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Book Review: *Synergetics and Dynamical Instabilities*

Synergetics and Dynamical Instabilities. (Course IC). G. Caglioli, H. Haken, and L. Lugiato, eds. North-Holland, Amsterdam, 1988.

Over the years scientists have come to expect a certain high level of quality in both presentation and content from the blue/grey volumes of the "Enrico Fermi" International School of Physics. The present volume continues in this tradition. The topic is a timely one, bringing together scientists with backgrounds in nonequilibrium statistical mechanics, the stability properties of complex dynamical systems, and even a few with a foot in both camps. The lectures are uniformly well written and successfully interleave experimental and theoretical investigations of particular topics.

Haken initiates the summer school with some introductory remarks on the nature and utility of synergetics. In short, synergetics is a strategy for understanding the emergence of macroscopic spatial, temporal, or functional patterns from complex systems. Arecchi follows with a discussion of instabilities and chaos in lasers, providing a good review of our state of experimental verification of the predictions made for the existence of chaos in lasers. He provides one with a clear, if brief, discussion of the underlying nonlinear dynamical equations and from these interprets the experimental results, e.g., comparing the fractal dimension from computation and measurement for certain kinds of lasers. Lugiato and Norducci continue the discussion of optical instabilities and provide a complementary discussion of the physics underlying dynamical equations. The third of these combined computational–experimental lectures is by Arimondo on the bistable laser with a saturable absorber. Here questions of the effects of noise in the classical sense on the laser operation are first addressed and critical slowing down of the lasing transition is observed. Haake investigates the general question of transitions between the two states of a bistable device, being particularly interested in the phenomenon of quantum tunneling rather than thermal activation. He analyzes the master equation using coherent states and shows a correspondence to classical behavior.

The above lectures are followed by a three-part sequence on the mechanical instabilities in metals. Caglioti provides a discussion of material phenomenology through such topics as deformation colorimetry and

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dislocation dynamics, combining stress/strain relations with thermodynamics and the microscopic mechanisms leading to the observed empirical macroscopic relations, e.g., use of thermal emissions as a sensitive probe of the initiation of plastic flow. Beghi describes the experimental method used in establishing the phenomenological relations previously discussed. This includes the study of crack propagation and the associated rise in temperature near the crack tip. Bottani completes this tritych with a discussion of instability in the dynamic interactions of dislocations. This is the most formal of the three lectures and develops in a scholarly way the nonlinear equations for dislocation dynamics.

In a transition from the physical to the biological, Gierer discusses biological pattern formation and the difficulties associated with extracting macroscopic spatial order from molecular interactions. Topics such as the reaction-diffusion equation, the molecular basis of morphogenetic fields, and the utility of synergetics are all addressed. Venkataraman and Balakrishnan take the type of analysis used by Gierer a step further and focus on analogies to phase transitions and the underlying mathematical descriptions. They are able to draw general conclusions; e.g., breaking continuous symmetry leads to long-range order. The nonequilibrium phase transitions they discuss are supported by experimental evidence as well as analysis. Castillo, Garcia-Ybarra, and Velarde sacrifice this breadth for depth and investigate in some detail Benard–Morangoni convection. They set up nonlinear thermohydrodynamic partial differential equations of motion and boundary conditions, and then use scaling techniques to solve the problem to various orders. They uncover a rich dynamic structure including regimes of chaos.

Caianiello and Noce develop a set of uncertainty relations for thermodynamically closed systems based on a correspondence between mechanical action and thermodynamic entropy. This association allows one to write formally a thermodynamic Hamilton–Jacobi equation and subsequently establish a metric for such a system. Graham also discusses action and entroy, but for a much different purpose. To him they are both examples of the utility of extremum principles in macroscopic nonequilibrium systems, forming the basis of reversible classical mechanics and reversible thermodynamics as they do. Irreversible therodynamics results from the effects of fluctuations and the attendant dissipation, and Graham generalizes the formal structure of equilibrium thermodynamics to the nonequilibrium situation. This includes discussing the thermodynamic properties of chaotic systems. Nicolis and Altores have the same purpose and their lecture complements that of Graham, making a probabilistic extension of the center manifold theorem. They also analyze the role of fluctuations in the static properties near bifurcation points. Lefever investigates the sensitivity of nonequilibrium systems to external (systemindependent) noise. The systems of interest have multiplicative colored noise. The transitions between states induced by the fluctuations are studied for a number of model systems. The phenomenon of noise-induced stability is also demonstrated.

The question of dynamic stability and the influence of noise was abandoned by Peitgen and Richter, who are interested in the fractal structure existing in the boundaries between phases. They discuss the Yang–Lee theory of phase transitions, renormalization group relations, and fractals. Geisel, Radons, Rubner, and Zacherl return to the discussion of classical and quantum dynamical systems and chaos. Their interest is in phase space diffusion and for this investigation they use the Lorentz gas (extended Sinai billiards) which gives rise to anomalous diffusion. In other classical systems they find $1/f$-noise diffusive behavior, and they also find distinctive quantum manifestations of classical chaos.

The last lecture, by Morchetti, is completely disconnected from the rest of the volume and addresses how predictions or forecasts can be made in the social arena, e.g., product replacements, technology increase, and even the number of papers published by a scientist. The lecture is interesting and probably even falls within the general context of the summer school, but that connection was not made clear by the author.

As I said earlier, the topic of the book is a timely one and the authors are experts on its various aspects and took pains to communicate difficult concepts in understandable ways. I recommend this book to the researcher and advanced graduate student interested in learning how two major areas of the physical sciences, nonequilibrium thermodynamics and nonlinear dynamics, are coming together to help us understand diverse complex phenomena.

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