AST2031: Knowledge and the Universe

I. General Information

Meeting days/times for Spring 2026: Mondays, Wednesdays and Fridays at 1:55 PM - 2:45 PM (Section: AB26)

Class location: FLG 0230

Instructor:

Name: Dr. Avrajit Bandyopadhyay
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Office Hours: Mondays, Tuesdays and Wednesdays Noon-1PM, and by appointment.

Teaching Assistant:

Name: TBD
Office Building/Number: TBD
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Office Hours: TBD

Catalog Description

Describes and evaluates the Bayesian inference model in various astronomical contexts and with regard to pressing societal issues.

Course Description

How can different people from all walks of life view the same evidence and yet form different conclusions? This course introduces students to the concept of inference: the process by which we convert information presented to us into new conclusions or new knowledge. Students will apply inference not just in a scientific context but also to pressing global issues. First, students will review the process of science, learning from a historical context (e.g., ancient Greece, the renaissance) through to the modern day. Then, they will learn about the Bayesian inference model, which qualitatively and quantitatively guides how to balance observations from real-world experiments with prior assumptions or knowledge. Finally, with these problem-solving tools, they will examine and discuss various astronomy (properties of our universe) and some non-astronomy (e.g., earth's origin) themed topics that interest and affect everyone in the world.

Prerequisites

None

General Education and Quest Designations

P, N, Q2

All General Education and Quest area objectives can be found here and here, respectively.

Course Materials

- *The Essential Cosmic Perspective* 9E, Bennett, Donahue, Schneider & Voit (ISBN:978-0134446431)
- Lecture notes provided on canvas
- "Introduction to Inference" course notes
- Excerpts regarding the Sun's Heat from the Lord Kelvin's speech addressed to the Friday Evening Discourse in Physical Science at the Royal Institution in London
- Lin et al. 2021, "TruthfulQA: Measuring How Models Mimic Human Falsehoods":
- Poirer 2017, "About the age of the Earth" (including excerpts from Comte de Buffon)
- Dalrymple 1991, "The age of the Earth in the twentieth Century: a problem (mostly) solved"
- Excerpts from the "The Great Debate": https://apod.nasa.gov/diamond_jubilee/1920/cs_nrc.html

Materials will be available through the following means:

Students will purchase access to the course textbook and be provided links to all other materials through Canvas.

Materials Fee:

N/A

II. Course Objectives

This course will…

✓ … expose students to the basic principles of astronomy fact-gathering and research. Astronomy is unique in that the object studied can be seen only at a distance, and often with limited direct observability. The limited availability of observational information impacts the conclusion drawing process (inference). This will be accomplished through examining historical examples within astronomy where great advancements where made. We will discuss what observations were made and how they led scientists to draw the conclusions that they did. **(P, Q2)**

✓ … deeply and continuously immerse students in the practice and discipline of probabilistic inference and Bayesian analysis: the subtle but critical underpinnings of the conclusion drawing process at the core of the Scientific Method. This will be accomplished through examining historical examples within astronomy where great advancements where made. In each case, advancement required not only evidence, but also confronting established (incorrect) common knowledge. **(P, Q2)**

- ✓ … use astronomy as a means for studying how observations can lead to new knowledge. This will be accomplished using two lab modules where students will gather or use data (e.g., on the Sun's temperature or the expansion of the Universe). Students will critically analyze the experiment design, data, and conclusions. **(P, Q2)**
- ✓ … examine how the *exact same* critical thinking and conclusion drawing process used in the Scientific Method can apply to the actual day-to-day lives of the students. This will be accomplished by examining historical examples where groups of highly educated scientists with expert knowledge examined the same evidence and drew varied conclusions. We will examine why that happened, and how that applies to students' everyday lives. **(P, Q2)**
- ✓ … have students gather real astronomy data to confirm/explore/validate/understand the origins of observational facts asserted in lecture. This will be accomplished by having students construct their own experiments and/or data processing to gather insight on the underpinnings of modern astronomy knowledge. **(P, Q2)**
- ✓ … use the advancement of science (astronomy) to probe the underpinnings of how humans vet knowledge which naturally includes intercultural awareness. This will be accomplished by using a Bayesian framework to probe how and why a person's upbringing and background can impact their views-on and perception-of the word. **(N)**
- ✓ … discuss how past experiences, education, and biases shape the 'priors' that any and all people bring to decision making processes. Emphasis will be placed on how variations in international or cultural norms impact individual prior development, and therefore knowledge development. This will be accomplished by discussing specific examples of when astronomy was misled by 'common knowledge' or dogmatic ideas, and how/why this happened (e.g., the slow advancement of the Copernican model, the poor estimations of the Age of the Earth). **(N)**
- ✓ … explore the role that priors (i.e. the past experiences, education, and biases) play in determining how a person makes decisions and reaches conclusions. Emphasis will be placed on understanding how an internationally connected community with access to the same information can remain in tension when drawing conclusions about important societal issues (climate change, and disinformation campaigns will be used as specific examples). This will be accomplished by exploring how scientists/astronomers draw varied conclusions based on the same data owing to their varied strongly held beliefs, past research history, and/or preferences (e.g., Einstein's unfounded insertion of a cosmological constant). A mirrored process will be used to explore the role of priors when examining climate change data, interpreting vaccine safety studies, or vetting social media information sources. **(N)**

III. Student Learning Outcomes

At the conclusion of this course, students will be able to…

- ✓ **(Content)** … identify, describe, and explain the physical principles that underly our current model for the cosmos as well as how scientists process evidence to come to conclusions and link this to how individuals and groups of people come to make decisions and form opinions while taking into account the influence of the priors that those individuals and groups possess. This will be assessed through bi-weekly writing assignments, problem sets, and experiential learning labs. **(P, Q2)**
- ✓ **(Critical Thinking)** … analyze and evaluate the role that priors play in setting opinions and beliefs so that students can critically analyze and more deeply understand what drives knowledge and opinion formation. This will be assessed through bi-weekly writing assignments, problem sets, and experiential learning labs. **(P, Q2)**
- ✓ **(Communication)** … write, present, and debate the basics of a quantitative formulation of the scientific method known as probabilistic inference. This will be assessed through biweekly written assignments requiring clear communication and thoughtful reasoning as well as final presentations. **(P, Q2)**
- ✓ **(Connection)** … apply the same thought patterns that govern in the scientific process to societal contexts in situations as wide-ranging as medical diagnoses, social media discourse, journalism, politics, and religion. This will be assessed through biweekly written assignments that require drawing parallels from the scientific process discussed in class to the real world. **(P, Q2)**
- ✓ **(Content**) … understand how groups of people can come to varied conclusions even when faced with the same evidence or testimony. This will be assessed through societal parallel writing assignments where students will discuss how both scientists and all humans draw conclusions drawn through a combination of accepted evidence and priors, which can vary dramatically based on background, upbringing, and subject education. **(N)**
- ✓ **(Critical Thinking)** … navigate the data-flooded world of the internet and social media using the same tools of inference to employ critical thinking in everyday life. This will be assessed through societal parallel writing assignments where students link the 'knowledge building' process we discuss in astronomy to the 'fact vetting' process that all humans carry out continuously. **(N)**

IV. Graded Work

Requirements for class attendance, assignments, and other work in this course are consistent with the university's excused absences policy and other university policies found in the Catalog.

Graded Components:

Homework Problem Sets and Written Reflections (25%): To assess student comprehension of physical concepts, students will complete physical calculations, brief reading analyses, and discussion questions. These are due approximately one week after assigned following the discussion of their associated topic in class. For the written reflections, students will identify and describe how they relate to the subject of the unit. Essays will be graded based on completion, accurate application of course material to the writing subject, logical consistency of any arguments presented, and grammatical and spelling accuracy. These are at due approximately one week after discussion of their associated topic.

Midterm Exam (20%):A midterm exam will be held during second half of October during class hours. The exam will have multiple choice questions and broad questions which will be based on the course materials covered till then.

Experiential Learning Observing Labs (20%): Using telescopes at the Campus Teaching Observatory, students will see for themselves some of the objects discussed in class: the Sun and at least one planet. Notes and sketches at the observatory will be submitted with brief written reflections of their experiences. ***N.B. Astronomical observations are subject to availability of clear observing conditions!*** Thus, while we can try to plan out our experiential learning lab schedule, our ability to observe on a given night will not be known until the day of the planned event, and sometimes only within one hour or two of the start time. The written reflections of the experiences are due approximately one week after the completion of observing.

Final Presentations (20%): With instructor approval, students will choose an approved topic of their interest beyond the scope of the units presented in the course. In small groups of the same topic, they will work together to prepare joint presentations, which will be given at the end of the semester during class. This work will apply the Bayesian inference model to address historical examples where humans acted irrationally based on either misinformation, limited scientific knowledge, dogmatism, or similar. Each student will also submit their own written reflection of the topic that is due the last day of class.

Attendance/Class participation (15%): Class attendance will be taken using specially designed, brief in-class activities and worksheets. These are designed to help the students follow along in class and prepare for each unit's problem set or writing assignment. These will be graded generously for completion only (a reasonable attempt) and students are generally encouraged to work with their classmates. *Additionally, three absences will not be penalized and do not require justification.*

TOTAL: 100%

N.B. There are no final exams in this course.

As a general matter:

- Most assignments are posted by the first day of class with due dates on Canvas so that students can plan accordingly.
- Except for the Class Preparation Quizzes that are not accepted late, assignments will be penalized 20%/day.
- Students must submit completed assignments via Canvas in the format specified in the assignment. Students must ensure that any submitted assignments are legible (i.e., can be easily read and graded), contain the correct information (i.e., that you don't submit last week's HW assignment for this week), and that the submitted files are not corrupted (i.e., that the file can be opened by the grader). ***Failure to submit the correct document in a readable form will be treated as equivalent to not submitting the document.***
- ***Except where explicitly instructed, students are not allowed to use any AI tools (e.g., including Grammarly) to assist with any assignments in this course. Doing so will be considered a violation of the student honor code, as it is not your own work (e.g., plagiarism).***

Grading Scale:

Letter Grade	Number Grade
A	100-92.5
A-	92.4-89.5
B+	89.4-86.5
B	86.4-82.5
B-	82.4-79.5
C+	79.4-76.5
C	76.4-72.5
C-	72.4-69.5
D+	69.4-66.5
D	66.4-62.5
D-	62.4-59.5
E	59.4-0

See the UF Catalog's "Grades and Grading Policies" for information on how UF assigns grade points.

Note: A minimum grade of C is required to earn General Education credit.

V. Calendar

Date	Topic	Readings/ Preparation	Work Due
01/23/2025	The science of astronomy -I	1-20	Homework 1
01/30/2025	The science of Astronomy - II	53-68	Homework problem set
02/06/2025	Light and Telescopes	105-120	Experiential Learning Observing Labs, Written Reflection
02/13/2025	Powering the Sun	290-305	Homework Problem Set
02/27/2025	Stars -I	334-348	Written Reflection
03/06/2025	Stars -II	348-360	Written Reflection
03/13/2025	Galaxies	390-404, 420-428	Homework Problem Set
03/27/2025	Cosmology - Birth of the Universe	444-458	Homework Problem Set
04/03/2025	Cosmology - Dark matter and Dark energy	471-490	Homework Problem Set
04/10/2025	Earth's Origins	140-160, 173-186	Homework Problem Set
04/17/2025	Are We Alone in the Universe?	500-514	Writing Assignment
04/22/2025	Final Project		Project report and Group Presentations

N.B.: Preparation for each class of all topics generally includes readings (typically one textbook section or equivalent; please see the course materials section above), and lecture from the previous class. The given page ranges are from the textbook *The Essential Cosmic Perspective* 9E, Bennett, Donahue, Schneider & Voit. Please see the Graded Work section above and the Canvas course for more details.

Brief Descriptions of Topics

The Science of Astronomy: Students will learn about the process of science (including concepts such as Occam's razor) through history, including from ancient Greece and the enlightenment up to the modern day. We will discuss the methods and data that ancient astronomers used to identify the motion of planets in their orbits. We will also discuss relevant societal factors (e.g. religious/cultural/dogmatic influence) that contributed to solar system model formation.

An Introduction to Inference: We will introduce the concept of inference and explore examples where students intuitively accept or reject testimony/evidence (e.g., when judging the validity of an alleged UFO photo). We will use these examples to build an intuitive framework for Bayesian analysis and to introduce the critical Bayesian concept of a 'prior'. Class discussions will be used to discuss further examples of priors in daily life, highlighting all the other names we might refer to them as (expectations, intuition, common knowledge, etc.). We will discuss the historical example of the relationship between the religious/ dogmatic beliefs and astronomy to reflect on the ways in which cultural beliefs influence the development of an individual's priors.

Light and Telescopes: We first will discuss the nature of light and what we can learn from it. Students will learn about two primary types of spectra, how we understand them, and how astronomers use them. Then students will learn about the benefits of using telescopes ahead of looking through the telescopes themselves.

Powering the Sun: Students will learn the concepts of energy and power in the context of our Sun. We will discuss modern and ancient methods to measure the Sun's power output, but highlight the difficulty in observing where this power comes from. We will discuss different options for powering the sun including chemical burning, gravitational contraction, and nuclear fusion. We will examine the historical evolution in our understanding of the Sun's power, and its coevolution with the available body of physical knowledge. Class discussions will prepare students for their experiential learning experiment, and discuss difficulties inferring knowledge about something we cannot directly see or touch.

Stars: After the sun, students will learn about the stars and generalize the knowledge of sun on other stars. This will allow them to appreciate the wide diversity and difference in the properties of stars. Class discussions will prepare students for their experiential learning experiment, and discuss difficulties inferring knowledge about something we cannot directly see or touch.

Galaxies: This module will focus on the revelation that the Universe is much larger than our own Milky Way. We will look at what earlier generations of astronomers saw in the night sky, and why they were confused about sizes. We'll establish the basic rungs of the 'distance ladder' that are used to establish distances to far-off objects that allow us to grasp the size and scale of our Universe.

Cosmology and Dark Matter: Students will learn about the current favored model for the Universe. Students will see Edwin Hubble's original dataset that he used to propose an expanding niverse. We will debate how confident Hubble should have been in his conclusion of an expanding Universe. We will explore the implications of an expanding Universe (specifically, the Big Bang, size, and fate). Also, we now have abundant evidence to conclude that the dominant composition of the Universe is dark matter and dark energy. These are 'substances' that (to this point) we cannot touch or directly probe. Instead, despite making up 95% of our Universe's composition, we only know of their existence through inference. We will discuss the transformative study that revealed the existence of dark energy. We will scrutinize the data and examine how scientists were able to draw this bold conclusion. Class discussions will focus on the essential role that detailed statistical analysis played in allowing scientists to be certain in this conclusion and relate this back to the main theme of the class.

Earth's Origins: At the turn of the 20th century, determining the age of the Earth was a hot scientific topic. There were many methods proposed to measure the age of the Earth. In this module, we'll cover the physical ideas that were presented to measure the age of the Earth, discuss the role that Lord Kelvin played in this debate, and finally present the currently accepted model for the Earth's origin.

Are We Alone in the Universe? While the formation model of stars and planets predicts planet around other stars, we have only observationally confirmed them in the last few decades. The past two decades have seen an explosion in our knowledge about the existence, statistics, and characteristics of exoplanets. Notably, quantifying how common exoplanets is one key piece in estimating the frequency of life in our galaxy or the universe through the Drake equation. Students will learn about and evaluate this calculation to determine the range of possibilities for life in our galaxy.

V. University Policies and Resources

Attendance policy

Requirements for class attendance, assignments, and other work in this course are consistent with university policies that can be found at: https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx.

Students requiring accommodation

Students who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. As early as possible in the semester, students should share their accommodation letter with their instructor and discuss their access needs.

UF course evaluation process

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online. Students can complete evaluations in three ways:

1. The email they receive from GatorEvals,

2. Their Canvas course menu under GatorEvals, or
3. The central portal at https://my-ufl.bluera.com

Guidance on how to provide constructive feedback is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/

University Honesty Policy

University of Florida students are bound by the Honor Pledge. On all work submitted for credit by a student, the following pledge is required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Student Honor Code and Conduct Code (Regulation 4.040) specifies a number of behaviors that are in violation of this code, as well as the process for reported allegations and sanctions that may be implemented. For example, "Plagiarism. A Student must not represent as the Student's own work all or any portion of the work of another person or Entity" ***(e.g., with artificial intelligence tools).*** Please also see section III for further clarification for this course. All potential violations of the code will be reported to Student Conduct and Conflict Resolution. If a student is found responsible for an Honor Code violation in this course, the instructor will enter a Grade Adjustment sanction which may be up to or including failure of the course. For additional information, see https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/.

In-class recording

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or guest lecturer during a class session.

Publication without permission of the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third-party-note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or

discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

Procedure for conflict resolution

Any classroom issues, disagreements or grade disputes should be discussed first between the instructor and the student. If the problem cannot be resolved, please contact Elizabeth Lada (chair; elada@ufl.edu; 352-294-1862). Be prepared to provide documentation of the problem, as well as all graded materials for the semester. Issues that cannot be resolved departmentally will be referred to the University Ombuds Office (http://www.ombuds.ufl.edu; 352-392-1308) or the Dean of Students Office (http://www.dso.ufl.edu; 352-392-1261).

Resources available to students

Health and Wellness

- U Matter, We Care: umatter@ufl.edu; 352-392-1575.
- Counseling and Wellness Center: http://www.counseling.ufl.edu; 352-392-1575.
- Sexual Assault Recovery Services (SARS): Student Health Care Center; 352-392-1161.
- University Police Department: http://www.police.ufl.edu/; 352-392-1111 (911 for emergencies).

Academic Resources

- E-learning technical support: learning-support@ufl.edu; https://elearning.ufl.edu; 352-392-4357.
- Career Connections Center: Reitz Union; http://www.career.ufl.edu/; 352-392-1601.
- Library Support: http://cms.uflib.ufl.edu/ask.
- Academic Resources: 1317 Turlington Hall; 352-392-2010; https://academicresources.clas.ufl.edu.
- Writing Studio: 2215 Turlington Hall; http://writing.ufl.edu/writing-studio/.