THE RADIAL VELOCITIES OF THE PLEIADES*

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ABSTRACT

The radial velocities of 71 stars have been determined from 237 spectrograms. Sixty-nine stars are regarded as members of the cluster. The mean velocity for all 69 stars is +4.08 ± 0.68 (m.e.) km/sec. If the stars are divided into two groups, according to rotational velocity, 50 of low rotation give +5.19 ± 0.70, while 19 of high rotation give +1.17 ± 1.41 km/sec. No explanation is offered for this systematic difference. The largest range in velocity for any star is 54 km/sec (No. 13). This star and No. 33, having a range of 45 km/sec, are regarded as spectroscopic binaries, while 8 other stars are suspected. The questions of internal motions and of spatial differences in the velocities are briefly discussed.

Nearly all of the brighter stars in the Pleiades have exceptionally broad and ill-defined lines in their spectra. The radial velocities determined from these stars are very uncertain. Those which are listed in Moore's catalogue[1] show a considerable amount of scatter. Very few radial velocities have been published for the fainter members of the cluster, although there have been numerous investigations of their proper motions. Trumpler[2] has recently published a mean velocity of + 7 km/sec for an unspecified number of stars in the cluster, which probably include many of the stars discussed in this paper. Pearce presented at the June, 1944, meeting of the American Astronomical Society results from measurements made at Victoria. These were not available to us until after the completion of this paper. From measurements of the brighter stars in the cluster he found, on the average, +7.86 km/sec.

The present investigation was undertaken in order to determine an independent value for the radial velocity of the Pleiades, using for this purpose not only the brighter stars but also those of intermediate brightness—to about magnitude 9.0. We were especially interested in finding whether the cluster contains a large percentage of spectroscopic binaries of considerable range, as does, for example, the galactic cluster NGC 6231. Finally, an attempt was to be made to discover whether there exist any spatial differences in the radial velocities of the various cluster stars or any differences depending upon the physical characteristics of the members.

The present discussion gives the results of measurements of 237 spectrograms of 71 stars.[3] Of the 237 spectrograms, 230 were taken with the quartz spectrograph attached to the 82-inch McDonald reflector, giving a dispersion of 55 A/mm at $H\gamma$; 4 were taken at McDonald with the $f/2$ glass spectrograph, giving a dispersion of 78 A/mm (Nos. 4066, 4067, 4068, 4069); and 3 were taken with the Bruce one-prism spectrograph attached to the 40-inch telescope of the Yerkes Observatory, giving a dispersion of 26 A/mm at $H\gamma$ (Nos. 12629, 12630, 12640). At least 2 spectrograms per star were obtained.

Of the 71 stars, one (our No. 23) is Hertzsprung No. 310,[4] and another (our No. 22) is

* *Contributions from the McDonald Observatory, University of Texas*, No. 97.

[1] *Pub. Lick Obs.*, **18**, 1932.

[2] *Pub. A.S.P.*, **56**, 68, 1944.

[3] The shell spectrum of Pleione has been omitted in this investigation, since it has been dealt with in a recent paper by Struve and Swings (*Ap. J.*, **97**, 426, 1943). It is not certain that the velocity of the shell spectrum is identical with the velocity of the cluster.

[4] *Mem. Acad. R. Sci. Denmark*, Ser. VIII, **4**, No. 4, 1923.

not listed as a member. The remaining 69 stars were taken from Trumpler's list of members of the cluster.[5] Most of the stars on our program were of photographic magnitude 9.0 or brighter, and only 8 were fainter. The faintest star (our No. 1) is of magnitude 10.1.

Three stars in our list are marked by Trumpler as "uncertain members," and 4 as "probable members." The radial velocities for these stars are as follows:

TRUMPLER'S "PROBABLE" CLUSTER MEMBERS

Our No.	Trumpler's No.	Plates	Velocity
66	S 142	2	− 7.0
59	S 26	2	+28.1
60	47	2	+ 1.2
64	S 115	2	+ 5.6

TRUMPLER'S "UNCERTAIN" CLUSTER MEMBERS

Our No.	Trumpler's No.	Plates	Velocity
69	S 177	2	+ 7.7
58	S 25a	2	− 6.3
63	S 84	2	+ 7.4

On the basis of these velocities, only No. 59 can be excluded as a background star. This star has been omitted from the following discussion, as has also star No. 22, which is not a member of the cluster, according to Trumpler. This leaves a total of 69 stars.

The wave lengths of the stellar lines used in determining the radial velocities for the A-type stars are taken from the papers by W. W. Morgan[6] and O. Struve.[7] For the B-type stars the wave lengths were taken from H. Kühlborn.[8] For the F-type stars the wave lengths of Adams and Harper were used,[9] together with data from other sources. Nearly all the plates were measured separately by Struve and by Smith, and the two measurers independently chose the star lines and their wave lengths.

Table 1 gives the average radial velocity of each star. The stars are numbered consecutively in column 1, and those which are in the outer parts of the cluster are listed separately at the end of the table. Some of these stars are as far as 3° from Alcyone. The photographic magnitudes are taken from Trumpler (except Nos. 22 and 23), and the spectral types are from the *Henry Draper Catalogue*. The "grade" denotes the estimated quality of the spectrum, which depends upon the number of lines suitable for measurement and their quality. Grade 1 represents the best quality. The rotational velocity at the equator in km/sec was estimated from the observed widths of the lines. Table 2 gives the mean results for all plates from the measures of Smith and of Struve.

[5] *Lick Obs. Bull.*, **10**, 110, 1921.

[6] *Pub. Yerkes Obs.*, **7**, Part III, 1935.

[7] *Ap. J.*, **90**, 699, 1939.

[8] *Veröff U.-Sternw. Berlin-Babelsberg*, **12**, Part I, 1938.

[9] *Trans. I.A.U.*, **5**, 193, 1935.

TABLE 1

RADIAL VELOCITIES FOR THE PLEIADES

Star	HD	Trumpler No.	α (1900)	δ (1900)	Mag. (Pg.)	Sp.	Vel. (Km/Sec)	m.e.	Plates	Grade	Rot. (Km/Sec)
1....	23061	R11	$3^h36^m58^s$	+24° 10′.5	10.1	F8	+ 7.2	± 1.1	3	1	0
2....	23157	50	37 46	23 19.9	8.3	A5	− 4.0	8.0	4	1	0
3....	23156	51	37 46	24 3.5	8.4	A5	+ 8.4	2.4	4	1	25
4....	23194	74	38 3	24 14.4	8.2	A2	+ 1.1	3.7	4	1	0
5....	23246	121	38 29	24 4.8	8.4	A5	+ 2.7	2.5	4	2	150
6....	23288	139	38 51	23 58.5	5.3	B5	+ 4.3	2.5	4	3	250
7....	23302	148	38 56	23 47.9	3.6	B5p	+14.9	11.5	3	3	200
8....	23289	149	38 57	22 57.3	9.3	F5	+ 6.9	1.9	4	1	0
9....	23326	163	39 10	23 23.3	9.3	F5	+ 8.7	4.6	3	2	0
10....	23325	162	39 10	23 57.0	8.8	A0	+ 8.7	1.8	4	1	75
11....	23324	166	39 12	24 31.5	5.7	B8	− 1.2	9.5	4	3	150
12....	23338	170	39 15	24 9.2	4.2	B5	+ 3.2	3.3	3	3	150
13....	23351	180	39 23	24 36.5	9.5	F5	+ 1.8	12.3	4	1	0
14....	23361	195	39 30	23 43.3	8.2	A3	+10.1	3.9	3	2	100
15....	23375	208	39 37	24 9.0	8.9	A2	+11.3	2.1	4	1	50
16....	23387	215	39 41	24 1.4	7.3	B9	+ 4.0	1.8	5	1	0
17....	23408	231	39 52	24 3.3	3.8	B5	+ 5.1	1.6	6	2	25
18....	23410	234	39 55	22 50.1	6.9	A0	+ 2.6	1.7	3	2	100
19....	23409	235	39 55	23 43.6	8.0	A0	+ 6.9	2.4	4	2	75
20....	23432	240	39 57	24 14.5	5.7	B8	− 0.2	2.6	5	3	150
21....	23441	247	40 5	24 12.9	6.3	B9	− 1.0	5.7	6	3	200
22....	23463	*	40 17	23 53.1	9.2	K2	− 8.7	.....	2	1	0
23....	23464	310†	40 18	22 49.0	8.3	G0	− 4.0	0.6	4	1	0
24....	23479	281b	40 19	23 52.7	8.7	A3	− 6.2	5.5	4	2	150
25....	23480	286	40 23	23 38.2	4.2	B5	+ 4.1	.....	2	3	300
26....	23489	295	40 30	23 56.6	7.4	A0	+ 3.1	1.9	4	2	50
27....	23512	311	40 39	23 18.8	8.5	A0	− 0.8	10.0	3	1	50
28....	23513	331	40 46	22 48.0	9.8	F8	− 2.4	9.5	3	1	0
29....	23568	354	41 2	24 12.6	6.7	B9	− 4.4	4.7	4	3	150
30....	23567	359b	41 5	24 30.6	9.0	A2	+ 9.6	4.8	3	1	50
31....	23585	365	41 8	23 41.1	8.6	A2	+ 4.7	2.9	3	2	75
32....	23607	390	41 23	23 49.8	8.4	A0	+ 5.9	2.3	3	1	0
33....	23629	395	41 24	23 48.4	6.3	A0	+ 5.6	10.2	4	2	100
34....	23632	397	41 25	23 29.6	6.9	A0	+ 2.4	2.2	3	3	150
35....	23628	399	41 26	24 16.7	7.8	A0	− 3.4	6.7	4	2	100
36....	23631	402	41 28	23 36.3	7.2	B9	+ 2.9	5.9	3	1	0
37....	23643	410	41 31	23 22.1	7.9	A0	+ 8.2	1.9	3	3	100
38....	23630	414	41 32	23 47.8	2.8	B5p	+ 9.1	6.7	3	3	250
39....	23642	413	41 32	23 58.8	6.8	B9	+14.6	10.5	3	1	0
40....	23733	493	42 16	24 0.6	8.5	A3	+ 7.8	3.0	3	2	100
41....	23753	506	42 26	23 6.8	5.4	B8	−14.4	9.5	3	3	300
42....	23763	518	42 33	24 2.3	7.0	A0	+14.2	3.2	3	1	50
43....	23791	551	42 49	22 57.2	8.6	A3	+ 2.0	2.7	3	1	50
44....	23850	594	43 13	23 44.8	3.6	B8	+ 1.7	.....	2	3	250
45....	23863	607	43 16	23 34.9	8.3	A2	+ 4.9	3.9	4	3	100
46....	23872	613	43 19	24 5.4	7.6	A0	+ 3.2	3.7	4	3	250
47....	23873	622	43 24	24 4.5	6.5	B9	+ 1.4	1.5	5	1	25
48....	23886	629	43 29	23 56.5	8.1	A0	+11.4	5.5	4	1	75
49....	23912	651	43 37	23 4.5	9.5	F8	+ 4.7	1.0	4	2	100
50....	23924	670	43 46	23 2.2	8.3	A2	+ 6.7	3.0	4	1	0
51....	23923	671	43 47	23 24.4	6.0	B8	+ 1.8	5.1	6	3	250
52....	23948	688	43 59	24 2.7	7.5	A0	+ 6.3	2.3	5	1	25
53....	23964	697	44 2	23 32.7	6.8	B9	+ 5.7	6.3	5	1	0
54....	24076	791	44 56	23 39.5	7.0	A0	+ 3.4	5.0	4	2	50
55....	24132	848	45 29	24 13.0	9.1	A5	+ 8.7	±3.9	4	2	75

* Magnitude from *Henry Draper Catalogue*.

† Hertzsprung's number and magnitude; see footnote 4.

TABLE 1—*Continued*

Star	HD	Trumpler No.	α (1900)	δ (1900)	Mag. (Pg.)	Sp.	Vel. (Km/Sec)	m.e.	Plates	Grade	Rot. (Km/Sec)
56....	22578	S23	$3^h32^m49^s$	+22°20′.0	6.7	A0	0.0	.....	2	3	150
57....	22614	S25	33 10	24 22.6	7.1	A0	− 1.4	.....	2	1	0
58....	22615	S25a	33 12	20 35.4	6.5	A0	− 6.3	.....	2	1	0
59....	22637	S26	33 23	21 31.1	7.4	A0	+28.1	.....	2	2	50
60....	23155	47	37 45	24 45.8	7.7	A2	+ 1.2	.....	2	2	75
61....	23388	S76	39 42	20 56.0	7.8	A3	+ 0.1	.....	2	3	50
62....	23402	S78	39 47	22 22.9	8.1	A0	+ 8.9	.....	2	3	150
63....	23430	S84	40 0	25 5.2	8.3	A0	+ 7.4	.....	2	1	75
64....	23664	S115	41 47	25 4.6	8.5	A2	+ 5.6	.....	2	1	25
65....	23852	S137	43 18	22 18.2	7.9	A0	+ 2.4	.....	2	1	75
66....	23913	S142	43 45	22 13.7	6.9	B9	− 7.0	.....	2	3	150
67....	23950	S149	44 2	21 56.4	6.0	B9	+13.9	.....	2	3	75
68....	24178	S165	45 56	25 41.9	7.9	A0	+ 3.6	.....	2	2	75
69....	24368	S177	47 33	25 23.1	6.3	A0	+ 7.7	.....	2	1	0
70....	24711	S185	50 32	22 51.6	8.5	A0	+15.8	.....	2	1	25
71....	24899	S194	52 23	23 47.7	7.1	B9	+ 9.4	.....	2	1	0

From Table 1 the following mean values have been derived:

Unweighted mean of all (69) stars.....	+4.08	±0.68 m.e.
Unweighted mean of all (31) stars of grade 1.....	+5.15	±0.99
Unweighted mean of all (17) stars of grade 2.....	+4.09	±1.01
Unweighted mean of all (21) stars of grade 3.....	+2.50	±1.45
Unweighted mean of all (50) stars of rotational velocity 0–100 km/sec.....	+5.19	±0.69
Unweighted mean of all (19) stars of rotational velocity 150–300 km/sec.....	+1.17	±1.41

In Figure 1 the radial velocities are plotted according to photographic magnitude. The open circles represent the 19 stars of large rotational velocity. The diagram suggests that the brighter stars, of the 19, have larger positive velocities than the fainter ones; but this may be entirely accidental. It should be remembered that the bright B-type stars are the ones that are most difficult to measure. There is no physical explanation of the systematic difference of 4 km/sec between the stars of large and those of small rotation. It is possible, though unlikely, that blends in the spectra of the high-rotation A and late B stars influence the results.

The Lick catalogue of radial velocities[1] lists 11 stars which are also in our list. A comparison of the measured velocities in the two lists is shown in Table 3. Using those stars for which the Lick catalogue contains more than 3 observations and those for which McDonald has more than 2 observations, the mean difference for the remaining 5 stars is

$$\text{Lick Catalogue } \textit{minus} \text{ McDonald} = +0.2 \text{ km/sec}.$$

In view of the fact that nearly all the stars in Table 3 have poor lines, this determination of the systematic difference carries little weight.

Of the 69 stars discussed, 8 are known or suspected, according to Trumpler, to be visual binaries, and one is a triple star. The radial velocities of these stars appear to be normal. In this investigation no stars were found with two spectra, and the greatest range in velocity for a single star (our No. 13) was 54 km/sec. It is perhaps surprising that there are so few spectroscopic binaries of large range in velocity. This may indicate that the masses of the stars are relatively small, and it does not necessarily prove that binaries are infrequent. There are 17 stars for which the observed range in velocity is

TABLE 2

RADIAL VELOCITIES FOR INDIVIDUAL SPECTROGRAMS

Star	Plate No.	Date	U.T.	Quality	V (Km/Sec)	Lines
1.....	1001	1941 Nov. 4	9:09	f	+ 8.5	12
	1273	1942 Jan. 22	2:17	f	+ 4.7	9
	2502	1943 Sept. 13	7:15	f	+ 8.3	6
2.....	1036	1941 Nov. 7	3:09	g	+ 4.1	22
	1326	1942 Jan. 27	3:12	g	+10.3	11
	2000	1943 Mar. 8	5:27	g	−25.0	7
	2427	Sept. 4	8:01	g	− 5.2	14
3.....	1002	1941 Nov. 4	9:55	g	+13.4	15
	1085	10	8:39	p	+ 2.9	6
	1274	1942 Jan. 22	2:52	g	+10.7	12
	2428	1943 Sept. 4	8:31	f	+ 6.5	9
4.....	1003	1941 Nov. 4	10:25	g	+ 7.0	11
	1086	10	9:26	f	− 8.5	9
	1275	1942 Jan. 22	3:15	g	− 2.1	17
	2429	1943 Sept. 4	9:08	g	+ 7.9	13
5.....	1004	1941 Nov. 4	11:01	g	− 0.6	10
	1062	9	7:16	g	− 1.2	8
	1276	1942 Jan. 22	3:39	g	+ 7.6	9
	2430	1943 Sept. 4	10:00	g	+ 5.0	10
6.....	1026	1941 Nov. 6	.....	f	+ 9.7	3
	1087	10	9:50	f	+ 0.9	7
	1272	1942 Jan. 22	1:48	g	+ 7.6	8
	2431	1943 Sept. 4	10:37	g	− 1.2	7
7.....	12629	1941 Oct. 24	4:26	p	+33.8	2
	1327	1942 Jan. 27	3:24	p	+14.9	3
	1366	31	1:45	f	− 4.1	6
8.....	987	1941 Nov. 3	11:44	g	+ 3.2	13
	1324	1942 Jan. 27	1:48	p	+11.8	4
	1346	28	2:47	g	+ 3.2	9
	2432	1943 Sept. 4	11:18	f	+ 9.2	12
9.....	1999	1943 Mar. 8	5:01	g	+ 1.4	10
	4066	Sept. 1	10:07	g	+16.4	11
	4067	1	10:41	g	+ 8.4	10
10.....	1037	1941 Oct. 7	3:58	g	+ 7.4	13
	1278	1942 Jan. 22	4:17	g	+ 5.6	13
	1297	24	6:21	g	+ 8.5	12
	2438	Sept. 5	7:51	g	+13.4	13
11.....	1027	1941 Nov. 6	8:38	f	+ 2.1	6
	1279	1942 Jan. 22	4:41	p	+14.5	6
	1367	31	1:49	p	−27.2	3
	2439	1943 Sept. 5	8:32	f	+ 5.9	7
12.....	12630	1941 Oct. 24	5:00	p	− 0.4	2
	1281	1942 Jan. 22	5:35	g	+10.5	9
	1368	31	2:56	g	− 0.5	9
13.....	1047	1941 Nov. 8	8:50	g	+ 0.9	16
	1280	1942 Jan. 22	5:16	p	+30.3	8
	2440	1943 Sept. 5	9:21	g	+ 0.3	15
	2513	14	7:27	f	−24.1	4

TABLE 2—*Continued*

Star	Plate No.	Date	U.T.	Quality	V (Km/Sec)	Lines
14.....	1058	1941 Nov. 9	4:19	g	+ 9.5	6
	1282	1942 Jan. 22	5:57	f	+16.9	4
	2441	1943 Sept. 5	10:28	f	+ 4.0	6
15.....	1038	1941 Nov. 7	5:06	g	+ 6.5	14
	1283	1942 Jan. 22	6:40	g	+11.8	14
	2442	1943 Sept. 5	10:27	g	+11.2	15
	2514	14	8:41	g	+15.8	15
16.....	1005	1941 Nov. 4	11:29	f	+ 2.5	4
	1061	9	6:42	g	+ 4.6	7
	1361	1942 Jan. 29	4:47	g	− 1.8	5
	2450	1943 Sept. 6	8:56	g	+ 8.1	5
	2515	14	9:25	g	+ 6.6	6
17.....	1298	1942 Jan. 24	6:41	g	+ 5.8	7
	1363	29	7:09	g	+ 4.3	11
	1364	31	1:05	g	+ 6.9	11
	1369	31	3:03	g	− 2.0	11
	1383	Feb. 1	0:58	g	+ 7.6	6
	1384	1	1:13	g	+ 8.1	12
18.....	984	1941 Nov. 3	9:14	f	+ 1.2	7
	1312	1942 Jan. 25	6:22	f	+ 6.2	4
	2453	1943 Sept. 6	9:29	f	+ 0.5	8
19.....	1012	1941 Nov. 5	5:48	p	+ 0.8	4
	1078	10	4:30	f	+11.4	5
	2449	1943 Sept. 6	8:16	f	+ 4.3	9
	2516	14	10:03	g	+11.0	8
20.....	1006	1941 Nov. 4	11:39	p	+ 4.9	6
	1299	1942 Jan. 24	6:47	f	− 0.7	7
	1370	31	3:13	g	− 9.4	5
	2451	1943 Sept. 6	9:06	f	+ 3.6	7
	2517	14	10:32	f	+ 0.6	8
21.....	1007	1941 Nov. 4	11:47	f	+10.0	8
	1300	1942 Jan. 24	6:55	f	+10.1	6
	1360	29	2:16	g	− 2.4	6
	1371	31	3:19	f	−26.3	5
	2452	1943 Sept. 6	9:15	g	+ 5.6	7
	2518	14	10:37	f	− 2.8	8
22.....	1997	1943 Mar. 8	4:18	g	−15.0	12
	4068	Sept. 1	10:59	g	− 2.4	11
23.....	985	1941 Nov. 3	9:52	f	− 2.9	13
	1345	1942 Jan. 28	1:47	f	− 3.9	14
	2454	1943 Sept. 6	10:05	f	− 5.5	12
	2519	14	11:13	p	− 3.8	12
24.....	1059	1941 Nov. 9	5:40	g	− 4.9	10
	1359	1942 Jan. 29	1:40	f	− 6.0	11
	1998	1943 Mar. 8	4:35	p	−19.0	7
	4069	Sept. 1	11:12	g	+ 5.2	10
25.....	1347	1942 Jan. 28	3:17	p	− 5.7	3
	1372	31	4:36	f	+14.0	6

TABLE 2—*Continued*

Star	Plate No.	Date	U.T.	Quality	V (Km/Sec)	Lines
26.....	1039	1941 Nov. 7	5:55	g	+ 8.5	7
	1060	9	6:22	g	+ 2.4	9
	2462	1943 Sept. 7	7:26	g	+ 0.3	7
	2520	14	11:57	g	+ 1.2	7
27.....	983	1941 Nov. 3	8:29	f	+ 4.3	7
	1329	1942 Jan. 27	3:51	p	−19.9	4
	2463	1943 Sept. 7	8:23	g	+13.2	7
28.....	986	1941 Nov. 3	10:51	g	+ 8.6	9
	1348	1942 Jan. 28	3:52	f	+ 6.7	8
	2455	1943 Sept. 6	11:05	f	−22.6	3
29.....	1029	1941 Nov. 6	9:01	f	− 2.2	5
	1088	10	10:02	f	− 6.6	4
	1380	1942 Jan. 31	4:51	p	−14.8	2
	2456	1943 Sept. 6	11:45	f	+ 6.0	8
30.....	1040	1941 Nov. 7	6:33	g	+ 3.2	12
	1337	1942 Jan. 27	6:48	f	+ 6.6	8
	2493	1943 Sept. 12	8:44	g	+19.0	17
31.....	974	1941 Nov. 2	7:27	g	+ 6.6	15
	1333	1942 Jan. 27	5:19	g	− 1.1	10
	2494	1943 Sept. 12	9:28	g	+ 8.5	15
32.....	959	1941 Oct. 29	10:09	g	+ 6.4	12
	1050	Nov. 8	11:22	g	+ 9.4	19
	1336	1942 Jan. 27	6:06	g	+ 1.9	17
33.....	958	1941 Oct. 29	8:59	f	+17.8	8
	979	Nov. 3	6:22	g	+28.3	8
	1335	1942 Jan. 27	8:59	f	−16.8	7
	2506	1943 Sept. 13	11:22	f	− 6.7	8
34.....	981	1941 Nov. 3	7:05	f	+ 3.1	7
	1331	1942 Jan. 27	4:36	f	− 1.6	8
	2465	1943 Sept. 7	10:09	g	+ 5.8	8
35.....	1030	1941 Nov. 6	9:39	f	−14.0	3
	1049	8	10:19	f	− 3.7	7
	2468	1943 Sept. 7	11:38	g	+15.6	3
	2507	13	11:41	g	−11.4	11
36.....	980	1941 Nov. 3	6:44	g	− 9.2	13
	1332	1942 Jan. 27	4:49	g	+10.1	12
	2466	1943 Sept. 7	10:43	g	+ 7.9	12
37.....	982	1941 Nov. 3	7:41	f	+12.0	7
	1330	1942 Jan. 27	4:19	f	+ 5.7	4
	2464	1943 Sept. 7	9:30	g	+ 6.8	10
38.....	12640	1941 Oct. 25	9:05	f	+10.4	4
	1334	1942 Jan. 27	5:42	g	+19.4	9
	1373	31	3:40	f	− 2.5	7
39.....	960	1941 Oct. 29	11:00	g	+16.3	7
	1048	Nov. 8	9:48	g	+30.9	9
	2467	1943 Sept. 7	11:11	g	− 3.5	10

TABLE 2—*Continued*

Star	Plate No.	Date	U.T.	Quality	V (Km/Sec)	Lines
40.....	990	1941 Nov. 4	2:41	g	+11.3	10
	1069	9	11:38	g	+ 1.5	10
	2503	1943 Sept. 13	8:34	g	+10.6	11
41.....	1028	1941 Nov. 6	8:46	f	−34.1	4
	1341	1942 Jan. 27	7:35	f	− 6.2	6
	1374	31	3:46	f	− 2.8	4
42.....	991	1941 Nov. 4	3:26	f	+13.9	7
	1338	1942 Jan. 27	7:20	f	+19.6	4
	2495	1943 Sept. 12	11:14	g	+ 9.1	9
43.....	999	1941 Nov. 4	8:08	g	+ 7.2	15
	1349	1942 Jan. 28	4:38	g	− 1.8	15
	2496	1943 Sept. 12	11:48	g	+ 0.5	17
44.....	1340	1942 Jan. 27	7:30	f	+ 3.8	8
	1375	31	3:50	f	− 0.4	7
45.....	977	1941 Nov. 2	10:54	g	+ 5.0	9
	1362	1942 Jan. 29	6:02	f	+14.8	7
	1994	1943 Mar. 8	3:26	g	− 2.3	6
	2505	Sept. 13	10:54	g	+ 2.0	8
46.....	992	1941 Nov. 4	3:45	f	+ 9.5	3
	1065	9	9:05	f	− 7.1	9
	1995	1943 Mar. 8	3:44	f	+ 4.8	6
	2485	Sept. 8	11:11	f	+ 5.5	4
47.....	1000	1941 Nov. 4	8:31	g	− 4.2	7
	1064	9	5:52	g	+ 2.9	5
	1377	1942 Jan. 31	4:03	p	+ 4.0	4
	1996	1943 Mar. 8	3:53	g	+ 2.5	8
	2484	Sept. 8	10:55	f	+ 1.7	5
48.....	993	1941 Nov. 4	4:18	g	− 1.7	9
	1066	9	9:29	g	+10.4	12
	1993	1943 Mar. 8	3:03	g	+14.1	9
	2483	Sept. 8	10:33	g	+22.7	11
49.....	997	1941 Nov. 4	7:02	g	+ 7.4	9
	1350	1942 Jan. 28	5:24	g	+ 3.2	6
	2481	1943 Sept. 8	9:05	f	+ 4.9	6
	2702	Nov. 16	2:58	g	+ 3.3	11
50.....	998	1941 Nov. 4	7:43	g	+ 8.9	12
	1351	1942 Jan. 28	6:07	g	+ 0.3	12
	2482	1943 Sept. 8	10:00	g	+ 3.8	13
	2703	Nov. 16	4:01	g	+13.8	14
51.....	1031	1941 Nov. 6	10:10	f	− 4.2	6
	1089	10	10:15	f	+15.6	7
	1378	1942 Jan. 31	4:17	f	−16.7	5
	2032	1943 Mar. 10	3:56	p	+ 2.0	6
	2479	Sept. 8	7:58	f	− 0.1	6
	2704	Nov. 16	3:55	g	+14.5	7
52.....	994	1941 Nov. 4	4:49	f	+ 6.9	4
	1067	9	9:54	f	− 0.7	7
	2030	1943 Mar. 10	3:19	g	+ 9.3	7
	2480	Sept. 8	8:13	g	+11.7	5
	2713	Nov. 17	2:26	g	+ 4.5	6

TABLE 2—*Continued*

Star	Plate No.	Date	U.T.	Quality	V (Km/Sec)	Lines
53.....	976	1941 Nov. 2	9:53	g	− 8.9	9
	1090	10	10:24	g	+16.4	5
	2031	1943 Mar. 10	3:40	g	+12.6	9
	2478	Sept. 8	7:42	g	−12.7	12
	2715	Nov. 17	4:07	g	+21.2	7
54.....	996	1941 Nov. 4	6:22	f	+ 0.5	8
	1342	1942 Jan. 27	7:44	f	− 4.7	5
	2035	1943 Mar. 10	4:13	f	+17.6	4
	2477	Sept. 8	7:20	f	0.0	6
55.....	995	1941 Nov. 4	5:37	f	+ 7.0	9
	1068	9	10:39	f	+ 8.6	6
	2504	1943 Sept. 13	9:46	f	+18.1	7
	2714	Nov. 17	3:14	f	+ 0.9	9
56.....	1021	1941 Nov. 6	5:20	f	+ 5.1	4
	1073	10	2:45	f	− 5.1	8
57.....	1025	1941 Nov. 6	8:19	g	−21.4	5
	1354	1942 Jan. 28	7:40	f	+18.7	4
58.....	1019	1941 Nov. 6	4:38	g	− 4.5	11
	1071	10	2:20	g	− 8.1	16
59.....	1020	1941 Nov. 6	4:59	f	+21.4	4
	1072	10	2:35	f	+34.9	4
60.....	1024	1941 Nov. 6	7:48	p	−13.8	4
	1075	10	3:13	f	+16.3	4
61.....	1023	1941 Nov. 6	7:00	f	− 3.1	4
	1082	10	6:52	g	+ 3.4	4
62.....	1022	1941 Nov. 6	6:00	p	+ 9.6	3
	1077	10	4:03	f	+ 8.3	6
63.....	1045	1941 Nov. 8	5:45	g	+ 5.1	13
	1076	10	3:38	g	+ 9.6	10
64.....	1046	1941 Nov. 8	7:14	g	+10.8	15
	1353	1942 Jan. 28	7:14	f	+ 0.5	5
65.....	1018	1941 Nov. 6	3:57	p	+ 3.1	5
	1079	10	4:58	f	+ 1.7	8
66.....	1017	1941 Nov. 6	3:14	f	−26.5	3
	1080	10	5:26	f	+12.5	4
67.....	1016	1941 Nov. 6	2:57	p	+34.3	2
	1057	9	3:26	f	− 6.5	9
68.....	1033	1941 Nov. 6	11:07	p	+ 2.6	3
	1084	10	7:50	f	+ 4.7	4
69.....	1032	1941 Nov. 6	10:26	g	+11.1	13
	1083	10	7:20	g	+ 4.3	12
70.....	1044	1941 Nov. 8	4:13	g	− 1.0	10
	1352	1942 Jan. 28	6:37	p	+32.6	7
71.....	1043	1941 Nov. 8	3:17	g	+10.2	7
	1355	1942 Jan. 28	7:55	g	+ 8.6	4

more than 30 km/sec. Only 10 of these have spectra of grades 1 and 2, and they may be suspected of being spectroscopic binaries. These are our Nos. 2, 13, 27, 28, 33, 39, 53, 57, 60, and 70. Only 2 of these, namely, Nos. 13 and 33, appear to be established with certainty because of the good accordance between the results of the two measurers. The scarcity in the Pleiades of binaries with large amplitudes is the principal conclusion of our investigation.

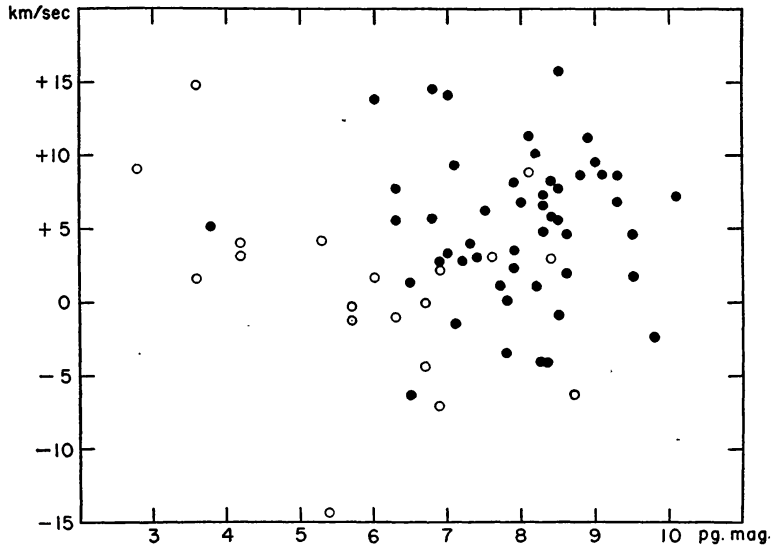

FIG. 1

TABLE 3

COMPARISON WITH LICK CATALOGUE OF RADIAL VELOCITIES

Our No.	Lick Catalogue		McDonald Obs.		Difference (Lick *minus* McDonald)
	Vel.	Plates	Vel.	Plates	
6	+ 2.2	17	+ 4.3	4	− 2.1
7	+11.9	14	+14.9	3	− 3.0
11	+24.8	1	− 1.2	4	+26.0
12	+ 5.4	17	+ 3.2	3	+ 2.2
17	+ 7.8	92	+ 5.1	6	+ 2.7
20	− 2.0	1	− 0.2	5	− 1.8
21	− 3.9	1	− 1.0	6	− 2.9
25	+ 6.8	12	+ 4.1	2	+ 2.7
38	+10.3	18	+ 9.1	3	+ 1.2
41	+ 8	3	−14.4	3	+22.4
44	+ 9.3	16	+ 1.7	2	+ 7.6

It is known from theoretical considerations that the internal motions in the Pleiades cluster must be small. Titus[10] found a mean internal space velocity for the Pleiades of ± 0.59 km/sec. In order to test whether there is any evidence of internal motions in the radial velocities, we have selected from Table 1 all stars of grades 1 and 2 which are not suspected of being spectroscopic binaries, which have small rotational velocities, and

[10] *A.J.*, **47**, 25, 1938.

which have more than 2 plates. This group of 29 stars gives an average mean error of ± 2.94 km/sec for one star. The individual mean errors in Table 1 were computed by means of Schlesinger's formula,[11] which makes an appropriate statistical correction when the number of observations is small. The unweighted mean radial velocity of the 29 stars is $+5.74 \pm 0.77$ (m.e.) km/sec. The mean error of a single star, computed from the departures (Star *minus* Mean), is ± 4.14 km/sec. The difference between the external and

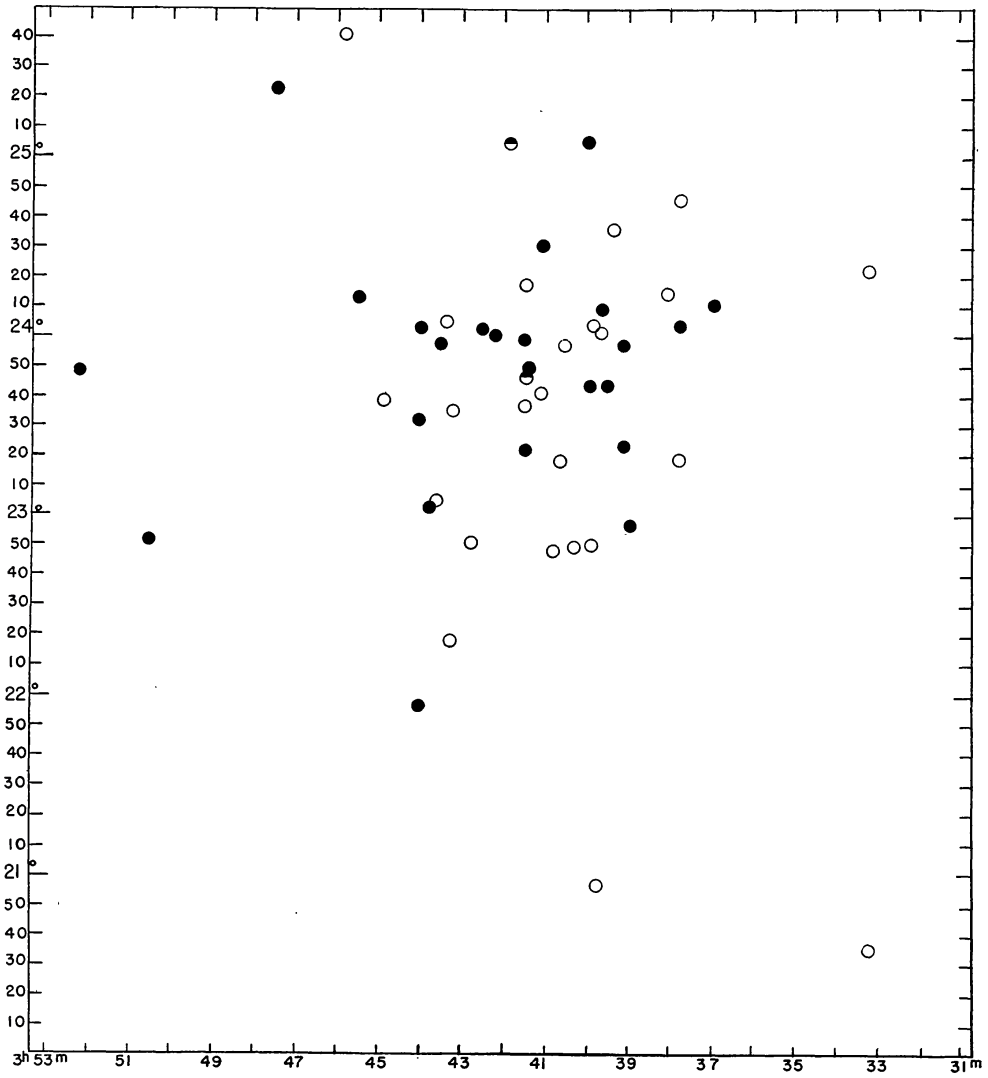

FIG. 2

internal mean errors of 1.2 km/sec suggests that there may exist internal motions of the order of 1 km/sec. This is sufficiently close to the theoretical value deduced by Titus.

An attempt was made to test whether there is evidence of rotation or of a spatial change in the velocities resulting from group motion. The median velocity for the 50 stars of low rotation, namely, +5.6 km/sec, was taken as the velocity of the center of gravity of the cluster. Figure 2 shows the location of these stars. Solid circles indicate positive residuals, and open circles negative residuals. Half-filled circles indicate the posi-

[11] *A.J.*, **46**, 161, 1937.

tions of the two stars, Nos. 33 and 64, which have zero residuals. There are no conspicuous differences in the residuals depending upon position.

If a straight line is drawn approximately through the geometrical center of the cluster, near Alcyone, at an angle of 25° west from the meridian, the residuals on the northeast side are slightly more positive than those on the southwest side. The mean velocities for four zones running parallel to this dividing line are shown in the upper part of Table 4. The lower part of the table gives the mean velocities for four zones oriented at right angles to those of the upper part.

The width of the zones was chosen so that there are roughly the same number of stars in each zone. Zones II and III are $\frac{1}{2}°$ in width on either side of the dividing line.

TABLE 4

	Zone I	Zone II	Zone III	Zone IV
	Zones at 25° from the Meridian			
No. of stars	10	12	17	11
Velocity	+7.3	+7.0	+5.1	+1.4
M.e.	±1.3	±1.2	±0.8	±1.9
	Zones at 115° from the Meridian			
No. of stars	15	12	12	11
Velocity	+4.1	+5.2	+7.0	+4.7
M.e.	±1.5	±1.2	±1.6	±1.3

TABLE 5

Character of Spectrum	No. of Stars	Mean (Struve *minus* Smith)
Grade 1	30	+0.9 km/sec
Grade 2	16	−1.8
Grade 3	14	−0.5
All	60	−0.15

We do not regard this effect as sufficiently pronounced to suggest that it be considered physically real, in the absence of much-needed additional material.

Our mean velocity for the cluster, as determined from stars of good spectral characteristics, is +5.2 km/sec. This is approximately 2 km/sec less than Trumpler's value and 2.5 km/sec less than Pearce's recent determination. A possible systematic error of our radial velocities may arise from the following sources: (1) a personal error of one or of both measurers; (2) a spurious shift due to blends or to incorrect identifications of the stellar lines; (3) systematic effects arising from the method of reduction, the curvature correction, etc.; and (4) faulty adjustment of the spectrograph or the effect of coma in producing unsymmetrical comparison lines.

In order to test the first source, we have compared the results of Struve and of Smith in Table 5. The differences are negligible for the mean of all stars.

The second source of error was carefully investigated for the measures by Struve. Since many Pleiades have but few lines, the probability of including blends is considerable. Table 6 gives all lines used by Struve with their wave lengths, for which there were at least three measures: the mean departures (line *minus* plate mean); the mean errors of one measurement of each line; the mean error of the systematic departure for each line; and the number of times the line was measured in the entire series. Twenty-eight measures of 21 additional lines were omitted in the tabulation because their effect is negligible. Since the omission of one residual, Δ, shifts the mean for the remainder of the series by $\Delta/(n-1)$, it is easy to verify that no appreciable change can be brought about by omitting

TABLE 6

STAR LINES USED BY O. STRUVE

Element	Wave Length	Mean Residual	ϵ	ϵ_0	n
Si II blend	3856.74	−37.6	±10.3	± 6.4	4
He I	4471.48	−15.4	27.3	10.3	11
Hε	3970.08	−14.2	20.9	3.4	59
Fe I	4045.82	−13.0	15.0	2.3	66
He I	4026.19	−12.4	23.0	8.6	11
Sr II	4077.71	− 8.8	22.3	4.2	44
Ca I	4226.73	− 8.4	18.8	2.4	95
Fe I	4071.74	− 6.7	15.3	3.1	39
H 10	3797.90	− 5.5	18.0	2.0	86
Fe I	4063.57	− 4.4	11.2	2.0	48
Hγ	4340.47	− 3.6	18.9	1.6	216
Si II	3862.60	− 1.8	9.5	6.9	3
Ti II	4289.84	− 1.5	16.0	2.8	51
Si II	4128.05	− 1.1	5.0	2.8	5
Hζ	3889.05	− 0.2	16.4	2.1	92
Ca II	3933.675	+ 0.5	13.7	1.3	164
Hδ	4101.745	+ 3.4	17.5	1.5	208
Hη	3835.39	+ 6.2	18.8	2.5	90
Si II	3856.025	+ 6.6	9.0	4.6	6
Fe I	4005.25	+ 6.8	15.0	2.5	55
Fe II	4351.79	+ 6.9	16.0	6.0	11
Sr II	4215.52	+ 9.1	19.0	5.0	23
Fe II	4233.175	+ 9.1	25.1	4.4	50
Mg II	4481.24	+10.4	20.5	1.9	176
Fe I	4383.55	+10.6	18.9	7.1	11
Fe I	3997.40	+14.6	11.0	6.9	4
Sc II	4314.09	+18.4	18.5	4.5	27
Ni II	4067.05	+18.5	15.6	4.0	24
Si II	4130.88	+32.4	±22.9	±14.2	4
Total	.....	.....	.....	.....	1683

those lines whose mean residuals are excessive. For example, omitting the first line (λ 3856.74) would shift the entire series by only +0.1 km/sec. Omitting all lines whose mean residuals exceed ± 10 km/sec would shift the result for the series by −0.6 km/sec. If, however, we should omit only those lines whose residuals are in excess of ± 10.5 km/sec, the mean of the series would be shifted by +0.7 km/sec. It is clear that in this manner small shifts of the order of 1 km/sec in the final mean can perhaps be accounted for. But it does not seem possible to explain a systematic difference of 2 km/sec.

The third and fourth sources were investigated together by means of measurements of a number of stars of constant radial velocity. Most of these spectra were obtained at approximately the same time as the spectra of the Pleiades and with identical adjustments

of the spectrograph. The stars were chosen from spectral classes A and F, and the methods of measurement and reduction were precisely the same as those used for the Pleiades. The results are summarized as follows:

53 standard stars: Lick *minus* Struve $= -1.1 \pm 0.7$ (m.e.)

21 standard stars: Lick *minus* Smith $= -1.4 \pm 1.5$ (m.e.)

The effect is in the *opposite* sense to that required for bringing our mean value of the Pleiades into harmony with Trumpler's and Pearce's results. We have preferred not to apply this correction because its mean error is of the same order of magnitude as the correction itself.

Although it is disconcerting that we have not been able to trace the cause of the difference between our mean radial velocity of the Pleiades and those of other workers, it is perhaps not impossible that several small *accidental* effects have combined to give this result. This is not contradicted by the values of the mean errors, which range from ± 0.7 to ± 1.4 km/sec, depending upon how the stars are arranged in groups. In view of the absence of any perceptible systematic errors in our work, we believe that it is best to present our measurements as they were obtained, despite this difference.

We are indebted to Dr. Gerard P. Kuiper for having suggested this investigation.