Thermodynamic Approach to Far From Equilibrium Nonlinear Systems

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Plasmas are typically born when intense violence is done to matter and are often observed in a far from equilibrium steady state. A thermodynamic approach holds the promise of defining features of the final observed state without analyzing the complex nonlinear dynamics of how it got there. One may distinguish between two kinds of steady states. Those that are born by intense and rapid rearrangement of the initial configuration on time scales so fast that the system has no significant matter or energy exchange with the external world. These isolated systems can be understood thermodynamically as nonlinear systems which minimize a properly identified free energy source subject to suitable constraints. Other steady states are driven steady states and acquire their characteristic configuration by constant exchange of matter and energy with the external world. There is no consensus on what the system is trying to optimize in the steady state. Here we show by making simple estimates that such "open configurations" in plasma physics are like negentropy machines which create a significant degree of order in their interior by ingestion of low entropy energy and expulsion of high entropy energy at the boundaries. We illustrate our ideas by making a quantitative comparison of negentropy generation by a tokamak with that generated by a piece of living matter and even with that generated by the whole web of life.