Hewitt/Lyons/Suchocki/Yeh

Conceptual Integrated Science

Chapter 29

THE UNIVERSE

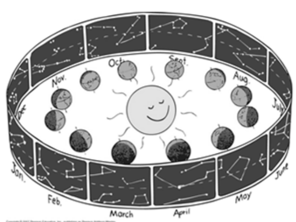
Observing the Night Sky

Constellations are groups of stars named over antiquity.

A familiar constellation is *Ursa Major*, the Great Bear.

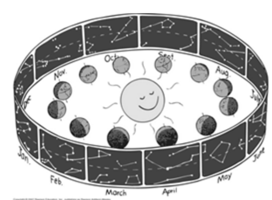
Observing the Night Sky

The monthly constellations seen in the night sky change as Earth's path around the Sun progresses.



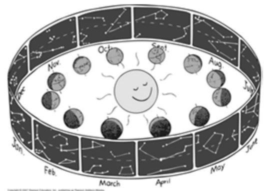
Observing the Night Sky

Can you see that during a solar eclipse, the darkened daytime sky would show constellation positions as normally seen six months earlier or later?



Observing the Night Sky

The position of the Earth's orbit around the Sun lead to certain constellations being near the ecliptic; these constellations came to be known as the Zodiac: Aquarius, Pisces, Ares, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, and Capricorn.

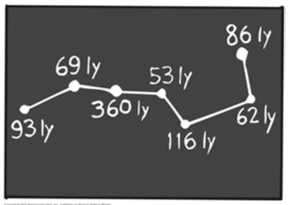


Observing the Night Sky

The Big Dipper is a well-known asterism. The pairs of stars at the end of its bowl point to Polaris, the North Star.

Observing the Night Sky

The seven stars of the Big Dipper are at very different distances from Earth.



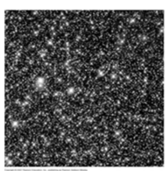
Observing the Night Sky

A time-exposure of the night sky shows streaks of stars from our “carousel Earth.”

The Brightness and Colors of Stars

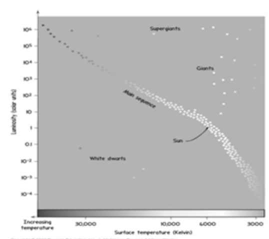
A star’s color indicates its temperature:

- A red star is cooler than a blue star
- A blue star is almost twice as hot as a red star
- blue light has almost *twice the frequency* of red light*, and ½ the wavelength.*

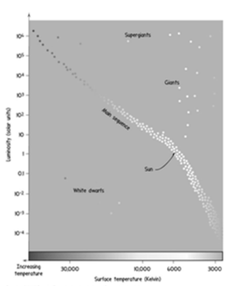


The Hertzsprung-Russell Diagram

Graph of intrinsic brightness versus surface temperature for stars



The Hertzsprung-Russell Diagram



Positions on the H-R diagram

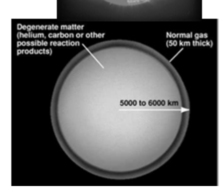
- Form a main sequence for average stars
- Show exotic stars above or below the main sequence.

The H-R diagram is to an astronomer what the Periodic Table is to a chemist.

The Life Cycles of Stars

- Begins as a *nebula*
- Advances to a *protostar*
- Becomes a star when fusion in its core occurs

- Depending on its mass, the star may become a *red giant*
- and then burn out to become a *white dwarf.*



The Life Cycles of Stars

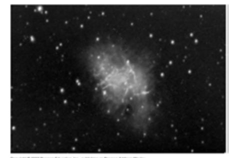
White dwarf:

- Cools for eons until it is too cold to emit light
- If part of a binary, pulls matter from its partner, which can lead to a nuclear blast (nova)

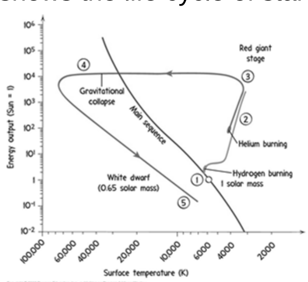
The Life Cycles of Stars

Final stage of more massive stars is collapse, then an explosion called a *supernova*.

The Crab Nebula is a remnant of a supernova.

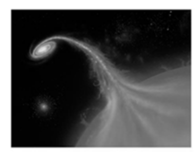


The Hertzsprung-Russell Diagram shows the life cycle of stars!



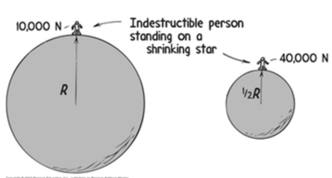
Black Holes

- A black hole is what remains when a supergiant star collapses into itself
- Named because gravitation at its surface is so intense that even light cannot escape



Black Holes

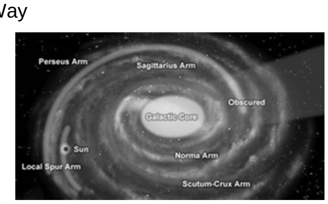
- Gravitation at the surface of a star increases when it collapses.
- If the star shrinks to half its radius ⇒ gravitation at its surface increases by 4 (inverse-square law)



Galaxies

Galaxy:

- A huge assemblage of stars, interstellar gas, and dust
- Most familiar - Milky Way

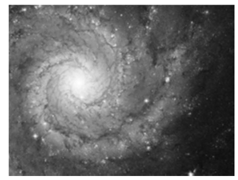


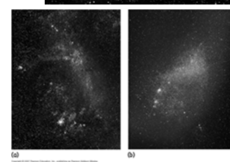
Galaxies

The Milky Way

Galaxies

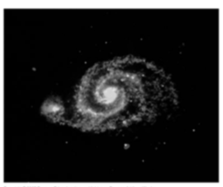
Three types of galaxies:
- Elliptical (most common)
- Irregular
- Spiral





Galaxies

This is Spiral Galaxy M83, thought to be much like our Milky Way.



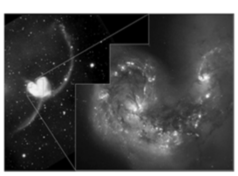
Galaxies are not the largest things in the universe. There are clusters of galaxies, and then galaxy superclusters—larger than can be imagined!

Galaxies

- Some galaxies are known as *active galaxies* and are emitting huge amounts of energy.
- Two examples of active galaxies are:
  - Starburst galaxies
  - Galaxies with an *active galactic nucleus*

Galaxies

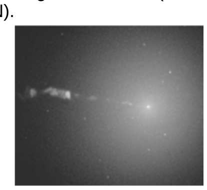
- Starburst galaxies form stars at a very fast rate. They result from violent disturbances, such as the collision between two galaxies.



- This image shows the aftermath of the collision of two spiral galaxies. Areas in blue are regions of rapid star formation.

Galaxies

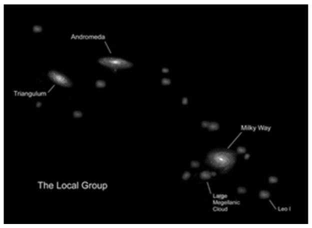
- Some active galaxies have supermassive black holes in their centers, sometimes emitting jets that extend thousands of light- years from the galactic center (called an active galactic nucleus, or AGN).



- This jet coming from M87 consists of charged particles being accelerated to velocities near the speed of light.

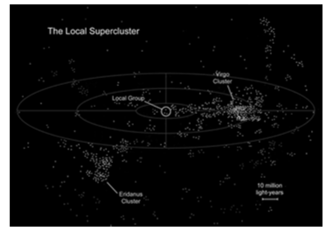
Clusters and Superclusters

- The Milky Way galaxy and its neighboring galaxies are known as the Local Group.



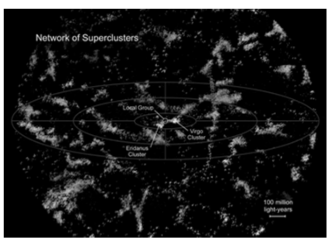
Clusters and Superclusters

- Our Local Group is situated between the Virgo and Eridanus Clusters, which together make up our Local Supercluster.



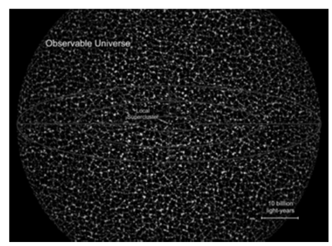
Clusters and Superclusters

- Our Local Supercluster is part of a network of superclusters.



Clusters and Superclusters

- As far as we can see, superclusters hold together like a foam within which there are bubbles of super-large voids.



Hubble's Law

- Our modern view begins in 1920
  - Until the 1920s, many people believed that the Milky Way galaxy made up the entire universe.
  - In the early 1920s, Edwin Hubble disproved this by discovering that the Andromeda "nebula" was in fact a distant galaxy, separate from our own.

Hubble's Law

- Hubble's measure of distance:
  - Hubble could deduce the distance of a star from Earth by comparing its luminosity (energy) and brightness.
  - The brightness of light obeys an inverse-square law.

Hubble's Law

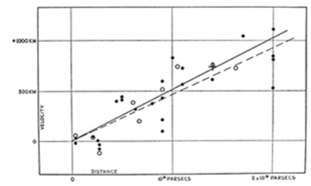
- Hubble's measure of redshift:

Light emitted from a source moving toward us will be shifted to the blue (high frequency), while light emitted from a source moving away from us will be shifted to the red (low frequency).

The faster an object moves toward us or away from us, the more its emitted light will be shifted.

Hubble's Law

- Hubble found that almost every object that he could see was moving away from every other object.
- The farther away an object was, the faster it was moving away (the greater the redshift).

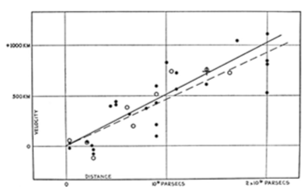


Hubble's Law

- From the graph, Hubble wrote his famous equation:

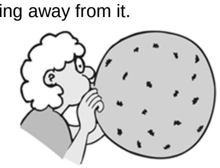
$$v = H \times d$$

- This equation shows that the velocity of an object is proportional to its distance from Earth.



Hubble's Law

- Hubble's law implies that the universe is expanding.
  - The expansion of the universe is like an ant on a balloon that is being blown up. The ant sees every point on the balloon moving away from it.



  - Hubble's law also provides extremely strong evidence for the *Big Bang*.

The Big Bang

Big Bang:

- Theory - our universe began with a primordial explosion some 13.7 billion years ago
- Marks the beginning of space and time

http://scienceblogs.com/startswithabang/upload/2010/07/the_last_great_prediction_of_t/bigbang.jpg

The Big Bang

Evidence for the Big Bang:

- Continuing expansion of the universe
- Measured cosmic background radiation, predicted before it was discovered and measured (2.7 K; microwave band)
- Measurements of element abundances, predicted before measured (H and He most common)
- Findings - early universe was much hotter than now

Dark Matter and Energy

- What is ordinary matter?
  - What we think of as ordinary matter is made of protons, neutrons, and electrons that form atoms that combine to make people, planets, stars, and suns.
  - Ordinary matter is composed of the elements listed in the periodic table.

Dark Matter and Energy

- What makes matter "dark"?
  - If matter does not exert the electromagnetic force, then normal matter cannot interact with it.
  - This "invisible" form of matter that we cannot see or interact with is known as dark matter.

Dark Matter and Energy

- If we can't see or interact with dark matter, how do we know that it exists?
  - Remember how gravity affects the motion of the planets orbiting the Sun: The closer the planet is to the Sun, the more gravitational force it experiences.
  - The greater the force on a planet, the faster that planet orbits the Sun.

Dark Matter and Energy

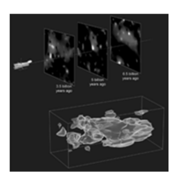
- We can apply the same principle to galaxies.
  - We should expect that objects closer to the center of a galaxy (which contains most of the ordinary matter) should orbit around the center faster than objects farther from the center.
  - This is not the case!
  - Objects in galaxies orbit at about the same speed no matter what their distance is from the center of the galaxy.

Dark Matter and Energy

- What does this imply?
  - If all objects in a galaxy have about the same orbital velocity, then most of the galactic mass must be outside of the galaxy in an "invisible halo" much bigger than the galaxy itself.

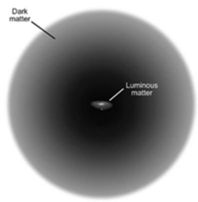
Dark Matter and Energy

- But what is dark matter really?
  - There have been no direct measurements of dark matter interactions.
  - Until we can directly observe it, we can only make hypotheses that explain the fundamental nature of dark matter.



Dark Matter and Energy

- Galaxy formation:
  - After the Big Bang, ordinary matter as well as dark matter began to clump together due to gravity.
  - When ordinary matter interacts with itself, energy is lost as heat.
  - As ordinary matter loses energy, it clumps together further and becomes concentrated at the center.



Dark Matter and Energy

- Galaxy formation (continued):
  - The concentrated clump of ordinary matter in the center allows for the formation of stars.
  - The group of stars that forms in the center of the clump becomes a galaxy.
  - As the matter becomes more concentrated, the matter begins to spin very quickly because it must conserve angular momentum.

Dark Matter and Energy

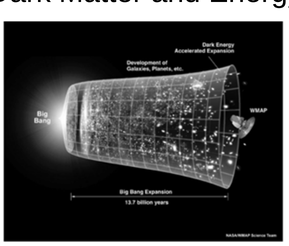
- Careful measurements of distant galaxies tell us that the universe is expanding at faster and faster rates. In other words, the universe is accelerating outward.
- We know, however, that acceleration requires the application of some force. What might be the nature of the force causing the universal acceleration?

Dark Matter and Energy

Scientists don't know the answer to that question, but they have given it a name:

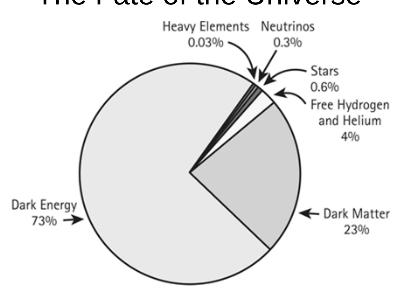
DARK ENERGY

Dark Matter and Energy



The accelerated expansion began about 7.5 billion years ago.

The Fate of the Universe



The composition of the universe

The Fate of the Universe

- Two possible scenarios for the fate of the universe are:
  - – Heat death
  - – The Big Rip

The Fate of the Universe

- Two possible scenarios