ASTR-5120: Radiative & Dynamical Processes CU Boulder Course Syllabus (Fall 2016)

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Course Times: Mon., Wed., Fri., 3:00–3:50 pm, Duane Physics room E-126
Course web page: http://lasp.colorado.edu/∼cranmer/ASTR_5120_2016/
Office hours: By appointment or drop in (at LASP: M/W/F before lunch, Tu/Th all day)

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

I will aim for everything discussed in class to be included in lecture notes posted on the course web page. 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 a crystal-clear 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. There will be an actively maintained web page that stays up-to-date on the topics to be covered in each class session.

Introduction & Overview	Aug 22
I. Collisions and Transport Phenomena	
Random walks and advection-diffusion equations	Aug 24
Brownian motion; Langevin equation; fluctuation-dissipation theorem	Aug 26, 29
Binary collisions; mean free paths; collision statistics	Aug 31; Sep 2, 7
II. Magnetohydrodynamics	
Kinetic theory; Vlasov equation; Boltzmann collision term	Sep 9, 12
Fokker-Planck equation	Sep 14, 16
Fluid moments of the Boltzmann equation for a plasma	Sep 19, 21
Ideal & resistive MHD; magnetic pressure & tension	Sep 23, 26, 28
Force-free fields; MHD waves, instabilities, and equilibria	Sep 30; Oct 3, 5
Braginskii transport coefficients	Oct 7, 10
Survey of plasma physics "beyond MHD"	Oct 12
III. Dynamical Processes	
Conservative forces in N-body systems	Oct 17, 19, 21
2-body Keplerian motion; the restricted 3-body problem	Oct 24, 26, 28, 31
Lagrangian dynamics & applications	Nov 2, 4, 7
Boltzmann stellar dynamics; tensor virial theorem	Nov 9, 11, 14
IV. Radiation Processes	
Defining the radiation field; equation of radiation transfer	Nov 16, 18
Solutions in useful limits; gray & irradiated atmospheres	Nov 28, 30; Dec 2
Atomic & molecular sources of opacity; ionization & recombination	Dec 5, 7, 9

GRADING

50% for exams and 50% for homework. One important goal of this class is to prepare you for Comps I type questions given under exam conditions. Thus, there will be two sit-down exams: a midterm on parts I and II (25%), probably given on October 14, and a final exam on parts III and IV (25%), given either on the last day of class or during finals week.

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. Problems are due on the dates listed, but *one* late submission can be arranged if necessary, as long as the arrangement is made at least one class session prior to the due date. Other late problem sets will incur a penalty of a 5% lower grade per business day that it is late. See notes under "Academic Integrity" below for more on homework collaboration.

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.

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 I *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.

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