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FROM CHEMICAL EVOLUTION ON EARTH TO INSTRUMENTATION ISSUES FOR TESTING SYSTEMS ASTROBIOLOGY ON EXO-WORLDS (*)

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Although astrobiology is a science midway between the life and physical sciences, it has surprisingly remained largely disconnected from recent trends in certain branches of both life and physical sciences. Aiming at discovering how systems properties emerge has proved valuable in chemistry and in biology and should also yield insights into systems astrobiology with data of a geophysical/astronomical kind, rather than the molecular biology data. (Chela-Flores, 2013). Of the two approaches top-down (Bruggeman and Westerhoff, 2008) and bottom-up systems biology (Guido et al, 2006), chemical evolution is an analogue of cell-free synthetic biology for which the bottom-up approach of systems biology has been useful (Simpson, 2006): In both cases we are dealing with the myriad of details for synthesizing biomolecules (proteins, nucleic acids and lipids). In other words, unlike synthetic biology the aim of chemical evolution has been to infer the pathway for the origin of life, as we do with simpler isolated experiments for the evolution of a progenote. An example is chemical evolution in a mixture of 4 amino acids, glycine, L-alanine, L-valine and L-aspartic acid, were circulated through a flow reactor simulating the thermodynamic conditions of a hydrothermal environment (Yokoyama et al., 2002).

The application of systems biology is illustrated for our own planetary system, where 3 Earth-like planets are within the habitable zone of a G2V star and where the process of photosynthesis has led to a single biosphere, the significance of which has been discussed (Kiang *et al*., 2007). Indeed, the bonding of O_2 ensures that it is stable enough to accumulate in a the atmosphere if triggered by a living process. The reduction of F and Cl deliver energy release per e^+-transfer, but unlike O_2 the weaker bonding inhibits large atmospheric accumulation (Catling et al., 2005). The evolution of photosynthesis is very likely on exo-worlds (Wolstencroft and Raven, 2002). We pay special attention to extending the graphs from our solar system to eventual planetary systems around red dwarfs.

Assuming the universality of biology (Dawkins, 1983; Chela-Flores, 2007) with evolutionary convergence allows addressing the question of a reliable biomarker in the exo-atmospheres of exo-worlds (planets, or their habitable satellites), orbiting stars of different luminosities and ages. We are treating the living process at the cosmic level as a system of exo-environments capable of radically modifying their geology, both for exo-planets, and especially for exo-moons: What we are learning about the moons of our own outer solar system (Chela-Flores, 2010), and will learn in the foreseeable future with the JUICE (JUpiter ICy moon Explorer) Mission (Dougherty et al., 2011), will be relevant in the present more comprehensive enquiry of systems astrobiology that was possible by exploring the Jovian System with the Galileo Mission in the period 1995-2003. In this context relevant instrumentation issues were discussed, but payload issues remain a strong constraint both on Europa (Gowen et al., 2011), or even on our own Moon (Smith et al., 2012).

The distribution of systems of habitable worlds with their biomarkers will be testable in the short term with forthcoming space missions: (a) FINNESSE, Fast INfrared Exoplanet Spectroscopy Survey Explorer, (Swain, 2010), (b) EChO, Exoplanet Characterisation Observatory (Tinetti et al, 2012), and (c) TESS, Transiting Exoplanet Survey Satellite (Ricker et al., 2010), together with the Giant Magellan Telescope, as well as with NASA's James Webb Space Telescope. To sum up, we have suggested a way to anticipate, organize and interpret the data that is provided by Kepler, as well as the data that is to come in the post-Kepler era. We have described how systems astrobiology can lead to relevant insights into the whole cosmos. This, in turn, would justify subsequent use of the methods from computational systems biology, thus extending the implications of chemical evolution from Earth to cosmic Darwinian evolution.

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