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Book reviews

L'espace chaotique (Chaotic Space) by **P. Bergé, Y. Pomeau, C. Vidal** (Hermann, Paris, 1998, 176 pp.) FF 180, paperback, ISBN 2 705 66345 2.

Systematic discovery of deterministic chaos in hydrodynamical instabilities is arguably the most important progress made recently in theoretical fluid mechanics. The wonderful previous book by the same authors, "Order in Chaos" is a fascinating introduction to this new field, and is in part remarkable because of the constant stress on physical intuition, despite the frequent use of rigorous and advanced mathematical concepts. This unique flavor in one of the first books on chaos was widely acclaimed.

The new book is a successful application of the same style to spatio-temporal chaos. This relatively new area of non-linear dynamics arises from two features: spatial extension or spatial patterns, and "ordinary" chaos in time-dependent systems. Taking into account spatial effects is a first step towards the rigorous analysis of fully-developed turbulence, the ever-elusive, fascinating goal of fluid mechanics. In that sense the study of spatially-extended chaotic systems is one more stage in the search for a theory of turbulence, just as chaos has been in the sixties and seventies. Admittedly this step does not yet lead us beyond relatively low Reynolds numbers, but the results are rich in physical content.

Despite its rigorous base in non-linear science, the book may be read without specialized preliminary knowledge. Some fundamental concepts and paradigms are reviewed, such as the Rayleigh-Bénard instability in extended systems. Two appendices on temporal chaos make the reading of this book possible without any knowledge of the previous book by the same authors.

The authors discuss many experimental cases, such as the plane Poiseuille and Couette flows, as well as less-well known flows: Faraday instability, hydrothermal waves and printer's instability. Moreover a purely mathematical case is treated as an appendix: Kuramoto's equation, a partial differential equation holding the same paradigmatic status for spatio-temporal chaos as Lorenz's equation in the temporal case.

These cases are characterized by spatial patterns diverse in their details but which all show coexistence of regular and irregular regions. This alternating pattern of laminarity and chaos is itself variously organized. In some cases chaos invades space in a sort of disordered way: spatio-temporal intermittency arises, to which a large part of the book is devoted.

Spatio-temporal intermittency is nowadays intensely studied. The phenomenon has all the specific aspects of transition to chaos in spatially-extended systems and involves delicate experiments. One thus starts from a system of great complexity, such as the Navier-Stokes equations, with thermal and surface effects, boundary conditions, a geometrical structure, and one arrives, in a surprising and yet unexplained way, at empirically verified laws that may be derived from very simple models. For instance, the directed-percolation model may be constructed from two states only (to be compared with the complexity of a solution of the Navier-Stokes equation) and the local chaotic dynamics may be viewed as a simple probabilistic law describing the transition between the two states of the system. It is amazing that this simple probabilistic law reproduces the statistical behavior of the fluid-mechanical system.

Although the subject involves many subtle theoretical concepts, the mathematical and technical developments are reduced to the minimum, and physical intuition is everywhere preferred. The book is abundantly illustrated

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without ever becoming flashy. A newcomer will easily and pleasantly discover the field. But there is a second possible reading of this book: it is a manifesto of the particular viewpoint of the authors on the field. Thus one may find general remarks on the validity of variational approaches, on the equations most often used to describe these systems such as the Ginzburg-Landau equations, or else statements on the important features of flows in transition to developed turbulence. The underlying idea is that there is a kind of thermodynamic picture adapted to chaotic systems, in which the transition to chaos is a phase transition. However the precise domain of applicability of these thermodynamics remains to be found. Nevertheless it allows us to derive most of the qualitative description of the transition to turbulence. This duality of viewpoints, both introductory and subtle makes this nice little book an excellent reference for the beginner as well as the specialist.

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Hydrodynamics and nonlinear instabilities, edited by **C. Godrèche, P. Manneville** (Cambridge University Press, 1998, 681pp.) £ 85.00, US$ 100.00, hardcover ISBN 0 521 45503 0.

The study of hydrodynamics has fascinated theorists since the early days of science and it is not hard to see why. Here is a subject which is not only concerned with many everyday phenomena, but which is in the main susceptible to experiments that do not demand the GDP of a small nation to construct. The governing equations are accepted by all as applying accurately to the vast majority of situations, but while they are easy to write down, their full solution is elusive. Their difficulty stems from their nonlinearity, and the fields of boundary layer theory, bifurcation theory, exponential asymptotics and nonlinear dynamics have all received a powerful impetus from the effort of trying to get to grips with their complexities. The present volume, a joint effort by a distinguished group of French scientists, is principally concerned with these and other theoretical tools, while remaining very much in touch with the experimental basis of the subject. There are five long chapters; an overview of hydrodynamics (Castaing), on instabilities in extended closed and open flows (Huerre & Rossi), a discussion of asymptotic methods (Hakim), an extensive treatment of pattern-forming instabilities (Fauve) and flames and explosions (Joulin & Vidal). There is a nice introduction by Manneville emphasising the importance of the link between experiments and their description in terms of nonlinear theoretical models. The chapters are self-contained, and each aims to give a pedagogical description of its subject, accessible to graduate students, while still discussing up-to-date topics that have not yet been exhaustively studied. In my view, while inevitably the style of the chapters is somewhat nonuniform, the book succeeds pretty well in its aim, and I would recommend it as important reading for students embarking on a research career in hydrodynamics.

Chapter 1 gives an enthusiastic introduction to the Navier-Stokes equations and explains the physics behind them. There are sections on low Reynolds number flow (including a discussion of wakes), the energetics of turbulence, boundary layers, flow measurement, dimensional analysis and (the author's favourite) a statistical mechanical description of turbulence. This is all covered in just over 50 pages! Inevitably the pace is very rapid, and each part can only be considered a taster to encourage more detailed study. Chapter 2 is a comprehensive study of instabilities of shear flows, including spatially developing flows. There is a detailed discussion of Rayleigh's equations and viscous stability theory, and an explanation of the absolute stability criterion for such flows, though some very recent work on nonlinear effects is not included. There are also very useful sections on elliptical instabilities and on nonlinear travelling wave states on e.g. Poiseuille flow, whose instabilities are more relevant to turbulent breakdown than those of the basic state.