SYLLABUS HEP-GR

Academic year 2014-2015

GENERAL RELATIVITY

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 Schwartzschild: 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.

12. Equilibrium thermodynamics

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

13. Beyond equilibrium

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