PHYSICS 198: Physics High-Performance and Scientific Computing and Technology (PhysCat)

University of California, Berkeley, Spring 2021

Units: 2

Faculty Sponsor: Yury Kolomensky

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Course Overview

Programming skills are essential to almost all physics research roles, and therefore prerequisite programming knowledge is often a prohibitive barrier to starting research. To meet this need, student-run and official courses such as the Astronomy department's Python DeCal, the ULab Physics and Astronomy program, and Physics 77 are available to students. However, there is only enough time to cover the basics in a one-semester course; a lot of subsequent computer science knowledge necessary for research careers is left to be learned by experience. Rather than leaving these knowledge gaps or forcing you to take advanced Computer Science department courses, this class proposes to teach you what you need to know to be an effective computational researcher!

The course will cover three broad topics:

1. The basics of computer architecture and high-performance computing
2. Scientific computing and computational efficiency
3. Best practices, tools, and documentation

Through learning about these concepts and completing assignments, students will become fluent in computational thinking, and gain an improved understanding of how programming can be efficiently used as a research tool.

This course has been roughly structured based on Astro 528, "High-Performance Scientific Computing for Astrophysics", at Pennsylvania State University in Spring 2019, and 18.S191, "Introduction to Computational Thinking", at MIT in Fall 2020.

Course Structure

The course will meet for one hour of lecture and one hour of discussion/office hours per week. Lecture will be held on Mondays from 7-8pm, and discussion/OH will be held on Wednesdays from 7-8pm.

Students taking this course are expected to have had some programming experience, usually in Python, at the level of the ULab Physics and Astronomy CS modules, the Astronomy department Python DeCal, Data 8, or Physics 77 (although this is not an exhaustive list). The first two homeworks will be representative of the background expected, and students for whom this material is not review may want to consider taking a different class to cover that material.

Based on the lectures, students will be expected to complete six homework assignments, and a final project incorporating some of the ideas discussed throughout the semester. The first two homework assignments will cover setup and review, and students will be given one week for each; the other four homework assignments will cover new course content, and students will be given two weeks for each.

The final four weeks of the class will be devoted to final projects, in which students complete a computational physics task of their choice using some of the principles from the class. Students are required to complete projects in groups of 2-3.

Projects must:

- be programming-based, in any language or languages of the group's choice;
- describe in their proposal how they will incorporate concepts from the class; and
- have written documentation and version control history that the facilitators can access.

If students are involved with research, clubs, or other classes for which they are required to complete a computational project, they may overlap it as their final project for this class, provided that they follow the guidelines above and the other classes allow it.

Schedule and Assignments

Week	Topic	Assignment	Primary Facilitator
(01/25)	Overview, Environment Setup, Future Concepts	HW 1	Aditya
(02/01)	Python Review	HW 2	Aled
(02/08)	Computer Architecture	HW 3	Aled
(02/15)	SIMD and Vectorized Computation	HW 3	Aled
(02/22)	Threading	HW 4	Aled
(03/01)	GPUs and High-Performance Computing	HW 4	Aled
(03/08)	The Julia Programming Language, Code Efficiency	HW 5	Aditya
(03/15)	Git, Github, Package Management	HW 5	Aditya
(03/22)	Spring Break		
(03/29)	Asymptotic Analysis, Parallel Computing	HW 6	Aditya
(04/05)	Numerical Methods, Probabilistic Programming	HW 6	Aditya
(04/12)	Applications to Computational Physics	Project Proposals	Aditya + Aled
(04/19)	Good Coding Practices and Documentation	Project	Aditya
(04/26)	Advanced Topics: FPGAs and Signals	Project	Aled
(05/03)	Project Presentations	Project	-

Grading Policy

Grading will be on a P/NP basis, and students must secure at least a 70% to pass. The course grade will be based on attendance (10%), homework (50%) and the final project (40%). Students must synchronously attend lecture on Mondays. Two unexcused absences are permitted; further absences may result in an NP. Homeworks 1 and 2 will have a weight of 5% each, and Homeworks 3-6 will have a weight of 10% each. The lowest homework score will be dropped (regardless of weight). For the final project, students must submit a project proposal (worth 5%) by the end of the week of 04/11, and must submit their final projects (worth 35%) by the beginning of RRR week.

COVID-19 Contingencies

We expect this DeCal to be held entirely online. In the event the university guidelines on in-person events are updated during the semester, the facilitators may hold some office hours in-person in accordance with university, state, and federal public health guidelines, but will default to online.