ASTR 414 – Astronomical Techniques
Syllabus for Spring 2016

version April 6, 2016

Instructor Information

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Teaching Assistant

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Course Information

CRN: 43741

Lectures: MWF, 10–10:50AM, 134 Astronomy

Credit: 4 credit hours. This is an advanced undergraduate level course.

Prerequisites: PHYS 212 (E&M); ASTR 210 (Intro to Astrophysics); Basic knowledge of a programming language or data reduction package (e.g. Python).

Course Description

This course will cover modern astronomical techniques with an emphasis on the production and propagation of light, photon detection, instrumentation, data analysis, and statistics. We will cover all wavelengths: γ-ray, x-ray, ultraviolet, visible, infrared, sub-mm, mm, and radio astronomy. We will cover cosmic rays, dark matter, and gravitational waves. We will cover the techniques of astrometry, photometry, imaging, spectroscopy, and interferometry. As with the modern field of astronomy, the course will be heavy with data analysis and programming. The course will have two lab projects: 1) reducing optical images from the Dark Energy Survey; and 2) reducing interferometric data from ALMA. A final project will be in the form of a (mock) telescope proposal. There will be 10 homework assignments. There will be two midterms and a final exam. This course can be taken in conjunction with ASTR 401 to satisfy the Advanced Composition requirement. (See instructor.)

Course Objectives

Here are the astronomer life skills we will be practicing:

- **Technology:** New instrumentation is essential to observational astronomy. We will study the basic physics of radiation detection. We will gain a general understanding of modern astronomical facilities.

- **Wavelengths:** We will work across the electromagnetic spectrum, and beyond.
- **Data Analysis:** We will analyze real data from state-of-the-art facilities. We will work with large data sets. We will make simulations.
- **Statistics:** We will study error in astronomical measurements: origins, types, characterization, and mitigation.
- **Communication:** How to plot data, make a pretty image, and use LaTeX.
- **Time:** Students will write a (mock) proposal for time on a (real) telescope.

Course Resources

Textbooks: *To Measure the Sky: An Introduction to Observational Astronomy* by Frederick **Chromey**, Cambridge University Press, 2010 (ISBN-10: 0521747686) is the official and required textbook for this course, which you can find at the bookstore. [Amazon link]

I plan on following **Chromey** as much as possible, but note that the last 3rd of the course will rely on supplementary materials which will be drawn primarily from the texts given below.

I also recommend looking at:

- *Data Reduction and Error Analysis for the Physical Sciences* by **Bevington** and Robinson, McGraw-Hill, 2004 (ISBN-10: 0072472278). Bevington is a useful reference text for data analysis and statistics. [Amazon link]
- *Astronomy Methods: A Physical Approach to Astronomical Observations* by Hale **Bradt**, Cambridge University Press, 2004 (ISBN-10: 0521535514). Bradt does the best job at high energy astrophysics. [Amazon link]
- *An Introduction to Radio Astronomy* by **Burke** and Graham-Smith, Cambridge University Press, 2009 (ISBN-10: 052187808X). This is a standard introduction to radio astronomy. I recommend it for the interferometry project. [Amazon link]
- *Electronic Imaging in Astronomy: Detectors and Instrumentation* by Ian **McLean**, Wiley, 2004 (ISBN-10: 3540765824). McLean does the best job on instrumentation, imaging, and CCDs. He goes into the most details on instruments. [Amazon link]
- *Measuring the Universe* by George **Rieke**, Cambridge University Press, 2012 (ISBN-10: 0521762294). Rieke does a very good job over-all. He does the best job at attempting to cover all wavelengths and get into the physics of the detectors. [Amazon link]

Course Web Page: Find the course webpage on Compass here: `https://compass.illinois.edu` Note that it may take a few hours to show up if you have just registered for the course. Everything for the course will be posted here.

Course Grade

Component	**Percentage of Overall Grade**
Homework	30%
Lab 1	10%
Lab 2	10%
Telescope Proposal	10%
Midterm 1	10%
Midterm 2	10%
Final Exam	20%
TOTAL	100%

The grades shall be normalized such that the median will be ∼B.

Assignments & Exams

Homework Problems: There will be ~10 homework assignments over the course of the semester. They will take a few hours to complete. Students are encouraged to discuss and collaborate with their peers. However, each student must submit their own work. There will be no tolerance for plagiarism or lack of academic integrity. Violations will immediately be dealt with according to the *Student Code* . You will turn in one single pdf to the TA before 5 PM on the date they are due. The title of the assignment, your name, your netid, and the date must be included at the top. You may be required to show your actual code. Do not delete anything until the end of the semester.

Projects: We are going to get our hands dirty with real data from modern, state-of-the-art facilities. Each project is 10% of the total course grade. Each will be written up in LaTeX.

- *Dark Energy Survey Lab*: Optical Data Reduction. We will get some raw data from the Dark Energy Survey (DES) reduce it ourselves. DES is the largest astronomical survey camera on the planet.
- *ALMA Lab*: We will learn to reduce interferometric data. We will work with real data from ALMA, the largest ground-based astronomical project in the history of humanity.
- *Telescope Proposal*: We will write a proposal to ESO to use the Very Large Telescope (VLT) to obtain a redshift of a DES source.

Exams: There will be two midterm exams for this course and a comprehensive final exam. The exams will be in-class. For examinations, all answers and work must be your own.

Class Policies

General: This course will follow all policies in the *Student Code*. **Turn off all cell phones and electronic devices. No open electronic devices during lecture. period.**

Email: If you email the professor, you **must** put "ASTR414" in the subject heading of the email. I am flooded with emails. If ASTR414 is *not* in the subject heading, then consider your email lost.

Attendance: You are expected to attend lectures. I will cover material in class that will not always be in the readings, and the lecture material will be included on the exams. Class time is the most valuable for you if you come prepared, ready to actively engage the material. Lecture slides will be posted to Compass.

Late Work: HW and reports turned in after 5 pm on the due date will be assessed a 10% penalty per day late (excepting weekends and University holidays). The maximum penalty is 50%.

Discussion Boards: The discussion boards on the class webpage are there for your benefit. You are expected be polite to your fellow students (and instructors). Discourteous behavior will result in being denied access to the discussion boards.

Exam Absences: Make-up exams will only be offered if the student has good reason, in accordance with sections 1-501, 1-502, and 3-201–3-204 of the *Student Code*. Advance notice and documentation are **required** for approved school events (e.g., athletic competition), religious observances, and other planned absences. In case of unforeseen circumstances (e.g., illness), contact the Emergency Dean request an Absence Letter to document the exam absence.

Personal Issues: To insure that concerns are properly addressed from the beginning, students who require reasonable accommodations to participate in this class are asked to see the instructor as soon as possible. All accommodations will follow the procedures as stated in sections 1-107 and 1-110 of the *Student Code*.

Research Conflicts: Students with research responsibilities will be accommodated. Talk to the professor ahead of time, *not* after.

Academic Integrity: The first skill of a good scientist is honesty. The rest is being curious, careful, and smart. I will have zero tolerance for cheating, copying, or plagiarism. Any instance of academic dishonesty will be handled in accordance with sections 1-401–1-406 of the *Student Code*. Do. Not. Mess. With. Me. On. This.

Course Schedule

Lecture	Day	Date	Topics	Reading	Assignments Due
–	M	Jan. 18	**MLK day – no class**		
01	W	Jan. 20	Introduction		
02	F	Jan. 22	Python & LaTeX Boot Camp	notes	
03	M	Jan. 25	Light	C 1.1–1.3	
04	W	Jan. 27	Luminosity & Magnitudes	C 1.4–1.6	
05	F	Jan. 29	redshift	notes	HW 1
06	M	Feb. 1	Uncertainty	C 2.1–2.2	
07	W	Feb. 3	Probability	C 2.3–2.6	
08	F	Feb. 5	Noise	notes	HW 2
09	M	Feb. 8	Astrometry	C 3.1–3.2	
10	W	Feb. 10	Time & motion	C 3.3–3.4	
11	F	Feb. 12	names, catalogs, & databases	C 4	HW 3
12	M	Feb. 15	Optics	C 5	
13	W	Feb. 17	Telescopes	C 6	
14	F	Feb. 19	ALMA Data Tutorial	–	HW 4
15	M	Feb. 22	DES Data Tutorial		
16	W	Feb. 24	Atoms+photons	C 7.1–7.2	
17	F	Feb. 26	Matter	C 7.3–7.9	HW 5
18	M	Feb. 29	CCDs	C 8.1–8.3	
19	W	Mar. 2	Infrared Detectors	C 8.4 ; R 3.4–3.5	
20	F	Mar. 4	Thermal Detectors	C 8.5 ; R 8.2	
–	M	Mar. 7	**Exam 1: Lectures 1–17**		
21	W	Mar. 9	Direct Detection	R 8.3–8.6	
22	F	Mar. 11	x-ray's and γ-rays	R 10	HW 6
23	M	Mar. 14	Cosmic Rays and Neutrinos	R 11.2	
24	W	Mar. 16	Dark Matter	R 11.3	
25	F	Mar. 18	Gravitational Waves	R 11.4	HW 7
March 21-25			**Spring Break**		
26	M	Mar. 28	Reducing Images I	C 9.1-9.4	
27	W	Apr. 30	Reducing Images II	C 9.5	
28	F	Apr. 1	Photometry	C 10	HW 8
–	M	Apr. 4	**Exam 2: Lectures 18–28**		
29	W	Apr. 6	Spectrometers	C 11.1–11.4	
30	F	Apr. 8	Spectroscopy	C 11.5–11.7	HW 9
31	M	Apr. 11	Interferometry I	R 9	
32	W	Apr. 13	Interferometry II	R 9	
33	F	Apr. 15	Multi-wavelength astronomy	notes	HW 10
34	M	Apr. 18	Ground-Based Telescopes	notes	
35	W	Apr. 20	Space Telescopes	notes	
36	F	Apr. 22	Wide Surveys	notes	Lab 1
37	M	Apr. 25	Deep Surveys	notes	
38	W	Apr. 27	Materials	notes	
39	F	Apr. 29	Instrumentation	notes	Lab 2
40	M	May. 2	Future Instruments	notes	
41	W	May. 4	How Astronomy works	notes	Telescope proposal

Final Exam: Thursday, May 12, 8:00–11:00 AM
Legend: C = Chromey ; R = Rieke