

Astronomy 396C: Elements of Cosmology

Unique Number 48395

(Also listed as Physics 396T: Special Topics in Particle Physics; Unique Number 57620)

Fall 2021

Class Meeting Times: TuTh 2:00pm-3:30pm

Course Mode: Hybrid (plan: in-person)

Instructor: Prof. Mike Boylan-Kolchin

Pronouns: he/him/his

email: mbk@astro.as.utexas.edu

Office hours: By appointment (office: PMA 16.324)

Course Overview and Objectives

AST 396C is an introduction to Cosmology at a level suitable for Astronomy or Physics graduate students. Cosmology is the study of the content of our Universe, where it came from, and how it evolves over time. This course covers basics of our understanding of the formation and evolution of structure in the Universe from the Big Bang to the present day. Cosmology is an exciting and still-changing discipline. In this course, you will:

- gain mathematical understanding of equations explaining the evolution of the Universe
- develop physical intuition the Universe, its contents, and its evolution over cosmic time
- learn about dark matter, dark energy, the cosmic microwave background, the intersection of astronomy and particle physics, and the expanding Universe, among other topics.

The first 40% of the course will cover the smooth universe (homogeneous models without any perturbations; the next 40% will cover perturbations and their evolution under gravitational instability; and the final 20% will cover a selection of topics that are at the forefront of cosmological research.

How Will I Succeed in this Course?

I have confidence that every single person in this course can learn the material and earn a good grade, provided you engage with the material deeply. I believe that the two most important components of success in this class are:

- **Understand the fundamental equations and their implications:** while much of the material can seem complicated, the underlying equations that govern the Universe's contents and its evolution can provide clarity. Understanding the basic equations of cosmology and their implications will help keep you grounded.
- **Be truthful with yourself about what you understand:** it's OK to be confused about a topic, an equation, or a concept! And it's definitely OK to ask questions, even if you're afraid they might be too simple! R. Feynman famously said "The first principle is that you must not fool yourself, and you are the easiest person to fool," and I think this is true in learning, too. It is easy to convince yourself that you understand something; it's important to be sure that you really do understand it.

Course Website and Email

The course website will be hosted on Canvas (<https://canvas.utexas.edu>). **Make sure that you are able to access and receive emails through Canvas.** Email is recognized as an official mode of university correspondence; you are responsible for reading your email for university and course-related information & announcements.

Course Textbook (recommended)

Galaxy Formation and Evolution, Mo, van den Bosch, & White (Cambridge U. Press, 2010). The book is available at the Co-op and at amazon.com (to purchase or rent), among other places.

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)
- *Cosmology*, S. Weinberg (Oxford University Press, 2008)
- *The Early Universe*, E. Kolb and M. Turner (Westview Press, 1994)
- *Galactic Dynamics*, J. Binney and S. Tremaine (Princeton University Press, 2008 – 2nd edition).

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

Course Expectations

- **Attendance and Engagement:** Course attendance is crucial for understanding the complex material we will be covering and for participating in discussions related to papers we will read (see grading scheme below). Absences for illness, religious observances, participation in University activities at the request of University authorities, and compelling circumstances beyond the student's control are excused under University policy. Please inform the instructor *in advance* of any absences or schedule conflicts for religious observances.
- **Assignments:** It is fine to discuss problems and concepts with your classmates – trying to explain something to someone else is a good way to see how well you understand it! We will also engage in group discussions in class. **However, it is crucial to remember that all graded assignment must consist of your own thoughts in your own words.** Please also see the statement on academic integrity below.

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* (assigned approximately once every two weeks): 50%.
On the due date, homework should be handed in at the beginning of the class; it will be considered late by the end of class. Late homework will be accepted for a week after the due-date and will be subjected to a penalty of up to 30%.

If you have an emergency or other valid excuse that prevents you from making a homework deadline, you should make all reasonable efforts to contact me before the due date telling me the nature of the situation. Please document all such emergencies; a self-signed note is sufficient provided that it contains a statement that (1) the information is

true and correct and (2) you are aware that providing false information is prohibited under the Code of Student Conduct. If, for any reason, the University is officially closed on the day of the due date, the due date will be moved to the next lecture.

To receive full credit for a given problem, you must (1) show your work, and (2) provide the code (via email) for any numerical calculations that are required.

- *Numerical projects (2): 40% (20% each)*

An essential part of modern cosmology is to calculate cosmological observables. While there are many codes available publicly, they are typically used as 'black boxes', without an understanding of the inputs or limitations. We will have two projects, one in the middle of the semester and one toward the end, that will involve building up the ability to do some of these calculations from scratch. More details will be given in the coming weeks.

- *Participation and engagement: 10%*

A crucial part of being a scientist is to be able to read papers and present your ideas about them in a fair but persuasive manner. Paper reading and related discussion will therefore be a regular part of class. I want to emphasize that I am *not* expecting you to be an expert on any paper we read; what I do expect is that you will read the papers, try to understand them, and come ready to discuss interesting, important, or confusing points.

Your grade will be computed as follows: the average grade you receive in each of the components listed above will be weighted by the percentage listed above and then rounded to the nearest 1 decimal place. Your final grade will be given by the following scale:

90 – 100: A

85 – 89.9: A-

80 – 84.9: B+

75 – 79.9: B

70 – 74.9: B-

67 – 69.9: C+

63 – 66.9: C

60 – 62.9: C-

57 – 59.9: D+

53 – 56.9: D

50 – 52.9: D-

< 50: F

Class Policies

- *Respect for others is vital.* I am: invested in the educational experience of each student in the class, respectful of individual differences, encouraging of creativity, available to discuss material and assignments; thorough in evaluating assignments; and rigorous yet supportive in maintaining high standards for performance. As a student, you are expected to work individually and with others, to create an atmosphere that is safe, valuing of one another, and open to diverse perspectives. Everyone is expected to show courtesy, civility, and respect for one another. Comments or postings that degrade or ridicule another, whether based on individual or cultural differences, are unacceptable.

- Classroom norms apply during a zoom call. If you wouldn't do something in a physical class setting, please don't do it in a digital classroom.
- My official responsibilities as a professor occasionally require me to participate in external events. I will do my best to ensure these events do not conflict with class time; if I do have to miss any instructional time, another PhD UT astronomer will lead the class.
- **Sharing of Course Materials is Prohibited:** No materials used in this class, including, but not limited to, lecture hand-outs, videos, assessments (quizzes, exams, papers, projects, homework assignments), in-class materials, review sheets, and additional problem sets, may be shared online or with anyone outside of the class unless you have my explicit, written permission. Unauthorized sharing of materials promotes cheating. It is a violation of the University Student Honor Code and an act of academic dishonesty. I am well aware of the sites used for sharing materials, and any materials found online that are associated with you, or any suspected unauthorized sharing of materials, will be reported to Student Conduct and Academic Integrity in the Office of the Dean of Students. These reports can result in sanctions, including failure in the course.
- **Class Recordings:** Class recordings are reserved only for students in this class for educational purposes and are protected under FERPA. *The recordings should not be shared outside the class in any form.* Violation of this restriction by a student could lead to Student Misconduct proceedings.
- **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.

COVID-19 Update

This course may be offered in a format to which you are unaccustomed. If you are looking for ideas and strategies to help you feel more comfortable participating in our class, please explore the resources available here: <https://onestop.utexas.edu/keep-learning/>

Personal Pronouns and Chosen Name

Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, culture, religion, politics, sexual orientation, gender, gender variance, and nationalities. Class rosters are provided to the instructor with the students legal name, unless they have added a "preferred name" with the Gender and Sexuality Center (<https://diversity.utexas.edu/genderandsexuality/publications-and-resources/>). I will gladly honor your request to address you by a name that is different from what appears on the official roster, and by the gender pronouns you use. Please advise me of any changes early in the semester so that I may make appropriate updates to my records.

For instructions on how to **add your pronouns to Canvas**, visit <https://utexas.instructure.com/courses/633028/pages/profile-pronouns>.

If you would like to update your **chosen name**, please see <https://onestop.utexas.edu/student-records/personal-information/> (note that your legal name

will still show up on a variety of official UT documents, and there is no way to change this at present).

University Deadlines

Please see <https://registrar.utexas.edu/calendars/21-22> for relevant University deadlines (including drop deadlines)

Academic Integrity

Each student in the course is expected to abide by the University of Texas Honor Code: As a student of The University of Texas at Austin, I shall abide by the core values of the University and uphold academic integrity. Plagiarism is taken very seriously at UT. Therefore, if you use words or ideas that are not your own (or that you have used in previous class), you must cite your sources. Otherwise you will be guilty of plagiarism and subject to academic disciplinary action, including failure of the course. You are responsible for understanding UT's Academic Honesty and the University Honor Code which can be found at the following web address: <https://deanofstudents.utexas.edu/conduct/standardsofconduct.php>

Services for Students with Disabilities

The university is committed to creating an accessible and inclusive learning environment consistent with university policy and federal and state law. Please let me know if you experience any barriers to learning so I can work with you to ensure you have equal opportunity to participate fully in this course. If you are a student with a disability, or think you may have a disability, and need accommodations please contact Services for Students with Disabilities (SSD): <https://diversity.utexas.edu/disability/>. If you are already registered with SSD, please deliver your Accommodation Letter to me as early as possible in the semester so we can discuss your approved accommodations and needs in this course. For more information, contact Services for Students with Disabilities at 471-6259 (voice) or 232-2937 (video phone) or <https://ddce.utexas.edu/disability/>

Counseling and Mental Health Center

The [Counseling and Mental Health Center](#) serves UT's diverse campus community by providing high quality, innovative and culturally informed mental health programs and services that enhance and support students well-being, academic and life goals. To learn more about your counseling and mental health options, call CMHC at (512) 471-3515. If you are experiencing a mental health crisis, call the CMHC Crisis Line 24/7 at (512) 471-2255.

Important Safety Information

If you have concerns about the safety or behavior of fellow students, TAs or Professors, call BCCAL (the Behavior Concerns and COVID-19 Advice Line): 512-232-5050. Your call can be anonymous. If something doesn't feel right it probably isn't. Trust your instincts and share your concerns.

BeVocal is a university-wide initiative to promote the idea that individual Longhorns have the power to prevent high-risk behavior and harm. At UT Austin all Longhorns have the power to intervene and reduce harm. To learn more about BeVocal and how you can help to build a culture of care on campus, go to <https://wellnessnetwork.utexas.edu/BeVocal>.

Title IX Reporting

Title IX is a federal law that protects against sex and gender based discrimination, sexual harassment, sexual assault, sexual misconduct, dating/domestic violence and stalking at federally funded educational institutions. UT Austin is committed to fostering a learning and working environment free from discrimination in all its forms. When sexual misconduct occurs in our community, the university can: (1) Intervene to prevent harmful behavior from continuing or escalating; (2) Provide support and remedies to students and employees who have experienced harm or have become involved in a Title IX investigation; (3) Investigate and discipline violations of the university's relevant policies.

Beginning January 1, 2020, Texas Senate Bill 212 requires all employees of Texas universities, including faculty, report any information to the Title IX Office regarding sexual harassment, sexual assault, dating violence and stalking that is disclosed to them. Texas law requires that all employees who witness or receive any information of this type (including, but not limited to, writing assignments, class discussions, or one-on-one conversations) must be reported. **I am a Responsible Employee and must report any Title IX related incidents that are disclosed in writing, discussion, or one-on-one. Before talking with me, or with any faculty or staff member about a Title IX related incident, be sure to ask whether they are a responsible employee.** By state law, any responsible employee who does not report any Title IX related incidents that are disclosed to them must be fired from the University (and can be charged with a criminal offense – Class B or Class A Misdemeanor).

If you want to speak with someone for support or remedies without making an official report to the university, email advocate@austin.utexas.edu For more information about reporting options and resources, visit <https://titleix.utexas.edu> or contact the Title IX Office at titleix@austin.utexas.edu.

Preliminary Course Outline

Note: changes to this schedule may be made at my discretion and if circumstances require. It is your responsibility to note these changes when announced (although I will do my best to ensure that you receive the changes with as much advanced notice as possible).

Dates	Topics
Aug 26	Astronomy units; cosmological principles; the expanding Universe
Aug 31, Sept 2	The Friedmann-Robertson-Walker model & the Friedmann equation
Sept 7, 9	Distances; the Einstein-de Sitter and Λ CDM models
Sept 14, 16	The hot big bang and the first minute of the Universe
Sept 21, 23	Big bang nucleosynthesis
Sept 28, 30	Recombination and the cosmic microwave background
Oct 5, 7	Inflation
Oct 12, 14	Linear perturbation theory
Oct 19, 21	Linear perturbation theory, statistical description of fluctuations
Oct 26, 28	Power spectra; CMB fluctuations
Nov 2, 4	CMB fluctuations and BAO; from linear to non-linear theory
Nov 9, 11	Gravitational collapse; dark matter halos and large-scale structure
Nov 16, 18	Cosmological frontiers: the Hubble tension, dark matter
	Thanksgiving Break: Nov. 25
Nov 30, Dec 2:	Cosmological frontiers: the next decade+ in cosmology