GALAXIES AND THE UNIVERSE | LESSON 9

To the Edge of Everything

A step-by-step zoom from Earth to the edge of the observable universe, and the tools that measure it.

Grades 6-12 | About 15 minutes of narrated flight, plus discussion stops | 11 stops | Start: learn.allseeing.space/edge-of-everything

What students will see and do

Students pull back from Earth to the Moon, the solar system, the nearest stars, the Milky Way, neighboring galaxies, galaxy clusters, the cosmic web and finally the edge of the observable universe, using light travel time as a ruler.

Learning objectives

- Order structures in the universe from smallest to largest
- Use light travel time to describe very large distances
- Describe parallax and Cepheid stars as distance tools
- Explain evidence for the Big Bang and why the observable universe has an edge

NGSS connections

MS-ESS1-3	Scale properties from planets to galaxy superclusters.
MS-ESS1-2	Gravity holds galaxies, groups and clusters together.
HS-ESS1-2	Evidence for the Big Bang: galaxies moving apart and the cosmic microwave background.
DCI ESS1.A	The Universe and Its Stars.

40-minute class plan

1. 5 min: pre-lesson prompt. Before we fly: rank these from smallest to largest: galaxy, solar system, planet, galaxy cluster, star.
2. 18-20 min: run the lesson. Keep discussion stops short (1-2 minutes each) or turn them off in the Lessons menu.
3. 8 min: whole-class discussion using two of the questions below.
4. 5 min: Exit ticket: If light from a galaxy took 50 million years to reach us, what are we really seeing? Explain in one sentence.

Full exploration (about 60 minutes)

1. 5 min: pre-lesson prompt, recorded so students can revisit it.
2. 25-30 min: run the lesson with every discussion stop at full length.
3. 15 min: follow-up activity. Powers of ten line: students place cards (Earth, Moon distance, Sun, Neptune, nearest star, Milky Way, Andromeda) on a log-scale string.
4. 10 min: revisit the pre-lesson ideas, then the exit ticket.

Before the lesson

Before we fly: rank these from smallest to largest: galaxy, solar system, planet, galaxy cluster, star.

Discussion stops: timing and key points

At Light-years (3-4 min): Light from Alpha Centauri takes over four years to reach us. If you were nine years old when its light left, how old would you be when it arrived? What does that mean about the stars we see?

- Nine plus about 4.4 years is about 13.
- We always see stars as they were when the light left them, not as they are now.

At The cosmic web (4-6 min): Most of the universe seems to be made of dark matter and dark energy that we cannot see. How can scientists study something they cannot see? Think of other invisible things you know exist.

- Scientists study dark matter by its effects: how fast galaxies spin, how its gravity bends light (gravitational lensing), and how structures grow.
- Everyday invisible things we detect by effects: wind, magnetism, air pressure, gravity itself.
- Dark energy is inferred from the speeding-up expansion of the universe.

More questions for after the lesson

1. Why can we not see beyond the observable universe?
2. What did Edwin Hubble discover in 1923, and why did it matter?
3. Why might predictions billions of years ahead, like Andromeda's future, be uncertain?

Vocabulary

light-year, parallax, galaxy, Local Group, supercluster, cosmic web, dark matter, cosmic microwave background

Exit ticket

Exit ticket: If light from a galaxy took 50 million years to reach us, what are we really seeing? Explain in one sentence.

Follow-up activities

- Powers of ten line: students place cards (Earth, Moon distance, Sun, Neptune, nearest star, Milky Way, Andromeda) on a log-scale string.
- Parallax with thumbs: measure the jump of a thumb against the wall at two arm lengths.
- Expanding balloon universe: draw dots on a balloon and measure how their distances grow as it inflates.

Full transcript

Introduction

Welcome to To the Edge of Everything. This is a journey about scale. We will start at home and keep pulling back, step by step, until we reach the edge of everything that can be seen. At each step, notice how long light takes to cross the distance. Light is the fastest thing there is, about three hundred thousand

kilometers every second, so it makes a perfect ruler.

Our question for this lesson: how can something so big be measured at all? Listen for the tools astronomers use.

1. Home

We begin with Earth, about twelve thousand seven hundred kilometers wide. Every person who has ever lived, every city, ocean, and mountain, is here. A beam of light could travel around Earth's equator about seven and a half times in one second.

More than two thousand years ago, a Greek scholar named Eratosthenes measured Earth's size using shadows. He knew that at noon on a certain day, the Sun shone straight down a well in one city, while in another city to the north, a stick cast a short shadow. From the angle of that shadow and the distance between the cities, he calculated Earth's circumference remarkably well. It was one of the first great measurements of scale.

2. One light-second

The Moon is about three hundred and eighty four thousand kilometers away. Light takes about one and a quarter seconds to cross that gap. When astronauts on the Moon talked to mission control, every reply had a small delay because of it.

Here is a surprising fact. You could fit all the other planets of the solar system side by side in the space between Earth and the Moon, with room to spare. Space is mostly empty, even close to home.

We know the Moon's distance to within a few centimeters. Apollo astronauts left mirrors on its surface, and scientists still bounce laser beams off them today, timing how long the light takes to come back.

3. Light-hours

Now the whole solar system. Light from the Sun takes about eight minutes to reach Earth, about forty three minutes to reach Jupiter, and around four hours to reach Neptune. The planets are tiny specks in a vast emptiness.

Our farthest messenger is the Voyager one spacecraft, launched in nineteen seventy seven. In twenty twelve it crossed into interstellar space, the region beyond the Sun's wind of particles. It is now nearly a full light-day from Earth. Its radio signals, traveling at the speed of light, take almost a day to reach us.

In nineteen ninety, as Voyager one headed out of the solar system, it turned its camera back toward home from about six billion kilometers away. In that picture, Earth is a single pale blue dot, smaller than a pixel, floating in a sunbeam. Everything you know fits inside that dot.

And still the Sun's gravity reaches farther. A huge cloud of icy comets, the Oort Cloud, may stretch more than a light-year away. Voyager will not reach it for hundreds of years.

4. Light-years

This is Alpha Centauri, the nearest star system, about four point four light-years away. Light from here takes more than four years to reach you. The starlight you see tonight left before many of you started school.

How do we measure the distance to a star? Hold a finger up and look at it with one eye, then the other. Your finger seems to jump against the background. That is called parallax. As Earth orbits the Sun, nearby stars seem to shift very slightly against far-away stars. By measuring that tiny shift, astronomers calculate their distances. The Gaia spacecraft has used parallax to map the positions of more than a billion stars.

Discussion stop: Light from Alpha Centauri takes over four years to reach us. If you were nine years old when its light left, how old would you be when it arrived? What does that mean about the stars we see?

5. Our galaxy

Pull back much farther, and here is our galaxy, the Milky Way. It is a flat, spinning disk with spiral arms, about one hundred thousand light-years across, holding a few hundred billion stars. The Sun is just one of them, about halfway out from the center.

On a dark night away from city lights, you can see the Milky Way as a pale band across the sky. That band is the disk of our galaxy, seen from inside. Your ancestors looked at the same glow for thousands of years before anyone knew what it was. In sixteen ten, Galileo turned his telescope on it and discovered it was made of countless faint stars.

Most of the Milky Way's mass is not in stars at all. It is in dark matter, something that has gravity but gives off no light. We know it is there because the galaxy spins too fast to hold itself together with the gravity of its visible stars alone.

6. A satellite galaxy

This is the Large Magellanic Cloud, about one hundred and sixty thousand light-years away, a small galaxy orbiting the Milky Way. From the southern hemisphere it looks like a detached piece of the Milky Way. It is named after Ferdinand Magellan, whose crew described it during their voyage around the world.

In nineteen eighty seven, a star in the Large Magellanic Cloud exploded as a supernova bright enough to see without a telescope. Its light had been traveling for about one hundred and sixty thousand years. When that light left, early modern humans were living in Africa.

7. Andromeda

Now we cross a real gulf, two and a half million light-years, to the Andromeda Galaxy. It is a spiral like ours, but bigger, with perhaps a trillion stars. On a dark night you can see it as a faint smudge. It is the most distant thing most people can see with their own eyes.

Until about a hundred years ago, many astronomers thought the Milky Way was the entire universe. In nineteen twenty three, Edwin Hubble found a special kind of pulsing star in Andromeda, a Cepheid, whose true brightness can be worked out from how fast it pulses. Comparing its true brightness with how faint it looked, he proved Andromeda was far outside our galaxy. Suddenly, the universe was full of galaxies.

Andromeda is moving toward us at more than one hundred kilometers per second. For a long time, astronomers expected a collision in about four to five billion years. Newer measurements suggest it is less certain than once thought, and the two galaxies might pass each other, or merge much later. Even if they do merge, stars are so far apart that they would almost never collide.

8. The Local Group

Pull back again. The Milky Way, Andromeda, the Triangulum Galaxy, and dozens of smaller galaxies form a family called the Local Group, about ten million light-years across. Gravity holds this family together.

Most of the galaxies in the Local Group are small dwarf galaxies, some with only a few thousand stars. New ones are still being discovered, because they are so faint.

Even this whole family is on the move. Measured against the afterglow of the Big Bang, the Local Group is traveling through space at about six hundred kilometers every second, pulled by the gravity of even larger structures around it.

9. The Virgo Cluster

This is the Virgo Cluster, about fifty four million light-years away, a huge city of more than a thousand galaxies. At its heart is the giant galaxy M87, home of the first black hole ever photographed.

Our Local Group is like a small town on the outskirts of the Virgo Cluster. Both are part of an even larger structure called the Laniakea Supercluster, about five hundred million light-years across, containing around a hundred thousand galaxies. Laniakea means immeasurable heaven in Hawaiian.

Light from the Virgo Cluster left about fifty four million years ago. That was not long after the dinosaurs disappeared from Earth. Every galaxy you see out here, you are seeing as it was, not as it is.

10. The cosmic web

Now we see the largest structure in the universe, the cosmic web. Galaxies are not scattered evenly. They gather along long filaments and sheets, surrounding enormous empty regions called voids, some hundreds of millions of light-years across. It looks a little like foam, or a spider's web.

Dark matter forms the scaffolding of this web. Its gravity pulled ordinary gas into the filaments, where galaxies formed. Scientists estimate that normal matter, everything made of atoms, is only about five percent of the universe. Dark matter makes up about twenty seven percent. The rest, about sixty eight percent, is dark energy, a mysterious something that is making the expansion of the universe speed up.

In the nineteen twenties, Edwin Hubble and others showed that distant galaxies are moving away from us, and the farther they are, the faster they recede. The universe is expanding. Run that expansion backward, and everything comes together about thirteen point eight billion years ago, at the Big Bang.

Discussion stop: Most of the universe seems to be made of dark matter and dark energy that we cannot see. How can scientists study something they cannot see? Think of other invisible things you know exist.

11. The edge of what can be seen

And here we reach the edge of the observable universe. It is a sphere around us with a radius of about forty six billion light-years. That may seem strange, because the universe is only thirteen point eight billion years old. But space has been stretching the whole time light was traveling, so the places that light came from are now much farther away.

The oldest light we can detect is called the cosmic microwave background. It was released about three hundred and eighty thousand years after the Big Bang, when the universe cooled enough to become transparent. It fills the entire sky, and it is the afterglow of the beginning of everything.

Within this sphere there are hundreds of billions of galaxies, perhaps more, each with billions of stars. And the edge is not a wall. It is only the limit of how far light has had time to travel to us. The universe almost certainly continues beyond it. We simply cannot see that far, yet.

Wrap-up

Think about where we started: one small planet, twelve thousand kilometers wide. Light crosses it in a fraction of a second. Light from the edge of what we can see has been traveling for nearly fourteen billion years. Parallax, Cepheid stars, the redshift of galaxies, and the glow of the Big Bang are the tools that let us measure it all from this one small world.

You are part of a universe far larger than anyone imagined a century ago. Press L to choose another lesson, or ask me to take you anywhere we passed along the way.

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