

# ASTR 5110 — Atomic and Molecular Processes

**Time and Place:** Duane E126: Lectures MWF 9:00–9:50

**Course Web Page:** <http://canvas.colorado.edu>

**Instructor:** Jeremy Darling (jeremy.darling@colorado.edu; Duane D341; 2-4881)

**Office Hours:** These will be TBD to best fit the needs and schedule of the students. You can also email, call, or speak to me in person to make an appointment.

**Aims:** The goal of this course is to provide a solid foundation in the interaction of radiation with matter with an emphasis on using astronomical spectra to understand the physical conditions of gas in galaxies, stars, and planets. We will learn about the excitation and structure of atoms and molecules, associated physical processes, and the statistical behavior of ensembles of particles including photons. *My aim is to provide you with the tools and knowledge to continue learning and to pursue your scientific and career goals.*

## Topics:

- Review of Non-Relativistic Quantum Mechanics
- The Hydrogen Atom and the Hydrogen Isosequence
- Time-Independent Perturbation Theory
- Multi-Electron Atoms and the Periodic Table
- Radiation and Time-Dependent Perturbation Theory
- Radiative Transfer
- Spectral Line Formation
- Ionization, Recombination, Excitation, and Cooling
- Non-Thermal Processes
- Molecular Structure, Excitation, and Spectroscopy
- Statistical Mechanics
- Quantum Statistics

**Texts:** Since the topics covered in this course are so diverse, there is no single adequate text. *Astronomical Spectroscopy* (Tennyson) is an excellent ground-level empirical resource for spectrum formation and atomic structure, and *Radiative Processes in Astrophysics* (Rybicki & Lightman) will be our reference for radiative transfer. Both of these books are a good investment, and Rybicki & Lightman will be useful in subsequent courses. *Astrophysics of Gaseous Nebulae and Active Galactic Nuclei* (Osterbrock & Ferland) is a nice reference, but will probably only be useful if you plan on a career in Galactic or extragalactic astrophysics. Likewise for *Physics of the Interstellar and Intergalactic Medium* (Draine).

Additional very good references include *Modern Quantum Mechanics* (Sakurai), *Introductory Quantum Mechanics* (Liboff), *Tools of Radio Astronomy* (Rohlfs & Wilson) for molecular physics and radiative transfer, and of course *The Feynman Lectures on Physics*.

**Grading:** Problem Sets — 50%; Midterms (2) — 10% each; Final Exam — 20%; Preparation and Participation — 10%. Problem sets will be frequent (~weekly) and relevant. There will be two in-class midterms during the semester that resemble Comps questions, and there will be a comprehensive final exam on Wednesday, December 18 at 1:30–4:00 pm. Coming prepared to and participating in lectures is critical. I will often assign reading to be done for specific lectures.

**Homework Policy:** Homework will be due at the start of class, usually on Fridays. Homework will not be accepted late except in extremely dire circumstances, and you must notify me before the due date. I will drop the lowest homework score. You are strongly encouraged to work on the problem sets on your own, but if you do collaborate with a classmate or consult a source (book, paper, wikipedia, etc), please give credit where it is due: cite your references and list your collaborators (follow the same guidelines you would use for a research publication). Show your work, state assumptions, use units, and employ words and sentences to elucidate your thinking.

**Class Time Policy:** I promise to respect your time and busy schedule by ending lectures promptly at the official time (50 minutes after the hour). In return, I ask that you be in class, prepared, and ready to participate *on the hour*. If you need to miss a class, please communicate this to me beforehand and make any necessary arrangements to cover your absence.

**Participation and Respect:** The classroom will be a place of civility, respect, collegiality, and learning. I encourage you to ask questions and volunteer answers. An honest attempt at an answer is better than a correct answer (we generally learn more by being wrong than when we are right).

## **Students with 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. Information on requesting accommodations is located on the Disability Services website<sup>1</sup>. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition or injury, see Temporary Medical Conditions<sup>2</sup> under the Students tab on the Disability Services website.

## **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<sup>3</sup> and the Student Code of Conduct.<sup>4</sup>

## **Honor Code**

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 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.<sup>5</sup>

## **Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation**

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 intimate partner abuse (including dating or domestic violence), stalking, protected-class discrimination or 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 cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting,<sup>6</sup> and the campus resources can be found on the OIEC website.<sup>7</sup>

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.

## **Observance of Religious Holidays**

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.<sup>8</sup> In this class, if you must miss an exam, assignment, lecture, or recitation because of observance of a religious holiday, please notify the professor in writing at least a week prior to arrange for accommodation.

<sup>1</sup> <http://www.colorado.edu/disabilityservices/students>

<sup>2</sup> <http://www.colorado.edu/disabilityservices/students/temporary-medical-conditions>

<sup>3</sup> <https://www.colorado.edu/policies/student-classroom-and-course-related-behavior>

<sup>4</sup> <http://www.colorado.edu/osccr/>

<sup>5</sup> <https://www.colorado.edu/osccr/honor-code>

<sup>6</sup> [https://cuboulder.qualtrics.com/jfe/form/SV\\_0PnqVK4kkIJIznf](https://cuboulder.qualtrics.com/jfe/form/SV_0PnqVK4kkIJIznf)

<sup>7</sup> <http://www.colorado.edu/institutionalequity/>

<sup>8</sup> <https://www.colorado.edu/policies/observance-religious-holidays-and-absences-classes-andor-exams>