SYLLABUS FOR GRAVITATION

The weakest of all the fundamental forces, gravity has fascinated scientists throughout the ages. The great conceptual leap of Einstein in his ‘General Theory of Relativity’ was to realize that mass and energy curve the space in which they exist. In the first part of the course we will develop the necessary mathematics to study a curved manifold and relate the geometrical concept of curvature to the energy momentum tensor. In second part of the course we solve he Einstein equations in a number of simple situations relevant to the solar system, black holes, and a homogeneous and isotropic universe.

1. Preliminaries (2 lectures)

Cartesian Tensors; Variational Calculus; Newtonian mechanics and gravity; Review of Special Relativity; Einstein’s lift experiment; Einstein’s vision of General Relativity.

2. Manifolds, metrics and tensors (4 lectures)

Manifolds, curves, surfaces; Tangent vectors; Coordinate transformations; Metric and line element; Vectors, co-vectors and tensors; Conformal metrics

3. Connection and tensor calculus (4 lectures)

Covariant differentiation and Torsion; Affine Geodesics; Metric Geodesics and the Metric Connection; Locally Interial Coordinates; Isometries and Killing’s Equation; Computing Christoffel symbols and Geodesics.

4. Curvature (2 lectures)

Riemann Tensor; Ricci Tensor and Scalar; Symmetries of the Riemann tensor and the Bianchi identities; Round trips by parallel transport; Geodesic deviation.

5. Einstein equations (3 lectures)

Energy-momentum tensor; Einstein tensor and the Einstein Equations; Newtonian limit; Gravitational radiation.

6. Schwarzschild Solution (5 lectures)

Spherically symmetric vacuum solution; Birkhoff’s theorem; Dynamics in the Schwarzschild solution; Gravitational Redshift; Light deflection; Perihelion precession; Black holes.

7. FRW universe (4 lectures)

Expansion, isotropy and homogeneity; FRW metricl; Friedmann and Raychauduri equations; Solutions in radiation and matter eras; Cosmological constant; Cosmological redshift; Cosmological distance measures; Flatness and horizon puzzles.