

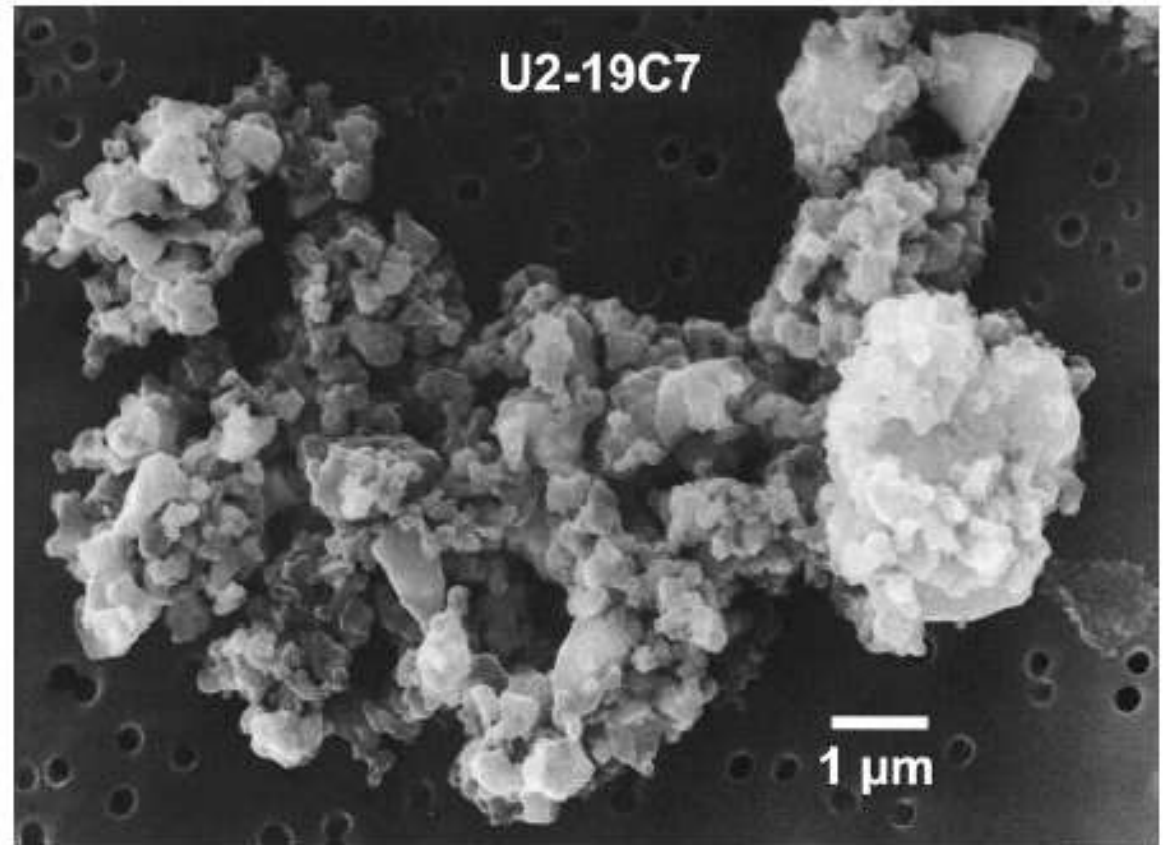
Formation of Glass With Embedded Metal and Sulfides from Shock- Accelerated Crystalline Dust in Superbubbles

Journal Club 31 May 2005

A. J. Westphal & J. P. Bradley, ApJ 617,
1131 (2004)

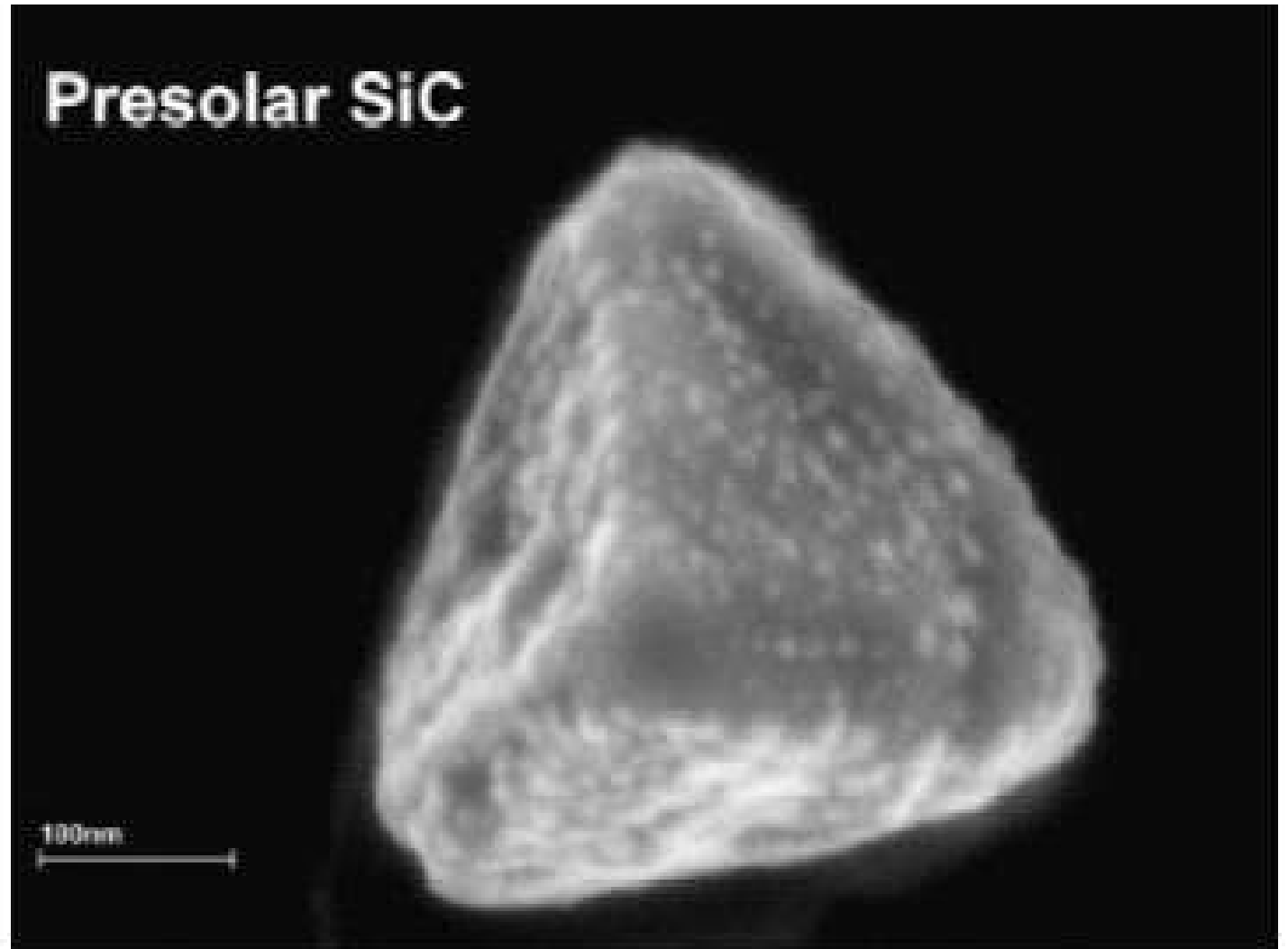
Interplanetary Dust Particles (IDPs)

- Collected in upper atmosphere
- Fluffy aggregates of relatively robust components
- Nomenclature can be a bit obscure



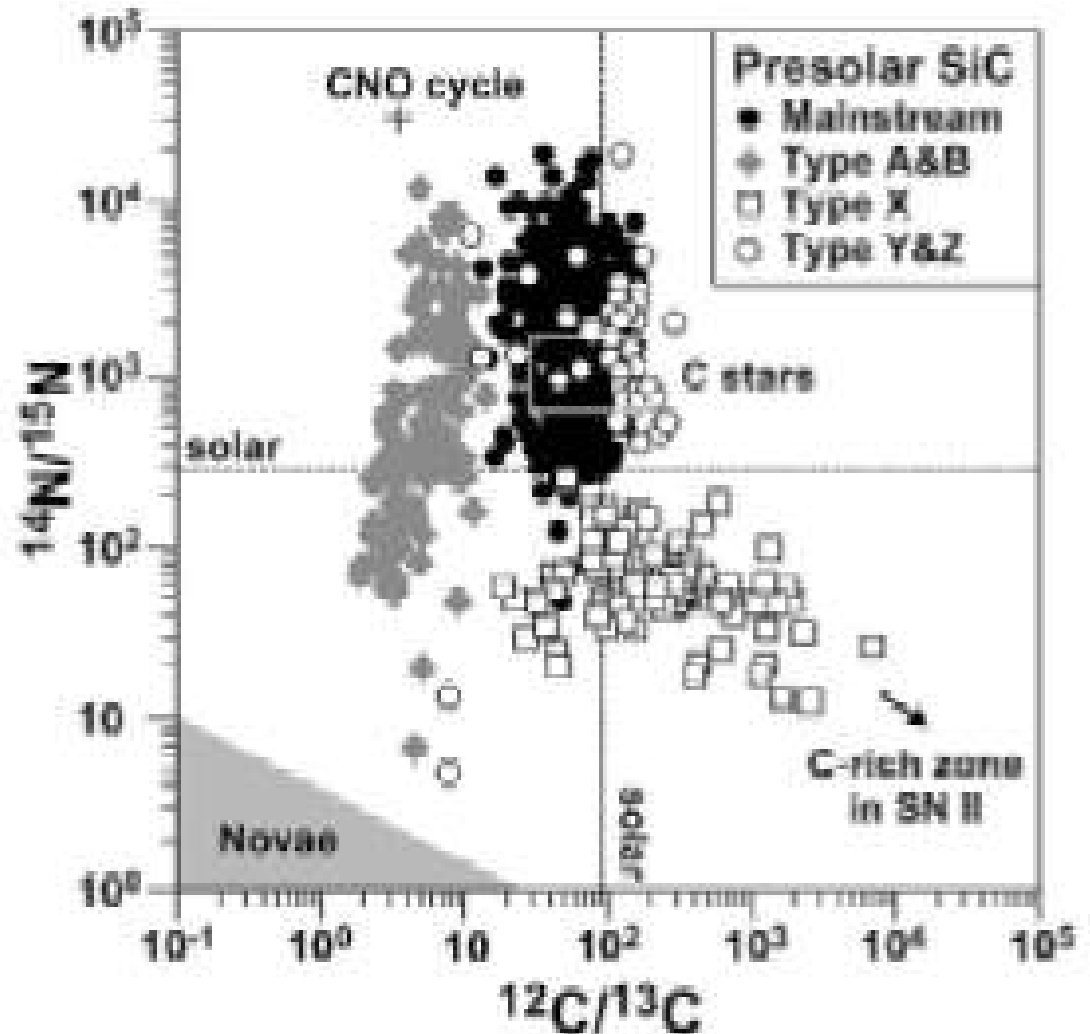
Presolar grain component

- Presolar grains show isotopic anomalies
- Very, very small!
- Also found in meteorites



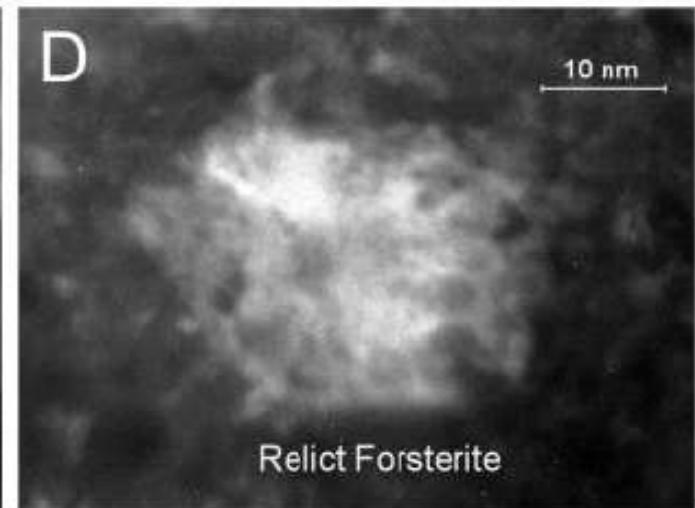
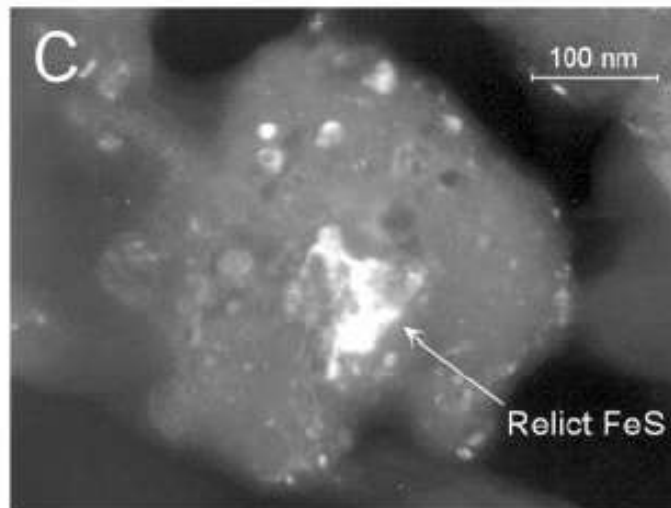
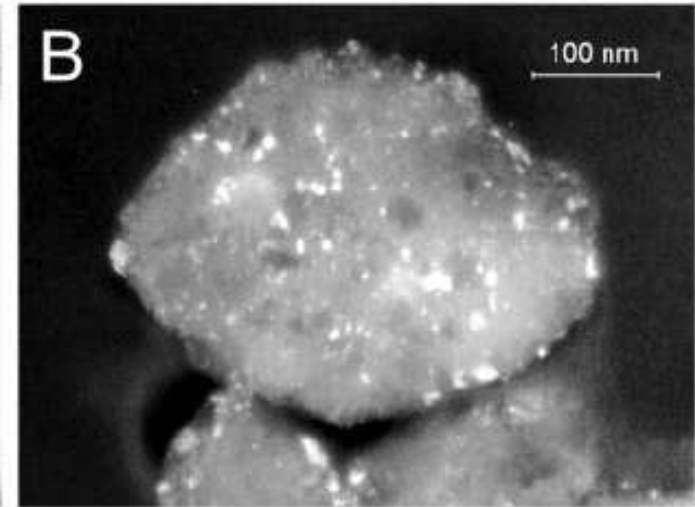
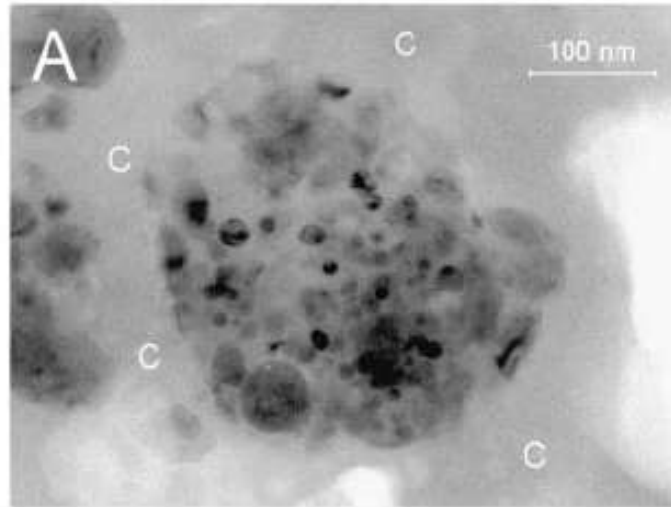
Presolar Isotopic Anomalies

- Different presolar grains come from different astrophysical environments
- Not all GEMS show isotopic anomalies

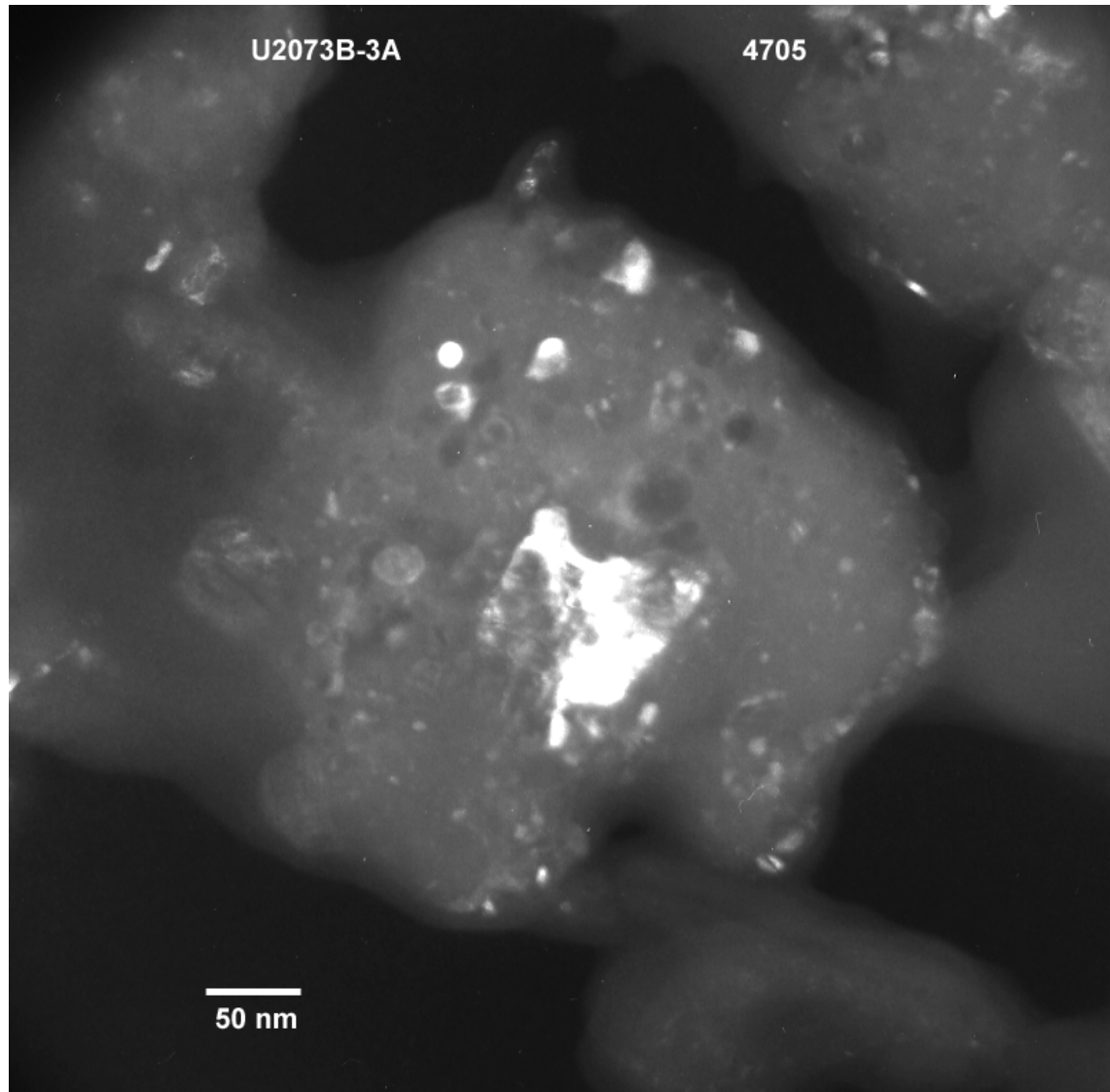


GEMS

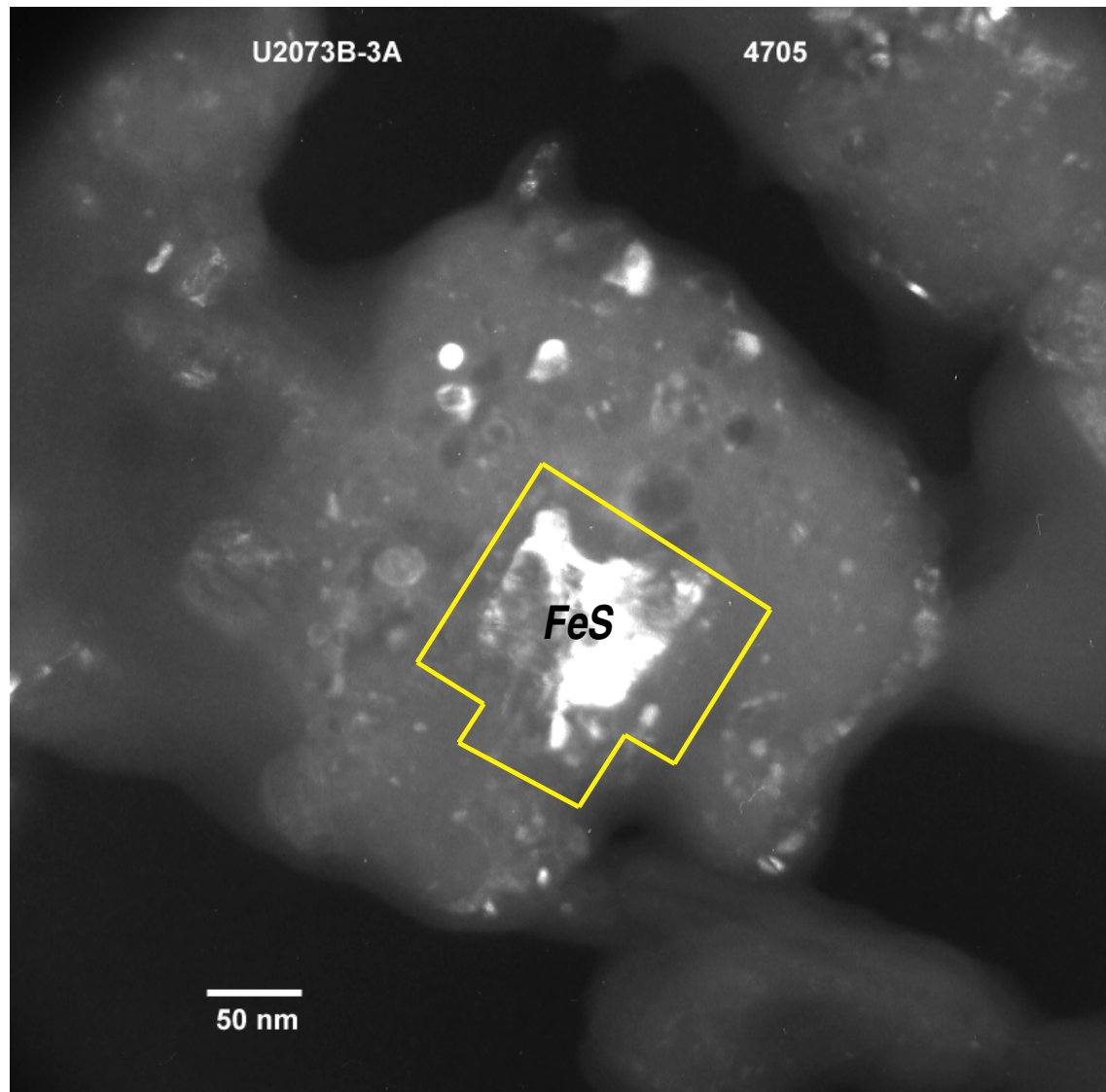
- Glassy particles with little bits inside them
- Different compositions
- Some have internal crystals



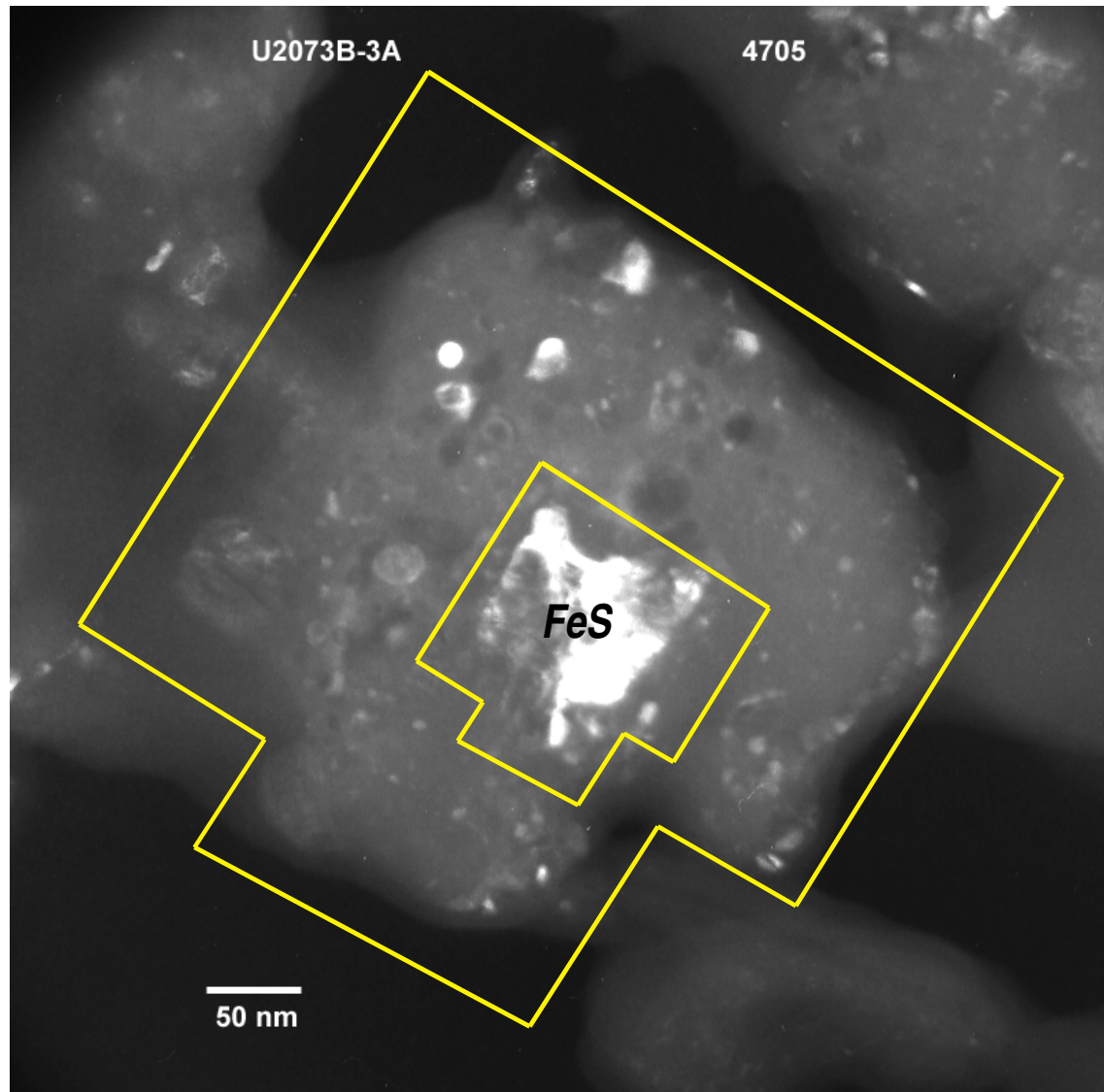
Relict Grain in GEMS (pyrrhotite)



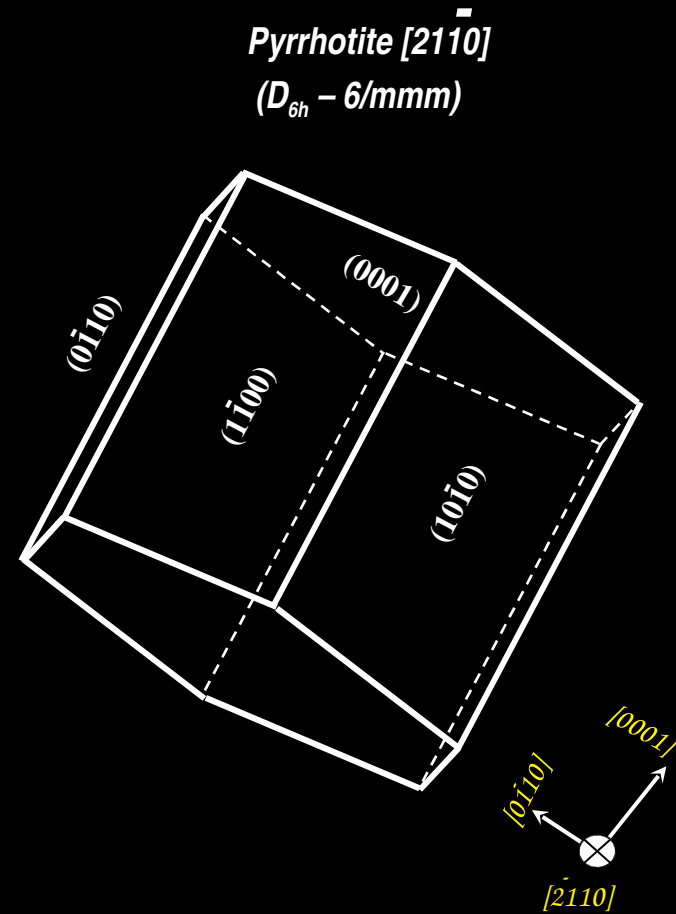
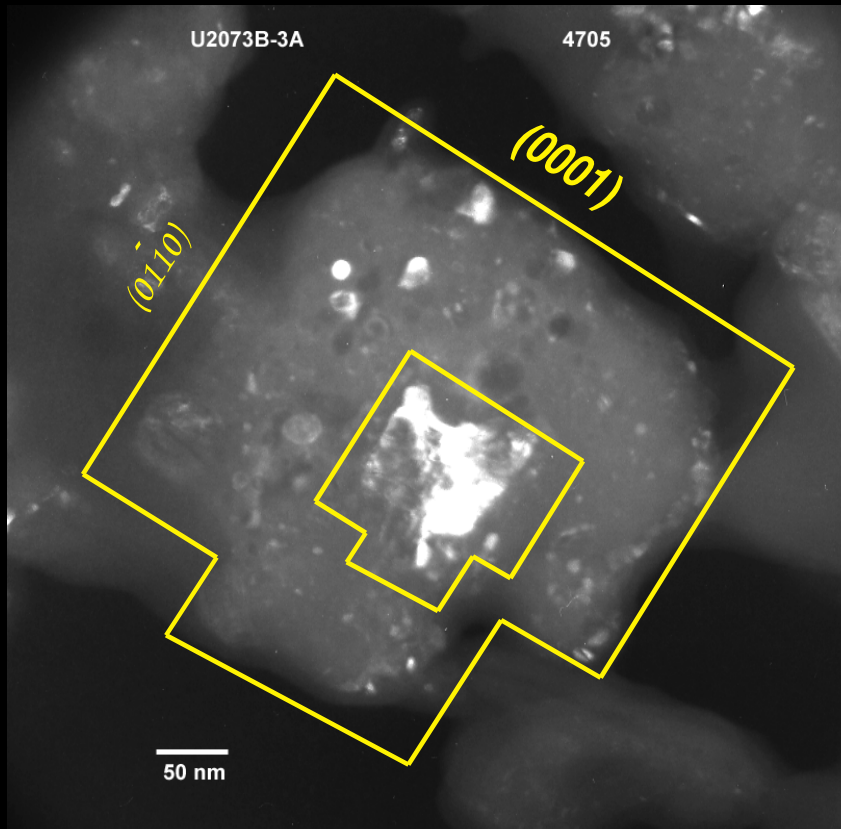
Relict Grain in GEMS (pyrrhotite)



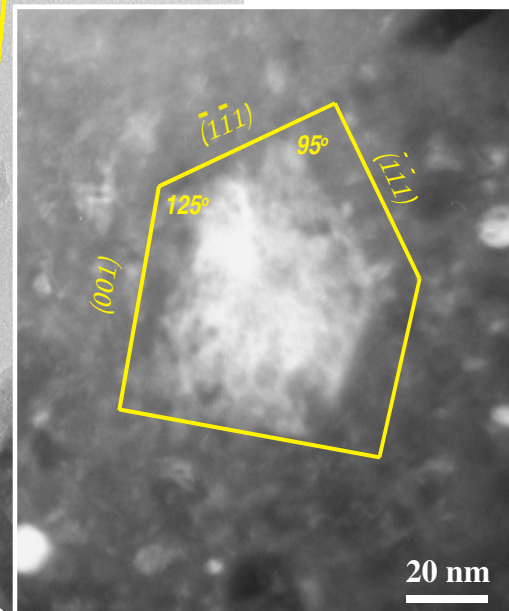
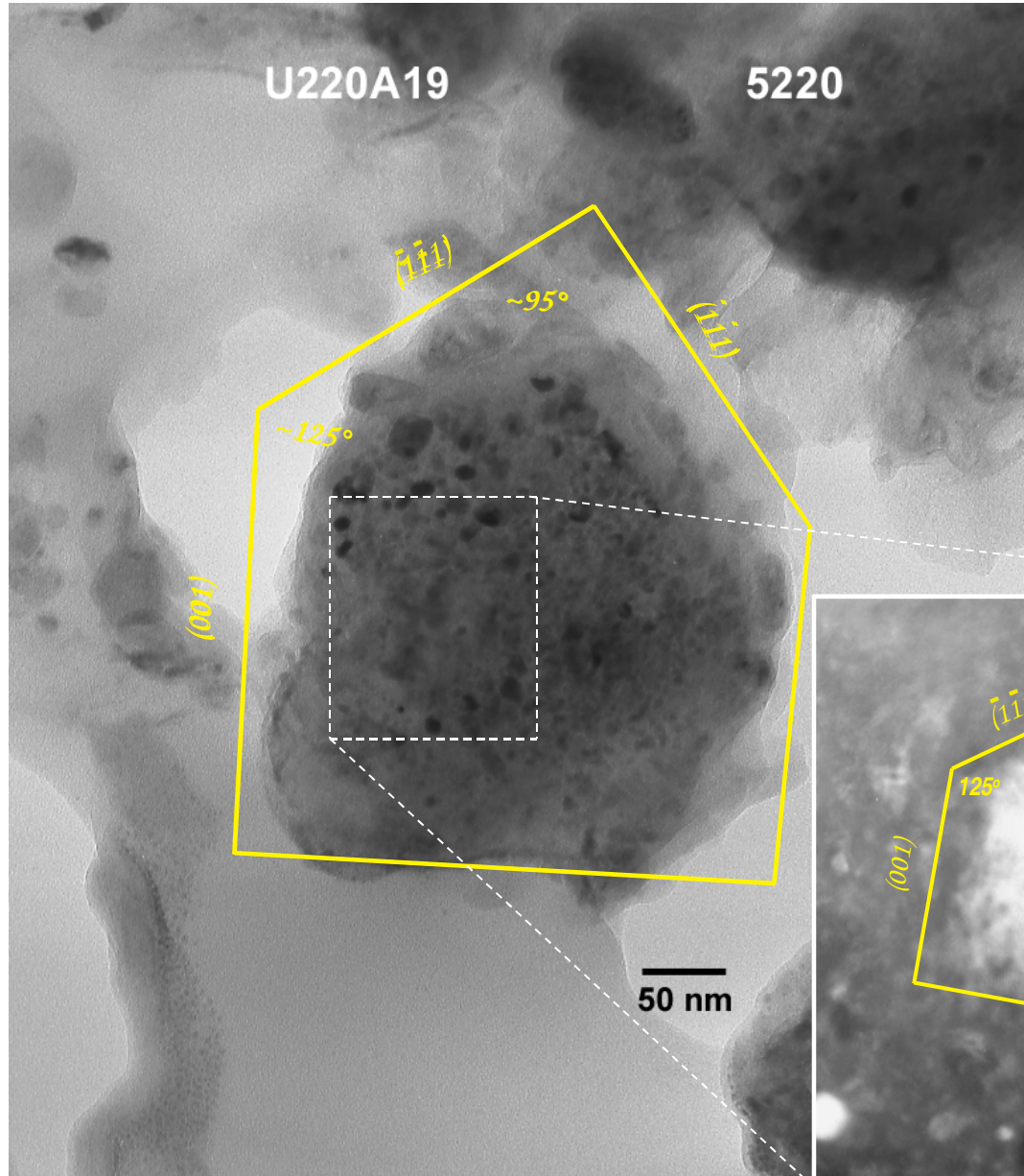
Relict Grain in GEMS (pyrrhotite)



Relict Grain in GEMS (pyrrhotite)



Forsterite GEMS

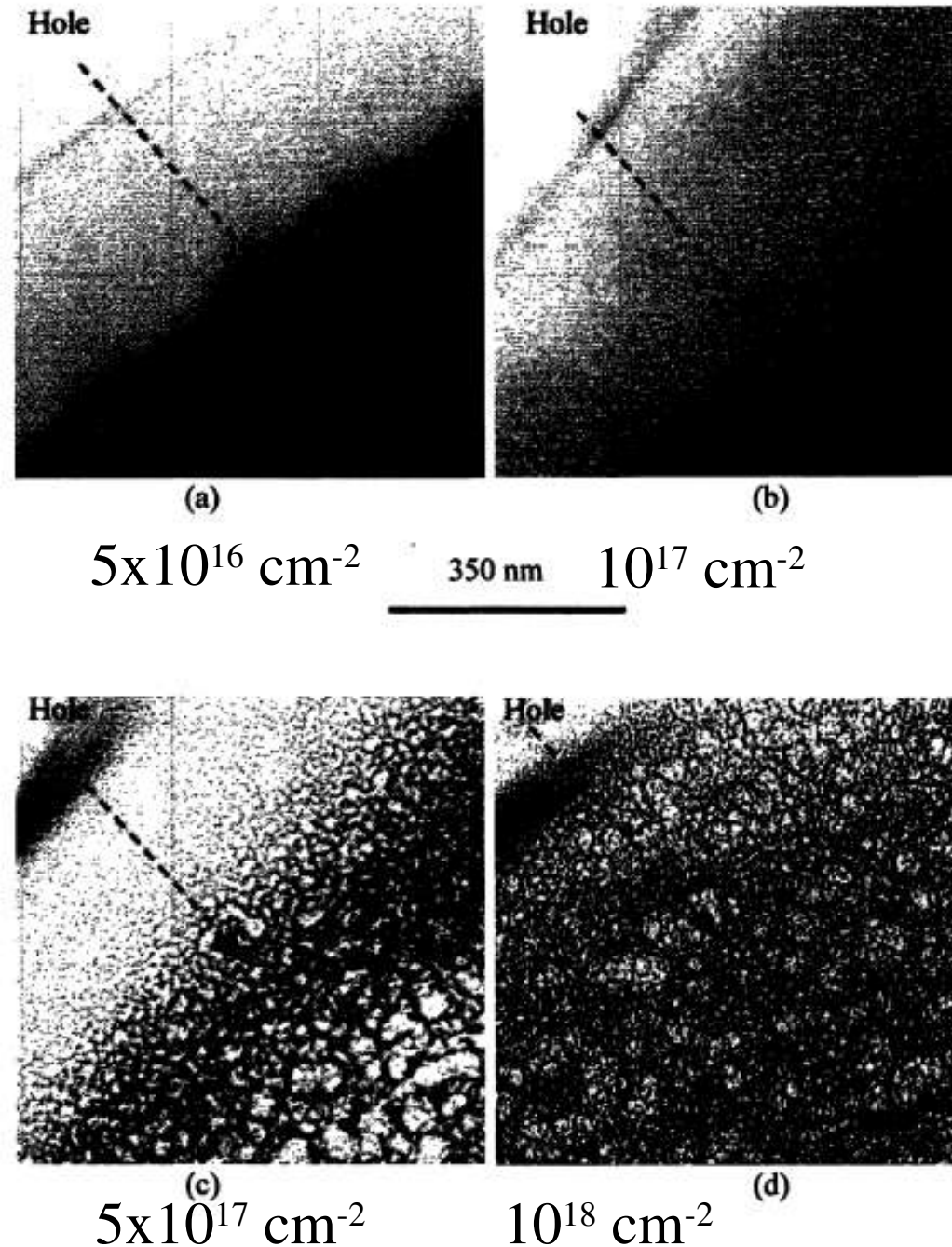


GEMS are unusual objects

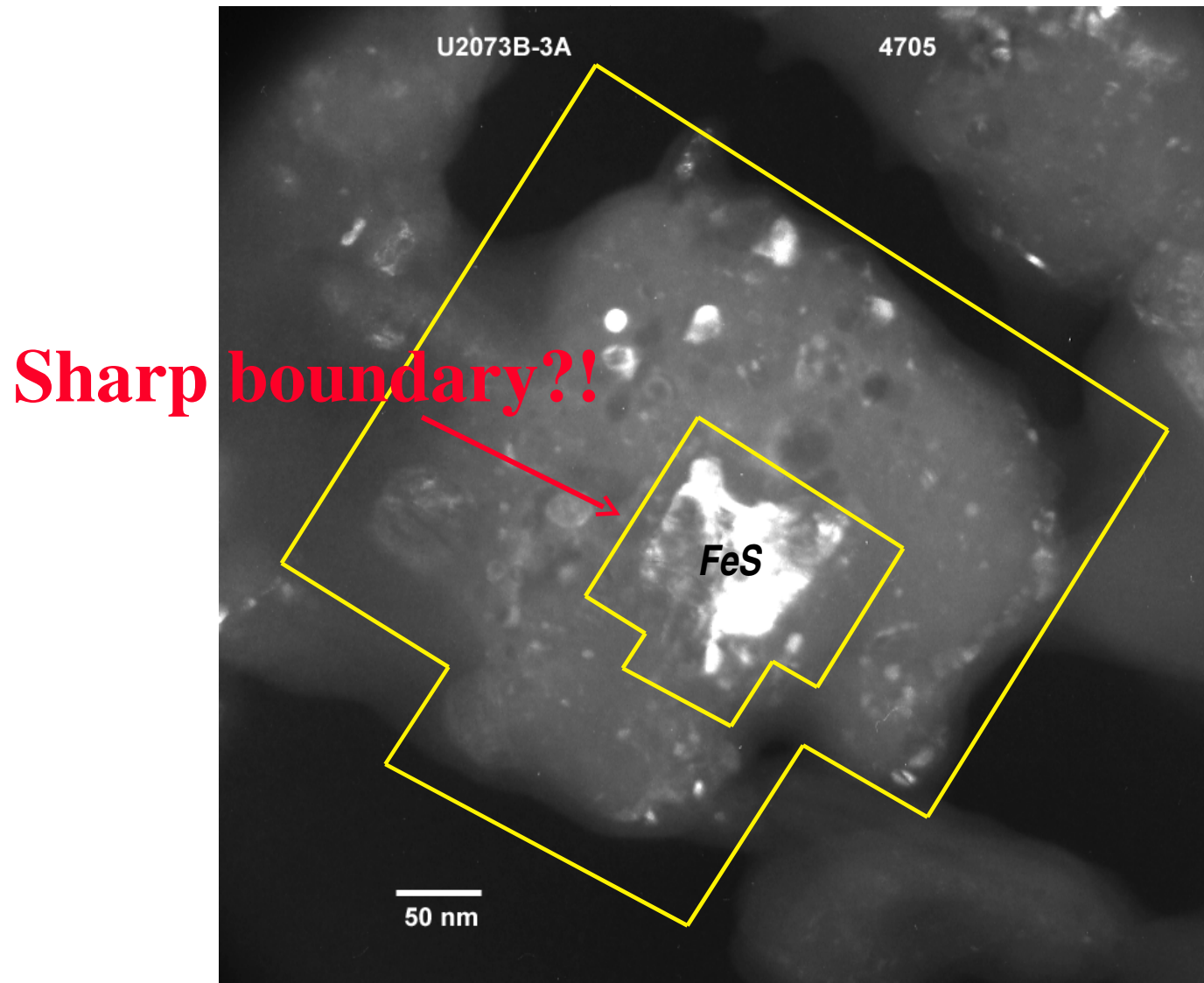
- Some GEMS are pseudomorphs
- GEMS occur in a narrow size range (100-500nm)
- GEMS have anomalous elemental compositions
- Some, but not all, GEMS show isotopic anomalies

Amorphization

- Carrez *et al.*, 2002
- 4 keV He ions
- Olivine (Mg_2SiO_4)
- Cosmic rays?

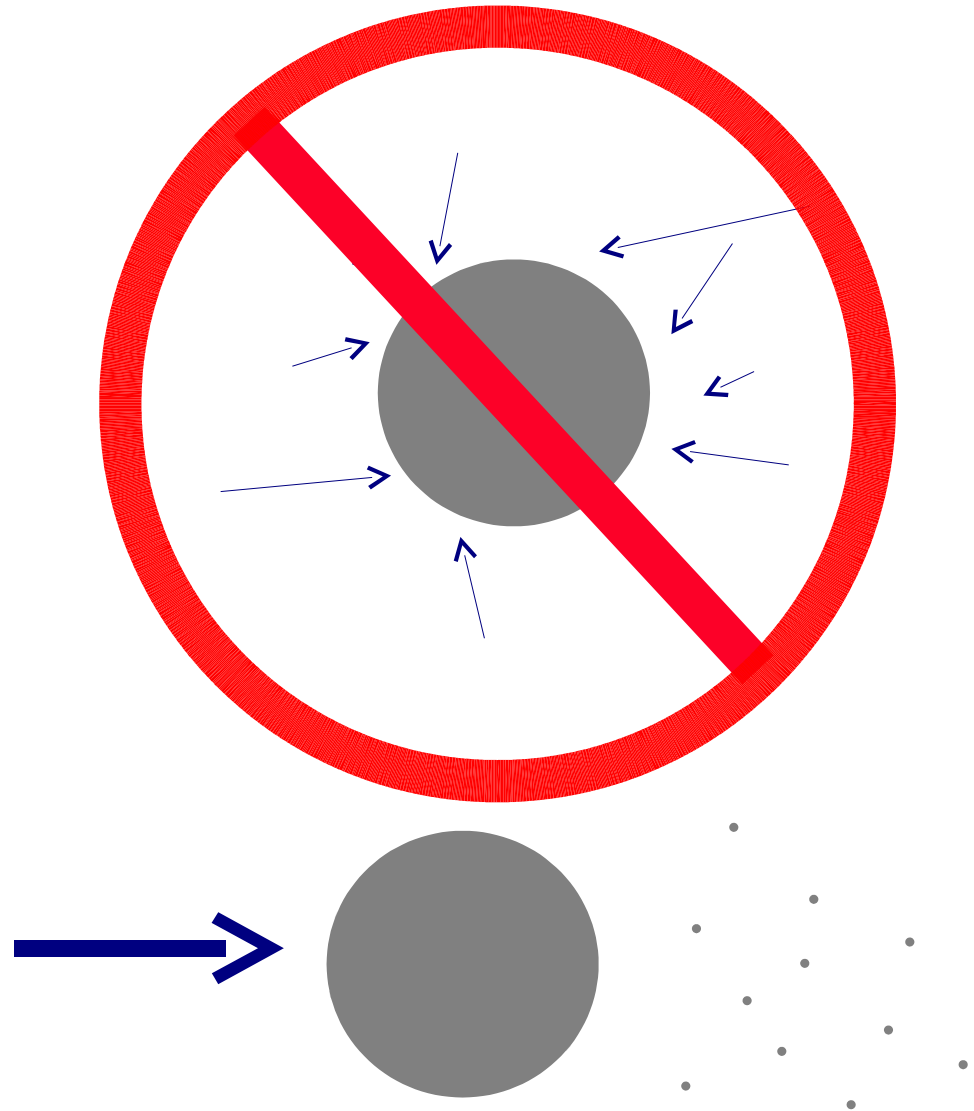


Inconsistent with GCR amorphization



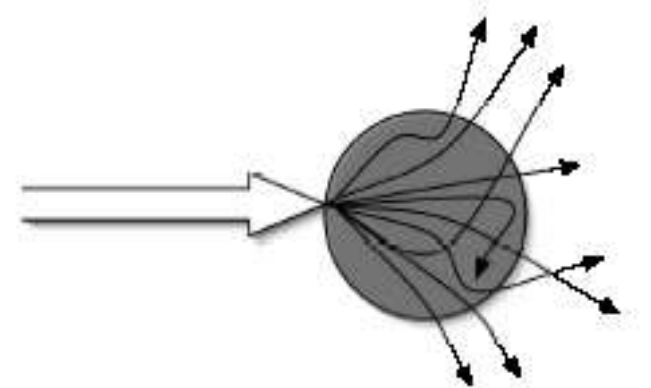
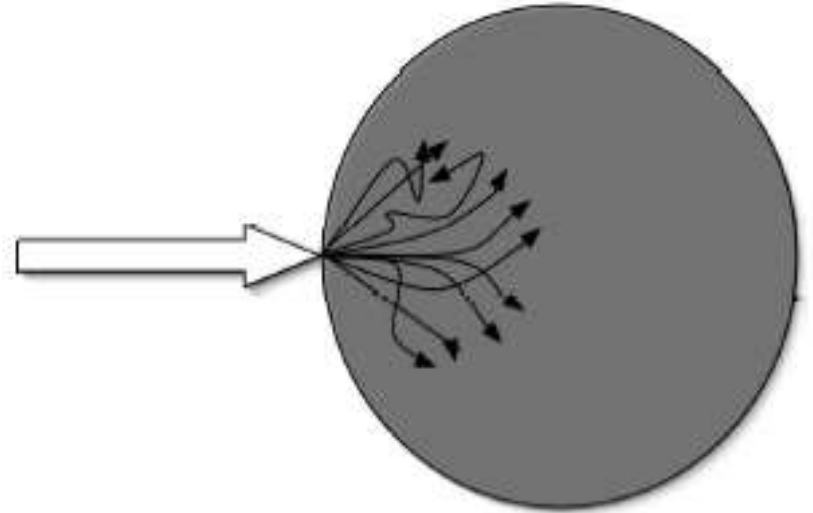
Monoenergetic Amorphization

- A uniform flux of cosmic rays would not leave a relict
- An accelerated grain will experience a monoenergetic flux



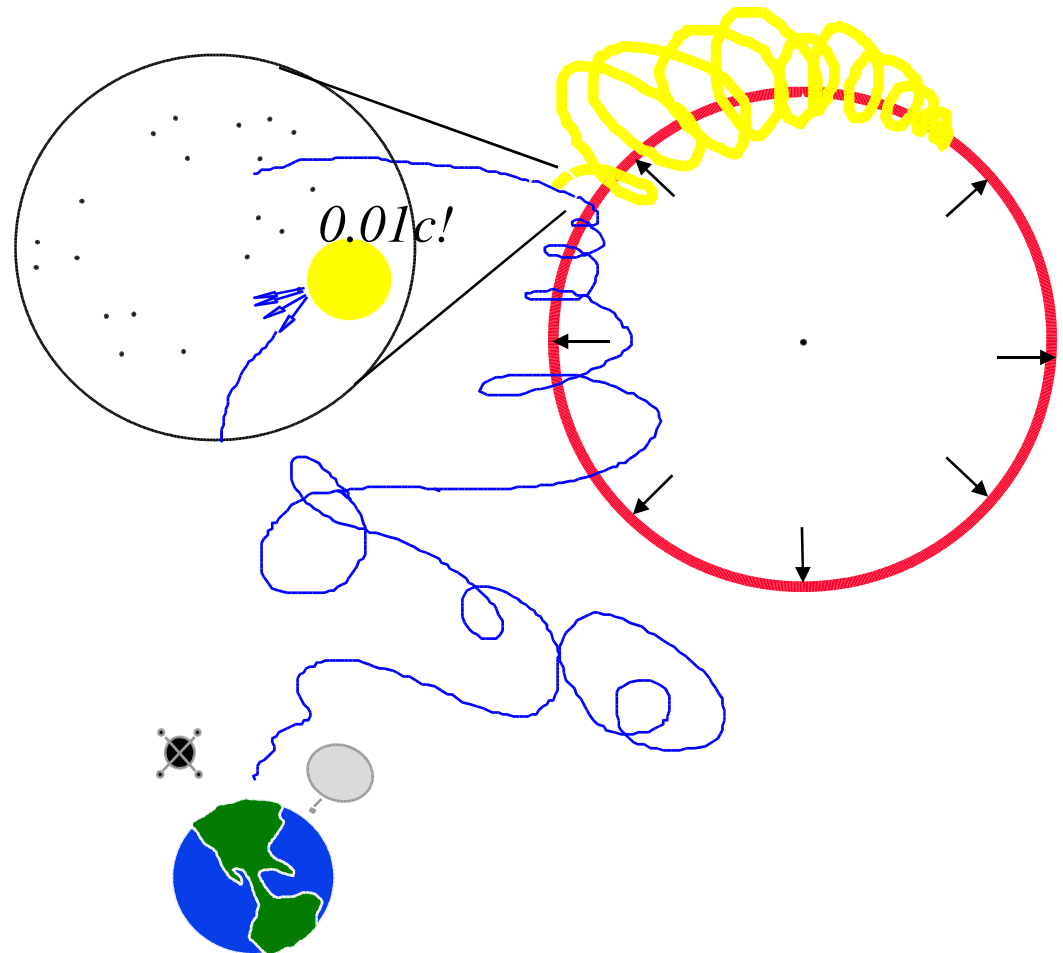
Sputtering

- Fast grains in the ISM are efficiently destroyed
- Fast grains in high metallicity environment can grow!
- Experimental measurement of sputtering yields needed
- Small grains still get destroyed



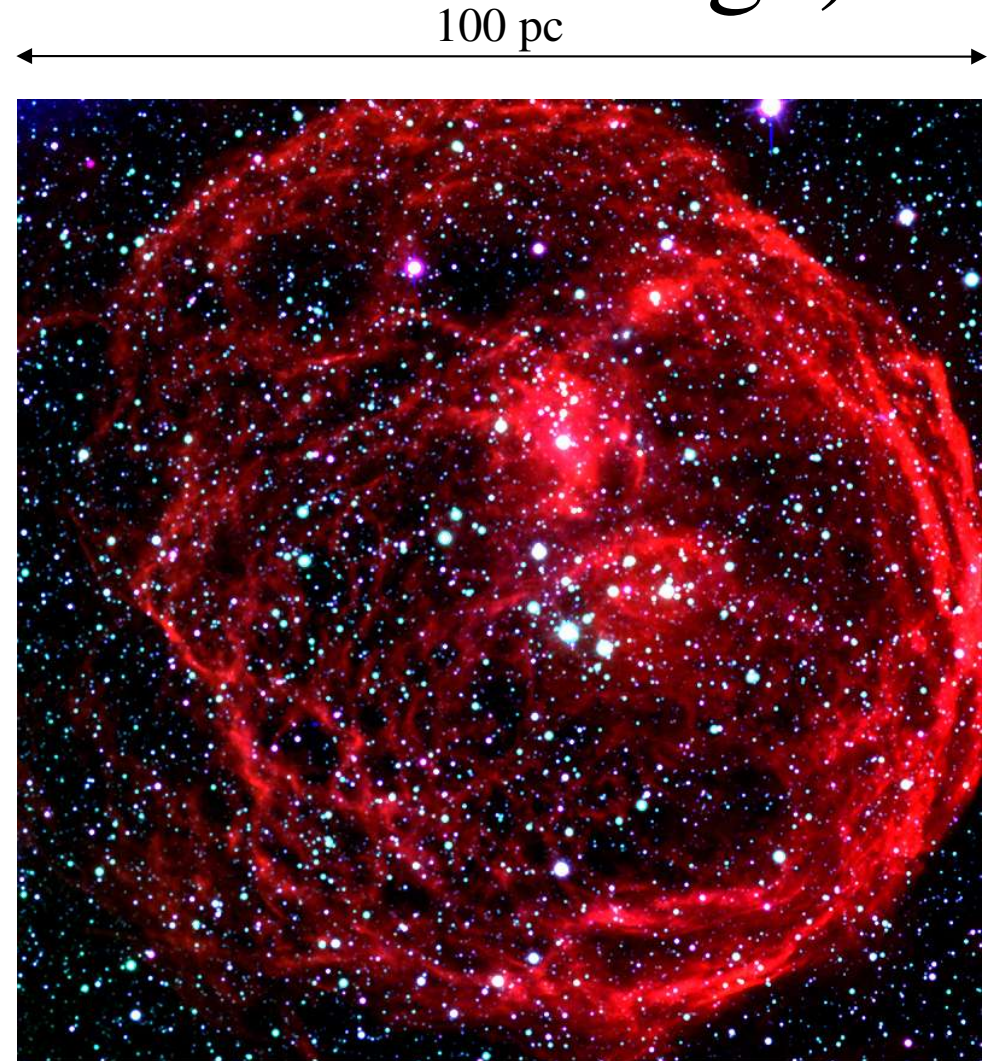
Grain Acceleration

- Grains *must* be accelerated by SN shocks
- Meyer, Drury & Ellison, ApJ 487, 182 (1998)
- Enhancement of refractory elements



Superbubbles (or It Takes a Village)

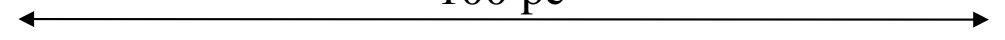
- Low density cavity created by OB outflows & SNe
- Emerging model of CR acceleration
- 1 SN not enough
- High metallicity environment
- GEMS abundances similar



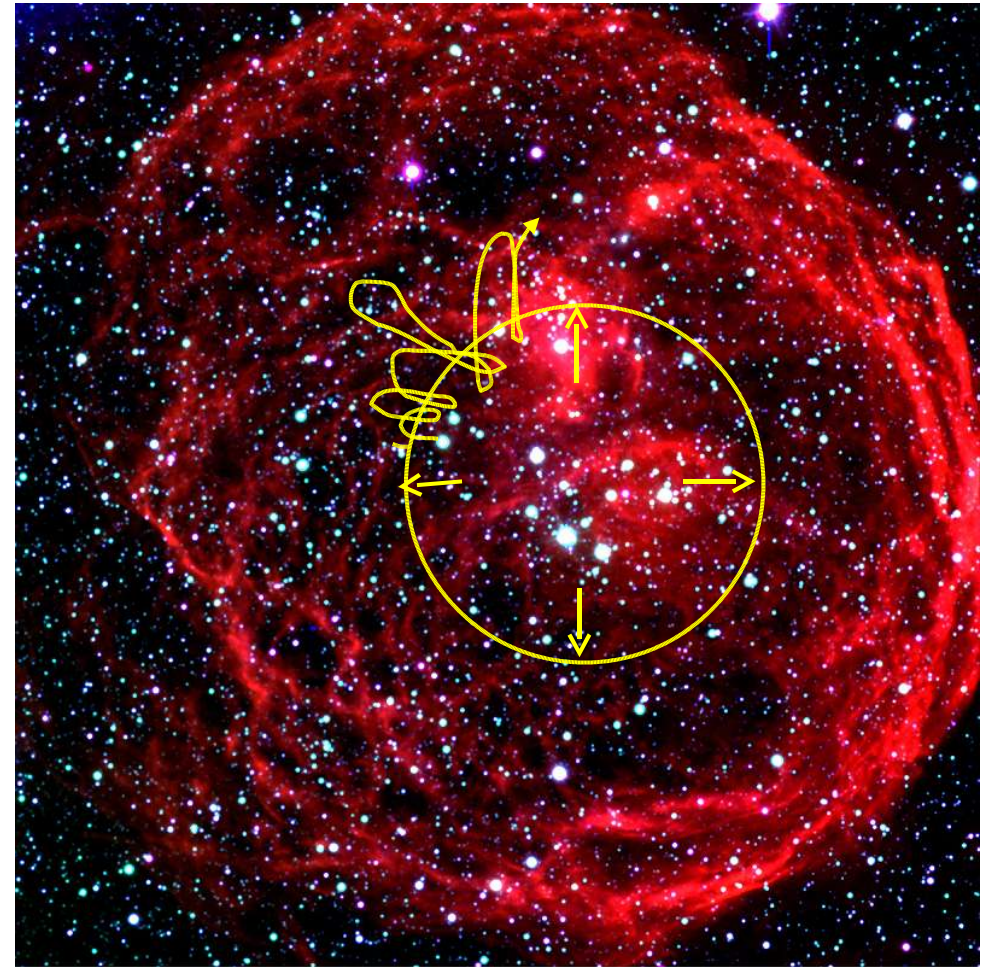
Superbubble (N 70) in the Large Magellanic Cloud
(ESO Very Large Telescope Image)

GEMS Formation in Superbubbles

100 pc



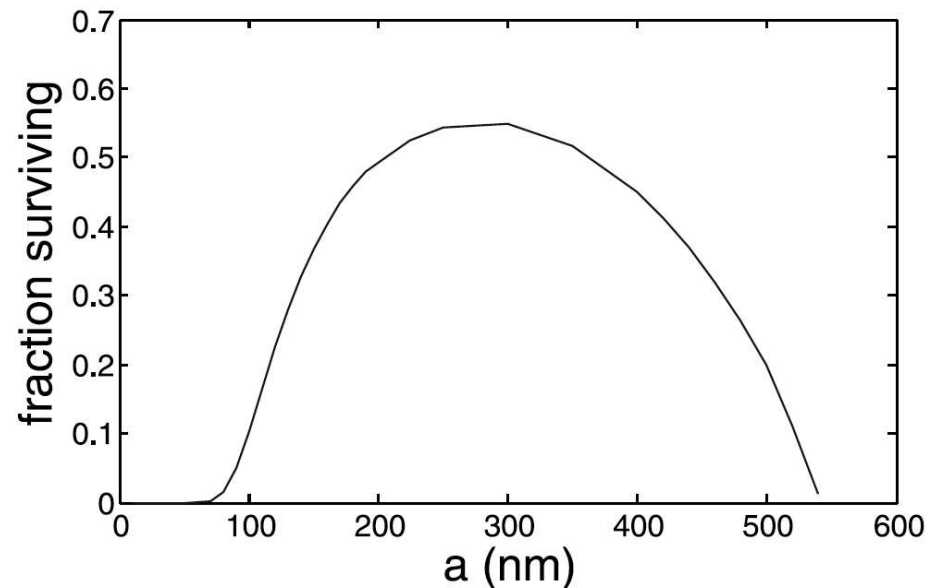
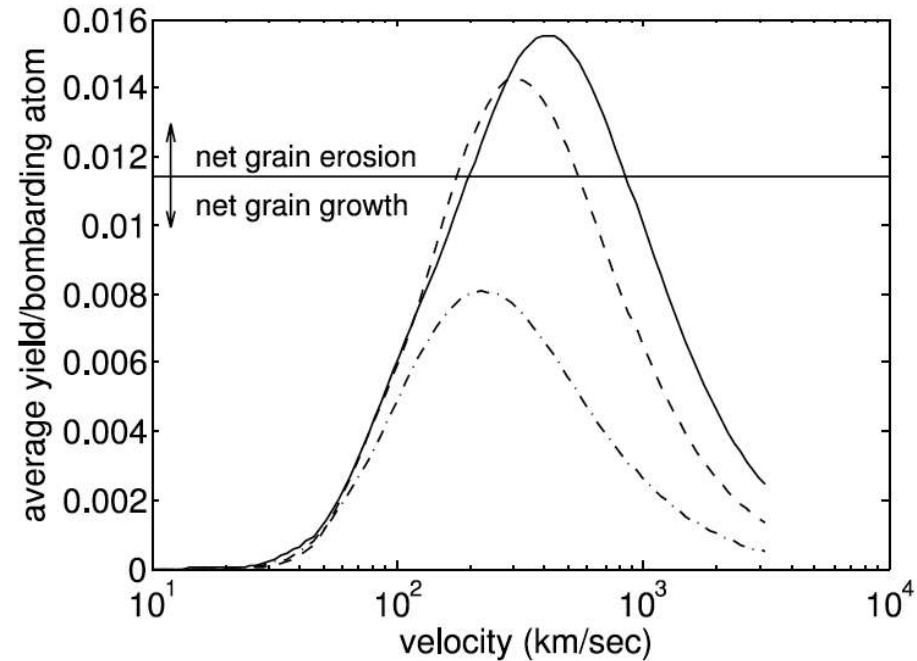
- Some GEMS are pseudomorphs
- GEMS abundance patterns
- **Very narrow size distribution**
- **Isotopic anomalies**



Superbubble (N 70) in the Large Magellanic Cloud
(ESO Very Large Telescope Image)

Sputtering Balance

- Balance effects of sputtering & growth
- Multiple boosts from SN shocks
- Monte Carlo simulation of reacceleration
- Only a narrow range of sizes survive



GEMS as the GCR source

- SN do not accelerate their own ejecta
- SN can accelerate ejecta from other SNe
- GEMS are a highly selected sample of the GCR source
- GEMS & GCR have similar isotopic abundances
- Solar except ^{22}Ne & ^{58}Fe

Outstanding Questions

- Sputtering yields need to be measured
- Assumptions about superbubble magnetic field
- Inefficient mixing of metal-rich core with ISM
- Gas metallicity is not reduced by grain formation
- Predictions on GEMS amorphous rim sizes
- GEMS isotopic abundances

A Century-old puzzle

- Cosmic rays were discovered almost 100 years ago, but their origin is still uncertain
- Has the source material of cosmic rays been awaiting discovery in dust labs for decades?