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On the relation of changes of the period and brightness in the close binaries SW Cygni and U Sagittae

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Abstract. The analysis of the available data allows to conclude that changes of the orbital periods in both Algol-type systems, SW Cyg and U Sge, are correlated with the brightness variations of the late-type loser. The episodes of decrease of the orbital period are accompanied by minimum of brightness of the loser in both cases.

Key words: binaries: eclipsing – stars: late-type – stars: individual: SW Cyg, U Sge

1. Introduction

The orbital periods of many eclipsing binaries have been known to vary for a long time. These variations can only rarely be explained by the light-time effect or apsidal motion. As Wood (1950) revealed these changes occur predominantly in systems containing at least one component on the Roche limit. Huang (1963) showed that period changes can be a result of the mass transfer and/or loss. The models of the mass transfer developed in sixties enabled to understand the evolutionary processes in binaries of the Algol-type and confirmed the importance of the semi-detached configuration (e.g. Paczynski 1967, Plavec 1968). Period changes were proved to be accompanying phenomenon of these processes in Algols. However, as Biermann and Hall (1973) pointed out the observed period variations in Algol-type systems were often much more complicated than would correspond to purely evolutionary changes. They offered a model incorporating temporary storage of the angular momentum of the transferred matter in the outer layer of the gainer. Unfortunately, this model would require mass transfer rate $\dot{m}$ significantly larger than corresponds to the observed amount of circumstellar matter and model computations.

Later an idea appeared that the mass transfer rate in most Algols is too small to be important for the observed changes. Matese and Whitmire (1983) offered changes of the stellar structure as an explanation for the observed period variations. Hall (1989) found that semi-detached binaries which contain at least one late-type star show cyclic course of the O–C variations while only monotonous course or constant period is observed in systems with purely early-type components. Hall attributed the cyclic course to cycles of magnetic activity in the late-type star with convective outer layer (COL). Applegate (1992) then presented a theory which explains the cyclic orbital period variations by changes of the internal structure caused by the subsurface magnetic field in the convective envelope of an active component of the binary. According to this theory the cyclic (but not strictly periodic) changes of the orbital period P are expected to be accompanied by variations of luminosity of this active star and thus allow for an observational test. These brightness changes must have the same cycle-length as those of P, with only possible phase shift. This theory can be in principle applied to any system containing star with COL.

Hall (1991) found that orbital period of CG Cyg, the RS CVn-type system (G9.5V + K3V), varies with the cycle-length of 50 years and these changes are accompanied by variations of brightness with the same cycle-length, maximum brightness occurring at minimum O–C. This behaviour was in agreement with Applegate's theory. On the contrary, as was shown by Šimon (1997, hereafter Paper I), period changes in the Algol-type system RW Tau (B8V + K0IV), namely two consecutive episodes of shortening the orbital period, each accompanied by decrease of brightness of the cool loser, and separated by an interval of constant P, were inconsistent with the Applegate model.

The available results really suggest that the cool loser is a major contributor to the observed period changes and that variations of luminosity of this star L_{los} and of P are related. However, owing to the controversial results in the sense of the variations it is necessary to extend the search to more systems because it is quite possible that not only one mechanism is active in the respective binaries. Since the losers in the Algol-type systems are generally much fainter than the gainers a passable way is a comparison of the O–C curve with the brightness variations of the center of the total primary eclipse when only the loser is visible. The homogeneous and at present the most extended available set of such long-term photometric observations is that

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presented by Olson and Etzel (1993, hereafter OE93). These authors also showed that these brightness changes are consistent with the temperature variations of the losers. Besides their observations of RW Tau used in Paper I suitable series of data published by OE93 exist also for U Sge and SW Cyg. Both these systems are typical evolved ($q < 0.4$) semi-detached Algols with the late-type loser filling in its lobe and both are in the phase of slow mass transfer.

SW Cyg (P = 4.57 days; A2V+K0IV): Mass transfer in this Algol-type system is still proceeding as is suggested by the presence of a symmetric accretion disk (Albright and Richards 1996a). The light curve of the eclipse shows disturbances, apparent namely in the U-band including an UV excess in totality (e.g. Hall and Garrison 1972). The period is highly variable and the O–C curve covers about a century of observations. This curve can be interpreted as an approximately sine wave with the cycle-length of 96 years (Berrington and Hall 1994ab, hereafter BH94). However, only a single cycle is covered.

U Sge (P = 3.38 days; B7.5V+G4III-IV): Recent photometric solution for this system was obtained by Olson (1987) who also noted variations of the level of totality and attributed them to brightness variations of the loser. Depression of the light curve caused by the mass stream and visible before the primary eclipse was used by Olson and Bell (1989) for determination of the mass transfer rate $\dot{m} = 2 \times 10^{-8}$ M$_\odot$ yr^{-1}. The system contains a transient accretion disk with interchanging epochs of prominent disk and stream (Albright and Richards 1996a,b). The O–C diagram presented by Kreiner and Ziolkowski (1978) shows small alternate period change. Another two episodes were mentioned by Olson (1987).

2. Collection and analysis of the data

The international database of timings of minima of the eclipsing binaries, founded by Mr Lichtenknecker and now directed by F. Agerer, was the main source of timings used for U Sge (Agerer 1997) while the observations tabulated by BH94 were used for SW Cyg. Since the data were obtained by various methods the widely accepted weights (photoel.=10, photographic=3, visual=1) were attributed to the respective timings. In some cases when a larger amount of visual minima was available these timings were grouped into bins and averaged with several largely deviating minima rejected. The one-year means which can help to resolve better the course of the variations were calculated for both systems, too.

Discussion and general considerations of analysis of an O–C diagram can be found in Paper I. Visibility of the period change becomes considerably suppressed with the growing slope of the O–C curve on the plot. The period lengths were therefore calculated to give such a slope of the curve which enables to resolve the changes as clearly as possible. We use the Julian Date as the primary scale here because it allows a better comparison of the O–C curves calculated for different elements. In the following text we will use the Julian Date with subtracted 2 400 000.

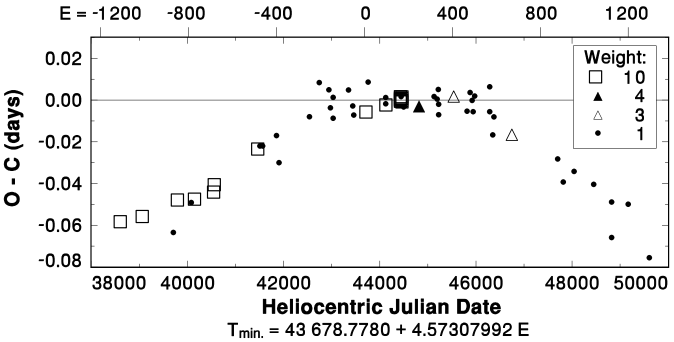

Fig. 1. Segment of the O–C curve of SW Cyg with the individual data. The O–C values were calculated according to Eq. 1. Errors of the photoel. timings (weight 10) are smaller than the symbols, errors of the visual data are discussed in the text.

2.1. SW Cygni

The O–C curves amounting about a century of observations and displaying the suggested 96-yr cycle were presented by BH94 and Todoran and Agerer (1994) and will not be repeated here. Instead, we will focus on the segment of the O–C curve which can be used for a comparison with the photometry of OE93. A part of the O–C curve roughly centered on this interval can be seen in Fig. 1. The O–C values displayed in this figure were calculated according to Eq. 1, modified from BH94. The most prominent event is a period decrease near the middle of the displayed interval and the elements in Eq. 1 keep both branches of the O–C curve in approximately the same slope.

$$T(min.I) = 43\,678.7780 + 4.57307992\ E \qquad (1)$$

Weights 1 and 10 correspond to the visual and photoelectric timings, respectively. Several groups of averaged visual data received w = 3 and 4. Errors of the photoel. timings, quoted by BH94, are of the order of a few 0.0001 days and are therefore smaller than the symbols used. Unfortunately, the accuracies of the visual timings are not available. One possible way how to assess them is a visual inspection of the O–C diagram. It can be seen that most visual data are in a good agreement with the photoelectric ones. Accuracy of the visual timings was further evaluated by a linear fit of the visual data in the segment of the O–C curve. The least squares method yielded 1σ error of the visual data 0.005 days (about 7 min).

Fig. 1 brings an evidence for an event of a large period decrease which occurred near JD = 46 000. The course of the O–C values after this event can be approximated by a straight line. Also the interval of the most positive O–C values (within JD≈43 000–46 000, i.e. about 8 years) appears flat and there is a suspicion that the period length may have been apparently constant in this interval.

Examinations of the O–C curve before this event revealed that its course cannot be fitted by straight line or monotonous change here. An episode of a period increase, defined by the photoelectric timings, occurred near JD = 40 800. The photoel. data within JD = 38 500– 40 500 (5.5 years) are consistent with a constant period while those within JD = 41 500– 44 500 have more positive O–Cs (see also Hall et al. 1979). Another episode of shortening P near JD = 43 000 is suggested.

The course of variations of brightness of the totality in SW Cyg reconstructed from the available data is displayed in Fig. 2a. According to the previous analyses the loser is responsible for these changes. The data in the *uvby* passbands, taken from OE93, represent a larger part. Their 1σ errors are shown, too, but they are usually smaller than the symbols. Although the photometric data contain gaps the courses in the *vby* bands are in a good agreement. A well defined drop of brightness can be resolved around JD = 46 300. Despite of the gaps namely the densely covered rising branch speaks in favour of a short-living episode (few years). Several additional points of the curve were derived from the UBV data of Hall and Garrison (1972) and Hall et al. (1979) by fitting a straight line to the flat undisturbed part of the totality. Error bars then represent the standard deviation of this fit. These UBV data can be seen in the inset of Fig. 2a. Since brightness in V is expected to be well compatible with *y* and because the same comparison star was used in all three papers it is, in principle, possible to join V and *y* data directly (main area of Fig. 2a). Brightness in V is constant within the 1σ errors through the interval of JD = 39 791–41 469 and is near the middle level of the *y* data of OE93. There might arise some doubts whether the large colour difference of the K-type loser and A-type comparison star cannot affect the zero point of the scale in the relatively wide V-band. In any case, the main result is that brightness in the yellow light isn't erratically variable on short time scales (days, weeks).

Reduction of the BU data into the Stromgren system couldn't be done but they still can serve a judgement of the time scales of the brightness variability. Brightness in the B-filter (as well as in V) can be considered constant within 1σ throughout the covered interval. On the other hand, the U-band data display a scatter larger than the errors but the reliable time scale of these U-band changes cannot be determined from the coverage. It is quite possible that the light in UV is contaminated by the circumstellar matter (CM), partially extending beyond the projected disk of the occulting loser even in totality, as supposed by Hall and Garrison (1972). It may also offer an explanation of the deviation in the courses in the *vby* and *u* passbands near JD = 45 900.

These brightness changes in Fig. 2a can be compared with the O–C curve, plotted in Fig. 2b. The same time scale was used for both figures. The one-year means of the O–C values are plotted together with their standard deviations (typical value about 0.005 days). The deviation of the means within JD = 38 000–42 000, formed mostly from the photoel. data, is smaller than the symbols used. The episode of a period decrease occurred around JD = 46 000, as is marked by the vertical line. This episode acceptably coincides with the minimum of brightness described above. It is possible that the drop in brightness lags slightly behind the episode of change in the O–C curve near JD = 46 000 but this lag is still within the 1σ error bars of the one-year means of O–C.

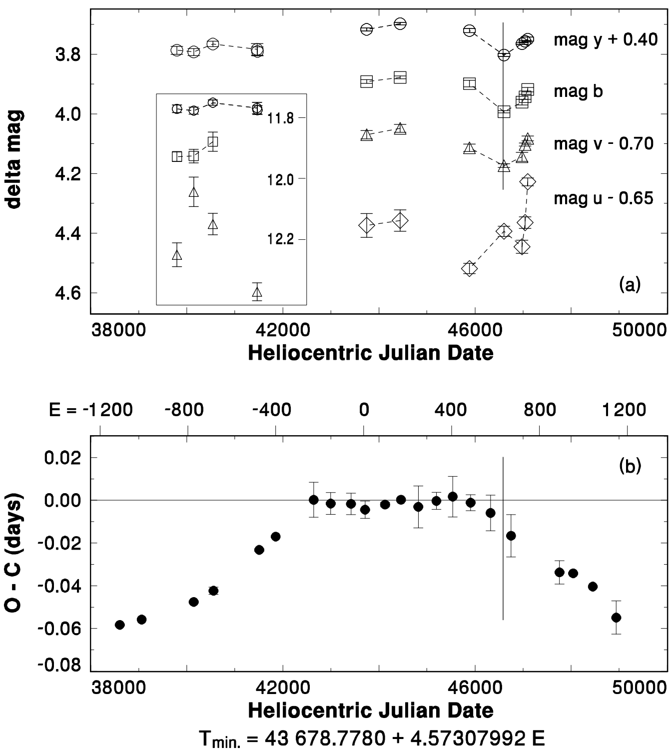

Fig. 2a and b. Comparison of the $O-C$ changes (**b**) with the photometry of variations of the level of the center of the total primary eclipse (**a**) in SW Cyg. The one-year means of the $O-C$ values, calculated according to Eq. 1, are plotted together with their standard deviations. The Stromgren photometry was published by OE93. The inset of **a** brings UBV data (V: *circles*, B–1 mag: *boxes*, U–1.6 mag: *diamonds*) derived from the tables of Hall and Garrison (1972) and Hall et al. (1979). The V-band data, reduced into the magnitude difference of OE93, are shown, too. The same time scale was used for **a** and **b**. The minimum of brightness occurred in the vicinity of the period decrease as is marked by the long vertical line in both figures. See the text for details.

Most UBV data fall into the epoch in which P can be considered constant. Only the last observation in JD = 41 469 was done after a period increase near JD = 40 800, mentioned above. The brightness in the V-band, which is expected to be least affected by CM and therefore representing light of the loser, remained constant within the errors for the whole covered interval.

Now let us bring the variations of P and brightness analysed above into a general context of the whole O–C curve, having the shape of the sine curve with the 96-yr cycle. This comparison is important namely for the test of the Applegate mechanism. The position of the changes from Fig. 1 in such a cycle can be easily recognized if the same data as in Fig. 1 are plotted with the O–C values calculated according to the ephemeris given by Todoran and Agerer (1994, here Eq. 2). As can be seen in the paper of Todoran and Agerer using these elements keeps both maxima of O–C of the cycle in the same height and therefore shows the course of the cycle with the best clarity. The result of this procedure can be seen in Fig. 3. The data segment from Fig. 1 clearly falls into the rising branch of the supposed 96-yr

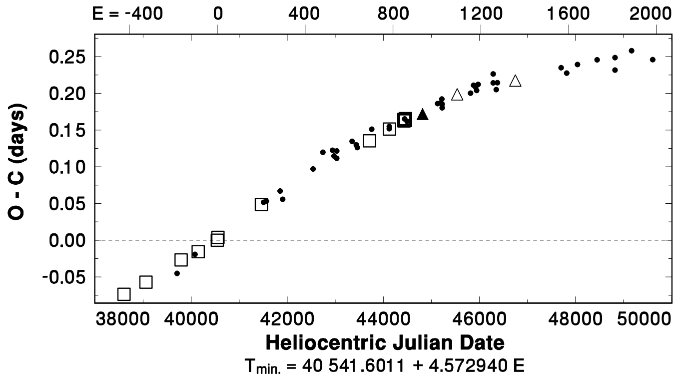

Fig. 3. The same data for SW Cyg as in Fig. 1 but with the O–C values calculated according to Eq. 2. Comparison with Fig. 1 shows that the discussed events occurred on the rising branch of the O–C curve of the supposed 96-yr cycle. See the text for details.

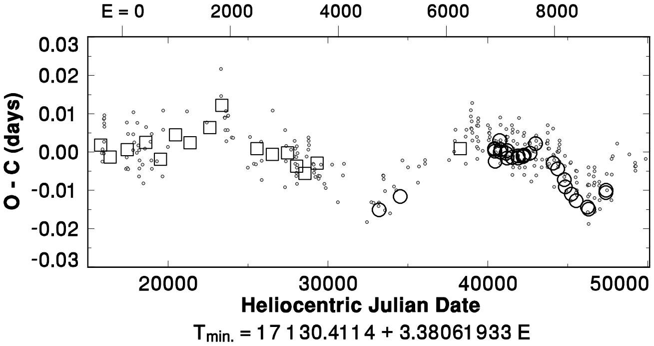

Fig. 4. The O–C curve of U Sge based on the individual timings obtained by photoelectric *(large empty circles)* photographic *(empty boxes)* and visual *(dots)* methods. The O–C values were calculated according to the ephemeris given by Kreiner and Ziolkowski (1978). See the text for details.

cycle. Maximum of this cycle would occur not earlier than in JD = 50 000 (see Todoran and Agerer 1994).

$$T(min.I) = 40\,541.6011 + 4.572940\ E \qquad (2)$$

2.2. *U Sagittae*

The complete O–C curve constructed from the available timings (almost 350) and representing about 95 years of observing is displayed in Fig. 4. The ephemeris given by Kreiner and Ziolkowski (1978, here Eq. 3) was used because it still plausibly satisfies the mean course of the O–C values. The period is clearly variable but the full amplitude is small and doesn't exceed 0.025 days. Although the photoelectric timings are available after JD = 33 000 the observations obtained by other methods including visual are plotted for the whole interval, too, because they enable to achieve a denser coverage and allow for establishing a connection of the newer and older data. Accuracy of the visual data was evaluated in the same way as for SW Cyg. Since it can be suspected from Fig. 4 that the scatter of the visual data obtained before JD $\approx$30 000 is usually larger than that of the newer timings the linear fits were applied to two segments of the O–C curve: JD = 24 500– 32 000 and JD = 41 000– 44 000. The least squares method yielded 1σ error of the visual data to be 0.0042 days (6 min) and 0.0035 days (5 min), respectively. The inspection of Fig. 4 reveals that the O–C values from the visual data after JD$\approx$43 000 tend to be slightly more positive than the photoelectric ones. Nevertheless, their courses are in agreement with each other. We therefore rose weight of the photoel. timings to 15 for calculation of the means. However, we note that we found the general course of the O–C values in Fig. 5b to be real and insensitive to the weighting.

$$T(min.I) = 17\,130.4114 + 3.38061933\ E \qquad (3)$$

Variations of the period have an alternate character. A possible roughly cyclic character of the O–C changes can be suspected from the inspection of Fig. 4, approximately two epochs being covered by the observations. Two well defined minima of O–C which could be attributed to this ”cycle” are apparent near JD = 33 000 and 46 300. Their separation is 13 300 days, that is about 36 years. If this interval is taken as a rough value of the cycle-length and extended to the past then one can expect another minimum near JD = 19 700. Indeed, such a minimum can be resolved around JD = 18 300. Maxima aren't so clearly pronounced but two such extrema can be resolved in the available data near JD = 23 700 and 39 100. They are separated by an interval of 15 400 days (about 42 years). The average value of the cycle-length determined from the minima and maxima is thus roughly 39 years. Another attempt to look for a periodicity in the one-year means of the O–C values using the PDM program written by Dr. J. Horn at the Ondřejov Observatory and based on the method of Stellingwerf (1978) was carried out, too. This method revealed a broad shallow minimum of the period significance Θ (the lower Θ, the better defined period). An interactive examination of the resulted foldings then showed an acceptable cycle-length 42 years long. However, its quite high value $\Theta = 0.652$ implies only a marginal fit. The O–C changes are therefore far from being periodic and the cycle is only suggested. Any other periods within 1 to 50 years had $\Theta > 0.9$ which doesn't mean any significance.

Since the curve of this supposed cycle doesn't repeat accurately we can conclude that a classic explanation in terms of the light-time effect cannot be applied here. There is also a suggestion that the course of the O–C variations during the ”cycle” described above is complicated as can be inferred from a closer examination of a part of the O–C curve plotted on the expanded time scale in Fig. 5b. The period can be considered constant within the 1σ errors in the interval of JD = 40 000 to 44 100 (about 11 years). Rapid decrease of the period then occurred near JD = 44 100. This course is also supported by the photoelectric timings (see Fig. 4). The photometric data in the *uvby* passbands published by OE93 already cover this event and allow for a search for a correlation of the brightness variations and the period changes, useful namely for the test of the Applegate mechanism.

The course of variations of brightness of the totality in U Sge reconstructed from the available data in the *uvby* passbands, taken from OE93, is displayed in Fig. 5a. Arrangement of this figure is the same as in case of SW Cyg. The 1σ error bars are shown, too, but they are usually smaller than the symbols. The courses in the respective bands are in a good agreement and can be described as follows: an epoch of the lowest brightness is apparent around JD = 44 100 (marked by the vertical line). The light curve can be further interpreted as having a flat maximum within JD = 45 000– 47 100, visible namely in the *by* bands. There is a hint of a slight depression near JD = 46 100, but it is represented by just a single point. It cannot be completely excluded that this point belongs to another less pronounced minimum, not so deep as that near JD = 44 100. Decrease of brightness occurred after JD = 47 100 and the observations ended in the brightness as low as in the epoch observed near JD = 44 100.

Let us add that as was found by Olson (1987) luminosity changes of the loser in U Sge on two largely different time scales are present. The light curve in Fig. 5a is dominated by the long-term wave course (years). Occasional rapid changes (few orbital epochs) with smaller amplitude and having much bluer colour indexes than the former ones are superposed. The change apparent between the first two points belongs to these rapid variations (Olson 1987). Then it isn't unreasonable to assume that the epoch of the low brightness near JD = 44 100 represents a real minimum of the long-term variations.

Comparison of these photometric data with the relevant part of the O–C curve can be made using Figs. 5a and b. An episode of the clear period decrease occurred around JD = 44 100 (marked by the vertical line) and plausibly coincides (within the 1σ error bars of the one-year means of O–C) with the epoch of the low brightness described above. Minimum in the O–C curve near JD = 46 100 then occurred around the flat maximum of brightness. The O–C curve definitely began to grow after JD = 46 100 and this increase may have continued till the end of the data set. Brightness of the loser was already decreasing in the same time.

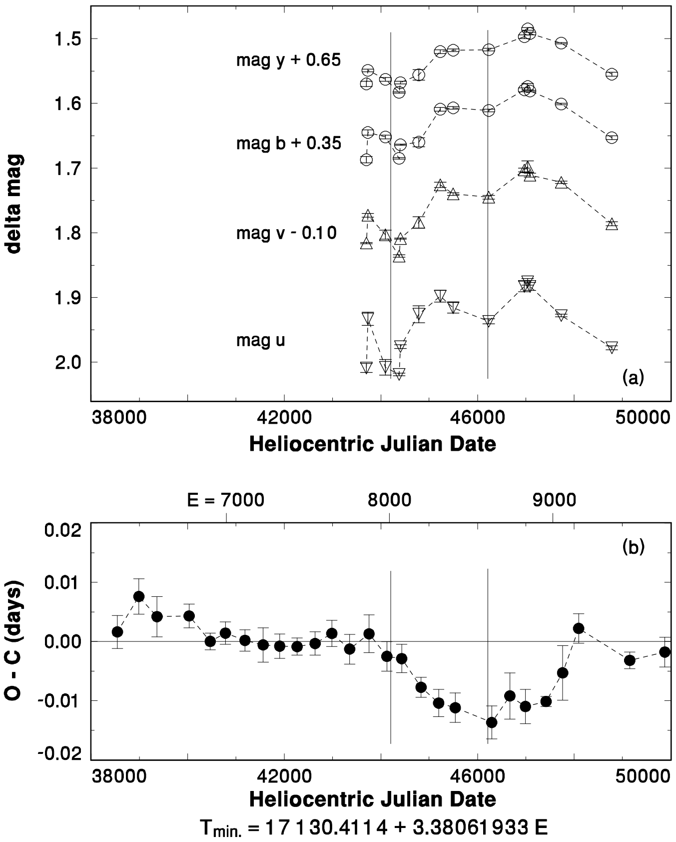

Fig. 5a and b. Comparison of the $O-C$ changes (**b**) with the Stromgren photometry of variations of the level of the center of the total primary eclipse (**a**) in U Sge. Arrangement of the figure is the same as in the case of SW Cyg. See the text for details.

3. Discussion

The analysis of the available data allows to conclude that a correlation of variations of the orbital period and changes of the level of totality exists in both Algol-type systems SW Cyg and U Sge. Since these photometric changes can be plausibly attributed to the temperature variations of the loser (Olson 1987; OE93) (maybe plus some contribution from CM in UV in the case of SW Cyg) we can establish connection of variations of the activity of the loser and of P. Moreover, we can state that *the episodes of decrease of the orbital period are accompanied by minimum of brightness of the loser*; the same sense of changes was previously revealed also in RW Tau (Paper I). This fact also brings an evidence that the photometric variations of the losers reported by Olson (1987) and OE93 are not only "surface effect" but they are related to the processes deep below the photosphere. Let us confront these results with the expected sense of the variations predicted by the mechanism proposed by Applegate (1992) in the first step. According to this theory the more or less continuous cyclic changes of the orbital period P and the accompanying variations of luminosity of the active star *must* have the same cycle-length, with only possible phase shift.

The presented O–C diagrams for SW Cyg, supported also by the photoel. timings, speak in favour of complicated alternate changes on the time scale of about a decade. Definitely, there are intervals in which P is almost invariable (about a decade long), separated by epochs of much more rapid change of P. Also the deep phase of the minimum of brightness, accompanying the decrease of P in the *vby* bands, expected to represent the light of the loser, is very narrow in comparison with the length of the supposed 96-yr cycle (only about 4%). Also the steep increase of brightness after the period decrease near JD = 46 000 speak in favour of a rather "isolated" episode. Another earlier episode of abrupt change of P near JD = 36 800 was already advocated by Frieboes-Conde and Herczeg (1973). These facts don't support the Applegate mechanism in case of SW Cyg. Instead, a series of episodes, forming in result the overall course of the period variations, is preferred. These respective episodes can be then considered as a "fine" structure. For the sake of completeness, let us add that if one would try to identify these observed changes with the Applegate mechanism, despite of the above arguments, then the largely divergent positions of the observed minimum of brightness and the extrema of the 96-yr cycle in O–C would imply a highly efficient storage of energy in COL.

We presented the longest available O–C curve of U Sge, covering about 95 years of observing. The alternate variations of P are apparent and a weakly-defined cycle-length of about 39 years is suggested. We argue that the relation of the O–C and brightness variations can hardly be explained by the Applegate theory if the cycle about 39 years long readily apparent in the O–C changes is assumed. In this case the second covered epoch has its maximum of O–C near JD = 39 000 surrounded by minima at JD = 33 000 and 46 300. On the other hand, the episode of a clear period decrease near JD = 44 100 and accompanied by a minimum of brightness (Fig. 5) occurred on the decreasing branch of this 39-yr cycle of O–C. It isn't clear why there should be a minimum of O–C plausibly coinciding with maximum brightness and, on the other hand, largely displaced positions of max. O–C and min. brightness, all taking place within a single about 39-yr cycle of O–C. Also the course of the correlated changes of period and brightness (Fig. 5) suggest a significantly shorter time scale than 39 years. Instead, there is a plausible relation of the respective episodes of enhanced period changes and extrema of brightness of the loser, occurring on the time scale of several years.

Of course, these results don't generally disprove the Applegate mechanism which can operate for example in the RS CVn system CG Cyg (Hall 1991) but having the available observational evidences of the correlation of changes of P and brightness of the loser in the Algol-type systems SW Cyg and U Sge (and also RW Tau–see Paper I) at hand we should turn to outlining a more general formulation of the mechanism of the period changes in Algols, at least in a qualitative way. Let us note only in advance that as the earlier spectroscopic and photometric analyses suggest the current mass transfer rate in these three Algols is too low to give rise to the observed rapid period changes directly via any of Huang's (1963) modes of mass transfer and/or loss (see also discussion in Paper I). Also possible magnetized winds from the cool loser removing angular momentum cannot play any role in these rapid alternate changes. Structure variations of a component of the binary must be therefore responsible for these changes. The decrease of P in SW Cyg, U Sge and RW Tau is correlated with the variation of brightness of the loser and therefore the mechanism appears to be confined to this star. Owing to the above reasons it is justified to treat the total angular momentum of the binary J_{tot} as conserved in the discussion of the observed rapid changes of P. This shortening P is then caused by a decrease of the orbital angular momentum J_{orb} and hence by an increase of the rotational momentum of the loser J_l. As can be inferred from the short time scale of the respective episodes (at most years) the source cannot lie very deep below the photosphere of the loser, following the arguments of Marsh and Pringle (1990). A promising source of the variation of the orbital period is a change of the constant of the apsidal motion k_{22} of a star (Matese and Whitmire 1983). k_{22} is very sensitive to the density profile $\rho(r)$. In this context we must stress that as the detailed calculations of the contributions of the respective parts of a star to k_{22}, presented by Petrova (1995), showed k_{22} is governed namely by the layers which contain 0.9 of the total mass of the star. Since the temperature gradient dT/dz and hence the slope of $\rho(r)$ are smaller in COL (in comparison with the radiative outer layers in early-type stars) it implies that 0.9 mass is contained within a significantly larger fractional radius in the late-type stars. This is valid for all stars with COL no matter what is their evolutionary status. Even the outer layers can therefore affect k_{22} in stars with COL. We can then infer from the calculations of Petrova (1995) that any disturbance occurring in COL and leading to changes of $\rho(r)$ can alter k_{22}. Presence of COL also plays an important role in the allowed time scales of the structure changes. Radiative outer layers can respond only on the Kelvin-Helmholtz time scale (thermal scale t_T) which is of the order of 10^5 years. On the other hand, convective energy transport in COL ensures that this layer can respond quickly on the diffusion time scale t_D. The observed variations of P in Algols are much closer to this scale than to t_T.

COL has a stochastic nature and instabilities can easily appear and propagate here. One of possible sources of instabilities in COL could be looked for in the mass loss (often highly intermittent) from the outer layer of the loser which can be of the order of 10^{-8} M$_\odot$ yr^{-1}. Moreover, this outflow is anisotropic in the sense that the regions of star near the L$_1$ point are most affected. The problem of response of the different parts of COL to this outflow (on the time scales much shorter than the evolutionary one) is very complicated and far from being completely understood. As was modelled by Gilliland (1985) the mass loss through the vicinity of the L$_1$ point causes a decrease of pressure in the neighbouring regions. Sideways mass motions in COL towards the cone near L$_1$ are then invoked. Gilliland (1985) suggested that the remaining part of the loser will behave like an "infinite" reservoir of mass. However, it can be suggested that the regions more distant from the L$_1$ point will react with an increasing delay and a large part of COL will be affected after some time. Since Gilliland's simulations were followed just for a limited time interval (several days) it remains unclear how long this reservoir can supply mass without reaction of a large part of COL. Anyway, these sideways flows inside the loser may offer a possible source of instability in COL.

At least one part of the correlation of changes of P and luminosity of the loser L_{los}, i.e. simultaneous decrease of P and L_{los}, appears to be well established and is common for SW Cyg, U Sge and RW Tau. This sense of the variation yields another constraint. As Olson (1981, 1987) and OE93 showed this changes of brightness in Algols can be explained by a decrease of T_{eff} of the loser (by about 120 K) without observable variations of its radius. Let us assume that a disturbance led to a transient decrease of T_{eff} of the cool loser and let us outline the response of its COL. The course of the temperature T with the optical depth τ depends on T_{eff} and is given by the well-known relation $T^4 = \frac{3}{4}\,\tau\, T^4_{eff} + T^4_{\tau=0}$. The observed decrease of T_{eff} then causes less steep dT/dz. Upper boundary of COL is shifted slightly deeper but the bottom boundary moves inwards by an even larger amount (e.g. Böhm-Vitense 1992).

The result is a vertical extension of the region of the convective instability. This process can be a plausible way how to decrease the fall of $\rho(r)$ with the radius in the outer layer and achieve thus the desired increase of k_{22}. It is probable that this decrease will be sooner or later compensated (for example by an increase of the efficiency of the convective energy transport) allowing for the subsequent period increase. The observations imply that the variations are completed on the time scale much shorter than the thermal scale t_T, it means that the nuclear energy source doesn't catch to react. The source of these variations on the observed time scales is thus confined to COL.

In conclusion, the main aim of this discussion was to show that even the pure presence of a late-type loser brings a potential source of instability of the orbital period of the binary on a relatively short time scales of years.

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