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AGB Stars in the Large Magellanic Cloud

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Abstract.
This paper reviews the luminosity distribution of AGB stars in the Large Magellanic Cloud. I briefly summarize the history and results of the previous surveys, and then present a first analysis of the DENIS survey in the IJK_S bands, and ISOCAM observations at 4.5 and 12 μm.

1. Brief History of Previous Surveys

Searches for AGB stars and red supergiants in the Large Magellanic Cloud started in the 1960's, and were based on optical/I-band photographic and objective prism surveys. One of the most important surveys was the deep survey by Blanco et al. (hereafter BMB) in 1980. Compared to the previous work which generally surveyed the whole LMC, they observed only 3 small regions in the LMC and 2 in the SMC, each of 23′ in diameter. However, the I limiting magnitude was much deeper at 17 compared to 14 in the early work. As a result, BMB found 50 times more AGB stars than previously known. Their survey was later extended to 52 regions in the LMC (Blanco & McCarthy 1990, hereafter BM). A key result was the derivation of the true luminosity function of LMC carbon stars (see e.g., Richer 1981, and Costa & Frogel 1996). This result was not consistent with the theory of the time which predicted a much higher luminosity for the onset of the formation of C stars. The theory has since been refined by taking into account physical phenomena such as high mass-loss rates and convective "overshooting" (see e.g., Bertelli et al. 1985).

These types of surveys, including those devoted to the search for Long-Period Variables (LPVs, see e.g., Hughes 1989), do not find AGB stars with high mass-loss rates which can be shrouded by dust in the optical. These surveys could only detect AGB stars with little or no mass-loss. An early explanation for the lack of high luminosity C stars as predicted by theories was that AGB stars all lose mass at a high rate when they evolve to high luminosity, and were just missed by BMB. The JHK survey of Frogel & Richer (1983), however, failed to find such very luminous and obscured sources. In 1986, IRAS was used to search for "dust obscured" AGB stars and red supergiants. To date, about 50 obscured AGB stars have been discovered with the IRAS satellite (see e.g., Reid et al. 1990; Wood et al. 1992; Zijlstra et al. 1996) and it is clear that some very luminous obscured AGB stars exist. Their numbers are small and do not substantially change the C-star luminosity function found by BMB.

Despite the impressive work performed by several groups between the 60's and the beginning of the 90's, our knowledge of the LMC AGB population is still very incomplete. Optical carbon stars and luminous (mainly luminosity type I and II) optically discovered M stars are well sampled over the LMC. But the bulk of M stars on the E-AGB and TP-AGB phases may not have been found, except in the BMB's Bar West field (Frogel & Blanco 1990). Searches for LPV's seem to be reasonably complete for optical Miras, but were not sensitive enough to extract semi-regular and irregular variables. For TP-AGB stars with high mass-loss rates, only the brightest and most luminous ones could have been detected by IRAS (Loup et al. 1997), missing obscured AGB stars with luminosities lower than about $10^4\,L_\odot$. Finally, AGB stars with intermediate mass-loss rates, well known and numerous in our Galaxy, would have been completely missed both by optical/I-band and IRAS searches.

2. First Results From the DENIS and ISO Surveys

New surveys are underway which address the deficiencies in the previous surveys. The EROS2 and MACHO experiments can detect almost every optical AGB variable in the LMC whatever the variability type due to very good time sampling and a reasonable spatial coverage of the data. In the near-infrared, the two sky surveys DENIS (the southern hemisphere survey in IJK_S) and 2MASS (the whole sky in JHK_S) have sufficiently faint detection limits to find the shrouded AGB stars in the LMC.

Two studies based on DENIS data have been performed, one in the BMB's Bar West and Optical Center fields (Loup 1998), and one in a 20 sq-deg field. These results were presented in these proceedings by Cioni et al. (1999) Here we summarize the main results. The DENIS data contain all but the most obscured TP-AGB stars (with $J-K_S > 4$) while the E-AGB and RGB stars are found to $M_{bol} \sim -2.7$. C- and M-type stars with low mass-loss rates follow two distinct sequences in the DENIS color-color diagram : (I–J) is a good indicator of the M subtype and varies from 0.9 to $\lesssim 4$ (influence of TiO and VO bands), whereas optical C stars are traced by $(J-K_S)$ from 0.8 to 2.2 (C_2, CN, and CO bands). The luminosity functions for these two samples contain 1200 and 10,000 AGB stars respetively. The RGB tip is located around $M_{bol} \simeq -3.45$. There is a clear bump in the luminosity distribution above the RGB-tip: this bump is formed by C stars and by the M stars with spectral types later than M5, i.e., by the TP-AGB stars. Statistically, we find that optical C stars, M5 to M10 stars, and AGB stars with intermediate and high mass-loss rates, have similar luminosity distributions.

The DENIS survey has been complemented by a mini-survey performed with the camera of the ISO satellite at 4.5 and 12 μm in 0.8 sq.degrees of the LMC bar region in order to detect sources with high mass-loss rates. To date 0.14 sq-deg have been fully analyzed. As expected, IRAS missed about 50% of the obscured AGB stars. The bolometric luminosities for these stars have been derived using both DENIS and ISO data. It confirms the previous result from DENIS data, i.e. that TP-AGB stars with high mass-loss rates are not significantly more luminous than optical C stars. This can be seen in Figure 1 where sources detected by ISO are drawn with squares, and sources only seen

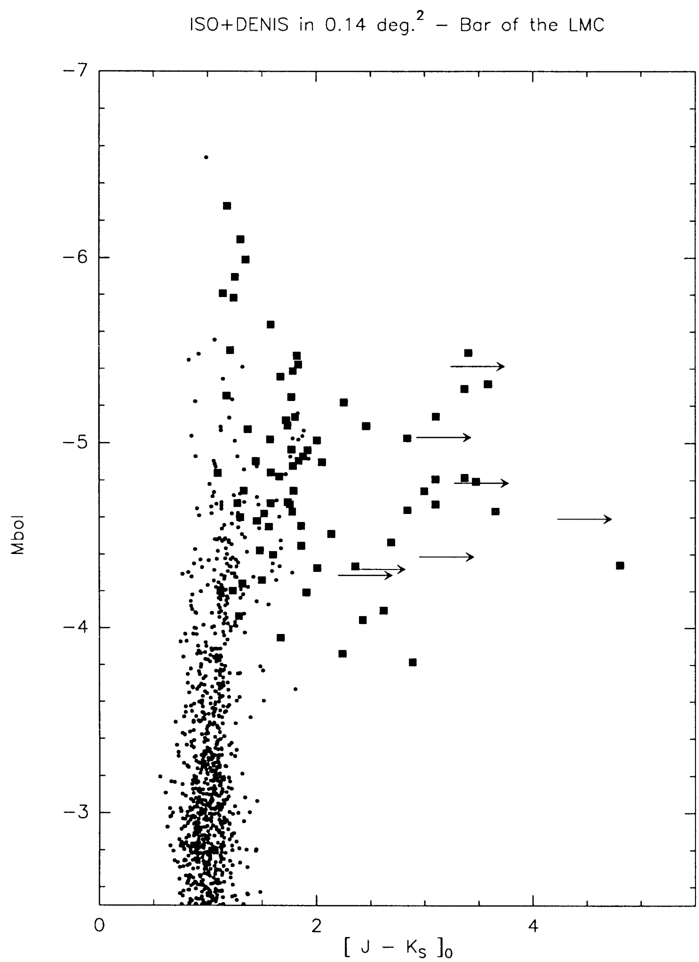

Figure 1. Luminosity distribution of AGB stars from ISO and DENIS data. See text at the end of section 2.

with DENIS by dots; the reddest sources (K_S–12 from 4 to 7.5) are not detected in J (arrows).

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Discussion

Michael Feast: Does the $I-J/J-K$ diagram distinguish between M giants and M-type Miras?

Loup: Very likely yes, because the $(I-J/J-K)$ diagram is a very good tracer of the M spectral index, and the Mira variables are in general of later spectral type than non-variable M giants. We did not check yet precisely, but this work will be done.

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