A NEW VARIABLE STAR OF UNUSUALLY SHORT PERIOD.[1]

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IN the course of the zone observations for Part III of the Potsdam *Photometric Durchmusterung* it appeared that the two regular measures of the brightness of the star of the seventh magnitude *B.D.* $+56°.1400$ ($\alpha=9^h\ 36^m\ 44^s$; $\delta=56°\ 24'.6$ [1900]) in 1899 and 1901 differed from each other by an amount greater than that considered permissible for this *Durchmusterung*. Although the revision observations in the period from April 19 to June 4, 1902, left no doubt as to the variability of the star, they nevertheless gave no indication as to the character of the variation. The measures were continued until the end of July, 1902, and later resumed after the appearance of the star in the eastern heaven, without our succeeding in detecting the character of the variation. It was not until the 13th of January of this year, when the star was several times observed during a period of three hours in the course of the evening, that a decline and rise of the light could be established and the time of minimum approximately derived as about $9^h\ 20^m$ Potsdam M. T. This showed that the light changes occurred in a comparatively short time, and the star was therefore observed on the same night at intervals of ten minutes until shortly before sunrise. A definitive conclusion as to the still somewhat doubtful character of the light-variation was reached through the observations of January 14, which were carried on without interruption from $4^h\ 48^m$ until $9^h\ 19^m$ Potsdam M. T. They furnished a complete view of the whole light-curve, and thus led to the discovery of a variable star with the extraordinarily short period of only four hours, the shortest so far known.

All of our measures of the new variable are summarized in tabular form below. The first six values are taken from the zone

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observations for Part III of the *Potsdam Durchmusterung* in which the variable is compared with fundamental stars. Fundamental stars were also used for comparison at the next three observations on June 10 and 25, 1902. But from June 28, 1902, the near-by star *B. D.* $+54^\circ 1329$ ($\alpha = 9^h\, 41^m\, 44^s$; $\delta = 54^\circ\, 43'.7$ [1900]) served exclusively as the comparison star. For its magnitude we obtain from comparisons with fundamental stars the following ten values: 7.65, 7.73, 7.81, 7.77, 7.68, 7.82, 7.64, 7.63, 7.75, and 7.85, the mean of which is 7.73.

The first five columns of the following table contain successively the date of observation, the local sidereal time, the Greenwich Mean Time, the designation of the observer, and the magnitude of the variable as derived from the measures. The last three columns of the table will be explained later.

Date	Sid. Time	G.M.T.	Obs.	Mag.	C.	O.-C.	Epoch
1899, May 29	$15^h 16^m$	$9^h 55^m$	K	7.76	7.94	−18	−7942
1901, January 17	4 50	8 12	M	8.33	8.04	+29	−4358
1902, April 19	14 13	11 32	M	8.12	8.18	− 6	−1617
April 22	14 2	11 9	K	8.58	8.40	+18	−1599
June 2	15 29	9 55	M	7.89	7.90	− 1	−1354
June 4	15 22	9 40	K	7.97	7.90	+ 7	−1342
June 10	15 15	9 10	M	7.84	8.01	−17	−1306
June 25	15 47	8 43	M	8.18	8.29	−11	−1216
	16 3	8 59	K	8.19	8.17	+ 2	
June 28	16 39	9 23	M	7.87	8.05	−18	−1198
June 29	16 42	9 22	K	8.06	8.07	− 1	−1192
July 5	17 17	9 33	M	8.13	8.05	+ 8	−1156
	17 21	9 37	K	8.11	8.03	+ 8	
July 6	16 53	9 5	M	8.28	8.23	+ 5	−1150
	16 58	9 10	M	8.18	8.20	− 2	
July 12	16 38	8 27	K	8.36	8.55	−19	−1115
	16 46	8 35	M	8.29	8.57	−28	−1114
July 15	17 19	8 56	M	8.43	8.40	+ 3	−1096
	17 24	9 1	M	8.27	8.35	− 8	
July 16	17 7	8 40	M	8.44	8.57	−13	−1090
	17 17	8 50	M	8.51	8.48	+ 3	
	17 23	8 56	M	8.60	8.41	+19	
July 19	18 6	9 27	M	8.30	8.19	+11	−1072
	18 11	9 32	M	8.29	8.16	+13	
July 21	16 57	8 10	M	8.14	8.12	+ 2	−1061
	17 2	8 15	M	8.04	8.16	−12	
	17 7	8 20	M	8.21	8.22	− 1	
July 28	17 10	7 56	M	8.07	8.00	+ 7	−1019
	17 15	8 1	M	7.91	8.02	−11	
	17 30	8 16	M	8.09	8.11	− 2	
November 27	3 3	9 47	M	8.11	7.90	+21	− 287

Date	Sid. Time	G.M.T.	Obs.	Mag.	C.	O.-C.	Epoch
1902, December 11	$3^h 11^m$	9^h 0	K	8.18	8.04	+14	− 203
December 12	3 7	8 52	M	8.17	8.08	+ 9	− 197
	3 13	8 58	K	8.09	8.05	+ 4	
December 13	3 36	9 17	M	8.02	7.98	+ 4	− 191
	3 43	9 24	K	8.03	7.95	+ 8	
December 14	3 53	9 30	M	7.81	7.94	−13	− 185
	3 59	9 36	K	7.91	7.92	− 1	
1903, January 12	4 23	8 6	M	8.16	8.26	−10	− 12
	4 31	8 14	K	8.34	8.41	− 7	
January 13	3 26	7 5	M	7.90	7.93	− 3	− 6
	3 29	7 8	K	7.90	7.93	− 3	
	4 20	7 59	K	8.06	8.15	− 9	
	4 25	8 4	M	8.15	8.21	− 6	
	5 18	8 57	K	8.35	8.32	+ 3	− 5
	5 24	9 3	M	8.19	8.27	− 8	
	6 21	10 0	M	8.00	7.96	+ 4	
	6 28	10 7	K	7.99	7.94	+ 5	
	13 0	16 38	M	8.53	8.52	+ 1	− 3
	13 3	16 41	M	8.46	8.49	− 3	
	13 17	16 55	M	(8.63)	8.34	+29	
	13 28	17 6	M	8.34	8.25	+ 9	
	13 35	17 13	M	8.28	8.20	+ 8	
	13 47	17 25	M	8.04	8.13	− 9	
	13 59	17 37	M	8.05	8.06	− 1	
	14 12	17 50	M	8.03	8.00	+ 3	
	14 21	17 59	M	7.99	7.97	+ 2	
	14 33	18 11	M	7.86	7.93	− 7	
	14 44	18 22	M	7.93	7.91	+ 2	
January 14	0 20	3 56	M	8.27	8.12	+15	− 1
	0 30	4 6	K	8.20	8.22	− 2	
	0 35	4 11	K	8.35	8.29	+ 6	
	0 43	4 19	M	8.38	8.45	− 7	
	0 49	4 25	M	8.64	8.55	+ 9	
	0 55	4 31	K	8.57	8.58	− 1	
	1 4	4 40	K	8.55	8.51	+ 4	0
	1 8	4 44	M	8.55	8.47	+ 8	
	1 15	4 51	M	8.38	8.39	− 1	
	1 22	4 58	K	8.30	8.32	− 2	
	1 26	5 2	K	8.33	8.29	+ 4	
	1 35	5 11	M	8.16	8.23	− 7	
	1 40	5 16	M	8.31	8.19	+12	
	1 45	5 21	K	8.22	8.16	+ 6	
	1 51	5 27	K	8.09	8.12	− 3	
	1 57	5 33	M	8.00	8.08	− 8	
	2 3	5 39	M	8.09	8.05	+ 4	
	2 10	5 46	K	8.02	8.02	0	
	2 15	5 51	K	8.15	8.00	+15	
	2 22	5 58	M	7.99	7.98	+ 1	
	2 29	6 5	M	7.98	7.95	+ 3	
	2 36	6 12	K	7.90	7.93	− 3	
	2 44	6 20	K	7.89	7.91	− 2	
	2 51	6 27	M	7.83	7.90	− 7	
	2 59	6 35	M	7.82	7.90	− 8	
	3 6	6 42	K	7.91	7.90	+ 1	
	3 12	6 48	K	7.88	7.90	− 2	

Date		Sid. Time	G.M.T.	Obs.	Mag.	C.	O.-C.	Epoch
1903, January	14	3h 22m	6h 57m	M	7.95	7.91	+ 4	
		3 28	7 3	M	8.00	7.92	+ 8	
		3 34	7 9	K	7.94	7.93	+ 1	
		3 43	7 18	K	8.06	7.95	+11	
		3 49	7 24	M	8.04	7.97	+ 7	
		3 55	7 30	M	8.03	7.99	+ 4	
		4 1	7 36	K	8.05	8.02	+ 3	0
		4 7	7 42	K	7.96	8.04	− 8	
		4 14	7 49	M	8.10	8.08	+ 2	
		4 19	7 54	M	8.21	8.11	+10	
		4 23	7 58	K	8.10	8.14	− 4	
		4 38	8 13	M	8.42	8.33	+ 9	
		4 42	8 17	M	8.43	8.41	+ 2	
		4 44	8 19	K	8.45	8.45	0	
		4 52	8 27	K	8.59	8.56	+ 3	
January	17	0 31	3 55	K	8.02	8.09	− 7	17
		0 38	4 2	K	8.16	8.14	+ 2	
		0 44	4 8	M	8.19	8.19	0	
		0 50	4 14	M	8.40	8.28	+12	
		0 54	4 18	K	8.35	8.35	0	
		1 0	4 24	K	8.41	8.48	− 7	
		1 5	4 29	M	8.50	8.55	− 5	
		1 12	4 36	M	8.56	8.58	− 2	18
		1 15	4 39	K	8.66	8.56	+10	
		1 22	4 46	K	(8.74)	8.49	+25	
		1 25	4 49	M	8.37	8.45	− 8	
		1 31	4 55	M	8.37	8.39	− 2	
		1 35	4 59	K	8.36	8.35	+ 1	
		1 41	5 5	K	8.35	8.30	+ 5	
		1 46	5 10	M	8.24	8.26	− 2	
		1 52	5 16	M	8.24	8.22	+ 2	
		1 55	5 19	K	8.05	8.20	−15	
		2 2	5 26	K	8.12	8.15	− 3	
		2 5	5 29	M	8.10	8.13	− 3	
		2 11	5 35	M	7.90	8.10	−20	
		2 15	5 39	K	7.99	8.07	− 8	
		2 20	5 44	K	8.09	8.05	+ 4	
		2 25	5 49	M	8.00	8.03	− 3	
		2 31	5 55	M	8.09	8.00	+ 9	
		2 36	6 0	K	7.97	7.98	− 1	
		2 42	6 6	K	7.94	7.96	− 2	
		2 48	6 12	M	7.91	7.94	− 3	
		2 55	6 19	M	7.88	7.92	− 4	
		3 3	6 27	K	7.89	7.91	− 2	
		3 10	6 34	K	7.90	7.90	0	
		3 17	6 41	M	7.83	7.90	− 7	
		3 23	6 47	M	8.00	7.90	+10	
		3 31	6 55	K	7.87	7.90	− 3	
		3 39	7 3	K	7.96	7.91	+ 5	
		3 45	7 9	M	8.07	7.93	+14	
		3 50	7 14	M	7.95	7.94	+ 1	
		3 56	7 20	K	8.01	7.95	+ 6	
		4 2	7 26	K	7.93	7.96	− 3	
		4 14	7 38	M	8.15	8.01	+14	
		4 19	7 43	M	8.11	8.03	+ 8	

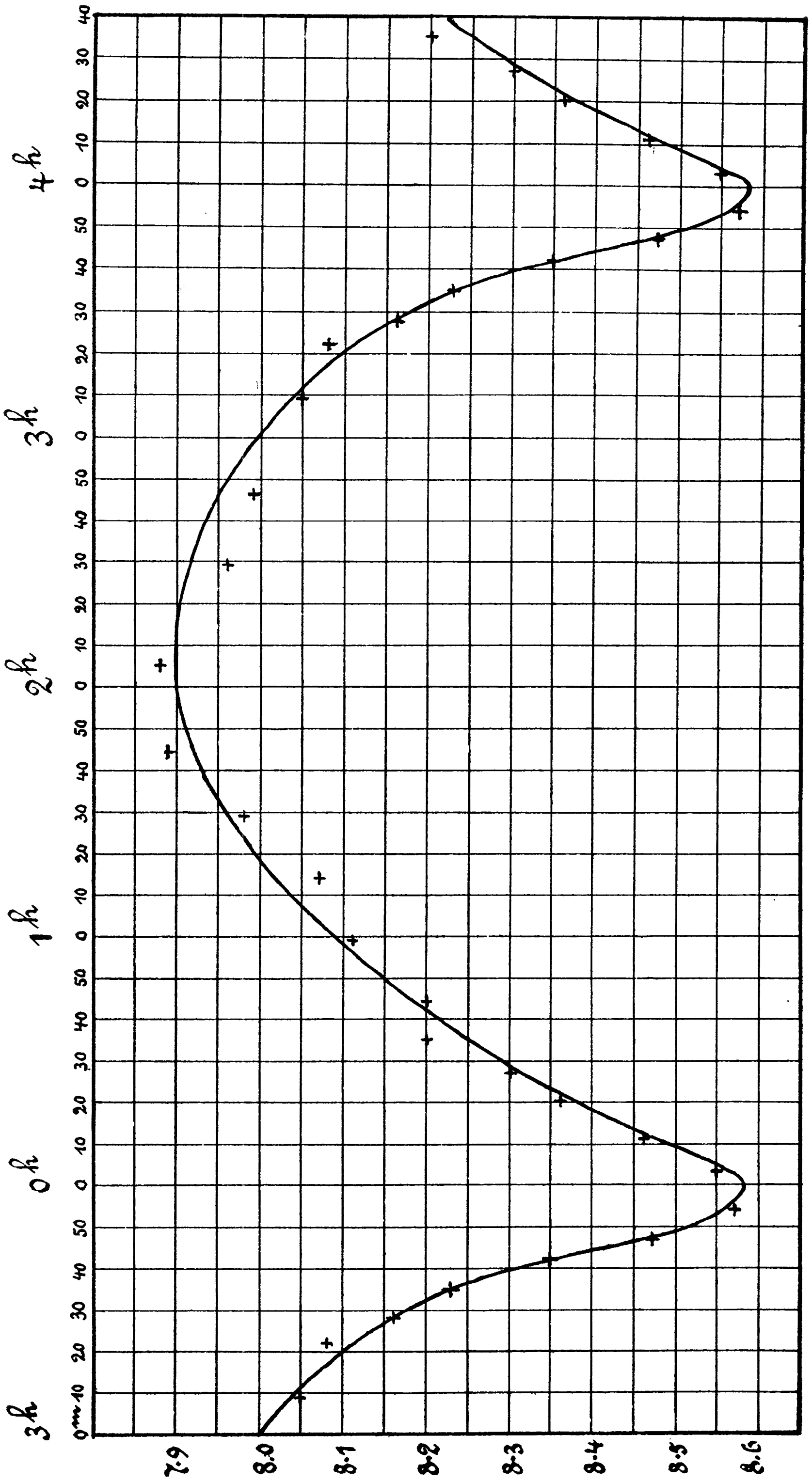
Date		Sid. Time	G.M.T.	Obs.	Mag.	C.	O.-C.	Epoch
1903, January	17	$4^h\ 26^m$	$7^h\ 50^m$	K	7.99	8.06	− 7	
		4 32	7 56	K	8.14	8.10	+ 4	
		4 37	8 1	M	8.08	8.13	− 5	
		4 43	8 7	M	8.28	8.18	+10	
		4 46	8 10	K	8.17	8.22	− 5	
		4 52	8 15	K	8.27	8.29	− 2	
		4 55	8 18	M	8.34	8.35	− 1	
		5 0	8 23	M	8.60	8.45	+15	
		5 3	8 26	K	8.58	8.52	+ 6	
		5 9	8 32	K	8.64	8.56	+ 8	
		5 13	8 36	M	8.61	8.58	+ 3	19
		5 18	8 41	M	8.37	8.54	−17	
		5 20	8 43	K	8.54	8.52	+ 2	
		5 26	8 49	K	8.34	8.45	−11	
		5 30	8 53	M	8.33	8.41	− 8	
		5 36	8 59	M	8.28	8.35	− 7	
		5 38	9 1	K	8.24	8.33	− 9	
		5 44	9 7	K	8.19	8.28	− 9	
		5 51	9 14	M	8.15	8.23	− 8	
		5 56	9 19	M	8.17	8.20	− 3	
January	18	4 30	7 50	M	8.01	8.06	− 5	24
		4 36	7 56	M	7.87	8.09	−22	
		4 39	7 59	K	7.99	8.11	−12	
		4 44	8 4	K	8.27	8.15	+12	
		4 48	8 8	M	8.07	8.18	−11	
		4 52	8 12	M	8.31	8.23	+ 8	
		4 55	8 15	K	8.24	8.28	− 4	
		5 1	8 20	K	8.36	8.37	− 1	
		5 4	8 23	M	8.45	8.43	+ 2	
		5 9	8 28	M	8.57	8.53	+ 4	
		5 12	8 31	K	8.45	8.56	−11	
		5 18	8 37	K	8.57	8.58	− 1	25
		5 21	8 40	M	(8.28)	8.56	−28	
		5 26	8 45	M	8.51	8.51	0	
		5 29	8 48	K	8.42	8.48	− 6	
		5 34	8 53	K	8.41	8.42	− 1	
		5 38	8 57	M	8.37	8.38	− 1	
		5 43	9 2	M	8.25	8.33	− 8	
		5 45	9 4	K	8.26	8.31	− 5	
		5 51	9 10	K	8.14	8.27	−13	

The graphical representation of the observations of January 14, 17, and 18 gave the following four minima, the uncertainty of which can be estimated at 10 minutes at most:

Jan. 14 - - - -	$4^h\ 34^m$ G.M.T.
17 - - - -	4 40
17 - - - -	8 31
18 - - - -	8 34

The combination of these data yielded the first provisional elements of the variable:

$$\text{Min.} = 1903 \text{ Jan. } 14^d\ 4^h\ 34^m \text{ G.M.T.} + 4^h\ 0^m.0\ E.$$



LIGHT-CURVE OF *B. D.* + 56°.1400.

The uncertainty of the period cannot in any case be assumed to be greater than 1 minute, whence the true value must lie between $3^h\ 59^m$ and $4^h\ 1^m$.

The observations of the year 1902 can be utilized for correcting the first approximation of the period. Since the brightness of the star at minimum is approximately 8.6, it is at once evident that the observations of April 22 and July 16 were made very nearly at the time of a minimum; the uncertainty could hardly amount to more than from 20 to 25 minutes. Combining these two dates together and with the minimum of January 14, it can easily be proved that only the four following periods can come into consideration, each of which can have a play of not more than ± 0.03 minutes:

$$4^h\ 0^m.65\ ;\ 4^h\ 0^m.21\ ;\ 3^h\ 59^m.77\ ;\ 3^h\ 59^m.33.$$

It may be further shown, with the employment of a light-curve provisionally derived by comparison with the remaining observations of 1902, that the first and the last two of the above four values are to be rejected within their whole range, because they yield inadmissibly large deviations between the computed and observed brightness. The second value only remains, and its application is limited to the range from $0^m.20$ to $0^m.22$. We therefore assume as the second approximation, after a slight displacement of the epoch, the elements:

$$\text{Min.} = 1903\ \text{Jan.}\ 14^d\ 4^h\ 32^m\ \text{G.M.T.} + 4^h\ 0^m.21\ \text{E.}$$

This formula was now used for constructing the light-curve of the variable from the measures of January 12–18, the epochs of minima being computed by it, and the differences of time of the separate data of observation as compared with the previous mimimum were formed. In all 143 measures were employed for the light-curve; three of these (distinguished in the table of observations by parentheses) were excluded, as they were clearly affected by somewhat large errors of observations, and would have influenced the result too strongly. The remaining 140 measures were arranged in order of their distance from a minimum and were finally combined in twenty mean values, each from seven measures. These normal values are contained in the following table:

NORMALS.

Distance from Minimum	Observed Magnitude	Curve	O.—C.
0^h 3^m	8.55	8.56	−1
0 11	8.46	8.48	−2
0 20	8.36	8.38	−2
0 27	8.30	8.31	−1
0 35	8.20	8.25	−5
0 44	8.20	8.19	+1
0 59	8.11	8.10	+1
1 14	8.07	8.02	+5
1 29	7.98	7.96	+2
1 44	7.89	7.92	−3
2 5	7.88	7.90	−2
2 29	7.96	7.92	+4
2 46	7.99	7.95	+4
3 9	8.05	8.04	+1
3 22	8.08	8.11	−3
3 28	8.16	8.15	+1
3 35	8.23	8.23	0
3 42	8.35	8.35	0
3 47	8.47	8.46	+1
3 54	8.57	8.56	+1

The accompanying light-curve was drawn with the aid of these values. The magnitudes read off from the curve for every five minutes are collected in the following table:

TABLE OF MAGNITUDES.

Distance from Minimum	Magnitude	Distance from Minimum	Magnitude	Distance from Minimum	Magnitude	Distance from Minimum	Magnitude
0^h 0^m	8.58	1^h 0^m	8.09	2^h 0^m	7.90	3^h 0^m	8.00
0 5	8.54	1 5	8.06	2 5	7.90	3 5	8.02
0 10	8.49	1 10	8.04	2 10	7.90	3 10	8.04
0 15	8.43	1 15	8.02	2 15	7.90	3 15	8.07
0 20	8.38	1 20	8.00	2 20	7.90	3 20	8.10
0 25	8.33	1 25	7.98	2 25	7.91	3 25	8.13
0 30	8.29	1 30	7.96	2 30	7.92	3 30	8.17
0 35	8.25	1 35	7.94	2 35	7.93	3 35	8.23
0 40	8.22	1 40	7.93	2 40	7.94	3 40	8.31
0 45	8.18	1 45	7.92	2 45	7.95	3 45	8.41
0 50	8.15	1 50	7.91	2 50	7.96	3 50	8.52
0 55	8.12	1 55	7.90	2 55	7.98	3 55	8.56
1 0	8.09	2 0	7.90	3 0	8.00	4 0	8.58

The magnitudes taken from this table are given, along with the observed magnitudes, in the above table of the normal values in the column entitled "Curve." The differences between observation and computation are given in the last column.

As may be seen from the table of magnitudes, and still better from the drawing, the light-variation proceeds very rapidly around the time of minimum, the curve at minimum almost forming an acute angle. The decline to the least brightness is somewhat steeper than the rise thereafter, the two branches not being entirely symmetrical. The maximum is far less sharply pronounced than the minimum, but the observations appear to exclude the possibility that the star remains at its greatest brightness without change for some time; wherefore it cannot be regarded as of the *Algol* type. It is somewhat striking that the normal values at about an hour before the maximum, and similarly some time afterward, lie in general below the curve. The impression is given of a short pause at these times in the increase or decrease of the light, and as if the curve ought to be drawn with two depressions. It cannot be proven without a much greater amount of observed data whether these irregularities are actually real, or are to be assigned to uncertainty or prepossession during the observations. We have paid no attention to them at present.

It should be remarked further that the observations up to this time give no indication of a different brightness at the even and the odd minima. Any irregularity in the intervals between every two successive minima is equally impossible of recognition.

The definitive table of magnitudes was further employed for more closely limiting the second approximation of the period. Here the first two observations of 1899 and 1901 could be employed, the one of which must lie at the time of maximum and the other not far from a minimum. Different trials showed that the most probable value of the period is included between $4^h\ 0^m.210$ and $4^h\ 0^m.220$, and in fact the sum of the squares of the residuals was least for the values $0^m.212$ and $0^m.214$. We adopted the mean from these values, and assume as the most probable elements of the new variable at the present time:

Min. = 1903, January $14^d\ 4^h\ 32^m$ G. M. T. + $4^h\ 0^m\ 12^s.8E$.

The error of the period can hardly be more than $0^s.5$, and the correction to it cannot be expected for a number of months. The last columns in the table of measures show how all the observations are represented by the above period. The magnitudes as taken from the light-curve are there given, together with the deviations between observation and computation. The last column contains further the number of the epoch of the minimum preceding the observations in question, reckoned from the initial epoch 1903, January 14. On the whole, the representation may be considered as satisfactory—among the 181 observations there is no deviation greater than $0^{m}_{.}29$.

The most rapid oscillations in brightness among the variables hitherto known are exhibited by two stars in the star cluster *ω Centauri*, which is rich in variables; their periods are $7^{h}\ 11^{m}_{.}4$ and $7^{h}\ 42^{m}_{.}8$. *S Antliae* follows next with a period of $7^{h}\ 46^{m}_{.}8$. Periods between 8^{h} and 9^{h} are found for several variables in that cluster. *U Pegasi* should be finally mentioned, the period of which is given as $5^{h}\ 32^{m}_{.}2$ in Chandler's third catalogue, but which exhibits secondary minima according to Pickering's investigations (*Harvard Circular* No. 23), and has a period of $8^{h}\ 59^{m}_{.}7$.

The discovery of the new variable raises the question of the cause of this exceedingly rapid light-variation. We might first think with Zöllner of a rotating body whose surface possesses a very unequal distribution of brightness as a consequence of an advanced stage of cooling. This view is opposed by the white color of the star, for we may assume a yellowish or reddish color for all stars which are strongly cooled off. Another natural supposition would be that of a figure widely departing from a sphere, perhaps a long ellipsoid or a body similar to one of Darwin's figures of equilibrium, which rotate about one of the lesser axes. This explanation, however, would meet with difficulties, because it can hardly be possible to represent the particular form of light-curve observed, especially the very rapid changes of brightness at minimum and the very slow changes around the time of maximum.

We may finally consider the hypothesis that the light-variation is produced by two celestial bodies almost equal in size and luminosity whose surfaces are at a slight distance from each other, and which at times almost centrally occult each other in their revolution. In this case the observed light-curve can be almost exactly represented by computation. The fact that the difference of brightness between maximum and minimum is somewhat less than $\frac{3}{4}$ mag. would indicate that one body is a little smaller than the other, or that the occultation is not quite central. On this hypothesis we have only one difficulty, and the not inconsiderable one, as to whether such a system is mechanically possible and can remain stable for any length of time. But in spectroscopic binaries we have already come to know systems the existence of which formerly had to be considered as doubtful on similar grounds, and it would perhaps be possible by more exhaustive theoretical investigations to demonstrate also the permissibility of the assumption of still closer double stars.

POTSDAM,
February 1903.