Modelling the AGB dust evolution

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1. Observational evidence

Cosmic dust (i.e., microscopic solid bodies with sizes on the order of μm) constitutes an essential ingredient of the cosmic cycle of matter. The dense outflows of stars in the late evolutionary stage of the Asymptotic Giant Branch (AGB) are believed to be the primary source of newly formed dust particles in the universe.

Observational studies of circumstellar dust around evolved red giants, as e.g. ... adopted from Speck (2012).

Based on data of Sloan et al. (2003b), the figure was stars exhibiting the 13μm-feature (solid) or not (dotted).

2. Modelling approach

- Models simulating stationary dust-enshrouded winds of AGB stars (beyond >2R_s) as described in Ferrarotti & Gail (2006) with recent improvements of the wind code (Gail et al., in prep.).

- The coupled set of equations of hydrodynamics, radiative transfer and dust formation is solved iteratively, which is necessary due to the strong backcoupling between (i) temperature-dependent dust condensation / evaporation, and (ii) the effect on the resulting wind structure caused by radiation pressure on the grains.

- Main asset: detailed circumstellar dust mineralogy including various relevant dust species for O- and C-rich chemistry.

- Not included are the layers of the (pulsating) photosphere (for the RT simulated by a blackbody emitter at the inner boundary).

- Fundamental input parameters: L, T_\text{eff}, M/M_\odot, Z/Z_\odot, C/O ratio, u_\text{initial}, MLR

- Outcome: (typical example → Fig. 2)
  - radial distribution of gas density / temperature / velocity in the wind region
  - for various dust species the radial distribution of condensation degrees, grain sizes / temperatures, drift velocities, and Mg/Fe-ratio (if needed)
  - resulting SED of the star including the influence of the dust shell (needed → Fig. 4)

3. Comparing models with observations

- One of the main aims of our modelling: reproducing the mineralogical composition of circumstellar dusty envelopes as a function of evolutionary stage (i.e. mainly MLR) during the AGB phase.

- Sequence of dust evolution along the AGB (as sketched in Sect. 1) traced with representative objects (g Mer → EP Aqr → Cet / Mira → AFGL 5379)

- of increasing mass loss from low MLRs to dust-enshrouded ...

- ... and a series of corresponding wind models successfully resembling the observational findings. → Fig. 4

- Intention: reproducing the variety based on a unique set of dust input data (considered species, optical constants, growth coefficients α), only varying the fundamental model parameters (esp. MLR, L/Z, C/O). Not fully reached, yet.

References:

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Fig. 1: Adopted from Speck (2012).

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