Term Information

Effective Term	Spring 2019

General Information

Course Bulletin Listing/Subject Area	Astronomy
Fiscal Unit/Academic Org	Astronomy - D0614
College/Academic Group	Arts and Sciences
Level/Career	Undergraduate
Course Number/Catalog	1221
Course Title	Astronomy Data Analysis with Python
Transcript Abbreviation	Astro Data Python
Course Description	Astronomy 1221 is an overview of data analysis in astronomy. The course will cover select topics in modern astronomy, combined with contemporary data analysis methods, illustrate how these data lead to scientific conclusions, and the limitations of data. The intended audience for the course is students with an interest in astronomy and the analysis of large datasets.
Semester Credit Hours/Units	Fixed: 3

Offering Information

Length Of Course	14 Week, 12 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	Pre- or co-requisites are Math 1151 or 1161.
Exclusions	
Electronically Enforced	Yes

Cross-Listings

Cross-Listings	

Subject/CIP Code

Subject/CIP Code	40.0201
Subsidy Level	General Studies Course
Intended Rank	Freshman, Sophomore, Junior, Senior

Requirement/Elective Designation

General Education course:
Physical Science

Course Details

Course goals or learning objectives/outcomes

- Students will understand how astronomical data lead to conclusions about the physical nature of celestial objects and the universe.
- Students will understand how measurement uncertainties affect the ability to discover new phenomena and to infer physical properties.
- Students will understand the basic tools of astronomical data collection and the technology that underpins them.
- Students will develop the skills needed to use the Python programming language for data visualization and manipulation, for numerical modeling, and for numerical problem solving.

Content Topic List

- Solar System: planets, moons, asteroids, and the Sun. Analysis tools will include basic statistics, such as mean, median, standard deviation, distributions.
- Stars: main sequence, hydrostatic equilibrium, nucleosynthesis, physical properties. Analysis tools will include uncertainties, model regression.
- Exoplanets: discovery techniques, demographics of exoplanet systems. Analysis tools will include time series analysis.
- Milky Way: distribution of stars, shape of the Galaxy. Analysis tools will include database structure, query design, data mining.
- Galaxies: morphological types, sizes, distances, stellar populations. Analysis tools will include classification with machine learning.
- Dark Matter: velocities from galaxy spectra, galaxy rotation curves, galaxy clusters. Analysis tools will include model development and testing methods.
- Cosmology: expansion of the universe, Type Ia SN, Hubble diagram, dark energy. Analysis tools will include model development and testing methods.

Sought Concurrence

No

Attachments

- Astro1221-Syllabus.pdf
  (Syllabus. Owner: Martini,Louis Paul)
- Astro1221-GE-Rationale.pdf: GE Rationale
  (Other Supporting Documentation. Owner: Martini,Louis Paul)
- Astro1221-GE-AssessPlan.pdf
  (GEC Course Assessment Plan. Owner: Martini,Louis Paul)

Comments

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Martini,Louis Paul	08/29/2017 09:02 PM	Submitted for Approval
Approved	Weinberg,David Hal	08/30/2017 12:50 PM	Unit Approval
Approved	Haddad,Deborah Moore	08/30/2017 01:49 PM	College Approval
Pending Approval	Nolen,Dawn Vankeerbergen,Bernadette Chantal Oldroyd,Shelby Quinn Hanlin,Deborah Kay Jenkins,Mary Ellen Bigler	08/30/2017 01:49 PM	ASCCAO Approval

Astronomy 1221 –Astronomy Data Analysis with Python

Syllabus Template

Instructor: Astronomy Professor, Dept. of Astronomy
Office: 40XX McPherson Lab (4th floor), mailbox in 4055 McPherson Lab
Phone: 614-292-1773
Office Hours: by appointment
Email: astronomer@osu.edu

Format of Instruction and Meeting Times:
Lectures: Days, Times
Location: Place

Web Page: Available through http://carmen.osu.edu

Course Description

Astronomy 1221 is an overview of data analysis in astronomy. The course will cover select topics in modern astronomy, combined with contemporary data analysis methods, illustrate how these data lead to scientific conclusions, and the limitations of data. The intended audience for the course is students with an interest in astronomy and the analysis of large datasets. The course will use the python programming language. No prior knowledge of astronomy or python is necessary.

General Education Category and Expected Learning Outcomes

Astronomy 1221 is a General Education (GE) Physical Science course in the Natural Science category that is intended for BS and BA students. The goals of this category are: Students understand the principles, theories, and methods of modern science, the relationship between science and technology, the implications of scientific discoveries and the potential of science and technology to address problems of the contemporary world.

The expected learning outcomes for GE courses in the Natural Science category are as follows:

1. Students understand the basic facts, principles, theories, and methods of modern science.
2. Students understand key events in the development of science and recognize that science is an evolving body of knowledge.
3. Students describe the inter-dependence of scientific and technological developments.
4. Students recognize social and philosophical implications of scientific discoveries and understand the potential of science and technology to address problems of the contemporary world.

Astronomy 1221 will satisfy these expected learning outcomes as follows:

(a) Students will understand how astronomical data lead to conclusions about the physical nature of celestial objects and the universe. Students will understand how measurement uncertainties affect the ability to discover new phenomena and to infer physical properties.

This will include analysis of data in: (1) “exploration mode” using visualization and classification to discover phenomena and identify patterns; (2) “model fitting and testing mode” using quantitative methods to infer values and uncertainties of model parameters and to test the validity of models. This maps to GE learning outcomes #1 and #2.

(b) Students will understand the basic tools of astronomical data collection and the technology that underpins them. This maps to GE learning outcomes #3 and #4.

(c) Students will develop the skills needed to use the Python programming language for data visualization and manipulation, for numerical modeling, and for numerical problem solving. Python has rapidly become the "lingua franca" for much astronomical data analysis and numerical computation, so these skills will be of great value to students in future courses in astronomy or other classes that involve numerical problem solving or analysis of data sets. This maps to GE learning outcomes #1, #3, and #4.

Prerequisites

The course is open to students with a strong interest in astronomy and modern methods of data analysis. Pre- or co-requisites are Math 1151 or 1161. There are no astronomy pre-requisites.

Textbook

There is no required textbook, although access to an introductory astronomy textbook will be useful. The course will also use many online tutorials for data analysis methods and python.

Grading Information

There will be an assignment for each of the astronomy and data analysis topics that will make use of the tools connected to those topics. These assignments will be due approximately every two weeks. Each assignment will have equal weight, and the total of the assignments will correspond to 80% of the course grade. There will also be a final project worth the other 20% of the course grade. The final project will be due during the last week of classes.

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

Course Outline

The course is split into seven topics, each of which pairs an astronomy topic with a data analysis method and contemporary tools used for the data analysis. Each of these topics will be covered in two weeks, with approximately equal time spent on the astronomy and analysis methods.

Topic 1: Solar System
Astronomy: planets, moons, asteroids, and the Sun
Analysis: basic statistics, such as mean, median, standard deviation, distributions
Tools: python basics, including syntax, functions, tables, and the astropy and numpy packages
Assignment: compute properties of various solar system bodies

Topic 2: Stars
Astronomy: main sequence, hydrostatic equilibrium, nucleosynthesis, physical properties

Analysis: uncertainties, model regression
Tools: visualization methods, especially the python matplotlib package
Assignment: create HR diagrams from GAIA data and compare to models

Topic 3: Exoplanets
Astronomy: discovery techniques, demographics of exoplanet systems
Analysis: time series analysis
Tools: python pandas package
Assignment: identify planet transits in Kepler data and estimate properties of planet systems

Topic 4: Milky Way
Astronomy: distribution of stars, shape of the Galaxy
Analysis: database structure, query design, data mining
Tools: data retrieval and database queries
Assignment: distribution of stars in the Galaxy with SDSS data, implications of uncertainties

Topic 5: Galaxies
Astronomy: morphological types, sizes, distances, stellar populations
Analysis: classification with machine learning
Tools: python skikit-learn package
Assignment: identify different classes of galaxies in SDSS images with machine learning

Topic 6: Dark Matter
Astronomy: velocities from galaxy spectra, galaxy rotation curves, galaxy clusters
Analysis: model development and testing
Tools: python scipy package
Assignment: fit galaxy rotation curves, measure cluster galaxy velocity distributions with SDSS

Topic 7: Cosmology
Astronomy: expansion of the universe, Type 1a SN, Hubble diagram, dark energy
Analysis: model development and testing
Tools: python scipy package
Assignment: determine the expansion rate and acceleration of the universe

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

Students with disabilities that have been certified by the Office for Disability Services will be appropriately accommodated and should inform the instructor as soon as possible of their needs. The Office for Disability Services is located in 150 Pomerene Hall, 1760 Neil Avenue; telephone 292-3307, TDD 292-0901; http://www.ods.ohio-state.edu/.

General Education Rationale for Astronomy 1221
"Astronomy Data Analysis with Python"

Astronomy 1221 is an overview of data analysis in astronomy. It is a General Education (GE) Physical Science course in the Natural Science category that is intended for BS and BA students. Astronomy 1221 is not intended to be a comprehensive survey of astronomy, nor of data analysis, but will instead cover a limited number of topics in astronomy and the analysis of large datasets to illustrate general principles of physical science and the scientific method. While the course is numbered at the 1000-level, it is our experience that astronomy GE courses are taken by students at all ranks.

The **expected learning outcomes** for GE courses in the Natural Science category are as follows:

1. Students understand the basic facts, principles, theories, and methods of modern science.
2. Students understand key events in the development of science and recognize that science is an evolving body of knowledge.
3. Students describe the inter-dependence of scientific and technological developments.
4. Students recognize social and philosophical implications of scientific discoveries and understand the potential of science and technology to address problems of the contemporary world.

We designed Astronomy 1221 based on **course-specific learning objectives**, and will use assignments to achieve these objectives. The course-specific objectives and their mapping to the GE expected learning outcomes are as follows:

(a) Students will understand how astronomical data lead to conclusions about the physical nature of celestial objects and the universe. Students will understand how measurement uncertainties affect the ability to discover new phenomena and to infer physical properties. This will include analysis of data in: (1) "exploration mode" using visualization and classification to discover phenomena and identify patterns; (2) "model fitting and testing mode" using quantitative methods to infer values and uncertainties of model parameters and to test the validity of models. This maps to GE learning outcomes #1 and #2.
(b) Students will understand the basic tools of astronomical data collection and the technology that underpins them. This maps to GE learning outcomes #1 and #3.
(c) Students will develop the skills needed to use the Python programming language for data visualization and manipulation, for numerical modeling, and for numerical problem solving. Python has rapidly become the "lingua franca" for much astronomical data analysis and numerical computation, so these skills will be of great value to students in future courses in astronomy or other classes that involve numerical problem solving or analysis of data sets. This maps to GE learning outcomes #1 and #4.

We next describe how each GE expected learning outcome (ELO) is met by the main components of the course, specifically the course objectives, the course topics, and the course assignments. We also describe why this course should be eligible for both BA and BS students, and why the prerequisites provide an appropriate level of preparation.

Q1: How is each individual GE ELO met by the course objectives?

- ELO1: This is met by course objectives (a), (b), and (c). Objective (a) is relevant because students will learn basic facts, principles, and theories of modern science as they learn about the physical nature of celestial objects and the universe. They will also learn the methods of modern science through data analysis. Objective (b) is relevant because the tools of data collection and technology are connected to methods of modern science. Objective (c) is also relevant because it includes data analysis tools, such as the python programming language, for astronomical data analysis.
- ELO2: This is met by course objective (a). Objective (a) will demonstrate how new data have led to the development of new theories and new understanding of the physical nature of celestial objects and the universe.
- ELO3: This is met by course objective (b). Objective (b) will demonstrate how new analysis methods and new technologies have lead to new scientific understanding.
- ELO4: This is met by course objective (c). Objective (c) will demonstrate how new technologies have lead to new discoveries.

Q2: How is each individual GE ELO met by the course topics?

The course consists of seven astronomical topics, each of which is paired with analysis methods and analysis tools, as well as an assignment. These topics are:

Topic 1: Solar System
Astronomy: planets, moons, asteroids, and the Sun
Analysis: basic statistics, such as mean, median, standard deviation, distributions
Tools: python basics, including syntax, functions, tables, and the astropy and numpy packages
Assignment: compute properties of solar system bodies

Topic 2: Stars
Astronomy: main sequence, hydrostatic equilibrium, nucleosynthesis, physical properties
Analysis: uncertainties, model regression
Tools: visualization methods, especially the python matplotlib package, file I/O
Assignment: create HR diagrams from GAIA data and compare to models

Topic 3: Exoplanets
Astronomy: discovery techniques, demographics of exoplanet systems
Analysis: time series analysis
Tools: python pandas package
Assignment: identify planet transits in Kepler data and estimate properties of planet systems

Topic 4: Milky Way
Astronomy: distribution of stars, shape of the Galaxy
Analysis: database structure, query design, data mining
Tools: data retrieval and database queries

Assignment: distribution of stars in the Galaxy with SDSS data, implications of uncertainties

Topic 5: Galaxies
Astronomy: morphological types, sizes, distances, stellar populations
Analysis: classification with machine learning
Tools: python skikit-learn package
Assignment: identify different classes of galaxies in SDSS images with machine learning

Topic 6: Dark Matter
Astronomy: velocities from galaxy spectra, galaxy rotation curves, galaxy clusters
Analysis: model development and testing
Tools: python scipy package
Assignment: fit galaxy rotation curves, measure cluster galaxy velocity distributions with SDSS

Topic 7: Cosmology
Astronomy: expansion of the universe, Type 1a SN, Hubble diagram, dark energy
Analysis: model development and testing
Tools: python scipy package
Assignment: determine the Hubble constant, demonstrate evidence for cosmic acceleration

These topics map to the ELOs as follows:

- ELO1: All of the topics will cover the basic facts, principles, theories, and methods of modern science.
- ELO2: Each topic will include the history of discovery to demonstrate that science is an evolving body of knowledge. Particularly noteworthy topics in this regard are exoplanets, dark matter, and dark energy (cosmology).
- ELO3: Each astronomy topic is combined with an analysis topic that will demonstrate the inter-dependence of scientific and technological developments.
- ELO4: The historical overview of each topic will include a description of the philosophical implications of the discoveries.

Q3: How is each individual GE ELO met by the course assignments?

- ELO1: The assignments will all involve the application of the methods of modern science to further student understanding of basic facts, principles, and theories.
- ELO2: The assignments will foster further understanding of key developments and discoveries
- ELO3: The assignments will demonstrate how new technological developments have let to new scientific discoveries.
- ELO4: The assignments will provide further opportunity to understand the philosophical implications of scientific discoveries.

Q4: Why should this course be eligible to both BA and BS students?

This course meets at least two of the guidelines provided by the ASCC Natural and

Mathematical Sciences Panel for courses eligible for both BA and BS students. The main one is that this course involves intensive data collection and analysis activities. Every course topic includes substantial material on analysis methods and python programming, and all of the assignments will require computations. The other guideline satisfied by the course is that we expect many astronomy and astrophysics majors will take the course, although we only plan to recommend and not require it. We plan to recommend that majors take this course before they get involved in undergraduate research projects, although will not require it because the astronomy topics will be covered at an inappropriately low level for majors.

Q5: How do the prerequisites provide an appropriate level of preparation for the course?

The assignments have been designed so that only basic mathematical knowledge is required. No previous astronomy coursework is required.

General Education Assessment Plan for Astronomy 1221
"Astronomy Data Analysis with Python"

Astronomy 1221 is an overview of the analysis of big data in astronomy. It is a General Education (GE) Physical Science course in the Natural Science category that is intended for BA and BS students. Astronomy 1221 is not intended to be a comprehensive survey of astronomy, nor of data analysis, but will instead cover a limited number of topics in astronomy and the analysis of large datasets to illustrate general principles of physical science and the scientific method.

We will employ rubrics to assess student understanding with programming assignments. These will take the form of embedded textual and numerical assignments that will be included in all assignments every time the course is offered. The text questions will correspond to multiple-choice and short answer questions that will be used to evaluate understanding of basic astronomical topics. These will include questions that are also asked as part of the assessment plans for Astronomy 1101, 1140, and 1144. The numerical questions will be basic, numerical results that demonstrate mastery of key concepts, and will be a useful gauge of student performance in these areas over time.

Examples of these questions are included below. The final set of questions will be determined when the course is offered for the first time.

We will also use indirect assessment through narrative evaluations to complement the student evaluation of instruction. These will ask about the GE learning objectives and for feedback on course components (lectures, assignments). This feedback will be used to refine the course content.

GE Expected Learning Outcomes	Methods of Assessment	Level of student achievement expected for the GE ELO	What is the process that will be used to review the data and potentially change the course to improve student learning of the GE ELOs?
ELO1. Students understand the basic facts, principles, theories and methods of modern science.	Embedded multiple choice, short-answer text, and numerical questions on assignments. The multiple choice questions are also used in Astronomy 1101, 1140, and 1144	>75% of students will answer questions correctly	We plan a two-step approach to periodically assess and improve student learning of the GE ELOs. 1. After the course has been offered for the first time, we will assess the multiple-choice questions shared with Astronomy 1101, 1140, and 1144 to search for potential improvements to the presentation of this content. We will also finalize the numerical and short-answer questions at this time. 2. After the course has been offered on subsequent occasions, the outcome of each ELO will be compared with the expected level of student achievement to identify potential improvements to course materials.
ELO2. Students understand key events in the development of science and recognize that science is an evolving body of knowledge.	Embedded multiple-choice questions in assignments that are also used in Astronomy 1101, 1140, and 1144	>75% of students will answer questions correctly	
ELO3 Students describe the inter-dependence of scientific and technological developments.	Embedded short-answer text questions on assignments	>75% of students will answer questions correctly	
ELO4 Students recognize social and philosophical implications of scientific discoveries and understand the potential of science and technology to address problems of the contemporary world.	Embedded short-answer text questions on assignments	>75% of students will answer questions correctly	

Sample questions:

<u>Topic 3: Exoplanets</u>

1. What method does the *Kepler* satellite use to identify exoplanets? (ELO1)
2. How does the number of exoplanets discovered by Kepler compare to other techniques? (ELO2, ELO3)
3. Search for a period transit signal in the light curve for the star in the datafile, identify the period of the transit event, and determine the distance of the transiting object from the star. (ELO1,3)
4. What are the prospects for life on this object? (ELO4)

<u>Topic 7: Cosmology</u>

1. Use data for the distances and velocities of galaxies to determine the local expansion rate of the universe. (ELO1, ELO2)
2. Use data for the distances and luminosities of supernovae create a figure of the distance-redshift relation. (ELO21, ELO2)
3. Describe the origin of the data necessary to measure the distance-redshift relation with supernovae. (ELO3)
4. What are the implications of this discovery for the fate of the universe? (ELO4)