

ASTR-5700: STELLAR ASTROPHYSICS

CU Boulder Syllabus (Spring 2022)

- Instructor:** Prof. Steven R. Cranmer (steven.cranmer@colorado.edu, 303-735-1265)
Office: Duane Physics D111, LASP/SPSC N218 (east campus)
- Course Times:** Mon., Wed., Fri., 9:05–9:55 am, Duane Physics room E126
- Course Web Page:** https://stevencranmer.bitbucket.io/ASTR_5700_2022/
- Office Hours:** TBD dates, times, & modes (in-person or virtual)

SUMMARY

Stars are the basic building blocks of the universe, and they are responsible for the production of most elements via nucleosynthesis. In this course, we will explore the physical principles that govern stellar interiors, evolution, and atmospheres, with the Sun and its heliosphere often being used as the closest and best-studied example of a star. The course will cover energy generation and transport in stars, principles of stellar structure, stellar rotation, pulsation, and evolution up to the supernova and compact object stages. The course will also include radiation transport in stellar photospheres, chromospheres, coronas, and winds. We will occasionally touch on topics in planetary science, especially in areas where the boundary lines between stars, brown dwarfs, and planets become somewhat ambiguous.

This course is an elective for APS graduate students. A definite pre-requisite is senior-level undergraduate physics. The catalog says that a recommended pre-requisite or co-requisite is Radiative and Dynamical Processes (ASTR–5120), but I won’t assume that students have taken it.

COURSE MATERIAL

The primary “required readings” are the lecture notes, which ought to contain everything discussed in class. They will be posted on the course web page as the semester progresses. The web page will also have a list of other books and lecture notes (many of which are available for free online) that are useful as supplements. I also recommend the following:

- *The Fundamentals of Stellar Astrophysics*, by George W. Collins II (originally published by W. H. Freeman in 1989; revised [online edition](#) published in 2003).
- *Stellar Structure and Evolution*, comprehensive [lecture notes](#) by Onno Pols from Utrecht University.
- The [Open Astrophysics Bookshelf](#) hosts a growing number of freely available textbooks on stellar physics, star formation, and astrophysical processes.

Please see me if you have any difficulty obtaining any of the recommended materials.

GRADING

The final course grade will be assembled from the following components:

Homework Problem Sets 1–5	50%
Take-Home Midterm Exam	15%
Participation in Biweekly Discussions	10%
Final Project & Presentation	25%

Each graded aspect of this course will be described in more detail below.

SCHEDULE OF TOPICS

The dates listed here for each set of topics are approximate. The web page will be kept up-to-date on the topics to be covered in each class session. The third column gives recommended readings for each topic, with book chapters referring to Collins (C) and Pols (P).

Introduction & Overview	Jan 10, 12	C1; P1
I. Stellar Interiors		
Thermodynamic properties of stellar gases/plasmas	Jan 14, 19, 21	C1,2; P2,3
Sources & sinks of energy	Jan 24, 26, 28; Feb 2	C3; P6
Energy transport from core to surface	Feb 2, 4, 7, 9, 11	C4; P5
Spherical stellar model interiors	Feb 14, 16, 18	C2,4; P4,7
Non-spherical effects: e.g., rotation	Feb 21, 23, 25	C7,8; P10
II. Stellar Evolution		
Star formation & pre-main-sequence evolution	Feb 25, 28; Mar 2, 4, 7, 9	C5; P9
MS & post-MS evolution	Mar 11, 14	C5; P10,11,12
Stellar death: supernovae & compact objects	Mar 16, 18, 28	P13
III. Stellar Atmospheres		
Radiative transfer & the full atmosphere problem	Mar 30; Apr 1, 4	C9,10,11
Non-LTE processes & spectral line diagnostics	Apr 6, 8, 11	C12,13,14
Chromospheres & coronal heating	Apr 11, 13, 15	—
Stellar winds	Apr 15, 18, 20, 22	—

CLASS PARTICIPATION

Once every two weeks (likely on Mondays) we will devote half a class to a recitation/discussion session that will be led mostly by student feedback. To prepare, there will be Canvas discussion boards where you will respond to specific prompts. In those responses, you can ask questions about the lectures or homework, point out steps you didn't understand, correct any errors of mine, or recommend cool/new/relevant papers you've seen on arXiv. Answering another student's question counts as a valid response, too. Over the semester, there will be 6 of these sessions, each with 3 to 4 prompts (so somewhere between 18 and 24 total prompts). To receive the full credit for this "participation" component of the course grade, each student will need to submit at least 15 individual responses.

HOMEWORK

There will be five primary homework assignments, each worth 10% of the course grade. A detailed schedule of distribution and due dates will be posted on the web page. Either hardcopy or online (Canvas) submission is fine, though if you choose the latter, please compile your submission into a single PDF. Problems will be due on the dates listed, but one late submission can be arranged if necessary (for a maximum delay of 1 week), as long as the arrangement is made at least 1 class prior to the due date. Other late problem sets will incur a penalty of a 5% lower grade per weekday that it is late. Submissions are no longer possible after answer keys are distributed (usually when graded homeworks are returned, about 1 week after the due date).

Four out of the five homeworks will be standard problem sets, and one will be more open-ended. In the latter, you can choose from several to-be-determined options, such as developing new hands-on tutorial activities (e.g., Jupyter notebooks), reviewing a relevant journal paper as if you're the referee, or crafting interesting new homework problems for this course.

MIDTERM EXAM

The format will be a take-home exam with problems having a similar scope as the homework problem sets; the primary difference being the **no-collaboration** aspect of an exam. Completed exams will be due one week after they are given to you, and exact dates will be given on the course web page.

FINAL PROJECT & PRESENTATION

There will also be a project that will count for 25% of the final grade. This will enable you to explore a chosen topic in a bit more detail and gain some extra experience with scientific writing and expressing your ideas in front of a group. The idea is to delve into a topic that's relevant to this course—and also goes well beyond the material discussed in class—and write a review paper. These kind of papers usually involve conveying the background (i.e., how did we come to understand the topic) and motivation (i.e., why is it relevant) to non-experts, as well as searching the literature to get a ~complete sense of chronological progress.

The written component of the project should end up around 2500 words (i.e., about 5 single-spaced pages or 10 double-spaced pages), not including the (required) bibliography. If you haven't learned L^AT_EX yet, this is a good opportunity. You will also prepare short presentations on what you have learned about this topic, and we will devote the last two days of class to hearing these presentations. Students can decide on whether their presentations will be high-tech (Powerpoint or Keynote) or low-tech (whiteboard only). The rest of the class will be encouraged to ask questions, request more in-depth derivations, and so on. Even if you have already taken your Comps exam, this kind of experience is valuable.

Additional information, including lists of possible topic ideas and deadlines, will be distributed during the semester. Please feel free to discuss possible topics with the instructor at any time.

ACADEMIC INTEGRITY

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu; 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the [Honor Code website](#).

For this course, I encourage you to discuss the assignments and topics with your fellow students. However, everything that is written up and submitted must be your own independent work. If you do collaborate with other students, a good time to split off from the group is when you start to write up your answers. If someone were to ask you questions about your work, you should be able to explain everything about how & why you did it the way you did.

ACCOMMODATION FOR DISABILITIES

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment, but please contact me to discuss how I can help even for conditions not on their list. Information on requesting accommodations is located on the [Disability Services website](#). Contact Disability Services at 303-492-

8671 or by email at dsinfo@colorado.edu for further assistance. If you have a temporary medical condition or injury, see the guidelines for [Temporary Medical Conditions](#) on the Disability Services website.

I try to provide a positive and supportive learning environment for everyone, and it's always helpful for me to hear what works best for you.

RELIGIOUS OBSERVANCES

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments, or required attendance. For full details, see the [campus policy regarding religious observances](#).

MISCONDUCT, DISCRIMINATION, HARASSMENT, AND/OR RETALIATION

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. The university will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or by email at cureport@colorado.edu. Information about university policies, [reporting options](#), and other support resources can be found on the [OIEC website](#). Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options. To learn more about reporting and support options for a variety of concerns, visit [Don't Ignore It](#).

PREFERRED STUDENT NAMES AND PRONOUNS

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

CLASSROOM BEHAVIOR

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on [classroom behavior](#) and the [Student Conduct & Conflict Resolution policies](#).

The policy of the Department of Astrophysical and Planetary Sciences is to ban any use of electronic devices (cellphones, tablets, laptops) in class except as an approved accommodation granted by Disability Services, or as explicitly authorized by the instructor. *In this course* I authorize the use of tablets and laptops for note-taking, but in-person students doing so must do their best to seat themselves with nobody behind them.

REQUIREMENTS FOR COVID-19

As a matter of public health and safety, all members of the CU Boulder community and all visitors to

campus must follow university, department, and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to [Student Conduct and Conflict Resolution](#). For more information, see the policy on [classroom behavior](#) and the [Student Code of Conduct](#). If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus.

CU Boulder currently requires masks in classrooms and laboratories regardless of vaccination status. This requirement is a precaution to supplement CU Boulder’s COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the [Public Health Office \(contacttracing@colorado.edu\)](#). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the [Public Health Office \(contacttracing@colorado.edu\)](#).