

ASTR 519/719.001 Fall 2022 Observational Astronomy

Prof. Gerald Cecil cecil@unc.edu Philips 268

TTh 2:00-3:15 Philips 222, office hr/occasional lab T 3:30-5:00 + by Zoom appointment¹

Course Description and Objectives

Introduce observational astrophysics with an emphasis on optical and near-infrared wavelengths. Topics include celestial coordinates, python for astronomy, telescopes and electronic imagers, time-series data, spectroscopy, astrostatistics, and accessing large astronomical surveys. By course end, students should be able to plan and execute an observing program and use data from astronomical surveys, including calibration and analysis of the resulting data.

This course will provide students with experience that comes from interacting with astronomical data as needed to understand scientific results from observations across the electromagnetic spectrum. It is divided into 9 modules with the learning topics that students will be able to explain listed below:

1. **Space, Time, and Motion:** celestial coordinates, sidereal time, target visibility, precession and nutation, refraction and atmospheric effects. Practical astronomy in python.
2. **Photons:** flux density, magnitude systems and corrections, introduction to telescopes.
3. **Parameter estimation:** basic statistics, signal-to-noise, and error analysis in astronomy. Bayes theorem and Monte Carlo methods, correlated errors.
4. **Filtering:** spatial frequencies, wavelets, convolution, sampling, data smoothing, atmospheric extinction, photometric calibrations.
5. **Astronomical Optics and Detectors:** image formation by optics, optical aberrations, coronagraphic light suppression, telescope designs, active optics, electronic imaging detectors used from X-rays to infrared, sub-mm to radio wavelength detectors.
6. **Multi-pupil telescopes:** interferometry with telescope arrays at infrared and radio frequencies, adaptive optics wavefront correction, astrometry.
7. **Dispersing Light:** spectroscopic techniques and instrument design, spectral resolution, flux and wavelength calibration, 3D spectroscopy, spectro-polarimetry.
8. **Time Series Data:** frequency analysis, sampling, window functions, periodograms.
9. **Getting telescope time:** writing and reviewing telescope proposals. Time Allocation Committee (TAC).

Within IDEAs in Action Student Learning Outcomes, this course

¹A new COVID wave may require that we revert to online meetings. Regardless, “long COVID” is real and damaging to all ages. Be aware that so-called “vaccines” and boosters do not prevent infection. I will be masked in class and the classroom windows will be open to improve ventilation.

- by emphasizing hands-on exploration of datasets that students will acquire themselves and analyze, meets the **Research & Discovery** outcome in the Reflection & Integration goal of IDEAs and the **Natural Science Investigation** outcome in the Focus Capacities goal;
- by requiring statistical analysis of data, in-class presentation, and a 10 page written project report, meets the **Recurring Capacities** outcome of IDEAs.

We are focused on the practicalities and technological limits of obtaining reliable astronomical datasets. We will not go deep into astrophysical processes that underlay what we will study, but your attention to detail and quantitative reasoning will be necessary and part of your course grade. Your other astrophysics courses will examine why and how things are the way we think they are. Skills developed here with data manipulation and analysis will serve you well, regardless of which field you are studying. The Universe is often transparent to us, so we can see deep into space and into the past. Endless discoveries await, so I hope that you will start/continue your journey with me this semester.

Course Structure

Classes will mix lectures and activities. Lectures may include multiple-choices to be answered instantly with ABCD cards. Modules will include at least one in-class activity exploring a dataset or concept through python. The class lecture component will be recorded and the Panopto link will be in Sakai shortly thereafter.

Class attendance is required. There is no penalty for missing class for University excused absences, including if sick or quarantined. Do not attend class if you are not feeling well. Please email me in such cases (in advance if possible) so we can arrange make up of essential work. I will make slides available on Sakai during the module. Active participation in both questions and exercises are required as part of the class participation grade. The in-class activities and questions are not graded in detail; students will receive full credit provided they are participating.

Labs in Tuesday “office-hours” are designed to help with programming aspects of the course. This includes setting up the appropriate python environment required to complete homework. Attendance is not mandatory for labs, but is recommended if you need help on programming as the course progresses. In addition, I am planning to conduct a few “real” observing sessions using the on-campus 24” aperture professional telescope atop Morehead Science Center. Details in Sept.

Exams mid-term will be open everything including internet, but you are not allowed to collaborate with others. It will be a single take home assignment that opens in the morning and is due at the end of the day.

Homework assignments will be distributed through Sakai Resources or Assignments, and should be submitted either through Sakai’s Assignment or drop box feature. Often your submission will include both the results/answers and the code used to generate them. Best is to program in an annotated Jupyter notebook and upload the .ipynb file that

includes your commented results together with a PDF copy after running your code. Both output and source code will be graded, so commenting your code is essential to receive partial credit for incorrect solutions. If something didn't work, seek help well before the deadline. An "Oops, it didn't work, what's wrong?" submission won't get you a grade. Nor will "I worked on this for hours and got nowhere!" Seek the professor's help, don't expect help the day before an assignment is due. Sakai's assignment feature handles large files poorly, so when in doubt use the drop box with NAMEassign# as the zip-filename.

Homework assignments will be made available near the start of each module above, total six. Due dates are listed below, but may be adjusted slightly. Except in the case of University-excused absences or prior arrangements with the professor, late assignments submitted within 48 hours of the deadline will be given a 20% penalty and no assignment will be accepted after 48 hours of the deadline.

Collaboration Group work on homework is encouraged, but each student must do their own work and submit their own independently prepared homework (code and final answers). Copying other student's code is prohibited. Group work on the project is allowed.

Textbook is *To Measure the Sky* 2nd ed. by Chromey on reserve at Davis Library Service desk and \$21 total to rent for the semester from Amazon. It is the right level to clarify material for ASTR 519 but needs supplementation for 719 students in this mixed class, so I'll distribute chapters from the one I'm writing *Observational Astrophysics: Illustrated by Mathematica and Python*. This interactive book is currently ten long *Mathematica* notebooks, with comparable code being written in python. You can install *Mathematica* for free at UNC to play with these, and is recommended provided you recognize that it will cost a lot to keep it up to date after graduation. However, we will develop and use the python side of this text.

Other assigned readings to be provided as PDFs through Sakai including *Data Reduction and Error Analysis for the Physical Sciences* by Bevington & Robinson. Good statistics reference for 719 students is the more advanced *Practical Statistics for Astronomers* 2nd ed. by Wall & Jenkins.

Computing hardware and software. Many in-class exercises will require your laptop, so bring it to class. Central to this course is to learn python tools used by astronomers. The first lab on Aug. 16 will focus on installing python 3 and notebooks. After installation, create/open a notebook in jupyterlab. Please attempt these steps before Thursday Aug 18 class:

Install the base system of python ² and then the following packages by typing in a terminal window:

```
conda install seaborn
conda install astropy
conda install scikit-image
conda install jupyterlab
conda install ipywidgets
pip install photutils
pip install ccdproc
```

²If you already installed python for another course, for consistency please make a new python environment for this course by following these steps and then proceed to install stuff in that environment.

pip install emcee
 pip install corner
 pip install astroML

519 students please install Mathematica Player from here.
 719 students please install Mathematica 13.1 from here.

Likely Schedule & Deadlines

Aug 16	Lab software installation help
Aug 18–25	M1 Space/Time/Motion
Aug 23	Lab software installation help
Aug 30–Sep 13	M2 Photons & introduction to telescopes
Sep 2	HW1 Due
Sep 6	Wellness break
Sep 15–27	M3 Parameter estimation
Sep 13	HW2 Due
Sep 29–Oct 11	M4 Filtering
Oct 10	HW3 Due
Oct 13–25	M5 & 6 Optics and detectors
Oct 19	HW4 Due
Oct 20	Fall break
Oct 26	Midterm on M1-6
Nov 4	HW5 due
Oct 27–Nov 10	M7 Dispersing light
Nov 15–22	M8 Time series
Nov 18	HW6 Due
Nov 24	Thanksgiving break
Nov 29	M9 Getting Telescope Time
Nov 30	Final project reports due

Grading Policy

Homework (40%) will be assigned from Sakai every 3-4 classes, generally be in the form of jupyterlab notebooks that you work through and embellish then upload to Sakai. If you have never used these, don't worry I will get you up to speed.

Mid-term (15%) will be take-home, **there will be no final.**

Class interactive aspects (10%, 1 point for each participation) with you working in pairs or sometimes alone. Lectures will feature ABCD votes in real time to give me feedback on whether the material is “sticking”.

Project (25%) culminating as a 10 page report with Web link to code and a class presentation. I'll work with each of you to develop an activity that aligns with your interests. **This is not something to start three weeks before semester end!** Therefore, about 1/3 of the way through the semester, you will submit a “project request” that outlines your project's goals and techniques to be employed. In turn you will receive five of these submissions from your classmates, suitably anonymized, that you will critique for **10% of your grade.** This “Time Allocation” activity mimics the peer review that all astronomical observing proposals

endure to access expensive and limited data acquiring facilities. Based on the outcome of this review (can it be done by you with the facilities and techniques proposed? In the time left?), you may have to modify your program.

We have limited direct access to radio and optical telescopes at UNC via SkyNet (limited because unfortunately it costs UNC real \$). For other wavebands generally accessed by space observatories, we will use data from various astronomical archives. I feel that it is important for you to directly experience telescopes and CMOS imagers, so we will also use (carefully!) my small refracting telescope on a computer controlled equatorial mount to image the Moon and Sun. A semester project for some of you as a “tiger team” group effort will be to automate narrow-band hydrogen imaging with this telescope, to feed those often spectacular and dynamic images to the Morehead Science Center on campus for public viewing on a large projected display. There are several technical challenges for you to overcome.

University Policies and Support Services (attached)

University of North Carolina at Chapel Hill
Information for Undergraduate Classes
Summer & Fall 2022

Syllabus Changes

The professor reserves the right to make changes to the syllabus including project due dates and test dates. These changes will be announced as early as possible.

Attendance Policy

University Policy: As stated in the University's [Class Attendance Policy](#), no right or privilege exists that permits a student to be absent from any class meetings, except for these University Approved Absences:

1. Authorized University activities
2. Disability/religious observance/pregnancy, as required by law and approved by [Accessibility Resources and Service](#) and/or the [Equal Opportunity and Compliance Office](#) (EOC)
3. Significant health condition and/or personal/family emergency as approved by the [Office of the Dean of Students](#), [Gender Violence Service Coordinators](#), and/or the [Equal Opportunity and Compliance Office](#) (EOC).

Class Policy: Instructors may work with students to meet attendance needs that do not fall within University approved absences. For situations when an absence is not University approved (e.g., a job interview or club activity), instructors determine their own approach to missed classes and make-up assessment and assignments.

University Approved Absence Office (UAAO): The [UAAO](#) website provides information and FAQs for students and faculty related to University Approved Absences.

Note: Instructors have the authority to make academic adjustments without official notice from the UAAO. In other words, it is not required for instructors to receive a University Approved Absence notification in order to work with a student. In fact, instructors are encouraged to work directly with students when possible.

Honor Code

All students are expected to follow the guidelines of the UNC Honor Code. In particular, students are expected to refrain from "lying, cheating, or stealing" in the academic context. If you are unsure about which actions violate the Honor Code, please see me or consult studentconduct.unc.edu.

Optional Mask Use Statement

UNC-Chapel Hill is committed to the well-being of our community – not just physically, but emotionally. The indoor mask requirement was lifted for most of campus on March 7, 2022. If you feel more comfortable wearing a mask, you are free to do so. There are many reasons why a person may decide to continue to wear a mask, and we respect that choice.

Acceptable Use Policy

By attending the University of North Carolina at Chapel Hill, you agree to abide by the University of North Carolina at Chapel Hill policies related to the acceptable use of IT systems and services. The Acceptable Use Policy (AUP) sets the expectation that you will use the University's technology resources responsibly, consistent with the University's mission. In the context of a class, it's quite likely you will participate in online activities that could include personal information about you or your peers, and the AUP addresses your obligations to protect the privacy of class participants. In addition, the AUP addresses matters of others' intellectual property, including copyright. These are only a couple of typical examples, so you should consult the full [Information Technology Acceptable Use Policy](#), which covers topics related to using digital resources, such as privacy, confidentiality, and intellectual property.

Additionally, consult the University website "[Safe Computing at UNC](#)" for information about the data security policies, updates, and tips on keeping your identity, information, and devices safe.

Accessibility Resources and Service

The University of North Carolina at Chapel Hill facilitates the implementation of reasonable accommodations, including resources and services, for students with disabilities, including mental health disorders, chronic medical conditions, a temporary disability or pregnancy complications resulting in barriers to fully accessing University courses, programs and activities.

Accommodations are determined through the Office of Accessibility Resources and Service (ARS) for individuals with documented qualifying disabilities in accordance with applicable state and federal laws. See the ARS Website for contact information: <https://ars.unc.edu> or email ars@unc.edu.

Counseling and Psychological Services

UNC-Chapel Hill is strongly committed to addressing the mental health needs of a diverse student body. The [Heels Care Network](#) website is a place to access the many mental resources at Carolina. CAPS is the primary mental health provider for students, offering timely access to consultation and connection to clinically appropriate services. Go to their website <https://caps.unc.edu/> or visit their facilities on the third floor of the Campus Health building for an initial evaluation to learn more. Students can also call CAPS 24/7 at 919-966-3658 for immediate assistance.

Title IX Resources

Any student who is impacted by discrimination, harassment, interpersonal (relationship) violence, sexual violence, sexual exploitation, or stalking is encouraged to seek resources on campus or in the community. Reports can be made online to the EOC at <https://eoc.unc.edu/report-an-incident/>. Please contact the University's Title IX Coordinator (Elizabeth Hall, titleixcoordinator@unc.edu), Report and Response Coordinators in the Equal Opportunity and Compliance Office (reportandresponse@unc.edu), Counseling and Psychological Services (confidential), or the Gender Violence Services Coordinators (gvsc@unc.edu; confidential) to discuss your specific needs. Additional resources are available at safe.unc.edu.

Policy on Non-Discrimination

The University is committed to providing an inclusive and welcoming environment for all members of our community and to ensuring that educational and employment decisions are based on individuals' abilities and qualifications. Consistent with this principle and applicable laws, the University's [Policy](#)

[Statement on Non-Discrimination](#) offers access to its educational programs and activities as well as employment terms and conditions without respect to race, color, gender, national origin, age, religion, genetic information, disability, veteran's status, sexual orientation, gender identity or gender expression. Such a policy ensures that only relevant factors are considered and that equitable and consistent standards of conduct and performance are applied.

If you are experiencing harassment or discrimination, you can seek assistance and file a report through the Report and Response Coordinators (see contact info at safe.unc.edu) or the [Equal Opportunity and Compliance Office](#), or online to the EOC at <https://eoc.unc.edu/report-an-incident/>.

Diversity Statement

I value the perspectives of individuals from all backgrounds reflecting the diversity of our students. I broadly define diversity to include race, gender identity, national origin, ethnicity, religion, social class, age, sexual orientation, political background, and physical and learning ability. I strive to make this classroom an inclusive space for all students. Please let me know if there is anything I can do to improve. I appreciate suggestions.

Undergraduate Testing Center

The College of Arts and Sciences provides a secure, proctored environment in which exams can be taken. The center works with instructors to proctor exams for their undergraduate students who are not registered with ARS and who do not need testing accommodations as provided by ARS. In other words, the Center provides a proctored testing environment for students who are unable to take an exam at the normally scheduled time (with pre-arrangement by your instructor). For more information, visit <http://testingcenter.web.unc.edu/>.

Learning Center

Want to get the most out of this course or others this semester? Visit UNC's Learning Center at <http://learningcenter.unc.edu> to make an appointment or register for an event. Their free, popular programs will help you optimize your academic performance. Try academic coaching, peer tutoring, STEM support, ADHD/LD services, workshops and study camps, or review tips and tools available on the website.

Writing Center

For free feedback on any course writing projects, check out UNC's Writing Center. Writing Center coaches can assist with any writing project, including multimedia projects and application essays, at any stage of the writing process. You don't even need a draft to come visit. To schedule a 45-minute appointment, review quick tips, or request written feedback online, visit <http://writingcenter.unc.edu>.

Grade Appeal Process

If you feel you have been awarded an incorrect grade, please discuss with me. If we cannot resolve the issue, you may talk to our departmental director of undergraduate studies or appeal the grade through a formal university process based on arithmetic/clerical error, arbitrariness, discrimination, harassment, or personal malice. To learn more, go to the [Academic Advising Program](#) website.