

Interactive comment on “Fundamental molecules of life are pigments which arose and evolved to dissipate the solar spectrum” by K. Michaelian and A. Simeonov

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Received and published: 23 June 2015

We thank Marko Vitas once again for his kind words and review of our manuscript. As suggested by Dr. Vitas, we will mention the theory of hydrothermal vents and the origin of life in the revised version of the article.

Concerning the relation of our paper to the theory of Gaia, we make the following remarks. The revelation of strong and complex interactions of living organisms with their physical environment discovered by Lovelock and collaborators while working on the Gaia theory led them to suggest that the entire Earth was one great living organism capable of the auto-regulation of its physical attributes such as; the global temperature,

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the amount of salinity in the oceans and the oxygen content of the atmosphere, among other characteristics. This auto-regulation was claimed to occur in order to increase the suitability of the Earth environment for life. Although during the early years of Gaia (the 1970's) the theory was unfairly discredited by neo-Darwinists who insisted on defending the deficient Darwinian paradigm and who maintained a very narrow view of the nature of life (see for example Richard Dawkins critique of Gaia in his book "The Selfish Gene" (Dawkins 1975) and Lovelock's response in "Gaia: Medicine for an ailing planet" (Lovelock, 2005)), it is now generally accepted that although Lovelock's Gaia may be more metaphoric than originally conceived, there is no question that the strong interaction with feedback between the biotic and the abiotic, as exposed in the theory of Gaia, is an accurate description of Nature.

This strong interaction between the biotic and abiotic is exactly what is expected from a thermodynamic perspective and we would simply call it a "coupling of irreversible processes". Onsager (1931) showed that this would happen as long as the entropy production of the coupled system increases as a result. There are many mundane examples of this type of coupling in the non-equilibrium thermodynamic literature such as, for example, the Seebeck effect in which an electrical current couples to a heat flow or thermo-diffusion in which diffusion and heat flow are coupled. We have maintained that photon dissipation in the pigments which are surrounded by water inside a leaf (or cyanobacteria) couples strongly to the water cycle (Michaelian, 2012). Together, the system as a whole, pigments plus water cycle, is much more efficient at dissipating the solar photon flux. The one great "living" organism of Gaia, could therefore be identified with the great non-equilibrium dissipative structure, involving the coupling of both biotic and abiotic processes, known as the biosphere. The biosphere is "living" off solar photon dissipation, as Boltzmann understood many years ago.

However, and this is where our view differs from that of Gaia, it is the photon dissipation which is of interest to Nature, not life. Although life may be locally stabilized through positive feedbacks which can be attributed to the mechanisms of Gaia, if other,

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largely abiotic processes are competitive at producing dissipation given the prevailing physical conditions at Earth's surface and atmosphere, then Nature will forsake life, or a great portion of life, for these other processes. This seems to have occurred during global glaciations (snowball-Earth events) where life became severely limited geographically. During these global glaciations photon dissipation seems to have been relegated to shorter wavelengths (where ice absorbs rather strongly) and dissipation proceeds through sublimation instead of the water cycle, and to photon scattering at longer visible wavelengths, which also produces entropy (see Michaelian (2012) for the cloud case of Venus as an example). This predominantly abiotic dissipation, perhaps involving organic pigments (e.g. Venus atmosphere), in fact, is apparently what seems to be occurring today on the rest of the planets in our solar system. We have included a short discussion of this in the revised version of our manuscript.

We have taken Dr. Vitas's previous remarks in his short comment regarding the replication of early RNA/DNA polymers in the prebiotic environment and a discussion of template-directed versus autocatalytic scenario into consideration in our revised version of the manuscript.

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Interactive comment on Biogeosciences Discuss., 12, 2101, 2015.

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