*Journal of Statistical Physics, Vol. 34, Nos. 1/2, 1984*

# **Book Review:** *Nonequilibrium Problems in the Physical Sciences and Biology. Volume II: Long-Time Prediction in Dynamics*

**Nonequilibrium Problems in the Physical Sciences and Biology. Volume II: Long-Time Prediction in Dynamics.** Edited by C. W. Horton, Jr., L. E. Reichl, and V. G. Szebehely. John Wiley & Sons, New York, 1983.

This volume consists of 24 lectures delivered at a workshop on long-time predictions in nonlinear conservative dynamical systems organized by the Center for Studies of Statistical Mechanics, the Center for Orbital Dynamics, and the Institute for Fusion Studies at the University of Texas at Austin. The organization of the lectures reflects this cooperative effort and is divided into four parts: Statistical Mechanics, Dynamics, Plasma Physics, and Beam–Beam Interactions. The recurrent theme in each of these areas of investigation is the determination of the general conditions for the onset of chaotic behavior in nonlinear systems, i.e., predictability and chaos are the two sides of the same coin. Thus, the predictability content of most of the lectures is implicit rather than explicit; it is assumed that measures for the onset of chaos and the growth rate of instabilities are sufficient indicators of predictability or rather its loss. Direct measures of predictability such as the variance of the error field used in meteorology were not discussed.

Much of the resurgence of interest in analytic dynamics has been motivated by problems arising in plasma physics, so much so that many scientists overlook the important applications not only in other areas of physics, but also in the life sciences and engineering as well. This series of lectures, which is of uniformly high quality, gives some indication of the general applicability of these methods and in so doing achieves a certain mathematical sophistication. Thus, the volume is not for the novice, but can be recommended as a useful research volume for the scientist/mathematician.

**Statistical Mechanics:** The theme of the lectures in this section is the formal relation between deterministic dynamics and probabilistic Markov



0022-4715/84/0100-0347$03.50/0 

processes. The point is repeatedly made that orbital complexity is the important issue, so that when the phase space is sufficiently chaotic, the notion of an individual trajectory ceases to be useful. In this region of unstable orbits, the concept of a probability distribution is more appropriate and the unstable dynamic equations are replaced with irreversible probabilistic kinetic equations. In this context, the central concept of a measure on the phase space is discussed.

**Dynamics:** These lectures are concerned with the transition from regular (quasi)-periodic behavior to chaotic behavior due to period doubling bifurcations induced by the variation of parameters in various model systems. Both area-preserving (conservative) and area-contracting (dissipative) mappings are considered. The values and rates of convergence of the Feigenbaum sequence in these two cases are shown to be quite different. Also, attempts are made to relate such concepts as fractals and critical exponents in Wilson's renormalization group theory to the breakdown of tori in KAM theory. The mechanisms of Arnol'd diffusion, modulational diffusion, and resonance streaming of chaotic motion along resonance layers in phase space are reviewed. Certain topics in celestial mechanics are discussed from which it is clear that the stability of the solar system is uncertain.

**Plasma Physics:** A symplectic map preserves the "two-form" structure of phase space and much of the discussion in this section is devoted to symplectic Hamiltonian dynamics. Certain technical issues arising from intrinsic chaos and the need for renormalization techniques are addressed such as: the penetration of plasma waves into the interior of a plasma, plasma stability, thermal radiation, and anomalous resistivity due to ion-acoustic turbulence. It is argued that a Lagrangian picture (normal stochastic approximation) of a nonlinear turbulent response of a system with intrinsic stochasticity and long-lived fluctuations is superior to an Eulerian one (direct interaction approximation). Also in this section were talks concerned with a generalization of the inverse scattering transform and a nonlinear model for the efficient energy transport in biological systems.

**Beam–Beam Interactions:** In these lectures the theory and phenomenology of beam blowup due to dynamical instabilities is reviewed for a number of high-energy colliding beam configurations. The emphasis is clearly on the application of area preserving mappings and the KAM theory of analytic dynamics. Although the models are treated in some detail, both analytically and numerically, it was pointed out by one of the authors that no satisfactory theory of beam–beam phenomena exists. Therefore, the models are interesting from a formal point of view, but whether they describe the interaction phenomenon is unclear.

In summary, I recommend this series of lectures to anyone interested in learning how the recent advances in analytic dynamics have influenced some of the fundamental questions in other scientific areas. I also caution the reader that the mathematics are often sophisticated and the questions subtle, but the value obtained is usually worth the effort.

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