VALUABLE CONTRIBUTION TO LITERATURE ON MODELING OF MAGNETIC SYSTEMS

Statistical Mechanics of Magnetically Ordered Systems

Yu. A. Izyumov and Yu. N. Skryabin (translated from Russian by Roger Cooke)
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Reviewed by Michael E. Fisher

The serious mathematical study of models of magnetic systems, dating back to the exact solution of the one-dimensional Ising model in 1925, has an illustrious history encompassing some of the outstanding achievements of statistical physics in this century. Early highlights are Hans A. Bethe's analysis of the eigenstates of the spin-$\frac{1}{2}$ Heisenberg chain, Rudolf E. Peierls's demonstration of the existence of spontaneous magnetization in the Ising model in two (or more) dimensions and Lars Onsager's exact solution of the two-dimensional Ising model in zero field in 1944–45.

The introduction of the Hubbard and the *s-d* models in the early 1960s allowed an attack on the collective role of electronic degrees of freedom, which soon focused on the Kondo problem for a single magnetic impurity. The last two decades have seen the growth of close ties to quantum field theory. In recent years, through the Yang–Baxter equations, surprising connections to new areas of mathematics have emerged. The theory has led, in turn, to profound insights into the nature of ordering and phase transitions in condensed matter physics, and into the role of fluctuations, symmetry and dimensionality in critical and multicritical phenomena.

At this stage it is likely that no single volume could do justice to all these significant theoretical developments. One must, therefore, forgive the authors of this book, two Russian theorists working at the Institute of Metal Physics in Sverdlovsk in the Urals, if their work does not fulfill the expectations raised by their ambitious title and introductory paragraphs. Nevertheless, this book deserves attention, and the last seven of its 21 sections in particular, represent a valuable contribution to the current literature.

Primarily this is a book about theoretical techniques for the Heisenberg, Hubbard and *s-d* models. Important results are derived with clear explanations, but their significance, even within a purely theoretical context, is hardly discussed; no references are made to experiments. The level is advanced; well-prepared graduate students will benefit from the book but it is not an introductory text. In this respect it contrasts markedly with the volumes by Daniel C. Mattis (*The Theory of Magnetism*, Harper and Row, New York, 1965; *The Theory of Magnetism I: Statics and Dynamics, II: Statistical Mechanics*, Springer-Verlag, New York, 1981, 1985). General concepts of long-range order, incommensurate and helical ordering, spin waves and Goldstone models, and so on, are not discussed *per se*. The critical exponents ν, η and z appear without warning on page 56; the reader is presumed to be familiar with the phenomenological theory of phase transitions and with the scaling relations for exponents. Random systems and spin glasses are not touched upon.

The book starts with an exposition of diagrammatic techniques for the Heisenberg model and later treats the Hubbard model similarly. The formalism is systematically developed but is heavy and the rewards presented—mainly various forms of mean-field theory—are relatively meager. The authors never mention the names of G. Stanley Rushbrooke, Cyril Domb, Martin F. Sykes and George A. Baker Jr, who showed how, by quite other means, long-series expansions could be generated for the three-dimensional Heisenberg and Ising models. Nor do they give the values of the critical exponents γ, ν, and so on, first found reliably from such series. Philip W. Anderson and Ryogo Kubo also make no appearance. Nevertheless, within the interesting bibliography of some 70 works published in Russian and some 100 or so papers and reviews in English, the non-Russian contributions are reasonably well sampled.

An instructive chapter addresses the method of path integration and outlines the renormalization-group approach and the ϵ expansion for critical exponents.

The book takes on a new and refreshing life once the authors embark on the analytical treatment of low-dimensional models. The square-lattice Ising model is solved following the fermion methods introduced by Elliot H. Lieb, Theodore Schultz and Mattis. The renormalization-group treatment of the XY and Heisenberg models in two dimensions is done succinctly but rather cleanly. It is nice to see a section on instantons in the Heisenberg model.

The main attraction of the book, however, is the long final chapter on exactly solvable *one*-dimensional models. This chapter, which constitutes over 30% of the text, starts with a description of the Bethe-ansatz approach—the key that in the hands of masters, particularly Chen Ning Yang, has led to so many mathematically beautiful and physically important results. After applying this approach to the anisotropic Heisenberg chain, the authors expound the important quantum-inverse-scattering method developed by Ludiwig D. Faddeev and his distinguished school. As

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noted, this technique may be regarded as an algebraic version of the Bethe ansatz. The pivotal role of the Yang–Baxter equations, derived from Rodney J. Baxter's deep exploitation of commuting transfer matrices, is well explained. The approach is then applied to the one-dimensional Hubbard model and also used to solve the Kondo problem. Some of the related further developments are sketched briefly.

The mathematical methods that have grown from the Bethe ansatz are unfamiliar to many theorists; they are subtle but powerful, and undoubtedly their applications are not yet exhausted. Yuri Izyumov and Yuri Skryabin deserve thanks for providing an accessible overview and introduction to this significant field and its original literature.

The book lacks an index (despite the assertion on the fly page), but has a detailed list of contents. The translation is competent although some infelicities and inappropriately translated terms appear. Despite its various shortcomings, this volume warrants a place in all libraries serving condensed matter theorists.

Creation of the Universe

Fang Lizhi and Li Shuxian
World Scientific, Teaneck, N.J., 1989. 180 pp. $41.00 hc ISBN 9971-50-600-9; $25.00 pb ISBN 9971-50-601-7

Fang Lizhi, China's leading cosmologist, and his wife Li Shuxian, a well-known Beijing University physics professor, present a unique approach to cosmology in *Creation of the Universe.* In this book Fang, one of the first scientists to recognize the excitement at the interface of cosmology and particle physics, and Li give their overview of an active and dynamic new field.

Fang and Li became internationally famous after they were forced to seek asylum in the US Embassy in Beijing this past spring. However, this book, except for a brief paragraph in the preface, is about cosmology, not politics. And well it should be since Fang and Li are first and foremost physicists, not politicians.

Creation of the Universe is an English edition of the authors' popular 1987 Chinese book. It was written for a general audience of educated Chinese. This in itself is quite revealing, since the book uses exponential notation and has many algebraic equations. A book written for an "equivalent" audience in the US would have to write out "billions" and "trillions," and, as Stephen Hawking noted, no equation other than $E = mc^2$ would be acceptable. Unfortunately this difference in the mathematical competence of what is considered a "general audience" means that in the US, the book's audience is restricted to, perhaps, technically oriented people from physics and other fields and college students taking introductory physics and astronomy courses. The book is also worthwhile for the specialist, not because of new science, but because the logic and order of presentation are unique to Fang and Li.

The book has a fine mix of ancient Chinese stories and some nice cartoons and sketches that give it a special quality that no other cosmology book has. Cosmology has become a very active area of physical research and is probably the subdiscipline that captured the most column inches of popular science writing in the 1980s. While there are many popular cosmology books written by both journalists and active researchers, Fang and Li take a unique approach. They develop Big-Bang cosmology as a natural consequence of the answer to the worries of the ancient men of Qi as to when the sky would fall and the earth collapse. This exercise in logic contrasts sharply with the more empirical approach used by most Western authors (including myself). Eventually, Fang and Li introduce some empirical evidence, such as the background radiation and the light-element abundances (my own "unbiased" favorite), but they do not focus on the empirical approach.

The problem with such a purely logical development is that it is counter to the recent historical development of the field, which has been dominated by experimental and observational information. In fact one key reason for so much recent interest in cosmology is that we have so many new ways to actually probe the universe and test our ideas, including both accelerator experiments and astronomical observations at a variety of wavelengths. Rearranging things for pedagogical reasons to make the development look purely logical—is an interesting approach. But could we really deduce the Big Bang from worrying about the sky falling if we didn't already know about the success of cosmological nucleosynthesis in explaining light-element abundances and the observation of the 3-K background radiation? I worry that casual readers might miss the fact that cosmology is an experimental as well as a theoretical field and that progress has occurred through a combination of approaches.