ASTR 230 ASTRONOMY LABORATORY

Spring 2019 – 3 CREDITS

I. Staff:

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Meeting Time & Place: Tuesday, 7:00 - 7:50 pm, HB 254

II. Course Description:

This 3-credit course is designed to give students hands-on experience operating telescopes, obtaining and analyzing data, presenting the results in a narrative report, all of which culminates in a special project of the student's choosing. The results of this final project will be presented both orally and as a Web page. The course lectures will introduce students to the motions of stars and planets in the night sky, describe the coordinate systems, telescopes and instruments that astronomers use, and show how to analyze these data. Graded work includes three main labs, a few short homework assignments, the final project, and class preparation.

The first lab teaches students the basics of telescope operation, while the second and third labs introduce the student to data reduction of images and spectra on unix computers with the IRAF software packages devised by the National Observatories and the Space Telescope Science Institute, as well as IDL. Special projects combine the skills learned in the first two labs, and may make use of the on-campus observatory or a remotely operable telescope at McDonald Observatory. This class is typically taken by astronomy and astrophysics majors. However, about half the class usually consists of non-majors who are willing to put in the long hours required by the lab assignments in order to get intensive training in observational astronomy. Non-majors with a more moderate interest in observational astronomy may consider taking Astr 201 or Astr 221, which is a new observational astronomy class for non-majors (2 credit) since it may better suit the needs of non-majors who wish to get some observing experience.

III. Overall Course Objectives and Expected Learning Outcomes:

The primary purpose of ASTR 230 is to train students in data acquisition and analysis so that these students can compete effectively for summer internships around the country, contribute to research within the Department, conduct their senior research projects, and operate telescopes and instruments at professional observatories. Many students make the Web pages for this class available to potential employers when they are applying to graduate schools or for jobs. By the end of the course students will understand how the stars, planets, Moon, and Sun move in the night sky throughout the year. Students will understand the primary astronomical coordinate systems and will be able to predict what time of year an astronomical object is visible given its coordinates. Students will understand how to take science quality CCD photometric and spectroscopic data, and they will be able to use IRAF to reduce this data to produce calibrated photometric and spectroscopic measurements of astronomical objects. Finally, students will understand how scientific papers are written so that an astronmically literate audience outside of the class will be able to understand what the student did and why in each of the lab exercises.

IV. Prerequisites:

ASTR 230 deals with observation of astronomical objects, and as such will mean more to a student that has had an astronomy class of some sort, such as ASTR 350, ASTR 201, or even ASTR 100 or NSCI 111. However, motivated students can have this prerequisite waived by the instructor. Students should be aware that the second half of the course uses UNIX/Linux computers extensively, though we will cover most of what you need to know in class. Mathematics used in class will be primarily trig, geometry, and logarithms; there are no specific calculus or vector prerequisites.

V. Lab Activities and Observing:

In ASTR 230 we will use a variety of telescopes ranging from "simple" 8-inch Celestrons that are set up from scratch, to the 16-inch research quality reflector housed in the dome on campus. First you will learn the basics of setting up an equatorial telescope and visual observing, then move up to operating computerized telescopes and digital imaging. Most of the data that you will deal with in the lab will be images of astronomical objects obtained with the modern astronomical detector known as the charged coupled device (CCD) at the telescope. The data reduction and analysis will be done using a variety of computers ranging from PC's to UNIX/Linux workstations that operate the same two major software pacjakges that astronomers use in professional research: *IRAF – Interactive Reduction and Analysis Facility* and *IDL – Interactive Data Language*.

In theory, students will need only two or three observing sessions for the first *Introduction to Telescopes and Observing* lab and two (maybe even just one...) for the special project. However, poor weather, inexperience, and Murphy's Laws will likely require more than five night sessions for students to finish the observing parts of the first and third labs. Aside from the observing (which is hopefully more fun than work...after all, that's why you are here!), the greatest amount of time will be spent doing data processing on computers. These skills are essential if you are thinking about doing an internship this summer or next at one of the national observatories, or other places that offer REUs.

This class is not as structured as some of your past lab courses – each person will need to take much of the initiative in gathering and reducing their observations. The class will meet once a week in the evening at 7:00 pm for a ~ 60 minute lecture and demonstration period with the instructor. The rest of the time for the first lab will be largely scheduled by the student at his/her convenience, provided the weather cooperates and no one else is using the equipment. What this means is that you <u>must</u> get started right away with your observations and not put off gathering your data, you can not tell in advance whether a night will be clear or cloudy. *Do not make the mistake of putting off your observations until later, only to encounter bad weather.* Unless there are not enough clear nights to finish the first lab (very rare), the due date will stay as in the syllabus even if the last few weeks before the due date are overcast.

We hold the lab in the spring because the demands of the football team add additional lights to the campus. However, the best weather usually occurs early in the spring semester while cold fronts still make it through. Observing will be much more restricted by weather the latter third of the semester, which is when we must do the projects. We will get started on these as soon as the Meade 16" is mounted in the new observatory location.

READ THIS: For the final project, for each student we must (i) schedule the telescope well in advance, (ii) get a clear night, and (iii) have no equipment or computer failures. These restrictions necessitate a limited enrollment, and can make it very difficult to complete projects. Hence, *part of the agreement you make by taking this 3-credit lab is that you will be available to observe whenever we schedule you to do so.* This means Friday, Saturday, Sunday nights at 3 am are fair game. We will try to accomodate your schedule if possible, but you need to let the professors know at the beginning of the semester if there are one or two dates that you cannot observe. You will have a general warning that you may be observing in the upcoming week, and then a specific warning of about 2 hours before you need to show up at the telescope. *It is your responsibility to keep informed of the schedule by email, phone, and in person if necessary and to coordinate a ride if you need one.*

VI. Textbooks & Equipment:

Peterson Field Guides: Stars and Planets, J. Pasachoff (ISBN = 0-395-93431-1). *Required.* Be sure to get the **4th** edition, *not* the 3rd edition. It also comes in hardcover, which you can get from any of the bookstores on the Web. This book is *required* and is a wonderful reference guide for observational astronomy. It covers the basics of observational astronomy and the night sky, and gives fundamental qualitative information on all types of astronomical objects. You should read through it during the first month of the semester to learn much about what's out there.

Observational Astronomy, 2nd Ed., D. S. Birney, G. Gonzalez, and D. Oesper (ISBN = 0-521-85370-2). *Required.* This is a relatively new book that serves as an excellent introduction to making astronomical observations suitable for scientific analysis. The focus on the book (and this class) is optical astronomy, which, while the oldest discipline of observational astronomy, remains in many ways the most important.

There are also optional books that you may wish to consider for this class. An Introduction to Error Analysis, 2nd Ed., by J. R. Taylor (ISBN = 0-935-70275-X). This text is an excellent introduction to uncertainty and error analysis in the physical sciences. Any student planning to continue on in the sciences or engineering needs to have a good understanding of measurements uncertainties and their implications. This book is one of the best starting points for that study.

A book of potential interest that goes into somewhat more detail on CCDs is Handbook of CCD Astronomy, 2nd Ed. by S. B. Howell (ISBN 0-521-61762-6). This small book overlaps a fair bit with the information in the Birney et al. required book, but it does have some additional information, not found in that book, and covers some of the same topics in a bit more detail. The last book of some interest is How to Use an Astronomical Telescope, by J. Muirden (ISBN = 0-671-66404-2). This book gives some additional basic discussion on using small to medium sized telescopes, which the true beginner may find very helpful. For example, Muirden contains substantially more discussion about telescopes themselves than found in the Peterson guide, which you may find useful both for the class and if you ever consider buying a telescope. There are also discussion on polar alignment and other operational details you will learn in this class. These will also be discussed during lecture and in handouts, but some of you may feel more comfortable with an additional reference. The book itself is not very expensive (∼$16).

At least one small battery operated **flashlight** (with a red lens or cover) is **required** for each student and a second (white light) one is highly recommended. Most of your observing will be conducted in the dark and away from other light sources. You need one or more flashlights for your safety, the safety of others and the equipment. Inexpensive models (around $10) can be purchased at Radio Shack, department, or other stores (even the campus bookstore has them sometimes).

A **lab notebook** is also **required** for this course so that you can keep all of your observations and data in one central location. Your notebook should have ruled or quadrille pages for ease of recording data. The notebook should have a hard, thick surface because you will be observing in a high humidity environment which will warp a thin cover. The standard lab books in the campus bookstore will do just fine.

Other references: *Land Sea and Sky*, a store on Richmond near Shepherd, has all sorts of telescopes and general references for sale. The staff there knows a lot about equipment, and is a good place to go for general advice on repair and purchases.

VII. Grading: There are no tests or quizzes in this lab. Your grade will be based on written reports for the first three lab projects, class preparation, and the combination of an oral report and web-page description of the results from the "special project" exercise, and a few short homework assignments. The reports for labs I, II, and III cover the same material for every person, and follow a series of specifically requested tasks. By contrast, the special project is more like a 'term paper' in some humanities courses or independent research in advanced SE courses. Class preparation includes *being on time for scheduled observing sessions*, and being prepared in class and at the telescope. When we go to the Meade 16" telescope for your special project observing, the professor and/or the lab assistants will be there primarily to facilitate your getting your observations made; however, you are expected to know what it is you want to look at, when it will be up, and what type of observations and calibrations you need to take.

Observing Lab Writeup (I)	15%
Basic Image Processing & Photometry Writeup (II)	15%
Image Processing Spectroscopy Writeup (III)	15%
Special Project (IV) Oral/webpage	30%
Small Assignments (∼ 4)	15%
Class Preparation	10%

Lab reports are due by 5:00 pm on the dates indicated if they are not a class day. Otherwise, the report is due in class. Unless you obtain permission beforehand, late reports will be reduced in point value by 10% for one day late, 20% for two days late, 25% for 1 week late, 50% for two weeks late and 75% for three weeks late. No reports are accepted later than 3 weeks after the due date.

Depending on the size of the class, your schedules, and whether or not we have graduating seniors, we will have one or two sessions during the last week of classes or during finals week where students present the results of their projects to the class. Class Web Pages are located at http://www.ruf.rice.edu/∼cmj/astr230/astr230.html. Your final Web projects, due May 7th, will be made accessible at this site.

VIII. Work Requirements:

- *Lectures* – are held most Tuesday evenings, beginning at 7:00 pm, and will last ∼60 minutes.
- *Evening Observing Sessions* – are the fundamental activities of the lab. These are undertaken primarily at the observatory deck located at the East end of the 4th floor of Brockman Hall, at a site of your choosing outside the city in darker skies, and possibly in group field trips to George Observatory or some dark site, to perform the observing tasks for Labs I and IV. Celestron telescopes are stored in BRK 400. It is even possible to take the equipment out (needs to be coordinated directly with the professors beforehand) for evening or weekend observing outside Houston. Much of the initial observing for the first lab can be done on campus with the C8 telescopes; however, some exercises, need a darker site. It will be primarily up to the student to get to a darker site to due the comparison of limiting magnitudes, and we will use the new on-campus telescope that is housed in the dome with video equipment to do deep sky observing in groups. You are encouraged to make at least one trip to George Observatory where they have public viewing on the weekends. While a bit inconvenient compared to observing on campus, the skies around Brazos Bend State Park are much darker than around Rice, so the extra effort is worth it when the weather is good.

The first lab (Lab I – *Introduction to Telescopes and Observing Techniques)* deals with basic observational techniques. During this lab, you must work with a group of 2 (no more or less!) people as a team. This is for reasons of safety and efficiency (remember that one of the goals in this class is to give each of you hands-on experience). Lab II and III – *Astronomical Image Processing* concentrates on CCD imaging procedures and computer image processing. You can work on your own or with others during this lab. However, write ups for labs I, II and III must be entirely your own work. Lab IV, the special project, requires you to select an object, or type of object to study (e.g., Jupiter, M42 - the Orion Nebula, M31 - the Andromeda Galaxy, etc.). Then you will have to make an observing proposal for the project of your choice (after consulting with the Profs); if approved, you will then obtain the observations, perform your own analysis, present the results in a talk at the end of the semester, and finally "publish" it to the world as a web page. With the new campus observatory, we can perform both spectroscopic and imaging projects.

- *Reading* – During the first two weeks of the course it is important to read through the Peterson Field Guide **and the Lab I writeup in detail** – before you undertake the telescope observing. For the Image Processing labs you will be given reference material on CCDs and IRAF and IDL to study, in addition to the specific tasks to be done in Lab II and III writeups themselves. Finally, for the special project, you will be expected to do library research on the object(s) that you choose to study, in addition to what is in the Peterson's Field Guide.

- *Computer Work* – This is an essential part of all of the labs. Students will use our own PCs in the lab for observing and CCD operations, as well as UNIX/Linux workstations throughout campus for the actual data analysis (and report writing). You may also use Rice computer lab computers on the labs. It is assumed that all students have an email account somewhere. By default, communications will be sent to your netid email account, but let the professor know if you have a different preferred email address. Much timely information will be passed along to everyone via electronic mail, which is much easier and more efficient for contacting a large number of people than by phone or posted announcements. You will sometimes need to check your electronic mail daily (just before a field trip or observing session) to see if there are any updates regarding weather, departure times, class assignments and such. Also, the data reduction and analysis for the Data Processing and Special Project labs require the use of UNIX/Linux and X-windows, so you will need to become familiar with this computer environment if you have not done so (there are several excellent intro handouts on this at the Mudd student computer help office).

- *Campus Observing Facilities* – We have a computerized Meade 16" telescope that was purchased for us by the University and Alumni. The observatory is located at the East end of the 4th floor of Brockman Hall. We also have 25% share of the 0.8 m telescope at McDonald Observatory which is capable of remote operation over the internet. These will be the workhorse instruments for your special projects, for two of the short assignments, and possibly some sightseeing for Lab I. Check out the observatory webpage at

  http://www.ruf.rice.edu/∼ruco/observatory.html.

- *Field Trip to McDonald Observatory (optional)* – We will attempt to arrange an opportunity to travel to McDonald Observatory, tour the facilities there, and observe with one of the smaller telescopes (30" diameter) at the observatory. This could serve as an opportunity for some of you to get high quality data from a dark site for your special project. The dates for this are not set, but will likely be sometime during Spring Break or the Midterm Recess. More details will be discussed in the first few class meetings. If you wish to go on this trip, please hold off making any plans for Spring Break or Midterm Recess until after we set a date for the class trip. This trip is entirely optional, but in the past has been perhaps the most rewarding experience for many of the students in this class.

IX. Schedule:

Date	Lecture	Comments
1/8	Orientation	read chapter 1 in Birney
1/15	Celestial Sphere & Telescope Basics	read Field Guide; First Observing Week
1/22	Adv. Telescopes & Instruments	Observing with Rice 16-inch
1/29	CCDs & Observing Techniques	Continue with C8s
2/5	Introduction to UNIX/IRAF	SP Meeting w/Prof
2/12	IRAF Image Arithmetic & Display	IRAF Practice, Photometry
2/19	Lab I Grades; More IRAF Topics	Lab I DUE; IRAF Practice, Spectra
2/26	Special Projects Overview	SP Observing
3/5	Lab II Grades and Review	Lab II DUE; SP Observing
3/12	Spring Break	Possible McDonald Trip
3/19	Error Analysis Techniques I	SP Observing
3/26	Error Analysis Techniques II	Observing and Data Analysis
4/2	Review Obs. Techniques/Problems	Lab III DUE; SP Observing and Data Analysis
4/9	Review Obs. Techniques/Problems	SP Observing and Data Analysis
4/16	Lab III Grades and Review	SP Observing and Data Analysis
TBD	SP Oral Presentations *DUE*	
5/1	SP WEB PAGES *DUE*	

X. Final Comments:

- *Honor Code* – Feel free to discuss any portion of your work with anyone inside or outside of the course. In fact, you are encouraged to discuss the labs with the instructors, lab assistants and fellow students. Also feel free to consult any reference material available to you. Your data collection, however, must be done on your own or as part of a team while you are present. You may discuss your lab writeups with anyone, but *the final report must be written by you* and you must understand what you have written. You will make an oral presentation of the work for your special project and will be asked questions about what you did.

- *Work in Parallel* – The nature of this course is such that you will have to work on more than one lab at a time. **For the observing labs, gather your data at the first available clear weather**. When you are clouded out of observing, work on the computer portion of your labs. You will probably have to begin Lab II before you have finished Lab I.

- *Safety* – Since you will be working at night: (a) have a working flashlight, (b) do not work alone, (c) take it slow and careful, and (d) report problems to the professors or lab assistants via email or phone mail ASAP!

- *Students with Disabilities* – If you have a documented disability that will impact your work in this class, please contact the professor to discuss your needs. Additionally, you will need to register with the Disability Support Services Office in the Ley Student Center.