

M SUPERGIANTS IN THE LARGE MAGELLANIC CLOUD

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ABSTRACT

Eight red stars in the Large Magellanic Cloud have been classified as high-luminosity M supergiants. Their absolute visual magnitudes range from -7.7 to -6.6 mag. These are the first extragalactic M supergiants to be recognized by MK spectral classification.

Subject headings: late-type stars — Magellanic clouds

I. INTRODUCTION

High-luminosity supergiants in the Large Magellanic Cloud (LMC) have been identified and studied by Feast, Thackeray, and Wesselink (1960) and more recently by Ardeberg *et al.* (1972). The latest type or coolest stars in their studies are the G-type supergiants. In an objective-prism infrared survey of the LMC Westerlund (1960) recognized TiO bands (2200 \AA mm^{-1}) in a number of red stars, which were possible supergiants; however, Thackeray (1963) reported that spectra of some of Westerlund's brighter stars failed to reveal any supergiants. Thus no stars have been previously classified as M supergiants in the Large Cloud or in any extragalactic system.

Spectrograms were obtained of 17 red stars in the LMC, and eight of these stars have been classified on the MK system as high-luminosity M supergiants. As members of the Large Cloud they provide important information on the intrinsic luminosities and colors of M supergiants. Their presence in clusters and associations in the LMC is important for studies of the evolution of the most massive stars. Tammann and Sandage (1968) have suggested that the most luminous red stars may be useful as extragalactic distance indicators.

II. OBSERVATIONS

Thirty-four red stars with B magnitudes ≤ 15 mag were selected from Westerlund's (1961) study of Population I in the LMC. Spectrograms of 17 of these stars were obtained with the Cassegrain spectrograph and Carnegie image tube with an F/1.4 camera on the 60-inch (1.5 m) telescope at the Cerro Tololo Inter-American Observatory. Eight of these stars were classified as supergiants, three were peculiar with composite spectra, and six were less luminous cool stars which are probably not members of the LMC.

The spectrograms were obtained on nitrogen-baked IIaO plates at a dispersion of 90 \AA mm^{-1} and widened to 0.6 mm. Typical exposure times with these conditions were 20 to 25 minutes for $B = 13$ mag. A large number

of stars were chosen from Morgan and Keenan (1973) to be used as standards for the classification. There were no obvious differences between the supergiant standards and the M supergiants in the LMC.

III. DISCUSSION

The results of the spectral classification are in tables 1, 2, and 3. The visual magnitudes and $B - V$ colors are from Westerlund (1961). All of the M supergiants (table 1) are early M stars of high luminosity (class Ia). The three composite spectra are interesting. Although the hot continuum makes it difficult to refine the classification and particularly to assign a luminosity class, these stars are probably cloud members. They may be similar to the VV Cephei stars in the Galaxy.

Estimates of the visual absorptions and color excesses for the eight M supergiants were made from neighboring early-type supergiants close to the red stars and from membership in clusters and associations for which values of the absorption were known. When these two approaches did not yield a value for the extinction, A_v was assumed to be 0.5 mag (Bok and Bok 1962) since these red stars are in associations and stellar concentrations. A value of 3.0 for the ratio of total to selective extinction was then used to determine the color excess from the visual absorption. In this way the unreddened visual magnitudes and intrinsic colors in table 1 were derived. The absolute visual magnitudes were then determined using a distance modulus of 18.6 mag for the LMC (Hodge and Wright 1967).

The luminosities of these M supergiants range from -6.6 to -7.7 mag, in reasonable agreement with the absolute magnitudes -6.5 to -7.0 mag (Blaauw 1963; Stothers 1972) for class Ia M, supergiants in the Galaxy. Star #67 in region b¹ ($M_v = -7.7$ mag) is the only star significantly more luminous. For some of these stars the intrinsic $B - V$ color tends to be a bit redder than the colors given by Johnson (1966) and Lee (1970) for M supergiants. If the visual absorption has been underestimated, producing colors which are too red, then these M supergiants will be even more luminous.

¹ These are Westerlund's (1961) identification numbers.

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TABLE 1
M SUPERGIANTS

Star*	Spectral Type	V	$B-V$	$(B-V)_0$	V_0	M_v	M_{bol}
Region b, #67.....	M0 Ia	11.48	2.08	1.88	10.9	-7.7	-8.9
Region b, #64.....	M1 Ia-Iab	12.28	1.78	1.66	11.9	-6.7	-8.0
Region b, #73.....	M2 Ia	12.14	2.12	1.92	11.5	-7.1	-8.6
Region b, #38.....	M0 Ia-Iab	12.23	2.07	1.87	11.6	-7.0	-8.2
Region cI, #1.....	M0 Ia:	12.15	1.45	1.41	12.0	-6.6	-7.8
Region cI, #6.....	M0 I	11.69	1.91	1.77	11.3	-7.3	-8.5
NGC 1984, #16....	M0 I	12.20	1.91	1.71	11.8	-6.8	-8.0
NGC 2021, #22....	M1 Ia	12.18	1.97	1.80	11.7	-6.9	-8.2

NOTE.— V and $B-V$ from Westerlund 1961.

* These are Westerlund's 1961 identification numbers. He gives identification charts.

TABLE 2
COMPOSITE SPECTRA

Star	V	$B-V$	Remarks
NGC 1962-5-6-70, #29.	11.86	1.46	Early M+hotter star, $H\beta$ em
Region b, #70.....	11.28	1.01	Early M+B
Region b4, #80.....	12.77	2.30	Cool star+strong hydrogen

NOTE.— V and $B-V$ from Westerlund 1961.

In figure 1 the eight M supergiants are shown on an H-R diagram together with the four well-studied (Feast *et al.* 1960; Morgan and Keenan 1973) intermediate-type supergiants in the Large Cloud. When the appropriate bolometric corrections (Lee 1970) are applied there are three M supergiants, #67 in region b, #73 in region b, and #6 in region cI, which are comparable in total luminosity to the most luminous (Class 0) F and G supergiants ($M_{bol} \sim -9.0$ mag). In Humphreys (1970) two galactic M supergiants also have absolute bolometric magnitudes near -9.0 mag. There should be no problem distinguishing the M supergiants from the very luminous F and G supergiants in photographic surveys since their intrinsic colors ($B-V$) are redder by 0.5-1.0 mag.

Higher-luminosity M supergiants may exist in the LMC. The study by Westerlund from which these stars were selected covered not the entire Large Cloud but essentially only three regions. However, it is unlikely that there are more luminous M stars in his

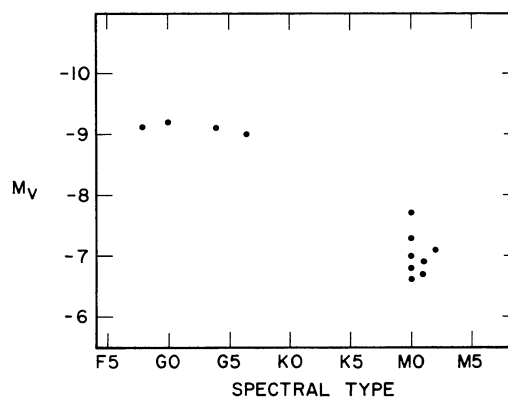


FIG. 1.—An H-R diagram, absolute visual magnitude versus spectral type, for eight M supergiants and four luminous G supergiants in the Large Magellanic Cloud.

paper since the brightest ones were selected for these observations.

Tammann and Sandage (1968) have suggested that the red super-supergiants in galaxies in the Local Group may have visual luminosities as high as -8.0 mag. Star #67 in region b with $M_v = -7.7$ mag may be an example of one of these red super-supergiants.

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TABLE 3
NON-MEMBERS

Star	Spectral Type	V	$B-V$	Remarks
Region cIII, #45.....	M0 III	10.35	1.57	HDE 269724
Region cIV, #78.....	K2-K5 III	10.28	1.32	
Region cIV, #86.....	K2 III	10.32	1.14	HDE 269871
Region b, #9.....	G0 V	10.39	0.73	
Region a, #36.....	G5 V	10.82	0.91	HDE 269979 (doubtful)
Region a, #90.....	K0 III	10.95	1.14	

NOTE.— V and $B-V$ from Westerlund 1961.

REFERENCES

- Ardeberg, A., Brunet, J. P., Maurice, E., and Prévot, L. 1972, *Astr. and Ap. Suppl.*, **6**, 249.
- Blaauw, A. 1963, in *Basic Astronomical Data*, ed. K. Aa. Strand (Chicago: University of Chicago Press), p. 383.
- Bok, B. J., and Bok, P. F. 1962, *M.N.R.A.S.*, **124**, 435.
- Feast, M. W., Thackeray, A. D., and Wesselink, A. J. 1960, *M.N.R.A.S.*, **121**, 337.
- Hodge, P. W., and Wright, F. W. 1967, *The Large Magellanic Cloud* (Washington: Smithsonian Press).
- Humphreys, R. M. 1970, *Ap. Letters*, **6**, 1.
- Johnson, H. L. 1966, *Ann. Rev. Astr. and Ap.*, **4**, 183.
- Lee, T. A. 1970, *Ap. J.*, **162**, 217.
- Morgan, W. W., and Keenan, P. C. 1973, *Ann. Rev. Astr. and Ap.*, **11**, 29.
- Stothers, R. 1972, *Pub. A.S.P.*, **84**, 373.
- Tammann, G. A., and Sandage, A. 1968, *Ap. J.*, **151**, 825.
- Thackeray, A. D. 1963, *Adv. Astr. and Ap.*, **2**, 263.
- Westerlund, B. 1960, *Uppsala Ann.*, Vol. **4**, No. 7.
- . 1961, *ibid.*, Vol. **5**, No. 1.