

ASTR-3760: Solar and Space Physics

CU Boulder Course Syllabus (Spring 2015)

- Instructor:** Prof. Steven R. Cranmer (email: steven.cranmer@colorado.edu)
Office: Duane Physics D-111, SPSC N-218 (research park) Phone: TBD
- Course Times:** Mon., Wed., Fri., 11:00–11:50 am
- Location:** Duane Physics, Room G-131
- Course web page:** http://lasp.colorado.edu/~cranmer/astr_3760_sp2015.html
- Office hours:** Duane D-111: Wed. 10:00-11:00, Fri. 12:00-1:00, or by appointment

SUMMARY

We live in the extended atmosphere of a magnetic variable star. Solar radiation enables and sustains life, but the Sun also produces streams of high energy particles and radiation that can be harmful to people and their technology. In this course we will explore the physical processes that link the Sun to the planets, and we will learn about the behavior of the tenuous, magnetized plasma that fills the rest of the solar system. Topics discussed in this course will include some basic plasma physics, the solar interior and atmosphere, the solar wind and coronal mass ejections, planetary magnetospheres, and space weather. Roughly half of the course can be considered “*the Sun as an example of stellar astrophysics*,” and the other half is “*Space plasma physics for astronomers*.”

This course is an elective for the APS undergraduate major and minor. Pre-requisite (or co-requisite) courses include Modern Physics (PHYS-2130 or PHYS-2170), and Calculus 3 (MATH-2400 or APPM-2350). A recommended, but not required, pre-requisite is Electricity & Magnetism (PHYS-3310).

COURSE GOALS

At the end of the course, you should be able to:

- Define what a plasma is, and describe (mathematically) the basic properties of some important plasmas in our solar system.
- Employ order-of-magnitude physical reasoning to describe how energy flows from the core of the Sun to the surface of the Earth.
- Discuss how measurements in solar physics and space plasma physics are carried out.
- Describe to interested laypeople and family members what we can learn from solar & space physics, and how it affects our everyday life.

COURSE MATERIAL

Primary textbook: *Physics of Solar System Plasmas*, by Thomas E. Cravens (Cambridge U. Press, 1997). The publisher makes this title available online in (paywalled) PDF ebook format. I will check about online access via the CU library system. See me if you have any difficulty in obtaining a copy of the textbook.

Secondary resources: 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 particularly nice set of lecture notes, which supplements some topics that Cravens’ textbook cuts short, is “*Stellar Structure and Evolution*” by Onno Pols.

GRADING

The final grade will be assembled from the following components:

| | |
|--|-------|
| 5 Homework Sets | 5/10 |
| Midterm Exam | 3/10 |
| Final Project/Paper & Presentation | 2/10 |
| In-Class Engagement | 1/10 |
| <hr/> | |
| Total | 11/10 |

Each of these components is described in more detail below. Note the total grade comes to 11 out of 10 points. To produce the final grade, I will drop the lowest 1/10 of your score from either the homework sets, midterm exam, or final project. (The score for in-class engagement is not droppable.)

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. Below, each sub-topic is listed along with relevant chapters from Cravens' textbook ('C') or from the Pols lecture notes ('P'). It is highly recommended that students become familiar with these topics before their discussion in class.

I. Preliminary Basics5 lectures (1/12–1/23)

- Course introduction (“Sun to mud”) C 1, also P 1
- Reviews of vector calculus, E&M C Appendix
- Summary of relevant “energy budgets” —

II. Magnetized Plasmas 7 lectures (1/26–2/9)

- Kinetic theory & thermodynamics C 2.1–2.5, also P 3
- Behavior of MHD fluids C 4.3–4.6
- Application: waves & shocks (maybe) C 4.8–4.9

III. Solar Interior & Atmosphere 11 lectures (2/11–3/6)

- Total stellar energy content C 5.1, also P 2
- Nuclear energy generation C 5.1, also P 6
- Radiative & convective energy transport C 5.1, also P 5
- Photosphere & chromosphere C 5.2

IV. Solar Activity 11 lectures (3/9–4/13)

- The Sun's magnetic field C 5.3, 6.3
- Coronal heating C 4.10, 5.2–5.3, 6.1
- The solar wind C 6.2, 6.4
- Coronal Mass Ejections C 6.4

V. Sun–Planet Interactions 6 lectures (4/15–4/27)

- Magnetospheres C 7.1–7.2, 8.1–8.2
- Single Particle Motions C 3
- Ionospheres & Space Weather C 7.3, 8.6

HOMEWORK 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. All but one of them will be mostly mathematical “problem sets.” The remaining one will be a mini-project to find a popular news article on a topic relevant to this course, and critique it. Requirements for this written critique will be handed out later.

Hardcopy submissions are preferred, but email is fine, too. Students choosing the latter option are encouraged to write out solutions long-hand (neatly!) and scan them. This way you won’t be tempted to leave out intermediate steps when typing in equations.

Homeworks are due at the beginning of class on the dates to be given. However, since it is our top priority that students have sufficient time to learn from the homework sets, we will grant one lateness exception per student: One homework set can be turned in up to three business days late with no penalty. (Though please let me know, in person or email, if/when you’ll be taking this option.) Any other homework that is late 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 in the week before Spring Break. There will be at least one full class period (maybe two) devoted to reviewing the relevant material prior to the exam. Details about its format will be forthcoming.

FINAL PROJECT OR PAPER

In lieu of a sit-down final exam, there will be a project or term paper that will enable you to explore a chosen topic in a bit more detail, and gain some extra experience with either scientific writing or computing. The project can involve either of the two following components (or, if you’re ambitious, both):

- A written review of a topic relevant to the course, that goes beyond the material discussed in class. The paper must convey some background (i.e., how did we come to understand the topic), motivation (i.e., why is it relevant), and some quantitative exploration of the physics (i.e., some relevant equations). The length to aim for is about 10 double-spaced pages—i.e., about 2500 words—not counting the (required) bibliography.
- Some kind of mathematical or computational calculation that explores some 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,
 - b. constructing your own model or simulation,
 - c. downloading and analyzing some publicly available data, or
 - d. testing (or debunking?) the claims made in a recent paper.

Feel free to use whatever tools you want (i.e., computing languages, software packages, output formats), but the whole thing—including source code and data—must be submitted.

Additional information, including lists of possible topic ideas and deadlines, will be distributed during the semester.

IN-CLASS ENGAGEMENT

Attendance is important, because frequently the class will separate either individually or into small groups. In these break-out sessions, you will work out some interesting implication, or draw some useful conclusion, from the lecture material. No written answers need to be submitted; just verbal discussion of the outcomes.

The grade for this component is essentially “try” or “not-try;” i.e., all you need to get your 1/10 (of the total grade) is to attend class regularly and show consistent engagement with the material. This can be demonstrated through asking questions in class, answering questions that someone else has raised, and/or participating actively in the break-out sessions.

ACADEMIC INTEGRITY

All students at CU 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 will 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).

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 me 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, and they can be contacted at 303-492-8671, by e-mail (dsinfo@colorado.edu), or on the web (disabilityservices.colorado.edu).

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.

DISCRIMINATION AND HARASSMENT

CU Boulder is committed to maintaining a positive learning, working, and living environment. The University of Colorado does not discriminate on the basis of race, color, national origin, sex, age, disability, creed, religion, sexual orientation, or veteran status in admission and access to, and treatment and employment in, its educational programs and activities. 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, or veteran status. Individuals who

believe they have been discriminated against should contact the Office of Discrimination and Harassment (ODH) at 303-492-2127 or the Office of Student Conduct (OSC) at 303-492-5550.

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.