Death of Massive Stars: Supernovae and Gamma-Ray Bursts
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Fate of most massive stars

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Abstract. The first generations of stars are thought to have been more massive than Pop I stars and therefore some of these are thought to have produced pair creation supernovae (PCSNe) at the end of their life. However, the chemical signature of PCSNe is not observed in extremely metal poor stars (e.g. Umeda and Nomoto 2002) and it raises the following questions: Were stars born less (or more massive) than the mass range expected to lead to the PCSNe? Or was mass loss too strong during the evolution of these stars and prevented them from retaining enough mass to produce PCSNe? The discovery of very massive stars (VMS, $M > 100\,M_{\odot}$) in the Milky Way and LMC (Crowther *et al.* 2010) shows that VMS can form and exist. The observations of PCSN candidates (2006gy & 2007bi) also seems to indicate that such SNe may occur. Mass loss plays a crucial role in the life of VMS since the star will only die as a PCSN if the star retains a high mass throughout its life. In this paper, we shall describe the dependence of VMS evolution on metallicity and present stellar evolution models at various metallicities, including the effects of mass loss and rotation. Based on our models, we will give our predictions concerning the fate of these VMS, either a PCSN or SNIc (possibly GRBs in some cases) as a function of metallicity.

Keywords. stars: evolution, rotation, supernovae

1. Introduction

The fate of very massive stars depends on their mass, composition and rotational rate. Stars with an initial mass in the range 10-140 $M_{\odot}$ produce a central iron core and eventually collapse (Heger & Woosley 2002). This type of collapse will result in a core collapse supernova (CC SN) of Type II, Ib or Ic or black hole (BH). The classification of these types of supernova depends on the existence of the hydrogen envelope in the star. Stars that undergo the core collapse at the end of their evolution will become either neutron stars or black holes. A star with initial mass in the range of 140-260 $M_{\odot}$ will become unstable due to the electron-positron pair creation in their oxygen-rich core (Barkat, Rakavy & Sack 1967). The instability starts when the central temperature increases above 5×10^9 K and leads to the explosion of the oxygen core to form a pair creation supernova (PCSN). The analysis of which models will end up as PCSN is done by considering the M_{CO} of the final model. Our models include both rotating and non-rotating models with mass range of 120-500 $M_{\odot}$ for SMC, LMC and solar metallicities.

2. Fate of very massive stars and PCSN candidates

We computed main sequence evolutionary models in order to determine the mass of the most massive stars known to date, R136a1 (Crowther *et al.* 2010). In this work (Yusof *et al.* in prep.), we evolved the models beyond the main sequence until at least the end of He-burning and in most cases until the start of O-burning. All the computed models

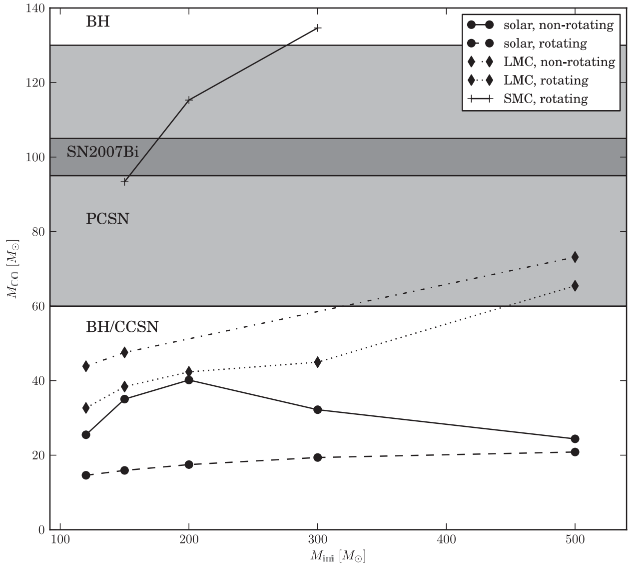

Figure 1. Fate of our models.

lose their H-rich envelope and end up as either as SN Ic, SNIc/Ib or SN Ib. Thus our models contradict the idea that SN2006gy (Smith *et al.* 2007) is a PCSN. In order to predict the fate of our models (PCSN or CCSN), we consider M_{CO} (Yoshida & Umeda 2011). In Fig. 1 the M_{CO} mass range expected to lead to PCSN is indicated. At $Z_\odot$, mass loss is too strong and all stars end as BH/CCSN. At Z_{LMC}, only the 500 $M_\odot$ models (both rotating and non-rotating) and at Z_{SMC} the 150 and 200 $M_\odot$ rotating models end as PCSN. We also include in Fig. 1 the suggested M_{CO} (Yoshida & Umeda 2011) for SN2007bi (Gal-Yam *et al.* 2009) since $Z_{SMC} < Z_{07bi} = 0.04 < Z_{LMC}$. We can see that possible progenitors for SN2007bi are 160-175 $M_\odot$ rotating models at Z_{SMC}.

Our models show that the mass loss and its metallicity dependence play a crucial role in determining the fate of very massive stars.

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