Publ. Astron. Obs. Belgrade No. 80 (2006), 205 *Contributed paper*

ASTROBIOLOGICAL PHASE TRANSITION

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Abstract. Can astrophysics explain Fermi's paradox or the "Great Silence" problem (i.e., the absence of extraterrestrial intelligent agents or signs of their activities)? If available, such explanation would be advantageous over most of those suggested in literature which rely on untestable assumptions of technological, culturological or sociological nature. Recent advances in astrophysics and astrobiology present us with uniquely convenient starting point for advancing such an explanation. Hereby, we suggest a general astrobiological paradigm which might offer a physical and empirically testable solution of the "Great Silence" problem. Based on the idea of James Annis, we develop a model of an astrobiological phase transition of the Milky Way, based on the notion of the global regulation mechanism(s) within the Galactic Habitable Zone of Gonzalez, Lineweaver and others. The dominant regulation mechanism, arguably, are γ-ray bursts, whose properties and cosmological evolution are increasingly well-understood. Secular evolution of the regulation mechanisms (i.e. their decrease with cosmological time with characteristic timescale of the order of several Gyr) leads in the astrobiological domain to the brief epoch of phase transition: from an essentially dead place, with pockets of low-complexity life restricted to planetary surfaces and preemted by occasional bursts of hard radiation and cosmic rays, Galaxy will, on a very short (Fermi-Hart-Tipler) timescale, become filled with high-complexity life. An observation selection effect explains why we are not, in spite of the very small prior probability, to be surprised at being located in that brief phase of disequilibrium. In addition, we show that, although the phase-transition model does explain the "Great Silence", it is not supportive of the "contact pessimist" position. Quite to the contrary, the phase-transition model offers a rational motivation for continuation and extension of our present SETI endevoars. Some of the unequivocal and testable predictions of the present model include confirmation of decreasing extinction risk in the history of terrestrial life, the absence of any traces of Galactic societies significantly older from us, complete lack of any extragalactic intelligent signals or phenomena, and the presence of ubiquitous low-complexity life in the Milky Way.

A natural way of extending, refining and testing the working hypothesis of the astrobiological phase transition is the application of methods of probabilistic cellular automata (henceforth PCA) well-studied in statistical physics. PCA will be used, in continuation of the present work, to simulate astrobiological **dynamics**, to which Fermi's paradox gives a boundary condition. This approach relies on the well-established indeterminism of biological evolution, and present a framework adaptable to future observations and detailed models of local conditions anywhere in the Milky Way. In the first place, we can rely on the wealth of information on data gathering and interpretation from the realm of statistical and applied physics. In particular, phase transitions are generic phenomena in PCA studied in, for instance, theoretical biology and medical physics under fairly general conditions, so sufficiently detailed future models will be able to settle the issue whether the phase-transition models in astrobiology are workable very soon.