
Can the biogenicity of Europa's surficial sulfur be tested simultaneously with *landers*, penetrators and ion traps?

Session GI5 Instrumentation in the Solar System

EGU 2009, Austria Center Vienna,

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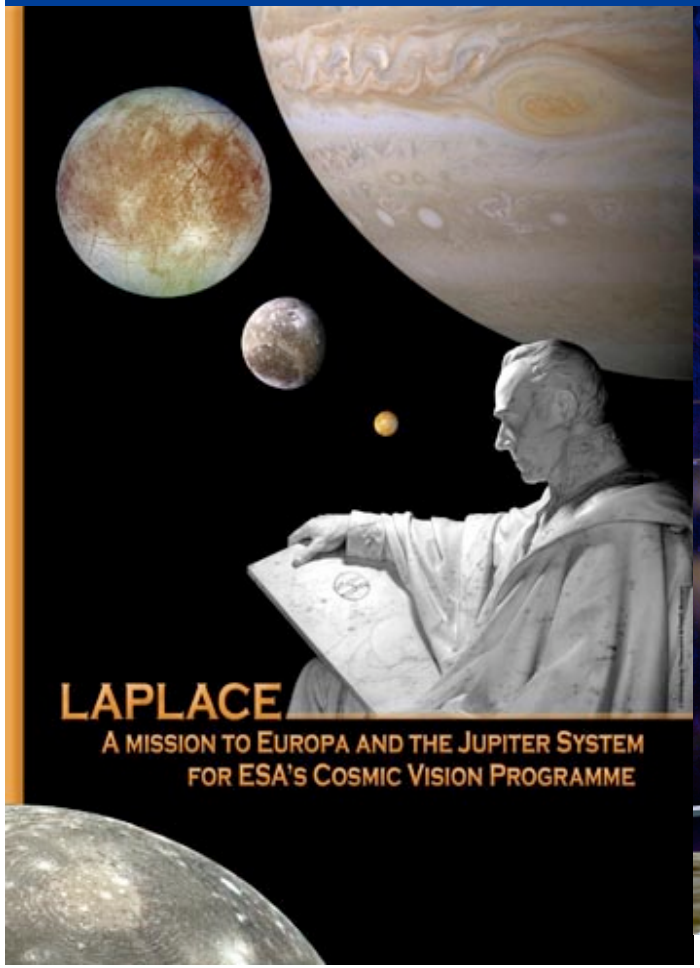
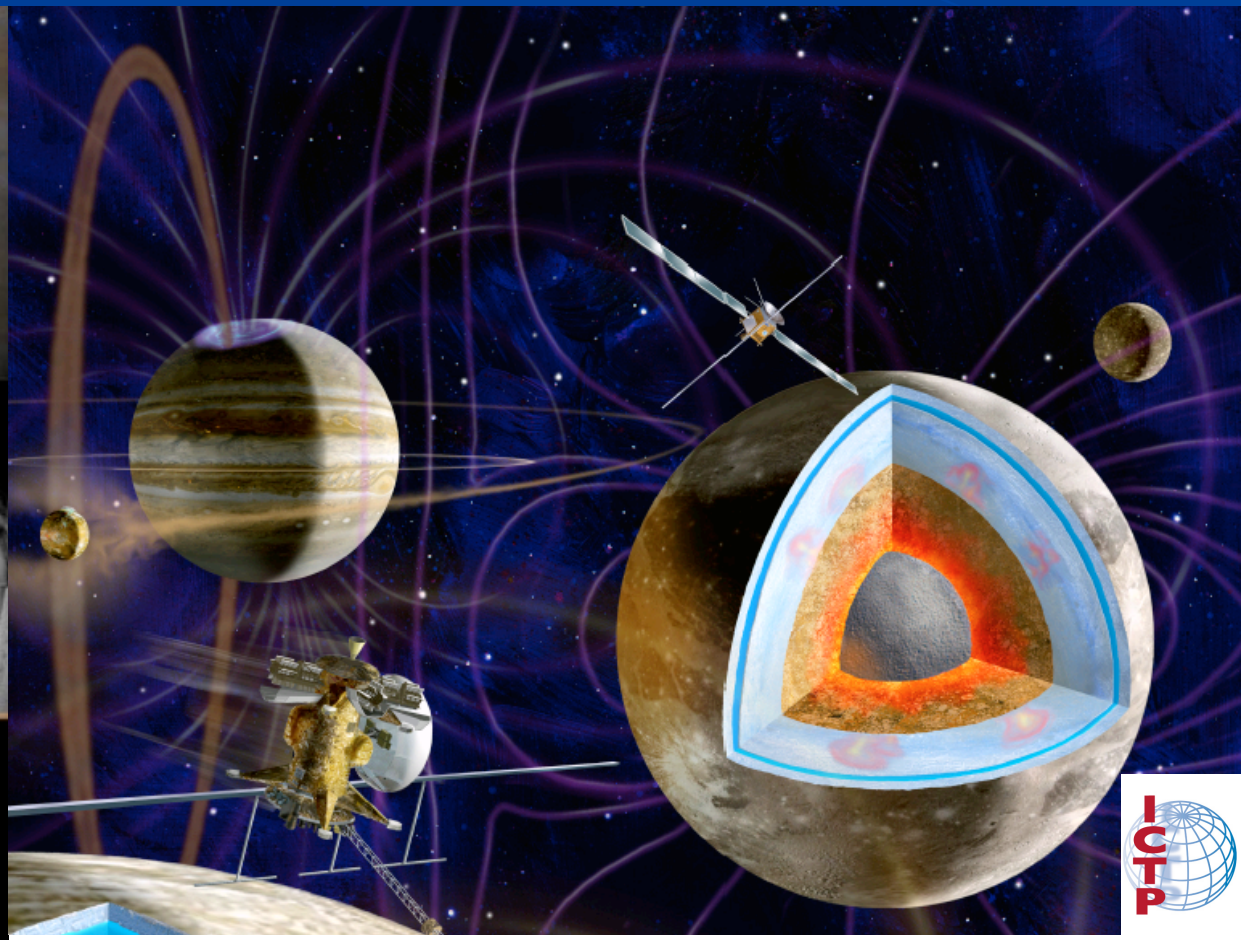
J. Chela-Flores[1,2], A. B. Bhattacherjee[3], S. Dudeja[1,4], N. Kumar[5] and J. Seckbach[6]

- 1. The Abdus Salam International Centre for Theoretical Physics (ICTP), Strada Costiera 11, 34014, Trieste, Italy
- 2. Instituto de Estudios Avanzados, Caracas 1015A, R. B. de Venezuela
- 3.Department of Physics, ARSD College, University of Delhi, India
- 4.Department of Chemistry, ARSD College, University of Delhi, India
- 5. Raman Research Institute, Bangalore-560080, India
- 6. The Hebrew University of Jerusalem, Israel.

To Europa with the Laplace/EJSM

- There is a possibility for returning to Europa in the 2020s





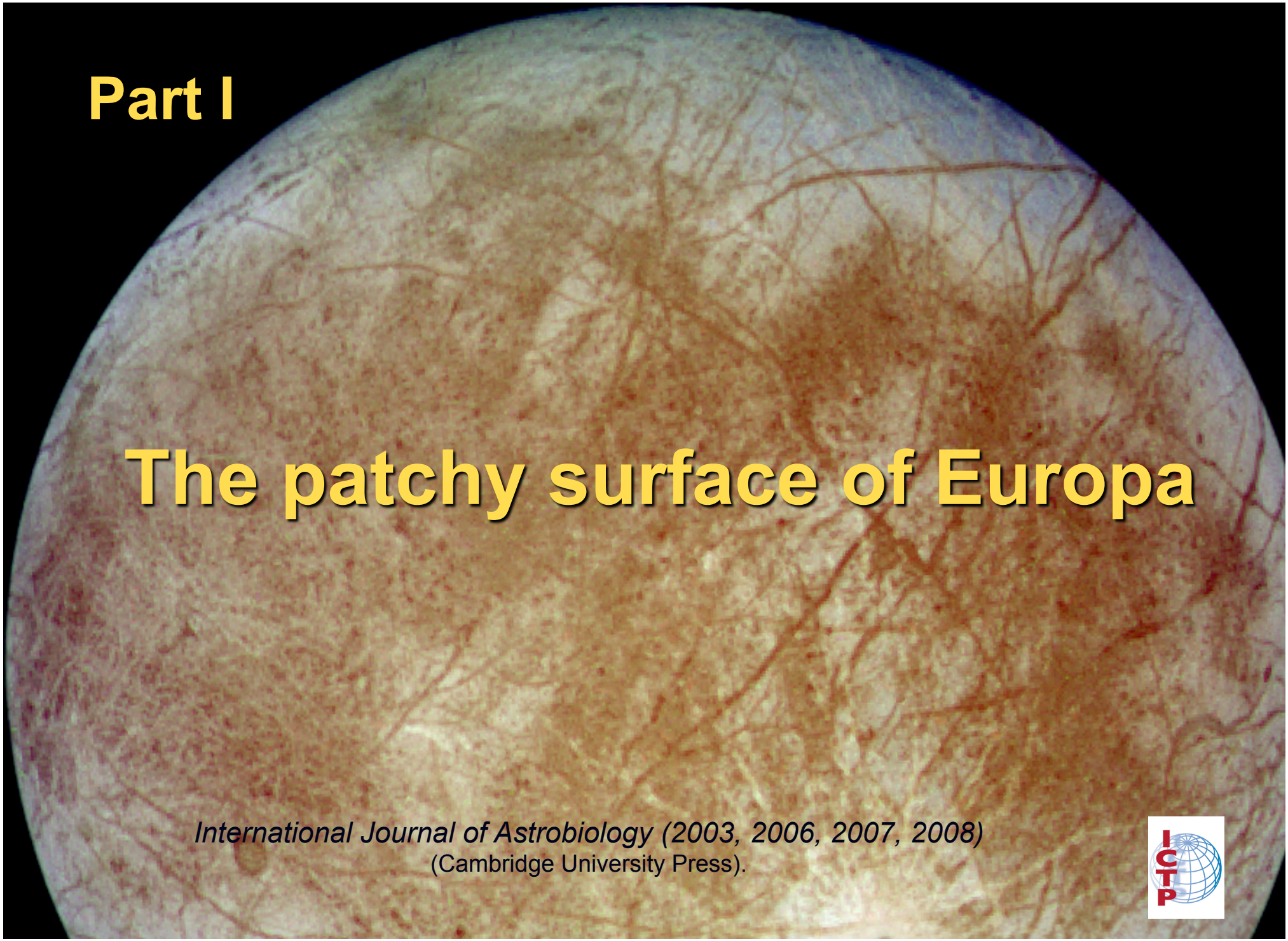
The question of habitability

"Is Europa habitable?"

- This has been a main objective for the LAPLACE mission.
- Habitability has also been adopted by the EJSM.

Plan of the talk

- The patchy surface of Europa.
- The surfaces of the Arctic, Antarctic and Europa.
- Testing biogenicity on Europa.
- Instrumentation.
- Concluding remarks.



Part I

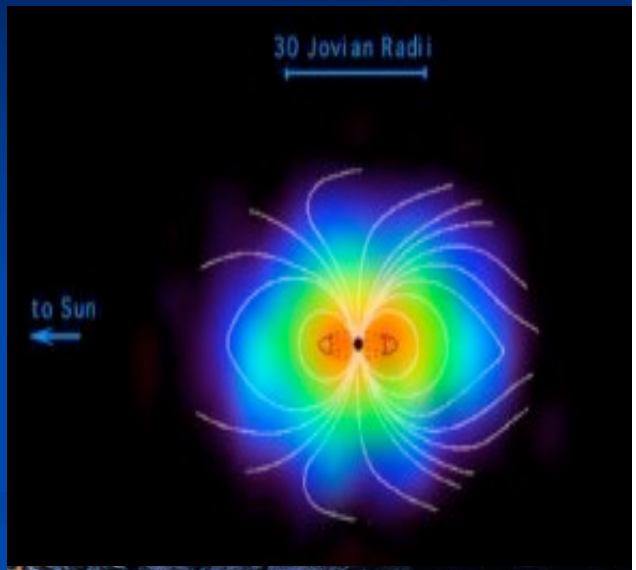
The patchy surface of Europa

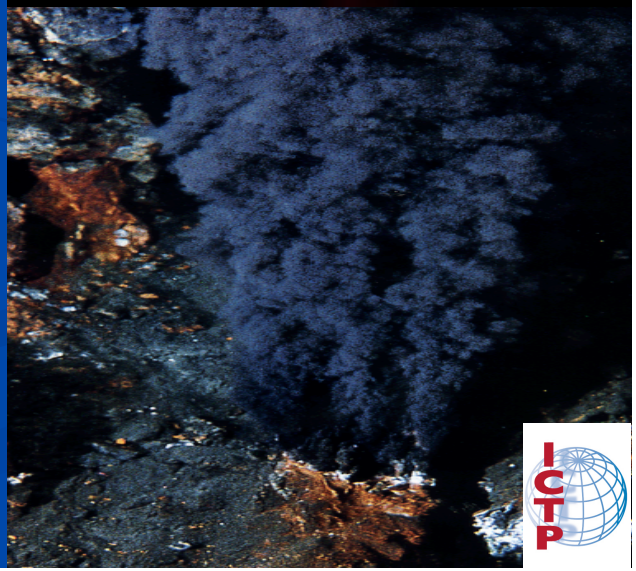
International Journal of Astrobiology (2003, 2006, 2007, 2008)
(Cambridge University Press).

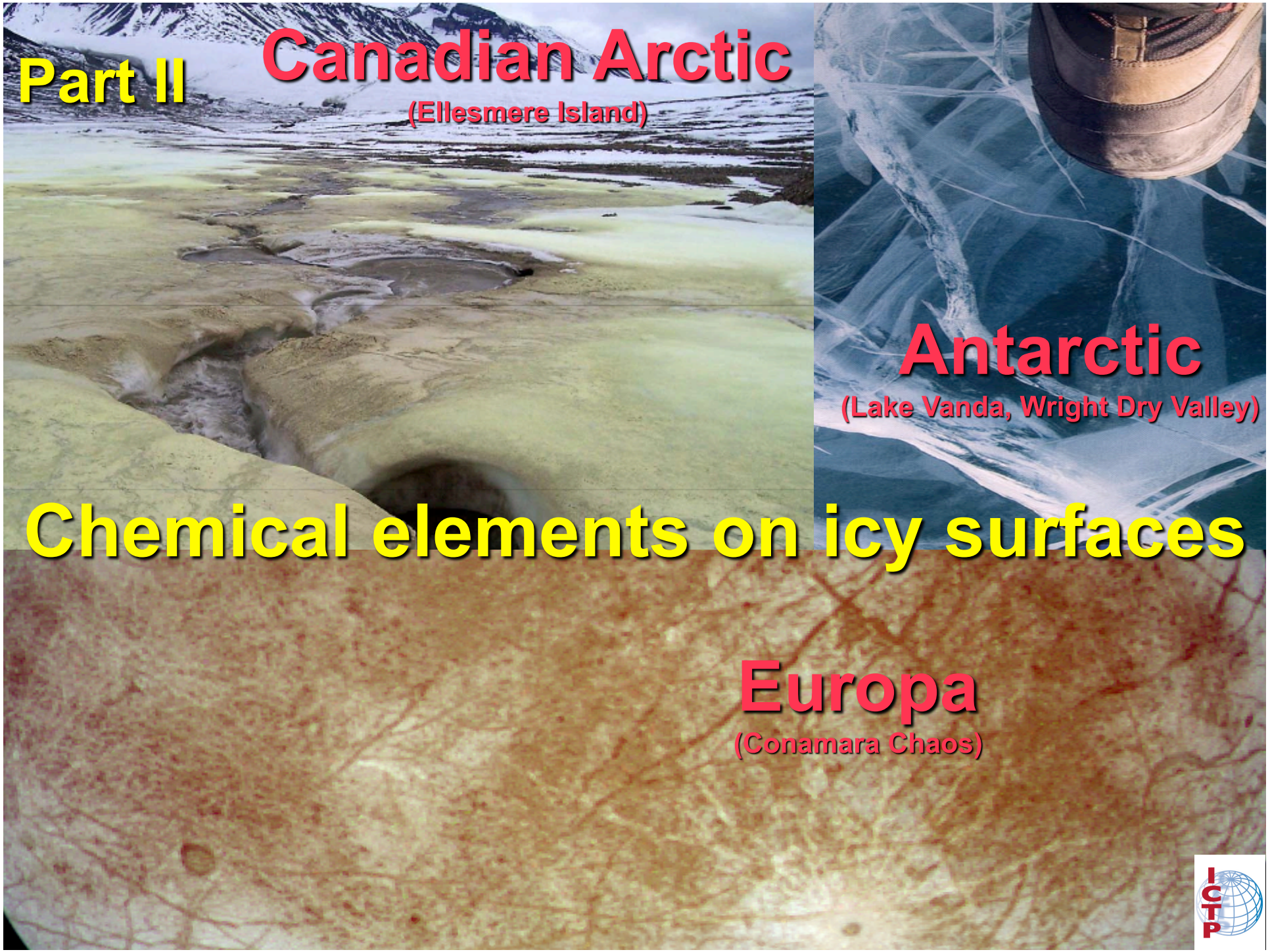
Stains on the icy surface

- External source.
- Internal source.
- We should test the biogenicity, or cryovolcanic origin of the sulfur patches.

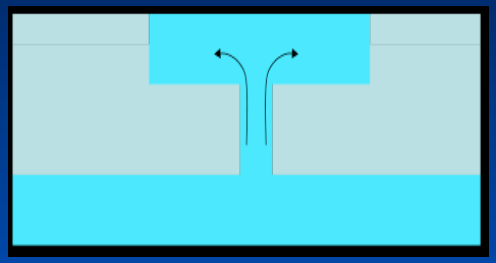
Mass spectrometry (MS) is the appropriate instrumentation.



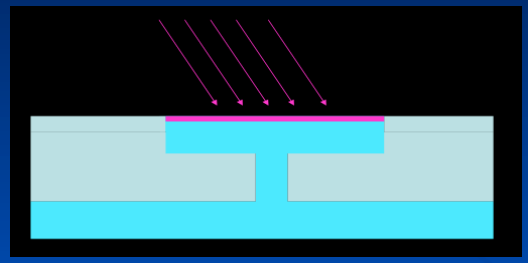



Part II
Canadian Arctic
(Ellesmere Island)
Antarctic
(Lake Vanda, Wright Dry Valley)
Chemical elements on icy surfaces
Europa
(Conamara Chaos)

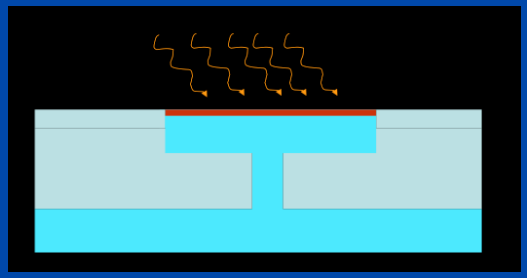
The Europan regolith



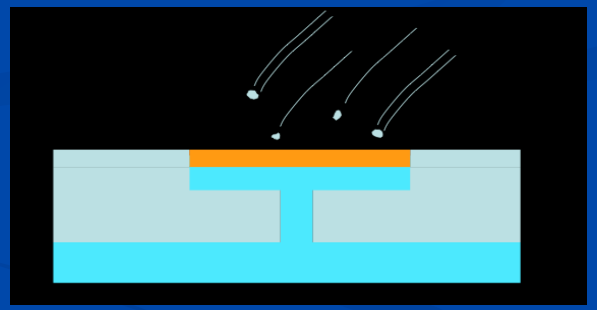
Emplacement



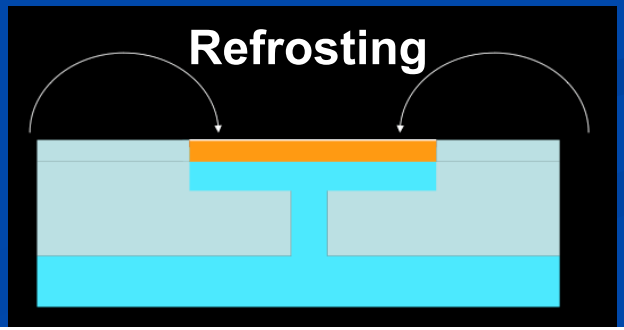
Micrometeorites



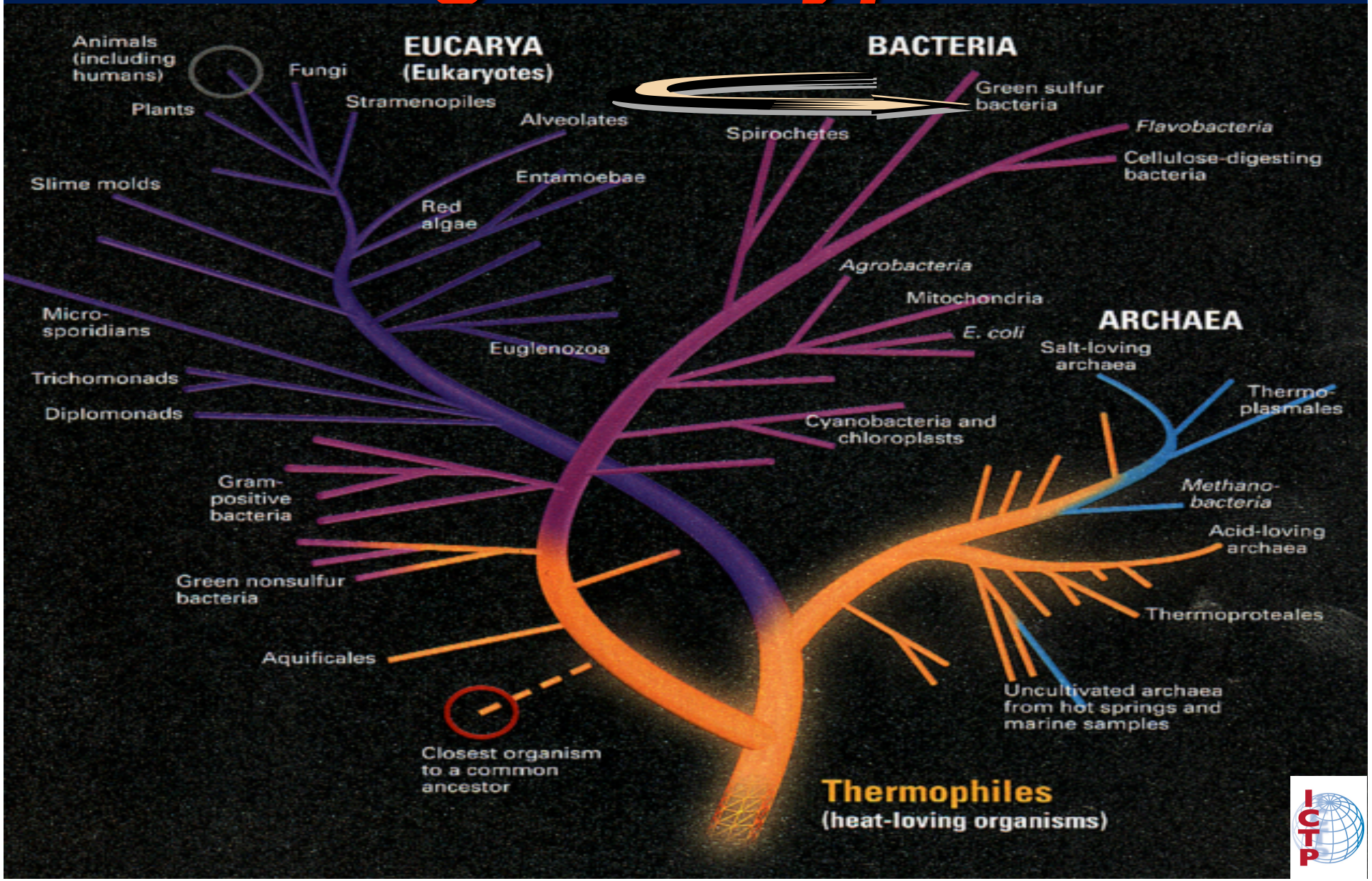
Radiation



Surface gardening



The biogenic hypothesis

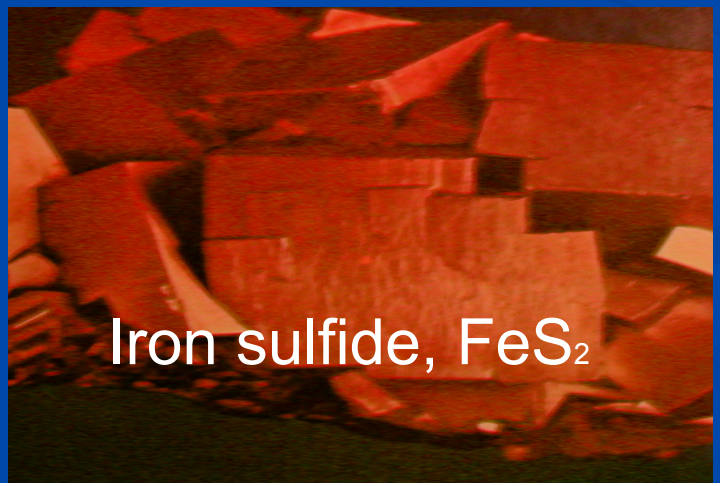


Sulfate-reducing bacteria

- Unite H with S atoms from dissolved sulfate (SO_4^{-2}) of seawater to form hydrogen sulfide H_2S :

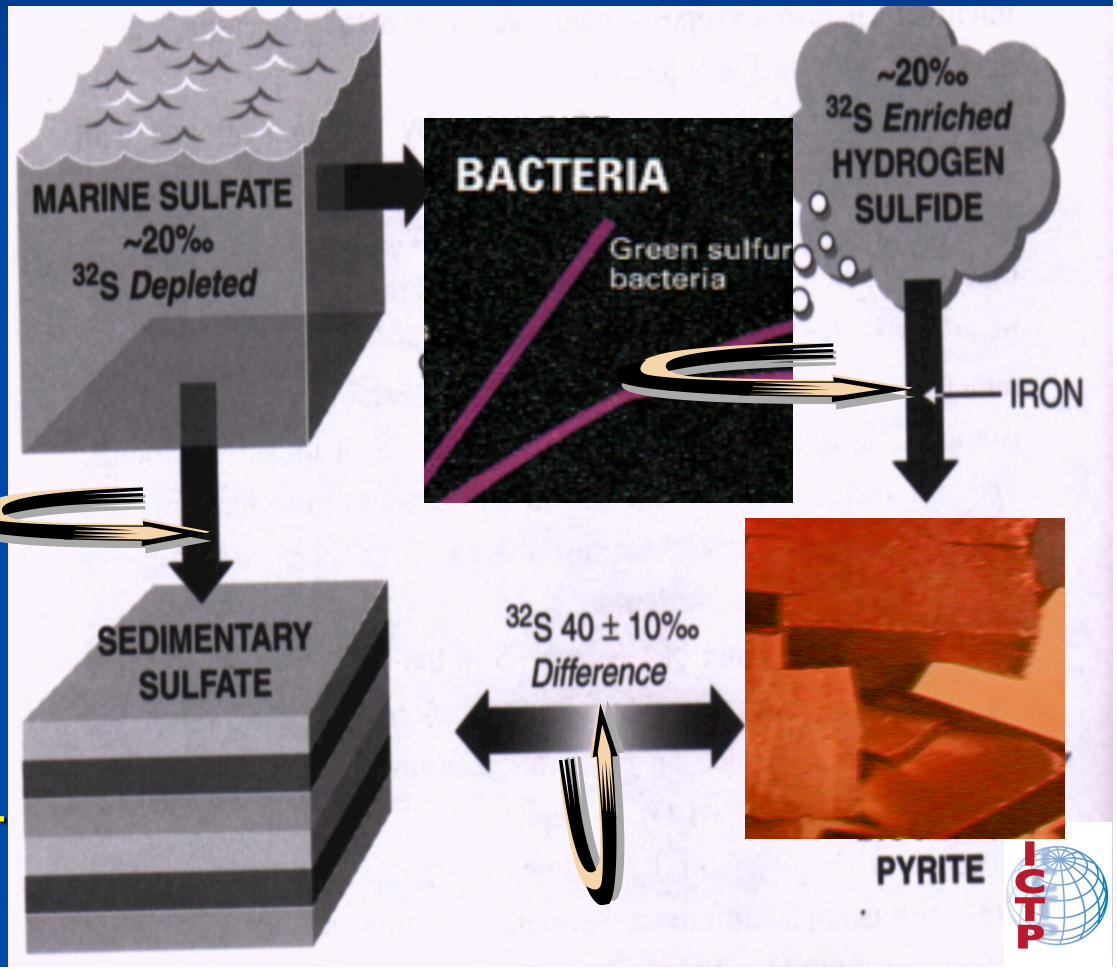
$$4H_2 + H_2SO_4 \rightarrow H_2S + 4H_2O + 39\ kilocalories$$

- The H_2S then combines with Fe in sediments to form grains of the biogenic mineral pyrite.



S-isotopes in biogenic and sulfate minerals

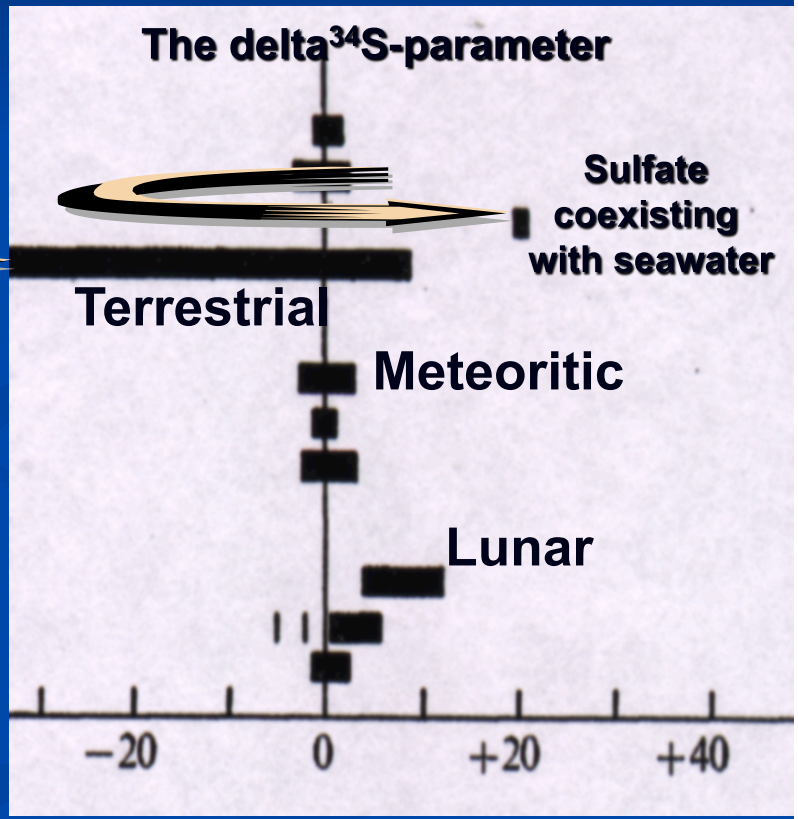
- Dissolved sulfate: on evaporation sulfate minerals are depleted of ^{32}S by 20 per mil.
- The H_2S given off by S-hungry bacteria is enriched in ^{32}S by 20 per mil.
- The net difference is 40 per mil.



Biogenic S on icy surfaces

- Sulfur is unique in the Solar System.

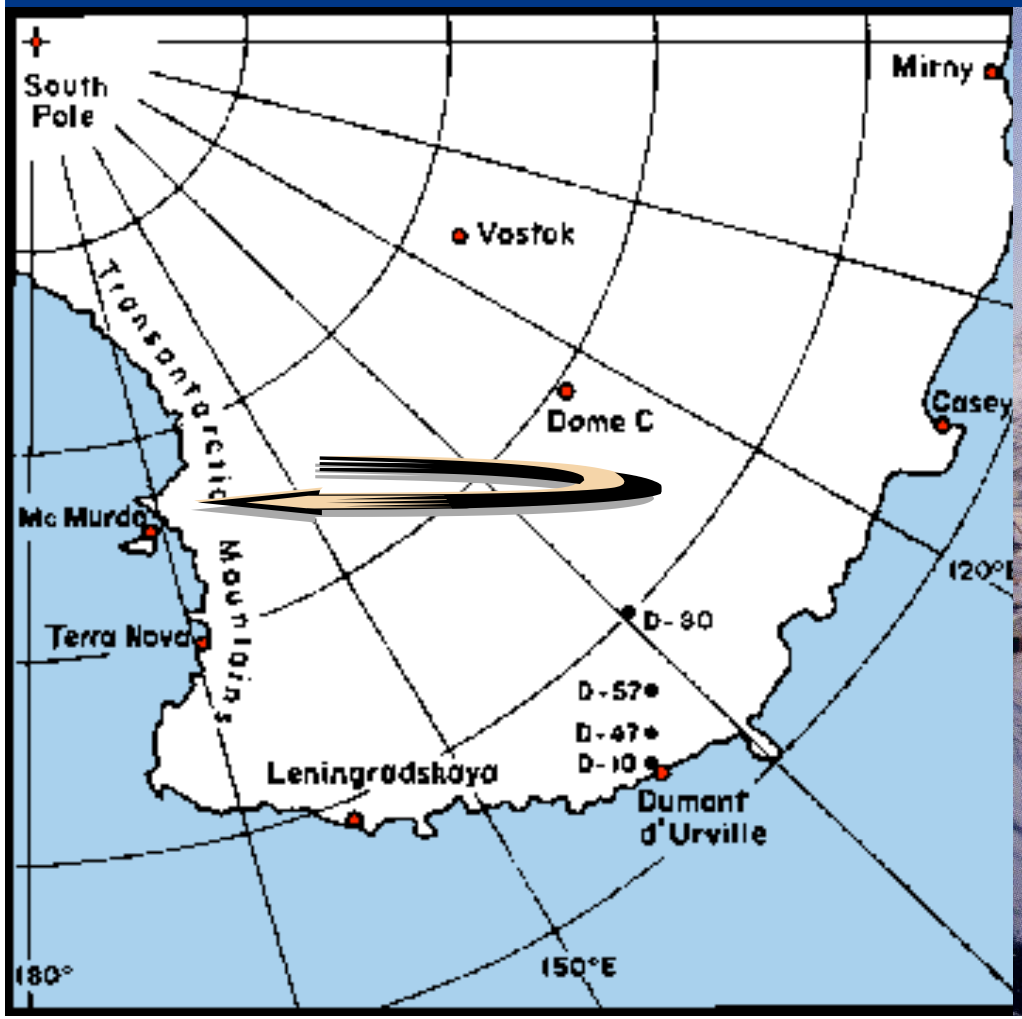
- Measurements in basins off California

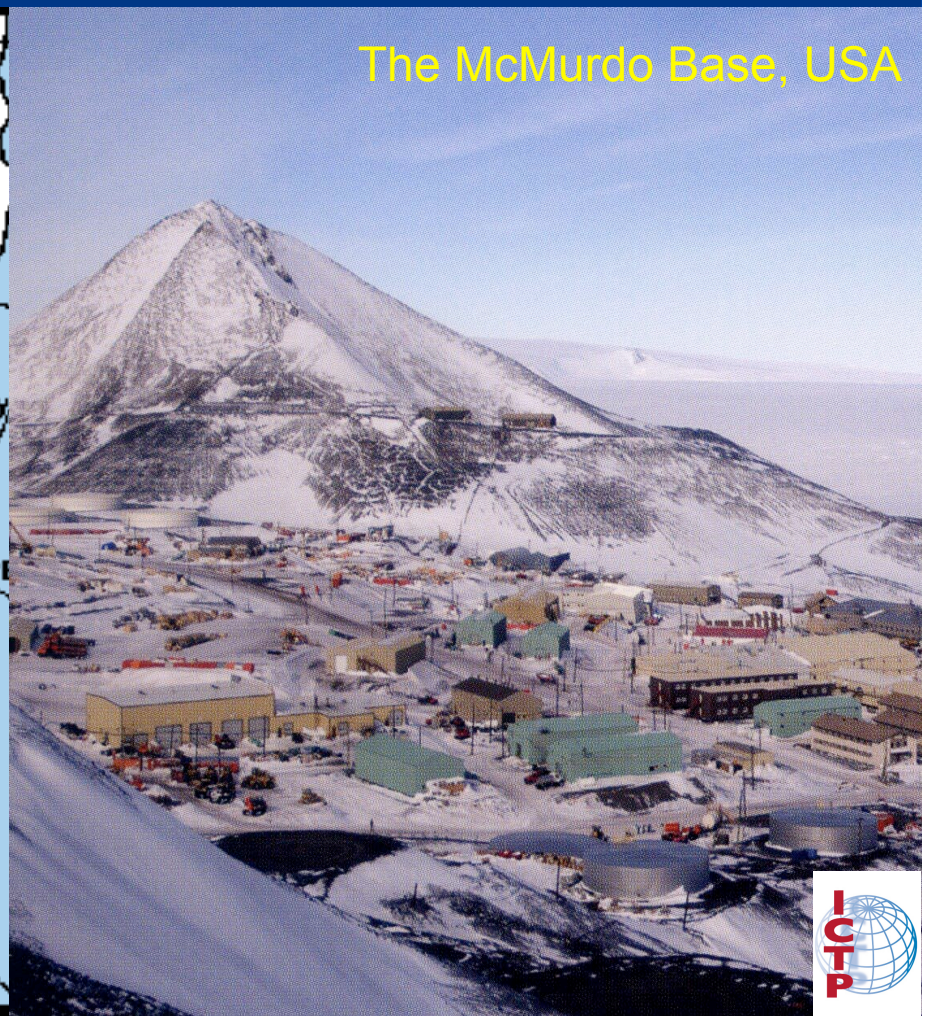


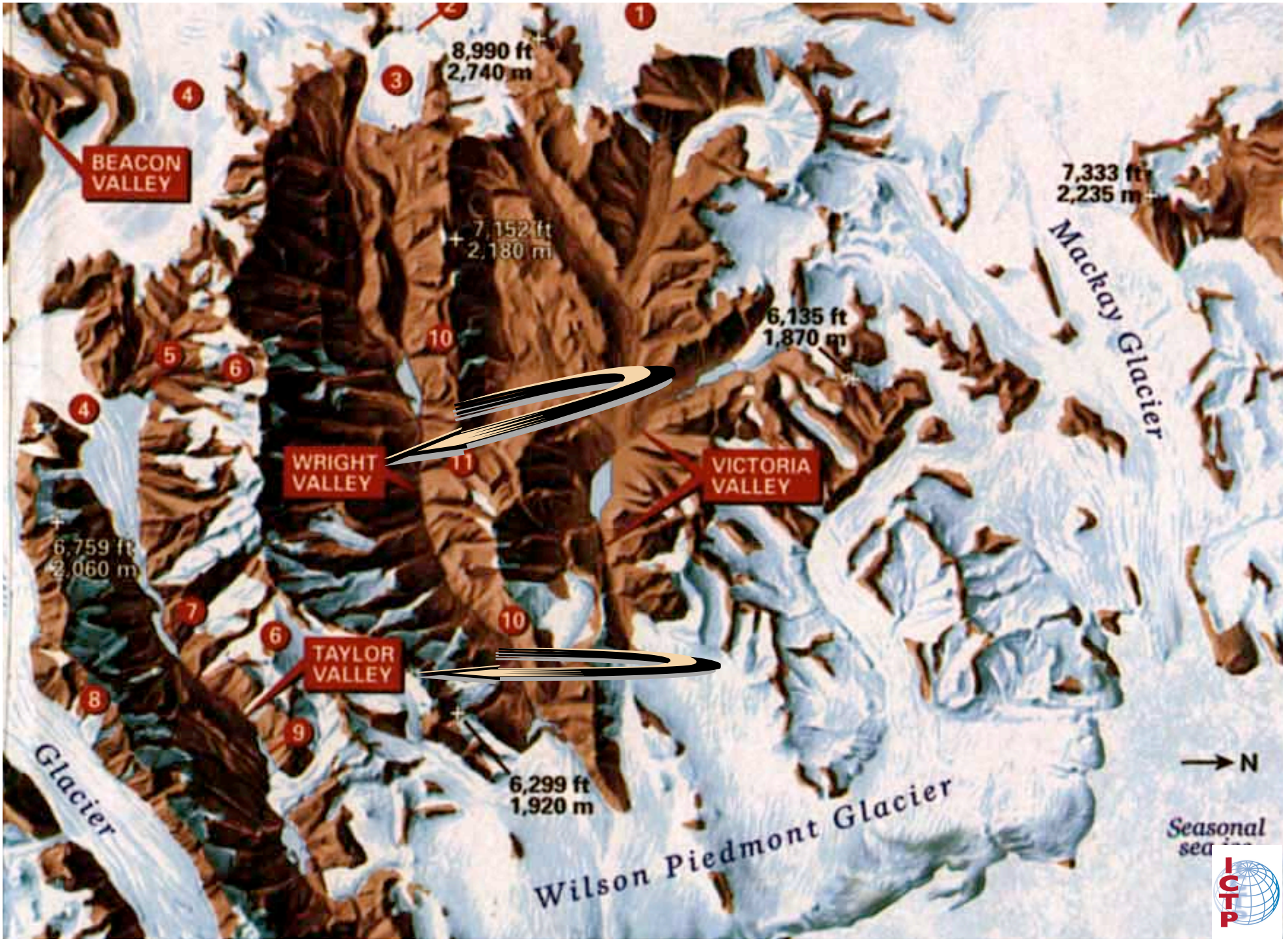
- Sulfur on icy surfaces is known on Earth and on Europa:

Biogenic sulfur on icy patches

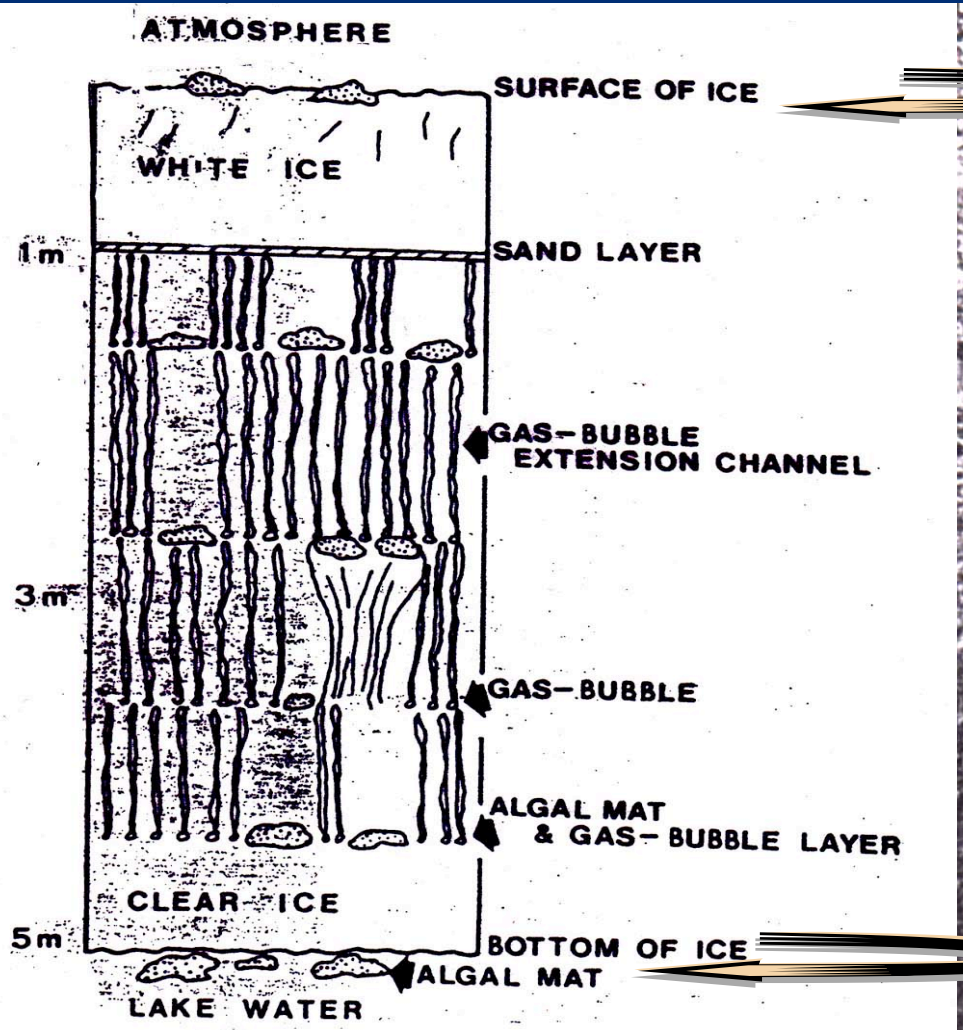
(Antarctica's Dry Valleys)






8,990 ft
2,740 m
BEACON VALLEY
7,152 ft
2,180 m
7,333 ft
2,235 m
Mackay Glacier
6,135 ft
1,870 m
WRIGHT VALLEY
VICTORIA VALLEY
6,759 ft
2,060 m
TAYLOR VALLEY
6,299 ft
1,920 m
Glacier
Wilson Piedmont Glacier
N
Seasonal

The icy surface of Lake Hoare
(Taylor Valley)

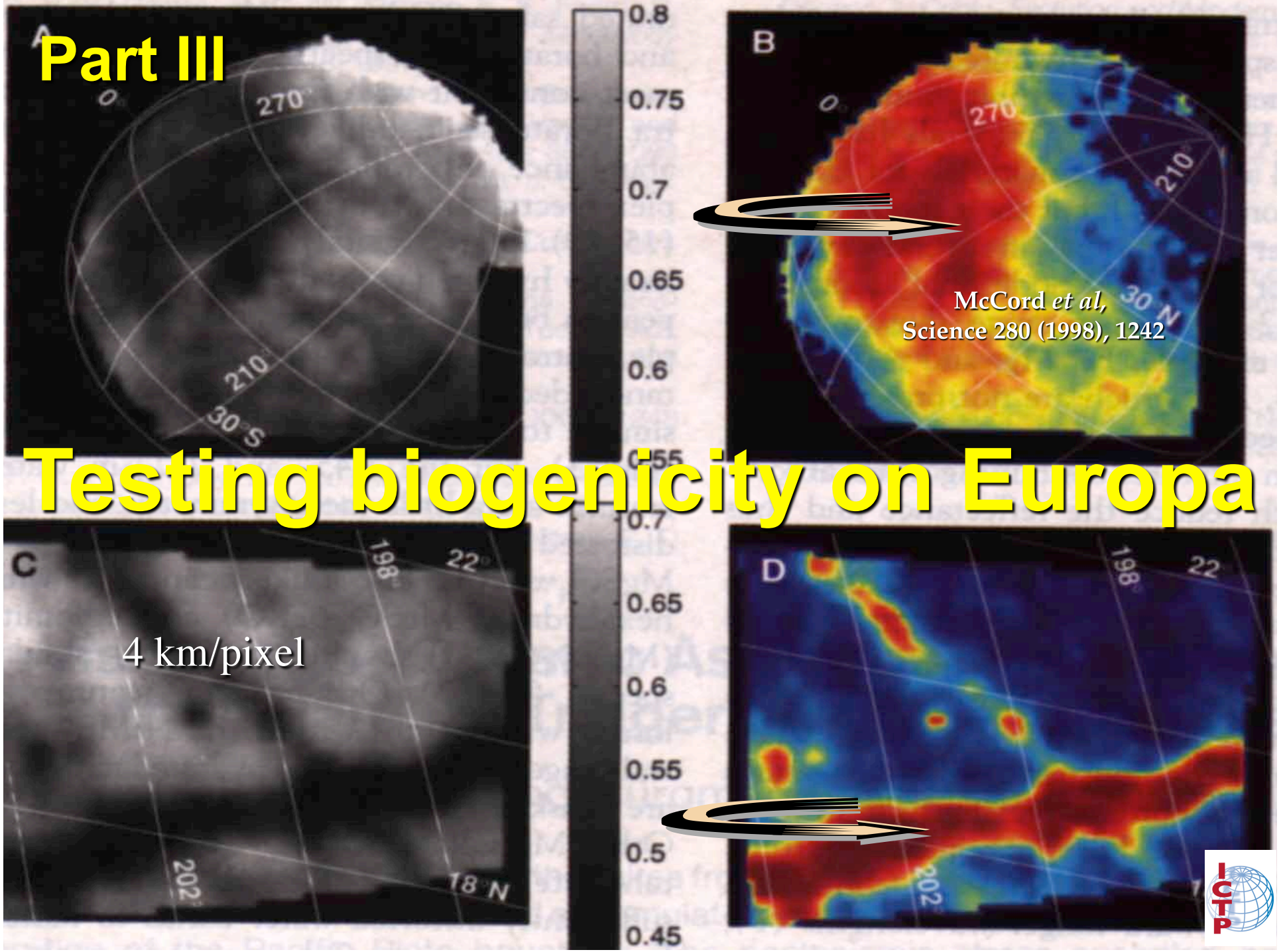


Algal mat pieces on the surface of Lake Hoare

(Parker et al, Phycologia, 1982)

Annual escape of biogenic sulfur (kg)

The Taylor Dry Valley Lakes	Chad	Hoare	Fryxell
Organic matter	8343.0	247.4	[illegible]0.0
Kjeldahl-N	188.5	33.1	[illegible]
Si	897.0	573.9	2640.0
Al	353.3	137.2	522.6
Ca	279.5	105.9	552.1
Fe	352.3	76.6	309.5
Mg	123.6	35.4	159.5
K	100.6	30.7	184.9
Na	49.4	18.6	147.4
P	18.5	10.2	31.2
S	104.0	56.0	40.1
Cl	9.2	4.6	419.4
Mn	20.2	3.8	59.0
Cu	0	0.7	0.02
Zn	0	0.2	0.40
Co	0	0.05	0.20
Mo	0.07	0.002	0.01


Part III
A
0
270
210
30 S
0.8
0.75
0.7
0.65
0.6
B
0
270
210
30 N
McCord et al,
Science 280 (1998), 1242
Testing biogenicity on Europa
C
198
22
4 km/pixel
202
18 N
0.7
0.65
0.6
0.55
0.5
0.45
D
198
22
202

Fluctuation test

(Luria and Delbruck)

- Infection implies that the number of resistant individuals would vary very little from one experiment to the next.

- The number of resistant bacteria would depend on the time elapsed since the mutation; this number would show ***exponentially large fluctuations***.

- ***Higher order statistics***

  helps us detect such deviations from Gaussianity.

The cloud around Europa

- The cloud mirrors the large S-isotope deviations on the surface.

- Dust detectors should record **non-vanishing cumulants**.

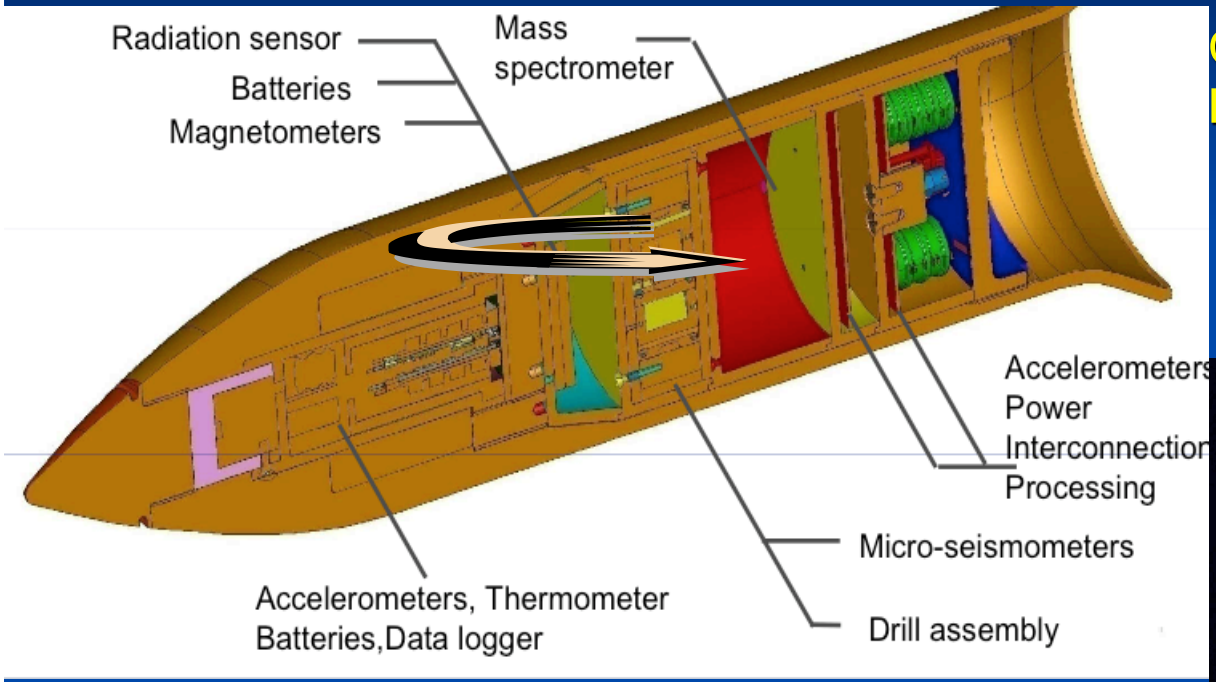
- The O_2 atmosphere should be described instead by a **Gaussian distribution** with **vanishing cumulants**.

Part IV

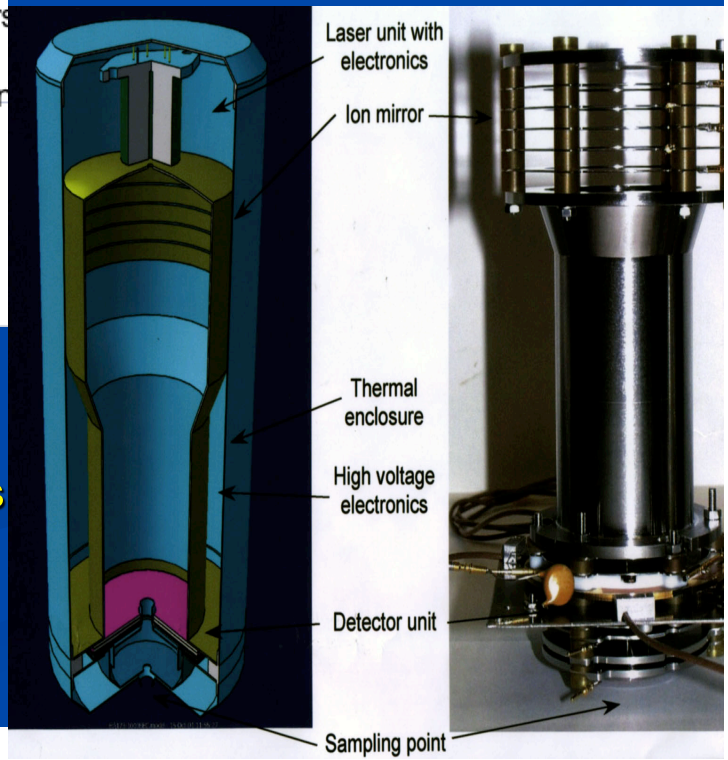
Instrumentation

Credit:
British Consortium and International support

MS on Europa's icy surface



Credit:
British Consortium



Credit: Peter Wurz and co-workers at the University of Bern.

120 x 60 mm; 500 g

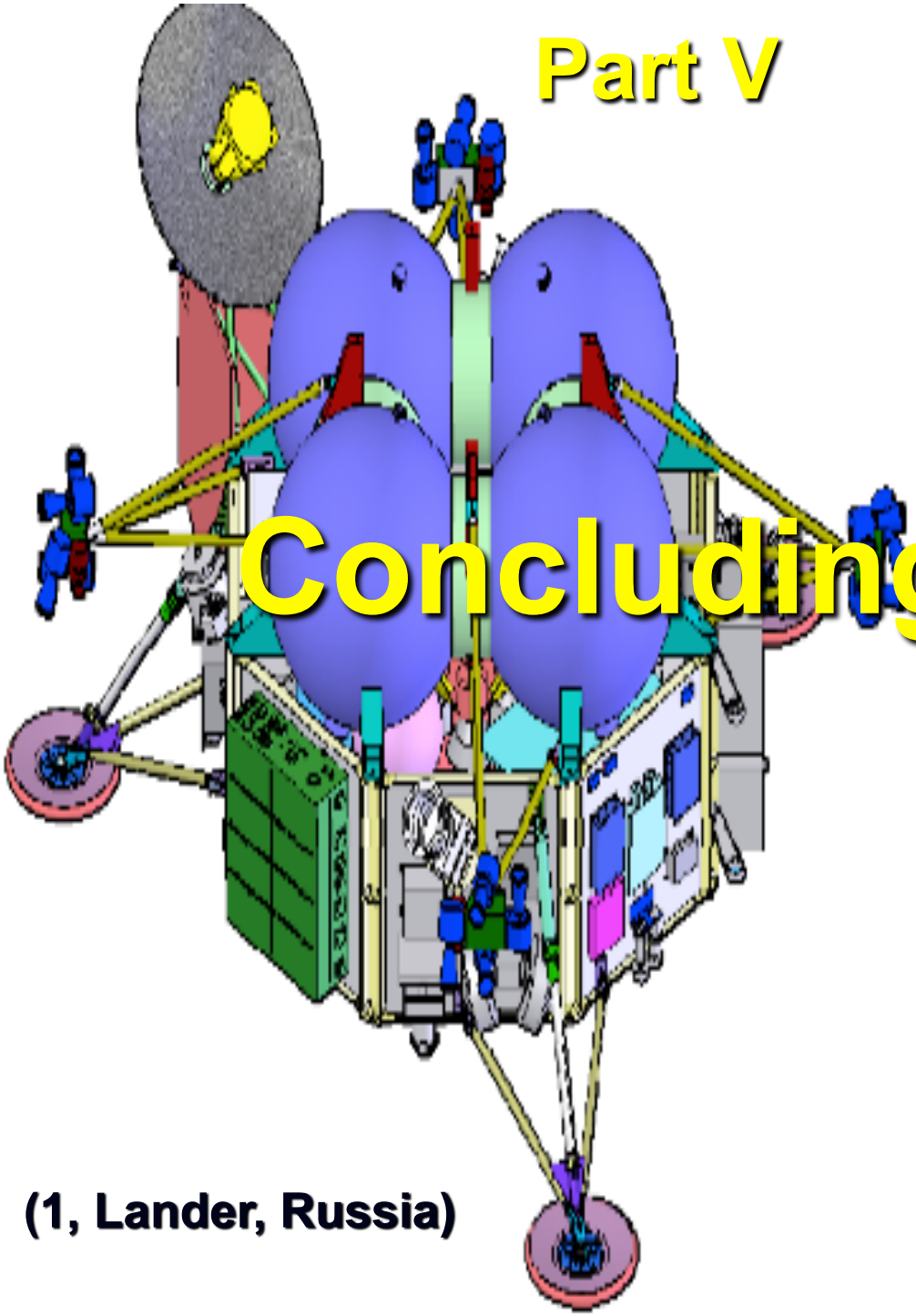
Difficulties with the the dust analyzers

- ^{32}S is isobaric (same m/z) with $^{16}O_2$.

- So the likely ion counts is a key issue.

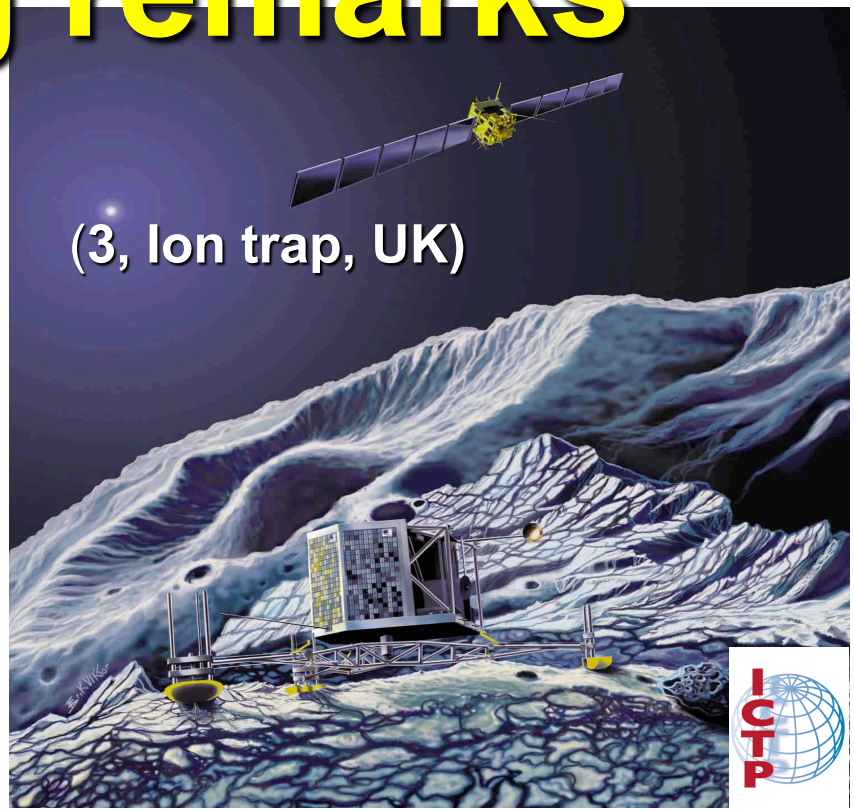
Part V

Concluding remarks



(1, Lander, Russia)

(2, Penetrator, UK)



(3, Ion trap, UK)

Recommendations

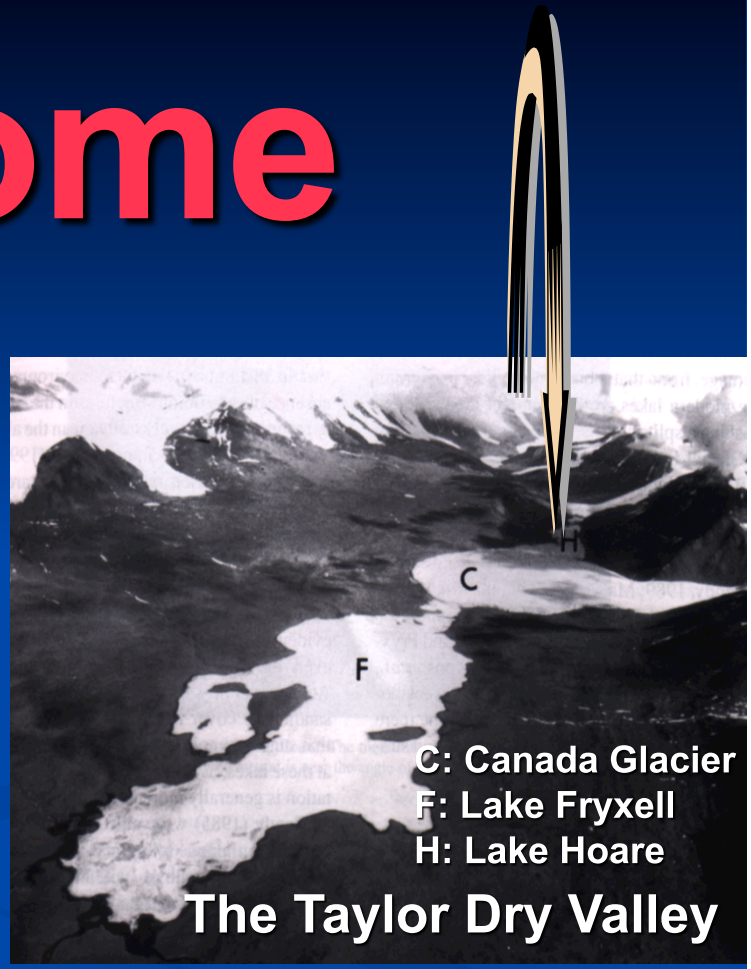
- The isotopic biosignatures of the patches would not be affected substantially by the reshuffling of the surficial material. (Nuclear binding forces.)

- The living-cell biosignatures are complicated by the factors modifying the surface. (Hydrogen bonds binding forces.)

Take Home

- Ice cores from the surface of the dry-valley lake (Hoare) should be inspected with MS.

- The delta parameter should have large statistical fluctuations from the Gaussian distribution (peaked at -40).



- A similar set of ice cores can be irradiated and the deviations from the mean should be non-Gaussian.

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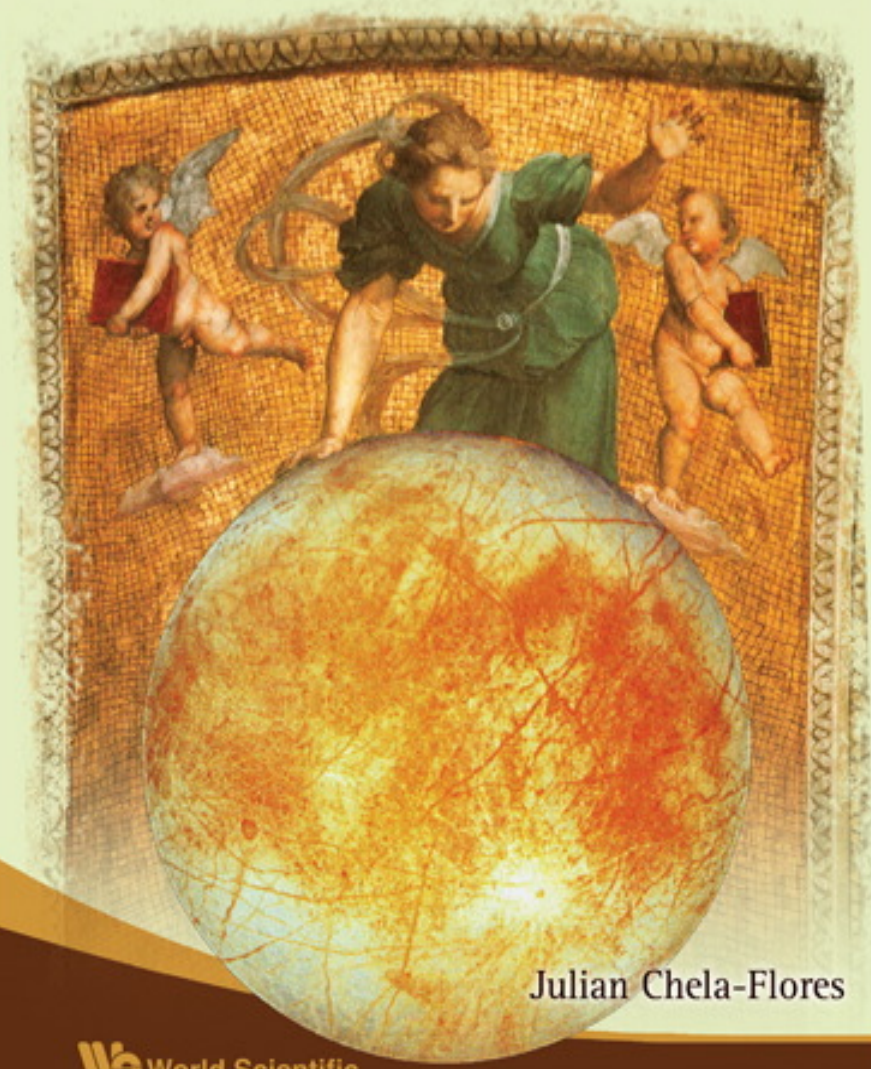

Julian Chela-Flores

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