BULLETIN OF THE ASTRONOMICAL INSTITUTES
OF THE NETHERLANDS.

1927 October 19 Volume IV. No. 135.

COMMUNICATION FROM THE OBSERVATORY AT LEIDEN.

The variable star of the δ Cephei type H.D. 154365; $16^h 59^m\!\cdot\!9$, $-26°27'$ (1900),

by *D. Brouwer*.

During his stay at the Harvard Observatory Professor HERTZSPRUNG estimated the brightness of the star H. D. 154365 on 603 plates, taken at Arequipa and Harvard during the years 1899—1926. In the H. D. Catalogue this star is indicated as variable, Class IV, period unknown. Professor HERTZSPRUNG sent his estimates to Leiden, where I undertook the reduction.

The comparison stars used are:

C. P. D.	H. D. Nr.	H. D. ptg.	H. D. Sp.
z — 26°5553	153571	8·0	A2
r — 26·5796	153636	8·0	A0
x — 26·5804	154053	8·6	A5
y — 26·5802	153886	8·8	F8
var. — 26·5814	154365	7·2—8·0	G5

Of the 603 plates used 468 are of the series AM, further 43 AX, 77 AC and 15 AY plates. The AM and AX plates have been taken at Arequipa, the AC and AY plates at Harvard. AX and AY plates only in the years 1924—1926.

Generally the variable star was compared with two comparison stars. The differences in brightness are expressed in steps. The scale of steps is arbitrary. The mean differences in steps between the comparison stars are:

	$y-x$		$x-r$		$r-z$	
	s		s		s	
AM 1st half	·48	(50)	·45	(50)	·36	(50)
2d „	·59	(54)	·45	(57)	·47	(38)
AC	·54	(15)	·49	(11)	·46	(22)
AX	·55	(4)	·44	(16)	·42	(10)
AY	·53	(5)	·38	(4)		
General mean	·54	(128)	·45	(138)	·42	(120)

The numbers between brackets are the number of plates used. There is an indication that one step represents a smaller difference in brightness during the second half of the work than during the first half. To avoid confusion with the following I emphasize that the plates were not estimated chronologically. Both groups of AM plates cover nearly the whole sequence of years.

I adopt the general mean. Thus, putting z equal to zero:

	s
z	·00
r +	·42
x +	·87
y +	1·41

The range being small, the photographic magnitudes of the H. D. Catalogue are not accurate enough for a reliable determination of the scale value.

On each plate the brightness of the variable was interpolated in the scale of steps given above for the comparison stars.

In determining the period I met with no difficulties. The provisional period used is:

$$P = 4^d\!\cdot\!06800 \pm \cdot 00008 \quad (m.\ e.)$$

or

$$P^{-1} = \cdot 245821 \pm \cdot 000005 \quad (m.\ e.)$$

There was no *a priori* reason not to treat all four series of plates together. I then divided the observations in two parts:

1899 — 1912
1913 — 1926

and found two lightcurves, which have practically identical shapes, but the average brightness of the variable during the second period is about $^s\!\cdot\!11$ fainter than during the first period. In order to examine this point more closely I now divided the estimates in three groups:

		number of plates
α	1899 — 1908	201
β	1909 — 1915	208
γ	1916 — 1926	190
		599

4 doubtful estimates have been neglected.

No difference in the shape between the three lightcurves α, β and γ was found. The average brightness in steps of the variable is:

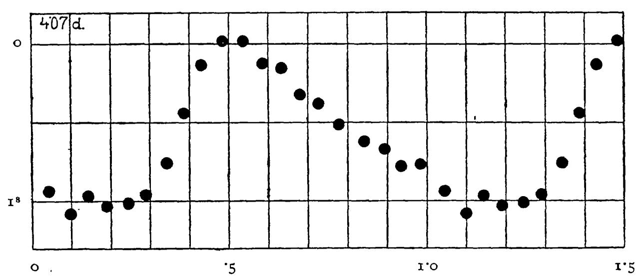
$$\alpha: +{}^{s}.52, \quad \beta: +{}^{s}.62, \quad \gamma: +{}^{s}.61.$$

This difference would be explained by the circumstance that the variable star is yellower than the four comparison stars, if during the years from which the curves β and γ are deduced the photographic plates have shown a yellow star relatively fainter than in years covered by group α. That this has really been the case is fairly well indicated by the two comparison stars y and r, between which the difference in colour is the greatest, the spectra being F8 and A0 respectively. The difference in steps, $y—r$, is

$$+{}^{s}.92 \;;\; +1^{s}.05 \;;\; +1^{s}.02$$

in the three groups α, β and γ respectively. I conclude that probably different instrumental conditions as to kind of plates and lenses used are the cause of the deviations. As the changes of the observational circumstances are not known, the best thing is to combine the three lightcurves after reducing them to the same mean brightness on the scale of steps. This has been done below, (fig. 1).

FIGURE 1.



From the phase differences between the light-curves the period was corrected. The shift of the lightcurve γ with respect to α is — ·037 P. The interval is 5988 days.

Or:

$$\Delta P = -{}^{d}.000102$$
$$P = 4.06790 \pm .00002 \; (m.\,e.)$$
$$P^{-1} = .245827.$$

The shift of the lightcurve β with respect to α is found — ·025 P. The interval is 2937 days. The agreement is fairly good.

The phase has been calculated from the formula

$$\text{Phase} = .245827 \; (\text{J. D. hel. M. T. Grw.} - 2400000).$$

The epoch when the variable passes the mean brightness between min. and max., viz: ${}^{s}.50$, on the ascending branch of the lightcurve, at phase ·377, is given by:

$$\text{J.D. hel. M.T. Grw. } 2419718.652 + 4.06790\,E$$
$$\pm .016 \pm .00002 \;\; (\text{m.e.})$$

The maximum occurs about ${}^{d}.541$ later, at phase ·510.

$$M—m = 1^{d}.26$$

The range between maximum and minimum brightness is $1^{s}.1$. The average brightness over the whole period is $+{}^{s}.58$ on the scale of steps used. The shape of the curve fits very well in the sequence of δ Cephei lightcurves, arranged according to the period by HERTZSPRUNG (*B. A. N.* **96**).

A more detailed study of the systematic differences in the estimates, revealed above by dividing the observations first in two and subsequently in three groups, was now made using the corrected period and the finally adopted lightcurve. The average residuals of the plates during separate years have been plotted in fig. 2. These residuals are given in Table 1. Between brackets the number of plates.

FIGURE 2.

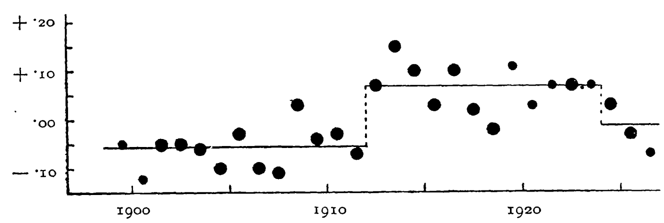


TABLE 1.

	res. s		*res.* s
1899 (8)	—·05	1913 (37)	+·15
1900 (8)	—·12	1914 (33)	+·10
1901 (17)	—·05	1915 (31)	+·03
1902 (21)	—·05	1916 (24)	+·10
1903 (22)	—·06	1917 (26)	+·02
1904 (28)	—·10	1918 (20)	—·02
1905 (28)	—·03	1919 (10)	+·11
1906 (24)	—·10	1920 (8)	+·03
1907 (20)	—·11	1921 (4)	+·07
1908 (25)	+·03	1922 (33)	+·07
1909 (29)	—·04	1923 (10)	+·07
1910 (25)	—·03		
1911 (20)	—·07	1924 (22)	+·03
1912 (33)	+·07	1925 (23)	—·03
		1926 (9)	—·07

The yearly means suggest that during the years 1899—1911 the instrument and plates used at Arequipa have not been much altered but that in 1912 a change has taken place in such a way that the yellow stars become relatively fainter.

The average residuals are:

	s		
1899 — 1911	— ·056	from 275	plates
1912 — 1923	+ ·070	„ 269	„
1924 — 1926	— ·030	„ 54	„

For the change in 1912 no reason can as yet be given. The change in 1924 is obvious. The plates taken in the years 1924 — 1926 are only AX and AY plates, taken with instruments of greater aperture the lenses of which probably absorb more blue light, so that a yellow star appears relatively brighter. The character of the secondary spectrum of the objective used may also affect the apparent difference in brightness between white and yellow stars.

The mean square deviations of the yearly means during the years 1899 — 1911 lead to a *m. e.* of one estimate of ± ^{s}·17; during the years 1912 — 1923 ± ^{s}·26. The former *m. e.* is in a very good agreement with the m. e. obtained from other sources, viz.:

± ^{s}·18 from about 100 residuals, taking 4 years at random
± ^{s}·16 from the AC plates.

The AC plates have contributed to the average residuals during the two groups of years, mentioned above. Separately they give:

1899 — 1903	(20)	— ·01
1904 — 1907	(22)	·00
1908 — 1911	(21)	— ·01
1915 — 1919	(13)	+ ·03
total mean.	(76)	— ·00⁴

Thus the AC plates show no change of relative sensivity for yellow light. The good quality of the AC plates is remarkable as they have all been taken at rather large zenith distances, the minimum being about 69°.

A change of the average magnitude of a variable, probably explained by a change of the instrumental conditions is not new. HERTZSPRUNG found the same examining the lightcurve of S Sagittae (*A. N.* **4917**). The variable star was found ^{m}.07 brighter in 1917 than in 1910 — 11.

In Table 2 are given the numbers constituting the three lightcurves α. β and γ. Each point represents the mean of 10 estimates. The corrections + ^{s}·06, — ^{s}·04 and — ^{s}·03 have been applied to the points of the lightcurves α, β and γ respectively. The final lightcurve, the points of which are plotted in fig. 1, is obtained by arranging the points of the three lightcurves according to the phase and combining three to one mean. Each dot in fig. 1 represents the mean of 30 estimates. The radius of the dots is equal to the *m. e.*, based upon ± ^{s}·19 for the mean error of one estimate. From the mutual deviations of the lightcurves α, β and γ this m. e. was confirmed.

TABLE 2.

α		β		γ		final lightcurve	
phase		phase		phase		phase	
	s		s		s		s
.026	·93	·051	1·02	·052	·88	·043	.94
·074	1·18	·107	1·09	·117	1·02	·099	1·08
·115	·97	·142	·97	·169	·93	·143	·97
·175	1·01	·180	1·03	·236	1·03	·190	1·03
·214	1·05	·226	1·05	·279	1·02	·244	1·01
·270	·96	·275	1·01	·339	·78	·290	·96
·317	·86	·318	·93	·375	·52	·342	·76
·368	·57	·377	·41	·415	·21	·386	·44
·405	·39	·421	·22	·481	·08	·430	·13
·454	— ·04	·459	·01	·533	— ·07	·483	— ·02
·524	— ·03	·510	— ·14	·580	·14	·536	— ·02
·584	.09	·550	·03	·639	·11	·585	·12
·621	.12	·592	·13	·706	·43	·632	·15
·659	.24	.636	·21	·750	·46	·680	·32
·720	.40	·676	·29	·795	·55	·726	·38
·782	.51	.708	·27	·852	·67	·778	·51
·839	.60	·757	·47	·906	·65	·841	·62
·891	.64	·833	·59	·944	·78	·894	·67
·924	.77	·886	·72	·988	·78	·935	·78
·973	.74	·936	·78			·984	·77
		·992	·79				