Syllabus

ASTR 3520
Astronomical Observations and Instrumentation II: Spectroscopy
Fall 2008

Location:
Class:
Tu, Th 12:30 -- 1:45 PM : ***E126 Duane Physics***
Lab:
Tuesdays, 6:30 -- 8:30+ : ***SBO class room, and at the 24 inch telescope***
http://casa.colorado.edu/~bally/ASTR3520/public/index.html

Instructor:

John Bally
John.Bally@colorado.edu
Duane 323A, 303 492 5786
Office Hours:
Wed & Thurs 2:00 PM in C323A, or by appointment

TA:
Adam Ginsburg
Adam.Ginsburg@colorado.edu
Duane C329, 303 667 3805
Office Hours:
Mon & Wed 11:00 to 12:00 AM, or by appointment

Purpose:

The purpose of ASTR3510/3520 is to introduce students to the principles of instrumentation used in astrophysics, planetary science, and space physics. The first semester emphasizes modern imaging technology while the second semester emphasizes spectroscopy. This course (the second semester) will explore the physics and use of spectroscopy in astrophysics, planetary science, and space physics.

The main goal this semester will be to prepare students to do serious research projects with the SBO 24" and/or the APO 3.5 meter telescope at Apache Point Observatory in New Mexico. My lectures, and the labs, will be aimed at teaching basic research skills including proposal writing, generation of an observing program, data acquisition at the telescope using tools such as CCDSoft and TUI, use of data reduction software packages such as IRAF and IDL, and the write-up and presentation of research results. As outlined below, we will discuss the basic physics involved in the emission, absorption, and detection of electromagnetic radiation, the design and use of spectrographs, the uses of spectroscopy in astronomy including stellar classification and the determination of basic stellar parameters, the study of the interstellar medium, and research into the properties of forming, main-sequence, and dying stars, galaxies, and the evolution of the Universe.

Grading:

The grade will be based on problems sets (30%), a midterm (10%), a final (20%) and a combination of lab write-ups, including an end-of semester, in-class oral plus written presentation of a student project (30%). The remaining 10% of your grade will be determined by your participation in discussions in class and lab. Class and laboratory attendance is mandatory.

All students are expected to do their own work. It is expected that when collaborating in projects with other students, each student will do a fair share of the work. Cheating, copying, or use of material without proper referencing or attribution is unacceptable.

Observing Projects:

In this class, you will have access to the SBO 24" and to the Apache Point Observatory (APO) 3.5 meter telescopes.

The end-of semester research project can be based on either data acquired with the SBO spectrograph or the APO 3.5 meter spectrographs obtained during our field-trip. All students will be required to submit a formal proposal for an observational research project. The project oral presentation and written report will be due during the last week of the semester. These proposals will be due at the end of September.

Projects can be collaborations of up to three students. If we have a small class, groups should only consist of 2 students per group so that we have at least 4 independent projects. In group projects, each student will have to identify specific roles and carry out their tasks on their own. These roles, along with the goals and methodology of your project, will be spelled out in the project proposal (more on this during the first two weeks of class).

I submitted a time request for four half-nights of observing time on the Apache Point Observatory 3.5 meter for use by our class. However, the status of this proposal is still unknown.

Field Trip:

We will have a field trip to the Apache Point Observatory where CU has access to a 3.5 meter telescope. On this field trip, we will visit the National Solar Observatory at Sunspot NM, and the Very Large Array radio telescope operated by the National Radio Astronomy Observatory near Socorro, NM. I have requested observing time on the 3.5 meter telescope for student projects. The field trip will tentatively occur during the second half of October and will last about 5 or 6 days, and 4 to 5 nights. Travel and lodging expenses will be covered by CU. The field trip is highly recommended, is a unique experience for undergrads, and is the highlight of the class, and possibly the major, but it is NOT required.

Observing with the 24":

Students will make extensive use of the 24" SBO telescope and spectrograph. During the course, students will obtain several types of spectra including spectra of stars and emission nebulae. These data can form the basis of the student presentations at the end of the semester.

TEXT BOOK:

``***Optical Astronomical Spectroscopy"*** , C. R. Kitchin, 1995, Institute of Physics Publishing, Bristol

REFERENCE MATERIALS:

``***Astrophysical Techniques"***, C. R. Kitchin 1998, Institute of Physics Publishing, Bristol

``***QED; The Strange Theory of Light and Matter",*** Richard P. Feynman, 1985, Princeton University Press

``***Electronic Imaging in Astronomy; Detectors and Instrumentation"***, 1997, Ian S. McLean, John Wiley and Sons, New York

``***Astronomical Observations; An Optical*** Perspective", 1987, Gordon Walker, Princeton University Press, Cambridge

``***Astronomical Optics"***, 1987, Daniel J. Schroeder, Academic Press, Inc., New York

Course Outline:

The schedule is meant to be flexible. The field trip to ARC and the VLA will take about 5 to 6 days. I requested the last week in October for the field trip, but we will not know the exact timing until we receive the Fall schedule (expected in late September). The outline below is intended to provide a summary of the course contents.

Week 1. Introduction:
Intro to class and logistics. Class overview. Discussion of field trip to Apache Point and the VLA and student semester projects. Form 24" observing groups. Overview of the lab exercises and demonstrations.

Review fundamentals of spectroscopy and operations of SBO spectrograph.

Week 2. Basics:
Read Kitchin pgs. 1 - 44 (Ch. 1 -- 3)

Numerical examples of image-scales, spectrograph optics, slit re-imaging and projection onto the sky. Introduction to IRAF (Image Reduction and Analysis Facility software). Review image reductions and photometric zero-points. Review electronic imaging fundamentals. Review CCD basics and operation. Data acquisition procedures. Why low-light level data acquisition is different from bright-object work. Review read noise, bias, and the need for flat fields. Review magnitude scale and relationship to flux and black-body spectra. Thermal emission, black-body spectra, and continua.

Week 3. The physics of radiation
Read Kitchin pgs. 45 - 113 (Ch. 4 -- 7) Blackbody continuum radiation. Overview / review of quantum mechanics. The wave-nature of matter. Discrete energy levels and transitions. Emission and absorption by atoms and ions.

Week 4. Astronomically important spectral features.
Hydrogen, forbidden lines of common neutrals and ions. Simple molecules such as H_2, CO. Spectra of molecules and solids. Spectra of interstellar grains and ices. Overview of spectroscopy and methods at other wavelengths (X-ray, IR, radio).

Week 5. Review Radio Astronomy.
Overview of radio astronomy: Discussion of the Very Large Array and interferometric methods and preparation for the field drip. Non-thermal / synchrotron emission by electrons. The Zeeman effect. Grain alignment. Polarized continua. Uses of the Doppler effect. Lab demonstration of interference, diffraction. The pinhole camera. Multi-aperture interference.

Week 6. Optical spectroscopes.
Read Kitchin pgs. 119 - 185 (Ch. 8 -- 10). More formal discussion of spectrograph optics: refraction, diffraction, interference. Design of practical spectrographs. Roles of collimator and camera, entrance slit. Gratings, orders, blazing.

Week 7. Advanced methods:
Cross-dispersion, image slicers. Fourier-transform devices. Interference filters and tunable filters ; Fabry-Perot interferometers.

Week 8. Advanced methods:
X-ray, IR, radio methods. The need for cryogenics at IR and radio wavelengths. Coherent (heterodyne) vs. incoherent (direct) detection. Radio interferometers and radio spectroscopy.

Week 9. Uses of spectroscopy: Stars.
Read Kitchin pgs. 189 -- 252 (Ch. 11 -- 17). Stellar classification. Spectral line formation in stellar atmospheres. Overview of radiative transfer.

Week 10 (?). Field Trip: Visit to the Very Large Array Radio Telescope, the Apache Point Observatory, and the National Solar Observatory in New Mexico

Week 11. Uses of spectroscopy: The interstellar medium.

Line formation in nebulae, molecular clouds, and other diffuse media. Temperature and density estimation. Use of forbidden lines to diagnose temperature and density.

Week 12. Uses of spectroscopy: Radiative transfer.
Stellar winds. Uses of the Doppler effect; binary stars, kinematics of nebulae, jets, explosions. Diagnosing motion: Infall, outflow, rotation. Rotation curves: Keplerian, rigid-body, flat. Relation to mass distribution and applications to proto-planetary disks and galaxies. Hubble expansion of the Universe.

Week 13. Advanced methods and the future:
1D, 2D, vs. 3D ``data-cube generators''. Integral-field, multi-object, and fiber spectroscopy. Precision Doppler methods and planet finding. STJs, energy-sensing imagers, and other future possibilities. Future developments in space and on the ground.

Week 14. Student presentations:

Week 15. Catch-up: