

STELLAR GROUPS IN THE OLD DISK POPULATION*

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Our horizon of some 300 parsecs, within which we can accumulate relatively accurate data, includes a large range of objects—very young stars, born within this horizon and still there; somewhat older stars, born in this region and revisiting because of nearly circular orbits about the center; still older stars, passing through from outer or inner reaches for the first or a rare visit; and very old stars, that may not be strangers to any part of the Galaxy, including regions away from the plane where younger objects can never reach.

We now have methods sufficiently accurate to sort these objects into relatively well-defined age groups, and these, coupled with the luminosity estimates and the available apparent motions, permit us to at least partially untangle the space motions of the various age groups. One of the outstanding features of the motions of young disk stars is that they are mainly members of a few stellar groups. It is also becoming clear that the old disk population also consists of many such groups.

I. Population Definition

- A. Young disk population, with an age less than that of the Hyades cluster (about 5×10^8 years).
- B. Old disk population, with an age between 5×10^8 and 5×10^9 years.
- C. Older, halo stars.

In terms of the (U, V, W) vectors of their space motions, and their galactic orbits, young disk stars are contained in the irregular region of the (U, V) plane in Figure 1 (e.g., Eggen 1969a). The old disk stars are mainly distributed within the ellipse marking the boundary of those galactic orbits with an eccentricity of $(R_{max} - R_{min}) / (R_{max} + R_{min}) = 0.5$, where R is the distance from the center of the galaxy (Eggen, Lynden-Bell, and Sandage 1962). The halo objects have $e > 0.5$.

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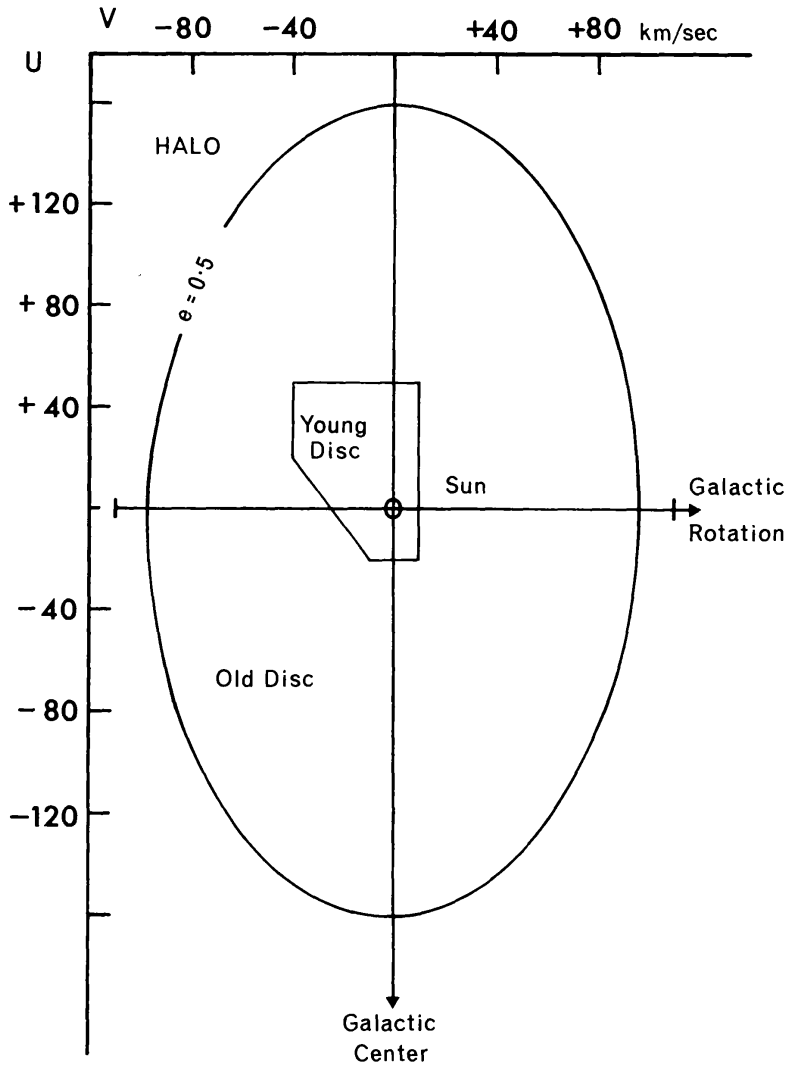


FIG. 1 — Schematic representation of the disposition of various populations in the (U, V) plane.

II. Motions of the Young Disk Stars

The motions of the young disk stars have been extensively discussed elsewhere. The youngest objects within our horizon, the B-type stars, are mainly members of the Gould Belt complex (Eggen 1961; Clube 1967) and are still very near the point of origin. The A-type stars in the young disk population are limited to a half dozen groups with the majority belonging to the Hyades or Sirius groups (e.g., Eggen 1969*a,b*). The Hyades group, with $(U, V) = (+40, -17)$, is nearly isoperiodic with the local standard of rest, $(U, V) = (+14, -15)$, (Eggen 1969*a*); and members of this group move from

their present distance only about one kiloparsec toward or away from the galactic center. Because the Hyades stars are among the oldest of the young disk population, those now within our horizon have made at least two galactic circuits. The group includes the Hyades cluster which—by the accident of its nearness to us—is used for fundamental calibrations, not only of our distance scale, but also of such astrophysical data as the position of the main sequence in the H-R diagram, and the ultraviolet excess $\delta(U-B)$ from which metal abundance determinations are made. It is perhaps fortunate that the metal abundance of the cluster and group stars is about as high as any observed. Within our horizon this high metal abundance also is almost an exclusive feature of Hyades group stars (e.g., Eggen 1965*a*). However, in using the group and cluster stars for such fundamental calibrations it is necessary to be aware of differences between these objects, which are indigenous to this part of the Galaxy, and others—even among the young disk stars—which are interlopers. For example, there is strong evidence that the mass-luminosity relation for Hyades cluster and group stars is not the same as that for other objects of both the young and old disk populations now in our horizon (e.g., Eggen 1969*c*).

III. Motions of Old Disk Stars

The older disk population around us is representative of more distant reaches of the Galaxy than the young disk population. Therefore, relative to the young disk population, more stellar groups will be represented, but also, normally, the representation within our horizon of a given group will be less. How much less will depend on the relative rates of star formation when the young and old disk stars were formed and on the size of the dispersion in the motions (especially the V motions) of the original stellar batch. Only those stars within a very narrow range of V motion will arrive within our horizon at a given time. If the original dispersion in the U and V motions were uncorrelated, those group members with the correct value of V to place them here now may still present the original dispersion in U . In the case of the young disk population, the Hyades and Sirius groups, the range of U is near 20 km/sec; for example, Hyades group members are restricted very closely to $V = -17$ km/sec but the U velocity ranges from +35 to +55 km/sec.

The presence of several groups among the old disk population has been suggested (e.g., Eggen 1958, 1964*a*, 1965*a,c*). These were mainly noted when accurate luminosities became available for such relatively pure samples of old disk stars as late-type subgiants (Eggen 1960) and evolved F- and G-type stars (Eggen 1964*b*). This method, of using accurate luminosities, is perhaps the most satisfactory for establishing the presence of groups. However, one of the important uses of the group phenomenon is to give some indication of the luminosity of stars for which other methods are not available; and for this reason, once the presence of groups is accepted, there is some advantage in having a purely dynamical criterion for identifying members. To investigate the feasibility of such an approach, a search for members of an old disk group, defined by motion alone, is described here.

Previous discussions of the motions of relatively large samples of stars (e.g., Eggen 1964*b*, 1967*a*, 1968*a*) have indicated a relative scarcity of stars with negative U velocities greater than -20 km/sec (i.e., stars now approaching the galactic center with velocities greater than 20 km/sec relative to the sun or about 35 km/sec relative to stars in circular orbits at the sun's distance from the center). The presence of a small group of old disk stars with (U,V) near $(-30, -33)$ was noted previously (Eggen 1965*b*). This group has the additional advantage that the defining star, Wolf 630, has the large and well-determined trigonometric parallax of $0''.155$ with a total weight greater than 100. Wolf 630 and Wolf 629 together with a faint, common proper-motion companion first noted by van Biesbroeck form a small cluster:

- | | |
|----------------|---|
| Wolf 630 A, B: | equal components, period near 1.7 years
and mean separation of $0''.2$. |
| Wolf 629: | $72''$ from Wolf 630 and about $2^m.5$ fainter |
| VB 8: | $122''$ from Wolf 630 and about $7^m.5$ fainter. |

The accurately determined parallax and apparent motions give $(U,V,W) = (-26, -33, +12)$ km/sec.

IV. The Wolf 630 Group

For the young disk groups we expect the group members to show a range in values of U near 20 km/sec. However, we have no prior

knowledge of where the defining star falls in this range; in the Sirius group for example, the Ursa Major cluster and Sirius itself lie near one extreme of the group range of U velocities. Therefore, in searching for members of the Wolf 630 group, the group velocity has been defined as follows:

$$U = -5 \text{ to } -45 \text{ km/sec}$$

$$V = -33 \text{ km/sec}$$

No condition has been imposed on the W velocity (i.e., the motion perpendicular to the galactic plane). The group members listed in Table I were chosen from a card catalog of all stars with accurately known radial velocity and proper motion and some estimate of the luminosity. The proper motions are mainly new determinations, on the N30 system, using all available positions. Many of these motions have been published elsewhere (e.g., Eggen 1962, 1964*a,b*, 1966*a*). The luminosity estimates are of many kinds, ranging from well-determined trigonometric parallaxes to the mere statement that the star is of a particular spectral type. Obviously a very large element of experience with, and personal judgment on, these estimates enters into their use. The procedure was to plot the individual (U,V) loci of the stars with a length related to the uncertainty of the estimated luminosity. These loci are straight lines in the (U,V) plane, and those which the luminosity estimate, or its uncertainty, placed in a region of the (U,V) plane outlined by $U = -5$ to -55 km/sec and $V = -25$ to -40 km/sec were accepted as candidates for membership in the group. A group parallax was then computed by forcing V to -33 km/sec. If the resulting value of U was still in the range -5 to -45 km/sec, the star was accepted as a possible group member.

The final distribution of the U velocities of the accepted group members is shown in Figure 2. The bulk of the stars have values of U between -10 and -30 km/sec.

V. Color-Luminosity Array for the Wolf 630 Group

The stars accepted as group members are listed in Table I and shown in the $(M_V, B-V)$ plane in Figure 3. The luminosities in Table I and Figure 3 are those derived from the group parallaxes. In addition to the (U,V,W) vectors, Table I also contains the positions of the stars, relative to the sun, with the (X,Y,Z) axes directed in the same way as the (U,V,W) vectors: X positive away from the

TABLE I
PROBABLE MEMBERS OF THE WOLF 630 GROUP

HD	V_E	$B-V$	$U-B$	Sp	M_V	U	V (km/sec)	W	X	Y (parsecs)	Z
1038	4.32	+1 ^m .61	+1 ^m .95	M1 III	- 1.1	-28	-33	+18	- 6	+235	-117
2454	6.04	+0.43	-0.07	F2 V	+ 3.0	-13	-33	-15	+ 10	+ 22	- 31
4188	4.75	+1.00	+0.84	K0 III	+ 0.15	-24	-33	-13	+ 11	+ 21	- 80
4256	8.03	+1.02	+0.88	dK5	+ 6.7	-25	-33	-31	+ 4	+ 8	- 16
4307	6.15	+0.585	+0.05	G0 V	+ 3.25	-27	-33	+ 3	+ 4	+ 8	- 37
4928	6.36	+1.07	+0.90	K0 III	+ 0.8	-10	-33	-26	+ 34	+ 52	-106
5384	5.85	+1.53	+1.96	gK5	- 0.6	-23	-33	-16	+ 39	+ 53	-184
5395	4.64	+0.96	+0.70	G8 III-IV	+ 2.8	-35	-33	- 2	+ 13	+ 19	- 2
6378	9.74	+1.19	-	K5 V	+ 7.5	-28	-33	- 5	+ 2	0	- 28
6479	6.32	+0.385	-0.025	F4 V	+ 2.35	-12	-33	-12	+ 13	+ 16	- 33
6480	7.23	+0.485	-0.04	F5 V	+ 3.3	-	-	-	+ 9	+ 12	- 12
6660	8.39	+1.12	+1.06	dG6	+ 7.0	-11	-33	-31	+ 18	0	- 138
7908	7.27	+0.27	-	A7 III	+ 1.5	-15	-33	-13	+ 15	+ 30	-242
8498	5.86	+1.60	+2.05	K5 III	- 1.1	-36	-33	+17	+ 54	+ 55	- 71
8763	5.49	+1.11	+1.06	gK1	+ 1.4	-10	-33	+17	+ 28	+ 24	- 55
8875*	7.07	+0.63	+0.15	dG0	+ 3.7	-28	-33	-11	+ 18	+ 3	- 98
9411	7.24	+0.27	-	F0 V	+ 2.35	-23	-33	- 1	+ 2	- 16	- 64
10142	5.93	+1.05	+0.90	K0 IV	+ 1.9	-27	-33	-24	+ 8	- 1	- 32
10718	8.18	+0.64	+0.11	dG4	+ 5.55	-34	-33	-11	+ 48	- 11	-116
14728	5.88	+1.23	-	K0	+ 0.35	-18	-33	0	+ 87	- 44	- 23
15652	6.10	+1.59	+1.99	gM1	- 0.9	-24	-33	+17	+ 81	+ 57	- 41
15656	5.16	+1.47	+1.77	K5 III	0.0	-10	-33	+29	+108	+ 45	- 89
17017	6.46	+1.07	+1.07	gK2	+ 1.6	-17	-33	+16	+ 33	- 55	-128
17829	5.48	+1.27	+1.31	gK5	- 0.4	-27	-33	- 7	+ 28	- 3	- 41
18322	3.90	+1.10	+1.00	K1 III-IV	+ 0.4	-24	-33	+11	+ 18	- 6	- 28
19467	6.94	+0.64	+0.12	G5 V	+ 4.3	-20	-33	-21	+ 27	+ 58	- 83
23508 A	6.50	+1.10	-	K1 III	+ 1.4	-24	-33	- 6	+ 27	+ 58	- 83

TABLE I (Continued)

HD	V_E	$B-V$	$U-B$	Sp.	M_V	U	V (km/sec)	W	X	Y (parsecs)	Z
23841	6.68	+1 ^m .21	+1 ^m .16	K2 III	+ 0.55	-36	-33	+87	+138	+ 35	- 91
24706	5.93	+1.23	+1.35	K3 III	+ 1.05	-21	-33	+35	+16	- 57	- 69
25621 A°	5.35	+0.51	+0.02	F6 IV	+ 2.4	-14	-33	+17	+32	- 4	- 23
26846 A°	4.87	+1.14	+1.13	K3 III	+ 1.0	-25	-33	-21	+42	- 18	- 37
26967	3.85	+1.09	+1.01	K1 III	+ 1.1	-22	-33	- 9	+10	- 22	- 26
28454	6.09	+0.48	-0.07	F8 V	+ 3.55	-33	-33	- 2	+ 7	- 22	- 22
30959	4.7V	+1.74	+2.03	M3S	- 1.4	-19	-33	-25	+180	- 17	- 60
33021	6.16	+0.62	+0.08	dG2	+ 3.5	-42	-33	-24	+31	- 7	- 10
39523	4.50	+1.10	+0.99	K1 III	- 0.1	-28	-33	+23	+ 7	- 71	- 42
40040	8.21	+0.64	+0.08	dG4	+ 5.0	-36	-33	-10	+42	- 9	- 3
41492	8.81	+1.14	-	K2 IV	+ 2.45	-36	-33	- 8	+81	-149	- 77
43745	6.03	+0.59	+0.09	G0 V	+ 2.95	-44	-33	+ 4	+26	- 31	- 12
47391	7.65	+0.70	+0.16	G5	+ 4.85	-16	-33	+43	+17	- 30	- 11
48217	5.18	+1.54	+1.89	gM0	- 0.8	-25	-33	+11	+120	-100	- 17
49878	4.53	+1.37	+1.62	K4 III	- 0.5	-23	-33	+ 9	+66	+ 60	+ 45
52395	7.79	+0.54	+0.035	G0 V	+ 3.0	-33	-33	-25	+44	- 77	- 18
54131	5.49	+1.00	+0.80	gC8	+ 0.7	-26	-33	-24	+83	- 31	+ 17
55383	5.0V	+1.66:	+1.82:	M4 III	- 1.2	-21	-33	+ 8	+158	- 60	+ 36
56176	6.41	+0.85	+0.51	G7 IV	+ 2.9	-12	-33	- 3	+46	- 8	+ 15
56513	8.03	+0.62	+0.08	G2 V	+ 5.1	-38	-33	+18	+36	- 7	+ 12
60341	5.64	+1.13	+1.085	gK3	+ 0.9	-18	-33	- 1	+52	- 80	- 0
60522	4.04	+1.54	+1.96	M0 III	- 0.6	-16	-33	-34	+77	- 17	+ 30
67767	5.72	+0.83	+0.44	dG6	+ 3.4	-38	-33	-41	+24	- 7	+ 14
71148	6.36	+0.63	+0.11	dG4	+ 5.1	-22	-33	-23	+14	+ 1	+ 10
73667	7.60	+0.82	+0.46	dK3	+ 6.1	-20	-33	-32	+14	- 10	+ 10
75767°	6.57	+0.63	+0.04	dG1	+ 4.0	-27	-33	+ 8	+21	- 18	+ 16
82870	5.55	+1.16	+1.13	gK1	0.0	-18	-33	- 8	+54	- 94	+ 68
83618	3.90	+1.32	+1.47	K3 III	- 0.7	-17	-33	+14	+37	- 56	+ 49
84542	5.78	+1.64	+1.95	gM1	- 1.5	-25	-33	- 6	+140	-162	+191

TABLE I (Continued)

HD	V_E	$B-V$	$U-B$	Sp.	M_V	U	V (km/sec)	W	X	Y (parsecs)	Z
84748*	6.1V	+1 ^m .28	+0 ^m .20	gM8e	+ 0.25	-10	-33	0	+122	-116	+163
85376	5.33	+0.225	+0.05	A5V	+ 2.2	-12	-33	-6	+25	-12	+33
85945	5.96	+0.89	+0.57	gC5	+ 1.45	-35	-33	-8	+12	+5	+14
87998 A*	7.25	+0.62	+0.08	G2V	+ 5.2	-10	-33	-30	+4	-22	+12
89269	6.62	+0.65	+0.16	dC5	+ 4.7	-15	-33	+3	+14	+1	+20
89619 AB*	7.34	+0.50	+0.06	gF7	+ 2.0	-18	-33	-12	+61	-91	+124
C	9.62	+0.58	+0.06	—	+ 3.5	-13	-33	+8	+46	-22	+77
89631	8.55	+0.46	-0.04	F5V	+ 3.7	-13	-33	+8	+46	-22	+77
89962	6.06	+1.12	+1.14	gK3	+ 0.8	-26	-33	-43	+42	-62	+87
94237	6.30	+1.50	+1.82	K5	- 1.15	-16	-33	-10	+62	-186	+239
94264	3.82	+1.03	+0.90	K0 III-IV	+ 1.6	-14	-33	+22	+12	-2	+25
94669	6.03	+1.13	+1.08	K2 III	+ 1.9	-38	-33	-39	+29	+4	+59
95364	8.57	+0.69	+0.14	G2V	+ 5.5	-13	-33	+10	+14	-10	+37
97605	5.78	+1.12	+1.14	gK3	+ 1.4	-27	-33	+8	+14	-35	+65
98562	8.78	+0.66	+0.21	G2V	+ 4.3	-16	-33	+10	+22	-17	+73
101408	7.26	+1 ^m .045	+0.74	G8 IV	+ 2.85	-14	-33	-24	-25	-69	+20
103459	7.58	+0.70	+0.23	dC5	+ 5.3	-36	-33	-1	-1	-15	+25
104350*	8.4V	+0.27	+0.06	A2	+ 2.0	-14	-33	-27	+14	-82	+250
105262	7.10	-0.01	-0.05	B9	+ 0.9	-37	-33	+34	+5	-50	+157
105601	7.39	+0.29	+0.10	Am	+ 2.65	-11	-33	-53	+19	+7	+79
105639	5.94	+1.12	+1.14	gK3	+ 2.15	-35	-33	-15	-4	-26	+51
106400*	9.0V	+0.77	+0.33	K0 V	+ 5.2	-27	-33	0	0	-24	+77
106760*	5.01	+1.14	+1.07	K1 III	+ 1.3	-10	-33	-40	+9	+1	+54
112735	7.24	+0.56	+0.09	G0	+ 3.5	-39	-33	-46	-4	-4	+61
117267	6.42	+1.11	+1.12	gK0	+ 2.4	-15	-33	+27	-25	-19	+54
+38°2457	10.05	+1.10	+1.00	dK8	+ 7.0	-20	-33	-17	-1	+9	+39
120033*	6.04	+1.42	+1.66	gK5	- 0.2	-25	-33	-23	-124	-87	+184
121953	7.55	+0.66	+0.14	dG2	+ 5.8	-24	-33	-4	+5	+13	+17

TABLE I (Continued)

HD	V_E	$B-V$	$U-B$	Sp.	M_V	U	V (km/sec)	W	X	Y (parsecs)	Z
122693	8.06	+0 ^m .57	+0 ^m .07	F8 V	+ 4.0	-18	-33	+ 1	- 16	+ 9	+ 64
124679	4.80	+1.05	+0.90	K0 III	+ 1.25	-23	-33	+ 6	- 23	- 2	+ 46
124850	4.08	+0.51	+0.03	F7 III-IV	+ 2.5	-24	-33	-13	- 12	- 5	+ 16
126660	4.06	+0.50	+0.01	F7 IV	+ 3.05	-11	-33	+ 7	+ 1	+ 8	+ 14
129357	7.81	+0.635	+0.115	G2 V	+ 4.2	-13	-33	-34	- 16	+ 15	+ 48
130989	6.50	+0.46	-0.04	dF5	+ 2.55	-26	-33	- 6	- 46	- 17	+ 37
131923	6.35	+0.715	+0.24	G5 V	+ 5.2	-22	-33	-20	- 13	- 10	+ 3
132683	9.49	+1.38	+1.29	dM0	+ 8.1	-25	-33	-16	- 14	- 3	+ 12
136366	6.16	+1.02	—	gC8	+ 0.45	-11	-33	-23	-114	- 29	+ 73
136514	5.34	+1.19	+1.22	K3 III	+ 1.3	-16	-33	- 1	- 72	+ 4	+ 73
139007	8.26	+0.525	+0.04	F8 V	+ 3.7	-28	-33	-28	- 38	+131	+ 65
139254	5.78	+1.10	+0.89	gK0	+ 0.9	- 7	-33	-15	- 83	- 20	+ 41
140301	6.31	+1.155	+0.96	sgK0	+ 1.5	-28	-33	-14	- 77	- 10	+ 46
142709	8.04	+1.12	+1.03	K5 V	+ 7.3	-24	-33	+ 6	- 13	- 6	+ 2
142804 A	6.56	+1.78	+2.10	gM1	- 1.7	-18	-33	-62	-391	- 36	+207
B	13.73	+0.70	+0.14	—	+ 5.5	—	—	—	—	—	—
144542	6.19	+1.57	+1.91	M1	- 1.0	-21	-33	+28	-250	-115	+ 25
147776	8.40	+0.96	+0.70	K3 V	+ 6.6	-10	-33	+ 8	- 21	+ 6	+ 9
148513*	5.39	+1.45	+1.77	K4 IIIp	- 0.7	-33	-33	-22	- 54	+ 15	+ 35
148897*	5.23	+1.26	+1.20	G8p	+ 0.3	-24	-33	+31	- 59	+ 46	+ 63
149822	6.30	-0.08	-0.20	Ap	- 1.6	-20	-33	+ 2	-264	+168	+231
152751 AB*	8.98	+1.60	+1.06	dM3e	+10.7	—	—	—	—	—	—
C	11.70	+1.70	+1.35	dM4	+12.7	-23	-33	+12	- 6	0	+ 2
D	16.66	+2.05	—	—	+17.7	—	—	—	—	—	—
154183	8.65	+0.66	+0.14	G0 V	+ 3.5	-11	-33	-14	- 60	+ 65	+ 60
154962	6.35	+0.70	+0.325	G8 IV-V	+ 2.9	-25	-33	- 2	- 44	+ 13	+ 17
156563	8.98	+0.71	+0.26	G8 V	+ 4.6	-24	-33	-10	- 44	+ 47	+ 39
+29°3029 AB*9.01	—	+1.14	+0.99	dM0	+ 7.7	-22	-33	+ 7	- 13	+ 17	+ 12

TABLE I (Continued)

HD	V_E	$B-V$	$U-B$	Sp.	M_V	U	V (km/sec)	W	X	Y (parsecs)	Z
161797 A*	3.42	+0 ^m .75	+0 ^m .39	G5 IV	+ 3.6	-19	-33	- 5	- 5	+ 6	+ 4
BC	9.78	+1.52	+1.00	dM4	+10.8						
165135	2.98	+0.99	+0.78	K0 III	+ 0.15	-22	-33	-10	- 37	0	- 3
166620	6.41	+0.87	+0.59	K2 V	+ 5.8	-22	-33	+ 1	- 5	+ 11	+ 5
169245	8.67	+0.535	+0.01	F8 V	+ 3.2	-19	-33	+ 4	- 67	+ 92	+ 31
169978	4.64	-0.12	-0.39	B8 III	+ 0.7	-27	-33	-28	- 47	+ 24	- 21
170525	6.43	+0.68	+0.17	G5 IV	+ 2.95	-14	-33	-27	- 43	- 19	- 18
181122	6.31	+1.05	+0.89	G9 III	- 0.4	-15	-33	-22	-155	+154	- 6
188268 A	8.78	+0.875	+0.615	dK0	+ 5.7	-35	-33	-24	- 30	+ 27	- 9
B	8.95	+0.905	+0.67	dK1	+ 5.85						
188807	9.31	+1.30	+1.22	dM1	+ 8.45	-12	-33	- 8	- 12	+ 7	- 5
188887	5.30	+1.22	+1.29	gK0	+ 0.4	-16	-33	-30	- 69	- 42	- 50
193307	6.26	+0.55	0.00	G2 IV-V	+ 4.55	-28	-33	+19	- 10	- 2	- 7
197635	5.40	+1.12	+1.10	gK0	+ 0.4	-21	-33	-18	- 67	- 46	- 58
197694*	4.27	+1.04	+0.97	K1 IV	+ 0.65	-34	-33	-19	- 24	+ 44	- 15
197963	5.14	+0.49	+0.08	F7 V	+ 1.55						
200565	8.45	+0.65	+0.13	dG3	+ 4.95	-26	-33	- 6	- 27	+ 36	- 23
200790	5.96	+0.54	+0.02	dF7	+ 2.9	-16	-33	+11	- 21	+ 30	- 18
201601	4.75	+0.25	+0.11	Fp	+ 1.45	- 2	-33	-20	- 20	+ 36	- 19
202573	7.00	+0.88	+0.50	G5 V	+ 3.7	-29	-33	+24	- 12	+ 42	- 13
203040	9.26	+1.35	+1.26	dK6	+ 8.7	-33	-33	-17	- 8	+ 5	- 9
203638	5.46	+1.15	+1.10	gK2	+ 1.2	-25	-33	-26	- 46	+ 25	- 48
204079	8.67	+1.12	+0.98	K1 V	+ 7.4	-11	-33	+ 9	- 4	+ 16	- 5
+22°4409	9.25	+1.05	+0.80	dK8	+ 7.2	-23	-33	-33	- 7	+ 23	- 9
205478*	3.75	+0.99	+0.90	K0 III	+ 3.0	-12	-33	-15	- 8	+ 8	- 8
206276	8.85	+1.035	+0.84	K5 V	+ 7.0	-24	-33	-56	- 15	0	- 17
206301*	5.18	+0.65	+0.20	G2 IV	+ 3.1	-25	-33	+ 1	- 14	+ 12	- 18
210066	4.98	+1.49	+1.81	gM1	- 0.8	-12	-33	-21	- 82	+ 17	-116

TABLE I (Continued)

HD	V_E	$B-V$	$U-B$	Sp.	M_V	U	V (km/sec)	W	X	Y (parsecs)	Z
214953 A	5.97	+0 ^m 58	+0 ^m 06	G1 V	+ 4.5	-12	-33	- 8	- 11	- 3	- 18
B	11.10	+1.41	—	M1	+ 9.6						
215104	4.84	+1.03	+0.81	gC8	+ 0.55	-14	-33	-26	- 36	- 3	- 63
215648	4.19	+0.50	-0.03	F7 V	+ 3.05	- 5	-33	-29	- 2	+ 13	- 11
217096	6.12	+0.58	+0.10	G3 IV	+ 2.0	-17	-33	-17	-28	+ 3	- 60
217459	5.83	+1.34	+1.55	gK4	0.0	-26	-33	-47	- 21	+ 90	-110
217701	6.14	+1.58	+1.90	gM2	- 1.35	-30	-33	- 2	- 66	+150	-252
218356*	4.78	+1.32	+1.10	K0 IIp	- 2.2	-26	-33	- 6	+ 19	+212	-132
220652	4.96	+1.66	+1.93	M1 III	- 1.0	-11	-33	- 5	-161	+142	+ 3
223029	7.97	+0.53	+0.03	dF6	+ 2.95	-17	-33	+18	0	+ 52	- 85
223633	7.55	+0 ^m 46	-0 ^m 03	F5 IV-V	+ 4.0	-12	-33	-18	- 16	- 6	- 48

NOTES TO TABLE I

8875	ADS 1158, equal components.	120033	$\Delta m = 1^m5, 0^s8.$
25621	8 ^m 5", Common proper motion.	148513	Strong CN.
26846	8 ^m 7", Common proper motion.	148897	Strong Si II.
75767	Sp. B, 10 ^a .	152751	Wolf 630.
84748	R Leo, 300 ^a .	+29°3029 AB	ADS 10585.
87998	11 ^m 5".	161797	ADS 10786.
89619	ADS 7730, the components of the close pair are nearly equal.	197963/4	ADS 14279.
104350	AG Vir, Contact binary, P = 0 ^d 64.	205478	SB, 1032 ^d .
106400	AH Vir, Contact binary, P = 0 ^d 41.	206301	Sp. B, 13 ^d .
106760	Sp. B, 1300 ^d .	218356	Strong Sr II.

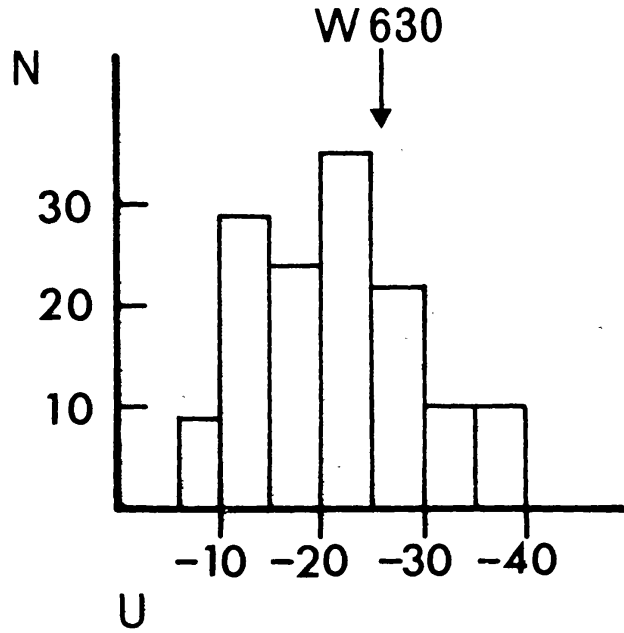


FIG. 2 — The distribution of U velocities of Wolf 630 group members.

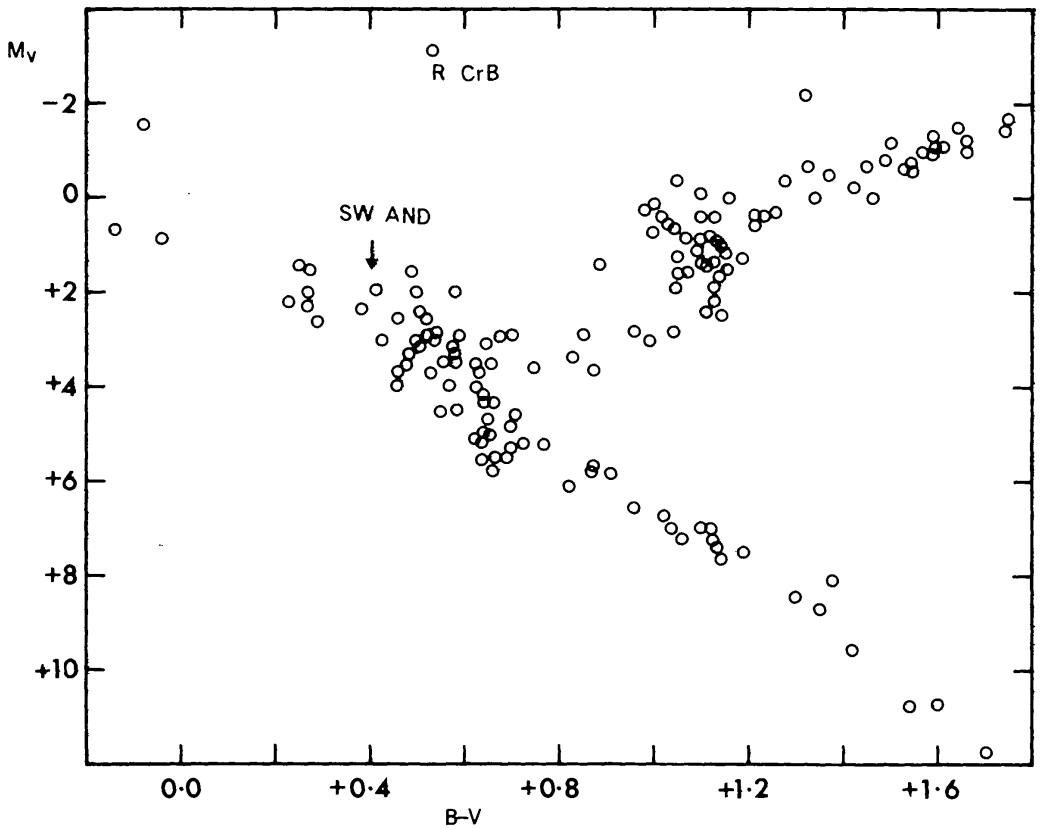


FIG. 3 — The distribution of Wolf 630 group members in the $(M_V, B-V)$ plane.

galactic center, Y in the direction of galactic rotation, and W in the direction of the north galactic pole. Most of the photometric observations in Table I have been obtained in various programs over many years at the Lick, Cape, Pretoria, Mount Wilson and Palomar, and Siding Spring Observatories.

The color-luminosity array in Figure 3 is strikingly similar to that for the old disk population cluster M 67 (Eggen and Sandage 1964), including the "blue stragglers" above, and on, the main sequence and bluer than the main-sequence turn-off point. The bluest star in M 67, Fagerholm No. 81, has $M_V = +0^m.5$ and $(B-V)_0 = 0^m.135$, which make it nearly identical to the group member HD 169978 (ν Pavonis). The clumping of giants near $(B-V) = +1^m.0$ is also a usual feature of the color-luminosity arrays for old disk clusters.

VI. Spatial Distribution of Wolf 630 Group Members

The (X,Y) and (X,Z) distributions of the group members are shown in Figures 4 and 5, respectively. The boxes in Figure 4 represent stars within 100 parsecs of the galactic plane whereas open and filled circles represent, respectively, stars more than 100 parsecs below and above the plane.

The distributions in both Figures 4 and 5 suggest nonuniformities that are difficult to explain as selection effects. But because the selection effects are many, except for the stars brighter than visual magnitude 6.5, these nonuniformities should not be overstressed. In the (X,Y) plane there appears to be an elongation to the group in the $(-,+)$ and $(+,-)$ quadrants of Figure 4. This elongation is nearly orthogonal to the mean motion of the group members, $(U,V) = (-20,-33)$. In the (X,Z) plane, if we omit the stars within 10 parsecs which are concentrated on the galactic center side of the sun, the majority of the more distant objects are in the anticenter direction.

Because, with three or four exceptions, the known group members are within 200 parsecs of the galactic plane, very little correlation between the Z distances and W velocities is expected. The maximum W velocity for stars now within 50 parsecs of the plane is 50 km/sec and this falls to 40 km/sec at 100 parsecs. From the force law K_z , perpendicular to the galactic plane, derived from young disk stars (e.g., Oort 1932; Woolley 1957; Eggen 1969*d*), we conclude that these objects can reach up to a kiloparsec from the

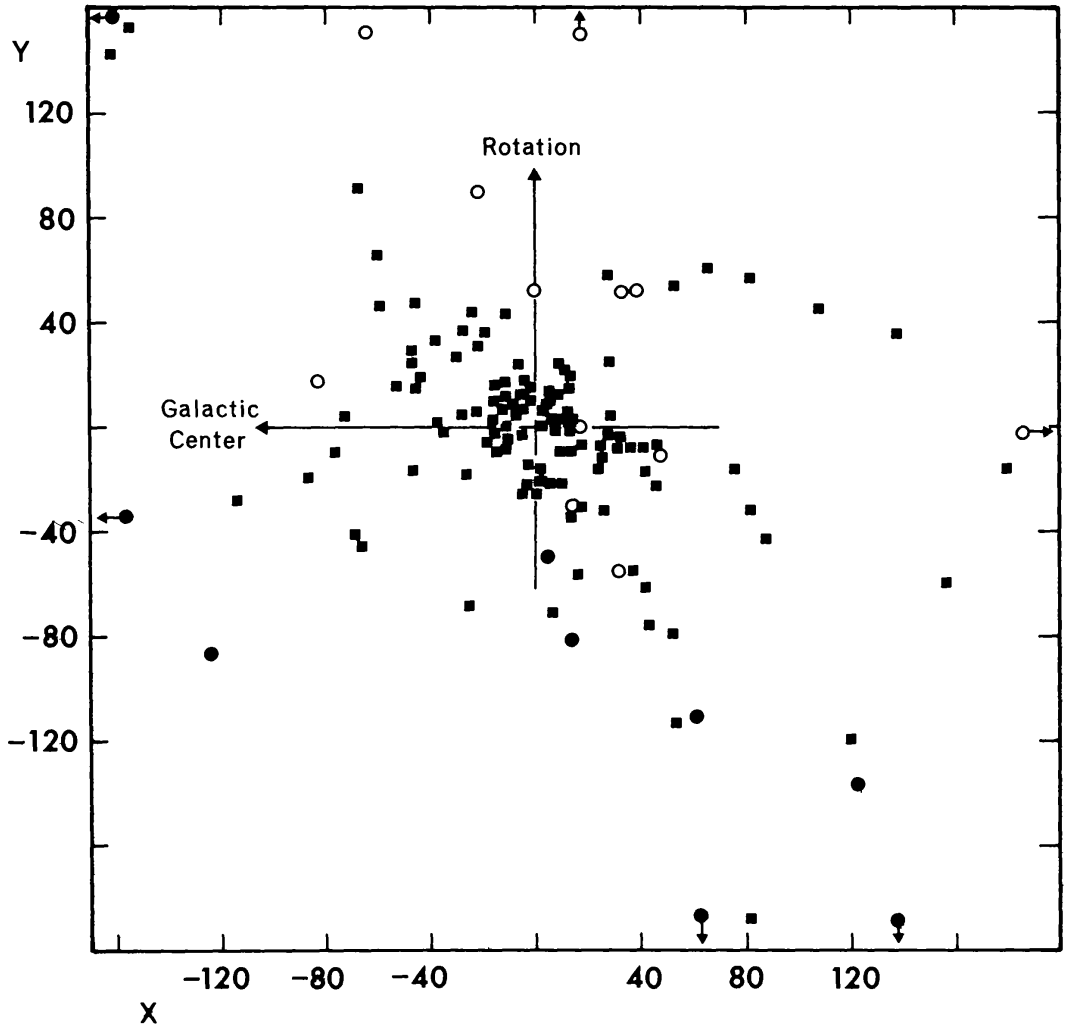


FIG. 4— The distribution of Wolf 630 group members in the (X, Y) plane. Stars represented by squares are within 100 parsecs of the galactic plane; the open and filled circles represent stars that are more than 100 parsecs below or above the plane, respectively.

plane. A reliable estimate of the density of group stars could be obtained by sampling the stellar population at the galactic poles to about a kiloparsec. A preliminary attempt at this was contained in a previous investigation of the proper motion stars near the south galactic pole (Eggen 1968*b*). Photoelectric (UBV) photometry was obtained for the 130 Bruce Proper Motion stars (Luyten 1963) in a 5° by $6^\circ 5'$ region centered on the south galactic pole. The radial velocities are not available so only (U, V) motions could be obtained, and because luminosity estimates are not available, only minimum space velocities, based on assumed main-sequence luminosities,

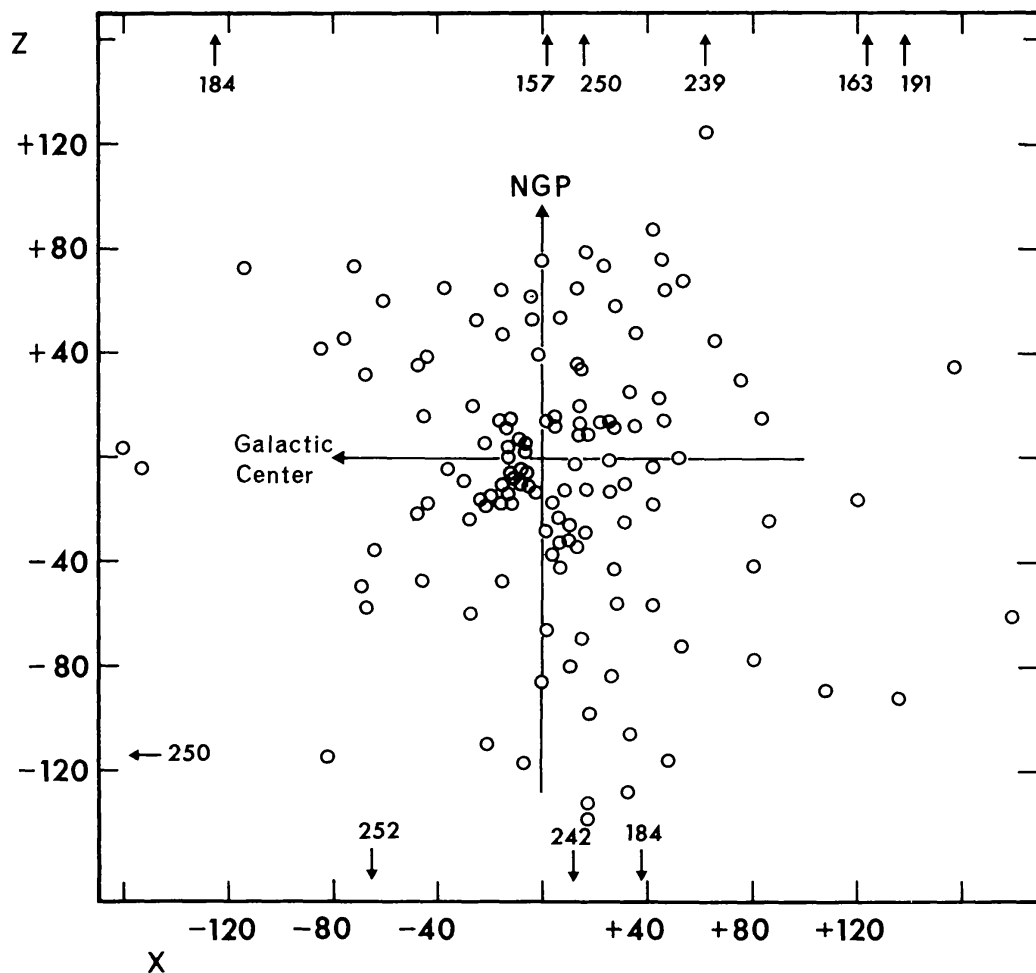


FIG. 5 — The distribution of stars in the Wolf 630 group on the (X,Z) plane.

could be derived. Nevertheless, some ten percent of these objects, essentially all of which have colors of G- or later-type stars, are candidates for membership in the Wolf 630 group.

VII. Comparison of Group Parallaxes with Other Luminosity Estimates

With one or two exceptions, noted below, all available luminosity estimates were examined when assigning the stars in Table I to the Wolf 630 group, so that large differences between these estimates and the final group values are not expected.

The comparison of the group parallaxes at least as large as $0''.02$ with the available trigonometric determinations is shown in Table II. The group parallaxes place 17 stars, or systems, within 20 parsecs of the sun whereas the mean trigonometric values give only 10.

TABLE II
 WOLF 630 GROUP STARS WITH GROUP PARALLAX
 AT LEAST AS LARGE AS 0".020

HD	π_g (0".001)	π_{tr}	Individual Values
2454	25	33	33A(20)
4256	54	41	41M(8)
4307	26		
5395	42	40	70A(16), -1M(8)
6378	36	39	39C(8)
6660	53	41	41M(8)
10718	30	25	22Y(12), 31C(7)
18322	20	29	21A(20), 70M(7), -6Y(7), 35C(7)
19467	30		
25621	26	14	14Y(10)
26967	28	19	15Y(12), 24C(7)
28454	31	26	26C(7)
33021	30	33	25A(28), 43M(8), 41Y(10), 39W(10)
40040	22	20	25A(2), 4M(2), 16Yk(5), 26S(8)
43745	24	11	11C(6)
47391	28	24	24C(6)
56176	20		
56513	26		
67767	34	29	34A(16), 15Yk(6)
71148	56	46	43A(20), 53M(6)
73667	50	51	56A(28), 27M(7), 79D(4)
75767	31	17	17A(20)
85376	24	38	38A(20)
87998	39	15	15C(6)
89269	42	20	20S(8)
94264	36	17	10A(20), 31M(8)
95364	24		
103459	35	11	73D(3), -14M(6)
+38°2457	29		
121953	44	33	33G(8)
124850	48	39	26M(6), 46Y(10)
126660	63	67	66A(16), 69M(8)
131923	52	31	29A(28), 48M, 19G(8)
132052	28	40	40A(28), 33Y(10)

TABLE II (*Continued*)

HD	π_g (0''.001)	π_{tr}	Individual Values
132683	52	46	54Y(12), 35C(7), 45M(7)
142709	72	55	60Y(12), 47C(7)
147776	45	56	46C(7), 61Y(12)
+29°3029	39	51	60M(8), 46Y(8), 48S(7)
154183	20		
154962	20		
161797	110	118	122A(20), 109M(8)
165135	26	18	18Y(10)
166620	79	92	89A(28), 107M(7)
170525	20		
188268	24	28	31A(12), 24M(10)
188807	69	55	74V(12), 28C(7), 53Y(12)
193307	45	37	39C(7), 37Y(12)
200565	20	11	11A(20)
200790	24	13	13A(16)
201601	22	21	13A(20), 41M(7)
202573	34		
203040	77	44	62Y(10), 35M(7), 27C(6)
204079	56		
+22°4409	38		
205478	71	45	45Y(12)
206276	42	47	47C(7)
206301	38	29	35Y(8), 20C(8), 29M(7)
214953	50	60	33C(7), 82Y(8)
215648	59	47	47A(16), 47M(6)

Additional trigonometric determinations, and in one or two cases first determinations, would be especially important in these cases.

The Mount Wilson spectroscopic luminosities (Adams, Joy, Humason, and Brayton 1935) were consulted only in a limited way in the assignment to group membership in that the spectroscopic estimates for stars brighter than M_v near +1 were not used because their scale is known to be distorted (e.g., Blaauw 1963). The comparison between group and spectroscopic luminosities for all stars in common is shown in Figure 6. The collapsed scale of the spectroscopic

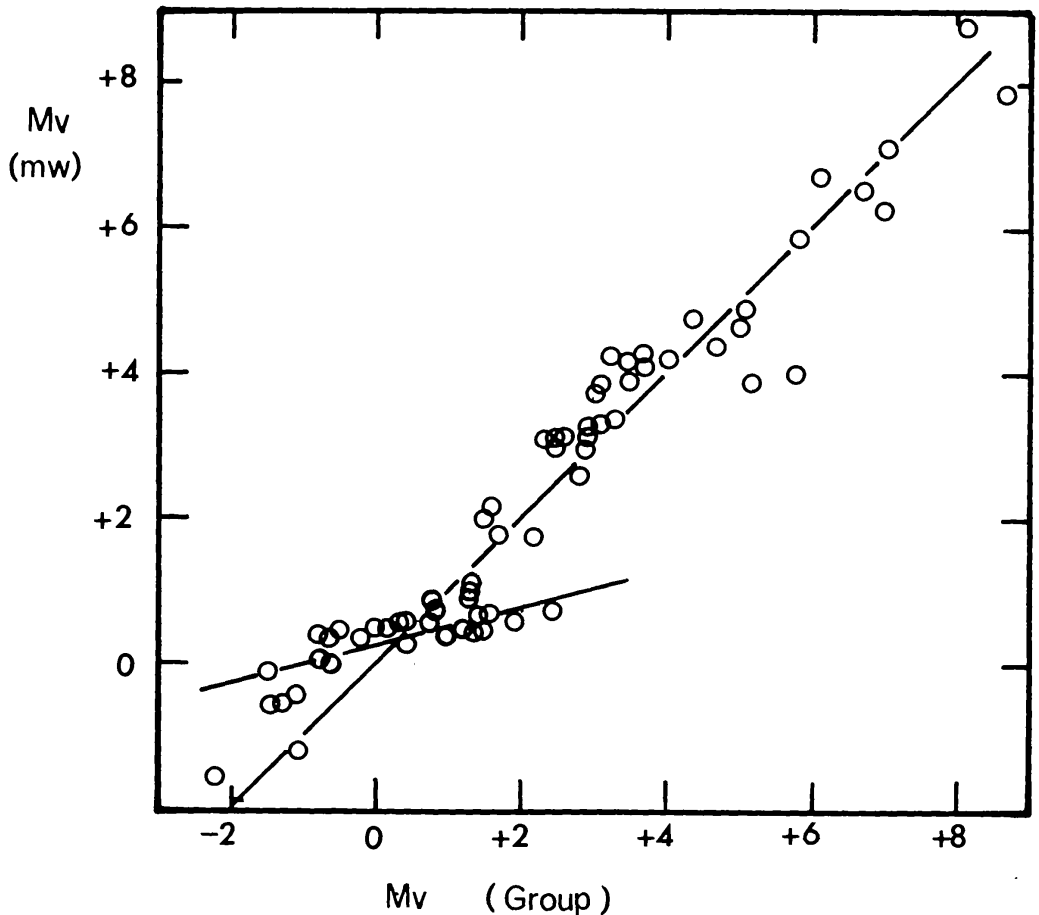


FIG. 6—Correlation of luminosities from group and spectroscopic (Mount Wilson) parallaxes.

values near $M_V = 0^m$, discussed by Russell and Moore (1940) and by van Rhijn (1939) and summarized by Blaauw, is shown in the nearly horizontal line in Figure 6 (cf., Blaauw 1963, Fig. 5).

The luminosity estimates from the widths of H- and K-emission lines in late-type stars by Wilson and Bappu (1957) were not used in selecting group members. A comparison between the group luminosities and those derived from the H- and K-emission lines is shown in Table III. Improved and unpublished spectroscopic values have been kindly supplied by O. C. Wilson. Omitting one discrepant case, HD 18322, which on this evidence may not be a group member, the average difference for the remaining stars is 0^m0 and the average deviation is 0^m3 .

TABLE III
COMPARISON BETWEEN GROUP LUMINOSITIES AND
THOSE OBTAINED FROM H- AND K-EMISSION WIDTHS

HD	OJE	OCW	OJ-OC
18322	+0.4	+1.6	(-1.2)
60522	-0.6	-0.5	-0.1
67767	+3.4	+3.4	0.0
94264	+1.6	+2.0	-0.4
148897	+0.3	+0.2	+0.1
181122	-0.4	+0.4	-0.8
206301	+3.1	+2.3	+0.8
218356	-2.2	-2.2	0.0
			0.0 ± 0.3 (a.d.)

VIII. Abundance and Gravity Effects in the Ultraviolet

The ultraviolet excess of the F- and G-type stars, compared with those in the Hyades cluster, is compounded of effects due to the different strength of the metal lines and of the different surface gravities in stars of different luminosities. The abundance effect shows as an ultraviolet excess with respect to Hyades main-sequence stars of the same luminosity and color, whereas the effect of the decreased surface gravity of higher luminosity stars is to show an ultraviolet deficiency with respect to main-sequence stars of the same abundance and color index. For luminosities in the range discussed here, the gravity effect becomes negligible for stars redder than $(B-V)$ near $+0^m6$ (Eggen 1966*b*). Therefore, the group stars in the color range from $(B-V) = 0^m3$ to 0^m8 have been divided into two groups. Those in the range 0^m3 to 0^m6 are shown in Figure 7 where the values of $\delta(U-B)$ compared to Hyades main-sequence stars (Sandage and Eggen 1959) are correlated with displacement from the Hyades main sequence, Δm . The gravity effect is obvious in Figure 7 and, for the few stars involved, it confirms the luminosities obtained from the group parallaxes.

The group stars with $(B-V)$ between 0^m6 and 0^m8 are shown in Figure 8 where the continuous curve represents the $(U-B)$, $(B-V)$ relation for main-sequence Hyades stars. The attenuation of the ultraviolet excess with increasing color (Sandage and Eggen 1959) is obvious, but both Figures 7 and 8 give a mean, group ultraviolet excess from the abundance effect for main-sequence stars with $(B-V) = 0^m6$ as 0^m06 . The *presence* of an ultraviolet excess for

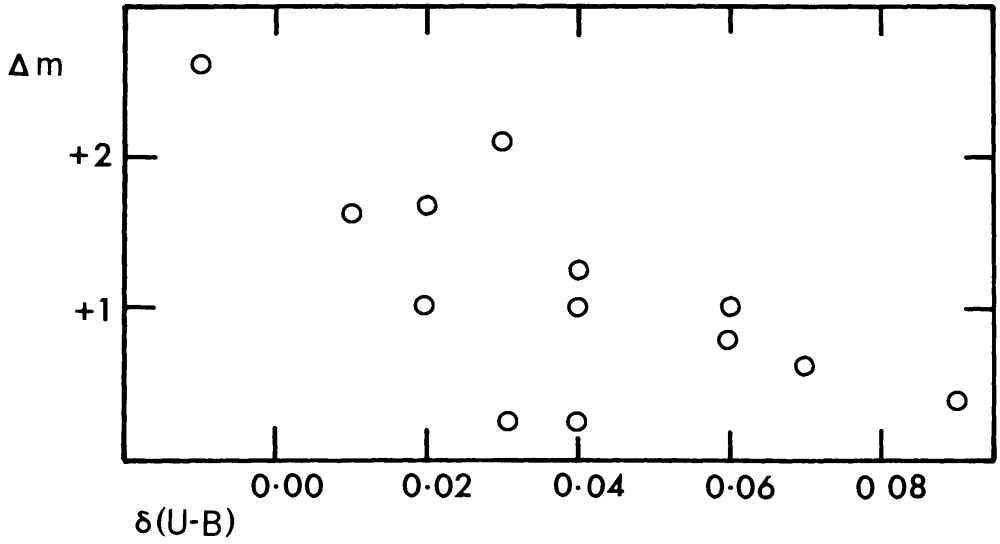


FIG. 7 — The correlation between displacement of Wolf 630 group members, with $(B-V)$ between $+0^m3$ and $+0^m6$, from the Hyades main sequence and the ultraviolet excess with respect to the Hyades stars.

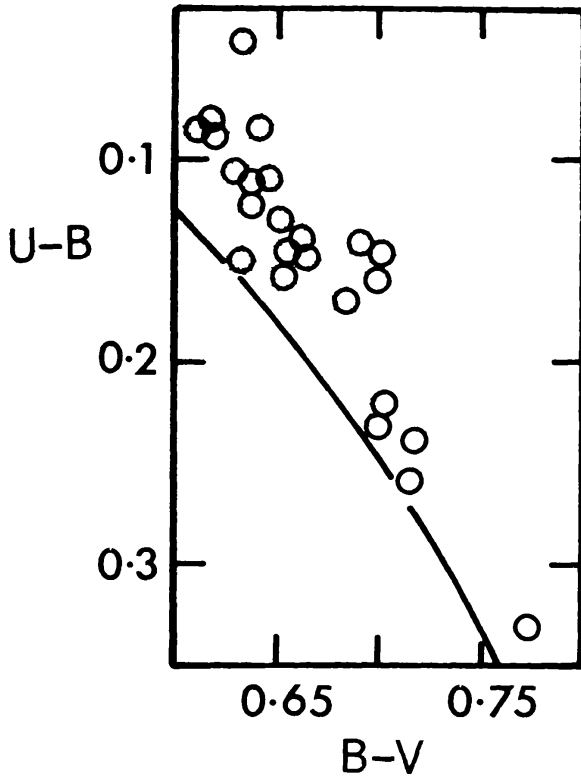


FIG. 8 — The $(U-B, B-V)$ relation for Wolf 630 group members with $(B-V)$ between $+0^m6$ and $+0^m8$. The continuous curve represents Hyades main-sequence stars.

these stars is itself not an argument for group membership because they are, in any case, old disk-population objects and an excess is expected; but the consistency of the *size* of the excess for most of the stars is something of a check on the assignment to the group.

IX. Narrow-Band Infrared Observations of the Red Stars

Observations in the narrow-band photometric system (102,65,62) are available for several of the red giants assigned to the group (Eggen 1967*a*; Eggen and Stokes 1970). The (102) magnitudes refer to about a 300 Å bandpass centered on a region free of TiO absorption at 10,200 Å, and the (102,65) color indices represent the difference between the radiation in this region and one of similar width centered on 6500 Å, which is also relatively free of TiO absorption. The (65,62) color indices include a measurement in a region of similar width centered on 6250 Å and containing a strong TiO bandhead.

The group members are shown in the $M(102)$, (102,65) plane in Figure 9. The values of $E(B-V)$ given in Table IV have been mainly derived from observations of early-type stars near the group members; $E(102,65)/E(B-V) = 1.25$.

In the $(M_{\text{bol}}, \log T_e)$ plane, because of the "funnel effect" on the evolutionary tracks of red giants with mass less than about $3M_{\odot}$, there is very little dispersion in the luminosities of the redder stars. The effect is shown in Figure 9 where the very tight relation between $M(102)$ and (102,65), previously derived for the stars in the young disk population Hyades group, is shown as a continuous curve (Eggen 1967*a*, 1969*e*). The relations for the globular clusters M 5, and M 92 (Eggen 1967*a*), ω Centauri, and 47 Tucanae (Eggen, unpublished) are also shown schematically. The Wolf 630 group members listed in Table IV are shown in Figure 9 as open circles. In general, the old disk stars are about $0^{\text{m}}5$ brighter than the young disk giants of the same color, with their sequence crossing that of the young disk objects near $(102,65) = -1^{\text{m}}3$ and joining it for stars redder than about $0^{\text{m}}0$. The reddest stars in the old disk population clusters M 67 (Eggen 1967*a*) and NGC 2477 (Eggen and Stoy 1961) are shown as a cross and a filled circle, respectively, in Figure 9. All stars with (102,65) redder than about $-0^{\text{m}}6$ are variable (Eggen 1969*f*); these include, in Figure 9, HD 8879 = R Sculptoris (a carbon star) and HD 84748 = R Leonis. The tightness of the relation

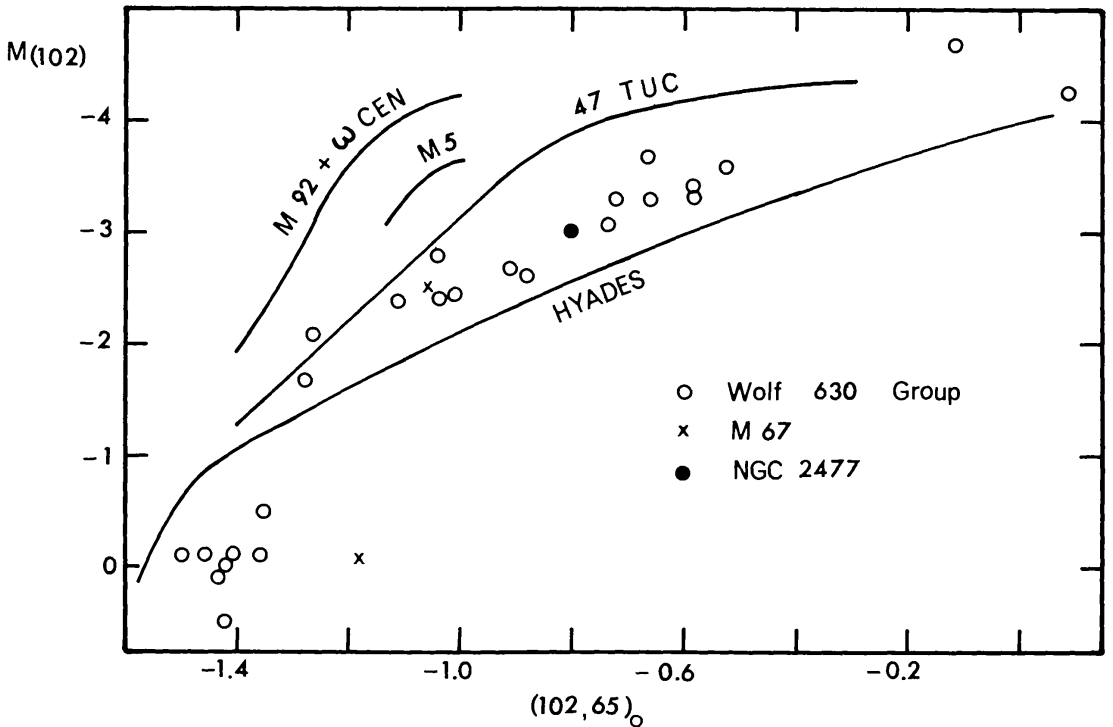


FIG. 9—The giants of the Wolf 630 group in the $M(102)$, $(102,65)$ plane, compared with young disk and halo stars.

between $M(102)$ and $(102,65)$ in Figure 9 is a sensitive test of group membership.

The relation between $(65,62)$ and $(102,65)$ previously derived for the young disk, Hyades group members (Eggen 1967*a*, 1969*e*) is shown as a continuous curve in Figure 10. This relation essentially measures the strength of the TiO absorption as a function of the continuum temperature. The few globular cluster stars shown in Figure 10 depart markedly from the relation for young disk-population stars and follow a blackbody relation (Eggen 1967*a*), as would be expected because of the lack of TiO in these objects. The Wolf 630 group stars, shown as open circles in Figure 10, do not obviously depart from the relation for young disk stars, at least in the range of temperatures discussed here.

The $(B-V)$ scale for the red giants collapses near $B-V = 1^m5$ (e.g., Eggen 1969*f*), but the $(U-B)$ remains a smoothly varying function of color temperature, $(102,65)$, for the reddest stars observed. A section of the $(U-B)$, $(102,65)$ relation for Hyades, young disk stars (Eggen 1969*c*) is shown as a continuous curve in Figure 11. The displacement from the Hyades relation for stars bluer than

TABLE IV
 NARROW-BAND INFRARED PHOTOMETRY OF RED GIANTS
 IN THE WOLF 630 GROUP

HD	(102)	(65,62)	(102,65)	$M(102)$	$E(B-V)$
1038	2.04	+0.485	-0.54	-3.4	3
5384	4.12	+0.365	-0.96	-2.4	4
8498	3.71	+0.445	-0.67	-3.3	4
8879	2.6V	+0.49	-0.13	-5.3	—
15652	3.99	+0.445	-0.68	-3.0	5
17829	4.12	+0.28	-1.24	-1.65	3
24706	4.78	+0.275	-1.33	-0.1	2
26846	3.74	+0.265	-1.38	-0.1	2
26967	2.74	+0.26	-1.42	0.0	1
30959	1.75	+0.61	+0.14	-4.3	20:
32831	3.32	+0.265	-1.33	-0.5	2
48217	3.33	+0.385	-0.88	-2.65	2
55383	1.95	+0.665	+0.15	-4.2	5
60341	4.64	+0.245	-1.45	-0.1	4
60522	2.04	+0.40	-0.88	-2.6	0
83618	2.51	+0.275	-1.245	-2.1	2
84542	3.62	+0.47	-0.63	-3.7	3
84748	-0.4V	+1.31	+2.24	-6.25	5
94237	4.67	+0.345	-1.00	-2.8	3
120033	4.51	+0.325	-1.08	-2.4	2
139254	4.82	+0.25	-1.45	-0.1	1
140301	5.27	+0.26	-1.38	+0.5	2
144542	3.93	+0.455	-0.65	-3.3	1
203638	4.38	+0.25	-1.40	+0.1	2
210066	3.43	+0.335	-1.035	-2.4	0
217701	3.94	+0.495	-0.515	-3.6	0
220652	2.56	+0.47	-0.56	-3.4	2

values of (102,65) near -1^m is a feature of old disk objects (Eggen 1969f) and, like the similar ultraviolet excess of the main-sequence stars, probably is a measure of the metal abundance. For stars redder than values of (102,65) near -0^m this displacement is not obvious. The Wolf 630 group members, shown in Figure 11 as open circles, indicate a mean ultraviolet excess of approximately 0^m ; but, as already mentioned in the case of the main-sequence stars, this displacement is not a critical test of group membership because from their motions these stars are old disk objects, regardless of their status as group members. The large ultraviolet excess of globular cluster giants is demonstrated in Figure 11 by members of the clusters M 92 and M 5 (Eggen 1967a).

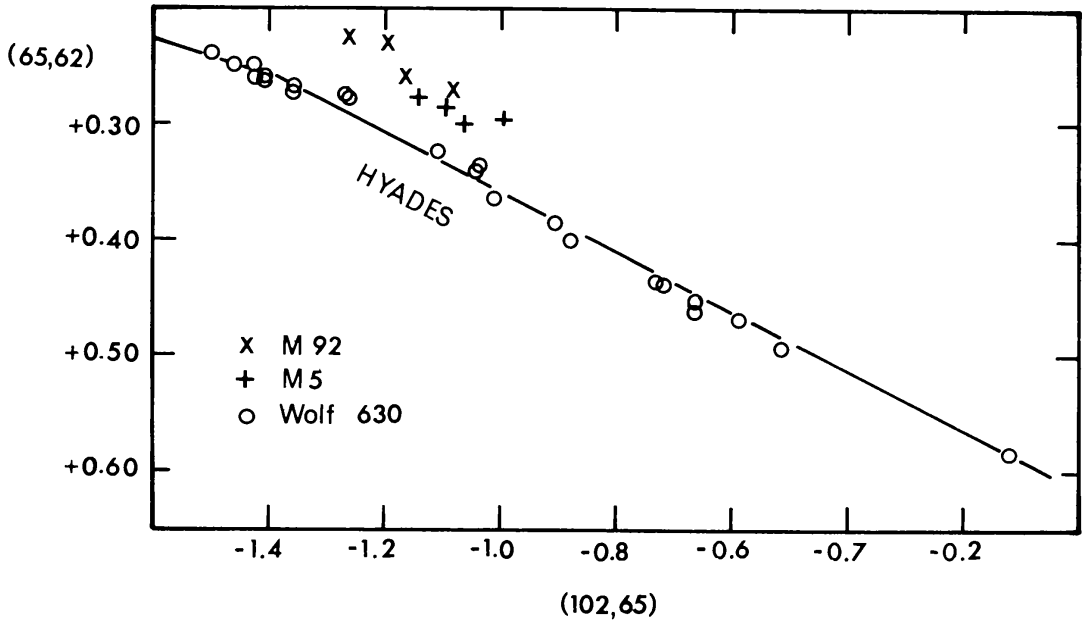


FIG. 10 — The giants of the Wolf 630 group in the (65,62), (102,65) plane compared with young disk and halo stars.

X. The 61 Cygni Group

The 61 Cygni group members have been selected in the same way as described above for the Wolf 630 group. The values of U lie between +80 and +100 km/sec with $V \equiv -53$ km/sec. The space motion is then nearly twice the size and roughly orthogonal in direction to that of the Wolf 630 group. The 61 Cygni group members are listed in Table V where the data, equivalent to that given in Table I for the Wolf 630 group, are also listed. The position of these stars in the $(M_V, B-V)$ plane is shown in Figure 12. The only essential differences between Figures 12 and 1 result from the fact that there are fewer members of the 61 Cygni group so that the subgiant sequence is less populated and the blue stragglers are missing.

XI. Broad-Band $(R-I)$ Observations of Group Members

Extensive observations in the $(R-I)$ system of Kron, Gascoigne, and White (1957; also Eggen 1968a) have been obtained for members of the Wolf 630 group as well as for the 61 Cygni group defined by the denoting star which has the large parallax of $0''.293$ (weight 87). These $(R-I)$ observations have been made with the original filters, kindly supplied by G. E. Kron.

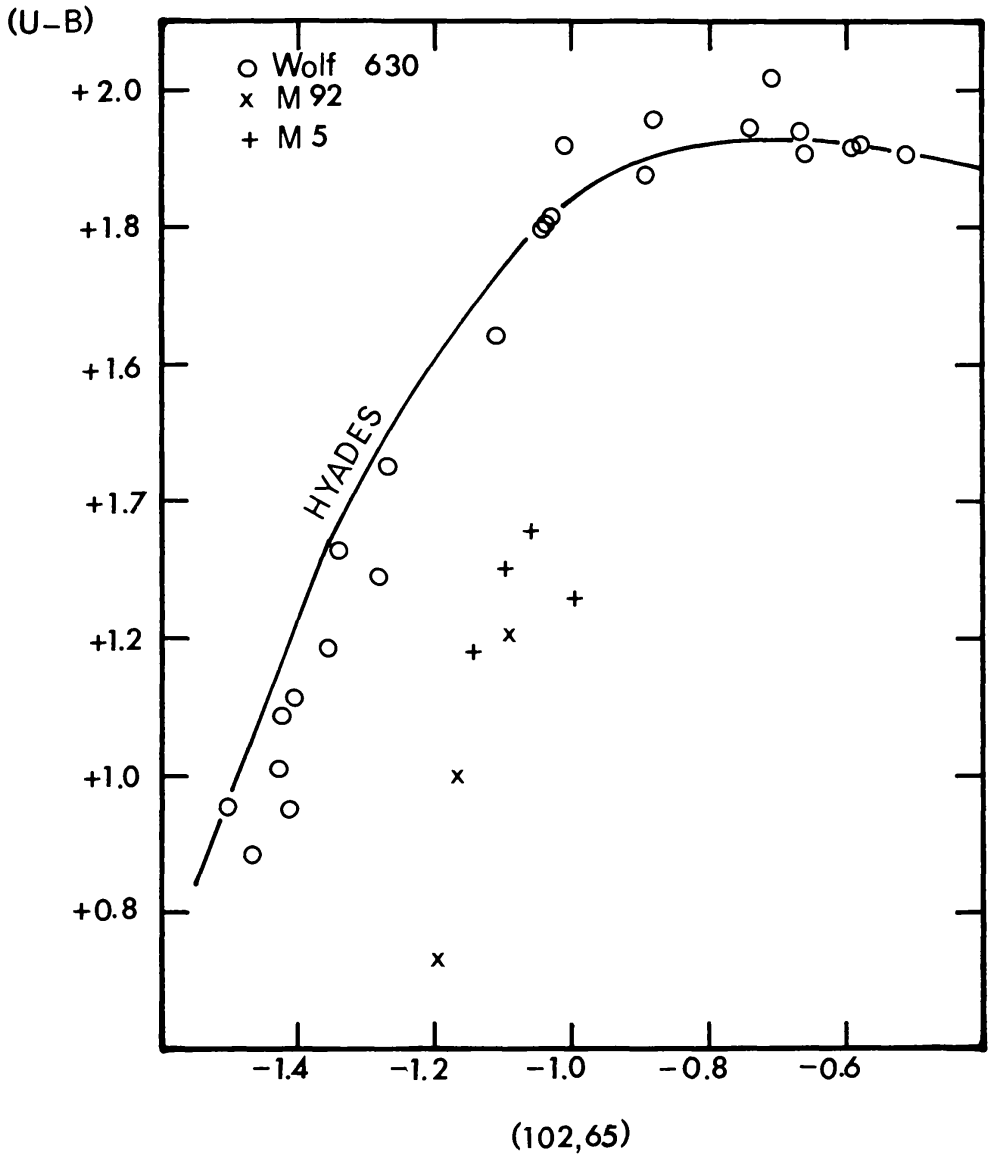


FIG. 11 — The giants of the Wolf 630 group in the $(U-B)$, $(120,65)$ plane compared with young disk and halo stars.

The available values of I and $(R-I)$ for the two old disk groups are listed in Tables VI (Wolf 630) and VII (61 Cygni) together with the number of observations; the southern stars were observed with the 40-inch reflector at Siding Spring and the northern with Mount Wilson and Palomar telescopes. The color indices and magnitudes for a few of the brighter and redder stars were transformed from observations in the $(102,65,62)$ system.

The group members are shown as open circles in the $(M_I, R-I)$ plane in Figures 13 (Wolf 630) and 14 (61 Cygni). The continuous

TABLE V
PROBABLE MEMBERS OF THE 61 CYGNI GROUP

HD	V_E	$B-V$	$U-B$	Sp.	M_V	U	V (km/sec)	W	X	Y (parsecs)	Z
142	5.69	+0 ^m .54	+0 ^m .03	G1 IV	+ 2.8	+ 88	-53	-18	- 12	- 10	- 35
1320	7.95	+0.66	+0.12	G5 IV-V	+ 4.6	+ 79	-53	-18	- 11	- 9	- 44
3443 AB*	5.60	+0.72	+0.24	G5 V	+ 5.4	+ 88	-53	-22	0	+ 1	- 15
5276	5.7V	+1.57	+1.77	gM5	- 1.7	+ 94	-53	+ 7	- 93	-147	-243
+31°719	11.02	+1.54	+1.08	dM4	+10.1	+ 98	-53	-11	+ 6	+ 11	- 8
5633	9.47	+1.32	—	K7 V	+ 8.0	+ 83	-53	-12	- 6	- 10	- 16
+63°137	8.98	+1.30	+1.21	K7 V	+ 8.3	+ 80	-53	+26	+ 8	+ 11	0
-11°220	9.21	+0.57	-0.02	F8	+ 8.3	+ 80	-53	+26	+ 8	+ 11	0
10145	7.66	+0.68	+0.21	G5 V	+ 4.9	+ 80	-53	-38	+ 16	+ 15	+ 70
10513	9.29	+0.70	+0.22	G5 V	+ 5.15	+ 97	-53	-17	+ 19	+ 25	+ 2
28183	6.14	+1.01	+0.74	K0 III	+ 4.7	+ 78	-53	+21	- 4	- 29	- 78
35783	7.69	+0.46	-0.02	F6 V	+ 1.85	+ 90	-53	-15	+ 63	+ 12	- 33
39091	5.64	+0.60	0.00	G3 IV	+ 3.25	+ 88	-53	- 9	+ 48	+ 48	+ 29
39425	3.10	+1.17	+1.21	K2 III	+ 4.05	+ 97	-53	+ 3	- 7	- 17	- 10
40460	6.59	+1.02	+0.84	K4 III	+ 0.75	+ 88	-53	-22	+ 13	- 23	- 13
50778	4.07	+1.42	+1.68	K4 III	- 0.2	+ 97	-53	-39	+180	- 10	+ 6
55526	5.14	+1.24	+1.42	K4 III	- 0.3	+ 78	-53	-54	+ 53	- 51	- 6
66171	8.20	+0.61	+1.30	K4	- 0.15	+ 90	-53	+ 5	+ 20	-108	- 34
72324°	6.93	+1.02	+0.05	G2 V	+ 5.05	+ 99	-53	- 9	+ 29	+ 22	+ 22
95272	4.09	+1.10	+0.88	G9 III	+ 0.75	+ 84	-53	-14	+138	- 51	+ 93
104216	6.20	+1.60	+0.99	K0 III	+ 0.8	+100	-53	+ 6	0	- 36	+ 27
106365 A	6.84	+1.15	+1.06	M2 III	- 1.15	+ 91	-53	+42	+134	+189	+169
B	8.77	+0.60	+0.07	K2 III } F9 V }	+ 0.45 } + 2.35 }	+ 84	-53	-24	+ 32	+ 2	+187
106849	4.1V	+1.58	+1.57	M5 III	- 0.8	+ 85	-53	-24	- 47	- 82	- 9
110313	7.87	+0.61	+0.08	dG1	+ 4.4	+ 90	-53	-13	+ 18	+ 27	+ 37
111884	5.92	+1.32	+1.40	K0	- 0.6	+100	-53	+ 9	-104	-166	+ 26
112943	9.80	+1.18	+1.15	dM0	+ 7.85	+ 81	-53	- 6	- 7	- 10	+ 21
116870	5.28	+1.53	+1.77	M0 III	- 0.7	+ 82	-53	-18	- 71	- 67	+114

TABLE V (Continued)

HD	V_E	$B-V$	$U-B$	Sp.	M_V	U	V (km/sec)	W	X	Y (parsecs)	Z
118767	5.2V	+1 ^m .60	+1 ^m .18	gM7	- 1.6	+ 89	-53	+32	-146	-169	+ 48
+34°2451	9.56	+1.28	+1.17	dM0	+ 7.6	+ 87	-53	- 1	- 5	+ 8	+ 23
128428	7.73	+0.72	+0.37	dG3	+ 3.8	+ 93	-53	+10	- 39	+ 10	+ 47
129245	6.26	+1.30	+1.46	K3 III	- 0.05	+ 95	-53	-33	+ 67	+129	+108
129902	6.03	+1.61	+1.93	gM1	- 1.5	+ 80	-53	- 3	-204	- 31	+250
130992	7.83	+1.00	+0.88	dK4	+ 6.6	+ 92	-53	-24	- 14	- 6	+ 9
131111	5.48	+1.02	+0.84	K0 III-IV	+ 1.25	+ 80	-53	-32	- 15	+ 28	+ 61
132142	7.76	+0.79	+0.33	K1 V	+ 6.0	+100	-53	+18	+ 2	+ 13	+ 18
137704	5.46	+1.40	+1.64	K4 III	- 0.45	+ 91	-53	+ 7	- 48	+ 69	+125
149324	4.23	+1.06	+0.96	K0 III	+ 0.75	+ 95	-53	+12	- 33	- 34	- 17
162756*	7.64	+0.62	+0.07	G2 V	+ 5.1	+100	-53	-25	- 19	+ 6	+ 3
188326	7.56	+0.78	+0.35	G8 IV	+ 3.7	+ 90	-53	+47	- 16	+ 56	+ 6
201091 A*	5.22	+1.18	+1.10	K5 V	+ 7.65	+ 91	-53	- 8	0	+ 3	0
B	6.05	+1.36	+1.23	K7 V	+ 8.5						
207692	6.88	+0.48	-0.03	F5 V	+ 2.95	+ 99	-53	-32	- 35	+ 18	- 45
210905	6.30	+1.12	+1.05	K0	+ 0.45	+ 97	-53	- 2	+ 35	+143	+ 6
216777	8.00	+0.62	+0.08	G6 V	+ 4.65	+ 99	-53	-33	- 12	+ 23	- 39
219409	6.52	+1.08	-	K1 III	+ 0.9	+ 98	-53	+ 8	- 45	+ 16	-124
224186	6.39	+1 ^m .56	+1 ^m .75	gM4	- 0.65	+ 89	-53	-37	+ 42	+174	-183

NOTES TO TABLE V

- 3443 ADS 520.
- 72324 Strong CN.
- 162756 ADS 10858, $\Delta m = 3^m 5, 1''$.
- 201091 61 Cygni.
- 216777 $V_E = 16.50, B-V = +0.42, U-B = -0.46; C.p.m.$ white dwarf.

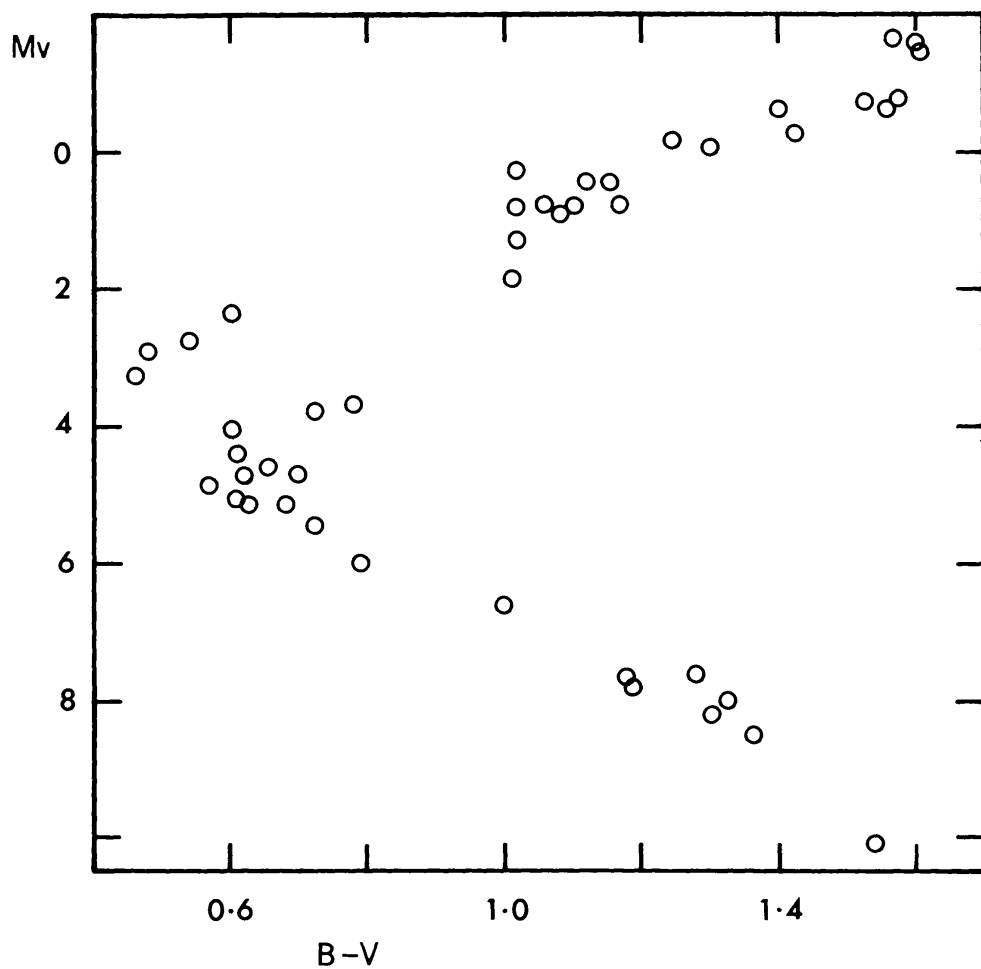


FIG. 12 — The color-luminosity array for the 61 Cygni group.

TABLE VI
MAGNITUDES AND COLOR INDICES OF STARS IN THE
WOLF 630 GROUP ON THE KRON ($R-I$) SYSTEM

HD	I	$R-I$	n	M_I
1038	2 ^m 4	+0 ^m 87	2	-3 ^m 0
4188	4.00	+0.37	1	-0.6
4256	7.18	+0.355	2	+5.9
5384	4.43	+0.64	2	-2.0
5395	3.72	+0.37	1	+1.9
6378	8.67	+0.485	2	+6.4
6660	7.28	+0.435	2	+5.9
8498	4.11	+0.84	2	-2.8

TABLE VI (*Continued*)

HD	<i>I</i>	<i>R-I</i>	<i>n</i>	<i>M_I</i>
15652	4 ^m 40	+0 ^m 84	2	-2 ^m 6
17829	4.37	+0.49	2	-1.5
18322	2.88	+0.43	1	-0.5
24706	5.02	+0.445	2	-0.4
26846	3.96	+0.42	2	0.0
26967	2.96	+0.40	2	+0.2
30959	2.31	+1.22	2	-4.1
48217	3.66	+0.685	2	-2.3
49878	3.24	+0.53	1	-1.8
55383	2.52	+1.24	2	-3.7
60341	4.84	+0.38	2	+0.1
60522	2.38	+0.685	2	-2.3
83618	2.76	+0.49	2	-1.8
84542	4.01	+0.815	2	-3.3
84748	0.6V	+2.35	5	-5.3
94237	4.98	+0.62	2	-2.45
94264	2.83	+0.40	1	+0.6
+38°2457	8.88	+0.445	2	+5.9
124850	3.62	+0.185	1	+2.0
126660	3.46	+0.17	1	+2.5
131923	5.94	+0.22	2	+4.8
132863	8.16	+0.64	2	+6.65
136366	5.26	+0.385	2	-0.45
136514	4.30	+0.435	2	+0.3
139254	5.02	+0.38	2	+0.1
140301	5.49	+0.42	2	+0.7
144542	4.32	+0.81	2	-2.9
147776	7.59	+0.345	2	+5.8
148513	4.02	+0.555	2	-2.0
152751 AB	6.68	+1.08	Std	+8.45
C	9.14	+1.21	Std	+10.1
154962	5.88	+0.215	2	+2.4
+29°3029 AB	7.87	+0.48	3	+5.85
161797 A	2.88	+0.24	Std	+3.1
BC	7.35	+1.10	Std	+8.3
165135	2.14	+0.37	1	-0.65

TABLE VI (*Continued*)

HD	I	$R-I$	n	M_I
166620	5 ^m 52	+0 ^m 34	Std	+4 ^m 9
170525	5.91	+0.24	2	+2.4
181122	5.45	+0.37	2	-1.3
188268 A	8.04	+0.305	2	+4.95
B	8.14	+0.31	2	+5.05
188807	7.90	+0.555	3	+7.05
188887	4.31	+0.415	2	-0.6
193307	5.89	+0.19	2	+4.2
197635	4.52	+0.375	2	-0.5
200790	5.52	+0.18	2	+2.5
203040	7.70	+0.60	2	+7.15
203638	4.60	+0.41	2	+0.35
+22°4409	8.15	+0.505	2	+6.15
206276	7.80	+0.425	2	+5.95
206301	4.60	+0.24	2	+2.5
210066	3.72	+0.60	2	-2.1
215104	4.00	+0.36	2	-0.3
215648	3.75	+0.21	1	+2.6
217096	5.75	+0.18	2	+1.65
217459	4.60	+0.505	2	-1.2
218356	4.53	+0.51	1	-2.5
220652	2.96	+0.85	2	-3.0

curve in Figure 13 represents the Hyades cluster main-sequence stars (Eggen 1969g) and that in Figure 14 represents the red giants in the Hyades group (Eggen 1969e). The slight displacement of group giants from the Hyades sequence is a reflection of the effect already noted in the $M(102)$, $(102,65)$ plane of Figure 9. The $(R-I)$ color indices, at least for small abundance differences, are essentially free of abundance effects so that the agreement between the Hyades and group main sequences is not affected by the difference in metal abundance between the group and Hyades stars. However, the bluest main-sequence stars in the group are obviously displaced from the Hyades main sequence by evolutionary effects. The abrupt change in the form of the main sequence for old disk stars near

TABLE VII
MAGNITUDES AND COLOR INDICES OF MEMBERS OF THE
61 CYGNI GROUP ON THE KRON ($R-I$) SYSTEM

HD	I	$R-I$	n	M_I
3443	5 ^m 06	+0 ^m 27	2	+4 ^m 85
5276	2.90	+1.40	2	-4.5
5633	8.12	+0.55	3	+6.65
+63°137	7.59	+0.565	2	+6.9
10513	8.45	+0.28	3	+3.85
39425	2.15	+0.40	2	-0.2
50778	2.69	+0.58	2	-1.7
55526	4.08	+0.47	2	-1.2
95272	3.08	+0.40	1	-0.2
104216	3.94	+1.04	2	-3.4
106849	1.24	+1.40	2	-3.7
111884	4.85	+0.495	2	-0.65
112943	8.57	+0.495	2	+6.6
116870	3.78	+0.66	2	-2.2
118767	2.34	+1.96	2	-4.5
+34°2451	8.27	+0.535	2	+6.3
128428	7.28	+0.235	2	+3.4
129902	4.23	+0.85	2	-3.3
130992	7.02	+0.355	3	+5.8
149324	3.40	+0.375	2	-0.25
201091 A	4.13	+0.465	Std	+6.6
B	4.66	+0.595	Std	+7.1
216777	7.48	+0.235	3	+4.4

($R-I$) = +1^m2 was discussed elsewhere on the basis of more extensive data (Eggen 1968*a*). This change is shown in Figure 13 by only one star, Wolf 629, which is redder than the termination ("Kelvin") point of the lower Hyades main sequence (Eggen 1969*g*).

Extensive observations on the ($R-I$) system have also been obtained for the brighter stars in M 67 with the 40-inch reflector at Siding Spring. The results are listed in Table VIII where the identifications are those of Johnson and Sandage (1955); Eggen and Sandage (1964); and, for the last four stars, Murray and Clements (1968). After correcting for $E(R-I) = 0.7 E(B-V) = +0^m04$, the values of ($R-I$)₀ and $I - 9^m38 = M_I$ are plotted in Figure 14. The

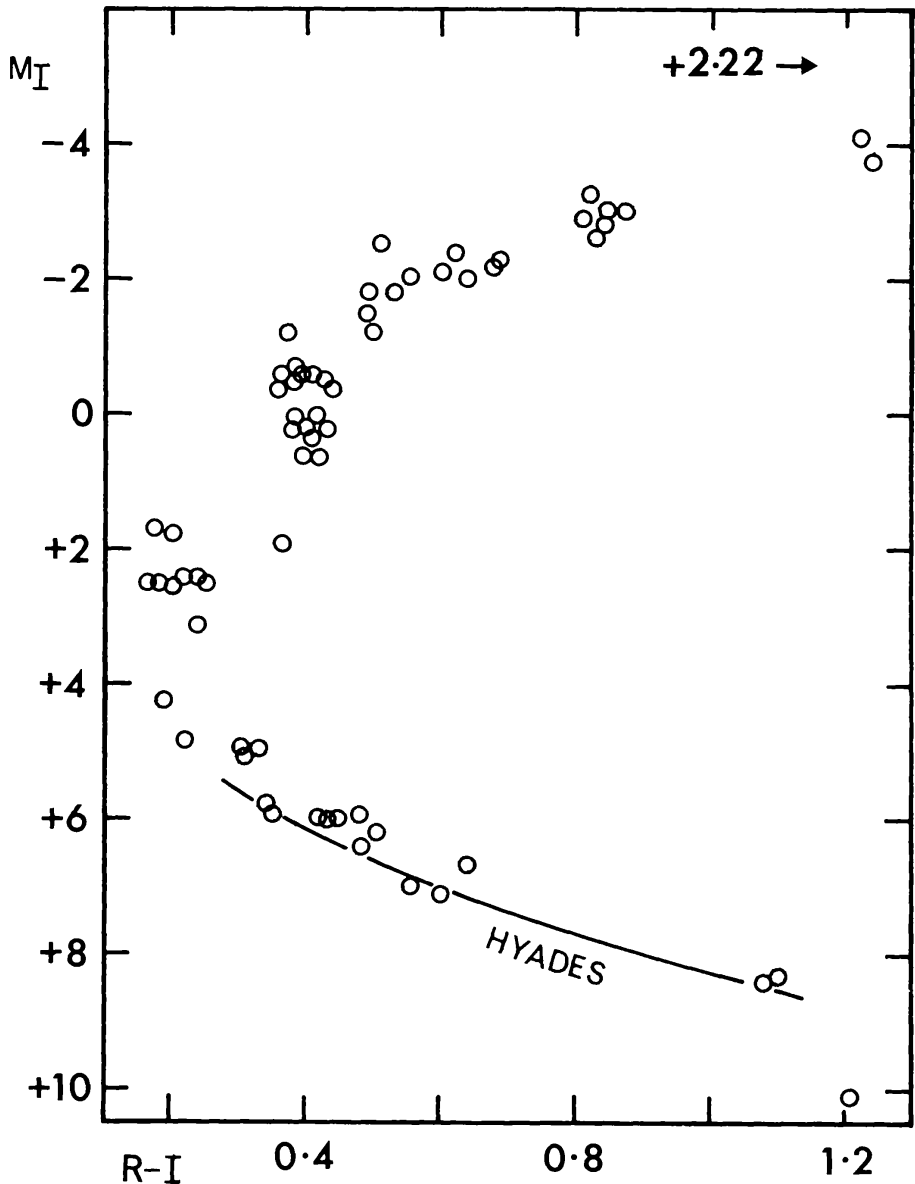


FIG. 13—The distribution of the Wolf 630 group members in the $M_I, (R-I)$ plane.

color-luminosity arrays for the two groups and for the cluster M 67 are remarkably similar.

The color-luminosity arrays in Figures 13 and 14 are essentially $M_{\text{bol}}, \log T_e$ diagrams. The values of M_I are transformed to M_{bol} over nearly the whole temperature range here discussed by the relation $M_{\text{bol}} = M_I + 1^m$ (Eggen 1969*e*). This simple relation is derived from the near identity of the bolometric corrections obtained by Johnson (1966) from observations in the far infrared and

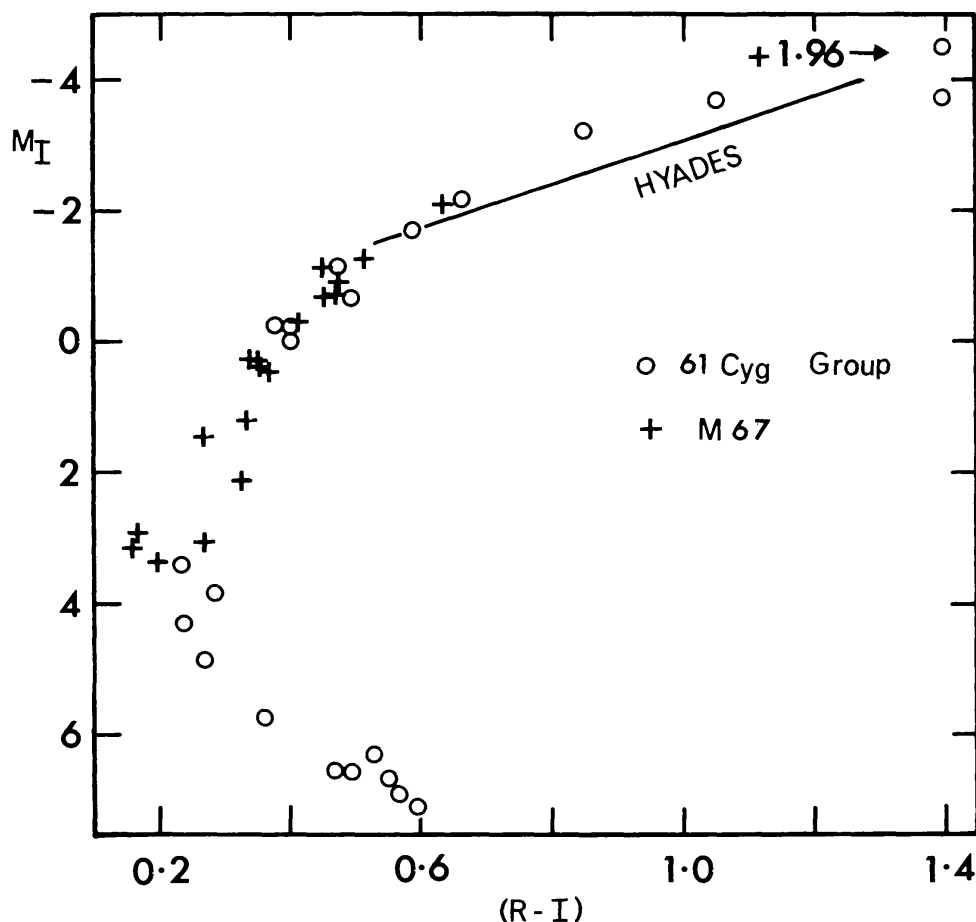


FIG. 14—The distribution of the 61 Cygni group members, and giants and subgiants of the cluster M 67 in the $M_I, (R-I)$ plane.

the values of $(V-I_J) + 1^m$. The I scales of Johnson and of Kron *et al.* are so nearly the same that this simple transformation can also be applied to the values of M_I used here. The $(R-I)$ temperature scale has been extensively discussed by Johnson (1966) and by Brooke (1969). For this purpose, the color indices $(R-I)_K$ and $(R-I)_J$ are related by $(R-I)_K = 0.79(R-I)_J - 0^m03$ in the color range J_1 discussed here.

XII. Masses of Group Binaries

Four members of the Wolf 630 group, and one of the 61 Cygni group, are short-period, visual binaries with well-determined orbital elements. These systems are listed in Table IX with the mean mass of the nearly equal components derived from the orbital elements and the group parallax. The observed masses are compared with those predicted from the “Sun-Sirius” mass-luminosity relation

TABLE VIII
GIANTS AND SUBGIANTS IN M 67

No.	I	$(R-I)_K$	N
84	9 ^m 63	+0 ^m 375	2
105	9.24	+0.46	5
108	8.47	+0.51	5
132	12.84	+0.235	2
135	10.58	+0.37	2
141	9.59	+0.395	4
143	10.82	+0.305	3
151	9.66	+0.39	3
170	8.52	+0.51	5
193	11.43	+0.37	4
224	9.84	+0.415	3
227	12.44	+0.305	2
241	12.45	+0.20	2
255	12.32	+0.20	2
T-856*	8.67	+0.49	3
T-829*	8.33	+0.49	4
4-202*	7.27	+0.67	3
T-626*	8.09	+0.55	3

NOTES TO TABLE VIII

T-829 = +12°1913
 T-856 = +12°1917
 4-202 = +12°1919
 T-626 = +12°1924

(Eggen 1965*b*, Table VII). The agreement is satisfactory except, perhaps, for the two faintest stars which represent a slight extrapolation of the mass-luminosity relation derived from accurate data. In fact, these two systems have large trigonometric parallaxes, and their deviation from the extrapolated mass-luminosity relation can be used to correct that relation.

Perhaps the most interesting pair is ADS 1158 (= HD 8875) in the Wolf 630 group. The equal components are evolved, and lie about 1^m2 above the main sequence. The main-sequence luminosity

TABLE IX
MASSES OF GROUP BINARIES

ADS*	P yrs.	a	π (group)	Mean Mass		M_V	Group
				Obs.	Pred.		
520	25.0	0".670	0".064	0.95 \odot	0.90 \odot	+ 5 ^m .4	61 Cyg
1158	63.8	0.311	0.015	1.1	1.3	+ 3.7	W 630
Wolf 630	1.714	0.201	0.155	0.37	0.27	+10.7	W 630
10585	62.04	0.60	0.039	0.47	0.52	+ 7.7	W 630
10786	43.02	1.287	0.110	0.40	0.28	+10.8	W 630

*References

- 520 Van den Bos, *Union Obs. Circ.* **98**, 342, 1937.
- 1158 Van den Bos, *Union Obs. Circ.* **109**, 366, 1950.
- Wolf 630 Wieth-Knudsen, *Lund. Ann.* **12**, 1953; Eggen, *A.J.* **70**, 19, 1965.
- 10585 Eggen, *Ann. Rev. Astr. Astroph.*, **3**, 1965.
- 10786 Silbernagel, *Astr. Nachr.* **233**, 257, 1928.

then predicts one solar mass, compared to the observed value of $1.1 M_{\odot}$. The old disk giants in the $M(102)$, $(102,65)$ plane of Figure 9 then represent stars of one solar mass, whereas the young disk, Hyades stars have masses near three M_{\odot} (cf., Sandage 1957).

XIII. Group Stars of Particular Interest

Two possible group members, not listed in Table I, are variable stars of special interest; they are SW Andromedae and R Coronae Borealis. Data pertaining to them are listed in Table X.

The RR Lyrae variable SW And represents a small group of stars that from the light curves alone are indistinguishable from the variables of the halo population but which metal abundance indicators (Preston 1959; $\Delta S = 0$; Sturch 1966; McNamara and Langford 1969) show to be strong-lined stars. Because none of these objects has been identified with clusters their origin is a mystery, although a reasonable assumption has been that they are associated with the old disk population. This assumption is borne out by the space motions of several of these variables, even when the assumed luminosity is taken to be that of halo variables, $M_V = +0^m5$. Space motions computed on the basis of this assumption are given in Table XI for three of the variables of this small group. Membership of SW And in the Wolf 630 group gives $M_V = +2^m0$. The median observed magnitudes and color indices, listed in Table X, are from Fitch, Wisniewski, and Johnson (1966). The resulting position of SW And in the color luminosity array of the Wolf 630 group is shown in Figure 3.

The peculiar variable R CrB may represent a transitional evolutionary stage and, because of the scarcity of similar stars, this stage may be a relatively rapid one. The luminosity derived from the group parallax is -3^m1 , which is about a magnitude fainter than many previous estimates. However, many of these estimates have been derived from equating the variable to the young disk population supergiants, but the space motion for any reasonable luminosity indicates that this is an old disk population object. Searle (1961) finds a carbon/iron ratio in R CrB that is 25 times larger than in the young disk supergiant δ Canis Majoris. He speculates that the variable may have formed from a star somewhat more massive than the sun, with an old disk-population composition, which has consumed almost all of its hydrogen.

TABLE X
TWO POSSIBLE GROUP STARS OF PARTICULAR INTEREST

	SW And	R CrB
P	0 ^d 44	Irr
V	9 ^m 75 (med.)	5 ^m 60 (max)
$(B-V)$	+0.41	+0.60
$(U-B)$	+0.20	—
M_V	+2.0	-3.1
Sp	F _{var.}	cFpe
15 $\mu_\alpha \cos \delta$	0''000	-0''011
μ_δ	-0.023	-0.018
ρ	-21.8	+24.8 km/sec
U	-22	-40
V	-33	-33
W	-21	-29
$E(B-V)$	+0 ^m 03	+0 ^m 07

TABLE XI
SPACE MOTIONS OF THREE VARIABLE STARS

Variable	P	ΔS	U	V	W
TZ Aur	0.39	2	+56	-83	-44
DM Cyg	0.42	0	+56	-45	-3
TW Her	0.40	2	-21	-19	-52

From the discussion of the visual binaries, given above, it is certain that the giants in the Wolf 630 group have masses between 1 and 1.5 M_\odot . Another group member, HD 218356 in Table I, may be a precursor of such stars. Roman (1952) classifies the spectra of this object as K0 IIp and states, "The hydrogen lines are too weak for the strength of Sr II and CN."

The reddest stars in the group include some interesting variable stars. The variable R Scl = HD 8879 in Table IV is not listed in Table I. The maximum magnitude is $V_E = 5^m7$ and $(B-V) = +3.8$; spectral type is N3p. The group parallax gives a luminosity of $M_V = -2^m2$, $(U, V, W) = (-38, -33, +11)$, and $(X, Y, Z) = (+21, -58, -353)$. Although strong carbon bands cause a very red

TABLE XII
MAJOR GROUPS OF OLD DISK POPULATION STARS

Group*	U	V	$\delta(U-B)$	C-L	SPECIAL INTEREST
W 630	- 10, -40	-33	+0 ^m 06	M 67	Blue stragglers, R CrB, red variables and carbon stars, SW And, contact binaries
61 Cyg	+100, +80	-53	+0.06	M 67	Red variables, white dwarfs
η Cep	+ 25, +45	-97	+0.07	M 67	UW Vir (eclipsing), CY Aqr (0 ^s 06)
σ Pup	+ 55, +85	-80	+0.15	47 Tuc?	Oldest disk population?
					Red variables, DY Peg (0 ^s 07)

*References

- W 630 This paper and Eggen 1965c.
 61 Cyg This paper and Eggen 1962, 1964a, 1965a, and *Obs.* 79, 135.
 η Cep Eggen 1964a.
 σ Pup Eggen 1964b.

$(B-V)$, the narrowband (102,65) color index indicates a color temperature between that of HD 1038 ($(B-V) = +1^m61$) and HD 55383 ($(B-V) = +1^m66$). However the value of $M(102) = -5^m3$ is, with the exception of HD 84748 = R Leo ($M(102) = 6^m25$), the highest in the group. Both R Leo and R Scl have mean periods somewhat greater than 300 days. HD 30595 (4 Orionis) is also of interest as intermediate between the S- and M-type stars. Keenan (1954) assigns the type M3S.

All of the blue stragglers are of interest, but the brightest examples, with the most extensive spectroscopic or photometric histories, are HD 85376 (22 Leonis) of type A5 V; HD 104350 (AG Virginis), a contact binary with a period of 0^d64 (Eggen 1967*b*); HD 149822 (HR 6176), which has the largest Si/H ratio of the Ap stars studied by Searle and Sargent (1964); and HD 201601 (γ Equulei, an Fp star with a fluctuating magnetic field (Babcock 1958). Two of the fainter blue stragglers are very near the south galactic pole (Wayman 1961), HD 7908 (A7 III) and 9411 (F0 V).

XIV. Dynamics of the Group Stars

In computing the space motions of the group members there are at least two sources of uncertainty that need examination.

1. The values of (U, V, W) are all referred to a reference frame centered on the sun with the $U(X)$ axis directed away from the galactic center. The method of determining group parallaxes by forcing the value of V to -33 km/sec, in the case of the Wolf 630 group, assumes that all values of V refer to this frame. However a star at $Y = \pm 1$ kpc will have $V = -33$ km/sec in a reference frame that is tilted about 6° with respect to the $U(X)$ axis at that point and relative to the galactic center this velocity will be 2 or 3 km/sec different from the same velocity at the sun. However, within the horizon imposed by the need for accurate proper motions, this correction need only be considered in exceptional cases.

2. The proper motions used are on the system of the N30 Catalog which, like all fundamental systems, depends on a conventional value of the constant of precession, which constant in turn is strongly suspect (e.g., Wayman 1966). The uncertainty may be $0''.4$ /century in the proper motion system which, at 1 kpc, introduces nearly 20 km/sec uncertainty into the space motion. The entire uncertainty will be fully introduced into the V velocity only in very special

regions of the sky, but nevertheless it must be recognized when considering the most distant objects.

The range of about 20 km/sec in the U velocities of most stellar groups means that the group membership includes stars with an appreciable difference in their orbital characteristics. If we adopt $U' = -15$ and $V' = +14$ km/sec as the motion of the sun with respect to the local standard of rest (Eggen 1969a), the range in U from about -10 to -30 km/sec for the members of the Wolf 630 group corresponds to apogalactic and perigalactic distances of (11.0, 8.1) and (10.4, 7.8) kps, respectively. This focusing effect puts the same stars in approximately the same volume of space they now occupy roughly every 1.8×10^8 years.

XV. Summary of Old Disk-Population Groups

Although nearly a dozen groups of old disk-population objects have been noted, several of these contain relatively few members. The major groups are the four listed in Table XII which also contains the approximate range in the U velocities, and V velocity of the defining star, and the ultraviolet excess for main-sequence stars near the turn-off point. The form of the color-luminosity array (C-L) is that of M 67 for all groups except that containing σ Puppis which is more nearly like the globular cluster 47 Tucanae. The last column of Table XII contains a summary of the most interesting group members. Detailed knowledge of some of these objects, and of the evolutionary phases they represent, can only be obtained from their group membership.

REFERENCES

- Adams, W. S., Joy, A. H., Humason, M. L., and Brayton, A. M. 1935, *Ap. J.* **81**, 187.
 Babcock, H. W. 1958, *Ap. J. Suppl.* **3**, 141.
 Blaauw, A. 1963, in *Basic Astronomical Data*, K. Aa. Strand, ed. (Chicago: University of Chicago Press), chap. 20.
 Brooke, A. 1969, Thesis, The Australian National University.
 Clube, S. V. M. 1967, *M.N.R.A.S.* **137**, 189.
 Eggen, O. J. 1958, *M.N.R.A.S.* **118**, 154.
 — 1960, *M.N.R.A.S.* **120**, 430.
 — 1961, *Roy. Obs. Bull.* No. 41.
 — 1962, *Roy. Obs. Bull.* No. 51.
 — 1964a, *Roy. Obs. Bull.* No. 84.
 — 1964b, *A.J.* **69**, 570.
 — 1965a, in *Galactic Structure*, A. Blaauw and M. Schmidt, eds. (Chicago: University of Chicago Press), chap. 6.

- 1965b, *The Observatory* **85**, 191.
— 1965c, *A.J.* **70**, 19.
— 1966a, *Roy. Obs. Bull.* No. 125.
— 1966b, *Roy. Obs. Bull.* No. 120.
— 1967a, *Ap. J. Suppl.* **14**, 307.
— 1967b, *Mem. R.A.S.* **70**, 111.
— 1968a, *Ap. J. Suppl.* **16**, 49.
— 1968b, *Ap. J.* **153**, 723.
— 1969a, *Ap. J.* **155**, 701.
— 1969b, *Vistas in Astronomy*, A. Beer, ed. (in press).
— 1969c, *Ap. J.* **156**, 241.
— 1969d, *Pub. A.S.P.* **81** (in press).
— 1969e, *Ap. J.* (in press).
— 1969f, *I.A.U. Inf. Bull. Var. Stars*, No. 355.
— 1969g, *Ap. J.* (in press).
Eggen, O. J., Lynden-Bell, D., and Sandage, A. R. 1962, *Ap. J.* **136**, 748.
Eggen, O. J., and Sandage, A. R. 1964, *Ap. J.* **140**, 130.
Eggen, O. J., and Stokes, N. R. 1970, *Ap. J. Suppl.* (in press).
Eggen, O. J., and Stoy, R. H. 1961, *Roy. Obs. Bull.* No. 24.
Fitch, W. S., Wisniewski, W. Z., and Johnson, H. L. 1966, *Pub. Lunar and Planetary Lab.* **5**, (No. 71).
Johnson, H. L. 1966, *Annual Rev. of Astr. and Astrophysics* **4**, 193.
Johnson, H. L., and Sandage, A. R. 1955, *Ap. J.* **121**, 616.
Keenan, P. C. 1954, *Ap. J.* **120**, 484.
Kron, G. E., Gascoigne, S. C. B., and White, H. S. 1957, *A.J.* **62**, 205.
Luyten, W. J. 1963, "Bruce Proper Motion Survey," *Pub. Minnesota Astr. Obs.* **2**, (No. 15).
McNamara, D. H., and Langford, W. R. 1969, *Pub. A.S.P.* **81**, 141.
Murray, C. A., and Clements, E. D. 1968, *Roy. Obs. Bull.* No. 139.
Oort, J. H. 1932, *B.A.N.* **6**, 249.
Preston, G. W. 1959, *Ap. J.* **130**, 507.
Rhijn, P. J. van 1939, *Pub. Kapteyn Astr. Lab.* No. 49.
Roman, N. G. 1952, *Ap. J.* **116**, 122.
Russell, H. N., and Moore, C. E. 1940, *Ap. J.* **92**, 354.
Sandage, A. R., 1957, *Ap. J.* **125**, 435.
Sandage, A. R., and Eggen, O. J. 1959, *M.N.R.A.S.* **119**, 278.
Searle, L. 1961, *Ap. J.* **133**, 531.
Searle, L., and Sargent, W. L. W. 1964, *Ap. J.* **139**, 793.
Sturch, C. 1966, *Ap. J.* **143**, 774.
Wayman, P. A. 1961, *Roy. Obs. Bull.* No. 36.
— 1966, *Quart. J.R.A.S.* **7**, 138.
Wilson, O. C., and Bappu, V. 1957, *Ap. J.* **125**, 661.
Woolley, R. v. d. R. 1957, *M.N.R.A.S.* **117**, 198.