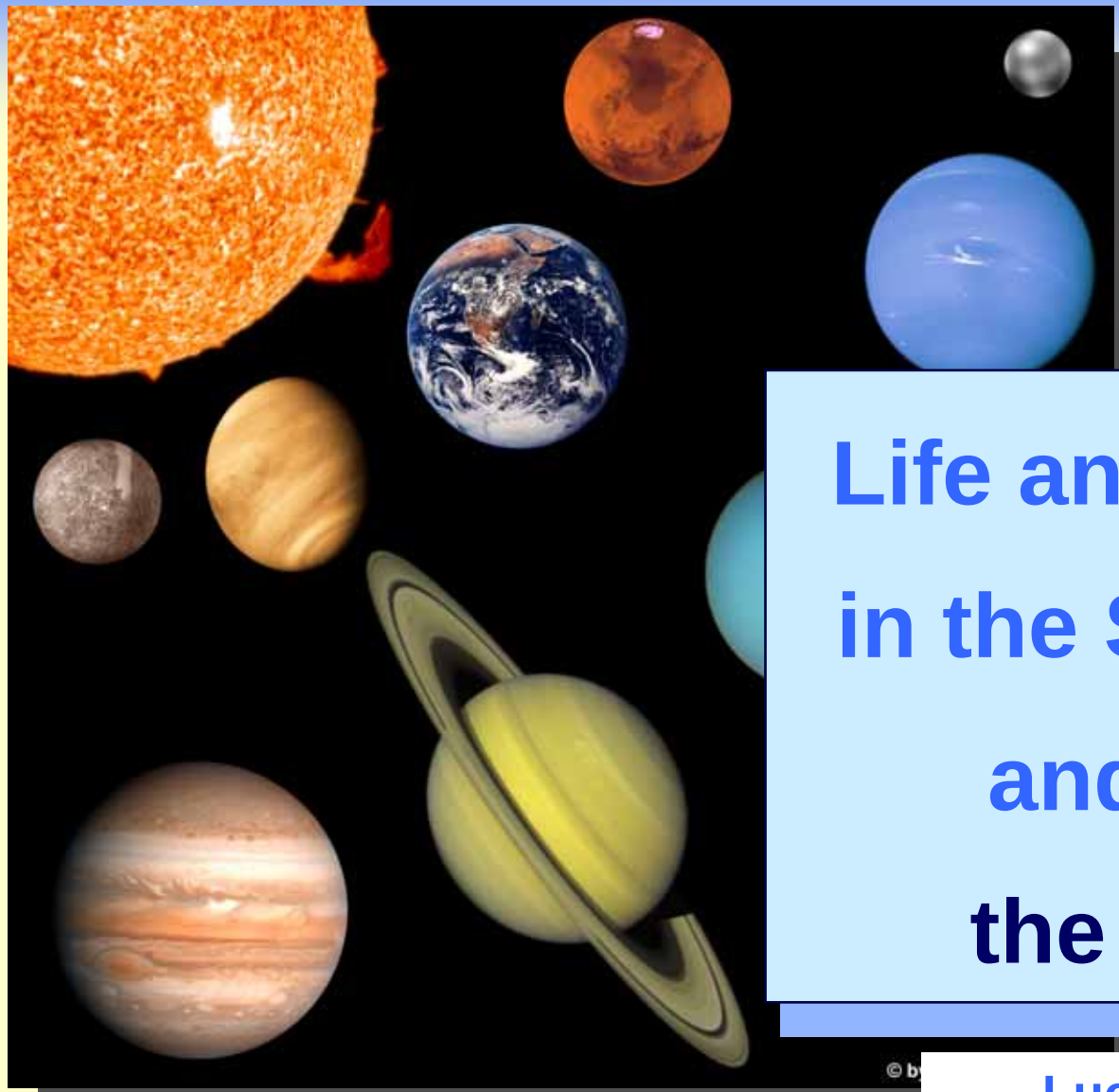


"There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy."
Hamlet (I, v, 166-167)

Life and habitability in the Solar System and beyond: the Roadmap

Lucia Marinangeli
and the
Solar System Working Group

Life and Habitability in the Solar System and Beyond: the Roadmap

Life and Habitability main sub-themes:

Evolution of Solar System environments:

characterization of the surface/subsurface context where life could be (or have been) harbored and atmosphere evolution

Traces of life in the solar system:

direct identification of biosignatures on samples

Comparison with extra-solar habitable worlds:

relevance of possible habitable environments on extra-solar bodies

Beyond 2025: Look deep below surfaces (Mars, Europa)

Life and Habitability in the Solar System and Beyond: the Roadmap

Evolution of Solar System environments

Characterization of the surface/subsurface context and atmosphere evolution

Life needs water

Geosphere-atmosphere-hydrosphere interactions produce the environment

- ✓ Detailed surface investigation of the geological-mineralogical-chemical evidences for water-related environments
- ✓ Determination of quantity and composition of atmosphere/volatiles species
- ✓ Geophysical investigation of the subsurface to find water reservoirs
- ✓ Reconstruction of the environment variations through time to define the life preservation potential
- ✓ Definition of present and past climate suitable for life
- ✓ Model the meteorological dynamic
- ✓ Identification of surface sites where potentially life signatures can be found (landing site selection)

Life and Habitability in the Solar System and Beyond: the Roadmap

Traces of life in the solar system

direct identification of biosignatures on rock samples

Microbial life produces textural, chemical, mineralogical signatures on rocks

Extant life may be found more likely in the subsurface

- ✓ Microscopic observation of biofilms and microfossils on rock samples for past life signatures
- ✓ Chemical and mineralogical composition of the overall sample and on specific mineral/structure
- ✓ Measurements of the organics content and molecules type
- ✓ Analyses of a variety of rock samples from different areas
- ✓ Collect samples from the subsurface (below 1-2 meters?) to avoid radiation sterilization/oxidation and detect present life
- ✓ Determination of the age of samples/biosignatures

Life and Habitability in the Solar System and Beyond: the Roadmap

Comparison with extra-solar habitable worlds

relevance of astronomical observations of possible habitable environments on extra-solar bodies

An habitable environment needs water and nutrients

✓ Application of knowledge on SS habitable enviroments to extra-solar bodies remote observations

✓ Compare the behavior of chemical signatures for habitability (oxygen, water, carbon) inside and outside the Solar System

✓ Synergies with the astronomy group for future Darwin mission observation

Life and Habitability in the Solar System and Beyond: the Roadmap

The received proposals indicate Mars and Europa as best candidates to search for life.

Why MARS?

- evidence for liquid water on the surface has been found widespread throughout the geological history

- water ice is nowadays trapped in the polar caps and soil

Why EUROPA?

- a liquid ocean is likely present below a thin icy/rocky crust

- spectral data of the surface suggest presence of nutrients

The two planets show high potentiality for hosting habitable environments.

Mars as testbed for life and habitability exploration

Life and habitability in the Outer Solar System
(and OSS evolution see theme 2)

Life and Habitability in the Solar System and Beyond: the Roadmap

The Science Case for Mars

Mars as testbed for life and habitability exploration

What have we discovered from current missions?

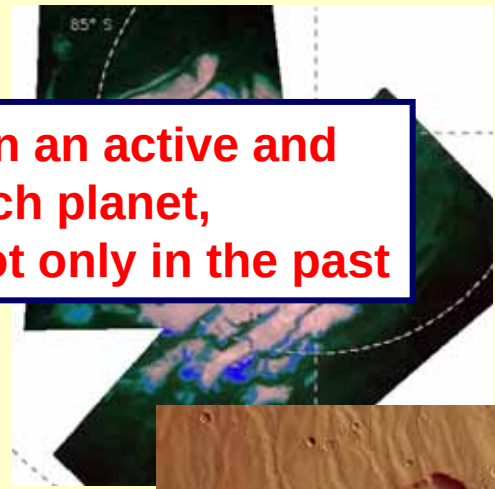
The theme: follow the water/climate

Mars Global Surveyor
2000, orbiter, NASA

Mars Odyssey
2002, orbiter, NASA

Mars Express
2003, orbiter, ESA

Mars Exploration Rovers
2003, two twin rovers, NASA



Mars has been an active and water-rich planet, and probably not only in the past

Mars shows a large variability of water-related surface settings and hosts water now!

Life and Habitability in the Solar System and Beyond: the Roadmap

The Science Case for Mars

Mars as testbed for life and habitability exploration

What do we plan for future missions (before 2015)?

The theme: follow the water/climate/search for life

Mars Reconnaissance Orbiter *(2005 orbiter, NASA)*

✓ Remote characterization of geological environments where life could have arose

✓ Identification of water reservoir at shallow depth in the subsurface

✓ Climat

Identify the right places where life could have been evolved and climate recent evolution

Phoenix *(2007 lander, NASA)*

✓ Characterization of ice deposits of the N Polar Cap

✓ Climatic variations recorded on ice layers

✓ Model the ice/atmosphere gas fluxes

✓ Search for trace of life in the ice

✓ Meteorological monitoring

Life and Habitability in the Solar System and Beyond: the Roadmap

The Science Case for Mars

Mars as testbed for life and habitability exploration

What do we plan for future missions (before 2015)?

The theme: follow the water/climate/search for life

Mars Laboratory Rovers *(2009? Two twin rovers, NASA)*

- ✓ analyze different areas for context studies
- ✓ potentiality for the identification of organic compounds
- ✓ sampling the subsurface (~ 1-2 meters)
- ✓ preparation for the sample return mission

Use long-range rovers to explore different areas and a complex analytic lab to find signs of life in situ

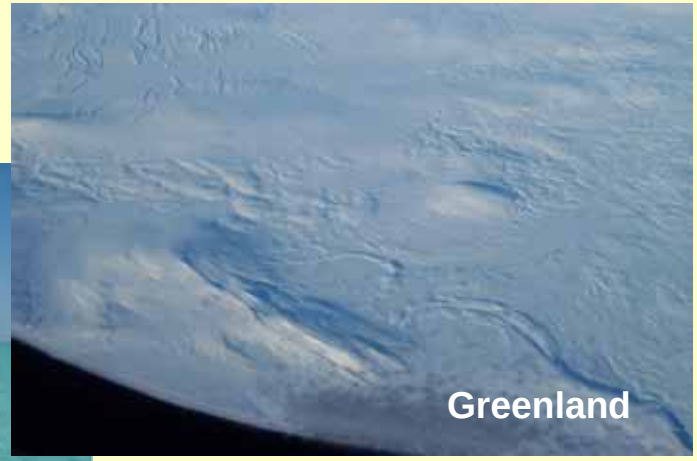
ExoMars *(2009?-2011 rover, ESA)*

- ✓ scientific package to identify biosignatures on the surface and below (~1-2 meters)
- ✓ characterization of local environments (dust, radiation) for Human Hazard
- ✓ part of a long-term plan in preparation to Human Exploration

Life and Habitability in the Solar System and Beyond: the Roadmap

Why the landing site selection and the high rover mobility are so important?

Just think about landing in different areas of the Earth…



You will obtain very different environmental measurements depending on where you are.

Mars appears to have undergone a complex evolution because shows a high variability of surface geological settings which need detailed investigations.

Thus, the probability to find life also depends on the selection of the right site.

Life and Habitability in the Solar System and Beyond: the Roadmap

The Science Case for Mars

Mars as testbed for life and habitability exploration

Summary of expected advances before 2015

⇒ Present distribution of water (subsurface) and ice

⇒ Identification and distribution of marker minerals indicating water interaction

⇒ Atmosphere composition and dynamics

⇒ Identification of the most promising sites for finding traces of extinct/extant life

⇒ Preliminary characterization of the environmental hazards for future human exploration

⇒ Detection of biomarkers from in situ analysis !

Technological development to achieve long-term and long-range rover missions.

Life and Habitability in the Solar System and Beyond: the Roadmap

The Science Case for Mars

Mars as testbed for life and habitability exploration

Open questions for 2015

What is needed?

Exploration of various surface environments in different geological settings, perform series of analyses on samples

Climate-Meteorological monitoring to understand present conditions

→ **Explore in situ, drill, move to different places**

A complete analysis of organic compounds maybe prevented during in situ exploration by complex sample preparation not achievable on the planet

Analysis of primordial atmospheric composition from gases inclusion in the rocks

Age determination of the samples and biosignatures

→ **Return rock samples back to Earth**

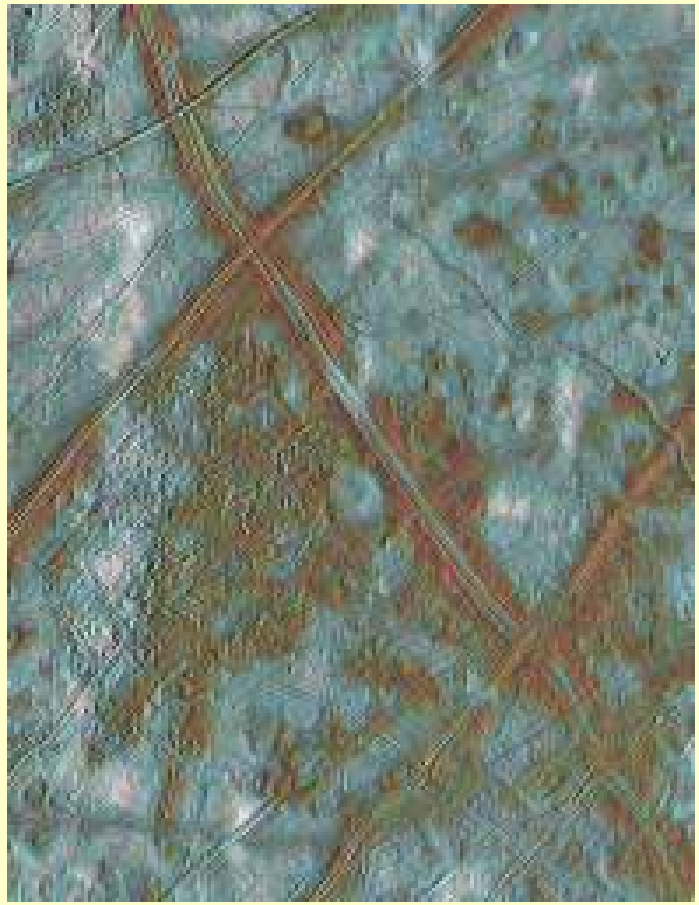
Life and Habitability in the Solar System and Beyond: the Roadmap

The Science Case for Europa.

Life and habitability in the Outer Solar System

The recent discovery

- ✓ Images from the Galileo mission show a complex surface pattern suggesting the presence of liquid ocean below the surface
- ✓ Melted water on Europa has been in contact with the surface in geologically recent times and may still lie relatively close to the surface
- ✓ NIMS spectral data show presence of H_2O_2, H_2SO_4, HCHO, and CO_2, Na_2SO_4
- ✓ NIMS pectral data show the presence of salts (NaCl, Mg and Na sulfates and sulfate hydrates) where putative ocean material reach the surface



Life and Habitability in the Solar System and Beyond: the Roadmap

The Science Case for Europa.

Life and habitability in Outer Solar System Icy Moons

Europa exploration: the future

Jupiter Ice Moons Orbiter - JIMO
(orbiter, NASA, 2015?)

Global imaging and chemical composition of the Europa, Callisto, Ganimede surfaces to define the habitability (nutrient and water content)

Technology:
Radioisotope or nuclear power system are under evaluation for a long term mission

Life and Habitability in the Solar System and Beyond: the Roadmap

The Science Case for Europa.

Life and habitability in Outer Solar System Icy Moons

Open questions in 2015 & beyond?

- mapping of the unknown surface not covered by the Galileo flyby
- dynamic and depth of the subsurface ocean

What is needed?

Surface Mapping and Geophysical investigations from orbiter and in situ

- chemical composition of ocean water
- identification of extinct/extant life in ice and water samples
- age of water and ice

Explore in situ ice and drill for water samples

Life and Habitability in the Solar System and Beyond: the Roadmap

Beyond 2025: what is missing?

Look deep below surfaces (Mars, Europa)

Extant life maybe harbored in subsurface niches were water and nutrients are trapped.

--> Find life and define habitable zones below the surface even at great depth

Human exploration

Human exploration should be taken into account as further step beyond 2025

Life and Habitability in the Solar System and Beyond: the Roadmap

SUMMARY

➲ The search for life and habitable zones in the SS requires a deep knowledge of the surface/subsurface environments and atmosphere composition.

➲ In situ exploration of planetary surfaces is necessary to identify and analyze potential habitable niches and find traces of life

➲ The return of samples from planetary surfaces can solve fundamental problems on the evolution of habitable environments and life development.

➲ ESA should develop appropriate technological knowledge to perform in situ investigations of planetary surfaces/subsurface in preparation of sample return which should be achieved in the 2015-2025 decade.