MINI-WORKSHOP @IMPU

INTERSTELLAR DUST IN EARLY SOLAR SYSTEM

Typhoon Lee

4/28/2010

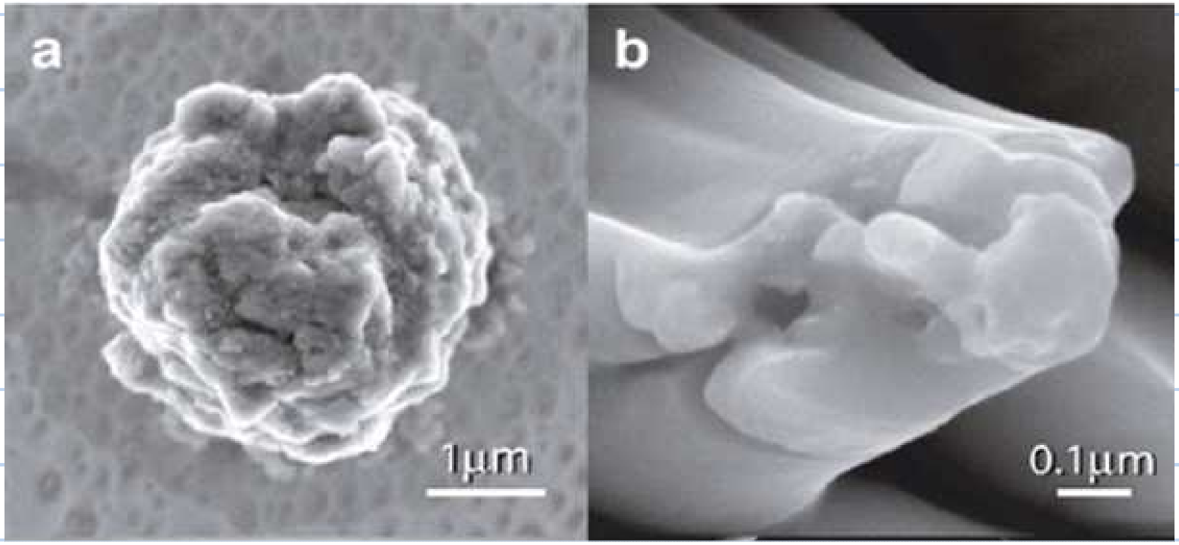
A Nuclear-astrophysical - Cosmo-chemical View

- **All grains were " pre-solar" initially.**
- **Most elements were carried by grains.**

  Grains were formed around AGB stars, SN, and Novae. i.e. they are circum (not inter)-stellar. Large isotopic fractionation in volatiles (H, N, etc.) near grain surface suggests low temperature overgrowth in ISM.
- **When these grains were heated by sunshine, reconnection,ss impact, or radio-active decay) they turned into "solar" grains.**

Normal vs. Anomalous

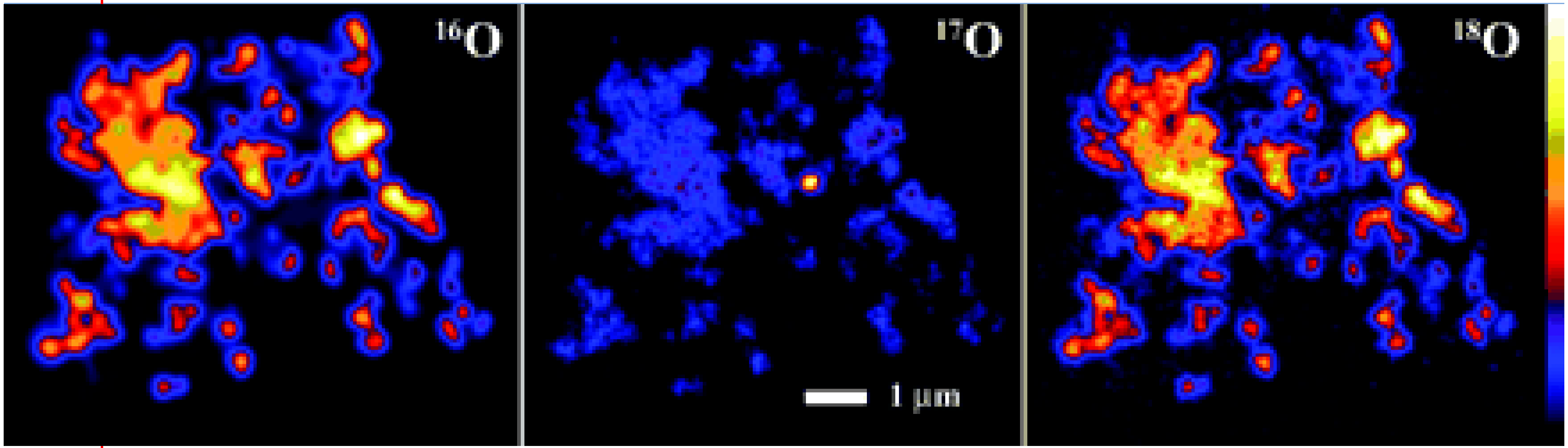
- **The uniform isotopic ratios found within men's sampling range is termed "normal", "solar", even "cosmic". "Pre-solar" grains are then identified by their large isotopic anomalies. e.g.**
- **SiC**
- **Spinel**
- **MgO***
- **Al_2O_3**



(a) 3 μm SiC grain (b) 0.8 μm Spinel grain (Larry R. Nittler)

Messenger et al 2003 Science

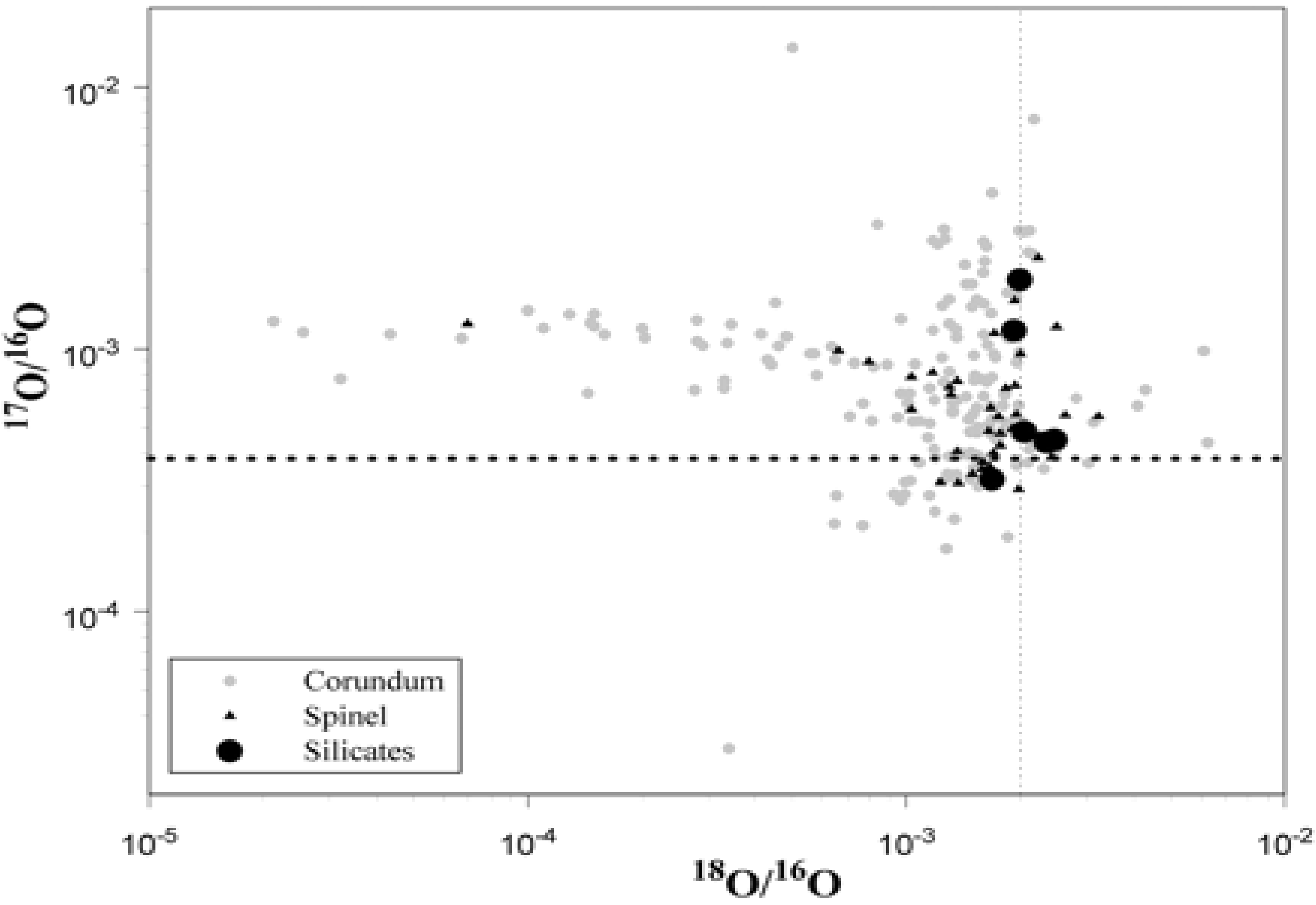
- O isotope mapping for pre-solar oxide-silicates in IDP



-

- Messenger et al 2003 SCIENCE

Oxygen isotope ratios of pre-solar oxides and silicates



“Pre-solar” Grains

- **Resisted re-crystalization into “solar” dust w/ normal composition**
- **Pre-solar grains have extremely large variation in their isotopic composition. e.g. Their 12C/13C varies between 3 (=> H-burning via CNO process) and 5000 (=> He –burning.) So, 89 is the ratio for the solar mix.**
  - **o up to -100%**
- **Insight on dust formation, nucleo-synthesis, and stellar evolution.**

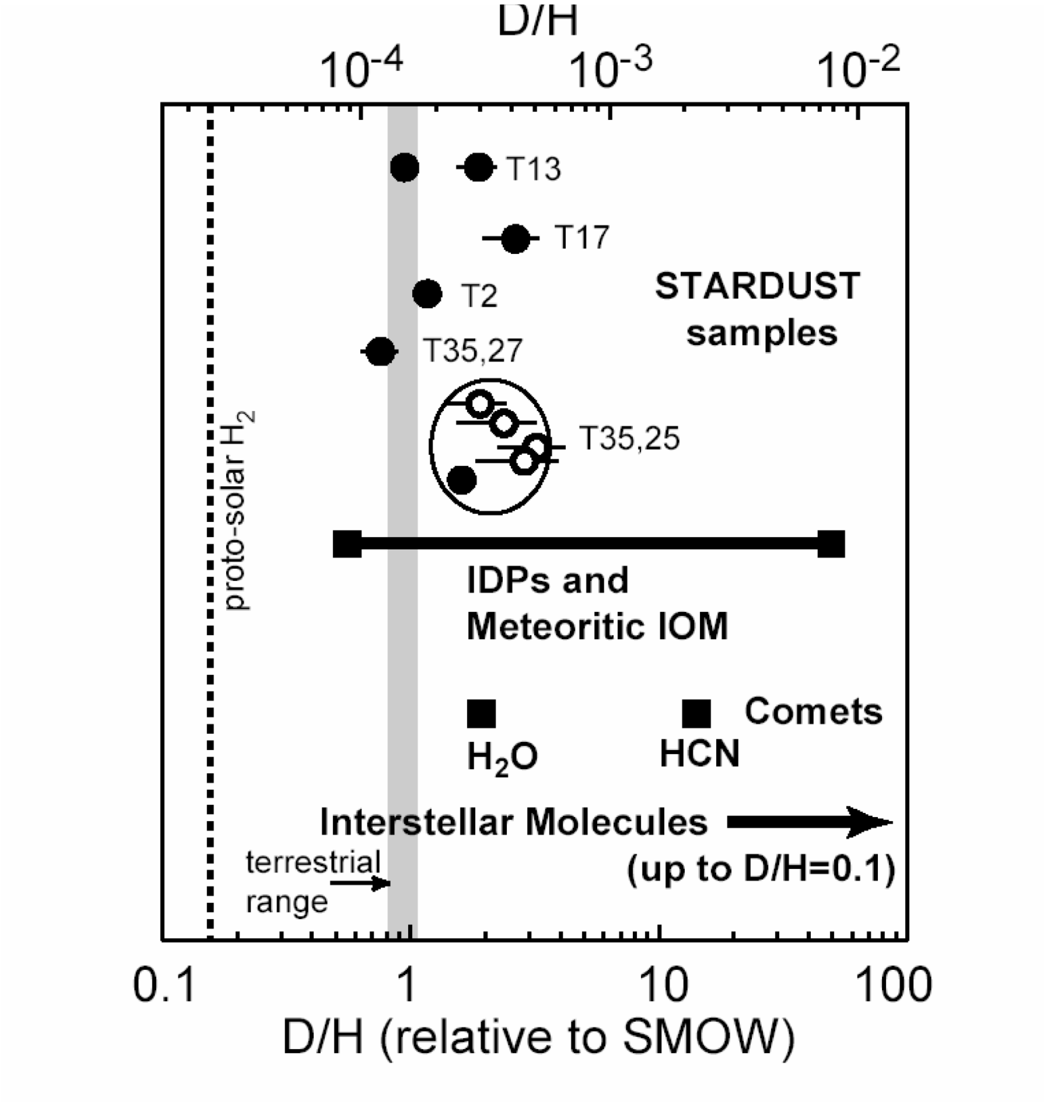


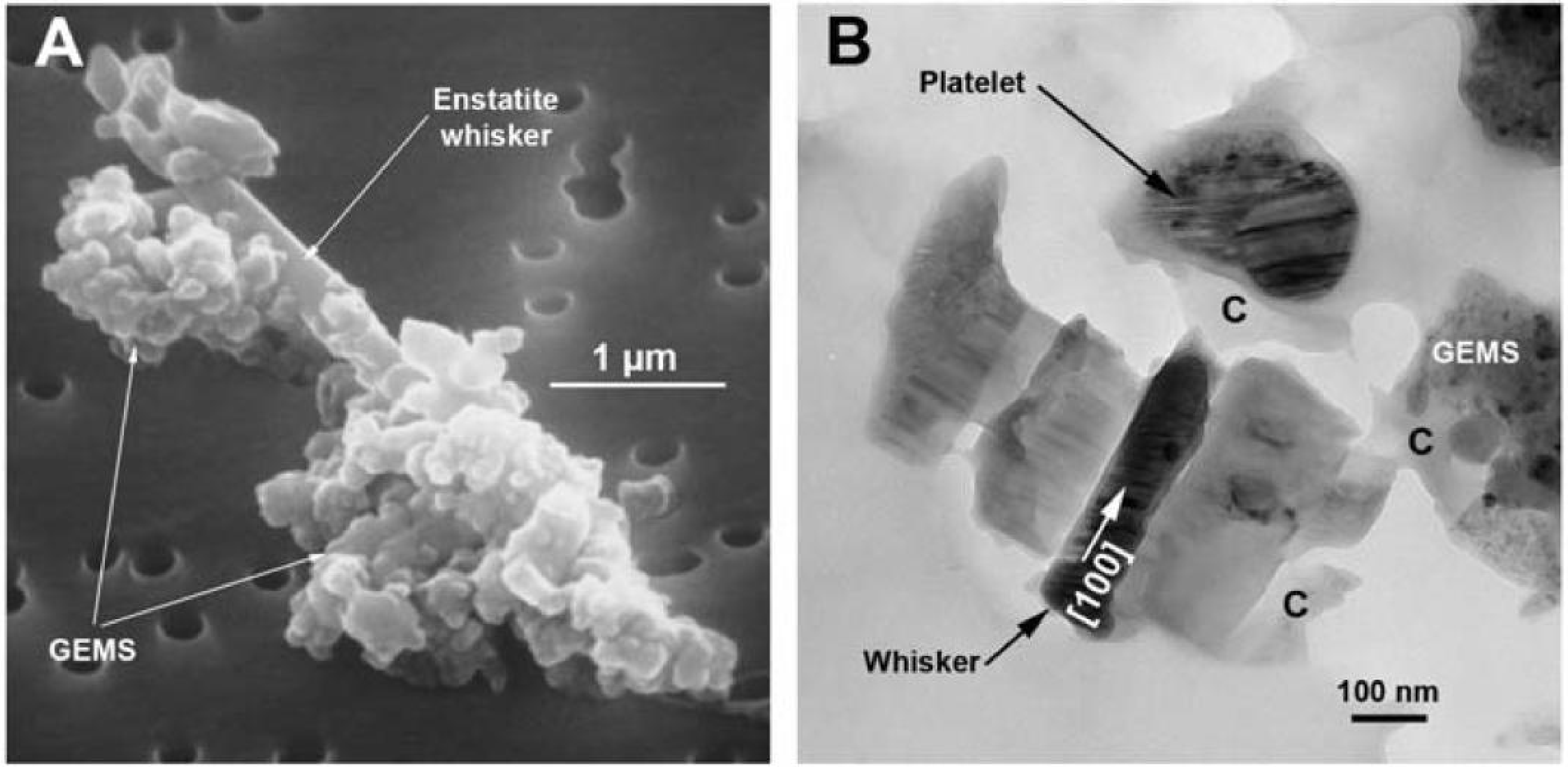
Figure 1. Hydrogen isotopic compositions in bulk fragments (solid circles) of 5 Wild2 particles and in micron-sized sub-areas of one particle (open circles) compared to Standard Mean Ocean Water (SMOW) and to ranges of laboratory measurements of D/H in stratosphere-collected Interplanetary Dust Particles (IDPs) and in Insoluble Organic Matter (IOM) from chondritic meteorites. Also shown are an estimate for protosolar H_2 and ranges of D/H measured remotely for specific gaseous molecules from comets and for molecular clouds. Error bars on STARDUST samples are 1σ.

D/H data =>
Comet Ice did not come from the hydrogen in the solar nebula. Its large isotope fractionation indicates a low temperature ISM origin which stayed in cold storage since 4.5 Ga ago.

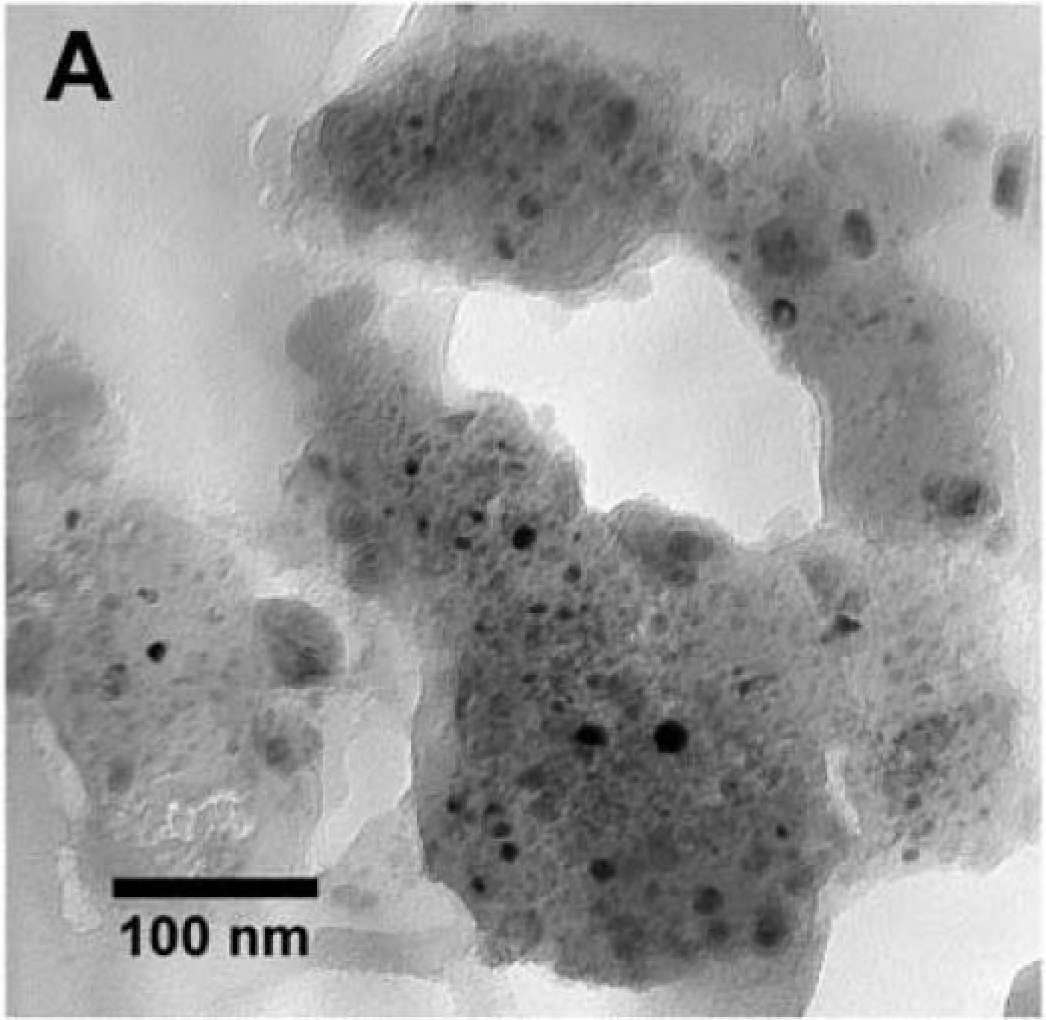
Where came the samples? Sample property altered?

- **Residue from meteorites dissolution,**
- **<0.1 wt.% & destroyed by heating.**
- **Inter-planetary Dust Particle (IDP) caught by high flying (>20 km) U2.**
- **Grains impacted (@6km/sec) the Stardust spacecraft during its 200km encounter (@) with comet Wild-2.**
- **Grain impacted (@30 km/sec) space-craft when it crosses the ISM streams.**

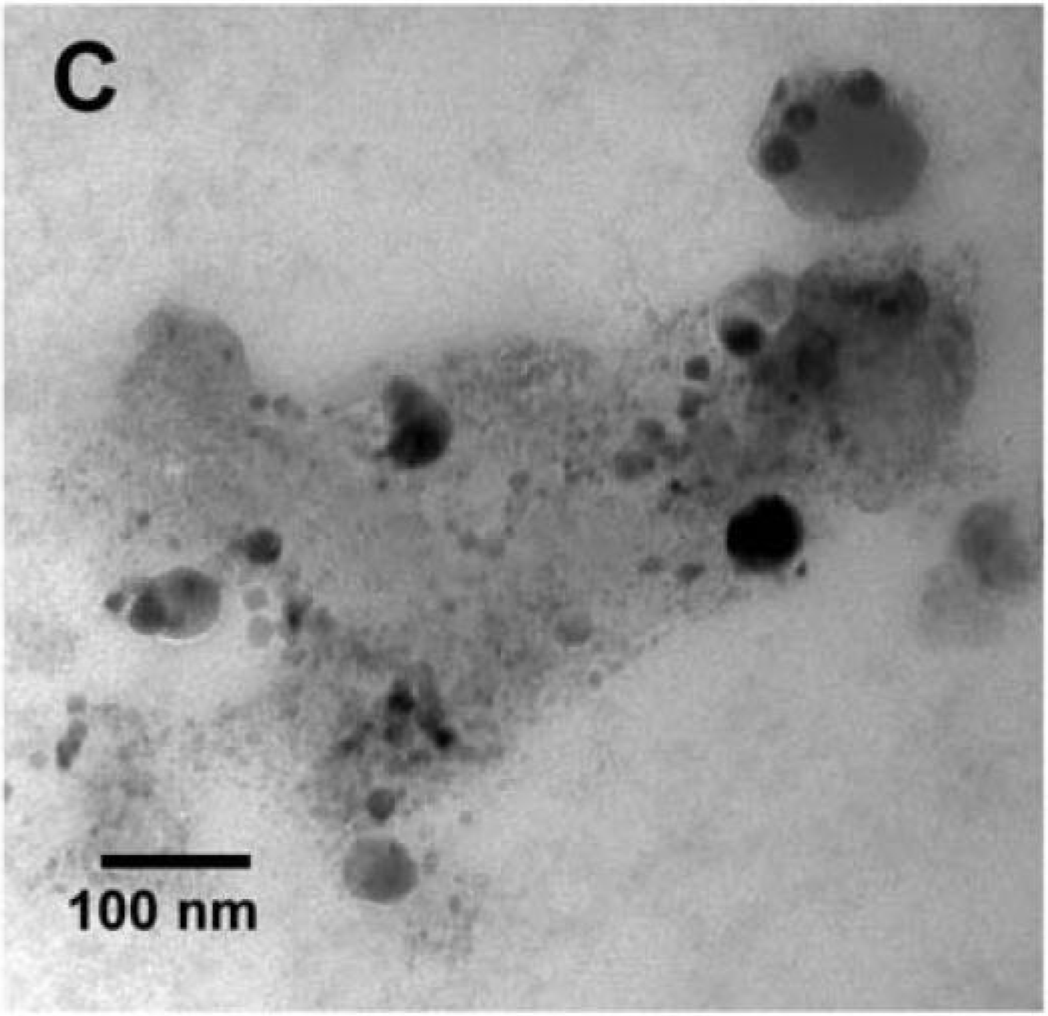
Glass w/ Embedded Metal Sulfides=GEMS (chondritic porous CP-) (Ishii et al 2008)



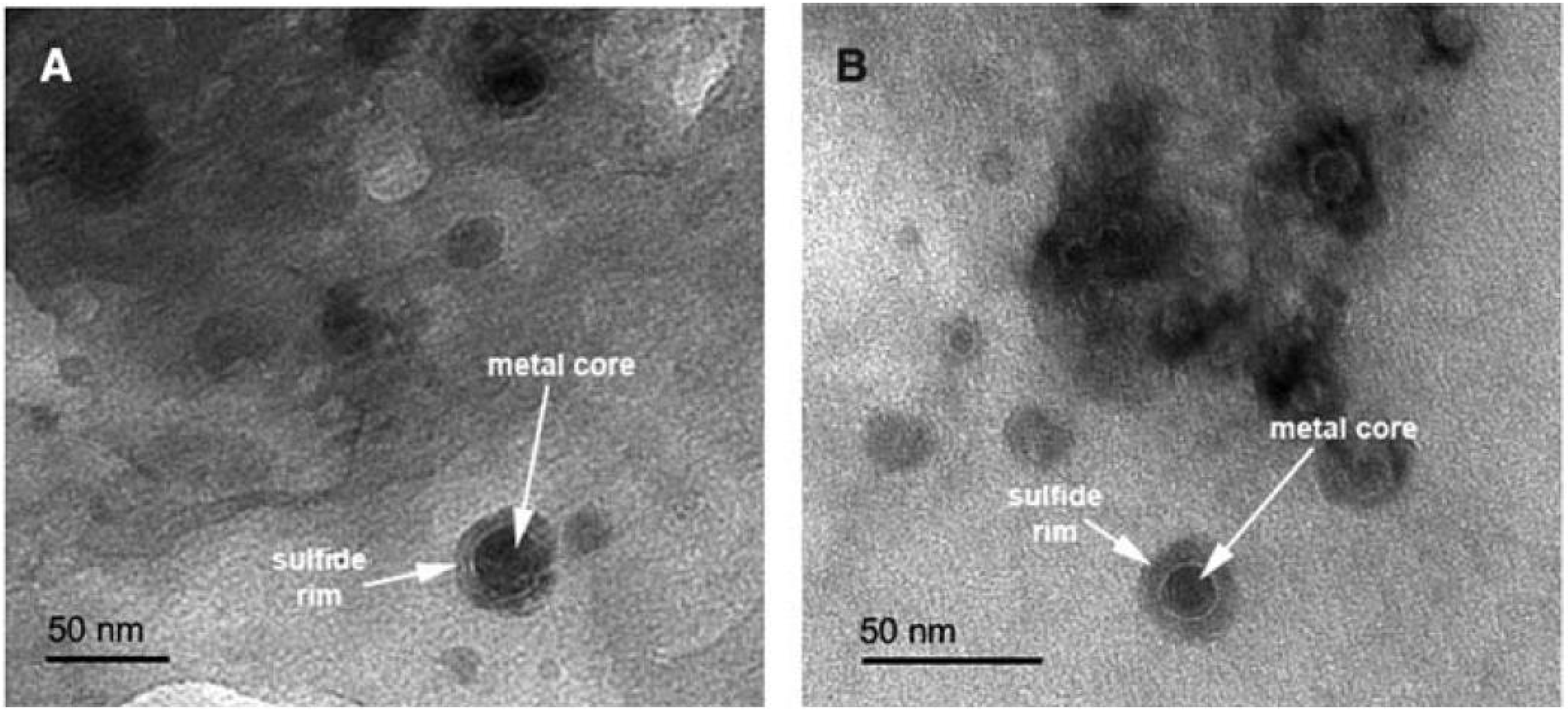
GEMS CP-IDP U220A19

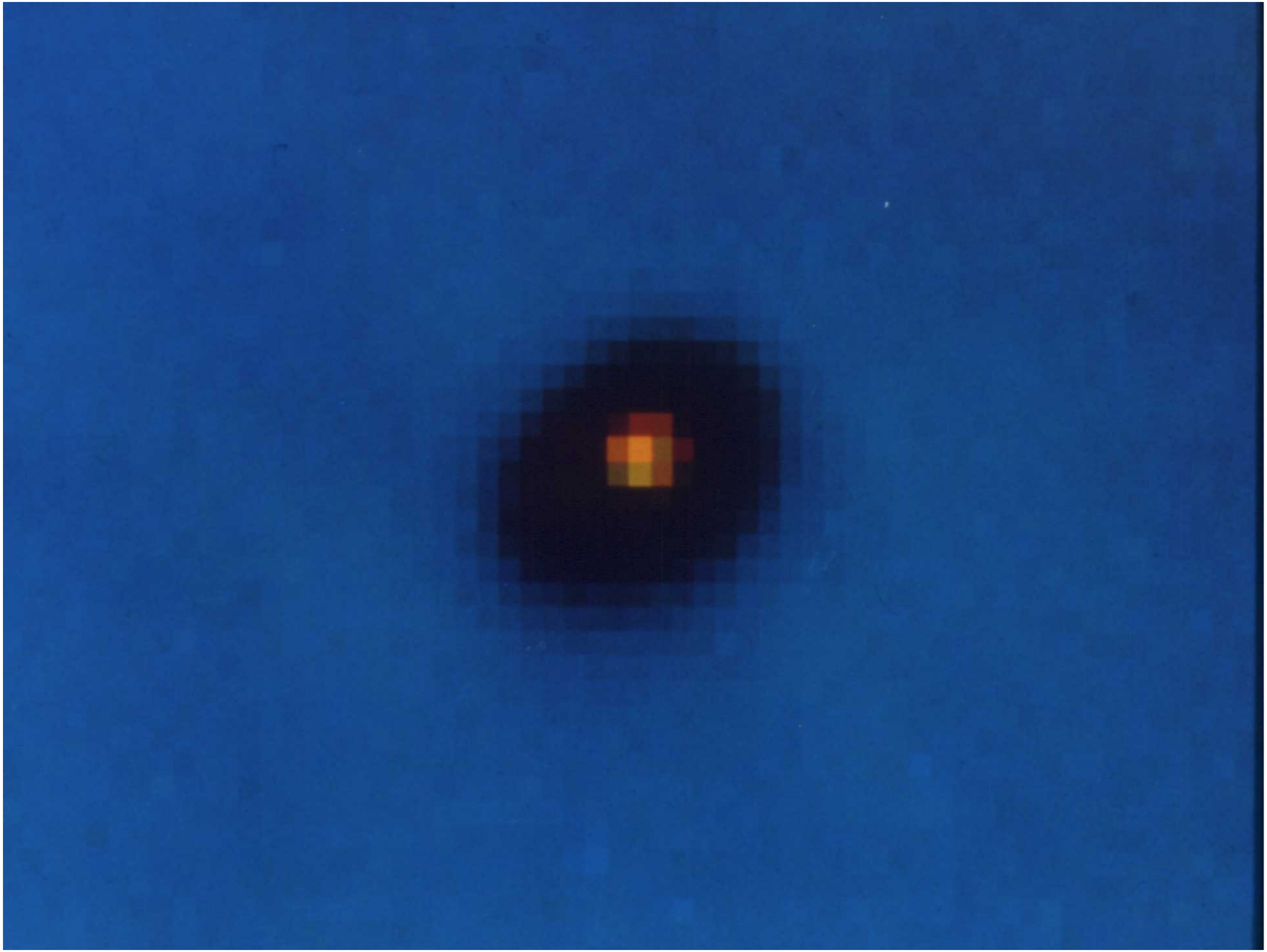


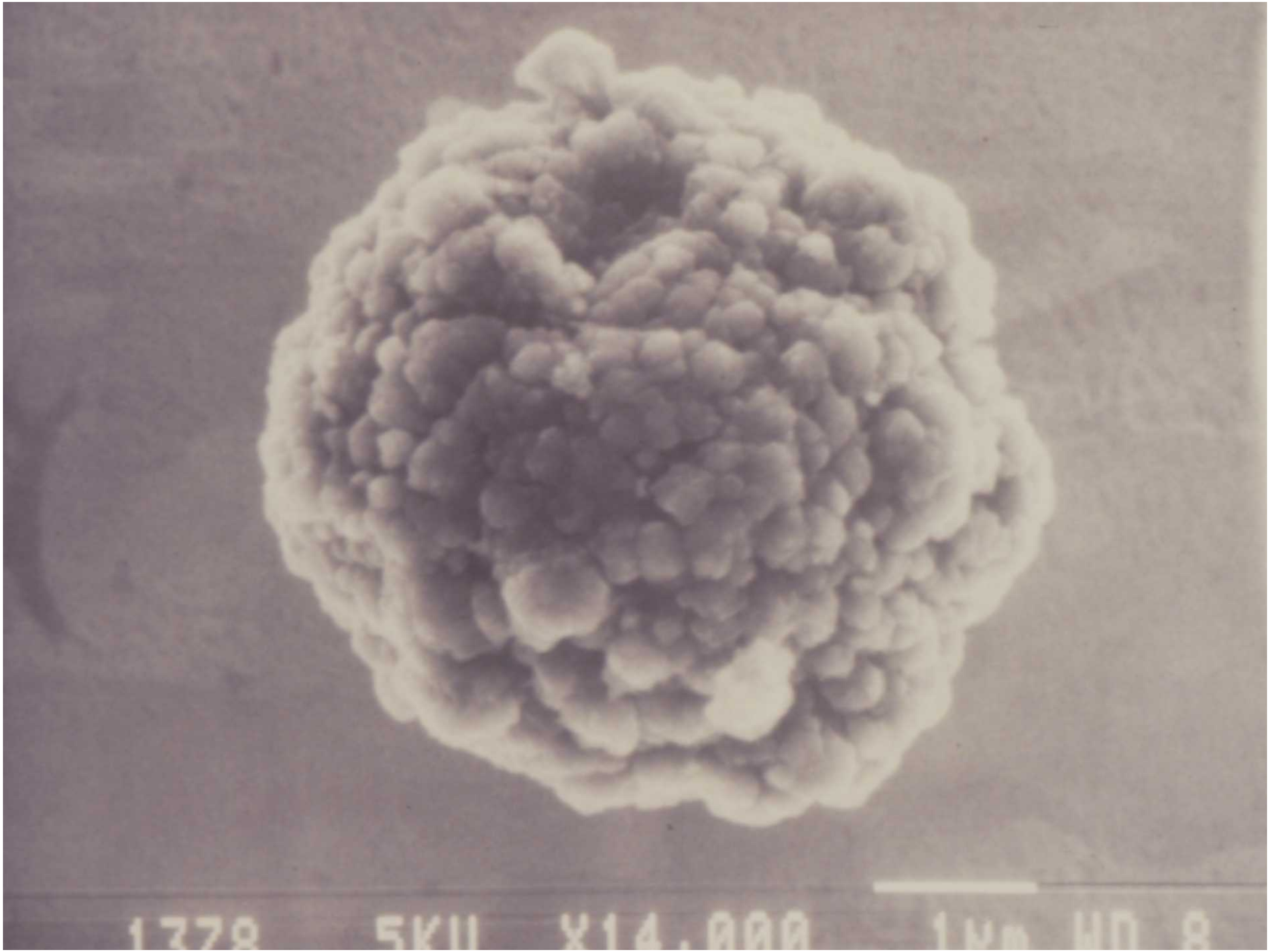
GEMS MADE BY IMPACT OF PYRRHOTITE INTO AEROGEL AT STARDUST SPEED



STARDUST COLLECTION VS. LAB HYPER-IMPACT






1378 5KV X14,000 1µm WD 8

Nucleo-synthetic processes have characteristic isotopic ratios

Carbon 12/13, an example

^{4}He fusion (3α= C-12) → C12/13 =∞

^{1}H-fusion (CNO catalyzed) →C 12/13=3

Present galactic disc C12/13=60

Red giants: C12/13, 3-3000

Pre-solar grains in meteorites: C12/13, 3-3000.

Solar system: 89 (=our ID)

We can tell ET or UFO from its C12/13 (≠ 89).

PRE-HISTORY OF SOLAR SYSTEM NUCLEI

- 1. Nucleosynthesis inside many stars. (e.g. 12C/13C)
- (= 3 for H-burnig (CNO), =∞ for He-burning)

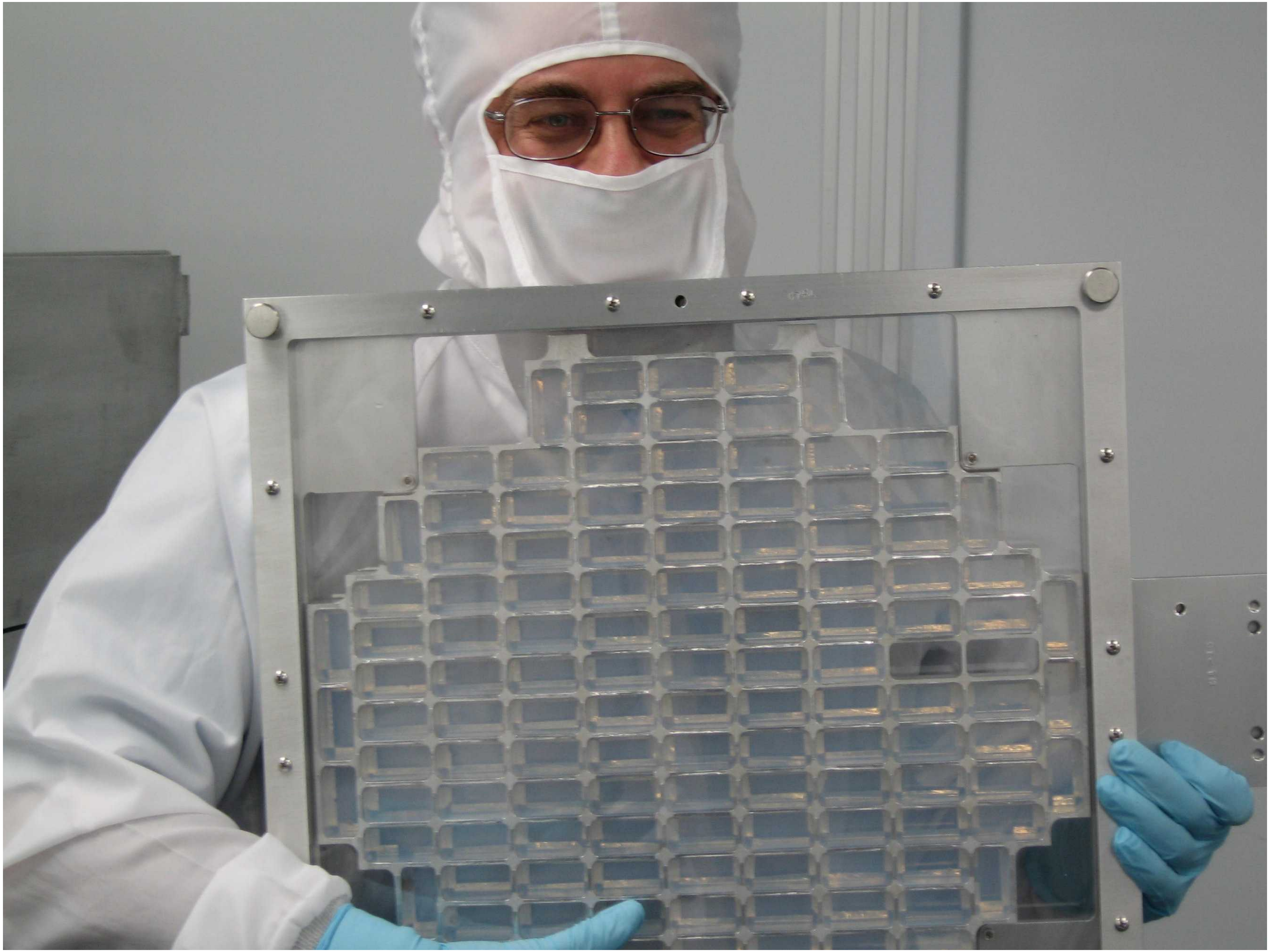
- 2. Mixing of the nuclear products to stellar
- surface by convection (e.g. AGB stars).

- 3. Condensation into circum-stellar dust (µm grains
- with isotopic signatures of their sources.)

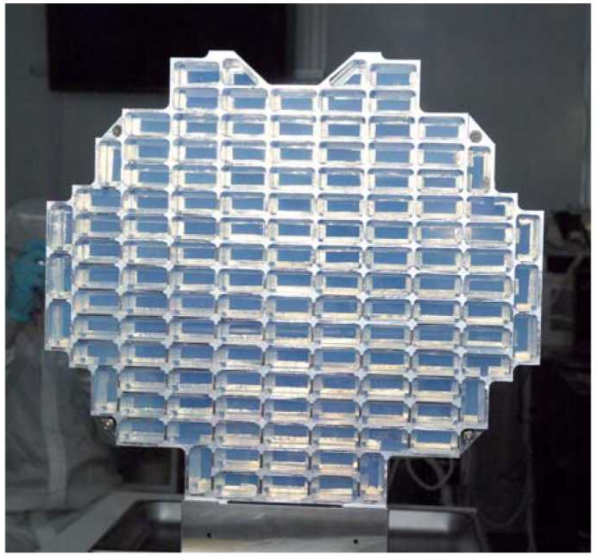
- 4. Interstellar travel in the Galaxy with gas (98%)
- which may react with grains to form mantle
- with large isotopic fractionation at low temp)

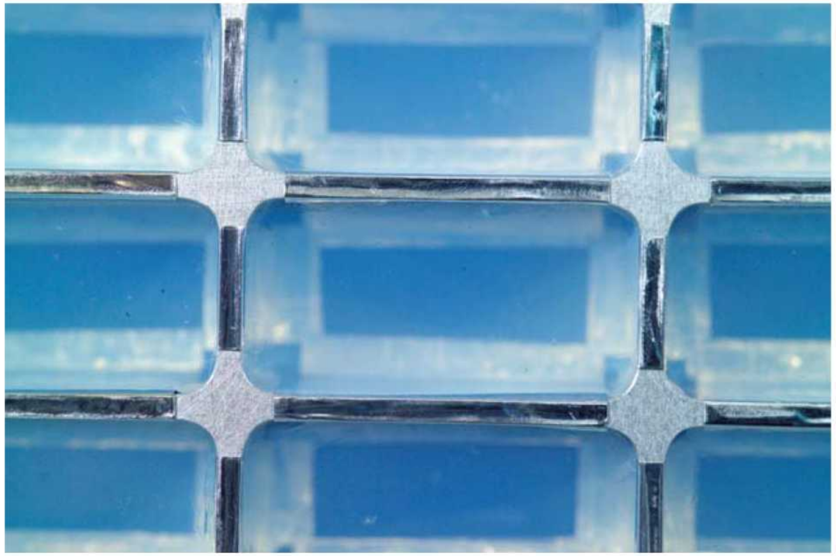
EARLY HISTORY OF SOLAR SYSTEM NUCLEI

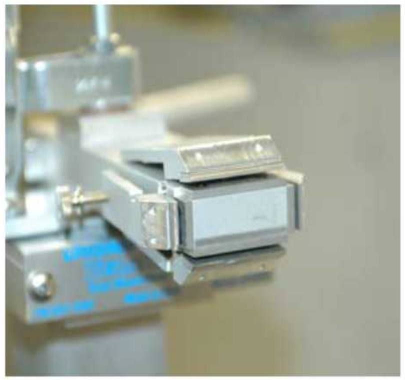
- 5. Entering the proto-solar molecular cloud
- (mix carbon ratios to 89, solar signature)
- 6. Transport through the accretion disc
- (=solar nebula) where solid bodies grew.
- Dust(um) => pre-solar & solar
- chondrules & CAI (mm) => melt droplets
- planetesimals (km) asteroids & comets.
- Planets (mega-m) differentiation
- ***When, where, and how to homogenize***
- ***pre-solar dusts into NORMAL solar solids.***



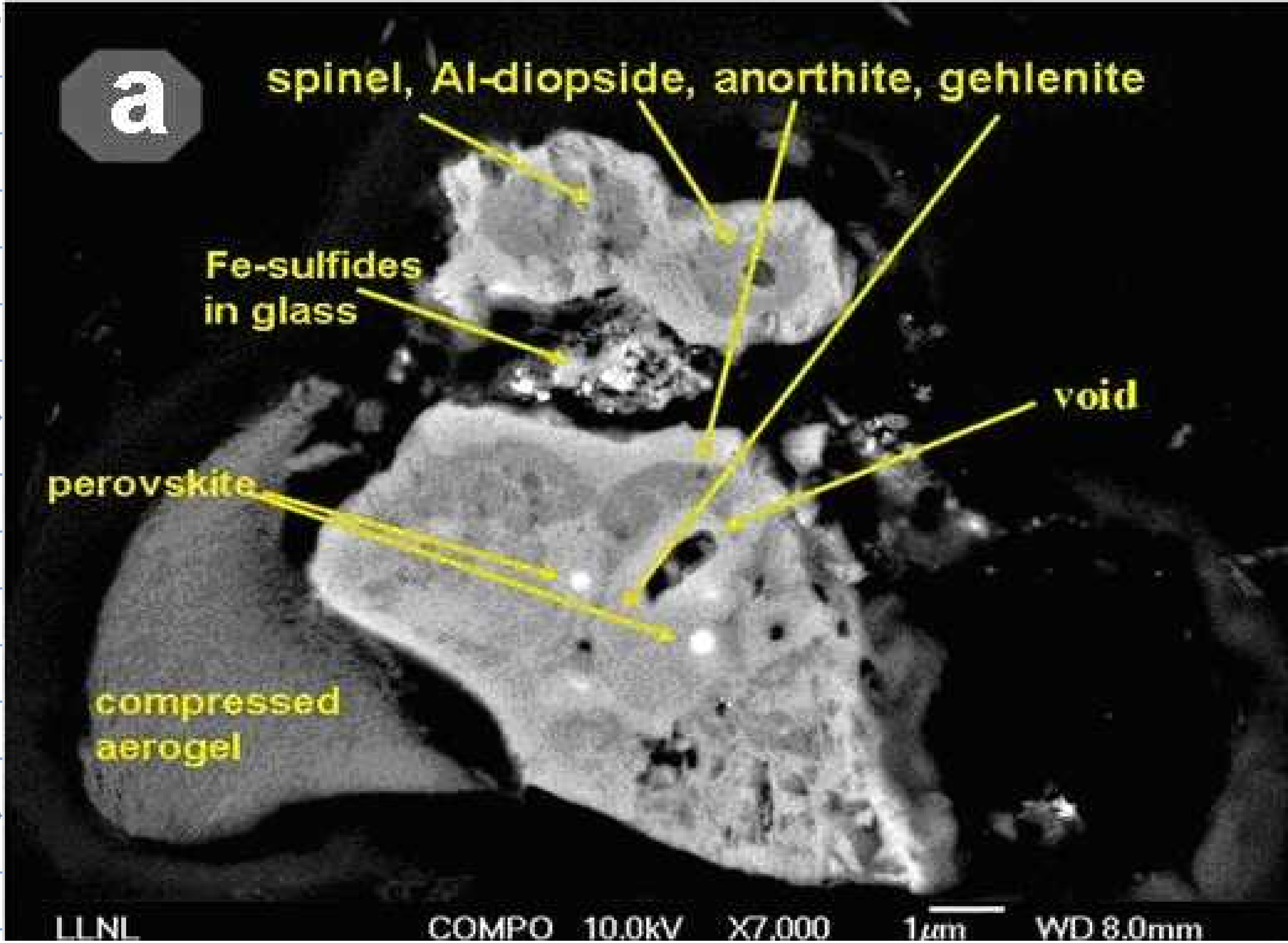
Wild-2 comet dusts approaching at 6 km/sec stop gently in aerogel or impact hard on the aluminum frame



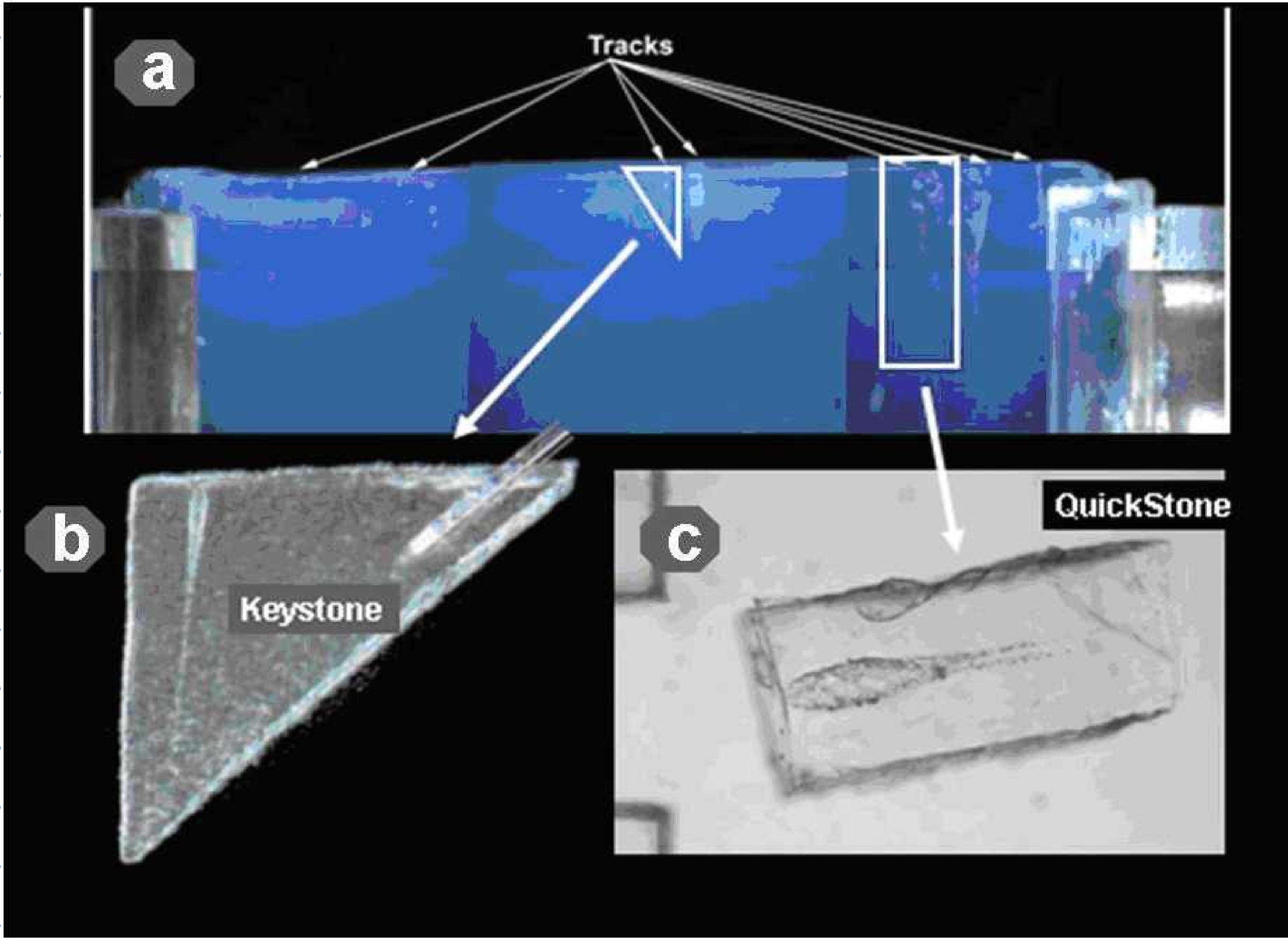




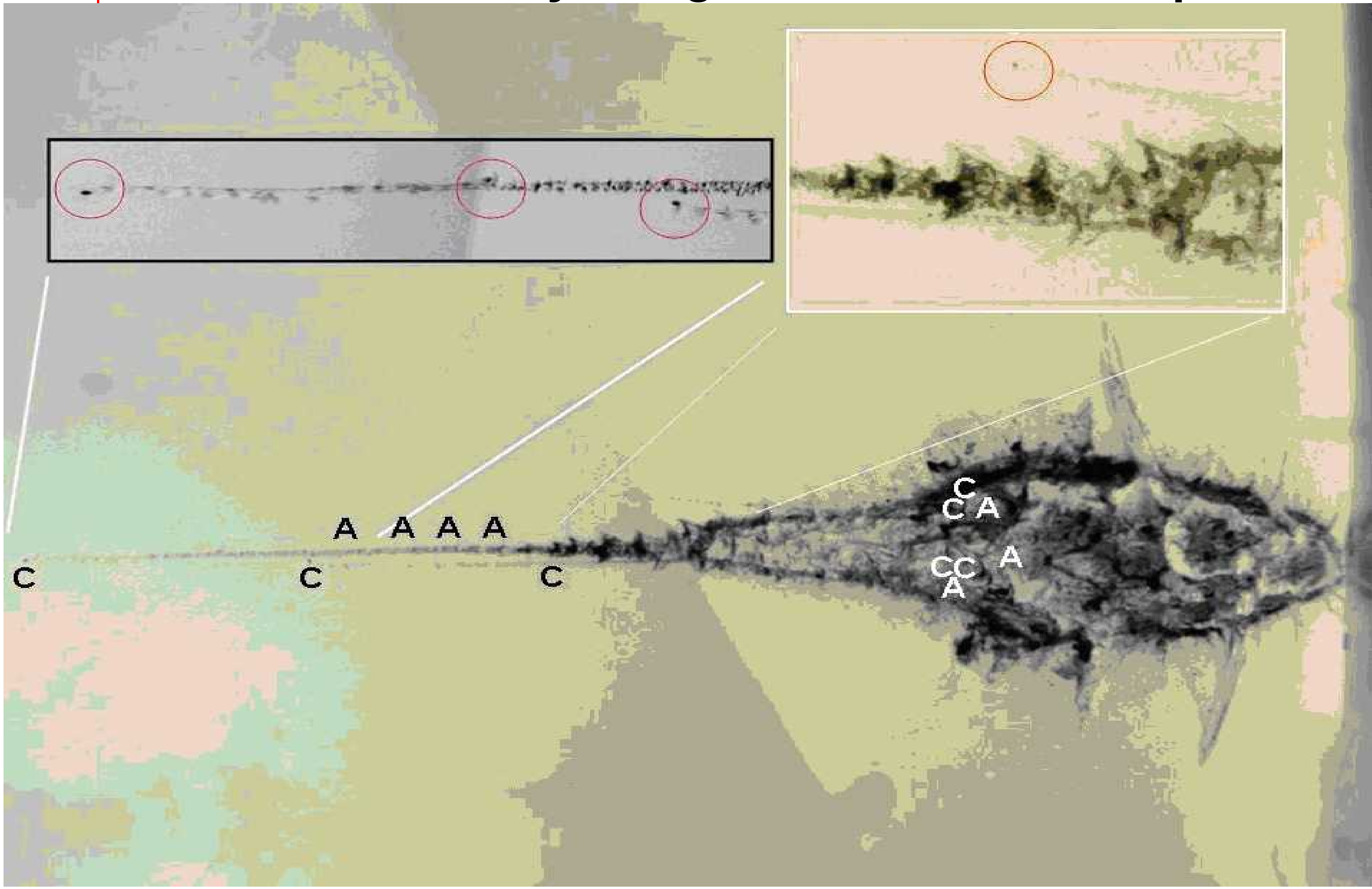
Micro-Ca-Al-Inclusion (T>1500K)

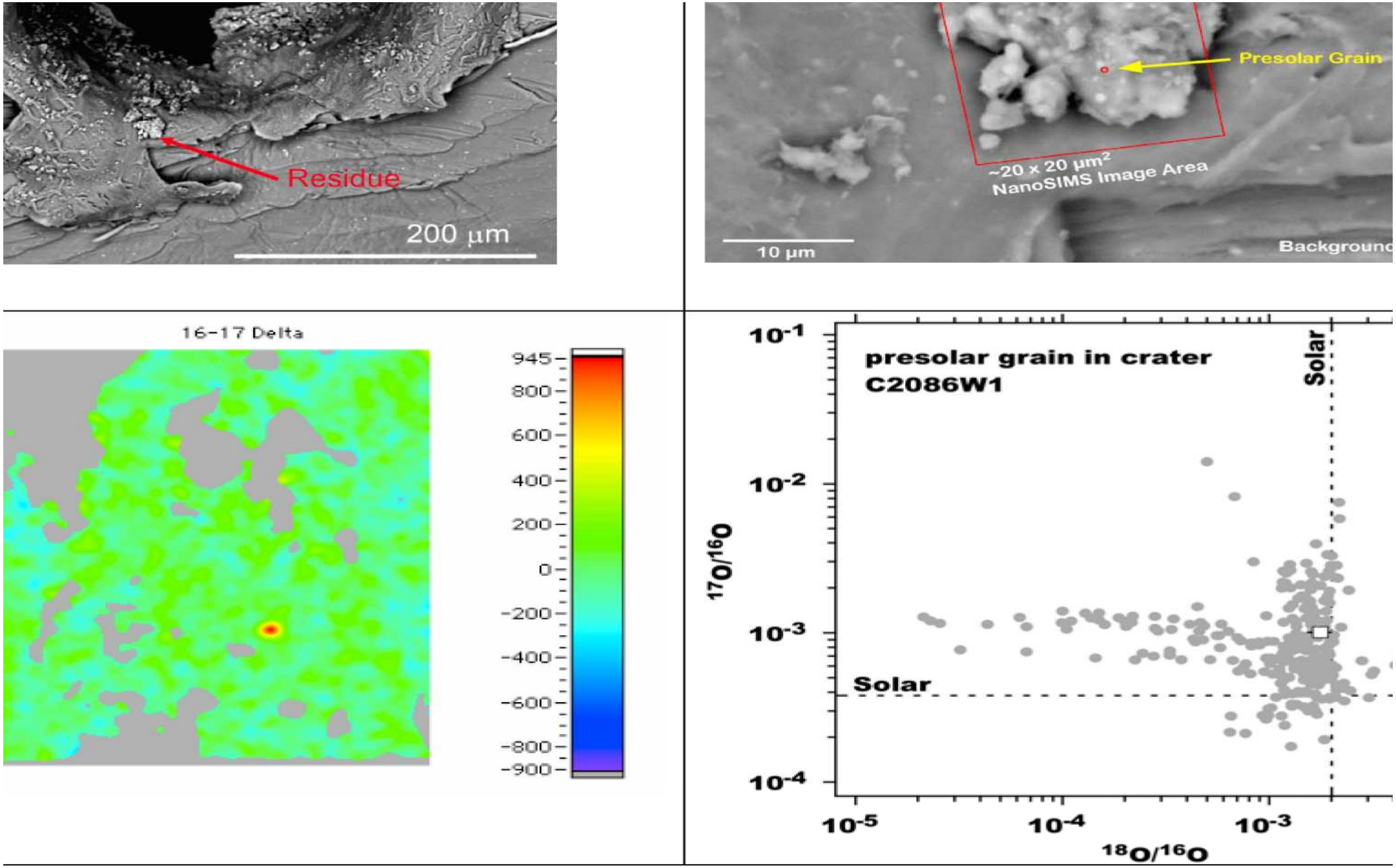


Micro-mining dust from aerogel



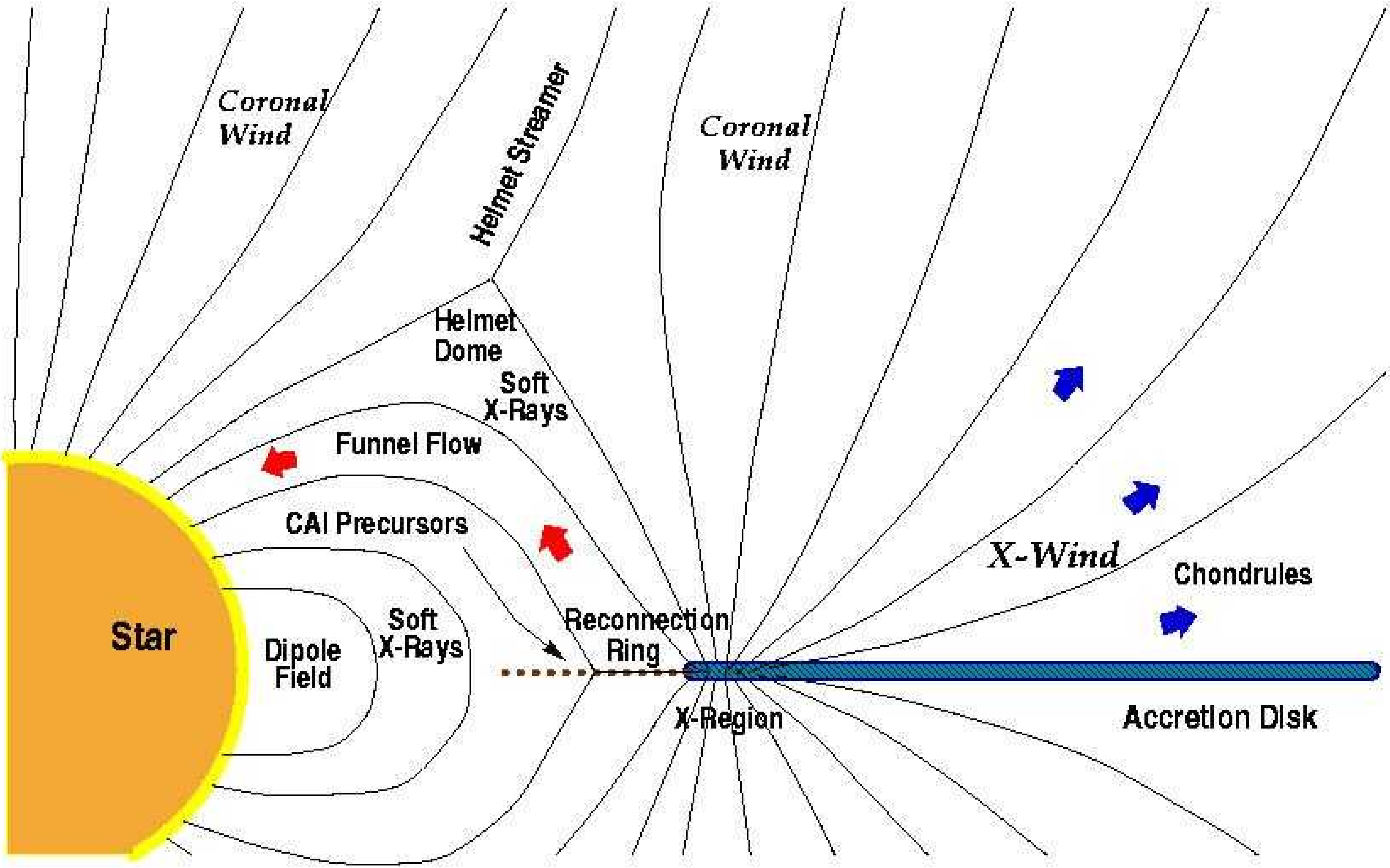
A comet grain entering aerogel from right, leaving a volatization bubble & a track of refractory fragments until stop.



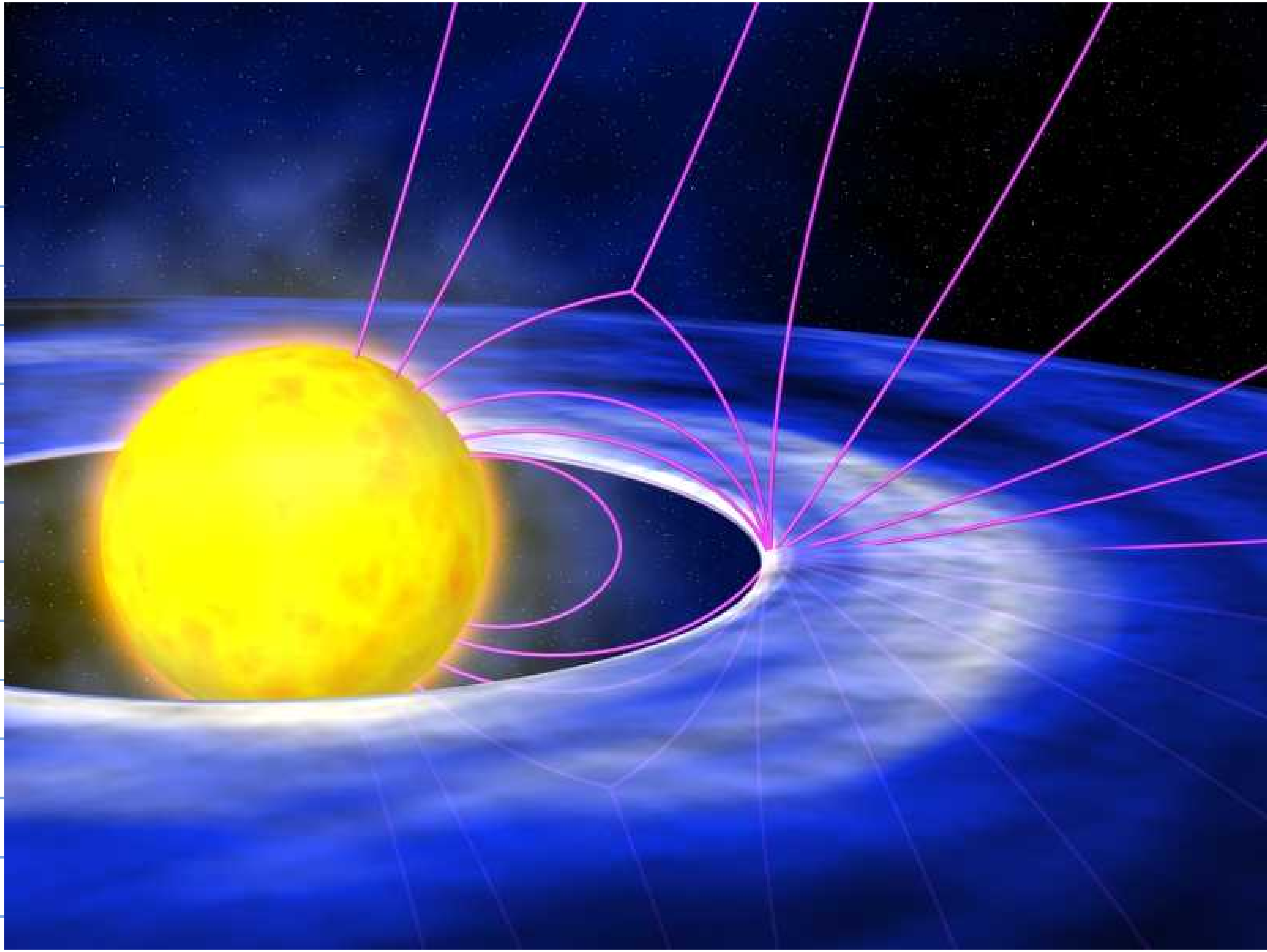


Presolar grain in residue of crater C2086W1. top left: Backscattered electro
crater which punctured Al-foil; top right: electron image of projectile residu
(scale bar = 10 µm); bottom left: 20 × 20 µm false color isotope map of δ^{17}O

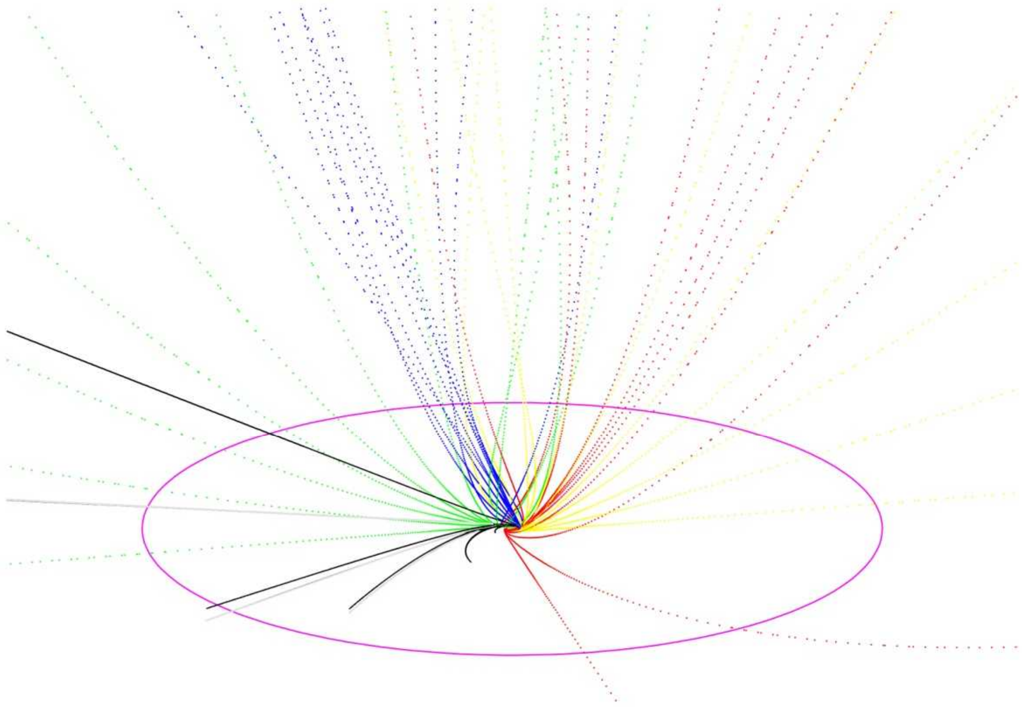
X-wind heats & irradiates solids @ 0.2 AU



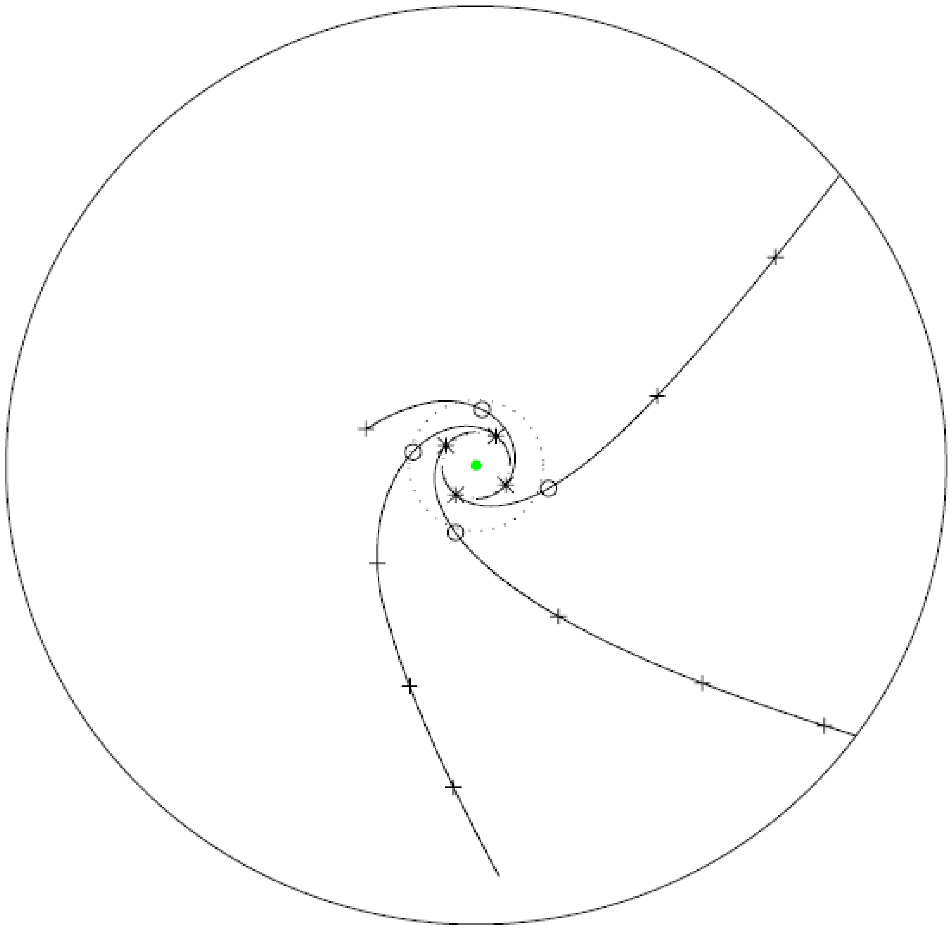
Proto-solar X-wind in 3D *from Mike Cai*

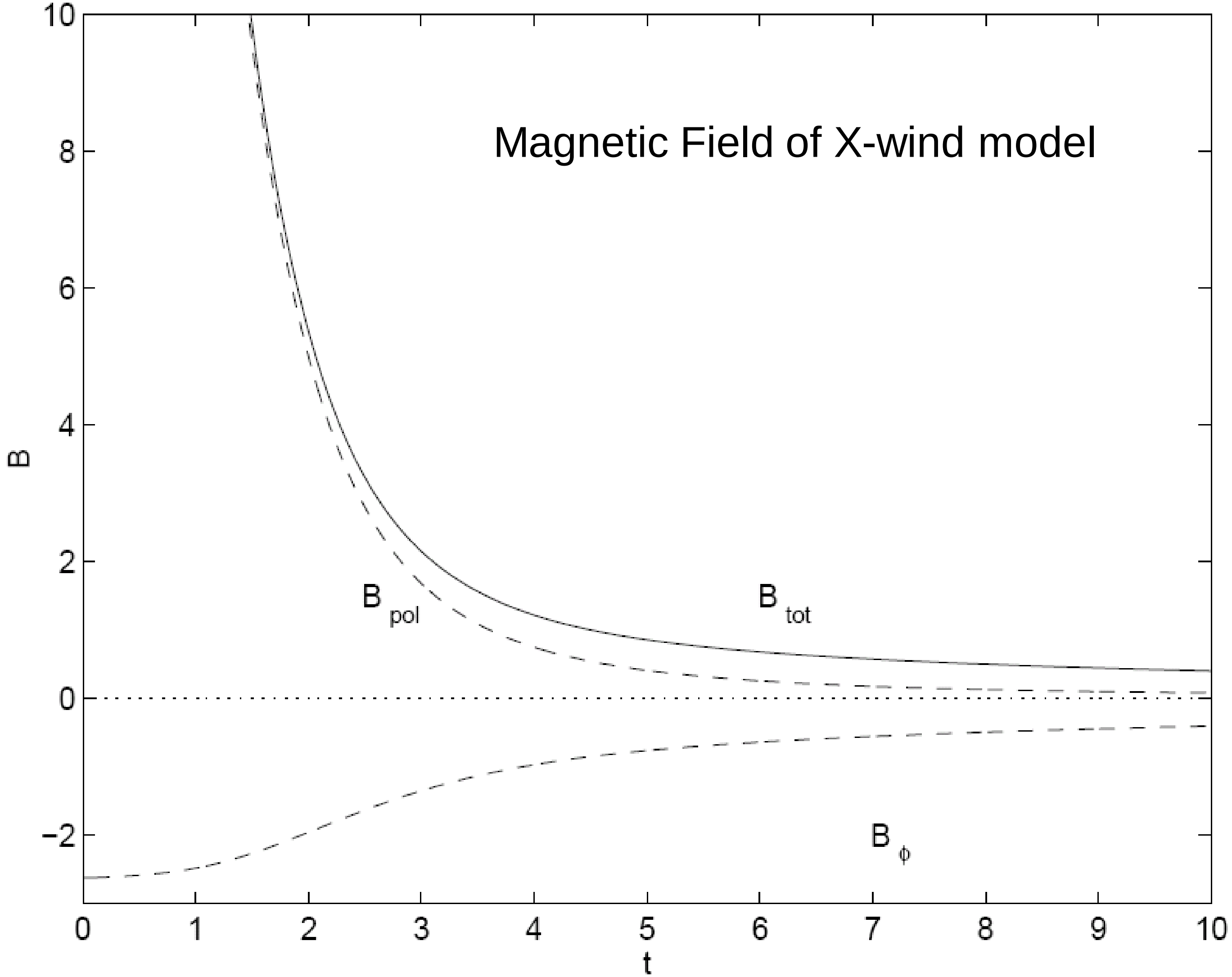


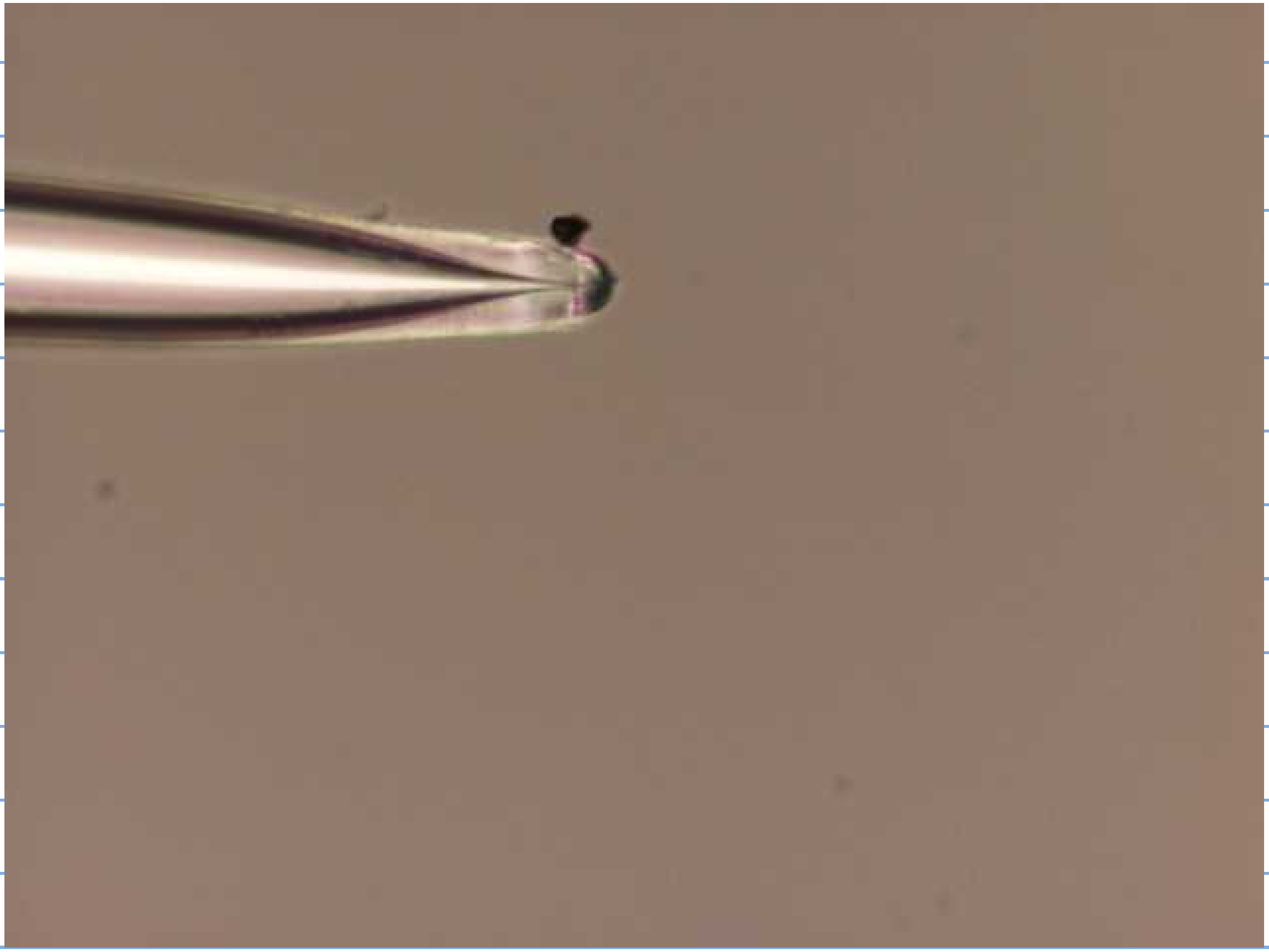
X-WIND CAN SPRAY THE ENTIRE SOLAR SYSTEM WITH HIGH TEMP. PHASES



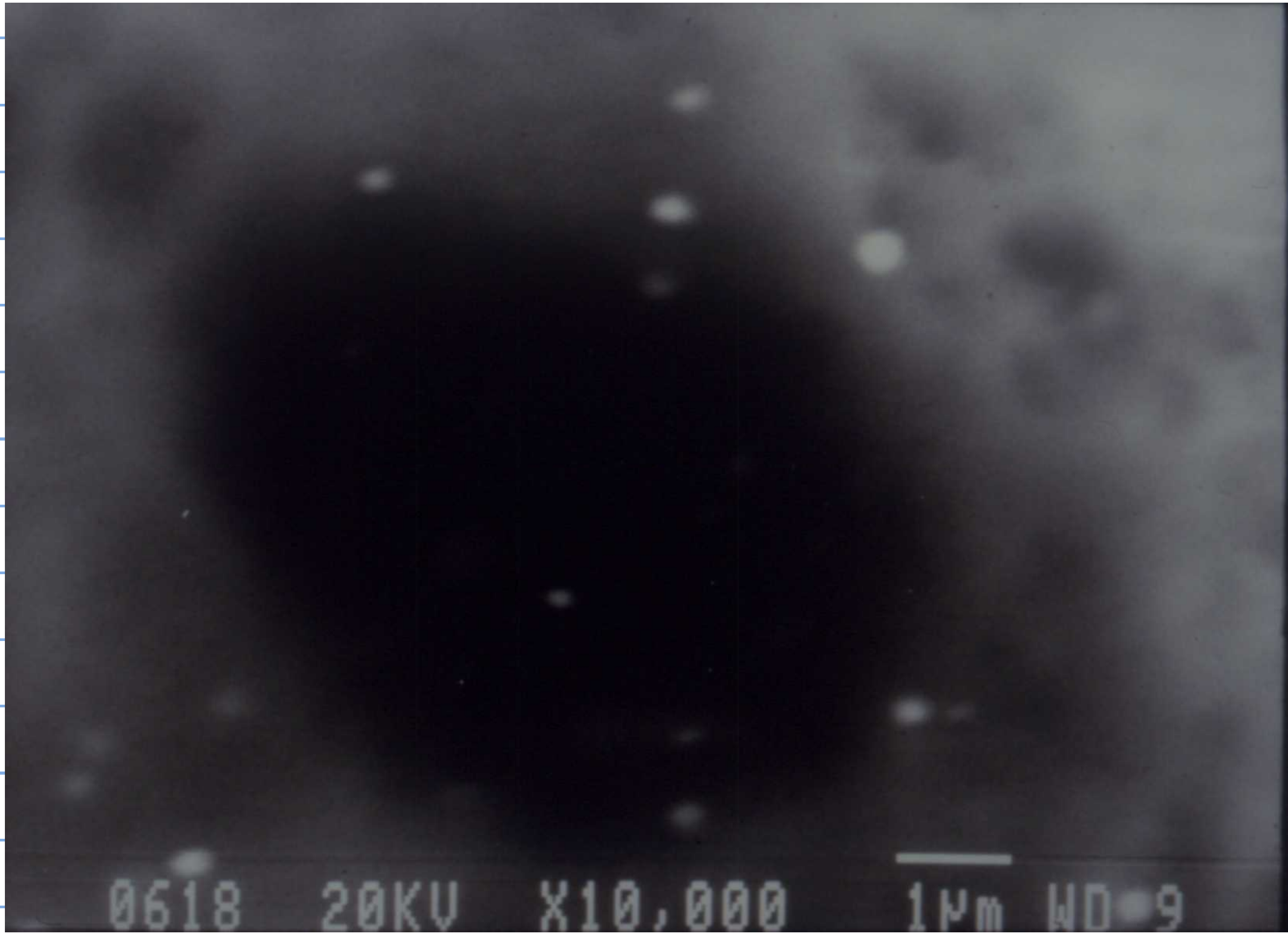
In order to form a 1 Mo sun, X-wind must threw away 0.5 Mo to satisfy angular momentum conservation.




Magnetic Field of X-wind model
B
t
B pol
B tot
B ϕ
10
8
6
4
2
0
-2
0
1
2
3
4
5
6
7
8
9
10



TiN seeds in a graphite stardust condensation nuclei in AGB atm.?

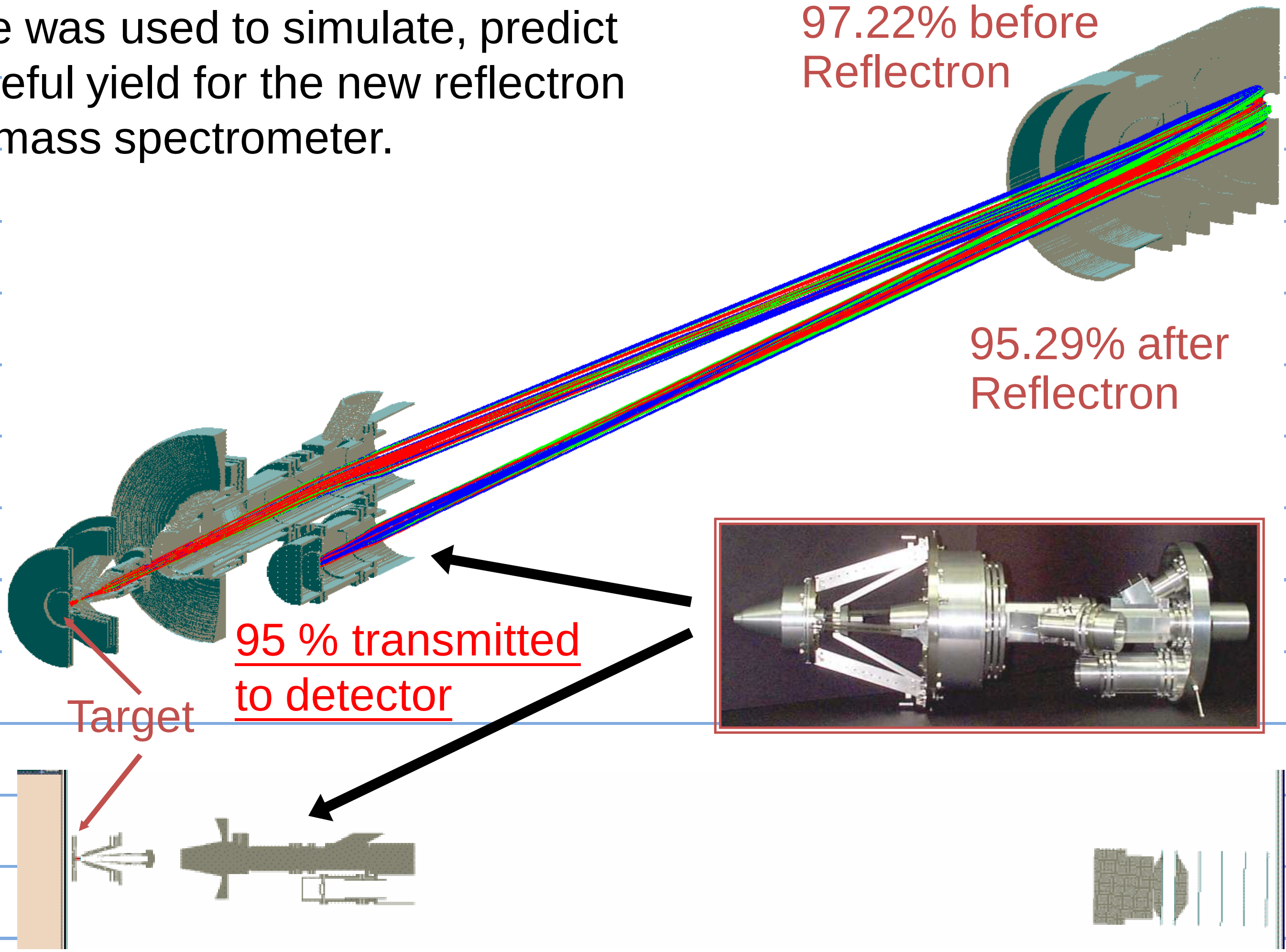


What is DustBuster?

- **A Post UV Non-Resonant Laser Ionization Secondary Neutral Time of Flight Mass Spectrometer (PLI-TOF-SNMS)**
- **Initiated by NASA Stardust Mission**
- **Built by the design of Argonne National Laboratory**

Simulating a New Instrument Design

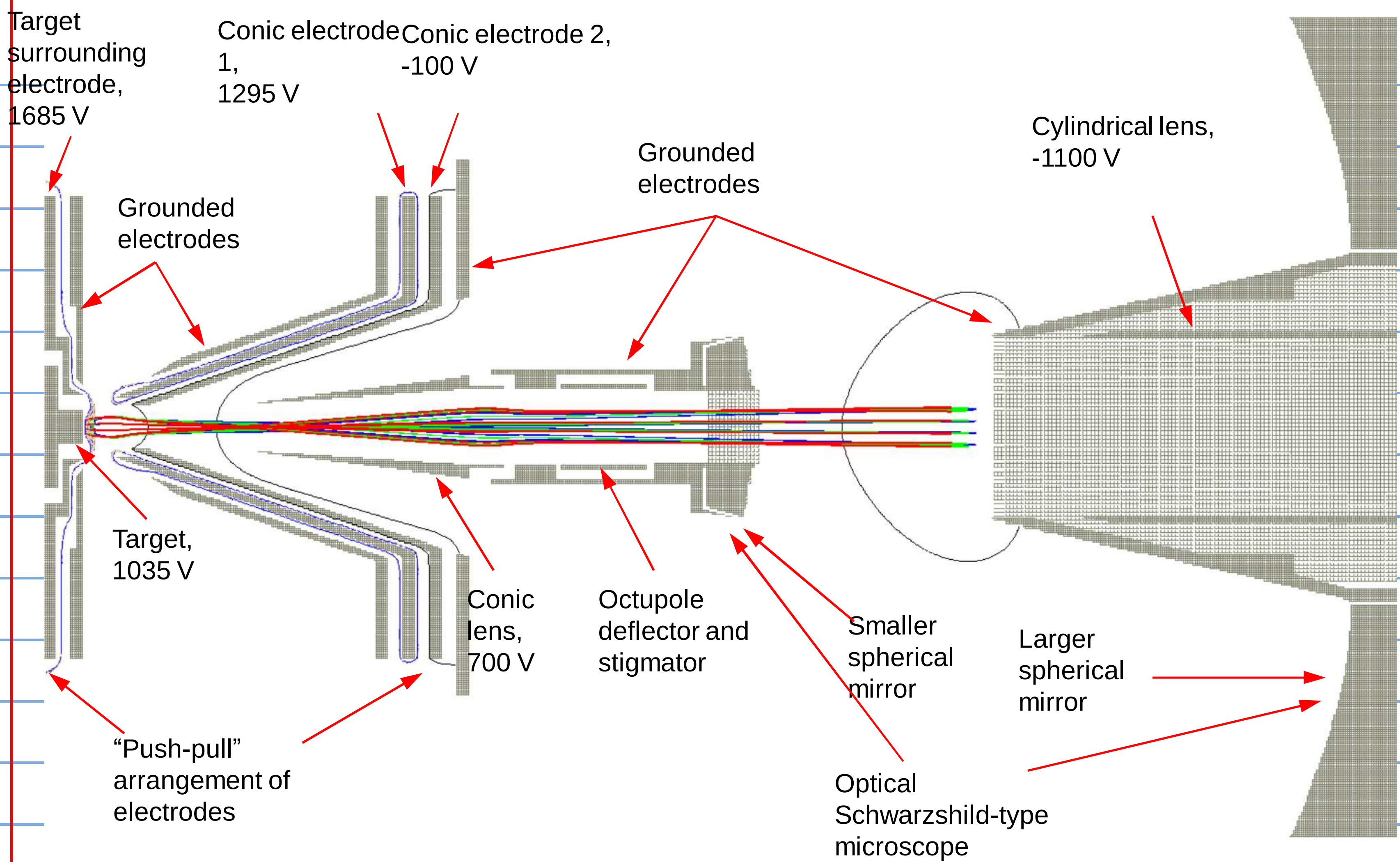
- 3D SIMION software was used to simulate, predict transmission and useful yield for the new reflectron time-of-flight (TOF) mass spectrometer.



Photoionization volume
$4x4x3\ mm^3$

Distance to target
0.5 mm

“Push-Pull” Extraction Ion Optics and Schwarzschild microscope



DustBuster