusoidal variation can be seen to be parabolic in character, and similarly a part of a complicated variation can be seen to be sinusoidal. The present (O-C) data for the eclipsing binaries usually cover less than one complete cycle and generally the character is not repeated in the next cycle. Thus, in order to decide on the character of the (O-C) variation, one has to wait a hundred years or more for a time span of minima observations. It is known by experience that many 0-C diagrams cannot be easily interpreted because they often derive from the superimposition of different phenomena. Therefore it is necessary to observe a great number of cycles in order to clearly identify the separate changes in the superimposed variations and estimate the causes of the separate changes in the 0-C diagram. For this reason, a precise timing of the phenomenon, such as the light minimum of an eclipsing binary star, is necessary as it will provide more precise estimate with large number of observations in a large phase interval around minimum(or maximum).

It is well-known that any arbitrary continuous non-linear function - and thus an O- C diagram - can be represented to any desired degree of accuracy by multiple trigonometrically series (Fourier series). This is doubtless the basis for the apparent success of the procedure. However, if we examine a greater number of such diagrams (see Fig, 4), then we realize that in most cases the O-C curves seem to be reproduced by a succession of linked straight lines. From a physical point of view this would mean that now and then the period values are subject to sudden changes, and that these are at irregular unpredictable intervals. Therefore the observers use instantaneous elements in the prediction of future times of minima (or maxima). In these the epoch and period were taken such as to satisfy the current behavior of the star and were changed if observations indicated unequivocal deviations.

A new dimension was brought to the discussion by Sterne [2] and recently by Lombard and Koen [3]. They asserted that the period changes of Mira stars and other variables did not have to be real, as they could be explained by means of an effect which he called cumulative error. He showed that by means of dice, one can draw up O-C curves that are very similar to those of the O-C diagrams formed by the minima or maxima of the light variations of variable stars.

Let us try to explain this briefly in a qualitative manner. If we use two dice, then the smallest throw is 2, the greatest 12, and the mean of all possible values 7. This latter value is the analogue of the mean period of the star. If we were able to throw the mean value on all occasions, then adding the numbers we would obtain the series 0,7,14,21,28, etc. The figures actually thrown will deviate from this, in other words they will fall around the theoretical value in accordance with the rules of chance. If we assume that at some time a very small value (2 or 3) has been thrown after a previously regular series, then the sum will be less than expected, so the O-C will be negative. For the following throw there will be three possibilities: it may again be too small, may be close to 7, or well above average. In the latter case it will compensate for the deficit incurred by the earlier throw. The first possibility increases the deficit, while the second leaves it unchanged. One thus has an approximate 2/3 probability that the following O-C value will again be negative. So there is a certain tendency for any large chance deviation of the sum from the average value to be maintained. With a long series the compensation is such that a series of deviations of opposite sign has the same probability of occurring.

Thus, the (O-C) diagrams, which are commonly used in studying P changes of many variable stars may not be real, reminding that the small random period changes may cause large accumulated changes in the minima (or maxima) timing, and may give rise to spurious indications of P changes. However, it was noted that this is not the case at least in eclipsing binary systems where P's are determined with a few orders better accuracy than the minima times. Thus, at least for the close binary systems, the (O-C) diagrams formed by the minima times provide the true basis for studying time dependent period changes.

4. Summary And Conclusıon On The Most Frequently Observed Eclıpsıng Bınarıes

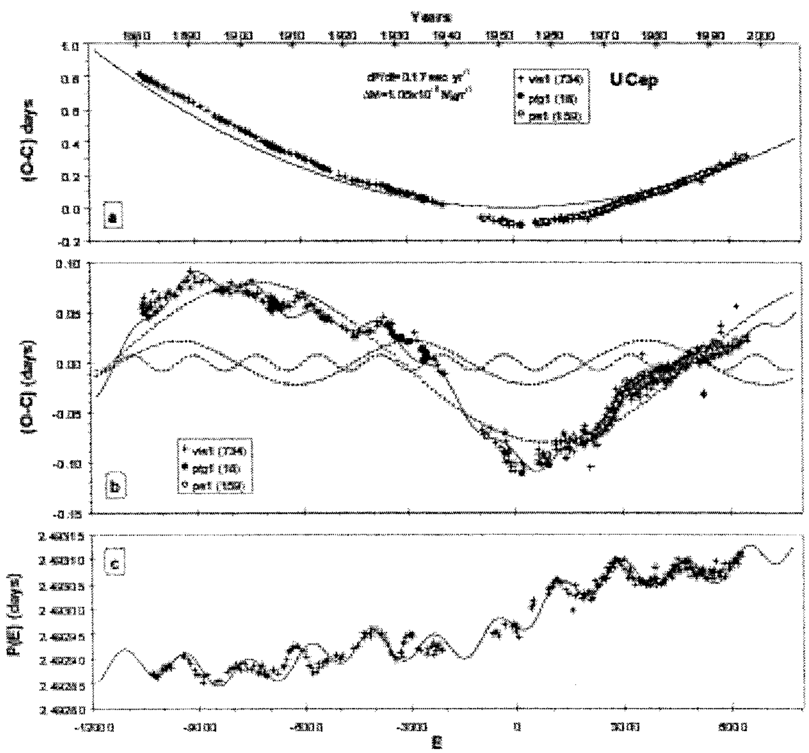
Usually the simplest linear character of the (O-C) variation is observed for detached binaries with radiative components. For them no P change is expected during a few hundred years if the orbit is circular, and if there is no gravitationally bound third body around. For semidetached binaries with radiative components monotonic period change (increasing or decreasing) due to mass transfer and mass loss is observed [4]. With the existence of cool secondaries in classical Algols, an additional magnetic braking effect on the orbital periods does not explain the alternating more complicated (O-C) changes of these systems. Such changes were modeled by the cyclic internal changes of the convective cool secondaries [5]. However, it seems there is still no clear proof of this model at present, and it is claimed that the third body effect and the apsidal motion cannot accound for all the alternating complex P changes. The third body effect, especially is expected with the same proportion in different types of binaries.

A parabola plus a trigonometric series representation of the most complicated (O-C) diagrams of the most frequently observed eclipsing binaries (which are all sd Algols) are presented in Fig 4. It is shown that the most complicated diagrams can be represented by the summation of a parabola and two or at most three sine curves. The P changes for the same Algols were also illustrated as the (P-E) diagrams which were formed by the running averages of the instantaneous periods from the minima observations. The time derivatives of the continuous best fit functions to the (O-C) diagrams were shown (as continuous lines among the (P-E) diagrams. It is seen that they very well represent the observational (P-E) diagrams.

The parabola in Fig 4 indicate that the mass transfer has a dominant effect on the P changes of U Cep, while the mass loss has a dominant effect in the case of beta Per. The residuals are clearly continuous and formed by two or three periodic phenomena in the systems. Some of the cyclic components (but not all) can be caused by the unseen third (or fourth) bodies in the systems. For the beta Per system the astrometric observations revealed that 32 yr and 180 yr periodicities do not correspond to orbital motions [6] and cannot be caused by the apsidal motion [7]. Söderhjelm speculated that the 32 yr periodicity can be interpreted as a cyclic magnetic effect of the cool secondary. 180 yr periodicity was interpreted as two abrupt changes of the orbital period in 1944 and in 1950 [6].

A Statistics: There are 719 eclipsing binaries with EA-type light curves in Kreiner, Kim and Nha's atlas [8]. These systems, which form 63 % of all included in the atlas, contain both evolved (semi-detached) and unevolved algols. However, the 256 of the sd-algols in the catalogue of sd-algols by Budding et al. 2004, have the O-C diagrams in the KKN atlas. For the 85 of the 256 systems, the (O-C) diagrams are indefinite due to insufficient number and insufficient time coverage of the data points. For the remaining 117 Algol systems, the 28 (16.4 %) display no period variation; the 23 (13.4%) display upward parabolic (O-C) diagram; the 14 (8.2 %) display downward parabolic (O-C) diagrams; the 28 (16.4 %) display periodic variation superimposed on the upward parabolic (O-C) diagram; the 12 (7.2 %) display periodic variation superimposed on the downward parabolic (O-C) diagram; the 47 (27.5 %) display cyclic (O-C) diagrams; and 19 (11.1 %) display more complicated variations in their (O-C) diagrams. The algol systems displaying increasing, decreasing and most complicated period variations are listed together with some system parameters in Table 1, Table 2 and Table 3, respectively. The system parameters in Tables 1, 2 and 3 (the spectral types of the component stars (sp), the mass ratio ($q=m_2/m_1$) and the orbital period P are from the new catalogue of Algols [9] whenever available, otherwise from the catalogue by Svechnikov and Kuznetsova [10].

It is known in general that the orbital period increasing systems in Table 1 which display upward parabolic variation in their O-C diagrams, should be dominantly under the mass transfer effect. All semi-detached systems are expected mass transferring systems, but only some of them exhibit period increases. Either the mass transfer effect is compensated by the mass loss effect in some algols or the mass transfer weakens or stops in time intervals as long as a century. If the mass loss effect becomes dominant in a binary, then the orbital period should decrease and the (O-C) diagram draws a downward parabola. The magnetic braking of the cool secondaries in the semi-detached algols also requires orbital period decays. Thus in period decreasing algols in Table 2 we expect either the magnetic braking effect or mass loss (loss of transferred mass) effect is dominant. As known, the mass transfer, mass loss and magnetic braking in algols causes one way simple effects (increase or decrease) on the orbital periods. But as it is seen in Kreiner, Kim and Nha's atlas [8] and in Table 3 that many algols (at least 30 %) exhibit alternating complex period changes. It is shown by Demircan [11] that the most complicated (O-C) diagrams of algol-type binaries can be represented by the summation of a parabola and two or three sine curves. For the sake of completeness the most complicated (O-C) diagrams extracted from Selam and Demircan [12] were reproduce here in Fig 1.. The cause of the alternating period changes is probably not single. Some of the alternating period changes must be due to unseen third (and/or fourth) bodies in the systems. However, constraints of the alternating changes in systems containing late-type Rocle-lobe filling secondaries [13] and absence of alternating period changes in radiative algols (containing two radiative components [4] strengthen the idea of convective cool star origin of the alternating period changes [5, 14]. In the future, high precision astrometric measurements by the upcoming astrometric missions; FAME, DIVA, SIM and GAIA, in addition to longer time base of the classical minima observations will answer whether the alternating changes in the (O-C) diagrams are caused by the unseen component stars around the binary systems or by the cyclic internal changes of cool convective secondary components of the systems.



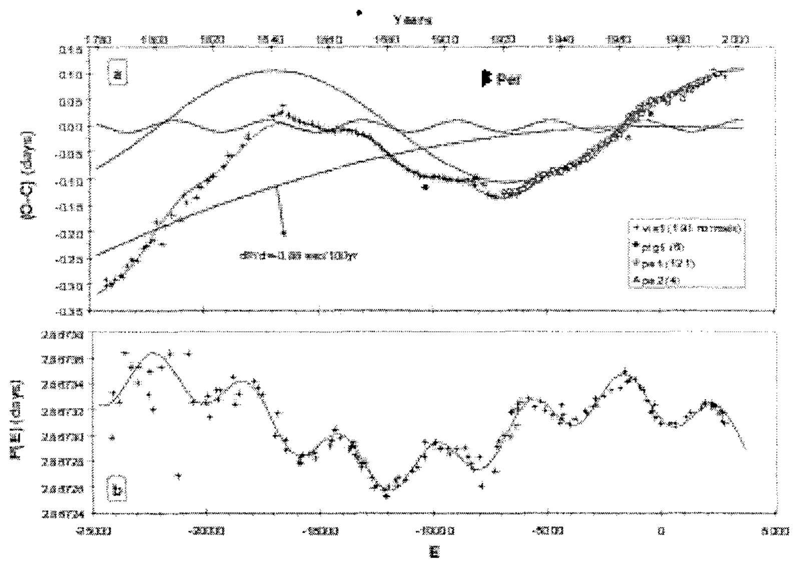


Figure 4: The (O-C) diagrams of some most frequently observed Algols: beta Per, and U Cep. The best fit continuous curves and their components as parabola and sine curves were shown on the diagrams. The (P-E) diagrams formed by the running averages of the instantaneous periods from the minima observations of the same Algols were also presented in the lower part of the diagrams. The time derivatives of the continuous best fit functions to the (O-C) diagrams were also shown (as continuous lines) among the (P-E) diagrams (From Selam and Demircan 2000).

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