DEATHSTAR

A new hope for accurate mass-loss rate estimates for AGB stars

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Context

Asymptotic giant branch (AGB) stars represent an important late stage of the evolution of low- and intermediate-mass stars. Through their dusty outflows, AGB stars are major contributors of newly synthesized elements and dust to their host galaxy. Accurate characterization of this mass loss phenomenon is, therefore, key to advancing our understanding of stellar evolution and of the galactic chemical enrichment.

The **DEATHSTAR*** (**DE**termining **A**ccurate mass-loss rates of **TH**ermally pulsing AGB **star**s) project aims to improve the accuracy of the stellar wind parameter measurements for AGB stars.

Dust RT tests for carbon stars

To determine the optimal approach for modelling the dust and stellar emission of carbon stars, we first investigated how the input stellar spectrum and optical properties of the dust influence the resulting best-fit model for spectral energy distributions (SEDs). We used the 1D Monte-Carlo-based dust radiative transfer (RT) code MCMax [1] to perform these tests on three carbon stars of low, intermediate, and high mass-loss rates.

Examined properties:

★ Stellar input spectra: **Black body** vs **COMARCS** model atmospheres [2].

★ Optical constants: **Rouleau & Martin** (1991, [3]) vs **Jäger** et al (1998, [4]) at 1000° C.

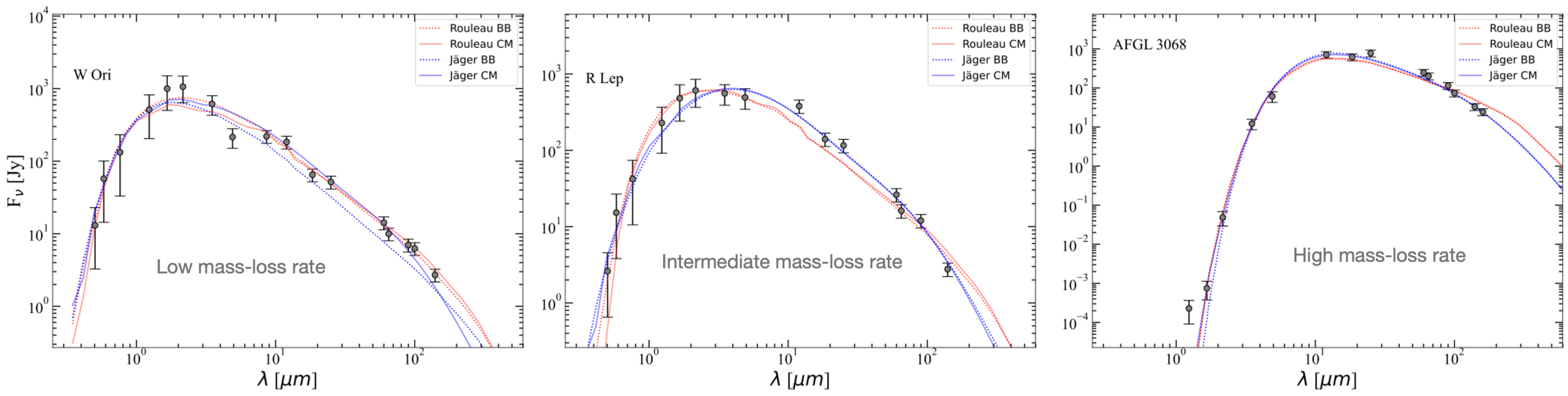

Fig 1. SEDs of the best-fit models for three test carbon stars. The different lines correspond to various combinations of input stellar spectra and optical constants. BB stands for blackbody, CM: COMARCS, Jäger: optical constants measured by [4], Rouleau: optical constants tabulated by [3].

Dust RT modelling of a sample of carbon stars

The results of the test above demonstrate that using the COMARCS input spectra and the Jäger optical constants produces the most optimal outcomes. With this approach, we proceeded to simulate the SEDs of a sample of 27 carbon stars within the DEATHSTAR sample.

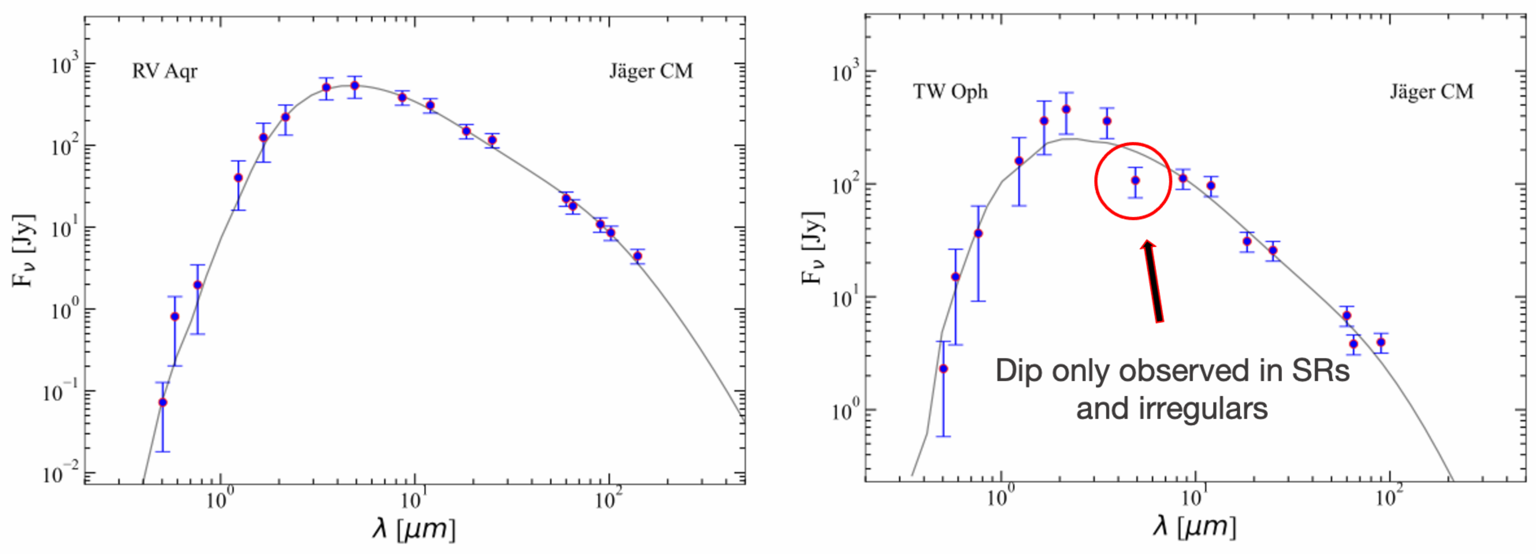

Fig 2. Examples of SEDs of a Mira (left) and a semi-regular (SR, right) variables. Most of the SRs exhibit a dip in the M-band, at ~4.9 μm. This is not the case for the Miras.

Obtained parameters from dust modelling

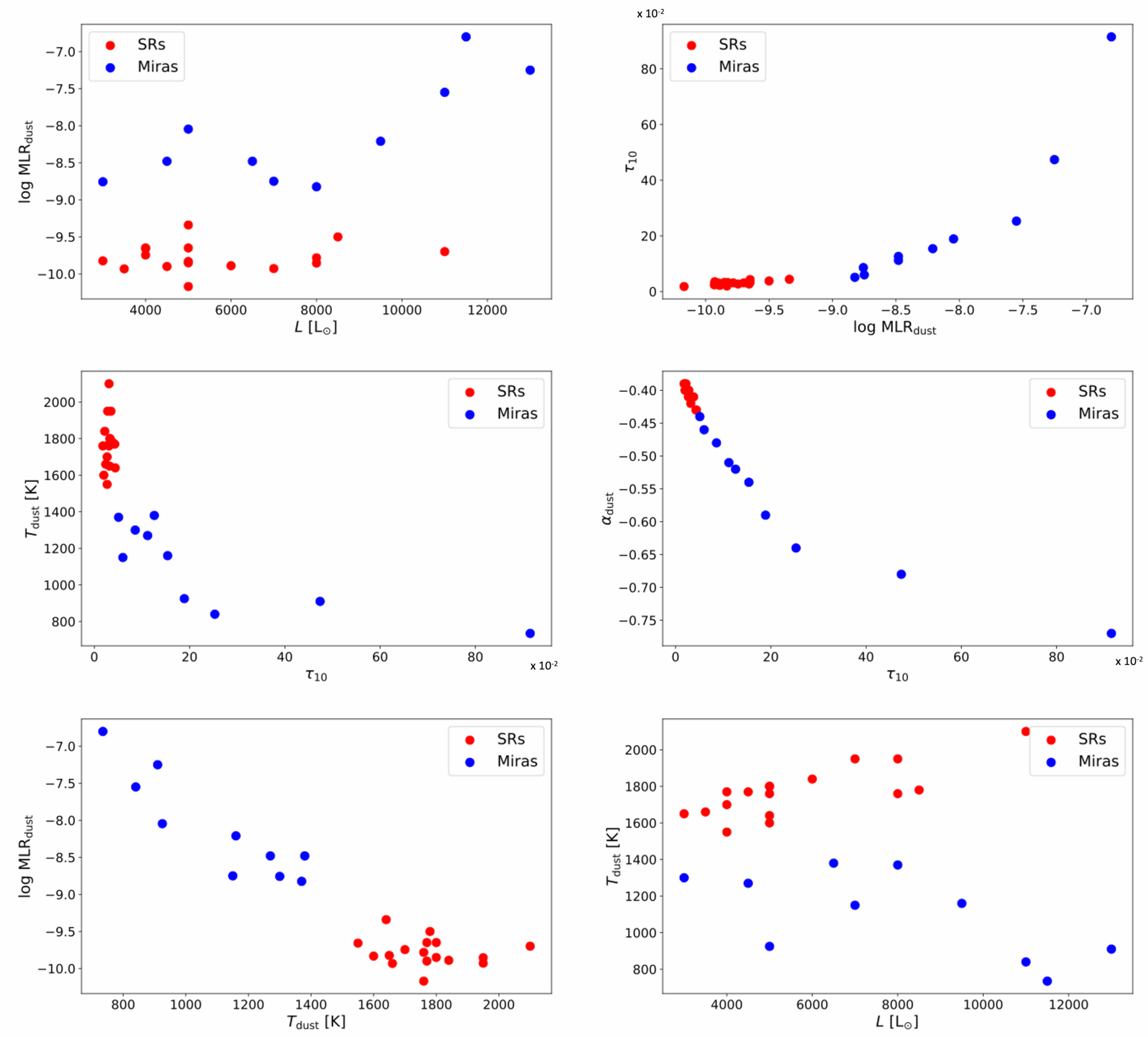

Fig 3. The parameters depicted are the dust mass-loss rate ($\mathbf{MLR_{dust}}$), the stellar luminosity (L in $L_\odot$), the optical depth at 10 μm (τ_{10}), the dust condensation temperature at the observed inner radius (T_{dust} in K), and the slope of the dust temperature profile when a power law is assumed (α_{dust}). The only output parameter not shown is the stellar temperature, which does not exhibit any trend with the other parameters.

Conclusions

★ **RT test results**: the synthetic SEDs obtained with the Jäger opacities show closer agreement with observations, especially in more accurately reproducing the long-wavelength slope.

★ **Miras VS semi-regulars**: the contrast in the results of the dust modelling for the two types of variables is evident.

- ❑ A dip is consistently present in the SEDs of SRs, but is absent in Miras.
- ❑ Miras are more optically thick than SRs. They have higher mass-loss rates and steeper dust temperature profiles.
- ❑ The obtained dust condensation temperatures of Miras are lower than of SRs (down to ~800 K), which correspond to large dust inner radii. This is likely a consequence of the high optical depths of Miras, which makes that the actual dust formation region is inaccessible with our current models.

Future work

These dust RT results will be used as input for upcoming CO RT modelling in order to determine the total **gas mass-loss rate** and the **dust-to-gas ratio** for these carbon stars.

References: [1] Min et al. 2009, A&A, 497, 155; [2] Aringer et al. 2019, MNRAS, 487, 2133; [3] Rouleau, F. & Martin, P. G. 1991, ApJ, 377, 526; [4] Jäger, et al. 1998, A&A, 332, 291.

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