ASTR-5700: Stellar Astrophysics CU Boulder Course Syllabus (Spring 2016)

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Office: Duane Physics D-111, LASP SPSC N-218 (east campus)

Course Times: Mon., Wed., Fri., 9:00–9:50 am, Duane Physics room E-126
Course web page: http://lasp.colorado.edu/∼cranmer/ASTR_5700_2016/
Office hours: By appointment or drop in (at LASP: M/W/F after class, Tu/Th in mornings)

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 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. A recommended pre-requisite or co-requisite is Radiative and Dynamical Processes (ASTR-5120).

COURSE MATERIAL

Everything that will be discussed in class will be included in lecture notes posted on the course web page.

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)
- *Solar Astrophysics,* Peter V. Foukal (Wiley-VCH, 2nd ed., 2004)
- *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 are 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 11	C1,P1
I. Stellar Interiors		
Thermodynamic properties of stellar fluids/plasmas	Jan 13, 15	C1,2; P2,3
Sources & sinks of energy	Jan 20, 22, 25	C3; P6
Energy transport from core to surface	Jan 27, 29; Feb 1	C4; P5
Spherical stellar model interiors	Feb 3, 5, 8	C2,4; P4,7
Rotation, pulsations, & dynamos	Feb 10, 12, 15, 17	C7,8; P10
II. Stellar Evolution		
Star formation & pre-main-sequence evolution	Feb 19, 22, 24	C5; P9
MS & post-MS evolution	Feb 26, 29; Mar 2, 4	C5; P10,11,12
Stellar death: supernovae & compact objects	Mar 7, 9, 11, 14, 16	P13
III. Stellar Atmospheres		
Radiative transfer & the full atmosphere problem	Mar 18, 28, 30	C9,10,11
Non-LTE processes & spectral line diagnostics	Apr 1, 4, 6, 8	C12,13,14
Chromospheres, coronal heating, & stellar winds	Apr 11, 13, 15, 18, 20	—

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 students have sufficient time to learn from the problem sets, we will grant one lateness exception per student: One problem set can be turned in up to three business days late with no penalty. Other late problem sets will incur a penalty of a 5% lower grade per business day that it is late.

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 we anticipate will be similar in scope 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). These will be whiteboard presentations—no Powerpoint—and 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.

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ACADEMIC INTEGRITY

All students of the University of Colorado at Boulder are responsible for knowing and adhering to the academic integrity policy of this institution. Violations of this policy may include: cheating, plagiarism, aid of academic dishonesty, fabrication, lying, bribery, and threatening behavior. All incidents of academic misconduct shall be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic sanctions from the faculty member and non-academic sanctions (including but not limited to university probation, suspension, or expulsion). Additional information regarding the Honor Code policy can be found online and at the Honor Code Office.

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.

STUDENTS WITH DISABILITIES

If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at dsinfo@colorado.edu. If you have a temporary medical condition or injury, see Temporary medical conditions under the Quick Links at the Disability Services website and discuss your needs with your professor.

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 discrimination or harassment based upon protected classes or related retaliation against or by any employee or student. For purposes of this CU-Boulder policy, "protected classes" refers to 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 discriminated against should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or the Office of Student Conduct and Conflict Resolution (OSC) at 303-492-5550. Information about the OIEC, the above referenced policies, and the campus resources available to assist individuals regarding discrimination or harassment can be found at the OIEC website. The full policy on discrimination and harassment contains additional information.

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, culture, religion, creed, politics, veteran status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. 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 conduct code.

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