Research and Technical Resources

Princeton Astrophysics

This guide is meant to provide an overview of essential tools used in astronomy and astrophysics research. They are primarily aimed at the undergraduates beginning to learn the ins and outs of research.

1 General Information about the Department

Here are some general things to be aware of as students in Peyton Hall.

- The undergraduate portion of the website: www.princeton.edu/astro/undergraduate. This is the best place to look for requirements.
- Peyton Hall documentation wiki: www.astro.princeton.edu/docs/Main_Page. Lots of information on technical matters, ranging from ssh-ing into workstations to setting up printers on your computer.
- See www.astro.princeton.edu/docs/Requesting_assistance for the email to contact for any IT assistance you need.
- Spring colloquium series: During the Spring semester, we host a speaker every Tuesday afternoon (at 4:30), followed by a reception. Speakers are invited at least partially based on their ability to give good talks. The schedule can be found at www.princeton.edu/astro/news-events/public-events.
- Wunch (Wednesday Lunch): www.astro.princeton.edu/~wunch. Slightly less formal talks are given throughout the academic year, Wednesdays, 12:30. The speakers are often postdocs or grad students. Feel free to bring (or order—see the website) lunch.
- Institute for Advanced Study colloquium: www.sns.ias.edu/~seminar/colloquia.shtml. Though not often frequented by undergrads, you are welcome to attend the Tuesday morning (11:00) talks they host. These are often given by well-known and established astrophysicists, so if one comes up on a topic you are interested in, you should check it out.
- Morning coffee: From about 10:30 to 11:00 just about every weekday morning, most of the faculty and researchers have an informal gathering in Grand Central to go over the latest papers on the arXiv (see below). It is a great chance to hear about current research in all parts of astro, as well as to hear about what people in this department are researching. There is of course coffee, and on Fridays there are even donuts or bagels served.
- Afternoon tea and cookies: This is less productive than Coffee, but still worth knowing about. Every weekday afternoon (roughly at 3:30), the grad students host tea and cookies in the lounge in the basement. Everyone is invited, and the setting is quite informal.

2 Web Resources

There are several online resources used every day by most researchers in astro, as well as others resources that are critical to certain subfields. The following is a list of the most important sites you should know are out there.

- arXiv (arxiv.org): This is a preprint server where physicists, mathematicians, computer scientists, and others post papers they are writing, often done concurrently with submitting the papers to journals.

  - Every paper on the arXiv is open-access (or at least that version is).
  - The site is updated every weeknight with new submissions, meaning it is *the* place to go to find the most cutting-edge research.
  - Astrophysics papers can be found in "astro-ph" (arxiv.org/list/astro-ph/new).
  - You can subscribe to receive an email notifying you of the day's submissions in your field(s) of interest; see arxiv.org/help/subscribe.

- Astrophysics Data System (ADS, www.adsabs.harvard.edu): This service collects abstracts for every paper in astronomy, astrophysics, and related fields it can find, allowing you to search via title, abstract contents, author, or keywords.
  - It is customary for astronomers to link to ADS abstract pages (which in turn link to versions of the article on publisher's websites or on the arXiv) when referring others to papers.
  - ADS conveniently provides citation information in BibTeX format (though you should double check that it doesn't have errors or poor formatting).
  - From the abstract page there will be links to lists of papers that cite the one in question and to papers that were cited by it.
  - If you make an account, you can keep track of references in private libraries (which you can also share with others).

- AstroBetter (www.astrobetter.com): A blog where professional astronomers share tips and tricks for being successful in the astronomy world.

- astrobites (astrobites.org): A website run by grad students *for* undergrads, where they summarize interesting astro-ph articles and provide general tips.

3 LaTeX

LaTeX is *the* typesetting language of academia. These days most journals in the sciences, and indeed all journals and preprint servers in astronomy and astrophysics, expect submissions to be written in LaTeX. As a result, it is absolutely essential that one is familiar with the language.

3.1 What is LaTeX exactly?

It is really just a computer language, based on the more primitive TeX (there are other TeX derivatives that function in largely the same way). The fundamental idea is that one should think about *content* separately from *formatting*. You write your document in plain text (using a good text editor, of course—see below), including appropriate markup commands (emphasize this word, put the following in "math mode," place a figure somewhere around this location, reference the automatically generated figure number at this point in the text, etc.). Then the "code" is compiled, and the output is a PDF that contains everything you wrote beautifully formatted.

3.2 Formatting math

One of the biggest draws of LaTeX is its ability to seamlessly combine normal text with mathematical expressions. Text enclosed between $-signs formats as math should, with proper italicizing and spacing. There are also more complicated environments for making equations offset from the text.

3.3 Figures and tables

Another key feature of LaTeX is that figures and tables are placed automatically where they best fit. If you change your document, you do not have to go back and rearrange all the material to make sure it looks nice.

3.4 Managing references

LaTeX can format references very nicely, but to really put it to good use one should also use its companion, BibTeX (www.bibtex.org). The idea is that in a separate file, you create entries for each of your sources, giving them a key and listing all the relevant information (title, authors, journal, etc.). In your LaTeX document, you can simply refer to the key with a citation command, and it will automatically typeset the citation as it is supposed to appear according to the style of the document. The references at the end of the paper are also sorted and formatted automatically.

3.5 Making presentations

One of the classes of documents in LaTeX is Beamer. This is designed to make slide presentations, where again you just worry about entering the content and let the formatting be done automatically. This can be very useful for making professional presentations that require equations and formulas. Beamer can also be used for making scientific posters.

3.6 Installation and usage

The LaTeX Project website can direct you to the installations most appropriate for your system (latex-project.org/ftp.html). For help making a document, there are a large number of guides available, compiled at latex-project.org/guides. A lengthy but thorough introduction is The Not So Short Introduction to LaTeX (http://tobi.oetiker.ch/lshort/lshort.pdf). There is also a commonly used wiki (en.wikibooks.org/wiki/LaTeX) and an online tool that will tell you the name of the command to generate whatever symbol you draw (detexify.kirelabs.org/classify.html).

4 Python and Matplotlib

One of the most common and versatile languages today is Python. It is an object-oriented scripting language good for tasks that are too unwieldy for shell scripts and at the same time do not require a heavy-duty compiled language. Perhaps Python's best feature is the large number of packages written for it, as these can easily be imported into any script. Some important components are:

- Python itself (www.python.org);
- iPython (ipython.org), an optional interactive environment some prefer to use that allows one to, e.g., update a plot in real time by entering successive commands;
- NumPy (www.numpy.org), a critical package providing a broad range of mathematical functionality that is often included with standard Python installations;
- SciPy (www.scipy.org/scipylib/index.html), a collection of useful functions not quite as critical as NumPy (note this name also applies to a bundled package including most items on this list);
- Matplotlib (matplotlib.org), *the* package for creating figures;
- Astropy (www.astropy.org), a package meant to provide some useful tools to astronomers, such as reading in FITS files or manipulating celestial coordinates.

Matplotlib in particular is very useful for creating publication-quality figures from data. One can make multiple similar figures that vary in slight ways (easily), alter basic ways plots are displayed (easily), alter anything whatsoever about the plot to get it to look just the way you want (sometimes not so easy), and add labels that include mathematical symbols formatted correctly with LaTeX (quite easy).

Some useful related resources include:

- A gallery of Matplotlib plots, complete with source code, at matplotlib.org/gallery.html;
- A collection of online workshops designed for astronomers learning to use Python, at python4astronomers.github.io.

5 Text Editors

Whether making simulations, reducing data, making graphics, or just compiling your results into a paper, you will find yourself writing and altering plenty of "source code," broadly construed. The more of this you do, the more critical it becomes to have a great text editor to work with. Great text editors are more than just things like Notepad or gedit; they have a multitude of features designed to make your life easier, including, at a minimum:

- Automatic syntax highlighting and indentation based on language,
- Ways to quickly navigate the text,
- Plenty of keyboard shortcuts so you can keep both hands on the keyboard and be *fast*.

That last item is one of the reasons advanced text editors can seem pretty intimidating. Nonetheless, getting over the learning curve is something best done early; your coding life will be much easier thereafter.

The two most common editors in use are:

- Emacs (www.gnu.org/software/emacs):
  - Has a *very* broad range of features and add-ons (everything from email clients to games);
  - Makes use of auxiliary characters (`alt`, `control`, etc.);
  - Works on all platforms, but Mac users may be more comfortable with Aquamacs (aquamacs.org);
- Vim (www.vim.org):
  - Has all the core features you might want for coding, but not much beyond that;
  - Avoids multi-key combinations by having multiple modes (issue commands, write text, etc.) that one can toggle;
  - Works on all platforms, but Mac users should check out MacVim (code.google.com/p/macvim) and Windows users can use gVim (www.vim.org/download.php#pc), both of which have some GUI features.

Indeed, there have been many debates between the two camps over which editor is better, as you can see on Wikipedia (en.wikipedia.org/wiki/Editor_war). There are other editors out there as well, far too many to list. Choose whichever one works best for you.

6 Package Management Systems

Sometimes one piece of software will require several others, each of which has their own prerequisites, etc. As a result, installing one thing can be quite arduous if you are unlucky. There are many package managers out there, designed to download and compile all prerequisites with a single command. For example, on Mac on can use MacPorts (www.macports.org) or Homebrew (brew.sh).

7 Books

One of the most universal reference books you should be aware of is *Numerical Recipes* (www.nr.com). It gives an introduction on myriad techniques you are likely to come across, ranging from statistical methods to integration routines to linear algebra. It also provides basic source code to see exactly how an algorithm is implemented, as well as plenty of references if you want more detail. A copy can be found on the bookshelf in Grand Central.