Analogues for planetary missions

Frédéric Foucher[1],

Frances Westall[1], Jutta Zipfel[2], Nicolas Bost[1,3], and the ISAR and Euro Cares teams

[1]Centre de Biophysique Moléculaire, CNRS, Orléans

[2]Senckenberg Gesellschaft für Naturforschung, Frankfurt

[3]CEMHTI, CNRS, Orléans

frederic.foucher@cnrs-orleans.fr

Analogue?

Here, we will consider as analogue something terrestrial presenting characteristics more or less representative of something extra-terrestrial.

Analogues can be used to:

- Test and calibrate instrumentation

- Help *in situ* interpretation

- Make science

Two main categories

Analogue sites

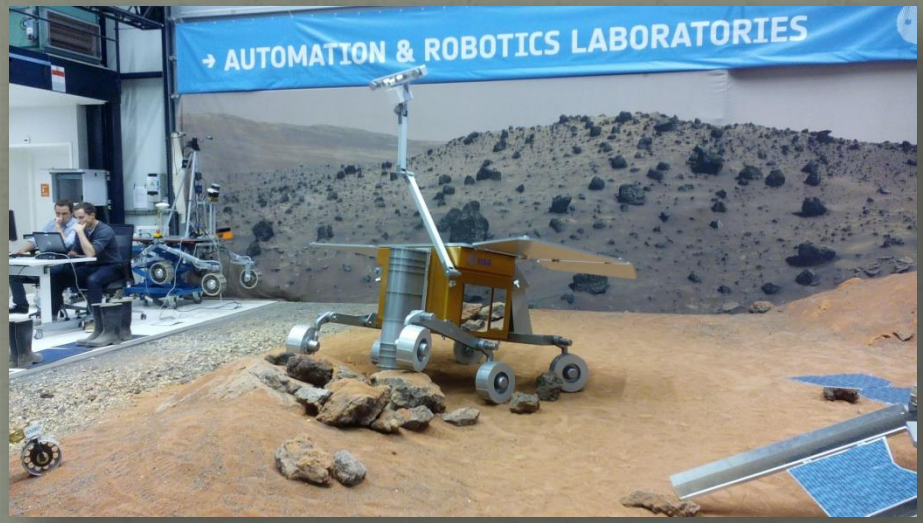
Analogue samples

Analogue sites

From mobility testing to fundamental science

Artificial analogue areas

Rover mobility testing



Mobility testing area at ESA ESTEC

Human space flight

Mars 500 facility at IBMP near Moscow

Natural analogue areas

In situ instrument testing

Rover testing during the Arctic Mars Analog Svalbard Expedition (AMASE) 2009

Human exploration

Mars Desert Research Station ,Utah (Foing et al. 2011)

HI-SEAS (Hawaii Space Exploration Analog and Simulation), since August 28th 2015

Natural analogue areas

Planetology

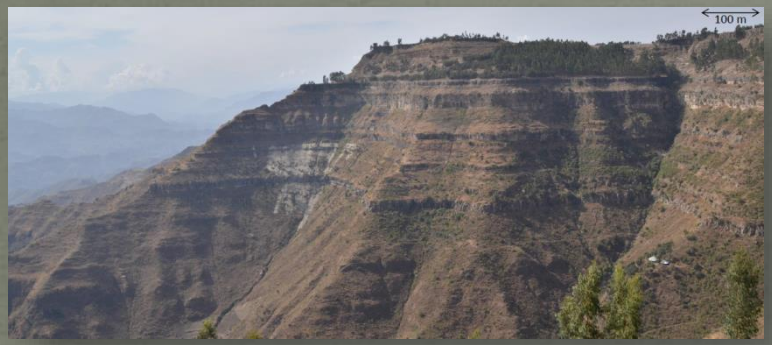
Meteor crater, Arizona, USA

Processes

Mars analogue for the mechanical and chemical alteration of volcanic Martian rocks in Iceland (Mangold et al., 2011)

Natural analogue areas

Mineralogy

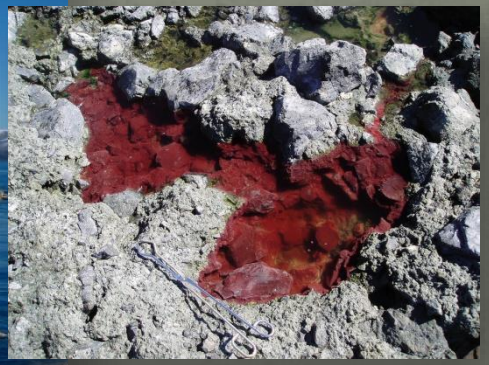


Opal deposit, Ethiopia (credit B. Chauviré)

Mineral deposit in Rio Tinto, Spain

Biology

Early Mars analogue of hypersaline environment at Mono Lake, California, USA



Kulp 2014

Analogue sites

Type	Relevance	Example	A few references
Artificial	Rover mobility	- ESA ESTEC - JPL	
	Human exploration	- Mars 500 experiment at IBMP	
Natural	*In situ* missions testing	- Svalbard, AMASE	Steele, 2007 Amundsen et al., 2010
	Human exploration	- Utah desert - Hawaii - Atacama desert	Ehrenfreund et al., 2011 Foing et al., 2011
	Planetology	- Impact craters (Meteor crater, Rochechouart, Lonar crater…) - Hotspot volcanoes (Hawaii, La Réunion, …)	
	Processes	- Iceland - Cyprus	Mangold et al., 2011 Bost et al., 2013
	Mineralogy	- Rio Tinto, Spain	Edwards et al., 2007
	Biology	- Mono Lake, USA - Yellowstone, USA - Patagonia	Wolfe-Simon et al., 2010 Campbell et al., 2015

General reports:

- Foing, Stoker & Ehrenfreund, (2011) Astrobiology field research in Moon/Mars analogue environments, *Special Issue of International Journal of Astrobiology*, 10:3, 137-305.
- Preston, Grady & Barber, (2012) CAFE, Concepts for Activities in the Field for Exploration, TN2: The Catalogue of Planetary Analogues, written by The Planetary and Space Sciences Research Institute, The Open University, UK

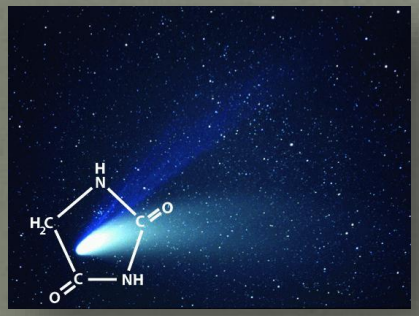
Analogue samples

From sample handling to fundamental science

Different types of analogue samples

For instrument testing: samples of particular mechanical, physical or chemical properties.

For geology: rocks and minerals.



For chemistry: molecules and reactions.

For biology: life in analogue sites and fossils.

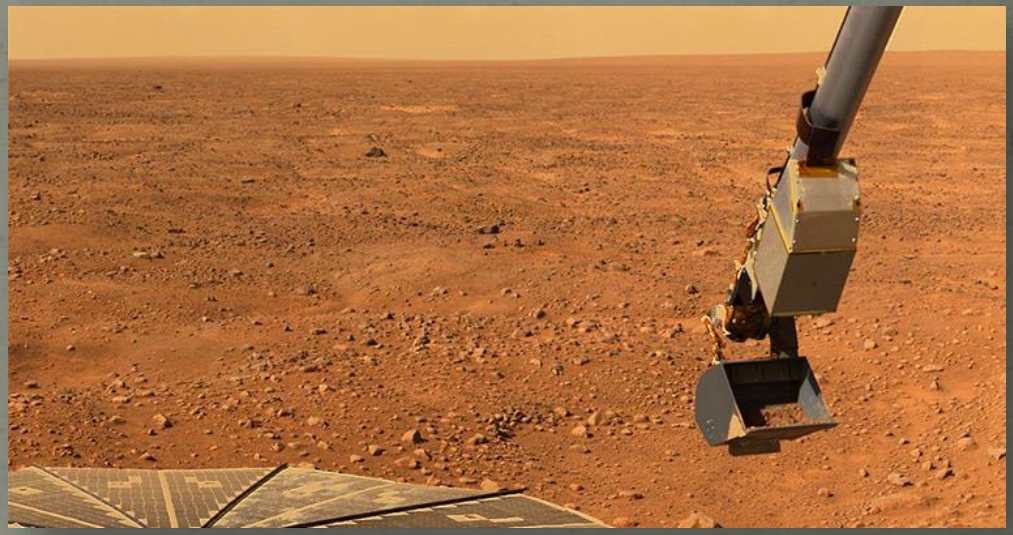
Material samples

Handling and preparation

Material samples

Samples with analogue properties:

- Size (drill core)
- Porosity (pumice)
- Density (hematite, d~5)
- Roughness (polished quartz)
- Consistency (sand)
- Physical properties (ice)



Samples particularly pertinent for testing sample handling and preparation (*in situ* missions and sample return missions).

Geological samples

Most obvious analogues

In situ space exploration

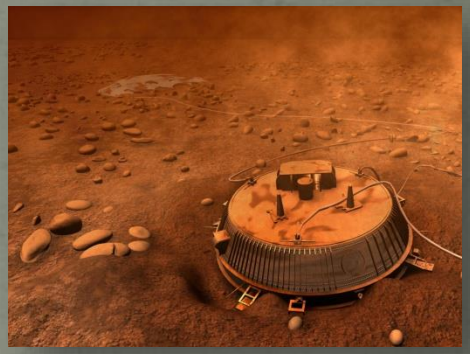
Mars

MSL, 2013

The Moon

Apollo 11, 1969

Titan

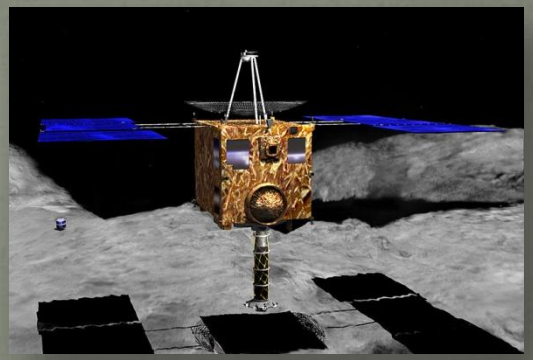


Huygens, 2005

Comets

Philaé (Rosetta), comet Tchourioumov-Guerassimenko, 2014

Asteroids

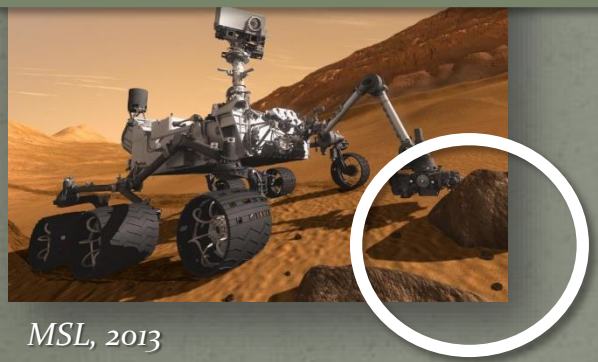


Hayabusa and Minerva , asteroid Itokawa, 2005

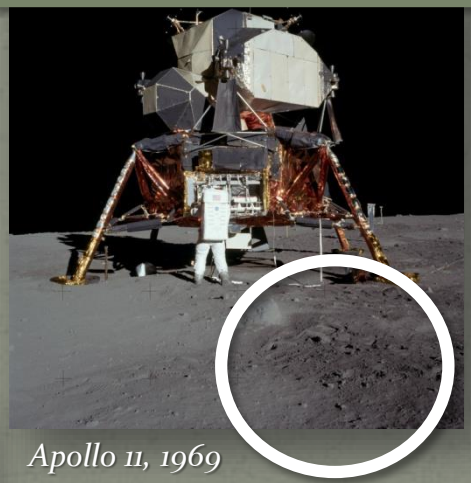
+ Europa, Enceladus…

Rocks (including ices) = the principal objects of study

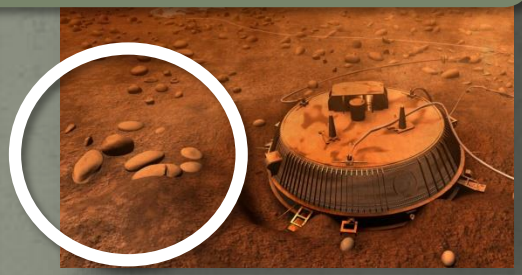
Mineralogy, geology, research and study of organic molecules, search for potential traces of life…



MSL, 2013

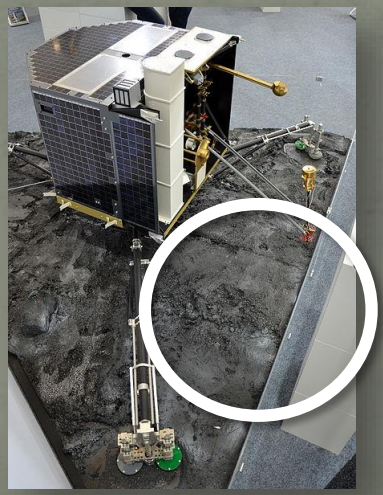


Apollo 11, 1969



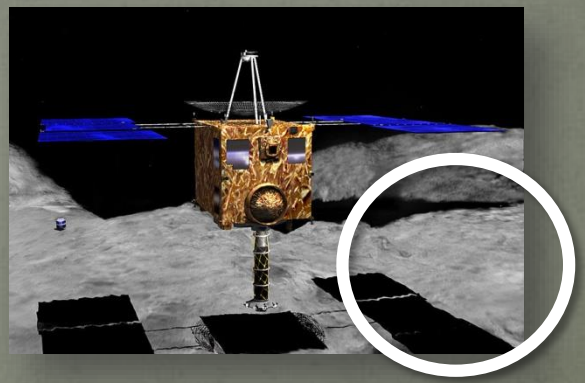
Huygens, 2005

Comets



Philaé (Rosetta), comet Tchourioumov-Guerassimenko, 2014

Asteroids



Hayabusa and Minerva , asteroid Itokawa, 2005

In situ limitations

Geology as an example

Rock study on Earth

Classical

-Camera (eyes)
-Hammer
-Optical microscope in transmitted light
using petrographic thin sections

Complementary

-Raman spectroscopy
-Infrared spectroscopy
-X Ray diffraction
-Electron microprobe
-ICP
-Drill
-Electron microscopes
-Mass spectrometers
-LIBS
-Mössbauer
-XRF
-PIXE
-Synchrotron analysis
…

Rock study *in situ*

Classical

-Camera ~~(eyes)~~
~~-Hammer~~
~~-Optical microscope in transmitted light~~
~~using petrographic thin sections~~

Complementary

-Raman spectroscopy
-Infrared spectroscopy
-X Ray diffraction
~~-Electron microprobe~~
~~-ICP~~
-Drill
~~-Electron microscopes~~
-Mass spectrometers
-LIBS
-Mössbauer
-XRF
-PIXE
~~-Synchrotron analysis~~
…

Limitations

Resolution and power of the instruments

+

Automation of the systems

Instrumental development

Calibration

Testing

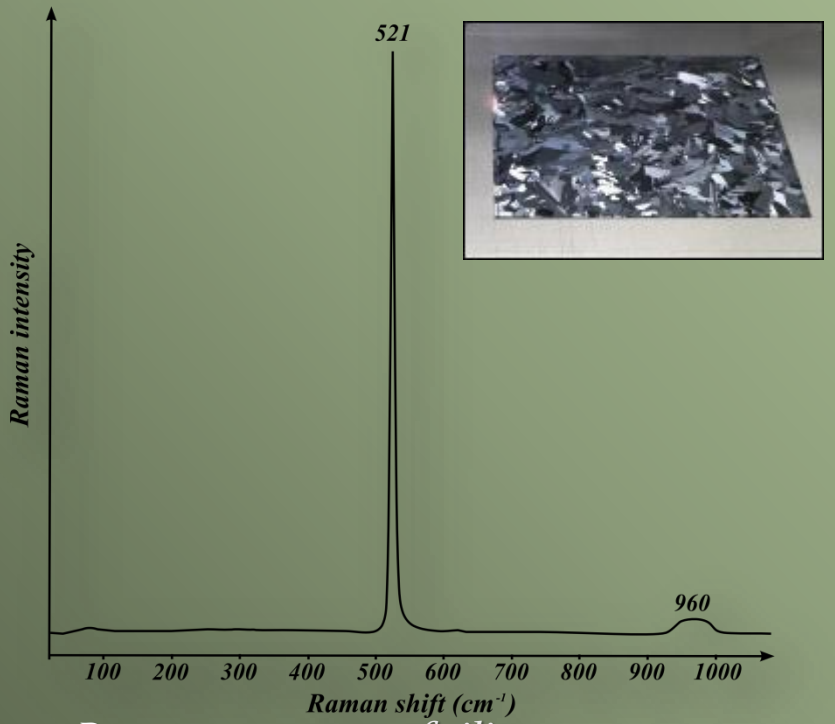
1- Instrumental calibration

Use of dedicated standards

Calibration target for camera

ColorChecker

Silicon for Raman spectrometer



Raman spectrum of silicon

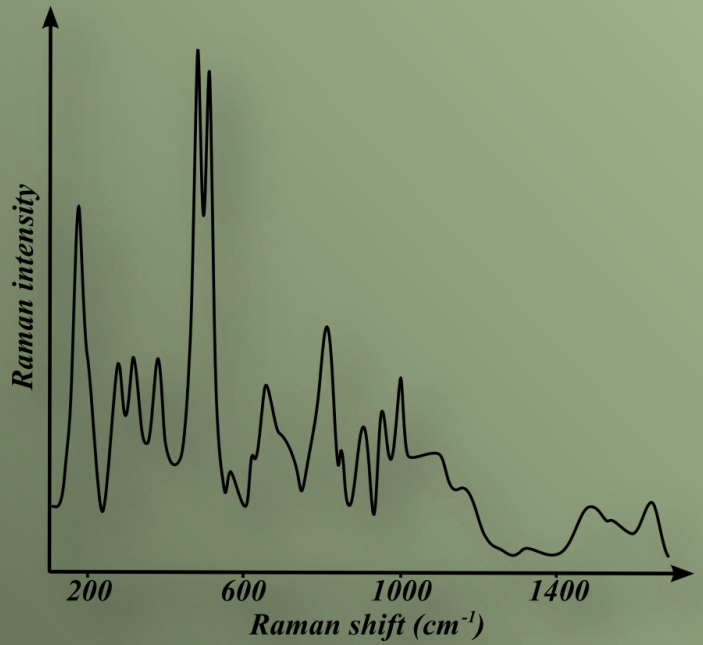
2- Instrumental testing

Use of analogue samples

Camera

CLUPI image (ExoMars) of a chert from Kitty's Gap, South Africa, 3.5Ga.

Raman spectrometer



Raman spectrum of a basalt from Perrier, France

Tricky interpretation!

Blind test of the ExoMars payload

On the utility of analogue samples

Principle

Two Mars analogue samples

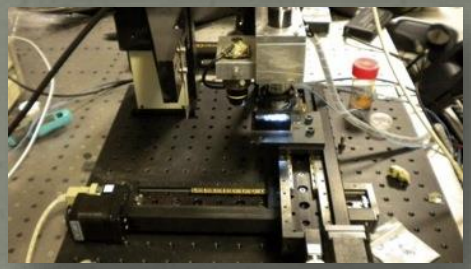
Fragments of rock and/or powder, depending of the instruments

That's all!

What interpretation can be made?

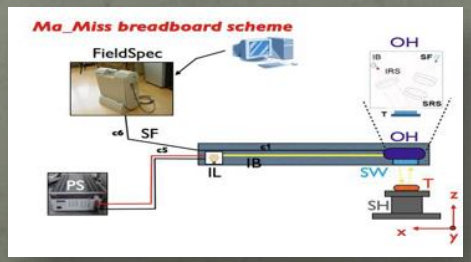
Analysis

MicrOmega
IAS, Orsay, France



RLS
CAB, Valladolid, Spain

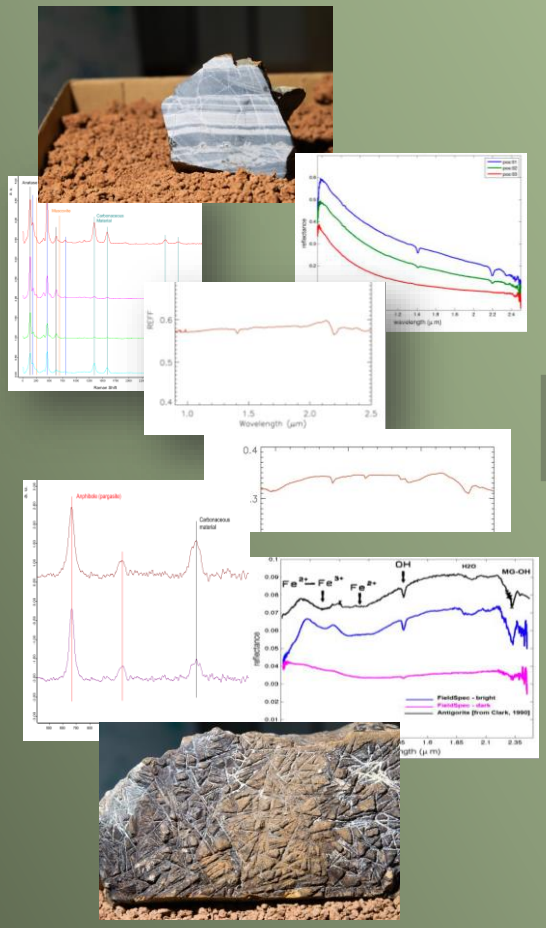
CLUPI
Space X, Neuchatel, Switzerland



Ma_Miss
INAF-IAPS, Roma, Italy

Geological interpretation

Data



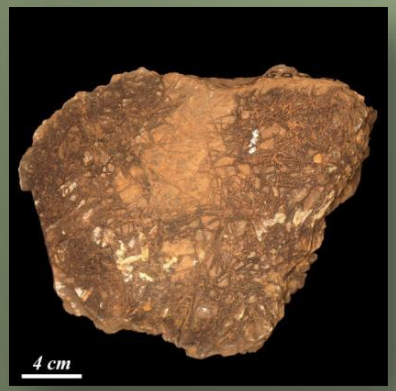
Brainstorming

C. Ramboz (geochemist)

N. Le Breton (mineralogist)

Interpretation

Sample 1 = chert



Sample 2 = komatiite

Conclusion of the experiment

With the ExoMars payload it is possible to identify and characterise rocks in a relatively precise way *(more information in Bost et al., 2015, PSS 108, 87-97)*.

The interpretation requires the use of all the instruments of the payload.

For a "scientific" calibration, it is necessary to test the instruments using the same analogue samples.

The International Space Analogue Rockstore

Bost et al., 2013, PSS 82-83, 113-127

A well characterized collection of analogue rocks and minerals dedicated to testing the payload for *in situ* missions.

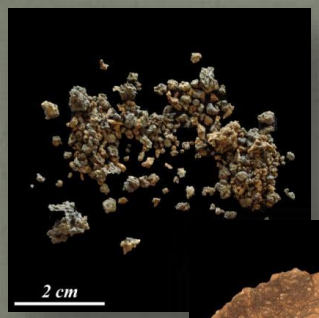
An online database with information on:
-the available samples,
-the sample lending system,
-data on the samples obtained using laboratory and space instruments.

www.isar.cnrs-orleans.fr

Next month, the collection will be transferred to the Natural History Museum of London under the responsibility of ESA.

Variety of samples

Volcanic rocks



Slag 09IT01

Komatiite 10ZA09

Komatiite 11CA02

Sedimentary rocks

Chert 00AU04

Chert 00AU05

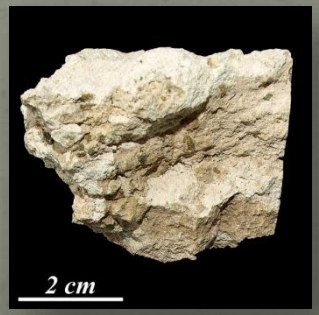
Minerals

Aragonite 12FR02

Apatite 12UN05

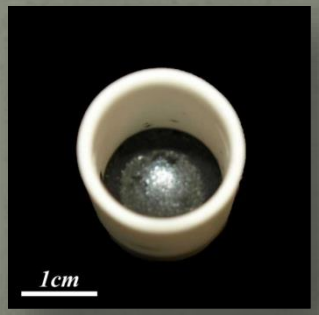
Epidote 12PK01

Products of altered rocks



Carbonate 11CY04

Artificial samples



Basalt 11AR02

Chemical samples

Compounds and reactions

Space chemistry

2 types of molecules:

"Known" molecules:
- Molecules detected in the interstellar medium
- Molecules found in meteorites (e.g. amino acids)

→ Just buy them ! *(except IOM)*

"Unknown" molecules:
- Molecules formed in comets and icy particles
- Molecules formed in extra-terrestrial atmospheres (tholins)

→ Simulate the conditions of synthesis

Simulation chambers

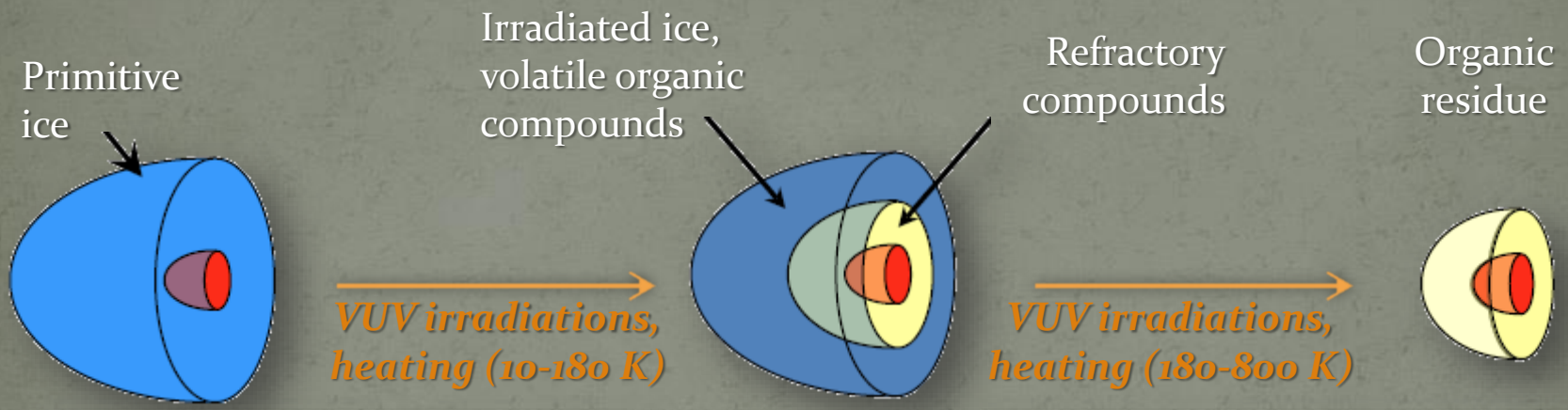
Analogue environments allowing to synthetize analogue molecules still detected in space or not.

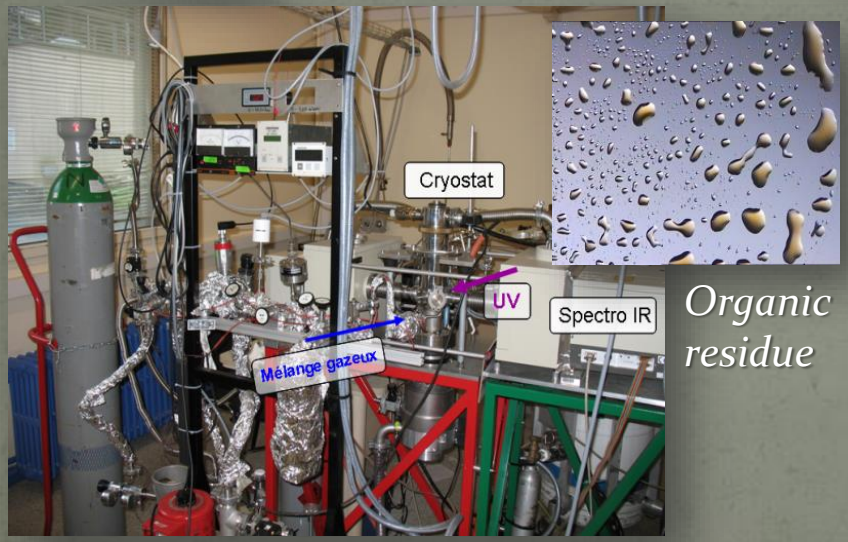
- **Understand the extra-terrestrial chemical reactions forming detected molecules.**

- **Synthetize analogue molecules.**

- **Discover the formation of molecules not yet detected in space and thus orientate the future instrumentation.**

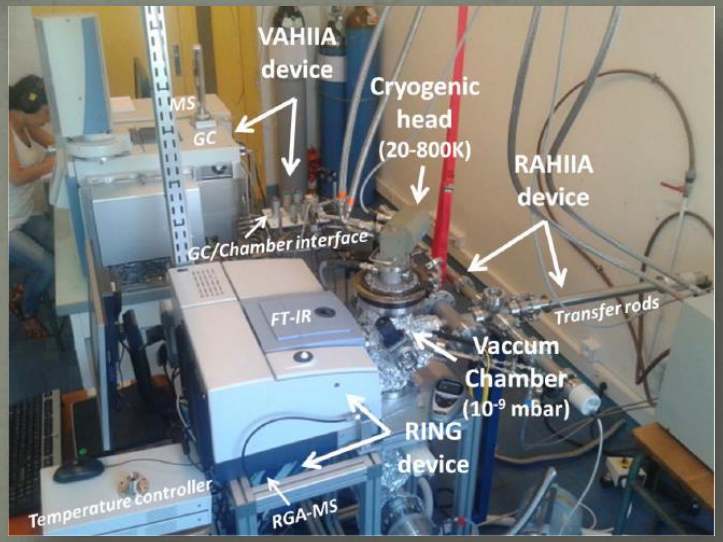
Comets and interstellar ices





Organic residue

L. Le Sergeant d'Hendecourt, IAS, CNRS-University of Paris Sud, Orsay



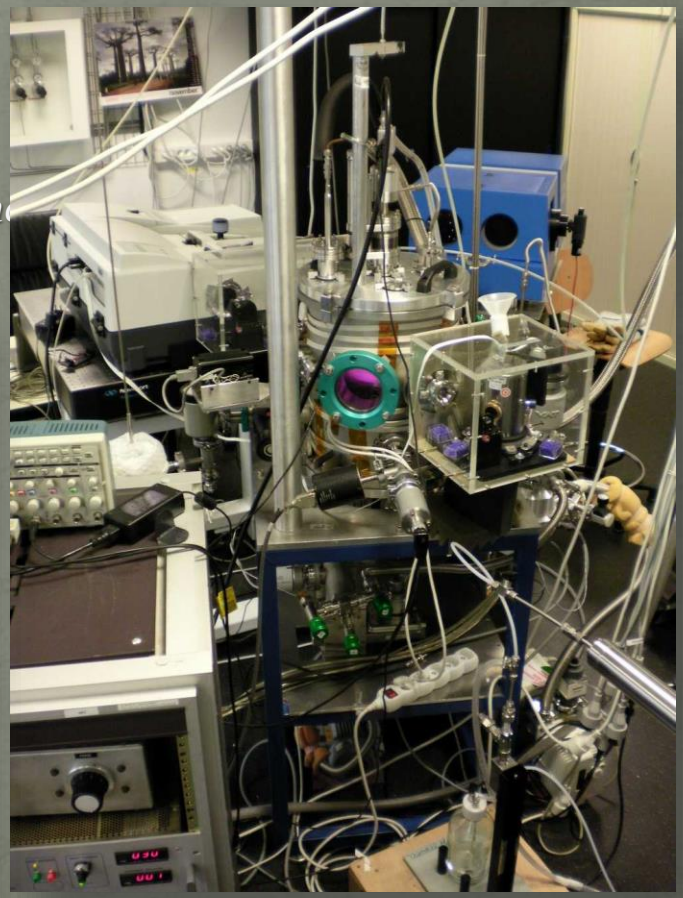
G. Danger, PIIM, CNRS-University of Marseille

Tholins

Titan's atmospheric aerosols analogue

Synthesis of tholins and analysis by IR, ellipsometry and HRMS by N. Carrasco, at LATMOS, UPMC, Paris.

Deposit of the produced solid particles

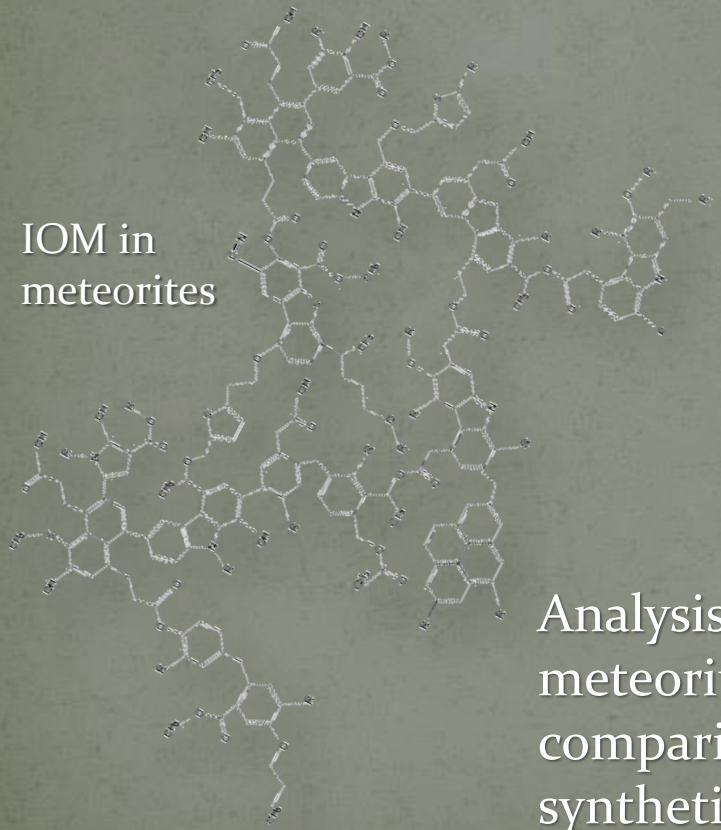


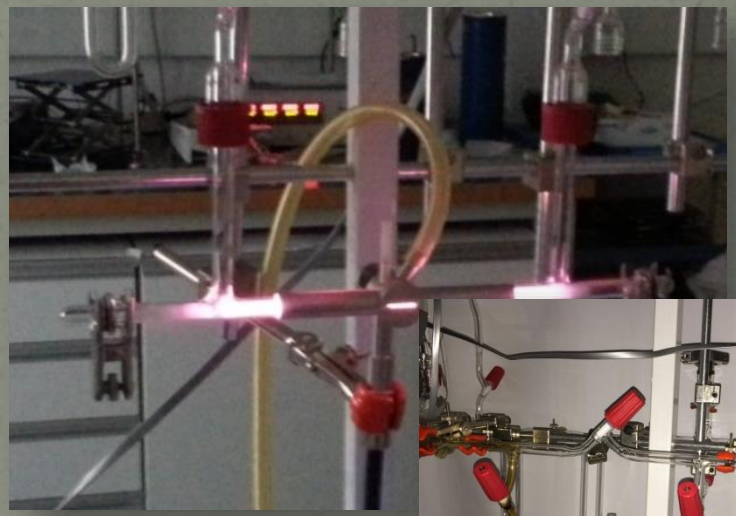
The PAMPRE device.

Insoluble Organic Matter

IOM found in meteorites is very complex and must be synthetized.

IOM in meteorites





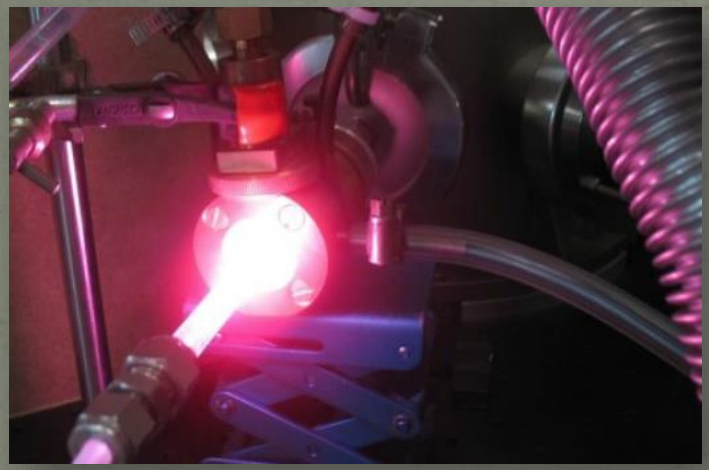
Analysis of IOM in meteorites and comparison with IOM synthetized in laboratory.

S. Derenne, BIOEMCO, UPMC, Paris

Problem of analogue molecules = low quantities

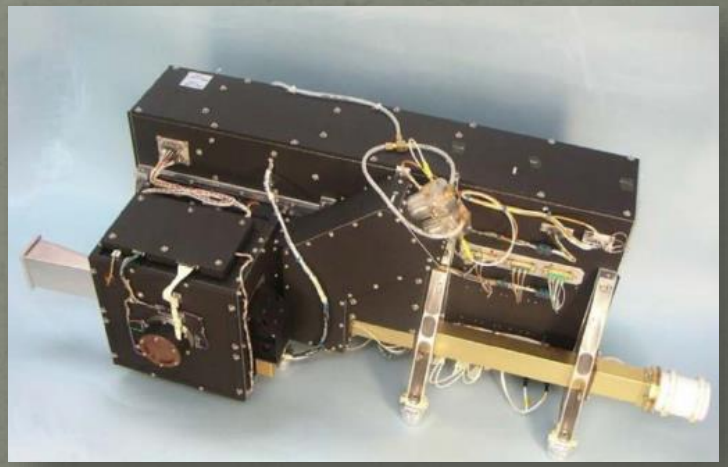
Only a very small amounts of material is produced by these simulation chambers, generally not enough for instrument testing.

Synthesis of cometary analogues to test the COSIMA instrument on board ROSSETTA.



Experiment OREGOC

N. Fray, LISA, UPEC, Paris



Observation COSIMA

Biological samples

Speculative analogues

Analogue?

Here, we will consider as analogue something terrestrial presenting characteristics more or less representative of something extra-terrestrial.

Example:

We have found basalts on Mars.

→ Thus, terrestrial basalts can be considered as analogue of Martian rocks.

Problem here:

We have never found any traces of extra-terrestrial life!

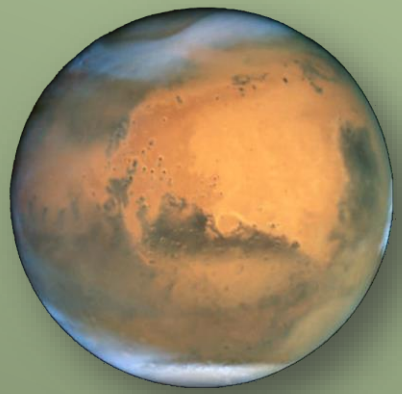
→ The analogy between terrestrial life and extra-terrestrial life is purely speculative.

What to search for?

In a general way we search for auto replicating systems made with organic molecules in contact with liquid water and the remains of these systems.

On Mars:

- Mars was habitable during the Noachian (~3,8 Ga ago).



→ Life may have appeared at this time and disappeared since.

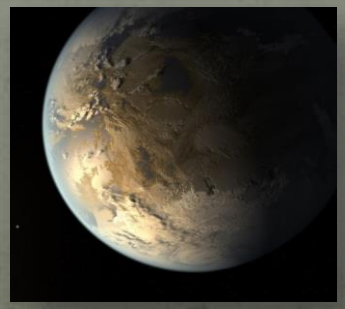
↳ Search for past traces of microbial life.

→ Life may have appeared at this time and still survives today in ecological niches.

↳ Search also for present microbial life.

On icy satellites:

- Microbial life may be present below the icy crust.



On exoplanets:

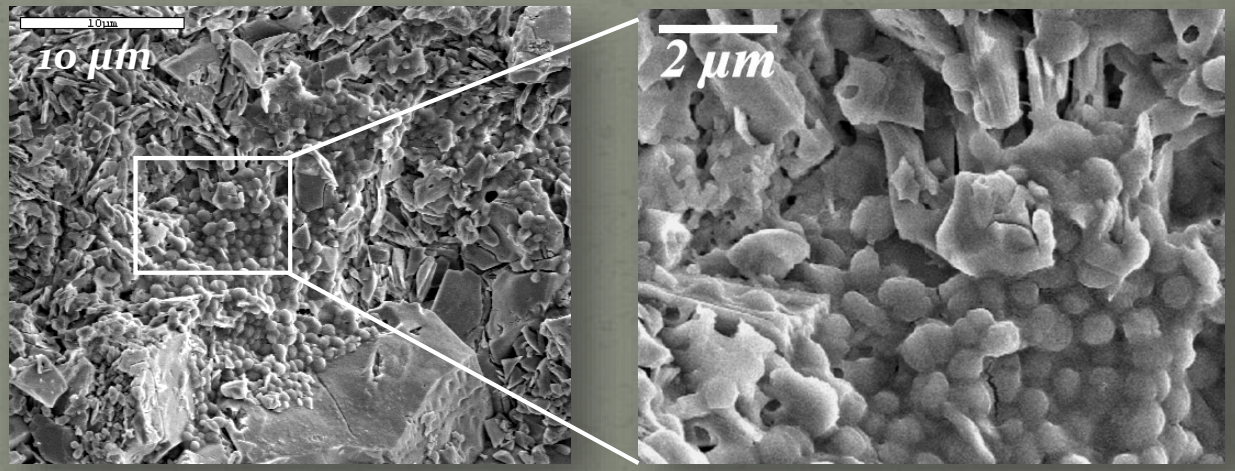
- Complex life is possible.

Analogues of past traces of life on Mars

Search for microfossils more or less similar to the oldest traces of primitive life on Earth.

Silicified microfossils from the Kitty's Gap Chert, Pilbara, Australia, -3.446 Ga

Westall et al., 2011



We can expect to find carbonaceous structures more or less similar in size and shape than those found in old silicified sediments.

Westall et al., 2015, Astrobiology, in press.

Analogues of present life

Life appeared more than 4 Ga ago on Earth and evolved, adapting to various environments.

It is very unlikely that life based on DNA appeared on another body and evolved in exactly the same way as on Earth.

Study the metabolisms of organisms living in analogue environments to search for the fundamental requirements necessary to live in these particular environments, *i.e.* study convergent evolution to find convergent biosignatures (C. Flores Martinez, 2015).

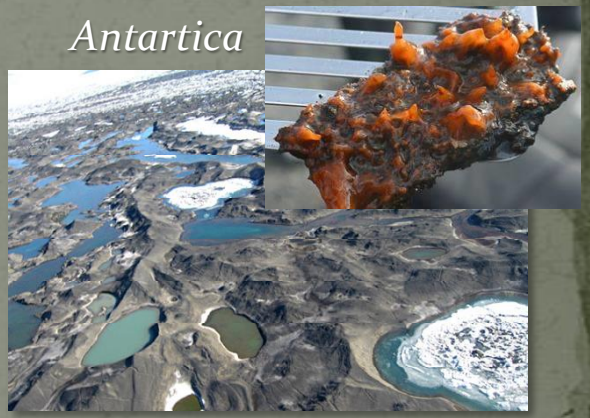
Life in analogue environments = extremophiles

Extremophiles from extremely hot, cold, acidic, alkaline, saline environments…

Yellowstone

Credits: Fouke lab.

Antartica

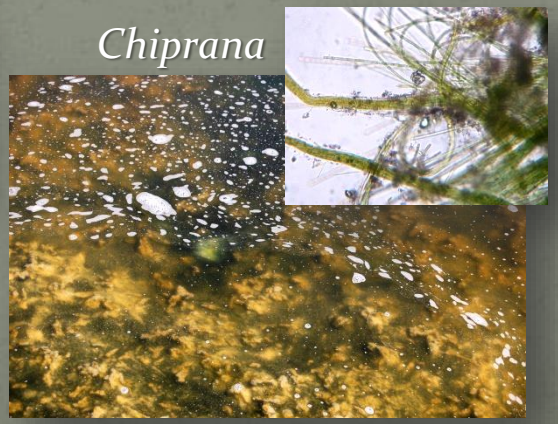


Credits: Ian Hawes.

Yellowstone

Credits: Ken Stedman.

Chiprana



Credits: Pascale Gautret.

Mono Lake

Credits: Kulp et al.,

Planetary protection and panspermia

Panspermia, 2014, by Colonel82, Digital Art / Mixed Media / Sci-Fi©2013-2015

Euro-Cares

EURO-CARES is a multinational project funded under the European Commission's Horizon2020 research programme.
The aim of the project is to develop a roadmap for a European Sample Curation Facility, designed to curate precious samples returned from Solar System exploration missions to asteroids, Mars, the Moon and comets.

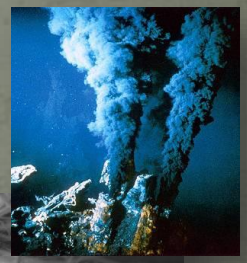
One of the Working Package is dedicated to analogue samples for instruments and protocols testing. We will also include calibration and contamination samples.

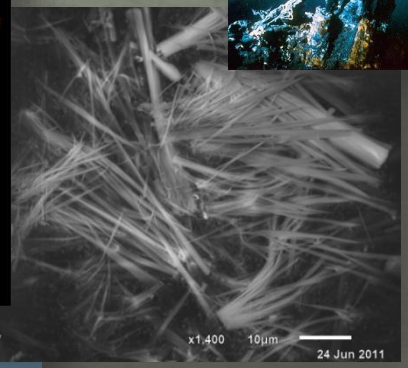
www.euro-cares.eu

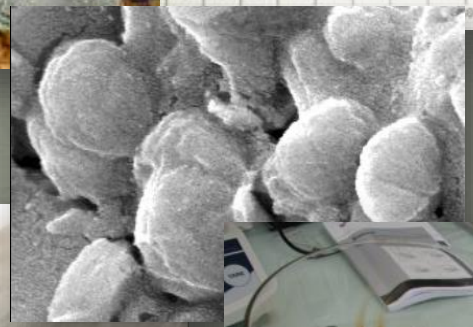
Summary

There is a huge variety of analogues:

sites, rocks, molecules, fossils, environments…







Thank you!