Universiteit Leiden
The Netherlands

Discussion of radial velocities and photometric observations of δ Cephei

Wesselink, A.J.

Citation

Wesselink, A. J. (1946). Discussion of radial velocities and photometric observations of δ Cephei. *Bulletin Of The Astronomical Institutes Of The Netherlands*, *10*, 88. Retrieved from https://hdl.handle.net/1887/6294

Version: Not Applicable (or Unknown)

License: Leiden University Non-exclusive license

Downloaded from: https://hdl.handle.net/1887/6294

Note: To cite this publication please use the final published version (if applicable).

1946BAN....10...88W

wavelength which is in focus with the change in focus reading. Near $^{\mu}$·55 we find: Δf(mm) = 118 $\Delta\lambda$ (in μ).

With the grating constant: d + l = 7·65 mm and f_0 = 5240 mm we have λ (in μ) = ·73 s (in mm). Hence Δf(mm) = 86 Δs, where s is the distance between the spectra. The dotted line in Figure 5 corresponds to this calculated slope. The agreement with the measured variation is satisfactory; we even note that the measured distance varies somewhat less with the focal reading than the calculated one, as it should. If the sensitivity were purely monochromatic the distance between the spectra would not vary at all with the focal reading.

With the same refractor, combination of gratings, plates and filter I have measured the difference in magnitude between the differently coloured components of the double stars ι Cancri and β Cygni. In both cases we encountered systematic errors between the results obtained in different nights of the same order of magnitude as found for δ Cephei. This result rules out the explanation of the systematic errors being due to real changes in the lightcurve of δ Cephei. It seems possible that the systematic errors in the observations of δ Cephei could have been determined if on the same plate some observations of β Cygni[1]), or some other suitable double star with components of different colour had been made, if it is assumed that the systematic error found in the variable pair is equal or eventually proportional to the error found in the constant pair.

I am indebted to Messrs KOOREMAN and KLEIBRINK for the part they took in the measurement and the reduction. Mr KLEIBRINK made the enlargements shown in Figures 1 and 2.

1) β Cygni is perhaps less suited, for the bright yellow component is spectroscopically double, showing a composite spectrum of a bright K star and an A component.

Discussion of radial velocities and photometric observations of δ Cephei,

by *A. J. Wesselink.*

A comparison has been made between the results of the preceding article and the lightcurve by JOEL STEBBINS. The effective wavelength of STEBBINS' visual lightcurve is found to be $^{\mu}$·60. The total weight is 125000 m^{-2}. The period satisfying both the observations by STEBBINS and the author is 5^{d}·366332. STEBBINS's observations have been helpful to bring other series of observations into phase with the lightcurve of the preceding article. The humps on the descending branch are not real.

P. GUTHNICK's observations with a potassium photoelectric cell have been corrected for the light of the companion. The agreement with SMART's photoelectric observations, also made with a potassium cell, is excellent. These two series have been combined into one accurate lightcurve with total weight 350 000 m^{-2}. The effective wavelength was found to be $^{\mu}$·44. The difference between this photoelectric curve and the photovisual curve of the preceding article is the colour-index curve used in the next article.

The radial velocity measures by J. H. MOORE and T. S. JACOBSEN have been combined into one curve. The velocity of the centre of gravity is −16·8 km/sec. The total weight is 72·8 km^{-2}sec^{2}. In the next article this curve has been used for the determination of the displacement of the star's surface as a function of the phase.

1. *Visual observations by Stebbins*[1]).

For his visual photometry of δ Cephei STEBBINS used a Pickering polarizing photometer, whereas the writer used objective gratings for his photovisual photometry (see the preceding article). We both used the 6^{m}·6 companion (spectrum A0) as comparison star. Details concerning the magnitude difference at minimum and at maximum between variable and companion will be found in Table 1.

The table contains also the results of a few observations on RT Repro lantern plates made by the writer with the same combination of gratings as was used for the photovisual photometry. Though the effective wavelength of these photographic magnitudes is not very well defined we may take $^{\mu}$·42 for it. The effective wavelength of the photovisual photometry is $^{\mu}$·55. If Δm is assumed[2]) to be a linear function of $(\lambda - {}^{\mu}\cdot275)^{-1}$, one finds by slight extrapolation for the effective wavelength of STEBBINS's visual photometry of δ Cephei from the minimum: $^{\mu}$·60, from the maximum: $^{\mu}$·60. These concordant results seem to be rather large for ordinary visual photometry but are hard to doubt.

TABLE 1

Observer	Technique	Difference in magnitude with companion at max.	at min.	Effective wavelength	
WESSELINK	photovisual	$1^{m}\cdot98$	$2^{m}\cdot83$	$^{\mu}$·55	
,,	photographic reproduction plates	·87	2·27	$^{\mu}$·42	
				computed from Δm	
STEBBINS	visual	2·17	2·93	$^{\mu}$·60 (max.)	$^{\mu}$·60 (min.)
GUTHNICK & SMART	photoelectric	1·08	2·34	$^{\mu}$·43 (max.)	$^{\mu}$·44 (min.)

Phases were computed from the Julian dates given in STEBBINS's article with the same formula as has been used in the preceding article:

$$\text{Phase} = {}^{d^{-1}}\cdot18634848\ (\text{JD}-2420000).$$

When a shift of $+^{P}\cdot015$ is applied to these phases STEBBINS's curve and mine agree.

1) *Ap. J.* **27**, 188, 1908.
2) *B.A.N.* **7**, 242, 1935.

© Astronomical Institutes of The Netherlands • Provided by the NASA Astrophysics Data System

In the following we shall discuss four series of observations. They have been brought into phase with the photovisual lightcurve of the preceding article by computing phases according to the formula: Phase = $^{d-1}$·18634848 (JD−2420000)+ a constant shift. This shift was chosen for each series dependent on the mean epoch and varied linearly with it from $+^{P}$·015 to zero in the interval from 1907 to 1935. If the period is supposed to be constant we find for the value satisfying both the observations by STEBBINS and the writer: 5^{d}·366332.

STEBBINS's published lightcurve of overlapping means shows some evidence of humps near the phases 4^{d}·6 and ^{d}·4, corresponding to phases ^{P}·92 and ^{P}·14 of the preceding article. As the lightcurve by GUTHNICK and SMART and the writer's curve are remarkably smooth, some explanation seems desirable. In Figure 1 STEBBINS's *independent* means have been plotted against phases computed with the formula: Phase = $^{d-1}$·18634848 (JD−2420000)$+^{P}$·015. By the present treatment the humps have disappeared.

The total weight of STEBBINS's visual lightcurve of δ Cephei is 125000 m^{-2}.

2. *Photoelectric observations with a potassium cell by W. M. Smart* [1]).

In the years 1933 and 1934 W. M. SMART made a number of photoelectric measures of δ Cephei with a potassium cell at Cambridge, England. As the mean epoch is rather close to that of my observations of the preceding paper, the phases were computed with the same formula as used there. I am indebted to Dr W. M. SMART for sending me the Julian Dates needed for this purpose. η Peg has been used as comparison star. The companion was not included in the measured light. SMART considers a difference in amplitude between his curve and one by GUTHNICK due to a difference in effective wavelength. However GUTHNICK included the companion in his measures of δ Cephei. When allowance is made for this the results of GUTHNICK and SMART are found in perfect agreement (see below), indicating that the respective effective wavelengths are equal. 52 of SMART's most accurate observations are represented graphically in Figure 1 of the next paper by dots. The numerical data are in Table 2.

Photoelectric measures with a potassium cell by P. Guthnick [2]).

Of the photoelectric observations of δ Cephei made by GUTHNICK, we shall discuss those made with a potassium cell prior to November 25, 1919. The

TABLE 2

Photoelectric differences at $^{\mu}$·44 of δ Cephei with η Pegasi by P. GUTHNICK and W. M. SMART.

Phase	Δm (photo-electric)	observer	Phase	Δm (photo-electric)	observer	Phase	Δm (photo-electric)	observer
P	m		P	m		P	m	
·009	+1·030	S	·372	+1·411	G	·691	+·285	S
·012	1·022	S	·395	1·381	G	·702	·328	G
·029	1·041	S	·403	1·403	S	·711	·356	S
·039	1·067	S	·404	1·421	S	·722	·363	S
·062	1·083	G	·406	1·429	S	·750	·499	S
·064	1·084	S	·410	1·418	S	·760	·496	G
·066	1·115	S	·411	1·416	S	·782	·543	S
·069*	1·095	G	·415	1·394	S	·798	·569	S
·071	1·146	S	·443	1·273	G	·799	·554	S
·071	1·100	S	·471	1·145	G	·809	·610	G
·076	1·100	S	·483	1·068	G	·810	·608	S
·106	1·127	S	·497	·974	S	·830	·670	G
·112	1·144	S	·499	·955	S	·858	·708	G
·117	1·152	G	·507	·890	G	·860	·738	S
·153	1·213	G	·526	·751	G	·889	·787	G
·169	1·220	S	·530	·690	S	·890	·750	S
·194	1·256	S	·540	·634	S	·899	·760	S
·223	1·294	S	·543	·603	S	·906	·833	G
·226	1·310	S	·559	·467	G	·925	·889	G
·228	1·315	G	·582	·338	S	·949	·914	S
·230	1·326	S	·585	·281	S	·954	·903	S
·230	1·310	S	·627	·173	G	·961	·953	S
·255	1·338	G	·635	·191	S	·979	·963	S
·296	1·409	G	·645	·173	S	·991	·976	S
·318	1·410	S	·648	·178	S	·994	·990	S
·362	1·436	G	·652	·183	S	·999	·995	G
·365*	1·434	G	·669	·258	G			

measures later than this date cannot be combined with the earlier ones because of a luminous discharge in the cell, which appears to have changed the effective wavelength. GUTHNICK used ε Cephei as a comparison star. The combined light of δ Cephei and its companion was measured. Fortunately GUTHNICK measured both the variable and its companion on a few occasions separately. GUTHNICK found: m (companion)−m(ε Cep) = 1^{m}·786, which result has been used to reduce the measures to differences: m (δ Cep)−m (ε Cep). Phases were computed with the formula:

$$\text{Phase} = \cdot 18634848 \text{ (J D}-2420000) + {}^{P}\cdot 008.$$

The observations are then in phase with those of the preceding article. The differences with ε Cep increased with ^{m}·72 have been plotted against these phases in Figure 1 of the next paper as open circles. The agreement with SMART's results is excellent and the difference m (ε Cep) − m (η Peg) is found to be + ^{m}·72 at the effective wavelength $_{\mu}$·44 of these photoelectric measures. The numerical data of GUTHNICK's measures are collected in Table 2. The two starred observations refer to the measures by GUTHNICK in which the companion was not included.

Though the curve of spectral sensitivity of a potassium photoelectric cell is comparatively broad and the effective wavelength consequently ill defined,

[1]) *M.N.* **95**, 644, 1935.
[2]) *Jubiläumsnummer der A.N.*, 10, 1921.

© Astronomical Institutes of The Netherlands • Provided by the NASA Astrophysics Data System

1946BAN....10...88W

we shall make two determinations of the latter.

OOSTERHOFF [1]) gives for the photographic difference ($\lambda_{eff.} = {}^{\mu}{\cdot}43$) between ε Cep and η Peg: $+{}^{m}{\cdot}58$. The visual difference according to the Potsdam photometry is $+1^{m}{\cdot}14$ ($\lambda_{eff.} = {}^{\mu}{\cdot}55$) [2]); the *H.R.* gives $+1^{m}{\cdot}13$ ($\lambda_{eff.} = {}^{\mu}{\cdot}51$) [2]). We take $m = 1^{m}{\cdot}14$ to correspond with a $\lambda_{eff.} = {}^{\mu}{\cdot}54$. If Δm is assumed to vary linearly with $(\lambda - {}^{\mu}{\cdot}275)^{-1}$, we find, corresponding to a $\Delta m = {}^{m}{\cdot}72$, for the effective wavelength of the photoelectric lightcurve by GUTHNICK and SMART: $\lambda_{eff.} = {}^{\mu}{\cdot}447$.

Almost the same result is obtained in another way, which makes use of the known difference in magnitude with the companion. We have for m (δ Cep) − m (companion) from GUTHNICK's measures: $1^{m}{\cdot}08$ at minimum and $2^{m}{\cdot}34$ at maximum; with the aid of the known differences in magnitude at ${}^{\mu}{\cdot}42$ and ${}^{\mu}{\cdot}55$ we find $\lambda_{eff.} = {}^{\mu}{\cdot}435$.

The total weight of the photoelectric lightcurve is 350000 m^{-2}.

3. *Radial velocity measures by J. H. Moore* [3]).

J. H. MOORE made a number of determinations of radial velocity of δ Cephei with the three prism new Mills spectrograph of the Lick Observatory in the years 1907 and 1908. Phases computed with the formula:

$$\text{Phase} = {}^{d-1}{\cdot}18634848\ (\text{JD}-2420000) + {}^{P}{\cdot}015$$

TABLE 3

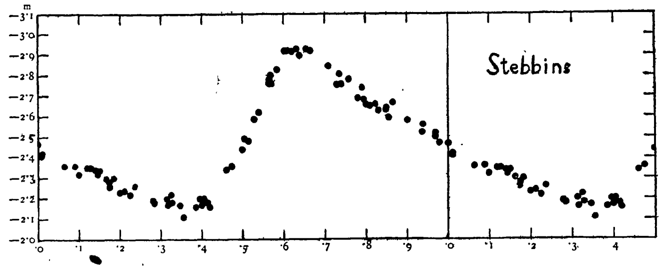
Measurements of radial velocity by J. H. MOORE and T. S. JACOBSEN.

Phase	rad. vel.	observer	Phase	rad. vel.	observer	Phase	rad. vel.	observer
P	km/sec		P	km/sec		P	km/sec	
·003	−19	J	·378	0	J	·640	−36	M
·005	−20	M	·385	+ 2	M	·657	−36	J
·013	−19	M	·402	+ 3	M	·671	−35	M
·029	−17	M	·431	+ 4	J	·679	−35	M
·036	−16	J	·438	+ 3	M	·698	−35	M
·049	−15	J	·446	+ 3	M	·714	−34	J
·073	−14	M	·468	+ 2	J	·716	−33	J
·085	−15	M	·472	+ 3	M	·737	−32	M
·085	−13	J	·483	+ 2	J	·745	−32	M
·099	−12	M	·484	− 2	M	·766	−31	J
·126	−12	M	·489	− 1	M	·768	−31	J
·144	−10	M	·499	− 4	M	·792	−29	J
·145	−12	J	·505	− 5	J	·800	−29	J
·168	−10	M	·507	− 6	M	·835	−27	M
·177	−10	J	·516	−10	M	·899	−25	M
·201	− 8	J	·528	−16	M	·902	−24	J
·259	− 7	M	·551	−25	M	·904	−24	M
·282	− 5	J	·561	−25	J	·937	−22	J
·288	− 5	M	·569	−29	M	·946	−22	M
·322	− 2	J	·585	−30	M	·960	−21	J
·331	− 1	J	·617	−36	M			
·369	− 0	M	·629	−36	M			

1) *B.A.N.* **10**, 45, 1944.
2) *B.A.N.* **7**, 243, 1935.
3) *L.O.B.* **7**, 153, 1913.

FIGURE 1

STEBBINS's visual lightcurve of δ Cephei; abscissae are phases according to the formula phase $= {}^{d-1}{\cdot}18634848$ (JD−2420000) $+ {}^{P}{\cdot}015$. Ordinates are differences in magnitude with the companion; 74 independent values.



bring these observations into phase with the lightcurve of the preceding paper. Velocities and phases are given in Table 3. They are shown graphically as dots, in Figure 1 of the next paper. The total number of observations is 38, of which 8 have half weight. However no distinction is made for different weight neither in the table nor in the diagram.

Radial velocity measures by T. S. Jacobsen [1]).

T. S. JACOBSEN made a number of radial velocity measures with the same spectrograph as was used by MOORE, in the years 1923 and 1924, also at the Lick Observatory.

Phases computed with the formula

$$\text{phase} = {}^{d-1}{\cdot}18634848\ (\text{JD}-2420000) + {}^{P}{\cdot}006$$

bring these observations into phase with the writer's lightcurve. I have added −1 km/sec to JACOBSEN's velocities, which reduction makes them in excellent agreement with the results by MOORE. This is shown in Figure 1 of the next article, where JACOBSEN's reduced velocities are represented by open circles. The numerical results are given in Table 3.

The total number of velocities by JACOBSEN is 26, of which two have half weight. This difference in weight is shown neither in the table nor in the diagram.

Velocities of unit weight of both series are equally accurate. The corresponding mean error is ±·90 km/sec.

TABLE 4

Coefficients of Fourier development of radial velocity-curve (unit km/sec).

n	coeff. of cos 2π nφ	coeff. of sin 2π nφ	m.e.
0	−16·84	—	±·12
1	− 3·51	+15·19	±·16
2	+ 3·12	− 6·04	,,
3	− 2·25	+ 3·26	,,
4	+ 1·32	− 1·48	,,
5	− ·78	+ ·81	,,
6	+ ·33	− ·60	,,

1) *L.O.B.* **12**, 243, 1935.

© Astronomical Institutes of The Netherlands • Provided by the NASA Astrophysics Data System