Book Reviews

Quantum Gravity

Quantum Theory of Gravity. Essays in Honor of the 60th Birthday of Bryce S. DeWitt. STEVEN M. CHRISTENSEN, Ed. Hilger, Bristol, 1984 (U.S. distributor, Heyden, Philadelphia). xvi, 483 pp., illus. $54.

It is often said that in science finding the right question is more difficult than finding the right answer. Whatever general truth this may have, it surely applies to what has come to be called the problem of quantum gravity, that is, the problem of reconciling our macroscopic understanding of space-time (or "gravity") with the quantum character that nature manifests on very small scales.

For a long time this problem was taken seriously only by a very few scientists, such as Bryce DeWitt, who were motivated by the need to restore to physics the unified foundation it had once possessed. Recently, however, fashions have changed to such an extent that the 30-odd contributions to the present festschrift for DeWitt are able to do no more than summarize a limited part of the effort now being devoted to the quantum gravity problem.

In part this change in fashion can be traced to the growing conviction that non-Abelian gauge theories provide the correct means for describing the interactions of subnuclear particles. The close mathematical affinity of such theories to general relativity has meant on the one hand that techniques developed for quantum gravity have become useful in particle theory and on the other hand that it has become possible to view gravity (that is, the space-time metric) as a stray classical field that could and should be brought into the quantum corral by the use of methods and criteria that have proved effective in flat space-time.

This relationship is well brought out in the contribution by Vilkovisky, which in particular contains a succinct exposition of DeWitt's geometrical approach that treats both general relativity and gauge theories as special cases to be handled within the common technical framework of covariant quantization. In fact the bulk of the technical contributions fit naturally into the program of bringing gravity within the flat-space tradition, and taken together they furnish the reader with a representative overview of work in that direction. Specifically there are four papers concerned with supersymmetry, three with higher derivative Lagrangians, and six with the properties of non-gravitational quantum fields in curved, but still non-quantum, space-times.

In flat space-time most quantum field theories are inconsistent in the sense that they predict infinite answers for the results of various experimentally accessible observables, and naively quantized general relativity is no exception to this rule. The main aim in formulating supergravity was to embed standard general relativity in a larger theory with precisely the right multiplicity and type of fields that all such infinities cancel, leaving behind well-defined, finite answers. In particular the hope is that the right choice of additional fields will be suggested by the requirement of supersymmetry, which pairs bosonic particles (such as the graviton) with fermions in a definite way. That such remarkable cancellations can actually occur has been confirmed in certain model theories, and the description of these results lends the papers on supersymmetry a certain excitement.

After finiteness, the next best thing to try for is "renormalizability," and several contributors deal with the attempt to attain it for gravity, not necessarily by adding more fields, but by modifying the gravitational field equations. These attempts also have promise and are well reviewed in the book. In addition, a paper by Boulware contains a valuable collection of formulas needed for the canonical quantization of such theories.

But even in the most optimistic of these papers the reader can sense a certain uneasiness. Perhaps what is being asked, that gravity be brought within the flat-space tradition, is not appropriate. But then how should one go about finding the "right question"? Several contributions bear directly on this issue, including Smolin's closely reasoned presentation of a new interpretation of quantum mechanics, Hartle and Kuchař's analysis of the role of time in the so-called path integral formulation of quantum theory, Deutsch's complaint that such methods of quantization are not yet "quantum enough," and Unruh's and Wheeler's reminders that it might be wise to pursue formal developments in closer conjunction with a study of how (or even whether) the basic objects introduced in the theory could in principle be measured. In addition, papers dealing with black holes and cosmological particle creation bring out some of the actual physical relationships (notably black-hole entropy and the smallness of the cosmological constant) that any ultimate theory will have to explicate. In this connection Parker's "quantum-gravitational Lenz's law" seems a particularly tantalizing heuristic principle.

Of concrete alternative proposals, though, the reader will find few except for Isham's discussion of quantum geometry. In the sense that current work on small-scale topology, on higher-dimensional gravity, and on asymptotic, complex, and other formulations of quantum gravity is barely represented, the title of this handsomely produced volume could be regarded as misleading. But no summary can cover everything, as I have been only too aware in writing the present review.

However, I cannot avoid a final observation, in connection with Christensen's absorbing historical paper. After describing his work on anomalies he writes, "We were under the extra pressure of secrecy. Once again we were in competition with other groups and not real happy about it." This sort of competition is something that had been absent among relativists until very recently, at least in my experience. We can only hope that the price of our being brought into the physics mainstream is not the loss of a working atmosphere fostering the cooperative and disinterested pursuit of truth, which, after all, is what scientific research in general is supposed to be about.

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Atmospheric Physics

Atmospheric Electrodynamics. HANS VOLLAND. Springer-Verlag, New York, 1984. x, 205 pp., illus. $35.50. Physics and Chemistry in Space, vol. 11.

"Atmospheric electrodynamics" is an apt term chosen by Hans Volland to describe the wide variety of electrical phenomena occurring in the lower and upper atmospheres. These phenomena include cloud electrification, lightning, the global atmospheric electrical circuit, ionospheric and magnetospheric electric fields and currents, upper atmospheric plasma dynamics, and naturally generated electromagnetic waves. This monograph is the first one of which I am aware to bring all of these topics together. Until recently the sciences of electrodynamics in the lower atmosphere and in the upper atmosphere have tended to evolve as separate disciplines, diverging from their common origins in the 18th century, when scientists like Benjamin Franklin viewed lightning and the polar lights as related electrical phenomena. In the past few years, however, there has been a renewed awareness of the electrodynamical coupling among atmospheric regions. This book is therefore a timely contribution to the field.

Many of the current scientific questions concerning atmospheric electrodynamics are of a fundamental nature. How do atmospheric aerosols and cloud particles interact with each other and with atmospheric ions to bring about the separation of electrical charges? Although many mechanisms have been proposed, the detailed microphysics of each and their relative importance in phenomena like thundercloud electrification are poorly understood. What factors determine the dynamical behavior of lightning strokes? The very nature of lightning makes it difficult to study comprehensively, yet an understanding of lightning has considerable practical value. What phenomena are involved in maintaining the positive charge of the ionosphere with respect to the earth? Thunderstorms are believed to be the primary charging mechanism, but much of the theory behind the global electrical circuit remains to be tested. How do ionospheric electric fields and currents interact with upper atmospheric winds and with the magnetosphere? How does the solar wind interact with the magnetosphere to energize the magnetospheric plasma? In the ionosphere and the magnetosphere, electrical phenomena become pervasive and play a major role in the structure and dynamics of the entire region. What electrodynamical processes determine the spectrum of electromagnetic waves generated in thunderclouds and in the magnetosphere? These waves can provide powerful diagnostic tools for studying the electrodynamic processes.

In this book Volland gives a brief overview of different aspects of atmospheric electrodynamics and then goes on to address the questions listed above, developing mathematical models intended to simulate certain features of selected phenomena. Although the mathematics are not always simple, the development of each model usually results in enough simplifications to permit an analytical solution. There are frequent analogies with equivalent electric circuits composed of wires, resistors, capacitors, inductors, and generators. Because many of the phenomena that are modeled are understood only poorly, the models that are presented must be considered more illustrative than definitive. Unfortunately, in many cases the parameters that are used in the models tend to conceal or distort some of the key physical processes that occur, a high price to pay for simplified analytical solutions. For example, the solar wind and magnetospheric plasmas are occasionally represented as ohmic media, in which current and electric field are linearly related by a conductivity parameter, even though collisionless plasmas come nowhere near to satisfying Ohm's law. The reader should therefore be cautious about trying to extend the predictions of these models beyond the results presented by Volland.

The book will be of interest to researchers with a background in electromagnetic theory who wish to learn more about applications of the theory to a wide range of problems in atmospheric physics. Because the book is selective rather than comprehensive, it will have only limited use as a reference work. Its greatest value may be in helping to stimulate a broader perspective among researchers in the field of atmospheric electrodynamics.

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Planetary Systems

Planetary Rings. RICHARD GREENBERG and ANDRÉ BRAHIC, Eds. University of Arizona Press, Tucson, 1984. xii, 784 pp., illus. $35. Space Science Series. Based on a conference, Toulouse, France, Sept. 1982.

The importance and timeliness of this compendium of review papers are highlighted by the range of the unsolved problems that are discussed in it. The first issue (which is not raised in a paper "Unsolved problems in planetary ring dynamics" by Borderies, Goldreich, and Tremaine) concerns the state of internal relaxation of the structure of the ϵ ring of Uranus. We do not know whether the shape of the radial profile of the ring is conserved even through periapsis (Elliot and Nicholson, "The rings of Uranus," figs. 8a and 8b). We may expect to learn whether it is from the observation from Space Telescope of a suitable stellar occultation by the ring (Smith, "Future observations of planetary rings from groundbased observatories and earth-orbiting satellites").

A second, more general issue concerns the observation of unexplained circular or nearly circular sharp edges (elliptical ones or those exhibiting wave structure seem either to be explained or to be well on the way to being explained; see "Waves in planetary rings," by Shu, "Dynamics of narrow rings" by Dermott, and the paper by Borderies *et al.*). The sharp edges show themselves mainly within the rings of Saturn and appear most impressively within the D ring, but they also appear within Cassini's division and at a few places within the C ring. (The absence of an adequate description of the D ring, which might have appeared in any of three papers, is the principal shortcoming of the book.) This concentration toward the inner portion of Saturn's rings suggests that perturbations by unseen satellites may not be the only mechanism for production of these sharp edges.

A third issue is that it remains to be seen whether spokes impinge in any way on the dynamics of the observed radial structures within Saturn's B ring. The need for at least one observing campaign from Space Telescope is expounded in the paper by Smith. Such a campaign combined with observations of many stellar occultations by the B ring from the same telescope should put our entire view of this ring on a new footing.

A welcome departure from a strict adherence to Occam's razor is provided by Weidenschilling, Chapman, Davis, and Greenberg in their paper, "Ring particles: collisional interactions and physical nature." Their principal suggestion is that particles accrete upon one another to grow to a maximum size ("dynamical ephemeral body") only to be disrupted. It will be some time before dynamical models can accomodate this proposed complication. A step on the way may be seen in the discussion of the behavior of a bimodal particle size distribution near the end of the review "Collision-induced transport processes in planetary rings" by Stewart, Lin, and Bodenheimer. In this context the issue of a diffusive separation of the two sizes has yet to be addressed. Such a process may help in the production of sharp circular edges.

Borderies *et al.* close their discussion