Testing dynamic models of AGB C-stars with uniform-disc fits

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Introduction

The AGB is the late evolutionary stage of stars with masses less than 8 $M_\odot$. These stars are characterized by a degenerate C-O core and an He/H-burning shell, a convective envelope and a very extended atmosphere characterized by molecules and dust formation and affected by pulsation of the interior. Due to the third dredge-up the AGB C-stars have [C/O] > 1 and their spectra are characterized by the presence of carbon species like C_2, C_2H_2, C_3, CN, HCN. Dust is mostly present as amorphous carbon. Due to their extended atmospheres and brightness in the red and infrared range, AGB stars are the perfect candidates for interferometric investigations. Studying AGB stellar atmospheres is essential for a better comprehension of the late stage of stellar evolution, to understand the complicate interaction of pulsation and the stellar atmosphere, the dynamical processes of dust formation and mass loss. For Carbon stars, available atmospheric models (Höfner et al. 2003) are more advanced than for M-type stars because the dust formation is better understood.

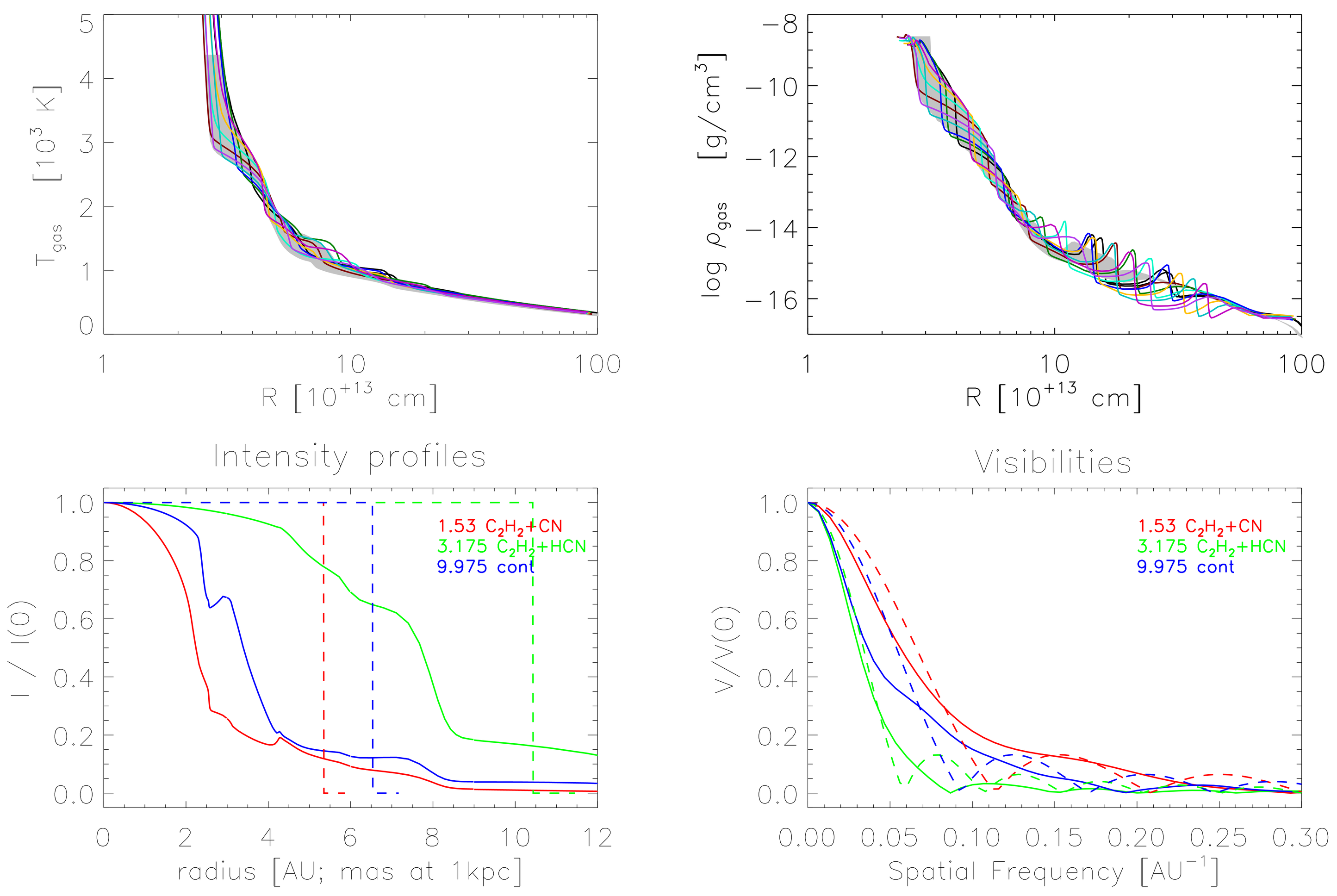

FIGURE 1: In the two upper figures the atmospheric structure of a dynamic model of a C-star (Gautschy-Loidl et al. 2004, Nowotny et al., 2005) is shown. In the two plots at the bottom the intensity profile and the visibility of the dynamic model in three narrow band filters (centered at 1.53, 3.175, 9.975 μm) are compared with UD profiles. The three filters are representative for the effects of C_2/CN, C_2H_2/HCN, and the dust opacity respectively. The UD represented is fitted to the point where visibility = 0.3.

Most of the previous studies concerning interferometry of red giant stars use simple approximations for interpreting visibility profiles. An overview for M-type stars can be found in Scholz (2003). Following the same approach as for M-stars, we computed synthetic intensity and visibility profiles for a set of dynamic models of C-stars. Visibility profiles are fitted with a uniform disc (UD) in order to obtain the UD radius and investigate the dependence of this on wavelenghts and pulsation phase.

Radius versus Wavelength

For studying the dependence of UD radius on wavelength, we defined 21 narrow filters in the near-to mid-IR chosen in a way to sample some particular features of the spectrum (e.g. C_2H_2). We computed UD-radii for a set of dynamical models which differ in luminosity, effective temperature ($T_{\rm eff}$), C/O ratio, piston velocity (Δu_p) and mass loss rate (dM/dt).

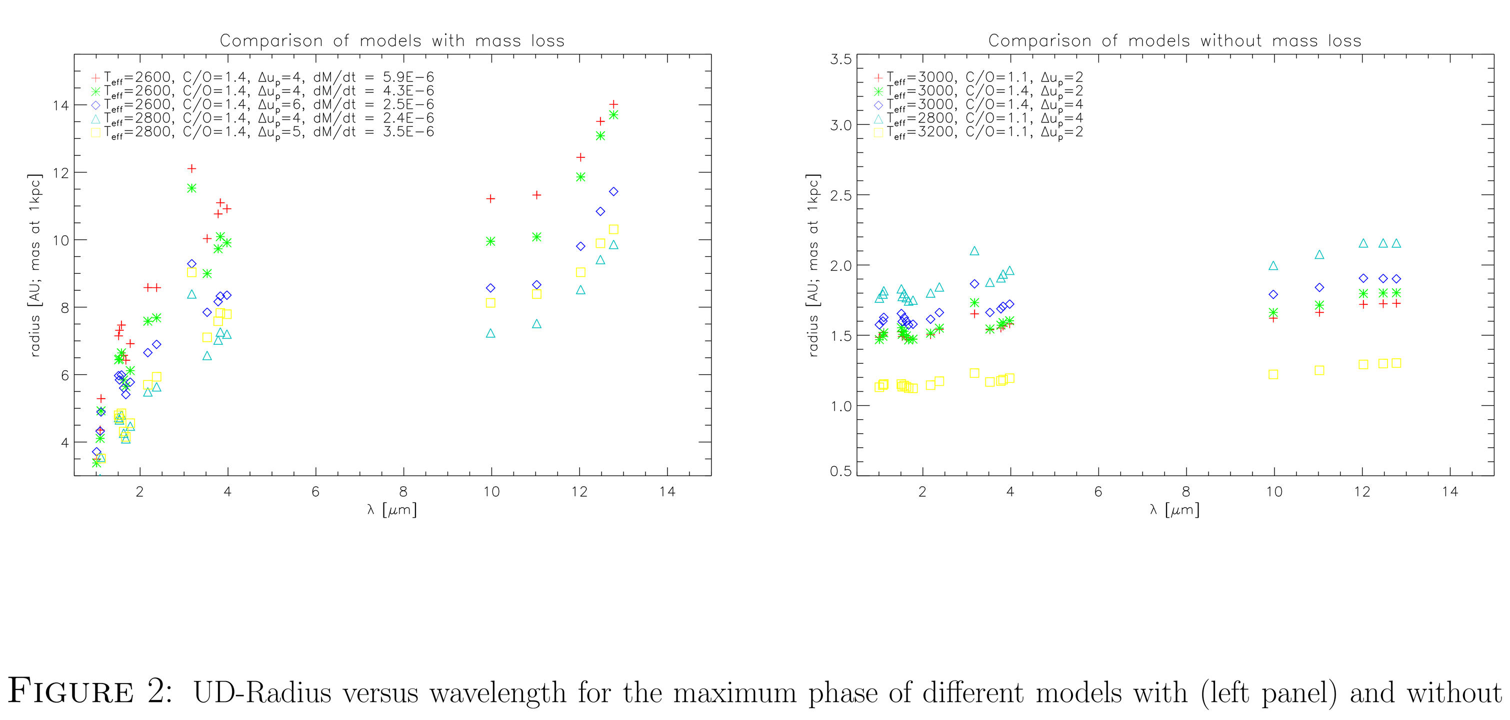

FIGURE 2: UD-Radius versus wavelength for the maximum phase of different models with (left panel) and without (right panel) mass loss. The legend shows the initial parameters of each model: effective temperature, C/O ratio, pitson velocity and mass loss ratio (Höfner et al, 2003). The method used for the UD determination is least square fit using all the points of the synthetic profile with visibility > 0.1.

The behavior of the UD-radius versus wavelength is different for models with and without mass loss. In both cases the UD-radius increases with the wavelength, but this behaviour is more pronounced for models producing dust. At 3.175 μm there is a "jump" of the UD-radius due to the C_2H_2 opacity.

We also aimed to study the influence of atoms, molecules and dust on the UD-radius. It turns out that the continuum radius is mostly independent upon wavelength so it can be adopted as a good reference radius (although being not observable!). The contributions to the UD-radius of continuum, molecules and atoms can be best seen in the right panel of the Fig.2 for models without mass loss, while the effect of dust opacity are notable in the left panel.

If a radial scaling factor is applied to the model profiles (equivalent to uncertains in the distance) the difference between the models largerly disappear.

Radius versus Phase

To investigate the dependency of the UD-radius on the phase we choose three different narrow band filters (bottom panels Fig.1), representative of the behaviour of our sample. We computed the radius using first 1 point fit with visibility of 0.3, then 2 points (visibility 0.1 and 0.4) and finally the least square method (all the points with visibility > 0.1). The same procedure was performed for the different models with and without dust and also for the continuum radius of each model.

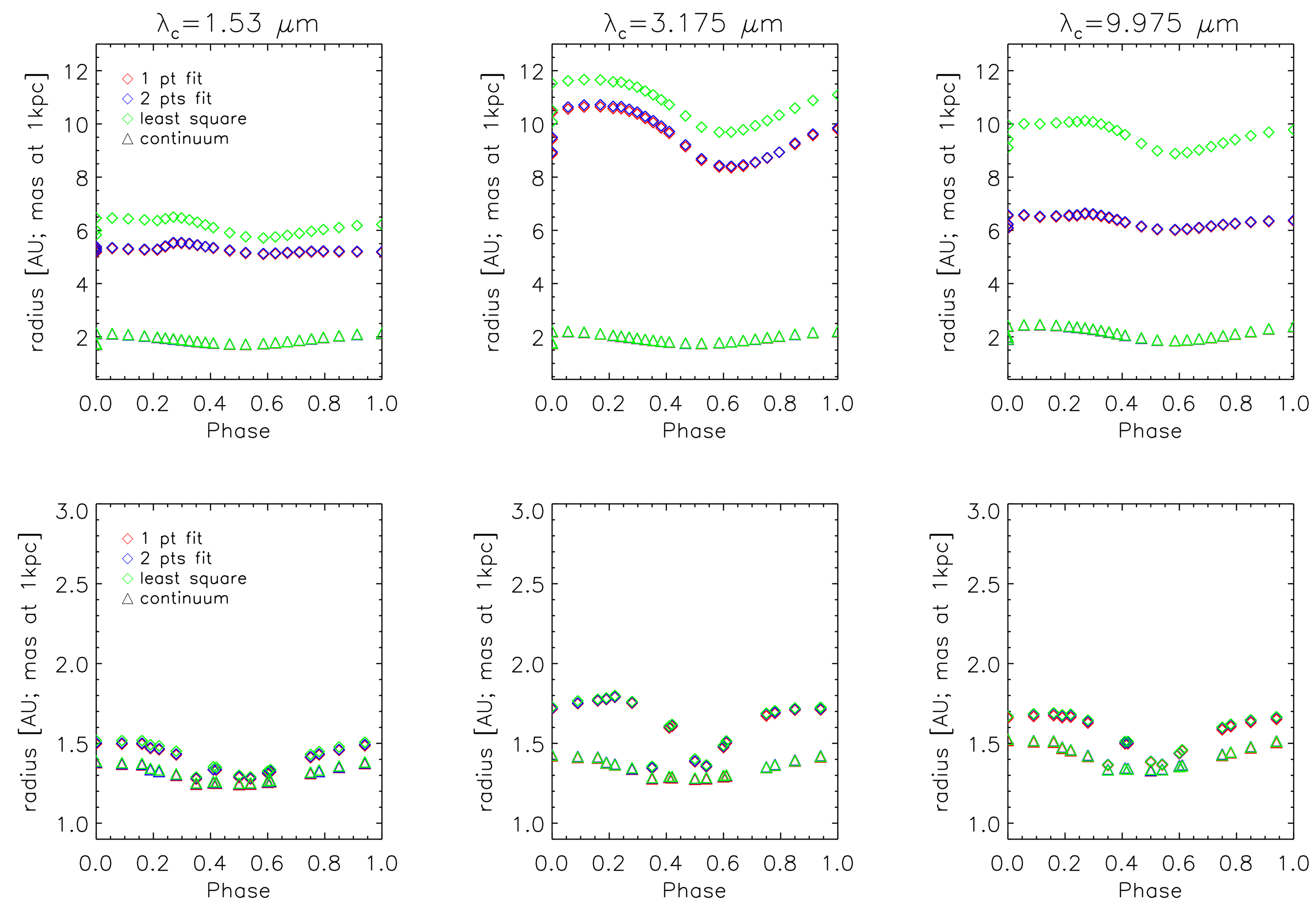

FIGURE 3: UD-Radius versus phase are shown for three different narrow filters. The three upper panels represent results for a dynamic model with mass loss, the three panels at the bottom are for the model without mass loss. Triangle stays for UD-radius computed taking in account only continuum opacity, diamonds are for continuum plus atoms and molecules, plus dust (when it is present). The three different colour correspond to the methods that we used to determine UD-radius: red for 1-point fit, blue for 2-points fit and green for least square fit.

Models with mass loss are obviously much more extended than models without and the continuum UD-radius in this case is very far from the other UD-radii. In both these types of models we can observe the periodic movement of the stellar interior but this is not the case for all the models of our sample. The 3 different methods of fitting give mostly the same result in the case of the model without mass loss, while the UD-radius is smaller for the first 2 methods (1 and 2 points) in the case of models with mass loss. This difference becomes important at longer wavelength in the N band where for example we observe with MIDI.

Conclusions

- A dependence of UD-radius on wavelength is evident and it is stronger in the case of models with dust included. Around 3 μm and in the N band the star is more extended due to C_2H_2 opacity.
- Using only 1 or 2 points of visibility to determine the UD-radius of the star we obtain smaller radii. The difference is stronger in the N band.
- The UD-radius is closer to the continuum UD-radius in the case of models without mass loss
- The radius computed with the UD function has to be condsidered only a first guess for the real radius of the star. As shown in Fig.1 the intensity profile and the visibility of a C-star is very far from being a Uniform disk.

References

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Acnowledgements

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