Constraining massive star activities in the final years through the properties of supernovae and their progenitors

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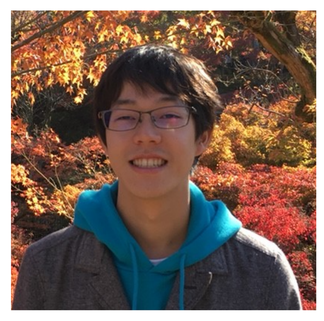
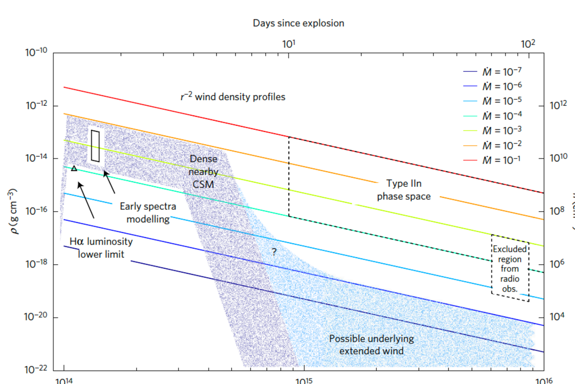


Recent observations of supernovae (SNe) just after the explosion suggest that a good fraction of SNe have the confined circumstellar material (CSM) in the vicinity. The energy deposition into the envelope has been proposed as a possible cause of the confined CSM. In this work, we have calculated the response of the envelope to various types of sustained energy deposition starting from a few years before the core collapse. We have further investigated how the resulting progenitor structure would affect appearance of the ensuing supernova. We have found that a highly super-Eddington energy injection into the envelope changes the structure of the progenitor star substantially, and the properties of the resulting SNe become inconsistent with usual SNe. This argument constrains the energy budget involved in the possible stellar activity in the final years to be at most one order of magnitude higher than the Eddington luminosity.

Introduction

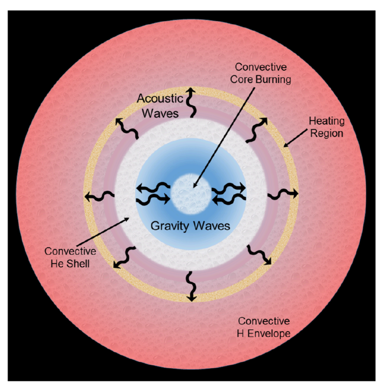
Recent observations of SNe just after the explosion suggest that a good fraction of SNe have **the confined circumstellar material (CSM)** in the vicinity (Smith 2014).

Yaron et al. 2017



The energy deposition to the envelope related to the advanced burning phases might be responsible for the enhanced mass loss (Dessart et al. 2010).

The possible reason for the energy deposition in the last few years are :
- Gravity waves (Quataert & Shiode 2012)
- Instabilities of the advanced burning.
(Arnett & Meakin 2011)



Fuller 2017

Aim

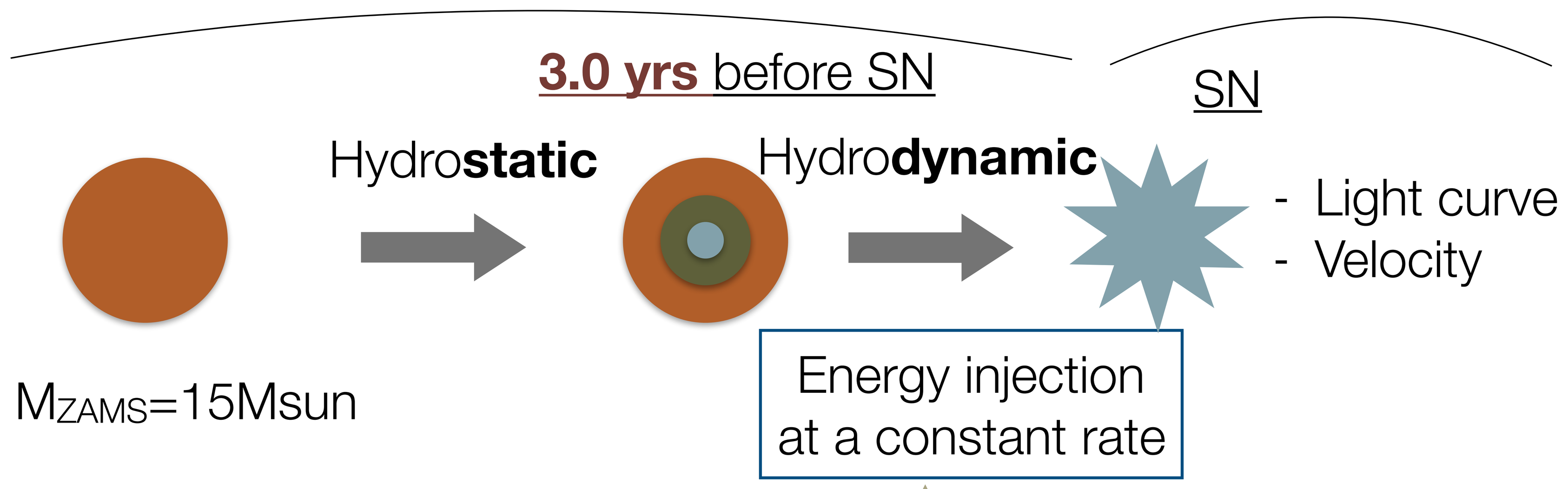
We have calculate **the response of the envelope to various types of sustained energy deposition** starting from a few years before the core collapse. We have further investigated how the resulting progenitor structure would affect the appearance of the ensuing supernova.

Method

○ Stellar evolution + Radiation-hydrodynamic simulation

MESA code (Paxton et al. 2011)

SNEC code (Morozova et al. 2015)



M_{ZAMS}=15Msun

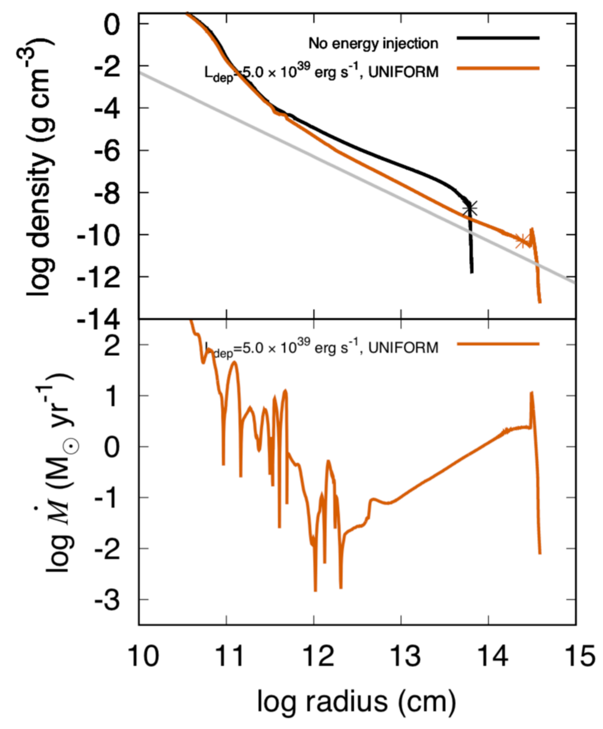
- Injection rate L_{dep} :
  10^{38} , 10^{39} , 5.0×10^{39} , 10^{40} erg/s
- Location of energy deposition
  - Uniformly into the envelope (**UNIFORM**)
  - Base at the hydrogen envelope with the width of $0.1M_{sun}$ (**BASE**)
  - Around the middle of the envelope with gaussian (**MIDDLE**)

Result

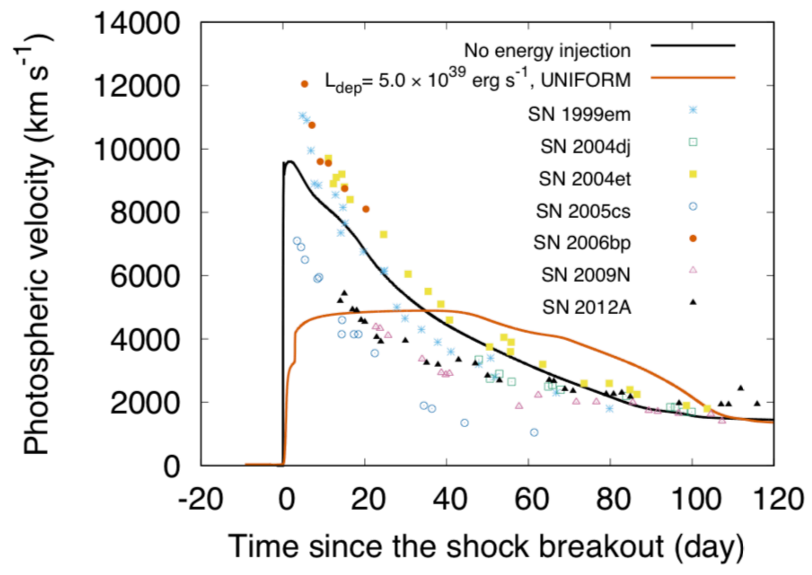
○Fiducial model (L_{dep} = 5×10^{39} erg/s, UNIFORM)

Black: Model without energy injection
Orange: Model with energy injection

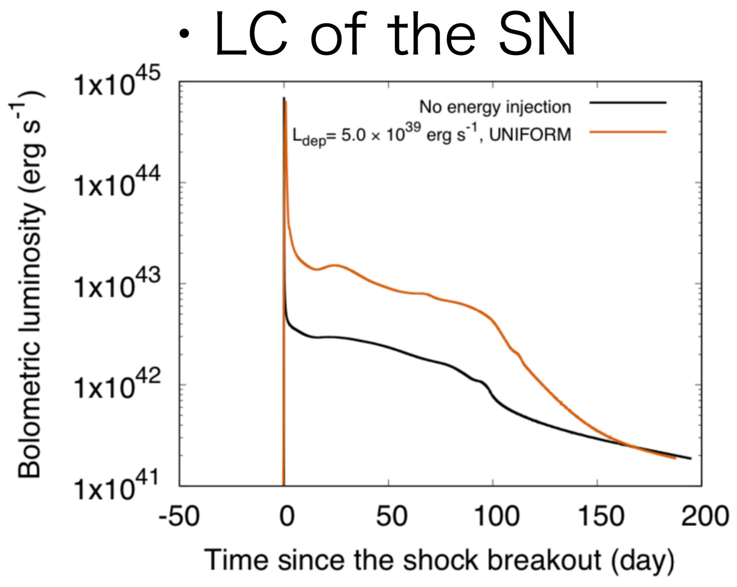
・Progenitor density profile

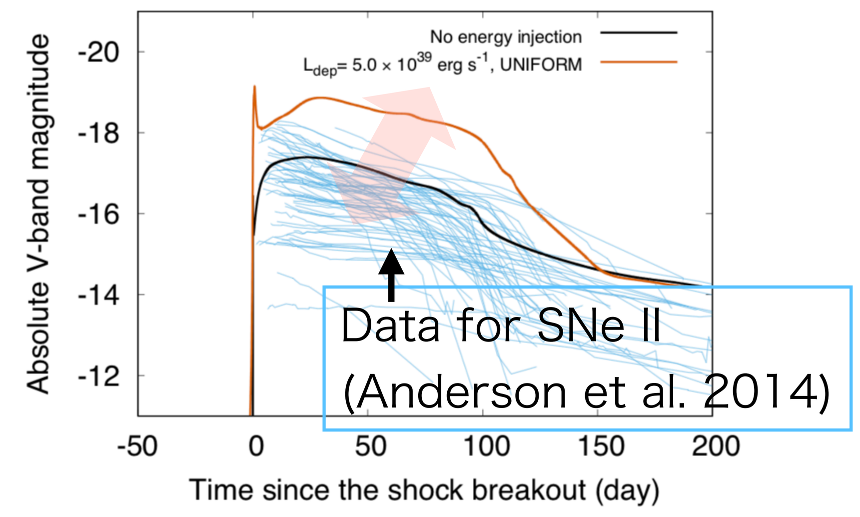


・Velocity of the SN



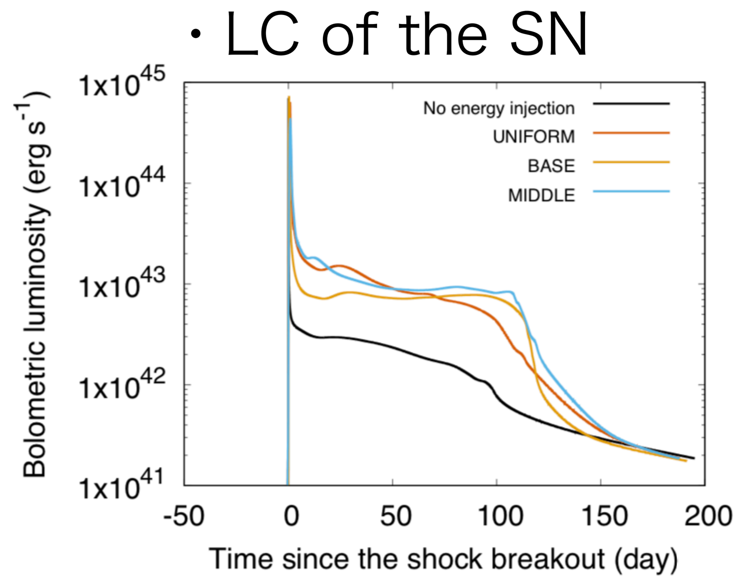
・LC of the SN



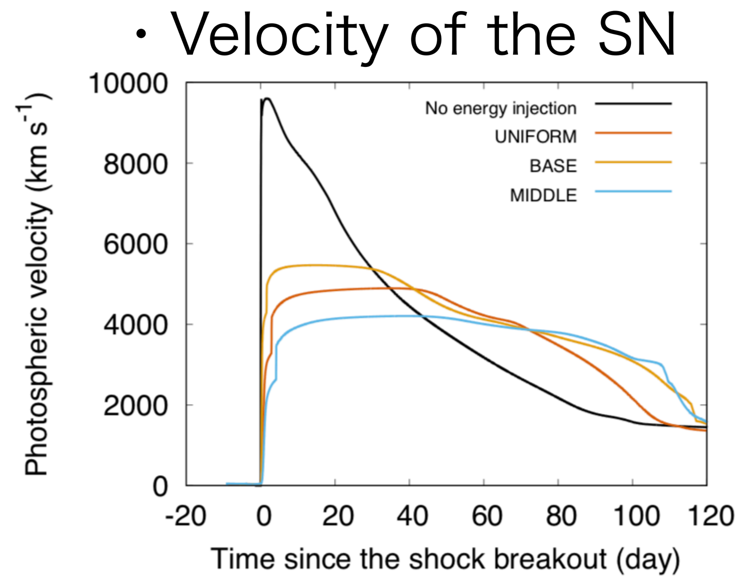


○ Dependence on the spatial distribution

・LC of the SN



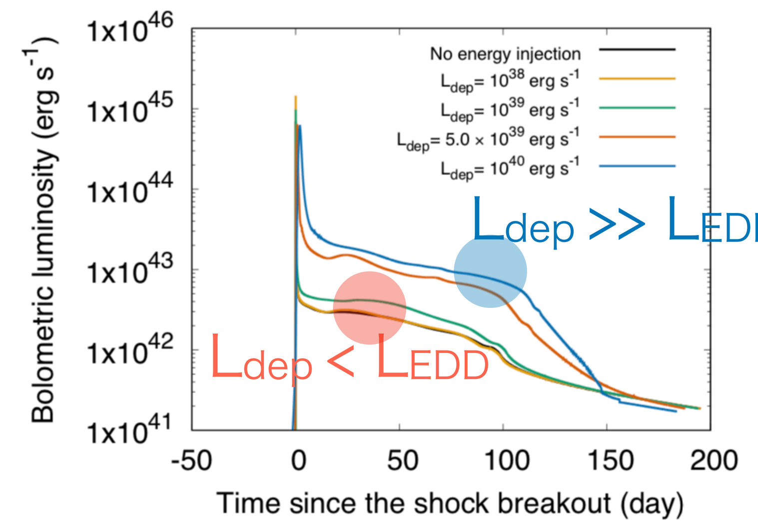
・Velocity of the SN



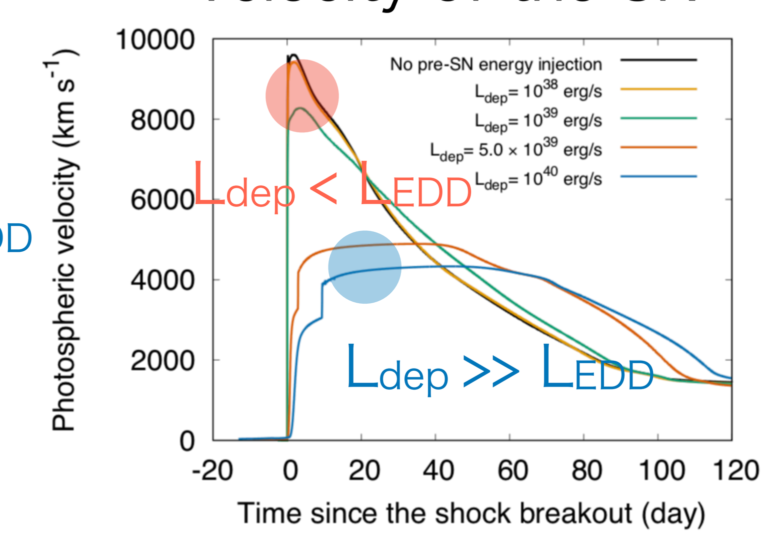
-> The effect of spatial distribution is **minor**.

○ Dependence on the energy injection rate (L_{dep})

・LC of the SN



・Velocity of the SN



Conclusion & Discussion

- The energy injection rate (L_{dep}) should be sub-Eddington in order to explain the usual SNe IIP.
- The secondary effects triggered by the sub-Eddington energy injection might be responsible for the mass loss (Stellar pulsation or binary mass transfer?).