Will the LSA detect continuum or line emission from AGB stars in the LMC ?

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Abstract. I predict the (sub-)mm continuum and line emission fluxes expected from the reddest and brightest AGB stars in the Large Magellanic Cloud.

Flux-densities at 1300 μm for AGB stars are expected to be less than 0.05 mJy in a $5''$ beam. This will make the detection of continuum emission in AGB stars virtually impossible. There are however a handful of red supergiants which are expected to be detectable.

Main-beam peak temperatures as high as 0.6 K are expected for the CO 2-1 transition of the reddest and most luminous AGB stars in the LMC. This implies that CO 2-1 could be detected in a few dozen AGB stars in a reasonable integration time.

1 Introduction

The LSA (Large Southern Array) will have unprecedented sensitivity and angular resolution. In the field of late-type (AGB) stars it will e.g. be possible to resolve the dust and molecular shell around nearby AGB stars and study the dust formation process and the acceleration of the dust and gas close to the central stars in detail. In the continuum it will be possible to map the dust shells out to large distances (with lower angular resolution) and address the question of mass loss rate variations with time.

The question I address here is whether AGB stars in the LMC can be detected in the continuum and/or in CO with the LSA. Continuum observations in the mm-range would give a handle on the dust opacity in that wavelength regime. Line emission data would allow first off all an estimate of the total mass loss rate. Since modeling of the spectral energy distribution (SED) gives the dust mass loss rate and the distance to the LMC is known this would allow a direct measurement of the dust-to-gas (DTG) ratio. It would therefore be possible to measure the DTG ratio as a function of position in the LMC. In addition, line emission data provides the expansion velocity of the envelope, a quantity which is thought to be lower than for Galactic AGB stars because of the lower metallicity.

2 CO line emission

To get an idea of the expected strength of the CO J = 1-0, 2-1 and 3-2 lines for AGB stars in the LMC I take the well known carbon Mira IRC +10 216 (= CW Leo = AFGL 1381) as an representative example.

Previously I have modeled the CO lines of this star (Groenewegen 1995). For an assumed luminosity of 15000 $L_\odot$ (based on a period-luminosity relation) the distance to CW Leo is 135 pc. For a mass loss rate of 2.2 10^{-5} $M_\odot$ yr^{-1} and an expansion velocity of 14.5 km s^{-1} the radius where the CO abundance has dropped to 1% of its value close to the star is $\sim$ 7.4 10^{17} cm (about twice the photodissociation radius). At a distance of 50 kpc this corresponds to 1.0″. This is very well matched to the spatial resolution of the LSA at 230 GHz using the smallest baseline. In Table 1 the expected main-beam peak temperatures and integrated line intensities are listed if CW Leo is placed at a distance of 50 kpc. The beam at all three wavelengths is assumed to be a Gaussian with a FWHM of 1″. The expected CO J = 2-1 line strength is 0.56 K. This calculation assumes a DTG ratio of 0.005. Table 1 also includes calculations with a DTG ratio of 0.0025 and FWHM beams of 2″. Both effects would decrease the expected flux.

Table 1. CO line emission: IRC +10 216 placed in the LMC

Transition	$T_{\rm peak}$ (K)	$\int T$ dv (K km s^{-1})	$T_{\rm peak}$ (K)	$\int T$ dv (K km s^{-1})	$T_{\rm peak}$ (K)	$\int T$ dv (K km s^{-1})
	FWHM = 1, Ψ = 0.005		FWHM = 1, Ψ = 0.0025		FWHM = 2, Ψ = 0.005	
1-0	1.03	23.3	0.47	10.4	0.33	7.3
2-1	0.56	11.9	0.16	3.4	0.13	2.6
3-2	0.25	5.2	0.068	1.1	0.096	0.79

3 Continuum emission

To estimate the continuum dust emission of AGB stars in the LMC I consider two approaches. First I will use IRC +10 216 as a template again and then I will extrapolate model fits to actual AGB stars in the LMC.

Regarding IRC +10 216, the size of the dust envelope, calculated as the radius where the dust temperature has dropped to 20 K, is 2.4 10^{18} cm which corresponds to 3.2″ at the distance of the LMC. Again, the synthesised beam size of the LSA at the smallest baseline is reasonably well matched to the expected physical size of circumstellar dust envelopes in the LMC. The calculations are summarized in Table 2. They are monochromatic flux densities in a Gaussian beam with a FWHM of 1″. The expected flux level at 1300 μm (230 GHz) is 0.018 mJy. The fluxes scale approximately linearly with the DTG ratio, for which a value of 0.005 is assumed. In a beam of 5″ FWHM the flux is about a factor of 2 higher (see Table 2).

Luminous and red AGB stars have been identified in the LMC, mainly using IRAS data (see e.g. Zijlstra et al. 1996, Wood et al. 1992 and references therein).

Groenewegen et al. (1995) obtained 8-13 μm spectra and identified the first silicate features in AGB stars outside our Galaxy. We also made model fits to the SEDs from 1.25 - 25 μm. We are now in the process of extending these calculations to a larger sample of stars (Groenewegen et al., in preparation). We obtain good quality fits and therefore it is reasonable to extrapolate these results to longer wavelengths. This basically assumes that the dust opacity which we know to work well for Galactic O-rich AGB stars also holds for AGB stars in the LMC. Based on the results so far I calculated the (sub-)mm fluxes for all stars in our sample. The one with the highest flux is LMC 1164 (Schwering & Israel 1989), which has an estimated luminosity of 46100 $L_\odot$ and a mass loss rate of 4.4 10^{-5} $M_\odot$ yr^{-1}. Its predicted (sub-)mm fluxes are listed in Table 2.

Table 2. Expected continuum emission

Wavelength	CW Leo scaled to LMC		LMC 1164		LMC 181
(μm)	FWHM = 1″	FWHM = 5″	FWHM = 1″	FWHM = 5″	FWHM = 1″
811	0.074 mJy	0.13	0.13	0.26	0.61
1300	0.018	0.034	0.023	0.048	0.12

4 Discussion

The continuum emission of AGB stars in the LMC at 1300 μm in a 5″ beam is expected to be less than 0.05 mJy. The quoted 1σ sensitivity for a 1 hour integration with the LSA is 0.02 mJy. This implies integration times of more than 16 hours to get a S/N of better than 10. This is prohibitively long.

Although the prospect to detect continuum emission of AGB stars in the LMC appears poor, the situation is better for red mass-losing supergiants. The most extreme case is LMC 181 (= IRAS 04553–6825; see Elias et al. 1986). I made a fit to its SED and 8-13 μm spectrum. It has a $M_{\rm bol}$ of -9.2 and mass loss rate of about 10^{-4} $M_\odot$ yr^{-1}. The predicted (sub-)mm fluxes are listed in Table 2. This object should be detectable with a S/N of 10 in 3 hours of integration.

The CO J = 2-1 main-beam peak temperature expected for IRC +10 216 if it were in the LMC is about 0.6 K. The 1σ sensitivity of the LSA at 230 GHz is 0.01 K in 1 hr of integration with a velocity resolution of 2 km s^{-1}. This implies that a S/N of 10 can be obtained in 2 minutes.

In summary, in its presently proposed configuration the LSA will be able to detect CO line emission in possibly up to 30 AGB stars (based on the number of luminous and red candidate objects, see Zijlstra et al. 1996) and red mass-losing supergiants in the LMC. This will allow an accurate determination of the DTG ratio and the mass loss rate. Regarding continuum emission the number of potential targets is much smaller.

References

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