The Israel Society for Astrobiology and the Origin of Life

32nd annual meeting, Tel Aviv, February 26, 2019

Abstracts

Session 1: Opening 9:00-10:30

Two Decades of Exoplanets

Tsevi Mazeh (TAU)

The Kepler space mission has retired last month after operating since 2009, discovering thousands of transiting planets and planet candidates. As a result, we know that exo-planets are quite frequent, many of them can be found in multiple planetary systems and some orbit binary stars. The dynamical features of most of the detected planets are quite different from those observed in our solar system. The newly discovered population of exo-planets can help us understand the formation and evolution of planetary systems.

Oumuamua, Loeb, and Extraterrestrial Life

Noah Brosch (Tel Aviv University)

I will discuss the object called Oumuamua that passed through the Solar System on a hyperbolic trajectory in 2017 indicating its origin from another stellar system, and was suggested by Bialy and Loeb that it might be an interstellar spaceship.

Session 2: Astrobiology 11:00-13:00

Habitability and Life on on planets of dim stars

Amri Wandel and Joseph Gale (Hebrew University of Jerusalem)

The Kepler data show that habitable small planets orbiting Red Dwarf stars (RDs) are abundant, and hence might be promising targets to look at for biomarkers and life. Planets orbiting within the Habitable Zone of RDs are close enough to be tidally locked. Some recent works have cast doubt on the ability of tidally locked planets (TLPs), in particular those orbiting RDs, to support life.

We present a new approach to habitability, in particular of planets of Red Dwarf stars. Using a simple climate model, we define the atmospheric habitable range. We show that temperatures suitable for liquid water and organic molecules may exist on RD planets over a wide range of atmospheric properties, such as greenhouse heating and circulation. Consequently, we argue that tidally locked and synchronously orbiting planets of Red Dwarf and K-type stars may support life for a wider range of atmospheres than G-type stars.

In particular, it is argued that life clement environments may be possible on TLPs and slowly rotating planets of RDs and K-type stars, with conditions supporting Oxygenic Photosynthesis, which on Earth was a key to complex life. We review different climate projections and the biological significance of tidal locking on putative complex life. We show that when the effect of *continuous* radiation is taken into account, the Photo-synthetically Active Radiation (PAR) available on TLPs could produce a high Potential Plant Productivity, in analogy to mid-summer growth at high latitudes on Earth. However, life on TLPs would have to adapt to their special environment. The difference to life on Earth is discussed.
Awaiting the findings of TESS and JWST, we discuss the implications of our results to the detection of biomarkers such as liquid water and oxygen, as well as to their interpretation and significance to the abundance of biotic planets and life.

Planet seeding and lithopanspermia through gas-assisted capture of interstellar objects

Hagai Perets (Tehnion)

Planet formation begins with collisional growth of small planetesimals accumulating into larger ones. Such growth occurs while planetesimals are embedded in a gaseous protoplanetary disc. However, small-planetesimals experience collisions and gas-drag that lead to their destruction on short timescales, not allowing, or requiring fine tuned conditions for the efficient growth of metre-size objects. Here we show that 104 interstellar objects such as the recently detected 1I/2017-U1 ('Oumuamua) could have been captured, and become part of the young Solar System, together with many km sized ones. The capture rates are robust even for conservative assumptions on the protoplanetary disc structure, local stellar environment and planetesimal ISM density. 'Seeding' of such planetesimals then catalyze further planetary growth into planetary embryos, and potentially alleviate the main-challenges with the meter-size growth-"barrier". The capture model is in synergy with the current leading planet formation theories, providing the missing link to the first planetesimals. Moreover, planetesimal capture provides a far more efficient route for lithopanspermia than previously thought.

AI, Astrobiology and SETI: from Sci.Fi to Reality

Joseph Gale, Amri Wandel (Hebrew University of Jerusalem)

A recent major breakthrough in Artificial Intelligence (AI) may change our thinking in Astrobiology and especially in relation to the Search for Extraterrestrial Intelligence (SETI).

Estimates of the values of the terms in the well-known Drake formula, which puts together the chances for contact with intelligent life forms, have made great progress in the last decade. The Kepler mission revealed the values of three terms: the fraction of stars with planets, the average number of planets per star in the habitable zone and the fraction of Earth-size planets. These key parameters, which until a few years ago were completely unknown, are now believed to be of order unity. Our main ignorance remains in the last three terms: the chances for the evolution of biological life, the probability of intelligence and the lifespan of a communicative civilization. As can be learned from Earth, planets with primitive biological life may be quite abundant (Wandel 2015). However, the last two terms may be small, which would make intelligent and technological civilizations extremely rare. This rarity may be compensated by robots fitted with Artificial Intelligence, e.g. automated space probes programmed for interstellar communication. In our vicinity such probes may have been left by civilizations that disappeared long ago.

Sci.Fi. is replete with humanoids, despite our short experience with them on Earth. However, some authors have introduced advanced computers, but always in the context of large calculators and data bases. Very few have considered intelligent computers, nearly always stopping at the inability of computers to carry out advanced pattern recognition, the basis of intelligent thinking. For this a huge computing ability is considered essential, as in the human brain.

In the last decades many scientists have proposed that in a few years, computers would have the same calculating capacity as human brains, which have $\sim 10^{11}$ neurons, each connected to thousands of synapses. Based on “Moore’s law” of the evolution of computers, this has been estimated to occur in about 2050, and may come earlier if quantum computers are realized. This has been termed “The Singularity”. However, biologists have long pointed out the poor correlation between brain size and advanced thought. Programming seems to be no less important than capacity.

In Dec. 2018, Silver et al described a new algorithm for a self- learning, pattern-recognizing, AI program. Given just the basic rules of Chess, Shogi and Go, Silver’s program plays itself millions of times over, choosing and remembering the most favorable winning strategies. So far, the program has beaten human masters in all three games, by using strategies **quite unknown to the programmers**.

On Earth the Silver program is predicted to solve many hitherto almost intractable problems e.g. in Astronomy (searching data banks for enigmatic radio bursts), Medicine (reviewing millions of combinations of illness-causing gene interactions, as opposed to single gene errors) and Meteorology (predicting weather patterns from huge data banks).

In Space – We may find that the universe is populated by advanced (intelligent) computing devices, made of silicon bits or quantum qbits, not organic life and the variants of humanoids, beloved of Sci. Fi. If SETI ever makes contact with communicating civilizations, it will probably be talking to intelligent computers!

As for humanity's future – who knows? In 2014 Stephen Hawkins predicted that: "AI and the Singularity may be humanities greatest and last advance".

The planet detected around Barnard's Star

Lev Tal-Or (Tel Aviv University)

A low-amplitude periodic signal in the radial-velocity (RV) time-series of Barnard's Star was recently attributed to a planetary companion with a minimum mass of ~3.2 M_Earth at an orbital period of ~233 days. The discovery was made possible by combining numerous measurements from high-precision RV instruments spanning almost 20 years. The proximity of Barnard's Star to the Sun, and the large star-planet separation of ~0.4 AU, make it an excellent target for complementary direct-imaging and astrometric observations. In this talk I will review the unique data-analysis techniques that lead to this discovery, as well as the prospects to detect the planet with direct imaging and astrometry.

Detecting habitable planets using deep learning

Shay Zucker (TAU)

Deep learning is taking the world of Artificial Intelligence by storm. Deep learning techniques already have proven success in varied fields, such as image processing, speech recognition and even drug discovery. Specifically, deep learning can provide new hope in needle-in-a-haystack problems, such as the detection of very faint signals in the presence of many kinds of noise. Detection of transitinghabitable planets in the presence of stellar-activity red noise is one such problem. The non-linear nature of deep learning renders it completely different from traditional techniques to detect transits. Such innovative approaches will be crucial in order to fully exploit the potential of future planet-detection space missions such as PLATO. We hereby present an extremely short tutorial of what deep learning is, and how it can be applied to detect and analyze transiting terrestrial planets. We also introduce preliminary results of a feasibility study we have performed which demonstrate the immense capability of this novel and exciting approach.

Session 3: Biochemistry of Life 14:00-16:00

On the emergence of complex life: Interactions between the mitochondrial and nuclear genomes

Dan Mishmar (BGU)

The emergence of eukaryote was accompanied by endo-symbiosis between a former free-living alpha-proteo bacteria and, most probably, a former archea-like host. This co-existence required adaptation of both host and new endosymbiont to interact at the protein-protein, protein-RNA and protein levels. Such adaptation was accompanied by transfer of much of the genetic information from the mitochondrial genome (mtDNA) to the nuclear genome, which added a regulatory challenge – co-regulation of the two genomes. Finally, the co-adaptation is also challenged by differences in the mutation rates of the two genomes – the mtDNA evolves an order of magnitude faster than the nuclear genome in vertebrates. In this talk I will discuss the various aspects of the bigenomic interactions and co-adaptation, and its putative role in facilitating the emergence of metazoans.

Enceladus-reported organic chemistry supports Origin of Life in a Lipid-World scenario

Amit Kahana and Doron Lancet (Weizmann Institute)

A recent breakthrough publication [1] has reported complex organic molecules in the plumes emanating from the subglacial water ocean of Saturn's moon Enceladus. Based on detailed chemical scrutiny, the authors invoke primordial or endogenously synthesized carbon-rich monomers (<200 u) and polymers (up to 8000 u). This appears to represent the first reported extraterrestrial organics-rich water body, a conceivable milieu for early steps in life's origin ("prebiotic soup"). One may ask which origin of life scenario appears more consistent with the reported molecular configurations on Enceladus. The observed monomeric organics are carbon-rich unsaturated molecules, vastly different from present day metabolites, amino acids and nucleotide bases, but quite chemically akin to simple lipids. The organic polymers are proposed to resemble terrestrial insoluble kerogens and humic substances, as well as refractory organic macromolecules found in carbonaceous chondritic meteorites. The authors posit that such polymers, upon long-term hydrous interactions, might break down to micelle-forming amphiphiles. In support of this, published detailed analyses of the Murchison Chondrite [2] are dominated by an immense diversity of likely amphiphilic monomers. Our specific quantitative model for compositionally reproducing lipid micelles [3] is amphiphile-based, and provides a simulatable path towards further molecular complexification [4]. It also benefits from a pronounced organic diversity [4], thus contrasting with other origin models that require the presence of very specific building blocks, and are expected to be hindered by excess of irrelevant compounds. Thus, the Enceladus finds optimally suit a Lipid-World scenario [5] for life's origin. The perspective provided by such a target origin model may also bring new insights regarding future planetary missions [6].

References

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[2] Schmitt-Kopplin, P., Gabelica, Z., Gougeon, R.D., Fekete, A., Kanawati, B., Harir, M., Gebefuegi, I., Eckel, G. & Hertkorn, N. 2010 High molecular diversity of extraterrestrial organic matter in Murchison meteorite revealed 40 years after its fall. *Proceedings of the National Academy of Sciences* **107**, 2763-2768.
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[6] Lancet, D. & Kahana, A. 2019 Enceladus: first observed primordial soup could arbitrate origin of life debate. *Astrobiology* **Sumbitted**.

From the Population to the Individual: A Generalized Biogenetic Law?

Avshalom Elitzur (Iyar & Chapman U)

Some of the most advanced life functions, usually considered possible only for high organisms, have appeared in evolution much earlier. They were manifested not by the single primitive organism but by its entire population. This suggests a non-trivial extension of the von Baer-Haeckel controversial “biogenetic law.” Complex functions like metabolism, locomotion and cognition served even the most primordial forms of life, at the population level, later tb incorporated into the individual organism. Unlike the onto-phylogeny transition in the original biogenetic law, the population-individual passage is admittedly random, not relying on a specific mechanism. There are however exceptions, like organisms that can switch between the unicellular and multicellular phases. Other possible mechanisms are reviewed.

Open Systems, Complexification and Emergence

Nathaniel Wagner (BGU)

We have been using models of self-replication and catalytic reaction networks as prototypes for modeling systems chemistry, complexification and emergence. While living systems are always open and function far from equilibrium, these networks may be open or closed, dynamic or static, divergent or convergent to a steady state. A more thorough analysis, however, shows how the interesting phenomena that lead to complexification and emergence indeed require open systems.