超新星起源プレソーラーグレインの Si同位体比の再現

Reproduction of Si Isotopic Ratios of Presolar Grains from Supernovae

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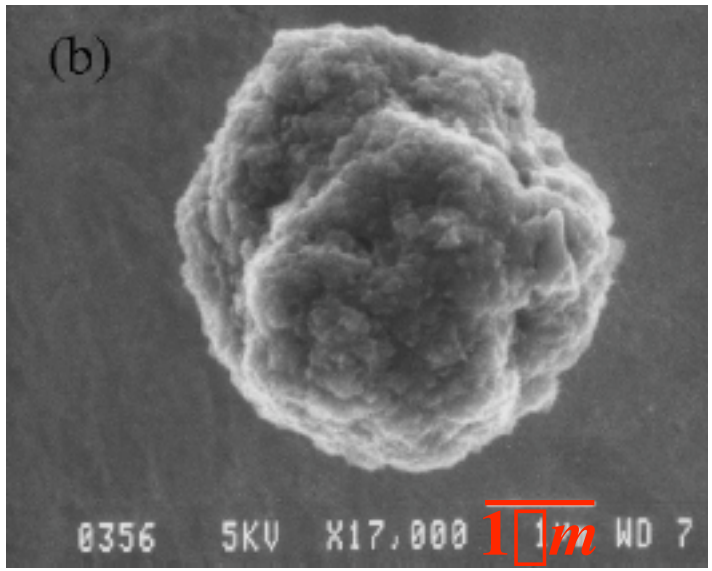
平成16年度21世紀COEプログラムシンポジウム
「物質階層融合科学の構築」
2005年3月4日　東北大学川内キャンパス・マルチメディア教育情報棟

Presolar Grains

Meteorites contain presolar grains.

→ Extremely large isotopic anomalies

Traces of Nucleosynthesis in stars and Galactic chemical evolution



Presolar graphite grain (Lodders & Amari, 2004)

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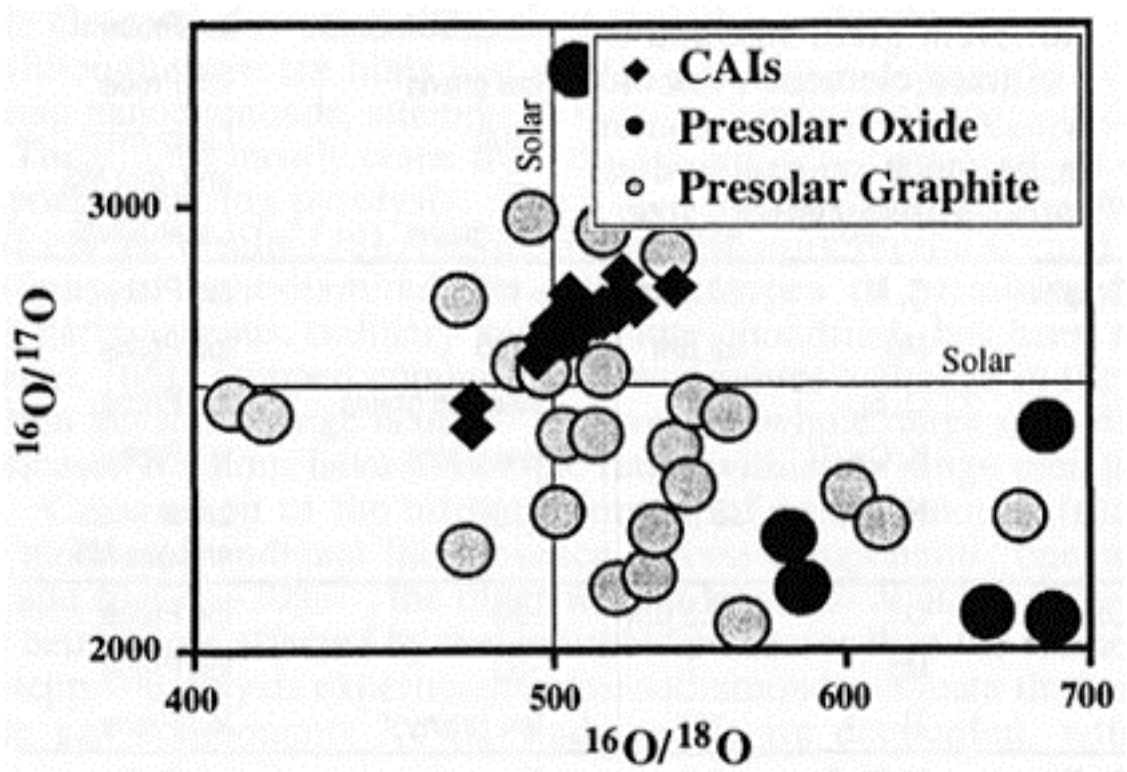

(Zinner, 1997)

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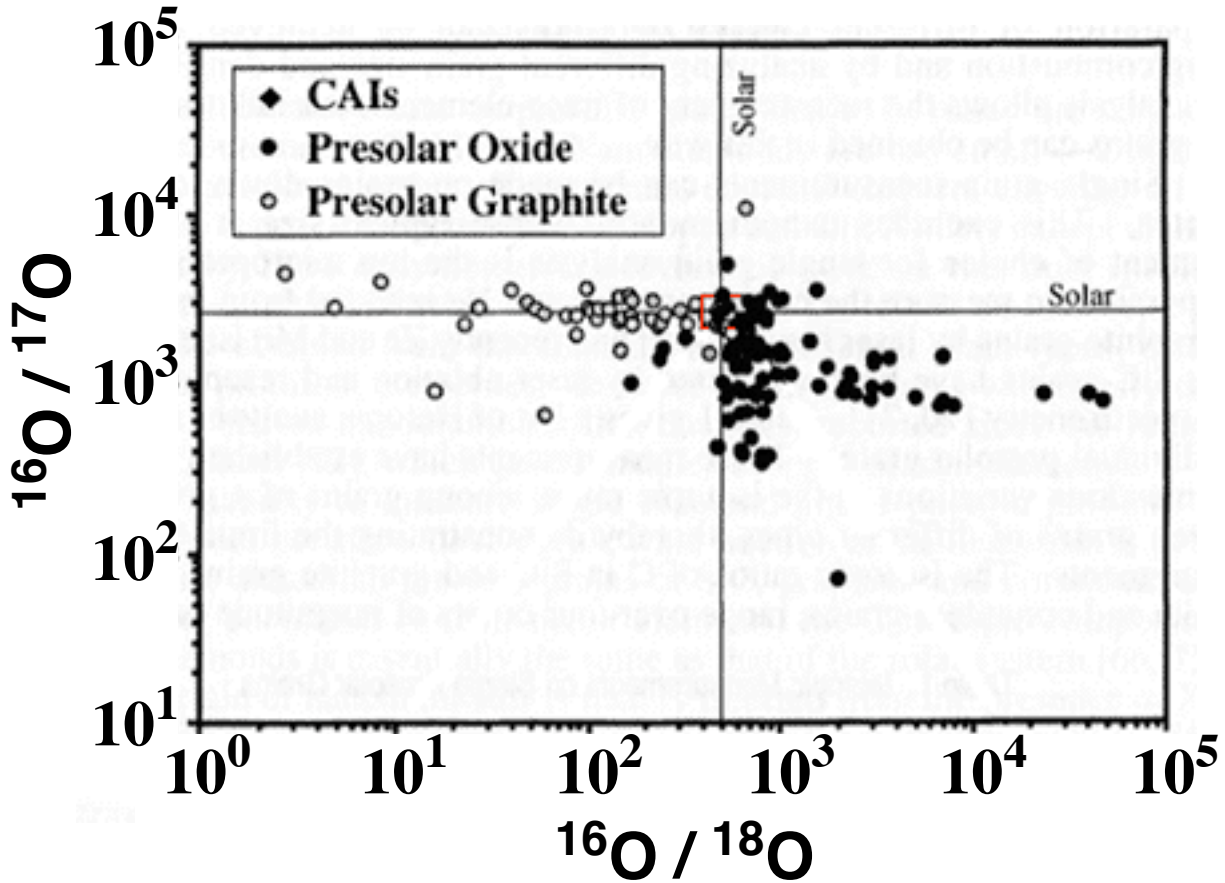
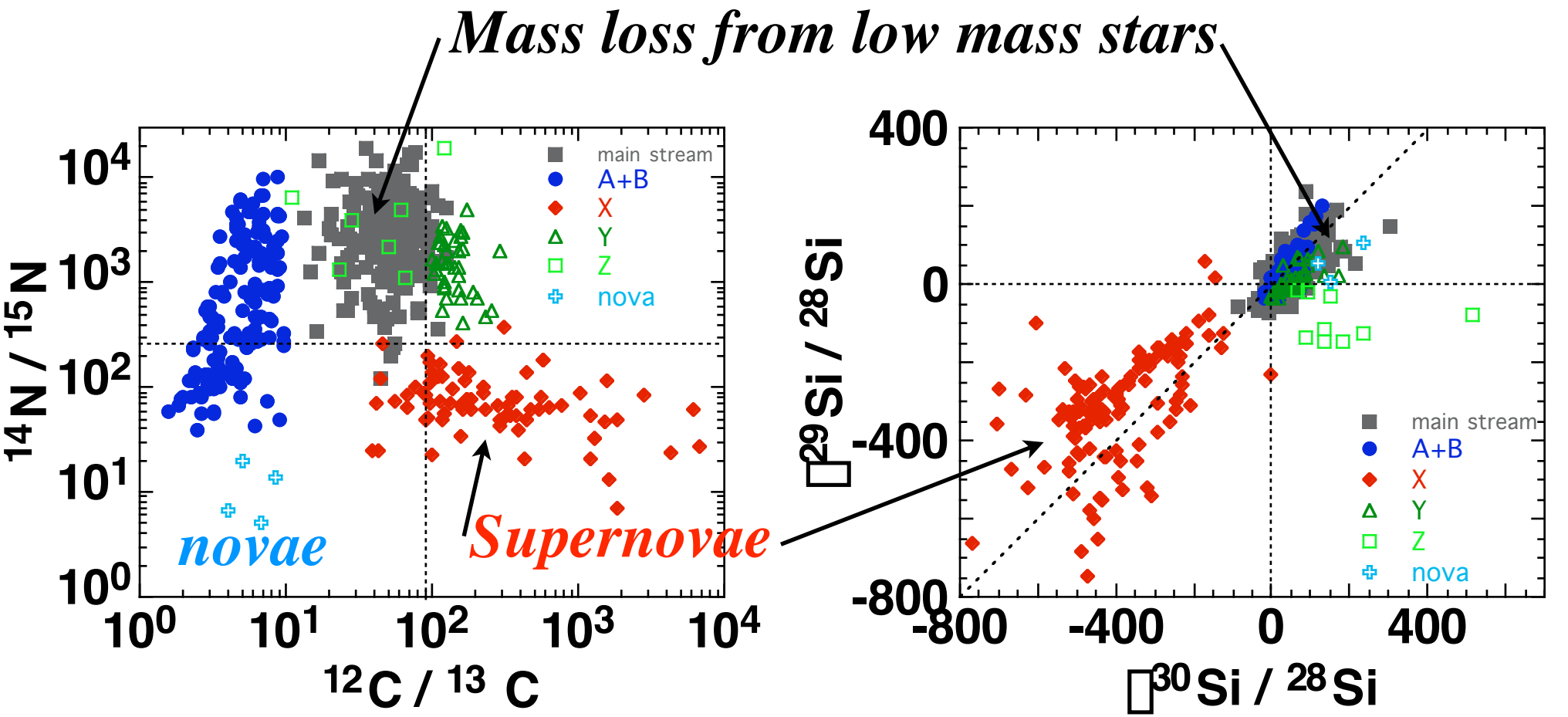


(Zinner, 1997)

Isotopic Ratios of Presolar Grains

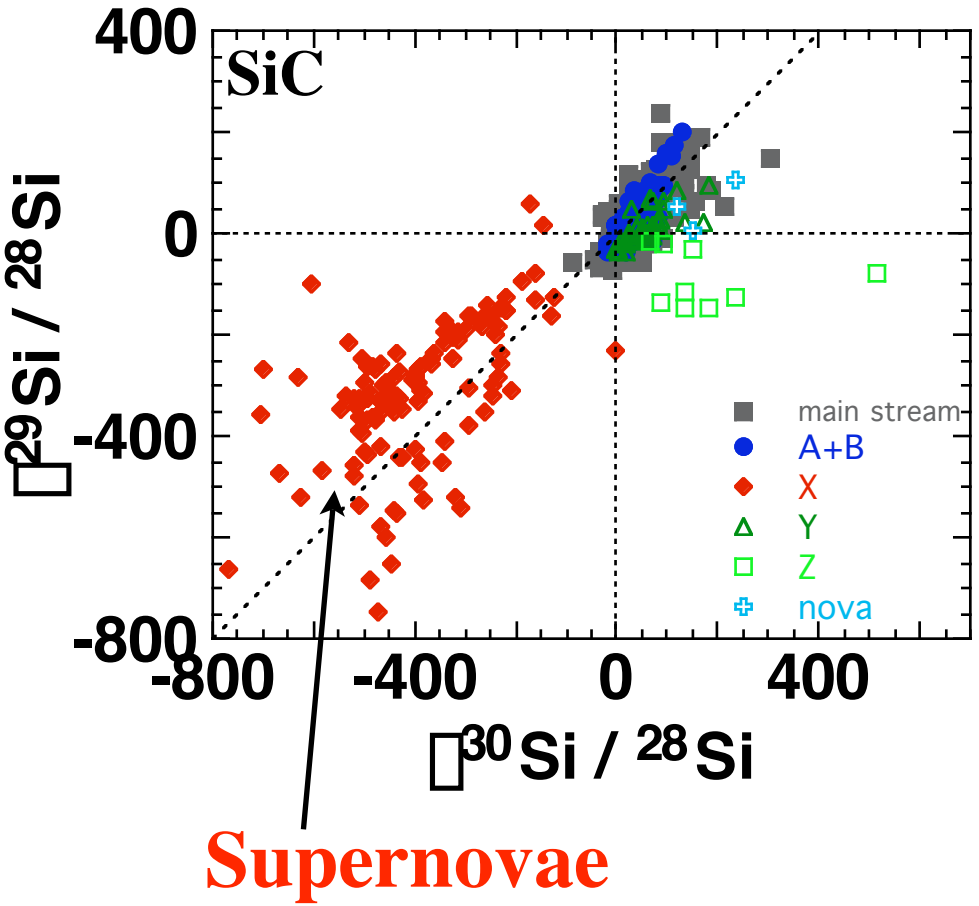
Isotopic ratios of Silicon Carbide presolar grains



$$\delta^{A}Si/^{28}Si = \{(^{A}Si/^{28}Si)/(^{A}Si/^{28}Si)_{\odot} - 1\} \times 1000$$

Data from Amari et al. (2001a, 2001b, 2001c), Hoppe et al. (1996, 1997, 2000), Lin et al. (2002)

Presolar Grains from Supernovae



Supernovae

Si Isotopic ratios

→ The excesses of ^{28}Si

Most of the grains show $\delta^{29}Si/^{28}Si > \delta^{30}Si/^{28}Si$.

SiC X, low density graphite

→ The excesses of ^{28}Si

Traces of short lived nuclei ^{44}Ti

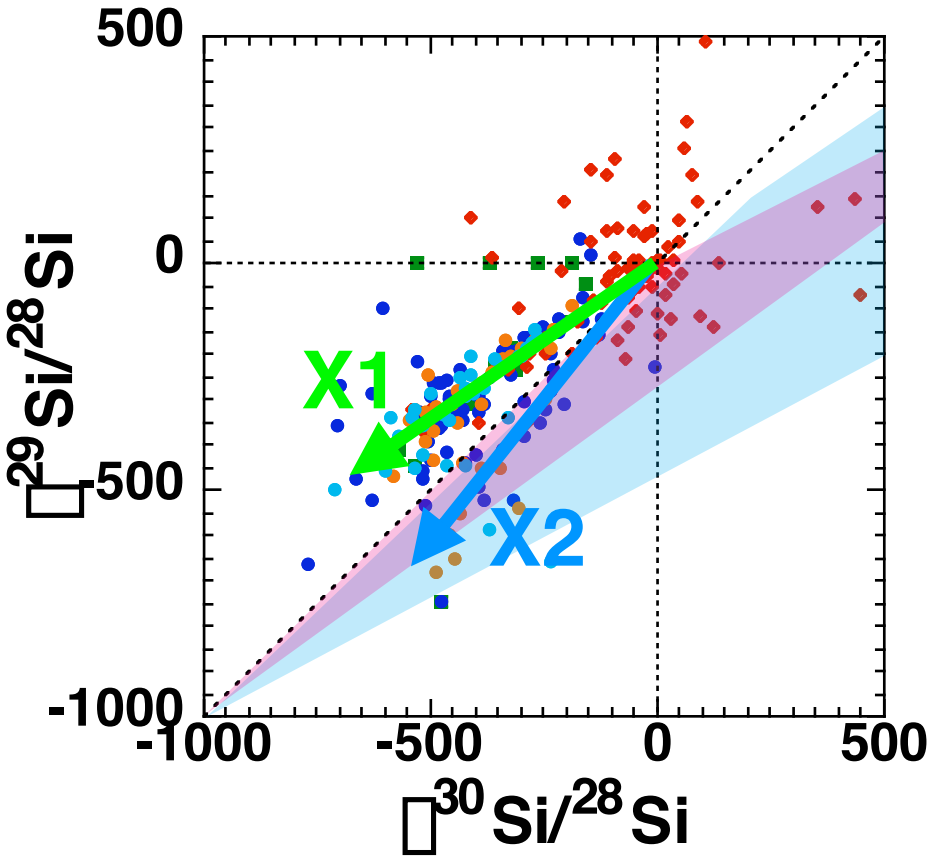
↓

Produced in Supernovae

Heterogeneous mixtures

Data from Amari et al. (2001a, 2001b, 2001c), Hoppe et al. (1996, 1997, 2000), Lin et al. (2002)

Purpose of the Present Study



Subtypes (Lin et al., 2002, etc)

→ **X1**: $\delta^{29}Si/\delta^{30}Si \sim 0.7$

X2: $\delta^{29}Si/\delta^{30}Si \sim 1.2$

Models of Supernova Nucleosynthesis and Mixing

→ **reproduce *only* X2 signature**

Supernova models are limited.

Travaglio et al. (1999), Hoppe et al. (2000)
Yoshida & Hashimoto (2004)

Purpose

We investigate the range of Si isotopic ratios of supernova ejecta with different progenitor masses.

→ **Reproduction of X1** $\delta^{29}Si/^{28}Si > \delta^{30}Si/^{28}Si$

SiC X: Nittler et al. (1996), Hoppe et al. (2000), Lin et al. (2002), Besmehn & Hoppe (2003)
Low density graphite: Amari et al. (1995)

Models of Supernova Nucleosynthesis & Mixing

- **Supernova models**

  3.3, 4.0, 8.0 $M_\odot$ He stars (13, 15, 25 $M_\odot$ ZAMS) (Nomoto & Hashimoto, 1988)

  Supernova: E=1□10^{51} ergs (Shigeyama et al., 1992)

  Hypernova: E=1□10^{52} ergs (8.0 $M_\odot$ He star)

  Postprocessing nucleosynthesis (Yoshida & Hashimoto, 2004)

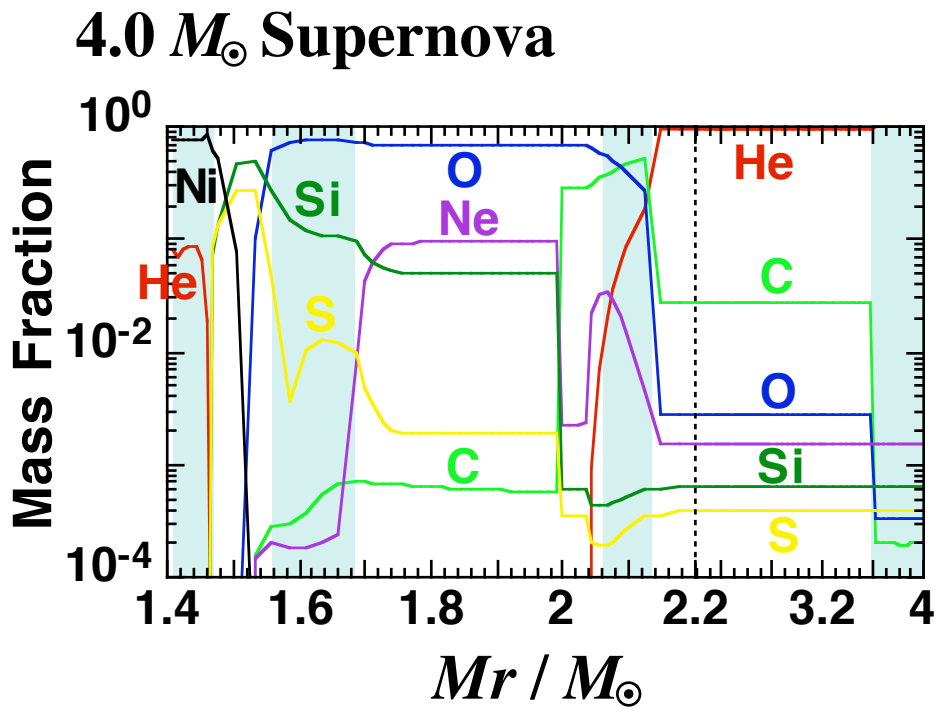
- **Four layer mixing**

  Supernova ejecta are divided into seven layers.

  → Ni, Si/S, O/Si, O/Ne, (C/O or O/C), He/C, He/N

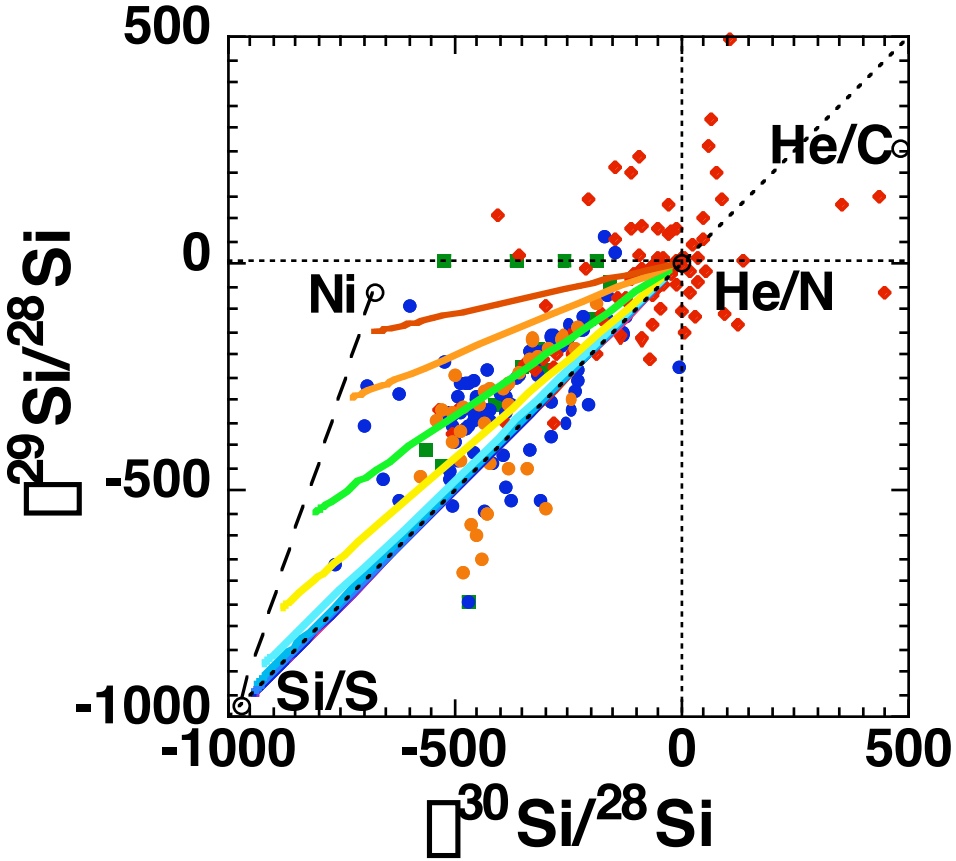
  Four layer mixtures

  → Ni, Si/S, He/C, He/N

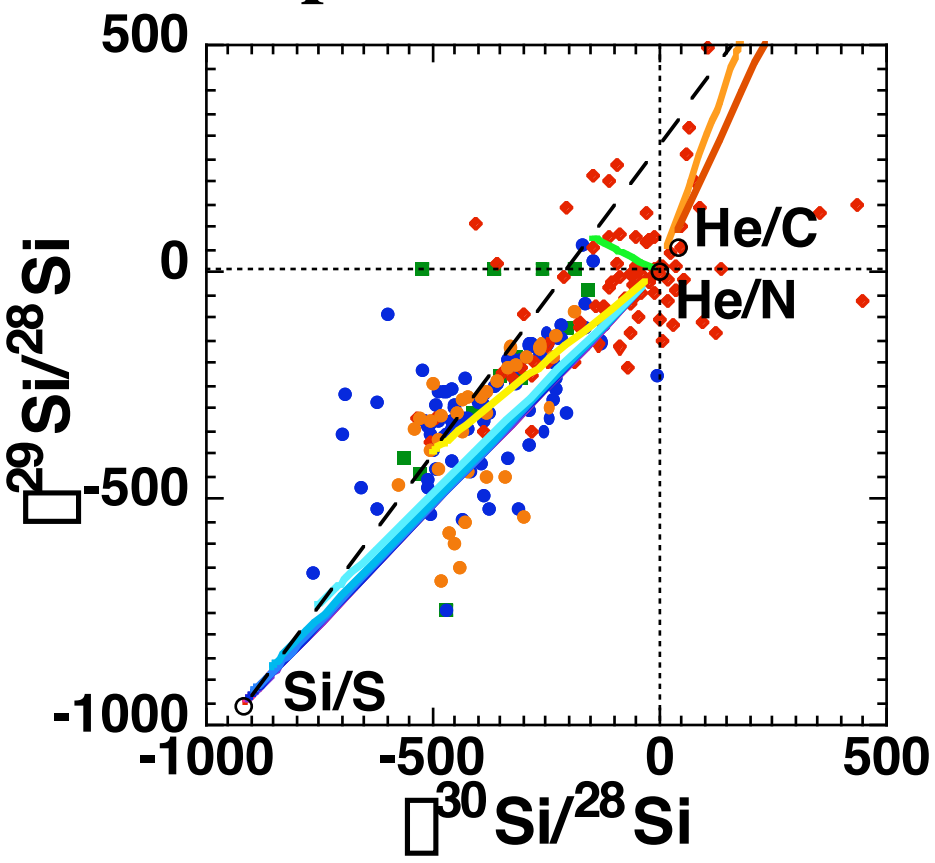


Si Isotopic Ratios of Supernova Mixtures (1)

3.3 $M_\odot$ Supernova



4.0 $M_\odot$ Supernova



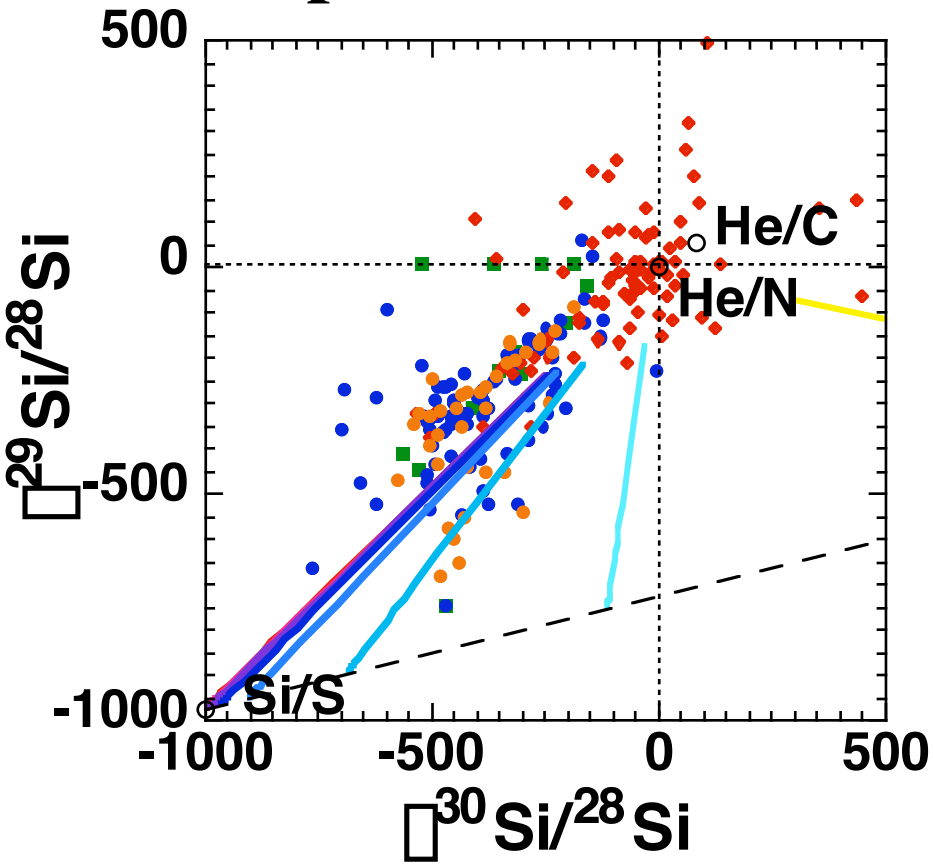
The mixtures of Ni, Si/S, He/C, He/N layers; n(C)/n(O)=1
y(Ni-layer)/y(Si/S-layer): parameter

- **Mixtures of 3.3, 4.0 $M_\odot$ supernova models**

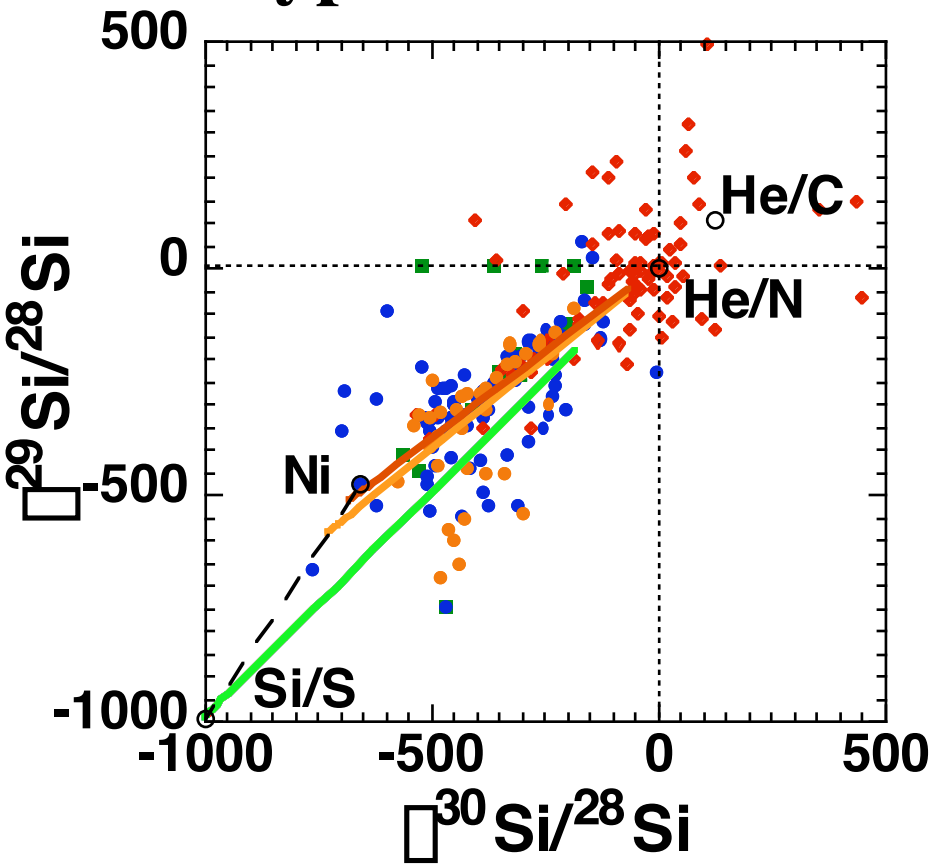
→ **X1 signature $\delta^{29}Si/^{28}Si > \delta^{30}Si/^{28}Si$**

Si Isotopic Ratios of Supernova Mixtures (2)

8.0 $M_\odot$ Supernova



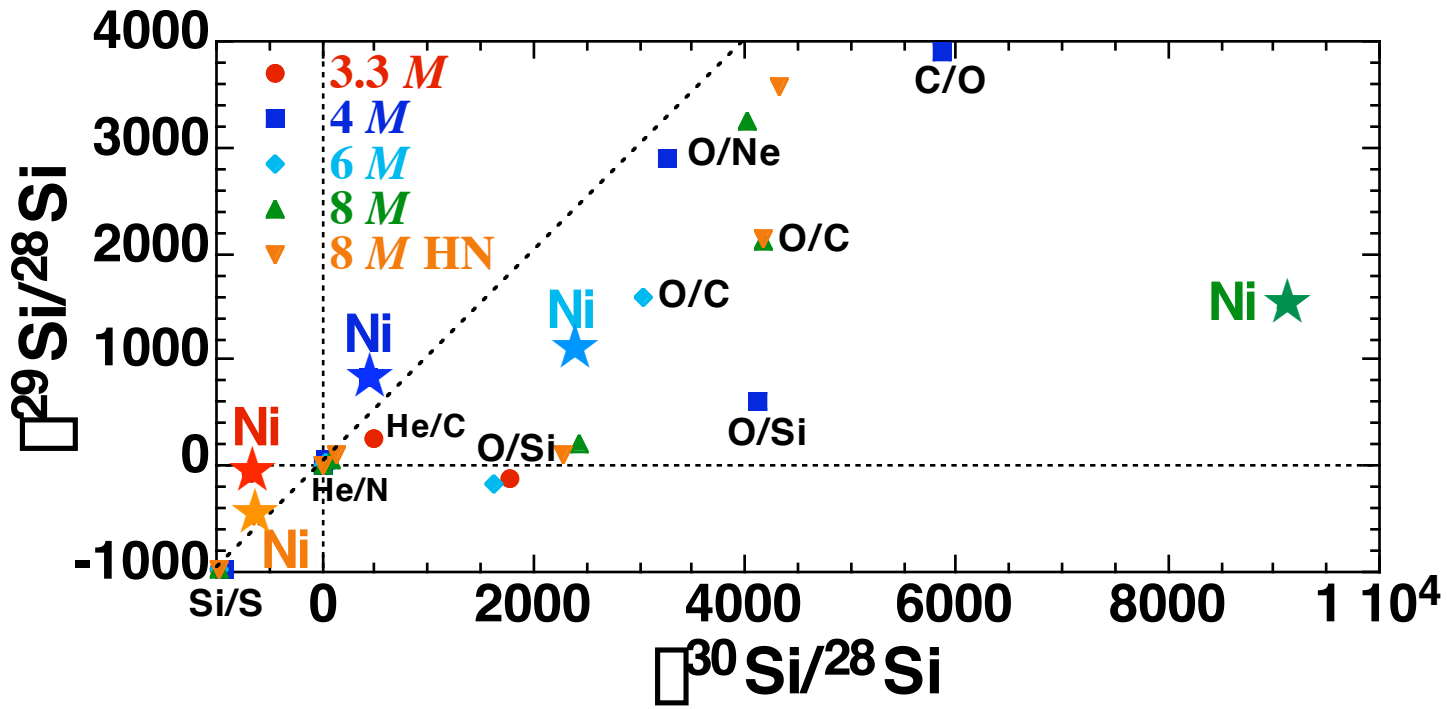
8.0 $M_\odot$ Hypernova



The mixtures of Ni, Si/S, He/C, He/N layers; n(C)/n(O)=1

- **8.0, 6.0 $M_\odot$ Supernova** → **X2: $\delta^{29}Si/^{28}Si < \delta^{30}Si/^{28}Si$**
- **8.0 $M_\odot$ Hypernova** → **X1: $\delta^{29}Si/^{28}Si > \delta^{30}Si/^{28}Si$**

Si Isotopic Ratios in Layers of the Ejecta

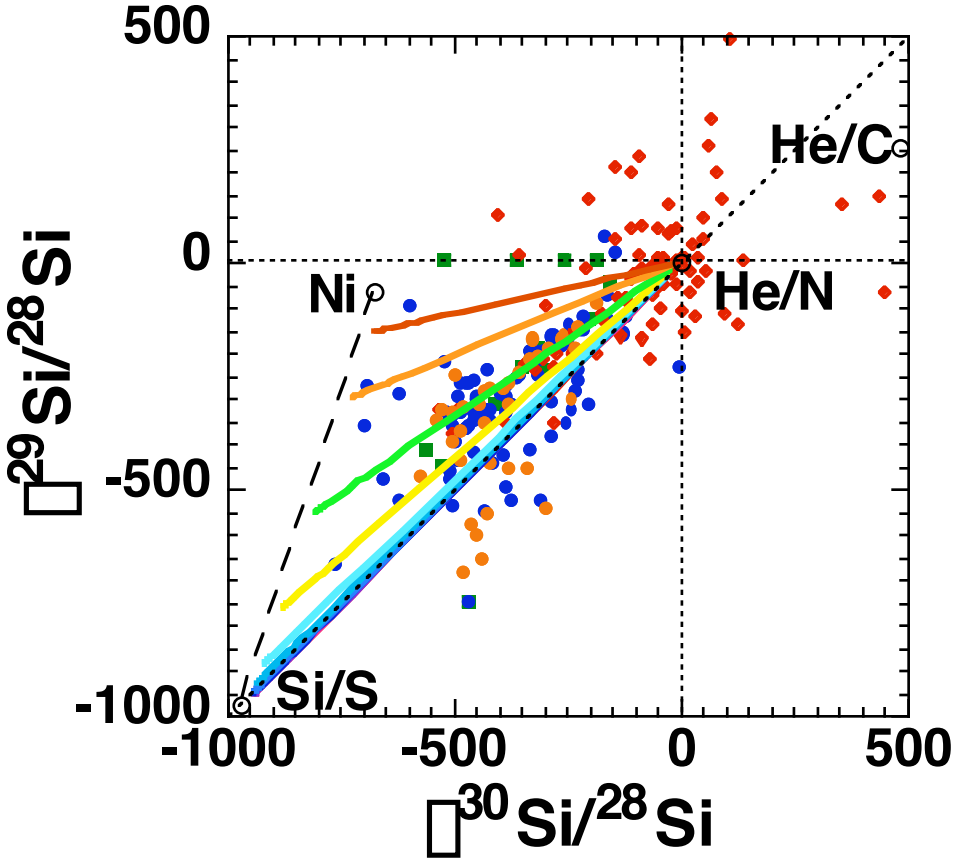


- Ni layer of 3.3, 4.0 $M_\odot$ supernovae &, 8 $M_\odot$ hypernova
  → $\delta^{29}Si/^{28}Si > \delta^{30}Si/^{28}Si$
- The Si ratios depend on the temperature decrease rate
  Less massive supernovae → Fast temperature decrease
  Massive supernovae → Slow temperature decrease

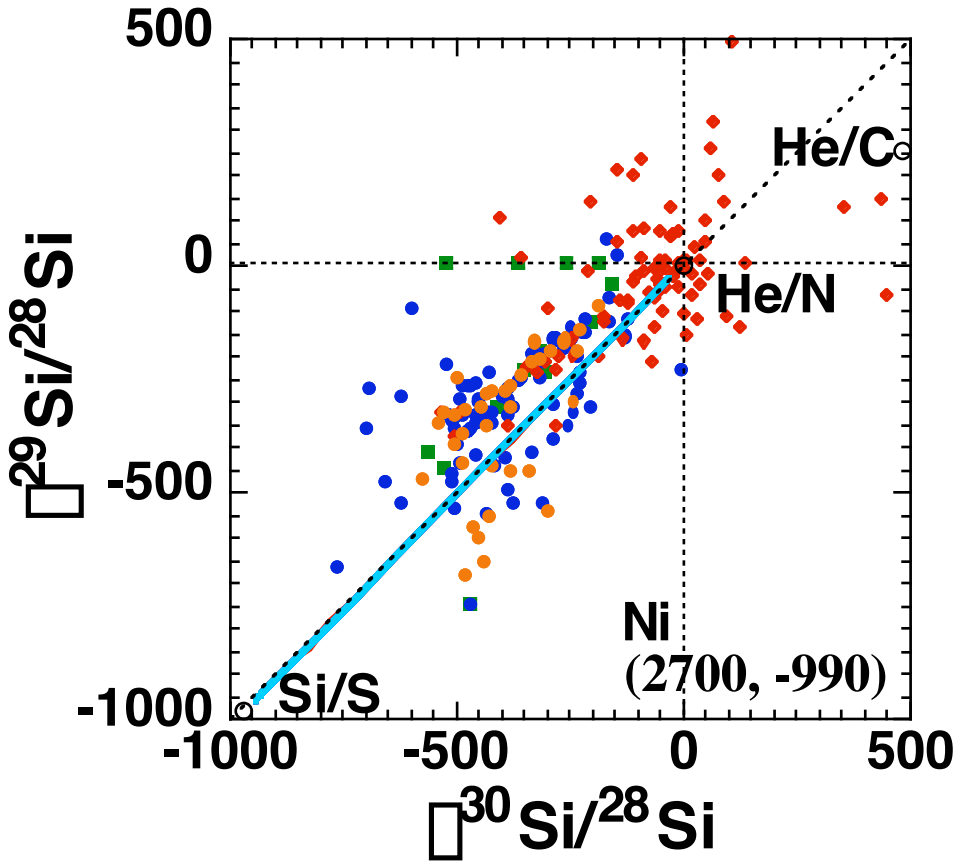
Effect of Supernova Neutrinos

3.3 $M_\odot$ Supernova

With neutrinos



Without neutrinos



- Ni layer

  → ^{29}Si and ^{30}Si are produced through the δ-porcess.

Summary

Range of Si isotopic ratios in 3.3, 4.0, 8.0 $M_\odot$ He star supernovae and an 8.0 $M_\odot$ He star hypernova

↔ Si ratios of grains from supernovae

- **3.3, 4.0 $M_\odot$ supernovae, 8.0 $M_\odot$ hypernova**
  - **→ X1 signature: $\delta^{29}Si/^{28}Si > \delta^{30}Si/^{28}Si$**
  - **← Contribution from the Ni layer**
    - ***Fast* temperature decrease**
    - **The γ-process**
- **6.0, 8.0 $M_\odot$ supernovae**
  - **→ X2 signature: $\delta^{29}Si/^{28}Si < \delta^{30}Si/^{28}Si$**
    - ***Slow* temperature decrease in the Ni layer**

Outlook

Isotopic Ratios of Presolar Grains from Supernovae

- **Seven layer mixing**
  (Ni, Si/S, O/Si, O/Ne, C/O or O/C, He/C, He/N)

  → **Evaluation of the mixing ratios of heterogeneous mixing to reproduce several isotopic ratios of the grains from superrnovae**

Light Element Synthesis through the ν-Process in Supernovae with Neutrino Oscillations

- **^{7}Li and ^{11}B are produced in supernovae.**

  ^{4}He(ν,ν'*p*)^{3}H,^{4}He(ν,ν'*n*)^{3}He,^{12}C(ν,ν'*p*)^{11}B,^{12}C(ν,ν'*n*)^{11}C

  However, ^{4}He(ν_e,e$^-$*p*)^{3}He,^{4}He($\bar{\nu}_e$,e$^+$*n*)^{3}H,^{12}C(ν_e,e$^-$*p*)^{11}C,^{12}C($\bar{\nu}_e$,e$^+$*n*)^{11}B

  Code for neutrino oscillations in supernova ejecta has been made.

Cross sections of the ν-process are NEEDED!

We have only neutrino temperature dependent cross sections.