THE ASTROPHYSICAL JOURNAL, 239:212–219, 1980 July 1

SPECTROSCOPIC STUDIES OF O-TYPE BINARIES. VI. THE QUADRUPLE SYSTEM QZ CARINAE (HD 93206)

NANCY D. MORRISON[1]
Ritter Astrophysical Research Center, The University of Toledo

AND

PETER S. CONTI[1]
Joint Institute for Laboratory Astrophysics, University of Colorado and National Bureau of Standards;
and Department of Astro-Geophysics, University of Colorado
Received 1979 November 16; accepted 1980 January 9

ABSTRACT

QZ Carinae is an O-type, double-lined, eclipsing binary in the Carina Nebula. Our radial-velocity study shows that this system actually consists of two single-lined spectroscopic binaries in the same line of sight, probably in wide orbit about each other. In one of these binaries, which undergoes eclipses with period 5.9980 days, the primary has spectral type roughly O9 III and produces the weaker of the two observed sets of spectral lines. The star responsible for the stronger set is 0.6 mag brighter, has spectral type O9.5 I, and moves in an eccentric orbit about an unseen companion with period 20.73 days. We present radial velocities and determine orbits for both systems. A systematic difference in velocity between He I and Si IV in the supergiant suggests appreciable mass loss. Our spectrograms show broad Hα emission, which appears to vary in phase with the eclipsing binary.

Subject headings: stars: binaries — stars: early-type — stars: individual

I. INTRODUCTION

For stars with masses greater than about 40 $M_\odot$, mass loss influences the evolution of the star. Several sets of evolutionary tracks with mass loss now exist (Stothers and Chin 1979; Dearborn *et al.* 1978; Chiosi, Nasi, and Sreenivasan 1978; de Loore, De Grève, and Lamers 1977). Little is known, however, about mass-loss rates for massive stars and how they vary with time, and other aspects of the calculations are also uncertain (Stothers and Chin 1979). Therefore, it is highly desirable to determine empirical masses for real stars of known luminosity, effective temperature, and (ideally) mass-loss rate, in order to check the evolutionary tracks. Since few O-type binaries have yielded well-determined masses (Stothers 1973; Conti 1978), much remains to be done in the field of spectroscopic orbital analysis. Walborn (1973) classified HD 93206 as O9.7 Ib:(n) and discussed the question of its membership in the cluster Collinder 228, part of the Carina Nebula complex. When Walker and Marino (1972) showed it to be an eclipsing binary and Conti, Leep, and Lorre (1977) reported that it has double lines, doubts about its membership in the cluster were removed. Its status as a double-lined, eclipsing binary with known distance and with an O-type supergiant primary made it an excellent prospect for a mass determination that would be useful for checking evolutionary tracks. Accordingly, we began high-dispersion spectroscopic observations in 1974 and photometry in 1976. Only when the radial velocities had been reduced did we realize that the orbital periods of the two stars whose spectra we observe are not the same. As this paper will show, QZ Carinae is actually a pair of single-lined spectroscopic binaries in a wide orbit about each other (Morrison and Conti 1979). The brighter of the observed stars (which we call "Component A") is the primary in a 21 day binary with an eccentric orbit, and the fainter ("Component B") is the primary in the eclipsing 6 day system. When we refer to either binary as a whole, we will use the term "System A" or "System B."

Recently, Leung, Moffat, and Seggewiss (1979) analyzed the light curve by Walker and Marino (1972) and concluded that System B is semi-detached. They presented radial velocities and determined masses for System B, but their data are too few to determine an orbit for System A. We have obtained radial velocities and determined orbits for both primary stars, and will emphasize Component A. In what follows, § II describes the observational material, § III the orbital analyses, and § IV the spectrophotometric results. Section V gives our conclusions.

II. OBSERVATIONS AND DATA REDUCTION

During four observing seasons, we obtained blue and yellow-red spectrograms of QZ Car with Camera 1 of the coudé spectrograph of the 1.5 m telescope of the

[1] Visiting Astronomer, Cerro Tololo Inter-American Observatory, which is supported by the National Science Foundation under grant AST 74-04128.

TABLE 1

OBSERVATIONAL PARAMETERS

Parameter	Plate Series		
	1	2	3
Focus of telescope	coudé	coudé	Cassegrain
Wavelength range (Å)	3300–4900	5400–6800	4000–5000
Dispersion (Å mm^{-1})	17.5	35	39
Projected slit width (μm)	20	30	10
Widening (mm)	0.6, 0.8	0.6	1.0
Emulsion	IIa-O bkd	098-02	IIIa-J bkd

Cerro Tololo Inter-American Observatory. In addition, V. S. Niemela kindly obtained one Cassegrain spectrogram for us with the same telescope. Table 1 gives the observational details for all the spectrograms. All but the IIIa-J plate (JD 2,443,203.69) were developed in D-76 for 15 minutes and calibrated with the coudé spot sensitometer.

We measured nearly all the spectrograms in both forward and reverse directions with the Grant comparator at JILA and some of the plates in only one direction with the single-coordinate Grant machine at the Kitt Peak National Observatory. For three plates that were measured on both machines, we found good agreement. We averaged the radial velocities of Si IV and N III in Component B, and we formed another average for He I. In Component A, we found averages of the following groups of lines: H8–H11; Si IV $\lambda\lambda$4089, 4116; and He I. Not all He I lines were measured on every plate. In order of decreasing frequency with which they were measured, we used He I $\lambda\lambda$4471, 4026, 3819, 4387, 4120, 3634, 4143, 4713, and 4009. The Balmer lines higher than H11 gave discordant results because of blending, and the O II and O III lines were too weak to yield a good orbit. The lower Balmer lines suffered from pair blending, and Hβ was too broad and weak to measure.

Table 2 gives the radial velocities for each of the usable groups of lines. The first column gives heliocentric Julian date. For each component star, the succeeding columns give orbital phase, radial velocity, number of lines used, and the internal standard error in the mean of each group. The orbital phases are calculated from the elements derived below for the He I lines. Where the number of lines is always the same, it is omitted from Table 2, and the standard error is omitted when only 1 or 2 lines were measured. We did not attempt to correct these velocities for pair blending.

We traced some of the blue spectrograms with the Boller and Chivens microdensitometer at the High Altitude Observatory, using a slit width and a sample interval of 10 μm. The results were written on magnetic tape and digitally calibrated and normalized to continuum with the CDC 6400 computer of the University of Colorado. Equivalent widths were found by numerical integration.

P. Massey kindly traced for us the yellow-red spectrograms with the PDS microphotometer at the High Altitude Observatory. Slit width, sampling, and reductions were as described in the preceding paragraph. From tracings of the comparison spectrum, we found the centroids of the moderately exposed lines and determined the plate constants as is usual for radial velocities. We found the velocities of lines in the stellar spectrum by reading the position of line center from the tracing. Therefore, these positions are precise only to about ± 5 μm, which corresponds to ± 8 km s^{-1} at Hα. Table 3 gives the radial velocities of He I λ6678 and of the main stellar emission component of Hα.

We used these plate materials to find the velocities of the interstellar absorption lines and the brightest emission lines from the Carina Nebula. Table 4 gives the results. The emission-line velocities are consistent with those given by Moffat and Seggewiss (1978), and the absorption-line velocities are reasonably consistent with those given by Walborn and Hesser (1975).

III. ORBITAL ANALYSIS

We used two separate differential-correction programs for the orbital analysis. The first is a version of the program by Wolfe, Horak, and Storer (1967) and runs on the CDC 6400 at the University of Colorado. The second is a version of the program described by Barker, Evans, and Laing (1967) and runs on the IBM 360/75 at the J. Preston Levis Regional Computer Center, Bowling Green, Ohio. The main difference between them is that, in the second program, the size of the correction is kept small, and convergence is gradual. When run with identical data sets, both programs gave the same result to well within the formal errors. In all orbital analyses, all the observations had equal weight.

a) Component B

For the orbital analysis of Component B, we used only spectrograms on which this star's lines are resolved, and we analyzed the two groups of lines separately. Table 5 gives the two sets of orbital elements, which agree reasonably well with each other

TABLE 2

JOURNAL OF RADIAL-VELOCITY OBSERVATIONS OF QZ CARINAE IN THE BLUE REGION

Heliocentric Julian Date	Phase	Component A						Phase	Component B					
		He I			Si IV λλ4088,4116	H			He I			Si IV, N III		
2440000 +		V ($km\ s^{-1}$)	N	σ ($km\ s^{-1}$)	V ($km\ s^{-1}$)	V ($km\ s^{-1}$)	σ ($km\ s^{-1}$)		V ($km\ s^{-1}$)	N	σ ($km\ s^{-1}$)	V ($km\ s^{-1}$)	N	σ ($km\ s^{-1}$)
2117.73	0.286	-67	7	8	-32	-52	11	0.829	-237	7	11	-250	2	--
2118.67	0.331	-51	9	3	-45	-55	2	0.985	---	-	--	---	-	--
2119.58	0.375	-56	4	17	-36	-37	12	0.137	+160	4	23	+107	3	25
2120.54	0.421	-27	3	10	+3	+16	23	0.297	---	-	--	---	-	--
2121.54	0.470	-9	8	8	+4	-5	7	0.464	---	-	--	---	-	--
2527.60	0.048	+4	3	2	+11	+5	14	0.163	---	-	--	---	-	--
2528.66	0.099	-11	5	7	-3	-10	17	0.329	---	-	--	---	-	--
2530.62	0.194	-68	6	13	-16	-75	13	0.667	-246	3	17	-283	2	--
2531.64	0.243	-62	5	9	-42	-54	9	0.837	-224	5	14	---	-	--
2532.68	0.293	-66	7	12	-41	-44	3	0.010	---	-	--	---	-	--
2533.70	0.342	-24	6	8	-42	-29	6	0.180	+230	5	14	+243	1	--
2850.76	0.630	+11	8	6	+21	+12	2	0.041	---	-	--	-86*	1	--
2851.81	0.680	-15	5	29	---	---	--	0.216	+168	5	40	---	-	--
2852.71	0.724	+31	9	14	+26	+13	10	0.366	+221	6	8	---	-	--
2853.67	0.770	+20	7	10	+39	+8	3	0.526	-157	4	8	-180	1	--
2854.68	0.819	+25	6	8	+60	+7	17	0.695	-234	6	39	-181	2	--
2882.67	0.168	-44	8	11	-22	-20	10	0.361	+182	6	18	+189	1	--
2887.69	0.410	-45	5	4	-7	-28	14	0.198	+210	4	16	+259	2	--
2889.61	0.503	-22	5	6	-8	-25	7	0.960	---	-	--	---	-	--
3203.69†	0.647	+4	2	--	+20	---	--†	0.882	-216	2	--	-208	3	7
3204.78	0.699	+21	9	8	+28	+3	14	0.064	---	-	--	---	-	--
3205.74	0.745	+22	7	12	+41	+11	11	0.224	+195	4	4	+255	2	--
3206.66	0.790	+41	5	7	+55	+48	9	0.377	---	-	--	---	-	--
3208.75	0.891	+37	9	7	+54	+24	21	0.726	-253	7	15	-225	3	38
3235.56	0.183	-77	8	9	-61	-68	12	0.196	+182	8	19	+242	2	--
3236.55	0.231	-60	9	8	-62	-49	6	0.361	+147	9	12	+146	2	--
3237.68	0.285	-60	9	12	-67	-75	10	0.549	---	-	--	---	-	--
3238.53	0.326	-45	8	7	-41	-51	10	0.691	-233	7	24	-317	1	--
3240.58	0.425	-1	9	7	-8	-11	6	0.033	---	-	--	---	-	--

† Cassegrain plate; does not include high Balmer lines

* Not included in orbital solution

TABLE 3

RADIAL VELOCITIES (km s^{-1}) IN THE YELLOW-RED SPECTRUM OF QZ CARINAE

HELIOCENTRIC JULIAN DATE 2,440,000+	COMPONENT A		COMPONENT B		MAIN-COMPONENT Hα EMISSION
	Phase	He I λ6678	Phase	He I λ6678	
2115.58	0.009	−67	0.470	...	+200
2852.74	0.569	+30	0.371	+197	+114
2854.76	0.666	+40	0.708	−210	+347
2855.70	0.712	+15	0.865	−252	−325
3205.81	0.601	+33	0.236	+217	+123
3206.64	0.641	...	0.374	...	+189
3207.73	0.693	+46	0.556	−221	+190
3208.78	0.744	+55	0.731	—	+261

TABLE 4

VELOCITIES FROM INTERSTELLAR LINES, QZ CARINAE

Line	Radial Velocity (km s^{-1})	Number of Plates	Standard Error in the Mean (km s^{-1})
Absorption:			
Ti II λ3383	−1.5	13	1.3
Ca II K	−2.7	30	0.5
Ca II H	−0.5	30	0.5
Emission (Carina Nebula):			
[O II] λ3729	−28	12	2
Hα	−27	7	5

and with the elements given by Leung, Moffat, and Seggewiss (1979). Since the orbit from He I shows less scatter, we adopt these orbital elements as representative of the system. They are consistent with zero eccentricity, as would be expected in a semi-detached system. As a check on the period, we phased our 1977 photometry together with that of Walker and Marino (1972). We determined the time of primary minimum to be JD 2,443,192.4 ± 0.2, and the resulting period is 5.9981 ± 0.0009 days, in agreement with the period given in Table 5 and that found by Leung *et al.* Table 5 gives the orbital elements as follows: the period in days (P), the time of periastron (T), the longitude of periastron (ω), the eccentricity (e), the radial velocity of the center of mass (γ), and the semi-amplitude of the velocity variation (K). The last column gives the standard deviation of the observed from the computed velocities, $\sigma(O - C)$. Figure 1 shows the observed velocities for He I, plotted with phases and theoretical velocities derived from the elements for He I in Table 5. From these elements, we obtain the semi-major axis of the primary orbit, $a_1 \sin i = (2.10 \pm 0.08) \times 10^7$ km and the mass function, $f(m) = 10.3 \pm 0.7\ M_\odot$. The large value of the mass function suggests that the observed star in System B is less massive than its companion (Leung *et al.*).

b) *Component A*

To determine the period initially for this component, we used the technique of Lafler and Kinman (1965). Table 5 gives the orbital elements that we derived from the high Balmer lines, from He I, and from Si IV. All are in good agreement, except that the barycentric velocity derived from Si IV is more positive than that derived from the other two sets of lines by 15 ± 4 km s^{-1}. This difference is consistent with the mean difference between the individual He I and Si IV velocities, 16 ± 3 km s^{-1}. The fact that Leung *et al.* failed to find this difference may not be significant, since they had fewer spectrograms than we and, of the Si IV lines, measured only λ4089. It is difficult to see how this systematic difference in velocity could be due to blends. Si IV λ4116 is not close enough to He I λ4120, nor Si IV λ4089 to Hδ, for the measurement of the position of the line to be affected (see Fig. 3). The shorter-wavelength forbidden components of the diffuse He I lines are inconspicuous in supergiants (Struve 1929). In any case, λ6678, which has no forbidden

TABLE 5

ORBITAL ELEMENTS FOR THE COMPONENTS OF QZ CARINAE

Lines	P (days)	T (JD) 2,440,000+	ω (deg)	e	γ (km s^{-1})	K (km s^{-1})	$\sigma(O - C)$ (km s^{-1})
Star A:							
H	20.75 ± 0.02	2530.3 ± 2.4	147 ± 18	0.41 ± 0.09	−8 ± 3	43 ± 5	14
He I	20.73 ± 0.01	2520.0 ± 0.7	131 ± 15	0.34 ± 0.06	−7 ± 2	49 ± 4	10
Si IV	20.73 (fixed)	2530.4 ± 1.5	134 ± 16	0.26 ± 0.08	+7 ± 3	47 ± 4	13
Star B:							
He I	5.9980 ± 0.0009	2108.7 ± 0.3	35 ± 20	0.09 ± 0.05	−34 ± 8	255 ± 6	35
Si IV, N III	5.9976 ± 0.0009	2108.7 ± 0.5	20 ± 18	0.26 ± 0.12	−47 ± 18	284 ± 27	34

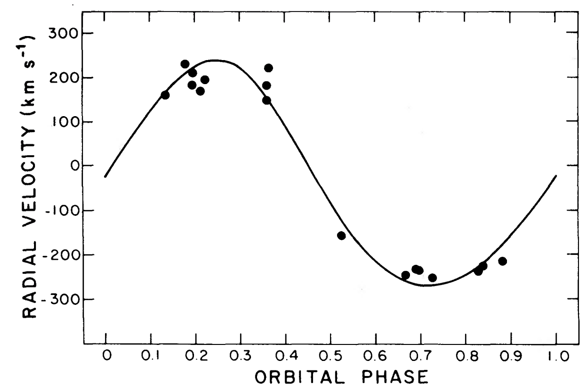

FIG. 1.—Radial velocities for He I in QZ Car B, plotted as a function of orbital phase. The solid curve represents theoretical velocities from the best-fitting orbit for He I given in Table 5. The orbital phase is zero at time T.

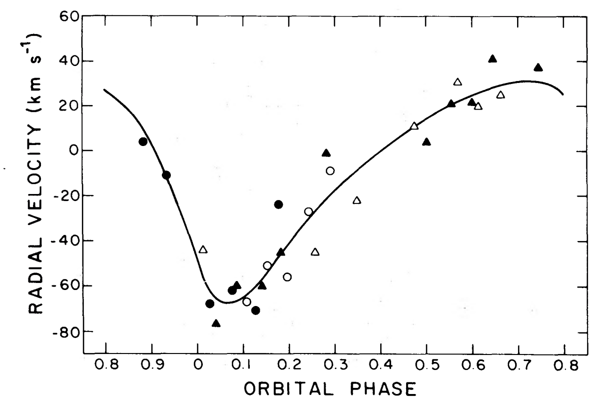

FIG. 2.—Radial velocities for He I in QZ Car A, plotted as a function of orbital phase. The various symbols indicate the year in which the observation was made: *open circles*, 1974 (JD 2,442,100 + . . .); *filled circles*, 1975 (JD 2,442,500); *open triangles*, 1976 (JD 2,442,800); *filled triangles*, 1977 (JD 2,443,200). The theoretical velocities and orbital phases are from best-fitting orbital elements for He I, which are given in Table 5. Phase is zero at time T.

component, shows no systematic difference from the lines in the blue: the mean difference, λ6678 − blue, is 4 ± 4 km s^{-1}. Finally, we see no such difference between He I and Si IV in Component B, in which the effect of blending should be similar.

We conclude that the systematic velocity difference between Si IV and He I is real and is probably due to a stellar wind, in which expansion velocity increases outward and temperature decreases outward. In such a wind, the lower-excitation He I lines are formed further from the center of the star and therefore show a more negative radial velocity. This situation also obtains in the B1 Ia–0 supergiant HD 152236 (Hutchings 1968). We were unable to obtain reliable velocities over a sufficient range in quantum number in the Balmer series to check whether the star shows a Balmer velocity progression (Hutchings 1968; Bohannan and Garmany 1978). Nevertheless, this star appears to show substantial mass loss.

The γ-velocity derived from Si IV probably represents the true motion of the center of mass of Component A. For the other orbital elements, we adopt those obtained from He I, since they are slightly better determined. From them, we derive $a_1 \sin i = (1.31 \pm 0.11) \times 10^7$ km, and $f(m) = 0.21 \pm 0.05\, M_{\odot}$. Figure 2 shows the velocities measured from the He I lines, together with theoretical velocities computed from the elements given for He I in Table 5.

c) The Wide Mutual Orbit of Systems A and B

If we take the center-of-mass velocity of System A to be $+7 \pm 3$ km s^{-1} (Si IV) and that of System B to be -34 ± 8 km s^{-1} (He I; see Table 5), then the velocity difference between the two binary systems is 41 ± 8 km s^{-1}, and the mean velocity is -13 ± 7 km s^{-1}. Since the total masses of Systems A and B are about equal (Leung *et al.*), this average is close to the velocity of the center of mass of the entire system and agrees well with the value those authors derived. This velocity is within the range observed for stars in the Carina Nebula (Conti, Niemela, and Walborn 1978; Moffat and Seggewiss 1978), but is not very close to the nebular velocities given in Table 4.

Figure 2 shows that any change in the center-of-mass velocity of System A over the 3 years spanned by our observations must have been less than about 10 km s^{-1}. This limit is consistent with the statement that the period is less than 25 years (Leung *et al.*), but only if the system is near quadrature or is at apastron in an eccentric orbit.

IV. SPECTROPHOTOMETRY

As described in § II, we used tracings of six blue spectrograms to derive line profiles and equivalent widths for Si IV λ4089, He I λ4144, He I λ4471, and He II λ4542, the lines that define spectral type and luminosity class on the system of Conti and Alschuler (1971). Sample tracings are shown in Figure 3. We used Petrie's (1940) method to derive the spectral type and luminosity class of Component B and the luminosity ratio of the two stars. This method can be used with either the central intensities or the equivalent widths of the lines. Note that the method is not sensitive to any third light that may contribute to the continuum.

The ratio of the strength of He II λ4542 to that of He I λ4471 determines spectral type. Since these lines are partly blended even on our best spectrograms, we used central intensities in Petrie's method. For the weaker lines Si IV λ4089 and He I λ4144, whose ratio determines luminosity class, the grain noise is sufficiently important that we used equivalent widths.

From single-lined spectrograms, we determined the composite spectral type and luminosity class of the system, O9.5I, and assumed that it applies to star A. Table 6A gives central intensities for He I λ4471 and He II λ4542 from one single-lined and three double-lined spectrograms. The number in the column labeled

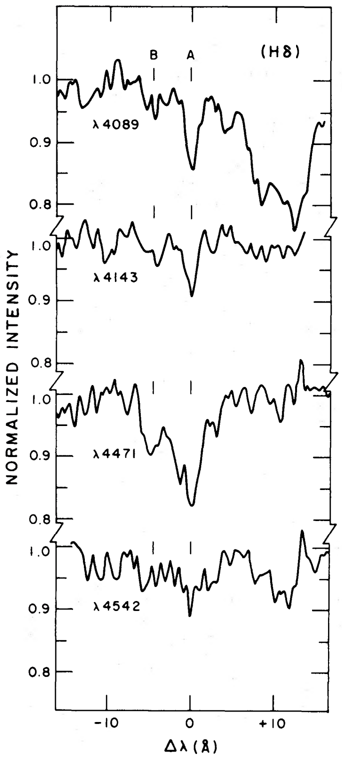

FIG. 3.—Tracings of the lines Si IV λ4089, He I λ4143, He I λ4471, and He II λ4542 from JD 2,443,208.75. The vertical scale is intensity in units of the continuum. The tracings have been smoothed with a running mean 100 μm wide, weighted by a Gaussian function with a full width at half-maximum of 30 μm.

"Ref." gives the intensity from the single-lined spectrograms of JD 2,442,850.76 at a distance from line center corresponding to the separation between the two lines on each double-lined spectrogram. Application of Petrie's (1940) formulae to these values, with the assumption that the ratio of equivalent widths between the two stars equals the ratio of central intensities, yielded the spectral type for Component B in the right-hand column. Though the mean of the three values is O7.5, we have reason to suspect the result from JD 2,442,853.67 and we adopt O9. In any case, Component B is hotter than Component A.

Table 6B gives equivalent widths for the lines Si IV λ4089 and He I λ4144 from four single-lined and two double-lined spectrograms. Though discordances occur, we are justified in adopting III for the luminosity class of star B. This result is not inconsistent with Leung *et al.*'s classification of Ib, since the equivalent width ratio we found lies near the bright end of the rather large range found in Conti and Alschuler's (1971) class III.

From the spectrograms of JD 2,442,854.68 and 2,443,208.75, we find that Component A is 0.6 ± 0.3 mag brighter than Component B. This difference is consistent with that found spectroscopically by Leung *et al.* and with the luminosity classifications of the two stars.

Table 6C gives the full width at half-intensity of He I λ4471 on three double-lined spectrograms. Since the lines are slightly blended, these values may be mildly overestimated. Table 6C also gives the mean and standard deviation in the mean of the widths and the rotational velocities, $v \sin i$, that we derived by the method of Conti and Ebbets (1977). For Component B, our result agrees well with that of Leung *et al.*, and implies synchronous rotation. For Component A, the rotation period times sin i is 7 days, if the star has a radius of 20 $R_{\odot}$; hence, the rotation is markedly faster than synchronous.

Figure 4 shows Hα profiles from our red spectrograms, arranged in order of orbital phase for Component B. Nebular emission dominates, but the broad stellar profile attains an intensity greater than 1.2 times the continuum. Since the width of the emission is greater than the entire velocity range of either binary, it is impossible to use the velocities to identify the emission with either star. The emission is up to a factor of 3 weaker after secondary minimum (phase 0.5) than before. Because all these spectrograms were obtained at essentially the same orbital phase of Component A, the variation suggests that at least some of the emission

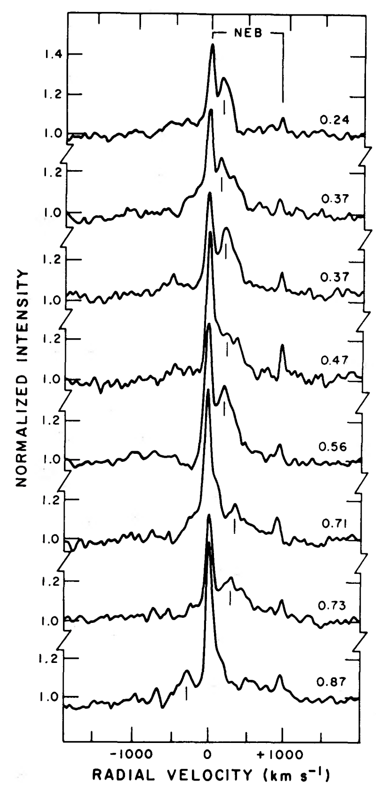

FIG. 4.—Tracings of Hα from each of the red spectrograms listed in Table 3. In each, the vertical scale is intensity in units of the continuum, and the horizontal scale is radial velocity. The most prominent nebular emission features, Hα and [N II] λ6583, are indicated at the top, and the orbital phase for star B at the time of each observation is given at the right. In each tracing, the vertical mark indicates the point that has the radial velocity given in Table 3. The tracings have been smoothed as in Figure 3.

TABLE 6

SPECTROPHOTOMETRY FOR QZ CARINAE

A. CENTRAL INTENSITIES

HELIOCENTRIC JULIAN DATE 2,440,000+	He I λ4471			He II λ4542			DERIVED SPECTRAL TYPE STAR B
	A	B	Ref.	A	B	Ref.	
2850.76[a]	0.71			0.87			...
2853.67	0.81	0.86	0.94	0.89	0.90	0.97	O5.5
2854.68	0.83	0.88	0.99	0.92	0.94	1.00	O8.5
3208.75	0.83	0.91	0.98	0.90	0.94	1.00	O9.5

B. EQUIVALENT WIDTHS (Å)

HELIOCENTRIC JULIAN DATE 2,440,000+	Si IV λ4089		He I λ4144		DERIVED LUMINOSITY CLASS	
	A	B	A	B	A	B
2550.76[a]	0.838		0.479		III	
2852.71[a]	0.723		0.597		V	
2853.67[a]	0.627		0.145		I	
3205.74[a]	0.529		0.223		I	
2854.68	0.358	0.160	0.120	0.120	I	III
3208.75	0.310	0.124	0.139	0.068	I	III

C. ROTATIONAL VELOCITIES

HELIOCENTRIC JULIAN DATE 2,440,000+	FWHI He I λ4471 A	B
2852.71	3.82	1.83
2854.68	2.82	2.82
3208.75	3.49	2.99
Mean	3.38	2.55
σ_m	±0.51	±0.63
$v \sin i$ (km s^{-1})	125 ± 22	80 ± 27

[a]Single lines.

comes from Component B. This origin is consistent with this subsystem being a semi-detached binary.

During our measurements with the Grant machine, we encountered weak third components (which we dismissed as being due to the graininess of the photographic emulsion) in the double-lined spectrograms more often than we would expect in material of this quality. A third component appears in a few of our tracings of double-lined spectrograms as well; in general, the velocity is roughly equal and opposite to that of Component B. We suspect that the secondary of System B appears in our spectra at a level just above that of the noise and is thus about 1 mag fainter than its primary.

We have obtained photometry of QZ Car on the *uvby* system, with *y* magnitudes transformed to *V*. At maximum light, $V = 6.23$ and $b - y = 0.17$. The spectral types derived above lead to an effective temperature of 30,000 K for star A and 33,000 K for star B (Conti 1973). Then the intrinsic $b - y$ color of the system is -0.09, and $E(b - y) = 0.26$. From Crawford (1975), this color corresponds to $E(B - V) = 0.35$, in reasonable agreement with Herbst (1976). According to the latter author, $R = 5$ in the Carina Nebula, but $R = 3$ applies to the 0.2 mag of foreground reddening. Then $A_V = 1.35$ and, with a distance modulus of 12.1 (Walborn 1973), $M_V = -7.3$ for the system as a whole. The light ratio yields $M_{VA} = -6.8$ and $M_{VB} = -6.2$.

With the bolometric correction from Morton (1969), the absolute bolometric magnitudes are -9.7 and -9.1, respectively. If $R = 3$ is correct for the Carina Nebula, all absolute magnitudes should be 0.3 mag more positive. These values agree reasonably well with those derived by Leung *et al.*

V. CONCLUSIONS

QZ Carinae (=HD 93206) consists of a pair of single-lined spectroscopic binaries, probably in wide orbit about each other. Leung *et al.* summarize the physical properties of the two systems, and, since our results agree well with theirs, we will not repeat their discussion. Star A (O9.5 I) has a relatively long-period (20.73 days) eccentric orbit. Star B, the eclipsing binary, has a 5.998 day period and a circular orbit.

Unfortunately, we have not bought two binary systems for the price of one. From an evolutionary standpoint, star A, with its apparently substantial mass-loss rate, is the most interesting one in the group. Since its companion is probably much fainter and since the primary does not fill its Roche lobe (Leung *et al.*), little more can be learned about its mass. System B may be more tractable. Leung *et al.* have used the light and the radial-velocity curve of the primary to estimate the masses of the two stars. The following observations might improve our knowledge of the system.

1. An improved light curve for System B would increase the reliability of the masses in this system. We have a partial light curve on the *uvby* system with HR 4217 as comparison star, and we urge other observers to use the same photometric system and comparison star. Cooperation is desirable, since the period is so nearly an integral number of days.

2. Spectroscopy with a high signal-to-noise ratio and at the appropriate orbital phases should allow the radial velocity of the secondary of System B to be measured. Then, the individual masses in this system would be better determined.

3. If Systems A and B are in a wide orbit about each other, speckle interferometry might yield an astrometric orbit and further constrain the masses in System B. Alternatively, the γ-velocities of the two systems could be determined over a substantial fraction of the wide orbit, perhaps by Wilson's (1941) short method. In principle, the total mass of System A could be derived, but its orbital inclination would remain unknown and the individual masses still could not be determined.

Since the mass of the supergiant in System A cannot be found, effort spent on QZ Car would have to be justified in terms of scientific return on System B. Though real, this return would require observations that are unusually difficult because of the proximity of QZ Car A. Perhaps the time would be better spent on some O-type eclipsing binary whose light is not confused with that of a brighter star!

Our special thanks go to P. Massey for tracing the red spectrograms of QZ Car and for help in the reduction of other microphotometer tracings. We thank V. S. Niemela for obtaining a spectrogram of QZ Car, F. C. Fekel for helpful comments, and A. F. J. Moffat for sending results in advance of publication. C. D. Garmany helped with JILA's Grant measuring machine, and P. Barker and B. W. Bopp supplied computer programs for the orbital analysis. We thank the High Altitude Observatory for the use of its microphotometers. We are grateful to the staff of the Cerro Tololo Inter-American Observatory, and N.D.M. is grateful to JILA for its hospitality during 1979 August. This research was partly supported by National Science Foundation grant AST 78-20135 to the University of Colorado.

REFERENCES

Barker, E. S., Evans, D. S., and Laing, J. D. 1967, *Royal Obs. Bull.*, No. 130.
Bohannan, B., and Garmany, C. D. 1978, *Ap. J.*, **223**, 908.
Chiosi, C., Nasi, E., and Sreenivasan, S. R. 1978, *Astr. Ap.*, **63**, 103.
Conti, P. S. 1973, *Ap. J.*, **179**, 181.
———. 1978, *Ann. Rev. Astr. Ap.*, **16**, 371.
Conti, P. S., and Alschuler, W. R. 1971, *Ap. J.*, **170**, 325.
Conti, P. S., and Ebbets, D. 1977, *Ap. J.*, **213**, 438.
Conti, P. S., Leep, E. M., and Lorre, J. J. 1977, *Ap. J.*, **214**, 759.
Conti, P. S., Niemela, V. S., and Walborn, N. R. 1978, *Ap. J.*, **228**, 206.
Crawford, D. L. 1975, *Pub. A.S.P.*, **87**, 481.
Dearborn, D. S. P., Blake, J. B., Hainebach, K. L., and Schramm, D. N. 1978, *Ap. J.*, **223**, 552.
de Loore, C., De Grève, J. P., and Lamers, H. J. G. L. M. 1977, *Astr. Ap.*, **61**, 251.
Herbst, W. 1976, *Ap. J.*, **208**, 923.
Hutchings, J. B. 1968, *M.N.R.A.S.*, **141**, 219.
Lafler, J., and Kinman, T. D. 1965, *Ap. J. Suppl.*, **11**, 216.
Leung, K.-C., Moffat, A. F. J., and Seggewiss, W. 1979, *Ap. J.*, **231**, 742.
Moffat, A. F. J., and Seggewiss, W. 1978, *Astr. Ap.*, **70**, 69.
Morrison, N. D., and Conti, P. S. 1979, in *IAU Symposium No. 83, Mass Loss and Evolution of O-Type Stars*, ed. P. S. Conti and C. de Loore (Dordrecht: Reidel), p. 277.
Morton, D. C. 1969, *Ap. J.*, **158**, 629.
Petrie, R. M. 1940, *Pub. Dom. Ap. Obs.*, **7**, 205.
Stothers, R. 1973, *Pub. A.S.P.*, **85**, 363.
Stothers, R., and Chin, C.-W. 1979, *Ap. J.*, **233**, 267.
Struve, O. 1929, *Ap. J.*, **70**, 85.
Walborn, N. R. 1973, *Ap. J.*, **179**, 517.
Walborn, N. R., and Hesser, J. E. 1975, *Ap. J.*, **199**, 535.
Walker, W. S. G., and Marino, B. F. 1972, *Inf. Bull. Var. Stars*, No. 681.
Wilson, O. C. 1941, *Ap. J.*, **93**, 29.
Wolfe, R. H., Horak, H. G., and Storer, N. W. 1967, in *Modern Astrophysics*, ed. M. Hack (Paris: Gauthier Villars), p. 251.

P. S. CONTI: Joint Institute for Laboratory Astrophysics, University of Colorado, Boulder, CO 80309

N. D. MORRISON: Ritter Observatory, University of Toledo, Toledo, OH 43606