Dynamics of hierarchical systems

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J. S. Nicolis, *Dynamics of Hierarchical Systems*: An Evolutionary Approach (Springer-Verlag, Berlin; Heidelberg; New York, 1986, pp. 397. (Springer Series in Synergetics. V.25/Eds H. Haken and J. S. Nicolis)

The series of books on synergetics has been extended to include a new interesting book by J. S. Nicolis "Dynamics of hierarchical systems: an evolutionary approach". At the present time synergetics is only at an early stage of its development, but already in a number of scientific fields: physics, chemistry, and biology some common approaches are being developed to the investigation of different complicated processes that lead to new effects of self-organization in nonequilibrium dynamical systems. The book under review differs in an essential manner from other books on synergetics. The principal attention in this book is paid to the analysis of the hierarchy of structures and the investigation of collective properties of different dynamical systems. An essentially new aspect is the involvement in the investigation of physics dynamical problems of concepts utilized in information theory. One of the principal aims of the book, as the author indicates, consists in the development of the evolutionary approach to the study of one of the main problems—the formation, accumulation and dissipation of new information arising in physical and biological systems as a number of dynamical processes take place in them. These processes are related to the appearance of new singularities in the evolutionary development of nonlinear systems (branchings, cascades, and bifurcations, which lead to changes in the symmetry of the systems).

The book consists of seven principal chapters and an appendix.

In the first introductory chapter the author formulates the basic aims and problems which were posed in writing the book and points out those scientific problems which are dealt with in the book. Here a discussion is given of the common special features of different dynamical systems which are manifested in the appearance of singular points (branchings, limit cycles, bifurcations, etc.).

The second chapter presents the basic information required in studying nonlinear dynamical systems, and also states the basic concepts of modern statistical physics. The same chapter also investigates individual instabilities associated with symmetric breaking, dissipation and irreversibility of different dynamical systems. For example, in so doing an analysis is given of the role played by gravity in the formation of tides on earth, which, as has been shown, occur due to the appearance of an instability caused by the gravitational interaction of the earth with the moon. Also here, using the examples of a nonlinear oscillator with an overcritical damping and a rotating pendulum, different cases of spontaneous symmetry breaking are examined. The principal tenets of the theory of stability of nonlinear systems are presented in detail. Particular attention is paid to the analysis of the behavior of dynamical systems near singular points with two degrees of freedom. It is shown here that the limit cycle in dissipative systems can be regarded as an attractor for such systems.

The principal elements of statistical physics are presented in detail and their connection is indicated with phenomena in the evolution of stochastic systems. With the aid of the information, physical and thermodynamical entropies introduced here some examples are examined of the behavior of different systems (ideal gas, photon gas, etc.) near thermodynamic equilibrium.

The third chapter analyzes the question of the role played by spherical electromagnetic waves as "information carriers". Here, using the example of a dipole consisting of two moving charges of opposite sign, a detailed discussion is given of the radiation emitted by these charges in a vacuum. In doing so, and utilizing the concept of "self-force" due to energy losses on radiation, an analysis is given of the stability of motion of charged particles. The propagation of electromagnetic waves in a dissipative medium and in a medium with high damping is examined. Particular attention is devoted in this connection to the theory of propagation of electromagnetic waves in waveguides. In analyzing the entropy of radiation of new information appearing as the result of scattering of an electromagnetic wave by a limited obstacle the attention of the reader is directed to the dual nature of light as electromagnetic waves and particles-photons.

The fourth chapter is devoted to elements of information theory and coding, and also to some applications associated with them. In this chapter mathematical aspects of information transfer are presented on the basis of the concept of information entropy.

Here also are presented certain aspects of the theory of coding, the methods of which enable one to minimize errors in receiving information. One of the most convenient quantities characterizing information transfer is the transmitting capacity of an information channel. With the aid of an analysis of this quantity it is possible to investigate the role played by quantum noise in optical channels, and also to make an approach to studying one the basic problems of modern biology—transmission of genetic code, the nature of which is determined by the transmission of information in the genetic channel. A discussion is given of the interrelationship between two biological hierarchical systems modelled by Markov chains.

The fifth chapter is devoted to game theory and its different applications. In this chapter an attempt is made to describe and formulate in dynamics the language of game theory with two partners. The mathematical examination is based on analyzing two coupled linear or nonlinear second order differential equations. This examination enables one by investigating the singular points, the type of singularities, and the bifurcations that are formed to analyze the possible outcomes of the games. The variable in these equations can be the probability of remaining in motion or some other strategy of the playing partner. Here also is shown that game theory can be applied in studying the genetic problem, spe-

cifically selection, viability and adaption of some biological species.

The sixth chapter examines the stochastic properties of systems due to deterministic dynamics in a space with three or more degrees of freedom. One of the basic assumptions of classical statistical mechanics is the ergodicity condition. In this chapter an analysis is given of the ergodicity of different systems which, as A. N. Kolmogorov had already shown on the example of a system of two nonlinear oscillators, can exist in systems with a small number (four) degrees of freedom. Strange attractors are examined in detail. A discussion is given of the possible role played by chaos in the information process, and the influence of internal fluctuations and external noise on the stability of dynamical systems are analyzed.

The seventh chapter is devoted to the problem of chaos in biology and in related fields.

In the appendix are presented individual points of view on the role played by external noise, affecting the neuron levels of organization. Attention is called to the difficulties arising in the investigation of connections between two hierarchical levels by utilizing nonlinear dynamics. In so doing special emphasis is placed on the study of the effect of external noise on the relaxation of a nonlinear oscillator.

On the whole the monograph of J. S. Nicolis under present discussion is quite an interesting publication which acquaints its readers with the basic concepts and the modern premises underlying the investigation of complex dynamical systems.

The book will doubtless be useful for physicists, biologists, and chemists who are studying processes of self-organization, occurring in nonlinear dynamical systems.

Kinetic theory of particles and photons

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J. Oxenius, *Kinetic Theory of Particles and Photons*: Theoretical Foundations of Non-LTE Plasma Spectroscopy. Springer-Verlag, Berlin; Heidelberg; New York; Tokyo, 1986, pp. 353 (Springer Series in Electrophysics V. 20) This monograph by J. Oxenius is devoted to the development of methods of describing the spectroscopy of nonequilibrium plasma. In the book a kinetic theory is constructed of weakly ionized plasma and photons, in which both the particles and the radiation field are described by distribution functions for which kinetic equations are obtained.

The book consists of seven chapters. In the first chapter the author discusses in detail the principle of detailed balance, and also different processes associated with the excitation of atoms and emission of photons. In the second and third chapters kinetic equations are derived which describe the dynamics of particles, and various integrals are discussed for collisions of particles with particles and of particles with photons. In the fourth chapter hydrodynamics equations are obtained both for particles, and for photons, taking into account different radiation processes, and a discussion is given of the limits of applicability of hydrodynamics. The fifth chapter is devoted to an examination of Boltzmann's H-theorem both for gas and for radiation. The sixth chapter examines processes associated with energy exchange between matter and radiation for the case of an optically thin plasma. In the seventh chapter processes are investigated in detail in which momentum exchange between radiation and matter is important.

The book examines many examples of concrete processes of interaction of matter and radiation. The majority of these processes refer to the interaction of radiation with hydrogen and helium. Therefore the book is of particular interest to specialists involved with problems of interaction of radiation with matter under cosmic conditions.

The material is presented in the book clearly and sequentially. The book contains seven appendices explaining and complementing the text. It is an excellent textbook and reference book.

Translated by G. M. Volkoff