PHYSICS 390 - GRAVITATION AND PHYSICAL COSMOLOGY – SPRING 2005
COURSE INFORMATION

Instructor: Victor DeCarlo
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Office Hours: 10:15-11:15 AM, MWF
9:00-11:00 AM, Th
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Required Texts: E. Taylor & J. Wheeler, *Exploring Black Holes* (Addison Wesley, 2000)
B. Ryden, *Introduction to Cosmology* (Addison Wesley, 2003)

About the course: This is, at its core, a course about gravity: its description as spacetime curvature in General Relativity, its effect on the motion of bodies, and its role in shaping the evolution of the universe. The first part of the course will be devoted to a discussion of General Relativity (Einstein's theory of gravity) and how the spacetime metric can be used to determine the trajectories of free-falling bodies and light rays, particularly in the vicinity of black holes. Part two of the course is an introduction to cosmology, with the focus on the past history and future evolution of the universe. Topics covered will include the Big Bang, inflation, dark matter, and the cosmic microwave background.

A word about mathematics: Full treatment of General Relativity involves the application of some hairy tensor mathematics in order to determine spacetime metrics. However, in this course we will bypass the steps leading to the metric and concentrate on learning how to use metrics to plot trajectories once the metric is given. This more limited objective requires only some basic calculus. If you can take derivatives and do some integrals, you're prepared to handle the mathematics used in the course.

Grading: Your final course grade will be determined according to the evaluation scheme outlined below:

Exam 1: 25%	Homework: 20%
Exam 2: 25%	Final Project: 30%

Once your cumulative percentage score has been calculated, letter grades will be assigned according to the following grading scale:

93-100 = A	90-92 = A-	87-89 = B+
83-86 = B	80-82 = B-	77-79 = C+
73-76 = C	70-72 = C-	67-69 = D+
63-66 = D	60-62 = D-	
00-59 = F		

The two exams will be given during the regular class period; see the class schedule below for approximate dates. You will be allowed to use an equation sheet for each exam, but otherwise you're on your own. Exams will consist of conceptual questions as well as numerical exercises.

Homework will be assigned and collected on a regular basis. Each problem collected will be graded on a 0-10 scale. I expect that submitted solutions will be neatly written and well-organized; deductions will be made for sloppy work. Whenever possible, you should follow the problem-solving framework you learned and practiced in introductory physics. <u>Late solutions will be accepted but given an automatic four-point deduction.</u>

Final Project: General Relativity and Cosmology are rich and diverse fields, and there's not nearly enough time in a one semester course to cover all the topics one might like. The Final Project for the course gives you an opportunity to research and report on some aspect of these fields that particularly interests you. The product of your project will take two forms: a 15-20 minute PowerPoint presentation to the class, and an 8-12 page formal paper. Presentations will be given during the last week of classes; the paper must be submitted no later than Thursday, May 19. More paper guidelines will be given to you later in the semester.

In addition, you will be expected to submit a one-page Preliminary Project Proposal (PPP) during the week after spring break. The PPP will summarize your project and give a short list of principal references. The earlier you submit the PPP the better, since project topics will be assigned on a first-come-first-served basis; no two students will do the same topic.

Below, I've listed some possible project topics but you are certainly encouraged to dig around the literature and suggest alternatives:

- High-Precision Tests of General Relativity
- The Global Positioning System: How GPS Depends on General Relativity
- The Thermodynamics of Black Holes (including Hawking radiation)
- The Spinning Black Hole
- Modeling the Power Spectrum of the CMB
- MOND: An Alternative to the Dark Matter Hypothesis
- The New Cyclic Universe Model
- Neutrino Oscillations: Implications for Cosmology
- Quintessence: A Possible Form of Dark Energy

CLASS SCHEDULE
(subject to revisions)

	Topic and Reading Assignment
Jan 31- Feb 4	**Review of SR and Introduction to GR** Thorne, "A Voyage to the Holes" EBH, Chapter 1
Feb 7 - 11	**The Schwarzschild Metric** EBH, Chapter 2
Feb 14 - 18	**Radial Plunge Toward a Black Hole** EBH, Chapter 3
Feb 21 - 25	**Orbits Near a Black Hole** EBH, Chapter 4
Feb 28 - Mar 4	**Light Paths in Curved Spacetime** EBH, Chapter 5
Mar 7 - 11	****Exam 1**** **Evidence of the Big Bang: Hubble's Law and The CMB** ITC, Secs. 2.3-2.5
Mar 14 - 18	**Curvature, The R-W Metric, and The Friedmann Equation** ITC, Secs. 3.2-3.4, 4.1-4.4
Mar 21 - 25	**Spring Break**
Mar 28 - Apr 1	****Preliminary Project Proposal Due**** **Model Universes I: Single-Component Universes** ITC, Chapter 5
Apr 4 - 8	**Model Universes II: Flat Multiple-Component Universes** ITC, Secs. 6.2, 6.4-6.5
Apr 11 - 15	**The Accelerating Universe** ITC, Chapter 7
Apr 18 - 22	****Exam 2**** **Dark Matter** ITC, Secs 8.1-8.2
Apr 25 - 29	**Big-Bang Nucleosynthesis** ITC, Secs. 10.1-10.4
May 2 - 6	**Inflation** ITC, Chapter 11
May 9 - 11	**Student Presentations**

Good Print Resources:

Kip Thorne, *Black Holes and Time Warps* (Norton, 1994)
A wonderful popular account of general relativity and black holes by one of the world's foremost experts on the subject.

James Hartle, *Gravity: An Introduction to Einstein's General Relativity* (Addison Wesley, 2003)
An excellent textbook on General Relativity at a mathematical level higher than *Exploring Black Holes*, but still accessible to undergraduates.

Peter Coles, *Cosmology: A Very Short Introduction* (Oxford Univ. Press, 2001)
In a mere 130 pages, Coles gives us a thorough and lucid discussion of what we know about the universe and also identifies the major unanswered questions in modern cosmology.

Edward Harrison, *Cosmology: The Science of the Universe, 2nd ed.* (Cambridge University Press, 2000)
The most comprehensive textbook on cosmology for the general college audience. Harrison's treatments of Olber's Paradox and cosmic horizons are particularly detailed.

John Hawley & Katherine Holcomb, *Foundations of Modern Cosmology* (Oxford University Press, 1999)
A fine, nonmathematical introduction to cosmology.

A Few World Wide Web Links:

Cosmology: A Research Briefing
http://www.nap.edu/readingroom/books/cosmology
A concise introduction to cosmology and current research problems prepared by the National Research Council.

Foundations of Modern Cosmology
http://www.astro.virginia.edu/~jh8h/Foundations/
Companion web site to the text of the same name. Rich source of information on many topics.

Sean Carroll
http://pancake.uchicago.edu/~carroll/
Sean Carroll is a cosmologist at University of Chicago. His web page includes technical papers, lecture notes, review articles, and even a blog.

Ned Wright's Cosmology Tutorial
http://www.astro.ucla.edu/~wright/cosmolog.htm
Extensive site containing lecture notes, a cosmology FAQ, and, yes, a comprehensive cosmology tutorial.

Wilkinson Microwave Anisotropy Probe
http://map.gsfc.nasa.gov
Site maintained by the WMAP group, whose experimental mission is to produce a detailed all-sky map of the CMB to high precision.

lanl.arXiv.org e-print archive
http://lanl.arxiv.org
A searchable archive of thousands of (mostly technical) papers and review articles on physics and astronomy from the present to 1991.

The Physics of Microwave Background Anisotropies
http://background.uchicago.edu/~whu/physics/physics.html
This part of physicist Wayne Hu's web site consists of tutorials on the CMB at three different levels, ranging from novice to advanced.

Cosmology With Supernovae
http://cfa-www.harvard.edu/cfa/oir/Research/supernova/HighZ.html
Web site maintained by the High-Z Supernova Search Team, one of the groups that has been using supernova data to measure changes in the Hubble parameter.

The Official String Theory Web Site
http://superstringtheory.com/index.html
Loads of material about strings, including the cosmological implications of string theory.