Towards 3D simulations of dust-driven winds of AGB stars

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Abstract

Stars on the asymptotic giant branch sustain phases of strong mass loss, a process which has been modelled successfully in terms of dust-driven winds. While detailed 1D radiation hydrodynamics calculations already give insight into characteristic properties like mass loss rates and wind velocities, it would be interesting to see a full 3D structure of these winds. In our earlier investigations we included dust formation and grain growth into 3D "star-in-a-box" simulations. In this contribution we report first results and challenges considering models which take radiation pressure on dust grains into account.

1. Introduction

Freytag & Höfner (2008, A&A 483, 571) presented results from simulations with the RHD code CO5BOLD developed by Freytag et al. These time-dependent 3D models of the outer convective layers and the atmosphere of an AGB star included dust treatment allowing for formation and growth of grains without feedback into the gas dynamics. They showed giant convection cells which led to atmospheric shocks and levitation comparable to the effects of pulsation in 1D models, but failed to produce a wind since the radiative pressure on dust was not included in these exploratory models.

2. Computations

- Here, we present a first simulation which includes the effects of radiation pressure on dust grains.
- We simulated a carbon-rich (C/O = 1.4) AGB star with effective temperature T_{eff} = 2800 K, mass M = 1 $M_\odot$, luminosity L = 7000 $L_\odot$.

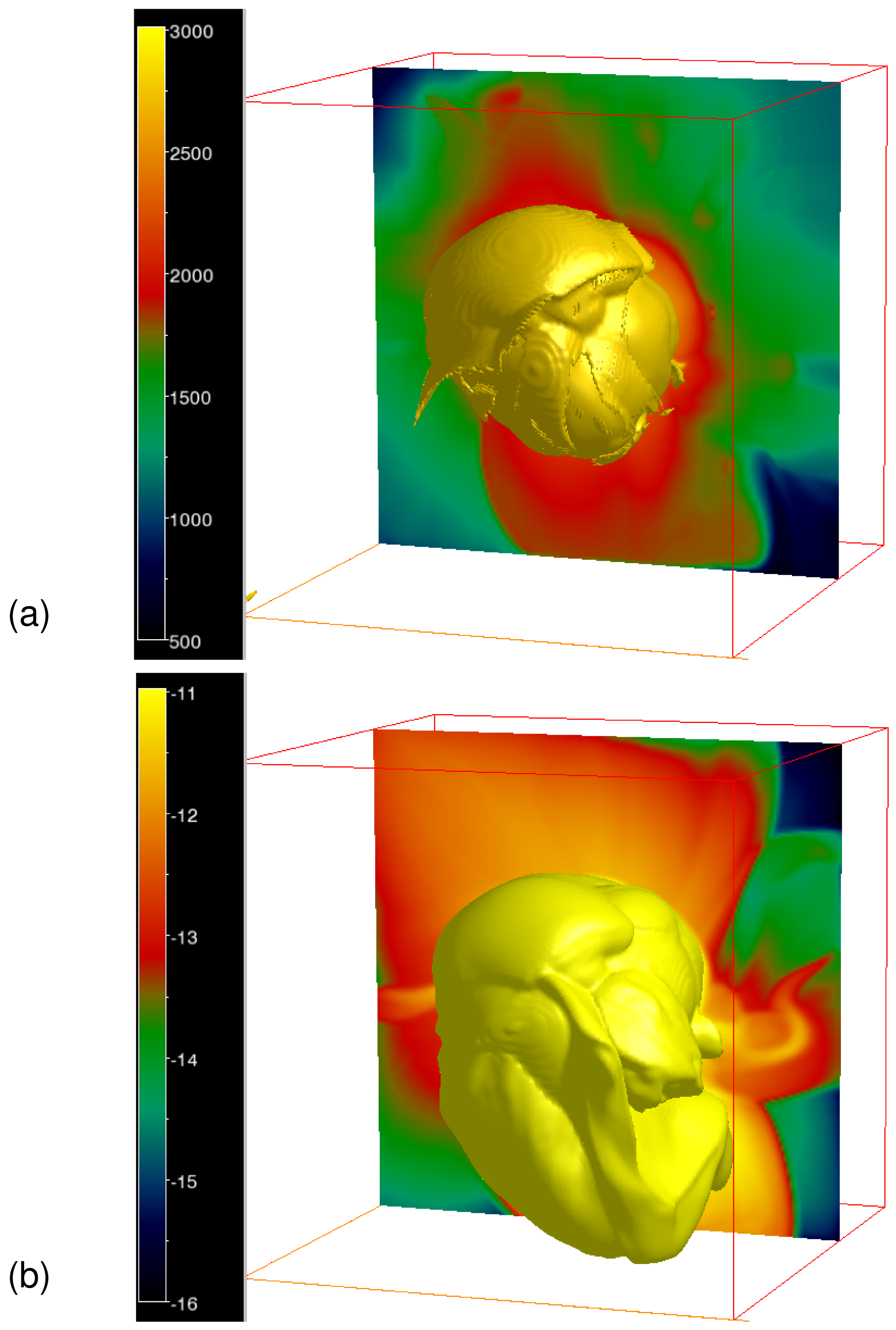

Figure 1: *Temperature (a) and density structure (b) of the common start model shown exemplarily at a slice at d = 2.05 $\cdot 10^{13}$ cm (d = 0.8 $R_\star$) from the center. The isosurfaces show T = 2800 K which is the assumed stellar temperature and $\rho = 10^{-11}$ g cm^{-3}, respectively.*

- We have been running this model with and without activated radiation pressure for 828 days in model time. The total run time for these runs was 94 and 44 days, respectively. This illustrates the underlying problem that the time step drops drastically once one takes the feedback of the dust grains into account.

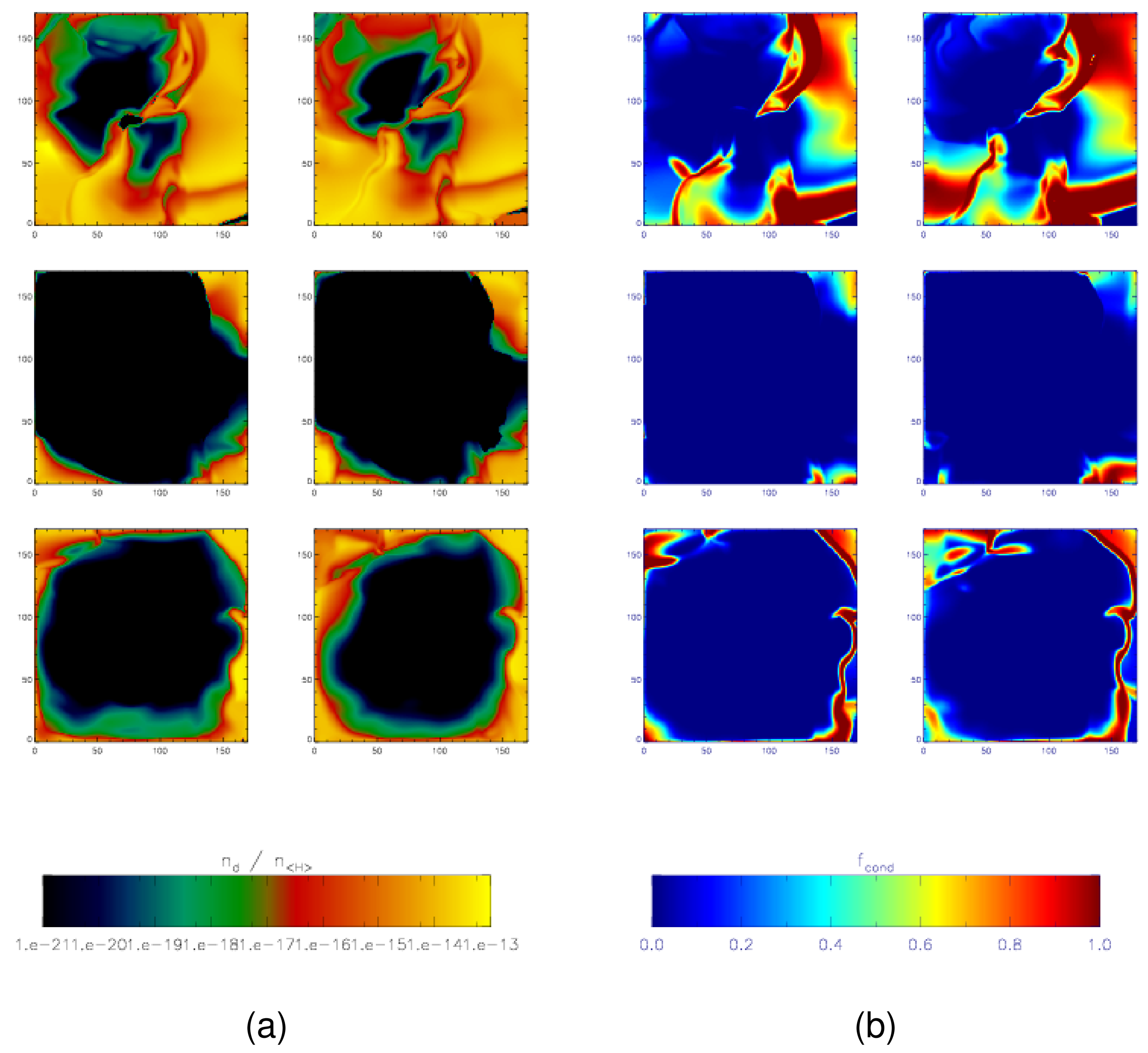

Figure 2: *Comparison of models in (a) number of dust particles per hydrogen atom and (b) degree of condensation for three slices at distance from centre d = -5.8 $\cdot 10^{13}$, -1.0 $\cdot 10^{13}$, and 4.4 $\cdot 10^{13}$ cm (-2.3, -0.4, and 1.8 $R_\star$; top to bottom). Left columns are models with radiation pressure activated, right columns are without.*

3. Conclusions and Outlook

- On a first glance the results from the two model runs are very similar (fig.2), i.e. there is no obious structural change. But in the radiatively driven case the areas with low dust density (the black / blue parts in the centre) are expanding as a result of the radiation pressure.
- It is important to point out that with the actual box size of $(1.16 \cdot 10^{14}\ \mathrm{cm})^3$ or $(4.7\ R_\star)^3$ one hardly covers the dust acceleration zone which starts typically at 2–3 $R_\star$.
- Therefore we persuit the idea to extend the box in one direction. In first test runs, however, numerical problems occured so that further investigation is needed. In this context the issue of small time steps certainly needs to be addressed.