Probing Strong Gravity by Black Holes Across the Range of Masses

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STRONGGRAVITY
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SEVENTH FRAMEWORK PROGRAMME

Who are we?

The Consortium of more than 20 European researchers from 7 European institutes:

• **AsU – coordinator**
Astronomický ústav Akademie věd České republiky
Prague, Czech Republic

• **CNRS**
Centre National de la Recherche Scientifique
Observatoire Astronomique de Strasbourg
Strasbourg, France

• **UNIROMA3**
Università degli Studi Roma Tre
Dipartimento di Matematica e Fisica
Rome, Italy

• **UCAM**
University of Cambridge, Institute of Astronomy
Cambridge, United Kingdom

• **CSIC**
Agencia Estatal Consejo Superior de Investigaciones Científicas, Centro de Astrobiología, Madrid, Spain

• **UCO**
Universität zu Köln, I. Physikalisches Institut
Cologne, Germany

• **CAMK**
Centrum Astronomiczne im. M. Kopernika
Polska Akademia Nauk, Warsaw, Poland

What do we study?

- strong gravitation near the most bizarre mathematical objects predicted by Einstein's theory of Gravity
- Black Holes as real astrophysical objects inhabiting and shaping our Universe and their close environment
  - → supermassive Black Holes residing in centres of galaxies, often exhibiting the power of their own gravity violently in Active Galactic Nuclei
  - → the peaceful supermassive Black Hole in the centre of the Milky Way
  - → stellar-mass Black Holes, as the endpoints of stellar evolution, in the binary systems of our Galaxy

Why do we study it?

- to investigate the influence of Black Holes' strong gravity on their neighbourhood
- to measure the properties of the Black Holes studied – their mass and their spin (rotation)
- to trace the components in the vicinity of the Black Holes – their accretion discs, coronae, winds and jets – and determine their geometrical layout and their physical properties
- to understand radiation processes in places of strong gravity

How do we want to do that?

- by proposing new observations with current observational facilities
- by extensive use of the archival data available
- through the use of multi-wavelength observations
- by creating new analytical tools that we will make publicly available to the astronomical community

The story of Black Holes

History...

It was as early as at the end of the 18th century that two of the famous scientists of that age, the English natural philosopher and geologist John Michell and the French mathematician and astronomer Pierre Simon Laplace, speculated about the existence of the "dark" stars. They would have such large mass that their light would not be able to escape their gravitational field. However, it was more than 100 years later that these ideas were given more solid foundations. In 1916, Albert Einstein formulated his theory of Gravitation and Karl Schwarzschild found an elegant mathematical solution to Einstein's equations with very peculiar properties. It was a point in space with infinite density hidden behind the sphere, the so-called event horizon, from which no light could escape. This object was given the name of "Black Hole" by another prominant scientist John Wheeler in 1967.

Are they real?

In 1963, the first quasar, 3C273, was discovered by astronomers Schmidt and Oke. This object was really very strange, it looked like a star but it was not. It lay too far away, outside of our own Galaxy, and it was also too bright, to be a star. Eventually, the only reasonable explanation was that it was a nucleus of a galaxy that harboured a giant Black Hole with mass of a billion suns. Nowadays, we think that such a supermassive Black Hole lies in the centre of each galaxy. We were even able to weigh our own Black Hole in the centre of the Milky Way, its mass is four million times that of our Sun.

Later in 1972, Webster and Murdin have found a body around which a blue supergiant, a very hot, luminous and massive star, orbited. Although invisible in optical light, this object was found to be a very strong and massive X-ray source. It was discovered that this object has to be a Black Hole 15 times heavier than our Sun and that it is surrounded by an orbiting matter in the form of an accretion disc with such high temperature that it shines in X-rays. Currently there are more than twenty known binary systems in our Galaxy that have a stellar-mass Black Hole as one of their components.

How can we see them?

The basic property of Black Holes is that due to their strong gravity nothing can escape their event horizon. Everything below this sphere is attracted towards the central point, where the space singularity lies. There, all objects are unavoidably smashed and become part of the Black Hole itself. Thus Black Holes appear black and remind us of a hole where things are lost forever. However, often due to their strong gravity they attract matter that may either fall directly onto them or orbit around them in the form of a disc. Black Holes may even eject matter from their neighbourhood, probably due to complicated interactions between the Black Hole, the matter and the electromagnetic field originating in the plasma of the accretion disc. Thus they may create winds and jets. The whole environment around the Black Hole is very active, various processes are under way, lots of photons with different wave-lengths are produced and many of them may be detected by our telescopes. These photons carry the most valuable information about the physical process that they were created by, about the properties of the matter emitting them as well as about the strong gravitation and the properties of the Black Hole itself.

Why do we care?

Astrophysical Black Holes themselves are very simple objects, characterised by two quantities only – their mass and their spin (the measure of their rotation); their electric charge is expected to be small enough to be neglected in real situations. Thus to measure these properties means to know everything about the particular Black Hole. However, it may also have wider astrophysical and cosmological implications, e.g. the knowledge of the spin can tell us something about the evolution of the Black Holes. For stellar-mass Black Holes, as the endpoints of the life of massive stars, this will shed light on supernovae and hypernovae explosions. For the super-massive Black Holes at the centres of galaxies this will tell us whether they grew in mass via accretion of matter or by merging between galaxies. Observations of systems with Black Holes will help us to understand their nearest neighbourhood – what the connection between the disc, corona and jet is, how the winds and jets are launched, why the corona is so hot and how compact it is.