Updating the ^{56}Ni Problem in Core-Collapse Supernova

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What is ^{56}Ni Problem in CCSNe ?

In the explosion mechanism of CCSNe, the appropriate explosion timescale should be constrained in order to reproduce the observational amount of synthesized ^{56}Ni.

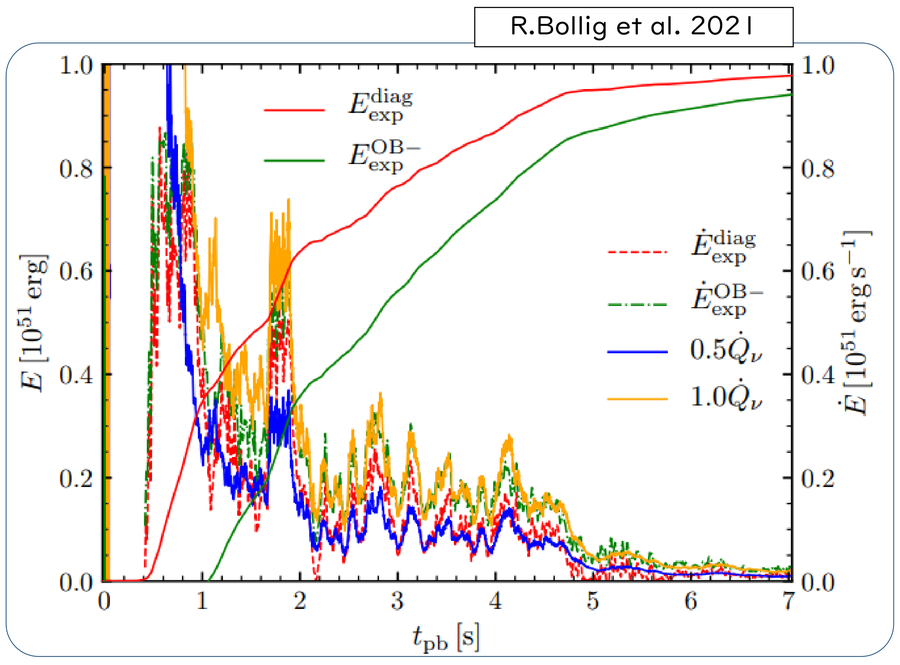
- **state-of-the-art multi-D simulations**

growing rate of the explosion energy

$\dot{E}_{\rm expl.} \sim \mathcal{O}(0.1)\ [10^{51}\ {\rm erg/s}]$（‘遅い爆発’）

especially for 3D simulations.

R.Bollig et al. 2021

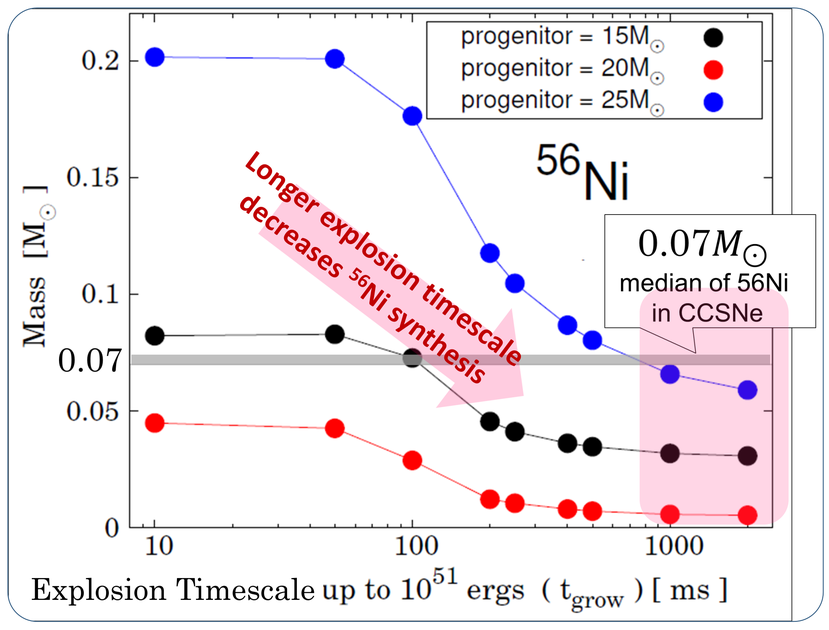


- **1D phenomenological model**

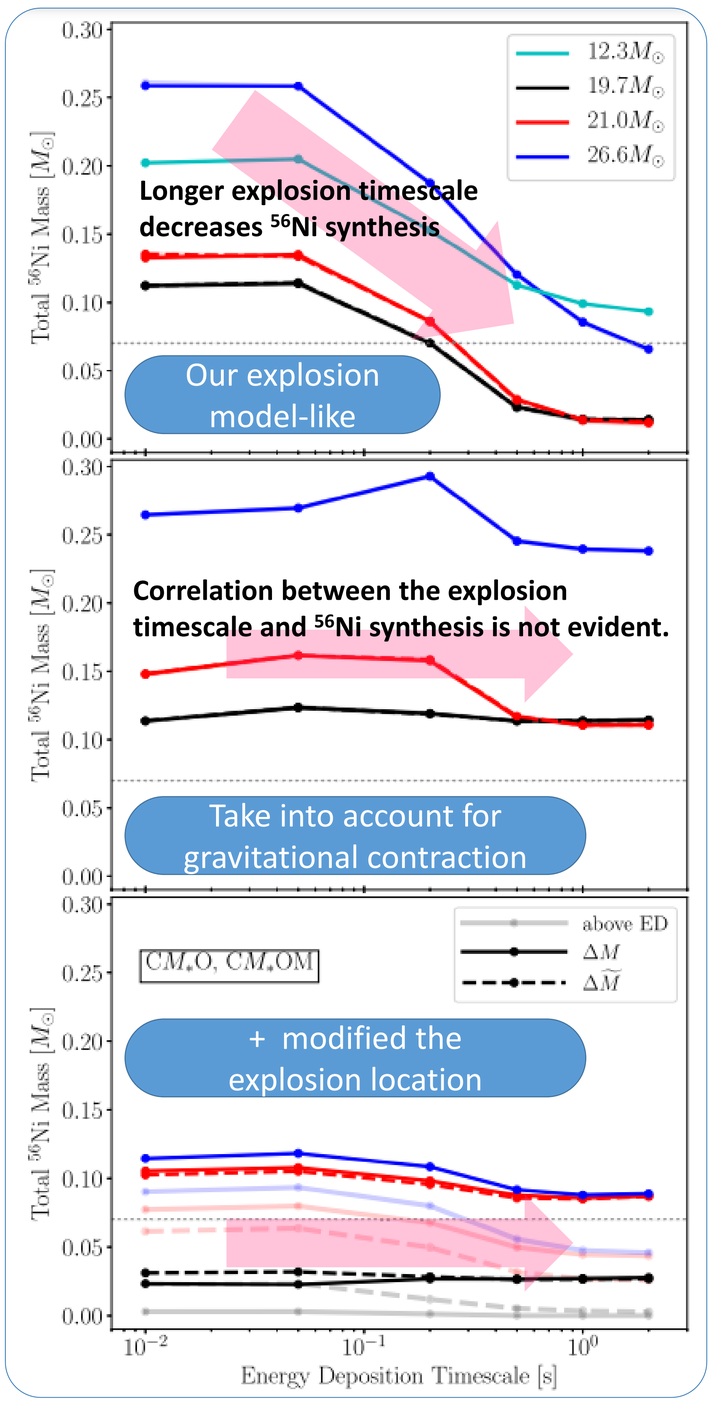
(e.g., Sawada & Maeda 2019)

For the typical mass $0.07M_\odot$ of 56Ni in CCSNe, the growth rate of the explosion energy of

$\dot{E}_{\rm expl.} \geq \mathcal{O}(1)\ [10^{51}\ {\rm erg/s}]$ is required !



Should exceed 0.07M⊙.
But the 'slow explosion' model cannot be reproduced!



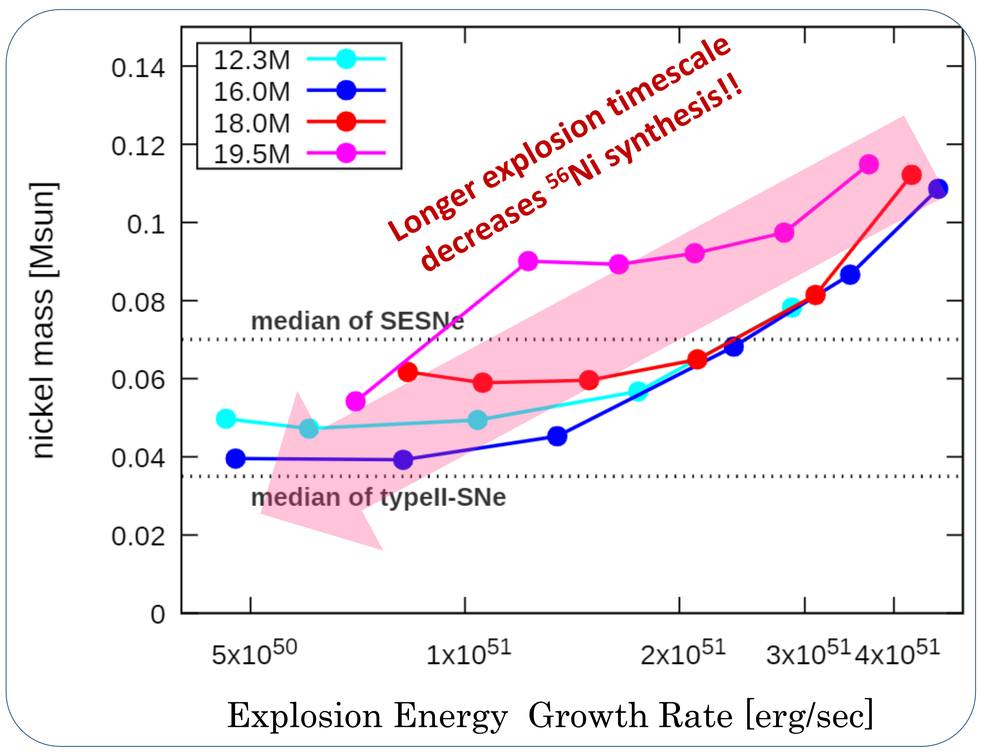
- **Rebuttal paper to the ^{56}Ni problem (Imasheva et al. 2022)**

They pointed out that

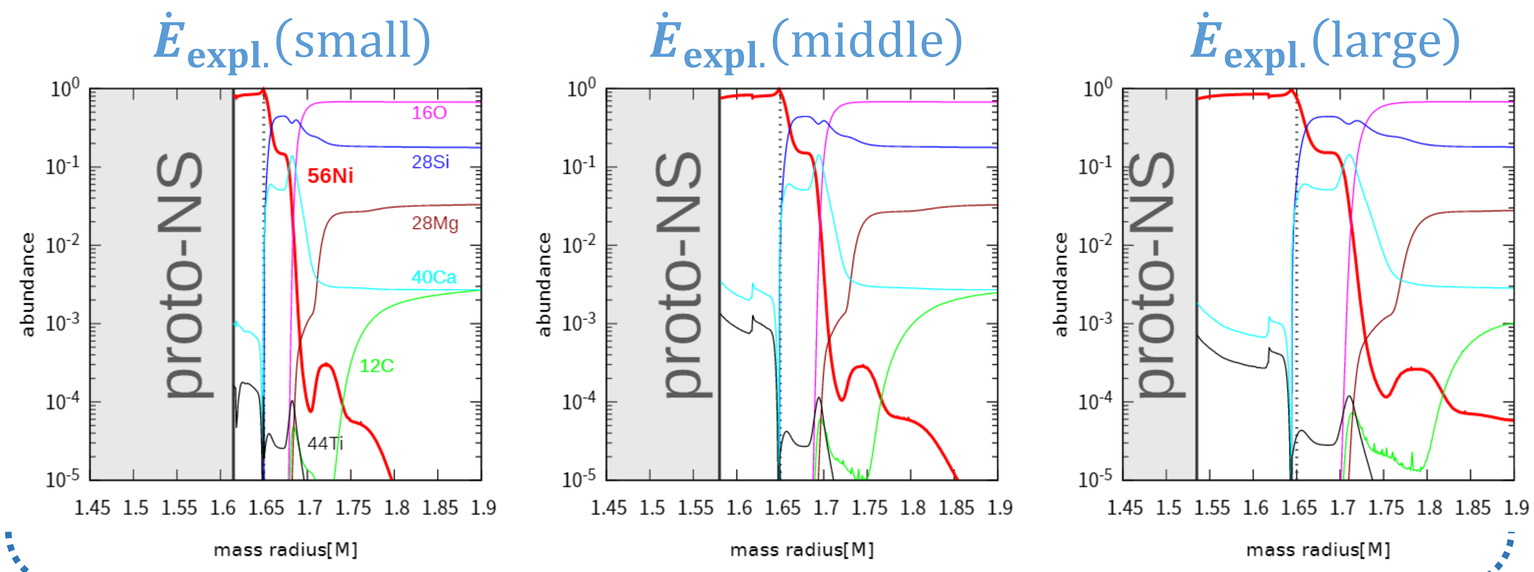
“The 56Ni problem may be due to the assumed explosion model being too simple?” (right figure)

This study: validation in a more realistic explosion model.

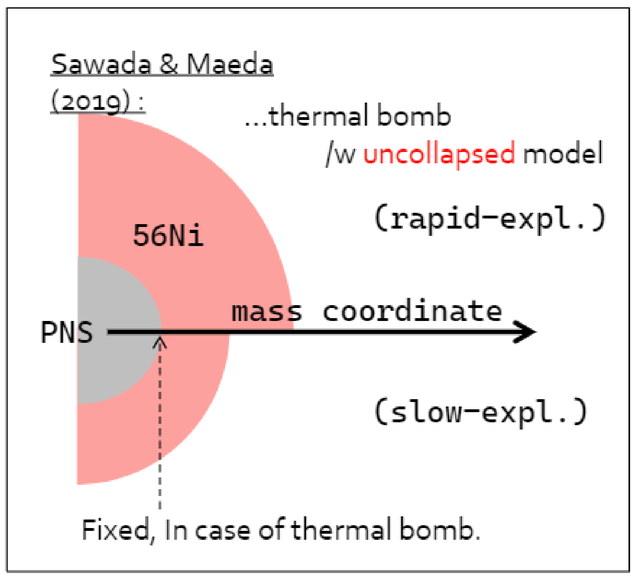
1D hydrodynamics and nucleosynthesis (/w lightbulb approximation)

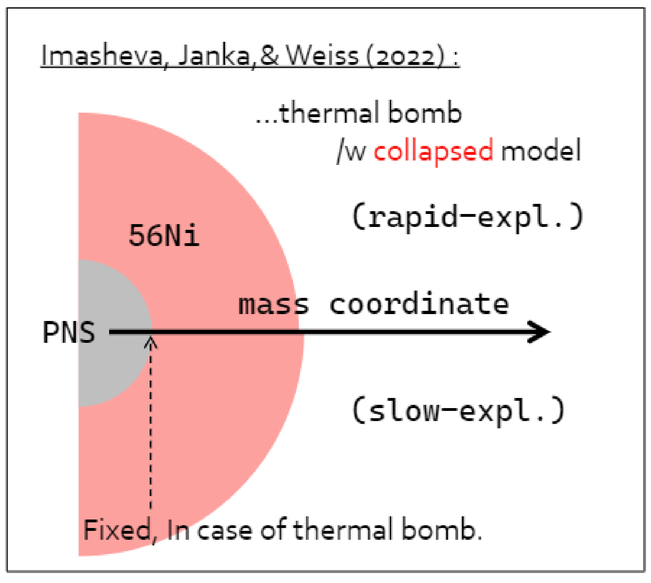


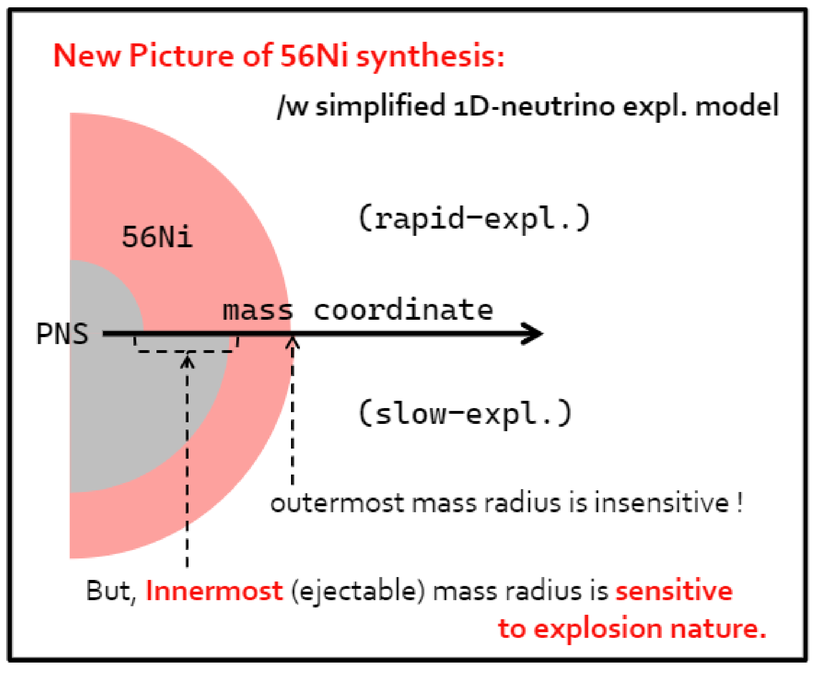
The outermost synthesized mass radius of ^{56}Ni is the same regardless of the explosion timescale. But, the ejectable innermost radius depends on!



Comparison with previous studies: a new picture of the ^{56}Ni problem







*slow-expl: $\dot{E}_{\rm expl.} \leq 1.0\times10^{51}\ [{\rm erg\ s^{-1}}]$, rapid-expl: $\dot{E}_{\rm expl.} > 1.0\times10^{51}\ [{\rm erg\ s^{-1}}]$