

# **AS 441 – Observational Astronomy**

Prof. Clemens – Spring 2007

## **Catalog Description:**

Astronomical techniques. Photometry, spectroscopy, photography, CCD imaging and interferometry. Statistical methods for data reduction and analysis. Strong laboratory component. Use of computers.

## **Meeting Times:**

Lecture: MWF 1-2pm in CAS 502  
Computer Lab: MF 2-3 in CAS 606  
Observatory: Wednesday Evenings

## **Office Hours:**

Mondays 11-noon, Wednesdays 9-10am, Fridays 11-noon in room CAS 417, and by appointment (3-6140; [clemens@bu.edu](mailto:clemens@bu.edu))

## **Synopsis:**

This course is the capstone course for Astronomy and Astronomy-and-Physics majors, normally taken at the end of their Junior or Senior year. The course will emphasize: (1) introduction to observational techniques, including photometry, imaging, spectroscopy, polarimetry, and interferometry; (2) development of error analysis skills, including basic statistics and regressions; (3) problem solving in analytic, computational, and telescope+detector systems; and (4) effective scientific writing through project reports.

This course represents a departure from previous courses (which emphasize lectures, homeworks, and exams) by encouraging students to research, design, develop, debug, and explore all aspects necessary for conducting quantitative astronomical observations. It will be strongly “hands-on” and will utilize a great deal of the understanding developed in previous courses (especially AS202, 203, 311, 312, and 413).

This semester we will use the small radio telescope, the computer-controlled 14” telescope and CCD imager, and the Mimir infrared instrument on the Perkins telescope in Flagstaff, Arizona.

## **Texts:**

“Data Reduction and Error Analysis for the Physical Sciences,” by Bevington and Robinson, 2<sup>nd</sup> Edition. ISBN 0-07-911243-9

“IDL Programming Techniques,” by Fanning, 2nd Edition. ISBN 0-9662383-2-X

## **Class Web Site:**

Information, programs, and other links may be found at the class web site:  
[http://people.bu.edu/clemens/as441\\_home.html](http://people.bu.edu/clemens/as441_home.html)

**Attendance & Absences:**

The lecture meetings (MWF1-2) and discussion meetings (MF2-3) are vital components of the course – every meeting should be attended by every student. Chronic absence and/or late arrival negatively impacts other students in the course and is to be eschewed. Any student missing from, and/or late to, more than 20% of the lecture meetings will be failed in the course.

The discussion sessions will be a mix of some lectures and some practical instruction in computer use or telescope/instrument use.

Operating the rooftop telescopes to conduct astronomical observations is a required component of this course. Students will coordinate their schedules in order to meet the observing needs of their group observing efforts while allowing for the safe execution of the observations and the transport of students to and from the observatory. A reasonable “average” observing time load to expect during the semester is about 3-4 hours per student per week. Students who fail to operate the telescope/instrument system for the completion of their observing projects will fail the course. It is my intention to be present most clear Wednesday evenings from 6-8 and 8-10pm to assist with observatory checkout and data collection. Students are encouraged to use the available other nights to complete their observing projects, as needed. There is a computerized sign-up system for use of the 14” telescope for nights other than Wednesdays.

**Grading:**

The course grade will be computed by weighting your performance in the following areas by the percentages listed:

Course Component	Percentage Weight
Lab Reports (4 expected)	40%
Homework (6 to 9 expected)	15%
Midterm Exam (48 hr take home)	12%
Oral Presentation (1 expected)	12%
Final Exam	12%
Attendance and Participation	9%

**Late Policy:**

In the real world, missing deadlines has dire consequences (e.g., failure of a NASA mission to launch on time could make it unable to answer the questions it was designed to address – representing a tremendous waste of taxpayer dollars). Since we are practicing for the real world in this class, and trying to instill the highest work ethic, the late policy for homework and reports this semester will be equally dire. Failure to turn in an assignment on the designated date, by the designated time, in the designated format will result in a loss of 15% of the total value of the assignment for each calendar day the assignment is late.

**Homework:**

Homework will allow students opportunities to practice computer programming, spreadsheet programming, error propagation and statistics, as well as other aspects of observational astronomy.

Homework must be written in **INK**, with only one problem per page (single sided only), must be highly legible, and must be written on ruled, 8.5x11” white paper, without “burstable” sides or spiral notebook holes.

**Lab Reports:**

In many professional fields including astronomy, an enormous emphasis is placed on strong writing and communication skills. In order to foster the continued development of good writing habits, this class will contain a significant writing component in the form of observing and project reports. The required components and format details are attached to this syllabus.

Every writing assignment must be typed or typeset, in double-spaced format on white, 8.5x11" unlined paper.

**Conduct Standards & Collaboration:**

In this course, students will work in a variety of settings from pure independence, to small groups, to larger groups. It is important that students submit for evaluation work that is properly executed and attributed. I encourage you to study together, but to write up and submit your homework assignments and reports separately. You may help each other to find how to solve a problem, but you must present your own discussion of the steps needed to achieve the solution. Do not copy from another student or from another student's work (including students not in this class).

*Data may not be shared between project groups*, unless such sharing is specifically allowed by the instructor. *Data from the telescope/instrument shall not be manufactured* or simulated, except as part of specific exercises or projects.

Students are reminded that their behavior is governed by the CAS Academic Conduct Code, copies of which are available from CAS 105. I am required to state that cases of suspected academic misconduct will be referred to the Dean's Office.

**Midterm Exam:**

There will be one 48-hour take home Midterm exam to be handed out on Wednesday, February 28th.

**Final Exam:**

The final exam will be from 9-11am on Monday, May 14<sup>th</sup>. It will be closed book, and cover all material in the course. Note that the final exam is not at the usual class meeting time. Also note that the final exam time and date cannot be changed for anyone, as per university rules.

**Lab Projects Schedule:**

The lab schedule that follows may be modified, depending on sky and equipment conditions, but students should hearken seriously to the lab report due dates listed.

Lab Project Name	Tools, Wednesdays Covered, day or night status	Lab Report Due Date
1. Night Sky Brightness	14" Celestron + CCD 1/17, 1/24, 1/31 rooftop nights	Mon, 2/5/2007
2. CCD Characterization	14" Celestron + CCD 1/31, 2/7, 2/14 rooftop nights	Fri, 2/23/2007
3. Infrared Spectroscopy	Perkins 72" Telescope Lowell Observatory 3/10-11; 3/12-14; 3/15-16	Fri, 4/6/2007
4. Radio Telescope Beamsize, HI Cloud Map	Small Radio Telescope 3/7, 3/21, 3/38, 4/4 rooftop	Wed, 5/3/2007

**Presentations:**

Oral presentations are an important aspect of modern astronomy and professional technical management. You will give one, 20 minute presentation to the class near the end of the semester. The topic will be an instrument of your choice, one not discussed in class and chosen in consultation with Professor Clemens. Powerpoint presentations are preferred, and should be prepared with the finest quality and using proper attribution. More information about the presentations will be provided later in the semester.

**Computers, Computer Programming, Computer Programs:**

We will use a variety of computer-based tools during the semester. These include the computer and programs that control the 14" telescope and CCD, the computer and program that control the Small Radio Telescope, the computers and programs that control the Perkins telescope and Mimir instrument, the data reduction and analysis computers in CAS 606, as well as your own home computer.

The computers in CAS 606 are used by both AS441 and AS203, and may be used in a more limited fashion by AS102. During our discussion time slots (MF2-3), AS441 has priority use of CAS 606 computers. At all times, AS441 students have priority use of the computer in the outer room of CAS 606 (the "observing room") and in the "old 14 inch dome" on the rooftop. At other times, AS203 may have priority use of the computers in the back room of CAS606. This is normally expected to be in the 4:30-6pm time slot. At other times, AS441 and AS203 students may share use of the computers in the back room.

Computer programming is an essential skill all astronomy students should have. Exposure to image analysis is another key skill. We will attempt to meet the first goal by learning the Image Display Language (IDL), and we will meet the second goal with a combination of IDL and MaxIm DL, the program we will use to operate the CCD camera.

You will also want to use Excel or a similar spreadsheet program to perform high-level analyses of your data sets, including linear regression, averaging, and simple statistical analyses.

**Lectures:**

The lectures will be ordered to try to present key concepts in advance of their use in the lab exercises. Thus we will begin learning about basic statistics and error analysis prior to the first lab, then build on our understanding by learning about different statistical populations (Poisson, Gaussian) prior to the second lab where these concepts will be applied. Similarly, we will learn about linear regression (line fitting) and convolution before the spectroscopy lab, and function fitting before the radio telescope lab.

**Exceptions to Normal Meetings:**

No Night Lab meetings: 2/21, 2/28, 4/11, 4/25, 5/2

No Lecture meetings: 3/9, 4/18, 4/27

No Computer meetings: 3/9, 3/18

**Goals, Hopes, Aspirations:**

My goals for the course are listed on the following page.

**Lab Report Contents, Format**

These are contained in the pages following the Goals page.

## Goals, Hopes, Aspirations:

1. Become conversant with basic error analysis and propagation
2. Conduct real, quantitative telescopic observations and experiments
3. Write comprehensive lab reports in good scientific writing style
4. Conduct quantitative image analyses
5. Write useful computer programs
6. Make oral presentations of a scientific nature
7. Perform quantitative photometry
8. Perform quantitative spectroscopy
9. Learn about the signal-to-noise ratio and its relation to the economics of astronomical observations
10. Be exposed to the concepts of convolution, deconvolution, and Fourier analysis
11. Perform function fitting to real data
12. Be exposed to optics concepts and optical designs
13. Practice data mining

## Lab Reports:

You will develop and submit lab reports similar in style to the papers found in the current scientific literature, such as the *Astrophysical Journal* or *Astronomical Journal* (see below). All reports must be typed or typeset on single-sided, unlined, white 8.5x11" paper with double spacing and one-inch margins from all edges. The font is Times New Roman, at 12pt size.

Each report should answer several basic questions that all scientific publications normally address:

- (1) Why was the work performed? How would these results aid future efforts or clarify current understanding?
- (2) How was the work performed? What equipment and facilities were employed? What procedure was followed? What was the nature and quality of the data obtained?
- (3) How were the data analyzed or processed to reach scientifically meaningful conclusions from raw image or other data? List all relevant processing steps and calculations.
- (4) What were the measured results of the experiments? What uncertainties or errors accompany the measured values?
- (5) What are the chief scientific conclusions of this experiment? How do the conclusions relate to the original goals? How might future improvements be implemented?

Each report should contain the following sections in the following order:

- (1) **Abstract:** the abstract should be a single, short paragraph that establishes why the work was performed, how it was performed, and the chief scientific conclusions.
- (2) **Introduction:** the introduction should establish a detailed description of the problem or question being addressed and the beneficial impact of obtaining an answer. The overall approach should be outlined. Findings from other such studies should be summarized (e.g., what are typical sky brightness values measured for Kitt Peak or Mauna Kea?).
- (3) **Observations:** this section should describe the equipment used in the experiment, the dates and location of the experiment, and should summarize the observations obtained. Note, however, that raw data should not be presented. Tables summarizing observations or key parameters are often presented.
- (4) **Analysis:** this section lays out the methods and procedures by which raw data were transformed or analyzed to yield scientifically useful results. Each step in the processing is described with adequate detail and examples to convey full understanding. Figures showing compilations of results or final maps are typically seen here.
- (5) **Discussion:** the scientifically meaningful values are described in light of other similar work or in comparison with the original questions or goals. Uncertainties are described and shown not to compromise the integrity of the scientific results. Limitations of the method, or anomalies in the experiment, are identified and also shown not to compromise the results. Some discussion of the implications of the importance of the results and some speculation are permitted here.
- (6) **Summary:** in this section, the experiment is summarized. This includes restating the purpose of the experiment, the methods used in the experiment, the chief scientific conclusions, and the implications these results have for the scientific field under study.
- (7) **Acknowledgements:** if you received important assistance from others in the conduct of the experiment or the analysis of the results, they need to be identified and their roles clarified.

- (8) **References:** throughout the paper, any assertion of fact must be tied to a published reference or established through the experiment being presented. The reference list collects all cited works. See the *Astrophysical Journal* for referencing style.
- (9) **Tables:** any tables referenced in the work are presented following the references. Note that tables are numbered and have titles.
- (10) **Figure Captions:** each figure is numbered and must have a figure caption. Short figure captions are best, but you should not assume the reader will understand what you are showing nor should you assume the points you seek to make through your figure will be obvious to the reader. The figure captions are your chance to convey critical figure information and to draw the reader's attention to items you feel are important in each figure.
- (11) **Figures:** the figures follow the captions, *one figure to a page*. Each figure must be numbered, but is not titled. Each plot is boxed, with both axes labeled and scales shown. Every image is also marked to indicate how the third dimension (usually intensity) is mapped into the gray-scale or color representations.