ASTRONOMY 5110: ASTRONOMICAL TECHNIQUES (Fall 2017)

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Office hours: 3:15 – 4:00 PM, T,Th or by appointment.

Course website: http://faculty.virginia.edu/ASTR5110/ (UNDER CONSTRUCTION!!)

Lecture time & location: 2:00 - 3:15 p.m. T,Th in ASTR 265

Practical/discussion/lab prep sessions: ASTR 8500, 4:00 PM, ASTR 265

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COURSE DESCRIPTION

This is a course in practical observational astronomy for graduate astronomy students and includes substantial lab-based work. Students not enrolled in the Astronomy Department graduate program must have the instructor’s permission to take this class.

The course will consist of lectures, practical sessions, problem sets and observing projects (“labs”) with an emphasis on building practical observing experience, which includes understanding the night sky, planning and making observations, using and understanding typical, modern astronomical instruments, reducing data, analyzing results, and reporting your results. My philosophy for the course is that it is meant to train students in a basic working knowledge of the practical use of optical/near-infrared observing facilities, especially those that they may need to undertake research for their thesis (and beyond). While this is obviously useful to students intending to undertake observationally oriented research projects and careers, this knowledge is also essential to theorists, who must develop a basic understanding of how data are collected, reduced and analyzed to have a proper appreciation for the meaning, methods, limitations and statistical interpretation of empirical work used to constrain and test theory. These skills are also needed to operate our department’s telescope facilities.

Schedule Flexibility: Some amount of time will be spent at our local observatories (McCormick and Fan Mountain), and this year we also plan to have a class field trip to visit and use the department’s observatory facilities in the southwest U.S., particularly the Apache Point Observatory (APO) in New Mexico. Your academic schedule should be flexible enough to allow you to observe at the local observatories on any or every clear night and to make the trip to Arizona/New Mexico, which usually takes nine days. Arrangements will be made with the other astronomy graduate course instructors to rearrange course schedules to accommodate your absence; however, if you are taking courses outside the Astronomy Department, special arrangements will have to be made to enable you to miss classes. If you are in this situation, please alert me and your extra-departmental instructor immediately of this pending situation.

Be forewarned that, due to increasing demands on the local telescopes as well as your own teaching assistant obligations, much of the local observing may include a non-negligible amount of time after midnight and on weekends.
Practical/Discussion/Lab Prep Sessions: This semester’s ASTR 8500 course will serve as a weekly “practical” session focused on reviewing basic night sky fundamentals and earning specific skills needed for taking data, running specific instruments, reducing data, using astronomical software, and performing basic statistical analysis of data. It is possible, hopefully likely, that at least some of this material will be familiar to you from your undergraduate training; if so, consider those particular sessions as review.

Group Work: While observing will be done in groups, you are expected to make sure the observing load is shared fairly. The goal of working in groups is to ease the observing burden, make efficient use of limited resources, and to share different areas of expertise, but not to help students escape from learning how to do different aspects of the experiments. Please make sure the observing work is distributed equitably and that everyone learns how to do each aspect of it.

I hope that this will be an enjoyable, challenging and rewarding course for observers and theorists alike. Though sometimes while in the “thick of the experiment” it may be easy to lose sight of this fact, I think that (at least eventually) most people find satisfaction with taking their own data and working it to a bona fide scientific result.

Members of the UVa Astronomy Department have access to a number of telescopes through our membership in the Large Binocular Telescope (2×8.4-m) consortium, Steward Observatory (including the Magellan 2×6.5-m, MMT 6.5-m, Bok 2.3-m, and VATT 1.8-m telescope facilities), and the Astrophysical Research Consortium (which runs the ARC 3.5-m and Sloan 2.5-m telescopes). Since a goal of this class is to prepare you for efficient use of these precious resources we will first do work at the local observatories to prepare you in basic observational techniques while classroom work, homework exercises and practical sessions will include an introduction to some of the instrumentation at our other facilities, and especially the APO 3.5-m.

Because of the opportunity for you to take ASTR 5340: Introduction to Radio Astronomy and/or ASTR 5450: High Energy Astrophysics, I will mostly avoid very long and very short wavelength astronomy and focus on optical and near-infrared wavelengths.

TRIP TO APACHE POINT OBSERVATORY (APO)

There are several goals for the planned class trip to APO. First, I want you to become familiar with operations at a modern large observatory, and, specifically, one that is ours (well, 1/16 ours). Some of you will be undertaking research with these facilities, so it is important for you to become familiar with them. It is even possible that we can take data useful for your research, or the research of other members of our department, on this trip. The APO 3.5-m is designed to be operated remotely from any appropriately configured computer, but for you to be allowed to do this, you must be “checked out” on-site; our trip to APO will take care of this requirement for all of you. Moreover, depending on how our observing time is awarded, we may have time not only to visit APO, but other observatories in New Mexico and Arizona (particularly, those facilities to which UVa has access).

The department deems this class trip as an important component of our graduate program and has allocated department resources to pay for travel for astronomy graduate students, including airfare, rental vehicles, room and board. For students not in the Astronomy Department graduate program, we may have to figure out alternative funding prospects.

We enlist a number of non-UVa people to volunteer to help us throughout the trip, giving us tours of the facilities, helping us at APO, etc. So we have a number of people, both locally as well as all along our trip, to thank for this opportunity. Therefore, I am asking that the
class formulate some kind of special (perhaps even personalized) small gifts we can give to people that are going to make this trip special and successful. Something on the order of 20 gifts may be needed. Please start thinking about this now, so that we can work on making the gifts and have the gifts available to present to the people as we make our way through the southwest.

Depending on how much observing time we are allocated on the APO 3.5-m, we may have time beyond that needed to do required class observations, and which we are expected to share with other members of the department. Thus, you might start thinking about whether there is a more senior member of the department (a faculty member, postdoc or advanced graduate student) with whom you and several classmates might collaborate on an observing project to undertake at APO. Ideally the project you do should be something that could potentially result in a publishable paper. It can be a project that is related to or will become your own master’s research. It can also be a project that another member of the department is already doing, but that you can productively join and to which you can contribute observing and data reduction effort. All projects will need to be approved by the instructor.

Plans for our trip to Arizona/New Mexico are not yet in place, because the specific dates for our time on the APO 3.5-m have not yet been assigned by the APO Telescope Allocation Committee (TAC). I’ve requested five half-nights (the units of observing time at APO) for late October or early November. We will likely miss a full week of classes. I realize this will impact not only your other classes and classwork, but Teaching Assistant (TA) duties as well. The department will try to cover your absence from TA work with older graduate student volunteers.

Finally, I will likely need some assistance with driving rental vehicles (e.g., passenger vans) during the trip; the University Office of Risk Management encourages such drivers to be as old as possible and with experience in driving similar, large-sized (SUV-like) vehicles. If you think you fit these characteristics, let me know. If you foresee any other complications regarding this trip, let me know as soon as possible.

**Class Session Time Swapping:** Because of other professional commitments, I may have to miss some lecture times due to travel. I would like to be able to reschedule for other days. This is most easily done by swapping classes with faculty teaching other graduate course instructors.

**COURSE REQUIREMENTS**

Your grade will be based predominantly on assignments, though we may have one or two exams, depending on the timing and planning of the field trip and how weather affects the progress of observing work. The assignments will be a mix of conventional “problem sets” and labs/observing projects, including some involving the APO trip.

Most observing work will be done in groups, but for most assignments you will be expected to write up your own analysis and interpretation of the results. In the latter case, the following applies: You can work together on problems, observing and data reduction, but in the end, you should write up material to be graded in your own words and work out all of the mathematics yourself. Please use a professional, journal article style in writing up formal lab experiments (you’ve all taken undergrad labs, so I don’t need to go through how a lab report should be done; if in doubt, pick up an issue of Astrophysical Journal Letters and peruse the structure of science journal articles).

For laboratory work, you must be prepared to take advantage of clear weather when it occurs or you will not be able to complete the labs. Because there will be multiple groups, you
will have to cooperate to share good weather. Because I don’t want to be mired in thinking about the vagaries of the grad student schedule, I will leave telescope time negotiations to you to work out. Please also be aware of the rules for coordinating with the TA, given below. Note also the constraints of Public Nights for both McCormick (Friday nights) and Fan Mtn., the fact that the local telescopes are also used for research projects and other courses. Given the high demand on the facilities, you may be forced to use the telescopes very late in the evenings, even after midnight. It is always important for you check the telescope schedule and sign up for the time you intend to use!

Please recognize that the uncertainties involved in the timing of the APO trip and the fact that the class has to be arranged around that focus means that the class may at times be loosely structured and there will inevitably be a few kinks that may not have been worked out in advance. Just let me or the TA know about problems as they arise and we will try to make mid-course corrections. Note that in some cases, assignments may have been done by students who took the class in previous years; you are expected to do the assignments on our own and you are not allowed to consult answer keys or other graded work from previous years.

LECTURES

My lecture notes should be considered a primary resource for class, along with the suggested readings and assignments. My notes pull together material from many secondary sources, and there is no single textbook that covers the range of topics well. But also note that I routinely update the lecture notes as the semester progresses. The lectures are “web-based” because of the complexity of many figures I want to show and the ease of display using webpages. You can expect a fair amount of web-lecturing in this class, but please don’t rely on it. You should be prepared to take notes for each class. In addition, I may have more material on my web notes than I can discuss in class, and you will be expected to learn all of the material in the notes whether I discuss it in lecture or not.

To my immense consternation, several years ago the university forced the department to get rid of its webserver, from where my class webpages were originally served. After moving these files to the allowed university webserver, many of the links have broken. I will do my best to fix them as the semester progresses.

TEXTS

Unfortunately, there are no textbooks that match well the range of topics that will be covered in this class and at an appropriate level, and this means that I have to rely on multiple texts. I appreciate that these are expensive, which is why I have assigned only one text that I think you should buy, Howell’s *Handbook of CCD Astronomy*. You will also need to reference the *Astronomy 3130/5110 Observatory Handbook* — which used to be online, and will be made available to you somehow and as needed. A second text, edited by Bely, *The Design and Construction of Large Telescopes*, has a lot of useful material that I include in the lectures, but is an expensive book and I’ve not made it a required text, only recommended. For the other texts, I will try to have copies on reserve in the Astronomy Library, and perhaps students can share texts. While I have not required you to buy many of these texts, assigned readings from them should be considered as required:

- *Handbook of CCD Astronomy, 2nd Edition* by S.B. Howell: This is a good practical guide to the taking and reduction of astronomical CCD data.

- *Astronomy 3130/5110 Observatory Handbook*: You will need this to understand how to operate some of the equipment. You can get a copy of the manual here:

*The Design and Construction of Large Telescopes*, edited by Bely: With its emphasis on design and construction of telescopes, this might seem a strange book to be used as a text for this course, but it contains very nice, basic discussions of a lot of practical observational astronomy topics I touch on in lecture.

*The Detection of Light from the UV to the Submillimeter (now in 2nd Edition)* by G. H. Rieke is a pretty good book that explains well the operation of astronomical detectors. I will rely on this for a lot of the detectors section of the course. Unfortunately, it doesn’t well describe how to *take and reduce data* with detectors, which is why I made the Howell book required instead.

Some other textbooks that can be useful on occasion:

*Astronomical Optics* by D. Schroeder has become something of a standard resource for understanding the optics of telescopes and astronomical instruments. Unfortunately it is very expensive and I’ve also come to learn that it is not written in a way that is very accessible to students.

*Astrophysical Techniques, 4th Ed.* by C. R. Kitchin. This is actually an upper-undergraduate level text, but I have never heard anyone complain about understanding a book completely! This book covers the range of topics I hope to cover but often it gives only bare sketches of the topics.

*CCD Astronomy* by C. Buil. Though written by a (very knowledgeable) amateur astronomer for amateur astronomers, I found this book to have very useful sections in it written in a more pedantic style than either Rieke or Howell. However, it does have a nice section on Fourier transforms and convolutions that you may find very helpful when/if we do the speckle interferometry lab.

*Observational Astrophysics* by P. Léna. This is somewhat at the other end of the scale from Kitchin – i.e., rather detailed and technical. Previous ASTR 5110 classes did not like this book (and I understand why). Nevertheless, you may find Léna helpful for in-depth coverage of some areas.

*Optics* by Hecht. This is an undergraduate textbook on optics that you may have used in college. I’ve been reading it and for some things it is very nice. Keep your college copy around during this class. Two other optics textbooks that are “classics” (which means these were the textbooks around when I was in college!) are *Principles of Optics* by Born & Wolf and *Fundamentals of Optics* Jenkins & White.

*Astronomical Observations* by Gordon Walker. A now fairly dated but sometimes useful basic discussion of observational astronomy.

Finally, there are two books that have recently come out that I am very suspicious have borrowed heavily from my publicly available lecture notes, without any attribution. Despite my personal feelings about giving these books any attention, because they in fact do so closely mirror my lecture notes, I feel that it is my obligation as a teacher to mention them to you as a potentially useful aid. You might consider them the books I would have turned my lecture notes into had I had the time or a coauthor willing to help me do this:

*To Measure the Sky: An Introduction to Observational Astronomy* by Frederick Chomney.

*Observational Astronomy* by D. Scott Birney, G. Gonzalez & D. Oesper.
Other useful books and articles may be placed on reserve in the Astronomy Library. You may find it beneficial to seek out original sources on specific topics when working on various labs. Use the http://adsabs.harvard.edu/abstract_service.html website for finding articles.

COMPUTING

You will need to have access to the LINUX computers in the Astronomy Department. You should request a LINUX account and department keys if you do not have them. You will be expected to be able to program in some useful language.

You will also need to use some canned package for image processing (unless you are a masochist and wish to write your own code). The choice of image processing packages can become a matter of strident religiosity to some people. Frankly, I don’t care what you use as long as you (a) can accomplish the assigned tasks, and (b) understand what the software is doing. At UVa there are at least three alternatives for canned image processing packages: IRAF, IDL, and MaxIm DL. I am not going to demand that you use any particular one of these. Note that (1) some of these packages are better at some things than others, (2) some particular applications needed for the class assignments may exist in only one of the packages, (3) the Fan Mtn. CCD computer works with IRAF while the ST8 and ST1000 cameras at McCormick work with MaxIm DL, and (4) I am most familiar with IRAF, MIRA and MaxIm DL, and not at all familiar with IDL. Therefore, I will probably be biased towards IRAF and will make no apologies about that. If you are not familiar with IRAF, you should go through the tutorials offered at

http://iraf.noao.edu/tutorials/tutorials.html

The first three exercises on that page (intro, ccd1, and ccd2) will be useful to start the course, and the phot and spec parts of IRAF will be helpful later on in the course.

We have also prepared a practicum on IRAF, which can be accessed off the main course website.

Bob O’Connell has put together a thorough IDL tutorial and other IDL resources for when he taught ASTR 511. See the main class website where I will try to link to them again. *I encourage you as soon as possible to look into either or both IRAF and IDL and start working on the tutorials now.*

On occasion you will need to make use of the joint ASTR5110 account. Its the login to use on the PCs and the laptop to access the disks on the server that are for ASTR5110. You will need to get the password from us.

POLICY ON SUBMITTED WORK

You are free to consult library/web resources and one another during work on assignments. However, excessive collaboration will obviously be a hindrance to learning the material well (some of which will surely appear on qualifying exams). Any work submitted – i.e., the detailed treatment of a problem – should be *entirely your own* except in the case of labs I allow for a group-submitted lab report. Penalties will be assessed for late work.

SAFETY AND RESPONSIBILITY

The telescopes and equipment which you will use in this course are delicate, expensive, and sometimes priceless and irreplaceable. The equipment on local telescopes you will be using is needed for other undergraduate and graduate courses. In some cases, the equipment is being used for NASA/NSF funded projects of faculty/students, who will be more than
displeased if it gets broken. Obviously, the equipment we use at APO or other research observatories is extremely expensive and irreplaceable and must be treated with the utmost care — you must make sure you are fully prepared and educated in its operation before proceeding to use it. There are many unavoidable hazards associated with an observatory: working in the dark, high voltages, heavy equipment, wires and cables, etc. Be very careful, and use common sense when moving around. You should get in the habit of moving about in the dark slowly and cautiously. It is very easy to bump into things, get tangled in cables or wires, or trip over things in the dark.

Read all instructions carefully and thoroughly, and then obey them. They are for your protection and for the safety of the equipment. Always carry a flashlight, and NEVER OBSERVE ALONE. It is imperative that you conduct your work with the utmost of care, patience and forethought. As with all delicate equipment, NEVER force any moving part beyond reasonable and expected resistance. Never move the telescope by pushing on the mounted instrumentation (CCD, spectrograph, etc.), and never lean or support yourself by holding onto the equipment. Optical elements, in particular, are very delicate and expensive. Never, NEVER, touch any optical element. Oils from your skin can be corrosive and permanently embed into glass surfaces and optical coatings. It is preferable to leave small amounts of dust on optical surfaces rather than risk scratching or marring the surfaces with attempts at cleaning. If the dust seems to you intolerable, have the TA let me know. THINK BEFORE DOING.

To minimize the potential for accidents, and to make the most efficient use of your observing time, read all lab instructions and relevant manual pages and prepare finding charts and coordinate lists in the daytime before you head to the observatory and make any attempt to touch the equipment. Make a plan of your activities and have a clear idea of your observing strategy for the evening, including the hour angles/airmasses of your targets at the time you intend to observe them. High airmass observations should be avoided for both scientific and safety reasons.

If you take the time to plan out the evening in advance, then you can concentrate on your project during the observing session, when telescope time is precious. Do not try to hurry. Always double check the safety of the equipment before you move the telescope, close the roof, etc., and be especially careful about opening and closing the telescope and dome during your observing session. Note that because the telescope will be tracking, you must not only be aware of where the telescope is, but where it will be throughout the time you observe any particular object. Collisions of the telescope with the pier, ladders and any other objects in the dome MUST be avoided.

If something breaks or jams, do not attempt to fix it yourself! If the problem does not endanger the damaged equipment or any other piece of equipment, you should shut the equipment down in accordance with the instructions. If equipment is endangered (e.g., the dome slit is jammed open), then you should try to contact the TA or Lab Technician (first) and me (second).

Always fill out the telescope log for every observing session.

Always check that the observatory is available for use before you go and sign up for the telescope in advance.

Fan Mountain: Be careful driving on the road up to Fan. Make sure you remember to bring the keys, especially the gate key!

Injuries: If an injury of any kind occurs, notify the instructor or TA if he or she is present. If the injury is minor and no supervisor is present, you should notify the instructor
the next day. If the injury appears even remotely serious call the rescue squad (295-1191 or 911). Notify the instructor immediately. (Call her/him at home if necessary.) Emergency numbers are posted by the phone.

**Wear suitable clothing at all times.** Remember that even 60 degree weather can be chilling if you are engaged in observing with a minimum of movement.

Metal surfaces get very cold; numbed hands can lead to accidents. Walk slowly and carefully when leaving a lighted room and entering the dark. It takes a minimum of 3 minutes for your eyes to adjust reasonably to darkness and more than a half hour for full adaptation. Once your eyes are night adapted, it is best to keep them that way until all observations are completed. Repeated switching from light to dark will cause eye strain.
1. Signing Out Time

(a) **TO BE DETERMINED:** The Head TA will provide us information on how to do this. Please stay tuned.

(b) **The standard time allotment is 2 hours.** We ask that you **not sign up for more than 2 hours in any 24 hour period** to allow all groups an equal opportunity to observe. However, obviously you can extend your time if no other group has signed up.

2. TA and Instructor Non-Abuse Policy

(a) **Either the TA or the Instructor must be accessible during all observing labs,** regardless of your state familiarity with the equipment. “Accessible” means that we are either in close physical proximity or reachable by telephone. This is so that if problems should arise we can either quickly travel to the observatory or talk you through them. This means, therefore, that **before you sign up for time** you need to check that either the TA or the Instructor will be accessible.

(b) **Note that the definition of “problem” is something that involves broken or uncooperative equipment or something where you or the equipment is in danger.** “Problem” does not include understanding the lab instructions or the principles involved with the lab that you should have understood before proceeding to the laboratory or after doing the work.

(c) **The TA or Instructor must always be present for the first observing session with any new instrument or telescope.**

(d) **The TA and Professor require 24 hours advance notice for any observing run.** The exception is if observing time is “dynamically” rescheduled by the TA or Instructor while at the observatory due to instrument problems or weather.

(e) **The groups are encouraged to make any weather decisions at the time of observing at the telescope.** Weather conditions can sometimes be consistently poor. Therefore, students are advised to **make the most of any time at the telescope.** Even though the full lab might not be viable for an observing session, individual parts of the lab may be feasible in non-optimal conditions.

(f) **In the event of an equipment problem, contact the TA and/or Instructor first.** The TA and/or Instructor will be able to assess the severity of the problem and take appropriate measures.