OBSERVATIONS OF STANDARD VELOCITY STARS WITH THE LOWELL SPECTROGRAPH (1905)

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In the present paper are given the results of my observations of the list of "Standard Velocity Stars,"[1] made with the Lowell Spectrograph during the summer and autumn of the present year. Owing to the circumstance that the time that the spectrograph is available for stellar radial velocity work is limited, I have not been able to follow closely the recommendation[1] that the three observations of each star be made at the beginning, middle, and end of the two months symmetrical about the date of the star's opposition with the Sun. Inasmuch as *α Crateris*, the faintest star of the regular list, has been, and will be for some time yet, too near the Sun for observation, I have substituted for it *γ Cephei*, the faintest star of the supplementary list, in order to bring these observations to an early conclusion. The ten stars that I have observed are, then, the following:

α Arietis	*β Ophiuchi*
α Persei	*γ Aquilae*
β Leporis	*ε Pegasi*
β Geminorum	*γ Piscium*
α Boötis	*γ Cephei*

I have secured, as was suggested, extra spectrograms of *α Persei* and *α Boötis;* and, in order to check the performance of the spectrograph, I have measured at frequent intervals the spectrographic velocities of *Venus*, *Mars*, and the Moon.

The spectrograph,[2] as employed in these observations, consists essentially of a collimator of 30 mm aperture and 490 mm focus, a train of three 63° dense flint prisms and a camera of 35 mm aperture and 471 mm focus, the whole inclosed in a box supplied with

[1] See Frost on "Coöperation in Observing Radial Velocities of Selected Stars," *Astrophysical Journal*, **16**, 169, 1902.

[2] A detailed description of this instrument was published in the *Astrophysical Journal* for July, 1904 (**20**, 1–20).

electrical heating. The construction of this instrument partakes of the universal type, having a device for automatically keeping the prisms in the position of minimum deviation, a feature almost indispensable in our varied program of spectroscopic work. But there is an insufficient number of clamp screws to hold the prisms rigidly without causing injurious pressure on the glass of the prisms, each prism being clamped by only one screw, which presses centrally upon the top plate of its mounting. When this screw is clamped too tightly, unequal pressure is transmitted to the prism, destroying its homogeneity. Although realizing that by so doing I was impairing the definition of the spectrograms, I have nevertheless turned down very tightly the clamp screws and thus insured the rigidity of the prisms. I have in this way obtained entirely trustworthy spectrograms, but, as might be supposed, the definition in the spectrum is rather inferior, being no better on Seed 23 plates than it should be on the coarser 27 emulsion. The full power of the spectrograph has therefore not been realized, and the agreement of the velocities from different lines of the same plate is not so close as it should be with a spectrograph of this size.

In these observations, the prisms have been used set at minimum deviation for wave-length 4415. The linear dispersion at different points through the part of the spectrum covered by my measures is as follows:

Wave-Length	Tenth-Meters per mm
4250	9.9
4300	10.6
4350	11.4
4400	12.3
4450	13.2
4500	14.1
4550	15.0

The star spectrum usually has a width on the plates of one-third of a millimeter, and is separated from the two parts of the comparison spectrum by about a tenth of a millimeter.

All the details relative to the making of the spectrograms are given in the accompanying table, which will be readily understood. The date of the observation is given in Greenwich Mean Time. Except in the case of a few of the short exposures, the comparison

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Object	Plate Number	Date, 1905	Length of Exposure	Slit-Width	Comparison Spectrum	Temperature Inside Prism-Box	Seeing Sky	Seeing Image	Seed's No. of Plates	Remarks
β *Geminorum*.	L 1833	April 7d 17h 0m	57m	0mm.019	*Ti, Cr*	12°.47–12°.56			23	
α *Boötis*......	L 1850	14 20 15	37	0.020	*Ti, Cr*	8.13– 8.18	Poor		23	
Mars........	L 1868	28 18 42	70	0.020	*Fe, Ti, Cr*	11.43–11.43	3	3	23	
Mars........	L 1881	May 18 16 30	72	0.022	*Mo, Fe*	15.00–15.02	3	3	23	
										Spectrograph readjusted
γ *Aquilae*.....	L 1921	July 5 21 5	120	0.025	*Mo,Ti,Fe,Cr*	24.73–24.76	4	2	27	
γ *Aquilae*.....	L 1926	7 20 25	128	0.028	*Mo, Fe*	24.72–24.70	4	2–1	27	
Venus........	L 1937	11 0 21	8	0.018	*Mo, Fe*	22.38–22.45	3	3	23	
Moon........	L 1944	13 18 35	36	0.020	*Mo, Fe*	19.26–19.15			23	
β *Ophiuchi*...	L 1947	14 19 10	110	0.028	*Mo, Fe*	18.20–18.21			27 N. H.	
ε *Pegasi*......	L 1948	14 21 18	90	0.028	*Mo, Fe*	18.20–18.23			27 N. H.	
γ *Aquilae*.....	L 1952	15 19 50	120	0.028	*Mo, Fe*	19.90–19.98	4	3	27 N. H.	
										Spectrograph readjusted
ε *Pegasi*......	L 2007	Aug. 10 20 42	120	0.028	*Fe, V*	17.90–18.02	4	2	27 N. H.	
α *Boötis*......	L 2011	12 16 6	40	0.020	*Fe, Cr, V*	19.40–19.55	5	2	23	
Moon........	L 2013	12 19 28	30	0.020	*Fe, Cr, V*	19.50–19.40	5	4	23	
α *Boötis*......	L 2016	15 16 8	40	0.020	*Fe, V*	21.20–21.18			23	
β *Ophiuchi*...	L 2017	15 17 50	120	0.027	*Fe, V*	21.14–21.15			27 N. H.	
										Spectrograph readjusted
α *Boötis*......	L 2043	29 15 34	40	0.024	*Fe, V*	21.37–21.55	4	1–2	23	
α *Persei*......	L 2049	30 23 6	58	0.025	*Fe, V*	20.65–20.70	3–4	3–4	23	
α *Boötis*......	L 2053	31 15 31	40	0.022	*Fe, V*	19.66–19.70	3	1–2	23	
ε *Pegasi*......	L 2054	Sept. 6 18 48	120	0.028	*Fe, V*	15.70–15.74	4	3	27 N. H.	
β *Ophiuchi*...	L 2058	8 16 32	120	0.028	*Fe, V*	17.56–17.56	3–4	1–2	27 N. H.	
α *Arietis*.....	L 2067	12 20 48	60	0.022	*Fe, V*	20.16–20.10	3–4	3–4	27 N.H.	
α *Persei*......	L 2068	12 21 59	40	0.024	*Fe,.V*	20.10–20.13	3	3–4	27 N. H.	

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Object	Plate Number	Date, 1905	Length of Exposure	Slit-Width	Comparison Spectrum	Temperature Inside Prism-Box	Seeing Sky	Seeing Image	Seed's No. of Plates	Remarks
				mm						
α Persei	L 2079	Sept. 25d 20h 49m	30m	0.025	*Fe, V*	13°.10–13°.10	4	3	27 N. H.	Spectrograph readjusted
ε Pegasi	L 2080	27 17 28	60	0.027	*Fe, V*	16.66–16.66	4	4	27 N. H.	
γ Piscium	L 2081	27 19 15	120±	0.029	*Fe, V*	16.67–16.63	3–0	4	27 N. H.	Clouds
α Arietis	L 2085	Oct. 2 20 8	50	0.020	*Fe, V*	13.62–13.68	4	3	27 N. H.	
β Leporis	L 2087	2 23 57	83	0.026	*Fe, V*	13.56–			27 N. H.	
Moon	L 2091	5 15 40	50±	0.020	*Fe, V*	18.17–18.11			23	Hazy
α Arietis	L 2094	5 18 54	50	0.024	*Fe, V*	18.10–18.14	3	3	27 N. H.	
Mars	L 2096	6 13 52	55	0.024	*Fe, V*	18.80–18.76	3	2	27 N. H.	
α Persei	L 2100	7 22 53	20	0.024	*Fe, V*	15.96–15.96	3–4	2	27 N. H.	
β Geminorum	L 2101	7 23 39	28	0.022	*Fe, V*	15.96–16.00	3–4	1–2	27 N. H.	Guiding interrupted
γ Cephei	L 2109	12 20 42	105±	0.027	*Fe, V*	13.98–13.95	4	3–4	27 N. H.	
β Leporis	L 2111	12 23 21	88	0.026	*Fe, V*	13.90–13.87			27 N. H.	
Venus	L 2113	13 1 15	12±	0.020	*Fe, V*	13.96–14.00			23	Clouds
β Geminorum	L 2117	15 1 5	20	0.023	*Fe, V*	9.60– 9.64	4	3	27 N. H.	Spectrograph readjusted
γ Piscium	L 2122	27 18 7	150	0.029	*Fe, V*	11.00–11.07	4	3–4	27 N. H.	
γ Cephei	L 2123	27 20 45	120	0.029	*Fe, V*	11.00–11.08	4	3	27 N. H.	
α Persei	L 2124	27 22 7	15	0.029	*Fe, V*	11.06–11.04	4	3	27 N. H.	
β Leporis	L 2125	27 23 17	84	0.029	*Fe, V*	11.01–10.94	4	3	27 N. H.	
γ Piscium	L 2129	Nov. 2 17 3	125±	0.029	*Fe, V*	8.90– 9.00	3–0–2	2	27 N. H.	Clouds
γ Cephei	L 2130	2 19 50	50±	0.028	*Fe, V*	9.12– 9.14	3–0	2	27 N. H.	Clouds

has been photographed at the beginning and end of the star exposure. The table gives in one column two readings of a large-scale thermometer whose bulb is inside the prism-box near the base of the middle prism. For the most part, the two readings are those made at the beginning and end of the exposure, but for the later plates they are the highest and lowest readings of the thermometer. The temperature control has worked well, and the range in the readings of the prism thermometer for the longest exposures ordinarily does not exceed 0°.1 C. and frequently is less than 0°.05. The double column headed "Seeing" gives the condition of the sky as regards transparency and the character of the stellar image, both on a scale increasing from 0 to 5, where 5 means perfection. The remark "Spectrograph readjusted" means that the spectrograph has been used for other lines of work requiring different adjustments, during the interval against which that note is placed. I have endeavored to keep all adjustments the same throughout this series of observations.

The electric spark has furnished the comparison spectrum. The induction coil supplying the high potential current receives its power from a 104-volt alternating current. A condenser is inserted in the secondary from the coil. To insure the complete illumination of the collimator lens with the light from the spark, a ground glass has been interposed between the electrodes and the slit.

Except for a few of the earlier plates, I have employed for comparison the spectrum of an alloy containing 10 per cent. of vanadium and 90 per cent. of iron. By occulting the twelve bright lines from λ 4379 to λ 4415 during the greater part of the exposure to the spark with a projection on the slide working in the end of the camera tube, an excellent series of uniformly spaced comparison lines is obtained. With only fairly well-timed exposures, there are many more good lines than are needed, so that it is always possible to choose for measures those lying nearest the best star lines.

I have employed throughout Rowland's wave-lengths for the comparison lines; for the vanadium lines, the arc values;[1] and for the iron lines, the arc values for those lines whose arc wave-lengths

[1] Published by Rowland and Harrison in *Astrophysical Journal*, 7, 273, April 1898.

he has published,[1] for the others, the values given in his table of solar wave-lengths.

Rowland's solar wave-lengths have been used for the wave-lengths of the stellar lines. I have, as far as possible, measured single lines, but have also employed a number of composite lines which appear single, and well suited to measurement, on my spectrograms. For the wave-lengths of these composite, or blended, lines, I have, as is customary, used the values resulting from giving to the wave-length of each component of the blend the weight of its intensity given in Rowland's table, and taking the weighted mean. The weakest line ordinarily taken into account is that of "0" intensity, which has generally been given a weight of one-half.

On some of the last Moon and planet plates, I have measured a rather large number of lines, both single and blended, for the purpose of seeing how the velocities from the blended lines compare with those from single lines. To the same end, I have also measured the strong solar lines at λλ 4326, 4384, 4405, and 4415. A comparison of the results from single and from blended and from the very strong lines shows that measures on the single lines are not noticeably more accurate than on the blends and heavy lines, and also that the values for the wave-lengths of the blended lines are reliable. Of course, with stars of the advanced solar type of spectrum, the class to which most of the "Standard Velocity Stars" belong, the relative intensities of lines must frequently be different from what they are in the Sun, and therefore the wave-lengths of the blends in such cases must be inaccurate. I have observed, for instance, that the blend $\lambda\, 4352.935 \begin{cases} 4352.908 \ (4) \ Fe \\ 4352.044 \ (1)^2 \ V \end{cases}$ in certain stars gives a larger positive velocity than the mean value of the other lines. However, similar uncertainties must attach to some of the lines which are single in the Sun. As an example of this kind may be mentioned the line at λ 4468.663, an excellent single in the Sun, of intensity 5, due to

[1] "A New Table of Standard Wave-lengths," *Astronomy and Astrophysics*, **12**, April 1903; and Frost's Scheiner's *Astronomical Spectroscopy*, p. 363.

[2] The vanadium lines are generally stronger in these stars than in the Sun, and in this blend I have given the *V* component weight 1, although its intensity is given as 0 by Rowland. I have used this wave-length for the blend, with Moon and planets, as well as with the stars.

titanium, which appears as a single on the star plates but which, in *a Boötis* for example, gives a too large positive velocity.[1]

I continued to measure certain stellar lines after I knew solar wave-lengths were not entirely applicable and that they were giving spurious velocities. The employment of such lines, however, has only slightly affected the velocity of a plate and they can at any time be excluded or their velocities corrected when the wave-lengths have been more accurately determined. The inclusion of such lines by the different co-operators in their first year's observations would give provisional corrections to their wave-lengths, thus making the lines useful for velocity observations of these and other stars of the same spectral type. I am of the opinion that, after all, one of the most important results of this co-operation in radial velocity observations will be the knowledge gained of the wave-lengths of the star lines.

The plates have been measured with a screw microscope[2] designed especially for measurement of spectrum plates. The screw, which has a pitch of half a millimeter, was examined for errors. Periodic errors were not revealed by the tests, although errors of run were quite apparent, and were of such a character as would be explained by a tapering of the screw from the middle toward the ends. I have not attempted to apply corrections to the measures to take up this error (which accumulates at a rate of about 0.3 μ per revolution), for the reason that its gradual change would practically affect equally the star and near-by comparison line. I do not consider that the measures are appreciably affected by this imperfection of the screw. I have always measured the plate in both positions, violet-right and violet-left, under the microscope, making generally four settings on the star line and two each on the upper and lower part of the comparison line. The best star lines have been measured, regardless of whether or not they existed in the comparison spectrum. The comparison lines lying nearest the measured star lines have been selected, the distance between the star and the comparison line amounting only in exceptional cases to as much as 3 tenth-meters. This close proximity of the spark and the star line practically renders inoperative the errors in run of the micrometer screw.

[1] Frost's and Adams's velocities verify my own as regards the wave-length of this line.

[2] This instrument was made by Gaertner & Co., of Chicago, and is a duplicate of those used by Frost and Adams.

A magnification of 21 diameters has been used in the measurements.

The measures in the two positions of the plate have not been reduced separately, but have been combined and the mean taken before the reduction was begun.

I have adopted the method of reducing each plate independently of every other, by computing for each plate a new Hartmann formula in the simple form

$$\lambda-\lambda_{0}=\frac{C}{R-R_{0}} ,$$

where R denotes the screw reading. The constants R_0, C, and λ_0 of the formula are computed (in the order given) from the observed screw-readings and known wave-lengths of three comparison lines so selected that there is one near each end and the third near the middle of the portion of spectrum measured. By casting away a factor to make the reading on one of the lines zero, and by the use of logarithms, the constants are derived in about eight minutes. The wave-lengths of all star and comparison lines are then computed. The differences between the computed and normal wave-lengths of the numerous comparison lines furnish the necessary corrections for reducing the star wave-lengths to the true dispersion-curve of the plate. I have applied these corrections to the star lines without the use of a curve, making linear interpolations where needed; the mean of the errors of two neighboring comparison lines frequently being employed for the correction to the intervening star line. The differences between these corrected stellar wave-lengths and their normal values are then taken as the velocity displacements for the star lines. These displacements are speedily converted into velocity in the line of sight by a Crelle's table suitably supplied with notes.

The theoretical velocities of the planets and the Moon have been computed from data given in the *American Ephemeris*, by the aid of Professor Campbell's convenient formulæ. In the reduction of the star velocities to the Sun, Schlesinger's line-of-sight constants have been employed for computing the factor V_a due to the Earth's orbital velocity. The other factor, V_d, due to the Earth's diurnal rotation, is read from a table. In the case of the earlier plates the correction for prismatic curvature has been applied to the mean velocity, and appears at the foot of the reduction table. In the other cases it has been introduced earlier in the reductions and affects the velocities of the individual lines.

Object	Number of Plate	Greenwich M. T.	Velocity Obs.	Velocity Comp.	Velocity Residu'ls O.—C.	No. of Lines	Quality of Plate
			km	km	km		
Mars	L 1868	1905 April 28^d 18^h 42^m	− 8.39	− 7.92	−0.5	21	Good
Mars	L 1881	May 18 15 30	− 1.10	− 1.62	+0.5	17	Good
Venus	L 1937	July 11 0 21	+13.72	+13.42	+0.3	26	Overexposed
Moon	L 1944	13 18 35	+ 1.30	+ 0.52	+0.8	27	Underexposed
Moon	L 2013	Aug. 12 19 28	+ 0.53	+ 0.25	+0.3	26	Good
Moon	L 2091	Oct. 5 15 40	+ 0.55	+ 0.65	−0.1	24	Excellent
Mars	L 2096	6 13 52	+ 9.02	+ 9.16	−0.1	35	Good
Venus	L 2113	13 1 15	+ 8.70	+ 8.64	+0.1	36	Excellent

The results from all the planet and Moon plates, made at intervals to test the performance of the spectrograph, are here summarized in a brief table. These check plates cover the whole period during which the "Standard Velocity Stars" have been under observation. The last two of these plates are also printed in detail to show the lines measured and to illustrate the character of the results from the individual lines. The mean value of O.—C. = +0.15 km is doubtless only accidental as it is due to the rather large positive value of one of the less reliable plates. (I consider plates having *V* comparison lines much more reliable than those having the *Mo* lines.) It seems safe to conclude from these tests that the spectrograph has not been affected by appreciable systematic errors during the period covered by this series of velocity observations.

In the following pages are given in tabulated form the detailed reductions of all the plates of the "Standard Velocity Stars." The date of the plate is given in Greenwich Mean Time, above the table. The hour angle is also added. Just over the head of the table is a note descriptive of the quality of the plate. The first column of the table contains the wave-length of the star line and the second column, the velocity deduced for the line, given to the tenth of a kilometer per second. At the foot of these columns is given the mean of the velocities from the several lines, followed by V_a and V_d, the reductions to the Sun; and next the value of the star's radial velocity. Below these will be found the mean error $\epsilon=\pm\sqrt{\frac{\Sigma v^2}{n-1}}$ of the determination of the velocity from a single line, and the mean error $\epsilon_0=\pm\sqrt{\frac{\Sigma v^2}{m(n-1)}}$ of the final velocity of the star deduced from the plate.

The stars are arranged in the order of their right ascensions and the plates of each are given in chronological order.

MARS—L 2096

1905 Oct. 6^d 13^h 52^m
Hour angle W 1^h 27^m
Planet spectrum good; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4274.911	+11.7km
93.241	11.7
94.273	8.7
4307.938	6.9
14.321	8.2
15.178	9.1
18.817	9.7
25.951	9.4
37.216	6.6
40.634	10.7
52.006	9.3
52.935	8.7
59.784	9.1
76.107	5.8
78.419	11.9
79.396	5.5
80.883	12.3
83.720	8.5
95.286	7.4
4404.951	7.1
06.810	6.7
07.851	7.2
08.549	7.1
15.244	10.2
27.420	9.1
35.184	7.5
42.510	10.3
43.976	13.0
47.892	10.0
56.030	10.7
59.304	11.7
68.663	8.3
76.214	8.5
82.376	11.0
94.738	6.4

Mean	+9.02km
Computed vel.	+9.16
O.—C.	−0.1km

No. of Martian lines 35
No. of comp. lines 32

VENUS—L 2113

1905 Oct. 13^d 1^h 15^m
Hour angle E 4^h 15^m
Planet spectrum excellent; comparison lines (*V*, *Fe*) excellent.

Line λ (Solar)	Velocity
4238.970	+9.1km
39.975	6.7
45.455	6.3
47.580	11.2
50.287	8.2
50.959	7.2
54.505	5.5
71.934	7.6
74.911	8.4
93.241	7.7
94.273	7.7
4306.938	6.8
14.321	10.2
15.178	7.4
18.817	9.6
25.951	7.2
40.634	8.4
52.006	9.1
52.935	8.9
59.784	7.0
83.720	7.2
95.286	8.3
4404.951	7.0
07.851	6.4
08.549	10.8
27.420	9.8
35.184	9.9
42.510	8.0
43.976	10.8
47.892	10.3
56.030	11.2
59.304	9.8
68.663	9.9
76.214	11.1
82.376	11.0
4528.798	11.3

Mean	+8.70km
Computed vel.	+8.64
O.—C.=	+0.1km

No. of *Venus* lines 36
No. of comp. lines 30

a ARIETIS—L 2067

1905 Sept. 12^d 20^h 48^m
Hour angle E 1^h 20^m
Star spectrum fair; comparison lines (*V*, *Fe*) excellent.

Line λ (Solar)	Velocity
4315.178	−35.3^km
18.817	33.5
28.080	35.0
37.216	35.2
40.634	33.7
52.006	36.3
52.935	33.6
59.784	37.7
76.107	38.4
95.286	37.7
4407.851	39.4
08.549	33.7
27.420	33.5
28.711	38.7
42.510	35.9
47.892	35.0
59.304	32.3
68.663	34.0
76.214	35.7
91.620	34.6
4505.003	31.0
28.798	35.5

Mean −35.26^km
V_a +20.80
V_d + 0.12
Red. to Sun +20.92

Rad. vel. −14.3^km

No. of star lines. 22
No. of comp. lines 25
ε ±2.05
ϵ_0 ±0.43

a ARIETIS—L 2085

1905 Oct. 2^d 20^h 8^m
Hour angle E 0^h 30^m
Star spectrum good; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4315.178	−29.7^km
18.817	24.9
28.080	25.9
40.634	27.3
41.530	26.9
52.006	30.6
52.935	27.2
59.784	30.9
76.107	28.5
95.286	28.0
4406.810	30.0
4407.851	−27.3^km
08.549	24.1
27.420	25.5
28.711	26.4
41.881	29.8
42.510	23.6
47.892	24.8
56.030	26.5
60.460	23.5
66.701	25.3
68.663	25.8
76.214	25.6
82.376	25.0
94.738	27.5
97.046	26.3
4501.422	30.9
28.798	24.8

Mean −26.88^km
V_a +12.81
V_d + 0.05
Red. to Sun +12.86

Rad. vel. −14.0^km

No. of star lines 28
No. of comp. lines 27
ε ±2.21
ϵ_0 ±0.42

a ARIETIS—L 2094

1905 Oct. 5^d 18^h 54^m
Hour angle E 1^h 40^m
Star spectrum good; comparision lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4318.817	−25.2^km
28.080	27.7
39.731	28.0
40.634	27.1
52.006	26.4
52.935	24.0
59.784	28.7
76.107	28.2
95.286	28.2
99.903	28.4
4406.810	27.2
07.851	28.9
27.420	23.4
28.711	28.2
35.851	28.2
41.881	26.8
43.976	22.0
47.892	24.9
56.030	22.6
68.663	25.4
76.214	25.8
82.376	24.5
82.904	22.3
4490.950	−27.6^km
97.046	24.9
97.842	23.5

Mean −26.08^km
V_a +11.47
V_d + 0.15
Red. to Sun +11.62

Rad. vel. −14.5^km

No. of star lines 26
No. of comp. lines 27
ε ±2.17
ϵ_0 ±0.43

a PERSEI—L 2049

1905 August 30^d 23^h 6^m
Hour angle E 1^h 0^m
Star spectrum good; comparison lines (*Fe*, *V*) excellent

Line λ (Solar)	Velocity
4308.023	−26.0^km
13.034	29.0
37.216	25.4
59.784	22.3
76.107	27.4
83.720	30.8
94.225	27.5
95.201	26.1
4404.927	28.0
16.985	29.9
27.420	23.6
43.976	26.0
47.892	25.2
59.301	25.5
66.727	28.0
68.663	28.9
76.214	29.9
82.376	24.3
94.738	30.7
4501.448	26.2
08.455	23.9
15.508	26.4
28.798	27.3

Mean −26.89^km
Curve corr. − 0.50
V_a +25.29
V_d + 0.06
Red. to Sun +25.35

Rad. vel. − 2.0^km

No. of star lines 23
No. of comp. lines 19
ε ±2.10
ϵ_0 ±0.40

α *PERSEI*—L 2068

1905 Sept. 12^d 21^h 59^m
Hour angle E 1^h 20^m
Star spectrum over-exposed; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4294.273	−23.1km
4300.211	21.6
03.419	26.0
05.871	28.9
08.023	24.0
13.034	27.4
15.178	23.0
25.939	23.3
40.634	24.0
52.006	28.1
83.720	28.9
91.146	24.8
95.201	26.1
4404.927	28.8
16.985	27.3
27.420	22.9
59.301	26.3
76.214	25.8
81.400	31.3
91.570	29.6
4508.455	26.9
15.508	26.2
28.798	27.8

Mean	−26.18km
V_a +24.04	
V_d + 0.08	
Red. to Sun	+24.12
Rad. vel.	− 2.1km
No. of stars line	23
No. of comp. lines	20
ε	±2.53
ϵ_0	±0.53

α *PERSEI*—L 2079

1905 Sept. 25^d 20^h 40^m
Hour angle E 1^h 35^m
Star spectrum good; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4294.273	−25.2km
4300.211	23.0
08.023	26.3
13.034	28.7
15.178	23.2
25.939	24.8
40.634	24.0
52.006	29.2
52.908	22.9
83.720	25.9
94.225	23.1
4395.201	−24.6km
96.008	22.9
4404.927	24.3
16.985	24.0
43.976	22.8
50.654	23.4
59.301	21.4
66.727	23.8
68.663	24.8
91.570	25.2
94.738	27.2
4501.448	21.4
08.455	23.0
15.508	24.5
20.397	21.5
28.798	24.1
34.139	18.7
49.767	23.8
54.211	25.3

Mean	−24.10km
V_a +21.59	
V_d + 0.10	
Red. to Sun	+21.69
Rad. vel.	− 2.4km
No. of star lines	30
No. of comp. lines	28
ε	±2.12
ϵ_0	±0.39

α *PERSEI*—L 2100

1905 Oct. 7^d 22^h 53^m
Hour angle W 1^h 10^m
Star spectrum very good; comparison lines (*V*, *Fe*) good

Line λ (Solar)	Velocity
4294.273	−21.1km
4308.023	17.9
13.034	21.4
14.321	20.0
15.178	20.6
25.183	21.4
25.939	20.1
38.084	25.3
40.634	22.9
52.006	24.1
52.908	19.9
59.784	15.2
76.107	23.0
83.720	23.1
94.225	20.5
95.201	20.5
4404.927	22.0
16.985	21.3
17.884	19.8
43.976	23.2
50.654	21.2
59.301	20.3
4468.663	−22.6km
69.545	23.4
76.214	21.9
81.400	20.1
82.376	19.4
89.351	20.9
91.570	19.5
94.738	23.6
97.023	18.0
4501.448	21.9
08.455	19.4
15.508	20.9
20.397	22.4
28.798	22.4

Mean	−21.14km
V_a +18.32	
V_d − 0.07	
Red. to Sun	+18.25
Rad. vel.	− 2.9km
No. of star lines	36
No. of comp. lines	28
ε	±1.94
ϵ_0	±0.32

α *PERSEI*—L 2124

1905 Oct. 27^d 22^h 7^m
Hour angle W 1^h 47^m
Star spectrum rather strong; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4308.023	−12.0km
13.034	12.5
14.321	11.5
25.939	13.7
40.634	14.9
52.908	11.6
76.107	13.1
83.720	15.4
95.201	15.0
4404.927	15.8
16.985	16.4
43.976	13.9
47.892	15.4
50.654	13.6
59.301	15.5
76.214	17.4
4501.448	15.7
28.798	15.9

Mean	−14.40km
V_a +11.18	
V_d − 0.11	
Red. to Sun	+11.07
Rad. vel.	− 3.3km
No. of star lines	18
No. of comp. lines	18
ε	±1.74
ϵ_0	±0.41

β LEPORIS—L 2087

1905 Oct. 2d 23h 56m
Hour angle E 0h 8m
Star spectrum good; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4315.178	−33.6km
25.951	29.7
28.080	30.4
37.216	32.3
40.634	30.8
41.530	33.9
52.006	32.4
52.935	32.5
59.784	34.7
76.107	32.6
83.720	35.0
91.146	35.0
4404.951	30.8
06.810	32.4
07.851	32.8
15.244	33.5
27.420	34.3
42.510	35.2
47.892	30.0
56.030	34.7
59.304	32.5
60.460	31.3
66.701	30.3
68.663	33.7
76.214	33.6
82.376	33.0
85.846	32.9
94.738	34.0
4500.480	32.7
01.422	32.5
15.475	30.5
28.798	31.8

Mean	−32.67km
V_a	+19.84
V_d	+ 0.01
Red. to Sun	+19.85
Rad. vel.	−12.8km
No. of star lines	32
No. of comp. lines	30
ϵ	±1.57
ϵ_0	±0.28

β LEPORIS—L 2111

1905 Oct. 12d 23h 20m
Hour angle E 0h 6m
Star spectrum somewhat weak; comparison lines (*Fe*, *V*) good.

Line λ (Solar)	Velocity
4314.321	−30.3km
25.951	32.9
4331.762	−30.7km
40.634	31.0
41.530	32.1
52.935	32.2
59.784	33.0
79.396	33.9
83.720	33.9
4404.951	32.6
06.810	31.7
07.851	31.4
08.549	33.3
27.420	32.0
35.184	28.4
43.976	29.4
47.892	30.1
59.304	32.8
60.460	33.2
68.663	31.5
76.214	30.0
94.738	30.0
4501.422	30.2
08.455	29.8
15.475	30.7
28.798	28.8

Mean	−31.38km
V_a	+18.22
V_d	+ 0.01
Red. to Sun	+18.23
Rad. vel.	−13.2km
No. of star lines	26
No. of comp. lines	25
ϵ	±1.56
ϵ_0	±0.30

β LEPORIS—L 2125

1905 Oct. 27d 23h 17m
Hour angle W 0h 47m
Star spectrum fair; comparison lines (*Fe*, *V*) good.

Line λ (Solar)	Velocity
4315.178	−27.1km
25.951	26.7
28.080	29.1
40.634	24.9
52.006	29.6
52.935	29.9
59.784	28.4
79.396	31.4
83.720	31.3
95.286	28.7
4404.951	28.7
06.810	32.9
08.549	28.8
25.608	24.6
27.420	26.6
42.510	27.0
47.892	29.0
4459.304	−25.2km
68.663	28.9
76.214	23.6
4501.422	24.9
08.455	28.1
22.853	23.6
28.798	24.3

Mean	−27.64km
V_a	+14.75
V_d	− 0.07
Red. to Sun	+14.68
Rad. vel.	−13.0km
No. of star lines	24
No. of comp. lines	24
ϵ	±2.56
ϵ_0	±0.52

β GEMINORUM—L 1833

1905 April 7d 17h 0m
Hour angle W 2h 58m
Star spectrum fair; comparison lines (*Ti*, *Cr*) weak.

Line λ (Solar)	Velocity
4274.911	+36.9km
93.241	35.5
94.273	30.5
4306.938	32.6
14.321	37.5
15.178	30.9
18.817	35.9
28.080	33.3
39.731	32.7
40.634	35.7
49.107	37.7
52.006	34.5
52.935	35.1
59.784	31.9
99.903	31.0
4406.810	31.0
07.851	34.6
08.549	32.3
27.420	30.8
42.510	33.0
57.656	33.7
59.304	32.2

Mean	+33.60km
Curv. cor.	− 0.60
V_a	−29.40
V_d	− 0.23
Red. to Sun	−29.63
Rad. vel.	+3.4km
No. of star lines	22
No. of comp. lines	13
ϵ	±2.13
ϵ_0	±0.45

β GEMINORUM—L 2101

1905 Oct. 7^d 23^h 39^m
Hour angle E 2^h 22^m
Star spectrum fair only; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4293.241	−27.8km
4314.321	21.6
15.178	28.2
18.817	23.1
25.951	26.6
28.080	27.7
37.216	27.7
40.634	29.6
52.006	28.4
52.935	26.8
59.784	27.4
83.720	27.7
95.286	27.4
99.903	29.9
4406.810	25.5
08.549	25.3
15.244	26.0
27.420	28.0
42.510	25.0
47.892	26.7
59.304	23.6
68.663	25.2
76.214	27.6
82.376	25.6
85.846	23.8
4528.798	25.7

Mean	−26.46km
V_a	+29.41
V_d	+ 0.20
Red. to Sun	+29.61
Rad. vel.	+ 3.2km
No. of star lines	26
No. of comp. lines	22
ε	±1.98
ϵ_0	±0.39

β GEMINORUM—L 2117

1905 Oct. 15^d 1^h 5^m
Hour angle E 0^h 20^m
Star spectrum fair only; comparison lines (*V*, *Fe*) a trifle weak.

Line λ (Solar)	Velocity
4314.321	−27.2km
15.178	29.8
18.817	27.5
4328.080	−28.9km
52.935	29.0
59.784	29.9
95.286	25.9
4407.851	26.2
08.549	23.0
27.420	25.5
28.711	27.8
47.892	23.3
56.030	23.2
57.656	26.4
68.663	24.7
76.214	26.5
82.376	26.2
94.738	24.5
4501.422	25.6
28.798	25.0

Mean	−26.30km
V_a	+29.66
V_d	+ 0.03
Red. to Sun	+29.69
Rad. vel.	− 3.4km
No. of star lines	20
No. of comp. lines	20
ε	±2.08
ϵ_0	±0.46

α BOÖTIS—L 1850

1905 April 14^d 20^h 15^m
Hour angle 0^h 0^m
Star spectrum fair only; comparison lines (*Ti*, *Cr*) weak.

Line λ (Solar)	Velocity
4293.241	−5.5km
4318.817	3.3
52.006	5.2
52.935	1.2
59.784	4.4
76.107	5.6
79.396	5.5
94.161	6.0
95.286	5.5
99.903	4.8
4400.615	3.5
06.810	6.5
08.549	2.5
27.420	4.3
42.510	4.4
45.641	2.0
47.892	3.4
57.656	7.4
68.663	6.2

Mean	−4.59km
Curv. corr.	−0.50
V_a	−0.37
V_d	±0.00
Red. to Sun	−0.37
Rad. vel.	−5.5km
No. of star lines	19
No. of comp. lines	15
ε	±1.69
ϵ_0	±0.37

α BOÖTIS—L 2011

1905 Aug. 12^d 16^h 6^m
Hour angle W 3^h 50^m
Star spectrum excellent; comparison lines (*Fe*, *V*) good.

Line λ (Solar)	Velocity
4344.597	+19.6km
52.935	19.3
59.784	17.2
69.933	20.0
79.396	17.5
90.149	16.1
91.146	17.9
4406.810	19.3
07.851	17.5
18.499	21.0
27.420	20.2
28.711	17.5
35.851	17.6
41.881	16.9
42.510	19.6
47.892	21.0
56.030	21.2
57.656	20.0
59.304	20.0
60.460	18.3
68.663	19.9
76.214	19.5
82.376	21.1
97.046	20.6
4501.422	20.8
28.798	20.7
29.774	19.7
34.953	20.6

Mean	+19.30km
Curv. corr.	− 0.55
V_a	−22.40
V_d	− 0.30
Red. to Sun	−22.70
Rad. vel.	− 4.0km
No. of star lines	28
No. of comp. lines	29
ε	±1.45
ϵ_0	±0.28

α BOÖTIS—L 2016

1905 Aug. 15ᵈ 16ʰ 8ᵐ
Hour angle W 4ʰ 10ᵐ
Star spectrum good; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4352.935	+18.8km
59.784	15.0
79.396	15.6
89.413	15.7
4406.810	16.3
07.851	15.1
18.499	19.2
27.420	19.9
28.711	17.9
35.851	14.0
41.881	14.9
42.510	18.1
47.892	19.9
57.656	18.1
60.460	19.1
61.818	19.6
66.701	20.4
68.663	19.7
76.214	18.6
82.904	19.7
94.738	19.9
97.046	21.4
4501.422	18.7
28.798	20.7
34.953	18.6

Mean +18.20km
Curv. corr. − 0.45
V_a −21.79
V_d − 0.32
Red. to Sun −22.11

Rad. vel. − 4.4km

No. of star lines 25
No. of comp. lines 22
ϵ ±2.08
ϵ_0 ±0.42

α BOÖTIS—L 2043

1905 Aug. 29ᵈ 15ʰ 34ᵐ
Hour angle W 4ʰ 30ᵐ
Star spectrum excellent; comparison spectrum lines (*V*, *Fe*) excellent

Line λ (Solar)	Velocity
4352.006	+13.6km
52.935	16.9
59.784	14.2
79.396	12.1
89.413	15.0
4390.149	+14.0km
99.903	13.8
4406.810	12.5
07.851	12.3
15.722	12.9
27.420	16.0
28.711	13.3
41.881	12.3
42.510	13.4
47.892	15.2
57.656	13.9
59.304	14.7
60.460	15.5
68.663	16.0
76.214	14.3
82.376	15.9
94.738	12.3
97.046	14.6

Mean +14.12km
Curv. corr. − 0.55
V_a −18.22
V_d − 0.33
Red. to Sun −18.55

Rad. vel. − 5.0km

No. of star lines 23
No. of comp. lines 23
ϵ ±1.26
ϵ_0 ±0.28

α BOÖTIS—L 2053

1905 Aug. 31ᵈ 15ʰ 31ᵐ
Hour angle W 4ʰ 35ᵐ
Star spectrum excellent; comparison lines (*Fe*, *V*) good.

Line λ (Solar)	Velocity
4337.216	+16.1km
48.045	13.8
52.935	16.3
59.784	13.3
69.933	14.2
79.396	11.1
89.413	14.8
91.146	11.3
4406.810	12.9
07.851	12.6
27.420	15.0
28.711	11.4
42.510	13.5
47.892	15.4
56.030	15.0
59.304	15.5
60.460	14.4
68.663	15.3
76.214	15.6
82.376	14.0

Mean +14.07km
Curv. corr. − 0.60
V_a −17.62
V_d − 0.33
Red. to Sun −17.95

Rad. vel. − 4.5km

No. of star lines 20
No. of comp. lines 20
ϵ ±1.60
ϵ_0 ±0.36

β OPHIUCHI—L 1947

1905 July 14ᵈ 19ʰ 10ᵐ
Hour angle W 1ʰ 45ᵐ
Star spectrum fair; comparison lines (*Mo*, *Fe*) fair.

Line λ (Solar)	Velocity
4352.006	+0.3km
52.935	4.0
59.784	2.3
79.396	−1.4
4406.810	1.5
07.851	+1.7
08.549	1.8
27.420	2.1
38.510	−1.1
42.510	+1.8
47.892	2.4
57.656	4.6
59.304	2.6
60.460	3.4
68.663	− 0.5
76.214	0.5
90.950	1.3
97.046	+1.3
4528.798	0.5
34.953	−1.9

Mean +1.03km
Curv. corr. −0.55
V_a −12.25
V_d − 0.16
Red. to Sun −12.41

Rad. vel. −11.9km

No. of star lines 20
No. of comp. lines 21
ϵ ±1.95
ϵ_0 ±0.44

β OPHIUCHI—L 2017

1905 Aug. 15d 17h 50m
Hour angle W 2h 30m
Star spectrum good; comparison lines (*Fe, V*) strong.

Line λ (Solar)	Velocity
4328.080	+15.0km
39.731	10.8
49.107	14.2
52.006	10.5
52.935	13.1
59.784	11.9
79.396	10.1
89.413	12.6
99.903	9.4
4406.810	11.4
07.851	13.0
08.549	13.2
27.420	13.5
42.510	10.5
47.892	8.1
57.656	13.9
59.304	14.0
60.460	11.3
68.663	14.8
76.214	12.7
90.950	11.0

Mean +12.14km
Curv. corr. −0.42
V_a −22.33
V_d −0.23
Red. to Sun −22.56

Rad. vel. −10.8km

No. of star lines 21
No. of comp. lines 23
ε ±1.71
ϵ_0 ±0.37

β OPHIUCHI—L 2058

1905 Sept. 8d 16h 32m
Hour angle W 2h 35m
Star spectrum fair; comparison lines (*Fe, V*) good.

Line λ (Solar)	Velocity
4328.080	+14.8km
31.762	12.7
52.006	12.8
52.935	15.4
59.784	13.8
69.868	18.4
79.396	12.4
4395.286	−13.9km
4406.810	16.9
08.549	13.6
15.244	18.1
27.420	16.0
28.711	11.9
42.510	16.5
47.892	14.3
59.304	18.4
60.460	18.0
69.549	19.4
76.214	14.6
82.376	18.1
94.738	12.7
4522.853	15.3
28.798	14.4

Mean +15.31km
Curv. corr. −0.45
V_a −25.89
V_d −0.22
Red. to Sun −26.11

Rad. vel. −11.3km

No. of star lines 23
No. of comp. lines 23
ε ±2.32
ϵ_0 ±0.48

γ AQUILAE—L 1921

1905 July 5d 21h 5m
Hour angle W 0h 50m
Star spectrum good; comparison lines (*Ti, Mo, Cr, Fe*) overexposed.

Line λ (Solar)	Velocity
4321.931	−13.4km
28.080	4.5
31.762	7.7
34.967	6.2
39.731	11.0
52.006	9.6
52.935	6.3
59.784	8.4
64.273	9.8
76.107	13.0
79.396	11.2
95.286	9.0
4400.615	7.7
27.420	7.3
42.510	9.8
47.892	10.1
59.304	9.3
68.663	8.1
75.026	7.1
76.214	10.6

Mean −9.00km
Curv. corr. −0.50
V_a +6.89
V_d −0.08
Red. to Sun +6.81

Rad. vel. −2.7km

No. of star lines 20
No. of comp. lines 14
ε ±2.30
ϵ_0 ±0.51

γ AQUILAE—L 1926

1905 July 7d 20h 25m
Hour angle W 0h 20m
Star spectrum good; comparison lines (*Mo, Fe*) weak.

Line λ (Solar)	Velocity
4328.080	−4.9km
31.762	6.9
39.731	7.1
52.935	6.6
59.784	7.4
69.933	7.2
79.396	9.7
95.286	9.1
4407.851	12.4
27.420	3.9
42.510	9.9
47.892	8.8
57.656	10.5
59.304	7.1
68.663	5.9

Mean −7.83km
Curv. corr. −0.50
V_a +6.08
V_d −0.03
Red. to Sun +6.05

Rad. vel. −2.3km

No. of star lines 15
No. of comp. lines 18
ε ±2.23
ϵ_0 ±0.57

γ *AQUILAE*—L 1952

1905 July 15^d 19^h 50^m
Hour angle W 0^h 15^m
Star spectrum fair; comparison lines (*Mo. Fe*) fair.

Line λ (Solar)	Velocity
4328.080	−2.4^km
49.107	1.8
52.935	2.2
59.784	2.4
62.262	6.9
76.107	2.7
79.396	3.7
4400.615	2.7
06.810	4.6
07.851	5.2
27.420	2.2
42.510	4.9
47.892	6.5
56.030	6.7
57.656	6.6
60.460	7.1
68.663	0.7
72.956	4.4

Mean −4.10^km
V_a +2.77
V_d −0.02
Red. to Sun +2.75

Rad. vel. −1.3^km

No. of star lines 18
No. of comp. lines 13
ε ±2.06
ϵ_0 ±0.49

ε *PEGASI*—L 1948

1905 July 14^d 21^h 18^m
Hour angle E 0^h 24^m
Star spectrum good; comparison lines (*Fe, Mo*) good

Line λ (Solar)	Velocity
4331.762	−12.6^km
52.935	7.9
59.784	6.1
76.107	11.4
79.396	10.9
4407.851	9.7
33.390	9.6
41.881	15.0
42.510	11.5
45.641	10.6
56.030	14.0
57.656	10.2
59.304	8.3
4468.663	−6.7^km
76.214	11.3
82.376	9.1
82.904	10.3
4501.422	9.5
05.003	8.7
28.798	10.7
29.774	10.0

Mean −10.20^km
Curv. corr. − 0.50
V_a +16.77
V_d + 0.04
Red. to Sun +16.81

Rad. vel. + 6.1^km

No. of star lines 21
No. of comp. lines 17
ε ±2.18
ϵ_0 ±0.47

ε *PEGASI*—L 2007

1905 Aug. 10^d 20^h 42^m
Hour angle W 0^h 50^m
Star spectrum very good; comparison lines (*Ti, Fe*) good.

Line λ (Solar)	Velocity
4318.817	+4.6^km
28.080	1.2
31.762	4.2
47.403	1.9
49.107	−0.6
52.935	+2.1
59.784	2.5
76.107	−2.9
79.396	1.9
89.413	1.2
91.146	2.9
94.161	+1.1
95.286	0.4
4406.810	−1.4
07.851	1.4
27.420	+0.4
41.881	−1.5
42.510	2.0
45.641	+2.4
47.892	0.9
57.656	−2.8
59.304	+0.9
60.460	−1.7
68.663	+1.4
76.214	0.4
85.846	2.5
97.046	−1.6
4500.480	+3.4
05.003	1.8
12.063	0.1
4512.906	−0.8^km
14.513	0.9
15.475	3.0
28.798	−1.7

Mean +0.39^km
Curv. corr. −0.45
V_a +5.65
V_d −0.08
Red. to Sun +5.57

Rad. vel. +5.5^km

No. of star lines 34
No. of comp. lines 25
ε ±2.01
ϵ_0 ±0.34

ε *PEGASI*—L 2054

1905 Sept. 6^d 18^h 48^m
Hour angle W 0^h 45^m
Star spectrum good; comparison lines (*V, Fe*) fair.

Line λ (Solar)	Velocity
4331.762	+15.5^km
49.107	12.5
52.935	16.1
59.784	14.2
76.107	11.2
79.396	11.9
89.413	14.0
91.146	11.6
95.286	14.7
98.272	14.1
4427.420	16.1
42.510	15.8
47.892	11.2
56.030	15.8
59.304	16.8
60.460	11.7
68.663	16.7
76.214	12.2
82.376	13.9
94.738	12.5
4515.475	16.6
28.798	14.9

Mean +14.10^km
V_a −6.74
V_d −0.08
Red. to Sun −6.82

Rad. vel. +7.3^km

No. of star lines 22
No. of comp. lines 23
ε ±1.79
ϵ_0 ±0.39

ε PEGASI—L 2080

1905 Sept. 27d 17h 28m
Hour angle W 0h 48m
Star spectrum good; comparison lines (*Fe*, *V*) somewhat strong.

Line λ (Solar)	Velocity
4328.080	+18.7km
49.107	19.3
52.935	23.0
56.110	19.9
59.784	18.4
76.107	19.0
89.413	21.2
90.149	19.8
95.286	18.0
4406.810	19.8
07.851	22.1
27.420	24.9
28.711	19.3
35.851	20.8
41.881	20.0
42.510	23.4
45.641	23.3
47.892	22.0
57.656	23.7
59.304	24.2
68.663	26.2
76.214	21.7
82.376	25.0
94.738	16.4
97.046	23.6

Mean +21.35km
V_a −15.71
V_d − 0.08
Red. to Sun −15.79

Rad. vel. + 5.6km

No. of star lines 25
No. of comp. lines 25
ε ±2.21
ϵ_0 ±0.44

γ PISCIUM—L 2081

1905 Sept. 27d 19h 15m
Hour angle W 1h 25m
Star spectrum fair; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4314.321	− 4.0km
15.178	8.4
25.951	3.7
28.080	3.0
37.216	5.4
40.634	5.7
41.530	0.7
52.006	7.5
52.935	6.0
4359.784	−7.8km
76.107	6.8
79.396	5.3
83.720	5.5
95.286	8.1
4406.810	2.3
08.549	3.1
15.244	2.5
27.420	4.3
41.881	1.5
42.510	1.0
45.641	0.2
47.892	4.0
57.656	3.1
59.304	1.7
68.663	5.0
76.214	3.0
82.376	1.4
88.363	0.0
94.738	4.9
97.046	0.0

Mean −3.86km
V_a −7.79
V_d −0.13
Red. to Sun − 7.92

Rad. vel. −11.8km

No. of star lines 30
No. of comp. lines 23
ε ±2.56
ϵ_0 ±0.45

γ PISCIUM—L 2122

1905 Oct. 27d 18h 22m
Hour angle W 2h 10m
Star spectrum fair; comparison lines(*V*, *Fe*) good.

Line λ (Solar)	Velocity
4294.273	+15.0km
4315.178	12.0
28.080	13.4
40.634	11.0
52.006	13.9
52.935	14.4
59.784	9.3
78.419	9.2
79.396	7.3
83.720	9.3
95.286	7.0
4404.951	6.3
06.810	12.0
07.851	8.0
08.549	9.0
15.244	13.9
27.420	10.9
42.510	10.0
68.663	8.4
76.214	7.2
94.738	5.4
4501.422	−9.4km
08.455	10.1
28.798	11.9

Mean +10.19km
V_a −20.99
V_d − 0.20
Red. to Sun −21.19

Rad. vel. −1.0km

No. of star lines 24
No. of comp. lines 24
ε ±2.60
ϵ_0 ±0.53

γ PISCIUM—L 2129

1905 Nov. 2d 17h 0m
Hour angle W 1h 20m
Star spectrum fair; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4293.241	+11.6km
94.273	10.6
4306.938	11.4
15.178	11.6
25.951	12.3
31.762	10.0
37.216	13.8
40.634	12.3
52.006	9.0
52.935	14.3
59.784	8.3
77.407	12.3
95.286	10.0
4404.951	9.8
08.549	12.3
27.420	11.2
41.881	11.6
42.510	12.9
47.892	13.7
57.656	12.4
59.304	12.0
60.460	12.9
76.214	15.4
82.376	15.4
4501.422	12.6
28.798	15.5

Mean +12.12km
V_a −23.08
V_d − 0.12
Red. to Sun −23.20

Rad. vel. −11.1km

No. of star lines 26
No. of comp. lines 24
ε ±1.88
ϵ_0 ±0.37

γ CEPHEI—L 2109

1905 Oct. 12d 20h 45m
Hour angle W 3h 5m
Star spectrum fair; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4293.241	−50.8km
94.273	49.4
4315.178	52.4
18.817	49.8
28.080	48.2
37.216	50.9
39.731	53.0
52.006	49.1
52.935	47.8
59.784	51.5
77.407	44.8
95.286	50.2
4406.810	48.3
07.851	51.8
08.549	49.0
27.420	46.4
28.711	49.8
42.510	47.7
43.976	46.5
47.892	46.3
57.656	43.3
59.304	48.0
68.663	51.6
76.214	45.9
82.376	44.9
97.046	44.5
4528.798	47.7

Mean	−48.50km
V_a +7.96	
V_d −0.06	
Red. to Sun	+ 7.90
Rad. vel.	−40.6km

No. of star lines	27
No. of comp. lines	28
ε	±2.60
$ε_0$	±0.50

γ CEPHEI—L 2123

1905 Oct. 27d 20h 45m
Hour angle W 4h 5m
Star spectrum fair; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4315.178	−45.9km
28.080	44.5
40.634	44.4
52.935	46.0
59.784	47.4
79.396	49.5
95.286	46.1
4408.549	49.2
27.420	46.7
28.711	49.3
47.892	47.1
59.304	45.1
68.663	47.2
76.214	47.7
94.738	47.6
96.046	49.8
4501.422	49.9
28.798	47.9

Mean	−47.30km
V_a +5.15	
V_d −0.08	
Red. to Sun	+5.07
Rad. vel.	−42.2km

No. of star lines	18
No. of comp. lines	19
ε	±2.00
$ε_0$	±0.47

γ CEPHEI—L 2130

1905 Nov. 2d 19h 50m
Hour angle W 3h 35m
Star spectrum weak and unsymmetrical; comparison lines (*V*, *Fe*) good.

Line λ (Solar)	Velocity
4315.178	−47.9km
28.080	48.2
52.006	49.8
52.935	46.9
59.784	48.3
4408.549	49.6
09.328	44.6
15.244	43.2
27.420	46.3
28.711	48.5
57.656	49.6
59.304	47.8
66.701	42.9
75.026	47.2
76.214	46.6
82.376	42.0
4528.798	47.6

Mean	−46.88km
V_a +3.91	
V_d −0.07	
Red. to Sun	+ 3.84
Rad. vel.	−43.0km

No. of star lines	17
No. of comp. lines	18
ε	±2.39
$ε_0$	±0.58

The resulting velocities for the different plates tabulated above are here collected into a table. The first part of this table contains the values of the velocity deduced from each star plate, followed by their unweighted mean, which is given as the velocity of the star. In the second part of the table are given for comparison the results by other observers of the same star.

It will be noticed that I have in general measured many more lines than is common in such observations. This has increased the accuracy of my velocities by decreasing the effect of accidental errors of measurement, which arise from the somewhat inferior definition in the spectrograms. Although fairly accurate results are obtained in this way, the extra labor in the measurement and reduction is quite considerable. The spectrograph is soon to be remodeled so as to improve the definition and to render accurate velocity observations possible with less labor.

α ARIETIS

Slipher		Other Observers			
Date, 1905	Velocity	Observer	Velocity	No. of Plates	Range
Sept. 12d 21h...	−14.3km	Frost[1]...........	−13.5km	3 (Frost and Adams[1])	0.8km
Oct. 2 20 ...	−14.0	Adams[1]..........	−13.9		0.7
Oct. 5 19 ...	−14.5	Adams[2]..........	−13.7	1	...
		Campbell[3].......	−14.1	4	0.6
Mean......	−14.3	Newall[4]..........	−14.3	3	2.8
		Lord and Maag[5]..	−12.4[7]	5	1.8
		Lord[3]...........	−14.0	2	2.7
		Newall[6]	−16.4	8	6.3

α PERSEI

Date, 1905	Velocity	Observer	Velocity	No. of Plates	Range
Aug. 30d 23h...	− 2.0km	Frost...........	− 2.3km	3 (Frost and Adams)	1.6km
Sept. 12 22 ...	− 2.1	Adams..........	− 2.0		1.3
Sept. 25 21 ...	− 2.4	Campbell[8].......	− 2.2	10	2.0
Oct. 7 23 ...	− 2.9	Bélopolsky[9]......	− 2.9	8	3.7
Oct. 27 22 ...	− 3.3	Lord and Maag...	+ 0.6	5	3.7
		Newall..........	− 2.6	14	5.7
Mean......	− 2.5	Vogel[10]..........	− 3.2	13	3.3
		Newall..........	− 4.6	5	5.5

β LEPORIS

Date, 1905	Velocity	Observer	Velocity	No. of Plates	Range
Oct. 3d 0h...	−12.8km	Frost...........	−12.2km	1 (Frost and Adams)	...km
Oct. 12 23 ...	−13.2	Adams..........	−12.6		
Oct. 27 23...	−13.0				
Mean......	−13.0				

1 "Spectrographic Observations of Standard Velocity Stars (1902–1903)," *Astrophysical Journal*, **18**, 273, 1903.

2 *Ibid.*, **15**, 24, 1902.

3 *Ibid.*, **8**, 150, 1898.

4 *Monthly Notices*, **63**, 298, 1903.

5 *Astrophysical Journal*, **21**, 297, 1905.

6 *Monthly Notices*, **65**, 651, 1905.

7 See footnote 2, page 339.

8 *Lick Bulletin*, No. 4, p. 24.

9 *Astrophysical Journal*, **19**, 85, 1904.

10 *Ibid.*, **13**, 322, 1901.

β GEMINORUM

April 7^d 17^h...	+3.4^{km}	Frost...........	+3.2^{km}	3	0.6^{km}
Oct. 8 0 ...	+3.2	Adams..........	+3.7		0.2
Oct. 15 1 ...	+3.4	Lord and Maag ..	+5.3	5	5.4
		Bélopolsky.......	+3.4	9	1.4
Mean......	+3.3	Newall..........	+2.0	6	3.0

α BOÖTIS

April 14^d 19^h...	−5.5^{km}	Frost...........	−4.7^{km}	5	1.3^{km}
Aug. 12 16 ...	−4.0	Adams..........	−4.9		0.9
Aug. 15 16 ...	−4.4	Bélopolsky.......	−6.1	9	3.3
Aug. 29 16 ...	−5.0	Lord and Maag...	−3.2	7	3.2
Aug. 31 16 ...	−4.5	Frost and Adams[1]	−4.3	8	1.8
		Newall..........	−5.8	5	2.7
Mean......	−4.7	Newall..........	−6.6	19	4.5

β OPHIUCHI

Slipher		Other Observers			
Date, 1905	Velocity	Observer	Velocity	No. of Plates	Range
July 15^d 18^h...	−11.9^{km}	Frost...........	−11.3^{km}	3	0.8^{km}
Aug. 15 18 ...	−10.8	Adams..........	−10.9		0.7
Sept. 8 17 ...	−11.3	Newall..........	−15.9	2	1.9
Mean......	−11.3				

γ AQUILAE

July 5^d 21^h...	−2.7^{km}	Frost...........	−1.4^{km}	3	0.7^{km}
July 7 20 ...	−2.3	Adams..........	−2.2		1.0
July 15 20 ...	−1.3	Bélopolsky.......	−2.0	10	3.8
		Newall..........	−1.9	4	4.2
Mean......	−2.1				

ε PEGASI

July 14^d 21^h...	+6.1^{km}	Frost...........	+6.2^{km}	3	0.5^{km}
Aug. 10 21 ...	+5.5	Adams..........	+6.2		0.4
Sept. 6 19 ...	+7.3	Campbell[2].......	+5.7	4	1.2
Sept. 27 17 ...	+5.6	Bélopolsky.......	+6.0	7	1.4
		Lord and Maag...	+6.1	5	5.8
Mean......	+6.1	Newall..........	+3.3	3	2.6

[1] *Publications of the Yerkes Observatory*, Vol. II, Part 4, p. 35, 1903.

[2] *Loc. cit.*

γ *PISCIUM*

Sept. 27^d 20^h...	−11.8^km	Frost............	−10.7^km	} 3	0.4^km
Oct. 27 18 ...	−11.0	Adams..........	−11.1		1.1
Nov. 2 17 ...	−11.1				
Mean......	−11.3				

γ *CEPHEI*

Oct. 12^d 21^h...	−40.6^km	Frost............	−41.0^km	} 3	1.0^km
Oct. 27 21 ...	−42.2	Adams..........	−41.4		0.2
Nov. 2 20 ...	−43.0	Bélopolsky.......	−39.9	4	2.7
Mean......	−41.9				

As regards the quality of the plates, the velocity of γ *Cephei* is subject to the greatest inaccuracy, due to the weak character of the last plate. The velocity of γ *Aquilae* is also somewhat uncertain, owing to lack of knowledge of the wave-lengths of the *Mo* lines, there being apparent disagreement between the arc[1] and spark values.

Comparison of my results with those of other observers seems to point toward slightly greater negative values for my velocities.[2] But as this depends largely upon the value got for γ *Cephei*, the most discordantly observed star of the ten, I consider it only apparent and due to accidental causes. It might, however, be interesting in this connection to point out that there is a slight difference between the arc wave-lengths[3] of the *V* lines (λ 4300–4500) and Rowland's solar wave-lengths of the lines assigned to *V*, the latter being about 0.0025 tenth-meters greater than the former.

The performance of the 24-inch glass has been, in these observations, entirely satisfactory, as may be judged from a comparison of the exposure times with those of the same stars by Frost and Adams with the great Yerkes refractor. The altitude of this observatory and the transparency of the sky must contribute very greatly

[1] The wave-lengths of the *Mo* lines in the arc were published by Hasselberg in the *Astrophysical Journal*, **17**, 20, January 1903.

[2] Mention should be made here that Professor Lord has called attention to the fact that his and Mr. Maag's velocities are systematically too large positive by about two kilometers.

[3] Rowland and Harrison, *Astrophysical Journal*, **7**, 273, 1898.

to the light-power of the equipment. Under fair conditions, with good guiding, satisfactory spectrograms of *a Persei*, for example, would be made (through a 0.025 mm slit) with a 15-minute exposure. My last plate of this star was given that length of exposure and was amply timed, whereas the shortest exposure given this star with the Yerkes equipment was 30 minutes. My earlier plates of this series were, in general, rather over-timed.

In conclusion, I wish to acknowledge my indebtedness to Professor Lowell for encouragement in carrying on these observations, and to Mr. J. C. Duncan, fellow in this observatory, for checking the reductions to the Sun and assisting in preparing the tables for the press.

Lowell Observatory,
Flagstaff, Ariz.,
November 7, 1905.