Wind mass transfer and the progenitors of Type Ia Supernovae

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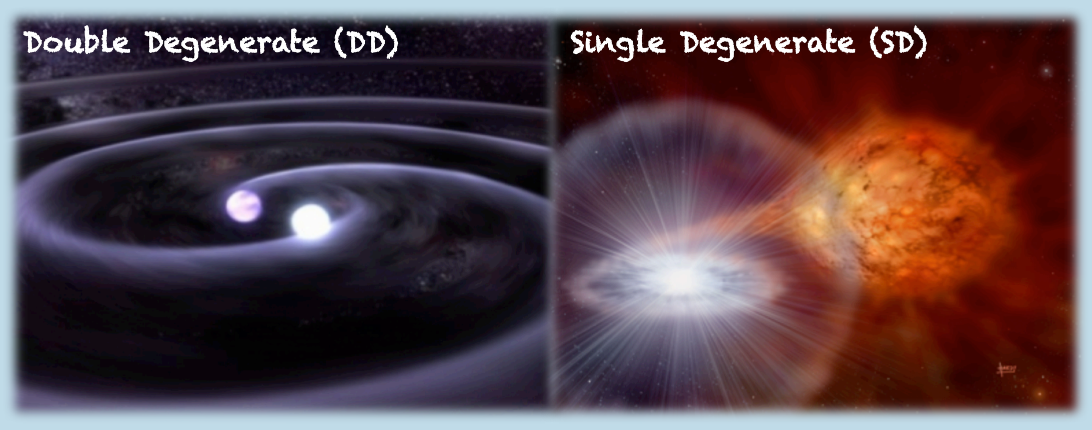
1. Introduction

The nature of the progenitor system of Type Ia Supernovae (SNe Ia) is still unknown. Two main scenarios have been proposed:

- The *single-degenerate* scenario (SD), in which a CO WD accretes material from a non-degenerate companion star.
- The *double-degenerate* scenario (DD), in which two WDs in a binary system merge.



Binary population synthesis (BPS) studies predict rates of SNe Ia several times lower than the observations [1]. Furthermore, these models predict that the contribution of asymptotic giant branch (AGB) stars is marginal, sharply in contrast with the properties exhibited by several SNe Ia and their remnants (e.g. SN 2002ic [2], Kepler's SNR [3]).

These discrepancies could potentially be explained by the simplified assumptions adopted in BPS studies about the angular momentum (AM) loss and wind accretion in binary systems.

In this work, we compute BPS simulations using a model for mass transfer processes and angular momentum losses based on ballistic and hydrodynamical simulations. We study how these processes impact the total rate of SNe Ia and the contribution of AGB progenitor stars.

2. Wind accretion and angular-momentum loss models

Wind accretion

- ***Canonical models***: spherically symmetric AGB winds (ssw), and low accretion efficiencies described by the canonical Bondi-Hoyle-Lyttleton (BHL) model.

- ***WRLOF model***: 3D hydrodynamical simulations [4] show that AGB outflows in binary systems can be highly aspherical and reach high accretion rates [5] (Fig. 1). This mode of mass transfer is called "Wind Roche-lobe overflow" (WRLOF).

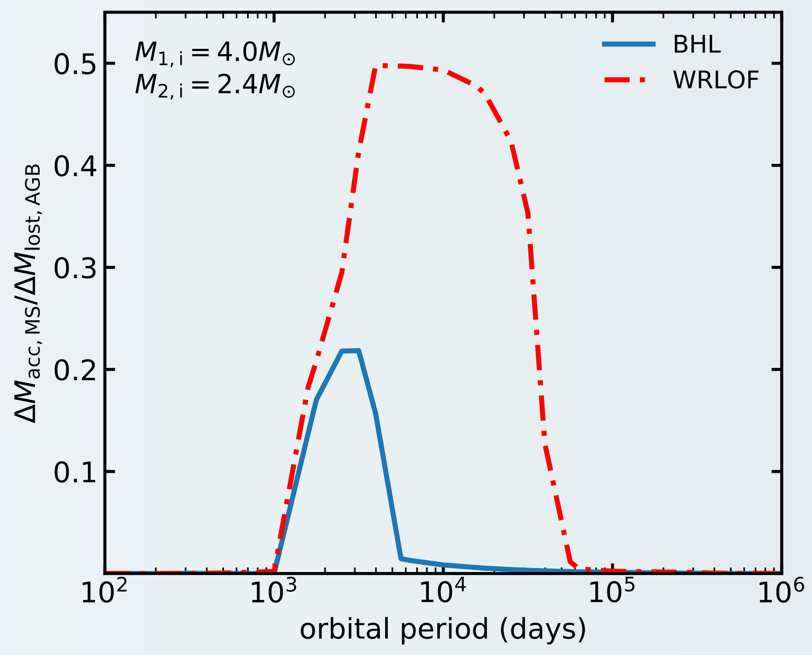


Fig. 1 The accretion efficiency at different initial orbital periods in the BHL (blue) and WRLOF (red) models, respectively.

Angular-momentum loss

- ***Canonical models:*** In spherically symmetric winds, the angular momentum carried away by the material expelled by the binary is:

$$\dot{J} = \gamma \times \frac{J_{orb}}{M_1 + M_2}(\dot{M}_1 + \dot{M}_2) \qquad (1)$$

with γ= q= M_2/M_1, the mass ratio.

- ***Ballistic model:*** the angular momentum loss is computed by Eq. (1) with γ defined as:

$$\gamma = \max \{q, h_{BT93}\}$$

where h_{BT93} is determined by ballistic simulations [6].

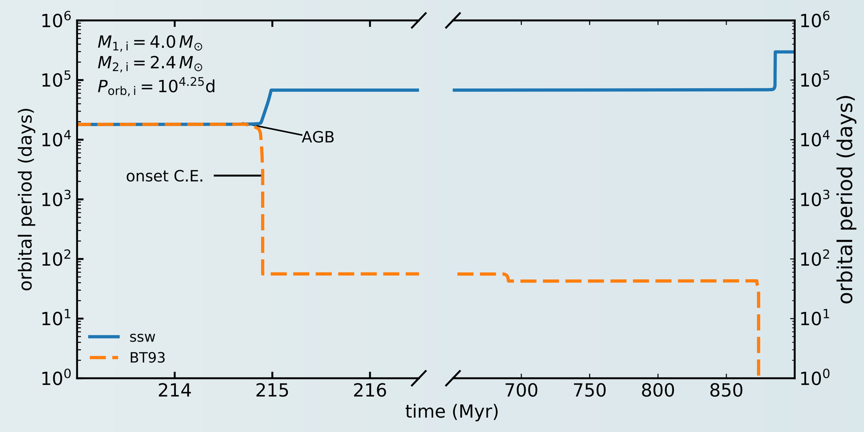


Fig. 2 Orbital-period evolution of a spherically-symmetric wind model (blue) Vs a model based on ballistic simulations (orange).

3. Binary population synthesis simulations

- The BPS code binary_c [7] is used to simulate the evolution of binary systems for a wide range of masses and orbital separations.
- We simulate the evolution of 3 binary populations using 3 different model sets (see Table below):
  S1: default assumptions as in [1], i.e. ssw model of AM loss and BHL model of wind accretion.
  S2: as S1, with WRLOF model of wind accretion
  S3: as S2, with Ballistic model of angular momentum loss.
- Figure 3a-c shows the delay-time distribution of SNe Ia predicted by these 3 model sets.

Model set	Wind accretion	Angular momentum
S1	BHL	SSW
S2	WRLOF	SSW
S3	WRLOF	Ballistic Simulations

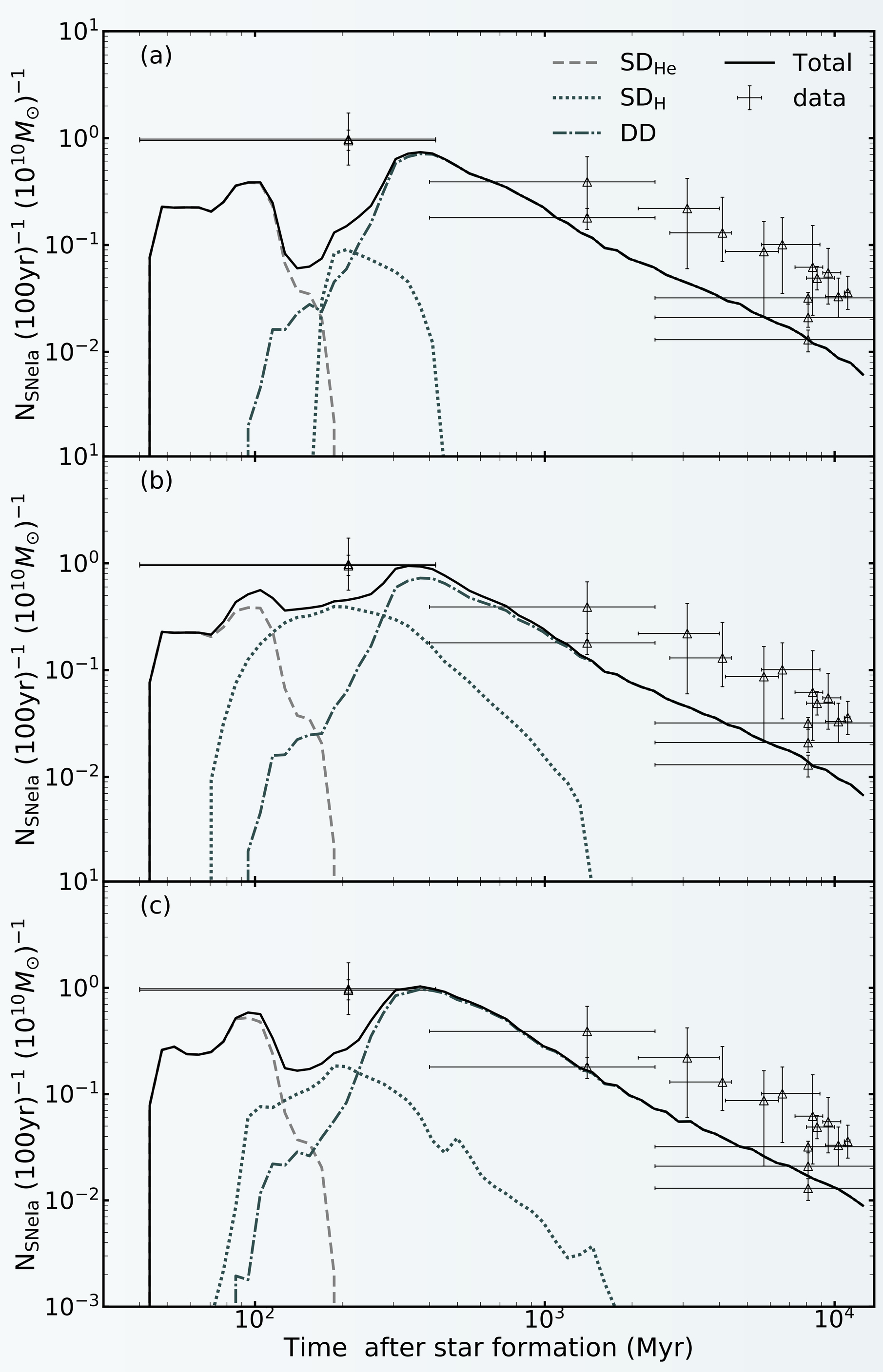


Fig. 3 Delay-time distributions calculated with models sets S1, S2 and S3 (panels a, b and c, respectively). The dashed and dotted lines represent the contributions to the SNe Ia rate from the SD channel with He-rich and H-rich donor stars, while the dot-dashed line shows the contribution of the DD channel. The solid line shows the total SNe Ia rate. The open triangles are the literature observed data [8].

4. Results

- Considering a less idealised model of mass transfer, the total contribution of ABG donor stars (model S2) to the SD channel is almost 10 times higher.
- The contribution of AGB donor stars is mostly evident at delay times between 100 and 300 Myr after star formation.
- The strong angular-momentum losses cause model set S3 to form many more double WDs is close orbits increasing the DD channel by ~ 35%.

5. Conclusions

- Less idealized treatment of wind mass transfer (WRLOF) in binary systems increases the contribution of AGB stars in SNe Ia progenitor systems and places them as the dominant SD channel within the time window of 100 - 300 Myr.
- Considering in addition more efficient angular momentum losses as described by ballistic simulations the contribution of AGB stars to the DD channel increases by a factor of three.
- Our results suggest that AGB stars may play a significant role as SNe Ia progenitors, both in the SD and DD channels.

References

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