# Black Holes (L24)

**J. E. Santos**

A black hole is a region of spacetime that is causally disconnected from the rest of the Universe. These objects appear to be pervasive in Nature, and their properties have direct implications for the recent advances in gravitational wave astronomy. Besides being astrophysically relevant, black holes also play a fundamental role in quantum theory and are a natural arena to study and test any consistent quantum theory of gravity.

The following topics will be discussed:

1. Upper mass limit for relativistic stars. Schwarzschild black hole. Gravitational collapse.
2. The initial value problem, strong cosmic censorship.
3. Causal structure, null geodesic congruences, Penrose singularity theorem.
4. Penrose diagrams, asymptotic flatness, weak cosmic censorship.
5. Reissner-Nordström and Kerr black holes.
6. Energy, angular momentum and charge in curved spacetime.
7. Positivity of energy theorem.
8. The laws of black hole mechanics. The analogy with laws of thermodynamics.
9. Quantum field theory in curved spacetime. The Hawking effect and its implications.

### Pre-requisites

Familiarity with the Michaelmas term courses *General Relativity* and *Quantum Field Theory* is essential.

### Literature

1. H. S. Reall, *Part 3 Black Holes: lecture notes* available at www.damtp.cam.ac.uk/user/hsr1000
2. R. M. Wald, *General relativity*, University of Chicago Press, 1984.
3. S. W. Hawking and G.F.R. Ellis, *The large scale structure of space-time*, Cambridge University Press, 1973.
4. V. P. Frolov and I.D. Novikov, *Black holes physics*, Kluwer, 1998.
5. N. D. Birrell and P.C.W. Davies, *Quantum fields in curved space*, Cambridge University Press, 1982.
6. R. M. Wald, *Quantum field theory in curved spacetime and black hole thermodynamics*, University of Chicago Press, 1994.

### Additional support

Four examples sheets will be distributed during the course. Four examples classes will be held to discuss these. A revision class will be held in the Easter term.