Class. Q. Grav. 12 9, 2361 (1995)

Gravitation and Spacetime
H C Ohanian and R Ruffini
New York: W W Norton 1994
600 pp price £38.00
ISBN 0-393-96501-5

This is an updated and extended edition of the book under the same title by H Ohanian, published in 1976. It is meant to be a textbook on relativity for beginners. Since several such textbooks have already been published, it is natural to ask: what does this book say that the others did not? The answer is: quite a bit, although one point may be controversial, and several subjects are just ignored.

This is a rather personal presentation of relativity. As the authors say themselves in the introduction: 'It is the objective of this book to develop gravitational theory in the most logical and straightforward way—in the way it probably would have developed without Einstein's intervention'. Accordingly, the authors introduce the linear approximation *first*, then they discuss the experimental tests and the gravitational radiation, and only then derive the full theory in their own way.

The book does have advantages. Perhaps the strongest of them is the discussion of those aspects of the Newtonian theory that are relevant for relativity. It includes an extended description of experimental tests. Particularly impressive is the detailed, but simple and clear description of tidal forces.

Somewhat less satisfactory is the presentation of special relativity. The theory is introduced as revealed truth, without any argument why its spacetime has the Minkowski geometry, and also some formulae are presented without derivation. The geometrical interpretation of the Lorentz transformations is not introduced at all, and the formula $E = mc^2$ is not even mentioned.

Next come three chapters on the linear approximation. The authors guess the form of the linearized field equations by formal arguments of field theory. Perhaps this is 'most logical', but this route bypasses all the beautiful insights of the original Einstein approach. The observable consequences of relativity are introduced at this stage (except for the perihelion advance which requires knowledge of the full theory). For the gravitational re-shift + time-delay of light signals, bending of light rays, gravitational lenses and for the consequences of rotation of the source the authors give an extended overview of results (actual and planned) from experiments and astronomical observations. The present burst of activity in the field of research on gravitational lenses is appropriately reflected in the book, and gravitational lenses are described in more detail than is usually done, both from the theoretical and the observational point of view.

The chapter on gravitational radiation is another of the stronger points of the book. The linearized theory of gravitational waves is introduced with good care for clarity and simplicity, and the experimental/observational search for gravitational radiation is described at length.

The chapter on Riemannian geometry is the least original and occasionally nonchalant. For example, it is rather improbable that any student would understand on first reading how the affine parameter in the geodesic equation is singled out from among all the possible parameters at the pre-metric level (pp 317–8). No mention is made about groups of symmetries, and no workable method is shown for finding the symmetry transformations once the Killing vectors are already known. The authors try to make up for the not-quite-perfect mathematical precision by appealing to intuition, but this is not everybody's favourite style.

As already mentioned, the derivation of Einstein's theory if far from conventional, but it will probably satisfy particle physicists trying to explain relativity in their own way. The rest of the chapter on Einstein's theory is in large part disappointing. It ignores the historical development of ideas, and in this way prevents students from understanding how the cosmological constant first appeared. Hilbert is mentioned as a co-discoverer of Einstein's equations, but his derivation of the equations from the variational principle, presented in the Appendix A.4, goes without credit to him. Scattered remarks imply that exact solutions of Einstein's equations, apart from the four described in the book, (Schwarzschild, Kerr, Reissner–Nordstrom and Friedmann-Lemaitre) are either very difficult to find or physically meaningless. It was customary to imply this still 20 years ago, today it is simply an incorrect statement! The derivation of the spherically symmetric fields repeats the decades-old error that the so-called standard coordinates (in which the metric of the t = const, r = const surfaces is $ds_2^2 = r^2(d\vartheta^2 + \sin^2\vartheta d\varphi^2)$) always exist. A trusting reader will then be very surprised to learn about the Kantowski–Sachs models and the Nariai vacuum solution (neither is mentioned in the book), and will be puzzled by the form of the Schwarzschild solution extended into the interior of the event horizon. The discussion of geodetic precession and of the experiment prepared to detect it is, however, very instructive.

The chapter on black holes and gravitational collapse contains clear descriptions of the Schwarzschild, Reissner–Nordstrom and Kerr solutions, and of their maximal extensions. This part of the book can be useful in any course on relativity. The Penrose energy-extraction process, Hawking radiation, ways to create black holes in the process of stellar collapse and the search for black holes in the observed Universe are all discussed.

The last two chapters, on cosmology and the early Universe, are up-to-date from the astrophysical point of view, but the relativity in them does not go beyond the knowledge of 30 years ago. The Robertson–Walker geometries are derived with a liberal attitude to precision of reasoning, and only their very basic properties are described. The need and possibility of generalizations or the problem of averaging the Einstein equations are not mentioned. Non-trivial topologies are dismissed as unnatural. The name 'Friedmann models' is given to the RW models with zero pressure and zero cosmological constant, and the name 'Lemaitre models' to those with zero pressure and non-zero cosmological constant; in a footnote the authors say: 'the terminology adopted here is as good as any' (p 553). Unfortunately, this terminology contradicts history: Friedmann considered models with non-zero cosmological constant, and did it in detail, by a method of which section 9.9 in the book is a simplification. Likewise, it is in contradiction to historical facts to reserve the name 'de Sitter model' only to the case with flat space sections. The three solutions with $A > 0$ that go under the name 'empty Lemaitre models' in the book are just three different coordinate representations of the same spacetime, first considered by de Sitter. The Hubble law holds in the Robertson–Walker models exactly, the derivation in the book suggests that it holds only approximately.

Two general advantages of the book should be noted. First, it contains a large number of problems for the reader, some of them ingenious; a few were an irresistible temptation for this reviewer. Second, each chapter contains an extended list of books for further reading, with short comments on their contents.

The greatest disadvantage are the topics that are not elaborated at all. Here is a sample list: 1. Conformal curvature and the Petrov classification. 2. The Einstein–Maxwell equations. 3. The singularity theorems (mentioned in just one phrase on p 496). 4. The conformal images of infinity and the Penrose diagrams. 5. Spatially homogeneous models and the Bianchi classification. 6. Exact solutions, apart from the four most basic ones (see above); in particular the reader learns nothing about the stationary-axisymmetric solutions and generating methods or about inhomogeneous cosmological models. 7. The initial value problem and the ADM formalism. 8. Global properties of spacetimes, e.g. singularities and geodesic completeness, global hyperbolicity. 9. Relativistic hydrodynamics and thermodynamics + evolution equations for kinematical tensors.

In defence of the authors one might say that they have concentrated on testable results, while the list above is pure theory. However, no matter how much we regret it, relativity is still much more of a theoretical than an experimental science, and any basic textbook should reflect this.

In summary, because of the omissions the book is not quite suitable as a basis for a full relativity course. It could be recommended as a basis for a part of a course, but with some hesitation—the nonchalant attitude of the authors to mathematics and history might induce undesirable habits in the students. However, the good coverage of experimental tests and relationships to field theory, the collection of problems, and the lists for further reading make the book itself a valuable 'further reading'. For this reason, this reviewer will happily keep his copy in his home library.

A Krasiński