

**PHYS 8900 Advanced Topics:  
Atomic and Molecular Astrophysics of Gaseous Nebulae  
Fall 2016**

**Instructor:** Phillip Stancil

**Times and Location:** TuTh 2pm-3:15pm, Physics 254

**Credits:** 3 hours

**Office:** Physics 325A

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**Prerequisite:** None, but ASTR 8090 (The Interstellar Medium) might be useful. The course will assume basic knowledge of upper level physics and astronomy undergraduate material.

## Introduction

The goal of the course is to give an introduction to the physics and chemistry of photoionized and collisionally-ionized gas in astrophysics. The basic flow of the course will follow the general outline given in Osterbrock and Ferland (2006), but additional topics will be introduced as appropriate. In particular, emphasis will be placed on relevant atomic, molecular, and solid-state processes and their role in the thermal balance, ionization balance, chemistry, and emergent photon spectra. Some fluid dynamics and radiative transport will be introduced. The course is intended to be an extension of ASTR 8090, but with a focus on higher-energy astrophysical environments and processes. A variety of applications, drawn from the current astrophysical literature, my interests, or the students', will be presented and discussed as time allows.

## Required Textbook

- *Astrophysics of Gaseous Nebulae and Active Galactic Nuclei*, 2nd Edition, by D. E. Osterbrock and G. J. Ferland (University Science Books, 2006).

## Additional Resources

- *The Physics and Chemistry of the Interstellar Medium*, by A. G. G. M. Tielens (Cambridge University Press, 2005). (I have this checked out)
- *Physics of the Interstellar and Intergalactic Medium*, by B. T. Draine (Princeton Univ. Press, 2011).
- *Spectroscopic Challenges of Photoionized Plasmas*, edited by G. J. Ferland and D. W. Savin, American Society of the Pacific Conf. Ser., Vol. 247 (2001).
- *The Formation of Stars*, by S. W. Stahler<sub>†</sub> and F. Palla (Wiley-VCH Verlag, 2004).

- *The Physics of Interstellar Dust*, by E. Krügel (Institute of Physics, 2003). (I have this checked out).
- *The Physics of the Interstellar Medium*, 2nd ed., by J. E. Dyson and D. A. Williams (Institute of Physics, 1997).
- Course website: [www.physast.uga.edu/classes/phys8900/stancil/](http://www.physast.uga.edu/classes/phys8900/stancil/)

## Assignments and Grading Policy

I expect to give 4-5 homework assignments throughout the semester involving typical analytical problem solving. We will also have a small, class computational project. Students are expected to read the textbook and are required to participate in class discussions. Attendance is mandatory, but the student will be allowed excused absences (if you contact me beforehand). Grades will be determined from:

- 80% Average of homework assignments
- 10% Computational project
- 10% In-class participation

The final letter grading scale determined from the composite of the course assignments will be: 100%-90% : A; 89.9%-85% : A-; 84.9%-77% : B+; 76.9%-70% : B; 69.9%-65% : B-; 64.5%-60% : C+; 59.9%-55% : C; 54.9%-50% : C-; 49.9%-45% : D; <45% : F.

## Computational Project

We will perform a class project in which we develop a computational tool (likely in python) for the analysis of molecular rotational emission lines. The final package will have the following components given a set of observed molecular line intensities: i) fit the observation to one or more equilibrium (or local thermodynamic equilibrium (LTE)) emission models to deduce the gas temperature, ii) fit the observations to a non-LTE model extracting temperature and density, iii) extract the incident radiation field, and iv) predict the emission spectra for wavelengths outside the observation window. v) Pre- and postprocessing features could be incorporated to obtain absolute calibrated intensities given detector efficiencies, line-profile fitting to determine gas velocity, display of final spectra and various diagnostic products, etc. Each student will be assigned a particular task. Other details to be discussed in class.

## Preliminary Course Outline

- Introduction to Gaseous Nebulae
- Ionization Balance, Atomic and Electron Collisions
- Thermal Balance in High Temperature Gas
- Line and Continuum Emission

- Temperature and Density Diagnostics
- Introduction to Gas Dynamics
- Dust (including PAHs) and Its Various Roles
- Thermal Balance and Collisions in Low Temperature Gas
- Chemistry in Gaseous Nebulae
- X-ray Processes in Gaseous Nebulae
- Application: Planetary Nebulae
- Application: Photodissociation Regions
- Application: X-ray Dominated Regions
- Application: Supernova Remnants and Ejecta
- Application: The Early Universe and Primordial Stars
- Application: Protoplanetary Disks
- Application: Circumstellar envelopes and outflows