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STUDY OF A SAMPLE OF FAINT M STARS IN THE DIRECTION OF THE NORTH GALACTIC POLE

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ABSTRACT

Slit spectra and *UBV* photometry of 27 M stars (ranging in *V* from 9.2 to 15.1) found in Sanduleak's low-dispersion objective-prism survey of the north galactic polar region show that most are nearby dwarfs; only six are halo giants. Since these 27 stars were selected on the basis of not showing appreciable proper motion, it appears that numerous nearby low-velocity M dwarf stars exist. Such stars, which do not show up in proper-motion surveys, increase the space density of intrinsically faint red stars by a significant amount.

I. INTRODUCTION

In order to avoid the kinematic bias that so strongly influences estimates of the space density of faint red stars (Vyssotsky 1963), Sanduleak (McCuskey 1964, 1966; Sanduleak 1965) undertook a low-dispersion objective-prism survey aimed at discovering faint M dwarfs. Because it is impossible to distinguish between M dwarfs and M giants at the low dispersion used, the survey was centered at the north galactic pole. Under the assumption that the space density of halo giants decreases rapidly with increasing distance from the galactic plane, very few giants fainter than $V \sim 12$ would be anticipated. The survey, which covered 120 square degrees, yielded more than 1200 M stars; and assuming that most of them were dwarfs, Sanduleak estimated that the space density of M dwarfs should be increased by a factor of 3 over that predicted (after correcting for the small contribution made by white dwarfs) by Luyten's (1939) luminosity function.

A small number of the stars found by Sanduleak were classified by him as M5 or later. This led the writer to suspect that some of these stars were actually halo giants, as no known dwarf—no matter how intrinsically faint—shows (on low-dispersion objective-prism plates) the VO bands that define types later than M6 in the Case system (Pesch 1965; Nassau and Velghe 1964; Wing and Ford 1969). This suspicion, plus the desire to verify Sanduleak's assumption that there were few giants in his sample of fainter stars, led us to various attempts to obtain distance estimates for the fainter M stars (McCuskey 1970). Even the most successful of these efforts—blinking first- and second-epoch *Palomar Sky Survey* plates (made possible through the kindness of W. J. Luyten)—were somewhat indeterminate (on the best plate pair, more than half of the M stars showed no motion). Thus further photometric and spectroscopic observations were made of a number of these objects.

II. OBSERVATIONS

Table 1 lists the observational data for 27 of Sanduleak's stars selected on the basis of not appearing in any proper-motion catalog, not having shown any motion on the plate pairs blinked by us (our conservative estimate for the lower limit of detectable motion is about 0″.05 per year), and for which no previous luminosity determination

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TABLE 1

OBSERVATIONS OF NORTH-GALACTIC-POLE M STARS

Sanduleak No.*	V	$B-V$	$U-B$	n†	Sp‡	Remarks§
24°69....	9.24	1.48	1.84	3	gM1	BD+24°2508
22°48....	10.02	1.53	1.90	3	gM0	BD+23°2507, Malm 22-468 D0 14653
23°54....	10.50	1.17	1.00	3	Late dK–dM0	BD+23°2508, Malm 23-504
27°128...	10.86	1.52	1.87	3	gM4	D0 14679, SW 61
25°89....	11.08	1.16	1.15	3	Late dK–dM0	Malm 25-461
27°53....	11.78	1.37	1.25	3	dM1	Malm 27-233
24°82....	12.14	1.49	1.90	3	gM0 IT	
27°1.....	12.18	1.45	1.26	3	dM1–2 IT	Malm 27-41
25°33....	12.19	1.31	1.23	3	dM1	Malm 25-283
25°34....	12.21	1.33	1.23	3	dM1	Malm 25-282
27°83....	12.66	1.28	1.33	3	dM0 IT	
31°90‖...	12.77	1.89	1.63	1	gM7e IT	FQ Com, Hγ, δ in emission (weak)
29°10....	12.95	1.41	1.23	3	dM2 IT	Malm 29-157
27°94....	13.10	1.46	1.13	3	dM1 IT	Image elongated, ft. comp?
31°17....	13.21	1.41	1.29	3	dM1 IT	
26°118...	13.44	1.47	1.27	1	dM1 IT	
23°75#...	13.65	1.94	0.36	1	gM8–9e IT	T Com, D0 14672
23°66....	13.97	1.46	1.25	1	...	Hγ, Si I λ3905, H8, 9, 10, 11 in emission
31°54....	14.10	1.48	...	1	dM3–4 IT	
23°8**...	14.19	1.56	...	1	dM5 IT	
30°36....	14.49	1.52	...	1	dM2–3 IT	
25°35....	14.53	1.43	...	1	dM3e IT	H and K in emission
23°85....	14.57	1.40	1.65	1	dM2–3 IT	
27°142...	14.73	1.48	...	1	dM3 IT	
26°95....	15.11	1.71	...	1	dM5e IT	H and K, Hα, β, γ, δ in emission
26°24....	15.24	1.59	...	1	dM3–4: IT	
27°7.....	15.30	1.66	...	1	dM3 IT	

* Numbers given by Sanduleak (1965), where finding charts are provided.

† Number of photometric observations.

‡ IT signifies spectrum was taken with image tube.

§ Remarks: Malm refers to numbers in catalog of Malmquist (1927, 1936); DO refers to Dearborn Observatory catalog by Lee and Bartlett (1944), SW refers to Stock and Wehlau (1956).

‖ Photometry obtained JD 2441065.88, spectrum on JD 2441099.67.

Photometry obtained JD 2441065.84, spectrum on JD 2441058.82.

** Coordinates and magnitude match those of BPM 88245, but we did not see any motion on the plates we blinked.

was available. The photometry was obtained in the spring of 1971 with the Kitt Peak National Observatory No. 2 36-inch (91-cm) reflector, using conventional photometric equipment and conventional reduction procedures. Red leaks through the ultraviolet filter were individually determined for each star. Spectra for the brighter stars (V less than about 12.5) were obtained with the Cassegrain spectrograph of the Kitt Peak National Observatory 84-inch (213-cm) reflector. These spectra were centered at λ5900 and had a dispersion of 204 Å mm^{-1}. Spectra of the fainter stars were obtained with the Cassegrain image-tube spectrograph on the 84-inch. These spectra have a dispersion of approximately 260 Å mm^{-1} in the first order and extend from slightly shortward of the H- and K-lines to $\sim\lambda$7065 in the first order. The second-order blue is also present, covering the range $\lambda\lambda$3800–4471. Spectra, both conventional and image-tube, were obtained of a variety of known giant—and dwarf—M stars. It was found that giants and dwarfs were easily distinguishable on the conventional spectrograms on the

basis of the appearance of the Na I D-lines and the Ca I lines at λλ6103, 6122, and 6162 (Luyten 1923; Burwell 1930; Öhman 1934; Spinrad 1962). Temperature classes were estimated by using the strengths of the TiO bands. According to Johnson and Morgan (1953), for types later than M0+, Kuiper's (1942) spectral types (based on the strength of the red TiO bands) are equivalent to MK types. Strong and time-variable nightsky emission in the Na I D-lines on the image-tube spectra unfortunately rendered this feature unreliable for luminosity discrimination. Furthermore, the considerably degraded resolution of the image-tube spectra obliterated all but the strongest (λ6162) of the three Ca I lines mentioned above, and this latter line is overlapped by a TiO band in the later-type stars. The *A* (λλ6700–7035) and the *B* (λ6385) bands of CaH were therefore used as additional luminosity criteria (Öhman 1934, 1936). In table 1, *g* and *d* prefixes are used in order to emphasize that these types should not be considered to be on the MK system.

The colors $(B - V)$ and $(U - B)$ are plotted, when available, in figure 1. The two points at (+1.9, 0.4) and (+1.9, 1.6) are the known giant variables T Com and FQ Com, respectively. With the exception of 23°85, the dwarfs and giants are quite clearly separated in this plot, as one might expect (Johnson and Morgan 1953). This separation, however, appears to hold only for M giants that are constant in light (Smak 1964), and since nothing was known about the variability of these stars, a purely photometric approach was not attempted. On the basis of its position in the color-color plot, star no. 23°66—for which no spectrum is available—is probably a dwarf.

III. DISCUSSION

a) Sanduleak's V-Magnitudes

Comparison of Sanduleak's photographically determined *V*-magnitudes (excluding the two known variables) with the writer's photoelectric *V*-magnitudes shows differences of the expected size (~0.2 mag average) with no systematic trend. Thus Sanduleak's space densities are not affected by a scale error in his magnitudes.

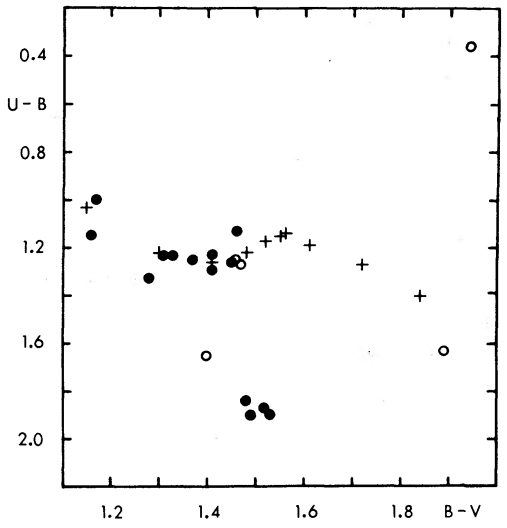

FIG. 1.—$U - B$, $B - V$ diagram for NGP M stars. Filled circles represent points based on three observations; open circles represent points based on one observation. Crosses represent lower main sequence K5 V to M7 V after Johnson (1965).

b) Agreement of Spectral Types

In general, the slit types agree well with Sanduleak's (1965) objective-prism types for the brighter and earlier-type stars (M0–2), but diverge for the fainter stars in the sense that the new types are systematically earlier by approximately 3 spectral subdivisions. There seems to be a tendency to assign too late a type to objective-prism spectra of M stars near the plate limit.

c) Number of Giants

Only two of the 17 stars fainter than $V = 12.5$ were found to be giants; these are both Mira-type variables and were called M8 by Sanduleak (such late-type stars are rare in his catalog). Thus Sanduleak's assumption that few of his fainter stars are giants is substantiated in the small sample of stars examined. Insofar as these results can be extended to all of his stars for which no motions have been detected, this supports his conclusion that faint red dwarfs are more numerous than previously supposed (slightly more than twice the number predicted by Luyten's luminosity function of 1968). This same conclusion is suggested by recently obtained kinematic data of another small (21 stars) sample of Sanduleak's M stars (Murray and Sanduleak 1972).

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