The Israel Society for Astrobiology and the Origin of Life
31th annual meeting, Jerusalem, April 11th, 2018

Abstracts

Session 1: Opening 9:00-10:40

The Unifying Power of Astrobiology
Nader Haghighipour (U of Hawaii)

Although habitability is commonly defined based on the existence of liquid water on the surface of a rocky planet, the emergence and sustainment of life are results of complicated processes that although seemingly unrelated, operate in perfect harmony. This multidisciplinary nature of life plays a fundamental role in the study of its origin and search for its existence elsewhere in the universe. In this talk, I will present a detailed definition of habitability, and discuss its implications for Astrobiology as a unifying power in bringing different disciplines together.

Where aliens may live: Towards filling the mass-radius diagram with the smallest planets
Aviv Ofir, Yoffe, Gidi; Aharonson, Oded (Weizmann Institute)

The usual procedure for detecting Transit Time Variations (TTVs) is biased to long-period, deep transit planets whereas most transiting planets have short periods and shallow transits. Here we introduce the Spectral Approach to TTVs technique: we assume that a sinusoidal TTV exists in the data and then calculate the improvement to chi^2 this model allows over that of linear ephemeris. This enables detection of TTVs even in cases where the transits are too shallow so individual transits cannot be timed, and it is more sensitive due to the reduced number of free parameters in its model. We used it to, among other things, detect 131 new periodic TTVs in Kepler data (an increase of ~2/3). Our extended sample of systems with measured TTVs shows no deficit of short period or low amplitude transits, in contrast to previous surveys. Recently Linial et al (2018)

developed a technique to decompose TTV signals to three base components corresponding to the mass and two eccentricity vector projections. Extending the the two-component spectral approach to three components is very simple, and it will soon allow to not just detect more TTVs but to assign masses and eccentricities to some of the smallest known planets.

Session 2: Astrobiology 11:05-13:00

The Potential for Life on tidally-locked planets

Joseph Gale, Amri Wandel (Hebrew University of Jerusalem)

Most of the numerous, recently detected, exo-planets orbit Red Dwarf Stars (RDS), which constitute about 75% of the stars in the Milky Way galaxy. RDS are characterized by a luminosity much lower than that of our sun. Consequently, planets in their Habitable Zone (defined as enabling surface liquid water in the presence of an adequate atmosphere) orbit closely and are tidally locked. The findings of the Kepler telescope have shown that 10-75% of the RDS have Earth-sized planets in their HZs, which may have life clement climates (see Wandel, ApJ 856, 165 and this meeting). We review here the biological significance of tidal locking on evolving life. The Photosynthetically Active Radiation (PAR) which would be available for life on RDS planets has been analyzed in recent publications. Available PAR has been calculated from Sub-Stellar Point incident radiation, and from this the Potential Plant Productivity (PPP) has been derived, per second or per hour. However, we show that when the effect of continuous radiation is calculated, PPP could be extremely high, resulting in a situation analogous to mid-summer growth, at high latitudes, on Earth. Life, both plant and animal, which evolves on such planets, would probably differ from life on Earth in many ways, such as: their genetic code; anabolic/catabolic enzyme balance; circadian and seasonal rhythms, such as hibernation and estivation, and different or complete absence of sleep patterns.

Climate and Biohabitability of Red Dwarf planets

Amri Wandel (Hebrew University of Jerusalem)

The recent detection of Earth-sized planets in the habitable zone of Proxima Centauri, Trappist-1, and many other nearby M-type stars has led to speculations whether liquid water and life actually exist on these planets. To a large extent, the answer depends on their yet unknown atmospheres, which may, however, be within observational reach in the near future by JWST, ELT,

and other planned telescopes. We consider the habitability of planets of M-type stars in the context of their atmospheric properties, heat transport, and irradiation. Instead of the traditional definition of the habitable zone, we define the biohabitable zone, where liquid water and complex organic molecules can survive on at least part of the planetary surface. Our results suggest that planets orbiting M-type stars may have life-supporting temperatures, at least on part of their surface, for a wide range of atmospheric properties.

Exobiology: what we might find out there

Maya Barzilay (Hebrew University of Jerusalem)

Looking out for life in the universe, we relay on the common life forms we know on earth today. But is it really what we should expect to find? Based on the assumption that life on earth was created randomly, we can deduce that other life forms on the universe was created in the same way, and that the same mechanism led those life forms to be very different than what we know. So looking out, exploring the universe what is it that we should really look for? Based on the extreme life forms known on earth we can expand the limits of our mind while thinking about the life we might find out there.

Titan – a lab for alien astrobiology

Tair Plotnik (Hebrew University of Jerusalem)

Cassini and Huygens mission on Titan, chemical composition of the atmosphere and surface, organic haze that may have been in a similar composition to the one in early Earth. Does it mean that there is alien biology on Titan?

Lithopanspermia revisited after Oumuamua

Noah Brosch (Tel Aviv University)

The panspermia theory claims that life fills the Universe and appeared on Earth from space. While theoretical models indicate that transport of micro-organisms is possible between the inner planets, provided the micro-organisms are shielded within a stony matrix, the possibility of transport between different solar systems (a.k.a. interstellar panspermia) was rejected, since theoretical calculations indicated this is an exceedingly rare event, given the paucity of massive interstellar meteoroids. This was recently shown to be

wrong with the detection of the first interstellar asteroid, hinting that a revision of the interstellar panspermia idea is necessary.

Session 3: Biochemistry of Life 14:15-16:15

And yet GARD evolves! A definitive case for metabolismbased origin via mutually catalytic networks

Doron Lancet (Weizmann Institute)

We advocate a systems view, whereby spontaneously accreting assemblages of heterogeneous amphiphiles were the first replicators. This is substantiated via rigorous chemical kinetics simulations within the Graded Autocatalysis Replication Domain (GARD) model, based on the notion that compositional information predated sequence information (PMID:10760281,24831416). Privileged non-equilibrium GARD assemblies ("composomes") portray catalysis-based cell-like homeostatic growth, which along with fission embody compositional replication and inheritance (PMID:11735293). GARD evolution is evidenced in composome selection within a sparse fitness landscape in response to environmental changes (PMID:19787385), refuting claims that composomes (or other mutually catalytic networks) cannot evolve. Composomes thus represent both a genotype and selectable phenotype in a systems chemistry embodiment of the metabolism-first framework. Detailed simulation analyses show that the attractor-like transitions from random assemblies to self-organized composomes (PMID:25547629) involve negative entropy change, which establishes GARD composomes as dissipative systems, non-equilibrium hallmarks of life. Analyzing composome emergence in a whole-planet context leads to potential capacity to assign a probability to life's emergence. Finally, we draft a new model version, metabolic GARD (M-GARD), in which lipid covalent modifications are catalyzed by non-enzymatic lipid catalysts, themselves compositionally replicated (PMID:16010993), as supported by a first published experimental instance of lipid GARD (PMID:26100914). With the expected immense acceleration of molecular dynamics (PMID:22183577), M-GARD could quantitatively depict elaborate GARD protocells, with orchestrated replication of both bilayer and lumenal content.

Life overnight? Why other biospheres are likely to have evolved much faster

Avshalom Elitzur (Iyar & Chapman U), Boaz Tamir (Iyar) & Eliahu Cohen (Ottawa U & Iyar)

Viewed from a purely thermodynamic viewpoint, biogenesis and evolution require the four most basic elements of physical reality: Space, time, matter and energy. Of these resources, time is particularly interesting for the estimate of the likelihood of life in the universe. We consider the possibility of an environment where the other three resources are much more abundant, namely a very large planet, possessing proportionately huge amounts of water and chemicals, and harboring a considerably warmer climate. The probability of biogenesis is expected to be much higher, and the subsequent evolution may be even orders of magnitude faster than the familiar billion-years scale of that of Earth.

Predator-Prey entanglement

Avishy Carmi (BGU & Iyar)

Darwinian evolutionary theory teaches that those species who are most responsive to change will endure. The laws of physics enters this doctrine through various interactions whereby energy and matter, or more broadly, information is exchanged between different species and between species and their natural environment. Adaptation then follows from a continued process with many such causal interactions. Quantum physics, on the other hand, shows that some fundamental aspects of Nature, which govern the limits of coordination between different processes, disallow any form of causal interaction. What if this game of species accounts for such features of quantum mechanics as entanglement and nonlocality ? Here we demonstrate that in an ecological system in which several predators feed on the same prey, those predators who are coordinated with prey to the extent allowed by quantum entanglement endure while those who are bound to the limits of classical physics are driven to extinction. Such a mechanism in the hands of evolution will inevitably promote those species who are the most synergic with their prey in terms of physical and mental fitness. Furthermore, the fact that quantum nonlocality accords with the theory of relativity guarantees that the likelihood of the ecological system as a whole to survive is independent of the decisions of different predators. It only depends on the number of resources allocated by the prey for coordination with its predators. This also shows that in such

physical realities where relativity does not apply the decisions of some predator species are inherently more influential than others.

Non enzymatic replications & autocatalytic sets

Itay Fayerverker & Tal Mor (Tehnion)

The genetic code and genetic evolution are at the core of complexity in biology, however, there is no reasonable explanation yet for the emergence of the genetic code. We present here a possible scenario accounting for the emergence of "coded life" in nature: We describe the emergence of the genetic code from molecular evolution (prior to genetic evolution). This process is based on increase in concentration of chemical self-replicating sets of molecules, located within (probably non-biological) compartments. Our scenario is obtained by combining the conceptual idea of "code-prompting autocatalytic sets" (Agmon and Mor, 2015), with recent results about non-enzymatic template replication methods (Prywes et al, 2016), possibly relevant to the prebiotic stage preceding RNA-world. In the scenario described here, we often use computer science viewpoint and abstraction: We consider sets of strings composed of letters, such that each letter represents a molecular building block — mainly nucleotides and amino acids, and each string represents a more complex molecule which is some concatenation of the simpler molecules represented by letters; the biochemical rules are described in an abstract language of rules and statistics of letters and strings. We then suggest a novel path, containing several phases, for the emergence of "coded life".

Towards a synthetic genetic polymer

Noam Prywes (Weizmann Institute)

Nucleic acid polymers are the only polymers known that can contain information and be copied. In order to demonstrate that these two properties are present elsewhere in chemical space, we have synthesized a synthetic polymer with a specified monomer at each position, which can also template its own replication. In place of hydrogen-bond-mediated base pairing found in nucleic acids, we employed reversible imine bond formation. The repeating aryl-yne backbone of the polymer is readily synthesized using standard Sonogashira chemistry. Here we demonstrate the copying of this polymer in a

model dimer system. This polymer, or others like it, provide alternatives to DNA for arbitrary data storage. Additionally, this polymer exhibits all of the informational properties that allow DNA to serve as the basis for heredity in life on earth.

Session 4: Origin of Life 16:30-18:15

Nonenzymatic replication of sequences containing four letters

Noam Prywes (Weizmann Institute)

The nonenzymatic replication of RNA is a potential transitional stage between the prebiotic chemistry of nucleotide synthesis and the canonical RNA world in which RNA enzymes (ribozymes) catalyze replication of the RNA genomes of primordial cells. However, the plausibility of nonenzymatic RNA replication is undercut by the lack of a protocell-compatible chemical system capable of copying RNA templates containing all four nucleotides. Over 30 years ago, Orgel et al. showed that 2-methylimidazole activated G and C monomers could copy short templates by primer extension, but the copying of templates containing all four nucleotides remains problematic. We show that short 5'- activated oligonucleotides act as catalysts that accelerate primer extension, and allow for the one-pot copying of mixed sequence RNA templates. The fidelity of the primer extension products resulting from the sequential addition of activated monomers, when catalyzed by activated oligomers, is sufficient to sustain a genome long enough to encode active ribozymes.

Nucleicacidpeptide Chimera in the Early Chemical Evolution

Agata Chotera & Gonen Ashkenasy (Ben Gurion University)

Outstanding synergy between nucleic acids and proteins is exhibited in living cells. Whether such mutual activity emerged in the early stages of chemical evolution or later on remains a mystery. We discuss here, the emergence of a primitive synergy in assemblies of short DNA–peptide (NA-pep) chimeras. Specifically, we have characterized multiple structures forming along a putative chemical evolution trajectory, in which a peptide solution was seeded with increasing amounts of NA-pep chimeras. We report on the systematic change from β-sheet-peptide-based fibrillar architectures into the spherical structures formed by the conjugates. Remarkably, we find that through forming onion-like structures, the conjugates exhibit increased DNA hybridization stability and bind small molecules more efficiently than the peptides or DNA alone. A brief

discussion highlights the implications of our findings for the production of new materials and for research on the origin of life.

Multistationarity in Catalytic Reaction Networks

Nathaniel Wagner (Ben Gurion University)

Multistationarity, an emergent property of catalytic reaction networks, is widely found in living systems, and may be a fundamental prerequisite of life. By studying relatively simple and then progressively more complex catalytic reaction networks, we can observe the onset of bistability and multistability and probe their scope and properties, both in steady state and switching modes. Recent experiments have confirmed our theoretical and computational findings. Our findings continue our efforts towards understanding fundamental processes of evolution, complexification and emergence.

From the contemporary ribosome towards the origin of life

Ilana Agmon (Technion)

A feasible scenario for the emergence of life as we know it, requires the spontaneous materialization and sustainability of a proto-ribosome that could have catalyzed the formation of the first peptides. Model of a dimeric proto-ribosome was derived from the symmetrical region encapsulating the ribosomal PTC, where peptide bond formation takes place. Probabilistic and energetic considerations show a realistic statistical likelihood for the spontaneous emergence of this proto-ribosome from random RNA chains. Complementarity is demonstrated in bacterial ribosomes, between nucleotides that constitute the two halves of the PTC cavity. The complementarity indicates a simple and efficient replication mode; the strand of each monomer could have acted as a template for the synthesis of its counterpart, forming a self-replicating ribozyme. Hence, the dimeric proto ribosome offers a feasible starting point for a continuous evolutionary path from the prebiotic matter, through natural processes, into the intricate modern translation system.