Syllabus

ASTR 3520
Astronomical Observations and Instrumentation II: Spectroscopy
Spring 2012

Class:
Tu, Th 12:30 -- 1:50 PM : ***G131, Duane Physics*** or ***SBO*** (on Thursdays, starting week 3)

Lab:
Tuesdays, 6:30 -- 8:30+ : ***SBO class room, and at the 24 inch telescope***

Instructor:

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Wed & Thurs 2:00 PM in C323A, or by appointment

TA:

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By appointment

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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 is to familiarize students with spectroscopy with emphasis on data acquisition, reduction, and presentation. The skills learned in this class should be applicable far beyond astronomy. While the class will 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, the skills learned will be applicable to in many other disciplines and serve the general astronomy student.

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%), three formal laboratory exercises (30%), a semester projects (30%), and class participation (10%). The lab grades will be based on write-ups. The semester project will be evaluated from a combination of formal write-up as a paper and in-class presentation of the student project (PowerPoint and poster). 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.

Labs:

There will be three formal laboratory exercises in this class. Each will take at least several weeks to complete. The labs are**:**

1. **Bench Spectrograph.** You will use the optics kits at SBO to build a bench spectrographs, measure its performance characteristics, and use if to observe laboratory sources.
2. **Solar Spectroscopy with the 24.** You will use the 24" spectrograph to obtain daytime solar spectra using the diffuse light scattered into the dome (dome will not be open for this). You will calibrate the acquired data and identify some spectral features.
3. **Planetary, Stellar, Nebular, and galactic spectroscopy.** Each student team will be assigned a list of astronomical target to observe. You will acquire, reduce, and analyze the resulting night-time observations.

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. 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).

Field Trip: 8 March to 13 March (end of week 8, start of week 9)

I submitted a time request, and have been granted for four nights of observing time on the Apache Point Observatory 3.5 meter for use by our class.

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.

TEXT BOOK:

None

REFERENCE MATERIALS:

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

``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 field trip to ARC and the VLA will take about 5 to 7 days in March (See the Apache Point Observatory web-pages at http://www.apo.nmsu.edu/ – We are listed as program ***CU01***. You can see the proposal I submitted last Fall by clicking on ***Program Proposal text.)*** Our observing nights on the 3.5 meter are (on the above web-pages, click on "3.5m Schedules"):

APO Field Trip:
9 March (all night), 10 March (all night), and first shift (sunset to midnight) on 11 and 12 March.

Week 1. 17 / 19 Jan
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. Numerical examples of image-scales, spectrograph optics, slit re-imaging and projection onto the sky. Field trip sign-up.

Week 2. 24 / 26 Jan
Basics: The physics of radiation:
Review fundamentals of spectroscopy. Blackbody continuum radiation. Introduction to quantum mechanics. The wave-nature of matter. Discrete energy levels and transitions. Emission and absorption by atoms and ions.

Review electronic imaging fundamentals. Review CCD image reductions.
Instructions for student projects. Use of APO 3.5 meter or 24"

Lab 0: Introduction to SBO 24" spectrograph operations (In dome).

Week 3. 31 Jan / 2 Feb
Optical spectroscopes.
Spectrograph optics: refraction, diffraction, interference. Design of practical spectrographs. Roles of collimator and camera, entrance slit. Prisms, gratings, orders, blazing.

Start Lab 1. (Bench Spectrograph)

Week 4. 7 / 9 Feb
Uses of spectroscopy: Nebulae
Hydrogen, forbidden lines of common neutrals and ions. Nebular spectroscopy. Physics of nebulae, and plasmas.

First draft student proposals are due:

Lab 1 continued. (Bench Spectrograph)
Start Lab 2 (Daytime Solar spectra)

Week 5. 14 / 16 Feb ***[Bally in Bologna at Herschel/Planck meeting]***
Spectral Reduction methods (in COSMOS lab).
Introduction to IRAF (Image Reduction and Analysis Facility software) for spectroscopy.

Continue Lab 2 (Daytime Solar spectra)
Start Lab 3 (Stellar and nebular spectroscopy with the 24")

Week 6. 21 / 23 Feb
Review Radio Astronomy.
Overview of radio astronomy: Discussion of the Very Large Array, ALMA, and interferometric methods in preparation for the field drip. Non-thermal / synchrotron emission by electrons. Radiation by molecules. And 21 cm HI. The Zeeman effect. Grain alignment. Polarized continua. Uses of the Doppler effect.

Lab demonstration of interference, diffraction. The pinhole camera. Multi-aperture interference.

Week 7. 28 Feb / 1 March
Uses of spectroscopy: Stars.
Stellar classification. Spectral line formation in stellar atmospheres. Overview of radiative transfer.

Final draft student proposals are due:

Week 8. 6 / 8 March ***[Bally at Jets meeting in Charlottesville, VA on 6 March.]***
Travel to APO on 8 March. [FIELD TRIP starts]
Preparation for field trip. Introduction to APO, TUI, etc.

Week 9. 13 / 15 March
[return from FIELD TRIP on 13-th]
Review projects and field trip results. Provide background discussion on projects.

Week 10. 20 / 22 March
Spectroscopy at other wavelengths:
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 11. 27 / 29 March ***[SPRING BREAK]***

Week 12. 3 / 5 April
Uses of spectroscopy in Astronomy:
Line formation in nebulae, molecular clouds, and other diffuse media. Radiative transfer. Temperature and density estimation. Use of lines to diagnose temperature, density, abundances. Stellar winds.

Week 13.   10 / 12 April

Doppler Effect.

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.

Precision Doppler methods and planet finding.

Week 14. 17 / 19 April

Advanced spectroscopic methods.

Fourier-transform devices. Interference filters and tunable filters ; Fabry-Perot interferometers.
Applications of spectroscopy outside astronomy.

Week 15. 24 / 26 April

Advanced methods and the future:

1D, 2D, vs. 3D ``data-cube generators''. Integral-field, multi-object, and fiber spectroscopy.
Cross-dispersion, image slicers. STJs, energy-sensing imagers, and other future possibilities.
Future developments in space and on the ground.

Week 16. 1 / 3 May

Student Project presentations: