Origin of the solar system
The astrobiology point of view
-
Pre-Workshop Contributions

This document gathers the contibutions received from some participants in advance of the *Origin of the solar system - The astrobiology point of view* workshop. They are provided as food for thoughts to the roadmap panel.

CONTRIBUTION 1

--- What are the main scientific challenges for the next

- 10 years

To search for extinct or extant life and clearly assess habitability for humans on Mars

- 20 years

To search for extinct or extant life on other bodies. To search for building blocks of Life on icy worlds.

- 50 years

To explore insitu the KBO searching for the origin of Life. To search for radio emission from earth-like exoplanets distant no more than 100 light years

--- What are the main gaps (blocking factors)?

o In current scientific knowledge

Better definition of life and habitable systems.

o In available technology

In order of priority:

-Develop technology for human exploration of the Solar System

-Develop robotic technology able to land safely on airless massive bodies

-Develop robotic technology able to drill several hundreds of meters underneath the planetary surfaces

-Develop high efficiency thrusters and energy systems able to reach the Solar System borders and maintain alive the space probes and payloads

o In available infrastructures

The existing facilities scattered around the world suffer of the original sin: a missing synergy. These facilities can be grouped virtually together to allow scientists from different countries to use them efficiently and concomitantly. The new facilities should be built and developed following this concept.

--- How to approach them?

o What Medium to long term techno and infra development are required?

All these kind of gaps can be filled faster (10-20 years) if the main advanced countries (EU, USA, China, India) will cooperate together.

--- International environment

o European strengths and weaknesses (science and technological competitiveness)

-strengths: Space planetary exploration, very good laboratories

-weaknesses: insitu exploration of Mars; competition among the different European countries, sample return missions, curation facilities

o What key expertise is available outside Europe and would require international cooperation?

Many are present in US, therefore I recommend, as said above, more and real collaborations.

o How can Europe involve emerging partner countries (capacity building) and vice versa (e.g. meteorites, telescope)

For Example EANA or other Research institutions, such as Europlanet, should promote exchange in this direction.

--- What would you recommend in the frame of education and training (including training of active researchers and engineers " exchange of knowledge)

A larger coordination among the different, unfortunately very few, schools of Astrobiology in Europe. I would recommend the creation of a large European educational network that could drive this action.

--- What about public outreach?

Always the public should be deeply involved in Science. Particularly in the astrobiology field all the discoveries should be driven by experts in order to avoid that pseudoscience blogs can use scientific results to disseminate false ideas among the people. On the web, pseudoscience blog hits are 10 more than NASA websites.

--- What 'outside' domain/expertise of science and technology would bring added value to the field?

I think that the IT field can support very well astrobiology research, such as for example the management of big, interdisciplinary, data archives. One of the first examples in this sense is the Seti@home project.

CONTRIBUTION 2

--- What are the main scientific challenges for the next

- 10 years

Identifying candidate worlds for extrasolar life.

- 20 years

Exploration of non-Martian solar system potentially habitable environments.

- 50 years

(not sure)

--- What are the main gaps (blocking factors)?

o In current scientific knowledge

What processes are necessary / sufficient for life? Where do those processes occur? Where could those processes occur?

o In available technology

Ability to do sample return with volatiles intact.

Telescope resolution for extrasolar planet studies.

o In available infrastructures

Ready and rapid communication across disciplines, esp. biology, physics, chemistry, and planetary science.

o What immediate actions should be taken (regardless of budgetary considerations) – with existing capacity

Development of international cross-disciplinary centers for astrobiology research, for research into formation of solar systems, etc. These centers need not be physical structures, but may be more like virtual institutes. However, the development of strong collaborations without stifling competition between the members is necessary for progress in these fields.

o What Medium to long term techno and infra development are required?

I am not entirely sure. One thing is an international commitment to scientific research in planetary science that includes both budgetary and policy-based support.

--- International environment

o How can Europe involve emerging partner countries (capacity building) and vice versa (e.g. meteorites, telescope)

Educational outreach.

Development of observation networks (e.g. fireball networks for observation of bolides and retrieval of meteorites; telescopes in remote dark areas, etc.)

--- What would you recommend in the frame of education and training (including training of active researchers and engineers " exchange of knowledge)

It is often beneficial to include educators in the scientific process where possible. Summer programs in which educators are immersed in laboratory settings working alongside the full-time scientists would be invaluable.

Not all educators could participate in such a program. Making educational materials easily available (for instance, in online forums) is also essential.

--- What about public outreach?

Public outreach is essential for maintaining positive public sentiment and keeping the public educated and informed. I am not an expert on techniques of outreach, but they should be easily accessible across all socioeconomic levels.

--- What 'outside' domain/expertise of science and technology would bring added value to the field?

Obviously, biology and biochemistry are important for understanding astrobiology.

I also think fields that work with "big data" may have something to add to analysis of existing and future data and may find something that more mundane analysis might miss.

CONTRIBUTION 3

--- What are the main scientific challenges for the next

- 10 years

Sample returns from comets and primitive asteroids will greatly expand opportunities to explore for prebiotic chemistry active in space and probably responsible of the origin of life on Earth using the most sophisticated analytical instruments available in terrestrial laboratories.

A long-term strategy for Mars exploration has focused on a variety of science objectives, including the search for evidence of extant or fossil life on Mars. Recently, serious consideration has been given to a Mars Sample Return mission, which could be launched next decade.

- 20 years

The water ocean inside Saturn and Jupiter' moons have all the markings of a habitable zone: salty water laced with organic compounds. But just how habitable is it? Could it sustain life even today? In-situ exploration of oceans of Enceladus, Europa and of Titan' lakes would provide "definitive" evidences of presence of life in our Solar System.

- 50 years

The origin of life is generally thought as having proceeded from the formation of organic compounds from environmentally-supplied precursors, to their self-organization under various environmental conditions into self-replicating and energy-transducing systems, and their further evolution into modern biochemical systems. Future challenging experimental investigation is to find types of chemistry and plausible geochemical environments that can be the initial set for the origin of life on Earth and elsewhere in space. Specifically, demonstrate experimentally the origin of membranes, metabolic cycles and nucleic acids (e.g., is the RNA World the path that life have choosen?) and how they combine to let the appearance of first living organism.

--- How to approach main gaps (blocking factors)?

Logical steps toward planning future sample returns include the development of reliable robotic systems for the *in situ* targeting, collection, and storage of sam- ples, the safe transport and delivery of samples to Earth, the construction of sample containment facilities on Earth for the safe handling and storage of extraterrestrial materials, and the distribution of samples to members of the scientific community for detailed laboratory analyses.

In particular, flight experience of autonomous navigation and control, and demonstration of the Earth re-entry capability are crucial components for the long-term goal of Mars sample return.

o What immediate actions should be taken (regardless of budgetary considerations) – with existing capacity

Invest in technological development for Mars sample return mission, ice penetrator to inside oceans of icy-moons.

--- International environment

o European strengths and weaknesses (science and technological competitiveness)

Europe is one of the major leaders in space exploration to maintain the leadership an investment in new technologies for the detection of life signs on Solar System objects.

o How can Europe involve emerging partner countries (capacity building) and vice versa (e.g. meteorites, telescope)

Studying the origin of life and the presence of past or present life in space is a strongly attractive scientific subject, with multidisciplinary aspects that can easily gather the interest of scientist and stakeholders of emerging countries, acting as stimulus to invest in research and space exploration.

--- What would you recommend in the frame of education and training (including training of active researchers and engineers " exchange of knowledge)

It would be desirable to have official graduate courses of astrobiology for master degree via videocon at European level with students attending the course from many universities simultaneously.

--- What about public outreach?

Young students of primary school should be involved in astrobiology topics, letting them to have access to space agency activities. Rowing exhibitions around European Countries on serch for life in space.

--- What 'outside' domain/expertise of science and technology would bring added value to the field?

Synthetic biology, genetics.

CONTRIBUTION 4

--- What are the main scientific challenges for the next

- 10 years

Determine the origin of water on Earth

- 20 years

In situ analysis of asteroids in the frame of the study of organic precursors of life on Earth

- 50 years

Sample return missions from comets, meteorites and planetary bodies

--- What are the main gaps (blocking factors)?

o In current scientific knowledge

The unknown contribution of exogenous and endogenous organic precursors of life on Earth

o In available technology

man-made meteorites (like stone/Biopan) for Erath re-entry experiments

o In available infrastructures

Ground and space laboratory simulations of primordial Earth environment

--- How to approach them?

o What immediate actions should be taken (regardless of budgetary considerations) – with existing capacity

Sending Rosetta-like missions with in situ analysis instrumentations to other targets (like asteroids, Mars, Enceladus, Europa, planetary bodies of interest)

o What Medium to long term techno and infra development are required?

In situ collection, return to earth and containment facilities for sample return missions

--- International environment

o European strengths and weaknesses (science and technological competitiveness)

Several space missions are led by European Teams, strong collaborations between different National Space Agencies and ESA. Weakness in independent man-access to space.

o What key expertise is available outside Europe and would require international cooperation?

Management of Large space missions.

o How can Europe involve emerging partner countries (capacity building) and vice versa (e.g. meteorites, telescope)

--- What would you recommend in the frame of education and training (including training of active researchers and engineers exchange of knowledge)

PhD program dedicated to Astrobiology

--- What about public outreach?

Development of networking between European outreach and educational initiatives; dissemination of the aims and results of space missions to the general public.

--- What 'outside' domain/expertise of science and technology would bring added value to the field?

The establishment of a virtual an European astrobiology center

CONTRIBUTION 5

---What are the main scientific challenges for the next

-10 years

The main theoretical chalenge is to better understand planet formation (planetesimal formation, formation of giant planet cores, gas accretion, terrestrial planets final assembly). Apart from formation of the planets, strong efforts have to be taken n order to reach final conclusions about the dynamical evolution of the newly formed solar system and in particular how it reached its present dynamical state (under planetary migration, due to interaction with the proto-planetary gas disk and, subsequently the primordial small-body belts). While a lot of progress has been made over the last decade, we still do not understand these issues in detail, partly because our modelling and computing capabilities are not at the desired level. Moreover, if we are to understand in more details the formation of the early Earth and its subsequent evolution, we need to understand first how the main sources of material (terrestrial region and asteroid belt) evolved in time, not only dynamically (following the dynamical evolution of the giant planets) but also compositionally. This is directly related to the question of delivery of water and organic material to the Earth. What was the original setting? What is the level of mixing between compositionally different populations ? These questions can be addressed only by a combination of theoretical/numerical models and detailed observations of small objects (asteroids / comets) across the full range of heliocentric distance .

From the point of view of planetary protection, more effort should be made to reach observational completion for NEOs down to sizes ~100 m and install an operation system of precise risk assessment. Moreover, a lot of ground has to be covered in what concerns physical characterization of NEOs and combined dynamical/spectroscopic studies of NEOs for the purpose of identifying main-belt parent bodies, most likely among young asteroid families.

- 20 years

While building a solid theoretical backgorund is important, high-quality real data are needed to consolidate our knowledge. For this, it would be necessary to launch missions that fill the gaps. For example, theoretical models suggest that water-rich outer-belt asteroids and Trojans could have originated from the outer parts of the primordial debris disk, penetrating the inner parts of the solar system during the LHB. This makes a mission to the Trojans quite appealing. Other missions to special types of objects (e.g. Active asteroids) should also be considered. The effort should be to collect data from all representatives of the small-body class in the solar system (to combine with data from Dawn, OSIRIS, Rosetta, New Horizons). For outer solar system bodies, an important point is to understand the variations in isotopic composition of water, and to compare with Earth data and dynamical/geochemical evolution models .

The theoretical framework, complemented with the data as described above, has to provide knowledge that could be used to understand the diversity of extrasolar system and the position of the solar system among them. Is the solar system a 'typical' system (or, better, does it belong to a typical class of systems) or is it a singular point? For this to be answered we need to collect not only orbital but also compositional data for extrasolar planets as well as protostars and protoplanetary discs. Then, we should be able to identify which of the mechanisms that we can fit to the solar system paradigm are generic to all systems or not and how they depends on the variation of stellar / disc parameters, across the HR diagram.

-50 years

This is a very long time to plan ahead for theory. However, the exploration of the solar system has to proceed, for what concerns the outer planets (in particular the ice giants) and the specific moons (e.g. Europa) that could potentially host primitive life forms. Also, ground-based observations aiming to the discovery of outer-solar-system objects (e.g. Inner-Oort cloud) should be encouraged.

---**What are the main gaps (blocking factors**?(

o In current scientific knowledge

As described above, more effort needs to be put into theoretical and numerical modelling of planet formation, planet migration and planet-disc interactions. The new models have to be applied not only to the solar system (still, this is the best proto-type we have) but also to understanding the dynamical formation of different types of systems. A key point in planet formation theory, is to understand the short time scale of formation of giant planet cores. Also, we do not understand well how the composition of minor bodies has been affected, mainly by their possible migration throughout the solar system (following the migration of the planets) and the different episodes of bombardment/erosion .

o In available technology

For theory, better computing capabilities are always desirable. This means that effort should be made to promote new hardware technologies (like GPUs) and related software solutions.

It seems that, for what concerns missions, the key will be to develop more reliable power systems (both for propulsion and for in situ analysis/communications) which would not depend critically on solar power.

o In available infrastructures

More efforts should be made in order for more countries to actively participate in distributed infrastructures (e.g. virtual telescope facilities .(

--**How to approach them**?

o What immediate actions should be taken (regardless of budgetary considerations) – with existing capacity

The development of Virtual institutes (possibly more than one) has to be encouraged. The example of NASA's Astrobiology Institute is indicative of how efficient coordination of different groups from various institutes but with complementary expertise can be achieved. Care should be taken as to enable small research groups but from less favored countries (which may not even have Space Agencies) to take part, on the grounds of research excellence .

o What Medium to long term techno and infra development are required

See above .

---**International environment**

o European strengths and weaknesses (science and technological competitiveness(

While on theoretical level Europe is traditionally strong and has also closed the gap with the US on both observations and missions, it still lags behind on specific topics (e.g. ground-based observations of the outer solar system). According to what described above, it seems that European competitiveness is weakened by fragmentation and competition on national level or small-scale European projects, as well as by the project-related bureaucracy. The E.C has to take action on better coordinating research, involving many groups from different countries along specific observational / theoretical programs of larger scale and longer duration, encouraging the development of trans-national Virtual Institutes .

---**What would you recommend in the frame of education and training (including training of active researchers and engineers " exchange of knowledge**(

The E.C. has to encourage countries with very limited or inexistent MSc/PhD level formal training on space sciences to commit into developing related courses on a specific time frame. Similarly for the development of space agencies. Moreover, the E.C and ESA should engage into a well-planed training program that will focus on the transfer of knowledge by senior researchers/engineers to younger researchers, in particular coming from countries which do not have a strong involvment in space missions. The program should be based on continuous mobility of trainees (for a period of 2-4 years) among different institutes that engage in the different levels of preparation and execution of missions.

CONTRIBUTION 6

--- What are the main scientific challenges for the next

- 10 years

The main challenge, at least from the perspective of meteoritics and planetary formation, will be to put more strict constraints on which is the source of Earth's water (asteroids or comets), at which stage this water was delivered (to the planetesimals from which the Earth was formed, directly to the primordial Earth or at a later stage like during the Late Heavy Bombardment) and through which mechanism (e.g. it is a natural by-product of the formation of the Solar System or does it require special conditions, like an extensive migration of the giant planets?).

- 20 years

The constraints on the origins of the Earth's water are not enough, *per se*, to fully understand the global picture. It will be necessary to improve our knowledge of the different sources of water (and volatile elements) present in the asteroids and the terrestrial planets. This implies the need to expand our knowledge of these bodies by collecting and bringing to Earth representative samples. At the same time, it will be necessary to systematically investigate the compositional signatures of extrasolar planets (both terrestrials and giants).

- 50 years

Over this timespan, the main scientific challenge will be to complete the exploration of the outer Solar System and the characterization of the potential habitable environments supplied by the icy moons of the giant planets. Together with the answers to the previous questions, this will provide enough data to understand the origins and evolution of water and habitability through the life of the Solar System and, more globally, of planetary systems.

--- What are the main gaps (blocking factors)?

o In current scientific knowledge

Theoretical models of planetary formation and evolution are still to loosely constrained by data, which are still too sparse and non-homogeneous, and in turn models are not physically complete enough to provide unequivocal indications.

o In available technology

Reliable power systems not based on solar power and propulsion systems need to be developed in view of the exploration of the potential habitable environment in the outer Solar System.

o In available infrastructures

Curation facilities for the returned samples are lacking in Europe.

--- How to approach them?

o What immediate actions should be taken (regardless of budgetary considerations) – with existing capacity

A virtual organization/multi-disciplinary network of institutions and research groups similar to the NASA Astrobiology Institute could be organized in order to increase the communication between the different scientific domains and help coordinate joint research efforts.

o What Medium to long term techno and infra development are required?

As mentioned above, technological efforts should be devoted to develop non-solar power sources for space missions and more attractive trasfer/propulsion systems for exploring the outer Solar System.

--- International environment

o European strengths and weaknesses (science and technological competitiveness)

Scientific and technological competitiveness in Europe is mainly weakened, in my opinion, by lack of a common framework and the fragmentation of the scientific community at national level.

o What key expertise is available outside Europe and would require international cooperation?

None that is not already under development/acquisition in Europe.

o How can Europe involve emerging partner countries (capacity building) and vice versa (e.g. meteorites, telescope)

The astrobiological and planetary science communities in Europe should initiate capacity building activities in third party countries: such activities should be arranged and coordinated 7at European level and should coordinate with similar activities performed by IAU and COSPAR. International agreements with countries where meteorites can be found more efficiently (e.g. Africa) should be made to facilitate the collection of more extraterrestrial samples: capacity building actions could help in this regard by training local scientists/volunteers in meteorite hunting.

--- What would you recommend in the frame of education and training (including training of active researchers and engineers " exchange of knowledge)

More interdisciplinary programs of education in astrobiology and planetary science should be organized and coordinated at European level by universities involved in higher education (especially at PhD/Postdoc level).In particular, training networks involving European countries where space science/planetary science/astrobiology courses are limited or absent should be arranged with the support of those countries where such subjects have a stronger tradition.

--- What about public outreach?

Public outreach would be strenghtened by the presence of a virtual astrobiology institute or network at European level that could act as a central hub to collect news and outreach activities performed at national levels and redistribute them to the international community and to advertise European results and activities in the relevant fields.

CONTRIBUTION 7

--- What are the main scientific challenges for the next

- 10 years

Are complex organic materials underneath Mars's surface?

- 20 years

Are oceans underneath icy layers a common property of the icy worlds in the outer solar system?

- 50 years

To find "robust" evidences for presence (or absence) of life outside the solar system.

--- What are the main gaps (blocking factors)?

o In current scientific knowledge

Understand what life is and have a "theory" of life

o In available technology

There are many well known facts on the chemical evolution driven by different processing (thermal, photolysis, radiolysis etc) as well as from observations: we need to look at them in a complessive way, considering all of the aspects at the same time.

o In available infrastructures

I think that, for the first time in the human history, we use available technologies at a small fraction of their capability. We need to increase our capability to use what is available

--- How to approach them?

o What immediate actions should be taken (regardless of budgetary considerations) – with existing capacity

Excellent laboratories and/or groups of researchers are sparse on the territory: we need large European infrastructures (e.g. European Lab for Astrobiology), with a consistent number of staff scientists/technicians and continuous flux of visiting scientists.

o What Medium to long term techno and infra development are required?

--- International environment

As said: one/two very large European laboratories.

o European strengths and weaknesses (science and technological competitiveness)

I do not think there are peculiar strengths or weakness.

--- What would you recommend in the frame of education and training (including training of active researchers and engineers " exchange of knowledge)

Concentrate the training in a few European places to "diffuse" the "basic" knowledge in the continent and avoid that e.g. "British" Astrobiology has a language and priorities different from e.g. the "French" one.

--- What about public outreach?

Be careful: leave it to experts i.e. scientists (and not all!!) and very well trained journalists

--- What 'outside' domain/expertise of science and technology would bring added value to the field?

Philosophical and religious aspects: is life an Earth peculiarity?