Astronomy 8824: Numerical and Statistical Methods in Astrophysics
Autumn 2013

Course Objectives

The goal of this course is to provide basic background in numerical and statistical methods relevant to astrophysical research. It is a new addition to the graduate curriculum; previously we covered this material informally or assumed that students would learn it by osmosis. By the end of the course, you should have a good gut-level sense for many of the statistical issues that will arise in your own research or when reading papers, listening to seminar talks, or following coffee discussions. You should also have an entry point for solving some of the most common types of numerical problems that arise in astronomical research.

I have decided to use Python as the common language for the course, in part because it is easier to get started in Python than in Fortran, C, or C++, but mostly because it has become a valuable language to have in your toolbox, as there are many useful, publicly available, scientific codes in Python. However, I should caution that I am new to Python myself, and this is *not* a course in Python programming techniques.

Books

There are two primary references for this course. The first is *Numerical Recipes*, by Press, Teukolsky, Vetterling, and Flannery. The book is available in several editions in different programming languages. You can choose whichever edition seems like it will be most useful to you; we will be interested primarily in the explanations that it provides of different numerical methods rather than the routines themselves. While one can often find better implementations of the methods elsewhere, this book is an indispensable resource for an astronomer.

The other primary reference is Statistics, Data Mining, and Machine Learning in Astronomy, by Ivezic, Connolly, VanderPlas, and Gray. Unfortunately, this book will not be published until January 2014. However, Zeljko Ivezic has kindly shared a copy with me, and I will distribute paper copies of the chapters that are most relevant to this course. This book is also a helpful practical introduction to Python.

Topics and Schedule

This is a 1.5-credit-hour course rather than a 3-credit-hour course. This time through, at least, we are going to implement that by meeting for 3 hours every other week. While there may be adjustments based on my travel or other interferences, I currently anticipate that we will have our class meetings on: 8/27, 8/29, 9/5, 9/12, 9/24, 9/26, 10/8, 10/10, 10/22, 10/24, 11/5, 11/7, 11/19, and 11/21. Note that 9/5 is out of the regular pattern because I will be away on 9/10.

The numerical and statistical topics will be intermingled throughout the course. Since this is the first time through the course, I don't know just how much I will have time to cover, but the topics I am hoping to discuss are:

- Basic principles of probability and statistics
- Parameter estimation and hypothesis testing
- χ^2 and other statistical tests
- Markov Chain Monte Carlo estimation of parameter distributions
- Fisher matrix forecasting
- Numerical integration
- Numerical solution of differential equations
- Minimization, zero-finding, equation solving
- Fourier transforms and their uses
- Matrices, eigenvalues, diagonalization, principal component analysis

We will take a mostly Bayesian outlook on statistical questions, though with some discussion of other viewpoints.

Assignments and Grading

Reading assignments will be given in class.

There will be seven problem sets, primarily numerical. I will generally hand out problem sets on Tuesdays, and they will be due at the start of the class session 2 weeks later. The problem sets should take 5-10 hours to complete.

There are no exams. The course grade will be based on the problem sets and class participation.

I will post notes and useful links on the course web page, `http://www.astronomy.ohio-state.edu/~dhw/A8824`.