The Theory of Black Holes

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Course Syllabus for the 2016 CRAQ Summer School on Compact Objects

1. A primer in General Relativity

a) Motivation for a theory beyond Newtonian gravity
b) The equivalence principle
c) Special relativity, Lorentz transformations and spacetime diagrams
d) Gravity as spacetime curvature
e) Describing curved spacetimes with differential geometry, 4-vectors and tensors
f) Motion along geodesics
g) Observations and measurements as co-ordinate transformations of 4-vectors
h) The Einstein field equations

2. Black holes in General Relativity

a) The Schwarzschild metric
b) Gravitational redshift
c) Radial and circular motion
d) Stability of orbits
e) Gravitational lensing
f) Event horizons
g) Spinning black holes and the Kerr metric

3. Accretion physics

a) Classical Shakura & Sunyaev accretion disks, dynamics and observed thermal emission
b) Accretion efficiency
c) Radiatively inefficient accretion flows

4. Theoretical modelling of black hole accretion

a) Introduction to ideal magnetohydrodynamics
b) Magnetic pressure and MHD waves
c) Magnetic flux freezing, viscosity and reconnection
d) Producing X-ray continuum emission in a Comptonizing corona
e) The principles of general relativistic magnetohydrodynamics (GRMHD)

5. Jets

a) Extracting energy from black holes through the Penrose process
b) The Blandford-Znajek mechanism

6. Observations of black holes and bridging the gap between theory & observations

a) X-ray reflection from black holes accretion discs
b) Relativistic blurring of X-ray emission lines
c) General relativistic ray tracing simulatiuons
d) X-ray timing and reverberation from accretion discs
e) Measuring the structure of the corona