SC.912.E.5.1	
Benchmark Description:	Cite evidence used to develop and verify the scientific theory of the Big Bang (also known as the big bang theory) of the origin of the universe.
Standard:	Earth in space and Time - The origin and eventual fate of the Universe still remains one of the greatest questions in science. Gravity and energy influence the development and life cycle s of galaxies, including our own Milky Way galaxy, stars, the planetary systems, Earth, and residual material left from the formation of thesolar system . Humankind's need to explore continues to lead to the development of knowledge and understanding of the nature of the Universe.

SC.912.E.5.In.a:	**Recognize that the Milky Way is part of the expanding universe.**

» SC.912.E.5.Su.a:	**Recognize that the universe consists of many galaxies, including the Milky Way.**

» SC.912.E.5.Pa.a :	**Recognize that when objects move away from each other, the distance between them expands.**

For centuries, humans have gazed at the stars and wondered how the universe developed into what it is today.

People who have tried to uncover the mysteries of the universe's development include such famous scientists as Albert Einstein, Edwin Hubble and Stephen Hawking.

Edwin Hubble and Albert Einstein

Photo Credit :http://media.radiosai.org/Journals/Vol_06/01MAR08/04-musings.htm

One of the most famous and widely accepted models for the universe's development is the big bang theory.

Big Bang Theory

Although the big bang theory is famous, it's also widely misunderstood.

A common misperception about the theory is that it describes the origin of the universe.
That's not quite right.

The big bang is an attempt to explain how the universe developed from a very tiny, dense state into what it is today.

It doesn't attempt to explain what initiated the creation of the universe, or what came before the big bang or even what lies outside the universe.

Another misconception is that the big bang was a kind of explosion.

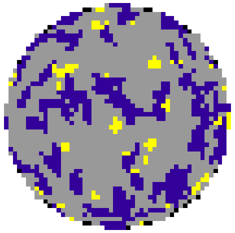
That's not accurate either.

The big bang describes the expansion of the universe.

It was an incredibly rapid expansion (possibly faster than the speed of light).

It's still not an explosion in the classic sense.

The most important concept to get across when talking about the Big Bang is expansion.

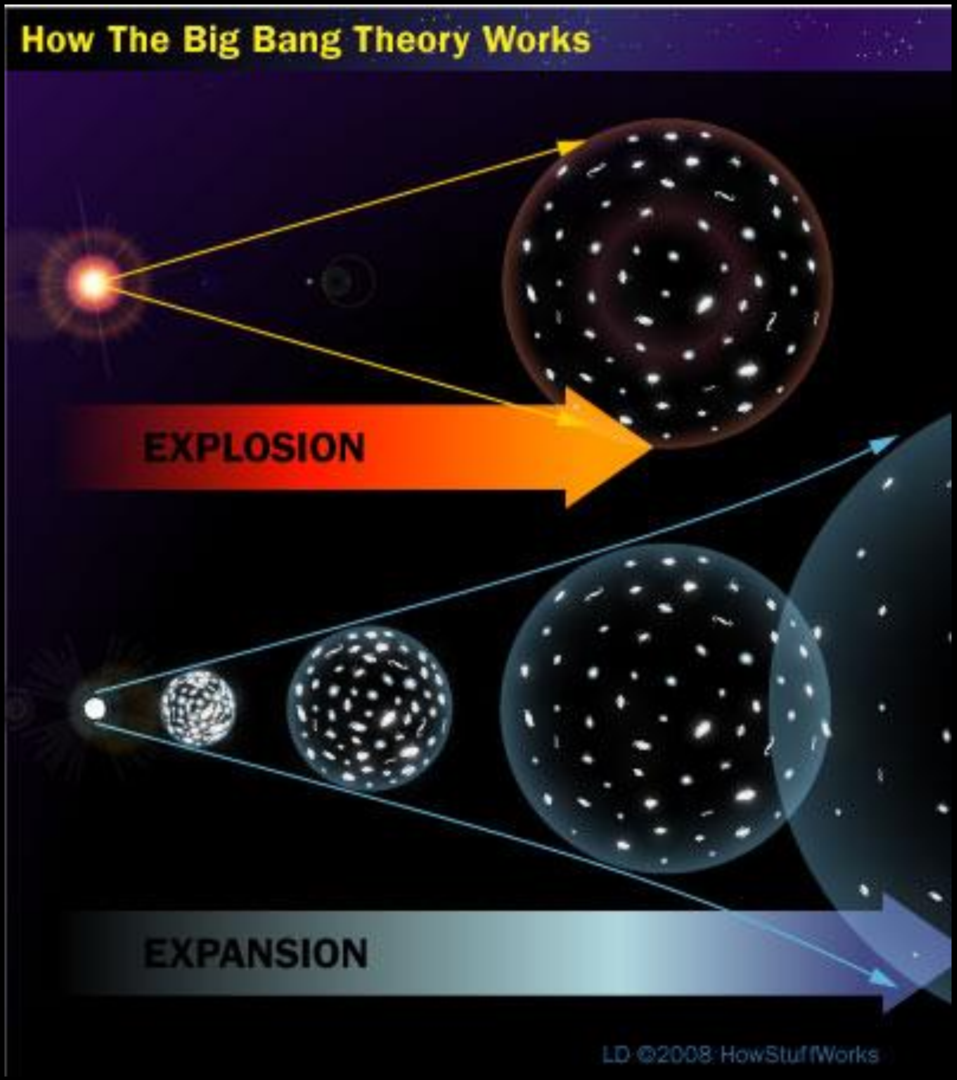


Many people think that the big bang is about a moment in which all the matter and energy in the universe was concentrated in a tiny point.

Then this point exploded, shooting matter across space, and the universe was born.

In fact, the big bang explains the expansion of space itself, which in turn means everything contained within space is spreading apart from everything else.

The illustration should help a little.



While many people believe that the Big Bang theory refers to an explosion, it actually refers to the expansion of the universe.

Today, when we look at the night sky, we see galaxies separated by what appears to be huge expanses of empty space.

At the earliest moments of the big bang, all of the matter, energy and space we could observe was compressed to an area of zero volume and infinite density. Cosmologists call this a singularity.

In only a few seconds, the universe formed out of a singularity that stretched across space.

Singularity

One result of the big bang was the formation of the four basic forces in the universe. These forces are:

Electromagnetism

Strong nuclear force

Weak nuclear force

Gravity

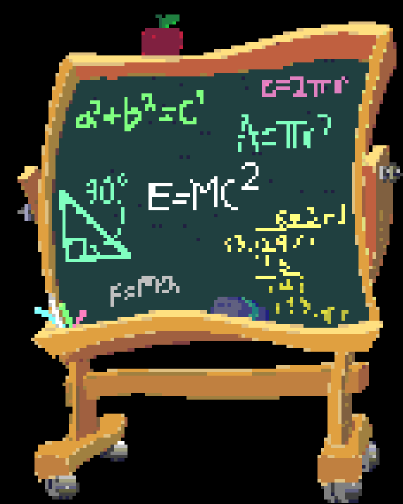
How these forces were once part of a unified whole is a mystery to scientists. Many physicists and cosmologists are still working on forming the Grand Unified Theory, which would explain how the four forces were once united and how they relate to one another.

Image Credit: Grand Unified Theory by Rob Kritkausky

The big bang theory is the result of two different approaches to studying the universe: astronomy and cosmology.

Astronomers use instruments to observe stars and other celestial bodies.

Cosmologists study the astrophysical properties of the universe.



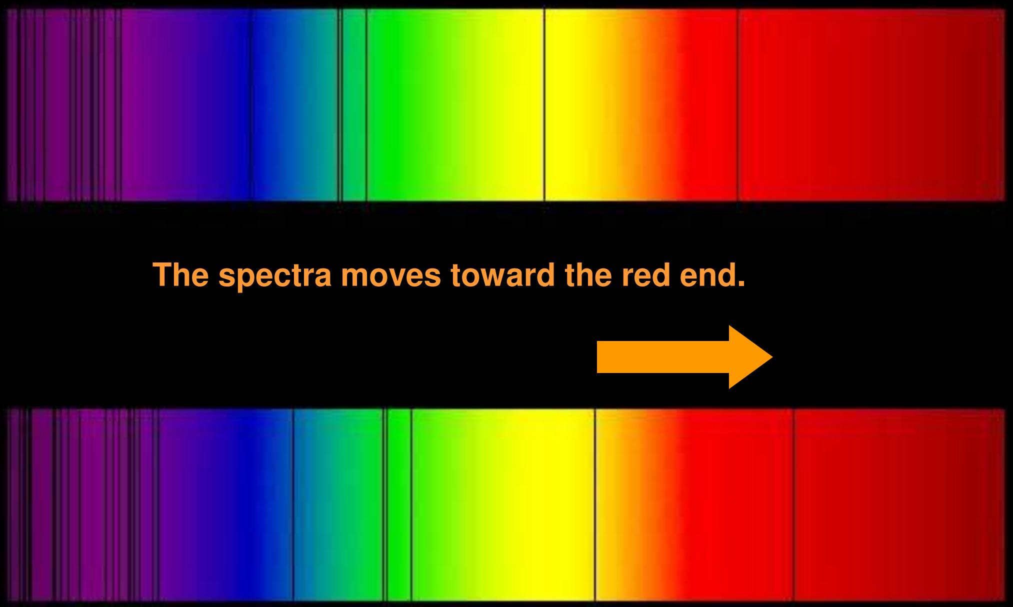
In the 1800s, astronomers began to experiment with tools called spectroscopes (also known as spectrographs).

A spectroscope is a device that divides light into a spectrum of its component wavelengths.

Spectroscopes showed that the light from a specific material, such as a glowing tube of hydrogen, always produced the same distribution of wavelengths unique to that material.

It became clear that by looking at the wavelength distribution from a spectrograph, you could figure out what kind of elements were in a light source.

Hydrogen spectra

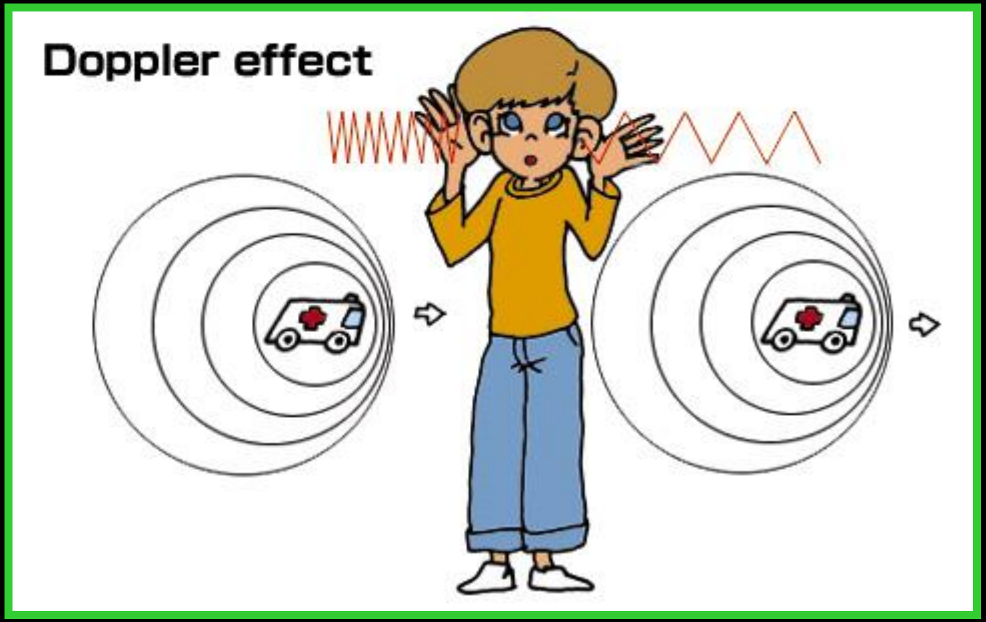


Hydrogen spectra from a galaxy moving away from Earth.

Meanwhile, Austrian physicist Christian Doppler discovered that the frequency of a sound wave depended upon the relative position of the source of the sound.

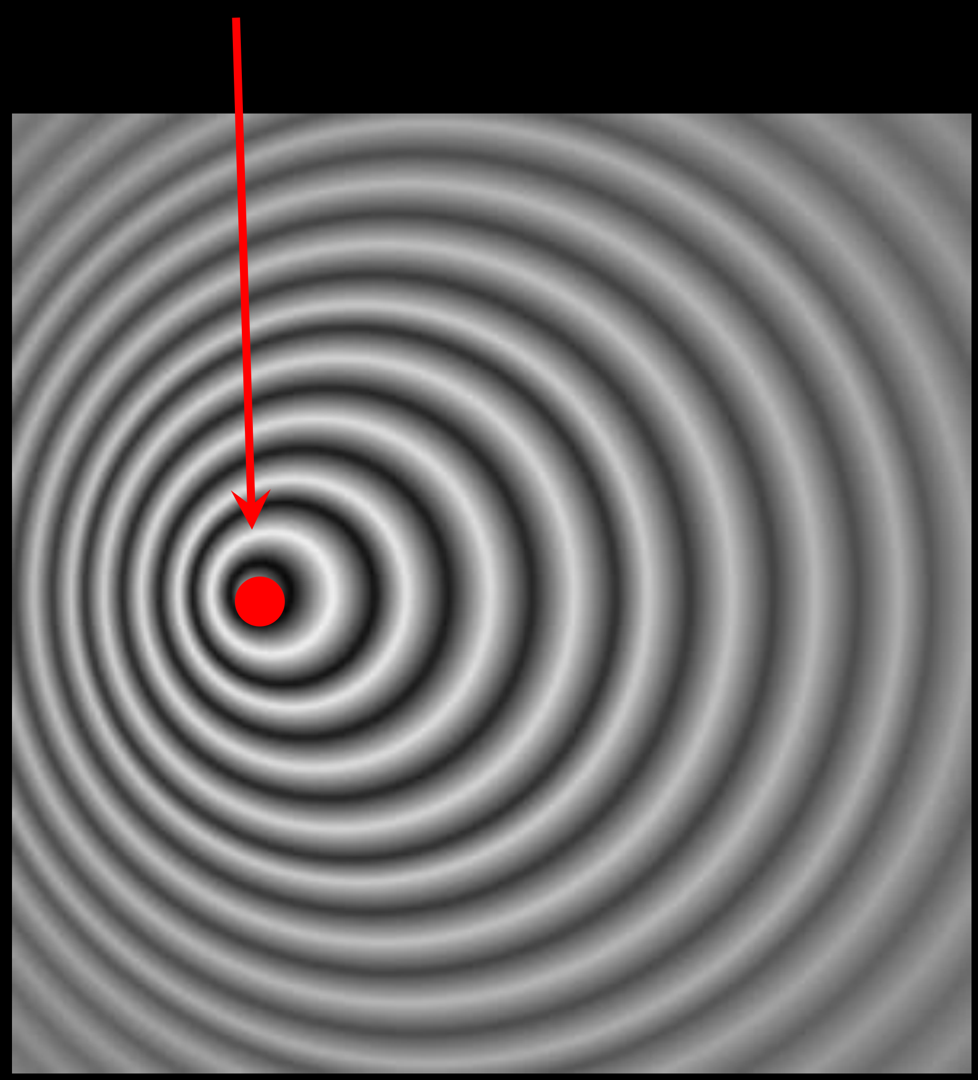
As a noisy object approaches you, the sound waves it generates compress. This changes the frequency of the sound, and so you perceive the sound as a different pitch.

When the object moves away from you, the sound waves stretch and the pitch goes down. It's called the Doppler effect.



While this illustration shows the Doppler effect with sound waves, light waves behave in a similar way.

Credit: Graphic illustration of the Doppler Effect



In the 1920s, an astronomer named Edwin Hubble noticed something interesting.

The velocity of a star appeared to be proportional to its distance from the Earth.

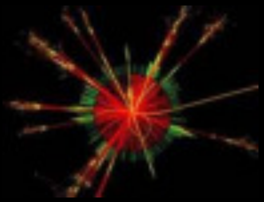
In other words, the further away a star was from Earth, the faster it appeared to move away from us.

Hubble theorized that this meant the universe itself was expanding.

Hubble theorized that the universe expands as time passes.

That meant that billions of years ago, the universe would have been much smaller and more dense.

If you go back far enough, the universe would collapse into an area with infinite density, containing all the matter, energy, space and time of the universe.

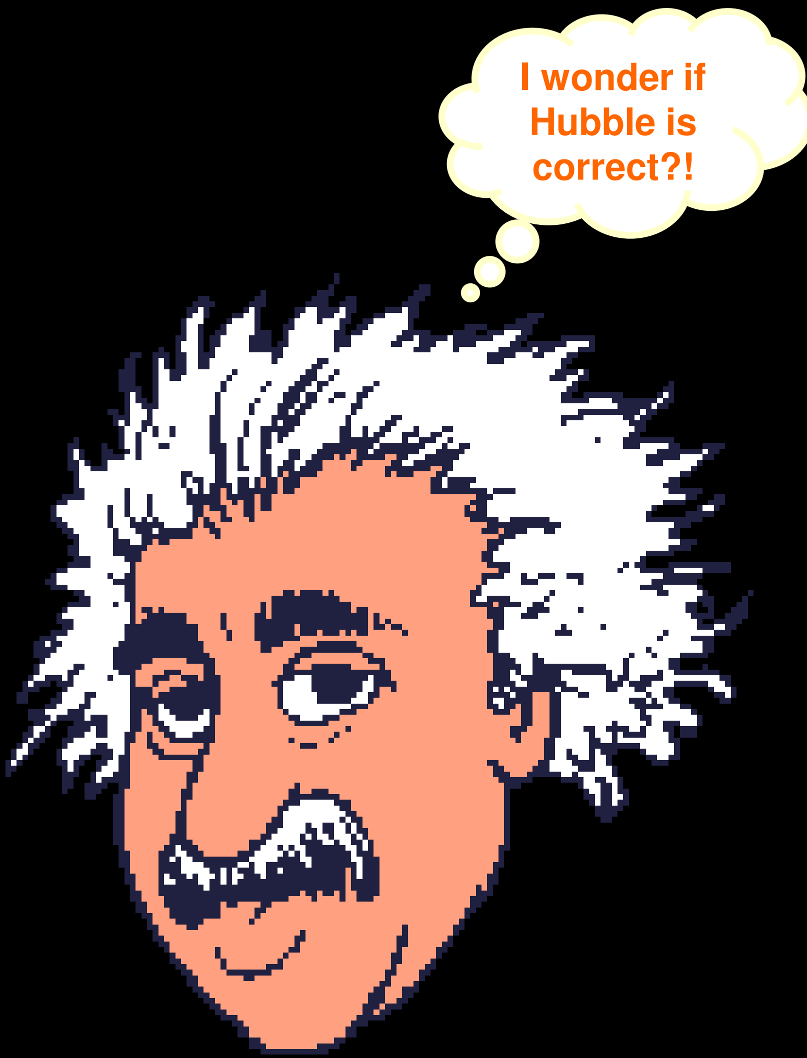


Some people had a real problem with this theory.

Among them was the famous physicist Albert Einstein. Einstein subscribed to the belief that the universe was static.

A static universe doesn't change.
It has always been and always will be the same.

Einstein hoped his theory of general relativity would give him a deeper understanding of the structure of the universe.



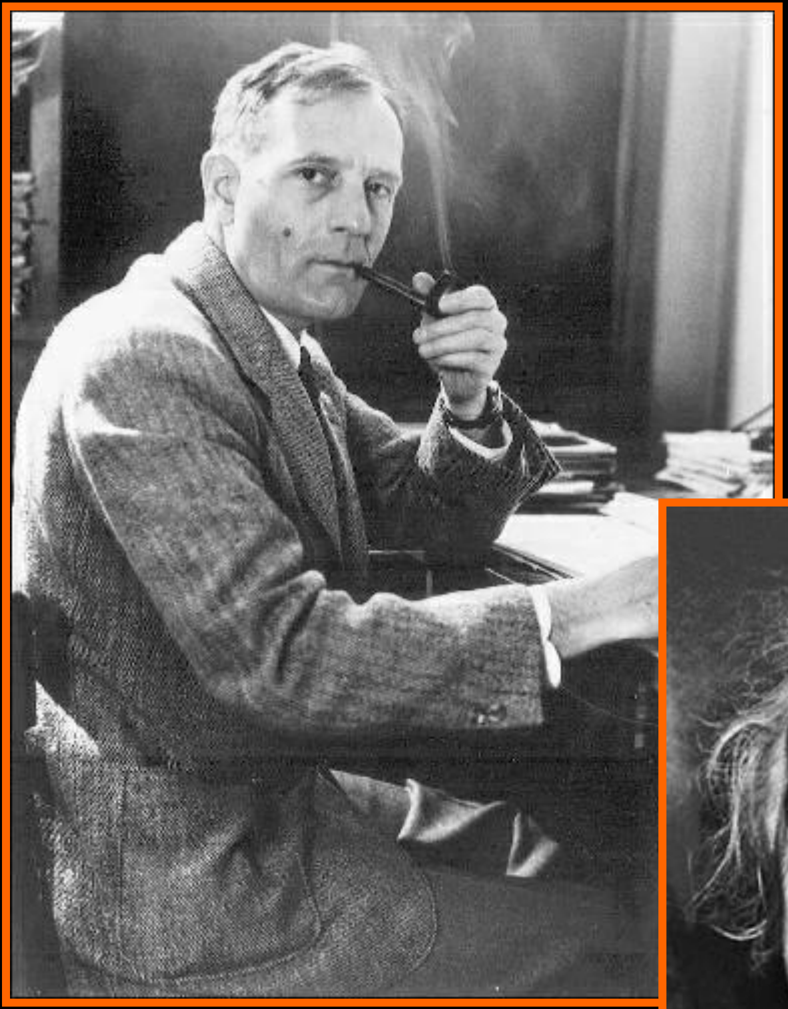
Upon completion of his theory, Einstein was surprised to discover that according to his calculations, the universe would have to be expanding or contracting.

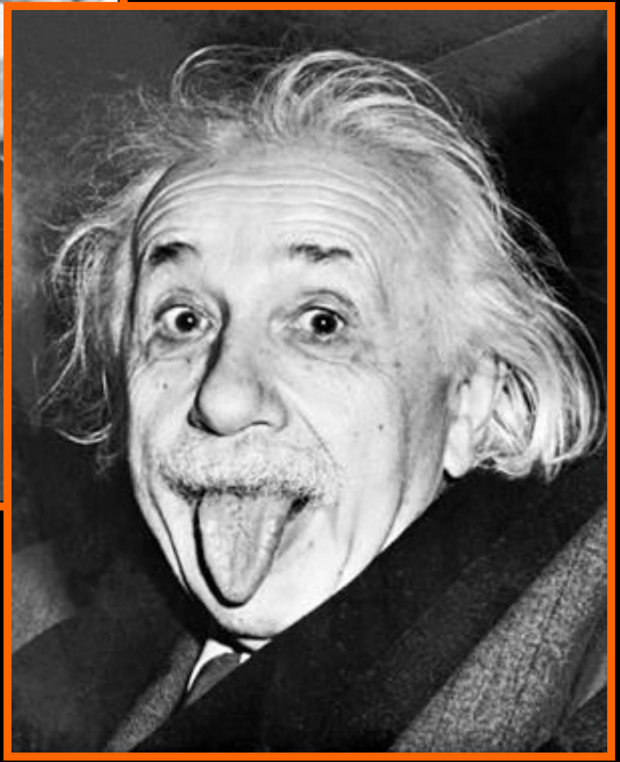
Since that conflicted with his belief that the universe was static, he searched around for a possible explanation.

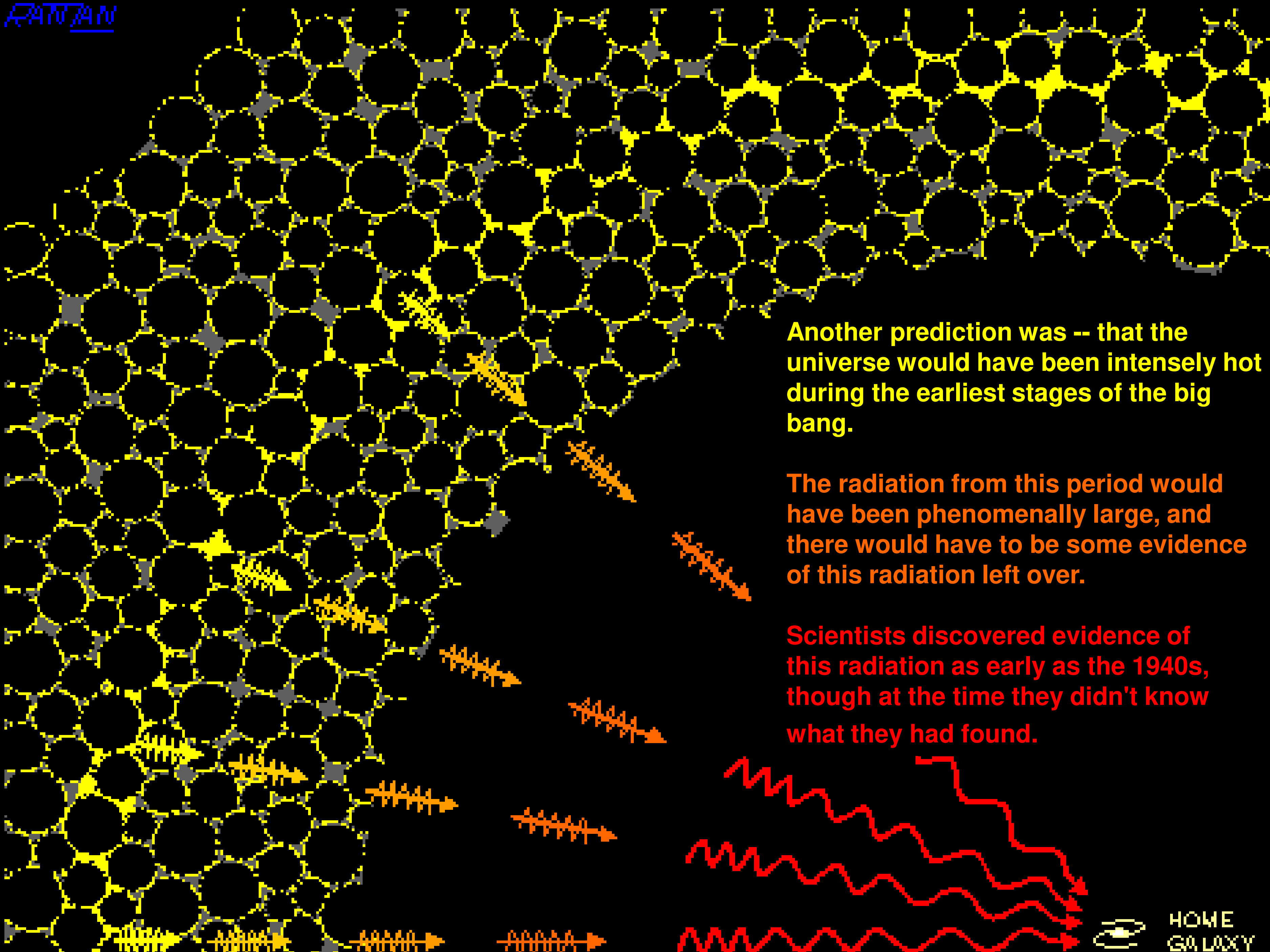
He proposed a cosmological constant -- a number that, when included in his general theory of relativity, explained away the apparent necessity for the universe to expand or contract.

When confronted with Hubble's findings, Einstein admitted that he was mistaken.

The universe did seem to be expanding, and Einstein's own theory supported the conclusion.







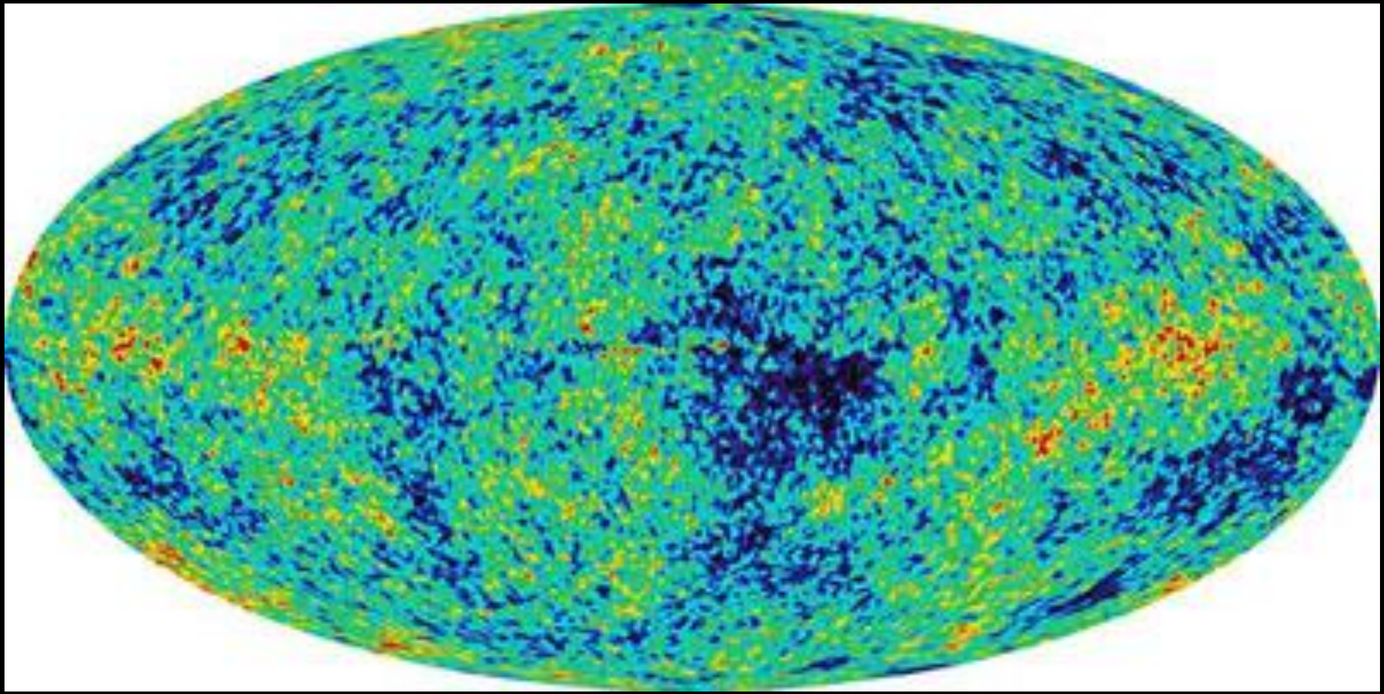
Another prediction was -- that the universe would have been intensely hot during the earliest stages of the big bang.

The radiation from this period would have been phenomenally large, and there would have to be some evidence of this radiation left over.

Scientists discovered evidence of this radiation as early as the 1940s, though at the time they didn't know what they had found.

It wasn't until the 1960s when two separate teams of scientists discovered what we now call the cosmic microwave background radiation (CMB). The CMB is the remnants of the intense energy emitted by the primordial fireball in the big bang.

These observations helped solidify the big bang theory as the predominant model for the evolution of the universe.



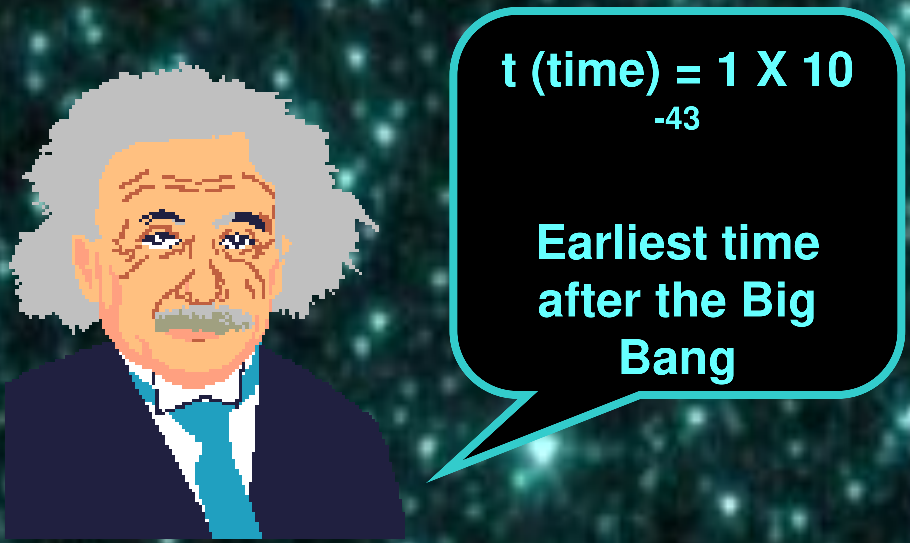
This image of the cosmic microwave background radiation was taken by the Wilkinson Microwave Anisotropy Probe.

Because of the limitations of the laws of science, we can't make any guesses about the instant the universe came into being.

Instead, we can look at the period immediately following the creation of the universe.

Right now, the earliest moment scientists talk about occurs at t = 1 x 10-43 seconds (the "t" stands for the time after the creation of the universe).

In other words, take the number 1.0 and move the decimal place to the left 43 times.

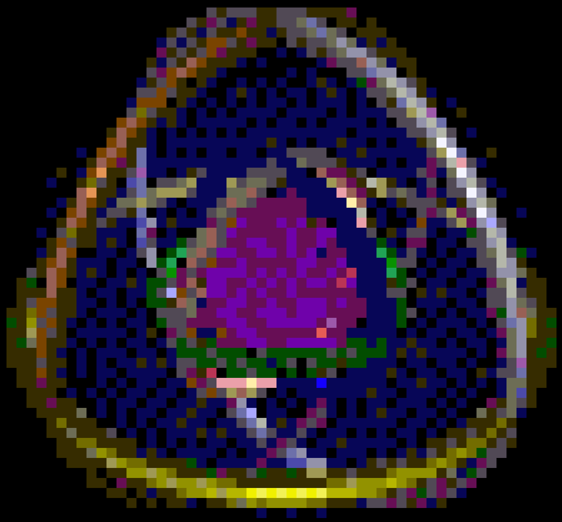


The study of these earliest moments is quantum cosmology

At the earliest moments of the big bang, the universe was so small that classical physics didn't apply to it. Instead, quantum physics were in play.

Quantum physics deal with physics on a subatomic scale. Much of the behavior of particles on the quantum scale seems strange to us, because the particles appear to defy our understanding of classical physics.

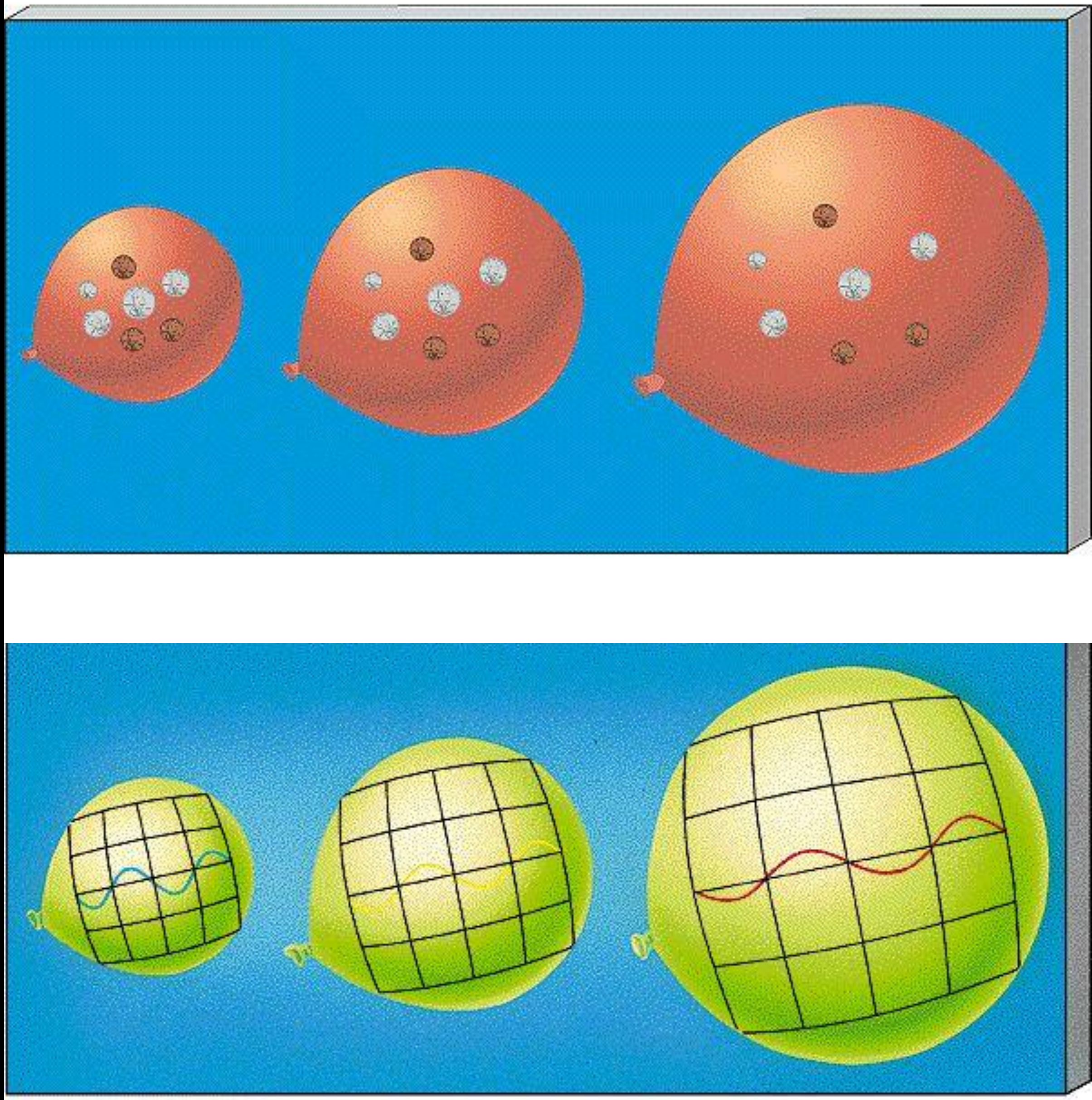
Scientists hope to discover the link between quantum and classical physics, which will give us a lot more information about how the universe works.



As tiny fractions of a second passed, the universe expanded rapidly.

Cosmologists refer to the universe's expansion as inflation.

The universe doubled in size several times in less than a second



Balloon Analog Of Cosmological Red shift - As the universe expands, photons of radiation are stretched in wavelength, giving rise to the cosmological red shift.

Image Credit: www.pas.rochester.edu/.../LectureXVI.html

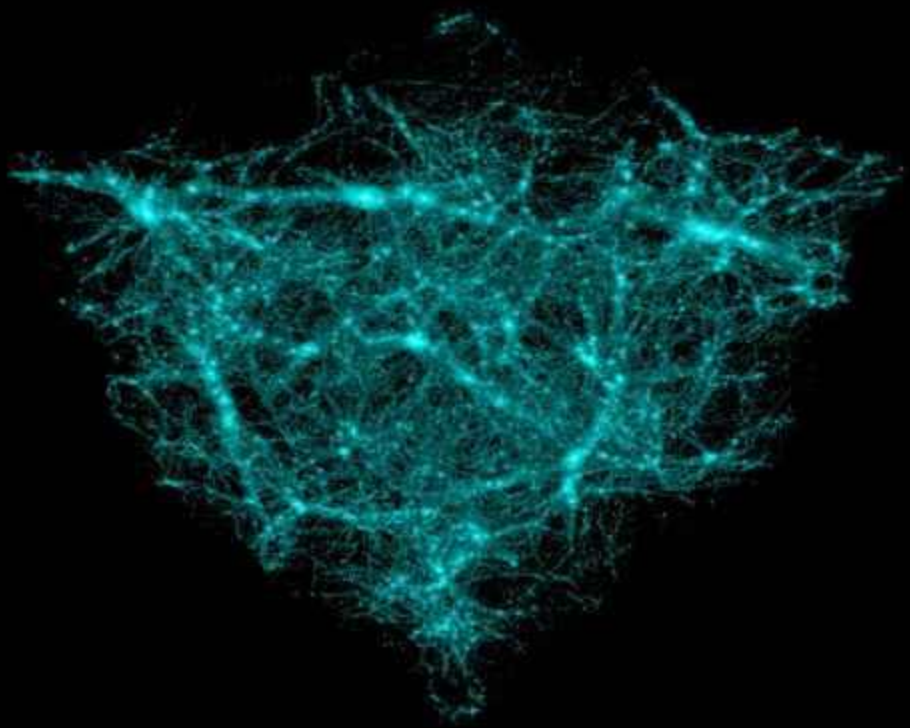
As the universe expanded, it cooled.

At around t = 1 x 10-35 seconds, matter and energy separated.

Cosmologists call this **baryogenesis** -- **baryonic matter** is the kind of matter we can observe. In contrast, we can't observe **dark matter**, but we know it exists by the way it affects energy and other matter.

During baryogenesis, the universe filled with a nearly equal amount of matter and anti-matter.

There was more matter than anti-matter, so while most particles and anti-particles annihilated each other, some particles survived.
These particles would later combine to form all the matter in the universe.

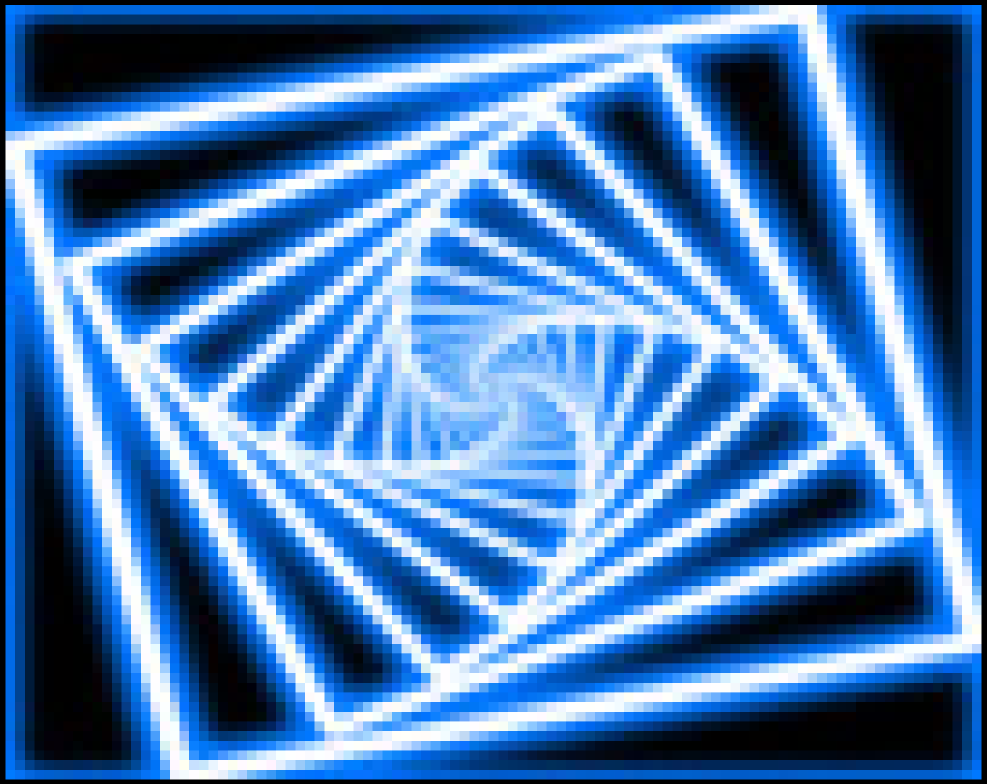


For the next 100 million years or so, the universe continued to expand and cool.

Small gravitational fluctuations caused particles of matter to cluster together.

Gravity caused gases in the universe to collapse into tight pockets.
As gases contract, they become more dense and hot.

Some 100 to 200 million years after the initial creation of the universe, stars formed from these pockets of gas.



Stars began to cluster together to form galaxies. Eventually, some stars went supernova. As the stars exploded, they ejected matter across the universe. This matter included all the heavier elements we find in nature (everything up to uranium). Galaxies in turn formed their own clusters.

Our own solar system formed around 4.6 billion years ago

The discovery that the universe is expanding led to another question.

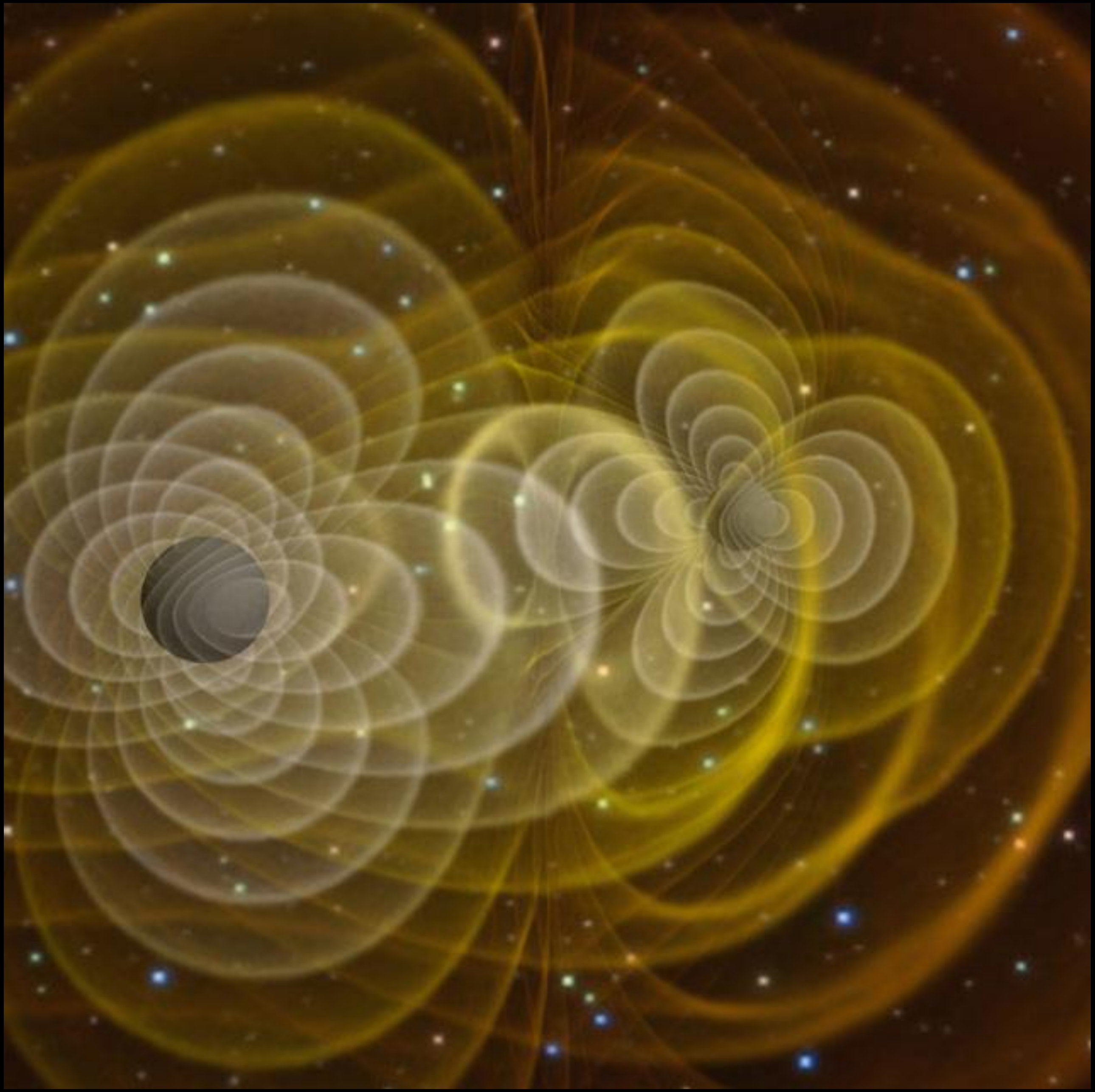
Will it expand forever? Will it stop? Will it reverse?

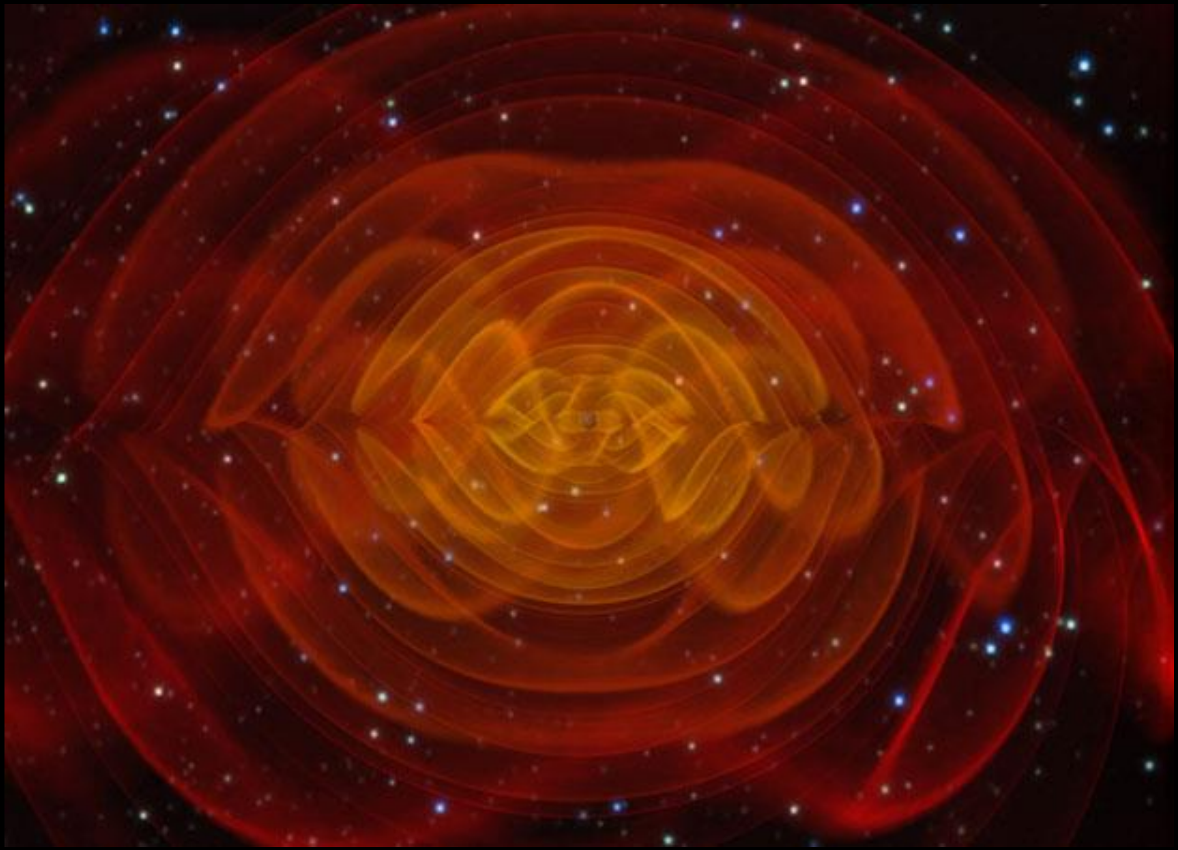
According to the general theory of relativity, it all depends on how much matter is within the universe.

It boils down to gravity.

Gravity is the force of attraction between particles of matter.

The amount of gravitational force one body exerts on another depends upon the size of the two objects and the distance between them.





If there's enough matter in the universe, the force of gravity will eventually slow the expansion and cause the universe to contract.

Cosmologists would designate this as a closed universe.

But if there isn't enough matter to reverse expansion, the universe will expand forever.

Caption: Artist depiction of gravity waves around merging black holes. Credit: NASA

Today’s funny…

Why do astronomers dislike cosmologists?
Because astronomers do all the counting while cosmologists do all the thinking.

Thanks for visiting.

See you soon!

This presentation is an adaptation of the following site:

Strickland, Jonathan. "How the Big Bang Theory Works." 18 June 2008. HowStuffWorks.com. <http://science.howstuffworks.com/big-bang-theory.htm> 02 April 2010.