H.D. 163181, A SPECTROSCOPIC BINARY[1]

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ABSTRACT

Bright hydrogen lines were discovered in the spectrum of H.D. 163181 during the systematic search for Be stars carried on at Mount Wilson by means of objective-prism photographs on red-sensitive plates.

Slit spectrograms indicated that it is a spectroscopic binary with a large range of velocity and that the bright lines are variable in intensity. The period is 12.0040 days and the velocity range nearly 400 km/sec. The eccentricity is small, and the mass function, $\frac{m_1^3 \sin^3 i}{(m+m_1)^2}$, equals 8.84 ⊙. The system is therefore one of the most massive known.

The southern star H.D. 163181, C.D. $-32°13517$, R.A. $17^h 49^m.7$, Dec. $-32° 27'$ (1900), mag. 6.6, is classified in the *Draper Catalogue* as Oe5, with the remark, "The lines are so indistinct that the spectrum appears at first glance to be continuous."

Observations of the star were begun at Mount Wilson in 1920 when $H\alpha$ was found to be bright on a 10-inch objective-prism plate taken in the survey for the discovery of Be stars by Merrill, Humason, and Burwell.[2] In accordance with their program, observations were begun with a slit spectrograph and the star was classified as B1e. As in other Be stars, $H\alpha$ is much the strongest of the bright hydrogen lines. $H\gamma$ is the last of the series to appear bright. The presence of emission lines in the spectrum and the fact that the absorption lines are weak at some phases would probably explain the remark in the *Draper Catalogue* that the spectrum appears continuous.

The first slit spectrogram was obtained in 1921, and an additional one in each of the following years, 1922, 1923, and 1924. Measurements of the radial velocity from these four plates showed that the star is a spectroscopic binary with a large range in velocity. In 1925 a series of twenty-seven plates was obtained, which, with the early plates, gave sufficient material for the computation of the preliminary orbit. The resulting period of twelve days and a veloc-

[1] *Contributions from the Mount Wilson Observatory, Carnegie Institution of Washington*, No. 353.

[2] *Publications of the Astronomical Society of the Pacific*, **34**, 351, 1922.

ity range of almost 400 km/sec. showed that the system is very massive and similar to B.D.+6°1309, the orbit and mass of which were determined by J. S. Plaskett.[1] In 1926 and 1927 ten additional

TABLE I

OBSERVATIONS OF H.D 163181

Plate No.	Date	J. D. 2420000+	Phase in Days	Velocity	O−C	Normal Place
		G.M.T.		km/sec.	km/sec	
C 1196	1921 Aug. 12	2914.648	4.287	−179.1	− 5.2	3
1782	1922 July 11	3247.754	1.281	+ 93.9	−14.9	13
2345	1923 July 4	3605.759	11.168	+132.2	− 7.6	10
2850	1924 June 23	3960.833	6.124	−229.8	− 9.2	5
3226	1925 Mar. 18	4228.025	9.228	− 26.9	− 4.9	8
3231	Apr. 3	4244.020	1.215	+104.1	− 9.8	13
3244	Apr. 10	4251.025	8.220	−114.4	− 0.5	7
3247	Apr. 12	4253.993	11.180	+150.9	+10.5	10
3253	May 1	4272.000	5.187	−219.5	− 4.9	4
3258	May 1	4272.990	6.177	−240.6	−20.7	5
3263	May 3	4274.000	7.187	−188.1	− 3.2	6
3270	May 3	4274.959	8.146	−116.8	+ 3.1	7
3278	May 5	4276.002	9.194	− 28.1	− 2.3	8
3283	May 5	4276.972	10.159	+ 62.8	− 3.5	9
3288	May 6	4277.973	11.160	+127.3	−12.0	10
3295*	May 8	4279.991	1.174	+115.8	− 1.1	13
3302	May 29	4300.904	10.083	+ 62.2	+ 2.7	9
3307	May 30	4301.956	11.135	+135.1	− 3.0	10
3314	June 5	4307.830	5.005	−218.1	− 9.0	4
3319*	June 6	4308.907	6.082	−199.9	+21.2	5
3323	June 7	4309.898	7.073	−173.9	+16.8	6
3329	June 11	4313.798	10.973	+142.3	+13.5	10
3333	June 12	4314.835	0.006	+158.2	− 3.9	11
3340	June 13	4315.848	1.019	+125.9	− 1.8	12
3342	June 14	4316.876	2.047	+ 57.1	+23.2	1
3346	June 15	4317.859	3.030	− 91.0	−24.4	2
3351	June 16	4318.857	4.028	−177.1	−21.0	3
3365	July 2	4334.751	7.918	−139.4	− 1.7	7
3381	July 6	4338.792	11.959	+168.5	+ 6.5	11
3390	July 10	4342.659	3.822	−152.2	−12.1	3
3398	July 12	4344.705	5.868	−208.5	+14.1	5
3787	1926 May 2	4638.959	0.022	+166.2	+ 4.1	11
3825	June 20	4687.859	0.906	+130.3	− 4.1	12
3832	June 21	4688.855	1.902	+ 74.0	+21.7	1
3874	July 1	4698.854	11.901	+138.1	−23.6	11
3991	Aug. 24	4752.670	5.697	−217.6	+ 4.8	5
3997*	Aug. 25	4753.661	6.688	−206.7	+ 0.2	5
4236	1927 Apr. 18	4989.014	1.961	+ 45.4	− 0.8	1
4280	May 22	5023.908	0.843	+151.1	+12.8	12
4315	June 17	5049.853	2.780	− 8.4	+32.2	2
4416	Sept. 9	5133.652	2.551	+ 2.8	+19.1	2

* Ten-inch camera.

[1] *Monthly Notices, Royal Astronomical Society*, **82**, 447, 1922.

plates were obtained. All the observations were then divided into thirteen normal places and corrections to the elements were derived by the method of least squares.

On account of the southern declination of the star, all plates have been made with the 100-inch Hooker telescope. The regular Cassegrain spectrograph has been used with one prism and the 18-inch camera for all but three of the plates. For these three plates a 10-inch camera was substituted. The observations are given in Table I. The decimal of a day in the third column is reckoned from Greenwich mean noon, and the phase, in the fourth column, in days, is from the time of maximum velocity.

TABLE II

ELEMENTS OF H.D. 163181

	Preliminary Elements	Final Elements
P	12.0040 days	12.0040 days
e	0.075	0.065
ω	23°0	23°2
K	200.0 km/sec.	192.4 km/sec.
T	J.D. 2424279.453 G.M.T.	2424279.497 G.M.T.
γ	−44.0 km/sec.	−41.8 km/sec.
$a \sin i$	....	31,700,000 km
$\frac{m_1^3 \sin^3 i}{(m+m_1)^2}$	....	8.84 ⊙

The ever changing character and intensity of the hydrogen emission seem to affect the measured position of the hydrogen absorption lines to some extent, apparently producing rather large negative residuals at most phases. The velocities given in Table I therefore do not include those obtained from the hydrogen lines.

The preliminary and final elements are given in Table II. The velocity of the center of mass, 41.8 km/sec., is rather large for the ordinary B-type star, for which the average velocity is of the order of 9.0 km/sec. The velocity-curve calculated from these elements and the individual observations are plotted in Figure 1.

Although plates at maximum and minimum velocity were examined carefully, no lines in the secondary spectrum were observed. One widened spectrum taken on a fine-grained plate near maximum velocity also failed to show lines belonging to the secondary spectrum. With only one spectrum available, the values of $m \sin^3 i$ can-not be obtained as they can for Plaskett's star B.D.+6°1309. The mass function $\frac{m_1^3 \sin^3 i}{(m+m_1)^2}$ for B.D.+6°1309, as derived for the primary, is 13.16, as compared with 8.84 for H.D. 163181. Assuming $m = m_1$, we find $m \sin^3 i = 35.4$ ⊙ for H.D. 163181, and, with the same as-

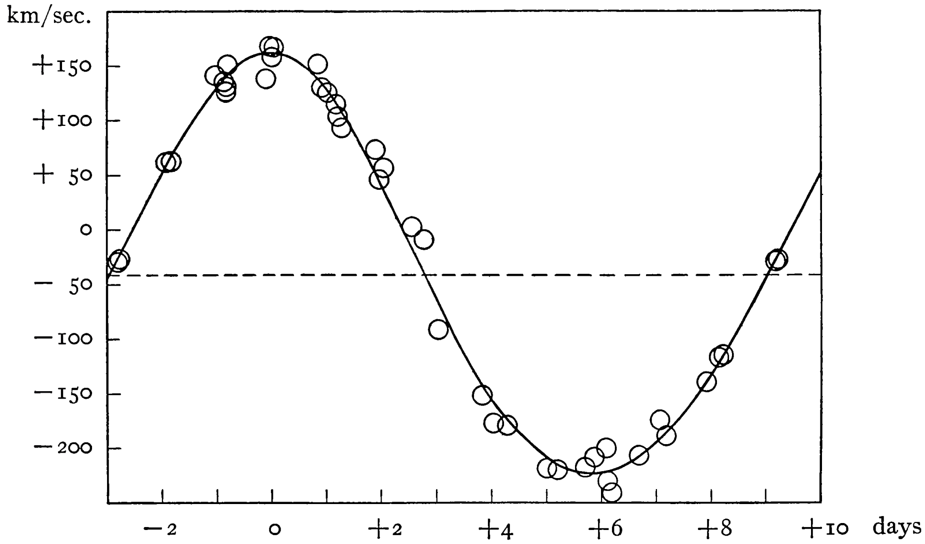

FIG. 1.—Velocity-curve for H.D. 163181

sumption, 52.6 ⊙ for B.D.+6°1309. The values for the individual masses of B.D.+6°1309 are

$$m_1 \sin^3 i = 75.6 \odot$$
$$m_2 \sin^3 i = 63.3 \odot$$

The mass of H.D. 163181 is therefore probably somewhat less than that of B.D.+6°1309, although of about the same order of magnitude.

On account of the southern declination of H.D. 163181, only one spectrogram was obtained in a night, and the possibility of a period of about one day must be given careful consideration. The observations are fairly well represented with a period of 1.08759 days. Eight of them, however, give residuals greater than 30 km/sec., and the mean residual without regard to sign is 19 km/sec. The period 0.92081 days also gives a fair representation, with ten residuals greater than 30 km/sec. and a mean residual of 23 km/sec. With the adopted period 12.004 days, only one residual is greater than

30 km/sec., and the mean residual is 10 km/sec. Although the long period is therefore probably the true one, attempts will be made to obtain two plates in a night, so that the question of a short period may be still more definitely settled.

The southern declination of H.D. 163181 means a loss of blue light when observed from Mount Wilson, and it has been rather difficult to obtain the proper amount of exposure to the violet of λ 4100. This difficulty may also be partly accounted for by the fact that the star seems to be abnormally red. The *Draper Catalogue*

TABLE III

LINES IN H.D. 163181

λ	Element	Int.	λ	Element	Int.	λ	Element	Int.
3933	*Ca*	......	4241	*N*	1	4601	*N*	1
3964	*He*	......	4253	*S* ?	0	4607	*N*	1
3968	*Ca*	......	4340	*H*γ	......	4621	*N*	1
3970	*H*ε	......	4387	*He*	5	4641	*O*	2
4026	*He*	1	4447	*N*	0	4685	*O*	......
4088	*Si*	3	4471	*He*	8	4713	*He*	3
4097	N^{+}	1	4481	*Mg*	1	4861	*H*β	......
4101	*H*δ	......	4552	*Si*	5	4921	*He*	3
4116	*Si*	2	4567	*Si*	3	5015	*He*	......
4120	*He*	1	4574	*Si*	1			

gives the photometric magnitude as 6.62 and the photographic magnitude as 7.5. The resulting color-index is +0.9, approximately that of a star of type K0, making it over a magnitude redder than stars of its class, B1, for which the normal color-index is −0.22.

The wave-lengths, intensities, and identifications of the absorption lines in H.D. 163181 are given in Table III. The intensities were estimated near phase 9.5 days, when the absorption lines have their maximum intensity.

A number of the lines in Table III have been measured on a few of the better plates only. The intensity of the lines varies with the phase, although for the weaker lines the apparent variation is probably affected by the exposure and the quality of the individual plates.

The hydrogen lines exhibit more conspicuous variation in structure than do the other lines, and are therefore ill adapted to velocity measurements.

Weak emission can usually be seen on the long wave-length edge of the dark helium lines, especially λ 4471. About two days before maximum velocity, however, the dark portions of the lines are relatively strong and the emission is very weak or absent.

The presence of emission near the helium lines has been observed in at least one other star of large mass, Plaskett's star B.D.+6°1309;[1] and this same condition has been mentioned in connection with 27 Canis Majoris[2] by Struve, who calls attention to observations by Merrill, which indicate that the helium lines are possibly accompanied by bright edges.[3] Struve states, however, that the helium lines "appear perfectly dark on all of our plates."

When the displacement of the absorption lines in H.D. 163181 is to the red, especially near maximum velocity, the emission is stronger on the violet edge; and when the displacement of the absorption lines is to the violet, the emission on the red edge is the stronger.

The absorption spectrum in general reaches a maximum at phase 9.5 days. A single plate taken at phase 3.0 days shows the emission very much stronger than at any other phase. The strengthening of the emission at this phase must occur in a very short interval, as a plate taken 0.3 day earlier and one 0.8 day later show the emission to be about normal. This is also the only phase where the emission at $H\beta$ is single and appears almost central on a wide absorption line. At all other phases the emission appears at one or both edges of the dark line.

The calcium lines H and K are present, but only two of the plates have sufficient density to show them. These two plates are decidedly under-exposed for this region, and the calcium lines are very weak and narrow. They are apparently stationary, but the measures have little weight.

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[1] *Monthly Notices, Royal Astronomical Society*, **82**, 448, 1922.

[2] *Astrophysical Journal*, **65**, 284, 1927.

[3] *Lick Observatory Bulletin*, **7**, 170 (No. 237), 1913.