An Extended Principle of Least Action for Self-organization in Complex Systems

Georgi Yordanov Georgiev

(1) Department of Physics, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609, USA
(2) Department of Physics, Assumption College, 500 Salisbury St., Worcester, MA 01609, USA
(3) Department of Physics, Tufts University, 4 Colby St., Medford, MA 02155, USA, ggeorgie@assumption.edu.

First principles determine the equations of motion and the conservation laws in physics. Those same principles should determine the evolution of complex systems towards more organized states [1]. The principle of least action states that all motions occur with the least amount of action as compared to alternatives. This can be translated that they occur with maximum action efficiency, if we divide by the action necessary for the occurrence of one event. In the language of flow networks in systems out of equilibrium, the motion on the network occurs with minimum action cost. Since this is a first principle in physics, there is no reason that it will be violated in complex systems. Therefore we investigate the action efficiency of organized systems, as a measure of their level of organization [2-7]. We find that they evolve toward more action efficient states. Therefore the principle of least action, not only determines all motions and all conservation laws in all of physics, but also the evolutionary states in complex systems. In order to measure action efficiency in complex systems, in flow networks out of equilibrium, the principle of least action needs to be modified, from the minimum of action along a single trajectory, to the minimum of the average action per one event in a complex system, within an interval of time. This is an extension of the principle of least action for complex systems. We measure that the increase of action efficiency in the evolution of complex systems happens in a positive feedback with the rest of the characteristics of the complex systems, such as the total amount of action for all events in it, the total number of elements in the system, the total number of events, the free energy rate density in it and others. This positive feedback leads to exponential growth in time of all of those characteristics, and a power law dependence between each two of them, which is supported by experimental data [2-7].

References

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