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Dust enshrouded AGB stars in the LMC

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Abstract. A near-infrared (J and K) survey of the LMC Bar West region was undertaken with CIRIM on the CTIO 1.5-m telescope to search for obscured carbon stars. A number of very red stars were detected, and from this list five highly reddened, 'obscured' stars were identified. Subsequent to our survey we identified these sources in the 2MASS survey data. Using our J, K photometry as well as J, H, K from 2MASS, 8.28 μm from the MSX satellite, and L photometry from Phoenix on Gemini, we have measured the color temperature and flux of the detected obscured stars. None of these objects is as cool as the bright galactic enshrouded carbon star CW Leo, although the MSX survey does appear to detect objects similar to CW Leo. Using the Phoenix high-resolution infrared spectrograph on Gemini we have observed the first overtone CO spectra of four of the LMC obscured stars. All the spectra are those expected for obscured carbon stars, but a surprising variety of line profiles was found.

1. Introduction

Stars with masses of less than $8\,M_\odot$ undergo extreme mass loss near the tip of the AGB allowing the mass of the stellar remnant to be less than Chandrasekhar limit of $\sim 1.4\,M_\odot$. Mass loss can be so severe that reddening by the star's circumstellar dust causes these stars to become enshrouded ("obscured" or "cocoon") stars. Heavily enshrouded AGB stars have the luminosity of an AGB star but the color of a circumstellar envelope. Bright examples in the solar neighborhood are the carbon-rich star CW Leo (IRC+10216) and the oxygen-rich star OH 26.5+0.6.

While examples of enshrouded stars are known within a few hundred parsecs of the sun, distances and luminosities are uncertain since these stars are faint in the optical. We became interested in searching for enshrouded stars in the LMC to calibrate the luminosity of enshrouded stars.

2. The Search

Our search for enshrouded stars in the LMC started in 1996 with J and K' CIRIM imaging of 14 fields, each 12.8 arcminutes square, in the Bar West region. The total coverage was 0.56 square degree. The J and K' images were blinked.

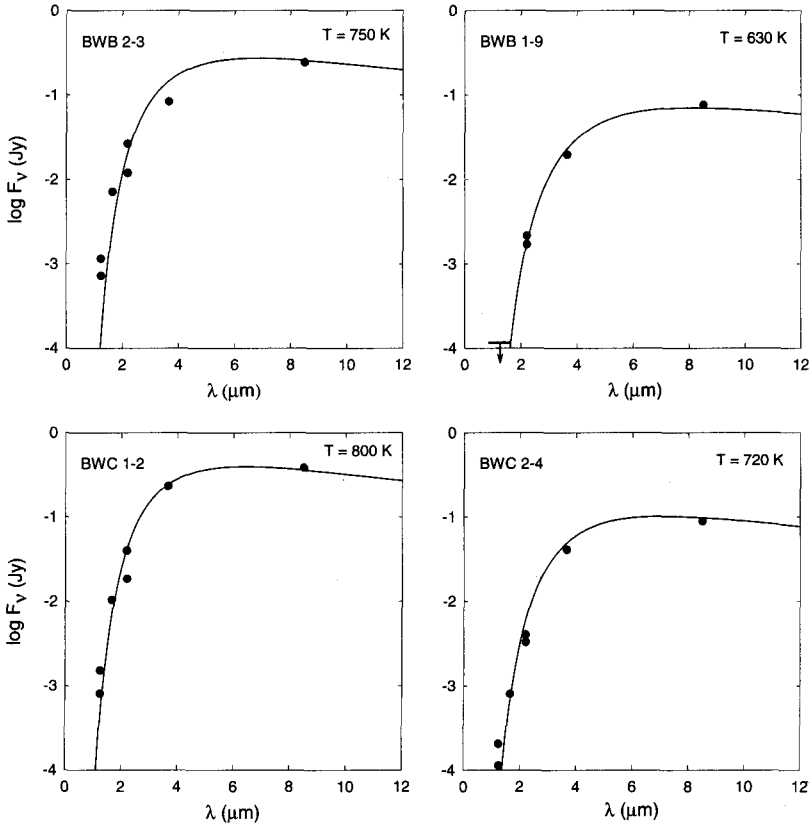

Figure 1. Spectral energy distributions for the four reddest sources with both 3.66 and 8.28 μm data, with a blackbody curve fit to the points. Differences between the CTIO and 2MASS measurements may represent intrinsic source variability.

This revealed a number of sources with $J - K' > 1.5$. Ninety-one sources were detected with 36 having $J - K' > 2$ and four having $J - K' > 4$. The five reddest objects found are listed in Table 1. By way of comparison, CW Leo has $J - K' \sim 6$.

Subsequent to our work the DENIS and 2MASS surveys have also covered the LMC. 2MASS had similar sensitivity to our survey. We have also imaged the reddest objects detected in our survey with a narrow band L filter [3.66] using Phoenix on Gemini South (Hinkle et al. 2003). Wood & Cohen (2001) searched for enshrouded stars in the LMC using the MSX survey, which detected our objects at 8.28 μm. Magnitudes from these various sources are also given in Table 1. The MSX designations for the sources in Table 1 are: BWB 1-9=MSX5C_G280.4962-34.1170, BWB 2-3=MSX5C_G280.5485-33.9951,

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Table 1. Photometry of LMC Enshrouded AGB Stars

Source	J_{CT}	J_{2M}	H_{2M}	K'_{CT}	K'_{2M}	[3.66]	[8.28]	T_{BB} (K)	M_{bol}
BWB 1-9	>17.8	...	...	13.95	13.69	10.35	7.17	630	−4.33
BWB 2-3	15.79	15.28	12.88	11.83	10.97	8.77	5.91	750	−5.32
BWC 1-2	15.68	14.98	12.48	11.36	10.52	7.67	5.43	800	−5.47
BWC 2-3	16.12	15.54	13.18	11.78	11.42	...	7.39	900	−4.55
BWC 2-4	17.16	17.8	15.26	13.01	13.23	9.54	7.01	720	−4.36

BWC 1-2=MSX5C_G279.9200-34.3081, BWC 2-3=MSX5C_G280.2304-34.2481, and BWC 2-4=MSX5C_G280.2635-34.3127.

The wavelength range observed spans the peak of the flux distribution and allows a blackbody fit to derive a color temperature and the bolometric magnitude. The fits to the four stars in Table 1 observed at 3.66 μm are shown in Fig. 1 and reported in Table 1. There is a surprising range in the bolometric magnitudes, from −4.33 to −5.47 as well as a range in color temperature from 630 to 900 K. None of the stars detected is as cool as CW Leo. There are MSX sources that are undetected in the near-infrared and could be as enshrouded as CW Leo. CW Leo has a $K-[8.3]$ color of 8.6 magnitudes. An LMC source with similar color and $m_{[8.28]} = 7.4$ would have $K' \sim +16$.

2.1. Spectroscopy

Phoenix on Gemini South has been used to observe the spectra of four of the enshrouded stars listed in Table 1. None of the spectra showed water lines as would be expected in oxygen rich stars, implying that these enshrouded stars are carbon rich.

The Phoenix resolution of R = 50 000 partly resolves the line profiles. The line profiles result from the staged acceleration of gas and dust away from the central star. Similar line profiles have been seen in CW Leo and reflect layered structure in the inner circumstellar shell which has periodic dust formation events (Winters et al. 2000). The line profiles have also been attributed to the freezing of circumstellar gases onto grains and the subsequent change of radiation pressure on the grains (Keady et al. 1988). Surprisingly for the LMC stars we find that there is no correlation between line profile and luminosity.

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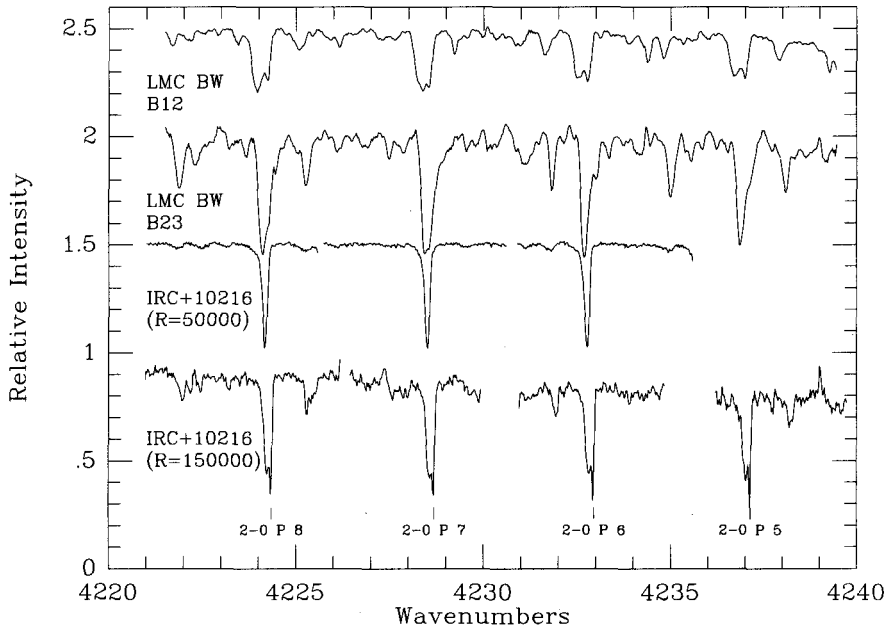

Figure 2. High-resolution (R = 50 000) spectra of three of the LMC sources and the bright galactic source IRC+10216, shifted to the CO rest frequencies. Note the line profiles of the low-excitation lines, which result from circumstellar density variations. Higher resolution observations, e.g. Winters et al. 2000, show similar structure in the CW Leo absorption lines.

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