ASTR-5700: Stellar Astrophysics CU Boulder Course Syllabus (Spring 2018)

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Office: Duane Physics D111, LASP SPSC N218 (east campus)

Course Times: Mon., Wed., Fri., 9:00–9:50 am, Duane Physics room E126
Course web page: http://lasp.colorado.edu/∼cranmer/ASTR_5700_2018/
Office hours: By appointment or drop in.

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 astrophysics, 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

Primary material: Everything that will be discussed in class will be included in lecture notes posted on the course web page. However, it's always good to have an alternate resource. I highly recommend *The Fundamentals of Stellar Astrophysics,* by George W. Collins II (originally published by W. H. Freeman in 1989; revised online edition published 2003). This book is highly focused on theoretical aspects of stellar interiors and atmospheres, but it conveys the physics nicely. The full book is available in PDF format at http://ads.harvard.edu/books/1989fsa..book/

Supplementary material: Quite a few intrepid instructors have assembled book-length versions of their lectures that often rival published texts in their completeness (though they sometimes lack the benefits of professional editing). There will be links to PDF copies of several useful sets of notes on this course's web page. One of my favorites is *"Stellar Structure and Evolution"* by Onno Pols.

For additional browsing on several important topics, see:

- *Principles of Stellar Evolution and Nucleosynthesis,* Donald D. Clayton (U. Chicago Press, 1984)
- *Stellar Atmospheres,* Dimitri Mihalas (W. H. Freeman, 1978)
- *Introduction to Stellar Atmospheres and Interiors,* Eva Novotny (Oxford U. Press, 1973)
- *An Introduction to Modern Stellar Astrophysics,* Dale Ostlie & Bradley Carroll (Addison-Wesley, 1996)

Clayton and Mihalas have been considered "bibles" by specialists in their respective fields. The two final entries (Novotny and Ostlie & Carroll) are undergraduate textbooks that may be useful for reviewing some basic ideas in ways that are more straightforward than are found in the graduate-level books.

GRADING

The final grade is broken down into contributions from problem sets (50%), a take-home midterm exam (20%), and a final project & presentation (30%). More details on these components are given below.

SCHEDULE OF TOPICS

The dates listed here for each set of topics are approximate. There will be an actively maintained web page that stays 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 17, 19	C1,P1
I. Stellar Interiors		
Thermodynamic properties of stellar fluids/plasmas	Jan 22, 24, 26, 29	C1,2; P2,3
Sources & sinks of energy	Jan 31; Feb 2, 5, 7	C3; P6
Energy transport from core to surface	Feb 9, 12, 14, 16	C4; P5
Spherical stellar model interiors	Feb 19, 21, 23	C2,4; P4,7
Non-spherical effects: e.g., rotation	Feb 26, 28	C7,8; P10
II. Stellar Evolution		
Star formation & pre-main-sequence evolution	Mar 2, 5, 7, 9, 12	C5; P9
MS & post-MS evolution	Mar 14, 16	C5; P10,11,12
Stellar death: supernovae & compact objects	Mar 19, 21, 23	P13
III. Stellar Atmospheres		
Radiative transfer & the full atmosphere problem	Apr 2, 4, 6	C9,10,11
Non-LTE processes & spectral line diagnostics	Apr 9, 11, 13	C12,13,14
Chromospheres & coronal heating	Apr 16, 18, 20	—
Stellar winds	Apr 23, 25, 27	—

PROBLEM SETS

There will be approximately five homework assignments distributed throughout the semester. A detailed schedule of distribution and due dates will be given out in class and posted on the course web page. Hardcopy submissions are preferred, but email is fine, too. Students choosing the latter option are encouraged to write out solutions long-hand and scan them. (That way you won't be tempted to leave out intermediate steps when typing in equations.)

Problems are due on the dates listed. However, since it is our top priority that you have sufficient time to learn from the problem sets, late homeworks will be accepted. Usually there will be an accumulating penalty (5% lower grade per weekday that it is late), but you can also arrange for one no-penalty late submission. In that one case, you can turn in a homework up to 3 days late, but you must inform me that you'll be invoking this option at least 1 class session prior to the due date! Late submissions are no longer possible after the answer keys have been distributed.

MIDTERM EXAM

This will be more like a "two thirds of the way through the semester" exam, to be given about a week before Spring Break. This is a take-home exam, which ought to be similar in length to one of the problem sets, but with a shorter turnaround time.

FINAL PROJECT & PRESENTATION

There will also be a project that will count for 30% 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. For the main project activity, feel free to choose between the following options:

- A review of a topic relevant to this course, that goes well beyond the material discussed in class. Reviews 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.
- Some kind of mathematical or computational calculation that explores a topic relevant to the course. The types of things you could do include:
    a. exploring a wider "parameter space" of a textbook model,
    b. numerically solving an equation (that was presented in class) that has no analytic solution,
    c. constructing your own model or simulation.
- Downloading and analyzing some publicly available observational data.
- Critical testing (or debunking?) of the claims made in a recent paper.

The written component of the project should end up around 10 double-spaced pages in length—i.e., roughly 2500 words—not counting the (required) bibliography. If there is a computational or observational aspect to your project, I may request to see some of the source code or data.

There will be a handful of class sessions reserved at the end of the semester for student presentations (exact number to depend on enrollment). 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 Comps II, 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 academic integrity policy of the institution. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, resubmission, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code Council (honor@colorado.edu; 303–735–2273). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code Council as well as academic sanctions from the faculty member. Additional information regarding the academic integrity policy can be found at the Honor Code Office 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.

ACCESSIBILITY AND LEARNING NEEDS

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services in a timely manner so that your needs can be addressed. For exam accommodations, provide your letter at least one week prior to the exam. 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. You can 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 Temporary Medical Conditions guidelines on the Disability Services website, and discuss your needs with your professor.

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. If you have religious obligations that result in schedule conflicts, please contact me in the first two weeks of class to make alternate arrangements. For full details, see the campus policy regarding religious observances.

DISCRIMINATION AND HARASSMENT

The University of Colorado Boulder (CU Boulder) is committed to maintaining a positive learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct, discrimination, harassment, or related retaliation against or by any employee or student. CU's Sexual Misconduct Policy prohibits sexual assault, sexual exploitation, sexual harassment, intimate partner abuse (dating or domestic violence), stalking, or related retaliation. CU Boulder's Discrimination and Harassment Policy prohibits discrimination, harassment or related retaliation based on race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation, or political philosophy. Individuals who believe they have been subject to misconduct under either policy should contact the Office of Institutional Equity and Compliance (OIEC) at 303–492–2127. Information about the OIEC, the above referenced policies, and the campus resources available to assist individuals regarding sexual misconduct, discrimination, harassment or related retaliation can be found at the OIEC website.

CLASSROOM BEHAVIOR

Students and faculty each have responsibility for maintaining an appropriate learning environment. 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 differences of race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation, or political philosophy. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on classroom behavior and the Student Code of Conduct.

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 students doing so must do their best to seat themselves with nobody behind them.