ASTR-5120: Radiative & Dynamical Processes CU Boulder Course Syllabus (Fall 2019)

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., 3:00–3:50 pm, Duane Physics room E126
Course web page: http://lasp.colorado.edu/∼cranmer/ASTR_5120_2019/
Office hours: D111: Mondays 12–1, Thursdays 10–11, or by appointment

SUMMARY

This course is an introduction to radiative and dynamical (R&D) processes aimed at graduate students in astrophysics, space physics, and planetary science. R&D is intended to cover a handful of topics that are central to much of astrophysical and planetary sciences, but are rarely encountered at the undergraduate level. We will cover particle collisions and transport phenomena, magnetohydrodynamics, gravitational dynamics (applied to both planetary orbits and N-body systems in galaxies), and a macroscopic treatment of radiation fields. This is a core required course for APS graduate students.

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. No one textbook covers all aspects of this class, but there are quite a few good resources:

Magnetohydrodynamics and Transport Phenomena:

- *Physics of Solar System Plasmas,* by Thomas Cravens (Cambridge U. Press, 1997) develops MHD nicely, but with a focus on solar/space physics applications.
- Henk Spruit's *"Essential Magnetohydrodynamics for Astrophysics,"* is online at arXiv:1301.5572.
- Richard Fitzpatrick's (U. Texas, Austin) lecture notes on *"Plasma Physics"* are posted online.
- James Callen's (U. Wisconsin, Madison) online draft version of much of his book *Fundamentals of Plasma Physics* covers Coulomb collisions & transport theory quite well.

Dynamical processes:

- The massive & mighty *Galactic Dynamics* by James Binney & Scott Tremaine (2nd ed.) is classic resource for large-scale N-body systems.
- *Solar System Dynamics* by Carl Murray and Stanley Dermott is considered a mainstay in covering the gravitational dynamics of small numbers of bodies (though I haven't yet read much of it).

Radiation processes:

- *The Fundamentals of Stellar Astrophysics,* by George Collins is a great resource on theoretical aspects of stellar atmospheres. The full book is available in PDF on ADS.
- *Radiative Processes in Astrophysics,* by George Rybicki & Alan Lightman, is an excellent introduction to the radiative topics of this course, but it's long out-of-print and absurdly expensive.

There will also be links to online material (e.g., some of the available books listed above, plus lecture notes from other courses) on this course's web page. For the books not freely available, some publishers provide paywalled e-books. I will check about electronic access via the CU library system. See me if you have any difficulty in obtaining copies of these books.

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.

Introduction & Overview	Aug 26
I. Collisions and Transport Phenomena	
Random walks and advection-diffusion equations	Aug 28
Brownian motion; Langevin equation; fluctuation-dissipation theorem	Aug 30
Binary collisions; mean free paths; collision statistics	Sep 4, 6, 9
II. Magnetohydrodynamics	
Kinetic theory; Vlasov equation; Boltzmann collision term	Sep 11, 13
Fokker-Planck equation	Sep 16
Fluid moments of the Boltzmann equation for a plasma	Sep 18, 20
Ideal & resistive MHD; magnetic pressure & tension	Sep 23, 25
Force-free fields; MHD waves, instabilities, and equilibria	Sep 27, 30; Oct 4
Braginskii transport coefficients	Oct 7, 9
Survey of plasma physics "beyond MHD"	Oct 11, 14
III. Dynamical Processes	
Conservative forces: work, energy, Euler-Lagrange formalism	Oct 18, 21
2-body Keplerian motion; restricted 3-body problem; resonances	Oct 23, 25, 28, 30
N-body Boltzmann stellar dynamics; tensor virial theorem	Nov 1, 4, 6, 8, 11
IV. Radiation Processes	
Defining the radiation field; equation of radiation transfer	Nov 13, 15
Solutions in useful limits; gray & irradiated atmospheres	Nov 18, 22
Beyond the gray atmosphere: non-LTE, spectral lines, H II regions	Dec 2, 4, 6, 9, 11

GRADING

The final grade will be assembled from the following components:

6 Homework Sets	45%
Midterm Exam (in-class: Oct. 16)	20%
Final Exam (take-home: Dec. 11–13)	20%
Student Presentation	10%
'Participation Potpourri'	5%

One important goal of this class is to prepare you for Comps 1. Thus, the midterm and final exams will try to approximate these types of questions, and there will be two additional classes devoted to real-time "Mock Comps" problem solving (not graded; Oct. 2 & Nov. 20).

For the homework sets, a detailed schedule of distribution and due dates will be posted on the web page. Either hardcopy or email submission is fine, though if you choose the latter, please compile your submission into a single attachment. Problems are due on the dates listed, but *one* late submission can be arranged if necessary (for a maximum delay of 3 weekdays), 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 about 1 week after the due date). See notes under "Academic Integrity" below for more on homework collaboration.

STUDENT PRESENTATIONS

On most Fridays of the semester, we will devote half of the class to either a student presentation or a discussion of a relevant journal paper. There will be approximately 9 student presentations and 2 journal paper discussions (see below for more about the latter).

The student presentation is essentially an opportunity for each of you to prepare a lecture and teach the class about some R&D topic. The mode of teaching (i.e., whiteboard vs. powerpoint; active learning, team inquiry, or traditional lecture) is up to each individual. In Homework 1, I will provide a list of example topics that would fit in well with the rest of the course material, but you can propose your own, too. Your Homework 1 submission will contain a ranked list of your preferred topics and presentation dates, and we will iterate to ensure everyone gets something they're happy with. (Homework 1 is due on Monday, September 9, and the first presentation will be on Friday, September 20.)

PARTICIPATION POTPOURRI

There are three ways that you can obtain the 5% of your grade via participation in the life of the class:

1. You can propose an R&D-relevant **journal paper** for one of the two paper discussion sessions. I will accept these up to a week prior to the scheduled date of each session. As a part of your submission, you must also provide a list of at least 4 discussion questions to be given to the class, and you must be willing to *lead the discussion* if your paper is chosen. If I receive more than one submission for a given session, you will still get the participation credit even if your paper is not chosen.

2. You can write a new **homework problem** of similar size and scope as the existing homework problems for this course. Of course, you must provide an answer key that is sufficiently detailed and helpful for graders. The new problem must test the students' knowledge of some aspect of the course. Did I neglect to assign a homework problem on some topic that you really knew well? Did I do a terrible job crafting one of the existing homework problems? Remedy that deficiency, and your new problem might be offered to future R&D students.

3. You can write a new **exam question** of similar size and scope as the existing exam questions for this course. The same constraints and motivations as #2 above apply.

ACADEMIC INTEGRITY

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the academic integrity policy and Honor Code of this institution. Violations of this policy may include: 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 who are 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 Office website.

Normally for graduate courses, your instructors encourage you to discuss the assignments and topics with your fellow students. Because of this course's focus on preparing you for the Comps 1 *individual* exam, I believe it is wise to collaborate less on homework problem-solving than you normally would. Discussion of methods and approaches is fine, as is spot-checking final answers with one another. However, everything that is derived, plotted, and written up must be your own independent work.

ACCESSIBILITY AND LEARNING NEEDS

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. 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 fostering a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (including sexual assault, exploitation, harassment, dating or domestic violence, and stalking), discrimination, and 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 the OIEC, university policies, anonymous reporting, and the campus 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, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

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 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.