Last Tuesday’s Class: The Takehome Message

Galaxies are (nearly) all moving away from us, with velocities proportional to their distances from us.

Big Bang: A theory of cosmology based on Einstein’s General Theory of relativity in which the expansion of the universe began with a primeval explosion.

Cosmology

The study of the Universe as a whole: its contents, structure, origin, evolution, and ultimate fate.

Geocentric: Earth-centered

Heliocentric: Sun-centered

The Hubble Deep Field
Two (Optional) Public Talks this Week

Talk 1
Who: Prof. George Fuller (UCSD)
What: “Neutrinos: Stealthy Agents of Destruction and Creation in the Cosmos”
When: Thursday, May 8, 7 PM
Where: Geology, Mathematics and Computer Science Building (GMCS), Rm. 333
Presented by: SDSU Dept of Physics

Talk 2
Who: Dr. Mark Phillips (Las Campanas Observatory)
What: “Exploding Stars and the Fate of the Universe”
When: Friday, May 9, 7:30 PM
Where: Geology, Mathematics and Computer Science Building (GMCS), Rm. 333
Presented by: SDSU Dept of Astronomy

Understanding Explosions
First picture: How long ago did explosion happen?
\[ v \times t = d \quad \text{or} \quad t = \frac{d}{v} \]
3 m/s \times t = 6 m
\[ t = 2 \text{ s} \]
The explosion occurred 2 seconds ago!

Some time later:

A linear relation between distance and velocity (faster objects are further away) indicates that an explosion has taken place at a distinct moment of time in the past.

Comparing Pieces of an Exploded Bomb to Galaxies

The greater the blue- (red-) shift, the greater the radial velocity of the object.
Radial velocity: Motion towards or away from an observer.
Comparing Pieces of an Exploded Bomb to Galaxies

**Hubble’s Original “Hubble Diagram”**

**A Modern Hubble Diagram**

**Hubble’s Law:** The linear relation between the speed of recession of a distant object and its current distance from us.

\[
v = H_0 d
\]

**Hubble constant \((H_0)\):** The constant of proportionality between the velocities of remote galaxies and their distances. (The slope of the line on the Hubble diagram.)

Hubble’s original estimate: \(H_0 = 500 \text{ km/s/Mpc}\).

Today’s best estimate: \(H_0 = 70 \text{ km/s/Mpc}\).

\(H_0 = 70 \text{ km/s/Mpc}\) yields a time since the Big Bang of about 14 billion years.

**Hubble’s Discovery**

Hubble Law: The linear relation between the apparent speed of recession (as revealed by the Doppler shifting of spectral lines) and its current distance from us:

\[
v = H_0 d
\]

**Hubble’s Constant:** Constant of proportionality between the velocities of remote galaxies and their distances. Units: \(\text{km/s/Mpc}\)

Example: The Sombrero galaxy is found to be receding from us at nearly 1,000 km/s. If \(H_0=100 \text{ km/s/Mpc}\), approximately how far away is it from us?

**Understanding Explosions**

(Reader, p. 114)

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Claudius Ptolemy ~140 AD

Book: *The Almagest*

Aristarchus ~280 BC

Copernicus

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Understanding Explosions

![First picture:](image: public domain)

First picture:

Some time later:

![Velocity-Distance Diagram](image: public domain)

A linear relation between distance and velocity (faster objects are further away) indicates that an explosion has taken place at a distinct moment of time in the past.

Hubble Diagram

![The Hubble Deep Field](image: public domain)

The Cosmological Principle: The assumption that, on large scales, the universe at any given time is the same everywhere; that is, it is isotropic and homogeneous. This is the starting point for most modern theories of cosmology, including the Big Bang.

Two Additional Discoveries by Hubble

On large scales, the universe appears to be:

**Isotropic:** The same in all directions.

![Hubble Diagram](image: public domain)
**Two Additional Discoveries by Hubble**

On large scales, the universe appears to be:

**Isotropic:** The same in all directions.

**Homogeneous:** The same average density at any given time.

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**A Modern Hubble Diagram**

**Hubble law:** The linear relation between the speed of recession of a distant object and its current distance from us.

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**Understanding Explosions**

A linear relation between distance and velocity (faster objects are further away) indicates that an explosion has taken place at a distinct moment of time in the past.

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**Galaxies are separating from each other due to the expansion of the space between them.**
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Big Bang: A theory of cosmology based on Einstein’s General Theory of Relativity in which the expansion of the universe began with a primeval explosion.

The greater the blue- (red-) shift, the greater the radial velocity of the object.

Radial velocity: Motion towards or away from an observer.
The redshift of distant galaxies is produced by the expansion of space, NOT the motion of galaxies through space.

Cosmological redshift: A redshift produced by the expansion of space itself.

Comparing Pieces of an Exploded Bomb to Galaxies

Hubble law: The linear relation between the speed of recession of a distant object and its current distance from us.

\[ v = H_0 d \]

Understanding Explosions

First picture:

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When Did the Universe Begin?

WHY is the exploding bomb model an inaccurate description of the Big Bang?

1) The Big Bang cosmology explains the recession of galaxies as being due to the expansion OF the space between galaxies, NOT as a result of a velocity of the galaxies THROUGH space.

If we accept the cosmological principle and believe the observations that produce Hubble’s Law, then, under the Big Bang cosmological model, we must conclude that there was no center to the primeval explosion, and that space itself is what is expanding.

Cosmological Principle: The assumption that, on large scales, the universe at any given time is the same everywhere; that is, it is isotropic (same in all directions) and homogeneous (same average density at any given time).
Today’s Class: The Takehome Message

Galaxies are separating due to the expansion of the space between them.