

THE ζ HERCULIS, σ PUPPIS, ϵ INDI, AND η CEPHEI GROUPS OF OLD DISK POPULATION STARS

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In the light of a previous discussion of two large groups (Wolf 630 and 61 Cygni) of old disk population stars, the possible members of four smaller groups, which had been isolated by various means, were subjected to the same analysis. Stars rejected from these groups on the basis of data now available are listed and (*UBVRI*) photometry of the remaining, as well as many new, members is discussed. (*R, I*) results are also presented for the subgiant and giant members of several old disk population clusters. The resulting color-luminosity arrays are very similar to those for the Wolf 630 and 61 Cyg groups although some variation in the giant branches is noted. The major revision of previous results is in the changed *V* velocity for the σ Puppis group, which removes the anomalous color-luminosity array previously found, although this group still contains stars with ultraviolet excesses larger than those known for any other disk group or cluster. A comparison between the group and *H* and *K* emission width luminosities suggests that either a half dozen stars now assigned to the groups are nonmembers or that systematic errors may arise in the values of $M_V(K)$ for old disk stars on the vertical subgiant branch in the (M_{bol} , $R-I$) plane. A close correlation is found between the values of $M_V(\text{Group}) - M_V(K)$ and ($R-I$) for several of the group members. The red variables in these groups are very similar to those in the Wolf 630 and 61 Cyg groups and the one variable in the old disk cluster NGC 6940.

Key words: disk population stars — space motions — photometry

I. Introduction

The probable members of two large groups of old disk objects (Wolf 630 and 61 Cygni groups) have been discussed elsewhere (Eggen 1969*a*). These probable members were selected from stars for which available luminosity estimates indicated values of (*U, V*) near $(-25 \pm 15, -33)$ for the Wolf 630 group and $(+80 \pm 15, -53)$ for the 61 Cyg group. The spread of *U* values is based on the observed range of 20 km/sec found for the Hyades group members. In practice the actual range of *U* for both the Wolf 630 group and 61 Cyg group was also found to be 20 km/sec, but there was no a priori knowledge as to where the *U* velocity of the defining star lies in this range. The groups discussed here were previously isolated in several ways, ranging from the application of a modified convergent point analysis, to the appearance of clumps in the (*U, V*) distributions of stellar samples for which relatively accurate luminosity estimates were available. A fifth group, associated with the old disk binary γ Leonis, will be discussed

separately. The members of this group, which were originally isolated on the basis of relatively accurate luminosity estimates for subgiants, are spatially distributed in such a way that the *V* velocities for the majority of the objects are little dependent on the proper motions and the normal method of determining group parallaxes is ineffective (Eggen 1959).

The remaining four groups are discussed below. The lists of possible members are taken from the following sources: ζ Herculis group (Eggen 1960, Table III); ϵ Indi group (Eggen 1958, Table II); η Cephei group (Eggen 1964*a*, Table G); and σ Puppis group (Eggen 1970*a*, but written in 1966). Each of the groups contains one or more blue stragglers but these have been omitted from the present discussion because of the emphasis on photometric observations in the near infrared. These blue stragglers, some of which are variable, will be discussed elsewhere (cf. Eggen 1970*c*). Improved data, mainly concerning the apparent motions, have eliminated several stars as group members and these are

TABLE I
STARS ORIGINALLY ASSIGNED TO THE GROUPS BUT NOT DISCUSSED HERE

Nonmembers		Insufficient Photometry	
Name	Group	Name	Group
+25°5073	σ Pup		
+20°363	σ Pup	+29°366	σ Pup
-23°2363	σ Pup	+65°737	σ Pup
81192	σ Pup	127339	σ Pup
84406	σ Pup	134585	σ Pup
102158	σ Pup	158226	σ Pup
107773	σ Pup	219953	σ Pup
119425	σ Pup		
211998	σ Pup	4075	ζ Her
		68788	ζ Her
25728	ζ Her	129245	ζ Her
98824	ζ Her	221354	ζ Her
100733	ζ Her		
136422	ζ Her	Little dependence of V on μ	
76830	η Cep		
92588	η Cep	55720	σ Pup
103500	η Cep		
146800	η Cep	70523	ζ Her
210918	η Cep	71377	ζ Her
		166207	ζ Her
39853	ε Ind		
96190	ε Ind		
112758	ε Ind		
135101	ε Ind		
137704	ε Ind		
148704	ε Ind		

listed in Table I. Also in Table I are a few stars for which appropriate photometry, mainly the (R, I) results, are not yet available. The V velocities of three stars originally assigned to the ζ Her group, and one to the σ Pup group, are so little dependent upon the proper motion that group parallaxes cannot be derived. These stars are listed at the end of Table I. In addition to the originally assigned group members that are still regarded as probable members, Tables II (ζ Her group), III (σ Pup group), IV (ϵ Ind group), and V (η Cep group) also contain new members, indicated by double asterisks after the HD number; $(UBVRI)$ photometry, where R and I are on the Kron system (Kron, Gascoigne, and White 1957; Eggen 1968*a*, 1971*a*); the modulus $(m-M)$ and bolometric luminosity resulting from the group parallax, where the bolometric luminosity is derived from $M(I_J) + 1^m$ (Eggen 1969*b*) and the conversion between the $(R, I)_K$ to $(R, I)_J$ systems is based on the following relations

$$\begin{aligned} R_K &= R_J + 0^m38 & (R-I)_K > +0^m4 \\ R_K &= R_J + 0^m18 + 0.5(R-I)_K & (R-I)_K < +0^m4 \\ (R-I)_K &= 0.80(R-I)_J - 0^m05 & ; \end{aligned}$$

the values of (U, V, W) and their change, (dU, dV, dW) , for a 100 parsec increase in the assumed distance; and the spectral type, mainly selected from the catalog of MK spectral types (Jaschek, Conde, and de Sierra 1964) or more recent publication by the Cape observers, and the mean trigonometric parallaxes with their total weight in parentheses. All parallaxes and their weights are on the system of the *General Catalogue of Trigonometric Stellar Parallaxes*. The (UBV) observations have been determined in several programs over many years. The (R, I) observations were mainly obtained with the Mount Wilson and Palomar Observatories' facilities or with the 40-inch reflector at Siding Spring Observatory. In a few cases, as

TABLE II
 ζ HERCULIS GROUP

HD Name	V_E R	$B-V$ $R-I$	$U-B$ $N, \bar{N}$	M_{bol} $m-M$	U dU	V dV	W dW	Sp. T. π_t (wt.) (0''001)
					km/sec			
1187** HR57	5. ^m 66 5.09	+1. ^m 35 +0.51	+1. ^m 50 2,5	-0. ^m 1 5.14	+ 49 + 49	- 47 - 44	- 34 - 8	K5 III -
2151 β Hyi	2.78 2.57	+0.61 +0.23	+0.10 2,2	+3.6 -0.65	+ 61 +950	- 47 -436	- 31 -221	G1 IV 153(18)
9166 +67 $\circ$ 133	6.76 6.16	+1.23 +0.44	+1.42 2,2	+0.8 5.40	+ 44 + 43	- 47 - 30	- 23 - 18	K3 III -1(10)
12274** $\dagger$ 59 Cet	3.95 3.36	+1.57 +0.75	+1.90 5,2	-1.95 4.94	+ 43 + 39	- 47 - 47	- 3 + 15	M1 III 3(12)
13596** 19 Ari	5.75 4.68	+1.55 +0.71	+1.96 2,1	-1.5 5.88	+ 59 + 29	- 47 - 37	- 4 + 8	M0 III -
13974** $\dagger$ δ Tri	4.85 4.65	+0.60 +0.24	+0.02 2,2	+4.8 0.11	+ 39 +367	- 47 -415	+ 12 + 80	G0 V 94(58)
44478** μ Gem	2.88 1.72	+1.65 +1.05	+1.85 8,2	-3.0 3.95	+ 55 - 10	- 47 - 59	+ 4 0	M3 III 21(34)
43899 $\dagger$ HR2263	5.58 5.11	+1.12 +0.395	+1.06 2,2	+0.6 4.57	+ 50 + 34	- 47 + 11	- 18 + 10	gK1 -
49601** +47 $\circ$ 1355	9.00 8.20	+1.235 +0.50	+1.165 2,1	+6.7 1.42	+ 45 +128	- 47 -264	- 33 -208	dK6 73(10)
+40 $\circ$ 1758A** LTT11946 LTT11947B	9.12 8.41 11.10 10.09	+1.12 +0.43 +1.43 +0.81	+1.05 2,2 +1.20 2,1	+6.65 1.88 +7.75	+ 51 + 18	- 47 -204	+ 12 - 15	K5 V 32(61) M1
60532** HR2906	4.44 4.20	+0.50 +0.165	+0.07 1,1	+3.0 1.55	+ 40 + 22	- 47 + 14	- 3 - 53	F5 IV 47(10)
88218** HR3992	6.18 5.70	+0.605 +0.25	+0.03 2,2	+4.0 2.00	+ 42 +166	- 47 - 33	- 17 -115	dF9 42(18)
CPD-53 $\circ$ 1708** LTT3152	9.50 8.88	+0.77 +0.34	+0.36 2,3	+6.05 3.01	+ 64 +161	- 47 + 18	- 69 -125	K0 V 8(7)
90250 29 LMi	6.45 5.97	+1.09 +0.37	+0.97 1,1	+0.75 5.35	+ 45 + 34	- 47 - 39	- 19 - 24	K1 III -
+46 $\circ$ 1635** LTT12813	8.84 8.02	+1.34 +0.59	+1.27 3,1	+7.1 0.80	+ 39 +189	- 47 -335	+ 5 - 84	K7 V 64(17)
96813** $\dagger$ HR4333	5.81 4.31	+1.49 +1.34	+1.53 5,Std	-3.75 6.95	+ 46 + 15	- 47 - 19	+ 2 - 7	gM3.5 -
108570** HR4749	6.15 5.57	+0.92 +0.38	+0.58 2,2	+1.65 4.15	+ 50 + 79	- 47 - 60	- 80 -118	dG8 14(8)
119425 84 Vir	5.35 4.87	+1.09 +0.38	+1.06 2,2	+1.45 3.52	+ 62 + 88	- 47 -110	- 31 + 14	K1 III-IV -
121416** HR5239	5.78 5.16	+1.12 +0.425	+1.08 1,2	+0.65 4.55	+ 44 + 53	- 47 - 60	- 18 - 20	K0 IV 18(7)

TABLE II (*Continued*)

HD Name	V_E R	$B-V$ $R-I$	$U-B$ N, N	M_{bol} $m-M$	U dU	V dV	W dW	Sp. T. $\pi_t(\text{wt.})$ (0'001)
						km/sec		
125455** -4°3665	7. ^m 55 7.17	+0. ^m 85 +0.30	+0. ^m 52 2, 3	+6. ^m 0 1.43	+ 40 +182	- 47 -251	+ 7 + 68	K0 V 50 (44)
125595** -39°8857	9.58 8.88	+1.195 +0.47	+1.14 2, 4	+7.0 1.85	+ 41 +182	- 47 -190	+ 5 + 60	K5 V 39 (26)
130669AB† ADS9397	8.45 7.94	+0.865 +0.32	+0.575 2, 2	+5.3 2.85	+ 42 - 18	- 47 -110	- 79 - 2	K2 V -
150680 ζ Her	2.81 2.58	+0.65 +0.22	+0.21 Std	+2.6 0.00	+ 53 +211	- 47 - 44	- 26 +193	G0 IV 100 (80)
158614AB**† ADS10598	5.31 5.02	+0.715 +0.235	+0.28 3, 4	+3.85 1.53	+ 60 - 36	- 47 - 93	- 21 + 8	G8 IV-V 50 (57)
196877**† -53°8617	8.83 8.04	+1.32 +0.61	+1.13 2, 3	+7.6 0.26	+ 48 +126	- 47 -490	+ 30 + 22	K6 V 84 (20)
217166AB† HR8737	6.45 6.18	+0.64 +0.24	+0.14 2, 2	+4.15 2.30	+ 39 +128	- 47 - 99	- 15 +118	dG1 33 (41)
219829AB† ADS16665	8.02 7.50	+0.82 +0.315	+0.42 1, 3	+5.05 2.63	+ 57 +168	- 47 -113	- 24 -105	K0 V 15 (31)

**New members.

†Notes to Table II:

- 12274 Proper motion in right ascension given, and used, with the wrong sign in *Royal Observatory Bulletin* No. 51.
 13974 Sp. B. 10^d.
 43899 The U velocity is incorrectly given as +63 km/sec in a previous paper (Eggen and Stokes 1970).
 96813 Probably variable.
 130669 The orbital period for the nearly identical components is near ten years.
 158614 The nearly equal components have an orbital period near 50 years.
 196877 Proper motion in right ascension given, and used, with the wrong sign in a previous paper (Eggen 1971a).
 217166 The equal components have a period near 30 years.
 219829 The components differ by 0^m3 or 0^m4.

TABLE III
MEMBERS OF THE σ PUPPIS GROUP

HD Name	V_E R	$B-V$ $R-I$	$U-B$ N, N	M_{bol} $m-M$	U dU	V dV	W dW	Sp. T. $\pi_t(\text{wt.})$ (0'001)
						km/sec		
2490** HR109	5. ^m 42 4.52	+1. ^m 55 +0.73	+1. ^m 90 3, 3	-1. ^m 9 6.10	+ 77 + 49	- 87.5 - 49	- 38 - 2	gK5 10 (10)
3457† HR161	6.40 5.65	+1.35 +0.53	+1.50 2, 3	-1.05 6.63	+ 54 + 25	- 87.5 - 42	- 37 - 16	K4 III -
5351 +68°60	9.13 8.52	+1.04 +0.41	+0.90 2, 2	+6.4 2.28	+ 51 +285	- 87.5 -175	+ 46 - 99	K4 V 38 (25)
7351**† HR363	6.43 5.06	+1.70 +0.98	+1.87 5, 2	-3.20 7.60	+ 58 + 17	- 87.5 - 27	- 51 - 15	M2S -

TABLE III (*Continued*)

HD Name	V_E R	$B-V$ R-I	$U-B$ N, N	M_{bol} m-M	U dU	V dV	W dW	Sp. T. π_t (wt.) (0''001)
						km/sec		
17288	9 ^m 86 9.61	+0 ^m 61 +0.24	-0 ^m 08 2, 3	+5 ^m 65 4.30	+ 77 +107	- 87.5 -114	+ 46 + 72	G8 VI -
20559AB+	5.46	+1.02	+0.78	+0.15	+ 64	- 87.5	+ 27	K1 IV
95 Cet	4.86	+0.375	3, 2	4.79	+ 50	- 97	+ 52	6 (40)
-1 ^o 474 C	10.03 9.82	+0.61 +0.20	+0.06 3, 2	+5.45				
21543	8.24	+0.62	+0.03	+5.15	+ 53	- 87.5	- 17	G2 VI
-7 ^o 603	8.00	+0.24	3, 1	3.21	+ 31	-182	+ 60	22 (8)
24049	9.47	+0.62	-0.01	+5.50	+ 64	- 87.5	+ 73	F8
-56 ^o 578	9.27	+0.20	2, 2	4.15	+ 94	-119	+112	22 (6)
27498**+	6.9-7.0	+1.56	+1.74	-3.5	+ 68	- 87.5	- 21	M4 III
-2 ^o 867	5.70	+1.13	3, 3	8.44	0	- 14	+ 6	-
30649	6.98	+0.59	+0.07	+4.5	+ 61	- 87.5	- 9	G1 V-VI
+45 ^o 992	6.75	+0.23	2, 4	2.60	+110	-302	- 30	38 (25)
37160	4.08	+0.95	+0.65	+0.55	+ 72	- 87.5	- 35	G8 IIIp
40 Ori	3.68	+0.38	2, 2	3.22	- 47	-139	- 33	24 (42)
37763**	5.18	+1.13	+1.18	+0.45	+ 80	- 87.5	- 5	K4 III
γ Men	4.70	+0.39	2, 2	4.32	+131	- 57	- 19	12 (17)
40801+	6.08	+0.98	+0.78	+0.6	+ 51	- 87.5	+ 25	K0 III
+42 ^o 1473	5.64	+0.36	A*	5.17	+ 13	- 87	+ 17	14 (28)
+47 ^o 1276	9.20	+0.77	+0.30	+5.95	+ 55	- 87.5	- 24	dG6
W 279	8.90	+0.30	2, 1	3.15	+ 69	-218	- 70	25 (24)
59717A	3.24	+1.52	+1.78	-1.8	+ 75	- 87.5	- 21	K5 III
σ Pup	2.33	+0.64	3, 3	3.90	+ 89	+ 20	+ 14	13 (16)
B	8.80 8.55	+0.705 +0.22	+0.19: 4, 2	+5.05				G5 V
77729	7.65	+1.40	+1.58	-1.0	+ 74	- 87.5	+ 43	K4 III
+26 ^o 1895	6.88	+0.595	2, 1	7.70	0	- 17	- 7	-
100470	6.38	+1.06	+0.91	-0.15	+ 78	- 87.5	- 6	K0 III
HR4452	5.93	+0.37	2, 1	6.22	+ 40	- 49	- 13	-14 (10)
107328	4.95	+1.15	+1.15	-0.15	+ 79	- 87.5	+ 8	K0 III
16 Vir	4.45	+0.44	2, 1	4.54	+103	- 90	- 29	- 5 (36)
-36 ^o 8429*	10.40	+0.58	-0.08	+5.65	+ 74	- 87.5	+ 17	G8 VI
LTT 4456	10.17	+0.225	3, 1	4.92	+ 95	- 41	- 10	-
108309A**	6.30	+0.68	+0.215	+3.45	+ 74	- 87.5	- 19	G5 IV-V
HR4734	6.05	+0.21	4, 3	3.03	+249	-155	- 64	36 (31)
-48 ^o 7414B	10.75 10.12	+1.12 +0.485	+0.96 4, 3	+7.05				32 (32)
120559	8.00	+0.655	-0.025	+4.6	+ 71	- 87.5	+ 6	G5 V
-56 ^o 5970	7.80	+0.23	2, 3	3.58	+154	-149	-147	25 (7)
124681**	6.4-6.6	+1.60	+1.77	-3.5	+ 73	- 87.5	- 29	gM4
HR5331	5.23	+1.08	4, 2	7.94	+ 13	- 24	+ 4	-
130227**	6.21	+1.13	+1.06	0.0	+ 58	- 87.5	- 51	K2 III
HR5515	5.80	+0.415	2, 2	5.87	+ 45	- 53	- 34	-
130694**	4.41	+1.40	+1.48	-1.1	+ 79	- 87.5	+ 27	gK4
58 Hya	3.69	+0.57	2, 2	4.96	+ 66	- 93	+ 29	5 (10)

TABLE III (*Continued*)

HD Name	V_E R	$B-V$ $R-I$	$U-B$ N, N	M_{bol} $m-M$	U dU	V dV	W dW	Sp. T. π_t (wt.) (0''001)
						km/sec		
134113 +9°3001	8 ^m .27 7.94	+0 ^m .57 +0.24	-0 ^m .04 3,2	+5 ^m .05 3.27	+ 80 +121	- 87.5 -180	+ 4 +113	F9 V 18 (10)
-8°3858	9.50 9.28	+0.72 +0.27	+0.16 2,3	+5.9 3.66	+ 57 + 10	- 87.5 -182	- 64 - 37	G0 -
165401** +4°3589	6.80 6.57	+0.615 +0.22	+0.03 2,2	+4.7 1.65	+ 80 - 83	- 87.5 -110	- 38 - 57	G2 V 43 (38)
178149 -48°12933	9.10 8.86	+0.67 +0.24	+0.025 2,2	+6.0 3.23	+ 65 + 60	- 87.5 -211	- 2 - 42	G0 3 (8)
181720** -33°14164	7.80 7.70	+0.585 +0.195	-0.065 2,2	+4.75 3.35	+ 63 + 20	- 87.5 -176	- 26 - 99	G2 14 (14)

**New members

†Notes to Table III:

3457 Erroneously called HD 2329 in Eggen (1970a). Roman (1955) gives $V = 6.98$.

7351 Possibly variable.

20559 The period of the close pair is 200 years. C is a common proper-motion companion (Eggen 1964b).

27498 Stokes (1970) finds $V_E = 6.95 \pm 0.03$ from seven observations.

40801 Photometry by Argue (1967).

TABLE IV
MEMBERS OF THE ϵ INDI GROUP

HD Name	V_E R	$B-V$ $R-I$	$U-B$ N, N	M_{bol} $m-M$	U dU	V dV	W dW	Sp. T. π_t (wt.) (0''001)
						km/sec		
6413**† -48°259	6 ^m .86 5.76	+1 ^m .60 +0.80	+1 ^m .90 1,1	-1 ^m .75 7.10	+ 79 + 31	- 39 - 13	- 13 0	M2 III -
6673** -51°273	8.88 8.45	+0.915 +0.35	+0.615 2,2	+6.1 2.50	+ 60 +192	- 39 -112	- 6 + 6	K1 V 40 (18)
22231** HR1090	5.68 5.27	+1.10 +0.385	+1.16 2,2	-0.4 5.77	+ 79 + 54	- 39 - 12	- 6 + 16	K3 III -
34411 λ Aur	4.71 4.46	+0.62 +0.20	+0.13 2,Std	+4.2 0.68	+ 76 + 85	- 39 -390	+ 5 + 24	G0 V 66 (29)
40409 HR2102	4.65 4.20	+1.05 +0.375	+0.96 2,2	+1.55 2.75	+ 79 +254	- 39 - 49	+ 10 + 65	gK3 40 (16)
72324 32 Cnc	6.35 5.56	+1.04 +0.37	+0.88 2,2	+0.8 4.90	+ 73 + 14	- 39 - 18	+ 11 - 31	G9 III 23 (6)
+43°1844** LTT 12258	9.32 8.69	+1.08 +0.405	+0.93 1,2	+6.5 2.25	+ 61 + 60	- 39 -132	+ 14 - 72	K5 -
90170** HR4087	6.26 6.00	+0.88 +0.315	+0.60 2,2	+0.3 5.90	+ 80 + 55	- 39 - 12	- 38 - 29	K0 -
96834** HR4336	5.90 4.65	+1.56 +0.97	+1.89 3,4	-3.3 7.30	+ 79 + 24	- 39 - 14	- 13 - 10	M2 III -

TABLE IV (*Continued*)

HD Name	V_E R	$B-V$ $R-I$	$U-B$ N, N	M_{bol} $m-M$	U dU	V dV	W dW	Sp. T. $\pi_t(\text{wt.})$ (0".001)
km/sec								
+22°2271** LTT 12876	10. ^m 13 9.40	+1. ^m 22 +0.48	+1. ^m 19 2, 3	+6. ^m 35 3.05	+ 72 +142	- 39 - 70	- 4 - 85	K8 -
102365 HR4523	4.90 4.68	+0.65 +0.225	+0.12 2, 2	+5. ^m 05 0.00	+ 66 + 707	- 39 - 259	+ 4 - 11	G5 V 92 (17)
104988 -0°2532	8.16 7.83	+0.76 +0.28	+0.255 3, 2	+5.4 2.70	+ 76 + 224	- 39 - 91	+ 2 - 30	G8 V 3 (13)
115539 +14°2593	7.22 6.80	+0.95 +0.355	+0.63 2, 1	+0.5 6.48	+ 72 + 35	- 39 - 20	+ 2 + 5	G8 IV -
142574 HR5924	5.44 4.55	+1.58 +0.72	+1.95 2, 1	-1.7 5.90	+ 79 + 30	- 39 - 11	- 2 + 28	K4 III 34 (10)
209100 ε Ind	4.68 4.18	+1.06 +0.405	+0.98 Std	+6.55 -2.28	+ 79 +1543	- 39 -1420	+ 3 -757	K5 V 285 (23)
219430A**† 91 Aqr BC	4.22 3.75 9.17 8.64	+1.10 +0.385 +1.05 +0.385	+1.04 4, 4 +0.90 3, 2	+0.75 3.08 +5.65	+ 68 + 150	- 39 - 66	- 5 - 66	K0 III 43 (22) dK6

**New members.

†Notes to Table IV:

6413 Radial velocity and spectral type kindly supplied by Wayman before publication.

219430 The equal components of this faint pair are separated by 1". The system was incorrectly assigned to the ζ Herculis group in a previous paper (Eggen and Stokes 1970).

TABLE V
MEMBERS OF THE η CEPHEI GROUP

HD Name	V_E R	$B-V$ $R-I$	$U-B$ N, N	M_{bol} $m-M$	U dU	V dV	W dW	Sp. T. $\pi_t(\text{wt.})$ (0".001)
km/sec								
4730** HR227	5. ^m 59 4.98	+1. ^m 30 +0.49	+1. ^m 54 3, 3	-0. ^m 9 5.85	+ 27 + 18	- 97 - 66	- 18 - 12	gK5 -
6254	8.01 7.62	+0.99 +0.385	+0.69 2, 2	+1.1 6.70	+ 36 + 15	- 97 - 44	- 51 + 1	G8 IV -
8638** -28°433	8.33 8.12	+0.685 +0.245	+0.13 2, 2	+5.2 3.24	+ 24 + 38	- 97 -208	- 65 + 21	G 68 (6)
10785 -16°301	8.50 8.30	+0.605 +0.19	+0.06 4, 4	+3.75 4.05	+ 28 + 46	- 97 -149	+ 12 + 9	dG4 13 (7)
27370 +23°675	7.14 6.64	+1.16 +0.40	+0.79 1, 1	+0.55 6.25	+ 44 + 20	- 97 - 55	+ 67 + 39	gG5 -
28595 84 Tau	6.31 5.02	+1.69 +0.975	+2.05 3, 2	-3.15 7.60	+ 39 0	- 97 - 29	- 4 + 3	M3 III -

TABLE V (*Continued*)

HD Name	V_E R	$B-V$ $R-I$	$U-B$ N, N	M_{bol} $m-M$	U dU	V dV	W dW	Sp. T. π_t (wt.) (0'001)
						km/sec		
30442** HR1527	5.41 4.05	+1.55 +1.17	+1.76 4, 2	-3.3 6.45	+ 28 + 29	- 97 - 40	- 21 - 11	gM2 -1 (7)
30562 HR1536	5.79 5.48	+0.645 +0.21	+0.17 2, 2	+2.9 3.05	+ 49 - 34	- 97 -172	- 13 + 65	dG0 33 (25)
36283 +15 ^o 838	8.69 8.40	+0.685 +0.24	+0.11 2, 2	+4.65 4.10	+ 21 - 41	- 97 -135	- 79 -107	G5 V -
43380 43 Aur	6.40 5.90	+1.10 +0.39	+1.12 3, 1	-0.15 6.10	+ 29 + 18	- 97 - 58	- 32 - 20	K2 III -
62044+ σ Gem	4.29 3.75	+1.12 +0.42	+0.97 2, 2	-0.65 4.45	+ 26 - 20	- 97 -113	+ 14 - 6	K1p 17 (30)
+31 ^o 1781** LTT 12172	8.87 8.29	+1.15 +0.43	+1.10 2, 1	+6.15 2.15	+ 23 + 50	- 97 - 355	- 17 - 204	K4 V 45 (56)
72184 HR3360	5.90 5.42	+1.10 +0.395	+1.15 2, 2	0.0 5.50	+ 49 + 28	- 97 - 75	- 52 - 47	K2 III 13 (20)
+48 ^o 1829** LTT 12682	10.07 9.05	+1.37 +0.82	+1.13 3, 2	+7.9 0.71	+ 26 + 20	- 97 - 69	- 10 - 5	dM2 55 (8)
93132 41 UMa	6.36 5.25	+1.57 +0.83	+1.90 2, 3	-2.6 7.40	+ 46 + 16	- 97 - 33	+ 4 + 2	M1 III -
96692** +16 ^o 2216	9.77 9.17	+1.12 +0.465	+1.01 2, 2	+6.65 2.60	+ 30 0	- 97 - 18	+ 72 - 7	dM0 -
114971** HR4996	5.88 5.44	+1.06 +0.385	+0.93 1, 2	-0.05 5.60	+ 21 + 41	- 97 - 41	- 13 - 35	K0 IV -
121146** HR5227	6.28 5.70	+1.00 +0.42	- 1, 2	+0.55 5.20	+ 36 + 49	- 97 - 69	- 37 - 4	SgK2 23 (8)
125932 51 Hya	4.78 4.12	+1.33 +0.50	+1.55 2, 3	-0.7 4.75	+ 37 + 54	- 97 - 93	+ 1 - 10	K5 III 32 (8)
126271 HR5394	6.20 5.68	+1.18 +0.455	+1.24 2, 3	-0.15 5.90	+ 32 + 12	- 97 - 70	- 12 + 4	gK4 -
129336 32 Boo	5.55 5.17	+0.95 +0.33	+0.65 2, 2	+0.3 5.05	+ 28 + 17	- 97 - 90	- 7 + 13	G8 III 24 (20)
183877 -28 ^o 15936	7.15 7.01	+0.665 +0.26	+0.12 2, 1	+5.05 2.20	+ 36 - 6	- 97 -319	- 26 -148	G5 IV 24 (20)
195962 -66 ^o 3496	8.31 8.21	+0.64 +0.22	+0.125 1, 1	+4.6 3.90	+ 46 +100	- 97 -160	- 3 - 4	G5 V 30 (8)
198149 η Cep	3.43 3.04	+0.92 +0.34	+0.61 2, 2	+2.5 0.70	+ 33 +326	- 97 - 86	+ 10 +197	K0 IV 71 (52)
203344 HR8165	5.56 5.06	+1.06 +0.38	+0.92 2, 1	+1.25 3.90	+ 48 + 41	- 97 - 27	- 39 -117	K0 IV -5 (12)
206804AB**+ -58 ^o 7893	8.80 8.01	+1.32 +0.58	+1.15 3, 4	+6.0 1.85	+ 22 + 7	- 97 - 42	+ 9 + 10	K7 V 46 (18)
208998** -53 ^o 9029	7.10 6.92	+0.59 +0.185	+0.01 2, 1	+4.1 3.26	+ 25 + 27	- 97 -226	+ 33 + 40	F8 10 (19)

TABLE V (Continued)

HD Name	V_E R	$B-V$ $R-I$	$U-B$ N, N	M_{bol} $m-M$	U dU	V dV	W dW	Sp. T. π_t (wt.) (0".001)
					km/sec			
217902** κ Gru	5.37 4.61	+1.45 +0.625	+1.75 2, 2	-1.55 6.0	+ 23 + 19	- 97 - 57	- 4 + 7	gK5 7 (12)
221830 +30°4982	6.86 6.60	+0.59 +0.245	+0.05 2, 2	+5.05 1.90	+ 43 +279	- 97 - 55	+ 59 + 28	G2 V 8 (5)

**New members.

†Notes to Table V:

62044 Sp. B. 20^d.

206804AB The equal components have an orbital period of six years.

noted, observations by others have been adopted. The column "N, N" lists the number of (UBV) and (R, I) observations, respectively.

II. Color-Luminosity Arrays

One of the features of the color-luminosity arrays in the ($M_V, B-V$) plane of clusters of old disk stars is the prominent clumping of the red-giant stars (cf. Eggen 1968*b*; Cannon 1970). The same effect appears in the ($M_V, B-V$) relation for the groups discussed here and shown in Figure 1. Also included in Figure 1 are the giants and subgiants in two clusters, IC 4651 (Eggen 1971*b* and the present Table VI) and M67 (Eggen and Sandage 1964 and unpublished). The modulus, $(m-M)_0$, and reddening, $E(B-V)$, are 9^m4 and +0^m06 for M67 and 9^m5 and +0^m15 for IC 4651. Values of $E(R-I) = 0.7$

$E(B-V)$ and $A(R) = 2E(B-V)$ have been adopted. Some of the luminosity dispersion in Figure 1 is obviously caused by small variations in the giant sequences from cluster to cluster, but a clumping, near M_V of 0^m to +1^m, is also apparently a feature of all the groups and clusters in the figure.

The ($M_{bol}, R-I$) relations are shown in Figure 2 where those previously derived for the 61 Cyg and Wolf 630 groups (Eggen 1971*d*) are indicated by triangles. The giant sequences are shown in more detail in the ($M_I, R-I$) plane of Figure 3 where the ($M_I, R-I$) relation for the giants in the young disk population Hyades group (Eggen 1971*c*) is represented by straight lines. The intersection of the Hyades relation by that of the old disk stars at ($R-I$) near +0^m5 is not as striking for the groups discussed here as was found for the 61 Cyg and Wolf 630 groups (Eggen 1971*d*). This difference between the luminosities of the giants of the latter two groups and of the four groups discussed here is also apparent in Figure 2. For comparison with Figure 3, the giant and subgiant members of three old disk clusters are shown in the ($M_I, R-I$) plane of Figure 4. The (R, I) observations of stars in IC 4651 and NGC 2477 were obtained with the 40-inch reflector at Siding Spring and are listed in Tables VI and VII, respectively. The results for M67 were published elsewhere (Eggen 1969*a*). The modulus, $(m-M)_0$, and reddening, $E(B-V)$, for NGC 2477 are 10^m0 and +0^m25 (Eggen and Stoy 1961). The clumps of red giants seen in Figure 1 are also obvious in both Figures 3 and 4.

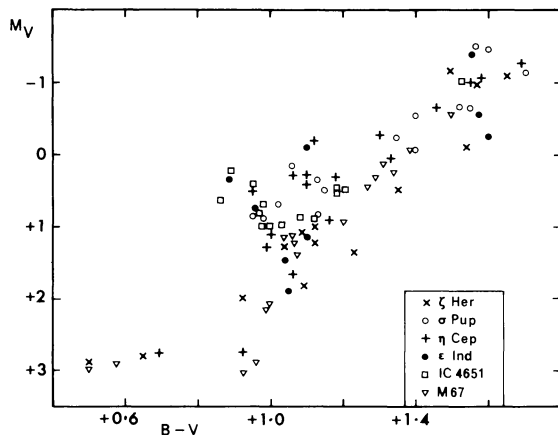


FIG. 1—The color-luminosity array in the ($M_V, B-V$) plane for subgiants and giants in several old disk population clusters and groups.

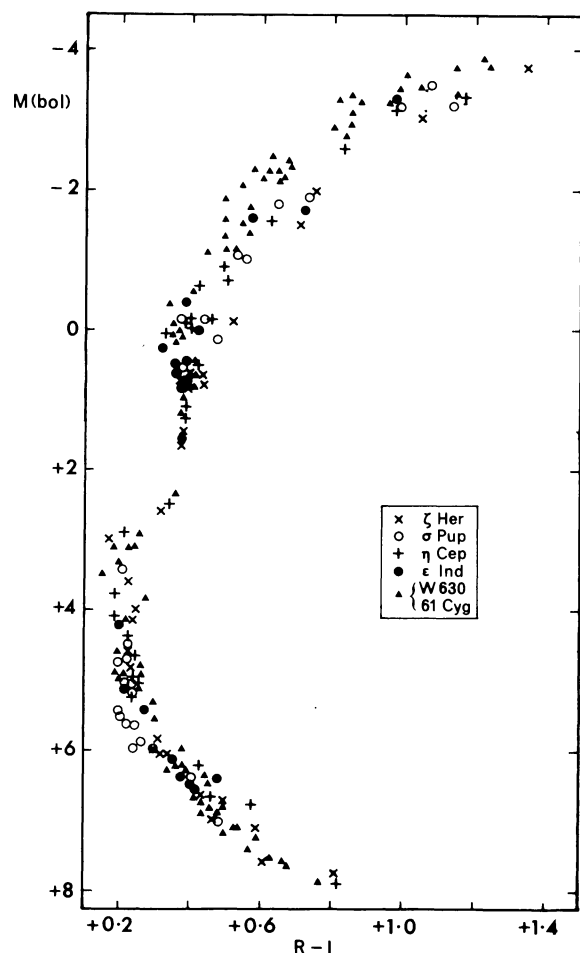


FIG. 2—The color-luminosity array in the $(M_{\text{bol}}, R-I)$ plane for members of six groups of old disk population stars.

III. Space Motions

Astrometric data that have become available since the groups discussed here were first isolated have not appreciably changed the adopted values of (U, V, W) for the defining stars of the η Cep, ζ Her, and ϵ Ind groups. However, the originally adopted velocity for the σ Pup group of -80 km/sec (Eggen 1964*b*) is incorrect and a more likely value of -87.5 km/sec has been used here. The use of the incorrect value of -80 km/sec was the partial cause of the peculiar color-luminosity array found for this group (cf. Eggen 1964*b*, Fig. 14) and the corrected value used here leads to an array that is more normal (Fig. 1) although, as discussed in the next section, the ultraviolet excess of the group members is still the largest known for any disk group or cluster.

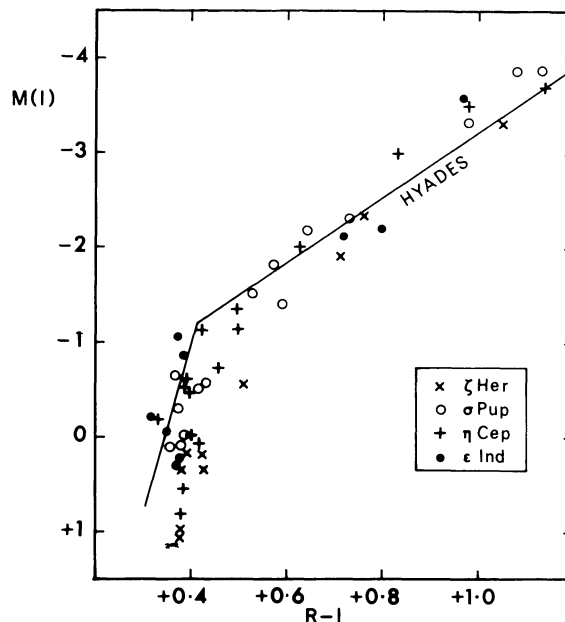


FIG. 3—The color-luminosity array in the $(M_I, R-I)$ plane for subgiants and giants in four groups of old disk population stars.

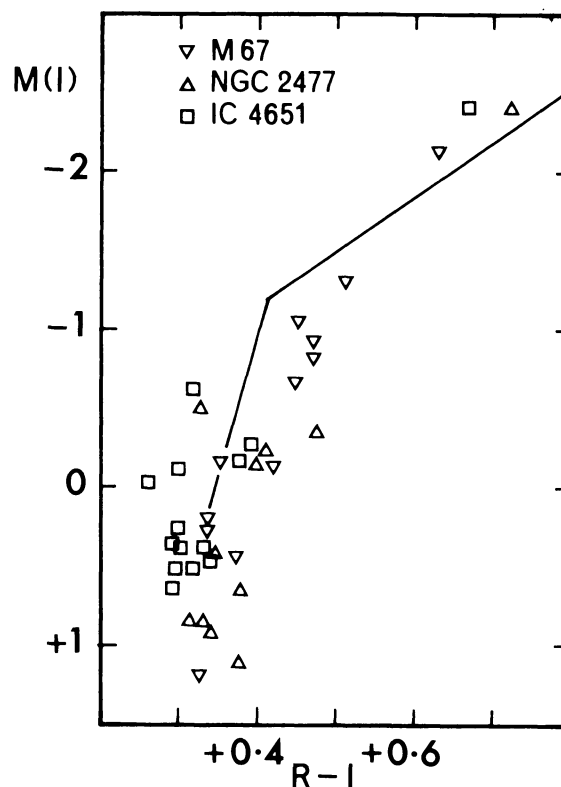


FIG. 4—The color-luminosity array in the $(M_I, R-I)$ plane for subgiants and giants in three clusters of old disk population stars.

TABLE VI
RED GIANTS IN IC 4651

No.	V	B-V	U-B	N	R	R-I	N
9	10. ^m 78	+1. ^m 11	+0. ^m 82	2	10. ^m 48	+0. ^m 405	1
12	10.40	+1.105	+0.90	2	10.02	+0.405	2
22	10.94	+1.14	+0.915	2	10.72	+0.42	2
23	10.68	+1.125	+0.89	2	10.45	+0.40	2
27	10.21	+1.04	+0.75	3	10.03	+0.365	2
58	10.86	+1.23	+1.19	3	10.60	+0.45	2
60	10.90	+1.13	+1.04	3	10.65	+0.40	2
65	10.88	+1.275	+1.185	2	10.58	+0.45	2
76	10.44	+1.35	+1.34	2	10.02	+0.48	2
83	10.94	+1.14	+0.94	2	10.70	+0.40	2
91	10.61	+1.01	+0.69	2	10.39	+0.405	2
93	8.95	+1.68	+2.01	2	8.07	+0.77	5
96	10.41	+1.33	+1.285	2	9.95	+0.50	2
98	10.94	+1.175	+1.025	2	10.62	+0.42	2

TABLE VII
RED GIANTS IN NGC 2477

No.	R	R-I	N
270	11. ^m 54	+0. ^m 555	1
396	11.66	+0.51	2
399	8.80	+0.895	4
695	10.76	+0.575	1
708	10.33	+0.50	3
752	11.26	+0.52	1
902	11.65	+0.49	1
911	11.74	+0.515	1
920	10.66	+0.67	1
956	10.70	+0.58	1
959	11.97	+0.555	1

The spread of *U* velocities in the four groups is shown by the histograms of Figure 5 where the location of the defining star in each group is also indicated. The groups discussed here are smaller than the 61 Cyg and Wolf 630 groups, but the search for group members has not been as extensive. All possible members of the 61 Cyg and Wolf 630 groups, brighter than visual magnitude near 7 and with accurate radial

velocities and proper-motion determinations available, have been discussed (Eggen 1969*a*, 1971*a*) whereas the only new members added to the original selection of members of the present groups are those for which (*R*, *I*) observations are available. However, in all four groups, the present search for members with available (*R*, *I*) photometry was extended over a wider range of *U* velocities than is represented in Figure 5 and no additional members were found.

The positions of the old disk groups in the (*U*, *V*) plane are shown in Figure 6; the young disk, Hyades group is also shown. The proximity in this plane of the 61 Cyg, ϵ Ind, and ζ Her groups can obviously lead to uncertainty in group assignment for some stars, especially when available luminosity estimates are uncertain. Two examples of possible confusion between members of the ϵ Ind and 61 Cyg groups are the following

Star	<i>m</i> - <i>M</i>	<i>U</i>	<i>V</i>	<i>W</i>	Group
		(km/sec)			
HR 5134	6 ^m 25	+70	-39	+24	ϵ Ind
	6.80	+89	-63	-32	61 Cyg
HD 111884	6.00	+79	-39	+7	ϵ Ind
	6 ^m 55	+91	-53	+9	61 Cyg.

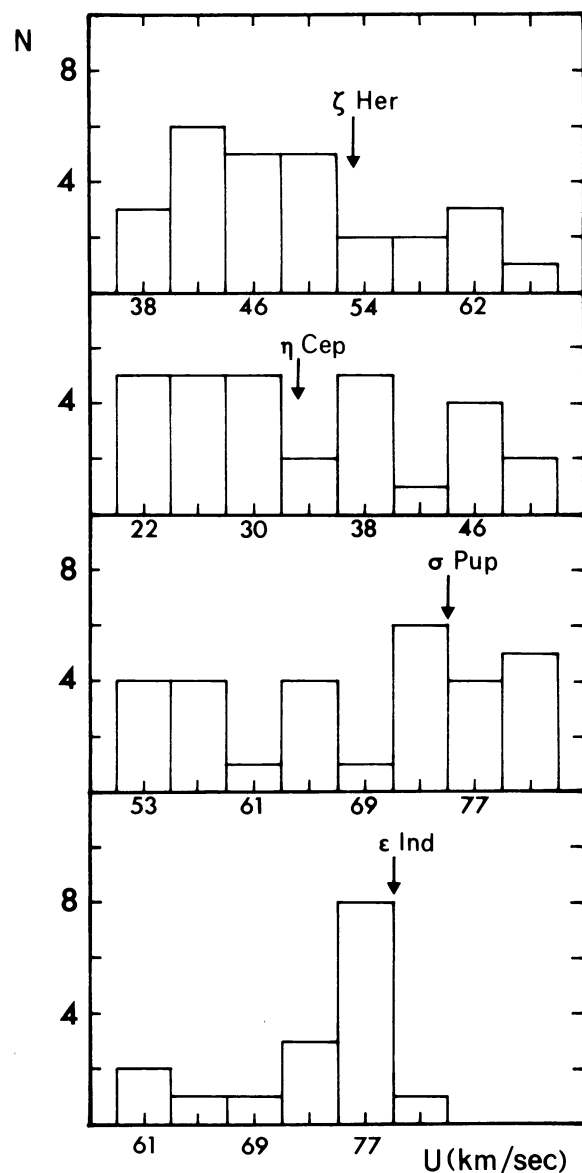


FIG. 5—The U velocity of the defining star is indicated in each case by the arrow.

The latter star is assigned to the 61 Cyg group (Eggen 1969a) and is clearly not a member of the ϵ Ind group from its resulting anomalous position in the $(M_I, R-I)$ plane. The first object, HR 5134, is a variable assigned to the 61 Cyg group (Eggen 1971d). It is also discussed below in section V where its assignment to the ϵ Ind group is preferred.

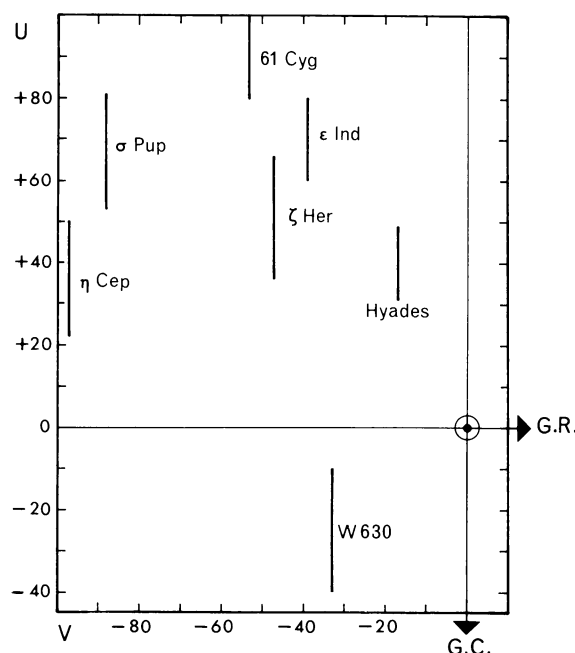


FIG. 6—The six old disk population groups and the young disk population Hyades group in the (U, V) plane.

IV. Luminosities

The only luminosity estimates not used in selecting possible group members are those based on the widths of H and K emission lines (Wilson and Bappu 1957). The luminosities derived from group parallaxes are compared in Table VIII with the spectroscopic values obtained by Wilson and Bappu (1957 and unpublished results kindly supplied by O. C. Wilson), and by Warner (1969) for some southern stars. These latter values are shown in parentheses in Table VIII. Only giants and subgiants, brighter than $M_V = +3^m$, are included here. Previous results for the members of the 61 Cyg and Wolf 630 groups (Eggen 1969a, 1971a,d) are also included in Table VIII. The presence of scatter in the calibration of the emission-width method of luminosity determinations has been suggested (cf. Eggen 1966; Pagel and Tomkin 1969) in the sense that the luminosity of stars having lower metal abundance than that of the Hyades will be underestimated by about 1^m .

The dependence of the differences, $G-K = M_V(\text{Group}) - M_V(K)$, in Table VIII on the $(R-I)$ colors is shown in Figure 7 where the

TABLE VIII

COMPARISON OF GROUP LUMINOSITIES WITH THOSE DERIVED
FROM THE EMISSION WIDTHS OF H AND K

HD	$M_V(\text{Group})$	$M_V(K)$	G-K	R-I
ζ Her				
44478	-1. ^m 05	-1. ^m 3	+0. ^m 25	+1. ^m 05
90250	+1.1	+1.3	-0.2	+0.37
119425	+1.85	+0.8	+1.05	+0.38
σ Pup				
37160*	+0.85	+2.5	-1.65	+0.38
37763	+0.85	(+1.4)	(-0.55)	+0.39
40801	+0.90	+2.6	-1.7	+0.36
59717	-0.65	(+0.3)	(-0.95)	+0.64
100470	+0.15	+1.4	-1.25	+0.37
107328	+0.5	+0.5	0.0	+0.44
ϵ Ind				
40409	+1.9	(+2.5)	(-0.6)	+0.375
72324	+1.45	+0.5	+0.95	+0.37
142574	-1.35	-0.2	-1.15	+0.72
η Cep				
28595	-1.3	-0.7	-0.6	+0.975
62044	-0.15	-1.6	+1.45	+0.42
120336	+0.5	+1.1	-0.6	+0.33
198149*	+2.75	+2.9	-0.15	+0.34
203344	+1.65	+0.4	+1.25	+0.38
W 630				
18322*	+0.35	+1.6	-1.25	+0.415
26967	-0.6	-0.5	-0.1	+0.43
94264	+1.55	+2.0	-0.45	+0.40
165135	+0.1	+1.4	-1.3	+0.36
181122	-0.4	+0.4	-0.8	+0.37
218356	-2.2	-2.2	0.0	+0.51
61 Cyg				
39425	+0.95	+1.0	-0.05	+0.41
50778	-0.3	+0.2	-0.5	+0.58
72324	+0.15	+0.5	-0.35	+0.35
95272	+0.8	+0.7	+0.1	+0.38
106849	-0.8	-0.8	0.0	+1.40
116870	-0.7	-0.5	-0.2	+0.66
131111	+1.3	+1.9	-0.6	+0.38
137704	-0.45	+0.8	-1.25	+0.56

* Trigonometric parallaxes with weight greater than 40 are available for HD 37160 (0".024, wt. 42 giving $M_V = +0.^m9$), HD 198149 (0".071, wt. 52 giving $M_V = +2.^m75$) and HD 18322 (0".029, wt. 41 giving $M_V = +1.^m2$).

symbols designating members of the various groups in Tables II, III, IV, and V are those used in Figure 1, and where the Wolf 630 and 61 Cyg groups are represented by upright and inverted triangles, respectively. The groups are separated in panels (a) and (b) of Figure 7 on the basis of the ultraviolet excess $\Delta(U-B)$, of main-sequence and subgiant stars in Figure 8, and giants in Figure 9. The values of $\Delta(U-B)$ in Figure 8 are derived from the standard, main-sequence $(U-B, R-I)$ relation for Hyades stars (Eggen 1971a, Table 3) and are plotted against M_{bol} for luminosities between $+3^m$ and $+7^m$. The ultraviolet excesses are truncated at the lowest luminosities by the small slope in the $\Delta(U-B)/\Delta(B-V)$ relation for these stars (Eggen and Sandage 1959; Eggen 1971a) and are masked at the brightest luminosities by an ultraviolet deficiency resulting from the lower gravities of these subgiants compared to unevolved Hyades stars. Although there is considerable scatter for members of an individual group, the ultraviolet

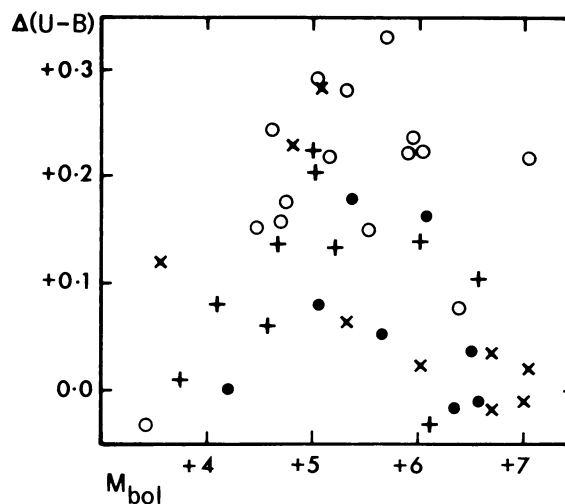


FIG. 8—The correlation between the ultraviolet excess and bolometric luminosity of faint subgiants and main-sequence stars in four old disk population groups. The symbols are the same as in Figure 1.

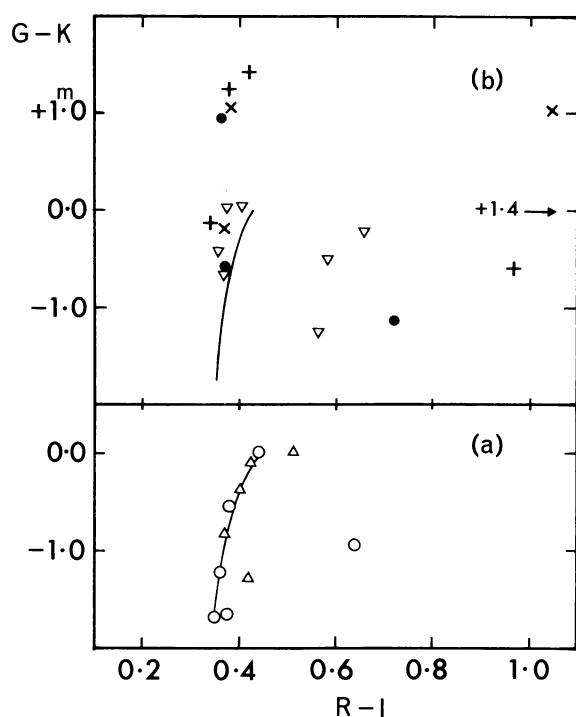


FIG. 7—The correlation between the luminosity residuals, $M_V(\text{Group}) - M_V(K)$ and the $(R-I)$ colors. The symbols are the same as in Figure 1 except that upright and inverted triangles represent members of the Wolf 630 and 61 Cygni groups, respectively.

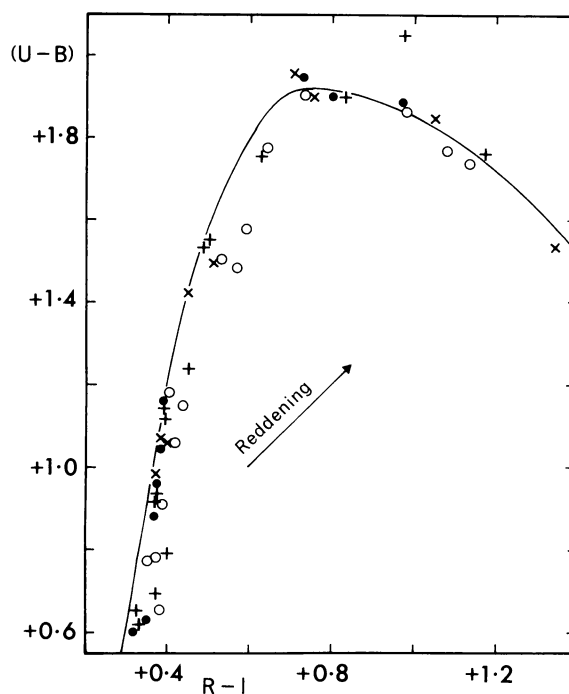


FIG. 9—The distribution of old disk group giants in the $(U-B, R-I)$ plane. The continuous curve represents the giants in the young disk population Hyades group. The symbols are the same as in Figure 1.

excesses of the σ Pup group (open circles) are apparently the largest in Figure 8.

The continuous curve in Figure 9 represents the $(U-B, R-I)$ relation for Hyades group giants (Eggen 1971*d*, Table 2). The deviation of the σ Pup group giants from the Hyades relation is also, in the mean, the largest of the four groups and is very similar to that found for the giants in the Wolf 630 group (Eggen 1971*d*, Fig. 5).

The correlation between the residuals in M_V , in the sense $M_V(G) - M_V(K)$, for members of the σ Pup group in Figure 7(a) show a remarkable run from -1^m7 at $(R-I) = +0^m35$ to 0^m0 at $+0^m45$. The members of the Wolf 630 group, shown as upright triangles in Figure 7(a), reinforce this correlation. Indeed, the deviant member of the Wolf 630 group, HD 18322 with $G-K = -1^m25$ and $(R-I) = +0^m415$, is one of only three stars noted in Table VIII to have a trigonometric parallax with weight greater than 40, and the value of $M_V(\text{trig})$ of $+1^m2$ may indicate that this is not a group member. On the other hand, HD 37160 in the σ Pup group also has a trigonometric parallax ($0''.024$) of high weight (42) which strongly supports the group value whereas the value of $M_V(K)$ would indicate a parallax of $0''.05$. The groups represented in Figure 7(b) also contain seven stars with $(R-I)$ between $+0^m35$ and $+0^m40$ that follow, with a small blueward displacement, the run of residuals from -0^m5 to 0^m0 in Figure 7(a). However the probable errors from both the group and the H and K emission-width methods would not preclude a range of 0^m5 from observational error alone. The nonrandomness of the distribution of residuals in Figure 7 is emphasized by a group of four stars, also with $(R-I)$ between $+0^m35$ and $+0^m45$, and a mean residual of $+1^m25$. The group stars in this color range lie on the vertical branch of the $(M_{\text{bol}}, R-I)$ relation in Figure 1 and until both the apparent correlation seen in Figure 7(a) and the general physical situation leading to the H and K emission widths are more fully understood, it would appear unsafe to eliminate any of the stars from group membership as a result of the present comparison of luminosities. It should be recalled that for twelve giants in the young disk Hyades group (Eggen 1966) the comparison $G-K$ gave $-0^m05 \pm 0^m20$ (a.d.).

V. Variable Stars

A study of the variable stars in the Wolf 630 and 61 Cyg groups (Eggen 1971*d*) showed that the red instability region begins near $(R-I) = +0^m85$ and between this value and $+1^m2$ the variables are mainly small amplitude ($\Delta V < 0^m3$) and quasi-periodic (20^d-60^d). The stars within this color range among the groups discussed here have insufficient photometric observations to give detailed information, but some are certainly variable. The M2S star HD 7351 in the σ Pup group shows a range of 0^m15 in V_E from five observations but seven observations, spread over 50 days by Stokes (1971), of HD 27498 in the same group give a probable error of only 0^m03 in both V_E and R . Four observations of HD 30442 in the η Cep group, spread over three months, show a range of only 0^m01 , and similar results were obtained for HD 28595 in the same group. The bright star HD 44478 (μ Geminorum) in the ζ Her group shows evidence of a variation of about 0^m15 in V_E from eight observations spread over three years with mean values of 2^m88 in December 1963, 2^m96 in December 1965, and 2^m87 in February 1966; and HD 96813 in the same group gives values ranging from 5^m80 to 5^m95 in five observations during 1966 although the star was used as a standard for the (102,65,62) photometric system (Eggen 1967) without noticing any variation in the red.

The redder, longer-period variables in the groups are listed in Table IX together with the total observed amplitude, ΔV ; period; galactic longitude, b ; reddening, $E(B-V)$, derived mainly from early-type stars in the region of the variable; the group modulus and resulting values of (U, V, W) as well as their change, (dU, dV, dW) for a one-hundred parsec increase in the distance; the proper motion and radial velocity used in computing the space motion; the spectral type; and the group to which the star belongs.

The proper motion of S Pavonis is the most uncertain of any used here and as a result the variable must be considered only as a possible member of the ϵ Ind group. The proper motions used here are based on all available meridian positions and are on the N 30 system.

The very few available observations of RT Cancri, θ Apodis, and ϵ Octantis are listed in Tables X, XI, and XII, respectively whereas

TABLE IX
VARIABLE STARS

Variable	Period ΔV	b $E(B-V)$	$m-M$ pcs	U dU	V dV	W dW	μ_α μ_δ	ρ Sp.	Group
R Hor	402 ^d 6 ^m 0	-57 ^o +0.08	6.20 173	+80 +46	-87.5 -34	- 4 +24	+0. ^m 128 +0.027	54.0 gM7e	σ Pup
RT Cnc	90 $\pm$ 1 $\pm$	+33 +0.05	7.33 292	+44 + 7	-47 -10	-32 -18	-0.037 -0.026	+36.0 gM5	ζ Her
ρ Per	60 $\pm$ 0.15	-17 0.00	4.65 86	+55 +37	-47 -71	-18 -12	+0.130 -0.106	+28.2 M4 III	ζ Her
ϵ Oct	80 $\pm$ 0.15	-34 0.02	6.25 178	+57 +33	-47 -21	-21 - 8	+0.075 -0.038	+11.7 M6 III	ζ Her
θ Aps	119 $\pm$ 0.15	-15 +0.10	6.02 160	+51 +35	-47 -25	-13 - 7	-0.083 -0.039	+ 9.8 gM5	ζ Her
HR 5134	90 $\pm$ 0.85	+12 +0.07	6.25 178	+70 +35	-39 -26	+24 +15	-0.097 +0.014	-10.7 M8 III	ϵ Ind
S Pav*	386 0.6	-31 +0.04	7.65 340	+73 +16	-39 -14	-46 -17	+0.040 -0.041	-22.0 gM7e	ϵ Ind

* The proper motion is of lower weight than any other used here and the variable must therefore be considered a provisional group member only.

TABLE X
OBSERVATIONS OF RT CANCRI

Date	V_E	$B-V$	$U-B$	R	$R-I$
13 Nov. 1970	7 ^m 16			4 ^m 94	+1 ^m 63
15	7.25			4.98	+1.64
24	7 ^m 37	+1 ^m 55	+1 ^m 10		
29				5 ^m 13	+1 ^m 78

TABLE XI
OBSERVATIONS OF θ APODIS

JD 2440000	V_E	$B-V$	$U-B$	R	$R-I$
2440346.5	5 ^m 53	+1 ^m 55	+1 ^m 05		
379.5	5.54	+1.55	+1.04		
403.5				3 ^m 00	+1 ^m 80
404.5	5.78	+1.55	+0.92		
425.5	5.67	+1.54	+0.85		
446.5	5.53	+1.57	+1.01		
450.5	5.57	+1.56	+1.00		
476.0	5.56	+1.60	+1.06		
478.0				2.90	+1.77

those for ρ Persei are published elsewhere (Eggen 1967). The more extensive observations of R Horologii and S Pav are in Tables XIII and XIV. The light and color curves of R Hor are in Figure 10 and of S Pav in Figure 11.

The variables in the 61 Cyg and Wolf 630 groups were found to lie, at maximum, on the extrapolated (M_{bol} , $R-I$) relation for nonvariable stars in the young disk population Hyades group. Although the old disk subgiants depart

TABLE XII
OBSERVATIONS OF ϵ OCTANTIS

JD	V_E	$B-V$	$U-B$	R	$R-I$
2440000					
2440405	5. ^m 05	+1. ^m 50	+1. ^m 26		
426	5.06	+1.45	+1.21		
735	5.20			3. ^m 32	+1. ^m 50
736	5.14			3.29	+1.49
790	5.04			3.21	+1.48
792	4.96			3.18	+1.49

TABLE XIII
OBSERVATIONS OF R HOROLOGII

JD	V_E	$B-V$	$U-B$	R	$R-I$
2440000					
2440483				6. ^m 45	+2. ^m 20
485				6.54	+2.20
497	11. ^m 67	+1. ^m 81	+0. ^m 20		
498				6.58	+2.15
529	11.97	+1.88	+0.21		
532	12.00	+1.88	+0.32		
534				6.71	+2.175
543	11.79	+2.02	+0.32		
546				6.47	+2.155
547	11.96	+1.83	+0.26		
559	11.48	+2.10	+0.38		
561				6.21	+2.20
571	11.07	+2.05	+0.40		
581				6.02	+2.21
583	10.77	+2.02	+0.45		
586	10.71	+2.00	+0.36		
590				5.50	+2.23
591	10.66	+2.00	+0.35		
618	10.04	+1.88	+0.57		
627	9.66	+1.84	+0.34		
628				5.27	+2.15
629				5.22	+2.14
643	8.59	+1.675	+0.36		
645				4.82	+2.03
647				4.80	+1.93
656	7.02	+1.60	+0.60		
657	6.93	+1.58	+0.58		
658				4.10	+1.81
666	6.25			3.87	+1.69
681				3.44	+1.70
683	6.14	+1.465	+0.59		
684				3.46	+1.695
689				4.16	+1.64

from the Hyades relation, the giants redder than $(R-I)$ near $+1^m2$ populate the same $(M_{\text{bol}}, R-I)$ relation in both the young and old disk populations (Eggen 1971*d*, Fig. 2). The variables in Table IX are shown in Figure 12 where the straight line represents the Hyades $(M_{\text{bol}}, R-I)$ relation. The small amplitude variables θ Aps, ϵ Oct, and ρ Per are shown as open circles, representing maximum light, whereas the course of variation of the larger amplitude variables is indicated schematically; RT Cnc has been extrapolated to fainter magni-

TABLE XIV
OBSERVATIONS OF S PAVONIS

JD	V_E	$B-V$	$U-B$	R	$R-I$
2440000					
2440380	7. ^m 67	+1. ^m 64	+0. ^m 58		
385	7.76	+1.62	+0.57		
403				4. ^m 55	+1. ^m 94
405	7.72	+1.63	+0.56		
420	7.70	+1.63	+0.44		
426	7.72	+1.58	+0.53		
429				4.59	+2.035
445	7.64	+1.54	+0.58		
451	7.54	+1.59	+0.69		
452				4.37	+2.015
453	7.51	+1.61	+0.64		
456				4.25	+2.00
474	7.34	+1.61	+0.62		
477	7.38	+1.58	+0.66		
483				4.26	+1.96
485				4.27	+1.98
497	7.37	+1.61	+0.67		
498				4.64	+1.89
518	7.58	+1.61	+0.62		
529	7.73	+1.59	+0.62		
530				4.57	+1.87
533				4.64	+1.97
534				4.62	+2.005
543	7.92	+1.58	+0.55		
545				4.69	+1.98
546				4.72	+1.965
559	8.04	+1.63	+0.57		
563				4.62	+2.05
733	7.75			4.38	+1.915
734	7.73			4.38	+1.885
735	7.82			4.42	+1.87
736	7.75			4.38	+1.895
760	7.97			4.51	+1.92
765	8.01			4.53	+1.90
790	8.03			4.49	+1.90
792	7.98			4.48	+1.915

tudes than observed by analogy with other, similar variables. For comparison, a single observation, $(R, R-I) = (7^m05, +1^m63)$, near maximum light was obtained of the variable, star No. 120 (Walker 1958), in the old disk cluster NGC 6940. Walker found that the characteristic period of this star, of spectral type M5 II-III, is near 80^d and the amplitude, which varies from cycle to cycle, is near 0^m4. The light curve (Walker 1958, Fig. 4) and period are almost identical with those of Z Eridani (Eggen 1971*d*, Fig. 8). If one adopts a reddening of $E(B-V) = +0^m19$ (Walker 1958) and a modulus of $(m-M)_0 = 9^m6$ (Larsson-Leander 1964) we find $(M_{\text{bol}}, R-I) = (-4^m25, +1^m50)$ (represented in Fig. 12 by a filled circle).

As mentioned in section V, HR 5134 has also been assigned to the 61 Cyg group. As a member of that group the path traced in the $(M_{\text{bol}}, R-I)$ plane lies mainly above the Hyades relation (Eggen 1971*d*, Fig. 2), unlike the other variables, and the present assignment (placing the star as shown in Fig. 12) is to be preferred.

The nature of the red variables in these groups is consistent with those previously discussed in the Wolf 630 and 61 Cyg groups (Eggen 1971*d*) where the variables with $(R-I)$ at maximum between about $+1^m3$ and $+1^m6$ are quasi-periodic with characteristic periods of 80-90 days and with a secondary oscillation in a period an order of magnitude longer. The young disk

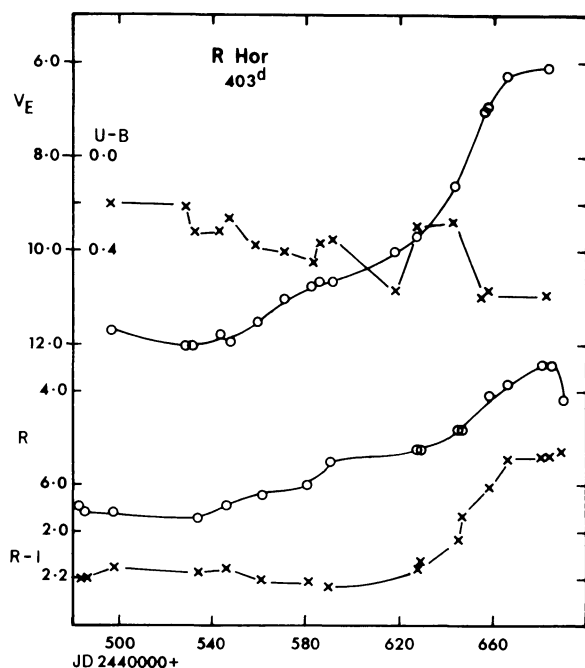
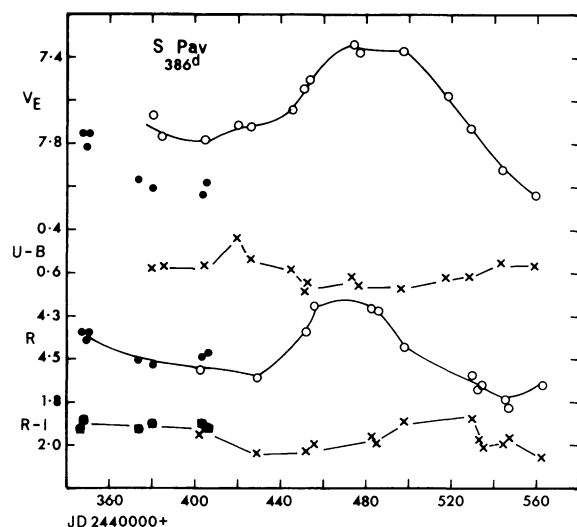
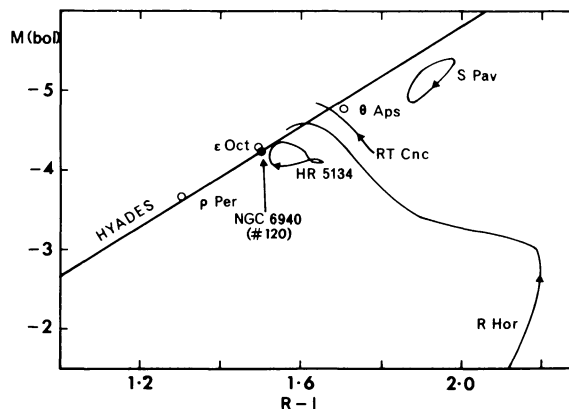


FIG. 10 — Light and color curves for R Hor.

FIG. 11 — Light and color curves for S Pav. The filled and crossed circles represent observations folded back one cycle (i.e., 386^d).

variables of this color in the Hyades group have half the period and do not show the secondary oscillation. The secondary oscillation of RT Cnc is well documented and has a period near 600 days but θ Aps and the new variable ϵ Oct have not yet been followed consistently enough. Like

FIG. 12 — The variable stars of the four groups, and of NGC 6940, in the (M_{bol} , $R-I$) plane. The straight line represents the stars in the young disk Hyades group.

R Leo (313^d) in the Wolf 630 group (Eggen 1971*d*, Fig. 12) and S Sculptoris (365^d) in the 61 Cyg group (Eggen 1970*b*, Fig. 12), S Pav (386^d) in the ϵ Ind group (present Fig. 11) shows large variations in visual amplitude from cycle to cycle although the characteristic period is little affected. This is in marked contrast to R Hydrae (388^d) in the young disk Hyades group (Eggen 1971*d*, Fig. 11) which is relatively stable from cycle to cycle, but the period is sharply decreasing at the rate of about 50^d per century (see *General Catalogue of Variable Stars*).

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