PHY 90

From Black Holes to Strings: The Early Universe and the Nature of Space-Time

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 90, Fall 2018
Time: Tue, Thurs 2:35am-3:50 pm
Location: Room 511, Lewis Lab (Physics)
Website: https://coursesite.lehigh.edu/

Course Description

In the early 20th century Einstein's theory of relativity drastically changed our understanding of gravity and the fabric of space-time. Despite its great successes, the theory of general relativity is incomplete. It does not take into account quantum mechanics and fails to describe fundamental properties of black holes and the very beginning of the universe. In this seminar we will explore the key developments in modern physics and the challenges of unifying all the fundamental forces. We will introduce the main ingredients of string theory, the most promising framework for a quantum description of gravity, and discuss its consequences for space-time at the smallest scales. As we will see, string theory has given us crucial insights into the structure of black holes and the early evolution of the universe. The format of the course will be discussion of weekly reading assignments, and a final paper.

Required Textbook

"The illustrated brief history of time" by Stephen Hawking.

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

- "The Hidden Reality" by Brian Greene
- "From Eternity to Here" by Sean Carroll
- "The First Three Minutes: A Modern View Of The Origin Of The Universe" by Steven Weinberg
- "The Inflationary Universe" by Alan Guth
- "Dark Matter and the Dinosaurs" by Lisa Randall

Course requirements and assessment criteria:

- **Weekly reading assignments and in-class discussions**.
- **Final Project:** paper (10-15 pages) on a topic of your choice, related to issues discussed in class.

The grades will be determined as follows:

- Class participation and discussions based on weekly reading assignments 50%
- Final Project 50%

Grading Scale

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

Syllabus:

- Space-time in special relativity
- Space-time curvature and general relativity
- The expanding universe
- The uncertainty principle and quantum mechanics
- Elementary particles and interactions in nature
- Black holes, singularities and Hawking radiation
- The evolution of the early universe
- The need for a theory of quantum gravity
- Strings, branes and extra dimensions
- Holography and its applications to strongly interacting quantum phases of matter

Initial competences:

No specific initial competences.

Course objective and final competences:

The students are expected to:

- Gain an appreciation for the major developments in particle physics, gravity and cosmology over the last century
- Learn the basic principles of special relativity, including concepts such as spacetime intervals, time dilation and length contraction.
- Develop intuition for the main principles of Einstein's theory of general relativity and properties of black holes, and an appreciation for the challenges of developing a theory of quantum gravity
- Learn to perform literature searches and discuss science topics with a general audience, by preparing oral presentations and writing research-style papers.

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, Williams Hall, Suite 301 (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.