

AS 713 Spectroscopy in Astrophysics
Fall 2000. Tuesday and Thursday 9:30-11:00
Astronomy Conference Room CAS 500

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Office Hours:

M 9-12 or by appointment

Subject:

This course presents the physical basis for spectroscopic measurements in astronomy. We will therefore cover elementary quantum mechanics, to see where the energy levels come from, and statistical mechanics, to see what determines the strength of a spectral line. Armed with our copious knowledge, we will then learn how to measure physical quantities (temperature, density, column density, composition...) from spectroscopic measurements. Finally, we will review current instrumentation used for spectroscopic measurements.

Grading:

problem sets 40%
midterm 30%
final 30%

Textbooks:

No single text covers all the material in this course. You are not required to purchase any texts. For the first part of the course, a good elementary text on quantum mechanics is best (e.g., Anderson, Cohen-Tannoudji...). For the second part of the course, there are a few good texts. Perhaps the best is:

Shu, *The Physics of Astrophysics, Vol. 1, Radiation*

I also urge you to peruse the following:

Rybicki and Lightman, *Radiative Processes in Astrophysics*

Spitzer, *Physics of the Interstellar Medium*

Townes and Schawlow, *Microwave Spectroscopy*

COURSE OUTLINE

- I. Review of Quantum Mechanics
 - a. Wave functions
 - b. Dispersion relations
 - c. Schrödinger's equation
 - d. Stationary states
 - e. Eigenvalues and quantization
 - f. Operators
 - g. Simple one dimensional potentials
 - h. Example – the simple harmonic oscillator
 - i. Central Potentials
 - ii. Spherical Harmonics
- II. Atoms
 - a. The hydrogen atom
 - b. Angular momentum and spin
 - c. Electronic orbitals and notation
 - d. More complicated atoms
- III. Molecules
 - a. Rotation
 - b. Vibration
 - c. Linear molecules
 - d. Symmetric rotors
 - e. Asymmetric rotors
- IV. Time Independent Perturbation Theory
 - a. Two level systems
 - ex 1. H I fine structure
 - ex 2. NH₃ inversion splitting
 - b. N-level systems
 - c. ex 1. Zeeman splitting
 - d. ex 2. Nuclear quadrupole hyperfine splitting
- V. Time Dependent Perturbation Theory
 - a. Electric dipole
 - b. Magnetic dipole
 - c. Electric quadrupole
- VI. Atomic Spectral Lines
 - a. Electronic orbital
 - b. Fine structure
- VII. Molecular Spectral Lines
 - a. Rotational
 - b. Lambda doubling
 - c. Vibrational
 - d. Inversion
 - e. Hyperfine
- VIII. Review of Statistical Mechanics
 - a. Thermal equilibrium
 - b. Maxwell-Boltzmann distribution
 - c. Connection to thermodynamics
 - d. Partition function
 - e. The Saha equation

- IX. Atomic and Molecular Excitation
 - a. Collisional excitation
 - b. Radiative excitation
 - c. Detailed balance
 - d. The rate equations
 - e. Critical density and excitation temperature
 - f. Examples
 - i. Two level system
 - ii. Multi-level system
 - g. Local Thermodynamic Equilibrium (LTE)
 - h. Non-LTE excitation
 - i. Subthermal excitation
 - ii. Masers
- X. Physical Parameters from Lines
 - a. Temperature
 - b. Column density
 - c. Density
 - d. Radiation fields
 - e. Kinematics
- XI. Line Shapes
 - a. Natural broadening
 - b. Thermal broadening
 - c. Pressure broadening
 - d. Doppler broadening
- XII. Spectrometers
 - a. Prisms
 - b. Gratings
 - c. Circular variable filters
 - d. Echelles
 - e. Fabry-Perots
 - f. Filterbanks
 - g. Autocorrelators
 - h. Acousto-optical spectrometers