DUST AND WINDMODELLING OF BORN-AGAIN PNE CORES

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ABSTRACT

It is a long, hard way to a fully consistent evolutionary hydrodynamic model in 3D to describe stellar winds and do we really need it after all? What makes born-again objects so special in the context of dust and windmodelling? I present a few of my ideas to achieve a hydro code combining photoionization of the gas, dust formation as well as evolution and also radiative transfer in 3D.

Key words: stars: AGB and post-AGB; stars: evolution; ISM: planetary nebulae.

1. INTRODUCTION

Many codes have been developed to treat gaseous media with hydrodynamic methods. In order to adapt these codes to a specific problem, appropriate source terms (wind acceleration, dust formation, external potential, radiative cooling), equations of state, boundary conditions and initial conditions have to be introduced.

Planetary nebulae (PNe) represent the final stage of thermonuclear burning stellar evolution of low to mid mass stars. We know very little about the transition of an AGB star to the PN phase. The observation of post-AGB stars shows complex repeating dust formation episodes (Simis et al., 2001). Still we have to estimate the timescales and the final motivation of the shell ejection. Due to their complexity the physical processes within the shells of PNe have been modelled assuming spherical geometry, homogeneity of the material, homogeneity and continuity of the density gradient and simple solutions of the radiative transfer (RT) equations.

A born-again PN arises from the central star of a normal PN that undergoes a very late helium flash before the final cooling of the white dwarf. As a result of this flash the star returns in an astoundingly fast transition to the tip of the AGB. The next transition from the AGB to the final white dwarf is performed at *fast forward* speed. Because of the short timescale, only few of these interesting objects are known. Their lower mass reduces the gravitational binding, and the higher metallicity enhances the dust formation mechanisms. Due to the unusual chemistry as shown e.g. in Blöcker (2001) we have got a totally different line absorption efficiency in the wind. New modules for treating dust together with this carbon rich wind have to be invented.

The status of the modelling nowadays covers static investigations containing either the gas or the dust component only. Other physical processes have been studied individually. All those investigations already show that the individual, decoupled descriptions of the physical processes are insufficient. Further, they still suffer from the restrictions of the spherical geometry and from the static solutions. As can be seen in images of the born-again PN V605 Aql (Hinkle et al., 2003) or in the H-deficient PN A30 (Borkowski et al., 1994), a spherical, symmetric approach is inadequate.

2. APPROACH TO A 3D HYDROCODE

A basic 3D hydro with piecewise parabolic (PPM) shock wave detection, radiative cooling kernel and the handling of an external gravitational potential already exists: CHARYBDIS (Ruffert, 1992), which is based on PROMETHEUS (Fryxell et al., 1991). This nested grid code was developed to calculate supernovae explosions and was also successfully applied to calculate the surroundings of neutron star collisions (Ruffert & Janka, 2001). Its code kernel is also the core of the adaptive mesh grid code FLASH (Fryxell et al., 2000), which is mainly used for cosmological calculations and for Novae explosions, but also by Woitke & Helling (2004) for AGB winds. CHARYBDIS was recently MPI parallized at my institute to model the Coma Cluster.

The advantage of a PPM code over the use of, e.g., DUSTY is the possibility of including shocks (Tyne et al., 2000). The He-line in post-AGB/proto-PNe at 1.08μm shows the need for such an extension for at least some periods. Up to now it lacks the treatment of optical thick radiative transfer computations.

The Plug-in Scheme:
The PROMETHEUS hydro core was extensively tested by various groups worldwide for stability against source and cooling terms. Thus, after each

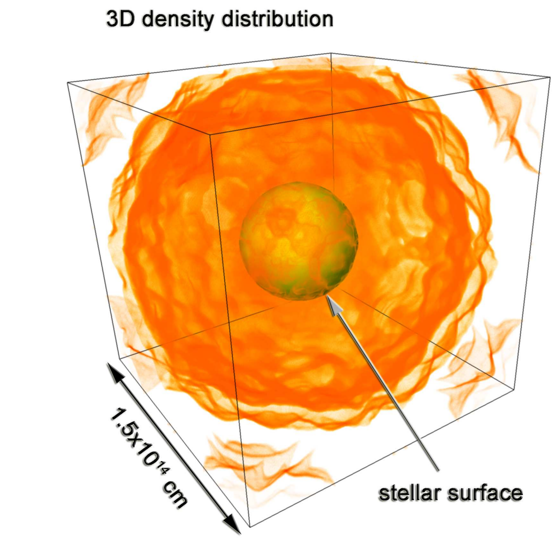

Figure 1. 3D snapshot visualization of a density profile for a static non rotating stellar model

time-step separate routines change the properties of the hydro result by nonlinear terms of the equation of state (EOS). It has been proven that this is even stable against thermonuclear runaway processes.
This is why we can apply various codes and descriptions for the other physical processes as kind of *plug-ins* to calculate the local EOS (e.g. additional forbidden line cooling) in every time step. The dust code NILFISC (Koller & Kimeswenger, 2001) already allows completely local calculations. CLOUDY (Ferland, 1996) also allows the calculation of a local slab. With the plug-in scheme the intended local modules don't need to be parallized individually, only appropriate input–output interfaces have to be written. This leads to a modular parallel code transportable to GRID-like parallel computer architectures.

2 Steps for 1 Goal:
First attempts with the PPM hydro code suggested a proceeding consisting of two steps as suggested by the special physical property of the wind solution. Up until the critical radius the stellar wind is only a logic continuation of the atmosphere, whereas beyond it, it gets a life of is own.

- In the first step hydrodynamic initial values will be generated with a resolution high enough for a round surface of the star starting hydrostatically with simplest possible star-models, but full control over initial disturbances.
- In the next step these hydrodynamic physical initial values beyond the critical radius will be used to calculate the time evolution in a resolution that best fits the size of the expanding shell and with fine time steps.

The number of nested grids in the CHARYBDIS will be reduced to 2, whereas the resolution will increase with available computer power. This not only suits the structure of the problem but also simplifies the demands on the parallel computing architecture.

The evolutionary tracks of central stars of PNs are not very well known. By applying the codes to different input radiation, we have to isolate the parameters which are significant for the evolution. The parameters for the initial values of the radius and corresponding temperatures at different time-positions in the Hertzsprung Russel Diagram (HRD) and for different final white dwarf masses will be taken from several evolution theories (Blöcker, 2001; Herwig, 2003). For every track in the HRD many step 1 calculations have to be carried out for one step 2 calculation.

3. CONCLUSION

Nowadays hydrodynamic simulations in the circumstellar environment suffer from the fact of 1D spherical simulations or 2D cylindrical solutions. A more general 3D code, not forcing a certain geometry, that imprints on the solution, is of high importance.
Additionally, a great variety of explicit source terms (wind acceleration, dust formation, etc.) and dedicated equations of state are needed. There exists a bundle of individual solutions for each of the problems in scalar codes. The physics is well understood. The coupling and the importance of individual tasks on the overall solution so far are unstudied.
A combination of 3D hydrodynamic simulations with radiative transfer codes and dust formation / evolution codes describing the observational data will deliver new insights in the mechanisms and interactions of the physical processes.

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