Astronomy 381: Formation of Galaxies

Spring 2019; TuTh 11am-12:30pm, PMA (RLM) 15.216B

Unique Number 46665

Instructor: Prof. Mike Boylan-Kolchin
email: mbk@astro.as.utexas.edu
Office: PMA (RLM) 17.212 (*phone*: 512.471.3343)
Office hours: By appointment (I typically have broad availability during the day, especially if given advanced request / notice).

Textbooks (recommended):

- *Galaxy Formation and Evolution*, Mo, van den Bosch, & White (Cambridge U. Press, 2010).

  This book is widely available, including in the bookstore and online (e.g., amazon.com), and one of the authors maintains a website that includes errata.

- *Galactic Dynamics*, J. Binney & S. Tremaine (Princeton University Press; 2nd edition, 2008).

  The standard reference for galactic dynamics. Love it, learn it.

Additional books: there are **many** books on cosmology and galaxy formation, covering a wide range of levels and topics. Some that I recommend are:

- *The Large-Scale Structure of the Universe*, P. J. E. Peebles (Princeton University Press, 1980).
- *Cosmological Physics*, J. Peacock (Cambridge University Press, 1998)
- *Modern Cosmology*, S. Dodelson (Academic Press, 2003)
- *The Early Universe*, E. Kolb and M. Turner (Westview Press, 1994)
- *Galactic Astronomy*, J. Binney and M. Merrifield (Princeton University Press, 1998)
- *Dynamics and Evolution of Galactic Nuclei*, D. Merritt (Princeton University Press, 2013)

These additional books either contain more detail on specific topics or are good references.

Course Description

This course explores the intersection of cosmology and galaxies. We will begin with an overview of the standard Friedmann-Robertson-Walker model of the Universe and a discussion of cosmological observables and their relations (redshift, time, distance, etc.). Next, we will cover our current cosmological model, ΛCDM, and explore how quantum fluctuations in the very early Universe grow to become observed cosmic structures today via the Jeans instability in an expanding Universe. We will examine simple models that relate the abundance of dark matter halos to properties of the initial perturbation spectrum (Press-Schechter theory) and various techniques for studying the evolution of perturbations into the non-linear regime. This will bring us to the structure of dark matter halos. We will then study the basics of galaxy formation within dark matter halos. We will also explore the use of the collisionless Boltzmann equation to understand galaxy dynamics. Finally, we will look at the intersection of cosmology and galaxy formation, focusing on how galaxies can be used to constrain cosmology.

Prerequisites

Graduate standing or permission of the instructor. AST 381 is suitable for beginning or advanced graduate students in Physics and Astronomy. Previous graduate work in galaxies or cosmology is not required; however, an understanding of both of these classes will be useful.

Course Goals

By the end of this course, my goal is for you to:

- Have a working understanding of the ΛCDM model, the evolution of density perturbations in the linear regime to non-linear structure formation
- Have a working understanding of the current picture of galaxy formation within the ΛCDM model
- Have a basic historical overview of cosmology and galaxy formation models
- Gain a basic understanding of possible shortcomings of our cosmological models and some potential solutions
- Be able to write basic code to compute cosmological quantities
- Be able to read papers of historical significance as well as state-of-the-art papers about cosmology and galaxy formation
- Be able to discuss papers and scientific topics from the class with me and with your peers, and to evaluate these papers and topics critically.

Class Website

This course website will be based on Canvas (canvas.utexas.edu). Make sure that you are able to access and receive emails through Canvas.

Grading

You will receive the grade you earn in this course. **There will be no extra credit awarded during or after the semester**, so please be sure to put in the effort during the semester to earn the grade you want. Your grade will be based on the following components components:

- **Homework** (approximately once every two weeks): 40%. Some homework will require basic programming and plotting. Please contact me privately if you have concerns.
- **Numerical project**: 20%. In the second half of the course, we will use techniques learned in the first half to develop a code. You will have a choice of two different problems, and you will be responsible for writing a numerical code to solve the problem. More details will be given later in the semester.
- **Oral presentations**: 20%. A crucial part of being a scientist is to be able to present your ideas in a fair but persuasive manner. We will spend time working on oral presentations, and you will be required to give 2 graded presentations in the course. Additionally, we will discuss papers regularly during the semester, and your participation (and readiness) in these discussions will contribute toward your oral presentation grade. More details will be provided during the class.
- **Funding proposal**: 20%. Persuasive writing is also crucial in most post-PhD careers. You will be required to write a 3-page funding proposal, modeled on the scientific justification section of *Hubble Space Telescope* proposals, toward the end of the semester. This can be on observational, theoretical, or computational topics that are related to the course material (the topic must be approved by me). More details will be provided later in the semester.

Grading scale
A: 85 – 100
B: 70 - 84
C: 60 - 69
D: 50 - 59
F: $<$ 50

Class Policies

- *Be respectful of your fellow students and the professor*. Please arrive on time. Do not pack up or leave class early unless you have talked to me in advance. Do not talk in class other than during designated group learning activities. Phone use and texting during class will not be tolerated. Make sure your phones are off, and keep them put away during the class. Students using their phones will be asked to leave, and will not earn participation for that day. If you are using a laptop or tablet to take notes, please make sure you are not a distraction to those around you. If laptop distraction becomes a persistent problem, I reserve the right to modify this policy accordingly.
- My official responsibilities as a professor include conducting astrophysics research, which requires travel during the semester. I will do my best to minimize the impact of this travel and will try to maintain Canvas communication at while out of Austin. When I am gone, another PhD UT astronomer will lead the class.
- **Video and/or audio recording of lectures is prohibited unless permission is explicitly granted by the instructor**.
- **Religious Holidays**: According to UT Austin policy, you must notify the professor of a pending absence at least fourteen days prior to the date of observance of a religious holy day. If you must miss a class, an examination, a work assignment, or a project in order to observe a religious holy day, you will be given an opportunity to complete the missed work within a reasonable time after the absence.
- **Expectations**: I realize this course is not the only commitment you have in your life and will not expect you to be able to devote all of your time to it. The course does have deadlines / due dates, and while accommodations can be made for exigent circumstances, this does not include items like "I have a really busy week" or "I'm trying to finish up work for another class/paper/project." When in doubt, communication with me ahead of time is the best option!

Academic Dishonesty

University of Texas Honor Code: The core values of The University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the university is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community. Students who violate University rules on scholastic dishonesty are subject to disciplinary penalties, including the possibility of failure in the course and/or dismissal from the University. Standards for Academic Integrity are posted at http://deanofstudents.utexas.edu/sjs/acint_student.php

Plagiarism: As a research university, The University of Texas at Austin takes plagiarism very seriously. Do not risk getting involved in a plagiarism infraction – the consequences simply are not work it. Always cite your sources, and when in doubt, consult a professor or librarian. You may also read more about plagiarism at the Student Judicial Services website: http://www.utexas.edu/cola/cwgs/_files/pdf-4/ai2012.pdf

Additional Items

Documented Disability Statement: Please notify me of any modification/adaptation you may require to accommodate a disability-related need. The University of Texas at Austin provides, upon request, appropriate academic accommodations for qualified students with disabilities. For more information, contact Services for Students with Disabilities at 471-6259 (voice) or 232-2937 (video phone) or http://ddce.utexas.edu/disability/

Email: Email is recognized as an official mode of university correspondence; you are therefore responsible for reading your email for university and course-related information and announcements.

Emergency Procedures: In the event of an evacuation, follow the instruction of faculty or class instructors. Occupants of buildings on The University of Texas at Austin campus are required to evacuate buildings when a fire alarm is activated. Students requiring assistance in evacuation should inform their instructor in writing during the first week of class. Familiarize yourself with all exit doors of each classroom and building you may occupy and remember that the nearest exit door may not be the one you used when entering the building. Do not re-enter a building unless given instructions by the following: Austin Fire Department, The University of Texas at Austin Police Department, or Fire Prevention Services office. Information regarding emergency evacuation routes and emergency procedures can be found at utexas.edu/emergency.

Behavior Concerns Advice Line (BCAL): The Behavior Concerns Advice Line is a service that provides The University of Texas at Austins faculty, students and staff an opportunity to discuss their concerns about another individuals behavior. This service is a partnership among the Office of the Dean of Students, the Counseling and Mental Health Center, the Employee Assistance Program, and The University of Texas Police Department. An individual can either call the line 512-232-5050 or report online at www.utexas.edu/safety/bcal/.

Last, but certainly not least: A climate conducive to learning and creating knowledge is the right of every person in our community. **Bias, harassment, and discrimination of any sort have no place here.** If you notice an incident that causes concern, please contact the Professor and/or the Campus Climate Response Team at http://diversity.utexas.edu/ccrt.