A Light-curve Investigation of Electron-capture Supernovae

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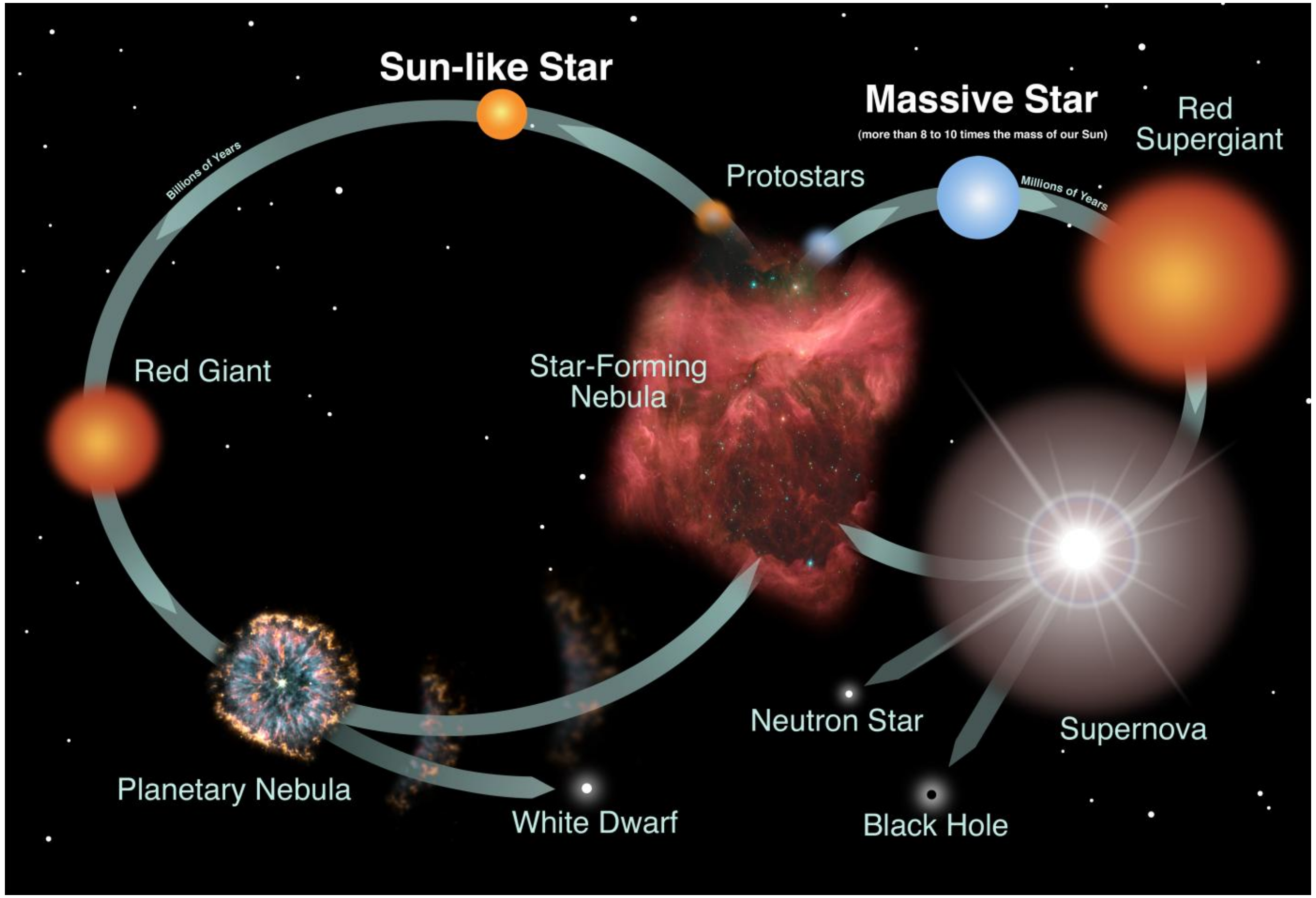
概要

- 最も低質量な重力崩壊型超新星である電子捕獲型超新星の光度曲線の特徴を明らかにし、その候補天体を調査することで、その発生率や爆発エネルギーに示唆を与えた。
- We investigate light-curve properties of the lowest-mass core-collapse supernovae, electron-capture supernovae. Investigating the ECSN candidates, we infer their occurrence rate and explosion energies.

Lifecycles of stars

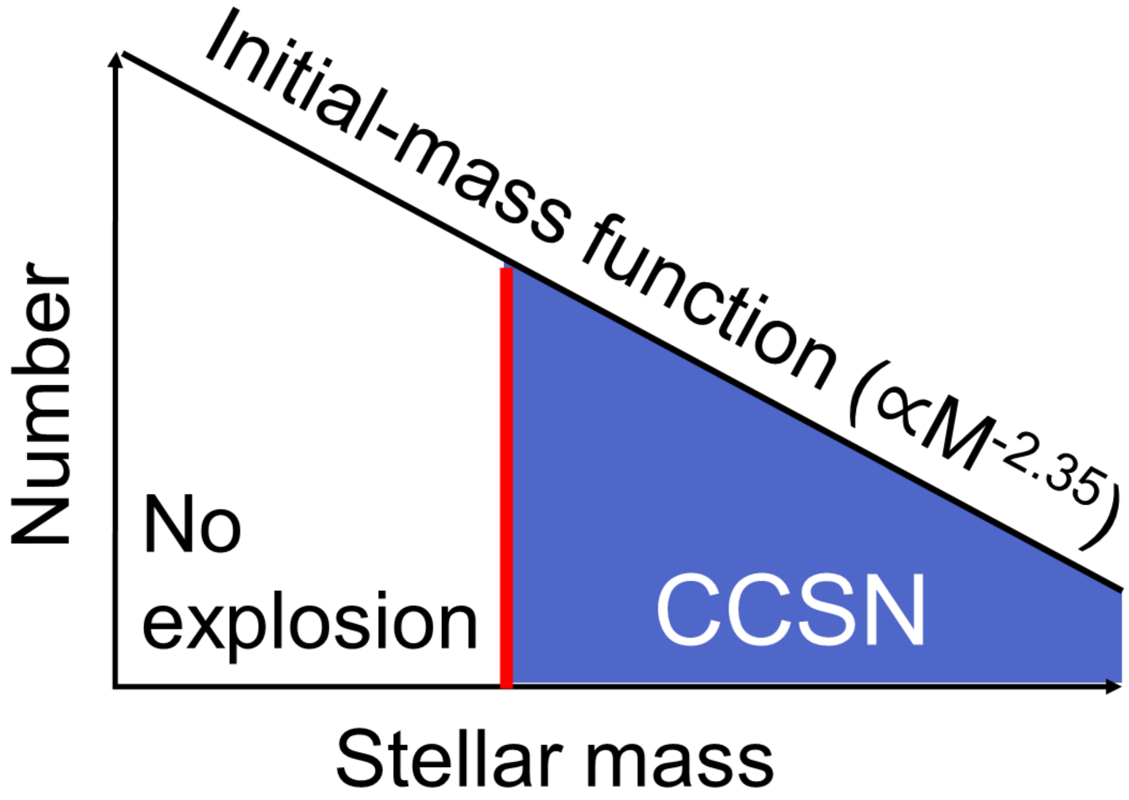


SNe contribute to …

- Star formation
- Galaxy evolution
- Chemical evolution
- Diffuse SN neutrino background

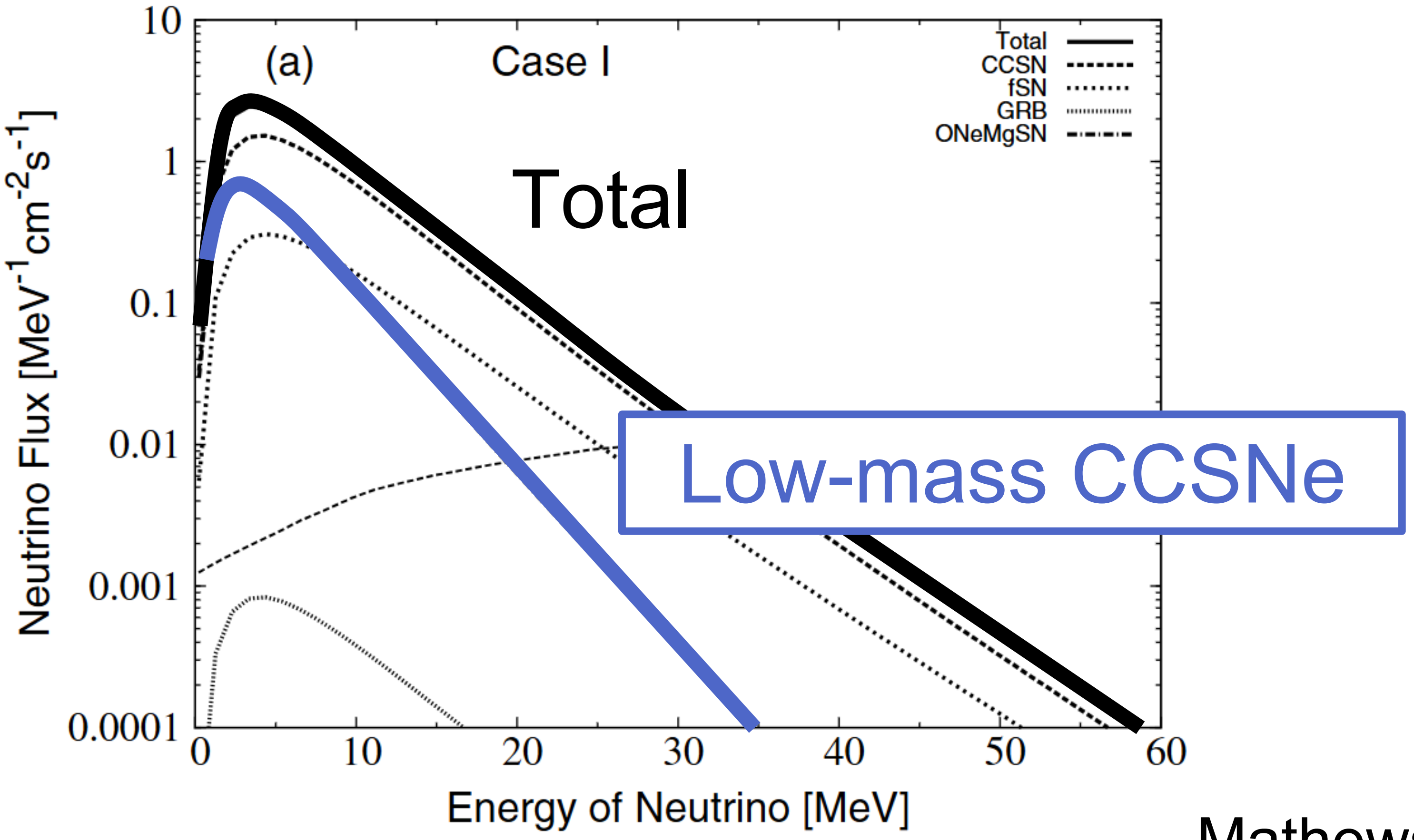
NASA,
Night Sky Network

Initial-mass range of CCSNe



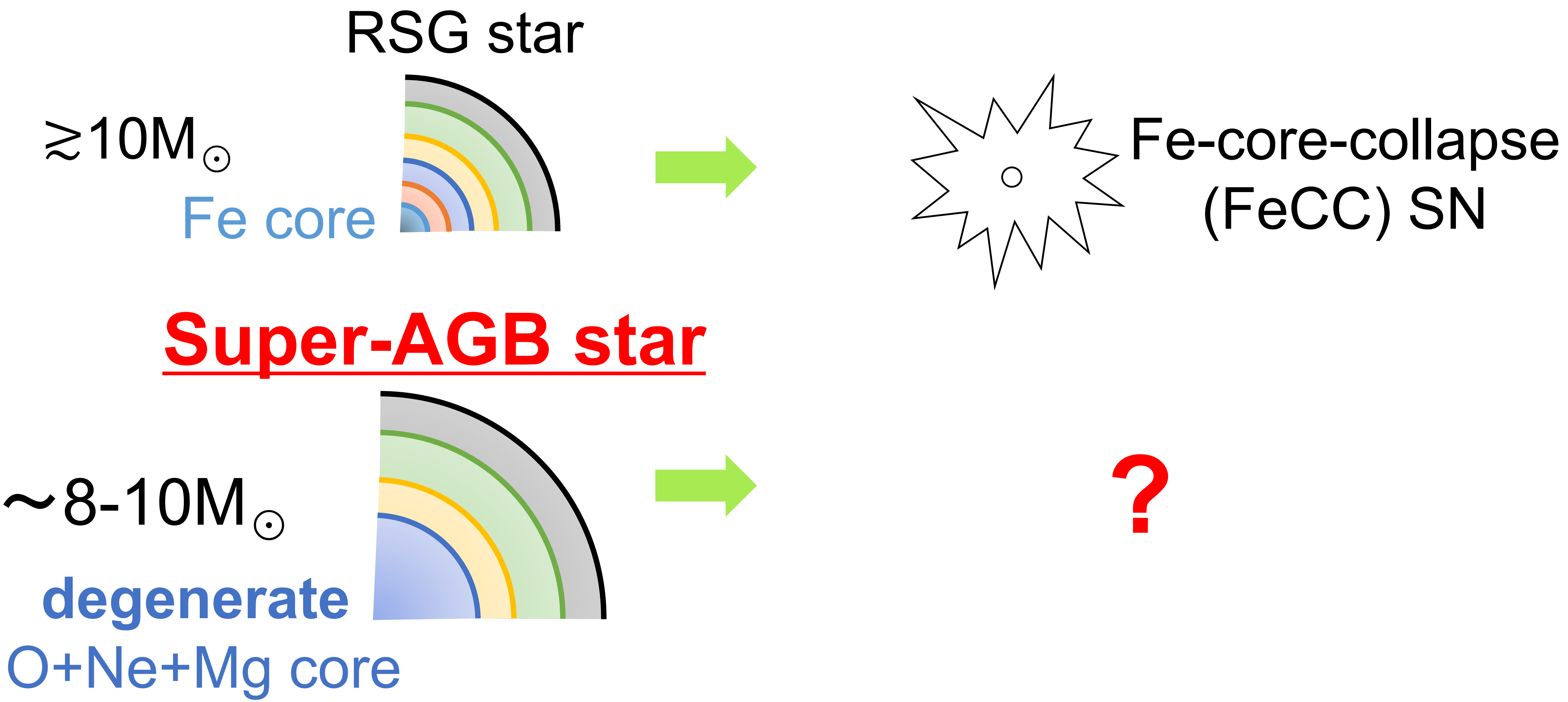
Low-mass limit strongly affects CCSN rate.

Diffuse SN neutrino background

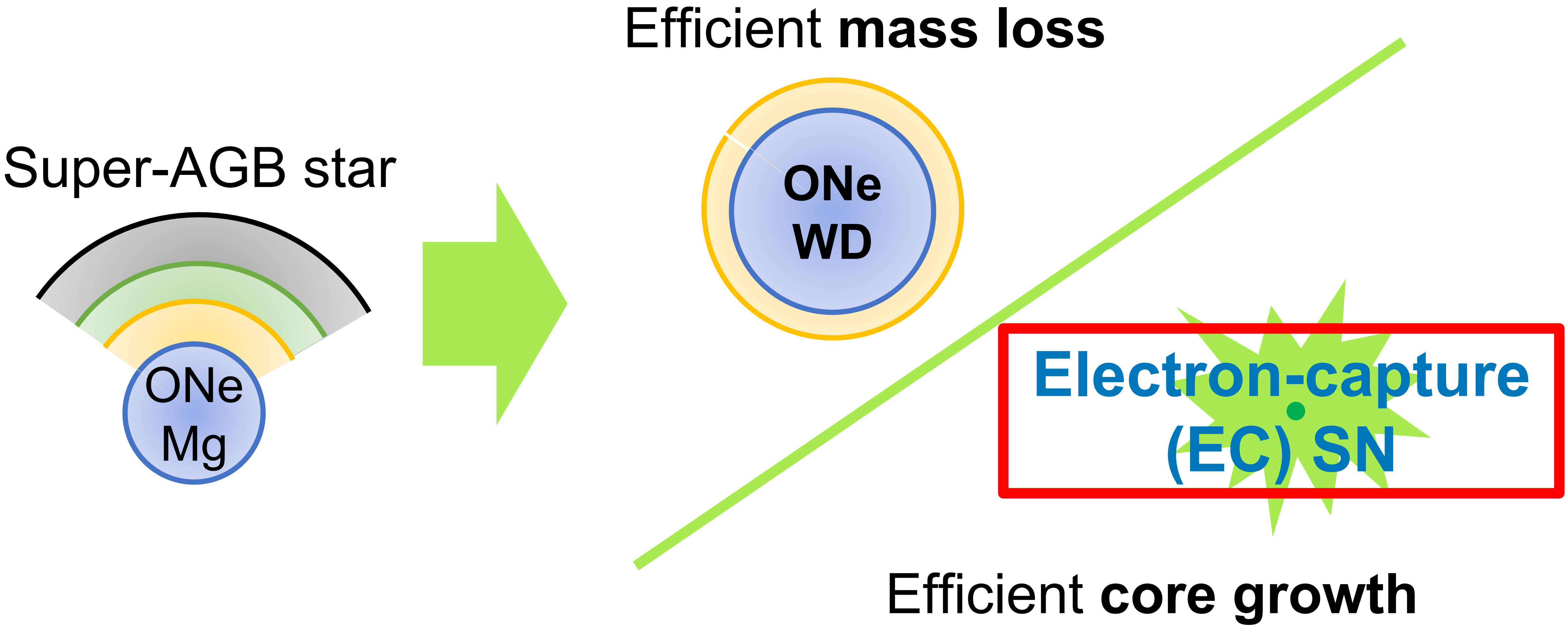


Mathews+14

Terminal fate of massive stars

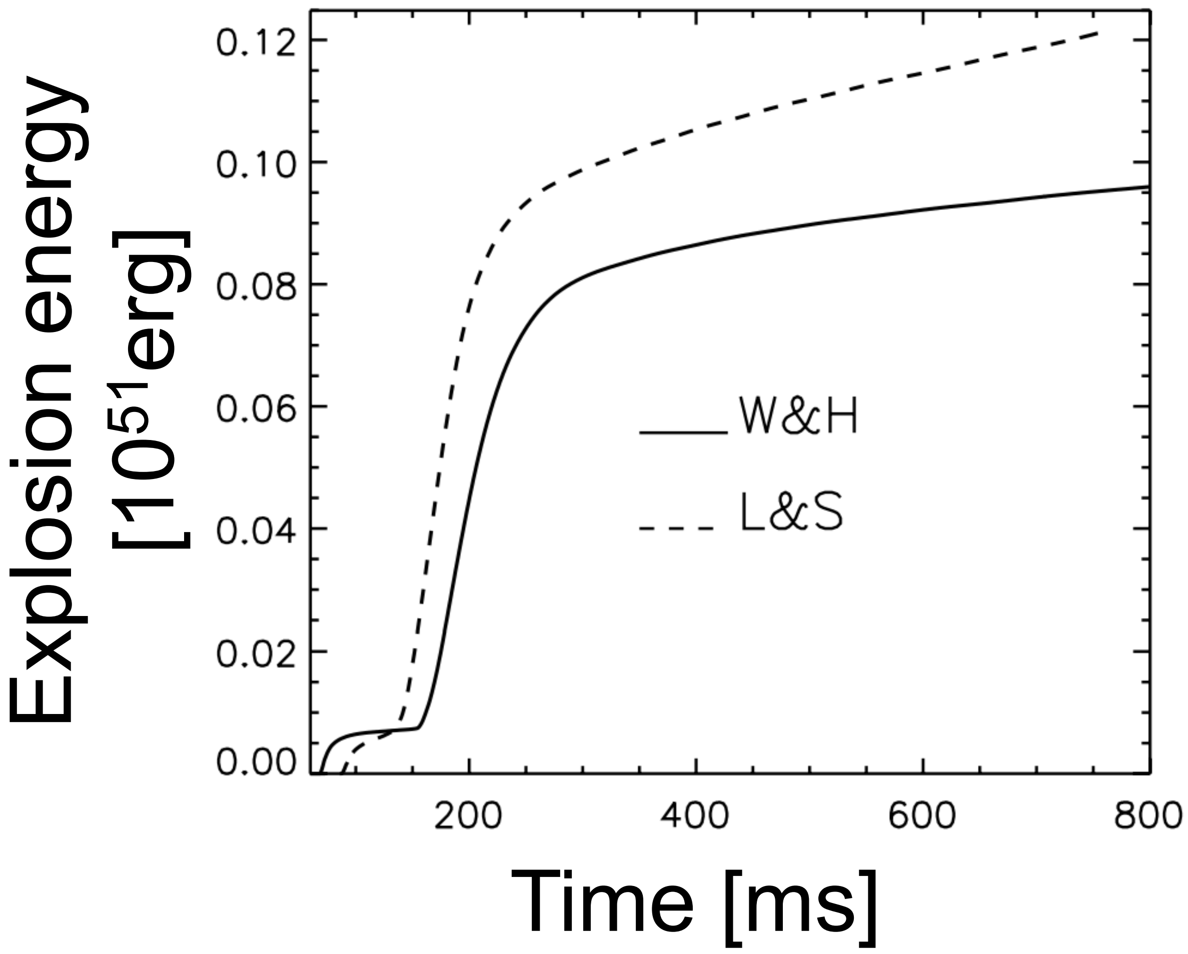


Terminal fate of super-AGB stars



Initial stellar mass of ECSNe is unclear

ECSN explosion



Low energy
~10^{50}erg

Kitaura+06

ECSN candidates

SN 1054 (Crab nebula, Nomoto+82)

NASA, ESA, J. Hester and A. Loll
(Arizona State University)

SN 2018zd (Hiramatsu+21)

Hiramatsu+21

Observational investigations are becoming feasible.

Aim of my research

Theory (Sato+24)

- ➢ Revealing a robust observational difference between ECSNe and low-mass FeCCSNe
- ➢ Proposing a diagnostic method to identify ECSNe

Observation (Sato+ submitted)

- ➢ Searching for ECSN candidates in the past
- ➢ Examining the consistency between ECSN theory and observation

Progenitor models

RSG stars

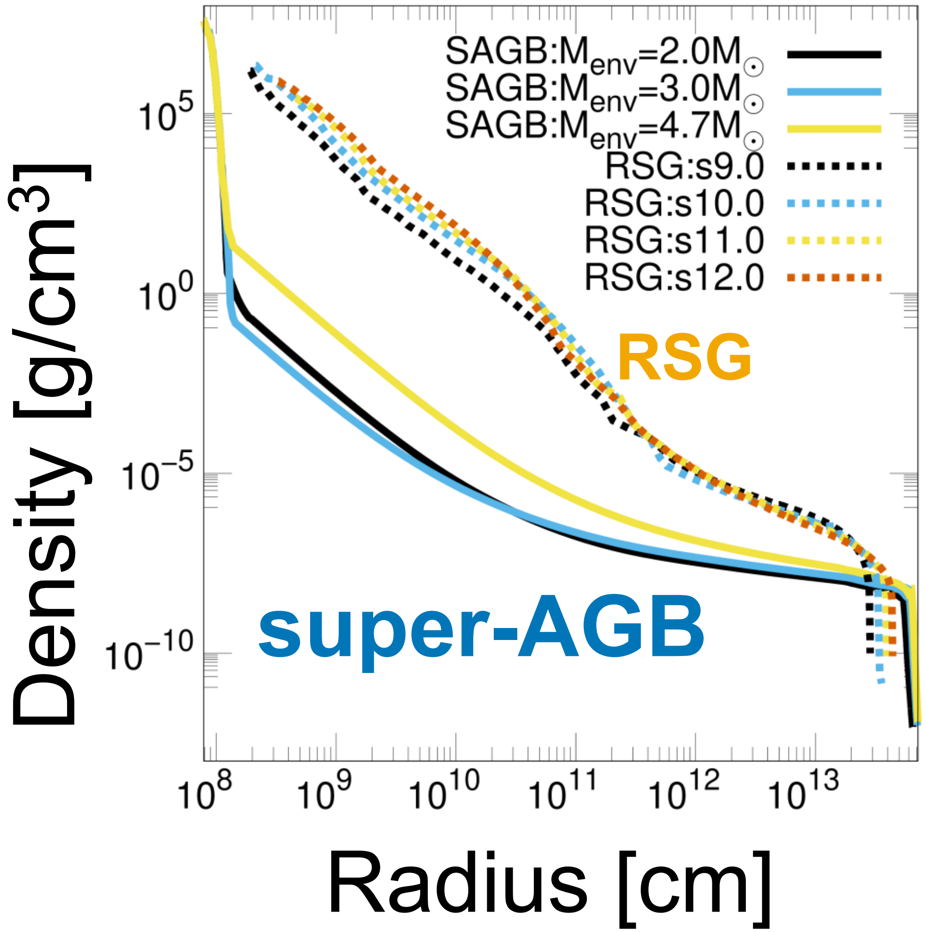
(for FeCCSN, Sukhbold+16)

- Initial mass M_{ZAMS} = 9-12 $M_\odot$

Super-AGB stars

(for ECSN, Tominaga+13)

- Envelope mass M_{env} = 2.0-4.7 $M_\odot$
- Envelope H abundance $X(H)_{env}$ = 0.2-0.7



Low-density and extended envelope

Light-curve models

Explosion

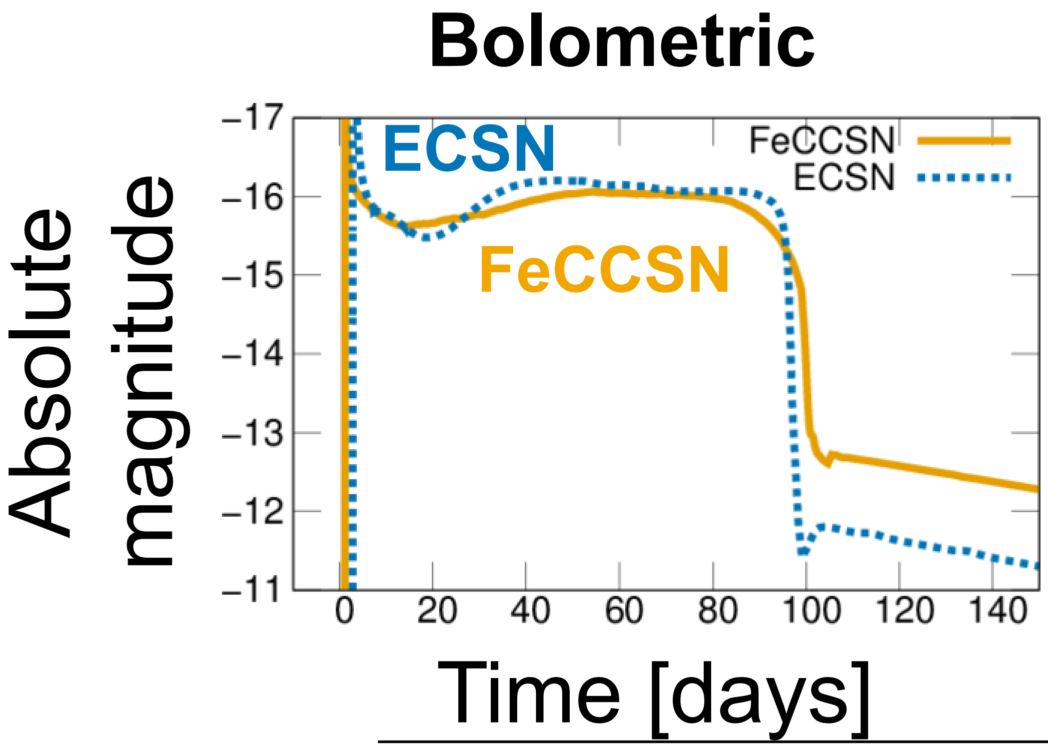
- Thermal bomb
- Explosion energy (0.1-14.2) $\times 10^{50}$ erg

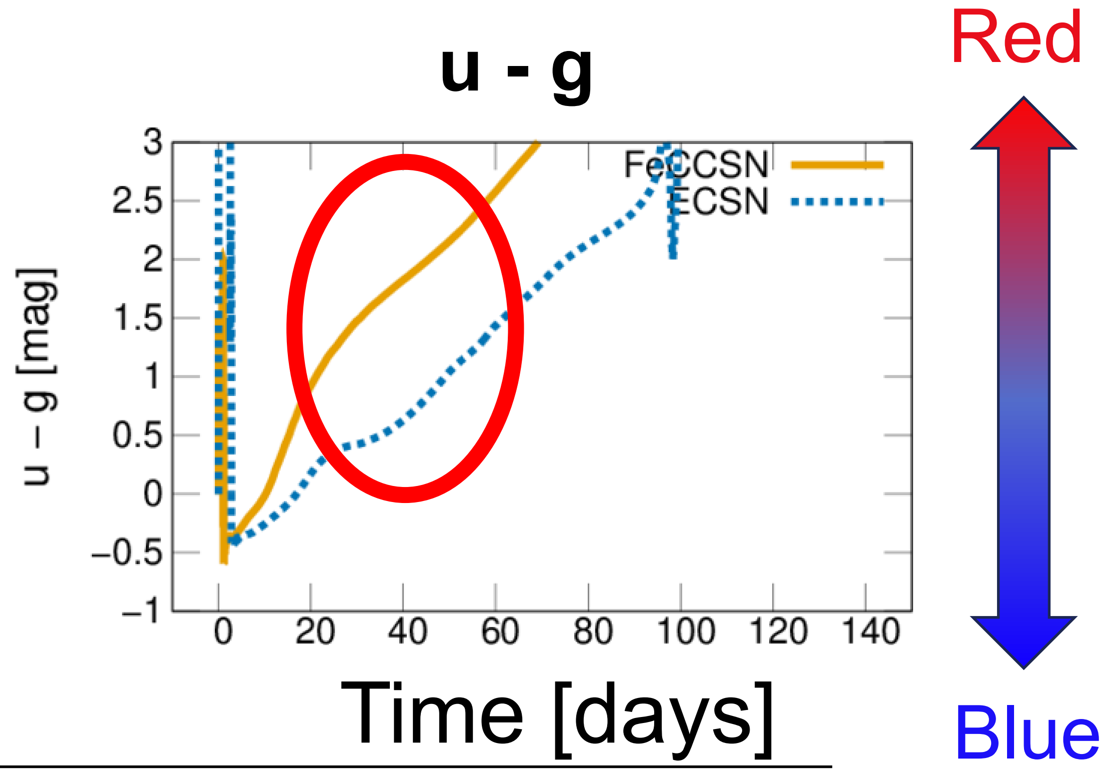
Light-curve calculation

- 1D multi-group radiation hydrodynamics code, STELLA (Bllinikov+93)

~ 2000 models

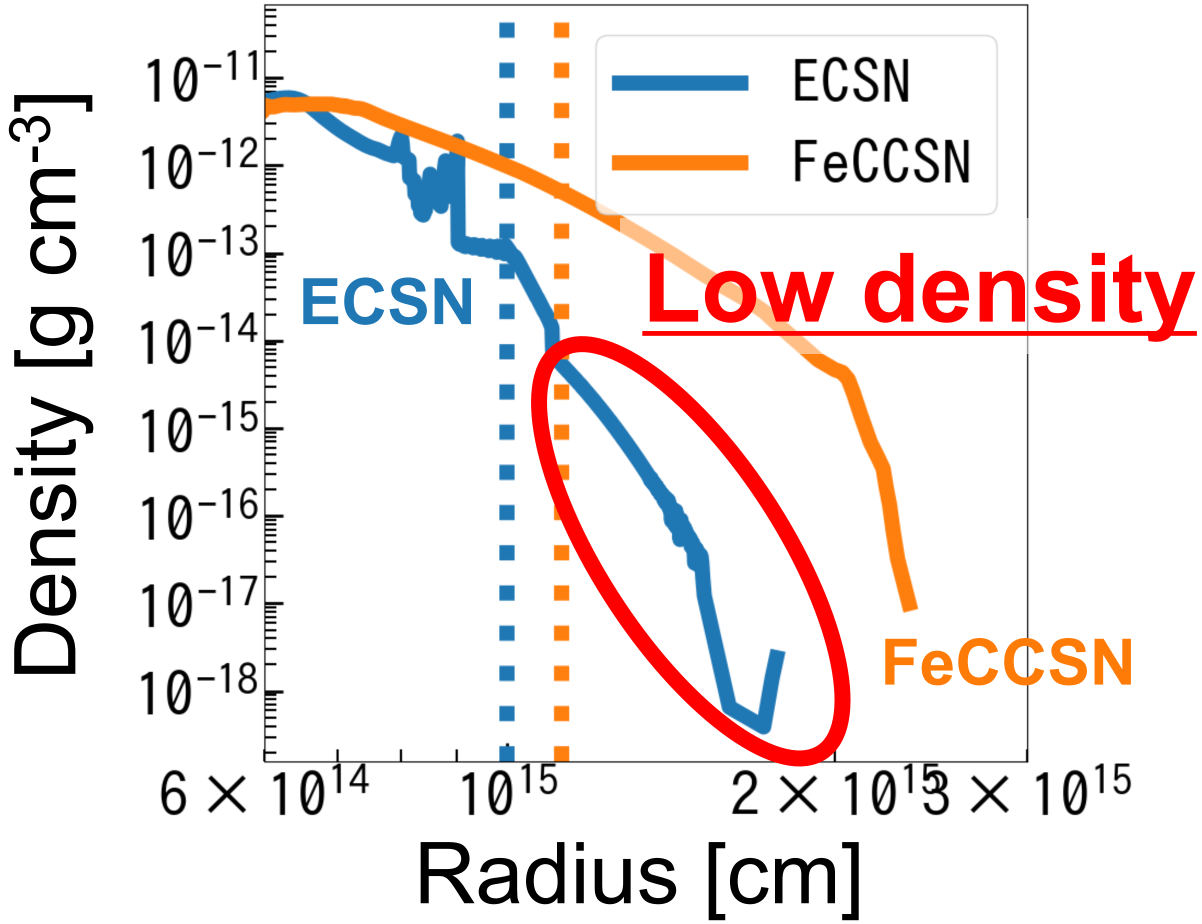
Light curves

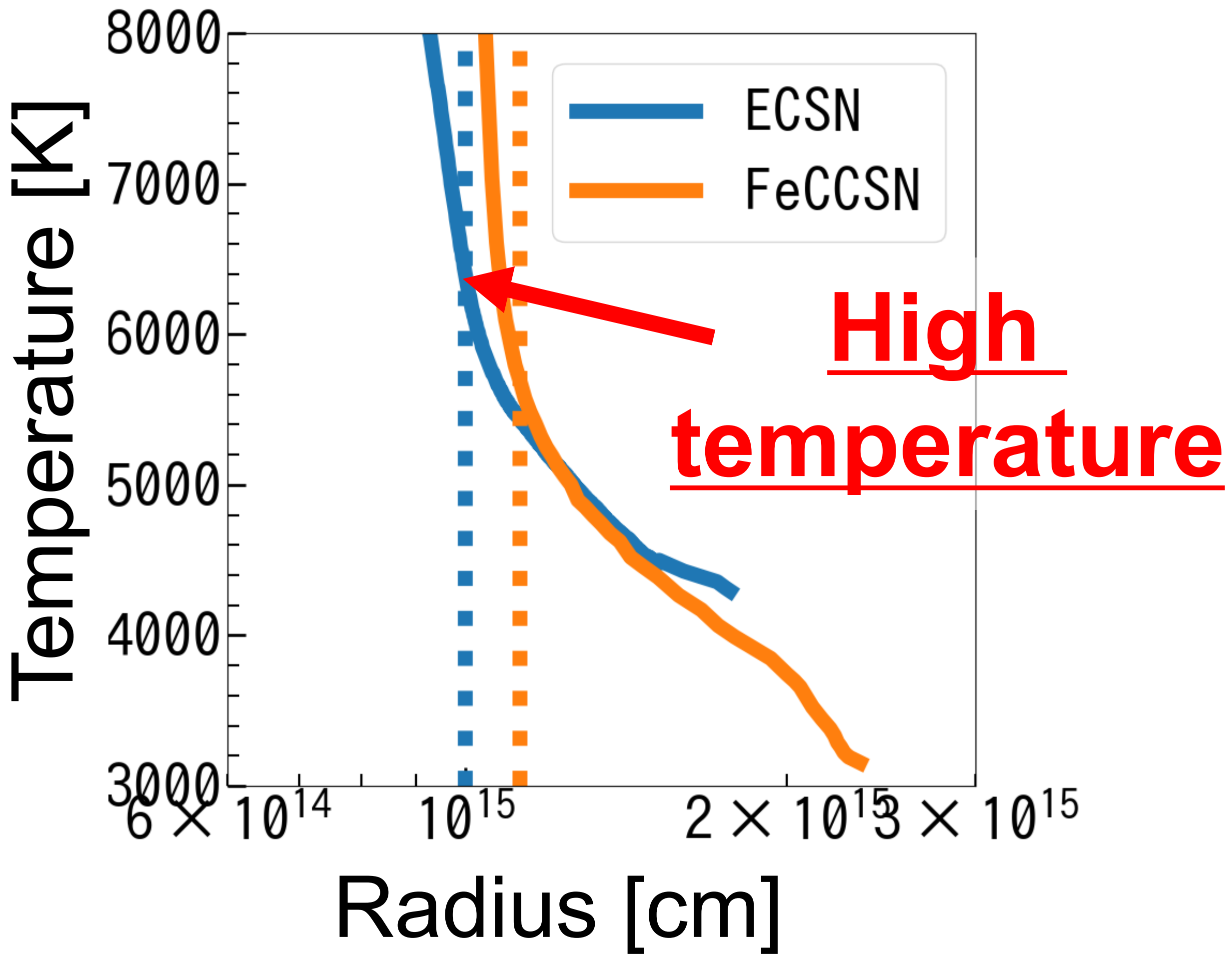




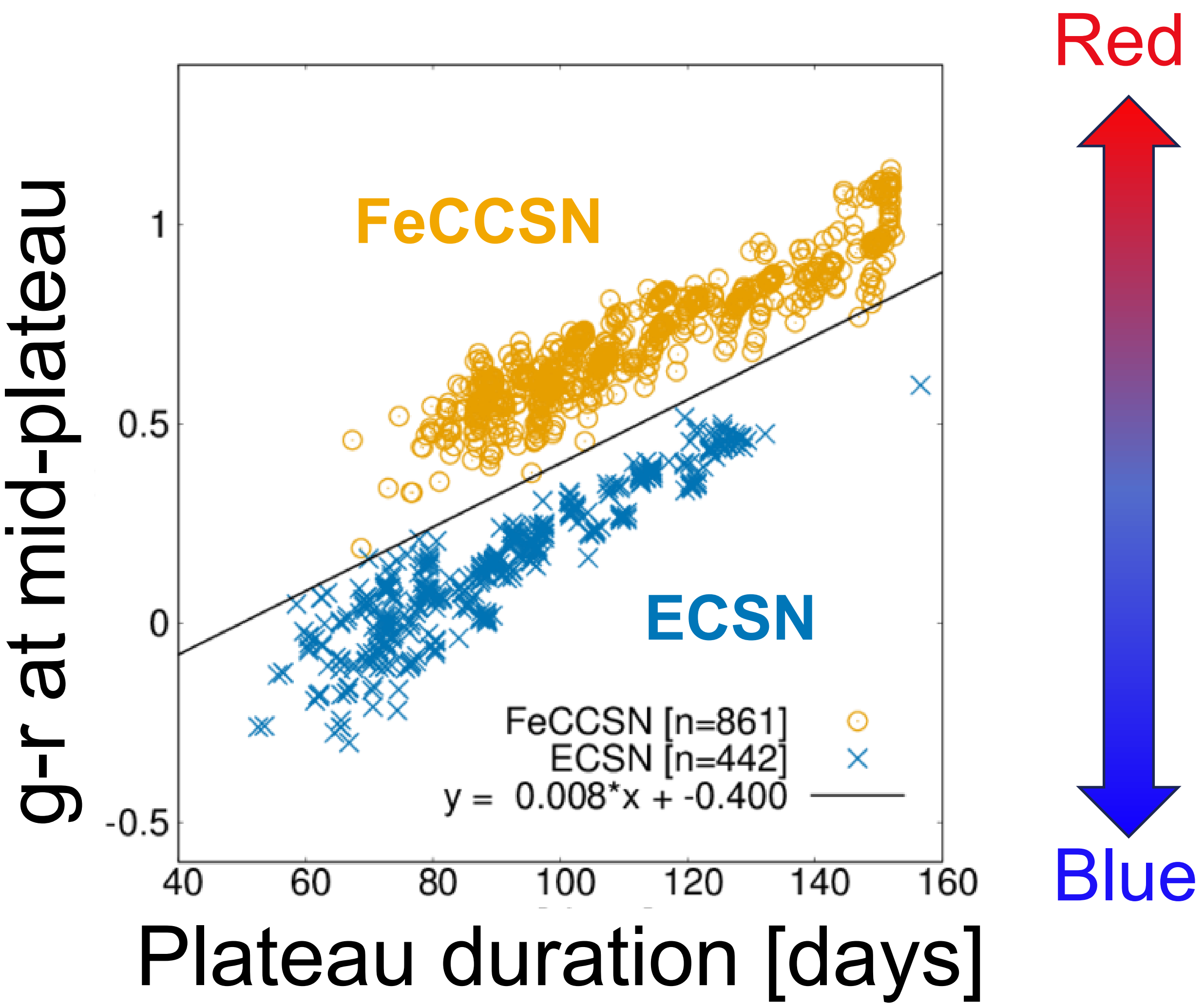
Blue plateau of ECSN

Hydrodynamical structure





Diagnostic method of ECSN



Identify ECSNe with blue plateau

Aim of my research

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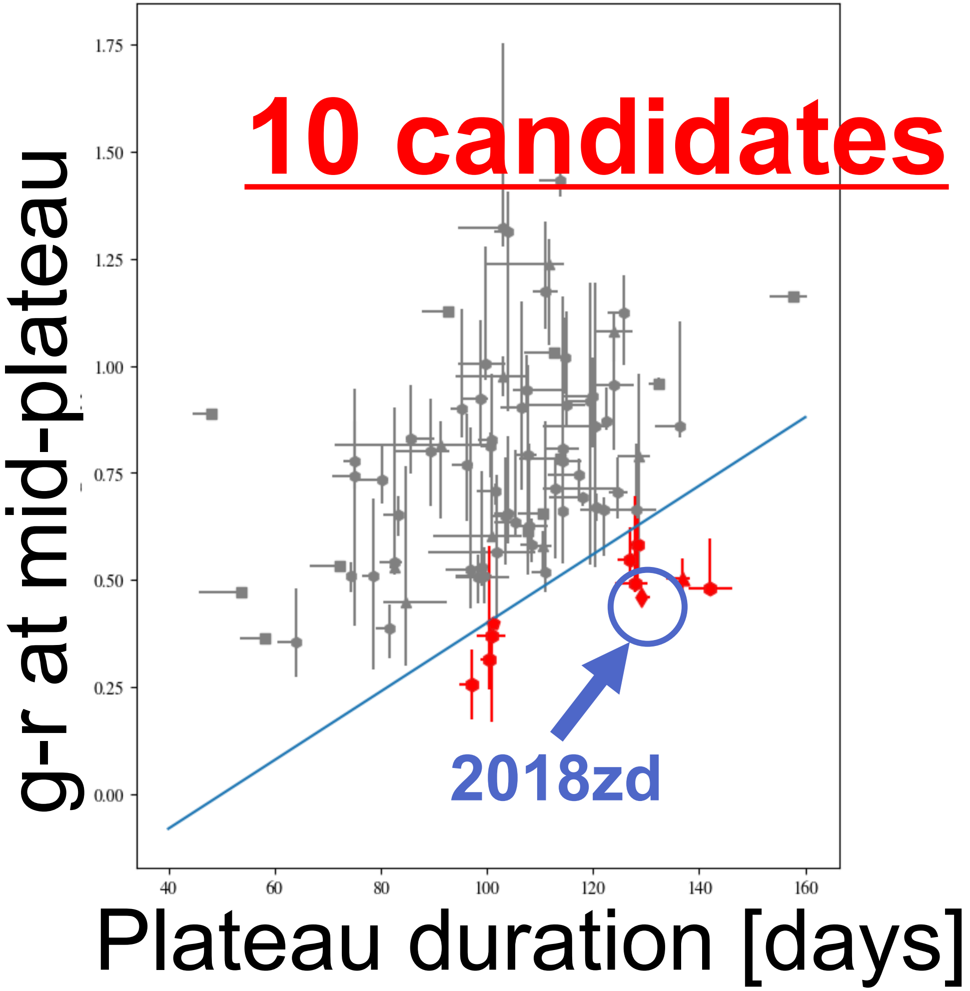
Applying the diagnostic to the past SNe

97 Type-II SNe

Literature sample: 35

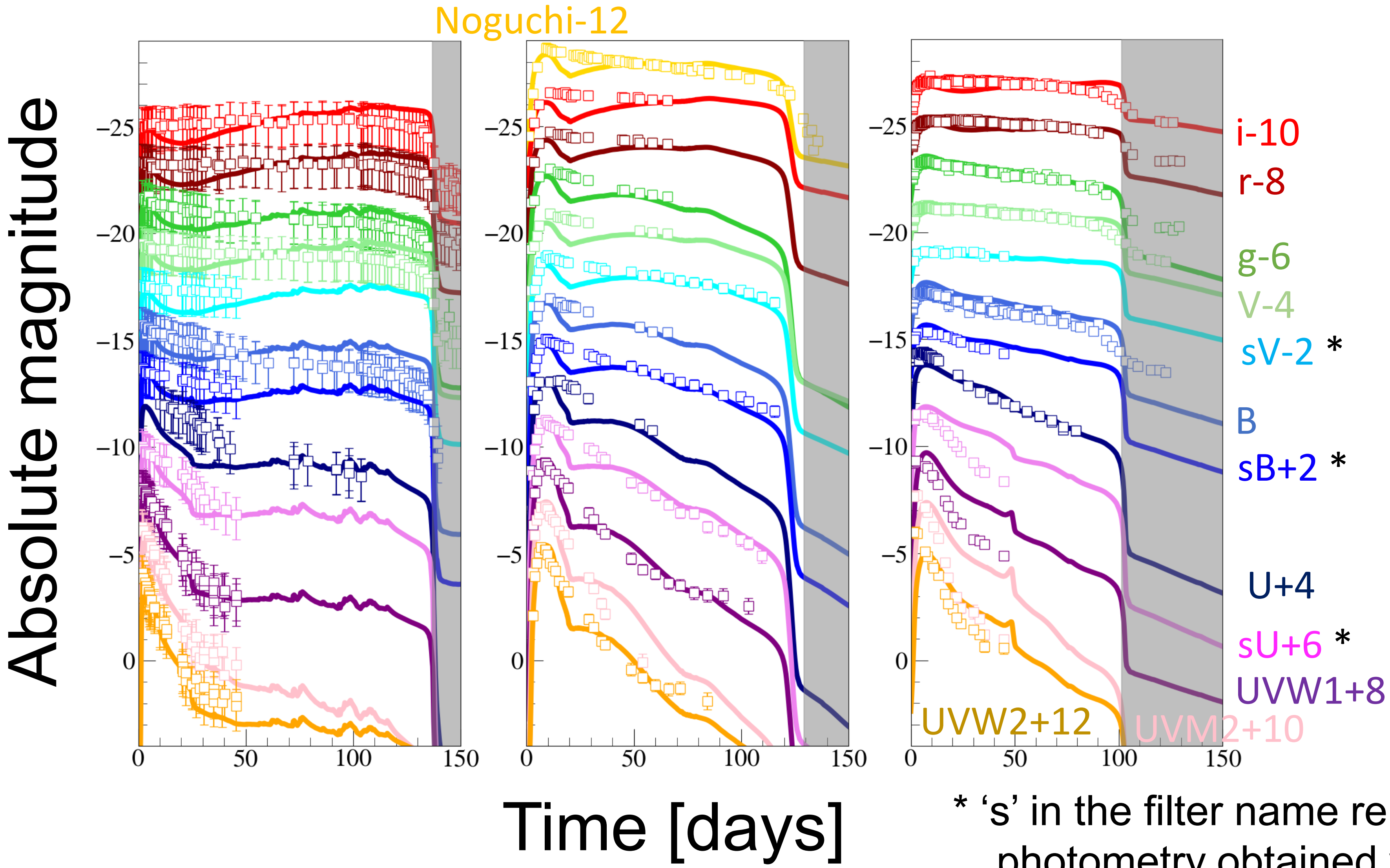
- Faran+14: 5
- Galbany+16: 7
- Valenti+16: 10
- Anderson+24: 11
- Hiramatsu+21: 1 (2018zd)
- Shrestha+23: 1 (2023axu)

ZTF survey sample: 62



Sato+ submitted

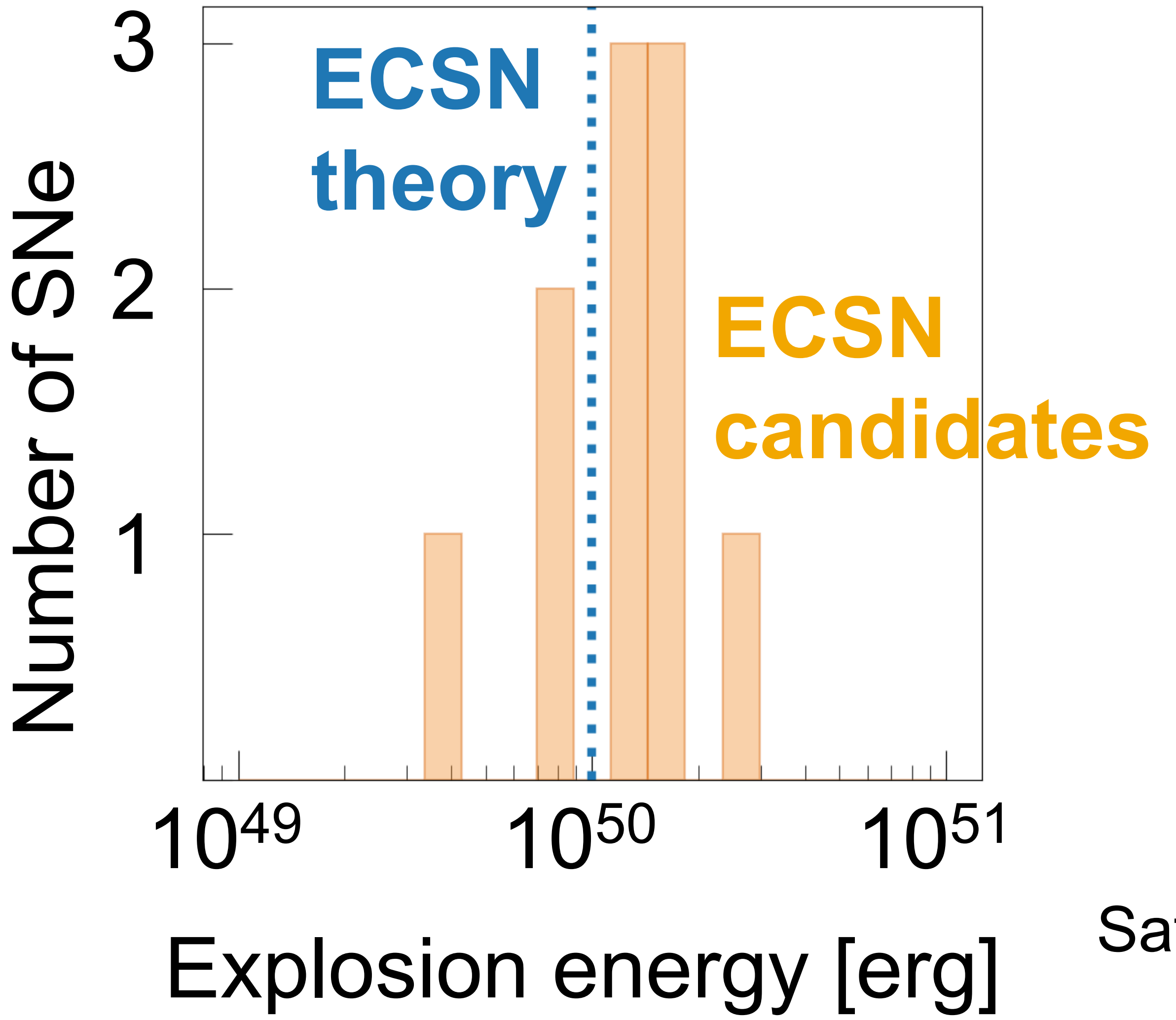
Comparison with models



Sato+ submitted

* 's' in the filter name represents the photometry obtained with Swift

Explosion energy



<u>Consistent with explosion theory</u>

Sato+ submitted

Occurrence ratio & Initial mass

Occurrence ratio

- **~ 3.0 - 15.7 %** of Type-II SNe (1.8 - 9.2 % of CCSNe).

Initial mass

- The initial stellar mass window may be **~ 0.1 - 0.7 $M_\odot$**.

Summary

- ECSNe show bluer plateaus than low-mass FeCCSNe.
- 10 ECSN candidates are found from 97 Type-II SNe in the past with the color-based diagnostic.
- The explosion energies of the candidates are inferred to be $\sim 10^{50}$ erg, consistent with the first-principles simulations.
- The occurrence ratio of ECSNe are inferred to be ~3.0-15.7 % of Type-II SNe.