

here interesting physics can be discovered and learned.

It is magnetic activity that makes the Sun truly fascinating. Differential rotation and convection in the Sun's interior act as a dynamo generating a global field, which reverses itself every 11 years. The magnetic field gives rise to the 22-year sunspot cycle as well as a wealth of nonlinear and nonlocal fluid and plasma processes in the solar atmosphere. The sequence is a highly structured atmosphere that evolves over all observable time scales down to subseconds, and a highly heated upper atmosphere, the corona, that expands to the solar wind blowing supersonically past the Earth.

A quarter of Zirin's book describes the hardware used for solar observations and treats elementary radiative transfer, atomic physics and plasma physics. The remaining, larger part of the book describes the Sun itself. Included are stimulating discussions of the new prospect of seismically probing the solar interior, the mysterious clumping of the photospheric magnetic field into discrete fibrils, the equilibrium of global and local structures, the general phenomenon of solar activity, and the puzzles posed by the solar flare and other eruptive phenomena—to name just some of the occupations of solar physics. In each of these topics, there is much we do not understand fully, and what we do know is physically intriguing. [See article by Eugene Parker in *PHYSICS TODAY*, July 1987, page 36.]

Zirin writes in a direct, personal style, voicing occasional strong opinions and conveying his excitement about the many beautiful observations he describes. He interprets these observations and evaluates the interpretations critically, using an entirely intuitive approach, but with little attempt to understand theory. Zirin holds the extreme opinion that the observers don't know how to calculate and the calculators don't know what is observed. Scattered throughout the book are many undeveloped, confused or incorrectly stated theoretical concepts; chapter 3 has several examples. Zirin's lack of appreciation for theory often results in a conspicuous lack of physical content. Many of his interpretive analyses read as though some of the phenomenological constructs have acquired a utility independent of physical principles. His discussions become burdened by a cumbersome nomenclature not always adequately explained in the book. Solar phenomena are complex, and more physical considerations should take over from pure

intuition in interpreting observations when enough of the pertinent physics has been identified. Getting at that physics requires that theorists and observers learn from each other rather than avoid the strong coupling of their trades. Otherwise, the awesome images of solar observation easily distract us from the true physical significance of the Sun which has taught us about atomic physics, radiative transfer and a host of fluid, hydromagnetic and plasma processes, among them the dynamo mechanism, magnetic heating, the solar wind, collisionless shocks and particle acceleration. Although Zirin's treatments will be discouraging to readers interested in the physics, his book is still recommended reading: The broad range of descriptive phenomenology covered, the wonderful collection of pictures and the fascination of the Sun are the selling points.

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Principles of Nuclear Magnetic Resonance in One and Two Dimensions

Richard R. Ernst,
Geoffrey Bodenhausen and
Alexander Wokaun
Clarendon (Oxford U. P.),
New York, 1987. 610 pp.
\$98.00 hc ISBN 0-19-855629-2

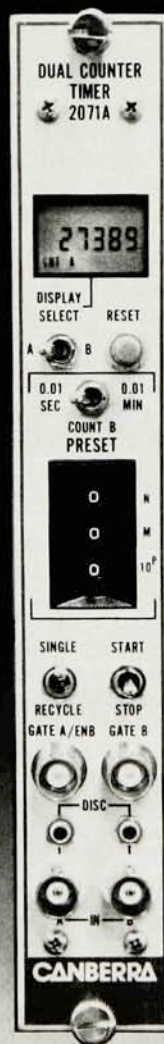
Nuclear magnetic resonance has been applied to an astonishing variety of problems and is the foremost analytic tool of the chemist. It has also been developed in truly unexpected and sophisticated ways, and this book documents the theory behind recent developments. The term "nmr in one dimension" refers primarily to pulsed Fourier-transform nmr, in which the transient signal stimulated by a short rf pulse is converted to low frequency, digitized and transformed to get a frequency-domain spectrum. A simple realization of two-dimensional nmr is a set of a few hundred spin-echo sequences in which the time between two stimulating pulses is varied from zero to several tenths of a second, and all the echoes are digitized and saved separately in a computer's memory. Fourier-transform spectra of each echo, transformed a second time with respect to the time between the stimulating pulses, produce a two-dimensional contour map in the spectral domain. In this case the map gives subspectra of pairs of spins in one spectral dimension, ver-

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sus their spin-spin coupling in the other dimension. The general method can be extended, almost without foreseeable limits. The single pulses used in this simple example can be elaborated to produce and to selectively read out many forms of coherence or other phenomena such as through-space Overhauser effects. These include coherences that are highly forbidden to direct magnetic detection, such as those between states that differ by more than a single spin flip. Not only are these methods interesting; they are also extremely useful for determining, for example, structure and dynamics of macromolecules.

Richard Ernst and his coworkers have undoubtedly developed a larger variety of two-dimensional nmr methods than anyone else, and they have also been in the forefront of theoretical analysis. Therefore it is a pleasure to welcome this treatise, which covers the theory of these methods in a unified way. The book is primarily concerned with nmr of molecules in solution. This subject lends itself to a unified theoretical approach because such molecules contain finite spin systems, which interact only weakly and for which a single kind of external operation—a short rf pulse—can be used, alone or in combination, to produce all the results described in this book.

Much of the discussion is couched in superoperator formalism, which is necessary for a unified treatment. The book is not written for the casual reader. It starts from elementary spin and statistical theory and carries the reader through the theory to the most sophisticated experiments in a way not hard to follow once the reader abandons trying to read the book through from beginning to end and instead pursues the many internal cross-references. These cross-references, and the literature references as well, are both frequent and excellent.

This is not really a comprehensive textbook of nmr theory or experimental technique, although it does treat a large number of topics outside its main subject of two-dimensional nmr in solution. Many of these, such as nmr in solids, have already been well covered in other treatises and are discussed rather briefly here. The book also does not impart much feeling for experimental strategy; the methods are all here, but you will have to look at the current literature to learn which ones are really used in practice. A beginner would want to read this text in conjunction with other, more experimentally oriented ones on nmr as applied to physics and

chemistry, or would want to ask for guidance from an nmr specialist.

Spectroscopists in other high-resolution fields of physics may find some useful ideas here. The book is also worthwhile reading for anyone interested in applications of superoperator theory. It joins the treatises of Anatole Abragam (*Principles of Nuclear Magnetism*; Oxford U. P., New York, 1961) and Charles Slichter (*Principles of Magnetic Resonance*; Springer-Verlag, New York, 1961; third edition in press) as an indispensable classic in nuclear magnetic resonance.

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