STRUCTURAL FORMS AND INTERACTIONS OF GALAXIES AND STAR CLUSTERS

Galactic Dynamics

James Binney and Scott Tremaine
Princeton U. P., Princeton, N. J., 1987. 733 pp.
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Reviewed by Donald Lynden-Bell

Anyone who wishes to understand the origin of the beautiful forms found in galaxies, the current status of the search for black holes in their nuclei, or the constraints on the nature of the dark matter that dominates the mass of the universe should read this book. Stellar dynamics, the first collisionless statistical dynamics to be studied, was developed originally by Arthur Eddington, James Jeans and Karl Schwarzschild in the early years of this century. Later the effect of weak encounters was beautifully incorporated into it by Subrahmanyan Chandrasekhar. The rapid development of plasma physics in the latter half of this century led to considerable cross-fertilization and to more powerful tools for the study of the temporal development of distribution functions. The progress in computers and computation has enormously extended the scope of numerical experiments, which have been a strong stimulus to theory, surpassing even real observations of galaxies. Those observations in turn have improved beyond recognition under the influence of much more sensitive detectors and larger telescopes in the optical, radio and x-ray bands. Thus there has been a great growth in accuracy, and many new phenomena can now be studied.

The classical books on stellar dynamics, by Chandrasekhar (*Principles of Stellar Dynamics*, U. of Chicago P., Chicago, 1942; Dover, New York, 1960) and by William Smart (*Stellar Dynamics*, Cambridge U. P., New York, 1938), have for some years needed to be supplemented by an account of these more modern developments. The account of them given by A. M. Fridman and V. L. Polyachenko in *Physics of Gravitating Systems* (Springer-Verlag, New York, 1984; reviewed in PHYSICS TODAY, November 1985, page 105) is confined to the mathematical side of the subject and is not very accessible to the student. James Binney and Scott Tremaine's *Galactic Dynamics* is both accessible and authoritative. It is written—and priced in paperback—at an appropriate level for graduate students in astrophysics. Its mathematical level is somewhat simpler than that of the famous series of physics texts by Lev Landau and Evgenii Lifshitz; nevertheless it gives a thorough account of the main ideas and developments in this broad subject. The text is fully supplemented by a wealth of problems that greatly enliven the mind. Only by such practice can students become "doers of the word, not hearers only."

Physicists conversant with statistical mechanics will find great interest in the negative specific heat displayed by *isolated* self-gravitating systems. Examination of the standard proof that specific heats are always positive shows that it does not apply to microcanonical ensembles or inhomogeneous isolated systems. Those interested in kinetics will find some nice problems in the evolution of stellar systems, as the stars undergo gravitational encounters with one another, and the role of binary stars as energy sources. A most welcome feature of the book is the emphasis on the use of the classical angle and action variables, which have been much exploit-

Spiral galaxy NGC 2997. The bright knots in the spiral arms are emissions from ionized-hydrogen gas clouds, which are believed to be star formation regions. (Illustration from *Galactic Dynamics*; courtesy of David Malin.)

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ed in recent decades. It is sad that Max Born's fine book *The Mechanics of the Atom*, which develops perturbation theory in classical mechanics around these variables, is again out of print. *Galactic Dynamics* has surprisingly little discussion of the analytical perturbation theory of the integrals of motion. In contrast to this neglect, it gives three methods of calculating the gravitational forces due to disks: via flattened spheroids, Bessel functions and elliptic integrals. To my great surprise the first of these, which involves only algebraic functions, is wrongly labeled as cumbersome. Preference is given to the latter two, but in fact the flattened-spheroid method is both the least cumbersome and most elementary.

It is always hard to decide the boundaries of a subject, and *Galactic Dynamics* expands in two directions that both have strong connections with its basic theme. In the solar neighborhood there is such a strong correlation between the abundances of the elements on stellar surfaces and the eccentricity of the stellar motions in the Galaxy that discussions of galaxy formation would be seriously incomplete without some discussion of the chemical evolution of galaxies. A full development of this subject could make a book in itself, so the authors wisely confine themselves to simple models that lump all the elements heavier than helium together and assume instantaneous recycling. The recent realization that oxygen, iron and nitrogen are not enhanced at the same rates will lead to further developments in this topic. Binney and Tremaine do include an extension of the simple model that allows for an accretion rate proportional to the star formation rate.

The other extension of the book, toward cosmology, arises from the wish to tie up ends that might otherwise have been loose. These concern primordial nucleosynthesis of the elements, the cosmological constraints on the nature of dark matter, and their relationship to the possible detection of dark matter in dwarf spheroidal galaxies. These topics are sufficiently important that it would be sad to leave them out; nevertheless the rather brief and descriptive treatment given them makes for the least satisfying part of an excellent book.

Research results not already published will not be found in the book. It gives a fine account of what is known, and its students will find encouragement in how much remains to be explained. We now know much about how stellar motions give the structures we see; we still know relatively little about *why* these particular structures are the ones that persist. Such questions as "Why are half the spiral galaxies barred?" and "Why are elliptical galaxies found preferentially in the densest clusters?" are still under active study.

Stellar dynamics is a rapidly developing subject providing a wealth of new problems to be explored. Binney and Tremaine have done a major service to astronomers and physicists alike by producing a magnificent book that will make this fascinating subject much more accessible. This is undoubtedly the best book from which to learn the subject.

Introduction to Superstrings

Michio Kaku
Springer-Verlag, New York, 1988. 568 pp. $49.95 hc ISBN 0-387-96700-1

String theory emerged in late 1984 as a leading candidate for a unified theory of all fundamental forces. Researchers and students turned to it in great numbers and discovered that they needed an enormous amount of mathematics and physics. Furthermore, that material was scattered throughout the literature, much of it in rather inaccessible forms.

A first attempt to give a coherent, up-to-date treatment of string theory in a pedagogical form was made by Michael Green, John Schwarz and Edward Witten's two-volume monograph *Superstring Theory* (Cambridge U. P., New York, 1987; reviewed in PHYSICS TODAY, November 1987, page 91). That book omitted large areas of string theory that were developing rapidly, since any treatment of them would become outdated very quickly. Those areas included conformal field theory, multiloop string amplitudes and string field theory. To cover the remaining topics with enough detail for the book to be self-contained required over 1000 pages. Clearly there remains a need for monographs on the topics omitted from our book. Also, there is always room for improving and updating the treatment of the other topics.

Michio Kaku's *Introduction to Superstrings* is the first attempt at a comprehensive treatment of string theory since ours. The subject has developed considerably in the intervening period, and so there is quite a bit that could be done differently. Four of the chapters, totaling about 200 pages, cover two of the topics that we omitted—multiloop amplitudes and string field theory. The remain-