Relativity and Cosmology (PHY/AST 342)

Prof. Sera Cremonini

Instructor's Coordinates:

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Office Hours: **by appointment only** (email me to schedule a meeting time)

Course Information:

PHY/AST 342, Spring 2018
Time: Tue, Thurs 9:20am-10:35 am
Location: Room 512, Lewis Lab (Physics)
Website: https://coursesite.lehigh.edu/

TA for the course: Anthony Hoover (arh314@lehigh.edu) Office hours: Tue, Thurs 2-3, room LL302.

Course Description

This course is an introduction to Einstein's theory of general relativity, and includes applications to early universe cosmology and the inflationary paradigm. The material is aimed at advanced undergraduate students and beginning graduate students. Special relativity will be reviewed in the first few lectures, to set the foundations for the remainder of the course. No prior knowledge of general relativity is expected.

Required Textbook

"Spacetime and Geometry" by Sean Carroll.

Additional references you might find useful and interesting (of various levels)

- "A first Course in General Relativity" by Bernard Schutz
- "General Relativity: An Introduction for Physicists" by A. Lasenby, G. P. Efstathiou and M. P. Hobson (comparable level to Carroll but more detailed)
- "Gravity" by James Hartle (comparable level to Carroll)
- "Gravitation and Cosmology" by Steven Weinberg (very clear but more advanced)
- "Einstein Gravity in a Nutshell" by A. Zee
- "General Relativity" by Robert M. Wald (advanced and very mathematical!)
- "Relativity: The Special and the General Theory" by A. Einstein
- "An Introduction to Modern Cosmology" by A. Liddle
- "The First Three Minutes: A Modern View Of The Origin Of The Universe" by Steven Weinberg
- "The Inflationary Universe" by Alan Guth
- Useful Websites and Online Lectures on early universe cosmology and inflation:
  - http://map.gsfc.nasa.gov/universe/
  - http://www.damtp.cam.ac.uk/user/db275/TEACHING/INFLATION/Lectures.pdf
  - http://arxiv.org/pdf/0907.5424v2.pdf
  - http://ned.ipac.caltech.edu/level5/Watson/Watson_contents.html

Course requirements and assessment criteria:

- **Homework** will be assigned on a weekly or by-weekly basis, depending on difficulty level.
- **Exams:** we will have **two in-class midterm exams**. There will **NOT be a final exam!**
- **Final Project:** learn to do general relativity calculations using Mathematica

The grades will be determined as follows:

- Homework 30%
- Two Midterm Exams, 25% each
- Final Project 20%
- Class participation will be taken into account for students on the border between two grades

Grading Scale

A = 88 – 100 B = 75 – 87 C = 60 – 74 D = 50 – 60

Initial competences:

Working knowledge of special relativity, classical mechanics and electromagnetism.

Course objective and final competences:

The students are expected to:

- Refine their knowledge of special relativity, and develop intuition for the main principles of general relativity
- Learn to manipulate curvature tensors and understand how they describe geometrical properties of spacetime
- Become familiar with the mathematical and physical structure of Einstein's equations and learn the basic analytical skills needed to solve them (for example, finding simple black hole solutions)
- Understand the main properties of black holes and the evolution of the early universe
- Learn to solve Einstein's equations using GR packages written for Mathematica

Accommodations for Students with Disabilities:

If you have a disability for which you are or may be requesting accommodations, please contact both your instructor and the Office of Academic Support Services, University Center C212 (610-758-4152) as early as possible in the semester. You must have documentation from the Academic Support Services office before accommodations can be granted.

The Principles of Our Equitable Community:

Lehigh University endorses The Principles of Our Equitable Community [http://www.lehigh.edu/~inprv/initiatives/PrinciplesEquity_Sheet_v2_032212.pdf]. We expect each member of this class to acknowledge and practice these Principles. Respect for each other and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.

Syllabus:

- The spacetime of special relativity
- Manifolds, coordinates and tensors
- Curvature and the gravitational field equations
- The Schwarzschild black hole geometry
- Additional spherically symmetric geometries
- Black hole thermodynamics and the Kerr black hole
- Linearized general relativity and gravitational waves
- The Friedmann–Robertson–Walker geometry and inflationary cosmology
- Dark energy and the cosmological constant problem
- General relativity on a computer
- If there is time: Quantum field theory in curved spacetime, the breakdown of general relativity, extra dimensions and quantum gravity