A broad, penetrating view of gravity

Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity

Steven Weinberg
657 pp. John Wiley and Sons, New York 1972. $18.95

Reviewed by Robert V. Wagoner

HALE OBSERVATORIES

Galaxy cluster in Hercules. Such clustering is the largest scale evidence of gravitation.

"But now the passage of time has taught us not to expect that the strong, weak, and electromagnetic interactions can be understood in geometrical terms, and too great an emphasis on geometry can only obscure the deep connections between gravitation and the rest of physics." These words from the preface illustrate the approach to physics that guided Steven Weinberg in his writing of this book, based on courses given at Berkeley and MIT over the past several years. They also indicate why this book should play a unique and leading role in the education of those interested in this rapidly expanding area of science. Weinberg's ability to probe to the heart of a problem, which has characterized his many important contributions to particle physics, has brought to this volume a view of the nature of gravitation that is both broad and penetrating.

An instructive method of summarizing the contents of the book is in terms of increasingly specific assumptions about the structure of the gravitational field. The first two chapters present an historical introduction and a very useful summary of special relativity. The strong equivalence principle is then introduced, providing the basis for a discussion of tensor analysis and the effects of any (metric) gravitational field on any physical system in chapters 3–6, and least-action principles in chapter 12. The following two chapters provide a very complete discussion of what can be learned about the universe if only the cosmological principle is in addition assumed.

The remaining chapters of the book are for the most part based upon the Einstein field equations, introduced in chapter 7, although the standard solar-system tests are discussed in a slightly more general framework in chapter 8, and other theories are applied to cosmology in the final chapter 16. The major applications of general relativity are to the post-Newtonian equations of motion, gravitational radiation, and stellar structure and collapse in chapters 9–11, and to an extensive discussion of the "canonical" big-bang model of the universe in chapter 15.

Weinberg has discussed many topics not often found in similar texts, including relativistic imperfect fluids (especially as applied to perturbations in the expanding universe), symmetric spaces, representations of the Lorentz group, the quantization problem and an unusually complete investigation of intergalactic emission and absorption processes. It is characteristic of the scope of this book that one can find thorough analyses of the methods of determination of the astronomical distance standards as well as the way to include the effects of gravitation on spinor fields. But perhaps its most startling feature is the amazing completeness of its references, compiled by an author who directs most of his research in other areas! The text is also relatively free of serious misprints.

In keeping with his philosophy, Weinberg employs the classical component tensor notation throughout, except during a brief discussion of differential forms where the abstract formulation is alluded to. A more serious deficiency is the lack of any problems. In addition, his decision only to touch upon the nature of black holes now appears overly pessimistic in view of the recently discovered binary x-ray sources as potential indicators of their existence. Also, Weinberg has not included any reference to the work of Kenneth Nordtvedt (as later extended by him, Kip Thorne, Clifford Will and others) on powerful new solar-system tests of gravitation theories. He laments the difficulty of measuring the ratio of gravitational to inertial mass of

the Earth, an experiment that is now being performed by lunar laser ranging, one hopes to the necessary accuracy.

The reader should be on the lookout for some confusing notation in the chapter on the principle of equivalence, and a discussion of counts of radio sources that neglects some of the observational problems that make their interpretation more difficult. Also, the cosmological constant appears in the Einstein field equations with opposite sign in chapters 7 and 16. These are examples of a few minor difficulties.

In general, however, one is continually impressed by the thoroughness of discussion, and Weinberg's ability to distill the essential features of a physical situation. This is not a book for casual reading, but one that must be worked with to obtain the fullest measure of its benefits. It is appropriate for a full year course for those students who have a solid foundation in special relativity and classical electrodynamics, although parts of the book can easily be adapted to a shorter time period. The reaction of my class in gravitation theory has been very favorable.

The ever-widening vista of possibilities for observing the effects of strong gravitational fields throughout the universe is inspiring a new generation of physicists and astronomers. After digesting this feast of knowledge provided by Weinberg, they should be well prepared to join in the quest to understand more fully the nature of this fundamental interaction.

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Enrico Fermi, Physicist

Emilio Segrè
University of Chicago, Chicago, Ill., 1970. $6.95

This biography of Enrico Fermi as a scientist inserts itself between the book *Atoms in the Family* (U. of Chicago Press, Chicago, 1954) written by Fermi's wife, Laura, one year before Fermi's death, and the two volumes of his collected papers, published a few years later by the Accademia Nazionale dei Lincei and the University of Chicago Press.

Segrè's book is addressed to a rather wide audience, including not only nonspecialized scientists, but also other people interested in the personality of a great scientist. Among Fermi's collaborators and friends, Emilio Segrè