

Preface

This book is an edited version of the review talks given in the Fourth Aegean School on Black Holes held in Mytilene on Lesbos Island, Greece, from 17 to 22 September 2007. The aim of this book is not to present another proceedings volume, but rather an advanced multiauthored textbook which meets the needs of both the postgraduate students and the young researchers in the fields of gravity, relativity, modern cosmology and astrophysics.

Black holes are the most mysterious and fascinating objects of our universe. They were predicted by the Einstein's theory of general relativity and their existence is the triumph of this theory. A possible detection of gravitational waves by the gravity experiments will give vital information on the nature and properties of black holes. On the other hand, the recent advances in string theory offered a new understanding of the classical and quantum properties of black holes. This book is a guided tour, by world experts, on the new developments in the physics of the black holes.

In the first part of the book, Samir Mathur discusses the information paradox of black holes. The information paradox connects quantum mechanics with gravity. As he says in his article "if quantum gravity effects are confined to within a given length scale and the vacuum is assumed to be unique, then there will be information loss". However, he goes one step further explaining how quantum effects in string theory resolve this problem.

Another important problem is discussed by Elizabeth Winstanley: do hairy black holes exist? She reviews the properties of hairy black holes in $SU(2)$ Einstein–Yang–Mills (EYM) theory in asymptotically anti-de Sitter space and she discusses recent work in which it is shown that stable hair also exists in $SU(N)$ EYM for arbitrary N . Next, the thermodynamics of black holes is discussed in Steven Carlip's article. He reviews what we currently know about black hole thermodynamics and statistical mechanics, which suggests a rather speculative "universal" characterization of the underlying states, and he describes some key open questions.

The first part of the book ends with the discussion of astrophysical black holes. In Ulrich Sperhake's article the basic techniques of numerical relativity and black holes simulations are presented, while Nikolaos Stergioulas describes the way black holes are formed through gravitational collapse of rotating stars. It is demonstrated, in the

case of rotating neutron stars which are unstable to quasi-radial oscillations, how a complete transition from one stationary solution of Einstein's equations to another occurs, including the formation of horizons and gravitational wave emission.

The second part of the book presents the new ideas in black hole physics coming from string theory and braneworlds. One of the basic ingredient of these theories is the existence of black holes in higher than four dimensions. Niels Obers reviews some of the recent progress in uncovering the phase structure of black hole solutions in higher-dimensional vacuum Einstein gravity. Ruth Gregory gives an overview of braneworlds and she discusses black holes on the brane, the obstructions to finding exact solutions and ways of tackling these difficulties. She describes also some known solutions and concludes with some open questions and controversies.

The next article by Christos Charmousis describes a higher-order gravity theory, the Lovelock theory, that generalizes in higher dimensions than four, general relativity. He discusses a generic staticity theorem, quite similar to Birkhoff's theorem in general relativity, which gives charged static black hole solutions. He also presents Lovelock exact black hole solutions in the context of braneworlds.

This part of the book also includes Sanjeev Seahra's article on a black string model of a braneworld black hole. He develops the perturbation formalism for Randall–Sundrum model and discusses the weak field limit of the model. He solves numerically the equations of motion for the gravitational waves in the black string background and discusses their behaviour. Finally, Panagiota Kanti in her article addresses the topic of the creation of small black holes during particle collisions in a ground-based accelerator, such as Large Hadron Collider at CERN, in the context of a higher-dimensional theory. She points out that the most important observable effect associated with their creation is likely to be the emission of Hawking radiation during their evaporation process.

The last part of the book deals with the very important issue of perturbations and stability of black holes in various dimensions. Hideo Kodama in his article explains the gauge-invariant formulation for perturbations of background spacetimes. He derives his famous master equations for a variety of important spacetimes such as static black holes, static black branes and rotating black holes in various dimensions. As applications, he discusses the stability of static black holes in higher dimensions and flat black branes. The article by George Siopsis discusses the analytic calculation of quasi-normal modes of various types of perturbations of black holes in both asymptotically flat and anti-de Sitter spaces. He pays special attention to low-frequency modes in anti-de Sitter space because, as it is known, they may have experimental consequences for the quark-gluon plasma formed in heavy ion collisions.

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Lefteris Papantonopoulos

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