Astronomy 436: Galaxies and Cosmology

Spring 2021 (3 credits) TuTh 2:50-4:05pm Online
Prerequisites: MATH 172 or 182; PHYSICS 202 or 206

Instructor: Dr. Matthew Duez

Office Location: Webster 947E
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Office hours: Wednesday 3-4pm

Textbooks

Required: *An Introduction to Modern Astrophysics* by Carroll and Ostlie

Student Learning Outcomes

This is a class about galaxies, black holes, and cosmology (the universe as a whole). Students will learn how astrophysicists use observation and theory to investigate these objects. One main goal will be learning to "think like an astronomer", i.e. to understand and apply the sort of reasoning that astronomers have used with such great success. They will become familiar with the observations and the physical laws (especially basic thermodynamics, kinetic theory, and general relativity) behind the conclusions of modern astrophysics. Students will learn to use order of magnitude timescale and energetic estimates to get at the heart of astrophysical problems.

To really have a sense of the state of a field of inquiry, one must not only grasp the core results of that field; one must also become aware of the current open questions, the current areas of active investigation. This brings us to the second goal: by the end of the semester, each student should be able to follow some current research in extragalactic astrophysics, as demonstrated by writing and presenting on some topic of contemporary investigation in relativistic, galactic, or cosmological astrophysics. (See below for details on this project.)

Grade Breakdown

Homeworks:	40%
Homework presentations	10%
Review paper and presentation	20%
Exam 1:	15%
Exam 2:	15%

Homework and homework presentations

There will be roughly one homework assignment per week. Homework will be distributed and submitted on the course blackboard page. At the beginning of class on the due day, a group of two students will present the solutions to the class. It is strongly recommended that the presenting students come to my office sometime before lecture (my office hour that week or by appointment) to check their work with me. Homework solution presentations are a non-negligible component of students' grades, as indicated above. After the presentation, attending students will be allowed to write a supplemental page to their homework listing things they think should be corrected in their original assignment. Depending on the quality of the supplement, students may recover up to 50% of the points they would have missed on the original assignment.

Exams

There will be two tests. Each one will be an oral exam, 20 minutes per student. A week before the test, a schedule spreadsheet with the instructor's available times will be made available, and students will fill in their preferences. Also, a study sheet will be provided, with a list of material covered and possible questions. The actual questions will be variations on the ones in the study sheet.

Final presentation and review

At the end of the semester, each student group will give a 15 minute presentation on some topic of its choosing (approved by the instructor) on galactic astronomy, relativistic astrophysics, or cosmology. The group will also submit a 3 page write-up with at least 4 references. At least two references should be peer-reviewed journal articles published after 2000. Nontechnical articles (e.g. *Scientific American*) may be references, but they don't count toward the two journal references. The textbook may count as one reference.

The written review should address all of the following. What question(s) are astronomers trying to answer? What is the recent major result(s)? How were the results obtained? How certain are the results? (Any untested assumptions?) What is still unknown? Any prospects for answering unanswered questions?

Intermediate Deadlines

Feb. 16: email the instructor your topic
March 9: email the instructor a list of reading materials
(Sources can be added/replaced later.)
March 30: email the instructor an outline
April 13: email the instructor a rough draft

Grade distribution

Below is a rough guide to how numerical grades will correspond to letter grades. I won't push the cutoffs up, but may push them a little bit down.

A	88-100%
B	75-87
C	63-74
D	50-62
F	< 50

Academic Integrity

Students may discuss and work together on assignments, but all submitted work must be original and individual. Academic dishonesty, including all forms of cheating, plagiarism, and fabrication, is prohibited as stated in the WSU Handbook. (See http://conduct.wsu.edu/.)

WSU Disability Statement

Reasonable accommodations are available for students with a documented disability. Please notify me the first week of class of any accommodations needed. Late notifications may cause requested accommodations to be unavailable. All accommodations must be approved through Disability Resource Center (DRC), Administration Annex 205, 335-1566.

WSU Safety

For WSU's general safety statements, see http://safetyplan.wsu.edu.
For current safety alerts, see http://alert.wsu.edu.
For advice on dealing with emergencies, see http://oem.wsu.edu/emergencies.

Course Synopsis

Unit 1: Galaxies

We start by reviewing how astronomers measure distances, speeds, and compositions. Then we study the Milky Way galaxy and discover evidence of the dark matter enveloping it and the black hole at its center. We then study the physics of galaxies and clusters in general, paying special attention to spiral arms, galaxy mergers, and the long-term evolution of star clusters.

Unit 2: Cosmology

The universe on its largest scales, particularly its expansion, is described using the tools of general relativity. The rate of expansion is related to the types and amounts of mass-energy (including the mysterious "dark energy") in the universe. Then we study the thermal/ compositional history of the universe, and in the process explain the cosmic microwave background and the relative abundance of hydrogen and helium. Finally, we consider the formation of structure (stars, galaxies, clusters) and speculate on the ultimate fate of the universe and its constituents.

Course Outline

Week	material	chapter in textbook	Assignment
1	celestial mechanics	2	
2	magnitude and color, H-R diagram	3	1
3	Milky Way galaxy	24	2
4	Galaxy morphology	25	3
5	dark matter, spirals	25	4
6	cluster relaxation, galaxy collisions	26	5
7	active galactic nuclei	28	exam 1
8	general relativity	17	6
9	cosmic expansion	29	7
10	Friedmann equation	29	8
11	horizons, distances	29	9
12	thermal history (BBN, CMB)	29	10
13	inflation, structure formation	30	
14	student presentations		exam 2