# Notes on variable stars of the δ Cephei type estimated on Harvard plates

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# Notes on variable stars of the δ Cephei type estimated on Harvard plates,

by *Ejnar Hertzsprung.*

The main purpose of my estimates of stars of the δ Cephei type on Harvard plates was to test the validity of the close connection between form of the lightcurve and length of the period as described in detail in *B. A. N.* **96.** I therefore included such special cases, where the lightcurves so far found did not seem to fit well into the scheme, such as RS Orionis and R Muscae.

Altogether 5999 estimates were made of the 9 objects given in Table 1. The main result is that no serious exception was found from the connection between period and shape of the lightcurve as established before. Especially the close resemblance between the lightcurves of the 4 stars RS Ori, W Gem, RX Cam and R Mus with periods ranging only from $7^{d}{\cdot}510$ to $7^{d}{\cdot}915$ is very striking.

For general remarks concerning the way of working see the beginning of the preceding note.

For each plate the J. D. hel. M. astr. T. Grw. was computed and the phase calculated according to the formula

$$\text{phase} = 1/P \text{ (J. D.} - 2400000).$$

The values of 1/P used in each case are given in the fifth column of Table 1. The estimates were then arranged according to phase and groups of ordinarily 10 observations each formed. The mean values thus obtained for each star are given in the tables and represented graphically in the accompanying diagrams.

The mean error of a single observation is given in the seventh column of Table 1 as derived from the differences between two estimates following each other in phase.

Though occasionally deviations occur, which look too serious to be due to ordinary accidental errors, no observation has been rejected for discordance.

TABLE 1.

| Star | α (1900) | δ (1900) | period | adopted reciprocal period | number of observations | mean error of a single observation | total weight of the observations | mean J. D. of the plates used |
|---|---|---|---|---|---|---|---|---|
| | h m s | ° ′ | d | d⁻¹ | | s | s⁻² | |
| RX Cam | 3 56 42 | +58 23·0 | 7·9120 | ·12639 | 1031 | ±·114 | 79300 | 2419443 |
| SW Tau | 4 19 17 | + 3 53·5 | 1·583645 | ·6314545 | 563 | ±·113 | 44100 | 246 |
| RS Ori | 6 16 31 | +14 43·5 | 7·5667 | ·132158 | 905 | ±·106 | 80500 | 512 |
| W Gem | 6 29 14 | +15 24·5 | 7·9150 | ·126342 | 1056 | ±·131 | 61500 | 520 |
| X Pup | 7 28 26 | −20 41·7 | 25·9560 | ·0385268 | 414 | ±·176 | 13400 | 634 |
| WZ Car | 10 51 20 | −60 24·4 | 23·0054 | ·043468 | 554 | ±·127 | 34300 | 432 |
| XX Car | 10 53 21 | −64 35·9 | 15·7238 | ·063598 | 390 | ±·161 | 15000 | 644 |
| R Mus | 12 35 58 | −68 51·5 | 7·5101 | ·1331536 | 702 | ±·134 | 39100 | 348 |
| U Nor | 15 34 37 | −54 59·3 | 12·6410 | ·0791077 | 384 | ±·112 | 30600 | 282 |

The plates used are approximately equally distributed over the last 25 or 30 years. The mean J. D. of the plates used for each star is given in the last column of Table 1.

The single estimates are not reproduced here, but a complete list of them, for each variable arranged according to the phase, is present at the Leiden observatory and may be consulted if wanted.

For each star the total weight of the observations is given in the eighth column of Table I in units of $s^{-2}$. The total weight of all 9 stars thus is 398000 $s^{-2}$.

The plates used are mainly of the Harvard series AC and AM. In recent years the series AY and AX were added. The latter series are not quite homogeneous with the old ones, as yellow stars appear relatively bright on AY and AX plates, but no corrections to the estimates have been applied for this reason.

The 603 estimates of H. D. 154365 = BF Oph have already been treated by D. Brouwer in *B. A. N.* **135.**

## RX Camelopardalis

The lightcurve of this variable has already been found by ZACHAROW (*A. N.* 5225, **218**, 271; 1923) to show the characteristics corresponding to its period of $7^{d}{\cdot}9$. The star was put on my programme to verify this result.

The comparison stars used are

B. D.

| | B. D. | m | s |
|---|---|---|---|
| *A* | + 57° 769 | 8·0 | ·000 |
| *a* | + 58° 672 | 8·2 | ·449 |
| *b* | + 58° 676 | 8.6 | ·813 |
| *c* | + 58° 684 | 9·0 | 1·108 |

The mean values obtained are given in Table 2.

TABLE 2

R X Camelopardalis

| number of plates | phase | brightness | mean values of larger groups | | number of plates | phase | brightness | mean values of larger groups | |
|---|---|---|---|---|---|---|---|---|---|
| n | P | s | P | s | n | P | s | P | s |
| 10 | ·006 | 1·06 | | | 10 | ·502 | ·39 | ·503 | ·410 |
| 10 | ·014 | 1·03 | ·014 | 1·052 | 10 | ·515 | ·39 | | |
| 10 | ·023 | 1·07 | | | 10 | ·524 | ·48 | | |
| 10 | ·032 | 1·02 | | | 10 | ·532 | ·44 | ·532 | ·444 |
| 10 | ·042 | ·99 | ·042 | ·996 | 10 | ·541 | ·41 | | |
| 10 | ·052 | ·97 | | | 10 | ·553 | ·53 | | |
| 10 | ·057 | ·86 | | | 10 | ·564 | ·56 | ·565 | ·563 |
| 10 | ·068 | ·84 | ·069 | ·853 | 10 | ·577 | ·60 | | |
| 10 | ·082 | ·86 | | | 10 | ·588 | ·68 | | |
| 10 | ·093 | ·80 | | | 10 | ·596 | ·71 | ·598 | ·703 |
| 10 | ·103 | ·68 | ·103 | ·703 | 10 | ·609 | ·72 | | |
| 10 | ·112 | ·64 | | | 10 | ·616 | ·75 | | |
| 10 | ·125 | ·64 | | | 10 | ·625 | ·78 | ·625 | ·765 |
| 10 | ·136 | ·61 | ·136 | ·597 | 10 | ·633 | ·76 | | |
| 10 | ·147 | ·54 | | | 10 | ·644 | ·78 | | |
| 10 | ·156 | ·55 | | | 10 | ·650 | ·74 | ·654 | ·809 |
| 10 | ·162 | ·45 | ·162 | ·479 | 10 | ·657 | ·90 | | |
| 10 | ·169 | ·44 | | | 10 | ·665 | ·82 | | |
| 10 | ·181 | ·40 | | | 10 | ·673 | ·83 | | |
| 10 | ·191 | ·39 | ·191 | ·355 | 10 | ·685 | ·92 | ·693 | ·854 |
| 10 | ·200 | ·27 | | | 10 | ·701 | ·78 | | |
| 10 | ·207 | ·32 | | | 10 | ·713 | ·88 | | |
| 10 | ·213 | ·30 | ·214 | ·307 | 10 | ·723 | ·84 | | |
| 10 | ·221 | ·29 | | | 10 | ·733 | ·89 | ·739 | ·888 |
| 10 | ·239 | ·17 | | | 10 | ·744 | ·90 | | |
| 10 | ·252 | ·25 | ·251 | ·230 | 10 | ·756 | ·93 | | |
| 10 | ·261 | ·27 | | | 10 | ·764 | ·94 | | |
| 10 | ·270 | ·24 | | | 10 | ·778 | ·95 | ·784 | ·966 |
| 10 | ·278 | ·28 | ·280 | ·282 | 10 | ·790 | 1·01 | | |
| 10 | ·292 | ·33 | | | 10 | ·806 | ·97 | | |
| 10 | ·305 | ·25 | | | 10 | ·820 | 1·01 | | |
| 10 | ·316 | ·36 | ·316 | ·328 | 10 | ·825 | 1·02 | ·831 | 1·047 |
| 10 | ·326 | ·37 | | | 10 | ·834 | 1·06 | | |
| 10 | ·332 | ·40 | | | 10 | ·843 | 1·10 | | |
| 10 | ·341 | ·36 | ·340 | ·384 | 10 | ·853 | 1·04 | | |
| 10 | ·347 | ·40 | | | 10 | ·864 | 1·10 | ·867 | 1·068 |
| 10 | ·354 | ·37 | | | 10 | ·872 | 1·04 | | |
| 10 | ·363 | ·44 | ·364 | ·468 | 10 | ·878 | 1·10 | | |
| 10 | ·374 | ·59 | | | 10 | ·885 | 1·14 | | |
| 10 | ·386 | ·44 | | | 10 | ·894 | 1·08 | ·896 | 1·092 |
| 10 | ·395 | ·48 | ·395 | ·473 | 10 | ·900 | 1·07 | | |
| 10 | ·404 | ·50 | | | 10 | ·907 | 1·07 | | |
| 10 | ·414 | ·44 | | | 10 | ·916 | 1·11 | | |
| 10 | ·423 | ·44 | ·424 | ·450 | 10 | ·926 | 1·10 | ·926 | 1·103 |
| 10 | ·434 | ·47 | | | 10 | ·935 | 1·09 | | |
| 10 | ·444 | ·49 | | | 10 | ·948 | 1·11 | | |
| 10 | ·450 | ·38 | ·450 | ·422 | 10 | ·959 | 1·08 | ·959 | 1·097 |
| 10 | ·458 | ·39 | | | 10 | ·970 | 1·10 | | |
| 10 | ·468 | ·40 | | | 10 | ·980 | 1·10 | | |
| 10 | ·477 | ·41 | ·476 | ·413 | 10 | ·988 | 1·06 | ·988 | 1·074 |
| 10 | ·483 | ·43 | | | 11 | ·995 | 1·06 | | |
| 10 | ·493 | ·45 | | | | | | | |

The lightcurve obtained here shows a pronounced secondary maximum, thus fully confirming ZACHAROW's results. It will be noted that the fall just after the secondary minimum is as steep as the main part of the rising branch.

For stars of this kind with asymmetrical lightcurves personality is liable to affect the determination of the epoch of maximum. It has been tried to avoid this difficulty by indicating the point on the ascending branch where a magnitude is reached midway between minimum and maximum, but it is evident that the sharpness of this determination will also depend on the way, in which the lightcurve has been drawn (more or less pointed maximum or minimum) and further on the homogeneity of the magnitude scale used. One way to elude these difficulties is to indicate two phases, which are separated by a given fraction of the period and at which the variable shows the same brightness on the ascending and descending branch of the lightcurve. E. g. on the lightcurve of RX Cam found here the brightness of the variable is the same at the two phases $^{P}$·145 and $^{P}$·565 separated by ·42 of the period.

## S W Tauri

The period 1$^{d}$·5839, given by HOFFMEISTER for this variable, is intermediate between the RR Lyrae and δ Cephei stars. Two other periods of this kind, viz. 1$^{d}$·48 of RZ Librae and $^{d}$·88 of R Muscae, have proved to be erroneous, the real periods being respectively $^{d}$·60 (*B. A. N.* **52**) and 7$^{d}$·51 (*B. A. N.* **116**).

SW Tauri was therefore taken up for investigation and estimated on 563 Harvard plates of the AC, AM, AY and AX series. The comparison stars used are

| | | |
|---|---|---|
| *a* | B D + 4°679 | $^{s}$·000 |
| *b* | B D + 3°597 | ·403 |
| *c* | B D + 3°600 | ·868 |

No evidence of HOFFMEISTER's period being wrong was found. Using 32 maxima a least square solution gave the period to be 1$^{d}$·583645 ± $^{d}$·000012 (m. e.) with a mean error of ± $^{d}$·12 for a single maximum.

Arranging according to phase and dividing in one group of 8, 5 of 9 and 51 of 10 observations each, the mean values given in Table 3 and graphically represented in the Figure were obtained. From this it is seen, that the lightcurve is as exceptional as the period, the maxium brightness being practically constant for about one fifth of the period. The range is $^{s}$·8 in my scale of steps.

Six AY plates taken in succession on 1925 Dec. 10 with an exposuretime of about an hour each happen to cover the steep ascending branch of the lightcurve. The speed of the increase shown by these plates is in accordance with the lightcurve using HOFFMEISTER's period. The six observations are

| | | | | | | |
|---|---|---|---|---|---|---|
| J. D. | 2424495·652 | ·700 | ·745 | ·790 | ·835 | ·880 |
| phase | ·890 | ·920 | ·948 | ·977 | ·005 | ·034 |
| brightness in steps | ·87 | ·90 | ·84 | ·61 | ·40 | ·00 |

Subsequently a new and sharper determination of the period was made using the 24 observations lying between the phases ·97 and ·02, which are on the steepest part of the ascending branch of the lightcurve. These observations are given in Table 4. The reduction of the J. D. to the brightness $^{s}$·55 was made according to the formula $^{d/s}$·1636 ($s$—·55).

A least square solution gave the period to be 1$^{d}$·583648 ± $^{d}$·000003 (m. e.) with a m. e. of ± $^{d}$·022 for the single epoch. This final period is so little different from the one used above that no new computation of the phases was deemed necessary. The brightness ranges between $^{s}$·2 and 1$^{s}$·0. The intermediary brightness $^{s}$·6 is reached on the rising branch of the lightcurve at the mean epoch J. D. 2419135·17.

TABLE 3.
S W Tauri

| number of plates | phase | brightness | number of plates | phase | brightness |
|---|---|---|---|---|---|
| | P | s | | P | s |
| 10 | ·011 | ·40 | 10 | ·515 | ·76 |
| 10 | ·025 | ·21 | 10 | ·541 | ·78 |
| 10 | ·038 | ·27 | 10 | ·553 | ·80 |
| 10 | ·055 | ·28 | 10 | ·572 | ·87 |
| 10 | ·074 | ·18 | 10 | ·591 | ·84 |
| 10 | ·088 | ·14 | 10 | ·607 | ·90 |
| 10 | ·103 | ·24 | 10 | ·634 | ·92 |
| 10 | ·113 | ·26 | 10 | ·647 | ·88 |
| 10 | ·126 | ·19 | 10 | ·656 | ·89 |
| 10 | ·146 | ·16 | 10 | ·669 | ·94 |
| 10 | ·167 | ·25 | 10 | ·681 | ·93 |
| 10 | ·181 | ·22 | 10 | ·693 | ·98 |
| 10 | ·200 | ·18 | 10 | ·705 | ·96 |
| 10 | ·214 | ·11 | 10 | ·720 | ·94 |
| 10 | ·230 | ·18 | 10 | ·739 | ·99 |
| 10 | ·244 | ·22 | 10 | ·764 | 1·01 |
| 10 | ·262 | ·27 | 10 | ·784 | 1·01 |
| 10 | ·278 | ·29 | 10 | ·798 | ·99 |
| 10 | ·293 | ·31 | 10 | ·818 | 1·01 |
| 10 | ·308 | ·34 | 10 | ·839 | ·96 |
| 10 | ·329 | ·45 | 10 | ·853 | ·91 |
| 10 | ·345 | ·54 | 10 | ·875 | ·99 |
| 10 | ·366 | ·54 | 9 | ·894 | ·91 |
| 10 | ·385 | ·65 | 9 | ·913 | ·90 |
| 10 | ·417 | ·65 | 9 | ·928 | ·89 |
| 10 | ·449 | ·71 | 8 | ·944 | ·86 |
| 10 | ·466 | ·71 | 9 | ·970 | ·70 |
| 10 | ·486 | ·75 | 9 | ·990 | ·61 |
| 10 | ·502 | ·80 | | | |

That the observations are scattered over nearly 30 years makes an accurate determination of the period possible, but the same fact prevents to make out, whether the differences in brightness observed at maximum light are wholly due to observational errors or partly to real differences between the lightcurves at different epochs.

As the period of SW Tauri is an unusual one for this type of variables, the question arises, whether such periods are rare, because stars do not keep them long. In view of this possibility SW Tauri deserves careful observation for change in period.

Another interesting question related to the intermediary period of SW Tauri is, whether the space-velocity of this star is high as is usually the case with variables of the RR Lyrae type or low as ordinarily found for δ Cephei stars.

From the differences between observations following each other in phase the mean error of a single estimate was found to be ± $^{s}$·113. From 150 such differences near maximum light a somewhat greater value of the m. e. is derived, viz. ± $^{s}$·14, while the 413 other differences indicate a m.e. of ± $^{s}$·10.

TABLE 4.
S W Tauri

| J. D. | observed brightness | reduction of J. D. to brightness $^{s}$·55 | fraction of J. D. reduced to brightness $^{s}$·55 | $O—C$ | epoch |
|---|---|---|---|---|---|
| d | s | d | d | d | |
| 2414906·872 | ·00 | — ·090 | ·782 | — ·055 | 0 |
| 14941·722 | ·35 | — ·033 | ·689 | + 12 | 22 |
| 15625·860 | ·40 | — ·025 | ·835 | + 23 | 454 |
| 16032·792 | ·40 | — ·025 | ·767 | — 44 | 711 |
| 16528·500 | ·42 | — ·021 | ·479 | — 13 | 1024 |
| 16843·649 | ·58 | + ·005 | ·654 | + 15 | 1223 |
| 16870·545 | ·70 | + ·025 | ·570 | + 10 | 1240 |
| 17258·589 | ·42 | — ·021 | ·568 | + 14 | 1485 |
| 18569·786 | ·75 | + ·033 | ·819 | + 4 | 2313 |
| 18680·646 | ·64 | + ·015 | ·661 | — 10 | 2383 |
| 18957·804 | ·64 | + ·015 | ·819 | + 10 | 2558 |
| 18984·762 | ·31 | — ·039 | ·723 | — 8 | 2575 |
| 19326·787 | ·68 | + ·021 | ·808 | + 9 | 2791 |
| 19337·868 | ·74 | + ·031 | ·899 | + 14 | 2798 |
| 19391·726 | ·64 | + ·015 | ·741 | + 13 | 2832 |
| 19472·512 | ·60 | + ·008 | ·520 | + 25 | 2883 |
| 20487·641 | ·32 | — ·038 | ·603 | — 10 | 3524 |
| 20775·838 | ·59 | + ·007 | ·845 | + 7 | 3706 |
| 21217·690 | ·62 | + ·011 | ·701 | + 26 | 3985 |
| 21540·763 | ·59 | + ·007 | ·770 | + 31 | 4189 |
| 21890·744 | ·40 | — ·025 | ·719 | — 7 | 4410 |
| 22593·845 | ·54 | — ·002 | ·843 | — 22 | 4854 |
| 24495·790 | ·61 | + ·010 | ·800 | — 27 | 6055 |
| 24495·835 | ·40 | — ·025 | ·810 | — 17 | 6055 |

## R S Orionis

This variable has been observed by LUIZET and MÜNCH, but their lightcurves do not agree very well with what should be expected according to *B. A. N.* **96**. The star was therefore taken up for examination at Harvard.

The comparison stars used are

| | B. D. | m | s | m |
|---|---|---|---|---|
| *a* | + 14°1258 | 8·7 | — ·113 | — ·14 |
| *b* | + 14°1260 | 8·4 | ·000 | ·00 |
| *c* | + 14°1262 | 9·1 | ·531 | ·61 |
| *d* | + 14°1275 | 9·4 | ·994 | 1·20 |

The differences in magnitude between the comparison stars have been determined by P. TH. OOSTERHOFF with the 34-cm Leiden refractor. According to this $1^{\rm s}$ is equivalent to $1^{\rm m}{\cdot}20$.

The mean values obtained are given in Table 5.

TABLE 5.

R S Orionis

| number of plates | phase | brightness | maen values of larger groups | | number of plates | phase | brightness | maen values of larger groups | |
|---|---|---|---|---|---|---|---|---|---|
| n | P | s | P | s | n | P | s | P | s |
| 10 | ·004 | ·03 | | | 10 | ·464 | ·50 | | |
| 10 | ·009 | ·01 | ·012 | —·014 | 10 | ·475 | ·60 | ·478 | ·571 |
| 10 | ·024 | —·08 | | | 10 | ·495 | ·61 | | |
| 10 | ·033 | —·08 | | | 10 | ·508 | ·62 | | |
| 10 | ·044 | —·06 | ·043 | —·082 | 10 | ·521 | ·71 | ·522 | ·673 |
| 10 | ·052 | —·10 | | | 10 | ·536 | ·68 | | |
| 10 | ·061 | —·10 | | | 10 | ·549 | ·68 | | |
| 10 | ·071 | —·09 | ·071 | —·099 | 10 | ·566 | ·73 | ·564 | ·708 |
| 10 | ·080 | —·10 | | | 10 | ·578 | ·71 | | |
| 10 | ·093 | —·06 | | | 10 | ·588 | ·73 | | |
| 10 | ·104 | —·07 | ·104 | —·056 | 10 | ·604 | ·77 | ·604 | ·739 |
| 10 | ·115 | —·03 | | | 10 | ·620 | ·72 | | |
| 10 | ·126 | —·00 | | | 10 | ·636 | ·82 | | |
| 10 | ·136 | —·04 | ·136 | —·005 | 10 | ·649 | ·80 | ·648 | ·808 |
| 10 | ·145 | ·03 | | | 10 | ·660 | ·81 | | |
| 10 | ·151 | ·06 | | | 10 | ·674 | ·80 | | |
| 10 | ·158 | ·02 | ·158 | +·024 | 10 | ·688 | ·87 | ·686 | ·841 |
| 10 | ·166 | —·00 | | | 10 | ·696 | ·85 | | |
| 10 | ·176 | ·12 | | | 10 | ·706 | ·89 | | |
| 10 | ·191 | ·09 | ·190 | +·094 | 10 | ·722 | ·86 | ·721 | ·894 |
| 10 | ·202 | ·07 | | | 10 | ·734 | ·93 | | |
| 10 | ·210 | ·09 | | | 10 | ·744 | ·80 | | |
| 10 | ·220 | ·11 | ·220 | ·139 | 10 | ·755 | ·91 | ·756 | ·872 |
| 10 | ·230 | ·22 | | | 10 | ·770 | ·91 | | |
| 10 | ·238 | ·18 | | | 10 | ·779 | ·90 | | |
| 10 | ·248 | ·19 | ·248 | ·201 | 10 | ·786 | ·92 | ·787 | ·917 |
| 10 | ·257 | ·24 | | | 10 | ·796 | ·93 | | |
| 10 | ·269 | ·15 | | | 10 | ·805 | ·87 | | |
| 10 | ·276 | ·24 | ·277 | ·199 | 10 | ·814 | ·89 | ·815 | ·875 |
| 10 | ·285 | ·21 | | | 10 | ·826 | ·86 | | |
| 10 | ·299 | ·22 | | | 10 | ·843 | ·80 | | |
| 10 | ·308 | ·21 | ·309 | ·211 | 10 | ·858 | ·75 | ·858 | ·735 |
| 10 | ·320 | ·21 | | | 10 | ·873 | ·66 | | |
| 10 | ·337 | ·20 | | | 10 | ·889 | ·68 | | |
| 10 | ·355 | ·20 | ·351 | ·220 | 10 | ·900 | ·67 | ·899 | ·664 |
| 10 | ·360 | ·26 | | | 10 | ·908 | ·64 | | |
| 10 | ·369 | ·29 | | | 10 | ·920 | ·52 | | |
| 10 | ·384 | ·27 | ·383 | ·297 | 10 | ·928 | ·49 | ·928 | ·460 |
| 10 | ·397 | ·34 | | | 10 | ·938 | ·36 | | |
| 10 | ·417 | ·42 | | | 10 | ·948 | ·40 | | |
| 10 | ·430 | ·41 | ·428 | ·423 | 10 | ·957 | ·38 | ·957 | ·338 |
| 10 | ·436 | ·44 | | | 10 | ·968 | ·23 | | |
| 10 | ·441 | ·42 | | | 10 | ·972 | ·23 | | |
| 10 | ·450 | ·52 | ·449 | ·469 | 12 | ·981 | ·14 | ·983 | ·149 |
| 10 | ·456 | ·47 | | | 13 | ·994 | ·10 | | |

The shape of the lightcurve is seen to resemble closely that of other δ Cephei variables of similar period, though the secondary wave on the descending branch is less pronounced than usually.

According to OOSTERHOFF the comparison star *a* is $1^{\rm m}{\cdot}34$ fainter than BD + 14°1254, which is again estimated to be equal to BD + 14°1247. For the latter star the photographic Göttingen magnitude is $7^{\rm m}{\cdot}44$. RS Orionis varies between $-{}^{\rm s}{\cdot}10$ and $+{}^{\rm s}{\cdot}91$, thus corresponding to the limits $8^{\rm m}{\cdot}8$ and $10^{\rm m}{\cdot}0$ on the scale of the Göttingen Actinometry.

A least square solution of 92 epochs derived from observations on the ascending branch of the lightcurve gave the period

$$7^{\rm d}{\cdot}566699 \pm {}^{\rm d}{\cdot}000041 \text{ (m. e.)}.$$

## W Geminorum

The lightcurve of this variable as given by LUIZET (*A. N.* 4056, **169**, 403; 1905) shows an unusually marked secondary maximum at the ordinary phase on the descending branch. For this reason the star was put on my Harvard programme.

The comparison stars used are

| | | s | m |
|---|---|---|---|
| *b* | + 15°1255 | ·000 | 7·47 |
| *c* | + 15°1230 | ·256 | 7·78 |
| *d* | + 15°1233 | ·695 | 8·39 |

The magnitudes are from the Götttingen Actinometry. According to this $1^{\rm s} = 1^{\rm m}{\cdot}33$.

The mean values obtained are given in Table 6.

The shape of the lightcurve is quite normal for δ Cephei stars of similar period. The star varies between $-{}^{\rm s}{\cdot}22$ and ${}^{\rm s}{\cdot}74$ or $7^{\rm m}{\cdot}18$ and $8^{\rm m}{\cdot}45$ on the scale of the Göttingen Actinometry.

TABLE 6.

W Geminorum

| number of plates | phase | brightness | mean values of larger groups | | number of plates | phase | brightness | mean values of larger groups | |
|---|---|---|---|---|---|---|---|---|---|
| n | P | s | P | s | n | P | s | P | s |
| 10 | ·005 | ·08 | | | 10 | ·141 | — ·05 | ·146 | —·076 |
| 10 | ·018 | — ·12 | ·016 | —·073 | 10 | ·151 | — ·06 | | |
| 10 | ·026 | — ·18 | | | 10 | ·162 | — ·08 | | |
| 10 | ·040 | — ·14 | | | 10 | ·175 | — ·02 | | |
| 10 | ·049 | — ·19 | ·050 | —·181 | 10 | ·184 | — ·09 | ·184 | —·044 |
| 10 | ·059 | — ·22 | | | 10 | ·193 | — ·02 | | |
| 10 | ·066 | — ·25 | | | 10 | ·202 | ·04 | | |
| 10 | ·071 | — ·25 | ·071 | —·248 | 10 | ·211 | — ·01 | ·211 | +·022 |
| 10 | ·077 | — ·24 | | | 10 | ·219 | ·03 | | |
| 10 | ·087 | — ·14 | | | 10 | ·234 | ·08 | | |
| 10 | ·099 | — ·14 | ·104 | —·154 | 10 | ·250 | ·15 | ·250 | +·089 |
| 10 | ·108 | — ·11 | | | 10 | ·264 | ·04 | | |
| 10 | ·120 | — ·22 | | | 10 | ·273 | ·12 | | |
| 10 | ·129 | — ·12 | | | 10 | ·284 | ·04 | ·282 | +·070 |

TABLE 6. (*Continued.*)

| number of plates | phase | brightness | mean values of larger groups | | number of plates | phase | brightness | mean values of larger groups | |
|---|---|---|---|---|---|---|---|---|---|
| n | P | s | P | s | n | P | s | P | s |
| 10 | ·291 | ·06 | | | 10 | ·650 | ·67 | | |
| 10 | ·299 | ·09 | | | 10 | ·662 | ·65 | | |
| 10 | ·307 | — ·02 | ·307 | +·034 | 10 | ·676 | ·68 | ·668 | ·681 |
| 10 | ·316 | ·03 | | | 10 | ·682 | ·72 | | |
| 10 | ·325 | ·00 | | | 10 | ·688 | ·69 | | |
| 10 | ·336 | ·05 | ·335 | +·054 | 10 | ·696 | ·70 | | |
| 10 | ·344 | ·11 | | | 10 | ·702 | ·72 | ·699 | ·685 |
| 10 | ·351 | — ·06 | | | 10 | ·710 | ·64 | | |
| 10 | ·358 | ·03 | ·358 | +·040 | 10 | ·716 | ·72 | | |
| 10 | ·366 | ·15 | | | 10 | ·723 | ·72 | | |
| 10 | ·372 | ·10 | | | 10 | ·731 | ·70 | ·727 | ·726 |
| 10 | ·382 | ·02 | ·381 | +·075 | 10 | ·738 | ·76 | | |
| 10 | ·388 | ·10 | | | 10 | ·744 | ·73 | | |
| 10 | ·394 | ·12 | | | 10 | ·751 | ·73 | ·756 | ·730 |
| 10 | ·404 | ·20 | ·404 | +·197 | 10 | ·760 | ·73 | | |
| 10 | ·414 | ·27 | | | 10 | ·772 | ·73 | | |
| 10 | ·422 | ·34 | | | 10 | ·781 | ·70 | | |
| 10 | ·432 | ·36 | ·434 | +·352 | 10 | ·790 | ·71 | ·796 | ·738 |
| 10 | ·447 | ·36 | | | 10 | ·802 | ·76 | | |
| 10 | ·460 | ·46 | | | 10 | ·809 | ·78 | | |
| 10 | ·472 | ·49 | ·470 | +·493 | 10 | ·817 | ·74 | | |
| 10 | ·478 | ·53 | | | 10 | ·831 | ·74 | ·836 | ·724 |
| 10 | ·485 | ·49 | | | 10 | ·841 | ·71 | | |
| 10 | ·497 | ·49 | ·496 | +·481 | 10 | ·854 | ·70 | | |
| 10 | ·506 | ·46 | | | 10 | ·865 | ·74 | | |
| 10 | ·516 | ·50 | | | 10 | ·878 | ·66 | ·878 | ·692 |
| 10 | ·530 | ·59 | ·528 | +·523 | 10 | ·891 | ·67 | | |
| 10 | ·539 | ·48 | | | 10 | ·901 | ·56 | | |
| 10 | ·552 | ·52 | | | 10 | ·911 | ·62 | ·910 | ·583 |
| 10 | ·563 | ·62 | ·563 | ·589 | 10 | ·919 | ·57 | | |
| 10 | ·576 | ·62 | | | 10 | ·930 | ·51 | | |
| 10 | ·582 | ·64 | | | 10 | ·938 | ·38 | ·937 | ·449 |
| 10 | ·590 | ·51 | ·593 | ·612 | 10 | ·943 | ·46 | | |
| 10 | ·595 | ·63 | | | 10 | ·952 | ·33 | | |
| 10 | ·605 | ·68 | | | 10 | ·959 | ·28 | ·959 | ·311 |
| 10 | ·613 | ·61 | | | 10 | ·966 | ·32 | | |
| 10 | ·622 | ·67 | ·628 | ·653 | 10 | ·976 | ·29 | | |
| 10 | ·633 | ·68 | | | 8 | ·987 | ·13 | ·981 | ·167 |
| 10 | ·643 | ·66 | | | 8 | ·994 | ·14 | | |

## X Puppis

The variability of X Puppis was discovered by KAPTEYN on C. P. D. plates (*A. N.* 2987). The period was found by INNES (*A. J.* 485), who observed the star systematically from 1899 Febr. 14 to 1900 Febr. 5, making in all 62 visual estimates. Unfortunately, one of the most convenient comparison stars used by INNES, viz. C. P. D. — 20°2574, has afterwards proved to be a variable itself. This may partly account for the difference in shape of the lightcurve found by INNES and of that derived here.

The comparison stars used for my estimates on Harvard plates are

| | C. P. D. | m | s |
|---|---|---|---|
| *a* | — 20°2587 | 8·5 | ·000 |
| *x* | — 20 2662 | 8·5 | ·278 |
| *y* | — 20°2666 | 8·5 | ·498 |
| *c* | — 20 2615 | 8·9 | 1·048 |
| *d* | — 20 2601 | 9·1 | 1·518 |
| *e* | — 20 2567 | 9·4 | 1·959 |
| *f* | — 20 2564 | 9·8 | 2·535 |

The mean values obtained are given in Table 7. The shape of the lightcurve is quite normal for δ Cephei stars of similar period.

The few observations available earlier or later than those used here do not seem to fit the adopted period well. On the plate B 4340 taken J. D. 2411279·877 corresponding to the phase ·578, my estimate is $1^s$·03, while $^s$·27 is read off from the curve. On 2 AC and 2 AY plates from 1926 Dec. 4, J. D. 2424854·826, phase ·577, my mean estimate is $^s$·87 or $^s$·59 fainter than read from the curve. These figures indicate an increase of the period, but further observations are needed to settle the question.

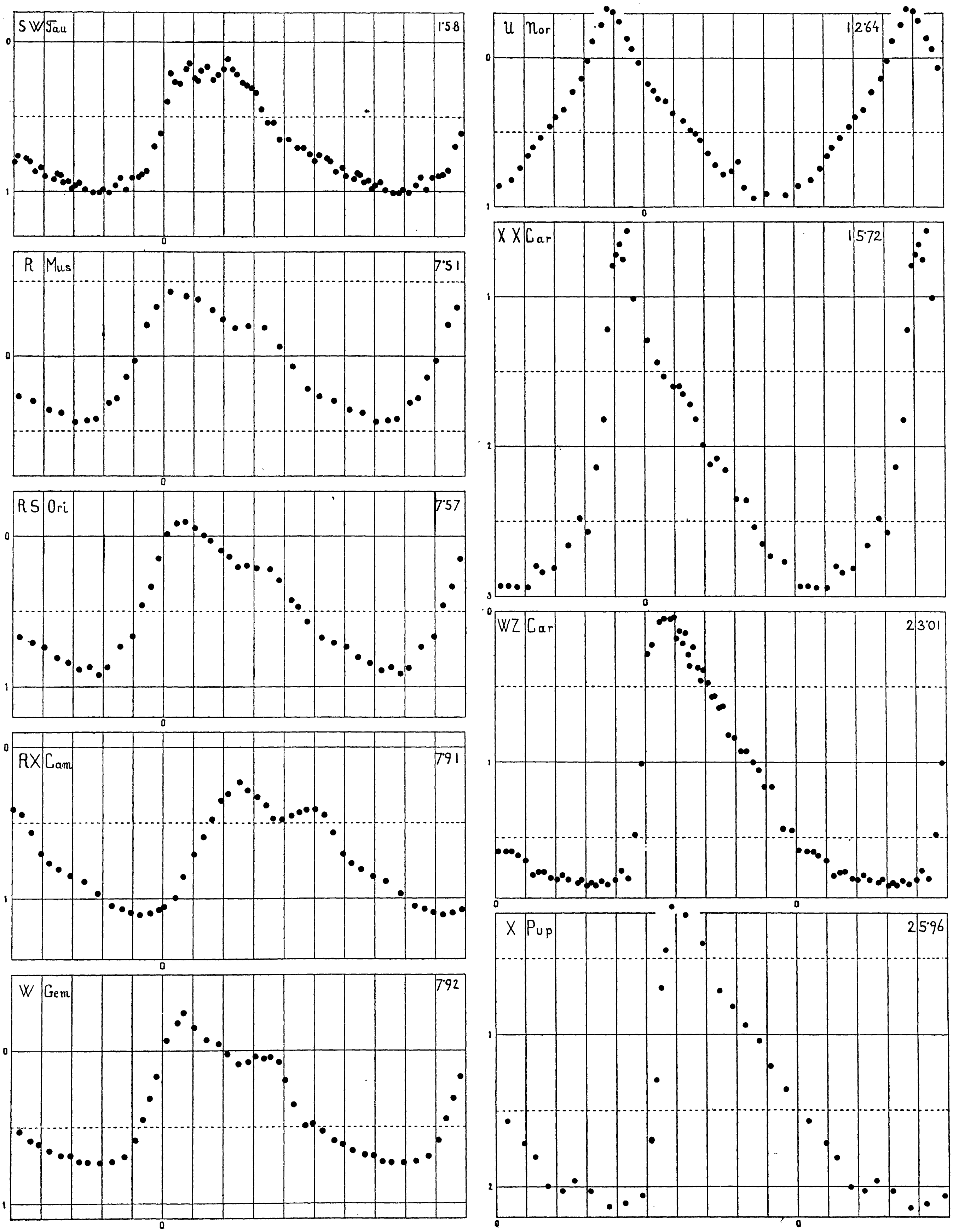
TABLE 7.

X Puppis

| number of plates | phase | brightness | mean values of larger groups | | number of plates | phase | brightness | mean values of larger groups | |
|---|---|---|---|---|---|---|---|---|---|
| n | P | s | P | s | n | P | s | P | s |
| 10 | ·016 | 1·50 | | | 10 | ·532 | 1·30 | | |
| 10 | ·038 | 1·52 | ·038 | 1·572 | 10 | ·550 | ·69 | | |
| 10 | ·060 | 1·69 | | | 10 | ·565 | ·44 | | |
| 10 | ·084 | 1·69 | ·094 | 1·718 | 10 | ·587 | ·15 | | |
| 10 | ·104 | 1·75 | | | 10 | ·616 | ·23 | ·630 | ·210 |
| 10 | ·121 | 1·84 | ·130 | 1·807 | 10 | ·644 | ·19 | | |
| 10 | ·139 | 1·77 | | | 10 | ·674 | ·32 | ·688 | ·400 |
| 10 | ·159 | 1·93 | ·176 | 2·000 | 10 | ·702 | ·48 | | |
| 10 | ·194 | 2·07 | | | 10 | ·729 | ·66 | ·742 | ·715 |
| 10 | ·209 | 2·07 | ·220 | 2·026 | 10 | ·755 | ·77 | | |
| 10 | ·230 | 1·98 | | | 10 | ·774 | ·85 | ·783 | ·823 |
| 10 | ·250 | 1·92 | ·260 | 1·960 | 10 | ·792 | ·80 | | |
| 10 | ·271 | 2·00 | | | 10 | ·816 | ·88 | ·828 | ·938 |
| 10 | ·294 | 1·98 | ·315 | 2·028 | 10 | ·841 | ·99 | | |
| 10 | ·335 | 2·07 | | | 10 | ·861 | ·96 | ·872 | 1·036 |
| 10 | ·358 | 2·12 | ·373 | 2·136 | 10 | ·882 | 1·11 | | |
| 10 | ·389 | 2·15 | | | 10 | ·902 | 1·11 | ·915 | 1·210 |
| 10 | ·413 | 2·17 | ·428 | 2·110 | 10 | ·927 | 1·31 | | |
| 10 | ·442 | 2·05 | | | 12 | ·946 | 1·33 | ·963 | 1·356 |
| 10 | ·484 | 2·06 | | | 12 | ·980 | 1·38 | | |
| 10 | ·512 | 1·70 | | | | | | | |

## W Z Carinae

The period of this variable is so near to 23 days, that during the time covered by the Johannesburg series of the η Carinae region practically only 23 points of the lightcurve were obtained. The greatest part of the steep rising branch of the lightcurve remained unobserved. As the Harvard plates are scattered over


SW Tau
1·58
R Mus
7·51
RS Ori
7·57
RX Cam
7·91
W Gem
7·92
U Nor
12·64
XX Car
15·72
WZ Car
23·01
X Pup
25·96

many years they would give a more complete light-curve.

The comparison stars used are

C. P. D.

| | | | |
|---|---|---|---|
| | | m | s |
| *r* | — 60°2411 | 8·5 | ·000 |
| *t* | — 60°2385 | 8·8 | ·474 |
| *q* | — 60°2408 | 9·2 | ·671 |
| *s* | — 60°2396 | 9·3 | ·930 |
| *x* | — 60°2381 | 9·4 | 1·285 |
| *u* | — 60°2391 | 9·9 | 1·699 |
| *y* | $10^h50^m20^s$, — 60°18′·5 (1875) | | 2·134 |

39 of the plates used here had already been estimated before at Harvard (*H. C.* 170). The comparison with the present estimates in steps showed that $1^m$ on the Harvard scale (*l. c.*) is equal to $1^s{\cdot}1$ and that $^s{\cdot}9$ corresponds to the magnitude $9^m{\cdot}3$.

The mean values obtained are given in Table 8.

As the observations on the steep part of the rising branch are of special interest, they are given in detail in Table 9.

TABLE 8.

W Z Carinae

| number of plates | phase | brightness | number of plates | phase | brightness |
|---|---|---|---|---|---|
| n | P | s | n | P | s |
| 10 | ·008 | 1·59 | 10 | ·583 | ·05 |
| 10 | ·036 | 1·59 | 10 | ·594 | ·04 |
| 10 | ·055 | 1·59 | 10 | ·606 | ·18 |
| 10 | ·075 | 1·62 | 10 | ·613 | ·13 |
| 10 | ·100 | 1·65 | 10 | ·625 | ·21 |
| 10 | ·123 | 1·75 | 10 | ·636 | ·14 |
| 10 | ·147 | 1·73 | 10 | ·642 | ·29 |
| 10 | ·161 | 1·73 | 10 | ·648 | ·36 |
| 10 | ·186 | 1·77 | 10 | ·659 | ·23 |
| 10 | ·203 | 1·78 | 10 | ·673 | ·37 |
| 10 | ·221 | 1·75 | 10 | ·684 | ·46 |
| 10 | ·242 | 1·78 | 10 | ·692 | ·39 |
| 10 | ·271 | 1·80 | 10 | ·709 | ·47 |
| 10 | ·286 | 1·78 | 10 | ·722 | ·57 |
| 10 | ·305 | 1·82 | 10 | ·731 | ·56 |
| 10 | ·320 | 1·80 | 10 | ·747 | ·64 |
| 10 | ·333 | 1·82 | 10 | ·759 | ·63 |
| 10 | ·351 | 1·79 | 10 | ·778 | ·82 |
| 10 | ·371 | 1·81 | 10 | ·799 | ·84 |
| 10 | ·399 | 1·78 | 10 | ·817 | ·93 |
| 10 | ·419 | 1·72 | 10 | ·836 | ·93 |
| 10 | ·440 | 1·77 | 10 | ·858 | 1·00 |
| 10 | ·463 | 1·48 | 10 | ·876 | 1·07 |
| 10 | ·484 | 1·01 | 10 | ·893 | 1·16 |
| 10 | ·508 | ·28 | 10 | ·920 | 1·16 |
| 10 | ·522 | ·22 | 12 | ·958 | 1·44 |
| 10 | ·549 | ·07 | 12 | ·987 | 1·45 |
| 10 | ·562 | ·05 | | | |

TABLE 9.

W Z Carinae

(single observations on the rising branch).

| number of plates | phase | brightness | number of plates | phase | brightness |
|---|---|---|---|---|---|
| d | P | s | d | P | s |
| 2422670·837 | ·456 | 1·76 | 2418093·580 | ·492 | ·67: |
| 21336·543 | ·457 | 1·70 | 20670·487 | ·505 | ·61 |
| 21336·630 | ·461 | 1·68 | 16644·586 | ·507 | ·01 |
| 16643·589 | ·464 | 1·22 | 16253·540 | ·509 | ·12 |
| 17241·747 | ·464 | 1·22 | 16575·613 | ·509 | ·15 |
| 20623·566 | ·465 | 1·70 | 20601·590 | ·510 | ·42 |
| 24649·519 | ·465 | 1·57 | 20624·607 | ·510 | ·00 |
| 20278·505 | ·466 | 1·56: | 16575·660 | ·511 | ·23 |
| 17287·788 | ·466 | 1·30 | 15885·533 | ·512 | ·25 |
| 16942·746 | ·467 | 1·11 | 19957·507 | ·513 | ·34 |
| 16459·855 | ·477 | ·89 | 20279·618 | ·514 | ·30 |
| 15470·668 | ·479 | 1·28 | 20601·688 | ·514 | ·40 |
| 23246·510 | ·479 | 1·49 | 19543·508 | ·517 | ·25 |
| 23522·618 | ·481 | 1·11 | 19911·611 | ·518 | ·32 |
| 23798·758 | ·484 | ·93: | 19566·573 | ·520 | ·32 |
| 15723·852 | ·484 | ·88: | 19888·674 | ·521 | ·01 |
| 23154·601 | ·484 | ·93 | 19543·609 | ·522 | ·29 |
| 22165·493 | ·490 | ·93 | 23822·624 | ·522 | ·26 |
| 13699·496 | ·490 | 1·21 | 22488·539 | ·532 | ·02 |
| 18093·558 | ·491 | ·47 | 18071·562 | ·535 | ·00 |

## X X Carinae

This variable is just outside the Johannesburg series of plates of the $\eta$ Carinae region. According to *B. A. N.* **96** its period of $15^d{\cdot}7$ corresponds to a characteristic shape of the lightcurve, the latter part of the rising branch being very steep. The star was therefore placed on my Harvard programme.

The comparison stars used are

C. P. D.

| | | | |
|---|---|---|---|
| | | m | s |
| *z* | — 65°1586 | 8·5 | ·000 |
| *s* | — 64°1604 | 8·8 | ·749 |
| *p* | — 64°1557 | 9·0 | 1·226 |
| *t* | — 64°1585 | 9·3 | 1·861 |
| *x* | — 64°1563 | 9·2 | 2·358 |
| *y* | — 64°1549 | 9·4 | 2·888 |

In the same way as in the case of W Z Car 37 plates formerly estimated at Harvard (*H. C.* 170) gave also in the present case $\Delta m = 1$ equivalent to $\Delta s = 1{\cdot}1$. To $1^s{\cdot}8$ corresponds the magnitude $9^m{\cdot}6$.

The mean values obtained are given in Table 10.

The shape of the lightcurve is in good agreement with what was expected.

TABLE 10.
X X Carinae

| number of plates | phase | brightness | number of plates | phase | brightness |
|---|---|---|---|---|---|
| n | P | s | n | P | s |
| 10 | ·009 | 1·29 | 10 | ·544 | 2·93 |
| 10 | ·042 | 1·44 | 10 | ·572 | 2·94 |
| 10 | ·064 | 1·53 | 10 | ·609 | 2·94 |
| 10 | ·096 | 1·60 | 10 | ·637 | 2·80 |
| 10 | ·117 | 1·60 | 10 | ·658 | 2·84 |
| 10 | ·128 | 1·65 | 10 | ·695 | 2·81 |
| 10 | ·151 | 1·72 | 10 | ·741 | 2·66 |
| 10 | ·171 | 1·82 | 10 | ·781 | 2·48 |
| 10 | ·194 | 1·99 | 10 | ·809 | 2·57 |
| 10 | ·218 | 2·02 | 10 | ·836 | 2·14 |
| 10 | ·242 | 2·08 | 10 | ·862 | 1·82 |
| 10 | ·270 | 2·16 | 10 | ·876 | 1·22 |
| 10 | ·306 | 2·35 | 10 | ·894 | ·79 |
| 10 | ·338 | 2·36 | 10 | ·905 | ·72 |
| 10 | ·365 | 2·54 | 10 | ·916 | ·65 |
| 10 | ·392 | 2·65 | 10 | ·929 | ·75 |
| 10 | ·417 | 2·73 | 10 | ·942 | ·56 |
| 10 | ·466 | 2·77 | 10 | ·962 | 1·01 |
| 10 | ·518 | 2·93 | | | |

## R Muscae

The period of nearly $^{d}$·9 indicated by GOULD and ROBERTS for this variable would be very unusual for a star of this kind. In fact, the estimates made on Harvard plates show, as already mentioned in *B. A. N.* **116**, that the reciprocal period is ·13 and not 1·13 $d^{-1}$.

The comparison stars used are

| | C. P. D. | m | Sp. | s |
|---|---|---|---|---|
| *a* | — 68° 1745 | 7·3 | G 0 | ·00 |
| *b* | — 68° 1744 | 7·4 | A 2 | ·44 |

For the difference in steps between *a* and *b* $^{s}$·44 has been adopted in the reductions. The mean of all estimates of this difference is $^{s}$·477.

The mean values obtained are given in Table 11.

According to GOULD (*Uranometria Argentina*, 258) "A laborious and very excellent series of observations "was begun by Mr. ROCK in Aug. 1871, and continued "for a considerable period." Perhaps it would be possible to derive a useful old epoch from these observations, if they are available in detail.

The numerous observations by ROBERTS of this star have not yet been published.

TABLE 11.
R Muscae.

| number of plates | phase | brightness | mean values of larger groups | | number of plates | phase | brightness | mean values of larger groups | |
|---|---|---|---|---|---|---|---|---|---|
| n | P | s | P | s | n | P | s | P | s |
| 10 | ·012 | —·42 | | | 10 | ·552 | +·25 | | |
| 10 | ·023 | —·45 | ·025 | —·43 | 10 | ·562 | +·29 | ·565 | +·30 |
| 10 | ·039 | —·41 | | | 10 | ·580 | +·36 | | |
| 10 | ·062 | —·42 | | | 10 | ·601 | +·35 | | |
| 10 | ·078 | —·40 | ·075 | —·40 | 10 | ·615 | +·37 | ·618 | +·36 |
| 10 | ·086 | —·39 | | | 10 | ·625 | +·31 | | |
| 10 | ·096 | —·44 | | | 10 | ·630 | +·39 | | |
| 10 | ·109 | —·34 | ·112 | —·38 | 10 | ·638 | +·33 | | |
| 10 | ·130 | —·36 | | | 10 | ·650 | +·33 | ·660 | +·38 |
| 10 | ·153 | —·37 | | | 10 | ·671 | +·41 | | |
| 10 | ·163 | —·34 | ·162 | —·31 | 10 | ·680 | +·45 | | |
| 10 | ·172 | —·23 | | | 10 | ·687 | +·46 | | |
| 10 | ·181 | —·24 | | | 10 | ·695 | +·42 | | |
| 10 | ·198 | —·32 | ·199 | —·25 | 10 | ·708 | +·41 | ·703 | +·44 |
| 10 | ·218 | —·17 | | | 10 | ·722 | +·47 | | |
| 10 | ·226 | —·16 | | | 10 | ·735 | +·46 | | |
| 10 | ·240 | —·20 | ·239 | —·19 | 10 | ·748 | +·43 | ·747 | +·43 |
| 10 | ·251 | —·21 | | | 10 | ·757 | +·40 | | |
| 10 | ·266 | —·23 | | | 10 | ·767 | +·40 | | |
| 10 | ·283 | —·14 | ·282 | —·20 | 10 | ·774 | +·45 | ·775 | +·42 |
| 10 | ·298 | —·23 | | | 10 | ·784 | +·40 | | |
| 10 | ·314 | —·18 | | | 10 | ·808 | +·32 | | |
| 10 | ·333 | —·24 | ·334 | —·19 | 10 | ·816 | +·31 | ·818 | +·31 |
| 10 | ·354 | —·17 | | | 10 | ·830 | +·31 | | |
| 10 | ·367 | —·13 | | | 10 | ·838 | +·28 | ·844 | +·28 |
| 10 | ·383 | —·01 | ·384 | —·06 | 10 | ·850 | +·27 | | |
| 10 | ·401 | —·05 | | | 10 | ·867 | +·14 | ·876 | +·14 |
| 10 | ·419 | —·00 | | | 10 | ·884 | +·14 | | |
| 10 | ·430 | +·15 | ·430 | +·07 | 10 | ·895 | +·06 | ·903 | +·03 |
| 10 | ·443 | +·05 | | | 10 | ·910 | +·00 | | |
| 10 | ·469 | +·22 | | | 10 | ·936 | —·17 | ·944 | —·21 |
| 10 | ·489 | +·21 | ·479 | +·22 | 10 | ·951 | —·25 | | |
| 10 | ·503 | +·31 | | | 10 | ·964 | —·31 | | |
| 10 | ·515 | +·26 | ·519 | +·27 | 10 | ·973 | —·24 | ·976 | —·33 |
| 10 | ·539 | +·25 | | | 12 | ·989 | —·41 | | |

## U Normae

The character of the variaton of this star was already known to be quite normal for δ Cephei variables of similar periods. The star was estimated on Harvard plates only to verify the earlier results found by INNES, ROBERTS and WORSSELL.

The comparison stars used are

| | C. P. D. | m | s |
|---|---|---|---|
| *A* | — 55° 6680 | 9·4 | ·000 |
| *a* | — 54° 6649 | 9·6 | ·258 |
| *b* | — 54° 6645 | 9·8 | ·632 |
| *c* | $15^{h}\,34^{m}$·0, — 55° 3′ (1875) | | 1·014 |

The mean results obtained are given in Table 12.

The lightcurve is nearly symmetrical and the maximum is much more pointed than the minimum. The maximum occurs at the phase ·905 and its mean epoch is J. D. 2419200·47. No correction to the period of WORSSELL was found.