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Probing the Mass Loss History of AGB Stars with Herschel[1]

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Abstract. An overview is given of AGB stars imaged with the PACS and SPIRE instruments on-board the *Herschel Space Observatory* in the framework of the MESS Guaranteed Time Key Programme. The objects AQ And, U Ant, W Aql, U Cam, RT Cap, Y CVn, TT Cyg, UX Dra, W Ori, AQ Sgr, and X TrA all show detached or extended circumstellar emission.

Introduction

While it is well established that mass-loss increases on average during the AGB evolution (Habing 1996), observational evidence for an episodic picture of this phenomenon had already been found in the late 1980s (van der Veen & Habing 1988; Olofsson, Eriksson, & Gustafsson 1988). Based on IRAS photometry, van der Veen & Habing identified a group of 60 μm excess objects with very low-temperature dust. Olofsson et al. (1988) found stars with obviously detached gas shells. These two indicators of perhaps the same phenomenon were subsequently used to study this interesting evolutionary phase. IRAS and ISO observations revealed a growing number of AGB stars with extended and sometimes clearly detached thermal dust emission (e.g. Young et al. 1993a,b; Waters et al. 1994; Izumiura et al. 1996). The study of detached shells in CO radio line emission has turned out to be most fruitful. Single-dish surveys (Olofsson 1996, and references therein) have revealed a number of these objects, and follow-up interferometric maps have uncovered their detailed structure (Lindqvist et al. 1999;

[1]*Herschel* is an ESA space observatory with science instruments provided by European-led Principal Investigator consortia, with important participation from NASA.

Olofsson et al. 2000). The available high spatial resolution has uncovered remarkably spherical and thin CO-line emitting shells, which indicate quite short phases of intense mass-loss probably associated with thermal pulses. An alternative origin of detached shells might be a shell–ISM interaction as described by Libert, Gérard, & Le Bertre (2007), i.e. the slowing down of the stellar wind by surrounding matter. One can probe cirumstellar dust also by looking for scattered star light (e.g. Mauron & Huggins 2000). Consequently, a number of detached shell objects were also imaged in the visual both from the ground and from space (e.g. González Delgado et al. 2001; Maercker et al. 2010). When comparing earlier dust emission observations with mm-CO and scattered light images, it is obvious that the former are hampered notoriously by the low spatial resolution that space telescopes of the 60- to 80-cm class can provide.

Consequently, the 3.5 m dish of the *Herschel Space Observatory* (Pilbratt et al. 2010) using PACS (Poglitsch et al. 2010) and SPIRE (Griffin et al. 2010) is ideally suited to change this situation. In this paper we report on 11 sources (AQ And, AQ Sgr, RT Cap, Y CVn, TT Cyg, U Ant, U Cam, UX Dra, W Aql, W Ori and X TrA) which were observed in the course of the MESS Guaranteed Time Key Programme (Groenewegen et al. 2011) in the 70 μm (P70) and 160 μm bands, some of which were also observed at the longer wavelengths of 250 (S250), 350, and 500 μm. First results on AQ And, TT Cyg, and U Ant were presented in Kerschbaum et al. (2010). For details on the data reduction we refer to Groenewegen et al. (2011) and Ottensamer et al. (2011). In order to measure shell radii we calculated radial profiles by azimuthally averaging the pixel intensities at a certain radius from the central star. Using the derived profiles, the approximate intensity peaks of the detached shells were located (Mecina et al. 2011).

Correlation

Having much higher spatial resolution dust-emission data available from our new *Herschel*–PACS imaging, one can compare them with the other two probes of circumstellar material, namely mm-CO emission and scattered light. Figure 1 gives three examples of what is possible, when applying deconvolution techniques (Ottensamer et al. 2011). In the case of U Ant we overplot our 70 μm emission with scattered light data in the visual Na I resonance line from (Maercker et al. 2010). While they see four shells in total, we observe only the one at 43″ radius that is also visible in mm-CO emission. The prototypical detached shell of TT Cyg is our second example. The new 70 μm material correlates very well with the overplotted velocity-integrated CO (1-0) emission from Olofsson et al. (2000), again giving no indication of any drift between dust and gas. The last example, namely U Cam, is overplotted with contours from an interferometric map in CO (1-0), this time only at the systemic velocity (Lindqvist et al. 1999). The small 9″ radius of the shell is a challenge for the 5.″5 PSF of *Herschel*–PACS at 70 μm. A detailed comparison of all the complementary datasets, including combined modeling, is planned for these objects and a few others.

Far Out and Faint

Another challenge is to look for extended, faint emission in our *Herschel* images. As outlined in Groenewegen et al. (2011) and Ottensamer et al. (2011), our current data reduction – partly based on high pass filtering – is prone to lose part of the extended structure of the observational material, structures in some cases well known from IRAS, ISO, or *Spitzer* observations at lower spatial resolutions. Nevertheless, in some objects

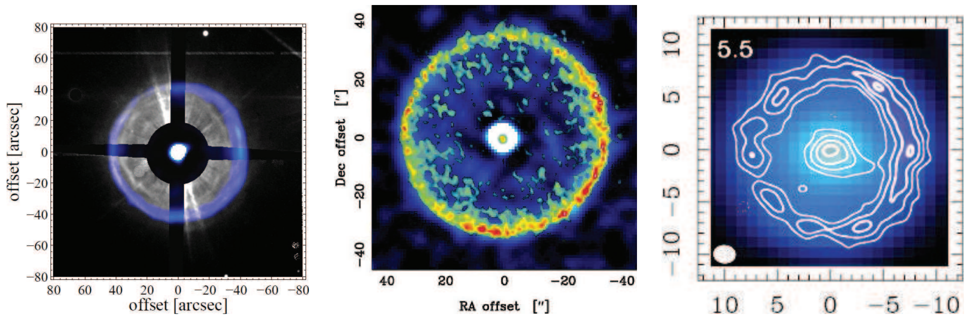

Figure 1. *Left*: U Ant, 70 μm (P70, deconvolved) with Na resonance line from Maercker et al. (2010); *center*: TT Cyg (P70, deconv.) with velocity-integrated CO (1-0) from Olofsson et al. (2000); *right*: U Cam (P70, deconv.) with systemic velocity CO (1-0) from Lindqvist et al. (1999).

interesting features are already seen far from the central object. Figure 2 gives three examples. Map sizes are given in arc minutes; moreover in two cases all detectable point sources (PS) are removed for clarity. U Ant, the first example, was already suspected of showing distant (and circular) emission at about 3′ radius from IRAS maps obtained at 60 and 100 μm by Izumiura et al. (1997). Now using SPIRE data at 250 μm, a direct relation to the stellar source turns out to be questionable. Large filamentary structures are extending far from the object and make an ISM background or foreground contribution more plausible. Nevertheless, a wind–ISM interaction (see Jorissen et al. 2011) cannot yet be excluded. A detailed temperature map using all bands and employing a new reduction conserving all the extended emission may solve this puzzle. U Cam with its small, spherically symmetric, detached shell (see above and the small insert in Fig. 2) provides surprises when looking at its larger field. An extended elliptical or double bow-like structure with radii between 60 and 100″ becomes visible. The different geometry points to a different origin, perhaps wind–ISM interaction or an inclined more ring-like outflow, possibly influenced by binarity (Proust, Ochsenbein, & Pettersen 1981). Whereas the inner detached shell corresponds to a time-scale of about 1,000 years, the new structure could then correspond to about 12,000 years. Finally, Y CVn's dusty detached shell is known from ISO imaging (Izumiura et al. 1996). We can now extend this imagery to longer wavelengths. Fig. 2 shows Y CVn looking very similar at 250 μm using SPIRE.

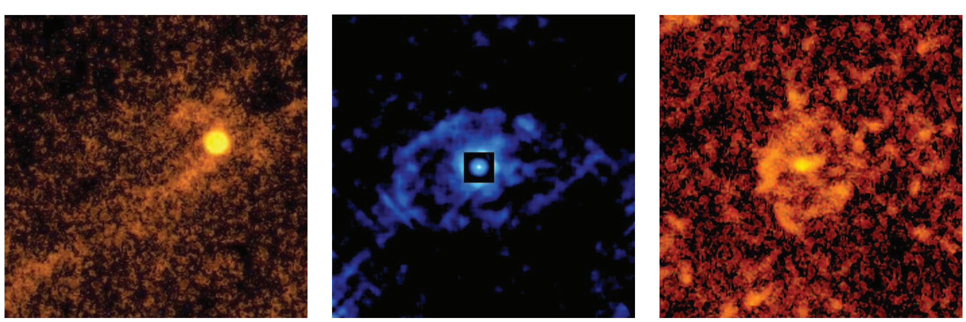

Figure 2. *Left*: U Ant, 250 μm (S250), 20′, point sources removed; *center*: U Cam, P70, 6′, two different intensity scales; *right*: Y CVn, S250, 20′, PS removed.

New Ones

When using *Herschel*–PACS on a larger sample of AGB stars for the first time, it does not come as a surprise that a number of new objects exhibiting faint detached emission structures are detected. The same holds for wind–ISM interactions discussed in Jorissen et al. (2011) and Mayer et al. (2011). Figures 3 and 4 show some typical examples. Some were already known by observations at other wavelengths and suspected to have extended shells (e.g. Young et al. 1993a,b).

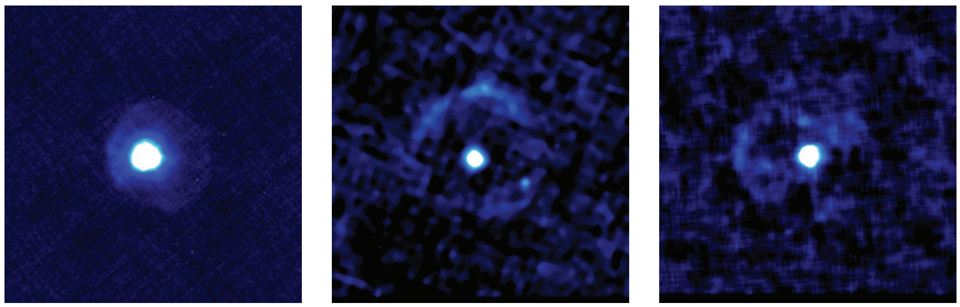

Figure 3. *Left*: W Aql (P70, 6′); *center*: UX Dra (P70, 6′); *right*: X TrA (P70, 10′)

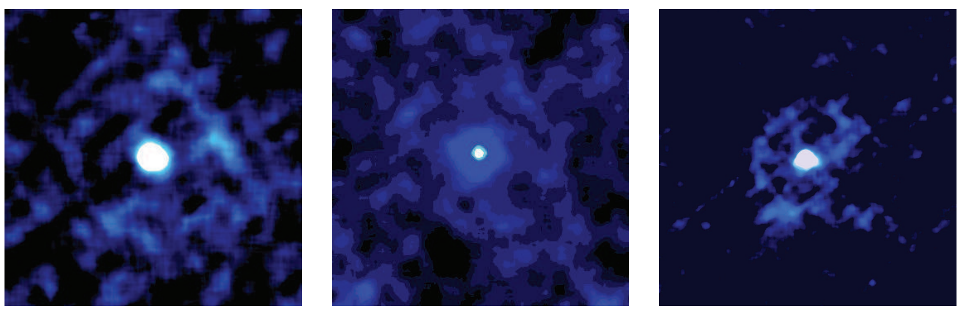

Figure 4. *Left*: RT Cap (P70, 6′); *center*: W Ori (P70, 6′); *right*: AQ Sgr (P70, 6′)

Some shells show offset emission with respect to the central star (e.g. W Aql, the only S star in our sample). In the faintest cases (e.g. RT Cap, W Ori) the detection of their shells is much more obvious in azimuthally averaged intensity profiles. Using distance and expansion velocity data from the literature and the apparent radii from the profiles, we calculated the actual physical radii and expansion time-scales (age, in Table 1) of the detached shells. Distance data from the Hipparcos catalog (van Leeuwen 2007, HIP) were used for most stars in our sample. For the remaining ones we used distances based on period-luminosity relations (Bergeat & Chevallier 2005, P-L). The expansion velocities of the dust were assumed to match the values of the gas component found from CO/HCN measurements (Loup et al. 1993). Taking into account these numbers we ended up with ages ranging from about 6,000 (W Aql) to almost 30,000 (X TrA) years, keeping in mind the rather large uncertainties. The profile for UX Dra is presented in Mecina et al. (2011). The derived values for the six new objects are summarized in Table 1.

Table 1. Basic geometrical and dynamical data for the new dust shells

object	distance [pc]	source	radius [″]	radius [pc]	v_{exp} [km/s]	age [yr]
W Aql	330	P-L	67	0.11	19	6,000
UX Dra	390	HIP	76	0.14	6	23,000
X TrA	360	HIP	155	0.35	9	30,000
RT Cap	290	HIP	95	0.13	9	14,000
W Ori	380	HIP	91	0.17	11	15,000
AQ Sgr	790	P-L	62	0.24	10	24,000

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Discussion

Engels: Is the predominance of detached shells in C-stars a selection effect?

Kerschbaum: From our Herschel sample one can say that we would detect comparable detached shells around O-rich objects which is not the case.

Lloyd Evans: W Aql has a near infrared excess, which may indicate a disc very unusual in a red giant star, as opposed to Post-AGB. Herbig (1964) reported a spectrum composite, type A-F in the violet. Does your work support a disc model?

Kerschbaum: From the imaging material we have, we at least see clear indication for a deviation from spherical symmetry!

Herschel rules (Franz Kerschbaum).