

Preface to the Second Edition

The second edition of this book closely follows the spirit of the first edition, keeping all its main features. It is a book primarily intended for graduate/advanced undergraduate students with a theoretical high-energy physics or astrophysics curriculum, but it is also accessible to students with different interests. It provides the reader with all information about gravitational theory that every graduate in physics nowadays should possess: starting from the basic notions of general relativity, the classical theory of gravity is developed up to include advanced topics such as the supersymmetric and higher-dimensional extension of the Einstein equations.

Since the appearance of the first edition, however, many important events in physics have occurred. The LHC experiment has produced more and more precision data confirming the discovery of the Higgs boson and may be pointing at some new, unexpected result such as the recently observed 750 GeV diphoton excess (December 2015, to be confirmed). In the field of cosmology and quantum gravity, there was the announcement (later confuted!) of the BICEP2 experiment (March 2014) about the polarization of the cosmic microwave radiation, possibly produced by primordial gravitons of inflationary origin. But, above all, we should recall the direct detection of gravitational waves from merging black holes reported by the LIGO Observatory on 11 February and 15 June 2016.

All these exciting news, together with the need of revising and improving various points of the original book, have stimulated the preparation of this second edition which differs from the first one for the addition of topics of strong current interest.

We have expanded, in particular, the Appendix B, in order to provide more details on the Dirichlet branes and their important gravitational application, the higher-dimensional “brane-world” scenario. We have added a new section to Chap. 10 for a deeper discussion of time dilatation effects in the presence of a static gravitational field, and their possible impact on the so-called twin paradox. We should mention, finally, the new sections of Chap. 9 introducing the study of the relic background of cosmic gravitational waves and discussing its possible detection, either directly (through interferometric antennas) or indirectly (through the

polarization of the cosmic electromagnetic radiation). We have also added throughout the book six new original figures.

I believe that this new edition provides a more complete reference textbook, better suited to the needs of students following modern academic plans to graduate in physics. Let me thank again Marina Forlizzi and Barbara Amorese for their continuous and excellent support during the preparation of this book and all stages of the publishing process.

Finally, I wish to thank in advance all those readers (students or not) who will report me about errors, inaccuracies and important omissions found in this book (as well as those readers wishing to present their personal comments/criticism). They can send an e-mail to gasperini@ba.infn.it, and they are welcomed for their useful collaboration.

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Preface to the First Edition

This book grew out of lectures given by the author at the University of Turin and at the University of Bari. It is primarily intended for undergraduate students taking classes in gravitational theory, as prescribed by modern academic plans to graduate in physics with a theoretical/high-energy physics or astrophysics curriculum. The challenge is to provide students with a textbook which, on one hand, can represent a self-contained reference for a semester cycle of lectures and, on the other hand, may be accessible and of profitable use also for students having different interests and following different academic tracks.

To this aim, the book includes a first, conventional, part introducing general relativity as a geometric theory of the macroscopic gravitational field, and a second, more advanced, part connecting general relativity to the gauge theories of fundamental interactions. A discussion of the deep analogies (and of the physical differences) existing between gravity and the other standard model interactions fills a gap which is present within the traditional geometric approach to general relativity, and which usually puzzles students about the role of gravity in the context of a unified model of all interactions.

In this spirit, the formalism of differential geometry has been reduced to the necessary minimum, leaving more room to current interesting aspects of gravitational physics of both applicative/observational type (such as the phenomenology of gravitational waves) and theoretical/fundamental type (such as the gravitational interactions of spinors, supergravity and higher-dimensional gravity). We have included, however, a final appendix introducing the so-called Cartan calculus of exterior (or differential) forms, in view of the important applications of this formalism not only to the gravitational theory but also to many other fields of theoretical physics. A second appendix introduces various possible approaches to the problem of embedding a four-dimensional theory of gravity in the context of a higher-dimensional space-time manifold.

For most profitable use of this book, the reader is expected to have a basic knowledge of special relativity, electromagnetic theory and classical theory of fields. Except for the above input, however, the book aims at being self-contained as much as possible, following the informal style of class lectures where all the

required notions and techniques are explicitly recalled and/or introduced whenever necessary. Also, for a better pedagogic efficiency, all computations are explicitly carried out in the main text (leaving no “voids” to be filled by the readers) or presented as solved exercises at the end of each chapter.

The present book is certainly not intended to represent a complete reference for a rigorous and comprehensive study of all theoretical aspects of the gravitational interaction. Its main purpose is to provide students with the basic starting notions, enabling them to do further independent work and subsequent deeper studies on more professional textbooks and papers. The readers interested in advanced discussions of some specific topic are strongly advised to refer to the list of specialistic books presented in the bibliography.

Finally, it should be noted that this book deliberately avoids any gravitational application to cosmology and large-scale astrophysics, because—according to modern academic plans of studies—they are a matter of specific courses and lectures, well separated from a course on the theory gravity. The field of relativistic cosmology is today so extended, with so many branches and applications, as to deserve by itself a dedicated book. We refer, for this purpose, to the excellent books quoted in the bibliography, as well as to an introduction to theoretical cosmology which represents the natural continuation of this book and which currently exists as a Springer Italian edition.¹

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Finally, I wish to thank Marina Forlizzi, Executive Editor, Springer-Verlag, for her kind encouragement, advice and many useful suggestions.

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¹M. Gasperini, *Lezioni di Cosmologia Teorica* (Springer-Verlag, Milano, 2012).

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