ADVANCED GENERAL RELATIVITY

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Outline for an online course organised by ICTS, Bengaluru,

March 20 – April 30, 2023.

The goal of this course is to provide a brief, but hopefully precise, overview of topics relevant to current research on General Relativity. The course will focus exclusively on classical aspects of gravity.

List of topics:

Brief review of basic General Relativity and relevant mathematics. [1]

Geometry and topology of spacetimes: causality, Cauchy hypersurfaces, globally hyperbolic space-times. [3]

Geodesics, focusing and Raychaudhuri equation, Hawking's singularity theorem. [2]

Null geodesics, focusing, trapped surfaces. [2]

Black holes: brief review, cosmic censorship, Penrose singularity theorem, Hawking's area theorem. [3]

Origins of black hole thermodynamics. [1]

Total: 10-12 lectures of 90 minutes each. [ ] = tentative number of lectures assigned to each topic. The topics may evolve slightly as the course progresses.

Pre-requisites: The course should be accessible to anyone who has had a one-semester course on basic General Relativity as well as some exposure to basic Topology and Differential Geometry. In GR, familiarity will be assumed with space-time metrics, general coordinate invariance, Riemann curvature, Einstein equations, Einstein-Hilbert action, isometries, geodesics and some classical solutions. In TDG, familiarity will be assumed with topological spaces, separability, connectedness, compactness, homotopy, differentiable manifolds.

References for the course:

Edward Witten, "Light Rays, Singularities and All That", arXiv:1901.03928.

Robert Wald, "General Relativity" (textbook).

Hawking and Ellis, "The Large Scale Structure of Spacetime"

References for the pre-requisites:

(i) Basic General Relativity:

- James Hartle, "Gravity – An Introduction to Einstein's General Relativity"
- Sean Carroll, "Spacetime and Geometry: An Introduction to General Relativity", Chapters 1—4.
- Steven Weinberg, "Gravitation and Cosmology". Chapters 1—7, 12, 13.
- Sunil Mukhi, "Classical General Relativity" (22 video lectures), https://youtu.be/f7LdeEKzIwY

(ii) Topology and Differential Geometry:

- Sunil Mukhi and N. Mukunda, “Lectures On Advanced Mathematical Methods For Physicists”, Chapters 1—4.
- Sunil Mukhi, “Topology and Differential Geometry for Physicists”, (11 video lectures) https://youtu.be/F_Ug6y54wJ4
- I.M. Singer and J.A. Thorpe, “Lecture Notes on Elementary Topology and Geometry”.