PHYS 615 – 616: General Relativity and Its Applications
Fall and Spring Semester, 2024 – 2025
Professor: Anthony Mezzacappa, 206 South College, 4-2621, mezz@utk.edu
Class Times: TTh, 12:55 – 2:10
Class Location: Ayres 114

Course Syllabus

1. Foundational Principles of General Relativity
2. The Mathematics of Tensors on Manifolds (Introducing the Fundamental Mathematical Building Blocks of General Relativity)
    a. Open Sets
    b. Topology
    c. Maps (Into, Onto, Continuous)
    d. Homeomorphisms
    e. Manifolds
    f. Coordinates
    g. Charts
    h. Atlases
    i. Differentiable Manifolds
    j. Curves on Manifolds
    k. Functions on Manifolds
    l. Vectors on Manifolds
    m. Covectors on Manifolds
    n. Tensors on Manifolds
3. Riemannian Manifolds (Introducing the Metric Tensor)
4. Geodesics on Manifolds (Introducing the Covariant Derivative)
5. Local Inertial Frames, Free-Falling Frames
6. The Riemann Curvature Tensor (Introducing Curvature on Manifolds)
7. The Relative Acceleration of Geodesics on Curved Manifolds
8. The Bianchi Identities and the Einstein Tensor
9. The Einstein Field Equations
10. The Newtonian Limit
11. Spherically Symmetric Solution to the Einstein Field Equations: The General Case
12. The Interior Schwarzschild Solution (Introducing the Equations of General Relativistic Hydrostatic Equilibrium, The Spatial Geometry Visualized: Embeddings)
13. The Exterior Schwarzschild Solution
14. Killing Vectors
15. Gravitational Redshift in the Exterior Schwarzschild Spacetime
16. Orbits in the Exterior Schwarzschild Spacetime
    a. Orbits of a Test Mass
    b. Precession of the Perihelion of Mercury
    c. Light Ray Orbits
    d. Deflection of Light in the Exterior Schwarzschild Spacetime
    e. Gravitational Lensing
    f. Shapiro Time Delay
17. The Black Hole Lectures
    a. The Schwarzschild Black Hole in Schwarzschild Coordinates
    b. The Schwarzschild Black Hole in Eddington–Finkelstein Coordinates
    c. Geodetic Completeness: The Schwarzschild Black Hole in Kruskal–Szekeres Coordinates (Introducing White Holes and Wormholes)

    d. Linearized (Weak Field) General Relativity
    e. Exterior Metric of a Slowly Rotating Source
    f. Dragging of Inertial Frames
    g. Axisymmetric Spacetimes: Generalities
    h. Exterior Kerr (Black Hole) Spacetime
    i. Orbits in the Exterior Kerr Spacetime
18. Gravitational Waves
19. Cosmology
    a. Survey of the Universe
    b. Robertson–Walker Metric
    c. Friedmann Equations
    d. Critical Density, Curvature, Singularities, and Fate of the Universe
    e. Time Evolution of Robertson–Walker Spacetimes
    f. Need for a Theory of Initial Conditions
    g. Physics of Inflation
    h. Fluctuations in the Cosmic Microwave Background

Course Texts

My lectures will draw primarily from the following texts, especially the three highlighted:

1. **Cheng, *Relativity, Gravitation, and Cosmology***
2. D'Inverno and Vickers, *Introducing Einstein's Relativity*
3. **Hartle, *Gravity, An Introduction to Einstein's General Relativity***
4. Misner, Thorne, and Wheeler, *Gravitation*
5. **Schutz, *A First Course in General Relativity***
6. Shapiro and Teukolsky, *Black Holes, White Dwarfs, and Neutron Stars*
7. Frankel, *The Geometry of Physics*
8. Schutz, *Geometrical Methods of Mathematical Physics*

Office Hours: TTh, 4:00 – 5:00
Grades: Grades will be based on graded homework assignments.