EPSC Abstracts
Vol. 14, EPSC2020-242, 2020
https://doi.org/10.5194/epsc2020-242
Europlanet Science Congress 2020

About metrics in phase space for detection of interstellar transmission of life

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The notion that exoplanets are in a state of equilibrium with their surroundings has not given place to the viewpoint of transmissivity of life on the interstellar scales. Spread of human diseases and life reemergence after mass extinction on Earth might show similar characteristics of highly clustered events in space and time. Here, we extend numerical tests of life's spatio-temporal clustering on the simple model of the Galactic patch. We use the cellular-automaton model that reproduces the hypothetical spatial and time evolution of the life spreading within a Galactic patch, adapting parameters relevant for pandemics. Such type of models highlights crucial mechanisms underlying complex behavior. Performed simulations aim to determine phase transition between the persistence and extinction of life spreading within the galactic patch. This phase space is defined by the interplay of planetary systems sterilization and life infection rates. The perseverance part of phase space is that the spreading of life will persist when the simulation parameters lie in this domain and vice versa. The realizations of phase space were calculated by simulating 100 x 100 cells network with ten independent runnings. Each running lasted for 500 arbitrary time units with time step 1. At the beginning of each run, the lattice has been initially set with a randomly chosen sample of planetary systems from used Galactic density distribution.

We observe a critical influence of mobility on regions of life perseverance, termination, and transition within the phase space. Life spreading through the Galactic patch is in at least three different geometrical shapes ('waves') differing from spherical. We set up that this phenomenon is robust, independent from the details of cyclic life termination rates. With increasing mobility above the specified threshold, these geometrical shapes ('waves') grow and saturate the patch, and they persist over a long time range. But there is no spatial pattern for mobility rate below the particular threshold, and the life spreading process is not persistent in time.

Based on our study, we propose that the life clustering within a specific region in our Galaxy can be reconstructed in a two-dimensional phase space using biomarkers and biosignatures data from future exoplanets extensive surveys. Also, this can be applied to the Galactic bulge habitability. Wislocka at al. (2019) calculated the possible atmospheric mass loss for 16 hot Jupiters residing in the Galactic bulge due to radiation from the Milky Way's (MW) central SMBH, Sagittarius A* (Sgr A*). They found that planets in the Galactic bulge could have lost up to several Earth atmospheres in mass during the AGN phase of Sgr A*. Bearing in mind the mass of these hot Jupiters, this fraction of atmospheric mass loss is not drastic, however for smaller, rocky planets within the bulge, such atmospheric mass loss can be essential but during the activity of Milky Way SMBH. However, Balbi et al. (2020) have shown that lithopanspermia scenarios would be more efficient in the bulge concerning the solar neighborhood. If the spreading of life between stellar systems is possible in such an environment, then the highest rate of life-termination events might be balanced by the possibility that life can migrate quickly to safer locations. Thus, it will be necessary to correctly define a metric on the observable biosignatures of exoplanets within the observed Galactic region. If this metric is time-dependent, there is a good chance that life transfer is occurring.

Acknowledgements. This work is supported by Ministry of Education, Science and Technological development of Republic Serbia through the *Astrophysical Spectroscopy of Extragalactic Objects* project number 176001.

References

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