About this course

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Black holes in the classical and quantum world

This is a short course on black holes and some aspects of their interacti on with the classical and the quantum world. In the classical realm, we will see how they react when they are disturbed (eg by infalling particles or by the presence of classical fields), and how they settle down to quiescence following their formation in eg a merger. Afterwards we will discuss what happens when the black hole is surrounded by quantum fields (as it always is).

The focus will be on phenomena of "fundamental physics" (classical and quantum fields, with little of astrophysics) in the immediate surroundings of the black hole. Since our allotted time is of necessity too short, much of great interest will not be covered: for instance, I will not touch at all on any aspects of binary configurations and their inspirals, nor astrophysics of the medium around black holes such as accretion disks. Of fundamental physics, nothing more exotic than Hawking radiation will be discussed, the idea being that a good grasp of the widely accepted, conventional lore in these lectures is necessary for assessing current speculations that aim at revealing new physics -- even quantum gravity -- from observations of the black holes in our universe.

When designing this course I have had in mind a student who does not necessarily intend to become an expert on General Relativity nor black hole theory, but who is interested in understanding the elementary concept of a black hole and the physics behind some of its main effects. This student does not need to see the detailed computations, but wants to get the gist of what the experts who perform them are doing, and why.

I will assume that the student has already been exposed to a conventional introduction to GR -- with the basic tensor calculus for understanding what the Einstein's equations are, and with a glancing acquaintance with the Schwarzschild solution. No more advanced differential geometry will be assumed, nor knowledge of the full structure of the Schwarzschild solution, even less so of the Kerr solution. When discussing quantum phenomena, I will not assume any more than an elementary appreciation of what a quantum field is; correspondingly, the exposition will remain at an even more qualitative level than it was for the classical aspects.

- Lecture 1: The black hole as a tale of light and darkness
- Lecture 2: The black hole that vibrates
- Lecture 3: The black hole that spins
- Lecture 4: The black hole that evaporates

The write-ups of the lectures cover more than will be explained in class. In particular there are two supplements for Lecture 1 which I will not discuss; they are mostly pictorial and intuitive explanations of two central ideas in black hole theory: the event and apparent horizons, and the singularity theorem. They may be brought up in the tutorials.

The exercises are intended to go beyond the lectures at interesting points, guiding the student step by step and explaining the results. The student should not feel intimidated by their lengthy wording: they are often shorter and easier than they may look. They can also be discussed in the tutorials.