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THE CLASSIFICATION OF INTRINSIC VARIABLES. VIII. ULTRASHORT PERIOD CEPHEIDS

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ABSTRACT

The photometric and astrometric data for ultrashort period Cepheids with maximum magnitude brighter than 11.5 visual are collected and discussed. Most of these variables are high-mass, little evolved stars which, in the halo and disk populations, are blue stragglers. The luminosities are calibrated from membership in disk and halo population groups; $M_V = 8(1 - [c_1]_c)$ for disk stars, where $[c_1]_c$ is a reddening- and temperature-free parameter.

Subject headings: photometry — stars: δ Scuti — stars: variables

I. INTRODUCTION

The Cepheid variable stars may be subdivided into groups most easily on the basis of the period:

long period Cepheids (LPCs).—$P = 10.0$–100.0 days. $\log P = 1.0$–2.0;
short period Cepheids (SPCs).—$P = 1.0$–10.0 days, $\log P = 0.0$–1.0;
very short period Cepheids (VSPCs).—$P = 0.275$–1.0 days, $\log P = -0.56$–0.0;
ultrashort period Cepheids (USPCs).—$P < 0.275$ days, $\log P < -0.56$.

These divisions are based entirely on convenience and are largely without astrophysical relevance. The LPCs, in the Galaxy and Magellanic Clouds, are discussed in Eggen (1977*a*, Paper VI). Typical representatives in the very young disk population are such bright galactic objects as U Car (38.8 days) and RS Pup (41.4 days). Representatives of the low-mass LPCs in the old disk and halo populations are W Vir (34.5 days), variable 1 in ω Cen (58.8 days), and AP Her (10.4 days). The SPCs are also represented in the young and old disk populations, as well as in the halo population. The VSPC variables, sometimes called RR Lyrae stars, are discussed elsewhere (Paper IX, in preparation). The muddled nomenclature now in general use for the USPC variables is probably the best argument for the simplification introduced here. It was noted early (Eggen 1956) that a small group of bright, little evolved stars showed light variations in a period of a few hours, and these were called δ Scuti stars, after the prototype, discovered (by Fath 1935) some years earlier; it was then believed that these were the young disk population, high-mass analogs of similar variables with larger amplitudes in globular clusters (Eggen 1957). At about the same time Smith (1955), referring to the few known USPCs with large amplitudes (e.g., CY Aqr) as well as to the δ Scuti stars, suggested the name "dwarf Cepheids." A general discussion of the situation some 20 years ago is given by Struve (1955). Some 10 years ago a quite general assumption was that the masses of the USPCs were smaller than that of the Sun, based mainly on spectrophotometric observations (e.g., Danziger and Dickens 1967; Danziger and Kuhi 1966; Danziger and Oke 1967; Kuhi and Danziger 1967). However, Bessell (1969*a*) demonstrated that this interpretation originated in an incorrect calibration of the absolute energy distribution of Vega and an underestimated line blanketing. In recent years the labels δ Scuti stars, dwarf Cepheids, and AI Velorum stars (Bessel 1969*b*) have been used, often in a random and confusing way. It was earlier proposed (Eggen 1970*a*) that the name USPC be used for all Cepheids in this period range, but other labels, especially δ Scuti star and dwarf Cepheid, are still widely used.

The known USPCs brighter than visual magnitude 11.5 mag at maximum light are listed in Table 1. The stars are arranged by constellation, and the list contains 16 variables which have not as yet been named. In addition to HD, HR, or BD designations, the table contains the median visual magnitude, the proper motion and radial velocity, the primary period, and estimates of the visual light amplitude. The last column contains two sets of references: the first, numbered set refers to the source of intermediate and Hβ photometry; the second, lettered set refers to the source of the apparent motions. These references are listed in Table 2. Table 3 contains a bibliography of references (1) to the discovery of the variable and (2) to a photometric discussion, usually of recent origin, that will contain most earlier references; the discovery reference is to the recognition of the correct nature of the variable and not necessarily to the actual discovery of the variations. For convenience and terseness, Table 3 and its notes refer only to the first author of multiauthored papers.

The luminosities and motions of the USPCs in the young disk, the old disk, and the halo populations will be discussed in subsequent sections, but those in the Hyades group, which offer an opportunity to examine the luminosity calibration, will be discussed first.

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TABLE 1

ULTRASHORT PERIOD CEPHEID VARIABLES

Var.	Name	$\langle V \rangle$	μ_α	μ_δ	ρ km sec^{-1}	P days	ΔV	S, S
CC And	BD +41°119	$9\overset{\text{m}}{.}35$	$-0\overset{''}{.}004$	$-0\overset{''}{.}014$	- 11.0	0.125	$0\overset{\text{m}}{.}1$-$0\overset{\text{m}}{.}3$:	-, A
GN	HR 114	5.2	+0.041	-0.054	- 10.2	0.069	0.02	2, A
GP	...	10.75	...	...	...	0.079	0.55	2, -
BS Aqr	HD 223338	9.4	+0.024	-0.018	+ 41.0	0.198	0.45	1, BGH
CY	BD +0°4900	10.85	+0.052	-0.061	- 32.0	0.061	0.65	1, BI
EM	HR 8006	6.55	+0.009	+0.021	...	0.06:	0.03±	3, A
...	HR 8676	6.2	+0.032	+0.006	- 5.8	0.09	0.02	5, AF
V 1208 Aql*	HR 7331	5.55	+0.008	+0.018	+ 3.2	0.150	0.05	2, AF
UU Ari	HR 729	6.15	+0.076	-0.036	+115:	0.08	0.03	3, AF
UV	HR 812	5.2	+0.121	-0.081	- 1.5	0.06:	0.02±	5, AF
...	HD 11285	6.7	+0.023	-0.010	...	0.075	0.02	2, A
...*	HD 15165	6.7	+0.042	-0.008	+ 34.0	0.10	0.07:	2, AF
KW Aur*	HR 1706	5.0	-0.024	+0.011	- 9.7	0.087	0.02-0.08	3, AF
OX Aur*	HR 2539	6,1	-0.003	+0.006	+ 1.0	0.136	0.03	6, AF
...	HR 2557	6.05	+0.001	-0.012	- 7.0	0.1:	0.02±	3, AF
YZ Boo	+37°2635	10.6	-0.013	-0.027	- 22.8	0.104	0.4-0.5	1, BF
κ*	HR 5329	4.5	+0.060	-0.006	- 15.6	0.067	0.02-0.03	6, AF
...	HR 5441	6.4	-0.002	-0.078	+ 1.8	0.15:	0.02±	6, AF
X Cae	HR 1653	6.3	+0.029	+0.035	+ 5.9	0.135	0.06-0.1	5, AJ
UY Cam	...	11.45	-0.004	-0.025	- 35	0.267	0.2-0.5	-, BF
VZ Cnc	HD 73857	7.65	-0.045	-0.010	+ 26.0	0.178	035-0.7	1, AF
BN	HD 73763	7.8	Praesepe	KW 323		0.038	...	3, Clus.
BQ	HD 73729	8.2	Praesepe	KW 292		0.074	...	3, Clus.
BR	HD 73175	8.25	Praesepe	KW 45		0.038	...	3, Clus.
BS	HD 73450	8.5	Praesepe	KW 154		0.051	...	3, Clus.
BT	HD 73575	6.65	Praesepe	KW 204		0.110	...	3, Clus.
BU	HD 73576	7.65	Praesepe	KW 207		0.05:	...	3, Clus.
BV	HD 73746	8.65	Praesepe	KW 318		0.2	...	3, Clus.
BW	HD 73798	8.5	Praesepe	KW 340		0.072	...	3, Clus.
BX	HD 74028	7.95	Praesepe	KW 445		0.053	...	3, Clus.
BY	HD 74050	7.9	Praesepe	KW 449		0.058	...	3, Clus.
AI CVn*	HR 4715	6.05	-0.080	+0.013	- 5.0	0.170	0.02-0.11	3, AFJ
AO	HR 5017	4.75	-0.124	+0.21	+ 7.5	0.135	0.02-0.03	3, AF
AD Cmi	HD 64191	9.25	-0.013	0.001	+ 34.5	0.123	0.295	1, DF
AZ	HR 2989	6.45	-0.033	-0.004	+ 14.7	0.095	0.055	3, AF
YZ Cap	HD 358431	11.25	-0.018	-0.013	- 88.0	0.273	0.45	2, BG
...	HR 8102	6.45	+0.038	+0.003	- 39.2	0.097	0.07	5, AF
...	HR 8024	5.95	-0.045	-0.016	...	0.1:	0.05±	5, A
V 521 Cas	...	13.75	NGC 7789	No. 573		0.17:	0.1:	-, Clus.
V 526	HR 238	6.35	+0.137	0.000	+ 2.3	0.136	0.02	6, AF
β	HR 21	2.3	+0.527	-0.181	+ 11.8	0.104	0.04	3, AF
V 743 Cen	HD 116994	8.7	+0.006	-0.051	- 5.5	0.102	0.25	2, AR
V 753	HD 302013	10.4	...	...	...	0.221	0.40	2, -
DQ Cep	HR 199908	7.25	+0.023	+0.021	- 21.9	0.079	0.04-0.08	-, AF
ε	HR 8494	4.15	+0.446	+0.049	- 1.6	0.04	0.02-0.03	3, AF
AV Cet	HR 401	6.2	+0.171	-00.070	...	0.07	0.02	3, A

TABLE 1—*Continued*

Var.	Name	< V >	μ_α	μ_δ	ρ km sec^{-1}	P days	ΔV	S, S
FM Com	HR 4684	6.45	Coma Ber. Tr 60			0.055	0.02-0.04	7, Clus.
GM	HD 10610	8.0	Coma Ber. Tr 19			0.2	0.02	7, Clus.
V 668 Cr A	HD 170625	8.7	+0.040	-0.078	...	0.088	0.025	2, A
γ Cr B	HR 5849	3,8	-0.100	+0.041	- 10.5	0.03	0.05±	6, AF
SU Crt	HD 100363	8.65	+0.042	-0.154	+132:	0.05	0.01-0.02	4, AF
XX Cyg	...	11.8	-0.007	+0.001	-135:	0.135	0.85	-, BF
V 1276	HR 7501	6.5	+0.063:	+0.046:	- 25.2	0.088	0.0-0.01	3, AF
δ Del*	HR 7928	4.45	-0.017	-0.044	+ 9.3	0.136	0.05-0.09	3, AF
CL Dra	HR 5960	4.95	-0.153	+0.110	- 17.2	0.063	0.02	3, AF
CN	HR 7563	6.3	+0.003	0.000	- 12:	0.1±	0.0-0.08	-, AF
S Eri	HR 1611	4.8	+0.053	-0.091	- 15.0	?	0.02±	5, AF
DL	HR 1225	6.2	+0.043	+0.015	...	0.16	0.04±	3, A
o^1	HR 1298	4.05	+0.006	+0.081	+ 11:	0.09:	0.01-0.02	3, AF
RS Gru	HD 20379	8.25	-0.064	-0.017	+ 81.5	0.147	0.50	1, A1
DY Her	BD +12°3028	10.45	-0.003	+0.015	- 45.8	0.149	0.5	1, BF
V 620	HR 6391	6.2	-0.006	+0.028	- 2.2	0.080	0.02-0.04	3, AF
V 644*	HR 6290	6.35	+0.037	-0.033	- 5.0	0.115	0.06	3, AF
V 648	DH 159223	6.85	+0.018	+0.041	- 29.9	0.3:	0.04:	2, CDF
VX Hya	...	10.7	+0.003:	0.000:	0.0	0.223	0.1-0.7	1, AK
HQ	HR 3265	6.3	-0.046	+0.035	+ 36.1	0.097	0.00-0.03	3, AJ
DE Lac	BD +40°4745	10.25	+0.005	-0.003	- 16.5	0.254	0.30	1, B1
DG Leo*	HR 3889 B	7.3	-0.046	-0.013	+ 27.2	0.081	0.04+	6, A1
TV Lib	...	11.95	+0.004	+0.010	- 52.4	0.270	1.25	2, BK
EH	BD -0°2911	9.85	-0.023	-0.016	- 54.5	0.088	0.70	1, BCF
... Lup	HR 5974	6.1	-0.032	-0.026	- 28.4	?	0.03:	5, AF
SZ Lyn*	HD 67390	9.45	-0.012	-0.036	+ 23.0	0.121	0.45	1, BC*
TV*	...	11.45	0.000	+0.005	- 4.3	0.241	0.40	-, B*
ZZ Mic	HD 199757	9.45	-0.004	-0.021	- 70	0.067	0.35	2, DF
V 474 Mon*	HR 2107	6.1	+0.013	+0.011	+ 12:	0.139	0.03-0.35	2, AF
V 571	HR 2707	5.45	-0.034	-0.015	+ 30:	0.110	0.02-0.05	3, AF
V 588	...	9.65	NGC 2264, W2			0.11	0.05±	-, Clus.
V 589*	...	10.25	NGC 2264, W20			0.124	0.05±	*, Clus.
BP Oct	HR 5491	6.45	-0.096	-0.067	- 14.5	0.08	0.00-0.04	2, AF
V 567 Oph	BD +1°3547	11.25	-0.022	+0.010	- 15.0	0.130	0.35	2, BK
...	HR 6434	6.5	+0.017	+0.018	- 25.2	0.1+	0.02+	6, AF
V 1004 Ori*	HR 2100	5.9	+0.004	-0.008	+ 45.3	0.05	0.01	5, AG
NZ Pav	HR 7524	6.05	+0.091	-0.162	- 40.9	0.080	0.02	3, AF
DH Peg	BD +6°4990	9.6	+0.019	0.000	- 55.5	0.255	0.50	2, BF
DY	HD 218549	10.35	+0.050	-0.018	- 25.0	0.073	1.0	2, BF
τ	HR 8880	4.6	+0.035	-0.006	+ 9.0	0.054	0.00-0.02	3, AF
GX*	HR 8584	6.3	-0.039	-0.028	- 1.6	0.056	0.02	3, AF

TABLE 1—*Continued*

Var.	Name	< V >	μ_α	μ_δ	ρ km sec^{-1}	P days	ΔV	S, S
KN Per	...	11.2:	+0.005	-0.016	...	0.232	0.4±	-, B
V 376	HR 1170	5.8	+0.001	+0.023	- 15:	0.098	0.02-0.1	3, AF
V 386	HR 1223	6.5	+0.025	-0.033	- 2.0	0.052	0.01-0.02	6, AF
...	BD +47°842	8.8	α Per	H 906		0.070	0.02	1, Clus.
...	BD +48°494	9.15	α Per	H 501		0.04	0.01	1, Clus.
...	BD +48°905	9.0	α Per	H 606		0.04	0.01	1, Clus.
SX Phe	HD 226035	7.0	+0.257	-0.859	- 29.0	0.055	0.3-0.6	2, AF
ρ	HR 242	5.2	+0.059	+0.038	+ 22.0	0.110	0.1	3, AF
...	HR 239	6.45	+0.006	+0.010	...	0.05	0.015	5, A
VX Psc	HR 432	5.9	+0.062	-0.004	+ 4.2	0.131	0.02	3, AF
VY	HR 515	6.55	+0.055	+0.012	+ 3.3	0.163	0.01	3, AF
XX	HR 214	6.0	+0.104	+0.007	0.0	0.104	0.04	6, AF
ρ Pup	HR 3185	2.8	-0.084	+0.050	+ 46.0	0.141	0.1	3, AF
ρ Sgr	HR 7340	3.95	-0.027	+0.022	+ 1.2	0.050	0.03	5, AF
V 703 Sco	HD 160589	7.85	+0.034	+0.015	- 51.0	0.115	0.1-0.7	2, DF
...	HD 153747	7.4	+0.001	+0.009	...	0.050	0.015	2, D
WZ Scl	HR 431	6.55	-0.038	-0.036	- 4.5	0.090	0.03	3, AF
XX	HD 9133	8.9	+0.014	-0.023	...	0.046	0.035	2, D
AI*	HR 359	5.9	+0.086	-0.033	+ 8:	0.05	...	5, AF
V 369 Sct	HD 174553	9.25	+0.018	-0.019	...	0.223	0.12	2, D
δ	HR 7020	4.8	+0.008	0.000	- 43.3	0.194	0.1-0.2	3, AF
AP Ser	...	11.1	-0.041	-0.037	- 80:	0.254	...	2, BF
CW	...	11.85	-0.015	+0.012	...	0.189	0.5	2, B
o*	HR 6581	4.25	-0.078	-0.057	- 30.0	0.053	0.06	6, AF
δ	HR 5718/9	4.2	-0.074	+0.007	- 39.7	0.13	0.04	-, AF
RX Sex	HD 90386	6.6	-0.001	-0.007	...	0.080	0.01±	-, A
IM Tau	HR 1287	5.4	-0.032	-0.038	+ 19.0	0.13:	0.05-0.1	3, AF
V 479*	HD 24550	7.4	+0.010	-0.020	+ 8:	0.076	0.02-0.03	2, AF
V 480	HR 1547	5.2	Hyades	VB 123		0.042	0.01	3, Clus.
V 483	HR 1351	5.55	Hyades	VB 30		0.054	0.03	3, Clus.
V 534	HD 23567	8.25	Pleiades	H 447		0.032	0.01-0.02	9, Clus.
V 624	HD 23156	8.5	Pleiades	H 28		0.024	0.01	9, Clus.
V 647	HD 23607	8.1	Pleiades	H 501		0.049	0.01	9, Clus.
V 650	HD 23643	7.75	Pleiades	H 534		0.031	0.03	9, Clus.
V 696	HR 1356	5.2	Hyades	VB 33		0.036	0.01	3, Clus.
Θ^{2*}	HR 1412	3.4	Hyades	VB 72		0.08	0.03	6, Clus.
BS Tuc	HD 6870	7.5	+0.127	-0.017	+ 12.4	0.065	0.015	2, AF
Θ	HR 139	6.5	+0.086	-0.018	+ 2.3	0.05	0.09	5, AF
υ uma	HR 3888	3.8	-0.293	-0.152	+ 21.6	0.13	0.07±	3, AF
...	HD 99002	6.7	-0.062	-0.012	- 12.3	0.05	0.02	-, AF
AI Vel	HD 69213	6.8	+0.026	+0.023	+ 15.0	0.112	0.1-0.7	1, AF
FZ	HR 3588	5.15	-0.092	+0.054	+ 18.6	0.065	0.1-0.02	3, AF
...	HR 3350	5.1	-0.066	+0.020	+ 24.7	0.07	0.02	5, AF
DK Vir	HR 5005	6.7	-0.030	-0.023	...	0.121	0.04	3, A
FG*	HD 106384	6.55	-0.082	+0.111	+ 9.1	0.07	...	8, AF
FM	HR 4847	5.1	-0.108	+0.004	- 8.7	0.075	0.01-0.035	1, AF
FT	HR 4746	6.2	-0.092	-0.011	- 12:	0.05	0.03	5-6, AF
GG	HR 4824	6.35	-0.104	+0.001	+ 8:	0.05	0.02	3, AF
LT Vul	HR 7222	6.5	+0.020	-0.008	+ 5.0	0.095	0.04	3, AF

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NOTES TO TABLE 1

V1208 Aql	Optical companion 60″ arcsec south.
— Ari	Cpm companion 74″ (HD 15165/4).
KW Aur	Sp. B. 3.79 days. ADS 3824 AC, 15″ Cpm; ($V, B - V, U - B$) = (7.95, +0.41, −0.06) mag. B, 11″, is optical.
OX Aur	ADS 5534. B, 22″, ($V, B - V, U - B$) = (10.22, +0.69, +0.18) mag.
ξ Boo	ADS 9173A. B component, 14″, has ($V, B - V, U - B$) = (6.72, +0.40, −0.03) mag.
AI CVn	Several series of radial velocity determinations give mean values from −15 to +5 km s^{-1}.
γ CrB	ADS 9757, Δm = 1.44 mag. P = 91.0 years, a = 0″.74.
SU Crt	The radial velocity shows a range of 25 km s^{-1} from six plates.
δ Del	Sp. B. 40 days, equal components.
V644 Her	Sp. B. 11.9 days.
DG Leo	ADS 6299, 0″.4. The A component is a Sp. B. P = 4.15 days, and all three components are of near equal magnitude. The B component in the visual pair is the USPC (Fekel and Bopp 1977).
SZ Lyn	The radial velocity is from McNamara and Feltz 1978.
TV Lyn	The radial velocity is from Penston 1972.
— Lup	HR 5974. Variable, but observations not yet complete.
V474 Mon	In Eggen 1976*a* the wrong apparent motions (those of 2 Mon, HR 2108) were inadvertently listed and used.
V589 Mon	The intermediate-band photometry is by Strom, Strom, and Yost 1971.
V1004 Oph	Sp. B. 2.74 days.
GX Peg	Sp. B. 2.34 days.
AI Scl	Probable Sp. B. Velocity range of 80 km s^{-1}.
o Ser	Possibly double-lined Sp. B.
δ Ser	ADS 9701, Sm = 1.0 mag, 3″.8. Slow orbital motion.
V479 Tau	ADS 2849A. BC, 59″ from A, has equal components separated by about 2″.0; ($V, B - V, U - B$) = (8.92, +0.32, +0.08) mag.
Θ^2 Tau	Sp. B. P = 140.75 days.
FG Vir	ADS 8471A. B component, 25″, has ($V, B - V, U - B$) = (13.51, +0.38, −0.17) mag; C, 75″, has (11.8, +1.33, +1.35) mag.
FM Vir	Possibly a double-lined binary; P = 38.3 days, and Δm = 0.5 mag.
HR 4824	There are 10 radial velocity determinations available from the Dominion Astrophysical Observatory and Royal Greenwich Observatory of this broad-lined (rotational velocity = 130 km s^{-1}) star. The six of highest weight give a mean of ~3 ± 2 km s^{-1}, and the remaining four give +27 ± 10 km s^{-1}. The proper motion is nearly identical to that of FM Vir (32 Vir), 3° distant.

II. HYADES GROUP

The USPCs in the Hyades and Praesepe clusters are listed in Table 4 together with the photometric parameters. It should be noted here that the observations from the source referenced as 2 in the last column of Table 1 are on the ($b - y, M_1, C_1, \beta$) system, whereas the other results are all on the Strömgren ($b - y, m_1, c_1, \beta$) system. However, as discussed elsewhere (Eggen 1976*b*), the values of $b - y$ and β are the same in the two systems, and for stars with $(b - y)_0 \lesssim 0.2$ mag, $M_1 = m_1$ and $C_1 = c_1$. Also, because of the strong CH in Hyades stars, the v filter in the Strömgren system, although considerably wider than that used in the present system, is effectively reduced to the same width, making c_1 and m_1 equivalent to C_1 and M_1 for Hyades stars with $b - y > 0.2$ mag (Eggen 1976*b*). This effect, which has contributed to the so-called Hyades anomaly (e.g., Barry 1974), will be discussed in more detail elsewhere.

TABLE 2

SOURCES OF APPARENT MOTIONS AND INTERMEDIATE-BAND PHOTOMETRY IN TABLE 1

1. Table 3 (reference photometry with asterisk)
2. Eggen 1978*c*
3. Eggen 1976
4. McMillan *et al.* 1976
5. Grønbech and Olsen 1976
6. Strömgren 1965
7. Crawford 1969
8. Eggen 1971
9. Crawford and Perry 1976

Proper Motion and Radial Velocity

A. New values based on all available positions
B. Clube 1968, 1971
C. AGK3
D. Yale or Cape Zone Catalog
F. Abt and Biggs 1972
G. Kinman 1961
H. Klemola 1971
I. Struve 1949
J. Jones 1971
K. Clube 1969

Table 5 contains nine noncluster USPCs that are members of the Hyades group. Some of these objects require discussion.

VZ Cancri.—The interpretation of VZ Cnc has had a varied history. The star is some 10° away from the Praesepe cluster and is probably at the same distance; it could easily be considered an outlying member of the cluster. A well-determined proper motion based on meridian observation (Table 1) agrees well with the value from AGK2. Danziger and Oke (1967) have suggested that the variable has a mass less than 0.5 solar and is slightly metal deficient, with a possible overabundance of lithium. A modulus of 6.0 mag, which is nearly the same as that of the Praesepe cluster (6.1 mag), gives (U, V, W) = (+36, −16.8, −17) km s^{-1}, making the variable a member of the Hyades group with median luminosity of +1.65 mag. McNamara

TABLE 3
DISCOVERY AND OTHER REFERENCES

Star		
CC	And	Eggen (2), Walker (2)
GN		Nishimura, Elliott
GP		Lange
BS	Aqr	Andrews, Langford
CY		Hoffmeister (1), Langford
EN		Breger (2), Contel
HR 8676		Weiss (1)
V 1208	Aql	Breger (2)
UU	Ari	Breger (2)
UV		Millis (2), Valtier (2)
HD 11285		Weiss (2)
HD 15165		Seeds, Mechler
KW	Aur	Danziger (1), Hudson
OX		Gupta (2)
HR 2557		Kurtz (2)
YZ	Boo	Eggen (3), Langford
κ		Millis (3), Elliott
HR 5441		Auvergne
X	Cae	Cousins (1), Jones (3)
UY	Cam	Williams
VZ	Cnc	Whitney, Langford
BN, BQ, BR BU, BV, BN BX, BY		Breger (4)
AI	CVn	Jones (2), Hayes
AO		Danziger (1), Penfold
AD	CMi	Abhyankar, Breger (8)
AZ		Percy (1), Percy (3)
YZ	Cap	Zessewitsch, Kinman
HR 8102		Eggen (12), Kilambi (2)
HR 8024		Kilambi (1)
DG	Leo	Elliott, Fekel
TV	Lib	Lange, Clube
EH		Code, Langford
-	Lup	Eggen (13)
SZ	Lyn	Eggen (7), Langford
TV		Lochet, Penston
ZZ	Mic	Churms, Chambliss (2)
V 474	Mon	Jones (1), Shobbrook
V 571		Eggen (8), Stobie
V 588		Breger (5)
BP	Oct	Bessell
V 567	Oph	Hoffmeister (2), Clube
HR 6434		Breger (7)
V 1004	Ori	Breger (7)
V 521	Cas	Danziger (2)
V 526		Bhatnagar
β		Millis (1)
V 743	Cen	Chen, Chambliss (1)
V 753		Cannon (1), Cannon (2)
DQ	Cep	Walker (1), Schroeder
ε		Breger (2)
AV	Cet	Jørgensen
FM	Com	Breger (1), Elliott
GM		Jackish
V 668	Cr A	Eggen (10)
γ	CrB	Percy (2)
SU	Crt	Eggen (10), McMillan
XX	Cyg	Detre, Fitch
V 1276		Breger (2)
δ	Del	Eggen (6), Van Genderen
DL	Dra	Millis (3), Breger (2)
CN		Breger (2), Warman
S	Eri	Millis (3), Jørgensen
DL		Jørgensen
o^1		Jørgensen
RS	Gru	Eggen (4), McNamara (2)
DY	Her	Soloviev (1), Langford
V 620		Breger (2), Elliott
V 644		Breger (7), Elliott
V 648		Jackish
VX	Hya	Lausse, Breger (9)
HQ		Cousins (1)
DE	Lac	Ischenko, McNamara (1)
V 703	Sco	Plaut, Oosterhoff
HD 153747		McInally
WZ	Scl	Demers
XX		Demers
AI		Eggen (11)
V 369	Sct	Hall
δ		Fath, Muir
AP	Ser	Soloviev (2)
CW		Hoffmeister (1), Bookmeyer
o		Millis (3)
δ		Millis (2)
RS	Sex	Jerzykiewicz
IM	Tau	Danziger (1), Percy (3)
V 479		Dickens
V 480		Millis (3)
V 483		Breger (3)
V 534, V 624		Breger (6)
V 647, V 650		Breger (6)

TABLE 3—*Continued*

Star			Star		
NZ	Pav	Eggen (10)	V 696		Breger (7)
			Θ^2		Horan, Duerbeck
DH	Peg	Jensch, Bookmeyer			
DY		Mongenroth, Bookmeyer	BS	Tuc	Eggen (10)
τ		Millis (4), Michael	Θ		Cousins (2)
GX		Breger (2)			
			υ	UMa	Danziger (1)
KN	Per	Hoffmeister (3)	HD 99002		
V 376		Breger (2), Warman			
V 386		Breger (2), Rydgren	AI	Vel	Hertzsprung, Breger (10)
+47°842		Slovak, Crawford	FZ		Eggen (9)
+48°494		Slovak, Crawford	HR 3350		Eggen (12)
+48°905		Slovak, Crawford			
			DK	Vir	Danziger (1)
SX	Phe	Eggen (1)	FG		Eggen (10)
ρ		Cousins (1)	FM		Bartolini (1), Kurtz (1)
HR 239		Weiss (1)	FT		Eggen (12)
			HR 4824		Bartolini (2)
VX	Psc	Breger (2), Valtier (1)			
VY		Breger (2), Valtier (1)	LT	Vul	Breger (2)
XX		Gupta (1)			
ρ	Pup	Eggen (5)			
ρ	Sgr	Millis (3)			

NOTES TO TABLE 3

Abhyankar 1959 Ap. J. 130, 834

Andrews 1936 Harvard Bull. 902

Auvergne 1977 IBVS 1365

(1) Bartolini 1972 IBVS 704

(2) Bartolini 1975 IBVS 981

Bessell 1972 Pub.A.S.P. 84, 72

Bhatnagar 1973 IBVS 778

Bookmeyer 1977 Revista Mex. 2, 235

(1) Breger 1968 Astrophys.Lett. 1, 103

(2) Breger 1969a A. J. 74, 156

(3) Breger 1969b Ap. J.Suppl. 19, 79

(4) Breger 1970 Ap. J. 162, 597

(5) Breger 1972a Ap. J. 171, 549

(6) Breger 1972b Ap. J. 176, 367

(7) Breger 1973 Astr.Astrophys. 22, 247

(8) Breger 1975 Ap. J. 201, 653

(9) Breger 1977a Pub.A.S.P. 89, 55

(10) Breger 1977b Pub.A.S.P. 89, 339

(1) Cannon 1971 IBVS 580

(2) Cannon 1972 Obs. 92, 234

(1) Chambliss 1968 MNRAS 138, 437

(2) Chambliss 1971 Ap. J. 165, 365

Chen 1966 IBVS 142

Churms 1961 Obs. 81, 25

Clube 1969 Mem.Roy.Astr.Soc. 72, 101

Code 1950 Pub.A.S.P. 62, 166

Contel 1974 Astr.Astrophys.Suppl. 15, 115

(1) Cousins 1969 MNASSA 28, 25

(2) Cousins 1971 MNASSA 30, 12

Crawford 1974 A. J. 79, 687

(1) Danziger 1967 Ap. J. 149, 55

(2) Danziger 1970 Pub.A.S.P. 83, 84

Demers 1969 Pub. A.S.P. 81, 861

Detre 1936 Astr.Nach. 258, 329

Dickens 1967 Ap. J. 148, L33

Duerbeck 1978 IBVS 1412

(1) Eggen 1952 Pub.A.S.P. 64, 31

(2) Eggen 1953 Pub.A.S.P. 65, 291

(3) Eggen 1955 Pub.A.S.P. 67, 357

(4) Eggen 1956a Pub.A.S.P. 68, 142

(5) Eggen 1956b Pub.A.S.P. 68, 238

(6) Eggen 1956c Pub.A.S.P. 68, 541

(7) Eggen 1962 Pub.A.S.P. 74, 159

(8) Eggen 1968 IBVS 250

NOTES TO TABLE 3—*Continued*

(9) Eggen 1970 Pub.A.S.P. 82, 274

(10) Eggen 1971 Pub.A.S.P. 83, 762

(11) Eggen 1973 Ap. J. 180, 857

(12) Eggen 1974 IBVS 935

(13) Eggen 1978 Unpublished

Elliott 1974 A. J. 79, 1082

Fath 1937 Lick Obs.Bull. 18, 77

Fekel 1977 Pub.A.S.P. 89, 216

Fitch 1966 Lunar Planet.Lab. 5, 71

(1) Gupta 1972 IBVS 751

(2) Gupta 1974 IBVS 908

Hall 1970 Pub.A.S.P. 82, 830

Hayes 1968 Pub.A.S.P. 80, 57

Hertzsprung 1931 BAN 6, 147

(1) Hoffmeister 1935 Sterne 15, 121

(2) Hoffmeister 1942 MVS 8

(3) Hoffmeister 1957 MVS 314

Horan 1977 IBVS 1232

Hudson 1971 Ap. J. 165, 573

Ischenko 1948 Tashkent Bull. 2, 499

Jackish 1972 Astron.Nach. 294, 1

Jensch 1935 Astron.Nach. 255, 422

Jerzykiewicz 1972 Pub.A.S.P. 84, 529

(1) Jones 1966 MNASSA 28, 168

(2) Jones 1969 Roy.Obs.Bull. 155

(3) Jones 1971 Roy.Obs.Bull. 163

Jørgensen 1971 Astr.Astrophys. 12, 223

(1) Kilambi 1975 IBVS 1024

(2) Kilambi 1978 Pub.A.S.P. 90, 194

Kinman 1961 Roy.Obs.Bull. 37

(1) Kurtz 1976 Ap. J. 207, 181

(2) Kurtz 1977 Pub.A.S.P. 89, 941

Lange 1969 Astr.Cir. 534

Langford 1976 Thesis, Brigham Young Univ.

Lause 1932 Astr.Narich. 246, 297

Lochet 1958 MVS 367

Mechler 1974 Pub.A.S.P. 86, 279

McMillan 1976 Pub.A.S.P. 88, 995

(1) McNamara 1976a Pub.A.S.P. 88, 168

(2) McNamara 1976b Pub.A.S.P. 88, 510

McInally 1977 IBVS 1257

Michael 1974 A. J. 79, 1081

(1) Millis 1966 Pub.A.S.P. 78, 340

(2) Millis 1967aPub.A.S.P. 79, 267

(3) Millis 1967b Thesis, Univ.Wisconsin

(4) Millis 1970 Pub.A.S.P. 82, 352

Mongenroth 1934 Astr.Nach. 252, 389

Muir 1976 Ap. J. 205, 155

Nishimura 1969 Tokyo Ann. 11, 142

Oosterhoff 1966 BAN 18, 140

Penfold 1971 Pub.A.S.P. 83, 497

Penston 1972 MNRAS 156, 103

(1) Percy 1970a IBVS 444

(2) Percy 1970b Pub.A.S.P. 82, 126

(3) Percy 1971 Pub.A.S.P. 83, 335

(4) Percy 1973 Obs. 93, 81

Plaut 1948 Leiden Ann. 20, 4

Rydgren 1971 Pub.A.S.P. 83, 656

Schroeder 1966 Ap. J. 146, 738

Seeds 1976 Pub.A.S.P. 88, 251

Shobbrook 1974 MN 169, 643

Slovak 1978 Ap. J. 223, 192

(1) Soloviev 1973a Tadjick Cir 20

(2) Soloviev 1973b Tadjick Cir 22

Stobie 1977 MN 179, 389

(1) Valtier 1972 Astr. Astrophy. 16, 38

(2) Valtier 1974 Astr. Astrophy. Suppl. 18, 235

Van Genderen 1973 Astr. Astrophy. Suppl. 9, 149

Warman 1974 Revista Mex. 1, 143

(1) Walker 1952 Pub.A.S.P. 64, 192

(2) Walker 1956 Ap. J. 124, 325

(1) Weiss 1977 IBVS 1364

(2) Weiss 1978 IBVS 1400

Whitney 1950 Pub.A.S.P. 62, 56

Williams 1964 Pub.A.S.P. 76, 50

Zessewitsch 1946 Var. Stars 6, 181

TABLE 4

ULTRASHORT PERIOD CEPHEIDS IN THE HYADES AND PRAESEPE CLUSTERS*

Var.	β	$b - y$	m_1	c_1	M_v	ΔC_1	ΔM_v
Θ² Tau	2.830	0.100	0.202	1.013	+0.35	0.183	2.25
V480 Tau	2.813	0.122	0.207	0.900	+1.9	0.096	0.8
BX Cnc	2.812	0.120	0.201	0.911	+1.85	0.088	0.85
BY Cnc	2.812	0.115	0.197	0.947	+1.8	0.144	0.9
BU Cnc	2.812	0.104	0.199	0.969	+1.55	0.166	1.15
V696 Tau	2.812	0.126	0.208	0.868	+2.05	0.065	0.65
BN Cnc	2.796	0.130	0.189	0.900	+1.7	0.116	1.05
BR Cnc	2.790	0.131	0.213	0.858	+2.15	0.093	0.65
BT Cnc	2.778	0.153	0.180	0.995	+0.55	0.260	2.3
BS Cnc	2.770	0.149	0.197	0.793	+2.4	0.073	0.5
V483 Tau	2.767	0.170	0.198	0.770	+2.6	0.058	0.3
BW Cnc	2.764	0.147	0.213	0.809	+2.4	0.104	0.55
BQ Cnc	2.742	0.198	0.172	0.809	+2.1	0.150	0.95

* All quantities are in units of mag.

and Feltz (1978) found $M_v = +1.1$ mag from intermediate-band photometry and +1.3 mag from gravity and temperature considerations. The available intermediate-band and Hβ photometry by Langford (1976), Epstein and Epstein (1973), and Jones (1973) gives significant differences in the various indices. The median values in Table 5 result from consideration of all the available data. A comparison with the (β, $b - y$)-relation in Table 6 (discussed below) shows no appreciable reddening, as might be expected from the position and distance with respect to the unreddened Praesepe cluster, and shows a Hyades metal abundance. In view of the high probability that this is a Hyades group member, the proper motion, which is especially critical in declination, and a well-calibrated photometric study are of some importance.

HR 8102 (*— Capricorni*).—Although noted in 1969 (Eggen 1973*b*), the variability of this star was apparently overlooked by Kilambi, DuPuy, and Koegler, (1978) who nevertheless confirmed the variation and also found cyclic changes in the photometric indices of a most remarkable nature. However, it is likely that this remarkable variation is caused by their observational technique; they observed u, v, b, and y magnitudes in several cycles and then combined these on the basis of an ephemeris before forming $b - y$, m_1, and c_1 indices. An inspection of their Figure 2 will readily explain the results obtained from this procedure.

υ Ursae Majoris.—The high-weight (20), Allegheny trigonometric parallax of 0″.036 is the same as the group value.

δ Scuti.—There is so little dependence of the V velocity on the proper motion that a group parallax cannot be obtained. The value of M_v in Table 5 is based on the value of c_1.

Standard relations between β and m_1 and $b - y$ for the Hyades cluster and between β and M_v and c_1 for young disk (Pleiades group) stars are tabulated in Table 6. The values for the Hyades stars are from Crawford and Perry (1966), and those for the Pleiades group (Local Association) are based on clusters in that group (Pleiades and α Per). Tables 4 and 5 list the cluster or group values of M_v for the variables and the values of Δc_1 and ΔM_v from Table 6. The moduli of the individual Hyades cluster stars are based on the high-weight, meridian proper motions and their

TABLE 5

ULTRASHORT PERIOD CEPHEIDS IN THE HYADES GROUP*

Var.	β	$b - y$	m_1	c_1	M_v	ΔC_1	ΔM_v
VZ Cnc	2.740:	0.200:	0.182	0.820	+1.65	0.165	1.4
AI CVn	2.707	0.226	0.178	0.833	+0.7	0.278	2.5
AO CVn	2.780	0.180	0.231	0.913	+0.5	0.173	2.35
HR 8102	2.747	0.182	0.178	0.901	+1.3	0.232	1.7
HR 5974	2.732	0.208	0.177	0.900	+0.45	0.265	2.65
VY Psc	2.777	0.158	0.173	0.979	+0.75	0.245	2.1
δ Sct	2.749	0.214	0.197	0.830	(+2.0)	0.157	(1.0)
υ UMa	2.738	0.196	0.162	0.830	+1.55	0.180	1.5
FZ Vel	2.786	0.124	0.227	0.934	+0.65	0.180	2.15

NOTES.—VZ Cnc: median light; (U, V, W) = (+36, −16.8, −17) km s^{-1}. AI CVn: (U, V, W) = (+41, −16.8, −12) km s^{-1}. AO CVn: (U, V, W) = (+37, −16.8, +10) km s^{-1}. HR 8102 (— Cap): (U, V, W) = (+39, −16.8, +10) km s^{-1}. HR 5974 (— Lup): (U, V, W) = (+36, −16.8, −6) km s^{-1}. VY Psc: (U, V, W) = (+34, −16.8, +11) km s^{-1}. δ Sct: (U, V, W) = (+42, −16.8, +7) km s^{-1}; little dependence of V on proper motion. υ UMa: (U, V, W) = (+46, −16.8, −3) km s^{-1}. FZ Vel: (U, V, W) = (+36, −16.8, −6) km s^{-1}.

* All quantities are in units of mag.

TABLE 6

STANDARD RELATIONS

	PLEIAD. G P.		HYADES	
β	M_V	c_1	b-y	m_1
$2^{\mathrm{m}}.900$	$+2^{\mathrm{m}}.15$	$0^{\mathrm{m}}.970$	-	-
2.890	+2.2	0.950	-	-
2.880	+2.3	0.920	-	-
2.870	+2.35	0.905	-	-
2.860	+2.4	0.885	$0^{\mathrm{m}}.076$	$0^{\mathrm{m}}.207$
2.850	+2.45	0.870	0.087	0.208
2.840	+2.5	0.855	0.098	0.208
2.820	+2.6	0.830	0.109	0.207
2.820	+2.65	0.815	0.120	0.206
2.810	+2.7	0.800	0.131	0.205
2.800	+2.75	0.780	0.142	0.203
2.790	+2.8	0.765	0.152	0.200
2.780	+2.85	0.740	0.162	0.196
2.770	+2.9	0.720	0.171	0.192
2.760	+2.95	0.695	0.179	0.188
2.750	+3.0	0.675	0.188	0.185
2.740	+3.05	0.655	0.198	0.182
2.730	+3.1	0.630	0.208	0.179
2.720	+3.15	0.590	0.218	0.177
2.710	+3.2	0.565	0.229	0.174
2.700	+3.3	0.530	0.240	0.172

convergent point (Wayman, Symms, and Blackwell 1965), and 6.1 mag has been adopted for the Praesepe cluster. The correlation between ΔM_v and Δc_1 for the stars in Tables 4 and 5 is shown in Figure 1. For stars more than about 1.5 mag from the main sequence the ratio $\Delta M_v/\Delta c_1$ becomes nonlinear. For $\Delta M_v < 1.5$ mag this ratio is 8, in agreement with previous results (e.g., Strömgren 1968); an overall, linear relation would require a ratio of 10, but the nonlinear relation shown in Figure 1 is to be preferred. For the cluster stars the dispersion in Figure 1 is compatible with the expected photometric errors. Three stars (*boxed*) in the figure are discordant, one is a cluster member (Θ^2 Tau), and two are group members (FZ Vel and AO CVn). The star Θ^2 Tau is a spectroscopic binary, and FZ Vel is possibly a binary on the basis of a difference of 3.5 km s^{-1} in the velocity derived from five Lick Observatory spectra and seven from the Cape Observatory. However, except for a small (about 2 km s^{-1}) variation due to pulsation, the extensive series of radial velocity determinations by Penfold (1971) show no indications that AO CVn is a spectroscopic binary. Apparently, although for most stars the values of c_1 lead to a luminosity with a probable error less than 0.2 mag, occasionally (one star in eight), it can give up to 0.5 mag error because of distortion, either observational or intrinsic, of the indices. Although it is tempting to reject the two group stars as nonmembers, the similarity to the cluster member makes this unwarranted. Figure 2*a* shows the luminosity-temperature array for the stars in Tables 4 and 5. The seven brightest variables, five group members and one each from the Hyades and Praesepe clusters, all have luminosities within 0.2 mag of +0.55 mag. Figure 2*a* may give some indications of a small age difference between the Hyades and Praesepe clusters, and between the clusters and the group. The only phenomenological difference previously noted between the Hyades and Praesepe clusters is that the white dwarfs in the later cluster are about a magnitude fainter than those in the former (e.g., Eggen 1970*b*, Fig. 1). This effect also suggests that Praesepe is slightly older.

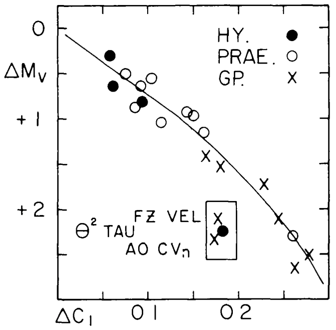

FIG. 1.—Correlation between Δc_1 and ΔM_V for Hyades stars.

The group and cluster stars are shown in the (β, m_1)-plane of Figure 2*b* and the (β, $b - y$)-plane of Figure 2*c*. The latter figure shows a systematic trend for the hottest (in β) Praesepe stars (*open circles*) to be slightly bluer than Hyades stars of the same temperature (*continuous curve*). Curiously, this same effect is obvious for all non-Am stars with $b - y$ between 0.1 and 0.2 mag in the Praesepe cluster, although it was not noted by Crawford and Barnes (1969, Fig. 1) in their study of the cluster.

Attention should be called to a group variable not listed in Table 5. The very peculiar star HD 137949 (33 Lib) has a strong magnetic field (Babcock 1958) and is variable in light with a range near 0.05 mag,

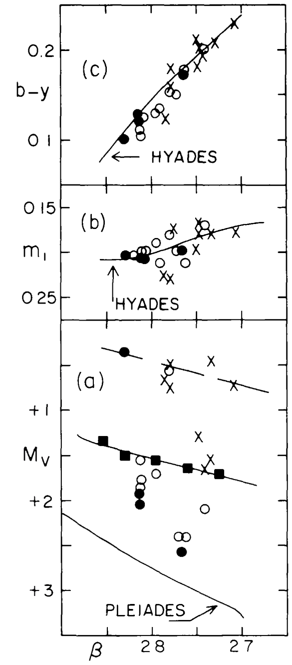

FIG. 2.—M_V, m_1, and $b - y$ as a function of β for the Hyades group stars. Symbols are as in Fig. 1.

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TABLE 7

ULTRASHORT PERIOD CEPHEIDS THAT MAY BE MEMBERS OF HYADES GROUP*

Var.	β	$b-y$	m_1	c_1	M_v	ΔC_1	ΔM_v
— Ari A	2.732	0.185	0.116	0.873	+0.65	0.238	2.45
— Ari B	2.744	0.192	0.160	0.710	+2.3	0.047	0.75
AD CMi:							
$0^{\mathrm{p}}.1$	2.784	0.154	0.184	0.935	+1.25	0.185	1.6
$0^{\mathrm{p}}.2$	2.769	0.169	0.180	0.901	+1.3	0.183	1.6
$0^{\mathrm{p}}.3$	2.758	0.186	0.180	0.859	+1.35	0.161	1.6

NOTES.—HD 15165 (— Ari): $(U, V, W) = (+41, -16.8, -16)$ km s^{-1}. AD CMi: $(U, V, W) = (+37, -16.8, -13)$ km s^{-1}.

* All quantities are in units of mag.

but a period has not yet been found. The photometric indices are distorted, $(b-y, m_1, c_1, \beta) = (0.206, 0.318, 0.487, 2.810)$ mag, indicating a large metal overabundance and an ultraviolet deficiency. The group modulus is 5.35 mag, giving $M_v = +1.35$ mag and $(U, V, W) = (+44, -16.8, +6)$ km s^{-1}. The value of β would then place the star near the concentration of cluster variables in Figure 2*a* with M_v between +1.5 and +2.0 mag. Further photometric and spectroscopic study of this object would appear to be warranted.

Two interesting possible members of the group are listed in Table 7. The pair HD 15164/5 (BDS 1269, — Ari) has common proper motion; the radial velocity of the brighter component is not available. Mechler (1974) noted the apparent metal deficiency of the primary star, with $\delta m_1 = 0.064$ mag compared with the Hyades (Table 6). Membership in the Hyades group gives a modulus of 6.05 mag and $(U, V, W) = (+41, -16.8, -16)$ km s^{-1}. In Figure 1 both stars would then be about 0.5 mag below the mean $(\Delta M_V, \Delta c_1)$-relation, indicating a photometric modulus of 5.6 mag and $(U, V, W) = (+38, -12, -18)$ km s^{-1}. Group membership places the A component among the bright variables in Figure 2*a*; it is very similar, except for m_1, to HR 5974 (— Lup) in Table 5. It also places the B component among the fainter variables; this component is very similar to BW and BQ Cnc in Table 4. Some unpublished observations indicate that the B component may also be variable, but this has not as yet been confirmed. The value of m_1 for the B component is also slightly small for a Hyades star, but it lies at the boundary of the dispersion for cluster members of this temperature. Obviously, a spectroscopic study of the A component would be of some interest. The other variable in Table 7 is AD CMi, and the photometry is by Breger (1975). The only reason for not including this star in Table 5 is that the proper motion needs confirmation. The value adopted here is a high-weight value based on two accordant determinations in the Yale Zone Catalogs and has a probable error of $0''.004$. Two μ_α, μ_δ other determinations are divergent: the AGK2 gives $\mu_\alpha, \mu_\delta = (-0''.023, -0''.002)$, and Clube (1968) derived $(-0''.002, -0''.005)$. Although the mean of these two values is near the adopted Yale value, a confirmation of the adopted value is critical. A modulus of 8.0 mag gives $(U, V, W) = (+37, -16.8, -13)$ km s^{-1}. The mean photometric parameters at phases 0.1, 0.2, and 0.3 in Table 7 indicate no reddening, in agreement with Jones (1973), and they indicate a Hyades abundance. The star is similar in most respects to HR 8102 (— Cap) in Table 5.

The seven brightest variables in Figure 2*a*, with a mean $M_v = +0.55$ mag and β from 2.83 to 2.7 ($T_e \approx 8500$–7000 K), lie near the evolutionary sequence generated by a star of about 2.2 solar masses, over a period of 5×10^6 years (Iben 1967*a*, *b*). In this case the change in temperature is that caused by the changing radius of a constant-mass star, which is similar to the situation in a pulsating star. For example, mean observations at several phases of GP And, listed in Table 8, are shown as filled squares in Figure 2*a*. The broken line through the bright USPC is parallel to that connecting the points representing the variation of GP And. The values of M_v for GP And were computed from the modulus derived for the companion, also

TABLE 8

PHOTOMETRIC PARAMETERS FOR GP ANDROMEDAE

Phase (1)	V* (2)	$b-y$* (3)	M_1* (4)	C_1 (5)	β* (6)	M_v* (7)	ΔC_1 (8)	ΔM_v (9)
$0^{\mathrm{p}}.1$	10.60	0.090	0.170	1.000	2.855	+1.35	0.123	1.05
$0^{\mathrm{p}}.2$	10.73	0.100	0.155	0.955	2.830	+1.5	0.125	1.1
$0^{\mathrm{p}}.3$	10.52	0.167	0.138	0.914	2.797	+1.55	0.138	1.2
$0^{\mathrm{p}}.4$	10.90	0.180	0.145	0.865	2.760	+1.65	0.170	1.3
$0^{\mathrm{p}}.5$	10.96	0.205	0.145	0.800	2.725	+1.7	0.190	1.4
B	12.50	0.364	0.141	0.439	...	+3.25	...	...

* In units of mag.

listed in Table 8. Observations of several field stars show very little, if any, reddening affecting the pair (separation of about 12″), and this is confirmed by the photometry of GP And itself. Unfortunately, no astrometric or radial velocity data are available for either GP And or its companion. However, the companion, (for which the luminosity was determined from Crawford's (1975) calibration, gives $\delta m_1 = 0.057$ mag compared with the Hyades, and the median value for the variable is 0.05 mag so that the stars may form a physical system. Strong confirmation of this is given by a comparison of the values of Δc_1 and ΔM_v for the variable in columns (8) and (9) of Table 8 with the mean relation in Figure 1; the values of Δc_1 would give the same modulus as is obtained from the companion. GP Andromedae and some of the Hyades group stars near it in Figure 2*a* are of smaller mass (near 2.0 solar) than the brightest USPC in the figure. The few Hyades variables that are still fainter are probably near 1.5 solar masses.

VX Hydrae is very probably similar to AD CMi, although it is not necessarily in the Hyades group. The photometry by Jones (1973) and by Breger (1977*a*) is slightly inconsistent, but median values are near $(b - y, m_1, c_1, \beta) = (0.215, 0.170, 0.840, 2.745)$ mag. The reddening is near $E(b - y) = 0.02$ mag. These results give $\delta m_1 = 0.007$ mag and $\Delta c_1 = 0.173$ mag, or $M_V \approx +1.6$ mag from Figure 1. Between phases 0.1 and 0.5 the ratio of $\Delta M_V/\Delta\beta \approx 3$, as for both GP And (Fig. 2*a*) and AD CMi. Both the proper motion and radial velocity are very poorly determined, but the space motion is probably that of a young disk star.

Another way to calibrate the luminosity is directly, in terms of c_1. The variation of c_1 with temperature (β) over the relevant range for main-sequence stars is nearly linear with a change of slope near $\beta = 2.75$ as shown in Figure 3, where c_1 is replaced by the reddening-free parameter $[c_1] = c_1 - 0.2(b - y)$. For $\beta > 2.75$, the main-sequence values are well represented by $[c_1] = 0.645 + 2.0(\beta - 2.750)$; and for $\beta < 2.75$, by $[c_1] = 0.645 - 3.2(2.750 - \beta)$. The values for GP And at the five phases listed in Table 8 are shown in Figure 3 as filled circles, and the broken line connecting them is parallel to the main-sequence relation. We can now eliminate the temperature effect in $[c_1]$ for the Hyades group variables in Figure 2*a* and plot the resulting values of $[c_1]_c$ against M_v as in Figure 4, where the symbols are the same as in Figure 2*a*; the three discordant stars shown boxed in Figure 1 are omitted. The mean relation shown by the straight line in Figure 4 is represented by $M_v = 8.0(1.000 - [c_1]_c)$. Applying this relation to the five phases of GP And, in Table 8, for example, gives a mean modulus of $V - M_v = 9.2 \pm 0.25(\sigma)$ mag. It should be noted that values of $[c_1]$ may also be a function of δm_1; but this effect was not found by Bell (1971) and will be omitted, so $[c_1]_c = [c_1] + \alpha(2.75 - \beta)$, where $\alpha = 2$ for values of β larger than 2.75 and $\alpha = 3.2$ for smaller values. This result can be tested with a young disk calibrator not used to obtain the results discussed above. OX Aurigae (ADS 5534) has a common proper motion companion (Eggen 1963). The bright star has $(V, m_1, c_1, \beta) = (6.05, 0.186, 0.764, 2.702)$ mag. From Table 6 $\delta m_1 = -0.014$ mag and the variable appears to be slightly overabundant with respect to the Hyades; $1 - [c_1]_c = 1 - (0.764 - 0.037 + 0.154) = 0.119$ mag, $M_v = 8(0.119) = +0.95$ mag, giving $V - M_v = 5.1$ mag. The companion, with $(V, B - V) = (10.25, +0.69)$ mag, then has $M_v = +5.15$ mag compared with the main-sequence value, at $B - V = +0.69$ (Eggen 1965), of $+5.25$ mag. The resulting space motion for OX Aur is $(U, V, W) = (+1, +3, 0)$ km s^{-1}.

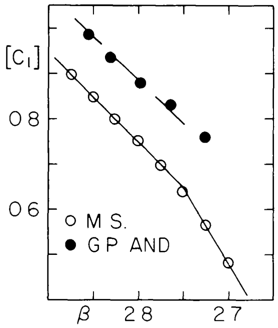

FIG. 3.—The variable GP And in the $([c_1], \beta)$-plane

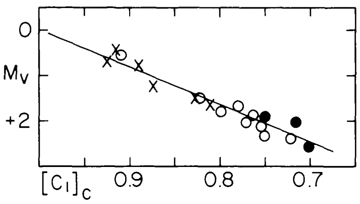

FIG. 4.—Calibration of $M_V = f([c_1]_c)$

III. YOUNG DISK VARIABLES

The variables in two clusters of the Local Association (Eggen 1975) and one probable field member of the association are listed in Table 9. The luminosities of the cluster stars are derived from moduli of 5.55 mag for the Pleiades and of 6.1 mag for the α Per cluster. The modulus of UV Ari is from the assignment to the association. The resulting values of $\Delta[c_1]$ and ΔM_v in columns (7) and (8) of the table agree well with the expected correlation in Figure 1. These stars are shown in the (M_v, β)-plane of Figure 5, where filled circles represent Pleiades and open circles α Per cluster members and UV Ari is shown as a cross. Three or four of the stars are on the main sequence, which is indicated by the continuous curve, but the remainder

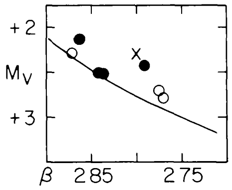

FIG. 5.—Local Association variables in the Pleiades (*filled circles*) and α Per (*open circles*) clusters and in the field (*cross*).

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TABLE 9

ULTRASHORT PERIOD CEPHEIDS IN THE LOCAL ASSOCIATION*

Var. (1)	β (2)	$(b-y)_0$ (3)	$(m_1)_0$ (4)	$(c_1)_0$ (5)	M_V (6)	Δc_1 (7)	ΔM_V (8)
Pleiades†							
V650 Tau	2.862	0.075	0.198	0.939	+2.15	+0.050	0.35
V647 Tau	2.841	0.104	0.203	0.813	+2.5	−0.043	0.0
V624 Tau	2.839	0.107	0.217	0.818	+2.5	−0.035	0.0
V534 Tau	2.788	0.154	0.195	0.733	+2.4	−0.027	0.4
α Persei‡							
+48°842	2.872	0.070	0.203	0.920	+2.3	+0.012	0.0
+48°905	2.775	0.166	0.190	0.757	+2.7	+0.027	0.2
+48°894	2.770	0.173	0.201	0.733	−2.8	+0.013	0.1
Field							
UV Ari§	2.800	0.136	0.185	0.842	+2.3	+0.062	0.45

* All quantities are in units of mag.

† Pleiades: $(U, V, W) = (+7, -25, -15)$ km s^{-1}.

‡ α Per: $(U, V, W) = (+14, -25, -6)$ km s^{-1}.

§ UV Aris: $(U, V, W) = (+7, -25, +1)$ km s^{-1}.

definitely depart from it. The clusters' age of near 3×10^7 (Pleiades) years places them in the last stages of contraction, rather than in post–main-sequence evolution, and probably explains these departures. The pre–main-sequence nature of the still younger variables V588 Mon and V589 Mon in NGC 2264 is well established (Breger 1972); unfortunately, accurate photometry is not available for these stars.

The remaining variables with the space motion of young disk population stars are listed in Table 10. The luminosities were obtained from the mean relation in Figure 1. However, if we had used the expression $M_v = 8.0(1000 - [c_1]_c)$ derived above, we would have obtained a mean difference from Table 10 of $+0.05 \pm 0.20(\sigma)$ mag, omitting two large differences for stars with small values of β; the mean relations in both Figure 1 and Figure 4 are independently derived, freehand plots. The stars of Table 10 are shown in the (U, V)-plane of Figure 6, where the young disk domain (Eggen 1973*a*) is outlined; the open circles in the figure represent stars for which the radial velocity is not available. The narrow rectangle at $V = -25$ km s^{-1} represents the Local Association (Pleiades group).

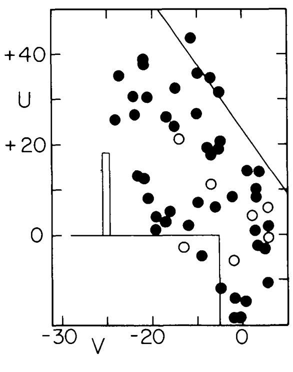

FIG. 6.—The young disk stars in the (U, V)-plane. The narrow, vertical column outlines the domain of the Local Association members. Open circles represent stars for which radial velocities are not available.

The young disk variables of Table 10 are also shown in the (M_v, β)-plane of Figure 7. The variables near $M_v = +2$ mag and $\beta = 2.75$–2.70 are probably 1.5 solar mass objects with an age near 10^9 years (e.g., Iben 1967*a*, *b*). Surprisingly, only one of two stars not in the Hyades group is as bright as the seven objects with M_V near +0.5 mag and $\beta = 2.85$–2.7 in Figure 2*a*. Two exceptions are the very bright variables VX Psc ($M_V = +0.05$ mag) and HR 2557 (— Aur) ($M_V = 0.0$ mag). On the other hand, a concentration of stars near $M_V = +1.25$ mag and $\beta = 2.725$ like that evidenced in Figure 7 apparently does not occur in the Hyades group (Fig. 2*a*).

Although often attempted (e.g., Breger and Bregman 1975), there seems little profit in trying to derive period-luminosity correlations for these variables,

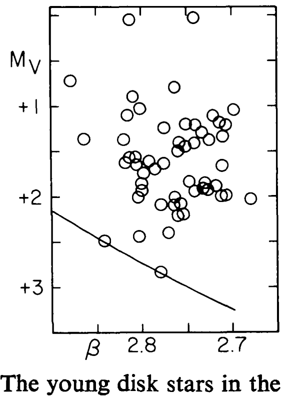

FIG. 7.—The young disk stars in the (β, M_V)-plane

TABLE 10

YOUNG DISK VARIABLES

Var	β	b-y	m_1	c_1	δm_1	Δc_1	M_V	U	V	W
								(km sec^{-1})		
GN And	$2^{\rm m}.752$	$0^{\rm m}.170$	$0^{\rm m}.165$	$0^{\rm m}.863$	$0^{\rm m}.021$	$0^{\rm m}.184$	+1.45	+ 1	-19	- 7
EM Aqr*	2.760	0.171	0.184	0.810	0.004	0.115	+2.1	+ 6	+ 6	+ 1
HR 8676*	2.763	0.166	0.184	0.914	0.005	0.111	+0.8	+19	- 5	- 2
V 1208 Aql	2.796	0.164	0.184	0.990	0.018	0.217	+1.0	+ 2	+ 6	+ 7
UU Ari	2.771	0.155	0.185	0.839	0.010	0.105	+2.1	+ 8	- 2	-17
HD 11285*	2.774	0.176	0.203	0.892	-0.009	0.164	+1.65	+ 7	-10	- 1
KW Aur*	2.799	0.130	0.180	0.998	0.023	0.218	+1.05	-11	+ 6	- 3
HR 2557*	2.741	0.221	0.142	1.023	0.034	0.328	0.0	- 5	- 9	- 5
X Cae	2.713	0.195	0.150	0.805	0.025	0.232	+1.2	+20	- 5	+10
AZ CMi	2.814	0.112	0.202	1.006	0.003	0.200	+1.1	+18	- 6	-14
HR 8024*	2.804	0.127	0.204	0.928	0.000	0.144	+1.65	-12	- 5	+10
V 526 Cas	2.770	0.166	0.216	0.780	0.024	0.060	+2.4	+37	-21	+ 1
β Cas	2.709	0.216	0.177	0.785	-0.003	0.223	+1.35	+37	- 7	-20
ε Cep	2.757	0.169	0.192	0.787	-0.005	0.098	+2.2	+44	-11	-24
V 1276 Cyg	2.728	0.222	0.187	0.768	-0.009	0.146	+1.9	+36	-10	-13
δ Del*	2.738	0.190	0.163	0.854	+0.018	0.204	+1.4	-15	+ 1	- 6
CL Dra	2.761	0.178	0.188	0.776	0.000	0.079	+2.35	+26	-22	+ 1
DL Eri*	2.757	0.161	0.188	0.881	0.000	0.192	+1.45	+11	- 7	+14
o^1 Eri	2.730	0.197	0.192	0.789	-0.013	0.159	+1.85	+14	+ 4	- 2
V 620 Her	2.798	0.124	0.200	0.897	0.000	0.120	+1.85	+10	+ 3	+ 3
V 644 Her	2.709	0.208	0.190	0.723	-0.016	0.161	+2.0	- 6	- 2	-16
V 648 Her	2.841	0.103	0.215	0.865	-0.007	0.008	+2.5	+27	-10	-15
HQ Hya	2.753	0.196	0.230	0.786	-0.044	0.105	+2.2	+33	-15	+ 1
DE Lac (1)*	2.713	0.300	0.153	0.825	-0.004	0.234	+1.2	+ 4	-19	- 8
DE Lac (2)*	2.708	0.325	0.155	0.788	-0.008	0.212	+1.45			
DE Lac (3)*	2.700	0.338	0.145	0.750	0.000	0.203	+1.6			
DE Lac (4)*	2.688	0.345	0.165	0.714	-0.019	0.193	+1.8			
DG Leo*	2.788	0.147	0.214	0.918	-0.015	0.158	+1.6	+35	-20	+ 1
V 474 Mon	2.738	0.200	0.190	0.800	-0.009	0.150	+1.9	+11	- 6	+ 2
V 571 Mon	2.740	0.184	0.187	0.878	-0.005	0.223	+1.2	+26	-17	-11
BP Oct*	2.780	0.190	0.205	0.722	-0.017	-0.023	+2.85	+32	- 5	+ 5
V 567 Oph* (1)	2.800	0.425	0.120	0.930	0.002	0.096	+2.0	+21	-14	+30
V 567 Oph* (2)	2.760	0.445	0.132	0.885	-0.025	0.136	+1.95			
V 1004 Ori	2.816	0.123	0.210	0.958	-0.004	0.149	+1.55	+39	-22	- 9
τ Peg*	2.808	0.104	0.166	1.013	0.038	0.217	+0.9	+ 8	+ 3	- 9
GX Peg	2.821	0.118	0.193	0.959	0.013	0.143	+1.6	-20	- 2	0
V 367 Per	2.743	0.179	0.154	0.826	0.029	0.165	+1.8	-14	- 2	+ 8
V 386	2.803	0.125	0.185	0.825	0.019	0.029	+2.45	+ 2	-12	- 2
ρ Phe	2.731	0.207	0.205	0.789	0.026	0.157	+1.9	+19	- 8	-26
HR 239*	2.765	0.168	0.210	0.817	-0.020	0.110	+2.1	+ 4	+ 2	- 1
VX Psc	2.817	0.090	0.166	1.093	0.040	0.282	+0.05	+25	-27	+ 1
XX Psc	2.773	0.165	0.178	0.929	0.015	0.203	+1.25	+38	-22	+ 1
ρ^1 Sgr	2.812	0.129	0.195	0.954	0.010	0.151	+1.6	- 2	+ 3	+ 7
HD 153747*	2.864	0.094	0.164	1.034	0.040	0.138	+1.35	- 1	+ 6	+ 3
WZ Scl*	2.722	0.217	0.144	0.764	0.033	0.166	+1.9	-21	- 1	+ 4
AI Scl	2.767	0.170	0.193	0.814	-0.002	0.102	+2.15	+13	-22	- 4
V 369 Sct*	2.725	0.318	0.153	0.842	-0.006	0.212	+1.4	- 4	-13	-35
o Ser	2.876	0.047	0.167	1.115	0.040	0.201	+0.7	+25	-28	+ 4
IM Tau	2.708	0.215	0.175	0.752	0.000	0.194	+1.65	+14	+ 1	-18
V 479 Tau*	2.730	0.239	0.193	0.846	0.014	0.216	+1.3	+ 3	-17	- 8
Θ Tuc	2.820	0.147	0.187	0.984	0.020	0.170	+1.35	+27	-24	+ 1
AI Vel*	2.800	0.150	0.175	0.890	0.025	0.110	+1.95	+ 5	-16	+13
HR 3350*	2.786	0.146	0.199	0.898	0.000	0.143	+1.7	+13	-23	-13
DK Vir	2.720	0.200	0.166	0.824	0.011	0.234	+1.1	+ 8	-21	- 5
FT Vir	2.674	0.280	0.175	0.650	-0.005	0.188	+2.05	-28	-14	-15
GG Vir	2.806	0.120	0.182	0.890	0.022	0.098	+2.0	+30	-21	+ 6
LT Vul	2.749	0.206	0.168	0.892	0.017	0.219	+1.2	- 3	+ 5	-11

NOTES TO TABLE 10

EM Aqr	(U, V, W) do not contain the radial velocity.
HR 8676	— Aqr. The companion, 60″ south, is optical.
DH 11285	— Ari. (U, V, W) do not include the radial velocity.
KW Aur	Fitting the companion to the main sequence gives $M_V = +0.9$ mag.
HR 2557	— Aur. Although slightly outside the young disk domain the (U, V)-plane, this nevertheless may be a young disk object in view of its high luminosity. $E(b-y) = 0.02$ mag.
HR 8024	— Cap. (U, V, W) do not include the radial velocity.
V743 Cen	$E(b-y) = 0.010$ mag.

NOTES TO TABLE 10—*Continued*

β Cas	The photometric parallax is 0″.066 compared with the mean trigonometric value of 0″.072 (wt. 23).
ϵ Cep	The photometric parallax is 0″.042 compared with the mean trigonometric value of 0″.037 (wt. 48).
δ Del	Sp. B. Equal components assumed.
DL Eri	(U, V, W) do not include the radial velocity.
DE Lac	(1) Phase 0.15, (2) phase 0.25, (3) phase 0.35, (4) phase 0.45. The mean reddening $E(b-y) = 0.087$ mag (McNamara and Laney 1976).
DG Leo	The variable is the B component of ADS 6299 (0″.4). The A component is a Sp. B., and all the stars are of about the same magnitude (Fekel and Bopp 1977).
BP Oct	$E(b-y) = 0.027$.
V567 Oph	(1) Phase 0.3, (2) phase 0.4 (see Eggen 1978*c*). $E(b-y) = 0.27$ mag.
HR 6434	— Oph. $E(b-y) = 0.025$ mag.
τ Peg	A high-weight Allegheny parallax of 0″.031 (wt. 20) would give $M_V = +2.0$ mag (see Breger and Bregman 1975).
HR 239	— Phe. (U, V, W) do not contain the radial velocity.
ρ^1 Sgr	The photometric parallax is 0″.034 compared with the trigonometric value of 0″.035 (wt. 23).
HD 153747	— Sco. $E(b-y) = 0.015$. (U, V, W) do not contain the radial velocity.
V369 Sct	$E(b-y) = 0.100$. (U, V, W) do not contain the radial velocity.
AI Vel	The photometry by Jones 1973 and by Breger 1977*b* is inconsistent, especially in β, but some of this probably results from the very strong variation of the amplitude with time. The adopted values represent a median based on all available data.
HR 3350	— Vel.

mainly because there is little certainty, in the smallest-amplitude stars, as to either the period or its meaning. However, because the intuitive opinion that small-amplitude, bright stars are the "δ Scuti" variables and large-amplitude, fainter objects are the "dwarf Cepheids" or "AI Velorum" stars is probably the main basis for the use of these terms, it is worthwhile to examine the visual light amplitudes. The largest amplitude (0.1–0.3 mag) among the bright stars (Bright Star Catalog) is that of δ Sct, and only four other bright stars reach an amplitude of 0.1 mag (AI CVn, V376 Per, ρ Phe, and ρ Pup); δ Sct and AI CVn are in the Hyades group. However, AI Vel, which might have been included in the Bright Star Catalog on the basis of its maximum magnitude, has a variable amplitude that ranges up to 0.7 mag. The mean luminosity and temperature of AI Vel ($P = 0.11$ days) are almost identical to those of V567 Oph ($P = 0.13$ days), which is a faint star with an amplitude of 0.35 mag, and GG Vir ($P = 0.05$ days), a bright star with an amplitude of only about 0.02 mag. Similarly, VZ Cnc ($P = 0.18$ days) in the Hyades group has an amplitude ranging up to 0.7 mag and luminosity and color very similar to υ UMa ($P = 0.13$ days) with an amplitude near 0.07 mag. The large-amplitude, faint variable GP And ($P = 0.08$ days, Table 8) is very similar in mean luminosity and temperature to the bright member of the Praesepe cluster BU Cnc (P near 0.05 days), which has a very small amplitude. The discovery of the largest-amplitude variables among the bright stars is probably nearly complete. From the ratio of large- to small-amplitude stars currently known among the fainter objects, it seems obvious that the unknown number of faint variables with small amplitudes is very great.

IV. OLD DISK VARIABLES

The young disk variables discussed above are apparently all little evolved stars of about 1.5–2.5 solar masses. In the old disk population the brighter objects of this kind will be blue stragglers—that is, variables less evolved than other objects of the same age because of some hitch in the evolutionary process. The old disk population could also contain low-mass variables that have passed through the red giant phase of their evolution. Most of the old disk variables in Table 1 appear to be little evolved blue stragglers. For example, EH Lib was earlier found to be a member of the ζ Her group (Eggen 1970*a*). The mean observations at four phases listed in Table 11 lead to a mean luminosity of $M_v = +1.9$ mag, from $M_v = 8.0(1000 - [c_1]_c)$, compared with +1.8 mag from the group parallax. The star is shown in the $([c_1], \beta)$-plane of Figure 8,

TABLE 11

EH LIBRAE*

Phase	β	$b-y$	m_1	c_1	G_p†	Comp.
0.1	2.850	0.120	0.160	0.990	+1.65	+1.85
0.2	2.810	0.140	0.160	0.915	+1.75	+1.85
0.3	2.780	0.175	0.155	0.860	+1.85	+1.85
0.4	2.750	0.190	0.150	0.790	+1.95	+2.0
Mean					+1.8	+1.9

* All quantities are in units of mag.

† Group: $(U, V, W) = (+47, -47, -34)$ km s^{-1}; $V_0 - M_V = 7.95$ mag.

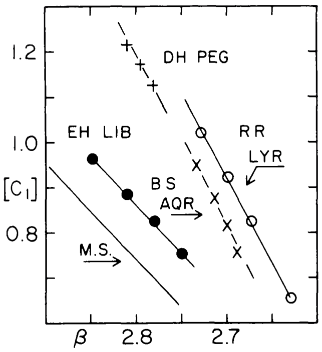

FIG. 8.—High-mass (EH Lib) and low-mass (RR Lyr) variables in the (β, $[c_1]$)-plane.

where the position with reference to the main sequence is very similar to that of GP And in Figure 3. Also, like GP And, the star shows a mean difference of $\delta m_1 = 0.045$ mag with respect to the Hyades. When Crawford's (1975) calibration is adopted, this gives $[\mathrm{Fe/H}] = -0.25$; the value for the group stars from the photometric indices will be discussed elsewhere, but a spectroscopic value for ζ Her itself is -0.2 (Glebocki 1972). Figure 8 also depicts the VSPC RR Lyr, a low-mass halo star (Langford 1976) between phases 0.1 and 0.5. The slope of the path traced by all low-mass halo population variables observed thus far, and which will be discussed elsewhere, is nearly identical to that of RR Lyr in Figure 8 and is markedly different from that of the high-mass variables discussed here.

A second USPC in the ζ Her group is probably SZ Lyn (Eggen 1970*a*), but unfortunately, Hβ observations are lacking for this object. Also, although slightly brighter than EH Lib, the apparent motions are more uncertain. Barnes and Moffett (1975) have suggested an unseen companion, but the radial velocity results by McNamara and Feltz (1976*a*) do not confirm this.

Because the luminosity derived from the relation based on high-mass stars agrees with the group value for EH Lib, there is some certainty about the mass of the star. However, the observations of BS Aqr listed in Table 12 and shown as crosses in Figure 8 present an enigma. The values of m_1 indicate a metal abundance that differs very little from that of the Hyades; yet the values of $b - y$ are systematically bluer than those of the Hyades stars of the same temperature (β) by about 0.04 mag, indicating $\delta m_1 = 0.1$ mag (Eggen 1972)—or more if the star is reddened. In Figure 8 the variable appears more comparable to RR Lyr than to EH Lib or to the brightest variables in Figure 2*a*. RR Lyrae has δm_1 near 0.1, so if we ignore the m_1 observations of BS Aqr, the stars may have the same abundance and mass; in this case the separation of 0.1 mag in c_1 in Figure 8 would give $\Delta M_v = 8 \times 0.1 = 0.8$ mag. The group parallax ($V - M_v = 7.35$ mag) for RR Lyr in the Groombridge 1830 group (Eggen 1977*c*) gives a median value of $M_v = +0.35$ for that variable when $E(b - y) = 0.035$ mag is adopted, so $M_v \approx +1.1$ mag for BS Aqr. Ignoring the differences in slope in Figure 8, McNamara and Feltz (1978) have obtained $M_v = +1.0$ mag for BS Aqr by averaging the indices over the cycle of variation and using Crawford's (1975) calibration. Obviously, the values of m_1 and of $b - y$ for this object need confirmation, and new observations are currently being made. The velocity vectors in Table 12 are based on $M_v = +1.1$ mag, and the large W motion may also be indicative of a star older than most old disk population objects. (New observations of BS Aqr are discussed in Eggen 1978*c*.)

Some other old disk variables are discussed below.

YZ Bootis.—The observations in Table 12 are of lower accuracy than those for the brighter star BS Aqr, but they show a slope in the ($[c_1]$, β)-plane that is very similar to that for EH Lib in Figure 8 and at a slightly higher luminosity. The values of M_v in Table 12 are computed from $M_v = 8(1.000 - [c_1]_c)$, and, like EH Lib, the variable appears to be a blue straggler of near solar composition in the old disk population.

HR 5441 (— *Bootis*).—This is the reddest variable included here, and its luminosity would indicate a star with mass near 1.5 the solar value. Additional photometry is important.

V668 Coronae Austrinae.—The radial velocity of this variable would be of some interest. The space motion vectors in Table 12 are similar to those of the HR 1614 group of overabundant stars (Eggen 1978*b*), and the value of δm_1 gives $[\mathrm{Fe/H}] = +0.35$ from Crawford's (1975) calibration. The star is on the young disk main sequence.

S Eridani.—This is a blue straggler in the Wolf 630 group. The group parallax gives $M_v = 0.0$ mag, as does the relation $M_v = 8(1.000 - [c_1]_c)$.

RS Gruis.—Balona and Martin (1978) have recently suggested that this variable has an unseen companion with a period longer than 1 week and an orbital velocity amplitude of some 30 km s^{-1}. A straight mean of all the available center-of-mass velocities gives a value of 10 km s^{-1} less than that listed in Table 1. McNamara and Feltz (1976*b*) derive a value of 3.1 solar radii for the variable from a combination of the photometric and radial velocity results; this, with a mean temperature from the photometry, leads to $M_v = +1.2 \pm 0.2$ mag. However, McNamara and Feltz (1978) later revised this value to $+0.7$ mag; the former value is identical to the mean of the values in Table 12. The star is obviously a high-mass blue straggler, and, as expected, the path traced in Figure 8 is parallel to that for EH Lib.

DY Herculis.—The observations scatter badly, especially in m_1, but this appears to be a metal-strong blue straggler in the old disk population.

DH Pegasi.—The phases for the observations in Table 12 were obtained by adding 0.25 to those from the ephemeris (Eggen 1978*c*). The path traced in the (β, $[c_1]$)-plane of Figure 8 indicates a low-mass Cepheid of luminosity similar to that of BS Aqr but at higher temperature. A comparison of β and $b - y$ shows a mean reddening near 0.067 mag compared with the Hyades. However, $\delta m_1 = 0.065$ mag, and adopting $\delta(b - y) = 0.4\delta m_1$ (Eggen 1972) gives

TABLE 12

OLD DISK VARIABLES

Var	β	b-y	m_1	c_1	δm_1	M_V	U	V (km sec^{-1})	W
BS Aqr (1)*	2.735	0.150	0.175	0.980	0.005	*	+24	-27	-63
BS Aqr (2)	2.715	0.180	0.175	0.910	0.000	*			
BS Aqr (3)	2.700	0.200	0.175	0.855	-0.003	*			
BS Aqr (4)	2.690	0.235	0.175	0.800	-0.003	*			
YZ Boo (1)*	2.795	0.115	0.175	0.950	0.027	+1.3	-40	-82	+ 6
YZ Boo (2)	2.783	0.130	0.180	0.910	0.017	+1.45			
YZ Boo (3)	2.770	0.165	0.165	0.865	0.027	+1.65			
YZ Boo (4)	2.750	0.180	0.165	0.800	0.020	+1.85			
HR 5441*	2.643	0.340	0.170	0.486	0.007	+1.9	-22	-20	+ 5
V 743 Cen*	2.765	0.190	0.164	0.855	0.022	+1.7	- 2	- 5	-56
AV Cet*	2.786	0.124	0.205	0.829	-0.007	+2.15	+20	-47	- 1
V 668 Cr A	2.877	0.110	0.211	1.010	-0.017	+2.1	+20	-45	-55
S Eri	2.743	0.164	0.169	1.011	0.026	0.0	-33	-33	+12
RS Gru (1)*	2.783	0.171	0.150	0.950	0.047	+1.2	-109	-23	- 9
RS Gru (2)	2.760	0.193	0.150	0.890	0.038	+1.35			
RS Gru (3)	2.739	0.207	0.150	0.854	0.032	+1.2			
RS Gru (4)	2.722	0.225	0.142	0.823	0.028	+1.05			
DY Her (1)*	2.758	0.187	0.199	0.890	-0.012	+1.3	+64	+ 8	- 5
DY Her (2)	2.702	0.235	0.197	0.741	-0.025	+1.2			
ZZ Mic*	2.762	0.157	0.161	0.868	0.025	+1.5	+ 2	-37	+ 9
HR 6434*	2.722	0.246	0.167	0.895	0.002	+0.5	+27	+ 5	-14
NZ Pav	2.745	0.185	0.185	0.800	-0.002	+1.8	+71	-24	- 5
DH Peg (1)*	2.810	0.195	0.110	1.260	0.068	+1.1*	+47	-45	+13
DH Peg (2)	2.795	0.215	0.110	1.220	0.065				
HD Peg (3)	2.782	0.230	0.110	1.175	0.060				
DY Peg (1)*	2.815	0.165	0.155	0.920	0.035	+1.95	+73	-68	-43
DY Peg (2)	2.785	0.190	0.150	0.860	0.043	+2.0			
DY Peg (3)	2.765	0.210	0.145	0.805	0.030	+2.15			
ρ Pup	2.715	0.260	0.215	0.730	-0.040	+1.7	+27	-38	0
V 703 Sco*	2.741	0.233	0.160	0.845	0.027	+1.4	+50	+30	-16
HD 153747*	2.865	0.094	0.164	1.034	0.035	+1.7	- 1	+ 5	+ 3
XX Scl	2.817	0.135	0.191	0.943	0.010	+1.75	- 4	+34	+ 5
CW Ser (1)*	2.720	0.206	0.180:	0.852	0.000	+0.75	+108	- 9	(+100)
CW Ser (2)	2.710	0.254	0.160	0.853	0.014	+0.55			
BS Tuc	2.750	0.150	0.144	0.814	0.041	+1.7	+62	-63	+ 2
FG Vir	2.754	0.160	0.173	0.857	0.012	+1.45	+66	+15	+35

NOTES TO TABLE 12

BS Aqr	(1) Phase 0.1, (2) phase 0.2, (3) phase 0.3, (4) phase 0.4. The luminosity is discussed in the text.
YZ Boo	(1) Phase 0.1, (2) phase 0.2, (3) phase 0.3, (4) phase 0.4.
HR 5441	— Boo.
V743 Cen	$E(b-y) = 0.012$ mag. Although in the young disk domain of the (U, V)-plane, the W velocity indicates that this is an old disk, blue straggler.
AV Cet	(U, V, W) do not contain the radial velocity.
V668 CrA	$E(b-y) = 0.045$ mag. (U, V, W) do not contain the radial velocity.
S Eri	Blue straggler in the Wolf 630 group.
RS Gru	(1) Phase 0.2, (2) phase 0.3, (3) phase 0.4, (4) phase 0.5. $E(b-y) = 0.025$ mag.
DY Her	(1) Phase 0.15, (2) phase 0.35.
ZZ Mic	The ephemeris no longer holds, and most of the observations (Eggen 1978*c*) were made on the rising branch of the light curve. The values of the indices in the table are for near maximum light. $E(b-y) = 0.020$ mag.
HR 6434	— Oph. $E(b-y) = 0.025$ mag.
DH Peg	(1) Phase 0.25, (2) phase 0.35, (3) phase 0.45. $E(b-y) = 0.09$ mag. See text.
DY Peg	(1) Phase 0.2, (2) phase 0.3, (3) phase 0.4. $E(b-y) = 0.05$ mag.
V703 Sco	$E(b-y) = 0.040$ mag.
HD 153747	— Sco. $E(b-y) = 0.03$ mag.
CW Ser	(1) Phase 0.385, (2) phase 0.64. (U, V, W) do not include the radial velocity.

$E(b-y) = 0.09$ mag. Crawford's (1975) calibration of δm_1 gives [Fe/H] = −0.45. A very similar USPC, TV Lyn, was omitted from Table 12 because of incomplete data. However, some *u*, *v*, *b*, and *y* observations by Epstein and Epstein (1973) allow a rough comparison with DH Peg and a demonstration of the advantage of β observations. The two variables are shown in Figure 9 between phases 0.1 and 0.5; the reddening of $E(b-y) = 0.15$ mag given by Epstein and Epstein is adopted for TV Lyn. The observations of TV Lyn scatter badly, and the means in Figure 9 are based on extensive averaging. The median values

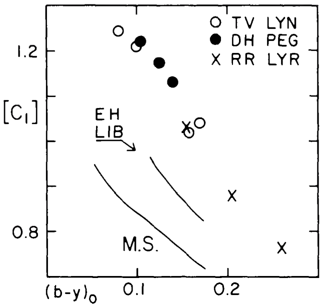

FIG. 9.—High-mass (EH Lib) and low-mass (RR Lyr) variables in the ($b - y$, [c_1])-plane.

of $(m_1)_0$ for TV Lyn is 0.12 mag compared with 0.135 mag for DY Peg. The difference in the position of the two old disk variables with respect to RR Lyr in Figures 8 and 9 is caused by different blanketing in $b - y$, and it is obvious that without β observations the nature of TV Lyn can only be inferred from its similarity to DH Peg in other respects. A full discussion of the luminosity calibration for low-mass Cepheids will be given elsewhere, but luminosities near +1.1 mag for both TV Lyn and DH Peg are adopted here from the similarity in Figure 8 between DH Peg and BS Aqr discussed above. The apparent motions of TV Lyn and DH Peg are poorly determined. The adopted radial velocity for DH Peg in Table 1 is from Bonsack (1957), but later results by Preston and Paczyński (1964) indicate that this may be at least 10 km s^{-1} too low. The adopted luminosity gives $(U, V, W) = (-7, +11, 0)$ km s^{-1} for TV Lyn. It may be noted that the velocity components for DH Peg in Table 12 are similar to those for EH Lib and other members of the ζ Her group, but in view of the uncertainties in the apparent motions and the relatively large value of δm_1, this near agreement is probably accidental.

DY Pegasi.—The mean observations in Table 12 would place this variable almost identically with EH Lib in Figure 8, and the mean value of $\delta m_1 = 0.04$ is also about the same.

V703 Scorpii.—The available observations (Eggen 1978*c*) were obtained at a minimum of the strong amplitude variation of this variable, and mean values for the indices over the observed visual light range of 0.07 mag are listed in Table 12.

The distribution of the old disk variables in the (U, V)-plane is shown in Figure 10, where the stars without radial velocity determinations are represented by open circles. The one object occurring in the outlined young disk domain (V743 Cen) has $W = 56$ km s^{-1}. Figure 11 shows the old disk variables in the (β, M_V)-plane, where the young disk main sequence and the evolved main sequences of NGC 752 (Crawford and Barnes 1970) and M67 (Strom, Strom, and Yost 1971 and some unpublished observations) are shown schematically. The plus signs indicate blue stragglers in M67, and these would obviously warrant testing for light variation. The question of the evolutionary history of these stragglers is still unanswered, but their existence is the reason for the occurrence of high-mass USPC. It would appear safe to assume that the discovery of USPCs among the bright stars is not dependent upon population characteristics, and this would indicate that in the mass range 1.5–3.5 solar masses there are 6 times as many USPCs among the young disk stars as among the blue stragglers in the old disk population. The susceptibility to pulsation of the high-mass stars may be independent of metal abundance, at least in the range [Fe/H] from about +0.35 to −0.2 shown by the values of δm_1 in Table 12; so the number of such variables among the bright stars may eventually give some clue to the total population of main-sequence stars in this mass range and at an early epoch. There is no certainty that the pulsation itself is not a contributing cause to the presence of blue stragglers. Such stars in most old open clusters, such as M67, are rather faint, and the absence of light variation is difficult to establish; V521 Cas in NGC 7789 is the one such variable so far found (Danziger 1971). The bright AF stars with β between 2.7 and 2.8 and with motions outside the young disk domain in Figure 10 are rare, and since many of them

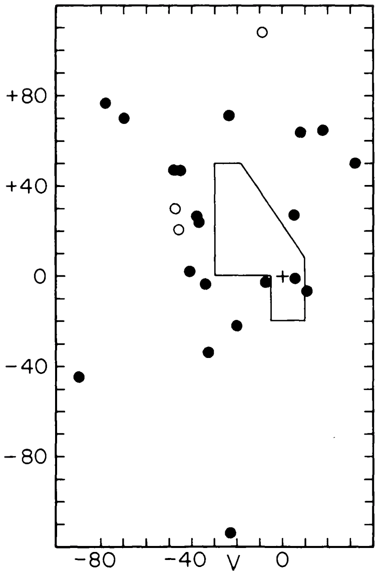

FIG. 10.—Old disk variables in the (U, V)-plane. Open circles represent stars for which radial velocities are not available. The outlined area is the domain of the young disk population.

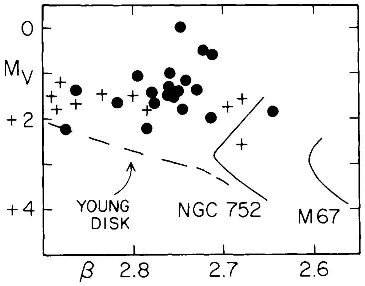

FIG. 11.—Old disk variables in the (β, M_V)-plane. Plus signs indicate blue stragglers (not known to be variable) in M67.

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are already included in Table 12, observations of the remaining stars will provide an easy test of the hypothesis that all such blue stragglers are USPCs.

V. HALO VARIABLES

The USPCs with space motions of halo stars and light amplitudes of a half magnitude or more can be divided into those with high and with low mass on the basis of the path traced in the (β, $[c_1]$)-plane (Fig. 8). The latter are undoubtedly similar to the very few USPC's that are confirmed members of globular clusters and have accurately determined periods, whereas the former are probably blue stragglers. However, there are several important differences between blue stragglers in the old disk population and those in the halo population that need to be considered and which, it is hoped, these variables can elucidate. The three USPCs with the shortest known periods are listed in Table 13. The first star, GD 428, is fainter than the limit adopted here and is not in Table 1, but extensive observations by McNamara and Feltz (1978) are available. The individual observations of SX Phe covering two cycles between phases 0.15 and 0.45 periods (Eggen 1978*c*) are shown in Figure 12 as open circles. Four means, from smoothed curves of the observations by McNamara and Feltz for GD 428 in the same phase range, are shown as filled circles. The observations of CY Aqr (Langford 1976) scatter badly, but in the mean they are indistinguishable from those of SX Phe and GD 428 in Figure 12. The main sequence and the path traced by the low-mass halo Cepheid RR Lyr are copied from Figure 8. As stragglers in the halo population, the three USPCs should presumably be referred not to the disk main sequence (MS) shown in Figure 12 but to the halo main sequence, whose position is unknown for this temperature range. If we overlook this fact and compute the luminosities on the same basis as we did for the old disk variables, $M_v = 8(1 - 0.75) = +2$ mag for all three stars. The resulting space motions are listed in Table 13; the proper motion of $(\mu_\alpha, \mu_\delta) = (+0''.140, -0''.038)$ and radial velocity of -52 km s^{-1} for GD 428 are taken from McNamara and Feltz (1978). It is probably safe to conclude that the resulting space motion of GD 428, if not of SX Phe, is too large for an object bound to the Galaxy. It was earlier proposed that SX Phe is a blue straggler in the Kapteyn's star group (Eggen 1971), which leads to $M_v = +3.1$ mag and the space motion vectors shown in the last three rows of Table 13; Kapteyn's star has $(U, V, W) = (-22, -289, +60)$ km s^{-1}. If this is the case and the factor 8 in the expression $M_v = 8(1 - [c_1]_c)$ holds also for the halo population, then the halo main sequence, if it has the same (temperature, c_1)-relation as the disk, is systematically 1 mag fainter than the disk main sequence in this temperature range. A difficulty with this interpretation of SX Phe is that the observations give $\delta m_1 = 0.049 \pm 0.004(\sigma)$ mag, or [Fe/H] near -0.2, whereas other members of Kapteyn's star group have values near -1.8. A further difficulty, which is common to one or two other halo stragglers discussed below, is that this high metal abundance conflicts with a previous discussion (Eggen 1979) that found [Fe/H] ≤ -0.6 for all known nonvariable halo stars of spectral type G–M. This situation may arise from the unknown process that produces such stragglers. But the straggler EH Lib in the old disk population, ζ Her group discussed above has the same value of [Fe/H] as the other group members, and the only apparent difference in the case of SX Phe is that the latter is undoubtedly older. An important contribution to this question would be intermediate-band photometry of the very similar blue stragglers in M3 (I-III-36, I-V-6) which have $(V, B - V, U - B) = (17.45, +0.20, 0.00)$ mag, or $M_v = +3$ mag for a modulus of 14.4 mag (Sandage 1970); the mean values of $B - V$ and $U - B$ for SX Phe are near $+0.2$ and $+0.05$ mag, respectively. Equally important, but much more difficult, would be a search for light variations in these stars. McCrae (1964) has suggested that blue stragglers result from a mass exchange in binaries, with components too close to allow expansion to the giant stage of normal stellar evolution. It is unclear how this situation could produce apparently metal rich stars in the time scale of the age of halo stars but have no apparent effect on the abundance of old disk stars such as EH Lib. Another possibility is that, as in ω Cen (e.g., Freeman and Rodgers 1975), several generations have been produced and SX Phe is of the latest and most enriched. However, this would appear to cause

TABLE 13

HIGH-MASS HALO CEPHEIDS WITH THE SHORTEST PERIODS

Parameter	GD 428	SX Phe	CY Aqr
$\log P$	-1.41	-1.26	-1.21
$E(b - y)$	0.295	0.00	0.00
δm_1 (mag)	0.145	0.050	0.08:
Disk population:			
M_v (mag)	$+2$	$+2$	$+2$
U(km s^{-1})	$+328$	-36	$+45$
V(km s^{-1})	-547	-457	-180
W(km s^{-1})	$+263$	$+1.5$	-138
Halo population:			
M_v (mag)	$+3.1$	$+3.1$*	$+3.1$†
U(km s^{-1})	$+172$	-17	$+30$
V(km s^{-1})	-313	-289	-116
W(km s^{-1})	$+150$	$+69$	-67

* Kapteyn's star group.

† Arcturus group.

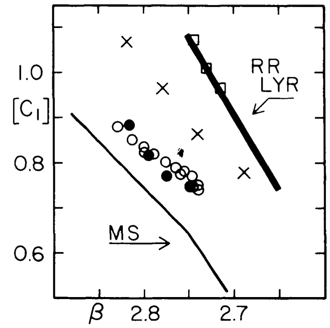

FIG. 12.—SX Phoenicis (*open circles*), GD 248 (*filled circles*), and TV Lib (*crosses*) in the (β, $[c_1]$)-plane.

the same difficulty, already noted, concerning the position of the variables relative to the main sequence in Figure 12. A similar situation obtains for CY Aqr, which may be a member of the old disk population, η Cep group (Eggen 1964) or of the halo population, Arcturus group (Eggen 1978*a*). The value of δm_1 would appear to eliminate the first possibility, although the observations of CY Aqr need to be considerably improved. As a member of the Arcturus group, $M_v = +3.1$ mag, identical to that for SX Phe, and $(U, V, W) = (+30, -116, -67)$ km s^{-1}. When the value of δm_1 from the available observations is accepted, [Fe/H] = −0.6 from Crawford's (1975) calibration compared with −0.7 determined spectroscopically for Arcturus itself (Mäckle *et al.* 1975). SX Phoenicis ($b = -70°$) and CY Aqr ($b = -50°$) are unreddened, but GD 428 ($b = +7°$) has $E(b - y) = 0.233 \pm 0.015(\sigma)$ mag from the four normal points adopted here from the smoothed color curves, and compared with the Hyades. However, the same normals give $\delta m_1 = 0.145 \pm 0.020(\sigma)$ mag, so $E(b - y) = 0.238 + 0.4 \times 0.140 = 0.295$ mag. If we adopt the value of $M_v = +3.1$ mag from the similarity to the other two variables, the resulting space motion, listed in the last three rows of Table 13, is no longer excessive. Adopting Crawford's (1975) calibration gives [Fe/H] = −1.25.

Other, possible halo variables are discussed below.

TV Librae.—The results for TV Lib at four phases between 0.2 and 0.55 periods read from the color curves (Eggen 1978*c*) are shown as crosses in Figure 12. This is apparently a high-mass Cepheid, but there is some doubt as to its halo membership. If we treat it as an old disk star, $M_v = +0.4$ mag and $(U, V, W) = (+55, +97, 0)$ km s^{-1}, and this indicates a halo star. The value of V, which is the largest velocity preceding the solar velocity in the direction of galactic rotation that has so far been noted, depends entirely on the proper motion listed in Table 1. The different motion of $(\mu_\alpha, \mu_\delta) = (-0''.002, +0''.006)$ found by Hemenway (1975) would lead to $(U, V, W) = (+70, +34, +7)$ km s^{-1}, which is similar to the motion of the old disk variable V730 Sco in Table 2. If we accept the proper motion in Table 1 and the indications from the three stars in Table 13 that the halo main sequence is 1 mag fainter, $M_v = +1.4$ mag and $(U, V, W) = (+50, +65, -2)$ km s^{-1}, still indicating a halo star. A more accurate proper motion is necessary if one is to determine the old disk or halo membership of the variable. The values of $(\beta, b - y)$ indicate a reddening of 0.025 mag for TV Lib compared with the Hyades; but the mean value of $\delta m_1 = 0.04$ mag, so $E(b - y) = 0.04$ mag. If this is a halo star, there is the same difficulty with the apparently high metal abundance as that discussed above for SX Phe.

AP Serpentis.—The available observations (Eggen 1978*c*) are mainly of the rising branch of the light curve. These indicate little or no reddening, in agreement with Jones (1973); at minimum, $\delta m_1 = 0.08$ mag or [Fe/H] = −0.6 from Crawford's (1975) calibration. *UBV* observations of the companion (Eggen and Greenstein 1965) give a median $M_v = +1.5$ mag for the variable if the companion is a main-sequence star and $(U, V, W) = (+47, -226, -26)$ km s^{-1}. However, since the companion is almost certainly an evolved star, the variable is brighter than derived here, and the observations are being continued in order to settle this point.

SU Crateris.—The available data indicate a long-term change in the photometric indices. At the discovery of this variable in 1971 (Eggen 1971), $(\beta, b - y, m_1, c_1) = (2.748, 0.192, 0.157, 0.752)$ mag, similar to the results referenced in Table 1, but two observations in 1976 give (2.740, 0.176, 0.178, 0.751) mag and two in 1978 give (2.750, 0.184, 0.160, 0.750) mag. The mean values give $\delta m_1 = 0.015$ mag and $M_v = +3.3$ mag, leading to $(U, V, W) = (-67, -134, +51)$ km s^{-1} if we adopt the indications from the three stars in Table 13 that the luminosity derived from $M_v = 8(1 - [c_1]_c)$ needs correction by +1 mag for halo stars. The variable is also a possible candidate for establishing the binary nature of a halo object because the radial velocity determinations are +152 and +116 km s^{-1} from two Mount Stromlo plates, with a mean of $+131 \pm 5$ km s^{-1} from four David Dunlap plates (see Abt and Biggs 1972). Like SX Phe and TV Lib discussed above, the value of [Fe/H] implied by the value of δm_1 is nearer the solar value relative to most objects in the halo population.

YZ Capricorni.—This may be the only low-mass halo USPC for which reliable photometry is available. The observations at three phases, between 0.2 and 0.5 periods, are shown in Figure 12 as open squares; the ephemeris has been corrected by +0.25 periods (Eggen 1978*c*). The similarity of YZ Cap to RR Lyr in Figure 12 leads to $M_v = +0.35$ mag from the membership of the latter variable in the Groombridge 1830 group (e.g., Eggen 1977*c*), giving $(U, V, W) = (-61, -117, +118)$ km s^{-1}. The reddening compared with the Hyades stars is 0.020 mag, but since the mean $\delta m_1 = 0.085$ mag, $E(b - y) = 0.05$ mag, in agreement with the determination by Jones (1973). The value of δm_1 gives [Fe/H] = −0.65 from Crawford's (1975) calibration. It is undoubtedly significant that this is both the longest-period (0.273 days) variable discussed here and the only low-mass halo population star in the present sample, although the period of TV Lib (0.270 days), discussed above, is only slightly shorter.

VI. DISCUSSION

A few variables listed in Table 1 have not been discussed for various reasons. Photometry is not available for eight variables, all but one of which is north of declination +40°: CC And, UY Cam, DQ Cep, XX Cyg, CN Dra, KN Per, RX Sex, and — UMa (HD 99002). The most interesting of these are probably UY Cam and XX Cyg, both of which may be halo variables. The remainder are most likely members of the young disk population, although radial velocity determinations are not available for KN Per, RX Sex, or HD 99002.

Neither the radial velocity nor proper motion of the interesting variable V753 Cen is available. The photometry (Eggen 1978*c*) indicates very little reddening, with δm_1 near 0.04 mag and M_V near 0 mag. The high luminosity indicates that the possible connection with the neighboring cluster NGC 3690 should be reexamined (e.g., Cannon and Eggen 1971).

Three variables are in close visual binary systems that make photometry of the variable alone difficult, if not impossible. Both Perry (1969) and Barry (1969) have published photometry of κ Boo A, but the results are widely divergent and probably reflect the influence of the visual companion. The variable γ CrB (ADS 9757) has a close companion, 1.44 mag fainter, and an orbital period of 91 years; the variable δ Ser (ADS 9701) has a companion 4″ distant and only about 1 mag fainter.

Attention should be called to the very interesting system of FM Vir. This variable (32 Vir) was classified an Am star by Roman, Morgan, and Eggen (1948). It is a spectroscopic binary, $P = 38.3$ days, with the components differing by 0.4 mag (Petrie 1950). Recent discussions of the system by Abt (1961) and by Kurtz, Breger, and Evans (1976) have not noted that the variable is a common proper motion companion to GG Vir (HR 4824), 3° distant. The available data for these stars are listed in Table 14. There is some uncertainty about the radial velocities, with values of -8 to -14 km s^{-1} derived for the systemic velocity of FM Vir; individual determinations of the velocity for GG Vir range from -7 to $+12$ for a mean of 0 km s^{-1} from five Herstmonceaux plates and from -6 to $+39$ for a mean of $+15$ km s^{-1} from five plates at the Dominion Astrophysical Observatory. The projected rotational velocities are 25 and 140 km s^{-1} for the brighter and fainter components of FM Vir and 130 km s^{-1} for GG Vir. There is no certainty as to which component of FM Vir is variable; indeed, as is probably the case for δ Del, both stars may vary. If we adopt -9.5 km s^{-1} for the systemic velocity of FM Vir and the photometric value of $M_V = +2$ mag for GG Vir, the resulting space motion in Table 14 is that of Hyades group members. Additional spectroscopic observations of both stars would obviously be of interest.

TABLE 14

FM VIRGINIS AND GG VIRGINIS

Parameters	FM Vir	GG Vir
β (mag)	2.755	2.005
$b - y$ (mag)	0.189	0.120
m_1 (mag)	0.227	0.182
c_1 (mag)	0.784	0.890
V (mag)	5.75	6.35
δm_1 (mag)	-0.041	$+0.022$
M_v (mag)	$(+2.1)$	$+2.0$
μ_α (arcsec)	-0.108	-0.104
μ_δ (arcsec)	$+0.004$	$+0.001$
ρ (km s^{-1})	-9.5	Var.
U (km s^{-1})	$+36$	...
V (km s^{-1})	-17	...
W (km s^{-1})	-9	...

The bulk of the variables discussed here are apparently high-mass, little evolved stars, with those in the old disk and halo populations being blue stragglers. Study of such stragglers in clusters of both the halo and old disk probably offers the best opportunity to increase our knowledge of USPCs.

REFERENCES

Abt, H. A. 1961, *Ap. J. Suppl.*, **6**, 37.
Abt, H. A., and Biggs, E. S. 1972, *Bibliography of Stellar Radial Velocities* (Tucson: Kitt Peak National Observatory).
Babcock, H. W. 1958, *Ap. J. Suppl.* **3**, 141.
Balona, L. A., and Martin, W. L. 1978, *M.N.R.A.S.*, **184**, 1
Barnes, T. G., and Moffett, T. J. 1975, *A.J.*, **80**, 48.
Barry, D. C. 1969, *Pub. A.S.P.*, **81**, 339.
———. 1974, *A.J.*, **79**, 616.
Bell, R. A. 1971, *M.N.R.A.S.*, **155**, 65.
Bessell, M. S. 1969*a*, *Ap. J. Suppl.* **18**, 167.
———. 1969*b*, *Ap. J. Suppl.*, **18**, 195.
Bonsack, W. 1957, *Ap. J.*, **126**, 291.
Breger, M. 1972, *Ap. J.*, **171**, 539.
———. 1975, *Ap. J.*, **201**, 653.
———. 1977*a*, *Pub. A.S.P.*, **89**, 55.
———. 1977*b*, *Pub. A.S.P.*, **89**, 339.
Breger, M., and Bregman, J. 1975, *Ap. J.*, **200**, 343.
Cannon, R., and Eggen, O. J. 1971, *Inf. Bull. Var. Stars*, No. 580.
Clube, V. M. 1968, *Roy. Obs. Bull.*, No. 136.
———. 1969, *Mem. R.A.S.*, **72**, 101.
———. 1971, *Roy. Obs. Bull.*, No. 161.
Crawford, D. L. 1969, *A.J.*, **74**, 407.
———. 1975, *A.J.*, **80**, 955.
Crawford, D. L., and Barnes, J. V. 1969, *A.J.*, **74**, 818.
———. 1970, *A.J.*, **75**, 946.
Crawford, D. L., and Perry, C. L. 1966, *A.J.*, **71**, 206.
———. 1976, *A.J.*, **81**, 419.
Danziger, I. J. 1971, *Pub. A.S.P.*, **83**, 84.
Danziger, I. J., and Dickens, R. J. 1967, *Ap. J.*, **149**, 55.
Danziger, I. J., and Kuhi, L. V. 1966, *Ap. J.*, **196**, 743.
Danziger, I. J., and Oke, J. B. 1967, *Ap. J.*, **147**, 151.
Eggen, O. J. 1956, *Pub. A.S.P.*, **68**, 238.
———. 1957, *A.J.*, **62**, 45.
———. 1963, *A.J.*, **68**, 483.
———. 1964, *Roy. Obs. Bull.*, No. 84.
———. 1965, *Ann. Rev. Astr. Ap.*, **3**, 235.
———. 1970*a*, *Pub. A.S.P.*, **82**, 274.
———. 1970*b*, in *Vistas in Astronomy*, Vol. **12**, ed. A. Beer (Oxford: Pergamon), p. 367.
———. 1971, *Pub. A.S.P.*, **83**, 762.
———. 1972, *Ap. J.*, **175**, 787.
———. 1973*a*, *Pub. A.S.P.*, **85**, 379.
———. 1973*b*, *Inf. Bull. Var. Stars*, No. 935.
———. 1975, *Pub. A.S.P.*, **87**, 37.
———. 1976*a*, *Pub. A.S.P.*, **88**, 402.
———. 1976*b*, *Pub. A.S.P.*, **88**, 732.
———. 1977*a*, *Ap. J. Suppl.*, **34**, 1 (Paper VI).
———. 1977*b*, *Ap. J.*, **213**, 767 (Paper VII).
———. 1977*c*, *Ap. J.*, **215**, 812.
———. 1978*a*, *Ap. J.*, **221**, 881.
———. 1978*b*, *Ap. J.*, **222**, 203.
———. 1978*c*, *Inf. Bull. Var. Stars*, No. 1517.
———. 1979, *Ap. J.*, **229**, 158.
Eggen, O. J., and Greenstein, J. L. 1965, *Ap. J.*, **142**, 925.
Epstein, I., and Epstein, A. E. A. 1973, *A.J.*, **78**, 83.
Fath, E. A. 1935, *Lick Obs. Bull.*, **17**, 175.
Fekel, F. C., and Bopp, B. W. 1977, *Pub. A.S.P.*, **89**, 216.
Freeman, K. F., and Rodgers, A. W. 1975, *Ap. J.* (*Letters*), **201**, L71.
Glebocki, R. 1972, *Acta Astr.*, **22**, 141.
Grønbeck, B., and Olsen, E. H. 1976, *Astr. Ap. Suppl.*, **25**, 213.
Hemenway, M. K. 1975, *A.J.*, **80**, 194.
Iben, I. 1967*a*, *Ap. J.*, **147**, 624.

Iben, I. 1967*b*, *Ap. J.*, **147**, 650.
Jones, D. H. P. 1971, *Roy. Obs. Bull.*, No. 163.
———. 1973, *Ap. J. Suppl.*, **25**, 487.
Kilambi, G. C., DuPuy, D. L., and Koegler, C. A. 1978, *Pub. A.S.P.*, **90**, 194.
Kinman, T. D. 1961, *Roy. Obs. Bull.*, No. 37.
Klemola, A. R. 1971, *Pub. A.S.P.*, **83**, 227.
Kuhi, L. V., and Danziger, I. J. 1967, *Ap. J.*, **149**, 47.
Kurtz, D. W., Breger, M., and Evans, S. W. 1976, *Ap. J.*, **207**, 181.
Langford, W. 1976, Ph.D. thesis, Brigham Young University.
Mäckle, R., Holweger, H., Griffin, R., and Griffin, R. 1975, *Astr. Ap.*, **38**, 239.
McCrae, W. H. 1974, *M.N.R.A.S.*, **128**, 146.
McMillan, R. S., Breger, M., Ferland, G. J., and Loumos, G. L. 1976, *Pub. A.S.P.*, **88**, 495.
McNamara, D. H., and Feltz, K. A. 1976*a*, *Pub. A.S.P.*, **88**, 164.
———. 1976*b*, *Pub. A.S.P.*, **88**, 510.
———. 1978, *Pub. A.S.P.*, **90**, 275.
McNamara, D. H., and Laney, C. D. 1976, *Pub. A.S.P.*, **88**, 168.
Mechler, G. E. 1974, *Pub. A.S.P.*, **86**, 279.
Penfold, J. E. 1971, *Pub. A.S.P.*, **83**, 493.
Penston, M. J. 1972, *M.N.R.A.S.*, **156**, 103.
Perry, C. L. 1969, *A.J.*, **74**, 139.
Petrie, R. M. 1950, *Pub. Dom. Ap. Obs.*, **8**, 319.
Preston, G., and Paczyński, B. 1964, *Ap. J.*, **140**, 181.
Roman, N. G., Morgan, W. W., and Eggen, O. J. 1948, *Ap. J.*, **107**, 107.
Sandage, A. R. 1970, *Ap. J.*, **162**, 841.
Smith, H. J. 1955, *A.J.*, **60**, 179.
Strom, S. E., Strom, K., and Yost, J. 1971, *Ap. J.*, **165**, 479.
Strömgren, B. 1965, manuscript catalog.
———. 1968, *Quart. J.R.A.S.*, **4**, 8.
Struve, O. 1949, *A.J.*, **54**, 137.
———. 1955, *Sky and Tel.*, **14**, 461.
Wayman, P. A., Symms, L. S. T., and Blackwell, K. C. 1965, *Roy. Obs. Bull.*, No. 98.

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