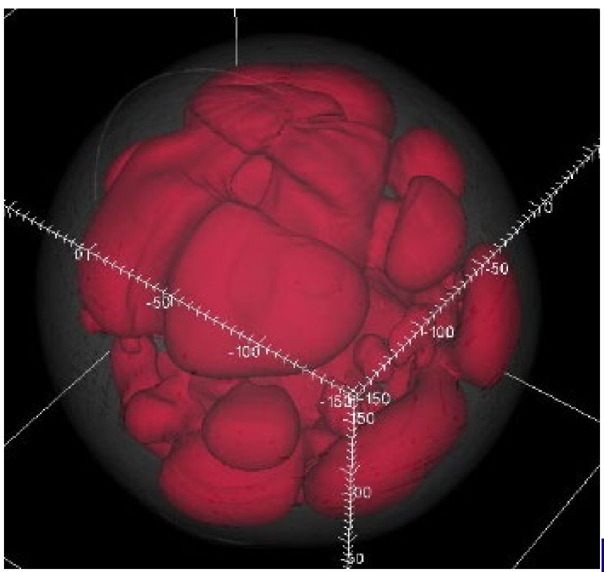
Neutrino radiation hydrodynamic simulation of an ultra-stripped Type Ic supernova



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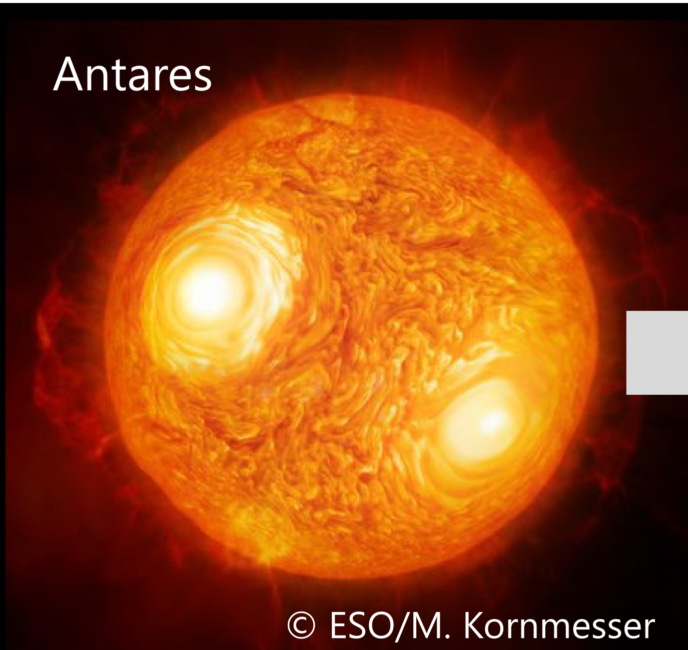
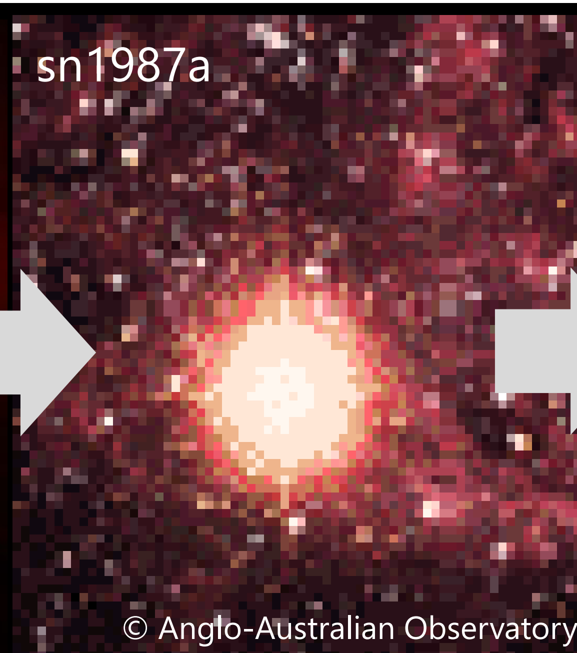
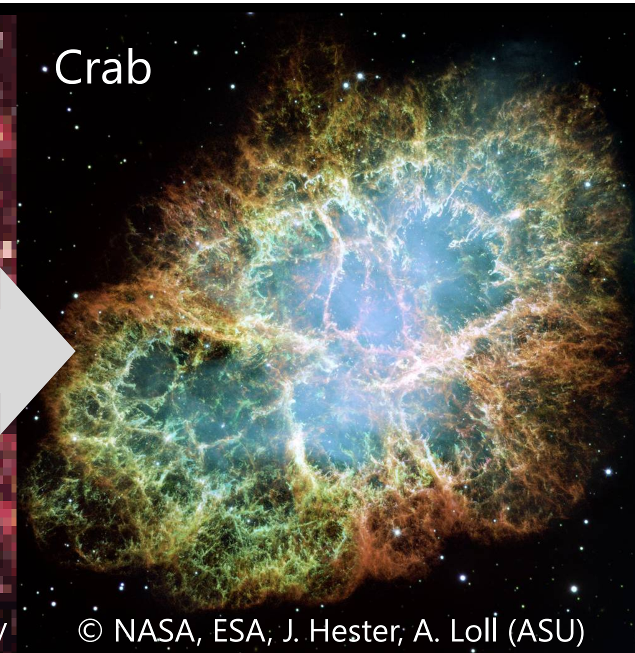
Connecting Links to Astro. Objects





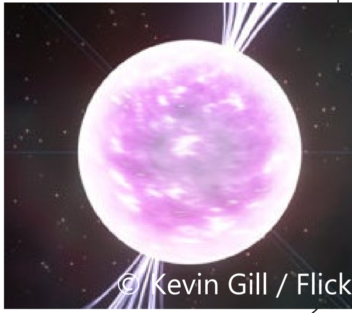


Supergiant

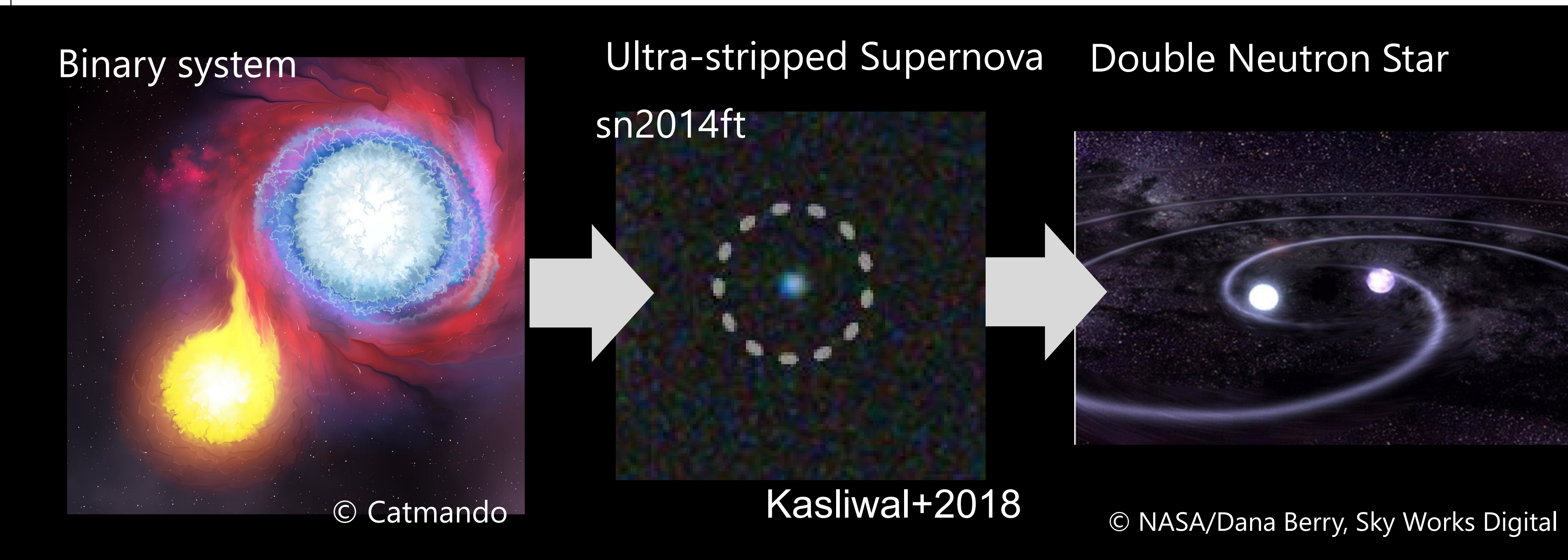
Supernova

Supernova Remnant and Neutron Star

Connecting each astronomical object and make a scenario is important task for astrophysicists.



Origin of Double Neutron star system?



NS – He star binary

Ultra-stripped Supernova

Supernova Remnant and Neutron Star

The formation of DNS system might be associated with ultra-stripped supernova.

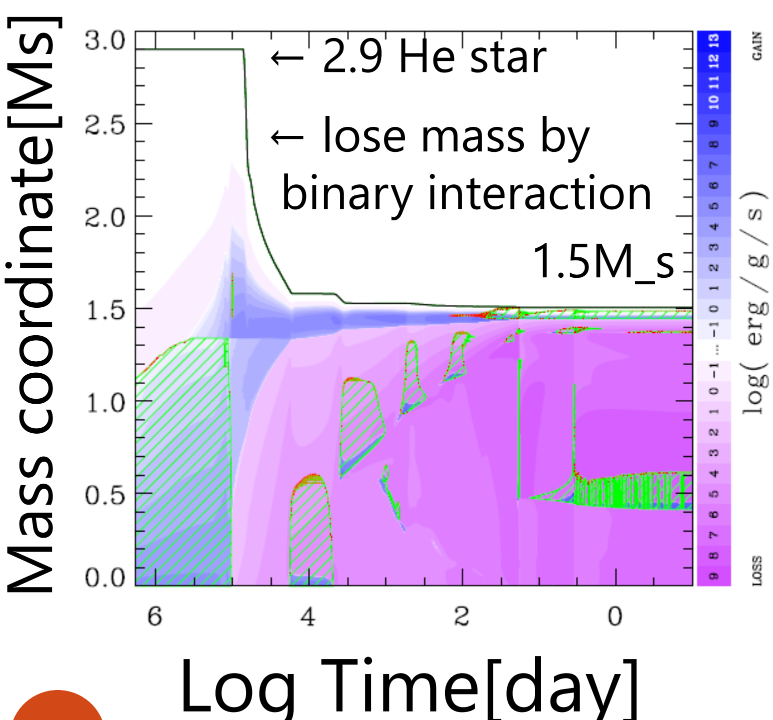
Small ejecta mass not to break the binary system.

See Tauris+2017 for detail

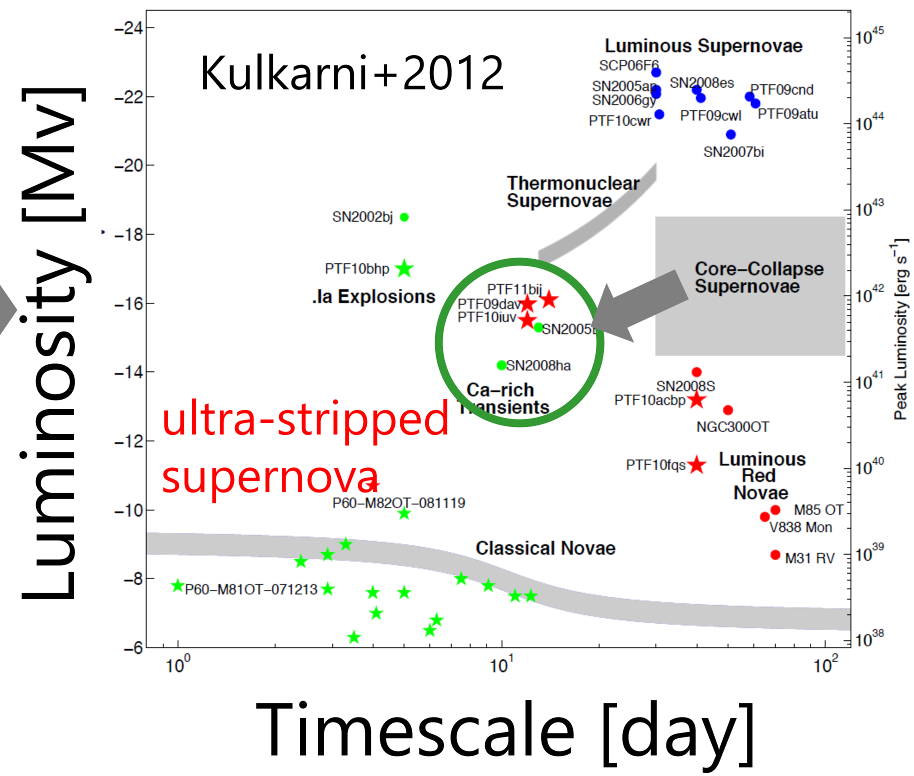
Question to answer

Question:

Does a star with stripped envelope explode as a ultra-stripped supernova?



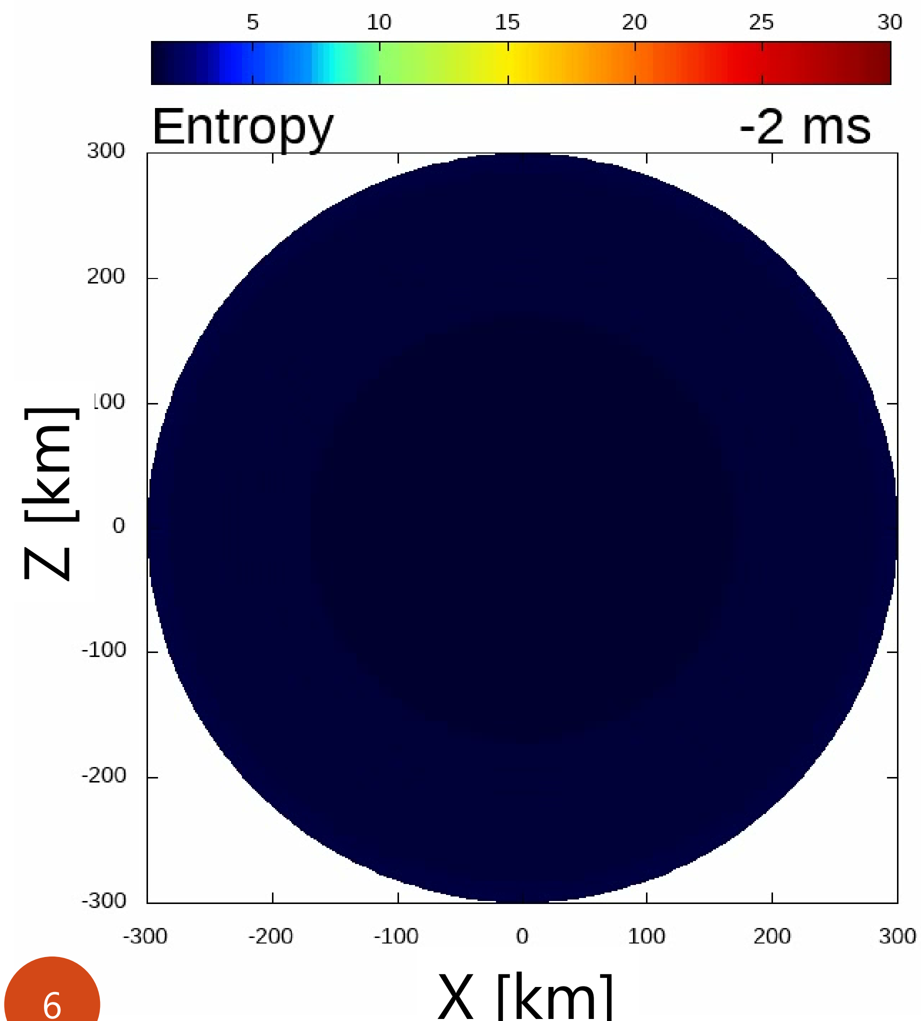
Tauris+2013



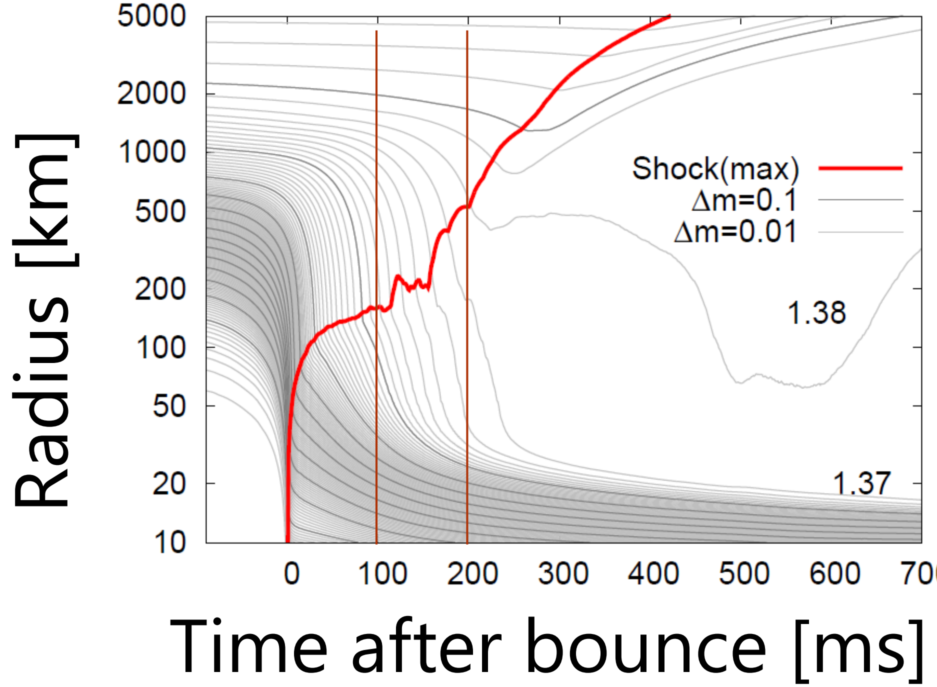
Setups and Comparison

	Suwa+2015 Yoshida+2017	Muller+2018	This study
Progenitor	HOSHI (only core)	BEC & Kepler	MESA (mimic BEC)
Dimension of hydrodynamics	2D axi-symmetry	3D(&2D)	2D axi-symmetry 3D is in prep.
Gravity	Newton	Effective GR	Effective GR
Neutrino transport	2flavor-IDSA(S) Light Bulb (Y)	3flavor-FMT	3flavor-IDSA
ν reaction rate	< Bruenn 1985	Rampp+2002	Kotake+2018
Nucleosynthesis	Tracer particle T_9 (S) Large Network (Y)	Mesh base Flashing Method	Mesh base Small Network
Remarks		PNS convection assumed	

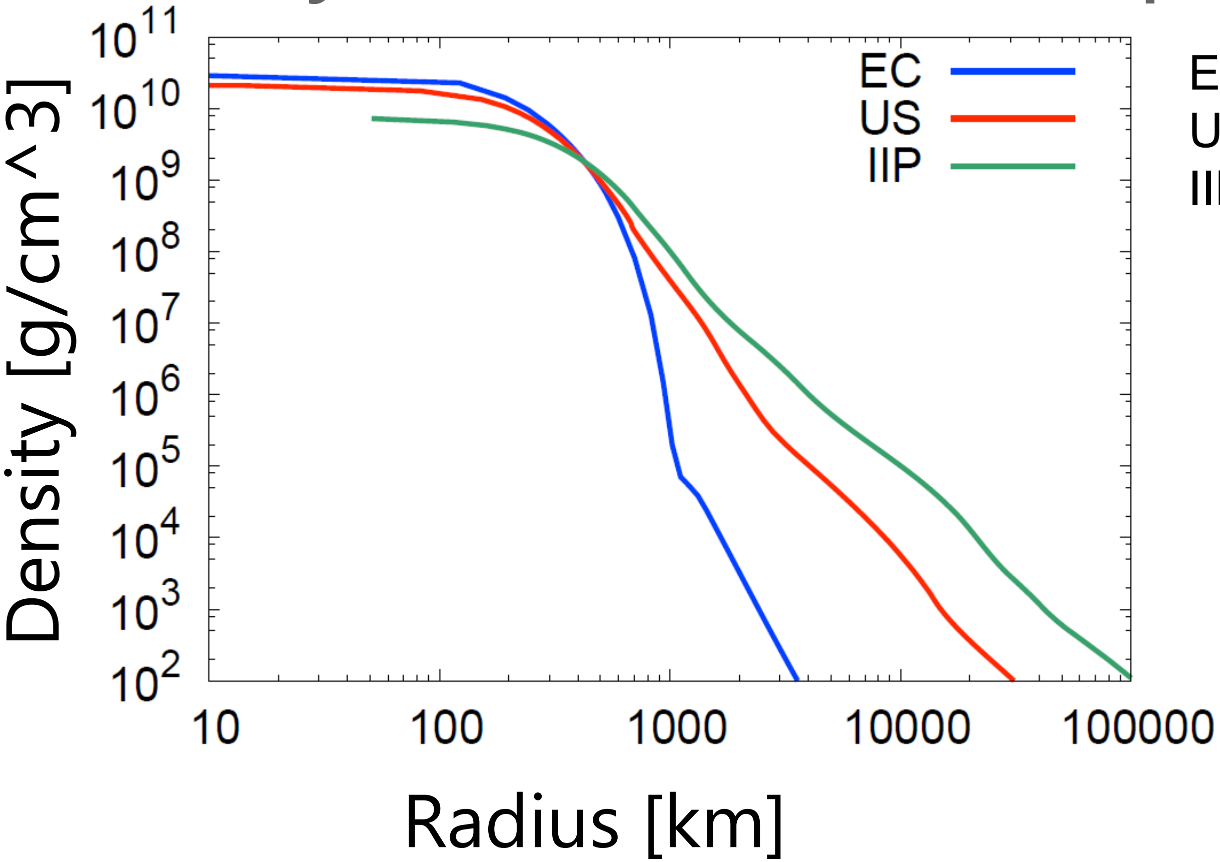
Evolution of Shock wave



Shock revival: 100ms



Density structure of the progenitor



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

$$\rho_{\mathrm{EC}} < \rho_{\mathrm{US}} < \rho_{\mathrm{IIP}}$$

Electron capture SN

IIP SN

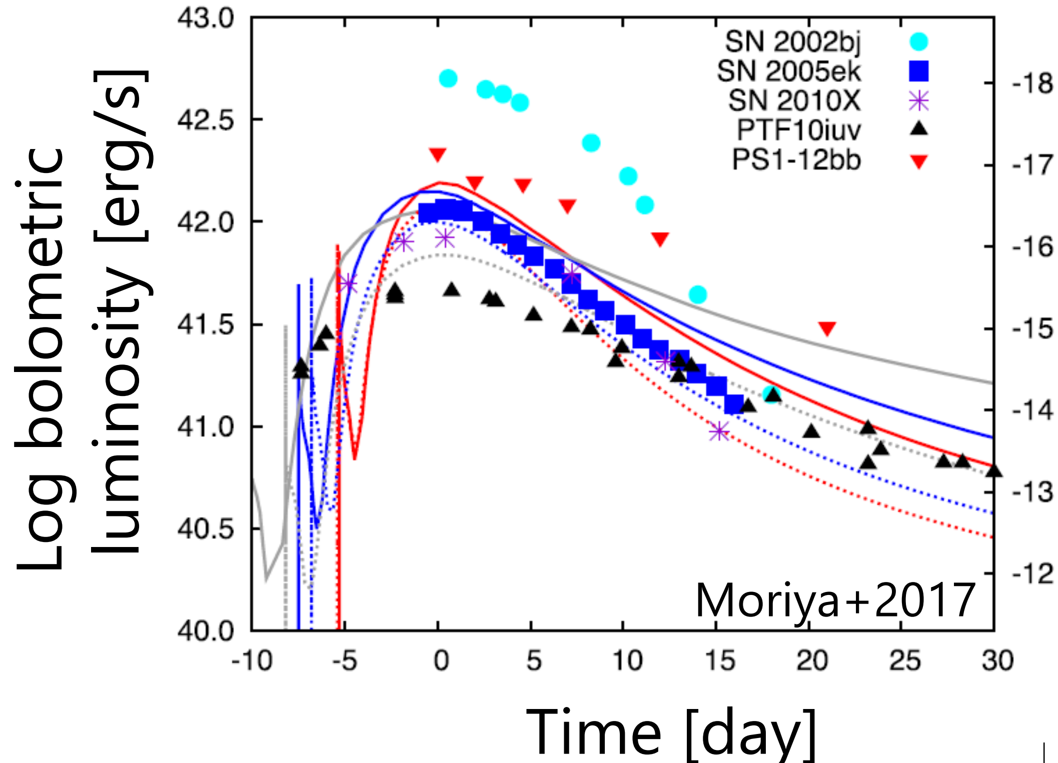
Ultra-stripped SN

The hierarchy of mass accretion rate would be same.

Does it explode as a ultra-stripped SN?

Everything is comparable to that estimated by light curve modeling (Tauris+2013, Moriya+2017).

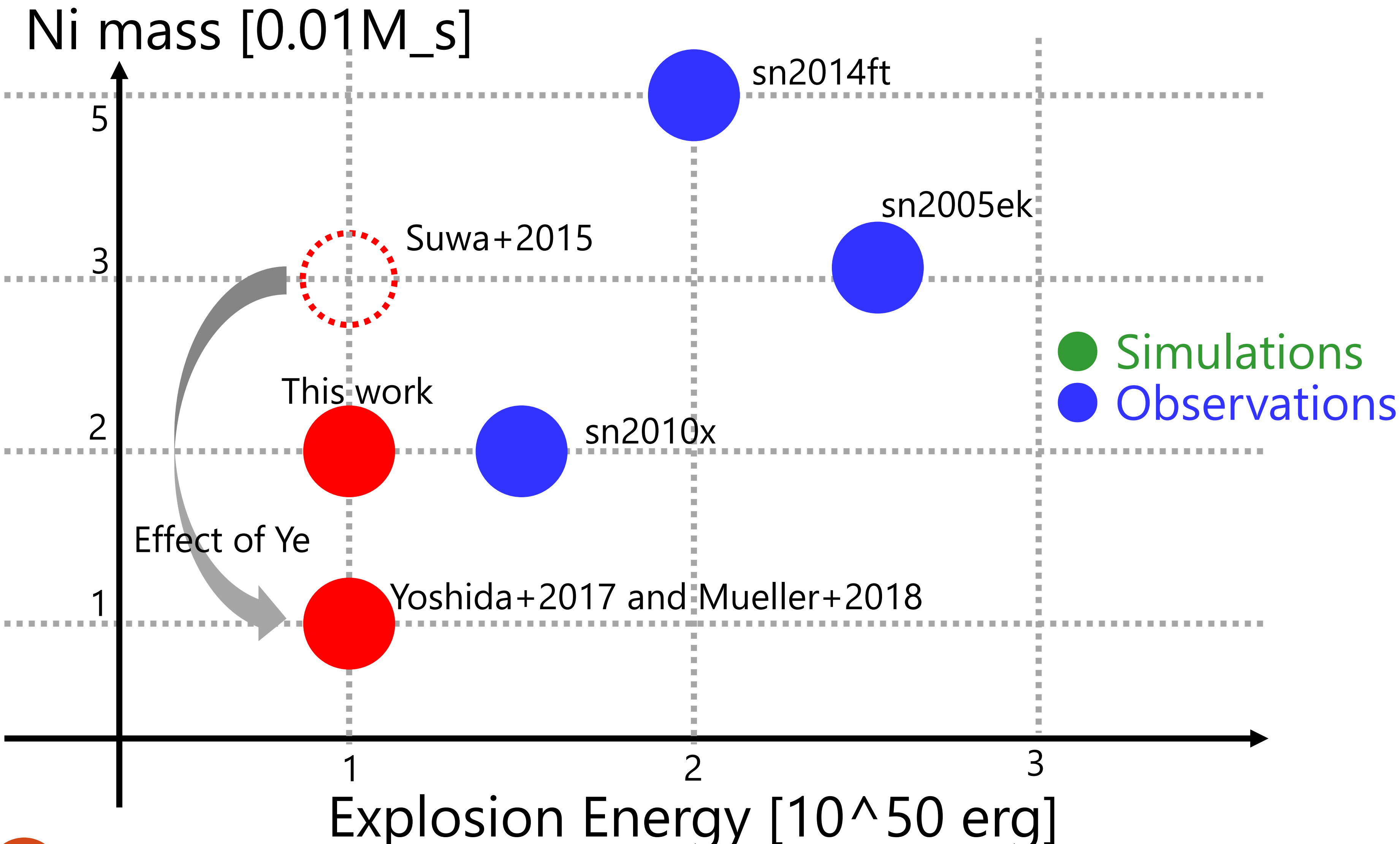
- M_ejecta ~O(0.1)Ms
- M_ns~1.4 Ms
- E_exp~O(10^50) erg
- M_Ni~O(0.01) Ms



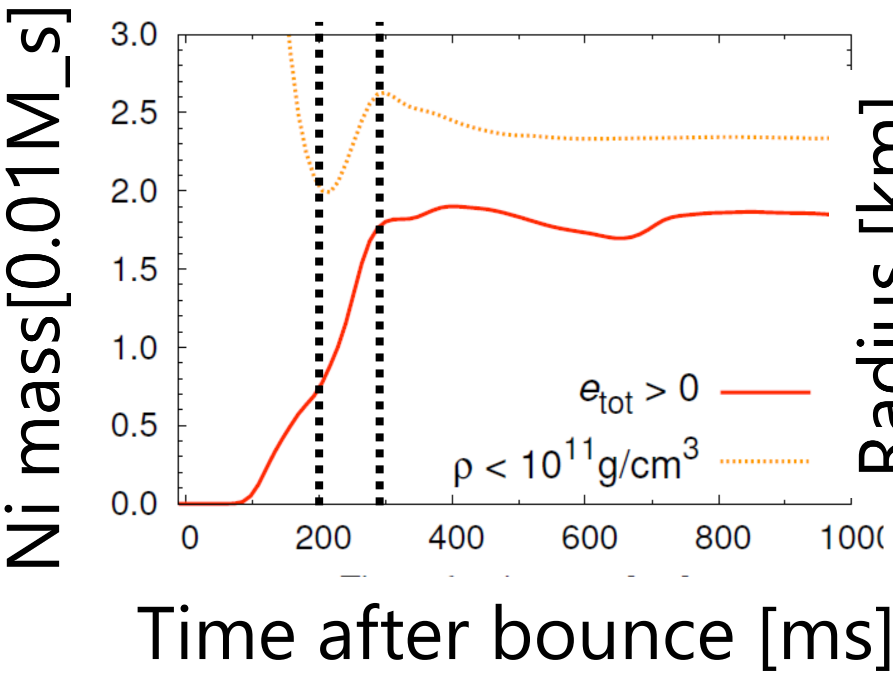
The answer is Yes, qualitatively.

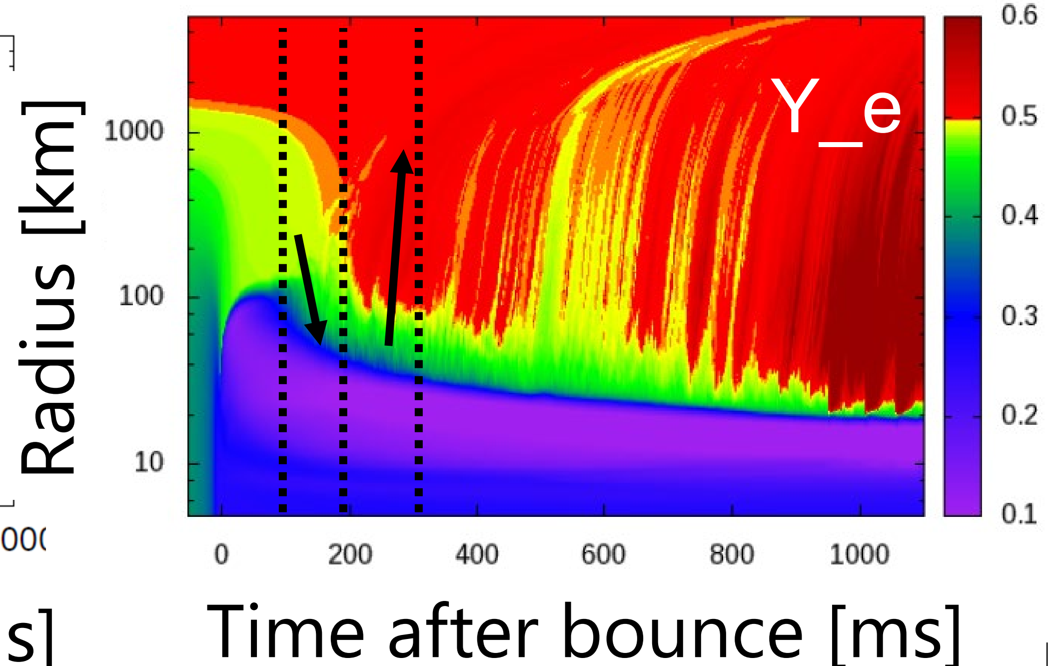
Suwa+2015, Yoshida+2017 and Mueller+2018 show the same conclusion.

Ni production Problem



When is Ni generated?

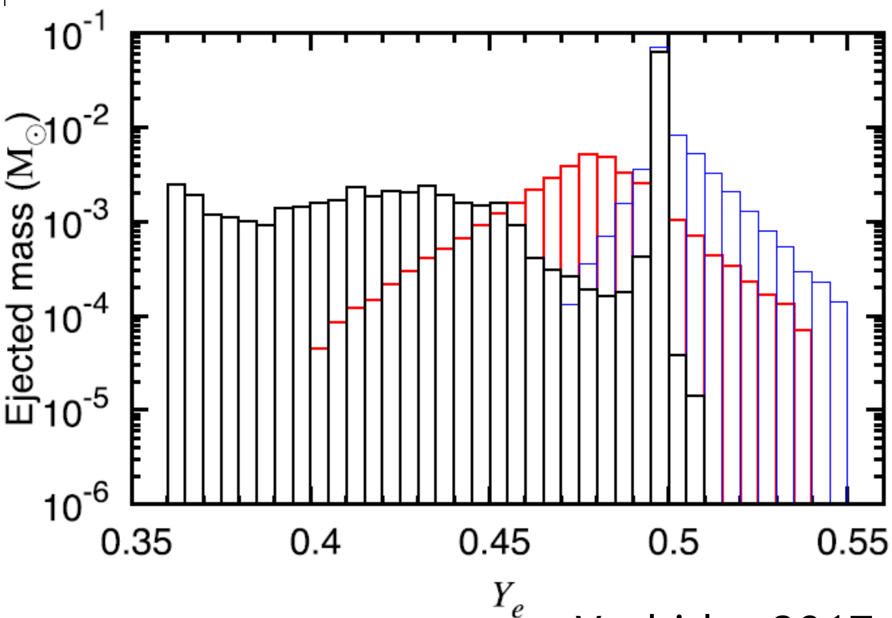




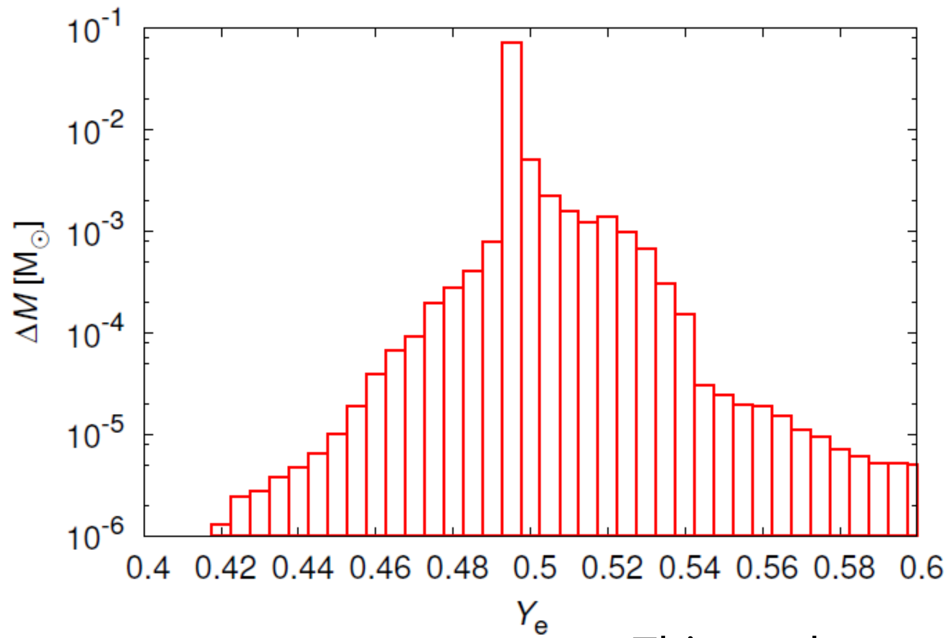
- Shock revival: 100ms
- Shock expands, but matter accretes in 100-200ms
- Time for Ni production: 200ms-300ms.
- The matter with high Ye is really ejected.

(This would be different from the model of Suwa 2015.)

Ye distribution



Yoshida+2017



This work

Black: original (Suwa+2015)

Red: mimic ECSN

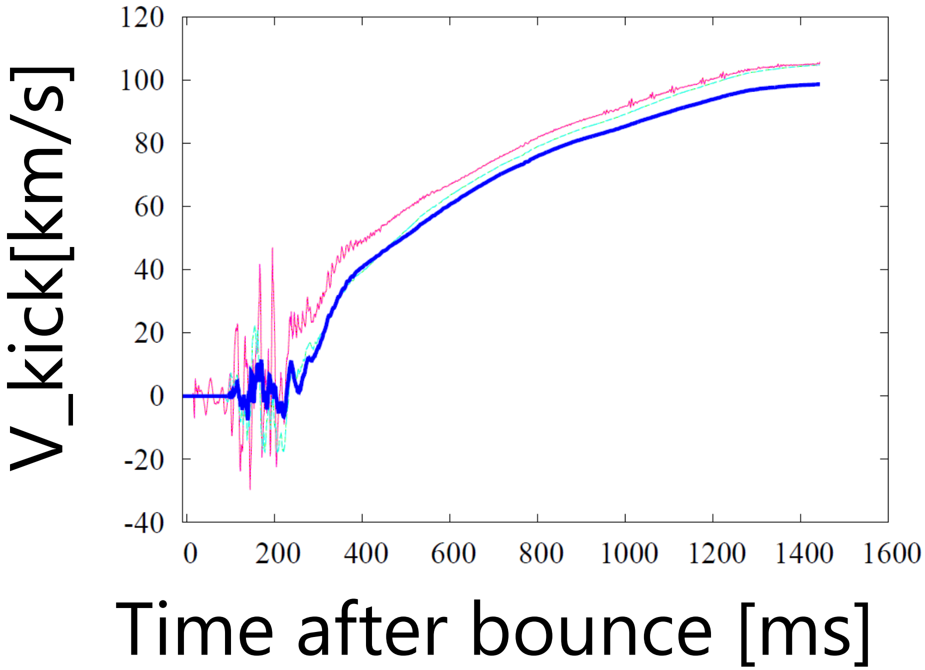
Blue: mimic normal SN

Our simulation suggests the Ye distribution is similar to the normal supernova.

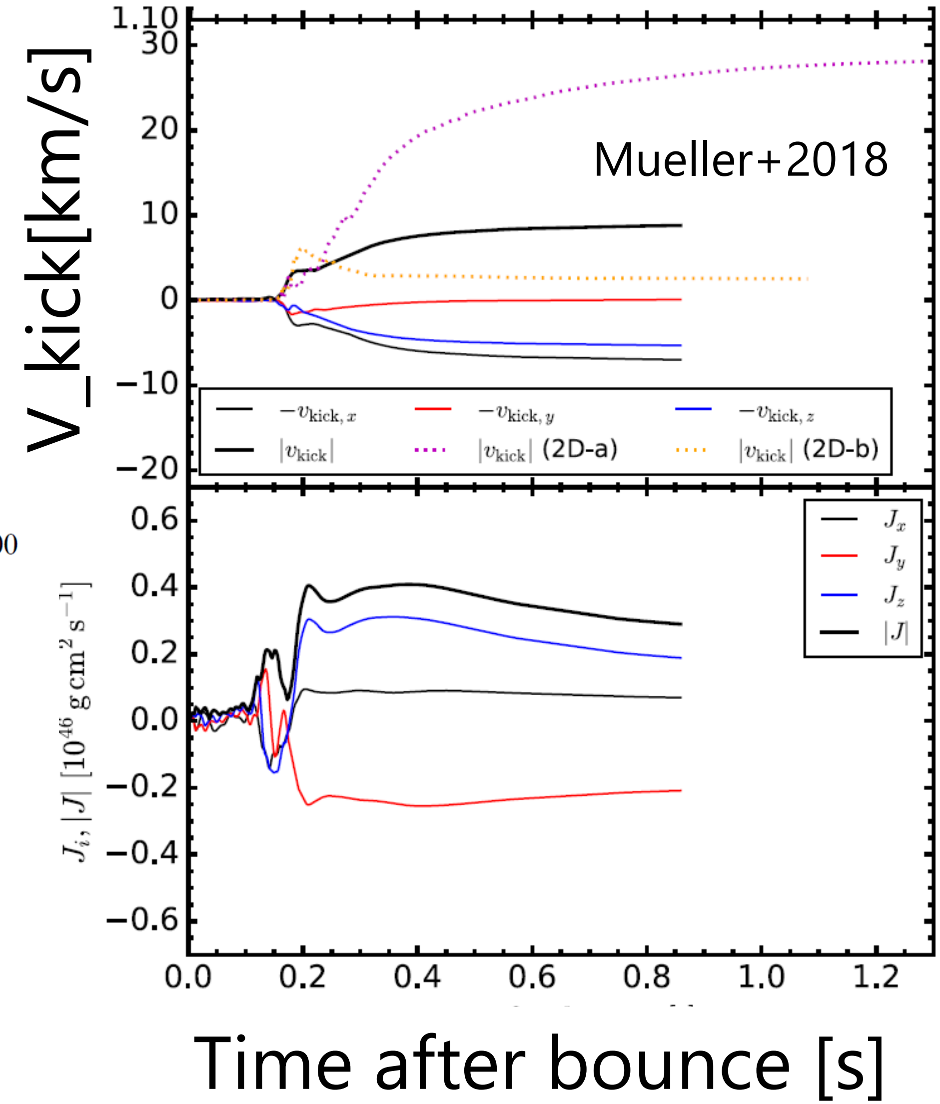
Summary

- We performed self-consistent simulations of ν-radiation hydrodynamics using a progenitor with stripped envelop to investigate whether ultra-stripped supernova is obtained or not.
- In an order of magnitude estimation, Ni mass, Eexp, Mpns, M_ejecta are consistent with the observation.
- A Problem: Simulation result of Ni mass is smaller than observations by a factor in the previous studies.
- Our new model relaxes the problem and can explain the amount of Ni for the less energetic ultra-stripped supernovae of sn2010x.

Kick Velocity



This work



Our kick velocity is larger than that of Mueller+2018.

Summary Table

Model Name units	$M_{\rm Ni}$ [a] [$M_\odot$]	$M_{\rm ej}$ [b] [$M_\odot$]	$E_{\rm exp}$ [c] [10^{50}erg]	$M_{\rm NS,by}$ [d] [$M_\odot$]	$M_{\rm NS,gr}$ [e] [$M_\odot$]
Suwa et al. (2015) & Yoshida et al. (2017)	0.01	0.1	1.0	1.35	-
Müller et al. (2018)	0.01	-	1.1	1.42	-
This study	0.02	0.13	1.0	1.37	-
PTF10iuv & sn2010x (Kasliwal et al. 2010; Moriya et al. 2017)	0.02	0.15-0.16	1.5	-	-
sn2005ek (Tauris et al. 2013; Moriya et al. 2017)	0.03	0.3	2.5	-	-