THE ASTROPHYSICAL JOURNAL, 275:84–91, 1983 December 1

AN INFRARED SEARCH FOR LUMINOUS STARS IN THE BAR WEST FIELD OF THE LARGE MAGELLANIC CLOUD

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Received 1983 February 28; accepted 1983 May 12

ABSTRACT

About half of the Bar West field in the Large Magellanic Cloud (LMC) was scanned at 2.2 μm (K) and 3.5 μm (L) in an attempt to find luminous asymptotic giant branch (AGB) stars with $M_{\rm bol}$'s brighter than -6.0 to -6.5. At L no sources were detected brighter than $L = 7.0$. The scans at K, which are complete for sources brighter than 11.0, revealed 85 sources of which 57 could be identified with previously known M and C stars, while four could be identified with early-type foreground or LMC stars. Of the 24 remaining objects, nine are similar in color and magnitude to a previously known sample of early M stars; three are among the reddest objects found to date in the LMC, but are not particularly luminous; the remaining 12 are blue—no later than early K—and could be foreground stars. Four of these relatively blue stars, though, would have $M_{\rm bol}$'s between -6.5 and -7.0 if members of the LMC.

We conclude that there are no objects in the area searched with $M_{\rm bol} < -6.4$ and $T_{\rm BB} > 700$ K. Any more luminous objects in the searched area would have to be cooler than 700 K. The recently launched *Infrared Astronomical Satellite* should, with a survey at 10 μm, be able to push the temperature limit down to 300 K for stars with $M_{\rm bol} \lesssim -6.5$. We suggest that the apparent scarceness of luminous AGB stars is due to high mass loss rates and hence short lifetimes.

Subject headings: galaxies: Magellanic Clouds — galaxies: stellar content — infrared: sources — stars: carbon — stars: late-type — stars: supergiants

I. INTRODUCTION

Infrared and optical observations have failed to reveal any significant population of luminous, i.e., $M_{\rm bol} \lesssim -6.0$, carbon stars in the Magellanic Clouds. Models, on the other hand, predict that 10%–20% of all asymptotic giant branch (AGB) C stars should have luminosities of $M_{\rm bol} \lesssim -6.0$. The reader is referred to papers by Frogel, Persson, and Cohen (1980), Cohen *et al.* (1981, hereafter CFPE), Richer (1981*a*, *b*), Blanco, McCarthy, and Blanco (1980, hereafter BMB), Iben (1981), Iben and Renzini (1983), and Renzini and Voli (1981) for a complete discussion of this problem. According to models of double shell burning AGB stars, all such objects with $M \gtrsim 1\ M_\odot$, and with a maximum mass of 8 $M_\odot$, should go through a carbon star phase. The apparent lack of C stars with $M_{\rm bol} \lesssim -6.0$, though, implies that no star more massive than 2 $M_\odot$ goes through a C star phase such as is predicted by theory. The importance of this disagreement cannot easily be overemphasized; it bears directly on how the interstellar medium is enriched with *s*-process elements and with carbon compounds (e.g., Iben and Truran 1978), and on a general understanding of how 1–8 $M_\odot$ stars evolve.

Iben (1981) and others have proposed a number of ways in which the *observations* could be incomplete and thus not be giving a true picture of the carbon star population of the Magellanic Clouds. These have included: luminous C stars are exceptionally red, perhaps due to circumstellar dust, and would not be detected in the spectroscopic surveys; luminous C stars are, for one reason or another, converted back into luminous M stars; the regions of the Magellanic Clouds surveyed by BMB are not representative in the sense that star formation in them ceased several times 10^9 yr ago and thus one would not expect to find luminous C stars with relatively massive progenitors in them. Becker's (1982) recent work has shown that the last explanation is largely specious since the MC regions surveyed contain significant populations of young, massive Cepheid variables. Also, integrated light observations of MC clusters of all ages (Persson *et al.* 1983), observations of individual stars in these clusters (e.g., Mould and Aaronson 1982; Frogel and Cohen 1982), and spectroscopic surveys followed by infrared photometry of "blue" globulars which contain Cepheids by Frogel and Blanco (1983*a*) such as NGC 1850, 1854, and 1856 have not given any hint of the

[1] Cerro Tololo Inter-American Observatory is supported by the National Science Foundation under contract AST 78-27879.
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presence of luminous C stars, either reddened or unreddened.

This paper discusses a survey of the Bar West field of the Large Magellanic Cloud (LMC-BW) at 2.2 μm and 3.5 μm. This field, one of the five surveyed by BMB, is becoming well studied (CFPE; Richer 1981*a*, *b*). The infrared survey was designed to address directly the first two ways out of the disagreement noted in the previous paragraph: are there any luminous AGB stars at all in the LMC-BW field, either C's or M's and, if not, what limits can be set on their temperatures and luminosities?

II. OBSERVATIONS—THE SCANS AT *L*

Seven nights in 1982 January were spent with the CTIO InSb system D3 on the 1.5 m telescope scanning the LMC-BW field at *K* (2.2 μm) and *L* (3.5 μm). The f/30 chopping secondary was oriented east-west, and scanning was accomplished by turning off the telescope drive and letting the sky drift by at sidereal rate. Thus, any source would first cause a negative deflection of the chart recorder pen and then a positive one. Although a digital record of the data was made, tests showed that for the magnitude limits adopted, no significant increase in detection efficiency (discussed below) would be obtained above that from visual inspection of the analog record. Scans were separated by half an aperture diameter so that most sources would appear twice. The length of each scan was about 24′, slightly greater than the diameter of the LMC-BW field surveyed by BMB. In declination the region scanned was centered approximately on the center of the LMC-BW field and extended just under 9′ north-south.

An aperture diameter of 13″.7 was used. Scans of stars at the same declination indicated that any source with an *L* magnitude brighter than 7.0–7.1 would have a peak-to-peak signal on the chart recorder such that it would easily be detected. In fact all candidates with peak to peak signals of about 30% less than this were selected from the scans for subsequent checking. There were 26 of them, and all were subsequently found to be spurious. Hence, we conclude that in the half of the LMC-BW field scanned there are no stars with *L* magnitudes brighter than 7.0.

III. THE 2.2 MICRON SURVEY

At *K* the region scanned extends 24′ east-west and just over 11′ north-south. A 27″ diameter aperture was used. Eighty-five potential sources were noted on the scans as having a peak to peak signal brighter than $K = 11.2$–11.3. These sources should include (except in cases of confusion) *all* objects with *K* magnitudes brighter than 11.0. We now discuss the identifications of these sources.

CFPE present IR photometry of 26 stars in the LMC-BW field. Blanco (reported in Frogel and Blanco 1983*b*, hereafter FB) reexamined the transmission grating prism plate used in the BMB survey and identified *all* early M stars which were not searched for by BMB. He found 101 stars of type M5 or earlier. Infrared photometry of an unbiased sample of two-thirds of these stars was obtained as well as IR photometry for all M stars in the original BMB sample not observed by CFPE (FB).

Thirty of the sources found in the course of our 2.2 μm survey are identified with M stars from the BMB survey or from Blanco's extended survey referred to above. All but five of these have IR photometry given in CFPE or FB. Photometry for these five stars is given in Table 1. We emphasize that with one possible exception (due to confusion), every previously known M star with *K* magnitude brighter than 11.0 in the survey area (including about 10 with $10.8 < K < 11.0$) as measured by CFPE or FB was found on our scans.

Eight C stars with IR photometry in CFPE were found in the course of scanning. These eight include all known C stars in the survey area with $K < 11.0$. In addition to these eight, Table 1 gives photometry for five other C stars identified with survey sources for which there is no preexisting photometry. Four of them are from the BMB survey, while the fifth is on the edge of the transmission grating prism field of the BMB survey and was missed by them, but was identified in the subsequent survey (FB). Fourteen more 2.2 μm sources were positively identified with other C stars from BMB but for which no IR photometry exists. However, their *I*, $R-I$ colors and magnitudes (BMB and Richer 1981*b*) and *K* magnitudes from the survey are typical of the C stars with infrared photometry (CFPE; FB; this paper, Table 1).

In summary, it appears that every C and M star identified on the basis of a transmission grating prism survey and subsequently found to be brighter than 11.0 at *K* was picked out as an IR source in the course of the 2.2 μm survey. This, then, is a good estimate of the infrared survey's completeness limit.

Twenty-eight of the 2.2 μm sources brighter than 11th at *K* could not be identified with any of the transmission grating prism C and M stars of BMB or FB. Infrared photometry was obtained for these stars on the 1.5 and 4 m telescopes, and the data are given in Table 2. A color-magnitude diagram of these sources is shown in Figure 1, while a color-color diagram is presented in Figure 2. For comparison purposes, a small selection of transmission grating prism survey M stars with IR photometry from CFPE or FB are also included in Figures 1 and 2. In all cases these stars were also picked up in the course of the 2.2 μm survey. Four of the 28 new sources (90-1, 119-1, 119-2, and 101-1) are judged to be K–M1 stars by their appearance on transmission grating prism plates. Since M2 is the earliest spectral type that can reliably and consistently be identified with the 2350 Å mm^{-1} dispersion achieved on the transmission grating prism plates (Blanco and Münch 1955; Blanco and McCarthy 1983), it is not surprising that these stars were not picked out in the extended transmission grating prism survey (FB). In any case, they are similar in color and magnitude to the M0's and M1's observed by FB and in Table 1 here (Figs. 1 and 2). They lie on the blue giant branch of the FB survey (see

TABLE 1

Photometry of Additional LMC "BW" (Bar West) Stars[a]

BW No.	Sp	Observed Values[b] K	$J-K$	$H-K$	$M_{\rm bol}$[c]	Notes[d]
47	C	10.23	1.50	0.52	−5.41	1
73	C	10.21	2.06(3)	0.84	−5.16	1, 2
99	C	10.15	1.93	0.70	−5.26	1
111	C	10.40	1.54	0.53	−5.22	1
115	M1	10.18	1.03	0.22	−5.73	3
134	M0	10.99(4)	0.91(4)	0.19(4)	−5.20	3
203	M0	10.36	0.92	0.18	−5.81	3
205	M1	10.41	1.03	0.24	−5.50	3
207	M1	10.86(3)	0.94(3)	0.17(3)	−5.23	3
213	C	10.30	1.51(3)	0.52	−5.33	4
Corrections	...	−0.05	−0.09	−0.04	...	5

[a] These are stars identified in the transmission grating prism surveys of the LMC-BW field of BMB and Frogel and Blanco 1983*b*, subsequently found in the course of the infrared scanning described in this paper, but for which no infrared photometry is given in either CFPE or Frogel and Blanco 1983*b*. The M stars in this table are *not* part of the unbiased sample of Frogel and Blanco 1983*b*.

[b] Photometric data were obtained on the 1.5 m telescope during 1982 January 14–20. Numbers in parentheses are combined photometric and statistical uncertainties in units of hundreths of a magnitude when greater than 2.

[c] Bolometric magnitudes are calculated as in Frogel, Persson, and Cohen 1980. A value of $(m-M)_0 = 18.6$ was used.

[d] Notes—(1) Identified in BMB. (2) $K-L = 0.84(25)$; $(K-L)_0 = 0.81$. (3) Early M stars in Bar West field identified in Frogel and Blanco 1983*a*. (4) Just outsdie of the transmission grating prism field used in BMB. Identified in Frogel and Blanco 1983*a*. (5) These are the reddening corrections to be applied to the observed values. Their derivation is discussed in CFPE.

Fig. 1). Four more of the 28 unidentified sources (106-2, 124-2, 102-1, and 127-4) are either out of the field of the original transmission grating prism plate or have images which are overlapped with other stars. Examination of other transmission grating prism plates (Blanco 1982) shows three of them to be of type M4 or earlier, while the fourth must be similar because of its IR colors and luminosity. A ninth source, 125-1, is probably a collection of faint red stars as no single, bright source could be found with a small aperture on the 4 m telescope. These nine sources, then, appear to be indistinguishable from the known population of C and M stars in the LMC-BW field. One of them has an $M_{\rm bol} \approx -6.4$. The others are fainter than -6.1.

Sixteen of the 28 unidentified sources have $J-K$ colors bluer than that of FB's blue giant branch

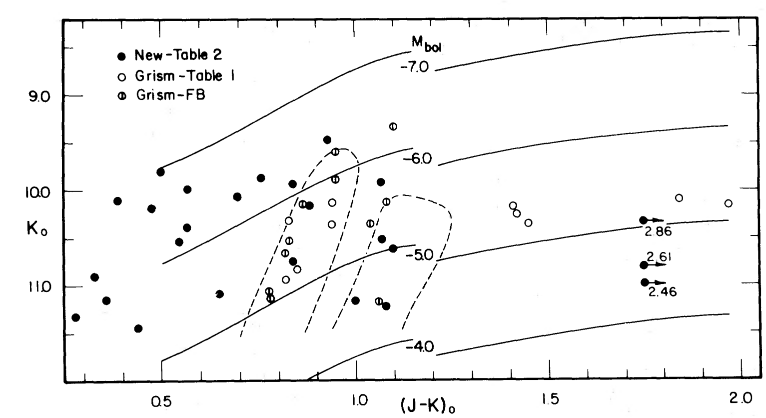

Fig. 1.—A reddening corrected color-magnitude diagram for LMC-BW sources found at 2.2 μm with photometry from Tables 1 and 2. Some additional early M stars from Frogel and Blanco (1983*b*) are also indicated. Neither the two blue galactic stars nor the B6I LMC star (Table 2) are plotted. The solid lines are lines of constant bolometric magnitude for oxygen rich stars on the left and carbon stars on the right. The two dashed area indicates the brighter parts of the two giant branches for M stars found by Frogel and Blanco (1983*c*).

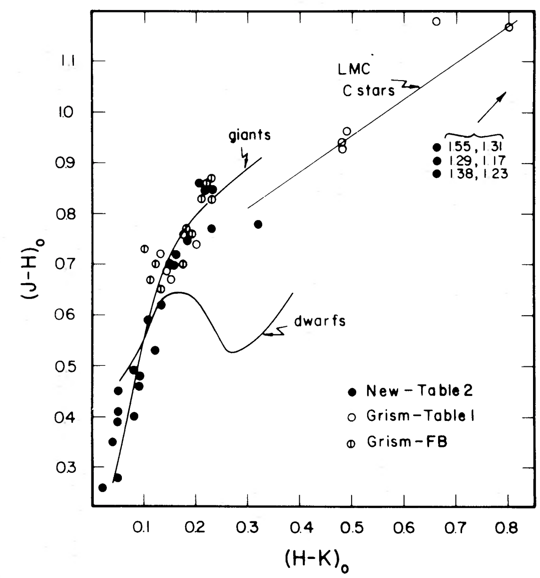

FIG. 2.—A reddening corrected color-color plot for the stars from Fig. 1. The mean relationships for local giants and dwarfs are indicated.

indicated in Figure 1. They are almost all quite bright visually and have overexposed or featureless spectra on transmission grating prism plates (Blanco 1982). The two brightest of these at K (80-1 and 121-1) are galactic foreground stars (Fehrenbach, Duflot, and Petit 1970). A third (119-8) is an LMC B supergiant (Fehrenbach, Duflot, and Petit 1970; Sanduleak 1970). A fourth, 93-1, is Harvard Variable 2326 and is one of the Cepheids in the LMC-BW field pointed out by Becker (1982). The nature of the remaining 12 blue sources is unknown. On the $(J-K)_0$, $(H-K)_0$ plot of Figure 2, they lie quite close to the mean line for field giants, although at these IR colors it would be difficult to distinguish dwarfs from giants. If they are foreground galactic giants, they would be at distances between 1.5 and 4 kpc from the Sun. They are most likely luminous F to early K stars in the LMC.[3] Four of the G type ones would have bolometric magnitudes between -6.5 and -7.0 if in the LMC. Velocity information for these stars would be useful. In any case, on the basis of current theory, luminous AGB stars should not have colors corresponding to spectral types F–G.

So we are left with the three unidentified sources 115-1, 89-1, and 144-2. They are interesting not because of their bolometric luminosities, which are actually rather faint,[4] but because they are the three reddest stars observed in the LMC-BW field. The two probable C stars lie at the red ends of the sequences in CFPE and are quite likely long-period variables. The red colors (their invisibility on the acquisition TV indicates a V magnitude fainter than 18th) probably arise from a combination of strong molecular blanketing and circumstellar emission. As argued in CFPE, an effective temperature should not be derived from these colors. Although 115-1 may be an M7 star (Blanco 1982), the strongly negative CO index is more characteristic of a C star similar to 114-2.

To summarize this section: two-thirds of the LMC-BW field was surveyed at 2.2 μm. The survey is complete to $K = 11.0$. A total of 85 sources were found, a few of which are somewhat fainter than the completeness limit. Fifty-seven of these sources could be identified with previously known C and M stars. Of the 28 remaining, all but three are blue. A few of these blue stars have bolometric magnitudes between -6.5 and -7.0. The three reddest stars could perhaps be called "dust enshrouded," but their bolometric luminosities are fainter than -5.5. Thus, *if there is any significant population of luminous (-6.5 to -7.0), red AGB stars, they must be so red as to be fainter than 11th magnitude at K*. The implications of this are discussed in the next section.

IV. DISCUSSION

The main result of our survey is that down to magnitude limits of 7.0 at L (3.5 μm) and 11.0 at K (2.2 μm) we have been unable to find any likely candidates for luminous AGB stars in the LMC-BW field. In this section we briefly examine the implications of these limits.

A second useful result is the almost complete overlap of red stars found at K and the brighter C and M giants identified from transmission grating prism surveys. This implies that with the exception of stars which might be missed by both survey techniques, they are both extremely successful in identifying cool, luminous carbon and oxygen-rich giants.

If the energy spectrum of a luminous AGB star is assumed to approximate that of a blackbody, then the observed upper limits to the flux at K and L set,

[3] Bahcall and Soneira's (1981) model of the stellar distribution in the galactic spheroid of the Milky Way can be used to estimate numbers of foreground stars, both giants and dwarfs. Their field 17 has galactic coordinates appropriate to those of the LMC. For the blue stars in Fig. 1, Johnson's (1966) tabulation of colors for giants and dwarfs is used to estimate that their I magnitudes will be brighter than 12. The K scans covered about two-thirds of the field examined by BMB, so that Table 3.3 of Bahcall and Soneira (1981) predicts that five galactic halo stars should have been found. As stated above, at least two such stars have been identified. Hence, the reason for this conclusion.

[4] Bolometric corrections for these stars were calculated by extending the BC_K vs. $(J-K)_0$ relation of Frogel, Persson, and Cohen (1980) with red C and M stars from Dyck, Lockwood, and Capps (1974). The $K-L$ colors of the LMC stars are, on the basis of the Dyck *et al.* data, consistent with their $J-K$ colors. Furthermore, if the energy distributions of very red stars are examined, e.g., OH/IR stars from Hyland *et al.* (1972) and Wilson *et al.* (1972) and IRC stars from Dyck *et al.* and Merrill and Stein (1976), one may ascertain that for a given $K-L$ color there is an upper limit to the $L-(10\ \mu\text{m})$ color. For stars with $K-L$ colors similar to the three red LMC stars, the flux at 10 μm does not contribute significantly to the total luminosity, *even for stars with the reddest $L-(10\ \mu m)$ colors*. This is obvious from Fig. 6 of Dyck *et al.* which shows that even for stars considerably redder than the LMC ones, the colors shortward of 3.5 μm are good predictors of total luminosity.

TABLE 2

LMC-Bar West Stars not in Transmission Grating Prism Surveys[a]

Source No.	Observed Values[b]							Appearance[d]		Location[e]			
	K	$J-K$	$H-K$	$K-L$	H_2O	CO	M_{bol}[c]	TV	Transmission Grating Prism	Near BW No.	mm (E-W)	mm (N-S)	Notes[f]
80-1	9.25	0.47	0.10	...	...	...	...	br.	early	104	17W	14N	1
103-2	10.03	0.66	0.13	...	...	...	−6.67	br.	early	99	17W	1S	
103-3	9.86	0.59	0.09	...	...	...	−6.99	br.	early	99	1E	2N	
78-1	10.58	0.64	0.13	...	...	...	−6.16	...	early	17	4W	4N	
87-1	10.43(3)	0.66(3)	0.12	...	...	...	−6.07	...	early	100	1SE	9S	
107-4	10.94(4)	0.42(4)	0.09(4)	...	...	...	...	...	early	72	6.5E	6N	
112-3	10.23	0.57	0.12	...	...	...	−6.65	br.	early	70	3W	8.5N	
121-1	8.81	0.15	0.04	...	...	...	...	v. br.	early	86	3W	12N	2
122-1	10.11	0.79	0.15	...	...	...	−6.31	br.	early	25	2W	2.5N	
124-4	9.92	0.85	0.17	...	...	...	−6.38	br.	early	107	24.5E	18.5S	
124-3	10.15	0.48	0.08	...	...	...	−6.87	v. br.	early	107	28E	15S	
92-3	11.19(3)	0.55(3)	0.09	...	...	...	−5.71	...	early	2	8E	5.5S	
93-1	11.12	0.74	0.16	...	...	...	−5.41	...	early	5	5.5W	9N	3
119-8	10.69	0.18	0.08	...	...	...	...	v. br.	early	107	7W	5.5S	4
122-3	11.48	0.53	0.09	...	...	...	−5.47	br.	early	25	10E	6N	
122-4	11.36	0.37	0.06	...	...	...	...	...	early	43	10W	5.5S	
101-1	9.52	1.02	0.22	...	0.05	0.25	−6.42	...	K–M0	89	0	5S	5
119-2	9.99	0.93	0.18	...	0.03	0.235	−6.12	br.	K–M0	3	13.5E	13S	5
119-1	10.20	0.97	0.20	...	0.04(3)	0.205	−5.84	...	K–M0	3	1E	13.5S	5
90-1	10.80	0.93	0.18	...	0.01(3)	0.165	−5.34	...	M0–M1	18	9E	2S	5
106-2	10.56	1.16	0.26	...	0.07(3)	0.205	−5.13	...	M4	27	17W	8S	5, 6
124-2	9.97	1.16	0.25	...	0.11(3)	0.21	−5.73	fnt.	out of field	107	26E	16S	5
125-1	10.66	1.19	0.36	...	...	...	−5.01	not vis.	nothing; crowding	74	9W?	2N?	7

TABLE 2

LMC-BAR WEST STARS NOT IN TRANSMISSION GRATING PRISM SURVEYS[a]

	Observed Values[b]							Appearance[d]		Location[e]			
Source No.	K	$J-K$	$H-K$	$K-L$	H_2O	CO	M_{bol}[c]	TV	Transmission Grating Prism	Near BW No.	mm (E-W)	mm (N-S)	Notes[f]
102-1	11.27	1.17	0.27	...	...	...	−4.41	v. fnt.	M3; overlapped	53	12E	4S	
127-4	11.21(3)	1.09	0.27(3)	...	...	...	−4.58	...	early M; overlapped	56	3E	5.5S	
115-1	10.29	2.93(3)	1.33	1.36(9)	...	...	−5.0	not vis.	v. fnt. and red; M7?	47	22W	3N	8
	10.39	2.95	1.35	1.45(4)	0.40(3)	−0.205	...	...	...	...	...	...	9
89-1	11.17	2.26(4)	1.18	...	...	...	−4.3	not vis.	v. fnt. C; overlapped	29	20.5E	0	
	11.05	2.55	1.21	1.06(6)	0.31(3)	−0.14	...	...	...	...	...	...	9
114-2	10.87	2.68	1.28	...	...	...	−4.5	not vis.	v. fnt. C	3	19.5E	3N	10
	10.86	2.70	1.27	1.35(5)	0.36(3)	−0.205	...	...	...	...	...	...	9
Corrections	−0.05	−0.09	−0.04	−0.03	−0.01	+0.005	...	...	...	...	...	...	11

[a] All stars found in the infrared survey of the Bar West Field with $K < 11.0$ and not identifiable with a star in the transmission grating prism surveys of BMB or Frogel and Blanco 1983*b* are listed in this table. Some of the sources turned out to have K magnitudes somewhat fainter than 11.0.

[b] Except when noted otherwise, photometric data were obtained with the CTIO 1.5 m telescope during 1982 January 14–20. Observations with the 4 m telescope were made during 1982 February 9–11. Numbers in parentheses are combined photometric and statical uncertainties in units of hundredths of a magnitude when greater than 3 for $K-L$ and 2 for the rest of the data. Reddening and extinction corrections (Cohen *et al.* 1981) are given on the last line of the table.

[c] Bolometric magnitudes are calculated as discussed in Frogel, Persson, and Cohen 1980 and CFPE except where noted. An $(m - M)_0 = 18.6$ was used.

[d] The column headed TV is simply a qualitative impression of a star's appearence on the Quantex TV system on the 1.5 m telescope. That headed transmission grating prism is based on reexamination of the transmission grating prism plates used in the surveys of the BW field. The designation "early" implies a blue, featureless spectrum which tended to be overexposed on most of the prism plates.

[e] To facilitate identification of the stars, their locations are given as offsets in millimeters from stars identified on the finding charts published by BMB. East-West and north-south refer to the horizontal and vertical axes, respectively, of the charts as published.

[f] NOTES.—(1) Foreground K star, HD 269133; P628 on list of Fehrenbach *et al.* (2) Foreground A star; HD 34144; P614 on list of Fehrenbach *et al.* (3) HV 2326. This is the only Harvard Variable identified on the Hodge and Wright Atlas in the BW field which was found in the infrared survey. (4) HD 269139; B6I (star 37-69 on list of Sanduleak 1970); radial velocity member of LMC (star G227 on list of Fehrenbach *et al.*). (5) *JHK* data is average of measurements on 1.5 and 4 m telescopes. The CO and H_2O values are from the 4 m telescope only. (6) This is the only star found in the course of the infrared scanning program which should have been readily identifiable in the original transmission grating prism survey of BMB. (7) This source, which could not be found on the 4 m survey, probably consists of a small grouping of faint, red stars. (8) We are not certain that the faint star at the indicated location on the BMB chart is 115-1. The slightly brighter star about 1 mm south is an M1 giant (FB). (9) These values are from measurements made on the 4 m telescope only. (10) Source 114-2 appears to be the fainter of the two stars at the indicated location on the BMB chart. (11) These are the reddening corrections to be applied to the observed values. Their derivation is discussed in CFPE.

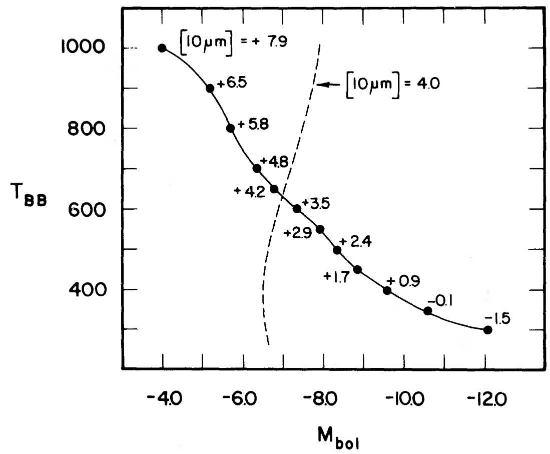

FIG. 3.—Sources with temperatures and bolometric magnitudes hotter and brighter, respectively, than the solid line should have been detected by the K and L surveys. Points along this line are labeled with their apparent 10 μm magnitudes if they radiate like blackbodies. The dashed line with constant 10 μm magnitude indicates the approximate limit of IRAS in its survey mode as described in the text.

respectively, lower and upper limits to its temperature as a function of luminosity.[5]

The combined magnitude limits are equivalent to $T_{\rm BB} = 570$ K and $M_{\rm bol} = -7.7$. For sources hotter than this, the upper limit to the flux at K is the determining factor, while the upper limit to the L flux is important for temperatures cooler than this. Figure 3 was constructed from these upper limits. Sources which lie in the region to the left of the curved solid line would not have been detected, while those which lie to the right of the line would have been detected by one or both of the surveys. This means, then, that any sources with $M_{\rm bol} < -6.4$ and $T_{\rm BB} > 700$ K would have been found. Cooler sources would have been found only insofar as they are brighter than $M_{\rm bol} \approx -6.4$.

Points along the solid line are labeled with the apparent 10 μm magnitude corresponding to the given $M_{\rm bol}$ and $T_{\rm BB}$. The *Infrared Astronomical Satellite* (IRAS) should have a 5 σ detection limit of 10 μm of $+4$ in its initial survey mode. It will be able to detect all sources to the right of the dashed line. In particular, this encompasses the critical region of $-6.5 > M_{\rm bol} > -8.0$ for $T_{\rm BB} < 500$ K. The IRAS then, can provide a more definitive answer to whether there are very heavily obscured, luminous AGB stars in the LMC-BW field. By contrast, a 10 μm survey with CTIO's 1.5 m telescope conducted in a manner similar to the shorter wavelength survey reported on here, would, with an 8″ diameter aperture, have a limiting 10 μm magnitude of only 2.5–3.0, depending on sky conditions. Such a survey would just miss the critical -6.5 to -8.0 region for sources cooler than 600 K.

For comparison purposes, IRC $+10216$, which is probably at a distance of 290 pc (Herbig and Zappala 1970), would have K, L, and 10 μm magnitudes of 11.23, 7.85, and 3.9, respectively, at the distance of the LMC (Becklin *et al.* 1969) and an $M_{\rm bol} \approx -7.0$ at mean light. Thus it would be just below our completeness limit. With the possible exception of VY CMa, all of the IR/OH sources discussed by Hyland *et al.* (1972) have $M_{\rm bol} > -6.0$ and hence are too faint to be considered candidates for the missing AGB stars. On the other hand, some of the much redder and hence cooler OH/IR stars, such as those discussed by Jones, Hyland, and Gatley (1983) may well have escaped detection in our present survey. These sources may also be of quite high luminosity. Becker (1982) has argued that because of the effects of envelope burning following dredge-up episodes while in the carbon star phase, "asymptotic giant branch stars having luminosities in the range $-6.5 > M_{\rm bol} > -7.3$ should be seen as red variables, bright early M giants, or possibly early supergiants." Wood, Bessel, and Fox (1983) have identified a number of long-period variables in the SMC and LMC with $M_{\rm bol} \approx -7.0$. Such stars, because of their IR colors, would have easily been detected in our 2.2 μm survey if present in the LMC-BW field. Their luminosities correspond to what would be expected for luminous AGB stars, but they do not appear to be particularly common throughout the LMC.

What happens to an AGB star once it gets more luminous than $M_{\rm bol} \approx -6.0$ to -6.5? If we believe the usual relationship between core mass and luminosity, where are AGB stars with $M \gtrsim 1.5$–$2\ M_\odot$? One suggestion is the following: the lifetime of a luminous AGB star is largely governed by mass loss rate. Nearly all extant models of AGB stars use a parameterized Reimers rate of one form or another. However, there is essentially no direct evidence for the applicability of such a mass-loss rate to cool, luminous, AGB stars. Recent radio observations of dust-embedded carbon stars (Knapp *et al.* 1982) indicate that these objects have mass loss rate one to two *orders of magnitudes* higher than that given by Reimer's law. To first order the lifetime of an AGB star will be reduced by the same factor as the mass loss rate is increased. What we suggest, then, is that, for one reason or another, dM/dt is large enough for cool AGB stars brighter than $M_{\rm bol} \sim -6.0$ to -6.5 to just evaporate.

We are grateful to Victor Blanco for his numerous contributions to the work reported on here. J. A. F. acknowledges useful conversations with Icko Iben, Jr., while a visitor at the University of Illinois under the aegis of Iben's NSF grant AST 78-20124. H. B. R.'s research was supported in part by grants from the Natural Science and Engineering Research Council of Canada.

[5] Examination of the data in Hyland *et al.* (1972), Dyck, Lockwood, and Capps (1974), and Merrill and Stein (1976) shows that a single blackbody fit is a simple, but reasonable, approximation to most of the infrared stars for which they present data. A somewhat more realistic assumption which has the emissivity proportional to λ^{-1} would result in even lower limits to the luminosity at a given temperature.

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