Term Information

Effective Term	Autumn 2014

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	1101
Course Title	From Planets to the Cosmos
Transcript Abbreviation	Planets to Cosmos
Course Description	Overview of the Copernican revolution, the discovery of the nature of our solar system, light, gravity, and planets around other stars; the nature and evolution of stars and origin of the chemical elements; the history of galaxies and the expanding universe. Weekly laboratory. Not recommended for students who plan to major in astronomy or physics.
Semester Credit Hours/Units	Fixed: 4

Offering Information

Length Of Course	14 Week
Flexibly Scheduled Course	Sometimes
Does any section of this course have a distance education component?	No
Grading Basis	Letter Grade
Repeatable	No
Course Components	Laboratory, 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	Math 1050 (075) or an ACT math subscore of 22 or higher that is less than two years old; or 102; or Math Placement R or higher; or permission of instructor.
Exclusions	Not open to students with credit for Astron 1140, 1144, 1161H (H161), 1162H (H162), 2161H, 2162H, 2291 (291), or 2292 (292).

Cross-Listings

Cross-Listings

Subject/CIP Code

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

Requirement/Elective Designation

General Education course:
Physical Science

Course Details

Course goals or learning objectives/outcomes

- Quantitative Reasoning: Students will understand how quantitative measurements and predictions are used to test scientific ideas and to draw new conclusions.
- Scientific Process: Students will understand the scientific method, interplay between theory and empirical evidence, notions of incremental science and scientific revolutions, and the simultaneous existence of established knowledge and open questions
- Physical Laws: Students will understand that the universe is governed by a set of physical laws and principles that determine the appearance, behavior, and evolution of astrophysical systems.
- Evolution: Students will understand how we infer the evolution of astrophysical systems and the universe from observations at the present day.
- Relevance: Students will identify ways in which science in general and astrophysics in particular are relevant to global issues, US politics, advances in technology, and understanding humanity’s place in the universe.

Content Topic List

- The Long Copernican Revolution. "We are not the center of the Universe." Solar system, heliocentric model, orbits. Gravity and the Newtonian revolution. Extrasolar planets: detection (emphasis on transit method), atmospheres, habitability.
- Stars. "We are star stuff." Distances and masses of stars. Nuclear fusion and the origin of the elements, nucleosynthesis, stellar lifetimes. Supernovae, white dwarfs, neutron stars, black holes.
- Galaxies. "Space is big, time is long." Dark matter, evolution and growth of structure. Evidence for the Big Bang.

Attachments

- Syllabus.pdf
  (Syllabus. Owner: Peterson,Bradley Michael)
- GEassessment.pdf: Assessment Plan
  (GEC Course Assessment Plan. Owner: Peterson,Bradley Michael)
- GErationale.pdf: Course Rationale
  (Other Supporting Documentation. Owner: Peterson,Bradley Michael)

Comments

- See 10-10 e-mail to B Peterson. *(by Vankeerbergen,Bernadette Chantal on 10/10/2013 11:49 AM)*
- The syllabus will need to include the general elective learning goals that this course will attain. See: http://asccas.osu.edu/files/ASC_CurrAssess_Operations_Manual.pdf
  for details. Since this course is also new, a document that outlines how the GE goals will be met will also be required. *(by Hadad,Christopher Martin on 09/17/2013 05:26 PM)*

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Peterson,Bradley Michael	09/17/2013 02:36 PM	Submitted for Approval
Approved	Peterson,Bradley Michael	09/17/2013 02:38 PM	Unit Approval
Revision Requested	Hadad,Christopher Martin	09/17/2013 05:26 PM	College Approval
Submitted	Peterson,Bradley Michael	10/02/2013 12:29 PM	Submitted for Approval
Approved	Peterson,Bradley Michael	10/02/2013 12:31 PM	Unit Approval
Revision Requested	Hadad,Christopher Martin	10/02/2013 01:07 PM	College Approval
Submitted	Peterson,Bradley Michael	10/02/2013 04:28 PM	Submitted for Approval
Approved	Peterson,Bradley Michael	10/02/2013 04:29 PM	Unit Approval
Approved	Hadad,Christopher Martin	10/02/2013 04:32 PM	College Approval
Revision Requested	Vankeerbergen,Bernadette Chantal	10/10/2013 11:50 AM	ASCCAO Approval
Submitted	Peterson,Bradley Michael	10/29/2013 04:52 PM	Submitted for Approval
Approved	Peterson,Bradley Michael	10/30/2013 12:08 PM	Unit Approval
Approved	Hadad,Christopher Martin	10/30/2013 12:48 PM	College Approval
Pending Approval	Hanlin,Deborah Kay Hogle,Danielle Nicole Jenkins,Mary Ellen Bigler Nolen,Dawn Vankeerbergen,Bernadette Chantal	10/30/2013 12:48 PM	ASCCAO Approval

Sample Syllabus
Astronomy 1101: From Planets to the Cosmos
Professor Name

Lectures: Days and times.
Weekly Laboratory: Day and time.

Professor:
Office: 4### McPherson Lab (292-####)
Office Hours: Monday 1:30-2:30pm, or by appointment
E-Mail: name.#@osu.edu

TA:
Office:
Office Hours:
E-Mail: name.#@osu.edu

Textbook: *Astronomy Today*, 7th Edition, by Chaisson & McMillan

Course Web Page: http://www.astronomy.ohio-state.edu/~professorname

Course Goals & Learning Objectives:
Astronomy 1101 is an overview of astronomy from our solar system to the universe as a whole. It is a General Education (GE) Physical Science course in the Natural Science category. The goals of courses in 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 1101 will meet these expected outcomes by through coverage of three overarching and interconnected themes: (1) the Copernican revolution, the discovery of the nature of our solar system and planetary systems around other stars, the physics of

light and gravity; (2) the nature and evolution of stars and black holes and the origin of the elements we find in nature; (3) the history of galaxies and the universe, evidence for the Big Bang, and the structure of the universe on its largest scales.
We will attempt to convey a number of the facts that astronomers and astrophysicists have learned about these topics, to describe the outstanding scientific problems that are the focus of current research, to illustrate ways in which physical principles are used to understand the universe, and to show how scientific theories are developed and tested against observations.

Among the questions that you should be able to answer by the end of the course are the following: What is the architecture of our solar system, and how do we find other planetary systems? What is a star? What is a galaxy? What is the evidence for dark matter? What is the Big Bang theory? What empirical evidence supports and/or challenges our explanations for the physical nature of stars, galaxies, and the cosmos?

Course Organization:
This is a four-credit hour course; each week, there will be 3 hours of lecture and one two-hour laboratory session. For Arts and Sciences students in a Bachelor of Arts program, this course meets the Arts and Sciences GE requirement of a natural sciences course that includes a laboratory component.

Weekly Laboratory Write-Ups and Homework:
There will be a weekly laboratory. Attendance is required. The primary goal is to reinforce the concepts covered in lecture. The lab will typically start with 0.5–1 hour in the Ohio State University Planetarium (5033 Smith Laboratory) or an introduction by the instructor to the topic and the analysis that will be carried out. Then the class will be divided into smaller groups of 3–5 students who carry out the work of the lab, answer questions presented by the TA or professor, and turn in a common laboratory write-up. Before leaving the lab, students will be given open-book, open-notes, questions that follow from the laboratory exercise and that will be due no later than a week following the laboratory. Collectively, the laboratory will count for 40% of your grade. No late homework will be accepted, except for legitimate, documented emergencies.

In-Class Midterm Exams:
There will be two in-class midterm exams, held at normal class time. There will be no lecture on exam days, and the exam will start promptly at class time. Each exam will cover the material in the lectures and laboratory sessions since the previous exam. All exams are closed-book, closed-notes multiple-choice tests. They will consist of approximately 40 questions. Collectively, the quizzes will account for 30% of your final grade.

Makeup exams are only offered by advance arrangement with the professor. Exceptions are for legitimate, documentable emergencies. If you will be away on an official University-sponsored activity (e.g., sports teams, band, etc.), please bring the professor a letter from your coach, director, etc. in advance of the exam. Exams must be made up by the Wednesday after the exam you missed. ,

Final Exam:
The final will be comprehensive, covering all lectures and laboratories, and has the same multiple-choice/short answer format as the in-class quizzes, only about two times longer. It is worth 30% of your grade.

Students who miss the final exam will be given an incomplete (I) with an alternative grade equal to getting a zero on the final, and have to make it up early the following Semester, as per University policy, to avoid the alternative grade. In keeping with official University policy, early finals will not be available for those persons who wish to depart early for break. Please plan ahead and make your travel plans accordingly.

Grading Policy:

- The weekly laboratory writeups and homework assignments collectively account for 40% of your final grade.
- Together, the two in-class midterm exams will account for 30% of your final grade.
- The final exam accounts for 30% of your final grade, and must be taken by all students.
- Attendance at lectures is strongly encouraged and will have a large impact on your performance on tests and thus on your grade. Attendance at the weekly laboratory session is required.
- Participation is strongly encouraged. The professor will often ask if there are any questions or comments on the topics covered, or on sample exam questions we discuss in class.
- Participation counts towards your final grade, and will be used to bump it up (e.g., from a B+ to an A-) in the event that your calculated final grade is within approximately 1% of the higher score.

Lectures, Notes, & Readings:
The lectures and laboratory meetings are your primary resource for this course. The textbook is used as a secondary reference from which related readings will be suggested.

In between these two resources in importance are the lecture notes available on the web. These notes are meant to be useful aids for studying and following along during lectures; they are no substitute for attendance. Most students find that the best strategy is to print out the notes, bring them to class, and then add their own notes in the margins. Remember, these are only outlines of what is covered each day in class, not comprehensive transcripts of the lectures.

Textbook:
Because introductory astronomy textbooks designed for non-majors are rarely organized exactly the same as our courses, we will not strictly follow the order of topics in the book. You can expect to jump around as the course progresses. As such, instead of specific reading assignments, each section of the course has related reading suggestions from the text. Not all topics in this course are covered by the book, and similarly not all topics

covered in the book will be discussed in class. You are only responsible for the contents of the lectures.

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 (ODS) 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/. We will rely on ODS to verify the need for accommodation and to help develop the appropriate strategies. Students with disabilities who have not previously contacted ODS are encouraged to do so, by visiting the ODS website and requesting an appointment. Please take care of this well in advance of the quizzes, as processing the paperwork takes time.

Date (2014)	Week	Day	Topic	Readings
27-Aug	1	W	Introduction to the course; big numbers, time/length scales;units of measurement	Chpt. 1
29-Aug		F	Flat vs. spherical Earth; Eratosthenes; the night sky	
		Lab	See and notice; plot and intfer; 2d vs 3d distribution of stars	
1-Sep	2	M	Labor Day: no class	
3-Sep		W	Retrograde motion of planets; Ptolemy	Chpt. 2
5-Sep		F	Copernicus	
		Lab	The rotating Earth, the Earth-Sun-Moon system; eclipses; Aristarchus	
8-Sep	3	M	Kepler; Galileo; phases of Venus	
10-Sep		W	Heliocentrism	
12-Sep		F	Newtonian revolution; gravitation; orbits	
		Lab	Retrograde motion explained; orbits; Jovian moons	
15-Sep	4	M	Emission/absorption; blackbodies; brightness at a distance	Chpts. 3&4
17-Sep		W	Temperatures of planets; rocky vs. gas/ice planets	
19-Sep		F	atmospheres of Venus, Earth, Mars; global warming; habitability	Chpt 6
		Lab	Spectroscopy; comets at the ice line; albedo	
22-Sep	5	M	Distances to stars; parallax; size scales	Chpt 17
24-Sep		W	Kepler's Laws; binaries; planet-hosting stars; eclipses	Chpt 15
26-Sep		F	MIDTERM 1	
		Lab	Parallax; transits; masses of stars	Chpt 17
29-Sep	6	M	Transit searches; extrasolar planets	
1-Oct		W	Properties of stars	
3-Oct		F	Hydrostatic equilibrium; interior temperatures of stars	
		Lab	HR diagram and the properties or stars; calculation of stellar radius, distance, luminosity	
6-Oct	7	M	Fusion; thermal equilibrium; neutrinos	
8-Oct		W	Lifetimes of stars	Chpt. 20
10-Oct		F	Stellar evolution	
		Lab	HR diagram for star clusters; interpretation	
13-Oct	8	M	Stellar evolution	
15-Oct		W	Tests of stellar evolution	
17-Oct		F	White dwarfs; neutron stars	Chpt. 22
		Lab	Energy production in stars	Chpt. 21
20-Oct	9	M	Star and planet formation; connections to planet census	Chpt. 19
22-Oct		W	Nucleosynthesis; chemical evolution	Chpt. 21
24-Oct		F	Great debate; Cepheids; standard candles	Chpt. 24
		Lab	Using standard candles	
27-Oct	10	M	Galaxies	Chpt. 25
29-Oct		W	Evidence for dark matter; galaxy rotation curves	

31-Oct		F	MIDTERM 2	
		Lab	Newtonian gravity and dark matter; Kepler's laws	
3-Nov	11	M	Expansion of the universe; Hubble Law	
5-Nov		W	Large-scale structure of the universe	
7-Nov		F	Galaxy clusters	
		Lab	Hubble Law and the Expansion of the Universe	
10-Nov	12	M	Cosmic Distance Scale	
12-Nov		W	Evidence for dark matter; strong gravitational lensing; X-rays from clusters	
14-Nov		F	Supermassive black holes	
		Lab	Using velocity dispersion to weigh clusters	
17-Nov	13	M	Quasars	
19-Nov		W	Galaxy evolution; intergalactic medium	
21-Nov		F	Fundamental cosmological observations	Chpt. 26
		Lab	Flux variability and the size of quasars	
24-Nov	14	M	Tests of the Big Bang	
26-Nov		W	Thanksgiving: no class	
28-Nov		F	Thanksgiving: no class	
		Lab	none	
1-Dec	15	M	The Early Universe	Chpt. 27
3-Dec		W	Acceleration of the Universe; Dark Energy	
5-Dec		F	Fate of the Universe	
		Lab	Acceleration of the Universe from Supernovae	
8-Dec	16		Review	

GENERAL EDUCATION RATIONALE FOR
ASTRON 1101 "FROM PLANETS TO THE COSMOS"

Astronomy 1101 is an overview of astronomy from our solar system to the universe as a whole. It is a General Education (GE) Physical Science course in the Natural Science category, with an integral laboratory component. It is intended for BA students. While the course is numbered at the 1000-level, it is our experience that astronomy GE courses are taken by students at all ranks (in 2012-13, 45% of the enrollments were rank 3 or higher in the most comparable courses).

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 have designed the course in collaboration with UCAT, starting by defining the course-specific objectives and designging assignments to achieve these objectives. The course-specific objectives and their mapping to the GE course goals are as follows:

(a) Quantitative reasoning. Students will understand how quantitative measurements and predictions are used to test scientific ideas and to draw new conclusions. Maps to GE Goal #1.
(b) Scientific process: Students will understand the scientific method, interplay between theory and empirical evidence, notions of incremental science and scientific revolutions, and the simultaneous existence of established knowledge and open questions. Maps to GE goals #1 and #2.
(c) Physical laws. Students will understand that the universe is governed by a set of physical laws and principles that determine the appearance, behavior, and evolution of astronomical systems. Maps to GE goal #1 and somewhat to goal #3.
(d) Evolution. Students will understand how we infer the evolution of astrophysical systems and the universe from observations at the present day. Maps to GE goals #1 and #4.
(e) Revelance. Students will identify ways in which science in general and astrophysics in particular are relevant to global issues, US politics, advances in technology, and understanding humanity's place in the universe. Maps to GE goals #3 and #4.

(a) How do the course objectives address the expected learning outcomes?

Astronomy 1101 will meet these expected outcomes by through coverage of three overarching and interconnected themes: (1) the Copernican revolution, the discovery of the nature of our solar system and planetary systems around other stars, the physics of light and gravity; (2) the nature and evolution of stars and black holes and the origin of the elements we find in nature; (3) the history of galaxies and the universe, evidence for the Big Bang, and the structure of the universe on its largest scales. Students will learn basic observational facts (motions of bodies in the Solar System and proof of the Earth's motion; nature and composition of stars; fossil evidence of the Big Bang, including elemental abundances and cosmic background radiation), the methodology used in astronomy (measurement of positions and brightness of celestial sources and principles of spectroscopy), and the theories derived from the observations (the Copernican Solar System, universal gravitation, stellar evolution, and the Big Bang). It is worth emphasizing that this course was designed in collaboration with UCAT personnel following the "Understanding by Design" framework, beginning with the high-level goals that are listed in the Course Request and proceeding to more specific objectives that then guide the ordering and design of individual laboratories and other assignments. The high-level goals, though constructed specifically for this course, map well to the four expected learning outcomes for GE courses in the Natural Science category. While the content and context of the course is defined by the astronomical themes above, the laboratories and associated assignments are intended specifically to achieve the learning objectives described in the Course Request and to assess the degree to which students are attaining the desired learning outcomes.

(b) How do the readings assigned address the expected learning outcomes?

Readings are selected to reinforce lessons learned in lecture and laboratory.

(c) How do the topics address the expected learning outcomes?

The three themes that will be covered form the underpinnings of modern astronomy and astrophysics. The first topic, "The Long Copernican Revolution" is the on-going development of humanity's place in the universe. Copernicus first elucidated our modern view of the Earth in the Solar System. In the last 100 years, we have come to understand that we are on the outskirts of an undistinguished galaxy that is in turn on the outskirts of a large, but typical, supercluster comprised of thousands of galaxies. The second topic, the evolution of stars, leads to an understanding of the origin of elements heavier than helium, i.e., the elements that are common on Earth, yet cosmically relatively rare. The third topic, history of the universe, affords an explanation for the origin of the universe that is consistent with a wide variety of basic data and amenable to rigorous tests. In each instance, understanding how we came to this realization requires understanding of the methodology, observations, and underlying physics.

(d) How do the written assignments address the learning outcomes?

Written assignments that accompany the laboratory sessions are designed to reinforce how the basic data are assembled coherently, lead to hypotheses that are then amenable to tests.

(e) How do the prerequisites provide an appropriate level of preparation for the proposed course?

The laboratories will be designed so that only very basic geometry, algebra, and trigonometry will be required to execute and understand the assignments.

(f) What type(s) of experience will students have in the laboratory component of the course?

The individual laboratory exercises will vary, both week-to-week, depending on content, and through the course as students develop skills and knowledge that they can build on. We attach detailed outlines of two related laboratories (for weeks 9 and 11).

Sample Lab: Using Standard Candles (Week 9)

The goal is to reproduce the Hubble law, a plot of recession velocity as a function of distance. This involves determining distances to relatively nearby galaxies via supernovae type Ia (SNe Ia). The final result anticipates discussion of the expansion of the universe in week 11.

Lab Prep & Execution:

0. Students should be instructed to bring their own calculators, graph paper, pencils, and rulers. TAs should bring extras.

1. Supernova Ia data: Lab TAs will provide students with lightcurves of Ia supernovae as a function of time at low redshift. The Y-axis will be in units of solar luminosities per square kiloparsec and the X-axis will be in days. We will need ~10, with different brightnesses, ostensibly from different galaxies at different distances larger than 10 Mpc. Each lightcurve should be stamped with a system name (e.g., M101). The students will be asked to measure the distances to the host galaxies from the Ia brightness by assuming a common true luminosity at peak. Each student will make his/her own measurements so that there is a measure of the uncertainty.

2. Galaxy data: Lab TAs will provide optical spectra showing emission or absorption lines. Y-axis will be brightness and X-axis will be wavelength in microns. These spectra will be zoomed in so that students can measure redshifts to the galaxies where the SNe Ia went off. The students will measure the Doppler shift $\Delta\lambda$ with a ruler and then use the Doppler formula to get the velocities for each galaxy. Each student will make his/her own measurements so that there is a measure of the uncertainty.

3. Using the Galaxy data, the students will produce a plot of D (in Mpc) versus V (in km/s). They will then fit a line and derive the Hubble expansion.

Time Flow I: Planetarium: 45 minutes.

Group of 60 students.

Lecturer introduces the exercise:
Discuss standard candles, Cepheids. Show images of Ia supernovae exploding in galaxies. Discovery images from ASAS-SN, as well as recent highlights like SN2011fe. Discuss the number of Ia supernovae that have been found and how they are found at OSU. Discuss the physics of Ia supernovae: thermonuclear detonation of a CO white dwarf, potentially as a result of exceeding the Chandrasekhar mass. Motivate a standard reservoir of energy and thus a standard event, with a standard peak luminosity. Describe why this is not quite true. Show successive images of a supernova fading with time. Then show the lightcurve. Show how the peak brightness might be measured and then describe how one infers the distance. Argue that because Ia's are much brighter, this method potentially works at very large distances. Mention potential sources of error.

Show images distant that have detectable SNe Ia. Show the spectra of the galaxies. Remind students about emission and absorption lines. Remind them of where these lines come from. Show them a zoom-in of the spectrum, around a narrow optical line. Identify the line. Identify where it might be produced in the galaxy in question, then show that it is displaced from its nominal position in wavelength, thus indicating a redshift from the Doppler formula. Show how

$\Delta\lambda$ translates into a velocity. Discuss peculiar velocities, formation of large-scale structure. Mention potential sources of error. Discuss the history of the measurement they are about to make and that it leads to one of the most profound implications about our universe.

Time Flow II: Exercise: 1 hour

Students breakout into groups of 20. Each group is divided into 5 teams of 4 people and each team is provided with a packet SNe Ia lightcurves and galaxy spectra, and a luminosity at peak for their SNe Ia (e.g., 10^{10} solar luminosities). Students are reminded that their goal is to get distance *D*; to do this they need luminosity (given to them) and apparent brightness *B*. They will then measure *B* for each supernova and find *D* for each one. They will then measure $\Delta\lambda$ for their galaxy spectra and derive *V*. All above using ruler, pencil, and paper.

Students will then produce a table of System Name, Distance (Method), Velocity. They will then plot this data as *V*-*D* and derive the slope, the current expansion rate of the universe, the Hubble constant.

Questions: To Take Home and Answer

1. How would obscuring dust along the line of sight between the telescope and the SNe Ia change your values of *D*?
2. Galaxies do not always lie exactly on the best-fit line, and part of this is real, not attributable to measurement error. What is the physical explanation for this?

Sample Lab: The Hubble Law and the Expansion of the Universe (Week 11)

Builds on exercise of week 9 on use of standard candles, which led to the Hubble Law. In this exercise, students learn that the Hubble Law is the same for every galaxy, and that the recession of galaxies does not imply that we are at the center of the universe.

Lab Prep & Execution:

0. Students should be instructed to bring their own calculators, graph paper, pencils, and rulers. TAs should bring extras. Students will need to measure time; seconds on clock should be sufficient, can also use stopwatch on an iPhone, for example.

1. Students will be provided with lengths of surgical tubing (a linear representation of space) and colored paper clips (representing galaxies). Students will attach paper clips to the surgical tubing, pull the surgical tubing taut, and measure the distances between the paper clips.

2. Students will then slowly stretch the surgical tubing by at least a factor of two, timing how long it takes to do so. They will then remeasure all the separations between the paper clips. Then, using each paper clip as a base, compute the distance and recession speed of each of the other paper clips. They will then produce a Hubble diagram (distance as a function of velocity) and determine the expansion rate (stretching rate) for the surgical tubing.

Time Flow I: Planetarium: 65 minutes.

Group of 60 students.

Lecturer:
Review week 9 laboratory results on using standard candles and measuring the expansion rate of the universe. Discuss generality of this result, how it should be independent of location, and the implications (couple with the Copernican principle, homogeneity and isotropy follow).

Time Flow II: Exercise: 45 minutes

Students break into groups of 20. Each group of 20 is divided into 5 teams of 4 students. Each team receives a length of surgical tubing and four different-colored paper clips. Each student adopts one of the paper clips as his/her "own galaxy." Tubing is drawn taut, and paper clips are affixed at semi-regular intervals, and separations of each pair of paper clips is recorded. Tubing is then stretched slowly, by at least a factor of two in length, with two students holding the ends of the tubing, and another student measuring the time of expansion. Measurement of separations between each pair of paper clips is recorded by the fourth student. Each student then makes a table of recession velocity $V = \Delta X/\Delta t$ and final distance for each of the other paper clips, as seen from his/her paper clip, and computes expansion rate $H = V/D$, in units like inches per second per inch. Students compare results. Repeat with a different timescale and length scale for expansion. Discuss the difference.

Go back to plots made for week 11 laboratory on using standard candles. Deduce the Hubble law, expansion of the Universe.

Questions: To Take Home and Answer

1. How would obscuring dust along the line of sight between the telescope and the SNe Ias change your values of *D*?
2. Knowing the expansion rate, if you extrapolated backwards in time, how long ago were all paper clips (galaxies) would have been in a single location?
3. Using the same logic, can you give an estimate for the age of the universe?

GENERAL EDUCATION ASSESSMENT FOR ASTRON 1101 "FROM PLANETS TO THE COSMOS"

Astronomy 1101 is an overview of astronomy from our solar system to the universe as a whole. It is a General Education (GE) Physical Science course in the Natural Science category that is intended for BA students. An integral laboratory component distinguishes Astronomy 1101 from other GE courses in astronomy. Astron 1101 is not intended to be a comprehensive survey of astronomy, but will instead cover a limited number of astronomical topics to illustrate general principles of physical science and the scientific method.

An outline of our assessment plan is appended to this document.

We will employ rubrics to assessing student understanding of laboratory exercises as articulated in their lab write-ups and homework. In the Table below, we give sample rubrics that we might use to evaluate the lab exercise on the Hubble Law (given as a lab example in the accompanying "GE Rationale" document) and another set of rubrics for a lab on the Sun-Earth-Moon system and the nature of eclipses. We will carefully evaluate student lab reports to assess student understanding of the material.

We will also use pre- and post-assessment short quizzes to determine how student understanding has changed as a result of the course.

Another direct method of assessment that we will employ is embedded testing. The final examination will include multiple-choice questions that address specific concepts that were emphasized in certain of the laboratory exercises. Examples of embedded questions that address the specific GE goals appear in the assessment plan below.

As an indirect method of assessment, we will employ exit surveys that will include the specific course objectives and the GE learning objectives and students will be asked whether they strongly agree, agree, disagree, strongly disagree, or neither agree nor disagree that these goals were met. Narrative responses also will be sought.

Feedback from all sources will be examined to determine which parts of the course and which individual laboratory exercises were effective or ineffective and whether or not some of the exercises were too complicated/difficult or trivial/too easy. Laboratory exercises that are deemed to be ineffective will be either redesigned or replaced.

Feedback from all these sources will also be used to evaluate the topical content of the course to determine whether or not the areas of selected emphasis are achieving the goals outlined in our GE rationale documents.

Student performance evaluation will be carried out as described in the sample syllabus, with components of the grade including examination and laboratory performance and participation.

Table: Sample Rubrics for Assessing Laboratory Exercises

Evaluation Laboratory Exercise	Does Not Yet Meet Expectations	Minimally Meets Expectations	Fully Meets Expectations	Exceeds Expectations
Eclipses (part of week 2)	Can explain eclipse phenomenon, but not eclipse conditions	Correctly explains solar/lunar eclipses and conditions where they occur	Can articulate why there are “eclipses seasons” rather than eclipses every month	Understands precession and why interval between eclipses seasons is less than half a year
Hubble Law (week 11)	Understands correlation between distance and recession velocity, but cannot explain clearly underlying assumptions and the correlation between luminosity and redshift	Can correctly explain variables used in the Hubble diagram, underlying assumptions, and their implications	Can correctly explain implications of the Hubble diagram for the age of the universe	Can correctly connect with Copernican principle and implications of homogeneity and isotropy.

GE Natural Science—Physical Science Assessment Plan for Astron 1101

a) Specific Methods used to demonstrate student achievement of the GE expected learning outcomes

GE Expected Learning Outcomes	Direct Methods (*assess student performance related to the expected learning outcomes. Examples of direct assessments are: pre/post test; course-embedded questions; standardized exams; portfolio evaluation; videotape/audiotape of performance*)	Indirect Methods (*assess opinions or thoughts about student knowledge, skills, attitudes, learning experiences, and perceptions. Examples of indirect measures are: student surveys about instruction; focus groups; student self-evaluations*)
1. Students understand the basic facts, principles, theories and methods of modern science.	Embedded questions on exams[1] Pre- and post testing.	Opinion survey [3]
2. Students understand key events in the development of science and recognize that science is an evolving body of knowledge.	Embedded questions on exams[1] Pre- and post testing	Opinion survey
3. Students describe the inter-dependence of scientific and technological developments.	Embedded questions on exams [1] Pre- and post testing	Opinion survey
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.	Embedded questions on exams [1] Pre- and post testing	Opinion survey

[1] On each lecture exam and the final, several questions will be written specifically to assess student achievement of each GE expected learning outcome. The scores on these questions will be included in the totals for the exam but will also be analyzed separately so that the data can be used in revising the course and for GE assessment reporting purposes. Examples of *specific* embedded questions follow.

GE Goal 1: "A Cepheid variable with a pulsation period of 10 days is observed in a galaxy at a distance of 50 Mpc. Another Cepheid with the same period is observed in another galaxy, but is 10,000 times fainter. What is the distance to the second galaxy?" Multiple choice: correct answer is 0.5 Mpc = 500 kpc.

GE Goal #2: "Give an example of a historically important observation that supported the Copernican picture of our solar system." Multiple choice: correct answers include "Phases of Venus" and "Orbital motions of the moons of Jupiter."

GE Goal #3: “The telescope was a key technological development that enabled experimental confirmation that the Earth orbits the Sun by detection of what effects?” Multiple choice: correct answer includes “parallax of stars, aberration of starlight, and stellar radial velocities.”

GE Goal #4:”Observations have shown that:” Multiple choice: correct answer is “there are no special places or directions in the universe.”

[2] At the end of the semester, each student will be asked to fill out an opinion survey comprised of specific questions asking to what extent each student has achieved the four GE expected learning outcomes in this course.

b) **Explanation of level of student achievement expected:**
In general, for exams, success means that students will answer 75% of the embedded GE questions correctly. For laboratories, success means that >75% of the students will achieve “minimally meets expectations”, >50% will “full meet expectations, and >10% will “exceed expectations.”

c) **Description of follow-up/feedback processes:**
At the end of the course, we will use an analysis of the embedded exam questions to identify problem spots and how we might change the course and the presentation of materials to insure better fulfillment of the four GE Natural Science-Physical Science expected learning outcomes. We will also analyze the self-evaluation questions carefully to judge how students evaluated their own progress and to determine whether student perception meshed with performance. There will be weekly meetings of faculty and GTAs in the course to assess the effectiveness of the previous week’s lab assignment and to prepare for that of the coming week.