Term Information

Effective Term	Autumn 2023

General Information

Course Bulletin Listing/Subject Area	Astronomy
Fiscal Unit/Academic Org	Astronomy - D0614
College/Academic Group	Arts and Sciences
Level/Career	Graduate, Undergraduate
Course Number/Catalog	5550
Course Title	Advanced Astronomical Data Analysis
Transcript Abbreviation	Adv Astro Data
Course Description	Overview of advanced astronomy data analysis methods with applications to the large datasets produced by modern surveys. Students will learn to apply these methods to reproduce several major astronomical results in collaborative research projects. The goal of the course is to better prepare students for graduate-level research in astronomy and other careers that use these methods.
Semester Credit Hours/Units	Fixed: 3

Offering Information

Length Of Course	14 Week
Flexibly Scheduled Course	Never
Does any section of this course have a distance education component?	No
Grading Basis	Letter Grade
Repeatable	No
Course Components	Lecture
Grade Roster Component	Lecture
Credit Available by Exam	No
Admission Condition Course	No
Off Campus	Never
Campus of Offering	Columbus

Prerequisites and Exclusions

Prerequisites/Corequisites	Astro 3350 or Physics 3700 or permission of the instructor
Exclusions	
Electronically Enforced	No

Cross-Listings

Cross-Listings

Subject/CIP Code

Subject/CIP Code	40.0201
Subsidy Level	Doctoral Course
Intended Rank	Junior, Senior, Masters, Doctoral

Requirement/Elective Designation

The course is an elective (for this or other units) or is a service course for other units

Course Details

Course goals or learning objectives/outcomes

- Be familiar with the basics of frequentist and Bayesian statistics and how to access, process, evaluate errors, and visualize large astronomical datasets
- Understand common data analysis and machine learning methods used in astronomy, including characterizing structure in discrete data, dimensionality reduction, regression, classification, and model fitting
- Work effectively in groups to complete projects

Content Topic List

- Access, visualization, and interpretation of astronomical survey data
- Concepts of probability, random variables, descriptive statistics, and probability distributions
- Frequentist and Bayesian inference, maximum likelihood estimation, Bayesian priors and parameter estimation, Markov chain Monte Carlo
- Structure in discrete data, dimensionality reduction, regression, classification, and model fitting

Sought Concurrence

No

Attachments

- AstronomyCurriculumMap.pdf: Curriculum Map

  (Other Supporting Documentation. Owner: Martini,Louis Paul)
- Astro5550-Syllabus.pdf

  (Syllabus. Owner: Martini,Louis Paul)

Comments

- I have updated the syllabus to include all of the items mentioned in the feedback email sent on 02-23-2023. I have also uploaded a Curriculum Map in the format recommended by OAA. *(by Martini,Louis Paul on 03/30/2023 05:41 PM)*
- Please see feedback email sent to department 02-23-2023 RLS *(by Steele,Rachel Lea on 02/23/2023 02:51 PM)*
- If this course can count in your major (even as an elective), please upload updated curriculum map. *(by Vankeerbergen,Bernadette Chantal on 01/18/2023 05:54 PM)*

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Martini,Louis Paul	01/13/2023 09:08 AM	Submitted for Approval
Approved	Weinberg,David Hal	01/17/2023 08:58 PM	Unit Approval
Revision Requested	Vankeerbergen,Bernadette Chantal	01/18/2023 05:54 PM	College Approval
Submitted	Martini,Louis Paul	01/19/2023 08:41 PM	Submitted for Approval
Approved	Weinberg,David Hal	01/20/2023 08:25 AM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	02/01/2023 09:28 AM	College Approval
Revision Requested	Steele,Rachel Lea	02/23/2023 02:51 PM	ASCCAO Approval
Submitted	Martini,Louis Paul	03/30/2023 05:41 PM	Submitted for Approval
Approved	Weinberg,David Hal	03/30/2023 06:33 PM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	04/05/2023 12:57 PM	College Approval
Pending Approval	Jenkins,Mary Ellen Bigler Hanlin,Deborah Kay Hilty,Michael Vankeerbergen,Bernadette Chantal Steele,Rachel Lea	04/05/2023 12:57 PM	ASCCAO Approval

Astronomy 5550 –Advanced Astronomy Data Analysis

Syllabus Template

Instructor:

Name: Paul Martini (he/him)
Office: 4021 McPherson Lab (4th floor), mailbox in 4055 McPherson Lab
Phone: 614-292-1773
Office Hours: by appointment
Email: martini.10@osu.edu
Preferred mode of communication: email

Course Information

Course Times: Tuesdays and Thursdays from 12:45-2:05pm
Credit Hours: 3
Format of instruction: In-person lectures
Web Page: Available through http://carmen.osu.edu

Course Description

Astronomy 5550 is an overview of advanced astronomy data analysis methods, with applications to the large datasets produced by modern astronomy surveys. The course will cover methods in common use by researchers and students will learn to apply these methods to reproduce several major astronomical results in collaborative research projects. The goal of the course is to better prepare students for graduate-level research in astronomy and to introduce many of the tools of data analysis for students interested in other careers that use these methods.

Prerequisites

Previous coursework or experience with the python programming language, statistical analysis, and linear algebra. Prerequisite courses are Astro 3350 or Physics 3700, Math 2568, or permission of the instructor. Astro 3350 and Physics 3700 provide sufficient programming background.

Expected Learning Outcomes

By the end of this course, students should:

- Be familiar with the basics of frequentist and Bayesian statistics and how to access, process, evaluate errors, and visualize large astronomical datasets
- Understand common data analysis and machine learning methods used in astronomy, including characterizing structure in discrete data, dimensionality reduction, regression, classification, and model fitting
- Work effectively in groups to complete projects

Required Textbook

The textbook is "Statistics, Data Mining, & Machine Learning in Astronomy" by Ivezic et al. (2nd edition, Princeton University Press). The course will also use online material available at astroml.org and numerous, online tutorials for data analysis methods.

Required Computing Equipment

A laptop, PC, or similar that provides internet access with a web browser. Writing and programming will be done in the browser, so I recommend a device with a sufficiently large screen and a keyboard. The operating system is not important since the coursework will be completed with Jupyter notebooks (or similar) in a browser-based environment.

Grading Information

The course will have weekly, short homework assignments designed to reinforce material covered in class. Each of these assignments will have equal weight and the total will correspond to 40% of the course grade.

There will be three group assignments in which teams of students will work together to apply the methods of the course to modern research questions in astronomy. Students will be assigned to teams at the beginning of the semester and continue with the same teams for all three projects. Group work will mostly occur outside of class, except for orientations to the projects during class time. These three group assignments will correspond to a total of 60% of the course grade. Grades on these group assignments will be based on the evaluation of the team's draft written report (20%), evaluations of individual contributions (20%), in-class presentations (20%) and the final written report (30%).

There will not be a final exam.

Grading Scale

93–100: A
90–92.9: A-
87–89.9: B+
83–86.9: B
80–82.9: B-
77–79.9: C+
73–76.9: C
70–72.9: C-
67–69.9: D+
60–66.9: D
Below 60: E

Weekly Topical Course Outline

The course will begin with an overview of common statistical methods used in data analysis, as well as data access and visualization, and then introduce different data analysis methods in an astronomy context. The schedule below is an approximate outline of the topics and when they are likely to be covered, along with readings from the textbook.

Week 1:
- Overview of course materials and schedule, including the computing environment, astroML.org, astropy.org, and astronomical survey data [text chapter 1]
- Concepts of probability, random variables, descriptive statistics, and probability distributions [text sections 3.1, 3.2, 3.5]

Week 2:
- Frequentist and Bayesian inference, maximum likelihood estimation [4.1, 4.2]
- Goodness of fit, correlated errors [4.3]
- Application: Measurement of constant quantities (e.g., stellar flux)
- Assignments to groups and orientation for first group project

Week 3:
- Bayesian priors [5.1, 5.2]
- Bayesian parameter estimation [5.6]

Week 4:
- Covariance matrices
- Markov chain Monte Carlo [5.8]
- Application: Measure the Hubble constant

Week 5:
- Nonparametric and nearest-neighbor density estimation [6.1, 6.2]
- Parametric density estimation [6.3]

Week 6:
- Cluster finding [6.4]
- Correlation function [6.5]
- Application: Large scale structure of galaxies
- Final report and individual evaluations due for first group assignment

Week 7:
- Curse of dimensionality, principal component analysis [7.1, 7.3]
- Non-negative matrix factorization [7.4]
- Application: Quasar spectra

Week 8:
- Linear models [8.2]
- Regularization and Penalizing the Likelihood, incl. Ridge and Lasso regression [8.3]
- Application: Distance modulus vs. redshift

Week 9:
- Nonlinear regression [8.7]
- Uncertainties in data [8.8]

Week 10:
- Gaussian processes and Gaussian process regression [8.10]
- Fitting and validation [8.11]
- Final report and individual evaluations due for second group assignment

Week 11:
- Introduction to classification [9.1, 9.2]
- Generative classification [9.3]
- Application: RR Lyrae stars

Week 12:

- K-Nearest-Neighbors, logistic regression [9.4, 9.5]
- Support Vector Machines [9.6]

Week 13:

- Decision Trees [9.7]
- Random Forests [9.7]
- Application: Photometric Redshifts

Week 14:

- Introduction to Time Series data [10.1]
- Fourier analysis, discrete Fourier transform [10.2]
- Application: Periodicity of variable stars
- Final report and individual evaluations due for third group assignment

Religious Accommodations

Our inclusive environment allows for religious expression. Students requesting accommodations based on faith, religious or a spiritual belief system in regard to examinations, other academic requirements or absences, are required to provide the instructor with written notice of specific dates for which the student requests alternative accommodations at the earliest possible date. For more information about religious accommodations at Ohio State, visit odi.osu.edu/religious-accommodations.

Weather Or Other Short-Term Closing

Should in-person classes be canceled, we will meet virtually via CarmenZoom during our regularly scheduled time. I will share any updates via CarmenCanvas.

Academic Misconduct

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct http://studentlife.osu.edu/csc/.

Students with Disabilities

The University strives to make all learning experiences as accessible as possible. In light of the current pandemic, students seeking to request COVID-related accommodations may do so through the university's request process, managed by Student Life Disability Services. If you anticipate or experience academic barriers based on your disability (including mental health, chronic or temporary medical conditions), please let me know immediately so that we can

privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion. SLDS contact information: slds@osu.edu; 614-292-3307; slds.osu.edu; 098 Baker Hall, 113 W. 12th Avenue.

Mental Health

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know are suffering from any of the aforementioned conditions, you can learn more about the broad range of confidential mental health services available on campus via the Office of Student Life's Counseling and Consultation Service (CCS) by visiting ccs.osu.edu or calling 614-292-5766. CCS is located on the 4th Floor of the Younkin Success Center and 10th Floor of Lincoln Tower. You can reach an on call counselor when CCS is closed at 614-292-5766 and 24 hour emergency help is also available 24/7 by dialing 988 to reach the Suicide and Crisis Lifeline.

Title IX

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at http://titleix.osu.edu or by contacting the Ohio State Title IX Coordinator at titleix@osu.edu

Diversity

The Ohio State University affirms the importance and value of diversity in the student body. Our programs and curricula reflect our multicultural society and global economy and seek to provide opportunities for students to learn more about persons who are different from them. We are committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters sensitivity, understanding, and mutual respect among each member of our community; and encourages each individual to strive to reach his or her own potential. Discrimination against any individual based upon protected status, which is defined as age, color, disability, gender identity or expression, national origin, race, religion, sex, sexual orientation, or veteran status, is prohibited.

			Astronomy & Astrophysics Major Learning Goals					
		Credits	Acquire a basic mastery of fundamental physics and astrophysics, including motion and structure through classical mechanics, electromagnetism, and modern physics	Develop analytical and problem solving skills involving physics and mathematics	Acquire a basic mastery of experimental methods	Acquire a basic mastery of data analysis	Learn to effectively communicate professionally and colloquially (orally and in writing)	Learn about and participate in research and outreach activities consistent with their interest, ability, and postgraduate plans
Required Courses (offered by the unit)	Astron 2895: Seminar	1					Light	Light
	Astron 2291: Intro Astrophys I	3	High	High				
	Astron 2292: Intro Astrophys II	3	High	High				
	Astron 3350: Methods of Observation	3	Light	High	High	High	High	Intermediate
Required 5000-level course (pick one)	Astron 5205: Planetary Science	3	High	High	Intermediate			
	Astron 5681: Stellar Evolution	3	High	High	Light			
	Astron 5682: Cosmology	3	High	High	Light			
Required Courses (offered outside the unit)	Math 2415: ODEs and PDEs	3		High				
	Math 2568: Linear Algebra	3		High				
	Physics 2300: Mechanics I	4	High	High	Light			
	Physics 2301: Mechanics II	4	High	High	Light			
	Physics 3700: Data Analysis Lab	3	Light	High	High	High	High	Light
	Physics 5400: Int. E&M I	4	High	High				
	Physics 5500: Quan. Mech I	4	High	High				
	Physics 5600: Stat Mech	4	High	High				
Only one of these is required	Physics 5401: Int. E&M II	4	High	High				
	Physics 5501: Int E&M II	4	High	High				
Elective	Astron 5550: Adv. Astro Analysis	3	Light	High	High	High	High	Intermediate