Models of C-type AGB stars: Dust opacities and wind properties

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Introduction

Dynamical atmosphere and wind models are used to explore the wind driving mechanism of AGB stars, including complex physical processes such as the formation and destruction of dust. In this work we generate and compare two grids of wind models for C-type AGB stars with different optical properties for the carbon dust. One grid is based on the laboratory optical data from Rouleau & Martin (1991, ApJ 377, 526) and the other on data from Jäger et al. (1998, A&A 332, 291). The grids are computed using the DARWIN code and consist of models with masses from 0.75 $M_\odot$ to 1.5 $M_\odot$, luminosities from 3500 $L_\odot$ to 10000 $L_\odot$, and effective temperatures from 2400 K to 3200 K. The pulsation amplitude and carbon excess are also varied. A selection of models will eventually be further analysed and compared to observations after computing spectra and photometry.

Dust Opacities

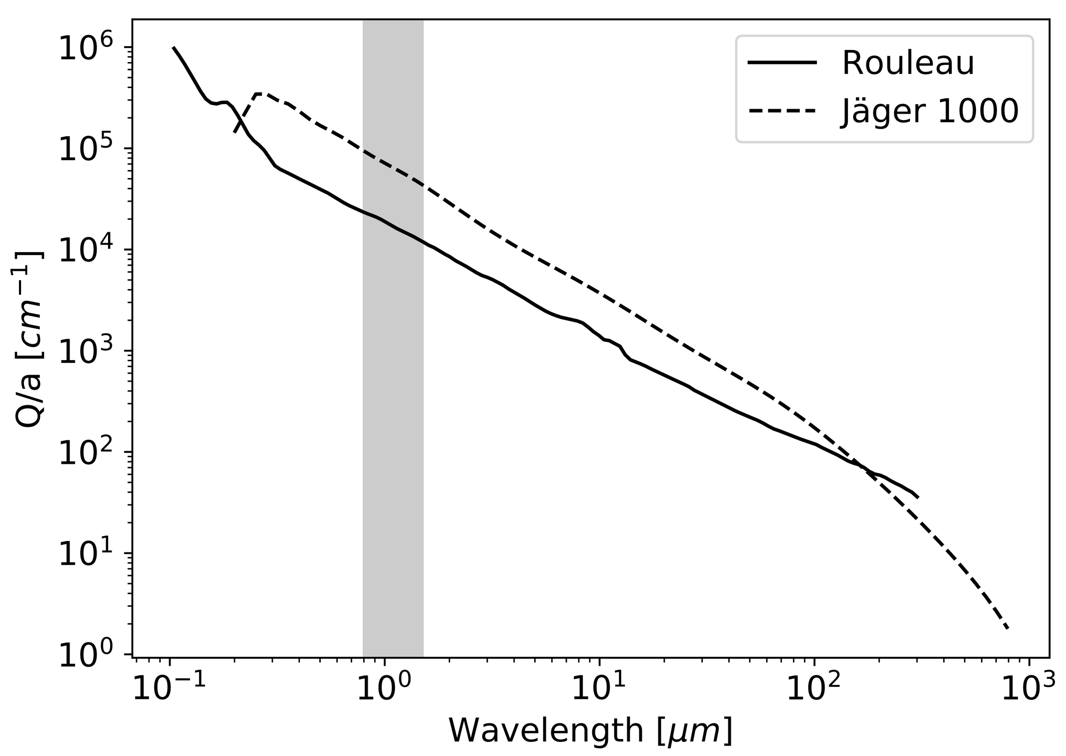

Figure 1: Extinction efficiencies of amorphous carbon from optical constants published by Rouleau & Martin (1991, designated Rouleau) and Jäger et al. (1998/cel 1000, designated Jäger 1000), as a function of wavelength. The shaded area marks the region where the stellar flux peaks.

The extinction efficiencies in Figure 1 are calculated under the assumption of the small particle limit and illustrates how the dust opacities of the two grain types differ from each other at a certain wavelength. Note, however, that the DARWIN models use size-dependent opacities.

Wind and Grain Properties

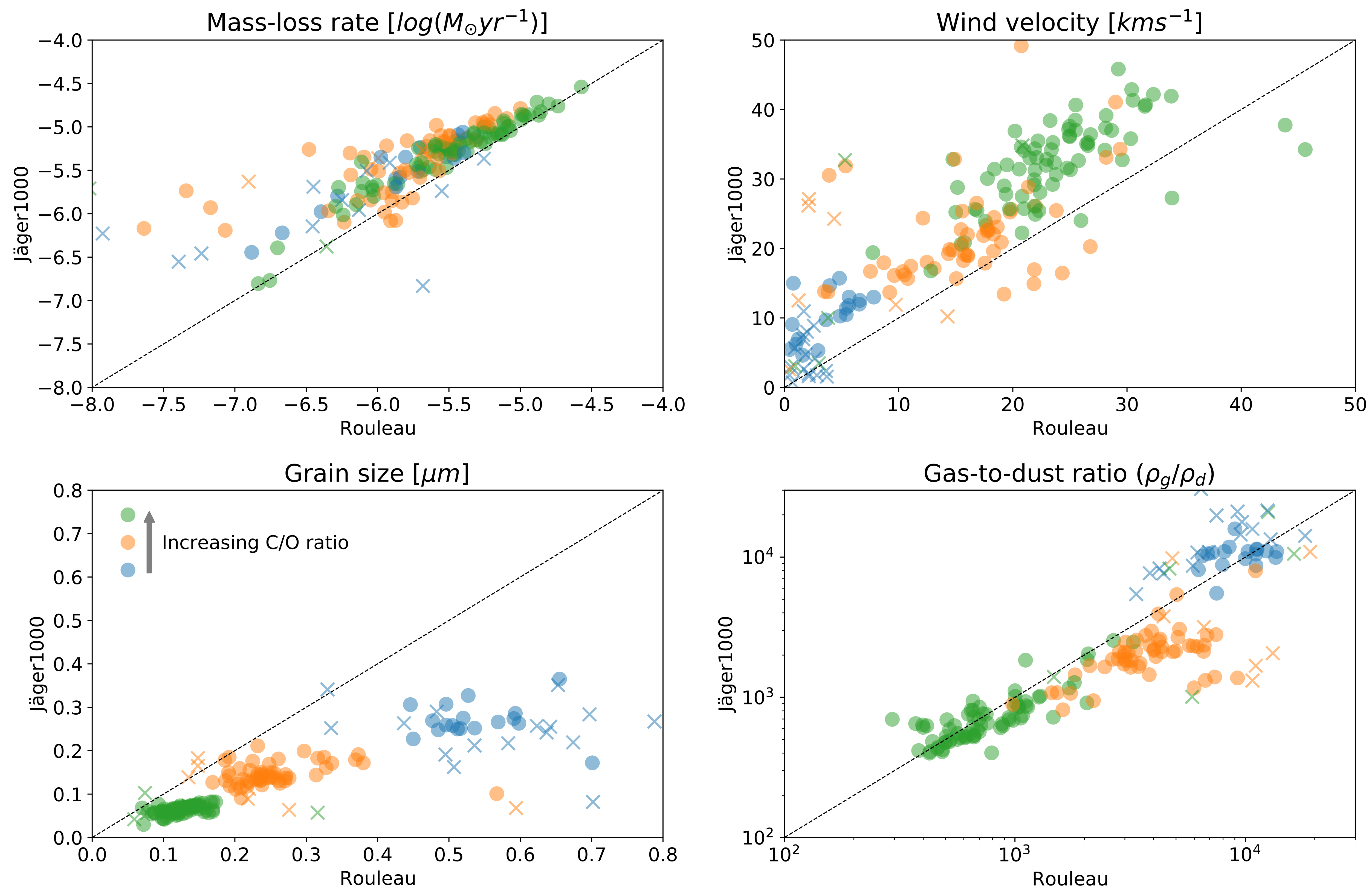

Figure 2: Wind and grain properties predicted by the models. The x and y-axes represent the results from models based on Rouleau & Martin (1991) and Jäger et al. (1998/cel 1000) opacity data respectively, the dashed line denotes the 1-to-1 relation. The blue, orange and green colors indicate the amount of excess carbon, or C/O ratio, where blue has the lowest ratio and green the highest (see illustration in the bottom left panel). The circles mark models with steady winds while the crosses denote that either of the models based on the different optical data sets show episodic winds.

Figure 2 show the results from the wind modelling. The mass-loss rates (top left panel), wind velocities (top right) and grain sizes (bottom left) show clear trends related to the opacity data used. The grid with Jäger et al. (1998/cel 1000) opacities result in smaller, more opaque particles and generally higher mass loss rates and wind velocities compared to the grid with Rouleau & Martin (1991) opacities. There is no clear trend related to the gas-to-dust ratios (bottom right) apart from the C/O ratios in the middle range (orange circles), where the ratio is higher for the Rouleau & Martin (1991) case than for the Jäger et al. (1998/cel 1000) case.

Comparison

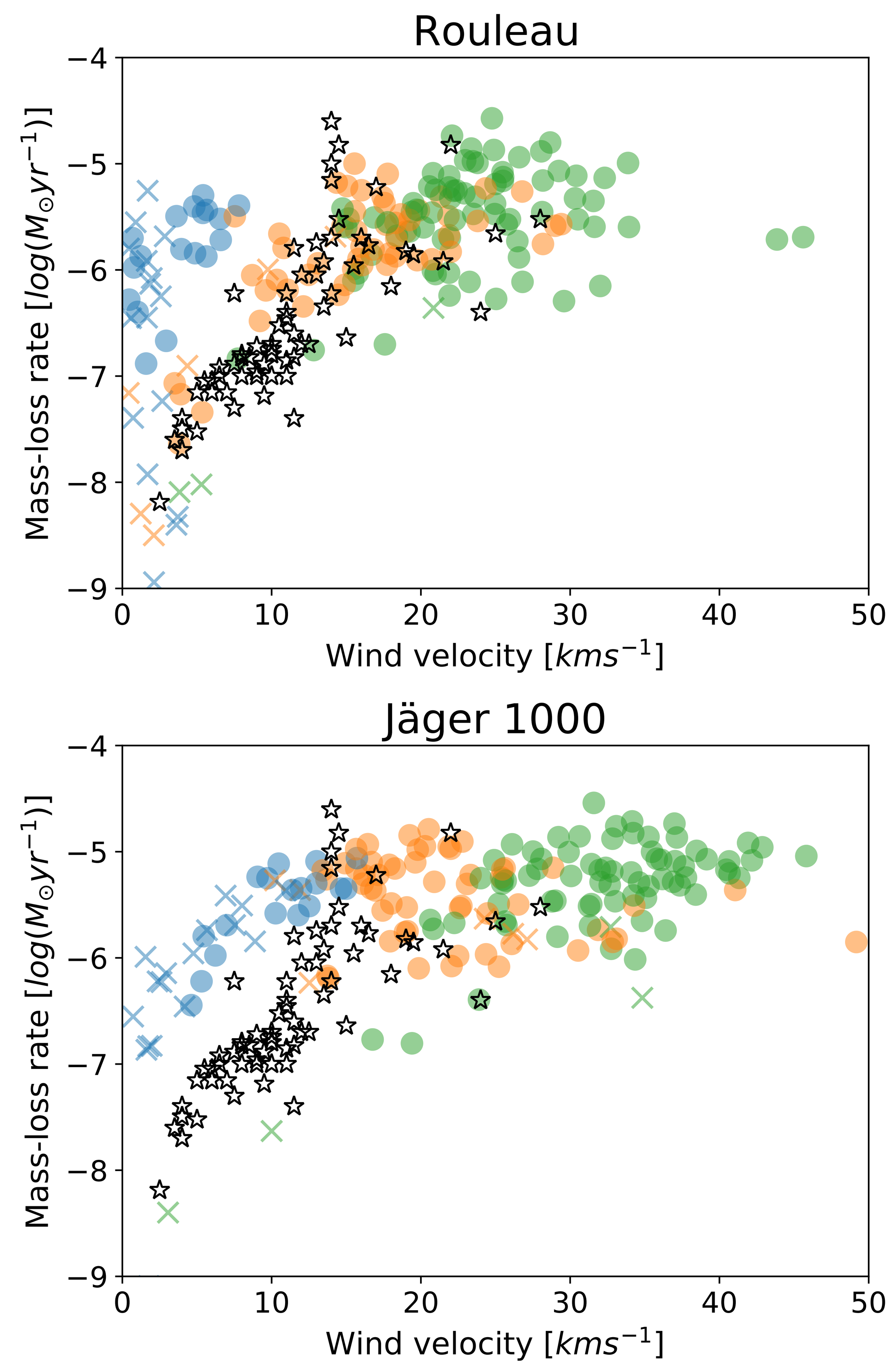

Figure 3: Mass-loss rates vs. wind velocities for models based on Rouleau & Martin (1991) data in the top panel and for models based on Jäger et al. (1998/cel 1000) data in the bottom panel. Observations by Schöier & Olofsson (2001, A&A 368, 969) are shown as black stars; other symbols and colors are the same as in Figure 2.

Figure 3 illustrate how the wind properties of the two model grids compare to corresponding observed properties of carbon stars, where the main purpose is to show that both grids are within the right parameter ranges.

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