Simulation of an Ultra-stripped Type Ic Supernova

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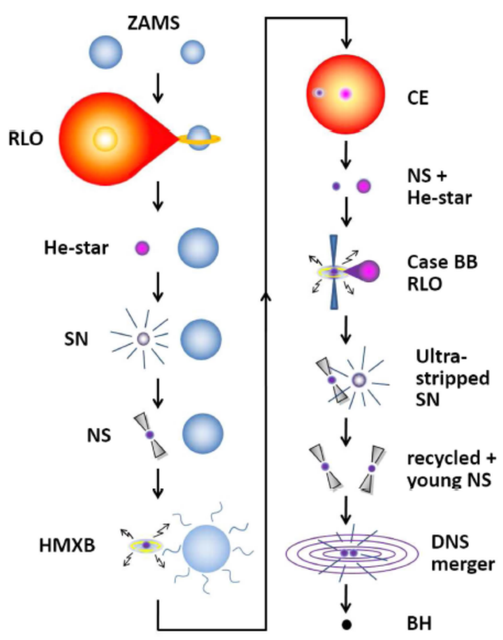
Introduction

Ultra-striped supernovae (US SNe) are considered to play an important role in the formation of double neutron star systems that attract special interest since the gravitational wave detection of binary neutron star merger (Tauris et al. 2017).

Simulations of the central engine of the ultra-stripped supernovae have been performed by a few groups (Suwa et al. 2015; Muller et al. 2018). The order of Ni mass, explosion energy and kick velocity are consistent with the observed ultra-stripped supernovae

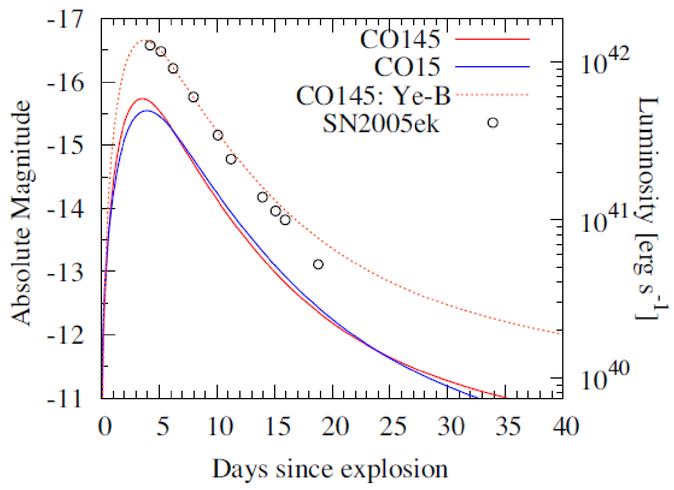


Tauris et al. 2017

Motivation

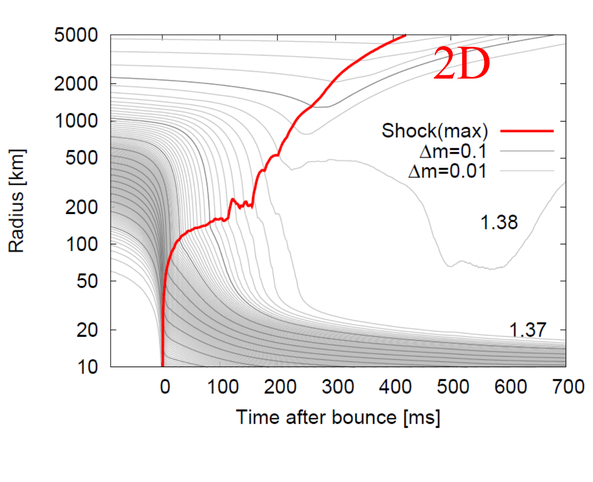
However, the ejected mass of Ni highly depends on the electron fraction of the ejecta, that is determined by the detailed method of neutrino transport (Yoshida et al. 2017). If the electron fraction is too low (the red or blue line of the figure below), the mass of 56Ni is too small and cannot explain the observed light curve of ultra-stripped supernovae.

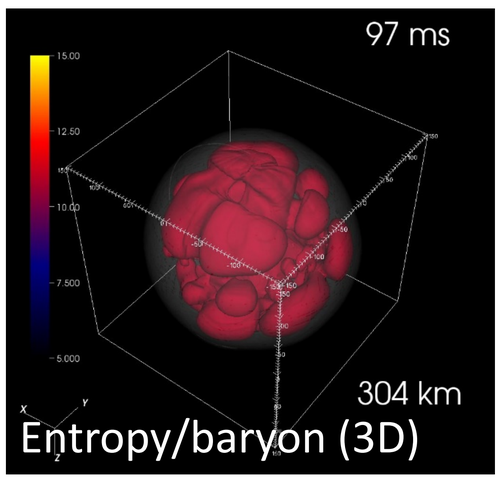
In this study, we investigate the hydrodynamics and nucleosynthesis of ultra-stripped supernovae using state-of-the-art neutrino reactions of Kotake et al. (2018).



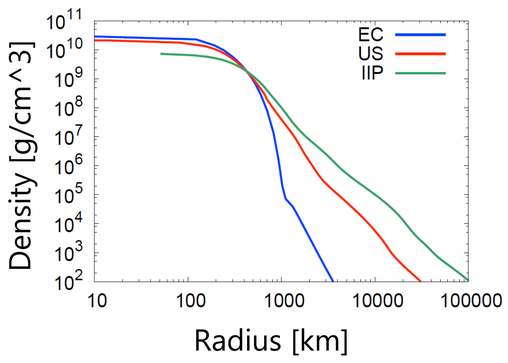
Yoshida et al. 2017

Results



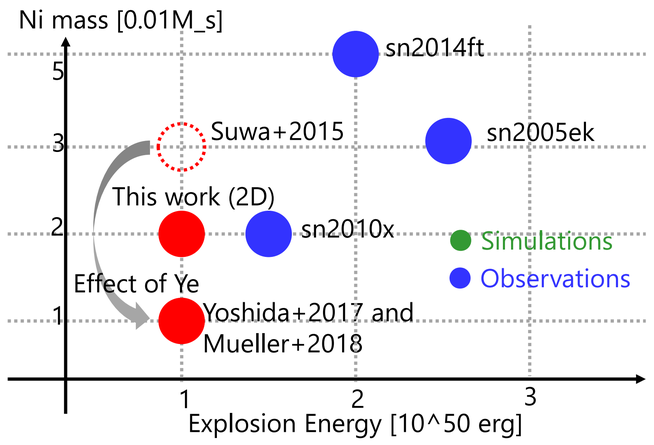


The progenitor of ultra-stripped supernova has dilute envelope compared the progenitors for the normal type IIP supernova. Due to the feature, the shock revival happens easily. Convection also helps the revival.

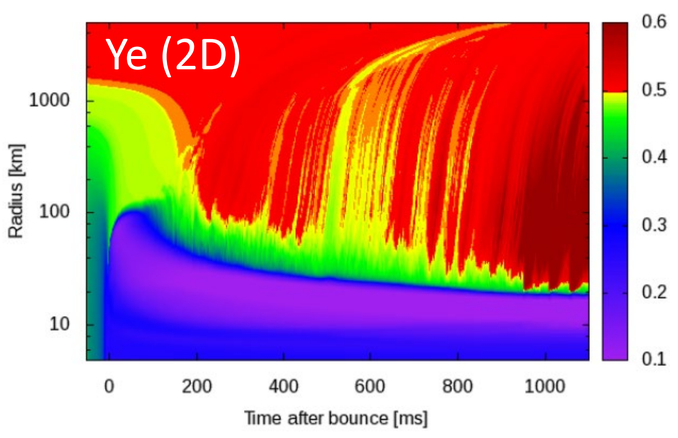


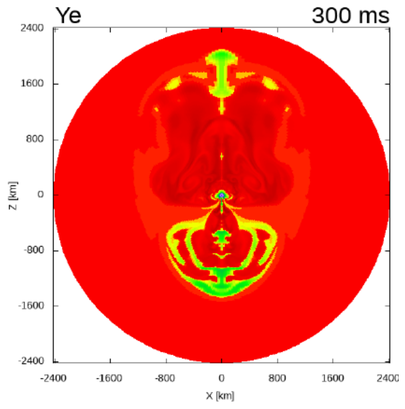
EC: Nomoto+1984,1987
US: Moriya+2017
IIP: s15 of Woosley+2007

A progenitor of electron capture (EC) supernova also has dilute envelope. It explodes in 1D and does not need the help of the convection. Note that the explosion mechanism of it is significantly different from that of US.



We obtained 0.02 M_s of Ni, that are larger than that of the previous studies and consistent with darker ultra-stripped supernovae.





The main difference from Suwa+ 2015 and Yoshida+2017 comes from the dynamics. In our model, the main part of Ni is ejected in 200-300ms and later than the shock revival time. The ejecta is strongly irradiated by ν and electron fraction becomes high enough to make 56Ni.

Question related to Supernova Remnant

The origin of double neutron star system can be the ultra-striped supernovae. Now that is indirectly supported by the observation of sn2014ft and the theorical works include our study. However, there is not direct evidence. the smoking gun for that should be the observation of the supernova remnant that include binary neutron star. Why is it not found? Will it be found in the future?