




Evidence for the Big Bang Theory

HAVE YOUR CORNELL NOTES HANDY!



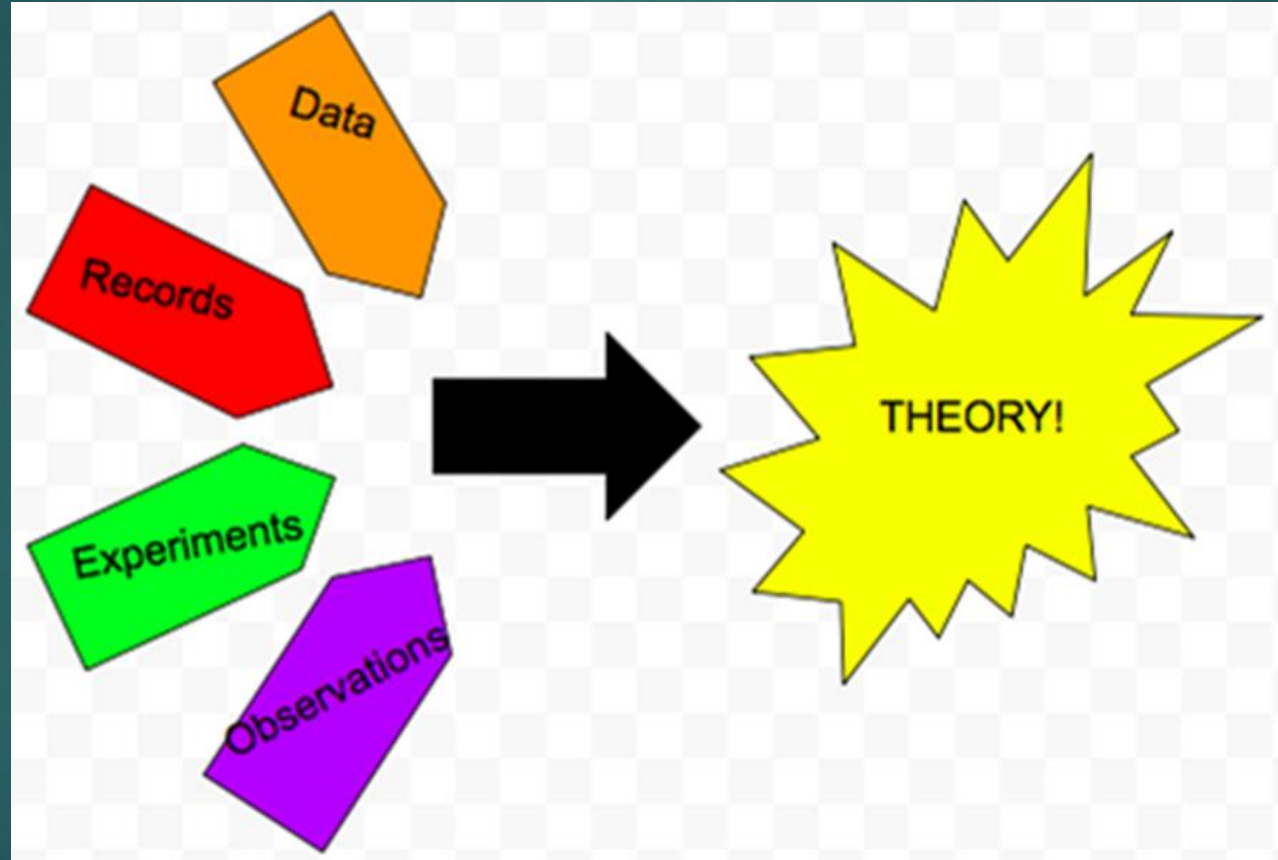
“In the very beginning, there was a void, a curious form of vacuum, nothingness containing no space, no time, no matter, no light, no sound. Yet the laws of nature were in place and this curious vacuum held potential. A story logically begins at the beginning, but this story is about the universe and unfortunately there are no data for the beginnings—none, zero. We don’t know anything about the universe until it reaches the mature age of a billion of a trillionth of a second. That is, some very short time after creation in the big bang. When you read or hear anything about the birth of the universe, someone is making it up—we are in the realm of philosophy. Only God knows what happened at the very beginning.”

--Taken from *The God Particle* by Leon Lederman, a Nobel Prize winner

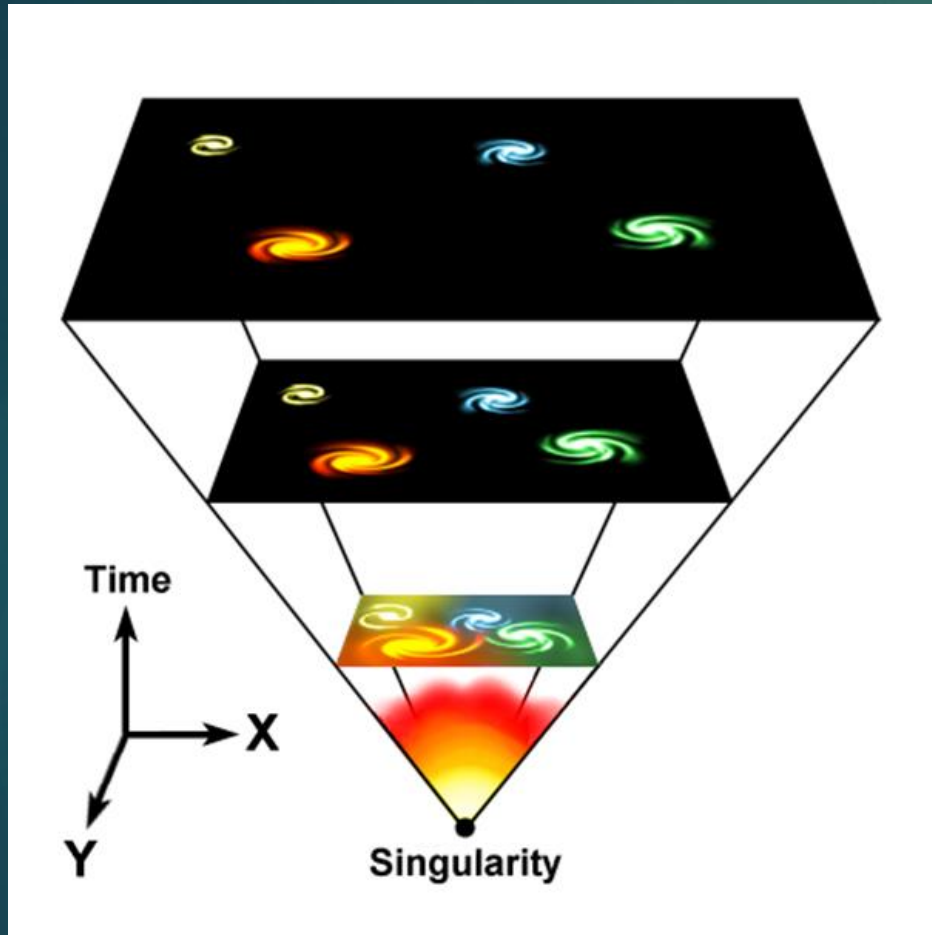
Learning Goal:

- ▶ By the end of this lesson, you will be able to explain three pieces of evidence for the Big Bang Theory:
 1. Cosmic Microwave Background Radiation
 2. Redshift of galaxies
 3. Elemental composition of our universe

Let's Review... A Theory



What is the Big Bang Theory?



- ▶ 1920's - George Lemaitre (a priest and physics professor)
- ▶ Proposed the theory of the expanding universe.
- ▶ It started from a single point – **The Singularity**
- ▶ 13.82 billion years ago, violent expansion occurred from a single point, the size of an atom.
- ▶ All matter and space were created

*The “Big Bang” was a name (mockingly) given to Lemaitre’s idea – and it stuck 😊

THE BIG BANG THEORY

Galaxy

7

TIME
BEGINS

ONE
SECOND

PRESENT
DAY

Time	10^{-43} sec.	10^{-32} sec.	10^{-6} sec.	3 min.	300,000 yrs.	1 billion yrs.	15 billion yrs.
Temperature		10^{27}°C	10^{13}°C	10^8°C	$10,000^{\circ}\text{C}$	-200°C	70°C

1 The cosmos goes through a superfast "inflation," expanding from the size of an atom to that of a grapefruit in a tiny fraction of a second.

2 Post-inflation, the universe is a seething, hot soup of electrons, quarks and other particles

3 A rapidly cooling cosmos permits quarks to clump into protons and neutrons.

4 Still too hot to form into atoms, charged electrons and protons prevent light from shining: the universe is a superhot fog.

5 Electrons combine with protons and neutrons to form atoms, mostly hydrogen and helium. Light can finally shine.

6 Gravity makes hydrogen and helium gas coalesce to form the giant clouds that will become galaxies; smaller clumps of gas collapse to form the first stars

7 As galaxies cluster together under gravity, the first stars die and spew heavy elements into space; those will eventually turn into new stars and planets.

Quarks

Proton

Neutron

Hydrogen nucleus

Hydrogen nucleus

Hydrogen atom

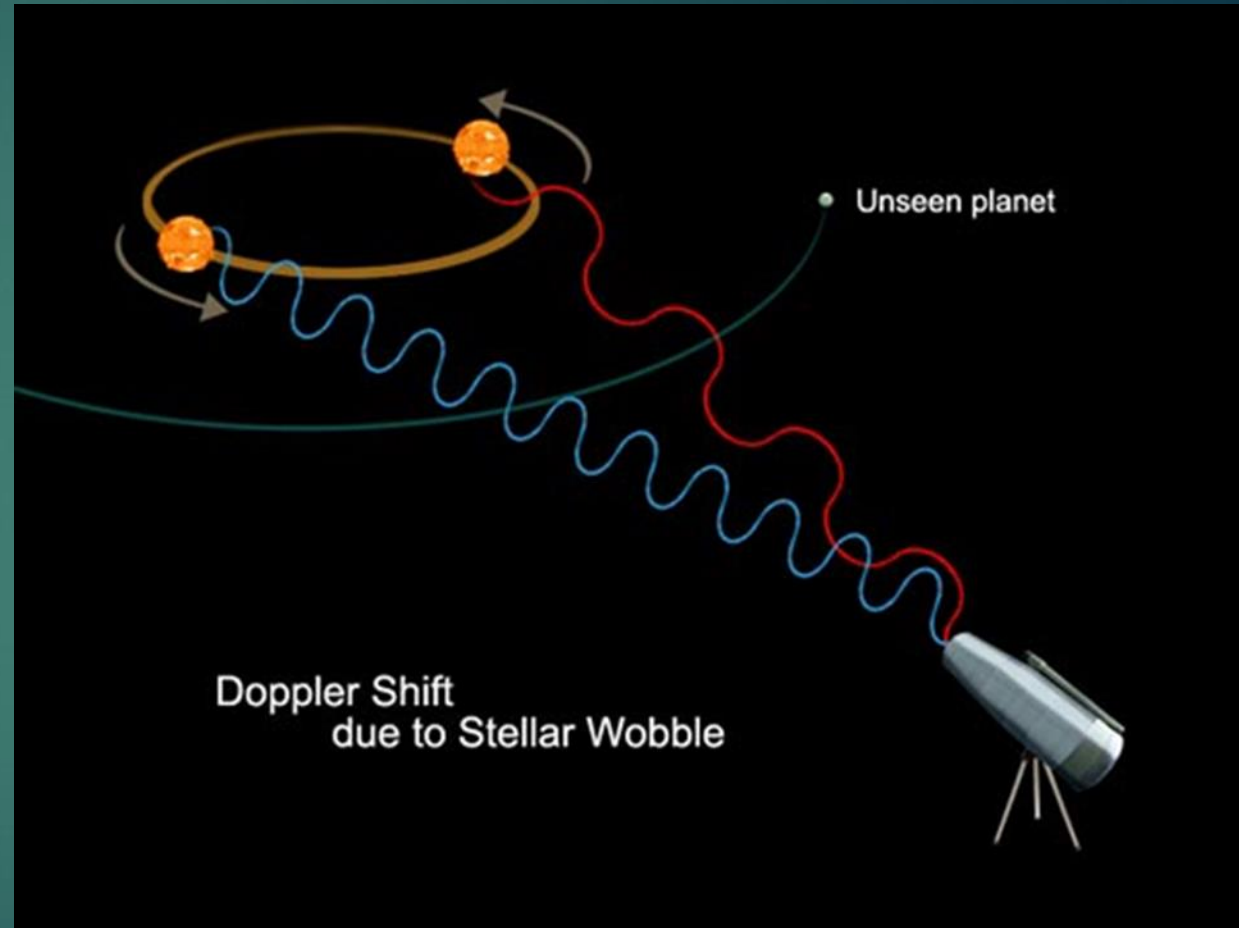
Helium atom



<https://youtu.be/DClEX00pCZ4>

Edwin Hubble – Red Shift of Galaxies

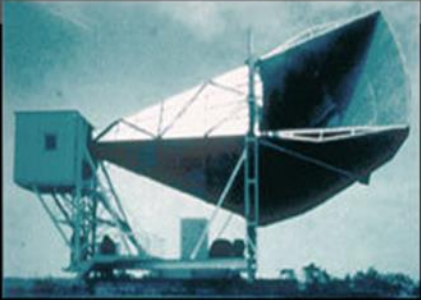
- ▶ 1929 - Studied light given off by galaxies.
- ▶ Light shifted to the red end of the EM spectrum.
- ▶ Proposed **Hubble's Law**
 - ▶ “The rate at which a galaxy is moving is directly proportional to its distance from us.”
 - ▶ The farther away a galaxy is from us, the faster it travels away from us.



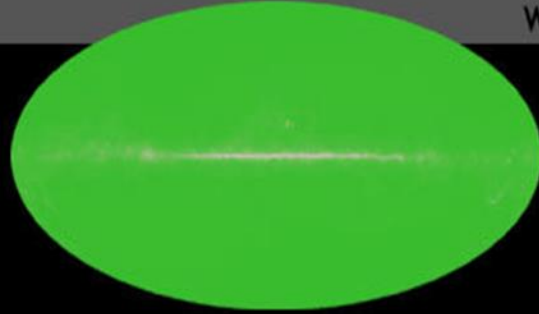
The universe is expanding

Cosmic Microwave Background Radiation

1965



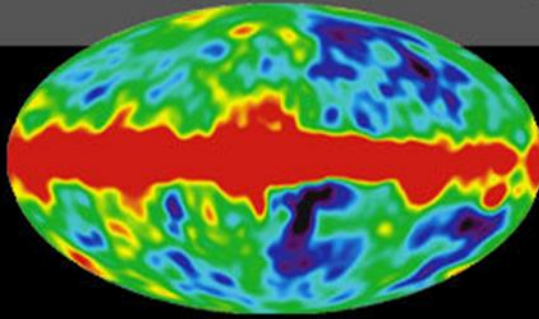
Penzias and
Wilson



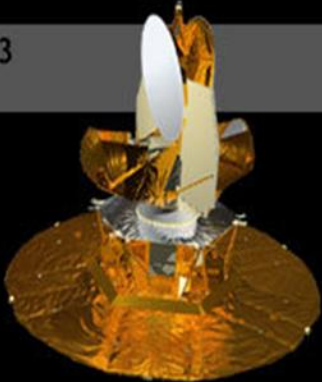
1992



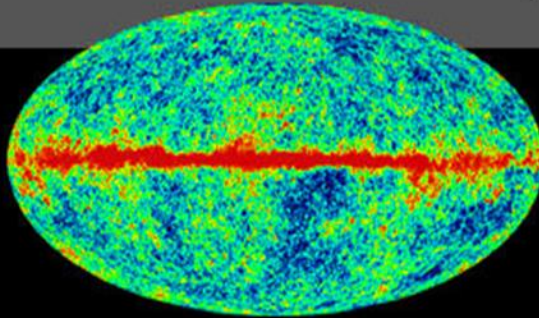
COBE



2003



WMAP



- ▶ CMB is the “after glow” or “leftovers” from the big bang that permeates (spreads) in all directions of the universe.
- ▶ CMB was leftover ‘heat’ in the form of microwave radiation, which was still cooling from the Big Bang
- ▶ The amount of cooling says how far the light has travelled, which determined the age of the universe: 13.82 billion years.

Mixture of Elements

- ▶ The **matter in the universe** is about **75% hydrogen** & **25% helium**.
- ▶ •The abundance of H & He supports a particular process of past atomic creation, where the larger elements formed from the smaller elements.

<div><div>H</div><div>B</div></div>	<div><div><div>B</div><div>Big Bang</div></div><div><div>L</div><div>Large stars</div></div><div><div>\$</div><div>Super-novae</div></div><div><div>C</div><div>Cosmic rays</div></div><div><div>S</div><div>Small stars</div></div><div><div>M</div><div>Man-made</div></div></div>																<div><div>He</div><div>B</div></div>																									
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<div><div>Rb</div><div>\$</div></div>	<div><div>Sr</div><div>L</div></div>	<div><div>Y</div><div>L</div></div>	<div><div>Zr</div><div>L</div></div>	<div><div>Nb</div><div>L</div></div>	<div><div>Mo</div><div>\$ L</div></div>	<div><div>Tc</div><div>L</div></div>	<div><div>Ru</div><div>\$ L</div></div>	<div><div>Rh</div><div>\$</div></div>	<div><div>Pd</div><div>\$ L</div></div>	<div><div>Ag</div><div>\$ L</div></div>	<div><div>Cd</div><div>\$ L</div></div>	<div><div>In</div><div>\$ L</div></div>	<div><div>Sn</div><div>\$ L</div></div>	<div><div>Sb</div><div>\$</div></div>	<div><div>Te</div><div>\$</div></div>	<div><div>I</div><div>\$</div></div>	<div><div>Xe</div><div>\$</div></div>																									
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																		<div><div>Ac</div><div>\$</div></div>	<div><div>Th</div><div>\$</div></div>	<div><div>Pa</div><div>\$</div></div>	<div><div>U</div><div>\$</div></div>	<div><div>Np</div><div>\$</div></div>	<div><div>Pu</div><div>\$</div></div>	<div><div>Am</div><div>M</div></div>	<div><div>Cm</div><div>M</div></div>	<div><div>Bk</div><div>M</div></div>	<div><div>Cf</div><div>M</div></div>	<div><div>Es</div><div>M</div></div>	<div><div>Fm</div><div>M</div></div>	<div><div>Md</div><div>M</div></div>	<div><div>No</div><div>M</div></div>	<div><div>Lr</div><div>M</div></div>										

Summary

► The Big Bang Theory:

“The universe began the size of an atom and violently exploded outwards, eventually cooling and creating larger atomic elements.”

1. Expanding Universe: Galaxy red shift shows that they are moving away from each other.
2. CMB: Cosmic microwave background radiation extends in all directions of the universe, which verifies that the universe is cooling from a large, rapid expansion.
3. Primordial Elements: The abundance of small elements (H and He) in the Universe suggests that they first formed at the Big Bang and are the precursors for all other elements.