Astronomy 601 - Fall 2012
"Radiative Processes"

Instructor

Prof. Massimo Ricotti
Office: CSS 0213
E-mail: ricotti@astro.umd.edu
Phone: (301) 405 5097
Office hours: by appointment
Class web page: http://www.astro.umd.edu/~ricotti/NEWWEB/teaching/ASTR601_12.html

Schedule

Lectures on Tuesday and Thursday from 12:30pm to 1:45pm
Room CSS 0201

Course Description

The emission, absorption and scattering of radiation by matter with astrophysical applications. Emphasis on basic theory and problem-solving. (i) *Radiative transfer:* specific intensity, transfer equation, opacity, diffusion, scattering. (ii) *Statistical mechanics of matter and radiation:* LTE, level populations, rate equations. (iii) *Electrodynamics:* Maxwell equations, spectra of radiation, polarization, dipole and multipole radiation, Thompson scattering. (iv) *Plasma radiation:* bremsstrahlung and synchrotron emission, Compton scattering, EM wave propagation in plasmas. (v) *Atomic and molecular radiation:* energy levels, Einstein coefficients, oscillator strengths, line broadening.

Textbooks

Required: *The Physics of Astrophysics Volume I: Radiation* by F.H. Shu
Recommended: *Radiative Processes in Astrophysics* by G. Rybicki and A. Lightman

Course Grading

Homework	50%
Midterm Exam	20%
Final Exam	30%

There will be one in-class Midterm exam and an in-class Final (the dates of the exams are shown below in the "Tentative course outline" section). Class participation is strongly encouraged. Class attendance is instead required. Homework will be assigned every week or every other week. Their due dates will be announced at the time they are assigned. On the due date the students will be expected to turn in their homework in class. The homework turned in will be graded and returned to the students. I will provide solutions and discuss them in class.

Letter Grades

90%-100%	A
80%-89%	B
70%-79%	C
60%-69%	D

I may rescale the grades depending on the average class performance. Of course the rescaling can only increase your final grade.

Course Evaluation

Your participation in the evaluation of courses through CourseEvalUM is a responsibility you hold as a student member of our academic community. Your feedback is confidential and important to the improvement of teaching and learning at the University. Please go directly to the website (www.courseevalum.umd.edu) to complete your evaluations starting December 1. By completing all of your evaluations each semester, you will have the privilege of accessing online, at Testudo, the evaluation reports for the thousands of courses for which 70% or more students submitted their evaluations.

Tentative Course Outline - *28 lectures & 2 exams*

A. Radiative transfer - *9 lectures*

1. **Th Aug 30**: Course Syllabus. Radiation definitions; specific intensity, photon distribution function, occupation number, energy density, flux, momentum flux, radiation pressure (Shu Ch. 1; R-L § 1.1-1.3)
2. **Tu Sept 4**: Radiation definitions *cont.*.
3. **Th Sept 6**: Equation of radiative transfer; emissivity and opacity. (Shu Ch. 1; R-L § 1.4)
4. **Tu Sept 11**: Blackbody radiation: radiation thermodynamics, Stefan-Boltzmann law; Bose-Einstein statistics; Planck spectrum; Rayleight-Jeans and Wien limits, radiation constant, effective temperature, color temperature and brightness temperature (Shu Ch. 1,2; R-L § 1.5)
5. **Th Sept. 13** : Moment equations; radiative diffusion approximation, Rosseland mean opacity, scattering and random walks (Shu Ch. 2; R-L § 1.7, 1.8)
6. **Tu Sept. 18**: Moment equations *cont.*
7. **Th Sept 20**: General solution of radiative transfer equation; source function; optically-thick and -thin limits; LTE; line formation: absorption and emission spectra, limb darkening (Shu Ch. 3; R-L § 1.4)
8. **Tu Sept 25**: General solution of radiative transfer equation *cont.*
9. **Th Sept 27**: Plane-parallel atmospheres: radiative equilibrium, grey opacity, Eddington approximation (Shu Ch. 4; R-L § 1.8)

B. Thermodynamics and Statistical Mechanics - *4 lectures*

1. **Tu Oct 2**: Statistical mechanics: definitions of entropy, temperature, chemical potential, pressure, grand canonical partition function (Gibbs sum); Thermodynamics: thermodynamic identity, grand potential, entropy (Shu Ch. 6; R-L § 1.5)
2. **Th Oct 4**: Quantum statistical mechanics: Fermion and Boson partition functions, grand potentials, occupation numbers (Shu Ch. 6; R-L § 1.5)
3. **Tu Oct 9**:Statistical equilibria: reaction equilibrium, Boltzmann law for internal level populations, Saha equation for ionization state populations; free particle partition functions (Shu Ch. 7; R-L § 9.5)
4. **Th Oct 11**: Rate equations and detailed balance; Einstein A and B coefficients, relations to emissivity, absorption opacity, cross-section, oscillator strength; collisional processes (Shu Ch. 8; R-L § 1.6)

C. Electrodynamics - *5 lectures*

1. **Tu Oct 16**: Maxwell equations; vacuum electromagnetic wave equations; plane parallel waves; EM energy and momentum flux [Poynting vector and Maxwell stress tensor] (Shu Ch. 11; R-L § 2.1-2.2)
2. **Th Oct 18**: Fourier spectra of radiation; Stokes parameters and polarization (Shu Ch. 12; R-L § 2.3-2.4)
3. **Tu Oct 23**: *Midterm exam*
4. **Th Oct 25**: EM wave equation with sources; scalar and vector potentials; gauge transformations; retarded potentials; Green's function solutions for inhomogeneous wave equations, single particle (Lienard-Wiechert) retarded potential (Shu Ch. 13; R-L § 2.5, § 3.1-3.2)
5. **Tu Oct 30**: Wave zone; electric dipole radiation; radiation reaction; Thomson scattering Rayleigh scattering (Shu Ch. 14; R-L § 3.3-3.6)
6. **Th Nov 1**: Multipole radiation: magnetic dipole, electric quadrupole, permitted and forbidden transitions (Shu Ch. 15; R-L § 3.3))

D. Plasma radiation and transfer - *5 lectures*

1. **Tu Nov 6**: Thermal Bremsstrahlung (Shu Ch. 15; R-L Ch. 5)
2. **Th Nov 8**: Compton scattering (R-L Ch. 7)
3. **Tu Nov 13**: Radiation from relativistic charges (Shu Ch. 16, 17; R-L Ch. 4)
4. **Th Nov 15**: Synchrotron radiation (Shu Ch. 18, 19; R-L Ch. 6)
5. **Tu Nov 20**: EM waves in plasmas; dispersion; Faraday rotation (Shu Ch. 20; R-L Ch. 8)
6. **Th Nov 22**: *Thanksgiving holiday*

E. Atomic and molecular structure and radiation (QED) - *5 lectures*

1. **Tu Nov 27**: Electromagnetic Hamiltonian (Shu Ch. 21; R-L § 10.1)
2. **Th Nov 29**: Semiclassical theory of radiative transitions: quantum matter/radiation interaction Hamiltonian, theory vector potential, **E** and **B** fields, semiclassical radiation energy density, absorption and emission Hamiltonians (Shu Ch. 22; R-L § 10.1)
3. **Tu Dec 4**: Time dependent perturbation theory; propagator; one- and two- photons transitions; transition probabilities and rates for absorption/emission [Fermi's golden rule] (Shu Ch. 22; R-L § 10.1)
4. **Th Dec 6**: Dipole approximation; bound-bound transition rates and cross-sections; oscillator strengths; matrix elements; Einstein A and B coefficients for bound-bound transitions (Shu Ch. 23; R-L § 10.2, 10.3, 10.5)
5. **Tu Dec 11**: Bound-free transitions in the Born approximation; photoionization and recombination rates and cross-sections; Einstein-Milne relations; linewidth and natural broadening (Shu Ch. 23; R-L § 10.5, 10.6)
6. **Tuesday Dec 18 (1:30pm-3:30pm)**: *Final exam*