Astronomy 871: Physics of the Interstellar Medium

Course Syllabus

Course Topics:

I. Introduction and General ISM Physics – 1 week

Historical & Phenomenological Overview of the ISM

Physical Description of the ISM

- Kinetic Equilibrium
- Excitation Equilibrium
- Ionization Equilibrium
- Pressure Equilibrium

Global Models of the ISM

- Heating & Cooling Mechanisms
- Thermal Stability & Equilibrium (2-phase models)
- The Hot "Third" Phase
- Multi-Phase Models

II. Neutral Atomic Gas (HI Regions) – 2 weeks

Interstellar UV & Visible Absorption Line

- Observations
- Radiative Transfer in Lines & Line Formation
- The Equivalent Width Curve of Growth
- Interstellar HI Lyman absorption lines
- Gas-phase abundances of metals

The HI 21cm hyperfine structure line

- Hyperfine structure overview
- Level populations, optical depth, stimulated emission
- 21cm line formation in absorption & emission
- Excitation of 21-cm emission
- Heating & cooling, radiative transfer

III. Ionized Gas (HII Regions) – 2 weeks

Photoionization Equilibrium & Ionization Structure

- Photoionization equilibrium
- Ionization Structure
- The Pure Hydrogen Nebula (Strömgren Spheres)
- Hydrogen & Helium, and the effects of metals and dust

Thermal Structure of Nebulae

- Heating
- Cooling (recombination, free-free, and collisional excitation)
- Collisional Cooling (electron-ion impact excitation line cooling)
- Thermal Equilibrium

Spectra of Ionized Hydrogen Regions

- The Recombination Spectrum (Case A & Case B recombination)
- Nebular Continuum (free-free, free-bound, 2-photon recombination continuum)

Nebular Diagnostics

- Basic spectra of ionized gas regions (HII regions, PNe, SNe)
- Emission Measure
- Lyman Continuum
- Nebular Temperature & Density Diagnostics
- Nebular Abundances.

IV. Interstellar Dust – 2 weeks

Interstellar Extinction

- Basic Phenomenology
- The Interstellar Extinction Curve (total & selective extinction)
- Correlation of Extinction and Total Hydrogen Column Density
- Fine Structure (2175Å bump, Diffuse IS bands, mid-IR bands, ices and aromatic features, silicate features)

Optical/material properties of dust grains

- Basic Grain Parameters
- Optical Depth & Albedo

Physical Properties of Dust Grains

- Grain Materials
- Grain Shapes & sizes
- Grain Mixture Models
- Grain Formation & Destruction

Interstellar Polarization

- Observed properties: "Serkowski Law", scattering and emission polarization.
- Grain alignment (Davis-Greenstein, Superparamagnetism, Superthermal rotation)

Emission from Dust Grains

- Equilibrium heating of large grains
- Dust mass estimates
- Non-equilibrium heating of tiny grains
- Dipole radio/microwave emission from spinning grains

Depletion of elements onto dust grains

- Observed elemental depletion patterns
- Implications for grain composition

V. Interstellar Molecules (H_2) – 2 weeks

Overview

Interstellar CO and other tracer molecules

- Radiative transfer for mm-wavelength transitions
- Critical Density & molecular line "visibility"
- Total Column Densities & Density/Temperature Diagnostics
- Radiative Trapping
- Anomalous Excitation
- The Standard CO Analysis

Molecular Hydrogen (H_2)

- UV Lyman-Werner Bands
- Near-Infrared Vibrational-Rotational Emission Lines
- Excitation Diagrams,
- H_2 formation and destruction mechanisms, self-shielding

Observed Properties of Molecular Clouds

- Cloud Structure
- Cloud Masses (standard virial analysis)
- Standard CO/H_2 conversion

Photodissociation Regions (PDRs)

- Basic overview of properties
- Heating & Cooling Balance
- Spectra of PDRs

VI. The Hot ISM – 1 week

Collisional Ionization Equilibrium (CIE)

- Collisional Ionization
- Radiative & Dielectronic Recombination
- Heating & Cooling of Hot Gas
- CIE and Astrophysical Plasmas

The Spectrum of the Hot ISM

- ISM Opacity and the observed spectrum
- Diffuse Soft X-ray Continuum
- UV and FUV Absorption Lines (esp. OVI absorption)

Textbook:

There is no textbook in print for this course at the appropriate level. Instead, the following books are provided as suggested references for further reading:

Osterbrock & Ferland, *Astrophysics of Gaseous Nebulae and Active Galactic Nuclei*, 3rd edition (2006 University Science Books). Mostly used for the ionized gas sections, still the classic and most detailed treatment in the field.

Tielens, *The Physics and Chemistry of the Interstellar Medium* (2005 Cambridge University Press). The main emphasis is on chemistry and dust properties plus molecules and photodissociation regions. A very lucid overview of those areas we do not cover in depth (or at all) in this class.

Dopita & Sutherland, *Astrophysics of the Diffuse Universe*, (2002 Springer Verlag). A more advanced monograph, it contains a lot of material covered in the Astrophysical Spectroscopy course and detailed discussions of shocks outside the scope of this course. Primarily a source book for the instructor.

Spitzer, *Physical Processes in the Interstellar Medium*, (1978 Wiley Interscience). Currently out of print and somewhat dated in many areas, but the basic physics sections are still sound. Not a book for wimps, it is very deep and challenging.

Lecture notes for this course are available online at this website:

http://www.astronomy.ohio-state.edu/~pogge/Ast871/

There is also a supplementary bibliography giving some of the primary research sources and key papers in the field that were consulted in preparing the material for this course.

Evaluation:

60% on homework assignments (typically 6 problem sets assigned during the quarter), 40% final exam.

Course Objectives:

This course is intended to provide students with a detailed overview of the physical processes and properties of the interstellar medium. Upon completion, students should be able to read and understand current research papers dealing with low-density gases in the form of HII regions, planetary nebulae, HI regions, molecular clouds, photodissociation regions, supernova remnants, etc. These topics form the fundamental physical basis of our current understanding of the observed properties of low-density astrophysical plasmas observed throughout the Universe. The syllabus is *extremely* ambitious for a 10-week quarter, and adjustments will be made depending upon how the course is going, and upon the interests of the students.

Students with Disabilities:

Any student who feels that s/he may need an accommodation based on the impact of a disability should contact the instructor to discuss specific needs. The instructor will rely on the Office of Disability Services to verify the need for accommodation and to help develop accommodation strategies. Students with disabilities who have not previously contacted the Office of Disability Services are encouraged to do so, by looking at their web site (http://www.ods.ohio-state.edu) and calling them for an appointment.

Academic Misconduct:

OSU professors are required to report suspected cases of academic misconduct to the Committee on Academic Misconduct. (The University's rules on academic misconduct can be found on the web at http://acs.ohio-state.edu/offices/oaa/procedures/1.0.html). The most common form of misconduct is plagiarism, often inadvertent. Remember that any time you use the ideas or the statements of someone else you must acknowledge that source in a citation. You should give accurate citations of sources in any research papers or oral presentations that you do for this class.