GRAVITATION

(2023-2024, IFT Madrid)

https://www.yashar-akrami.com/gravitation2023

Lectures: **Yashar Akrami (yashar.akrami@csic.es)**

Exercise sessions: **Matilda Delgado (matilda.delgado@uam.es)**

(Lectures: **30 hours**, Exercise sessions: **8 hours)**

We mainly follow:

Lecture Notes on General Relativity by Daniel Baumann

(We cover all sections except Section 7 on Cosmology.)

Additional Resources

- Sean M. Carroll, **Spacetime and Geometry: An Introduction to General Relativity**
- James Hartle, **Gravity: An Introduction to Einstein's General Relativity**
- Bernard Schutz, **A First Course in Relativity**
- Ray d'Inverno, **Introducing Einstein's Relativity: A Deeper Understanding**
- M. P. Hobson, G. P. Efstathiou, and A. N. Lasenby, **General Relativity: An Introduction for Physicists**
- Anthony Zee, **Einstein Gravity in a Nutshell**
- Robert M. Wald, **General Relativity**
- Steven Weinberg, **Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity**
- P. A.M. Dirac, **General Theory of Relativity**
- Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler, **Gravitation**
- Eric Poisson, Clifford M. Will, **Gravity: Newtonian, Post-Newtonian, Relativistic**
- Yvonne Choquey-Bruhat, **Introduction to General Relativity, Black Holes and Cosmology**

Outline

- **Elements of Special Relativity**
  - Lorentz Transformations
  - Spacetime and Four-Vectors
  - Relativistic Kinematics
  - Relativistic Dynamics
- **Gravity is Geometry**
  - What's Wrong With Newton?
  - The Equivalence Principle
  - Observational Consequences
  - Gravity as Curved Spacetime
- **Some Differential Geometry**
  - Manifolds and Coordinates
  - Functions, Curves and Vectors
  - Co-Vectors and Tensors
  - The Metric Tensor
  - Integration Over Manifolds
- **A First Look at Geodesics**
  - Action of a Point Particle
  - Geodesic Equation
  - Newtonian Limit
  - Geodesics on Schwarzschild
  - Precession of Mercury
  - Bending of Light
- **Spacetime Curvature**
  - Covariant Derivative
  - Parallel Transport and Geodesics
  - Symmetries and Killing Vectors
  - The Riemann Tensor
  - Geodesic Deviation
- **The Einstein Equations**
  - Einstein's Field Equations
  - Einstein-Hilbert Action
  - Including Matter
  - The Cosmological Constant
  - Some Vacuum Solutions
- **Black Holes**
  - Schwarzschild Black Holes
  - Charged Black Holes
  - Rotating Black Holes
- **Gravitational Waves**
  - Linearized Gravity
  - Wave Solutions
  - Creating Waves
  - September 14, 2015