# A425: Cosmology

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The Github repository for this course is at
https://github.com/connolly/A425_2015

## Class and Office hours

Class will be held Mondays and Wednesday in the Physics and Astronomy Auditorium (PAA A212) from 11.30am to 12.50pm.

Office hours are on a drop in basis and by appointment. My office is in the Physics and Astronomy building (B355). If the door is open feel free to drop in, or send me an email to arrange a time.

## Goals and Objectives

This is a self-contained course designed to introduce students to the basics of cosmology. The course has a significant mathematical content, principally geometry, algebra and calculus. The topics we will cover include: the cosmological principle, expansion of the universe, the Robertson-Walker metric, dynamics of an expanding universe, observational constraints on the expansion of the universe, the role of dark matter and dark energy, the cosmic microwave background, gravitational lensing, inflation, new probes of cosmology.

By the end of this class you should expect to be able to:

- Explain the physical principles that describe the expansion of the universe
- Calculate distance, volume and age of the universe as a function of redshift for a range of different cosmological models
- Measure the scales on which structures collapse due to gravity and how this depends on the nature of the dark matter.
- Characterize the observational probes of cosmology and how they can be used to measure the properties of dark matter and dark energy

## Text Book

There are a number of useful textbooks that you can draw information from. We will be using: "Introduction to Cosmology: Barbara Ryden (Pearson Addison-Wesley)

## Research opportunities

If you are interested in research there are many opportunities available in astronomy. The data professional astronomers take is usually public. If you are interested in finding asteroids, measuring the clustering of galaxies, searching through massive data sets of interacting with visual tools let me know and we will try to arrange something.

## Study Techniques

There are many ways to succeed in this class:

- Read the chapters in the book before the class (see the syllabus below)
- Take notes in class
- Do the homework as it will be a good practice for the exams
- Ask questions – in class, at office hours

## Exams and Homework

There will be two exams, one mid term and one final. Homework will be made available every two weeks and will be due back the following week. When working through the homework:

- Always show your workings in a problem (I want to be able to give partial credit and I need to understand how you are approaching a problem so I can help if you)
- Don't copy other students work for the homework but you can discuss problems with others
- Homework is meant to help you learn – I don't deduct points for asking me questions about the homework
- Exams and homework questions will be similar
- We will use Github and iPython notebooks to submit homework

The grade will be broken down as:

Mid term 25%, Final 50%, Homework 25%

Midterm will be on Wednesday Ocober 10$^{th}$ 2015

I don't give make-ups without a doctor's note or an earth-shattering event.

## Lecture Schedule

## (This is a guide and is not set in stone)

### Week 1

- **Introduction (Chapter 2)**: Review of astronomy needed for the course (magnitudes, luminosities, distances), Obler's paradox, galaxy number counts, redshift and Hubble's law, the Cosmological Principle
- **Robertson Walker (RW) Metric (Chapter 3):** equivalence principle in cosmology, curvature and measuring distance, volume and area as a function of redshift

### Week 2

- **Cosmological Dynamics – Friedmann equation (Chapter 4)**: Using General relativity, using Newtonian mechanics, equation of state of the universe
- **Cosmology Dynamics (Chapter 5)**: expansion rates for different cosmological models, curvature dominated, flat, radiation dominated, matter dominated, cosmological constant

### Week 3

- No Class
- **Standard cosmologies (Chapter 6)**: expressing a cosmological model in terms of: density, matter and the cosmological constant, matter, curvature and the cosmological constant, radiation and matter.

### Week 4

- **Measuring the universe (Chapter 7)**: Taylor expansion for the expansion rate and the q parameterization, using standard candles as a distance indicator, measuring $H_0$ and $q_0$, the age controversy, SNe and the distant universe, the (re)appearance of the cosmological constant, the state of the universe
- **Dark Matter (Chapter 8)**: Evidence for dark matter from galaxies, clusters of galaxies, and gravitational lenses, probes of dark matter and the case for modified gravity

### Week 5

- **Dark Matter (Chapter 8)**: Candidates for dark matter, WIMPS, MACHOS, neutrinos, searches for dark matter particles.
- Midterm

## Week 6

- **Cosmic Microwave Background (Chapter 9)**: Observations and detection of the CMB, recombination and decoupling, the physics of recombination
- **Cosmic Microwave Background (Chapter 9)**: Temperature fluctuations, the amplitude and scale of fluctuations, baryon acoustic oscillations as a standard ruler

## Week 7

- No class
- **Nucleosynthesis (Chapter 10)**: physics of neutrons and protons, the synthesis of deuterium, the formation of the light elements in the early universe

## Week 8

- **Inflation (Chapter 11)**: Problems in cosmology due to flatness, the horizon, the lack of monopoles, the physics of inflation
- **Formation of structure (Chapter 12)**: Gravitational instability, the Jeans length and Jeans mass, formation of structure, the power spectrum, hot and cold dark matter in structure formation.

## Week 9

- **Gravitational lensing**: the lens equation, strong lenses, weak lensing.
- **Gravitational lensing**: estimating mass using gravitational lenses, probing cosmology with lensing and the growth of structure

## Week 10

- **Future probes of gravity and the nature of dark energy**: Baryon acoustic Oscillations and the BOSS survey, the Joint Dark Energy Mission, the Large Synoptic Survey Telescope (LSST)