The detached dust shells of AQ And, U Ant and TT Cyg

F. Kerschbaum[1], D. Ladjal[2], R. Ottensamer[1,5], M.A.T. Groenewegen[3], M. Mecina[1], J.A.D.L. Blommaert[2], B. Baumann[1], L. Decin[2,4], B. Vandenbussche[2], C. Waelkens[2], T. Posch[1], E. Huygen[2], W. De Meester[2], S. Regibo[2], P. Royer[2], K. Exter[2] , and C. Jean[2]

[1] University of Vienna, Department of Astrnomy, Türkenschanzstraße 17, A-1180 Vienna, Austria; [2] Instituut voor Sterrenkunde, Katholieke Universiteit Leuven, Celestijnenlaan 200 D, B-3001 Leuven, Belgium; [3] Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; [4] Sterrenkundig Instituut Anton Pannekoek, University of Amsterdam, Kruislaan 403, NL-1098 Amsterdam, The Netherlands; [5] Institute of Computer Vision and Graphics, TU Graz, Inffeldgasse 16/II, A-8010 Graz, Austria

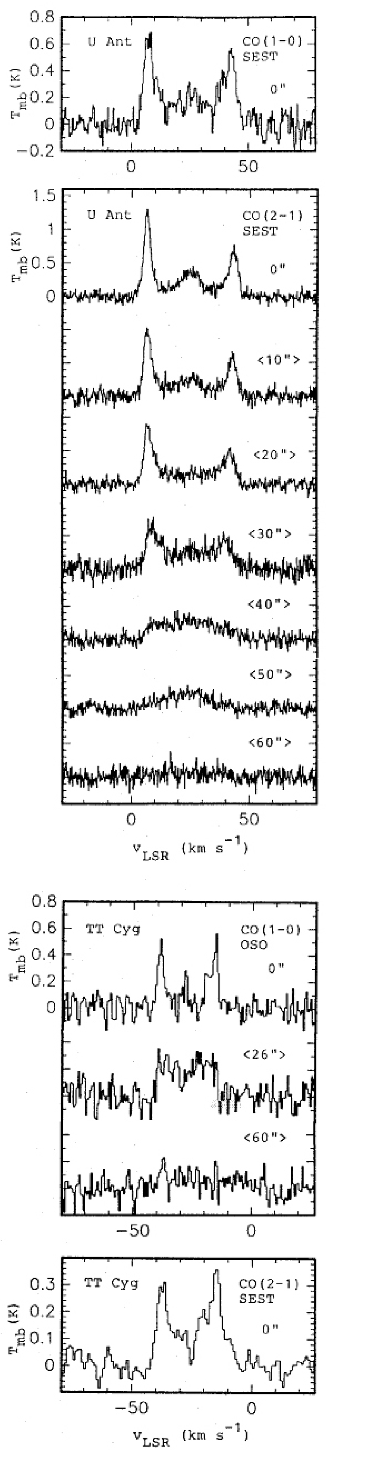
Abstract

Detached circumstellar dust shells are detected around three carbon variables using Herschel-PACS. Two of them are already known from their thermal CO emission and two from an extension in IRAS imaging data. By model fits to the new data sets physical sizes, expansion timescales, dust temperatures and more are deduced. A comparison with existing molecular CO material shows a high degree of correlation for TT Cyg and U Ant but also distinct differences with other observables are found.

MESS

The Herschel Mass-loss of Evolved StarS (MESS) guaranteed time key program investigates the dust and gas chemistry and the properties of CSEs for a large sample of post-main-sequence objects using both imaging and spectroscopy. The sample is a good representation of the various types of objects, in terms of general type (early-, thermally pulsing and post-AGB), spectral type (covering the M-subclasses, S-stars, carbon stars), variability type (L, SR, Mira), and mass-loss rates.

Detached shells and mass-loss

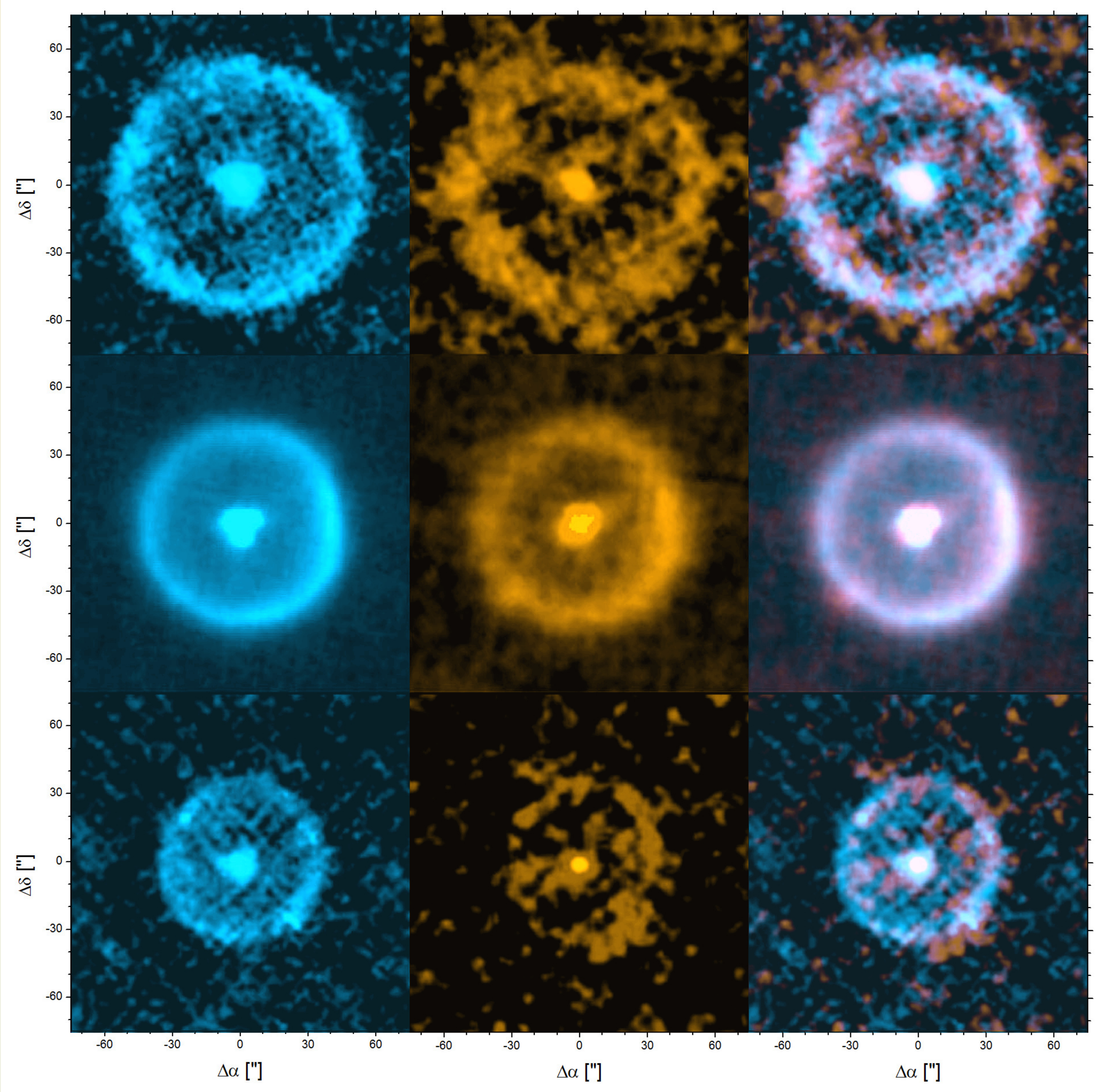


CO map data from SEST, the offset spectra are azimuthal averages (Olofsson et al. 1990).

Mass-loss increases (on average) during the evolution along the AGB [1], but already in the late 80s observational evidence was found for a more episodic picture of the mass-loss evolution [2,3]. With IRAS photometry a group of 60µm excess objects with very low temperature dust was identified, and in the course of a larger CO survey stars with obviously detached gas shells were found. These two indicators for maybe the same phenomenon were used in the following years to study this interesting evolutionary phase.

With IRAS it was possible to measure the size of a few detached dust shells in the mid 90s, but even with ISO, imaging of extended dust emission was hampered by the low spatial resolution these space telescopes could deliver.

Gonzales et al. [4] studied some detached shell objects in visible light. The detected detached molecular shells are geometrically thin and probably smaller in size than the detached dust shells revealed by IRAS. It may be that they have different origin - episodic mass-loss on one hand and ISM-wind or wind-wind interaction on the other. Objects like U Ant [5] could show both types of phenomena.



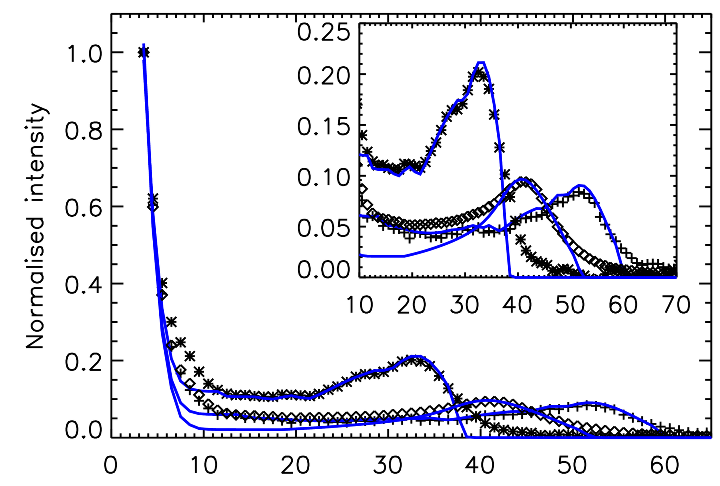
Herschel-PACS scan maps (left to right: at 70 µm, 160 µm, two colour composite) of AQ And, U Ant, and TT Cyg (top to bottom).

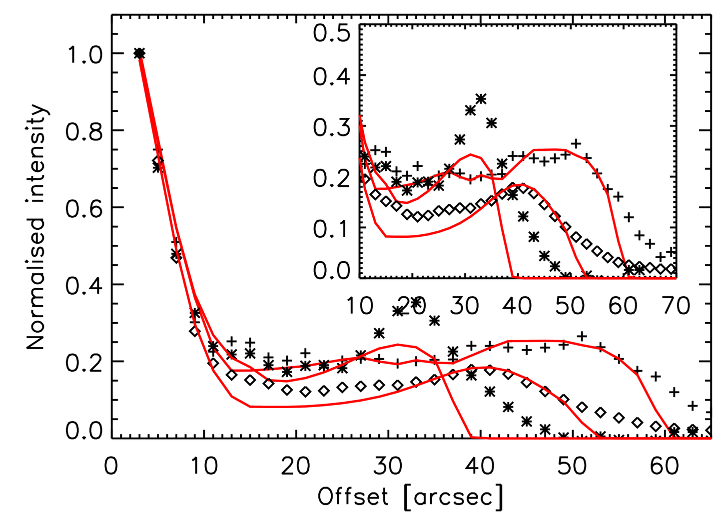
Observations & data reduction

The Herschel observations above are scan maps done with the Photodetector Array Camera & Spectrometer (PACS) [6] at 70 µm (blue filter) and 160 µm (red filter). Two orthogonal scans with several parallel scan legs were made at constant speed (20"/s) to achieve a homogeneous coverage of the required area. We used the Herschel interactive processing environment (HIPE) for data processing, but the nature of our data (bright central star surrounded by faint emission) made it necessary to pay special attention to the correlated noise without influencing the photometry of the central star. For this purpose we used baseline fitting and multiple passes of median filtering. In order to recover very faint extended emission the Madmap module of HIPE was used together with custom preprocessing taking care of detector drifts.

Modeling

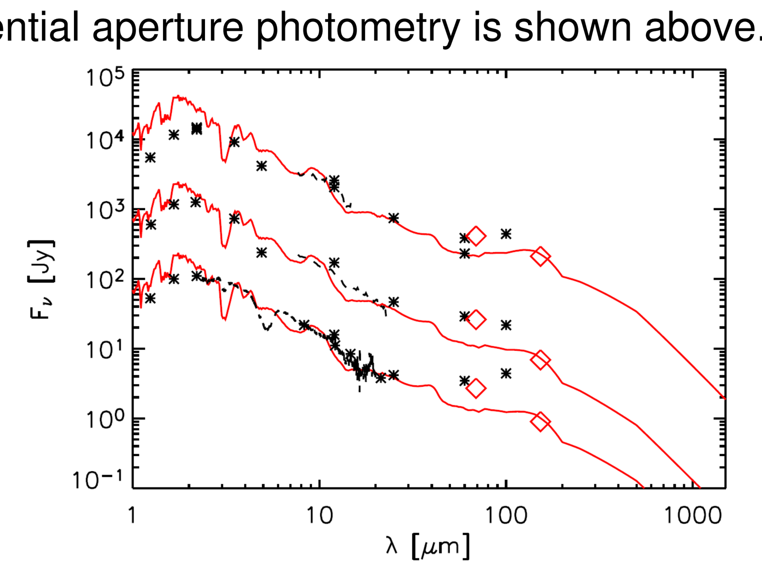
We consider the star as composed of two spherically symmetric components: an attached shell reflecting the actual mass-loss and a detached shell representing the old mass-loss. For the chemical composition we used amorphous carbon with an average spherical radius of 0.05 µm for the grain size. Using these parameters, a grid of attached and detached shells was constructed by varying the dust condensation temperature, the optical depth at 0.55 µm and the maximum outer radius of the shell.





In blue 70 µm-profiles: crosses indicate AQ And, normalised by 6.14 mJy/"², diamonds, U Ant norm. by 40.27 mJy/"², stars, TT Cyg, norm. by 3.8mJy/"². In red 160 µm-filter, norm. by 0.98 mJy/"², 5.68 mJy/"², and 0.47 mJy/"². The lines are the best fits to the data. Inserted is a zoom.

The theoretical spectral energy distributions (SED) and intensity maps were computed by the 1D radiative transfer code DUSTY [7]. By comparing these SEDs with observational data (our PACS data as well as photometry from the literature) we arrived at a best-fitting combined dust shell model, based on which synthetic intensity maps could be constructed. A comparison of the latter with intensity maps from PACS derived using differential aperture photometry is shown above.



SED fitting results. The dashed black line is the observed ISO short wavelength spectrum (SWS) and the long wavelength spectrum (LRS) (Sloan et al. 2003), the black symbols are literature photometry points, the red diamonds the PACS photometry and the continuous red line is the model. From bottom to top : TT Cyg, U Ant and AQ And, which was shifted up by 10^2 Jy for clarity.

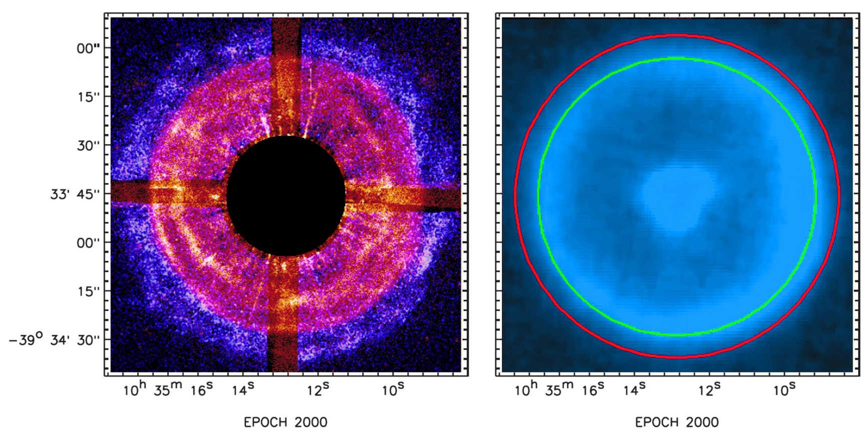
Results

AQ And intensity profiles show various peaks within the outer shell (52"), indicating mass-loss variation over time. We estimate a variation between 10^{-10} (actual) and 1.52×10^{-5} $M_\odot$/yr for the rate of previous mass-loss episodes (~19000 years ago).

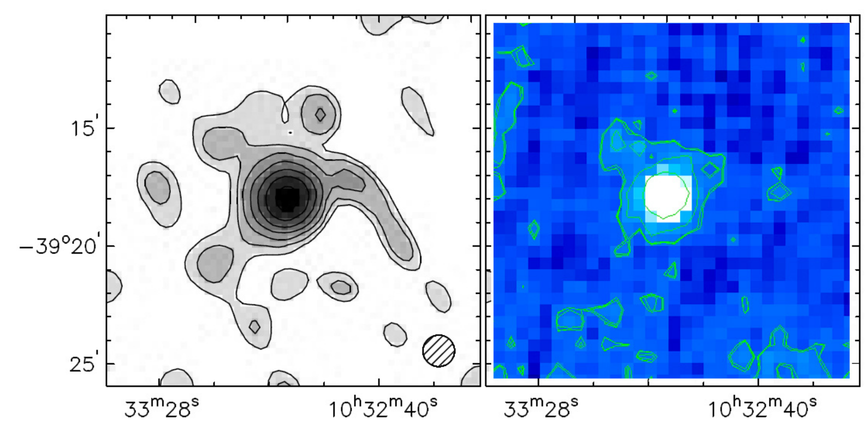
The smooth profile of **U Ant** suggests that after a sudden increase in mass-loss 2800 years ago, the rate dropped and didn't vary much. The dust shell we detect at 43" coincides with the detached shell observed in scattered light [4,8]. The thin shell at 50" has no counterpart in our data and we could only reconstruct part of the extended emission [5].

Like AQ And, **TT Cyg** shows significant variation of the mass-loss rate. The shell at 33" – caused by increased mass-loss 7000 years ago – is in very good agreement with the CO shell. The fact that our dust data for TT Cyg and U Ant coincide well with CO measurements questions the drift velocity theory which suggests that dust moves faster than gas.

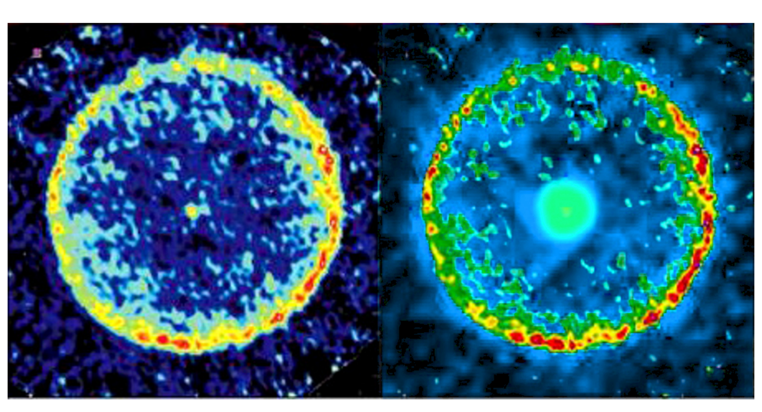
Furthermore, in all cases we see that there is still varying dust emission in the inner parts of the detached shells. This can be seen clearly from the intensity profiles. For more details we refer to [10].



U Ant: Left: Scattered light through NaD filter (red) [4] + polarised Hα (blue) [8]; Right: PACS 70µm, circles indicate the corresponding "optical" shells.



Extended field of U Ant: Left: HIRAS image at 100 µm [5]; Right: Herschel-PACS image at 70 µm rebinned to 30"/pixel.



Left: integrated CO map of TT Cyg [9]; Right: CO map superimposed on PACS 70 µm data.

References

[1] Habing, H. 1996, A&AR, 7, 97
[2] van der Veen, W.E.C.J., Habing, H.J. 1988, A&A, 194, 125
[3] Olofsson, H., Eriksson, K., Gustafsson, B. 1988, A&A, 196, L1
[4] Gonzalez Delgado, D., Olofsson, H., Schwarz, H.E., Eriksson, K., Gustafsson, B. 2001, A&A, 372, 885
[5] Izumiura, H., Waters, L.B.F.M., de Jong, T., et al. 1997, A&A, 323, 449
[6] Poglitsch, A., et al. 2010, A&A, in press
[7] Ivezic, V., Nenkova, M., & Elitzur, M., 1999, User Manual for DUSTY
[8] Maercker, M., Olofsson, H., Eriksson, K., Gustafsson, B., Schöier, F. L. 2010, A&A, in press
[9] Olofsson, H., Bergman, P., Lucas, R. 2000, A&A, 353, 583
[10] Kerschbaum, F., Ladjal, D., Ottensamer, R., et al. 2010, A&A, in press