Astro 9: Introduction to Scientific Programming for Physics and Astronomy

Instructor: Abigail Polin

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E-mail: abigail@berkeley.edu
Class Hours: M/W/F: 10am-12:30pm (PDT)
Office Hours: W: 2-3pm (or by appointment)
Slack: Astro9
Zoom ID: 957 4650 4439
Zoom Password: Astro9-20A

Course Description

This is an introductory course in scientific programming with emphasis on learning the techniques used to model the universe and analyze data. The focus of the course will be on the application and implementation of practical computational techniques useful throughout the physical sciences. In particular we will extensively use the python numpy/scipy/matplotlib stack to create programs and apply them to data drawn from a number of real world sources (astronomy, physics, finance, etc.). Topics covered in the course will include numerical integration, sampling (i.e. Markov Chain Monte Carlo), optimization, interpolation and extrapolation of data, and the basic techniques used in astrophysical simulations (numerical solutions to differential equations etc.). Students will complete a final project on a topic of their choosing to explore how the topics learned in class are used in cutting edge scientific research. This course is designed to be an introduction for students interested in research in physics and astronomy.

Prerequisites

There are no formal pre-requisites to this class but I will assume you have comfort with multi-variable calculus. You can find some wonderful online supplementary material here[1] if you are rusty.

[1]https://math.berkeley.edu/ hutching/teach/53videos.html

Course Objectives

At the end of this course successful students:

1. Will have comfort doing basic programming in python.
2. Understand how to design and implement a jupyter notebook.
3. Are comfortable synthesising reports in LaTeX.
4. Have developed a skill set of understanding the basic building block of scientific computing techniques.
5. Can interface with GitHub.

Course Structure

Class Structure

This course will be taught remotely and I will do my best to format it in a way that takes advantage of this situation. My aim is to have pre-recorded lectures that you may watch either before class, or during the first $\sim$30 minutes of each lecture. The remaining time will be spent actively coding together. In this time you will have the opportunity to work on problems that you will later expand upon, and write up to turn in as homework.

Homework

You will be responsible for completing one homework set (roughly three problems each) per week. You must write up your homework describing your methods and results using LaTeX. I recommend using overleaf so you can share the document with me if you run into problems. There is a sample LaTeXtemplate in the course materials to help you get started. Your write ups and the (properly commented) code used to produce your results should be turned in on the GitHub classroom by midnight (PDT) on the due date.

You may work on your homework with other students, I encourage this, but your code and your write up need to be your own. If you use any code or packages you find elsewhere you need to cite where it comes from. Copying code you find on the internet is plagiarism. Please see the Berkeley student code of conduct for more information about academic honsety.

Final Project

Towards the middle of the course I will provide a list of topics in Physics and Astronomy research that rely upon the techniques we have learned in class. You will be responsible for investigating one of these topics and writing up a final report. You will also be required to present a short (roughly 10 min) summary of your findings to the class during the last week of the course.

Grading Policy

I reserve the right to curve the scale dependent on overall class scores at the end of the semester. Any curve will only ever make it easier to obtain a certain letter grade. The grade will count the assessments using the following proportions:

- **60%** Homework. Late homework will typically not be accepted.
- **30%** Final Project. This will be a combination of your report and presentation.
- **10%** Class participation. This can be either in the form of interacting during lectures and/or office hours, or participating in Slack discussions.

Course Policies

During Class

I encourage you to turn your video on in class (but this is not required). If you're not comfortable showing your face during the zoom I encourage you to create an avatar or cartoon that fits your personality so I can at least get to recognise you by more than your initials.

Science is a collaborative field and I would like this course to reflect that. Attendance during class time is not required but highly encouraged. Lectures will be recorded an available outside of class time, but we will be doing a large part of the homework, or exercises that will make the homework easier, together during these times.

Outside of Class

We will use Slack for class communications. I will set up channels for each homework set, as well as one for lecture questions, and others as the need comes up. Messaging me on slack will also be the most effective way to get a speedy answer. I recommend you try this first rather than email.

Policies on Late Assignments

Typically I do not accept late homeworks, however there is a pandemic going on right now. If you need a homework extension let me know BEFORE THE DEADLINE and we can talk about it. Late homeworks without prior approval will not be accepted.

Disabled Student's Program: https://dsp.berkeley.edu/

All students who have special needs can receive appropriate accommodations. The DSP office must determine or verify these accommodations before they can be offered. Students who are requesting academic accommodations are responsible for contacting the DSP Coordinator immediately. Please contact the instructor when a request for accommodation has been filed.

Code of Conduct: https://sa.berkeley.edu/code-of-conduct

The instructor and students are expected to behave with the utmost of integrity, responsibility, and civility towards all members of the classroom as well as UC Berkeley staff. Additionally, all members of the community are expected to comply with all laws, University policies, and campus regulations, conducting themselves in ways that support a thriving learning environment. For more information, see the linked document. Violation of the code of conduct can result in disciplinary steps as outlined in the code.

Use of Course Materials

The materials provided by the instructor in this course including, but not limited to, lecture notes, homework assignments, solution sets, exams, exam solutions, and study materials (collectively "course materials") are for the use of the students current enrolled in the course only. Distribution or public display of the course materials by students for non-enrolled students is not permitted, and may constitute academic misconduct under Sections 102.01, 102.05, and 102.23 of the student code of conduct. The course materials are also subject to copyright protection, with copyright held by the instructor. As such, the course materials may not be duplicated, distributed, publicly displayed, or modified in a manner contrary to law.

Feedback

I want you all to get the most you can out of this course. And I want it to be fun for all of us. For this I will need feedback from you on the aspects that are working and especially the ones that are not. I have an open anonymous google form here[2] for you to keep me updated on what I can do to make this the best class possible.

Schedule and weekly learning goals

The schedule is tentative and subject to change.

Week 01: Introduction to Python, 05/25 - 05/29:

- Setting up Anaconda Python
- Jupyter Notebooks
- Numpy, Matplotlib
- Data Structures
- Functions
- Plotting & Visualization

Week 02: Basic Numerics, 06/01 - 06/05:

- Numerical Math: Machine Precision, Representation of Numbers etc.
- Interpolation and Approximations
- Numerical Differentiation and Integration
- Random Numbers

Week 03: Ordinary Differential Equations, 06/08 - 06/12:

- Basic Methods: Euler, Runge-Kutta, etc.
- Implicit Methods
- Applications to Physics & Astronomy

Week 04: Spectral Methods, 06/15 - 06/19:

- Random Gaussian Fields, Power Spectrum, Correlation Functions
- Fast Fourier Transform
- Applications to Physics & Astronomy

Week 05: Monte Carlo Methods, 06/22 - 06/26:

- Random Walks, Monte Carlo, Markov Chains
- Applications to Physics & Astronomy

Week 06: Final Projects, 06/29 - 07/03:

- Final Project Presentations

[2] https://docs.google.com/forms/d/e/1FAIpQLSdN8042MHqULtplSjvJa1sd82r81IVXCz1xRfkyULeW4pKYWA/viewform?usp=sf$_l i$