

ASTR 111: The Dark Side of the Universe

Winter Session 2020

Evenings 5:00 – 10:00 pm, VVO 110

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Course Overview:

The physical world we experience is one of normal matter, energy, and – if one looks up at night – stars. But on larger scales, the universe has an exotic and much less-well understood side dominated by things we call dark matter, dark energy, and black holes. What are these mysterious components, and what is the relationship between them and the world that is familiar to us? The answers lie at the frontier of modern astrophysics. In this course, we explore the evidence for the existence of these dark components and the current debates regarding their nature and origin. In different ways, each of them has a vital role in the evolution of the universe and its ultimate fate.

Required text:

Your Cosmic Context, by T. Duncan & C. Tyler (Pearson Addison-Wesley).

Two copies are on 2-hour reserve at the Science Library.

Schedule:

Lectures: We will meet 8 times — one lecture every other day.

Observing: Weather permitting, we will observe the night sky using the telescopes at VVO.

Detailed schedule:

Tue. 1/7.....	Lecture 1
Wed. 1/8.....	off
Thu. 1/9.....	Lecture 2
Fri. 1/10	off
Sat. 1/11	Lecture 3
Sun. 1/12	off
Mon. 1/13	Lecture 4
Tue. 1/14.....	off
Wed. 1/15	Lecture 5
Thu. 1/16.....	off
Fri. 1/17	Lecture 6
Sat. 1/18.....	off
Sun. 1/19	Lecture 7
Mon. 1/20	off
Tue. 1/21.....	Lecture 8
Wed. 1/22.....	Final Exam, 5 pm, VVO 110

General Requirements and Grading:

Reading (15%): The concepts in this course build vertically on each other, and because of the compressed format of this offering, it is crucial to complete all of the necessary reading prior to our first meeting. You may not fully grasp everything in the reading, but it is important that you be familiar with the concepts and how they fit together *before* they are presented in class. Eleven reading assignments from the textbook (~ 30 pages each) will be given. These are to be completed in late December/early January. You will take running notes as you read; these notes must be handed in at the first lecture to receive credit.

Attendance (10%): The organization and content of the lectures, on which the final exam will be based, do not mirror the textbook exactly, so *your attendance in class is essential*. Those with no unexcused absences will receive the attendance credit.

Related to attendance, we will be doing telescope **observing** (weather permitting!) and/or **in-class projects** during each of the lectures. Everyone who takes an astronomy course should have an opportunity to see, with their own eyes, some of the phenomena discussed in the class. Hands-on projects (either with the telescopes or in the classroom) can provide powerful illustrations of important concepts.

Assignments (50%): There will be five take-home assignments, which are designed to complement the lecture material. The first, a short writing assignment, is to be completed prior to the start of the course. The other four assignments will be due in class.

Question-of-the-day: (10%): From Lecture 2 onward, we will begin each class with a straightforward, one-question quiz based on a fundamental concept discussed in the previous lecture. This will let me know how well you are grasping the most important ideas, and it will give you an indication of the format of the final exam and the types of questions that will appear on it.

Final Exam (15%): The course will conclude with a comprehensive final exam that focuses on the key concepts discussed in the lectures, both basic and complex.

ASTR 111 — Assignment 1

Due: Saturday, January 4, 2020, by email

Introduction. Chapter 1 of *Your Cosmic Context* touches on the *process* of science. Although some aspects of this process were undoubtedly familiar to you already, many of the concepts encountered in this course are completely alien to our experience, and it is important to understand that they have been developed using the same principles that are employed in all other scientific disciplines. The goals of this assignment are twofold: you will (a) explore the philosophical issues associated with how knowledge is gained in science, which have a central role in the way astronomical research is conducted, and (b) examine how the process of science is communicated to non-scientists.

Reading. The readings listed here are intended to help you to complete the assignment described below. They will also help you to understand better how progress is made in science, so I encourage you to review them all. But there is no reason to read every word — there is a fair amount of overlap in the articles, and there will be no exam questions based on this material.

Begin by refamiliarizing yourself with the details of the process of science by reading the Wikipedia entry on the *Scientific Method*. Section 6 of this article briefly discusses the Philosophy of Science, and at the end of Section 7, the ideas of one of the greatest philosophers of science, Karl Popper, are introduced. Popper's most important contributions include the establishment of (a) how science is distinguished from other forms of intellectual activity, and (b) the concept that progress in science is made via *falsification*, not *verification*. Popper's ideas are outlined in the supplementary reading included on Moodle, which contains the first chapter of his seminal book, *The Logic of Scientific Discovery*.

You may delve further into the Philosophy of Science by examining the Wikipedia pages on *Karl Popper*, *Falsifiability*, *Occam's Razor*, and the *Philosophy of Science*. As you are reading, please focus on the following:

- the difference between deduction and induction
- the roles of positive testing/verification and negative testing/falsification
- the falsifiability of hypotheses and theories
- choosing between competing theories: Occam's razor
- the goals of science: Realists vs. Instrumentalists
- sociological issues: normal vs. revolutionary science

Assignment. Scientific research benefits society in a variety of ways. At one end of the spectrum, science addresses the fundamental questions we have about our origins and how things in the natural world work. At the other end, research can lead to technological advances or improvements in health and medicine that impact the lives of people directly. Coupled with the fact that most

of the support for scientific research is provided by society, we have an important responsibility to communicate our findings to the public.

How effective is that communication? Does it succeed in informing and inspiring non-scientists? Or does the way it is presented create confusion about the process or value of scientific research? For this assignment, you are going to examine a popular science article of your choosing through this lens. Select your article using the following guidelines:

- The topic should be of interest to you, and the article must contain enough information for you to answer **all** of the questions listed below.
- It does *not* have to be about astronomy. For example, articles about medicine, psychology, and the environment would be entirely appropriate for this assignment. But make sure your article is fundamentally about science and **not** technology or engineering. Check with me if for any reason you are unsure about the suitability of your article.
- It should be a fairly recent article — within the last two months.
- Please select an article from a popular news outlet (e.g., nytimes.com, huffingtonpost.com, cnn.com, npr.org, nbcnews.com, time.com, etc.) rather than sources dedicated to science (such as *Scientific American*). The latter may be more rigorous or accurate, but they typically have small audiences. This is about science news that is aimed at (and reaches) the most people.
- Please choose an article that differs from those selected by other students you know in class.

Send me the link to your article along with your typed, itemized responses to the following questions (those in **bold**). Again, if for any reason the article you have chosen does not allow you to address all of these questions, select another article. Some sample sub-questions are provided to guide your analysis. Please note that your answers do not have to be lengthy — a paragraph or two should suffice for each. I am mainly looking for thoughtful responses and evidence of effort.

1. In a sentence or two, **please summarize what the article is about**. (Don't evaluate the article in any way.)
2. **What elements of the scientific method appear in the article?** Some possible things to consider: How is the scientific problem or motivation described? What *evidence* is presented? How is the concept of *testing* conveyed to the reader, e.g., was an experiment devised to test an existing theory, or has a new observation or serendipitous discovery provided such a test? What important aspects of the scientific method (if any) seem to be missing in the article?
3. **How is the process of science portrayed in the article?** Some possible things to consider: Do you get the impression that the approach to testing is positive (perhaps via words like “prove” or “confirm”) or negative (i.e., via falsification)? How much emphasis is placed on the *repeatability* of results? How is the concept of *uncertainty* dealt with, and does one get a sense of its role in the interpretation of evidence? Does the process seem systematic? Does the science seem sound or speculative? What related future work (experimental or theoretical) is described?

4. **Does the article you chose include any statements or sentiments that could inadvertently undermine science in the eyes of the public?** For example, is the reader given the impression that scientists are uncritical, dogmatic, prone to error, or people who change their minds easily? Does the science seem to be esoteric, useless, or overly expensive? Along these lines, **what impression is given of the benefit or value of the work described?**