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散逸構造と静的安定性から動的安定性へのパラダイムシフトのための一般化自己組織化理論

Dissipative structures, and a theory for a paradigm shift from stationary stability to dynamically evolving stability

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In the theory of dissipative structures by Prigogine, the minimum entropy production state is used for a necessary and sufficient condition for the assessment of the dissipative structure appeared in an open system with a boundary. In general, the state with the minimum rate of change of entropy, which has the dissipative structure, is one of the self-organized states observed in various dynamical systems. In the theory by Prigogine, entropy is the key indicator for the assessment of the self-organized states. However, entropy cannot be defined for magnetic and electric fields included in fusion plasmas, space plasmas, and others. A key indicator for the assessment of the self-organized states available to general dynamical systems is global autocorrelations defined by volume integrals of an autocorrelation for every dynamical variable as is used in a generalized theory of self-organization [cf. Phys. Rev. E 49, .5546 (1994); Phys. Rev. E 70, 066312 (2004); Phys. Plasmas 16, 052509 (2009)]. The necessary and sufficient condition for the assessment of the self-organized states is the minimum rate of change of the global autocorrelations for multiple dynamical field quantities. Here, electron density ne(r, t), electron temperature Te(r, t), and others are include in the multiple dynamical field quantities include, and they have their autocorrelations of [ne(r, t)] 2, [Te(r, t)] 2, and so on. Energy of ion flow velocity ui (r, t) corresponds to the autocorrelation of [ui (r, t)] 2. On the other hand, the energy conservation law indicates that the increase of thermal energy yielding entropy production comes from the decrease of non-thermal energy, i.e., the rate of change of entropy is equal to the rate of change of non-thermal energy. In other words, the minimum entropy production state is physically equivalent to the state with the minimum rate of change of non-thermal energy. The set of the global autocorrelations includes the set of non-thermal energy. The set of change of the global autocorrelations consequently includes the set of change of non-thermal energy, i.e., the set of change of the global autocorrelations includes the set of change of entropy. Therefore, the minimum rate of change of the global autocorrelations includes the minimum rate of change of entropy. This result leads to a conclusion that the generalized theory of self-organization covers the theory of dissipative structures by Prigogine, and the generalized theory is available for various dynamical systems including thermodynamic systems, fusion plasma systems, space plasma systems, dynamically controlling systems, and so on. Every dynamical system is evolving along time t, and therefore every self-organized state must be on the trajectory of the time evolution of the system itself mapped to an abstract state phase space. When the dynamical system is in a self-similar state, it has been traditionally assumed to be in a stable steady or constant state. The steady state, however, is intrinsically defined for the stationary state with zero partial derivative with respect to t. The configurations of experimental quantities are never stationary, but instead are always evolving in time, i.e., the experimental system of interest is always in a dynamically evolving state with non-zero derivative by t. Only when the dynamic system in experiments or in simulations has come to a self-similarly evolving stage without any structural change, can the system then be generally judged and identified to be in a real stable state with non-zero partial derivative by t. In other words, the stable state of any dynamic system is not a stationary state but a dynamically evolving state. This consideration on stability leads us to the necessity of a paradigm shift away from the traditional concept of stationary stability and toward the realistic concept of dynamically evolving stability. This realistic paradigm is applicable to various dynamical and control systems.

キーワード:散逸構造,自己組織化,パラダイムシフト,静的安定性,動的安定性,一般化理論

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