Radial and Nonradial Pulsations as Probes of Stellar Physics
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Dust and Wind Formation in Low-Metallicity AGB-Stars

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1. Introduction

The formation of dust and wind in luminous AGB-stars has been studied so far mainly for solar metallicities. Here, the impact of the dust component on the driving mechanism of the massive outflows and the non-linear coupling to hydro/-thermodynamics leads to the creation of dust-induced shock waves, the occurrence of onion-like spatial dust distributions around the star, time-dependent dust-size distributions, multi-periodicity, and the onset of a super-wind phase (see Sedlmayr, these proceedings). The question remains whether these phenomena appear also in metal-deficient models of AGB-stars like those in the Large Magellanic Cloud (LMC).

2. The effect of LMC metallicity

Time-dependent, spherically symmetric models of carbon-rich dynamical atmospheres of LPVs are calculated by means of the CHILD-code (Fleischer et al., 1992) in an updated version of Helling et al. (2000; also Winters et al., 2000). The one-dimensional numerical simulations are carried out by solving the equations of time-dependent hydrodynamics, dust formation (nucleation, growth, evaporation; Gail & Sedlmayr, 1988), grey time-independent radiative transfer ($\kappa_{\rm gas} = \kappa_{\rm Planck}$), and equilibrium chemistry. These time-dependent models are completely determined by 4 stellar parameters ($T_\star$, $L_\star$, $M_\star$, C/O) and 2 pulsational parameters (pulsation period P and velocity amplitude Δu).

HYDRODYNAMICS: The small efficiency of dust formation at low LMC metallicities causes the models to evolve very slowly. Episodic events of outward acceleration due to $a_{\rm rad} > g_\star$ are followed by long periods of matter falling inward. Radiation pressure on the gas has to provide a substantial part of the driving force to overcome the stellar gravity. Nevertheless, the total radiative acceleration is sufficient to *slowly expand the shell which surrounds the star.* Apart from the innermost, shocked and levitated layers, the calculated models ($T_\star = 2600, 3000$K; $L_\star = 10^4 L_\odot$; $M_\star = 1\,M_\odot$; C/O= 1.8; $\Delta u = 2$km s^{-1}; $P = 650\,$d) appear quasi-static over hundreds of periods. In contrast to the solar metallicity case, the dust is mainly located in a single (not necessarily homogeneous) shell around the star, since the backwarming by dust is not large enough to trigger the exterior κ-mechanism (Fleischer et al., 1995).

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DUST: Multiply peaked dust-size distributions are characteristic for the circumstellar dust shell. They are the result of the time dependent dust formation history which influences the pulsational appearance of the star (double pendulum: interior pulsation and dust shell formation in the CSE). The largest amount of small particles appears at $\sim 3\,R_0$ where the nucleation rate peaks. Most of the largest particles (up to $\sim 0.5\mu$m) are found here, too, since dust particles, accumulated by various infall events, continue to grow if conditions remain favorable.

WIND PROPERTIES: Mean values of the mass loss rate $\dot{M}$, the outflow velocity v_∞ and the dust-to-gas ratio $\rho_{\rm dust}/\rho_{\rm gas}$ are rather difficult to define because of the quasi-static shell structure. Considering the time means $\langle\ \rangle_t$ at various radial positions, one observes from the time dependent models:

- $\langle\dot{M}\rangle_t$, $\langle v_\infty\rangle_t$, $\langle\rho_{\rm dust}/\rho_{\rm gas}\rangle_t$ vary depending on the radial distance.
- Dust containing regions show the largest values for $\langle\dot{M}\rangle_t$, $\langle v_\infty\rangle_t$, $\langle\rho_{\rm dust}/\rho_{\rm gas}\rangle_t$.
- Locally, $\langle v_\infty\rangle_t < 0$ and $\langle\dot{M}\rangle_t > 0$ may occur since low density material falls inward for a long time, but dense material flows outward only in short time intervals.

The radially averaged time-mean values $\langle\dot{M}\rangle_{t,r}$ and $\langle v_\infty\rangle_{t,r}$[2] deviate largely from the values of the solar metallicity case. $\langle\rho_{\rm dust}/\rho_{\rm gas}\rangle_{t,r}$ is much less affected but smaller than for solar metallicity. However, recent observations indicate that the mass loss rate of LMC AGB-stars does not differ significantly from solar metallicity AGB-stars but the dust-to-gas ratio is smaller (van Loon et al., 2001).

3. Conclusions

Our results suggest that the metal content of an LMC gas in the extended atmosphere of an AGB star (*dustosphere*; see Schirrmacher et al., 2001) is too low to efficiently drive a wind by radiation pressure on dust grains alone. An additional driving mechanism – different from those already included in the models (pulsation, radiation pressure on dust and molecules) – has yet to be identified.

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