PHYS 615 – 616: General Relativity and Its Applications
Fall and Spring Semester, 2023 – 2024
Professor: Anthony Mezzacappa, 206 South College, 4-2621, mezz@utk.edu
Class Times: TTh, 12:55 – 2:10
Class Location: Nielsen 608

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. Special Relativity in the Language of General Relativity (Tensors)
5. Geodesics on Manifolds (Introducing the Covariant Derivative)
6. Local Inertial Frames, Free-Falling Frames
7. The Riemann Curvature Tensor (Introducing Curvature on Manifolds)
8. The Relative Acceleration of Geodesics on Curved Manifolds
9. The Bianchi Identities and the Einstein Tensor
10. The Einstein Field Equations
11. The Newtonian Limit of the Geodesic Equation
12. The Metric of a Uniformly Accelerated Observer in Minkowski (Flat) Spacetime
13. Spherically Symmetric Solution to the Einstein Field Equations: The General Case
14. The Interior Schwarzschild Solution (Introducing the Equations of General Relativistic Hydrostatic Equilibrium, The Spatial Geometry Visualized: Embeddings)
15. The Exterior Schwarzschild Solution
16. Killing Vectors
17. Gravitational Redshift in the Exterior Schwarzschild Spacetime
18. 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. Shapiro Time Delay
19. Relativistic Stars
    a. Cold Equation of State below Neutron Drip
    b. White Dwarfs
    c. The Chandrasekhar Mass

    d. Cold Equation of State above Neutron Drip
    e. Neutron Stars
    f. The Maximum Mass of Neutron Stars
    g. General Relativistic Stability Analysis
20. 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)
21. Rotation
    a. Dragging of Inertial Frames
    b. The Exterior Kerr (Black Hole) Spacetime
    c. Orbits in the Exterior Kerr Spacetime
22. Gravitational Waves
23. Classical Cosmology
    a. Friedman–Robertson–Walker Spacetimes
    b. The Cosmological Constant
    c. The Flatness and Horizon Problems
24. Modern Cosmology
    a. Inflation
    b. Fluctuations in the Cosmic Microwave Background
    c. Dark Matter and Structure Formation
    d. Dark Energy and the Accelerating Universe
    e. The Fate of the Universe
    f. The Multiverse
25. The Origin of the Universe
    a. The Universe as a Vacuum Fluctuation
    b. The Ekpyrotic Universe
26. Tests of General Relativity
    a. Parameterized-Post-Newtonian (PPN) Framework
    b. Deflection of Light by the Sun
    c. Shapiro Time Delay
    d. Precession of Mercury's Perihelion

Course Texts

My lectures will draw primarily from the following texts:

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. Ryden, *Introduction to Cosmology*
8. Weinberg, *Cosmology*
9. Frankel, *The Geometry of Physics*
10. Schutz, *Geometrical Methods of Mathematical Physics*

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