

TOWARD THE FINDING OF EXTRATERRESTRIAL LIFE FORM IN HUMAN TIME SCALE OBSERVATIONS. C. Fosseprez¹ and A. Gucsik^{2,3} ¹Mathematical and Physical Ethology laboratory, Research institute for electronic science, Hokkaido university (Email: charles.fosseprez.me@gmail.com), ²Research Group in Planetology and Geodesy, Department of Physics, Eszterházy Károly Catholic University, H-3300, Eger, Eszterházy tér 1., Hungary, ³Institute of Low Temperature Science, Hokkaido University; Kita-19, Nishi-8, Kita-ku Sapporo 060-0819, Japan (E-mail: sopronianglicus@gmail.com)

Introduction: The definition of life itself is not trivial, but there is a general agreement that it is based on certain key properties, such as the ability to perform self-sustaining chemical reactions, consume energy, and transmit information. These properties enable life to exhibit distinct behaviors compared to non-living materials. When searching for life on other planets, we should look for these properties, particularly self-sustaining chemical reactions i.e. autopoiesis. Note that this definition is not limited to water-, carbon-, and oxygen-based life, but it does exclude other potential "life-like" forms that lack these key properties. One of the major challenges in analyzing exoplanets is the limited sampling capability due to the vast distance between the observer and the target system.

Life in itself can reach various stages of evolution and niche occupancy. Earth is a prime example, with simple catalytic life forms such as lithotrophic microorganisms in its early history, and now a globalized industrial society that has sent robots and signals into space. Let's explore several ways of finding life on a remote planet at various stages of its development.

Reservoir sampling: One way to search for life on other planets is to look for signs of its presence on a planetary scale. A planet can be thought of as a large reservoir in which the traces of life are visible through their impact on the overall planet. For example, the impact of humanity on the Earth's atmosphere in the last few centuries. However, this approach has its limitations, as it can be difficult to attribute variations in a planet's conditions to life rather than to other catastrophic events. Additionally, the time scale over which such modifications occur may be very long.

For example, consider the typical logistic curve used to describe the growth of a bacterial population (Figure 1). This curve describes the growth of an efficient life form in a resource-rich environment. However, as seen with human development on Earth, the lag phase (the initial period of slow or no growth) can be very long compared to the exponential phase (the rapid increase in growth). It took thousands of years before the human population began its exponential growth. Furthermore, as recent events have shown, one of the challenges for a society is to reduce its impact on the environment in order to avoid the death phase (the decline in population size). Without this reduction in impact, a society

may exhibit a "self-destructive tendency," as described in the Fermi paradox, and the sampling window for observing the exponential phase may be reduced, making it difficult to differentiate it from a geological event.

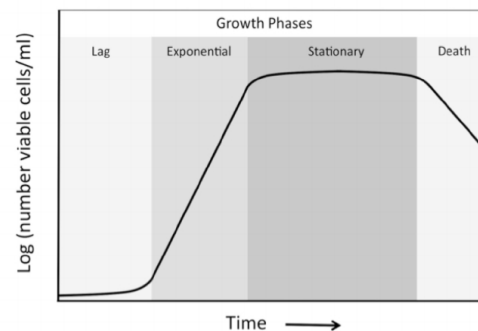


Figure 1: Logistic growth curve [1] of a bacterial population in a finite space with depletable resources. One limitation of using reservoir sampling to search for life in its lag phase or neutral phase is that the interconnectedness of a planetary system (Figure 2) may make it more resilient, decreasing the signal-to-noise ratio and the detectability of life.

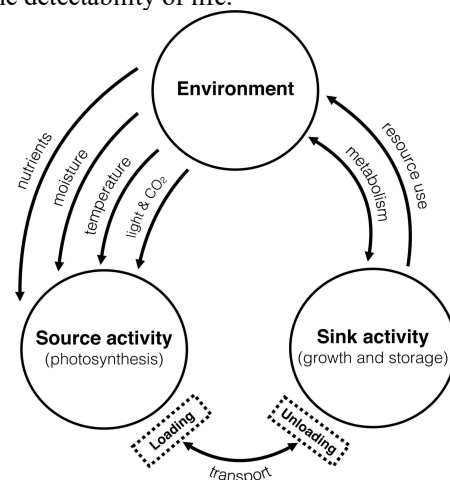


Figure 2: [2] Relation between ecological compartment biotic and abiotic may reduce the ability to observe variation at reservoir scale.

In microbiology, it is often necessary to sample an object in order to detect the presence of microbes, such as by taking a sample from the surface and attempting to grow the organism or by using a specific biochemical marker and amplifying it through a catalytic process with enzymes (e.g. metabolic products or DNA). How-

ever, these approaches may not be applicable for distant exoplanets, where the biochemical markers and conditions are unknown.

Also in nature, many animals take great care to cover their tracks in order to avoid attracting predators or repelling prey. It is likely that many viable space societies would also try to reduce their visibility as much as possible. Therefore, the reservoir sampling approach may be limited in many cases.

Dynamical nature of living processes lead to self organization: The dynamic nature of living processes leads to self-organization. Life can be characterized as an out-of-equilibrium process, which displays oscillatory patterns over time (see Figure 3).

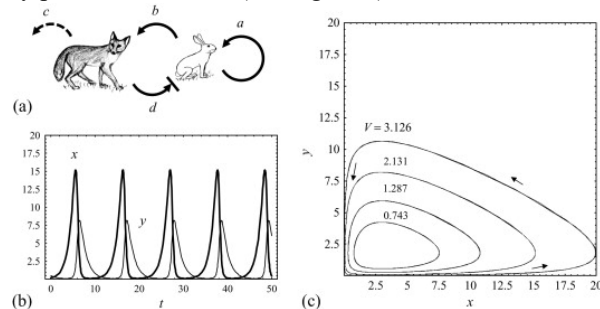


Figure 3: [3] Example of foxes and rabbits population oscillations over time with the Lotka-Volterra model

One challenge in observing these oscillations is the difficulty in detecting markers of such dynamics at a reservoir scale. To plot a graph like Figure 3, it is necessary to count the individuals, but as described in Figure 2, the oscillations of life co products that could be measured may be dampened when viewed at a reservoir scale. Additionally, seasonality within a solar system may induce oscillations that are difficult to distinguish from those of a potential living system. However, these types of reactions can also create patterns through reaction-diffusion processes, such as Turing-like patterns. These patterns of self-organization are one of the macroscopic characteristics of living systems, but they are not limited to what can be defined as life. Figure 4 shows an example of self-organization purely generated by a chemical reaction-diffusion process.

How to discriminate between living and non living self organization? The integration of information might be one of the differences between a simple out of equilibrium system and a living system. One way to distinguish between living and non-living self-organization is to consider the integration of information. Living systems are able to process and integrate information in a way that non-living systems are not. For example, living cells are able to sense their environment and respond to stimuli in a coordinated way, while non-living systems do not have this ability. Additionally, living

systems are able to replicate and transmit information to future generations, while non-living systems do not fully have this capability. These are some of the key differences between living and non-living self-organization.

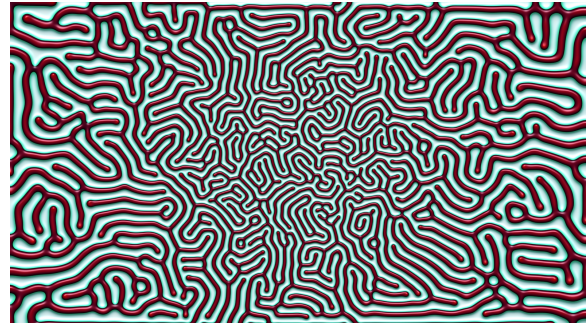


Figure 4: [4] Reaction-diffusion pattern

Entropic analysis and Complexity: Many attempts have been made to describe life from an entropic and information perspective (e.g. [5], [6]). The relationship between life and information appears to be one of its key discernible characteristics.

Complexity is a powerful indicator of life. Particularly its fluctuations over time. However, the sampling of complexity requires high spatial resolution, which may be difficult to achieve from a distance due to the diffraction of light. Therefore sending a probe at closer range in order to get a spatial resolution over the surface of the planet could be the only way to validate the presence of life on an astral body.

Perturbative observations: In order to be certain of the presence of life (i.e. integration of information) and not just a complex system that could be mistaken for life based on complexity alone, it may be possible to conduct a protocol of stimulation via light. This could involve sending a signal and then reading the response, in order to determine whether a potential intelligent life form on the surface of the planet is able to integrate the signal. This approach could be used to study the feasibility of interacting with a distant world.

However, great care should be taken in the type of signal sent to a planet in order to avoid damaging any existing life. It may also be necessary to mask the origin of the signal in order to protect our own position.

References: [1] Hester LL et al. (2014) Proc. Assoc. for Bio. Lab. Edu. 35:140-183. [2] Smith MR et al. (2018) Front. Plant Sci. 9, :1889. [3] Kinoshita S. (2013) Pattern Formations and Oscillatory Phenomena. Elsevier, 1-59. [4] RD Tool, Karl Sims (<https://www.karlsims.com/rdtool.html>) [5] Schrodinger E. (1951) "What is life? The physical aspect of the living cell." At the Univ. Press. [6] Stonier T. (2012) "Beyond information: The natural history of intelligence." Springer Science & Business Media.