Astronomy 601 - Fall 2017
“Radiative Processes”

Instructor

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Schedule

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

In addition, I will post the lecture notes I use to teach on ELMS or hand out hardcopies.

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 roughly 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 with solutions and the solution may be discussed in class. In case of well motivated circumstances a late homework will be accepted, but a penalty (that will be gradually more severe depending on number of days the homework is late) will be applied to the grade. After the solution is published I will not accept a late homework. A missed homework will receive a “zero” grade and there will not be extra credit or dropping of the lowest grade.

I will post the homework assignments, solutions and grades on ELMS.

Exams

The exams will be closed book, but calculators will be allowed. University regulations will apply regarding academic honesty and excused absences.

The midterm and final exams are a major scheduled grading event and is covered by the relevant rules for excused absence. If you are not able to take an exam due to illness or other legitimate reasons, you must make every reasonable attempt to contact me on or before the day of the exam either by email or voice mail. In addition, you must provide documentation detailing the reason for your absence. A self-signed note is insufficient. A make up exam must be taken promptly. I will give at most one make-up exam. If, for whatever reason, the University is officially closed on the day of the exam, the exam will be re-scheduled for the next lecture date.

The final exam will cover all material discussed in this course after the midterm exam.

Letter Grades

90%-100%	A
80%-89.9%	B
70%-79.9%	C
60%-69.9%	D

I may rescale the grades depending on the average class performance. Of course the rescaling can only increase your final grade. I will also adopt a finer letter grading using “+” and “-” (*e.g.,* A+, A, A-).

Academic Integrity

The Universitys policies and rules on academic integrity are laid out in this document: `http://www.president.umd.edu/policies/docs/III-100A.pdf`. In essence, you must never engage in acts of academic dishonesty at any time. Acts of academic dishonest include cheating, fabrication, plagiarism, or helping any other person to do any of these things.

These rules apply to homework and quizzes as well as exams. As a part of these rules, you must give credit to any published article or webpage that you have used to help you with a particular assignment. The University takes these issues extremely seriously, as do I.

Course expectations

Attendance: Attendance in class is crucial. A major part of this course will center around in-class discussions. simply getting hold of the lecture notes will not allow you to be successful in this course. In the event of an emergency where you have to miss class, you must make sure that you complete all of the assigned reading, get hold of any lecture notes, and see me in my office hours.

Preparation: I expect you to be prepared to work. We will be covering some fascinating but challenging concepts - you will understand this material much more easily if you preview the recommended reading material ahead of time, as well as giving it a more careful read after the lecture. You also should review your class notes sometime before the next lecture to make sure everything is clear. I encourage you to ask questions in the lectures or during my office hours.

Study Habits: Study wisely and ask for help if you need it. It is better to keep up with the material on a daily basis than cram the night before the exam. I encourage you to chat about problems with your friends and classmates you will learn a huge amount from trying to explain confusing issues to each other. However, please keep in mind that all graded materials, including class-assignments and home-works, must be your own thoughts in your own words.

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. 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.

Course Policies

You can find updated information on Course Related Policies at `http://www.ugst.umd.edu/courserelatedpolicies.html`.

Tentative Course Outline - *28 lectures & 2 exams*

A. Radiative transfer - *9 lectures*

1. **Tu Aug 29**: 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. **Th Aug 31**: Radiation definitions *cont.*.
3. **Tu Sept 5**: Equation of radiative transfer; emissivity and opacity. (Shu Ch. 1; R-L § 1.4)
4. **Th Sept 7**: 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. **Tu Sept. 12** : Moment equations; radiative diffusion approximation, Rosseland mean opacity, scattering and random walks (Shu Ch. 2; R-L § 1.7, 1.8)
6. **Th Sept. 14**: Moment equations *cont.*

7. **Tu Sept 19**: 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. **Th Sept 22**: General solution of radiative transfer equation *cont.*
9. **Tu Sept 26**: Plane-parallel atmospheres: radiative equilibrium, grey opacity, Eddington approximation (Shu Ch. 4; R-L § 1.8)

B. Thermodynamics and Statistical Mechanics - *4 lectures*

1. **Th Sept 28**: 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. **Tu Oct 3**: Quantum statistical mechanics: Fermion and Boson partition functions, grand potentials, occupation numbers (Shu Ch. 6; R-L § 1.5)
3. **Th Oct 5**: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. **Tu Oct 10**: 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. **Th Oct 12**: 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. **Tu Oct 17**: Fourier spectra of radiation; Stokes parameters and polarization (Shu Ch. 12; R-L § 2.3-2.4)
3. **Th Oct 19**: 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)
4. **Tu Oct 24**: *Midterm exam*
5. **Th Oct 26**: Wave zone; electric dipole radiation; radiation reaction; Thomson scattering Rayleigh scattering (Shu Ch. 14; R-L § 3.3-3.6)
6. **Tu Oct 31**: 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. **Th Nov 2**: Thermal Bremsstrahlung (Shu Ch. 15; R-L Ch. 5)
2. **Tu Nov 7**: Compton scattering (R-L Ch. 7)
3. **Th Nov 9**: Radiation from relativistic charges (Shu Ch. 16, 17; R-L Ch. 4)

4. **Tu Nov 14**: Synchrotron radiation (Shu Ch. 18, 19; R-L Ch. 6)
5. **Th Nov 16**: EM waves in plasmas; dispersion; Faraday rotation (Shu Ch. 20; R-L Ch. 8)

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

1. **Tu Nov 21**: Electromagnetic Hamiltonian (Shu Ch. 21; R-L § 10.1)
2. **Th Nov 23**: *Thanksgiving holiday*
3. **Tu Nov 28**: 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)
4. **Th Nov 30**: 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)
5. **Tu Dec 5**: 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)
6. **Th Dec 7**: 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)
7. **Monday Dec 18 (1:30pm-3:30pm)**: *Final exam*