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The Fast Fertile Universe and the Unstable Habitable Zone

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Abstract

The purpose of this essay is to ponder the implications of the Fast Fertile Universe (FFU) hypothesis which states that life appears early (< 100 Myrs) in the development of a planetary body. In particular, we shall examine the potential of bodies beyond the snow line where life may have emerged using accretion heat. Although in a long-term perspective such bodies cannot sustain a biosphere, their role may be significant for the development of life in the classic stable habitable zone (HZ). We propose a quantitative assessment of these habitats in view of the ongoing search for extraterrestrial life.

1 The Fast Fertile Universe Hypothesis

Our major premise is the Fast Fertile Universe (FFU) hypothesis [1], stating that life on a given planetary body (planet, dwarf planet, moon, etc.) may emerge relatively soon ($<$ 100 Myrs) after the body's formation. Although it may very well turn out to be false, we propose to pursue it to its logical conclusions.

The FFU hypothesis appears to be worth exploring since our knowledge of the origins of planetary systems and of life, while rapidly expanding, is still far from definitive, and no avenue of research should be overlooked. Apart from these methodological reasons, there are other considerations that make the hypothesis, if not plausible, then at least noteworthy (e.g., the Martian meteorite ALH840001 which appears to be more than 4 Gyrs old and yet contains possibly biogenic magnetite crystals [2]).

2 The instability of the Habitable Zone

What does the FFU hypothesis imply about the conditions in which life emerged? We shall consider one of them in particular, viz., the available sources of energy. If life emerges early in the evolution of a planetary body, the energy source to examine first is accretion heat. This observation is very significant because it renders early life independent of insolation. In a given circumstellar environment, life could first appear beyond the snow line. Apart from the fact that the greater distance from the nascent star may protect it from the star's turbulent beginnings [3, 4], and that volatiles are more abundant there (whereas in the classic HZ there may be a shortage of volatiles during this early era [5]), we shall attempt to assess quantitatively the number of such habitats which is significantly greater than the number of bodies in the classic HZ.

In other words, the FFU hypothesis leads to the idea that life may emerge on bodies regardless of their orbital parameters, provided they are sufficiently massive to go through differentiation and retain their accretion and radioactive heat for about 100 Myrs.

The obvious problem with such habitats is that they cannot sustain life on a long-term basis. Indeed, the FFU hypothesis seems to imply that most biospheres are destined for extinction. Some biological material may be transported to bodies in the classic HZ or elsewhere (e.g., tidally heated moons [6]) where it can be develop. Seen from this perspective, habitability is a dynamic concept linked to the evolution of a given circumstellar system as a whole.

The idea of most biospheres becoming extinct (or glaciated, with a remnant of microbial activity) is in accord with the principle of superabundance discernible in certain aspects of our Universe. The sheer size of the "empty space" in our Universe, or the periods of intense speciation followed by mass extinctions in the evolution of life on Earth are just two examples of such superabundance. Seen from this perspective, the idea that most biopheres are ephemeral is not without a certain credibility.

In any case, this essay addresses the ongoing discussion on the concept of circumstellar HZs [7, 8], examining the implications of the FFU hypothesis on such habitats as exomoons [9], binary and multiple star systems [10, 11], globular clusters, rogue planets, etc. [12].

3 Research strategies in Astrobiology

A key aspect of the discussion presented in the paper concerns the implications of the FFU and the HZ instability for the search-for-life strategies, both astronomical and in situ. After a brief consideration of young planetary systems and their potential for unambiguous biomarkers, the paper will review the astrobiological programme within the context of Solar System exploration. Special emphasis will be placed on smaller bodies which may reveal traces of biospheres of an independent origin from our own. The discovery of such a second and independent biosphere in a single circumstellar family would constitute a powerful argument in the discussion of the uniqueness or ubiquitousness of life.

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