ASTR-5120: RADIATIVE & DYNAMICAL PROCESSES

CU Boulder Syllabus (Fall 2020)

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Course Times: Mon., Wed., Fri., 4:10–5:00 pm, Duane Physics room E126

Course Web Page: https://stevencranmer.bitbucket.io/ASTR_5120_2020/

Office Hours: Zoom: dates & times TBD

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 planetary orbits, stellar binaries, and N-body systems like 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.

Gravitational Dynamics:

- 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:

- *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.
- *The Fundamentals of Stellar Astrophysics,* by George Collins is a great resource on theoretical aspects of radiation transfer in stellar atmospheres. The full book is available on ADS.

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. The primary lectures will be provided as "asynchronous" videos, usually on Mondays and Wednesdays of each week. You can view them—and read along in the lecture notes and specified chapters of various recommended online sources—at your own pace.

Introduction & Overview	Aug 24
I. Collisions and Transport Phenomena	
Random walks and advection-diffusion equations	Aug 26
Brownian motion; Langevin equation; fluctuation-dissipation theorem	Aug 31
Binary collisions; mean free paths; collision statistics	Sep 2, 9
II. Magnetohydrodynamics	
Kinetic theory; Liouville's theorem & Vlasov's equation	Sep 11
Boltzmann collision term & the Fokker-Planck equation	Sep 14
Fluid moments of the Boltzmann equation for a plasma	Sep 16
Ideal & resistive MHD; magnetic pressure & tension	Sep 21, 23
Force-free fields; MHD waves, instabilities, and equilibria	Sep 28, 30
Braginskii transport coefficients; fluid collision terms	Oct 5
Survey of plasma physics "beyond MHD"	Oct 7
III. Dynamical Processes	
Conservative forces: work, energy, Euler-Lagrange formalism	Oct 12
Two-body Keplerian motion & applications	Oct 14, 19
Restricted three-body problem; resonances; tides	Oct 21, 26
N-body Boltzmann stellar dynamics; tensor virial theorem	Oct 28; Nov 2, 4
IV. Radiation Processes	
Defining the radiation field; equation of radiation transfer	Nov 9, 11
Solutions in useful limits; the stellar gray-atmosphere problem	Nov 16, 18
Beyond the gray atmosphere: non-LTE & spectral lines	Nov 23, 25
Ionization & recombination; irradiated bodies; radiation pressure	Dec 2, 7

GRADING

The final course grade will be assembled from the following components:

Homework Problem Sets 1–5	50%
Homework 6: video or extra-credit	10%
Midterm Exam (take-home)	10%
Final Exam (take-home)	15%
Contributions to Recitation Discussion	15%

Due to: (1) the hybrid in-person/remote-learning conditions that we will experience in Fall 2020, and (2) the elimination of the written Comps 1 exam, for which this course was previously geared to prepare you, we will be exploring some new pedagogical territory. Each graded aspect of this course will be described in more detail below.

Graduate students in the APS Department need to earn a grade of B– or higher in this course to meet the *Preliminary Exam* requirement. If a lower grade is received, there are a variety of other options, including taking the course again or arranging an independent study. Contact the APS Office for the rules. For students

in other departments, this does not apply to you, although your department may have its own separate rules.

HOMEWORK

There will be five primary problem-set based homeworks. 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 will be due on the dates listed, but one late submission can be arranged if necessary (for a maximum delay of 1 week), 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).

As listed above, an additional 10% of your grade will be based on "Homework 6." For this, you can choose from several options:

1. Each of the five homework problem-set homework assignments will contain an **extra-credit** problem. Doing all five of them gets you the credit for Homework 6.

2. Multimedia teaching is on the minds of many in academia these days. If you would like to produce a **video/multimedia lecture** on a topic relevant to this course, you can have the rest of the class watch it and learn something. Your video can provide an alternate way of teaching a concept that I covered in the main lectures (in case you have a better way of explaining it), or it can branch off into other related topics or applications. The goal for length is roughly 10–20 minutes. On the course web page, I'll post a list of example topics, as well as production resources and relevant deadlines.

3. Of course, videos aren't everything. You may be involved with programs such as CU's Center for Teaching & Learning (CTL) or the UCSC ISEE Professional Development Program (PDP), which champion **science-inquiry activities** that go way beyond lecturing. If you want to develop a way to convey a topic relevant to this course to your peers—which uses a mode that's more innovative than a plain old video lecture—please let me know and we can agree on a plan.

MIDTERM AND FINAL EXAMS

The format will be "take-home" exams with problems having a similar scope as the homework problem sets; the primary difference being the no-collaboration aspect of an exam. The final exam will comprehensively cover material from the entire course. Completed exams will be due 48 hours after they are given to you, and exact dates will be given on the course web page.

RECITATION DISCUSSION SESSION

Most weeks of the semester will have two 50-minute class periods of asynchronous lecture content, and one 50-minute class of synchronous "in-person" (physical or online) interaction. This recitation/discussion session will be led mostly by students. In order to prepare for each week's session, on Canvas we will have a way for students to post written "responses to prompts" that consist of, e.g., questions about the lectures or homework, pointing out any steps you didn't understand, correcting any errors of mine, sharing tricks/tips for solving homework problems, or even chatting about any aspects of the material that interest you the most. Answering another student's question counts as a valid response, too. Each student will need to submit a minimum of 24 responses/answers (with each numbered item counting as a separate response) to get full credit for this "participation" component of the course grade.

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 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 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.

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.

ACCOMMODATION FOR DISABILITIES

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. 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 are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. 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. 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.

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.

REQUIREMENTS FOR COVID–19

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements, and public health orders in place to reduce the risk of spreading infectious disease. Required safety measures at CU Boulder relevant to the classroom setting include:

- maintain 6-foot distancing when possible,
- wear a face covering in public indoor spaces and outdoors while on campus consistent with state and county health orders,
- clean local work area,
- practice hand hygiene,
- follow public health orders, and
- if sick and you live off campus, do not come onto campus (unless instructed by a CU Healthcare professional), or if you live on-campus, please alert CU Boulder Medical Services.

Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policies on COVID-19 Health and Safety and classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please see the "Accommodation for Disabilities" statement on this syllabus. Before returning to campus, all students must complete the COVID-19 Student Health and Expectations Course. Before coming on to campus each day, all students are required to complete a Daily Health Form. Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home and complete the Health Questionnaire and Illness Reporting Form remotely. In this class, please feel free to alert me if you will be absent for an extended time due to illness or quarantine, but you do not need to give me details about your condition.