AST 810, Fall 2013

Radiation Astrophysics

Edward Brown

This graduate-level course covers the physics of radiation, the interaction of radiation with matter, and the application of radiative processes to astrophysical phenomena.

Course goals

The primary purpose of a graduate-level course is to weave together the threads of physics and astronomy knowledge you possess into a coherent whole, and to teach you to "think like an astrophysicist." Accordingly, by the conclusion of this course you should be able to

- solve simple radiative transfer problems at a blackboard;
- solve more complicated radiative transfer problems by finding, reading, and applying methods from the current scientific literature; and
- interpret spectra and make good inferences about the physical characteristics of their sources.

A knowledge of undergraduate-level electrodynamics, quantum mechanics, and thermodynamics is assumed. Advanced topics in these areas will be brought into the class discussion as needed, so that the course is self-contained.

Contact information

Assoc. Prof. Edward Brown
3258 BPS
4-5620
mailto:ebrown@pa.msu.edu
http://www.pa.msu.edu/~ebrown

Class meetings and office hours

The class meets Tuesdays and Thursdays from 10:20 to 11:40 in 1300 BPS. Office hours are informal: if my door is open, you are welcome to drop in; alternatively, you may contact me for an appointment. To date, I have two scheduled absences: Tuesday, 10 September, and Thursday, 12 September. We will make arrangements to recover this time later in the semester. Course materials, including a copy of this syllabus, are posted in a Dropbox™ folder at this link.

Text

The primary text is Rybicki & Lightman (1979). The course notes will additionally draw on the sources listed in the references. You are welcome to borrow these books, or any others, from me for a limited time. Updates to the course notes will be posted to Dropbox™ as they are completed.

Course requirements

Expect weekly to biweekly problem sets, normally due on Tuesday. As you know, most of the gain in skill occurs while working the assigned problems and discussing them with peers. We'll discuss these homework problems and shorter "reading assignments" in class, so come ready to present your work—class participation is expected, and your contribution to the in-class discussion will be evaluated. There will be a written midterm and final. You will also make a presentation on a topic related to radiative processes in astrophysics. You will decide on this topic in consultation with me; further details will be announced a few weeks into the course.

Grading policy

The weights for the course grade are as follows.

Coursework: 70%	
Homework	40%
Participation	15%
Presentation	15%
Exams: 30%	
Midterm	10%
Final	20%

No rule of scholarly activity is more important than giving proper credit for the contributions of others. Although you are free to consult with classmates while working on assignments, you must explicitly acknowledge them by name and indicate their contributions in the write-up. The work on the exams must be entirely your own.

For many problems, the grading will be on a three-point scale: $\{-, \checkmark, +\}$, in which the symbols respectively stand for "needs improvement", "satisfactory", and "outstanding." For selected problems I will grade the write-up in detail and assign a numerical grade.

Outline of topics

1. Physics of radiative processes
   (a) From Maxwell to Planck to Einstein
      i. The classical wave equation; quantization of the field; statistics of phonons; thermal spectrum
      ii. Absorption, spontaneous emission, and stimulated emission: Einstein's A and B coefficients; detailed balance
   (b) Phenomenological description of radiation
      i. Thermodynamics of radiation
      ii. Moments of the radiative intensity: radiative flux and pressure
      iii. Polarization, Stokes parameters
   (c) Equation of transfer
      i. Optical depth
      ii. Large optical depth limit; scattering as a random walk
      iii. Radiative diffusion; local thermodynamic equilibrium
   (d) Radiation from free particles
      i. Simple non-relativistic radiating systems; Larmor formula
      ii. Thomson/Compton scattering
      iii. Bremsstrahlung
      iv. Synchrotron
   (e) Radiation from bound atoms and molecules
      i. Equivalent width; curve of growth
      ii. Oscillator strengths; selection rules
2. Application of radiative processes
   (a) Ionization balance

        i. HII regions
        ii. Line formation in a wind; P Cygni profiles
    (b) Scattering by dust
        i. Mie theory
        ii. Extinction coefficient
        iii. Infrared emission
    (c) Interactions with plasma waves
        i. Dispersion
        ii. Scintillation
        iii. Faraday rotation

References

Baym, G. 1990, Lectures on Quantum Mechanics (Addison-Wesley)

Bethe, H. A., & Salpeter, E. E. 2008, Quantum Mechanics of One- and Two-Electron Atoms (Dover)

Chandrasekhar, S. 1960, Radiative Transfer (Dover)

Feynman, R. P., Leighton, R. B., & Sands, M. 1989, The Feynman Lectures on Physics (Addison-Wesley)

Heitler, W. 1984, The Quantum Theory of Radiation (Dover)

Jackson, J. D. 1975, Classical Electrodynamics, 2nd edn. (Wiley)

Landau, L. D., & Lifshitz, E. M. 1975, Course of Theoretical Physics, Vol. 2, The Classical Theory of Fields, 4th edn. (Pergamon)

Longair, M. S. 1992, High Energy Astrophysics, Vol. 1, Particles, Photons, and Their Detection, 2nd edn. (Cambridge University Press)

Mihalas, D. 1978, Stellar Atmospheres, 2nd edn. (W. H. Freeman)

Osterbrock, D. E. 1989, Astrophysics of Gaseous Nebulae and Active Galactic Nuclei (University Science Books)

Rybicki, G. B., & Lightman, A. P. 1979, Radiative Processes in Astrophysics (Wiley)

Shu, F. H. 1991, The Physics of Astrophysics, Vol. I, Radiation (University Science Books)

Spitzer, L. 1978, Physical Processes in the Interstellar Medium (Wiley)

van de Hulst, H. C. 1981, Light Scattering by Small Particles (Dover)