The effect of dust opacities on winds of carbon-rich AGB stars

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Summary

Stellar winds of asymptotic giant branch (AGB) stars play an important role in enriching the interstellar medium. Dust grains are formed in the wake of pulsation-induced shock waves and later accelerated outwards by radiation pressure. The main wind-driving dust species in carbon-rich AGB stars is amorphous carbon (amC).

In this work, we compare two commonly used optical data sets of amC:

- Rouleau & Martin (1991, *ApJ* 377, 526) – **RM**
- Jäger et al. (1998, *A&A* 332, 291), *cel1000* – **J10**

RM vs J10

The aim is to investigate how the micro-physical properties of dust grains influence the wind and photometric properties of carbon-rich AGB stars.

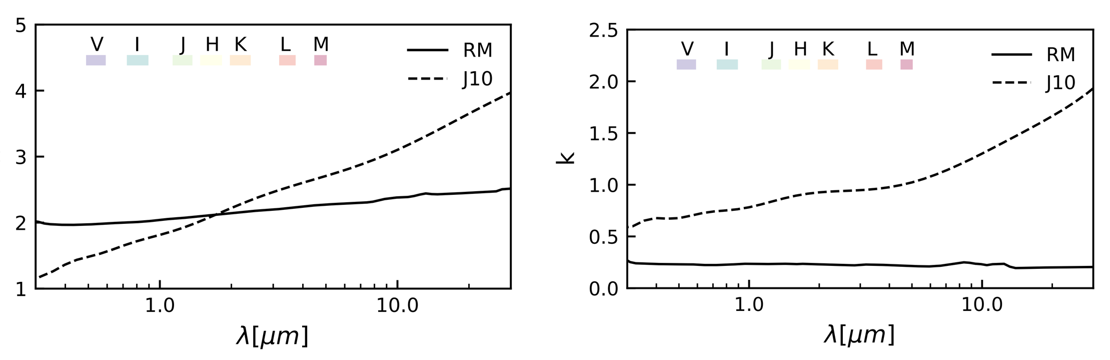
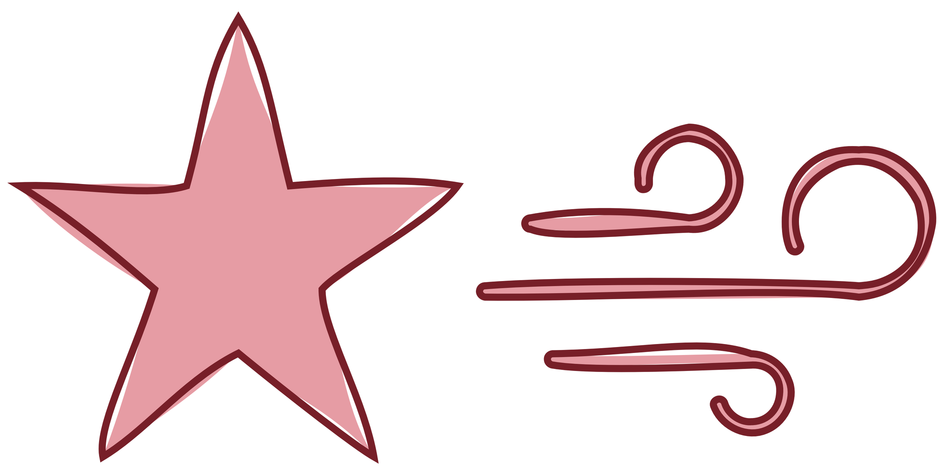


Fig. 1: Optical data, n and k, of RM and J10. The wavelength coverage of photometric filters is illustrated in each panel.

Two extensive grids of carbon star atmosphere and wind models are computed using the 1D radiation-hydrodynamical code DARWIN. The stellar parameters of the models are varied in effective temperature, luminosity, stellar mass, carbon excess and pulsation amplitude to cover a wide range of possible combinations. We assume spherical dust grains and include a size-dependent description of dust opacities. *A posteriori* radiative transfer calculations are made for a subset of the models, resulting in spectra and filter magnitudes.
We find that the average mass loss rates do not change significantly, however, grain sizes and photometric properties are greatly affected by the different dust optical data, see Figs. 2-5.
Our findings suggest a preference for using J10 optical data in future grids due to the significant influence on grain sizes and photometric properties.



Wind and grain properties

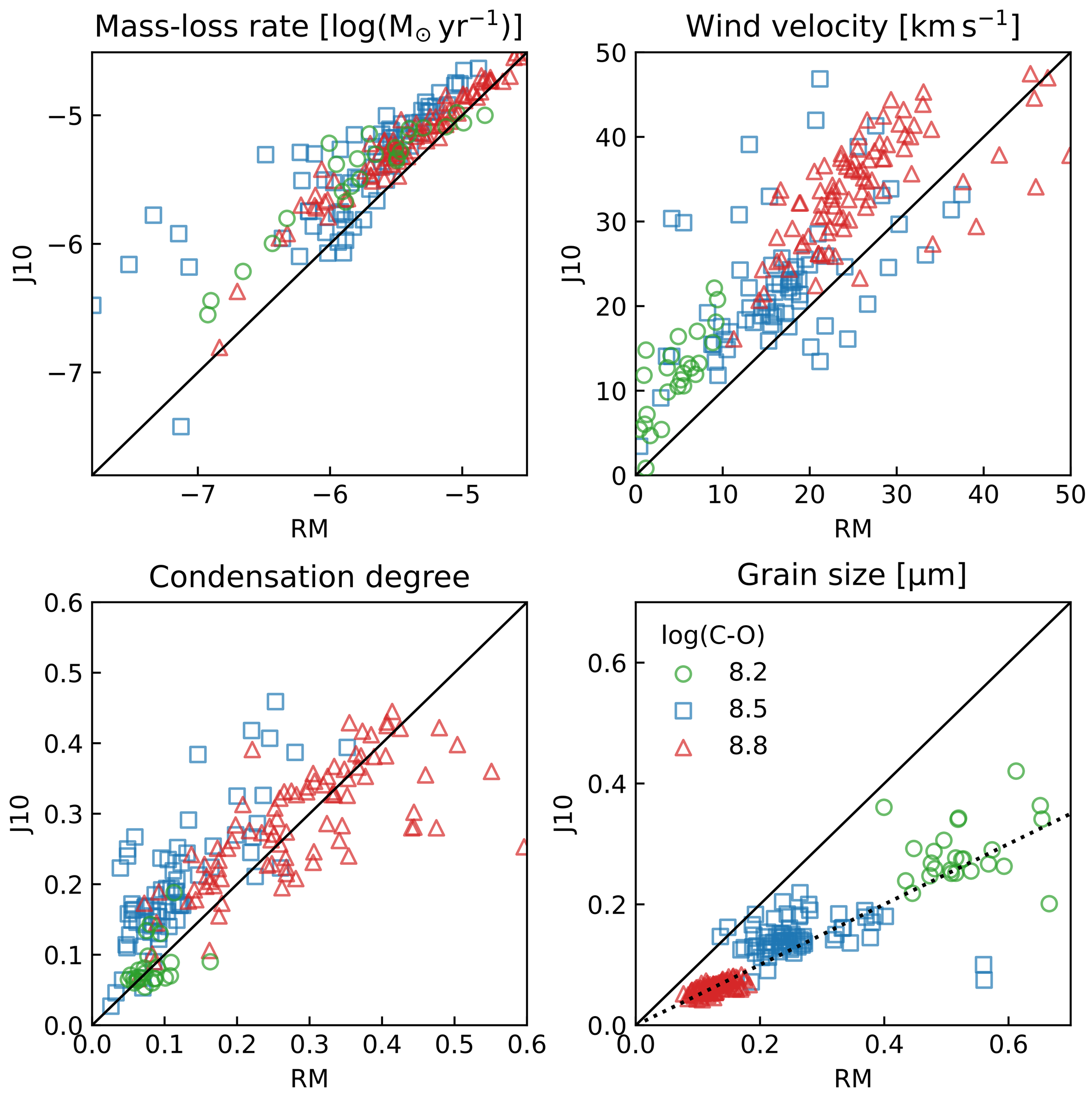


Fig. 2: Comparison of wind and grain properties predicted by the models. The x-axis represents the results from models based on RM opacity data and the y-axis represents the results based on J10 opacity data. The colours indicate the amount of excess carbon (see legend in the bottom right panel). Only models with steady winds are depicted.

Comparison to observations

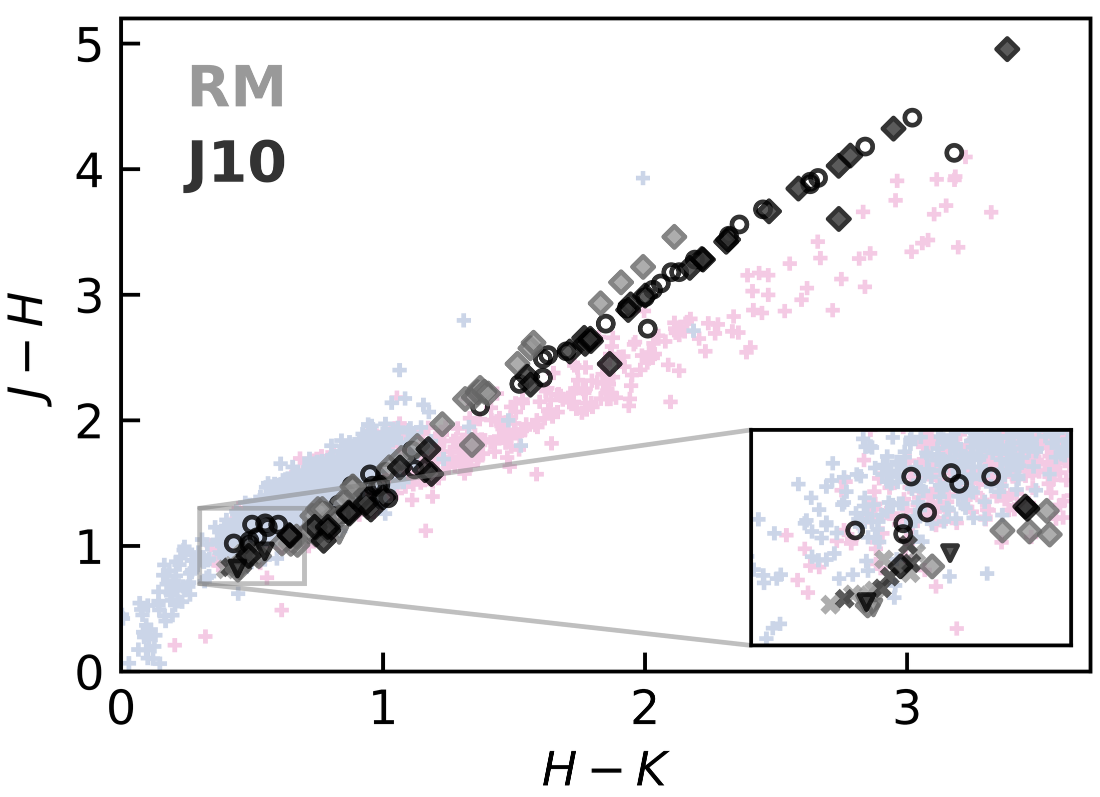


Fig. 3: Mean (*J-H*) vs. mean (*H-K*) *2MASS* colours. Model symbols are explained in Fig. 5, black circles are models with J10 optical data and COMA 12a gas opacities. Coloured symbols represent observations compiled by Suh (2022, JKAS 55, 195). The zoomed-in region highlights models with little to no dust.

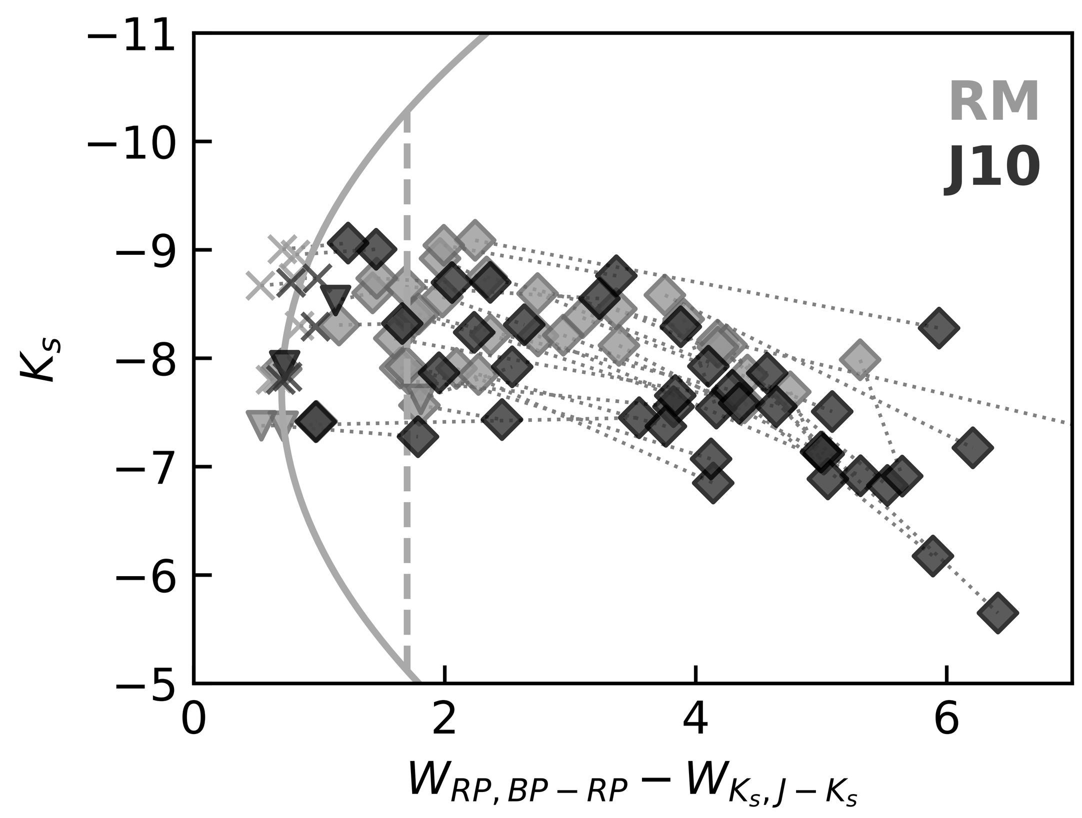


Fig. 4: *Gaia-2MASS* diagram. C-rich AGB stars are theoretically situated to the right of the curved line. The dashed line separates C-rich (left of the line) and extreme C-rich (right of the line) sources. Colours and symbols are explained in Fig. 5.

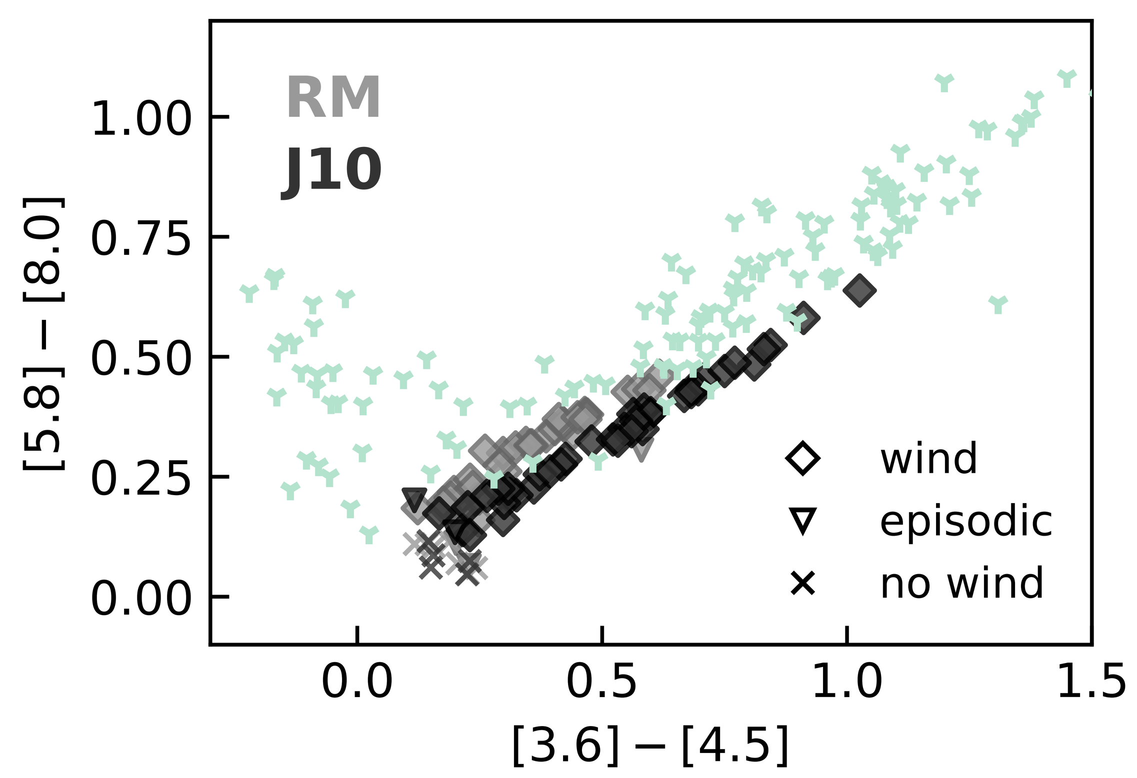
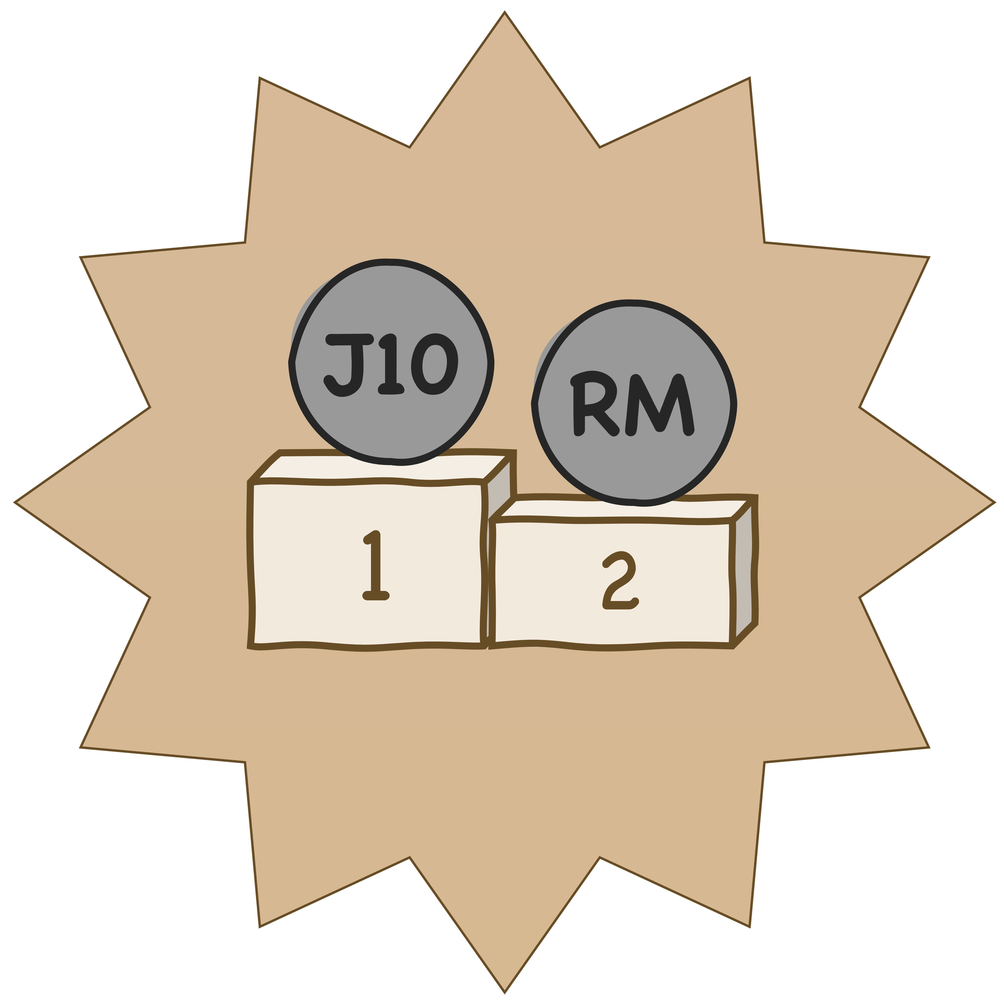


Fig. 5: Mean [5.8] - [8.0] vs. mean [3.6] - [4.5] *Spitzer* colours. Models are depicted in grey (RM) and black (J10); diamonds: models with wind; triangles: models with episodic mass-loss; crosses: models with no wind. Green symbols show observed carbon stars from Jones et al. (2017, MNRAS 470, 3250).

Conclusions

- J10 data are more efficient at driving the winds:
  - more stellar parameter combinations result in winds
  - more opaque and more efficient absorbers of stellar radiation
- J10 data result in smaller grain sizes *(on average by a factor of 2 compared to RM data)*
- RM and J10 data are both in good agreement with observations, although J10 covers a wider range of colour
- J10 data show fainter visual and near-IR magnitudes for dust-enshrouded models
- J10 data *(and updated gas opacities, see Fig. 3)* suggested for future grids due to the significant influence on grain sizes and photometric properties



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