

## Module 3: Astronomy – The Universe

### Topic 1 Content: Cosmology Presentation Notes

#### Introduction



Pretend that you have been given the opportunity to travel through time to explore cosmology. Cosmology is the study of how the universe formed and what will happen to it. Watch through your viewport as you journey billions of years into the past and then into the future. Hang on it could be a bumpy ride!

Image source: NASA

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**The Big Bang**

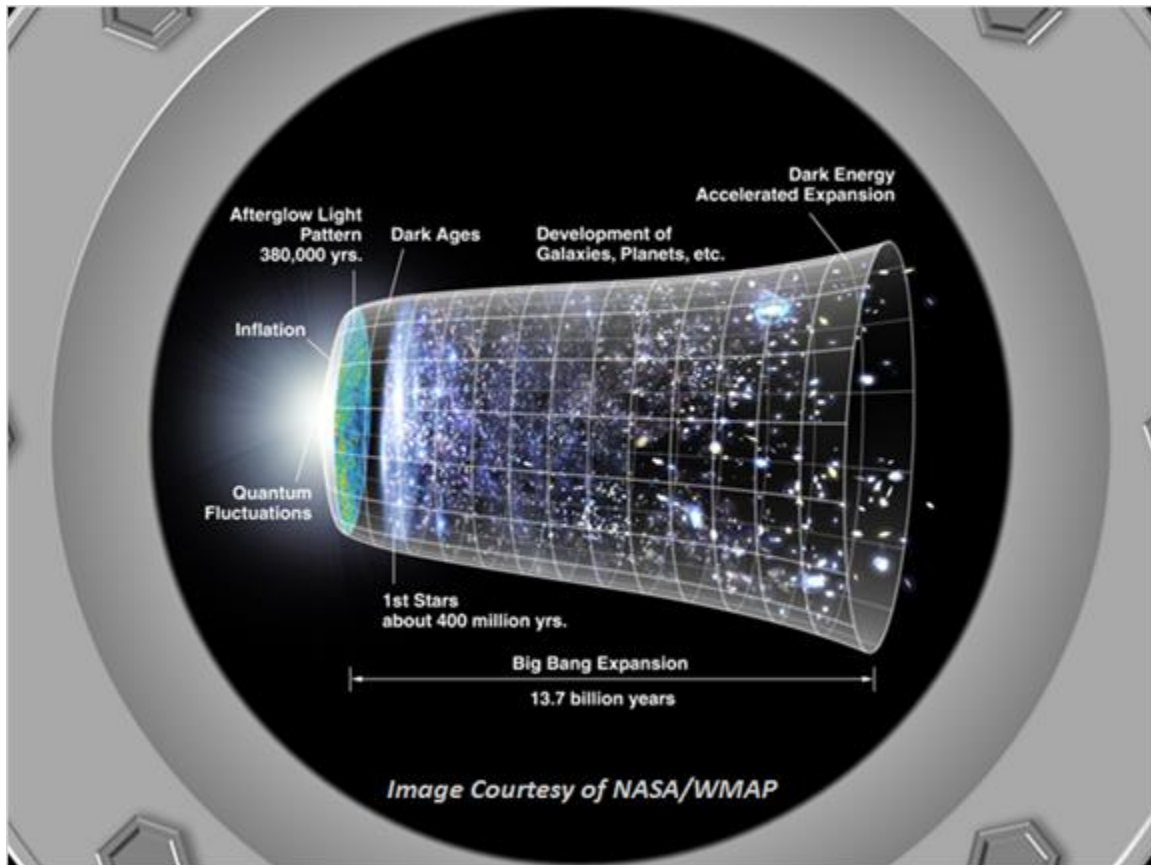


Imagine a time almost 14 billion years ago. Picture a place where an infinite density of matter exists in an infinitesimal space. According to scientists, the singularity was an invisible point from which emerged all of the matter and energy that would eventually become the universe, as you know it today. In 1949, Sir Fred Hoyle, an English scientist, named this phenomenon the Big Bang. Today, the theory that surrounds this idea is known as the Big Bang Theory.

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#### The Big Bang (continued)



Although scientists continue to study how the universe evolved, they theorize that the Big Bang was more of a big expansion of sorts, rather than an explosion. Around 13.7 billion years ago, an extremely hot and dense state of matter and energy suddenly emerged from the singularity. This hot and dense state expanded rapidly in all directions as it cooled over billions of years.

Gradually, the cooling matter and energy formed the elements that would become galaxies, stars, and eventually, planets like Earth. The image shown here illustrates one of the key pieces of evidence that makes the Big Bang Theory so widely accepted. Over time, galaxies expand and spread out. It was Edwin Hubble who first suggested that galaxies redshift, or appear redder in color on the electromagnetic spectrum as they move away from the viewer. This shows that the universe is continually expanding as time progresses.

Image source: NASA/WMAP

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**The Steady State Theory**



Prior to the Big Bang Theory, astronomers believed that the universe was eternal and unchanging. The leading theory of this time was the Steady State Theory. This theory simply states that the universe had no beginning; therefore, a Big Bang could have never occurred. The Steady State Theory states that new matter appeared from nothing to maintain the density of an expanding universe.

As technology advances were made in the field of astronomy, the Steady State Theory was abandoned. In 1965, astronomers discovered cosmic microwave background radiation. This type of radiation was not found to have a source. The leading explanation is that this radiation is leftover from the Big Bang. Using today's technologies, like radio and infrared telescopes, astronomers can collect clues that suggest a Big Bang event. Shown here is a high-resolution map of microwave light that scientists theorize was emitted from the Big Bang. This image has helped astronomers define the universe.

Image Courtesy of NASA

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### Universe Shape – Introduction

Introduction

The diagram shows three representations of universe shapes. At the top is a spherical grid with a red triangle and the word 'Closed' written on it. Below it is a curved, saddle-shaped grid with a red triangle and the word 'Flat'. At the bottom is a flat, rectangular grid with a red triangle and the word 'Open'.

What is the shape of the universe? Based on the amount of critical density, or the amount of matter in the universe, three different universes could exist. Click on each of the barred sections to learn more about each universe shape.

Closed Universe

Flat Universe

Open Universe

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**Universe Shape – Closed Universe**

Closed Universe

Closed Universe


Closed Universe

Flat Universe

Open Universe

Closed Universe

A closed universe could expand and evolve to a certain point. Once the critical density goes above the current estimate of  $9 \times 10^{-30} \text{ g/cm}^3$ , expansion stops and contraction begins. The universe could contract to one single point, the singularity, and another Big Bang could take place.



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#### Universe Shape – Closed Universe

Closed Universe

Flat Universe

### Flat Universe

A flat universe has the average critical density of  $9 \times 10^{-30} \text{ g/cm}^3$ , which means that the universe could continue to expand.



Open Universe

The image shows a 3D perspective of a flat universe represented by a black grid. A red triangle is drawn on the grid, with its vertices at the corners of a square. The grid extends into the distance, suggesting a flat, infinite plane.

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**Universe Shape – Open Universe**

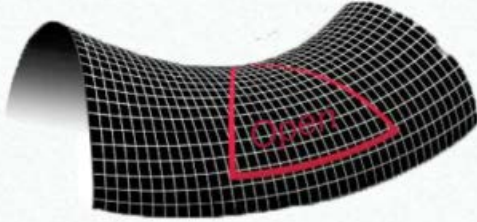
Closed Universe

Flat Universe

Open Universe

Open Universe

An open universe is one that does not have enough density to stop expansion and will continue to expand with no edge. Based on current calculations, the universe is part of an open universe.



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**The Big Chill**



The fate of the universe will ultimately depend on the type of universe. For instance, if the critical density increases, then the universe may be pulled back together to start another Big Bang. This is called the Big Crunch.

If the universe continues to expand and move away, then a Big Chill may take place. Over many billions of years, the Sun will no longer produce energy through fusion and will turn into a white dwarf. Eventually, it will stop producing light and energy of any kind. As the stars and galaxies are moving farther away from each other, so will the gas and dust. Stars will not be producing as much energy. As no new stars are created, the universe will grow dark and cold, hence the name, the Big Chill.

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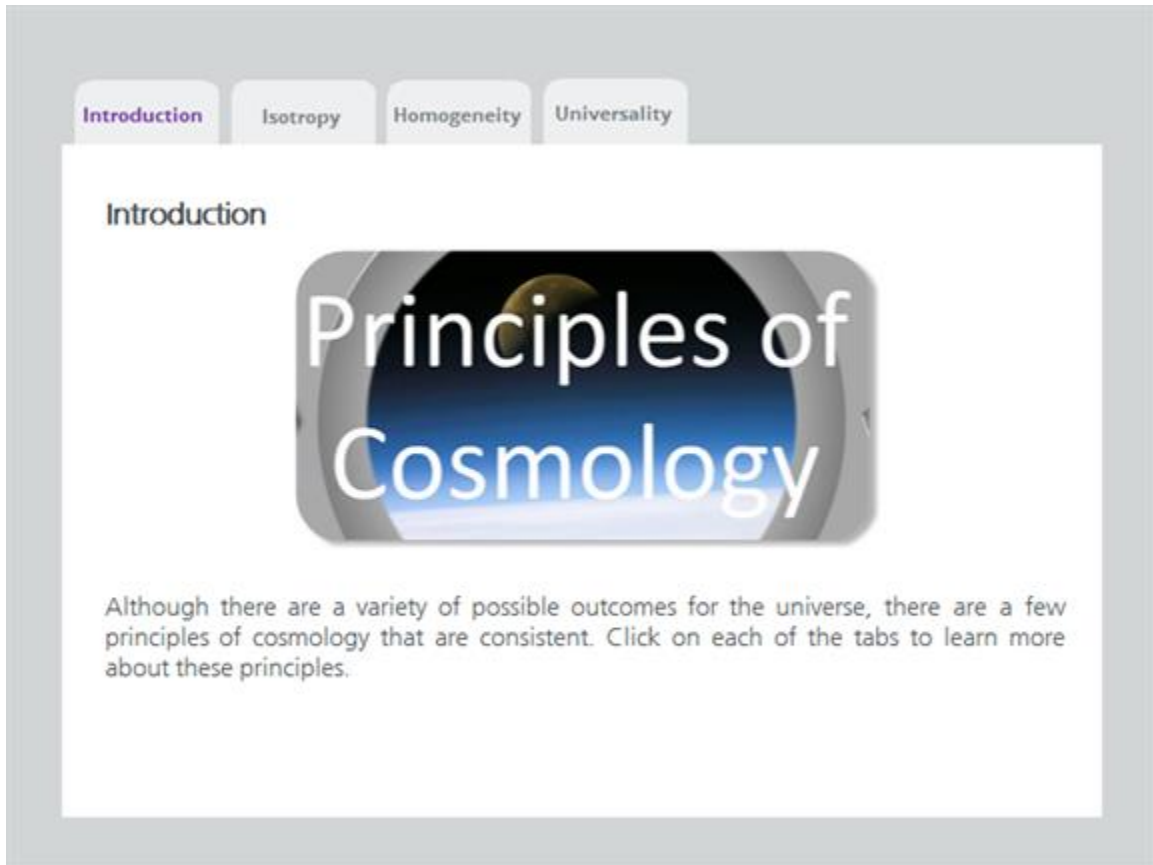
**Back to Safety**



Wow! You made it back safely. Before you deboard, there are a few more principles of cosmology that you should know.

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**Principles of Cosmology - Introduction**

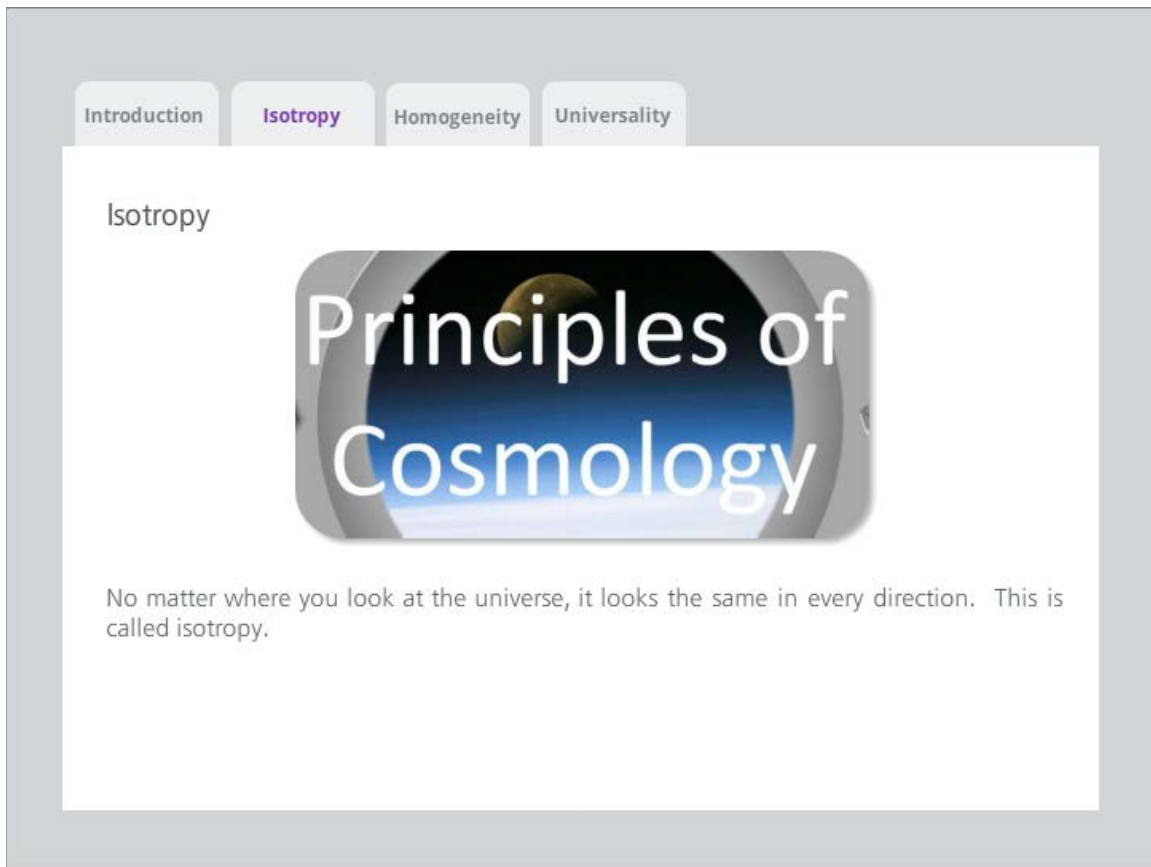


The image shows a presentation slide with a light gray background. At the top, there are four tabs: 'Introduction' (highlighted in purple), 'Isotropy', 'Homogeneity', and 'Universality'. Below the tabs, the word 'Introduction' is written in a simple font. In the center, there is a large graphic with the title 'Principles of Cosmology' in white text over a dark blue and black background featuring a planet and a star. Below the graphic, there is a paragraph of text: 'Although there are a variety of possible outcomes for the universe, there are a few principles of cosmology that are consistent. Click on each of the tabs to learn more about these principles.'

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**Principles of Cosmology – Isotropy**

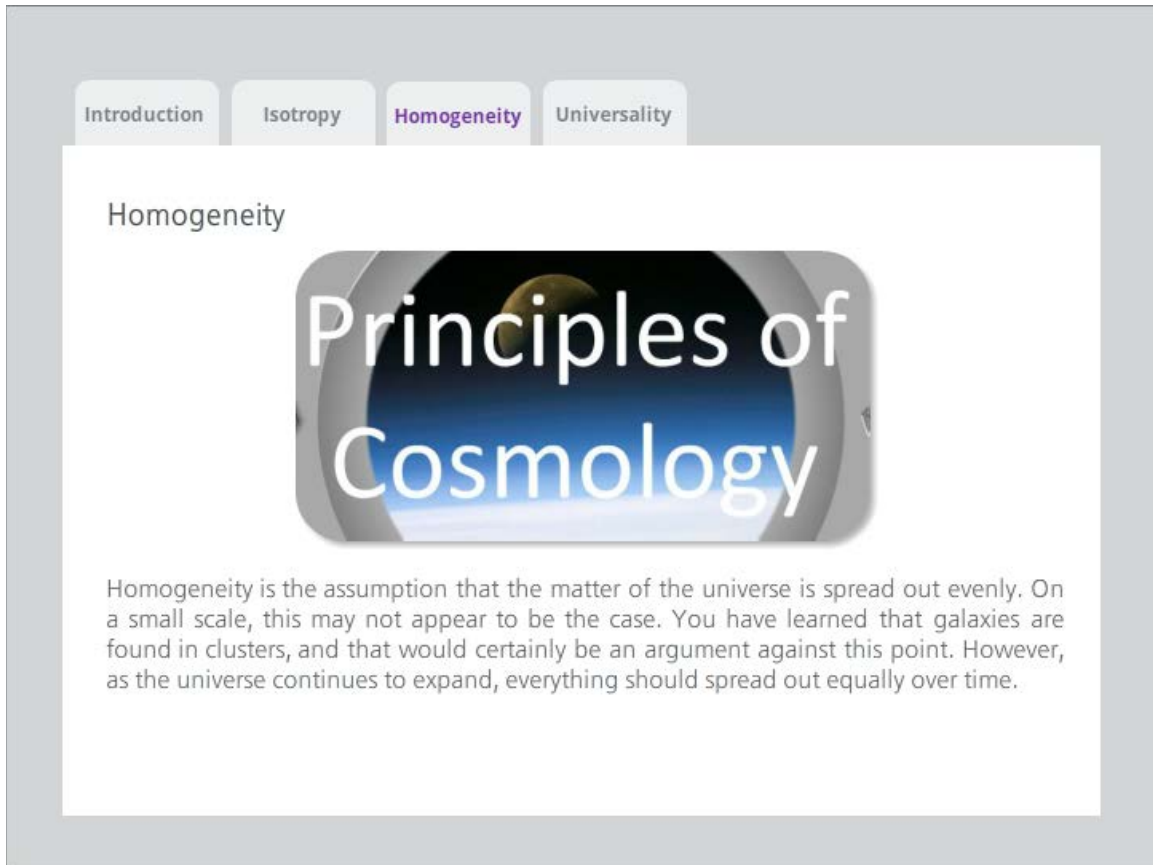


The image shows a screenshot of a presentation slide. At the top, there are four navigation tabs: 'Introduction', 'Isotropy' (highlighted in purple), 'Homogeneity', and 'Universality'. The main content area has the word 'Isotropy' at the top left. In the center is a graphic with the text 'Principles of Cosmology' overlaid on a view of Earth from space. Below the graphic, the text reads: 'No matter where you look at the universe, it looks the same in every direction. This is called isotropy.'

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**Principles of Cosmology – Homogeneity**

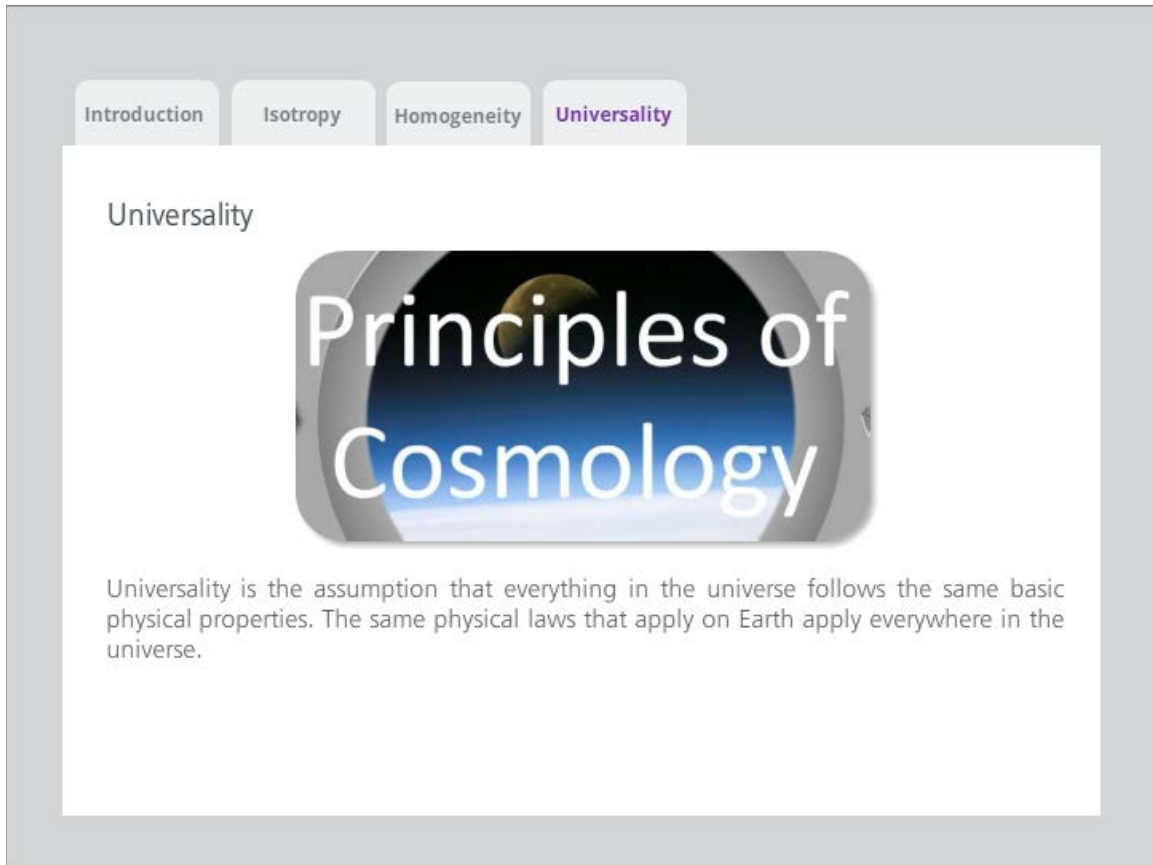


The image shows a screenshot of a presentation slide. At the top, there are four navigation tabs: 'Introduction', 'Isotropy', 'Homogeneity' (which is highlighted in purple), and 'Universality'. Below the tabs, the word 'Homogeneity' is written in a simple font. In the center, there is a graphic with the title 'Principles of Cosmology' overlaid on a background of a planet and a blue sky. Below the graphic, there is a paragraph of text explaining the concept of homogeneity.

Homogeneity is the assumption that the matter of the universe is spread out evenly. On a small scale, this may not appear to be the case. You have learned that galaxies are found in clusters, and that would certainly be an argument against this point. However, as the universe continues to expand, everything should spread out equally over time.

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**Principles of Cosmology - Universality**



The image shows a screenshot of a presentation slide. At the top, there are four navigation tabs: 'Introduction', 'Isotropy', 'Homogeneity', and 'Universality'. The 'Universality' tab is highlighted in purple. Below the tabs, the word 'Universality' is written in a simple font. In the center, there is a large graphic with the text 'Principles of Cosmology' overlaid on a background of a planet and a blue sky. Below the graphic, there is a paragraph of text: 'Universality is the assumption that everything in the universe follows the same basic physical properties. The same physical laws that apply on Earth apply everywhere in the universe.'

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