

ICTP DIPLOMA PROGRAMME IN HIGH ENERGY, COSMOLOGY AND ASTROPARTICLE PHYSICS 2015-2016

SYLLABUS

General Relativity - {30 Lectures = 45 hours} P. Creminelli

Part I: Towards the Einstein equations

1. Review of special relativity

Vectors and tensors in Minkowski. The energy-momentum tensor.

2. The equivalence principle

Statement and motivation for a geometrical perspective. Gravitational redshift.

3. Differentiable manifolds

Definition. Vectors and tensors on manifolds. The metric.

4. Covariant derivative

Covariant derivative and Christoffel's symbols. Metric compatibility. Geodesic equation.

5. Curvature

Riemann tensor and its properties. Bianchi identities.

6. Einstein equations

Principle of general covariance. Newtonian limit. Einstein equations.

Part II: Selected Applications of General Relativity

7. The Schwarzschild Metric

Derivation. Study of singular places. Geodesics in Schwarzschild: gravitational redshift, precession of orbits and light deflection. Physics inside the horizon: Kruskal-Szekeres coordinates.

8. Isometries

Isometries, Killing fields. Geodesic deviation equation.

9. Gravitational waves

Wave equation: spin 2. Production of GWs. Energy and momentum tensor in GR.

10. GR as field theory

Einstein-Hilbert action. Matter stress-energy tensor. Weinberg's theorem on massless spin 2- particles.

Part III: Basics of Cosmology

11. FRW metric

Isotropic and homogeneous cosmology. Friedmann equations. Various phases of the Universe and cosmological constant. Hubble law. Luminosity distance.

Equilibrium thermodynamics

Fermi and Bose statistics. Thermodynamical quantities. Entropy conservation. Neutrino decoupling.

Beyond equilibrium

Boltzmann equations. Dark Matter decoupling and WIMP miracle. Nucleosynthesis. Recombination