Relativity and Cosmology (PHY/AST 342)

Prof. Sera Cremonini

Instructor's Coordinates:

Office: Room 417, Physics Department
Phone: 8-3924
Email: cremonini@lehigh.edu
Office Hours: **by appointment only** (email me to schedule a meeting time)

Course Information:

PHY/AST 342, Spring 2022
Time: Tue, Thurs 9:20am-10:35 am
Location: Room 512, Lewis Lab (Physics)
Website: https://coursesite.lehigh.edu/

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 **one in-class midterm and a final exam**.

The grades will be determined as follows:

- Homework 40%
- Midterm Exam 30%
- Final Exam 30%
- 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

Accommodations for Students with Disabilities:

Lehigh University is committed to maintaining an equitable and inclusive community and welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact Disability Support Services (DSS), provide documentation, and participate in an interactive review process. If the documentation supports a request for reasonable accommodations, DSS will provide students with a Letter of Accommodations. Students who are approved for accommodations at Lehigh should share this letter and discuss their accommodations and learning needs with instructors as early in the semester as possible. For more information or to request services, please contact Disability Support Services in person in Williams Hall, Suite 301, via phone at 610-758-4152, via email at indss@lehigh.edu, or online at https://studentaffairs.lehigh.edu/disabilities.

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 (if there is time)