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64 ORI (=HR 2130), A B-TYPE TRIPLE SYSTEM[a]

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ABSTRACT

64 Ori is a close triple system consisting of three B stars which has recently been resolved by speckle interferometry. High-dispersion spectroscopic observations show that the probable visual primary is a double-lined spectroscopic binary with a period of 14.57221 days, which orbits a broad-lined ($v \sin i = 163$ km s^{-1}) third star with a period of 13.03 yr. From a consideration of magnitude differences and line-strength ratios we classify the components as B7 III, B8 III, and B5 V for the short-period primary, Aa, short-period secondary, Ab, and visual secondary, B, respectively. Components Aa and Ab both have $v \sin i \leqslant 5$ km s^{-1}. Since it is shown that both are intrinsically slow rotators with no Hg-Mn abundance peculiarities, any mechanism which attempts to explain the presence of such peculiarities in late B stars must also explain their absence in these two stars.

I. INTRODUCTION

The star 64 Ori [HR 2130 = HD 41040, $\alpha = 5^{\mathrm{h}}\ 57^{\mathrm{m}}\ 32^{\mathrm{s}}$, $\delta = 19°\ 42'$(1900), $V = 5.15$, spectral class = B8 V] is a close multiple system. Campbell (1922) announced the star to be a double-lined spectroscopic binary from observations obtained at Lick Observatory. Campbell and Moore (1928) commented in their catalog of Lick radial velocities that the star had easily measurable He I 4471 Å and Mg II 4481 Å lines. Although several additional plates were obtained at Lick over the years (Kron 1977), there were not enough observations to determine the orbital elements.

The third component of the system was first detected in an occultation observation (Africano *et al.* 1976). Combining two occultation events, Africano *et al.* (1977) found a mean separation of 0."06 for the epoch 1976.12. Since that time the system has been resolved by speckle interferometry (McAlister and Fekel 1980; McAlister and Hendry 1982a,b).

The current spectroscopic observations were begun to detect the third component and to determine the period of the double-lined binary. By combining these observations with those from Lick, we have determined the long-period orbital elements as well.

II. OBSERVATIONS AND ORBITS

Observations of 64 Ori have been obtained with a variety of different telescopes and instrument combinations. Those used in the present analysis are summarized in Table I.

From 1918 to 1959, observations were sporadically obtained at Lick Observatory. Although nearly all the plates, many of them double lined, were measured (Kron 1977), only a few of the velocities were previously published (Campbell and Moore 1928). One of us (F.C.F.) remeasured with a Grant measuring machine all of the plates with double lines and most of those with blended lines. For these remeasurements only the Mg II line at 4481 Å was used.

During a survey of duplicity of late B type stars, Wolff (1978), at Mauna Kea Observatory, obtained and measured several plates of 64 Ori showing double lines. The velocity of the short-period secondary is from only the Mg II line at 4481 Å (Wolff 1977).

Our observations were begun in 1976 and have continued to the present. The McDonald plates were measured with the Grant measuring machine at Johnson Space Center, Houston, Texas. The lines measured are from the list given in Table II. From seven to 14 lines of Aa and from four to nine lines of Ab were measured, depending on orbital phase and plate quality. A correction of -0.7 km s^{-1} (Fekel 1981b) has been added to the McDonald plate velocities to place them on the International Astronomical Union (IAU) velocity system.

The Dominion Astrophysical Observatory (DAO) plates were measured with the ARCTURUS measuring machine at the DAO. An average of 19 lines for Aa and 14 for Ab, chosen from the list in Table II, were measured. A correction of $+0.6$ km s^{-1} (Batten *et al.* 1983) has been applied to the observations at 6.5 Å mm^{-1} to correct them to the IAU system. No such correction has been applied to those at 2.4 Å mm^{-1} since that spectrograph seems to give velocities in very good accord with the IAU system (Scarfe 1985).

At McDonald Observatory, observations also were obtained with a Reticon RL-1024B self-scanned silicon photodiode array (Vogt, Tull, and Kelton 1978). The velocities of Aa and Ab were determined by cross correlation of the Mg II 4481 Å line and several Fe II and Ti II lines near 4500 Å with the same lines in 68 Tau, a star of similar rotational velocity and spectral type. Details of the reduction procedure have been given by Fekel, Bopp, and Lacy (1978). A velocity, corrected to the IAU system, of 38.0 ± 0.8 (m.e.) km s^{-1} was determined for 68 Tau from five plates taken with the McDonald 2.1 m telescope over the same time interval as the Reticon observations. Comparison with velocities obtained

TABLE I. Telescope and instrument combinations.

Observatory	Telescope	Instrument	λ Range (Å)
Lick	0.9 m (refractor)	Cassegrain 3 prism	4481 only
McDonald	2.1 m	coudé B Camera	3800–4800
McDonald	2.7 m	coudé Reticon	4450–4550
DAO	1.2 m	coudé	3800–4600
Kitt Peak	0.9 m	coudé	6340–6430

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[a] This paper is based in part on observations obtained at the Dominion Astrophysical Observatory.

TABLE II. Wavelengths of stellar lines measured.

λ(Å)	Ident.	λ(Å)	Ident.
3853.667	Si II	4351.764	Fe II
56.021	"	85.381	"
62.592	"	4416.817	"
3933.664	Ca II	81.129	Mg II
68.492	"	81.327	"
4128.053	Si II	4508.283	Fe II
30.884	"	15.337	"
4233.167	Fe II	22.634	"
67.020	C II	58.659	Cr II
67.270	"	83.829	Fe II
4503.166	Fe II		

at other observatories (Campbell and Moore 1928; Stickland 1980) suggests that 68 Tau may be a long-period binary with a small velocity amplitude. The velocities are listed in Table III (as $V_{\rm Aa}$ and $V_{\rm Ab}$), together with a few obtained by one of us (F.C.F.) recently at Kitt Peak, and those of Stickland and Weatherby (1984), obtained at the Royal Greenwich Observatory.

The solution for the orbital elements was accomplished in three stages. First a preliminary short-period orbit was found from 21 McDonald observations obtained between August 1976 and January 1977, during which time the velocity of the center of mass of this pair in the long-period orbit varied less than 0.5 km s^{-1}. A solution was obtained with the differential correction program described by Barker, Evans, and Laing (1967).

Preliminary elements for the long-period orbit were obtained from the center-of-mass velocities $\gamma_{\rm A}$ of the short-period pair. These were calculated from the short-period elements and the velocities by means of

$$\gamma_{\rm A} = \frac{V_{\rm Aa} + rV_{\rm Ab}}{1+r}, \text{ where } r = \frac{K_{\rm Aa}}{K_{\rm Ab}}.$$

Once again the program of Barker, Evans, and Laing (1967) was used.

Finally, all the observations were used to obtain a simultaneous solution for the long- and short-period orbits by means of an iterative differential correction program written by D. J. Barlow. This program achieved convergence only slowly, presumably due in part to the very nonuniform coverage that still exists for the long-period orbit. For all of these solutions, the data were weighted in rough accord with their adjudged reliability; the weights are indicated in Table III or in the notes that follow it. The Kitt Peak and RGO observations were not included, because of uncertainties in zero-point correction, but as can be seen from their residuals in Table III, they agree very well.

The elements derived in this final program are given in Table IV, and the phases in both orbits and residuals from the combined solution are incorporated into Table III.

The center-of-mass velocity calculated from the long-period elements was subtracted from the observed velocities and the remainders are plotted against the short-period phase in Fig. 1. In Fig. 2, $\gamma_{\rm A}$ is plotted against the long-period phase, again from Table III.

Although we have not completely covered the long-period orbit spectroscopically, its orbital elements are reasonably well determined because of the inclusion of the old Lick observations and because our observations cover periastron and both nodes of this highly eccentric orbit. Thus, although we are continuing observations to improve the phase coverage, we do not expect this to produce major changes from the present set of elements.

III. SPECTRAL TYPES AND MAGNITUDE DIFFERENCES

Both Osawa (1959) and Molnar (1972) classified the combined system as B8 III, while A. Cowley (1972) classified it as B8 V. However, C. Cowley and Houk (1977) found conflicting criteria and estimated that the spectral type probably is closer to B6 than to B8. Their classification difficulties are apparently due to the presence of a broad-lined earlier-type star.

A portion of a high-signal-to-noise ratio Reticon observation centered on 4500 Å (Fig. 3) shows the broad He I 4471 Å and Mg II 4481 Å lines of B, the third component. A reticon spectrum of the B7 V star π Cet was compared with one of 64 Ori when the short-period pair was at single-lined phase. Although difficult to determine accurately, the equivalent width of the broad-lined star's He I line appears to be somewhat greater than the equivalent width of its Mg II line, and therefore we estimate its spectral type to be B5–6.

Cowley (1980) agrees with the assessment that the broad-lined star is of earlier spectral type. He notes that the strength of the He I lines increases at shorter wavelengths relative to those of HR 7878.

Adelman and Pyper (1983) obtained spectrophotometry of 64 Ori. They found that the energy distribution which best fits the Balmer jump had a higher effective temperature, $T = 13\,175$ K, than that which best fits the Paschen continuum (12 000 K). Such a temperature difference supports the conclusion of an earlier-type star in the system.

The magnitude difference of the short-period spectroscopic pair was determined with Petrie's (1939) method. Measurement of the depths of six pairs of lines on the McDonald 3 Å/mm plates taken on JD 2443087 and JD 2443122 plates gives a luminosity ratio of 0.498 ± 0.021 or a magnitude difference at 4000 Å of 0.76 ± 0.05 mag. Two Si II lines near 6360 Å give a similar magnitude difference of 0.80 mag. For the occultation pair, A and B, Africano *et al.* (1977) found Strömgren $\Delta b = 1.15 \pm 0.04$ mag and $\Delta y = 1.0 \pm 0.3$ mag.

Comparing the relative depths of the He I and Mg II lines of π Cet with those of 64 Ori when the short-period pair was at a double-lined phase, and keeping in mind the estimated magnitude difference for the pair from Petrie's method, we classify the short-period pair B7 and B8. Each of these two stars might be one subclass later in type, but the fainter cannot be as late as A0 because of its relatively strong He I line.

If because of its earlier spectral type the broad-lined third component is assumed to be the occultation primary and is called component A, this identification is consistent with the assumed spectral types and the absolute magnitudes of main-sequence components (Keenan 1963) but means that Bb is 2.35 mag fainter than A. This magnitude difference is inconsistent with the spectroscopic detection of Bb since it is generally assumed that a secondary component more than 1.5 mag fainter than the primary cannot be detected on a photographic spectrogram.

If, instead, the broad-lined component is assumed to be the occultation secondary, B, then this component and the short-period secondary are both about 0.7 mag fainter than the short-period primary and these magnitude differences would be consistent with seeing lines of all three components in one spectrogram. However, if all the components are dwarfs, the spectral types and absolute magnitudes of the

TABLE III. The observations.

HJD 2400000+	ϕ_s	ϕ_L	Disp	V_{Aa}	V_{Ab}	γ_A	$(O-C)_{Aa}$	$(O-C)_{Ab}$	Wt
a. Lick Observations									
21594.847	0.8296	0.1795	10.9	36.1	-32.8	3.5	-3.4	-4.7	1/4
21945.903	0.9204	0.2532	10.9	50.6	-28.7	13.1	0.2	6.9	1/4
22265.047	0.8213	0.3203	10.9	37.7	-27.6	6.8	-4.1	-4.5	1/4
22945.014	0.4832	0.4603	10.9	14.5			12.1		0
30312.050	0.0368	0.0117	10.9	-4.5			-2.0		1/4
30419.728	0.4261	0.0343	10.9	-21.5	9.7	-6.7	-2.2	-5.0	0
30422.717	0.6312	0.0349	10.9	0.2			-1.4		1/4
33277.923	0.5661	0.6351	10.9	14.4			1.1		1/4
33287.886	0.2498	0.6372	10.9	-12.4	51.9	18.0	-0.1	5.0	1/4
33653.928	0.3690	0.7141	10.9	1.4	43.0	21.1	5.3	3.3	0
33659.904	0.7791	0.7154	10.9	40.1	- 8.9	16.9	-1.1	1.5	1/4
33967.068	0.8578	0.7799	10.9	50.5	-14.8	19.6	-3.0	7.6	1/4
33975.039	0.4048	0.7816	10.9	0.5	50.1	24.0	0.7	12.6	0
34741.919	0.0310	0.9428	10.9	25.0			1.2		0
34747.931	0.4436	0.9441	10.9	5.5	42.2	22.9	1.8	7.8	0
34752.840	0.7804	0.9451	10.9	43.6	- 6.8	19.7	0.8	2.4	1/4
35439.968	0.9337	0.0895	10.9	45.7	-45.1	2.7	2.8	-3.4	1/4
35506.759	0.5172	0.1035	10.9	2.9			6.4		1/4
36267.706	0.7362	0.2635	10.9	26.6	-14.2	7.3	-1.1	-4.3	0
36605.783	0.9363	0.3346	10.9	51.1	-20.3	17.3	-0.4	-13.2	0
b. Mauna Kea Observations									
42302.130	0.8410	0.5318	13.6	52.5	-24.3	16.1	4.4	-1.2	1/4
42361.120	0.8891	0.5442	13.6	54.9	-35.0	12.4	0.9	-5.6	1/4

HJD 2440000+	ϕ_s	ϕ_L	Disp	V_{Aa}	V_{Ab}	γ_A	$(O-C)_{Aa}$	$(O-C)_{Ab}$
c. McDonald Observations								
2853.732	0.6940	0.6478	8.6	30.1	1.6	16.6	1.7	-0.3
2854.696	0.7602	0.6480	8.6	38.6	- 6.9	17.1	1.1	1.3
2855.626	0.8240	0.6482	8.6	47.4	-16.1	17.3	0.4	2.7
2856.689	0.8969	0.6484	8.6	56.7	-26.6	17.3	0.8	2.1
2999.976	0.7298	0.6785	8.6	34.4	- 0.8	17.7	0.8	2.2
3000.981	0.7988	0.6787	8.6	43.4	-12.1	17.1	-0.2	2.1
3001.985	0.8677	0.6789	8.6	53.1	-22.3	17.4	-0.4	2.8
3002.980	0.9360	0.6791	8.6	57.1	-25.6	18.0	1.0	2.5
3060.953	0.9143	0.6913	8.6	59.0	-27.2	18.2	1.8	1.7
3061.997	0.9859	0.6915	8.6	43.1	-13.9	16.1	-0.3	-0.4
3064.004	0.1237	0.6920	8.6	- 8.6	44.3	16.4	0.2	-0.2
3064.024	0.1250	0.6920	3.0	- 9.5	42.8	15.3	-0.5	-2.0
3064.913	0.1860	0.6922	8.6	-14.1	46.9	14.8	-1.3	-2.1
3065.939	0.2565	0.6924	8.6	-12.7	45.2	14.7	-1.4	-2.1
3085.974	0.6313	0.6966	3.0	20.7	9.7	15.5	-0.6	-1.4
3086.921	0.6963	0.6968	3.0	29.8	1.6	16.5	0.5	-0.6
3087.988	0.7695	0.6970	3.0	39.5	-10.1	16.0	0.0	-1.0
3088.014	0.7713	0.6970	8.6	38.5	-11.7	14.7	-1.3	-2.3
3119.946	0.9626	0.7037	8.6	52.2	-21.3	17.4	0.5	1.2
3120.864	0.0256	0.7039	3.0	23.9	8.9	16.8	0.0	0.4
3121.892	0.0962	0.7041	3.0	- 4.2	38.3	15.9	-0.6	-0.8
3122.848	0.1618	0.7043	3.0	-12.7	48.5	16.3	-0.7	0.1
3153.644	0.2751	0.7108	8.6	-12.5	46.7	15.5	-2.4	0.2
3155.698	0.4161	0.7112	8.6	- 1.1	36.6	16.7	-1.2	1.4
3156.782	0.4904	0.7115	3.0	5.2	26.6	15.3	-1.5	-1.2
3267.614	0.0962	0.7348	8.6	- 2.2	40.6	18.1	1.0	1.1
3268.633	0.1661	0.7350	8.6	-10.9	52.8	19.2	0.9	3.8
3269.598	0.2323	0.7352	8.6	-12.4	49.4	16.8	-0.7	0.5
3271.604	0.3700	0.7356	8.6	- 4.5	43.2	18.1	-1.2	3.6
3451.875	0.7408	0.7735	3.0	35.7	- 3.0	17.4	-0.7	0.5
3540.719	0.8376	0.7922	3.0	50.0	-19.3	17.2	-0.9	-0.2
3541.718	0.9062	0.7924	3.0	57.4	-27.7	17.1	-0.9	-0.4
3542.731	0.9757	0.7926	3.0	47.8	-17.1	17.1	-0.9	-0.4
3860.746	0.7991	0.8594	8.6	44.8	-12.7	17.6	-1.2	-0.8
3880.824	0.1769	0.8637	4.4	-11.5	49.3	17.3	-1.0	-1.7
4181.914	0.8388	0.9269	8.6	51.6	-16.8	19.2	-0.5	1.5
4182.971	0.9114	0.9272	8.6	60.2	-22.7	21.0	0.8	3.8
4357.645	0.8982	0.9639	4.4	54.9	-28.7	15.3	-1.5	-0.3
4358.600	0.9637	0.9641	4.4	49.2	-25.1	14.0	-1.8	-2.6
4474.962	0.9489	0.9885	4.4	45.0	-35.7	6.8	-0.6	-0.8
4625.683	0.2919	0.0202	4.4	-31.5	23.0	- 5.7	-1.0	-1.1
4626.623	0.3564	0.0204	4.4	-23.5	20.3	- 2.8	2.5	1.1
4896.986	0.9098	0.0772	4.4	44.1	-43.6	2.6	1.6	-0.2

TABLE III. (continued)

HJD 2440000+	ϕ_s	ϕ_L	Disp	V_{Aa}	V_{Ab}	γ_A	$(O-C)_{Aa}$	$(O-C)_{Ab}$
d. DAO Observations								
3216.646	0.5983	0.7241	2.4	18.1			0.2	
3235.644	0.9022	0.7280	2.4	57.2	-28.9	16.4	0.0	-0.9
3240.665	0.2468	0.7291	2.4	-10.3	48.0	17.3	0.9	-0.2
3501.797	0.1667	0.7840	2.4	-11.0	50.4	18.1	0.2	0.7
3550.770	0.5274	0.7943	2.4	13.5	25.8	19.3	2.1	0.9
3586.648	0.9895	0.8018	2.4	43.8	- 9.7	18.5	0.5	0.7
4183.967	0.9797	0.9274	6.5	47.8	-15.8	17.7	-0.4	-1.8
4183.978	0.9805	0.9274	6.5	46.6	-14.6	17.6	-1.3	-0.9
4197.919	0.9372	0.9303	2.4	59.1	-25.2	19.2	0.6	0.3
4320.684	0.3618	0.9561	2.4	- 2.5	41.7	18.4	1.2	1.1
4580.888	0.2179	0.0108	2.4	-32.5	29.0	- 3.4	0.6	0.7
4618.796	0.8193	0.0188	2.4	25.2	-38.7	- 5.0	-0.6	-0.1
4646.721	0.7356	0.0246	2.4	13.4	-24.0	- 4.3	-0.4	0.6
4677.698	0.8614	0.0311	2.4	32.9	-45.4	- 4.2	0.2	-1.2
4707.673	0.9184	0.0374	2.4	38.1	-49.2	- 3.2	0.2	-1.1
5021.696	0.4678	0.1034	2.4	- 8.2	17.4	3.9	0.0	0.1
5048.680	0.3196	0.1091	2.4	-19.7	30.9	4.2	0.1	-0.1
5218.980	0.0062	0.1449	2.4	23.9	-12.2	6.8	0.4	1.0
5261.016	0.8909	0.1538	2.4	47.3	-37.4	7.2	1.2	0.1
5349.863	0.9879	0.1724	2.4	32.9	-22.4	6.7	-0.4	-0.6
5428.676	0.3963	0.1890	2.4	-10.7	28.3	7.8	-0.3	0.2
e. RGO Observations								
2850.340	0.4613	0.6471	8.5	4.8	29.8	16.6	1.6	-0.1
3150.487	0.0585	0.7102	8.5	12.1			3.6	
3151.458	0.1251	0.7104	8.5	- 9.7	44.8	16.1	-0.9	-0.2
3233.316	0.7425	0.7276	8.5	37.1	- 2.9	18.2	1.1	1.5
3438.695	0.8364	0.7707	8.5	50.9	-20.8	17.0	0.5	-1.6
3464.640	0.6168	0.7762	8.5	17.0			-3.7	
f. Kitt Peak Observations								
5075.689	0.1730	0.1148	14.8	-23.8	38.8	5.8	0.6	1.9
5076.700	0.2424	0.1150	14.8	-25.0	37.8	4.7	-1.3	1.7
5077.649	0.3075	0.1152	8.9	-19.7	30.1	3.9	0.5	-2.2
5078.657	0.3767	0.1154	14.8	-17.8	22.8	1.4	-2.6	-3.9

Note: In this table the phases ϕ_s and ϕ_L are in units of the short and long periods respectively, the dispersion is in Å/mm., and V_{Aa}, V_{Ab}, γ_A, $(O-C)_{Aa}$ and $(O-C)_{Ab}$ are in km s^{-1}. γ_A was determined using the final short-period mass ratio.

Weights for Lick and Mauna Kea observations are given in the table. For those from the other observatories they are as follows: McDonald: 3Å/mm, 3; others, 1. DAO: 2.4 Å/mm, 3; 6.5Å/mm, 1. Kitt Peak and RGO: 0.

components are inconsistent with each other since the broad-lined component is earlier in spectral type but fainter than the short-period primary.

A solution to this dilemma is to postulate that the latter identification of the components is correct, but that the components of the close binary have evolved off the main sequence and are giants. Tables V(a) and V(b) compare the magnitudes and magnitude differences for such a case. Table V(a) assumes spectral classifications of B5 V for B, B7 III for Aa, and B8 III for Ab. The observed magnitudes for the system are from Crawford (1963) and it is assumed that the magnitude difference $\Delta B \simeq \Delta b = 1.15$ mag. Colors for the individual stars are from the tables of FitzGerald (1970). As might be expected for stars of similar type, the computed magnitudes for the combined system agree well with the observed ones. In Table V(b) the V magnitude differences computed from the V magnitudes of Table V(a) are compared with those of Keenan (1963) for the assumed spectral classes. Although not exact, the agreement is certainly good.

TABLE IV. The elements.

	Short	Long
P (days)	14.57221 ± 0.00007	4758 ± 19 (13.03 ± 0.05 yr)
T(J.D.)	2443164.21 ± 0.02	2444529.5 ± 8.9
γ(km/s)	variable	12.12 ± 0.12
K_{Aa} (km/s)	35.02 ± 0.19	
K_{Ab} (km/s)	38.98 ± 0.20	
K_A (km/s)		11.81 ± 0.19
e	0.387 ± 0.004	0.734 ± 0.009
ω	65°.1 ± 0°.6	125°.3 ± 1°.7
$a_{Aa} \sin i$(Gm)	6.47 ± 0.04	
$a_{Ab} \sin i$(Gm)	7.20 ± 0.04	
$M_{Aa} \sin^3 i(M_\odot)$	0.253 ± 0.003	
$M_{Ab} \sin^3 i(M_\odot)$	0.227 ± 0.003	
M_{Aa}/M_{Ab}	1.113 + 0.008	
$a_A \sin i$(Gm)		525 ± 11
$f(M)(M_\odot)$		0.255 ± 0.016

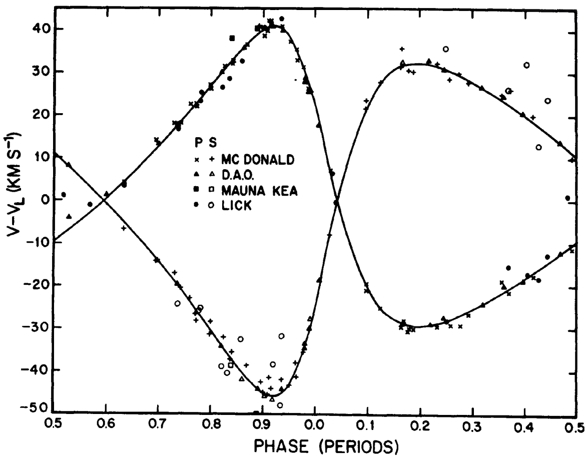

FIG. 1. Observations of 64 Ori, from which the long-period variation has been removed using the elements of Table IV, plotted against phase computed from periastron in the short-period orbit. Symbols for the velocities of the primary and secondary obtained at various observatories are indicated. The solid curves represent the short-period elements of Table IV.

Thus, we have assumed that this is the correct identification of the components in what follows. Further observations to confirm this identification would be valuable, since the evolutionary status and properties of the system are affected by these assumptions.

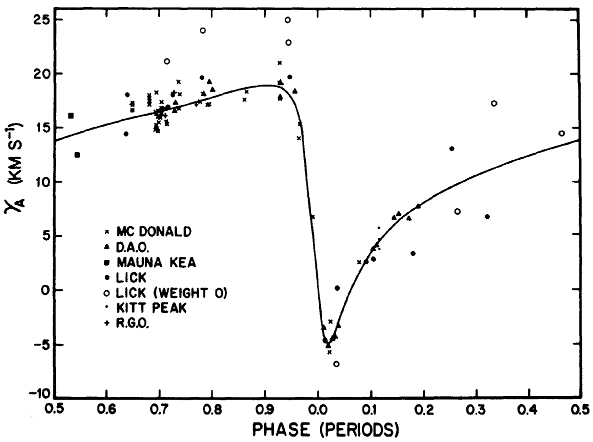

FIG. 2. Long-period radial-velocity curve from the elements given in Table IV compared with the center-of-mass velocities of the short-period pair. Symbols for observations obtained at different observatories are indicated. Phase is computed from periastron passage.

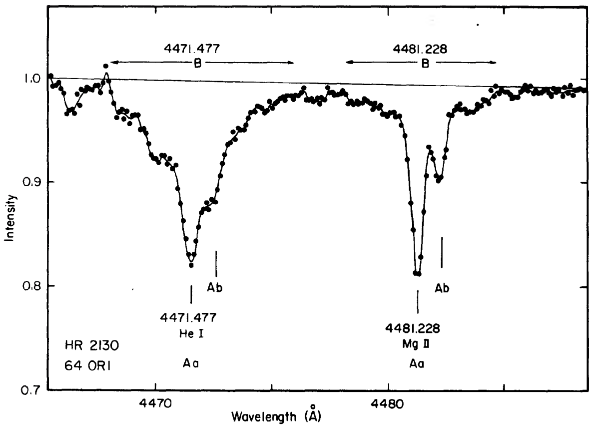

FIG. 3. A portion of a Reticon observation of 64 Ori showing the He I and Mg II lines of Aa, Ab, and B. The nearly horizontal solid line is the continuum level, determined from the whole Reticon observation. The curve through the points is a smoothed fit, determined from a filtered power spectrum.

If the mass ratio, B/A, could be determined from the ratio of radial-velocity variations in the long-period orbit, this would help to identify the components, since the masses of the individual stars would be directly determined. Unfortunately, as with other early-type triple systems, the single star, B, has very broad lines. Measurement of the full-width at half-maximum of the Mg II 4481 Å line from three Reticon observations and use of an empirical relationship to convert this to velocity (Fekel, Moffett, and Henry 1986) result in $v \sin i = 163 \pm 10$ (1σ) km s^{-1}. Attempts to measure accurately (± 2 km s^{-1}) the radial velocity of this component have been unsuccessful so far. Some kind of spectrum synthesis such as that done by Barden (1985) might prove successful for high-signal-to-noise observations.

IV. DISCUSSION

The range of possible masses for the components could be restricted if the inclination of the visual orbit were known. The presently available occultation (Africano *et al.* 1977) and speckle (McAlister and Fekel 1980; McAlister and Hendry 1982a,b) observations cover only a very small portion of the orbit. Nevertheless, it is possible to use them to get a preliminary value for the inclination. Halliwell (1983) assumed the elements of the long-period spectroscopic orbit and found $i = 45° \pm 15°$, $a \simeq 0\farcs06$, and $\Omega \simeq 244°$. Table VI shows the possible mass of B for an inclination in this range and with the sum of the masses of the short-period pair in the range of 5–11 $M_\odot$, appropriate for late B to mid B main-sequence stars, respectively (Popper 1980).

Parentheses have been placed around those masses of B which are less than that for Ab and so would be consistent with our hypothesized evolutionary state of the system, that is Aa and Ab more massive and, thus, more evolved than B. From Table VI we conclude that the inclination must be $> 50°$ for this to occur. This assumes B is a single star. If it is a binary containing a low-mass star as a companion, then the combined mass of B could be greater, and the inclination correspondingly smaller.

TABLE V(a). Magnitudes of the components.

Component	Sp. class	*U* (mag)	*B* (mag)	*V* (mag)
Aa	B7 III	5.36	5.80	5.92
Ab	B8 III	6.15	6.56	6.66
B	B5 V	5.93	6.51	6.67
Combined		4.57	5.04	5.16
Observed		4.60	5.04	5.15

TABLE V(b). Magnitude differences.

Component	Δ*V* (mag)	Δ*V* Keenan (mag)
B − A	1.19	1.1
B − Aa	0.75	0.5
B − Ab	0.01	0.1

TABLE VI. Possible masses of component B ($M_\odot$).

$M_{\rm Aa}+M_{\rm Ab}$ ($M_\odot$)	Inclination				
	30°	40°	45°	50°	60°
5	6.5	4.4	3.8	3.4	2.7
6	7.1	4.9	4.2	3.8	3.2
7	7.6	5.3	4.6	4.1	3.5
8	8.1	5.6	4.9	4.4	3.8
9	8.6	6.0	5.3	4.7	(4.1)
10	9.0	6.4	5.6	5.0	(4.3)
11	9.5	6.7	5.9	5.3	(4.6)

The projected rotational velocities of Aa and Ab are extremely low for early-type stars. On the McDonald 3 Å mm^{-1} and DAO 2.4 Å mm^{-1} plates of 64 Ori the Mg II 4481 Å doublet, which has a velocity separation of 13.3 km s^{-1}, is resolved. In addition, the two stellar Ca II K lines are similar in width to the interstellar K line. From this information it is estimated that $v \sin i$ for both components is 5 km s^{-1} or less. Such an estimate is similar to that made by Wolff and Preston (1978), 5 km s^{-1}, and by Cowley (1980), 4 km s^{-1} or less.

Wolff and Preston (1978) have concluded that the Hg-Mn peculiarities are confined to slowly ($v \sin i < 100$ km s^{-1}) rotating stars. However, they also claim that there is no critical velocity below which every star is peculiar. Indeed, they note at least four stars, including 64 Ori, that have $v \sin i < 10$ km s^{-1} but appear to be "normal." However, it is possible that these stars are the few expected statistically which are rotating rapidly but are seen pole-on.

This hypothesis may be tested for 64 Ori, since it is a spectroscopic binary, if we assume that the orbital and rotational angular momenta are parallel. With this assumption, which is made more plausible by the near equality of $v \sin i$ for Aa and Ab, a mass for Aa in the range of 2.5–6 $M_\odot$ yields $28° \geqslant i \geqslant 20°$ for the short-period orbit, and $v \sin i = 5$ km s^{-1} in turn yields an equatorial rotational velocity between 11 and 15 km s^{-1} for both Aa and Ab. Thus they appear to be intrinsically slow rotators, and support the conclusion of Wolff and Preston that slow rotation is a necessary, but not sufficient, condition for the occurrence of abundance peculiarities.

We note that the above results indicate that the long and short orbits are not coplanar. This is also the case for several of the systems discussed by Fekel (1981a).

Future observations will be needed (and are being obtained) to improve our knowledge of the properties of the long-period orbit. Additional spectroscopic observations will be used to refine the orbital elements. If possible, measurement of accurate radial velocities of B will yield the mass ratio of the speckle components. Additional speckle observations with large telescopes should now be possible since the separation of the components is increasing, estimated to be about 0.″05 in 1986. The inclination of the orbit, determined from such observations, can be used to confirm that the system is noncoplanar (e.g., Fekel 1981a) and, combined with results from the above observations, to determine the masses of the components and the distance to, and evolutionary status of, the system. Determination of the evolutionary status is important since any explanation of a mechanism for abundance peculiarities in late B stars must be able to explain the lack of peculiarities in the slowly rotating short-period pair.

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