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M SUPERGIANTS IN THE PERSEUS ARM*

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ABSTRACT

Radial velocities measured from infrared spectra are given for the M supergiants in the Perseus arm. Thirteen M supergiants were confirmed from the MK classification of a number of suspected M supergiants. The space distribution and kinematics of these stars agree well with the other Population I objects in the Perseus arm. Seventy percent of the M supergiants are probable members of stellar associations and open clusters. The advantages of infrared spectra for the M supergiants make these stars useful for studies of spiral structure at great distances.

A study of the supergiants in Perseus OB1 gives an internal velocity dispersion of 7.2 km sec^{-1}. Evidence for structure in the association is also discussed.

I. INTRODUCTION

Bidelman's (1947) study of the M supergiants around h and χ Persei indicated that these stars were members of a surrounding association and were young Population I objects. Evidence that the M supergiants were tracers of spiral structure came from the infrared objective-prism survey at the Warner and Swasey Observatory (Nassau, Blanco, and Morgan 1954; Blanco and Nassau 1957). With infrared surveys the M supergiants can be detected at great distances. These stars show a high concentration to the galactic plane and a tendency to occur in groups. In a two-color photograph of M33 (Walker 1967) the blue and red supergiants can be clearly seen mapping out the spiral features.

In surveys at infrared wavelengths the M supergiants have considerable potential as tracers of spiral structure at large distances, but unfortunately little is known about these luminous red stars, particularly about their kinematics. This paper presents radial velocities measured from infrared spectra and additional new spectroscopic and photometric data for the M supergiants in the Perseus arm. The Perseus arm was chosen because of its abundance of M supergiants, and because the other Population I objects in that region have been well-studied. Section II of this paper describes the observations, § III discusses M supergiant membership in stellar groups, and § IV presents a discussion of the Perseus OB1 association.

II. THE OBSERVATIONAL DATA

New observational data on the M supergiants were acquired during two observing sessions at Kitt Peak National Observatory. These data consist of radial velocities measured from infrared spectra, spectral types of a number of suspected M supergiants, and *UBV* photometry of all the stars in the program.

The list of known M supergiants came mostly from published data, although a few unpublished spectral types were obtained from W. P. Bidelman. Additional suspected M supergiants were obtained from an unpublished list compiled by Bidelman.

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a) The Radial Velocities

The advantages of using infrared spectra are quite apparent, since the M supergiants radiate most of their energy in the red and near-infrared. Exposure times at the telescope were decreased by a factor of 3 or more over exposures with the same resolution in the photographic. It is also difficult to measure accurate radial velocities from blue spectra of these stars due to the large number of blended lines. Previous use of infrared spectra for radial velocities was made by Keenan and Aller (1951) in their study of μ Cep and R And.

The infrared spectra were taken on ammonia-sensitized I-N plates with the Cassegrain spectrograph of the 84-inch telescope at a dispersion of 78 Å mm^{-1}. A typical exposure time in the infrared was 10 minutes for an M supergiant of visual magnitude 8.0 with the spectra widened 0.3 mm. Most of the spectra were well exposed from the atmospheric A-band at about 7500 Å out to 8800 Å.

TABLE 1

LINES MEASURED IN THE INFRARED SPECTRA OF M SUPERGIANTS

Wavelength (Å)	Comment	Identification Multiplet	Laboratory Intensity
8364.24	...	Ti I (33)	2
8377.90	...	Ti I (33)	100
8382.67	Blend	Ti I (33)	100, 90
8387.781	...	Fe I (60)	1200
8396.93	...	Ti I (33)	90
8412.36	...	Ti I (33)	150
8426.50	...	Ti I (33)	200
8435.335	Blend	Ti I (33)	300, 300
8468.425	Blend	Fe I (60)	300
		Ti I (150)	100
8498.018	...	Ca II (2)	300
8542.082	...	Ca II (2)	1500
8662.140	...	Ca II (2)	1000
8675.200	...	Fe I (339)	60
8688.633	Blend	Ti I (68)	150
		Fe I (60)	1500

Radial velocities were obtained for forty-seven M supergiants, and three or four standard stars were observed each night to determine the instrumental correction to the velocities. The line identifications were taken from the work of Keenan and Aller (1951) on μ Cep, and laboratory wavelengths were used for the reductions. Table 1 gives the identifications and wavelengths of the lines measured in the stellar spectra, and Figure 1 (Plate 8) shows a few of the infrared spectra.

Generally about twelve lines were measured in each spectrogram, and the internal probable errors were typically 2–3 km sec^{-1}. Table 2*a* gives the results for the standard stars from which a correction of -1.7 km sec^{-1} was determined for all of the observations. Table 2*b* contains the individual plate results for the forty-seven M supergiants measured for radial velocities, and Table 2*c* compares the previously published radial velocities for nine of these stars with the new infrared velocities.

b) Spectral Classification

Spectra of twenty suspected M supergiants were obtained for MK classification at a dispersion of 128Å mm^{-1} with the 36-inch telescope. The new spectral types for these

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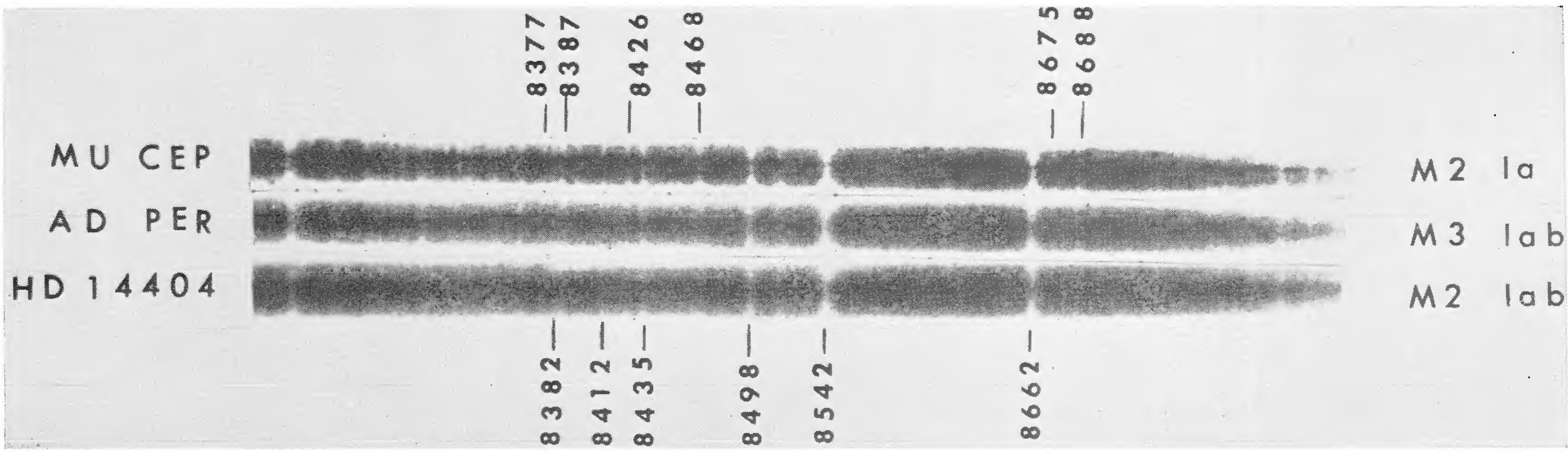

FIG. 1.—Examples of the infrared spectra of the M supergiants (78 Å mm^{-1}) showing the region of the spectrum measured for radial velocities (8300–8800 Å)

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TABLE 2a

RADIAL VELOCITIES OF STANDARD STARS

Star	Spectral Type	Published Velocity (km/sec)	Observed Velocity (km/sec) P.E.	No. of Spectra	Wt.	Correction
η Per	K3 Ib	- 1.0(a)	+ 0.1 ± 1.3	7	3	-1.1
HD 4817	K5 Ib	-21.2(b)	-20.0 ± 0.6	15	2	-1.2
HD 20797	M0 II	-21.0(b)	-18.0 ± 0.6	10	1	-3.0
χ Peg	M2 III	-45.8(b)	-42.3 ± 1.3	10	1	-3.5

TABLE 2b

RADIAL VELOCITIES OF M SUPERGIANTS

Star	ℓ^{II}	Plate	Velocity (km/sec) P.E.	No. of lines
μ Cep	100°6	C534	29.4 ± 1.6	14
		C539	19.4 ± 1.9	10
		C552	22.7 ± 1.1	10
		C558	23.2 ± 3.0	11
VV Cep	104.9	C534	-31.0 ± 3.8	7
		C539-1	-40.5 ± 1.9	13
		C539-2	-46.2 ± 2.5	12
		C545-1	-39.3 ± 2.8	8
		C545-2	-28.7 ± 3.2	10
		C552-1	-34.2 ± 2.3	10
		C552-2	-37.0 ± 1.9	10
		C558-1	-33.2 ± 2.9	12
		C558-2	-37.5 ± 3.1	10
		C558-3	-38.7 ± 2.9	10
W Cep	105.5	C546	-32.5 ± 4.5	9
U Lac	105.8	C540	-67.0 ± 2.4	13
		C546	-69.0 ± 2.7	5
Case 80	111.1	C555	-60.7 ± 3.0	12
Case 81	111.5	C561	-81.7 ± 1.6	10
+57° 2750	112.3	C555	-76.5 ± 2.8	13
HD 219978	112.6	C553-1	-23.7 ± 2.6	10
		C553-2	-30.8 ± 2.5	11
		C553-3	-30.3 ± 3.6	11
		C559-1	-37.3 ± 2.5	11
		C559-2	-29.4 ± 3.0	10
		C559-3	-31.6 ± 2.9	12
		C529-1	-24.0 ± 3.0	7 1/2 wt
		C529-2	-21.0 ± 3.0	7 1/2 wt
PZ Cas	115.2	C546-1	-58.1 ± 3.6	6
		C546-2	-56.5 ± 3.5	7
		C553-1	-60.7 ± 3.6	12
		C553-2	-62.3 ± 3.8	12
TZ Cas	115.9	C541	-50.9 ± 3.5	6
		C550	-53.4 ± 3.0	7
KN Cas	118.2	C555	-87.3 ± 2.5	7
MZ Cas	119.2	C550	-47.2 ± 2.0	11
HD 236697	126.6	C541	-31.1 ± 3.9	5
		C548	-35.4 ± 3.6	9
+59° 274	128.0	C548	-54.0 ± 3.3	11
HD 11092	128.3	C536	-28.6 ± 2.6	9
AZ Cas	128.9	C550	-39.5 ± 2.5	10
+60° 335	129.5	C555	-48.4 ± 2.0	11

TABLE 2b—Continued

Star	ℓ^{II}	Plate	Velocity P.E. (km/sec)	No. of lines
HD 236871	129.7	C548	-55.3 ± 3.1	7
+55° 388	130.1	C548	-45.4 ± 3.2	8
+59° 372	131.3	C562	-59.7 ± 2.5	10
HD 236915	131.4	C555	-39.7 ± 3.1	12
HD 236947	132.5	C556	-47.8 ± 2.5	12
XX Per	133.1	C556	-33.3 ± 1.8	13
		C531	-50.3 ± 3.8	11 1/2 wt
HD 13658	133.5	C548	-47.4 ± 3.0	9
KK Per	133.7	C557	-34.3 ± 2.6	13
		C531-1	-40.0 ± 3.5	10 1/2 wt
		C531-2	-45.9 ± 3.9	9 1/2 wt
		C531-3	-54.6 ± 5.2	6 1/2 wt
+57° 530a	133.9	C562	-61.4 ± 2.8	14
		C532	-62.7 ± 2.5	6 1/2 wt
T Per	134.1	C557	-44.8 ± 3.4	11
		C532	-48.1 ± 4.0	10 1/2 wt
HD 14242	134.2	C543	-34.2 ± 2.5	13
BU Per	134.5	C562	-42.4 ± 2.0	7
		C532	-52.9 ± 3.0	6 1/2 wt
S Per	134.6	C562	-38.1 ± 1.8	8
HD 14404	134.7	C536	-46.0 ± 2.3	12
AD Per	134.9	C536	-54.7 ± 2.5	12
		C549	-50.4 ± 2.0	9
FZ Per	134.9	C536	-53.0 ± 3.0	13
		C549	-53.0 ± 1.5	13
RS Per	135.1	C537	-43.6 ± 3.0	7
+56° 595	135.1	C537	-45.2 ± 3.2	12
		C549	-41.1 ± 2.9	12
HD 14580	135.2	C537	-46.4 ± 3.0	10
		C549	-52.1 ± 3.4	9
SU Per	135.2	C537	-35.7 ± 1.0	11
HD 14826	135.3	C537	-46.5 ± 2.4	10
GP Cas	136.2	C556	-51.3 ± 3.0	13
YZ Per	137.1	C543	-53.3 ± 2.0	13
HD 237006	138.0	C543	-43.2 ± 2.9	8
		C556	-42.3 ± 2.7	9
+57° 647	138.6	C563	-30.9 ± 3.0	8
W Per	138.7	C563	-50.2 ± 2.9	10
+59° 594	139.0	C543	-61.5 ± 2.1	12
HD 17306	139.9	C549	-40.9 ± 2.8	6
+54° 651	142.6	C550	-50.4 ± 3.6	11
Case 34	142.6	C563	-37.0 ± 2.7	12

TABLE 2c

M SUPERGIANTS WITH PREVIOUSLY PUBLISHED RADIAL VELOCITIES

Star	Published Velocities (km/sec)	Infrared Velocity (km/sec)	Average
AD Per	-34,-45,-51	-54.7,-50.4	-47.0 ± 2.4
FZ Per	-44 (3)	-53.0,-53.0	-47.6 ± 1.5
HD 14404	-38.5 (3)	-46.0	-40.4 ± 1.3
SU Per	-39,-39,-44,-36,-43,-34	-35.7	-38.7 ± 0.9
RS Per	-36,-39,-41	-43.6	-39.9 ± 1.1
+56° 595	-46.6 (2)	-43.2	-45.5 ± 0.8
HD 14826	-41.6 (3)	-46.5	-42.8 ± 0.8
also:			
μ Cep	+19.3 var.	+23.7 (September 5, 1968)	
VV Cep	-18.7 var.	-36.6 (September 5, 1968)	

stars are given in Table 3. Thirteen of the stars were found to be M supergiants. One star, HD 237006, has a composite spectrum of the VV Cephei type (Humphreys 1969).

The infrared spectra were also used to assign a luminosity class to the M supergiants. Previous infrared classification has been done by Keenan and Hynek (1945) at 48 Å mm^{-1} and by Sharpless (1956) at 200 Å mm^{-1}. The criteria adopted were mainly those used by Keenan and Hynek.

Most of the lines, especially those of Ti I and Fe I, show increasing strength with increasing luminosity. The Ca II triplet at λλ8498, 8542, and 8662 is also luminosity-sensitive. To distinguish the Ia, Iab, and Ib supergiants, the following line ratios were particularly useful:

λλ7665 and 7699 (K I) compared with λ7715;
λ8468 (blend, Fe I and Ti I) compared with λ8435 (Ti I);
λ8514 (blend) compared with λ8435 (Ti I);
λ8688 (Fe I) compared with λ8675 (Fe I).

TABLE 3

CLASSIFICATION OF SUSPECTED M SUPERGIANTS

Star	l^{II}	Spectral Type	Star	l^{II}	Spectral Type
PZ Cas..........	115.2	M3 Ia	+59°372.......	131.3	K5–M0 Ib
+64°1842........	115.9	M2 II	HD 236915.....	131.4	M2 Iab
+63°2073........	116.7	M0 Ib:	+59°420.......	133.3	K5 I:+A III:
Mz Cas..........	119.2	M2 Ia–Iab	HD 237025.....	137.8	K5–M0 II
HS Cas..........	124.8	M4 Ia	HD 237006.....	138.0	M1 Ib:+B:
+60°335.........	129.5	M3 Iab–Ib	+59°580.......	138.4	M1 Ib
HD 236871......	129.7	M3 Iab–Ib	Case 32........	138.8	M0 Ib
WX Cas.........	130.3	M2 Iab–Ib	+54°739.......	145.8	M0 III
+59°344.........	130.6	M4 III	HD 23082......	151.5	K5 II–III
+58°340.........	131.3	M3 II	+44°1005......	159.9	M0 III

The luminosity classes estimated from the infrared spectra have been used in the subsequent discussion and are given in Table 4 with previous classifications and their source. There were no systematic differences with the luminosities determined from the blue region.

III. M SUPERGIANTS IN STELLAR ASSOCIATIONS AND GALACTIC CLUSTERS

Distances, corrected for interstellar extinction for the individual stars, were determined from their spectroscopic absolute magnitudes by using Blaauw's (1963) luminosity calibration for the MK system, the observed $B - V$ color excesses from Johnson's (1966) intrinsic colors, and a value of $R = 3.0$ for the ratio of total to selective absorption.

Since the space distribution of the M supergiants shows considerable clumpiness, these stars were checked for possible membership in stellar groups. A star's position in galactic coordinates, its distance, and its radial velocity were used to determine its possible membership in a stellar group. Seventy percent of the M supergiants in the Perseus arm were found to be members of either stellar associations or open clusters. The radial velocities of the M supergiants from the infrared spectra also agree well with those for the other supergiants in the same group. The M supergiants, except for those in Perseus OB1 which are discussed in the next section, are given in Table 5 wtih their galactic coordinates, distance, velocity, and the stellar group to which each may belong.

Table 6 lists the stellar groups in the Perseus arm with supergiant members and the

TABLE 4

INFRARED LUMINOSITY CLASSIFICATION OF M SUPERGIANTS

Star	Plate	Infrared Type	Previous Type	Source
Case 80	C555	Iab	M2 Iab:	1
Case 81	C561	Iab	M2 Ib	2
+57°2750	C555	Ia-Iab	M3 Ia	2
HD 219978	C553	Iab-Ib	K5 Ib	3
	C559	Iab-Ib		
	C529	Ib		
PZ Cas	C546	Ia	M3 Ia	4
	C553	Ia-Iab		
TZ Cas	C550	Iab	M2 Iab	5
KN Cas	C555	Ib:	M1ep Ib + B:	6
MZ Cas	C550	Iab	M2 Ia-Iab	4
HD 236697	C548	Ib	M2 Ib	1
+59°274	C548	Iab-Ib	M0 Ib	1
HD 11092	C536	Iab-Ib	K5 Iab-Ib	3
AZ Cas	C550	Iab-Ib	M Ib + Be	1
+60°335	C555	Iab-Ib	M3 Iab-Ib	4
HD 236871·	C548	Iab	M3 Iab-Ib	4
+55°388	C548	Ib	M2 Ib:	2
HD 236915	C555	Iab-Ib	M2 Iab	4
HD 236947	C556	Iab-Ib	M Iab:	1
XX Per	C556	Ib	M4 Ib+	1
	C531	Ib		
HD 13658	C548	Iab	M Ib	1
KK Per	C557	Iab-Ib	M2 Ib	7
	C531	Iab		
+57°530a	C562	Iab-Ib	M Ib:	1
	C532	Iab-Ib		
T Per	C557	Iab	M2 Iab	7,8
	C532	Iab		
HD 14242	C543	Iab	M2 Iab	1
BU Per	C562	Ib	M4 Ib	7
	C532	Ib		
S Per	C562	Iab-Ib	M3e Ia(max.)	7
HD 14404	C536	Iab	M2 Ib	7
AD Per	C536	Iab	M3 Iab	7,8
	C549	Iab		
FZ Per	C536	Iab	M1 Iab	7,8
	C549	Iab		
RS Per	C537	Iab-Ib	M4 Iab	7,8
+56°595	C537	Iab	M0 Iab	7,8
	C549	Iab		
HD 14580	C537	Iab	M0 Iab	7,8
	C549	Iab		
SU Per	C537	Iab	M3 Iab	7,8
HD 14826	C537	Iab	M2 Iab	7,8
GP Cas	C556	Iab:	M2 Iab	1
			M2 Iab	2
YZ Per	C543	Iab	M2 Iab	7,8
HD 237006	C543	Iab-Ib	M1 Ib: + B:	9
	C556	Ib		
+57°647	C563	Iab:	M2 Ia	2
			M2 I:	1
W Per	C563	Iab:	M3 Ia	1
+59°594	C543	Iab	M1 Iab	2
HD 17306	C549	K3 Iab-Ib	K3 Iab + ?	10
+54°651	C550	Iab	M1 Ib:	1
			M1 Iab	2
Case 34	C563	Iab	M3 Ib:	1
			M1 Ib	2

1. Bidelman (1969)
2. Sharpless (1966)
3. Bidelman (1957b)
4. Humphreys, this paper
5. Keenan (1942)
6. Bidelman (1954)
7. Bidelman (1947)
8. Blanco (1955)
9. Humphreys (1969)
10. Bidelman (1957a)

TABLE 5

M SUPERGIANTS IN THE PERSEUS ARM

Star	Spectral Type	l^{II}	b^{II}	Distance (kpc)	Velocity (km sec^{-1})	Cluster or Association
RW Cep	M0: Ia0*	103°2	−1°1	...	−54.0	Cep OB1
W Cep	K0ep Ia+B:†	105.5	−0.7	...	−32.5:	Cep OB1
U Lac	M4 Iab+§‡	105.8	−3.4	...	−68.0	Cep OB1
Case 75	M1 Ia‖§	105.9	+0.6	4.07	...	Cep OB1
Case 78	M2 Ib‖§	107.0	0.0	2.61	...	Cep OB1
Case 80	M2 Iab	111.1	+0.7	3.08	−60.7	Cas OB2
Case 81	M2 Iab	111.5	−0.1	2.94	−81.7:	Cas OB2, NGC 7510
+57°2750	M3 Ia–Ib	112.3	−3.2	5.06	−76.5	...
PZ Cas	M3 Ia	115.2	−0.1	3.09	−59.4	Cas OB5
TZ Cas	M2 Iab	115.9	−1.1	2.78	−52.1	Cas OB5
+63°2073	M0 Ib:	116.7	+1.6	4.37	...	...
KN Cas	M1ep Ib+B:	118.2	+0.2	...	−87.3	Cas OB5:
MZ Cas	M2 Iab	119.2	−2.7	2.94	−47.2	Cas OB4
Case 23	M1 Iab‖§	122.8	+1.9	3.75	...	Cas OB7:
HS Cas	M4 Ia	124.8	+0.8	6.49	...	...
HD 236697	M2 Ib	126.6	−4.4	2.39	−33.3	NGC 457
+59°274	M0 Iab–Ib	128.0	−1.8	3.08	−54.0	Cas OB8, near NGC 581
AZ Cas	M Ib+Be	128.9	−0.9	...	−39.5	Cas OB8, near NGC 663
ES 1181	M Ib:‖	129.2	−0.6	4.21	...	Cas OB8, near NGC 654
+60°335	M3 Iab–Ib	129.5	−1.2	2.98	−48.4	Cas OB8, NGC 663
HD 236871	M3 Iab–Ib	129.8	−1.8	3.09	−55.3	Cas OB8, near NGC 663
+55°388	M2 Ib	130.1	−5.6	3.39	...	...
WX Cas	M2 Iab–Ib	130.4	−0.8	3.26	...	Cas OB8
+59°580	M1 Ib	138.4	+1.1	3.40	...	Cas OB6:
Case 32	M0 Ib	138.8	+1.1	4.41	...	Cas OB6:
+59°594	M1 Iab	139.0	+1.9	2.79	−61.5	...
Case 31	M1 Ib§	139.2	−1.3	1.91	...	Per OB1:
Case 33	M2 Iab§	141.2	−2.3	2.41	...	...
+54°651	M1 Iab	142.6	−2.4	3.03	−50.4	...
Case 34	M3 Iab	142.6	−2.4	2.17	−37.0	...
+55°780	K5 Ib‖	143.5	−1.0	4.17	...	...
Dearb. 27553	M3 I +?‖	147.7	−1.2	...	...	...

NOTE.—Those in Perseus OB1 have been excluded.
* Keenan (1942).
† Bidelman (1954).
‡ Bidelman and Böhm (1955).
§ Sharpless (1966).
‖ Bidelman (1969).

TABLE 6

ASSOCIATIONS AND CLUSTERS IN THE PERSEUS ARM WITH SUPERGIANT MEMBERS

Association or Cluster	O9–A5	F0–K5	K5–M	Blue/Red
Cep OB1	13	2	4	3.3
Cep OB5	1	1	0	...
Cas OB2	8	1	2	4
Cas OB5	13	0	3	4.3
Cas OB4	6	0	1	6
Cas OB7	8	1	1	8
Cas OB1	4	0	0	...
NGC 457	1	1	1	1
Cas OB8	7	2	6	1.2
Cas OB6	2	0	2:	1
Per OB1	34	1:	25	1.4
Cam OB3	6	0	0	...

number in various spectral ranges. The ratio of blue to red supergiants gives important information on the relative lifetimes of these massive stars in different stages of stellar evolution. Cep OB1 has many supergiant members including several of late spectral type. The very luminous star RW Cep (M0 Ia0) is a probable member, as well as the two VV Cephei–type stars W Cep and U Lac. Cas OB8 is a large, distant association and may contain six M supergiants. It appears to be centered on the cluster NGC 663. The new M supergiant BD+60°335 is a probable member of this cluster, and another star, HD 236871, is nearby. It is also worth noting that the VV Cephei–type star AZ Cas is a probable member of Cas OB8.

IV. THE PERSEUS OB1 ASSOCIATION

The Perseus OB1 association is particularly notable for the large number of supergiants in the same region. Table 7 summarizes the data available on the supergiants which are probable members of the association. The boundaries are essentially those given by Bidelman (1943). Thirteen of the M supergiants were initially included by Bidelman (1947), and seven more were added by Blanco (1955) and by Sharpless (1958). Of the remaining five, two are unpublished types by Bidelman and three were found in this study.

With the new infrared velocities, velocity data are now available for almost all the supergiants in this association. These data have been used to determine the velocity dispersion of the association. From fifty-six supergiants the mean velocity corrected for the standard solar motion (Delhaye 1965) is -39.9 km sec^{-1} with an internal velocity dispersion of 7.2 km/sec. For the early- and late-type supergiants the results are given in Table 8 for zones within 2° and 4° of the center of the association.

It is apparent that the new radial velocities for the M supergiants give results comparable with those for the early-type supergiants. If the 1965 Schmidt model is used, an object at the position and distance, 2.3 kpc, of the Double Cluster should have a velocity of -32.4 km sec^{-1}, but the observed mean velocity is -39.9 km sec^{-1}. This difference suggests that the association may have a peculiar velocity of -7.5 km sec^{-1}. Bidelman (1943) suggested many years ago that h and χ Persei may have a peculiar velocity of -9 km sec^{-1}.

Schild (1967) has presented evidence for structure in the region of the Double Cluster with an "inner group" centered on χ Per and an "outer group" associated with h Per. If one examines the surface distribution of the supergiants, it is apparent that an inner group of M supergiants is centered on χ Per. This concentration of the M supergiants was first pointed out by Bidelman (1947). The nine innermost M supergiants have a mean velocity of -41.5 km sec^{-1} with a dispersion of only 3.6 km sec^{-1}. However, some of the early-type supergiants included in Schild's "inner group" could be associated with h Per just as well as with χ Per. This possibility can also be seen from his H-R diagrams for the "inner" and "outer groups."

There is a concentration of supergiants within 2° of the center of the Double Cluster, and most of the remaining possible supergiant members lie 3°–4° from the center. This suggests two regions of supergiants in the association, but of course there is a projection effect in the inner region. There is also evidence from both the distances and the radial velocities of the individual supergiants, particularly in the outer regions, of a notable scatter about the mean position of the association. Figure 2 is a diagram of the suggested structure of the supergiants in Perseus OB1.

Schild also mentions five intermediate-type supergiants near Perseus OB1. These stars are listed in Table 9. HD 17306 has a radial velocity measured in the infrared which places it in the Perseus arm, and it is a possible member of the association. HD 14662 is probably a foreground star as indicated by both its velocity and its distance. For the other three supergiants the distances, which were estimated by using the total absorption for a nearby star in the Perseus arm, suggest that HD 11544 is probably in the Orion arm, but HD 17971 and HD 18391 are considerably more distant.

TABLE 7

PROBABLE SUPERGIANT MEMBERS OF PERSEUS OB1

Boundaries: 1^h50^m to 2^h50^m, +54° to +60° (1900)

Star	Spectral Type	ℓ^{II}	b^{II}	Distance (kpc)	Velocity (km/sec)
+59°372:*	K5-M0 Ib	131°3	-1°5	2.69	-59.7
HD 236915	M2 Iab	131.4	-2.5	2.78	-39.7
HD 236947	M2 Iab-Ib	132.5	-2.6	2.92	-47.8
HD 12953	A1 Ia	132.9	-2.9	1.75	-36.3
+59°540	K5 I:+AIII:	133.1	-1.1		
XX Per	M4 Ib+	133.1	-6.2	2.23	-38.9
HD 13402	B0.5 Ib	133.1	-1.7	1.83	-46.3
HD 13476	A3 Iab	133.5	-2.6	2.22	-40.5
HD 13658	M1 Iab	133.5	-2.9	3.15	-47.4
HD 13267	B5 Ia	133.5	-3.6	2.61	-33.8
KK Per	M2 Iab	133.7	-4.7	2.00	-41.8
HD 13744	A0 Iab	133.9	-2.8	2.52	-52.0
+57°530a	M Iab-Ib	133.9	-2.5	2.57	-61.8
T Per	M2 Iab	134.1	-2.0	2.87	-45.9
HD 14242	M2 Iab	134.2	-2.0	2.29	-34.2
HD 13659	B1 Ib	134.2	-4.1	2.63	
HD 13841	B2 Ib	134.4	-3.9	2.32	-39.0
HD 13854	B1.5 Ia	134.4	-3.9	2.22	-40.2
+60°478	M1 Ib	134.4	0.0	1.96	
HD 13866	B2 Ib	134.5	-4.2	2.61	-46.6
BU Per	M4 Ib	134.5	-3.5	1.87	-45.9
HD 14052	B1 Ib	134.5	-3.7	2.91	-41.0
S Per	M Iab-Ib	134.6	-2.2	2.19	-38.1
HD 14134†	B3 Ia	134.6	-3.7	2.00	-43.7
HD 14143†	B2 Ia	134.6	-3.7	1.91	-41.7
HD 14404	M2 Iab	134.7	-2.9	2.04	-40.4
AD Per	M3 Iab	134.9	-3.8	2.13	-47.0
FZ Per	M1 Iab	134.9	-3.6	2.22	-47.6
HD 14433§	A1 Ia	135.0	-3.5	2.64	-46.7
HD 14443§	B2 Ib	135.0	-3.6	2.74	-40.0
HD 14542	B8 Ia	135.1	-3.3	2.69	-47.4
RS Per§	M4 Iab	135.1	-3.6	2.98	-39.9
HD 14535	A2 Ia p	135.1	-3.5	3.93	-53.5
+56°595	M0 Iab	135.1	-3.5	2.50	-45.5
HD 14580	M0 Iab	135.2	-3.4	2.67	-49.3
SU Per	M3 Iab	135.2	-4.1	2.32	-38.7
HD 14322	B8 Ib	135.3	-4.8	1.83	-35.0
HD 15785	B1 Iab	135.3	+0.2	2.72	-37.0
HD 14826	M2 Iab	135.3	-3.1	2.29	-42.8
HD 14956	B2 Ia	135.4	-2.9	1.80	-24.0
HD 14489#	A2 Ia	135.5	-4.8	2.21	-15.2
HD 14899	B8 Ib	135.5	-3.3	2.07	-42.0
HD 14818	B2 Ia	135.6	-3.9	2.10	-46.0
HD 15316	A3 Iab	135.8	-2.6	2.49	-43.8
HD 15497	B6 Ia	136.0	-2.6	1.94	-39.0
HD 15620	B8 Iab	136.1	-2.3	2.04	
GP Cas	M2 Iab	136.2	-0.6	2.50	-51.3
HD 15690	B1.5 Ib	136.3	-2.7	1.68	-44.8
HD 16778	A2 Ia	136.6	-0.0	3.40	-36.0
YZ Per	M2 Iab	137.1	-2.8	2.31	-53.3
HD 16808	B0.5 Ib	137.3	-1.4	2.37	-37.4
HD 16779	B2 Ib	137.4	-1.8	2.28	-49.0
+57°626	B1 Ib	137.7	-1.9	4.06	-33.9
HD 17088	B9 Ia	137.9	-1.7	2.67	-38.7
HD 236995	A0 Ib	137.9	-0.3	2.90	-52.0
HD 17145	B8 Ia	138.0	-1.8	3.42	-43.0
HD 237006	M1 Ib:+ B:	138.0	-1.4		-42.8
HD 17378	A5 Ia	138.5	-2.2	2.11	-37.8
+57°647	M2 Iab	138.6	-1.4	2.31	-30.9
W Per	M3 Iab	138.7	-2.2	4.31	-50.2
HD 17306**	K3 Iab+	139.9	-4.7		-40.9

* possible member Cas OB8

† h Persei

§ χ Persei

questionable velocity

** possible member

V. SUMMARY

This study of the M supergiants has shown that accurate radial velocities can be obtained for these stars from infrared spectra. The advantages of infrared spectra for the M supergiants are important, since exposure times at the telescope are notably decreased. With the rapid decrease in interstellar absorption at longer wavelengths, the infrared velocities and spectral types combined with the high luminosities and low velocity dispersion of these stars make the M supergiants useful for studying the structure and kinematics of the Galaxy at large distances.

There is evidence for structure in the Perseus OB1 association, although the observational data are not sufficiently accurate to establish the true stellar distribution.

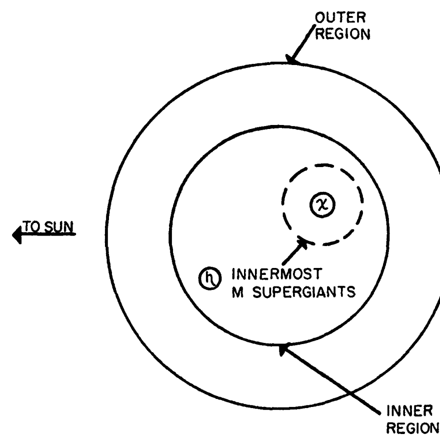

FIG. 2.—Suggested structure of the supergiants near Perseus OB1

TABLE 8

MEAN VELOCITIES AND VELOCITY DISPERSIONS FOR FOUR SUPERGIANTS

	Early-Type		Late-Type	
Variable	2° (No. 21)	4° (No. 32)	2° (No. 15)	4° (No. 24)
$\langle V \rangle$ (km sec^{-1})	−38.1	−38.1	−41.6	−42.3
σ (km sec^{-1})	8.2	7.6	5.9	6.7

TABLE 9

F–K SUPERGIANTS NEAR PERSEUS OB1

Star	l^{II}	b^{II}	Spectral Type	m_v(HD)	Velocity (km sec^{-1})	Distance (kpc)
HD 11544	131°6	−5°2	G2 Ib	7.0	...	(1.0)
HD 14662	135.9	−5.2	F7 Ib	6.5	−25.6	0.76
HD 17306	139.9	−4.7	K3 Iab+	7.8	−40.9	...
HD 17971	137.8	+1.1	F5 Ia	7.8	...	(3.7)
HD 18391	139.4	−1.0	G0 Ia	7.5	...	(3.3)

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