Astronomy 17 — Galactic and Extragalactic Astronomy

Draft Syllabus, August 14, 2024
Harvard University, Fall 2024
Class: Monday & Wednesday 1:30 pm – 2:45 pm
Section: Friday 1:30 pm – 2:45 pm

Course Summary

This course will introduce you to the physical principles describing galaxies and the composition and evolution of the Universe. We will cover a wide range of topics from nearby galaxies to quasars to the Big Bang.

The goals of the course are 1) to introduce you to the broad sweep of extragalactic astronomy and cosmology, including major concepts and common jargon, 2) to develop detailed applications of physics, particularly mechanics, to galaxies and cosmology, 3) to gain exploratory experience in observational astronomy.

The course is structured to integrate observational methods and survey astronomy on a weekly basis, using the Dark Energy Spectroscopic Instrument at the Kitt Peak National Observatory Mayall telescope as a continuing example (http://desi.lbl.gov). In small groups, students will explore the imaging and spectroscopic data sets of DESI, the Legacy Survey, and the Sloan Digital Sky Survey, as a way to learn about the observational practice of astronomy as well as the engineering considerations of a major observatory.

The course requires attendance at both the Monday and Wednesday classes as well as at the Friday section. These classes will be interactive discussion and problem-solving sessions, rather than traditional lectures. There will be required readings before the in-class discussions. Each week will involve a multi-step assignment, including in-class group work in class and section, a problem set, and a short quiz due by the end of the module. The course is designed to require about 10 hours/week, including class time.

Astronomy 17 is a required course for both the concentration and the secondary field in Astrophysics. Astronomy 16 & 17 form a complete introductory survey of astrophysics. You can take these courses in either order.

Instructors

Prof. Daniel Eisenstein (he/his)
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Office or by Zoom or by appointment

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The TFs will hold a section each week on Friday at the normal course time and location. This section is required and will be organized around in-class group problems, as well as a recap of class material and discussion of the week's assignment.

You can make appointments to meet with the TFs or with Prof. Eisenstein at other times.

A note regarding office hours in this and other courses: You can use office hours for more than just asking questions immediately related to a problem set or that week's material. It is a good way to get to know the course staff better, to explore your curiosity about astrophysics, to discuss career plans, etc. So we encourage you to drop by!

Prerequisites

College-level mechanics (e.g., Physics 12a, 15a, or 16) is a co-requisite. The concepts of mechanics figure heavily in this course, so please discuss with Prof. Eisenstein if you are taking mechanics concurrently or relying on previous high-school preparation.

This course will use single-variable calculus (e.g., Math 1a and 1b or AP calculus BC) extensively. We recommend treating Math 1b as a co-requisite; please discuss with Prof. Eisenstein if you are taking it concurrently. You are not expected to have preparation in multi-variable calculus (e.g., Math 21a) or linear algebra and differential equations (e.g., Math 21b).

Astronomy 16 is *not* a pre-requisite for this course. Indeed, this may be your first course in astronomy.

Course Structure

The weekly cadence of the course will be based around a multi-step assignment. This has the following weekly components:

1) Readings that should be completed prior to class, usually Wednesday, to inform in-class discussions. Each week, a portion of the class will be required to submit some discussion questions on Tuesday night, to inform the Wednesday class.
2) A set of group activities, usually around the on-sky data or some initial quantitative questions, that will be completed during class and section.
3) The written assignment, which is due on Sunday at 9 pm, consisting of homework problems

that you should work individually but on which you are permitted to consult with classmates. 4) A 30-minute timed quiz, also due on Sunday at 9 pm, that must be done strictly individually.

For the in-class group activities, you do not need to turn in a record of these activities, unless we explicitly include instructions as part of the written assignment. However, participation in in-class activities will be factored into your class participation grade.

Weeks with only 1 class will obviously require some adjustments to this pattern; we will announce these at the time. There will be a short reading before the first class on Wednesday, September 4 and the first (short) assignment will be due on Sunday, September 8.

The readings will be a mixture of class handouts and sections from the required text, *An Introduction to Galaxies and Cosmology*, Second Edition, by Jones, Lambourne, and Sarjeant.

Alas, the order of topics for this course is not identical to that of the book. We are therefore going to read the book out of order; please attend to the announced sections.

You are responsible for the major concepts in the assigned sections of the book, regardless of whether we cover them in class. The midterm and final exam will include material from the book, not simply the classes. However, astronomy has many tiny details and the book is dense with facts that support the major concepts. Try not to get bogged down in the minutia; we are focusing on the bigger concepts.

The textbook is at a good level as regards the descriptive topics we intend you to learn. However, the other course material will go into substantially more quantitative detail. You will exercise the quantitative side of the course on the assignments and in the quizes.

Readings are marked as assignments in Canvas, with a class date as the due date, and you are expected to complete the assigned readings before coming to that class. Usually this is assigned for Wednesday, on the idea that you should have read in detail by then, but I encourage you to have done some browsing before Monday's class.

I stress that the classes will not be full-length formal lectures. Lecture portions will be interspersed with discussion time and small-group problem solving. The lectures will not be "comprehensive" but rather will try to provide a summary framework and present some of the more difficult topics in detail.

Substantial portions of the class time will be spent in response to student-supplied questions and topics. So it is important that each student do the reading in advance of class so as to consider what topics they would like to hear more about.

To encourage this and to assure a base level of input, the class will be divided into four groups: Andromeda, Cygnus, Lyra, and Orion. For each assigned reading, one group will be assigned to pose questions/topics to help provide topics for the in-class discussion. Each student in the assigned group should provide their questions no later than the evening before the relevant class discussion day. Students not in the assigned group are also welcome to send questions. Participation on the assigned weeks is part of the class participation grade.

If there isn't enough class time to address all submitted questions, some response will be

given on Slack.

The readiness to present questions and the participation in the resulting discussion will figure into the class participation grade.

Expectations for Classroom Work

Classroom time will involve both full-group and small-group periods. For small-group work, we will move chairs to form the discussion groups or we will direct students to gather at a chalk board.

The course will use a Slack workspace, which you should join. This is simply to facilitate communication among the group. We note that the course instructors may not be available all of the time! We will also use Slack during class to gather questions from multiple groups. You can also ask questions to the in-class TF using Slack.

During discussions, the instructors may call on students by name to contribute. It is acceptable to say "Pass".

To help with names, we will be using individualized table tents; please keep these visible.

If at all possible, you should bring a laptop computer or web-capable tablet toall classes. We will be relying on the computer to browse through astronomical data sets. When we have our computers out, please avoid multitasking with non-classroom activities (email, web, etc) so that you can focus on the class.

Because of the focus on discussion and group work, it is important to be mindful of behavior both in live interactions and in electronic communications. Be careful to take turns speaking, avoiding interruptions but also pausing so that others can have a turn. As always, courtesy matters! Be careful to give others credit for the ideas that they have introduced. We want to create a supportive environment for collective learning. If you are having repeated problems with another classmate, please speak to the instructional staff so that we can help.

Grading

Weekly assignments, including quizzes 60%,
Class Participation 10%,
Midterm 10%,
Final Exam 20%.

There will be a total of 12 assignments, which include the associated quiz that reflects about 25% of the credit. However, the grade on the first assignment and its quiz (both due Sept 8) will not be included in the final grade, to avoid concerns about shopping churn in the opening days of the course.

Of the remaining 11, the lowest grade on an assignment will be dropped from the final grade. Assignments may differ mildly in the amount of credit for each.

Assignments can be either typed or hand-written and scanned. You should submit each assignment via Canvas as one PDF.

You are expected to attend and participate in both Monday and Wednesday classes and

in the Friday section. We understand that you may have to miss a couple classes during the term, but please make every effort to attend. Please notify Prof. Eisenstein or a TF in advance if you are unable to attend.

Late Assignments

Assignments will be due weekly on Sunday at 9 pm Eastern. There will be no credit for assignments turned in late, as we plan to distribute the solution sets promptly. If you run short on time, you are encouraged to turn in what you have completed for partial credit.

Each student has permission for two no-questions-asked extensions until Wednesday at 1:30 pm (i.e., class time).

Beyond this, exceptions can be made for extraordinary circumstances, such as medical or family emergencies; please contact Prof. Eisenstein. Not planning ahead to handle the deadlines of your courses and extracurricular activities is not sufficient for an extension.

If you feel that you are falling behind in your work for this course or otherwise struggling, please do reach out, whether to the course staff, your Resident Dean, or Academic Resource Center. We are here to help!

We note that the Sunday evening due date was chosen to give students the flexibilty to schedule their week of work, but also to have the work completed before the next week's topics (in this course and others) are introduced. We encourage you to start the assignment after Wednesday's class and to use Friday's section and the late-week office hours to address any lingering questions.

Exams

There will be two exams, a midterm and a final. Both exams are closed book and closed note.

The midterm exam will be in class on Wednesday, October 16. This exam will be 1 hour long and will focus on descriptive questions covering material from the class, problem sets, and textbook. It will not include substantial quantitative derivations/calculations.

The final exam will be a timed 3-hour in-person exam that will draw from all areas of the course, with a mixture of descriptive questions and quantitative problems (i.e., problem-set-style short derivations and calculations).

Independence of Work

All material submitted to meet course requirements is expected to be a student's own work unless otherwise indicated.

Notably, your response to questions must be your own words, not those of the textbook, wikipedia, or other sources. Small excerpts from external sources may be used, with appropriate citation. However, since the point of the questions is to engage the textbook, you do not need to cite the textbook when you use (in your own words) information that it provides.

Regarding the assignments, you are permitted to consult with your classmates about the substance of the problems, save for the quiz portion. **However, after discussions with**

peers, you must write your answers separately. The answers and reports that you submit for evaluation must be the result of your own efforts. In addition, you must cite any books, articles, websites, lectures, etc that have helped you with your work using appropriate citation practices. Similarly, you must list (on page 1) the names of students with whom you have discussed the problem set.

The quiz portion is open-book and open-notes (including your answers for the rest of the weekly assignment), but must be done strictly individually, without discussion with others save the course instructional staff. Further, it must be done within the 30-minute time limit, although each student can schedule that whenever they want before the deadline of the assignment. Students must hold the contents of the quiz confidential until the assignment deadline, and later if requested by the course staff. If an extraordinary circumstance interrupts a quiz after it has started, please alert the course staff as soon as possible.

Any use of solution sets, student solutions, or student laboratory reports from past years of this course is strictly forbidden.

Your adherence to the above is required as a matter of the Honor Code.

We note that for any open-book portion of the course, it is also permitted to use the internet and in particular AI tools like ChatGPT. We do not expect this to be particularly useful for the bulk of the course, and of course we caution that the midterm and final are closed-book, so it's important to be self-sufficient with the material! We think it is possible that AI tools may be more helpful for the minor programming portion of the problem sets. We do not think that they are necessary or even particularly advantageous for novice users, but we do not object to using them.

Accomodations for students with disabilities

Any student needing academic adjustments or accommodations is requested to present their letter from the Accessible Education Office (AEO) and speak with the professor by the end of the second week of the term. Failure to do so may result in the course head's inability to respond in a timely manner. All discussions will remain confidential, although AEO may be consulted to discuss appropriate implementation.

Note that the first assignment is due on Sunday, September 10, and there are reading assignments for the prior class, so if you need adjustments or accommodations in regard to problem sets or reading assignments, please talk to the AEO or the professor as soon as possible.

Required Text

An Introduction to Galaxies and Cosmology, Second Edition, by Jones, Lambourne, and Sarjeant.

Other References

Extragalactic Astronomy and Cosmology, by Peter Schneider. This book covers many topics to moderate depth and with modern notation. It is more quantitative than Jones &

Lambourne, which may be helpful for some of the lecture material. Harvard has an electronic subscription to this book, so you can get to the full book from the course website.

Beyond this, there are many books about galaxies and cosmology. Here are a few at the advanced undergraduate level.

An Introduction to Modern Astrophysics, by Carroll and Ostlie.

Galaxies in the Universe: An Introduction, by Linda Sparke and Jay Gallagher.

Introduction to Cosmology, by Barbara Ryden.

Order of Topics

1. Exploring the extragalactic sky; introduction to deep-sky imaging; galaxy colors, morphologies, scales; astronomical coordinate systems.
2. Observing with light: the electromagnetic spectrum; optical telescopes principles and engineering.
3. Stars and spectroscopy: Atomic lines; stellar populations; distances; doppler shifts; stellar spectroscopy
4. The Milky Way and Local Group: gravitational orbits; dynamical masses; Sag A*; shell theorem; dark matter
5. Galaxies: distances & the Hubble law; galaxy spectroscopy; redshifts
6. Galaxy demographics: statistical populations of galaxies; scaling relations
7. Galaxy clusters: dynamics and dark matter; morphology-environment relations
8. Non-optical astronomy and quasars: atmospheric windows; engineering constraints; active galactic nuclei and accretion disks; AGN spectroscopy
9. Homogeneous cosmology: dynamics of the expanding universe; comoving coordinates.
10. Distances and cosmological tests: cosmological distance calculations; applications to the deep sky.
11. Cosmic microwave background: recombination; thermal history of the universe; acoustic oscillations.
12. Dark matter and dark energy: large-scale structure; galaxy redshift surveys; cosmic composition.

Schedule of Course Reading Assignments and Deadlines (subject to change)

In the case of reading assignments, you should come to class with one or more questions to initiate discussion about the material.

Wed 9/4:	First class. Light reading before class.
Fri 9/6:	First section; overview of python programming.
Sun 9/8	Assignment #1 due.
Mon 9/9:	Reading assignment and prepare for discussion (Andromeda).
Wed 9/11:	Reading assignment and prepare for discussion (Cygnas).
Fri 9/13:	Section
Sun 9/15:	Assignment #2 due.
Mon 9/16:	Overview class
Wed 9/18:	Reading assignment and prepare for discussion (Lyra).
Fri 9/20:	Section
Sun 9/22:	Assignment #3 due.
Mon 9/23:	Overview class
Wed 9/25:	Reading assignment and prepare for discussion (Orion).
Fri 9/27:	Section
Sun 9/29:	Assignment #4 due.
Mon 9/30:	Overview class
Wed 10/2:	Reading assignment and prepare for discussion (Andromeda).
Fri 10/4:	Section
Sun 10/6:	Assignment #5 due.
Mon 10/7:	Overview class
Wed 10/9:	Reading assignment and prepare for discussion (Cygnas).
Fri 10/11:	Section
Sun 10/13:	Assignment #6 due.
Mon 10/14:	NO CLASS
Wed 10/16:	Midterm
Fri 10/18:	No section this week
Sun 10/20:	No assignment due.
Mon 10/21:	Reading assignment and prepare for discussion (Lyra).
Wed 10/23:	Reading assignment and prepare for discussion (no group).
Fri 10/25:	Section
Sun 10/27:	Assignment #7

Mon 10/28:	Overview class
Wed 10/30:	Reading assignment and prepare for discussion (Orion).
Fri 11/1:	Section
Sun 11/3:	Assignment #8
Mon 11/4:	Overview class
Wed 11/6:	Reading assignment and prepare for discussion (Andromeda).
Fri 11/8:	Section
Sun 11/10:	Assignment #9
Mon 11/11:	Overview class
Wed 11/13:	Reading assignment and prepare for discussion (Cygnas).
Fri 11/15:	Section
Sun 11/17:	Assignment #10
Mon 11/18:	Overview class
Wed 11/20:	Reading assignment and prepare for discussion (Lyra).
Fri 11/22:	Section
Sun 11/24:	No assignment due
Mon 11/25:	Reading assignment and prepare for discussion (Orion).
Wed 11/27:	NO CLASS (Thanksgiving)
Fri 11/29:	No section (Thanksgiving)
Sun 12/1:	Assignment #11
Mon 12/2:	Reading assignment and prepare for discussion (all groups).
Wed 12/4:	NO CLASS
Fri 12/6:	NO SECTION
Fri 12/6:	Assignment #12