Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
Proceedings IAU Symposium No. 343, 2019
F. Kerschbaum, M. Groenewegen & H. Olofsson, eds.

doi:10.1017/S1743921318005082

Dust properties in the circumstellar environment of carbon stars

M. Mečina[1], B. Aringer[2], M. Brunner[1], F. Kerschbaum[1], M. A. T. Groenewegen[3] and W. Nowotny[1]

[1]Institut für Astrophysik, Universität Wien, Türkenschanzstraße 17, 1180 Wien, Austria
email: marko.mecina@univie.ac.at

[2]Dipart. di Fisica e Astronomia, Universit di Padova, via Marzolo 8, 35131 Padova, Italy

[3]Royal Observatory of Belgium, Ringlaan 3, 1180 Brussels, Belgium

Abstract. Herschel PACS imaging observations of carbon stars show well-resolved spherically symmetric detached shells around several objects. In the case of U Hya the shell is additionally detected in scattered visible light and in the far UV. The remarkable spherical symmetry justifies a straightforward application of 1D models to constrain the properties of the dust envelope, whose modulation in density is a consequence of short epochs of highly increased mass loss and/or wind-wind interaction between outflows of different velocity. We perform dust radiative transfer calculations, first based on a parametrised density distribution, and in a more sophisticated approach on a combination of stationary wind models. The impact of dust properties, particularly grain geometry, on the results is highlighted.

Keywords. stars: AGB and post-AGB, stars: carbon, stars: mass loss

---

U Hya, a semi-regular carbon star, is surrounded by a thin detached dust shell with a radius of 114″ (0.12 pc) that has been resolved in detail by Herschel/PACS. The spherically symmetric dust structure also shows up, and very well resembles the far IR data, in optical scattered light observations by the Pan-STARRS programme. In addition, Sanchez *et al.* (2015) found clumped far UV emission in GALEX observations, cospatial with Herschel and Pan-STARRS data. Since in the near-UV band corresponding signatures could not be clearly identified, they concluded that shocks in the shell due to the stellar motion through the ISM, rather than scattering of the (inter-)stellar radiation field are causing the high-energy emission. Such interaction is also indicated by minor deviations from spherical symmetry seen in scattered light and far IR. There is no observed gaseous counterpart to the dust, likely due to photodissociation and low densities ten thousands of AUs from the star.

All detached shell objects in our sample for which ISO spectra are available show a very distinct C_3 feature at 5 μm. This strongly suggests that they are carbon-rich objects with a fairly high C/O and thus must have undergone several dredge up events. Hence one can assume that the dust in the detached shell is also already dominated by carbonaceous species. However, inconsistencies in JHK colours between observations and stationary wind models indicate that additional factors such as the role of C_2H_2 must be considered (Aringer, priv. comm.). Models using more complete molecular line data may shed new light on this discrepancy.

We use *More of DUSTY* (Groenewegen 2012) to calculate the radiative transfer through the circumstellar dust envelope. Adopting a dust mixture of amorphous carbon and SiC, a best fit model is evaluated regarding photometric data, IR spectra, and PACS imaging data. The results suggest a rather gradual decrease in mass loss after a high mass loss period that presumably caused the detached shell.

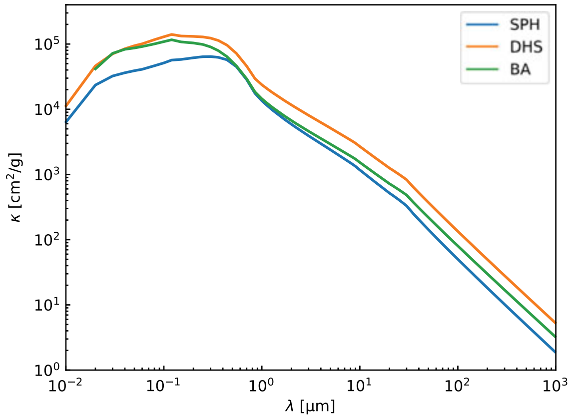

Figure 1. Opacities calculated for solid spheres, a distribution of hollow spheres, and ballistic agglomeration models with the same effective size, using optical properties from Suh (2000).

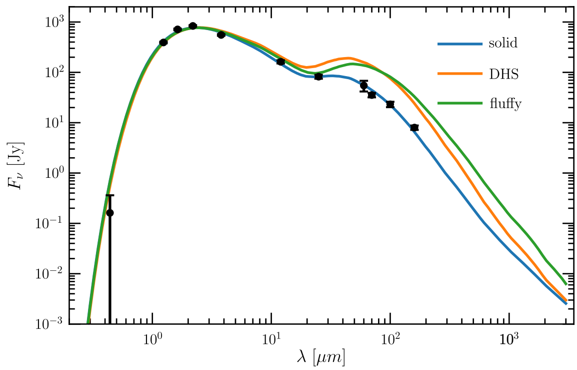

Figure 2. SED model fits to a carbon star with detached dust shell. All models contain the same amount of carbon dust, but differ in the used opacities (see Fig. 1).

Grain geometry plays a crucial role in dust opacity calculations (Fig. 1). We compare solid spheres, distributions of hollow spheres (DHS), and "fluffy" grains formed by ballistic agglomeration (BA, see Draine & Flatau 1994). DHS and BA mimic the porous structure of, e.g., amorphous carbon, thus requiring models to assume significantly less dust mass to match the observations (Fig. 2). In addition, the shape of narrow spectral features as well as the slope of the SED are affected.

Acknowledgements

This work was supported by the Austrian Science Fund FWF under project number AP23586 and the FFG ASAP HIL project. BA acknowledges the support from the project STARKEY funded by the ERC Consolidator Grant, G.A. n.615604. MB acknowledges funding through the Abschlussstipendium fellowship of the University of Vienna.

References

Draine, B.T. & Flatau, P.J. 1994, *Journal of the Optical Society of America A*, 11, 1491
Groenewegen, M.A.T. 2012, *A&A*, 543, A36
Sanchez, E., Montez, R., Ramstedt, S., *et al.* 2015, *ApJL*, 798, 39
Suh, K.-W. 2000, *MNRAS*, 315, 740

https://doi.org/10.1017/S1743921318005082 Published online by Cambridge University Press