Terrestrial and Extraterrestrial Applications of the Carnegie NanoSIMS

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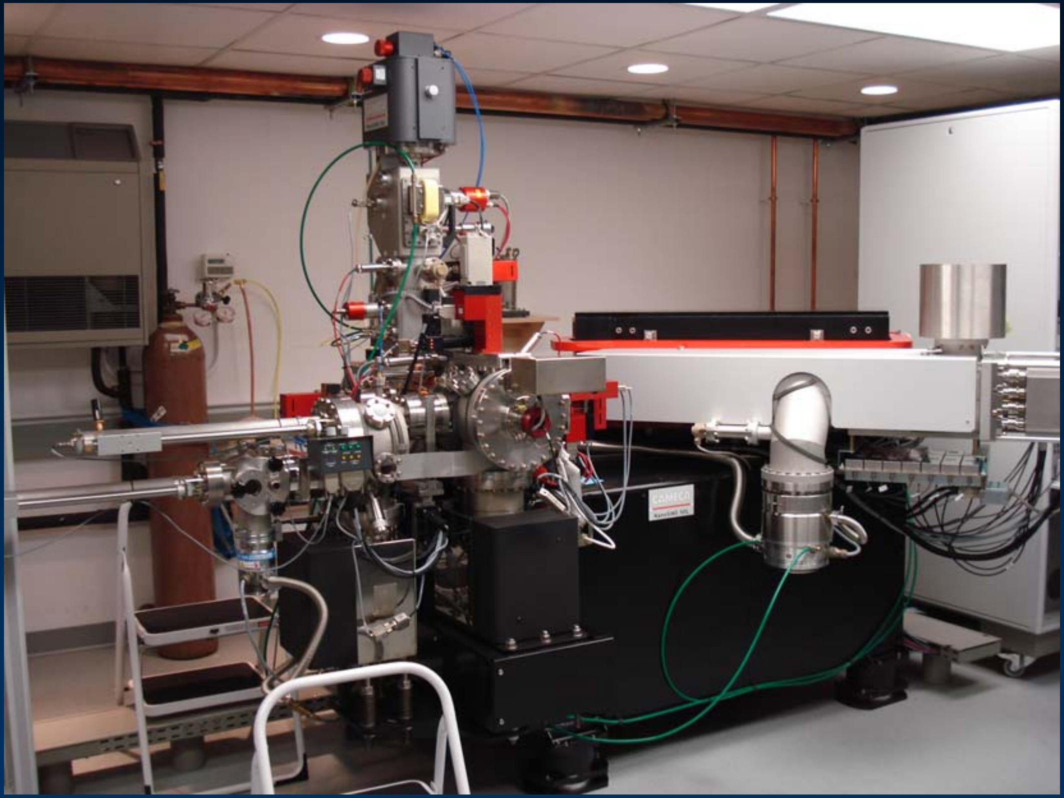
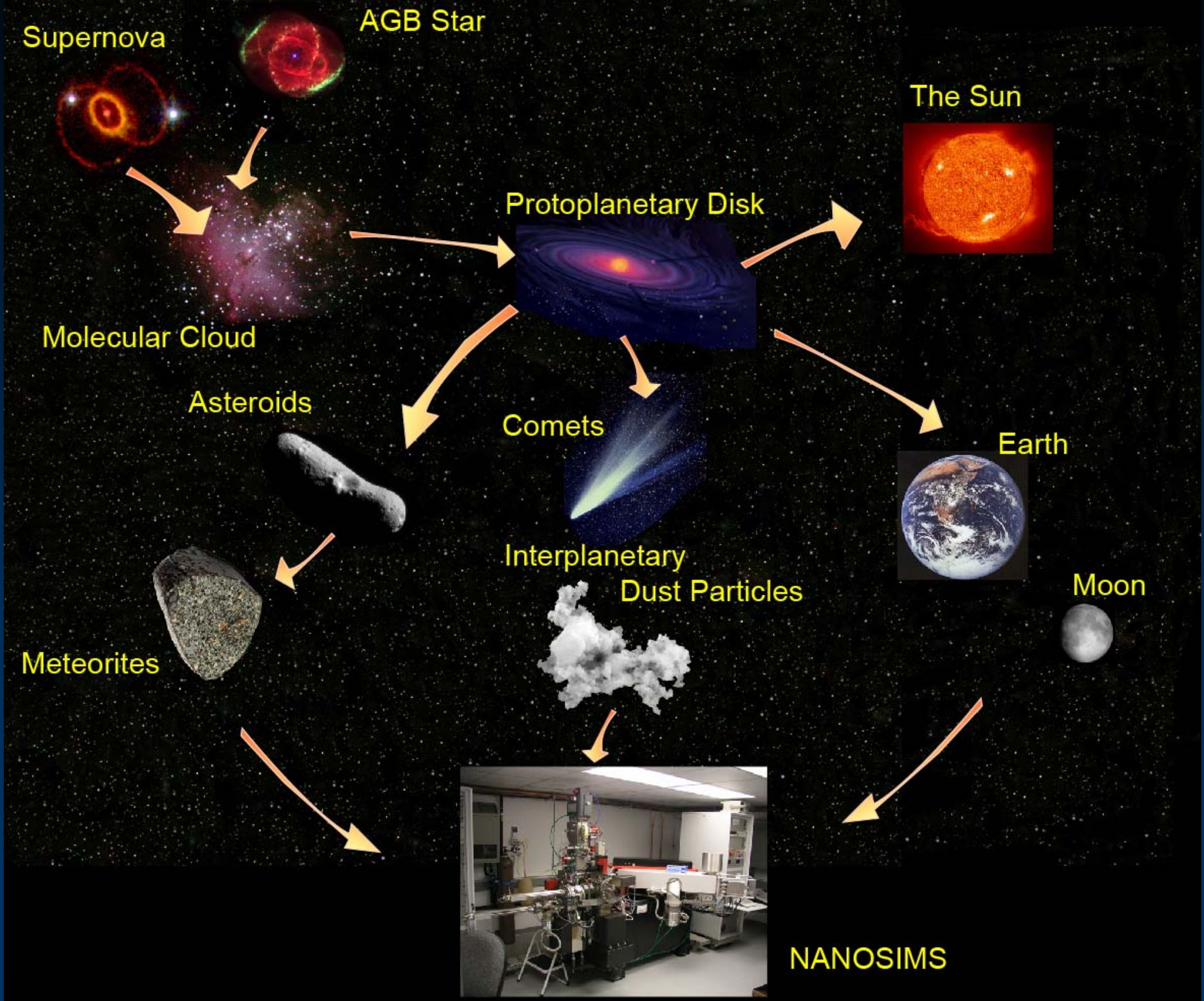
Carnegie NanoSIMS 50L

- Installed Jan 2006 (NS #15, 50L #2)
- Passed performance specs April 2006
- Worked on and off since
- <100 nm spatial resolution, very high sensitivity
- Simultaneous collection of up to 7 masses and e^-
- EM/ FC switching on 4 trolleys
- Particle analysis system under development (with Cameca, Washington U.)



The Universe in the NanoSIMS

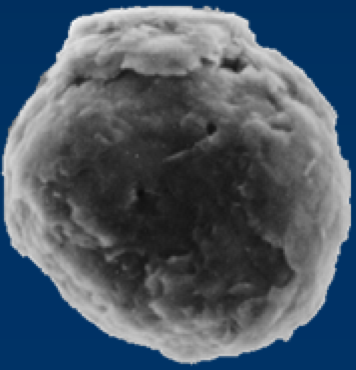


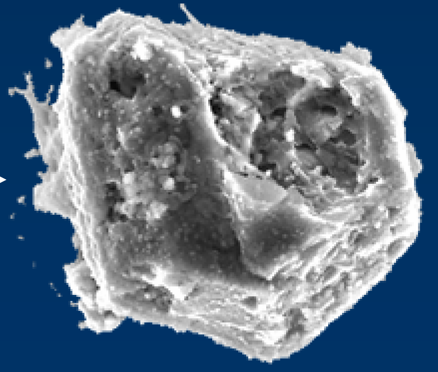
- Extraterrestrial Applications
  - Presolar Grains / Organic Matter
  - Stardust Samples
  - Genesis Samples
  - Lunar Samples
  - Meteorite Chronology
- Terrestrial Applications
  - Element partitioning at high pressure (diamond anvil cell experiments)
  - High-precision C, N, O, S isotopic analysis with multiple Faraday Cups (5μm scale)
  - Element/isotope partitioning in ancient rocks to ascertain evidence for early life

Stars in the NanoSIMS

- Presolar Grains: Microscopic dust that formed in the winds and explosions of previous generations of stars, survived passage in the interstellar medium and became part of forming Solar System
  - Identified by extremely unusual isotopes
  - Provide information on broad range of astrophysical processes

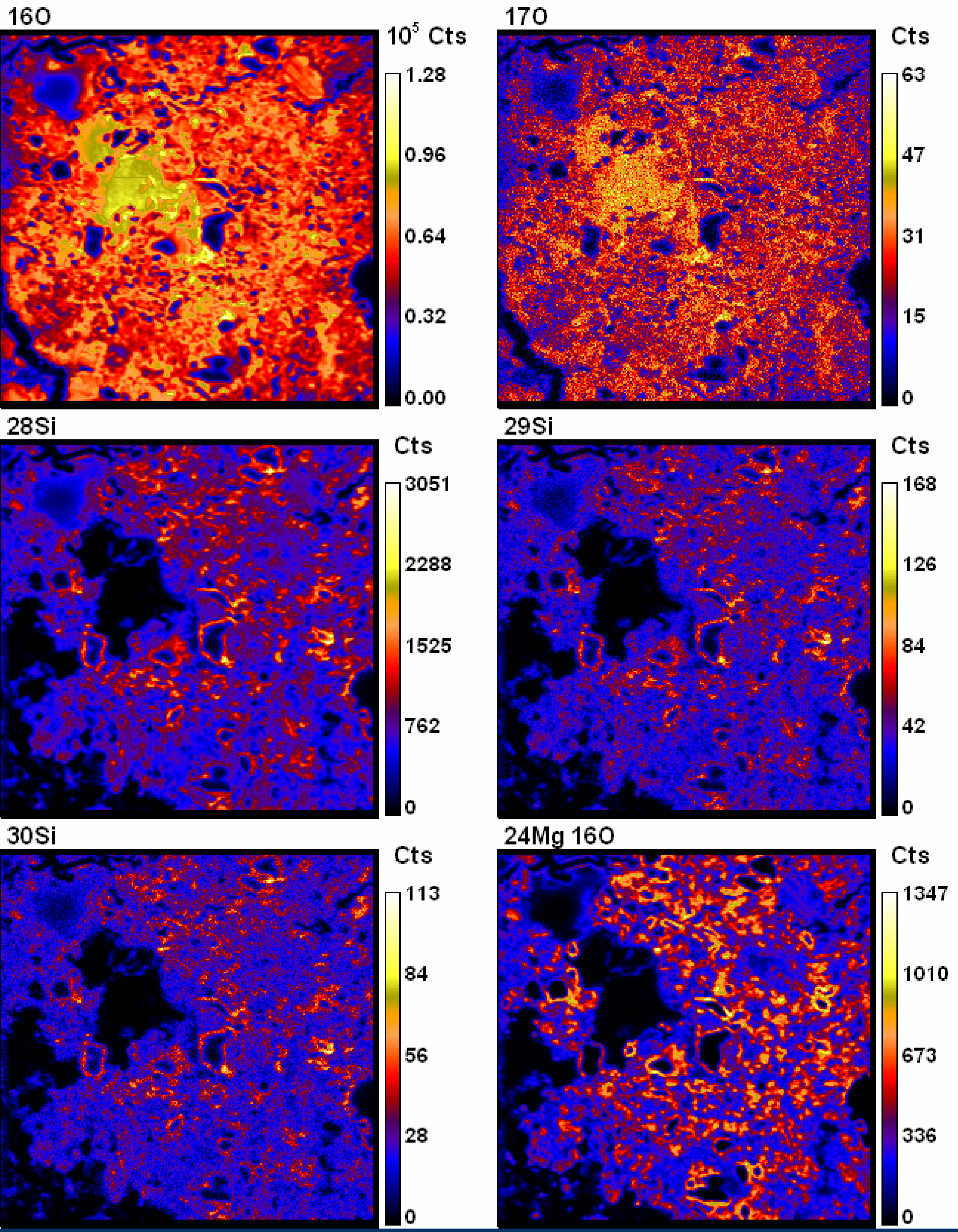
Astronomy in the Laboratory!





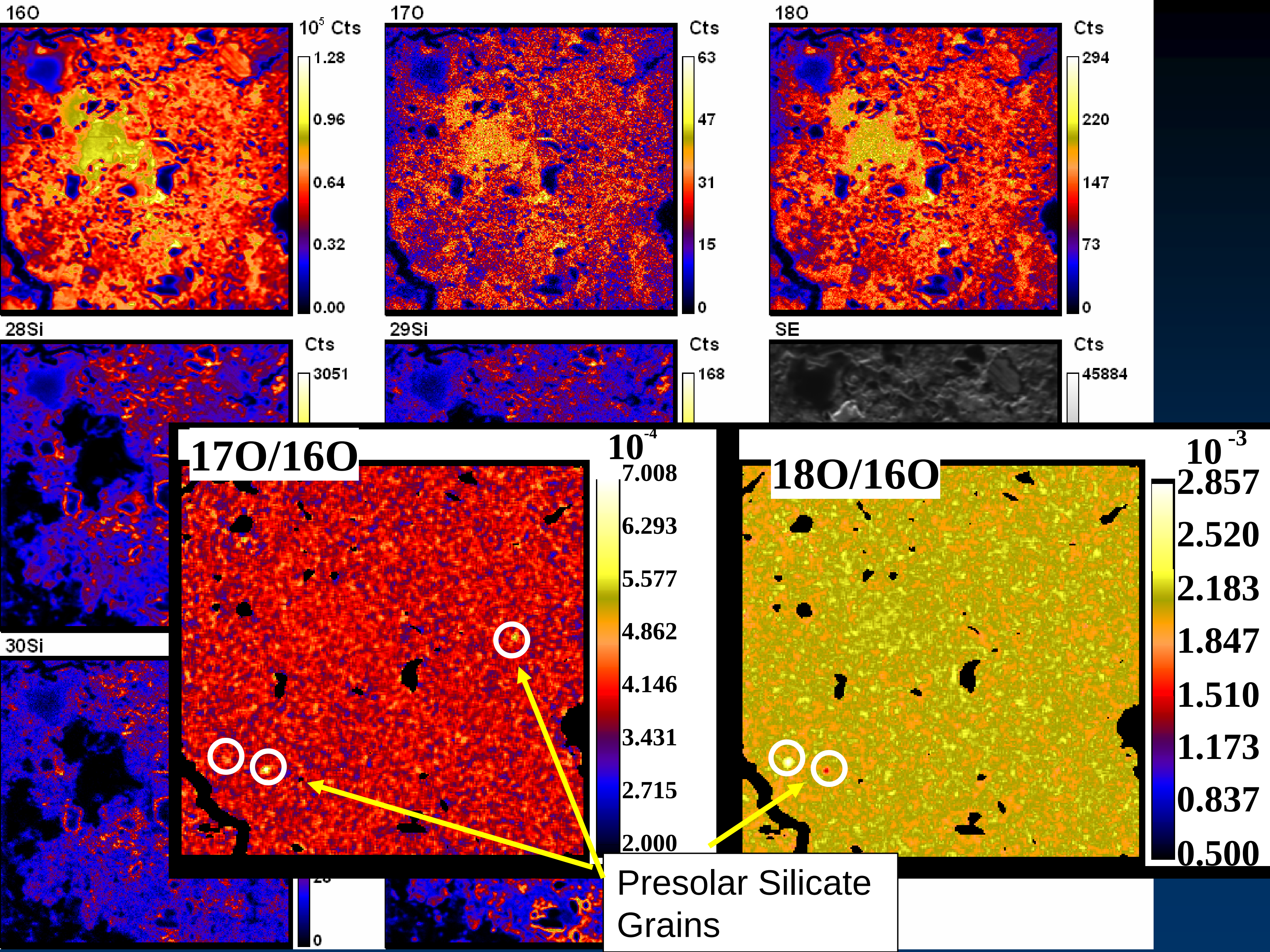
Presolar Grains in the NanoSIMS

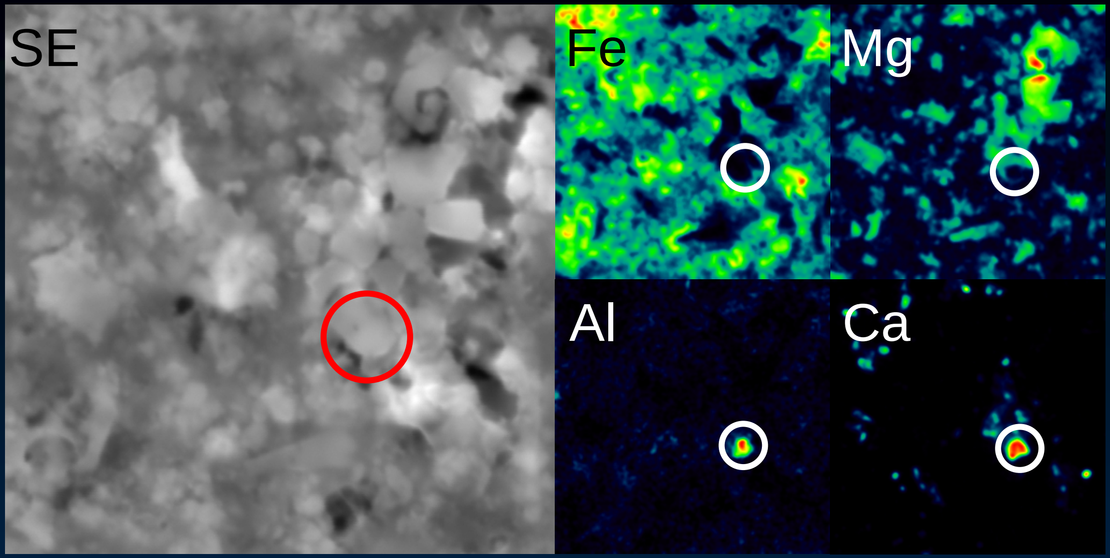
- High spatial resolution and high sensitivity allow:
  - Identification of smaller grains than before (e.g. sub-micron presolar silicates, Messenger et al 2003; Nguyen & Zinner 2004)
  - Characterization of sub-μm isotopic/elemental homogeneity in μm sized grains *(e.g., supernova dust aggregates, Stroud et al 2004)*
  - Multiple elements to be measured in single grains *(tight constraints on stellar models)*
  - Coordinated isotopic-structural analysis



Meteorite ALHA77307

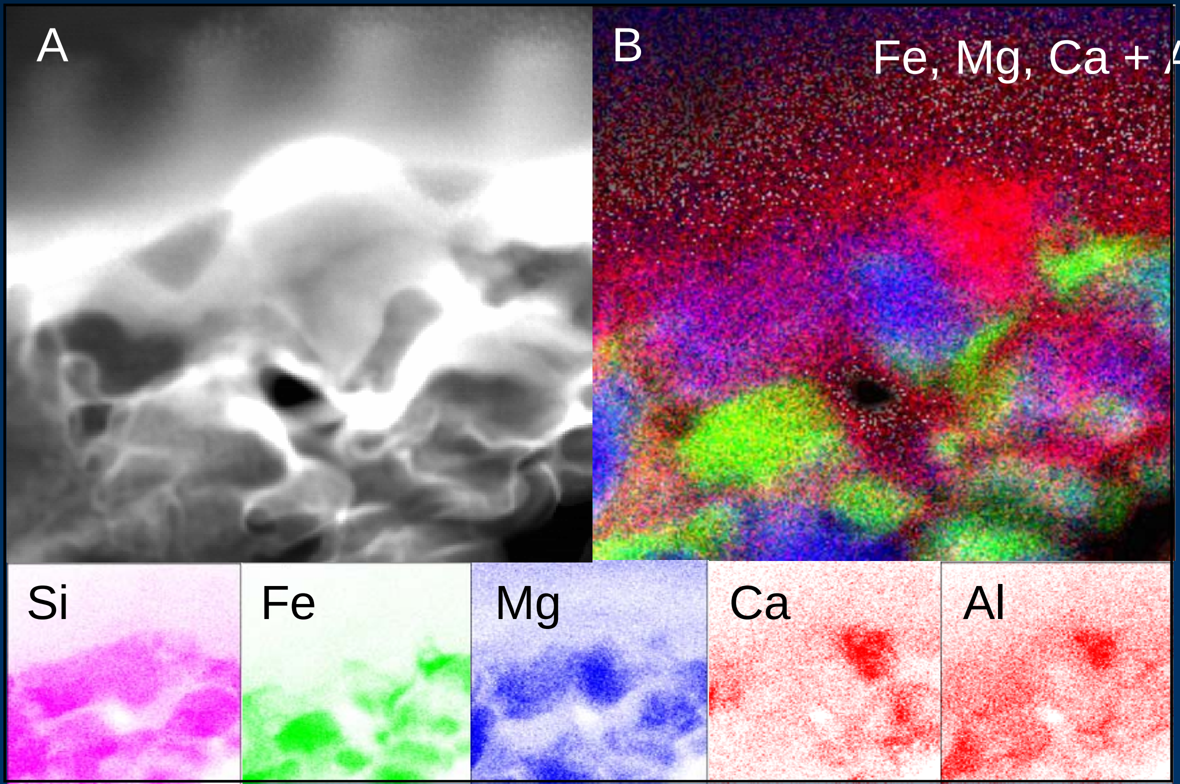
- 20 x 20 μm raster
- 7 species + SE


16O
10^5 Cts
1.28
0.96
0.64
0.32
0.00
17O
Cts
63
47
31
15
0
18O
Cts
294
220
147
73
0
28Si
Cts
3051
29Si
Cts
168
SE
Cts
45884
30Si
0
17O/16O
10^-4
7.008
6.293
5.577
4.862
4.146
3.431
2.715
2.000
18O/16O
10^-3
2.857
2.520
2.183
1.847
1.510
1.173
0.837
0.500
Presolar Silicate Grains

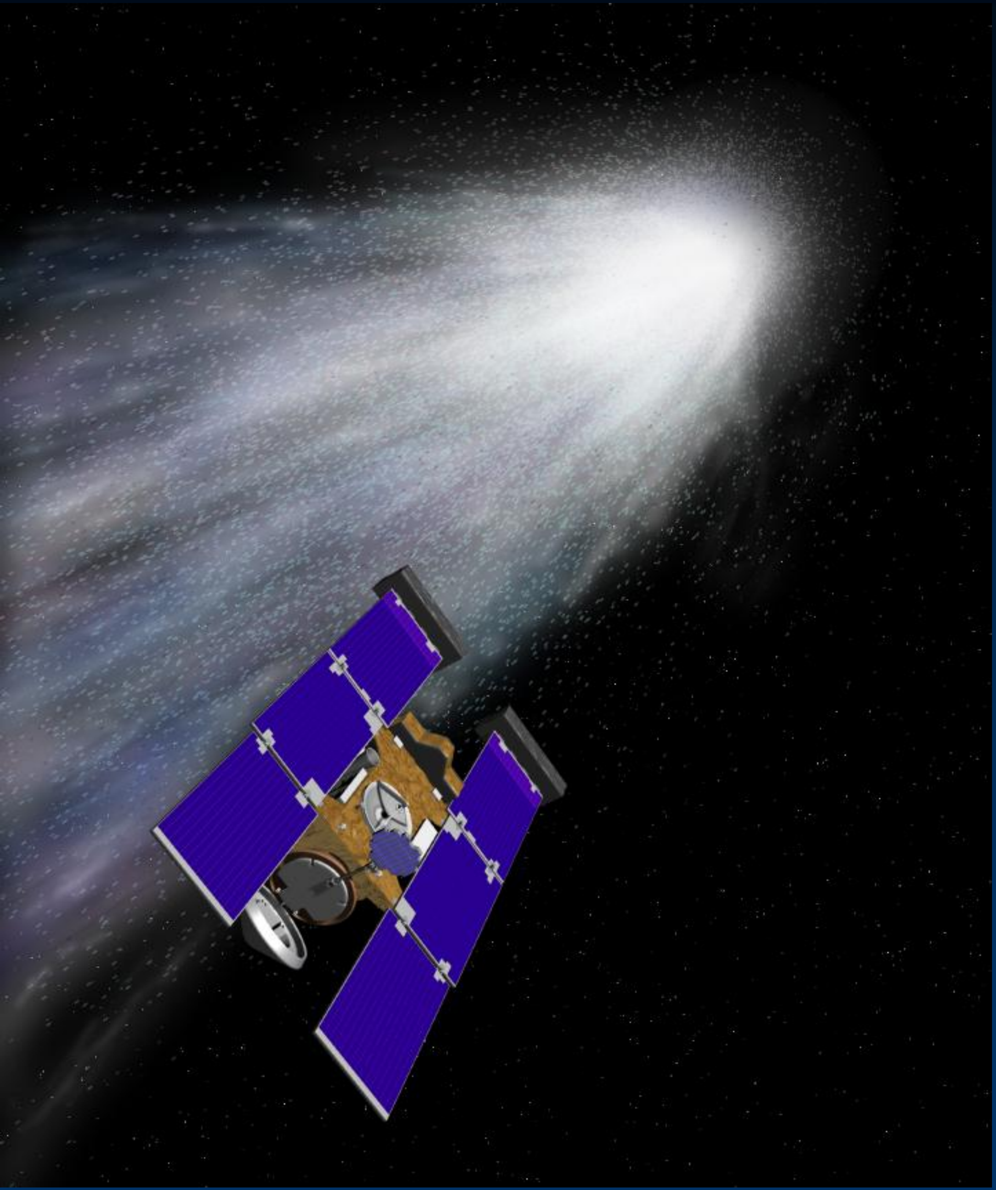


Auger analysis (Nguyen et al. LPSC 08)

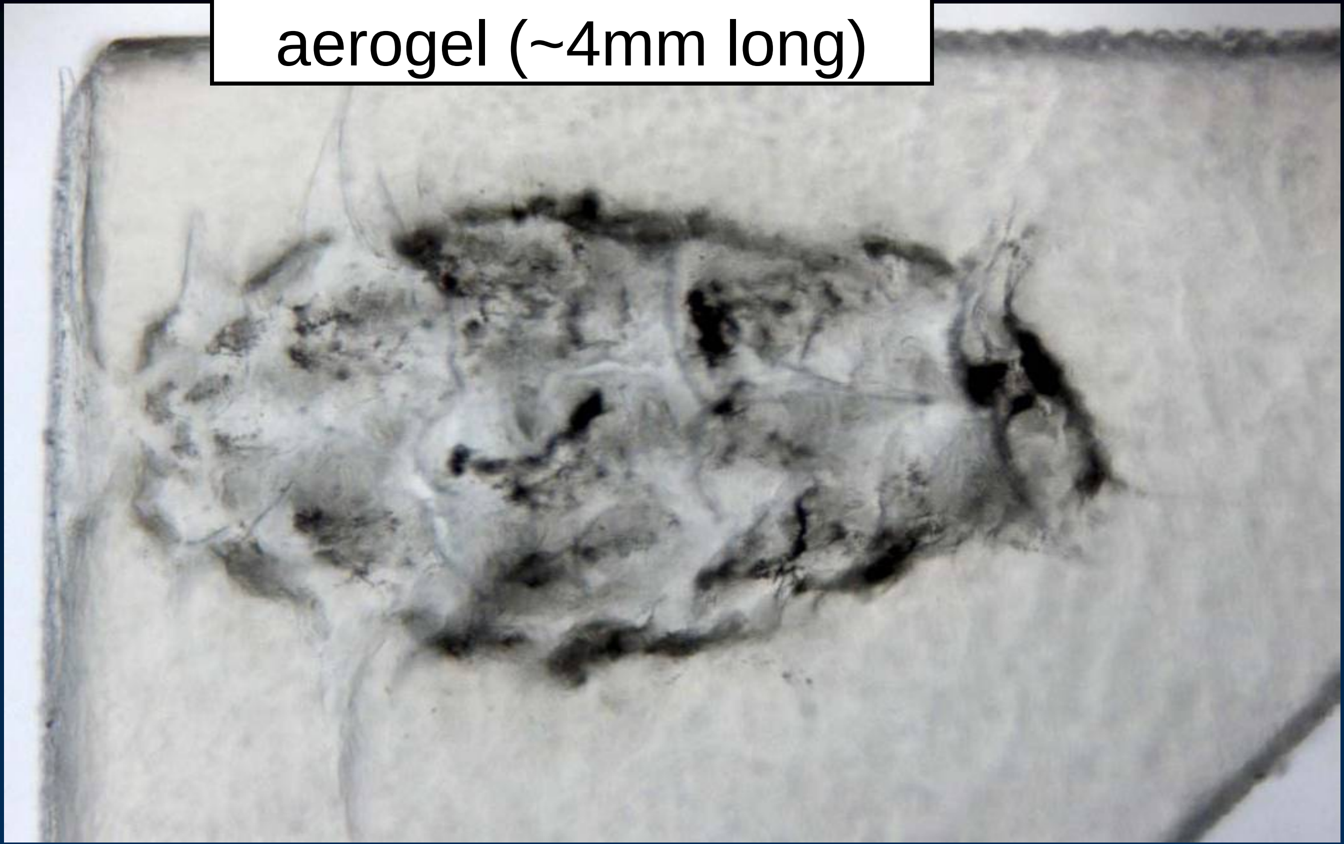
FIB-TEM (Stroud et al. Metsoc 08)



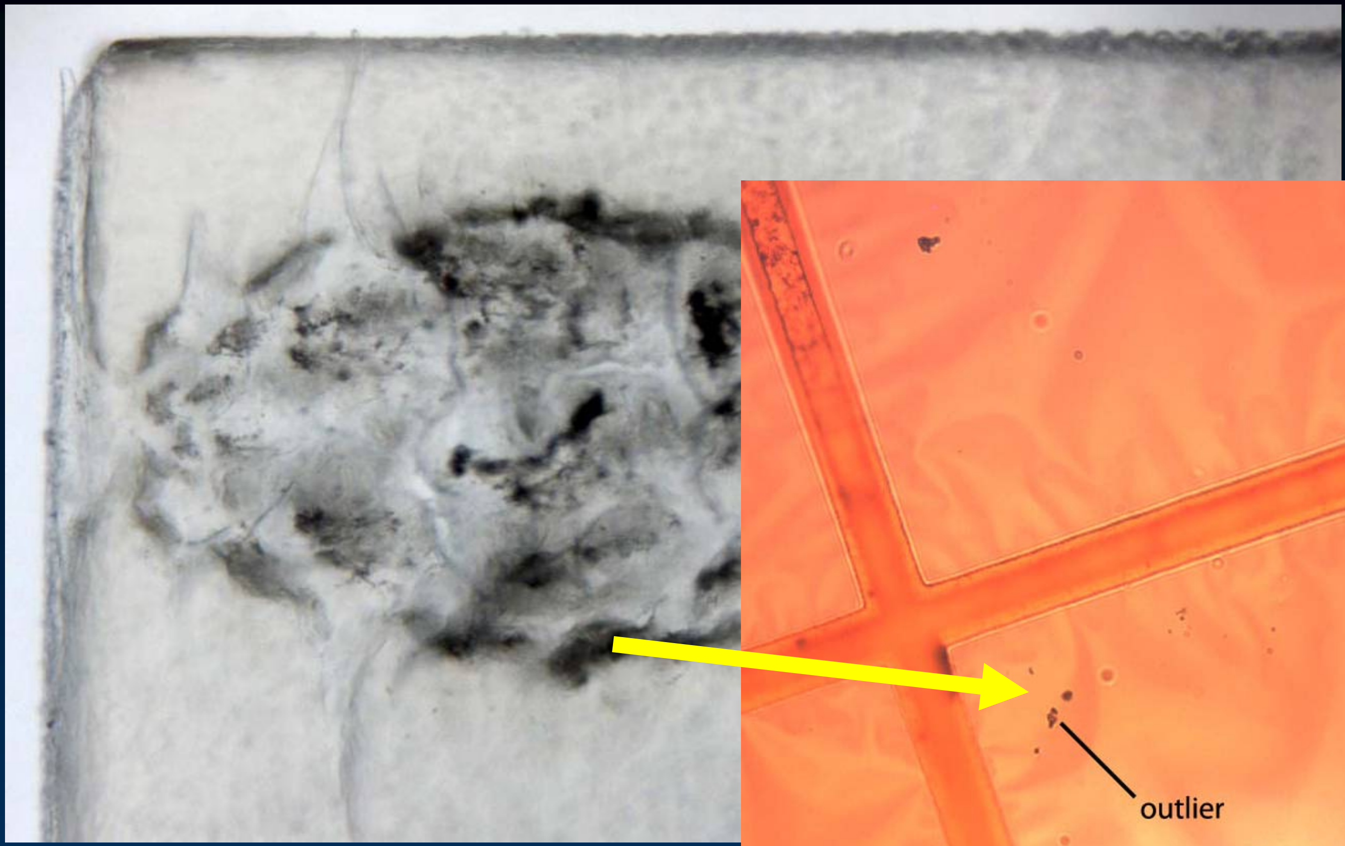
Stardust Mission

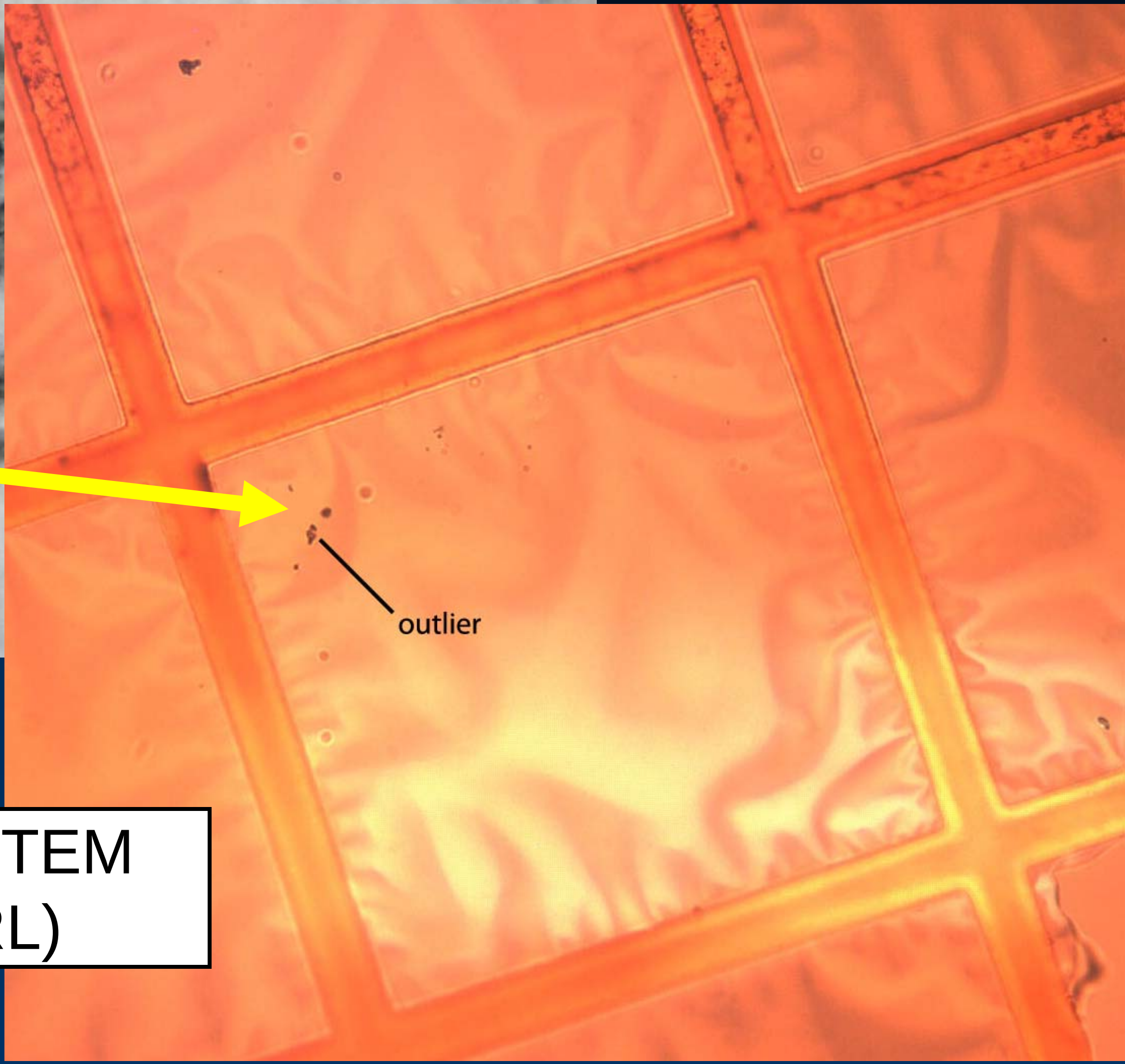


- NASA Discovery mission: First sample-return from a comet
- Returned samples of comet Wild-2 January 15, 2006
- Samples less primitive than expected, but significant sampling biases

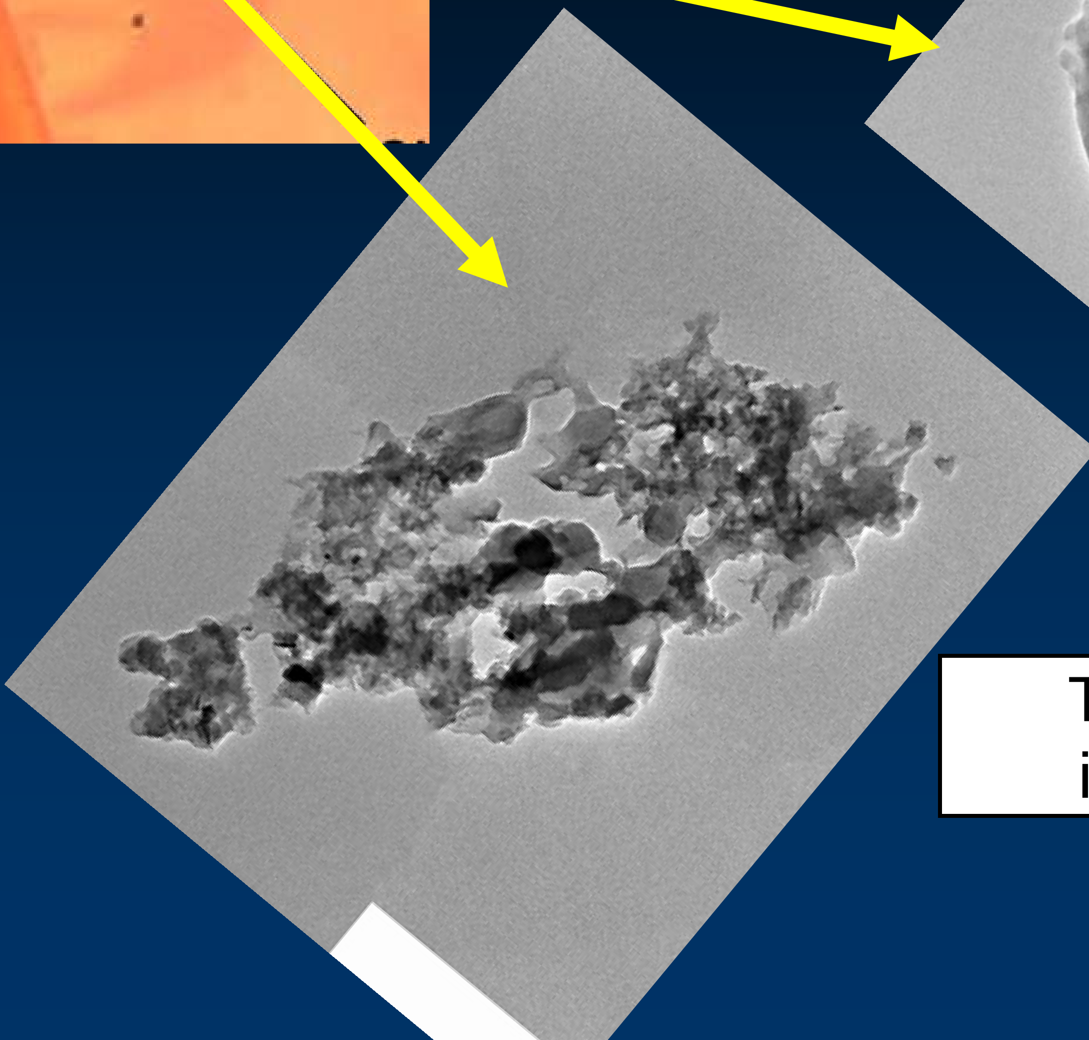


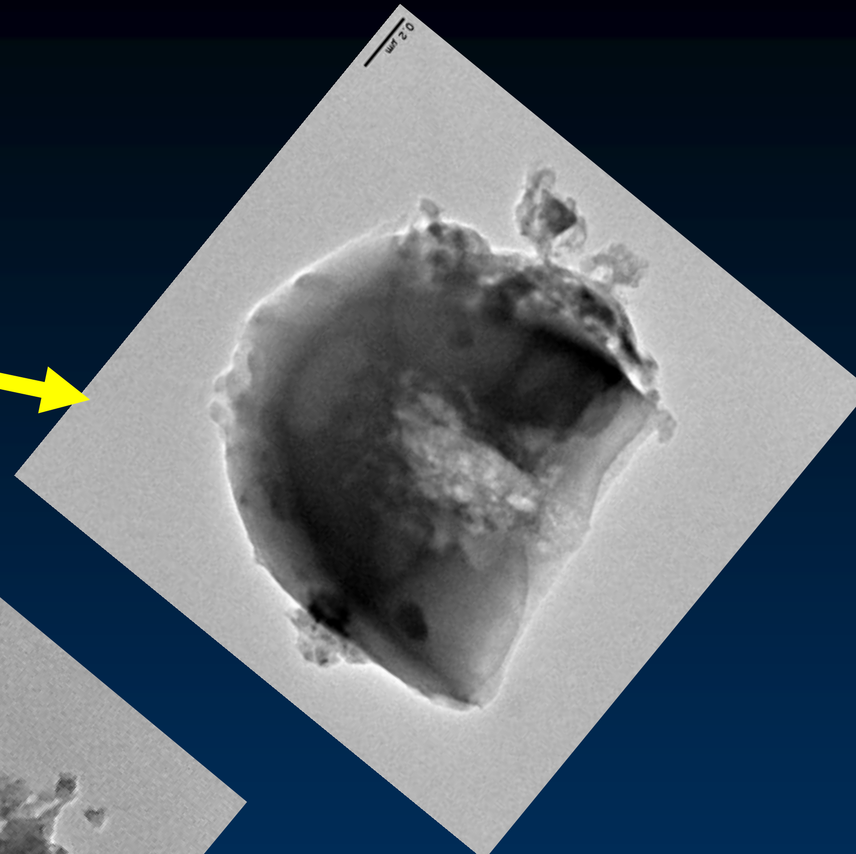
Comet dust track in aerogel (~4mm long)



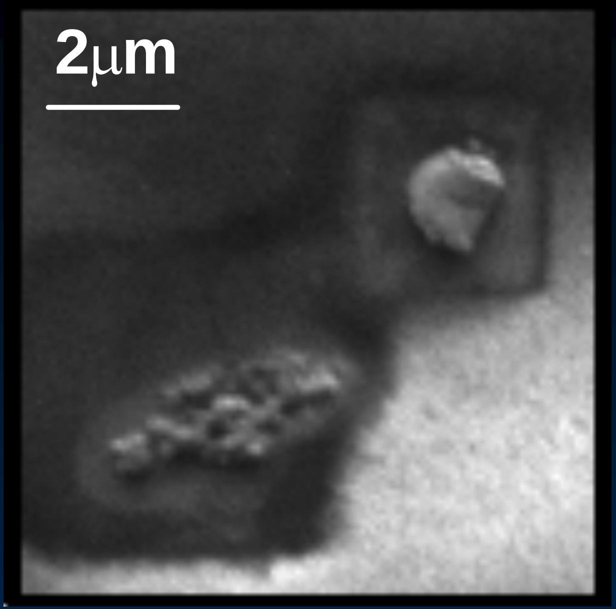


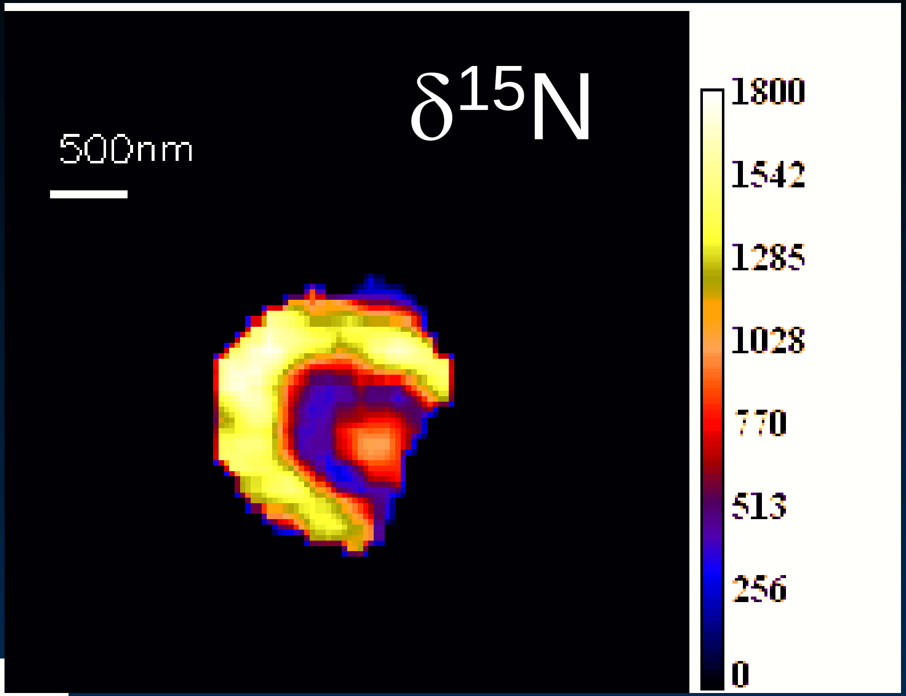
100nm thick section on TEM grid (DeGregorio, NRL)

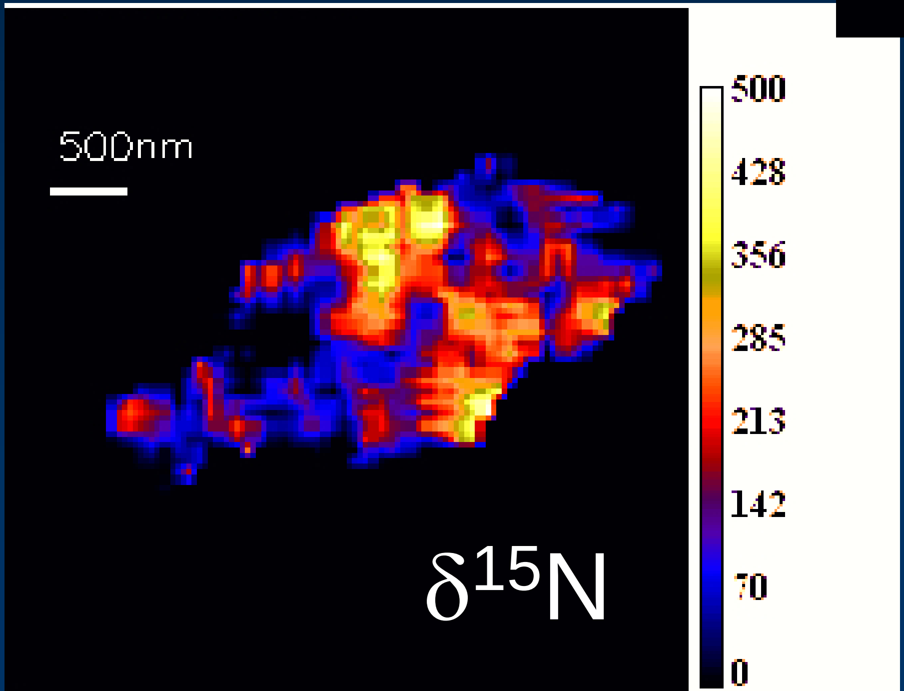




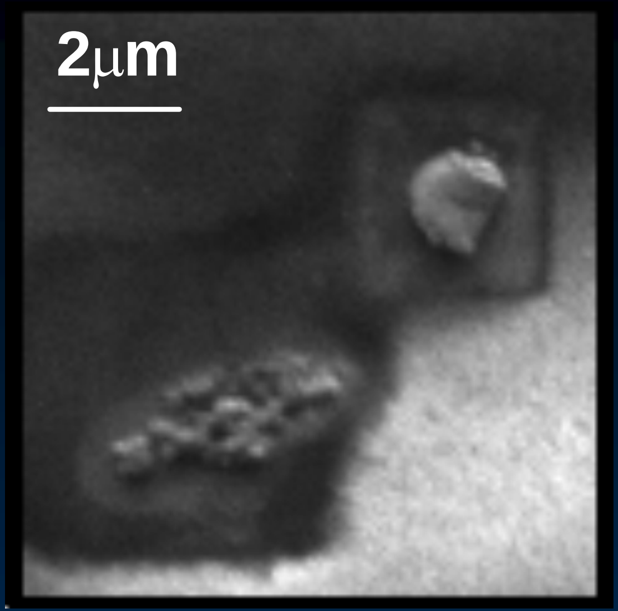
TEM and STXM analysis
indicates mostly organic

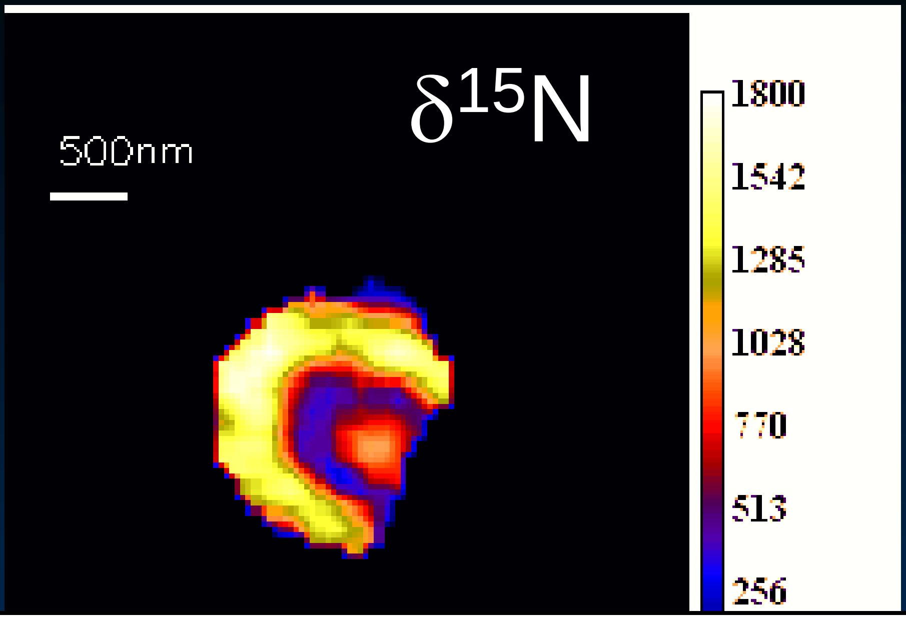


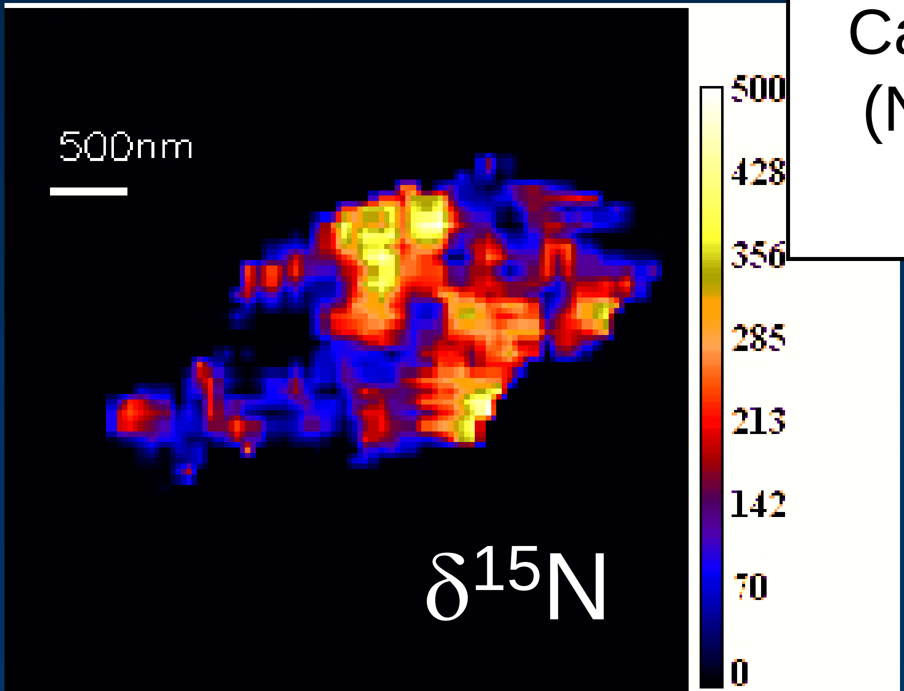




Both fragments rich in ^{15}N

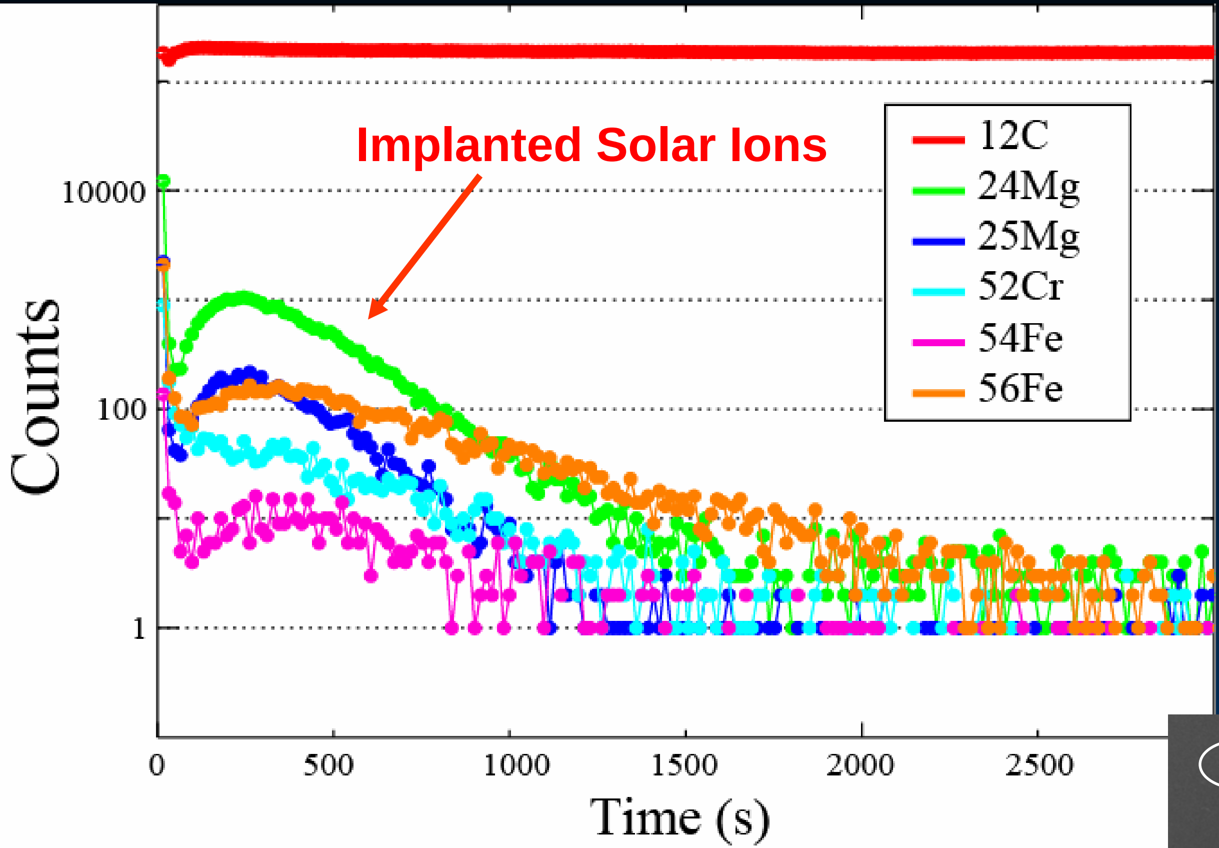




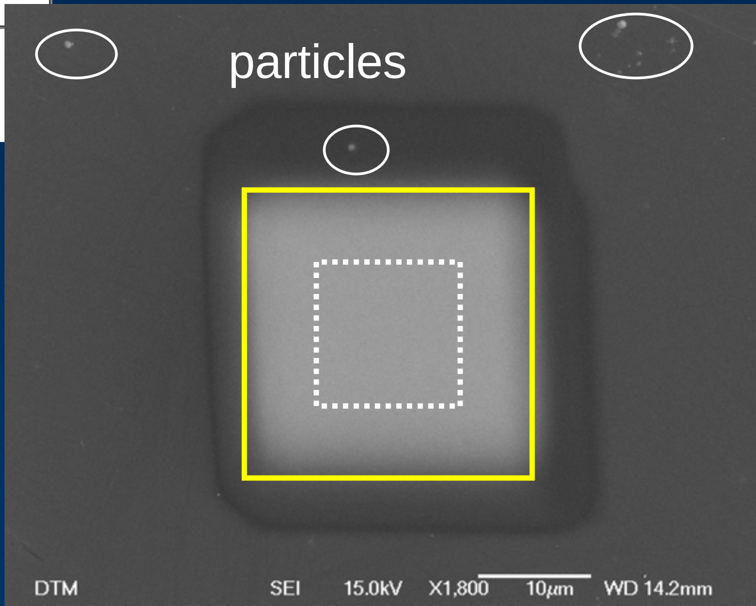


Carbonaceous nano-globule? (Nakamura-Messenger et al. 2006)

The Sun in the NanoSIMS



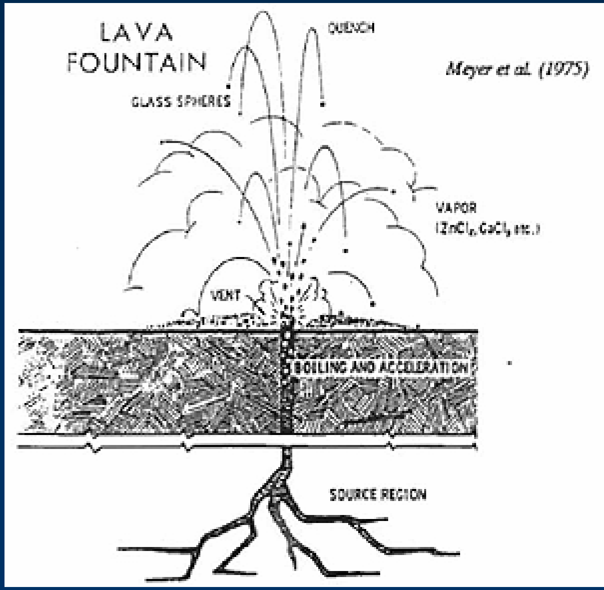
Wang, Nittler and Burnett, 2007



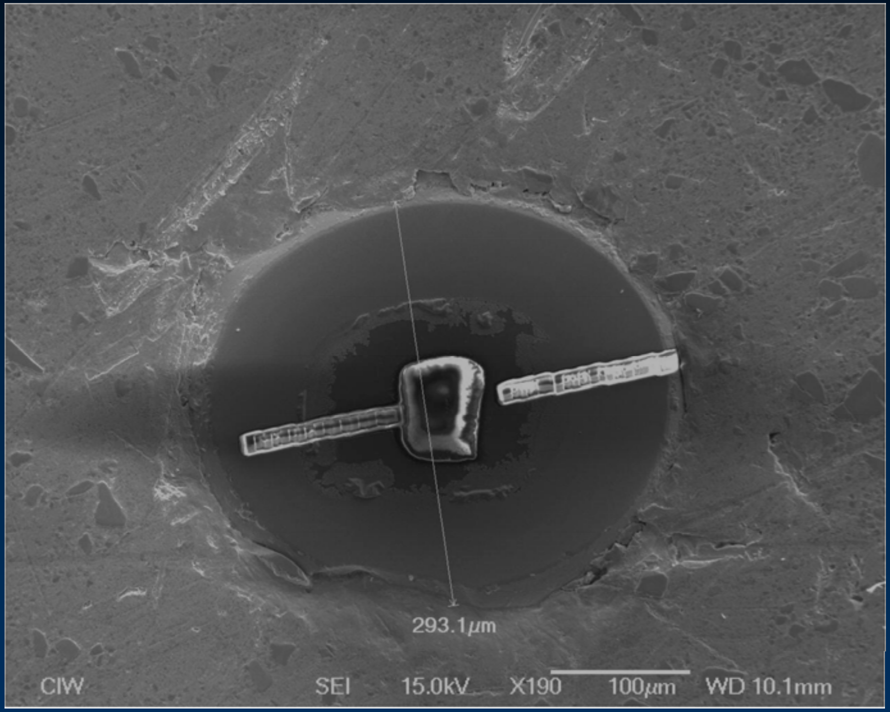
- 4nA, 16kV O^- beam (~5 μm diameter)
- 25 × 25 μm raster, only collect ions from central 25% of craters

The Moon in the NanoSIMS

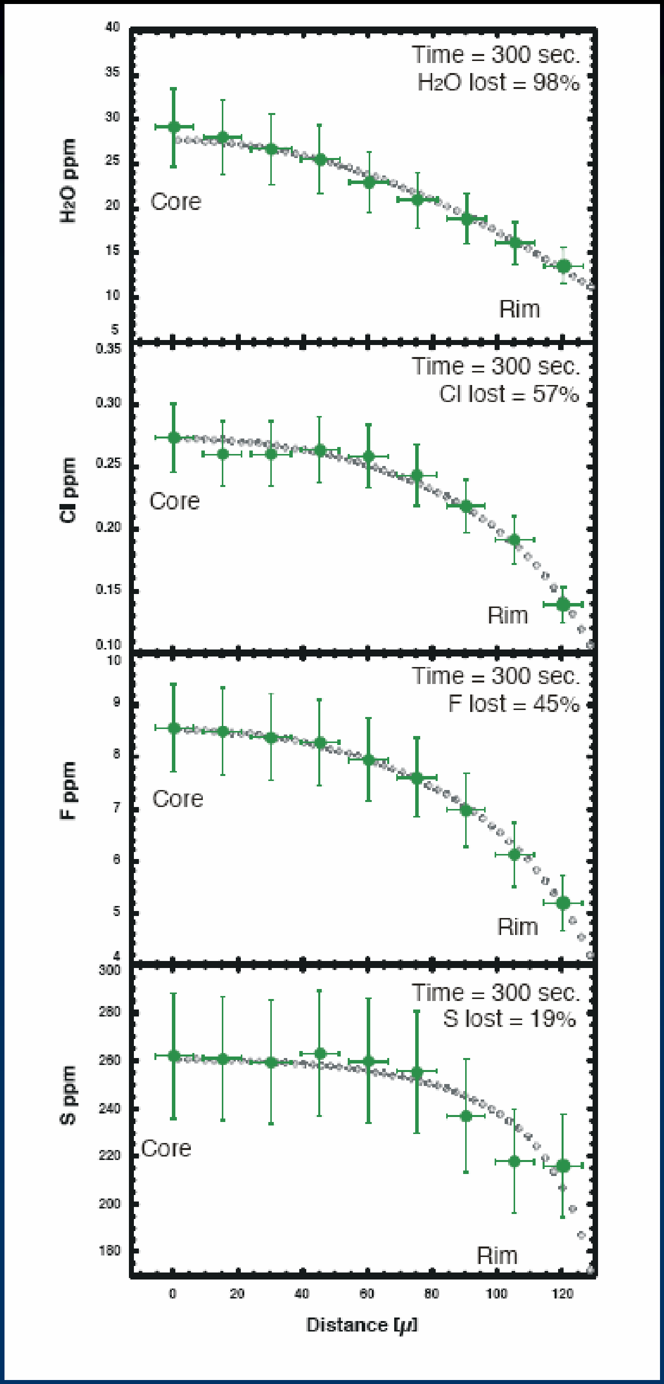
- Moon most likely formed in catastrophic impact between small body and Earth
  - Long thought that all volatiles lost
- Volatile trace element contents in NanoSIMS
- H2O Detection Limits:
  - 50 ppm (200 pA 330 nm)
  - 5 ppm (2 nA, 700 nm)



The Moon in the NanoSIMS

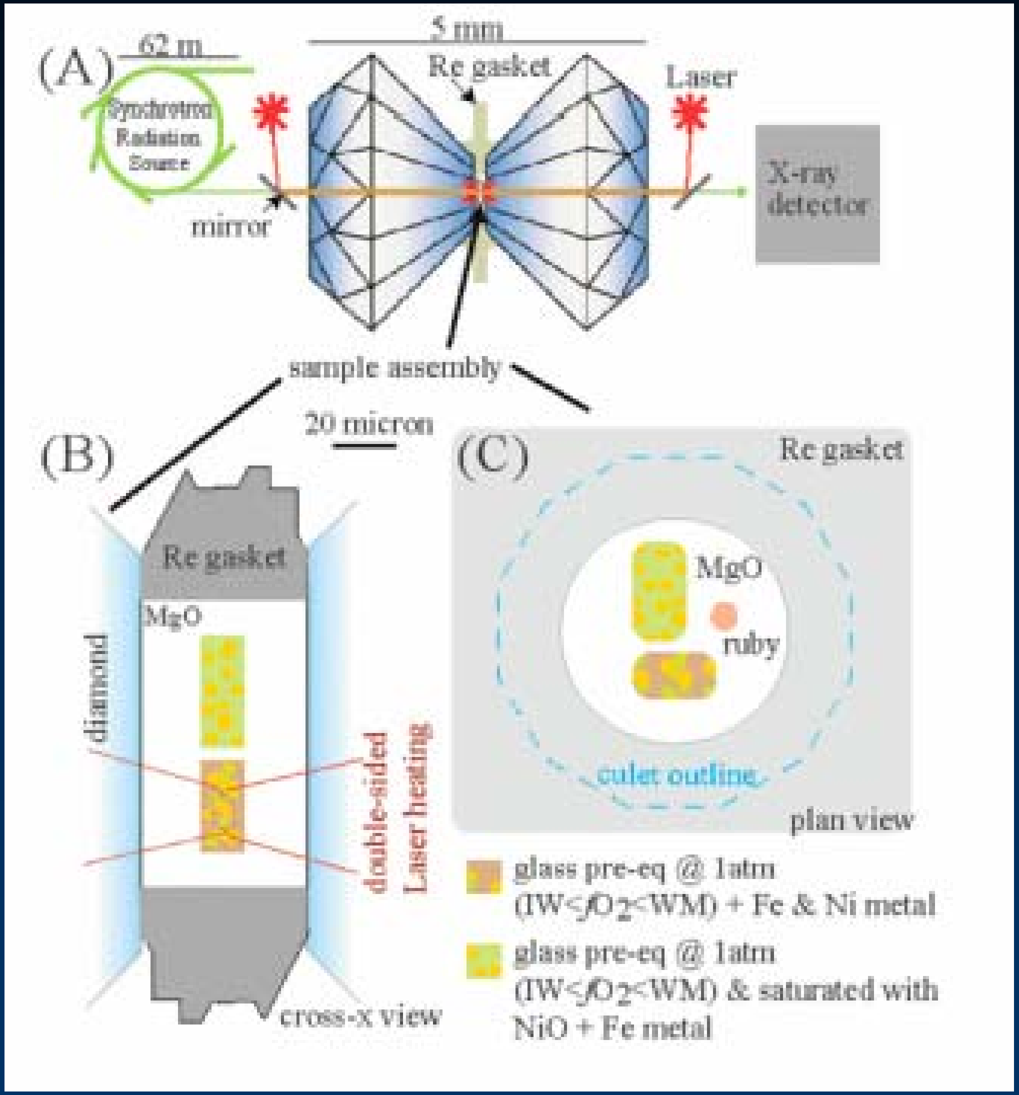


- Results indicate significant water, other volatiles, in lunar interior (Saal et al, *Nature*, in press)



Earth in the NanoSIMS : Laser-heated high-pressure experiments

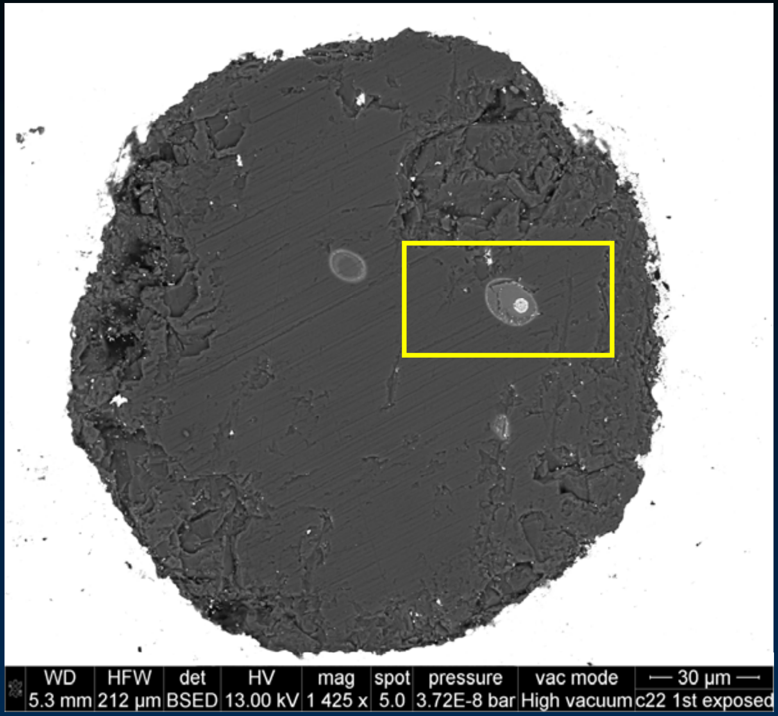
- Squeeze materials together in DAC and heat with laser to simulate high T, high P conditions of deep Earth

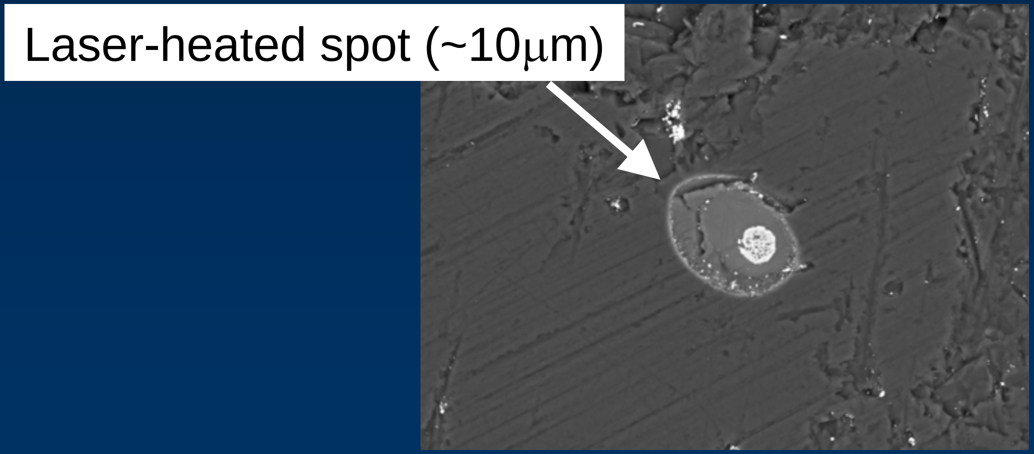


L. Cottrell (Smithsonian), E. Hauri, Y. Fei (CIW)

Laser-heated high-pressure experiments

- Use NanoSIMS to analyze run products (too small for traditional electron probe analysis)





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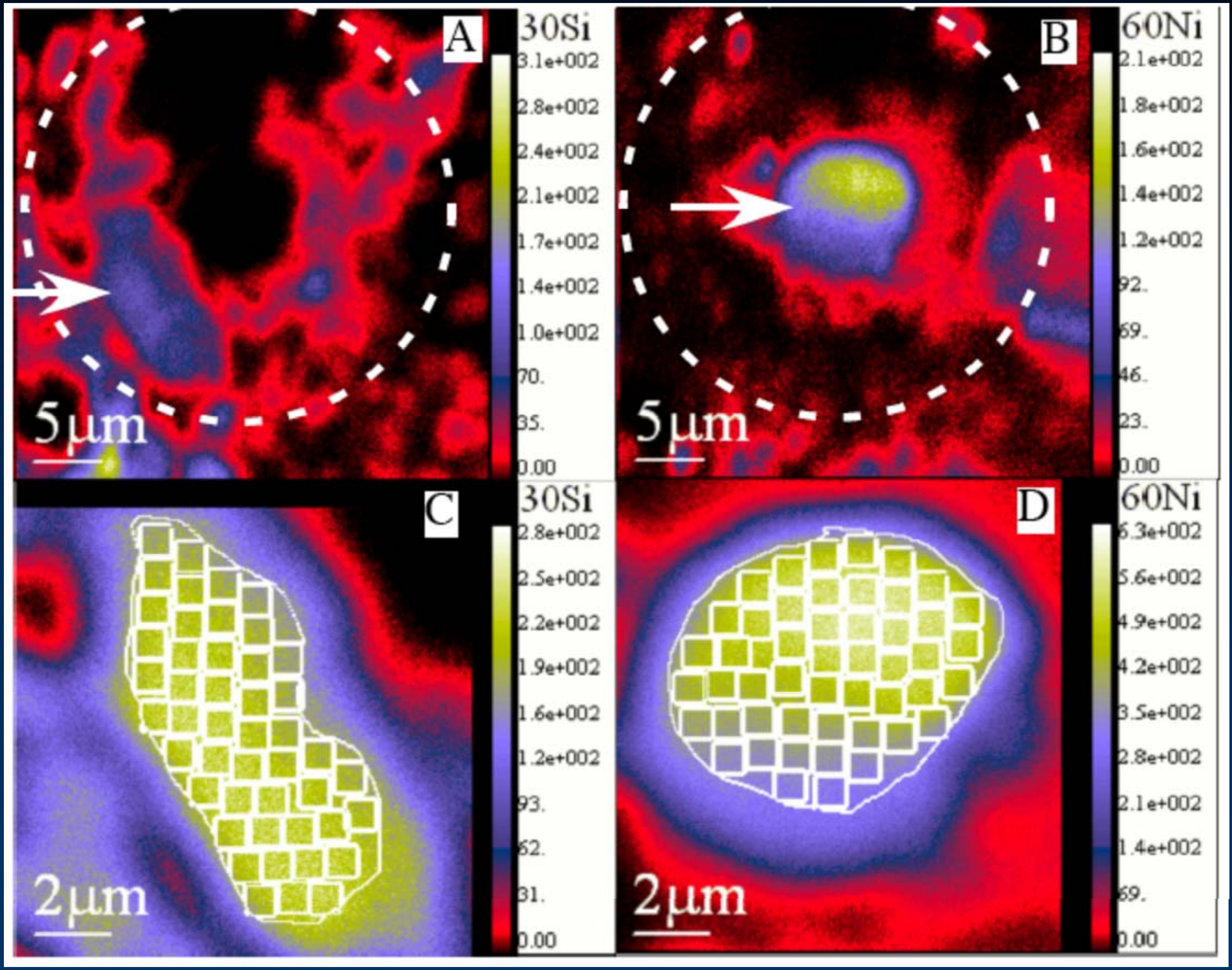
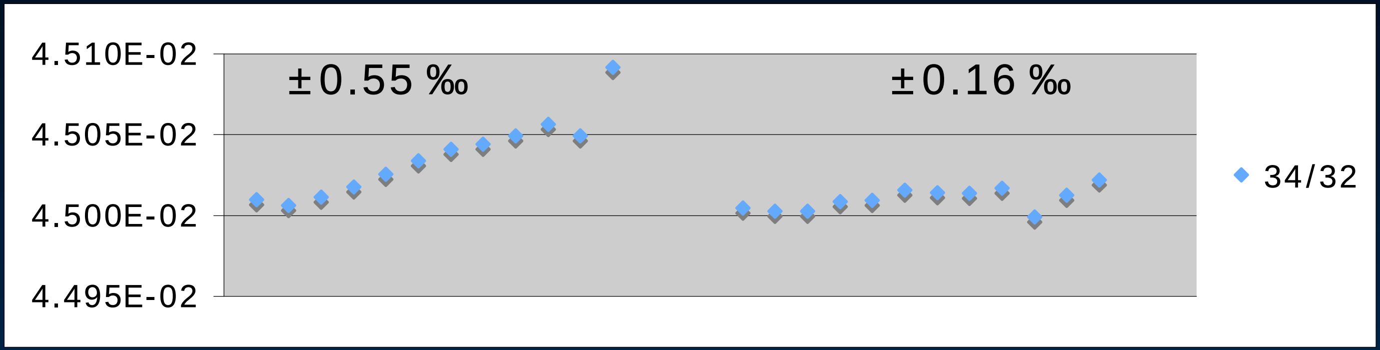
Laser-heated high-pressure experiments

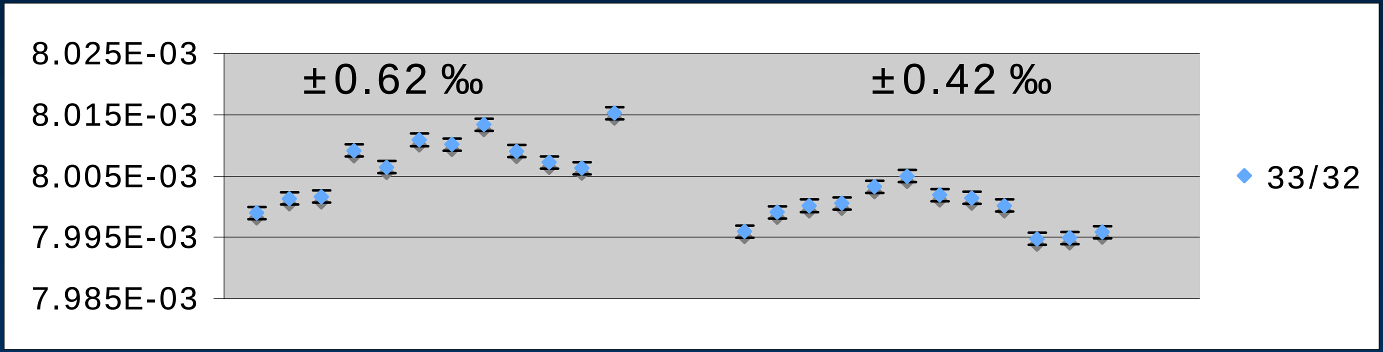


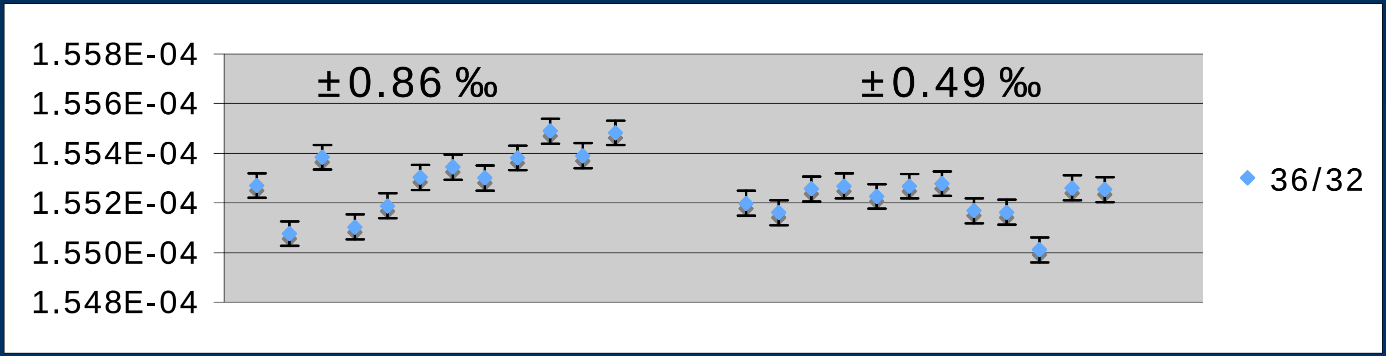
Earth in the NanoSIMS: Sulfur Isotopes

- Balmat Pyrite
- 2.3 nA (800 nm) beam, 15x15µm raster
- 32(FC) - 33(FC) - 34(FC) - 36(EM)
- 90 pA (9V) 32S in FC @ 6000 MRP
- ~4% useful ion yield

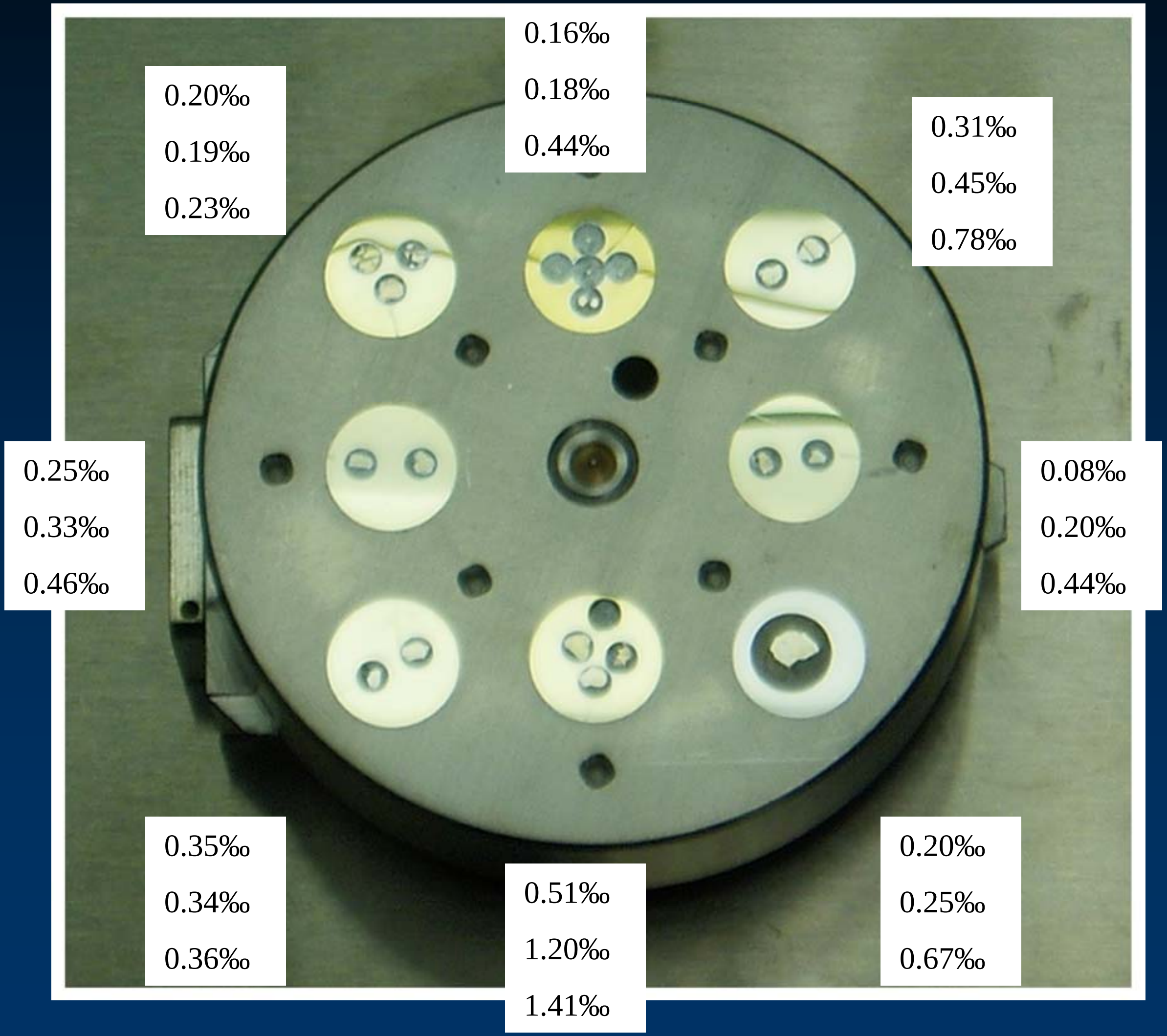
NS50L S Isotopes: 10 spots 1 grain



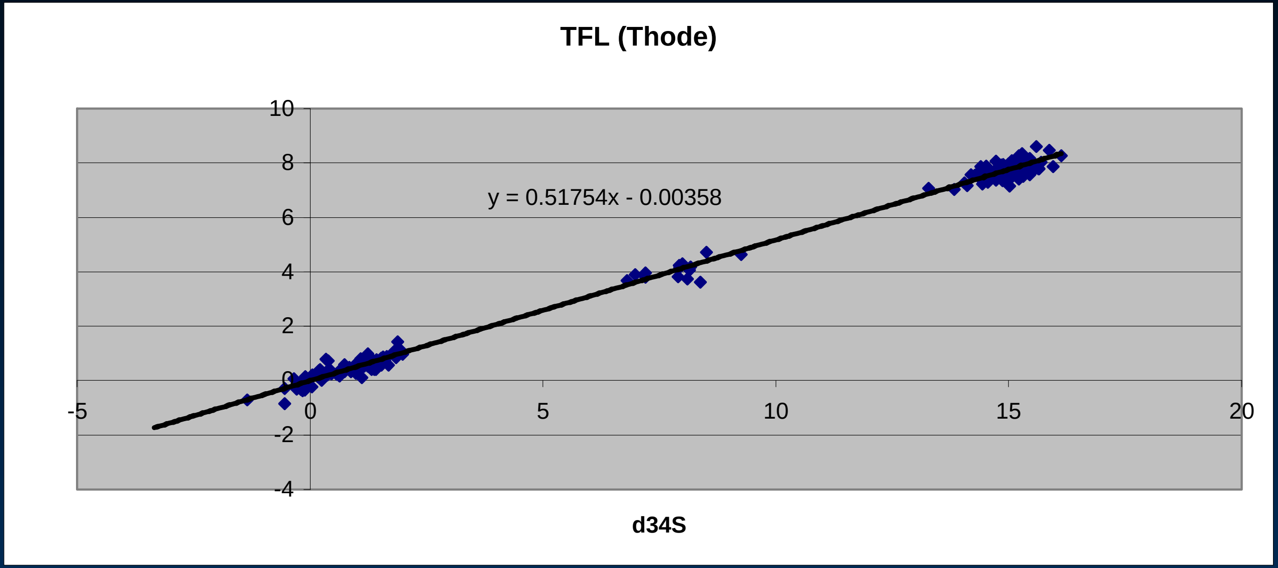


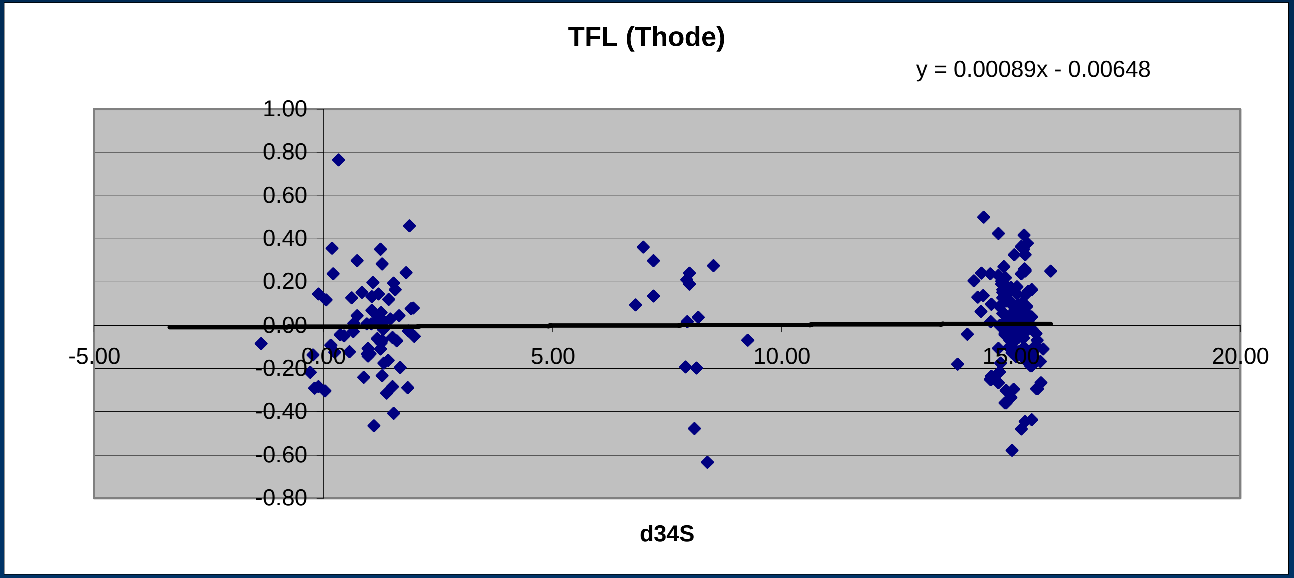


NS50L S Isotopes: 15 grains 8 holes

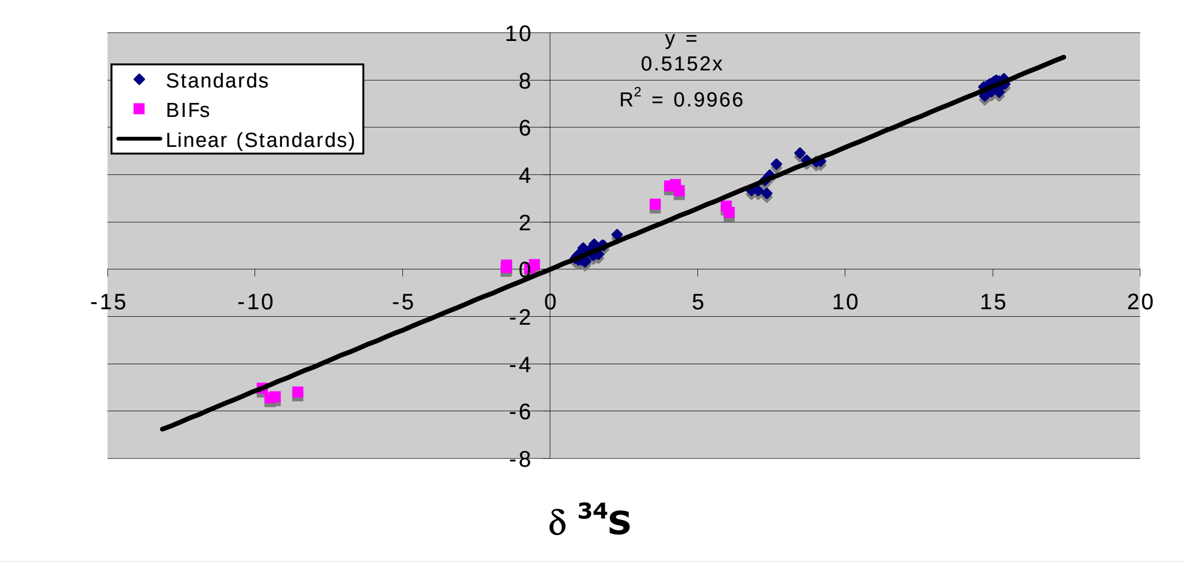


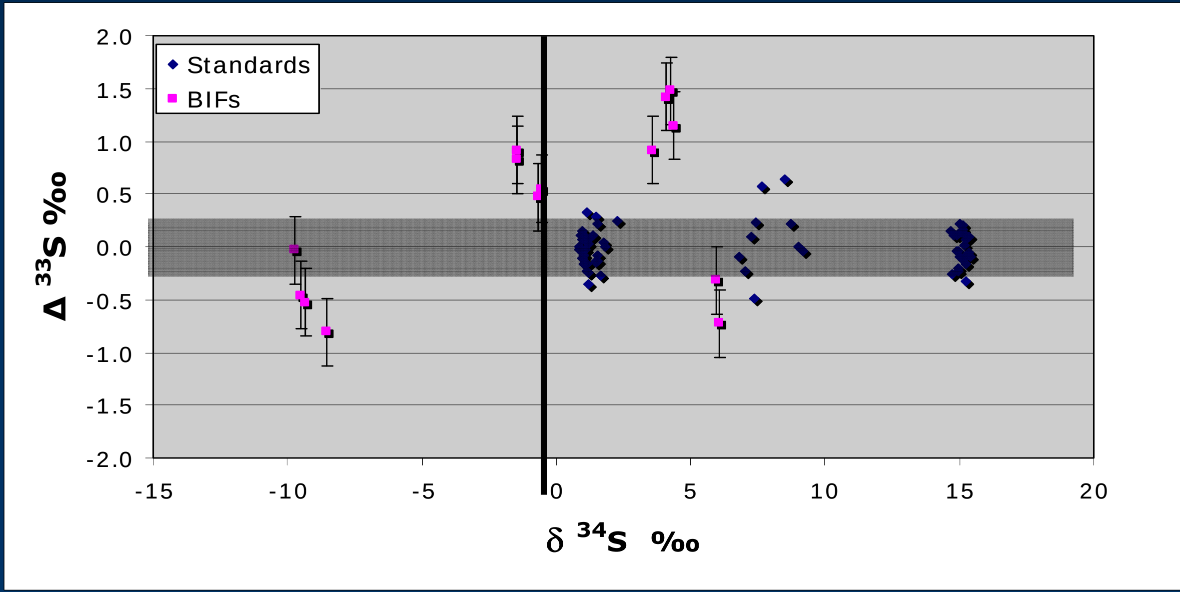
NS50L S Isotopes: TFL & MIF





NS50L S Isotopes: TFL & MIF





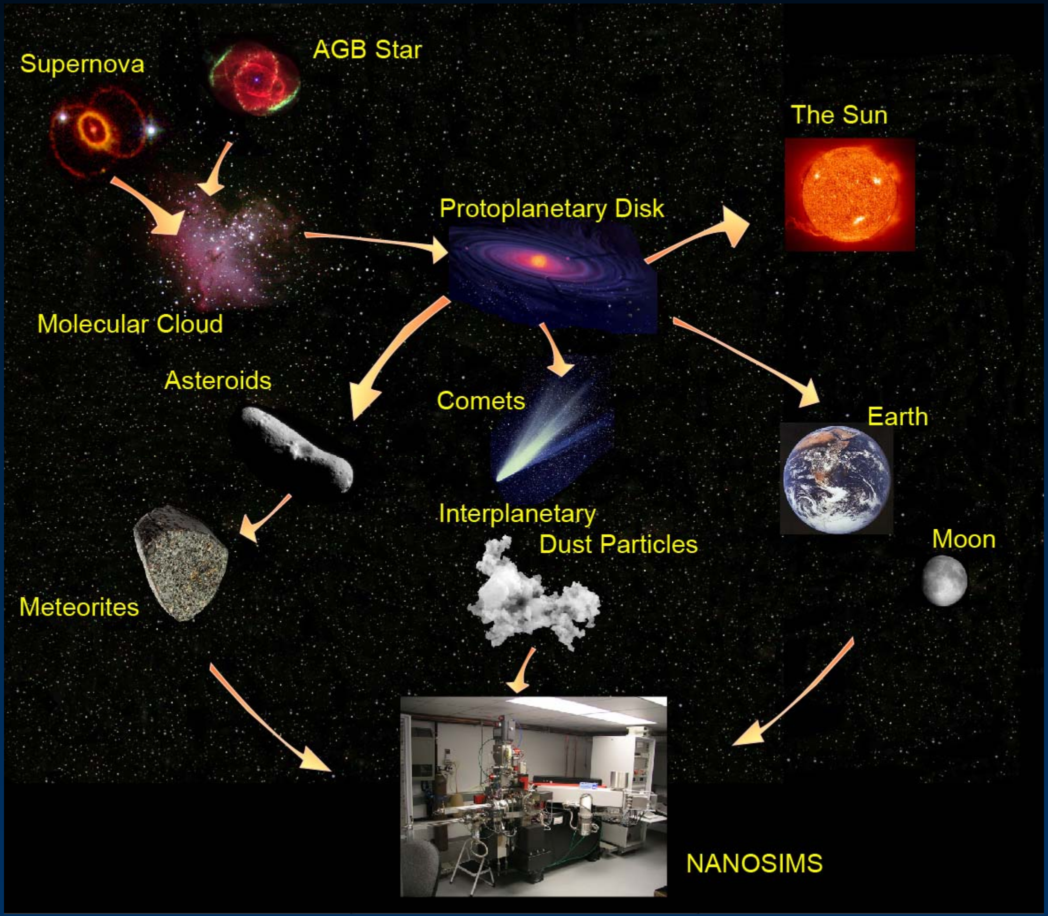
NS50L Successes for Terrestrial Geochemistry

•Beam Currents: perfectly useful even down to v. low current (few pA for imaging, more for quality analysis)

•Faraday Cups: primary beam density better than 6F/1280 permits use of Faradays for high-precision work using Cs+ beam (S in sulfide, O in silicates, H in hydrous phases). No advantage over 1280 for O- beam (U/Pb, B isotopes)

•High Precision Isotopes: better than 0.2‰ data compares v. well with 1280, even when jumping between different holes of a single sample holder (e.g. standards-unknowns)

The Universe in the NanoSIMS



Thanks

- CIW:
  - Erik Hauri
  - Conel Alexander
  - Henner Busemann (now in UK)
  - Ann Nguyen
  - Jianhua Wang
  - George Cody
- Naval Research Lab:
  - Rhonda Stroud
  - Tom Zega
  - Brad DeGregorio

Extra thanks to NASA and CIW for providing funds to purchase machine!

Happy Father's Day