ORBIT OF THE SPECTROSCOPIC BINARY 36 τ^9 ERIDANI

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ABSTRACT

The *radial velocity* of 36 τ^9 Eridani was measured on 53 one-prism spectrograms. The *period* was found to *change* appreciably during the course of one year. Between September, 1926, and February, 1927, $P=0.85437$ day. This period does not satisfy our observations of 1924–1926, requiring a correction of +0.0009 day to bring them into agreement with the later observations. An average period of 0.8544075 day is indicated, but the deviation from this value in 1926–1927 is well marked.

The *orbital elements* were derived from the observations of 1926–1927, and a least-squares solution was carried through. The orbit is *circular;* the semi-amplitude of the variation in velocity is 35.7 km/sec., and the velocity of the system is +19.7 km/sec.

The lines of the *second component* could be measured on several plates and the resulting *mass-ratio is 0.35.*

The *silicon lines* λ 4128 and λ 4132, which are unusually strong in the spectrum of this star of type A0, give the same velocity as the other lines. The *spectrum resembles* that of *α Canum Venaticorum,* but the Europium lines are absent or very faint. Some of the lines are suspected to vary in intensity. These are identical with the so-called "second group" of variable lines in α Canum Venaticorum.

The *two components* of this system are believed to be *almost in contact.* The small width of the absorption lines is probably due to the fact that the planes of orbital motion and of axial rotation of the two stars coincide, and that their inclination is small.

The radial velocity of 36 τ^9 Eridani was found to be variable by E. B. Frost,[1] in 1907, when nine spectrograms were obtained with the Bruce spectrograph of the Yerkes Observatory. After that the observations of this star were discontinued. At the suggestion of Professor Frost a new series of observations was begun in December, 1924, and the material available at present is sufficient for a determination of the orbit.

The position of τ^9 Eridani, or Boss 923, for 1900 is: α $3^h15^m.7$, $\delta - 24^\circ18'$. Its visual magnitude is 4.69[2] and its color-index is zero. The spectral type is given in the *Henry Draper Catalogue* as A0p, and a remark calls attention to the unusual strength of the silicon lines 4128.1 and 4131.1 and of the strontium line 4077.9. A more detailed description of this spectrum is given in a later section of this paper.

The radial velocities.—In addition to 9 early plates taken in 1907–1908, we have utilized 41 spectrograms taken with the one-

[1] *Astronomische Nachrichten,* **177**, 174, 1908.

[2] *Henry Draper Catalogue,* No. 25267.

TABLE I

Radial Velocities of 36 τ^9 Eridani

Date	G.C.T.	Observer	Quality	Velocity				Mean Velocity
				σ	σ	Hu	Hu	
1907 Feb.	16.040	F, Fox	g	+ 7.9	....	+12.3	....	+10.1
Dec.	20.153	F, L, S	f	+31.8	....	....	....	+31.8
Dec.	30.167	Fox, S	g	−25.8	−27.1	−33.2	....	−28.7
1908 Jan.	13.113	F, L, S	g	+50.1	....	....	....	+50.1
Jan.	17.151	L, S	g	−17.3	−31.6	−29.2	....	−26.0
Jan.	18.018	B, F, S	g	+11.3	....	+ 3.8	....	+ 7.5
Jan.	21.076	L, S	g	+37.9	....	+30.6	....	+34.2
Jan.	28.083	B, S	g	+ 5.2	....	−11.6	....	− 3.2
Feb.	3.054	B, S	g	+ 1.4	....	+ 8.2	....	+ 4.8
1924 Dec.	1.242	σ, S	f	+ 7.2	+ 3.1	+ 3.1	....	+ 4.5
1925 Jan.	10.090	σ, S	g	− 5.2	− 7.4	− 4.3	....	− 5.6
Jan.	31.038	σ	p	+55.6	+39.7	+45.7	....	+47.0
Feb.	1.044	B	f	+61.0	+52.8	+48.1	....	+53.9
Feb.	5.070	B, S	p	+ 3.7	+ 0.3	+19.8	....	+ 7.9
Feb.	12.050	B, σ, S	g	+24.7	+23.9	+29.2	....	+25.9
Nov.	2.350	B, S	g	+68.4	+67.0	+63.7	....	+66.4
Nov.	14.292	σ, S	g	+58.3	+59.1	+51.6	....	+56.3
1926 Jan.	10.131	σ, S	g	−11.4	− 9.5	−24.9	−15.9	−15.4
Sept.	15.490	σ	g	+33.9	+35.1	....	....	+34.5
Sept.	15.510	σ	g	+27.1	+25.8	....	....	+26.4
Sept.	16.471	σ	g	−13.9	−12.9	....	....	−13.4
Oct.	13.374	σ, M, S	f	+55.2	+64.9	+64.2	....	+61.4
Oct.	13.408	σ, S	f	+60.8	+60.2	+53.7	....	+58.2
Oct.	15.317	σ, S	g	+30.1	+29.5	+28.1	....	+29.2
Oct.	15.353	σ, S	g	+41.5	+40.8	+36.3	....	+39.5
Oct.	15.392	σ, S	g	+38.9	+33.6	+32.4	....	+35.0
Oct.	21.317	σ, M, S	g	+32.7	+33.3	+30.4	....	+32.1
Oct.	26.288	σ, M, S	g	+55.9	+61.0	+54.8	+61.3	+58.3
Oct.	26.324	σ, S	f	+62.6	+63.2	+49.8	+56.1	+56.4
Nov.	2.278	σ, S	g	+22.3	+22.2	+21.9	....	+22.1
Nov.	2.312	σ, M	g	+18.3	+21.8	+22.8	....	+21.0
Nov.	23.335	σ, S	f	+35.7	+30.7	+32.1	....	+32.9
Nov.	27.277	σ, S	p	−18.3	−41.0	....	....	−29.5
Dec.	30.165	B, S	g	+56.6	+52.9	+48.4	+43.4	+50.2
1927 Jan.	6.102	B, S	g	+45.9	+52.0	+39.5	....	+45.8
Jan.	7.077	σ, Hu, S	g	+14.3	+16.2	+14.6	....	+15.0
Jan.	7.118	σ, Hu, S	g	+18.6	+17.5	+20.4	....	+18.8
Jan.	7.159	σ, Hu, S	g	+11.6	+12.0	+11.1	....	+11.6
Jan.	14.123	σ, S	g	−15.6	−10.8	−18.8	....	−15.1
Jan.	14.167	σ, S	f	−22.8	−24.4	−28.3	....	−25.2
Jan.	15.002	σ, M, S	g	− 0.4	+ 3.6	+ 6.7	....	+ 3.3
Jan.	15.053	B, M, S	g	+ 6.2	+ 8.8	+ 6.7	....	+ 7.2
Jan.	15.098	σ, M, S	g	+ 1.6	+ 7.8	+16.2	....	+ 8.5
Jan.	15.138	σ, M, S	f	+ 9.0	+ 6.8	....	....	+ 7.9
Jan.	15.178	σ, M, S	p	+18.9	+18.6	+14.4	....	+17.3
Jan.	20.015	B, σ, M	g	−16.8	....	−14.2	....	−15.5
Jan.	20.133	M, σ, S	f	−22.4	....	−32.4	....	−27.4
Jan.	27.104	B, M, S	g	+18.0	....	+20.9	....	+19.4
Jan.	27.144	B, M, S	g	+19.4	....	+19.9	....	+19.6
Feb.	1.088	σ, Hu, S	f	−12.0	....	− 5.3	....	− 8.6
Feb.	4.004	B, M, S	g	+55.2	....	+56.8	....	+56.0
Feb.	4.056	B, M	g	+57.7	....	+54.0	....	+55.8
Feb.	4.102	M, S	f	+59.3	....	+62.5	....	+60.9

The names of the observers and the quality of the plates are designated as follows: B=S. B. Barrett; F=E. B. Frost; Fox=Philip Fox; Hu=C. Hujer; L=O. J. Lee; M=W. W. Morgan; σ=O. Struve; S=F. R. Sullivan; g=good; f=fair; p=poor.

prism Bruce spectrograph during the years 1924–1927. Three additional spectrograms were secured by Struve with the 60-inch reflector of the Mount Wilson Observatory, on two consecutive nights in September, 1926. All 53 plates were measured by Struve, and most of them were independently remeasured by Hujer. Since the lines are sharp and well defined, the precision of setting should be greater than is usually the case for stars of early spectral types. This

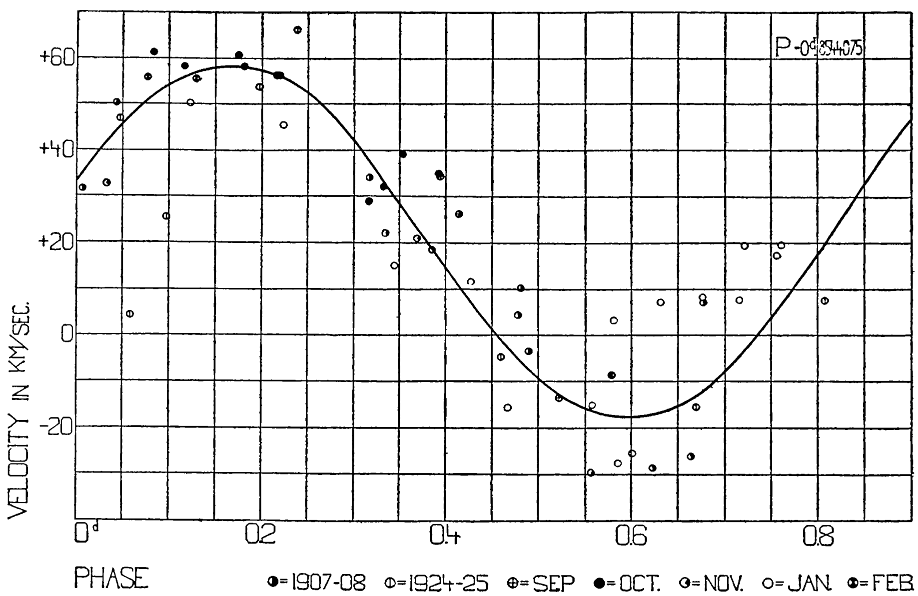

FIG. 1.—Velocity curve of 36 τ^9 Eridani. The observations were reduced with the average period 0.8544075 day. Velocities obtained in September, 1926, are shifted slightly to the right of the curve. Those of October and November, 1926, agree with the curve, while January and February are shifted to the left. Phase zero corresponds to J.D. 2424804.000. G.C.T.

is brought out by the individual results collected in column 4 of Table I. The lines used for determining the radial velocity were: *Ca*+3933.667, *Hδ* 4101.738, *Si* +4128.053, *Si*+ 4130.884, *Hγ* 4340.467, *Mg*+ 4481.230, *Fe* 4549.474, and *Hβ* 4861.326. Systematic corrections have been applied to all of the measures, and the results are believed to be free from any appreciable errors due to the instrument or to the method of reduction.

The period.—An inspection of the three Mount Wilson plates of September, 1926, showed that the period must be short. In fact, the two plates of September 15, separated by an interval of only 30 minutes, clearly show the change in velocity. Later observations fixed the period at about 0.85 day. Long series of observations obtained during the same night show that the period cannot be very different from this value. After a number of attempts, it was found possible to combine all observations with a period of 0.8544075 day. Figure 1 shows the observations plotted against phase computed

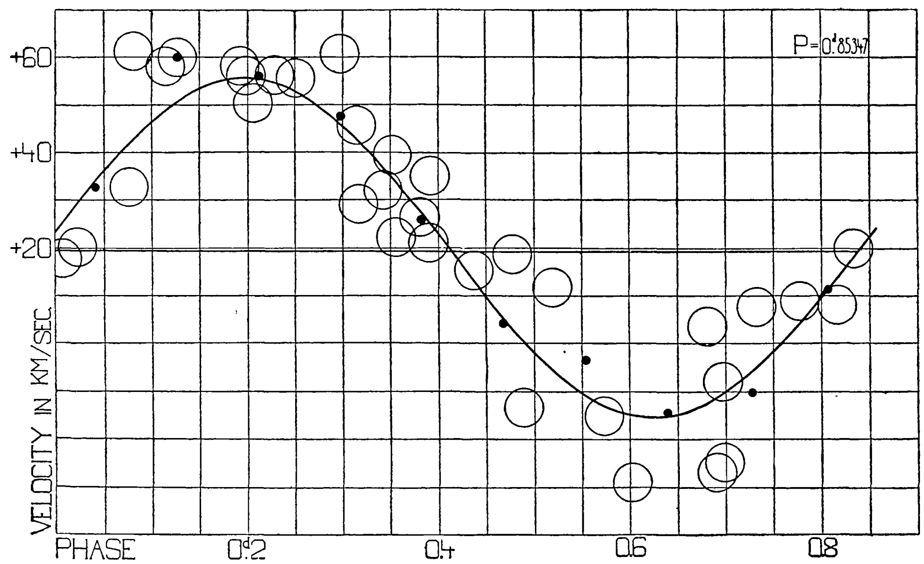

FIG. 2.—Velocity curve of 36 τ^9 Eridani used for orbit-determination. The open circles represent the individual observations. Their radii correspond to the probable errors. The black dots are normal points. Phase zero corresponds to J.D. 2424804.000 G.C.T.

with this value. Although, in general, the observations follow the smooth curve of the diagram, it will be seen that the residuals are very large, amounting in a few cases to as much as 40 km/sec. The good inner agreement of our measurements convinced us that errors of observation could not be responsible for such residuals. A closer inspection of Figure 1 discloses the real cause of the large deviations from the curve. It will be seen that the observations of January and February, 1927, are noticeably displaced toward the smaller phases, indicating that the adopted period is too long. It was found, accordingly, that the observations beginning in September, 1926, and ending in February, 1927, could best be represented by a period of

0.85347 day. The corresponding velocity curve is shown in Figure 2. With this period we have computed the phases for all preceding observations. Figure 3 shows a plot of the observations between December 1, 1924, and January 10, 1926. They fall into two distinct groups corresponding to the seasons 1924–1925 and 1925–1926. The first group is separated by about 735 revolutions from our principal epoch in October, 1926, or J.D. 2424804.000 G.C.T. For the second group the separation is 385 revolutions. It is obvious that the

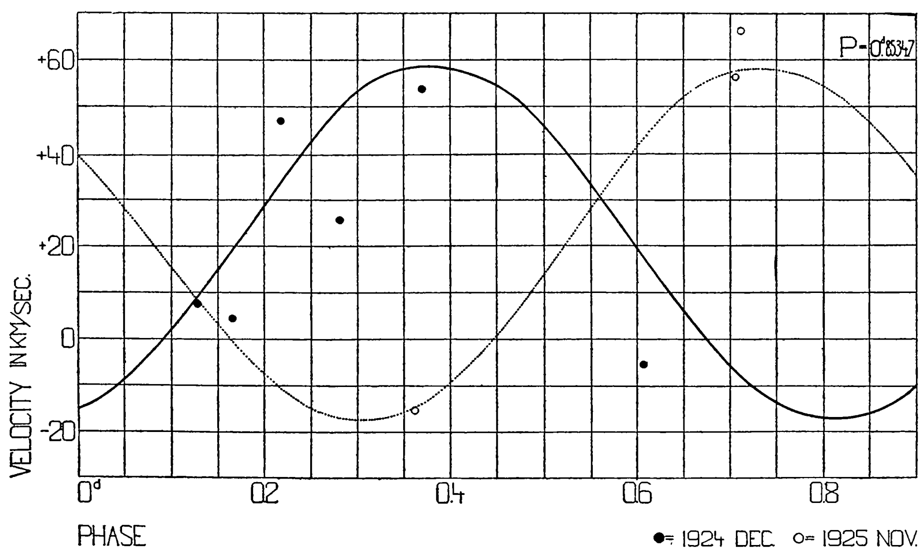

FIG. 3.—Radial velocities of 36 τ^9 Eridani, December, 1924—January, 1926, reduced with $P=0.85347$ day.

adopted period does not satisfy these observations. In order to bring them into agreement with the observations of 1926–1927, we have either to shorten the period by about 0.00143 day or to lengthen it by 0.00086 day. The first alternative leads to a period of 0.85204 day, which cannot be used to represent the observations of 1926–1927. Figure 4 illustrates this point. The second alternative brings us back to our original period of 0.8544 day which we discarded as being too long. It is, therefore, clear that the period is variable, and that the changes are sufficiently large to show from one season to the next. Tentatively, we may assume that our original value of 0.8544075 day represents the average period. If this is correct, a change of 0.00094 day, or 1.5 minutes, takes place in about two years or 430 revolutions. This would amount to a change of 0.2 second per revolution. The effect upon the phase amounts to at least 0.1 day, and perhaps even more. The observations are not sufficiently numerous to permit investigating these changes in greater detail.

A period of 20.5 hours is rather unusual for a binary of spectral type A0. However, in this particular case, there is good evidence that the star is actually a double. It is not known to be a Cepheid variable, nor does it exhibit any of the spectral peculiarities of these

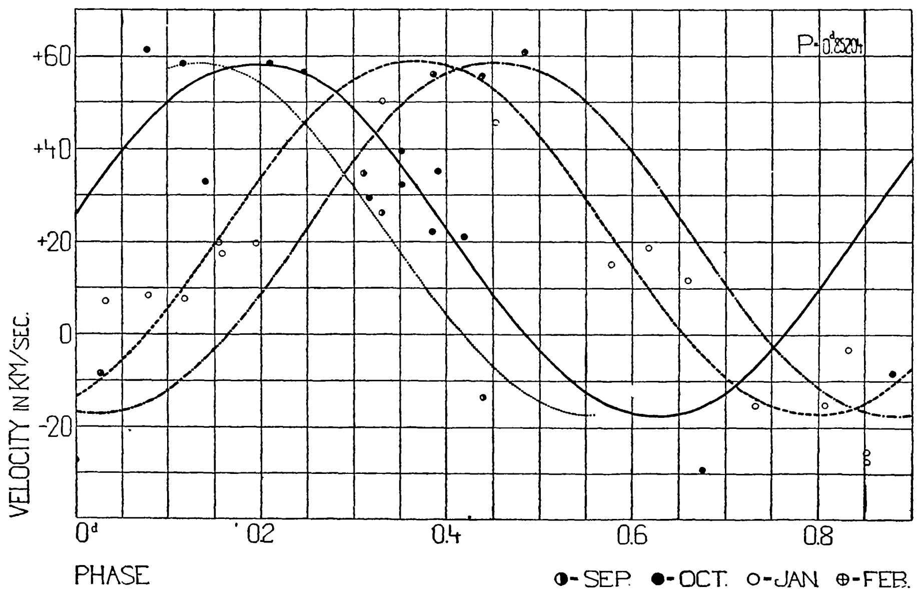

FIG. 4.—Radial velocities of 36 τ^9 Eridani, September, 1926—February, 1927, reduced with $P = 0.85204$ day.

stars. At maximum relative velocity faint lines due to the second component are just discernible and have been measured on several plates. As far as is known to us, the only other A-type star that is definitely known to be double, and that has a period shorter than one day, is S Antliae.[1] This star is, according to A. H. Joy, of spectral type A8 and has a period of only 15.5 hours.

The orbit.—In view of the observed changes in the period of τ^9 Eridani, we have considered it best to base the determination of the orbit exclusively upon the observations of 1926–1927, reduced with a period of 0.85347 day. A preliminary graphical determination of

[1] A. H. Joy, *Astrophysical Journal*, **64**, 287, 1926.

the elements was carried out according to the method of Lehmann-Filhés. Since the eccentricity was found to be less than 0.01, we have assumed the orbit to be circular and have carried through a least-squares solution for the velocity of the system, the principal epoch of maximum positive velocity, and the semi-amplitude of the variation in velocity. For this purpose we formed 10 normal points. The residuals δV were computed from the preliminary elements for each individual observation. The normal velocity for each interval of 0.0854 day was then computed in the following way:

$$\text{Normal velocity} = \text{Computed velocity} + \frac{\Sigma \delta V}{n} \cdot$$

This method takes care of the curvature of the velocity curve, and the small number of normal points is not objectionable. The

TABLE II

NORMAL VELOCITIES

No.	Phase	No. of Plates	Velocity	$(O-C)_1$	$(O-C)_2$
1	0.0426	4	+32.7	−3.6	−1.5
2	.1279	1	+60.0	+8.0	+9.4
3	.2132	5	+55.9	+0.3	+0.7
4	.2985	3	+47.6	+1.8	+1.4
5	.3838	7	+25.9	−0.3	−1.3
6	.4691	3	+ 4.2	−0.2	−1.0
7	.5544	2	− 3.7	+7.6	+7.5
8	.6397	3	−15.1	−0.1	+0.7
9	.7250	4	−10.1	−4.9	−3.2
10	0.8103	3	+12.1	−2.2	−0.1

normal velocities were weighted according to the number of observations included. They are shown in Table II, together with their residuals. In Figure 2 they are represented by small dots. The adjustment by the method of least squares considerably improved the elements, as shown by the value of $[pv^2]$ which was reduced from 51.2 to 35.3. Table III shows the elements and their probable errors.

The epoch T in the circular orbit denotes the time of maximum positive velocity. The phases are counted from J.D. 2424804.000 G.C.T. The probable error of one normal velocity of weight unity is ±1.5 km/sec. The probable error of one individual observation is ±4.0 km/sec.

The secondary component.—The best plates show at maximum relative velocity faint lines belonging to the second component. These were measured on seven plates for the determination of mass-ratio. The resulting velocities are given in Table IV. They are based

TABLE III

ORBITAL ELEMENTS

	Elliptical Graphic	Preliminary Circular	Corrections	Final	Probable Errors
γ	+20.5 km/sec.	+20.5	−0.8	+19.7	±1.1
P	0ᵈ85347	0ᵈ85347	Assumed	0ᵈ85347	....
e	0.007	0.000	Assumed	0.000	....
K	38.0 km/sec.	38.0	−2.3	35.7	±1.1
ω	90°	0°	Assumed	....	....
T	0ᵈ406	0ᵈ193	+0ᵈ006	0ᵈ199	0ᵈ0032
$a \sin i$	....	....	....	419,000 km	....
$m_1 \sin^3 i$	....	....	....	0.17☉	....
$m_2 \sin^3 i$	....	....	....	0.06☉	....

TABLE IV

MASS-RATIO

Date	V1	V2	m_2/m_1
1925 Nov. 2.350	+70.7	− 80.3	0.50
1926 Oct. 13.408	+68.7	−105.7	.39
1927 Jan. 14.123	−23.1	+197.9	.24
1927 Jan. 20.015	−20.4	+142.6	.31
1927 Feb. 4.004	+58.9	−121.7	.28
1927 Feb. 4.102	+60.0	− 92.8	0.36
Mean	....	....	0.35

only on the magnesium line 4481. The mass-ratio in the last column is the ratio V1/V2, corrected for the velocity of the system.

It was estimated that the magnesium lines of the second component are about 0.15 magnitude fainter than the background of the continuous spectrum. For the brighter component this value is about 0.6 magnitude. The two spectra seem to be similar in type.

The silicon lines.—In view of the extraordinary strength of the lines of ionized silicon in the spectrum of τ^9 Eridani, we have examined, separately, the radial velocities obtained from them. B. P.

Gerasimovič[1] has pointed out the importance of these lines and has suggested to us that it would be desirable to find whether this abnormal intensity is caused by a blending of a normal line with one of interstellar origin. The strontium lines 4078 and 4215 would be even more interesting; but contrary to the remark in the *Draper Catalogue*,[2] they appear extremely faint on all of our plates, and are measurable only with difficulty. The line 4078 is, furthermore, complicated by the existence of a line at 4076 the origin of which is doubtful.

The silicon lines 4128 and 4132, however, give very reliable results, and the velocities derived from them agree with those from the magnesium line 4481 and from the iron line 4550. A velocity curve was constructed separately for the silicon lines, and it was found to agree in phase and in amplitude with the curve from other spectral lines. The average difference between the silicon and the magnesium velocities is smaller than the probable errors of the measurements. This proves that if an effect of blending is present at all, the interstellar line must be very faint and cannot account for the great intensity of the observed line. It seems decidedly probable that the silicon lines originate in the atmosphere of the star.

The evidence concerning the strontium lines is less conclusive. They were measured on several plates for determination of wavelength, and the results seem also to indicate that they behave normally with respect to velocity.

The spectrum.—The general appearance of the spectrum of τ^9 Eridani greatly resembles that of α Canum Venaticorum. We have examined plates of both stars under the Hartmann spectrocomparator and have found that the calcium line 3933, the hydrogen lines, and the lines of ionized silicon are of nearly the same intensity in both stars. Belopolsky's[3] and Kiess's[4] second group of variable lines are also represented in τ^9 Eridani. But the first group, assigned by Baxandall[5] and by Kiess[4] to Europium, is very faint or absent in τ^9 Eridani. Table V gives a list of all such lines as could be measured

[1] *Astronomische Nachrichten*, **228**, 427, 1926.

[2] *Annals of the Harvard College Observatory*, **91**, 290, No. 25267, 1918.

[3] *Astronomische Nachrichten*, **196**, 1, 1913.

[4] *Publications of the Astronomical Observatory, University of Michigan*, **3**, 106, 1919.

[5] *Monthly Notices of the Royal Astronomical Society*, **74**, 32, 1913.

TABLE V

WAVE-LENGTHS OF ABSORPTION LINES IN 36 τ^9 ERIDANI

Wave-Length I.A.	Intensity	Identification
3930.43	1	*Eu* 3930.51?
3933.68	3	*Ca*+ 3933.67
3954.40 *v*	2	*Tb* 3954.06?
3967.89	2	*Ca*+ 3968.48
3970.07	50	*H*ϵ 3970.08
3991.95	1	....
4002.83 *v*	1	*Tb* 4002.58?
4012.76	1	*Tb* 4012.84? *Ti*+ 4012.39*
4025.52	1	*Ti*+ 4025.14*
4045.88	1	*Fe* 4045.82
4049.37 *v*	3	....
4057.50 *v*	1	....
4070.76	1	....
4075.77	1	....
4077.37	2	*Sr*+ 4077.74
4102.01	50	*H*δ 4101.74
4122.93	2	*Fe*+ 4122.67*
4128.31	10	*Si*+ 4128.05
4131.07	10	*Si*+ 4130.88
4143.83	1	....
4151.58 *v*	1	....
4179.02	1	*Fe*+ 4178.87
4187.75 *v*	1	....
4190.99 *v*	2	....
4200.96 *v*	4	*Tb* 4201.00?
4203.46	1	....
4215.82	1	*Sr*+ 4215.52
4233.81	4	*Fe*+ 4233.17
4242.76	1	*Tb* 4242.58? *Cr*+4242.38*
4263.03	1	....
4267.24	1	*C* 4267.22?
4278.48 *v*	1	....
4284.72 *v*	1	....
4325.75	2	*Fe* 4325.77
4340.37	50	*H*γ 4340.47
4342.10	1	*Tb* 4342.54?
4349.02 *v*	1	....
4351.79	2	*Fe*+ 4351.76*
4353.01	1	....
4371.96	1	....
4373.22 *v*	1	....
4377.44	2	....
4384.57	1	*Fe* 4385.38*
4394.67	1	*Ti*+ 4395.04
4430.58 *v*	1	....
4434.21 *v*	1	....
4472.19	1	....
4481.24	9	*Mg*+ 4481.23
4508.42	1	*Fe*+ 4508.27
4515.51	1	*Fe*+ 4515.34*
4534.37	1	*Ti*+ 4533.98 *Fe*+ 4534.17*
4549.46	5	*Fe*+ 4549.47 *Ti*+ 4549.64*
4555.81	1	*Fe* 4555.92*

TABLE V—*Continued*

Wave-Length I.A.	Intensity	Identification
4559.58	1	*Cr*+ 4558.64
4564.00	1	*Ti*+ 4563.76
4572.08	1	*Ti*+ 4571.98
4583.82	2	*Fe*+ 4583.83
4588.65	1	*Cr*+ 4588.20*
4621.72	2	....
4813.60	1	....
4861.34	40	$H\beta$ 4861.33

on our one-prism plates. The spectrograms were compared with one another in the spectrocomparator, and only such lines were measured as could be seen on several plates.

In the early stages of this work it was noticed that some of the fainter lines, chiefly the ones at λ 4123 and λ 4472, were occasionally fairly strong, while at other times they could not be seen on some of the best plates. This led us to the suspicion that the two lines in question were variable in intensity. At first it was believed that they were due to helium, and indeed the same assumption had been made by the Harvard observers.[1] The wave-lengths in Table V show, however, that they are not identical with the helium lines, and it is reasonable to assume that they are the same lines which occur in the spectrum of α Canum Venaticorum. The line at λ 4123 was found to be variable by Belopolsky and confirmed as such by Kiess. The probable variability in the intensity of λ 4472 was first pointed out by H. Ludendorff.[2] In view of the variability of these lines in α Canum Venaticorum, and also because of the suspected changes in intensity in τ^9 Eridani, we have estimated the intensity of a selected number of lines on most of our newer plates. The results, expressed on an arbitrary scale, are given in Table VI. Complete absence of a line was denoted by 0. A line that was only suspected was called "1"; "2" was used to denote a very faint, but undoubtedly real line; while a line visible at the first glance was called "3"; "4" and "5" denote strong lines. In Table VII the estimates are arranged in groups of 0.1 day in phase. There seems to be a drop in intensity for all lines listed around phase 0.4 day to 0.5 day, and a maximum at or

[1] *Annals of the Harvard College Observatory*, **28**, 186, Remark 144, 1897.

[2] *Astronomische Nachrichten*, **173**, 5, 1906.

TABLE VI

INTENSITIES OF LINES IN τ^9 ERIDANI

Date	Line				
	4123	4201	4233	4325	4472
1924 Dec. 1.242	....	....	....	....	3
1925 Jan. 10.090	1	3	3	2	1
1925 Feb. 12.050	0	2	1	0	1
1925 Nov. 2.350	0	1	2	3	3
1925 Nov. 14.292	1	3	3	0	0
1926 Jan. 10.131	0	4	3	0	0
1926 Oct. 13.408	....	2	3	3	3
1926 Oct. 15.317	1	2	2	1	1
1926 Oct. 15.393	1	1	3	1	1
1926 Oct. 15.352	1	1	2	1	2
1926 Oct. 21.317	1	1	2	2	3
1926 Oct. 26.288	4	0	0	4	2
1926 Oct. 26.324	1	3	3	3	3
1926 Nov. 2.278	0	0	1	1	0
1926 Nov. 2.312	1	1	1	1	0
1926 Dec. 30.165	1	4	3	2	2
1927 Jan. 6.102	0	1	3	0	1
1927 Jan. 7.077	2	2	2	1	1
1927 Jan. 7.118	0	2	2	2	1
1927 Jan. 7.159	0	2	2	1	2
1927 Jan. 14.123	1	3	3	4	4
1927 Jan. 14.167	3	2	4	4	4
1927 Jan. 15.002	3	3	3	2	2
1927 Jan. 15.053	3	3	4	3	2
1927 Jan. 15.098	3	2	5	2	1
1927 Jan. 15.138	2	4	4	2	2
1927 Jan. 20.015	0	3	1	1	0
1927 Jan. 20.133	1	2	3	0	....
1927 Jan. 27.104	2	1	4	2	0
1927 Jan. 27.144	1	2	1	1	0
1927 Feb. 4.004	1	3	2	1	1
1927 Feb. 4.056	2	4	3	1	2

TABLE VII

INTENSITIES OF LINES GROUPED ACCORDING TO PHASE

Phase in Days	Line				
	4123	4201	4233	4325	4472
0.1.............	2.3	2.0	2.0	2.5	1.8
.2.............	1.2	3.5	2.8	1.8	2.0
.3.............	0.5	1.0	2.0	2.0	1.4
.4.............	1.0	1.2	2.0	1.0	1.0
.5.............	0.5	2.5	1.9	1.2	0.6
.6.............	1.7	2.7	3.0	2.2	3.0
0.7.............	2.8	2.0	4.2	2.8	1.9

near phase 0.7 day. However, this result must be regarded as uncertain since the number of plates was so small that accidental distribution of the observations may easily result in an effect as shown in Table VII. The total amplitude of intensity is not large. Thus the line λ 4123 reaches an intensity equal to about one-half of the silicon line 4128 on only one plate; on other equally good plates it is entirely absent. For the other lines the variation is even smaller. We feel that the question of the variability of the lines in τ^9 Eridani is not completely established, although there remains a strong suggestion that it is real.

As to the identification of the lines in Table V we have in general followed the identifications made by Kiess for α Canum Venaticorum. The identification by Kiess of some of the lines with terbium seems possible although by no means certain. The fairly strong line λ 4233 is evidently chiefly due to ionized iron, and not to terbium. Again, some of the stronger terbium lines listed by Kayser[1] do not occur in τ^9 Eridani, nor do they occur in the list of lines of α Canum Venaticorum given by Kiess.[2] Probably many of the fainter lines in τ^9 Eridani are enhanced metallic lines.

Mr. F. E. Baxandall has had the kindness to read our paper before publication and has suggested a number of additional or alternative identifications. These are shown by asterisks in the last column of Table V. Mr. Baxandall also remarks that some of the lines in τ^9 Eridani are probably identical with lines in the spectrum of 46 *υ* Sagittarii, as observed by J. S. Plaskett. Mr. Baxandall's identifications were made on a paper print of the spectrum of this star prepared at Victoria. We have noted these lines in the first column of Table V by the letter *υ*.

General conclusions.—τ^9 Eridani is not known as an eclipsing variable, and we have no definite information concerning the actual dimensions of the system. Nevertheless it is possible to make certain plausible suppositions and to gain an insight into the structure of this double star. We have estimated that the intensity difference between the continuous spectrum and the lines of the two components is 0.6 magnitude for the brighter and 0.15 magnitude for

[1] H. Kayser, *Handbuch der Spectroscopie*, **6**, 595, 1912.

[2] *Publications of the Astronomical Observatory, University of Michigan*, **3**, 113, 1919.

the fainter component. These values do not directly indicate the respective brightnesses of the two stars. The continuous background is formed by the light of both stars, while the lines of the brighter component are superposed upon the continuous spectrum of the fainter, and vice versa. Previous experiments of superposition of spectra of different stars indicate that a difference in observed line-intensity, as given above, corresponds to a difference in brightness between the two components of about 0.5 magnitude. Since the total visual magnitude of τ^9 Eridani is 4.7, the magnitudes of the components would be 5.2 and 5.7 respectively.

The parallax of τ^9 Eridani has not been determined by the trigonometric methods. But its absolute magnitude was estimated by Miss A. V. Douglas[1] as +0.5, making the absolute parallax about 0.012. The corresponding absolute magnitudes of the components would be +1.0 and +1.5 respectively. Knowing the absolute magnitudes and adopting for both components the spectral type A1s, as given by Miss Douglas, we estimate by the method of Russell[2] that the linear diameters of the components are 2.9 and 1.8 times that of the sun. The masses are not known, since the inclination remains undetermined. We may assume, however, with a reasonable degree of certainty that the total mass of the system is twice that of the sun.[3] This value is probably rather underestimated, but it conforms with our general knowledge of masses of A-type spectroscopic binaries. If these data are correct, a period of 20.5 hours must correspond to a distance of 3,200,000 km between the centers of the two stars. But the first star has a radius of about 2,030,000 km, while that of the second is 1,260,000 km. The sum of these radii is nearly identical with the distance of their centers. The stars are, therefore, in contact, or, making allowance for possible errors in our estimated values, they must be very close to one another.

One feels inclined to attribute the observed changes in the period to this proximity of the surfaces of the two components and to the effect of tidal disturbances. However, it seems very strange that a star so similar to τ^9 Eridani, in period as well as in dimensions, as

[1] *Journal of the Royal Astronomical Society of Canada*, **20**, 285, 1926.

[2] *Publications of the Astronomical Society of the Pacific*, **32**, 307, 1920.

[3] O. Struve, *Monthly Notices of the Royal Astronomical Society*, **86**, 67, 1925.

S Antliae, does not exhibit any variations in the period.[1] Even more surprising is the difference in the general appearance of the spectral lines of these two stars. In S Antliae the lines are, according to Joy, "wide and hazy, because of a large rotational effect like that found in W Ursae Majoris." In τ^9 Eridani the lines are narrow and sharp, although the velocity of axial rotation must be even greater than in S Antliae. It seems to us that this difference in the widths of the lines is a strong observational argument in favor of the hypothesis that the planes of axial rotation and orbital motion coincide in such close binaries. The evidence available from S Antliae and τ^9 Eridani is, of course, only of a qualitative nature, since the actual width of the lines in S Antliae is not mentioned in Joy's paper and since the line-width in τ^9 Eridani is close to the limit imposed by the construction of the spectrograph. However, as far as can be judged from Joy's description, the values agree well with the hypothesis.

In view of the additional information that can be gained from the observation of eclipses, it would seem desirable to test τ^9 Eridani for variability in light. Unfortunately, the comparatively small value of K points to a small inclination. Continuing our deductions made from the above estimates of mass and diameter, we would expect the inclination to be of the order of only 10°.

Yerkes Observatory
March 1, 1927

[1] *Astrophysical Journal*, **64**, 287, 1926.