DUST DRIVEN WINDS

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Abstract. The status of dust driven winds, constituting an important subclass of essentially radiation generated winds, is surveyed. Dust driven winds are conceived as a long lasting phenomenon of heavy mass loss concerning those luminous cool giants and supergiants, where dust condensation in the expanding flow determines both the stellar mass loss rate and the subsonic-supersonic transition of the velocity field. Our contribution aims at a self-consistent description of the dynamical shell structure with particular emphasis to the theoretical aspects of this important phenomenon. Thus, not only the complex coupling of the various ingredients (hydrodynamics, chemistry, radiative transfer, dust nucleation, and growth) is outlined in detail, but also general arguments regarding the overall structure of such winds and the expected position of their central objects in the Hertzsprung–Russel diagram are conducted. A selected typical self-consistent model for a stationary C-star shell demonstrates the characteristic wind structure and gives insight into the close nonlinear interplay between dust formation and wind generation. During the late evolutionary stages of a star along the AGB dust driven mass loss provides a natural self-accelerating mechanism which easily can produce very high mass loss rates, an effect which possibly might play an important role for the Tip-AGB objects and the AGB-PN-transition.

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1. Introduction

Stellar winds are a common phenomenon which is observed at nearly all stages of Main-Sequence and post-Main-Sequence evolution, thus causing a continuous mass loss during most of the active life time of a star. For the sun, the present mass loss rate \( \dot{M} = 2 \times 10^{-14} M_\odot \text{yr}^{-1} \) is very small, but for very luminous red giants and supergiants \( \dot{M} \) can amount to tremendously high values up to \( 10^{-4} M_\odot \text{yr}^{-1} \).

Inspection of the Hertzsprung–Russell-diagram shows that significant mass loss rates (say \( \dot{M} > 10^{-6} M_\odot \text{yr}^{-1} \)) caused by winds only are to be expected for high luminosity objects like massive hot stars at the upper region of the Main Sequence (in this context see the review of Kudritzki et al.: 1991) or low mass cool giants and supergiants with effective temperatures \( T_e \) below 3500 K (e.g., de Jager, 1983; de Jager et al., 1988; and Lafon and Berruyer, 1991).

These investigations indicate that nearly 90% of the total stellar mass loss in our galaxy originates from cool high luminosity stars, i.e., red giants and supergiants, in particular from Asymptotic Giant Branch (AGB) stars, which by far provide the largest contribution to the stellar mass injection rate into the interstellar medium (cf. Gehrz, 1989). Since the outflows of these stars usually show considerable fractions of circumstellar dust, a close connection between dust condensation and the dynamical wind structure is naturally suggested (cf. Sedlmayr, 1994).

Regarding the driving mechanism for a stellar wind, basically two possibilities are distinguished:
- radiation driven winds,
- pressure driven winds.

In the case of radiation driven winds, the acceleration of the matter is caused by the absorption of radiative momentum in the outermost layers of the stellar atmosphere by either the plasma components (winds of hot stars) or by molecules and dust particles (winds of cool stars). In the case of pressure driven winds, the acceleration is attributed to the dissipation of mechanical energy provided by convection zones, stellar pulsations, shock waves etc. at some outer region of the star’s atmosphere. Examples for pressure driven winds are the solar wind, which is generated by the dissipation of mechanical energy originating from the solar convection zone, and winds of pulsating variables which are induced by shock wave dissipation in the extended shells.