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THE ORBITS OF THE SPECTROSCOPIC BINARIES RHO ORIONIS, ETA BOOTIS, AND 32 VIRGINIS*

F. C. BERTIAU, S.J.†
Lick Observatory, University of California
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ABSTRACT

Orbital elements for the single-line spectroscopic binaries ρ Orionis, η Bootis, and 32 Virginis have been obtained from Mills observations at a dispersion of 11 A/mm. A combination of astrometric information with the spectroscopic results for η Bootis explains the invisibility of the companion. The form of the velocity-curve of the metallic-line star 32 Virginis appears to have changed since the time of the Ottawa and Victoria observations.

I. ρ ORIONIS

$$\alpha = 5^h08^m.1 \qquad \delta = +2°45' \ (1900)$$
$$= 5^h10^m.7\,, \qquad = +2°48' \ (1950)\,.$$

According to Miss Roman (1952), the spectral type of ρ Orionis is K3 III on the MK system. The radial-velocity variation was discovered by Moore (1908) from six Lick spectrograms; only one spectrum is visible. In the interval 1940–1954, thirty-six more spectrograms were obtained with the Mills spectrograph (of dispersion 11 A/mm at λ 4500), and these plates have now been measured in a Hartmann spectrocomparator against a standard spectrogram of α Arietis (type K2 III). Measurement of two plates of β Geminorum and four of α Arietis along with those of ρ Orionis indicated that the measured velocities of these two standard-velocity stars require a correction of -0.7 km/sec to reduce them to the mean values given in *Lick Publications*, Vol. **16** (Campbell and Moore 1928). The correction to the Lick system, as defined by the larger body of material from all observatories, contained in R. E. Wilson's *General Catalogue of Stellar Radial Velocities*, is -1.0 ± 0.2 (p.e.) km/sec. The former correction has been applied to the measured velocities of ρ Orionis in deriving the elements and is contained in the observed radial velocities of Table 1. The velocities adopted for the 1905–1908 Lick observations are not the original values published by Moore but are the revised values given in *Lick Publications*, Vol. **16**.

A preliminary set of elements was adjusted by least squares; the solution was made by Dr. K. Osawa. The set of corrected values given in Table 2, together with their probable

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[When the Lick program for the determination of the radial velocities of stars brighter than magnitude 5.51 was completed in 1926, observations were begun with the Mills three-prism spectrograph, under the direction of J. H. Moore, on a number of stars whose variable velocity had been discovered in the course of the large program. Because of other demands on telescope time and especially because many of these stars were of long period, additional observations accumulated so slowly that, by 1949, the final results had appeared for only a portion of the stars on the program. In 1949, under the direction of the undersigned, the program was reviewed, observations were begun on a systematic basis, and a number of additional stars was added to the observing list. Since that time, as observations of a star have been completed, the material usually has been prepared for publication by an observatory assistant or a graduate student. The present paper by Father Bertiau contains the results of his study of three single-line binaries, the first two of which were found at Lick, while the third (32 Virginis) was added to the program in 1950 because of its interest as a metallic-line star. The following papers by Dr K Osawa and by E. S. Jackson, W. W. Shane, and Mrs. Beverly T. Lynds also deal with stars whose variable velocities were detected at Mount Hamilton.—G. H. HERBIG.]

† Assistant, Lick Observatory, 1953–1954; present address: University of Louvain, Louvain, Belgium.

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TABLE 1

RADIAL-VELOCITY OBSERVATIONS OF ρ ORIONIS

Plate No *	JD (Geocentric) 2400000+	Phase† (Days)	Observed Velocity (km/sec)	Residual, O−C (km/sec)
4023	17114 994	215 1	+39 8	+0 6
4434	17471 030	571 2	+32 8	−1 3
5028	17887 895	988 0	+49 1	−0 9
5549	18242 992	311 3	+34 3	−0 7
5562	18248 966	317 3	+33 3	−1 4
27281	29970 915	694 3	+39 0	+0 6
27653.	30275 047	998 4	+50 6	+0 7
27713‡	30307 930	1031 3	+49 4	−0 1
27733	30323 917	15 9	+49 6	+0 4
27751	30339 832	31 8	+48 4	−0 3
27767	30365 751	57 7	+48 4	+0 6
27863.	30403 675	95 6	+45 9	0 0
27872‡	30410 646	102 6	+45 1	−0 4
27873	30411 685	103 6	+45 2	−0 3
27885	30419 660	111 6	+45 1	+0 1
28276	30649 020	341 0	+34 9	+0 9
28507	30728 737	420 7	+33 6	+0 9
30161	31441 863	102 4	+46.2	+0 7
31460	32168 856	829 4	+45 4	+0 3
31472	32193 822	854 4	+47 2	+0 9
33151	33177 990	807 1	+43 6	−0 5
33237	33224 997	854 1	+46 2	−0 2
33264	33262 844	892 0	+47 9	−0 1
33302	33321 755	950 9	+49 2	−0 4
33803	33547 029	144 8	+42 2	−0 9
34688	33904 028	501 8	+32 4	−0 5
34798	33950 918	548 7	+34 5	+1 0
34819	33978 940	576 7	+33 9	−0 3
34916	34067 709	665 4	+37 0	−0 2
36984	34609 003	175 3	+41 3	0 0
37110	34640 008	206 3	+39 8	+0 1
37149	34650 980	217 3	+38 5	−0 6
37260	34681 070	247 4	+38 0	+0 4
37324	34721 720	288 1	+35 2	−0 6
37359	34733 806	300 1	+35 5	+0 2
37461	34782 694	349 0	+34 0	+0 2
37510	34804 654	371 0	+34 1	+0 7

* The following groupings of individual observations were made in order to simplify the least-squares solution: plates Nos. 5549 and 5562; 27713, 27733, and 27751; 27863, 27872, 27873, and 27885; 31460 and 31472; 34798 and 34819; 37110 and 37149; 37324 and 37359; 37461 and 37510

† The phases are referred to T

‡ These observations were given half-weight

TABLE 2

ORBITAL ELEMENTS OF ρ ORIONIS

$P = 1031.40 \pm 0.39$ days,	$\omega = 17\overset{\circ}{.}9 \pm 8\overset{\circ}{.}1$,
$K = 8.70 \pm 0.13$ km/sec,	$T =$ JD 2426182.46 $\pm$ $23\overset{d}{.}0$,
$\gamma = +40.5$ km/sec,	$a \sin i = 122.8 \times 10^6$ km,
$e = 0.098 \pm 0.015$,	$f(m) = 0.0695\ m_{\odot}$

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errors, was obtained. The probable error of an observation of unit weight is ± 0.5 km/sec. The elements are based on the thirty-seven spectrograms listed in Table 1; a number of additional observations was rejected on account of low plate quality. The velocity-curve of ρ Orionis is shown in Figure 1; the phases are referred to the T of Table 2.

II. η BOOTIS

$$\alpha = 13^h 49^m.9 \qquad \delta = +18°54' \ (1900)$$
$$= 13^h 52^m.3 , \qquad = +18°39' \ (1950) .$$

The variability of the radial velocity of η Bootis, of MK type G0 IV, was discovered by Moore (1905). The orbit was determined by Harper (1910) from twenty-four three-prism observations made at Ottawa; additional Ottawa one-prism, Lick, and Bonn

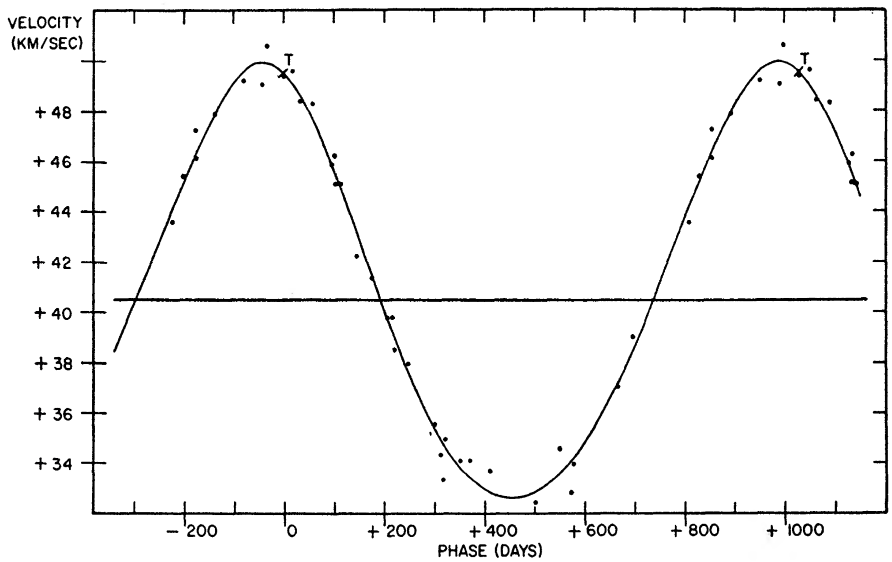

FIG. 1.—The radial-velocity-curve of ρ Orionis; the solid curve results from the elements of Table 2

velocities were used by Harper only to improve the period, for which he obtained a value of 497.1 days. Bianchi (1920) determined the elements by using the Ottawa three-prism velocities, the thirteen Lick and six Bonn observations, and eight new Cape velocities. Bianchi's elements were as follows:

$$P = 495 \text{ days}, \qquad \omega = 305°,$$
$$K = 8.0 \text{ km/sec}, \qquad T = \text{JD } 2418225,$$
$$\gamma = -0.15 \text{ km/sec}, \qquad a \sin i = 53.1 \times 10^6 \text{ km}.$$
$$e = 0.232,$$

The Lick velocities available to Bianchi, however, were only provisional values and were subsequently replaced by the results given in *Lick Publications*, Vol. **16**. Harper later (1935) revised his period to 492.5 days on the basis of the corrected Lick velocities and new Victoria one-prism observations obtained in 1923–1929.

In the years 1935–1947, eighty-four new three-prism spectrograms of η Bootis were obtained at Mount Hamilton. This new material has been combined with the earlier Lick observations of 1897–1922 and with the 1907–1910 Ottawa three-prism velocities, to derive definitive spectroscopic elements for the system. In order that the velocities

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might be as homogeneous as possible, all the Lick spectrograms taken with the "New" Mills spectrograph (i.e., those obtained during and after June, 1904) have been measured anew by the author in a Hartmann spectrocomparator against a plate of the sky spectrum. During this work, eight spectrograms of stars of constant velocity (β Leporis, β Virginis, and β Comae), which have about the same spectral type as η Bootis, were measured as a check on the velocity system. Since a negligible systematic correction of 0.0 ± 0.2 (p.e.) km/sec was found, the measured velocities of these stars are essentially on the Lick system as given in Wilson's *General Catalogue*. The February 10, 1897, to March 31, 1904, Lick observations as given in *Lick Publications*, Vol. **16**, have been used without change. Weights of either 1.0 or 0.5 were assigned to the Lick velocities according to the plate quality, and five observations (listed at the end of Table 3) were rejected because of poor plate quality. The weighting system used by Harper for the Ottawa three-prism velocities has been retained, but in a simplified form.

Provisional elements were computed for the system after it was found that a systematic correction of about +1.5 km/sec was required to make the Ottawa velocities consistent with the Lick observations. The provisional elements were corrected by least squares; a correction to the systematic difference between the two velocity systems was also carried as an unknown. The final computations were carried out by Mrs. Marcia Stone and Mr. C. B. Stephenson. The final elements, together with their probable errors, are given in Table 4. The probable error of an Ottawa observation of unit weight is ± 0.66 km/sec, and of a Lick velocity, ± 0.45 km/sec. Table 3 gives the essential data on the plate material and the representation of the observations by the elements of Table 4. The Ottawa velocities in Table 3 do not contain the correction required to reduce them to the Lick system, the final value of which was found to be $+1.43 \pm 0.1$ (p.e.) km/sec. The phases in Table 3 and in Figure 2 are referred to T. It will be noted that the new period is in better accord with the astrometric value of "about 494 days" derived by Daniel and Burns (1938) than were previous spectroscopic determinations.

No sign of the spectrum of a secondary star has been observed in η Bootis. It can be demonstrated in the following way that this result is consistent with other properties of the system. First, the astrometric and double-star data (Strand and Hall 1954) indicate that ζ Herculis, a visual binary whose primary, like η Bootis, is of type G0 IV, has masses of 1.2 and 0.8 $m_\odot$. Second, the astrometric observations of η Bootis (which has not been observed as a visual binary) by Daniel and Burns lead to an orbital inclination of 73°. Under the assumption that the mass $m_\odot$ of the brighter component of η Bootis is 1.2 $m_\odot$ with $f(m) = 0.0276\ m_\odot$ and $i = 73°$, the expression for the mass function may be solved for the mass of the fainter component, m_2, thus:

$$\frac{m_2^3}{(1.2 + m_2)^2} = 0.032 ,$$

which gives $m_2 = 0.45\ m_\odot$. On this basis the fainter component of η Bootis has the mass of a late K- or early M-type dwarf. If the companion is such a star, the visual difference in magnitude would be about 5 mag., which quite accounts for the absence of the companion in the combined spectrum. Such a faint companion of η Bootis would be somewhat similar to ζ Herculis B, for which Struve and Ratcliffe (1954) give a spectral type of dK0.

III. 32 VIRGINIS

$$\alpha = 12^h40^m.6 \qquad \delta = +8°13' \ (1900)$$
$$= 12^h43^m.1 , \qquad +7°57' \ (1950) .$$

32 Virginis was recognized as a metallic-line star by Roman, Morgan, and Eggen (1948). The metallic lines indicate a type of F6 IV, while the K-line strength corresponds

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TABLE 3

Radial-Velocity Observations of η Bootis

OTTAWA OBSERVATIONS

JD (Geocentric) 2400000+	Phase (Days)	Observed Velocity (km/sec)	Weight	Residual, O−C (km/sec)
17710 75	446 366	−0 1	1 0	−1 3
17716 68	452 296	+2 9	1 0	+0 7
17795 58	37 023	+9 0	0 8	−0 6
17968 84	210 283	−3 8	1 0	+0 2
17970 88	212 323	−3 5	1 0	+0 6
17989 94	231 383	−5 2	1 0	−0 2
17996 80	238 243	−6 8	1 0	−1 5
18031 91	273 353	−7 2	1 0	−0 8
18066 78	308 223	−6 7	0 8	+0 3
18085 67	327 113	−7 7	0 8	−0 7
18087 67	329 113	−7 1	1 0	−0 1
18115 59	357 033	−6 0	0 5	+0 5
18129 61	371 053	−7 5	0 8	−1 5
18138 61	380 053	−5 5	0 8	+0 1
18192 54	433 983	−0 3	1 0	+0 2
18314 97	62 240	+8 6	1 0	+0 6
18337 78	85 050	+5.2	1 0	−0 7
18355 85	103 120	+6 0	0 8	+1 9
18386 71	133 980	+2 8	0 8	+1 6
18529 56	276 830	−6 5	0 5	0 0
18549 56	296 830	−7 2	1 0	−0 3
18713 78	461 050	+5 3	0 5	+1 7
18727 70	474 970	+6 7	0 8	+0 8
18742 82	490 090	+8 0	0 8	+0 1

LICK OBSERVATIONS

Plate No	JD (Heliocentric) 2400000+	Phase (Days)	Observed Velocity (km/sec)	Weight	Residual, O−C (km/sec)
330	14035 794	230 621	− 2 9	0 5	+0 6
332	14036 827	231 654	− 5 1	0 5	−1 5
358	14057 744	252 571	− 6 4	0 5	−2 0
1160	14693 020	393 674	− 2 5	1 0	+0 8
2146	15524 755	237 063	− 5 2	1 0	−1 4
2798	16259 792	477 927	+ 6 8	0 5	−0 9
3189	16571 961	295 923	− 2 4	0 5	+3 0
3265	16646 711	370 673	− 5 3	0 5	−0 7
5240	18051 927	293 370	− 5 3	0 5	+0 1
5340	18136 707	378 150	− 4 6	0 5	−0 3
12337	23175 708	475 421	+ 7 4	1 0	0 0
22530	27928 875	286 858	− 4 5	0 5	+0 8
22567	27936 853	294 836	− 4 7	1 0	+0 7
22631	27958 823	316 806	− 6 5	1 0	−0 9
22665	27972 782	330 765	− 6 1	0 5	−0 5
22674	27975 804	333 787	− 6 6	1 0	−1 1
25364	28989 942	359 579	− 4 7	1 0	+0 3
25403	29011 840	381 477	− 4 5	1 0	−0 4
25458	29037 780	407 417	− 1 5	1 0	+0 7
26071	29277 003	152 467	+ 1 1	1.0	0 0

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TABLE 3—*Continued*

LICK OBSERVATIONS—*Continued*

Plate No	JD (Heliocentric) 2400000+	Phase (Days)	Observed Velocity (km/sec)	Weight	Residual, O−C (km/sec)
26081	29278 019	153 483	+ 0 7	1 0	−0 4
26087	29278 991	154 455	+ 1 5	1 0	+0 5
26142	29317 042	192 506	− 0 8	1 0	+0 8
26166	29339 009	214 473	− 1 8	1 0	+1 0
26193	29359 009	234 473	− 3 3	1 0	+0 4
26248	29383 941	259 405	− 2 7	0 5	+1 9
26409	29455 688	331 152	− 4 7	1 0	+0 9
26858	29695 005	76 296	+ 7 7	1 0	−0 5
26886	29709 010	90 301	+ 7 2	1 0	+0 4
26954	29758 835	140 126	+ 2 4	1 0	+0 2
26977	29767 831	149 122	+ 1 9	1 0	+0 5
26995	29776 852	158 143	+ 0 6	1 0	−0 1
27025	29793 740	175 031	− 1 3	1 0	−0 8
27047.	29800 732	182 023	− 1 6	0 5	−0 7
27340	30097 930	479 221	+ 8 7	1 0	+0 8
27343	30098 883	480 174	+ 8 0	1 0	−0 1
27351	30104 922	486 213	+ 8 9	1 0	0 0
27368	30112 906	0 024	+ 8 6	1 0	−1 2
27372	30121 858	8 976	+10 7	0 5	+0 1
27428	30154 753	41 871	+11 2	1 0	+0 2
27433	30158 696	45 814	+11 1	1 0	+0 4
27840	30402 023	289 141	− 4 9	1 0	+0 4
27867	30404 000	291 118	− 5 2	1 0	+0 2
27881	30418 049	305 167	− 5 8	1 0	−0 3
27898	30422 000	309 118	− 5 1	1 0	+0 5
27933	30427.015	314 133	− 5 4	1 0	+0 2
27938	30435 954	323 072	− 5 2	1 0	+0 4
27971	30444 985	332 103	− 4 2	1 0	+1 4
27985	30456 895	344 013	− 4 7	1 0	+0 7
28000	30468 892	356 010	− 5 1	0 5	0 0
28009	30474 893	362 011	− 4 2	1 0	+0 8
28016	30481 840	368 958	− 5 3	1 0	−0 6
28047	30511 762	398 880	− 3 4	1 0	−0 5
28054	30514 769	401 887	− 2 9	1 0	−0 2
28072	30530 704	417 882	− 0 5	0 5	+0 6
28091	30541 698	428 816	− 0 4	0 5	−0 6
28124	30557 679	444 797	+ 3 4	0 5	+0 9
28173	30595 659	482 777	+ 8 3	1 0	−0 1
28588	30767 004	159 949	+ 0 9	0 5	+0 3
28617	30783 998	176 943	− 0 9	1 0	−0 3
28645	30802 992	195 937	− 2 0	0 5	−0 2
28649	30808 889	201 834	− 3 1	1 0	−1 0
28691	30824 932	217 877	− 3 0	1 0	0 0
28769	30862 768	255 713	− 4 8	1 0	−0 3
29386	31159 000	57 772	+ 9 5	0 5	−0 3
29427	31170 963	69 735	+ 8 6	1 0	−0 2
29534	31216 899	115 671	+ 4 3	1 0	0 0
29598	31249 798	148 570	+ 1 2	1 0	−0 3
29693	31299 680	198 452	− 2 9	1 0	−1 0
30270	31484 071	382 843	− 5 1	0 5	−1 1

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TABLE 3—*Continued*

LICK OBSERVATIONS—*Continued*

Plate No	JD (Heliocentric) 2400000+	Phase (Days)	Observed Velocity (km/sec)	Weight	Residual, O−C (km/sec)
30345	31511 032	409 804	− 2 5	1 0	−0 6
30409	31546 983	445 755	+ 2 3	1 0	−0 3
30495	31567 859	466 631	+ 6 1	1 0	+0 1
30547	31599 757	4 356	+10 1	1 0	−0 1
30556	31615 708	20 307	+12 0	1 0	+0 8
30585	31633 713	38 312	+10 0	1 0	−1 0
30616	31659 683	64 282	+ 9 1	1 0	−0 2
30639	31677 681	82 280	+ 7 2	1 0	−0 4
30679	31699.655	104 254	+ 5 4	1 0	0 0
30921	31834 992	239 591	− 3 9	1 0	0 0
30968	31853 038	257 637	− 4 2	1 0	+0 4
31017	31881 016	285 615	− 4 6	1 0	+0 7
31064	31924 876	329 475	− 6 1	1 0	−0 5
31118	31946 808	351 407	− 5.5	1 0	−0 2
31168	31977 728	382 327	− 4 1	1 0	−0 1
31221	31999 697	404 296	− 2 3	1 0	+0 2
31272	32032 681	437 280	+ 1 7	0 5	+0 3
31301	32050 672	455 271	+ 3 0	0 5	−1 1
31326	32072 651	477 250	+ 8 6	0 5	+1 0
31779	32365 710	276 136	− 4 5	1 0	+0 6

EARLY LICK OBSERVATIONS REJECTED

Plate No	JD (Heliocentric) 2400000+	Observed Velocity (km/sec)	Plate No	JD (Heliocentric) 2400000+	Observed Velocity (km/sec)
277	13966 570	−0 5	3295	16658 783	−6 2
3178	16542 954	−2 4	3654	16851 009	+6 0
3215	16603 832	−7 1			

TABLE 4

SPECTROSCOPIC ORBITAL ELEMENTS OF η BOOTIS

$P = 494.173 \pm 0.05$ days, $\omega = 326^\circ.33 \pm 1^\circ.9$,

$K = 8.42 \pm 0.08$ km/sec, $T =$ JD $2428136.19 \pm 2^d.4$,

$\gamma = +1.01$ km/sec, $a \sin i = 55.3 \times 10^6$ km,

$e = 0.2575 \pm 0.009$, $f(m) = 0.0276\ m_\odot$.

to A6 and the hydrogen lines to F2. The velocity variation was detected by Adams (1914), and the first orbit was determined by Cannon (1915) from thirty-nine Ottawa observations. Cannon found a period of 38.3 days, and on twelve plates taken near the nodes he measured lines that he ascribed to a secondary star. The values of K for the two components were determined as 41 and 80 km/sec. Harper (1935) revised the period to 38.321 days on the basis of 1929–1932 observations at Victoria, and he expressed some skepticism over the reality of the line duplicity. After an examination of the Ottawa

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spectrograms, he regarded most of the double lines measured by Cannon as spurious, but he concluded that "doubling, while not pronounced, occasionally is present." Harper regarded only one of the nine Victoria plates as suggesting "anything like reality in the doubling." In 1941–1942 six additional Victoria plates with dispersion 30 A/mm were taken of 32 Virginis by Petrie (1950) for spectrophotometric purposes. (Dr. Petrie very kindly supplied us with unpublished data regarding these spectrograms.) He observed double lines on these plates, and, although the amount of the splitting was small, he was able to measure the difference in magnitude between the two components. He obtained a value of $\Delta m = 0.43 \pm 0.11$ mag. from lines in the λ 4100 region, and he assigned types of A5 and A6 to the brighter and fainter components, respectively.

In the years 1950–1954, twenty-three spectrograms of 32 Virginis were obtained at Mount Hamilton with the Mills spectrograph. The F-type spectrum visible on these

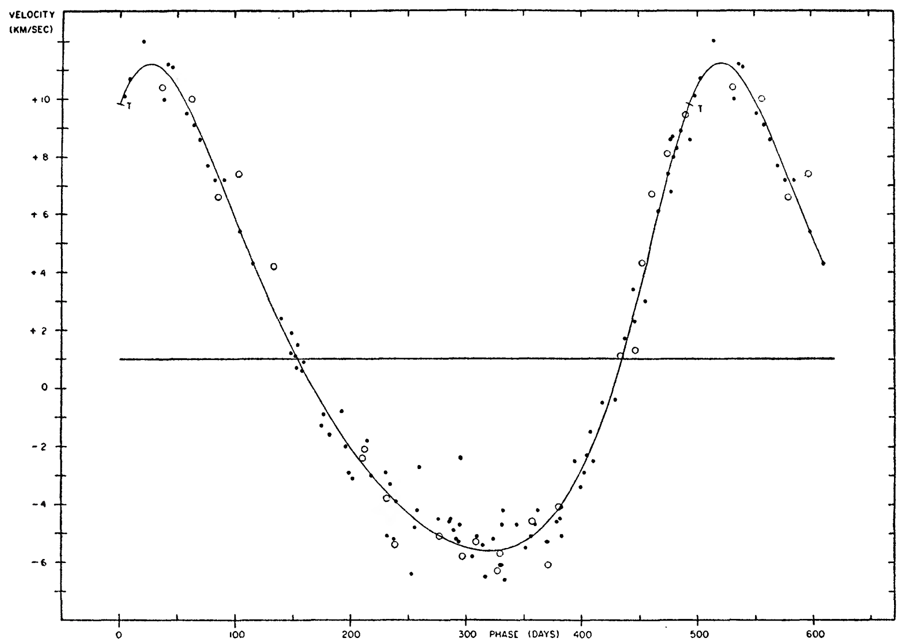

FIG. 2.—The radial-velocity-curve of η Bootis The small, filled circles represent Lick observations, while the larger, open circles correspond to the Ottawa three-prism observations of Harper, which have been reduced to the system of the Lick velocities. The solid curve corresponds to the elements given in Table 4.

plates has been measured in a spectrocomparator against a standard spectrogram of γ Cygni. A correction of $+2.3$ km/sec has been applied to all the measured velocities of 32 Virginis; this correction was obtained from a comparison of the measured velocities of six plates of α Persei with the velocity of that star given in Wilson's *Catalogue*. The plate material is listed in Table 5.

A preliminary study of the velocity variation showed that the shape of the curve given by the new Lick results differs systematically from the velocity-curve that fits the older Ottawa and Victoria observations. Consequently, the Canadian velocities were employed only to improve the period, which was found to be 38.324 days. Periods near 1 day could be ruled out. A small eccentricity, 0.07, given by a preliminary solution for the elements, indicated that the first method of Sterne (1941) for the least-squares correction of orbits of small eccentricity was appropriate. This method led to the elements and probable errors given in Table 6; no attempt at further improvement of the period was made in the solution.

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The lines of the brighter component of 32 Virginis are quite narrow. A determination of the line width by the method of Herbig and Spalding (1955) led to a value of the broadening, expressed as a rotational velocity, of $v \sin i = 20$ km/sec. This small width is quite inadequate to account for the fact that the scatter of individual velocities about the velocity-curve is fairly large; the probable error of a Mills radial-velocity observation of 32 Virginis having unit weight is ± 0.93 km/sec, which is about twice as large as one would expect for modern three-prism observations of a spectrum of this quality. Although no lines of the fainter star have been observed in the Mills region (λλ 4350–4650), the lines of the primary star are shallow, as if filled in by the continuous spectrum of a companion. However, any uncertainty in setting on the lines due to this moderate

TABLE 5

RADIAL-VELOCITY OBSERVATIONS OF 32 VIRGINIS

Plate No	JD (Geocentric) 2430000+	Phase* (Days)	Observed Velocity† (km/sec)	Weight	Residual, O−C (km/sec)
33306	3321 947	10 64	−17 4	1 0	−1 8
33322	3371 942	22 31	−56 5	0 5	−1 0
33330	3374 876	25 24	−36 1	1 0	+0 7
33341	3383 843	34 21	+26 0	1 0	−1 5
33349	3390 848	2 89	+29 7	1 0	+0 8
33359	3397 781	9 83	− 7 7	1 0	+1 9
33367	3413 816	25 86	−31 4	1 0	+0 4
33376	3418 689	30 73	+ 7 0	1 0	−1 2
33381	3418 867	30 91	+10 4	1 0	+1 0
33454	3464 751	0 15	+36 3	0 5	+2 2
34940	4093 950	16 16	−50 4	0 5	+2 4
34962	4100 995	23 21	−51 5	1 0	−0 7
36499	4466 869	5 84	+15 2	1 0	−0.9
36514	4470 818	9 79	−11 7	1 0	−2 3
36530	4473 784	12 76	−29 4	1 0	+1 8
36544	4482 927	21 90	−57 2	1 0	+0 1
36630	4509 764	10 41	−13 4	0 5	+0 5
37383	4742.056	12 76	−32 1	1 0	−0 8
37402	4748 028	18 73	−62 2	1 0	−1 0
37500	4802 010	34 39	+28 0	1 0	−0 1
37536	4827 721	21 78	−58 5	1 0	−0 8
37612	4864 808	20 54	−60 3	1 0	+0 7
37689	4911 787	29 20	− 2 9	1 0	+0 7

* The phases are referred to T_0

† These velocities include the correction of +2 3 km/sec required to reduce them to the Lick system

TABLE 6

SPECTROSCOPIC ORBITAL ELEMENTS OF 32 VIRGINIS

$P = 38.324$ days, $\omega = 210\overset{\circ}{.}02 \pm 5\overset{\circ}{.}1$,

$K = 48.05 \pm 0.33$ km/sec, $T_0 = \text{JD } 2434039.463 \pm 0\overset{d}{.}038$,*

$\gamma = -10.6$ km/sec, $a \sin i = 25.35 \times 10^6$ km,

$e = 0.074 \pm 0.006$, $f(m) = 0.438\, m_{\odot}$.

* T_0 is the epoch when the mean longitude is zero.

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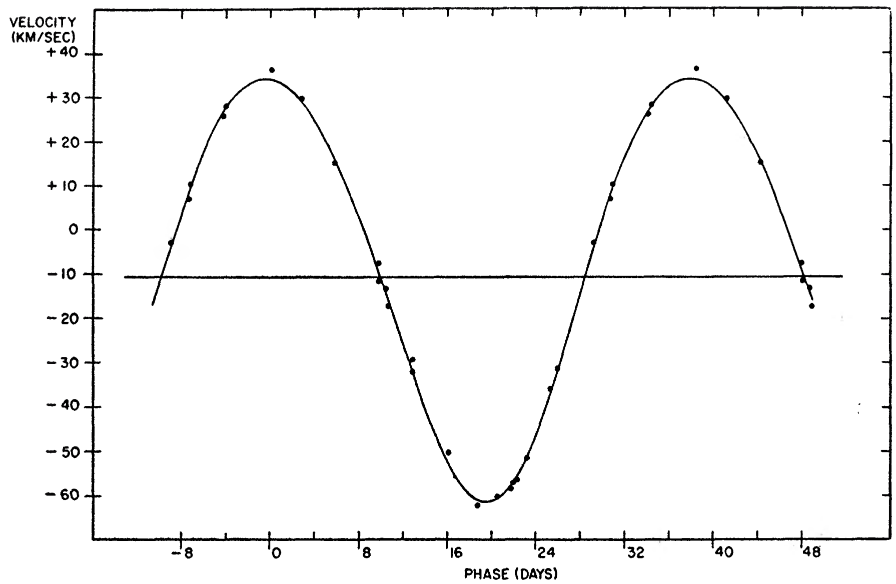

FIG. 3.—Lick radial-velocity observations of 32 Virginis, made in 1950–1954. The curve corresponds to the elements of Table 6.

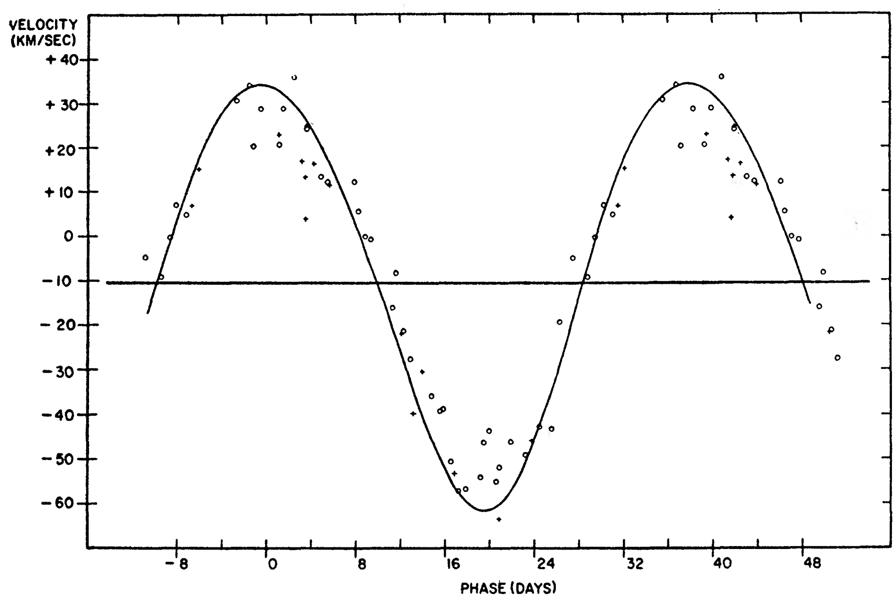

FIG. 4 —Representation of the 1915 Ottawa observations (*open circles*) of 32 Virginis and the 1929–1932, 1941–1942 Victoria observations (*crosses*) by the velocity-curve of Fig. 3, which was based on 1950–1954 Lick observations.

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amount of filling in would not suffice to produce the observed scatter, which therefore remains unexplained.

The Lick observations and the velocity-curve corresponding to the elements of Table 6 are shown in Figure 3. The Ottawa and Victoria observations are plotted in Figure 4, together with the Lick velocity-curve of Figure 3. It is clear that the 1915 Ottawa and the 1929–1932 Victoria velocities cannot be reconciled with the 1950–1954 observations. Because of the greater amount of data, the clearest discrepancy is with Ottawa: Cannon obtained a value of K of 41 km/sec, while the new value is 48 km/sec. Other elements have changed as well. Harper's Victoria observations depart systematically from the new curve in the region of maximum velocity, but their number is too small to make departures elsewhere entirely certain. Likewise, the 1941–1942 Victoria velocities are too few to establish any systematic differences. The apparent changes are of such an unusual character that, before accepting them, one should be certain that they do not arise somehow in the comparison of the Mills results with velocities determined at one-third the dispersion in a spectrum whose lines were described by Harper as "rather ragged and fuzzy." A redetermination of the spectroscopic elements after another decade, with a dispersion of about 10 A/mm, might shed some light on the question.

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