# Light- and Heavy-element Isotopic Compositions of Presolar Silicon Carbide Grains from AGB Stars

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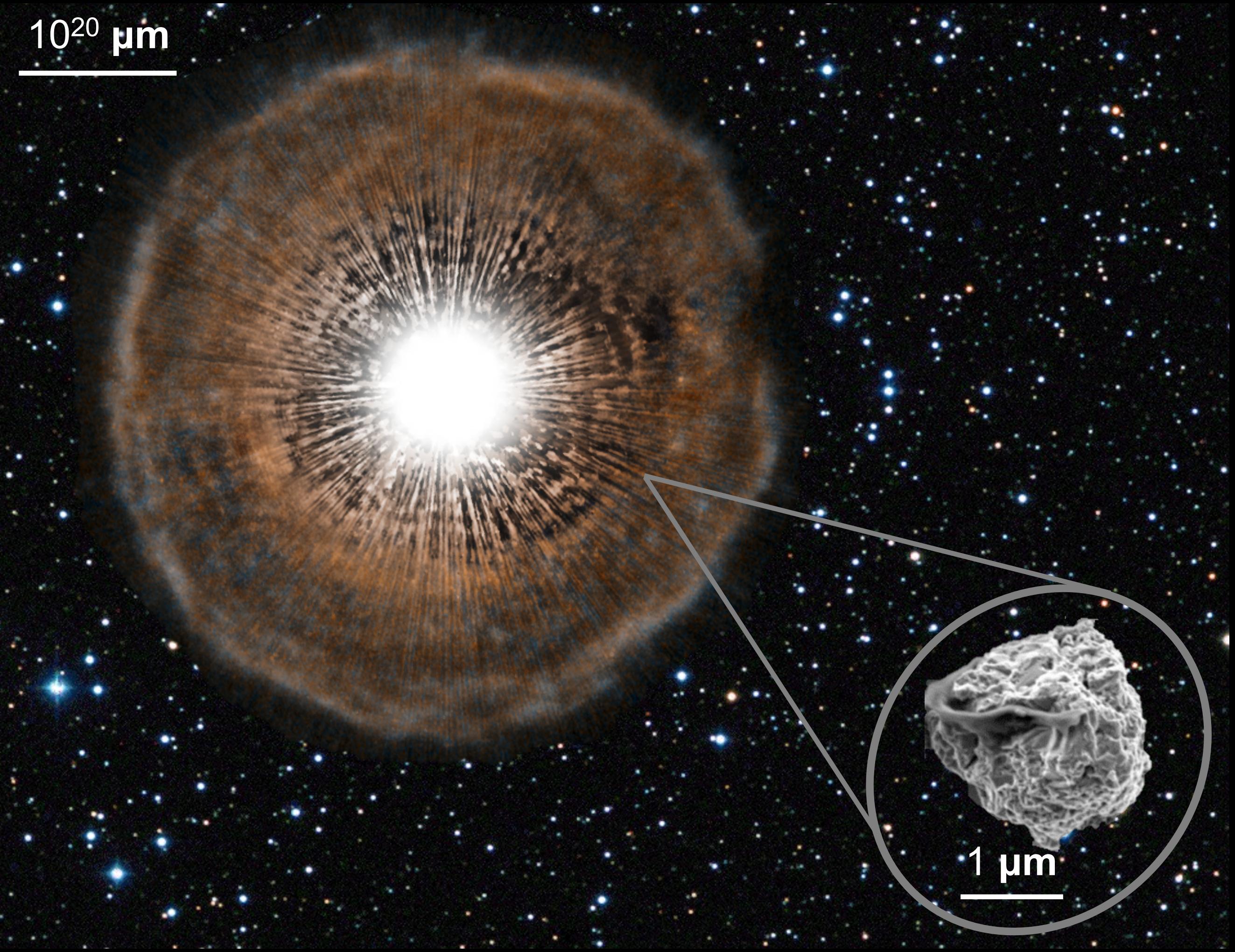
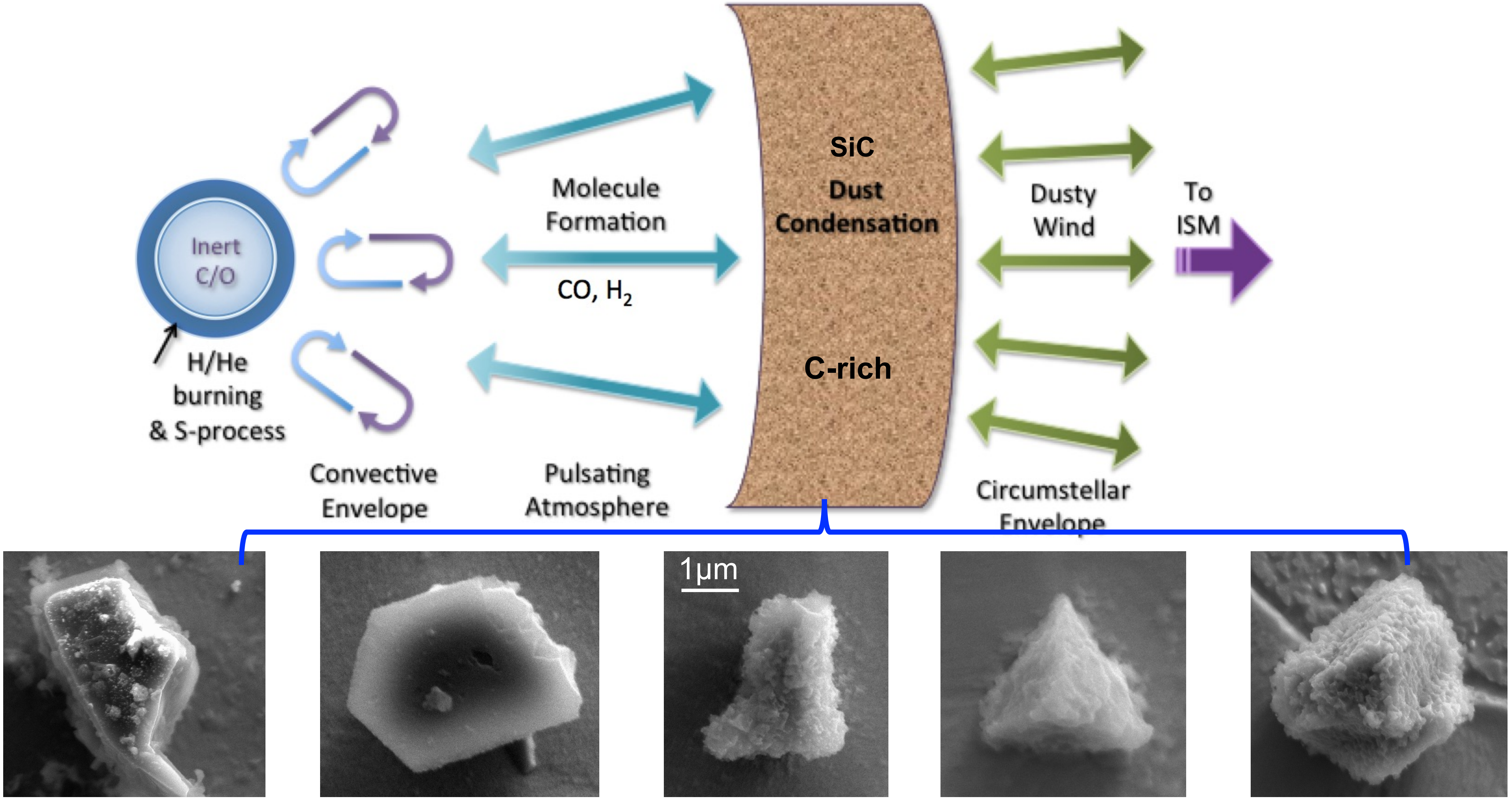
# Outline




1. Light-element Isotopes
   (C, N, Si, Mg-Al)
2. Heavy-element Isotopes

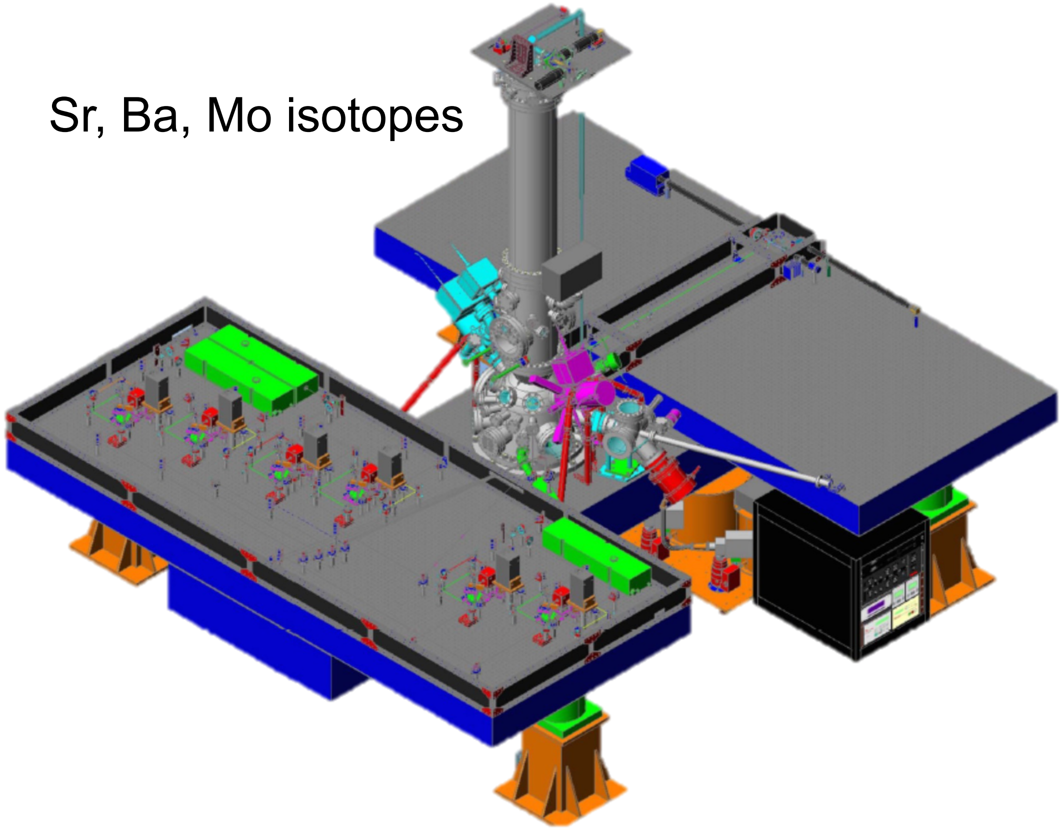
# Dust Formation in Low-mass AGB Stars



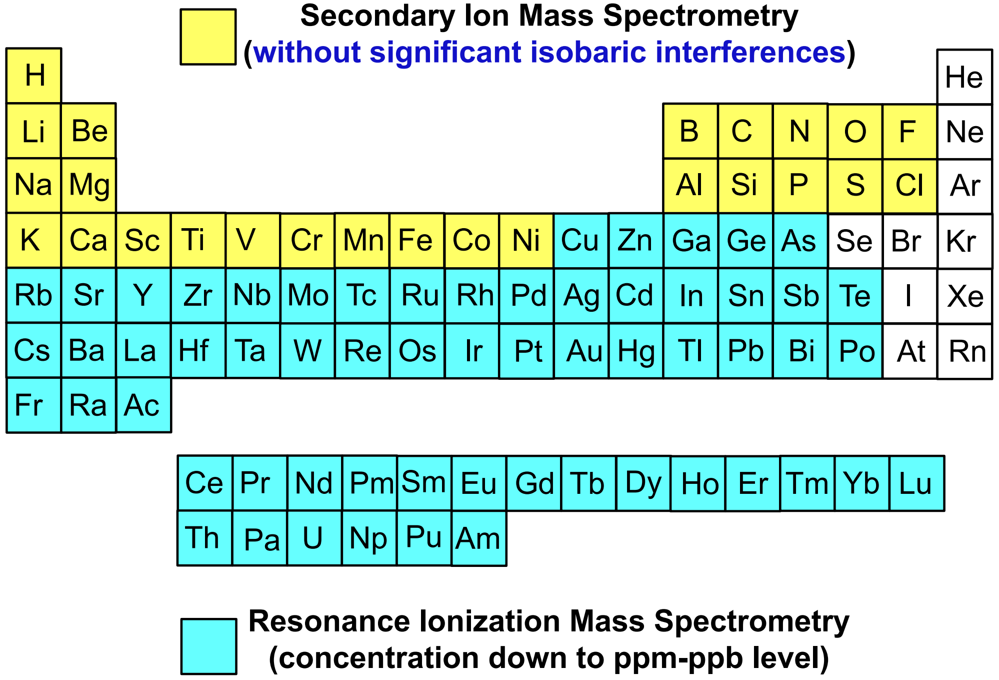
# Presolar Grain Analysis in Laboratory

**CHILI**
**(Chicago Instrument for Laser Ionization)**

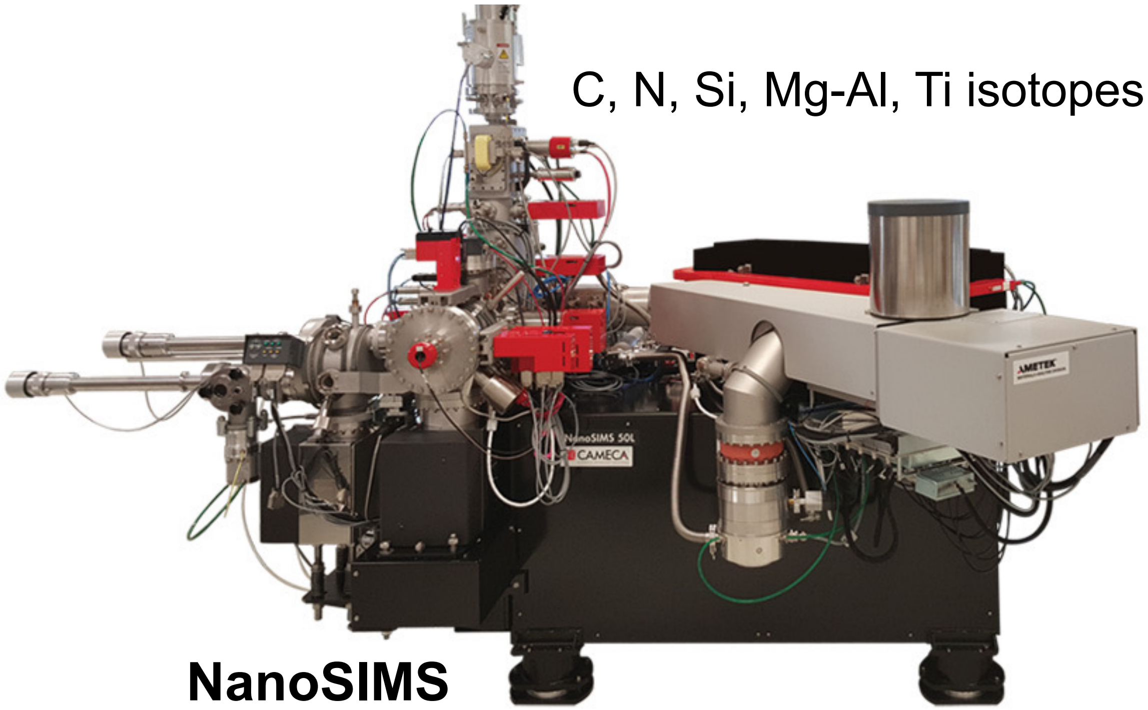
Sr, Ba, Mo isotopes



Stephan et al. (2016) *IJMS*

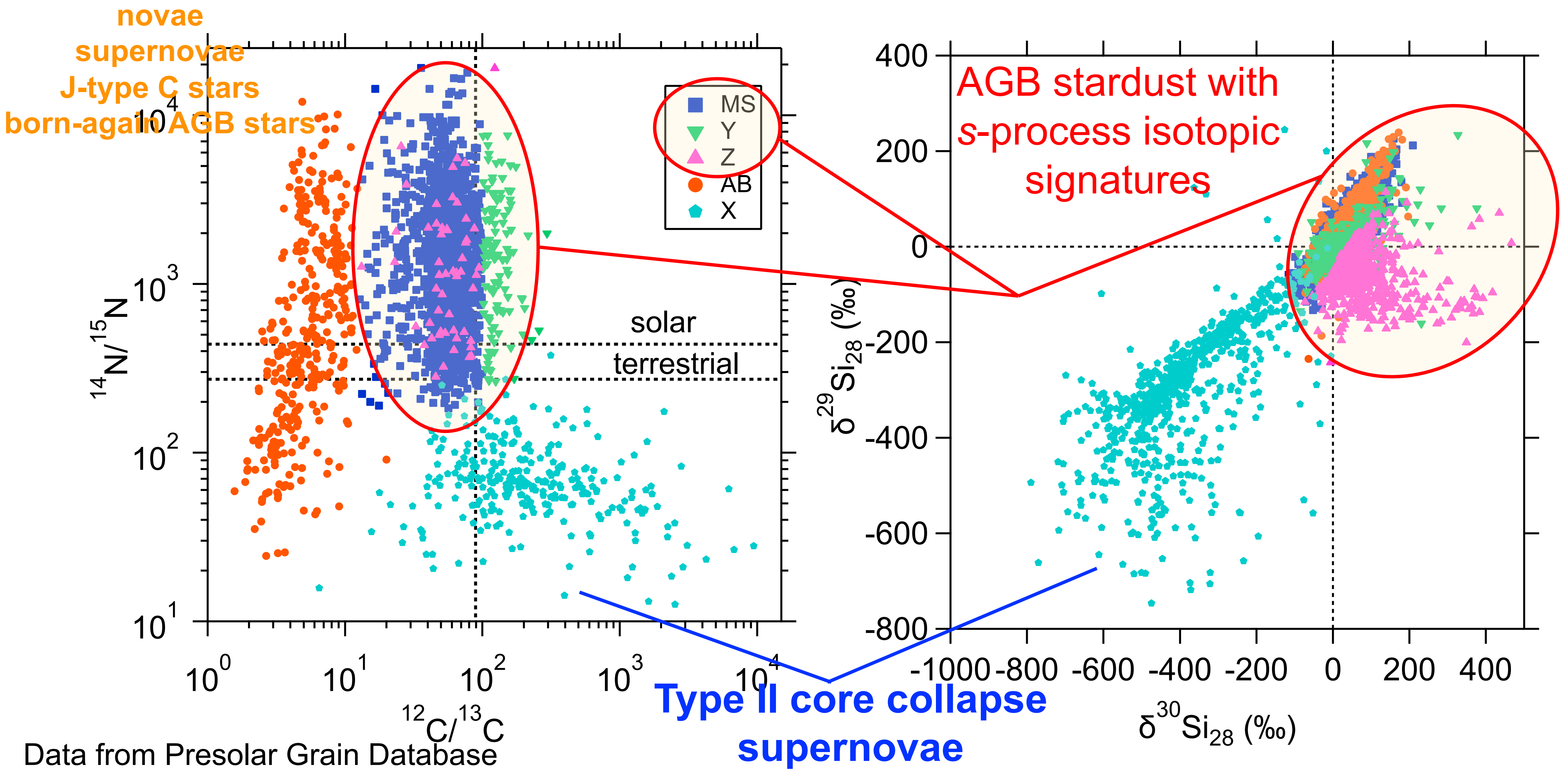



C, N, Si, Mg-Al, Ti isotopes



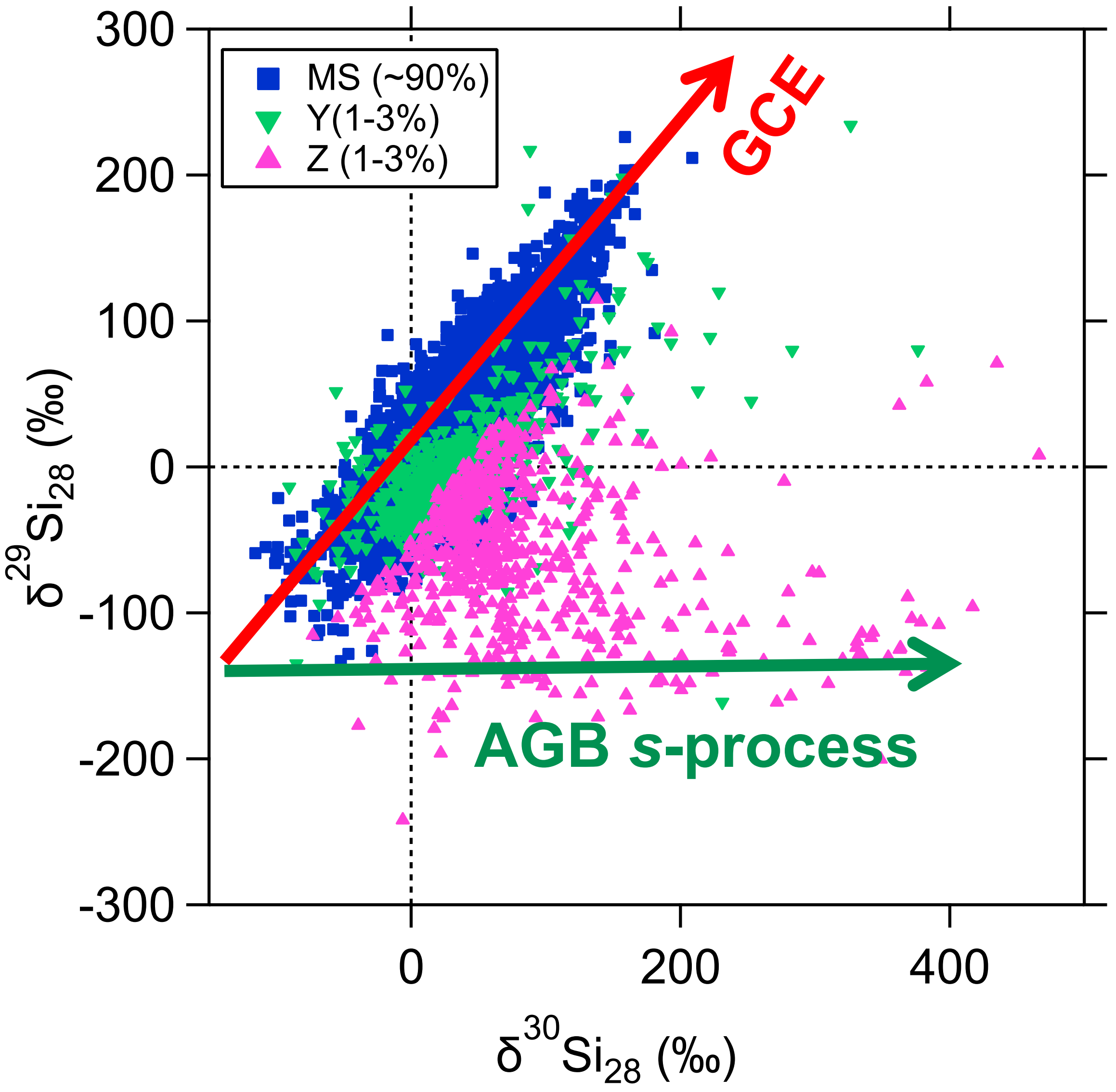
**NanoSIMS**

# Classification of Presolar SiC Grains




Data from Presolar Grain Database
(Stephan et al. 2021)

# MS, Y, and Z Grains from AGB Stars

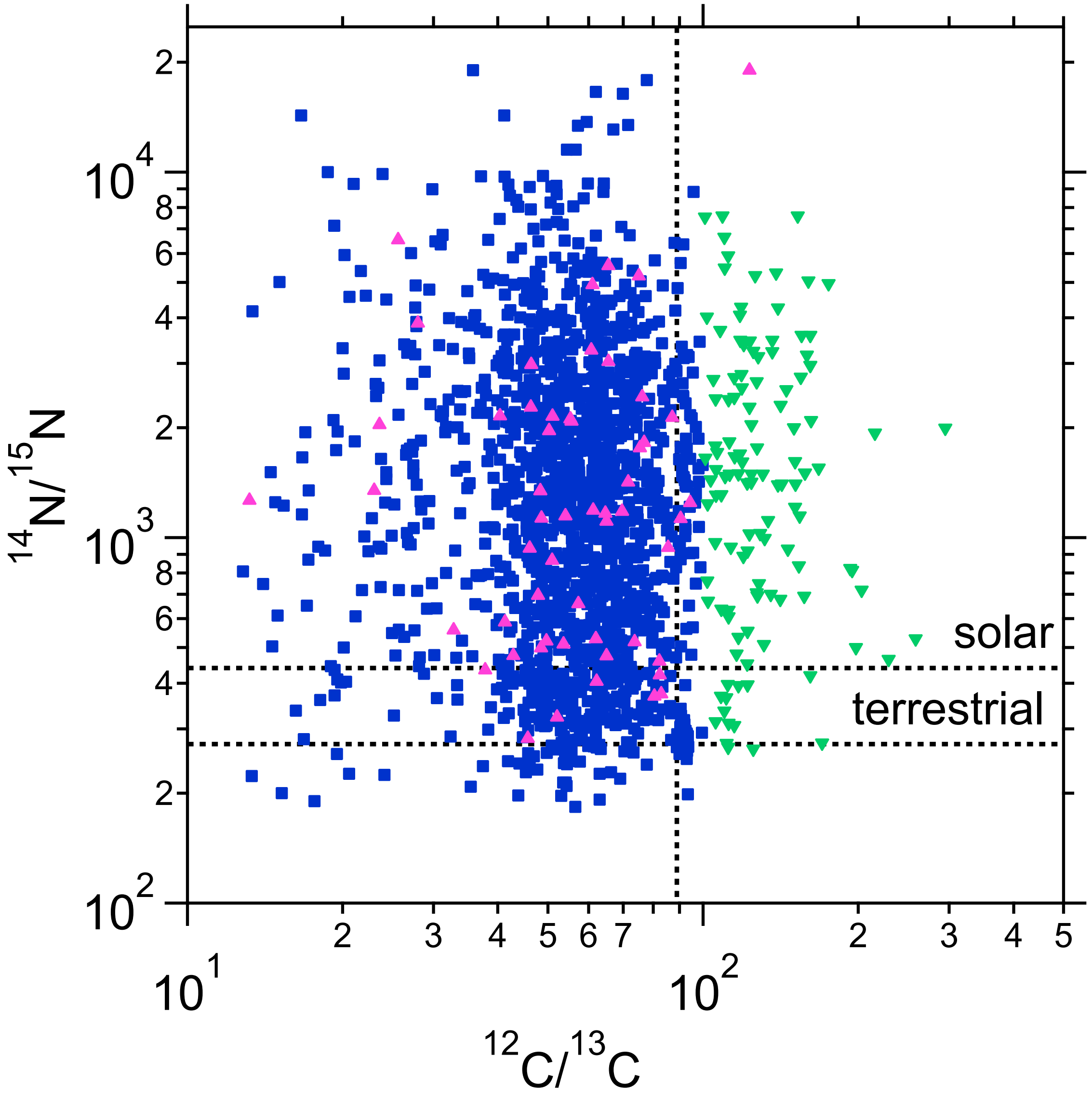



- **$^{29}Si/^{28}Si$**: a proxy of stellar metallicity
→Y and Z grains from lower metallicity stars than MS grains

- **$^{30}Si/^{28}Si$**: a proxy of *s*-process efficiency
→s-process efficiency follows the order of Z > Y > MS

- **lower metallicity stars**: lower *s*-process seeds and higher $T_{max}$
→ increasing *s*-process efficiency with decreasing metallicity

# Why Such A Wide Range of $^{14}N/^{15}N$ Ratios?

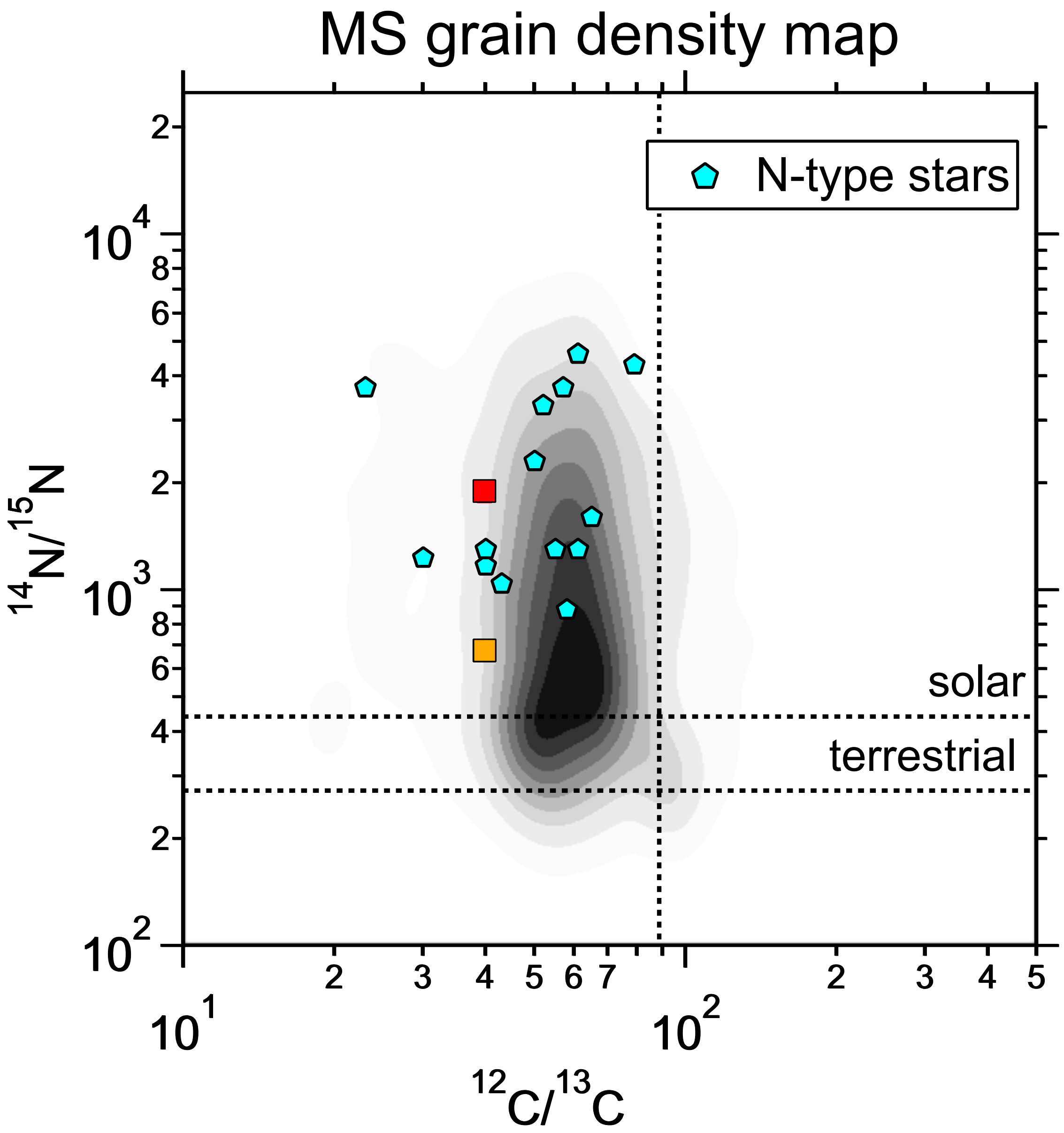


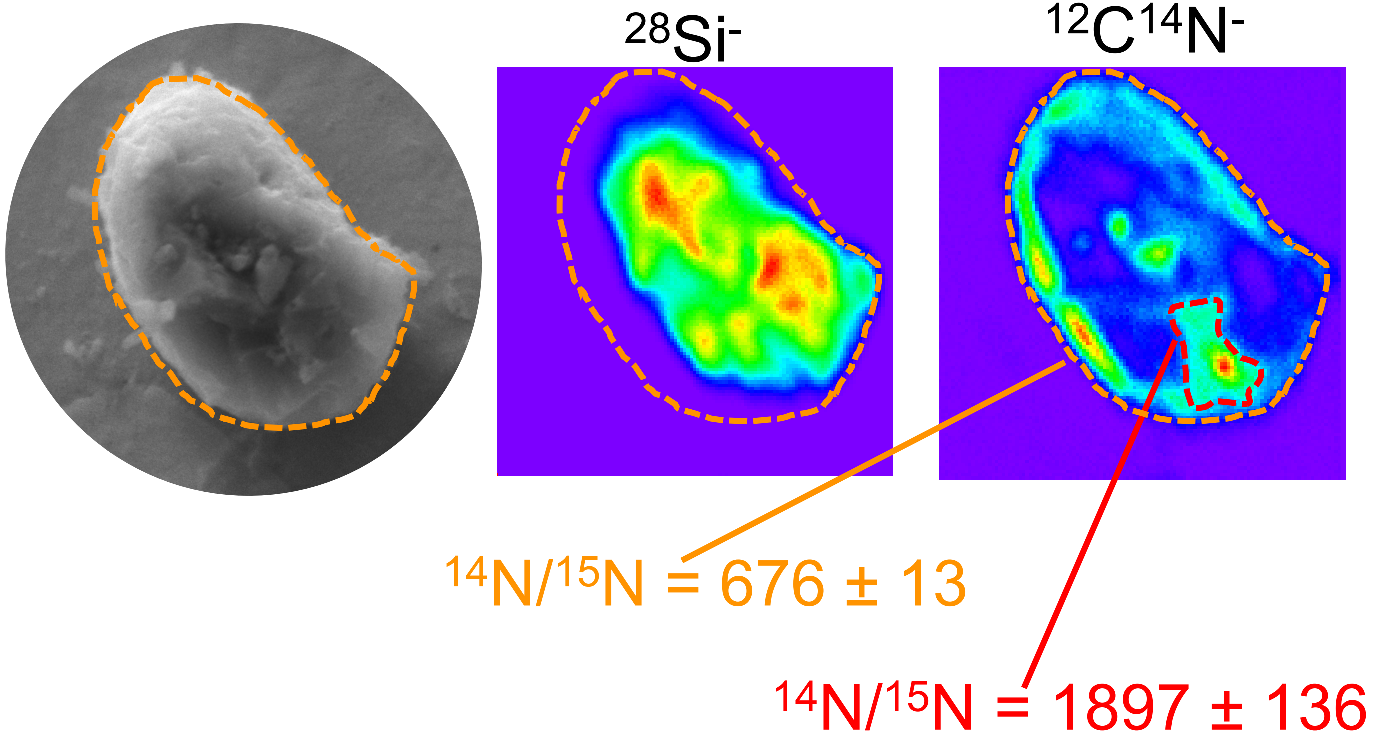

MS/Z and Y: Different $^{12/13}C$ ratios

MS, Y, and Z : Different Si isotope ratios

MS, Y, and Z: Similar $^{14}N/^{15}N$ ratios?

# Why Such A Wide Range of $^{14}N/^{15}N$ Ratios?

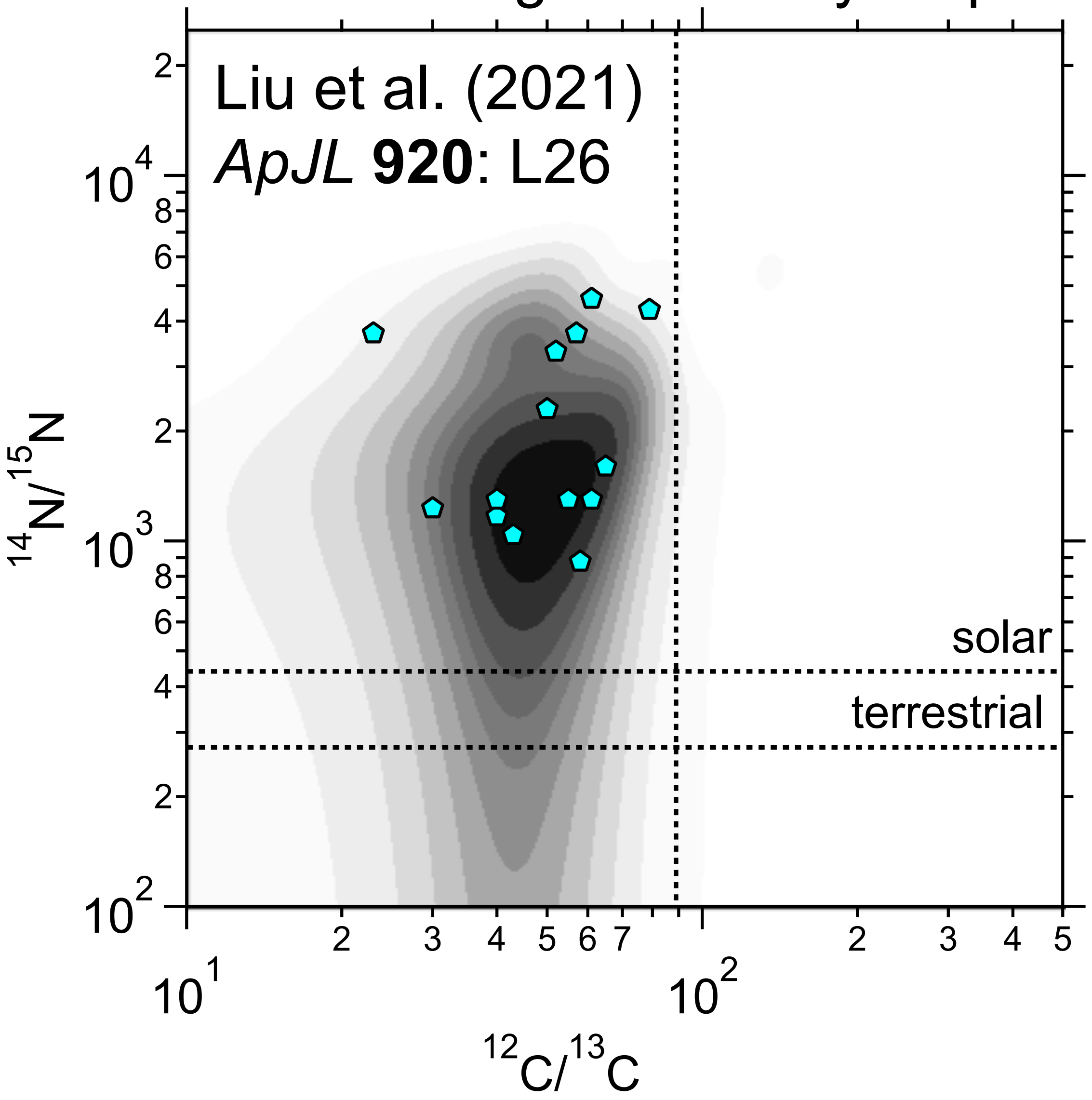


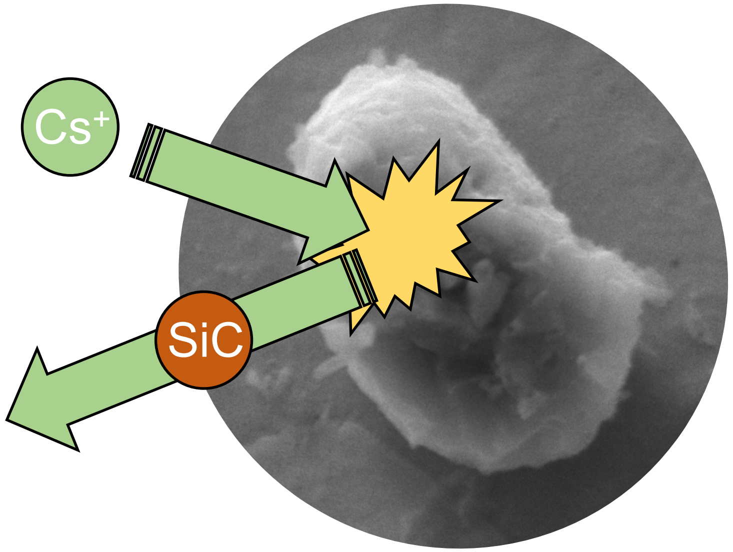



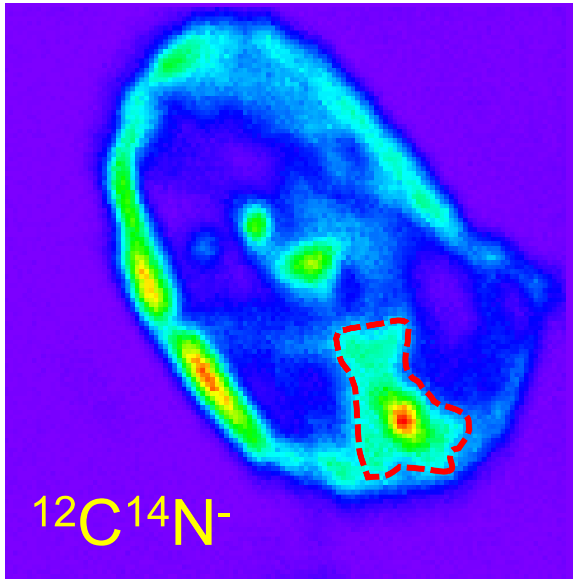

Isotope data of presolar grains are subject to contamination and may not reflect intrinsic stellar signatures!

# Suppressing N Contamination

NEW MS grain density map



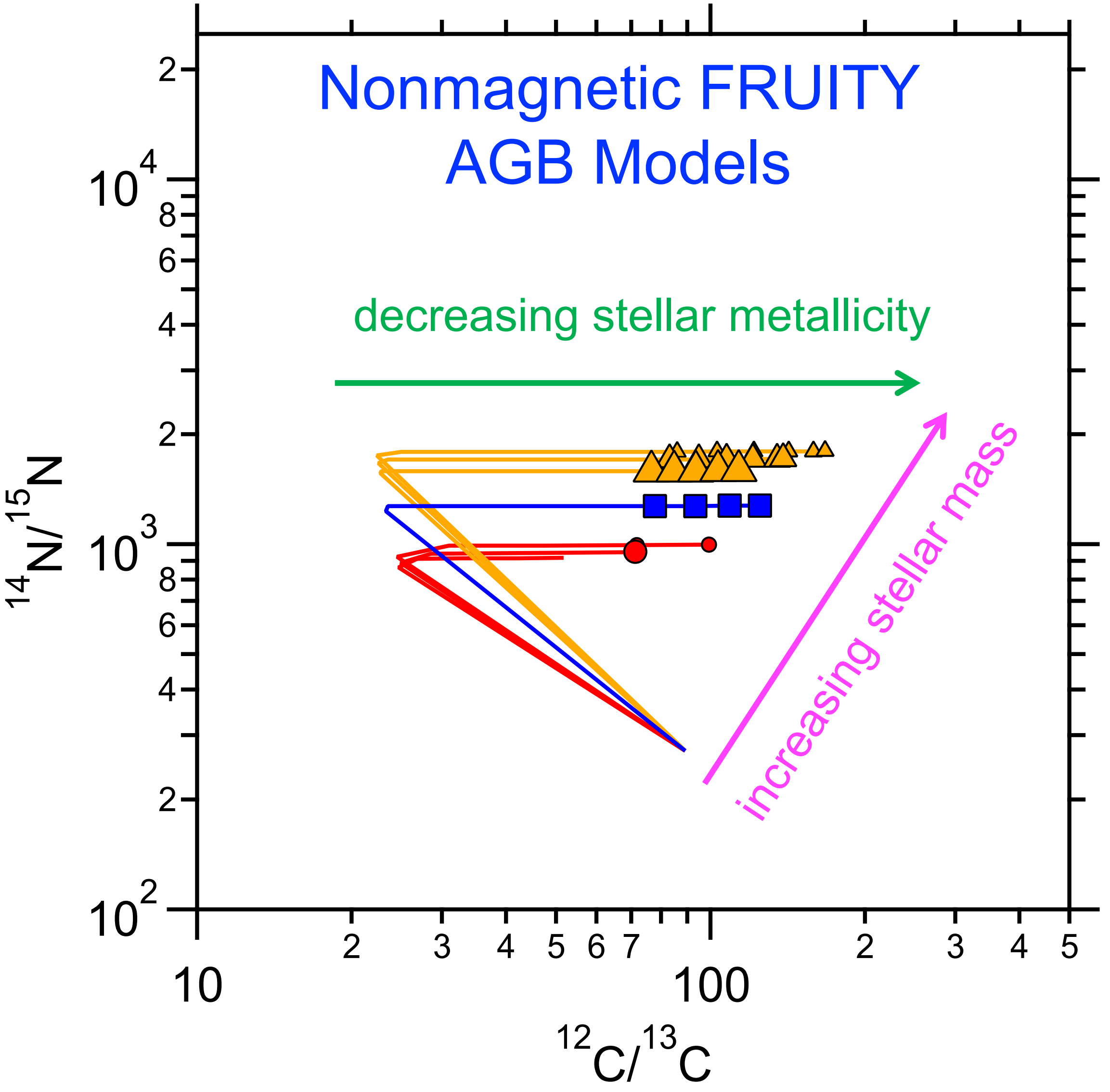




Extensive sputtering to remove surface material

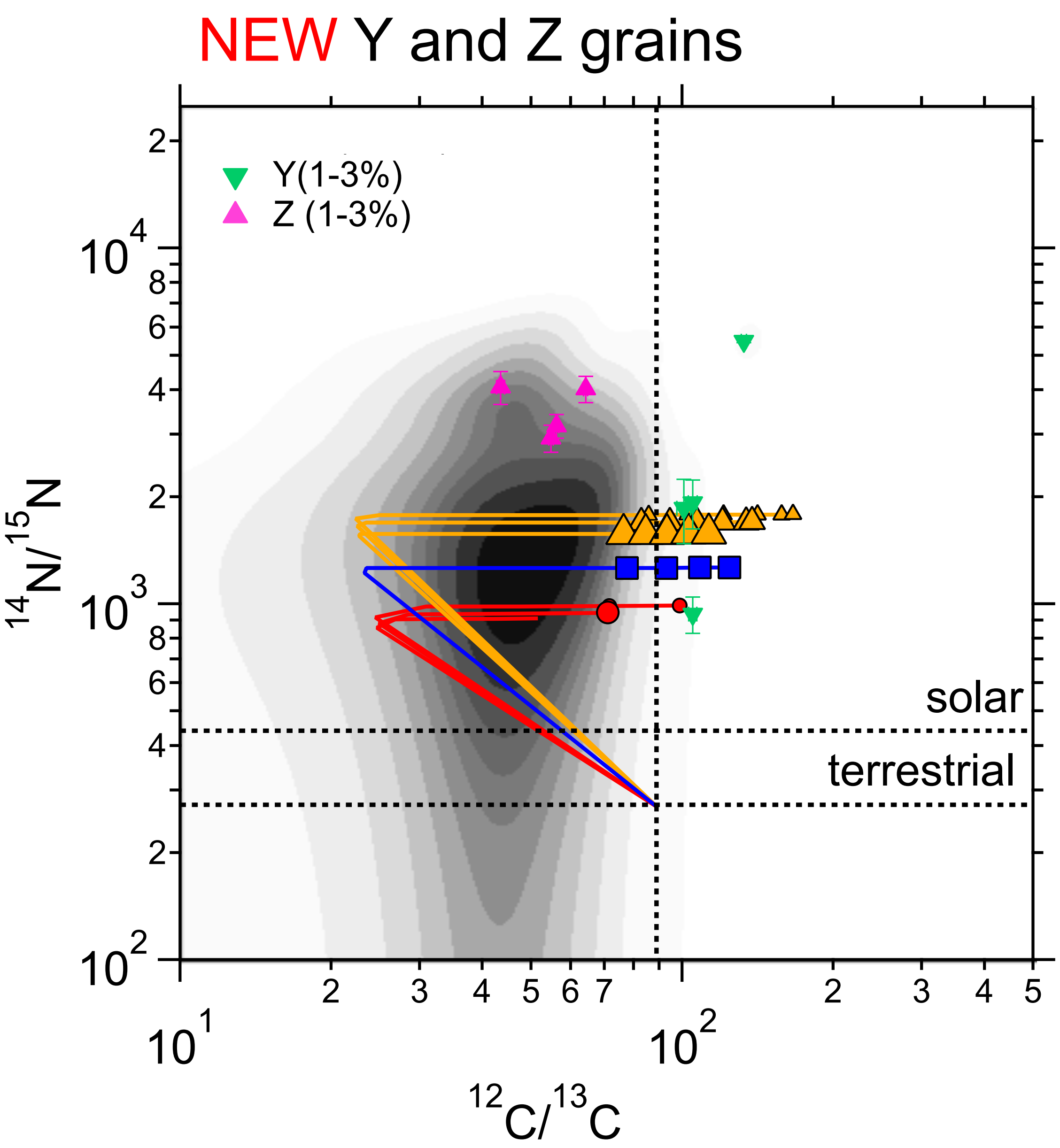
choose small region of interest for data reduction

# $^{14}N/^{15}N$ Affected by Stellar Mass and Metallicity




- **$^{14}N/^{15}N$**: increases with increasing stellar mass
- **$^{12}C/^{13}C$**: increases with increasing stellar mass and decreasing stellar metallicity

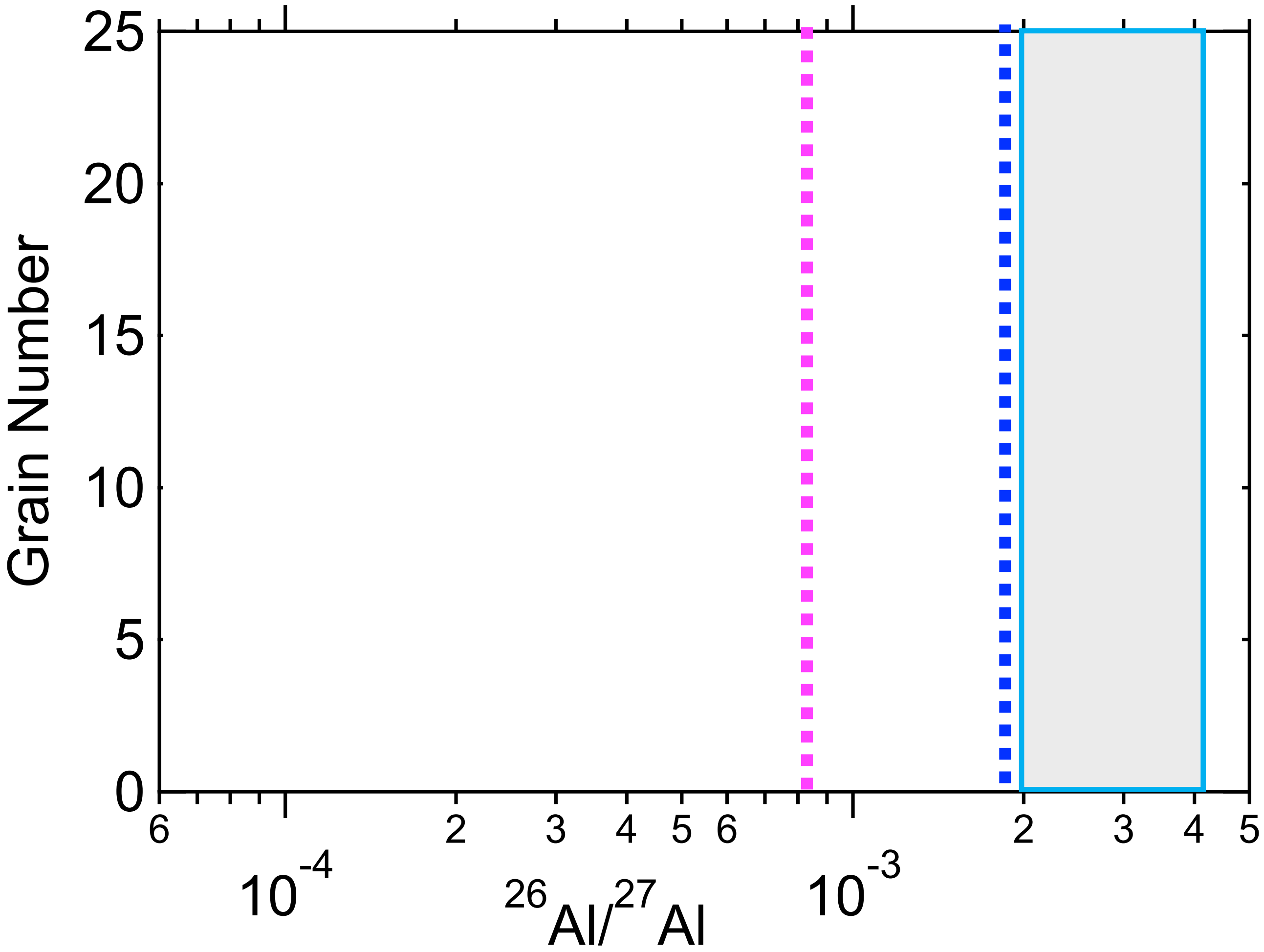
# MS, Y, and Z: Different $^{14}N/^{15}N$ ratios?



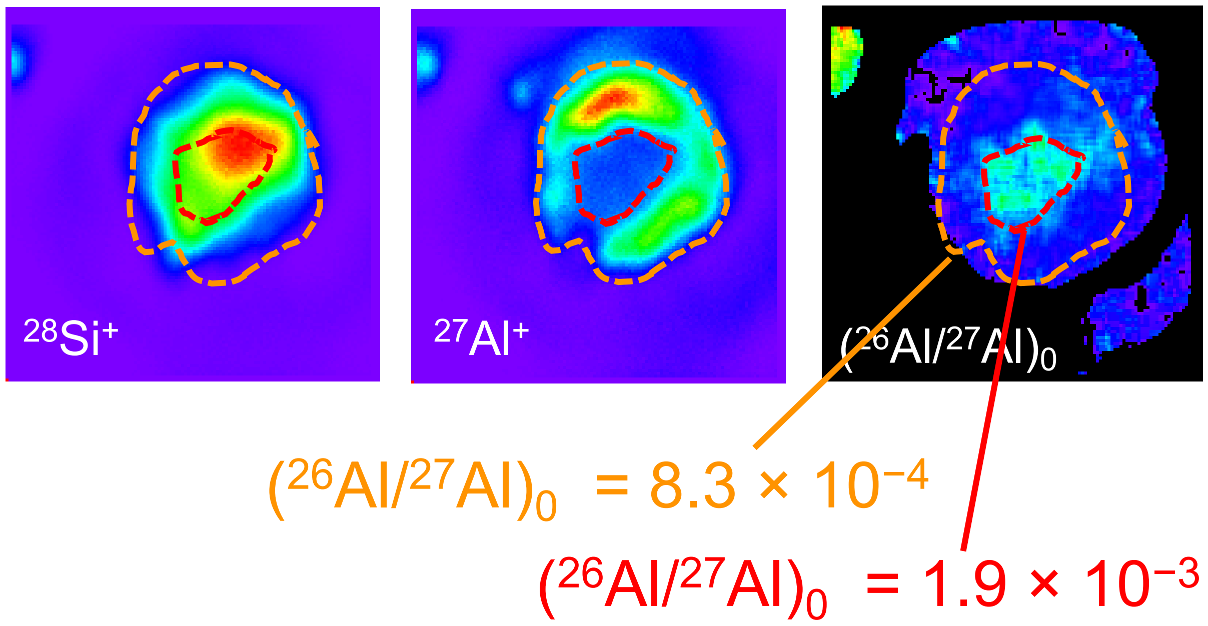

- **$^{14}N/^{15}N$**: increases with increasing stellar mass
- **$^{12}C/^{13}C$**: increases with increasing stellar mass and decreasing stellar metallicity

- Higher $^{14}N/^{15}N$ in Z grains: higher stellar mass?
- Effects of extra mixing on $^{12}C/^{13}C$ and $^{14}N/^{15}N$?

# $^{26}Al/^{27}Al$ in AGB SiC Grains



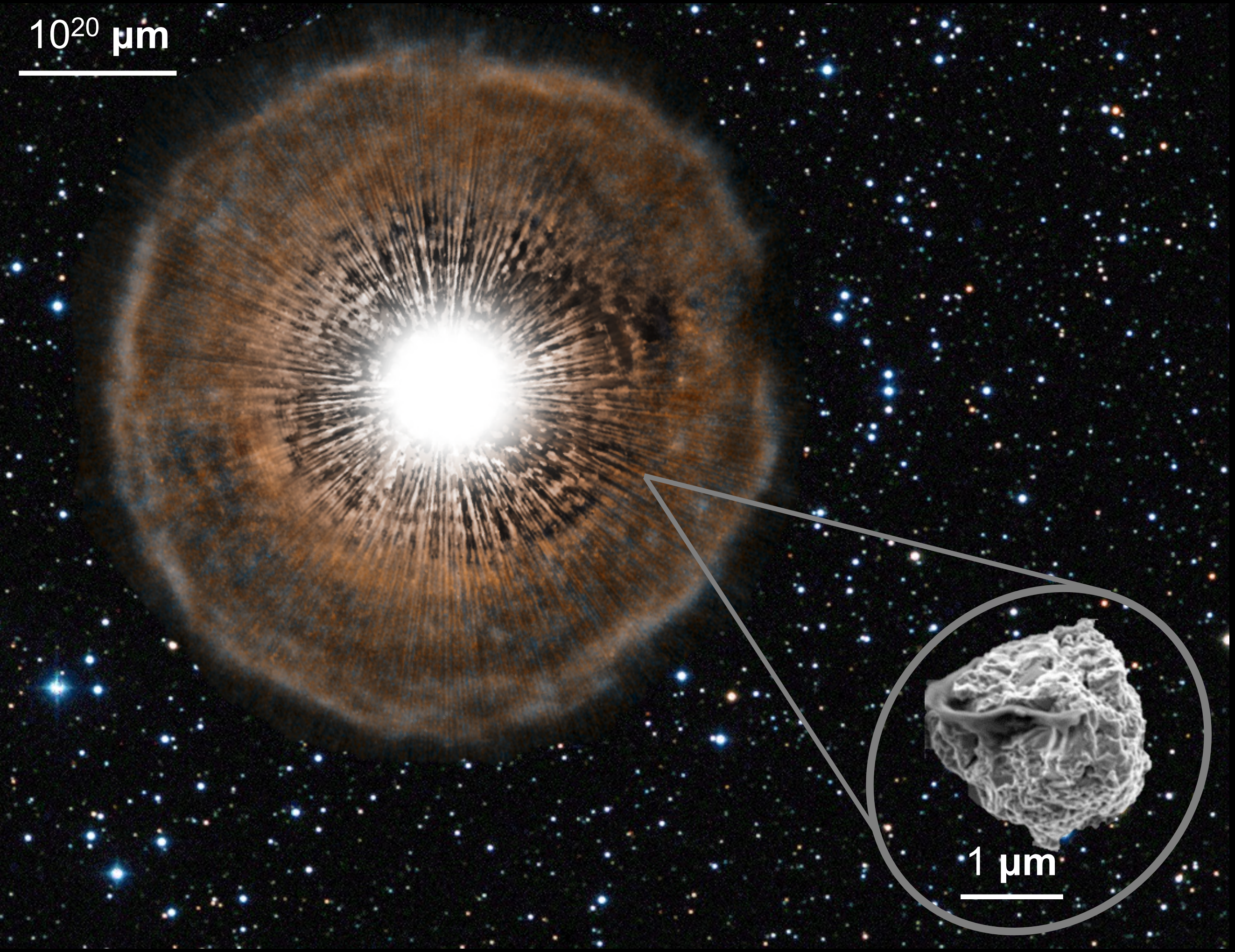

Liu et al. (2021) *ApJL* **920**: L26




- Al contamination affected literature data for $(^{26}Al/^{27}Al)_0$
- New data suggest most AGB grains have $(^{26}Al/^{27}Al)_0$ of $(1-2) \times 10^{-3}$

- Nonmagnetic FRUITY models predict $(^{26}Al/^{27}Al)_0$ of $(2-4) \times 10^{-3}$ for C-rich phase
- The model results can be reduced by increasing the $^{26}Al_g(p,\gamma)^{27}Si$ rate

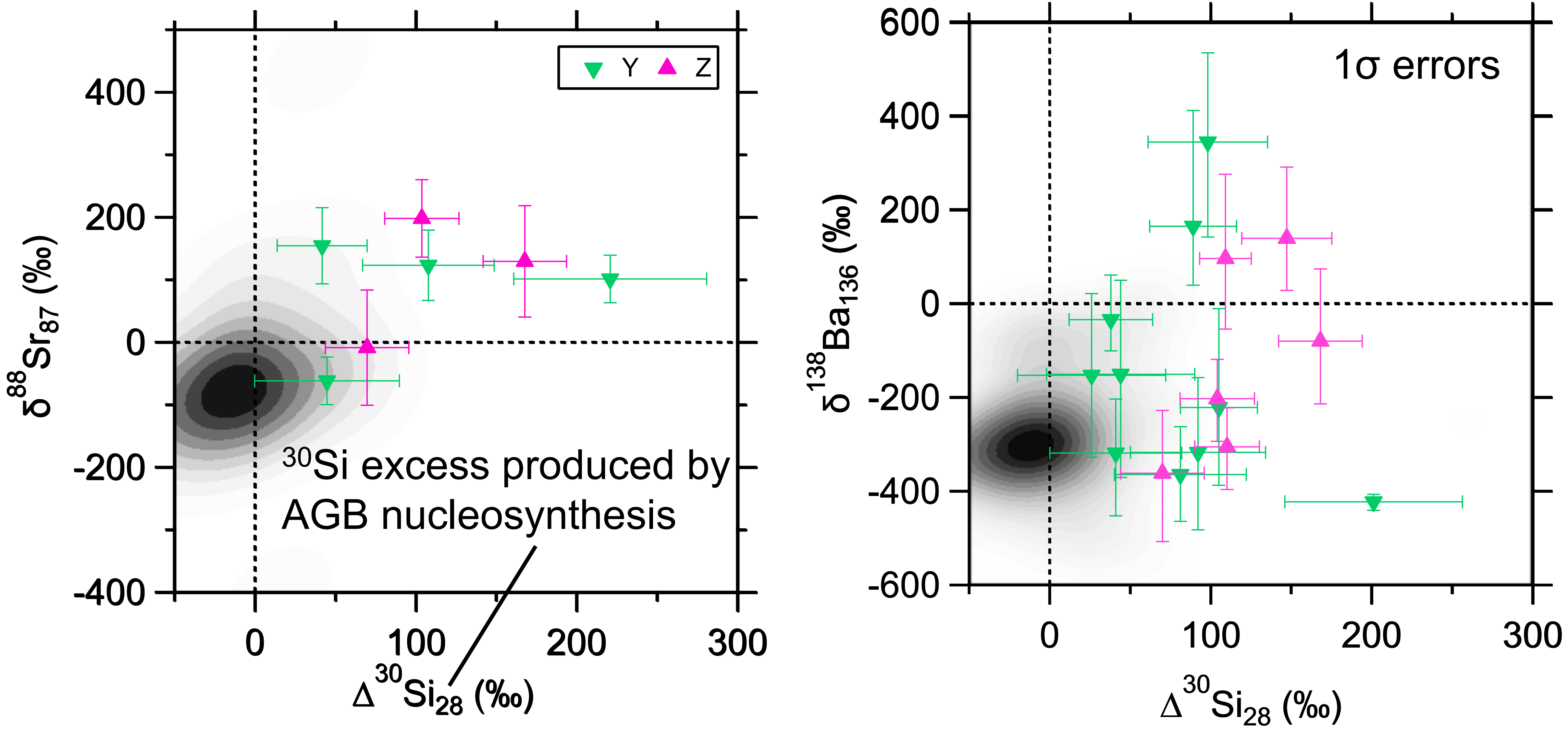
# Outline




1. Light-element Isotopes (C, N, Si, Mg-Al)
2. Heavy-element Isotopes (Sr, Mo, Ba)

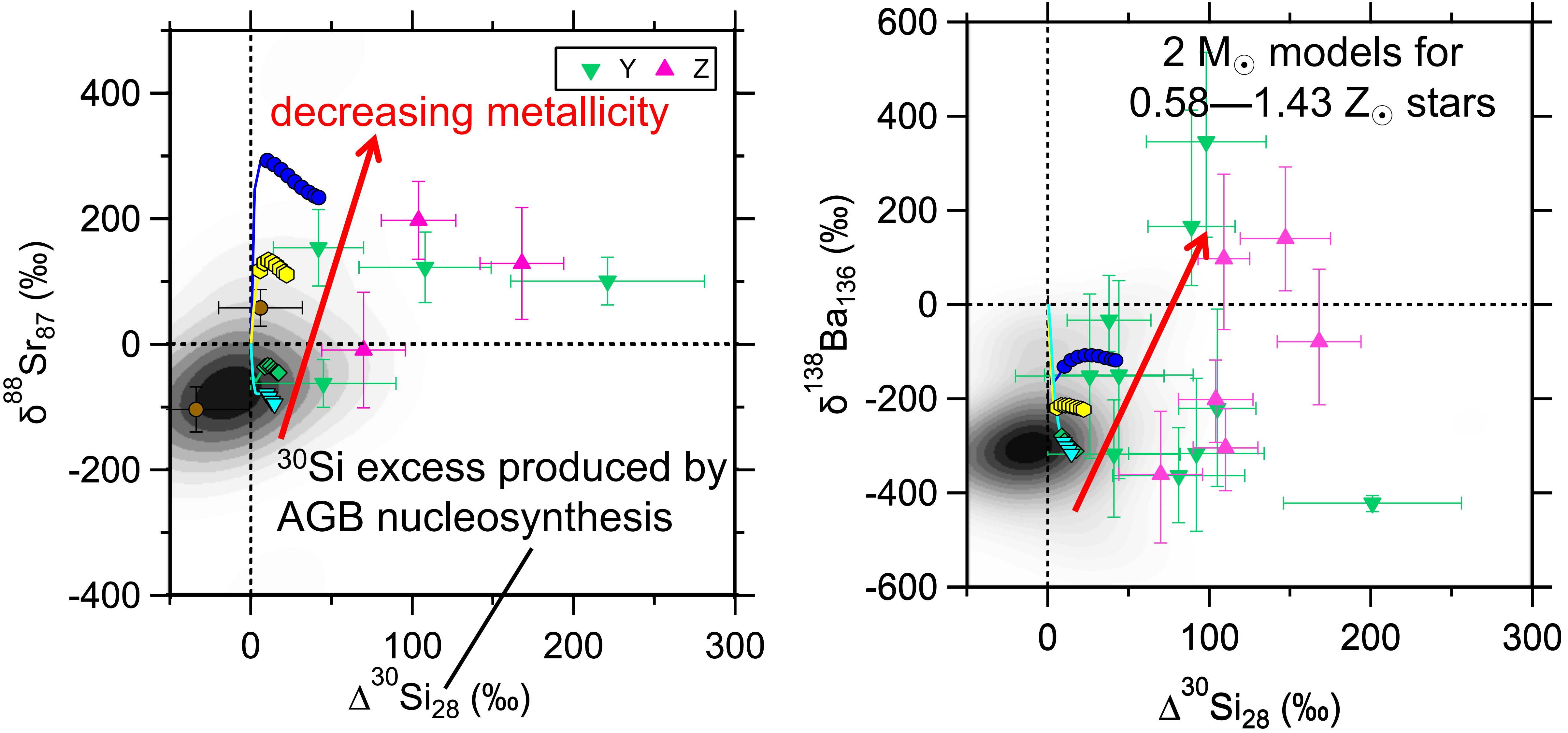
# MS, Y, and Z Grains: Sr and Ba isotopes

MS Grain Distribution

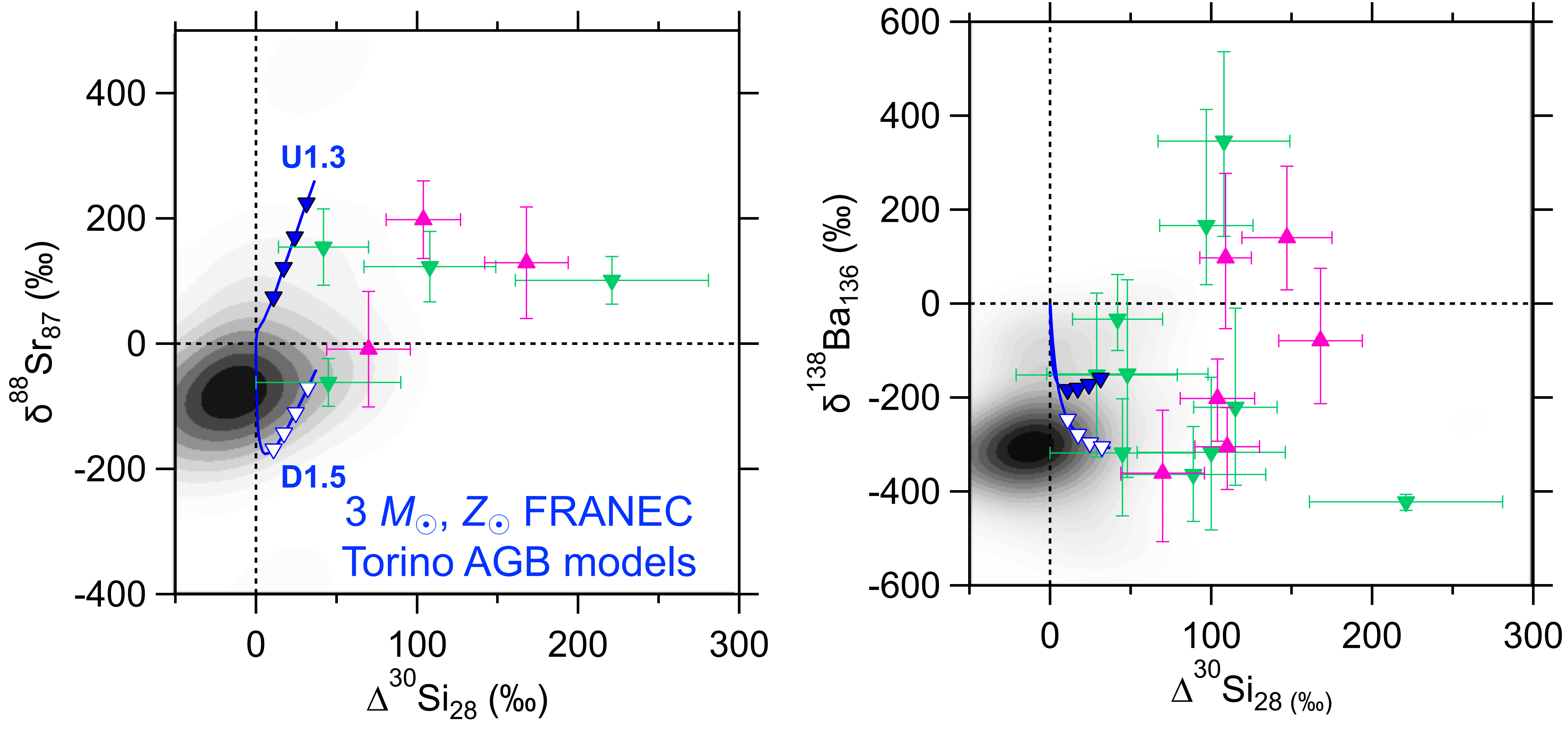


# Magnetic FRUITY AGB Models

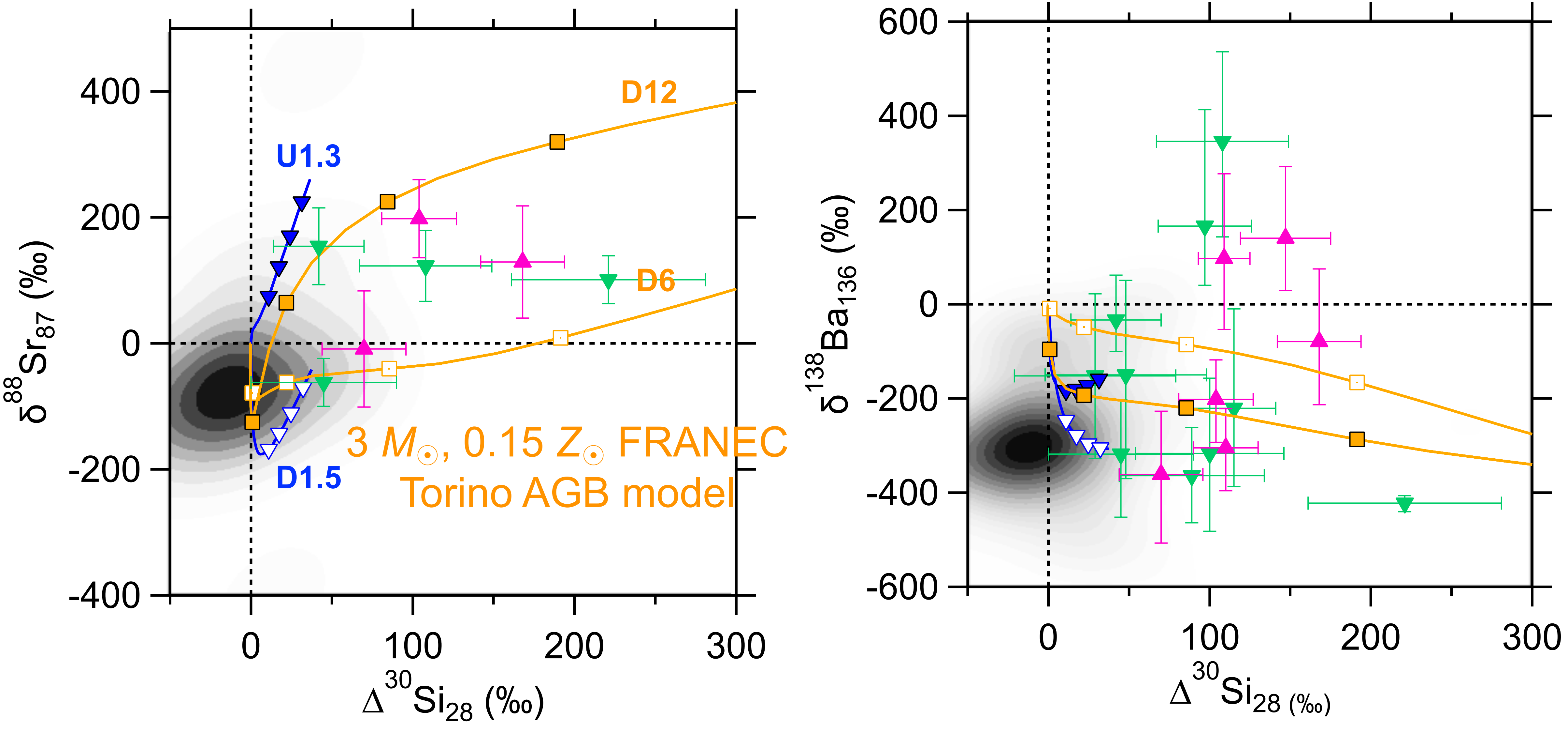
MS Grain Distribution



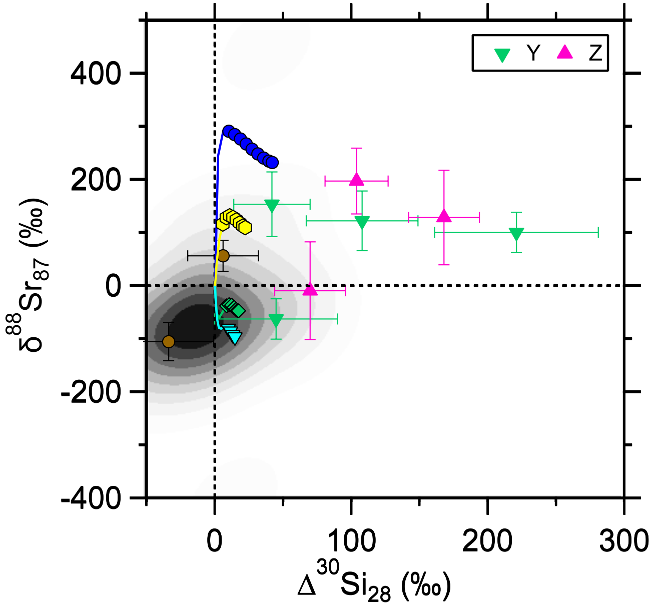
# FRANEC Torino AGB Models

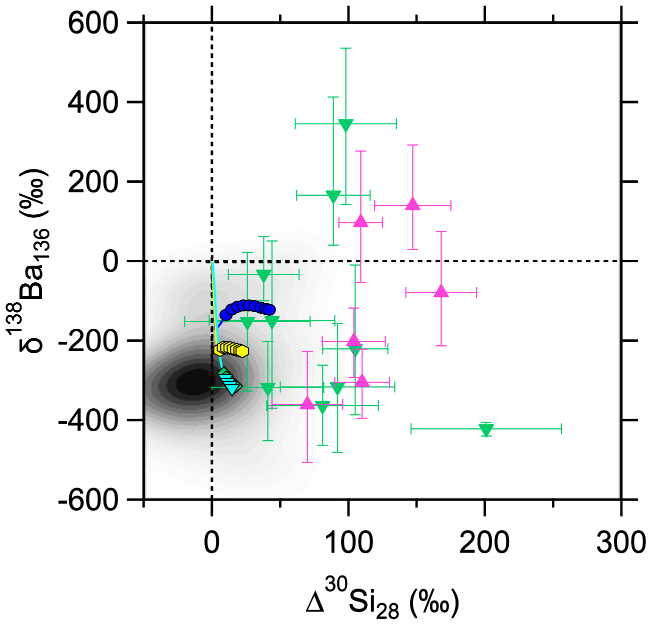


# FRANEC Torino AGB Models



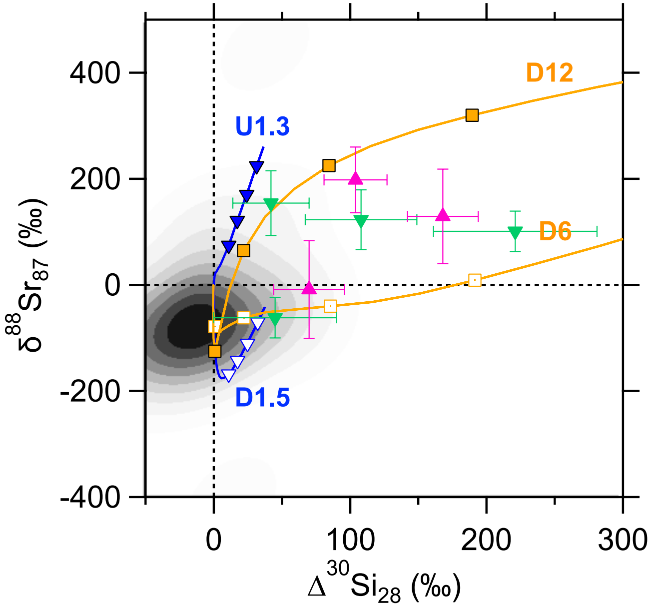
# Grains versus Models

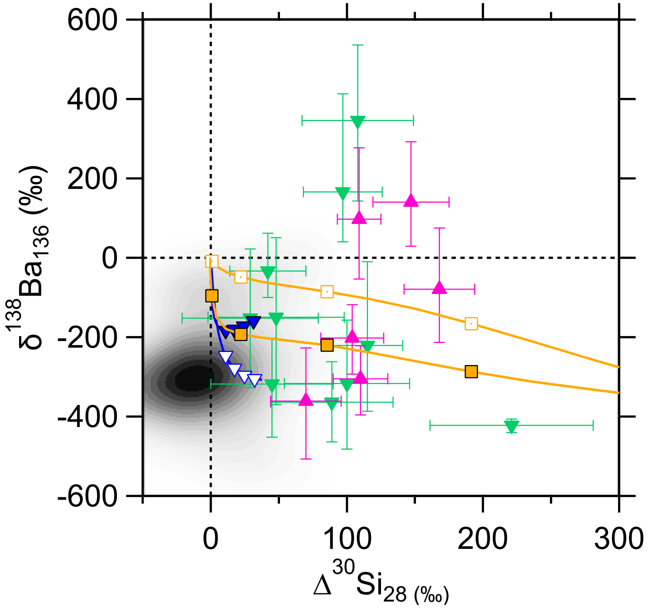



Magnetic FRUITY AGB Models

**Problem**: cannot reproduce the large $^{30}$Si excesses in Y and Z grains

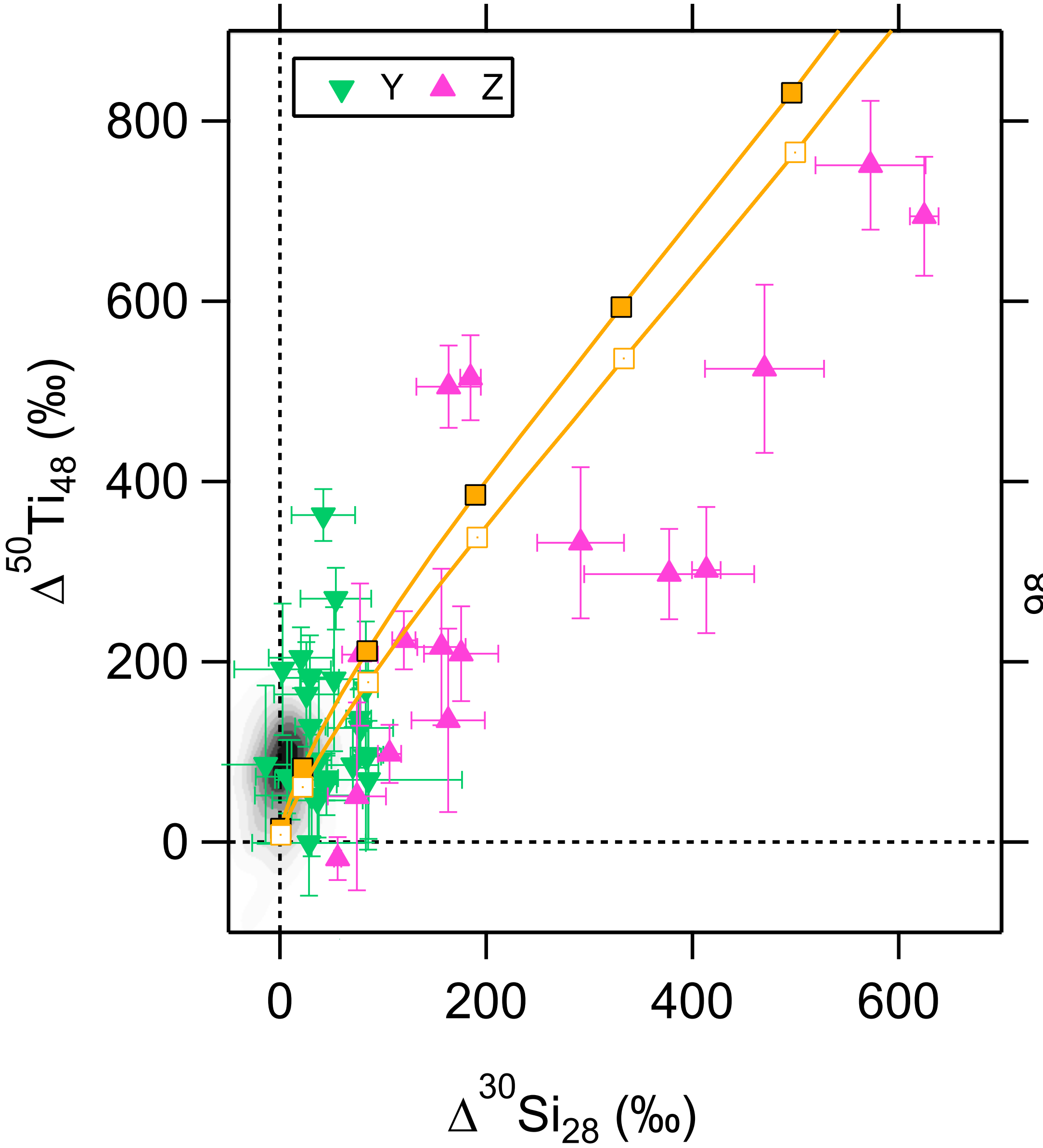


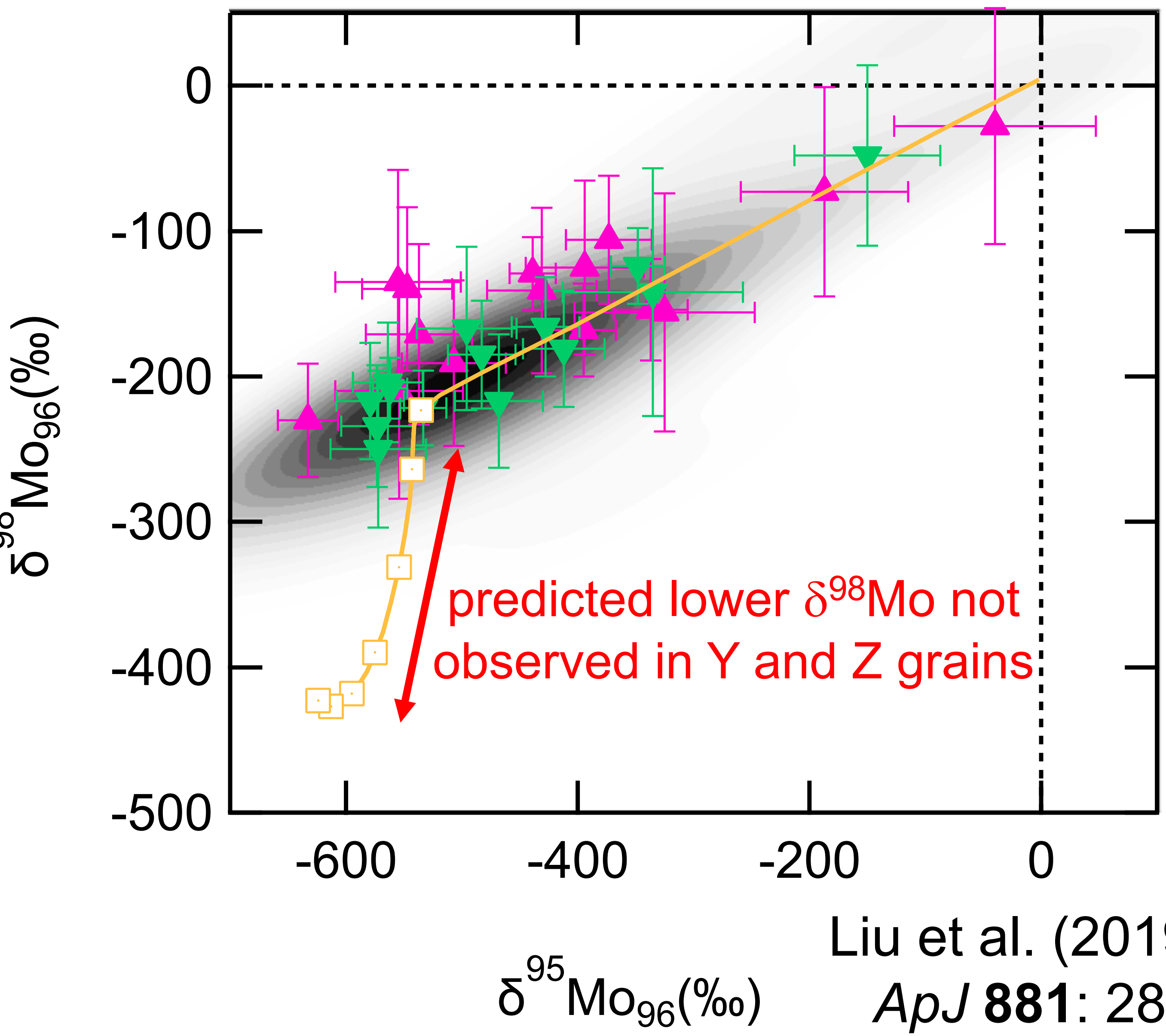




FRANEC Torino AGB Models

**Problem**: Why parent stars of Y and Z grains had such low amounts of $^{13}$C?

# Y and Z Grains: SiC from low-metallicity AGB stars?




Liu et al. (2019)
*ApJ* **881**: 28

# Conclusions

- MS, Y and Z grains show systematic differences in C, Si, Ti, Sr, Ba isotope ratios
- The large $^{30}$Si, $^{50}$Ti, $^{88}$Sr, and $^{138}$Ba enrichments observed in Y and Z grains are in line with signatures expected for low metallicity AGB stars, but AGB models cannot quantitatively explain the grain data

- MS, Y, and Z grains show similar N, Mg-Al, and Mo isotope ratios, and the similar N and Mg-Al isotope data may have been caused by contamination and need further investigation
- The new NanoSIMS analytical approach is needed to obtain more N and Mg-Al isotope data for Y and Z grains
- That the Mo isotopic pattern varies with varying metallicity is caused by the MACS values of Mo isotopes deviating from $1/v_{th}$, and better cross-section measurements are needed to test whether this is true.