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THE COLOR-LUMINOSITY DIAGRAM OF THE URSA MAJOR GROUP *

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Abstract. Color-luminosity diagrams are given for the probable members of the Ursa Major group identified by Miss Roman. They are based on (a) spectroscopic absolute magnitudes, and (b) apparent magnitudes and stream parallaxes. The colors and magnitudes were photoelectrically measured and transformed into the B, V system of Johnson and Morgan. The arrays consist of a main sequence, of a richly populated branch of yellow giants, and of brighter giants bridging the Hertzsprung gap—stars of luminosity class II. A number of late-type dwarfs seem to be considerably below the ordinary sequence.

1. *Introduction.* The Ursa Major group of stars may be considered to consist of two subgroups: one of few stars that form a loosely condensed cluster spread over the constellation of Ursa Major, the other of about 100 stars distributed over all the sky. The 13 known members of the cluster share accurately the same space motion and fill a volume of less than 10 pc diameter. Many investigations of the nucleus group have been made and they show beyond doubt that the motions of its members satisfy the conditions required for a true cluster.

The stars of the extended group, which we shall refer to as the Ursa Major stream, fill a volume containing the sun and such galactic clusters as the Hyades, Pleiades and that in Coma Berenices. The limits of the space outside of which no members are known are set by observational selection.

The stars of the stream share the motion of the nucleus group only approximately. They are scattered through a region of about 200 pc diameter. Observational errors and the dispersion in the radial velocities make it difficult definitely to segregate all the stream stars, but at least 70 are known that almost certainly are true members. In 1949 Miss Roman published a list of 135 probable members of the stream, based on all the observational material available.¹ She also pointed out that the nucleus stars define only the main sequence, whereas the stream contains in addition many giants. But there are no stars

of spectral type earlier than A0 in either the nucleus or the stream.

To study in more detail the question of the color-luminosity diagram of the whole Ursa Major group, photoelectric measurements of magnitudes and colors were made at the Lick Observatory on all stars known to belong to the nucleus, or listed by Miss Roman as probable members of the stream; some of them have previously been observed photoelectrically by O. J. Eggen.² In order to make this discussion as objective as possible it was decided to accept Miss Roman's selection of probable stream members. It is true, of course, that an unambiguous decision cannot be reached on many of the stars that she has considered to be cluster members.

2. *Equipment, observing technique, reductions.* The observations were made in two colors during 1953 with the 12-inch refractor and an EMI 5659 eleven-stage end-on photomultiplier. The filters used were Corning 3385 for the yellow and Corning 5543 for the blue magnitudes, both of optical standard thickness. The transmission curves of the filters and the objective (Fig. 1) were measured by the author;³ those for the filters agree very closely with the data given in the catalogue of the Corning Glass Co. The spectral sensitivity curve of the multiplier is that given by the EMI data sheet. The photo-current was recorded, after amplification by a DC amplifier, on a Brown potentiometer. The sensitivity

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Figure 1. Spectral sensitivity curve of EMI-multiplier 5659, and transmission curves of 12-inch objective and Corning filters Nos. 3385 and 5543.

of the photometer was monitored by means of an artificial source made from a luminescent radioactive substance.

The observing technique and the method of reduction were those generally employed at the Lick Observatory for magnitude and color work on scattered stars. Extinction coefficients were determined each night. Except for stars far south of the equator, air masses of more than 1.6 were avoided. The extreme values of the measured extinction coefficients for A0 and K0 stars are given in the following tabulation:

	blue	yellow
A0	0.26-0.37 mag.	0.13-0.25 mag.
K0	0.19-0.30	0.10-0.23

The individually measured magnitudes and colors for all program stars were reduced, in the natural system of the photometer, to a common zero-point.

To transform the natural magnitudes and colors into the B, V system of Johnson and Morgan,⁴ 23 of their stars were observed. These are listed in Table I with the photometric values of Johnson and Morgan and with the present observations. The author is indebted to Dr. H. L. Johnson for permission to include in this list some stars not contained in the published catalogue.

It was found that the natural colors C_{Li} could be transformed into $B-V$ colors by the equation

$$B-V = +0^m439 + 0.978 C_{Li} \pm 0^m002 \pm 0.005 \text{ (p.e.)}.$$

The relation is linear over the color range considered in this work, and the scale is very closely the same in both systems.

The yellow magnitudes V and the measured ones m_{Li} are linearly related by

$$V = m_{Li} + 2^m129 - 0.151 (B-V) \pm 0^m010 \pm 0.016 \text{ (p.e.)}.$$

Comparisons of the colors and magnitudes after the reduction of the natural values to the B, V system are illustrated in Figure 2. The probable errors following from these comparisons, under the assumption that both series are of equal weight, are ± 0.025 mag. for the magni-

TABLE I. STANDARD STARS

Name	α 1900	δ	Sp	Johnson, Morgan V $B-V$	Miczaika V $B-V$
HR 875	2 ^h 51 ^m 6	-04°07'	A1 V	5 ^m 17 +0 ^m 085	5 ^m 19 +0 ^m 061
HR 1046	3 22.4	+55 06	A1 V	5.06 +0.05	5.10 +0.045
β Eri	5 2.9	-05 13	A3 III	2.77 +0.12	2.72 +0.146
λ Gem	7 12.3	+16 43	A3 V	3.57 +0.10	3.52 +0.103
β Cnc	8 11.1	+09 30	K4 III	3.53 +1.478	3.52 +1.472
θ UMa	9 26.2	+52 08	F6 III	3.21 +0.43	3.14 +0.472
11 LMi	9 29.7	+36 16	G8 IV-V	5.47 +0.75	5.48 +0.745
21 LMi	10 01.5	+35 44	A7 V	4.47 +0.16	4.52 +0.174
ζ Leo	10 11.1	+23 55	F0 II-III	3.49 +0.28	3.46 +0.291
46 LMi	10 47.7	+34 45	K0 III-IV	3.84 +1.03	3.79 +1.037
β Vir	11 45.5	+02 20	F8 V	3.63 +0.54	3.59 +0.541
γ UMa	11 48.6	+54 15	A0 V	2.43 0.00	2.42 -0.005
δ UMa	12 10.5	+57 35	A3 V	3.27 +0.08	3.34 +0.068
31 Com	12 46.8	+28 05	G0 III	5.03 +0.66	4.95 +0.637
78 UMa	12 56.4	+56 54	F2 V	4.93 +0.37	4.97 +0.348
80 UMa	13 21.2	+55 30	A5 V	4.01 +0.16	3.95 +0.180
τ Vir	13 56.6	+02 02	A5 III*	4.26 +0.10	4.32 +0.108
ρ Boo	14 27.5	+30 49	K3 III	3.57 +1.29	3.59 +1.286
ι Dra	15 22.7	+59 19	K2 III	3.26 +1.17	3.34 +1.177
α CrB	15 30.5	+27 03	A0 V	2.23 -0.02	2.24 -0.034
β Ser	15 41.6	+15 44	A2 IV	3.67 +0.07	3.74 +0.060
ϵ CrB	15 53.4	+27 10	K3 III	4.15 +1.227	4.19 +1.217
η Ser	18 16.1	-02 55	K0 III-IV	3.26 +0.94	3.24 +0.952

* Spectral type according to Miss Roman.

tudes and ± 0.008 mag. for the colors. Johnson and Morgan found a slightly smaller value for their V magnitudes, but the same value for their $B-V$ colors, from a discussion of the internal agreement of their measurements. Stars of different luminosity classes occurring in this investigation do not seem to require different transformation formulae for the color range covered by the observations.

On the average, 3.75 observations were obtained for each program star. The probable error, derived from the internal agreement of the measurements, is ± 0.033 mag. for a single magnitude and ± 0.020 mag. for a single color measurement. After a reduction to air mass 1, with the assumption that the errors of observation are proportional to the air mass passed by the star's light, the probable errors of the catalogue values in Table 2 average ± 0.011 mag. for the V magnitudes, and ± 0.007 mag. for the $B-V$ colors.

For a comparison with the magnitudes of the Henry Draper Catalogue, a plot of the differences, $HD - V$, of all the stars in Tables I, II and III against color, $B-V$, was prepared (Fig. 3). The differences show, besides a considerable scatter, a color equation between the two systems in the sense that red stars are fainter in the HD system than in the V system. This difference amounts on the average to 0.2 mag. for $B-V = +1.4$ mag. whereas A0 stars, for which $B-V = 0.0$ mag., are of the same brightness in both systems.

Figure 2. Comparison between magnitudes (V^J and V^M) and colors $[(B-V)^J$ and $(B-V)^M]$ of the standard stars as determined by H. L. Johnson and the author; different symbols indicate the several luminosity classes.

Figure 3. Comparison of the HD magnitudes and the magnitudes V of the stars in Tables I, II, and III.

Figure 4. The spectrum-color relationship of the Ursa Major stars. Lines represent the relationships given by Johnson and Morgan for dwarfs (LCV) and yellow giants (LC III).

3. *The catalogue.* Table II contains a list of all the probable member stars observed. The colors and magnitudes are transformed to the B , V system, and spectral types and luminosity classes are those published by Miss Roman. The spectroscopically determined absolute magnitudes M_{sp} and the stream parallaxes π_{cl} are also due to Miss Roman. In a few cases where the stream parallaxes were discordant with the proper motion data, they were recomputed with the cluster elements derived by Miss Roman. Absolute magnitudes M_{cl} were computed from these parallax values and the apparent magnitudes.

Magnitudes and colors were obtained for a few additional non-program stars that served as extinction stars; they are listed in Table III with spectral types from the Henry Draper Catalogue.

4. *The relationship between color and spectral type.* The mean relationship between intrinsic color index $B-V$ and spectral type in the revised system of the Yerkes *Atlas* has been established by Johnson and Morgan.⁴ Miss Roman's spectral types of the probable stream stars are in the original *Atlas* system. A plot of the $B-V$ colors against these types is given in Figure 4. For comparison the mean intrinsic color relations between $B-V$ and the revised MK system for main-sequence stars and yellow giants are put in the diagram. These lines represent the rela-

tionships for the old system very well, as expected, since the changes between the original and the revised system are of minor nature and concern mostly the luminosity classes. In the spectral range Go-K2 the well-known fact is revealed that the giants do not show a smooth relationship with color in the original *Atlas* system.⁴

5. *The color-luminosity diagram.* A color-luminosity diagram of the stream stars for Miss Roman's spectroscopic absolute magnitudes is given in Figure 5. The plot contains all the stars for which spectroscopic magnitudes are available. Obviously, non-members would not be revealed by their spectroscopic absolute magnitudes because such stars would not fall in improbable places in the diagram. The plot clearly shows Miss Roman's calibration of the main-sequence and of luminosity classes II and III (giants). The remarkable sharpness, especially of the ordinary giant branch, is thus an artificial phenomenon.

The main sequence is richly populated, beginning with stars between 0 and +1 absolute magnitude. In addition, there is a horizontal giant branch beginning with $B-V = +0.8$ mag., corresponding to spectral type Go, and extending to $B-V = +1.75$ mag., or M 2. These giants are all of luminosity class III. The most interesting feature, however, is a bridging of the Hertzsprung gap for Baade's Population I stars by a number of bright luminosity class II giants, which start at the upper end of the main sequence and extend to $B-V = +1.4$ mag., which corresponds to spectral type K. The existence of a bright giant branch above the Hertzsprung gap was already indicated in the Hertzsprung-Russell diagram that Miss Roman derived with her spectral types.

Figure 6 shows a color-luminosity diagram based on absolute magnitudes derived from apparent magnitudes V and the cluster parallaxes. There is no essential difference between this diagram and that using spectroscopic magnitudes,

TABLE II. PROBABLE STREAM MEMBERS

Name	α 1900 δ	Sp	π_{cl}	V	B-V	M_{sp}	M_{cl}	Notes
	^h ^m			^m	^m			
σ And	0 13.1 +36°14'	A2 V	0.019	4.55	+0.042	+1.2	+0.94	Radial Velocity (RV) variable
32 And	0 35.7 +38 55	G5 III	0.003	5.31	+0.873	+0.3	-2.30	
φ Cet	0 45.1 -11 11	F8 IV	0.100	5.19	+0.482	+2.7	+5.19	
η And	0 51.9 +22 53	G5 III	0.014	4.40	+0.957	+0.3	+0.13	RV variable, 2 spectra
HR 276	0 52.7 +13 09	G5 III	0.004	6.30	+0.879	+0.3	-0.69	
39 And	0 57.3 +40 48	A7 V	0.006	5.93	+0.164	+2.4	-0.18	
27 Cet	1 00.6 -10 31	K0 III	0.014	6.06	+1.023	+0.2	+1.79	
80 Psc	1 03.2 +05 07	F0 V	0.090	5.52	+0.313	+3.0	+5.29	
89 Psc	1 12.6 +03 05	A3 V	0.015	5.16	+0.051	+1.6	+1.04	RV variable
HR 461	1 31.6 +57 28	G5 II	0.003	5.50	+1.397	-1.6	-2.11	
HR 485	1 36.0 +29 32	K0 III	0.004	5.96	+1.021	+0.2	-1.03	
1 Ari	1 44.6 +21 47	G0 III+A	0.004	5.83	+0.719	+1.0	-1.16	visual binary, 5.2:7.6
χ Cet	1 44.7 -11 11	F2 III	0.050	4.65	+0.309	+1.1	+3.14	
HR 534	1 45.6 +10 33	F0 V	0.020	5.93	+0.281	+3.0	+2.44	
ϵ Tri	1 57.1 +32 48	A2	0.005	5.51	+0.030	+1.2	-1.1	RV variable?
HR 647	2 07.6 +47 01	F5 V	0.026	6.03	+0.437	+3.7	+3.10	visual binary, 6.4:7.3
HR 710	2 21.2 -15 47	A7p	0.021	5.80	+0.140	---	+2.41	strontium star; companion 9 mag.
ν Cet	2 30.6 +05 09	G5 III	0.010	4.94	+0.863	+0.3	-0.06	companion 9 magnitude
HR 797	2 37.1 +10 19	A1	0.008	6.32	+0.081	+0.8	+0.84	
γ^1 Cet	2 38.1 +02 49	A3 V	0.059	3.44	+0.114	+1.6	+2.29	visual binary, 3.7:6.2
HR 875	2 51.6 -04 07	A3 V	0.014	5.19	+0.061	+1.6	+0.91	RV variable ?
ϵ Ari	2 53.5 +20 56	A2 V	0.004	4.66	+0.056	+1.2	-2.33	visual binary, 5.3:5.6
HR 906	2 56.2 +81 05	A7m	0.018	5.93	+0.144	---	+2.21	metallic-line star
τ^8 Eri	2 58.0 -24 01	A5 V	0.048	4.06	+0.158	+2.2	+2.47	
HR 1016	3 17.0 -24 00	G5 II	0.010	5.48	+0.873	-1.6	+0.48	
HR 1046	3 22.4 +55 06	A3 V	0.015	5.10	+0.045	+1.6	+0.98	companion 9 magnitude
HR 1327	4 11.3 +64 54	G2 III	0.011	5.28	+0.819	+0.7	+0.49	
66 Tau	4 18.4 +09 14	A2	0.006	5.07	+0.102	+1.2	-1.04	visual binary, 5.8:5.8
ξ Eri	4 18.7 -03 58	A2	0.022	5.17	+0.070	+1.2	+1.88	RV variable ?
HR 1448	4 28.8 +05 21	A2	0.006	5.63	+0.004	+1.2	-0.48	
2 Aur	4 45.9 +36 32	K3 III	0.010	4.71	+1.419	-0.2	-0.29	
7 Cam	4 49.3 +53 35	A0 V	0.009	4.40	-0.013	+0.5	-0.83	Comp. 8 and 11 mag.; RV variable
β Eri	5 02.9 -05 13	A3 III	0.039	2.72	+0.146	-0.4	+0.68	
38 Ori	5 29.0 +03 42	A2	0.012	5.35	+0.059	+1.2	+0.75	RV variable ?
α Aur	5 38.2 +49 47	A0p	0.006	5.43	+0.030	---	-0.68	

TABLE II.—Continued

Name	α 1900	δ	Sp	π_{cl}	V	B-V	M_{sp}	M_{cl}	Notes
γ Lep	5 40.3	-22°29'	F6 V	0.135	3.63	+0.447	+3.9	+4.28	visual binary, 3.8:6.4; RV variable ?
τ Aur	5 42.2	+39 09	G8 III	0.018	4.52	+0.937	+0.3	+0.80	
χ^1 Ori	5 48.5	+20 16	G0 V	0.092	4.39	+0.567	+4.5	+4.21	
β Aur	5 52.2	+44 56	A2 IV	0.029	1.86	+0.062	+0.1	-0.83	RV variable, 2 spectra
42 Aur	6 10.1	+46 27	F0 V	0.027	6.48	+0.238	+3.0	+3.63	
8 Gem	6 10.2	+24 00	G5 III	0.007	5.98	+0.905	+0.3	+0.21	
RR Lyn	6 18.0	+56 20	A5m	0.016	5.54	+0.209	---	+1.56	RV and light variable, 5.5-6.0
ν^1 Cam	6 33.5	-18 09	G5 III	0.004	4.36	+1.139	+0.3	+4.36	
α CMa	6 40.8	-16 35	A1 V	0.426	-1.47	+0.01	+0.8	+1.68	RV variable; note 1.
16 Lyn	6 50.3	+45 13	A2 V	0.017	4.90	+0.012	+1.2	+1.05	
λ Gem	7 12.3	+16 43	A3 V	0.037	3.52	+0.103	+1.6	+1.36	
ϵ CMi	7 20.2	+09 28	G5 III	0.006	4.97	+1.014	+0.3	-1.14	
HR 2967	7 36.4	+14 27	M2 III	0.006	5.72	+1.693	-0.2	-0.39	
9 Pup	7 47.1	-13 38	G0 V	0.123	5.16	+0.572	+4.5	+5.61	visual binary 5.8:6.4; RV variable
HR 3131	7 55.4	-18 07	A3 V	0.017	4.61	+0.079	+1.6	+0.76	
HR 3279	8 16.9	-19 46	G2 III+A	0.008	5.53	+0.790	+0.7	+0.05	RV variable, 2 spectra
π^1 UMa	8 30.3	+65 22	G0 V	0.053	5.62	+0.607	+4.5	+4.23	
9 Hya	8 37.1	-15 35	G8 III	0.034	4.80	+1.042	+0.3	+2.46	no member ?
46 Cnc	8 39.2	+31 04	G5 III	0.013	6.10	+0.933	+0.3	+1.67	no member ?
ν Cnc	8 56.9	+24 51	A0 V	0.007	5.38	-0.054	+0.5	-0.39	RV variable ?
18 UMa	9 09.0	+54 26	A5	0.069	4.80	+0.196	+2.2	+3.99	RV variable
ν^1 Hya	9 46.7	-14 23	G5 III	0.014	4.13	+0.942	+0.3	-0.14	
21 LMi	10 01.5	+35 44	A5	0.044	4.52	+0.174	+2.2	+2.74	RV variable ?
34 Leo	10 06.3	+13 51	F6 V	0.030	6.35	+0.470	+3.9	+3.74	visual binary 6.8:7.6
ζ Leo	10 11.1	+23 55	F0 II-III	0.015	3.46	+0.291	-0.8	-0.66	RV variable
37 UMa*	10 28.7	+57 36	F1 V	0.043	5.18	+0.325	---	+3.35	
HD 94686	10 50.7	+80 13	F8 V	0.034	7.31	+0.533	+4.3	+4.97	
β UMa	10 55.8	+56 55	A0 V	0.046	2.40	-0.029	---	+0.71	RV variable
δ Leo	11 08.8	+21 04	A4 V	0.089	2.57	+0.108	+1.8	+2.32	RV variable ?
ι Leo	11 18.7	+11 05	F2 V	0.072	3.97	+0.404	+3.3	+3.26	visual binary 4.1:6.8; RV variable ?
τ Leo	11 22.8	+03 24	G8 II	0.010	4.97	+1.002	-1.9	-0.03	
ζ Crt	11 39.7	-17 48	G5 III	0.016	4.76	+0.992	+0.3	+0.79	
γ UMa*	11 48.6	+54 15	A0 V	0.042	2.42	-0.005	---	+0.54	
α Crv	12 03.3	-24 10	F2 V	0.028	4.06	+0.334	+3.2	+1.30	no member ?
δ UMa*	12 10.5	+57 35	A3 V	0.044	3.34	+0.068	---	+1.56	
HR 4725	12 20.2	+24 29	K0 III	0.026	6.04	+1.089	+0.2	+3.11	
HD 109011*	12 26.5	+55 40	K2 V	0.045	8.11	+0.953	---	+6.38	H and K emission
HR 4803	12 32.4	-26 35	F2 V	0.034	5.46	+0.292	+3.2	+3.12	
HD 110463*	12 37.2	+56 17	K3 V	0.050	8.29	+0.954	---	+6.78	H and K emission
HR 4837	12 38.5	-01 02	G8p III	0.030	5.99	+0.799	---	+3.38	high-velocity giant ?
29 Com	12 43.9	+14 40	A2	0.013	5.74	+0.029	+1.3	+1.31	
HR 4867*	12 44.3	+60 52	F6 V	0.041	5.85	+0.470	---	+3.91	
41 Vir	12 48.8	+12 58	A7p	0.019	6.23	+0.299	---	+2.62	RV variable ?
ϵ UMa*	12 49.6	+56 30	A0p	0.043	1.80	-0.028	---	-0.03	RV and spectrum variable
HD 112394	12 51.3	+57 39	G8 IV-V	0.040	9.23	+0.727	+4.5	+7.24	note 2.
78 UMa	12 56.4	+56 54	F0 V	0.043	4.97	+0.348	---	+3.14	companion 10 magnitude
49 Vir	13 02.6	-10 12	K2 III	0.006	5.20	+1.134	+0.1	-0.91	
HD 115043*	13 09.5	+57 14	G2 V	0.041	6.86	+0.600	---	+4.92	H and K emission
HDE 238208	13 10.7	+57 32	K2 V	0.040	9.68	+0.826	+6.3	+7.69	
γ Hya	13 13.5	-22 39	G5 III	0.025	2.97	+0.945	+0.3	-0.04	
HDE 238224	13 19.5	+58 25	M0 V	0.032	9.77	+1.205	---	+7.30	
ζ UMa*	13 19.9	+55 27	A2 V, A2m	0.044	2.046	+0.047	---	+0.27	RV variable; note 3.
80 UMa*	13 21.2	+55 30	A5 V	0.043	3.95	+0.180	---	+2.12	RV variable
78 Vir	13 29.1	+04 10	A2p	0.018	4.94	+0.053	---	+1.22	
83 Vir	13 39.1	-15 41	G0 II	0.004	5.58	+0.782	-1.7	-1.41	
HD 120528	13 44.9	+53 44	G5 V	0.047	8.55	+0.660	+5.2	+6.91	note 4.
HR 5214	13 46.7	+35 16	A3	0.011	6.63	+0.106	+1.7	+1.84	
τ Vir	13 56.6	+02 02	A5 III	0.008	4.33	+0.108	0.0	-1.15	RV variable ?
κ Boo	14 09.9	+52 15	F0 V	0.018	4.35	+0.188	+3.0	+0.63	visual binary 4.6:6.6; RV variable ?
HD 124752*	14 10.3	+68 03	K0 V	0.043	8.54	+0.791	---	+6.71	
HR 5343	14 11.4	+19 23	A6m	0.016	6.08	+0.224	---	+2.10	metallic-line star
18 Boo	14 14.4	+13 28	F2 V	0.031	5.40	+0.365	+3.2	+2.86	
HR 5373	14 15.7	+39 15	A2	0.008	6.37	+0.041	+1.3	+0.89	
ζ Boo	14 36.4	+14 09	A2	0.017	3.78	+0.047	+1.3	-0.07	visual binary 4.4:4.8
HR 5492	14 39.6	+61 41	F2 III	0.025	6.29	+0.350	+2.5	+3.28	visual binary 6.3:8.5; note 5.

TABLE II.—Continued

Name	α 1900 δ	Sp	v_{cl}	V	B-V	M_{sp}	M_{cl}	Notes
ξ Boo	^h 14 46.8 ^m +19°31'	G8 V	0.048	^m 4.59	+0.754	+5.7	+3.00	visual binary 4.8:6.7; H and K emission
45 Boo	15 02.9 +25 16	F5 V	0.071	4.96	+0.409	+3.7	+4.22	
8 Ser	15 18.6 -00 40	F0 V	0.022	6.16	+0.226	+3.0	+2.87	visual binary 5.6:6.1; RV variable
η CrB	15 19.1 +30 39	G2 V	0.066	5.02	+0.560	+4.8	+4.12	H and K emission
ν Boo	15 27.3 +41 10	K5 III	0.004	5.07	+1.594	-0.2	-1.92	
α CrB	15 30.5 +27 03	A0 V	0.042	2.24	-0.034	+0.5	+0.30	eclipsing binary, RV variable
HR 5830	15 35.1 +47 08	F2 V	0.044	5.78	+0.325	+3.2	+4.00	
τ Ser	15 36.4 +16 21	G5 III	0.009	6.00	+0.888	+0.3	+0.77	
χ Ser	15 37.1 +13 10	---	0.012	5.42	+0.017	---	+0.82	spectrum variable
HR 5859	15 40.4 +05 46	A2 V	0.008	5.67	+0.016	+1.3	+0.19	
β Ser	15 41.6 +15 44	A2 IV	0.026	3.74	+0.060	+0.3	+0.81	companion 9 magnitude
ω Ser	15 45.2 +02 30	G8 III	0.016	5.34	+1.023	+0.3	+1.36	no member?
ν CrB	16 12.7 +29 24	A3 V	0.007	5.88	+0.038	+1.7	+0.12	RV variable
HR 6076	16 13.3 -19 58	K5 III	0.004	6.46	+1.306	-0.2	-0.53	
ω Her	16 20.8 +14 16	A0p	0.020	4.64	-0.001	---	+1.15	RV variable; spectrum resembles ϵ UMa
HD 151044	16 39.8 +50 09	F8 V	0.047	6.60	+0.475	+4.3	+4.96	
52 Her	16 46.3 +46 10	A2p	0.017	4.88	+0.075	---	+1.03	strontium star; companion 10 magnitude
56 Her	16 50.9 +25 54	G5 III	0.007	6.13	+0.903	+0.3	+0.36	companion 10 magnitude
α Oph	17 30.3 +12 38	A5 III	0.079	2.11	+0.150	0.0	+1.60	RV variable
HR 6917	18 22.1 +29 46	A2 V	0.007	5.88	+0.056	+1.3	+0.11	RV variable
HR 6993	18 32.5 -00 24	A2	0.009	5.86	+0.061	+1.3	+0.63	
5 Aql	18 41.3 -01 04	A2m	0.009	5.88	+0.164	---	+0.65	metallic-line star; visual binary 5.9:7.4
11 Aql	18 54.5 +13 29	F8 V	0.041	5.30	+0.531	+4.3	+3.36	
16 Lyr	18 58.6 +46 48	A7	0.023	5.09	+0.180	+2.4	+1.90	
59 Dra	19 12.8 +76 24	F2 V	0.039	5.21	+0.272	+3.2	+3.17	
HR 7451	19 31.7 +51 01	F8 V	0.052	5.84	+0.430	+4.3	+4.42	
18 Sge	20 11.9 +21 17	K1 III	0.007	6.12	+1.039	+0.2	+0.39	
HR 7781	20 15.9 +55 05	A2	0.006	5.73	+0.105	+1.3	-0.38	companion 7.4 magnitude
HR 7784	20 16.6 +39 05	A3 V	0.005	6.24	+0.027	+1.7	-0.27	triple system, 6.2:7.4:8.2
ω Cap	20 45.8 -27 18	K5 III	0.011	4.09	+1.742	-0.2	-0.70	
HR 8170	21 17.1 +39 55	F8 V	0.014	6.43	+0.516	+4.3	+2.16	RV variable
35 Cap	21 21.6 -21 38	K5 III	0.032	5.80	+1.478	-0.2	+3.33	no member?
ρ Cyg	21 30.2 +45 09	G5 III	0.025	4.09	+0.878	+0.3	+1.07	H and K emission
HR 8263	21 32.4 -00 50	A2	0.011	6.14	+0.074	+1.3	+1.35	companion 9 magnitude
76 Cyg	21 37.5 +40 21	A2	0.012	6.08	+0.072	+1.3	+1.48	RV variable
HR 8407	21 58.9 +44 10	A0	0.008	5.55	-0.032	+0.5	+0.07	visual binary 5.6:8.0
32 Aqr	21 59.6 -01 23	A5m	0.033	5.28	+0.232	---	+2.87	RV variable; metallic-line star
π Peg	22 05.5 +32 41	F5 II	0.006	4.36	+0.432	-2.0	-1.74	see Greenstein, Ap.J. 117, 269, 1953
HR 8461	22 07.0 +15 33	K1 III	0.005	5.98	+0.934	+0.2	-0.53	RV variable
HR 8473	22 08.3 +71 37	A0	0.006	6.38	+0.081	+0.5	+0.27	
66 Aqr	22 38.2 -19 21	K3 III	0.019	4.67	+1.375	-0.2	+1.06	
δ Aqr	22 49.4 -16 21	A3 V	0.020	3.28	+0.052	+1.7	-0.21	
4 And	22 03.1 +45 51	K5 III	0.008	5.32	+1.392	-0.2	-0.16	
99 Aqr	23 20.8 -21 11	K5 III	0.033	4.45	+1.505	-0.2	+2.04	no member?
15 And	23 29.7 +39 41	A1 V	0.012	5.60	+0.067	+0.8	+1.00	
λ Psc	23 36.9 +01 14	A5	0.050	4.53	+0.187	+2.2	+3.02	RV variable
ψ Psc	23 52.6 +24 35	M3 III	0.012	4.65	+1.606	-0.2	+0.05	

* Member of the nucleus.

1. Color and magnitude according to Johnson and Morgan.

2. Sp and M_{sp} according to a private communication of Miss Roman.

3. 2.4:4.0, two spectra, B metallic-line star.

4. No H and K emission according to G. H. Herbig.

5. M_{sp} according to a private communication of Miss Roman.

although there is more scatter resulting chiefly from the observational errors of the proper motions. The scatter to a lesser degree is produced by errors in the radial velocities, and, because the gravitational interaction between members is small, by the genuine dispersion of the motions of the stream stars. Furthermore, stars erroneously considered as stream members may contribute to the scatter in the various branches.

The stars bridging the Hertzsprung gap are again clearly visible. The main sequence extends to fainter dwarfs than in the preceding diagram, for no spectroscopic absolute magnitudes are available for the faintest dwarfs. The possibility of the main sequence splitting into a normal dwarf sequence and a fainter one at $B-V \sim +0.6$ mag., corresponding to F5 or F8, may be mentioned. The slope of Johnson and Morgan's

Figure 5. Color-luminosity diagram of the probable stream members, based on spectroscopic magnitudes. Open circles in this and the following diagrams represent known visual and spectroscopic binaries; half-filled circles, stars with variable radial velocity (RV); circles with dashes, stars with H and K emission.

standard main sequence is drawn in the diagram. The fainter sequence seems to be about 1 mag. or 1.2 mag. below the main sequence in the Ursa Major stream. Its existence has already been

Figure 6. Color-luminosity diagram of the probable stream members, based on stream parallaxes and apparent magnitudes V . The line represents H. L. Johnson's standard main sequence.

Figure 7. Color-luminosity diagrams of the most probable stream members, excluding stars for which the spectroscopically and astrometrically determined absolute magnitudes disagree by more than 0.7 mag. Lines represent H. L. Johnson's standard main sequence.

suggested by Eggen in his work on the Hyades and the nearby stars.⁵ None of the stars of the fainter kind is known to have H and K emission lines, whereas several of the brighter sequence do.

There are a few stars between the conventional sequences in this plot, and it is highly probable either that they do not belong to the Ursa Major stream, or that their proper motions or radial velocities are considerably affected by errors. This conclusion is supported by the fact that for most of them the differences between the observed and computed radial velocities, and between the observed and computed directions of motion are considerably larger than the average deviations for the other stars. A number of giants

TABLE III. ADDITIONAL STARS (NON-STREAM MEMBERS)

Name	α	1900	δ	Sp	V	$B-V$
α Cet	2 ^h 57 ^m 1		+03° 42'	Ma	2 ^m 56	+1 ^m 611
β CMi	7	21.7	+08 29	B8	2.84	-0.094
α Hya	9	22.7	-08 14	K2	1.93	+1.474
π Leo	9	54.9	+08 31	Ma	4.72	+1.579
η Leo	10	01.9	+17 15	Aop	3.44	-0.026

that seem to be doubtful members, according to astrometric and photometric data, are represented by smaller dots in Figure 6.

As further evidence for the reality of the three sequences, a plot was prepared (Fig. 7) showing only stars for which the astrometric absolute magnitudes and the spectroscopic absolute magnitudes agree within 0.7 mag. This selection removes many of the spurious members, especially those stars that deviate strongly from the mean stream motion. In this way, we may deal with the most probable members of the stream. Again, the same distribution over the diagram as before is found, except, of course, that the stars scattered between the sequences have disappeared.

Figure 8. Color-luminosity diagram of the nucleus stars, based on stream parallaxes and apparent magnitudes V .

The color-luminosity diagram of the nucleus consists only of the main sequence (Fig. 8). Since the components of the double star ζ UMa, 1.5 mag. difference in brightness, could not be measured separately, they were not plotted. The absolute magnitudes were computed with the cluster parallaxes, since no spectroscopic magnitudes are available for these stars. A redetermination of the convergent point and the space motion has been made by R. M. Petrie and B. N. Moys, but the results came too late to be used. The brightest star, ϵ UMa, is a spectrum variable. One K star, HD 124752, is about 1 mag. below the main sequence, and it is worth mentioning that this star shows no $Ca II$ emission lines H and K, whereas all the late-type dwarfs

of the nucleus have these lines. Joy has already pointed out that the late-type subdwarfs show no H and K emission,⁷ which is more common in normal dwarfs. On this basis HD 124752 may be considered a subdwarf.

The main sequence of the nucleus closely resembles the main sequence of the Hyades and Praesepe, for it starts very nearly with the same spectral type, color, and absolute magnitude at the bright end. The limit of the main sequence at its faint end probably is set by observational selection.

The solid lines drawn in Figures 6 and 7 represent the standard main sequence in the B, V system as derived by Johnson and Morgan for the nearby stars with $\pi < 0''.100$, and for clusters like the Pleiades, Praesepe and NGC 2362 (Fig. 5 of their paper). The main sequence of the Ursa Major group deviates from the standard main sequence in two respects: (1) the bright stars are too red for their luminosities, and (2) a number of stars lie well below the standard. The latter result suggests a surprisingly high number of subluminous dwarfs in the stream. This difference between the stars comprising the stream and those defining the standard main sequence is also apparent in Figure 3 of Miss Roman's paper.

When compared with other galactic clusters, the Ursa Major stream seems to be unique in its high number of ordinary giants, luminosity class II giants, and dwarfs below the main sequence; some implications of these features have been discussed elsewhere.⁸

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