Rosetta, Mars, and the emergence of life: genericity and contingencies

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1. Introduction

The solar system space exploration is revolutionizing fundamental paradigms, with outcomes far beyond the mere scientific community. The *plurality of worlds*, conceived as a direct consequence of universality of laws, which justifies the search for extraterrestrial life, is getting replaced by that of *diversity of worlds*, both while characterizing the planets within our solar system, and the solar system within the stellar systems. What drives the diversity of evolutionary pathways? How can similar processes account for such distinct evolutions? At what scale, in time and space, is Earth unique, and the life it harbours? Does the extreme ability of terrestrial live to get adapted to a wide variety of environments favour the presence of life beyond Earth? Rosetta and Mars space missions offer key contributions to these new addresses.

2. Generic processes, contingent forms

The extreme and totally unexpected diversity of the solar system planets, in their evolution and present status, is one of the dominant outcomes of the solar system space missions. It contrasts with their originating from the collapse of the same protosolar cloud, which loaded their evolution with a large level of initial commonalities. The planet size and heliocentric distance are by far not sufficient to account for their present diversity: what then are the major drivers? Although the involved processes, as such, are generic, the forms they took are highly contingent, dictated by the specifics of each set of conditions. Two examples can be outlined for illustration. 1. Early planet migration appears to constitute a very general process in stellar system evolution. However, each exoplanet seems to have followed a very specific migration, depending of the specific disk structure and stellar evolution in which it took place. This might in particular be the case of the solar system, as suggested by the Nice model of “grand tack” migration of Jupiter and Saturn [1], which resulted in a very specific space and mass distribution of the inner planets, including that of Earth. In addition, the turbulent input of outer icy-rich bodies during their accretion is required to account for the presence of water, at least in Earth and Mars. 2. Giant impacts, among the inner proto-planets, likely constitute a very general process which was first suggested to account for the formation of the Earth Moon. Actually, this impact has played a critical role on the further highly specific evolution of the Earth, as for the Moon stabilizing Earth obliquity, the building of perennial surface oceans, the hydration of mantle materials driving a specific plate tectonics etc. Noticeably, these effects are very sensitive to the parameters of the giant impact (geometry, mass ratio etc.), emphasizing the role the specific form taken by a generic process, does play.

3. ORGANiCeS, and contingent emergence of (terrestrial) life

Rosetta and Philae have ruled out the comet as a dirty ice ball. Instead, it is likely made predominantly of a carbon-rich matrix, with carbon-rich grains up to a few mm in size, in which both silicates and ices are embedded. They would thus more appropriately be quoted “ORGANiCeS”, to translate and emphasize that ice is trapped within complex organics. Although the analysis of the most refractory phase could not be performed on Philae, by lack of energy to initiate the long term science, the coupling of measurements performed on Rosetta and Philae exhibits a large suite of compounds, sufficient to account for most, if not all building blocks of terrestrial living structures. Enantiomeric excesses might even have been produced by a specific UV irradiation of the early Sun in carbon-rich grains within the turbulent accretion disk. Objects similar to the Churyumov-Gerassimenko nucleus, with the presence of a sintered crust similar to that which forced Philae to bounce, operating as a thermal shield against atmospheric disruption, might have favoured the seeding of these “organices” in Earth long standing bodies of liquid water, with specific conditions such as temperature, pH and cations. In such contingent conditions, autocatalytic reactions would have been initiated, leading to “living structures” from the ingredients contingently synthesized through a specific chemistry within the protosolar disk.

4. Mars, as a potential witness

Mars Express, followed by MRO, has driven a major revisiting of Mars history, by indicating that Mars might have hosted, soon after it formed, conditions enabling surface liquid water to remain stable over geologic timescales, before having disappeared following a global climate change. We have identified and located at the surface of Mars a few sites which have preserved, as a unique feature possibly in the entire solar system, the conditions which prevailed at these ancient times: the evolution of Mars early environment can be deciphered in the sequence of aqueously altered minerals, such as the phyllosilicates of distinct Mg/Fe/Al content. Sites with such a preserved stratigraphy do thus constitute ideal targets for the upcoming roving Mars space exploration (EXoMars 2020, NASA Mars 2020, China Mars 2020). Supposedly life ever emerged other than on Earth, these locations are likely the most favourable to have preserved its record. If some form of chemical evolution of the organics is discovered trapped within one of these phases (e.g. smectite or kaolinite), one would be able to identify the environment more favourable to life emergence at Mars, and thus possibly on Earth as well. If, on the other hand, no complex organics are detected, other than those, unprocessed, coupled to extraterrestrial material, it would increase the contingent character of the emergence of life on Earth.

5. Discussion

The sequence of processes which built Earth as a "habitable" planet reveals a key role played by contingency; it forces an in depth revisiting of previous paradigms, in which the occurrence of stable liquid water was the driving condition. Although zones in which liquid water cannot be stable are likely non habitable, quoting habitable zones those in which water might be stable does severely ignore the wealth of progress our understanding of planet evolution has gained recently.

At the same time Earth is recognized unique, in time and space (at a scale still to be determined), life might be as well, a contingent product of a specific evolution: life on Earth emerged only once, and the coming space solar system exploration will try to address the contingent/generic ratio of the processes involved.

6. Reference

[1] Walsh, K.J., Morbidelli A., Raymond S.N., O'Brien D.P., and Mandell A.M., A low mass for Mars from Jupiter's early gas-driven migration, Nature, 206, Vol. 475, pp 206-208, 2011.

Short Summary

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