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Evolutionary effects of stellar rotation of massive stars in their pre-supernova environments

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Abstract. Massive main sequence stars are fast rotators. Stellar rotation affects massive stellar rotation due to rotationally induced mixing processes, the increase of mass loss rates, etc. and also affects the circumstellar medium due to their interaction with the stellar wind. The parameters of stellar winds depends on stellar parameters so the wind parameters change as the star evolves, coupling the evolution of circumstellar medium to the star itself. In this work we used a stellar code to build models of two massive stars (30 and 40 $M_{\odot}$) and we used their wind parameters to simulate the hydrodynamics of their surrounding gas with the ZEUS-3D code in order to explore the effects of stellar rotation in the pre-supernova environments.

Keywords. stars: rotation, stars: evolution, stars: circumstellar matter

1. Introduction

The strong mass loss in massive stars affects significantly their stellar evolution. When the stars pass through evolutionary phases they develop different stellar wind parameters which may produce a wide variety of structures in the surrounding gas. At the end of its life, the star will explode in a SN explosion and the resulting shock wave will interact with this modified medium. In this work we built up several stellar evolution models (using the STERN code, Langer & El Eid, 1986) and their corresponding circumstellar gas evolution. We calculate four stellar models with masses of 30 and $40 M_{\odot}$ in two sequences of stellar models that are calculated with the same input physics, differing only in the value of their initial rotational velocity in order to compare the effect of rotation in stellar evolution and their circumstellar pre-SN environment. We calculated a non-rotating model with an initial rotational velocity of $V_{rot} = 0$ km/s (**model A**) and a rotating model with $V_{rot} = 200$ km/s (**model B**) as the models used by Pérez-Rendón *et al.* (2008). Then we have used the values of mass loss rate and stellar wind velocity as inner boundary conditions in an explicit hydrodynamical code ZEUS-3D (Stone & Norman, 1992) to simulate the hydrodynamical evolution of the circumstellar medium. These numerical simulations are done in the same way as García-Segura *et al.* (1996), Pérez-Rendón *et al.* (2009).

2. Rotational effects

The stellar evolution of **model A** (30 $M_{\odot}$) was computed from the ZAMS up to oxygen core exhaustion prior to Si burning (pre-SN stage). After the RSG stage, this star

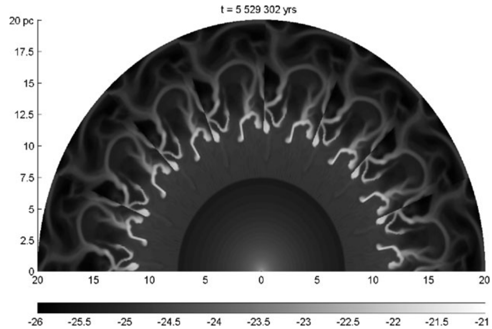

Figure 1. Circumstellar medium pre-SN in 30 $M_{\odot}$, model B. The figure shows the logarithm of gas density (g cm^{-3}).

evolves to the blue side of the HRD as a Luminous Blue Supergiant (LBSG), performing a blue loop. **Model B** (30 $M_{\odot}$) stellar evolution was computed from the ZAMS until Ne exhaustion in the core. The rotating star has a shorter RSG phase than the non-rotating star, but the mass loss rate is enhanced and the rotating star evolves to a Wolf-Rayet H-rich (WNL) star. In our 30 $M_{\odot}$ models the stellar evolution was different and each model built up different pre-supernova media. The distributions of density, temperature, chemical composition and velocity field of the pre-supernova environment are different in both cases, for the same initial mass.

In both models, the mass loss during the MS built up a circumstellar wind-blown cavity surrounding the star, bordered by a thin, dense, cold shell (Weaver *et al.*, 1977) with a radius greater than 30 pc. In the RSG stage, a shell of shocked RSG wind starts to build up closer to both star models (R $<$ 5 pc). During the post-RSG evolution the stellar wind velocity increases to 500 km/s in the LBSG case (**model A**), and to 1500 km/s in the WR case (**model B**). We observe the formation of a "blue" shell around the non-rotating star and the WR shell built by the rotating star. These shells are unstable due to Vishniac and/or Rayleigh-Taylor instabilities while they propagates outwards. The post-RSG shell eventually hits the RSG shell with different velocities, forming a swept "blue+RSG" unstable shell around the 30$M_{\odot}$ (**model A**) star at a radius of 6pc, and the **model B** star pre-SN environment is a fragmented "WR+RSG" shell around the WR progenitors at a distance of approximately 12 pc from the star, as is shown in Fig. 1. In the 40 $M_{\odot}$ models, the rotation does not affect the evolutionary track of the star (both models become a WR star at the pre-SN stage) but it affects the CSM morphology and chemical environment. This work will be discussed in a forthcoming paper.

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