Term Information

Effective Term	Autumn 2023
Previous Value	*Spring 2016*

Course Change Information

What change is being proposed? (If more than one, what changes are being proposed?)

We propose a re-numbering of Astronomy 1143 to 2143. The revised course, Astronomy 2143, is proposed for inclusion in both the Origins and Evolution and the Number, Nature and Mind Themes. It will also continue to satisfy the legacy Foundations course requirement, although it is not eligible for the new Foundations (which require 4 credits and a lab).

What is the rationale for the proposed change(s)?

Astronomy 2143 was one of the 10 initial courses submitted in the approved proposal for both Themes. To create Astronomy 2143, we extensively revised the prior Foundations 1143 course, and we view 2143 as a logical replacement for 1143. The proposed changes include a number of elements that require a 2000-level designation rather than a 1000-level designation. These include the requirement that the natural sciences Foundation be satisfied, readings, more in-depth problem sets, in-class discussions, a summary written essay, a variety of assessment tools, and a greater emphasis on interdisciplinary questions. We also note that, from student feedback, even the 1000-level class is already regarded as being at a higher level than typical GE courses, and a 2000 level designation is likely to be more appropriate.

What are the programmatic implications of the proposed change(s)?

(e.g. program requirements to be added or removed, changes to be made in available resources, effect on other programs that use the course)?

The new course will satisfy the GE Themes, but not the foundations. The precursor course was not a prerequisite for other courses, and neither is the proposed 2143 course. We therefore expect no net impact on other programs. Neither course requires a laboratory, so there is no change in required laboratory facility needs.

Is approval of the requrest contingent upon the approval of other course or curricular program request? No

Is this a request to withdraw the course? No

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	2143
Previous Value	*1143*
Course Title	Cosmology: History of the Universe
Transcript Abbreviation	Cosmology
Course Description	Description of the history of the universe from Big Bang to present; how observations led to discovery of this history.
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
Previous Value	**Yes**
Previous Exam Types	*Departmental Exams*
Admission Condition Course	Yes
Admission Condition	Natural Science
Off Campus	Never
Campus of Offering	Columbus, Lima, Mansfield, Marion, Newark, Wooster
Previous Value	*Columbus, Newark*

Prerequisites and Exclusions

Prerequisites/Corequisites	Prereq: Completion of the Natural Science GE Foundation and Math at the level of 1050 or higher, or permission of instructor.
Previous Value	
Exclusions	Not open to students with credit for 1143 or 2292 or 1162.
Previous Value	Not open to students with credit for 2292 (292) or 1162 (162) or 143 or 172.
Electronically Enforced	No

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; Number, Nature, Mind; Origins and Evolution

Previous Value

General Education course:

Physical Science

Course Details

Course goals or learning objectives/outcomes

- The course goals and learning objectives are taken from those required for all new GE courses, as well as those specific to the Origins and Evolution Theme and the Number, Nature and Mind Theme. The goals are below. ELOs are in the attached file.
- General GE Goal 1: Successful students will analyze an important topic or idea at a more advanced and in-depth level than the foundations. (abridged)
- General GE Goal 2: Successful students will integrate approaches to the theme by making connections to out-of-classroom experiences with academic knowledge or across disciplines and/or to work they have done or will do in other courses. (abridged)
- Number, Nature and Mind GOAL 1: Successful students will analyze the nature of mathematics and/or mathematical reasoning at a more advanced and in-depth level than in the Foundations component.
- Number, Nature and Mind GOAL 2: Successful students will integrate approaches to number, nature, and mind by making connections to their own experiences and to other course work they have done or will do. (abridged)
- Origins and Evolution GOAL 1: Analyze the origins and evolution of natural systems, life, humanity, or human culture at a more advanced and in-depth level than in the Foundations component.
- Origins and Evolution GOAL 2: Integrate approaches to the origins and evolution of natural systems, life, humanity, or human culture by making connections to their own experiences and to other course work they have done or will do. (abridged)
- Origins and Evolution GOAL 3: Appreciate the time depth of the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.
- Origins and Evolution GOAL 4: Understand the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.

Previous Value

- *Understanding the principles, theories, and methods of modern cosmology, the relationship between cosmology and technology, the implications of cosmological discoveries, and the potential of science to address problems of contemporary world.*

Content Topic List

- The origins of cosmology
- The nature of light
- Constituents of the universe: stars, galaxies, dark matter
- The expanding universe and theory of gravitation
- Relic evidence of the early hot universe: big bang nucleosynthesis and the cosmic microwave background
- Structure in the universe: large-scale structure, galaxies, stars, and planets
- Formation of planets and the origin of life

Sought Concurrence

No

Attachments

- Astronomy_2143_syllabus.pdf: Sample new syllabus

  (Syllabus. Owner: Pinsonneault,Marc Howard)
- syllabus_a1143.pdf: Prior syllabus

  (Syllabus. Owner: Pinsonneault,Marc Howard)
- Astron2143_NNMelo_questionnare.docx: NNM ELO questionnaire

  (GEC Model Curriculum Compliance Stmt. Owner: Pinsonneault,Marc Howard)
- Astronomy_2143_OE elo_questionnare.docx: EO ELO questionnaire

  (GEC Model Curriculum Compliance Stmt. Owner: Pinsonneault,Marc Howard)

Comments

- This is one of four astronomy courses being transitioned from the 1000 level to the 2000 level. *(by Pinsonneault,Marc Howard on 08/31/2022 12:17 PM)*

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Pinsonneault,Marc Howard	08/31/2022 12:17 PM	Submitted for Approval
Approved	Weinberg,David Hal	08/31/2022 02:31 PM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	09/27/2022 01:54 PM	College Approval
Pending Approval	Cody,Emily Kathryn Jenkins,Mary Ellen Bigler Hanlin,Deborah Kay Hilty,Michael Vankeerbergen,Bernadette Chantal Steele,Rachel Lea	09/27/2022 01:54 PM	ASCCAO Approval

Astronomy 2143: Cosmology – The History of the Universe
Template Syllabus

3 contact hours per week, lecture format with in-class participation and questions
GE Themes: (1) Origins, (2) Number, Nature, and Mind

Course Material

Why is there something, rather than nothing? This is one of the oldest questions in human thought, and astronomers and physicists have made extraordinary progress towards answering it over the last century. We now know that the universe we see today has expanded from an extremely hot, extremely dense state — the "Big Bang" — that existed about 14 billion years ago. We know that the rich structure in today's universe — billions of galaxies that are arranged in enormous filaments and sheets and filled with stars and planets — emerged from the action of gravity on tiny primordial fluctuations. We know that the matter that makes up our everyday world, comprised of protons, neutrons, and electrons, accounts for only about 5% of the total matter and energy in the universe. We know something about the other dominant components, known as dark matter and dark energy, but their true nature remains mysterious, and a subject of intense research by astronomers and physicists.

This course will teach you about the history of the universe as we currently understand it and about the history of cosmology as a subject. We will see how astronomers have used observations from telescopes and satellites together with basic physical principles to piece together the picture summarized above. We will learn about some of the research that is being done today to gain deeper understanding of the matter and energy contents of the cosmos, the physics of the Big Bang, and the origin of galaxies. Along the way we will learn about light and its role as a messenger from the distant universe, about gravity and its impact on the motions of galaxies and the expansion of the cosmos, and about atoms and how they are forged in the hot early universe and the centers of stars.

Course Topics

The course will cover the following topics. The week-by-week breakdown is approximate.

- Measuring distances (1 week)
- Properties of light, redshift, expansion of the universe (2 week)
- Hubble's expansion law and its implications (1 week)
- Newtonian gravity (2 weeks)
- Evidence for dark matter (1 week)

MIDTERM EXAM

- Einstein's gravity and the expanding, homogeneous universe (2 weeks)
- Atoms, heat, and light (1 week)
- Big Bang Nucleosynthesis and the Cosmic Microwave Background (1 week)
- Cosmic acceleration and dark energy (1 week)
- The formation of cosmic structure (1 week)
- Inflation and the very early universe (1 week)

Prerequisites

The prerequisites for this course are completion of the Natural Science GE Foundation and math at the level of Math 1050. The math in this course will not go beyond simple algebra, but there will be equations and geometrical or mathematical reasoning in the lectures and in the assignments. The math itself will not be difficult, but the concepts will be challenging, and *translating concepts into equations and back is one of the major things you will learn during the course.*

Textook and Course Materials

The primary course textbook is *Your Cosmic Context*, by Todd Duncan and Craig Tyler, which is available at the campus bookstore or via online vendors. It is a good book: thoughtful, clear in its explanations and broad in its view. The course will proceed in a different order from the textbook, but the readings from the book assigned for each section will be a useful complement to what is covered in the lectures.

In addition, during the second half of the course we will read *The First Three Minutes* by the Nobel Prize winning physicist Steven Weinberg, also available at the campus bookstore or via online vendors. This short book is one of the classics of popular science writing, describing the big bang theory and the history of its discovery.

Required and optional reading assignments will be specified as the course progresses. The homework assignments and in-class questions will draw on these readings.

The instructor will provide additional course materials through Carmen or a dedicated course web page. At the instructor's discretion these additional materials may include lecture notes and/or copies of slides shown in class, as well as links to images, videos, and other resources that are helpful in learning the course material or exploring further.

Assignments, exams, and grading

Grades will be based on four take-home assignments (30% total), in-class questions (20% total), a take-home essay (10%), a midterm exam (15%), and a final exam (25%). The take-home assignments will consist of questions from the lectures and reading and multi-part problems for you to work out, and they should typically take 4-8 hours apiece. The essay (3-5 pages) will be assigned near the end of the course and will involve reflection on the course's central themes. The exams will be primarily multiple choice or short answer questions and may include short essays.

There will be in-class questions on most class days. The three lowest scores from the in-class questions will be dropped in computing the average score. While there is no direct attendance grade, if your attendance is poor you will inevitably do poorly on the in-class question grade, and probably on everything else as well.

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. 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.

Learning objectives

The Curriculum Committee of the College of Arts & Sciences requests that syllabi of all GE courses list the goals and learning objectives for the relevant category of the GEC. This course is applicable to *both* the *Number, Nature, and Mind* GE theme and the *Origins and Evolution* GE theme. We therefore list the goals and expected learning outcomes (ELOs) of both themes below, plus a brief explanation of how the course is intended to address these objectives.

The goals of the *Number, Nature, and Mind* GE Theme are:

1. Successful students will analyze the nature of mathematics and/or mathematical reasoning at a more advanced and in-depth level than in the Foundations component.

2. Successful students will integrate approaches to number, nature, and mind by making connections to their own experience of mathematical thinking and its application in the world, and by making connections to work they have done in previous classes and/or anticipate doing in the future.

3. Successful students will experience and examine mathematics as an abstract formal system accessible to mental manipulation and/or mathematics as a tool for describing and understanding the natural world.

More specifically, the "Expected Learning Outcomes" for this theme are:

Successful students are able to:

1.1 Engage in critical and logical thinking about the nature and/or application of mathematical reasoning.

1.2 Engage in an advanced, in-depth, scholarly exploration of the philosophical and/or cognitive foundations of mathematics and/or the application of mathematics in understanding the natural world.

2.1 Identify, describe, and synthesize approaches to or experiences of the role of mathematics and mathematical reasoning in different academic and non-academic contexts.

2.2 Demonstrate a developing sense of self as a learner through reflection, self-assessment, and creative work, building on prior experiences to respond to new and challenging contexts.

3.1 Analyze and describe how mathematics functions as an idealized system that enables logical proof and/or as a tool for describing and understanding the natural world.

The topics at the core of Astronomy 2143 — Einstein's conception of gravity and curved spacetime, the expanding universe, the big bang theory, dark matter, and dark energy — are striking examples of mathematics as a tool for describing and understanding the natural world, making them an ideal subject for addressing these objectives.

You will experience these striking applications of mathematics to physics — Number to Nature — throughout the lectures, readings, and homework assignments. You will learn how mathematics functions as a tool for analyzing the natural world from lectures and readings and, above all, from solving multi-part problems on homework assignments which take you from initial assumptions to sometimes surprising conclusions. One option for the concluding essay will invite you to reflect on the role of mathematical reasoning in the origin of the big bang theory and the discovery of dark matter and dark energy. These examples demonstrate that the human application of the abstract language of mathematics can lead to startling predictions about the natural world that can then be tested and confirmed by observations and experiments, the interplay at the heart of the *Number, Nature, and Mind* theme.

The goals of the *Origins and Evolution* GE Theme are:

1. Successful students will analyze the origins and evolution of natural systems, life, humanity, or human culture at a more advanced and in-depth level than in the Foundations component.

2. Successful students will integrate approaches to the origins and evolution of natural systems, life, humanity, or human culture by making connections to their own experiences and by making connections to work they have done in previous classes and/or anticipate doing in the future.

3. Successful students will appreciate the time depth of the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.

4. Successful students will understand the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.

More specifically, the "Expected Learning Outcomes" for this theme are:

Successful students are able to:

1.1 Apply their understanding of scientific methods to quantitative calculations.

1.2 Engage in critical and logical thinking about the origins and evolution of the universe, physical systems, life on earth, humanity, or human culture.

2.1 Identify, describe, and synthesize approaches to or experiences of origins and evolution questions in different academic and non-academic contexts.

2.2 Demonstrate a developing sense of self as a learner through reflection, self-assessment, and creative work, building on prior experiences to respond to new and challenging contexts.

3.1 Illustrate the time depth of the universe, physical systems, life on earth, humanity, or human culture by providing examples or models.

3.2 Explain scientific methods used to reconstruct the history of the universe, physical systems, life on earth, humanity, or human culture and specify their domains of validity.

3.3 Engage with current controversies and problems related to origins and evolution questions.

4.1 Describe how the universe, physical systems, life on earth, humanity, or human culture have evolved over time.

4.2 Summarize current theories of the origin and evolution of the universe, physical systems, life on earth, humanity, or human culture.

Astronomy 2143 addresses the origins and evolution of the largest physical system of all, the entire universe, on timescales that range from the first seconds after the big bang to the 14 billion year present-day and the possibly infinite future. From the lectures and readings, you will learn how astronomers and physicists have pieced together a detailed description of cosmic evolution and discovered striking observational evidence for the big bang origin of the universe and the existence of dark matter and dark energy. From in-class questions and homework assignments you will learn how scientists make predictions from cosmological theories and use observational data to measure the key parameters of the universe, such as its age, spatial extent, geometry, and matter and energy contents. These questions and the concluding essay will invite you to reflect on the span of cosmic evolution and the remarkable fact that we can deduce the history of the universe from our vantage in the present-day.

Astronomy 1143: History of the Universe
Spring 2017

Meetings: MWF, 11:30-12:25, Journalism Building 375

Midterm exam: Friday March 3, in class

Final exam: Friday April 28, noon-1:45 pm, in regular classroom

Instructor: Professor David Weinberg, Dept. of Astronomy

4055 McPherson Lab (4th floor), 292-2022, weinberg.21@osu.edu

Mailbox in 4055 McPherson Lab, phone messages can be left at 292-1773

Office hours: Thursday 9-10:15 am. Also available MWF after class until 1 pm, or by appointment.

Course Material

Why is there something, rather than nothing? This is one of the oldest questions in human thought, and astronomers and physicists have made extraordinary progress towards answering it over the last century. We now know that the universe we see today has expanded from an extremely hot, extremely dense state — the "Big Bang" — that existed about 14 billion years ago. We know that the rich structure in today's universe — billions of galaxies that are arranged in enormous filaments and sheets and filled with stars and planets — emerged from the action of gravity on tiny primordial fluctuations. We know that the matter that makes up our everyday world, comprised of protons, neutrons, and electrons, accounts for only about 5% of the total matter and energy in the universe. We know something about the other dominant components, known as dark matter and dark energy, but their true nature remains mysterious, and a subject of intense research by astronomers and physicists.

This course will teach you about the history of the universe as we currently understand it and about the history of cosmology as a subject. We will see how astronomers have used observations from telescopes and satellites together with basic physical principles to piece together the picture summarized above. We will learn about some of the research that is being done today to gain deeper understanding of the matter and energy contents of the cosmos, the physics of the Big Bang, and the origin of galaxies. Along the way we will learn about light and its role as a messenger from the distant universe, about gravity and its impact on the motions of galaxies and the expansion of the cosmos, and about atoms and how they are forged in the hot early universe and the centers of stars.

Course Topics

More specifically, the topics I aim to cover are:

- Measuring distances and velocities; properties of light; expansion of the universe
- Gravity; the influence of gravity on cosmic expansion; evidence for dark matter
- The Big Bang theory; the geometry of space
- The cosmic microwave background
- The origin of atoms: nucleosynthesis in stars and the early universe
- Galaxies, dark matter, and the large scale structure of the universe
- Inflation and the pre-history of the Big Bang
- Exotic energy and the fate of the universe

Prerequisites

The only prerequisite is math at the level of Math 1050 (actually, well below this level would be sufficient). The math in this course will not go beyond simple algebra, but there will be equations and geometrical or mathematical reasoning in the lectures and in the assignments. The math itself will not be difficult, but the concepts will be challenging, and *translating concepts into equations and back is one of the major things you will learn during the course.*

Textbook

The textbook is *Your Cosmic Context*, by Todd Duncan and Craig Tyler, which is available at the campus bookstore or via online vendors. It is a good book: thoughtful, clear in its explanations and broad in its view. I will proceed in a quite different order from the textbook, but I will assign readings from the book for each section, which should be a useful complement to what I cover in lecture. However, the book cannot possibly substitute for the lectures.

Assignments, exams, and grading

Grades will be based on four take-home assignments (30% total), in-class questions (20% total), a midterm exam (20%), and a final exam (30%). The take-home assignments will consist of questions from the lectures and reading and problems for you to work out, and they should typically take 4-8 hours apiece. I will accept assignments up to 3 days late but with a substantial penalty (see individual assignments for specifics). There will be in-class questions on most class days. I will drop the three lowest scores from the in-class questions and average the rest. While there is no direct attendance grade, if your attendance is poor you will inevitably do poorly on the in-class question grade (and probably on everything else as well).

Homework assignments must be submitted on paper, not electronically. If you are unable to attend class on the day an assignment is due, turn the assignment in to my mailbox in 4055 McPherson Lab prior to class.

The midterm exam will be on Friday, March 3, in class, full class period.

The final exam will be on Friday, April 28, noon - 1:45 pm, in the regular classroom.

You will be allowed one page (both sides) of handwritten notes for the midterm and two pages (both sides) of handwritten notes for the final.

Makeup exams will be allowed only under exceptional circumstances and by prior arrangement. Makeup exams will be oral and/or essay exams that cover the same general topics as the original exam but in different form.

How To Do Well In This Course

The most important advice is: come to class, start early on the take-home assignments, and get help on those assignments if you need it.

The take-home assignments are intended to be challenging. However, you are welcome to come to my office hours to get help on them. You may also want to form study groups with others in the class to work on the assignments. You are welcome to do so, though the assignment you turn in at the end must be your own work. If you devote enough time to the assignments and get help on them as needed, you should be able to do well on this portion of the course grade. The work you put into the assignments will also improve your performance on the exams, but that is not the primary purpose of the assignments. They are an integral part of the course in their own right.

For doing well on the exams, my advice is to spend some time each week going over the lecture notes, identify any things you don't understand, and ask me about them. There will also be question &

answer review sessions before the midterm and the final, and attending these will likely improve your performance. I will give other advice in advance of the exams themselves.

Electronics

Use of laptops, cell phones, etc. is not allowed during class or during exams. Calculators are allowed in class and exams. For the take-home assignments, you will need a calculator with scientific notation, and you will need to know how to use it.

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 (studentconduct.osu.edu).

Students with Disabilities

Students with disabilities (including mental health, chronic or temporary medical conditions) that have been certified by the Office of Student Life Disability Services will be appropriately accommodated and should inform the instructor as soon as possible of their needs. The Office of Student Life Disability Services is located in 098 Baker Hall, 113 W. 12th Avenue; telephone 614-292-3307, slds@osu.edu.

Learning objectives

The Curriculum Committee of the College of Arts & Sciences requests that syllabi of all GE courses list the goals and learning objectives for the relevant category of the GEC.

As a Natural Science GE course, the goals 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."

More specifically, the "Expected Learning Outcomes" for GE Physical Science courses are:

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.

Cosmology as a subject is an ideal vehicle for objectives 1-3, as we will closely examine one of the most exciting fields of modern science, one in which theory, observation, and technology all play crucial and interlocking roles. It's not clear that cosmology can do much to address problems of the contemporary world, other than providing a sense of perspective. However, cosmology is perhaps the field of science with the greatest philosophical implications, and I hope that learning about the history of the universe will inform your own philosophical world view.

New Theme Course Submission Form

Astronomy 2143: Cosmology – The History of the Universe

Submitted for approval for the new theme Number, Nature, and Mind

Background Statement

Astronomy 1143, Cosmology – The History of the Universe, has been taught as a Natural Sciences GE course since 2009. Traditionally, Astronomy has numbered all of its GE classes at 1000-level and used 2000-level and above for calculus-based courses designed for astronomy & astrophysics majors. Under the revised GE, we are numbering Foundation courses at 1000-level and renumbering the Theme courses to 2000-level. These courses, including Cosmology, have always required the application of algebra and geometry to understanding the physical universe and solving astrophysics problems. Our renumbering partly acknowledges that students have always regarded these courses as challenging, and it also recognizes the higher level of presentation, discussion, and assignments that are feasible now that students will have completed the Natural Sciences Foundation requirement before taking them.

As described in detail on the syllabus, Astronomy 2143 covers one of the most revolutionary transformations in modern science: the discovery that the earth occupies a "non-privileged" position in an expanding universe of enormous physical size and enormous but *finite* age, and that the dominant constituents of the cosmos are radically different from those we encounter in our everyday lives. These discoveries are based on Einstein's theory of gravity and curved spacetime and on the physical understanding of light, atoms, and sub-atomic particles developed over the past 300 years. The story of cosmology is one of the most stunning examples of the power of mathematics to explain the natural world and predict startling new phenomena, making Astronomy 2143 an ideal course for the *Number, Nature, and Mind* GE Theme.

The 3-credit hour course is comprised of class meetings involving lecture and small-group discussions, in-class questions based on those discussions, readings from the textbook *Your Cosmic Context* and from *The First Three Minutes* by Nobel Prize winning physicist Steven Weinberg, homework assignments that include reflection questions based on lectures and reading and multi-part calculational problems that guide students through key topics in cosmology, a concluding essay assignment in which students reflect on course themes, and a midterm and final exam that test mastery of course material. *The First Three Minutes* is one of the classics of popular science writing, an accessible but sophisticated account of the history of cosmology that is unusually good at demonstrating the often circuitous track of major scientific advances. *Your Cosmic Context* has an unusually broad perspective for a science textbook, covering topics clearly and accurately while also inviting students to make connections to their own experience and philosophical ideas. The in-class questions and homework assignments play central roles in achieving the ELOs and assessing that achievement. Examples of the multi-part questions from the homework assignments include: using data on variable stars to measure the distance to a nearby galaxy; building on this measurement and data on supernovae to measure the cosmic expansion rate (a.k.a. Hubble's constant); demonstrating that Hubble's linear expansion law is consistent with a homogeneous universe; inferring the amount of dark matter in a galaxy from measurements of its rotation speed; and using an observed map of the cosmic microwave background to infer the geometry of space. For in-class questions, students first work individually, then discuss their answers with a small group of peers before submitting them. Some of these are reflective, asking students to identify questions they have about cosmology or the results they find especially surprising, or to speculate on the spatial extent of the universe or the future duration of the cosmos and the human species. Some are review, helping students synthesize recently covered material and prepare for exams. Some are advanced, asking students to estimate the age of the universe from the value of the Hubble constant, to calculate a galaxy's light-travel distance from the wavelengths of absorption lines in its spectrum, or to explain the relation between cosmic expansion and the temperature of the universe or the synthesis of helium in the big bang.

In the remainder of this form, instructions and examples have been set in blue type while the new responses are set in black type.

Overview

Each category of the General Education (GE) has specific learning goals and Expected Learning outcomes that connect to the big picture goals of the program. Expected Learning Outcomes (ELOs) describe the knowledge or skills students should have by the end of the course. Courses in the GE Themes must meet the ELOs common for **all** GE Themes and those specific to the Theme, in addition to any ELOs the instructor has developed specific to that course.

The prompts below provide the goals of the GE Themes and seek information about which activities (discussions, readings, lectures, assignments) provide opportunities for students to achieve the ELO's associated with that goal. The answer should be concise and use language accessible to colleagues outside of the submitting department or discipline. The specifics of the activities matter—listing "readings" without a reference to the topic of those readings will not allow the reviewers to understand how the ELO will be met. However, the panel evaluating the fit of the course to the Theme will review this form in conjunction with the syllabus, so if readings, lecture/discussion topics, or other specifics are provided on the syllabus, it is not necessary to reiterate them within this form.

Goals and ELOs shared by *all* Themes

Goal 1: Successful students will analyze an important topic or idea at a more advanced and in-depth level than the foundations. In this context, "advanced" refers to courses that are e.g., synthetic, rely on research or cutting-edge findings, or deeply engage with the subject matter, among other possibilities.

Goal 2: Successful students will integrate approaches to the theme by making connections to out-of-classroom experiences with academic knowledge or across disciplines and/or to work they have done in previous classes and that they anticipate doing in future.

For each of the ELOs below, please identify and explain course assignments, readings, or other activities within this course that provide opportunity for students to attain the ELO. If the specific information is listed on the syllabus, it is appropriate to point to that document. The ELOs are expected to vary in their "coverage" in terms of number of activities or emphasis within the course. Examples from successful courses are shared on the next page.

ELO 1.1 Engage in critical and logical thinking.	As described in the syllabus and background statement, students will engage in logical thinking as they infer properties of galaxies and the cosmos using Newton's and Einstein's theories of gravity by applying physical intuition and mathematical reasoning, in lectures and small-group discussions and, especially, in answering in-class questions and homework problems. Students will engage in critical thinking as they reflect on the theoretical and experimental advances that led to the modern understanding of cosmology, addressed in lectures, in small-group discussions and some in-class questions, in readings, and in reflection questions on homework assignments and the concluding essay.
ELO 2.1 Identify, describe, and synthesize approaches or experiences.	Astronomy 2143 shows how the detailed and empirically successful theory of contemporary cosmology emerges from Newtonian and Einsteinian gravity and the properties of atoms and electromagnetic radiation. In understanding and describing this edifice, students will build on the knowledge they have gained from the Natural Sciences foundation courses. The story of modern cosmology involves an extraordinary, century-plus interplay between theoretical development and experimental or observational discoveries. Throughout the course students are challenged to identify these approaches, describe the interplay between them, and explain how the synthesis of theory and experiment leads to scientific advances. Students experience this challenge in lectures and reading, in in-class questions, and in homework assignments and exams.
ELO 2.2 Demonstrate a developing sense of self as a learner through reflection, self-assessment, and creative work, building on prior experiences to respond to new and challenging contexts.	At a concrete level, the development and progression of students in Astronomy 2143 is traced most clearly through the increasing sophistication of the multi-part problems in the homework assignments. For example, in the first assignment students use observations of Cepheid variable stars to infer the distance to a galaxy; in the second, they use distances of galaxies measured in this way to calibrate the luminosity of supernovae and use them to measure the cosmic expansion rate; in the third they use measured galaxy rotation speeds to infer the mass of the galaxy's dark matter, then use inferred galaxy masses and the cosmic expansion rate to determine whether the expansion of the universe will continue forever; in the final assignment, they revisit these topics from a more sophisticated viewpoint, using observations of supernovae and the cosmic microwave background to demonstrate that we live in a universe with accelerating cosmic expansion and flat spatial geometry. At a more abstract level, student reflection and self-assessment occurs through in-class, homework, and exam questions. For example, early in the course students are asked to speculate on whether the universe is finite or infinite in extent and in age and on whether the earth occupies a special location; they revisit these questions after learning more about modern cosmology.

Example responses (from Sociology 3200, Comm 2850, French 2803):

ELO 1.1 Engage in critical and logical thinking.	*This course will build skills needed to engage in critical and logical thinking about immigration and immigration related policy through:* • *Weekly reading response papers which require the students to synthesize and critically evaluate cutting-edge scholarship on immigration;* • *Engagement in class-based discussion and debates on immigration-related topics using evidence-based logical reasoning to evaluate policy positions;* • *Completion of an assignment which build skills in analyzing empirical data on immigration (Assignment #1)* • *Completion 3 assignments which build skills in connecting individual experiences with broader population-based patterns (Assignments #1, #2, #3)* • *Completion of 3 quizzes in which students demonstrate comprehension of the course readings and materials.*
ELO 2.1 Identify, describe, and synthesize approaches or experiences.	*Students engage in advanced exploration of each module topic through a combination of lectures, readings, and discussions.* *Lecture* *Course materials come from a variety of sources to help students engage in the relationship between media and citizenship at an advanced level. Each of the 12 modules has 3-4 lectures that contain information from both peer-reviewed and popular sources. Additionally, each module has at least one guest lecture from an expert in that topic to increase students' access to people with expertise in a variety of areas.* *Reading* *The textbook for this course provides background information on each topic and corresponds to the lectures. Students also take some control over their own learning by choosing at least one peer-reviewed article and at least one newspaper article from outside the class materials to read and include in their weekly discussion posts.* *Discussions* *Students do weekly discussions and are given flexibility in their topic choices in order to allow them to take some control over their education. They are also asked to provide information from sources they've found outside the lecture materials. In this way, they are able to explore areas of particular interest to them and practice the skills they will need to gather information about current events, analyze this information, and communicate it with others.* *Activity Example: Civility impacts citizenship behaviors in many ways. Students are asked to choose a TED talk from a provided list (or choose another speech of their interest) and summarize*

	and evaluate what it says about the relationship between civility and citizenship. Examples of Ted Talks on the list include Steven Petrow on the difference between being polite and being civil, Chimamanda Ngozi Adichie's talk on how a single story can perpetuate stereotypes, and Claire Wardle's talk on how diversity can enhance citizenship.
ELO 2.2 Demonstrate a developing sense of self as a learner through reflection, self-assessment, and creative work, building on prior experiences to respond to new and challenging contexts.	*Students will conduct research on a specific event or site in Paris not already discussed in depth in class. Students will submit a 300-word abstract of their topic and a bibliography of at least five reputable academic and mainstream sources. At the end of the semester they will submit a 5-page research paper and present their findings in a 10-minute oral and visual presentation in a small-group setting in Zoom.* *Some examples of events and sites:* – *The Paris Commune, an 1871 socialist uprising violently squelched by conservative forces* – *Jazz-Age Montmartre, where a small community of African-Americans–including actress and singer Josephine Baker, who was just inducted into the French Pantheon–settled and worked after World War I.* – *The Vélodrome d'hiver Roundup, 16-17 July 1942, when 13,000 Jews were rounded up by Paris police before being sent to concentration camps* – *The Marais, a vibrant Paris neighborhood inhabited over the centuries by aristocrats, then Jews, then the LGBTQ+ community, among other groups.*

Goals and ELOs of the GE Theme: Number, Nature, and Mind

GOAL 1: 1. Successful students will analyze the nature of mathematics and/or mathematical reasoning at a more advanced and in-depth level than in the Foundations component.

GOAL 2: Successful students will integrate approaches to number, nature, and mind by making connections to their own experience of mathematical thinking and its application in the world, and by making connections to work they have done in previous classes and/or anticipate doing in the future.

GOAL 3: Successful students will experience and examine mathematics as an abstract formal system accessible to mental manipulation and/or mathematics as a tool for describing and understanding the natural world or human cognition.

Enter your ELOs in the Table below, editing and removing rows as needed. There should be at least one ELO for each goal, and they should be numbered to correspond to the goal (e.g., ELO1.1 is the first ELO for Goal 1, ELO 2.2 would be the second ELO for the second goal).

For each ELOs, please identify and explain course assignments, readings, or other activities within this course that provide opportunity for students to attain the ELO. If the specific information is listed on the syllabus, it is appropriate to point to that document. The number of activities or emphasis within the course are expected to vary among ELOs. Examples from successful courses are shared below.

ELO 1.1 Engage in critical and logical thinking about the nature and/or application of mathematical reasoning.	As described in the syllabus and background statement, students will engage in logical thinking about the application of mathematical reasoning as they derive the consequences of theories of gravity and infer properties of galaxies and the cosmos from empirical data, in lectures and small-group discussions and, especially, in answering in-class questions and homework problems. Students will engage in critical thinking about the application of mathematical reasoning as they reflect on the way that it leads to novel predictions and on the experimental tests of those predictions. These reflections arise in lecture, in small-group discussions and some in-class questions, in readings, and in reflection questions on homework assignments, and in the concluding essay (discussed further under ELO 3.1).
ELO 1.2 Engage in an advanced, in-depth, scholarly exploration of the philosophical and/or cognitive foundations of mathematics and/or the application of mathematics in understanding the natural world or human cognition.	The topic of cosmology engages students in an advanced, in-depth, scholarly exploration of the application of mathematics in understanding the natural world. Through lectures, students encounter this application to understanding Newtonian and Einsteinian gravity, the geometry of curved space and curved spacetime, and the dynamics of the expanding universe. Through lectures, in-class questions, and, especially, the multi-part problems on homework assignments, they experience the application of mathematical reasoning to deriving empirically testable consequences of theories and to interpreting observational or experimental data. They demonstrate their understanding of this process in the assignments themselves and in answers to exam questions.
ELO 2.1 Identify, describe, and synthesize approaches to or experiences of the role of mathematics and mathematical reasoning in different academic and non-academic contexts.	The story of cosmology involves an extraordinary, century-plus interplay between theoretical development and experimental or observational discoveries. Throughout the course students are challenged to identify these approaches, describe the interplay between them, and explain how the synthesis of theory and experiment leads to scientific advances. Students experience this challenge in lectures and reading, in in-class questions, and in homework assignments and exams. In all aspects of the course, students apply mathematical reasoning in the context of physics and astrophysics, from geometric distance measurements and Newtonian gravity through to cutting-edge cosmological discoveries of the 21st century. To build familiarity with and

	intuitive understanding of physical phenomena and the equations that describe them, lectures refer frequently to everyday experience, such as cars, playgrounds, and sports to illustrate acceleration and forces, or balloons and cooking to illustrate pressure, temperature, and thermodynamics. In homework assignments students apply mathematical reasoning to distance measurements and dynamical calculations; for some students, this means relearning algebraic or geometrical techniques that have become unfamiliar through disuse. Students emerge from the course with a refreshed understanding of how to apply quantitative reasoning to the everyday world, a strength that will serve them in context beyond academia.
ELO 2.2 Demonstrate a developing sense of self as a learner through reflection, self-assessment, and creative work, building on prior experiences to respond to new and challenging contexts.	At a concrete level, the development and progression of students in Astronomy 2143 is traced most clearly through the increasing sophistication of the multi-part problems in the homework assignments. For example, in the first assignment students use observations of Cepheid variable stars to infer the distance to a galaxy; in the second, they use distances of galaxies measured in this way to calibrate the luminosity of supernovae and use them to measure the cosmic expansion rate; in the third they use measured galaxy rotation speeds to infer the mass of the galaxy's dark matter, then use inferred galaxy masses and the cosmic expansion rate to determine whether the expansion of the universe will continue forever; in the final assignment, they revisit these topics from a more sophisticated viewpoint, using observations of supernovae and the cosmic microwave background to demonstrate that we live in a universe with accelerating cosmic expansion and flat spatial geometry. At a more abstract level, student reflection and self-assessment occurs through in-class, homework, and exam questions. For example, early in the course students are asked to speculate on whether the universe is finite or infinite in extent and in age and on whether the earth occupies a special location; they revisit these questions after learning more about modern cosmology.
ELO 3.1 Analyze and describe how mathematics functions as an idealized system that enables logical proof and/or as a tool for describing and understanding the natural world or human cognition.	The topics at the core of Astronomy 2143 --- Einstein's conception of gravity and curved spacetime, the expanding universe, the big bang theory, dark matter, and dark energy --- are striking examples of mathematics as a tool for describing and understanding the natural world. Students experience these striking applications of mathematics to physics – Number to Nature – throughout the lectures, small-group discussions, readings, and homework assignments. They learn how mathematics

	functions as a tool for analyzing the natural world from lectures and readings and most viscerally from the experience of solving multi-part problems on homework assignments, which take them from initial assumptions to sometimes surprising conclusions. The concluding essay invites students to reflect on the role of mathematical reasoning in the development of modern cosmology and on the empirical confirmation of mathematically derived consequences of that theory. This interplay goes to the heart of the Nature, Number, and Mind theme, illustrating that human application of the abstract language of mathematics can lead to startling predictions about the natural world that can then be tested and confirmed by observations and experiments.

Example responses (from History/Religious Studies 3680, Music 3364; Sociology 3200) for the "Citizenship" Theme:

ELO 1.1 Describe and analyze a range of perspectives on what constitutes citizenship and how it differs across political, cultural, national, global, and/or historical communities.	*Citizenship could not be more central to a topic such as immigration/migration. As such, the course content, goals, and expected learning outcomes are all, almost by definition, engaged with a range of perspectives on local, national, and global citizenship. Throughout the class students will be required to engage with questions about what constitutes citizenship and how it differs across contexts.* *The course content addresses citizenship questions at the global (see weeks #3 and #15 on refugees and open border debates), national (see weeks #5, 7-#14 on the U.S. case), and the local level (see week #6 on Columbus). Specific activities addressing different perspectives on citizenship include Assignment #1, where students produce a demographic profile of a U.S-based immigrant group, including a profile of their citizenship statuses using U.S.-based regulatory definitions. In addition, Assignment #3, which has students connect their family origins to broader population-level immigration patterns, necessitates a discussion of citizenship. Finally, the critical reading responses have the students engage the literature on different perspectives of citizenship and reflect on what constitutes citizenship and how it varies across communities.*
ELO 1.2 Identify, reflect on, and apply the knowledge, skills and dispositions required for intercultural competence as a global citizen.	*This course supports the cultivation of "intercultural competence as a global citizen" through rigorous and sustained study of multiple forms of musical-political agency worldwide, from the grass-roots to the state-sponsored. Students identify varied cultural expressions of "musical citizenship" each week, through their reading and listening assignments, and reflect on them via online and in-class discussion. It is common for us to ask probing and programmatic questions about the musical-political subjects and cultures we study. What are the possibilities and constraints of this particular version of musical citizenship? What might we carry forward in our own lives and labors as musical citizens Further, students are encouraged to apply their emergent intercultural competencies as global, musical citizens in their midterm report and final project, in which weekly course topics inform student-led research and creative projects.*

ELO 2.1 Examine, critique, and evaluate various expressions and implications of diversity, equity, inclusion, and explore a variety of lived experiences.	*Through the historical and contemporary case studies students examine in HIST/RS 3680, they have numerous opportunities to examine, critique, and evaluate various expressions and implications of diversity, equity, and inclusion, as well as a variety of lived experiences. The cases highlight the challenges of living in religiously diverse societies, examining a range of issues and their implications. They also consider the intersections of religious difference with other categories of difference, including race and gender. For example, during the unit on US religious freedom, students consider how incarcerated Black Americans and Native Americans have experienced questions of freedom and equality in dramatically different ways than white Protestants. In a weekly reflection post, they address this question directly. In the unit on marriage and sexuality, they consider different ways that different social groups have experienced the regulation of marriage in Israel and Malaysia in ways that do not correspond simplistically to gender (e.g. different women's groups with very different perspectives on the issues).* *In their weekly reflection posts and other written assignments, students are invited to analyze the implications of different regulatory models for questions of diversity, equity, and inclusion. They do so not in a simplistic sense of assessing which model is "right" or "best" but in considering how different possible outcomes might shape the concrete lived experience of different social groups in different ways. The goal is not to determine which way of doing things is best, but to understand why different societies manage these questions in different ways and how their various expressions might lead to different outcomes in terms of diversity and inclusion. They also consider how the different social and demographic conditions of different societies shape their approaches (e.g. a historic Catholic majority in France committed to laicite confronting a growing Muslim minority, or how pluralism *within* Israeli Judaism led to a fragile and contested status quo arrangement). Again, these goals are met most directly through weekly reflection posts and students' final projects, including one prompt that invites students to consider Israel's status quo arrangement from the perspective of different social groups, including liberal feminists, Orthodox and Reform religious leaders, LGBTQ communities, interfaith couples, and others.*
ELO 2.2 Analyze and critique the intersection of concepts of justice, difference, citizenship, and how these interact with cultural traditions, structures of power and/or advocacy for social change.	*As students analyze specific case studies in HIST/RS 3680, they assess law's role in and capacity for enacting justice, managing difference, and constructing citizenship. This goal is met through lectures, course readings, discussion, and written assignments. For example, the unit on indigenous sovereignty and sacred space invites students to consider why liberal systems of law have rarely accommodated indigenous land claims and what this says about indigenous citizenship and justice. They also study examples of indigenous activism and resistance around these issues. At the conclusion of the unit, the neighborhood exploration assignment specifically asks students to take note of whether and how indigenous land claims are marked or acknowledged in the spaces they explore and what they learn from this about citizenship, difference, belonging, and power. In the unit on legal pluralism, marriage, and the law, students study the personal law systems in Israel and Malaysia. They consider the structures of power that privilege certain kinds of communities and identities and also encounter groups advocating for social change. In their final projects, students apply the insights they've gained to particular case studies. As they analyze their selected case*

	studies, they are required to discuss how the cases reveal the different ways justice, difference, and citizenship intersect and how they are shaped by cultural traditions and structures of power in particular social contexts. They present their conclusions in an oral group presentation and in an individually written final paper. Finally, in their end of semester letter to professor, they reflect on how they issues might shape their own advocacy for social change in the future.