Astronomy 501: Introduction to Computing

Fall 2020

Once per week
Steward Observatory, Room 208

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Description: This course is intended as an introduction to using computers in astrophysical research. Of course, computers are used widely in different ways throughout astronomy, and we cannot hope to touch on everything in any detail. There are a number of tasks which nearly everyone performs regularly with data, however, in one form or another: creation (simulation) or acquisition, organization, visualization, and description.

All of these tasks require programming. While you may not need to delve into the details of Intel assembly language, at the very least you will need to glue various tools together. You will likely want to script a set of tasks which are performed repeatedly, creating a "data pipeline".

While it is often most expedient to use software which is readily available, inevitably one finds that no tool exist which perfectly suit ones needs for a given task – we are, after all, in the business of doing original research! In this case, one is faced with the more complex programming task of creating one's own tools.

One would like to have a programming environment which makes all of these tasks both easy and efficient. Sadly, we know of no environment which works well in all cases. On the other hand, the situation is continuously improving. In this course we will, to the extent possible, help you to build an environment which is flexible, extensible, powerful, and portable which will serve as a tool for your own research.

In addition to teaching you some programming, we will give some examples of how to think like a computer scientist. Understanding algorithms, how they scale with problems size and the average and worst-case performance, becomes increasingly important as the size of your problem grows. For large problems, the choice of algorithm may mean the difference between spending hours or years waiting for the program to complete. In many cases, if you can abstract the essentials from what you are trying to accomplish, you will find that it is a classic problem in computer science and that there are well-established (if not necessarily optimal in the technical sense) approaches to solving the problem.

We will also take a brief look at modern computer hardware and architectures – what is going on "under the hood" of your computer.

The course will begin with some basic programming in Python and C++ and setting up a basic computing environment. We will then progress to doing some graphical exploration of data. After these preliminaries, the amount of time we spend on individual topics will largely be governed by the interests of the class.

Most of you will be taking this course concurrently with ASTR 513, Statistics and Computation. That course will concentrate more on mathematics and numerical techniques, while this course will provide a more practical introduction to programming and computers,

Expected Learning Outcomes: By the end of this course you should be able to implement and debug, in Python, moderately complex algorithms of the sort that frequently crop up in astrophysical research using a code development environment you have assembled from elements introduced in the course. You should also be able to implement simpler, more numerically intensive algorithms in the C++ language with routines that interoperate with Python drivers.

Prerequisites: This course is designed especially for those with little if any previous experience with programming or of the Unix (Linux) operating system.

We will assume that you have (substantially) completed a usual physics and/or astronomy undergraduate major. Your mathematical preparation should include vector calculus, complex analysis, ordinary differential equations, Fourier series, and at least some linear algebra and partial differential equations.

Computing Environment: All incoming astronomy graduate students are provided with a computer running the Linux operating system. Others taking the course may obtain an account on the departmental server. Using your own laptop will make things more convenient; we will provide assistance in setting up your own computing environment on whatever machine you use.

Texts: There is no official text for this course, but from time to time reading will be assigned. These will typically be papers available on-line at ADS, ArXiV, and other standard sites, or through the University Library. An important maxim to remember in this course is: *Google is your friend*. Help in Python and C++ programming and relevant documentation is widely available on-line.

Assignments: Problem sets will be assigned weekly at first. Later in the semester some will take two weeks to complete. You are encouraged to work together in figuring out how to do the problem sets; especially while debugging code, a second pair of eyes is extremely helpful in spotting errors. The actual coding and running of the assigned solution must, however, be done and be understood by each of you *individually*. Beware of not being able to explain why you did the assignment the way you did!

Warning!

Writing and debugging computer code takes time, even when you know what to do – more time than most problem sets you are used to. Do not start the problem sets the day before they are due. Start them as soon as they are assigned. You have been warned!

Grading: The goal of each problem set is to submit a working piece of code which solves the assigned problem. By "working", we mean a piece of code and the relevant input data which demonstrate that the code functions as assigned. Usually, any code which works will be satisfactory; occasionally, we will specify the method of solution you must employ.

Your final score in this course will be the average of your scores on the problem sets, with the worst score among those assignments turned in on time omitted from the average. Missing or late problem sets *will be counted as zero* in the average; *i.e.*, a missing assignment will not be counted as a "worst score" to be left out.

There will be no exams, and specifically no final exam, in this course.

Final letter grades will be determined from final scores as follows: "A" for 85% or better; "B" for 70% to 85%; "C" for 65% through 70%; "D" for 50% through 65%; "F" below 50%.

Late and missing assignments: Late assignments will not be graded, except when *prior* arrangement has been made with one of the instructors. If you have a legitimate reason such as a family emergency or travel to attend a conference or to observe, we will be very accommodating. We will often grant extra time for a project which is *substantially* complete but which needs some extra work; we will not grant extra time for projects which have barely been started.

Office Hours: Some fraction of class time will typically be allocated to working on the assignments. During this time, your instructors will peer over your shoulders and provide help. When we see that several of you are having a similar problem, we will stop and discuss possible solutions with the whole class.

There will be no formal office hours. We are both at the office much of the day and very often until late at night. Please do not hesitate to stop by for help. If the door to one of our offices is closed, do not hesitate to knock! If we are not there, keep trying; we're probably in a meeting and will be back within an hour.

We will have to travel at from time to time during the semester and will keep the class abreast of our travel schedule. We expect that at least one of your instructors will be present at all times during the semester.

Finally, we cannot guarantee that we will *promptly* read your email. If you need to contact us in a hurry, come find us, or call us to arrange to meet.

Nota Bene! In this class, a few words of guidance from the instructors will often save many hours of struggle. We expect that you will need a few hints from time to time and are happy to provide them. Do not underestimate the value of stopping by for help, early and often!

We also note that you are in a large department, full of expertise! Make use of your fellow graduate students, postdocs, faculty, programmers, and engineers. Science is a collegial endeavor – the large majority of people at Steward are more than willing to share their knowledge and experience. Don't be afraid to knock on doors for help!

Attendance: You are not *required* to come to class – but neither are your instructors required to explain to you what you missed by not coming to class. You are responsible for knowing everything that goes on in class, including all course material, handouts, what has been assigned as problem sets and any modifications thereto, as well as any hints, help, due dates, extensions, *etc.*. In particular, due dates are often changed, and these changes will only be announced in class.

If you know that you will be absent from class on a given day (for a legitimate reason, of course), please let us know in advance. We may be able to give you the appropriate class notes and/or any assignments. If you have cleared your absence with us in advance, make sure that you contact us promptly upon return to find out what you may have missed.

All holidays or special events observed by organized religions will be honored for those students who show affiliation with that particular religion.

Incompletes: A grade of "Incomplete" will only be given in this course if a student has satisfactorily completed the majority of the work in the class and has a valid reason, *e.g.* a medical problem, for not completing the remainder of the course. Students must make arrangements with us *in advance* in order to receive an incomplete.

Dropping the Class: Please note that the last day to drop this class from your schedule without a grade is TBD.

Academic Integrity: Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed (see above). Students are responsible for understanding and following the UA Code of Academic Integrity (http://deanofstudents.arizona.edu/codeofacademicintegrity). Students engaging in academic dishonesty diminish their education and bring discredit to the academic community and the campus. Students should avoid situations likely to compromise academic integrity.

Special Accommodation: If you anticipate barriers related to the format or requirements of this course, please meet with one of us so that we may discuss ways to ensure your full participation. If you determine that disability-related accommodations are necessary, please register with Disability Resources (621-3268; drc.arizona.edu) and notify us of your eligibility for reasonable accommodations. We can then plan how best to coördinate these.

Decorum: Students are expected to maintain a high level of decorum in the classroom. In particular, the use of cell phones, computers, or other devices to communicate (by voice or by text) during class is bad manners and should be eschewed. We will follow all University policies on disruptive behavior in an instructional setting: see http://policy.arizona.edu/education-and-student-affairs/disruptive-behavior-instructional-setting

Disclamer: Information contained in this course syllabus is subject to change with advance notice, as deemed appropriate by the instructor. NB: notice of such changes may only be given in class.