The variable stars R Sagittae, V Vulpeculae, RV Tauri

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RECHERCHES ASTRONOMIQUES DE L'OBSERVATOIRE D'UTRECHT

VI

STELLINGEN

STELLINGEN.

I

Het karakter der lichtwisseling van *R V Tauri* tusschen J D 7129 en J D 7687 is onbekend.

II

De uitkomsten aangaande *S S Cygni,* door WHITTAKER en GIBB afgeleid met behulp van het periodogram dezer ster, hebben geen waarde.

III

NIJLAND heeft als kenmerk van zijne interpolatie-methode aangegeven, dat het schatten der *verhoudingen* van de in „Stufen" uitgedrukte helderheidsverschillen hoofdzaak is, de absolute waarde van deze verschillen bijzaak. Men moet echter beide schattingen als even belangrijk beschouwen.

IV

Ten onrechte meent SHAPLEY bij de afleiding van de lichtkromme eener *Algol*-veranderlijke, stufenwaarnemingen te mogen verwerpen wanneer hij tevens over photometrische waarnemingen kan beschikken.

The Astrophysical Journal XXXVIII No. 2.

V

Aan beschouwingen, zooals KIESS, MARTIN en PLUMMER en ten slotte PRAGER gegeven hebben over *R R Lyrae,* had een kritisch onderzoek van het waarnemingsmateriaal vooraf behooren te gaan.

Lick Bulletins VII; Monthly Notices LXXV; Sitzungsberichte der Königl. Preuss. Akademie der Wissenschaften 1916 VIII.

VI

Het optreden van „stationnaire" radianten is door W. H. PICKERING voldoende verklaard.

The Astrophysical Journal XXIX.

VII

De meening van EASTON dat ons zonnestelsel zich dichter bij *Cygnus* dan bij *Argo* bevindt, heeft door sterren-tellingen steun gevonden.

VIII

De radiale verdeeling der straling over de zonne-schijf is voor de lange golven gelijkmatig.

IX

Voor het onderzoek van de wisselende samenstelling van den dampkring der aarde zijn stralingsmetingen onontbeerlijk.

X

Het is niet aan te nemen dat bij het tot stand komen der geluidstiltegordels, de bovenste lagen van den dampkring een rol spelen.

Versl. Kon. Ak. v. Wetensch. Amsterdam XXIV. Hemel en Dampkring 12_6.

XI

De door VAN LOHUIZEN bij de afleiding van zijne spectraalformule toegepaste benadering is niet geoorloofd.

T. VAN LOHUIZEN. Bijdrage tot de kennis van lijnenspectra. Den Haag 1912.

XII

De beoefening der sterrenkunde in Nederland zou er bij gebaat zijn, wanneer een der sterrenwachten werd vrijgemaakt van het Universitair verband.

XIII

De strijd tegen den oorlog zal eer gewonnen worden door de beoefenaars der natuurwetenschappen, dan door de pacifisten.

Diss. Utrecht 1916

94.

THE VARIABLE STARS R SAGITTÆ V VULPECULÆ RV TAURI

PART I

AN ANALYSIS OF THE LIGHT-CURVE OF RV TAURI

PROEFSCHRIFT

TER VERKRIJGING VAN DEN GRAAD VAN DOCTOR IN DE WIS- EN STERRENKUNDE AAN DE RIJKS-UNIVERSITEIT TE UTRECHT OP GEZAG VAN DEN RECTOR-MAGNIFICUS DR. ERNST COHEN HOOG-LEERAAR IN DE FACULTEIT DER WIS- EN NATUUR-KUNDE VOLGENS BESLUIT VAN DEN SENAAT DER UNIVERSITEIT TEGEN DE BEDENKINGEN VAN DE FACULTEIT DER WIS- EN NATUURKUNDE TE VERDEDIGEN OP VRIJDAG 7 APRIL 1916 DES NA-MIDDAGS TE 4 UUR DOOR

JAN VAN DER BILT

GEBOREN TE KAPELLE (ZUID-BEVELAND)

DRUKKERIJ J. VAN BOEKHOVEN — UTRECHT

RECHERCHES ASTRONOMIQUES

DE L'OBSERVATOIRE D'UTRECHT

VI

UTRECHT
J. VAN BOEKHOVEN
1916

THE VARIABLE STARS

R Sagittæ *V Vulpeculæ* *RV Tauri*

BY

J. VAN DER BILT

OBSERVATOR AT THE UTRECHT OBSERVATORY

PART I

An analysis of the light-curve of *RV Tauri*

CONTENTS.

INTRODUCTION.

Ten years ago, at a meeting of the Dutch Physical and Medical Congress, Prof. Dr. A. A. NIJLAND, Director of the Utrecht Observatory, maintained the view that the variable stars of the *Mira* type must be considered as a physically connected class, not only on account of the well known correlation between their periods and their colours, but also on account of the fact that the lengths of their periods are grouped around the mean value of 300 days, according to the probability-curve. The number of variable stars and the knowledge of their elements have been considerably increased since then, and it is worth while to see whether NIJLAND's view still holds good. If we take the periods from the latest publication available (E. HARTWIG, Katalog und Ephemeriden veränderlicher Sterne für 1915), and if we consider all the periods in excess of 100 days, the material consists of 532 periods, ranging from 100 to 698 days. The mean period is 297, the probable error 64; the first of these quantities (the mean period) enables us to give the *observed* number of deviations from the mean, between successive limits; the second quantity enables us to *calculate* the same numbers, considering these deviations to be "accidental errors".

The results are given in the following table:

Number of errors	O	C	O—C
between 0^d and 40^d	174	174	0
,, 40 ,, 80	158	146	+12
,, 80 ,, 120	100	102	— 2
,, 120 ,, 160	55	61	— 6
,, 160 ,, 200	31	30	+ 1
above 200 days	14	19	— 5

This table shows that the agreement is all that can be desired, seeing that the assumed number of 100 days for the shortest period is somewhat arbitrary, and only the periods, not the light-curves, have been considered, whereas it is not certain whether all the stars with periods of about 100 days show a light-variation of the *Mira* type.

Since in the Ephemeris there are 117 stars of the *Algol* class, 82 *Cepheids*, 17 and 8 stars belonging to the β *Lyrae* and ζ *Geminorum* types respectively, and 4 stars, which show the characteristic light-variation of *U Geminorum*, making a total of 760 stars belonging to definite classes, we may conclude, in accordance with our present knowledge, that 55 % of the variable stars have not yet been admitted to the typical classes. Nor has there been in the last 60 years any reason to establish a new class of variable stars.

There is perhaps one exception. At the close of a paper by F. H. Seares and E. S. Haynes, concerning the light-changes of *R V* = *V* 14 *Tauri* *) (period about 79 days), after observations made at the Laws Observatory of the University of Missouri, between 1906 Nov. 27 and 1908 March 11, the following interesting remark occurs:

"The unusual character of the variation, recorded by these observa-
"tions recalls that of the stars *R Sagittae* and *V Vulpeculae*, both of which
"have been classed as of the *Beta Lyrae* type, and both of whose light-curves
"have undergone very curious changes"

And further on:

"Thus far it has not been possible to formulate a satisfactory theory,
"accounting for the alterations of light-curve in either *R Sagittae* or *V Vulpe-*
"*culae*. The discovery of a third object presenting some points of resemblance
"to these stars is therefore a matter of considerable interest".

In these sentences we find, mentioned in the same connection, the names of three stars, none of which belong to the *Mira* variables or to any of the three standard types of short period variables, the light-variations of which however seem to be ruled by the same (apparently complicated) law.

*) See "Astronomische Nachrichten" no. 4765.

Let us first consider the data on which the remarks of SEARES and HAYNES are based.

The variability of the star *R Sagittae* was detected in the year 1859 by J. BAXENDELL SR., whose first series of observations showed the occurrence in the light-curve of a distinctly marked secondary minimum between each of two principal minima, thus presenting a similarity with the *β Lyrae* type. But the period was much longer ($70^d.88$) and the light-curve far less regular, since the maxima preceding and following a principal minimum had unequal brightness; and the elements, computed from observations extending over a period of 9 minima, could only represent these with residuals to an amount of 3 days. Thus, BAXENDELL concluded that "this star may "be ranked in the class of moderately regular variables".

Till 1865 *R Sagittae* was only observed by its discoverer, but in that year E. SCHÖNFELD became interested in the star, and his observations soon led him to the same conviction, that no mean curve can exactly represent the remarkable light-variation. In the "Astronomische Nachrichten" no. 1857 he deals elaborately with the observations made by BAXENDELL and himself up to the year 1871, producing the first, but at the same time the last treatise on this variable. It had been proved already that the elements derived from his earlier observations gave the epochs of minimum brightness too early, and that many principal minima of the years 1869 and 1870 were much fainter than those of the years 1865 and 1866. Though for his exhaustive discussion 25 principal minima were available, extending over 58 periods of about 70 days, and a quadratic term had been involved in the formula, there remained large residuals.

This formula ran as follows:

Ep. of min. = 1865 Oct. 24.587 + $70^d.42338\ (E-31) - 0^d.0037369\ (E-31)^2$.

The residuals have the largest values around the principal minima, and SCHÖNFELD makes the interesting remark, that they look as if a regular process of the light-variation is disturbed by causes working for a long time in the same direction.

"Man kann sich dies so vorstellen, dass die störenden Ursachen eine "Zeitlang wenig oder gar nicht wirken, und dass dann ihre Wirkung plötzlich, "oder wenigstens sehr rasch anwächst, sich auf dieser Höhe einige Zeit erhält, "und dann ebenso rasch wieder abnimmt."

But, besides these irregular changes, the period seems to have shortened since the year 1860, and the secondary minimum is no longer, as a rule, observed to fall midway between two principal minima.

The observations of the years 1871 and 1872, did not confirm the shortening of the period, and those of 1873 gave a slight indication of its lengthening.

Next year SCHÖNFELD drew attention to a phenomenon of still greater importance, viz. that of the changing brilliancy of consecutive minima.

"Während in den letzten Jahren die Minimalhelligkeit durchgehends "über der der mittleren Curve geblieben ist, und ins besondere die vom Jahre "1869 um durchschnittlich 6 Stufen übertroffen hat, ist andererseits die "Helligkeit im secundären Minimum stets kleiner gefunden worden als früher; "*so dass man, wäre R Sagittae erst neuerdings entdeckt worden, geneigt sein* "*könnte die beiden Minima nicht zu unterscheiden, und die Periode nur* 35T "*lang anzunehmen*".

The observations made by GLASENAPP in December 1875 and during the year 1876, according to BELJAVSKY who reduced them, point to the same fact. He concludes his paper on that subject by saying: "Der Stern "R Sagittae scheint einem ausgeprägten δ Cephei-Typus mit einer Licht-"änderung von 35.3 Tagen Dauer anzugehören".

SCHÖNFELD, after having been called to the Directorship of the Observatory at Bonn, was obliged to stop his work on variable stars, in consequence of which his researches into the character of the light-changes of *R Sagittae* came to a premature end.

S. C. CHANDLER JR., well aware of the peculiar behaviour of this star in the year 1875, formulated his conclusions in the following sentence:

"The results, when charted, exhibit a well marked minimum on Sept. "22, but only a slight depression of the light-curve at about Aug. 23. These "phenomena, which seem to indicate a reversal of the principal and secondary "minima as given by Prof. SCHÖNFELD, are so anomalous, that, as I cannot "deem the observations, on which they rest, though somewhat fragmentary, "to be at fault, I have thought proper to submit them in detail."

And still the full measure of the caprices of this star had not been observed. BAXENDELL, who had stopped his observations in the year 1869, but had taken them up 8 years later, reports on his estimates of the year 1885, that *"in August, when a secondary minimum was due, the magnitude remained "constant* (*at* $8^m.8$) *for a period of* 16 *days*".

But after SCHÖNFELD, though the star was put on the list of many observers, none of them has ever tried to detect the true character of its light-fluctuations. In the meantime, the problem received an increased interest, when in the year 1904 STANLEY WILLIAMS discovered the variability of the star *BD* + 26°3937, *V Vulpeculae*, the light-curve of which exhibited, in approximately the same period, the same type as *R Sagittae* had shown at the time of its discovery. The period was 75.3 days, the secondary minimum fell midway between two principal minima and exceeded these by a full magnitude in brightness. But here too, in the years that followed, information of a different kind came in, first of all from E. C. PICKERING, who, from a series of 58 photometric measurements made by O. C. WENDELL, remarked: "they show that the successive light-curves are not the same, "and that therefore this star cannot be regarded as of the *β Lyrae* type. "The form of the light-curve appears rather to be of Class II*) and resembles "*R Sagittae* in having a secondary minimum nearly midway between the "principal minima".

The short photometric series of WENDELL was followed by an extensive, likewise photometric, series by F. H. SEARES and E. S. HAYNES. Neither did they find the *β Lyrae* type confirmed, but thought that the star had to be incorporated with the short period variables, with a period half as long as that derived by WILLIAMS; a result running parallel with SCHÖNFELD's remark about *R Sagittae* in the year 1875.

What has been said of *R Sagittae* applies equally to *V Vulpeculae*. The light-changes of this star also have not been thoroughly examined over a period of sufficient length. Moreover, the conformity of the character of the light-variations of both of them has never been proved.

*) Variables of long period.

Shortly after the discovery of *V Vulpeculae*, Mrs. CERASKI, examining the plates taken at the Moscow Observatory by BLAJKO between 1895 and 1905, found the star *BD* + 25°732 to be variable. Very soon after its discovery, this star, *R V* = *V* 14 *Tauri*, happened to be put on the programme of several keen observers (i. e. ENEBO, HAYNES, NIJLAND), and it has been kept under examination by these three observers in such a regular manner, that the story of its light-variation — apart from the unavoidable gaps resulting from the star's place near the ecliptic — has been set down very completely. But of this star also the data of observation have not been uniformly studied, and what has been published by the separate observers was derived from their personal work only. The results they have reached, strongly recall the vicissitudes of *R Sagittae* and *V Vulpeculae*, with this exception, that the order of things is now reversed. In the first instance the star was considered by both SEARES and ENEBO to be one of the short-period type, with a period of about 40 days; but a closer examination revealed the fact that the light-curve was of the *β Lyrae* type, having a period of about 79 days, which compares with the periods of 70 and 75 days assigned, as we have seen, to the two stars which were discovered earlier.

SEARES and HAYNES were struck, moreover, by the appearance of irregularities in all the phases of the light-variation; and it was this fact, taken in connection with the general character of the light-curve, which led them to the remark quoted on p. 2 of this work.

After the rejection of the short-period hypothesis, ENEBO discussed his observations in three separate papers. In the first of these he says that the star probably belongs to the *β Lyrae* type, but that there exists a secondary variability, which finds its expression in the fluctuating values of the maximum brightness. Taking BLAJKO's photographic magnitudes into account, the period of this secondary variation seems to him to be about three years. The mean period of the principal variation is 78.57 days.

In the second paper, the suggestion regarding the long-period variability of the maximum brightness is fully confirmed, the phase of that variation being in the spring of 1910 the same as in that of 1907. Moreover it would seem that, roughly speaking, the minimum brightness follows a parallel curve.

The minima observed in the beginning of 1910 differ from each other so little in brightness, that a strong probability arises, that the succession of principal and secondary minima will shortly be reversed, thus reproducing the same phenomenon as has been observed in *R Sagittae* and *V Vulpeculae*. The mean period of 79.0 days, given by SEARES and HAYNES, seems to be more accurate than that of 78.57 given in his first paper.

The third paper corrects the 79.0 days' period, since it was discovered that the minima of 1911 March and 1912 January fell, respectively 4 and 6 days earlier than was anticipated. A mean period of 78.76 days must be preferred to that of 79.0 days. In accordance with the three years' period of the secondary variation, the maximum brightness reached its greatest value towards the end of 1911.

NIJLAND, arguing from a first series of observations, is inclined to reject the *β Lyrae* type, and, in view of the many different values of the depth of the consecutive minima, to consider the star an irregular short-period variable, with a period of about 39 days.

All that has been said and suggested about the light-changes of *R Sagittae, V Vulpeculae* and *R V Tauri*, justifies a thorough investigation of the observed light-variation of these stars, from the date of their discovery till the present time; and the fact that all three have been under regular observation at the Utrecht Observatory during the last 8 years (*R V Tauri* by NIJLAND, *R Sagittae* and *V Vulpeculae* by the writer), provides an additional reason for undertaking the present work. It embraces the following points:

(*α*) to secure copies of all the series of observations in the form of the original note-book records.

(*β*) to adopt a scale of photometrically determined magnitudes of the comparison stars, and to bring the individual conceptions of the observers, regarding the differences between the comparison stars, into harmony with the photometric scale.

(*γ*) to derive from this newly adjusted scale the brightness of the variable, and to construct a light-curve, which shall be homogeneous, from a consideration of the systematic differences between the results obtained from the various observers.

(δ) to study the details of the light-curves, to embody in a mathematical formula the law which governs them, and to seek for a possible physical interpretation.

(ϵ) and, finally, to see whether the three stars under investigation may be regarded as specimens of a new class of variables.

The latter point is of special interest, since ENEBO, in his latest publications, announces that the same kind of light-variation as is found in *R V Tauri*, is to be observed in the stars *T V* = *V* 29 *Andromedae* and *S W* = *V* 23 *Persei*, and probably also in *R X* = *V* 16 *Ursae majoris*, *T Y* = *V* 32 *Draconis*, *R Y* = *V* 17 *Lacertae*, *T X* = *V* 31 *Persei*, *A V* = *V* 76 *Cygni*, and *U Y* = *V* 38 *Pegasi*.

Though the present writer is unable to estimate the soundness of this presumption, it appears to him that a warning should be uttered against any premature association of an observed light-curve with such a complicated type as that of *R V Tauri*.

The material at hand consists of

1938	observations	of	*R Sagittae.*
817	,,	,,	*V Vulpeculae.*
1129	,,	,,	*R V Tauri.*

making a total of 3884 observations. Most of these have never been published before, and were handed to us by the courtesy, either of the observers themselves, or of the astronomers in whose care the manuscripts have been placed. Our special thanks are due to Prof. H. H. TURNER and Miss M. A. BLAGG for BAXENDELL's valuable observations of *R Sagittae*, and to Prof. F. H. SEARES for sending us, in the most complete form, not only his own observations, but also those made by Mess[rs] E. S. HAYNES and H. SHAPLEY, upon *V Vulpeculae* and *R V Tauri*.

In the following table a summary is given of the manuscripts used.

Star	Author	Number of observ.	Period
R Sagittae	J. Baxendell	370	1859—1869
	,,	403	1877—1887
	P. S. Yendell	171	1891—1902
	J. van der Bilt	302	1907—1915
V Vulpeculae	St. Williams	298	1903—1907
	E. S. Haynes	118	1906—1908
	F. H. Seares	24	1906—1908
	H. Shapley	8	1908
	S. Beljavsky	48	1907—1910
	J. van der Bilt	225	1908—1915
R V Tauri	See p. 14.		

As we have already mentioned, the observations of *R V Tauri* have been very complete. In the series of *R Sagittae* gaps of several years appear, and in that of *V Vulpeculae* unnecessary gaps of several months. Moreover it proved possible in the case of *R V Tauri* alone, to reduce the whole material to one single observer; whereas the light-variation of the other two could only be studied in separate periods; a fact which, to some extent, affects the uniformity of the results. For these reasons it seemed to be preferable to devote attention first of all to *R V Tauri*, rather than to consider the stars in the chronological order of their discovery.

CHAPTER I.

THE REDUCTION OF THE OBSERVATIONS TO A PHOTOMETRIC SCALE.

A. **The polarizing photometer.**

In the summer of 1913 the instrumental equipment of the Utrecht Observatory was enlarged by the purchase of a polarizing photometer. It was supplied by O. TOEPFER of Potsdam, and differs from the original ZÖLLNER type only in the fact that the lamp is an incandescent one of 2 candle power (requiring 1 Ampère at 8 Volts), while the colorimeter is replaced by coloured glasses. It can be adjusted both to the $4\frac{1}{2}$ inch and to the 10 inch refractors; in the former case the eye-piece has a field of 50′ and a magnifying power of 49, in the latter the field is 30′ and the magnifying power 78.

The constancy of the current can be kept under control by using a milliampère-meter. The influence of any change in the current-intensity on the brightness of the artificial star can easily be expressed in terms of stellar magnitude. For this purpose, while continually varying the current-intensity, we have compared the maximum brightness of the artificial star with that of a few faint stars; and we have moreover carefully noted the reading of the ampère-meter at which the artificial star became invisible. The results of several nights were plotted and a correction-table derived from the curve. This table shows that, from the maximum reading used, viz. I = 104.5 (1.045 Ampère) to I = 85, the change in magnitude may be considered to be directly proportional with the change in current-intensity, and that, for values of I smaller than 0.85 Ampère, the brightness decreases more rapidly than the intensity.

But these low values of current-intensity have seldom been used in the observations.

The artificial star becomes invisible at a current-intensity of 0.64 Ampère.*).

The light-intensity of the artificial star can also be changed by the use of different diaphragms. But though there are 8 of them, it proved in practice to be preferable always to use the same opening of an intermediate size.

The sector for the coloured glasses contains three openings; one of them is empty, while the other two contain a red and a blue glass respectively. If the intention of the constructor was to give a yellow, red or blue tint to the artificial star, he has not succeeded, since, even with the "blue" glass, the colour, as compared with that of a few Potsdam stars, is not appreciably different from the designation WG of the Potsdam scale. In consequence of this the whole series of photometric measurements has been made with the "blue" glass; but the observation of really blue or white stars has proved to be very difficult.

The star to be measured has always been compared with the image formed by reflexion on the front side of the glass plate. Since care was taken to keep the light source to the right in every position of the telescope, this was always the right-handed image. During the observations it was found convenient always to place the object between the two images of the artificial star, which are 5′.4 apart; the line joining the observer's eyes was kept parallel with that joining the star images.

*) After the brightness of the comparison stars for *R V Tauri* had been photometrically determined, the same curve could be derived, with still greater accuracy, by determining, from a large number of measurements, the full brightness (M) of the artificial star at different current intensities (I). This gave the following results:

I	M	Δ M	I	M	Δ M
	m	m		m	m
105	6.70		90	8.20	
100	7.20	0.50	85	8.75	0.55
95	7.70	0.50	80	9.35	0.60
90	8.20	0.50	75	10.00	0.65

The distance of the object from the right-handed image of the artificial star was not always the same; for experience showed that, in ascertaining their equal brilliancy, a feeling of confidence in the results was attained, in the case of the brighter stars, when the images were kept at a distance of about 1′; while, in the case of the fainter stars, the equality could best be ascertained when the images were seen as a relatively close double star.

An "observation" consisted of 8 readings of the intensity circle, two in each of the quadrants. These two were obtained (1) by diminishing the light of the artificial star until it had attained the brightness of the object, (2) after having carried on the darkening process nearly to the zero-point, by brightening the image again until the equality of light was once more verified. The current-intensity was read off before and after each observation, and the changes were taken into account by using the correction-table mentioned above.

Group	Pair		M. K.		Δ m M.K.	Δ m B	m.e.	B — M.K.
			m	m	m	m	m	m
Pleiades	11	15	6.17	6.75	0.58	0.57	0.07	—0.01
	21	25	7.24	7.53	0.29	0.41	0.07	+0.12
	18	31	7.15	7.99	0.84	0.98	0.09	+0.14
	27	49	7.78	9.05	1.27	1.12	0.08	—0.15
	12	22	6.51	7.28	0.77	0.86	0.03	+0.09
	17	39	7.10	8.43	1.33	1.25	0.05	—0.08
	14	44	6.72	8.65	1.93	2.03	0.06	+0.10
	9	32	5.84	8.03	2.19	2.01	0.05	—0.18
	19	26	7.18	7.63	0.45	0.57	0.04	+0.12
	10	45	5.98	8.85	2.87	2.76	0.10	—0.11
	34	37	8.12	8.33	0.21	0.38	0.07	+0.17
	23	26	7.31	7.63	0.32	0.42	0.08	+0.10
	20	41	7.23	8.53	1.30	1.14	0.10	—0.16
	12	33	6.51	8.31	1.80	2.06	0.06	+0.26
	22	23	7.28	7.31	0.03	—0.01	0.04	—0.04
	27	29	7.78	7.84	0.06	0.14	0.07	+0.08
BD + 20° (*Praesepe*)	2150	2149	6.68	6.79	0.11	0.18	0.06	+0.07
	2158	2159	6.54	6.78	0.24	0.34	0.06	+0.10
	2149	2172	6.79	7.07	0.28	0.29	0.06	+0.01
	2178	2185	6.92	7.18	0.26	0.04	0.08	—0.22

Before proceeding to the measurements of the magnitudes of the comparison stars for *R V Tauri, V Vulpeculae* and *R Sagittae,* a small series of test-measurements was made with the $4\frac{1}{2}$ inch refractor on a number of selected pairs of *Pleiades* and *Praesepe* stars. The magnitudes of the former were taken from the MÜLLER and KEMPF list in the "Astronomische Nachrichten" no. 3587; those of the latter from the "Potsdam Durchmusterung" (PD).

The preceding list contains, in the fifth column, the results of these test-measurements. Each pair has been measured on one night only; no observation has been rejected.

The sixth column gives the mean error of the interval B; it shows that the differences B—M. K. in the last column are not much greater than could have been expected.

Together with these measurements the number of observations made with the ZÖLLNER photometer was 341, most of which concern the three variable stars, forming the subject of this paper. To these are added a small number of measurements of the variables *R Leonis* and *R Boötis,* and of some faint stars mentioned on p. 10.

From a consideration of the different data which can be derived from these measurements, it appears that the mean error of an "observation" (i. e. of the mean of 8 readings) is $0^m.037$, that is to say, about half the value of the mean error given in the preceding table. The intensity-circle shows an index-error of $0°.5$, whereas there is no appreciable effect due to eccentricity, or to the personal error alluded to on p. 12.

B. **The material at hand.**

The following list contains a complete enumeration of the observations made on the star under investigation since its discovery, and which were either available when the work was started, or were sent to me in response to a request, published in the "Astronomische Nachrichten" no. 4693 and the "Astronomical Journal" no. 657.

Observer	No. of obs.	Epoch	Reference
Mrs. Ceraski. .	11	1895/1905	Discovery. Measures on plates taken by Blajko. Astron. Nachr. no. 4010.
E. Hartwig . .	7	1905/1907	Veröffentlichungen der Remeis-Sternwarte zu Bamberg. Reihe II. Band I, Heft II.
L. Pračka. . . .	8	1906/1907	Beiträge zur Untersuchung des Lichtwechsels veränderlicher Sterne. 1—2. Prague 1910. (Bulletin international de l'Académie des sciences de Bohème. 14—10—1910).
S. Enebo	239	1906/1912	Beobachtungen veränderlicher Sterne, angestellt auf Dombaas (Norwegen). Teil II; IV; VI. (Archiv for Mathematik og Naturvidenskab Bd. XXIX; XXX; XXXII.)
,,	43	1912/1915	MS
E. S. Haynes	73	1906/1908	Publications of the University of Missouri. Laws Observatory Bulletin no. 14.
,,	66	1908/1909	MS
F. H. Seares	4	1908	Publications of the University of Missouri. Laws Observatory Bulletin no. 14.
,,	31	1908	MS
H. Shapley . .	46	1908/1910	MS
A. A. Nijland	533	1908/1915	MS. Preliminary results have been published in the "Astronomische Nachrichten" nos. 4404, 4485, 4560, 4642, 4765 and 4797.
J. Voûte	47	1908/1909	MS
A. Brill	10	1913	MS
K. Boda.	11	1913	MS

C. The comparison stars.

The estimates of the various observers have, as a rule, been made with the use of the 10 comparison stars given in the table below. The first column contains either the star's designation after the "Bonn Durchmusterung", or the coördinates which relate them to the variable. The next 5 columns give the letters, with which these stars appear in the publications or MSS of the observers. The last column gives the notation adopted in the following pages and which is also used in the chart, to be found at the end of the volume.

Star	Hartwig Pračka	Enebo	Seares Haynes Shapley	Nijland Voûte	Brill Boda	Adopted
+25° 734	*b*	*m*	*c*	*A*		*a*
+25° 742				*a*		*b*
+26° 746	*c*	*c*	*a*	*b*	*c*	*c*
+25° 728		*n*				*d*
+25° 733	*e**	*a*			*d*	*e*
+26° 747	*d*	*b*	*b*	*c*	*a*	*f*
+25° 735	*f*	*d*		*e*		*h*
-14^s; $-8'.7$		*h*		*d*		*g*
$+88^s$; $+2'.8$		*g*				*k*
$+49^s$; $+7'.8$		*e*		*g*		*l*

Comparison stars for *R V Tauri.*

No photometric magnitudes of these stars were available. The extensive series of measurements of the variable, which were made with the wedge photometer of the Laws Observatory, furnish accurate values for the intervals *c*—*a* and *f*—*c*; but none of these 3 stars have been brought into connection with an existing photometric scale.

A complete list of photometric magnitudes of the comparison stars being of great value for the reduction of the observations, the necessary meas-

*) Probably by a misprint Pračka gives + 26° 733.

urements for this have been made by the writer with the photometer described above. The magnitudes so obtained are based on the photometric values, taken from the Potsdam "Generalkatalog", of the two following stars.

A = BD + 26° 759 = PD 2956 Colour WG $M = 7^m.65$
B = BD + 25° 720 = PD 2816 Colour WG $M = 7^m.69$

The star BD + 25° 731 = PD 2890. $M = 8^m.08$, which, by its central position among the comparison stars, lent itself still better to the purpose, could not be used on account of its colour GW- (See p. 11).

Using A and B as a basis, the magnitudes of the comparison stars *a—h* have been derived by photometric triangulation, after the scheme given below. This produced 25 equations (considered to be of equal weight), with 10 unknown quantities, which had to be solved by the method of least squares. The faint stars *k* and *l* have not been measured, since they have been used only twice and by a single observer.

The photometer was attached to the 10 inch refractor, and each interval was measured on three separate nights. Though the observations were commenced on 1914 March 2, when the star group was still conveniently placed, the unfavourable conditions of the weather did not allow of the series of measurements being completed in similar circumstances. On a few occasions the measurements had even to be made at zenith distances of 50 to 60 degrees. This should generally be avoided here, both on account of the haze which lies above the town, and because the observatory is shut in by high trees, especially on its Western side. Though the corrections for atmospheric extinction amounted to no more than $0^m.01$ and $0^m.02$, they were duly applied.

Interval \ Date 1914	March 2	6	11	17	18	21	22	26	27	28	April 3	6	12	14	mean	m.e. of mean
															m	m
a—B		1.83					1.65					1.72			1.73	0.052
a—A			1.56		1.80							1.64			1.67	070
b—B			1.79				2.04				1.84				1.89	076
b—A		2.24	2.11								1.93				2.09	090
b—a		0.35					0.40		0.63						0.46	086
c—B			2.40				2.52				2.77				2.56	109
c—A						2.86					2.85	2.73			2.81	042
c—a		1.02					0.88			0.97					0.96	058
d—b		0.88					0.94			1.08					0.97	059
e—c		0.59			0.60			0.54							0.58	018
e—d			0.52		0.33					0.31					0.39	067
f—B	2.50						2.77				2.87				2.71	110
d—f		0.16			-0.14					0.17					0.06	102
f—c						0.29	0.25						0.27		0.27	012
h—a								2.06	1.91	1.98					1.98	043
h—c	0.97						1.00			1.01					0.99	012
h—e				0.39				0.37		0.48					0.41	033
h—f					0.79				0.65					0.69	0.71	042
g—a								1.91	1.97	1.98					1.95	022
g—c								1.15		0.99			0.91		1.02	070
g—e								0.60		0.48				0.40	0.49	058
g—f									0.69	0.86			0.64		0.73	066
g—h								0.02	0.04	0.00					0.02	012
															mean : $0^m.064$	

Photometric triangulation of the comparison stars for *R V Tauri*.

The normal equations come out as follows:

$$
\begin{aligned}
5B - a - b - c - f &= -1.20 \\
4A - a - b - c &= +1.08 \\
-B - A + 6a - b - c - g - h &= -1.95 \\
-B - A - a + 4b - d &= +3.47 \\
-B - A - a + 7c - e - f - g - h &= +3.47 \\
-b + 3d - e - f &= +0.64 \\
-c - d + 4e - g - h &= +0.07 \\
-B - c - d + 5f - g - h &= +1.48 \\
-a - c - e - f + 5g - h &= +4.21 \\
-a - c - e - f - g + 5h &= +4.07
\end{aligned}
$$

These equations can easily be solved by using a method of approximations. When the values of A and B are left as the Potsdam catalogue gives them, and the values of the measured intervals are applied directly, we get a set of approximated magnitudes for the comparison stars, from which the true values can be derived by means of the normal equations. In the present case the third approximation, which indeed differs but little from the first, gives the final result.

Star	1[st] appr.	2[nd] appr.	3[rd] appr.
	m	m	m
A	7.65	7.63	7.63
B	7.69	7.76	7.77
a	9.37	9.37	9.37
b	9.72	9.72	9.72
c	10.35	10.35	10.36
d	10.69	10.64	10.64
e	11.01	10.96	10.95
f	10.55	10.59	10.59
g	11.39	11.37	11.37
h	11.35	11.35	11.34

From these results we learn that the star *f* must, as regards its photometric brightness, be placed between *c* and *d*; but the notations given had been previously chosen after ENEBO'S list of comparison stars (so far as his material carries us), which gives *f* fainter than *d* and *e*.

The stars *g* and *h* may be considered as equally bright. ENEBO sees $g < h$, NIJLAND $g > h$. Since these differences persist after the reduction of their light-scales to that of the photometric, the already adopted notation for the comparison stars has not been altered.

The observer's estimates of the intervals between the comparison stars give a scale in which the light-values are represented by a sequence of "steps", commencing from the arbitrary value of 1.0 for the faintest star. With the aid of the photometric results, this light-scale must be changed to a magnitude-scale. This can be done graphically, or by computation.

By the latter method, a set of equations of the form

$$x - a_n\, y = p_n$$

had to be solved by the method of least squares. In these equations p_n means the photometric magnitude of the comparison stars, x the reduced magnitude of one of them, a_n the difference, expressed in steps, between x and the other comparison stars, and y the value of one step.

We have slightly changed the above method on the following grounds:

1. For certain intervals, the conceptions of the observers frequently appear to differ from the photometric results to such an extent, that, when they are admitted into the computation, they are apt to affect the accuracy of the reduction of the other intervals.

2. It is evident that the photometric scale is not absolutely correct, and that the difference between this scale and the observer's conception is not entirely attributable to the latter.

The following method, which is used in the present paper, seems to meet these objections with some adequacy.

The light-scales of the observers are first constructed and reduced to the photometric scale. The resulting magnitude-scales are then compared with this scale; and when, for a certain star, the values taken from the magnitude-scales differ from the photometric value *in the same direction for all observers*, this value is changed in the same direction to an amount not exceeding the mean error.

With this definitive photometric scale, the construction of the magnitude-scales is repeated, and new values for the differences Observer minus Photometry result. If, for one or more of the stars, this difference exceeds the somewhat arbitrarily chosen value of $0^{m}.20$, such stars are excluded; the step-values of the remaining stars are again reduced to the photometric scale, and, finally, the excluded stars are inserted, using for this purpose the value of one step, which has resulted from the final computation.

By this means we obtain this double advantage; that the greater part of the comparison stars can be reduced with fair accuracy to the photometric scale; and that a value, best suited to the observer's conception can be adopted for one or two divergent stars, *without spoiling the precise results of the others.*

For each individual observer, the value of one step has been treated as a constant quantity throughout the whole range of the light-variation.

In the case of *R V Tauri* the preliminary reduction to the photometric scale gave the following differences Observer minus Photometry. Unit = $0^m.01$ (E = Enebo, L = Laws observers, N = Nijland, V = Voûte).

Star	E	L	N	V
a	+07	+08	—02	—06
b			+02	+09
c	+02	—11	—07	—08
e	—15			
f	+38	+04	+15	+17
g	+10		—19	—11
h	—28		+08	

The star *d* does not appear in this comparison, since it has been used by one observer only, and by him on very few occasions.

The differences for the stars *b* and *f* being all positive, we have made their photometric magnitudes fainter; while the magnitude of *e* has been made brighter, to an amount as large as the mean error would permit.

This mean error does not result from the normal equations, as they have been solved by an approximative method; but it can readily be estimated from the mean error of the measured intervals (see p. 17 last column). This comes out at $0^m.064$, making the mean error of each of the magnitudes forming the interval $= \frac{0^m.064}{\sqrt{2}} = 0^m.045$*)

Thus the photometric scale finally adopted, was not that resulting directly from the solution of the normal equations, but the following:

$a = 9^m.37$	$d = 10^m.64$	$g = 11^m.37$
$b = 9.76$	$e = 10.91$	$h = 11.34$
$c = 10.36$	$f = 10.63$	

*) Since this "internal" mean error must be smaller than the "external" mean error, which would have resulted from the normal equations, we are sure to be on the safe side as to the corrections, which we now apply.

D. **The observations of Hartwig.**

The observations of Hartwig have been made at Bamberg with a 10 inch refractor; they are very few in number, one estimate being made in 1905, one in 1906, and 5 in 1907.

It is, sometimes, very difficult to bring the observations of this observer into connection with a photometric scale, for the following reasons. They are recorded in an unusual form, the differences in brightness being very seldom expressed in steps. As soon as these differences exceed about $0^{m}.25$, three different symbols are used, two of which are explained in the introduction, but in terms too vague to be of much use to the computer. The latter has thus to compare the records themselves for more detailed information; and this leads to still further confusion. For each variable the adopted magnitudes of the comparison stars have been given, but without any information as to their origin; and in the reductions of the observations these magnitudes are apparently independent of the instrument used.

The brightness of the variable is derived in a way which is not described, and which in several cases is wholly incomprehensible. Each method consistently adopted for examining his results, is found to lead to conclusions different from Hartwig's own. Consequently, since the meaning of Hartwig's symbols is not clear, and the course which he followed in deriving the light of the variable is not explained, a computer finds himself unable to attach to the observations the weight which they probably merit.

In the few cases, however, in which *R V Tauri* was observed, we can derive more or less trustworthy values for the brightness of the variable, if we adopt the direct photometric magnitudes of the comparison stars.

Here follows, in the notation adopted by us, a summary of Hartwig's estimates; the third column gives the magnitude derived by HARTWIG himself; and the last column contains criticisms, to which, according to the present writer, these records are liable.

Comparison stars: BD + 25° 725 (A) $8^m.0$ f $9^m.6$
a 8.5 e 10.0
c 9.2

no.	Date	Estimate	M	Remarks.
1	1905 Oct. 10	$a \gg v \gg c \gg f$	8.9	Apparently reduced as $v = \frac{1}{2}(a+c)$, neglecting the star f. Then the first two symbols $\gg$ have values less than $0^m.5$, contrary to the statement in the introduction.
2	1906 March 3	$A > v\ 3.5\ a$	8.3	Apparently reduced with a value $0^m.06$ for one step and neglecting the comparison with A.
3	1907 March 4	$f\ 3.5\ v\ 3\ e$	9.8	Value of one step in accordance with 2.
4	1907 Oct. 15	$a \gg v = c$	9.2	The comparison with a has been neglected.
5	,, ,, 18	$a\ 6\ v \gg c$	8.8	Reduced with the same value for one step as under 2 and 3; the comparison with c has been neglected.
6	,, ,, 19	$a \gg v \gg c$	8.85	See 1.
7	,, ,, 29	$a \ggg c = v \gg f$	9.2	The symbol $\ggg$ is not explained in the introduction of HARTWIG's work; in this case it seems from a comparison with 4 not to differ from the symbol $\gg$. Reduced as $v = c$.

E. The observations of Pračka.

Pračka observed *R V Tauri* at Bamberg, sometimes with the 10 inch refractor, sometimes with the $6\frac{1}{3}$ inch comet-seeker of the Observatory, and he obtained 1 observation in 1906 and 7 in 1907.

He too has made an extensive use of the symbols $>$, $>>$ and $>>>$.

No explanation of these is given, but apparently no definite value has been attached to them in the reduction of the observations.

For star-magnitudes within the limits $7^m.5$ and 12^m Pračka arrived at the value $0^m.06$ as being the photometric equivalent of one step. In view of the small number of observations, we have in their reduction applied this same value, leaving the photometric magnitudes of the comparison stars unaltered.

F. The observations of Enebo.

These were made at Dombaas in Norway, in 1906 with a $2\frac{3}{4}$ inch refractor, and from 1907 to 1915 with a $4\frac{1}{4}$ inch.

The observations made with the former instrument have been reduced to the photometric scale with the following result:

Star	Light-scale (L)	M	M—Ph.
		m	m
c	5.59	10.35	—0.01
e	1.00	10.80	—0.11
f	1.41	10.75	+ 0.12

1 Step = $0^{m}.097$

Since none of the differences in the last column exceeds $0^{m}.20$, a second reduction (see p. 19) is not necessary.

From a first review of ENEBO's long series of observations made with the larger instrument, it appears that his conception of the differences in brightness between the various comparison stars was a different one for each season. To illustrate this, we give, in the following list, for the different seasons the values, expressed in steps, of the star-intervals which have been generally used. The second column represents the values for the period 1907 Jan. 3 to April 10, and the following 5 columns give those belonging to the observational seasons between 1907 and 1912. The last column has been constructed by making use of three seasons, the number of observations being too small to treat each season separately.

Interval \ Season	1907	1907/08	1908/09	1909/10	1910/11	1911/12	1912/15
a—*c*			9.5		10.5	10.4	12.4
c—*e*	3.5	2.5	3.6	5.3	5.7	6.6	7.1
c—*f*	4.1	5.4	4.6	7.2	6.6	7.2	7.6
e—*f*	2.3	2.2	0.5	2.3	1.1	0.8	1.6
e—*g*	4.0			8.3			
f—*g*	1.1			5.9			7.0

Attention was drawn to the differences exhibited in the foregoing table in the following way. In the course of a preliminary investigation, ENEBO's light-scale was deduced from his observations as a whole, and his results were compared with those of NIJLAND in the way described on p. 35. From this comparison it appeared that the remaining errors, which should have shown a distribution in harmony with the probability-curve, as a matter of fact revealed a systematic discordance, whereby errors of an intermediate value were found to be abundant, and smaller errors were fewer in number than were expected. For this reason, we have treated the different seasons separately, with (as will be shown on p. 41) a corresponding improvement in the results.

The reduction to the photometric scale gave the following results:

I. Season 1907. 1st reduction.

Star	L	M	M—Ph
		m	m
c	7.38	10.40	+ 0.04
e	4.59	10.73	— 0.18
f	2.56	10.98	+ 0.35
g	1.00	11.17	— 0.20

2nd reduction. Star *f* excluded.

Star	M	M—Ph	
	m	m	
c	10.40	+ 0.04	1 Step = 0.157 m
e	10.84	— 0.07	*f* = 11.16
g	11.40	+ 0.03	

II. Season 1907—'08. 1st reduction.

Star	L	M	M—Ph
c	6.19	$10^m.48$	$+ 0^m.12$
e	3.42	10.64	— 0.27
f	1.00	10.77	+ 0.14

2nd reduction. The number of stars being only 3, no star can be excluded from the reduction. Perhaps the most natural way would now be to discard the chosen criterion, and to accept the first reduction, though for *e* the value M—Ph is larger than $0^m.20$. But, on the following grounds we have preferred another course.

The first reduction is not only unsatisfactory for *e*, but for *c* and *f* as well. The following pages will show that, for the stars involved in the final reduction, the value M—Ph can nearly always be kept under $0^m.10$.

Further: the differences for the various seasons, though in some way irregular, show a marked tendency to a gradual diminution of the value of one step. Now, while for the preceding season this value is $0^m.157$, and for the following $0^m.105$, the first reduction for 1907—'08 would give it as $0^m.056$; that is to say, a value smaller than that acquired even after six years' observation (see p. 29). On these grounds we have preferred to adopt for this season the values for *c* and *f* of the preceding one, and to insert the star *e*. The original estimates give the interval *c*—*f* directly = 5.43 steps, and the same interval via *e* = 4.70 steps. The mean is 5.07 steps for a magnitude-interval of $0^m.76$. Hence 1 step = $0^m.150$.

$$c = 10^m.40 \qquad e = 10.40 + 0.38 = 10.78$$
$$f = 11.16 \qquad e = 11.16 - 0.33 = 10.83 \Big\} \ 10^m.81$$
$$e = 10.81$$

III. Season 1908—'09. 1st reduction.

Star	L	M	M—Ph
a	14.55	$9^m.38$	$+ 0^m.01$
c	5.30	10.36	0.00
e	1.77	10.73	— 0.18
f	1.00	10.81	+ 0.18

1 step = $0^m.105$

The step-estimates give for the stars *d*, and BD + 25° 729 = *p*, which were only used on a single occasion, $10^m.37$ and $10^m.39$ respectively. A second reduction is unnecessary.

IV. Season 1909—'10. 1st reduction.

Star	L	M	M—Ph
c	14.35	$10^m.39$	+ $0^m.03$
e	9.02	10.80	— 0.11
f	7.09	10.95	+ 0.32
h	6.00	11.04	— 0.30
g	1.00	11.43	+ 0.06

2nd reduction. Stars *f* and *h* excluded.

Star	M	M—Ph
c	$10^m.42$	+ $0^m.06$
e	10.81	— 0.10
g	11.41	+ 0.04

1 step = $0^m.074$
f = 10.96
h = 11.04

V. Season 1910—'11. 1st reduction.

Star	L	M	M—Ph
a	17.96	$9^m.44$	+ $0^m.07$
c	7.46	10.34	— 0.02
d	5.96	10.47	— 0.17
e	2.26	10.78	— 0.13
f	1.00	10.89	+ 0.26

2nd reduction. Star *f* excluded.

Star	M	M—Ph
a	$9^m.37$	$0^m.00$
c	10.41	+ 0.05
d	10.57	— 0.07
e	10.93	+ 0.02

1 step = $0^m.099$
f = $11^m.06$
p (see under III) = $10^m.40$

VI. Season 1911—'12. 1st reduction.

Star	L	M	M—Ph
a	18.64	9ᵐ.53	+ 0ᵐ.16
c	8.26	10.34	— 0.02
d	8.64	10.31	— 0.33
e	1.74	10.84	— 0.07
f	1.00	10.90	+ 0.27

2nd reduction. Stars *d* and *f* excluded.

Star	M	M—Ph	
a	9ᵐ.38	+ 0ᵐ.01	1 step = 0ᵐ.092
c	10.33	— 0.03	*d* = 10.30
e	10.93	+ 0.02	*f* = 11.00
			p = 10.41

VII. Seasons 1912—'15. 1st reduction.

Star	L	M	M—Ph
a	29.15	9ᵐ.39	+ 0ᵐ.02
c	16.13	10.29	— 0.07
e	9.12	10.76	— 0.15
f	8.00	10.88	+ 0.25
g	1.00	11.33	— 0.04

2nd reduction. Star *f* excluded.

Star	M	M—Ph	
a	9ᵐ.40	+ 0ᵐ.03	1 step = 0ᵐ.072
c	10.34	— 0.02	*f* = 10.92
e	10.84	— 0.07	*p* = 10.42
g	11.43	+ 0.06	

In the following table a summary is given of the preceding results. From an observer's point of view it is worth while to remark here, that three of the comparison stars which Enebo used (i. e. *c*, *p* and *d*) are practically equal in brightness, viz. $10^m.38$, $10^m.40$ and $10^m.41$. On the other hand he has not interpolated a star between *a* and *c*, which differ by a whole magnitude.

Though its distance from the variable is somewhat great, such a star presents itself in b, which has been used with great advantage by both NIJLAND and VOÛTE.

Star	1906	1907	1907 / 1908	1908 / 1909	1909 / 1910	1910 / 1911	1911 / 1912	1912 / 1915	Mean
	m	m	m	m	m	m	m	m	m
a				9.38		9.37	9.38	9.40	9.38
c	10.35	10.40	10.40	10.36	10.42	10.41	10.33	10.34	10.38
p				10.39		10.40	10.41	10.42	10.40
d				10.37		10.57	10.30		10.41
e	10.80	10.84	10.81	10.73	10.81	10.93	10.93	10.84	10.84
f	10.75	11.16	11.16	10.81	10.96	11.06	11.00	10.92	10.98
g		11.40			11.41			11.43	11.41
h					11.04				11.04
1 step =	0.097	0.157	0.150	0.105	0.074	0.099	0.092	0.072	

G. The observations of Haynes, Seares and Shapley.

With the exception of the measurements taken on 1907 July 31; Aug. 3, 10, 18; Sept 12, 18; Oct 4, 5, 8, which were made with a polarizing photometer, all the observations were made with the Zeiss wedge photometer, attached to the $7\frac{1}{2}$ inch equatorial of the Laws Observatory. A description of this instrument is given in the Laws Observatory Bulletin no. 7, and the method of observation has been explained in Bulletin no. 8.

The measurements yield, not only the differences in magnitude between the variable and one or two of the comparison stars *f*, *c*, and *a*, but also an extensive series of mutual differences between the latter. These differences we have closely examined in the case of each observer separately, with the following results:

Observer / Interval	HAYNES Δ m	HAYNES obs.	SEARES Δ m	SEARES obs.	SHAPLEY Δ m	SHAPLEY obs.
	m		m		m	
c—*a*	0.74	50	0.71	12	0.70	34
f—*c*	0.41	82	0.35	8	0.48	10

Since the three values of each interval differ by so little, the mean value can be taken without having recourse to weights. The result is:

$$c - a = 0^{m}.72 \qquad f - c = 0^{m}.41$$

These values, together with the photometric magnitudes of *a*, *c* and *f*, give 5 equations, from which the magnitudes to be used for reducing the Laws observations can be derived by the method of least squares. The solution gives:

Star	M	M—Ph
a	$9^{m}.45$	$+ 0^{m}.08$
c	10.26	—0.10
f	10.65	+ 0.02

H. The observations of Nijland.

These were made at Utrecht, the instruments used being the 10 inch refractor of the University Observatory, and its 3 inch finder.

The method of observation is the direct interpolation method, designed by the observer himself.*)

The following table gives the results of the reduction to the photometric scale.

	L		M		M—Ph	
Star	10″	3″	10″	3″	10″	3″
a	25.18	23.80	$9^m.37$	$9^m.36$	$0^m.00$	$-0^m.01$
b	20.62	18.70	9.76	9.80	0.00	+ 0.04
c	14.15	13.11	10.31	10.29	— 0.05	— 0.07
f	8.89	8.89	10.76	10.66	+ 0.13	+ 0.03
g	3.75		11.20		— 0.17	
h	1.00		11.43		+ 0.09	

1 step = $0^m.085$ (10″ refractor)

,, = 0.087 (3″ finder)

A second reduction is not necessary.

*) "Astronomische Nachrichten" no. 3695.

I. The observations of Voûte.

These were made at Leiden with the 6 inch refractor of the University Observatory; the method of observation is NIJLAND'S interpolation method.

The observations have been reduced to the photometric scale with the following result:

Star	L	M	M—Ph
a	20.16	$9^m.32$	$-0^m.05$
b	15.24	9.82	+ 0.06
c	10.64	10.29	— 0.07
f	5.83	10.78	+ 0.15
g	1,00	11.28	— 0.09

1 step = $0^m.102$.

A second reduction is not necessary.

On two days in February 1909 VOÛTE saw the variable brighter than *a*. On these occasions he interpolated it between *a* and BD + 26° 750, which he estimated to be 6 steps brighter than *a* on Feb. 1 and 6½ steps on Feb. 5. Using the value of one step as derived above, the resulting magnitude of BD + 26° 750 is $8^m.68$.

K. **The observations of Brill and Boda.**

These have been made with the 8 inch refractor of the Astronomical Observatory of the "Physikalischer Verein", Frankfurt a. M. The variable has been compared with *c* and *f* only, after the direct ARGELANDER method.*) The interval between these comparison stars has been estimated at from 0 to 6 steps, which difference the observers themselves are inclined to ascribe to a variability of the star *c*. This, however, is not evident from the long series of estimates made by the other observers.

The mean value of the interval *c*—*f* is 3.36 steps for BRILL, and 3.21 for BODA, from which, retaining the photometric magnitudes of these stars, the value of one step becomes $0^m.089$ and $0^m.094$ respectively. With these values the brightness of the variable has been deduced from the direct photometric values of the comparison stars.

*) The observations contain one single comparison with the star *e*.

L. Summary.

The following table gives a summary of the reductions discussed in the preceding pages, exclusive of the stars which have been used only by one observer.

Star	E	L	N	V
a	+01	+08	00	—05
b			+02	+06
c	+02	—10	—06	—07
f	+35	+02	+08	+15
g	+04		—17	—09
h	—30		+09	

In ENEBO's case we have taken the mean value for the two instruments and for the different seasons, in NIJLAND's the mean value for the two instruments. The first column gives the designation of the stars, and the following 4 columns the differences: Adopted minus Photometric magnitude, $0^m.01$ being the unit. (See also p. 20.)

From this table it appears that the star *f* is, for all the observers, a fainter object than is given by the photometric measurement, which is practically the same for the Laws and the Utrecht photometers. Differences of this kind, which have often been remarked in other cases, must probably be ascribed to the difference in colour between the real and the artificial stars.

CHAPTER II.

The reduction of the observations to one observer.

With a star like *R V Tauri*, which has been observed over a long period by more than one observer, and frequently on the same night, the opportunity is presented of reducing all the observations to the standard of one observer, after a careful investigation of the systematic differences between the various results. For the purpose of this reduction, that observer should obviously be chosen, whose contributions have been most continuous, and have spread over the longest period. In the case of *R V Tauri* this observer is Nijland. Thus our next task will be to give the results of the following comparisons:

1. The observations of Nijland with the 3 inch finder, and those made with the 10 inch refractor. Abbreviation N — n.
2. Enebo compared with Nijland (N — E).
3. The Laws observers compared with Nijland (N — L).
4. Voûte compared with Nijland (N — V).
5. The Frankfurt observers compared with Nijland (N — F).

In certain cases, allowances have been made for the difference in Greenwich M.T. at which the observations were taken. As will be seen on pp. 76—77 the change in magnitude was, in some extreme instances, about $0^{m}.01$ to $0^{m}.02$ per hour; and, had no allowance been made for the time-difference, this would have led to erroneous results.

Since the observations of Hartwig and Pračka are very few in number, and fall entirely beyond Nijland's period of observation, they have been excluded from this final reduction.

1. N — n. The first table gives, in the second column, the magnitudes as observed in the finder, and, in the third, the differences N — n, expressed

in $0^m.01$ as the unit. From the second table, it appears that these differences do not depend upon the brightness. The mean value is $N - n = -0^m.17$.

Date	n	N—n	Date	n	N—n	Date	n	N—n	Date	n	N—n
1908 Nov. 4	9.58	08	1910 March 27	10.44	13	1912 Febr. 21	10.44	17	1913 Dec. 1	10.38	23
6	9.43	06	29	10.44	30	April 10	10.42	24	7	10.24	21
28	10.16	20	Sept. 30	10.54	01	21	9.80	24	18	10.41	10
Dec. 30	10.04	26	Oct. 2	10.51	08	Sept. 14	10.46	28	19	10.48	17
1909 Jan. 8	10.41	18	6	10.17	14	15	10.41	10	30	10.57	15
15	10.44	21	12	10.13	13	17	10.22	15	1914 Jan. 4	10.34	20
15	10.22	08	13	10.16	22	Oct. 17	10.21	16	19	10.39	16
23	9.80	21	14	10.19	21	Dec. 2	10.25	15	March 1	10.57	10
March 7	9.58	21	Nov. 2	10.29	16	1913 Jan. 8	10.07	10	14	10.66	08
April 7	10.48	17	Dec. 7	10.18	11	Febr. 6	10.29	19	27	10.25	20
8	10.36	14	26	10.29	28	8	10.38	24	31	10.19	09
10	10.05	11	1911 Febr. 19	10.09	08	21	10.29	24	April 12	10.38	16
Aug. 10	9.87	05	22	10.18	15	March 23	10.38	20	16	10.33	20
22	10.18	11	26	10.37	23	April 2	10.13	07	Aug. 4	10.29	19
Sept. 16	10.46	33	March 19	10.13	08	Aug. 14	10.38	29	17	10.29	15
19	10.10	16	April 11	10.09	09	Sept. 6	10.48	25	Sept. 24	10.29	11
Oct. 6	10.54	23	15	10.25	22	16	10.13	10	30	10.01	07
24	10.46	23	Aug. 6	10.20	17	24	10.45	30	1915 Jan. 2	9.96	29
Nov. 7	10.38	16	20	10.05	18	25	10.54	11	11	10.29	26
8	10.38	21	Sept. 21	10.29	23	26	10.57	04	16	10.18	03
Dec. 5	10.51	33	22	10.19	04	Oct. 9	10.38	15	18	10.29	14
8	10.29	24	Oct. 24	10.36	09	25	10.29	19	22	10.19	16
15	10.46	23	26	10.29	24	26	10.29	19	March 2	10.46	32
1910 Febr. 24	10.29	26	31	10.38	24	28	10.45	23	29	10.29	26
March 1	10.21	18	Nov. 1	10.29	15	Nov. 3	10.54	23	31	10.17	14
5	10.38	07	Dec. 11	10.17	08	22	10.57	06	April 11	10.08	05

$$N - n = -0^m.17$$

Interval	comps	mean n	N—n
m m		m	m
9.40—10.00	7	9.72	—0.16
10.00—10.20	27	10.13	—0.13
10.20—10.40	41	10.31	—0.19
10.40—10.60	29	10.49	—0.18

2. For the argument E, the table contains not only the direct differences N — E, but also those resulting from (n — $0^m.17$) — E, on the nights when NIJLAND used the finder only. Here, too, there is no systematic change corresponding with that of the brightness. The mean value is N—E = —$0^m.20$.

Date	E	N–E	Date	E	N–E	Date	E	N–E
1908 Oct. 19	10.43	—33	1910 Jan. 17	10.62	—35	1911 Oct. 28	10.45	—14
20	10.46	—31	30	10.88	—12	31	10.54	—40
21	10.53	—26	Febr. 9	11.37	—24	Dec. 15	9.90	—02
24	10.70	—22	12	11.24	—11	1912 Jan. 17	10.74	—41
Nov. 4	9.87	—37	March 1	10.27	—24	27	9.86	—41
Dec. 15	9.89	—45	13	11.05	—34	Sept. 21	9.83	00
1909 Jan. 8	10.42	—19	15	11.19	—47	Oct. 8	9.87	—29
9	10.51	—28	26	10.76	—08	15	10.00	—08
13	10.49	—03	April 1	10.15	—11	Dec. 30	10.01	—22
24	9.76	—19	4	10.09	+06	1913 Jan. 9	9.98	—06
27	9.76	—22	Sept. 8	9.98	—46	Aug. 30	11.14	—03
28	9.87	—41	Oct. 1	10.63	—10	Sept. 4	10.66	—06
Febr. 25	10.16	—14	14	10.10	—12	27	10.70	—17
April 1	10.56	+14	28	10.54	—44	Oct. 9	10.57	—34
3	10.56	+16	Nov. 23	10.14	—23	Nov. 18	10.88	—12
Oct. 6	10.62	—31	1911 Jan. 9	10.10	—10	Dec. 18	10.63	—32
Nov. 13	10.73	—01	31	10.09	—12	1914 Jan. 19	10.51	—28
19	11.09	+04	Febr. 22	10.27	—24	Nov. 17	10.08	—20
21	11.14	—07	March 5	11.06	—49	Dec. 21	10.00	—27
Dec. 5	10.61	—43	20	10.11	—07	1915 Febr. 13	10.34	—32
8	10.58	—53	April 15	10.16	—13			
1910 Jan. 10	10.65	—08	Oct. 18	9.85	+11			

N — E = — $0^m.20$

Interval	comps	mean E	N—E
m m		m	m
9.76—10.20	25	9.98	—0.18
10.20—10.60	17	10.47	—0.24
10.60—11.00	14	10.70	—0.20
11.00—11.40	8	11.16	—0.21

3. The number of nights, on which both Nijland (N) and one of the Laws observers measured the star's brightness, being relatively small, the number of comparisons has been augmented by adding the indirect comparisons: (E — $0^m.20$) — L and (n — $0^m.17$) — L. The table contains both the direct and indirect comparisons. There being no perceivable relation between difference and brightness, the result is the mean: N — L = —$0^m.09$.

The first and the last numbers have been rejected for the present purpose.

Date	L	N–L	Date	L	N–L	Date	L	N–L
1907 Febr. 7	11.95	[—52]	1908 March 14	9.62	—17	1908 Oct. 21	10.24	+03
March 1	10.72	00	15	9.63	—33	27	10.65	+02
5	11.12	—24	16	9.65	—20	28	10.65	+23
14	11.27	—18	17	9.57	—12	Nov. 8	9.38	—14
23	10.93	—05	20	9.60	—15	Dec. 19	9.64	—02
Oct. 12	10.24	—10	23	9.58	—13	21	9.49	+13
1908 Jan. 1	10.09	—36	24	9.61	+04	1909 Febr. 10	9.68	—09
4	9.98	—38	25	9.63	—05	16	9.88	00
Febr. 19	10.24	—29	26	9.73	—15	19	9.92	+11
27	10.57	+27	April 1	10.14	—26	25	10.25	—23
29	11.09	—01	2	10.10	—15	April 1	10.70	00
March 5	10.93	—11	5	10.20	—25	8	10.33	—11
6	10.68	—14	11	10.24	—10	1910 March 2	9.95	+03
13	9.62	—17	Sept. 6	9.94	+09	11	9.90	[+63]

N — L = — $0^m.09$

Interval	comps	mean L	N—L
m m		m	m
9.38— 9.63	8	9.56	—0.09
9.63— 9.94	8	9.72	—0.09
9.94—10.24	8	10.08	—0.17
10.24—10.68	8	10.40	—0.02
10.68—11.27	8	10.93	—0.09

4. N — V. For N, as before, both N and n — $0^m.17$ have been used. When taken in groups of four, as is done in the left half of the second table, we see at a glance that the values of N — V vary in a systematic way with the brightness. These values have been plotted, and the reduction table given in the right half of the same table has been deduced.

Date	V	N–V	Date	V	N–V	Date	V	N–V
	m			m			m	
1908 Dec. 15	9.50	—06	1909 Jan. 26	9.63	—07	1909 Febr. 23	10.29	—21
27	9.59	+04	27	9.46	+08	25	10.29	—27
28	9.69	—13	28	9.40	+06	April 3	10.78	—06
30	9.52	+26	Febr. 1	9.16	+21	Sept. 3	11.16	—33
1909 Jan. 8	10.39	—16	6	9.32	+13	Oct. 6	10.68	—37
12	10.40	+13	7	9.42	+02	14	10.99	—28
15	10.16	+02	10	9.71	—12	21	10.41	+01
18	9.67	+28	12	9.74	+04	Nov. 7	10.20	+02
20	9.71	00	16	9.82	+06	13	10.70	+02
23	9.65	—06	17	9.82	+10	15	11.03	—14
24	9.68	—11	19	10.01	+02	17	11.10	—19
25	9.68	—11	21	10.40	—44	19	11.16	—03

V	N—V	V	N—V	Reduction table			
				V	N—V	V	N—V
m	m	m	m	m	m	m	m
9.32	+0.11	10.40	—0.12	9.00	+0.14	10.20	—0.08
9.52	+0.08	10.79	—0.17	9.20	+0.10	10.40	—0.11
9.66	+0.01	11.11	—0.17	9.40	+0.07	10.60	—0.15
9.70	—0.09			9.60	+0.03	10.80	—0.19
9.85	+0.05			9.80	0.00	11.00	—0.22
10.23	—0.11			10.00	—0.05	11.20	—0.26

5. The comparison N — F leads to the following result:

Date	F	N—F
	m	m
1913 Febr. 20	10.31	+0.15
21	10.24	—0.19
22	10.19	—0.15
24	10.12	—0.19
March 25	10.94	—0.29

If the first value is rejected as being discordant, the mean is N — F = — 0m.20; whereas the general mean is — 0m.13. We have preferred to adopt the latter value.

The foregoing comparisons have enabled us to reduce all the observations to one observer, excepting only (perhaps) the short series which Enebo made with the 2¾ inch refractor; for, with regard to these observations, no means were available for comparing them, either with the results obtained with the larger instrument, or with those of Nijland. It will be noticed further on, that the corrections applied to Enebo's observations with the 4¼ inch have, for this reason, been applied to those with the 2¾ inch refractor also.

Before proceeding to discuss a light-curve based on the newly reduced observations, a final criterion is wanted, for deciding whether we now have the right to consider this curve as homogeneous. Such a criterion may be established in the following way. The difference $N - n$ being very constant throughout, the results $n - 0^m.17$ may be considered to be equivalent with the results N. Assuming this, there remain 147 differences between Nijland and the other observers who have contributed to the light-curve.

If we find the values of these differences grouped as if they were residuals from a mean value (N), according to the probability-curve, the light-curve we have obtained may be considered as homogeneous. The following table shows that there is an excellent accordance between the number of cases (O), in which a difference has been "observed" within certain limits, and the number of cases (C) which we should have expected to find, if these differences had been purely accidental errors.

Limits	O	C	O—C
m m			
0.00—0.10	74	72	+2
0.10—0.20	44	43	+1
0.20—0.30	22	25	—3
0.30—0.50	7	7	0

From this table it appears that our investigation has enabled us to construct a light-curve, which would have been the same *had all the observations been made by a single observer, using the same instrument during the whole period.* Therefore we are warranted in regarding this light-curve (with perhaps the one provision we have alluded to above) as being strictly homogeneous.

CHAPTER III.

THE MAGNITUDES.

The following pages contain a complete list of all the visual observations of the light of the variable, from its discovery until May 1915. This list is given in two divisions, separated from each other by a double line. The first division, filling the left-hand side of the page, contains all that is directly connected with the work done by the *observers;* the second division contains the data which the *computer* derived, to form a basis for the construction of a homogeneous light-curve.

In detail, the contents of the different columns are as follows:

1st Division.

Col. 1. The date, and, so far it is given by the observer, the time of observation. This time is expressed by ENEBO in M. E. T. (G. M. T. + $1^h 0^m 0^s$), by NIJLAND in Utrecht M. T. (G. M. T. + $0^h 20^m 31^s$), by VOÛTE in Leiden M. T. (G. M. T. + $0^h 17^m 56^s$), and by BRILL and BODA in Frankfurt M. T. (G. M. T. + $0^h 34^m 36^s$). HARTWIG, PRAČKA and the Laws observers have expressed the hour of observation directly in G. M. T.

Col. 2. The observers. In this column the abbreviations have the following meaning:

e E = ENEBO when using the 2¾ and 4¼ inch refractors respectively.

Hg = HARTWIG P = PRAČKA.

H = HAYNES S = SEARES Sh = SHAPLEY.

n N = NIJLAND when using the 3 and 10 inch refractors respectively.

V = VOÛTE Br = BRILL B = BODA.

Col. 3. The estimates. These are given in three different forms, viz.

a. the direct ARGELANDER form. Thus (ENEBO, BRILL, BODA) *c* 3 *v*; *v* 2 *f* or (HARTWIG, PRAČKA) *c* 3 *v* 2 *f*, means that the variable was 3 steps fainter than *c*, and 2 steps brighter than *f*. Equality of brightness is indicated by the sign = ($v = c$), not by the designation 0 steps ($v\,0\,c$), as preferred by some observers.

b. the photometric form (the Laws observers), the measured differences being expressed in $0^m.01$ as the unit. Thus $c + 27$; $f - 03$ means that the variable was $0^m.27$ fainter than *c*, and $0^m.03$ brighter than *f*.

c. the interpolation form (NIJLAND, VOÛTE). In this form the notation $a\,3\,v\,1\,b$ simply means $(v - a) : (b - v) = 3 : 1$.

Col. 4. The brightness. This column needs no further explanation after what has been said above. For the results of the estimates of HARTWIG and PRAČKA see pp. 22—23.

Col. 5. Remarks. These have been taken exclusively from the MSS or publications of the observers, and condensed into the following system of abbreviations:

m = moon	M = moon bright or troublesome
t = twilight	T = twilight strong
g = seeing good	G = seeing very good
b = seeing bad	B = seeing very bad
h = haze, dampness, mist	H = strong haze or fog
c = clouds w = wind	W = strong wind

d, D, u, U = observation difficult, very difficult, uncertain or very uncertain.

! = observation very good   l = star at a low altitude.

In this column the reader will find a few estimates of the colour of the variable made by NIJLAND, and expressed in the well known OSTHOFF scale.

2nd Division.

Col. 1. The Julian day and its fraction in Greenwich Mean Time, given in two decimals. In a few cases only was this impossible, viz. when the time given by the observer was only accurate to the nearest hour.

Col. 2. The brightness, reduced to N, as derived from col. 4 of the 1st Division by means of the data arrived at in the preceding chapter.

Col. 3. References to the remarks suggested by the values of col. 2, or by the light-curve which was constructed from these values.

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
1905					241		
Oct. 10	Hg	*v* between *a* and *c*	9.87		7129.44	—	
1906							
March 3	Hg	*v* 3.5 *a*	9.16		7273.37	—	
Aug. 27 13.0	e	*v* = *e* *f* 0.5 *v*	10.80	G m u	7450.50	10.60	
Sept. 7 12.3	,,	*v* 2 *e* *v* 2 *f* *c* 2 *v*	10.57	G m	61.47	10.37	
10 12.0	,,	*v* = *c*	10.35	g m u	64.46	10.15	
11 11.3	,,	*v* 4 *e* *v* 4 *f* *c* 1 *v*	10.41	g	65.43	10.21	
13 11.4	,,	*v* 4 *e* *v* 4 *f* *c* 1 *v*	10.41	G	67.44	10.21	
18 10.7	,,	*v* 4 *e* *v* 4 *f* *c* 1 *v*	10.41	g l	72.40	10.21	
23 10.6	,,	*v* 3 *e* *c* 2 *v*	10.52	G	77.40	10.32	
24 11.3	,,	*v* 3 *e* *c* 2 *v*	10.52	G	78.43	10.32	
28 11.7	,,	*v* 3 *e* *c* 2 *v*	10.52	g	82.45	10.32	
Oct. 9 9.5	,,	*v* 1 *e* *v* 1 *f* *c* 2.5 *v*	10.65	G l	93.36	10.45	
13 11.0	,,	*v* 1 *e* *v* = *f* *c* 3 *v*	10.70	G	97.42	10.50	
15 10.2	,,	*v* 1 *f* *c* 2.5 *v*	10.62	G	99.38	10.42	
16 9.4	,,	*v* 3 *f* *c* 1 *v*	10.45	G	7500.35	10.25	
18 10.0	,,	*v* 3 *f* *c* 1.5 *v*	10.48	g	02.37	10.28	
21 11.6	,,	*v* 3 *f* *c* 1.5 *v*	10.48	G	05.44	10.28	
25 9.6	,,	*c* 1 *v*	10.45	g u	09.36	10.25	
Nov. 9 7.2	,,	*v* = *e* *f* 1 *v*	10.82	G l	24.26	10.62	
11	P	*v* 3.5 *h*	11.14		26.49	—	
14 7.0	e	*e* 2 *v*	10.99	G u	29.25	10.79	
25 8.3	,,	*c* 2 *v*	10.54	g u	40.37	10.34	
27	H	*c* + 15 *f* — 06	10.50		42.7	10.41	
Dec. 5 8.2	e	*v* 3 *e* *v* 2 *f* *c* 2 *v*	10.54	G	50.30	10.34	
6	H	*c* + 10 *f* — 38	10.31		51.8	10.22	
10 7.7	e	*v* 2 *e* *v* 2 *f* *c* 2.5 *v*	10.59	G	55.28	10.39	
11	H	*c* + 42 *f* — 23	10.55		56.8	10.46	
17	,,	*c* + 82 *f* + 02	10.87		62.8	10.78	1
18 6.4	e	*v* 1 *e* *v* = *f* *c* 3 *v*	10.70	G	63.23	10.50	
1907							
Jan. 3 7.8	E	*v* 2 *e* *v* 1.5 *f* *c* 3 *v*	10.78		79.28	10.58	
5	P	*f* 4 *v* 2.5 *e*	10.81		81.3	—	
6 8.2	E	*v* = *e* *v* = *f* *c* 3 *v*	10.96	G	82.30	10.76	
13 7.2	,,	*v* 1 *e* *v* 2 *f* *c* 3 *v*	10.80	g	89.26	10.60	
19 7.9	,,	*e* 2 *v* *v* = *f*	11.15	G	95.29	10.95	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Jan. 20	H	c + 55 f + 11	10.78		7596.8	10.69	
21	,,	c + 80 f + 47	11.09		97.8	11.00	
25	,,	c + 97 f + 54	11.21		7601.8	11.12	
27	,,	c + 212 f + 159	12.31	m	03.7	12.22	2
Febr. 2 6.9	E	e 4 v f 3 v	11.55	G	09.25	11.35	
4 8.7	,,	v = k v = g v 2 l	11.40	G	11.32	11.20	
5 9.9	,,	v = k v = g v 2 l	11.40	G	12.37	11.20	
7 8.7	,,	e 4 v f 4 v	11.63	b w u	14.32	11.43	
,,	H	c + 180 f + 119	11.95		,, .8	11.86	3
8	,,	c + 159 f + 103	11.75		15.7	11.66	
11	,,	c + 115 f + 70	11.38		18.7	11.29	
12	,,	c + 94 f + 55	11.20		19.6	11.11	
14	,,	c + 69 f + 23	10.91		21.7	10.82	
15	,,	c + 50 f + 21	10.81		22.6	10.72	
16	,,	c + 42 f + 11	10.72		23.7	10.63	
17 8.2	E	e 2 v v 1 f v 2 g	11.08	G !	24.30	10.88	
23 8.7	,,	e 1 v v 1 f c 3 v	10.96	G M	30.32	10.76	
24	H	c + 63 f + 18	10.86		31.7	10.77	
26	,,	c + 39 f + 17	10.73		33.7	10.64	
28 8.1	E	e 1 v v 2 f	10.92	g m	35.29	10.72	
March 1 9.8	,,	e 1 v v 2 f	10.92	G m	36.36	10.72	
,,	H	c + 48 f + 05	10.72		,, .6	10.63	
2 8.9	E	e 1.5 v v 1 f	11.03	G	37.33	10.83	
3 7.7	,,	e 2 v v 1 f	11.07	G	38.28	10.87	
,,	P	e 2 v 4 h	11.07		,, .34	—	
4	Hg	f 3.5 v 3 e	10.79		39.39	—	
5 7.8	E	e 2.5 v v 1.5 f	11.08	G	40.28	10.88	
,,	H	c + 90 f + 46	11.13		,, .7	11.04	
6 8.6	E	e 3 v v 1 f	11.15	G	41.32	10.95	
9 7.8	,,	e 3 v v = f	11.23	G	44.28	11.03	
10 8.1	,,	e 3 v v = f v 1 g	11.24	G	45.29	11.04	
11 8.2	,,	e 3 v v 1 f v 1 g	11.24	G	46.30	11.04	
14 8.0	,,	e 3 v f 0.5 v v 0.5 g	11.29	G	49.29	11.09	
,,	H	c + 99 f + 64	11.27		,, .6	11.18	
15	,,	c + 106 f + 74	11.35		50.6	11.26	
16 9.1	E	e 4 v f 2 v v = g	11.45	G	51.34	11.25	
18 10.8	,,	e 4 v f 2 v v = g	11.45	G	53.41	11.25	
21	H	c + 125 f + 76	11.46		56.7	11.37	24
22 9.2	E	e 3 v v 1 f v 2 g	11.13	G m	57.34	10.93	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
March 23 8.3	E	e 2 v v 1 f v 2 g	11.08	G m	7658.30	10.88	
,,	H	c + 77 f + 18	10.93		,, .6	10.84	
25	,,	c + 61 f + 26	10.89		60.6	10.80	
26 9.3	E	e 2 v v 1 f v 2 g	11.08	G m	61.34	10.88	
31	P	c 5 v = f	10.64		66.37	—	
,, 8.7	E	e 1 v v = f	11.08	G	,, .32	10.88	
April 1	H	c + 57 f + 11	10.79		67.6	10.70	
2 9.5	E	e 1 v v = f	11.08	G	68.35	10.88	
3	P	f 3 v 2 e	10.80		69.40	—	
8	H	c + 61 f + 23	10.87		74.7	10.78	
9	,,	c + 58 f + 08	10.78		75.6	10.69	
10 9.5	E	e 3 v v = f v 1 g	11.24	G	76.36	11.04	4
July 31	H	c — 45 f — 86	9.80		7788.9	9.71	
Aug. 3	,,	c — 14 f — 51	10.13		91.8	10.04	
10	,,	c + 11 f — 68	10.17		98.9	10.08	5
12	,,	c + 12 f — 40	10.31		7800.9	10.22	
18	,,	c + 08 f — 27	10.36		06.9	10.27	
Sept. 11 12.9	E	v 2 e v 3 f c 1 v	10.59	g	30.50	10.39	
12	H	c + 00 f — 35	10.28		31.9	10.19	
18	,,	c + 21 f + 11	10.61		37.8	10.52	
Oct. 4	,,	c + 23 f + 00	10.57		53.8	10.48	6
5	,,	c + 43 f — 15	10.59		54.8	10.50	
8	,,	c — 31 f — 49	10.05		57.8	9.96	34
9 10.8	E	v 3 e v 4 f c 1 v	10.49	G	58.41	10.29	
11	H	c — 04 f — 73	10.07		60.9	9.98	
12 10.0	E	v 4 e v 5 f v = c	10.34	G	61.37	10.14	
,,	P	v 7 e	10.50		,, .44	—	
,,	H	c + 09 f — 56	10.22		,, .8	10.13	
15	Hg	v = c	10.36		64.66	—	
16 9.8	E	v 5 e v 5 f v 2 c	10.19	G m	65.36	9.99	
18	Hg	a 6 v	9.73		67.35	—	
,,	H	c — 19 f — 66	10.03		,, .0	9.94	
19 11.4	E	v 5 e v 5 f v 2 c	10.19	G m	68.43	9.99	
,,	Hg	v between a and c	9.87		,, .45	—	
21	H	c — 28 f — 69	9.97		70.7	9.88	
23	,,	c — 36	9.90		72.8	9.81	
29	Hg	v = c	10.36		78.47	—	
Nov. 1 9.5	E	v 2 e v 4 f c 2 v	10.59	G	81.35	10.39	
2	P	v 3 f	10.46		82.3	—	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Nov. 4	H	c + 28 f — 17	10.51		7884.0	10.42	
8	P	c 7 v 3 f	10.61	orange red	88.39	—	
25	H	c + 06 f — 55	10.21		7905.8	10.12	
29 9.5	E	v 4 e v 4 f v 1 c	10.34	G	09.35	10.14	
Dec. 4	H	c + 01 f — 35	10.28		14.9	10.19	
5	,,	c + 21 f — 22	10.45		15.8	10.36	
6 10.3	E	e 1 v v 3 f c 2 v	10.79	G	16.39	10.59	
23 8.8	,,	v 2 e v 3 f c 1 v	10.59	G	33.32	10.39	
25 7.9	,,	v 5 e v 6 f v 2 c	10.14	G	35.29	9.94	
27 7.4	,,	v 6 e v 3 c	9.93	G !	37.27	9.73	25
30	H	c — 15 f — 46	10.15		40.8	10.06	23
1908							
Jan. 1 7.6	E	v 3 c v 6 e	9.93	G !	42.27	9.73	
,,	H	c — 10 f — 62	10.09		,, .7	10.00	
4 7.8	E	v 4 c	9.80	g !	45.28	9.60	
,,	H	c — 22 f — 73	9.98		,, .8	9.89	7
6 10.6	E	v 3 c v 5 e v 6 f	10.09	G	47.40	9.89	
7 9.0	,,	v 3 c v 5 e	10.00	G	48.33	9.80	
8	H	c — 13 f — 29	10.24		49.7	10.15	33
14	,,	c — 30 f — 67	9.97		55.6	9.88	
16	,,	c — 14 f — 25	10.26		57.6	10.17	
17	,,	c — 06 f — 36	10.24		58.7	10.15	
18	,,	c — 05 f — 36	10.25		59.6	10.16	
19 7.2	E	v = c v 4 e v 5 f	10.34	G m	60.26	10.14	
21	H	c + 05 f — 37	10.29		62.6	10.20	
22 8.6	E	v = c v 4 e v 6 f	10.29	G	63.31	10.09	
23	H	c + 13 f — 34	10.35		64.5	10.26	
24	,,	c + 06 f — 34	10.31		65.6	10.22	
25 7.8	E	v 2 e v 4 f c 2 v	10.59	g	66.28	10.39	
27	H	c — 05 f — 30	10.28		68.6	10.19	
29	,,	c — 06 f — 33	10.26		70.7	10.17	
31 8.2	E	v 4 c v 8 e	9.70	G	72.30	9.50	8
Febr. 1 7.4	,,	v 5 c	9.65	G !	73.27	9.45	
4 6.8	,,	v 4 c	9.80	G	76.24	9.60	
5 6.4	,,	v 4 c	9.80	g	77.22	9.60	
6	H	c — 27 f — 49	10.07		78.7	9.98	30
9 8.2	E	v 3 c v 6 e	9.93	G m	81.30	9.73	
12 6.8	,,	v 1 c	10.25	g M u	84.24	10.05	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Febr. 16	H	c — 14 f — 50	10.13		7988.6	10.04	
17 7.6	E	v 1 c v 5 e	10.15	g m	89.27	9.95	
18 8.1	,,	v 2 c	10.10	G m	90.29	9.90	
19 7.2	,,	v 1 c v 5 e	10.15	G	91.26	9.95	
,,	H	c + 03 f — 42	10.26		,, .7	10.17	
21	,,	c + 15 f — 18	10.44		93.6	10.35	
22	,,	c + 10 f — 22	10.39		94.6	10.30	
24 7.2	E	c 2 v v 3 e v 5 f	10.49	G !	96.26	10.29	
25	H	c + 23 f — 17	10.48		97.6	10.39	
26 7.3	E	e 1 v v 2 f c 3 v	10.89	G !	98.26	10.69	
27 8.2	,,	e 2 v v 1 f	11.06	G	99.30	10.86	
,,	H	c + 49 f — 04	10.68		,, .6	10.59	
28 9.1	E	e 3 v f 1 v	11.28	G !	8000.34	11.08	
29 7.8	,,	e 3 v f 1 v	11.28	G !	01.28	11.08	
,,	H	c + 83 f + 45	11.09		,, .6	11.00	
March 1 8.6	E	e 3 v v = f	11.21	G !	02.32	11.01	
3 8.3	,,	e 3 v f 1.5 v v 3 g	11.20	G	04.30	11.00	
4 9.1	,,	e 2.5 v v = f	11.17	g	05.34	10.97	
5 8.0	,,	e 2 v v 1.5 f	11.02	G	06.29	10.82	
,,	H	c + 58 f + 22	10.85	h b	,, .6	10.76	
6 8.5	E	v 1 e v 3 f c 3 v	10.74	g m	07.31	10.54	
,,	H	c + 43 f — 01	10.66		,, .6	10.57	
,,	S	c + 27 f — 05	10.56		,, .6	10.47	
9	H	c — 01 f — 43	10.23		10.6	10.14	
,,	S	c — 13 f — 51	10.13		,, .6	10.04	
10	H	c — 18 f — 59	10.07		11.6	9.98	
,,	S	c — 32 f — 54	10.02		,, .7	9.93	
11	H	c — 34 f — 72	9.92		12.56	9.83	
,,	S	c — 47 f — 68	9.88		,, .57	9.79	
12	,,	c — 59 f — 102	9.65		13.56	9.56	
,,	H	c — 49 f — 84	9.79		,, .57	9.70	
13 8.1	E	v 5 c	9.65	G m	14.30	9.45	
,,	S	c — 67 f — 106	9.59		,, .57	9.50	
,,	H	c — 63 f — 100	9.64		,, .57	9.55	
14 7.9	E	v 5 c	9.65	G m	15.29	9.45	
,,	H	c — 58 f — 96	9.68		,, .55	9.59	
,,	S	c — 69	9.57		,, .66	9.48	
15 8.1	E	v 6 c	9.50	G m	16.30	9.30	
,,	S	c — 67 a + 23	9.63		,, .57	9.54	

Date local time	Obs.	Estimate		M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
March 15	H	c — 67	a + 20	9.62		8016.57	9.53	
16 8.1	E		v 5 c	9.65	G m	17.29	9.45	
,,	S		a + 20	9.65		,, .67	9.56	
17 8.4	E		v 5 c	9.65	G m	18.31	9.45	
,,	S		a + 19	9.64		,, .60	9.55	
,,	H		a + 06	9.51		,, .60	9.42	
18 8.0	E		v 5 c	9.65	G m	19.29	9.45	
19 7.8	,,		v 5 c	9.65	G	20.28	9.45	
20 8.1	,,		v 5 c	9.65	G t	21.30	9.45	
,,	H	c — 67	a + 16	9.60		,, .60	9.51	
,,	S	c — 55	a + 02	9.60		,, .61	9.51	
22	,,	c — 68	a + 04	9.53		23.58	9.44	
23 8.8	E		v 5 c	9.65	g	24.32	9.45	
,,	S	c — 72	a + 17	9.58		,, .56	9.49	
,,	H	c — 63	a + 10	9.59		,, .57	9.50	
24 8.0	E	v 5 c	v 5 e	9.85	G	25.29	9.65	
,,	H	c — 61	a + 15	9.62		,, .55	9.53	
25 9.1	E	v 5 c	v 6 e	9.78	G	26.34	9.58	
,,	S		a + 16	9.61		,, .56	9.52	
,,	H		a + 22	9.67		,, .57	9.58	
26 8.8	E	v 5 c	v 6 e	9.78	G	27.32	9.58	
,,	S		a + 30	9.75		,, .63	9.66	
30 8.9	E	v 4 c	v 5 e	9.93	G	31.33	9.73	
April 1 8.9	,,	v 3 c	v 4 e	10.08	G	33.33	9.88	
,,	S		c — 07	10.19		,, .58	10.10	
,,	H		c — 14	10.12		,, .58	10.03	
2 9.2	E	v 2 c	v 4 e	10.15	G	34.34	9.95	
,,	H		c — 16	10.10		,, .58	10.01	
3	,,	c — 17	a + 57	10.05		35.64	9.96	
5 9.3	E	v 2 c	v 4 e	10.15	G t	37.35	9.95	
,,	H	c — 04	f — 47	10.20		,, .63	10.11	
6 9.0	E	v 2 c	v 3 e	10.23	G	38.33	10.03	
8	S		c — 01	10.25		40.61	10.16	
11 9.5	E	v 1 c	v 2.5 e	10.34	G m	43.35	10.14	
,,	S		c — 02	10.24		,, .63	10.15	
12	H	c + 14	f — 43	10.31		44.61	10.22	
,,	S		c + 00	10.26		,, .62	10.17	
13 9.4	E		v 1 c	10.25	G m u	45.35	10.05	
16	H	c — 44	a + 42	9.84		48.57	9.75	

Date local time	Obs.	Estimate		M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
April 18	S	*c* — 57	*a* + 25	9.69		8050.59	9.60	
,,	H	*c* — 54	*a* + 16	9.66		,, .59	9.57	
19	S	*c* — 60	*a* + 24	9.67		51.61	9.58	
21	H	*c* — 67	*a* + 13	9.58		53.58	9.49	
22	,,	*c* — 66	*a* + 04	9.54		54.59	9.45	
,,	S		*a* + 21	9.66		,, .60	9.57	
25	,,		*a* + 33	9.78		57.59	9.69	27
,,	H		*a* + 09	9.54		,, .60	9.45	
29	S		*a* + 04	9.49		61.59	9.40	
,,	H		*a* + 00	9.45		,, .60	9.36	
30	S		*a* + 10	9.55		62.59	9.46	
,,	H		*a* + 05	9.50		,, .59	9.41	
May 1	S		*a* + 15	9.60		63.59	9.51	
9	H		*a* + 19	9.64		71.59	9.55	
,,	S		*a* + 27	9.72		,, .60	9.63	
July 10	H	*c* — 74	*a* + 09	9.53		8133.91	9.44	
16	,,	*c* — 72	*a* + 04	9.51		39.89	9.42	
25	S	*c* — 39	*a* + 21	9.76		48.87	9.67	
,,	H	*c* — 45	*a* + 30	9.78		,, .88	9.69	
27	,,		*a* + 48	9.93		50.93	9.84	
28	,,	*c* — 23	*a* + 52	10.00		51.86	9.91	
29	,,	*c* + 00	*f* — 49	10.21		52.90	10.12	
Aug. 1	S	*c* + 26	*f* — 26	10.45		55.89	10.36	
,,	H	*c* + 05	*f* — 27	10.34		,, .89	10.25	
4	,,	*c* + 03	*f* — 33	10.30		58.88	10.21	
8	,,	*c* + 06	*f* — 37	10.30		62.87	10.21	
14	,,	*c* — 53	*a* + 43	9.80		68.92	9.71	
15	,,	*c* — 41	*a* + 32	9.81		69.81	9.72	
16	,,	*c* — 51	*a* + 33	9.76		70.92	9.67	
19 12.—	E	*v* 5 *c*	*a* 4 *v*	9.82	G m	73.5	9.62	
25	H	*c* — 32	*a* + 36	9.87		79.80	9.78	
27	,,	*c* — 47	*a* + 31	9.78		81.89	9.69	
30	,,	*c* — 51	*a* + 39	9.79		84.91	9.70	
Sept. 1	,,	*c* — 44	*a* + 32	9.79		86.79	9.70	
4 11.—	E	*v* 4 *c* *v* 6 *e*	*a* 6 *v*	10.02	G	89.4	9.82	
6 15.—	,,	*v* 2 *c*	*v* 4 *e*	10.23	G u	91.6	10.03	
,,	Sh	*c* — 29	*a* + 49	9.95		,, .74	9.86	
,,	H	*c* — 31	*a* + 46	9.93		,, .81	9.84	
7	,,	*c* — 31	*a* + 41	9.90		92.81	9.81	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Sept. 7	Sh	c — 19 a + 38	9.95		8192.81	9.86	
10	H	c — 16 a + 54	10.04		95.88	9.95	
23 11.—	E	v 2 c v 5 e	10.18	G u	8208.4	9.98	
26 16.—	,,	v 4 c v 8 c a 5 v	9.91	G	11.6	9.71	
29	Sh	c — 55 a + 15	9.65		14.71	9.56	
,,	H	c — 57 a + 25	9.69		,, .72	9.60	
Oct. 1	S	c — 39 a — 04	9.64		16.68	9.55	9
2	,,	c — 46 a + 14	9.69		17.73	9.60	
,,	H	c — 69 a + 17	9.59		,, .73	9.50	
3	,,	c — 41 a + 26	9.78		18.70	9.69	
,,	S	c — 51 a + 17	9.68		,, .70	9.59	
5	,,	c — 57 a — 02	9.56		20.69	9.47	
,,	H	c — 53 a + 23	9.70		,, .69	9.61	
7	S	a + 17	9.62		22.68	9.53	
8	,,	a + 18	9.63		23.68	9.54	
,,	H	a + 22	9.67		,, .68	9.58	
10	,,	a + 31	9.76		25.67	9.67	
12	,,	c — 43 a + 31	9.79		27.70	9.70	
13 10.—	E	v 4 c	9.94	G m u	28.4	9.74	
14	Sh	c — 26 a + 17	9.81		29.68	9.72	
,,	H	c — 44 a + 34	9.80		,, .68	9.71	
15	,,	c — 48 a + 36	9.79		30.67	9.70	
17	,,	c — 32 a + 40	9.89		32.76	9.80	
19 10.—	E	c 2 v v 4 e	10.43	g	34.4	10.23	
,, 10.6	N	b 4 v 2.5 c	10.10	a7 b6.5c c4 f5 g2h	,, .43	10.10	
20 8.3	E	c 2 v v 3 e v 4 f	10.46	g l	35.31	10.26	
,, 13.7	N	b 3.5 v 1.5 c	10.15		,, .56	10.15	
21 9.8	E	c 2 v v 2 e v 3 f	10.53	G	36.37	10.33	
,, 11.6	N	v = c ? v 1 c	10.27	4^c ?	,, .47	10.27	
,,	H	c + 03 f — 43	10.25		,, .69	10.16	
22 8.4	E	c 3 v v 2 e v 2 f	10.60	g l	37.31	10.40	
24 8.2	,,	c 3 v v = e v 1 f	10.70	G !	39.30	10.50	
,, 8.7	N	c 2.5 v 4 f	10.48		,, .35	10.48	
25 8.3	E	v = e v 0.5 f c 3 v	10.72		40.30	10.52	
27 10.0	N	c 6 v 1.5 f	10.67		42.41	10.67	
27	Sh	c + 39 f + 00	10.65		,, .70	10.56	
28 12.7	N	f 1.5 v 4 g	10.88		43.52	10.88	
,,	H	c + 51 f — 12	10.65		,, .68	10.56	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Oct. 29 10.2	N	*c* 5 *v* 1 *f*	10.69		8244.41	10.69	
30 13.0	,,	*c* 2 *v* 4 *f*	10.46		45.53	10.46	
31 10.8	,,	*v* = *c*	10.31	f 8 g 2 h	46.44	10.31	
Nov. 3	H	*c* — 45 *a* + 38	9.82		49.72	9.73	
4 7.3	E	*v* 4 *c* *a* 4 *v*	9.87	G m	50.26	9.67	
,, 12.7	N	*a* 2 *v* 4 *b*	9.50	M	,, .52	9.50	
,, ,,	n	*a* 2.5 *v* 2.5 *b*	9.58	,,	,, .52	9.41	
6 13.4	N	*v* = *a*	9.37	G M 3[c]	52.55	9.37	
,, ,,	n	*a* 1 *v* 5 *b*	9.43	,, ,,	,, .55	9.26	
7	Sh	*c* — 57 *a* + 10	9.62		53.62	9.53	
8 13.4	N	*v* 1.5 *a*	9.24	G M	54.55	9.24	
,,	Sh	*c* — 84 *a* — 10	9.38		,, .65	9.29	
11	H	*c* — 60 *a* + 06	9.58		57.68	9.49	
,,	Sh	*c* — 80 *a* — 06	9.42		,, .69	9.33	
14	,,	*c* — 80 *a* — 04	9.43		60.63	9.34	
15 8.1	n	*a* 3 *v* 2 *b*	9.63		61.33	9.46	
17 10.4	E	*v* 6 *c* *a* 4 *v*	9.76	G !	63.39	9.56	
19 7.9	n	*a* 5 *v* 1 *b*	9.73		65.32	9.56	
20	H	*c* — 62 *a* + 11	9.60		66.64	9.51	
,,	Sh	*c* — 64 *a* + 09	9.58		,, .65	9.49	
23 8.2	E	*v* 4 *c* *a* 6 *v*	9.97	G	69.30	9.77	
25 8.3	N	*b* 4 *v* 3 *c*	10.07		71.34	10.07	
26 8.1	E	*v* 0.5 *c* *v* 4 *e*	10.31	G	72.29	10.11	
28 9.0	N	*b* 2 *v* 3.5 *c*	9.96		74.37	9.96	
,, ,,	n	*b* 4 *v* 1.5 *c*	10.16		,, .37	9.99	
29 7.6	E	*v* = *c* *v* 4 *e* *v* 4 *f*	10.35	G	75.27	10.15	
30 9.3	,,	*v* 1 *c* *v* 4 *e* *v* 4 *f*	10.32	G	76.35	10.12	
Dec. 2 6.2	,,	*v* 1 *c* *v* 4 *e* *v* 4 *f*	10.32	G m	78.22	10.12	
3 9.3	,,	*v* 2 *c* *v* 5 *e* *v* 5 *f*	10.22	G m	79.34	10.02	
4	Sh	*c* — 43 *a* + 42	9.85		80.61	9.76	
8 14.8	N	*a* 2 *v* 2 *b*	9.56	M d	84.61	9.56	
12 8.3	E	*v* 5 *c* *a* 4 *v*	9.82	g	88.30	9.62	
13 12.8	n	*a* 3 *v* 3 *b*	9.58	m	89.52	9.41	
14	Sh	*c* — 74 *a* + 10	9.53		90.65	9.44	
15 7.1	n	*a* 4 *v* 3 *b*	9.61		91.29	9.44	
,, 8.5	E	*v* 5 *c* *a* 5 *v* *v* 4 *p* *v* 5 *d*	9.89	g	,, .31	9.69	
,, 11.5	V	*a* 2 *v* 3.5 *b*	9.50		,, .47	9.55	
18 13.0	,,	*a* 3.5 *v* 1.5 *b*	9.67		94.53	9.69	
19 7.7	E	*v* 6 *c* *a* 4 *v* *v* 8 *e* *v* 5 *d*	9.82	G	95.28	9.62	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Dec. 19	Sh	c — 57 a + 15	9.64		8295.64	9.55	
20	,,	c — 71 a + 12	9.56		96.57	9.47	
21 9.7	E	v 5 c a 4 v	9.82	G	97.36	9.62	
,,	Sh	c — 69 a — 04	9.49		,, .75	9.40	
22	,,	c — 100 a + 16	9.43		98.62	9.34	
26 12.2	n	b 1 v 5 c	9.88		8302.50	9.71	
27 9.5	,,	v = b	9.80		03.38	9.63	
,, 11.8	V	a 3 v 2.5 b	9.59		,, .48	9.62	
28 6.1	n	a 5 v 1 b	9.73	m d h	04.24	9.56	
,, 6.9	V	a 3 v 1 b	9.69		,, .28	9.71	
,, 15.0	n	b 2 v 4 c	9.96	G	,, .62	9.79	
30 7.8	,,	b 3 v 3 c	10.04		06.31	9.87	
,, ,,	N	b = v 6 c	9.78	3^c	,, .31	9.78	
,, 7.9	V	a 2 v 3 b	9.52		,, .32	9.57	
31 8.1	N	b 1 v 6 c	9.84	m d	07.33	9.84	
1909							
Jan. 2 7.1	E	v 2 c v 5 e	10.18	g M u	09.25	9.98	
6 7.7	,,	v 1 c v 5 e	10.23	G M	13.28	10.03	
8 6.4	,,	c 2 v v 4 e v 4 f	10.42	G m	15.22	10.22	
,, 10.1	N	v 1 c	10.23	M 3^c	,, .41	10.23	
,, ,,	n	c 1 v 2 f	10.41	M d	,, .41	10.24	
,, 12.6	V	c 1 v 4 f	10.39	M	,, .51	10.28	
9 6.0	E	c 2 v v 2.5 e v 3 f	10.51	g	16.21	10.31	
,, 8.0	N	v 1 c ?	10.23	c 4^c	,, .32	10.23	
12 6.0	,,	c 3 v 3 f	10.53		19.24	10.53	
,, 12.1	V	c 1 v 3.5 f	10.40		,, .49	10.29	
13 6.0	E	c 1 v v 2 e v 3 f	10.49	G	20.21	10.29	
,, 13.5	N	c 2.5 v 5 f	10.46	m	,, .55	10.46	
15 7.1	V	b 4 v 1.5 c	10.16		22.28	10.09	
,, 8.6	N	v 1 c ?	10.23	b h	,, .35	10.23	
,, ,,	n	c 2 v 3 f	10.44	b h	,, .35	10.27	
,, 11.5	N	v 2 c	10.14	g 4^c	,, .47	10.14	
,, ,,	n	b 6 v 1 c	10.22	g	,, .47	10.05	
18 6.1	,,	b 4.5 v 2.5 c	10.12		25.24	9.95	
,, 6.7	V	a 3.5 v 1.5 b	9.67		,, .27	9.69	
20 6.2	n	b 1 v 5 c	9.88		27.25	9.71	
,, 8.7	V	a 3.5 v 1 b	9.71		,, .35	9.72	
22	Sh	c — 41 a + 16	9.73		29.70	9.64	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Jan. 23 6.6	V	a 4 v 2 b	9.65		8330.26	9.66	
,, 13.6	N	v 2 b	9.59	h l d u	,, .56	9.59	
,, ,,	n	v = b	9.80	,, ,, ,, ,,	,, .56	9.63	
24 6.1	,,	a 6 v 1 b	9.74	m	31.24	9.57	
,, 9.3	E	v 5 c a 3 v	9.76	G	,, .35	9.56	
,, 11.4	V	a 4 v 1.5 b	9.68		,, .46	9.70	
25 7.0	,,	a 2.5 v 1 b	9.68		32.28	9.70	
,, 10.7	n	a 6 v 1 b	9.74		,, .44	9.57	
26 10.9	,,	a 5 v 1 b	9.73		33.44	9.56	
,, 10.9	V	a 2.5 v 1.5 b	9.63		,, .44	9.65	
27 6.6	,,	a 1 v 2.5 b	9.46	m	34.26	9.51	
,, 7.6	E	v 6 c a 4 v	9.76	G m	,, .28	9.56	
,, 8.5	n	a 5.5 v 1.5 b	9.71		,, .34	9.54	
28 6.4	E	v 5 c a 5 v	9.87	G m	35.22	9.67	
,, 6.9	V	a 1 v 5 b	9.40	m	,, .27	9.47	
,, 7.6	n	a 4 v 2.5 b	9.63	G m	,, .31	9.46	
Febr. 1 7.1	,,	a 2 v 3 b	9.54	M	39.29	9.37	
,, 12.7	V	B 4.5 v 1.5 a	9.16	M	,, .52	9.27	10
5 12.0	,,	B 5.5 v 1 a	9.22	M	43.49	9.32	
6 7.6	n	a 3 v 2 b	9.62	M	44.31	9.45	
,, 11.7	V	v = a	9.32	M	,, .48	9.40	
7 7.8	n	a 4 v 3 b	9.61		45.31	9.44	
,, 11.6	V	a 1 v 4 b	9.42	M	,, .47	9.49	
8 12.6	,,	a 2 v 3 b	9.52	M	46.51	9.57	
10 7.7	n	a 4.5 v 0.5 b	9.76		48.31	9.59	
,, 12.1	V	a 3.5 v 1 b	9.71	M	,, .49	9.72	
,,	Sh	c — 43 a + 13	9.70		,, .67	9.61	
11 12.6	V	a 4 v 1 b	9.72		49.51	9.73	
12 7.5	n	b 2 v 4.5 c	9.95		50.30	9.78	
,, 12.6	V	a 5 v 1 b	9.74		,, .51	9.75	
16 11.5	n	b 3 v 3 c	10.05		54.47	9.88	
,, 12.6	V	v = b	9.82		,, .51	9.82	
,,	H	c — 29 a + 35	9.88		,, .62	9.79	
17 10.2	n	b 3 v 2 c	10.09		55.42	9.92	
,, 12.0	V	v = b	9.82		,, .49	9.82	
18 9.4	,,	b 1.5 v 2 c	10.02		56.38	9.97	
19 8.7	n	b 4.5 v 1 c	10.20		57.35	10.03	
,, 9.0	V	b 2 v 3 c	10.01		,, .37	9.96	
,,	Sh	c — 19 a + 37	9.94		,, .74	9.85	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Febr. 20 11.9	V	*b* 2.5 *v* 1.5 *c*	10.11		8358.48	10.04	
21 8.2	n	*b* 4 *v* 2 *c*	10.13		59.33	9.96	
,, 12.0	V	*c* 1 *v* 3.5 *f*	10.40		,, .49	10.29	29
23 8.7	n	*b* 5 *v* 0.5 *c*	10.25		61.35	10.08	
,, 10.4	V	*v* = *c*	10.29		,, .42	10.20	
24	Sh	*c* — 04 *a* + 45	10.06		62.59	9.97	
,,	H	*c* — 07 *a* + 44	10.04		,, .59	9.95	
25 7.8	n	*b* 4 *v* 1 *c*	10.19	m	63.31	10.02	
,, 9.5	E	*v* 3 *c* *v* 4 *e* *v* 2 *p* *a* 7 *v*	10.16	G	,, .35	9.96	
,, 11.0	V	*v* = *c*	10.29		,, .45	10.20	
,,	H	*c* — 02 *f* — 33	10.28		,, .62	10.19	
,,	Sh	*c* — 08 *f* — 41	10.21		,, .62	10.12	
26	,,	*c* + 04 *f* — 18	10.38		64.69	10.29	
27	H	*c* — 24 *a* + 59	10.03		65.61	9.94	
March 1	Sh	*c* — 21 *a* + 30	9.90		67.60	9.81	
,,	H	*c* — 40 *a* + 37	9.84		,, .60	9.75	
3	Sh	*c* — 60 *a* + 00	9.55		69.61	9.46	
6	,,	*c* — 60 *a* + 06	9.58		72.64	9.49	
,,	H	*c* — 70 *a* + 04	9.52		,, .64	9.43	
7 9.4	N	*v* = *a*	9.37	M d	73.38	9.37	
,, ,,	n	*a* 2 *v* 2 *b*	9.58	,, ,,	,, .38	9.41	
10	Sh	*c* — 62 *a* — 02	9.53		76.64	9.44	
12 9.0	n	*a* 4 *v* 1 *b*	9.71	b	78.37	9.54	
13	Sh	*c* — 73 *a* — 01	9.48		79.58	9.39	
16 9.1	n	*a* 3 *v* 1.5 *b*	9.65		82.37	9.48	
17 10.3	N	*a* 3.5 *v* 1.5 *b*	9.65		83.42	9.52	11
,,	H	*c* — 52 *a* + 04	9.61		,, .59	9.52	
,,	Sh	*c* — 53 *a* + 01	9.59		,, .59	9.50	
18	H	*c* — 64 *a* + 07	9.57		84.64	9.48	
20	Sh	*c* — 58 *a* + 18	9.65		86.70	9.56	
23 9.4	E	*v* 3 *c* *v* 2 *p* *v* 6 *e* *a* 8 *v*	10.14	G	89.35	9.94	
25	Sh	*c* — 33 *a* + 49	9.93		91.59	9.84	
April 1 8.8	N	*c* 3.5 *v* 0.5 *f*	10.70	G M	98.36	10.70	
,, 9.4	E	*c* 3 *v* *v* 2 *e* *v* 3 *f*	10.56	G m	,, .36	10.36	
,,	H	*c* + 49 *f* + 05	10.72		,, .59	10.63	
2 8.4	N	*c* 2 *v* 2 *f*	10.53	G M	99.34	10.53	
3 9.1	,,	*f* = *v* 4 *g*	10.77	G M	8400.35	10.77	
,, ,,	,,	*c* 3 *v* 1 *f* *c* 3 *v* 4 *g*	10.67		,, .35	10.67	
,, 9.4	E	*c* 3 *v* *v* 2 *e* *v* 3 *f*	10.56	g m	,, .35	10.36	31

Date local time		Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
April	3 10.3	V	$v = f$	10.78		8400.42	10.59	
	4 8.5	N	$v = f$	10.76	G M	01.34	10.76	
	5 8.2	,,	$c\,2.5\,v\,1.5\,f$	10.59	G M	02.33	10.59	
	6 8.4	,,	$c\,2.5\,v\,2.5\,f$	10.53	G M	03.34	10.53	
	7 8.7	,,	$v = c$	10.31	G	04.35	10.31	
	,, ,,	n	$c\,2\,v\,2\,f$	10.48		,, .35	10.31	
	8 8.4	N	$b\,5\,v\,1\,c$	10.22	G	05.34	10.22	
	,, ,,	n	$c\,1\,v\,4\,f$	10.36		,, .34	10.19	
	,, ,,	Sh	$c + 02 \quad f - 39$	10.27		,, .65	10.18	
	10 8.8	N	$b\,2\,v\,4\,c$	9.94		07.36	9.94	
	,, ,,	n	$b\,2.5\,v\,2.5\,c$	10.05		,, .36	9.88	
	11 9.1	N	$v = b$	9.76	l	08.37	9.76	
	13	Sh	$c - 58 \quad a + 08$	9.60		10.61	9.51	
	14 8.4	n	$b\,1\,v\,3\,c$	9.92		11.34	9.75	
	23	Sh	$c - 58 \quad a + 12$	9.62		20.59	9.53	
May	6	,,	$a + 41$	9.86		33.60	9.77	
July	17	H	$c - 54 \quad a + 15$	9.66		8505.89	9.57	
	19	,,	$c - 54 \quad a + 16$	9.66		07.90	9.57	
	23 13.3	N	$v\,1.5\,c$	10.18	t l	11.55	10.18	
	24 14.0	,,	$b\,5\,v\,3\,c$	10.10	t	12.57	10.10	
	26 14.4	,,	$b\,4\,v\,4\,c$	10.03	t d	14.59	10.03	
	30 14.3	,,	$b\,5\,v\,2\,c$	10.17	d h	18.59	10.17	
Aug.	4 14.7	,,	$b\,3\,v\,5\,c$	9.97	M d	23.60	9.97	
	5 14.4	,,	$b\,2\,v\,4\,c$	9.94	G M	24.59	9.94	
	10 14.6	,,	$b = v\,5\,c$	9.82	G m	29.60	9.82	
	,, ,,	n	$b = v\,4\,c$	9.87		,, .60	9.70	
	15 13.6	V	$b\,1\,v\,2.5\,c$	9.95		34.56	9.91	
	22 14.4	N	$b\,4\,v\,3\,c$	10.07		41.59	10.07	
	,, ,,	n	$b\,3.5\,v\,1\,c$	10.18		,, .59	10.01	
	25 14.6	N	$b\,4\,v\,2\,c$	10.13		44.60	10.13	
	28 13.5	,,	$c\,2\,v\,4\,f$	10.46	M	47.55	10.46	
	29 14.0	,,	$c\,1.5\,v\,3\,f$	10.46	M	48.57	10.46	
Sept.	1 13.6	,,	$c\,3\,v\,3\,f$	10.53	G M	51.56	10.53	
	2 14.0	,,	$v = f$	10.76	M h	52.57	10.76	
	3 12.6	V	$f\,3\,v\,1\,g$	11.16		53.51	10.91	
	,, 13.9	N	$f\,1\,v\,5\,g$	10.83	M	,, .57	10.83	
	4 14.9	,,	$f\,2.5\,v\,1.5\,g$	11.04	m	54.61	11.04	
	5 13.8	,,	$f\,3\,v\,3\,g$	10.98		55.56	10.98	
	7 14.3	,,	$f\,3\,v\,1\,g$	11.09		57.58	11.09	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Sept. 9 12.2	N	*f* 3 *v* 3 *g*	10.98	b	8559.50	10.98	
10 12.2	V	*f* 3.5 *v* 1.5 *g*	11.13		60.50	10.89	
14 13.7	N	*c* 3 *v* 4 *f*	10.50	b	64.56	10.50	
16 13.4	,,	*b* 4 *v* 2 *c*	10.13	h	66.55	10.13	
,, ,,	n	*c* 2 *v*	10.46	h	,, .55	10.29	
19 15.5	N	*b* 2.5 *v* 5 *c*	9.94	G	69.64	9.94	
,, ,,	n	*b* 4 *v* 2.5 *c*	10.10	G	,, .64	9.93	
20 13.3	,,	*b* 4 *v* 3 *c*	10.08	G	70.54	9.91	
22 12.9	,,	*b* 4 *v* 4 *c*	10.05		72.53	9.88	
24 13.7	,,	*b* 4 *v* 4 *c*	10.05		74.56	9.88	
Oct. 2	Sh	*c* — 30 *a* + 36	9.88		82.77	9.79	
6 10.5	E	*v* 2.5 *e* *v* 4 *f*, *c* 2 *v*	10.62	g	86.40	10.42	
,, 10.8	V	*c* 4 *v* 1 *f*	10.68		,, .44	10.51	
,, 12.9	N	*v* = *c*	10.31	G m	,, .53	10.31	
,, ,,	n	*c* 3 *v* 1.5 *f*	10.54		,, .53	10.37	
9 10.8	V	*c* 4 *v* 1 *f*	10.68		89.44	10.51	
10 11.3	N	*c* 2 *v* 3 *f*	10.49		90.46	10.49	
14 10.8	V	*f* 1.5 *v* 2 *g*	10.99		94.43	10.77	
,, 12.7	N	*c* 4 *v* 0.5 *f*	10.71	G	,, .52	10.71	
15 11.3	E	*e* 2 *v* *v* = *f*	10.96	G	95.43	10.76	
17 11.4	N	*f* 1 *v* 4 *g*	10.85		97.47	10.85	
18 14.4	,,	*v* = *f*	10.76		98.59	10.76	
21 11.1	,,	*c* 1 *v* 3 *f*	10.42		8601.45	10.42	
,, 11.2	V	*c* 1 *v* 3 *f*	10.41		,, .46	10.30	
24 10.8	N	*v* 1 *c*	10.23	m	04.44	10.23	
,, ,,	n	*c* 2 *v*	10.46	m	,, .44	10.29	
25 13.3	N	*b* 6 *v* 1 *c*	10.23	m	05.55	10.23	
28 14.0	,,	*b* 4 *v* 3 *c*	10.07	M d	08.57	10.07	
Nov. 2 9.0	E	*c* 2 *v* *v* 4 *e*	10.54	G m	13.33	10.34	12;35
5	Sh	*c* — 35 *f* — 98	9.79		16.78	9.70	13;32
6	,,	*c* + 18 *f* — 48	10.30		17.57	10.21	
,,	,,	*c* + 35	10.61		,, .78	10.52	35
7 13.9	V	*b* 4 *v* 1 *c*	10.20		18.57	10.12	
,, 14.4	N	*b* 5 *v* 1 *c*	10.22	G m	,, .59	10.22	
,, ,,	n	*c* 1 *v*	10.38	G m	,, .59	10.21	
8 9.6	N	*b* 4.5 *v* 1.5 *c*	10.17	G	19.39	10.17	
,, ,,	n	*c* 1 *v*	10.38	G	,, .39	10.21	
9	Sh	*c* + 39 *f* — 10	10.60		20.61	10.51	
10 12.5	V	*c* 3.5 *v* 1 *f*	10.67		21.51	10.50	

Date	local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Nov. 13	8.1	E	*v* 1 *e* *v* 3 *f* *c* 4 *v*	10.73	g	8624.30	10.53	
,,	9.6	V	*c* 5 *v* 1 *f*	10.70		,, .38	10.53	
,,	15.5	N	*v* 0.5 *f*	10.72	G	,, .64	10.72	
14	8.4	,,	*v* = *f*	10.76		25.34	10.76	
15	12.3	,,	*f* 2 *v* 5 *g*	10.89		26.50	10.89	
,,	12.9	V	*f* 2.5 *v* 2.5 *g*	11.03		,, .52	10.80	
17	8.7	N	*f* 2 *v* 4 *g*	10.91	G	28.35	10.91	
,,	13.8	V	*f* 3.5 *v* 2 *g*	11.10		,, .56	10.86	
18	11.3	N	*f* 3 *v* 3 *g*	10.98	G	29.46	10.98	
19	9.4	E	*e* 5 *v* *f* 3 *v* *v*=*h* *v* 6 *g*	11.09	g	30.35	10.89	
,,	12.6	V	*f* 4.5 *v* 1.5 *g*	11.16		,, .51	10.91	
,,	13.5	N	*f* 5 *v* 1 *g*	11.13	G	,, .55	11.13	
20	8.5	V	*v* = *g*	11.28		31.34	11.00	
21	7.8	E	*f* 5 *v* *v* = *h* *v* 5 *g*	11.14	g m	32.28	10.94	
,,	8.1	N	*f* 5 *v* 2 *g*	11.07	G m	,, .33	11.07	
22	8.3	,,	*f* 5 *v* 2 *g*	11.07	G M	33.33	11.07	
23		Sh	*c* + 87 *f* + 52	11.15		34.57	11.06	
25	7.9	N	*f* 3.5 *v* 2 *g*	11.04	M	36.32	11.04	
30	9.4	,,	*c* 2 *v* 2 *f*	10.53	M	41.38	10.53	
Dec. 3	8.4	,,	*c* 3 *v* 4 *f*	10.50		44.34	10.50	
5	7.3	E	*c* 3 *v* *v* 3 *e*	10.61	g	46.26	10.41	
,,	8.1	N	*v* 1.5 *c*	10.18	5° ?	,, .33	10.18	
,,	,,	n	*c* 3 *v* 2 *f*	10.51		,, .33	10.34	
8	7.4	E	*c* 3 *v* *v* 4 *e* *v* 5 *f*	10.58	G	49.27	10.38	
,,	6.9	N	*v* 3 *c*	10.05		,, .28	10.05	
,,	,,	n	*v* = *c*	10.29		,, .28	10.12	
11	7.5	E	*c* 3 *v* *v* 3 *e*	10.61	G !	52.27	10.41	24
12	14.7	n	*v* = *c*	10.29		53.60	10.12	
13	11.6	,,	*b* 5 *v* = *c*	10.27		54.47	10.10	
14	14.1	E	*c* 4 *v* *v* 2 *e* *v* 4 *f*	10.68	G	55.55	10.48	23
15	14.1	N	*v* 1 *c*	10.23	h	56.58	10.23	
,,	,,	n	*c* 2 *v*	10.46	h	,, .58	10.29	
16	14.0	N	*v* = *c*	10.31	h	57.57	10.31	
18	14.5	,,	*c* 1.5 *v* 4 *f*	10.43		59.59	10.43	
19	13.9	,,	*c* 3.5 *v* 2.5 *f*	10.57	c	60.57	10.57	
20	7.6	E	*c* 5 *v* *v* 1 *e* *v* 4 *f*	10.73	G m	61.27	10.53	
21	7.9	N	*c* 2 *v* 2 *f*	10.53	m	62.32	10.53	
29	7.0	E	*v* 1 *f* *e* 2 *v*	10.92	G	70.25	10.72	
30	6.3	,,	*v* = *f* *e* 2 *v* *h* 1 *v*	11.01	g	71.22	10.81	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
1910							
Jan. 3 12.6	N	*c* 4 *v* 1 *f*	10.67	h	8675.51	10.67	
6 7.—	E	*c* 3.5 *v* *v* 1 *e* *v* 2 *f*	10.75	g	78.2	10.55	
8 7.1	N	*c* 3.5 *v* 3.5 *f*	10.53	h	80.29	10.53	
10 9.7	,,	*c* 4 *v* 3 *f*	10.57		82.40	10.57	
,, 11.—	E	*c* 3 *v* *v* 2 *e* *v* 4 *f*	10.65	g	,, .4	10.45	
11 10.—	,,	*c* 3 *v* *v* 3 *e* *v* 4 *f*	10.65	G	83.4	10.45	
17 7.6	N	*v* 0.5 *c*	10.27	m	89.31	10.27	
,, 9.—	E	*c* 3.5 *v* *v* 3 *e* *v* 5 *f*	10.62	G m	,, .3	10.42	
22 10.2	N	*c* 3 *v* 1.5 *f*	10.61	G M c	94.42	10.61	
24 9.—	E	*c* 3 *v* *v* 2 *e* *v* 4 *f*	10.65	G m	96.3	10.45	
29 11.—	,,	*c* 5 *v* *e* 1 *v* *v* 2 *f*	10.82	G ! m	8701.4	10.62	
30 8.4	N	*v* = *f*	10.76		02.34	10.76	
,, 10.—	E	*e* 2 *v* *v* 2 *f*	10.88	G	,, .4	10.68	
Febr. 1 8.6	N	*f* 1.5 *v* 4 *g*	10.88		04.35	10.88	
4 8.—	E	*e* 4 *v* *f* 1 *v* *v* 3.5 *g*	11.06	g	07.3	10.86	
6 9.—	,,	*e* 5 *v* *f* 1 *v* *v* 3 *g*	11.13	g	09.3	10.93	
7 8.—	,,	*e* 5 *v* *f* 2 *v* *v* 4 *g*	11.13	G	10.3	10.93	
8 8.—	,,	*f* 3 *v* *v* 4 *g* *v* = *h*	11.11	G !	11.3	10.91	
9 8.—	,,	*g* 1 *v* *f* 4 *v*	11.37	G u	12.3	11.17	
,, 7.5	N	*f* 5 *v* 1 *g*	11.13	G	,, .30	11.13	
11 8.—	E	*f* 3 *v* *v* 2 *g* *h* 3 *v*	11.23	G	14.3	11.03	
12 7.—	,,	*f* 4 *v* *v* 2 *g* *h* 2 *v*	11.24	G	15.2	11.04	
,, 7.1	N	*f* 5 *v* 1 *g*	11.13		,, .29	11.13	
13 8.6	,,	*f* 5 *v* 1 *g*	11.13		16.35	11.13	
18 8.5	,,	*v* 4 *f* *v* 1 *c*	10.29	m	21.34	10.29	
24 8.8	,,	*b* 4 *v* 4 *c*	10.03	G M d 3^c	27.36	10.03	
,, ,,	n	*v* = *c*	10.29	,, ,, ,,	,, .36	10.12	
27 8.—	E	*c* 1 *v* *v* 7 *e*	10.42	G	30.3	10.22	14;25
28	Sh	*c* — 16 *a* + 53	10.04		31.55	9.95	
March 1 7.5	N	*b* 4 *v* 4 *c*	10.03		32.30	10.03	
,, ,,	n	*b* 5 *v* 1 *c*	10.21		,, .30	10.04	
,, 10.—	E	*v* 2 *c*	10.27	G u	,, .4	10.07	
2 9.2	n	*b* 5 *v* 2 *c*	10.15		33.37	9.98	
,,	Sh	*c* — 23 *a* + 42	9.95		,, .71	9.86	
3 8.2	n	*v* = *c*	10.29		34.33	10.12	
4 7.6	,,	*v* = *c*	10.29		35.31	10.12	
5 8.1	N	*v* = *c*	10.31	G	36.33	10.31	
,, ,,	n	*c* 1 *v*	10.38	G	,, .33	10.21	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
March 6	Sh	c + 17 f — 42	10.33		8737.59	10.24	
8	,,	c + 16 f — 33	10.37		39.67	10.28	
10	,,	c — 39 a + 34	9.83		41.85	9.74	15
11 8.—	E	c 4 v v 1 e	10.73	G	42.3	10.53	
,,	Sh	c — 39 a + 48	9.90		,, .76	9.81	15
13 7.8	N	c 4.5 v 0.5 f	10.71	G	44.31	10.71	
,, 11.—	E	f 1 v e 2 v h 1 v v 4 g	11.05	G	,, .4	10.85	
15 7.6	N	c 5 v 0.5 f	10.72	c	46.31	10.72	
,, 9.—	E	f 3 v h 2 v v 3 g	11.19	G m	,, .3	10.99	
20 8.0	N	g 1.5 v 3 h	11.28	G M	51.32	11.28	
22 8.1	,,	g 0.5 v 2 h	11.25	M	53.33	11.25	16
23 7.7	,,	g 0.5 v 1.5 h	11.26	M	54.31	11.26	
26 8.1	,,	c 5 v 2 f 3.5 g	10.68	G M	57.33	10.68	17
,, 9.—	E	v = e v 3 f c 4 v	10.76	G m	,, .3	10.56	
27 8.4	N	v = c	10.31		58.34	10.31	
,, ,,	n	c 2 v 3 f	10.44		,, .34	10.27	
29 8.1	N	v 2 c	10.14	G	60.33	10.14	
,, ,,	n	c 2 v 3 f	10.44	G	,, .33	10.27	
April 1 8.6	,,	b 5 v 1 c	10.21	G	63.33	10.04	
,, 9.—	E	v 3 c v 4 p	10.15	G	,, .3	9.95	18
2 9.3	n	v = c	10.29	h	64.38	10.12	
3 8.5	N	b 6 v 2 c	10.17	h d	65.34	10.17	
4 10.—	E	v 3 c a 8 v	10.09	G	66.4	9.89	18
,, 9.4	N	b 5 v 2 c	10.15	h	,, .38	10.15	
9 10.—	E	v = c v 5 e	10.43	G	71.4	10.23	
July 27 14.4	N	a 7 v 3.5 c	10.00	G m t	8880.59	10.00	
29 14.4	,,	b 4 v 4 c	10.03	d	82.59	10.03	
Aug. 9 14.4	,,	b 5 v 2 c	10.15	G	93.59	10.15	
10 13.8	,,	b 5 v 2 c	10.15	h	94.57	10.15	
11 14.2	,,	b 4 v 3 c	10.07		95.58	10.07	
13 13.7	,,	v 0.5 c	10.27	G	97.56	10.27	
14 13.8	,,	v = c	10.31		98.57	10.31	
15 13.4	,,	c 3.5 v 2 f	10.60		99.55	10.60	
16 14.2	,,	c 4 v 1.5 f	10.64		8900.58	10.64	
19 15.5	,,	c 4 v = f v 1 f	10.70		03.64	10.70	
21 14.8	,,	v = f	10.76	M	05.61	10.76	
29 14.1	,,	b 4 v 2.5 c	10.10	m	13.58	10.10	
31 14.4	,,	b 2.5 v 2.5 c	10.03	c	15.59	10.03	
Sept. 1 12.2	,,	b 1 v 4 c	9.87		16.50	9.87	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Sept. 7 11.4	n	*v* = *b* *a* 4 *v* 1 *b*	9.75		8922.47	9.58	19
8 12.—	E	*v* 4 *c* *a* 6 *v*	9.98	G	23.5	9.78	
,, 11.4	n	*a* 3 *v* 1 *b*	9.69		,, .47	9.52	19
14 11.—	E	*v* 3 *c*	10.11	G u	29.4	9.91	
15 11.0	N	*v* = *b* ? *v* 3 *c*	9.90		30.45	9.90	
18 13.6	,,	*b* 3.5 *v* 2.5 *c*	10.08	M	33.56	10.08	
20 13.4	,,	*v* = *c*	10.31	G M	35.55	10.31	
21 14.6	,,	*b* 5 *v* 2 *c*	10.15	G M	36.60	10.15	
25 11.1	,,	*v* = *f*	10.76	G m	40.45	10.76	
26 15.9	,,	*f* 1 *v* 4 *g*	10.85	g m	41.65	10.85	
28 12.9	,,	*c* 4 *v* 1 *f*	10.67		43.53	10.67	
30 12.8	,,	*c* 3 *v* 3 *f*	10.53	G	45.52	10.53	
,, ,,	n	*c* 3 *v* 1.5 *f*	10.54	G	,, .52	10.37	
Oct. 1 11.—	E	*c* 1 *v* *v* 3 *e* *v* 3 *f*	10.63	g	46.4	10.43	
,, 12.4	N	*c* 3 *v* 3 *f*	10.53	d	,, .51	10.53	
2 15.3	,,	*c* 1.5 *v* 4 *f*	10.43	G	47.63	10.43	
,, ,,	n	*c* 3 *v* 2 *f*	10.51		,, .63	10.34	
6 11.4	N	*b* 4 *v* 4 *c*	10.03		51.47	10.03	
,, ,,	n	*b* 6 *v* 2 *c*	10.17		,, .47	10.00	
7 12.6	,,	*b* 6 *v* 2 *c*	10.17		52.51	10.00	
9 13.5	E	*v* 3 *c* *v* 3 *p* *a* 8 *v*	10.12		54.52	9.92	14
12 13.0	N	*b* 4 *v* 5 *c*	10.00	b D	57.53	10.00	
,, ,,	n	*b* 4 *v* 2 *c*	10.13	D	,, .53	9.96	
13 11.3	N	*b* 2 *v* 4 *c*	9.94	G m w	58.46	9.94	
,, ,,	n	*b* 4 *v* 1.5 *c*	10.16		,, .46	9.99	
14 10.—	E	*v* 3 *c* *v* 3 *p*	10.10	G m	59.4	9.90	
,, 14.1	N	*b* 2 *v* 3 *c*	9.98	G m	,, .58	9.98	
,, ,,	n	*b* 4 *v* 1 *c*	10.19	G m	,, .58	10.02	
15 13.3	N	*b* 3 *v* 4 *c*	10.00	G M w d	60.55	10.00	
20 12.9	,,	*b* = *v* 5 *c*	9.82	G M d	65.53	9.82	
22 11.6	,,	*b* 2 *v* 4 *c*	9.94	G M	67.47	9.94	
23 13.6	,,	*b* 3 *v* 3 *c*	10.03	m	68.55	10.03	
24 10.5	,,	*b* 3 *v* 3 *c*	10.03	4[c]	69.43	10.03	
26 10.—	E	*v* 1 *c*	10.31	g u	71.4	10.11	
28 10.—	,,	*c* 1 *v* *v* = *d*	10.54	g	73.4	10.34	
,, 9.7	N	*b* 4 *v* 2.5 *c*	10.10		,, .40	10.10	
30 10.—	E	*v* 2 *c* *v* = *d*	10.39	G u	75.4	10.19	
Nov. 2 14.5	N	*b* 4 *v* 2 *c*	10.13	G	78.59	10.13	
,, ,,	n	*v* = *c*	10.29	G	,, .59	10.12	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Nov. 4 9.—	E	*c 2 v* *v 4 e*	10.57	G	8980.3	10.37	
5 13.3	N	*v 1 c*	10.22	G	81.55	10.22	
6 9.—	E	*c 3 v* *v 3 e*	10.67	G	82.3	10.47	
8 13.3	N	*v 1 c*	10.22	G	84.54	10.22	
10 10.—	E	*c 3 v* *v 3 e*	10.67	b	86.4	10.47	
11 9.2	N	*b 6 v 1 c*	10.23	G m	87.37	10.23	
14 12.9	,,	*b 3 v 4 c*	10.00	M	90.53	10.00	
19 9.8	,,	*b 2 v 5 c*	9.92	M c	95.40	9.92	
20 15.6	,,	*v = b*	9.76	G M 3^c	96.64	9.76	
21 9.3	n	*b 2 v 4 c*	9.96	G m	97.38	9.79	
22 12.9	N	*v = b*	9.76	G m	98.53	9.76	
,, ,,	n	*b 4 v 2 c*	10.13	G m	,, .53	9.96	
23 8.—	E	*v 3.5 c* *v 2 p* *a 8 v*	10.14	G	99.3	9.94	14
,, 11.4	n	*b 4 v 3 c*	10.08	G m	,, .47	9.91	
25 13.6	,,	*b 5 v 3 c*	10.11	G	9001.56	9.94	
Dec. 3 8.—	E	*v 2.5 c* *v 3 p* *a 7 v*	10.12	G	09.3	9.92	14
4 13.6	n	*b 4.5 v 1.5 c*	10.17	b	10.56	10.00	
7 13.4	,,	*b 5 v 1.5 c*	10.18		13.55	10.01	
,, ,,	N	*b 4 v 3 c*	10.07		,, .55	10.07	
9 14.8	,,	*v = c*	10.31		15.61	10.31	
11 13.3	,,	*c 1.5 v 4 f*	10.43	m c	17.54	10.43	
13 13.7	,,	*c 3 v 2 f*	10.58	M c	19.56	10.58	
18 7.6	,,	*f 2.5 v 2.5 g*	10.98	G M	24.31	10.98	
19 14.1	,,	*f 2.5 v 2 g*	11.00	M	25.58	11.00	
20 7.—	E	*v = f* *e 2 v* *v 4 g*	11.07	G	26.2	10.87	
21 12.7	N	*f 3 v 2 g*	11.02	h m	27.52	11.02	
24 7.3	,,	*c 4 v 2 f*	10.61		30.30	10.61	
25 7.—	E	*c 3 v* *v 3 e*	10.67		31.2	10.47	
26 8.2	N	*b 3 v 3.5 c*	10.01		32.33	10.01	
,, ,,	n	*v = c*	10.29		,, .33	10.12	
27 6.2	,,	*b 4 v 2 c*	10.13	G	33.25	9.96	
30 6.9	,,	*b 2 v 4 c*	9.96		36.28	9.79	
1911							
Jan. 1 11.6	n	*b 3 v 4 c*	10.01		38.47	9.84	
2 8.—	E	*v 4 c* *v 4 p* *a 6 v*	10.00	g	39.3	9.80	14
4 9.—	,,	*v 5 c* *a 6 v*	9.93	g	41.3	9.73	
9 7.—	,,	*v 3 c* *v 3 p*	10.10	G m	46.2	9.90	
,, 12.5	N	*b 3 v 4 c*	10.00	m d	,, .51	10.00	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Jan. 13 6.1	N	b 1 v 5 c	9.85	GMd3.5°	9050.24	9.85	
22 9.—	E	v 2 c v 2 p	10.20	G !	59.3	10.00	
23 7.—	,,	c 3 v v 4 e v 4 f	10.63	g	60.2	10.43	
27 8.—	,,	c 1 v v 4 e	10.52	G	64.3	10.32	
28 8.—	,,	v 1 c v 4 e	10.42	g	65.3	10.22	
29 11.5	n	b 5 v 2 c	10.15	G	66.47	9.98	
30 6.7	,,	b 5 v 1 c	10.21	G	67.27	10.04	
31 7.—	E	v 3 c a 7 v	10.09	G w	68.2	9.89	
,, 7.2	n	b 4.5 v 2 c	10.14	G	,, .29	9.97	
Febr. 2 7.8	E	v 4 c a 7 v v 3 p	10.06	G w	70.28	9.86	
3 9.6	n	b 1.5 v 5 c	9.91	G	71.39	9.74	
8 9.5	N	v = b	9.76	G M	76.39	9.76	
9 7.9	,,	b = v 5 c	9.82	G M	77.32	9.82	
15 8.—	E	v 5 c a 6 v v 5 p	9.92	G	83.3	9.72	
,, 8.3	N	b 3 v 3 c	10.03	M	,, .33	9.90	11
19 9.6	,,	b 3 v 3.5 c	10.01	4°	87.39	10.01	
,, ,,	n	b 3 v 2 c	10.09		,, .39	10.09	
22 8.—	E	v 3 c v 5 e	10.27	G	90.3	10.07	
,, 7.9	N	b 3 v 3 c	10.03		,, .32	10.03	
,, ,,	n	b 5 v 1.5 c	10.18		,, .32	10.01	
26 7.8	N	v 2 c	10.14		94.32	10.14	
,, ,,	n	c 1 v 3.5 f	10.37		,, .32	10.20	
27 8.—	E	c 3 v v 3 e v 5 f	10.63	G	95.3	10.43	
March 1 7.3	N	v 1 c	10.22		97.30	10.22	
2 8.—	E	v 1 e v 3 f c 4 v	10.80	g	98.3	10.60	
3 10.—	,,	v 1 e v 2 f c 5 v	10.83	g	99.4	10.63	
4 8.—	,,	e 1 v v 1 f	10.99	G	9100.3	10.79	
5 8.—	,,	e 1 v f 1 v v 4 g	11.06	G	01.3	10.86	
,, 7.9	N	c 3.5 v 2.5 f	10.57	m	,, .32	10.57	
17 9.—	E	v 2 e c 2 v	10.67	G	13.3	10.47	20
19 8.2	N	b 4 v 3.5 c	10.05	G t	15.33	10.05	
,, ,,	n	b 4 v 2 c	10.13		,, .33	9.96	
20 7.6	,,	b 5 v 1 c	10.21		16.31	10.04	
,, 10.—	E	v 3 c	10.11	G u	,, .4	9.91	
22 8.5	n	b 4 v 1.5 c	10.16		18.34	9.99	
24 10.—	E	v 5 c a 6 v	9.93	G	20.4	9.73	
27 10.—	,,	v 5 c a 5 v	9.89	G	23.4	9.69	
29 7.9	n	b 2 v 3 c	10.00	h t	25.32	9.83	
April 1 10.—	E	v 5 c a 5 v	9.89	G	28.4	9.69	

Date local time			Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
April	3	8.9	n	b 2 v 3 c	10.00	G M	9130.36	9.83	
	5	8.4	,,	b 2.5 v 2 c	10.07	G m	32.34	9.90	
	6	8.5	N	b 3 v 2.5 c	10.06	G m	33.35	10.06	
	11	8.3	,,	b 3 v 4 c	10.00	G d	38.33	10.00	
	,,	,,	n	b 3 v 2 c	10.09	G d	,, .33	9.92	
	13	8.6	N	b 1 v 4.5 c	9.86	G M	40.35	9.86	
	15	8.8	,,	b 3 v 3 c	10.03		42.36	10.03	
	,,	,,	n	v 0.5 c	10.25		,, .36	10.08	
	,,	10.—	E	v 2 c v 3 p a 8 v	10.16	G	,, .4	9.96	
July	27	14.2	N	b 1 v 5 c	9.85	d	9245.58	9.85	
	29	14.0	,,	b 1 v 6 c	9.84	G	47.57	9.84	
Aug.	4	14.5	,,	b 4 v 2 c	10.13	d	53.59	10.13	
	6	14.3	,,	b 3 v 3 c	10.03		55.59	10.03	
	,,	,,	n	v 1 c	10.20		,, .59	10.03	
	7	14.4	N	v = c	10.31		56.59	10.31	
	8	14.4	,,	c 2 v 4 f	10.46	M	57.59	10.46	
	9	14.2	,,	c 3 v 2 f	10.58	M	58.58	10.58	
	11	14.3	,,	c 6 v 0.5 f	10.73	G M	60.58	10.73	
	12	13.7	,,	v = f	10.76	G M	61.56	10.76	
	13	13.4	,,	v = f	10.76	G M	62.55	10.76	
	17	14.8	,,	c 3 v 2 f	10.58	G m	66.61	10.58	
	20	13.5	,,	b 1 v 4 c	9.87	d m c ?	69.55	9.87	
	,,	,,	n	b 2 v 2 c	10.05	,, ,, ,,	,, .55	9.88	
	24	14.2	,,	v = b	9.80		73.58	9.63	
	25	13.9	,,	a 3 v 3 b	9.58		74.57	9.41	
	27	14.8	,,	a 3 v 2 b	9.62		76.61	9.45	
	30	14.3	,,	a 2.5 v 3 b	9.56	G	79.59	9.39	
Sept.	21	12.0	N	b 3 v 2.5 c	10.06		9301.49	10.06	21
	,,	,,	n	v = c	10.29		,, .49	10.12	
	22	13.1	N	b 5 v 2 c	10.15		02.53	10.15	
	,,	,,	n	b 5.5 v 1.5 c	10.19		,, .53	10.02	
	23	13.2	,,	b 5.5 v 0.5 c	10.25		03.54	10.08	
	26	11.0	E	v 2 c v 2 d a 7 v	10.09	g	06.42	9.89	
	28	12.4	n	b 2 v 3 c	10.00		08.51	9.83	
Oct.	1	10.9	,,	b 1 v 4.5 c	9.89	G	11.45	9.72	
	8	15.1	,,	a 3 v 1 b	9.69	G M d	18.62	9.52	
	9	13.5	,,	a 2 v 1.5 b	9.61	G M	19.55	9.44	
	14	9.6	E	v 4 c a 4 v	9.85	G	24.36	9.65	
	16	13.0	n	v = b	9.80	m	26.53	9.63	

Date local time		Obs.	Estimate			M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Oct.	18 9.3	E	*v* 5 *c*		*a* 5 *v*	9.85	G	9328.34	9.65	
	,, 14.2	n		*b* 4 *v* 2 *c*		10.13		,, .58	9.96	
	20 13.6	,,		*b* 5.5 *v* 1 *c*		10.21	G	30.56	10.04	
	23 9.1	E	*v* 1 *c*	*v* 3 *d*	*a* 8 *v*	10.12	g	33.34	9.92	
	24 11.8	N		*v* 0.5 *c*		10.27		34.48	10.27	
	,, ,,	n		*c* 1 *v* 4 *f*		10.36		,, .48	10.19	
	26 11.8	N		*v* 3 *c*		10.05		36.48	10.05	
	,, ,,	n		*v* = *c*		10.29		,, .48	10.12	
	28 9.3	E	*c* 1 *v*		*v* 5 *e*	10.45	G	38.35	10.25	
	,, 13.0	N		*v* = *c*		10.31	G	,, .53	10.31	
	31 9.0	E	*c* 3 *v*		*v* 5 *e*	10.54	G m	41.33	10.34	
	,, 14.4	N		*v* 2 *c*		10.14	G	,, .59	10.14	
	,, ,,	n		*c* 1 *v*		10.38	G	,, .59	10.21	
Nov.	1 12.3	N		*v* 2 *c*		10.14	m	42.50	10.14	
	,, ,,	n		*v* = *c*		10.29	m	,, .50	10.12	
	5 7.9	N		*b* 2 *v* 3 *c*		9.98	G M	46.32	9.98	
	7 9.3	E	*v* 5 *c*		*a* 6 *v*	9.90	G M	48.35	9.70	
	9 13.2	n		*a* 3 *v* 1 *b*		9.69	M	50.54	9.52	
	12 15.8	,,		*a* 3.5 *v* 1 *b*		9.70	G m	53.65	9.53	
	16 8.1	E	*v* 5 *c*		*a* 5 *v*	9.85	G	57.30	9.65	
	20 8.4	,,	*v* 6 *c*		*a* 5 *v*	9.81	G	61.31	9.61	
	21 8.8	n		*a* 5 *v* 0.5 *b*		9.76		62.36	9.59	
	24 13.6	,,		*b* 2 *v* 2 *c*		10.05	G	65.56	9.88	
	25 8.8	,,		*b* 2.5 *v* 2.5 *c*		10.05	G	66.36	9.88	
	27 8.8	E	*v* 4 *c*		*a* 8 *v*	10.02	G u	68.33	9.82	14
	29 9.6	,,		*v* 3 *c*		10.06	G m u	70.37	9.86	
Dec.	4 12.5	n		*b* 4 *v* 2 *c*		10.13	M d	75.51	9.96	
	8 9.2	,,		*c* 2 *v* 4 *f*		10.41	M	79.37	10.24	
	9 8.6	,,		*v* 1 *c*		10.20	G M	80.35	10.03	
	11 13.6	N		*b* 3 *v* 2 *c*		10.09	m	82.56	10.09	
	,, ,,	n		*b* 3 *v* 1 *c*		10.17	m	,, .56	10.00	
	14 7.3	,,		*b* 3 *v* 1.5 *c*		10.13		85.29	9.96	
	15 8.5	,,		*b* 2 *v* 2 *c*		10.05	G	86.35	9.88	
	,, 11.—	E	*v* 5 *c*		*a* 6 *v*	9.90		,, .4	9.70	
	17 11.9	n		*b* 0.5 *v* 4 *c*		9.85		88.49	9.68	
	23 7.7	,,		*v* = *b*?		9.80	c h d	94.31	9.63	
	29 6.—	E	*a* 3 *v*		*v* 5 *c*	9.76	G m	9400.2	9.56	
	30 13.6	n		*v* = *a*		9.36	c m	01.56	9.19	

Date local time			Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
1912									
Jan.	6	6.8	E	$v\,3\,c$ $a\,8\,v$	10.08	g	9408.24	9.88	14
	7	9.5	n	$b\,4\,v\,2\,c$	10.13	G	09.38	9.96	
	8	8.3	E	$v\,4\,c$ $v\,3\,p$ $a\,8\,v$	10.07	G	10.30	9.87	14
	14	5.9	n	$c\,2\,v\,3\,f$	10.44		16.24	10.27	
	15	8.1	E	$v\,2\,e$ $v\,3\,f$ $c\,4\,v$	10.72	G	17.29	10.52	
	17	6.8	,,	$v\,2\,e$ $v\,2.5\,f$ $c\,4\,v$	10.74	G	19.24	10.54	
	,,	6.8	n	$c\,4\,v\,3\,f$	10.50	b	,, .27	10.33	
	18	6.2	E	$v\,2\,e$ $v\,3\,f$ $c\,5\,v$	10.75	G	20.22	10.55	
	22	7.4	,,	$v = c$ $v\,2\,p$	10.28	G	24.27	10.08	
	26	7.3	n	$v = b$	9.80	G m	28.29	9.63	
	27	7.0	,,	$a\,3\,v\,2\,b$	9.62	G m	29.28	9.45	
	,,	8.0	E	$v\,5\,c$ $v\,6\,p$ $a\,5\,v$	9.86	G m	,, .29	9.66	
	28	12.3	n	$a\,2.5\,v\,2.5\,b$	9.58	m	30.50	9.41	
Febr.	2	6.9	,,	$a\,2\,v\,2\,b$	9.58	G M	35.28	9.41	
	4	7.6	,,	$a\,3.5\,v\,1\,b$	9.70	M h	37.31	9.53	
	5	7.3	E	$v\,5\,c$ $a\,7\,v$ $v\,6\,p$	9.92	g	38.26	9.72	
	7	7.6	n	$b\,0.5\,v\,5\,c$	9.84		40.31	9.67	
	8	7.0	n	$b\,2\,v\,5\,c$	9.94	b	41.28	9.77	
	9	7.0	,,	$b\,3\,v\,4\,c$	10.01		42.28	9.84	
	10	9.8	,,	$b\,2.5\,v\,2.5\,c$	10.05	h	43.40	9.88	
	11	11.7	,,	$b\,4\,v\,2\,c$	10.13		44.48	9.96	
	12	10.4	,,	$b\,4\,v\,2.5\,c$	10.10		45.42	9.93	
	14	9.7	E	$v\,3\,c$	10.06	b c u	47.36	9.86	
	18	9.4	,,	$v\,2\,c$ $v\,3\,p$ $a\,10\,v$	10.17	G	51.35	9.97	14;27
	21	7.4	N	$v\,0.5\,c$	10.27	G m	54.30	10.27	
	,,	,,	n	$c\,2\,v\,3\,f$	10.44	G m	,, .30	10.27	
March	3	7.5	,,	$b\,2.5\,v\,2.5\,c$	10.05	M	65.30	9.88	
	6	7.2	,,	$b\,1\,v\,4\,c$	9.90	G	68.29	9.73	
	7	7.3	,,	$a\,4\,v\,1\,b$	9.71	G	69.29	9.54	
	10	7.8	,,	$a\,2\,v\,2\,b$	9.58	c	72.32	9.41	
	12	8.1	E	$v\,5\,c$ $a\,5\,v$ $v\,6\,p$	9.86	G	74.29	9.66	
	17	9.4	n	$b\,1\,v\,3\,c$	9.92		79.38	9.75	
	19	7.6	,,	$b\,1\,v\,4\,c$	9.90		81.31	9.73	
	21	8.2	,,	$b\,1.5\,v\,2\,c$	10.01	m	83.33	9.84	
April	1	9.2	N	$v\,1\,c$	10.22	G M	94.37	10.22	
	3	7.6	,,	$v = c$	10.31	G t	96.31	10.31	
	9	8.7	,,	$v = c$	10.31	G	9502.35	10.31	
	10	8.4	,,	$v\,1.5\,c$	10.18	G	03.34	10.18	

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April 10	8.4	n	*c* 1.5 *v*	10.42	G	9503.34	10.25	
21	8.7	N	*a* 2 *v* 2 *b*	9.56	G d	14.35	9.56	
,,	,,	n	*v* = *b*	9.80	G d	,, .35	9.63	
23	8.5	N	*a* 3 *v* 1 *b*	9.66	m	16.34	9.66	
25	8.5	,,	*a* 2 *v* 2 *b*	9.56	G m t d	18.34	9.56	
Aug. 6	14.9	,,	*b* 1 *v* 5 *c*	9.85	m D	9621.61	9.85	
9	14.7	n	*a* 4 *v* 1 *b*	9.71	m d	24.60	9.54	28
16	14.1	,,	*a* 4 *v* 1.5 *b*	9.68		31.58	9.51	
18	14.3	,,	*v* = *b* ? *a* 3.5 *v* 0.5 *b*	9.77	h c ? b	33.59	9.60	
19	15.0	n	*v* = *b*	9.80		34.62	9.63	
27	15.0	,,	*a* 2 *v*	9.53	M d	42.62	9.36	
Sept. 4	14.3	N	*v* 2 *c*	10.14	m h d	50.58	10.14	
12	12.7	,,	*c* 3.5 *v* 2 *f*	10.60		58.52	10.60	
14	15.6	,,	*v* 1.5 *c*	10.18	G	60.64	10.18	
,,	,,	n	*c* 2 *v*	10.46	G	,, .64	10.29	
15	13.0	N	*v* = *c*	10.31		61.53	10.31	
,,	,,	n	*c* 1 *v* 2 *f*	10.41		,, .53	10.24	
17	14.7	N	*b* 4 *v* 3 *c*	10.07		63.60	10.07	
,,	,,	n	*b* 5 *v* 1 *c*	10.22		,, .60	10.05	
19	12.9	,,	*b* 3 *v* 1.5 *c*, *b* 3.5 *v* 2 *c*	10.12	G c	65.53	9.95	
20	12.6	,,	*b* 2 *v* 2.5 *c*	10.02		66.51	9.85	
21	11.2	E	*v* 6 *c* *a* 5 *v*	9.83	G	67.42	9.63	
,,	13.4	n	*b* 2 *v* 3 *c*	10.00		,, .55	9.83	
22	14.2	,,	*a* 4 *v* 1 *b*	9.71		68.58	9.54	
24	12.8	,,	*a* 2 *v* 2 *b*	9.58	M D	70.53	9.41	
26	14.1	,,	*a* 1 *v* 3 *b*	9.47	M D	72.58	9.30	
27	13.5	,,	*v* 1 *a*	9.27	G M	73.55	9.10	
Oct. 2	12.2	,,	*v* 1 *a*	9.27	G m 3[c]	78.50	9.10	
3	13.3	,,	*v* = *a*	9.36	m	79.54	9.19	
4	13.4	,,	*a* 1.5 *v* 2 *b*	9.55	G m	80.55	9.38	
5	12.8	,,	*a* 2 *v* 3 *b*	9.54		81.53	9.37	
7	11.3	,,	*a* 2.5 *v* 1.5 *b*	9.64		83.46	9.47	
8	10.3	E	*v* 5 *c* *a* 5 *v*	9.87	G	84.39	9.67	
,,	11.8	n	*a* 4 *v* 0.5 *b*	9.75	G	.48	9.58	
9	13.6	,,	*v* 0.5 *b*	9.76		85.56	9.59	
10	13.8	,,	*v* = *b*	9.80		86.56	9.63	
12	15.3	,,	*b* 1 *v* 5 *c*	9.88	G	88.63	9.71	
14	15.3	,,	*b* 2.5 *v* 1.5 *c*	10.11	G	90.63	9.94	
15	9.0	E	*v* 4 *c* *a* 7 *v* *v* 5 *p*	10.00	G	91.33	9.80	

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Oct. 15 14.1	n	b 3 v 2 c	10.09		9691.58	9.92	
17 12.2	,,	b 5 v 1 c	10.21		93.50	10.04	
,, ,,	N	v 3 c	10.05		,, .50	10.05	
27 10.6	,,	v = b v 5 c	9.82	M h d	9703.43	9.82	
31 14.6	n	a 4 v 1.5 b	9.68	m	07.60	9.51	
Nov. 3 8.6	,,	a 3 v 2 b	9.62		10.35	9.45	
14 8.1	E	v 4 c a 8 v	10.03	G	21.30	9.83	14
20 14.0	N	v 0.5 c	10.27	M c	27.58	10.27	
27 7.2	,,	c 5 v 0.5 f	10.72	M h	34.29	10.72	
28 12.5	,,	c 5 v 2 f	10.63	M	35.51	10.63	
Dec. 2 7.7	,,	v 2.5 c	10.10		39.31	10.10	
,, ,,	n	v 0.5 c	10.25		,, .31	10.08	
3 7.2	,,	b 4 v 1 c	10.19		40.29	10.02	
5 7.7	,,	b 2 v 2 c	10.05		42.31	9.88	
6 6.7	E	v 6 c a 8 v	9.94	G w	43.24	9.74	
9 7.2	n	a 4 v 0.5 b v 3.5 c	9.87		46.29	9.70	
12 7.5	,,	a 3 v 2 b	9.62	a 5 b 3 c	49.30	9.45	
16 12.7	,,	a 4 v 0.5 b v 4 c	9.84	m	53.52	9.67	
18 12.9	,,	a 3 v 1 b a 3 v 4 c	9.72	M	55.53	9.55	
25 13.9	N	a 3 v 7 c v = b ?	9.70	M d	62.57	9.70	
29 6.9	n	b 1 v 3 c	9.92		66.28	9.75	
30 6.2	E	v 4 c a 8 v	10.01	G	67.22	9.81	
,, 7.0	n	b 1.5 v 3 c	9.96	h	,, .28	9.79	
1913							
Jan. 3 12.5	n	b 3 v 3 c	10.05		71.51	9.88	
4 7.4	,,	b 3 v 2 c	10.09	h c ?	72.30	9.92	
8 8.0	,,	b 2.5 v 2 c	10.07		76.32	9.90	
,, ,,	N	v 4 c	9.97		,, .32	9.97	
9 7.8	n	b 3 v 2 c	10.09		77.32	9.92	
,, 9.4	E	v 5 c a 8 v	9.98	G	,, .35	9.78	
10 9.9	n	b 3 v 3 c	10.05		78.40	9.88	
15 11.4	,,	b 2 v 3 c	10.00	G m	83.47	9.83	
24 8.3	E	v 4 c a 8 v	10.03	G m	92.30	9.83	14
25 10.4	n	b 3 v 3 c	10.05	G M	93.42	9.88	
28 7.8	,,	b 3 v 2 c	10.09	c d	96.32	9.92	
31 6.9	,,	b 3 v 2 c	10.09		99.28	9.92	
Febr. 6 8.0	,,	v = c	10.29		9805.34	10.12	
,, ,,	N	v 2.5 c	10.10		,, .34	10.10	

Date local time		Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Febr. 8	6.8	N	*v* 2 *c*	10.14		9807.27	10.14	
,, ,,		n	*c* 1 *v*	10.38		,, .27	10.21	
12	7.6	E	*v* 4 *e* *c* 4 *v*	10.59	G	11.27	10.39	
13	8.2	,,	*v* 4 *e* *c* 4 *v*	10.59	G m	12.30	10.39	
14	10.9	N	*v* 0.5 *c*	10.27	m	13.44	10.27	
18	8.2	Br	*c* 2.5 *v* *v* 3.5 *f*	10.45	M b	17.32	10.32	
,,	8.3	B	*c* 4 *v* *v* 2 *f*	10.59	M b	17.36	10.46	
19	7.0	N	*c* 2 *v* 2 *f*	10.53	G M	18.28	10.53	
20	7.1	N	*c* 1 *v* 2 *f*	10.46	G M	19.29	10.46	
,,	9.4	B	*c* 0.5 *v* *v* 4.5 *f*	10.31	G M	,, .37	10.18	
21	6.9	N	*v* 3 *c*	10.05	G M	20.28	10.05	
,, ,,		n	*v* = *c*	10.29	G M	,, .28	10.12	
,,	9.2	Br	*v* 1 *c* *v* 4 *f*	10.27		,, .36	10.14	
,,	9.1	B	*v* 2 *c* *v* 4 *f*	10.21		,, .36	10.08	
22	7.4	n	*b* 5 *v* 1 *c*	10.21	G	21.30	10.04	
,,	8.8	B	*v* 2.5 *c* *v* 4.5 *f*	10.17		,, .34	10.04	
,,	8.9	Br	*v* 2 *c* *v* 4 *f*	10.22		,, .35	10.09	
23	7.6	n	*b* 4 *v* 1 *c*	10.19		22.30	10.02	
24	7.7	,,	*b* 4 *v* 2.5 *c*	10.10		23.30	9.93	
,,	8.9	B	*v* 3 *c* *v* 5 *f*	10.12		,, .35	9.99	
26	9.0	,,	*v* 5 *c* *v* 7 *f*	9.92		25.35	9.79	
,,	9.2	Br	*v* 3 *c* *v* 6 *f*	10.09	h u	,, .36	9.96	
March 1	7.6	n	*b* 2 *v* 3 *c*	10.00		28.30	9.83	
2	8.9	,,	*b* 3 *v* 3 *c*	10.05		29.36	9.88	
11	9.0	B	*v* 4 *c* *v* 7 *f*	10.02		38.35	9.89	
,,	9.1	Br	*v* 1.5 *c* *v* 4.5 *f*	10.23	b h	,, .36	10.10	26
12	7.8	N	*b* 1.5 *v* 4 *c*	9.91		39.32	9.91	
,, ,,		n	*b* 2 *v* 2.5 *c*	10.02	m c? d	,, .32	9.85	
18	9.8	B	*v* 7 *c* *v* 7 *f*	9.82		45.38	9.69	31
,,	9.9	Br	*v* 2 *c* *v* 5 *f*	10.18	b u	,, .39	10.05	
19	7.8	N	*b* 3 *v* 2 *c*	10.09	M	46.32	10.09	
23	8.5	,,	*v* 1.5 *c*	10.18		50.34	10.18	
,, ,,		n	*c* 1 *v*	10.38		,, .34	10.21	
25	8.4	N	*c* 3 *v* 1 *f*	10.65		52.34	10.65	
,,	8.9	B	*c* 5.5 *v* *f* 3 *v*	10.89	h d	,, .35	10.76	
,,	9.3	Br	*c* 6 *v* *e* 2 *v* *f* 4 *v*	10.99		,, .36	10.86	
26	7.5	N	*v* = *f*	10.76		53.30	10.76	
April 2	8.7	,,	*b* 3.5 *v* 3 *c*	10.06		60.35	10.06	
,, ,,		n	*b* 3 *v* 1.5 *c*	10.13		,, .35	9.96	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
April 7 8.0	n	*b* 2 *v* 2 *c*	10.05	G t	9865.32	9.88	
9 8.4	N	*b* 2 *v* 4 *c*	9.94	c ? d	67.34	9.94	
13 8.1	,,	*b* 2.5 *v* 4 *c*	9.97	G m	71.33	9.97	
20 8.6	,,	*b* 3 *v* 3 *c*	10.03	G M d	78.35	10.03	
Aug. 14 15.1	N	*b* 4 *v* 2.5 *c*	10.09	t	9994.62	10.09	
,, ,,	n	*c* 1 *v*	10.38	t	,, .62	10.21	
					242		
22 14.4	N	*c* 4 *v* 1.5 *f*	10.64	G m	0002.59	10.64	
24 14.4	,,	*f* 1 *v* 3 *g*	10.87	m	04.59	10.87	
25 13.1	,,	*f* 0.5 *v* 2.5 *g*	10.83	G ! m	05.54	10.83	
26 13.7	,,	*f* 3 *v* 1 *g*	11.09	G m	06.56	11.09	
27 11.1	E	*f* 4 *v* *v* 3 *g*	11.21	G l	07.42	11.01	
28 13.0	N	*g* 1 *v* 1 *h*	11.32	G	08.53	11.32	
29 15.0	,,	*v* 0.5 *g*	11.16		09.61	11.16	
30 11.3	E	*f* 3 *v* *v* 4 *g*	11.14	G l	10.43	10.94	
,, 14.5	N	*f* 4 *v* 1 *g*	11.11		,, .59	11.11	
Sept. 4 11.1	E	*v* 3 *f* *c* 4 *v*	10.66	G l	15.42	10.46	
,, 14.1	N	*c* 3.5 *v* 2 *f*	10.60		,, .58	10.60	
6	,,	*v* 1 *c*	10.23	G	17.55	10.23	
,, 13.3	n	*c* 2 *v* 2 *f*	10.48	G	,, .55	10.31	
7 14.0	,,	*v* = *c*	10.29	G	18.57	10.12	
8 14.4	,,	*b* 6 *v* 1 *c*	10.22	G	19.59	10.05	
9 15.5	,,	*b* 6 *v* 1 *c*	10.22	G	20.64	10.05	
12 14.8	,,	*b* 6 *v* 1.5 *c*	10.19	G	23.61	10.02	
15 13.8	N	*b* 3 *v* 3 *c*	10.03	M d	26.56	10.03	
16 13.1	n	*b* 2 *v* 1 *c*	10.13	G M D	27.54	9.96	
,, ,,	N	*b* 3 *v* 3 *c*	10.03	G M D	,, .54	10.03	
19 13.5	,,	*b* 3 *v* 3 *c*	10.03	M h d	30.55	10.03	
23 10.5	E	*v* 4 *f* *c* 2 *v*	10.55	G m	34.40	10.35	
24 13.6	N	*b* 5 *v* 2 *c*	10.15	G m	35.56	10.15	
,, ,,	n	*c* 1.5 *v* 2 *f*	10.45	G m	,, .56	10.28	
25 13.0	,,	*c* 2 *v* 1 *f*	10.54		36.53	10.37	
,, ,,	N	*c* 1.5 *v* 4 *f*	10.43		,, .53	10.43	
26 12.8	,,	*c* 2.5 *v* 2.5 *f*	10.53	d	37.53	10.53	
,, ,,	n	*c* 3 *v* 1 *f*	10.57	d	,, .53	10.40	
27 10.5	E	*v* 2 *f* *c* 4 *v*	10.70	G	38.40	10.50	
,, 14.5	N	*c* 3 *v* 3 *f*	10.53	G	,, .59	10.53	
28 13.2	,,	*c* 2 *v* 2 *f*	10.53		39.54	10.53	
29 11.8	,,	*c* 3 *v* 3 *f*	10.53		40.48	10.53	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Sept. 30 14.1	N	. c 3.5 v 2 f	10.60	G	0041.58	10.60	
Oct. 3 13.5	,,	c 3 v 1.5 f	10.61		44.55	10.61	
5 9.5	E	v 1 e c 4 v v 4 f	10.68	G 1	46.35	10.48	
9 9.2	,,	v 3.5 e c 3 v	10.57	G	50.34	10.37	
,, 14.4	N	v 1 c	10.23	G	,, .59	10.23	
,, ,,	n	c 1 v 3 f	10.38	G	,, .59	10.21	
16 11.9	N	b 4 v 3 c	10.07	M d	57.49	10.07	
19 14.6	,,	b 4 v 2 c	10.13	M d	60.60	10.13	
25 11.2	,,	b 5 v 3 c	10.10	d	66.46	10.10	
,, ,,	n	v = c	10.29	d	,, .46	10.12	
26 14.5	,,	v = c	10.29	G	67.60	10.12	
,, ,,	N	b 5 v 3 c	10.10	G	,, .60	10.10	
28 13.3	,,	v 1 c	10.22		69.55	10.22	
,, ,,	n	c 1.5 v 2 f	10.45		,, .55	10.28	
Nov. 3 13.7	,,	c 2 v 1 f	10.54	G	75.56	10.37	
,, ,,	N	v = c	10.31	G	,, .56	10.31	
5 8.5	E	v 2.5 e v 3 f c 4 v	10.66	G	77.31	10.46	
6 14.8	N	c 3 v 3 f	10.53	b	78.61	10.53	
11 13.6	,,	f 2 v 1 g	11.05	G M	83.55	11.05	
13 14.2	,,	f 3 v 1 g	11.09	M B	85.58	11.09	
18 6.5	E	v = e v = f	10.88	G W	90.23	10.68	
,, 13.3	N	v = f	10.76	m	,, .55	10.76	
20 9.4	E	v 2 e v 3 f c 4 v	10.68	G	92.35	10.48	
22 11.7	n	c 3 v 1 f	10.57	G	94.48	10.40	
,, ,,	N	c 2 v 2.5 f	10.51	G	,, .48	10.51	
24 7.2	E	v 4 e v 5 f c 4 v	10.58	G	96.26	10.38	
Dec. 1 11.8	N	b 5 v 2 c	10.15	G	0103.48	10.15	
,, ,,	n	c 1 v	10.38	G	,, .48	10.21	
6 9.0	,,	v = c	10.29	M	08.37	10.12	
7 13.6	,,	b 4 v 0.5 c	10.24		09.56	10.07	
,, ,,	N	b 3 v 3 c	10.03		,, .56	10.03	
18 8.2	E	v 3 e v 4 f c 4 v	10.63	G	20.30	10.43	
,, 8.9	N	v = c	10.31	G	,, .36	10.31	
,, ,,	n	c 1 v 2 f	10.41	G	,, .36	10.24	
19 8.7	,,	c 2 v 2 f	10.48		21.35	10.31	
,, ,,	N	v = c	10.31		,, .35	10.31	
20 8.0	,,	c 3 v 3 f	10.53		22.32	10.53	
24 13.3	,,	c 2 v 3 f	10.49		26.54	10.49	
26 6.4	E	v = e v 2 f c 8 v	10.83	G	28.22	10.63	14

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Dec. 30 14.7	N	c 1 v 3 f	10.42	G	0132.60	10.42	
,, ,,	n	c 3 v 1 f	10.57	G	,, .60	10.40	
31 13.0	N	c 3 v 3 f	10.53		33.53	10.53	
1914							
Jan. 1 7.3	E	v 3 e c 3 v	10.59	g	34.26	10.39	
4 13.9	N	v 2 c	10.14		37.57	10.14	
,, ,,	n	c 0.5 v 3 f	10.34		,, .57	10.17	
5 7.0	E	v 2 p c 1 v v 6 e	10.36	G m	38.25	10.16	14
11 7.3	N	b 4 v 3 c	10.07	G M d	44.29	10.07	
14 8.8	n	c 1.5 v 1.5 f	10.48	G M d	47.36	10.31	27
15 10.1	,,	b 4 v 1 c	10.19	G M	48.41	10.02	
17 8.0	,,	b 5 v 0.5 c	10.25	G	50.32	10.08	
19 6.7	E	p 3 v c 2 v v 6 e	10.51	G	52.24	10.31	
,, 12.2	N	v 1 c	10.23		,, .50	10.23	
,, ,,	n	c = v 2 f	10.39		,, .50	10.22	
20 8.4	,,	v = c	10.29		53.34	10.12	
22 13.6	N	v 1.5 c	10.18		55.56	10.18	
23 8.1	E	c 4 v v 3.5 e	10.61	G	56.30	10.41	
Febr. 1 8.4	N	c 3 v 2.5 f	10.56		65.34	10.56	
2 7.1	,,	c 3.5 v 2.5 f	10.57	m	66.29	10.57	
4 7.4	,,	c 4 v 0.5 f	10.71	G m	68.30	10.71	
10 11.0	,,	b 3 v 3 c	10.03	M	74.45	10.03	
12 12.4	,,	b 4 v 4 c	10.03	M b d	76.51	10.03	
23 7.8	,,	v = c	10.31	B d	87.31	10.31	
27 9.0	E	c 4 e v 4 e p 2 v	10.58	G	91.33	10.38	
March 1 8.1	N	c 2 v 3 f	10.47	m	93.32	10.47	
,, ,,	n	c 3 v 1 f	10.57	m	,, .32	10.40	
2 8.2	E	c 5 v v 2 e	10.70	g m	94.30	10.50	
10 8.4	N	f 1.5 v 2 g	10.95	M	0202.34	10.95	
11 7.3	,,	f 1.5 v 2.5 g	10.92	M H d	03.30	10.92	
13 8.8	E	e 2 v v 1 f	10.91	g	05.33	10.71	
14 7.8	N	c 3 v 2 f	10.58		06.32	10.58	
,, ,,	n	v = f	10.66		,, .32	10.49	
16 9.2	E	v 1.5 c a 8 v	10.15	G	08.34	9.95	14;34
18 8.8	n	b 5 v 0.5 c	10.25	c ?	10.36	10.08	
22 7.6	,,	b 5 v 1 c	10.21		14.30	10.04	
27 8.9	,,	v 0.5 c	10.25		19.36	10.08	
,, ,,	N	v 3 c	10.05		,, .36	10.05	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
March 29 9.9	E	*v* 3 *c* *v* 4 *p* *a* 15 *v*	10.20	g	0221.37	10.00	14
31 8.6	N	*b* 4 *v* 3 *c*	10.10	m	23.35	10.10	
,, ,,	n	*b* 4 *v* 1 *c*	10.19	m	,, .35	10.02	
April 3 8.9	N	*b* 3 *v* 3 *c* 3 *f*	10.06	G m d	26.36	10.06	
4 9.9	E	*v* 3 *c* *v* 4 *p* *a* 10 *v*	10.12	g m	27.37	9.92	14
6 8.2	N	*b* 2.5 *v* 4 *c*	9.97	m	29.33	9.97	
12 9.5	,,	*v* 1 *c*	10.22		35.39	10.22	
,, ,,	n	*c* 1 *v*	10.38		,, .39	10.21	
14 8.0	N	*b* 4 *v* 1 *c*	10.20	G t	37.33	10.20	
16 8.7	,,	*b* 4 *v* 2 *c*	10.13	G t d	39.35	10.13	
,, ,,	n	*c* 0.5 *v*	10.33	G t d	,, .35	10.16	
18 9.1	N	*c* 3 *v* 3 *f*	10.53	b d l	41.37	10.53	
19 8.7	,,	*c* 2 *v* 2 *f*	10.53	t	42.35	10.53	
20 8.8	,,	*c* 1 *v* 3 *f*	10.42	G l D 4.5^c	43.36	10.42	
22 8.9	,,	*c* 3 *v* 3 *f*	10.53	G l d	45.36	10.53	
Aug. 2 14.5	n	*b* 4 *v* 1 *c*	10.19	G t	0347.59	10.02	
4 14.9	,,	*v* = *c*	10.29	G t d	49.61	10.12	
,, ,,	N	*v* 2.5 *c*	10.10	G t d	,, .61	10.10	
11 14.6	,,	*c* 3 *v* 3 *f*	10.53	G m	56.60	10.53	
12 13.6	,,	*c* 3 *v* 2 *f*	10.58	G m	57.56	10.58	
13 14.0	,,	*c* 3.5 *v* 2 *f*	10.60	G m	58.57	10.60	
17 14.2	,,	*v* 2 *c*	10.14	G m	62.58	10.14	
,, ,,	n	*v* = *c*	10.29	G m	,, .58	10.12	
19 14.1	,,	*b* 3 *v* 2 *c*	10.09		64.58	9.92	
Sept. 1 13.8	,,	*b* 2 *v* 2 *c*	10.05	G M	77.57	9.88	
3 14.5	,,	*b* 3 *v* 1 *c*	10.17	G M	79.60	10.00	
4 13.8	,,	*b* 2 *v* 2 *c*	10.05	G M d	80.57	9.88	
6 14.0	N	*b* 3 *v* 2.5 *c*	10.06	G M d	82.57	10.06	
7 13.4	,,	*b* 4 *v* 2.5 *c*	10.10	M	83.55	10.10	
9 13.2	,,	*b* 4 *v* 2.5 *c*	10.10	M d	85.54	10.10	
15 13.9	,,	*c* 2 *v* 2 *f*	10.53	m b	91.57	10.53	
20 12.8	,,	*f* 1 *v* 2 *g*	10.91	G	96.52	10.91	
22 14.0	,,	*c* 2.5 *v* 1.5 *f*	10.59	G	98.57	10.59	
23 15.5	,,	*c* 1 *v* 3 *f*	10.42	G	99.64	10.42	
24 14.4	,,	*v* 1.5 *c*	10.18		0400.59	10.18	
,, ,,	n	*v* = *c*	10.29		,, .59	10.12	
25 12.8	,,	*v* = *c*	10.29		01.52	10.12	
30 11.5	,,	*b* 1.5 *v* 2 *c*	10.01	G M	06.47	9.84	
,, ,,	N	*b* 2 *v* 4 *c*	9.94	G M	,, .47	9.94	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Oct. 6 13.9	n	*b* 2 *v* 2 *c*	10.05	G M d	0412.57	9.88	
11 12.9	,,	*b* 1 *v* 2 *c*	9.96	G m	17.53	9.79	
12 13.0	,,	*b* 1 *v* 2 *c*	9.96	m h	18.53	9.79	
13 9.—	E	*v* 2 *c*	10.20	G c	19.33	10.00	
Nov. 11 11.8	n	*b* 1.5 *v* 2 *c*	10.01		48.48	9.84	
12 11.6	,,	*b* 2.5 *v* 2.5 *c*	10.05		49.47	9.88	
13 13.6	,,	*b* 3 *v* 2.5 *c*	10.07	G	50.56	9.90	
16 14.7	,,	*b* 3 *v* 3 *c*	10.05		53.60	9.88	
17 8.—	E	*v* 4 *c* *a* 10 *v*	10.08	G	54.29	9.88	14
,, 13.1	n	*b* 3 *v* 3 *c*	10.05	G	,, .53	9.88	
21 12.3	,,	*b* 3 *v* 2.5 *c*	10.07		58.50	9.90	
22 8.3	,,	*b* 3 *v* 2 *c*	10.09		59.33	9.92	
28 13.1	N	*b* 3 *v* 3 *c*	10.03	M d	65.55	10.03	
Dec. 1 12.8	,,	*b* 4 *v* 2 *c*	10.13	G M d	68.52	10.13	
3 11.2	,,	*b* 5 *v* 1.5 *c*	10.18	G M	70.45	10.18	
5 8.0	,,	*v* 1.5 *c*	10.18		72.32	10.18	
10 6.5	E	*c* 5 *v* *v* 2 *e* *v* 5 *f*	10.65	G	77.23	10.45	
14 8.4	n	*b* 4 *v* 2 *c*	10.13		81.34	9.96	
16 15.0	,,	*b* 3 *v* 2.5 *c*	10.07		83.61	9.90	
20 7.0	,,	*b* 1 *v* 3.5 *c*	9.91	m	87.28	9.74	
21 10.0	E	*v* 4 *c* *a* 7 *v*	10.00		88.37	9.80	14
,, 14.2	n	*b* 1 *v* 4 *c*	9.90		,, .58	9.73	
24 12.4	,,	*v* = *b*	9.80	G	91.50	9.63	
25 7.5	,,	*a* 5 *v* 0.5 *b*	9.76	m	92.30	9.59	
1915							
Jan. 2 13.6	n	*b* 1 *v* 2 *c*	9.96	M D	0500.55	9.79	
,, ,,	N	*v* 1 *b*	9.67	M D	,, .55	9.67	
8 10.5	n	*b* 4 *v* 2.5 *c*	10.10		06.42	9.93	
11 9.1	,,	*v* = *c*	10.29		09.36	10.12	
,, ,,	N	*b* 3 *v* 3 *c*	10.03	G	,, .36	10.03	
12 11.4	n	*b* 6 *v* 1.5 *c*	10.19	G c	10.46	10.02	
16 8.6	,,	*b* 5 *v* 1.5 *c*	10.18		14.34	10.01	
,, ,,	N	*b* 5 *v* 2 *c*	10.15		,, .34	10.15	
17 8.—	E	*c* 2 *v* *v* 5 *h*	10.55	G	15.29	10.35	22;26
18 10.5	n	*v* = *c*	10.29		16.42	10.12	
,, ,,	N	*b* 5 *v* 2 *c*	10.15		,, .42	10.15	
22 6.8	,,	*b* 3 *v* 3 *c*	10.03	m	20.27	10.03	
,, ,,	n	*b* 4 *v* 1 *c*	10.19	m	,, .27	10.02	

Date local time	Obs.	Estimate	M	Remarks see page 43	J. D. G. M. T.	M′	Remarks see page 76
Jan. 27 8.0	N	*b* 1 *v* 4 *c*	9.87	G M d	0525.32	9.87	
29 10.1	n	*v* = *b*	9.80	M D	27.41	9.63	
Febr. 4 8.1	,,	*b* 3 *v* 3 *c*	10.05		33.33	9.88	
5 10.9	,,	*b* 2 *v* 3 *c*	10.00		34.45	9.83	
6 11.—	E	*v* 5 *c* *a* 5 *v*	9.87	G	35.42	9.67	
8 7.9	n	*b* 2.5 *v* 3 *c*	10.02		37.32	9.85	
11 12.4	,,	*b* 2 *v* 1.5 *c*	10.08	m c ? h	40.51	9.91	
13 8.—	E	*v* = *c*	10.34	b d	42.29	10.14	
,, 10.2	n	*b* 4 *v* 1 *c*	10.19		,, .42	10.02	
15 10.—	E	*v* 5 *c* *v* 4 *p* *a* 10 *v*	10.07	g	44.37	9.87	14
16 7.0	n	*b* 5 *v* 1 *c*	10.21	m	45.28	10.04	
18 7.0	,,	*b* 4 *v* 0.5 *c*	10.24	G m	47.28	10.07	
21 7.6	N	*v* = *c*	10.31	m	50.31	10.31	
25 7.6	,,	*v* = *f*	10.76	M	54.31	10.76	
26 9.2	,,	*c* 3 *v* 2 *f*	10.58	M	55.37	10.58	
28 7.4	,,	*c* 0.5 *v* 3.5 *f*	10.37	M	57.30	10.37	
March 1 9.4	,,	*v* 1 *c*	10.22	G M	58.38	10.22	
2 7.1	,,	*v* 2 *c*	10.14	M	59.28	10.14	
,, ,,	n	*c* 2 *v*	10.46	M	,, .28	10.29	
8 8.9	,,	*b* 1.5 *v* 3 *c*	9.96		65.36	9.79	
20 7.4	,,	*b* 1.5 *v* 2 *c*	10.01	m d	77.30	9.84	
21 7.3	,,	*b* 2 *v* 3 *c*	10.00	G m	78.30	9.83	
23 10.0	N	*v* = *b*	9.76	m d	80.40	9.76	
26 9.0	,,	*v* = *b*	9.76	G M D	83.36	9.76	
28 7.7	n	*b* 2 *v* 2 *c*	10.05	G M	85.31	9.88	
29 8.2	,,	*v* = *c*	10.29	M D	86.33	10.12	
,, ,,	N	*b* 4 *v* 4 *c*	10.03	M D	,, .33	10.03	
30 7.5	,,	*b* 3 *v* 3 *c*	10.03	G M d	87.30	10.03	
31 7.7	,,	*b* 4 *v* 4 *c*	10.03	G M	88.31	10.03	
,, ,,	n	*b* 3 *v* 1 *c*	10.17	G M	,, .31	10.00	
April 4 7.7	N	*b* 4 *v* 2.5 *c*	10.09	d	92.31	10.09	
7 8.1	,,	*b* 5 *v* 2.5 *c*	10.13		95.32	10.13	
11 7.8	,,	*b* 4 *v* 4 *c*	10.03	G t d	99.31	10.03	
,, ,,	n	*b* 2 *v* 1.5 *c*	10.08	G t d	,, .31	9.91	
14 8.4	,,	*b* 2 *v* 2 *c*	10.05	l d	0602.33	9.88	

REMARKS.

(Δc stands for deviation from the light-curve. See p. 78).

1. The two photometric measurements differ by $0^m.41$.
2. This value seems to be discordant. The curve gives $11^m.04$.
3. ENEBO's observations of J D 7611 and 7612 oblige us to draw the curve at a distance of $0^m.20$ above the photometric result 11.86 on J D 7614.
4. Ten days later HAYNES gave an estimate for the star's brightness of at least $2^m.17$ fainter than *c*, and at least $1^m.79$ fainter than *f*. This would give the following result: J D 7686.6 var. $<$ $12^m.45$; which would be the lowest value recorded throughout the whole history of the star's light-variation.
5. The two photometric measurements differ by $0^m.40$.
6. From lack of observations between J D 7837 and 7853, the intermediate minimum on J D 7846 is uncertain both in time and brightness.
7. In the observations grouped around the maximum on J D 7945, a systematic difference L — E seems to prevail to an amount of about $0^m.2$, which causes an uncertainty as to the star's brightness at this maximum.
8. The curve shows a very steep rise to maximum brightness; the mean increase per hour being $0^m.02$. The secondary curve in the descent is not established by a sufficient number of observations.
9. The two photometric measurements differ by $0^m.46$.
10. The secondary curve in the ascent, between the minimum on J D 8320 and the maximum on J D 8340, is established without ambiguity by 14 points.

11. Observation made with the $4\frac{1}{2}$ inch refractor; the reduction for the 3 inch being — $0^m.17$, the reduction for the $4\frac{1}{2}$ inch has been taken, somewhat arbitrarily, as — $0^m.13$.

12-13. These points lie $0^m.45$ below and $0^m.32$ above the curve, causing an uncertainty in the position of the maximum on J D 8612.

14. The last estimate has been given half the weight of the other observations, in accordance with the observer's intention.

15. Discordant results. If *f* were to be read for *c*, and *c* for *a*, the values would become $10^m.43$ and $10^m.50$, in perfect agreement with those of the other observers; though the photometric measurements would in that case show differences of $0^m.34$ and $0^m.48$ respectively.

16. The curve shows, after the minimum on J D 8752, a very steep rise of $1^m.04$ in 5 days.

17. This estimate has been reduced, as if it had been recorded as *c* 5 *v* 2 *f*; *c* 5 *v* 5.5 *g*.

18. For the magnitudes of the stars *p* and *a*, which have not been used on other nights during this season, the mean values $10^m.40$ and $9^m.38$ (see p. 29) have been adopted.

19. There would be a better agreement if for n we were to read N.

20. The gap of 12 days, lying between this observation and the preceding one, causes the minimum on J D 9105 to be only roughly determinable.

21. There are no observations to establish with certainty the curve between the maximum on J D 9279 and the minimum on J D 9301.

22. For *h* the same magnitude has been adopted as was derived for the season 1909—10; and to the last estimate half the weight has been attached. Still, under the influence of this comparison star, the result deviates from the light-curve by an amount of $0^m.24$.

23. $\Delta c = 0^m.21$	28. $\Delta c = 0^m.26$	33. $\Delta c = 0^m.33$
24. ,, = 0. 22	29. ,, = 0. 27	34. ,, = 0. 40
25. ,, = 0. 23	30. ,, = 0. 29	35. ,, = 0. 42
26. ,, = 0. 24	31. ,, = 0. 30	
27. ,, = 0. 25	32. ,, = 0. 32	

CHAPTER IV.

THE LIGHT-CURVE.

The values of the brightness of the variable, taken from the second division of the list given on pp. 44—75, were plotted on squared paper, on a scale of 1 mm. equalling 0.5 day and 0.01 magnitude; and a smooth curve was drawn through the points. In connection with this curve the following particulars should be noted: —

Total number of points	1222
Number of points above the curve	595
,, ,, ,, below ,, ,,	627
Recurrences of the sign of the deviation	592
Changes ,, ,, ,, ,, ,, ,,	629
Mean deviation of a point above the curve	= $0^m.057$
,, ,, ,, ,, ,, below ,, ,,	= $0^m.058$

In a few cases the deviation of an observed brightness exceeded $0^m.20$; these cases are particularly mentioned on pp. 76–77, which contain also the remarks to which the process of curve-drawing gave rise.

The ordinates of the light-curve were read off for each five days (Greenwich mean noon), and the results are given in the first and third columns of the list on pp. 79—86. The dates of maximum and minimum brightness are inserted, the phase in each case being indicated, in the second column, by M and m respectively. The details of these phases will be given later on.

J D	phase	M	corr	M′	L	J D	phase	M	corr	M′	L
241		m	m	m				m	m	m	
7455		10.45	—.31	10.14	46	7615	m	11.66	—.83	10.83	24
60		10.33	—.33	10.00	52	20		10.95	—.84	10.11	47
65		10.22	—.34	9.88	59	25		10.73	—.85	9.88	59
68	M	10.20	—.35	9.85	60	30	M	10.69	—.87	9.82	62
70		10.21	—.36	9.85	60	35		10.73	—.88	9.85	60
75		10.27	—.38	9.89	58	40		10.85	—.90	9.95	55
80		10.33	—.39	9.94	56	45		11.05	—.90	10.15	46
85		10.39	—.40	9.99	53	50		11.23	—.91	10.32	39
90		10.45	—.42	10.03	51	53	m	11.28	—.91	10.37	37
95		10.48	—.43	10.05	50	55		11.25	—.92	10.33	39
96	m	10.48	—.43	10.05	50	60		10.83	—.92	9.91	57
7500		10.42	—.44	9.98	53	65		10.79	—.92	9.87	59
05		10.24	—.46	9.78	64	67	M	10.79	—.92	9.87	59
06	M	10.24	—.47	9.77	65	70		10.80	—.91	9.89	58
10		10.27	—.48	9.79	64	75		10.84	—.91	9.93	56
15		10.40	—.50	9.90	57	80		10.94	—.91	10.03	51
20		10.52	—.51	10.01	52						
25		10.69	—.53	10.16	45	7785		9.90	—.57	9.33	97
30		10.82	—.55	10.27	41	88	M	9.86	—.56	9.30	100
32	m	10.85	—.56	10.29	40	90		9.88	—.55	9.33	97
35		10.80	—.57	10.23	43	95		9.99	—.53	9.46	86
40		10.47	—.59	9.88	59	7800		10.15	—.50	9.65	72
45		10.29	—.60	9.69	70	05		10.35	—.47	9.88	59
48	M	10.27	—.61	9.66	72						
50		10.28	—.62	9.66	72	7825	M	10.29	—.34	9.95	55
55		10.39	—.64	9.75	66	30		10.35	—.32	10.03	51
60		10.57	—.65	9.92	56	35		10.47	—.30	10.17	45
65		10.72	—.67	10.05	50	40		10.61	—.27	10.34	38
70		10.80	—.69	10.11	47	45		10.69	—.25	10.44	35
71	m	10.80	—.69	10.11	47	46	m	10.69	—.24	10.45	35
75		10.76	—.70	10.06	50	50		10.64	—.22	10.42	36
80		10.66	—.72	9.94	55	55		10.45	—.19	10.26	41
84	M	10.64	—.73	9.91	57	60		10.13	—.17	9.96	54
85		10.65	—.74	9.91	57	65		9.93	—.15	9.78	64
90		10.70	—.76	9.94	55	70	M	9.89	—.13	9.76	66
95		10.83	—.78	10.05	50	75		9.99	—.10	9 89	58
7600		10.98	—.79	10.19	44	80		10.21	—.08	10.13	46
05		11.10	—.80	10.30	40	7905		10.14	+.03	10.17	45
10		11.29	—.82	10.47	34	08	M	10.12	+.04	10.16	45

J D	phase	M	corr	M′	L	J D	phase	M	corr	M′	L
		m	m	m				m	m	m	
7910		10.14	+.05	10.19	44	8075		9.67	+.37	10.04	51
15		10.40	+.07	10.47	34						
20		10.66	+.09	10.75	26	8135		9.43	+.39	9.82	62
25	m	10.70	+.10	10.80	25	37	M	9.43	+.39	9.82	62
30		10.60	+.12	10.72	27	40		9.44	+.39	9.83	61
35		10.13	+.14	10.27	41	45		9.55	+.39	9.94	55
40		9.85	+.15	10.00	52	50		9.77	+.39	10.16	45
45		9.78	+.17	9.95	55	55		10.19	+.40	10.59	30
46	M	9.78	+.17	9.95	55	59	m	10.35	+.40	10.75	26
50		9.84	+.19	10.03	51	60		10.33	+.40	10.73	27
55		10.00	+.21	10.21	43	65		9.96	+.40	10.36	38
60		10.19	+.22	10.41	36	70		9.70	+.40	10.10	48
65		10.30	+.23	10.53	32	75		9.64	+.40	10.04	51
67	m	10.31	+.23	10.54	32	76	M	9.63	+.40	10.03	51
70		9.75	+.24	9.99	53	80		9.66	+.40	10.06	50
72	M	9.49	+.24	9.73	67	85		9.72	+.40	10.12	47
75		9.54	+.25	9.79	64	90		9.82	+.40	10.22	43
80		9.78	+.26	10.04	51	95		9.94	+.40	10.34	38
85		9.92	+.27	10.19	44	8200		10.05	+.40	10.45	35
90		10.06	+.27	10.33	39	03	m	10.06	+.40	10.46	34
95		10.32	+.28	10.60	30	05		10.05	+.40	10.45	35
8000		10.92	+.29	11.21	17	10		9.82	+.40	10.22	43
03	m	11.01	+.30	11.31	16	15		9.60	+.40	10.00	52
05		10.97	+.30	11.27	16	20		9.53	+.40	9.93	56
10		10.00	+.31	10.31	40	21	M	9.53	+.40	9.93	56
15		9.51	+.32	9.83	61	25		9.57	+.40	9.97	54
19	M	9.45	+.33	9.78	64	30		9.75	+.40	10.15	46
20		9.45	+.33	9.78	64	35		10.14	+.40	10.54	32
25		9.54	+.33	9.87	59	40		10.59	+.40	10.99	21
30		9.78	+.34	10.12	47	43	m	10.70	+.40	11.10	19
35		10.03	+.35	10.38	37	45		10.56	+.40	10.96	22
40		10.15	+.35	10.50	33	50		9.65	+.39	10.04	51
41	m	10.16	+.35	10.51	33	55		9.32	+.39	9.71	69
45		10.12	+.36	10.48	34	56	M	9.31	+.39	9.70	69
50		9.64	+.36	10.00	52	60		9.36	+.39	9.75	66
55		9.47	+.37	9.84	61	65		9.58	+.39	9.97	54
60	M	9.43	+.37	9.80	63	70		9.89	+.39	10.28	41
65		9.46	+.37	9.83	61	75		10.14	+.39	10.53	32
70		9.55	+.37	9.92	56	76	m	10.14	+.39	10.53	32

J D	phase	M	corr	M′	L	J D	phase	M	corr	M′	L
		m	m	m				m	m	m	
8280		9.96	+.39	10.35	38	8515		10.13	+.09	10.22	43
85		9.57	+.39	9.96	54	16	m	10.13	+.09	10.22	43
90		9.49	+.39	9.88	59	20		10.10	+.08	10.18	45
92	M	9.49	+.39	9.88	59	25		9.86	+.06	9.92	56
95		9.50	+.39	9.89	58	30	M	9.76	+.06	9.82	62
8300		9.58	+.38	9.96	54	35		9.83	+.05	9.88	59
05		9.72	+.38	10.10	48	40		9.99	+.03	10.02	51
10		9.97	+.38	10.35	38	45		10.19	+.02	10.21	43
15		10.24	+.38	10.62	30	50		10.51	00	10.51	33
20	m	10.41	+.38	10.79	25	55		11.01	—.01	11.00	21
25		9.84	+.38	10.22	43	57	m	11.05	—.02	11.03	20
30		9.66	+.38	10.04	51	60		10.98	—.03	10.95	22
35		9.47	+.37	9.84	61	65		10.35	—.04	10.31	39
40	M	9.35	+.37	9.72	68	70		9.92	—.05	9.87	59
45		9.44	+.37	9.81	62	75		9.83	—.06	9.77	65
50		9.70	+.36	10.06	50	77	M	9.83	—.07	9.76	66
55		9.86	+.36	10.22	43	80		9.87	—.08	9.79	64
60		10.04	+.35	10.39	37	85		10.22	—.09	10.13	46
64	m	10.15	+.34	10.49	33	90		10.59	—.10	10.49	33
65		10.14	+.34	10.48	34	95		10.77	—.12	10.65	29
70		9.51	+.34	9.85	60	96	m	10.77	—.12	10.65	29
75		9.43	+.34	9.77	65	8600		10.59	—.14	10.45	35
76	M	9.43	+.34	9.77	65	05		10.21	—.15	10.06	50
80		9.45	+.33	9.78	64	10		9.94	—.16	9.78	64
85		9.56	+.32	9.88	59	12	M	9.91	—.17	9.74	67
90		9.87	+.31	10.18	44	15		9.94	—.18	9.76	66
95		10.27	+.31	10.58	31	20		10 32	—.19	10.13	46
8400		10.66	+.30	10.96	22	25		10.72	—.20	10.52	33
01	m	10.67	+.30	10.97	21	30		10.97	—.21	10.76	26
05		10.23	+.29	10.52	32	34	m	11.07	—.22	10.85	24
10		9.63	+.28	9.91	57	35		11.06	—.22	10.84	24
15		9.50	+.27	9.77	65	40		10.78	—.23	10.55	32
16	M	9.49	+.27	9.76	66	45		10.36	—.24	10.12	47
20		9.53	+.26	9.79	64	50		10.19	—.25	9.94	56
25		9.62	+.25	9.87	59	51	M	10.18	—.26	9.92	57
30		9.71	+.24	9.95	55	55		10.25	—.27	9.98	54
						60		10.46	—.28	10.18	45
8505		9.56	+.11	9.67	71	65		10.72	—.29	10.43	35
10		10.00	+.10	10.10	48	70	m	10.80	—.30	10.50	33

J D	phase	M	corr	M′	L	J D	phase	M	corr	M′	L
		m	m	m				m	m	m	
8675		10.68	—.31	10.37	37	8935		10.26	—.18	10.08	49
80		10.52	—.32	10.20	44	40		10.77	—.17	10.60	30
85		10.40	—.33	10.07	49	41	m	10.79	—.17	10.62	30
89	M	10.35	—.34	10.01	52	45		10.54	—.16	10.38	37
90		10.35	—.34	10.01	52	50		10.11	—.15	9.96	54
95		10.45	—.35	10.10	48	55		9.98	—.13	9.85	60
8700		10.63	—.35	10.28	41	60		9.94	—.12	9.82	62
05		10.85	—.36	10.49	33	63	M	9.94	—.12	9.82	62
10		11.05	—.37	10.68	28	65		9.95	—.10	9.85	60
12	m	11.09	—.37	10.72	27	70		10.00	—.09	9.91	57
15		11.05	—.38	10.67	28	75		10.14	—.08	10.06	50
20		10.65	—.38	10.27	41	80		10.31	—.07	10.24	42
25		10.19	—.39	9.80	63	84	m	10.37	—.06	10.31	39
30		9.99	—.39	9.60	76	85		10.36	—.06	10.30	40
32	M	9.98	—.39	9.59	77	90		10.11	—.05	10.06	50
35		10.08	—.40	9.68	70	95		9.88	—.04	9.84	61
40		10.40	—.40	10.00	52	9000		9.83	—.03	9.80	63
45		10.81	—.40	10.41	36	01	M	9.82	—.03	9.79	64
50		11.21	—.40	10.81	25	05		9.85	—.02	9.83	61
52	m	11.27	—.41	10.86	24	10		9.95	—.01	9.94	56
55		11.17	—.41	10.76	26	15		10.26	00	10.26	41
60		10.16	—.41	9.75	66	20		10.70	+.02	10.72	27
64	M	10.05	—.41	9.64	73	25		11.00	+.03	11.03	20
65		10.05	—.41	9.64	73	26	m	11.02	+.03	11.05	20
70		10.15	—.40	9.75	66	30		10.65	+.04	10.69	28
						35		9.87	+.05	9.92	56
8880		10.00	—.29	9.71	69	40		9.78	+.06	9.84	61
82	M	9.99	—.28	9.71	69	41	M	9.78	+.06	9.84	61
85		10.00	—.28	9.72	68	45		9.81	+.07	9.88	59
90		10.04	—.27	9.77	65	50		9.90	+.08	9.98	53
95		10.15	—.26	9.89	58	55		10.05	+.09	10.14	46
8900		10.50	—.25	10.25	42	60		10.27	+.10	10.37	37
05	m	10.75	—.24	10.51	33	62	m	10.31	+.10	10.41	36
10		10.41	—.23	10.18	44	65		10.20	+.11	10.31	39
15		9.98	—.22	9.76	65	70		9.84	+.11	9.95	55
20		9.66	—.21	9.45	87	75		9.75	+.12	9.87	59
22	M	9.61	—.20	9.41	90	78	M	9.74	+.12	9.86	60
25		9.66	—.20	9.46	86	80		9.75	+.13	9.88	59
30		9.87	—.19	9.68	70	85		9.84	+.14	9.98	54

J D	phase	M	corr	M′	L	J D	phase	M	corr	M′	L
		m	m	m				m	m	m	
9090		10.01	+.16	10.17	45	9360		9.59	+.38	9.97	54
95		10.25	+.17	10.42	36	65		9.75	+.38	10.13	46
9100		10.66	+.18	10.84	24	70		9.95	+.38	10.33	39
05		10.84	+.18	11.02	20	75		10.13	+.38	10.51	33
06	m	10.84	+.18	11.02	20	79	m	10.18	+.38	10.56	31
10		10.70	+.19	10.89	23	80		10.17	+.39	10.56	31
15		10.10	+.19	10.29	40	85		9.88	+.39	10.27	41
20		9.75	+.20	9.95	55	90		9.63	+.39	10.02	51
25		9.67	+.20	9.87	59	95		9.57	+.39	9.96	54
						98	M	9.56	+.39	9.95	55
9245		9.82	+.31	10.13	46	9400		9.56	+.40	9.96	55
50		9.90	+.32	10.22	43	05		9.65	+.40	10.05	50
55		10.10	+.32	10.42	36	10		9.93	+.40	10.33	39
60		10.72	+.33	11.05	20	15		10.36	+.40	10.76	26
62	m	10.77	+.33	11.10	19	19	m	10.48	+.40	10.88	23
65		10.72	+.34	11.06	20	20		10.47	+.40	10.87	24
70		10.13	+.34	10.47	34	25		10.06	+.40	10.46	34
75		9.45	+.34	9.79	64	30		9.45	+.40	9.85	60
79	M	9.40	+.35	9.75	66	32	M	9.39	+.40	9.79	64
80		9.40	+.35	9.75	66	35		9.42	+.40	9.82	62
85		9.48	+.35	9.83	61	40		9.70	+.40	10.10	48
90		9.75	+.35	10.10	48	45		9.96	+.40	10.36	38
95		10.04	+.35	10.39	37	50		10.18	+.40	10.58	31
9300		10.15	+.36	10.51	33	54	m	10.27	+.40	10.67	28
01	m	10.15	+.36	10.51	33	55		10.27	+.40	10.67	28
05		10.03	+.36	10.39	37	60		10.12	+.40	10.52	32
10		9.73	+.36	10.09	48	65		9.85	+.40	10.25	42
15		9.51	+.36	9.87	59	70		9.50	+.40	9.90	58
19	M	9.45	+.36	9.81	63	73	M	9.47	+.40	9.87	59
20		9.46	+.36	9.82	62	75		9.51	+.40	9.91	57
25		9.60	+.36	9.96	54	80		9.72	+.40	10.12	47
30		9.90	+.37	10.27	41	85		9.89	+.40	10.29	40
35		10.18	+.37	10.55	32	90		10.04	+.40	10.44	35
40		10.26	+.37	10.63	29						
41	m	10.26	+.37	10.63	29	9625		9.78	+.40	10.18	44
45		10.13	+.37	10.50	33	30		9.57	+.40	9.97	54
50		9.58	+.37	9.95	55	35		9.42	+.40	9.82	62
54	M	9.52	+.37	9.89	58	38	M	9.40	+.40	9.80	63
55		9.52	+.37	9.89	58	40		9.42	+.39	9.81	62

J D	phase	M	corr	M′	L
		m	m	m	
9645		9.63	+.39	10.02	52
50		10.10	+.38	10.48	34
55		10.59	+.38	10.97	22
57	m	10.60	+.37	10.97	22
60		10.50	+.37	10.87	24
65		9.88	+.37	10.25	42
70		9.42	+.36	9.78	64
75		9.12	+.35	9.47	85
77	M	9.10	+.35	9.45	87
80		9.25	+.34	9.59	77
85		9.61	+.33	9.94	56
90		9.89	+.32	10.21	43
94	m	10.01	+.31	10.32	39
95		10.00	+.31	10.31	40
9700		9.87	+.30	10.17	45
05		9.59	+.30	9.89	58
10		9.45	+.29	9.74	67
11	M	9.45	+.29	9.74	67
15		9.51	+.28	9.79	64
20		9.73	+.27	10.00	52
25		10.08	+.26	10.34	38
30		10.57	+.25	10.82	25
33	m	10.73	+.24	10.97	22
35		10.70	+.24	10.94	22
40		10.08	+.23	10.31	40
45		9.67	+.22	9.89	58
50		9.55	+.21	9.76	65
52	M	9.55	+.20	9.75	66
55		9.57	+.19	9.76	65
60		9.64	+.18	9.82	62
65		9.75	+.17	9.92	56
70		9.87	+.16	10.03	51
75	m	9.94	+.15	10.09	48
80		9.82	+.14	9.96	54
85		9.73	+.13	9.86	60
87	M	9.72	+.12	9.84	61
90		9.74	+.11	9.85	60
95		9.83	+.10	9.93	56
9800		9.95	+.09	10.04	51

J D	phase	M	corr	M′	L
		m	m	m	
9805		10.11	+.08	10.19	44
10		10.28	+.07	10.35	38
15		10.46	+.05	10.51	33
17	m	10.49	+.04	10.53	32
20		10.25	+.03	10.28	41
25		9.88	+.02	9.90	57
30		9.84	+.01	9.85	60
33	M	9.83	00	9.83	61
35		9.83	00	9.83	61
40		9.87	—.01	9.86	60
45		9.98	—.02	9.96	54
50		10.21	—.03	10.18	45
54	m	10.76	—.05	10.71	27
55		10.72	—.05	10.67	28
60		10.04	—.06	9.98	53
65		9.90	—.07	9.83	61
9995		10.15	—.21	9.94	56
242					
0000		10.27	—.22	10.05	50
05		10.74	—.22	10.52	32
08	m	11.22	—.22	11.00	21
10		11.15	—.22	10.93	22
15		10.45	—.23	10.22	43
20		10.08	—.23	9.85	60
25		9.99	—.23	9.76	65
26	M	9.99	—.23	9.76	65
30		10.02	—.24	9.78	64
35		10.28	—.24	10.04	51
40		10.58	—.24	10.34	38
42	m	10.61	—.24	10.37	37
45		10.55	—.25	10.30	40
50		10.26	—.25	10.01	52
55		10.12	—.26	9.86	60
60		10.07	—.26	9.81	63
61	M	10.07	—.26	9.81	63
65		10.09	—.26	9.83	61
70		10.19	—.26	9.93	56
75		10.34	—.26	10.08	49

J D	phase	M	corr	M′	L	J D	phase	M	corr	M′	L
		m	m	m				m	m	m	
0080		10.58	—.27	10.31	39	0350		10.12	—.15	9.97	54
85		11.10	—.27	10.83	24	55		10.47	—.15	10.32	39
86	m	11.10	—.27	10.83	24	57	m	10.56	—.14	10.42	36
90		10.65	—.27	10.38	37	60		10.41	—.13	10.28	41
95		10.36	—.27	10.09	48	65		9.98	—.13	9.85	60
0100		10.20	—.28	9.92	56	70		9.91	—.12	9.79	64
05		10.11	—.28	9.83	61	73	M	9.90	—.12	9.78	64
10	M	10.08	—.28	9.80	63	75		9.91	—.11	9.80	63
15		10.13	—.28	9.85	60	80		9.95	—.11	9.84	61
20		10.29	—.28	10.01	52	85		10.08	—.10	9.98	54
25		10.54	—.28	10.26	41	90		10.40	—.10	10.30	40
28	m	10.57	—.28	10.29	40	95		10.88	—.09	10.79	25
30		10.56	—.28	10.28	41	96	m	10.91	—.08	10.83	24
35		10.26	—.28	9.98	53	0400		10.25	—.08	10.17	45
40		10.09	—.28	9.81	63	05		9.92	—.07	9.85	60
45		10.06	—.28	9.78	64	10		9.83	—.07	9.76	65
46	M	10.06	—.28	9.78	64	15		9.81	—.06	9.75	66
50		10.07	—.28	9.79	64	18	M	9.80	—.06	9.74	67
55		10.20	—.28	9.92	57	20		9.81	—.05	9.76	65
60		10.39	—.27	10.12	47	25		9.84	—.05	9.79	64
65		10.61	—.27	10.34	38						
67	m	10.66	—.27	10.39	37	0450		9.88	00	9.88	59
70		10.61	—.27	10.34	38	53	M	9.86	+.01	9.87	59
75		10.09	—.27	9.82	62	55		9.87	+.01	9.88	59
80	M	10.02	—.27	9.75	66	60		9.91	+.02	9.93	56
85		10.10	—.27	9.83	61	65		9.99	+.03	10.02	52
90		10.32	—.27	10.05	50	70		10.14	+.03	10.17	45
95		10.65	—.27	10.38	37	75		10.41	+.04	10.45	35
0200		10.93	—.26	10.67	28	76	m	10.42	+.04	10.46	34
01	m	10.95	—.26	10.69	28	80		10.12	+.05	10.17	45
05		10.72	—.26	10.46	34	85		9.79	+.05	9.84	61
10		10.20	—.26	9.94	55	90		9.65	+.06	9.71	69
15		10.07	—.26	9.81	63	93	M	9.62	+.06	9.68	71
20		10.04	—.26	9.78	64	95		9.63	+.07	9.70	69
22	M	10.04	—.26	9.78	64	0500		9.72	+.08	9.80	63
25		10.04	—.25	9.79	64	05		9.94	+.09	10.03	51
30		10.07	—.25	9.82	62	10		10.09	+.10	10.19	44
35		10.15	—.25	9.90	57	14	m	10.12	+.11	10.23	42
40		10.31	—.25	10.06	50	15		10.11	+.11	10.22	43

J D	phase	M	corr	M′	L	J D	phase	M	corr	M′	L
		m	m	m				m	m	m	
0520		10.01	+.12	10.13	46	0565		9.83	+.16	9.99	53
25		9.82	+.13	9.95	55	70		9.78	+.16	9.94	55
30		9.74	+.14	9.88	59	74	M	9.77	+.16	9.93	56
31	M	9.73	+.14	9.87	59	75		9.77	+.16	9.93	56
35		9.76	+.15	9.91	57	80		9.80	+.16	9.96	54
40		9.85	+.16	10.01	52	85		9.95	+.16	10.11	47
45		10.05	+.16	10.21	43	90		10.11	+.16	10.27	41
50		10.35	+.16	10.51	33	92	m	10.12	+.16	10.28	41
54	m	10.66	+.16	10.82	25	95		10.10	+.16	10.26	41
55		10.65	+.16	10.81	25	0600		9.92	+.16	10.08	49
60		10.05	+.16	10.21	43						

The light-curve is of a very peculiar form, and up to the present time may be regarded as unique. The secondary variation, mentioned by ENEBO (see p. 6), which in the following pages we shall call "the long periodicity", is of a very marked character; and round this "curved central line" the principal variation winds itself in a more or less regular fashion. The recurrence of the maxima and minima, in periods practically amounting to 39 days, (see p. 93) is to a certain extent regular. In fact, our first examination of the curve exhibits this as its most regular phenomenon. All the other phenomena seem to be irregular. The values of maximum and minimum brightness fluctuate to such an extent, that (even after eliminating the long periodicity) the least maximum brightness is equal to the greatest minimum brightness, and the form of the curve between the principal phases is continually changing. Moreover the maxima and minima (but especially the former) are sometimes sharp, and at other times flat. The ascending as well as the descending branches in some instances show a secondary curvature, displaying degenerated minima or maxima.

It is obvious that the principal variation can be studied in detail the better, after it has been freed from the long periodicity; this being a phenomenon which we shall have to consider as an isolated feature. Though this long periodicity is more manifest in the maxima, a glance at the light-curve teaches us that the minima are affected by the same disturbance. This view is supported by a consideration of the amplitudes. When we adopt, as the amplitude of the light-variation, the difference in brightness between a maximum and the *preceding* minimum, and plot its consecutive values (as is done in Fig. 1) we at once remark that the amplitude is sensibly constant; and this

FIG. 1.

constancy may be considered as an indication that the long periodicity is a phenomenon apart, affecting all the phases of the principal variation. We have given on Pl. II (a) the curve of the long periodicity as derived from the observed maxima, which exhibit it better than the minima. This curve gives us the means of "leveling" the observed light-curve, i. e. of reducing it to a horizontal central line. We have chosen for this purpose the line $9^m.80$; and we have constructed a table which gives for each 5 days the amount of the necessary reduction. This table is given in the fourth column of the list on pp. 79-86, and the reduced magnitudes are given in the next column. For reasons which will be obvious, from considerations advanced in the following chapters, these reduced magnitudes are changed in the sixth column into light-intensities, the brightest magnitude being equal to the light-intensity 100.

The values of the fifth and sixth columns form what we shall call the *leveled light-curve*. This light-curve is given on Pl. I; its ordinates are expressed in intensities. It shows all the characteristics of the principal variation, unaffected by the influence of the long periodicity. These characteristics may once more be summarised under the following heads:

1. The successive maxima, as well as the successive minima, are for the most part unequal, but they show now and then periods of approximate equality. In the cases of inequality of successive minima we may roughly speak of a β *Lyrae* type, though in fact only an irregular succession of principal and sec-

ondary minima is observed. In the case of equality we may roughly speak of a ζ *Geminorum* rather than of a δ *Cephei* type, since the steep rise to maximum, followed by a slow descent, which is an essential feature of the latter kind of light-variation, seems to be absent. The greatest likeness to the β *Lyrae* type is presented during the period marked β_1 on the Plate, and again during the period marked β_2; whereas the ζ *Geminorum* type is best represented during the period marked ζ.

2. The order of succession of deep and shallow minima is frequently reversed. Thus, for instance, the minima numbered 39, 64 and 69 in the list on p. 92 are what the observers have called "principal" minima.

3. The form of the ascending and descending branches varies frequently, and sometimes deviations in the ascending and descending processes have been observed.

4. The "duration" of a maximum or minimum is far from constant, and as a rule that of the maximum is the longer.

All these characteristics suggest the existence of a *compound* variation, with perhaps some fluctuations in the amplitudes of the components. If this suggestion is right, the principal variation must have a period of about 39 days, and an amplitude much exceeding that of the other. In order to get an idea of the period of the latter component, a series of about 16 compound vibrations, as given by two tuning forks of different periods of vibration, has been registered. To one of these forks was attached a sooted glass plate, while the other one bore a metal pen. The result of this investigation was that the combination of two periods, standing in the proportion of 1 to 1.4, gave a curve which bore a strong resemblance to the observed light-curve, especially in the way in which a "β *Lyrae*" type was changed into a "ζ *Geminorum*" type, and in the different forms of the ascents and the descents. This proportion would make the second period, if it existed at all, about 54 days; and so it was decided to undertake a search for a second periodicity.

In order to check the 39 days' period, and the more problematical one of 54 days, we have chosen to cover, in our search, the whole ground between the extreme limits 35 and 60 days. The result of this investigation will be given in chapter VI.

CHAPTER V.

THE MAXIMA AND MINIMA.

The following pages contain a list of the observed dates of maximum brightness. The first column gives the number of the epoch, the second the date, and the third the number of days elapsed between two consecutive maxima. The fourth column contains the values O—C, which result from a comparison of the *observed* dates of maximum with those *calculated* upon the supposition of a constant mean period of 39.267 days (see p. 93). The last column contains a few remarks in connection with the type of maximum, and the degree of certainty with which it is given.

LIST OF MAXIMA.

E	JD	P	O – C	REMARKS
	241		d	
0	7468.0	d	—3.7	
1	7506.5	38.5	—4.5	
2	7548.0	41.5	—2.2	
3	7584.0	36.0	—5.5	Uncertain
4	7630.0	46.0	+1.2	Good
5	7667.5	37.5	—0.5	
8	7788.0		+2.2	Uncertain
9	7825.0	37.0	—0.1	Uncertain
10	7870.0	45.0	+5.7	
11	7907.5	37.5	+3.9	
12	7945.5	38.0	+2.6	
13	7972.0	26.5	—10.1	Very steep
14	8019.0	47.0	—2.4	
15	8060.0	41.0	—0.7	Flat

E	J D	P	O - C	REMARKS
		d	d	
17	8137.5		—1.7	Uncertain
18	8176.0	38.5	—2.5	
19	8221.0	45.0	+3.2	
20	8256.5	35.5	—0.5	
21	8291.5	35.0	—4.8	
22	8340.0	48.5	+4.4	
23	8375.5	35.5	+0.7	
24	8416.5	41.0	+2.4	
27	8530.0		—1.9	
28	8576.5	46.5	+5.3	
29	8612.5	36.0	+2.1	Uncertain. See Rem. 12—13 p. 77
30	8651.0	38.5	+1.3	
31	8689.5	38.5	+0.5	Flat
32	8731.5	42.0	+3.3	
33	8764.5	33.0	—3.0	
36	8882.5		—2.8	Uncertain. Very flat
37	8922.5	40.0	—2.1	
38	8962.5	40.0	—1.3	Flat
39	9001.0	38.5	—2.1	
40	9041.0	40.0	—1.4	
41	9077.5	36.5	—4.1	
46	9279.0		+1.0	
47	9319.0	40.0	+1.8	
48	9354.5	35.5	—2.0	
49	9398.5	44.0	+2.7	Flat
50	9432.5	34.0	—2.5	Steep
51	9472.5	40.0	—1.8	
55	9637.5		+6.1	Not quite certain
56	9676.5	39.0	+5.9	Very steep
57	9711.0	34.5	+1.1	
58	9751.5	40.5	+2.3	
59	9787.0	35.5	—1.4	
60	9833.5	46.5	+5.8	Very flat
	242			
65	0026.0		+2.0	
66	0061.5	35 5	—1.8	
67	0110.0	48.5	+7.4	
68	0146.0	36.0	+4.2	
69	0180.0	34.0	—1.1	Not quite certain

E	J D	P	O – C	REMARKS
		d	d	
70	0222.5	42.5	+2.1	Very flat
74	0373.0		—4.4	Flat
75	0417.5	44.5	+0.8	Flat
76	0453.0	35.5	—3.0	Flat. Good
77	0493.0	40.0	—2.2	
78	0531.0	38.0	—3.5	
79	0574.0	43.0	+0.2	Flat

If we are justified in considering the differences in the observed periods as residuals from a mean period, this period and the date of a normal maximum can easily be derived by the method of least squares. For this purpose the normal maximum was supposed to have occurred on J D 8922.5 + x (E = 37), and the mean period to be 39.286 + y days. The observed maxima then yielded 59 equations of condition.

Solving the normal equations we get

$$x = +2^{d}.06 \qquad y = +0^{d}.0013$$

$$\text{Mean period} = 39^{d}.2873 \pm 0^{d}.0199 \text{ (m.e.)}$$

In the following pages the minima have been treated in the same way.

List of minima.

E	J D	P	O − C	REMARKS
	241		d	
0	7496.0	d	+1.7	Very flat
1	7532.5	36.5	—1.1	Not quite certain
2	7571.0	38.5	—1.8	Uncertain. Amplitude = $0^m.15$!
3	7615.0	44.0	+2.9	Uncertain. See p. 76. Very steep
4	7653.0	38.0	+1.6	Good
9	7846.0		—1.7	Uncertain; nearest observations 9^d before and 7^d after the minimum phase.
11	7925.0		—1.2	Same uncertainty as above
12	7966.5	41.5	+1.0	Good
13	8003.0	36.5	—1.8	Very steep. Good
14	8041.5	38.5	—2.5	Good
17	8158.5		—3.3	
18	8203.0	44.5	+1.9	Not quite certain
19	8243.0	40.0	+2.6	Steep. Good
20	8276.0	33.0	—3.6	
21	8320.0	44.0	+1.1	Good
22	8364.5	44.5	+6.3	
23	8401.0	36.5	+3.6	Steep. Good
26	8516.0		+0.8	Flat
27	8557.5	41.5	+3.0	Steep. Good
28	8596.0	38.5	+2.2	
29	8634.0	38.0	+1.0	
30	8670.0	36.0	—2.3	Uncertain
31	8712.5	42.5	+0.9	Good
32	8752.5	40.0	+1.7	Very steep
36	8905.0		—2.9	
37	8941.5	36.5	—5.7	
38	8984.0	42.5	—2.4	
39	9026.5	42.5	+0.8	
40	9062.0	35.5	—3.0	Not quite certain
41	9105.5	43.5	+1.3	See Rem. 20 p. 77
45	9262.5		+1.2	
46	9300.5	38.0	—0.1	
47	9340.5	40.0	+0.6	
48	9379.0	38.5	—0.1	
49	9419.0	40.0	+0.6	

E	J D	P	O – C	REMARKS
		d	d	
50	9454.5	35.5	—3.2	
55	9657.0		+3.0	Steep. Not quite certain
56	9694.5	37.5	+1.2	
57	9733.5	39.0	+1.0	Steep. Good
58	9775.0	41.5	+3.2	Very flat. Amplitude $0^m.20$!
59	9817.0	42.0	+5.9	Good
60	9854.0	37.0	+3.7	Very steep
	242			
64	0008.5		+1.1	Very steep
65	0042.0	33.5	—4.7	Good
66	0085.5	43.5	—0.4	
67	0128.5	43.0	+3.3	
68	0167.5	39.0	+3.0	Not quite certain
69	0201.5	34.0	—2.2	Good
73	0357.5		—3.3	
74	0396.0	38.5	—4.1	Very steep. Not quite certain
76	0476.0		—2.6	
77	0514.0	38.0	—3.9	Flat
78	0554.0	40.0	—3.1	
79	0592.5	38.5	—3.9	Good

Supposing a normal minimum to have occurred on J D 8941.5 + x (E = 37), and the mean period to be 39.286 + y days, we get 54 equations. Solving the normal equations, we get

$$x = + 5^d.68 \qquad y = - 0^d.0387.$$

$$\text{Mean period} = 39^d.2473 \pm 0^d.0181 \text{ (m. e.)}$$

Taking the mean of this period, and of that resulting from the foregoing consideration of the maxima, we get **39.267** days. Starting from the normal dates of maximum and minimum, and using the mean period just obtained, (which is compatible with the mean errors stated above), we arrive at a list of calculated maxima and minima, which differ from the observed phases by a number of days given in the fourth columns of the two preceding lists. In the next chapters we shall have occasion to see whether the adoption of a mean period, as obtained above, is justified.

CHAPTER VI.

THE PERIODOGRAM.

In the Monthly Notices of the R. A. S. VOLS. LXXI p. 686 and LXXIV p. 678, E. T. WHITTAKER and D. GIBB have given an account of the way in which they were able to undertake a search (within certain limits) for possible periodicities in the light-variation of SS Cygni*). The method is a simplification of that frequently used by A. SCHUSTER in his search for periodicities in magnetic and solar phenomena.

When we wish to discover whether a periodicity of, say, 40 days is "active" in a series of, say, 3200 values of a certain quantity, obtained at equal intervals of time, the method consists in writing these values down in rows of 40, and taking the sum of the 80 values of each column. Suppose these sums to be S_1, S_2, ...S_{40}; then, according to WHITTAKER, the difference between the greatest and smallest values of the quantities S, measures the "activity" of a 40 days' period. SCHUSTER analysed the whole sequence S_1......S_{40} by means of simple harmonics, and measured the same "activity" by a function of the two coefficients.

The latter method is the more accurate, but the former, which is the shorter, gives satisfactory results in cases where there are very pronounced periodicities.

It is evident that, instead of taking the sums of the numbers of each column, we may as well take their mean values; and where, as in the case of *R V Tauri*, many gaps occur, we are even obliged to do so.

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*) Another example is treated in detail by G. A. CARSE and G. SHEARER in no. 4 of the Edinburgh Mathematical Tracts: "A course in Fourier's Analysis and Periodogram Analysis for the Mathematical Laboratory" London 1915. G. BELL AND SONS LTD. This example is apparently based upon a fictitious light-curve, which is to be regretted.

x	35	36	37	38	39	40	41	42	43	44	45	46	47
n	61–66	59–63	58–62	56–60	54–60	52–59	51–56	49–55	49–54	48–52	47–51	43–53	45–49
1	48.8	47.3	49.2	45.4	**40.2**	49.6	49.2	49.8	47.7	50.2	47.8	48.9	49.8
2	48.6	47.6	49.3	45.4	40.3	49.6	49.4	49.8	47.1	51.7	47.9	48.6	50.3
3	48.5	48.1	49.1	45.9	40.6	49.6	49.6	49.8	46.9	52.2	47.7	48.6	50.3
4	49.1	48.2	49.3	46.2	40.5	50.3	49.6	49.6	47.1	52.5	47.7	48.4	50.3
5	49.2	48.3	49.3	46.7	40.6	**50.5**	49.6	49.8	**46.8**	52.4	48.0	48.3	**50.4**
6	48.8	48.4	49.8	47.1	40.8	50.0	49.5	49.7	46.9	52.6	**47.6**	48.5	50.2
7	48.6	49.0	49.6	47.6	41.0	49.9	49.6	49.7	47.2	**53.1**	**47.6**	48.4	50.1
8	48.2	49.0	**49.9**	48.0	41.6	49.8	49.7	49.8	47.4	53.0	47.7	49.0	50.0
9	47.9	49.3	49.6	48.2	42.4	49.8	**49.8**	49.7	47.6	52.9	47.7	49.0	49.7
10	48.4	49.6	49.2	48.3	43.5	49.7	49.7	49.6	47.7	52.7	47.7	49.3	49.3
11	48.1	49.8	49.6	48.5	45.7	49.3	49.5	49.1	47.6	52.9	47.7	49.5	48.9
12	48.4	50.3	49.7	49.1	46.9	49.0	49.6	48.8	47.4	52.7	47.8	49.5	48.3
13	48.6	**50.4**	49.0	49.5	48.1	48.5	49.4	48.7	48.1	51.9	47.8	50.0	48.0
14	48.9	50.2	48.8	49.9	49.8	48.0	49.4	48.2	48.0	51.3	48.8	**50.1**	47.7
15	**49.6**	50.3	48.4	50.5	51.6	47.6	48.8	47.4	48.0	50.4	49.6	50.0	47.5
16	49.5	50.2	48.2	50.6	53.2	47.2	48.8	47.8	48.5	50.1	49.6	49.6	47.1
17	49.4	50.3	47.9	50.7	54.6	46.8	48.8	48.1	48.7	49.2	49.7	49.6	47.8
18	49.4	50.1	47.6	**51.5**	55.8	**46.4**	48.5	48.0	48.7	48.3	49.8	49.6	47.9
19	49.5	50.3	47.2	51.3	56.7	**46.4**	48.2	48.3	48.9	47.4	49.8	49.5	47.5
20	49.3	50.2	47.1	51.1	57.4	46.9	48.4	48.0	49.4	47.5	50.0	49.1	47.0
21	48.5	50.1	46.8	51.3	57.8	47.0	48 9	47.7	49.3	46.7	**50.1**	49.0	46.9
22	48.2	49.7	46.6	51.1	**58.0**	47.1	48.5	47.4	49.2	45.5	49.7	48.7	**46.7**
23	47.9	49.4	**46.5**	50.7	57.7	47.1	48.4	47.1	49.2	44.9	49.3	48.5	46.8
24	47.8	48.9	46.6	50.8	57.3	46.7	48.0	46.9	49.3	44.4	49.2	48.5	46.8
25	47.8	48.6	47.6	50.7	56.9	47.2	47.9	46.7	49.2	44.2	49.5	48.6	46.8
26	**47.7**	47.9	48.0	50.3	56.0	46.9	47.8	46.8	**50.3**	43.7	48.9	48.4	47.1
27	47.9	47.5	48.6	50.3	54.8	47.4	47.8	46.9	50.2	43.7	48.6	48.1	47.1
28	48.0	46.9	48.7	49.9	53.7	47.8	47.8	46.6	50.1	**43.6**	49.1	47.5	47.1
29	48.2	46.8	48.9	49.5	52.3	48.3	47.6	46.6	50.1	**43.6**	49.1	47.1	47.1
30	48.4	46.3	49.4	48.9	51.5	48.9	47.6	**46.5**	49.9	43.9	49.4	**46.8**	47.7
31	48.7	**46.0**	49.3	48.5	50.1	49.3	47.4	46.9	49.6	44.8	49.2	46.9	48.0
32	48.8	46.6	49.2	47.9	48.7	49.3	**47.1**	48.0	49.4	45.1	48.9	46.9	48.3
33	49.0	47.0	49.3	47.3	47.1	49.3	47.4	48.3	49.5	45.8	48.7	46.9	48.5
34	48.9	47.1	49.2	46.8	45.4	49.3	47.5	48.7	49.5	46.1	48.7	47.1	48.7
35	48.8	47.2	48.6	46.3	44.1	49.6	47.5	49.0	49.2	46.6	48.6	47.4	49.0
36		47.0	48.9	45.9	42.8	49.5	47.7	49.6	49.2	47.2	48.1	47.6	49.2
37			49.0	45.7	41.9	49.5	47.7	49.7	49.0	48.1	48.1	48.0	49.3
38				**45.3**	41.2	49.7	48.6	49.9	49.0	48.5	48.0	48.2	49.3
39					40.6	49.8	48.8	**50.4**	49.0	48.8	48.1	48.5	49.3
40						49.8	48.9	50.3	48.9	49.2	48.0	49.0	49.2
41							48.9	50.1	48.7	49.5	47.9	48.9	49.4
42								50.0	48.4	49.6	48.0	48.6	49.6
43									48.1	50.2	48.0	48.9	50.1
44										50.6	48.1	48.8	49.7
45											48.1	48.6	49.5
46												48.8	49.7
47													49.7
y	1.9	4.4	3.4	6.2	**17.8**	4.1	2.7	3.9	3.5	**9.5**	2.5	3.3	3.7

x	48	49	50	51	52	53	54	55	56	57	58	59	60
n	45–47	43–47	41–47	41–45	40–45	38–45	39–43	38–42	37–42	35–42	35–41	34–40	35–39
1	48.8	49.3	45.5	49.1	48.4	48.4	48.0	47.4	48.7	49.4	50.9	48.9	47.9
2	48.5	49.1	45.0	49.7	49.1	48.9	48.1	47.3	48.0	49.4	51.0	49.3	48.2
3	48.7	48.6	44.6	50.3	49.7	49.0	48.2	47.1	47.8	49.4	51.0	49.2	48.3
4	48.7	48.3	**44.3**	50.5	50.0	49.3	48.0	46.8	49.0	49.6	**51.1**	48.9	48.4
5	48.8	48.3	44.7	**50.7**	**50.3**	49.3	47.8	47.1	49.1	49.8	**51.1**	48.6	48.8
6	49.0	48.0	44.5	**50.7**	**50.3**	49.2	47.5	46.4	49.0	50.0	51.0	48.0	48.5
7	49.4	47.9	44.8	50.3	50.1	49.3	47.8	**46.3**	49.4	50.0	50.9	47.8	49.3
8	49.5	48.4	45.4	50.1	49.8	49.1	47.9	**46.3**	49.5	**50.2**	50.5	47.7	49.7
9	49.3	48.2	45.9	50.0	49.4	49.2	48.0	47.7	49.4	49.9	50.1	47.7	50.3
10	49.0	48.5	46.4	49.8	49.1	48.9	47.9	48.4	49.3	49.9	49.6	47.7	50.6
11	49.0	48.3	46.9	49.8	48.9	48.6	48.3	48.8	49.2	49.7	49.2	47.4	50.5
12	49.1	48.0	47.4	49.8	48.6	48.6	48.7	49.5	49.1	50.2	48.6	47.4	50.3
13	48.8	47.8	47.8	49.7	48.2	48.6	48.9	50.0	49.0	49.9	48.2	47.4	50.0
14	48.3	47.4	48.1	49.6	47.5	48.8	50.4	50.4	48.3	49.7	47.4	47.8	49.5
15	48.2	**47.3**	48.5	49.4	47.7	48.9	50.7	51.3	48.3	49.6	47.0	48.0	49.1
16	48.0	**47.3**	48.7	49.5	47.6	48.7	50.8	51.1	48.3	49.3	46.4	48.3	48.6
17	47.9	47.4	49.2	49.1	48.3	48.3	50.9	**51.5**	48.3	48.5	46.1	48.9	48.2
18	47.8	47.5	49.8	48.9	48.2	48.3	**51.0**	51.2	48.3	48.5	**45.9**	49.6	47.9
19	47.8	47.8	50.6	48.6	48.3	49.3	50.9	51.1	49.0	47.2	46.8	50.3	47.9
20	**47.7**	48.2	51.3	48.1	48.3	**49.5**	50.8	51.0	49.2	47.9	46.8	50.6	47.7
21	47.9	48.4	51.7	47.7	48.4	49.2	50.6	50.8	49.5	47.7	47.1	50.8	47.3
22	47.9	48.6	52.0	47.5	48.4	49.1	50.3	50.5	49.6	48.0	47.4	50.6	47.0
23	48.4	48.6	52.4	47.6	48.5	49.2	50.1	50.2	49.6	48.3	47.5	**50.9**	46.3
24	48.4	48.6	**52.7**	47.4	49.9	49.1	49.5	49.9	49.7	48.5	47.8	50.4	46.7
25	48.4	49.1	52.5	47.1	49.7	49.1	49.5	49.7	49.8	48.8	48.1	49.7	46.8
26	48.4	49.0	52.0	46.8	49.4	48.9	49.3	49.3	49.5	49.0	48.0	49.5	46.7
27	48 4	48.7	51.9	46.5	49.3	48.9	48.7	49.1	49.4	49.1	48.3	49.0	46.9
28	48 4	48.8	51.7	**46.2**	49.8	48.7	48.6	48.7	49.2	49.1	48.3	48.3	47.5
29	48 4	48.7	51.6	47.2	49.6	48.0	47.8	48.6	48.8	48.6	48.4	47.8	47.9
30	48.4	48.5	51.8	47.1	49.3	48.4	47.9	48.8	48.4	48.1	48.3	48.0	48.5
31	48.5	48.7	51.7	47.4	49.3	48.2	47.5	48.2	48.4	47.7	48.0	47.8	48.9
32	48.6	48.6	51.5	47.5	48.8	48.0	**46.2**	48.0	47.9	47.3	47.6	47.2	49.2
33	48.6	48.6	51.0	47.3	48.3	47.9	47.3	47.9	47.1	46.9	47.4	46.7	49.3
34	48.6	48.7	51.5	47.3	48.2	**47.4**	47.2	48.0	47.0	**46.3**	47.2	46.6	49.6
35	48.6	48.5	51.4	47.5	48.2	47.7	47.2	48.1	46.6	46.4	46.9	**46.0**	50.1
36	49.0	48.5	50.9	48.4	47.8	47.5	47.1	48.0	47.0	47.0	47.0	46.3	50.1
37	48.9	48.4	50.2	48.5	47.8	47.8	47.5	47.8	46.7	47.0	47.0	46.7	50.0
38	49.1	48.5	49.6	48.7	48.0	47.9	47.9	47.8	46.9	46.9	47.5	47.0	49.7
39	49.0	**49.8**	49.4	48.8	48.2	48.2	48.2	47.8	**46.2**	47.0	48.0	47.5	49.8
40	48.7	49.7	49.0	48.7	48.2	48.4	48.4	47.8	46.4	47.6	48.4	48.1	49.9
41	48.5	49.7	49.0	48.7	48.2	48.6	48.6	47.7	46.3	47.7	48.8	48.7	50.1
42	48.1	49.6	48.0	48.7	48.5	48.6	48.8	47.8	46.9	47.3	49.1	49.6	49.5
43	48.1	49.5	47.5	48.9	48.5	48.6	49.0	47.8	47.1	47.8	49.2	48.6	50.2
44	49.1	49.3	46.8	48.7	48.5	48.5	48.7	47.8	47.7	48.1	49.0	49.4	51.0
45	**49.6**	49.6	46.5	48.5	48.5	48.5	48.8	48.0	48.6	47.5	48.9	49.6	**51.1**
46	49.1	49.1	46.2	48.5	48.0	48.7	48.3	48.0	49.0	48.0	48.9	49.2	50.2
47	49.0	49.8	45.7	48.2	47.8	48.7	48.5	48.4	49.7	48.3	48.7	48.8	49.8

x	48	49	50	51	52	53	54	55	56	57	58	59	60
n	45–47	43–47	41–47	41–45	40–45	38–45	39–43	38–42	37–42	35–42	35–41	34–40	35–39
48	48.7	49.7	45.7	48.1	47.6	48.2	48.3	48.5	49.8	48.1	48.5	49.9	49.4
49		49.2	45.5	48.2	47.5	48.1	48.0	48.7	49.7	48.4	48.6	49.8	49.1
50			45.8	48.5	**47.3**	48.0	48.1	48.9	**49.9**	48.4	48.5	49.6	48.9
51				48.7	47.6	48.6	48.0	48.7	49.6	48.6	48.2	49.3	48.5
52					47.7	48.1	47.9	48.7	49.4	48.9	49.3	49.3	47.9
53						48.2	47.9	48.3	49.7	49.5	49.0	48.8	47.3
54							47.7	48.2	49.5	49.2	49.0	48.5	46.8
55								47.9	49.3	48.9	49.6	48.4	46.4
56									48.9	50.0	50.2	48.4	46.2
57										49.7	50.3	48.8	**46.1**
58											50.5	48.9	46.2
59												49.0	46.3
60													47.3
y	1.9	2.5	**8.4**	4.5	3.0	2.1	4.8	5.2	3.7	3.9	5.2	4.9	5.0

For convenience' sake, and also for the reason explained on pp. 40—41, the first observation was considered to be that of J D 7501. The *daily* values of the intensity were taken from Pl. I; they were written on wooden cubes, as advised by Gibb (*Op. cit.* p. 680), and arranged in 88 rows of 35 cubes and 1 row of 20 cubes, the gaps being filled by blank cubes. After having obtained the sums, and the number of observations contained in each column, with the aid of a comptograph, the material was re-arranged in rows of 36, then in rows of 37, and so on, until in the final arrangement the rows contained 60 cubes*).

*) The process is, even with this practical arrangement, a very laborious one; the number of cubes which must be picked out from one row and placed in a higher one increasing from 1 to the number given by the trial period.

The result is stated in the preceding table. The first row gives the abscissae of the periodogram; the second row contains the limits of the numbers n, by which the sums S had to be divided; and the following rows contain the mean values $M = S : n$. The last row gives the differences between the greatest and smallest values of M which appear in each column, i. e. the ordinates of the periodogram.*) The latter is given in Fig. 2. It shows, contrary to what had been expected, *two* secondary peaks instead of one. They occur at 44 and 50 days respectively, with ordinates of about half the value of that of the principal periodicity.

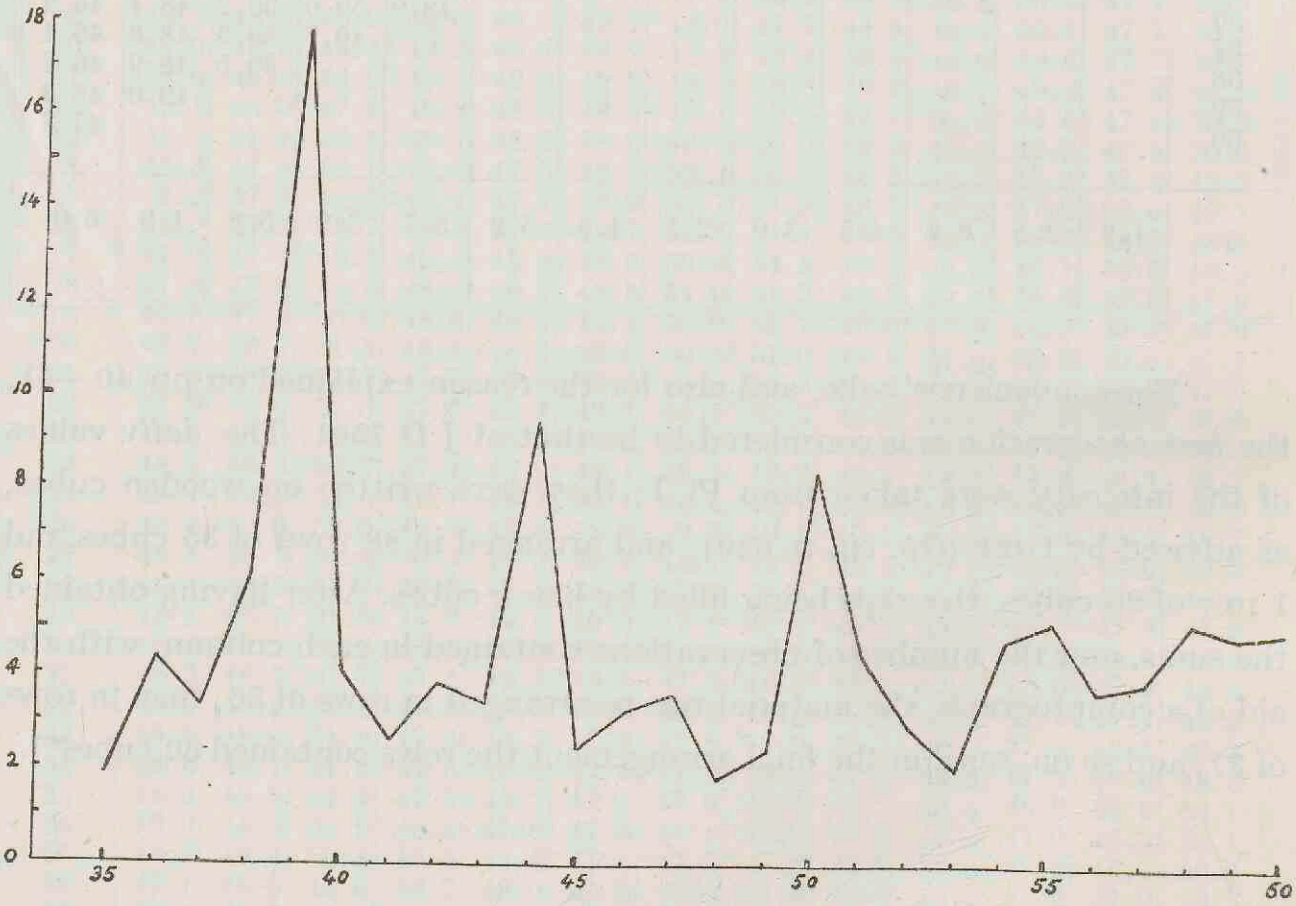

FIG. 2. The periodogram of *R V Tauri*.

The process used is, however, a rough and, to some extent, a precarious one; and we should exercise great care in deducing results from it. The first question which arises is, whether we are obliged to extend the periodogram beyond the limits 35 and 60 days. The lower limit was chosen simply in order

*) See the note on p. 99.

to start the process at a certain distance from the high peak, which *a priori* could be expected at 39 days; and the higher limit, to conclude it at a certain distance from the secondary peak, which was anticipated at about 54 days. Now this peak did not show itself; but, instead of it, two peaks appeared at 44 and 50 days. Since the ordinates of the three periodicities which manifested themselves measure together about 37 units, whereas (neglecting the extreme, and rarely observed, values of the brightness, and taking 80 and 20 as the ordinary limits) the amplitude of the light-curve is about 60 units, we should be inclined to say that, with the three periodicities we have found, the observed amount of amplitude is not yet exhausted; so that we have either to consider some of the smaller peaks as so many periodicities, or to extend the periodogram for further researches.

With regard to the first of these points, the following criterion is available. Not only does the difference between the greatest and smallest values of M give us an idea of the amplitude of a hidden periodicity, but the whole curve of the quantities M forms an image of that periodicity.*) SCHUSTER used to treat that curve by harmonic analysis; a necessary process in the attempt to discover periodicities which were not very prominent. But if, in the process we have used, and in view of the marked periodicities which we expect, the curve of the quantities M is fairly smooth and regular, we are justified in considering it as the image of a real periodicity. If such a periodicity is absent, the curve of the quantities M will be an irregular line. This graphical process, of which we shall speak more in detail in chapter VII, displayed regular single curves only for the arguments 39, 44 and 50 days; and so the three peaks mentioned above stand unrivalled.

Therefore we must consider the other alternative, viz. a search for other periodicities beyond the limits 35 and 60 days. But, as this would mean a considerable, and in fact an unlimited amount of additional work, we have not felt obliged to undertake it even to a small extent. The fact that the three

*) In fact it is the amplitude of this curve, rather than the difference between the extreme values of the quantities M, which ought to be taken as the ordinate of the periodogram; Under the influence of systematic or accidental errors these values need not coincide exactly with the maximum and minimum of the smooth curve just mentioned.

periodicities we have found do not, in their sum, yield the necessary amplitude, may be wholly due to the number of rows which we have used. It would seem, at first sight, as if any increase in this number would reveal a periodicity more clearly; but, as a matter of fact, the result of such an increase may be the "washing out" of the whole oscillation. To show this, let us consider the following example:

If, in an extensive series of daily values, there exists a periodicity of *exactly* 40 days, there is an advantage in taking a large number of rows, since this will allow the peak to come out more clearly above the general level; and this without any corresponding disadvantage. But if, in the same arrangement, the constituent period is not exactly 40 days, an increase of the number of rows will necessarily introduce a danger. Let us suppose, for instance, that the true period is 40.4 days. In that case, the trial period being 40 days, the maxima will almost immediately begin to shift slowly from their column, until, after 50 rows, minimum values take their place, causing such a marked diminution in the height of the peak that it may fail to draw attention. A further increase of 50 periods will give an equal distribution of all the phases of the light-variation *in each of the columns*, i.e. the effect of the periodicity will have vanished entirely. After that, the chance of getting a high peak presents itself again; but the preceding 100 rows have been not only useless, but even a disadvantage, since they have caused a rise of the general level (which is proportional to $\sqrt{n}$).

This reasoning finds its analytical expression in the fact that the amplitude of a periodicity p' will be zero when

$$p' = p\,(1 \pm \frac{1}{n})$$

in which formula p is the trial period, and n the number of periods (i. e. the number of rows) involved in the process. Thus in our case, since $p = 39$ and $p' = 39.25$ (see p. 108), the high peak in Fig. 2 would have disappeared if we had used a number of rows in the neighbourhood of 156.

Many authors, who applied the method of periodogram-analysis, have repeatedly advocated an increase in the number of rows, under the false impression that it will run strictly parallel to an increase of the resolving power in spectrum-analysis. Though both the process by which the results are reached, and the formulae which can be derived from it, suggest a close analogy between periodogram-and spectrum-analysis, there remains this striking difference between the two, that in spectrum-analysis we are not concerned, *a priori*, with the period, while in periodogram-analysis we are. In spectrum-analysis the periods are given in advance; in periodogram-analysis they must be sought for. This essential difference materially affects the details of the comparison. An increase of resolving power, for instance, increases the purity of the whole spectrum, whereas an increase of the number of rows affects the different unknown periods in a variety of ways, and, in fact, may even occasionally vitiate the results.

According to the above formula, each number of rows n is connected with two periods p' in the neighbourhood of the trial period p ($p \times n$ = the total number of observations), the existence of which cannot be detected unless a new arrangement is expressly made for the purpose. In the case of *R V Tauri* $p \times n = 3100$; for $p = 53$ ($n = 59$) the formula gives $p' = 52.10$ and 53.90; but since $p = 52$ and $p = 54$ have been examined, there is a very small probability that the two other periods, which differ so little from them, have any existence. Doubtful cases, however, arise when p' falls about midway between two of the trial periods used in the periodogram. In the following list these cases are numbered 1—9.

no.	p	n	p'		no.	p	n	p'	
1	35	89	34.60	35.40	14	48	65	47.26	48.74
2	36	86	35.58	36.42	15	49	64	48.23	49.77
3	37	83	36.55	37.45	16	50	62	49.19	50.81
4	38	81	37.53	38.47	17	51	61	50.16	51.84
5	39	79	38.51	39.49	18	52	60	51.13	52.87
6	40	77	39.48	40.52	19	53	59	52.10	53.90
7	41	76	40.46	41.54	20	54	57	53.05	54.95
8	42	74	41.43	42.57	21	55	56	54.02	55.98
9	43	72	42.40	43.60	22	56	55	54.98	57.02
10	44	70	43.37	44.63	23	57	54	55.94	58.06
11	45	69	44.35	45.65	24	58	53	56.91	59.09
12	46	67	45.32	46.68	25	59	53	57.88	60.12
13	47	66	46.29	47.71	26	60	52	58.85	61.15

As will be seen later on, the course of the work led to a special consideration of the periods 38.5, 39.5 and 43.5. Of the other doubtful periods, 40.5, 41.5 and 42.5 have been examined, but with a negative result. The existence of periodicities smaller than 38 days, with amplitudes large enough to be detected by periodogram-analysis, seemed to the writer to be very improbable, and no special investigation regarding their existence has been undertaken.

Having once established the fact that the sum of the amplitudes given by the periodogram is certainly less than that of the true ones, we have not extended the search for periodicities beyond the limits of 35 and 60 days; and we have contented ourselves with gathering from the periodogram, as a preliminary result, the fact that, in the phenomenon shown by the leveled light-curve of *R V Tauri*, three periodicities are active, namely those which occur in the neighbourhood of 39, 44 and 50 days. The possibility of a period in the neighbourhood of twice the principal periodicity will be considered on p. 112.

CHAPTER VII.

A CLOSER EXAMINATION OF THE THREE PERIODS.

The preliminary result arrived at in the preceding chapter, makes it an attractive and interesting inquiry to discover whether the whole leveled light-curve can really be built up by three single curves. This problem requires, in the first place, a more accurate knowledge of the lengths of the periods. In order to obtain this, the time-interval had to be taken as 0.5 instead of 1 day. This is usually done, in a search for a periodicity of $p + 0.5$ day, by arranging the material alternately in rows of p and $p + 1$ numbers, and by neglecting the last numbers of the longer rows. In other words, where in the arrangement for p and $p + 1$ days the first columns would contain the observations numbered:

	1	$p + 1$	$2p + 1$	$3p + 1$	$4p + 1$	etc.	
and	1	$p + 2$	$2p + 3$	$3p + 4$	$4p + 5$	etc.	respectively,

the first column in the arrangement for $p + 0.5$ day contains the observations numbered:

1	$p + 1$	$2p + 2$	$3p + 2$	$4p + 3$	etc.

In our examination of the doubtful periods, mentioned in the preceding chapter, we have used this method with great advantage; but, in considering the true periods, we have preferred to follow a more correct course, by doubling the number of cubes, and interpolating between each two values used in the preliminary research. Where this interpolation did not give a whole number, the nearest even number has been taken. In the determination of the ordinate for 38.5 days, each row thus consisted of 77 cubes; in that of the ordinate for 39 days of 78 cubes, and so on. In order not to extend the amount of work in an unnecessary way, and with the hope of getting a greater intensity (see p. 100), the whole available material has not been used in this closer examination; but such a number of days has, in each case, been chosen as would guarantee the values of n being of the same order for the three periods. Starting from J D 7501 for all three periods, the investigation of the 39 days' period has been carried to J D 9490 (1990 days); that of the 44 days' to J D 9848 (2348 days); and that of the 50 days' to J D 0230 (2730 days). The results are given in the following tables, which are arranged in the same way as in the preliminary research. The separate parts of the periodogram, which they establish, are given in Fig. 3.

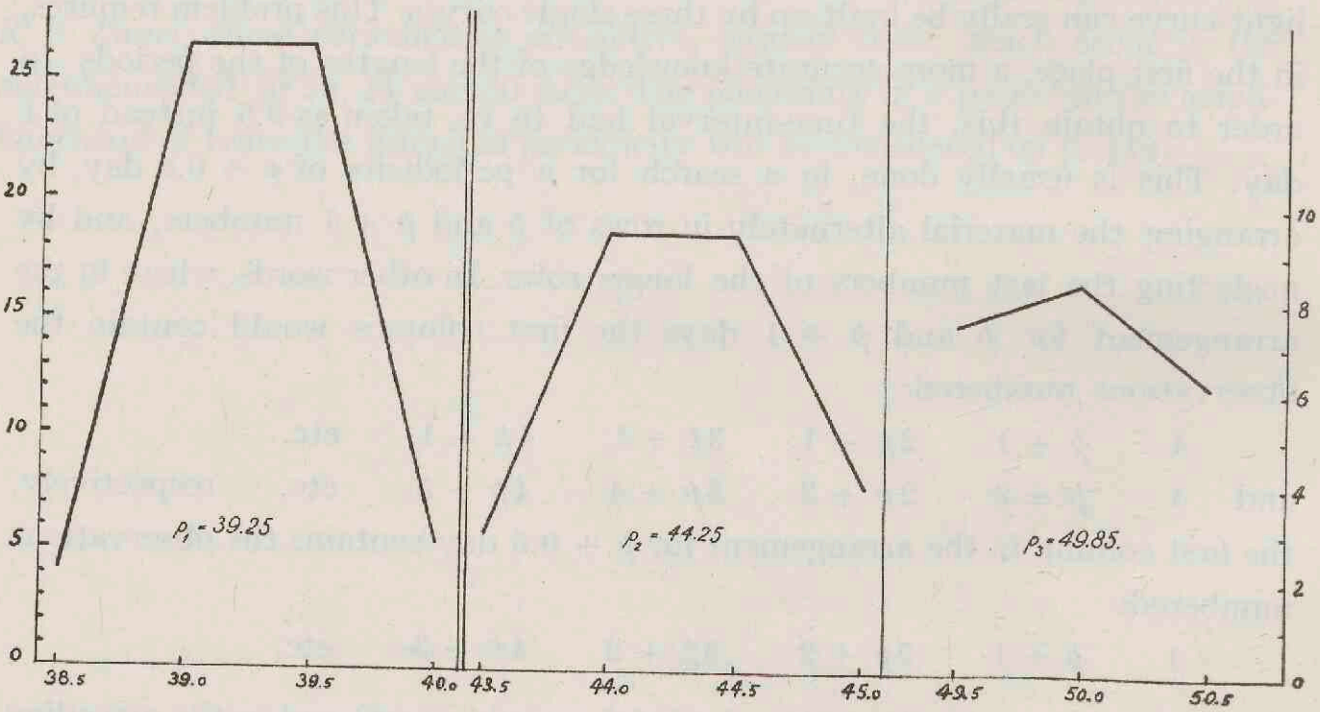

FIG. 3.

x =	38.5	39.0	39.5	40.0	x =	38.5	39.0	39.5	40.0
1	48.7	34.6	57.9	46.8	46	46.1	56.4	34.7	46.9
2	48.7	34.9	58.6	46.6	47	46.2	55.8	34.5	47.1
3	48.7	35.4	59.0	46.4	48	46.4	55.2	34.2	47.3
4	48.8	36.0	59.3	46.3	49	46.5	54.6	33.6	47.4
5	48.8	36.5	59.7	46.1	50	46.8	53.7	33.5	46.9
6	48.8	37.1	59.9	45.9	51	46.9	52.9	**33.4**	47.1
7	**49.3**	37.7	60.1	47.1	52	47.0	51.7	**33.4**	47.5
8	49.3	38.2	**60.2**	47.1	53	47.7	50.8	33.6	47.9
9	49.0	38.8	**60.2**	47.7	54	47.7	49.9	33.8	48.3
10	48.8	39.5	**60.2**	47.6	55	47.9	48.9	34.1	48.5
11	48.7	40.2	59.9	47.6	56	48.1	47.9	34.4	48.8
12	48.5	40.9	59.4	47.6	57	48.2	46.9	34.2	49.2
13	48.3	41.6	58.8	47.5	58	48.4	45.9	34.9	49.6
14	48.2	42.5	59.5	47.5	59	48.6	45.5	35.7	49.8
15	48.1	43.4	59.2	47.4	60	48.7	44.6	36.3	50.0
16	47.7	44.5	58.7	47.5	61	48.7	43.6	36.9	**50.5**
17	47.6	45.5	58.3	47.5	62	48.7	42.7	37.9	50.4
18	47.4	46.8	57.8	47.5	63	48.6	41.8	38.9	50.3
19	47.2	47.9	56.9	47.5	64	49.1	40.3	39.9	50.1
20	47.0	48.9	56.2	47.4	65	49.2	39.5	41.0	49.9
21	47.1	51.5	55.5	47.2	66	49.2	38.3	42.4	49.8
22	46.5	52.3	54.8	47.1	67	49.1	37.3	43.6	49.6
23	46.2	53.1	54.1	47.1	68	49.0	36.6	44.9	49.3
24	46.0	53.8	53.5	47.0	69	49.0	35.9	46.3	49.6
25	45.6	54.7	52.4	46.8	70	48.8	35.3	47.6	49.2
26	45.3	55.6	51.6	46.7	71	48.7	34.7	48.8	48.9
27	**45.0**	56.3	50.8	46.5	72	48.6	34.2	50.1	48.9
28	46.1	56.9	49.9	46.3	73	48.6	33.9	51.7	48.7
29	46.0	57.4	49.0	46.1	74	48.7	33.6	53.1	48.5
30	45.9	58.0	48.4	45.9	75	48.8	**33.3**	54.2	48.3
31	45.8	58.6	47.4	45.8	76	48.4	33.4	55.2	48.1
32	45.7	59.0	46.5	45.7	77	48.4	33.4	56.1	47.8
33	45.7	59.4	45.5	45.4	78		33.7	56.9	47.5
34	45.7	59.5	45.2	45.3	79			57.5	47.4
35	45.4	59.8	44.2	45.1	80				47.1
36	45.3	**59.9**	43.2	45.3					
37	45.6	**59.9**	42.2	**45.0**					
38	45.7	59.8	41.2	45.3					
39	45.8	59.5	40.4	45.9					
40	45.8	59.3	39.5	46.0					
41	45.8	59.0	38.7	46.2					
42	45.9	58.6	38.0	46.4					
43	45.9	58.0	36.9	46.5					
44	46.0	57.4	35.6	46.6					
45	46.1	56.9	35.2	46.8					
					y	4.3	**26.6**	**26.8**	5.5

$x =$	43.5	44.0	44.5	45.0	$x =$	43.5	44.0	44.5	45.0
1	47.3	50.0	50.0	47.1	46	48.9	44.4	47.9	48.9
2	47.2	50.2	49.6	47.1	47	48.8	44.1	48.0	48.4
3	47.0	50.5	49.1	47.1	48	48.7	43.8	48.0	48.3
4	47.0	50.8	48.7	47.1	49	48.6	43.7	48.3	48.1
5	46.9	51.0	48.3	47.1	50	48.7	43.5	48.5	47.9
6	46.8	51.2	47.9	47.1	51	49.1	43.2	49.3	47.7
7	46.8	51.3	47.5	47.1	52	49.0	**43.1**	49.3	47.6
8	47.4	51.5	47.1	47.1	53	48.8	**43.1**	49.4	47.5
9	47.3	51.7	46.5	47.6	54	48.7	**43.1**	49.4	47.6
10	46.9	51.9	46.1	47.1	55	48.6	**43.1**	49.6	47.6
11	46.8	51.9	45.7	47.1	56	48.6	43.2	49.7	47.4
12	46.8	51.9	45.3	47.2	57	48.6	43.2	49.7	47.4
13	46.5	52.0	45.0	47.1	58	48.5	43.5	49.7	47.5
14	46.5	51.9	44.6	47.2	59	48.3	43.7	49.9	48.0
15	46.4	52.0	44.3	47.2	60	48.3	44.0	49.9	47.9
16	46.5	52.2	43.9	47.1	61	48.4	44.4	49.9	47.8
17	**46.3**	51.9	43.7	47.1	62	48.9	44.6	49.9	47.7
18	46.4	51.8	43.5	46.9	63	48.8	44.8	50.0	47.7
19	46.5	52.0	43.3	47.1	64	48.9	45.2	50.6	47.8
20	46.6	**52.4**	43.2	47.0	65	**49.2**	45.4	50.7	47.5
21	47.0	**52.4**	**43.1**	47.3	66	**49.2**	45.6	50.6	47.6
22	47.2	52.3	**43.1**	47.6	67	49.0	45.8	50.8	47.6
23	47.5	52.2	43.5	47.7	68	49.0	46.2	51.0	47.6
24	47.7	51.9	43.3	47.8	69	48.9	46.3	51.1	47.6
25	47.8	51.3	43.3	48.0	70	48.8	46.5	51.2	47.2
26	48.0	51.0	43.6	48.3	71	48.7	46.8	51.6	47.0
27	48.1	50.7	43.7	49.6	72	48.6	47.1	52.0	47.1
28	48.2	50.3	43.8	49.7	73	48.2	47.8	52.1	47.1
29	48.4	50.0	43.7	50.5	74	48.0	48.0	52.1	47.1
30	48.6	49.6	43.8	50.6	75	48.0	48.1	52.3	47.0
31	48.3	49.7	43.8	50.6	76	48.0	47.9	52.4	47.0
32	48.4	49.1	43.8	50.5	77	48.0	48.0	52.4	47.1
33	48.1	48.8	45.1	**50.7**	78	48.0	48.2	**52.5**	47.1
34	48.0	48.2	45.1	50.5	79	48.1	48.3	52.2	47.0
35	47.8	47.8	45.4	50.4	80	48.2	48.5	52.0	46.9
36	47.7	47.2	45.6	50.3	81	48.2	48.6	51.9	46.9
37	47.7	47.1	45.8	50.1	82	48.2	48.2	51.8	46.9
38	47.6	46.5	45.8	50.1	83	48.2	48.5	51.7	46.9
39	47.6	47.3	45.9	50.0	84	48.0	48.9	51.5	46.9
40	47.8	46.9	46.2	50.0	85	47.8	49.2	51.2	47.0
41	47.7	46.4	46.6	49.9	86	47.5	49.3	50.8	46.9
42	47.8	46.0	47.0	49.6	87	47.4	49.6	50.5	46.9
43	47.8	45.4	47.3	49.4	88		49.7	50.2	46.9
44	47.6	45.0	47.6	49.1	89			50.3	**46.6**
45	49.0	44.7	47.8	48.9	90				46.9
					y	2.9	**9.3**	**9.4**	4.1

x =	49.5	50.0	50.5	x =	49.5	50.0	50.5	x =	49.5	50.0	50.5
1	49.6	45.0	48.5	35	45.7	49.1	**51.1**	69	49.0	51.1	46.9
2	49.2	44.7	48.7	36	45.7	49.5	51.0	70	49.3	50.7	46.9
3	49.0	44.6	48.9	37	45.9	49.9	50.9	71	49.5	50.6	46.8
4	48.8	44.4	48.9	38	46.1	50.4	50.8	72	50.9	50.3	46.5
5	48.7	44.2	49.2	39	46.4	50.8	50.8	73	51.1	50.0	46.2
6	48.6	**44.0**	49.4	40	46.4	50.9	50.7	74	51.3	49.7	46.1
7	48.2	**44.0**	49.6	41	46.5	51.2	50.9	75	51.6	49.4	46.0
8	48.0	**44.0**	49.8	42	46.7	51.5	50.5	76	51.9	49.4	46.0
9	47.9	44.6	50.0	43	46.8	51.6	50.5	77	51.8	49.3	45.6
10	47.6	44.2	50.3	44	46.9	51.9	50.2	78	51.9	49.0	45.8
11	47.4	44.2	50.4	45	47.0	52.1	49.8	79	52.1	48.8	45.6
12	47.3	44.4	50.5	46	47.1	52.2	49.5	80	52.1	48.9	45.6
13	47.1	44.6	50.6	47	47.2	**52.4**	49.2	81	52.0	48.5	45.5
14	46.8	44.9	50.7	48	47.4	**52.4**	48.9	82	52.2	48.3	45.3
15	46.6	45.1	50.3	49	47.5	52.3	48.5	83	52.1	48.0	45.4
16	46.2	45.3	50.4	50	47.6	52.1	48.1	84	52.3	47.8	**45.0**
17	45.9	45.5	50.4	51	47.6	51.9	47.9	85	52.4	47.6	**45.0**
18	45.7	45.8	50.1	52	47.5	51.9	47.8	86	**52.7**	47.3	45.4
19	45.5	46.0	50.2	53	47.4	51.8	47.5	87	52.6	47.0	45.2
20	45.7	46.2	50.2	54	47.3	51.7	47.2	88	52.3	46.7	45.2
21	45.6	46.4	50.0	55	47.5	51.5	47.0	89	52.2	46.7	45.2
22	45.5	46.6	49.9	56	47.5	51.4	46.8	90	51.9	46.5	46.2
23	45.5	46.8	49.7	57	47.4	51.3	46.8	91	51.4	46.4	46.3
24	45.5	46.9	49.5	58	47.3	51.1	46.8	92	51.3	46.4	46.4
25	45.4	47.1	49.6	59	47.4	51.4	46.7	93	51.1	46.2	46.6
26	45.3	47.3	49.7	60	47.5	51.5	46.4	94	50.9	45.9	46.9
27	45.3	47.3	49.7	61	47.5	51.3	46.2	95	50.6	45.7	47.0
28	**45.2**	47.6	49.6	62	47.7	51.1	47.4	96	50.4	45.6	47.3
29	45.9	47.8	49.7	63	47.9	51.0	47.3	97	50.2	45.4	47.4
30	45.9	47.6	50.2	64	48.1	50.7	47.2	98	49.9	45.2	47.6
31	45.8	47.9	50.2	65	47.9	50.5	47.1	99	49.6	45.1	47.9
32	45.8	48.2	50.9	66	48.1	50.3	47.0	100		45.0	48.2
33	45.7	48.5	51.0	67	48.4	50.6	46.9	101			48.3
34	45.7	48.9	51.0	68	48.8	51.0	46.9				
								y =	**7.5**	**8.4**	**6.1**

The ordinates for the trial periods 39 and 39.5 days, and again those for 44 and 44.5 days, are almost exactly equal to each other; and we may conclude from this that the true periods will not differ much from the mean values 39.25 and 44.25 days. This conclusion tacitly assumes that, since the time-interval is only 0.5 day, we may consider that the ordinates within that interval change proportionately in the neighbourhood of the true period. Using the same assumption in the case of the third period, we get 49.85 days as the most probable value of the true period.

As an illustration of what has been said about the amplitude, we may remark that in the preliminary research, when 3100 days were used, the height of the 39 days' peak was 18.7 units, whereas in the second research, using 1990 days, the height of the peak rose to 26.6 units. In the case of the other two periods the increase of amplitude is not so striking; a fact which may partly be due to the smaller diminution of the resolving power.

We have now to consider the phases of the three periodicities at the starting point J D 7501. As we have remarked on p. 99, the curve of the quantities M is the image of the periodicity to which they belong; its maximum is the first maximum which occurred after J D 7501. We have drawn on Pl. II (b, c, d) the six curves belonging to the trial periods 39.0, 39.5, 44.0, 44.5, 49.5 and 50.0 days. *)

The curves for 39.0 and 39.5 days are very characteristic. Even when we take the ordinates M to two decimals, the points lie almost exactly on a very smooth and regular curve. There is one discontinuity, which occurs in these and all the curves, at the moment marked ×, in which the extreme maximum at J D 7788 sets in with the intensity 97 (see p. 79). Its influence is very perceptible, especially when it occurs on a descending branch.

As an illustration of the abrupt way in which the image of a marked periodicity, such as we encounter here, appears and disappears, we have drawn on the same scale the graphs of the values of M for the trial periods 38.5 and 40.0 days (Pl. II e and f).

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*) For clearness' sake we have preferred to reproduce only the points through which the curves ought to be drawn. In the diagrams c and d small lines indicate the continuity of the curves at the points of their intersection.

On the line of the abscissae the number 1 means J D 7501, and we see at a glance that the epoch of maximum of the trial period 39.0 days is J D 7518.6, and that of the trial period 39.5 days, J D 7505.0. The difference is 13.6 days; and as the true period lies midway between the two trial periods, we are justified in fixing its epoch of maximum at J D 7511.8. *)

The curves for the other two periodicities are not so regular as those for the first one; a fact which will be fully understood later on. The epochs of maximum of the curves for 44.0 and 44.5 days being J D 7494.5 and 7509.0, the true periodicity of 44.25 days will have a maximum on J D 7501.8.

The curves for 49.5 and 50.0 days are not similar to each other, since they lie at unequal distances from the true period. The 50.0 days'curve, which is lying nearer to the true curve, is the more regular of the two. The maxima lie at J D 7543.0 and J D 7524.5, from which it follows that the 49.85 days' periodicity had a maximum on J D 7530.0 (and 7480.2).

It will be perceived that the conclusions arrived at in the two preceding chapters, do not allow us to say more than that the leveled light-curve of *R V Tauri* is very probably in some way a combination of the following three periodicities:

	Maximum	M — m	
I	J D 7511.8 + 39.25 E	27	or more (see p. 102.)
II	J D 7501.8 + 44.25 E	10	
III	J D 7480.2 + 49.85 E	9	

*) If the difference between the trial period and the true period is m days, and if the number of periods involved in the process is n, the change in phase is $\frac{(n-1)}{2} \times m$ days.

CHAPTER VIII.

The three periodicities combined, and the possibility of a solution with only two periods.

We have seen on p. 86 that the observed light-curve has a curved central line. By the "leveling" process we transformed this into a straight line, which we shall now call the "axis" of the leveled light-curve. The ordinates of this curve (Pl. I) are expressed in intensities; in that scale the mean value of the maxima is 64, and that of the minima 30; from which it follows that the axis coincides approximately with the intensity 47. In what follows we shall assume its value to be $47 + x$.

Each ordinate of the light-curve, diminished by this amount, is the sum of the simultaneous ordinates of the three single curves. If we consider these to be sinusoids with amplitudes y_1, y_2 and y_3; and if the phases on J D 7500 (intensity 53, see p. 79) are φ_1, φ_2 and φ_3 respectively, the relation between the unknown quantities is at this starting point:

$$x + y_1 \sin \varphi_1 + y_2 \sin \varphi_2 + y_3 \sin \varphi_3 = +6$$

Five days later, the phases are advanced with amounts a, b and c, which are known from the periods.

If we put:

$$y_k \sin \varphi_k = z_k \qquad y_k \cos \varphi_k = z_k' \qquad (k = 1, 2, 3)$$

we get from the intensities, given for each five days in the list on pp. 79-86, 449 equations of the form:

$$x + z_1 \cos na + z_1' \sin na + z_2 \cos nb + z_2' \sin nb + z_3 \cos nc + z_3' \sin nc = l$$

$$(n = 0, 1, 2, \ldots\ldots\ldots\ldots)$$

which must be solved by the method of least squares.

For this purpose we have, for the sake of accuracy, enlarged the scale of the intensities, 1000 being now the greatest intensity instead of 100, and $470 + x$ being the intensity of the axis. Moreover we have thought it best not to treat the material as a whole, for the following reason.

We have on p. 100 referred to one circumstance which requires some care in the practice of periodogram-analysis; but there is another pit-fall which, so far as we can see, has escaped the attention of previous investigators. This is the possibility that a peak in the periodogram is not the result of any periodicity, but of a non-periodical "outburst", or of a number of intermittent outbursts which reinforce each other. In the former of these cases (e. g. a new star) a high peak will occur *whatever may be the trial period*; and this characteristic of the peak will directly point to its origin.*) In the latter case, it will be important to locate the outbursts as accurately as possible; and this can only be done by dividing the material. For our present purpose we have taken 12 groups, each of which consists of about 6 periods of 39 days.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Interval			x		Amplitudes			Phases			Maxima		
no.	Limits	Centre	Δl	Δm	y_1	y_2	y_3	φ_1	φ_2	φ_3	M_1	M_2	M_3
				m				°	°	°	d	d	d
1	7500—7680	7590	+47	—0.10	89	50	16	— 3.87	50.70	288.32	7510.2	7504.8	7522.3
2	7785—8000	7899	—11	+0.02	271	257	171	—18.83	225.00	58.40	11.9	7483.4	7504.4
3	8005—8240	8128	—16	+0.04	147	28	16	—16.00	191.58	257.00	11.5	7487.5	7476.9
4	8245—8430	8338	+11	—0.02	132	60	43	—35.33	90.75	257.83	13.7	7499.8	7526.6
5	8505—8690	8598	—21	+0.05	195	74	81	—48.50	178.33	282.67	15.1	7533.4	7523.2
6	8695—8985	8848	+66	—0.14	155	87	68	— 8.47	110.11	204.64	10.7	7497.5	7484.1
7	8990—9290	9113	—24	+0.06	165	18	37	—23.36	305.30	130.06	12.4	7473.5	7494.4
8	9295—9480	9388	—34	+0.08	173	41	25	—24.45	307.75	51.95	12.5	7517.5	7505.3
9	9485—9800	9700	+37	—0.08	203	104	50	—43.65	320.25	351.17	14.6	7515.9	7513.7
10	9805—0115	9980	+32	—0.07	149	30	36	—47.66	99.98	56.40	15.0	7498.8	7504.6
11	0120—0410	0248	+62	—0.13	121	53	62	—38.25	182.62	274.05	14.0	7488.6	7474.5
12	0415—0600	0516	+33	—0.07	153	64	54	— 4.55	87.51	148.33	7510.3	7500.3	7491.9

*) For an illustration see the discontinuity in all the curves of the quantities M (p. 108)

The results of this computation are given above. The first three columns give the number, the limits and the "centre" of each interval; the latter differing from the mean of the interval, since the 12 groups do not exactly coincide with the observational seasons. The fourth and fifth columns give the quantity x by which the intensity 470 (magn. $10^m.12$), assumed for the axis, has to be corrected, both in the scale of intensities and in that of magnitudes. The columns 6—8 give the amplitudes of the three waves, whereas 9—11 give the phases on J D 7500. And, finally, the columns 12—14 give the dates of the initial maxima derived from these phases. It will be noted that for the 2nd and 3rd waves these dates do not always give the maxima next to J D 7500. The reason for this will be given later on.

A glance at the last three columns of the preceding table, shows us that the first wave, which has a period of 39.25 days, may alone be considered as relatively stable; the 44.25 and 49.85 days' periods being decidedly unstable. This being so, it seems advisable, before starting to investigate the character of these unstable waves in detail, to make sure that no solution presents itself in which a *single* additional wave, with a period lying beyond the periodogram-limit of 60 days, can replace them with the same degree of accuracy. Roughly speaking, the appearance of a kind of β *Lyrae* variation always suggests the influence of a period of about twice the principal one; i. e. in our case, of a period in the neighbourhood of 78.5 days. A study of the aspect of the light-curve gives the impression that, at intervals of, say, about $940 = 12 \times 78.5$ days, the same character presents itself again; a repetition which might be ascribed to the existence of an interfering period of $78.5\ (1 \pm \frac{1}{12})$ days.

In order to test this, the 39.25 days' curve was alternately combined with two curves having periods of 72 and 85 days respectively. After a consideration of the different values of the maxima and minima, in those parts of the light-curve where the β *Lyrae* type was most prominent, amplitudes of 80 units were assigned to the additional waves. The amplitude of the stable wave was kept constant at 159. These two combined curves were compared with the observed one, and this resulted in the rejection of the 85 days'period. As to the 72 days'period, the computations were simplified by taking equal numbers of days from 6 different seasons, and by starting each season with its own phase. By doing so, the 6 sets of normal equations had the same coefficients throughout, and could be solved very quickly.

The result was, that the suspected 72 days' periodicity would have had maxima on the following dates, falling about the middle of each season:

1.	8135.7	
		386.6
2.	8522.3	
		326.7
3.	8849.0	
		377.1
4.	9226.1	
		395.0
5.	9621.1	
		393.8
6.	0014.9	

But we should recall the fact that our hypothesis required a 72 days' curve which should be continuous. This would mean that the 6 maxima, derived from the partial investigations, would be maxima of the continuous curve as well. Since, however, this does not appear, the hypothesis must be rejected.

The following is an analytical criterion of the existence of a single additional periodicity:

If the first period is exactly known, and if, from a certain starting-point (phases φ and ψ) we take the ordinates of the combined curve, at distances which exactly equal 120° of the known period, each interval of three of these periods will yield the following 6 equations:

$$x \sin \varphi + y \sin \psi = l_0$$
$$x \sin (\varphi + 120) + y \sin (\psi + a) = l_1$$
$$\cdots\cdots\cdots\cdots$$
$$x \sin (\varphi + 5.120) + y \sin (\psi + 5a) = l_5$$

In these equations a° is the equivalent of 120° for the second periodicity, and the quantities l are the ordinates of the combined curve.

If we put:

$$\tfrac{1}{2}\sqrt{2} = f \qquad \begin{array}{ll} x \sin \varphi = z_1 & y \sin \psi = z_1' \\ x \cos \varphi = z_2 & y \cos \psi = z_2' \end{array}$$

these equations become:

$$\begin{array}{lr} z_1 + z_1' = l_0 & (1) \\ -\tfrac{1}{2} z_1 + f z_2 + z_1' \cos a + z_2' \sin a = l_1 & (2) \\ -\tfrac{1}{2} z_1 - f z_2 + z_1' \cos 2a + z_2' \sin 2a = l_2 & (3) \\ z_1 + z_1' \cos 3a + z_2' \sin 3a = l_3 & (4) \\ -\tfrac{1}{2} z_1 + f z_2 + z_1' \cos 4a + z_2' \sin 4a = l_4 & (5) \\ -\tfrac{1}{2} z_1 - f z_2 + z_1' \cos 5a + z_2' \sin 5a = l_5 & (6) \end{array}$$

From these equations we can eliminate z_1 and z_2 by subtracting (4) from (1), (5) from (2), and (6) from (3). We then get 3 equations with 2 unknown quantities (z_1' and z_2'), giving rise to the following determinant:

$$\begin{vmatrix} l_0 - l_3 & \sin \tfrac{3}{2} a & \cos \tfrac{3}{2} a \\ l_1 - l_4 & \sin \tfrac{5}{2} a & \cos \tfrac{5}{2} a \\ l_2 - l_5 & \sin \tfrac{7}{2} a & \cos \tfrac{7}{2} a \end{vmatrix} = 0$$

whence:

$$\cos a = \frac{(l_0 + l_2) - (l_3 + l_5)}{2\,(l_1 - l_4)}$$

Since each of the nine observed seasons contains 3 groups of 3 periods of 39.25 days, each value of $\cos a$ in the following table is the mean of three.

Season	$\cos a$	Season	$\cos a$	Season	$\cos a$
1	—0.07	4	—0.51	7	+0.60
2	—0.01	5	—0.52	8	+0.13
3	+7.40	6	—0.80	9	+1.01

The result is again entirely negative. We have made another arrangement, advancing 180° of the first period instead of 120°, but without success. This means that we are justified in leaving the possibility of *one* additional period out of further consideration, and may procced to a more detailed analysis of the three waves, which we had previously discovered.

CHAPTER IX.

A DETAILED ANALYSIS OF THE THREE WAVES.

I. The correction of the assumed axis.

The quantities x must be considered as resulting from the errors made in the course of the "leveling" process; and we may use them to correct the curve of the long periodicity. The curve thus corrected is represented by the dotted line on Pl. II (a). It has 2 maxima, which occur after an interval of 1210 days, and 3 minima, occuring after intervals of 1170 and 1350 days respectively (mean = 1260 days); whereas the rising branch crosses the line $9^m.80$ at intervals of 1130 and 1465 days (mean = 1292 days). From these numbers we conclude that the long periodicity is a more or less regular wave with a period of about 1250 days. $M - m$ is about $1^m.2$ *), and its value seems slightly to decrease.

The observations do not extend over a period long enough to give a more detailed knowledge of this interesting element in the process of the star's light-variation.

II. The amplitudes.

The amplitudes of the three waves, taken from the table on p.111, have been plotted in Fig. 4. The principal feature of this representation is the remarkable rise between J D 7600 and 7900, which, considering the light-curve itself, must have been even more abrupt than could be gathered from the smoothening process of computation **). The exact outbreak of the disturbance, which must have caused this abrupt rise of amplitude, has not been observed. A glance at the curve of the long periodicity, shows us that the observations

*) See Appendix.

**) See also p. 130.

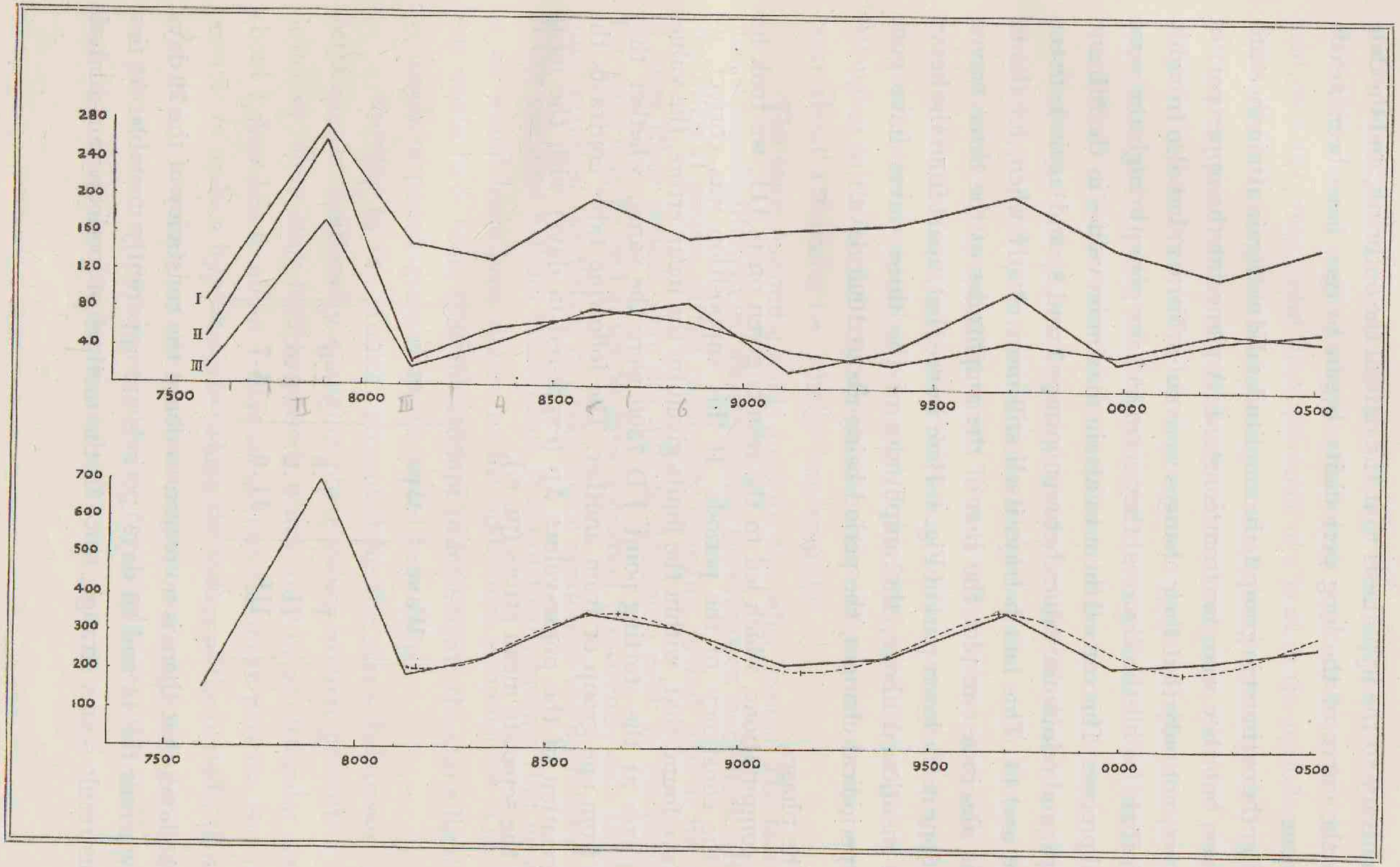

FIG. 4. The amplitudes of the three periodicities.
I. Period = $39^d.25$ II. Period = $44^d.25$. III. Period = $49^d.85$.

are not contrary to the hypothesis that the date of the outbreak, and the date on which the curve of the long periodicity began to rise, have been nearly simultaneous.

After the outburst in group 2, the amplitudes did not again attain the same large values; but they were far from constant. A glance at the upper part of Fig. 4 shows, not only that their changes were not arbitrary, but also (roughly speaking) that, for all three waves, they seem to have gone through the same periodical process. This caused them to attain maximum values in the 5th and 9th groups, and minimum values between groups 7 and 8, and again between groups 10 and 11. This fact betrays itself still more clearly when, for the 12 centres as abscissae, we plot the *sum* of the amplitudes of the three waves, which is done in the lower part of Fig. 4. Here we see that, apart from the heavy outburst mentioned above, the amplitudes of the three waves have gone through periodical changes, the period being about 1000 days.

III. The phases.

In the computations, which led to the results given on p. 111, we took for granted the constancy of the periods. If this supposition was correct, we should have found that, within the limits given by the mean errors, the values for the phase at the starting point J D 7500 were the same, whether they resulted from one group or from another. The following table contrasts the mean deviation of the phase-values Δp (expressed in days) with the mean value of the separate mean errors (m. e.).

Wave	Δp	m. e.
I	1.5	2.0
II	9.2	2.5
III	11.6	3.7

It shows that there is no reason to doubt the constancy of the 39 days' period, whereas the 44 and 50 days' periods are apparently unstable. At first sight this result seems strange, since in the method of periodogram-analysis the constancy of the periodicity is tacitly assumed; and it proves once more that this method ought to be handled with some caution. We have already said, on p. 111, that, from the appearance of a peak in the periodogram, we need not necessarily conclude that some periodicity has been active during the whole interval of time under investigation. It is, moreover, obvious that when a periodicity has been active during separate parts of the interval only, the appearance of a peak will depend upon its amplitudes. For instance, let us consider an extreme value of the amplitude of the second wave, i. e. the value 104 in group 9. Since, in the periodogram, we get the double amplitude, and since we have used in its construction a 10-fold smaller scale, the amplitude 104 is equivalent to a peak of 21 units. But if it has been active only during an interval of about 200 days, (and this seems to have occured here), then, since the total interval which has been analysed is 2348 days, the height of the peak, belonging to the periodicity which was active in the 9th group, would have been about 1.7 units, i.e. wholly imperceptible.

The same reasoning holds good for the other groups. The fact that the phases possess different values, means that the vibration made itself felt through the different groups with a constantly changing period; and in the majority of cases these periods were not able to develop a peak in the periodogram. The same may be said of the 50 days' vibration. Apparently only those periods could manifest themselves in peaks, which reinforced the outburst in group 2. If this outburst had not taken place, it is practically certain that no attention at all would have been drawn to the additional periodicities. The result of this would have been, that the attempt to investigate the star's light-changes by means of periodogram-analysis, would have failed.

Turning to the problem presented by the star's behaviour after the outburst, the continually changing phase-values at first presented a serious difficulty, since they lead to periods which vary in an irregular way, from about 4 days less to about 4 days more than the mean periods. But it proved possible to make a hypothesis by which the values of the periods, though they increased in amount, yet changed in a regular way, and along a curve which ran parallel to the 1000 days' curve of the amplitudes. We shall proceed to show this *in extenso* for the second wave.

The phases, as given in columns 9—11 of the table on p. 111, resulted from the computations without any ambiguity; and from them we are inclined to derive the corresponding divergences from the mean period, by combining the adjoining maxima (or other characteristic points) in such a way that the resulting changes in phase will be as small as possible. The following table shows the results. Its first column gives the number of the group; the second, the phase-angle; and the third, the nearest value of the maximum. Thus for instance, the normal maximum as derived from group 8 is found to be either 7517.3 or 7473.1. The nearest value to J D 7500 has been adopted.

Group	φ	M	Δ M	M′	Δ M′	m. e.
3	191.58	7487.5	—13.8	7487.5	—13.8	3.8
4	90.75	7499.8	— 1.5	7499.8	— 1.5	2.2
5	178.33	7489.2	—12.1	7533.4	+32.1	2.2
6	110.11	7497.5	— 3.8	7497.5	— 3.8	1.5
7	305.30	7517.8	+16.5	7473.5	—27.8	7.5
8	307.75	7517.3	+16.0	7517.3	+16.0	2.4
9	320.25	7515.9	+14.6	7515.9	+14.6	0.2
10	99.98	7498.8	— 2.5	7498.8	— 2.5	3.0
11	182.62	7488.6	—12.7	7488.6	—12.7	1.7
12	87.51	7500.3	— 1.0	7500.3	— 1.0	1.9
		7501.3		7501.3		

The fourth column gives the differences between these maxima and their mean value. These differences do not follow a regular curve; and if we were to adopt them, we should be forced to conclude that, after the outburst, the star has been subjected to smaller disturbances in periods which appear to change capriciously. This is not impossible, but a physical explanation would be difficult; and it would be of great value if the maxima in the centres of the groups could be combined, so as to represent *regular* changes of the periods, *even if the amount of the differences Δ M were to increase.* Such a combination has been arrived at by taking, in group 5, the following and, in group 7, the preceding maximum. The new combination is given in the fifth column of the same table. The sixth column gives the new values of the differences; and the last column the mean errors of M′. To obtain these we have made a fair estimate of the mean errors of the quantities z and z' (p. 110); and, after that, those of y and φ could be derived by computation.

In the same way, for the third wave we have to change two values only in order to get similar results; and when the values $\Delta M'$ for both waves are plotted, they prove to follow a curve which, roughly speaking, *is identical with the* 1000 *days' curve of the amplitudes**). This relation is at once evident from Fig. 5, in which all the points are surrounded by circles, with radii equal to the mean errors.

For the 39 days' wave, the changes in the phases are of the same order as the mean errors, and this prevents an exact conclusion as to their periodical character. We might be inclined to accept the probability that a wave, which is unstable in amplitude, will also be unstable in phase; but the fact is that we are not able to show it in a quantitative way.

Thus, from the analysis of the leveled light-curve of *R V Tauri*, we may gather the following facts:

(1) the principal feature is a wave with a period of 39.25 days, which, so long as we are in want of more precise knowledge, must be considered as stable;

(2) apart from this principal wave, the star's light is constantly disturbed by the influence of vibrations, occuring in periods which may be considered as being grouped around the values 44.25 and 49.85 days, but which differ from these by amounts covering the whole distance from — 4 to + 4 days, and from — 4.5 to + 4.5 days, respectively;

(3) the amplitudes of both (1) and (2) undergo periodical changes, the period being about 1000 days;

(4) each change of period is accompanied by a corresponding change of amplitude;

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*) In this arrangement smaller amplitudes coincide with smaller periods. We can get a complementary arrangement whereby smaller amplitudes coincide with larger periods; but then we must change, in the preceding table, 4 values instead of 2.

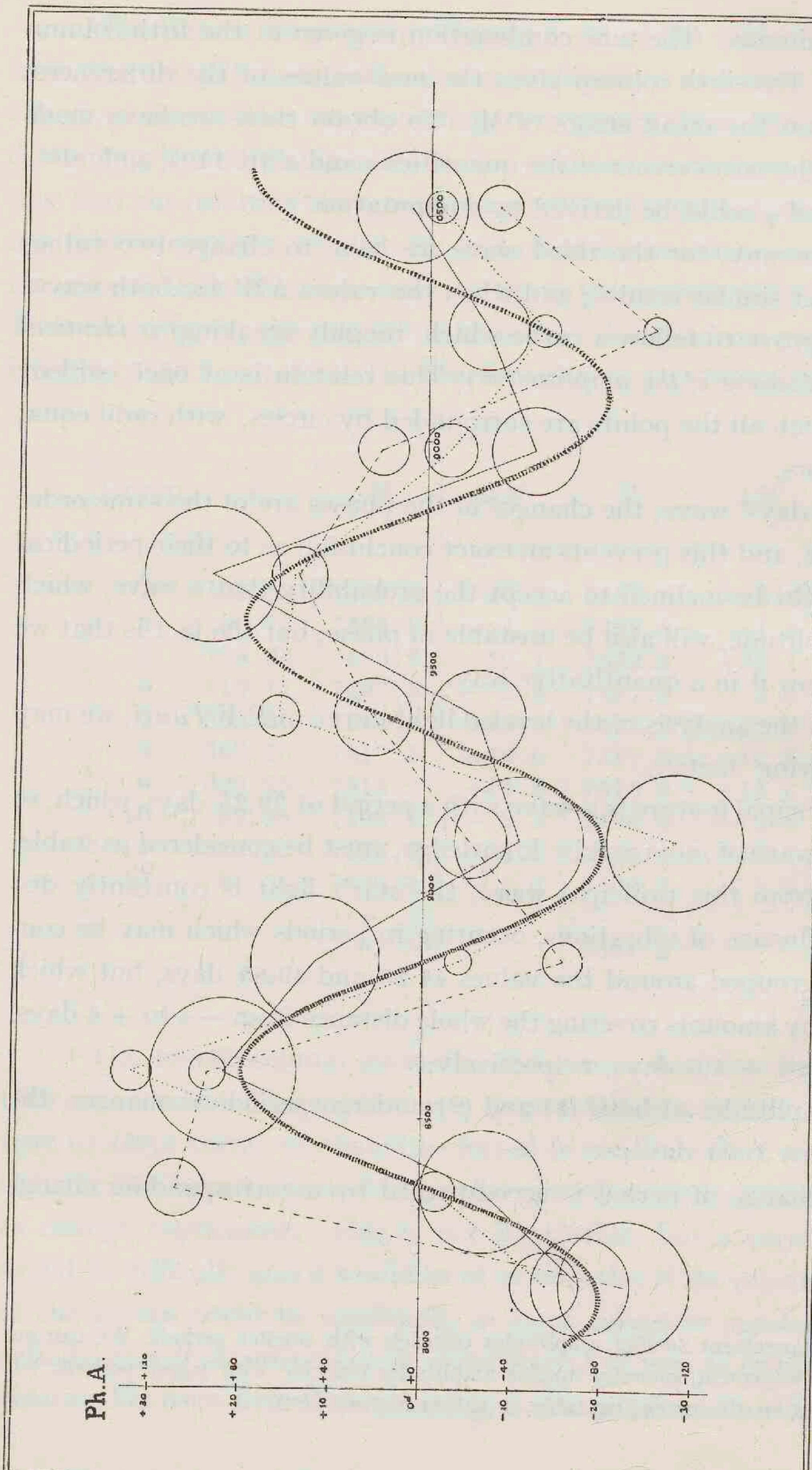

FIG. 5. The 1000 days' curve of the phases and amplitudes.

------- = Phases of wave II. .... = Phases of wave III. ——— = Amplitudes.

(5) the star is occasionally subjected to an outburst, which affects the amplitudes of all three mean periods.

We have already remarked that, without an outburst, such as that which took place between J D 7687 and 7785, the waves mentioned under (2) would have escaped detection. In the light of the above results we may now conclude that, if we had not taken the precaution to use a 10-fold extended scale of intensities in the computations, it is exceedingly doubtful whether the facts mentioned under (3) and (4) could have been laid down. Even now, the results cannot pretend to a high degree of accuracy; for not only are the mean errors relatively large, but the 1000 days' curves do not show more than the general progress of the periods and amplitudes. These circumstances make it hardly possible to represent the observed light-curve with precision. A value of the phase, taken from this curve, may have an error of several days; moreover (and this is a material difficulty), for any particular day we get only the *sum* of the three amplitudes. The separate values cannot be given with anything approaching to certainty.

We have devoted much time, and have tried in several ways, to solve this problem, but without success. When we use fixed laws of variability, it seems impossible to obtain a close approximation to the observed light-variation. The combined curves persist in differing from the observed one even in their mere aspect. We have therefore desisted from a precise comparison between the observed curve, and a curve based upon the results of our analysis, and we have contented ourselves with showing:

I. that both these curves, though of different aspects, are alike in the essential features, which may be taken to represent the character of any combined vibration;

II. the degree of instability which may be assigned to the calculated curve (apart from unknown, and perhaps irregular, perturbations), owing to the relatively large errors in the quantities which play a part in its contruction.

I. A hypothetical light-curve has been constructed in the following way. The period of the first wave was kept constant at 39.25 days; its phase on J D 7500 was the mean of the results for the different groups (see p. 111).

For the second and third waves the values representing the phases were plotted on a large scale, and, taking the mean errors into account, a curve was drawn which seemed to represent, as accurately as possible, the change in phase common to both waves. This curve was slightly different from the curve of Fig. 5, in which both phases and amplitudes are represented. We preferred to adopt a curve *common* to both waves, because this makes the drawing of it less arbitrary. Its ordinates were read off for every 5 days, and were applied as corrections to the Julian dates.

The 1000 days' curve of the amplitudes, mentioned before, gave the correction to be applied to the sum of the amplitudes. The question arose as to which part of this sum had to be assigned to each of the waves. A glance at Fig. 4 will show that it was impossible to treat the changes of amplitude for the three waves separately; and the best thing to do seemed to be to divide each corrected sum, in the proportion of the mean values of the amplitudes. This proportion was as 3 : 1 : 1; and so, having obtained from the 1000 days' curve the total amount of amplitude, we assigned three fifths of it to the principal wave and one fifth to each of the additional waves.

Finally, to the ordinates of the combined curve the quantity x (see p. 111) has been applied, so as to make the comparison with the observed light-curve still more effective.

The results of this comparison are given in the following tabular form, which contains 20 points of comparison, most of which do not need explanation. Under the heading of "amplitude" we have, as before, taken the difference between the brightness of a maximum and that of the *preceding* minimum.

The numbers 10 and 11 contain the actually observed periods, without regard to whether they resulted from maxima or minima.

The numbers 19 and 20 have the following meaning. For both curves a mean period (no. 12) was adjusted to normal epochs of maximum and minimum brightness by the method of least squares, and the residuals in the dates of maximum and minimum brightness were recorded. For the observed curve this had already been done when treating the light-curve as a whole (see p. 93); and now it was repeated for that part of the curve, which was observed after the star's outburst (groups 3 to 12).

Element		O	C	Element		O	C
		m	m			d	d
Maximum	1. Highest	9.41	9.54	Period	10. Greatest	48.5	43.0
	2. Lowest	10.03	10.01		11. Smallest	33.0	33.0
	3. Mean	9.79	9.80		12. Mean	39.25	39.22
Minimum	4. Highest	10.09	10.21	Duration of Ascent	13. Longest	24.5	22.0
	5. Lowest	11.10	10.94		14. Shortest	11.0	16.0
	6. Mean	10.64	10.50		15. Mean	17.0	19.2
Amplitude	7. Greatest	1.52	1.40	Duration of Descent	16. Longest	30.0	22.0
	8. Smallest	0.25	0.24		17. Shortest	16.0	15.5
	9. Mean	0.83	0.72		18. Mean	22.3	19.3
				Residual	19. Greatest	7.0	5.7
					20. Mean	2.5	2.0

The comparison between the observed light-curve and a hypothetical one, based upon the results of our analysis and computations, proves, as might be expected, that both curves present the same characteristic features. There is but one exception; for the calculated curve the mean duration of the ascent (element no. 15) must have the same value as that of the descent (no. 18), since the constituent curves are sinusoids. The observed curve, however, shows for the ascent a mean duration of 5.3 days shorter than that of the descent. This would mean that, either the principal wave, or the secondary waves, or all three, are of the *Cepheid* type. In order to see how this compares with the results we have already obtained, let us return to the curves of the quantities M (Pl. II), which should be the images of the periodicities. They show us that, for the principal wave, the duration of the ascent (A) is a little less than that of the descent (D), viz. about 2 days. As to the additional waves, we get:

Trial period 44.0 days	A — D	= + 7.0 days
,, ,, 44.5 ,,	,,	= + 10.3 ,,
,, ,, 49.5 ,,	,,	= + 3.5 ,,
,, ,, 50.0 ,,	,,	= — 9.2 ,,

These numbers show that the *Cepheid* type is distinctly seen in the principal wave alone.

II. To show the influence of a change in the quantities by which the hypothetical curve has been calculated, we must have recourse to the mean errors. When we draw the curve of the amplitudes, so as to touch the mean error-circles on each side alternately, we obtain perfectly legitimate corrections, + Δ a and — Δ a, which we shall have to apply to the sum of the amplitudes. But it was less easy to obtain, in this way, the corrections which should be applied to the curve of the phases; since we have adopted a curve which is common to both periodicities, and its mean error is a function of the individual mean errors. We have therefore applied to the ordinates of the 1000 days' phase-curve a correction Δφ of 5 days; a value, which, since it is larger in many parts of the curve, will allow us to remain on the safe side.

Correction Δa	Correction Δφ	Maxim.	Br.	Maxim.	Br.	Maxim.	Br.
			m		m		m
+	+	9395.0	9.98	9433.5	9.65	9476.0	9.59
—	+	9396.5	10.03	9434.5	9.79	9476.5	9.73
+	—	9399.5	9.84	9435.5	9.99	9472.5	9.71
—	—	9399.5	9.93	9435.0	10.04	9472.0	9.84
Observ.		**9398.5**	**9.95**	**9432.5**	**9.79**	**9472.5**	**9.87**
Correction Δa	**Correction Δφ**	**Minim.**	**Br.**	**Minim.**	**Br.**	**Minim.**	**Br.**
			m		m		m
+	+	9378.0	10.37	9414.0	10.80	9455.5	11.50
—	+	9378.0	10.32	9413.5	10.58	9454.5	10.88
+	—	9379.0	10.92	9418.5	10.49	9453.0	10.60
—	—	9379.0	10.68	9418.0	10.39	9453.0	10.46
Observ.		**9379.0**	**10.56**	**9419.0**	**10.88**	**9454.5**	**10.67**

The corrections Δa and Δφ can be combined in four different ways according to their signs, and have been adjusted to an arbitrary part of the calculated curve, extending from J D 9370 to J D 9485. In this interval 3 consecutive maxima and minima occur, whose dates and magnitudes will be changed under the influence of Δa and $\Delta \varphi$. In the preceding table the results of an application of these corrections are given; the last row gives the values as they appear in the *observed* light-curve.

This table shows that, at least for this portion, the calculated curve is very unstable, and that the differences between observation and calculation may be due wholly to the fact that the constituent quantities of the latter are deficient in point of accuracy.

If, to this inaccuracy, we add the facts:

(α) that we have considered the 39.25 days' wave as perfectly stable in phase; whereas it is uncertain whether it is not to a small extent unstable;

(β) that we have considered the 1000 days' curve for the 44.25 and 49.85 days' periodicities as being regular and the same for both; two facts which are not beyond doubt;

(γ) that we have divided the total amount of amplitude in the proportion 3 : 1 : 1 throughout the whole interval considered; which however is only a working hypothesis;

(δ) that probably none of the waves are sinusoidal;

(ε) that, where such a marked outburst as that which occurred in group 2 has been noted, it is very probable that the more or less regular process by which the calculated curve has been constructed, is liable to frequent perturbations;

we need not be astonished that the calculated curve, *while keeping as a whole its essential features intact*, cannot be compared in any strict sense with the observed light-variation.

CHAPTER X.

On a possible interpretation of the results of the analysis.

Though the aim of this volume has been merely to consider the light-curve of *R V Tauri*, and not to attack the problem of its origin before the analysis of the light-curves of the two other stars (*R Sagittae* and *V Vulpeculae*) has been completed, we cannot resist the temptation to say a few words about a possible interpretation of our results at the close of this part of the work.

If the 44.25 and 49.85 days' periods had proved to be constant, a mechanical interpretation, e.g. a triplicity of the star, would naturally have presented itself. Since, however, we have found that these periods are constantly and systematically changing, so that there are actually two light-phenomena with periods from 40 to 48 and from 45 to 54 days, the idea of a triple star may frankly be abandoned.

If, then, we consider the star to be single, the results obtained for the "leveled light-curve" are not inconsistent with the following suggestions concerning its origin:

(1) The principal feature is a wave with a constant amplitude, and a constant period which represents the star's equatorial rotation. This feature is a light-phenomenon belonging to the star's photosphere.*)

*) A tentative explanation would be that the rotating star has the form, either of an *apioid*, or of a Jacobian ellipsoid. In the latter case the period of rotation must be considered as equal to twice the period of the light-variation.

(2) This photosphere, having exhibited immediately beforehand (group 1) very small values for its light-variation, was heated through some internal process, which caused the intensity to rise in an abrupt way to an exceptionally high value, such as was never attained again during the interval of 10 years in which the star has been under investigation.

(3) The combined effect of two other light-phenomena which belong to the star's atmosphere is superposed upon the regular wave (1). In this atmosphere luminous matter, bursting from certain "weak spots", subsequently travelled in different directions. These weak spots, i. e. the centres of activity of the ejected matter are located at latitudes where the periods of rotation equal 44.25 and 49.85 days respectively. If the equatorial rotation is 39.25 days, they may occur both in the same hemisphere, or each hemisphere may contain one of them; if the equatorial rotation is 78.5 days, they must be locat ed both in the two hemispheres. Let us consider, as the most probable case that in which each of the hemispheres contains one centre of activity; then we should have been able to fix the date of the star's outburst, on the supposition that at that starting-point, for reasons of symmetry, the phases of the two waves differed by 180°. But such a supposition is not consistent with our results. The outburst must have taken place between J D 7687 (see remark 4 p. 76) and J D 7785, and from the normal maxima given by the periodogram we deduce that in that interval the phase-difference increased from 18° to 107°. This eliminates the possibility of the outburst having occured at spots which are placed diametrically opposite each other; a position in favour of which one would be inclined to have a certain prejudice.

(4) The luminous matter, after having made its appearance at the centres of activity, travelled through the outer layers of the star's atmosphere, probably (in connection with the repeated recurrence of the initial period) in some cyclonic movement, and changed its brigthness in a fashion which suggests a correlation with the latitude reached. If this hypothesis is right, the starting-point of the 1000 days' phase-curve (Fig. 5) should be the moment of the outburst, i.e. the axis of this curve should coincide with the normal maximum given by the periodogram, and the curve itself, when traced back-wards, should meet the axis at a point, the abscissa of which is the date of the

outburst. As to the 44.25 days' periodicity, this suggestion is in perfect accordance with our results. The axis coincides with the normal maximum J D 7501.3 (see p. 120), while the periodogram yields the normal maximum J D 7501.8. And, when the curve is traced backwards it meets the axis at a point, the abscissa of which is J D 7740. Moreover, the normal maximum of group 2 (J D 7483; see the table on p. 111) is in accordance with the same hypothesis, since it lies very close to the curve. This means that in Fig 4 the points indicating the amplitudes of group 2 do not belong to the top of the outburst, but to its decline.

As to the 49.85 days' periodicity, the axis of the 1000 days' phase-curve does not coincide with the value given by the periodogram; and it would have been more correct, on the line of our present hypothesis, to reconstruct that curve so as to make the mean value of the normal maximum coincide with that which is given by the periodogram. We have, however, preferred to keep the previous arrangement intact; in this way the computations have been simpler, and the results have certainly not been in our favour.

(5) Apart from the phenomena described above, the star's light is subjected to a long periodical disturbance (period about 1250 days), which in all probability rose to a maximum shortly before the outburst of the photosphere.

Now, since we are acquainted with a "long periodicity" in the 11 years' sun-spot cycle, and since NIJLAND's frequent colour-estimates of *R V Tauri* (mean value = $3^c.6$) allow us to consider this star as being of the solar type, we are naturally led to draw a closer analogy between it and our sun.

According to ABBOT ("The Sun" p. 125), the general character of the solar rotation is expressed by the following data:

Latitude	0°	30°	60°	80°
Period of rotation	$24^d.6$	$26^d.3$	$31^d.2$	$35^d.3$ or, using proportion-
ality factors	1.00	1.07	1.27	1.44.

When we plot these values, and if we adopt the same curve to express the law which rules the rotation of *R V Tauri*, we learn that the period 44.25 days belongs to the latitude 41°, and the period 49.85 days to the latitude 60°.

Assuming the greatest deviation from the last-mentioned period to be 4.5 days, we derive 73° for the highest latitude which has been reached by the luminous matter. This result suggests the following interesting fact, with regard to the position of the star's axis of rotation. If we can observe the rotation of luminous spots at different latitudes, in both hemispheres, as periodical phenomena, it is obvious that the inclination of the star's axis to the line of sight must be greater than the highest latitude in which a spot can be seen. In our case this means an inclination of at least 73°. It is, however, probable that it is nearer to 90°, since the image of the 50 days' periodicity (Pl. II) is but very little sharper than that of the 44. But, if, as a working hypothesis, we assume the axis to lie in a plane which is exactly perpendicular to the line of sight, it is interesting to note that the position of *the axis of our sun is parallel to this plane.*

For an answer to the question, whether there occur in the sun's atmosphere centres of activity and currents of luminous matter such as we have found (on a much larger scale) in *R V Tauri*, we may refer to an interesting paper by F. HENROTEAU "On convection currents in high regions of the solar atmosphere" (Monthly Notices of the R. A. S. LXXVI p. 18). In this paper the writer calls our attention to the fact, 1. that the spectroheliographic studies of the upper layers of the sun made by DESLANDRES, 2. that MASCARI's results concerning the distribution of the faculae, and 3. that SLOCUM's researches on solar prominences, all clearly point to the existence of systematic movements in the high regions of the sun's atmosphere. A detailed examination of a number of sun-spots, associated with large regions of faculae, led HENROTEAU to deduce the course of these movements with still more certainty, and to show that the area of the luminous matter underwent changes during the progress. The movements proved to follow a meridian; but the number of groups examined seems too small as a basis for generalisation.

SLOCUM's results,*) based upon the examination of 1094 prominences, are of special interest to our present problem, inasmuch as they show that the

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*) F. SLOCUM. "Circulation in the solar atmosphere as indicated by prominences." The Astrophysical Journal XXXIII p. 108.

conditions are not the same in the two hemispheres. In the northern hemisphere for instance, the tendency of movement towards the pole has a maximum value at the latitude 33°; in the southern hemisphere such a maximum occurs at the latitude 52°.

If now, with HENROTEAU, we admit the existence, in the outer layers of the solar atmosphere, of convection currents, which carry luminous matter from one latitude to another; and if the brightness of this matter differs from that of the general mean, and its extension changes in its progress; then we have in a qualitative sense the same phenomenon as that which a disclosure of the complex light-curve of *R V Tauri* has brought to light. In the star the process is even more regular, since we have found the brightness (which, as a working hypothesis, we may regard as proportionate to the extension *) distinctly correlated with the latitude. Thus the difference between the sun and the star is only a *quantitative* one, i.e. the difference between the brilliancy of the travelling matter and that of its surroundings must be much greater in the star than on the sun. There can be no *a priori* objection to this assumption.

Conversely, if *R V Tauri* only presents an extreme case of solar variation, the disclosure of its light-curve may perhaps encourage the detailed study of those two phenomena, to which the attention of astrophysicists has been strongly drawn during the last years, viz. the movements of the sun's outer gases and the variability of its radiation.

*) Smaller brightness may just as well be due to greater depth.

APPENDIX.

The technical side of the problem which has been considered in this volume, gives rise to the following observation, which is worth noticing.

When, for the purpose of analysing a compound light-curve into its single curves, the combined brightness has been expressed in intensities, and the amplitudes of the single curves have been obtained in the same scale, it is natural that we should wish to translate these results back again into terms of stellar magnitude. *This, however, is impossible,* since only the sum of the axes of the single waves is known; their individual values cannot be given. Thus, in the case of *R V Tauri*, we have, in general, found the following mean results, expressed in intensities:

Combined axis			$= 485$	
Wave I	Amplitude	(a_1)	$= 159$	(Axis $= x_1$)
,, II	,,	(a_2)	$= 55$	(,, $= x_2$)
,, III	,,	(a_3)	$= 44$	(,, $= x_3$)

If, now, we should wish to know the values $M - m$, which express the difference between the maximum and minimum brightness in the magnitude-scale, we discover that the problem is an indefinite one. A few suppositions as to the values of the three axes (which measure together 485 units) will not only yield us totally different results, but they will also teach us that, though a_1 much exceeds a_2 and a_3, the corresponding values of $M - m$ may very well be of the same order.

1st case. The axes have the same values in the intensity scale

$$x_1 = x_2 = x_3 = 162$$

Then we have:

$x_1 + a_1 = 321$	$M_1 = 10^m53$	$M_1 - m_1 = 5^m10$	Axis $X_1 = 13^m08$
$x_1 - a_1 = 3$	$m_1 = 15.63$		
$x_2 + a_2 = 217$	$M_2 = 10^m96$	$M_2 - m_2 = 0^m77$	,, $X_2 = 11^m35$
$x_2 - a_2 = 107$	$m_2 = 11.73$		
$x_3 + a_3 = 206$	$M_3 = 11^m01$	$M_3 - m_3 = 0^m61$	,, $X_3 = 11^m32$
$x_3 - a_3 = 118$	$m_3 = 11.62$		

2nd case. x_1 has $^2/_3$, x_2 and x_3 have $^1/_6$ of the total intensity.

Then:

$x_1 + a_1 = 482$	$M_1 = 10^m09$	$M_1 - m_1 = 1^m17$	Axis $X_1 = 10^m68$
$x_1 - a_1 = 164$	$m_1 = 11.26$		
$x_2 + a_2 = 136$	$M_2 = 11^m47$	$M_2 - m_2 = 1^m83$	,, $X_2 = 12^m38$
$x_2 - a_2 = 26$	$m_2 = 13.30$		
$x_3 + a_3 = 125$	$M_3 = 11^m56$	$M_3 - m_3 = 1^m32$	,, $X_3 = 12^m22$
$x_3 - a_3 = 37$	$m_3 = 12.88$		

3rd case. The three axes have the same value in the magnitude-scale.

Then:

$x_1 + a_1 = 364$	$M_1 = 10^m40$	$M_2 - m_1 = 2^m25$	Axis $X_1 = 11^m52$
$x_1 - a_1 = 46$	$m_1 = 12.65$		
$x_2 + a_2 = 197$	$M_2 = 11^m06$	$M_2 - m_2 = 0^m90$	,, $X_2 = 11^m51$
$x_2 - a_2 = 87$	$m_2 = 11.96$		
$x_3 + a_3 = 182$	$M_3 = 11^m15$	$M_3 - m_3 = 0^m72$	,, $X_3 = 11^m51$
$x_3 - a_3 = 94$	$m_3 = 11.87$		

The results of this case have been derived in the following way:

The well-known relation between intensities and magnitudes gives rise in our case, where $9^m.30$ has the intensity 1000, to the following equalities:

$$1000 = (x + a)\, p^c - \Delta m = (x - a)\, p^c + \Delta m = I p^c$$

in which $p = 2.512$

$c = x - 9^m.30$ and

$I =$ the equivalent of X in intensities.

Hence:

$$(x + a)\,(x - a) = I^2.$$

If $X_1 = X_2 = X_3$, we thus get, besides the relation $x_1 + x_2 + x_3 = 485$ the two relations

$$x^2_1 - a^2_1 = x^2_2 - a^2_2 = x^2_3 - a^2_3.$$

A short way to solve these equations, is to start from the supposition $x_2 = x_3$.

We then get

$$x_1 = 205 \qquad x_2 = x_3 = 140.$$

By trial and error the values of x_2 and x_3 which render the quantities X exactly equal to each other, proved to be $x_2 = 142 \qquad x_3 = 138$.

We gather from a consideration of these 3 cases (which all lead to the same combined effect) that, in the language of stellar magnitude, it is not certain (though of course highly probable) that wave I is the principal one; and that, in each case, waves II and III have values $M - m$, which are greatly in excess of what a study in intensities might have anticipated. The fact that the relation between the intensity-and magnitude-scales is a logarithmic one, necessarily leads to an under-estimate of the importance of the lower-leveled waves.

SUMMARY.

The variable stars *R Sagittae, V Vulpeculae* and *R V Tauri* exhibit irregular light-curves, with mean periods of about 35, 37 and 39 days respectively. The variation is of an unusual character, but seems to be ruled by some complicated law, which may be the same for each of the three stars. A thorough investigation of the observed light-variation is therefore justified, and it has been preferred for various reasons to devote attention first to *R V Tauri*.

In chapter I the observations of 8 observers have been reduced to a photometric scale of comparison stars, whose brightness has been determined by the writer with the polarizing photometer of the Utrecht Observatory. Nearly all the observations could be reduced to one observer (chapter II); and, as a result of this, a strictly homogeneous light-curve was drawn, based upon 1222 estimates of magnitude. These estimates are given in chapter III (pp. 44—75).

The light-curve is described in chapter IV, and its ordinates are given in tabular form on pp. 79—86. It exhibits, when plotted, a more or less regular "principal variation" winding itself round a "curved central line", which indicates a long periodical secondary variation. This "long periodicity" (Pl. II a) has been treated as an isolated feature, and its ordinates were used to reduce the observed light-curve to a horizontal central line. In this way the principal variation was obtained in the form of a "leveled" light-curve. Since the characteristics of this curve suggest the existence of some compound variation, the magnitudes were changed into intensities, and the new curve (Pl. I) was submitted to periodogram-analysis.

The resulting periodogram is given in chapter VI (p. 98); it shows three peaks, which occur at 39, 44 and 50 days. This chapter contains some remarks and criticisms on the method of periodogram-analysis.

In chapter VII the same analysis is repeated for a few trial periods in the immediate neighbourhood of those mentioned above; the time-interval, which had been 1 day in the first investigation, being now taken as 0.5 day. This resulted in fixing the definitive periods at 39.25, 44.25 and 49.85 days respectively. For each of these waves a date of normal maximum could be derived by a graphical process (Pl. II b, c, d).

The periods now being known with sufficient accuracy, they could be used, in chapter VIII, to give the progress of the three waves per five days in 449 equations, in which the amplitudes and the initial phases constituted 6 unknown quantities. A seventh unknown quantity was added, by assuming a correction which must be applied to the "leveling" process. In the solution of these equations, the material, which covered an interval of 3100 days, was divided into 12 groups; and the scale of intensities was enlarged 10-fold.

The results of this computation are given in a table on p. 111. It shows that the 39.25 days' wave is relatively stable, whereas the two other waves are unstable. It seemed advisable, before entering into the details of these unstable waves, to investigate the possibility of a solution with a single additional periodicity. This has been done both graphically and analytically (p. 113), but the result was negative.

Chapter IX treats of a more detailed analysis of the three periodicities given by the periodogram. The general results of this can be summed up as follows:

I. The amplitudes are small in group 1 and very large in group 2, suggesting some "outburst". They are again smaller in group 3—12, in which groups they pass through periodical changes; the period being roughly 1000 days.

II. The phases are fluctuating, but to an extent which, in the case of the 44.25 and 49.85 days' periodicities only, exceeds the mean errors. For these waves the fluctuations followed the 1000 days' curve of the amplitudes.

III. When the results found under I and II were used to derive a hypothetical combined light-curve (C), this could not be made to represent the observed light-variation (O) satisfactorily. It could, however, be shown that in respect of 20 essential features, the curves C and O did not appreciably differ (p.125), and that the differences O—C may be smaller than the uncertainty in C (p. 126).

In chapter X a tentative explanation is given of the results of the analysis. The colour-estimates of the star and the long periodicity suggest some analogy with our sun. This analogy is extended by the fact that the adoption of a law of rotation, common to both objects, leads to reasonable latitudes for the periods 44.25 and 49.85 days, if the period 39.25 days is supposed to represent the star's equatorial rotation. The results of the analysis are, therefore, not inconsistent with the suggestion that spots of luminous matter should suddenly have appeared, as the consequence of an outburst in the star's photosphere, in the outer layers of the atmosphere at latitudes 41° and 60° respectively, and should have been subjected to changes in position and brightness, which were both systematic in character (1000 days'curve) and correlated with each other.

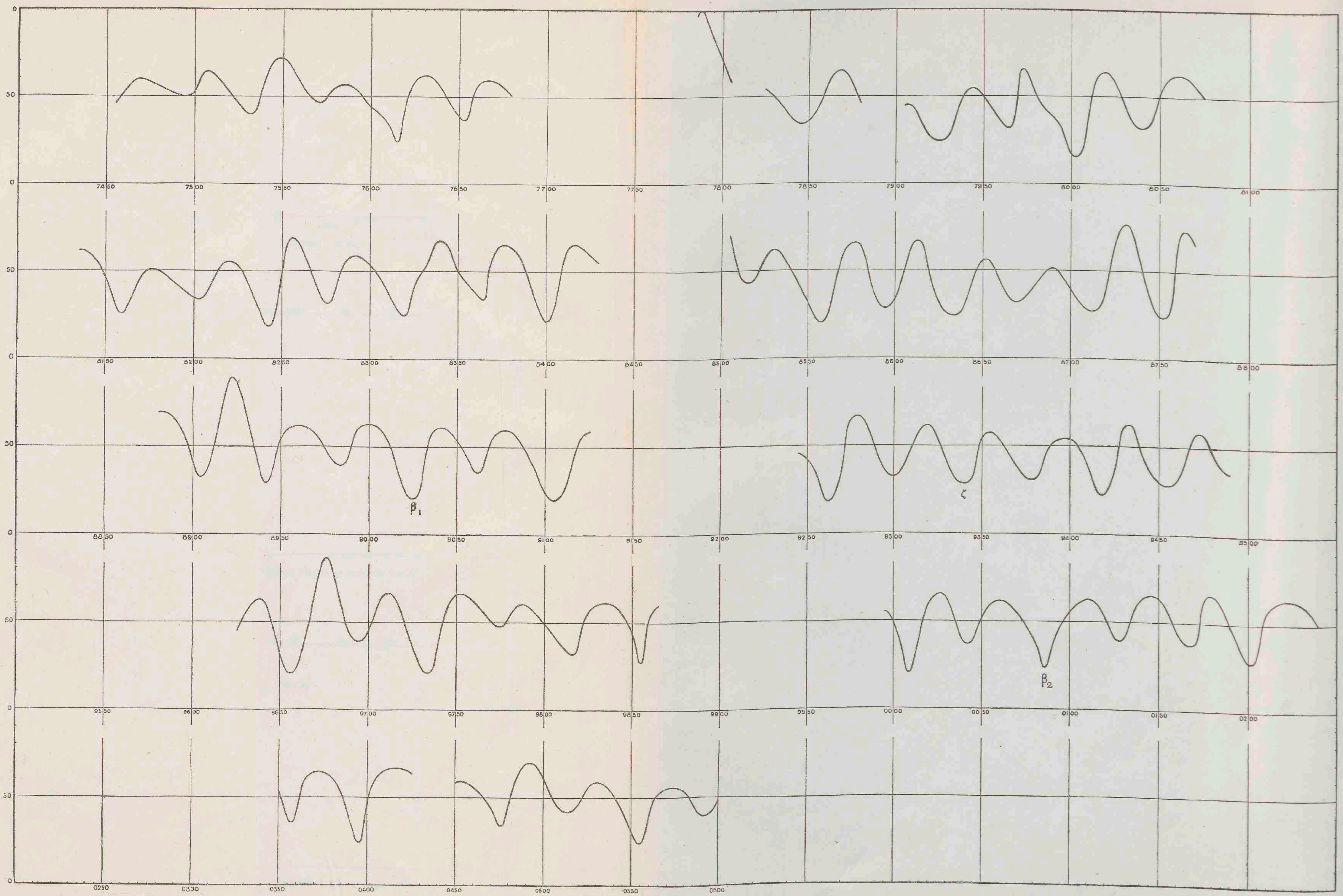
If this explanation holds good, it can easily be shown that the axis of rotation of the star lies in a plane, which is perpendicular to the line of sight. It is interesting to notice that the axis of our sun happens to be parallel to this plane.

Finally the attention of the reader is drawn to a paper by HENROTEAU (p. 131), the tendency of which lends an emphasis to our suggestion of a qualitative analogy between *R V Tauri* and the sun. The conditions, of course, are not comparable in a quantitative sense.

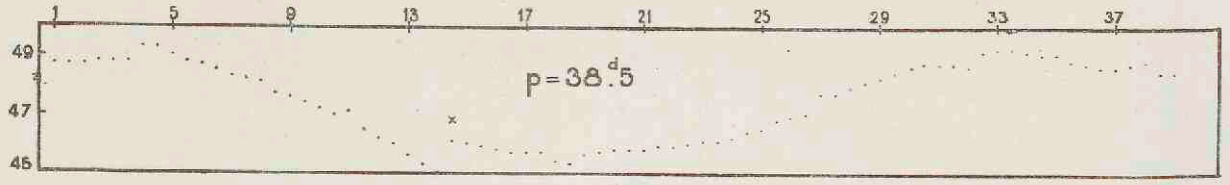
The conditions of the problem before us, as the analysis will have sufficed to show, are of so complicated a character that no apology will be necessary for an explanation which is obviously exceedingly tentative.

The present research has led to our classing *R V Tauri* amongst the semi-regular variable stars, of which *Mira* is the proto-type. While most of these are more regular, some of them (e. g. *W Cygni*) are decidedly less regular in aspect than *R V Tauri*. It is very probable that an application of the method we have used would yield some important results in the case of all the *Mira* variables. The few results already obtained along different lines by A. THOM, (The Journal of the British Astronomical Association XXVI p. 162) seem to confirm this suggestion.

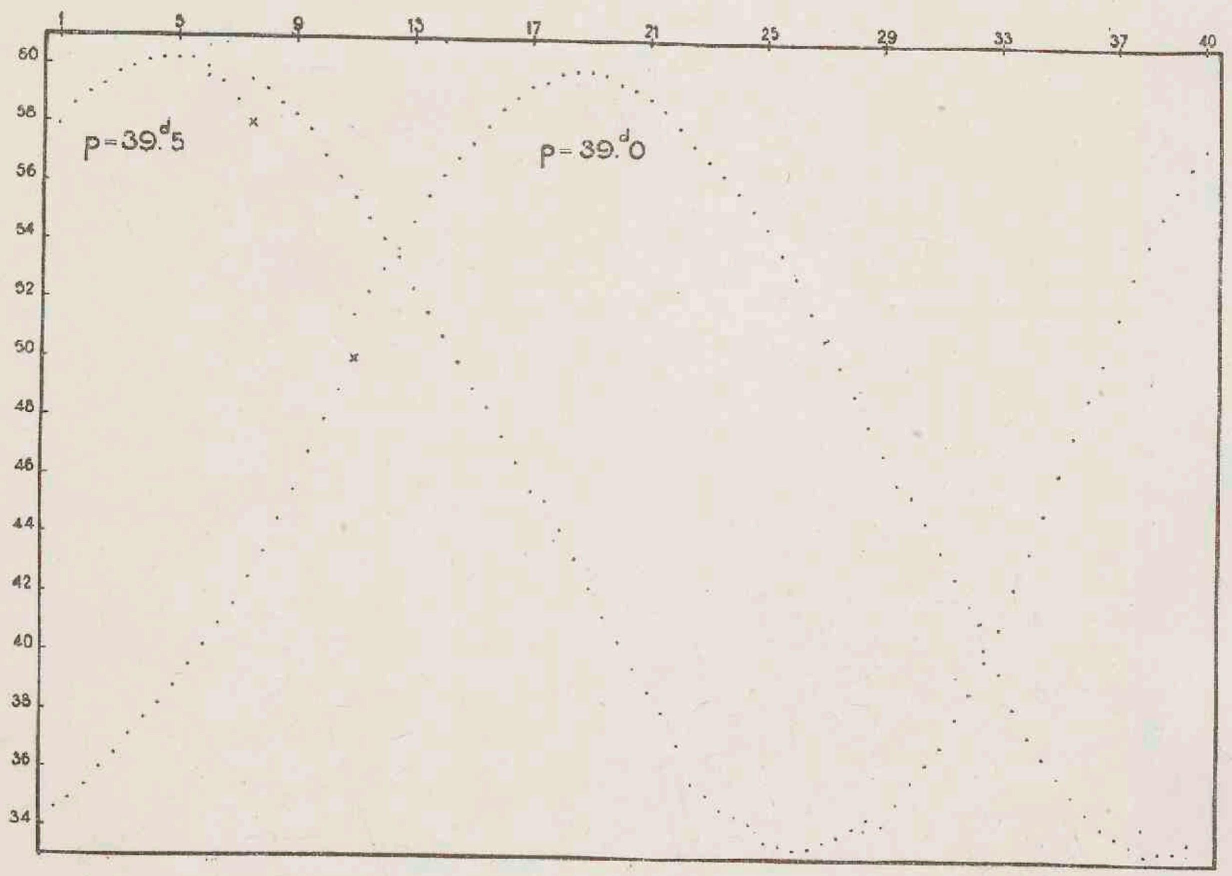
Grateful acknowledgement is due to Professor A. A. NIJLAND for his valuable criticisms and advice, so freely given during the preparation of this work; and to the Reverend A. BLAKISTON for the labour and time he has devoted to the revision and correction of the manuscript and proof-sheets.



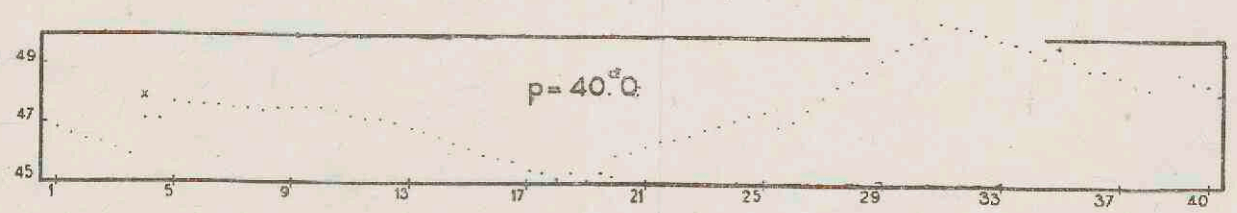
The leveled light-curve of *R V Tauri.*



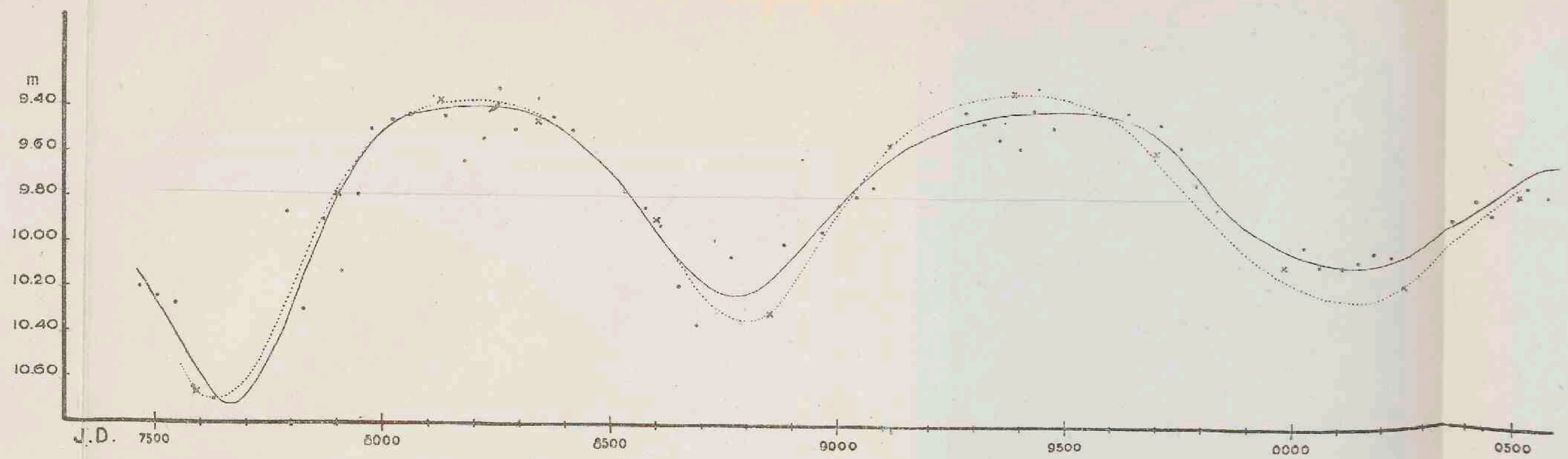
e. Trial period = 38^{d}.5.



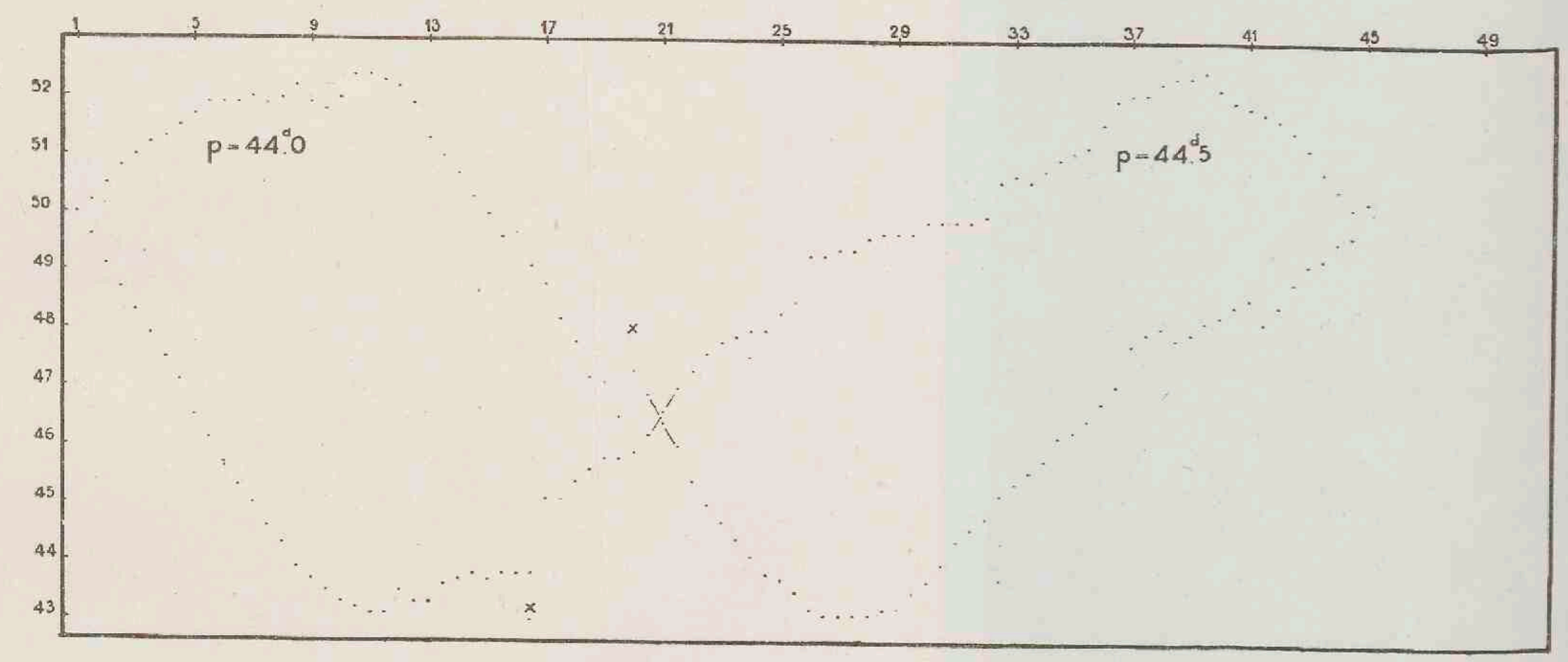
b. Curves of the quantities M for the trial periods 39^{d}.0 and 39^{d}.5.



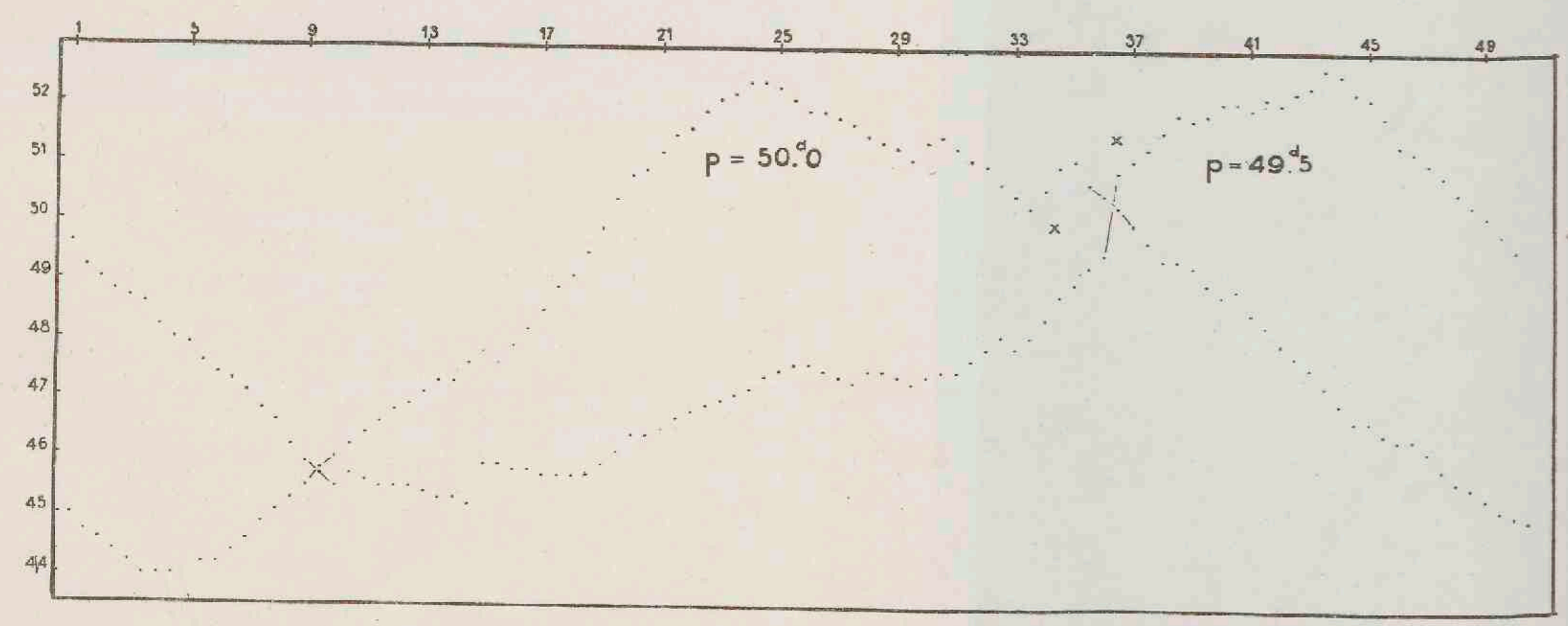
f. Trial period = 40^{d}.0.



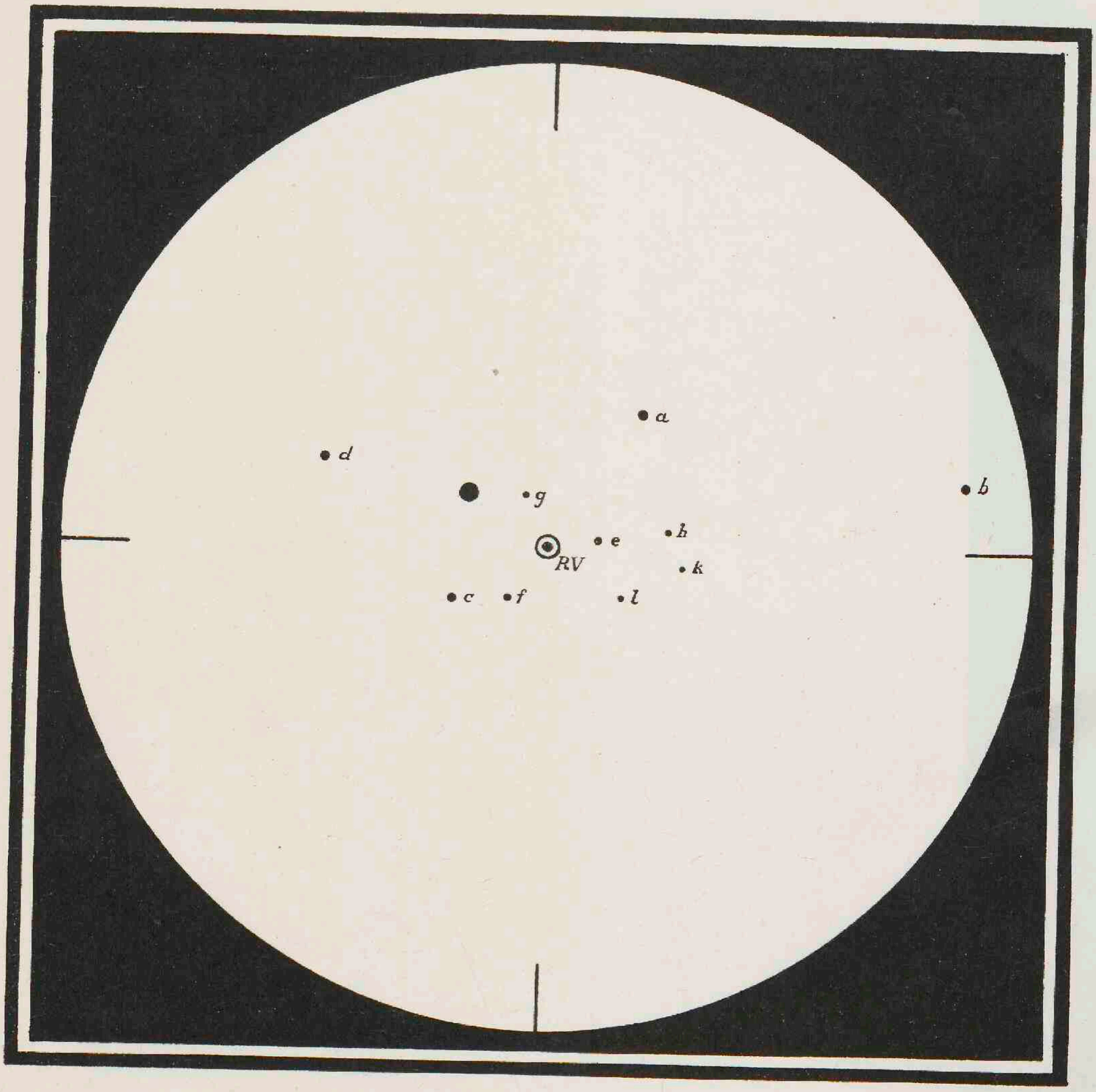
a. The long periodicity. ———— the original curve. .... the corrected curve.



c. Curves of the quantities M for the trial periods 44^{d}.0 and 44^{d}.5.



d. Curves of the quantities M for the trial periods 49^{d}.5 and 50^{d}.0.



NORTH.

Stars surrounding *R V Tauri*. Scale 1 c.M. = 10′.

The principal star is BD + 25° 731.

A photographic chart of the same field has been published by W. Ceraski in: „Cartes photographiques d'étoiles variables découvertes à l'observatoire de Moscou" 2me Serie. Pl. III.