

## STELLAR GROUPS. I. THE HYADES AND SIRIUS GROUPS

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*Summary*

The accurate proper motions of the FK<sub>3</sub> and the available radial velocities have been used to establish the reality of an extended Hyades Group. The possible members of this group among the nearer stars are also discussed. The colour-luminosity array for the group is similar to that for two clusters, Hyades and Praesepe, included in it, except that stars of higher luminosity appear in the group at large than in clusters themselves. Also, 67 stars that appear to share the space motion of Sirius, here called the Sirius Group, present a colour-luminosity array that indicates, on the basis of the current theories of stellar evolution, that this group is probably younger than the Hyades Group.

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*Introduction.*—As a result of many investigations, beginning with Richard Proctor (1869) nearly a century ago, the existence of at least two extended stellar streams has been firmly established in the literature. Part of the extensive literature concerning one—the Ursa Major stream—has been catalogued by Roman (1949); the other—the Taurus stream—was noted by Strömberg (1922) and later more fully discussed by Wilson (1932). In recent years (cf. Bok 1934, 1946) these two streams have been considered as resulting from the break-up, through encounters with field stars and the tidal forces of differential galactic rotation, of the Hyades and of the Ursa Major nucleus clusters, the smallness of the nuclear remnant of the latter being taken as indicating a greater age than that of the more compact Hyades nucleus of the Taurus stream.

The purpose of the present series of investigations is to determine (1) to what extent the well-determined space motions of certain stars, or groups of stars, might be shared, within certain limits, by other stars; and (2) with what degree of certainty the resulting “groups” of stars can be considered as physically significant. The present paper deals with those stars which appear to share the space motion of the Hyades cluster; for comparison purposes, the stars which share the motion of  $\alpha$  Canis Majoris, here called the “Sirius Group”, will also be discussed.

*Hyades Group.*—Undoubtedly the most convenient method of choosing stars with common motion would be an examination of the vector space motions. However, the observed radial velocities,  $\rho_0$ , the two components of the annual proper motion,  $15\mu_\alpha \cos \delta$  and  $\mu_\delta$ , and the parallax,  $\pi$ , enter into these vectors in a complicated and irregular way, making any assessment of the spread to be allowed for observational inaccuracy difficult.

Since parallax is usually the greatest source of error in computing the vector motions, it seems advisable to adopt criteria for group membership which eliminate it by the following procedure. Although the tangential components

of velocity cannot be found without knowledge of the parallax, the ratio of the two tangential velocities, in right ascension and in declination, is equal to the ratio of the proper motions which can, of course, be found independently of the star's distance. This ratio gives  $\theta_o$ , the position angle of the star's apparent motion from  $\tan \theta_o = 15\mu_\alpha \cos \delta / \mu_\delta$ , which may be compared with  $\theta_c$ , the position angle of the group motion projected on to the tangential plane. The agreement between  $\theta_o$  and  $\theta_c$ , together with the agreement between the observed radial velocity and that computed from the radial component of the group motion, provide two criteria by which a star's membership in the group can be judged, without having recourse to the parallax.

Let  $(A, D)$ , computed from the radial velocity, proper motion and parallax of the defining star, or from the convergence of the proper motions of the defining cluster, be the direction of the apparent motion of the group. Then the observed direction of the proper motion,  $\theta_o$ , of a suspected group member may be compared with the expected direction, computed from the following:

$$\cot \theta_c = \cos \delta \tan D \operatorname{cosec} (A - \alpha) - \sin \delta \cot (A - \alpha).$$

From a definitive discussion of the observed motions of the Hyades cluster members, van Bueren (1952) has found

$$A = 6^{\text{h}} 18^{\text{m}}.5 \pm 2^{\text{m}}.1 \text{ (mean error),}$$

$$D = 7^\circ 29' \pm 11' \text{ (mean error).}$$

The mean errors in the observed values of  $\theta_o$  are equal to  $\epsilon/\mu$ , where  $\epsilon$  represents the (equal) mean errors in  $15\mu_\alpha \cos \delta$  and  $\mu_\delta$ , and  $\mu$  is the total proper motion. Also, the "point"  $(A, D)$  has a dispersion, the size of which, for a particular star, will depend upon the angular distance,  $\lambda$ , from  $(A, D)$ . The size of this dispersion could be evaluated from the stated mean errors of  $A$  and  $D$ , but we have preferred to derive it from the Hyades stars of brightness comparable to the group members discussed below. Of the 56 Hyades stars brighter than visual magnitude 7.0, and considered to be "certain cluster members" by van Bueren, 46, or 80 per cent, satisfy the criterion  $\theta_o - \theta_c \leq 2^\circ / \sin \lambda$ , which is based on the observed position angles alone. Therefore, combining the errors in the observed and computed values of  $\theta$ , we might call "candidates for group membership" those stars for which

$$\theta_o - \theta_c \leq (\epsilon^2/\mu^2 + 4/\sin^2 \lambda)^{1/2}. \quad (1)$$

However, since from practical considerations it is necessary to exclude very small and poorly determined values of  $\mu$ , we impose the further *ad hoc* condition that  $\epsilon/\mu \leq 2^\circ / \sin \lambda$ . This condition then gives equation (1) the extreme values of  $2^\circ / \sin \lambda$ , when  $\epsilon/\mu = 0$ , and  $2\sqrt{2}/\sin \lambda$ , when  $\epsilon/\mu = 2^\circ / \sin \lambda$ . For simplicity then we will call candidates for membership those stars that meet the following requirement:

$$\theta_o - \theta_c \leq 2^\circ.8 / \sin \lambda. \quad (2)$$

This criterion passes 96 per cent of the "certain" members of the Hyades and, with the appropriate  $(A, D)$ , 90 per cent of the "certain" members of the Pleiades cluster that are brighter than visual magnitude 7.0. It should be emphasized that equation (2) merely represents a convenient criterion and, obviously, is not the result of mathematical rigour since it combines the empirically determined limit,  $2^\circ / \sin \lambda$ , with the more formally determined errors in the proper motions which, in the discussion below, are mean square errors,

Group members were then selected from the candidates for membership on the basis of the observed radial velocities. The velocity of the Hyades cluster relative to the Sun is  $V = 43.95 \pm 0.6$  (mean error) km/sec (van Bueren 1952); the expected velocity for any group member is then  $\rho_c = 43.95 \cos \lambda$ . The observed radial velocities and their quality,  $Q$ , have been taken from the catalogue compiled by R. E. Wilson (1953) and if  $\rho_o - \rho_c$  is less than, or equal to, 3, 4 or 5 km/sec for velocities of quality  $a$ ,  $b$  or  $c$ , respectively, the star was considered to be a member of the group

A convenient list of stars to search for possible members of the Hyades Group is the FK3 (Kopff 1937, 1938). After rejecting from further consideration all stars for which  $\epsilon/\mu > 2^\circ/\sin \lambda$  and six known members of the Hyades cluster (van Bueren 1952) there remained 56 stars that satisfy the condition  $\Delta\theta \sin \lambda \leq 2^\circ.8$  (class I). When the acceptance limits of the convergent point are doubled (class II), that is, when  $2^\circ.8 > \Delta\theta \sin \lambda \leq 5^\circ.6$ , 40 additional stars are admitted. The radial velocity criterion, described above, was then applied and the stars admitted to group membership are listed in Table I. The results may be summarized as follows.

Class	Candidates	Members	Field stars
I ( $\Delta\theta \sin \lambda \leq 2^\circ.8$ )	56	20	36
II ( $2^\circ.8 > \Delta\theta \sin \lambda \leq 5^\circ.6$ )	40	4	36.

It should be noted that if we increased the radial velocity limits to 5, 6 and 7 km/sec for stars of quality  $a$ ,  $b$  and  $c$ , respectively, we would admit three additional members to class I and five to class II.

TABLE I

*Proper motions and radial velocities of members of the Hyades Group*

FK3	$\theta_o$	$\Delta\theta \sin \lambda$	$\rho_o$	$\Delta\rho$	$Q$	$\mu$
Class I	°	°	(km/sec)			"
48	98.7	-1.5	+7	-4	b	0.301
126	44.4	+1.1	+12	+3	a	.533
339	239.7	+2.1	+26	-3	a	.510
383	255.0	+1.5	+18	-2	b	.172
457	275.8	-1.7	-4	-3	b	.160
485	282.0	+0.7	-3	-1	b	.241
501	277.1	-0.7	-13	+1	b	.287
609	311.2	+1.1	+35	-1	b	.066
698	177.4	+2.2	-17	+2	a	.160
701	7.1	+2.5	-16	-3	c	.082
711	12.8	+1.3	-28	-1	a	.085
812	96.6	+1.4	+31	-2	a	.189
881	77.5	0.0	-11	-4	b	.194
1081	96.9	+0.7	+28	0	b	.234
1173	199.1	+2.4	+39	-3	a	.019
1609	85.2	+0.2	-10	+2	d	.045
1623	82.7	-0.2	-7	0	b	.091
N $\gamma$	162.9	-0.7	+6	-3	d	.085
N $\delta$	69.8	+1.3	+3	-1	a	.096
S $\lambda$	254.0	+1.8	-9	-2	d	.082
Class II						
15	78.1	-5.0	-5	-2	c	.176
250	192.6	+1.8	+33	-4	b	.118
476	268.1	-3.0	-8	-1	b	.190
709	50.0	+3.2	-45	-2	c	0.057

The equal number of field stars in the two equal acceptance areas and the large ratio of class I to class II members is a strong indication of the reality of the group. This is, if satisfaction of the membership requirement was a matter of chance, we would expect a nearly equal ratio between members and field stars of classes I and II. A similar classification previously applied to a different selection of bright stars (Eggen 1958) yielded approximately the same ratios between members and field stars of classes I and II.

As a further check on the method used to segregate the group members we have applied the same test to the same stars in the FK3 but with a synthetic convergent point,  $\delta = -90^\circ$ ; the "special" lists of 52 polar stars in the FK3 were omitted. This convergent point was chosen because (1) the computations are greatly simplified, since  $\theta_c = 180^\circ$  and  $\sin \lambda = \cos \delta$ , and (2) it has no particular galactic significance. The candidates for membership in the synthetic group are as follows.

Class	Candidates
I	27
II	28

The number of "members" resulting from four assumed values of the group velocity relative to the Sun are as follows.

Class	km/sec			
	$V=5$	10	20	50
I	2	4	2	2
II	4	2	2	1

It is noteworthy that even for a group with the high velocity relative to the Sun of 50 km/sec, that is, similar to the Hyades Group, five per cent of the candidates may accidentally be admitted as members and for smaller velocities, ten per cent might be expected.

The colours and luminosities computed from the group parallaxes are listed in Table II and plotted in Fig. 1, where the main sequence is shown with a half-width of  $0^m.2$ ; the form of this "standard" main sequence was derived (Eggen 1955 *b*) from (a) the dwarfs of the Praesepe cluster with  $(P-V)_E = +0^m.3$  to  $+1^m.24$  and (b) the Pleiades cluster stars with  $(P-V)_E = -0^m.2$  to  $+0^m.3$ , and the zero-point was obtained from the stars with parallaxes greater than  $0''.2$ . The class I members of the Hyades Group are represented with filled circles, the class II members with open circles. The known members of the Hyades cluster, brighter than visual magnitude  $5^m.0$  (van Bueren 1952) are represented with crosses in the figure; the moduli of the individual cluster members are those given by van Bueren. Also, the ten brightest stars in the Praesepe cluster, whose membership in the group was discussed in a previous note (Eggen 1958), are indicated by plus signs.

The distribution in the colour-luminosity array of the brighter members of the clusters is very similar to that of the more widely scattered members of the group, although stars of both early and late type occur with higher luminosity in the group at large than within the clusters themselves.

The trigonometric parallaxes (Jenkins 1952) and the spectroscopic values determined at Mt Wilson (Adams *et al.* 1935), which were not used in the

method of selecting group members, are compared in Table IV with the values derived from the group motion. Theoretically we could exclude any accidental members as a result of this comparison but, keeping in mind the inherent errors of all three sources of parallax, in all cases where parallaxes are available for comparison the agreement is such that none of the members selected in Table I can definitely be eliminated on this basis.

TABLE II

*Group parallaxes, colours and luminosities of Hyades Group stars*

FK3	Name	$V_E$	$(P-V)_E$	Sp.	$\pi_g$	$M_V$
I.		m	m		"	m
48	$\delta$ Cas	2.70	+0.02	A5 V	0.0335	+0.32
126	$\kappa$ Ret	4.66	+0.28	dF5	0.0590	+3.51
339	10 UMa	4.01	+0.30	F5 V	0.0725	+3.31A
383	$\lambda$ UMa	3.46	-0.12	A2 IV	0.0210	+0.07
457	$\gamma$ Crv	2.60	-0.23	B8 III	0.0175	-1.28
485	$\alpha$ CVn	2.89	-0.02	A0p	0.0260	-0.04
501	$\zeta$ Vir	3.38	-0.01	A3 V	0.0325	+0.94
609	$\gamma$ Her	3.74	+0.18	A9 III	0.0110	-1.05
698	$\zeta$ Pav	3.96	+1.06	K0	0.0190	+0.35
701	HR 7013	6.0:	—	A3	0.0095	+0.9:
711	R Lyr	4.0:	+1.45	M5 III	0.0115	-0.7:
812	$\gamma$ Cap	3.86	+0.22	F0p	0.0270	+1.02
881	$\nu$ Peg	4.38	+0.51	F8 IV	0.0210	+1.00
1081	47 Ari	5.8:	—	F0	0.0325	+3.4:
1173	$\nu$ Gem	4.00	-0.20	B7 IV	0.0095	-1.12
1609	95 Aqr	5.2:	—	A0	0.0050	-1.3:
1623	20 Psc	5.6:	—	K0	0.0100	+0.6:
N $\gamma$	HR 1616	6.5:	—	A5	0.0095	+1.4:
N0	HR 8748	4.70	+1.37	K4 III	0.0105	-0.20
S $\lambda$	$\kappa$ Oct	5.6:	—	A2	0.0090	+0.4:
II.						
15	$\lambda'$ Phe	4.81	-0.10	A0 V	0.0160	+0.83
250	51 Aur	5.7:	—	K0	0.0240	+2.6:
476	$\gamma$ Cen	2.14	-0.12	A0 III	0.0205	-1.30L
709	$\theta$ Ser A	4.59	+0.03	A5 V	0.0240	+1.49
	$\theta$ Ser B	4.99	+0.08	A5		+1.89

A Faint companion disregarded.

L Corrected for equal components.

Considering the reality of the Hyades Group as established, an attempt was made to pick out possible members among the nearest stars, and the convenient listing by Gliese (1957) of the stars that may be closer than 20 parsecs was examined for this purpose. These objects are, in general, fainter than those discussed above and the observed proper motions and radial velocities are therefore less accurately determined; only estimates of the proper motions of the faintest stars are available and the radial velocities have not been obtained for about 20 per cent. The 32 stars, and binary systems, selected as quite likely group members are given in Table III together with the following information:

No./Name: the number in the Yale parallax catalogue (Jenkins 1952) and the name or DM number of the star.

$\mu$ ,  $\theta_0$ , Auth.,  $\Delta\theta \sin \lambda$ : the observed proper motion, its position angle and source, and the normalized value of the position-angle residual.

$\rho_o$ ,  $\rho_o$ : the computed and observed radial velocities. The observed values, the observatory abbreviations and the number of plates, were taken from the catalogue compiled by R. E. Wilson (1953); the designations  $C_1$  (Evans, Menzies and Stoy 1957), Dy (Dyer 1954) and Sa (Sahade 1952) indicate determinations not included in that catalogue.

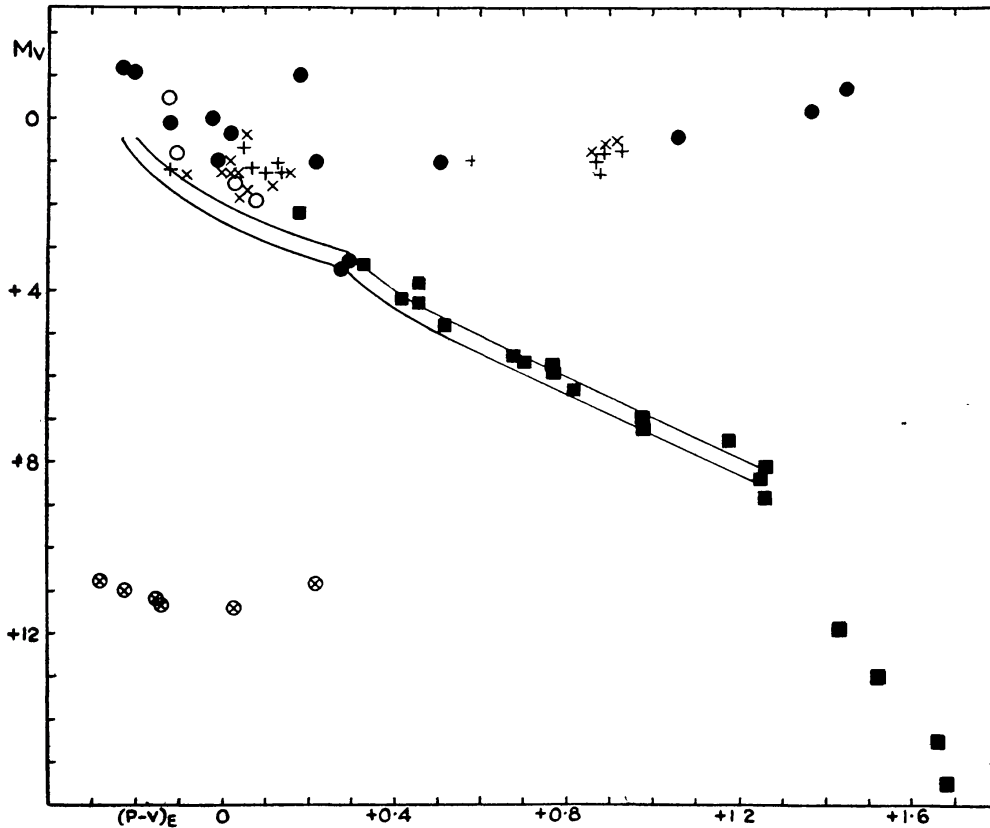


FIG. 1.—The colour-luminosity array for the Hyades Group. The filled circles represent the class I members from Table II, the open circles the class II members. The crosses and plus signs indicate the brightest members of the Hyades and Praesepe clusters, respectively. The possible members among the nearest stars are represented by filled squares and the five known white dwarf members of the Hyades cluster by crossed circles.

$\pi_g$ : the group parallax computed from the relation  $\pi_g = 4.74 \mu / 43.95 \sin \lambda$ ,  $V_E$ ,  $(P-V)_E$ : the visual magnitude and colour. When a colour is listed, both it and the magnitude are photoelectric determinations on the  $(P, V)_E$ -system (Eggen 1955a) or reduced to that system from several sources (Johnson and Morgan 1953; Johnson 1955; Evans, Menzies and Stoy 1957); when a colour is listed with a magnitude given only to one decimal, the listed values were both reduced from the red and infra-red magnitudes published by Kron (1956).

Sp,  $M_V$ : the spectral type, from several sources mostly on the Yerkes or Mt Wilson systems, and the absolute visual magnitude computed from the group parallax.

TABLE III

Possible members of the Hyades Group among the nearer stars

No./Name	$\theta_0$	$\Delta\theta \sin \lambda$	Auth.	$\mu$	$\rho_c \rho_0$ km/sec	$\pi_g$	$V_E$	$(P-V)_E$	Sp.	$M_V$
							m	m		m
45	80°	4°	Cin 20	0.55	+ 3 +12W(3)	0.060	8.96	+1.26	dM0	+ 8.83
+40°45										
66	83	0	GC	0.647	- 2 +6W(3)	0.0725	8.0:	—	dK6	+ 7.3:
-27°108										
86	84	1	Cape	0.671						
	86	3	Yale	0.671						
97	93	+9	GC	0.410	+ 2 +9Yk(90)	0.0445	5.18	+0.42	F8 V	+ 3.43*
13 Cet										
162	78	-2	GC	0.529	+ 3 +5W(3)	0.0565	7.11	+0.77	dG7	+ 5.87
-23°315										
177	76	-4	Cape	0.516						
-31°325										
	86	+5	GC	0.620	+ 3 -5W(3)	0.0670	7.13	+0.82	K3 V	+ 6.26
					+2McD(2)					
257	74	0	GC	0.686	+ 3 +11L(12)	0.0740	4.91	+0.46	F8 V	+ 4.26
v Phe										
UV Cet	80	+3	Luyten	3.355	+12 +29W(4)	0.385	11.8	+1.68	dM6	+14.8*
350										
+41°328	100	+2	GC	0.823	+14 +4L(5)	0.0940	4.94	+0.52	G2 V	+ 4.81
					+5B(3)					
					+1W(6)					
					+2V(1)					
551	92	-2	GC	0.387	+16 +17L(3)	0.0460	5.42	+0.46	F9	+ 3.73
+18°339										
724	57	-3	GC	0.614	+28 +31W(4)	0.0870	8.39	+1.26	dM0	+ 8.09
-20°643										
754	56	-4	Yale	0.634						
-48°1011										
808	124	+8	Cin 20	0.42	+33 +38 Dy(2)	0.068	9.7:	—	K7	+ 8.4:
+25°613										
1010	145	0	Yale	0.55	+28 +36W(6)	0.077	8.66	+1.25	dM1	+ 8.19
+52°857										
1668	207	+3	Ross	1.03	+37 +52W(5)	0.204	11.5	+1.52	dM5	+13.0
Ross 986										
1864	320	-6	GC	0.314	+30 +29L(4)	0.0460	5.03	+0.33	F5 V	+ 3.34
-34°4036										
					+27C(4)					
					+27C <sub>1</sub> (4)					
2117	244	-2	GC	0.537	+33 +26W(7)	0.0875	5.96	+0.77	dK0	+ 5.67
+28°1660					+28V(3)					
2256	281	+4	Grnwh.	0.52	+30 +27W(3)	0.076	7.4:	—	dK5	+ 6.8:
+6°2182										
2403	299	-4	Cape	0.27	+11 0C <sub>1</sub> (4)	0.030	8.17	+0.68	G8 V	+ 5.51
-46°2953										
2480	280	+3	Luyten	0.68	+20 +21W(4)	0.082	12.5:	—	dM4	+12.1:
L1113-55										
2701	287	+4	GC	0.710	+ 2 +13C <sub>1</sub> (4)	0.0765	7.77	+0.98	K5 V	+ 7.19
-43°7228										
2841	290	+6	Cape	0.703						
+26°2329										
2890	276	-1	GC	0.146	+ 3 + 4W(4)	0.0160	6.18	+0.18	dA8	+ 2.20
Wolf 424AB										
3101	270	-2	Wolf	1.87	- 2 - 5W(6)	0.202	12.2	+1.66	M7	+13.8*
3458	266	-4	Ross	0.38	-15 -26Dy(1?)	0.044	9.3:	—	K5	+ 7.5:
-7°4003										
4049	347	-5	Titus	1.21	-31 -30W(4)	0.184	10.56	+1.43	dM5	+11.89
+71°851										
5076	94	0	GC	0.388	-33 -37W(4)	0.0630	7.1:	—	dK1	+ 6.1:
-14°5936										
5487	86	-9	Cape	0.391	-19 -21C <sub>1</sub> (5)	0.0440	7.41	+0.705	G8 V	+ 5.63
-32°17191										

\*Luminosity corrected for equal components before plotting in Fig. 1.

The colours and luminosities in Table III are represented in Fig. 1 with filled squares. Also, for completeness, the following known white dwarf members of the Hyades cluster are plotted in the figure as crossed circles:

Name	$V$	$(P-V)$	$M_V$
	m	m	
H-Z 4	14.47	+0.03:	+ 11.4
H-Z 7	14.18	-0.15:	+ 11.2
H-Z 9	13.95	+0.22:	+ 10.9
H-Z 14	13.83	-0.28:	+ 10.8
VR 7	14.29	-0.14:	+ 11.3
VR 16	14.02	-0.22:	+ 11.0

The magnitudes and colours were determined on the  $(B-V)$ -system by D. L. Harris (1957); the colours on the  $(P-V)_E$ -system are uncertain since the transformation equations used may not be applicable to white dwarfs. The luminosities have been derived from a mean modulus of  $+3^m.03$  for the Hyades cluster (van Bueren 1952).

TABLE IV

*Trigonometric, spectroscopic and group parallaxes of Hyades Group stars*  
(unit =  $0''.001$ )

Name	$\pi_g$	$\pi_{tr}$	$\pi_{sp}(w)$
+20°45	60	81M(7), 22 St(4)	72
-27°108	72	48C(7)	76
$\lambda'$ Phe	16	18Y(10)	-
13 Cet	44	28M(5), 50Y(10), 64S(20), 75C(6)	46
-23°315	56	58Y(10), 53C(7)	48
-31°325	67	100C(8)	83
$\nu$ Phe	74	74Y(8), 76C(6)	-
$\delta$ Cas	34	25A(20), 60M(8), 10W(8)	52
UV Cet	385	385 (Gliese 1957)	-
+41°328	94	84A(20), 93M(6)	72
+18°339	56	53M(10)	-
74 Ari	32	30A(28)	30
-20°643	87	98C(6), 64Y(10), 65V(8), 40M(7)	110
$\nu$ Gem	10	8Y(10), 11M(8)	-
$\kappa$ Ret	59	55Y(10), 47C(8)	-
-48°1011	60	72Y(12), 99C(7)	-
+25°613	68	85M(6)	-
+52 857	77	88V(12), 82M(7), 94Yk(7)	100
HR1616	10	-	-
51 Aur	24	-	-
Ross 986	46	68Y(12), 66C(7)	46
+28°1660	88	72A(16), 77M(7)	60
10 UMa	72	70A(16), 74M(8), 69S(20)	69
+6°2182	76	77M(6), 90V(10)	69
-42°2953	30	60C(6)	-
$\lambda$ UMa	21	-12M(7)	-
L1113-55	82	65Yk(7)	-
-43°7228	76	70Y(12), 85C(6)	-
$\gamma$ Crv	18	-	-
+26°2329	16	56M(8)	-
Wolf 424	202	218M(7), 215Y(5), 224Yk(8)	-
$\gamma$ Cen	20	14Y(10), 18c(10)	-
$\alpha$ CVn	26	25A(20), 31M(4), 8Yk(8)	-
$\zeta$ Vir	32	38A(28), 38M(6), 22Y(12)	-
$\kappa$ Oct	9	-	-
-7°3646	44	58M(8)	-
-7°4003	184	142M(8), 135Y(10), 173V(10), 144C(6)	-
$\gamma$ Her	11	15A(16)	30
+71°851	38	60G(7)	-
-14°5936	63	54M(6), 48C(7)	55
$\gamma$ Cap	27	14M(6), 30Y(10), 22C(7)	35
-32°17191	44	55C(7)	-
HR8748	10	0G(8)	10
$\nu$ Peg	21	36A(14), 8M(7)	44
95 Aqr	5	6A(20), 10Y(7)	-
20 Psc	10	-	10

The comparison between the group parallaxes, for the stars in Table IV, and the absolute trigonometric values (Jenkins 1952) and spectroscopic determinations made at Mt Wilson (Adams *et al.* 1935) is given in Table IV. The observatory abbreviations used to designate the source of the trigonometric values, and the weight of the determinations, in parentheses, are those assigned by Jenkins. In most cases the group parallax is within the range covered by the trigonometric and spectroscopic values although a few stars may be eliminated as group members when more accurate parallaxes, velocities and proper motions become available.

*Sirius Group.*—The well-determined space motion relative to the Sun of  $\alpha$  Canis Majoris can be expressed as follows:

$$A = 20^{\text{h}} 44^{\text{m}}, \quad D = -42^{\circ} \cdot 7, \quad V = 18 \cdot 4 \text{ km/sec}, \quad \pi = 0'' \cdot 375.$$

This bright star has been included in most listings of members of the Ursa Major stream. This latter stream has often been considered an extension of the so-called Ursa Major nucleus cluster. However, although this “cluster” is only about 50 or 60 parsecs from the Sun, even the most extensive searches have not yielded more than a dozen members and it seems more likely that it is a local condensation, rather than the nucleus, of the stream. The difficulties peculiar to the determination of the convergent point of the motion of the Ursa Major stars have been extensively investigated by Brown (1950) and by Petrie and Moyls (1953). The numerous lists of possible members of the extended cluster have been collated by Roman (1949) and the collated list has been used to select members of what will here be called the “Sirius Group”.

After eliminating 22 stars with proper motions less than  $0'' \cdot 02$  and 4 stars with no available radial velocity determination, values of  $\theta_c$  and  $\rho_c$ , based on the convergent point and velocity given above for Sirius, were computed for the remaining 122 stars in Roman’s list of “probable members of the Ursa Major stream”. The following preliminary criteria for group membership were adopted:  $(\theta_o - \theta_c) \sin \lambda < 10^\circ$ ;  $\rho_o - \rho_c \leq 5, 6$  and  $7$  km/sec for velocities of quality *a*, *b* and *c*, respectively. The 58 accepted stars are listed in Table V; the rejected stars are in Table VI. Table V also includes seven stars, indicated by (§) following the luminosities in the last column, which were recovered from Roman’s list of “stars probably not members of the Ursa Major stream”; most of these stars are south of  $-30^\circ$  and were not observed by Roman. If similarly stringent criteria were applied to the values of  $\theta_o - \theta_c$  listed by Roman, approximately the same selection of stars would result; a not surprising result since her tabulated values are based on  $A = 20^{\text{h}} 28^{\text{m}}$ ,  $D = -36^\circ \cdot 7$ ,  $V = 17 \cdot 0$  km/sec.

Although the proper motions for all except a half dozen stars in Table V are contained in the *General Catalogue* (Boss 1937), they are on the average much less accurately determined than those of the FK3 stars used in the discussion of the Hyades Group and none of the stars could be eliminated from group membership on the basis of the tabulated values of  $\Delta\theta \sin \lambda$ . The observed radial velocities and their quality, *Q*, have been taken from Wilson’s catalogue (1953). Weighting values of quality *a*, *b* and *c* by 3, 2 and 1, respectively, the weighted mean value of  $\Delta\rho$  is  $-0 \cdot 1$  km/sec and the average value without regard to sign is  $3 \cdot 4$  km/sec. Although there do appear to be systematic runs to  $\Delta\rho$  in localized areas—for example all of the Ursa Major stars have positive residuals and most of the Leo–Hydra stars negative residuals—the general agreement is satisfactory, especially since many of the stars have spectra that are difficult to measure.

TABLE V

Name	$\theta_0$	$\Delta \theta \sin \lambda$	Members of the Sirius Group								$M_V$
			$\rho_0$ (km/sec)	$\Delta \rho$	$Q$	$\mu$	$\pi_g$	$V_E$	$(P-V)_E$	Sp	
						"	"	m	m		m
$\phi^2$ Cet	226°	-1°	+ 8	-1	a	0.320	0.0930	5.20	+0.39	F8 V	+5.04
27 Cet	233	-6	+12	+4	b	0.047	0.0135	6.13	+0.91	K0 III	+1.78
HR 647	228	-5	- 8	0	b	0.087	0.0250	6.07	+0.28	F5 V	+3.06*
HR 710	234	+5	+ 8	+4	c	0.074	0.0195	5.84	+0.02	A7p	+2.29
$\nu$ Cet	231	+4	+ 5	+5	a	0.038	0.0100	4.86	+0.77	G5 III	-0.14
$\gamma$ Cet	224	-3	- 5	-4	b	0.203	0.0525	3.46	-0.01	A2 V	+2.06†
								10.14	+1.22	K7 V	+8.74
HR 1016	219	-8	+ 8	+5	b	0.033	0.0085	5.52	+0.79	G5 III	+0.16
HR 1327	268	+1	-18	-4	a	0.027	0.0100	5.27	+0.715	G5 III	+0.27
$\xi$ Eri	221	-3	-10	-4	c	0.075	0.0205	5.17	-0.04	A2	+1.73
2 Aur	249	+4	-16	-3	a	0.025	0.0090	4.77	+1.34	K3 III	-0.46
$\beta$ Eri	229	+8	- 8	-2	c	0.122	0.0335	2.78	0.00	A3 III	+0.40
$\gamma$ Lep	218	+4	-10	-5	a	0.470	0.1240	3.59	+0.36	F6 V	+4.05
								6.18	+0.85	dK5	+6.64
$\beta$ Aur	265	+3	-18	-2	a	0.051	0.0260	1.90	-0.09	A2 IV	-1.03‡
$\delta$ Col	208	+2	- 3	+1	a	0.064	0.0170	3.76	+0.79	gG5	-0.09§
$\alpha$ CMa	207	0	- 8	0	a	1.324	0.3750	-1.47	-0.125	A2 V	+1.40
16 Lyn	259	-5	- 9	+6	c	0.020	0.0085	4.89	-0.09	A2 V	+0.46
HR 3131	191	+1	-12	-3	c	0.048	0.0140	4.61	-0.03	A3 V	+0.34
HR 3279	188	+3	- 8	0	c	0.022	0.0065	5.58	+0.67	G2 III(A)	-0.36†
$\pi'$ UMa	344	-4	-12	+5	c	0.088	0.0610	5.64	+0.52	G0 V	+4.57
HR 3512	174	-5	- 8	-3	b	0.049	0.0130	4.92	+0.81	G3	+0.49§
$\alpha$ Vol	179	+2	+ 5	-1	b	0.104	0.0285	4.00	+0.03	A5 V	+1.28§†
$\nu'$ Hya	157	-8	-14	-5	a	0.035	0.0110	4.14	+0.84	G5 III	-0.65
34 Leo	137	-9	-16	-1	b	0.057	0.0260	6.44	+0.35	F6 V	+3.51
$\zeta$ Leo	124	-7	-15	+1	b	0.023	0.0130	3.43	+0.19	F0 III	-1.00
37 UMa	63	0	-12	+5	a	0.074	0.0500	5.14	+0.22	F1 V	+3.63
HD 97686	42	+3	-21	-7	c	0.080	0.0325	7.32	+0.47	F8 V	+4.88
$\beta$ UMa	71	0	-12	+4	a	0.087	0.0520	2.36	-0.15	A0 V	+0.94
61 Leo	158	+6	-14	-3	a	0.040	0.0120	4.55	+1.58	K5 III	-0.05§
$\delta$ Leo	133	0	-21	-6	b	0.201	0.0845	2.57	+0.02	A4 V	+2.21
$\tau$ Leo	135	+8	- 9	+2	a	0.025	0.0080	4.95	+0.91	G8 II	-0.53
$\xi$ CrI	138	-9	- 5	0	a	0.051	0.0130	4.63	+0.88	G8 III	+0.20
$\gamma$ UMa	88	0	-13	+3	a	0.084	0.0450	2.44	-0.125	A0 V	+0.71
$\delta$ UMa	88	0	-13	+2	b	0.106	0.0475	3.29	-0.05	A3 V	+1.68
HD 109011	93	-1	-13	+1	b	0.111	0.0465	8.12	+0.84	K2 V	+6.46
HR 4803	142	-2	- 1	0	a	0.123	0.0315	5.45	+0.22	F2 V	+2.95
29 Com	135	+3	- 7	+3	b	0.045	0.0135	5.70	-0.10	A2	+1.35
HR 4867	93	+1	-12	+2	b	0.107	0.0430	5.85	+0.34	F6 V	+4.02
41 Vir	123	-8	-10	-1	c	0.059	0.0175	6.25	+0.15	A7p	+2.47
$\epsilon$ UMa	96	-1	- 9	+5	a	0.113	0.0445	1.78	-0.13	A0p	+0.03
78 UMa	98	-1	-10	+4	b	0.115	0.0445	4.94	+0.25	F2 V	+3.19
HD 115043	105	+3	- 9	+4	b	0.117	0.0440	6.83	+0.50	G2 V	+5.05
$\gamma$ Hya	127	-9	- 5	-5	a	0.086	0.0220	2.99	+0.80	G5 III	-0.30
$\zeta$ UMa	103	-1	- 9	+4	a	0.127	0.0460	2.04	-0.10	A2 V	+0.35†
80 UMa	101	-3	- 8	+5	a	0.121	0.0440	4.00	+0.04	A5 V	+2.22
HR 5214	123	0	-12	-2	b	0.035	0.0110	6.65	-0.01	A5 III	+1.86
HR 5373	134	+9	-10	-1	b	0.029	0.0085	6.35	-0.10	A2	+0.89
HR 5473	123	-8	- 8	-5	b	0.062	0.0160	6.0:	—	A2	+2.0:§
HR 5492	117	-3	- 6	+5	b	0.080	0.0260	6.25	+0.30	F2 III	+3.32
45 Boo	134	+3	- 7	-3	b	0.255	0.0675	4.93	+0.32	F5 V	+4.08
$\alpha$ CrB	129	-4	+ 2	+5	a	0.154	0.0405	2.22	-0.14	A0 V	+0.26

TABLE V (continued)

Name	$\theta_0$	$\Delta\theta \sin \lambda$	$\rho_0$	$\Delta\rho$	$Q$	$\mu$	$\pi_g$	$V_E$	$(P-V)_E$	Sp	$M_V$
			(km/sec)			"	"	m	m		m
HR 5840	132	-2	+3	+3	a	0.034	0.0085	6.01	+0.81	G5 III	+0.65
$\beta$ Ser	130	-5	-1	-1	b	0.086	0.0220	3.66	-0.05	A2 IV	+0.37
								9.95	+0.90	dK3	+6.66
HD 151044	134	-4	0	+5	c	0.170	0.0455	6.47	+0.44	F8 V	+4.76
HR 6917	153	-2	+8	+5	a	0.028	0.0075	5.83	-0.06	A2 V	+0.21
5 Aql	158	+6	+19	+7	c	0.025	0.0085	5.66	+0.05	A2	+0.30
59 Dra	159	-1	-4	+5	a	0.129	0.0385	5.12	+0.185	F2 V	+3.05
HR 7382	159	-6	0	-1	b	0.031	0.0080	5.7:	—	gG5	+0.2:§
HR 7451	173	+6	+1	+3	b	0.194	0.0500	5.72	+0.36	F8 V	+4.21
HR 8170	186	0	+1	-1	a	0.208	0.0540	6.36	+0.44	F8 V	+5.02
76 Cyg	198	-8	+3	+1	d	0.047	0.0125	6.10	-0.07	A2	+1.58
HR 8473	203	+5	-3	+5	b	0.026	0.0075	6.38	-0.175	A0	+0.76
$\gamma$ PsA	236	-3	+16	0	b	0.042	0.0245	4.48	-0.14	A0 V	+1.42§
$\delta$ Aqr	207	-8	+18	+4	b	0.047	0.0195	3.27	-0.06	A3 V	-0.28
4 And	210	+5	-6	-5	b	0.034	0.0095	5.33	+1.34	K5 III	+0.10
99 Aqr	224	-3	+16	+2	a	0.078	0.0315	4.38	+1.41	K5 III	+1.88
$\lambda$ Psc	223	+5	+12	+3	b	0.199	0.0595	4.52	+0.08	A7 V	+3.39

\* Companion disregarded.

† Not plotted in Fig. 2: Companion between  $0^{m.5}$  and  $2^{m.5}$  fainter.

‡ Luminosity corrected for equal companion before plotting in Fig. 2.

|| Indicated by a cross in Fig. 2.

§ Selected from Roman's list of "stars probably not members of the Ursa Major stream".

The values of  $\pi_g$  listed in Tables V and VI were computed from the relation  $\pi_g = 4.74\mu/18.4 \sin \lambda$ ; the proper motions are uncorrected GC values except for a half-dozen taken from the Yale zone catalogues. The colours and magnitudes are by Eggen (1955a) and by Johnson and Knuckles (1957); when more than one determination was available, unweighted means were formed. The spectral types for a few stars are by Johnson and Morgan (1953) and the remainder are by Roman (1949).

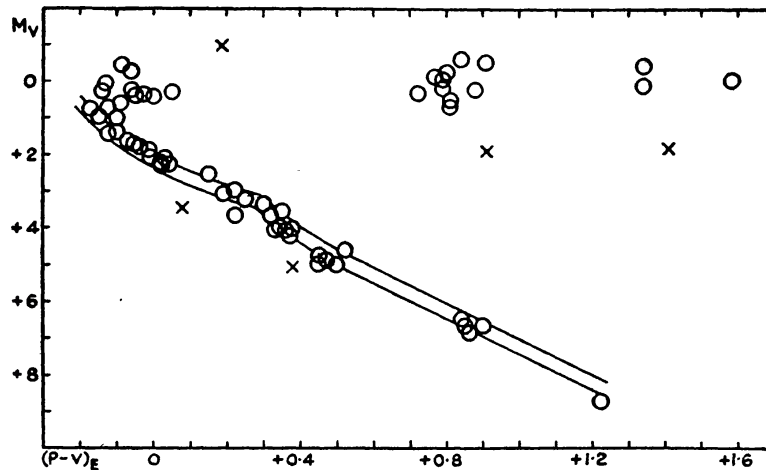


FIG. 2.—The members of the Sirius Group listed in Table V; the crosses indicate the five stars that stand out from the general run of the other members and may have been accidentally admitted to group membership.

TABLE VI

Stars included by Roman as "probable members of the Ursa Major stream" but rejected as members of the Sirius Group

Name	$\Delta\theta \sin \lambda$	$\Delta\rho$	$Q$	$\mu$	$\pi_g$	Name	$\Delta\theta \sin \lambda$	$\Delta\rho$	$Q$	$\mu$	$\pi_g$
				"	"					"	"
$\sigma$ And	25°	10	a	0.071	0.0185	8 Vir	5°	7	b	0.050	0.0135
$\eta$ And	2	11	a	0.054	0.0140	$\tau$ Vir	16	5	b	0.030	0.0135
39 And	29	8	b	0.025	0.0065	$\kappa$ Boo	13	6	a	0.064	0.0205
80 Psc	10	3	b	0.320	0.0850	HR 5343	0	10	c	0.055	0.0150
89 Psc	25	1	b	0.055	0.0145	18 Boo	21	2	a	0.110	0.0290
$\chi$ Cet	12	7	b	0.176	0.0475	$\zeta$ Boo	15	2	b	0.058	0.0150
HR 534	27	10	b	0.076	0.0195	$\xi$ Boo	3	8	a	0.172	0.0450
HR 792	5	8	b	0.031	0.0080	8 Ser	17	4	b	0.080	0.0205
HR 875	10	15	c	0.050	0.0130	$\eta$ Cr B	14	3	a	0.236	0.0625
HR 906	0	10	b	0.049	0.0170	HR 5830	17	5	b	0.158	0.0440
HR 919	30	14	b	0.152	0.0400	HR 5859	3	14	b	0.032	0.0085
HR 1046	9	12	b	0.044	0.0145	$\omega$ Ser	20	7	a	0.062	0.0160
HR 1448	16	0	b	0.022	0.0060	$\nu$ CrB	10	4	c	0.030	0.0080
7 Cam	16	6	a	0.020	0.0080	$\omega$ Her	10	9	a	0.077	0.0200
38 Ori	17	1	c	0.036	0.0110	52 Her	19	3	a	0.066	0.0175
$\tau$ Aur	15	5	a	0.033	0.0155	56 Her	15	0	a	0.028	0.0070
$\lambda'$ Ori	11	0	a	0.204	0.0780	$\alpha$ Oph	17	7	b	0.260	0.0710
42 Aur	15	8	c	0.042	0.0240	HR 6993	11	1	a	0.025	0.0080
RR Lyn	13	3	a	0.027	0.0155	11 Aql	16	7	a	0.126	0.0370
$\lambda$ Gem	10	7	b	0.061	0.0290	16 Lyr	10	8	b	0.089	0.0230
9 Pup	2	8	a	0.345	0.1050	18 Sge	21	12	b	0.026	0.0075
9 Hya	1	9	b	0.094	0.0285	HR 7781	24	4	c	0.026	0.0070
18 UMa	13	3	b	0.078	0.0935	35 Cap	10	6	c	0.040	0.0275
21 LMi	17	0	a	0.053	0.0465	$\rho$ Cyg	6	6	a	0.094	0.0240
$\iota$ Leo	18	3	a	0.188	0.0670	HR 8263	22	4	b	0.029	0.0110
$\alpha$ Crv	25	7	a	0.096	0.0250	HR 8407	15	1	b	0.038	0.0100
HR 4725	1	7	b	0.074	0.0255	32 Aqr	2	7	a	0.052	0.0190
HO 110463	3	7	b	0.128	0.0520	$\pi$ Peg	18	2	b	0.027	0.0070
HR 4837	11	8	a	0.095	0.0260	66 Aqr	6	7	a	0.039	0.0180
HD 238179	10	20	c	0.096	0.0375	15 And	3	16	c	0.047	0.0120
HD 238208	8	29	c	0.108	0.0405	$\psi$ Peg	20	7	a	0.049	0.0130
$\gamma$ Hyd	10	5	a	0.086	0.0220						

The colours and luminosities are plotted in Fig. 2. Five stars, distinguished only by the fact that two fall well below the standard main sequence and the other three above it, in regions uncommon to the run of the rest of the group members, are indicated by crosses. It is possible that these five stars, and perhaps others not so distinguished, are accidental "members" of the group. The remaining stars form a compact main sequence with little dispersion for stars bluer than  $+0^m.5$  and a compact group of yellow giants of spectral type near G5 and  $M_V \sim 0$ .

The colour-luminosity array constructed for these same stars, with luminosities derived from the group parallaxes computed by Roman, is nearly identical with Fig. 2, the only noticeable difference being that it exhibits roughly twice the dispersion in the main sequence. The scattering of yellow giants with  $M_V \sim +1$  to  $+2$  that were included in Roman's list of members of the Ursa Major stream have, except for the two indicated with crosses in Fig. 2, been excluded by the membership criteria employed here for the Sirius Group. Also, Roman included

nine stars with computed luminosities brighter than  $M_V = -1$  but eliminated five of them on the basis of the spectroscopic parallaxes; the other four were eliminated here, two with  $\mu < 0''.02$  and two, listed in Table VI, which did not meet the membership requirements for the Sirius Group.

TABLE VII

*Group, trigonometric and spectroscopic parallaxes for members of the Sirius Group*  
(unit  $0''.001$ )

Name	$\pi_g$	$\pi_{tr}$	$\pi_{sp}(w)$
$\phi^3$ Cet	93	72M(8), 48Y(12), 56C(7)	60
27 Cet	14	—	8
HR 647	25	45M(7), 11W(7), 35S(8)	—
HR 710	20	15Y(8)	—
$\nu$ Cet	10	6M(7), -8Y(12), -11C(8)	13
$\gamma$ Cet	52	48A(28), 48M(8), 47Y(8), 45Yk(7)	40
HR 1016	8	—	10
HR 1327	10	—	13
$\xi$ Eri	20	11A(28), 11M(8), -19Y(8), 12C(7)	—
2 Aur	9	—	11
$\beta$ Eri	34	33A(28), 50M(8), 53Y(16)	63
$\gamma$ Lep	124	145M(8), 100Y(12), 123C(10)	110
$\beta$ Aur	26	39A(28), 27M(8)	63
$\delta$ Col	17	12Y(16)	—
$\alpha$ CMa	375	375 (Mean)	363
16 Lyn	8	7A(28)	—
HR 3131	14	14Y(12)	—
HR 3279	6	—	10
$\pi'$ UMa	61	—	50
HR 3512	13	21Y(8)	—
$\alpha$ Vol	28	13Y(10)	—
$\nu'$ Hya	11	11M(10), 19Y(10)	17
34 Leo	26	—	—
$\zeta$ Leo	13	9A(20), 6M(8)	30
37 UMa	50	32A(12), 4M(7)	32
HD 94686	32	—	—
$\beta$ UMa	52	46A(20), 26M(8)	46
61 Leo	12	24Y(10)	10
$\delta$ Leo	84	29A(28), 74M(8)	79
$\tau$ Leo	8	33A(20), 23Y(8)	9
$\xi$ Crt	13	22Y(10)	14
$\gamma$ UMa	45	26A(20), -1M(8)	—
$\delta$ UMa	48	49A(28), 64M(5)	—
HD 109011	46	—	—
HR 4803	32	30Y(10)	33
29 Com	14	—	—
HR 4867	43	37A(12), 41W(4)	27
41 Vir	18	—	16
$\epsilon$ UMa	44	6M(10)	—
78 UMa	44	29A(16)	24
HD 115043	44	45W(6)	—
$\gamma$ Hya	22	18M(7), 29Y(8), 13C(7)	29
$\zeta$ UMa	46	39A(20), 32M(8)	38
80 UMa	44	38A(16), 30M(7)	—
HR 5214	11	—	—
HR 5373	8	—	—
HR 5473	16	—	—

TABLE VII (*continued*)

Name	$\pi_g$	$\pi_{tr}$	$\pi_{sp}(w)$
HR 5492	26	17A(28)	22
45 Boo	68	57A(16), 68M(6)	46
$\alpha$ CrB	40	37A(20), 57M(8)	79
HR 5840	8	—	7
$\beta$ Ser	22	34A(16), 30M(8)	—
HD 151044	46	35A(28)	—
HR 6917	8	—	10
5 Aql	8	—	17
59 Dra	38	46A(28)	—
HR 7382	8	—	8
HR 7451	50	35A(20)	33
HR 8170	54	37A(28)	—
76 Cyg	12	14A(20), 6M(7)	—
HR 8473	8	—	—
$\gamma$ PsA	24	36Y(8)	—
$\delta$ Aqr	20	32M(7), 42Y(12)	33
4 And	9	—	8
99 Aqr	32	—2Y(10)	8
$\lambda$ Psc	60	30A(10), 15Y(10)	—

The group parallaxes given in Table VI are compared with the trigonometric and spectroscopic values in Table VII. The agreement for most of the stars is satisfactory; the agreement for at least two of the five stars indicated in Fig. 2 by crosses, is as unsatisfactory as any in the table.

*Discussion.*—The space motions of the Hyades and Sirius Groups, relative to the Sun, in  $U, V, W$  space are as follows ( $U$ ;  $l=178^\circ$ ,  $b=0^\circ$ :  $V$ ;  $l=58^\circ$ ,  $b=0^\circ$ :  $W$ ;  $b=+90^\circ$ ):

	$U$	$V$	$W$	
Hyades	+40	-18	-2	km/sec
Sirius	-14	0	-12	km/sec.

The galactic orbits of the group members are, therefore, of type  $A$  for the Sirius Group and type  $B$  for the Hyades Group in the notation of a previous paper (Woolley and Eggen 1958); that is, the points of closest approach of the orbits to the galactic centre are about 200 (Sirius) and 600 (Hyades) parsecs closer to the centre than the present positions of the stars. Also, the colour-luminosity arrays for the two groups are similar to those derived previously (Woolley and Eggen 1958) for stars within 20 parsecs of the Sun and with galactic orbits of the same types.

An interesting aspect of the colour-luminosity arrays in Figs. 1 and 2 is their interpretation in the light of current theories of stellar evolution (Sandage 1954). Omitting for the moment the five stars indicated with crosses in Fig. 2, the array for the Sirius Group shows an absence of O- and B-type stars, an A-type main sequence similar to that of the Pleiades, and a sharply defined "break-away" from the main sequence at  $M_v = +0.5$ . The A-type stars in the Hyades Group, however, are above the main sequence and show considerably greater dispersion for a given colour. Also, the Hertzsprung gap is more marked in the Sirius Group with a large concentration of G5 giants on the red end of the gap; the composite spectra of HR 3279 in Table VI, G2 III + A, indicates that the components of this binary straddle the gap with the A-type star being the fainter,

The yellow giants of the Hyades Group show a greater spread in colour, although there is some concentration near a colour of  $+0^m.9$ , or spectral type K<sub>0</sub>, due to the members of the Praesepe and Hyades clusters. From the evolutionary theory, therefore, these features indicate that the Sirius Group is younger than the Hyades Group.

The galactic distribution of the group members and the dynamics of the group motions will be included in a later discussion to be published by the author and R. v. d. R. Woolley.

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