Syllabus: DRAFT

ASTR 3510
Astronomical Observations and Instrumentation I: Imaging
Fall 2020

Class: Tu, Th 2:20 – 3:35 PM : ***Sommers-Bausch Observatory classroom (OBSV S175)***
Synchronous, on-line
Remote via Zoom: Meeting ID: 945 2135 1675 Passwd: ASTR3510
Lab: Tuesdays, 7:30 + : ***SBO computer room and telescopes (OBSV S125)***
In person with TAs:

Instructor: *John Bally,* John.Bally@colorado.edu (Duane D349), 970 547 1200
http://casa.colorado.edu/~bally
Office Hours: Tuesday 4:00, Wednesday 4:00 PM Via Zoom, or by appointment
TAs: *William Waalkes,* William.Waalkes@colorado.edu
Jay Chittidi, Jay.Chittidi@colorado.edu
Office Hours: TBD

Purpose:

ASTR3510/3520 introduce students to the principles of instrumentation used in astrophysics, planetary science, and space physics. The first semester emphasizes imaging while the second semester emphasizes spectroscopy. This course (the first semester) explores the physics and use of telescopes, visual-wavelength imaging with CCDs, photometry, and astrometry. We will also review imaging at other wavelengths including gamma and X-rays, UV, infrared, and radio.

Students will use the SBO 20" and 24" telescopes extensively. Lectures will be held at SBO in the evening, just before labs. Lectures will teach the physical basis of imaging, optics and telescope design, telescope and camera operation, data reduction, and analysis. However, most of the effort in this class will in night-time observing, data reduction, and analysis using `PyRAF, ds9, Python`, and the `astropy` package designed for astronomical data. Students will do research, write-up, and present their research results.

The class will be subdivided into observing teams of no more than 3 students per team. Each team will be expected to spend 1 to 2 nights per week (weather dependent) observing with either the 20" observing deck scopes (from 10:30 PM when the lower-division classes leave till sunrise) , or the 24" after sunset till sunrise. Student groups will be asked to sign-up for specific time slots to avoid conflicts.

I will reserve two weeks of time on the ARCSAT 20" telescope at Apache Point Observatory in New Mexico in early October and November for the class by the class. This telescope will be remote operated from you laptops from home. We will have a remote training session with APO staff during the week of 21 September. More details to come.

COVID-19 Impacts:

This Fall, all ASTR3510 Tuesday & Thursday ***lectures*** will be ***taught on-line*** via Zoom in ***synchronous mode***. I expect all students to participate. I've set-up a recurring Zoom meeting for the class. The Meeting is called ASTR 3510 Fall 2020 with Meeting ID 945 2135 1675. On your browser, go to `Zoom.com`, put it this Meeting ID, followed by the password, ASTR3510. I will start the Zoom session around 2:00 PM. Please turn-on your video when you sign-in so I can see you. But mute your microphone. The lectures will be recorded, and will be available for review after class.

I don't want lecture to be "me talk - you listen" sessions. My goal is to use lecture-time for discussion, not one-way communication. Lectures should be interactive with a very high-degree of student participation. Questions during lecture can be asked by means of text sent to the chat-window on Zoom. I will ask our TAs to monitor the chat window, and to interrupt me so we can discuss the issue. We will see how this works. I will also allow students to un-mute and interrupt me directly. We will be learning how to make discussion work best as we go along.

Following our initial meeting on Tuesday, 25 August, I will post the lecture material at least 24 hours prior to class. Material will consists of pdf, PowerPoint slides, or links to material on the Internet. I will expect all students to review this material prior to class, so that when we go over these items, we can have an active discussion about their contents. During lecture, I will be supplementing the material with live demonstrations of software (we will be using `Unix` commands, text editors, `SAOImageDS9, Pyraf` (or IRAF), `Python` (Ipython, Jupyter Notebooks, and elements of `astropy`) used to process, display and analyze images..

Observing Labs (scheduled for Tuesday evening at SBO) will be in-person for training and in small-groups to work with the telescopes at SBO. Telescope training will occur during the first weeks of the semester. Details are still being worked, and will be discussed in class during the 1st lectures.

There will be two types of training: Operations of the 20" and 24" telescopes at SBO, and Remote Operation of the ARCSAT 20" telescope at Apache Point Observatory in New Mexico (https://www.apo.nmsu.edu/).

Once you are trained on the SBO telescopes, you will form observing teams of ~3 students , and will be assigned observing time on the 24" telescope (our class has exclusive use of the 24"), and on the 20" Deck scopes after 10:30 PM. When at SBO, please wear masks, practice social distancing, and "best-practices" to prevent virus spread. When using the 24", only one person is allowed in the control room, and one person in the student lounge where there will be a separate control computer.

Data processing can be done in the SBO computer labs, or remotely on your laptops via "Remote Desktop" application to the SBO computers. I will provide more details once these have been worked out with Fabio Mezzalira at SBO.

We must prepare for the possibility of closure of CU Boulder facilities because of COVID-19. If this were to happen, we would lose access to SBO. Thus, I will request two weeks of observing time on the 20" ARCSAT telescope in at APO in New Mexico for use by this class for projects. The proposal for this will be submitted to APO in early September. Training for remote operations on ARCSAT will occur during the end of September (stay tuned fro details). I will request one week for this class in October, and another week in early November (around new-Moon). ARCSAT can be the basis for your semester project. See https://www.apo.nmsu.edu/Telescopes/ARCSAT/index.html .

Finally, in the event the APO is forced to shut down prior to our observing dates, I will share my personal archive of imaging data with the class.

Grading:

The grade will be based on problems sets (**30%**), one paper (**15%,** details will be provided in Week 3), and a combination of lab write-ups and an end-of semester, in-class oral plus written presentation of a student project (**45%**). The remaining **10%** of your grade will be determined by your participation in discussions in class and lab. We will not have exams – your project presentations will serve the purpose of a final. Class and laboratory attendance is mandatory.

There will be multiple instances where the homework will not directly give you all the information required to solve problems. For all of these instances it will be possible to find the relevant information with independent research. Try to see if you can find what you need and cite your sources. If **after searching** you are still unsure of what you need or where to find what you need to solve a problem, cooperate with your classmates and ask your TA or the professor for help. As always, the CU Honor Code applies.

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 20" telescopes. The end-of semester research project can be based on data acquired with the SBO CCD cameras. 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.

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)

No Textbook required: **Useful References*:***

``***To Measure the Sky"***, Frederich R. Chromey

``***Data Reduction and Error Analysis in the Physical Sciences''***, Philip Bevington, & D. Keith Robinson

"An Introduction to Astronomical Photometry Using CCDs," by W. Romanishin.
This manual contains a lot of very useful things that we will be using in this class, though not perhaps in the same order. Use it as a practical guide and a supplement to your class notes.

``***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 topics to be covered are listed below, but the schedule may vary.

Lecture Topics:

- Intro to class and logistics. Class overview.
- Introduction to the SBO telescopes & telescopes in general.
  Three electronic handouts: Posted on Canvas Modules
  Syllabus.pdf
  Constants and Formulae for Majors.pdf)
  CCD_Telescope_Notes.pdf

- Astronomical coordinates, scales, and time-keeping, angular units and standard conversions (arc-seconds, arc-minutes, degrees, radians, steradians, etc).
- Magnitudes & flux; the Jansky (1 Jy = 10^{-26} W m^{-2} Hz^{-1}) as it relates to magnitudes.
- Sidereal time and relation to Solar and local time.

- Basic telescope properties. Aperture, focal-length, image scale, magnification (when using an eyepiece).
- The diffraction limit and atmospheric turbulence (seeing) limit.

- Review properties of light. Light as a wave and light as a particle.
- Continuum and blackbody radiation, emission & absorption lines.
- Photo-electric effect and modern imaging devices. History of astronomical imaging.
- Introduction to low-light image acquisition and instrumental artifact removal.

- Basic geometric optics: Fermat's principle and image formation.
- Spheres, parabolas, and compound optics (Cassegrain, Ritchey-Chrétien, etc).
- Snell's law and refractive optics.
- Common telescope designs.
- Aberrations.
- Introduction to diffraction. Theoretical limits to resolution.

- Determining the zero-point (ZPT) and photometric calibration.
- Magnitude, Janskys, and estimating limiting magnitude and flux as function of exposure time and instrument parameters.

- Overview of modern imaging. Camera design (what's in your SLR or snapshot digital camera?).
- Optical transformers (changing the image-scale and FOV).
- CCD fundamentals.
- Limitation to resolution – the atmosphere. Turbulence, transmission, air-mass.
- Observing practicalities. Focusing, tracking.
- Diagnosing problems (optical alignment, CCD problems, S/N, finding sources, measuring image scales & orientations).

- Use of public-domain resources (USNO, Web-based data bases, etc.). When discussing USNO, note that that images + catalog are directly accessible through DS9 – this saves a good deal of pattern-matching-with-circles pain.

- Introduction to the use and importance of statistics.
- Signal-to-noise. Sources of noise.
- Why and when do we need darks, bias frames, flats? How do we use them?
- Standard stars.
- Exposure time estimation.

- Radiative transfer concepts.
- Extinction, reddening.
- Interstellar dust and its effects on stellar and nebular light.
- Color-corrections, measuring the atmosphere.
- Emission vs. absorption as a function of wavelength.

- Astrometry basics. Proper motions.
- Distortions in optics.
- Practical astrometry.

- Parallax. (Discuss *Gaia* mission briefly)
- Error estimation.
- Deep-sky imaging.
- Planetary imaging.
- Morphological classification of astronomical objects.
- The use of color in astronomy.
- Color-color and color-magnitude diagrams.
- Variability monitoring; variable stars, and AGN.
- Synoptic monitoring programs, exoplanet transits, asteroids, gamma-ray bursts, pulsars, and exotic phenomena. (Discuss *LSST* briefly)
- Single-object vs. crowded-field photometry.

- Imaging in the UV, X-ray, gamma-ray, near-IR, far-IR, and radio
- Space vs. ground
- Photometric bands, atmospheric characteristics.
- Detector technologies outside the Visual atmospheric window.
- Optimizing optics and telescopes for each wavelength range.

- Overview of radio astronomy: Discussion interferometric methods. Non-thermal / synchrotron emission by electrons.
- The Zeeman effect. Grain alignment. Polarized continua.
- Applications of imaging in astronomy.
- Overview of the world's observatories.
- Current and future projects. Synoptic surveys.
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- Student Project Presentations.

CU Mandated section of the Syllabus:

ACCOMMODATION FOR DISABILITIES

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition or injury, see Temporary Medical Conditions under the Students tab on the Disability Services website.

Classroom Behavior

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on classroom behavior and the Student Code of Conduct.

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu); 303-492-5550). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the Honor Code Office website.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to fostering a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (including sexual assault, exploitation, harassment, dating or domestic violence, and stalking), discrimination, and harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting, and the campus resources can be found on the OIEC website.
Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. See the campus policy regarding religious observances for full details.