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
Grader: TBD
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 Building Blocks of General Relativity)
3. Riemannian Manifolds (Introducing the Metric Tensor)
4. Calculus on Manifolds: Differentiation (Introducing the Lie and Covariant Derivatives)
5. Geodesics on Manifolds
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 (Tidal Forces as the Relative Acceleration of Geodesics)
11. Uniform Acceleration in Minkowski (Flat) Spacetime
12. Spherically Symmetric Solution to the Einstein Field Equations: The General Case
13. 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. The Kerr Black Hole
14. The Schwarzschild Interior Solution (The General Relativistic Equations of Hydrostatic Equilibrium
    a. The Tolman–Oppenheimer–Volkov Equation
15. Neutron Stars
16. The Newtonian Limit of the Equations of General Relativistic Stellar Hydrostatic Equilibrium
17. Stellar Evolution
18. White Dwarfs
19. Gravitational Waves
20. Classical Cosmology
    a. Friedman–Robertson–Walker Spacetimes
    b. The Cosmological Constant
    c. The Flatness and Horizon Problems
21. Modern Cosmology
    a. Inflation
    b. Fluctuations in the Cosmic Microwave Background
    c. Dark Matter and Structure Formation
    d. Dark Energy and the Accelerating Universe
22. The Origin of the Universe
    a. Quantum Cosmology
    b. The Hartle–Hawking Wavefunction of the Universe
    c. The Ekpyrotic Universe

## Course Texts

My lectures will draw primarily from the following texts:

1. Hartle, *Gravity, An Introduction to Einstein's General Relativity*
2. Cheng, *Relativity, Gravitation, and Cosmology*
3. Schutz, *A First Course in General Relativity*
4. D'Inverno and Vickers, *Introducing Einstein's Relativity*
5. Misner, Thorne, and Wheeler, *Gravitation*
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 Gravitational Physics*

## Office Hours

TTh, 4:00 – 5:00

## Grades

Grades will be based on: (1) graded homework assignments, (2) a midterm exam, and (3) a final exam. All three will be equally weighted. The midterm and final exams will be open-book, take-home exams. The grader will grade the homework assignments. I will grade the midterm and final exams.