ASTRON 1120: Stars, Stellar Structure and Stellar Evolution
Course Syllabus

Revised August 28, 2023

Basic Course Information

Term: 2241 (Fall 2023-2024)
Credits: 3
Prerequisites: ASTRON 0113 or 0413, and MATH 0240 and (MATH 1270 or MATH 0290 or MATH 0250)
Corequisites: PHYS 0477 or 0479 and PHYS 0111 or 0175, or 0476
Meeting Time: Tuesdays and Thursdays 11:00 to 12:15 PM, **Thaw 104**.

Instructor

Prof. Carles Badenes
Office: 309 Allen Hall
Office Hours: Monday & Tuesday 2:00 to 3:00 PM (or by appointment)
Email: badenes@pitt.edu (email is generally the best way to contact me)
Website: https://carlesbadenes.github.io/
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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 Mondays and Tuesdays between 2:00 and 3:00 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 and Rationale

This course is an **introduction to the study of stars at the advanced undergraduate level**. We will use state-of-the-art astronomical datasets and theoretical models to explore the fundamental properties of stars, their internal structure and evolution, their interaction with the interstellar medium, and their contribution to the global properties of galaxies. The course is designed as a complement to ASTRON 1121 (Galaxies and Cosmology), 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 ASTRON0113/0413.

Learning Objectives

The primary learning objectives of this course are twofold:

1. To provide a basic knowledge of stellar astrophysics, with sufficient grounding to engage in undergraduate research in this field.
2. To develop skills in exploring astronomical data, understanding astronomical models, and using them to solve practical problems in astrophysics.

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

- The basic properties of stars.
- The fundamental physical processes that determine these basic properties, through a working knowledge of the equations of stellar structure.
- The fundamental features of stellar evolution, and its relation to binary interactions, stellar transients and explosions, compact objects (white dwarfs, neutron stars, and black holes), and the chemical evolution of galaxies.
- The basic properties of stellar populations and their relation to the properties of galaxies.

Textbook

Stellar 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. A good textbook at the advanced undergraduate level is *Stars and Stellar Processes*, by Guidry (Cambridge, 2019), which I will use throughout the course, but I will also draw material from the lecture notes by Onno Pols (available at http://astro.ru.nl/~onnop/education/stev_utrecht_notes/) and Ed Brown (available at https://web.pa.msu.edu/people/ebrown/docs/stellar-notes.pdf). I recommend you download these lecture notes and keep them handy for reference.

If you want to pursue the study of stellar astrophysics on your own, you should probably buy a published graduate level textbook. The most popular one is the classic *Stellar Structure and Evolution*, by Kippenhahn & Weigert (Springer, 1996), on which the Pols notes are based, but it is a bit formal and outdated. Other good books in the 'classic' tradition are *Principles of Stellar Evolution and Nucleosynthesis* by Clayton (Chicago, 1968) and *Stellar Interiors* by Hansen, Kawaler, and Trimble (Springer, 2004). More updated textbooks have been published by Iben (*Stellar Evolution*, Cambridge, 2013, two volumes), Prialnik (*Theory of Stellar Structure and Evolution*, Cambridge 2009), and Pinsonneault and Ryden (*Stellar Structure and Evolution*, Cambridge 2023).

If you need to review any general concepts in astronomy, I recommend *Astrophysics in a Nutshell* by Maoz (Princeton, 2007). This is an excellent, concise review of the fundamental physics at the basis of many fields of astrophysics.

Assessment and Grading Information

The grading policy for undergraduate classes at the Department of Physics and Astronomy states that the final letter grade should reflect the mastery of the learning objectives demonstrated by each student. The final grade will be calculated from a direct assessment of these learning objectives through the students' answers to the assignments and their performance on the final project, according to these percentages:

- **60%** for the course assignments.
- **30%** for the final project.
- **10%** discretionary, to reward class participation.

A final letter grade of C or higher will indicate a satisfactory performance in the course, while a grade of C- or lower will indicate an unsatisfactory performance.

Tentative Course Schedule

Here is a rough outline of what will be covered in ASTRON 1120. This plan may be modified according to student interests, to accomodate 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 at https://www.provost.pitt.edu/students/academic-calendar.

Week 1: Aug 29, 31	Introduction to the Course. Overview of stellar astrophysics. Diagnostic test. Assignment 1 (A1) in class, Aug 31
Week 2: Sep 5, 7	Physical Properties of Stars (*Guidry* Ch.1 and/or *Pols* Ch. 1). **A1 due Sep 7**, A2 in class Sep 7 *Add/drop period ends Sep 8*
Week 3: Sep 12, 14	Equations of Stellar Structure: Basic Formulation. Hydrostatic Equilibrium. (*Pols* Ch. 2) *Extended add/drop period ends Sep 15*
Week 4: Sep 19, 21	Equation of State and Energy Transport (*Pols* Ch. 3 and 5)
Week 5: Sep 26, 28	Thermonuclear Reactions (*Pols* Ch. 6)
Week 6: Oct 3, 5	Stellar Evolution: star formation, main sequence, Red Giant Branch
Week 7: Oct 10, 12	Stellar evolution after the RGB: low-mass and high-mass stars
Week 8: Oct 17, 19	Compact objects: White Dwarfs, Neutron Stars and Black Holes. Core Collapse Supernovae
Week 9: Oct 24, 26	Binary Interactions. Mass Transfer and Accretion. Thermonuclear explosions: Novae and Type Ia Supernovae *Monitored withdrawal deadline is Oct 27*
Week 10: Oct 31, Nov 2	Chemical Enrichment
Week 11: Nov 7, 9	Stars in galaxies: Stellar Populations
Week 12: Nov 14, 16	Special Topics *Thanksgiving Recess: Nov 19-27*
Week 13: Nov 28, 30	Special Topics
Week 14: Dec 5, 7	Final Project Presentations

Canvas

ASTRON 1120 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 Thaw 312, 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 doughnut 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 or quizzes, 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 Understanding and Avoiding Plagiarism tutorial.

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.

Equity, Diversity, and Inclusion

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 https://www.diversity.pitt.edu/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 titleixcoordinator@pitt.edu. Reports can also be https://www.diversity.pitt.edu/civil-rights-title-ix-compliance/make-report/report-form. You may also choose to report this to a faculty/staff member; they are required to communicate this to the University's Office of Diversity and Inclusion. If you wish to maintain complete confidentiality, you may also contact the University Counseling Center (412-648-7930).

Health and Safety Statement

During this pandemic, it is extremely important that you abide by the public health regulations, the University of Pittsburgh's health standards and guidelines, and Pitt's Health Rules. These rules have been developed to protect the health and safety of all of us. The University's requirements for face coverings will at a minimum be consistent with CDC guidance and masks are required indoors (campus buildings and shuttles) on campuses in which COVID-19 Community Levels are High. This means that when COVID-19 Community Levels are High, you must wear a face covering that properly covers your nose and mouth when you are in the classroom. If you do not comply, you will be asked to leave class. It is your responsibility to have the required face covering when entering a university building or classroom. Masks are optional indoors for campuses in which county levels are Medium or Low. Be aware of your Community Level as it changes each Thursday. Read answers to frequently asked questions regarding face coverings. For the most up-to-date information and guidance, please visit the Power of Pitt site and check your Pitt email for updates before each class.

If you are required to isolate or quarantine, become sick, or are unable to come to class, contact me as soon as possible to discuss arrangements.

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.