PUBLICATIONS OF
THE DAVID DUNLAP OBSERVATORY
UNIVERSITY OF TORONTO

Volume II | Number 14

SPECTROGRAPHIC ORBITS OF THE ECLIPSING SYSTEMS V822 AQUILAE, BV 241, BV 342, BV 374

PIM FITZGERALD

1964
TORONTO, CANADA

PRINTED AT
THE UNIVERSITY OF TORONTO PRESS

SPECTROGRAPHIC ORBITS OF THE ECLIPSING SYSTEMS V 822 AQUILAE, BV 241, BV 342, BV 374

By Pim FitzGerald

These four eclipsing systems have been studied spectrographically at this observatory in the years 1962 and 1963. Earlier observations of the star V 822 Aquilae, made between the years 1936 and 1939, have also been employed in the spectrographic study of this star.

Photometric studies made of V 822 Aquilae by Nicolini at Naples, and of the other three systems by the observers at Bamberg, had identified the stars as eclipsing systems. Periods were established by these observers, though not the other photometric elements.

The secondary component is visible in each spectrum, but it is too weak for accurate estimation of the mass-ratio except in the case of BV 241. Some indication of the mass-ratio is given with the spectrographic elements of each. The spectra of each system have been classified according to the MK system.

V 822 Aquilae

The star V 822 Aquilae, H.D. 183794, $\alpha(1900)$ 19^h $26^m.0$, $\delta(1900)$ $-02° 19'$, m_{pg} 6.7—7.3, sp. B8V, had been observed spectroscopically at this observatory by the late F. S. Hogg between 1936 and 1939.

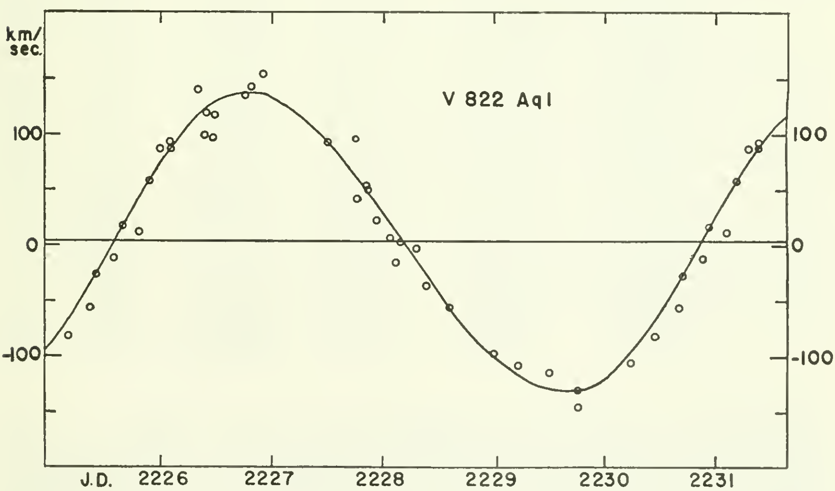

Figure 1

TABLE I

RADIAL VELOCITY OBSERVATIONS OF V 822 AQUILAE

J.D.	V_o km./sec.	$V_o - V_c$ km./sec.	Phase from final T	Dispersion A./mm.
2428272.676	− 14.6	−23.9	2.187	33
282.874	+ 96.2	+34.0	1.795	33
296.832	+ 12.0	−22.1	5.369	33
310.850	−108.2	+ 7.0	3.294	66
311.866	−105.2	− 1.1	4.310	66
314.673	+ 53.8	− 4.7	1.917	66
317.800	− 11.8	− 5.7	4.951	66
323.846	+140.5	+24.2	0.408	66
325.816	− 2.2	+14.2	2.378	66
328.800	+ 87.7	+18.3	0.063	66
355.693	+119.3	− 4.2	0.482	66
362.641	+ 7.0	− 9.4	2.134	66
400.639	− 96.7	+ 0.4	2.071	66
407.608	− 56.2	−12.2	4.744	66
800.544	+ 97.1	−31.2	0.545	66
2429165.514	+ 93.4	+ 9.8	0.154	66
176.507	+117.8	−11.2	0.561	66
183.494	+ 3.3	+ 2.3	2.235	66
432.793	− 55.8	− 0.7	2.679	66
465.719	−129.2	+ 2.1	3.834	66
469.648	− 36.0	− 7.6	2.468	66
486.663	−114.5	+15.0	3.580	66
2437558.566	+ 99.3	−23.3	0.471	33
563.553	+ 97.4	+12.2	0.164	33
569.516	+134.5	− 3.8	4.522	33
570.535	+ 41.8	−13.2	1.853	33
572.534	−145.5	−14.6	3.839	33
816.778	− 82.6	− 3.8	4.522	33
823.838	+154.7	+18.9	0.990	33
824.785	+ 50.7	+ 7.1	1.938	33
840.750	+ 23.3	− 9.5	2.017	33
843.749	+ 16.8	+10.8	5.014	33
864.694	+ 26.6	+10.9	4.781	33
891.653	+ 57.3	+ 4.9	1.075	33
892.579	+142.9	+ 4.9	0.895	33
898.565	+ 92.9	+ 4.8	1.583	33

Observation was recommenced in 1962 by J. F. Heard as a result of the photoelectric observations of Nicolini (Fresa 1961), which identified the star as an eclipsing system of period 2.6477 days. A total of thirty-six measurable plates have been used to determine the spectrographic

TABLE II

ORBITAL ELEMENTS OF V 822 AQUILAE

Element	Preliminary	Final	m.e.
Period	P 5.2949 days	5.29510	0.00004
Eccentricity	e 0.0	0.089	0.028
Angle of periastron	ω	294°	19°
Epoch of mean longitude	T_o J.D. 2432227.020	J.D. 2432226.900	0.022
Epoch of periastron	T	J.D. 2432225.924	0.279
Velocity of the system	γ +4.0 km./sec.	−1.6	2.7
Semi-amplitude	K 138.0 km./sec.	135.0	4.1
$a \sin i$		9.8×10^6 km.	0.4×10^6
Mass-ratio		1.0:	0.1:
m $\sin^3$ i		5: ⊙	2:

orbit. The spectral lines are broad, and on most plates only the lines of hydrogen and sometimes λ4481 of Mg II are measurable. Lines of the secondary spectrum appear on a few plates, but ought only to be used to give a rough indication of the mass-ratio, since they are very weak and indistinct.

Since the spectrographic observations cover a long interval (between 1936 and 1963), the period determined by Nicolini has not been used in the solution. The period obtained here, 5.29510 days, is close to double that of Nicolini. This may be explained by his observing primary and secondary minima of equal depth, and by his making the reasonable assumption that he had observed only one of two eclipses.

The six elements were obtained from the pre-computed curves of R. K. Young (1936), and then corrected by a computer programme of least squares employing the method of Sterne (1941) for zero eccentricity. The mass-ratio was estimated from the method of Wilson (1941). The velocity of the interstellar medium, determined from the Ca II lines λ3933 and λ3968, was found to be -9.8 ± 1.0 km./sec.

Table I lists the observed velocities and velocity residuals; Table II lists the preliminary and final elements; and figure 1 shows the velocity curve of the system. The average internal probable error of a single velocity determination is about 5 km./sec.

BV 241

The star BV 241, H.D. 190020, α(1900) $19^h\ 57^m\!.9$, δ(1900) 73° 21′, m_{pg} 9.4–10.3, sp. F5V, F5V, was identified as an eclipsing variable of period 1.682000 days by the Bamberg observers from photographic

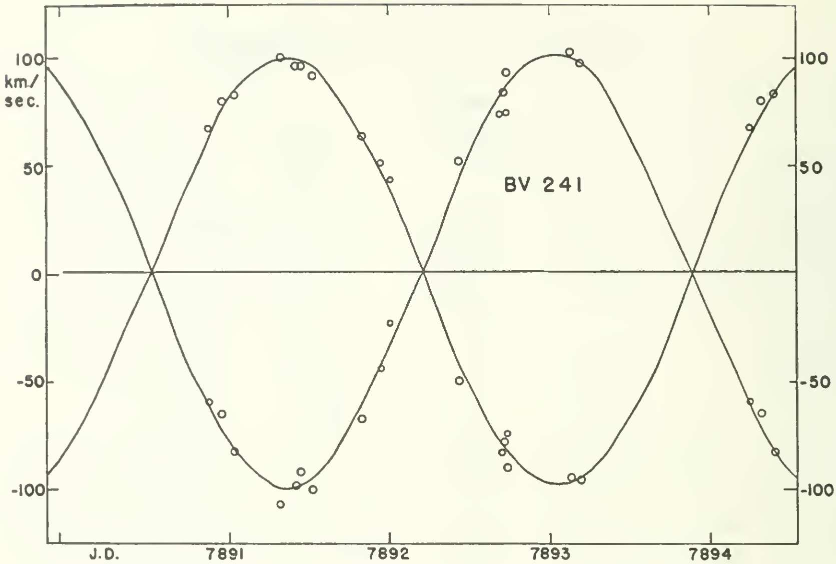

FIGURE 2

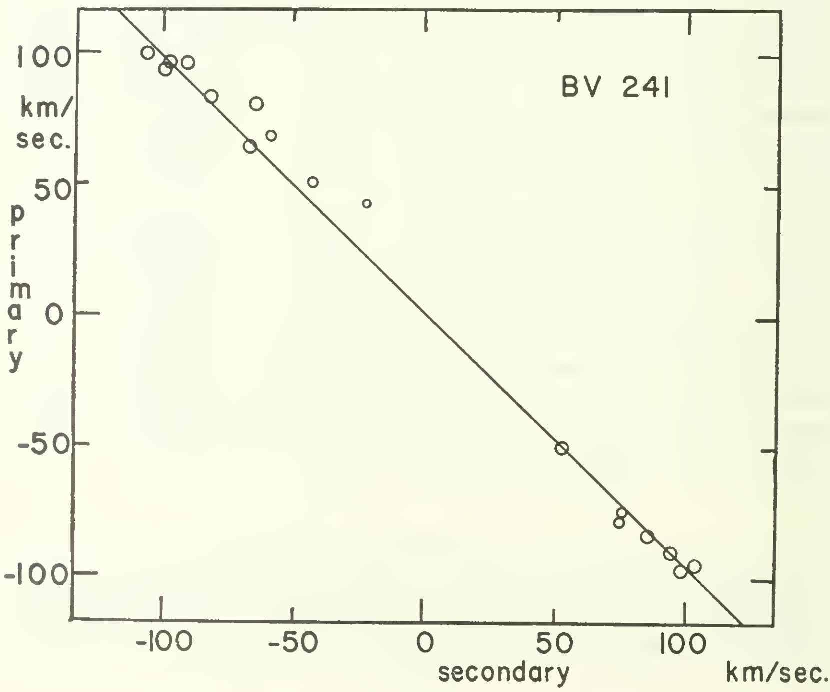

FIGURE 3

TABLE III

RADIAL VELOCITY OBSERVATIONS FOR BV 241

J.D.	Primary V_o km./sec.	Primary $V_o - V_c$ km./sec.	Secondary V_o km./sec.	Secondary $V_o - V_c$ km./sec.	Phase from final T_o	Weight
2437843.785	+ 68.7	+4.4	− 59.3	+ 3.0	2.870	0.7
7844.741	+ 63.7	+0.9	− 67.4	− 6.7	0.462	1.0
7847.741	+ 93.9	−2.1	− 99.6	− 5.3	0.152	1.0
7855.733	− 89.2	−6.8	+ 93.4	+ 7.6	1.362	1.0
7858.797	− 49.6	−7.5	+ 52.1	+ 7.0	1.062	1.0
7860.768	+ 83.4	−1.4	− 82.4	+ 0.6	3.033	1.0
7865.802	− 77.9	+2.2	+ 73.6	− 9.9	1.339	0.7
7879.678	− 94.7	+1.3	+102.8	+ 3.2	1.759	1.0
7884.723	+ 96.3	−3.3	− 91.7	+ 6.3	0.076	1.0
7892.702	− 82.9	−4.1	+ 84.2	− 2.0	1.327	1.0
7894.685	+100.1	−1.0	−107.1	− 7.6	3.310	1.0
7898.679	+ 51.5	+6.8	− 43.3	− 0.7	0.576	0.7
7906.647	− 95.6	−2.0	+ 97.4	+ 0.2	1.816	1.0
7911.606	+ 96.3	−4.2	− 97.7	+ 1.1	0.047	1.0
7915.559	+ 43.8	+9.4	− 23.0	+ 9.2	0.636	0.5
8161.852	− 74.0	+7.9	+ 74.5	−10.8	1.357	0.7
8166.808	+ 80.3	+5.2	− 64.9	+ 8.3	2.949	1.0

TABLE IV

ORBITAL ELEMENTS FOR BV 241

Element		Preliminary	Final	m.e.
Period	P	3.364000 days	3.364000	
Eccentricity	e	0.0	0.0	0.014
Epoch of mean longitude	T_o	J.D. 2437891.320	J.D. 2437891.375	0.025
Velocity of the system	γ	0.0 km./sec.	+1.3	1.0
Semi-amplitude, primary	K_1	100.0 km./sec.	99.4	1.7
Semi-amplitude, secondary	K_2	105.0 km./sec.	100.4	1.7
$a_1 \sin i$, primary			4.60×10^6 km.	0.08×10^6
$a_2 \sin i$, secondary			4.65×10^6 km.	0.08×10^6
Mass-ratio			1.01	0.02
$m_1 \sin^3 i$, primary			1.38 ☉	0.03
$m_2 \sin^3 i$, secondary			1.37 ☉	0.03

photometry (Strohmeier 1959). Spectrographic observation was started at this observatory in 1962. Nineteen usable plates were obtained during the summers of 1962 and 1963 using a dispersion of 33 A./mm.

Both spectra are visible and are of approximately equal strength. The number of lines in the spectrum of each component which could be measured was about fifteen on plates of normal exposure and reasonably large doublet separation, and about five on those of weak exposure or those on which the double lines were close. Weights based on the plate quality and velocity separation were assigned to the individual velocity determinations and these are given in Table III. The average internal probable error of a velocity measure from a well exposed plate is 2 km./sec., and from a weak plate is 5 km./sec.

Exactly double the period obtained from the photometric investigation has been used in the solution for the elements, since it fitted our observations well. The explanation for the difference in period is the same as that given for V 822 Aquilae. The remaining elements were obtained from the pre-computed curves of R. K. Young (1936), and then corrected by a computer programme of least squares following the method of Sterne (1941) for double-line binaries of zero eccentricity.

The mass-ratio was estimated from the ratio of semi-amplitudes and by the method of Wilson (1941). Agreement was found within the mean error for both the mass-ratio and the velocity of the system as found from each method. The mass-ratio and velocity of the system given by the least-squares solution were, respectively; 1.01 ± 0.02, and $+1.3 \pm 1.0$ km./sec., and by Wilson's method: 1.03 ± 0.02, and $+1.2 \pm 0.8$ km./sec.

Table III lists the observed velocities and velocity residuals; Table IV lists the preliminary and final elements; figure 2 shows the velocity curves of both components of the system; and figure 3 shows the diagram for Wilson's method of obtaining the mass-ratio.

BV 342

This star, BV 342, H.D. 204038, $\alpha(1900)$ 21^h $20^m\!.8$, $\delta(1900)$ 33° 16′, m_{pg} (1931–1939) 8.6–9.1, m_{pg} (1952–1960) 8.35–8.85, sp. A3Vm, was identified as an eclipsing variable of period 0.7858620 days by the Bamberg observers from photographic photometry (Strohmeier, Knigge and Ott 1962). They have pointed out that the character of the light curve and photographic magnitude of the system have changed considerably between 1931 and 1960. Twenty-seven spectrograms of the system were obtained during 1962 at this observatory using a dispersion of 33 A./mm. The mean exposure time was about 0.06 days.

The spectrum of the primary component is that of a metallic line A-star having very wide absorption lines. The classification of A3V

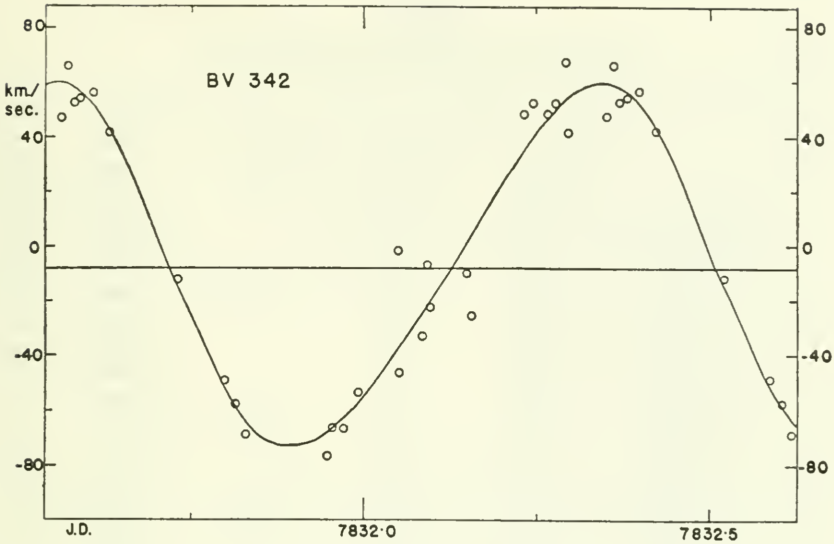

FIGURE 4

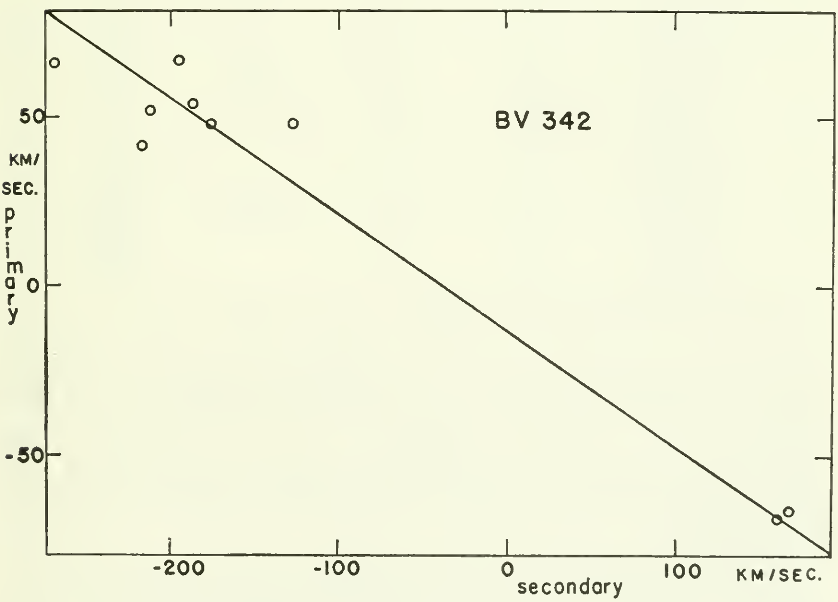

FIGURE 5

TABLE V

Radial Velocity Observations of BV 342

	Primary			
J.D.	V_o km./sec.	$V_o - V_c$ km./sec.	Secondary V_o km./sec.	Phase from final T
2437831.799	−49.0	+ 3.7		0.104
840.790	− 9.5	−11.8		0.451
844.817	+52.3	+11.5	−212.2	0.549
852.782	+47.2	−12.2		0.655
855.658	−32.9	− 8.7		0.388
858.709	−53.6	+ 3.4		0.295
861.808	−76.8	− 9.4		0.251
869.674	−66.3	− 0.3	+166.9	0.258
878.760	+56.4	+ 4.1		0.700
886.043	+42.0	− 1.7		0.724
888.870	+67.1	+13.7	−195.3	0.594
891.691	−66.6	− 3.4		0.271
895.749	−22.0	− 2.7		0.400
898.613	−57.8	+ 1.1		0.120
898.888	− 6.5	− 6.5		0.395
899.847	+48.3	+ 1.3	−127.7	0.568
904.658	+66.3	+ 7.4	−269.3	0.664
906.703	− 1.8	+36.5		0.351
907.716	+52.3	+ 2.5		0.579
907.818	+54.2	− 2.5	−187.1	0.681
911.664	+41.7	−12.5	−217.0	0.597
915.669	+52.3	− 4.6		0.673
915.818	−12.0	+ 2.5		0.036
918.674	+48.5	+12.5	−175.5	0.535
938.706	−68.7	− 5.2	+160.8	0.134*
954.642	−46.4	− 8.7		0.353
955.533	−25.8	−31.2		0.458

*Secondary given only half weight.

was based on the hydrogen line strength in the spectrum. The measured line broadening of 150 km./sec. for the iron lines coincides well with the value given by Babcock (1960) for rotational broadening in an early A-star with a period of the order of 0.8 days. This indicates that the orbital and rotational periods of the primary component may be synchronized.

The spectrum of the secondary component is visible on several of the plates, but is extremely weak and diffuse, being measurable on only a few of the plates near phases of extreme velocities. Between fifteen and twenty-five lines were measured on each plate for the primary com-

TABLE VI

ORBITAL ELEMENTS FOR BV 342

Element	Preliminary	Final	m.e.
Period	P 0.7858620 days	0.7858620	
Eccentricity	e 0.21	0.115	0.053
Angle of periastron	120°	76°	34°
Epoch of periastron	T J.D. 2437831.800	J.D. 2437831.695	0.076
Velocity of the system	γ −4.5 km./sec.	−8.1	2.8
Semi-amplitude, primary	K_1 71.0 km./sec.	65.9	3.8
$a_1 \sin i$, primary		7.03×10^5 km.	0.43×10^5
Mass-ratio		2.95	0.12
$m_1 \sin^3 i$, primary		1.02 ⊙	0.36
$m_2 \sin^3 i$, secondary		0.35 ⊙	0.24

ponent, giving an average internal probable error for one velocity determination of 3 km./sec. On the nine plates measured for the secondary component, only the lines of hydrogen, Hβ and Hγ, could be measured, giving an average internal probable error of 9 km./sec. for one velocity determination.

Strohmeier's period fitted our observations well, and it was therefore used in the solution for the orbit. The remaining elements were obtained from the pre-computed curves of R. K. Young (1936), and then adjusted by a computer programme of least squares employing the method of Lehmann-Filhés (1894) for a single-line binary.

The mass-ratio has been estimated using the method of Wilson (1941). Agreement was found within the mean errors between the velocity of the system as determined from Wilson's method (−9.5 ± 1.0 km./sec.) and from the Lehmann-Filhés method (−8.1 ± 2.8 km./sec.).

Table V lists the observed radial velocities and the velocity residuals; Table VI lists the preliminary and final elements; figure 4 shows the velocity curve of the primary component; and figure 5 shows the diagram for Wilson's method of obtaining the mass-ratio.

BV 374

This star, BV 374, H.D. 217224, α(1900) $22^h\ 54^m.2$, δ(1900) 67° 52′, m_{pg} 8.2–8.8, sp. B3V, was found to be an eclipsing variable of period 4.908756 days by the Bamberg observers from photographic photometry (Strohmeier, Knigge and Ott 1962). Nineteen usable spectrograms have been obtained at this observatory in the summer of 1962 with a dispersion of 33 A./mm.

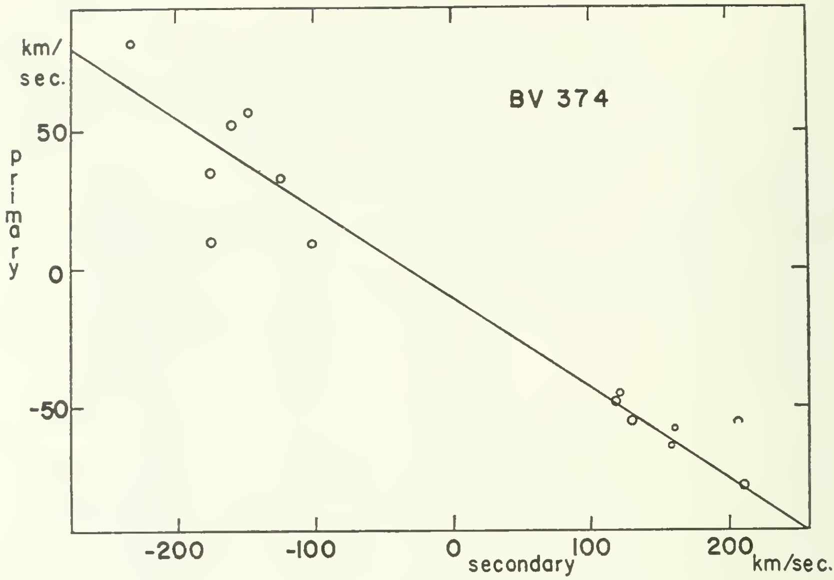

Figure 6

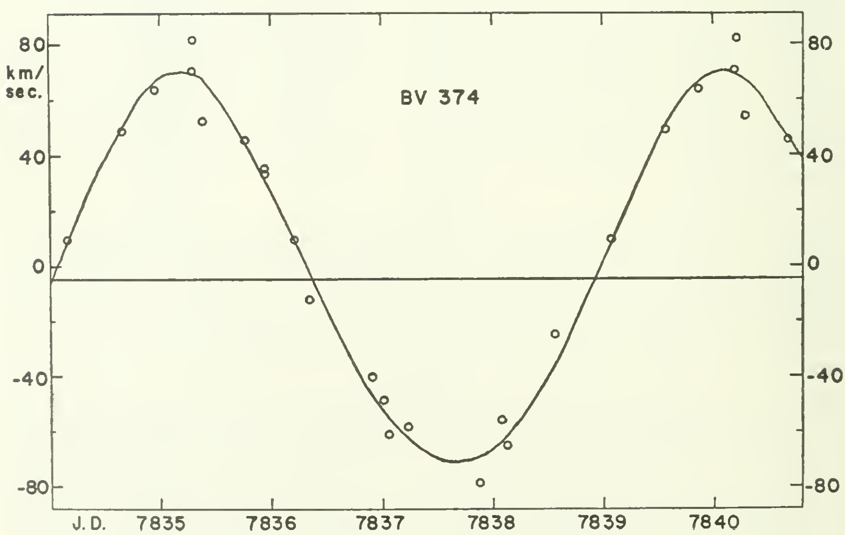

Figure 7

TABLE VII

RADIAL VELOCITY OBSERVATIONS FOR BV 374

J.D.	Primary V_o km./sec.	Primary $V_o - V_c$ km./sec.	Secondary V_o km./sec.	Secondary Weight	Phase from final T
2437840.830	+35.0	+ 2.8	−174.6	1.0	0.951
844.817	+70.6	+ 2.2			0.029
855.817	+ 9.7	0.0	−176.1	1.0	1.212
860.862	−12.2	− 9.2			1.355
864.814	+52.4	−14.1	−158.6	1.0	0.391
878.810	+48.7	− 2.7			4.570
882.817	−25.5	+ 2.2			3.668
884.833	+45.7	− 0.2			0.775
895.793	−40.2	+ 6.1	+121.0	0.5	1.917
898.793	+63.9	− 2.5	−147.1	0.7	4.864
899.773	+33.2	+ 4.1	−123.1	0.7	0.949
900.796	−48.4	+ 3.5	+118.9	1.0	2.012
905.750	−60.8	− 6.4	+130.0	1.0	2.057
906.779	−55.9	+ 7.5	+207.7	0.7	3.086
907.767	+ 9.4	+ 0.4	−112.2	0.7	4.074
911.730	−64.8	− 3.0	+159.3	0.5	3.129
915.743	−58.1	+ 4.3	+160.3	0.5	2.233
918.720	+82.2	+ 2.1	−232.8	0.7	0.301
955.661	−78.4	− 9.2	+212.0	1.0	2.881

TABLE VIII

ORBITAL ELEMENTS OF BV 374

Element	Preliminary	Final	m.e.
Period	P 4.908756 days	4.908756	
Eccentricity	e 0.060	0.063	0.037
Angle of periastron	ω 45°	346°	34°
Epoch of mean longitude	T_o J.D. 2437834.547	J.D. 2437835.170	0.030
Epoch of periastron	T	J.D. 2437834.970	0.484
Velocity of the system	γ −5.0 km./sec.	−4.9	1.8
Semi-amplitude, primary	K_1 70.0 km./sec.	70.5	2.4
$a_1 \sin i$, primary		4.66×10^6 km.	0.17×10^6
Mass-ratio		2.94	0.27
$m_1 \sin^3 i$, primary		7.58 ⊙	0.96
$m_2 \sin^3 i$, secondary		2.58 ⊙	0.21

The spectral lines are well defined in the primary component, the most prominent being those of hydrogen, helium, and ionized oxygen. About ten lines were measured on each plate, yielding an average internal probable error of 3 km./sec. for each velocity determination. The secondary component is visible on many of the plates, but is considerably weaker than the primary and consequently gave high internal probable errors of about 9 km./sec. for individual velocity determinations.

The Bamberg period fitted our observations well, and was therefore used here. The remaining elements were obtained from the pre-computed curves of R. K. Young (1936), and then adjusted by a computer programme of least squares employing the method of Sterne (1941) for a single-line binary of non-zero eccentricity.

The method of Wilson (1941) has been employed to estimate the mass-ratio, using the observations weighted according to the probable error of the velocity determination for the secondary component. Agreement within the mean errors was found between the velocity of the system as determined from Wilson's method (-7.8 ± 3.7 km./sec.) and from Sterne's method (-4.9 ± 1.8 km./sec.).

Table VII lists the observed radial velocities and velocity residuals; Table VIII lists the preliminary and final elements; figure 6 shows the velocity curve of the primary component; and figure 7 shows the diagram for Wilson's method of obtaining the mass-ratio.

Acknowledgements

The author would like to thank Dr. J. F. Heard for suggesting the study of these systems, and him and Dr. J. D. Fernie for their help and encouragement. This research was supported in part by a grant from the National Research Council.

References

Babcock, H. W. 1960, "Stellar Atmospheres", p. 309 (vol. 6, "Stars and Stellar Systems"), Univ. Chicago Press.

Fresa, A. 1961, *Annali dell' Istituto Universitario Navale di Napoli*, vol. 30.

Lehmann-Filhés, R. 1894, *A.N.*, no. 3242, p. 136.

Sterne, T. E. 1941, *Proc. of Nat. Acad. of Sci.*, vol. 27, p. 175.

Strohmeier, W. 1959, *Kleine Veroffentichungen der Remeis-Sternwarte Bamberg*, no. 24, p. 2.

Strohmeier, W., Knigge, R. and Ott, H. 1962, *Veroffentichungen der Remeis-Sternwarte Bamberg*, vol. 5, no. 13, pp. 3, 10.

Wilson, O. C. 1941, *Ap. J.*, vol. 125, p. 661.

Young, R. K. 1936, Pre-computed Curves for Orbital Elements, unpublished.