THE 3-D UNIVERSE

THE 3-D UNIVERSE CONCEPTS

1. **2-D images cannot show the depth of the 3-D Universe**
2. **Our eyes alone cannot judge the distances to objects in space**
3. **If we know an object's true brightness, we can determine its distance**
4. **3-D models help us understand our place in the Universe**

Find out how the data collected by astronomers can be used to create three-dimensional models of the Universe. Explore these concepts further using the recommended resources mentioned in this reading selection.

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1 2-D images cannot show the depth of the 3-D Universe

All pictures of the sky taken from Earth are two-dimensional, but a flat picture or star map cannot show the true shape of the Universe. All it can show is how the Universe looks from Earth. To represent the actual shape and structure of the Universe, you need a three-dimensional map.

When astronomers talk about two-dimensional and three-dimensional maps, they describe them as **2-D** or **3-D** for short. A 2-D map is flat, like a picture or a map you would find in a book. To reach any position on the map, you need to move along one of two directions—either up and down, or left and right. On a map of the Earth, you would say north and south, or east and west. A scientist refers to these two directions as **dimensions.**

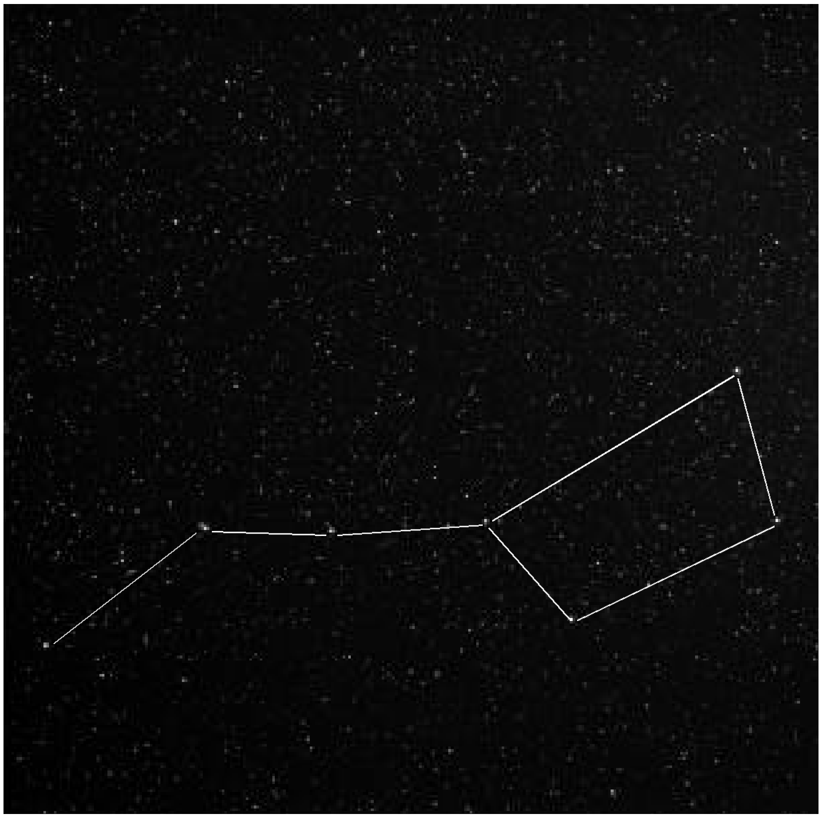
2-D maps work fine for a lot of things —cities, countries, even the surfaces of other planets can be depicted usefully in two dimensions. But what if you wanted to map out a six-story building, a complicated system of caves, or the structure of our galaxy? You would need a 3-D map to accomplish the task. In a 3-D map, we can move up and down, left and right, and additionally, forward and backward. Thus, a 3-D map more accurately describes the world we experience.

Once astronomers have created a 3-D map of the stars, they can store it on a computer and navigate through it. But to create these 3-D maps, astronomers must first calculate the distance between the various celestial bodies and Earth—information that is not apparent in a 2-D picture. Fortunately, astronomers have developed several clever methods to calculate the distances to the stars.

Try this Resource!

Students construct a **3-D Model of the Big Dipper** to demonstrate that stars and constellations are not arranged in a flat, 2-D pattern. This resource is available at http://www.amnh.org/education/resources/rfl/pdf/du_u09_bigdipper.pdf

John Sanford/SPL/Photo Researchers, Inc.



Although the Big Dipper appears as a 2-D, flat image, some stars which make up the dipper are nearly twice as far from Earth as others.

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Constellations Are Not What They Seem

When we look up at the sky to find constellations, we draw imaginary lines between the stars as if they were on a flat surface. But these flat patterns are not what they seem. For example, some of the stars in the Big Dipper are nearly twice as far from Earth as others, even though they appear to be right beside each other. If viewed from a different location in the Milky Way, these stars would not look like a dipper at all.

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If you're visiting the Moveable Museum, you can explore a 3-D model of the Big Dipper. It shows that the 2-D pattern formed by these stars can be seen from only one viewpoint.

2 Our eyes alone cannot judge the distances to objects in space

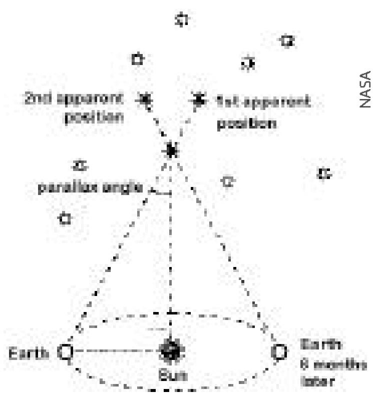
It is impossible to determine the distance to a star using your eyes alone. You are able to judge the distance to nearby objects because each eye views them from a different angle. Your brain combines these two perspectives to give you a 3-D view of the world, which allows you to judge distances up to about 20 feet. When the object you are looking at is trillions of miles away, however, having two viewpoints a few inches apart makes no difference. To determine distances greater than about 20 feet, you would need to move your eyes farther apart. Astronomers accomplish this by comparing pictures taken from different points in space.

To understand how distances can be judged by comparing views from two different angles, hold your thumb a few inches in front of your face and close one eye. Now open that eye and close the other. Your thumb appears to jump back and forth. Obviously, your thumb did not move. But depending on which eye you are looking from, your thumb appears to be in front of a different spot in the background. Your brain determines how far away your thumb is by noticing the differences between the two images provided by your eyes. The closer your thumb is, the greater its apparent shift against the background. This apparent displacement of an object caused by changing the angle of view is called parallax.

Astronomers use parallax to determine the distances to nearby stars. Instead of comparing the views from two eyes, however, they compare pictures taken millions of miles apart from different points in Earth's orbit. As Earth orbits the Sun over the course of a year, we view space from different vantage points. Since Earth is about 93 million miles from the Sun, Earth's position on one side of its orbit is about 186 million miles from its position six months later,when it is on the opposite side of the Sun. By comparing two pictures taken six months apart, astronomers can get two separate perspectives, allowing them to establish the distances to nearby stars. But even changing our perspective by 186 million miles is not enough to judge the distance to most celestial objects. Fortunately, astronomers have developed other ways to estimate the distances to stars, nebulae, and other celestial bodies.

Try this Resource!

Parallax demonstrates how to construct a simple astrolabe and calculate the distance to an object using mathematical principles related to parallax. This resource is available at http://www.amnh.org/education/resources/rfl/pdf/du_u10_parallax.pdf



NASA

! Some stars are a thousand times dimmer than the Sun; others are a million times brighter. Exploding stars called **supernovas** can blaze 10 billion times brighter than the Sun for a few days, emitting more light in that short period of time than the Sun does in its entire lifetime.

3 If we know an object's true brightness, we can determine its distance

One important clue to a star's distance is how bright it appears from Earth. The farther away a star is, the fainter it looks. Of course, you cannot tell a star's distance just by how bright it appears from Earth. For instance, a close, faint star can appear just as bright in the sky as a brighter star that is farther away. The difference between a star's actual brightness and its apparent brightness when seen from Earth indicates how far away it is.

To judge a star's distance, astronomers must first calculate how much light the star actually emits, which is called its luminosity. When estimating a star's luminosity, astronomers turn to clues contained in its "light fingerprint," or spectrum. By analyzing a star's spectrum, astronomers can determine its temperature. For the vast majority of stars, the temperature of the star is directly linked to its luminosity. This lets astronomers estimate the star's distance by comparing its luminosity to its apparent brightness in the sky.

However, distance estimates become less accurate for more distant stars. When distances become too large to estimate by either parallax or spectra, other methods must be used.

Cosmic Landmarks

Some kinds of stars can be used as landmarks even at very great distances. These stars are known as **standard candles**. Certain types of supernovas, for example, always explode at a predictable luminosity. Because these supernovas glow at a standard brightness, their distance can be estimated even when they are in galaxies or star clusters that are extremely far away.

Another example of standard candles are Cepheid variable stars. The brightness of these stars varies over a regular cycle. Astronomers have found that the time it takes a Cepheid to complete one cycle, or period, reveals its luminosity. Its distance can then be calculated from the difference between its luminosity and its apparent brightness. Cepheid variable stars, supernovas, and other standard candles serve as milepost markers for all the other stars in their galaxy or cluster.

As astronomers peer farther into space, their distance estimates build on each other and are checked against each other. Thus, astronomers continually build on what is known to extend their estimates one step farther into space.

4 3-D models help us understand our place in the universe

The science of astronomy addresses many fundamental questions: How did the Sun and Earth originate? How was the Universe born, and how will it end? Where do we fit into the big picture? Equipped only with the information that comes to Earth in light from distant objects, astronomers have made great strides in answering these questions.

Because astronomers can calculate the distances to celestial bodies, we are no longer limited to seeing the 2-D constellations of our ancestors. Today, astronomers can make 3-D maps, or computer models, that show the form and structure of the observable Universe, with planets revolving around stars, stars inhabiting galaxies, and clusters of galaxies expanding outward. These 3-D models free us from the limited perspective of our vantage point on Earth and help us find our place in the Universe.

Computer models of the Universe let astronomers translate their data into something they can see and experience. For example, astronomers can make predictions about what happens when two galaxies interact. They can then plug their data into a computer program and fly through a simulated 3-D model to see whether the results fit their predictions.

Looking Back in Time

The farther away an object is, the longer it takes for its light to reach Earth. In some cases, light that reaches Earth today actually left its source billions of years ago. The images formed by capturing this light in a telescope show the object not as it is today, but as it was when the light began its journey. When astronomers see these images, they are literally looking back in time.

If astronomers know how far away an object is, they can then determine how long it took for the light to reach them, and thus how far back in time they are looking. Seeing snapshots of the Universe at various stages in its history shows astronomers how the Universe has grown and evolved.

As more and more powerful telescopes are built, and as digital image processing improves, astronomers can see farther back in time than ever before. The most distant light sources yet observed show the Universe as it appeared more than ten billion years ago, when it was in its infancy. Images such as these provide vital clues toward understanding the origin and evolution of the Universe.

M If you're visiting the Moveable Museum, you can take a tour through a 3-D computer model of the Solar System, which lets them view the Sun and planets from points in space other than Earth.