## ASTR–5700: STELLAR ASTROPHYSICS

CU Boulder Syllabus (Spring 2026)


**Instructor:** Prof. Steven R. Cranmer (steven.cranmer@colorado.edu)
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_2026/

**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 atmospheres, and (if there is time) the physics of chromospheres, coronas, and winds. We may occasionally touch on topics in planetary science, especially in areas where the boundary lines between stars, brown dwarfs, and planets become a bit ambiguous.

This course is a three-credit elective for APS graduate students. Strongly recommended pre-requisites include upper-level undergraduate astrophysics and electricity & magnetism (E&M). The catalog says that a recommended pre-requisite or co-requisite is Radiative & Dynamical Processes (ASTR–5120), but we won't assume 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. My web page will also provide a list of other books and lecture notes (many of which are available for free online) that are useful as supplements, and I'll also post all of these resources on Canvas, too. 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.

I will also provide a reference document with useful math formulas & physics units that you can use for all work in this class. 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 (5 Problem Sets) | 55% |
| Take-Home Midterm Exam | 15% |
| Class Participation | 5% |
| Final Project & Poster Session | 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. A corresponding page on Canvas will be kept up-to-date on the exact topics 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 9, 12 | C1; P1 |
| **I. Stellar Interiors** | | |
| Thermodynamic properties of stellar gases/plasmas | Jan 14, 16, 21, 23 | C1,2; P2,3 |
| Sources & sinks of energy in stars | Jan 26, 28, 30; Feb 2, 4 | C3; P6 |
| Energy transport from core to surface | Feb 6, 9, 11, 13 | C4; P5 |
| Spherical stellar model interiors | Feb 16, 18, 20, 23 | C2,4; P4,7 |
| Non-spherical effects: e.g., rotation, tides | Feb 25, 27 | C7,8; P10 |
| **II. Stellar Evolution** | | |
| Star formation & the interstellar medium | Mar 2, 4, 6 | C5; P9 |
| Pre-main-sequence stellar evolution | Mar 9, 11, 13 | C5; P9 |
| Main-sequence (MS) & post-MS evolution | Mar 23, 25, 27, 30 | C5; P10,11,12 |
| Stellar death: supernovae & compact objects | Apr 1, 3, 6 | P13 |
| **III. Stellar Atmospheres** | | |
| Radiative transfer & the full atmosphere problem | Apr 8, 10, 13 | C9,10,11 |
| Non-LTE processes & spectral line diagnostics | Apr 15, 17 | C12,13,14 |
| Overview of stellar winds & mass loss | Apr 20, 22 | TBD |

## HOMEWORK

There will be five problem-set homework assignments, each worth 11% of the course grade, that will involve combinations of analytic and computational exploration of the topics of this course. For problems that involve coding, feel free to use whatever programming languages or packages you're most comfortable with. On the web, I've posted some links to resources and tutorials for scientific computing with Python. Upon request, I can also provide example Jupyter notebooks for some topics from Math Methods (ASTR–5540) and Fluids (ASTR–5400).

Submitting these homeworks either on paper or electronically (on Canvas) is fine, though if you choose the latter, please compile your submission into a single PDF. When grading, I usually have each numbered problem be worth 10 points. Thus, if a given homework set has 4 problems, the grade will probably be listed in Canvas as out of 40 points. Only at the end of the semester will we "renormalize" each homework set to be worth (55% / 6) = 9.16667% of the total course grade.

Problems will be due on the dates listed, but one late submission can be arranged if necessary (for a maximum delay of one week), as long as the arrangement is made at least one 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).

## 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 that collaboration is not allowed for the 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 and Canvas.

## CLASS PARTICIPATION

For me, a perpetually unsolved problem is *"How does one assign grades for in-class engagement?"* for classes that do not use clickers or other straightforward ways of quantifying participation. I'm never going to take attendance in a graduate course, and it would be impossible (and a bit unfair) to count the number of times students raise their hands to ask questions in class. My current favorite solution to this problem is the following smörgåsbord approach, in which you can gather participation credit in a number of different ways. Each time you do any of the following things, you'll get one point:

- Come to Office Hours with specific course-relevant things to ask or chat about.
- Post a question (or any course-relevant thoughts) to the Canvas Discussion Board, or answer someone else's question in that forum.
- Ask a question in class that either: (a) kicks off an extended and lively discussion, or (b) requires me to go off and do some extra research to determine the answer.
- Actively work on one of the few in-class exercises that we we'll try to do (the dates of which I'll announce well in advance).

Repetitions in any category are allowed. Accumulate 5 points, and you've got full participation credit.

## FINAL PROJECT & POSTER SESSION

In lieu of a final exam, there will 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, scientific computing, and presenting your work in front of a group. The idea is for each student to identify a topic relevant to this course—which also goes well beyond the material discussed in class—and write a *review paper* on that topic. Papers like this usually involve: (a) conveying the background (i.e., how did we come to understand the topic) and motivation (i.e., why is it relevant) to non-experts, (b) doing a bit of literature-searching to get a ∼complete sense of chronological progress, and (c) demonstrating what you've learned by deriving a few equations, finding some relevant online data, and/or making a few plots. As a part of this project, students will also prepare conference-style posters to present during the final class session on April 24, 2026. The rest of the class (and any other members of the APS Department that we may invite to attend) will be encouraged to ask probing questions. More details about the written and poster components of this project will be provided soon. Please feel free to discuss ideas and potential topics with the instructor any time.

## ADDITIONAL GRADING NOTES

At the end of the semester, numerical scores from each of the four primary components will be summed up. Also, to account for the overall challenge level of the course, I usually add some number of extra (percentage) points to everyone's course totals. For example, some homework problems were honed from ones used in earlier courses, but many have been crafted for the first time. Thus, these extra points are a kind of compensation for you being "guinea pigs" on the brand-new subset of the coursework. Although this is not really a "curve" (because it doesn't depend on the relative distribution of grades) it does attempt to provide a corrective to aspects that may have been overly difficult. Once the extra points have been added, the conversion to letter grades will be done using the following standard CU system:

| | | | | |
|---|---|---|---|---|
| **A** (93 and up) | **A–** (90 to 93) | **B+** (87 to 90) | **B** (83 to 87) | **B–** (80 to 83) |
| **C+** (77 to 80) | **C** (73 to 77) | **C–** (70 to 73) | **D+** (67 to 70) | **D** (63 to 67) |
| **D–** (60 to 63) | **F** (below 60) | | | |

Please feel free to email, drop by Office Hours, or just chat informally after class, if you have questions.

## ACADEMIC INTEGRITY

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the Honor Code may include, but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), 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. Understanding the course's syllabus is a vital part in adhering to the Honor Code.

All incidents of academic misconduct will be reported to the Student Conduct & Conflict Resolution office (StudentConduct@colorado.edu). Students found responsible for violating the Honor Code will be assigned resolution outcomes from Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Visit Honor Code for more information on the academic integrity policy.

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. The APS Department also provides some additional guidance on coursework collaboration.

## CLASSROOM BEHAVIOR

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure 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 classroom behavior policy, the Student Code of Conduct, and the Office of Institutional Equity and Compliance.

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.

## ACCOMMODATION FOR DISABILITIES & MEDICAL CONDITIONS

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. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or 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.

## 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.

## MISCONDUCT, DISCRIMINATION, HARASSMENT, AND/OR RETALIATION

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits protected-class discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner abuse (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-campus. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who believe they have been subjected to misconduct can contact OIEC at 303-492-2127 or email 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 they are made aware of incidents related to these policies regardless of when or where something occurred. This is to ensure that individuals impacted receive outreach from OIEC about resolution options and support resources. To learn more about reporting and support resources for a variety of concerns, visit Don't Ignore It.

## 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.

## MENTAL HEALTH AND WELLNESS

The University of Colorado Boulder is committed to the well-being of all students. If you are struggling with personal stressors, mental health or substance use concerns that are impacting academic or daily life, please contact Counseling and Psychiatric Services (CAPS) located in C4C or call 303-492-2277. Free and unlimited telehealth is also available through Academic Live Care. The Academic Live Care site also provides information about additional wellness services on campus that are available to students.

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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. Have a great semester!