MAPPING AND CLASSIFICATION OF EXOGEOGRAPHIES POTENTIALLY FAVORING THE DEVELOPMENT OF ADVANCED EXTRATERRESTRIAL LIFE. H. I. Hargitai[1], [1]ELTE University Budapest Hungary hargitaih@caesar.elte.hu.

Introduction: For centuries, Earth has been progressively displaced from the center-of-the-universe concept and became less and less unique. New stars, galaxies, and planets have been discovered. This led to the concept of common life in the universe. However, the discoveries of exoplanets showed that the known Earth-type planets are not forming a separate, common class of planets and the Solar System is not a typical solar system. The detailed survey of Solar System planetary bodies show that the Earth is not only biologically but also geologically unique among the known few worlds (Rare Earth hypothesis). Life on Earth had about 4 billion years of continuous trial-and-error process that led to the development of several different and convergent shapes, sensors and minds, and only one species was capable of leaving the planet. Convergent shapes and organs originating from different genetic lineages and in microbial level even different metabolisms show that there is a kind of redundancy in terrestrial evolution.

As we learned only in the latest decades, some animals are capable of highly advanced thinking, however, we could not achieve interspecies communication the way we fantasize to communicate with “aliens”. This shows that even though intelligent species may be developed in very different environments, they may only be able to meaningfully exchange ideas when their life experiences are based on similar types of interactions. Therefore, to search for a galactic companion, we may not only follow water and search only in water based habitable zones, but also on planets that provide similar environments to ours. This might be symbolized with the sound of ocean waves, at the interface of the atmosphere, hydrosphere and exposed lithosphere.

Overall Goal(s) and Objective(s): I propose a project that defines planetary requirements for a water-and-land planet, periodic environmental changes locally and globally, and periodic isolation and connection between land surface localities. In particular, learning from the difficult birth of the intelligent species, I will suppose that the following factors are necessary for our development:

1. Water and land surface. Water isolates and connects land surfaces. Water is the where life was born but land is where technology could develop. Liquid water and land was co-present for likely all time when life existed. Although water is one of the most common planetary materials, aquaplanets [1] and planets where water exists only as ice for longer periods or from where water escapes will not be able to develop advanced technology-using life.

It is a paradox though that Earth has been in the habitable zone for all its history, and its oceans were indeed inhabited, however, the land surface remained uninhabited – or at least did not show any fossilized evolutionary process to take place – for billions of years, despite the presence of liquid freshwater, ideal temperature, pressure and shielding by the magnetosphere. This shows that habitability expressed in terms of the presence of liquid water, is not sufficient for advanced life. This has implications on life on Mars. Source of energy from oxygen or similar element is likely also an essential factor.

2. *Climatic excursions.* Sustained habitability over Gyr periods might not be a critical factor for advanced life. *Environmental changes* locally and globally triggering evolutionary changes may be more important. This translates to orbital and rotational elements, e.g., the Milankovic cycle, that change but remain within critical values.

3. Periodic isolation and reconnection of land surface localities may be important to increase the “surface of evolution” on a planet. Isolated trial-and-error experiments could take place in parallel if several isolated areas are available, and the resulting organisms can be contested during re-connection times. This translates to the presence of plate tectonics (and supercontinent cycles) or a highly variable level ocean, or processes of similar results. On Earth, humans appeared on only one of the 7 continents. Humans are therefore alien species in 6 continents on Earth. In other words, human did not appear on 6 experiment sites of evolution: 6 “worlds” out of 7 that started with similar biological diversities, and were isolated for 10s-100s myrs, failed to develop technology-using lifeform. The time of evolution on Earth is not 4 Gyr, but many times longer if we take into account the isolated periods on continents or parts of continents.

Methods: I propose a research that tests the combinations of a pre-defined set of a range of parameters of planets and moons for meeting the following criteria: 1) there is temporally sustained liquid water - soil interface, 2) the local environments do change but not in an extreme way, 3) extended habitable areas are isolated and reconnected periodically in myr timescales. Earth meets these criteria for Gyrs. Evidently, even a second Earth would not guarantee the appearance of a human-like species but this gives the highest chance we know about. In this project, instead of finding Earth 2.0 we would extend the parameters to other worlds that can sustain the aforementioned parameters. We would also include Early Earth (Hadean [2], Snowball [3, 4]) and Future Earth models [5, 6], which are tested to provide habitable environments.

We would consider orbital parameters [7, 8], stellar parameters [9, 10], obliquity [11], planetary rotation [12, 13], planetary material [14], planetary mass, planet-moon dynamics, solar distance, solar system dynamics, impact flux, atmospheric parameters [15], water inventory [16, 17], surface and subsurface environments in planetary and satellitic settings. We would consider landscape building characteristic times and include the interaction of remnant and newly produced landscape elements in the resulting relief or spatial environment.

The research would first identify the variables and potential scenarios of the aforementioned parameters. Then it would define theoretically (qualitatively) possible models for processes within these variables. The next step would be to couple interior [18] and exterior processes. The potential planetary surface types would be categorized and those that fulfill the requirements of the 3 criteria would be selected as potential worlds where intelligent life may be developed with the highest chance. This would produce a range of worlds, where multiple criteria meet. Finally, we would apply these ranges to the known exoplanets and define those world types that are most promising but are currently beyond the detection limits; and determine potential geosignatures [19] of these types of planetary bodies.

Testing technological civilizations: If any known exoplanet potentially satisfies the criteria, those can be tested for technical civilization. In this stage, in addition to spectral analysis, I propose to attempt receiving radio signals on a frequency band that is 1) outside the terrestrial atmospheric window, 2) is the most noise-free in interstellar space, 3) is at a unique frequency characteristic of a life-related molecule. Joining a segment of space community with some level of paranoia, I assume that a technical civilization can reach a level of thinking when it can go beyond the tribal instincts humanity is still determined by. It may be useful for such a civilization not to initiate contact with a tribal society. The discovery of radio communication and space travel may or may not follow each other as fast as it was forced on Earth due to the space race, but it can be assumed that radio communication is easier than space travel and requires much less resources. Not transmitting in atmospheric window frequencies would prevent unwanted detection of radio messages.

Furthermore, a neural network (AI) may be able to develop a statistical probability for the used frequency based on technical input parameters.

Testing the criteria. Water-land interface, periodic climatic excursions and separation-reconnection events can be theoretically tested on Solar System bodies as well. The first test could be run qualitatively on Early Earth, Early Venus, Noachian Mars, and Titan to see if these bodies fulfill these criteria. If not, that might suggest a lesser chance for life to develop even at an early, water-rich stage of the evolution of these planetary bodies.

Other uses of the criteria. These three criteria could also be used for testing the potential success of a future Mars terraforming process. Although there is little chance to test if these criteria are sufficient or necessary for advanced life, it can be used in practice as Earth-similarity criteria. If endemic organisms would not be found on the surface and subsurface of Mars, is there any potential in starting to populate Mars with Mars-tailored microorganisms for creating more Earth-like (or life-favoring) conditions and potentially starting a second lineage of DNA-based biology that may result in advanced lifeforms over Gyr time scales that are available in the Solar System? One could run this test to see if current starting conditions on Mars could be altered to meet the criteria.

Further directions. Although I selected three criteria, this list can be extended or refined before a concrete project would start working with them. This requires a team of earth scientists and biologists. Further research may be focused on the identification of abiotic environmental parameters that accompanied or potentially triggered critical changes of general and human evolution.

Contribution to SETI: The discoveries of exoplanets led to the development of numerous new classification systems for planetary and satellitic bodies, however, these focus on the planetary body but not surface, the interface between the exterior and internal forces that can be modeled separately and are affected by parameters beyond the physical planetary body (e.g., solar, and orbital changes). A geologically meaningful and realistic system for potential types of planetary bodes that takes into account numerous types of parameters, could set a solid, scientific framework for the characterization of exoplanetary *surface conditions* and gain a wide attention to SETI research as such classification have the potential to infiltrate into the popular culture. The criteria could also refine and provide an alternative to the habitable zone concept at least theoretically delimiting the number of possible of surface parameters even when atmospheric conditions, greenhouse effect, albedo, rotation parameters are not known for an exoplanet.

Furthermore, this hypothesis provides a potential solution to the Fermi Paradox, stating that a dynamic and cyclically changing geographic configuration of land and water bodies may be a rare planetary phenomenon that most planets do not possess. Such configuration may be a unique result of the interaction of a unique planetary interior with a unique atmosphere and unique extraplanetary parameters (a large moon, favorable impact flux) in the middle of a wide and stable habitable zone.

Additional Information:

(A) Which Question(s) of the *Alien Mindscape* article is your white paper is relevant to? It is Q1 (How abundant and diverse is intelligent life in the Universe?)

(B) How Big Data Analysis can help you advance this project/concept (and which datasets/databases)?

The first stage of this project is qualitative and does not require big data. A second, numerical modeling stage requires the coupling of circulation models and planetary interior models which is not resolved.

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