Why Galaxies Care About AGB Stars: A Continuing Challenge through Cosmic Time
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The dust production rate of carbon-rich stars in the Magellanic Clouds

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Abstract. We present our new investigation aimed to estimate the mass-loss and dust production rates of carbon-rich stars (C-stars) in the Magellanic Clouds (MCs). We compute dust growth and radiative transfer in circumstellar envelopes of C-stars for a grid of stellar parameters and for selected optical constants that simultaneously reproduce the main colour–colour diagrams in the infrared. We employ these grids of spectra to fit the spectral energy distribution of C-stars in the MCs. We find that our estimates can be significantly different from the other ones in the literature.

Keywords. stars: AGB and post-AGB– stars: carbon – circumstellar matter – stars: mass loss – stars: winds, outflows – Magellanic Clouds

1. Introduction

The spectra and colours of thermally pulsing asymptotic giant branch (TP-AGB) stars are deeply affected by the properties of dust grains condensed in their circumstellar envelopes (Nanni *et al.* 2016). For carbon (C-) stars, amorphous carbon (amC) dust is particularly relevant. In radiative transfer calculations, the grain size distribution and optical constants of amC dust are chosen among several data sets (Hanner 1988; Rouleau & Martin 1991; Zubko *et al.* 1996; Jager *et al.* 1998). Such a choice affects the estimate of the dust production rate (DPR) and mass-loss rates of C-stars (Nanni *et al.* 2018; Groenewegen & Sloan 2018).

2. Model

In our description, grain growth is coupled with a spherical symmetric, stationary wind, as described in Nanni *et al.* (2013, 2014), based on Ferrarotti & Gail (2006). This scheme is coupled with a radiative transfer code (MoD; Groenewegen (2012) Ivezic & Elitzur 1997), and allows one to compute large grids of spectra reprocessed by dust. The input quantities of our code are the stellar parameters and the photospheric spectra (COMARCS; Aringer *et al.* 2016). The outflow expansion velocity ($v_{\rm exp}$) and the gas-to-dust ratio are predicted by our calculations. We employ the combinations of optical constants and grain sizes of amC dust that reproduce the main colour–colour diagrams (CCDs) in the infrared (Nanni *et al.* 2016). We then estimate the DPR and mass-loss rates of C-stars in the Magellanic Clouds (MCs), by fitting their spectral energy distribution (SED) over the grids.

Table 1. Total DPR for the MCs computed with the ACAR sample by Zubko *et al.* (1996), and compared with the results in the literature. The C- and extreme (x-) stars are classified according to Cioni *et al.* (2006) and Blum *et al.* (2006).

LMC			
	C-stars	X-stars	Total
This work, Zubko *et al.* 1996	$(2.60 \pm 0.52) \times 10^{-6}$	$(1.72 \pm 0.43) \times 10^{-5}$	$(1.98 \pm 0.49) \times 10^{-5}$
Riebel *et al.* 2012	$(1.34 \pm 0.40) \times 10^{-6}$	$(1.29 \pm 0.27) \times 10^{-5}$	$(1.43 \pm 0.31) \times 10^{-5}$
Srinivasan *et al.* 2016	7.6×10^{-7}	1.2×10^{-5}	1.2×10^{-5}
Dell'Agli *et al.* 2015	–	–	$\approx 4 \times 10^{-5}$
SMC			
This work, Zubko *et al.* 1996	$(4.4 \pm 1.2) \times 10^{-7}$	$(2.6 \pm 1.1) \times 10^{-6}$	$(3.0 \pm 1.2) \times 10^{-6}$
Srinivasan *et al.* 2016	$\approx 1.2 \times 10^{-7}$	$\approx 6.8 \times 10^{-7}$	$\approx 8.0 \times 10^{-7}$
Boyer *et al.* 2012	$\approx 1.2 \times 10^{-7}$	$\approx 6.3 \times 10^{-7}$	$\approx 7.5 \times 10^{-7}$
Matsuura *et al.* 2013	–	–	$\approx 4 \times 10^{-6}$

3. Results

In Table 1, we provide the DPR derived with our method for one selected optical data set for amC dust (ACAR sample; Zubko *et al.* 1996) with grain size between 0.06 and 0.09 μm. The DPRs from the literature are also listed. For the SMC, our DPR is, within the uncertainty, in agreement with the one by Matsuura *et al.* (2013), while the DPRs of Boyer *et al.* (2012) and of Srinivasan *et al.* (2016) are about four times lower than our estimate. Such a discrepancy is due to the different grain size distributions and $v_{\rm exp}$.

For the LMC, our DPR is in agreement with the one derived by Riebel *et al.* (2012) and about 1.7 times larger than the one by Srinivasan *et al.* (2016). On the other hand, our DPR is about two times lower than the one from Dell'Agli *et al.* (2015). A complete analysis performed with all the well-performing optical constants will be soon published.

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