CIEE in Merida, Mexico

Course name: Mayan to Modern Astronomy and Cosmology
Course number: ASTR 2101 MEME
Programs offering course: Science and Society
Language of instruction: English
U.S. semester credits: 3
Contact hours: 45
Term: Fall 2019

Course Description

This class focuses on the evolution of the key ideas that underlie our understanding of the Universe. It begins with naked-eye astronomy and the periodic phenomena associated with it: the astronomy of prehistoric and ancient cultures, focusing on Mayan beliefs. The fundamental question of how astronomy evolved into a science leads from this early astronomy to the development of the first physical theories. Observing and understanding the periodic motion of the celestial objects was (and still is) a key component of astronomy. Students will examine how making sense of the motion of the various astronomical objects led Mayans to questions their origin. Students will explore different concepts of our universe and their scientific ties. Students will then discover how science has pushed us to expand our concept of the universe and our place in it.

Learning Objectives

By the end of this course, with special emphasis on the Maya, students will be able to,

- Identify, describe and explain major celestial bodies and their observable movement.
- Use “naked eye” astronomy techniques and understand what factors impact their placement, including using tools for determining astronomical positions and alignment.
- Summarize strengths and limitations of using observable astronomical motion.
- Illustrate how astronomical knowledge impacted ancient societies, their concepts of time, architecture, customs and their cosmology
- Explore and critique case studies where astronomy has been invoked as impacting both ancient Mayan and contemporary society and culture.
- Visit Mayan archeological sites and explain in detail their relevance to Mayan astronomy and cosmology.
- Contrast how contemporary cosmology diverges from ancient and explain current scientific evidence from astronomy supporting it.

Course Prerequisites

None

Methods of Instruction

The course will be taught using lectures, seminars, case study discussions, group presentations of case studies, as well as sky gazing, field trips to local Mayan archaeological sites and Merida's Arcadio Poveda Ricalde Planetarium. Classroom activities will involve group projects and critical discussion groups considering ancient and contemporary cosmology based on astronomy. Students will also be expected to carry out studies of the night sky, build a sun dial, research Mayan ruin and deliver an oral presentation on a research project exploring aspects of Mayan astronomy and cosmology. Invited guest speakers will explore ancient and contemporary contributions of Mexico to astronomy and cosmology.

Assessment and Final Grade

Participation and Engagement	10 %
Group Presentation	10 %
Mayan Calendar Project	5 %
Mayan Architecture Project	5 %
Weekly Quizzes	20 %
Night Sky Notebook	10 %
Written Report	10 %
Final Exam	30 %

Course Requirements

Participation and Engagement

Each student is required to attend all sessions of the course and to participate actively in class discussions and during site visits. Be prepared to read approximately 100-150 pages per week and take notes during lectures and with invited speakers.

Group Presentation

Students in small groups of three must conduct a 15-minute presentation on a Mayan archaeological site and its significance to Mayan astronomy and cosmology. The presentation must include critical interpretation of peer-reviewed scientific literature, a model of the site and a clear explanation of its celestial relevance.

Mayan Calendar Project

Each student will construct and demonstrate to the instructor how to use the Mayan calendar. They will use the calendar to show their birthday and other important dates. In addition, they will research and explain how the calendar was used by the Maya. Finally, they will compare the Mayan calendar to at least one other ancient calendar, explaining the astronomical data upon which the calendars are based and how that explains their differences.

Mayan Architecture Project

Each student will research and build a replica or map the site of a Mayan city. They will use the replica or map to demonstrate how architecture based on astronomical understanding of the Mayan and a reflection of their Cosmology.

Quizzes

Each week, students will take a quiz on the previous week's course material. Quizzes will have True/False, Multiple Choice, calculations, filling in blanks and short answer questions. Quizzes will cover only new material, but similar questions to those on the quizzes will be seen again on the comprehensive final exam.

Night Sky Notebook

Students will keep a journal of the night sky for two weeks (14 nights), mapping celestial bodies and using tools of "naked eye astronomy" to measure movement, position and alignment.

Written Report

Each student will write a 3-5 page paper, complete with supporting literature. This paper will be on the ancient civilization of the student's choosing. It will focus on that society's understanding of Astronomy, tools they used to measure celestial positions, movement and time, the impact of Astronomy on their architecture and how the society differed from the Maya.

Final Exam

At the end of the course, students will take a final exam covering all previous material. As with quizzes, the final exam will have a variety of question formats, including True/False, Multiple Choice, calculations, filling in blanks and short answer questions.

Class Attendance

Regular class attendance is required throughout the program. Students must notify their instructor via Canvas, beforehand, if possible, if they will miss class for any reason. Students are responsible for any materials covered in class in their absence. Students who miss class for medical reasons must inform the instructor and the Academic

Director (or a designated staff member) and provide appropriate documentation as noted below. A make-up opportunity will be provided to the extent this is feasible.

Due to the intensive nature of the block schedule, all unexcused absences will result in a lower final grade for the course. Each unexcused absence will cause 3 percentage points to be dropped from the final grade. For example, a student with an 88% final grade (B+) and 1 unexcused absence will see it reduced to 85% (B).

Students who transfer from one class to another during the add/drop period will not be considered absent from the first session(s) of their new class, provided they were marked present for the first session(s) of their original class. Otherwise, the absence(s) from the original class carry over to the new class and count against the grade in that class.

CIEE program minimum class attendance standards are as outlined below. Center-specific attendance policies may be more stringent than the policies stated below. The Center / Resident Director sets the specific attendance policy for each location, including how absences impact final grades. Such policies are communicated to students during orientation and via Study Center documents. In the event that the attendance policy for host institution courses differs from CIEE's policy, the more stringent policy will apply.

- Excessively tardy (over 15 minutes late) students will be marked absent.
- Students who miss class for personal travel will be marked as absent and unexcused. No make-up opportunity will be provided.
- An absence will only be considered excused if:
  - A doctor's note is provided.
  - A CIEE staff member verifies that the student was too ill to attend class.
  - Evidence is provided of a family emergency.
- Attendance policies also apply to any required co-curricular class excursion or event.
- Persistent absenteeism (students approaching 20% or more of total course hours missed, or violations of the attendance policies in more than one class) may lead to a written warning from the Academic Director or Resident Director, notification to the student's home school, and/or dismissal from the program in addition to a reduction in class grade(s).

Weekly Schedule

NOTE: this schedule is subject to change at the discretion of the instructor to take advantage of current experiential learning opportunities.

Week 1 Naked Eye Astronomy

Lecture 1.1: Overview of course and Introduction to basic Earth – Celestial interactions. This opening lecture will introduce students to how the course is constructed, its scope and its expectations. Students will study astronomical symbols and abbreviations and

how they are used. They will differentiate terrestrial, horizontal and celestial coordinates. Students are introduced to how the sky tells time, how time zones relate to Earth-Sun position and movement, the use of sun dials, the Equation of Time, the Seasons, parallax and axis precession. This will provide a modern use of astronomy as a foundation to explore how ancient astronomies differed.

Readings: Madli 2015, Chapter 1, Aveni 2001, Chapter 1

Local Field Trip: The Night Sky Beyond City Lights Part 1. Without telescopes, students will examine the night sky using only their eyes. Major celestial bodies and constellations will be pointed out. Students will begin keeping a notebook of the night sky to measure position and movement of what they see. Special attention will be given to viewing the Moon, Venus, Mars, Jupiter and its moons.

Lecture and Workshop 1.2: Position of the Earth, Moon and Planets. Students will construct and use tools ancient civilizations used to map celestial bodies. These will be contrasted with later innovations and modern conventions. Students will review concepts of Distance, Angles and Coordinates used in ancient and modern Astronomy. Students will work in groups to illustrate and use some of these tools and apply them to object position and movement. Students will learn to make and use a magnetic compass, clinometer, cosmolabe, planisphere, Nebra sky disk and will examine a celestial sphere, among others.

Reading: Magli 2015, Chapter 2, Aveni 2001, Chapter 3

Lecture and Workshop 1.3: Reconstructing the Ancient Sky. Students will analyze data consistent with what was known to ancient astronomers. They will use the data to reconstruct visual alignments and derive the Horizon Formula. Students will use graphing and statistics to do this.

Reading: Magli 2015, Chapter 3

Week 2 Mayan Astronomy and Cosmology

Lecture 2.1 Mayan Concepts of Astronomy, Time and Space. Students will explore the connections between Astronomy and Time, the structure of the world and the Mayan cosmos. Students will review written evidence from Mayan texts and carvings to support our view of Mayan Astronomy and Cosmology.

Reading: Magli 2015, Chapter 9, Aveni Chapter 4

Lecture and Workshop 2.2: The Mayan Calendar. Students will learn how the Mayan calendar works, its relationship to Astronomy. Each student will construct and demonstrate to the instructor how to use the Mayan calendar. They will use the calendar to show their birthday and other important dates. In addition, they will research and explain how the calendar was used by the Maya. Finally, they will compare the Mayan calendar to at least one other ancient calendar, explaining the astronomical data upon which the calendars are based and how that explains their differences.

Reading: Zender, M. and J. Skidmore. 2012. Unearthing the Heavens: Classic Maya Murals and Astronomical Tables at Xultun, Guatemala; Saturno, W.A., et al. 2012. Ancient Maya Astronomical Tables from Xultun, Guatemala. Science 336(6082): 714-717.

Local Field Trip: The Night Sky Beyond City Lights Part 2. Without telescopes, students will examine the night sky using only their eyes. The instructor will quiz students on how much they recognize from the first Night Sky trip. More difficult celestial bodies and constellations will be pointed out. Students will continue taking measurements and recording them in their notebook of the night sky to measure position and movement of what they see. Special attention will be given to viewing the Moon, Venus, Mars, Jupiter and its moons.

Lecture 2.3 Mayan Astronomy and Cosmology in Daily Life. Students will learn the significance of Mayan knowledge of Astronomy impacted ancient life and how the cosmology resulting informed pre-Columbian life. They will also research how ancient beliefs based on Mayan Astronomy continue to inform Mayan life today.

Reading: Sosa, J. R., 1989, Cosmological, symbolic and cultural complexity among the contemporary Maya of Yucatan. V: A. F. Aveni, World Archaeoastronomy, Cambridge: Cambridge University Press, 130-142

Week 3 Mayan Astromony in Architecture

Lecture 3.1: Astronomy and Architecture in the Mayan World. Students will learn how architecture informs our understanding of Mayan Astronomy. They will see that orientations of Mayan structures were largely astronomical, referring to sunrise and sunset on important dates, many related to agricultural practices. They will also discover that ruins cannot be understood only from a utilitarian perspective. Instead, study will reveal that Mayan architecture and urban planning were also outcomes of Astronomy embedded in a broader framework of cosmology. Mayan ruins and their significance to astronomy and Mayan cosmology.

Begin Mayan Architecture Project: Students will begin research and construct models of Mayan ruins, document their roots in Mayan Astronomy and explore their expression of Mayan Cosmology

Readings: Aveni 2001. Chapter 5, Aldana, G. 2016. Discovery Discovery: Chich'en Itza, the Dresden Codex Venus Table and the 10th Century Mayan Astronomical Innovation ; University of California – Santa Barbara. 2016. An ancient Mayan Copernicus: Scholar says ancient hieroglyphic texts reveal Mayans made major discovery in math, astronomy.

Lecture and Activity 3.2: Field Trip to Chichen Itza with instructor to explore its relevance to Mayan Astronomy and Cosmology

Readings: Aveni 2001. Chapter 5, Sprajc, I. 2009. Astronomical and Cosmological Aspects of Maya Architecture and Urbanism

Lecture and Workshop 3.3: Student presentations of Mayan Architecture Project. Students will make formal presentations to their instructor and other students on a particular Mayan archeological site, reporting on the site's foundation in Mayan Astronomy and its relevance to Mayan Cosmology. The instructor will build on student presentations to give a fuller understanding of Mayan architecture and its relationship to Astronomy.

Readings: Magli 2015, Chapter 9

Week 4 Astronomy and other Ancient Cosmologies

Lecture 4.1: Ancient American Astronomy and Cosmology. Aztec, Inca. Students will investigate other civilizations of Mesoamerica, including Aztec constellations and the importance of the Zenith Solar Passage. They will contrast Mesoamerican Astronomy and Cosmology with South American Incan and other societies. Student comparisons will focus on differences in knowledge of Astronomy and how that impacted differences in the Cosmology of ancient American people

Readings: Aveni 2001. Chapter 2

Field Trip: Arcadio Poveda Ricalde Planetarium. While at the Planetarium, students will be guided through a sky show of ancient Mayan and other American Astronomies.

Lecture 4.2: Ancient Mediterrranean and Egyptian Astronomy and Cosmology. Students will learn about Stonehenge and other European sites based on ancient Astronomy. They will also explore Egypt and learn of ancient Egyptian Astronomy and its relationship to their beliefs, concepts of time and architecture.

Readings: Magli 2015. Chapters 7 and 8

Workshop and Presentations 4.3: Other Ancient Societies, their Astronomy and Cosmology. Students will pick an ancient society based upon their own interest. They will carefully answer specific questions posed by the instructor on how these societies were unique, with special attention to how they differ from the Maya. Students will present their findings to one another and in the form of a written report (due the following week).

Week 5 The Science of Developing our Modern Cosmology

Lecture 5.1: Ancient Greek and Roman societies will be explored as foundational to our current comprehension of the cosmos. They will be compared with Chinese and Arab Astronomy of the same time period. The origin of the scientific method and its significance to later innovation will be presented.

Readings: Magli. 2015, Chapter 10

Lecture 5.2: Astronomy and Cosmology from Middle Ages to Renaissance. This is generally regarded as a shift from ancient to modern science and Astronomy. Students will learn of a series of paradigm shifts in Western science that inform our contemporary Astronomy and Cosmology. Students will learn about advances from Copernicus, Tycho Brahe and Johannes Kepler.

Readings: Hawking and Mlodinow. 2008, Chapters 1-4.

Field Trip: The Night Sky Beyond City Lights Part 3. Now with telescopes, students will examine the night sky and compare it to using only their eyes. The instructor will quiz students on how much they recognize from the previous Night Sky trips. New celestial bodies and constellations will be pointed out that can only be seen with telescopes. Students will continue taking measurements and recording them in their notebook of the night sky to measure position and movement of what they see.

Seminar 5.3: Renaissance to Modern Astronomy and Cosmology. Students will view the universe through the eyes of Galileo and Copernicus. Students will learn how Galileo and Copernicus's Astronomy impacted Judeo-Christian Cosmology and how science provided a road map to separating religion and science-based Cosmology. They will also learn of Newton's contributions, including concepts of gravity and orbit. This provides a basis for building our solar system and beyond.

Readings: Hawking and Mlodinow. 2008, Chapters 5 and 6.

Due date for Written Report

Week 6 Astronomy and Contemporary Cosmology

Lecture 6.1: Students will learn about rapid innovations in modern Astronomy that bring us to our current understanding of the universe and our place in it. For example, students will learn about the advancement of telescopes and other instruments. They will learn basic concepts of relativity and modern cosmogony. This lecture will end with the steady state model of the universe.

Reading: Hawking and Mlodinow. 2008, Chapters 6-8.

Dissemination and Amalgamation: Popular Music and Telecommunications

Lecture 6.2: The Big Bang and Beyond. Students will learn about the expanding universe and its basis in science. They will explore the controversy between steady state, expanding and quasi-steady state models of the universe. They will assess the re-emergence of the Steady State universe concepts, how it differs and how it eliminates the need for a time of origin.

Reading: Hawking and Mlodinow. 2008, Chapters 9 and 10.

Lecture 6.3: Our Current Cosmology: what It owes to Ancient Astronomy and Our Next Steps. In part, this will be a review of all important concepts so far, in light of our current understanding of our place in the universe. It will point to new ideas and new directions that contemporary Astronomy is likely to take our ideas of origin, place and our future in the greater cosmos.

Reading: Hawking and Mlodinow. 2008, Chapters 11 and 12.

Final Exam

Course Materials

Course Textbooks

Aveni, A.F., 2001. *Skywatchers: a revised and updated version of Skywatchers of ancient Mexico*. University of Texas Press.

Hawking, S. and Mlodinow, L., 2010. *A Briefer History of Time*. Random House.

Magli, G., 2015. *Archaeoastronomy: introduction to the science of stars and stones*. Springer. . Good for methods.

Readings

Aldana, G. 2016. Discovery Discovery: Chich'en Itza, the Dresden Codex Venus Table and the 10th Century Mayan Astronomical Innovation. Journal of Astronomy in Culture 1: 57-76Chartrand, M.R., 1991. The Audubon Society field guide to the night sky. New York: AA Knopf: Distributed by Random House

Aveni, A.F., 2001. *Skywatchers: a revised and updated version of Skywatchers of ancient Mexico*. University of Texas Press

Aveni, A.F., 2008. *Foundations of new world cultural astronomy: a reader with commentary*. Univ Pr of Colorado

Hawking, S. and Mlodinow, L., 2010. *A Briefer History of Time*. Random House.

Magli, Giulio. 2009. Mysteries and Discoveries of Archaeoastronomy. Copernicus Books, 2009

Magli, G., 2015. *Archaeoastronomy: introduction to the science of stars and stones*. Springer

Photinus, Panos. 2015. Visual Astronomy: A Guide to Understanding the Night Sky: Morgan & Claypool

Saturno, W.A., et al. 2012. Ancient Maya Astronomical Tables from Xultun, Guatemala. Science 336(6082): 714-717

Sosa, J. R., 1989, Cosmological, symbolic and cultural complexity among the contemporary Maya of Yucatan. V: A. F. Aveni, World Archaeoastronomy, Cambridge: Cambridge University Press, 130-142

Sprajc, I. 2009. Astronomical and Cosmological Aspects of Maya Architecture and Urbanism. Comsomology across Cultures. Pp. 303-314

University of California – Santa Barbara. 2016. An ancient Mayan Copernicus: Scholar says ancient hieroglyphic texts reveal Mayans made major discovery in math, astronomy. Science Daily. www.sciencedaily.com /releases/2016/08/160816134024.htm

Zender, M. and J. Skidmore. 2012. Unearthing the Heavens: Classic Maya Murals and Astronomical Tables at Xultun, Guatemala. Mesoweb Reports. www.mesoweb.com/reports/Xultun.pdf