ASTRON 1121: Galaxies and Cosmology
Course Syllabus

Revised August 11, 2025

Basic Course Information

Term: 2261 (Fall 2025-2026)
Credits: 3
Prerequisites: ASTRON 0113 or 0413, and MATH 0240 and (MATH 1270 or MATH 0290 or MATH 0250)
Corequisites: PHYS 0477 or 0479
Meeting Time: Tuesdays and Thursdays 11:00 to 12:15 PM, **Chevron 132**.

Instructor

Prof. Carles Badenes
Office: 309 Allen Hall
Office Hours: Tue 3-4 PM, Wed 2-3 PM (or by appointment)
Email: badenes@pitt.edu (email is generally the best way to contact me)
Website: https://carlesbadenes.github.io/

Background I am a Professor at the Department of Physics and Astronomy at the University of Pittsburgh. I hold a Ph D in astrophysics, and my research specialty is stellar evolution, in particular supernova explosions.

Goals My main goal is to work with students to make this course engaging, interesting, and fun. Do not hesitate to contact me with **any** questions or concerns, either by email or by coming to office hours. I need your feedback in order to improve your learning experience! Please let me know if you have issues with the course material, or you would like me to cover some topic that you are particularly interested in. Of course, I have to abide by University and Department rules and I have to work within the Physics and Astronomy curriculum, so I cannot accommodate all requests, but I will do my best. I am looking forward to a great semester!

Logistics I will hold regular office hours on Tuesdays between 3 and 4 PM, and Wednesdays between 2 and 3 PM in 309 Allen Hall. If you cannot make these times, please contact me and we can arrange to meet at another time. If you need further help or would prefer to seek help from a tutor, the Department of Physics and Astronomy maintains a Physics Resource Room that is staffed by tutors between 9 AM and 5 PM on weekdays throughout the semester. Please take advantage of this service.

Course Description

This course is an **introduction to the study of galaxies and cosmology at an advanced undergraduate level**. These fields have advanced greatly in recent years; we will use state-of-the-art datasets to explore the properties of galaxies and the nature of the expanding Universe. We will begin by establishing a cosmological framework for the study of galaxies, then explore the properties of our own galaxy, the Milky Way, move on to the study the formation and evolution of galaxies in general, and conclude by exploring current constraints on models of the Universe now and in the future.

The course is designed as a complement to ASTRON 1120 (Stars, Stellar Structure, and Stellar Evolution), ASTRON 1122 (Solar System and Exoplanets), and ASTRON 1263 (Techniques of Astronomy). Together, these four advanced courses are meant to provide a solid background in undergraduate astrophysics, and they should be a good preparation for students interested in applying to a graduate program in astrophysics.

Note that ASTRON 0113/0413 (Introduction to Astrophysics) is **a prerequisite** for this course. I will assume that you are broadly familiar with the material covered in ASTRON 0113/0413.

Learning Objectives

This course has two primary objectives:

1. To provide a basic introduction to galaxies and cosmology, with sufficient grounding to engage in undergraduate research in these fields.
2. To develop skills in exploring astronomical data and solving problems using the Python programming language.

At the end of the course, you should be able to explain, among other things:

- How the Milky Way Galaxy, which we live in, is similar to (or different from) other galaxies.
- Where galaxies come from and how they may transform amongst types.
- Why we believe that many galaxies have black holes at their center.
- What the main constituents of the Universe are.
- How the Universe began and what its ultimate fate will be.
- How the Universe has grown and changed over time.
- How to perform basic calculations, file input/output, and plotting in the Python programming language.

Textbook

Extragalactic astrophysics is a mature subject, and several excellent textbooks are available that cover most of the course topics, as well as many aspects that we will not see in detail. We will use Extragalactic Astronomy and Cosmology: An Introduction, by Peter Schneider (Springer, Second Edition, 2015) throughout the course. **The e-book is available for free via SpringerLink to anyone with a Pitt login**. You can also purchase a hardcover/paperback version, if you prefer (∼$80) (though frankly, the book's many images are reproduced in higher quality on a laptop display than in print).

We will also use the e-book Python for Astronomers, by Imad Pasha and Chris Agostino, as a reference for scientific programming and data manipulation.

If you need to review any general concepts in astronomy, I recommend *Astrophysics in a Nutshell* by Dan Maoz (Princeton, Second Edition, 2016). This is an excellent, concise review of the fundamental physics at the basis of many fields of astrophysics.

Grading Policy

There will be between 5 and 10 problem sets due throughout the course of the semester, as well as a midterm exam that will be given during class, and a cumulative final exam that will take place during finals week. There will also be group assignments in the form of Python notebooks throughout the semester. These items will be weighted as follows:

- **50%** for the homework assignments.

- **20%** for the midterm exam on October 16.
- **20%** for the final exam on finals week.
- **10%** for the group assignments.

Arrangements for make-up exams must be made well in advance of the exam. Acceptable excuses for missing an exam include being out of town for a verified University-related activity or illness. If you miss an exam for any reason, be prepared to provide a signed letter from your doctor, from the University health service, or from your coach or person responsible for the University-related activity.

In all assignments, the focus will be on showing the correct reasoning. **NO CREDIT** will be given for a correct answer without the reasoning being clearly explained. A great deal of the credit for a problem may be given if the reasoning is correct, but the numerical answer is incorrect for one reason or another. To get full credit for a problem, you must give a complete explanation of your reasoning. Occasionally, you may find an answer that is obviously incorrect. For example, say you derived the distance to the Sun to be three miles. In such a situation, you can still get partial credit for the problem simply by recognizing that the answer obviously does not make sense and explaining why the answer is manifestly incorrect. **NO CREDIT** will be given for an answer that has incorrect units unless you comment on the fact that your answer is wrong and take a guess where you may have gone wrong. For example, if you expect an answer that should have units of length (inches, meters, miles, etc.) but give an answer of 25 seconds you will get no credit unless you comment on this. Finally, your work must be legible. **NO CREDIT** will be given for work that I find illegible. One way to prevent this is to submit your answers as a typeset document. **NO CREDIT** will be given if I find it difficult to follow the sequence of steps in your reasoning. Your work must flow sequentially from left to right across the page and from the top to the bottom of the page. It is your responsibility, and yours alone, to make sure that your work is legible and orderly.

You may discuss the problems on homework sets with other students, but the solutions you hand in must be your original work. Homework should be turned in by the beginning of class on the day that assignments are due. Late homework will be accepted with the grade reduced by 10% for each 24 hour period elapsed since the due date, unless I have approved an extension. I will post all solutions to problem sets approximately a week after the due date. Once I have posted the solutions on Canvas, no late credit may be obtained for that assignment.

Tentative Course Schedule

Here is a rough outline of what will be covered in ASTRON 1121, with a reference to the corresponding chapters in the Schneider textbook (e.g., [Sch 1] = Schneider, Chapter 1). This plan may be modified according to student interests, to accommodate questions that may arise during the course, and to adapt to the pace at which we proceed. For reference, the official Academic Calendar can be found here.

Week 1: Aug 26, 28	Introduction to the Course. Basics of galaxies and cosmology [Sch 1]
Week 2: Sep 2, 4	The Milky Way. Magnitudes and Distances. Color [Sch 2]. **Diagnostic Test due**. *Add/drop period ends Sep 5*
Week 3: Sep 9, 11	Milky Way Structure [Sch 2]. Introduction to Python. **Homework 1 due**. *Extended add/drop period ends Sep 12*
Week 4: Sep 16, 18	Milky Way Structure continued [Sch 2]. Plotting in Python. **Homework 2 due**.
Week 5: Sep 23, 25	Milky Way Kinematics. The Galactic Center [Sch 2]. Interpolation and integrals in Python.
Week 6: Sep 30, Oct 1	Other Galaxies [Sch 3]. **Homework 3 due**.
Week 7: Oct 7, 9	Galaxy Populations and Scaling Relations [Sch 3]. **Homework 4 due**.
Week 8: Oct 14, 16	Exploring the SDSS database. **MIDTERM: OCTOBER 16**.
Week 9: Oct 21, 23	Galaxy Groups and Clusters [Sch 6], Active Galactic Nuclei [Sch 6]. *Monitored withdrawal deadline is Oct 24*

Week 10: Oct 28, 30	Basic Cosmology: the Friedmann equations [Sch 4]. **Homework 5 due**.
Week 11: Nov 4, 6	Basic Cosmology: Distances, Thermal History of the Universe, the Big Bang [Sch 4]. **Homework 6 due**.
Week 12: Nov 11, 13	Large Scale Structure of the Universe [Sch 7].
Week 13: Nov 18, 20	Measuring Cosmological Parameters [Sch 8]. **Homework 7 due.** *Thanksgiving Recess: Nov 23-30*
Week 14: Dec 2, 4	Galaxy Evolution [Sch 10].
Finals Week	**FINAL EXAM:**

Canvas

ASTRON 1121 will be hosted in the Canvas Learning Management System (LMS). To get started with Canvas, go to https://canvas.pitt.edu. This link appears on my.pitt.edu but you may wish to bookmark it. Log in with your Pitt User ID and password, and click on the course card for this class.

To aid in your use of Canvas, I suggest familiarizing yourself with the LMS through the short, helpful Canvas Student Tour video series, which you can find here. I also encourage you to try the Canvas mobile app for Android and iOS devices. The full Canvas student guide can be found here.

If you experience any issues using Canvas, you can click the Help button within Canvas, which includes 24/7 chat or telephone support. If you are having issues logging in to Canvas, call the University Help Desk at 412-624-HELP [4357].

The Department of Physics and Astronomy

As students at the University of Pittsburgh, you have access to a Physics and Astronomy Department that is highly recognized and is performing world-class research. The Department of Physics and Astronomy wants you to feel welcome. If you are interested in further study of or research in physics or astronomy please talk to me or any other faculty member.

The Department of Physics and Astronomy provides free assistance for all students. The **Physics Exploration Center** allows students to operate some simple experiments and demonstrations. Within the Exploration Center is the **Physics Resource Room**, staffed with TAs who can answer homework related questions, explain basic concepts and help you with the math. This is a free service and you are encouraged to use it. The Physics Exploration Center and the Physics Help Room are both located in Allen 509, and a detailed schedule is posted here. In addition, tutoring is available through the Academic Support Center (WPU 311). You may also make use of the undergraduate lounge off of the mail room on the second floor of the Old Engineering Hall. This is a good place to meet with classmates to discuss problem sets and course material. You might also meet physics and astronomy majors here that can help you, discuss other classes with you, or inform you about the major program. The Department hosts a donut and coffee hour every Wednesday at 4PM, which is designed to encourage discussion. The Astrophysics group within the Department hosts seminars on topics of current interest in astronomy and astrophysics every other Friday at noon. The talks are typically at an advanced level, but eager students can learn a great deal about contemporary astronomy and astrophysics by attending. You can find the talk schedule in the Department web site, www.physicsandastronomy.pitt.edu. We also hold bi-weekly coffee discussions on several astronomy-related topics that are regularly attended by faculty, graduate students, and undergraduate students who are completing guided research projects in the astronomy group. Please ask me to provide you with updated information about these events if you want to attend.

Course Policies

Medical Absences

Unless you are going to miss a substantial number of lectures, there is no need to let me know about absences for medical or personal reasons or due to athletic events.

Academic Integrity

Students in this course will be expected to comply with the University of Pittsburgh's Policy on Academic Integrity. Any student suspected of violating this obligation for any reason during the semester will be required to participate in the procedural process, initiated at the instructor level, as outlined in the University Guidelines on Academic Integrity. This may include, but is not limited to, the confiscation of the examination of any individual suspected of violating University Policy. Furthermore, no student may bring any unauthorized materials to an exam, including dictionaries and programmable calculators.

To learn more about Academic Integrity, visit the Academic Integrity Guide for an overview of the topic. For hands- on practice, complete the Academic Integrity Modules.

No Use of Generative AI Permitted

Intellectual integrity is vital to an academic community and for my fair evaluation of your work. All work completed and/or submitted in this course must be your own, completed in accordance with the University's Guidelines on Academic Integrity. You may not engage in unauthorized collaboration or make use of ChatGPT or any other generative AI applications at any time.

Disability Services

If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact both your instructor and Disability Resources and Services (DRS), 140 William Pitt Union, (412) 648-7890, drsrecep@pitt.edu, (412) 228-5347 for P3 ASL users, as early as possible in the term. DRS will verify your disability and determine reasonable accommodations for this course.

Civil Rights and Title IX

The University of Pittsburgh does not tolerate any form of discrimination, harassment, or retaliation based on disability, race, color, religion, national origin, ancestry, genetic information, marital status, familial status, sex, age, sexual orientation, veteran status or gender identity or other factors as stated in the University's Title IX policy. The University is committed to taking prompt action to end a hostile environment that interferes with the University's mission. For more information about policies, procedures, and practices, visit the Civil Rights & Title IX Compliance web page.

I ask that everyone in the class strive to help ensure that other members of this class can learn in a supportive and respectful environment. If there are instances of the aforementioned issues, please contact the Title IX Coordinator, by calling 412-648-7860, or e-mailing . Reports can also be filed online. You may also choose to report this to a faculty/staff member; they are required to communicate this to the University's Office of Institutional Engagement and Wellbeing. If you wish to maintain complete confidentiality, you may also contact the University Counseling Center (412-648-7930).

Your Well-being Matters

College can be an exciting and challenging time for students. Taking time to maintain your well-being and seek appropriate support can help you achieve your goals and lead a fulfilling life. It can be helpful to remember that we all benefit from assistance and guidance at times, and there are many resources available to support your well-being while you are at Pitt. You are encouraged to visit Thrive@Pitt to learn more about well-being and the many campus resources available to help you thrive.

If you or anyone you know experiences overwhelming academic stress, persistent difficult feelings and/or challenging life events, you are strongly encouraged to seek support. In addition to reaching out to friends and loved ones, consider connecting with a faculty member you trust for assistance connecting to helpful resources.

The University Counseling Center is also here for you. You can call 412-648-7930 at any time to connect with a clinician. If you or someone you know is feeling suicidal, please call the University Counseling Center at any time at 412-648-7930. You can also contact Resolve Crisis Network at 888-796-8226. If the situation is life threatening, call Pitt Police at 412-624-2121 or dial 911.