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THE DISTRIBUTION OF LATE M-TYPE STARS ALONG THE GALACTIC EQUATOR

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ABSTRACT

An extension of the infrared survey of M5 and later stars in the Milky Way is given The previous survey was confined to a zone 4° wide centered at the galactic equator. The present investigation extends it to a zone 12° wide In the new areas surveyed, the surface distribution of 4953 stars of type M5 or later shows a gradual diminution in their number as the anticenter of the Galaxy is approached A similar distribution was obtained for the 941 stars of class M7 and later. The average number of late M stars per square degree in the zone 12° wide is 2 9. In the direction of the anticenter the corresponding number is 1 5 A catalogue of all the late M-type *BD* stars is given.

INTRODUCTION

This report deals with an extension of the survey of the late M-type stars along the galactic equator from $l = 333°$ to $l = 201°$. The previous investigation (Nassau and Blanco 1954*b*) was confined to a zone 4° wide, centered at the galactic equator, while the present extends it to a zone 12° wide. Carbon and S-type stars and suspected M supergiants which were considered in the previous survey are not included. They will be discussed later. The two catalogues of *BD* stars given here, together with a similar catalogue for the central zone already published, furnish complete spectral data of *BD* M5 and later stars in the galactic zones surveyed. It should be recalled in this connection that many of the late M-type stars are variable with variable spectra; hence it is not possible to claim completeness.

DATA

To cover the additional area of the sky, two sets of overlapping plates were taken. The plates of zone *a* were centered at $b = +4°$, and those of zone *b* at galactic latitude of $-4°$. Each of these zones is approximately 4° wide. The distance between centers of plates for each zone was 3°.5, and, since their diameter is 5°.2, a complete coverage with generous overlaps was obtained for the two zones.

As in the previous survey, the 2° objective prism was used. All exposures, with the exception of regions of declination of $-10°$ or less, were of 5 minutes' duration. The estimated limiting infrared magnitude of the survey is about 10.2. The complete 12°-wide zone was also covered by plates taken with the 4° objective prism and with a basic exposure of 10 minutes. On each of these plates two additional short exposures were taken to permit the classification of the brighter stars. As a rule, these plates reach M stars somewhat fainter than 10.2 infrared mag.

THE DISTRIBUTION OF THE LATE M STARS

All stars of spectral classes M5–M10 were marked on the 2° objective-prism plates. The total numbers for the two zones are given in Table 1. In deriving these figures the actual counts were adjusted for the effects of overlapping plates. Since the distribution in longitude for the two zones was found to be about the same, Figure 1 shows a combined distribution. A gradual diminution in the number of M stars as the anticenter of the Galaxy is approached is apparent. Discontinuities, however, exist which are usually associated with known obscurations. Similar results were obtained for the M stars of the central zone as were pointed out in the previous paper. For the sake of completeness, the stars of the three zones are combined and their distribution shown in Figure 2. The number of late M stars in the central zone is given in Table 1.

The classification of M-type stars from infrared objective-prism spectra is based on Mount Wilson Standards (Adams, Joy, and Humason 1926) and has proved satisfactory for classes M0 through M6 (Nassau and van Albada 1949). The progressive strengthening of the titanium oxide bands provides the criteria. However, the classification of very late M stars, M7 and later, has been found unsatisfactory for several reasons. A system of classification for these late-type stars has been proposed by Cameron and Nassau

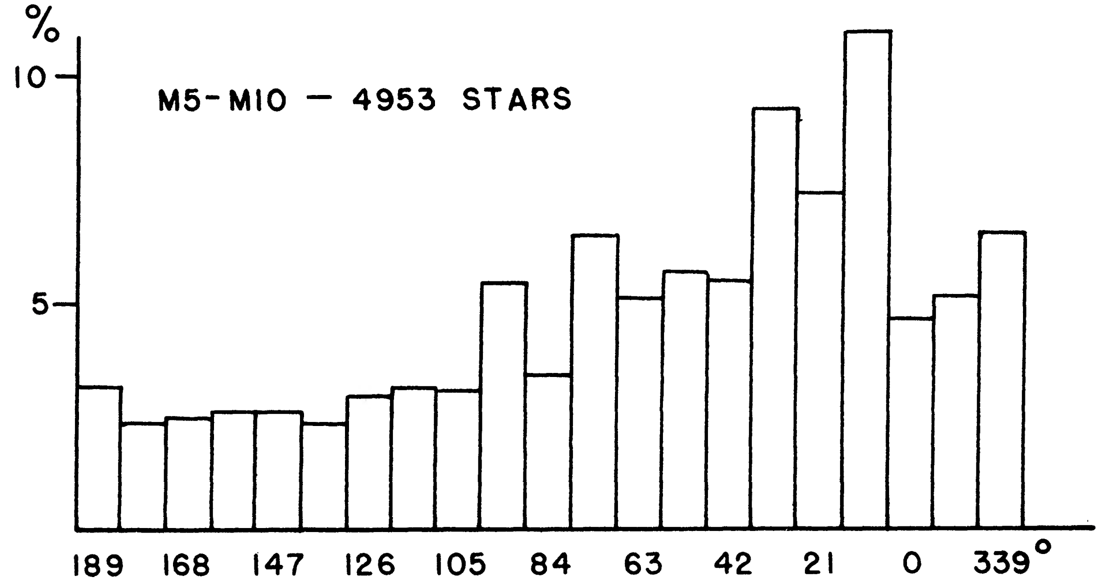

FIG. 1.—The distribution of M5–M10 stars for zones *a* and *b* combined Each interval includes 10°5 in longitude.

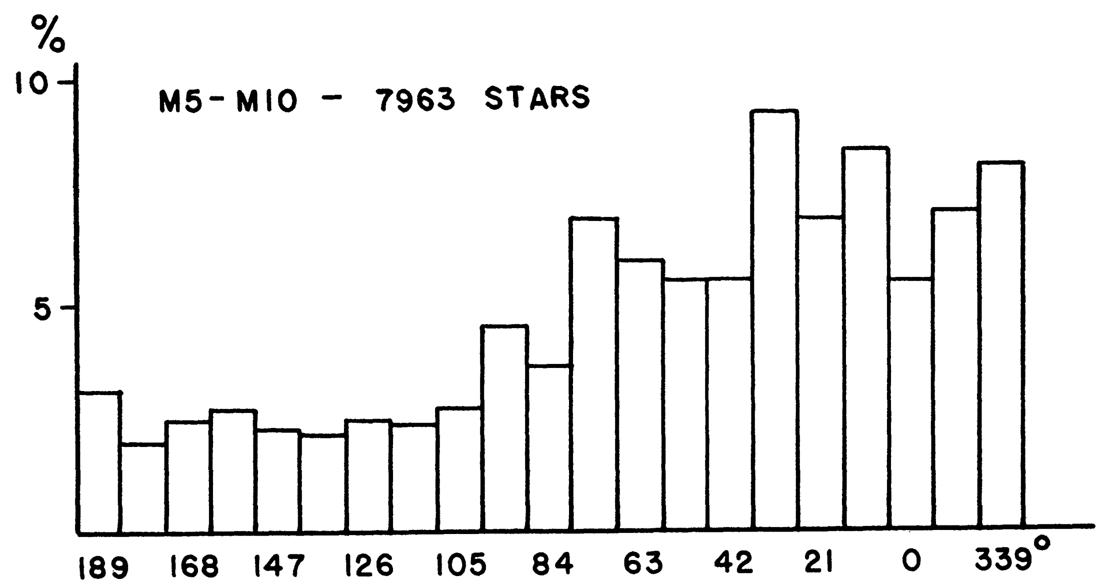

FIG. 2.—The distribution of M5–M10 stars for the galactic belt of 12° width Each interval includes 10°5 in longitude

(1955) which is based primarily on the progressive strengthening of the vanadium oxide bands. The stars of class M7 begin to show these bands, and they increase in strength with later classes. These very late M stars have been given a distinct marking, as they were detected in zones *a* and *b*. Table 1 gives the number of such stars contained in each of the two zones. The published data (Nassau and Blanco 1954*b*) for the central zone (the M7–M10 stars are called "M's with VO" in the Nassau and Blanco paper) cannot be compared with the numbers of the outer zones, as the classification of the very late M stars did not follow the same system. For this reason the distribution in longitude

TABLE 1

NUMBER OF STARS IN THE ZONES

	Zone *a*	Zone *b*	Central Zone		Zone *a*	Zone *b*	Central Zone
M5–M10	2319	2634	3010	M7–M10	446	495	

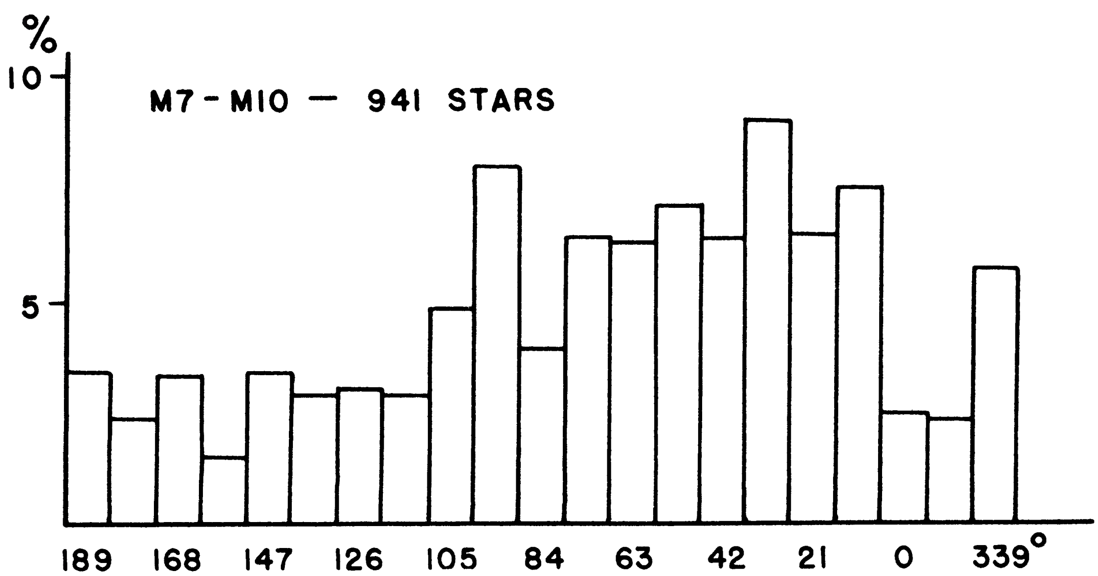

FIG. 3.—The distribution of M7–M10 stars for zones *a* and *b* combined. Each interval includes 10°.5 in longitude.

given in Figure 3 includes only the stars of zones *a* and *b*. No marked difference from that of all the M5–M10 stars is apparent. That is, the gradual decrease in number of stars as the direction of the anticenter is approached is shown. It is interesting to compare the numbers of M stars found near the galactic plane with those observed in the direction of the galactic poles. An unpublished study by W. Wehlau of a region covering 300 square degrees in the vicinity of the north galactic pole shows a total of eleven stars of type M5 or later brighter than the limiting magnitude of the Milky Way plates. Long-exposure plates taken within this region indicate that this number does not increase with distance. Seven of these stars are *BD* objects and are within a limiting distance of 1 kpc from the galactic plane. These figures strengthen the hypothesis that the giant M stars have a disklike distribution in the Galaxy. The average number of late M stars per square degree in the zone 12° wide is 2.9. In the direction of the anticenter the corresponding number is 1.5.

TABLE 2

LATE M-TYPE BD STARS - ZONE a

No.	B.D.		1900				m	Sp	l	b	Remarks
1	+65°	179	1h	27.8m	+65°	17′	8.8	M6	95°	+4°	
2	+64	208	1	32.0	+65	01	8.9	M6	95	4	
3	+63	312	2	10.6	+63	25	9.5	M6	100	3	
4	+65	267	2	24.1	+66	03	9.4	M5	100	6	
5	+62	461	2	38.8	+62	35	9.4	M7	103	4	CQ Cas, I
6	+57	756	3	47.9	+57	23	9.1	M6	113	4	
7	+48	1136	4	36.8	+48	34	9.5	M6	125	3	431
8	+51	980	4	43.1	+52	04	8.6	M5:	123	6	
9	+45	1002	4	48.4	+45	57	9.5	M6	128	3	
10	+42	1180	5	01.8	+42	27	8.8	M6	132	3	
11	+39	1225	5	08.3	+40	01	8.8	M5	135	2	UZ Aur, M4, I
12	+42	1239	5	11.1	+42	41	6.0	M5:	133	4	524
13	+40	1250	5	12.9	+40	53	8.8	M5	135	3	
14	+44	1187	5	15.3	+44	34	9.5	M6	133	6	
15	+38	1168	5	22.1	+38	58	9.5	M6.5	137	4	AD Aur, M6, I
16	+32	1050	5	30.8	+32	15	9.2	M5	144	1	
17	+37	1300	5	37.3	+37	57	9.5	M5	140	6	
18	+27	933	5	52.5	+27	50	9.5	M5:	150	3	
19	+29	1068	5	53.8	+29	14	9.5	M5	149	4	BO Aur, SR
20	+25	1097	5	57.7	+25	05	9.0	M5	153	3	
21	+25	1112	5	59.5	+25	53	9.3	M5	153	4	
22	+26	1101	6	03.1	+26	33	9.5	M6.5	152	5	
23	+22	1199	6	03.9	+22	59	9.5	M5	156	3	
24	+26	1131	6	06.1	+26	22	9.5	M5.5	153	5	
25	+17	1187	6	09.7	+17	47	9.0	M5	161	2	
26	+21	1185	6	12.2	+21	08	9.5	M5.5	158	4	
27	+17	1236	6	19.4	+17	04	9.5	M7	163	4	GN Ori, M
28	+15	1236	6	27.4	+15	54	9.0	M6.5	164	5	
29	+14	1350	6	30.2	+14	16	9.4	M5	166	5	DY Gem, M, SR
30	+13	1349	6	33.6	+13	29	9.5	M6	167	5	
31	+ 6	1377	6	40.5	+06	32	9.3	M5	174	3	
32	+12	1305	6	43.6	+12	18	9.1	M6.5	170	7	FK Gem, M7, I
33	+ 4	1476	6	46.7	+ 4	53	7.9	M6.5	176	4	SX Mon, M6, SR?
34	+ 0	1689	6	49.0	+ 0	55	9.4	M6.5	180	2	898, L
35	+ 3	1452	6	49.1	+ 3	01	9.2	M6	178	3	
36	- 1	1503	6	56.2	- 2	01	9.5	M5	184	3	
37	+ 0	1814	7	03.2	+ 0	13	9.4	M5.5	183	5	
38	- 3	1772	7	05.3	- 3	38	9.9	M5:	186	4	
39	- 6	1977	7	07.0	- 6	46	9.5	M5	189	3	
40	- 3	1800	7	08.8	- 3	47	9.0	M6.5	187	5	
41	-10	1983	7	14.6	-10	44	8.9	M6	194	2	
42	-12	1936	7	19.1	-12	57	9.4	M5	196	2	
43	- 7	1946	7	20.4	- 7	42	9.8	M5.5	192	5	1042, M
44	- 8	1913	7	21.6	- 8	43	9.5	M6	193	5	1047, L?
45	- 9	2060	7	23.0	- 9	22	9.4	M5	193	5	
46	- 7	4569	18	04.9	- 7	23	9.5	M7	349	4	
47	- 2	4585	18	12.1	- 2	30	9.7	M6.5:	355	5	
48	+ 6	3849	18	30.1	+ 6	59	9.5	M6	5	5	V851 Oph, M4, SR
49	+ 8	3780	18	33.7	+ 8	44	8.6	M9	7	5	X Oph, M6e, M
50	+ 9	3809	18	35.3	+ 9	53	8.0	M6	8	+6	101752, M5e

TABLE 2

LATE M-TYPE BD STARS - ZONE a (Cont'd.)

No.	B.D.		1900				m	Sp	l	b	Remarks
51	+ 8°	3835	18^h	40.9^m	+ 8°	38′	9.0	M5	8°	+4°	T Aql, M5, I ?
52	15	3579	18	44.8	15	48	9.5	M5:	15	7	
53	11	3649	18	48.2	11	34	9.5	M5:	11	4	VW Aql, M5, I
54	16	3696	18	56.0	16	51	9.5	M5	17	4	
55	20	4027	18	58.6	20	34	9.5	M7	20	6	
56	22	3659	19	15.2	22	51	9.3	M6	24	3	
57	22	3660	19	15.3	22	23	7.7	M6:	24	3	
58	30	3564	19	22.8	30	35	9.1	M6	32	6	
59	33	3507	19	31.3	33	35	7.5	M6:	35	5	
60	33	3546	19	36.0	33	41	9.3	M5	36	5	
61	35	3810	19	44.3	35	10	9.4	M5p	38	4	
62	37	3622	19	45.5	37	07	9.4	M6.5	40	5	
63	36	3812	19	56.8	36	52	9.0	M5	41	3	
64	39	3997	19	57.2	39	54	9.3	M6.5	43	4	AH Cyg, M5, SR
65	40	4001	20	00.9	40	09	9.5	M7	44	4	GN Cyg, M5, SR
66	43	3490	20	03.7	43	24	9.4	M5	47	5	
67	40	4065	20	09.7	40	31	9.4	M5	45	3	
68	46	2892	20	12.8	46	36	9.5	M5	51	6	
69	47	3096	20	21.0	47	24	9.3	M5	52	5	
70	46	2998	20	35.7	46	28	9.5	M5	53	3	
71	50	3186	20	41.9	50	35	9.5	M6	57	4	
72	50	3217	20	48.9	50	55	9.4	M6	58	4	
73	54	2511	21	15.2	54	51	9.5	M6.5	63	4	
74	54	2517	21	16.7	55	02	7.2	M6:	64	4	
75	64	1710	22	42.1	65	13	9.5	M6	78	6	
76	+63	1954	23	10.6	+63	40	9.5	M6.5	80	+3	

TABLE 2a

BD STARS WITH A LATE M COMPANION - ZONE a

No.	B.D.		1900				m	Sp	l	b
1	+20°	1365	6^h	12.9^m	+20°	06′	9.5	M7	159	+3
2	-17	4970	17	51.9	-17	07	9.2	M6	21	2
3	+11	3631	18	45.8	+11	16	9.5	M6	10	4
4	+ 9	3922	18	50.0	+ 9	46	9.5	M5	10	2
5	+38	3762	19	44.6	+38	35	9.5	M8	41	+6

Notes: 20° 1365 - M star 15" east of blue star; -17° 4970 - M star about 20" of arc south of blue star; 11° 3631 - M star 10" west of blue star; 9° 3922 - M star 17" north-west of blue star; 38° 3762 - M star 20" south-east of blue star.

TABLE 3

LATE M-TYPE BD STARS - ZONE b

No.	B.D.		1900				m	Sp	l	b	Remarks
1	+58°	127	0^h	$46^m.4$	+59°	11′	8.8	M6	91°	-3°	
2	+55	224	0	55.0	+56	05	9.1	M6	92	6	
3	+56	194	1	00.4	+57	02	9.5	M5	93	5	
4	+56	229	1	09.1	+56	50	9.5	M5	94	5	
5	+57	237	1	12.0	+57	16	7.0	M6:	94	5	
6	+51	629	2	40.9	+51	54	8.5	M6	108	6	
7	+53	580	2	45.2	+53	37	8.9	M5	108	4	
8	+54	622	2	49.6	+54	15	9.2	M6.5	108	3	ER Per, M8, SR
9	+48	928	3	22.1	+48	24	9.5	M6	116	5	
10	+48	986	3	37.9	+48	41	9.5	M5	118	4	
11	+44	806	3	45.6	+44	47	9.5	M8	121	6	
12	+42	898	4	01.4	+42	09	9.3	M6.5	125	6	
13	+41	824	4	04.0	+41	57	8.5	M5	126	6	SW Per, M5, SR
14	+42	935	4	11.1	+42	29	9.3	M5	126	4	
15	+40	933	4	13.2	+40	50	9.2	M6.5	127	5	
16	+41	871	4	20.1	+41	18	9.5	M5	128	4	
17	+39	1046	4	34.6	+40	00	9.5	M6	131	3	HO Per, M7, I
18	+40	1022	4	34.7	+40	18	9.5	M6	131	3	
19	+32	890	5	00.9	+32	47	9.1	M5	140	3	
20	+30	786	5	01.1	+30	39	9.0	M5	142	4	
21	+24	815	5	13.0	+24	40	9.5	M6.5	148	6	532
22	+21	912	5	32.1	+21	50	9.0	M5	153	4	
23	+18	915	5	36.1	+18	29	9.0	M5	156	5	DY Tau, M2, I
24	+21	940	5	36.5	+21	58	9.5	M6	153	3	
25	+18	984	5	44.6	+18	54	9.4	M5	157	3	BD star is double, M star has smaller R.A.
26	+10	979	5	56.1	+10	55	9.5	M7	165	4	DP Ori, M6, I?
27	+10	1005	6	00.9	+10	10	9.4	M6	166	4	
28	+11	1028	6	01.7	+11	49	9.1	M5	165	3	
29	+ 5	1113	6	04.0	+ 5	18	9.4	M6	171	5	
30	+ 2	1196	6	15.8	+ 2	37	7.8	M5:	175	4	
31	- 2	1581	6	17.8	- 2	09	var	M8	179	6	V Mon, M5e, M
32	- 2	1596	6	20.0	- 2	55	9.1	M5:	180	6	
33	- 5	1699	6	30.9	- 5	18	9.2	M6.5:	184	4	GL Mon, Mc, SR
34	-14	1681	6	56.0	-14	12	9.8	M6.5	194	3	RV CMa, M6, I
35	-16	1709	6	56.7	-16	59	9.7	M5:	196	4	
36	-20	4986	18	00.6	-20	23	9.0	M5	337	1	
37	-21	4940	18	12.3	-21	37	9.6	M6	338	4	
38	-12	5123	18	32.5	-12	27	9.9	M6.5	348	4	
39	- 5	4748	18	40.4	- 5	42	9.6	M5	355	3	4355
40	- 2	4786	18	50.9	- 2	45	9.8	M5	359	4	
41	+ 2	3825	19	08.9	+ 2	27	8.8	M6	6	5	V842, Aql, M7, I
42	+ 8	4051	19	15.6	+ 9	02	9.5	M6.5	12	4	
43	+ 9	4142	19	27.7	+ 9	48	9.1	M5	14	6	
44	+15	3891	19	34.3	+15	30	9.2	M5	20	4	
45	+15	3937	19	42.1	+15	47	9.5	M6	21	6	V830 Aql, M2, I
46	+21	3966	19	49.8	+21	22	9.2	M5	27	4	
47	+25	4035	19	53.1	+25	27	9.5	M6	31	3	
48	+32	3852	20	27.7	+32	12	9.0	M6:	41	5	AI Cyg, M5, I
49	+35	4211	20	37.0	+36	00	9.5	M5	45	4	
50	+36	4211	20	40.1	+36	31	9.0	M6:	46	-4	

TABLE 3

LATE M-TYPE BD STARS - ZONE b (Cont'd.)

No.	B.D.		1900				m	Sp	l	b	Remarks
51	$+36^{\circ}$	4272	20^{h}	$46^{m}.6$	$+36^{\circ}$	42′	8.6	M6:	47°	-5°	
52	37	4101	20	50.7	37	55	8.9	M5	48	5	
53	43	3790	20	58.6	44	01	9.5	M5	54	2	V354,Cyg, M6, SR
54	39	4457	21	05.6	39	57	9.1	M5:	52	6	
55	43	3827	21	07.2	43	46	9.5	M6	55	3	V579 Cyg, M5, I
56	45	3483	21	13.8	45	17	9.4	M6	56	3	V590 Cyg, M5, I
57	46	3338	21	25.9	46	31	9.4	M5	59	4	
58	45	3583	21	29.5	46	02	9.5	M6	59	4	
59	47	3563	21	45.2	47	29	9.5	M6	62	5	
60	45	3700	21	47.2	46	08	9.4	M6	61	6	
61	47	3658	21	57.3	48	04	9.4	M6.5	64	6	
62	48	3582	21	58.0	48	15	9.4	M7	64	6	GY Cyg, M3, I
63	50	3571	22	03.7	50	29	9.0	M6	66	4	
64	51	3283	22	08.2	51	44	8.8	M5:	67	4	
65	+55	3011	23	40.0	+55	55	8.6	M5	82	-5	

TABLE 3a

BD STARS WITH A LATE M COMPANION - ZONE b

No.	B.D,		1900				m	Sp	l	b
1	-8°	4755	18^{h}	$48^{m}.8$	-8°	15′	9.7	M6	6°	-6°
2	+ 8	4090	19	20.2	+ 8	49	9.4	M6:	13	5
3	+15	3890	19	34.3	+15	57	9.3	M7	20	4
4	+22	3840	19	48.2	+22	12	8.0	M6.5	27	4
5	+51	3348	22	17.5	+51	18	9.2	M6.5	68	5
6	+52	3237	22	28.4	+52	43	8.7	M6.5:	71	-4

Notes: -8° 4755 - Three stars within 20" of arc; 8° 4090 - M and A star are 10" apart, M star south of A star; 15° 3890 - M and A star are 15" apart; 22° 3840 - M star about 15" south of A star; 51° 3348 - M star is 8" west of blue star; 52° 3237 - M star is about 8" south-west of blue star.

Since a great percentage of stars of classes M7 and later are either long-period variables or Mira type (Cameron and Nassau 1956), their distribution in the Milky Way is of considerable interest. For this reason, particular attention was paid to the possible clusterings of these stars. In the 12°-wide galactic zone no apparent clusterings were in evidence. In addition, a region which extended to galactic latitude $\pm 18°$ was examined. It was in the form of a rectangle at longitude 6°.5 containing 385 square degrees (see Fig. 4, Nassau and Blanco 1954*b*). The uniform surface distribution of stars of class M5 and later did not differ from that of M7–M10 stars.

A list of bright late M stars in the central zone has been published by Nassau and Blanco (1954*a*). It included 121 *BD* stars and 263 non-*BD* stars. Tables 2 and 3 give a similar list for the *BD* stars in zones *a* and *b*, respectively. The spectral classes were secured from 4° spectral plates, and they were classified on the basis of the system proposed by Cameron and Nassau (1955). The description of the columns in these tables is as follows: Column 1, the Warner and Swasey Observatory number of the star; column 2, the *BD* number; columns 3 and 4, the co-ordinates for the epoch of 1900; column 5, the *BD* magnitudes; column 6, the spectral class secured from our plates; columns 7 and 8, the galactic co-ordinates; and column 9, under "Remarks" the known variables are indicated. The variable-star designation, spectral class, and type of variability are obtained from the *General Catalogue of Variable Stars* (Kukarkin and Parenago 1948) and its supplements. The notations used for type of variability are the same as given by Nassau and Blanco (1954*a*). When a number alone or a number followed by type of variability or spectral class is given, the number refers to the *Catalogue of Stars Suspected of Being Variable* (Kukarkin, Parenago, Efremov, and Kolorov 1951). Table 2*a* gives the *BD* stars in zone *a* which have late M companions. Similar data are given for zone *b* in Table 3*a*.

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