Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
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Exploring dust mass and dust properties of nearby AGB stars

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Abstract. Low and intermediate mass stars evolve to the asymptotic red giant branch (AGB) late in their lives. These are surrounded by a circumstellar envelope (CSE) filled with gas and dust. The dust is formed close to the star at sublimation radii and is pushed away by the stellar wind. The dust in turn pushes gases from the envelope into the interstellar medium, thus enriching it with metals. This poster summary is a general description of the next piece of a larger project, whereas the first half has been published by Nicolaes *et al.* (2018). We now aim to use radiative transfer simulations to model spectral energy distributions (SED) of dust and fit them to far-infrared observations for the same 40 sources. We will use 2D and 3D simulations and models containing several dust species simultaneously.

Keywords. stars: AGB and post-AGB, (stars:) circumstellar matter, stars: mass loss, stars: winds, outflows, infrared: stars, submillimeter

1. Introduction

Low and intermediate mass stars, up to about 8 $M_\odot$, enter the AGB in the late stages of their lives. AGB stars are surrounded by a CSE consisting of a rich mix of molecules and dust. The dust, which is formed relatively near the star at certain condensation radii (a few up to $\sim$ 10 stellar radii), is pushed outwards by intense stellar winds through the CSE. This outflow pulls with it gases from the CSE which enriches the interstellar medium (ISM) with metals, see e.g. review by Höfner & Olofsson (2018).

Our aim is to use more detailed models for SED fitting than what is commonly used, and to estimate the morphology and mass of the dust in the envelopes of a sample of 37 AGB stars and 3 red super giants (Nicolaes *et al.* 2018) for which *Herschel*/PACS (Pilbratt *et al.* 2010, Poglitsch *et al.* 2010) and, in some cases SPIRE (Griffin *et al.* 2010) spectra are available. A large portion of these sources were also in the Mass loss of Evolved StarS *Herschel* Key Programme (MESS, Groenewegen *et al.* 2011). Archived observational photometric and spectral data will also be used, mainly to determine the stars' SEDs. Models of the stellar photospheric SEDs are extracted from the MARCS grid (Gustafsson *et al.* 2008)†.

We will simulate dust SEDs with MoD (More of Dusty, Groenewegen 2012)‡ and the monte-carlo based program RADMC-3D (Dullemon 2012)§ for non-standard morphologies and dust distributions. This way we may obtain estimates on grain sizes and constituents, which gives dust masses and also dust mass losses. In the cases where the gas mass is known we may estimate dust-to-gas ratios.

† http://marcs.astro.uu.se
‡ http://homepage.oma.be/marting/codes.html
§ http://www.ita.uni-heidelberg.de/~dullemond/software/radmc-3d/index.html

2. Project description

We employ SED fitting to estimate e.g. total dust masses, dust properties, and to explore the spatial distribution of different dust species around nearby AGB stars. The sources are within 1 kpc with few exceptions. The most distant source is V1365 Aql at 4.30 kpc (Justtanont *et al.* 2006).

We will use 2D and 3D radiative transfer. The aforementioned RADMC-3D is still under development, but is already applicable and has been proven useful in a variety of publications†. Some of the strengths of RADMC-3D are that we can assume any dust distribution of several arbitrary species and any number of stellar sources.

It is common to assume spherical symmetric dust distributions of one species when studying dust in CSEs. We will initially assume spherical dust distributions also, however, we will consider several dust species simultaneously, and will vary the density distributions (assumed to be a powerlaw, $\rho \propto R^{-k}$) and size of the dust cloud. The inner radii of each species is constrained by their sublimation temperatures and we will also consider interferometric observations, when available, to better model the inner part of the dust shell.

The risk is an ever-growing parameter tree while SED fitting relies on only one dimension. This issue can be addressed with spectral data from which the constituents and the size range of the dust grains can be constrained. We can also use theory to constrain some of the parametres as e.g. the inner radii, the density distribution, and a range of realistic grain size distributions. The grain sizes will initially be monosize, however, later we may adopt e.g. an MRN-like distribution as in the ISM (Mathis *et al.* 1977).

We limit the dust species to two cases. For O-rich stars, we will initially assume that iron poor magnesium-silicates are formed at ~ 2 to $3\,R_{\rm star}$ from the stellar centre (we also note that aluminium-oxides and titanium-oxides may be important as grain seeds). Iron will be added further out as $MgFeSiO_4$-dust (~ 4–5 to $9\,R_{\rm star}$). For C-rich stars the model is similar, but we will assume amorphous carbon grains as initial grains instead.

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† An incomplete list of publications at:
http://www.ita.uni-heidelberg.de/~dullemond/software/radmc-3d/publications.html

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