Setting the scene for Gaia and LAMOST
Proceedings IAU Symposium No. 298, 2013
S. Feltzing, G. Zhao, N. A. Walton & P. A. Whitelock, eds.

doi:10.1017/S1743921313007072

Helium double-detonation explosions for the progenitors of type Ia supernovae

B. Wang, D. Liu, S. Jia and Z. Han

Key Laboratory for the Structure and Evolution of Celestial Objects, Yunnan Astronomical Observatory, CAS, Kunming, 650011, China (email: wangbo@ynao.ac.cn)

Abstract. Thermonuclear explosions from helium double-detonation sub-Chandrasekhar mass model have been considered as an alternative way for the production of type Ia supernovae (SNe Ia). In this work, we systematically studied the helium double-detonation model, in which a carbon–oxygen white dwarf (CO WD) accumulates a helium layer from a non-degenerate helium star.

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

1. Introduction

Type Ia supernovae (SNe Ia) play an important role in astrophysics and are crucial for the studies of stellar evolution, galaxy evolution and cosmology. They are generally thought to be thermonuclear explosions of accreting carbon–oxygen white dwarfs (CO WDs) in close binaries, however, the nature of the mass donor star is still unclear (e.g., Han & Podsiadlowski 2004; Wang & Han 2012). A CO WD can accrete material from a helium star to increase its mass until it ignites near to the Chandrasekhar mass limit (e.g., Wang *et al.* 2009). However, standard Chandrasekhar mass explosion models have difficulty in reproducing the low luminosities of SNe Ia. It is therefore natural to consider whether sub-luminous SNe Ia might be produced by sub-Chandrasekhar mass explosions, in which the explosion of a CO WD is triggered by the detonation of a substantial surface layer of accreted helium (e.g., Nomoto 1982).

2. Model and Results

In this work, we performed detailed binary evolution calculations for the double-detonation model, in which CO WD accumulates a helium layer from a non-degenerate helium star. According to these calculations, we obtained the initial and final parameters for SNe Ia in the orbital period–secondary mass plane for various initial WD masses, respectively. We have incorporated detailed binary evolution calculations for the progenitor systems into a binary population synthesis model to obtain SN Ia birthrates and delay times. The predicted Galactic SN Ia birthrate from this model is $\sim 0.6 - 1.8 \times 10^{-3}\,\mathrm{yr}^{-1}$, and that this model has the delay times of $\sim$70 Myr−710 Myr. Based on the CO WD mass at explosion and previous detonation models, we also estimate the distribution of resulting SN brightness ($-13 \gtrsim M_{\rm bol} \gtrsim -19$ mag).

References

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