Martin Rees's Compelling, Unified View of the Universe

Just Six Numbers: The Deep Forces that Shape the Universe

Martin Rees
Basic Books (Perseus Group), New York, 2000. 173 pp. $22.00 hc
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Reviewed by Edward W. Kolb

In the world of astrophysics, Martin Rees is the summarizer of choice for major international meetings. His clear, reasoned concluding remarks often make the most complicated and confusing astrophysical problems seem tractable. Rees brings the same clarity of exposition to *Just Six Numbers*, his most recent book. Few people see the big picture as Rees does, and he paints a big picture indeed.

Just Six Numbers offers much more than just six numbers. Rees uses the seeming "fine tuning" of six numbers, ranging from the cosmological constant to the ratio of the electric force and gravitational force between two electrons, as threads that weave a tale of the shaping of our universe by a few fundamental forces and concepts. In explaining how our existence depends on six numbers having values in a surprisingly narrow range of possibilities, Rees connects the nature of fundamental forces with the development of the universe.

Rees's breadth of vision and his ability to synthesize apparently disparate facts into a compelling whole are evident throughout the book. Among the subjects Rees touches on are stellar nucleosynthesis, the development of intelligence in our biosphere, black holes, gravitational entropy, the arrow of time, and the dimensionality of space.

Many of the topics in the book are at the leading edge of research. In a field as active and vital as modern cosmology, some of the subjects in the book are likely to evolve in fundamental ways in the next few years. Where appropriate, Rees is clear about how the picture may change. As he notes, we have only outlined our view of the universe; our view will evolve as the details are developed.

Although the details may change, many of the fundamental ideas Rees develops undoubtedly will survive. Throughout the book, Rees emphasizes that complex structures may emerge from a simple set of laws and initial conditions. The interplay of simplicity and complexity is sure to remain part of the way we understand the universe.

Thought-provoking questions, such as the existence of other "universes" beyond our cosmic horizon, are discussed with confidence and flair. Rees's ability to present his own viewpoint while still giving a fair hearing to other viewpoints is manifest here. For instance, the concept of "multiverses," the idea that the observable region of the universe is just one member of a possibly infinite ensemble in which even the laws of physics may vary, often elicits a discussion of the anthropic principle. Although he never explicitly mentions the controversial anthropic principle, Rees presents a well-balanced discussion of the concept.

The book is accessible to a wide audience. Although it is targeted toward the nonspecialist, Rees never "talks down" to his audience. Even specialists in the field can benefit from the book. Although it is not a textbook, it would be ideal supplementary reading for an undergraduate course in "cosmology for poets."

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Concepts of Mass in Contemporary Physics and Philosophy

Max Jammer
Princeton U. P., Princeton, N.J., 2000. 180 pp. $39.50 hc
ISBN 0-691-01017-X

Investigating the conceptual foundations of contemporary physics is an activity to which both philosophers and physicists can contribute. Such an activity is important, not only to philosophers interested in such esoteric matters, but also to practicing physicists. In particular, the conceptual foundations of space, time, and, indeed, mass are important issues in ongoing research into quantum theories of gravity. In such cutting-edge fields, the overlap between physics and philosophy is most evident. Max Jammer's *Concepts of Mass in Contemporary Physics and Philosophy* contributes to the widening of that overlap.

Jammer treated space and time in his *Concepts of Space* (Harvard, 1957; Dover, 1993). Now he focuses on mass. "Next to space and time, mass is the most fundamental notion in physics . . ." Jammer declares in the preface of his new book.

In one sense, the book may be viewed as an up-to-date philosophical and thematic supplement to his previous historical survey, *Concepts of Mass in Classical and Modern Physics* (Harper & Row, 1964; Dover, 1997). The new book emphasizes developments since 1960, and thus provides a needed service in assembling current research on the subject. In a larger sense, however, the book stands on its own, combining historical elements of *Concepts of Mass in Classical and Modern Physics* with a thematic analysis to produce a coherent whole.

The book is unique in bringing together a number of diverse topics concerning the concept of mass in modern physics. These topics include inertial mass, relativistic mass, the mass–energy relation, gravitational mass, and the nature and origin of mass. Jammer begins by considering operational definitions of inertial mass and the related question of whether inertial mass should be viewed as a theoretical or an observational concept. His discussion of relativistic mass centers on the distinctions between relativistic mass, rest mass, and classical (Newtonian) mass, and the debate over their relationships. He then considers derivations of the mass–energy relation and its interpretations. The background for much of this material is presented in more detail in his *Concepts of Mass*

in Classical and Modern Physics. The present work, however, focuses primarily on formulations of the issues in the recent literature and points up the fact that these issues are still the subjects of contentious debate.

Jammer's subsequent discussion of gravitational mass includes the distinctions between inertial mass and active and passive gravitational mass, and formulations of the equivalence principle as applied to these distinctions. This latter material is new, deriving from the resurgence of interest in tests of general relativity during the 1960's in the work of Clifford Will and colleagues and in the subsequent development of the Parameterized Post-Newtonian (PPN) formalism.

The final chapter of the book is on theories of the origin and nature of mass. Jammer considers local dynamical theories, such as the electromagnetic theory (again, given a more detailed historical treatment in the 1964 book), global dynamical theories motivated by Mach's principle, quantum field-theoretic analyses such as the Higgs mechanism in electroweak theory, and the recent Haisch–Rueda–Puthoff theory of inertial mass as a reaction to the quantum vacuum. The book ends with a brief mention of the notion of mass in string theory.

Concepts of Mass in Contemporary Physics and Philosophy is also significant in its weaving into the discussion of various topics in the philosophy of science. In the context of inertial mass, Jammer considers the structuralist approach to theories and the manner in which structuralism distinguishes between theoretical concepts and observational concepts. He considers the notion of incommensurability in the context of competing views on the relationship between relativistic and classical mass, and he touches on the nature of scientific explanation in the context of the claim that general relativity explains the equality between inertial mass and (passive) gravitational mass. Such topics are grist for the mill of the practicing philosopher of science, but they still may not be all that familiar to the practicing physicist.

Physicists and philosophers of science will both benefit greatly from the book. It provides an invaluable source and commentary on the relevant contemporary literature. While the minimal use of technical exposition makes the book very readable to the nonspecialist, enough mathematical detail is provided to satisfy the curiosity of the expert. Jammer is unique in his experience as a physicist with a philosophical bent and as a philosopher with a physicist's training. His contributions to the conceptual foundations of physics have been, and continue to be, both fruitful and enlightening.

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The Accelerating Universe: Infinite Expansion, the Cosmological Constant, and the Beauty of the Cosmos

Mario Livio
Wiley, New York, 2000. 274 pp.
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One of the most surprising recent results from observational cosmology is the evidence that the expansion of the universe is accelerating. If gravity were the only force acting to alter the expansion rate, then the universe would be expected to be decelerating or, in the extreme case of a universe with essentially zero mass, expanding at a constant rate. Acceleration implies that the cosmological constant postulated and then discarded by Einstein is in fact not zero.

The initial evidence for acceleration came from a particular type of supernova explosion that in all cases reaches a uniform (or at least easily calibrated) intrinsic luminosity. Observations show that the most distant examples of this type of supernova are intrinsically about 20% fainter than those nearby. This observation is easily explained, if the universal expansion is accelerating: Our motion away from the distant supernovae has speeded up since the light left them, sweeping us farther away than we would be in a universe with a constant or decelerating rate of expansion.

Naturally, astronomers sought other explanations for the faintness of these distant supernovae. Intervening dust would also dim the light, for example. But no observational support has been found for any such alternative explanations. More important, in the past two years several other lines of evidence have emerged to support the conclusion that we live in a low-mass universe (matter density about one-third the critical value) that is accelerating and is flat. These include measurements of the cosmic microwave background and estimates of the amount of matter in all its forms—bright, dark, and baryonic.

Mario Livio's *The Accelerating Universe*, which was written primarily for the interested layperson, covers the work on supernovae but was completed before much of the supporting evidence became available. However, the book covers a much broader range of subjects than is suggested by its title. The author has set himself the task of showing how the search for beauty has shaped the development of physical theories of the universe.

He starts by defining what constitutes beauty in theory: symmetry, simplicity, and adherence to the Copernican principle that we do not occupy a privileged place in the universe. He then goes through basic cosmology in nontechnical terms, describing what we know about the universal expansion, dark matter, inflation, and so on. He concludes with a discussion of the recent discoveries of other planetary systems and an exploration of the anthropic principle—the hypothesis that certain physical constants and other properties of the universe, for which we as yet have no fundamental explanation, may have the properties that they do because we are here to measure them. Other equally arbitrary values would not have allowed carbon-based life forms such as ourselves to evolve, but such forms might well exist in other universes.

This book is clear, well written, and a pleasure to read. Livio's interest in the concept of beauty, and more specifically in the visual arts, manifests itself in well-chosen analogies that help the nonastronomer develop a mental image of what is implied by various physical theories.

At the same time, the book contains an enormous amount of information, sometimes with only the most superficial explanation. As a nonartist, I was familiar with only some of the paintings to which Livio refers in his discussions of beauty. Nonscientists are likely to have a similar problem with the discussions of astronomy. For example, in three pages, Livio covers stellar evolution; nuclear reactions; the equivalence between mass and energy; the inverse relation between mass and stellar lifetime; the Pauli exclusion principle; the Chandrasekhar limit; evolution from the main sequence to red giants; and brown dwarfs and white dwarfs. How much of this can the reader truly follow and remember unless most of the material is already familiar?

Because of this concern, I think the book would be most useful for teachers of introductory college astronomy