AST1430: Cosmology

Winter 2023

(last updated: January 18, 2023; rev. 6a77076)

Course description

The goal of this course is to provide a more complete coverage of cosmology, and to develop concepts to the point of calculation. The topics to be covered include a brief introduction to relevant concepts from General Relativity, the model of an isotropic, homogeneous, expanding Universe, inflation, the origin and nature of the Cosmic Microwave background, Big-Bang Nucleosynthesis and baryogenesis, dark matter, linear perturbation theory, large-scale structure beyond linear perturbation theory, dark energy, and a discussion of the main observational cosmological probes.

Logistics

See the README file of this repository.

Learning objectives

Students will develop an understanding of diverse concepts in cosmology, and the physics that governs them. Specifically, the objectives are

- Understanding and being able to explain the physical principles that are relevant for the large scale structure and evolution of the Universe from the Big Bang until the present;
- Being able to derive equations for the evolution of all of the major components of the Universe (baryons, dark matter, dark energy, photons) from the basic physical principles
- Solving these equations analytically and numerically, sometimes with the aid of basic mathematical software like Mathematica or Python packages such as numpy or scipy;
- Understanding how the cosmological model is observationally constrained and how we that the Universe is dominated by dark energy and dark matter

Reading

The main material will be presented in the slides and, in the second half, in a set of lecture notes. Additionally, the following books are recommended for further reading:

- Malcolm Longair, *Galaxy Formation*, 2007, Springer.
- John Peacock, *Cosmological Physics*, 1998, Cambridge University Press.
- Mo, van den Bosch, & White, *Galaxy Formation and Evolution*, 2010, Cambridge University Press. Errata can be found here.
- Dodelson & Schmidt, *Modern Cosmology*, 2020, Academic Press.

Grading scheme

- **Assignments:** 40 % over three assignments; see course website for due dates.
- **Participation:** 20 %
- **Presentations:** 20 %
- **Take-home final + oral exam:** 20 %

  You are allowed to (and are encouraged to!) work together with classmates on the assignments, but each student must hand in an independent write-up of their solutions. The take-home final should be your own work. Solutions must be written up in a detailed enough manner to demonstrate that you understand each step. The oral exam will consist of a discussion of the take-home final with follow-up questions.

Academic integrity

From Appendix D of the Academic Integrity Handbook:

> Academic integrity is one of the cornerstones of the University of Toronto. It is critically important both to maintain our community which honours the values of honesty, trust, respect, fairness, and responsibility and to protect you, the students within this community, and the value of the degree towards which you are all working so diligently.
>
> According to Section B of the University of Toronto's Code of Behaviour on Academic Matter (`http://www.governingcouncil.utoronto.ca/policies/behaveac.htm`) which all students are expected to read and by which they are expected to abide, it is an offence for students to:
>
> - Use someone else's ideas or words in their own work without acknowledging explicitly that those ideas/words are not their own with a citation and quotation marks, i.e. to commit plagiarism.
> - Include false, misleading, or concocted citations in their work.
> - Obtain unauthorized assistance on any assignment.
> - Provide unauthorized assistance to another students. This includes showing another student your own work.
> - Submit their own work for credit in more than one course without the permission of the instructors.
>
> There are other offenses covered under the Code, but these are the most common. You are instructed to respect these rules and the values that they protect.

Schedule

- **Week 1:** Class logistics, introduction, basic observations.
- **Week 2:** Basic GR, RW metric, Distances, coordinates, Friedmann equations.
- **Week 3:** Cosmological models, consistency with observations, early hot Universe, BBN.
- **Week 4:** Inflation, perturbations & structure pre-recombination.

- **Week 5:** CMB: basics, polarization, secondaries.
- **Week 6:** Early-universe presentations.
- **Week 7:** Post-recombination growth of structure, formation of dark matter halos, halo mass function.
- **Week 8:** The relation between dark matter halos and galaxies.
- **Week 9:** Probing the cosmic density field / clustering.
- **Week 10:** Late-time cosmological observations: BAO, supernovae, weak lensing, etc.
- **Week 11:** The H0 controversy: how fast exactly is the Universe expanding today?
- **Week 12:** Late-universe presentations and review.