SpS6 - Planetary Systems as Potential Sites for Life

Preface

Special Session 6 entitled "Planetary Systems as Potential Sites for Life" was organized jointly by Commission 16 (Physical Study of Planets and Satellites), Commission 51 (Bio-Astronomy), and Commission 53 (Extrasolar Planets). It took place over two days (August 10-11) during the XXVIIth General Assembly of the IAU held in Rio de Janeiro, Brazil.

Until recently, the characterization of solar system objects, the search for extrasolar planets, and the study of the origins of life were carried out in parallel, although not totally in isolation from each other. Indeed, many bridges have produced significant advances among these disciplines in the past few decades. This situation is rapidly evolving however, and a more integrated field is emerging. More and more, national agencies are creating programs under the general heading of "Origins", with the aim of integrating investigations related to planetary formation and evolution, the search and characterization of extrasolar planetary systems, and exobiology.

Solar system studies have reached a point where several objects have been identified as possible sites for life, past or present (Mars, Europa, Enceladus, Titan). The characterization of extrasolar planetary systems is already providing us with hints of habitable worlds around other stars. Modeling and laboratory experiments are also rapidly progressing, leading the way for more and more refined observational investigations. Thus, a synergy is truly operating.

The purpose of this Special Session was to explore the many facets of this emerging multidisciplinary field, to summarize recent advances, and to bring together investigators in the various disciplines in order to foster future projects and collaboration. Some time was also devoted to the evocation of several outstanding figures in the development of this field. The session was divided into six parts: I. Sites for Life in the Solar System; II. Laboratory and Space Experiments; III. The Search for Low-Mass Extrasolar Planets; IV. Habitability of Extrasolar Planets; V. Missions and Surveys under Development; VI. Remembering Pioneers in Astrobiology.

A total of 26 oral contributions were presented, most of them invited papers, and nearly 40 posters were on display during the second week of the General Assembly. The diversity and completeness of these presentations were outstanding. The following proceedings, which are organized according to the six parts of the session, are excellent samples of the wealth of information that was shared with the numerous audience.

We sincerely thank all the speakers and participants.

Régis Courtin (Chair SOC), Alan Boss, and Michel Mayor (co-Chairs SOC)
Meudon, Washington, and Genève, November 30, 2009

The Scientific Organizing Committee was: Carlo Blanco (Italy), Alan Boss (USA), Guy Consolmagno (Vatican City), Cristiano Cosmovici (Italy), Régis Courtin (France), Pascale Ehrenfreund (The Netherlands), Leonid Ksanfomality (Russian Federation), Luisa Lara (Spain), David Latham (USA), Michel Mayor (Switzerland), Melissa McGrath (USA), Karen Meech (USA), David Morrison (USA), John Spencer (USA), Victor Tejfel (Kazakhstan), and Stephane Udry (Switzerland).

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Europa, Enceladus, and Titan as possible sites for life

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Abstract. Despite quite distinct bulk properties, Europa, the third largest Jovian satellite (d=3138 km), and the Saturnian satellites Enceladus (d∼500 km) and Titan (d=5151 km) share a remarkable common feature which is a strong indication of the presence of liquid water at some level below the surface. The possibilities for the development of life organisms on these bodies are reviewed.

1. Europa and Enceladus

On Europa, observational evidence from the Galileo orbiter strongly suggested the presence of a water ocean beneath an ice shelf of unknown thickness. Gravity measurements showed that the outer layer has a density of 1000 kg.m^{-3} and a thickness between 80 and 170 km (Anderson *et al.* 1998). In addition, spectroscopic studies of the surface composition showed the presence of salty minerals along the prevalent cracks in the icy crust, most probably hydrated sulfate and carbonate minerals (hexahydrite, epsomite, and natron) (McCord *et al.* 1998). A possible explanation of the presence of these salty minerals is a global salty water ocean, which reaches the surface in places of recent geologic activity and leaves salts behind. However, the presence of these salts does not unambiguously require a global ocean (Chyba & Phillips 2002). Despite remaining uncertainties on its existence, one can evaluate the potential biomass in Europa's water ocean. Conservative estimates suggest that it could be limited to $\sim 10^{23}$-10^{24} prokaryotic-analog cells, and that it would be very difficult to supply the ocean with enough radiation-produced oxygen to sustain a terrestrial-type macrofauna (Chyba & Phillips 2001a). More favorable assumptions on the availability of oxygen and/or hydrogen through the ice shell and in the ocean itself led Chyba & Hand (2001b) to estimate a steady-state biomass of $\sim 10^{13}$-10^{15} g, compared with the terrestrial biomass of $\sim 10^{18}$ g.

On Enceladus, the discovery of the quasi-continuous ejection of plumes from the south polar region led to a "cold geyser" scenario whereby liquid water stored in high pressure pockets below the surface is vented into space in the form of vapor and fine ice particles (Porco *et al.* 2006, Matson *et al.* 2007, Waite *et al.* 2009). The presence of an alkalin ocean, with a composition dominated by NaCl, $NaHCO_3$, Na_2CO_3, and K^+, is strongly suggested by the analysis of the ejected icy particles (Postberg *et al.* 2009). Thus, the internal environment is thought to be favorable for aqueous catalytic chemistry, permitting the synthesis of many complex organic compounds. Following the approach used by Chyba & Phillips (2002) for Europa, Parkinson *et al.* (2008) estimated at 10^{19}-10^{20} the total number of cells that could exist in an ecosystem underneath the ice crust in the vicinity of the plume vents. They conclude that on Europa and Enceladus, the biomass per unit area could have reached similar orders of magnitude, i.e. 10^{13}–10^{14} cells.km^{-2}.

2. Titan

On Titan, indirect evidence for a deep (water) ocean comes from radar measurements (Lorenz *et al.* 2008). Even more to the point perheaps, the rich organic chemistry taking place in the atmosphere, as well as the presence of free H_2 near the surface, and the existence of a methane cycle involving rains/rivers/lakes, support the notion of the sustainability of life. Indeed, Baross *et al.* (2007) noted that Titan's environment meets the absolute requirements for life, including thermodynamic disequilibrium, an abundant carbon inventory, and a fluid environment. They go as far as to conclude that "this makes inescapable the conclusion that if life is an intrinsic property of chemical reactivity, life should exist on Titan". Specifically, Schulze-Makuch & Grinspoon (2005) have speculated on possible life using metabolic pathways involving acetylene, while McKay & Smith (2005) have considered the possibility of widespread methanogenic life in liquid methane, with hydrogenation reactions as a possible source of free energy.

3. Conclusions and future prospects

Many questions still need to be resolved regarding the sustainability of life on Europa, Enceladus, and Titan. Are their putative sub-surface water oceans real, and if so, what is the thickness of the overlying ice-shell? What is the role of cryovolcanism in surface-interior interactions? What is the amount of free energy available at the surface or in the subsurface environments?

Because of the most favorable combination of parameters for the development of life, Titan may be considered as the prime target in the search for extraterrestrial life in the solar system, with Europa (and Mars) as close alternative(s) (Shapiro & Schulze-Makuch 2009). Many more high-quality data are expected for Titan and Enceladus from the Cassini Solstice mission (2010–2017), and these will provide a more solid basis in the search for ecosystems on these bodies. On a longer timescale, dedicated international missions (EJSM/Laplace to Europa, and TSSM/TandEm to Titan/Enceladus) are under study for the 2020-2025 horizon.

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