



PHYSICS 477/577/790

Northern Illinois University

Department of Physics

Faraday Hall FR 143 (?)

Tue & Thu, 12:30 – 13:45

Spring 2018

January 16, 2018 – May 11, 2018

COSMOLOGY

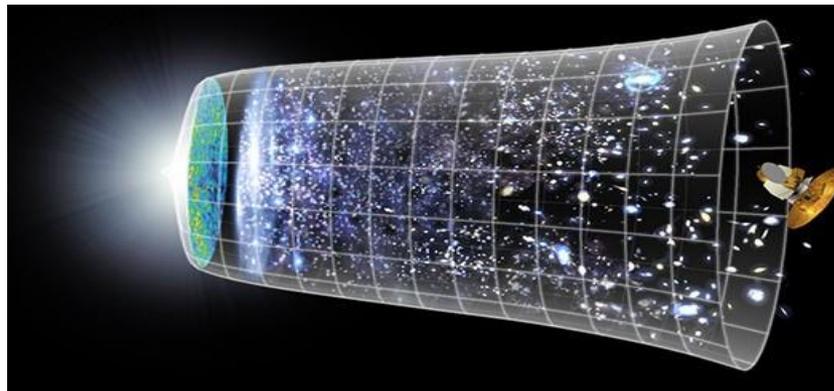
Space – Time – Energy – Acceleration -- Matter

Prof. Swapan Chattopadhyay

schaterji@niu.edu

La Tourette 230A

Office hours: Tue, Th: 13:45 – 14:45



PHYS 477/577/790 COSMOLOGY

This course in its current format is being taught for the first time and does not follow a single textbook. Much has changed in our understanding of the universe in last two decades. Even traditional experts are novices in some sense. Given above, the course pace and material will be adjusted with continuing student feedback.

The main purpose of the course is to bring an intelligent scientifically oriented person up to date, as well as introduce junior and senior undergraduate, master's level and aspiring PhD students to the fundamentals of what we know and more importantly, what we DO NOT know, about our universe today and various models to understand it. Our journey will offer us a brief exposure to the underlying mathematical formalisms as a bonus.

This is an advanced course not in the sense of complex mathematics (though underlying mathematical formalism is quite sophisticated), but in the sense of its stress being on fundamental physical concepts and advanced perspectives.

Homework, Exams and Grading

The homework will be tailored according to the level of the individual students enrolled. A poll will be taken on the first day of class to get feedback from each student on their preparation and study background in science in general, physics in particular and mathematical background, etc.

Beginning students will be expected to focus on concepts, ideas, models and simple numerical scale of physical parameters, with elementary mathematics (algebra, geometry and calculus) as needed. Advanced students will be given an introduction to the theoretical and simple mathematical formulation of space-time geometry and associated calculus.

Grade will be based on:

- 60 % on lecture and field trip attendance, classroom engagement and learning attitude; 20% on homework readings/essays/reports/problems as suitable for the student; 20% on final exam or essay.
- There will be a mid-term lecture/QUIZ session dedicated to RECAPITULATION and feedback from students and final RECAPITULATION and DISCUSSION at the end of the semester.

Course Material

I will instruct mostly via direct verbal interaction in class combined with prepared slide presentations. Occasionally, chalkboard will be used as needed for supplemental explanations. Complete lecture notes will be in the form of slides and there will be access to the slides by enrolled students, which will form the primary course material. But the slides will be posted only after the lecture has already taken place. No standard text book for the class, but only a few Reference books if interested, but not essential:

- **Seven Brief Lessons on Physics:** *Carlo Rovelli*, Penguin 2014
→ VERY LUCID and EASY READING. No MATHEMATICS.
- **The Inflationary Universe:** *Alan H. Guth*, Perseus Books, 1997
→ PERSONAL STORY TELLING STYLE.
- **Space-Time and Geometry:** *Sean Carroll*, Pearson, 2014
→ VERY ADVANCED at MATURED GRADUATE STUDENT LEVEL. Rigorous text-book.
- **The Nature of Space-Time:** *Steven Hawking & Roger Penrose*, Princeton, 1996
→ CONCEPTUAL, BUT REQUIRES ADVANCED MATHEMATICAL PREPARATION
- **The Road to Reality:** Roger Penrose, Vintage, 2004
→ PERSONAL MAGNUM OPUS, HYBRID OF CONCEPTS, THEORY AND MATHEMATICS

Course Content

(Planned at the beginning of start of class, subject to adjustment pending continuous student feedback)

- **Lecture 1, Jan 16:** *Discussion of Course Syllabus, content, sequence of lectures, instructor expectations on students, grading philosophy, general discussions and feedback from students.*
- **Lecture 2, Jan 18:** *SPACE –TIME: Big Picture: Our place in space-time: “Big Bang” and other Metaphors. Big questions: Is our universe infinite in size or finite? Is our universe infinitely old or does it have a beginning? Will our universe last forever? Are there other universes?*
- **Lecture 3, Jan 23:** *SPACE 1: Our place in space – how big is space? Sizes of and Distances to moon, sun, planets, stars, galaxies, outer space,....*
- **Lecture 4, Jan 25:** *SPACE 2: What is Space? Is it vacuum? Does it have any intrinsic shape, geometry or structure or topology? Is it flat, concave, convex or other complicated shape?*

Course Content (cont'd)

- Lecture 5, Jan 30: *Time 1: Our place in time -- history of time evolution of radiation, matter, galaxies, solar systems,....*
- Lecture 6, Feb 1: *Time 2: Does time have direction? What decides its flow forward? Does it exist by itself? Does it have structure? Is it continuous or granular? When did it begin? Will it ever end?*
- Lecture 7, Feb 6: *Geometry of Space-time 1: Cartesian linear space and linear time Minkowski Space-time – Einstein's Special Theory of Relativity*
- Lecture 8, Feb 8: *Geometry of Space-time 2: Distortion of space by gravity -- Curved space-time of Einstein's General Theory of Relativity: Riemann curvature*
- Lecture 9, Feb 13: *General Relativity, Gravitation and Space-time: Three fundamental equations: Einstein's Field Equation, Friedman's Equation of Evolution and Raychaudhuri-Newman-Penrose equation for Geodesics.*
- Lecture 10, Feb 15: *Space-time Quakes: Gravitational Waves*

Course Content (cont'd)

- **Lecture 11, Feb 20:** *Echoes of the scorching past: Cosmic Microwave Background Radiation*
- **Lecture 12, Feb 22:** *Detection and Probes of Cosmic Microwave Background Radiation – microwave antennae and satellites*
- **Lecture 13, Feb 27:** *Tremors from the “Big Bang”: Cosmic Gravitational Background Radiation*
- **Lecture 14, Mar 1:** *Detection and Probes of Cosmic Gravitational Background Radiation – Laser Interferometry (LIGO) and Atom Interferometry (AIGO)*
- **Lecture 15, Mar 6:** *Experimentally Observed Matter-Energy Content of the Universe: “Dark Matter” and “Dark” Energy -- Hint at the Ultimate Free Lunch --- A Funny Force that is Gravity!*
- **Lecture 16, Mar 8:** *Recapitulation of Space-time and Gravitation and Dedicated Mid-term Discussion Session/QUIZ*

Course Content (cont'd)

March 11-18 Spring Recess

- Lecture 17, March 20: *Guest lecturer (Fermilab) TBD*

March 22: Possible Field trip to Fermilab

- Lecture 18, March 27: *The Particle Physics Revolution of the 1970s and the Standard Model – Bosons as Force Carriers (photon, W, Z and Higgs) and Fermions as Constituents (quarks and leptons and neutrinos)*
- Lecture 19, March 29: *Experimental Searches of “Dark” Matter : particles and/or astrophysical/cosmological composite objects*
- Lecture 20, Apr 3: *“Dark” matter search (cont'd): Axions, primordial black-holes,...*
- Lecture 21, Apr 5: *Experimental and theoretical conjectures on “Dark” Energy*
- Lecture 22, Apr 10: *Merging of Particle Physics, Astrophysics and Cosmology*

Course Content (cont'd)

- Lecture 23, Apr 12: *Cosmological Models*
- Lecture 24, Apr 17: *The Inflationary Universe*
- Lecture 25, Apr 19: *Big-bounce and Big-crunch Universe*
- Lecture 26, Apr 24: *Fate of the Universe and Space-time*
- Lecture 27, Apr 26: *Are we humans significant or insignificant in Cosmology?*
- Lecture 28, May 1 : *Recap/Discussions*
- Lecture 29, May 3: *Recap/Discussions*

Week of May 4-11: Final Exam/Report/Wrap-up student feedback