Astronomy 396C: Elements of Cosmology  
Unique Number 48405  
Fall 2023

Class Meeting Times: TuTh 9:30-11am  
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 (strongly recommended)
*Cosmology*, Daniel Baumann (Cambridge U. Press, 2022). The book is available at the Co-op and at amazon.com, among other places. The website linked here has a few resources, including pdf versions of many of the color figures and an ipython notebook.

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

- *Cosmology*, S. Weinberg (Oxford University Press, 2008)

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 subject 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): 30% (15% 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 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: 20%
  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; we will also engage in occasional group exercises, etc.. 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.

- 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’s 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:** Any 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. Note: classes will not be recorded.

- **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**

COVID-19 continues to circulate and can lead to serious (and sometime chronic) illness. Stay up-to-date on COVID-19 vaccinations by getting all available boosters when eligible. Vaccines are available through University Health Services. Masks, when properly worn, reduce the spread of COVID-19. For any illness, students should stay home if they are sick or contagious, not only to stop the spread, but also to prioritize their personal well-being. UHS provides symptomatic COVID-19 testing for students. Schedule your appointment by calling 512-471-4955 or online within the MyUHS patient portal. Learn more about symptomatic COVID-19 testing here. I encourage everyone to proactively test for COVID-19 throughout the semester as well.

**Personal Pronouns**

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 student’s
legal name, unless they have added a “chosen name” with the Gender and Sexuality Center (http://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.

University Deadlines
Please see http://registrar.utexas.edu/calendars/23-24 for relevant University deadlines (including drop deadlines)

Academic Integrity Expectations

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 academic misconduct are subject to the student conduct process and potential disciplinary action. A student found responsible for academic misconduct may be assigned both a status sanction and a grade impact for the course. The grade impact could range from a zero on the assignment in question up to a failing grade in the course. A status sanction can range from probation, deferred suspension and/or dismissal from the University. To learn more about academic integrity standards, tips for avoiding a potential academic misconduct violation, and the overall conduct process, please visit the Student Conduct and Academic Integrity website at http://deanofstudents.utexas.edu/conduct

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.

Accessible, Inclusive, and Compliant Statement

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 Disabilities and Access (D&A). If you are already registered with D&A, 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.

Behavior Concerns Advice Line (BCAL)

If you have concerns about the safety or behavior of fellow students, TAs or professors, contact BCCAL (the Behavior Concerns and COVID-19 Advice Line) or by calling at 512-232-5050. Confidentiality will be maintained as much as possible, however the university may be required to release some information to appropriate parties.
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, 2022, Texas Education Code, Section 51.252 (formerly known as 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, written forms, applications, one-on-one conversations, class assignments, class discussions, or third-party reports) must report it to the Title IX Coordinator. Before talking with me, or with any faculty or staff member about a Title IX related incident, please remember that I will be required to report this information.

Although graduate teaching and research assistants are not subject to Texas Education Code, Section 51.252, they are mandatory reporters under federal Title IX regulations and are required to report a wide range of behaviors we refer to as sexual misconduct, including the types of misconduct covered under Texas Education Code, Section 51.252. Title IX of the Education Amendments of 1972 is a federal civil rights law that prohibits discrimination on the basis of sex – including pregnancy and parental status – in educational programs and activities. The Title IX Office has developed supportive ways and compiled campus resources to support all impacted by a Title IX matter.

If you would like to speak with a Case Manager for Support and Resources, who can provide support, resources, or academic accommodations, in the Title IX Office, please email: supportandresources@austin.utexas.edu. A Case Manager can also provide support, resources, and accommodations for pregnant, nursing, and parenting students. For more information about reporting options and resources, please visit: http://titleix@austin.utexas.edu, contact the Title IX Office via email at: titleix@austin.utexas.edu, or call 512-471-0419.
Preliminary Course Outline

Note: changes to this schedule may be made at my discretion and if circumstances require. This is the rough outline of when and what we will cover, but the exact dates may change slightly depending on a variety of factors.

<table>
<thead>
<tr>
<th>Dates</th>
<th>Topics</th>
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<tbody>
<tr>
<td>Aug 21, 23</td>
<td>Astronomy units; some fundamental cosmological observations; the expanding Universe</td>
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<tr>
<td>Aug 28, 30</td>
<td>The Friedmann-Robertson-Walker model &amp; some key cosmological equations</td>
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<tr>
<td>Sept 5, 7</td>
<td>Distances in cosmology; the Einstein-de Sitter and ΛCDM models</td>
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<td>Sept 12, 14</td>
<td>ΛCDM; The hot big bang and the early Universe</td>
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<td>Sept 19, 21</td>
<td>The early Universe; big bang nucleosynthesis</td>
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<td>Sept 26, 28</td>
<td>Recombination and the cosmic microwave background</td>
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<td>Oct 3, 5</td>
<td>Inflation</td>
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<td>Oct 10, 12</td>
<td>Linear perturbation theory</td>
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<td>Oct 17, 19</td>
<td>Linear perturbation theory, statistical description of fluctuations</td>
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<td>Oct 24, 26</td>
<td>Power spectra; CMB fluctuations</td>
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<td>Oct 31, Nov 2</td>
<td>CMB fluctuations and BAO; from linear to non-linear theory</td>
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<td>Nov 7, 9</td>
<td>Gravitational collapse; dark matter halos and large-scale structure</td>
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<td>Nov 14, 16</td>
<td>Cosmological frontiers: the Hubble tension, dark matter, dark energy, etc.</td>
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<td><strong>Thanksgiving Break: Nov. 21, 23</strong></td>
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<tr>
<td>Nov 28, 30:</td>
<td>Cosmological frontiers: high-redshift structure formation and JWST; the next decade+ in cosmology</td>
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