

Preface

This book is an edited version of the review talks given in the Seventh Aegean Summer School on *Beyond Einstein's Theory of Gravity*, held in Parikia on Paros Island, Greece, from 23 to 28 September 2013. The aim is to present an advanced multiauthored textbook meeting the needs of both postgraduate students and young researchers, in the fields of gravity, relativity, cosmology and quantum field theory.

In the past few years gravity theories were proposed which can be considered as extensions of Einstein's theory of gravity. Their main motivation was to explain the latest cosmological and astrophysical data on dark energy and dark matter. Advances in string theory also motivated the study of gravity theories in higher dimensions and higher curvature. These theories introduced large scale modifications of General Relativity giving a plethora of new gravity theories based mainly on various forms of couplings of matter to gravity and to the introduction of high curvature terms in the gravity action. Also they renewed the interest of the community to the long standing problem if the graviton has a mass leading to a fast growing field of massive gravity. Higher spin fields were also motivated leading to the study of higher spin gravity theories. Finally, motivated by string theory, holography was applied to modified gravity theories in a hope to understand perplexed strong coupled phenomena using the gauge/gravity duality.

The selected contributions to this volume discuss the main ideas and models of modified gravity. The long standing problem of massive graviton is discussed in detail and the fast growing field of massive gravity is explored. Higher spin theories and their connection to gravity are discussed and also Chern–Simons theories are presented and their holographic perspective is explored. Finally, dynamical processes like scattering amplitudes in gravity are discussed. The aim of this volume is to introduce postgraduate students and young researchers to these very challenging topics which constitute modifications of Einstein's theory of gravity and recently have attracted much interest.

In the first part of the book modifications of General Relativity at large distances are discussed mainly due to various forms of matter coupled to gravity and to

the introduction of higher curvature terms. The first chapter by Thomas Sotiriou discusses gravity theories with non-minimally coupled scalar fields to demonstrate the challenges and future perspectives of considering alternatives to general relativity and reviews the generalized scalar-tensor theories. Next, the second chapter by Christos Charmousis reviews the recent progress in Lovelock and Horndeski theories, discusses how the Kaluza-Klein reduction of Lovelock theory can lead to scalar-tensor actions of the Horndeski type and presents black hole solutions of these theories. The third chapter by Christof Wetterich discusses the equivalence of models of modified gravity to couple quintessence and presents a modified gravity model by introducing a field dependent Planck mass, discussing also its cosmological implications. Finally the chapter by Shinji Tsujikawa introduces first an effective field theory of cosmological perturbations, applies it to Horndeski theories, and also it studies the equations of matter density perturbations based on Horndeski theory in connection to observations.

In the second part of the book the basic ideas and models of massive gravity are presented. In the first chapter by Claudia de Rham recent progress on massive gravity is reviewed. Special emphasis is paid to the ghost problem and its resolution and also drawbacks on superluminalities and strong coupling and their consequences are discussed. In the second chapter by Mikhail Volkov black hole solutions in ghost-free bigravity and massive gravity are presented. The next chapter by Eric Bergshoeff, Paul Townsend and collaborators introduces a wide class of three-dimensional gravity models which can be put into “Chern–Simons-like” form and then specializes these models to general massive gravity. Finally the last chapter in this part of the book is by Andrew Tolley in which an overview of cosmological solutions in extensions of massive gravity such as bi-gravity and quasi-dilaton massive gravity is presented.

The last part of the book deals with high spin theories, Chern–Simons theories and applications of holography to gravity theories. The first chapter is by Mikhail Vasiliev in which higher-spin gauge theory is introduced with the emphasis given on qualitative features of the higher-spin gauge theory and peculiarities of its space-time interpretation. The chapter by Ricardo Troncoso and collaborators reviews recent results in higher spin black holes in three-dimensional spacetimes, focusing for simplicity on the case of gravity nonminimally coupled to spin-3 fields, which nonperturbatively are described by a Chern–Simons theory. Next the chapter by Jorge Zanelli presents a review of the role of Chern–Simons forms in gravitation theories while the chapter by Daniel Grumiller and collaborators shows that Chern–Simons theories in three dimensions being topological field theories may have a holographic interpretation for suitable chosen gauge groups and boundary conditions on the fields. The last two chapters of the book deal with holographic aspects of gravity theories. The chapter by Marios Petropoulos discusses self-duality in Euclidean gravitational set ups which allows holographically to relate the boundary energy-momentum tensor and the boundary Cotton tensor and shows that this relation results from a topological mass term for gravity boundary dynamics. The chapter by Diana Vaman discusses stringy excitations of the graviton and using the AdS/CFT correspondence studies their dynamics.

The Seventh Aegean Summer School and the present book became possible with the kind support of many people and organizations. The Seventh Aegean Summer School was organized and supported by Paris-Sud (Orsay) University, University Francois Rabelais-Tours, Groningen University, and the National Technical University of Athens. It was sponsored by Paris-Sud (Orsay) University, University Francois Rabelais-Tours, Groningen University, National Technical University of Athens, Springer Lecture Notes in Physics, Municipality of Paros and Preservation Society of the Traditional Settlement of Parikia.

We specially thank the Municipality of Paros and the Preservation Society of the Traditional Settlement of Parikia for their kind hospitality in the island of Paros and their support. We also thank George Roussos for his valuable help in organizing the school in Paros. Without his endless help and support the organization of the Aegean School in Parikia would have been impossible. The administrative support of the Seventh Aegean Summer School was taken up with great care by Maria Kazadei and Katerina Papantonopoulou. We acknowledge the help of Vassilis Zamarias who designed and maintained the website of the School.

Last, but not least, we are grateful to the staff of Springer-Verlag, responsible for the Lecture Notes in Physics, whose abilities and help contributed greatly to the appearance of this book.

Athens, Greece
June 2014

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Modifications of Einstein's Theory of Gravity at Large
Distances

Papantonopoulos, E. (Ed.)

2015, XVI, 426 p. 20 illus., 14 illus. in color., Softcover

ISBN: 978-3-319-10069-2