ASTRON 3705

Astronomical Techniques

Course Information

Meeting Time: Monday and Wednesday, 1:15 PM – 2:30 PM, Online
Credits: 3
Prerequisites: None

Instructor Information

Lecturer: Prof. Jeffrey Newman
Office: 310 Allen Hall (though you won't find me there…)
Office Hours: TBD
Email: janewman@pitt.edu
Phone: (412) 592-3853

Textbook

Practical Statistics for Astronomers, by Wall & Jenkins, **Second Edition**

The textbook is available online through the University Library System at
https://pitt.primo.exlibrisgroup.com/permalink/01PITT_INST/g3767l/alma9979140963406236

From the PittCat record, you can click on either Ebook Central link in the white box, under "View Online"; or you can use the Cambridge University Press link at the bottom of the page (which will allow you to download the entire book as a zipfile of PDFs).

Course Description

Modern astrophysics relies heavily on advanced techniques for data analysis and the ability to deal with large datasets from survey projects. The principal aim of the course will be to provide practical experience with statistical techniques, obtained by applying them to state-of-the art astronomical datasets.   It will cover topics such as data analysis techniques, interfacing with data files, statistics and machine learning methods, and experiment design. Some prior knowledge of astronomy will be helpful but will not be necessary for the class. However, students should have

some prior experience with computer programming (language does not matter). This course is designed to be useful for students with both theoretical and observational interests.

Course Objectives

The principal goal of this course is for students to gain the skills needed to perform research in astrophysics (or physics) making use of measurements from data (in any fashion). Today, even theorists in astrophysics make frequent use of statistical "survey" datasets; this course should be helpful for anyone pursuing research. The emphasis will be on developing practical skills in applied statistics, data processing/interfacing, and programming, primarily through hands-on experience with all of these.

By the end of this course, you should be able to:
- Apply a variety of statistical tests to measurements, and identify the correct test for the problem being faced
- Apply Monte Carlo and resampling techniques to predict distributions of errors, estimate significances, etc.
- Perform linear and nonlinear curve fitting
- Apply maximum likelihood techniques and robust statistics to make measurements
- Describe the basic functionality of astronomical imaging and spectroscopic instruments
- Perform basic reductions of imaging data from the Hubble Space Telescope
- Read in databases from a survey dataset, select objects of interest, and apply statistical methods to those data
- Apply a few machine learning techniques for classification and regression (continuous variable prediction)
- Perform data analysis, I/O, and plotting in the Python programming language

If time allows, we will also cover basics of Fisher matrix, Markov Chain Monte Carlo, and/or broader sets of machine learning techniques. Overall, roughly 20% of the content of the class is specific to astrophysics, while the rest should be useful to any student who will need to apply or understand statistical results in their research. The capstone of the course is for students to undertake original research projects applying statistical or machine learning methods to a problem (which may be related to but should not be identical to their current research effort).
In general, I will try to adjust course content to reflect student interests.

Grading

Grading will be based on:

30%	Homework
20%	In-class activities
40%	Final project
10%	Astro Coffee Participation

Homework:
Every week or two there will be 1-2 small homework problems/tasks.

Students are allowed (and encouraged) to collaborate on homework assignments in developing basic algorithms, but must present their own work (programs/plots, results, etc.).

Please provide either code or notes describing how you did a calculation, to help me understand the cause of any errors. I do not expect a detailed writeup of Python-based problems (e.g., it is not necessary to spend time on nicely formatted equations) unless I specify otherwise. If I say I want a plot, I want a plot; if I want a particular number, I care more about the process of getting that number in Python than a detailed derivation of the methods. Source code or notes allows me to assess that process and help me to provide more useful feedback.

Conceptual problems are a different case, and I do expect you to explain your reasoning there.

I will accept at most 2 late homeworks from any letter-grade-option student, except in extreme (e.g. medical) circumstances or via prior arrangement more than two days before the deadline. The first late homework will have no penalty, the second one will have a grade penalized by 10%. Late homeworks must be turned in within 24 hours of the nominal due date unless otherwise arranged in advance.

In-class activities:
We will periodically split into breakout rooms for students to work together in groups to solve problems. Class time will be a mix of lecturing with activities (e.g. solution of some problem or reduction of data). This will often yield some work product which will contribute to your in-class activities grade (as completion/noncompletion, not graded in detail). If you do need more time, submission after class will be acceptable. You should send me all of your Jupyter notebooks at the end of the semester for this part of your grade.

Astro Coffee: I expect astro graduate students to regularly attend astro coffee (the journal club held twice a week). This does not mean that you have to be present

every single meeting, but you should be there frequently. I expect that over the course of the semester each student will present at least two papers. I will set up a google form that you can fill out quickly each time you present so that I have a record. Grading will be based on completion: zero papers = F, 1 paper = C, 2 papers = A .

Alternatively, students can produce an astrobites.org - style, 2-3 page summary of a paper in your field that applies some statistical or machine learning method, written for nonexperts.

Final Project:
The capstone of the course will be an original project – development of a new data reduction algorithm, a new analysis of a dataset, etc. One option is to develop an original astronomical observing proposal, in the format required for actual submission; such a proposal must be entirely the student's own work. I will provide a list of some project ideas early in the semester, which students may sign up for, or am happy to discuss your own project ideas (e.g., ways to incorporate new statistical methods into your current research). Projects should **not** simply consist of the research you are already doing, however. Many projects should be suitable for working in groups of 2 or 3.

At the end of the semester, students will give a 10-20 minute presentation of their project to the class. They will also provide a brief writeup (this should be provided in a manuscript format with a minimum font size of 12 points; the length should ideally be 2-3 pages, with 5 pages for the text plus figures maximum) to allow both oral and writing skills to be evaluated; presentation of results is a key skill for all scientists.

Calendar

We will not meet on Wednesday, March 24 as it is a self-care day.

Academic Integrity

Students in this course will be expected to comply with the University of Pittsburgh's Policy on Academic Integrity. Any student suspected of violating this obligation for any reason during the semester will be required to participate in the procedural process, initiated at the instructor level, as outlined in the University Guidelines on Academic Integrity. This may include, but is not limited to, the confiscation of the examination of any individual suspected of violating University Policy. Furthermore, no student may bring any unauthorized materials to an exam,

including dictionaries and programmable calculators. **Use of graphing calculators, cell phones, web pages outside of Canvas, textbooks, search engines, tutoring services, or any other supplementary devices or materials, electronic or otherwise, is NOT permitted during exams and will be treated as academic dishonesty.** A minimum sanction of a zero score for the quiz or exam will be imposed for violations of the Academic Integrity policy.

To learn more about Academic Integrity, visit the Academic Integrity Guide for an overview of the topic. For hands-on practice, complete the Understanding and Avoiding Plagiarism tutorial.

Disability Services

If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact both your instructor and Disability Resources and Services (DRS), 140 William Pitt Union, (412) 648-7890, drsrecep@pitt.edu, (412) 228-5347 for P3 ASL users, as early as possible in the term. DRS will verify your disability and determine reasonable accommodations for this course.

Diversity and Inclusion

The University of Pittsburgh does not tolerate any form of discrimination, harassment, or retaliation based on disability, race, color, religion, national origin, ancestry, genetic information, marital status, familial status, sex, age, sexual orientation, veteran status or gender identity or other factors as stated in the University's Title IX policy. The University is committed to taking prompt action to end a hostile environment that interferes with the University's mission. For more information about policies, procedures, and practices, see: https://www.diversity.pitt.edu/civil- rights-title-ix-compliance/policies-procedures-and-practices .

I ask that everyone in the class strive to help ensure that other members of this class can learn in a supportive and respectful environment. If there are instances of the aforementioned issues, please contact the Title IX Coordinator, by calling 412-648-7860, or e-mailing titleixcoordinator@pitt.edu. Reports can also be filed online: https://www.diversity.pitt.edu/make-report/report-form. You may also choose to report this to a faculty/staff member; keep in mind that as mandatory reporters they are required to communicate this to the University's Office of

Diversity and Inclusion. If you wish to maintain complete confidentiality, you may also contact the University Counseling Center (412-648-7930).

Take Care of Yourself

Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep, and taking time to relax. Despite what you might hear, using your time to take care of yourself will actually help you achieve your academic goals more than spending too much time studying. All of us benefit from support and guidance during times of struggle. There are many helpful resources available at Pitt. An important part of the college experience is learning how to ask for help. Take the time to learn about all that's available and take advantage of it. Ask for support sooner rather than later – this always helps. If you or anyone you know experiences any academic stress, difficult life events, or difficult feelings like anxiety or depression, we strongly encourage you to seek support. Consider reaching out to a friend, faculty or family member you trust for assistance connecting to the support that can help.

The University Counseling Center is here for you: call 412-648-7930 and visit their website.

If you or someone you know is feeling suicidal, call someone immediately, day or night: University Counseling Center (UCC): 412 648-7930
University Counseling Center Mental Health Crisis Response: 412-648-7930 x1
Resolve Crisis Network: 888-796-8226 (888-7-YOU-CAN)

If the situation is life threatening, call the Police: On-campus: Pitt Police: 412-268-2121 Off-campus: 911

Copyright Notice

Note: The schedule and procedures in this course are subject to change. Any changes will be posted on the ASTRON 3705 Canvas site and announced in class in the case of major changes.