SPECTROGRAPHIC AND PHOTOMETRIC OBSERVATIONS OF SOME STARS FROM THE *LUMINOUS STARS IN THE NORTHERN MILKY WAY I* AND *II* CATALOGUES*

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ABSTRACT

MK spectral types based on slit spectra and photometric observations on the U, B, V system are presented of a group of B, A, and F stars selected from the catalogues *Luminous Stars in the Northern Milky Way I* and *II*. The stars selected for observation were those which, according to the objective-prism spectral types and apparent magnitudes listed in the catalogues, were the most distant ($r \geq 5$ kpc). The luminosity classes assigned here are systematically lower than those assigned in the second catalogue.

INTRODUCTION

The results of the objective-prism surveys for luminous stars in the northern Milky Way, undertaken jointly by the Hamburg and the Warner and Swasey Observatories, have been presented in the form of two catalogues, *Luminous Stars in the Northern Milky Way I* (Hardorp, Rohlfs, Slettebak, and Stock 1959) and *II* (Stock, Nassau, and Stephenson 1960). Since these two surveys are complete to approximately the twelfth magnitude photographic, they constitute the most complete lists of very distant stars yet available for our Galaxy. With an awareness of the importance of these stars for studies of galactic dynamics, the author undertook to determine distances to some of these stars by means of spectrograms suitable for classification on the MK system and photometric observations in the U, B, V system.

SELECTION OF STARS

As part of another program, approximate distances were determined (Nassau and Stephenson 1961) for all the B, A, and F stars in the two catalogues *Luminous Stars in the Northern Milky Way I* ("*L.S.* I") and *Luminous Stars in the Northern Milky Way II* ("*L.S.* II"). Absorption was accounted for by a mean absorption coefficient which varied with height above the galactic plane (Trumpler and Weaver 1953). All B, A, and F stars from both catalogues with distances greater than, or equal to, 5 kiloparsecs were selected for observation. Not surprisingly, almost all these stars were listed in the catalogue as being of luminosity class I with apparent photographic magnitudes in the range 10 to 12. However, not all such stars (luminosity class I, $m_{pg} \geq 10$) from the catalogues were included by this selection procedure, because of the latitude-dependent absorption correction. Finding charts were prepared from the original Hamburg Schmidt plates for the stars from *L.S.* II. Most of the stars selected from *L.S.* I were BD stars and so presented no problem; the non-BD stars were identified with the aid of the BD charts and the catalogue positions precessed back to 1855. Charts are not presented here because complete charts will soon be published for both catalogues.

OBSERVATIONS

The observations were made in the months of July and August, 1961, at the McDonald Observatory. The spectrograms were taken with the 118-mm camera (Hiltner 1956) of

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TABLE 1

PHOTOMETRIC AND SPECTROGRAPHIC OBSERVATIONS OF STARS FROM THE CATALOGUES

Luminous Stars in the Northern Milky Way I and *II*

No.	BD	1950				Spectrum		V	$B-V$	$U-B$	Remarks*
		α	δ	l^{II}	b^{II}	Catalogue Type	Present Type				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
59°16. .	+58°2651	23^h45^m8	+59°12'.8	115°.2	−2°.5	B8 I*a*	B5 I*b*	9.93	+0.83	+0 02	
63 9 .	+62 2308	23 47.8	63 15.5	115.3	+1.4	A0 I*a*	. .	9.98	0.90	+0.24	
58 7 .	+58 2683	23 57.2	58 55.8	116.3	−3 0	A0 I*a*	A1 I*b*	9.12	0 76	+0.18	
60 87 . .	.	0 4.6	60 2.4	117 4	−2.1	B9 I*ab*	. .	10.75	0.55	+0.12	
58 11. .	+57 2870	0 4.7	58 3 6	117.2	−4.0	B8 I*ab*	. .	9.92	0.52	−0.02	
66 8.	+66 52	0 38.1	66 34.3	121.9	+4.0	(A0 I*ab*)	.	10.77	0 74	+0.19	
65 8. .	+65 121	0 58.1	65 38.8	123.9	+3.1	(B9 I*ab*)	.	10.54	1.03	+0.52	
58 26. .	.	1 12.0	58 2.3	126.0	−4.4	A1 I*a*$^+$	B2–5: V.	11.24	0.19	−0.14	Shell star
67 16. .	+66 100(?)	1 13.3	67 14.3	125 4	+4.7	A0 I*b*	. .	10.34	0.90	+0.32	
63 144. .	+63 180	1 20.9	63 41.4	126.5	+1.3	B8 I*ab*	.	9.96	1.05	+0.29	
64 77 .	. .	1 41.5	64 9 6	128.7	+2.1	A1 I*ab*	.	11.45:	0 42	+0.38	

* Stars with an asterisk in the "Remarks" column are as follows:

15°2 AP Her.—This star is listed as a W Virginis type variable in the *General Catalogue of Variable Stars* (Kukarkin, Parenago, Efremov, and Kholopov 1958). The spectrographic and photometric observations, along with the Julian dates, are given in Table *A*. The phase was not included, since there are insufficient observations to determine the epoch of maximum light and the most recent determination of epoch (Weaver, Steinmetz, and Mitchell 1960) does not describe the present observations.

TABLE *A*

OBSERVATIONS OF AP HER

Julian Date 2437000+	Sp.	V	$B-V$	$U-B$
494.75. .	F2 I*b*–II	. .	. .	. .
515.69 .	... .	10.60	+0.69	+0.46
516.66. .	... .	10.30	+ .64	+ .43
518.65... .	. ...	10.48	+ .76	+ .50
521.66.....	....	10.96	+0.94	+0.65

38°1.—Adopting the intrinsic color for an F6 I*b* star from Kraft (1961*b*), and a value of −4.5 mag. for the absolute visual magnitude (Arp 1958), the resulting distance is about 4.3 kpc. The height z above the galactic plane is 470 pc.

15°17 KL Aql.—This star is listed as a classical cepheid in the *General Catalogue of Variable Stars* (Kukarkin *et al.* 1958). The spectrographic and photometric observations, with their respective Julian dates, are given in Table *B*. The epoch of maximum light which was used to determine the phase is from Weaver *et al.* (1960).

TABLE *B*

OBSERVATIONS OF KL AQL

Julian Date 2437000+	Phase	Sp.	V	$B-V$	$U-B$
491.73. .	0.67	G0 I*b*	. .	. .	.
515.78. .	.60	. .	10.46	+1.17	+0.95
518.75 .	.09	. .	9.92	+0.91	+ .64
521.72. .	0.58	. .	10.42	+1.14	+0.91

The writer's photometric observations were plotted with those of Weaver *et al.*, and excellent agreement was obtained except near minimum light, at which point the present magnitudes are somewhat brighter. By combining the extensive observations by Weaver *et al.* with the spectrographic data of the author, we can apply the machinery developed recently by Kraft (1961*a*, *b*) to determine the distance to KL Aql. The resulting distance is 3.2 kpc, and the distance below the plane is 420 pc.

32°21.—The discrepancy between the objective-prism type (A2 I*a*$^+$) and the slit spectrogram type (B3 I*a*) suggests that this star has an anomalous Balmer jump, since no star as early as B3 should show as strong a jump as an early A-type supergiant.

TABLE 1—*Continued*

No.	BD	1950 α	1950 δ	l^{II}	b^{II}	Spectrum: Catalogue Type	Spectrum: Present Type	V	$B-V$	$U-B$	Remarks*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
60°198.	..	1h48m8	60°43′.6	130°.3	−1°.0	B8 Iab, r	.	10.54	1.26	+0.68	
66 17	+66°205	2 18.6	66 50.7	131.7	+6.0	B9 Ib	.	9.35	0.52	+0.17	
54 10.	+54 544	2 23.0	54 48.6	136.3	−5.4	B8 Iab	.	9 73	0.18	−0.28	
63 194.	+63 365	2 50.0	63 37.9	135.9	+4.1	A1 Ia	. . .	9.13	0.95	+0.36	
59 186.	..	3 25.0	59 55.6	141.5	+3.0	A2 Iab	. .	10.54	1.03	+0.79	
58 126.	+58 622	3 30.6	+58 28.7	142.8	+3.6	B6 Iab	.	9.19	+1.08	+0.17	
16 1.	.	18 39 4	16 3.7	46.1	+9 7	F(I)p	F6–8 II–III	11.17	0.92	+0.36	Sp. underexposed
15 2.		18 48.2	15 52.8	47.1	+7.5	F3 I	F2 Ib–II	.	.	.	AP Her*
18 2.		18 52.1	18 4.8	49.6	+7 6	F5 I	F6 II	11.21	0.69	+0.30	
17 2.		18 53 0	17 8.1	48.7	+7.0	F8 I	F4 III.	11.08	0.64	+0.15	
21 3	.	19 6.8	21 14.3	53.9	+5.9	F9 I	F6 III	11.26	0.79	+0.30	
30 2.	+30 3482	19 12.6	30 58.1	63.3	+9.1	F7 I	F6 II	10.33	0.55	+0.07	
31 2.	.	19 22.8	31 10.4	64.4	+7.3	F8 I	F3 II	10.33	0.48	+0.16	
25 2.	+25 3852	19 27 6	25 54.5	60.3	+3.9	F1 I	F2 II	10.72	0.79	+0.66	
22 8.	.	19 38.1	22 24.6	58.5	0.0	B9 Ia, h	B2–5: V	11.78	0.54	+0.37	Shell star
21 13		19 47 6	21 2.8	58.4	−2.5	B8 Iab	B3 II.	10.81	0.40	−0.29	
38 1.	+38 3786	19 49.3	38 49 4	73.0	+6.3	F8 I	F6 Ib	9.86	0.81	+0.52	*
10 10..		19 50.9	10 10.7	49.3	−8.7	F8 I	F6–8 II–V	11.87	0.56	+0.07	Sp. underexposed
14 15.		19 51.3	14 50.2	53.8	−6.4	F0 Ib	.	12.21	0.45	+0.06	
24 23		19 52.5	24 47 4	62.1	−1.6	A4 Ia	B8 III	11.07	0.86	+0.27	
15 17	.	19 58.9	15 39.9	55.1	−7.5	F6 Iab	G0 Ib	.	.	.	KL Aql.*
22 19		19 59.3	22 40.2	61.2	−3.9	(A1 Ia)	F4 II	11.63	0.74	+0.39	
29 41.	+28 3612	20 3 4	29 12.3	67.1	−1.2	F2 Ia	F2 Ib–II	9.50	1.38	+1.10	
38 6.		20 6.1	38 4.7	75.2	+3.1	A2 Iab	A0 III	11.50	0.39	+0.17	
35 46.	+35 3981	20 6.2	35 58.7	73.2	+1.9	A2 Ia, h	B2–5: V	10.23	0.18	+0.14	V425 Cyg, shell star
32 21.	+32 3761	20 14.3	32 31.7	71.3	−1.4	A2 Ia+	B3 Ia	9.97	0.53	+0.09	*
23 59	+23 4002	20 22.0	23 37 6	64.8	−7.8	B9 Ib	A1 II	10.21	0.26	+0.12	
21 20.		20 22.6	21 12.0	62.9	−9.3	B8 II	.	11.11	0.26	+0.28	
25 24.		20 44.2	25 53.6	64.8	−7.8	A4 Ib	A5–7 Ib–II	10.61	0.26	+0.30	
39 54.	+39 4313	20 44.7	+39 44.7	80.7	−2.1	A9 Ia	F4 II	9 43	+1.14	+0.84	

the Cassegrain spectrograph of the 82-inch reflector. The dispersion is 86 A/mm at Hδ. All spectra were taken on Eastman 103*a*-O emulsion, widened 0.5 mm, and developed under identical physical conditions. Since the spectrograms were taken before the photometric observations, exposure times were based on the photographic magnitudes given in the catalogue; this procedure proved to be entirely satisfactory. Standard stars of the MK system (Johnson and Morgan 1953) were observed on nights of bad seeing. Most of the stars selected from *L.S.* II were observed, but spectra were obtained for only three of the stars selected from *L.S.* I.

The photometric observations were made with the 36-inch reflector, using a conventional photometer containing a refrigerated 1P21 photomultiplier cell and the recommended filters (Johnson and Morgan 1951) for the *U*, *B*, *V* system (Johnson and Morgan 1953). Mean values of the extinction were used in the reductions. Approximately thirty standards were observed each night, and these were used to transform the observations to the *U*, *B*, *V* system. The standard stars were selected from the list of Johnson and Harris (1954) and included six of the ten primary standards. All stars were observed at least twice, and the majority were observed three or four times. Most of the stars selected from both catalogues were observed, with the exception of a few for which identification was unusually difficult.

RESULTS

The results are presented in Table 1. Columns 1 through 6 list, respectively, the number assigned in *L.S.* I or *L.S.* II, BD designation, if any, right ascension and declination for 1950, and galactic longitude and latitude on the new system (Blaauw, Gum, Pawsey, and Westerhout 1960) for the same epoch. Column 7 gives the catalogue spectral type, while column 8 contains the MK type assigned by the author. When a range of types is given, this does not indicate higher accuracy but rather uncertainty due to faintness of the spectrogram or shortage of standards or both. Columns 9, 10, and 11, respectively, list the magnitude *V* and the colors $(B - V)$ and $(U - B)$. Remarks are given in column 12. An asterisk in this column refers to a footnote at the end of the table.

CONCLUSIONS

A comparison of columns 7 and 8 of Table 1 shows a systematic difference in the assigned luminosity classes for the stars from *L.S.* II in the sense that the catalogue luminosity classes are too bright. Most of these stars are of spectral types A and F and are rather faint. This discrepancy points out the errors which could arise if the catalogues were used for anything but finding lists for luminous stars.

The identification of three shell stars among the catalogue stars means that this type of star is indistinguishable from high-luminosity early-type stars on the objective-prism plates; and the observed frequency—3 out of 24 stars for which slit spectra were taken—suggests that such stars may be relatively plentiful in the catalogues. However, for two of these stars, Hα was seen in emission, which was a warning that the assigned spectral type might be in error.

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