
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

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

Comments

- I have included an updated curriculum map. This course could count as an elective. *(by Martini,Louis Paul on 01/19/2023 08:41 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 |
| Pending Approval | Cody,Emily Kathryn Jenkins,Mary Ellen Bigler Hanlin,Deborah Kay Hilty,Michael Vankeerbergen,Bernadette Chantal Steele,Rachel Lea | 02/01/2023 09:28 AM | ASCCAO Approval |

Astronomy 5550 –Advanced Astronomy Data Analysis

Syllabus Template

Instructor:

Name: Paul Martini

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 and statistical analysis. Prerequisite courses are Astro 3350 or Physics 3700 or permission of the instructor.

Textbook

The required textbook is “Statistics, Data Mining, & Machine Learning in Astronomy” by Ivezić 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.

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

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 also be three collaborative assignments in which teams of students will work together to apply the methods of the course to modern research questions in astronomy. These three assignments will correspond to a total of 60% of the course grade. There will not be a final exam.

The course will be graded on the standard OSU grading scale.

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, 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)

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

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]

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

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](tel: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](tel: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

| Year | Autumn Semester | Credit Hours | Comment | Spring Semester | Credit Hours | Comment |
|------|--------------------|--------------|------------------------|--------------------------|--------------|---------------------------|
| 1 | ASC Survey 1101 | 1 | | Astron 1221 [^] | 3 | Data Analysis (Python) |
| | Astron 2895 | 1 | Seminar | Math 1152* | 5 | Calculus II |
| | Math 1151* | 5 | Calculus I | Physics 1251# | 5 | Intro Physics II |
| | Physics 1250 | 5 | Intro Physics I | World Lang 2 | 4 | |
| | World Lang 1 | 4 | | GenEd 1201 | 1 | Launch Seminar |
| | Total Hours | 16 | | Total Hours | 18 | |
| 2 | Astron 2291 | 3 | Intro Astrophys I | Astron 2292 | 3 | Intro Astrophys II |
| | Math 2153 | 4 | Calculus III | Math 2415* | 3 | Differential Equations |
| | Physics 2300 | 4 | Mechanics I | Math 2568* | 3 | Linear Algebra |
| | World Lang 3 | 4 | | Physics 2301# | 4 | Mechanics II |
| | | | | GE Found | 3 | |
| | Total Hours | 15 | | Total Hours | 16 | |
| 3 | Astron 3350 | 3 | Methods of Observation | Astron 5550@ | 3 | Adv. Astro Analysis |
| | Astron 5682@ | 3 | Cosmology | Astron 5205/5681@ | 3 | Planet Sci./Stellar Evol. |
| | Physics 5500 | 4 | Quantum Mechanics I | Physics 5400 | 4 | E&M |
| | GE Found | 3 | | Physics 5501 | 4 | Quantum Mechanics II |
| | GE Found | 3 | | GE Found | 3 | |
| | Total Hours | 16 | | Total Hours | 17 | |
| 4 | Physics 5600 | 4 | Statistical Mechanics | Astron 5205/5681@ | 3 | Planet Sci./Stellar Evol. |
| | GE Found | 3 | | GE Theme | 3 | |
| | GE Theme | 3 | | GE Theme | 3 | |
| | GE Theme | 3 | | Elective+ | 3 | |
| | | | | Gen Ed 4001 | 1 | Reflection Seminar |
| | Total Hours | 13 | | Total Hours | 13 | |

Courses in YELLOW are only offered in the term shown

NOTE: this is only one of many possible ways to move through the Astronomy & Astrophysics curriculum. Consult with an academic advisor to develop and refine an academic plan that is appropriate for you.

*Many variations on the calculus sequence can be used in place of the standard sequence shown. Additional math

[^]The Astronomy 1221 programming class can be substituted by taking either CSE 1222 (C++) , CSE 1223 (Java), or CSE 1224 (Python). These are offered year-round.

Certain Physics courses require a minimum grade of C+ to move on to the next course(s) in the sequence.

@ Only one of 5681 or 5682 are required for the major. Both 5205 and 5500 are electives.

+ Free electives are only required if a student needs to take extra courses in order to reach the minimum