Astronomy 540: Structure & Dynamics of Galaxies

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1 Contact Information

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2 Course Description

This is a core graduate level class that reviews how galaxies form and evolve, from the first stars at redshifts $z > 10$ to massive disks such as the Milky Way today. We will study how the physical properties and physical conditions of galaxies change over time. Broadly speaking, the objects and related phenomena include: stellar birth and death as ensemble populations, super-novae, formation of supermassive black holes, star formation feedback mechanisms, emergence of the Hubble sequence of galaxies, environmental factors that influence galaxy evolution, and reionization of the intergalactic medium. We will also study specifics of the Milky Way galaxy and the dwarf satellites that surround it. As part of the class, students will implement their own semi-analytic model, which will include the physical processes necessary to go from dark matter halos to galaxies. The final course project will be to incorporate an extra physics module of your choice into your semi-analytic model and give a class presentation of the results. Classes will be structured around Python notebooks instead of the traditional lecture format.

This course was revised and re-introduced by Peter Behroozi and Brenda Frye a few years ago. Thanks to them for the workbook course structure and exercises.

3 Learning Outcomes

Upon successful completion of the course, a student will be able:

- to understand the physics relating to galaxy formation
- to understand papers and presentations on galaxy formation
- to learn how galaxies evolve, and how this depends on galaxy environment
- to learn the impact of galaxy feedback, from central AGN to supernovae
- to learn the epoch and process of the reionization of the IGM
- to learn about the formation and evolution of disk, elliptical and starburst galaxies
- to study the Milky Way and its surrounding satellites
- to be more proficient at programming in Python to work through the problem sets
- to construct a model to explore galaxy evolution in dark matter halos
- to discuss in-class topics relevant to each week's Python notebook assignment
- to present an independent project at the end of the term in front of the class

These learning outcomes will be met through the attendance of lectures, writing assignments, problem sets, an independent galaxy modeling project, and in-class discussions.

4 Grades

Your final course grade will come through assessments of the regular Workbook assignments(70%) and the final project plus presentation to the class (30%). The Workbook assignments can be done independently, or with a partner. If working with a partner, then it is expected that each student show the work independently. If you have a true emergency and cannot attend the final presentation of your project, please contact us immediately with documentation.Workbook grades will be based in part on demonstrated effort, completion & correctness of the results, and on clarity/accessibility of presentation, including documentation of any code, aesthetics and clarity of figures, etc. We may discuss especially clear (and reserve the right to discuss especially unclear) submissions in class anonymously, so that everyone can learn by example.

5 Recommended Text Book

Mo, van Den Bosch & White (2010). Do not need to purchase for course.

6 Starting Out

Equipment and software requirements: For this class you will need daily access to the following hardware: computer (laptop since you will bring it to class); regular access to reliable internet signal; ability to download and run the following software: web browser, zoom (perhaps), slack, python, jupyter.

7 Lectures

The lectures will chiefly involve providing the background material for working through provided Python notebooks. Attending the lectures is strongly encouraged, and it will be mandatory to bring your laptop with you to each class. If you know that you will be away at some point in the semester, please let us know in advance so we can accommodate you.

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.

8 Workbooks

The Python notebooks will include problem sets at the end, which will be posted in advance of each week on our course website. You are allowed to work in groups to share ideas, but all code, figures, and write-ups must be your own. Problem sets will be due on the Monday following the scheduled end of completion of the workbook unit. If there is a true emergency, then please let us know as soon as possible so we can help you.

9 Galaxy Modeling Project

A significant fraction of the course grade will be to add an independent module to the galaxy formation model that you develop during the course. This will be on an aspect of your choice, and can either represent improved physics compared to the class implementation or an entirely new calculation. We will mention opportunities for both during the class, but you are also welcome to choose an entirely different topic (e.g., galactic planet formation rates). This project will consist of:

• 40%: A 4-page science write-up, with 1 page each spent on introduction/motivation(i.e., why it's interesting to add the module and what you expected to learn from it),a description of the method/equations that you used, comparison with observations or theoretical expectations, and discussion of how the module could be improved in the future. This write-up should include embedded references.

• 50%: A 10-minute in-class presentation covering the same topics (intro, methods, comparison, future).

• 10%: Documented code for your implementation. For each item, half of the grade will come from completeness/accuracy of content, and half will come from clarity/accessibility of that content. (Remember, no-one will care about how great a scientist you are if they can't understand you!)

10 Schedule

Week	Dates	Topics
1	August 24, 26	Syllabus, Workbook 1 (Dark Matter & Halo Trees)
2	August 31, Sept. 2	Workbook 1 (Cont'd) & Workbook 2 (Cooling & Gas Infall)
3	September 7, 9	Workbook 2 (Cont'd) & Workbook 3 (Star Formation in Galaxies)
4	September 14, 16	Workbook 3 (Cont'd) & Workbook 4 (Intergalactic Medium and Feedback)
5	September 21, 23	Workbook 4 (Cont'd.))
6	September 28, 30	Workbook 5 (Black Holes & AGN)
7	October 5, Oct. 7	Workbook 6 (Satellites)
8	October 12*, 14*	Stellar Dynamics
9	October 19, 21	Workbook 7 (Shaping Galaxies)
10	October 26, 28	Workbook 8* (Galaxy Clusters)
11	November 2, 4	Workbook 9 (Ensemble Stellar Populations)
12	November 9	Workbook 10 (Classical Galactic Structure & Dynamics)
13	November 16, 18	Workbook 11* (Milky Way & Gaia)
14	November 23	Review and Discussion
15	Nov. 30, Dec. 2	Review & Final project presentations
16	December 7	Final Project Presentations

11 Academic Honesty

We follow the policies outlined in the Dean of Students code of academic integrity, including cases of plagiarism and cheating (see http://deanofstudents.arizona.edu). We encourage you to work with your peers on the Workbooks. Such collaborations can include a discussion of the qualitative concepts and on the quantitative aspects (i.e., whether you get the same conclusions),but in the end you must do your own work. Academic honesty also extends to printed texts,websites, and video content. If an assignment even only appears to be copied from someone else,or copied from a source without a reference, or copied from a referenced source and only a few words changed, then the assignment will be assumed to be plagiarized. We will give a grade of"F" for the assignment, and further to that the Dean may assign a grade of "F" for the course and/or pursue a more stringent repercussion.

12 Attendance and Classroom Etiquette

Students are expected to attend all lectures. Please turn off cell phones in class, and refrain from extraneous talking, distracting/discourteous behavior, distracting use of laptops/cellphones, and coming late and/or leaving early.

The UAs policy concerning Class Attendance, Participation, and Administrative Drops is available at:
http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable,
http://policy.arizona.edu/human-resources/religious-accommodation-policy

Absences pre-approved by the UA Dean of Students (or their designee) will be honored,
https://deanofstudents.arizona.edu/absences

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See
http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students

The University is committed to creating and maintaining an environment free of discrimination; **http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy**

13 Assistance

We are here to help you, so please take advantage of office hours. Please contact us promptly if you have any questions or concerns regarding this class. The University of Arizona provides a wide variety of resources to help you feel more at home in the UA environment. Examples of student resource/cultural centers include:

- The African-American Student Affairs Center
- The Asian & Pacific American Student Affairs Center
- The Guerrero Student Center
- The Immigrant Student Resource Center
- The LGBTQ+ Student Affairs Center
- The Native American Student Affairs Center
- The Transfer Student Center
- The Veterans Education and Transition Services Center
- The Women Gender Resource Center

We encourage you to take advantage of the community, support, and learning opportunities afforded by these centers, and to encourage your friends and colleagues to do the same.

Accessibility and Accommodations: At the University of Arizona, we strive to make learning experiences as accessible as possible. If you anticipate or experience barriers based on disability or pregnancy, please contact the Disability Resource Center (520-621-3268, https://drc.arizona.edu) to establish reasonable accommodations and the let me know as well.

14 COVID Related Text

This class is scheduled to be taught in the IN-PERSON modality. UArizona COVID guidelines are an evolving mess - see **https://covid19.arizona.edu/** for the latest.

Life challenges: If you are experiencing unexpected barriers to your success in your courses, please note the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office can be reached at 520-621-2057 or DOS-deanofstudents@email.arizona.edu. Physical and mental-health challenges: If you are facing physical or mental health challenges this semester, please note that Campus Health provides quality medical and mental health care. For medical appointments, call (520-621-9202. For After Hours care, call (520) 570-7898. For the Counseling & Psych Services (CAPS) 24/7 hotline, call (520) 621-3334.