The Abdus Salam
International Centre for Theoretical Physics

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Educational, Scientific
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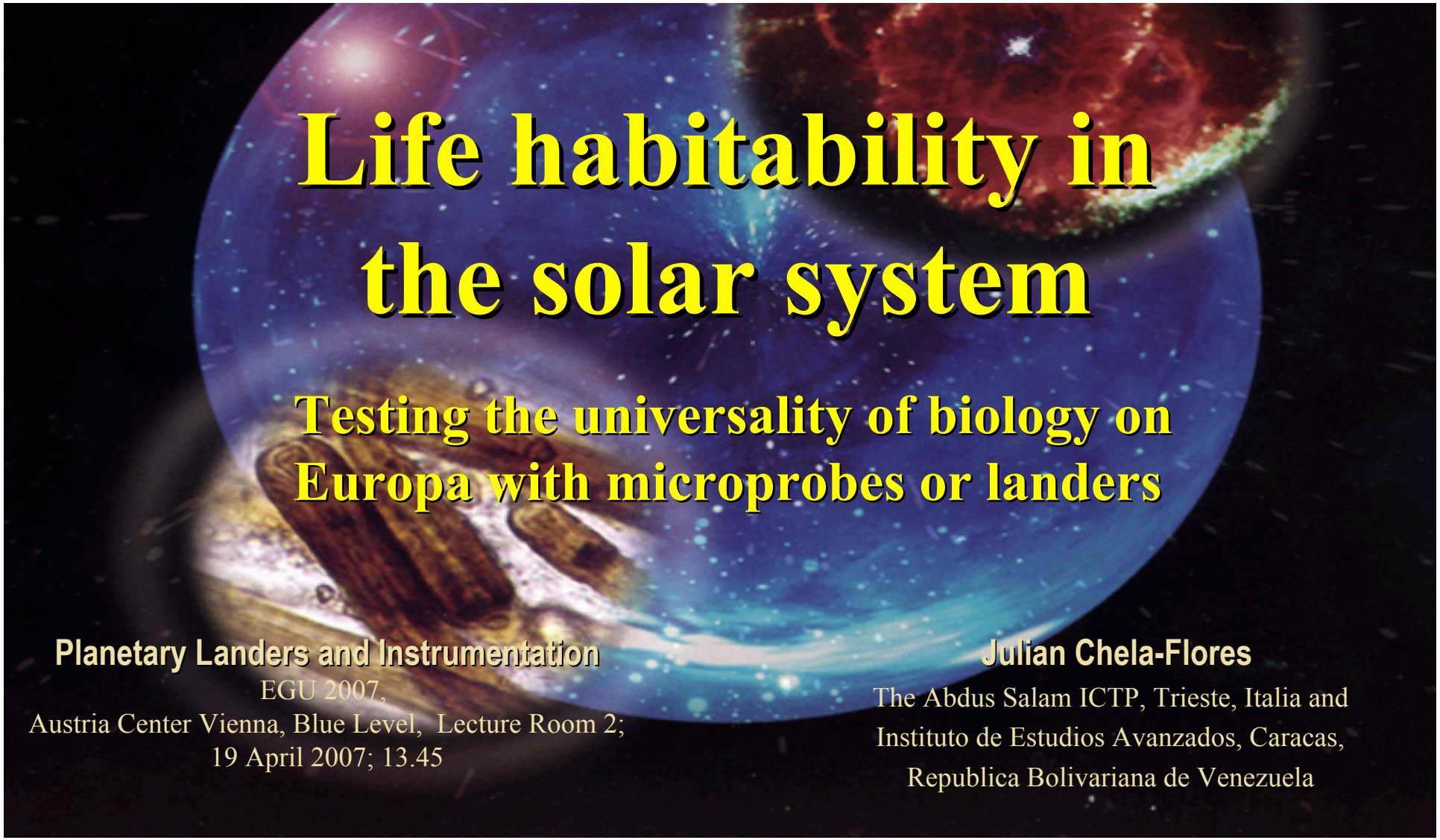


Life habitability in the solar system

Testing the universality of biology on Europa with microprobes or landers

Planetary Landers and Instrumentation
EGU 2007,
Austria Center Vienna, Blue Level, Lecture Room 2;
19 April 2007; 13.45

Julian Chela-Flores
The Abdus Salam ICTP, Trieste, Italia and
Instituto de Estudios Avanzados, Caracas,
Republica Bolivariana de Venezuela

Plan of the talk

- The question of the universality of biology.
- The icy and patchy surface of Europa.
- Biogeochemistry on the surface of Europa.
- Towards the Athens Workshop and beyond the Aurora Programme.

Part I

The universality of biology

International Journal of Astrobiology (2007, in press)

Is Darwinism universal?

The theory of evolution discusses the relative importance of:

- contingency,
- gradual action of natural selection.

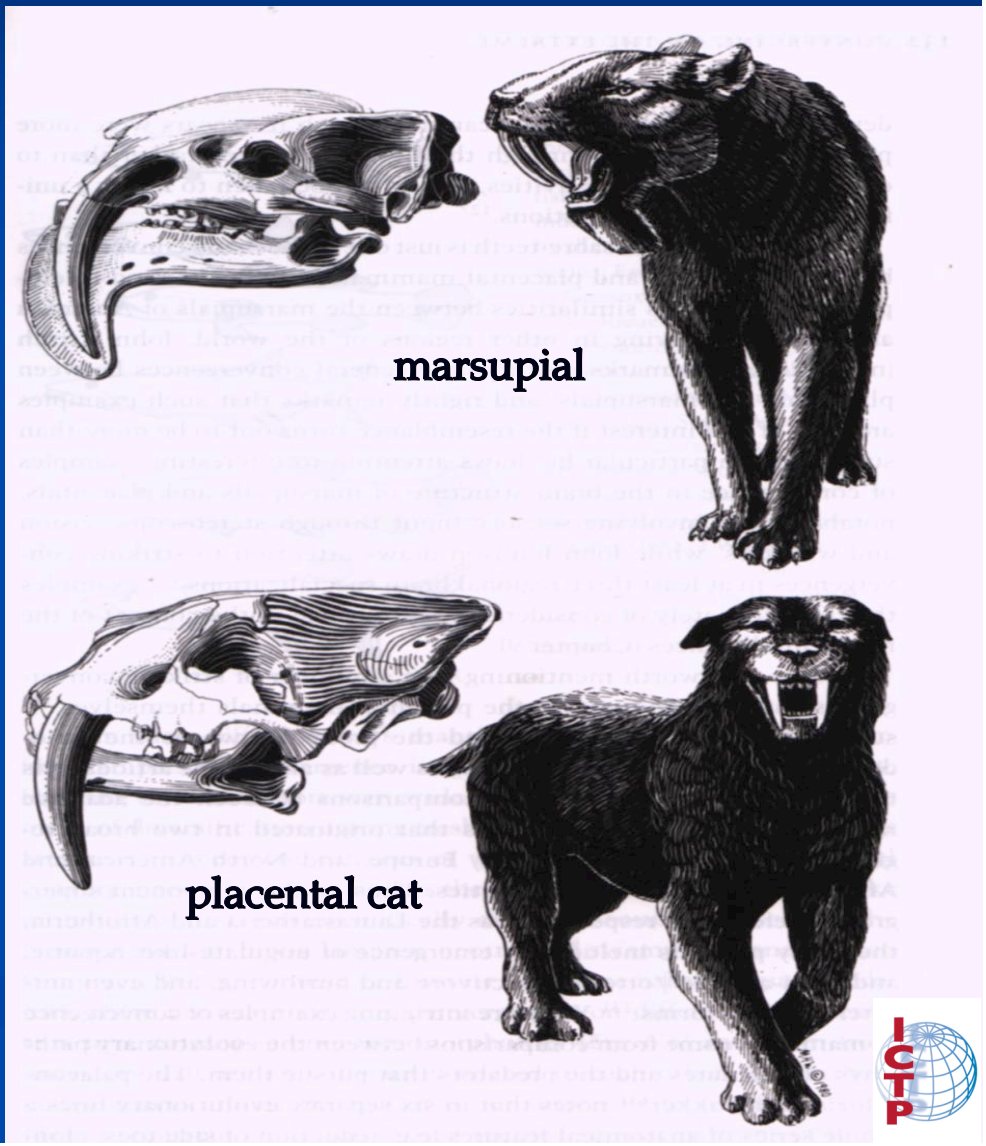
Can the outcome of evolutionary processes be predictable?

- Independent of historical contingency, natural selection is powerful enough to shape organisms in similar environments (anywhere) to similar ends.
  - To a certain extent and in certain conditions, natural selection may be stronger than chance.
  - The ubiquity of evolutionary convergence argues against the view that biological diversity on Earth is unique.

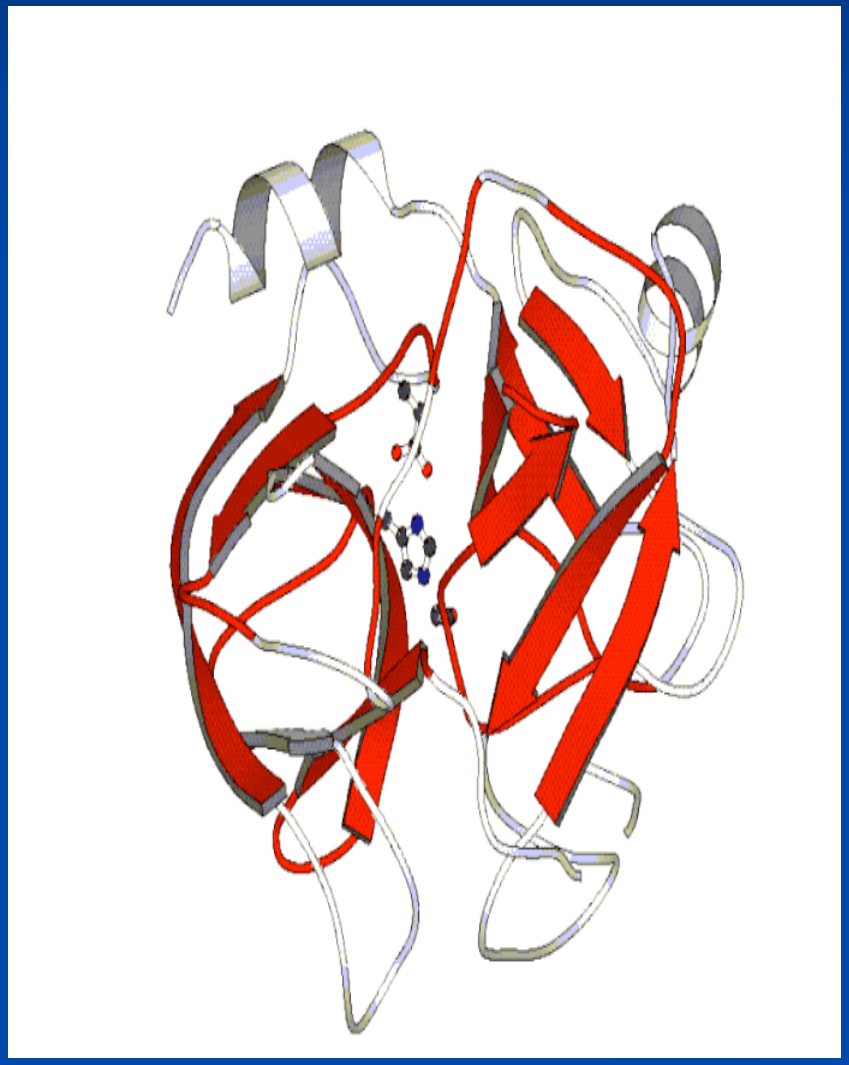
Convergence in mammalian evolution

Dagger-like cannines evolved independently in:

- A group of South American marsupials related to the kangaroo and opossum, and
- Placental cats (the extinct 'sabre-tooth' felids), were probably the ancestors of present-day cats.



Convergence in biochemistry

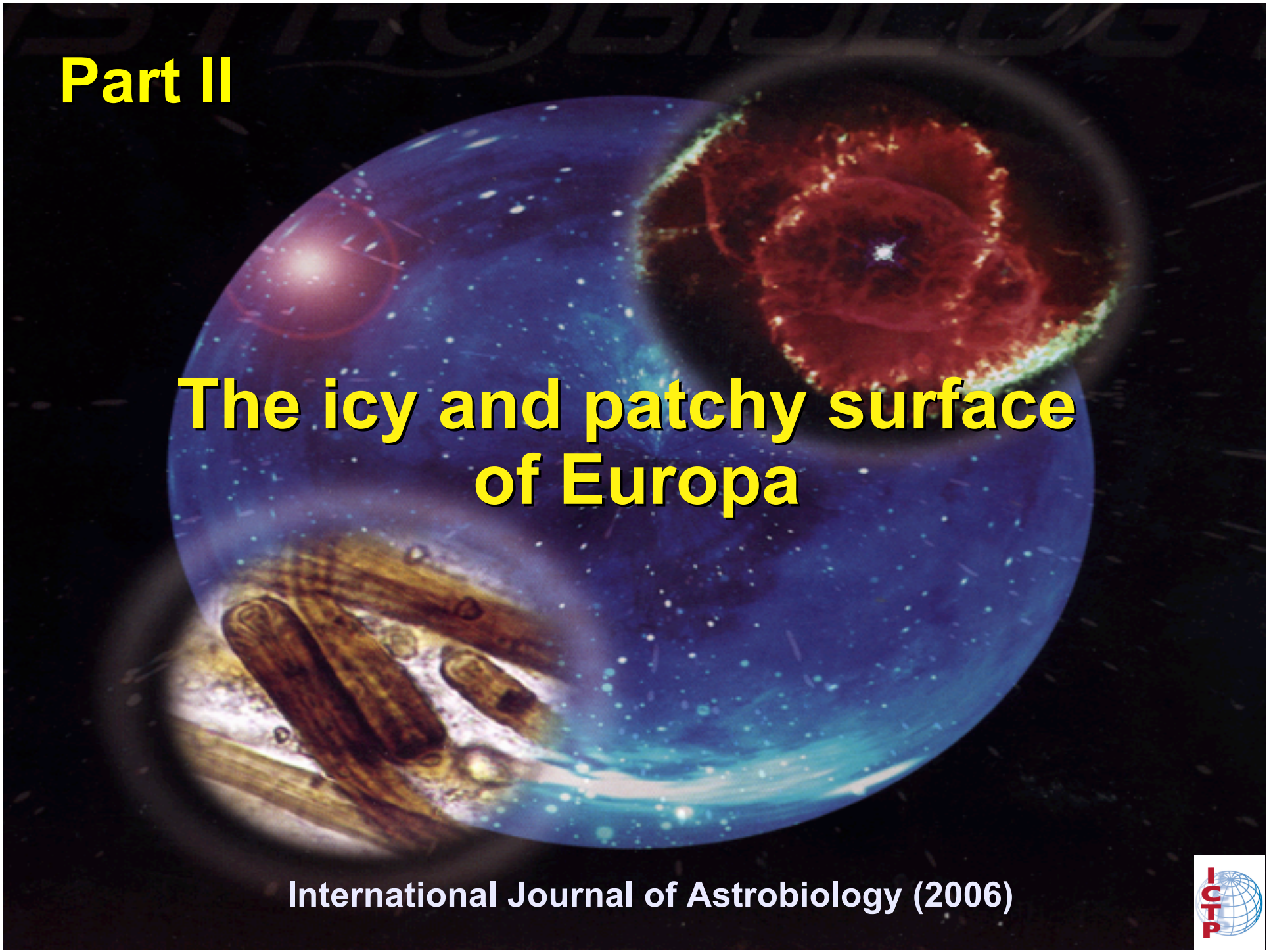


- Lipases are secreted by the glands of vertebrates to catalyze fats and glycerol.

- Proteases are housekeeping genes that are needed for the sustenance of all cells (catalyzing the digestion of proteins into its amino acids).

- Their active sites are an identical set of 3 amino acids (histidine, serine, and aspartic acid), but their folding is different.

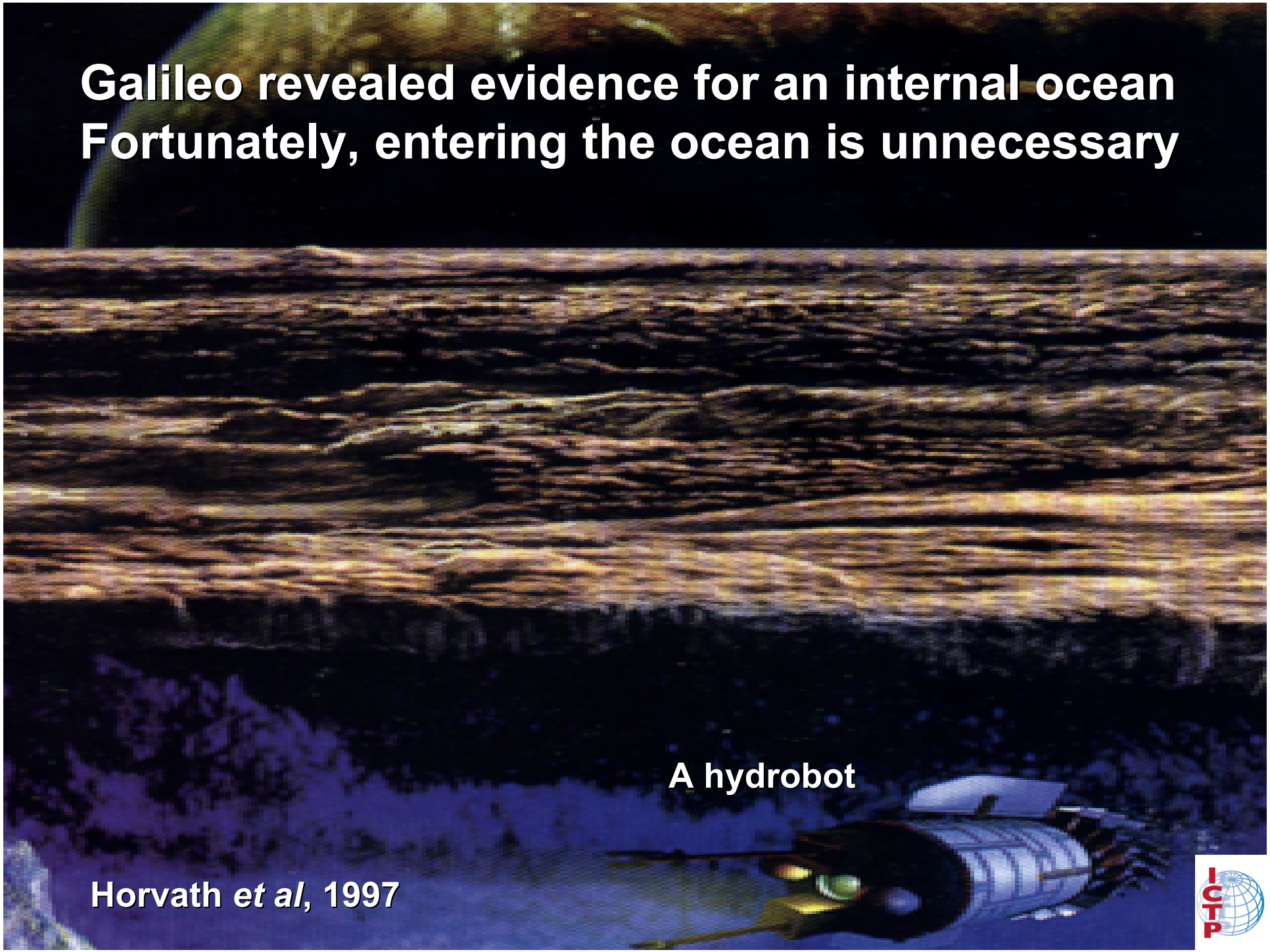
Part II



The icy and patchy surface of Europa

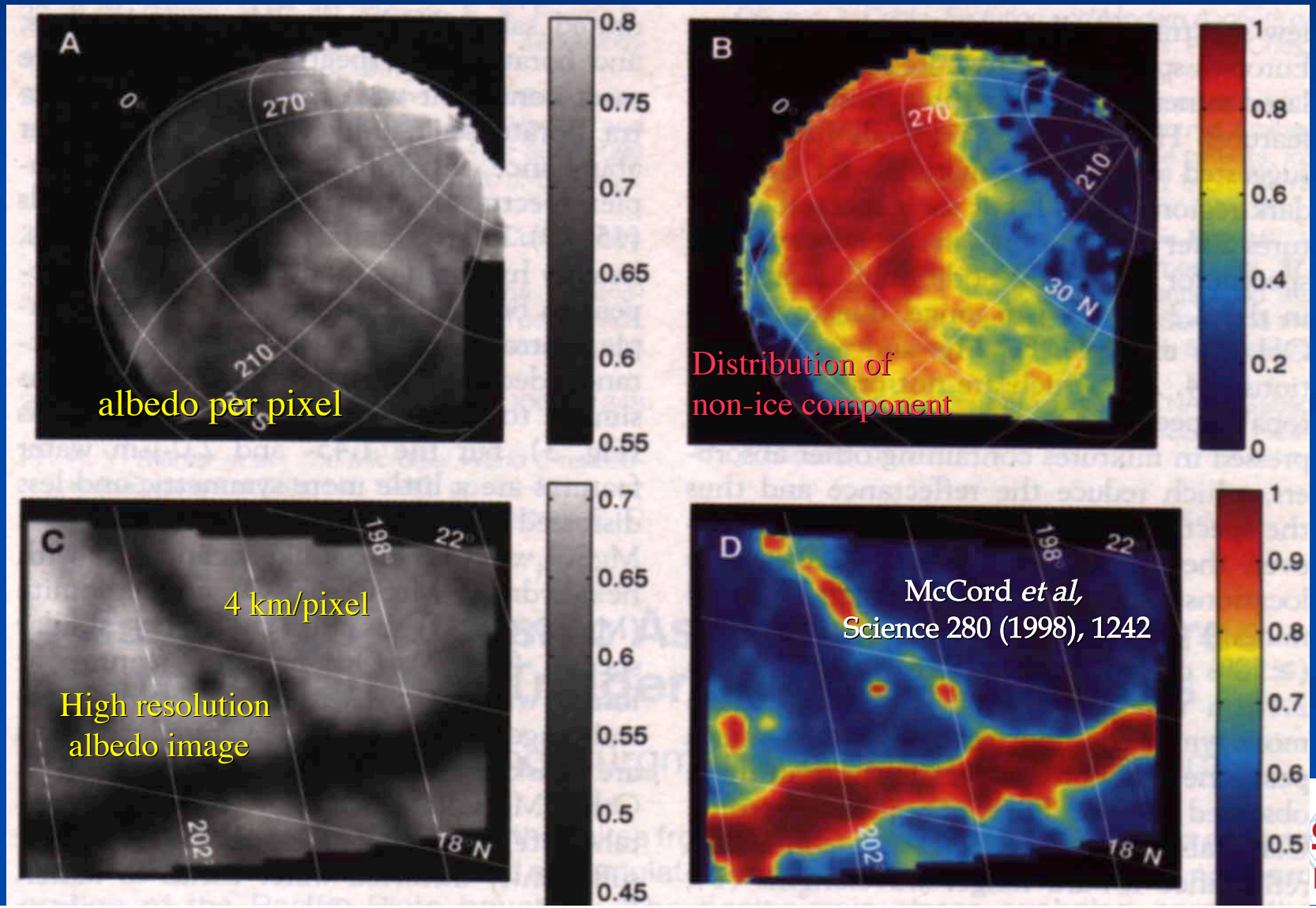
International Journal of Astrobiology (2006)

Galileo revealed evidence for an internal ocean
Fortunately, entering the ocean is unnecessary



The Europa icy and 'patchy' surface

(Spectrometer data from near IR)



Possible sources of the stains

- **External source:**

  Ions may be implanted from the Jovian plasma.

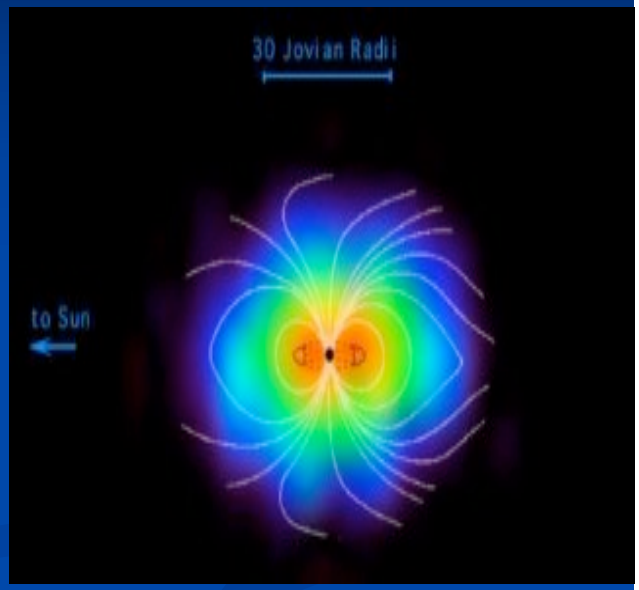
- **Internal source:**

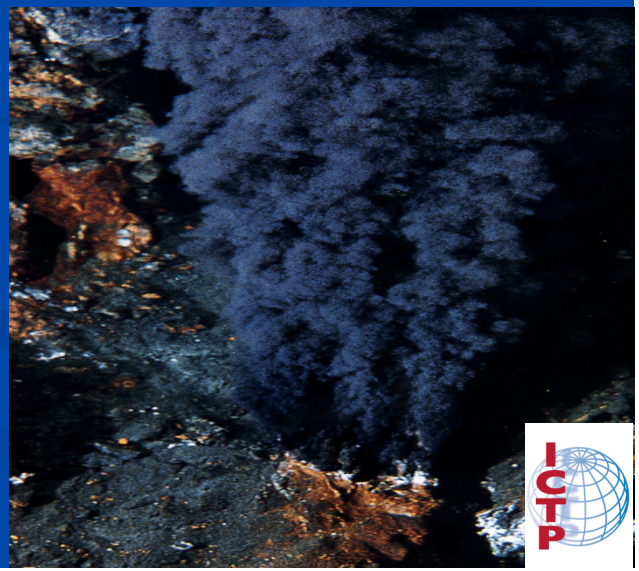
  Sulfur may be due to cryovolcanism,

- **Could the source be biogenic?**

- **One way to decide:**

  Develop planetary landers.





An array of four microprobes for Europa

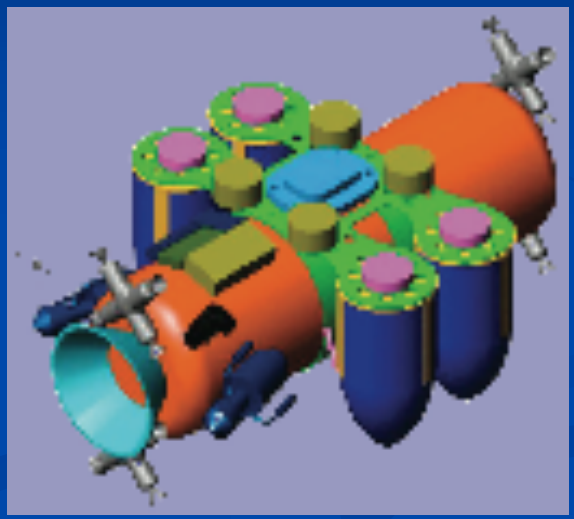
- Europa landers were included in the Cosmic Vision Report. But landers would have to guarantee likely science return to justify the resources to be invested.

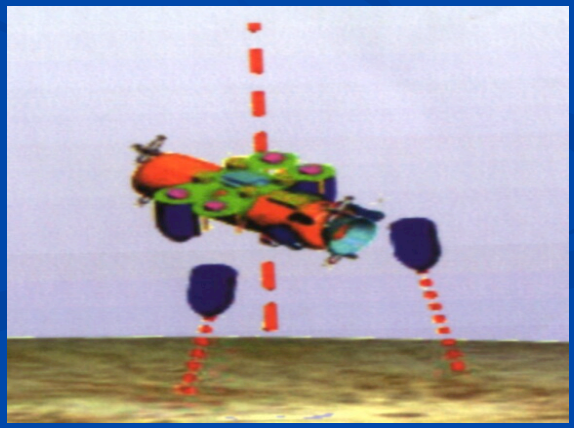
- In spite of this cautious note, we should still consider landers as an option in any Jupiter Exploration Programme that would eventually be envisaged in the future.

The Europa Microprobe *in-situ* Explorer
(The "EMPIE study")

- The lander discussed in the Cosmic Vision document would have a set of 4 microprobes (350 gm each).

- Mass constraint for the microprobes would be 1.7 kg.



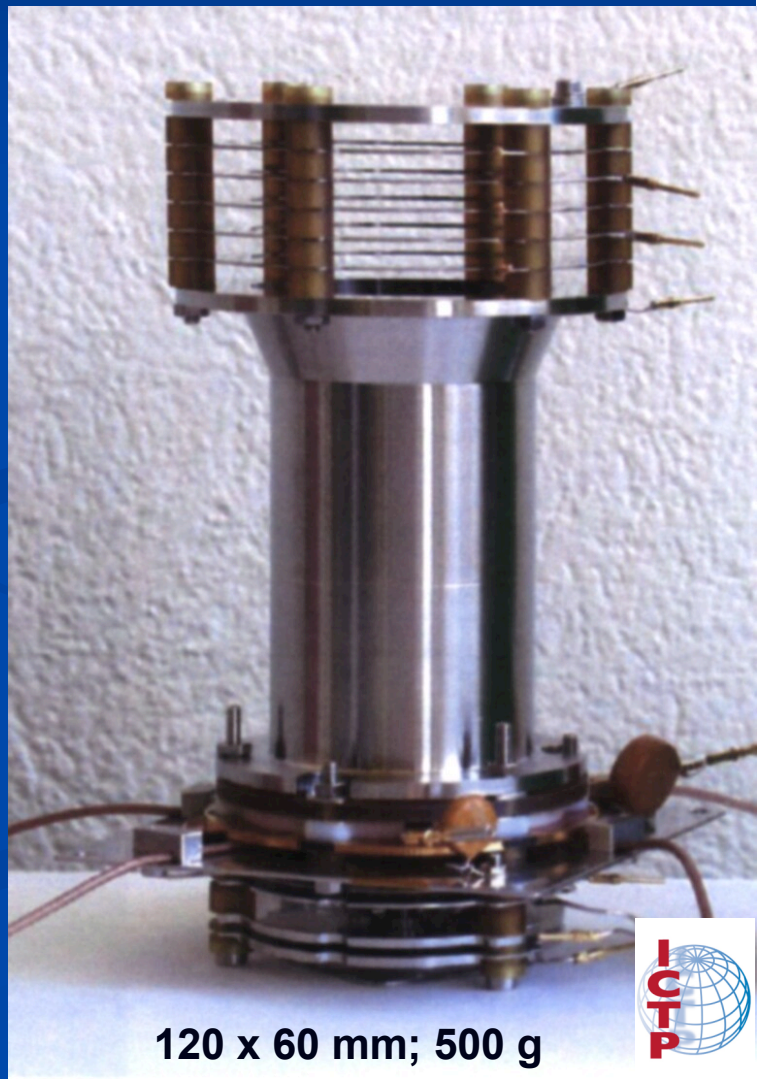


Tirso Velasco and colleagues

Mass spectrometry for biogeochemistry

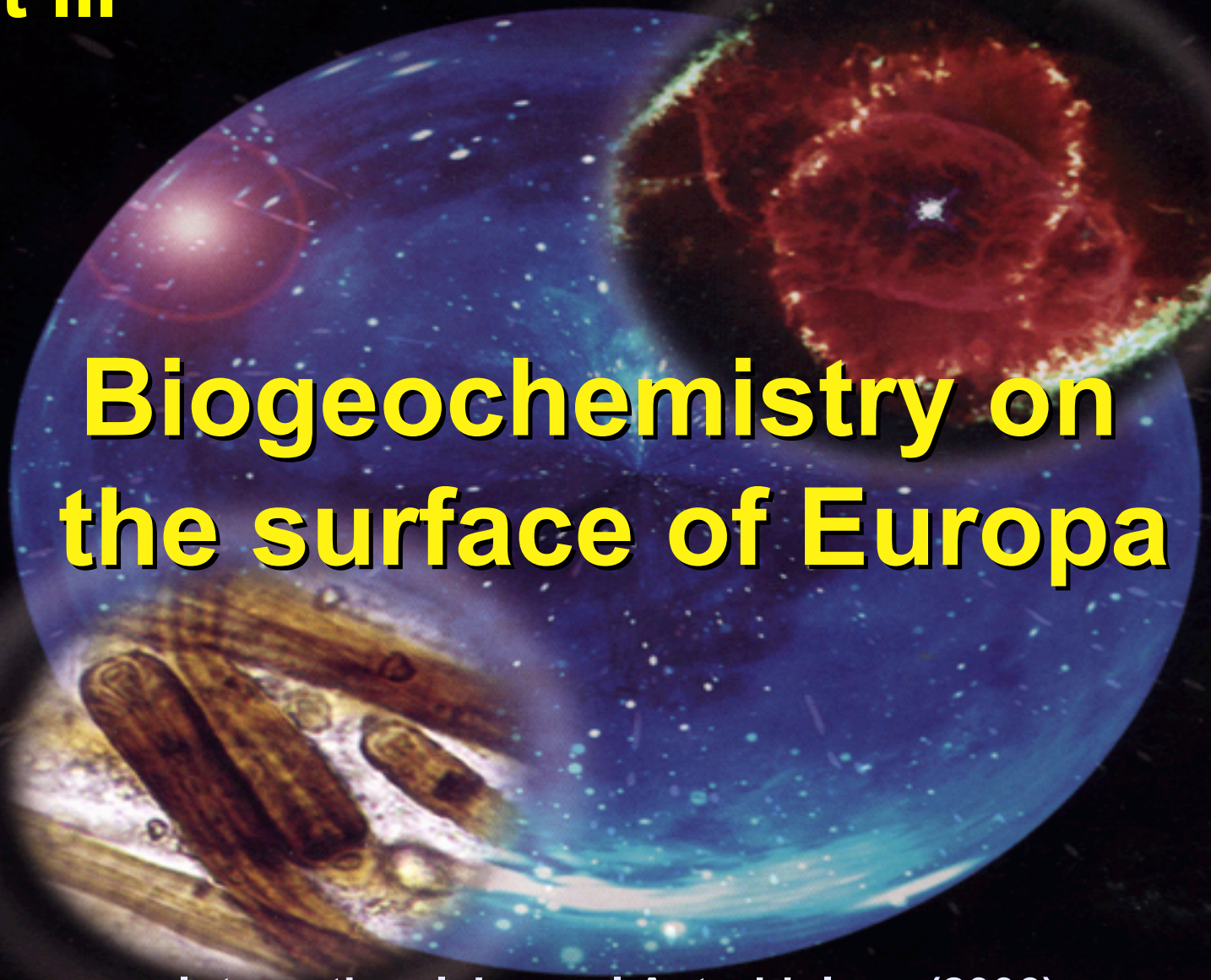
- A light MS built for the Bepi-Colombo mission to Mercury was developed. (The lander has been cancelled.)

- When life processes the element sulfur, it tends to fractionate isotopes differently from geology.



Part III

Biogeochemistry on the surface of Europa



International Journal Astrobiology (2006)

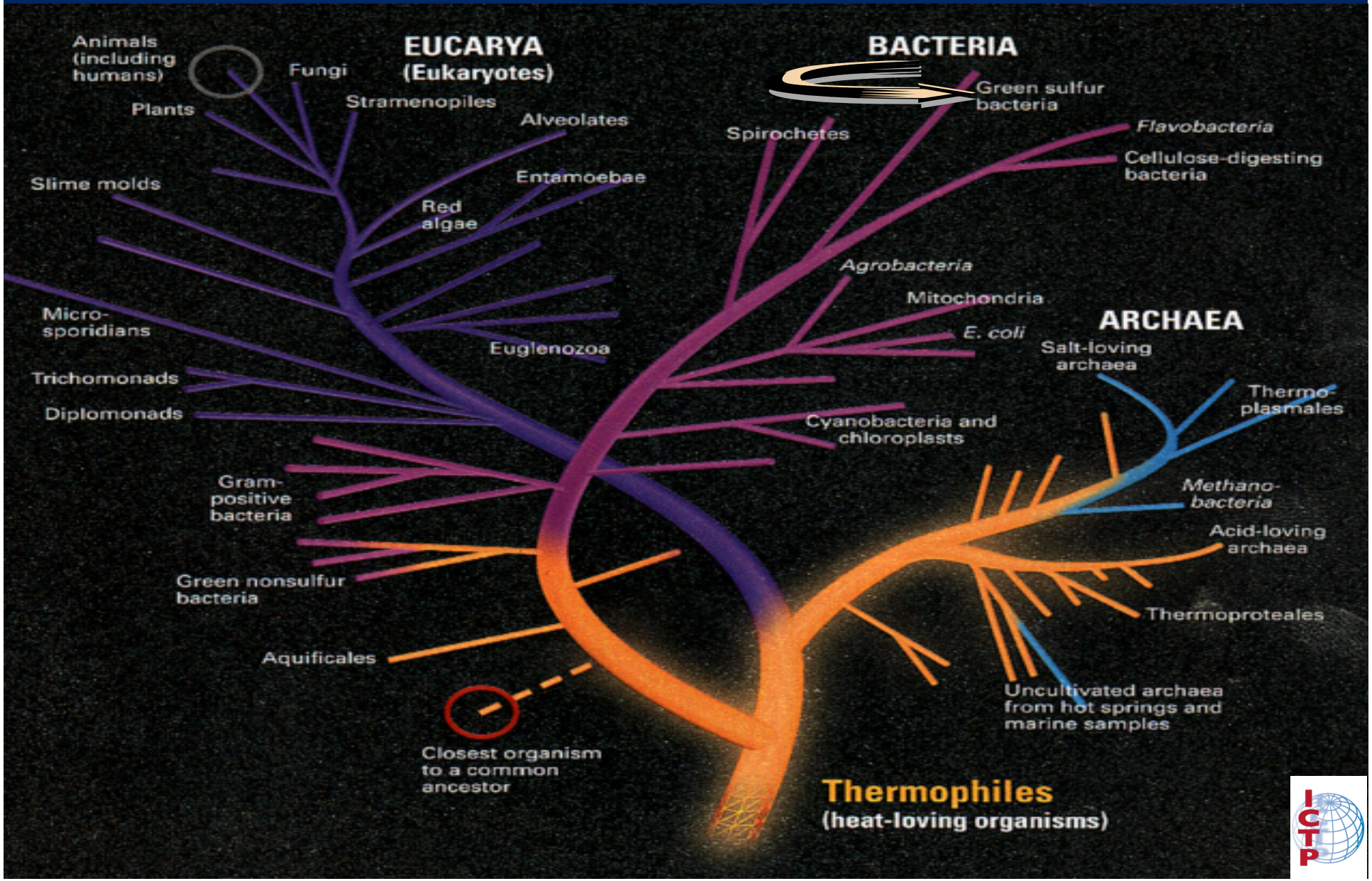
The delta ^{34}S-parameter

- Canyon Diablo Meteorite (CDM) is a troilite (FeS), that was found in Arizona.

$$\delta^{34}S = \left[\frac{(^{34}S/^{32}S)_{sa}}{(^{34}S/^{32}S)_{st}} - 1\right] \times 10^3 \text{ [‰, CDM]},$$

- CDM coincides with the average terrestrial ratio of the isotopes ^{32}S and ^{34}S.

Sulfate-reducing bacteria



Sulfate-reducing bacteria

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

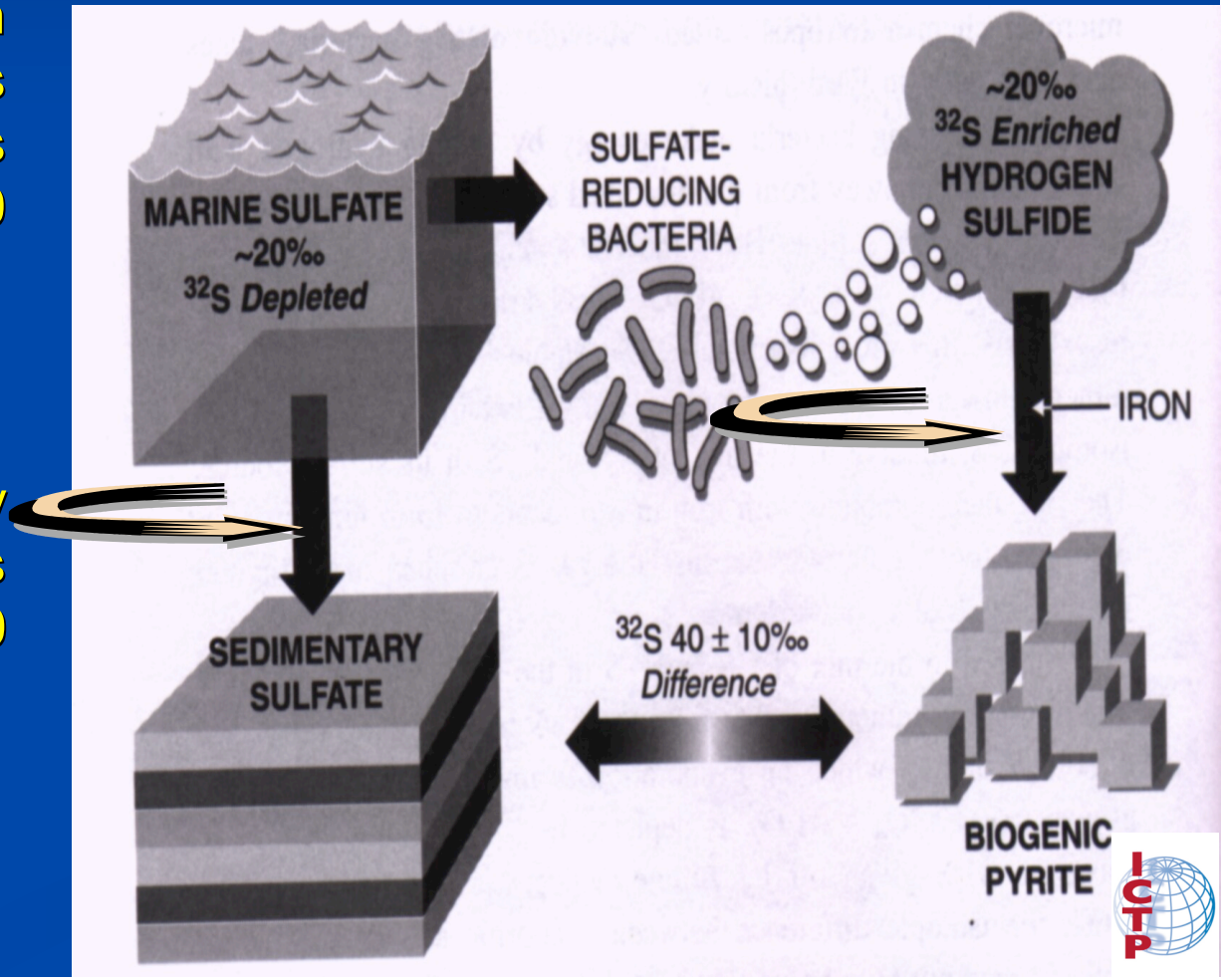
$$4H_2 + H_2SO_4 \rightarrow H_2S + 4H_2O + 39\ kilocalories$$

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

Iron sulphide, FeS_2

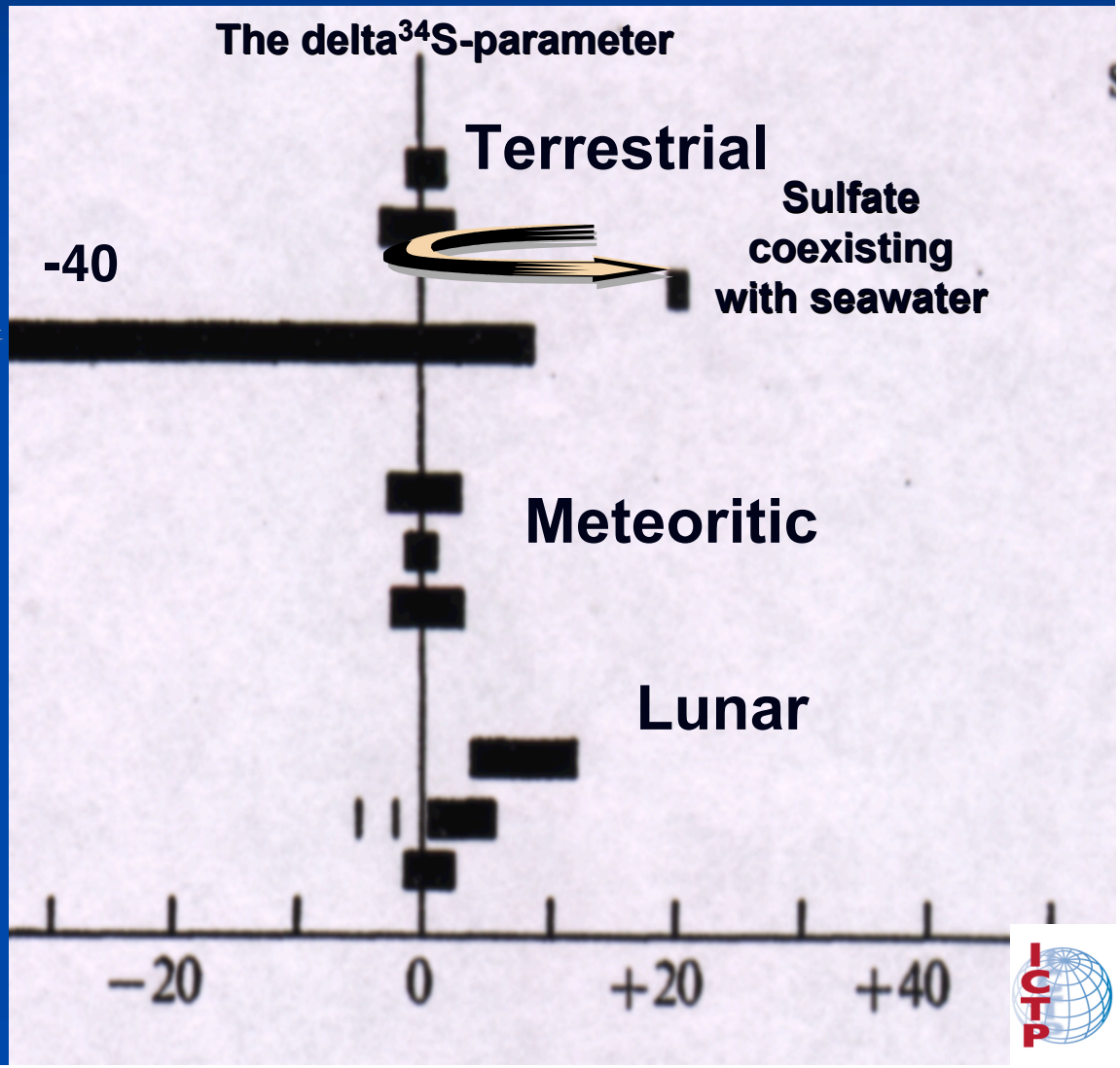
The sulfur isotopes are divided between biogenic minerals and sulfate minerals

- Dissolved sulfate on evaporation forms sulfate minerals depleted of ^{32}S by 20 per mil.
- The H_2S given off by the bacteria is enriched in ^{32}S by 20 per mil.

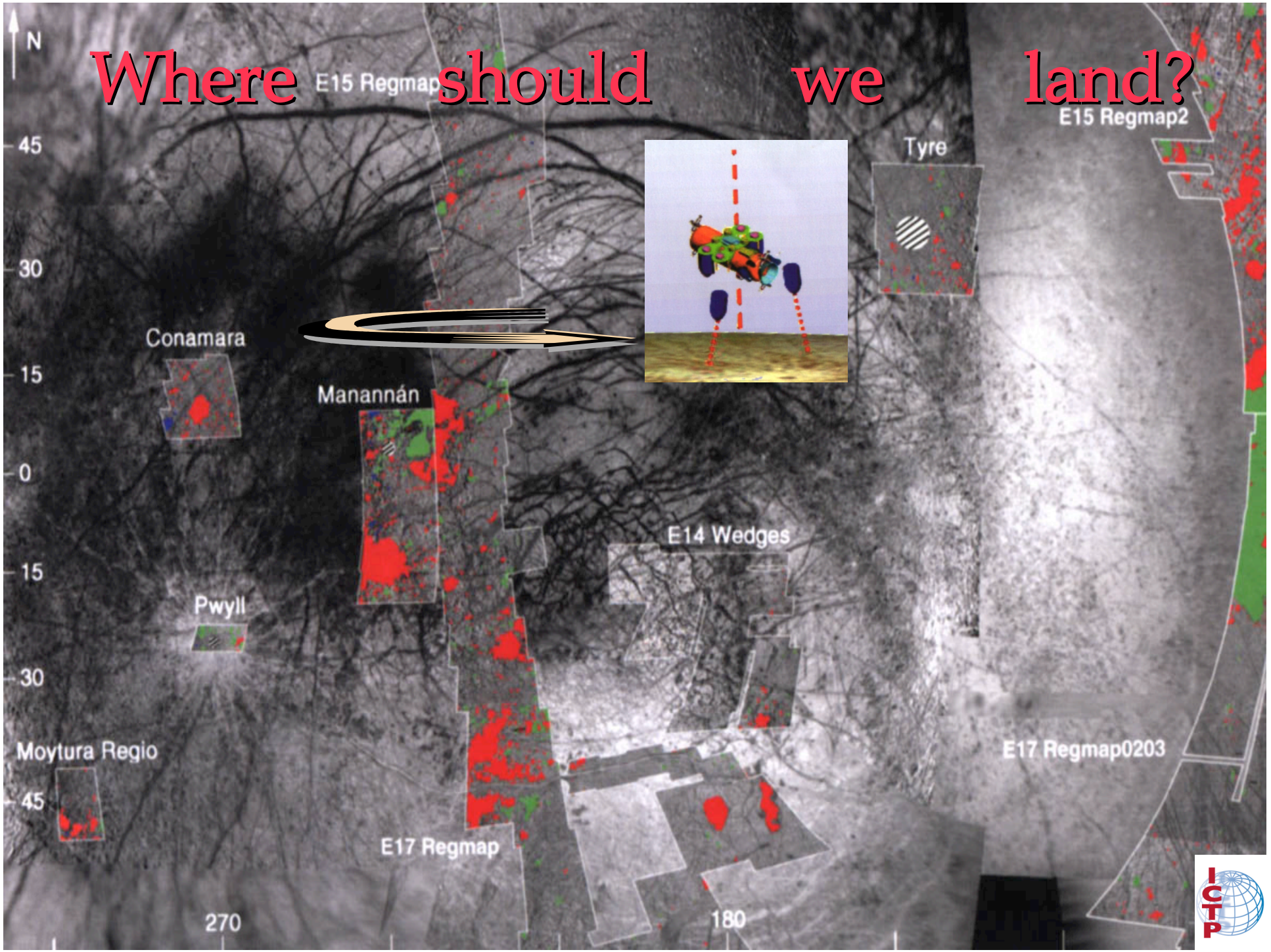


Sulfur ions on Earth, meteorites and Moon

From measurements in basins off California: insoluble sulfide, mostly pyrite



Where should we land?



Part VI

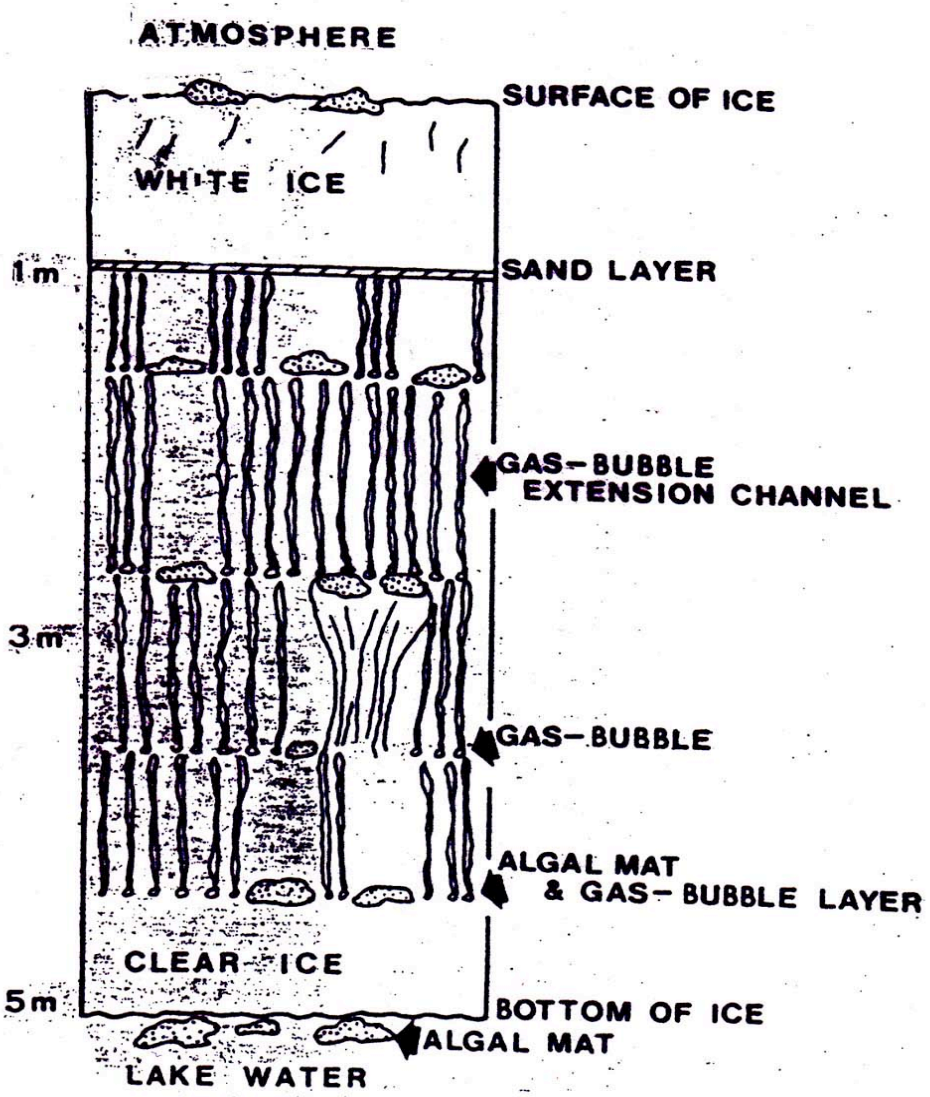
Discussion

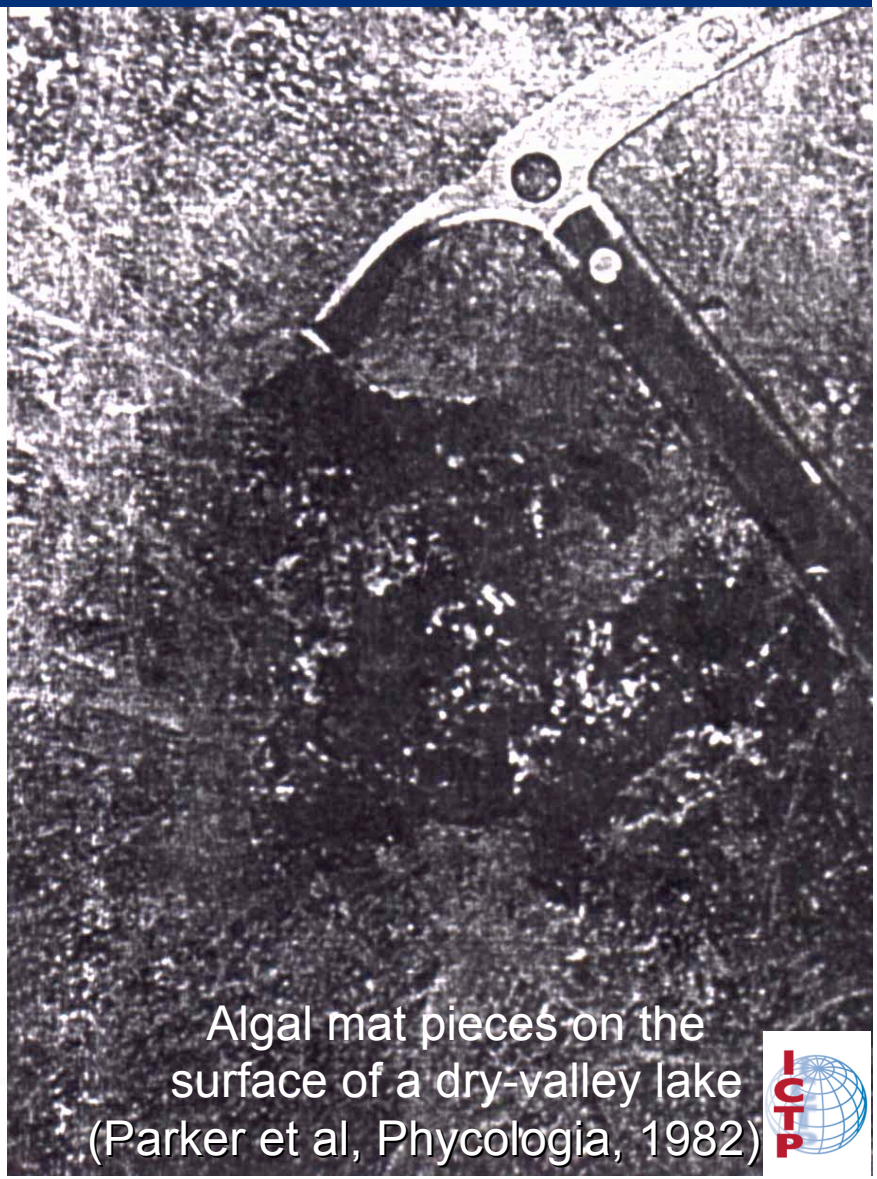
- On Earth there are ice-locked ecosystems that can stain the icy surface without a cryovolcanic source.

- It is the biology instead of the geology that does the job by staining the ice.

The dry valley lakes

A section of the icy surface of Lake Hoare





Algal mat pieces on the surface of a dry-valley lake (Parker et al, Phycologia, 1982)

Annual escape of sulfur (kg) by the loss of algal mats

	Chad	Hoare	Fryxell
Organic matter	8343.0	247.4	1450.0
Kjeldahl-N	188.5	33.1	55.0
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

Beyond the Aurora Programme

- Testing the universality of biology on Europa is feasible with microprobes or landers.

- This militates in favour of eventually considering the extension of the Aurora Programme to include a Europa landing mission.

- To sum up:

Europa should be an objective of space exploration in the foreseeable future.

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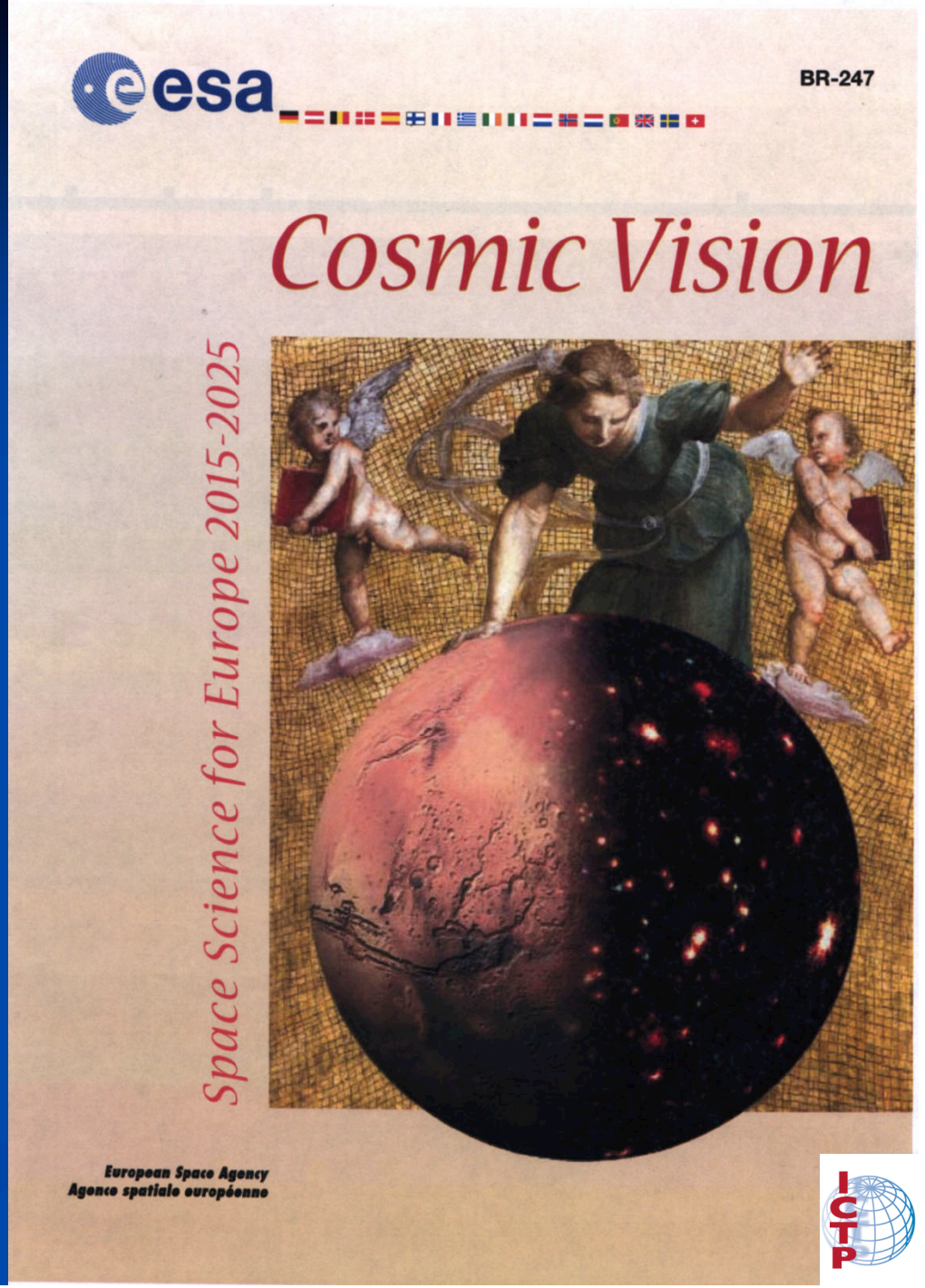
Mars may not be the target with the most easily accessible biomarkers.



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