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THE WOLF-RAYET STAR HD 193077: EVIDENCE FOR A LOW-MASS COMPANION AND THE POSSIBILITY OF A THIRD BODY

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ABSTRACT

The Wolf-Rayet component of HD 193077 is shown to consist of a WN 6 star orbited by an unseen, low-mass, probably neutron star with a period of 2.3238 ± 0.0001 days. This system in turn may be in mutual orbit around a rapidly rotating, but modest, OB star in a period of 1763 ± 15 days.

Subject headings: stars: binaries — stars: individual — stars: Wolf-Rayet

I. INTRODUCTION

With magnitude $v = 8.2$, HD 193077 is one of a group of eight relatively bright ($v < 8.5$) Wolf-Rayet stars in the Cygnus region of the Milky Way. Only two of the eight stars, HD 193576 = V444 Cygni and HD 190918, show unequivocal, double-line, W-R + OB binary orbits (see Moffat and Seggewiss 1980). If any of the remaining stars are binaries with detectable orbital motion, it has not been obvious. Recently, Koenigsberger, Firmani, and Bisiacchi (1980) have suggested that another of the Cygnus stars, HD 192163, is a single-line binary with a low-mass, probably compact companion. This, and the fact that one expects to find many such low-amplitude binaries among single-line W-R stars (Moffat and Isserstedt 1980; Vanbeveren and Conti 1980), justifies a more intense search for binaries among the remaining Cygnus W-R stars which are bright enough to observe at relatively high dispersion.

With spectral class WN 5 (+OB) according to Smith (1968), HD 193077 has always been assumed to be a binary with two distinct sets of lines: emission from the W-R component and absorption fom an OB companion. Recently, however, Massey (1980*a*) has analyzed radial velocity measurements of a large number of high-dispersion, photographic coudé spectra spread mainly over about a year. The velocity variations of the best emission line yield $\sigma = 20$ km s^{-1}, allegedly due to measuring error. Massey (1980*a*) claims that the extremely high rotational velocity implied by the broad absorption lines imposes a limit on any possible orbital inclination ($i > 42°$). This excludes the possibility of a massive companion except for the case of a high eccentricity or a very long period. Consequently, he did not conduct a period search and concluded that the wide absorption lines are intrinsic to the W-R star, which would then be a peculiar WN 5 object.

A closer examination of the Massey (1980*a*) published radial velocity data for the relatively narrow, moderately strong, symmetric emission line due to N IV λ4058 reveals the possibility of a period of 2.321 days. Subsequent analysis of independent spectroscopic data obtained before, during, and after those of Massey gives strong support to the reality of this periodicity. In addition, a long period is also found. We present here an analysis and an interpretation of all these observations.

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II. OBSERVATIONS

Five distinct groups of spectroscopic data are available as well as several sporadic observations; they are described in Table 1. Of all the emission lines measured for radial velocity, only N IV λ4058 and He II λ4686 are *sufficiently narrow*, intense, and symmetric (see Fig. 1) to be worth retaining for analysis. Despite the extremely wide and shallow nature of the absorption lines, we also consider Massey's (1980*a*) mean velocities of H8–11 and He I λ3820, which are the best data available to study the OB component of the spectrum.

Radial velocities for groups III–V and the 1945–1952 plates from the archives of the Dominion Astrophysical Observatory (see Table 2) were measured in the photographic density mode using the PDS at the David Dunlap Observatory (see Moffat 1978). The continuum was reduced to constant density by quadratic interpolation. Group I spectra were measured by Bracher (1966) on a Grant comparator, while group II was obtained by Massey (1980*a*) using the PDS at the High Altitude Observatory. For the emission in group II, we consider only the velocities v_1, which correspond more than v_2 to Bracher's and our mode of measurement.

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TABLE 1

SPECTROSCOPIC OBSERVATIONS OF HD 193077[a]

	Group I	Group II	Group III	Group IV	Group V
Observatory[b]	KPNO	KPNO	KPNO	DAO	MMO
Source/ Date obtained	1/ 1964	2/ 1978	3/ 1978, 1979	3/ 1978	3/ 1979, 1980
Wavelength range (Å)	3400–5000	{3600–4900 / 3740–4150}	3800–4900	3900–4800	3800–4900
Dispersion (Å mm^{-1})...........	128	{16.9 / 9.9}	46	78	43
Emulsion	IIa-O	{IIa-O / IIIa-J}	IIIa-J	IIa-O	IIa-O
Image tube	No	{No / Yes}	Yes	No	No
Mean exposure (minutes)............	2	{80 / 10}	1.5	4	60
No. plates	13	38	12	13	13

[a] Individual plates were also measured from DAO (prism plates with 50 Å mm^{-1} at H_γ from 1945 [4], 1948 [1], and 1952 [1]), and some isolated plates were considered (11 plates from Bracher 1966 communicated to Massey 1980*b* and the first plate in Massey's 1980*a* list).

[b] KPNO, Kitt Peak National Observatory; DAO, Dominion Astrophysical Observatory; MMO, Mont Mégantic Observatory.

SOURCES.—(1) Bracher 1966; (2) Massey 1980*a*; (3) this paper.

In addition to the above spectroscopic observations, we obtained intermediate-band photoelectric photometry in 1979 September for HD 193077, alternatingly with the comparison stars HD 192445 (B3) and HD 192538 (A2). We used the No. 4, 0.4 m telescope at Kitt Peak National Observatory (KPNO). After interpolation, values of *m* (HD 193077) minus *m* (comparison, reduced to HD 192445) are listed in Table 3.

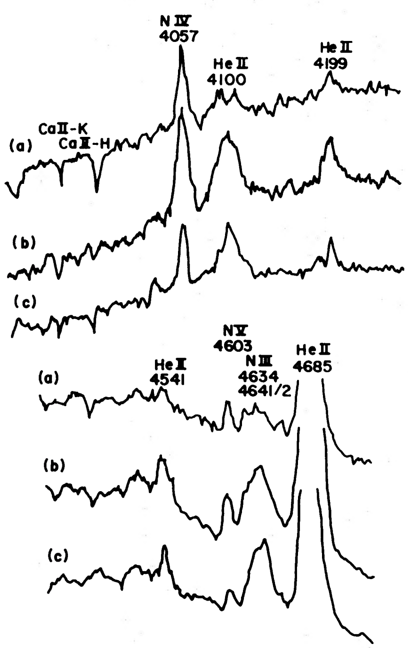

FIG. 1.—Photographic density tracings of single IIIa-J image tube plates from group III of (*a*) HD 219460, WN 4.5 + B0 III (*b*) HD 193077, WN 6 + O, and (*c*) HD 214419, WN 7.

III. ANALYSIS OF THE DATA

a) *Spectral Classification*

We reexamine in Figure 1 the spectral class for HD 193077 by interpolation between stars whose spectra straddle it morphologically. Two stars which have the most similar overall line widths to HD 193077, and for which we have similar KPNO spectra, are the slightly cooler WN 7 star HD 214419 = CQ Cep (Smith 1968 gives WN 7 + O7, but the absorption lines appear to be intrinsic to the WN 7 star [Leung, Moffat, and Seggewiss 1981]) and the hotter WN 4.5 star HD 219460. The latter star has a 1″ B0 III visual companion which was unavoidably allowed to pass through the spectrograph slit. Following the system of Smith (1968), we estimate the relative emission intensities of N V ($\lambda\lambda$4603, 4619); N IV (λ4058); N III ($\lambda\lambda$4634, 4641/4642). By interpolation, we obtain the type WN 6 for HD 193077 with an uncertainty of about $\pm$ half a subclass. This is slightly cooler than the WN 5 class assigned previously to the component by Smith (1968) and van der Hucht *et al.* (1981) and is due primarily to the relatively strong N III emission.

The strength of He I λ3820 relative to neighboring Balmer lines (see Massey 1980*a*) suggests a spectral type of O9 or slightly later for the OB absorption spectrum.

b) *Period*

For each of groups I–V, we subjected the radial velocity measures of the best emission line, N IV λ4058, to a test for periodicity using (1) the method of Lafler and Kinman (1965) and (2) a simple sine-wave fit of the form $C_0 + C_1$

TABLE 2

EMISSION LINE VELOCITIES (km s^{-1}) OF GROUPS III–V

Plate	JD 2,440,000+	Phase	N IV 4057.80	He II 4685.68
		Group III		
4831 c........	3766.784	0.491	−87	10
4832 d	3767.622	0.851	−102	66
4834 d	3768.733	0.329	−90	22
4838 e........	3769.720	0.754	−89	55
4844 g	3771.754	0.629	(−44)	88
4849 c........	3772.776	0.069	−99	19
Mean (σ)	...	...	−93 (7)	43 (31)
5117 e........	4125.831	0.997	−54	100
5121 g	4126.783	0.406	−23	98
5126 a	4127.749	0.822	−58	92
5130 a	4128.667	0.217	−49	80
5135 a	4129.666	0.647	−73	87
5141 c........	4132.708	0.956	(−77)	(27)
Mean (σ)	...	...	−51 (18)	91 (8)
		Group IV		
82362	3648.983	0.799	(−43)	30
82376	3649.960	0.219	−83	28
82418	3651.889	0.045	−116	15
82446	3652.975	0.516	−141	32
82470	3656.972	0.236	−93	82
82494	3657.973	0.667	−123	41
82515	3658.974	0.098	−87	29
82542	3659.972	0.527	−137	52
82568	3660.968	0.956	−104	57
82583	3661.971	0.387	−116	54
82603	3662.974	0.819	−146	56
82608	3663.823	0.184	−112	52
82617	3663.979	0.152	(−204)	79
Mean (σ)	...	...	−114 (21)	47 (20)
		Group V		
90 a	4031.754	0.513	−52	119
122 a	4068.724	0.422	−75	108
Mean (σ)	...	...	−64 (16)	113 (7)
168	4363.788	0.395	−96	122
171 a	4364.758	0.812	−76	122
208 a	4474.618	0.087	−79	87
209 b	4474.741	0.140	−93	98
210 b	4475.819	0.604	−107	89
212 a	4476.602	0.941	−95	103
213 b	4476.731	0.997	−87	103
218 b	4480.627	0.673	−103	87
223 c	4481.634	0.107	−102	82
249 a	4504.579	0.980	−83	88
250 b	4504.735	0.047	−93	85
Mean (σ)	...	...	−92 (10)	97 (14)

INDIVIDUAL PLATES MEASURED FROM DAO

Plate	JD 2,430,000+	N IV 4057.80	He II 4685.68
35215	1621.890	−59	77
35591	1729.685	−53	86
35610	1733.647	−43	...
35611	1733.700	−53	106
Mean (σ)	...	−52 (7)	90 (15)
38572	3710.869	−138	28
43636	4212.858	−121	74

NOTE.—Bracketed values are uncertain and are omitted from the mean. Phases are based on the 2.3238 day ephemeris in Table 5 ($e = 0$).

$\sin(2\pi/P)t + C_2 \cos(2\pi/P)t$. Periods were searched from $P = 0.25$ to 20 days with increment $\Delta P = P^2/16\pi T$, where T is the total time span of the group. Since the N IV velocities (VR) vary slowly with time (see below) and are subject to differences arising from various instruments used, we have subtracted off the mean for each subgroup, yielding VR'. We limit ourselves to subgroups containing at least five data points; there are one, six, two, one, and three subgroup(s) in each of groups I–V, respectively.

Table 4 presents a resumé of the five best periods found in each group except group V, which suffers from phase crowding. The uncertainties in the periods are estimated from the width of the local minimum of the period selection parameter. We note that two periods dominate: 2.33 and 0.39 days, with the former being more consistent from one group to another. Although several other simple aliases of 2.33 days occur below 2.0 days for a sampling interval of 1 day (see Table 4), the clearest alias period is $P' = 0.39$ days, where $1/P' = 3 - 1/2.33$. Thus, it appears that one or the other of these is likely to represent the true period. To determine which one does, we subjected *all* the data for N IV λ4058 from groups I–V simultaneously to a period search centered on $P = 2.33$ and 0.39 days, respectively, using the techniques mentioned above. Clearly, $P = 2.3238 \pm 0.0001$ days dominates, and we adopt it as

TABLE 3

PHOTOELECTRIC OBSERVATIONS m(HD 193077) − m(comparison)[a]

JD 2,440,000+	PHASE	λ4886	λ4672 − λ4886	λ4257 − λ4886
		CENTRAL WAVELENGTHS (Å)		
4119.775	0.390	1.036	−0.144	0.330
4120.839	0.848	1.051	−0.160	0.334
4121.738	0.235	1.053	−0.141	0.328
4121.948	0.325	1.039	−0.147	0.337
4122.804	0.693	1.042	−0.153	0.336
4123.803	0.124	1.019	−0.165	0.330
4123.926	0.177	1.039	−0.138	0.345
Mean (σ)	...	1.040 (0.011)	−0.150 (0.010)	0.334 (0.006)

[a] For three filters with central wavelengths as given and FWHM of 213, 168, and 94 Å from red to blue, obtained just before the 1979 KPNO data in Table 2.

TABLE 4

BEST PERIODS[a] IN THE RANGE $0.25 \leq P \leq 20$ days FOR N IV

Group	Period (days)
I	0.406 ± 0.003
	2.33 ± 0.01
	0.698 ± 0.004
	0.517 ± 0.006
	1.160 ± 0.003
II	0.3098 ± 0.0001
	2.325 ± 0.005
	0.470 ± 0.002
	0.3989 ± 0.0001
	0.6205 ± 0.0001
III	2.30 ± 0.04
	0.3918 ± 0.0005
	0.2708 ± 0.0007
	0.649 ± 0.0003
	1.86 ± 0.03
IV	0.412 ± 0.001
	0.700 ± 0.001
	2.30 ± 0.002
	0.280 ± 0.0003
	0.634 ± 0.002

Aliases[b]

n	P'
1	1.755, 0.699
2	0.637, 0.411
3	0.389, 0.292
4	0.280, 0.226

[a] Top is best.

[b] $1/P' = n \pm 1/P$ for $P = 2.3238$ days.

final. Evidently, the sampling interval is not precisely constant and thus allows a choice between the two possibilities.

In Figure 2, we show a phase plot with this period for the data of each group separately. We note here that the amplitude *appears* to be variable from group to group. Although this may be partly intrinsic to the star, the amplitude tends to be smaller where a relatively small number of observations is encountered or where the data are inadvertently accumulated in a relatively narrow phase interval (III and V in Fig. 2). Despite these difficulties, we assume the variation to be real and lasting since the data were obtained with different instruments over an interval of ~ 16 years. The fact that the same period (and its aliases) shows up in at least four independent data sets makes for a convincing case.

c) *The Orbital Parameters*

Using all the data of groups I–V for N IV λ4058, after subtracting off the subgroup means, we made an orbit analysis for the case of an eccentric and a circular orbit. The results for each are presented in Table 5. Since the

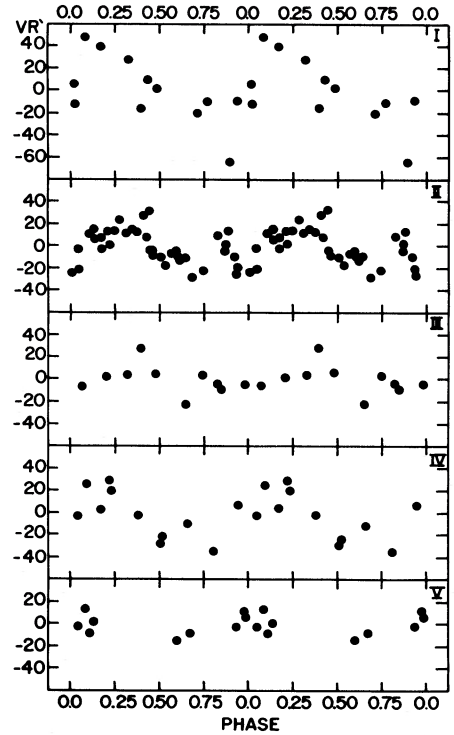

FIG. 2.—Radial velocity of N IV λ4058 minus mean for the corresponding subgroup, VR' (km s^{-1}), versus the 2.3238 day phase for the circular orbit from Table 5 for groups I–V. Only subgroups with at least five data points are included.

eccentric solution is not significantly different from $e = 0$, we adopt the circular solution, which is shown along with the data in a phase plot in Figure 3. The rms residual is 13.0 km s^{-1} and does not vary significantly from one group to another. Lines like N IV can apparently be measured as well at moderate dispersion as at high dispersion. Using an F-test, the circular orbit in Figure 3 fits the data better than constant velocity at the 93% significance level. This includes the 13 degrees of freedom from subtracting the subgroup means. With the second-best period, one obtains 88%.

TABLE 5

ORBITAL PARAMETERS FROM N IV λ4058 AFTER SUBTRACTING OFF I–V MEAN VELOCITIES[a]

Parameter	Eccentric	Circular
P (days), fixed	2.3238 ± 0.0001	
K (km s^{-1})	16.2 ± 2.7	15.5 ± 2.6
T (JD)	2,438,628.51 ± 0.28	...
ω (°)................	45 ± 45	...
e	0.19 ± 0.16	0 (fixed)
E_0 (JD)	2,438,627.68 ± 0.06	2,438,627.64 ± 0.05
σ (km s^{-1})	12.9	13.0

NOTE.—E_0 is the time of passage through the γ-velocity from negative to positive.

[a] Based on data of groups I–V.

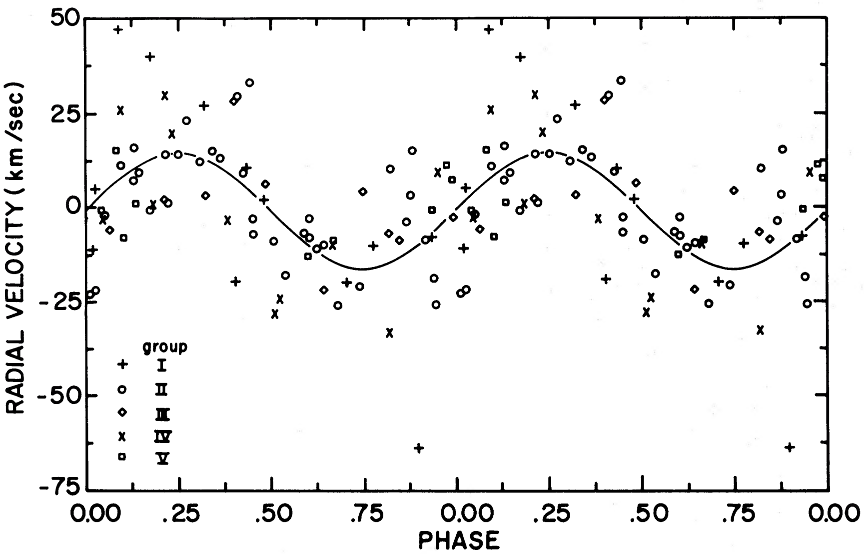

FIG. 3.—VR' and fitted curve for all N IV $\lambda 4058$ data versus phase for the circular orbit in Table 5

With the above circular orbit ephemeris for N IV $\lambda 4058$, we looked for phase-dependent variation in the emission line He II $\lambda 4686$, again after subtracting off subgroup mean values. No such variations are seen (Fig. 4) in either the raw or the smoothed data; a circular orbit fit yields $K(\lambda 4686) = 3 \pm 4$ km s^{-1}. All other emission lines, including N III $\lambda 4097$ measured by Massey (1980*a*), are too broad, weak, or asymmetric to permit a better determination or to pose more stringent limits on the velocity amplitude. We note, however, that many of Massey's (1980*a*) N III $\lambda 4097$ velocities follow the N IV orbit quite closely except those of his last subgroup, where the rms noise is increased considerably.

The only reliable, individual velocity measurements available for the absorption lines are from group II, where the signal-to-noise ratio is sufficiently high. After subtracting off subgroup means, the raw absorption line data plotted versus phase in Figure 5*a* show no significant systematic variation, although the scatter is high: $\sigma = 56$ km s^{-1} (Massey 1980*a*). The smoothed values in Figure 5*b* reveal a possible trend with phase, similar to the N IV $\lambda 4058$ emission. However, no point is located more than 1 σ from the zero level; hence, the probability of a real variation is very low.

IV. INTERPRETATION

a) *Nature of the Absorption Lines*

Although one could postulate that the absorption lines do in fact arise in the photosphere of the W-R component as suggested by Massey (1980*a*), this makes HD 193077

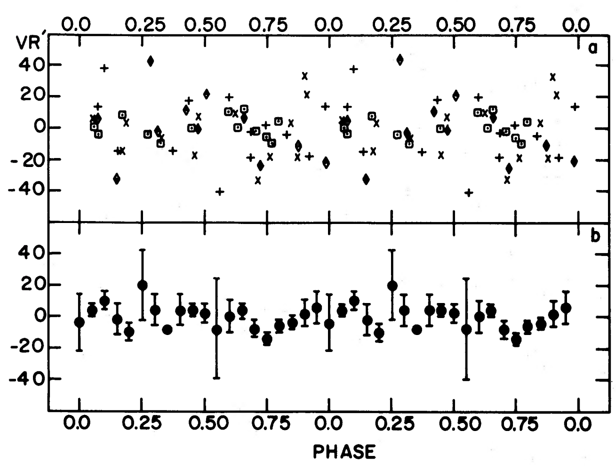

FIG. 4

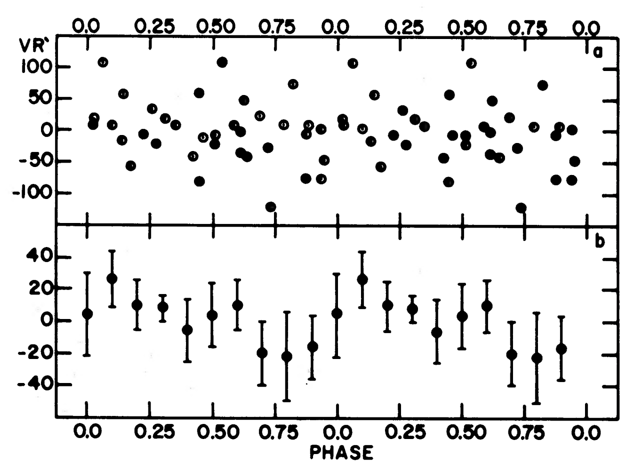

FIG. 5

FIG. 4.—VR' versus circular orbit phase in Table 5 for He II $\lambda 4686$ for (*a*) raw data (symbols as in Fig. 3) and (*b*) running means, each spanning 0.1 in phase. Error bars have total lengths of twice the standard error of the mean.

FIG. 5.—VR' versus circular orbit phase in Table 5 for the absorption lines from group II for (*a*) raw data and (*b*) running means, each spanning 0.2 in phase. Error bars as in Fig. 4.

unnecessarily peculiar. Not only would it be the only WN 6 star known so far whose envelope density is low enough to allow one to see down to the photosphere, but there is another problem: the width of the absorption lines implies a high rotational velocity, $v \sin i \approx 500$ km s^{-1} (Massey 1980*a*). In a binary with a period as short as $P = 2.3238$ days and an age of several million years, one would expect that synchronization of the rotation with the orbit would be established. With a likely radius of $R_{\rm WN\,6} \approx 5\ R_\odot$ (Rublev 1975), we obtain a hypothetical value $(v \sin i)_{\rm synch} < 2\pi R/P = 110$ km s^{-1} (even smaller for WN 5). If the absorption lines arise in the W-R star, we could thus be confronted with a highly nonsynchronous rotation, contrary to what is expected. To reach agreement between $(v \sin i)_{\rm synch}$ and $(v \sin i)_{\rm obs}$, $R_{\rm WN\,6}$ would have to be increased by a factor of 4–5, a rather unlikely situation.

b) *Triple System?*

The most natural explanation of these apparent abnormalities is to invoke a triple system composed of the WN 6 component orbiting a low-mass object (see § IV*c*) in 2.3238 days, while this combined system orbits a broad-line OB star with a much longer period.

We therefore subjected the mean of each subgroup of N IV λ4058 and He II λ4686, as well as the sporadic velocity measures in Tables 1 and 2, to the same test of periodicity using the sine-wave fit described earlier. The best periods found in a search from 100 days to ~ 50 years were 1763 ± 15 days, followed by 1533 ± 20 days, the latter being slightly less probable. We tentatively adopt $P = 1763 \pm 15$ days and make a circular orbit for each of the two lines; there are insufficient data to warrant fitting an elliptical orbit, although such an orbit might be expected in a long-period system. A fit was also made to the absorption line velocities. Due to the small number of data points for the absorption (group II only), the phase zero point from N IV λ4058 was adopted, and only γ and K were allowed to vary. The solutions for all of these lines are listed in Table 6 and shown in Figure 6.

Using a weighted mean from N IV λ4058 and He II λ4686, we derive a mass for the W-R star plus its companion and for the OB component:

$$M_{(\rm W\text{-}R+comp)} \sin^3 i = 41^{+37}_{-24}\ M_\odot\ ,$$

$$M_{\rm OB} \sin^3 i = 30^{+27}_{-18}\ M_\odot\ .$$

The mass ratio is $M_{(\rm W\text{-}R+comp)}/M_{\rm OB} = 1.4 \pm 0.6$.

TABLE 6

ORBITAL PARAMETERS FROM N IV λ4058 AND He II λ4686, AND THE MEAN OF THE ABSORPTION LINES[a]

Parameters	N IV λ4058	He II λ4686	Absorption[b]
P (days)........	...	1763	...
γ (km s^{-1})	−92 ± 3	69 ± 6	22 ± 7
K (km s^{-1})	28 ± 6	36 ± 8	42 ± 17
E_0 (JD).........	2,433,204 ± 30	2,433,250 ± 50	2,433,204 (fixed)
σ (km s^{-1})	11	10	14

[a] For the long period.

[b] From Bracher 1966; Massey 1980*b*.

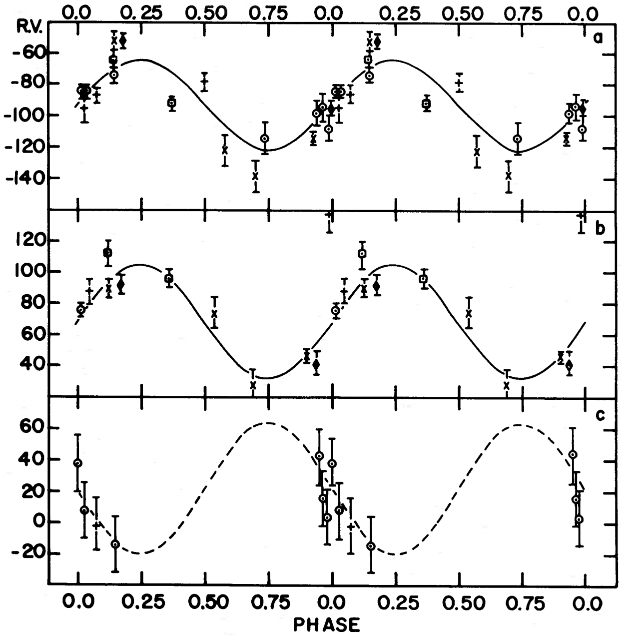

FIG. 6.—Mean radial velocity (km s^{-1}) for each subgroup and fitted curve versus long-period phase with symbols as in Fig. 3 for (*a*) N IV λ4058, (*b*) He II λ4686, and (*c*) absorption. Orbit parameters are from Table 6. Weights were assigned in proportion to the number of plates.

If the rotational and orbital axes are aligned, one expects $i \geq 42°$ for rotational stability (Massey 1980*a*). Neglecting its small-mass companion, the mass of the W-R star in HD 193077 would then be similar to that of the WN 6 component in HDE 311884 (Niemela, Conti, and Massey 1980).

Such multiple systems are not uncommon; Batten (1973) notes that about one-third of all systems containing two or more stars are triple. Theta Muscae is a good example of a likely triple system containing a W-R component (Moffat and Seggewiss 1977). Also, GP Cep (WN 6 + O) contains two spectroscopic pairs (Massey 1981).

Assuming that the OB spectrum arises from a third object, this object would have to be close to the main sequence in order to account for the dominance of the WN 6 component ($M_v \approx -4.8$ from the calibration of Smith 1973). Furthermore, if its spectral type is later than O9, this means that the OB component has $M_v \gtrsim -4.7$ and, along with the broad lines, explains why it is seen only with relative difficulty in the combined spectrum. Given an uncertainty at best of ±0.5 mag, these magnitudes yield a distance modulus of 12.0 ± 0.5 (see Moffat and Isserstedt 1980), which is marginally consistent with HD 193077 being a member of the Cyg OB1 association with a distance modulus of 11.3 ± 0.1 (Humphreys 1978).

c) *The Short-Period Pair*

From the circular orbit elements in Table 5, the mass function is $f(m) = 0.0009^{+0.0005}_{-0.0004}\ M_\odot$, which is very low compared to that of classical W-R + OB binaries. The virtually constant light curves both in the continuum and in the He II λ4686 line filters (Fig. 7) yield no precise

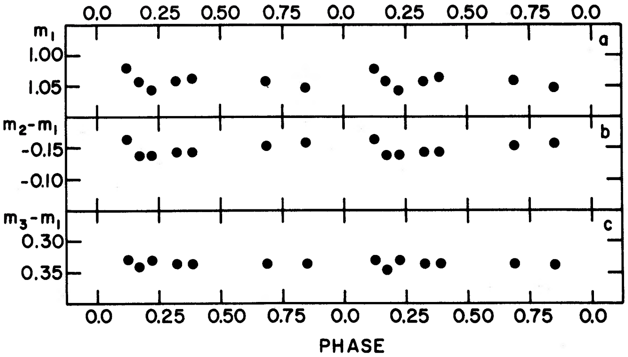

FIG. 7.—Light curves with phase from Table 5. Magnitudes refer to HD 193077 minus comparison star with indices 1 = λ4886, 2 = λ4672 and 3 = λ4257.

information concerning the orbital inclination of the short-period pair other than that suggested by the lack of an occultation. This implies that $i \leq 75°$ for the continuum if the unseen star has a negligible radius (see below). For the emission, a lack of a clear occultation does not necessarily imply a decreased upper limit for *i*, in view of the uncertainty of the integrated optical thickness of the W-R envelope. Therefore, assuming a nominal value $i \approx 60°$ for both pairs of orbits, and using the results obtained above for the (W-R + comp) and OB stars, we get

$$M_{\text{W-R}} = 61^{+57}_{-37}\ M_{\odot}\ ,$$

$$M_{\text{comp}} = 1.8^{+1.1}_{-0.7}\ M_{\odot}\ ,$$

$$M_{\text{OB}} = 46^{+41}_{-28}\ M_{\odot}\ .$$

While the W-R and OB star masses are not extraordinary, the low-mass companion is small, but in the range for observed neutron stars in binary X-ray sources (Crampton, Hutchings, and Cowley 1978).

The fact that He II λ4686 does not yield a velocity amplitude significantly different from zero may seem rather unusual. However, this line often shows reduced amplitude compared to other emission lines of similar ionization potential in close short-period W-R binaries; e.g., the shortest period (1.64 days) W-R binary known, CQ Cep (WN 7), has $K(\lambda4686) = 181 \pm 7$ km s^{-1}, while $K(\lambda4058) = 310 \pm 7$ km s^{-1} (Leung, Moffat, and Seggewiss 1981). Presumably, the He II λ4686 emission line is so strong that it arises from a much larger volume in the W-R envelope than occurs for weaker lines of similar potential. The outer regions of the envelope where λ4686 is formed are more susceptible to perturbations by a close companion. For the wider, long-period orbit, on the other hand, this line retains its full amplitude like that of N IV λ4058.

V. CONCLUSIONS

HD 193077 probably consists of three stars: a WN 6 star with a neutron star in a 2.3238 day orbit, both circling a slightly fainter, rapidly rotating, late O, main-sequence star in 1763 days. This makes it the sixth galactic W-R star suspected to contain a compact companion (see Isserstedt and Moffat 1980), with the complication here, however, of a third body. The runaway kick on the present system, produced by the rapid ejection of a supernova shell in the formation of the supposed neutron star, will have been considerably reduced by the presence of the OB star. More data are desirable to confirm the periods and to improve the mass estimates.

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