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Foreword

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Black holes were predicted long before the beginning of the space age; they were perceived as by-products of mathematical theories, existed only in the imagination of a few scientists. The idea of "dark stars" (they were dubbed "black holes" only in 1968) can be traced back to the late 18th century, when John Michell (English philosopher and geologist) and some years later to Pierre-Simon Laplace (French mathematician and astronomer) speculated that, if a planet or a star were dense enough, their escape velocity would equal the speed of light. Light particles (photons) leaving the surface of such a world, would rise, stop, and then fall back down like projectiles do. This "Newtonian" view of black holes, while conceptually interesting, is not an adequate description of what happens to light near a massive dense body.

By the end of the 19th century strong evidence had been found that the speed of light is a universal constant, which remains the same in any reference frame. By exploiting the constancy of the speed of light and the principle of relativity (stating that the laws of physics should remain the same in any *inertial* reference frame) in application to Maxwell's equations of electromagnetism, Albert Einstein developed in 1905 a new theory (the Theory of Special Relativity) that led to a deep revision of the concepts of space and time: contrary to simple intuition, space and time intervals do not remain unchanged for observers in motion with respect to one another.

After a decade of attempts, Einstein succeeded in formulating a theory gravity (and electromagnetism) obeying the general principle of Relativity, i.e. that physical laws are the same in *all* reference frames (inertial or non-inertial). Einstein's basic concept was to drop Newton's idea of a force (the gravitational force) that is responsible for the attraction of masses. In place of that he was guided by of what he defined the "happiest thought of his life": that the effects of gravity are cancelled in a body that accelerates because it falls

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freely, no matter what the body is. Stated differently, acceleration can mimic gravity and, vice-versa, gravity can mimic acceleration: that is the "Equivalence principle". By using the mathematical instrument of differential geometry, Einstein formulated a new theory, the Theory of General Relativity, in which gravitation and motion of both matter and light result from the geometric properties of space-time (rather than Newton's attraction force). In turn the geometry of space-time, the matter and light in particular, determine its varying curvature.

Some solutions of Einstein's equations of General Relativity predict that a sufficiently compact mass will curve space-time such much that nothing, not even light, can escape from inside a critical surface, the so-called event horizon: that provided the modern foundation of the black hole concept. According to the so-called "No Hair Theorem" stationary black holes are completely characterized by only three observables: mass, angular momentum and electric charge (the latter being irrelevant in astrophysical black holes). All other information (for which "hair" is a metaphor) about the matter which formed the black hole (or fell into it after formation) is lost behind the event horizon, and remains permanently inaccessible to external observers.

Since the early seventies, a wealth of observational evidence has been found for the presence of black holes in the universe. While nothing can escape from the event horizon, the regions in its immediate surroundings (that is, say, tens of times the horizon radius) can become very luminous and launch jets at speeds close to the speed of light. This happens when matter flows towards the black hole and releases up $\sim$40 % of its rest mass energy in the process. This "accretion" energy, might be supplemented by the extraction of part of the black hole's rotational energy.

Stellar mass black holes (4–15 solar masses) in binary systems are being discovered in increasing numbers in the Milky Way and nearby galaxies. Super-massive black holes, from millions to billion solar masses, exist in the centre of most if not all galaxies; the radiation they release when they are active deeply influences the evolution of their hosts. Though relatively quiescent, the $\sim$4 million solar mass black hole in the centre of our Milky Way is one of the best studied and offers very good prospects for direct imaging of the "shadow" caused by light bending in the vicinity of the event horizon.

Black holes are ideal laboratories for studying both physical properties of accretion onto compact objects and probing the effects of General Relativity in the strong field regime. These extreme phenomena are inaccessible to laboratory experiments. Through observations at high energies (mainly in the X-rays) and multiwavelength programs spanning the widest range of the electromagnetic spectrum, from the radio to TeV energies), our knowledge of astrophysical black holes has advanced considerably over the last two decades. Diagnostics have emerged which can directly probe the dynamics of matter motion very close to the black hole, where the strong field general relativistic effects become important. At the same time, considerable progress has been made developing advanced models and understanding the physics of accretion onto compact objects. Yet, a number of key issues remain poorly understood. For instance the interpretation and decomposition of the energy spectra of accreting black holes are still much debated. Similarly, different competing models are being investigated which explain at least part of the variability properties of black.

This book is presents a collection of reviews of astrophysical black hole. The first section of the contains very valuable introductory material about the history of the first observed black hole. The second section describes the physical models for the accretion flow around black holes of all masses, where the third and fourth sections describe the accretion on black holes from stellar mass to supermassive and its fundamental parameters. The fifth section is devoted to the accretion-jet interplay, while the last section reports an overview and outlook of black hole research.

It is our honour to warmly compliment the conveners and organizers of the Workshop; they conducted the whole workshop with great enthusiasm and dedication. We thank all those who participated in the workshop it is them who made it successful. This excellent book represents also an important outcome of the workshop: congratulations to all.