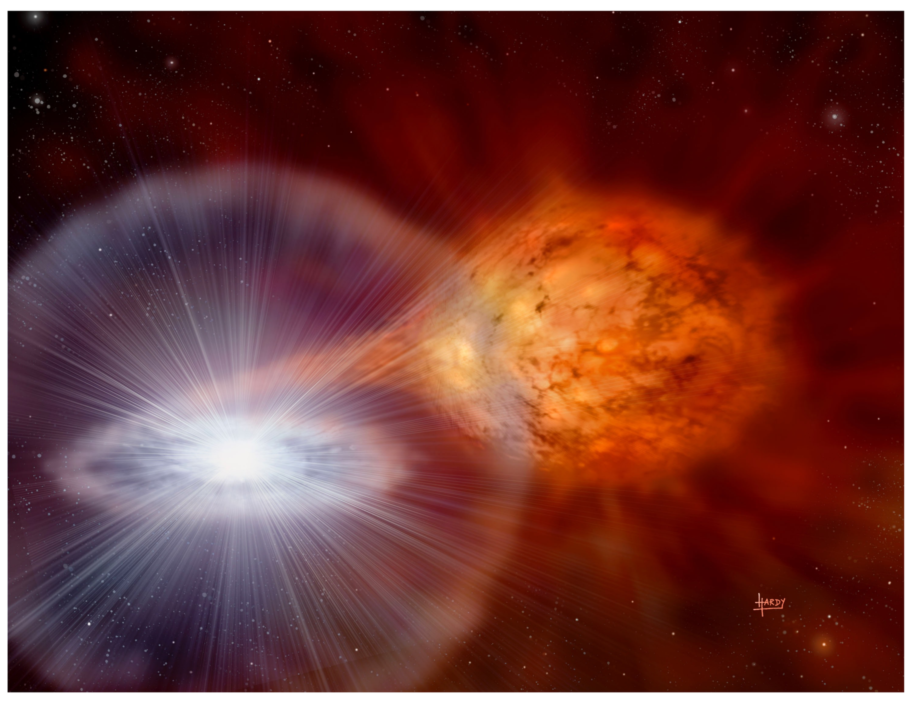
Circumstellar properties of Type Ia supernovae with helium star donors

Takashi Moriya (NAOJ); takashi.moriya@nao.ac.jp
Dongdong Liu, Bo Wang, Zhengwei Liu (Yunnan observatories)

国立天文台 NAOJ National Astronomical Observatory of Japan

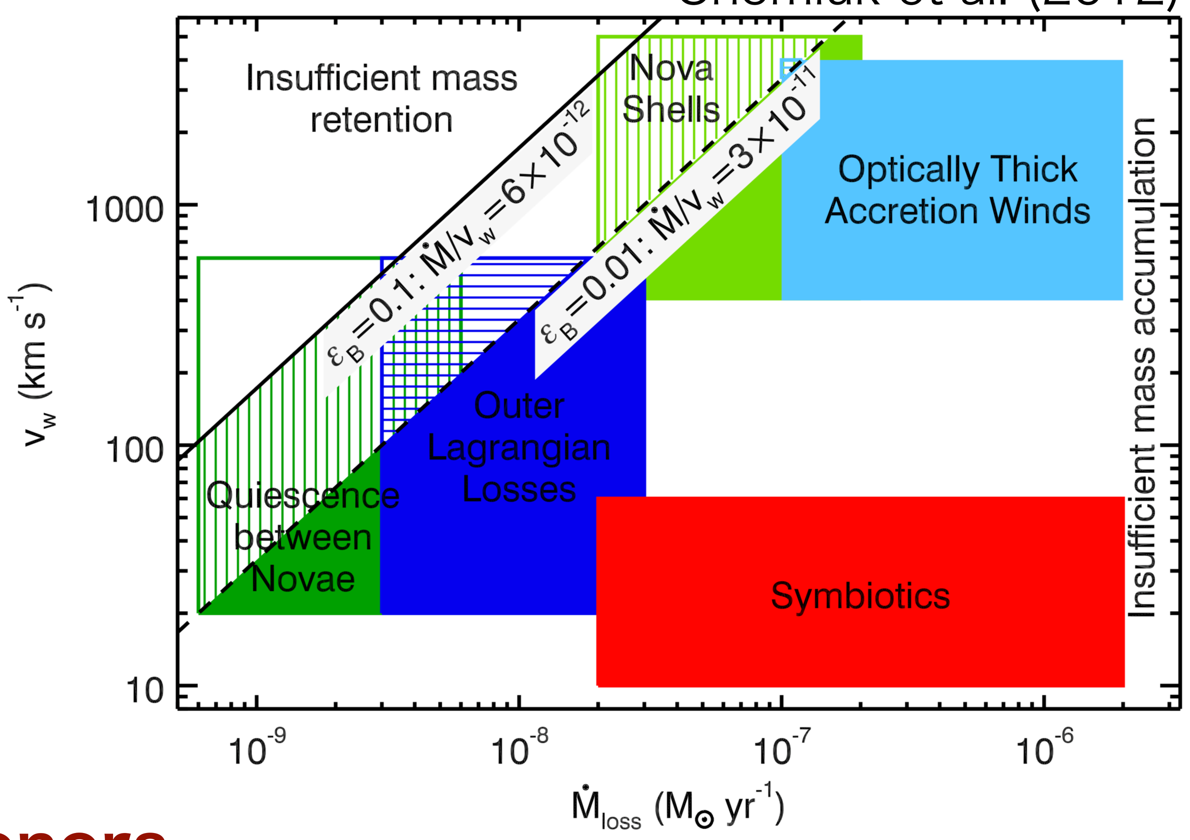
We investigate predicted circumstellar properties of Type Ia supernova progenitor systems with non-degenerate helium star donors. A system with a carbon+oxygen white dwarf and a helium star has been suggested to lead to Type Ia supernova explosions. Among all, Type Ia supernovae with short delay times are particularly dominated by this helium star donor channel. Binary evolution models predict that such progenitor system in either a stable He-shell burning phase or a weak helium-shell flash phase at the time of the explosion. By taking the binary evolution model of Wang et al. (2009), we show that a large fraction of the progenitor systems have low enough density to explain the current non-detection of radio emission from Type Ia supernovae.

Type Ia supernovae and their circumstellar environment



Progenitors of SNe Ia are still uncertain. In the single degenerate scenario, SNe Ia are expected to occur in a ciruscumstellar medium (CSM) formed through accretion processes. CSM density around SNe Ia has been constrained by radio observations. Many single-degenerate channels with hydrogen-rich donor stars are currently excluded (the right figure for SN 2011fe).

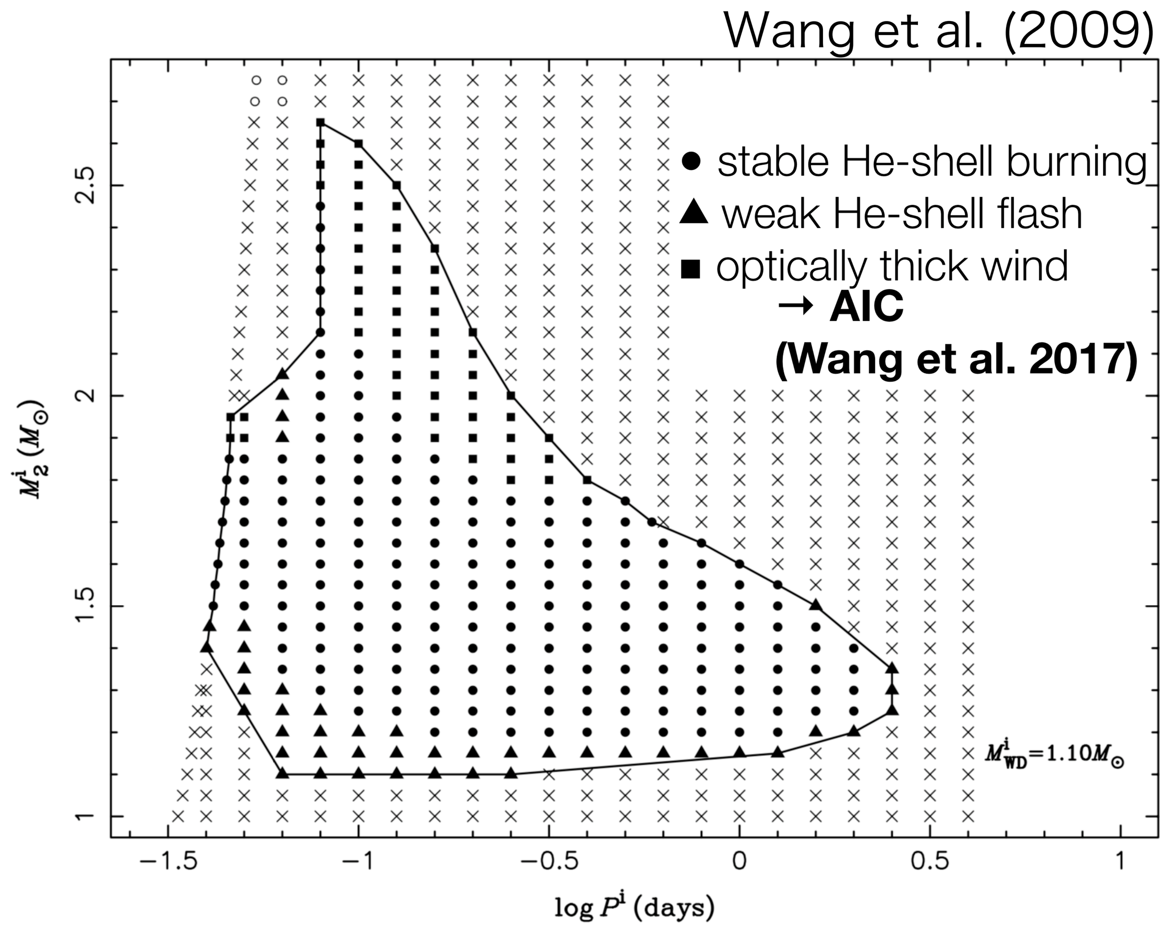
Chomiuk et al. (2012)



Type Ia supernovae with helium star donors

Donor stars in the single-degenerate channel are not necessarily hydrogen-rich stars. Helium star donors can also lead to SNe Ia (e.g. Yoon & Langer 2003). Wang et al. (2009) calculated ~ 2400 evolution models of He star + WD binaries to investigate the parameter range of He star + WD systems leading to SNe Ia assuming that SNe Ia occur when WDs reach the Chandrasekhar limit. The right figure shows an example of the results for the case of the initial WD mass of 1.10 Msun. The models of the filled symbols lead to SNe Ia. Systems leading to SNe Ia are found to be in three different states: (i) stable He-shell burning, (ii) weak He-shell flash, and (iii) optically thick wind. We here investigate the circumstellar properties of the He star donor channel based on this binary evolution model. We note that a follow-up study by Wang et al. (2017) found that those in the optically thick wind phase lead to accretion-induced collapse rather than SNe Ia, but we also results from these systems as well for completeness.

Wang et al. (2009)



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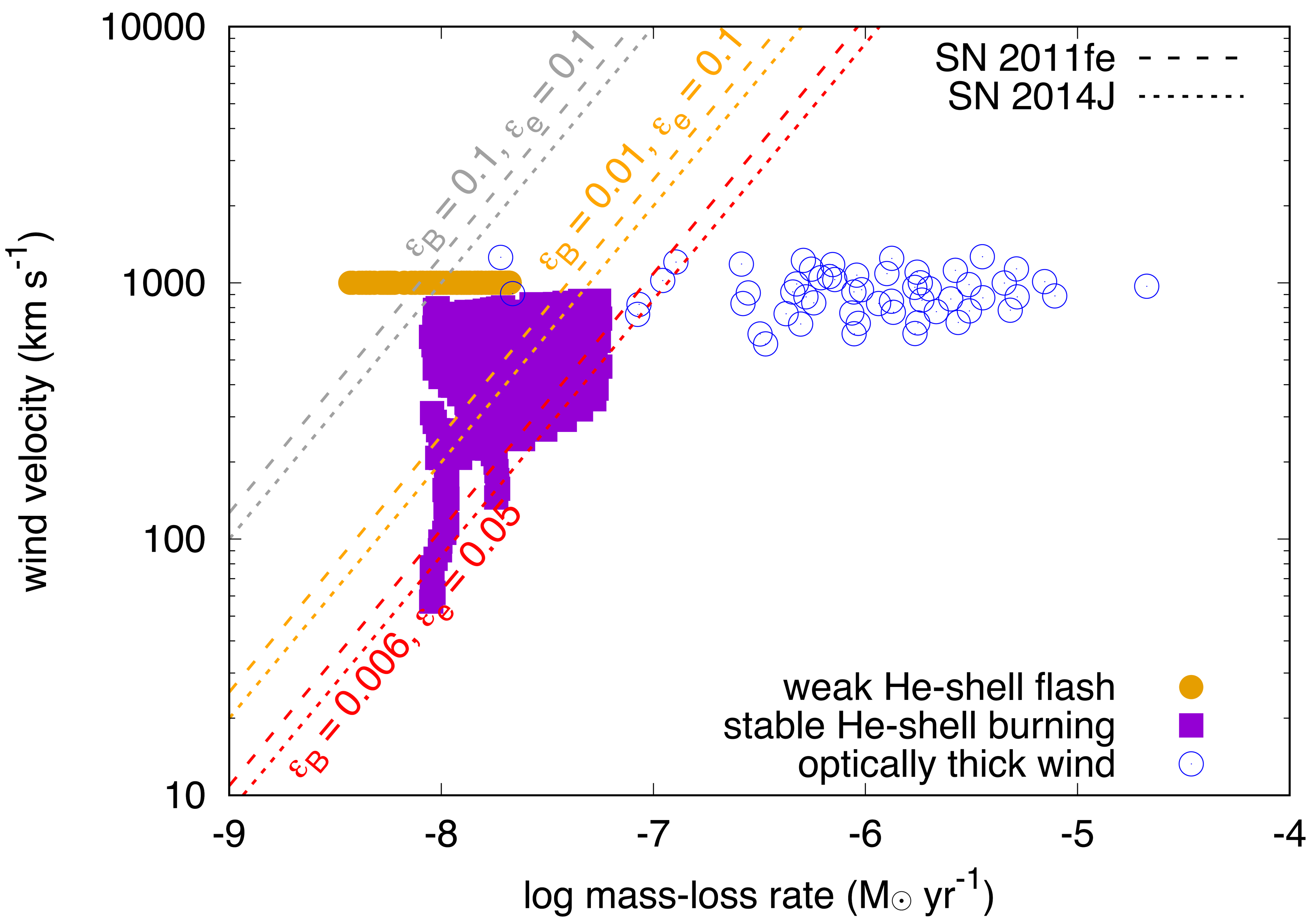

Table 1. Galactic SN Ia rate from the He star donor channel.

	rate (10^{-3} yr^{-1}) $\alpha_{CE}\lambda = 0.5$	rate (10^{-3} yr^{-1}) $\alpha_{CE}\lambda = 1.5$
total	1.07	1.10
stable He-shell burning	0.25 (23%)	0.59 (54%)
weak He-shell flash	0.82 (77%)	0.51 (46%)
optically thick wind[a]	0.11	0.11

[a] AIC progenitors.

The left figure shows the estimated CSM properties from the He star donor channel. We also show the CSM density constrained by radio observations of SN 2011fe and SN 2014J with several microphysics assumptions. We find that many systems, especially those in the weak He-shell flash phase, are not excluded by the current observations. The donor stars are also predicted to be faint enough to be consistent with the non detection of the companion (the bottom figure). A large fraction of prompt SNe Ia could be dominated by those in the weak He-shell flash phase according to Wang et al. (2009). **Because SN 2011fe and SN 2014J could be both from young environment, they might be both prompt SNe Ia and originate from the He-star donor channel.**