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Reply on RC2

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Community comment on "Comment on "Fundamental molecules of life are pigments which arose and co-evolved as a response to the thermodynamic imperative of dissipating the prevailing solar spectrum" by K. Michaelian and A. Simeonov (2015)" by Lars Olof Björn, Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-135-CC2, 2021

We agree with Axel Kleidon that the Comment by Lars Olof Björn is "not strong enough to challenge" our original postulate. We also agree with Kleidon that the comparison of the albedo of the Earth and the moon is not relevant, not only because they are very different astronomical bodies, but also because albedo is a poor proxy for entropy production. A simple calculation including not only the reflected light (albedo), but also the emitted red-shifted spectrum, shows, in fact, that the Earth's interaction with its solar environment produces significantly more entropy per unit surface area than does the moon, even though the Earth has larger albedo.

We also agree with Axel Kleidon that our proposition (that the fundamental molecules of life were dissipatively structured ("self-organized") pigments from simpler precursor molecules under UVC light as a result of the thermodynamic imperative to dissipate the impressed UV photon potential into heat) should be subjected to rigorous scientific debate. This is important in order to establish elements of plausibility for our thermodynamic dissipation theory for the origin of life (Michaelian 2009;2011;2016;2017;2021; Michaelian and Simeonov 2015) and to establish how entropy production fits into the scheme of biological evolution and Earth System evolution. Finally, we believe that it is important to present these ideas to biologists who traditionally are not trained in non-equilibrium thermodynamics but nonetheless have an important perspective and we therefore welcome and appreciate the challenges of Björn and Martin.

The article that Kleidon references by Volk and Pauluis (2010) which criticizes the maximum entropy production (MEP) hypothesis is not relevant to our paper since we neither reference, employ, nor endorse the MEP hypothesis. Our paper is instead based on Classical Irreversible Thermodynamic theory developed by Lars Onsager and Ilya Prigogine and coworkers. The work of Prigogine and coworkers showed that far from equilibrium there does not exist a potential whose optimization could describe the evolution of a system. For non-linear systems far from equilibrium, beyond a bifurcation point in a given parameter, multiple stationary states become available, each with a distinct entropy production rate and distinct local stability. The system can evolve over these states through fluctuations near the bifurcation points. The entropy production of the system could either increase or decrease in the new stationary state. However, when states with autocatalytic routes to dissipation exist, they provide large attraction basins in generalized phase space and a small fluctuation near a bifurcation would be more likely to lead the system towards these autocatalytic greater entropy producing stationary states (Michaelian, 2021).

Evolution of systems far from equilibrium, therefore, involves both deterministic and stochastic elements. The path taken by the system can only be determined probabilistically by doing a local calculation of the stability in the neighborhood of the stationary states (Glansdorff and Prigogine, 1971), which is related to the sizes and shapes of the respective attraction basins. The probabilistic tendency of autocatalytic systems (having the possibility of autocatalytic routes to dissipation) to move towards increasing their entropy production over time is therefore scientifically sound within the range of applicability of Classical Irreversible Thermodynamic theory in the non-linear regime, but, a general potential, such as MEP, for describing the evolution of arbitrary systems far from equilibrium has not been found.

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