Chapter 25: Beyond our Solar System

25.3 The Universe

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The Milky Way Galaxy

• On a clear and moonless night, away from city lights, you might see a band of light in the sky. This band is *The Milky Way Galaxy*. 
• A **galaxy** is a group of stars, dust and gases held together by gravity.
• There may be more than 100 billion stars in the Milky Way alone.
• Our galaxy looks “milky” because our solar system is located within a flat disk – the *galactic disk*.

• We view it from the inside and see stars in every direction.
• Scientists have found out that our solar system is located towards the edge of our galaxy, which is shaped like a huge spiral.

• We are on one of the spiral’s “arms.”
Size of the Milky Way

• The Milky Way is….
  – A large spiral galaxy,
  – Whose disk is about 100,000 light years wide,
  – And about 10,000 light years thick at the nucleus.
More facts...

• Our solar system is about 30,000 light years from the galactic nucleus.

• It takes our solar system about 200 million years to orbit this nucleus.
Types of Galaxies

• The universe contains hundreds of billions of galaxies.
• Each galaxy can contain hundreds of billions of stars.
• (They also contain nebulae & protostars.)
Irregular Galaxies

- Irregular galaxies are composed mostly of young stars, often with many cosmic dust clouds.
- Irregular galaxies have relatively weak gravitational pulls, and because of this they have irregular shapes (AKA shapelessness).
- Only 10% of all galaxies are irregular.
Spiral Galaxies

- Shaped as a disk, with arms sweeping away from the center.
- Tend to be quite large.
- Have both young and old stars.
- Youngest stars in arms, oldest at center.
- About 20% of all galaxies are spirals.
Spiral Galaxy NGC 1232 - VLT UT 1 + FORS1

ESO PR Photo 37d,98 (23 September 1998)

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Spiral Galaxy NGC 1232 - VLT UT 1 + FORS1
Barred Spirals

• A type of spiral galaxy which has its stars arranged in the shape of a bar “across” its disk.

• The Milky Way may be a barred spiral galaxy.
Elliptical Galaxies

- Contains the oldest stars, and almost no nebulae.
- Most – but not all! - are small.
- Definite shape - round-to-oval.
- No spiral arms.
- About 60% of all galaxies are elliptical.
Galaxy Clusters

• Just like stars, galaxies are grouped in clusters.
• Some clusters may contain thousands of galaxies.
• Our own cluster, The Local Group, contains at least 28 galaxies.
• Galaxy clusters also make up huge groups called superclusters.
Virgo Galaxy Cluster
The Expanding Universe

Have you ever noticed how a fire truck siren gets **higher** as the truck races towards you, then **lower** as it races away?
This effect is called “The Doppler Shift,” which was first observed and named by Johann Doppler in the 19th century.

We can see the Doppler Shift in any wave phenomena.
If a fire engine is stationary and turns its siren on, no matter where a person stood, the pitch (also known as frequency) of the siren sound would sound the same.

This is because the sound waves carrying the sound are traveling at the same speed, no matter which direction they travel in.
HOWEVER, when the fire truck starts to move, it starts to “catch up” to the siren’s sound waves. The waves start to bunch up as they reach an observer’s ear drum, and he hears the siren’s pitch get higher.

As the truck passes the observer, the sound waves stretch out behind it, and the observer hears the siren’s pitch get lower.
The Doppler Shift works for light waves, too. As an object – such as a star or galaxy – travels **TOWARDS** us, we see its light appear more **BLUE** than it really is, since the light waves become **SHORTER** as they reach earth and “bunch up.”

This is called **“Blueshift”**
If a star is moving **AWAY** from us, its light will appear more **RED** than it really is, as its light waves are being **STRETCHED OUT** behind it as it moves away.

This is called “**Redshift.**”
Hubble’s Law

- Edwin Hubble, by using the Doppler Shift, discovered in 1929 that most galaxies are moving away from us. In fact, the galaxies with the greatest redshift are the ones farthest from us.

This is called “Hubble’s Law.”
Hubble’s Law states that galaxies are retreating from each other at a speed that is proportional to their distance.

This means that galaxies that were farther apart at their beginning travel a greater distance than those originally located closer together during the same amount of time.
The Big Bang: how did the universe begin?

- At one time, the entire universe was confined to a dense, hot, supermassive ball.

- This ball contained all matter, energy, space and time of our universe.

- This ball was incredibly small and incredibly dense.
• About 13.7 billion years ago, an explosion occurred, and all of this material began expanding in all directions.

• All matter, energy and space began at that moment.

• Time also began at that moment.
Big Bang Starts Here…

First stars and galaxies form about 200 million years after big bang…

Stars and galaxies continue to expand and move farther apart.

If the universe continues to expand, what can you infer about its average density through time?
• First of all, we are reasonably certain that the universe had a beginning.

• Second, galaxies appear to be moving away from us at speeds proportional to their distance. This is called "Hubble's Law."

• This observation supports the expansion of the universe and suggests that the universe was once compacted.
• Third, if the universe was initially very, very hot as the Big Bang suggests, we should be able to find some remnant of this heat.

• In 1965, Radioastronomers Arno Penzias and Robert Wilson discovered Cosmic Microwave Background radiation (CMB) which pervades the observable universe. This is thought to be the remnant which scientists were looking for.
A “heat photo” of Cosmic Microwave Background temperature fluctuations over five years as seen over the full sky.
• Finally, the abundance of the "light elements" Hydrogen and Helium found in the observable universe are thought to support the Big Bang model of origins.
Dark Matter

- **DARK MATTER** is matter that cannot be directly observed because it does not react to any light waves.
- It can exist in the same place as regular matter, and has gravitational pull on it.
- Regular matter, however, does **NOT** have gravitational pull on dark matter.
- Dark matter might make up **90%** of the universe’s matter.
This telescope camera used regular, optical light to photograph this section of space.
When a camera using x-ray waves was used, this strange, bullet-shaped nebulae was discovered.

Why this shape? Was something that scientists couldn’t see “pulling” on it?
When a camera that photographs gravity was used, these strange blue shapes became viewable.

These two clouds of “dark matter” had collided with the nebula and was pulling it in two as through traveled through!