REDDENED EARLY M- AND S-TYPE STARS NEAR THE GALACTIC EQUATOR

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ABSTRACT

A list is given of 89 early M-type stars whose objective-prism spectra indicate abnormal reddening. The catalogue probably contains a high proportion of distant supergiants. In addition, a list of 31 new S-type stars is given which were detected by the presence of *LaO* bands in their spectra. Both groups of stars are within a galactic belt 4° wide from longitude 333° through zero to 201°. The catalogues are accompanied by a brief discussion of the distribution of these objects.

In the course of the Warner and Swasey Observatory infrared spectral surveys of the Milky Way, a number of early M-type stars were segregated which probably have higher than normal color indices, as suggested by the appearance of their spectra. The region covered in these surveys and the mode of observing have been described in previous publications (Nassau and Blanco 1954). In the unwidened spectra used, some stars of class M0–M4 show images that are wedge-shaped, with the tapering toward the shorter wave lengths. This unique appearance has been interpreted as indicative of an abnormally high color index. Photoelectric observations (Blanco 1954) of the colors of 16 such stars support this interpretation. In the same galactic region, in addition to these stars, 31 S-type stars were recognized by means of the *LaO* bands at λ 7400 and λ 7900 (Keenan 1948). The present paper presents these two groups of stars.

EARLY M-TYPE STARS

Since spectra tapered in the manner described are also shown by the known early M supergiants in the h and χ Persei clusters, these stars were used as standards in the segregation of the reddened early M stars. The eighty-nine stars in Table 1, *a* and *b*, were segregated by direct comparison with the M supergiants of the clusters. Each of the stars listed shows a spectrum whose wedge-shaped appearance is somewhat more pronounced than the spectra of the standards of the same spectral class. The high color indices of these stars are caused principally by interstellar reddening. Photoelectric observations (Blanco 1954) of known supergiant early M stars in the blue and visual regions show that their intrinsic color index is about 0.3 mag. higher than that of the giants of the same spectral class. That the color differences between giants and supergiants are also small in the red and infrared regions follows from a comparison of the six-color photometric data of Stebbins and Whitford (1945) for α Orionis and the M2 giant HD 120933.

The stars in Table 1, *a* and *b*, may be distant supergiants or relatively near-by giants showing the effects of abnormally high obscuration. As explained later, it is also possible that a few of these stars are of S type. Since the infrared absolute magnitudes of the M supergiants are −7 or brighter and since the effect of interstellar absorption is much less in the infrared, they can be observed at great distances.

Estimates of the degree of tapering that should appear in unwidened spectra for various amounts of interstellar absorption have been made with the help of Whitford's (1948) observations of the interstellar absorption-curve. The results indicate that a total visual absorption of about 2 mag. should produce the degree of tapering used as a lower limit in the present survey. For a number of these stars it can be shown from the color excesses of the near-by O and B stars that this amount of absorption or more may exist within

TABLE 1

REDDENED EARLY M-STARS

(a)

No.	BD	R.A. 1900	Dec.	m_i	Sp.	Group	l	b	Remarks
1	+58°501	2^h32^m3	+59°10'	5.2	M3	A	104°	0°	*
2	+57 647	2 43.6	+57 26	5.2	M3	A	106	-1	
3	+54 651	3 06.5	+54 34	6.9	M3	A	110	-2	*
4	+55 778	3 17.2	+56 09	8.0	M1	C	111	+1	
5	+44 1005	4 34.0	+44 30	7.5	M3	C	128	0	
6	+39 1070	4 41.6	+39 46	7.6	M1	B	132	-2	
7	+42 1065	4 43.1	+42 57	8.5	M2	A	130	0	
8	+28 834	5 31.6	+28 55	7.5	M2	B	147	0	
9	+19 1183	5 57.0	+19 29	6.9	M0	B	158	+1	
10	+13 1110	6 01.2	+13 35	6.7	M1	A	163	-2	
11	+10 1085	6 13.5	+10 22	5.5	M2	A	168	-1	
12	+13 1212	6 15.4	+13 58	6.3	M3	A	165	+1	
13	-12 5055	18 21.9	-12 32	4.6	M3	B	347	-2	*
14	+ 0 4030	18 45.3	+ 0 40	6.5	M2	C	1	-1	
15	+24 3902	19 45.9	+24 41	5.7	M3	A	29	-2	
16	+35 4077	20 17.3	+35 18	6.0	M2	A	42	-2	
17	+36 4025	20 17.6	+36 37	4.9	M4	A	43	-1	*
18	+37 3903	20 17.9	+37 13	4.9	M4	A	44	0	*
19	+39 4208	20 25.2	+39 39	4.7	M4	A	46	0	*
20	+59 2541	22 30.8	+59 59	8.1	M2	C	75	+2	
21	+60 2613	23 39.2	+61 14	3.9	M3	A	83	0	

(b)

No.	BD	x	y	R.A. 1900	Dec.	m_i	Sp.	Group	l	b	Remarks
22	+61°153	+1.9	+1.0	0^h38^m0	+61°44'	7.5	M1	A	90°	0°	
23	+63 94	+1.9	+0.9	0 43.4	+64 13	6.9	M2	A	90	+2	
24	+62 247	+1.8	-0.4	1 19.1	+62 59	8.5	M1	C	94	+1	
25	+60 312	+3.7	+3.8	1 37.7	+61 07	7.1	M1	C	97	0	
26	+60 385	-0.4	-0.3	1 49.6	+60 19	8.0	M2	C	99	-1	
27	+59 411	-0.5	-0.3	2 00.0	+59 46	7.4	M1	C	100	-1	
28	+58 508	+1.9	+2.8	2 36.4	+58 54	8.2	M2	C	105	0	
29	+60 574	0.0	-2.2	2 42.0	+60 37	6.7	M1	C	104	+2	*
30	+60 588	+5.2	+1.6	2 48.7	+60 24	7.7	M1	C	105	+2	
31	+56 749	-2.8	-0.5	2 49.4	+57 08	6.3	M3	B	107	-1	
32	+59 587	+0.9	-0.5	2 55.2	+59 26	7.9	M1	C	107	+2	
33	+55 739	-1.8	-0.4	2 59.4	+55 21	6.2	M4	A	109	-1	
34	+54 655	-0.6	+0.1	3 07.7	+54 31	5.9	M2	A	111	-2	
35	+55 780	0.0	-0.5	3 17.7	+55 12	8.1	M2	C	111	0	
36	+52 711	+3.5	+2.7	3 39.6	+52 46	6.5	M2	A	115	0	
37	+46 906	+1.0	+0.2	4 37.8	+46 13	8.7	M2	C	127	+2	
38	+45 987	-3.9	+1.4	4 39.5	+45 23	8.9	M1	C	127	+1	
39	+39 1085	+1.6	+1.6	4 45.1	+39 53	7.8	M2	B	132	-1	
40	+25 1011	-0.6	+0.4	5 46.0	+25 48	7.4	M0	B	151	+1	*
41	- 9 1796	+1.0	+0.6	6 57.0	+ 9 32	9.4	M1	C	190	-1	
42	-14 1784	-2.0	-1.0	7 09.5	-14 27	6.6	M1	A	196	0	
43	-15 4856	-1.4	+0.3	18 05.8	-15 41	8.4	M2	C	342	0	
44	-16 4761	+0.5	+2.2	18 08.8	-16 25	8.2	M1	C	342	-1	
45	-16 4788	-2.4	+0.4	18 10.6	-16 43	5.5	M4	A	342	-2	
46	-16 4786	-1.8	-1.7	18 10.6	-16 39	7.8	M3	B	342	-2	

TABLE 1 (Continued)

No.	BD	x	y	1900 R.A.	Dec.	m_i	Sp.	Group	l	b	Remarks
47	-15°4911	+0.2	+2.8	18^h11^m8	-15°19'	7.5	M3	B	343°	-1°	
48	-12 5023	+0.8	-0.6	18 17.7	-12 45	5.9	M3	C	346	-1	*
49	-13 4973	-0.2	-1.7	18 19.9	-13 49	6.9	M3	C	346	-2	
50	- 9 4753	+1.3	-1.4	18 25.6	- 9 27	6.8	M3	C	350	-1	*
51	- 2 4686	-0.9	-0.7	18 33.8	- 2 04	7.5	M3	C	357	0	
52	+ 2 3681	+2.8	+2.2	18 42.2	+ 2 53	8.4	M3	C	3	+1	
53	+ 4 3900	+2.2	+3.1	18 47.7	+ 4 34	9.0	M4	C	5	0	
54	+ 8 3898	-1.2	+0.8	18 50.2	+ 8 08	7.7	M0	C	8	+2	
55	+ 5 4002	+0.2	+2.4	18 54.5	+ 5 14	5.7	M1	B	6	-1	*
56	+ 7 3976	-1.8	-1.3	19 03.5	+ 7 44	8.5	M2	C	10	-2	
57	+10 3796	+0.5	-1.3	19 04.0	+10 10	8.9	M1	C	12	0	
58	+13 3984	-0.2	-3.0	19 15.4	+13 23	7.1	M1	C	16	-1	
59	+17 3977	+1.7	-0.2	19 24.0	+17 06	7.5	M2	C	20	-1	
60	+19 4103	+0.3	-0.9	19 34.9	+19 57	7.0	M4	C	24	-2	
61	+30 3854	-0.8	-0.5	19 57.0	+30 33	6.7	M2	A	36	-1	
62	+30 3854	+1.2	-1.2	19 57.6	+30 31	7.2	M2	A	36	-1	
63	+29 3869	+0.2	+2.6	19 58.9	+30 05	8.4	M3	A	35	-1	
64	+30 3866	+0.2	-0.4	19 59.6	+30 11	6.9	M4	A	36	-1	
65	+35 4010	0.0	-0.8	20 07.6	+35 25	8.0	M4	A	41	0	*
66	+37 3934	-2.8	-1.2	20 22.2	+38 02	5.3	M4	A	45	-1	*
67	+40 4160	+3.0	+2.6	20 22.6	+40 48	8.0	M2	C	47	+1	
68	+36 4072	+2.0	-0.9	20 23.2	+36 13	5.0	M4	A	43	-2	*
69	+40 4217	-2.1	+1.0	20 27.8	+40 18	7.8	M2	C	47	0	
70	+40 4226	-0.8	+2.3	20 29.3	+40 24	8.2	M1	C	47	0	*
71	+43 3708	+0.4	-2.6	20 41.9	+43 54	8.2	M1	C	52	0	
72	+46 3140	+0.3	-0.1	20 57.4	+46 42	7.6	M4	C	56	0	
73	+56 2739	+1.3	+1.3	22 11.8	+57 16	8.1	M2	B	71	+1	
74	+58 2436	+2.0	+1.1	22 24.7	+58 44	5.8	M3	A	73	+1	
75	+58 2450	+2.5	-2.6	22 29.8	+58 23	6.1	M1	A	74	+1	
76	+59 2549	+2.6	+4.4	22 34.1	+59 51	7.3	M2	B	74	+2	
77	+58 2473	-1.2	+2.0	22 39.4	+59 14	6.6	M4	B	75	+1	
78	+58 2485	+1.6	+1.4	22 45.4	+58 46	6.7	M2	B	76	0	
79	+60 2452	+2.2	+2.0	22 49.3	+60 45	5.7	M3	B	77	+2	
80	+60 2492	+1.6	+1.5	23 06.0	+60 42	6.1	M3	B	79	+1	
81	+59 2675	-1.7	+1.0	23 09.2	+59 58	5.9	M0	A	79	0	
82	+59 2676	+0.5	+3.0	23 10.3	+60 23	7.2	M1	B	79	0	
83	+60 2512	-1.1	+0.9	23 12.0	+60 25	7.1	M2	B	79	0	
84	+57 2718	-1.7	+0.1	23 13.0	+58 08	7.9	M1	C	79	-2	
85	+59 2727	+0.3	+0.3	23 23.0	+59 54	6.7	M3	A	81	-1	
86	+58 2598	-0.5	-0.2	23 24.3	+59 13	7.7	M2	B	80	-1	
87	+59 2734	+1.3	-1.0	23 25.6	+59 44	7.3	M4	B	81	-1	
88	+59 2738	-0.8	-0.2	23 26.2	+59 42	6.4	M3	A	81	-1	
89	+61 2466	+2.2	-2.6	23 27.7	+61 25	8.0	M2	C	82	+1	

REMARKS TO TABLE 1

1. GP Cas, I. 3. NE star of double. 13. UY Sct. 17. BI Cyg, I. 18. BC Cyg, I. 19. RW Cyg, LP. 29. Extremely red. 40. BB Tau, I. 48. FR Sct, I. 50. BP Sct, extremely red. 55. V492 Aql, I, extremely red. 65. V430 Cyg, I? 66. KY Cyg, I. 68. V441 Cyg, LP. 70. Hα in emission

1 or 2 kiloparsecs. An effort has been made to divide the reddened early M stars into three groups in accordance with the estimated amount of absorption to various distances in the direction of each star. Group A contains stars in whose directions there is an apparent lack of near-by absorption sufficiently strong to produce the observed tapered spectra; group B contains stars for which the absorption is intermediate; and group C stars are located in regions where strong near-by absorption is suspected. The proportion of supergiant M stars is higher in groups A and B than in group C. As expected from the foregoing arguments, the stars selected by the tapered-spectrum criterion should, in general, avoid the clearer regions of the Milky Way. This agrees with observations.

Table 1, *a* and *b*, gives the reddened early M stars. These lists differ in one respect only: the first contains all stars which are in the BD catalogue; the second gives a reference BD star near the M star and co-ordinates in millimeters in the scale of the BD charts from the reference star to the M star. Positive Δx indicates the direction of increasing R.A., while positive Δy is in the direction of north. The infrared magnitudes designated by m_i are approximate and were estimated from the spectra as described in an earlier paper (Nassau and Blanco 1954). The spectral classes are followed by a column in which the stars are assigned to one of groups A, B, or C described earlier. The last two columns give the galactic longitude and latitude to the nearest degree. In the "Remarks" column "I" designates an irregular variable, "LP" a long-period variable, and "M" a Mira type. These designations are taken from the *General Catalogue of Variable Stars* (Kukarkin and Parenago 1948). From an available red-sensitive plate, star No. 70 was found to have *Hα* in emission. In the future, for convenience, stars in this table will be designated by the letters RM-WS followed by the star's number.

S-TYPE STARS

As has been stated, S-type stars are detected in the near infrared region of the spectrum from the presence of the *LaO* bands. However, in overexposed spectra these bands are not visible and the spectra appear similar to those of the reddened early M stars. A number of plates were taken with the 4° and 6° objective prisms, in order to remove ambiguities in the classifications. About one-third of the region of the survey was covered with these dispersions. A few S stars were found in this manner and are included in the list of S stars. However, the list of reddened early M stars may still contain stars of class S, particularly in those cases where the spectrum has been classified M0 or M1. The S stars are given in Table 2 and will be designated in the future by the letters S-WS followed by the star's number. The arrangement of the table is identical with that of Table 1, *b*, with the exception of the column designating groups A, B, and C. The present survey, which is confined within a galactic zone 4° wide from longitude 333° through zero to 201° and which has a limiting infrared magnitude of about 11, is not expected to include all the new S stars in the area. The identification was made by means of the *LaO* bands, and not all S stars show these bands (Keenan 1954).

GALACTIC DISTRIBUTION OF S AND REDDENED M STARS

A discussion of the galactic distribution of these stars is to be included in a paper describing the results of the infrared surveys at this observatory. However, in order to point out the significance of the present lists, some brief remarks may prove appropriate. The surface distribution of these stars shows marked clustering tendencies. This is most evident for the M stars of groups A and B and for the S stars. Provisional studies at higher galactic latitudes indicate that these stars have a high degree of galactic concentration. From these observations it appears that the stars presented in this paper may be associated with the galactic spiral arms. Keenan (1953) has shown that S stars may be associated with spiral arms.

In conclusion it may be pointed out that, by means of the spectral criterion given here, early M stars were picked out and were found to be supergiants from slit spectra

TABLE 2

S STARS

No.	BD	x	y	R.A. 1900	Dec.	m_i	l	b	Remarks
1	+62°147	-1.6	+3.2	$0^h41^m.1$	+63°24'	8.3	90	+1	
2	+59 128	+ .9	+1.6	0 44.8	+59 40	7.9	91	-2	*
3	+61 256	- .7	- .8	1 16.4	+61 28	9.8	94	0	
4	+59 239	+2.0	-1.2	1 17.0	+59 47	9.6	95	-2	
5	-19 4886	+1.6	- .5	18 05.7	-19 53	9.3	339	-2	
6	-15 4902	+1.6	+2.5	18 11.1	-15 12	10.7	343	-1	
7	-14 5004	- .6	+ .6	18 14.8	-14 09	9.0	345	-1	
8	- 9 4762	+2.7	-2.1	18 27.2	- 9 33	10.0	350	-2	
9	- 4 4509	+ .7	-1.6	18 31.2	- 4 28	9.5	355	0	
10	- 5 4710	+ .4	-2.3	18 32.9	- 5 31	8.0	354	-1	
11	- 5 4719	-1.4	- .1	18 34.8	- 5 48	10.5	354	-2	
12	- 4 4559	+1.8	+1.2	18 37.7	- 4 34	9.3	356	-2	
13	+ 4 3936	-2.6	- .6	18 53.5	+ 4 32	5.0	6	-1	
14	+11 3709	+ .4	-2.8	18 58.7	+11 50	8.1	13	+1	
15	+10 3818	+3.2	+ .3	19 07.5	+10 45	8.8	13	-1	
16	+22 3675	0.0	+ .9	19 18.0	+22 23	8.3	24	+2	*
17	+21 3839	- .3	+ .9	19 31.4	+22 07	8.1	25	0	
18	+28 3485	-2.4	-1.0	19 44.4	+28 31	9.5	32	0	
19	+25 4000	+ .2	- .9	19 47.4	+25 52	9.5	31	-1	
20	+27 3561	-1.5	-1.3	19 51.6	+27 23	8.6	32	-1	
21	+37 3867	-1.6	-2.2	20 13.4	+37 48	9.5	44	+1	
22	+40 4243	- .3	+ .1	20 32.1	+41 01	9.5	48	0	
23	+45 3297	+1.9	- .9	20 47.4	+45 24	11.0	53	0	
24	+44 3619	+2.0	+ .3	20 50.6	+44 28	10.4	53	-1	
25	+48 3281	-1.6	+2.5	21 01.3	+49 05	9.5	58	+1	
26	+45 3429	-1.3	+ .2	21 05.7	+45 46	8.8	56	-2	
27	+51 3048	+1.6	+1.5	21 18.8	+51 46	9.7	62	+1	
28	+60 2497	+3.3	+3.6	23 09.2	+60 33	7.9	79	0	
29	+57 2718	+ .8	-2.6	23 14.0	+58 00	7.4	79	-2	
30	+62 2266	+ .3	-1.1	23 35.2	+62 47	9.5	83	+2	
31	+62 2315	-1.8	- .1	23 46.5	+62 18	8.6	84	+1	*

REMARKS TO TABLE 2

2. 97, L. 16. 4639. 31. EO Cas, M.

taken at the Yerkes Observatory. These stars are BD 57°524 and 58°445 (near the h and χ Persei clusters) and BC Cyg. In addition, RW Cyg has been classed by Keenan (1942) as M3 I*a*.

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