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

Revised August 31, 2021

Basic Course Information

Term: 2221 (Fall 2021)
Credits: 3
Prerequisites: ASTRON 0113 or 0413, 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 (3rd floor)
Office Hours: Mondays 3 to 4 PM, Thursdays 2 to 3 PM (or by appointment)
Email: badenes@pitt.edu (email is generally the best way to contact me)
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Office Phone: (412) 624-9039

Background I am a member of 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 3:30 and 4:30 PM and Thursdays between 2:30 and 3:30 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 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.

Course Objectives

The primary goals 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.

Course Structure

Physics and Astronomy education research has found in recent years that the most lasting learning comes not from lectures, but from active engagement with material. This course will employ techniques that have proved effective in the past, in particular group problem-solving. I expect that a significant fraction of class time will be devoted to working together in groups of 3 or so students to solve problems or explore astronomical data sets. **Students are expected to have read the relevant sections of the textbook or online readings (listed on Canvas) before class.** The course lectures and activities are a supplement to the textbook, not a replacement for it. The goal is not for you to understand everything after reading, but you should come to class ready to ask questions about the parts that are unclear!

Canvas

The course 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. Our class materials will not be available in Blackboard (CourseWeb), only in Canvas.

To aid in your use of Canvas, I suggest familiarizing yourself with the new 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].

Course Grades

The final course grade will be calculated in the following way:

- 60% for course assignments.
- 30% for a final project.
- 10% discretionary to award class participation.

Assignments: There will be 6-7 assignments during the semester. The assignments will usually have a preliminary section to be completed before class, an in-class section to be completed during class in groups, and an assignment section with deliverable results that should be submitted by each student before the beginning of class on the due date.

Students are allowed (and encouraged) to collaborate in finding the solutions to assignments, but each student should present their own reasoning and plots, and write up their own solution. The focus will be on having the correct reasoning, and **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. 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.

Final Project: This will be a longer assignment, with intermediate milestones to be completed and a final report to be submitted by the end of the course. I will give you a choice of several topics for final projects, but I encourage you to propose your own.

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) and Prialnik (*Theory of Stellar Structure and Evolution*, Cambridge 2009).

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.

Tentative Calendar

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 31, Sep 2	Introduction to the Course. Overview of stellar astrophysics. Assignment 1 (A1) in class, Sep 2
Week 2: Sep 7, 9	Physical Properties of Stars (*Guidry* Ch.1 and/or *Pols* Ch. 1). A1 due Sep 9, A2 in class Sep 9 *Add/drop period ends Sep 10*
Week 3: Sep 14, 16	Equations of Stellar Structure: Basic Formulation. Hydrostactic Equilibrium. (*Pols* Ch. 2) *Extended add/drop period ends Sep 17*
Week 4: Sep 21, 23	Equation of State and Energy Transport (*Pols* Ch. 3 and 5)
Week 5: Sep 28, 30	Thermonuclear Reactions (*Pols* Ch. 6)
Week 6: Oct 5, 7	Stellar Evolution: star formation, main sequence, Red Giant Branch
Week 7: Oct 12, 14	Stellar evolution after the RGB: low-mass and high-mass stars
Week 8: Oct 19, 21	Compact objects: White Dwarfs, Neutron Stars and Black Holes. Core Collapse Supernovae
Week 9: Oct 26, 28	Binary Interactions. Mass Transfer and Accretion. Thermonuclear explosions: Novae and Type Ia Supernovae *Monitored withdrawal deadline is Oct 29*
Week 10: Nov 2, 4	Chemical Enrichment
Week 11: Nov 9, 11	Stars in galaxies: Stellar Populations
Week 12: Nov 16, 18	Special Topics *Thanksgiving Recess: Nov 21-29*
Week 13: Nov 30, Dec 2	Special Topics
Week 14: Dec 7, 9	Final Project Presentations

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 Help 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.

Academic Integrity

The integrity of the academic process requires fair and impartial evaluation on the part of faculty and honest academic conduct on the part of students. To this end, students are expected to conduct themselves at a high level of responsibility in the fulfillment of the course of their study. It is the corresponding responsibility of faculty to make clear to students those standards by which students will be evaluated and the resources permissible for use by students during the course of their study and evaluation. The educational process is perceived as a joint faculty-student enterprise which will perforce involve professional judgment by faculty and may involveâĂŤwithout penaltyâĂŤreasoned exception by students to the data or views offered by faculty.

Cheating/plagiarism will not be tolerated. Students suspected of violating the University of Pittsburgh Policy on Academic Integrity, from the February 1974 Senate Committee on Tenure and Academic Freedom reported to the Senate Council, will be required to participate in the outlined procedural process as initiated by the instructor. A minimum sanction of a zero score for the quiz or exam will be imposed. For details, refer to the University Guidelines on Academic Integrity.

Code of Conduct

Communication is key to a productive learning environment, and we can maintain productive communication by exhibiting respect for one another. The success of the course for yourself and others depends on all of our commitment to behavior that demonstrates respect for differences, understanding towards others and a willingness to listen and learn. For these reasons, it is unacceptable to harass, discriminate against, or abuse anyone because of race, ethnicity, gender, disability, religious affiliation, sexual orientation, or age. If you you witness or are subject to such harassment, please report it to me or to the Office of Diversity and Inclusion

Title IX

Legal text: "No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance".

As a professor I am a mandatory reporter, and I am required to report violations of Title IX that I observe or am made aware of to the Title IX Office. Title IX violations include, but are not limited to, sexual harassment, sexual violence and verbal or sexual abuse. Within the classroom, behavior in violation might appear as: suggestive jokes or innuendos, inappropriate touching, and unwanted sexual behavior or advances, but my capacity and obligation to report does not end at the classroom.

Disabilities

If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact both me and the Office of Disability Resources and Services, 140 William Pitt Union, 412-648-7890/412-624-3346 (Fax), as early as possible in the term. Disability Resources and Services will verify your disability and determine reasonable accommodations for this course. For more information, visit www.studentaffairs.pitt.edu/drsabout.