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Preface

The first exact solution to the general relativity field equations that would be, much later, interpreted as a black hole was published by Karl Schwarzschild in 1916 (but communicated by letter to Einstein in December 1915). The subsequent decades witnessed considerable controversy on the interpretation of this solution and, in particular of the "Schwarzschild singularity" — the coordinate singularity corresponding to the black hole horizon in what are commonly called Schwarzchild coordinates, but, strictly speaking, that were actually introduced by Johannes Droste, a student of Hendrik Lorentz, in 1916. The interpretation of the Schwarzschild solution only settled down to the modern one with Martin Kruskal's paper published in 1960, discussing what is now known as the *maximal analytic extension* of the Schwarzschild solution, independently worked out by George Szekeres. The terminology *black hole* was subsequently coined by John Wheeler in 1967.

On top of the understanding of the Schwarzschild solution, the 1960s brought other remarkable developments that gave an enormous impetus to the black hole concept. In particular, in 1963, Roy Kerr presented his celebrated solution in the First Texas Symposium on *Relativistic Astrophysics*, on what is considered the dawn of this entirely new research field. That meeting was planned to address the most pressing issue in astrophysics at the time, namely the mechanism sourcing *quasars*, powerful energy sources known in the sky that had been discovered in the 1950s. Relativistic phenomena had to be involved and, as the dust settled, strongly accreting black holes became the most plausible explanation for such luminosities.

In parallel, other pieces of evidence for astrophysical black hole candidates, both of stellar mass as well as supermassive, started to pile up, from X-ray and radio observations. In time, it became the ruling paradigm that a large number of galaxies have supermassive black holes at their center, with masses ranging from 10^6–$10^{10}\,M_\odot$. In our own galaxy, the Milky Way, the radio source known as Sagittarius A* is thought to be a $\sim 4\times 10^6\,M_\odot$ black hole. Moreover, a few dozens of strong X-ray sources in the Milky Way are consensually accepted as stellar mass black holes, within the mass range $\sim 5-30\,M_\odot$, accreting from a companion star. Even though black hole mimickers, i.e. compact objects without a horizon, are not completely excluded by observations, there is by now a strong theoretical bias towards black holes.

And it so happens that the present time is no less exciting than the 1960s. Technologically impressive observational developments promise to give us unprecedented information about astrophysical black hole candidates. Gravitational wave detection by either ground-based observatories such as aLIGO or Pulsar Timing Array (PTA) techniques is more likely than ever to become a reality before the decade is over. The *Event Horizon Telescope* promises to resolve the horizon scale for Sagittarius A* and its counterpart in M87. Astrometric observations will have increased precision with a new generation of instruments, such as *Gravity*, that will attempt to identify new stellar orbits around and closer to the galactic center. X-ray observations of accretion disks may acquire enough precision to constrain metric properties around stellar mass black hole candidates. Overall, it is reasonable to expect that relativistic astrophysics, besides branching up to new fields such as gravitational wave astrophysics, will see unprecedented precision in the near future, hopefully of the necessary kind to test Einstein's gravity in the strong field regime.

No less important from a theorists' viewpoint, black holes — and in particular the Kerr metric — have been shown to have remarkable mathematical properties, such as uniqueness, under certain assumptions, within vacuum Einstein's gravity and hidden symmetries, that allow test particles motion to be Liouville integrable and gravitational (and other) perturbations to decouple and separate. To this beautiful mathematical properties of the most relevant black hole solutions to the *classical* theory of general relativity, the 1970s added the discovery of *quantum* and thermodynamical phenomena. These latter developments opened up yet another completely new research direction in black hole physics and unveiled the astonishing fact that they provide a unique arena for unifying all physics, as it is elegantly expressed by Stephen Hawking's temperature formula for a black hole, which contains the four fundamental constants of physics — Newton's, Planck's, Boltzmann's and the velocity of light.

Finally, surprising developments have dressed the black hole concept with yet more guises. Adding to the traditional interest by astrophysicists, cosmologists and mathematical physicists, recent years have seen increasing interest by particle physicists, fluid physicists or even condensed matter physicists, motivated by various analogies and dualities. How would Einstein react — he, who had so much reluctance in accepting the physical existence of the "Schwarzschild singularity"! — if told that black hole properties can be (have been?) mimicked in laboratory controlled experiments, using surprising analogies between black hole physics and fluid/condensed matter systems? Or that it became possible (convincing?) that information about the quark–gluon plasma can be extracted by colliding black holes, or creating a black hole by colliding shock waves, in asymptotically anti-de Sitter spacetimes? A measure of the grandness of his masterpiece, is that Einstein's general relativity has led to what are certainly unimaginable consequences to its creator.

Instrumental to some of these applications have been technical developments, mainly in the field of computational general relativity, which over the last decade underwent breakthroughs and a fast expansion, leading to impressive physical results and very cool animations! The latter are an example on how the field can play a captivating role in outreach. Indeed, the communication with the general public is, in our opinion, an important task of scientists, and, more than ever, black hole physics has a tremendous potential for increasing public awareness of science and for attracting youth into science in general.

Motivated by all of the above, in the Spring 2008 we have launched an idea to organize a meeting of the "Portuguese" community working in black hole physics. This idea was motivated by the increasing number of Portuguese researchers working in this topic, from different perspectives, as well as their increasing influence in the international development of this area. With the success of the first workshop, and realizing the potential of the format, the original idea of a single workshop was quickly replaced by a yearly meeting, always around Christmas, as to facilitate the participation of Portuguese researchers working abroad. These local meetings, moreover, have grown more and more international; but they still keep a relatively small size so as to allow a true interaction between all participants as well as an informal and friendly atmosphere.

The VIIth Black Holes Workshop took place in Aveiro, hosted by the Gr@v group, in 18–19 December 2014, at the doorstep of the centennial of general relativity. These proceedings are a celebration of the 100 years of the most elegant theory in physics and of one of its most dramatic consequences — black holes.

Carlos A. R. Herdeiro
Departamento de Física da Universidade de Aveiro and CIDMA,
Campus de Santiago, 3810-183 Aveiro, Portugal
herdeiro@ua.pt

Vitor Cardoso* and José P. S. Lemos†
CENTRA, Departamento de Física,
Instituto Superior Técnico, Universidade de Lisboa,
Avenida Rovisco Pais 1, 1049 Lisboa, Portugal
**vitor.cardoso@ist.utl.pt*
†*joselemos@tecnico.ulisboa.pt*

Filipe C. Mena
Centro de Matemática, Universidade do Minho,
4710-057 Braga, Portugal
fmena@math.uminho.pt

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