Double White Dwarf Merger Rates

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Abstract. Type Ia supernovae (SNe Ia) are very successfully used as standard candles on cosmological distance scales, but so far the nature of the progenitor(s) is unclear. A possible scenario for SNe Ia are merging carbon/oxygen white dwarfs with a combined mass exceeding the Chandrasekhar mass. We determine the theoretical rates and delay time distribution of these mergers for two different common envelope prescriptions and metallicities. The shape of the delay time distributions is rather insensitive to the assumptions. The normalization is a factor $\sim$3-13 too low compared to observations.

Keywords. stars: evolution, white dwarfs — binaries: close

1. Method

We simulate the population of SNe Ia progenitors using the fast binary evolution code SeBa (Portegies & Verbunt 1996, Nelemans *et al.* 2001). The revised version of SeBa (Toonen *et al.* in prep.) contains stellar evolution tracks from Hurley *et al.* (2000). Considering that SNe Ia progenitors are believed to encounter at least one phase of common envelope (CE) evolution, we study the effect of two models for the CE: one based on the conservation of orbital energy ($\alpha-$prescription, Webbink 1984) and one on angular momentum conservation ($\gamma-$prescription, Nelemans *et al.* 2000). Currently, only the $\gamma-$scenario is able to explain the observed population of close double helium white dwarfs. We utilize two CE models and consider two values of the metallicity. In model $\alpha\alpha$, the $\alpha-$prescription is used for every CE. In model $\gamma\alpha$, the $\gamma-$prescription is applied unless the binary contains one or more compact objects or the CE is triggered by a tidal instability. Model $\alpha\alpha\tilde{z}$ and $\gamma\alpha\tilde{z}$ are the same CE models but for stars of metallicity $z = 0.001$ instead of $z = 0.02$.

2. Three Binary Paths to SNe Ia

• *Common envelope channel*: The canonical path in which both stars lose their hydrogen envelope via two episodes of CE.

• *Stable mass transfer channel*: The first phase of mass transfer (MT) is stable. When the massive secondary fills its Roche lobe, a CE commences.

• *Formation reversal channel*: In this scenario the initially less massive star becomes the first formed white dwarf (WD). The evolution is similar to that of the stable track, though after the first phase of MT a low mass helium star forms with a lifetime of $\sim 10^8$ yr. The evolution of the secondary that has accreted significantly, speeds up. The secondary loses its envelope in a CE and becomes a WD. Subsequently the original primary evolves off the helium main–sequence and becomes a WD.

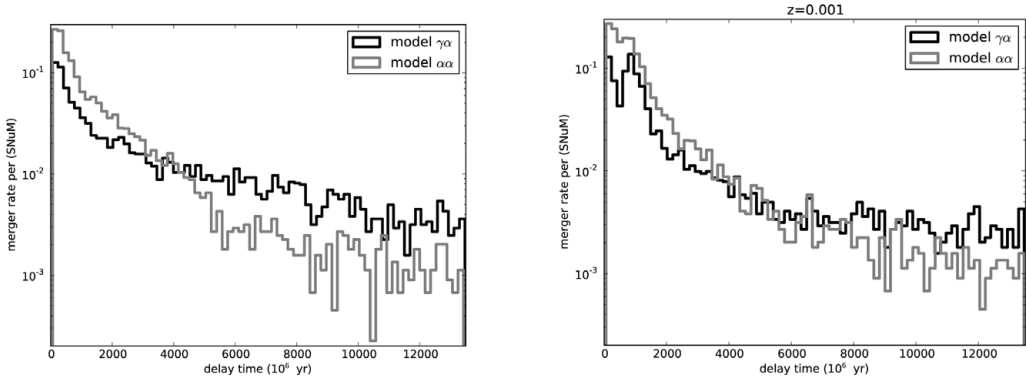|	Observations	Model $\alpha\alpha$	Model $\gamma\alpha$	Model $\alpha\alpha\tilde{z}$	Model $\gamma\alpha\tilde{z}$
Time-integrated number of SNe Ia ($M_\odot^{-1}$)	$2.3 \cdot 10^{-3}$	$2.7 \cdot 10^{-4}$	$1.8 \cdot 10^{-4}$	$3.1 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$
Galactic merger rate (yr^{-1})	$(4 \pm 2) \cdot 10^{-3}$	$6.3 \cdot 10^{-4}$	$5.9 \cdot 10^{-4}$	-	-

Figure 1. Merger rate of Type Ia supernova progenitors as a function of delay time. Black represents a simulation using model $\gamma\alpha$ for the common envelope evolution, grey $\alpha\alpha$. On the left delay times for a metallicity of $z = 0.02$ are shown, on the right $z = 0.001$. Rates are in $(100 \text{ yr})^{-1}$ per 10^{10} $M_\odot$ of the parent galaxy (SNuM).

3. Delay Times of Double White Dwarf Mergers

The SNe Ia progenitor scenario can be constrained by the delay time distribution (DTD), where the delay time is the time between star formation and the SN explosion. For a single burst of star formation the DTD gives the SNe Ia rate. The shape of the DTDs for both models are similar, approximately $\propto 1/t$. This is expected when the delay time is dominated by the merger time of a double white dwarf as a result of gravitational wave emission. Figure 1 shows that these mergers are expected to take place in young as well as old populations. In absolute numbers the DTD of model $\gamma\alpha$ is similar to model $\alpha\alpha$, where we have assumed a 50% binary fraction. We also adopted the Galactic star formation rate of Boissier & Prantzos 1999 to calculate the Galactic merger rate. Both the time-integrated number of SNe Ia from Maoz *et al.* (2011) and the empirical Galactic SNe Ia rate from Cappellaro *et al.* (1999) are a factor $\sim$3-13 larger than the simulated values (see table). The DTD for $z = 0.001$ are similar to the ones for $z = 0.02$. There is an increase of SNe Ia at short delay times, caused by the increased radii of stars of low metallicity filling their Roche lobe earlier on in their evolution. Concluding, the DTDs show the characteristic shape of a decay inversely proportional to time, though the normalization is a factor $\sim$3-13 too low. Neither the common envelope parameterization nor the metallicity effects the normalization significantly. For details see Toonen *et al.* in prep.

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