Why Galaxies Care About AGB Stars: A Continuing Challenge through Cosmic Time
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WD+AGB star systems as the progenitors of type Ia supernovae

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Abstract. WD+AGB star systems have been suggested as an alternative way for producing type Ia supernovae (SNe Ia), known as the core-degenerate (CD) scenario. In the CD scenario, SNe Ia are produced at the final phase during the evolution of common-envelope through a merger between a carbon-oxygen (CO) WD and the CO core of an AGB secondary. However, the rates of SNe Ia from this scenario are still uncertain. In this work, I carried out a detailed investigation on the CD scenario based on a binary population synthesis approach. I found that the Galactic rates of SNe Ia from this scenario are not more than 20% of total SNe Ia due to more careful treatment of mass transfer, and that their delay times are in the range of $\sim 90 - 2500$ Myr, mainly contributing to the observed SNe Ia with short and intermediate delay times.

Keywords. binaries: close – supernovae: general – white dwarfs

1. Introduction

Type Ia supernovae (SNe Ia) have high scientific values in the cosmic evolution. They are thought to be arised from thermonuclear explosions of carbon-oxygen white dwarfs (CO WDs) in binaries, although their progenitor systems are still unclear. Over the past few years, two classic progenitor models of SNe Ia have been suggested, i.e., the single-degenerate model and the double-degenerate model (e.g., Hachisu *et al.* 1996; Han & Podsiadlowski 2004; Wang *et al.* 2009; Toonen *et al.* 2012). Some variants of these two progenitor models are proposed to reproduce the observed diversity of SNe Ia (e.g., Wang & Han 2012; Maoz *et al.* 2014; Wang 2018).

Previous simulations on the double-degenerate model are mainly related to the merger of two cold CO WDs (e.g., Toonen *et al.* 2012). However, a CO WD can also merge with the hot CO core of an asymptotic giant branch (AGB) star, and then produce a SN Ia, known as the core-degenerate (CD) scenario (e.g., Soker 2013). In the CD scenario, a SN Ia explosion might occur shortly or a long time after the common-envelope (CE) phase. Although the CD scenario may explain some properties of SN Ia diversity, SN Ia rates from this scenario are still uncertain (e.g., Ilkov & Soker 2013). Ilkov & Soker (2013) argued that the CD scenario can explain the observed rates of total SNe Ia based on a simplified binary population synthesis (BPS) code. The purpose of this study is to investigate SN Ia rates and delay times for the CD scenario using a detailed Monte Carlo BPS approach.

2. Model and Results

In the CD scenario, a WD with Chandrasekhar or super-Chandrasekhar mass could be produced through the merger of a cold CO WD with the hot CO core of an AGB star.

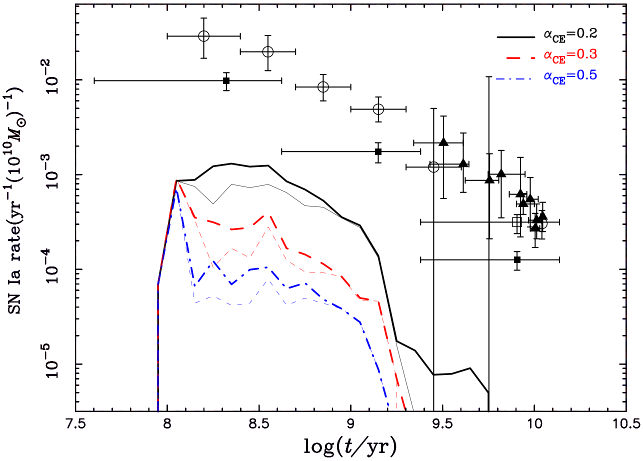

Figure 1. SN Ia delay time distributions based on a single starburst of 10^{10} M$_\odot$. The thick lines are for all SNe Ia from the CD scenario, and the thin lines are only for ones with circumstellar material like PTF 11kx. Source: From Wang *et al.* (2017).

A series of Monte Carlo BPS simulations for the CD scenario are performed using the Hurley binary evolution code (e.g., Hurley *et al.* 2002). Here, I consider three different values (e.g., 0.2, 0.3 and 0.5) of the CE ejection efficiency $\alpha_{\rm CE}$ to examine its influence on the final results. I adopted the following assumptions as the criteria for producing SNe Ia through the CD scenario (e.g., Soker 2013; Wang *et al.* 2017): (1) The WD and the AGB core merge during the final stage of CE evolution. (2) The combined mass of the CO WD ($M_{\rm WD}$) and the AGB core ($M_{\rm core}$) during the final phase of CE evolution is larger than or equal to the Chandrasekhar limit. (3) If $M_{\rm WD} > M_{\rm core}$, I assume that the SN explosion occurs shortly after the CE stage, resulting in a SN Ia inside a planetary nebula shell like PTF 11kx.

Fig. 1 presents the SN Ia delay time distributions for the CD scenario based on a single starburst of 10^{10} M$_\odot$. The delay times of SNe Ia for this scenario are mainly in the range of $\sim 90 - 2500$ Myr after the starburst, which may contribute to the SNe Ia with short and intermediate delay times. I also found that the theoretical Galactic rates from this scenario are no more than 20% of the total SNe Ia in the observations. Especially, SNe Ia with circumstellar material from this scenario contribute to 0.7−10% of total SNe Ia, which indicates that the CD scenario can reproduce the observed rates of SNe Ia like PTF 11kx.

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