Observational Cosmology

Observational Cosmology has several goals: to measure the size and age of the Universe; to take a census of what the Universe contains; and to measure how and why the Universe changes over time. Much of this work is done with traditional telescopes, measuring the size and shape and distances to galaxies, or seeking the light from distant supernovae to measure enormous distances across the Universe. Still other telescopes seek to find the most distant galaxies known, or look for light from the first stars, or map out the faint microwave whisper of light that was released when the first atoms were formed.

Theoretical Cosmology

Theoretical Cosmology has similar goals: to understand the history and predict the future of the Cosmos; to describe the Universe in the context of the laws of Nature; and to explain the origin and contents of the Universe. The heart of our understanding of how the Universe changes and evolves derives from ***general relativity***, the modern description of gravity used in physics and astronomy. Mathematical work coupled with computer simulations of the Universe use general relativity to compare models of the Universe with our observations of galaxies, large scale structure, and the cosmic microwave background. The models are constantly updated and modified to see if they match observations of the Universe as accurately as possible, leading to a better understanding of the properties of the Universe and the relative importance of different astrophysical phenomena on the evolution and fate of the Cosmos.

What's going on at Northwestern?

Dark Matter Searches

Northwestern physicists are part of many experimental efforts to determine what the dark matter is, including **PICO, LZ, SuperCDMS,** and **Micro-X**.

Illustris

CIERA astronomers use the Illustris super-computer simulation of the Universe to understand galaxies, dark matter, and massive black holes. **http://www.illustris-project.org**

Gravitational Waves

CIERA scientists work on both LIGO and LISA, new observatories studying the Universe in gravitational waves. **http://lisa.nasa.gov , http://ligo.northwestern.edu**

Learn more…

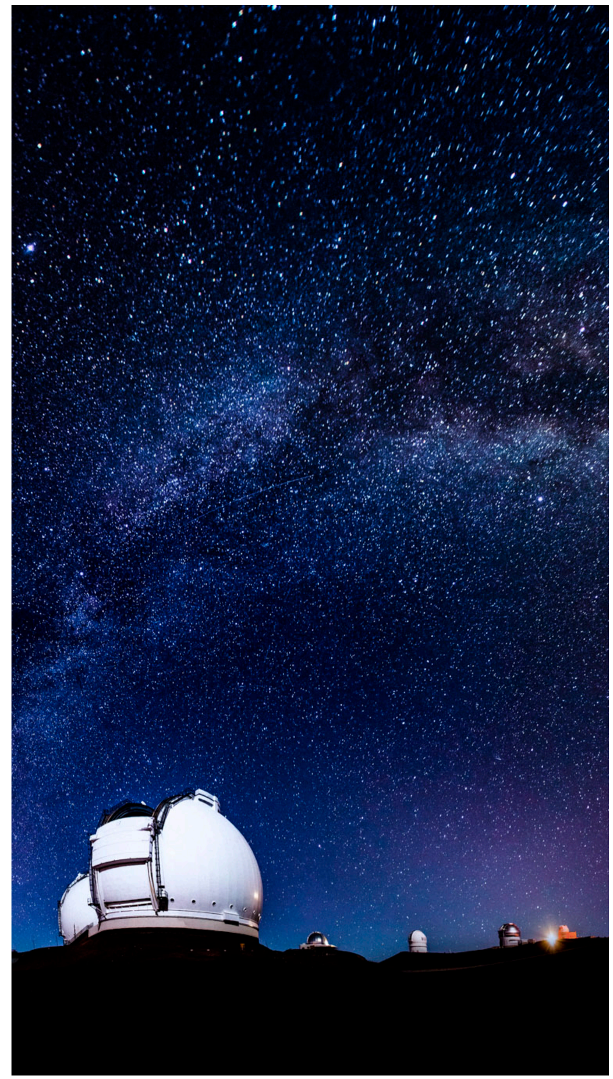
There are great resources you can use to learn more about cosmology, and the Universe.

- **Universe 101 Cosmology Tutorial (WMAP)** https://map.gsfc.nasa.gov/cosmology/cosmology.html
- **Beginning Cosmology (Khan Academy)** https://www.khanacademy.org/science/cosmology-and-astronomy
- **The Day We Discovered the Universe** by Marcia Bartusiak
- **The First Three Minutes** by Steven Weinberg
- **The Cosmic Cocktail: 3 parts dark matter** by Katherine Freese

Cosmology

Northwestern | CIERA — Center for Interdisciplinary Exploration and Research in Astrophysics

CIERA Pathfinder Series
Explore more by scanning →



What is the Universe?

This is one of the most perplexing questions in cosmology. Simply: *the Universe is everything that exists*. While cosmologists can certainly think about the Universe, and some do, what we are normally interested in is ***the observable Universe.*** The Observable Universe is only that part of the Universe from which emitted light could reach us on Earth in the time since the Big Bang.

Image: Hubble Extreme Deep Field (NASA)

The Stuff Filling the Universe

At the turn of the 20th Century, humans were slowly filling in the entries of the Periodic Table, the list of 92 known atomic elements from which everything on Earth is made. Today, a century later, we've discovered that those elements only make up about 5% of all the substances that fill the Universe. About 27% of the Universe is made up of an unknown substance called ***dark matter***, the existence of which is known from its influence on galaxies. The remaining 68% of the composition of the Universe is a mysterious substance known as ***dark energy***, the existence of which is known from its influence on the expansion of the Universe. Identifying *what* the dark matter and dark energy are is one of the most important objectives in modern cosmology.

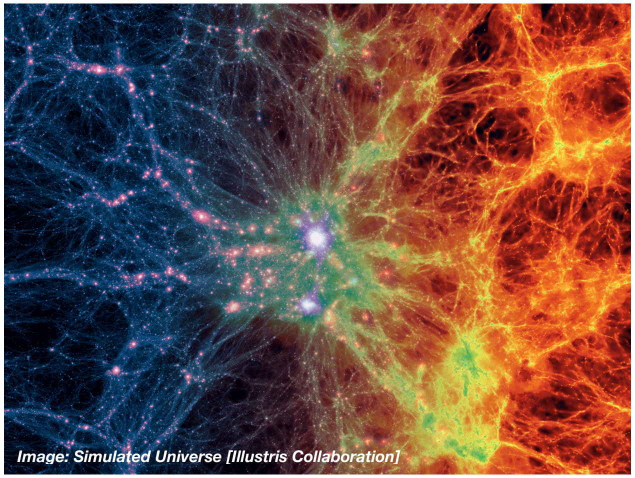


Image: Simulated Universe [Illustris Collaboration]

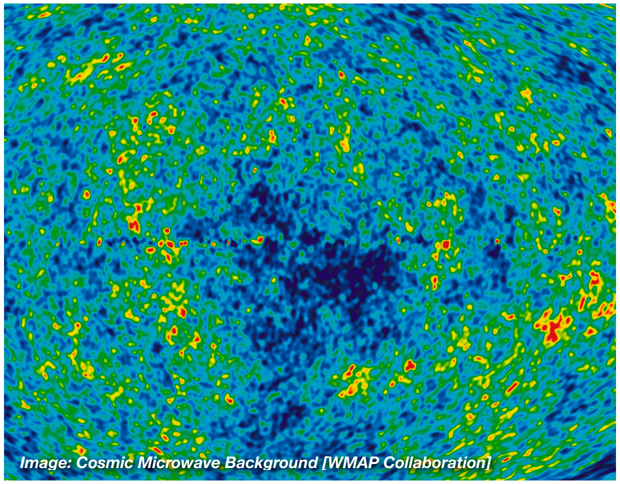


Image: Cosmic Microwave Background [WMAP Collaboration]

Mapping the Cosmos

Measuring distances is the hardest problem in astronomy, and it is even harder when the distances span the Universe. Mapping the Universe begins by measuring distances to the nearest galaxies. We know galaxies tend to group together in clusters, and as we map the clusters out we find they are strewn through the Universe in an intricate web of cosmic structure. The filamentary structure of this web is a signature of how matter was distributed in the earliest times after the birth of the Universe. The record of those times is encoded in the Cosmic Microwave Background, the relic light that was set free when the first atoms were formed.

From Quarks to the Cosmos

The Universe is the largest thing we can observe. In a curious coincidence of nature, we can learn about the Universe through particle physics, the study of the smallest objects in the Universe. Modern particle accelerators can squeeze matter and energy into small packets, to enormous densities that are reminiscent of the early Universe. By studying these brief moments in our particle accelerators, we hope to understand the conditions near the birth of the Universe. It also seems likely that whatever the dark matter and dark energy are, their identity may be discerned through particle physics experiments.