The Galactic Chemical Evolution of Mg- (and Si-) Isotopic Compositions Inferred from Presolar Silicate Grains

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Introduction (I)

Presolar Grains

- Primitive meteorites contain small quantities (ppb to per mill) of refractory dust grains with highly anomalous isotopic compositions
- First hints on the presence of meteoritic minerals with highly anomalous isotopic compositions in the 1960s
- Separation of SiC as carrier of anomalous noble gas components in the 1980s

→ Presolar origin
→ Stardust (presolar grains)

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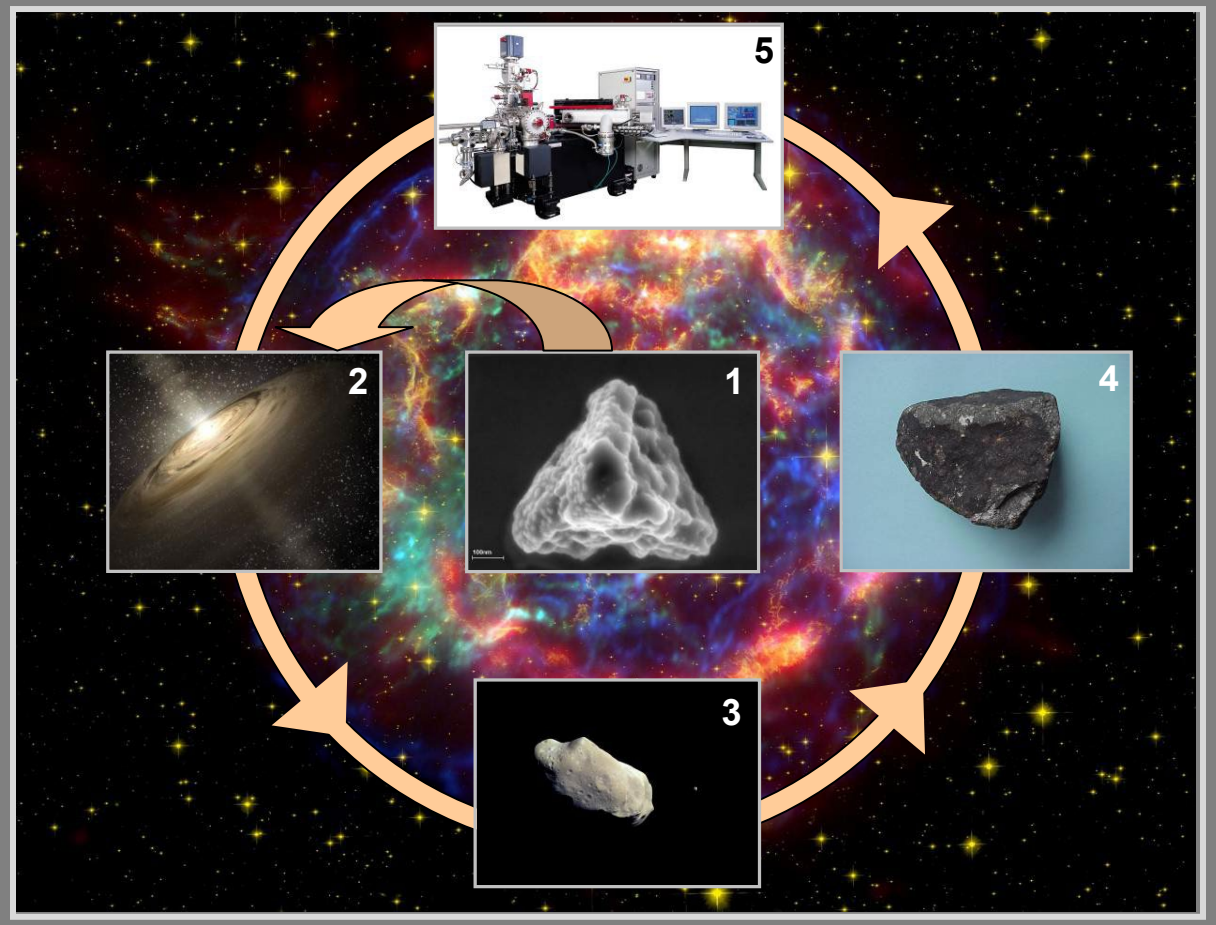
Introduction (II)

Presolar Grains: Path from Stars to the Laboratory



Hoppe P. 2015, J Phys Conf Ser, 665:012075

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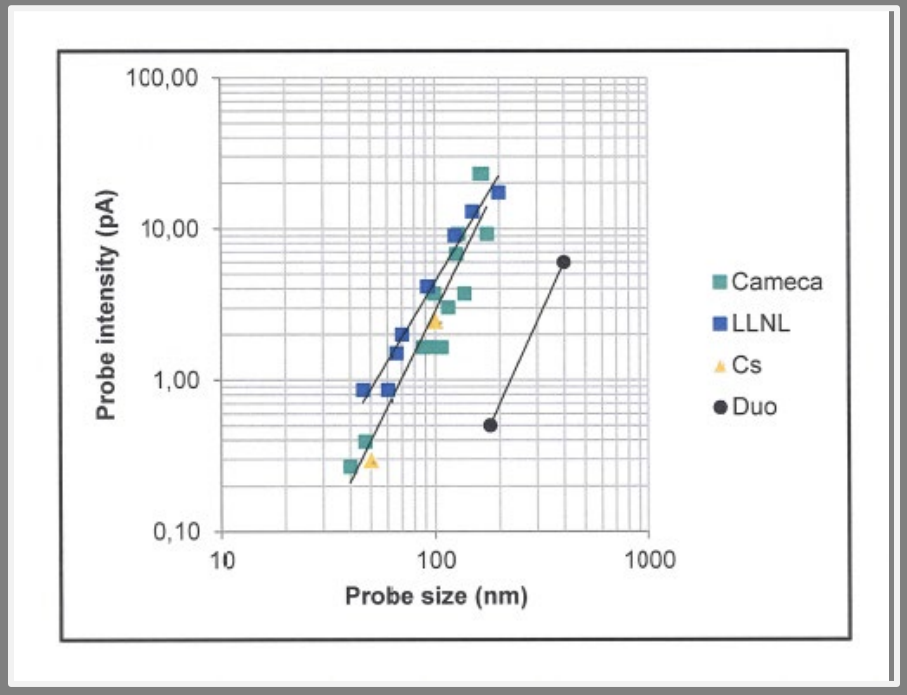
Introduction (III)

Presolar Silicates

- Silicates are the most abundant group of presolar (stardust) grains
- Can be identified only in situ by ion imaging techniques, preferentially in the NanoSIMS
- Typical sizes of 150 nm, only a small fraction has sizes >300 nm
- For a long time useful isotope data existed mostly only for O (Cs ion source, <100 nm resolution) because in situ studies of electropositive elements (e.g., Mg) with the Duoplasmatron O ion source were limited to 300 nm spatial resolution
- New Oregon Physics Hyperion O ion source now permits in situ studies of electropositive elements with a spatial resolution comparable or even better than with the Cs ion source

Introduction (IV)

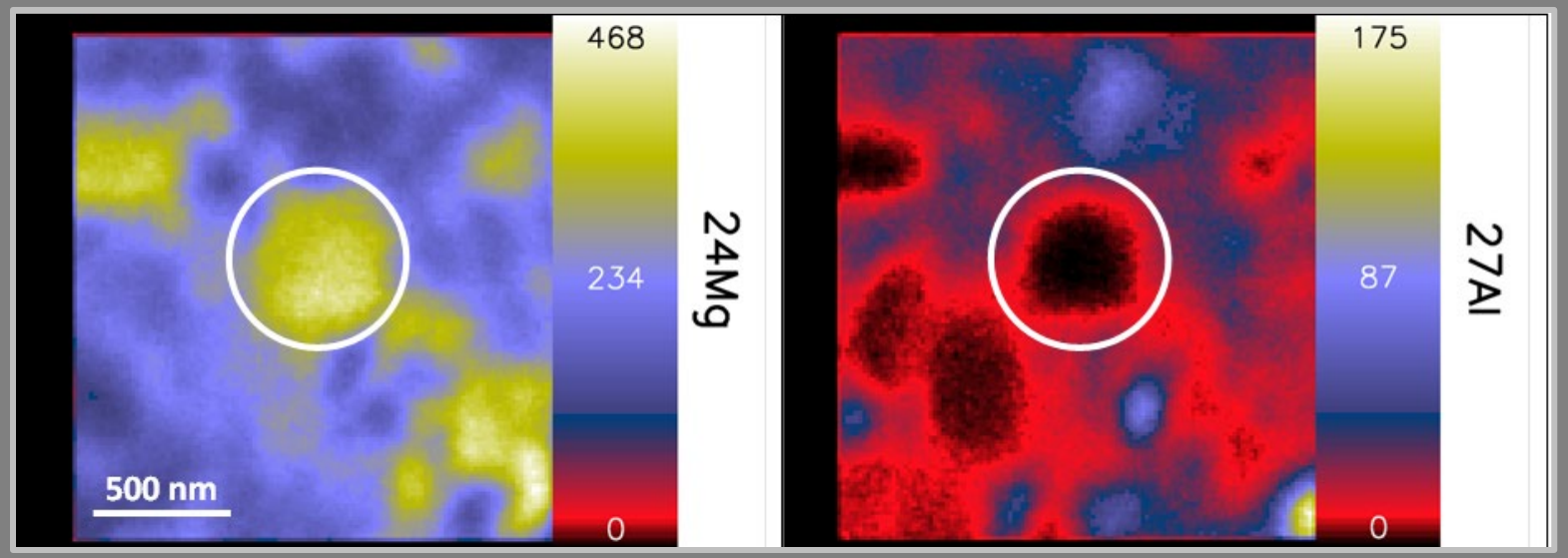
The NanoSIMS Ion Probe



Credit: Cameca

Introduction (V)

Ion Imaging

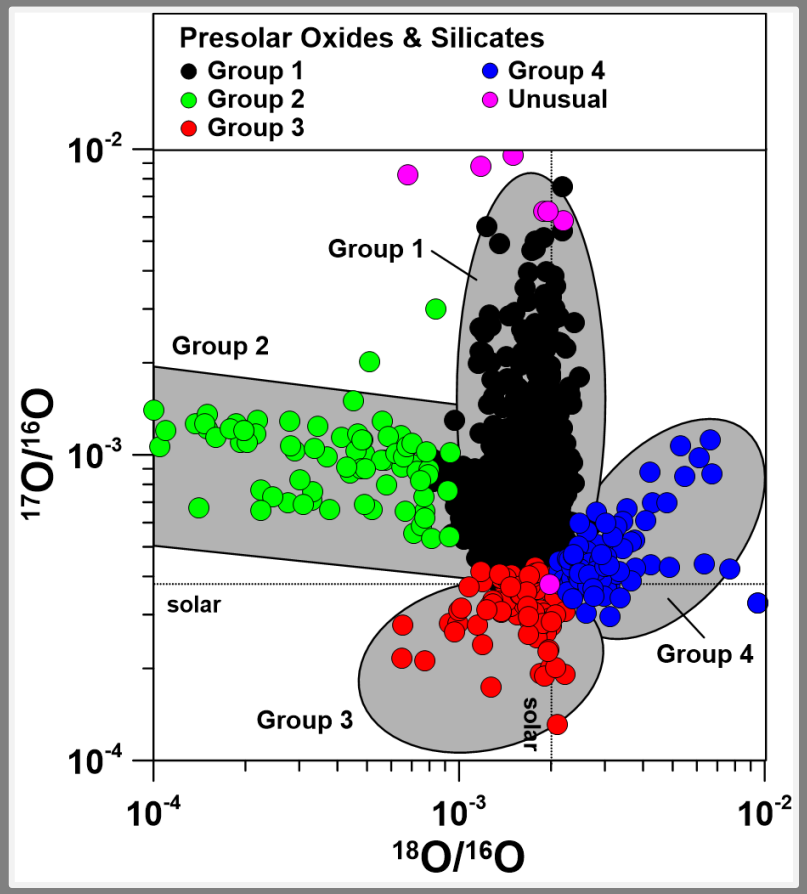


Hoppe P. et al. 2018, ApJ, 869, 47

- Focused O^- ion beam (<100 nm) was rastered over 2 x 2 μm^2-sized area around the presolar silicate grain

Introduction (VI)

O-Isotopic Systematics of O-Rich Presolar Grains



- 4 distinct O Isotope groups
- Group 1 (80%):
  - Low-mass AGB stars
  - SNe, supergiants, intermediate-mass AGB stars
- Group 2:
  - Intermediate-mass AGB stars with HBB
  - SNe, supergiants, super AGB stars
- Group 3:
  - Low-mass, low metallicity AGB stars
  - SNe
- Group 4 (10%):
  - SNe

Data from WU PSG Database; Hynes & Gyngard 2009

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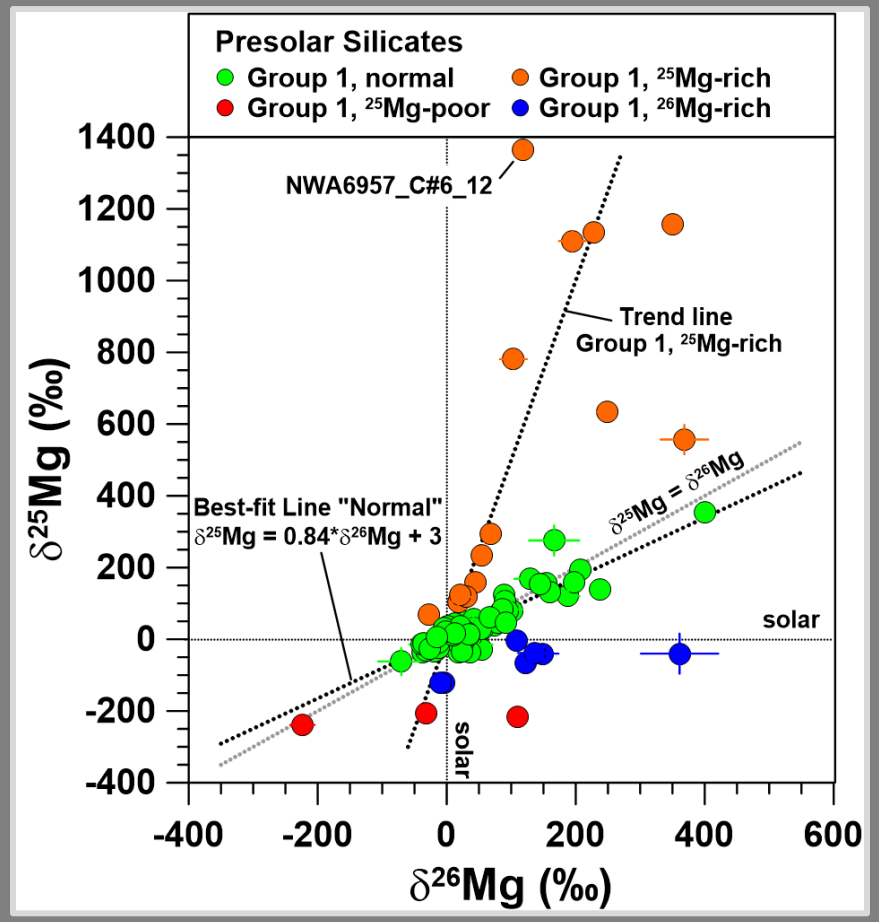
Mg-Isotopic Systematics (I)

Magnesium Isotopes of Group 1 Silicates



Hoppe P. et al. 2021, ApJ, 913,10; MPIC 2024, unpub.

- 4 distinct subpopulations of Group 1 grains
- Normal (60%):
  - Low-mass AGB stars
- ^{25}Mg-rich (25%):
  - At least 50% from SNe
  - Intermediate-mass, high metallicity AGB stars
- ^{26}Mg-rich & ^{25}Mg-poor (15%):
  - Supergiants
  - SNe
- SNe/supergiants contribution (Groups 1-4) >30%

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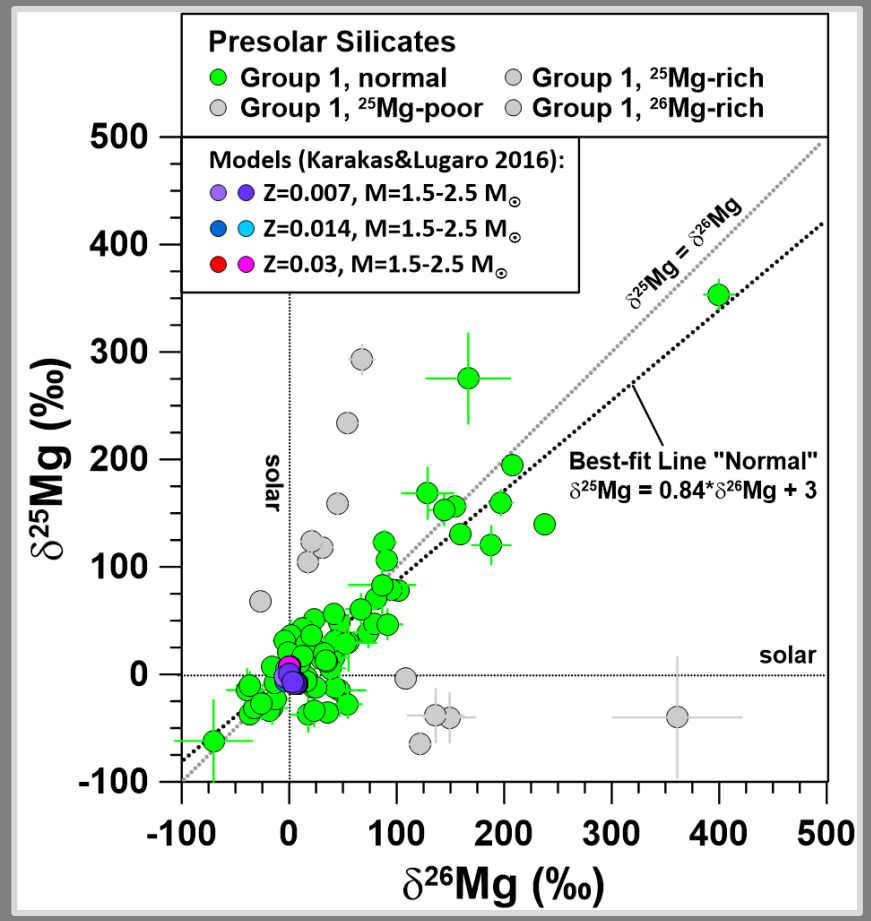
Mg-Isotopic Systematics (II)

Normal Group 1 Silicates

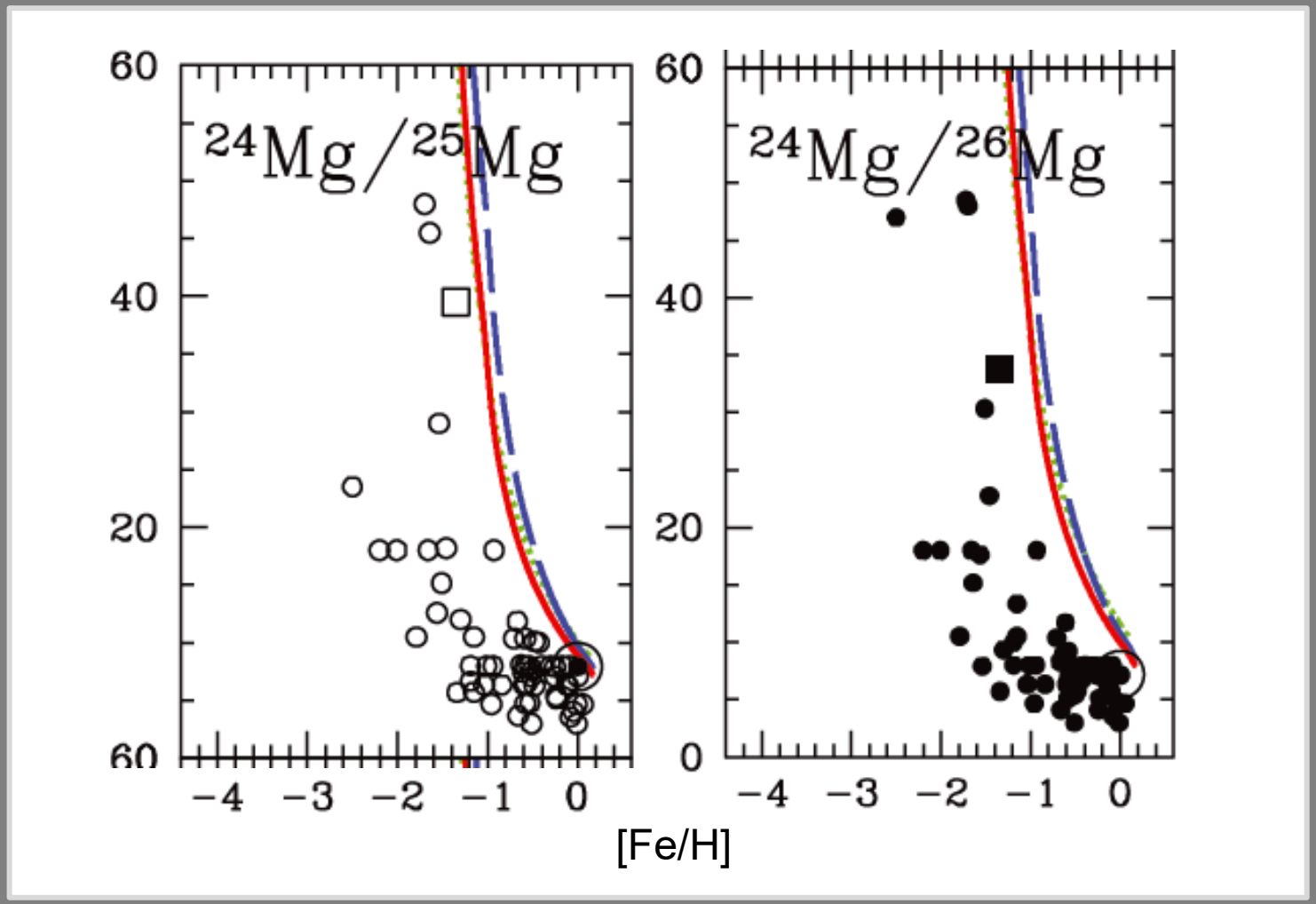


Hoppe P. et al. 2021, ApJ, 913,10; MPIC 2024, unpub.

- Mg isotopes plot along slope ~1 line ($\delta^{25}Mg = 0.84\pm0.05 \times \delta^{26}Mg + 3\pm4$), the Mg mainstream line, which likely represents GCE
- Origin from low-mass AGB stars
  - O-isotopic signatures
  - Only small Mg isotope anomalies expected according to stellar models (e.g., Karakas & Lugaro 2016)
- Si-isotopic compositions supports GCE intepretation

Mg-Isotopic Systematics (III)

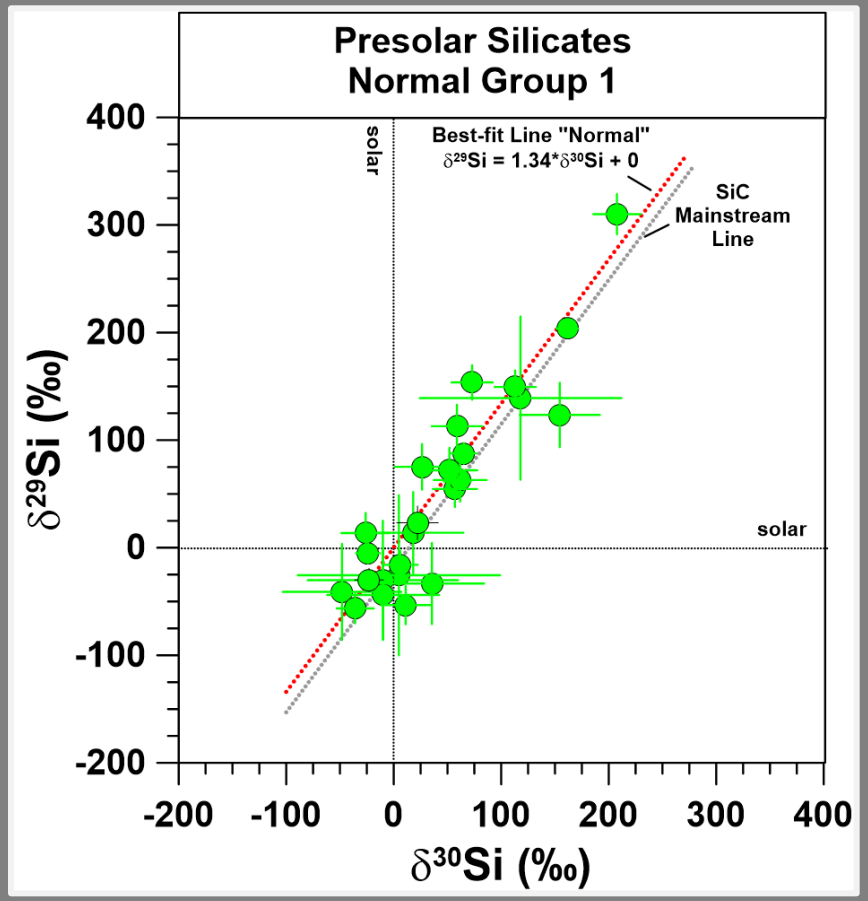
GCE Models



Kobayashi C. et al. 2011, MNRAS, 414, 3231

Si-Isotopic Systematics (I)

Silicate Si Mainstream Line



Hoppe P. et al. 2021, ApJ, 913,10; MPIC 2024, unpub.

- Normal Group 1 silicate grains plot along a line $\delta^{29}Si = (1.34\pm0.09) \times \delta^{30}Si - (0\pm7)$, the "Silicate Si mainstream line"
- Same slope as SiC Si mainstream line but shifted by 14±5 ‰ to ^{30}Si-poor side
  - Overprint of s-process Si from 3. DUP in low-mass AGB stars in SiC Si mainstream line
  - Silicates form before SiC, when DUP of s-process matter is less efficient
  - Silicate Si mainstream line may be a better proxy for GCE

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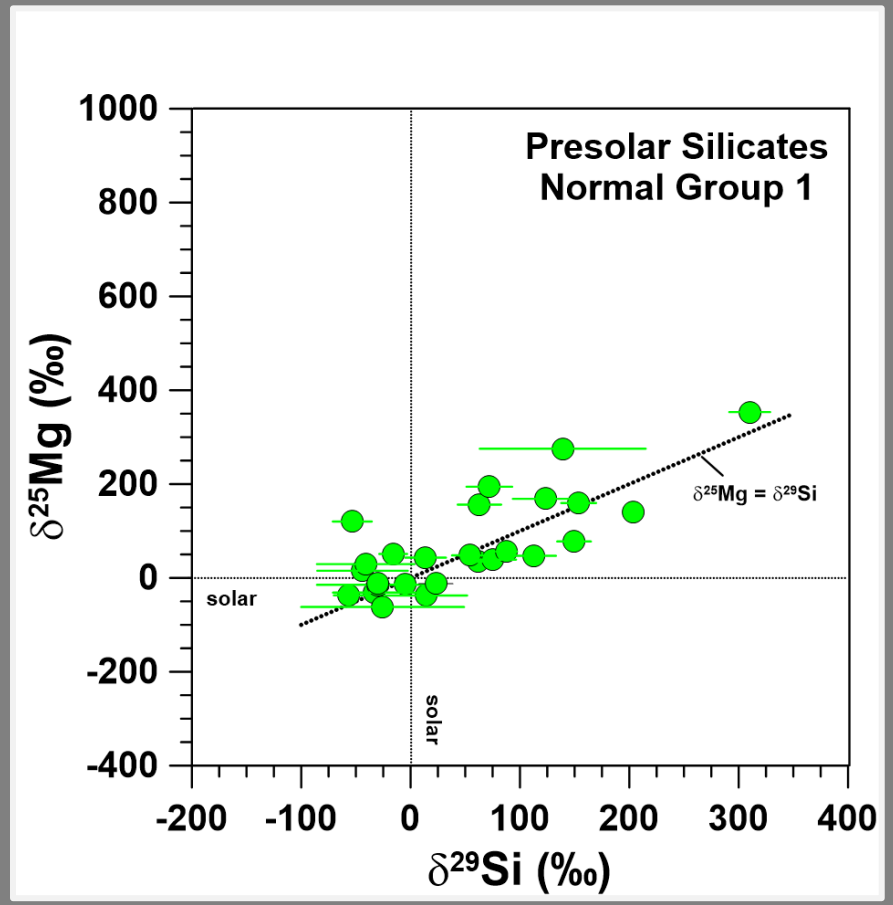
Si-Isotopic Systematics (II)

GCE of Mg & Si



- δ^{25}Mg and δ^{29}Si of normal Group 1 silicate grains are correlated along a slope ~1 line
- Support for GCE interpretation of Mg and Si in normal Group 1 silicates

Hoppe P. et al. 2021, ApJ, 913,10; MPIC 2024, unpub.

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Summary (I)

- Based on Mg-isotopic compositions, O isotope Group 1 grains (majority of presolar silicates) can be divided into 4 subpopulations: Normal (60%), ^{25}Mg-rich (25%), ^{25}Mg-poor (5%), and ^{26}Mg-rich (10%)
- Stellar sources:
  - Normal Group 1 grains: Low-mass AGB stars
  - ^{25}Mg-rich, ^{25}Mg-poor, ^{26}Mg-rich grains: SNe, supergiants, intermediate-mass AGB stars with super-solar metallicities

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Summary (II)

- Normal Group 1 grains show imprints of GCE in Mg and Si isotopes
  - Mg- and Si-isotopic compositions fall along linear arrays in three-isotope plots (“mainstream lines”)
  - Silicate Mg mainstream line has a slope 0.84±0.05
  - Silicate Si mainstream line has a slope 1.34±0.09, i.e., identical to that of SiC mainstream grains, but is slightly shifted to ^{30}Si-poor side of SiC Si mainstream line by 14±5 ‰ and may be a better proxy for the GCE of Si isotopes
  - Mg and Si isotopes are correlated which gives further support for the GCE interpretation of Mg- and Si-isotopic compositions

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