(2) total absorption in the $H_\gamma$ line much larger than would correspond to the $H_\alpha$ line; and

(3) too great absorption in the metallic lines when compared with the small optical thickness of the cloud in the lines of the Balmer series.

Therefore, the cause of the asymmetry observed must be searched inside the flare, in some intrinsic movements in the flaring region. We cannot agree with Severny [6], who explains wings of the Balmer lines in flare spectra as a conglomerate of moustaches and the asymmetry as due to non-uniform macroscopic motions inside these moustaches. The great majority of moustaches observed individually shows a striking asymmetry towards the blue side of the spectrum, i. e. just in the opposite sense than the flare asymmetry is observed. Therefore, the asymmetry seems to be quite a special characteristics of flares, and as its explanation is extremely important when discussing the line-profiles, we will discuss it more in detail in another paper which is now being prepared.

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# PROBLEM OF PERIOD VARIABILITY OF THE DETACHED ECLIPSING BINARY SYSTEMS

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A survey of periods of detached eclipsing binary systems is presented. For 12 out of 28 stars only the material available is sufficient for a discussion of possible period variations. Two systems display marked apsidal motion, for two other systems apsidal motion can be expected. Period variation other than apsidal motion has been found in two (possibly three) systems; it is small, slow, and probably of a cyclic character.

In general, detached systems do not display large or abrupt period changes (apsidal motion disregarded), but small and slow period variations may be present. It is not certain whether such variations are their typical feature rather than an actual constancy of periods.

Incidentally, our discussion supports Colacevich's conclusion that the period of V 451 Ophiuchi, assumed previously to be $1^{\cdot d}098$, should be doubled.

*Проблема изменчивости периодов разделенных затменных систем.* Приводятся общие рассуждения о изменчивости периодов для затменных переменных типа ,,разделенные системы‘‘. Лишь для 12 из 28 звезд имелись материалы наблюдений, достаточные для отыскивания периодов изменчивости. Исключив апсидальное движение было установлено, что 5 систем имеют по всей вероятности постоянный период, 2 или 3 обнаруживают небольшие и плавные изменения периодов. У трех дальнейших периодов периоды, повидимому, также постоянны, однако имеющиеся данные наблюдений не охватывают достаточно продолжительный промежуток времени. У двух систем движение линии апсид вполне известно, а у дальнейших двух наличие этого движения можно предполагать.

Не были обнаружены ни крупные изменения, ни скачкообразные изменения периода. Итак типичным признаком этих систем является либо полная неизменчивость периода, либо скорее медленные и незначительные вариации, носящие, по-видимому, циклический характер.

Второстепенным результатом наших рассуждений являются подтверждения заключений Colacevicha, касающихся того, что длительность периода звезды V 451 Ophiuchi не 1.098 дней, а в два раза больше.

Variations of the period of eclipsing binaries present a puzzling problem. It is probably generally believed that the erratic changes of period are in some way associated with the unstability of the subgiants in the semi-detached systems (see, e. g., [99]). We think, however, that before we can state with certainty that the erratic period changes are typical for semi-detached systems, we must prove that they are absent in other types of eclipsing binaries.

In this article we propose to investigate the constancy or variability of periods in systems with detached components. We have found that a great obstacle is a lack of observations; systems of this kind are far less observed than the semi-detached systems. For one thing, the minima of the detached systems are as a rule less deep and therefore less suitable for visual or photographic observations. But there seems to be another reason: after a few first determinations of the period, the observers found that it was probably constant and the system therefore less interesting, and gave up further observation. Thus the *belief* that the periods are constant makes it difficult to *prove* the constancy. At the beginning, our list contained all the 28 stars classified by Kopal and Mrs. Shapley [100] as genuine detached systems. Some of them, however, had to be rejected since the number of observations was extremely low.

## 1. *WW Aurigae*

This system was discovered in 1916 by Solowiew and two years later independently by Schwab. Both minima are of about the same depth and can be well observed photoelectrically. The early visual and photographic observations, however, display a great scatter (Fig. 1), which must have puzzled the observers. A comparison with the recent photoelectric observations shows quite convincingly that the scatter was entirely due to the inaccuracy of the observations. If we form a normal point from all the visual and photographic observations up to J. D. 2430000, we get $O - C = -0\overset{d}{\cdot}0004 \pm \pm 0{\cdot}0017$ (m. e.) with respect to Piotrowski and Serkowski's elements [14]:

(1) $M(E) = 2432945\overset{d}{\cdot}5389 + 2{\cdot}52501906\,E\,.$

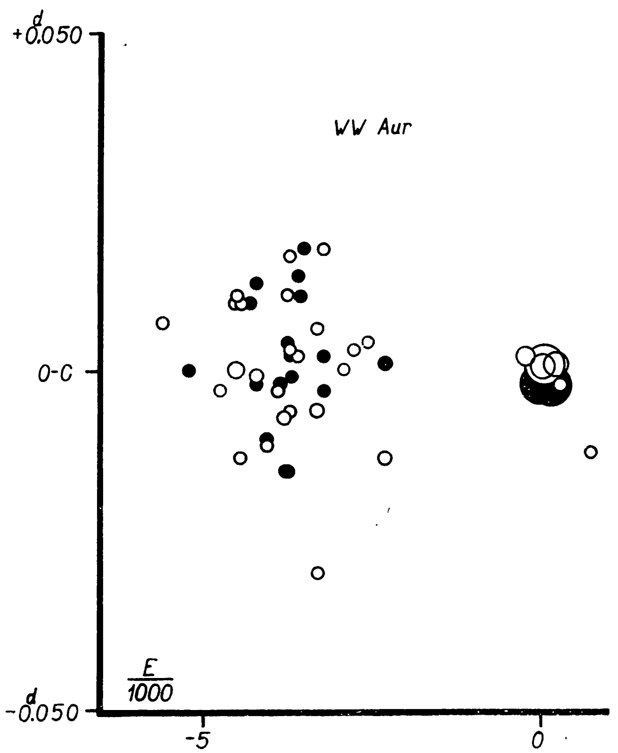


Fig. 1. WW Aurigae. Open circles represent primary minima, full circles secondary minima. The size of the circles is proportional to the weight.

Combining this normal point with the new photoelectric observations, we get the following elements for primary minima:

(2) $M(E) = 2432945\overset{d}{\cdot}53930 + 2\overset{d}{\cdot}52501922\,E$
$\qquad\qquad \pm 4 \qquad\qquad \pm 8$ (m. e.)

In computing these elements, the minima No. 17, 27 and 39 were omitted, their deviations being too large.

As the modern photoelectric minima are currently given with a precision to $0\overset{d}{\cdot}0001$, it is worth while to look whether the deviations of the universal time from the ephemeris time can play any role. The observed minima were corrected to the ephemeris time by means of the following little critical table:

| J. D. | correction of U. T. to E. T. |
|---|---|
| | $+\,0\overset{d}{\cdot}0001$ |
| 2417500 | |
| | $+\,0\overset{d}{\cdot}0002$ |
| 2420000 | |
| | $+\,0\overset{d}{\cdot}0003$ |
| 2424000 | |
| | $+\,0\overset{d}{\cdot}0004$ |
| 2434000 | |

It is evident that these differences are of no importance; they are smaller than the mean errors of the observed photoelectric minima as given in Tables 1 and 2. Moreover, these mean errors indicate rather an intrinsic accuracy of the given result, for sometimes a different interpretation of the same observations leads to differences greater than the mean errors. This can be seen from the comparison of the minima published by Huffer and Kopal [13] and their rediscussion by Piotrowski and Serkowski [14]:

| Minimum and date | Huffer and Kopal | Piotrowski and Serkowski m. e. |
|---|---|---|
| Prim. 2433225 | ·8159 | ·8157 ± ·0002 |
| Prim. 2433263 | ·6905 | ·6903 ± ·0002 |
| Sec. 2432888 | ·7263 | ·7250 ± ·0007 |
| Sec. 2432936 | ·6998 | ·6997 ± ·0008 |
| Sec. 2433249 | ·8035 | ·8032 ± ·0003 |
| Sec. 2433292 | ·7299 | ·7295 ± ·0003 |
| Sec. 2433297 | ·7776 | ·7788 ± ·0004 |

For the sake of uniformity, we accepted the values given by Piotrowski and Serkowski.

Thus the correction to ephemeris time is quite unimportant, but it is very easy to apply it and therefore we did so.

A similar treatment of 29 observed secondary minima (Table 2) led to the ephemeris

(2) $M_s(E) = 2432945\overset{d}{\cdot}53910 + 2{\cdot}52501880(E + \tfrac{1}{2})$
$\qquad\qquad \pm 5 \qquad\qquad \pm 10$

Thus the secondary minimum is displaced with respect to the point exactly halfway between the primary minima by the amount

$$-\,0\overset{d}{\cdot}0002 - 0\overset{d}{\cdot}0000004\,E\,.$$

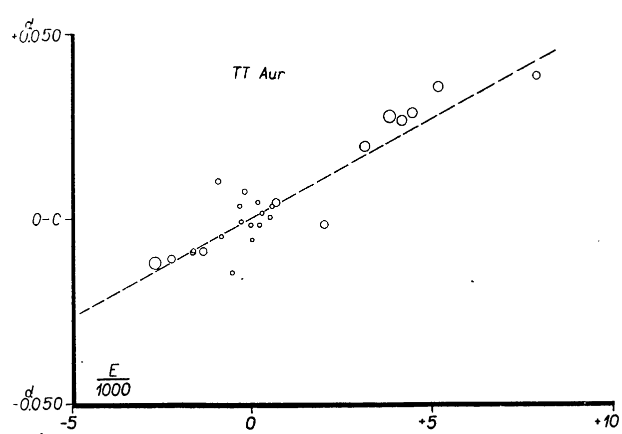


Fig. 2.

This is a value hardly perceptible even by photoelectric photometry and we cannot wonder that the observers did not find any eccentricity; therefore hardly any weight can be attributed to this result. Naturally a very small eccentricity is possible and a shift of the differences $M_{prim}(E) - M_{sec}(E)$ may be due to the rotation of the line of apses. Both the components of WW Aur are very nearly identical, so that the ratio of the orbital period $P$

Table 1

Primary minima of WW Aurigae

| No. | $M(E)$ J. D. | $E$ | $(O-C)_1$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| | | | d | | | | |
| 1 | 2418749·888 | − 5622 | + 0·007 | 1 | vp | Hellerich | 1 |
| 2 | 20959·270 | − 4747 | − 3 | 1 | ve | Solowiew | 1 |
| 3 | 21623·353 | − 4484 | 0 | 8 | vp normal | Wylie | 2 |
| 4 | 21623·364 | − 4484 | + 11 | 2 | ve | Schwab | 3 |
| 5 | 21666·288 | − 4467 | + 10 | 1 | ve | Dziewulski | 4 |
| 6 | 21671·338 | − 4465 | + 10 | 1 | ve | Dziewulski | 4 |
| 7 | 21681·415 | − 4461 | − 13 | 1 | ve | Hartwig | 5 |
| 8 | 22307·632 | − 4213 | − 1 | 4 | vp 17 | Dugan | 6 |
| 9 | 22759·600 | − 4034 | − 11 | 1 | vp 9 | Dugan | 6 |
| 10 | 23133·311 | − 3886 | − 3 | 1 | ve | Seliwanow | 7 |
| 11 | 23375·709 | − 3790 | − 7 | 4 | vp 21 | Dugan | 6 |
| 12 | 23446·428 | − 3762 | + 11 | 2 | ve 11 | Tsessewich | 8 |
| 13 | 23484·295 | − 3747 | + 3 | 1 | ve 8 | Tsessewich | 8 |
| 14 | 23489·359 | − 3745 | + 17 | 1 | ve 9 | Tsessewich | 8 |
| 15 | 23504·486 | − 3739 | − 6 | 2 | ve 13 | Tsessewich | 8 |
| 16 | 23855·471 | − 3600 | + 2 | 3 | ve 27 normal | Gadomski | 9 |
| 17 | 24552·345 | − 3324 | − 30 | 1 | ve 9 | Tsessewich | 8 |
| 18 | 24557·431 | − 3322 | + 6 | 1 | ve 8 | Tsessewich | 8 |
| 19 | 24620·545 | − 3297 | − 6 | 4 | vp 22 | Dugan | 6 |
| 20 | 24840·245 | − 3210 | + 18 | 2 | ve 156 norm. | Kukarkin | 10 |
| 21 | 25701·259 | − 2869 | 0 | 2 | ve 16 normal | Zverev | 11 |
| 22 | 26029·514 | − 2739 | + 3 | 1 | ve 6 normal | Zverev | 11 |
| 23 | 26461·293 | − 2568 | + 4 | 2 | ve 13 normal | Zverev | 11 |
| 24 | 27062·231 | − 2330 | − 13 | 4 | vp 58 | Gadomski | 12 |
| 25 | 32480·9370 | − 184 | + 25 | 30 | pe ± 0·00040 | Huffer | 13 |
| 26 | 32528·9381 | − 165 | + 0·0273 | 5 | pe ± 0·00110 | Huffer | 14 |
| 27 | 32791·316 | − 61 | − 197 | 1 | ve 7 (3, 4) ± 0·010 | Wróblewski | 15 |
| 28 | 32892·5129 | − 21 | − 08 | 25 | pe ± 0·00047 | Piotrowski Serkowski | 14 |
| 29 | 32945·5389 | 0 | 00 | 25 | pe ± 0·00049 | Piotrowski Serkowski | 14 |
| 30 | 32945·5403 | 0 | + 13 | 20 | pe ± 0·00060 | Huffer | 14 |
| 31 | 33031·3878 | + 34 | − 18 | 15 | pe ± 0·00080 | Piotrowski Serkowski | 14 |
| 32 | 33190·4670 | + 97 | + 11 | 20 | pe ± 0·00060 | Piotrowski Serkowski | 14 |
| 33 | 33215·7165 | + 107 | + 05 | 40 | pe ± 0·00034 | Huffer | 14 |
| 34 | 33225·8157 | + 111 | − 05 | 45 | pe ± 0·00025 | Huffer | 13, 14 |
| 35 | 33263·6903 | + 126 | − 10 | 50 | pe ± 0·00018 | Huffer | 13, 14 |
| 36 | 33594·4695 | + 259 | + 05 | 25 | pe ± 0·00047 | Piotrowski Serkowski | 14 |
| 37 | 33599·5173 | + 257 | − 18 | 5 | pe ± 0·00130 | Piotrowski Serkowski | 14 |
| 38 | 33690·4196 | + 295 | − 03 | 5 | pe ± 0·00120 | Piotrowski Serkowski | 14 |
| 39 | 34791·316 | + 731 | − 12 | 1 | ve 7, ± 0·010 | Wróblewski | 16 |

Table 2

Secondary minima of WW Aurigae

| No. | $M(E)$ J. D. | $E$ | $(O-C)_2$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| | | | d | | | | |
| 1 | 2419809·122 | − 5203 | − 0·007 | 2 | pg normal | Kohlschütter | 7 |
| 2 | 22013·480 | − 4330 | + 10 | 1 | ve | Seliwanow | 7 |
| 3 | 22278·61 | − 4225 | + 13 | 1 | pg 14 poor | Dugan | 6 |
| 4 | 22349·295 | − 4197 | − 2 | 1 | ve | Seliwanow | 7 |
| 5 | 22725·515 | − 4048 | − 10 | 1 | ve | Seliwanow | 7 |
| 6 | 23182·551 | − 3867 | − 2 | 3 | pg 18 fair | Dugan | 6 |
| 7 | 23321·415 | − 3812 | − 15 | 1 | ve 12 | Tsessewich | 8 |
| 8 | 23374·440 | − 3791 | − 15 | 2 | ve 20 | Tsessewich | 8 |
| 9 | 23460·310 | − 3757 | + 4 | 1 | ve 8 | Tsessewich | 8 |
| 10 | 23518·380 | − 3734 | − 1 | 2 | ve | Hellerich | 17 |
| 11 | 23523·433 | − 3732 | + 2 | 2 | ve 12 | Tsessewich | 8 |
| 12 | 23856·748 | − 3600 | + 14 | 3 | ve 22 normal | Gadomski | 9 |
| 13 | 23884·52 | − 3589 | + 11 | 1 | pg 24 poor | Dugan | 6 |

*Table 2 (continued)*

| No. | $M(E)$ J. D. | $E$ | $(O-C)_2$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| 14 | 24038·553 | − 3528 | + 18 | 1 | ve 6 | Tsessewich | 8 |
| 15 | 24788·468 | − 3231 | + 2 | 2 | ve 11 | Tsessewich | 8 |
| 16 | 24838·963 | − 3211 | − 3 | 3 | ve 156 normal | Kukarkin | 10 |
| 17 | 27149·359 | − 2296 | + 1 | 4 | vp 53 | Gadomski | 18 |
| 18 | 32868·525 | − 31 | − 08 | 5 | pe 28 ± 0·0030 | Piotrowski Strzalkowski | 19 |
| 19 | 32888·7250 | − 23 | − 08 | 20 | pe ± 0·0007 | Huffer | 13, 14 |
| 20 | 32936·6997 | − 4 | − 15 | 15 | pe ± 0·0008 | Huffer | 13, 14 |
| 21 | 32946·8002 | 0 | − 10 | 5 | pe ± 0·0014 | Huffer | 14 |
| 22 | 33002·3510 | + 22 | − 08 | 20 | pe ± 0·0006 | Piotrowski Serkowski | 14 |
| 23 | 33209·4042 | + 104 | + 10 | 10 | pe ± 0·0009 | Piotrowski Serkowski | 14 |
| 24 | 33249·8032 | + 120 | − 05 | 40 | pe ± 0·0003 | Huffer | 13, 14 |
| 25 | 33292·7295 | + 137 | + 05 | 40 | pe ± 0·0003 | Huffer | 13, 14 |
| 26 | 33297·7788 | + 139 | − 02 | 30 | pe ± 0·0004 | Huffer | 13, 14 |
| 27 | 33358·3816 | + 163 | + 23 | 20 | pe ± 0·0006 | Piotrowski Serkowski | 14 |
| 28 | 33570·4817 | + 247 | + 08 | 20 | pe ± 0·0006 | Piotrowski Serkowski | 14 |
| 29 | 33646·2338 | + 277 | + 23 | 10 | pe ± 0·0009 | Piotrowski Serkowski | 14 |

Table 3
Observed (primary) minima of TT Aurigae

| No. | $M(E)$ J. D. | $E$ | $(O-C)_3$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| 1 | 2419065·904 | − 2656 | d − 0·012 | 5 | vp 12 | Joy, Sitterly | 23 |
| 2 | 19697·619 | − 2182 | − 11 | 3 | vp | Balanowsky | 24 |
| 3 | 20458·608 | − 1611 | − 9 | 2 | pg | Jordan | 25 |
| 4 | 20462·606 | − 1608 | − 9 | 1 | pg | Jordan | 25 |
| 5 | 20871·754 | − 1301 | − 9 | 3 | pg | Jordan | 25 |
| 6 | 21431·519 | − 881 | + 10 | 2 | ve 11 | Nijland | 22 |
| 7 | 21531·458 | − 806 | − 5 | 1 | ve 10 | Nijland | 22 |
| 8 | 21907·278 | − 524 | − 15 | 0·5 | ve 6 | Nijland | 22 |
| 9 | 22180·505 | − 319 | + 3 | 1 | ve 12 | Nijland | 22 |
| 10 | 22256·466 | − 262 | − 1 | 1 | ve 8 | Nijland | 22 |
| 11 | 22416·402 | − 142 | + 7 | 2 | ve 20 | Nijland | 22 |
| 12 | 22612·304 | + 5 | − 2 | 1 | ve 11 | Nijland | 22 |
| 13 | 22652·281 | + 35 | − 6 | 1 | ve 13 | Nijland | 22 |
| 14 | 22921·502 | + 237 | + 4 | 1 | ve 10 | Nijland | 22 |
| 15 | 22969·475 | + 273 | − 2 | 1 | ve 19 | Nijland | 22 |
| 16 | 23049·441 | + 333 | + 1 | 1 | ve 13 | Nijland | 22 |
| 17 | 23341·308 | + 552 | 0 | 1 | ve 14 | Nijland | 22 |
| 18 | 23413·278 | + 606 | + 3 | 1 | ve 16 | Nijland | 22 |
| 19 | 23575·872 | + 728 | + 4 | 3 | ve 86 | Tsessewich | 26 |
| 20 | 25324·405 | + 2040 | − 2 | 3 | ve 51 | Mergentaler | 27 |
| 21 | 26221·399 | + 2713 | + 66 | 3 | ve 40 | Terkán | 28 |
| 22 | 26827·743 | + 3168 | + 19 | 4 | pg 60 | Ivanowska | 21 |
| 23 | 27755·330 | + 3864 | + 27 | 5 | ve 100 | Lause | 29 |
| 24 | 28248·438 | + 4234 | + 26 | 4 | ve 90 | Lause | 29 |
| 25 | 28544·306 | + 4456 | + 28 | 4 | ve 79 | Lause | 30 |
| 26 | 29555·853 | + 5215 | + 35 | 4 | pg 993 | Woodward | 31 |
| 27 | 33183·542 | + 7937 | + 38 | 3 | ve 69 | Ahnert | 32 |

Table 4
Primary minima of TX Herculis

| No. | $M(E)$ J. D. | $E$ | $(O-C)_5$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| 1 | 2418215·579 | − 5879 | d 0·000 | 0·5 | pg 1 | Cannon | 35 |
| 2 | 18967·406 | − 5514 | − 4 | 8 | ve 237 normal | Zinner | 36 |

*Table 4 (continued)*

| No. | $M(E)$ J. D. | $E$ | $(O-C)_5$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| 3 | 19964·344 | − 5030 | − 14 | 5 | vp 91 | Lazzarino | 37 |
| 4 | 19999·368 | − 5013 | − 6 | 8 | vp 370 normal | Balanovskij | 38 |
| 5 | 21008·670 | − 4523 | − 11 | 15 | pg 326 normal | Baker | 39 |
| 6 | 22959·314 | − 3576 | − 7 | 7 | ve 76 normal | Hellerich | 40 |
| 7 | 23682·320 | − 3225 | + 4 | 3 | ve 95 | Okunev | 41 |
| 8 | 24619·529 | − 2770 | + 1 | 2 | ve 15 | Gadomski | 42 |
| 9 | 25474·346 | − 2355 | − 3 | 2 | ve normal | Szczyrbak | 43 |
| 10 | 25855·423 | − 2170 | + 9 | 2 | ve normal | Szczyrbak | 43 |
| 11 | 26821·473 | − 1701 | + 8 | 8 | vp 89 | Gadomski | 44 |
| 12 | 27367·328 | − 1436 | + 13 | 4 | ve 90 normal ± 0·003 | Himpel | 45 |
| 13 | 27398·225 | − 1421 | + 13 | 5 | vp 52 | Gadomski | 46 |
| 14 | 28022·342 | − 1118 | + 9 | 3 | ve normal ± 0·0035 | Lause | 47 |
| 15 | 28366·329 | − 951 | + 6 | 3 | ve normal ± 0·003 | Lause | 48 |
| 16 | 28782·414 | − 749 | + 10 | 10 | ve normal ± 0·001 | Lause | 48 |
| 17 | 30325·198 | 0 | − 4 | 2 | | Mergentaler | 49 |
| 18 | 33054·445 | + 1325 | − 5 | 15 | pe 55 ± 0·003 | Piotrowski | 50 |
| 19 | 33124·479 | + 1359 | − 5 | 12 | pe 48 (33, 15) | Piotrowski | 50 |
| 20 | 33394·310 | + 1490 | − 9 | 15 | pe | Botsula | 34 |
| 21 | 33779·496 | + 1677 | − 7 | 1 | ve | Domke, Pohl | 51 |
| 22 | 33849·531 | + 1711 | − 6 | 1 | ve | Domke, Pohl | 51 |
| 23 | 33880·440 | + 1726 | + 6 | 1 | ve | Domke, Pohl | 51 |
| 24 | 33992·497 | + 1727 | + 3 | 1 | ve | Domke, Pohl | 51 |
| 25 | 33882·498 | + 1727 | + 4 | 1 | ve | Domke, Pohl | 51 |
| 26 | 33911·330 | + 1741 | − 1 | 1 | ve | Domke, Pohl | 51 |
| 27 | 33911·320 | + 1741 | − 11 | 15 | pe | Botsula | 34 |
| 28 | 34088·467 | + 1827 | − 8 | 15 | pe | Botsula | 34 |
| 29 | 34665·212 | + 2107 | − 10 | 15 | pe | Botsula | 34 |

Table 5

Secondary minima of TX Herculis

| No. | $M(E)$ J. D. | $E$ | $(O-C)_5$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| | | | d | | | | |
| 1 | 2419639·926 | − 5188 | − 0·012 | 7 | vp 75 | Lazzarino | 37 |
| 2 | 19998·340 | − 5014 | − 5 | 8 | ve normal | Balanovskij | 38 |
| 3 | 20603·915 | − 4720 | − 14 | 3 | pg 16 | Baker | 39 |
| 4 | 22960·340 | − 3576 | − 11 | 4 | ve 38 normal | Hellerich | 40 |
| 5 | 24620·566 | − 2770 | + 8 | 2 | ve | Gadomski | 42 |
| 6 | 26820·442 | − 1702 | + 7 | 7 | vp 76 | Gadomski | 44 |
| 7 | 27368·369 | − 1436 | + 24 | 3 | ve 64 normal ± 0·005 | Himpel | 45 |
| 8 | 27399·254 | − 1421 | + 12 | 6 | vp 57 | Gadomski | 46 |
| 9 | 28023·376 | − 1118 | + 12 | 3 | ve normal ± 0·005 | Lause | 47 |
| 10 | 28373·535 | − 948 | + 3 | 4 | ve 3 normal | Lause | 48 |
| 11 | 28979·331 | − 751 | + 16 | 3 | ve 2 normal | Lause | 48 |
| 12 | 33883·531 | + 1728 | + 8 | 1 | ve | Domke, Pohl | 51 |
| 13 | 33883·521 | + 1728 | − 2 | 0,5 | ve asc. branch | Domke, Pohl | 51 |
| 14 | 33974·151 | + 1772 | − 4 | 15 | pe | Botsula | 34 |
| 15 | 33976·209 | + 1773 | − 6 | 15 | pe | Botsula | 34 |
| 16 | 34664·186 | + 2107 | − 6 | 15 | pe | Botsula | 34 |

to that of the rotation of the apsidal line can be taken to be

$$\frac{P}{U} = 34 k_2 r^5 .$$

Both components can be represented by a model lying between Kushwaha's models for a star of 2·5 solar masses corresponding to initial as well as advanced main sequence stars [20]. The corresponding apsidal motion constant is $k_2 = 0{\cdot}007$ and therefore $U = 40\,000\,P$. Thus we can expect a very long period of apsidal motion, of which the observed interval is only a small portion.

Disregarding this possible period change, we conclude that there are no indications against the constancy of period of WW Aurigae.

## 2. *TT Aurigae*

27 individual minima have been collected in Table 3 and plotted in Fig. 2 against Nijland's elements [22]

(3) $M(E) = 2422605\cdot^{d}642 + 1\cdot^{d}332728\,E\,.$

Obviously, as has already been shown by Iwanowska [21], this period is too short. The elements by Iwanowska,

(4) $M(E) = 2422605\cdot^{d}6420 + 1\cdot^{d}3327333\,E\,,$

are fairly well satisfied even by the more recent observations. They are marked by the broken line in Fig. 2. As the observations are neither too numerous nor sufficiently accurate, no attempt has been made to improve her elements.

There are no reliable indications of a variation of the period.

## 3. *RX Herculis*

No minima have been found beyond those listed and treated by Wood [33]. They are plotted in Fig. 3. The scatter of individual observations is rather large, but there are no traces of any variation of period. The linear elements by Wood are the best available.

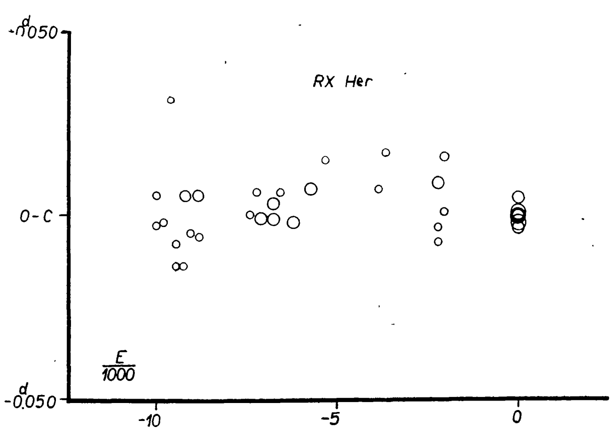


Fig. 3.

## 4. *TX Herculis*

This star was discovered by Miss Cannon on Harvard plates; its character as an eclipsing binary was confirmed by Zinner in 1908. The secondary minimum is deep enough to make its photoelectric study well possible.

Variation of the period of this system was discussed recently by Botsula [34]. A list of primary minima is given in Table 4, secondary minima are in Table 5. Fig. 4 gives their plot against the linear elements by Botsula:

(5)
$$M(E)_{prim} = 2430325\cdot^{d}202 + 2\cdot^{d}059810\,E$$
$$M(E)_{sec} = 2430326\cdot^{d}232 + 2\cdot^{d}059810\,E\,.$$

It is seen that the period is almost certainly variable. The observed variation can be approximated by a periodic curve similar to the radial-velocity curve of a moderately eccentric spectroscopic binary. The semi-amplitude is about $0\cdot^{d}012$ and the period can be estimated as 6500—7000 orbital periods, or 36—40 years. Botsula's conclusion is very similar; he takes the amplitude to be $0\cdot^{d}020$ and the period 31 years. Thus he finds that the hypothetical third body would have a mass of $0\cdot47\ \odot$; our data would lead to a slightly lower value. If this body obeys the mass-luminosity relation, its light could not make itself sensible in the system.

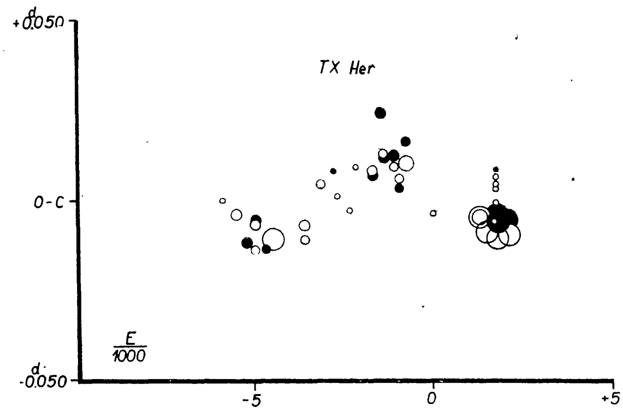


Fig. 4.

Thus we can say that the assumption of a third body does not contradict the observations, but hardly anything more. The time-interval covered by observations is too short to make us sure that the variation is regular and periodic: little more than one cycle is covered, and even within this cycle any regularity is somewhat conjectural. Moreover, the case of TX Her should not be considered separately. The presence of a third body cannot be a general explanation of period variations. If there were many such systems as TX Her, the probability of this explanation would be very low. Thus it will be logical to postpone further discussion till we have surveyed all the systems.

Only one conclusion is safe: the cause of the variation cannot be a rotation of the apside line, since the residuals for both minima are in accord.

## 5. *YY Geminorum*

The variability of Castor C was discovered by van Gent in 1925. Owing to its particular position, the observations are rather few, but their scatter is much smaller than usual, since there are no inaccurate visual estimates. As both components are practically identical, both minima are equally well observed. Very good elements were deduced by Binnendijk [54] from photographic observations:

(6)
$$M(E)_{prim} = 2426228\cdot^{d}45368 + 0\cdot^{d}81428230\,(E - 2005)$$
$$\pm 28 \qquad\qquad \pm 14$$

(7)
$$M(E)_{sec} = 2426228\cdot^{d}04778 + 0\cdot^{d}81428216\,(E - 2005)$$
$$\pm 42 \qquad\qquad \pm 19$$

These elements require a small correction when we complete the list of minima by two accurate photoelectrif minima secured by Kron [56]. Applying the method oc

Table 6

Primary minima of YY Geminorum

| No. | $M(E)$ J. D. | $E$ | $(O - C)_6$ | $(O - C)_8$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|---|
| | | | d | d | | | | |
| 1 | 2424500·5471 | − 117 | + 0·0005 | + 0·0010 | 4 | pg | van Gent | 52 |
| 2 | 24584·4125 | − 14 | − 52 | − 47 | 2 | pg | van Gent | 52 |
| 3 | 24619·4308 | + 29 | − 11 | − 6 | 4 | pg | van Gent | 52 |
| 4 | 24916·6466 | + 394 | + 17 | + 21 | 4 | pg | van Gent | 53, 54 |
| 5 | 24921·5306 | + 400 | 0 | + 4 | 4 | pg | van Gent | 53, 54 |
| 6 | 24922·3441 | + 401 | − 8 | − 4 | 4 | pg | van Gent | 53, 54 |
| 7 | 24961·4304 | + 449 | 0 | + 3 | 4 | pg | van Gent | 53, 54 |
| 8 | 25242·3568 | + 794 | − 10 | − 7 | 4 | pg | van Gent | 53, 54 |
| 9 | 25698·3561 | + 1354 | + 2 | + 3 | 4 | pg | van Gent | 53, 54 |
| 10 | 27158·3641 | + 3147 | 0 | − 3 | 4 | pg | Binnendijk | 54 |
| 11 | 27461·2782 | + 3519 | + 11 | + 7 | 4 | vp | Gadomski | 55 |
| 12 | 28596·3861 | + 4913 | − 5 | − 12 | 4 | pg | Binnendijk | 54 |
| 13 | 29639·4827 | + 6194 | + 5 | − 6 | 4 | pg | Binnendijk | 54 |
| 14 | 32605·9146 | + 9837 | + 20 | + 1 | 20 | pe | Kron | 56 |
| 15 | 32965·8275 | + 10279 | + 21 | + 1 | 20 | pe | Kron | 56 |

Table 7

Secondary minima of YY Geminorum

| No. | $M(E)$ J. D. | $E$ | $(O - C)_7$ | $(O - C)_9$ | $(O - C)_{10}$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|---|---|
| | | | d | d | d | | | | |
| 1 | 2424573·4233 | − 27 | − 0·0031 | − 0·0012 | − 0·0029 | 2 | pg | van Gent | 52 |
| 2 | 24591·3347 | − 5 | − 59 | − 40 | − 57 | 2 | pg | van Gent | 52 |
| 3 | 24595·4105 | 0 | − 15 | + 4 | − 13 | 4 | pg | van Gent | 53, 54 |
| 4 | 24639·3854 | + 54 | + 21 | + 40 | + 23 | 8 | pg | van Gent | 52 |
| 5 | 24791·6548 | + 241 | + 7 | + 26 | + 9 | 4 | pg | van Gent | 53, 54 |
| 6 | 24848·6537 | + 311 | − 1 | + 17 | + 1 | 4 | pg | van Gent | 53, 54 |
| 7 | 24875·5268 | + 344 | + 17 | + 35 | + 18 | 4 | pg | van Gent | 53, 54 |
| 8 | 24920·3112 | + 399 | + 6 | + 24 | + 7 | 4 | pg | van Gent | 53, 54 |
| 9 | 25230·5519 | + 780 | − 2 | + 14 | − 2 | 4 | pg | van Gent | 53, 54 |
| 10 | 25234·6211 | + 785 | − 24 | + 8 | − 24 | 4 | pg | van Gent | 53, 54 |
| 11 | 25687·3656 | + 1341 | + 12 | + 26 | + 11 | 4 | pg | van Gent | 53, 54 |
| 12 | 27160·4011 | + 3150 | + 2 | + 10 | − 3 | 4 | pg | van Gent | 53, 54 |
| 13 | 28545·4929 | + 4851 | − 19 | − 18 | − 29 | 4 | pg | Binnendijk | 54 |
| 14 | 28571·5540 | + 4883 | + 22 | + 13 | + 11 | 4 | pg | Binnendijk | 54 |
| 15 | 30466·3861 | + 7210 | − 3 | − 11 | − 19 | 4 | pg | Binnendijk | 54 |
| 16 | 32606·3222 | + 9838 | + 23 | + 5 | 0 | 20 | pe | Kron | 56 |
| 17 | 32966·2353 | + 10280 | + 27 | + 7 | + 2 | 20 | pe | Kron | 56 |

Table 8

Primary minima of UV Leonis

| No. | $M(E)$ J. D. | $E$ | $O - C$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| 1 | 2424802·562 | − 13653 | − 0·027 | 2 | pg | Solowiew | 58 |
| 2 | 26384·396 | − 11017 | − 18 | 1 | pg | Jensch | 59 |
| 3 | 27502·392 | − 9154 | + 19 | 1 | pg | Jensch | 59 |
| 4 | 27517·415 | − 9129 | + 39 | 2 | pg | Solowiew | 58 |
| 5 | 27544·367 | − 9084 | − 12 | 1 | pg | Jensch | 59 |
| 6 | 27568·379 | − 9044 | − 4 | 1 | pg | Jensch | 59 |
| 7 | 27571·398 | − 9039 | + 15 | 1 | pg | Jensch | 59 |
| 8 | 27925·428 | − 8449 | − 6 | 1 | ve | Jensch | 59 |
| 9 | 27928·434 | − 8444 | 0 | 1 | ve | Jensch | 59 |
| 10 | 28958·785 | − 6727 | + 4 | 3 | vp | Pierce | 60 |
| 11 | 29050·603 | − 6574 | + 9 | 3 | vp | Pierce | 60 |
| 12 | 29069·208 | − 6543 | + 11 | 2 | ve normal | Solowiew | 61 |
| 13 | 29299·635 | − 6159 | + 6 | 3 | vp | Pierce | 60 |
| 14 | 29306·832 | − 6147 | + 2 | 3 | vp | Pierce | 60 |
| 15 | 29321·836 | − 6122 | + 3 | 3 | vp 30 | Pierce | 60 |
| 16 | 29339·838 | − 6092 | + 3 | 5 | vp 56 | Pierce | 60 |
| 17 | 29377·643 | − 6029 | + 2 | 3 | vp 23 | Pierce | 60 |
| 18 | 29675·886 | − 5532 | + 3 | 2 | vp 14 | Pierce | 60 |

*Table 8 (continued)*

| No. | *M*(*E*) J. D. | *E* | *O* − *C* | *w* | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| 19 | 29725·691 | − 5449 | + 1 | 2 | vp 20 | Pierce | 60 |
| 20 | 29734·694 | − 5434 | + 3 | 4 | vp 48 | Pierce | 60 |
| 21 | 29755·697 | − 5399 | + 3 | 2 | vp 19 | Pierce | 60 |
| 22 | 29927·927 | − 5112 | + 8 | 2 | vp 12 | Pierce | 60 |
| 23 | 32995·5559 | − 0 | 0 | 20 | pe 40 | Perek | 57 |
| 24 | 32997·3561 | + 3 | 0 | 15 | pe 29 | Perek | 57 |
| 25 | 33000·3565 | + 8 | 0 | 25 | pe 57 | Perek | 57 |
| 26 | 33006·3571 | + 18 | 0 | 15 | pe 31 | Perek | 57 |
| 27 | 33021·3615 | + 43 | + 2 | 12 | pe 21 | Perek | 57 |
| 28 | 33024·3602 | + 48 | 0 | 12 | pe 16 | Perek | 57 |
| 29 | 33027·3627 | + 53 | + 2 | 30 | pe 74 | Perek | 57 |
| 30 | 33030·361 | + 58 | 0 | 15 | pe 34 ±0·003 | Piotrovski, Strzalkovski | 50 |
| 31 | 33030·3619 | + 58 | + 1 | 25 | pe 60 | Perek | 57 |
| 32 | 33033·3618 | + 63 | + 1 | 10 | pe 8 | Perek | 57 |
| 33 | 33039·360 | + 73 | − 2 | 15 | pe 31 ±0·002 | Piotrovski, Strzalkovski | 50 |
| 34 | 33039·3639 | + 73 | + 2 | 15 | pe 25 | Perek | 57 |
| 35 | 33354·4025 | + 598 | − 4 | 12 | pe 17 | Wallenquist | 57 |
| 36 | 33386·811 | + 652 | − 1 | 25 | pe ± 0·001 | Nason, Moore | 62 |
| 37 | 33772·666 | + 1295 | 0 | 4 | pg 36 | Preston | 63 |
| 38 | 34080·506 | + 1808 | − 4 | 1 | ve | Jahn | 64 |
| 39 | 34134·523 | + 1898 | + 5 | 1 | ve | Pohl | 64 |
| 40 | 34439·357 | + 2406 | − 4 | 0·5 | ve asc. branch | Pohl | 64 |
| 41 | 34442·361 | + 2411 | − 1 | 0·5 | ve asc. branch | Pohl | 64 |
| 42 | 34451·358 | + 2426 | − 5 | 1 | ve | Pohl | 64 |
| 43 | 34454·358 | + 2431 | − 6 | 1 | ve | Pohl | 64 |
| 44 | 34454·360 | + 2431 | − 4 | 0·5 | ve asc. branch | Domke | 64 |
| 45 | 34454·360 | + 2431 | − 4 | 1 | ve | Sofronovitsch | 64 |
| 46 | 34454·364 | + 2431 | 0 | 1 | ve | Jahn | 64 |
| 47 | 34490·368 | + 2491 | − 1 | 1 | ve | Pohl | 64 |

Table 9
Secondary minima of UV Leonis

| No. | *M*(*E*) J. D. | *E* | *O* − *C* | *w* | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| 1 | 2425574·600 | − 12367 | + 0·001 | 1 | pg | Jensch | 59 |
| 2 | 25999·451 | − 11659 | − 8 | 1 | pg | Jensch | 59 |
| 3 | 26056·474 | − 11564 | + 6 | 1 | pg | Jensch | 59 |
| 4 | 26422·494 | − 10954 | − 26 | 1 | pg | Jensch | 59 |
| 5 | 26832·402 | − 10271 | + 24 | 1 | pg | Jensch | 59 |
| 6 | 27180·422 | − 9691 | − 6 | 1 | pg | Jensch | 59 |
| 7 | 27397·667 | − 9329 | + 8 | 1 | pg | Jensch | 59 |
| 8 | 27474·452 | − 9201 | − 17 | 1 | pg | Jensch | 59 |
| 9 | 27477·484 | − 9196 | + 14 | 1 | pg | Jensch | 59 |
| 10 | 27534·469 | − 9101 | − 9 | 1 | pg | Jensch | 59 |
| 11 | 27890·330 | − 8508 | + 1 | 1 | ve | Jensch | 59 |
| 12 | 27914·334 | − 8468 | + 2 | 1 | ve | Jensch | 59 |
| 13 | 27926·351 | − 8448 | + 17 | 1 | ve | Jensch | 59 |
| 14 | 28980·685 | − 6691 | + 1 | 3 | vp | Pierce | 60 |
| 15 | 29295·729 | − 6166 | 0 | 3 | vp | Pierce | 60 |
| 16 | 29307·732 | − 6146 | + 1 | 3 | vp | Pierce | 60 |
| 17 | 29308·936 | − 6144 | + 5 | 3 | vp | Pierce | 60 |
| 18 | 29325·739 | − 6116 | + 6 | 5 | vp 84 | Pierce | 60 |
| 19 | 29345·543 | − 6083 | + 7 | 2 | vp 12 | Pierce | 60 |
| 20 | 29399·548 | − 5993 | + 4 | 4 | vp 42 | Pierce | 60 |
| 21 | 29681·589 | − 5523 | + 5 | 3 | vp 29 | Pierce | 60 |
| 22 | 30015·835 | − 4966 | + 4 | 3 | vp 24 | Pierce | 60 |
| 23 | 30030·836 | − 4941 | + 2 | 3 | vp 30 | Pierce | 60 |
| 24 | 32951·4513 | − 74 | + 2 | 20 | pe 89 | Perek | 57 |
| 25 | 32981·4535 | − 24 | 0 | 25 | pe 104 | Perek | 57 |
| 26 | 32999·4559 | + 6 | 0 | 30 | pe 123 | Perek | 57 |
| 27 | 33011·462 | + 26 | + 4 | 1 | ve 11 | Ashbrook | 63 |
| 28 | 33349·3052 | + 589 | − 1 | 12 | pe 23 | Wallenquist | 57 |
| 29 | 33390·713 | + 658 | + 1 | 20 | pe ± 0·002 | Nason, Moore | 62 |
| 30 | 33413·522 | + 696 | + 7 | 1 | ve | Pohl | 65 |
| 31 | 33740·563 | + 1241 | + 1 | 2 | pg 12 | Preston | 63 |
| 32 | 33743·563 | + 1246 | + 1 | 3 | pg 26 | Preston | 63 |
| 33 | 34078·413 | + 1804 | + 3 | 1 | ve | Jahn | 64 |
| 34 | 34135·415 | + 1899 | − 3 | 1 | ve | Pohl | 64 |

least squares, we have found for primary minima

$$(8)\quad M(E)_{prim} = 2424595{\cdot}^{d}81720 + 0{\cdot}^{d}81428254\,E \quad \pm 40 \quad \pm 4$$

$$(9)\quad M(E)_{sec} = 2424595{\cdot}^{d}41176 + 0{\cdot}^{d}81428242\,E \quad \pm 28 \quad \pm 4$$

Fig. 5 represents a plot of the residuals $(O - C)$ with respect to the elements (8) for primary minima, and with respect to the same elements with $M_0$ shifted by half the period for secondary minima:

$$(10)\quad M(E)_{sec} = 2424595{\cdot}^{d}41006 + 0{\cdot}^{d}81428254\,E\,.$$

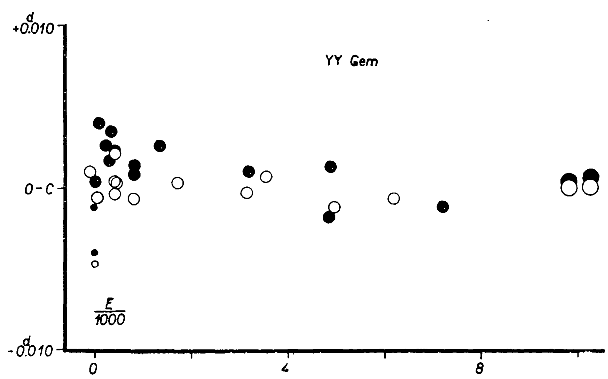


Fig. 5.

In Table 6, we list for primary minima the residuals $O - C$ with $C$ calculated from (6) and (8) respectively, and in Table 7 for secondary minima we give the deviations from (7), (9), and (10).

Both minima are well represented by the linear formulae and there has been either no change of period or a negligibly small one. Binnendijk finds that the secondary minima are not situated exactly half-way between the primary ones; he finds a deviation of $0{\cdot}^{d}00133 \pm \pm 0{\cdot}^{d}00053$ corresponding to $e \cos \omega = 0{\cdot}0024 \pm 0{\cdot}0010$. More recent Kron's photoelectric minima, however, show a displacement of $+ 0{\cdot}^{d}0006 \pm 0{\cdot}^{d}0001$ only, which would correspond to $e \cos \omega = 0{\cdot}0011$.

Can this shift be real and due to the rotation of the apside line? As both the components of Castor C are almost identical, we can again apply the approximate formula

$$\frac{P}{U} = 34 k_2 r^5\,.$$

Now the model of Castor C published by Schwarzschild [68] gives a relatively high apsidal-motion constant; according to approximate calculations [69]

$$k_2 = 0{\cdot}0565\,,$$

but the relative radii of the components in terms of their mutual distance are small: $r = 0{\cdot}156$. Thus our formula gives $U/P$ of the order of $6\,.\,10^3$. The mean epoch of Kron's observations is J. D. 2432800, while that of Binnendijk can be taken to be 2426000. The difference is about 8500 epochs, or more than one whole revolution of apses may have been completed! Thus the difference between Kron's and Binnendijk's observations may well be due to the rotation of the apses, but the eccentricity is obviously so small that many more accurate observations would be necessary to detect reliably the unusually rapid apsidal motion.

### 6. *AI Crucis*

The observations of this star are too few (Fig. 6) to make any discussion possible. Ollongren's linear elements [70]

$$M(E) = 2423959{\cdot}^{d}906 + 1{\cdot}4177073\,E$$

are the best we can have at the present time.

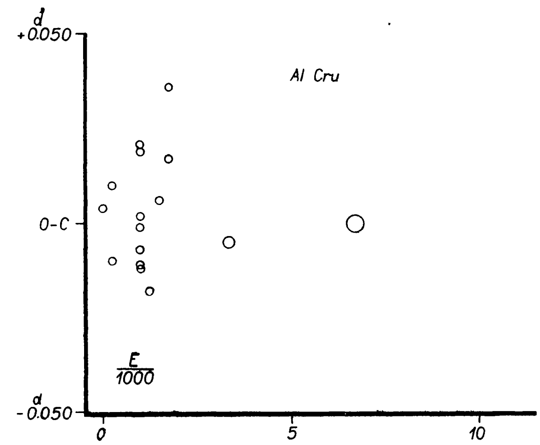


Fig. 6.

### 7. *UV Leonis*

This variable was discovered in 1934 only, but owing to its short period (0·6 day), it has been watched already for over 15,000 revolutions. Both minima are of about equal depth and the star is very suitable for observation. It cannot be said that the observed minima are too few; yet they are distributed very unequally, as Fig. 7 shows, so that virtually no conclusions about the variability of the period can be drawn. Secondary minima are placed symmetricaly and do not display any shift of the residuals with respect to the primary minima.

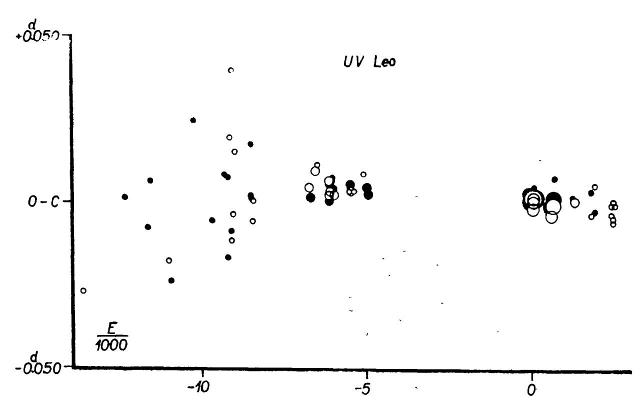


Fig. 7.

The period was thoroughly discussed by Perek [57] who also gave a complete list of observed minima. His linear elements

$$M(E) = 2432995{\cdot}^{d}5558 + 0{\cdot}^{d}60008546\,E$$

represent the observations very well. (Tables 8 and 9). Gaposchkin's photographic normal minima, presented also by Perek, cover a wider time-interval and are better distributed in time, but their scatter is too large, as Fig. 8 shows; they only confirm that the period has been approximately constant.

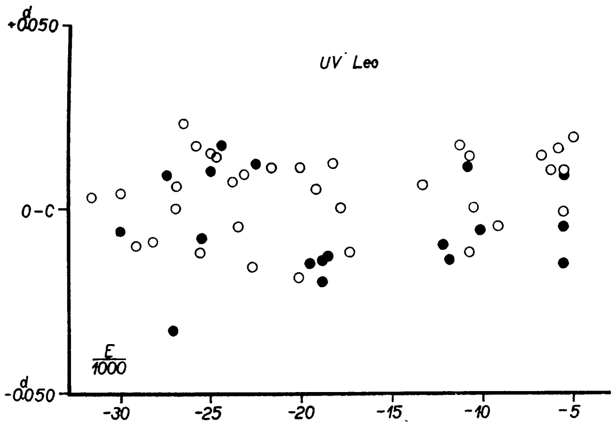


Fig. 8. UV Leo — Gaposchkin's minima.

## 8. *RS Sagittarii*

We have not found any minima beyond the 27 published and discussed by O'Connell [66]. Fig. 9 represents

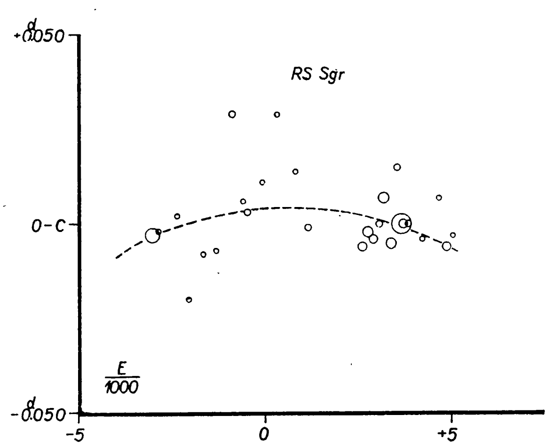


Fig. 9.

their residuals with respect to O'Connell's linear elements

$$M(E) = 2420586{\cdot}^{d}387 + 2{\cdot}^{d}4156832\, E\,.$$

The representation is fairly good, but O'Connell thinks that the residuals indicate a shortening of the period, and derives the following parabolic elements:

$$M(E) = 2420586{\cdot}^{d}391 + 2{\cdot}^{d}4156840\, E - 5{\cdot}5\,.\,10^{-10}\, E^2\,.$$

The parabolic term is represented by the broken curve in Fig. 9.

The variation of period and, in particular, its character, cannot be considered as firmly established. The parabolic term is mainly based on a few photographic estimates by Dugan and Wright, to which O'Connell himself does not give great weight. The more reliable minima determined by Roberts (at $E = -3002$), by Redman ($E = +3683$) and by O'Connell (five minima between $+2628$ and 3690) can be satisfied almost equally well by linear elements. The secondary minimum is shallow so that nothing can be said about its residuals.

## 9. *U Ophiuchi*

This star has been almost continually watched since the beginning of the present century. Both minima can be equally well observed. The observations are fairly numerous, but their scatter is very disappointing, as Fig. 10 shows. The explanation is probably that many observers consider U Ophiuchi to be an easy object owing to its brightness, but in fact the rather small depth of the minima (about $0{\cdot}7^m$) and the rather long duration of the minimum make this star not too suitable for visual estimates. Several photoelectric minima secured in recent years mainly by Piotrowski and Strzalkowski show a very small scatter only, thus proving that the larger scatter of earlier observations is entirely due to observational errors.

The actual period variations are probably rather small. The reader will probably agree that it is rather hopeless to extract them from the disagreeing observations. An attempt was made by Parenago in 1949. He thinks he has found a periodic term, so that his elements are [67]

$$M(E) = 2408279{\cdot}^{d}643 + 1{\cdot}^{d}6773460\, E + 0{\cdot}^{d}009 \sin 0{\cdot}^{\circ}036(E - 4800)\,. \quad (11)$$

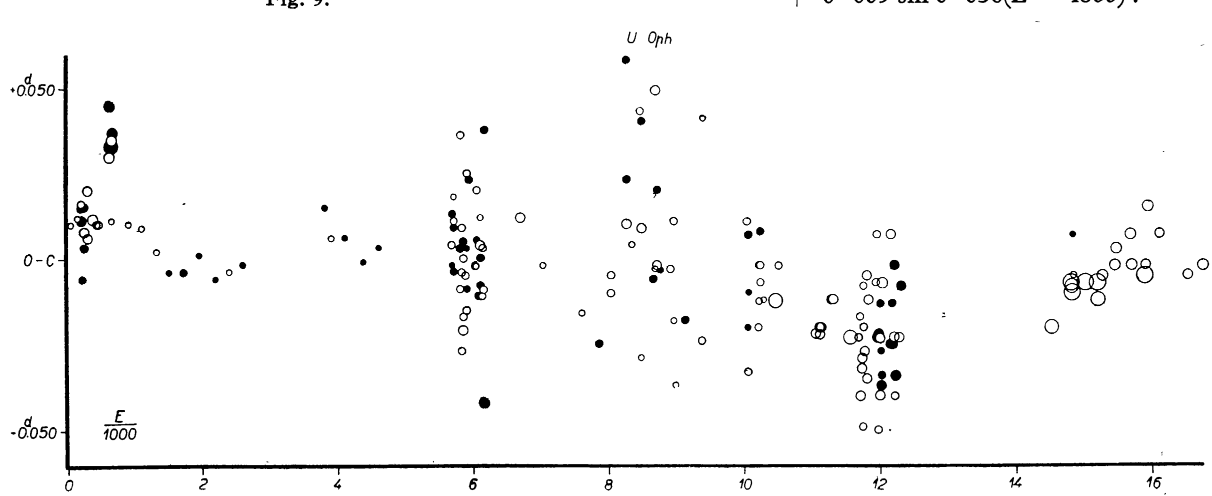


Fig. 10. U Ophiuchi — individual minima.

Table 10
Primary minima of U Ophiuchi

| No. | $M(E)$ J. D. | $E$ | $(O - C)_{12}$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| 1 | 2408368·5498 | + 53 | + 0·010 | 0·5 | ve 1 | Luizet | 71 |
| 2 | 08554·7361 | + 164 | + 11 | 0·5 | ve 1 | Luizet | 71 |
| 3 | 08633·5766 | + 211 | + 16 | 1 | ve 4 | Luizet | 71 |
| 4 | 08680·534 | + 239 | + 8 | 2 | ve 11 | Bailey | 72 |
| 5 | 08690·596 | + 245 | + 6 | 2 | ve 10 | Bailey | 72 |
| 6 | 08690·610 | + 245 | + 20 | 2 | ve 10 | Bailey | 72 |
| 7 | 08727·504 | + 267 | + 12 | 3 | ve 15 | Bailey | 72 |
| 8 | 09002·5873 | + 431 | + 10 | 1 | ve 4 | Luizet | 71 |
| 9 | 09049·5523 | + 459 | + 10 | 1 | ve 5 | Luizet | 71 |
| 10 | 09346·463 | + 636 | + 30 | 3 | vp | Wilsing | 73 |
| 11 | 09356·532 | + 642 | + 35 | 3 | vp | Wilsing | 73 |
| 12 | 09386·7006 | + 660 | + 11 | 0·5 | ve 2 | Luizet | 71 |
| 13 | 09787·5857 | + 899 | + 10 | 0·5 | ve 1 | Luizet | 71 |
| 14 | 10146·5368 | + 1113 | + 9 | 0·5 | ve 1 | Luizet | 71 |
| 15 | 10520·5783 | + 1336 | + 2 | 0·5 | ve 2 | Luizet | 71 |
| 16 | 12303·5926 | + 2399 | − 4 | 0·5 | ve 1 | Liuzet | 71 |
| 17 | 14836·3961 | + 3909 | + 6 | 0·5 | ve 3 | Luizet | 71 |
| 18 | 17815·363 | + 5685 | + 4 | 1 | ve 5 | Nijland | 74 |
| 19 | 17830·473 | + 5694 | + 18 | 0·5 | ve 3 | Nijland | 74 |
| 20 | 17847·240 | + 5704 | + 11 | 1 | ve 6 | Nijland | 74 |
| 21 | 18026·696 | + 5811 | − 9 | 1 | ve 5 | Nijland | 74 |
| 22 | 18038·482 | + 5818 | + 36 | 1 | ve 4 | Nijland | 74 |
| 23 | 18048·483 | + 5824 | − 27 | 1 | ve 5 | Nijland | 74 |
| 24 | 18053·538 | + 5827 | − 4 | 1 | ve 6 | Nijland | 74 |
| 25 | 18058·583 | + 5830 | + 9 | 1 | ve 5 | Nijland | 74 |
| 26 | 18080·380 | + 5843 | 0 | 1 | ve 7 | Nijland | 74 |
| 27 | 18090·427 | + 5849 | − 17 | 1 | ve 6 | Nijland | 74 |
| 28 | 18095·455 | + 5852 | − 21 | 2 | ve 8 | Nijland | 74 |
| 29 | 18147·469 | + 5883 | − 5 | 1 | ve 5 | Nijland | 74 |
| 30 | 18152·531 | + 5886 | + 25 | 1 | ve 7 | Nijland | 74 |
| 31 | 18194·425 | + 5911 | − 15 | 1 | ve 4 | Nijland | 74 |
| 32 | 18449·416 | + 6063 | + 20 | 1 | ve 6 | Nijland | 74 |
| 33 | 18454·426 | + 6066 | − 2 | 0·5 | ve 3 | Nijland | 74 |
| 34 | 18464·497 | + 6072 | + 4 | 2 | ve 9 | Nijland | 74 |
| 35 | 18511·462 | + 6100 | + 4 | 1 | ve 7 | Nijland | 74 |
| 36 | 18516·502 | + 6103 | + 12 | 0·5 | ve 3 | Nijland | 74 |
| 37 | 18553·381 | + 6125 | − 11 | 0·5 | ve 3 | Nijland | 74 |
| 38 | 18590·285 | + 6147 | − 9 | 1 | ve 6 | Nijland | 74 |
| 39 | 19514·5243 | + 6698 | + 12 | 2 | ve 8 | Lehnert | 75 |
| 40 | 20066·357 | + 7027 | − 2 | 0·5 | ve 5 poor | Hoffmeister | 76 |
| 41 | 21012·367 | + 7591 | − 16 | 0·5 | ve 3 | Ellsworth | 77 |
| 42 | 21745·374 | + 8028 | − 10 | 1 | ve 5 | Ellsworth | 77 |
| 43 | 21750·411 | + 8031 | − 5 | 1 | ve 4 | Ellsworth | 77 |
| 44 | 22114·410 | + 8248 | + 10 | 2 | ve 8 | Ellsworth | 77 |
| 45 | 22250·269 | + 8329 | + 4 | 0·5 | ve 3 | Ellsworth | 77 |
| 46 | 22473·395 | + 8462 | + 43 | 1 | ve 5 | Ellsworth | 77 |
| 47 | 22483·425 | + 8468 | + 9 | 2 | ve 8 | Ellsworth | 77 |
| 48 | 22498·484 | + 8477 | − 29 | 0·5 | ve 3 | Ellsworth | 77 |
| 49 | 22820·560 | + 8669 | − 3 | 0·5 | ve 3 | Ellsworth | 77 |
| 50 | 22842·418 | + 8682 | + 49 | 2 | ve 8 | Ellsworth | 77 |
| 51 | 22899·396 | + 8716 | − 2 | 2 | ve 8 | Ellsworth | 77 |
| 52 | 23226·478 | + 8911 | − 3 | 1 | ve 6 | Ellsworth | 77 |
| 53 | 23283·522 | + 8945 | + 11 | 1 | ve 5 | Ellsworth | 77 |
| 54 | 23305·298 | + 8958 | − 18 | 0·5 | ve 3 | Ellsworth | 77 |
| 55 | 23320·376 | + 8967 | − 37 | 0·5 | ve 3 | Ellsworth | 77 |
| 56 | 24001·392 | + 9373 | − 24 | 1 | ve 5 | Ellsworth | 77 |
| 57 | 24006·489 | + 9376 | + 41 | 0·5 | ve 3 | Ellsworth | 77 |
| 58 | 25113·508 | + 10036 | + 11 | 1 | ve 5 | Ellsworth | 77 |
| 59 | 25123·528 | + 10042 | − 33 | 1 | ve 7 | Ellsworth | 77 |
| 60 | 25378·498 | + 10194 | − 20 | 1 | ve 4 | Ellsworth | 77 |
| 61 | 25420·450 | + 10219 | − 2 | 1 | ve 6 | Ellsworth | 77 |
| 62 | 25435·542 | + 10228 | − 7 | 1 | ve 4 | Ellsworth | 77 |
| 63 | 25467·404 | + 10247 | − 13 | 1 | ve 6 | Ellsworth | 77 |
| 64 | 25509·339 | + 10272 | − 12 | 0·5 | ve 3 | Ellsworth | 77 |
| 65 | 25826·358 | + 10461 | − 12 | 5 | ve 31 (26, 7) normal | Parenago | 78 |
| 66 | 25888·430 | + 10498 | − 2 | 1 | ve 4 | Ellsworth | 77 |
| 67 | 26802·564 | + 11043 | − 22 | 2 | vp | Skoberla | 79 |
| 68 | 26881·401 | + 11090 | − 20 | 2 | vp | Skoberla | 79 |
| 69 | 26866·433 | + 11093 | − 20 | 2 | vp | Skoberla | 79 |
| 70 | 26901·528 | + 11102 | − 22 | 2 | vp | Skoberla | 79 |

*Table 10 (continued)*

| No. | $M(E)$ J. D. | $E$ | $(O - C)_{12}$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| 71 | 27245·394 | + 11307 | − 12 | 2 | ve ± 0·005 | Himpel | 45 |
| 72 | 27661·364 | + 11555 | − 23 | 4 | ve 49 (18, 7) ± 0·004 | Szafraniec | 80 |
| 73 | 27877·743 | + 11684 | − 23 | 1 | ve | Lause | 81 |
| 74 | 27926·392 | + 11713 | − 17 | 1 | ve | Lause | 81 |
| 75 | 27946·497 | + 11725 | − 40 | 2 | ve | Lause | 81 |
| 76 | 27951·541 | + 11728 | − 29 | 3 | ve 42 (14, 9) ± 0·008 | Szafraniec | 80 |
| 77 | 27961·601 | + 11734 | − 32 | 2 | ve | Lause | 81 |
| 78 | 27966·645 | + 11737 | − 20 | 1 | ve | Lause | 81 |
| 79 | 27988·450 | + 11750 | − 20 | 2 | ve | Lause | 81 |
| 80 | 27993·454 | + 11753 | − 49 | 1 | ve | Lause | 81 |
| 81 | 28015·300 | + 11766 | − 8 | 1 | ve | Lause | 81 |
| 82 | 28035·410 | + 11788 | − 27 | 2 | ve | Lause | 81 |
| 83 | 28067·270 | + 11797 | − 35 | 2 | ve | Lause | 81 |
| 84 | 28072·333 | + 11800 | − 5 | 2 | ve | Lause | 81 |
| 85 | 28109·228 | + 11822 | − 12 | 2 | ve | Lause | 81 |
| 86 | 28285·355 | + 11927 | − 7 | 1 | ve | Lause | 48 |
| 87 | 28332·334 | + 11955 | + 7 | 1 | ve | Lause | 48 |
| 88 | 28357·466 | + 11970 | − 22 | 2 | ve | Lause | 48 |
| 89 | 28367·501 | + 11976 | − 50 | 1 | ve | Lause | 48 |
| 90 | 28389·333 | + 11989 | − 23 | 2 | ve | Lause | 48 |
| 91 | 28399·380 | + 11995 | − 40 | 2 | ve | Lause | 48 |
| 92 | 28446·379 | + 12023 | − 7 | 2 | ve | Lause | 48 |
| 93 | 28664·449 | + 12153 | + 7 | 2 | ve | Lause | 48 |
| 94 | 28753·317 | + 12206 | − 23 | 2 | ve | Lause | 48 |
| 95 | 28790·202 | + 12228 | − 40 | 1 | ve | Lause | 48 |
| 96 | 28837·185 | + 12256 | − 23 | 2 | ve | Lause | 48 |
| 97 | 32624·638 | + 14514 | − 20 | 4 | ve 50 (13, 16) ± 0·004 | Szafraniec | 82 |
| 98 | 33067·468 | + 14778 | − 10 | 20 | pe 42 ± 0·003 | Piotrowski, Strzalkowski | 19 |
| 99 | 33067·469 | + 14778 | − 8 | 4 | ve 54 (23, 14) ± 0·004 | Szafraniec | 83 |
| 100 | 33067·471 | + 14778 | − 7 | 20 | pe 42 ± 0·002 | Piotrowski, Strzalkowski | 19 |
| 101 | 33151·34 | + 14828 | − 5 | 0·5 | ve 42 ± 0·01 | Anzinger | 51 |
| 102 | 33436·4871 | + 14998 | − 7 | 20 | pe ± 0·0018 | Piotrowski Strzalkowski | 84 |
| 103 | 33753·501 | + 15187 | − 12 | 4 | ve 50 (11, 12) ± 0·0012 | Szafraniec | 85 |
| 104 | 33753·503 | + 15187 | − 10 | 20 | pe ± 0·002 | Piotrowski | 86 |
| 105 | 33753·506 | + 15187 | − 7 | 20 | pe ± 0·003 | Piotrowski | 86 |
| 106 | 33842·408 | + 15240 | − 5 | 3 | ve 17 (4, 11) ± 0·008 | Szafraniec | 85 |
| 107 | 34164·462 | + 15432 | − 2 | 3 | ve 25 (8, 4) ± 0·008 | Szafraniec | 87 |
| 108 | 34238·269 | + 15476 | + 3 | 3 | ve 28 (6, 8) ± 0·012 | Szafraniec | 88 |
| 109 | 34513·358 | + 15640 | + 7 | 3 | ve 29 (10, 14) ± 0·013 | Szafraniec | 89 |
| 110 | 34580·444 | + 15680 | − 2 | 3 | ve 13 (7, 6) ± 0·004 | Wroblewski | 15 |
| 111 | 34900·808 | + 15871 | − 10 | 15 | pe | Koch | 90 |
| 112 | 34976·298 | + 15916 | − 2 | 2 | ve 9 (2, 7) ± 0·010 | Szafraniec | 91 |
| 113 | 34981·346 | + 15919 | + 15 | 3 | ve 8 (4, 2) ± 0·006 | Wroblewski | 15 |
| 114 | 35303·388 | + 16111 | + 7 | 2 | ve normal ± 0·004 | Szafraniec | 92 |
| 115 | 35989·411 | + 16520 | − 5 | 2 | ve ± 0·003 | Szafraniec | 93 |
| 116 | 36348·367 | + 16734 | − 2 | 3 | ve 23 (4, 17) ± 0·010 | Szafraniec | 94 |

In Fig. 11 we present the plot of normal points against the linear elements by Hellerich [101]

$$M(E)_{prim} = 2408279{\cdot}^{d}6402 + 1{\cdot}^{d}6773472\,E \tag{12}$$
$$M(E)_{sec} = 2408280{\cdot}^{d}4789 + 1{\cdot}^{d}6773472\,E\,,$$

Parenago's periodic term is represented by a broken curve. Mean errors of the normal points are indicated, but the actual uncertainty must be much greater: sometimes we found a very good internal consistency of observations made by the same observer, but great

Table 11

Secondary minima of U Ophiuchi

| No. | $M(E)$ J. D. | $E$ | $O - C$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| | | | d | | | | |
| 1 | 2408669·617 | + 232 | − 0·006 | 1 | ve 6 | Bailey | 72 |
| 2 | 08669·638 | + 232 | + 15 | 1 | ve 7 | Bailey | 72 |
| 3 | 08679·699 | + 238 | + 11 | 2 | ve 8 | Bailey | 72 |
| 4 | 08696·464 | + 248 | + 3 | 1 | ve 7 | Bailey | 72 |
| 5 | 08701·518 | + 251 | + 15 | 1 | ve 4 | Luizet | 71 |
| 6 | 09320·479 | + 620 | + 45 | 3 | vp 13 | Wilsing | 73 |
| 7 | 09325·504 | + 623 | + 38 | 4 | vp | Wilsing | 73 |
| 8 | 09414·408 | + 676 | + 42 | 3 | vp | Wilsing | 73 |
| 9 | 10816·624 | + 1512 | − 4 | 0·5 | ve 1 | Luizet | 71 |
| 10 | 11190·672 | + 1735 | − 4 | 1 | ve 4 | Luizet | 71 |
| 11 | 11554·662 | + 1952 | + 1 | 0·5 | ve 1 | Luizet | 71 |
| 12 | 11970·637 | + 2200 | − 6 | 0·5 | ve 2 | Luizet | 71 |
| 13 | 12666·740 | + 2615 | − 2 | 0·5 | ve 2 | Luizet | 71 |
| 14 | 14513·516 | + 3716 | + 15 | 0·5 | ve 2 | Luizet | 71 |
| 15 | 15184·446 | + 4116 | + 6 | 0·5 | ve 1 | Luizet | 71 |
| 16 | 15610·486 | + 4370 | − 1 | 0·5 | ve 1 | Luizet | 71 |
| 17 | 15959·378 | + 4578 | + 3 | 0·5 | ve 2 | Luizet | 71 |
| 18 | 17799·437 | + 5675 | + 13 | 1 | ve 7 | Nijland | 74 |
| 19 | 17804·454 | + 5678 | − 2 | 0·5 | ve 3 | Nijland | 74 |
| 20 | 17831·290 | + 5694 | − 4 | 1 | ve 7 | Nijland | 74 |
| 21 | 17841·367 | + 5700 | + 9 | 1 | ve 5 | Nijland | 74 |
| 22 | 18032·579 | + 5814 | + 3 | 1 | ve 5 | Nijland | 74 |
| 23 | 18089·610 | + 5848 | + 5 | 1 | ve 6 | Nijland | 74 |
| 24 | 18168·432 | + 5895 | − 9 | 0·5 | ve 3 | Nijland | 74 |
| 25 | 18205·345 | + 5917 | + 3 | 0·5 | ve 3 | Nijland | 74 |
| 26 | 18215·430 | + 5923 | + 23 | 1 | ve 4 | Nijland | 74 |
| 27 | 18448·556 | + 6062 | − 2 | 0·5 | ve 3 | Nijland | 74 |
| 28 | 18453·579 | + 6065 | − 11 | 1 | ve 4 | Nijland | 74 |
| 29 | 18490·496 | + 6087 | + 5 | 0·5 | ve 3 | Nijland | 74 |
| 30 | 18505·580 | + 6096 | − 8 | 1 | ve 5 | Nijland | 74 |
| 31 | 18527·382 | + 6109 | − 11 | 1 | ve 5 | Nijland | 74 |
| 32 | 18532·425 | + 6112 | 0 | 1 | ve 6 | Nijland | 74 |
| 33 | 18559·298 | + 6128 | + 35 | 1 | ve 6 | Nijland | 74 |
| 34 | 18574·317 | + 6137 | − 42 | 0·5 | ve 3 | Nijland | 74 |
| 35 | 21459·371 | + 7857 | − 25 | 1 | ve 6 | Ellsworth | 77 |
| 36 | 22103·555 | + 8241 | + 58 | 1 | ve 4 | Ellsworth | 77 |
| 37 | 22130·358 | + 8257 | + 23 | 1 | ve 4 | Ellsworth | 77 |
| 38 | 22499·391 | + 8477 | + 40 | 1 | ve 5 | Ellsworth | 77 |
| 39 | 22816·364 | + 8666 | − 6 | 1 | ve 5 | Ellsworth | 77 |
| 40 | 22873·420 | + 8700 | + 20 | 1 | ve 4 | Ellsworth | 77 |
| 41 | 22962·296 | + 8753 | − 3 | 0·5 | ve 3 | Ellsworth | 77 |
| 42 | 23606·382 | + 9137 | − 18 | 1 | ve 4 | Ellsworth | 77 |
| 43 | 25119·380 | + 10039 | + 12 | 1 | ve 6 | Ellsworth | 77 |
| 44 | 25124·390 | + 10042 | − 10 | 0·5 | ve 3 | Ellsworth | 77 |
| 45 | 25129·413 | + 10045 | − 20 | 0·5 | ve 3 | Ellsworth | 77 |
| 46 | 25436·396 | + 10228 | + 8 | 1 | ve 6 | Ellsworth | 77 |
| 47 | 25451·480 | + 10237 | − 2 | 1 | ve 6 | Ellsworth | 77 |
| 48 | 27244·556 | + 11306 | − 12 | 2 | ve ± 0·004 | Himpel | 45 |
| 49 | 28373·399 | + 11979 | − 23 | 3 | ve | Lause | 48 |
| 50 | 28395·214 | + 11992 | − 13 | 1 | ve | Lause | 48 |
| 51 | 28405·265 | + 11998 | − 27 | 1 | ve | Lause | 48 |
| 52 | 28457·252 | + 12029 | − 37 | 2 | ve | Lause | 48 |
| 53 | 28472·353 | + 12038 | − 32 | 1 | ve | Lause | 48 |
| 54 | 28690·416 | + 12168 | − 25 | 2 | ve | Lause | 48 |
| 55 | 28695·448 | + 12171 | − 25 | 2 | ve | Lause | 48 |
| 56 | 28705·523 | + 12177 | − 13 | 1 | ve | Lause | 48 |
| 57 | 28742·413 | + 12199 | − 25 | 3 | ve | Lause | 48 |
| 58 | 28752·500 | + 12205 | − 2 | 2 | ve | Lause | 48 |
| 59 | 28779·307 | + 12221 | − 34 | 2 | ve | Lause | 48 |
| 60 | 28938·680 | + 12316 | − 8 | 2 | ve | Lause | 48 |
| 61 | 33152·19 | + 14828 | + 7 | 0·5 | ve 42 ± 0·02 | Anzinger | 59 |

discrepancies between individual observers observing almost simultaneously. Our mean errors indicate the degree of internal agreement; systematic personal errors must have been much greater.

Parenago's periodic term represents the variations of period to some extent, but it is obvious that many other curves would do equally well. Parenago is probably right that the variation of period is not due to apsidal motion, since the secondary minima follow roughly the same curve as the primary ones; besides, no displacement of the secondary minimum has been found photometrically (the residuals of secondary minima have been computed with respect to the point half-way between primary minima).

Parenago suggests that the variation can be due to the presence of a third body and finds its mass to be probably smaller than that of the Sun, so that its light would be negligible. This assumption does not cotradict the observations just as the periodic term does not; but nothing more can be said in favour of it. The authors' opinion is that we have to deal with slow variations of period of a cyclic (but not periodic) character. The greatest deviation from the linear elements (12) probably did not exceed $\pm\, 0{\cdot}^{d}020$ and a wave may be as long as some 10 000 periods (46 years).

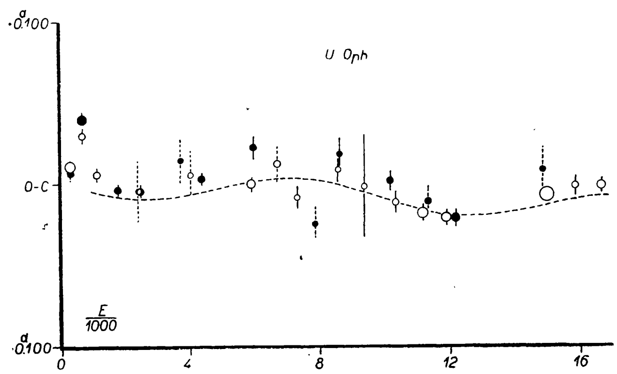


Fig. 11. U Ophiuchi — normal points and Parenago's periodic term.

Table 12

Primary minima of U Ophiuchi — normal points

| Normal No. | No. of observat. | $E$ | $(O-C)_{12}$ | Mean error |
|---|---|---|---|---|
| | | | d | |
| 1 | 9 | + 267 | + 0·012 | ± 0·002 |
| 2 | 3 | + 641 | + 31 | 4 |
| 3 | 3 | + 1116 | + 7 | 2 |
| 4 | 1 | + 2399 | − 4 | — |
| 5 | 1 | + 3909 | + 6 | — |
| 6 | 21 | + 5906 | 0 | 4 |
| 7 | 1 | + 6698 | + 12 | — |
| 8 | 2 | + 7309 | − 9 | 7 |
| 9 | 14 | + 8536 | + 8 | 6 |
| 10 | 2 | + 9374 | − 2 | 31 |
| 11 | 9 | + 10312 | − 11 | 4 |
| 12 | 5 | + 11127 | − 19 | 2 |
| 13 | 25 | + 11867 | − 22 | 3 |
| 14 | 12 | + 14999 | − 8 | 1 |
| 15 | 6 | + 15851 | − 3 | 4 |
| 16 | 2 | + 16648 | − 3 | 2 |

Table 13

Secondary minima of U Ophiuchi — normal points

| Normal No. | No. of observat. | $E$ | $(O-C)_{12}$ | Mean error |
|---|---|---|---|---|
| | | | d | |
| 1 | 5 | + 240 | + 0·008 | ± 0·004 |
| 2 | 3 | + 638 | + 41 | 2 |
| 3 | 3 | + 1734 | − 3 | 2 |
| 4 | 2 | + 2408 | − 4 | 2 |
| 5 | 1 | + 3716 | + 15 | — |
| 6 | 3 | + 4355 | + 3 | 2 |
| 7 | 17 | + 5932 | + 22 | 6 |
| 8 | 1 | + 7857 | − 25 | — |
| 9 | 7 | + 8593 | + 18 | 10 |
| 10 | 5 | + 10137 | + 1 | 5 |
| 11 | 1 | + 11306 | − 12 | — |
| 12 | 12 | + 12134 | − 22 | 3 |
| 13 | 1 | + 14828 | + 7 | — |

As the paper by Parenago is not easily accessible and several important observations have been made after 1949, we give a complete list of individual observed minima (Tables 10 and 11) as well as a list of normal minima formed from them (Tables 12 and 13).

### *10. V 451 Ophiuchi*

This star has long been thought to have a period of 1·098 day, and this period is still used in the Cracow ephemerides. But the only precise observations, those by Colacevich [96], show rather convincingly that the period should be doubled. Colacevich's conclusion is supported by our analysis of observed minima. In Fig. 12, we give a plot of all observed minima (as listed in Tables 14 and 15) against his elements,

$$(13)\quad \begin{aligned} M(E)_{prim} &= 2434165{\cdot}^{d}4990 + 2{\cdot}^{d}1965962\, E \\ M(E)_{sec} &= 2434166{\cdot}^{d}5973 + 2{\cdot}^{d}1965962\, E\,. \end{aligned}$$

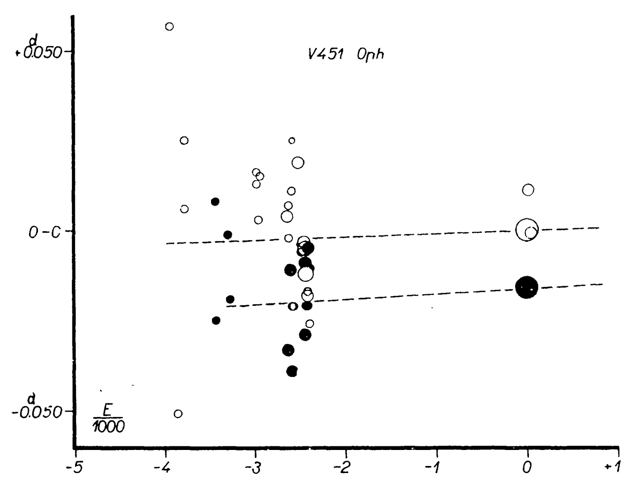


Fig. 12.

Note. On p. 124 of his paper, Colacevich gives the epoch of primary minimum to be J. D. $2434165{\cdot}^{d}4900$, contrary to p. 129. Judging from his original observations, we hold it as a misprint.)

It is seen from the figure that the minima that must be considered as secondary according to Colacevich are fairly well separated from the primary minima. If we form a normal minimum of all the earlier observations, we find $O - C = -\,0{\cdot}^{d}002$ at $E = -\,2741$ for primary minima, and $O - C = -\,0{\cdot}^{d}020$ at $E = -\,2711$ for secondary minima. The difference of $0{\cdot}^{d}018$ is very similar to the difference of $0{\cdot}^{d}016$ found by Colacevich at $E = 0$. This displacement of secondary minima makes Colacevich's value for orbital eccentricity $e = 0{\cdot}025$ very plausible.

We must therefore also expect rotation of the apside line and the corresponding variation of the period. The

Table 14

Primary minima of V 451 Ophiuchi

| No. | $M(E)$ J. D. | $E$ | $(O-C)_{13}$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| | | | d | | | | |
| 1 | 2425504·377 | − 3943 | + 0·057 | 1 | ve | Hoffmeister | 95 |
| 2 | 25686·587 | − 3860 | − 51 | 1 | ve | Hoffmeister | 95 |
| 3 | 25851·388 | − 3785 | + 6 | 1 | ve | Hoffmeister | 95 |
| 4 | 25862·390 | − 3780 | + 25 | 1 | ve | Hoffmeister | 95 |
| 5 | 27606·476 | − 2986 | + 13 | 1 | ve | Hoffmeister | 95 |
| 6 | 27628·445 | − 2976 | + 16 | 1 | ve | Hoffmeister | 95 |
| 7 | 27683·347 | − 2951 | + 3 | 1 | ve | Hoffmeister | 95 |
| 8 | 27694·342 | − 2946 | + 15 | 1 | ve | Hoffmeister | 95 |
| 9 | 28366·489 | − 2640 | + 4 | 2 | ve | Lause | 48 |
| 10 | 28377·475 | − 2635 | + 7 | 1 | ve | Lause | 48 |
| 11 | 28399·432 | − 2625 | − 2 | 1 | ve | Lause | 48 |
| 12 | 28454·360 | − 2600 | + 11 | 1 | ve | Lause | 48 |
| 13 | 28465·311 | − 2595 | − 21 | 1 | ve | Lause | 48 |
| 14 | 28498·260 | − 2580 | − 21 | 2 | ve | Lause | 48 |
| 15 | 28614·719 | − 2527 | + 19 | 2 | ve | Lause | 48 |
| 16 | 28689·379 | − 2493 | − 6 | 1 | ve | Lause | 48 |
| 17 | 28757·476 | − 2462 | − 3 | 2 | ve | Lause | 48 |
| 18 | 28779·440 | − 2452 | − 5 | 3 | ve | Lause | 48 |
| 19 | 28719·416 | − 2447 | − 12 | 3 | ve | Lause | 48 |
| 20 | 28834·345 | − 2427 | − 17 | 1 | ve | Lause | 48 |
| 21 | 28845·325 | − 2422 | − 18 | 2 | ve | Lause | 48 |
| 22 | 28867·283 | − 2412 | − 26 | 1 | ve | Lause | 48 |
| 23 | 34165·4990 | 0 | 0 | 20 | pe 37 normal | Colacevich | 96 |
| 24 | 34211·639 | + 21 | + 11 | 2 | ve ± 0·005 | Ashbrook | 97 |
| 25 | 34244·575 | + 36 | − 1 | 2 | ve ± 0·007 | Ashbrook | 97 |

Table 15

Secondary minima of V 451 Ophiuchi

| No. | $M(E)$ J. D. | $E$ | $(O-C)_{13}$ | $w$ | Note | Observer | Source |
|---|---|---|---|---|---|---|---|
| 1 | 2426599·331 | − 3445 | + 0·008 | 1 | ve | Hoffmeister | 95 |
| 2 | 26621·264 | − 3435 | − 25 | 1 | ve | Hoffmeister | 95 |
| 3 | 26825·498 | − 3342 | − 75 | 1 | ve | Hoffmeister | 95 |
| 4 | 26924·419 | − 3297 | − 1 | 1 | ve | Hoffmeister | 95 |
| 5 | 26946·367 | − 3287 | − 19 | 1 | ve | Hoffmeister | 95 |
| 6 | 28387·320 | − 2631 | − 33 | 2 | ve | Lause | 48 |
| 7 | 28422·487 | − 2615 | − 11 | 2 | ve | Lause | 48 |
| 8 | 28455·408 | − 2600 | − 39 | 2 | ve | Lause | 48 |
| 9 | 28690·479 | − 2493 | − 4 | 1 | ve | Lause | 48 |
| 10 | 28778·338 | − 2453 | − 9 | 2 | ve | Lause | 48 |
| 11 | 28780·514 | − 2452 | − 29 | 2 | ve | Lause | 48 |
| 12 | 28802·488 | − 2442 | − 21 | 1 | ve | Lause | 48 |
| 13 | 28833·257 | − 2428 | − 5 | 2 | ve | Lause | 48 |
| 14 | 28844·224 | − 2423 | − 21 | 1 | ve | Lause | 48 |
| 15 | 28866·201 | − 2413 | − 10 | 1 | ve | Lause | 48 |
| 16 | 34166·581 | 0 | − 16 | 20 | pe 27 normal | Colacevich | 96 |

Note. The column "note" gives information about the method of observation and number of comparisons made, as far as these data have been available to us. Abbreviations: *ve* — visual estimates, *vp* — visual photometer, *pg* — photography, *pe* — — photoelectric photometer. Numbers as 13(6, 5) say that of the total of 13 observations, 6 were made on the descending and 5 on the ascending branches, respectively. ± means the mean error, ± the limits of error as given by the Cracow observers. Column *w* gives the weight.

semi-amplitude is likely to be $e\dfrac{P}{\pi} = 0\cdot^{d}017$, i. e. fairly large. However, the observations, covering about 24 years, do not show any clear change.

We can make an estimate of the period of apsidal rotation. Using Colacevich's values of $e = 0\cdot025$, $m_2/m_1 = 0\cdot76$, $r_1 = 0\cdot216$, $r_2 = 0\cdot173$, we find

$$P/U = 6\cdot2\,.\,10^{-3}\,k_{21} + 3\cdot4\,.\,10^{-3}\,k_{22}\,.$$

Now the primary can be represented by Kushwaha's advanced main sequence model 2·5 ⊙, while the secondary lies somewhere between this model and the Sun. Adopting therefore $k_{21} = 0\cdot005$, $k_{22} = 0\cdot007$, we find $U = 1\cdot8\,.\,10^4\,P = 108$ years.

If this estimate is correct, our observations should cover about one quarter of the cycle and the period variation ought to be perceptible. But the early observations are too uncertain, there is a long gap between them and the photoelectric observations by Colacevich; besides, our adopted values of $k_2$ may be exaggerated.

Nevertheless it can be concluded that V 451 Oph promises to yield new useful values of the apsidal constant in the near future, provided it is studied with precise methods.

### 11. GL Carinae

This is an excellent example of a system with apsidal motion. Fig. 13 gives a plot of the residuals with respect to the linear elements

$$M(E)_{prim} = 2424264{\cdot}^{d}448 + 2{\cdot}^{d}422232\,E$$
$$M(E)_{sec} = 2424263{\cdot}^{d}236 + 2{\cdot}^{d}422232\,E\,,$$

while the curves represent the periodic terms

$$\pm\, 0{\cdot}^{d}121 \sin \frac{360^\circ}{3800}\, E\,.$$

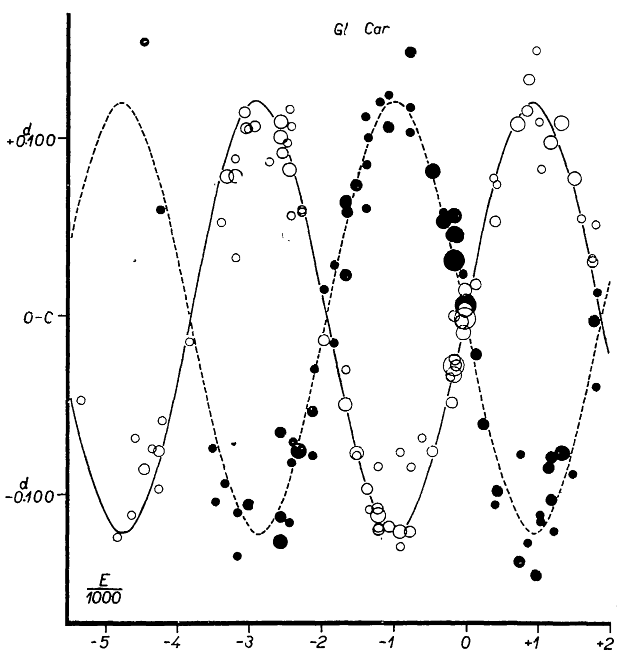


Fig. 13.

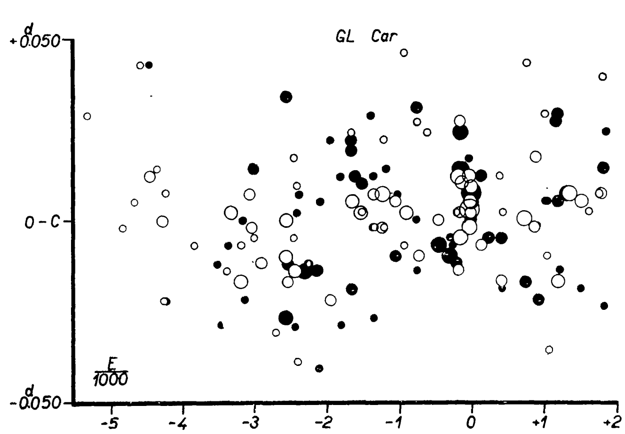


Fig. 14.

The full-dress formula representing the variation due to the apsidal motion is, after Swope and Shapley [98],

$$M(E)_{prim} = 2424264{\cdot}^{d}448 + 2{\cdot}^{d}422232\,E + $$
$$+\, 0{\cdot}^{d}121 \sin \frac{360^\circ}{3800}\, E - 0{\cdot}^{d}007 \sin 2\, \frac{360^\circ}{3800}\, E\,,$$

$$M(E)_{sec} = 2424263{\cdot}^{d}236 + 2{\cdot}^{d}422232\,E - $$
$$-\, 0{\cdot}^{d}121 \sin \frac{360^\circ}{3800}\, E - 0{\cdot}^{d}007 \sin 2\, \frac{360^\circ}{3800}\, E\,.$$

If we allow for these two periodic terms, the residuals give a considerable scatter (Fig. 14), but do not indicate any other variation of period. A more recent investigation by Van Wijk, Rogerson and Skumanich [102] has improved the period of apsidal motion, but is too isolated to provide any conclusion about other variable terms in the period.

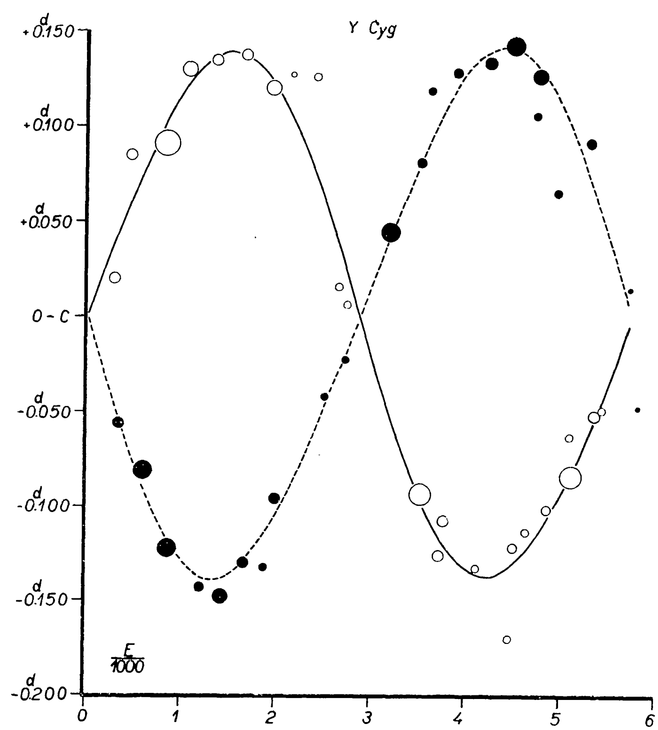


Fig. 15.

### 12. Y Cygni

This is a very similar case to GL Carinae. The periodic terms due to the apsidal motion are very pronounced, as Fig. 15 shows. The figure was drawn according to Dugan [103], using both linear and periodic parts of his formulae

$$M(E)_{prim} = 2409534{\cdot}^{d}3195 + 2{\cdot}^{d}9963331\,E + $$
$$+\, 0{\cdot}^{d}1380 \sin 0{\cdot}^{\circ}06266\, E$$
$$-\, 0{\cdot}^{d}0074 \sin 2(0{\cdot}^{\circ}06266\, E)\,,$$

$$M(E)_{sec} = 2409535{\cdot}^{d}8175 + 2{\cdot}^{d}9963331\,E - $$
$$-\, 0{\cdot}^{d}1380 \sin 0{\cdot}^{\circ}06266\, E$$
$$-\, 0{\cdot}^{d}0074 \sin 2(0{\cdot}^{\circ}06266\, E)\,.$$

The circles represent Dugan's supernormals. If the periodic terms are allowed for, the residuals of the supernormals show a moderate scatter and no other variable term can be traced out (Fig. 16).

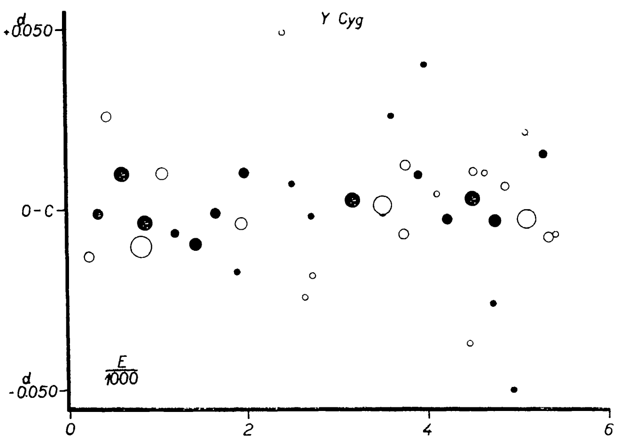


Fig. 16.

Thus for Y Cygni, too, no other variability of period except that due to apsidal motion need be postulated.

### *Conclusions*

The first and most unpleasant conclusion is that the material available is insufficient for the present study. Of the 28 detached systems listed by Kopal and Mrs. Shapley, 16 had to be rejected at the very beginning because only a few observations were available for each of them.

Considering now the remaining 12, we find that in two the apsidal motion is proved (GL Car, Y Cyg) and in two others it may be expected (YYGem — short period, but probably very small amplitude; V 451 Oph-fairly large amplitude, but probably longer period). These systems probably do not display other changes of period.

Two systems (U Oph, TX Her) change their periods, the cause being other than apsidal motion. For both stars, periodic terms have been suggested, but the evidence for them is not at all convincing. The variations of period have been explained as due to the presence of a third body. In both cases this hypothesis is not at variance with the photometric evidence. Statistically, 10% of double systems can be expected to be actually triple; thus 2 out of 12 is acceptable even from this point of view. But it must be repeated that the direct evidence in favour of this hypothesis is very inconclusive. It is believed that further observations shall prove that the deviations $O - C$ do not follow any regular periodic curve. Slow cyclic changes of a small amplitude without any definite periodicity are more probable.

For another system, RS Sgr, variation of period has been suggested. O'Connell suggests a parabolic term in $O - C$, but this may well be a rough approximation. Apsidal motion cannot be excluded here, since secondary minima are too shallow to be timed with sufficient accuracy.

For three systems (WW Aur, AI Cru, UV Leo) we cannot but give linear elements, as the observations are very inadequately distributed: there are many low-accuracy observations following the discovery, and then — usually much later — a few precise measurements from recent days. We can only say that large variations of period are improbable; small slow variations would have remained undetected.

RX Her and TT Aur have been followed more or less continuously (although usually by low-accuracy methods) and have not displayed perceptible period variations. The same applies, in fact, to GL Car, Y Cyg and YY Gem, leaving aside the apsidal motion.

Thus we conclude that large period variations (disregarding apsidal motion) are absent in detached systems. Also no indications of any abrupt period changes have been found. But it cannot be said with certainty that real constancy of periods is a typical feature of detached systems. Small and slow variations (probably of a cyclic, not really periodic nature) are present in two systems at least; they may be present in many more systems. In some of them, they may be hidden in the dispersion of observations, or cannot be detected owing to large gaps in observations. A long series of accurate photoelectric minima would be necessary to solve this question. Visual minima (and probably photographic, too) are of little value for this purpose.

It is our aim to survey similarly also the semi-detached and contact systems. Only after this survey has been completed will it be possible to say whether the detached systems behave in a specific manner as to the constancy of their periods.

### *Acknowledgment*

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# INFLUENCE OF PRECESSION AND NUTATION ON THE PERIOD OF ECLIPSING VARIABLES

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In his new book, Kopal introduces 9 new periodic terms in his generalized expression for the variation of apparent period of eclipsing variables. In this paper, periods and amplitudes of these terms are discussed on theoretical models, representing 12 well-known systems. It is shown that the periods of the new terms are as a rule short, although there are characteristic differences between the detached, semi-detached and contact systems. The amplitudes found are very small and in general undetectable. Thus it is concluded that the causes of the observed variations of periods must be looked for elsewhere.

*Влияние прецессии и нутации на периоды затменных переменных.* З. Копал в своей новой книге вводит 9 новых периодических членов в свое обобщенное выражение для изменчивости периодов затменных переменных. В этой работе рассмотрены периоды и амплитуды этих членов при помощи теоретических моделей, отображающих 12 хорошо известных систем. Оказывается, что периоды в общем коротки, однако между разделенными, полуразделенными и контактными системами имеются характеристические различия. Амплитуды весьма малы и практически не поддаются наблюдениям. Поэтому причина наблюденных изменений периодов должна отыскиваться в ином месте.

It is a well-established fact that some eclipsing binary systems change their periods. The "classical" explanation of this phenomenon is that the changes of period are apparent only, due either to the rotation of the apside line or the presence of a third body. This latter explanation can naturally hold true in a limited number of cases only; in fact, in the majority of the systems for which the presence of a third body has been suggested, this assumption still remains doubtful.

In recent years, several authors suggested that the variability of the periods is primarily a typical feature of the semi-detached systems and that it is associated with the dynamical instability of the subgiant components of these systems. It is true that many semi-detached systems display period changes of an erratic character; as a matter of fact, some authors are convinced that they have found *sudden* changes of period. However attractive the idea of a mass loss may be, it still lacks deeper foundations.

It is therefore very important that in his recent book [1] Kopal returns to the discussion of the dynamical behaviour of close binary systems and studies it on a broader