

J. S. PLASKETT'S STAR OF LARGE MASS, HD 47129*

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ABSTRACT

Spectrographic observations at the McDonald Observatory confirm the general character of the velocity-curve of the primary star derived by Plaskett but show that the maximum of the curve is not always the same. There are also small, irregular changes in the intensities and profiles of the absorption lines. The secondary set of absorption lines shows very large and erratic fluctuations in velocity and intensity, so that it cannot have its origin in a normal, quiescent stellar atmosphere. Nor can its radial velocities be used to derive the mass ratio of the system. There are indications that this set of lines is affected by dilution of the exciting radiation and that it is produced in a rapidly moving stream of gas which is most conspicuous when it is seen projected against the receding hemisphere of the primary star. The spectrum exhibits other peculiar features, most of which are probably related to the unique value of the mass-function of this system, $\sin^3 i m_2^3 / (m_1 + m_2)^2 = 13.1 \odot$. It is not certain that any of the observed features are really due to the second component of this double-star system.

The spectroscopic binary, HD 47129 = BD+6°1309¹ was investigated by J. S. Plaskett in 1922. On December 16, 1921, he found double lines in its spectrum, both components belonging to about spectral class Oe5. The measurements of thirty Victoria spectrograms led him next to derive a period of 14.414 days. The semi-amplitude of the primary was 206 km/sec, that of the secondary, 247 km/sec. The eccentricity was 0.035, and the longitude of the line of apsides, 182°. With these elements Plaskett computed the mass-functions

$$m_1 \sin^3 i = 76 \odot, \quad m_2 \sin^3 i = 63 \odot.$$

The total mass of more than 139 $\odot$ was exceptional in 1922. It has remained unique to this day; all other known spectroscopic binaries have smaller mass-functions than $f(m) = 13.1 \odot$. Plaskett investigated the possibility of a period of the order of $1 \pm 1/14.4$ days; but he concluded from observations on four nights with two spectrograms on each, separated by an interval of about 4 hours, that such a short period would not be consistent with his measurements. This is fully confirmed by observations at the McDonald Observatory. On December 1, 1947, four spectrograms were obtained, over an interval of 5 hours. The entire range in velocity was 10 km/sec. The phases in the 14.4-day period were 4.507, 4.555, 4.605, and 4.716 days. In the corresponding part of the velocity-curve the change is about 60 km/sec per day. Hence, if the period were close to 24 hours, we should have observed a change of 60 km/sec within an interval of about 2 hours. The change in 5 hours would have been about 150 km/sec. It is therefore certain that Plaskett's period is approximately correct.

Efforts to find variations in the brightness of this star were unsuccessful. J. Stebbins announced in 1928,² from a series of photoelectric observations made in 1923 and 1924, that the "results are discordant and unsatisfactory, but Plaskett's star is not an eclipsing variable. One or both comparison stars are suspicious, but no variation was established." Similarly, P. Guthnick³ concluded from photoelectric observations made in 1922 and 1923 that the star "is not noticeably variable." Despite these negative results, S.

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¹ *Pub. Dom. Ap. Obs., Victoria*, 2, 147, 1922. The position for 1900 is $\alpha = 6^h 32^m 0^s$; $\delta = +6^\circ 13'$. The visual magnitude is 6.06.

² *Pub. Washburn Obs.*, Vol. 15, 1928.

³ *Vierteljahrsschr. der Astr. Gesellsch.*, 58, 83, 1923.

Gaposchkin⁴ has included Plaskett's star in his list of "some important eclipsing systems," with the remark: "It is very probable that this most massive spectroscopic binary (Plaskett's star) is an eclipsing variable with a range of about 0.10 mag." No observations have been published by Gaposchkin in support of this opinion.

The large mass-function of HD 47129 is so remarkable that a new study of its spectrum was undertaken at the McDonald Observatory during the winter of 1947-1948. The total number of spectrograms obtained was seventy-three. They were distributed over two complete cycles: November 25-December 9, 1947, and December 24, 1947-January 7, 1948. We shall designate these cycles as "I" and "III," respectively. The phases, in days, were computed with Plaskett's elements:

$$T = \text{JD } 2423031.870 + 14.414 E.$$

All spectrograms were taken with the quartz spectrograph at the Cassegrain focus, giving a dispersion of 40 Å/mm at λ 3933. Plaskett's dispersion was probably about twice as great. But this difference was not objectionable in the measurement of the star lines because of their intrinsic widths and, occasionally, shallow profiles. The McDonald plates have the advantage of extending beyond the Balmer limit into the ultraviolet and of requiring such short exposures that about one-third of them were made on Eastman Process emulsion. With the exception of a few II-O and 103a-F plates, the rest were exposed on emulsion 103a-O.

The general appearance of the spectrum is very similar to that described by Plaskett. The lines of the primary component are strong and are easily measurable. Those of *He* I, *Si* IV, and *N* III are not very broad. On some plates they are only slightly broader than the instrumental profile of the spectrograph. The *He* I series ($2^3\text{P}^\circ - n^3\text{D}$) is especially strong in absorption, and its members extend far into the ultraviolet as moderately narrow lines. The lines *He* I 3965 and *He* I 3889 are both present; the former is exceptionally narrow and weak, the latter is seen only on a few spectrograms distinct from *H* ζ . On these plates it appears as a very narrow, but rather weak, absorption line. Neither shows any emission above the level of density of the neighboring continuous spectrum. Since the lower levels of both lines are metastable, the corresponding transitions are known to be sensitive to the dilution effect. Because both lines are weak, I believe that dilution plays no significant role in the atmosphere of the principal component of HD 47129. But the differences in the widths of the *He* I lines (in the order, $2^3\text{S} - n^3\text{P}$, $2^1\text{S} - n^1\text{P}$, $2^3\text{P} - n^3\text{D}$, and $2^1\text{P} - n^1\text{D}$, of increasing diffuseness) are undoubtedly real and must have some, as yet mysterious, explanation. The lines of the Pickering series of *He* II are somewhat more diffuse. Those of *H* are peculiar: *H* β is very weak and often present only as a diffuse absorption feature between extremely wide and barely perceptible emission components; *H* γ and *H* δ are strong and surprisingly well-defined absorption lines between excessively weak emission borders whose total widths may be estimated as 30 Å. These double emission lines are seen only with difficulty, even on the Process plates; *H* ϵ is blended with interstellar *Ca* II H; *H* ζ and all the higher members of the Balmer series, as far as *H* β , are quite diffuse, though the degree of diffuseness varies with the phase. The series terminates rather abruptly at *H* 13. There are no *H* emission lines beyond *H* δ . The Fowler line *He* II 4686 is, in accordance with Plaskett, seen only as a depression between two very weak and broad emission components.

The spectrum of Plaskett's second component was easily detected on the first spectrogram of the new series. Its absorption lines are weak and more diffuse than are those of the principal component. I have measured them on many plates, usually in the case of *H* and *He* I. Contrary to Plaskett's description, I find that this component is relatively weak in *He* II. Moreover, I have found some very remarkable and unusual features among the lines of this spectrum which I shall describe farther on.

⁴ *Variable Stars* ("Harvard Observatory Monographs," No. 5 [Cambridge, 1938]), p. 92.

Table 1 lists the star lines used for the determination of the radial velocities. Many lines are seriously blended: all H lines have violet components due to He II; $H\delta$ is seriously blended with N III 4103. Despite these blends, I have used the wave lengths listed in the table, because the errors tend to cancel one another. Nevertheless, the velocity of the system cannot be accurately determined, and Plaskett's value of $+24$ km/sec is probably as good as can be determined with the help of the new material. The radial velocities are listed in Table 2. Those of the principal component are plotted in Figure 1. The character of the curve closely resembles that published by Plaskett. There is a shift of the entire curve in phase, by about $+2.6$ days. Since 660 cycles had elapsed between the mean dates of his and of my series of observations, this would correspond to a correction in the period of $+0.0039$ day, assuming, of course, that no complete cycles were lost or gained during the interval. Plaskett's series extended over an interval of 110 days, or about 8 cycles. Within a single cycle the period would be determined within about ± 0.05 day. Hence the probable error of his final value, 14.414 days, was of the order of ± 0.01 day.⁵

Between phases 0 and 6 days the measurements are in excellent accord, and the two cycles agree perfectly. Between phases 8 and 13 days, the results from cycle III are

TABLE 1

STAR LINES IN HD 47129

He I.....	3705.04	Si IV.....	88.86
H 12.....	50.15	N III.....	97.31
H 10.....	97.90	$H\delta$	4101.74
He I.....	3819.64	Si IV.....	16.10
He I+ $H\zeta$	88.85	He I.....	20.86
Ca II.....	3933.67	He I.....	43.76
He I.....	64.73	He II.....	99.83
Ca II.....	68.47	$H\gamma$	4340.47
He	70.07	He I.....	87.93
N III.....	4003.64	He I.....	4471.51
He I.....	09.27	He II.....	4541.59
He I.....	26.22	He II (emission).....	4685.80

systematically lower than those from cycle I. The effect is quite large—of the order of 30 km/sec—and, since care was taken in measuring the same lines on all plates, as nearly as was possible, I believe that the difference must be real. The maximum of the velocity-curve in cycle I (filled circles) was more peaked than in cycle III (open circles). Perhaps this phenomenon is connected with the well-known tendency of certain spectroscopic binaries to produce spuriously peaked maxima in their velocity-curves, which I have attempted to explain as the result of blending of the true stellar line with a line produced in a receding stream of gas, seen projected upon the disk of the principal component a short time prior to superior conjunction (or principal eclipse).⁶ There is, however, no certain variation of a periodic nature in the relative intensities of the absorption lines. In view of this uncertainty concerning the maximum of the velocity-curve, I have decided not to derive a new set of orbital elements. Cycle I would suggest an appreciable eccentricity, perhaps of the order of 0.05 with a value ω close to 0° . Cycle III would give almost no eccentricity. The departure from Plaskett's value $\omega = 182^\circ$ is probably not dynamically significant.

⁵ It would seem that the procedure used by Plaskett of solving for P in his least-squares solution of the orbit was inadvisable and that the close agreement of his value with that found from the new material must have been largely accidental; perhaps he had already ascertained the second decimal place of the period by means of the conventional procedure.

⁶ *Ap. J.*, 99, 95, 1944.

TABLE 2
RADIAL VELOCITIES OF HD 47129

Plate (CQ)	Date	U.T.	Phase (In Days)	Vel. I (Km/Sec)	Vel. II (Km/Sec)	Vel. Ca II (Km/Sec)
	1947					
6305.....	Nov. 25	6 ^h 50 ^m	12.916	+ 52	-225	+17.6
06.....	25	7:52	12.959	+ 62	.....	- 4.5
07.....	25	8:26	12.982	+ 68	-277	+17.7
26.....	26	7:59	13.963	- 33	.....	- 1.7
27.....	26	8:15	13.975	- 39	.....	+17.3
46.....	27	6:44	0.498	- 95	+ 55	+21.7
47.....	27	7:35	0.533	- 87	.....	+10.2
55.....	27	11:09	0.682	-110	.....	+17.8
67.....	28	6:14	1.477	-157	+163	+16.4
68.....	28	6:34	1.491	-165	+161	+11.8
69.....	28	6:55	1.505	-172	+ 55	+13.3
73.....	28	9:12	1.600	-162	+129	+15.7
85.....	29	6:45	2.498	-169	+164	+ 9.4
86.....	29	7:55	2.547	-177	+118	+12.4
87.....	29	9:10	2.599	-185	+143	+12.2
6403.....	30	6:05	3.471	-164	+157	+15.5
04.....	30	7:17	3.521	-167	+102	+ 9.4
05.....	30	8:26	3.568	-160	+169	+ 8.9
22.....	Dec. 1	6:57	4.507	-107	.....	+21.5
23.....	1	8:07	4.555	-103	.....	+25.9
24.....	1	9:19	4.605	-112	.....	+16.3
28.....	1	11:58	4.716	-114	.....	+ 6.5
33.....	2	8:23	5.566	- 27	.....	+14.5
34.....	2	9:27	5.611	- 38	.....	+ 9.8
46.....	4	9:25	7.609	+137	.....	+ 7.1
47.....	4	10:32	7.656	+148	.....	- 0.3
51.....	5	7:35	8.533	+224	-247	+25.7
52.....	5	8:46	8.582	+223	-243	+22.5
53.....	5	9:56	8.631	+177	-245	+14.8
63.....	6	6:43	9.497	+235	-167	+ 6.0
64.....	6	7:40	9.537	+273	-187	+26.5
65.....	6	8:34	9.574	+256	-207	+ 7.8
76.....	7	9:11	10.599	+242	-229	+12.1
77.....	7	10:10	10.640	+208	-268	+10.5
78.....	7	11:09	10.682	+224	-242	+28.9
93.....	8	9:56	11.631	+161	-219	+28.7
94.....	8	10:28	11.653	+172	.....	+33.4
95.....	8	11:06	11.680	+180	-221	+33.1
6505.....	9	11:08	12.681	+ 95	.....	+29.5
06.....	9	12:01	12.718	+ 89	-176	+ 9.3
15.....	24	10:38	13.247	+ 17	.....	+22.2
16.....	24	11:10	13.269	+ 11	.....	+14.7
34.....	26	10:17	0.818	-123	.....	+10.7
35.....	26	11:17	0.860	-137	+ 63	+ 9.0
44.....	27	6:53	1.677	-169	+ 91	+15.0
45.....	27	7:52	1.718	-160	+137	.....
46.....	27	8:57	1.763	-164	.....	.....
55.....	28	7:59	2.723	-163	.....	+23.2
56.....	28	8:56	2.762	-173	+146	+13.4
57.....	28	9:52	2.801	-161	+178	+ 9.7
67.....	29	8:35	3.748	-138	+157	+12.4
68.....	29	9:33	3.788	-161	.....	+16.8
69.....	29	10:40	3.835	-161	.....	+22.7
76.....	30	9:43	4.795	- 73	.....	+27.3
77.....	30	10:00	4.807	- 81	+178	+10.9
93.....	31	10:53	5.833	- 39	.....	+26.6
94.....	31	11:23	5.864	- 31	.....	+11.1

TABLE 2—*Continued*

Plate (CQ)	Date	U. T.	Phase (In Days)	Vel. I (Km/Sec)	Vel. II (Km/Sec)	Vel. Ca II (Km/Sec)
	1948					
6596.....	Jan. 1	7 ^h 11 ^m	6.689	+ 59	—230	+15.2
97.....	1	8:08	6.729	+ 78	.....	+27.7
6614.....	3	6:06	8.644	+198	—260	+11.2
15.....	3	7:09	8.688	+213	—309	+10.0
16.....	3	8:37	8.749	+225	—332	+20.3
34.....	4	7:38	9.708	+216	—185	+17.0
35.....	4	8:25	9.741	+211	—175	+15.3
36.....	4	9:15	9.775	+192	—256	+ 9.2
46.....	5	9:38	10.791	+216	—195	+25.7
47.....	5	10:35	10.831	+183	.....	+ 5.5
63.....	6	9:21	11.780	+164	—251	+20.3
64.....	6	10:21	11.821	+166	—246	+17.2
65.....	6	11:26	11.866	+132	—195	+22.1
75.....	7	8:03	12.725	+ 55	.....	+23.4
76.....	7	9:20	12.779	+ 64	—178	+25.9
80.....	7	10:58	12.847	+ 40	.....	+10.6

The emission lines are so broad and so faint that I was not able to measure them. They are undoubtedly variable in intensity, and often these variations are erratic in character. It is probable that they are systematically stronger at phases between about 9 and 12 days than at other phases. The entire range of oscillation of the absorption lines is about 8 Å; they are never far removed from the geometrical centers of the broad, double emission features. It is certain that the latter do not oscillate by any large amount, either in phase or out of phase with the absorption lines; I should estimate that, if such oscillation does take place, it must have a range of less than about 5 Å. On several spectrograms taken near the minimum of the velocity-curve of the primary, the violet emission looks stronger than the red component; but this may mean only that the rise from the bottom of the absorption line to the top of the emission component is more abrupt. Similarly, near maximum radial velocity the red emission component is often more conspicuous.

Throughout the entire series of measurements I was struck by the fact that the blend of $H\zeta$ and $He\ I\ 3889$ is usually weaker than are several of the higher members of the Balmer series. Normally, we should expect the blend to be distinctly stronger, especially if $He\ I\ 3889$ is strengthened by the dilution effect. At phases 3.5 days of cycle I and 3.8 days of cycle III the line $He\ I\ 3889$ is visible as a very narrow, but weak, absorption on top of the diffuse absorption line $H\zeta$. There is no emission visible in either line. At other phases the $He\ I$ line is not seen distinct from $H\zeta$, except in the case of the secondary's spectrum, at phases between 8 and 11 days. The blend seems to be especially weak between phases 2 and 6 days, that is, in the vicinity of the minimum of the velocity-curve.

A somewhat similar phenomenon is present at $He\epsilon$. This line is strong near the maximum of the velocity-curve; it is not much affected by the interstellar line of $Ca\ II$ at phases around 13.5 days and 0.5 days; even at phases 1.6 and 1.7 days it is clearly visible on the violet side of the interstellar line. But at phases between 2.5 and 5 days it is exceedingly faint. The other H lines are not affected in this manner. It is probable that the narrow absorption lines of $He\ I$, $\lambda\ 3965$ and $\lambda\ 3889$, are in reality flanked by extended emission wings, which cut down the intensities of the H lines. This would, of course, be possible only if the emission features are stationary or if they oscillate opposite in phase to the absorption lines.

The diffuse character of the higher absorption members of H deserves attention. The profiles produced by the Stark effect in ordinary main-sequence O stars (for example, in 10 Lacertae) are of an entirely different character: as far as H 11 they are quite deep in their centers, and their wings have the usual exponential profiles. Even the higher members, to H 14, are narrower than in HD 47129.⁷ Moreover, in the latter star $H\delta$ and $H\gamma$ do not have the exponential wings associated with the Stark effect. If we should attribute the diffuse character of the H lines to rotation, then the relatively narrow profiles of the He I lines would be unexplained. Similarly, there is no simple explanation for the differences between the profiles of the He I lines of different series. If we should attribute the very narrow lines λ 3965 and λ 3889 to dilution, then we should have to explain why there are no other, broader, lines present at these wave lengths which would correspond in origin to the rest of the He I spectrum. It would be tempting to investigate

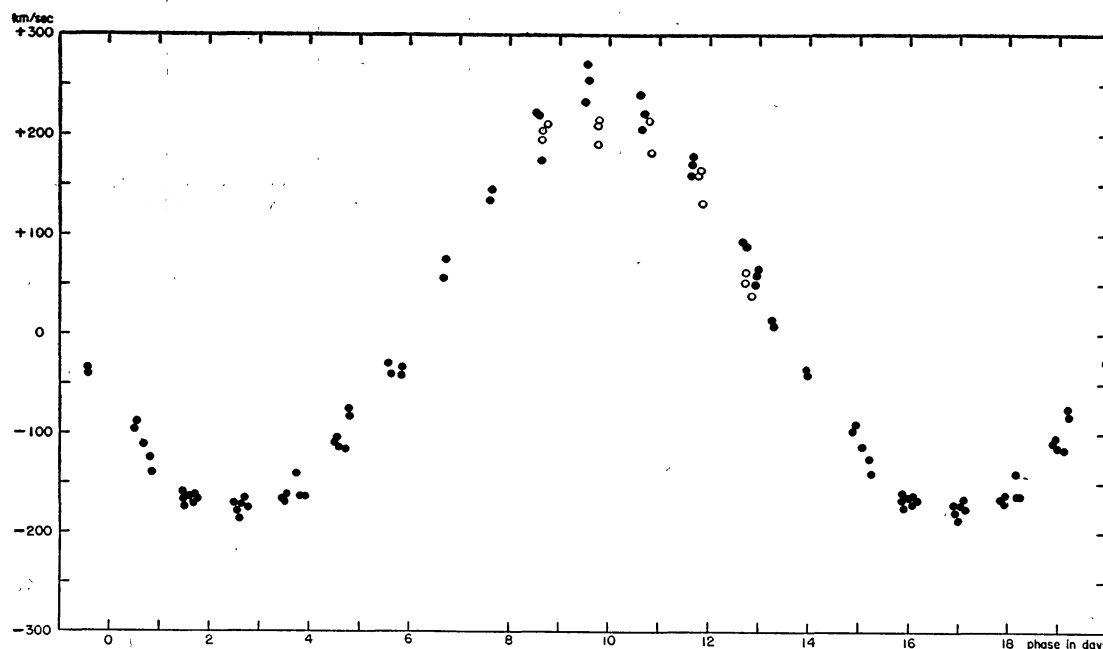


FIG. 1.—Velocity-curve of the primary component of HD 47129. The open circles near the maximum of the curve represent observations made 2 weeks later than the observations indicated by the filled circles.

whether differences in the formation of the He I lines, coupled with rapid axial rotation, could produce the observed effects.

The mean of all the interstellar Ca II velocities is $+16.0$ km/sec, in exact agreement with Plaskett's result.

The measurements of the fainter component show several interesting features (Figs. 2, 3, and 4).

1. Between my phases 0 and 4 days (when the primary is near minimum radial velocity) the velocities of the secondary are all systematically smaller than those predicted from Plaskett's elements, the average departure being about:

$$\text{Measured} - \text{computed} = -100 \text{ km/sec.}$$

A similar departure, though of a smaller amount, is clearly shown in Plaskett's velocity-curve. Since the lines are separated, near my phase 2.6 days, by about 325 km/sec, there can be no serious error resulting from the blending of the two components.

⁷ See the spectrum of 10 Lacertae (*Ap. J.*, 90, 699, 1939, Pls. XII and XIII).

2. Between my phases 6 and 13 days the velocities of the secondary show a large amount of scatter—far greater than can be attributed to errors of measurement—and the plotted points fail to show the curvature required by Plaskett's velocity-curve. The mean value is about -250 km/sec, which produces, over the interval of phases from 6 to 13 days, a large departure from Plaskett's curve in the sense

$$\text{Measured} - \text{computed} = -100 \text{ km/sec}.$$

This lack of curvature, with a general tendency of the plotted points to fall below the computed curve is also evident in Plaskett's results. We are faced with the peculiar conclusion that, on the average, the fainter component requires a γ -velocity which is about 100 km/sec less than that derived from the principal component.

3. The secondary spectrum was measured on four plates with phases between 12 and 13 days. The corresponding velocities of the primary are about $+60$ km/sec, which

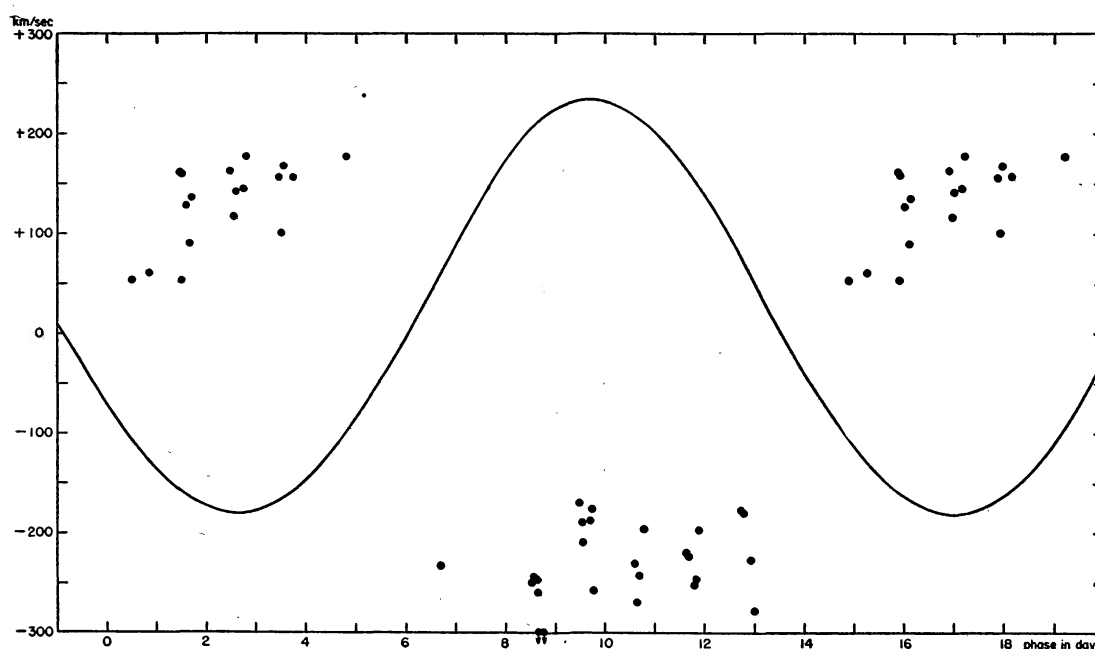


FIG. 2.—Radial velocities of the secondary component of HD 47129. The curve represents the average velocity-curve of the primary component.

differs by only 36 km/sec from the γ -velocity. Yet at these same phases the secondary gave an average velocity of the order of -220 km/sec, or about 244 km/sec less than the γ -velocity. It is clear that the ratio $36/244$, which would normally be identical with the mass-ratio, m_2/m_1 , has no real significance.

4. On all spectrograms between phases 0 and 4 days the lines of the secondary are weak. They are best seen in $H\gamma$, but they were also measured in the case of $He\ I\ 4026$, 4472 , and several other lines. They were not seen in $H\delta$, probably because of the blending effect with $N\ III\ 4103$. Between phases 6 and 13 days the intensities of the secondary component are subject to very large variations. For example, in cycle I at phase 9.5 days (December 6) the secondary was very strong—almost as strong as the principal component. But on the following night, phase 10.6 days (December 7) the secondary was very weak. I estimate that the equivalent widths of these lines had decreased by a factor of 3 or 4. Yet from the velocity-curve it appears that both phases fall very close to the time of elongation (maximum radial velocity of the primary) so that the separa-

tion of the components on the plates should have been about the same. There is no dynamical interpretation of this result. Nor is it possible to attribute variations of brightness to the secondary, sufficient to produce the observed changes in the equivalent widths of the lines and at the same time consistent with the negative results of the photoelectric observers.

5. In cycle I the secondary component was very strong at phases 9.497, 9.537, and 9.574 days. In cycle III this component was weak at phases 9.708, 9.741, and 9.775 days. Instead, it was fairly strong at phases 8.644, 8.688, and 8.749 days of cycle III. The material is not sufficient to detect any periodicity in the recurrences of the large intensities of the secondary; but they certainly do not repeat themselves with $P = 14.4$ days. There are no such variations between phases 0 and 4 days.

6. The most unexpected result is perhaps obtained from a comparison of spectrograms taken near phase 9.5 days of cycle I with those taken near phase 8.7 days of cycle III. On both nights (December 6 and January 3) the secondary was strong—more so on the former than on the latter. Both sets of plates show several widely separated pairs of lines, especially of $He\ I$ and H . From the velocity-curve we should expect that the separation of each pair of lines would be slightly larger at phase 9.5 than at phase 8.7 days. Figure 3 shows that, instead, the separation of the $He\ I$ pairs is very much larger at phase 8.7 days than at phase 9.5 days. The separation of the H lines is also different on the two dates. If we take the two Process plates, CQ 6464 (phase 9.537 of cycle I) and CQ 6615 (phase 8.688 of cycle III), we obtain the summary given in the accompanying tabulation. This proves that the secondary component of the spectrum does not origi-

LINE	CYCLE I		CYCLE III	
	Principal Component	Secondary Component	Principal Component	Secondary Component
	(km/sec)	(km/sec)	(km/sec)	(km/sec)
$He\ I\ 3819$	+265	.....	+209	-351
$He\ I\ 4026$	+247	-184	+214	-356
$He\ I\ 4471$	+267	-200	+179	-390
Mean $He\ I$	+260	-192	+201	-366
Separation.....	452		567	
$H\delta$	+174	-243	+158	-305
$H\gamma$	+218	-204	+199	-355
Mean H	+196	-224	+178	-330
Separation.....	420		508	

nate in an ordinary star. Its intensities and radial velocities vary from cycle to cycle in such an erratic manner that no confidence can be placed in the mean velocity-curve derived from its lines. The mass-ratio of HD 47129 must therefore be regarded as unknown. It is, however, important to realize that this result in no way invalidates Plaskett's conclusion concerning the large mass of this system. The mass function is

$$\frac{m_2^3}{(m_1 + m_2)^2} \sin^3 i = [3.01642 - 10] K_1^3 P (1 - e^2)^{3/2} = 13.1 \odot.$$

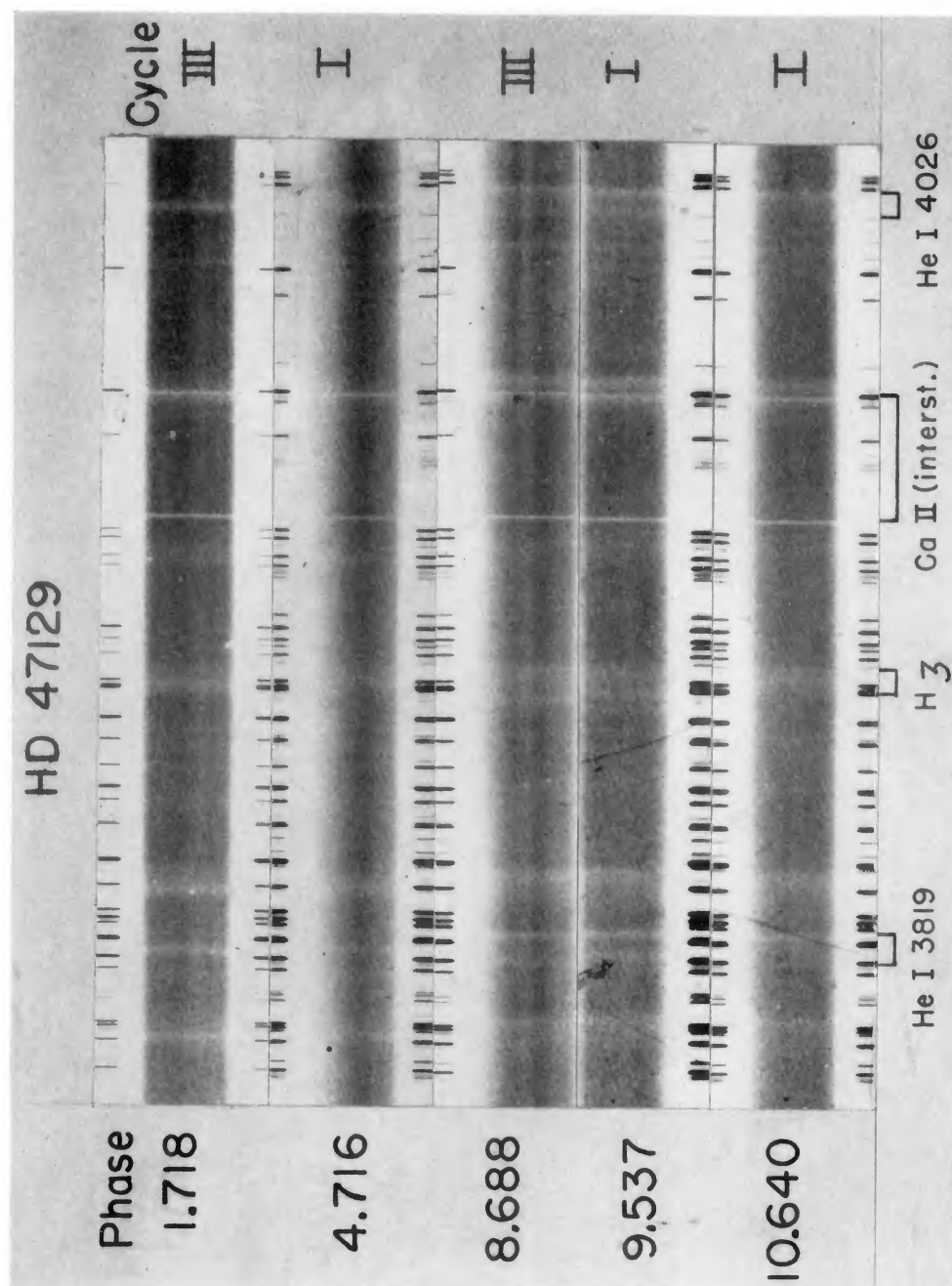


FIG. 3.—The spectrum of HD 47129. Notice that at phase 1.7 days the secondary is visible only as a faint, broad feature on the red sides of $H\zeta$, $H 9$, and $H 10$. The secondary is not clearly visible at $He I$. At phase 4.7 days the lines are almost single; notice that the blend $H\zeta + He I 3889$ is weaker than $H 9$ or $H 10$. At phase 8.7 days of cycle III the lines are widely double, and the secondary is strong in $He I$; it is somewhat weaker and more diffuse in H ; notice the strength of the violet component (secondary) for the blend $H\zeta + He I 3889$. The velocity-curve predicts that at phase 9.5 days the separation of the components should be even greater than at phase 8.7 days. Yet, in cycle I, at 9.5 days the separation was much smaller than at phase 8.7 days of the same cycle. At the same time, the intensity of the secondary was exceptionally great. On the following night, phase 10.6 days, the secondary had become very weak.

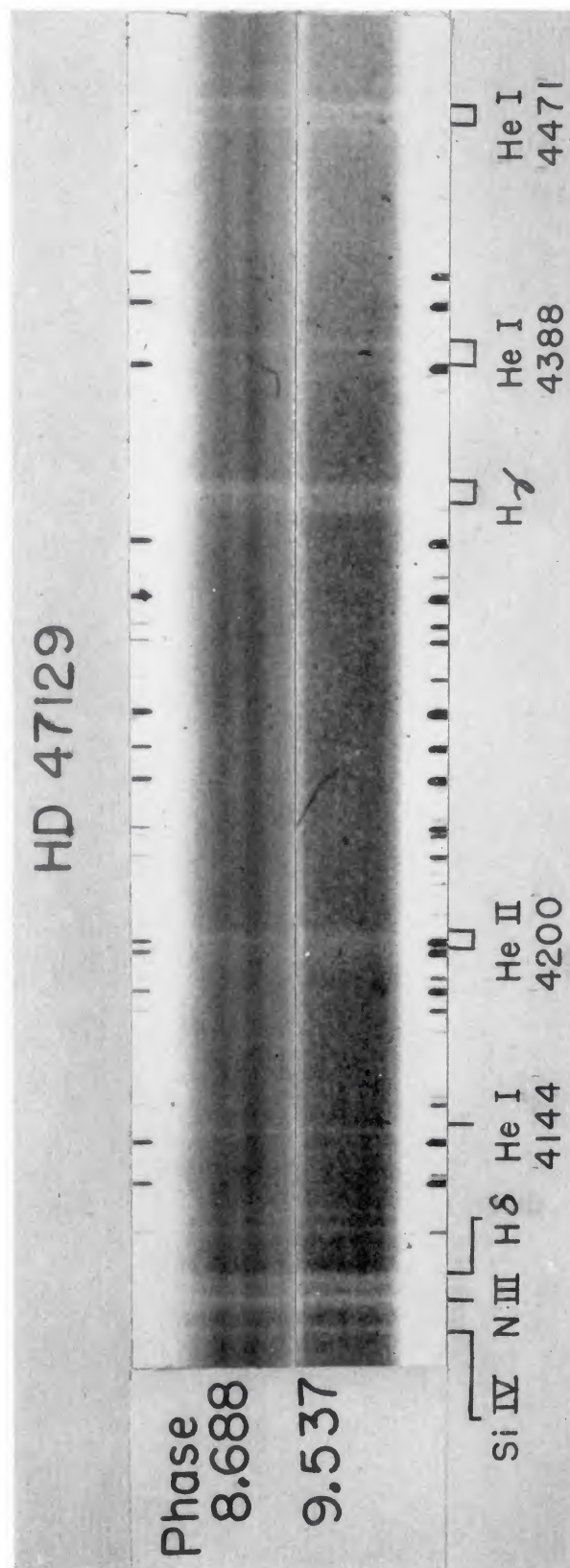


FIG. 4.—The spectrum of HD 47129. The difference in the separations of the two components is greater in the case of *He* I 4471 than in that of *H* γ .

Plaskett's individual masses are obtained with $m_1/m_2 = 1.2$. This value is now under suspicion. But, even with $m_1 = m_2$, we should still have $m_1 = m_2 = 52 \odot$. The only manner in which the mass of the principal component can be reduced below this value is to assume that the secondary is more massive than the primary. This might be possible if m_2 were a very red star, completely invisible in the photographic region of the spectrum. There is no observational evidence of the existence of such a red component. Several spectrograms on 103a-F emulsion show $H\alpha$ and D3 of $He\ I$ as fairly strong, widely separated, double emission lines. But there is no indication of a composite character in the spectrum, as far as $H\alpha$, which could be attributed to the blending with the light of a hypothetical red companion.

7. An interesting clue concerning the character of the source which gives rise to the erratic lines of the secondary spectrum appears in the blended line $H\zeta + He\ I\ 3889$. On all those spectrograms which show double absorption lines of H and $He\ I$ the lines of the secondary are always fainter than those of the primary. The only exception occurs near phases 9.5 of cycle I and 8.7 of cycle III, on both of which, as we have just seen, the lines of the secondary are *relatively* strong. Even on these dates all double lines show the violet component (secondary) as a fainter line than the red component (primary). The exception is $\lambda\ 3889$, in which the violet component is much the stronger. I have investigated the possibility that this may be caused by a blend. But the blending of $H\zeta$ with the $He\ I$ line cannot of itself be the cause of this effect, because their separation is only 0.4 Å. Nor can the blending with $He\ II\ 3887.44$ produce this effect, because the other H lines, all of which are blended with $He\ II$, are not affected in the same manner. It was at first disturbing that another absorption line appeared at phase 9.5 days of cycle I, just to the violet of the strong violet component of the $H\zeta + He\ I$ pair at $\lambda\ 3889$. This extra line gives to the entire feature the appearance of a triple line. Could the central component be the blend of the violet member of one pair and the red member of another pair? I believe that this is not the case. In the first place, we do not see the extra line at all in cycle III. In the second place, the undisturbed wave length of this extra line is $\lambda\ 3879.4$. Its identification is not known, but it can hardly represent the weaker (violet) component of a pair whose red component must, then, be even stronger. There is no such line to be found in the spectra of the normal O-type stars. It seems to me more plausible to suggest that the spectrum of the secondary component of HD 47129 is affected by the dilution of radiation, which results in the strengthening of the violet component of $He\ I\ 3889$. This spectrum is probably produced in a stream of gas not directly connected with any star.

8. The preceding section shows that there are unmistakable small differences in the appearance of the principal spectrum from cycle to cycle. These differences are erratic in character and occur rapidly—perhaps even between successive nights. They affect the relative intensities of the lines of different elements and, perhaps even more so, the profiles of the absorption lines. The latter are sometimes diffuse, while at other times they are quite narrow. These variations are, however, of a minor character and do not compare with those in the spectrum of the secondary. Together with the observed changes in the height of the maximum of the primary's velocity-curve, they suggest that the radial velocities of some O-type stars may be vitiated by streams of gas or perhaps by large masses of prominences whose integrated absorption effects need not always be symmetrical with respect to the undisplaced wave length of each line. It is possible that such a phenomenon is responsible for the anomalous velocities of such stars as 15 S Monocerotis,⁸ and it may not be necessary to attribute to the Trumpler stars the very large masses required to explain the anomalous velocities as gravitational red shifts.

9. Because of the large variations in the intensities of the lines of the secondary spectrum, it is probable that the gaseous streams responsible for them absorb the light of the

⁸ *Ap. J.*, 105, 499, 1947.

principal star and not that of the secondary; the latter may be invisible in the region covered by my spectrograms. Otherwise, it would be difficult to explain the great intensity of the secondary at phase 9.537 days of cycle I, without a marked "filling-in" of the lines of the primary by the continuous spectrum of the secondary. In reality, the lines of the primary are no shallower than is normal for a star of spectral class O. There is no parallel to this conclusion among other binary systems with gaseous streams: in β Lyrae the secondary spectrum gives a more or less uniform velocity of expansion; in UX Monocerotis the stream can be roughly described as a ring of gas, rotating in the same direction as the system of the two stars and set in motion by prominences erupting from the advancing hemispheres of both stars. In HD 47129 the lines of the secondary are strongest when they have a relative velocity of -400 or -500 km/sec with respect to the receding hemisphere of the primary star. It would be premature to attempt a dynamical explanation of the conditions in such a stream. It would have been more satisfactory in this respect, if we could have connected the streams with the secondary star. In that case the motion of the stream would depart by a smaller amount from that of the star and could perhaps be explained by assuming an expanding mass of prominences surrounding the latter and having an average velocity of the order of -100 km/sec with respect to it. But there is probably no escape from the conclusion that the changes of intensity are caused by varying amounts of gas in front of the brighter source of continuous spectrum.

10. The lines of the secondary are usually broader than those of the primary, and on some spectrograms (for example, at phase 8.688 days of cycle III) the space between the two widely separated absorption components seems to be affected by a slight amount of uniform absorption.

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