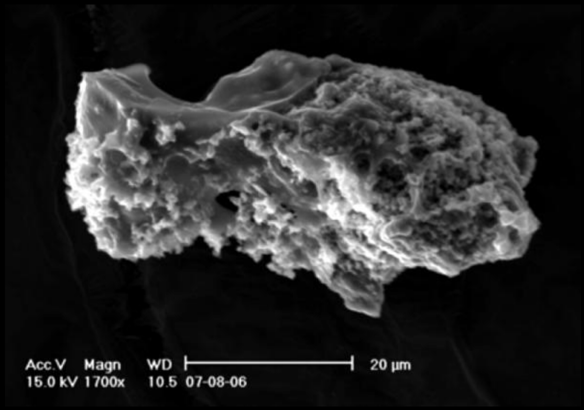


Giacomo Briani
Cécile Engrand, Jean Duprat, Elena Dobrică

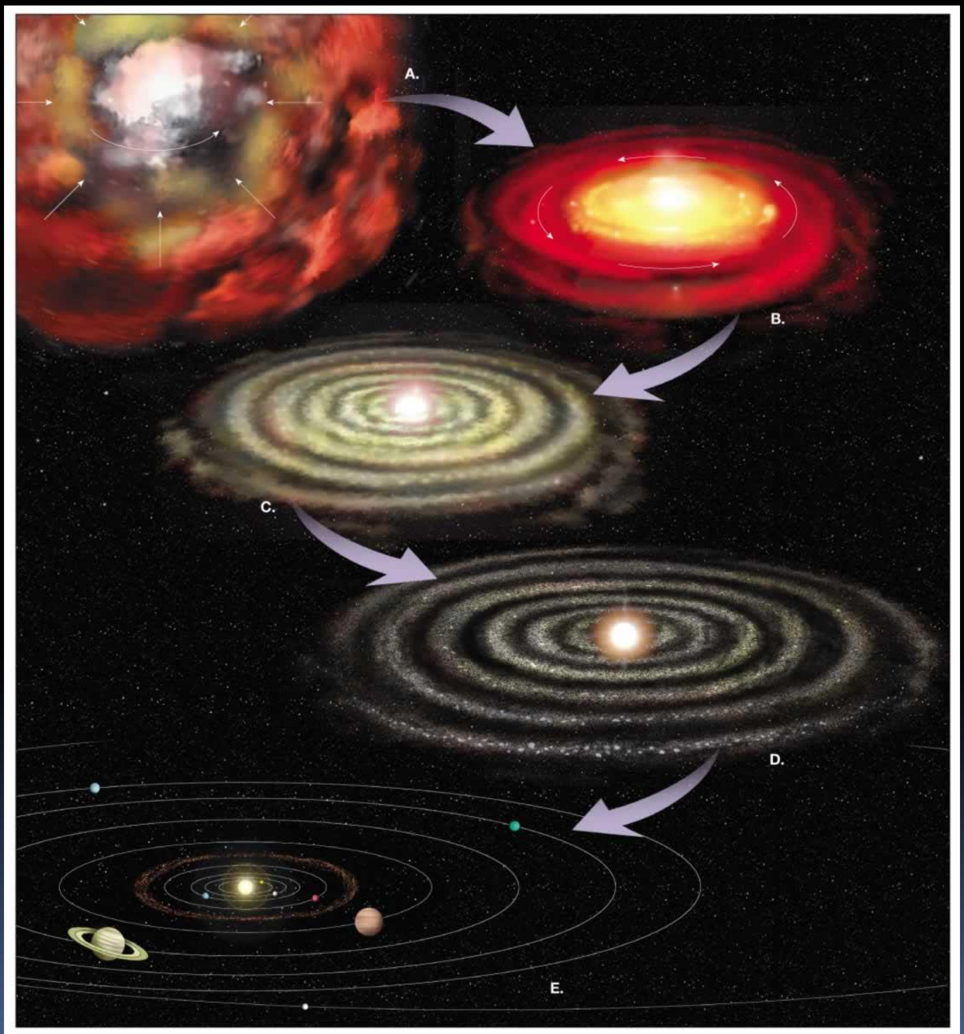
Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse
Université Paris Sud – CNRS

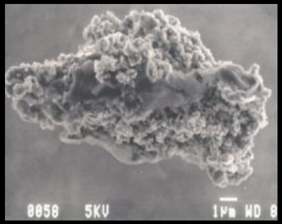
ULTRACARBONACEOUS ANTARCTIC MICROMETEORITES: A NEW WINDOW ON THE SOLAR SYSTEM ORIGIN

Plan

- The protoplanetary disk
- Micrometeorites
- The CONCORDIA collection
- Ultracarbonaceous micrometeorites
  - principal properties
  - cometary origin
  - a new window on the protoplanetary disk

Solar system formation





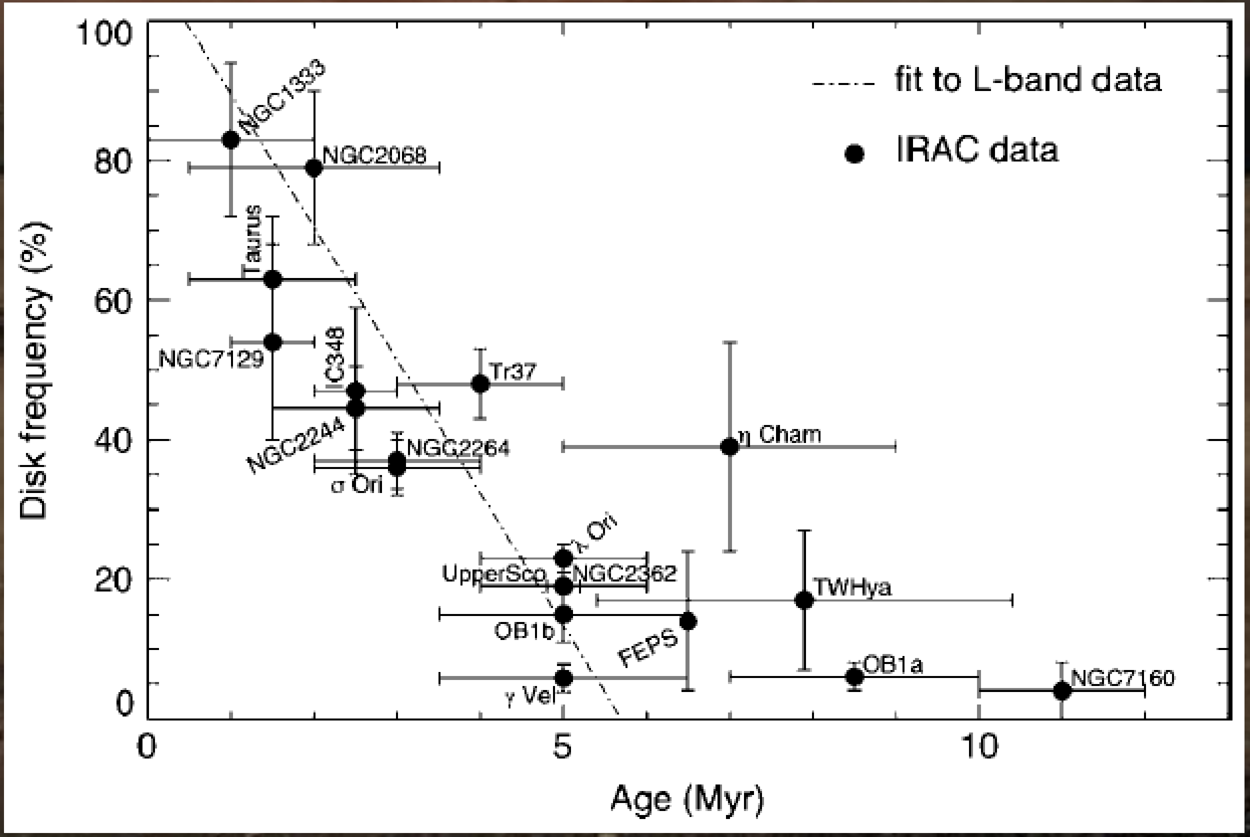
dust grains

undifferentiated planetesimals

differentiated planetesimals

planets

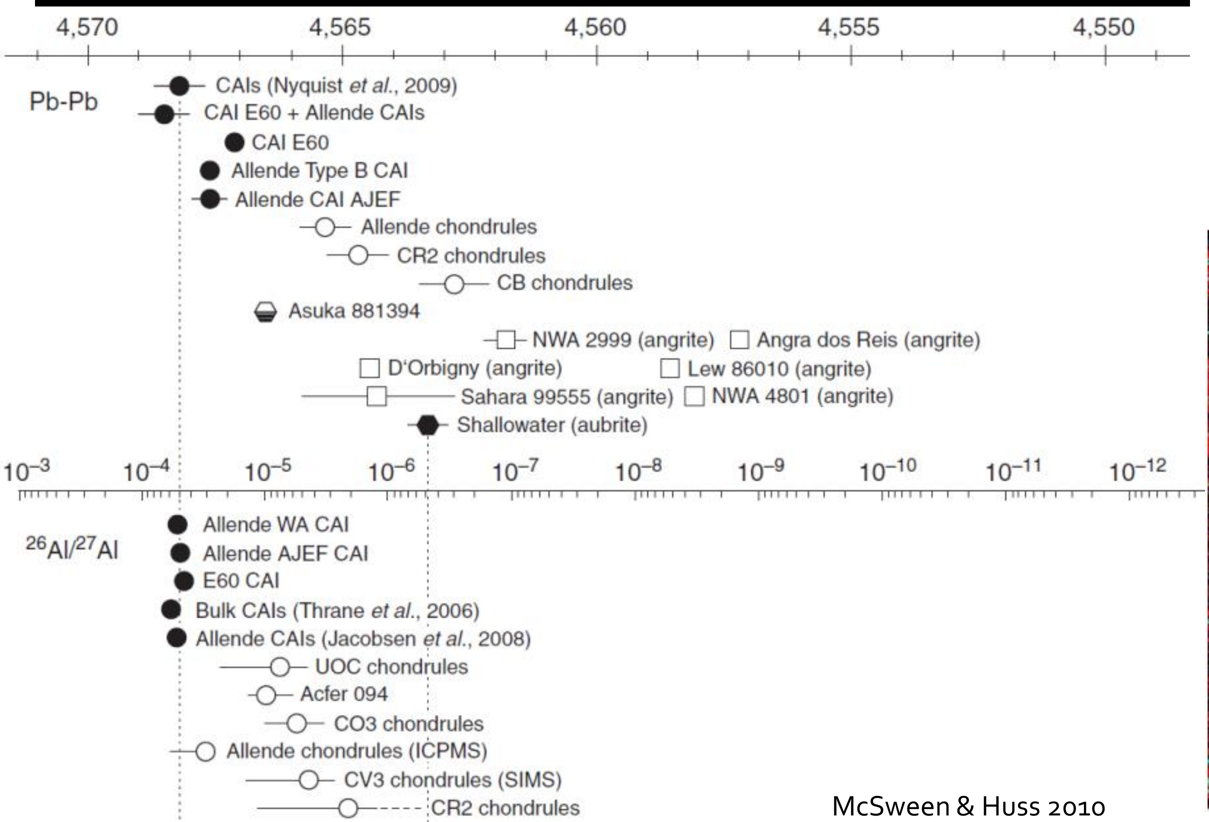
The first 10 Myr: astrophysics



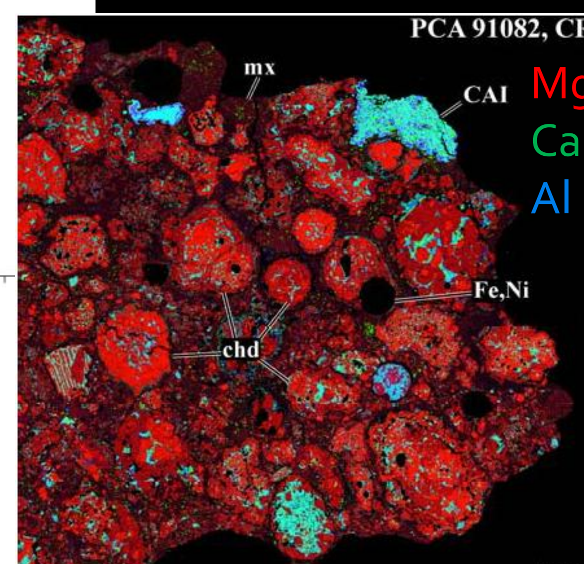
The first 10 Myr: cosmochemistry

First solids in the solar system:
CAIs and chondrules

NWA 2086

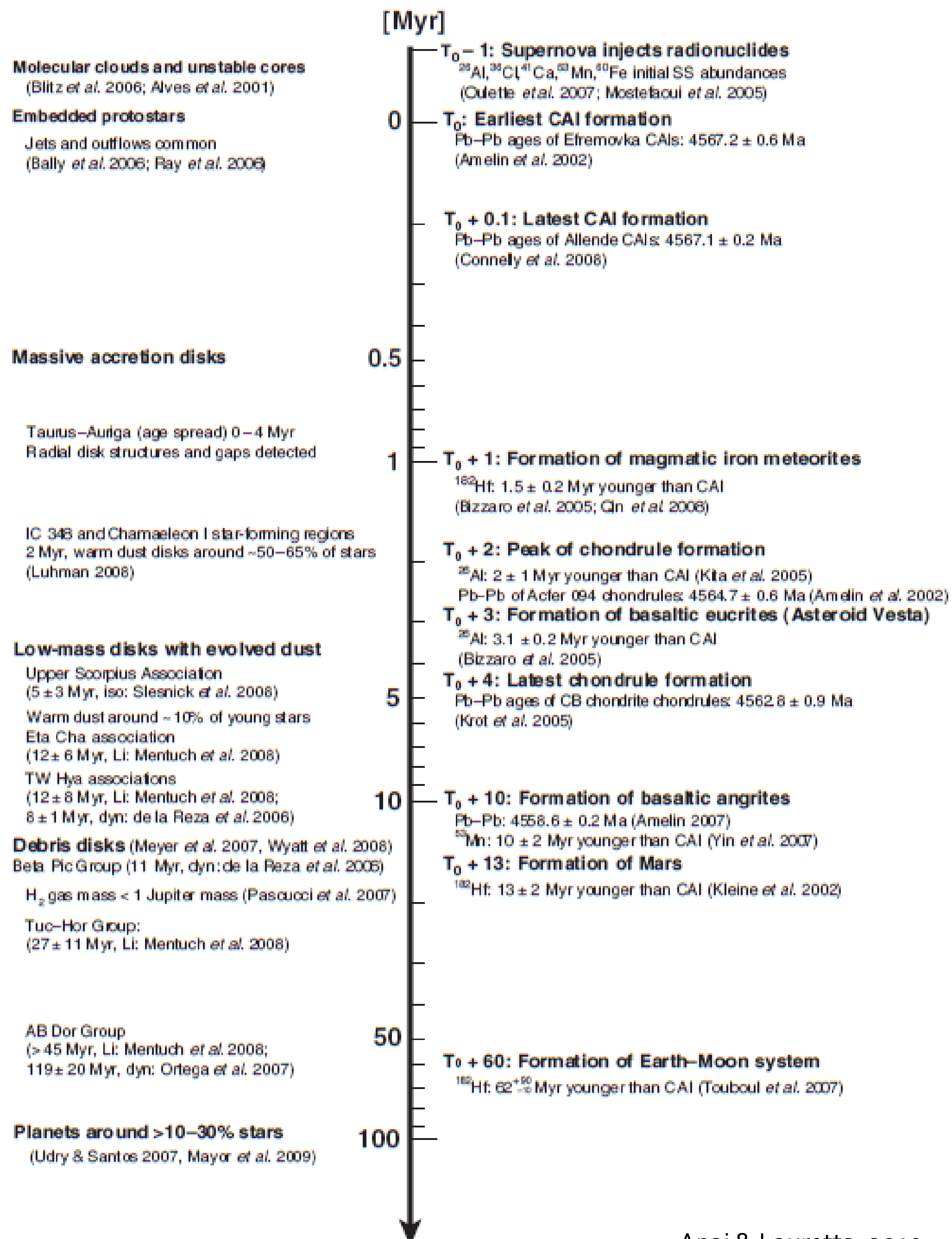


McSween & Huss 2010



Krot et al. 2009

Chronology of planet formation



Apai & Lauretta, 2010

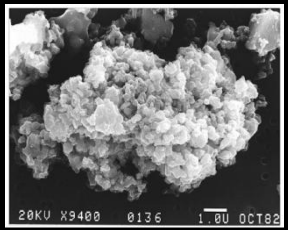
What are micrometeorites

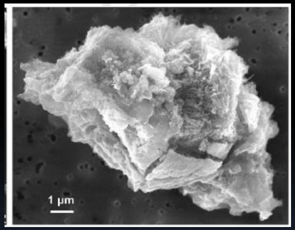
Zodiacal cloud particles accreted by the Earth

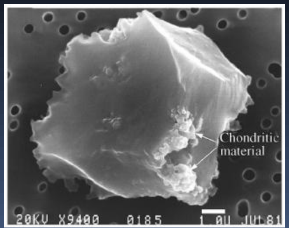
IDPs

Micrometeorites

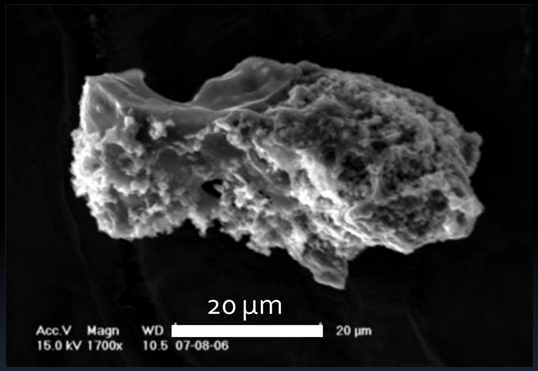
Meteorites







Bradley, 2005

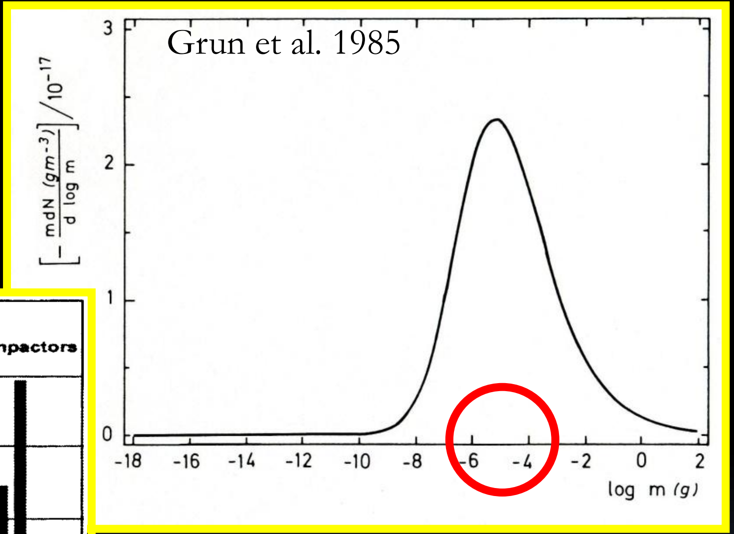


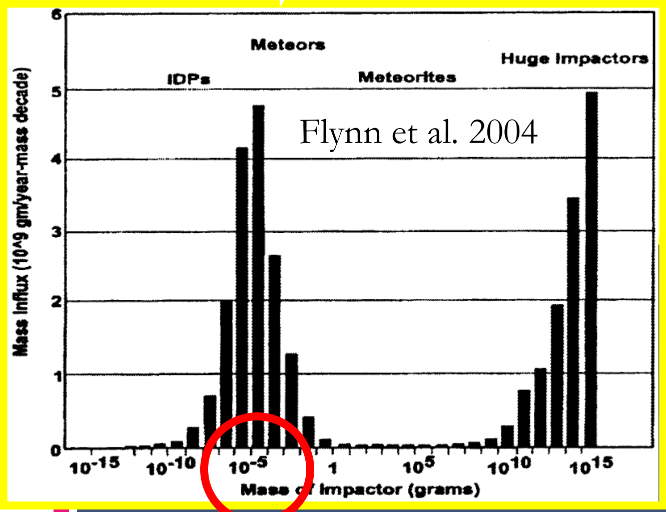
Paris (CM)

5 cm

Micrometeorites in the solar system

mass distribution in the inner solar system





Micrometeorites in the solar system

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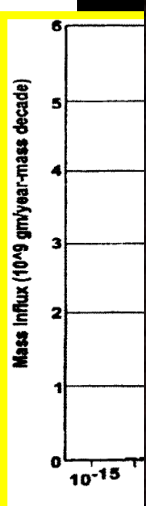
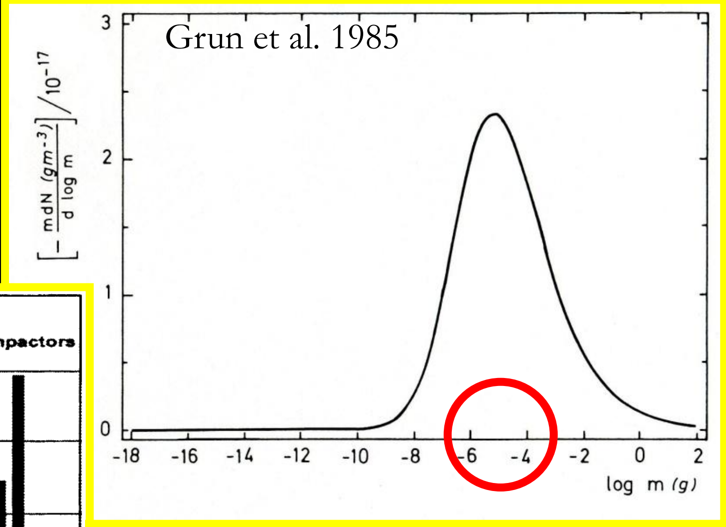
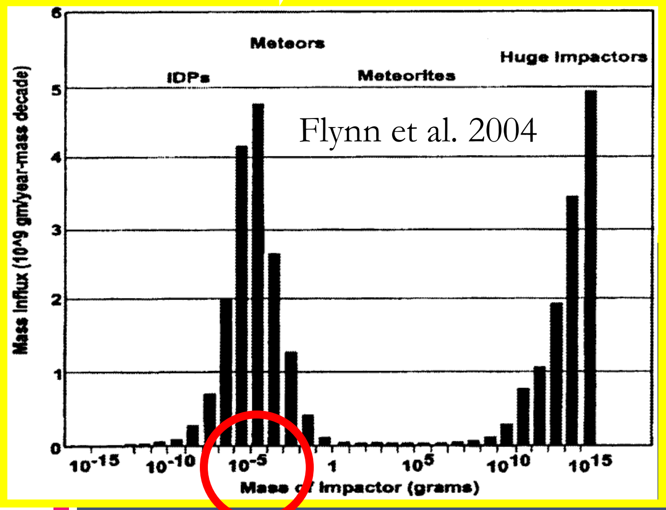


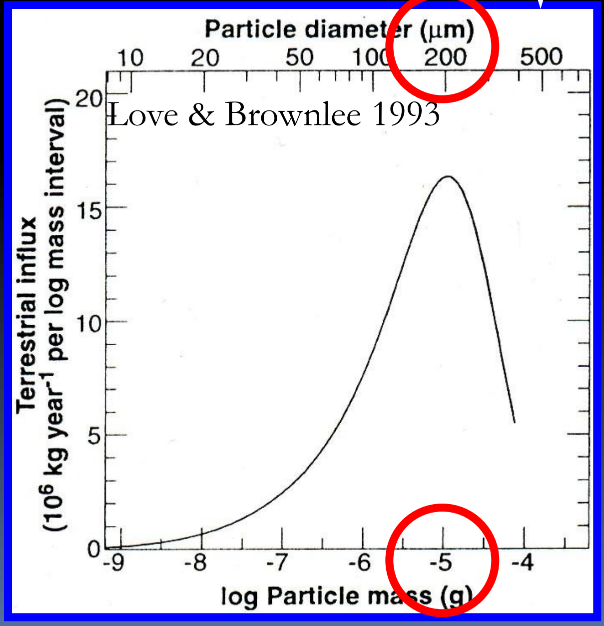
Micrometeorites in the solar system

mass distribution in the inner solar system





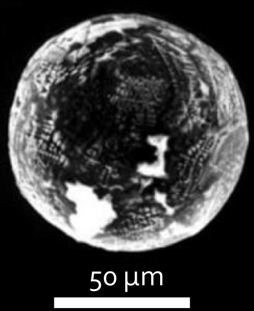
ET matter entering the Earth atmosphere



Micrometeorites

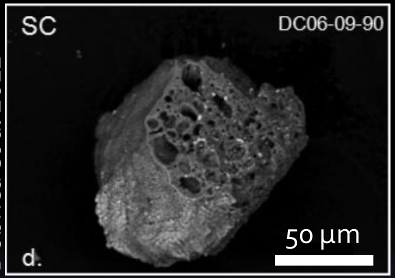
Classification :
effects of the interaction with the Earth's atmosphere

Genge 2008



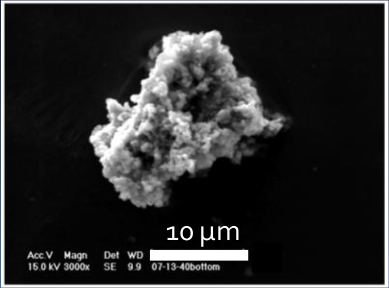
totally melted micrometeorites
cosmic spherules

Dobrica et al 2011

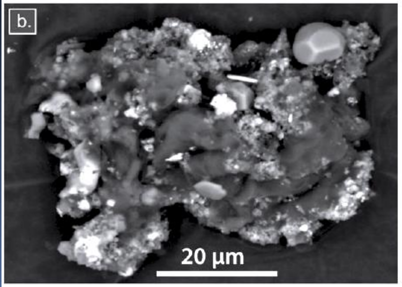


partially melted micrometeorites:
scoriacous micrometeorites

Dobrica et al. 2008

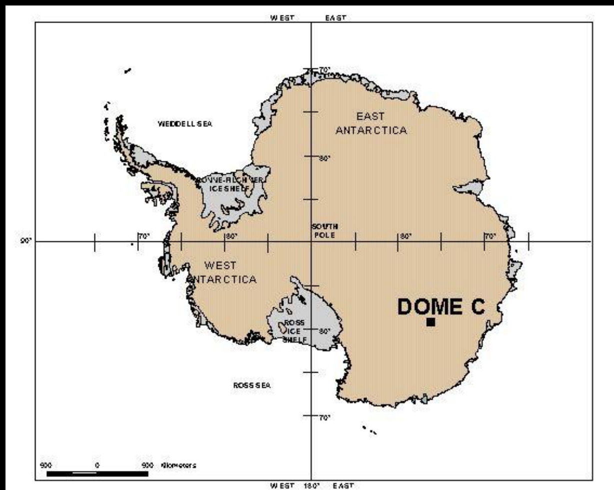


Dobrica et al. 2012



unmelted
micrometeorites

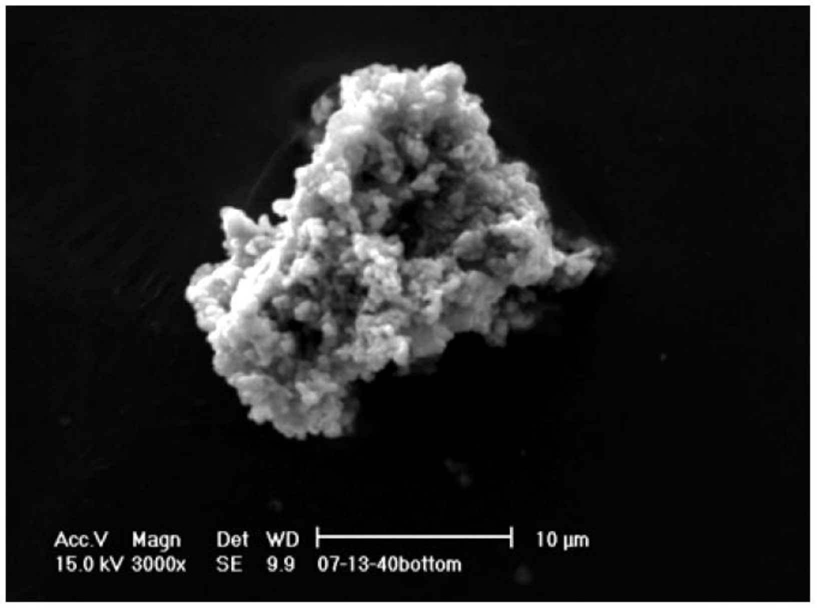
Dome C - Concordia



Duprat et al., 2007

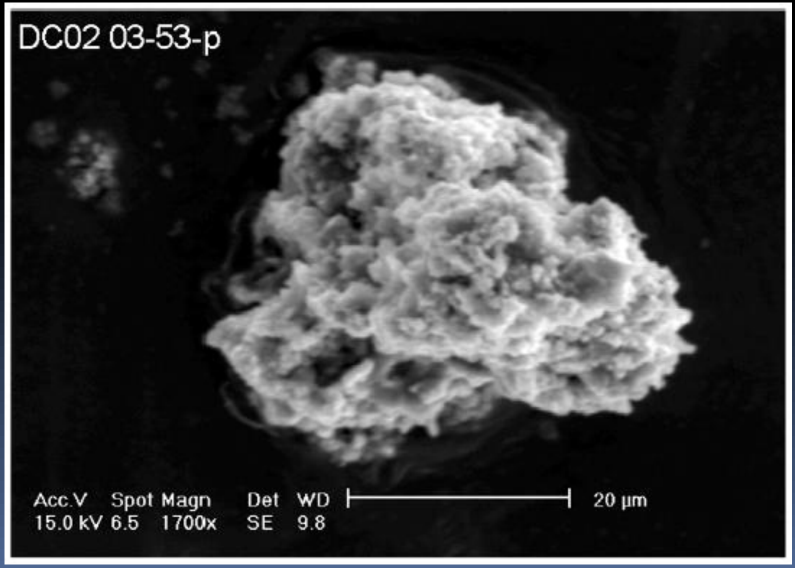
- 1100 km from the coast (S 75°, E 123°)
- no terrestrial dust thanks to catabatic winds
- collection in surface snow (down to 4 m depth)
- snow isolated from the bedrock by >3 km of ice
- no terrestrial aqueous alteration
- snow melting: 1 – 20 hours

Fine-grained fluffy micrometeorites



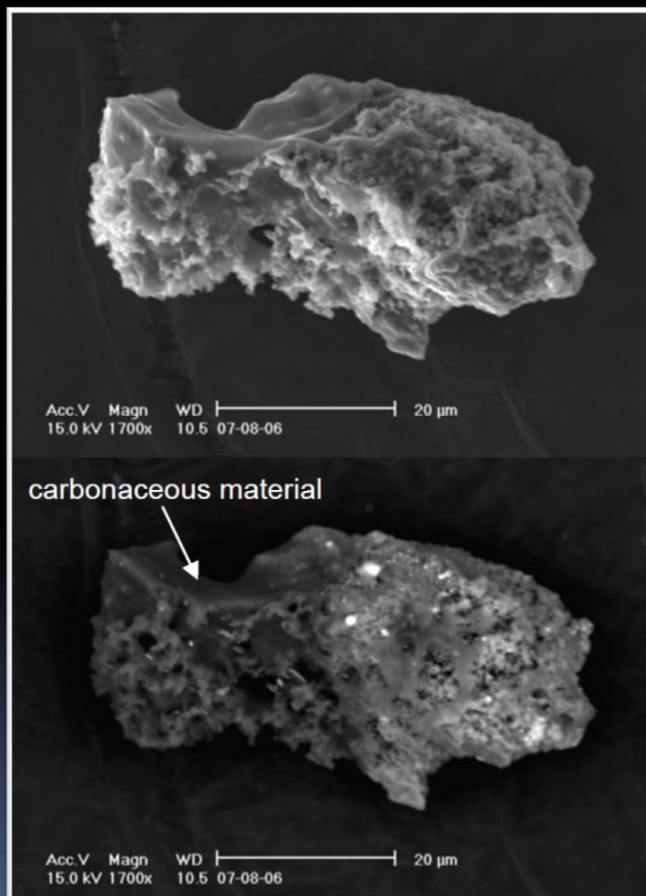
Dobrica et al. 2008

Duprat et al. 2007

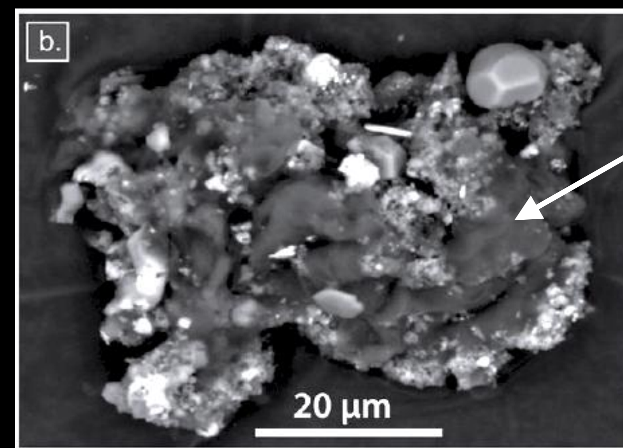


UCAMMs

Rare micrometeorites: 2% of the CONCORDIA collection



Dobrica et al 2008



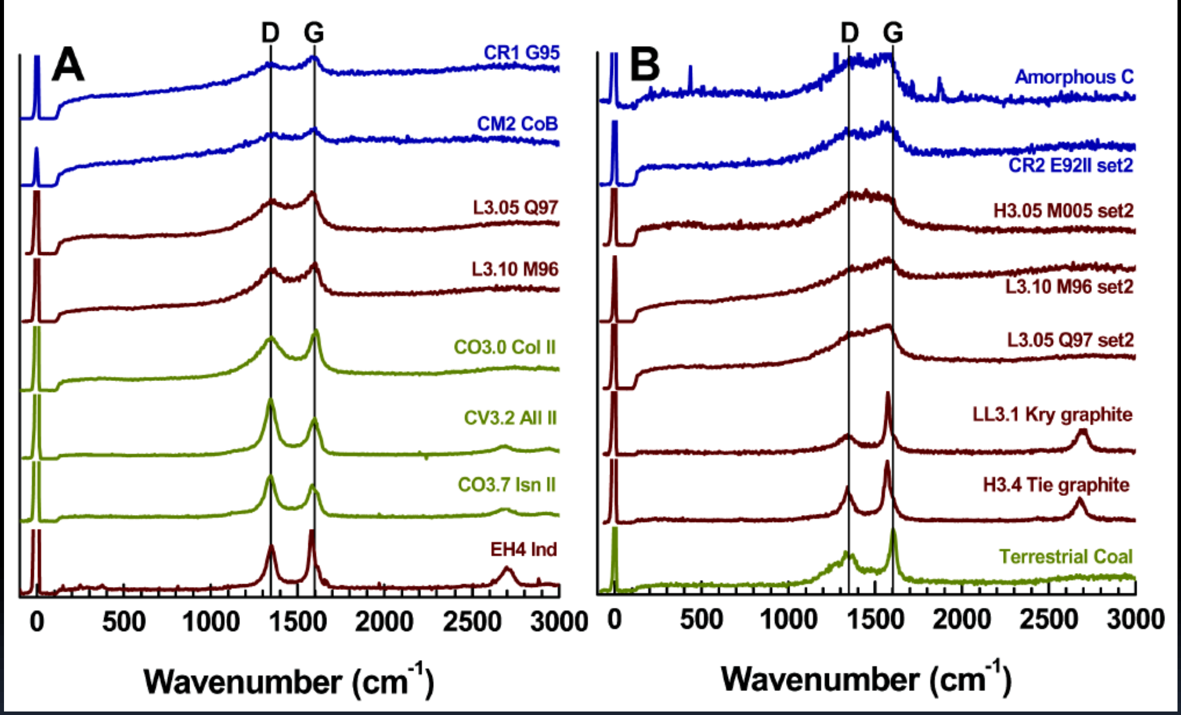
carbonaceous material

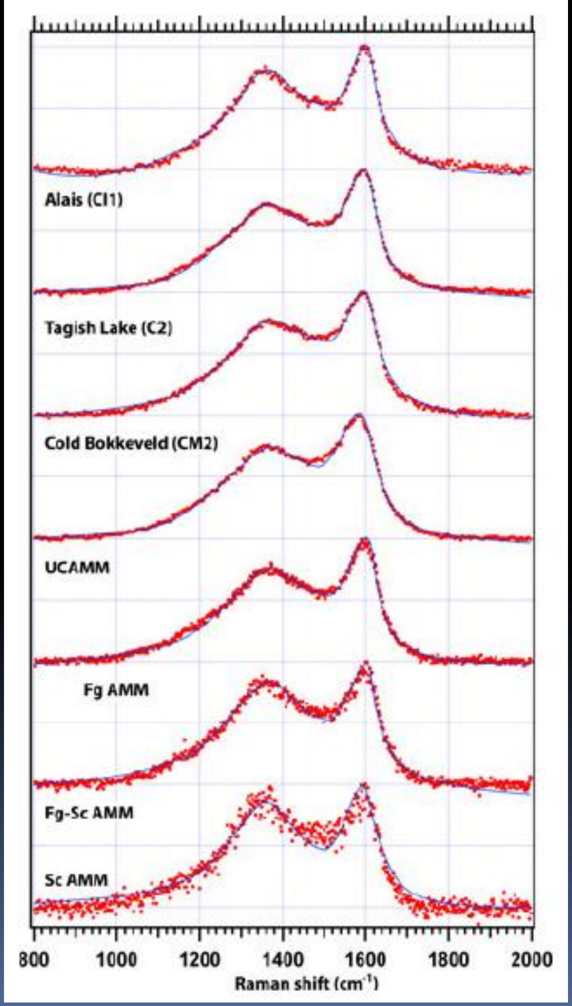
Dobrica et al 2012

Carbon content
up to 80% in volume.

UCAMMs

Unmetamorphosed organic matter

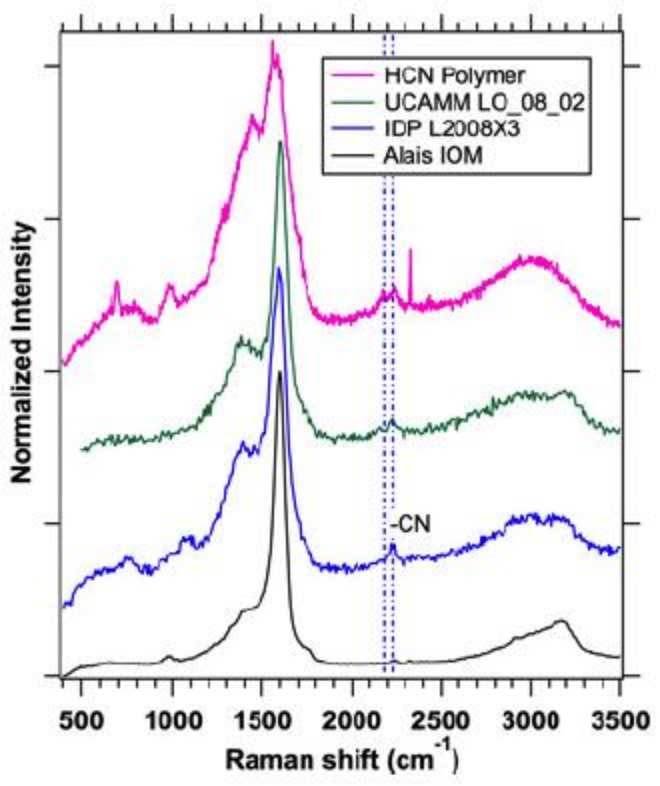




Dobrica et al 2011

UCAMMs

Raman spectroscopy of carbonaceous matter



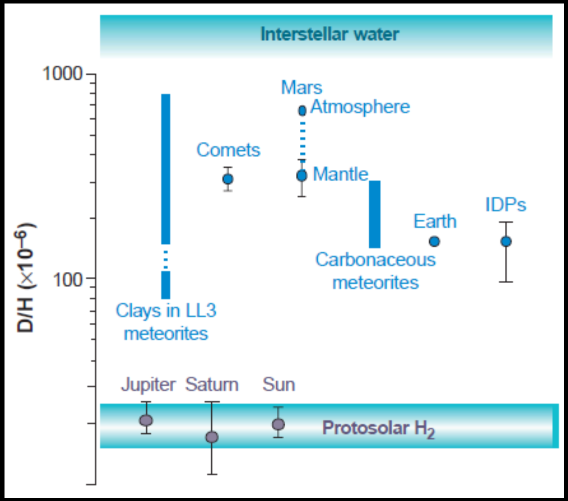
Dobrica et al. 2011

- Observation of the cyanide (-CN) functional group
- Cyanides commonly observed in ISM and comets
- Low abundances in chondritic organic matter

➢ UCAMMs avoided hydrothermal alterations

UCAMMs

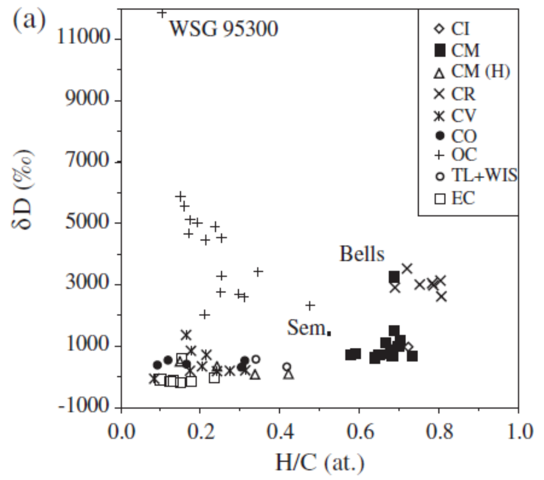
Hydrogen isotopic composition



Robert 2001

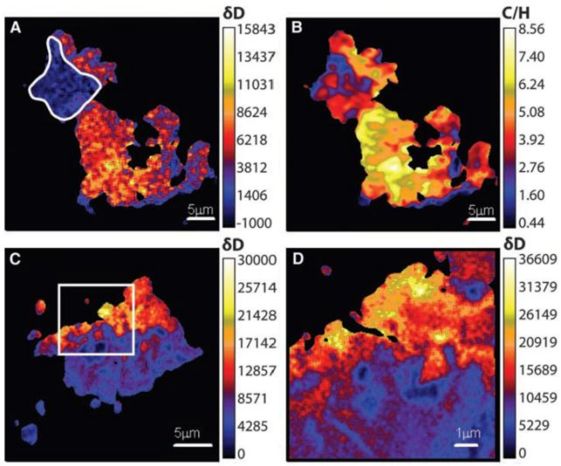
$D/H_{SMOW} = 1.5 \times 10^{-6}$

$$\delta D = \left(\frac{D/H}{D/H_{SMOW}} - 1 \right) \times 1000$$



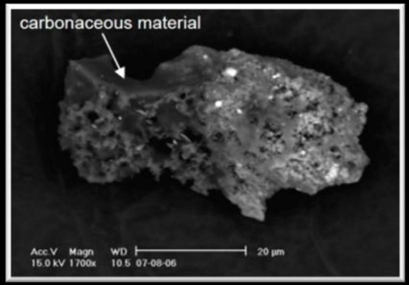
Alexander et al 2010

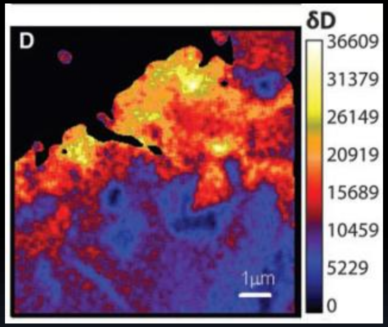
Duprat et al 2010



UCAMMs

Possible cometary origin

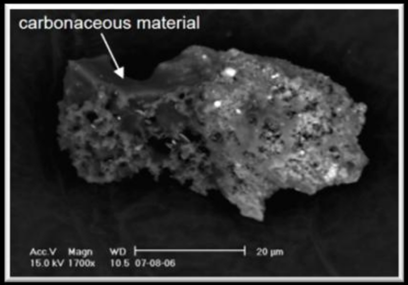


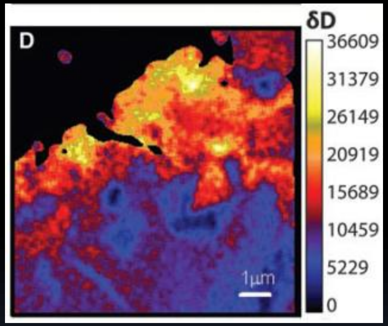


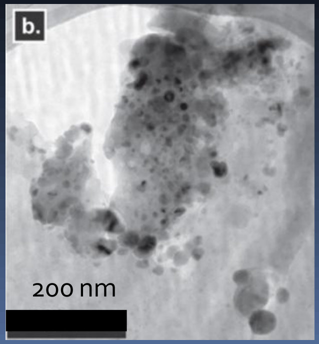
- High carbon content
- Unmetamorphosed carbonaceous matter
- Detection of the –CN group
- High D enrichments

UCAMMs

Possible cometary origin





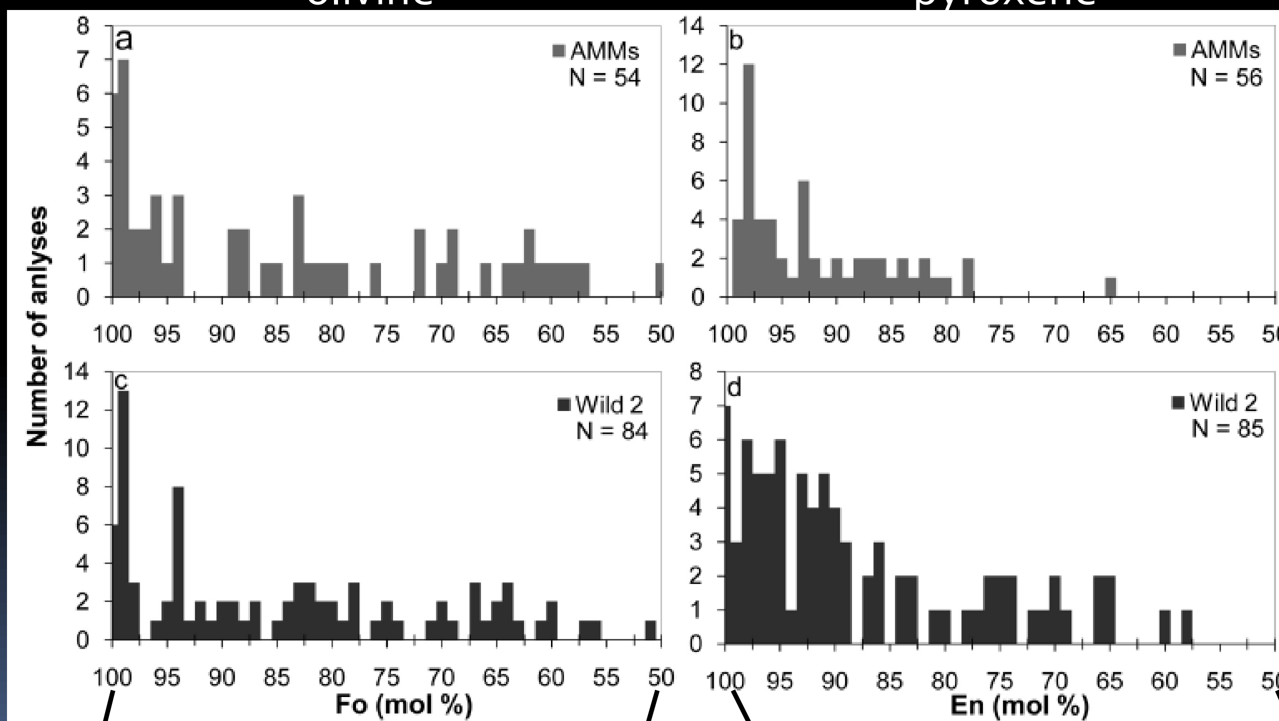


- High carbon content
- Unmetamorphosed carbonaceous matter
- Detection of the –CN group
- High D enrichments
- Anhydrous mineralogy
- GEMS-like inclusions

UCAMMs

Mineralogy dominated by olivine and pyroxene, phyllosilicate content < 1%.

olivine pyroxene

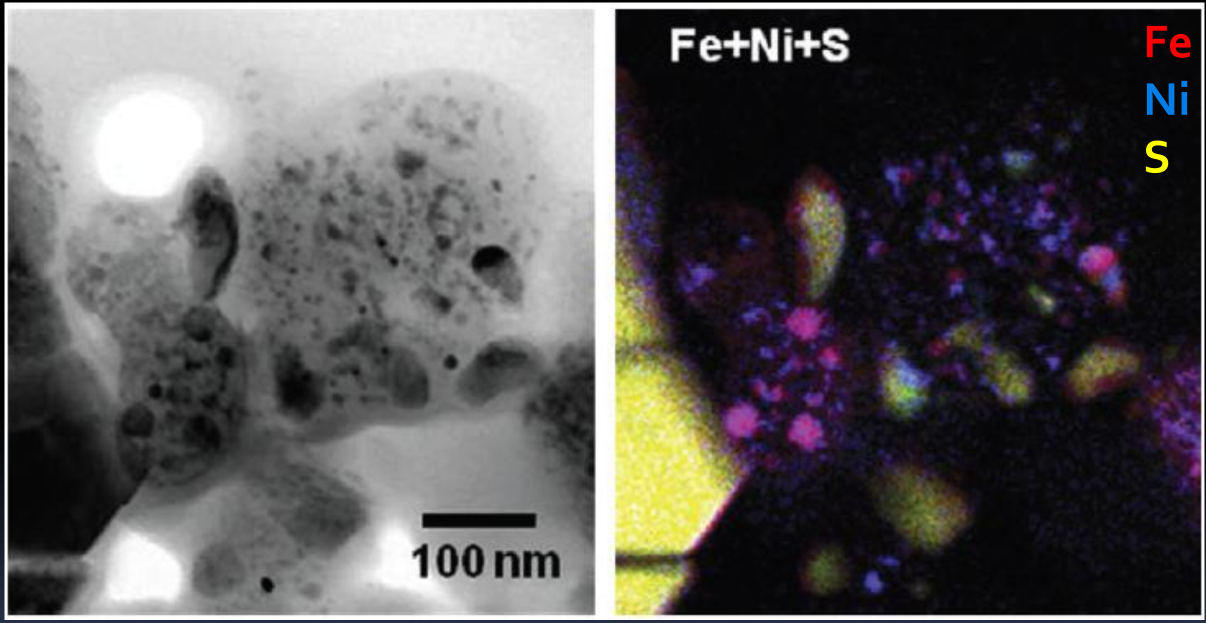


Dobrica et al. 2009

Mg_2SiO_4 $(Mg,Fe)_2SiO_4$ $MgSiO_3$ $(Mg,Fe)SiO_3$

UCAMMs

GEMS
Glass with Embedded Metals and Sulfides

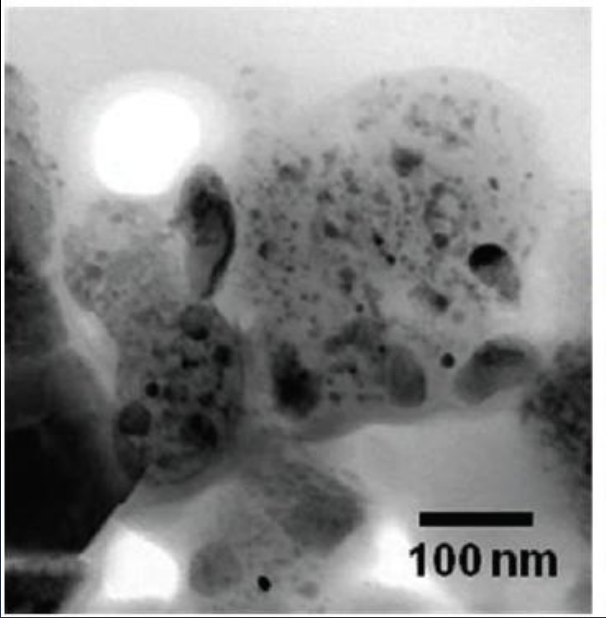


Keller & Messenger 2011

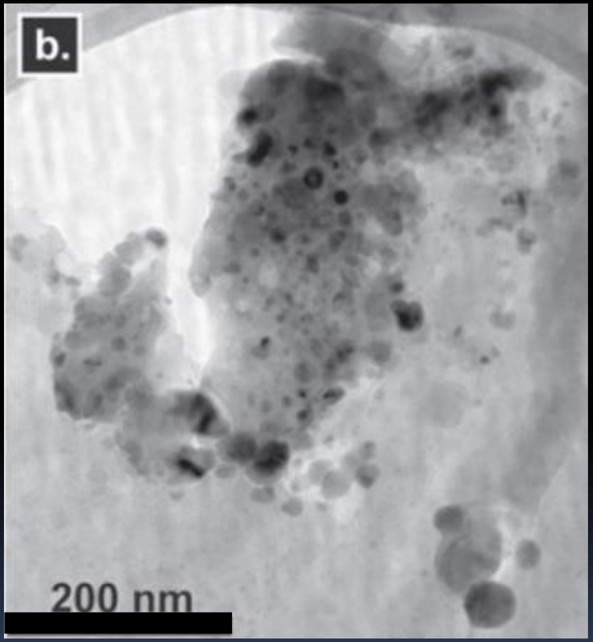
GEMS may account for as much as half of the mass of some IDPs

UCAMMs

GEMS
Glass with Embedded Metals and Sulfides



Keller & Messenger 2011

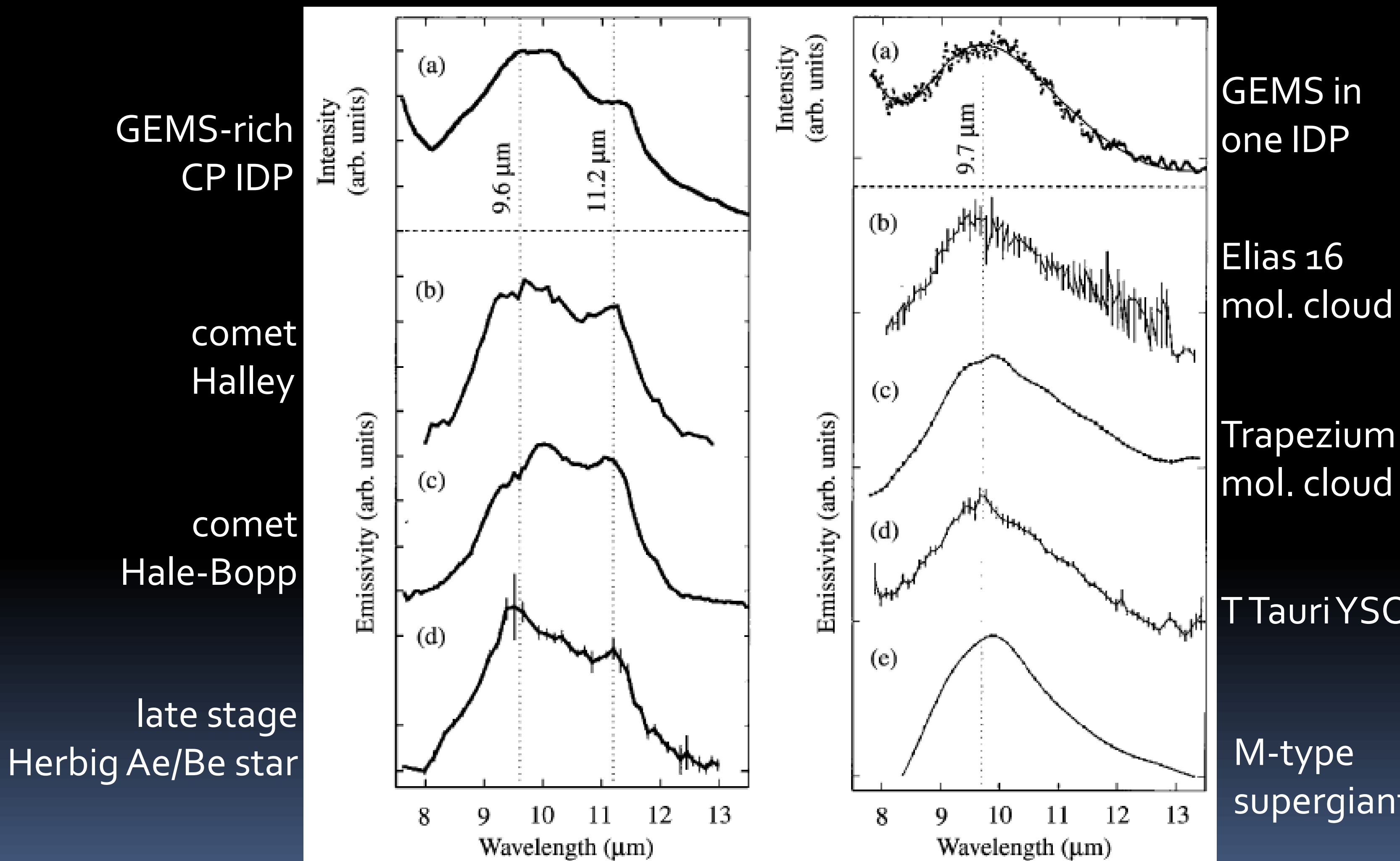


Dobrica et al. 2012

GEMS have been detected in UCAMMs, but never in meteorites

GEMS: an interstellar origin?

Si-O stretch band

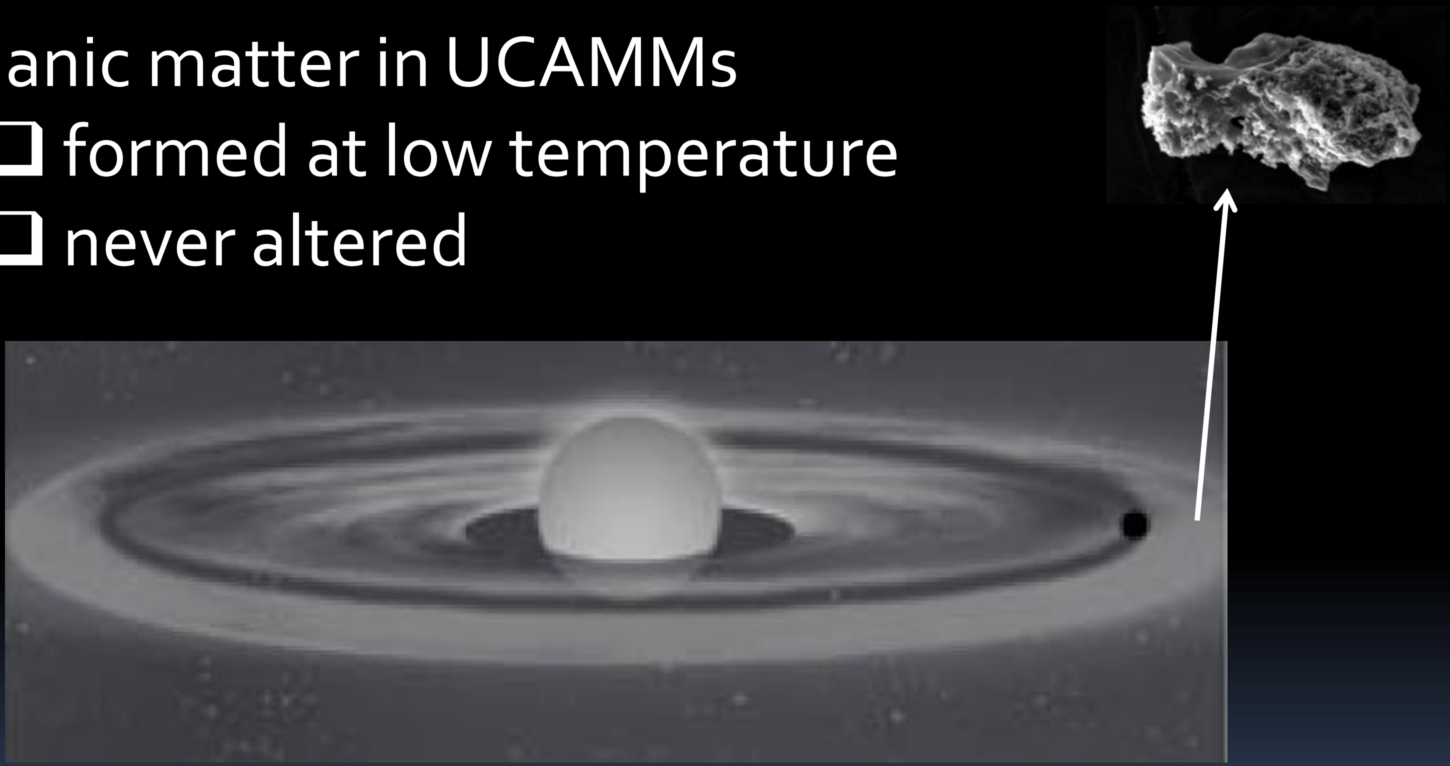


Bradley 2003

UCAMMs and the protoplanetary disk

Organic matter in UCAMMs

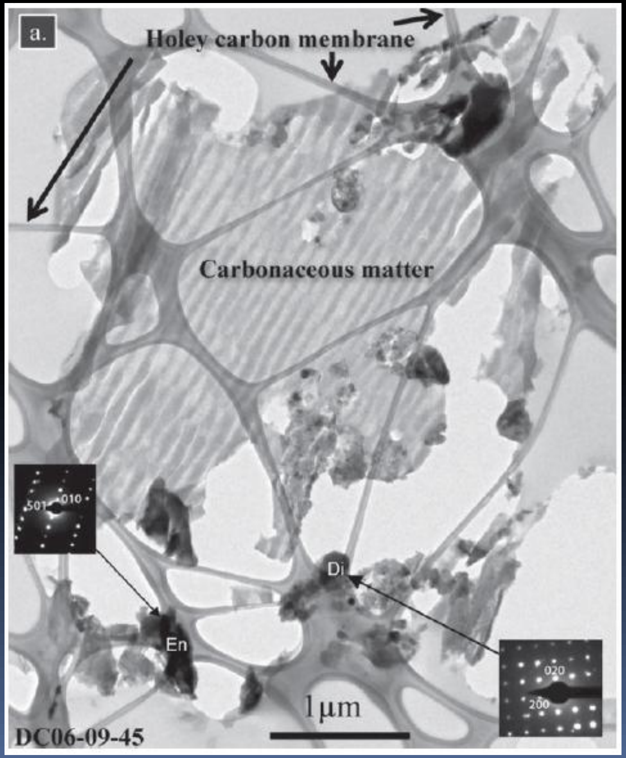
- ❑ formed at low temperature
- ❑ never altered

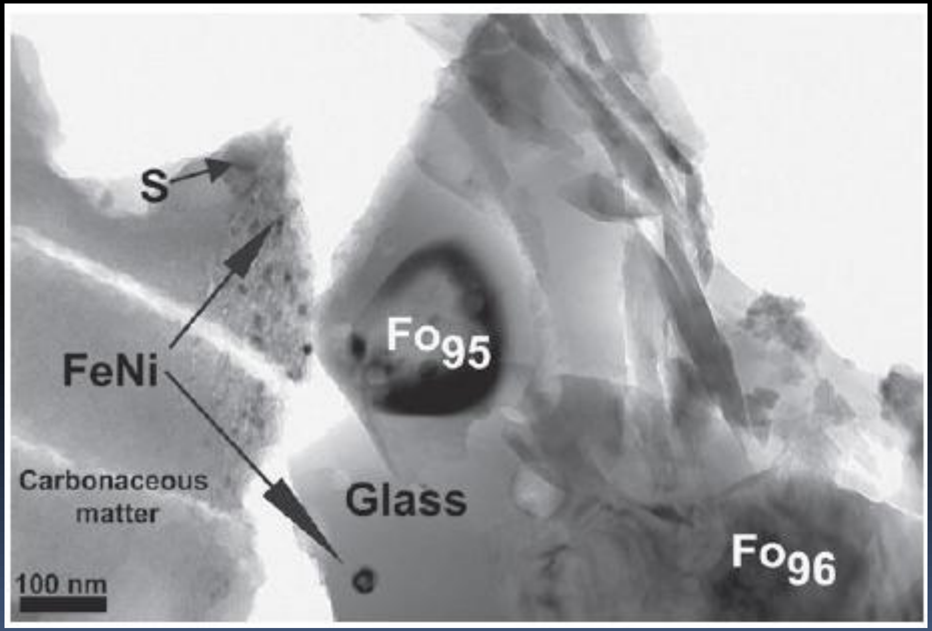


Low-temperature phases in UCAMMs attest they are samples from the outer solar system

UCAMMs and the protoplanetary disk

Association at very small scale of carbonaceous and mineral components





Dobrica et al. 2012

UCAMMs and the protoplanetary disk

Association at very small scale of carbonaceous and mineral components

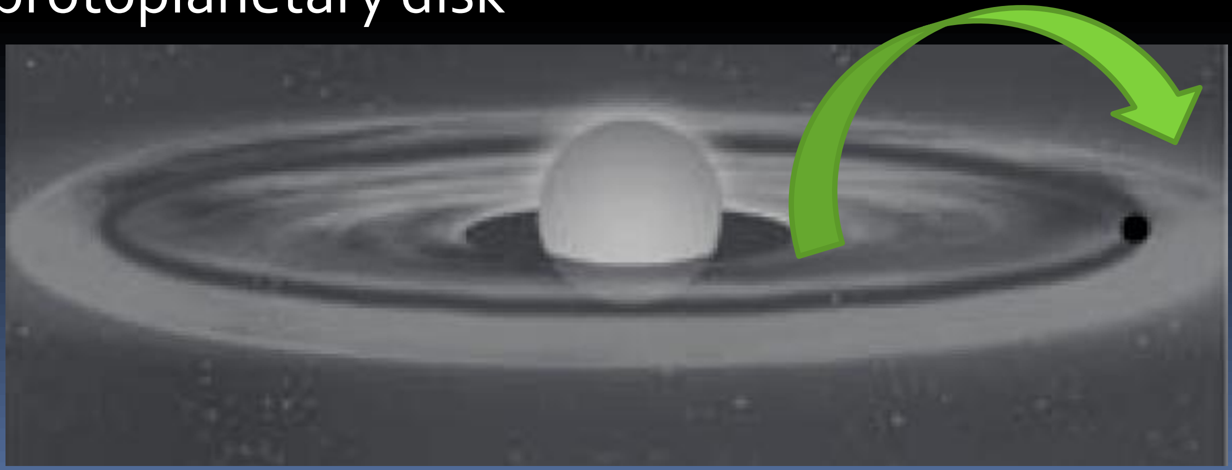
--> What mineral phases were present when comet accreted?

UCAMMs and the protoplanetary disk

Association at very small scale of carbonaceous and mineral components

--> What mineral phases were present when comet accreted?

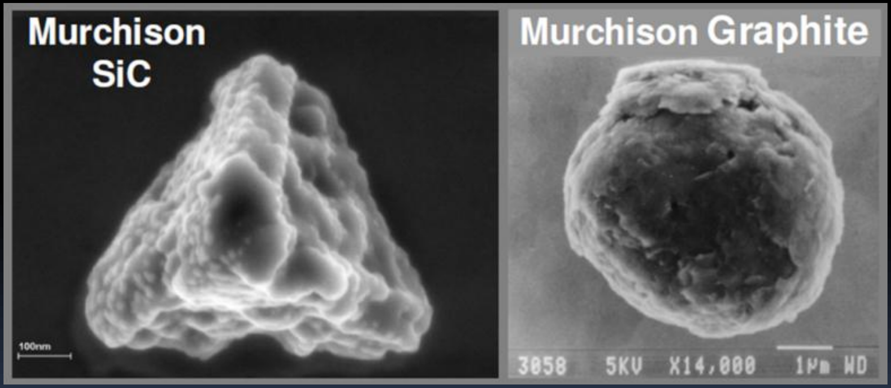
--> Crystalline silicates in cometary matter require transport in the protoplanetary disk



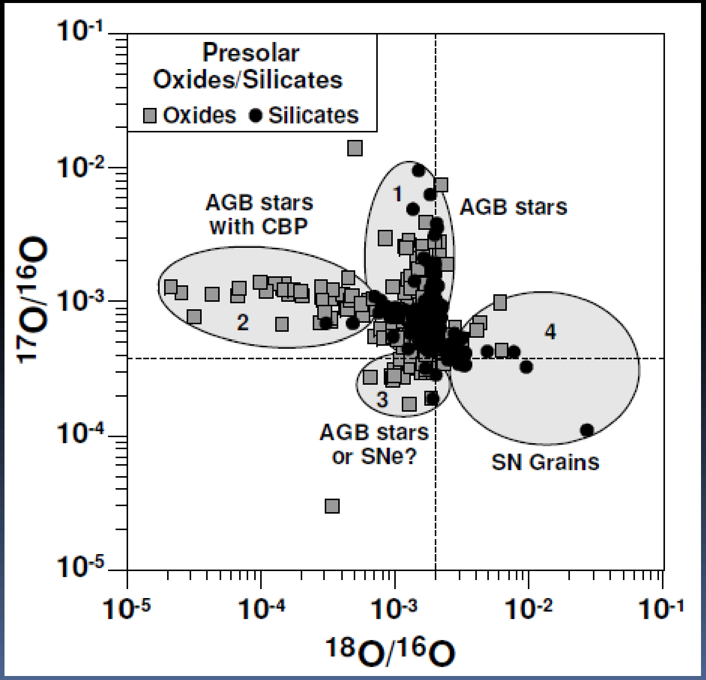
UCAMMs and the protoplanetary disk

How much of the cometary matter is a direct interstellar heritage?

1) presolar grains



Hoppe 2009



UCAMMs and the protoplanetary disk

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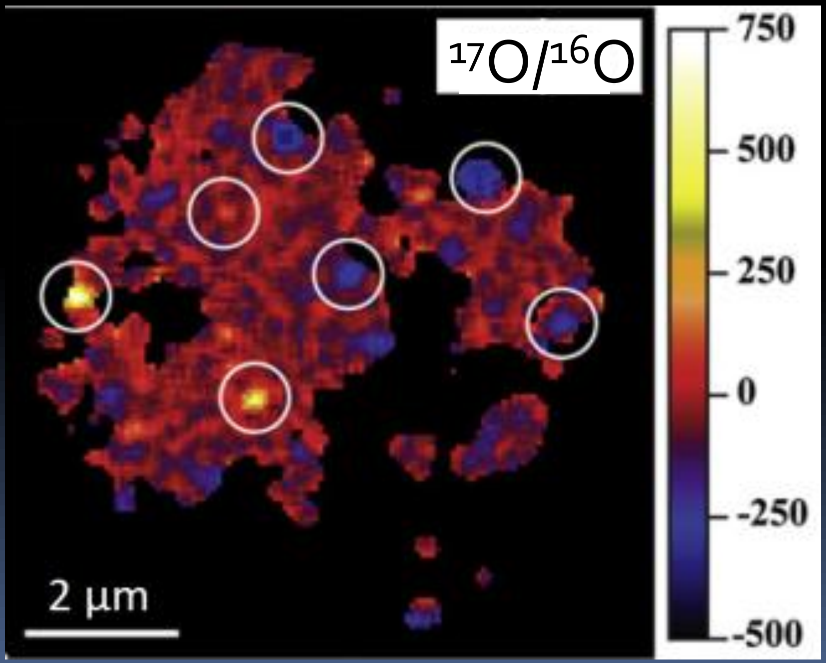
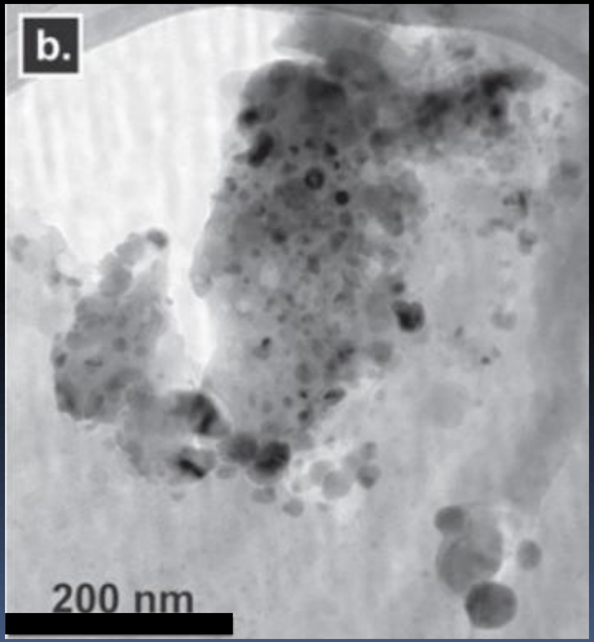


Busemann et al, 2009

UCAMMs and the protoplanetary disk

How much of the cometary matter is a direct interstellar heritage?

2) GEMS



Dobrica et al. 2012

First measurements of O isotopic composition in GEMS from one UCAMM: ~solar composition

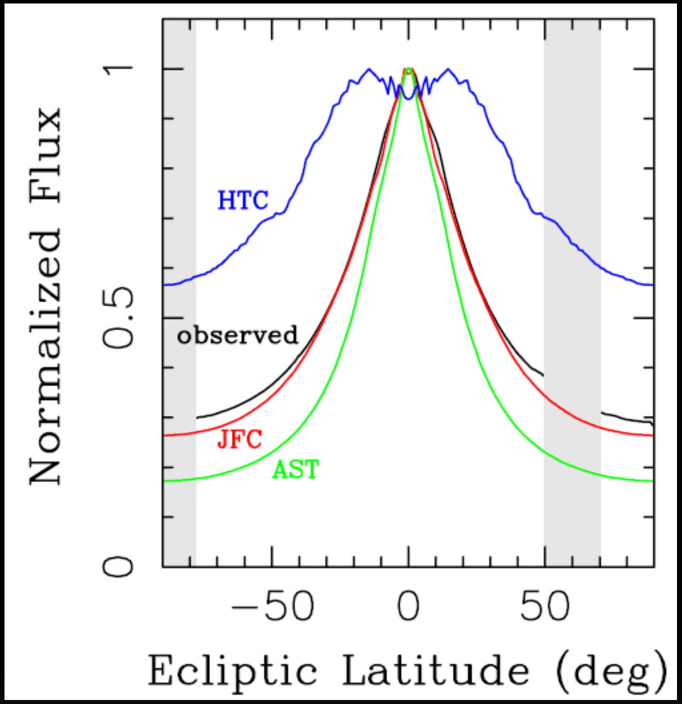
Conclusions

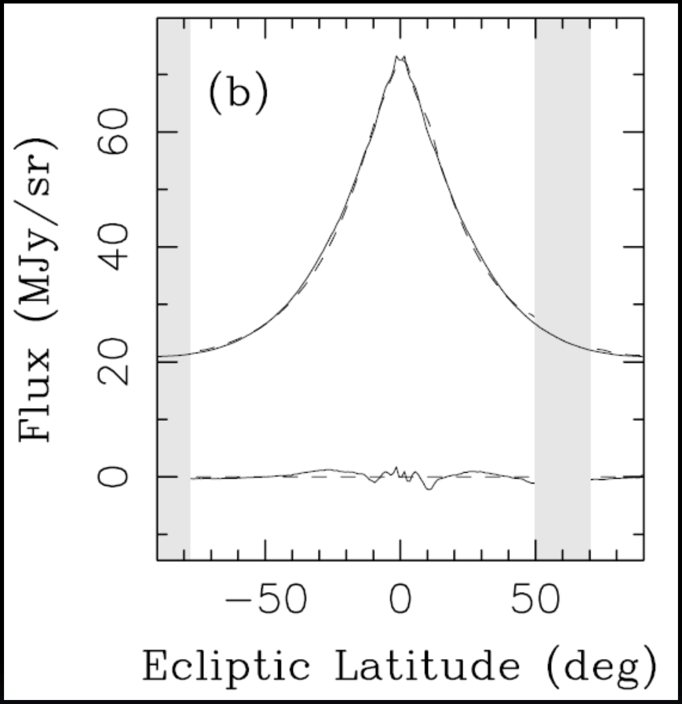
- UCAMMs: tiny extraterrestrial samples with huge amount of information on the protoplanetary disk
  - samples from the outer solar system
  - pristine low temperature and high temperature phases
  - sampling not ONE comet, but a population of comets
  - new constraints on the mixing processes in the protoplanetary disk

PLUS

Origin of micrometeorites

Zodiacal cloud dust bands: IRAS observations at 25 µm.





Nesvorny et al., ApJ 2010

Best fit:

$\alpha_{JFC} = 0.97$, $\alpha_{OCC} = 0.03$,
$D = 100$ µm, and $t_{JFC} = 12000$ yr

JFC particles represent ~ 85%
of the total mass influx in the Earth's atmosphere

Identification