Chapter: Stars and Galaxies

Section 1: Observing the Universe

Section 2: Evolution of Stars

Section 3: Galaxies and the Milky Way

Section 4: Cosmology
• Long ago, people named patterns of stars after characters in stories, animals, or tools.

• Many of the names given to these star patterns by ancient cultures survive today and are called constellations.
Telescopes

• Constellations and the stars that make them up are visible with the unaided eye.

• However, to see other objects in space, or to see some objects better, you need a telescope.

• Optical telescopes are used to study objects in visible light, and radio telescopes are used to study objects in the radio wavelengths.
Optical Telescopes

• There are two basic types of optical telescopes.

• One type uses only lenses to study light and the other uses lenses and mirrors.

• The distance from the objective to the focus is the focal length of the telescope.
Optical Telescopes

• You can find the magnifying power \( (M_p) \) of a telescope by dividing the focal length of the objective \( (f_o) \) by the focal length of the eyepiece \( (f_e) \).

\[
M_p = \frac{f_o}{f_e}
\]
A **refracting telescope** uses a convex lens.

- Light passes through the objective lens.
- The eyepiece then magnifies the image.
Reflecting Optical Telescopes

• A **reflecting telescope** uses a mirror as an objective to reflect light to the focus.

• The figure shows how light passes through the open end of a reflecting telescope and strikes a concave mirror at the base of the telescope.
New Telescope Design

• The most recent innovations in optical telescopes involve active and adaptive optics.

• With active optics, a computer is used to correct changes in temperature, mirror distortions, and bad viewing conditions.

• Adaptive optics uses a laser to probe the atmosphere and relay information to a computer about air turbulence.
Radio Telescopes

• A telescope that collects and amplifies radio waves is a radio telescope.

• Because radio waves have long wavelengths, a radio telescope must be built with a very large objective, usually some form of dish antenna.

• Astronomers often build several radio telescopes close together and connect them to form one large telescope.
Even using active and adaptive optics, the atmosphere limits what Earth-based telescopes can achieve.

For this reason, astronomers use space telescopes, such as the Hubble Space Telescope.

Large distances in space are measured in a unit called a light-year, the distance that light travels in one year.
A spectroscope is a device that uses a prism or diffraction grating to disperse the light into its component wavelengths.

This tells astronomers a great deal about a star.

For example, they can determine its chemical composition, its surface temperature, and whether it is moving away from or toward Earth.
Spectra

- A spectroscope disperses light into its individual wavelengths, or its spectrum.
- Visible light yields a spectrum of colors, including red, orange, yellow, green, blue, indigo, and violet.
Question 1

A refracting telescope uses a ________ as an objective.

A. mirror  
B. wave  
C. convex lens  
D. laser
The answer is C. Convex lenses are curved outward like the surface of a ball.
Question 2

What does a spectroscope do?

Answer

A spectroscope disperses the light from a star or other celestial object collected by a telescope into an electromagnetic spectrum.
Question 3

What is the distance that light travels in one year?

A. 15 million km
B. 9.5 trillion km
C. 12 billion km
D. 2 million km
The answer is B. Large distances in space are measured in a unit called a light-year, which is 9.5 trillion km.
How do stars form?

H-R Diagram

• In the early 1900s, Ejnar Hertzsprung and Henry Russell studied the relationship between absolute magnitude and temperature of stars.

• As stars form, they can be plotted on the Hertzsprung-Russell (H-R) diagram.
About 90 percent of all stars fall on a line drawn from the upper left to the lower right of the H-R diagram called the **main sequence**.
How do stars change?

- Stellar equilibrium is the balance between outward pressure due to energy released in fusion and inward pressure due to gravity.
- Once this state of equilibrium is lost, the star enters the next stage of its life.
Main Sequence

- As long as the star’s gravity balances outward pressures, the star remains on the main sequence.
- When its hydrogen fuel is depleted, a star loses its equilibrium and its main sequence status.
Evolution of Stars

2

Giants and Dwarfs

- When hydrogen in a star’s core is used up, its outward pressure is overcome by gravity.
- Its core contracts and increases in temperature.
- The outer layers expand and cool.
- In this late stage of its life cycle, an average star like our Sun is called a giant.
2. **Giants and Dwarfs**

- When temperature reaches 100 million K, helium fuses, forming carbon.
- Now the star is enormous and its surface is much cooler.
- Its outer layers escape into space leaving behind the hot, dense core that continues to contract.
Evolution of Stars

Giants and Dwarfs

- At this final stage in an average star’s evolution, it is a **white dwarf**.

- When the core of stars over eight times more massive than our Sun reach temperatures high enough to cause fusion that produce heavier elements, the star expands into a supergiant.
Evolution of Stars

2

Giants and Dwarfs

• A supernova is a gigantic explosion in which the temperature in the collapsing core reaches 10 billion K and atomic nuclei are split into neutrons and protons.

• When very massive stars, with masses greater than 25 times that of the Sun, collapse past the neutron-star stage, they form a black hole.
Giants and Dwarfs

- Type I supernovas form from hydrogen-poor, low mass stars.
- Carbon detonation causes carbon fusion almost everywhere inside the star and is thought to destroy the star completely.
- Type II supernovas form from hydrogen-rich, high mass stars.
- They leave behind a collapsed core that can then condense to form a neutron star or black hole.
The Sun—A Main Sequence Star

- A **solar mass** is simply the mass of the Sun.

- For most stars, the relationship between mass and luminosity can be approximated by

\[
\frac{L}{L_\odot} = \left(\frac{M}{M_\odot}\right)^{3.5}
\]

where \(L_\odot\) and \(M_\odot\) are the luminosity and mass of the Sun.
The Sun—A Main Sequence Star

• The solar interior is composed of the core, the radiation layer, and the convection layer.
• The surface of the Sun is called the photosphere.
• This is the layer of the Sun that gives us light.
• The atmosphere above the photosphere is composed of the chromosphere and the corona.
Evolution of Stars

2

Solar Interior

- The innermost layer of the Sun is the core. This is where fusion occurs.
- The layer of the Sun just above the core is the radiation zone.
Solar Interior

• As you move farther outward from the Sun’s core, the temperature drops and some electrons remain bound to their atoms.

• The energy from these photons is carried to the Sun’s surface by convection through the next layer, the convection zone.
Photosphere

- The Sun’s photosphere, or surface is at the top of the convection zone and has a mottled appearance, called granulation.

Sunspots

- These darker areas of the Sun’s photosphere, called sunspots are cooler than surrounding areas.
- Sunspots aren’t permanent features of the Sun.
- They appear and disappear over periods of days, weeks, or months.
Prominences and Flares

- Intense magnetic fields associated with sunspots can cause huge arching columns of gas called prominences to erupt.

- Gases near a sunspot sometimes brighten suddenly, shooting gas outward at high speed in what are called solar flares.
CMEs

- Sometimes large bubbles of ionized gas are emitted from the Sun. These are known as CMEs (coronal mass ejections).
Question 1

How do stars form?

Answer

Stars form from a large cloud of gas, ice, and dust. Once the temperature inside the nebula reaches 10 million, fusion begins.
Question 2

Explain the difference between Type I and Type II supernovas.

Answer

Type I supernovas form from hydrogen-poor, low mass stars. Type II supernovas form from hydrogen-rich, high mass stars.
Question 3

Which are NOT types of galaxies?

A. elliptical
B. irregular
C. spiral
D. colliding
The answer is D. There are three major types of galaxies: spiral, elliptical, and irregular.
• A **galaxy** is a large group of stars, gas, and dust held together by gravity.

• Our galaxy, called the **Milky Way** contains 400 billion stars, by most recent estimates, including the Sun.
Spiral Galaxies

• Spiral galaxies have spiral arms that wind outward from the galaxy’s center.

• These spiral arms are made up of bright stars, dust, and gas.
Spiral Galaxies

- A normal spiral galaxy with its arms starting close to center.
- Barred spirals have spiral arms extending from a large central bar of stars, dust, and gas that passes through the center, or hub, of the galaxy.
Elliptical Galaxies

- Elliptical galaxies are shaped like large, three-dimensional ellipses.
- Many are football-shaped, but other are spherical.
Irregular Galaxies

- Most galaxies that aren’t elliptical or spiral are considered irregular galaxies.
Irregular Galaxies

- They take many different shapes and contain 100 million to 10 billion stars, making them larger than dwarf ellipticals but smaller than spirals.
The Local Group

• Just as stars are grouped together within galaxies, galaxies are grouped into clusters.

• Our Milky Way galaxy belongs to a cluster called the **Local Group**.

• It is a relatively small cluster containing about 45 galaxies of various types and sizes.
How do galaxies form?

Colliding Galaxies

• Galaxy collisions have a strong effect on the overall structure and shape of the colliding galaxies.

• They may lose all of their spiral shape, if they had any.
The Milky Way

Structure of the Milky Way

- The Milky Way galaxy measures about 100,000 light-years from one side to the other. The Sun lies about 26,000 light-years from the galactic center on the edge of one of the spiral arms. The Milky Way’s disk is about 1,000 light-years thick.
Spiral Arms

• The arms of a spiral galaxy look like pinwheels that begin near the galactic center and extend outward through the disk of the galaxy.

• The spiral arms contain both young stars and prestellar material, such as glowing nebulae.

Galaxy Center

• Recent theories suggest that extremely massive black holes might exist at the cores of galaxies.
Question 1

Which is NOT a type of galaxy?

A. elliptical  
B. irregular  
C. round  
D. spiral
The answer is C. “Round” is not recognized as a major type of galaxy.
Question 2

How do galaxies grow?

A. by producing new stars
B. by emitting light
C. by absorbing other galaxies
D. by absorbing stars that don’t belong to other galaxies
The answer is C. The Milky Way has been gobbling up the Sagittarius dwarf elliptical galaxy for 2 billion years.
Question 3

Where is the Sun located in the Milky Way galaxy?

A. at the center of the galaxy
B. at the edge of one of the spiral arms
C. 100,000 light-years from the center
D. 1,000 light-years from the center
The answer is B. The Sun lies about 26,000 light-years from the center of the galaxy on the edge of one of the spiral arms.
How did it begin?

• The study of the universe—how it began, how it evolves, and what it is made of—is known as **cosmology**.
The most accepted theory of how the universe formed is the **big bang theory**.

It states that the universe started with a big bang, or explosion, and has been expanding ever since.

The big bang is not like an explosion of matter into empty space; it is the rapid expansion of space.
The motion of the stars within the Milky Way can be detected by using the Doppler effect.

Doppler shifts occur in light as well as sound.
If a star approaches Earth, its wavelengths of light are compressed, causing a blue shift. If a star moves away, its wavelengths are stretched, causing a red shift.
What is the universe made of?

- Visible or otherwise detectable mass, called regular matter, appears to make up only a very small amount of the known universe.

- Unseen and little-understood matter that affects galaxies has been named dark matter.
Data indicate that the expansion of the universe is accelerating.

Explaining this acceleration is difficult.

One hypothesis is that a form of energy, called dark energy, might be causing the acceleration.
Question 1

When did the universe begin?

A. 13.7 billion years ago
B. 5 million years ago
C. 25 trillion years ago
D. 14 trillion years ago
The answer is A. The Wilkinson Microwave Anisotropy Probe team proposed that the universe began about 13.7 billion years ago with a big bang.
Question 2

What causes the Hubble red shift?

Answer

The Hubble red shift is caused by the expansion of space, not the movement of galaxies.
Question 3

_____ might be causing accelerated expansion of the universe.

A. Kinetic energy
B. Potential energy
C. Dark energy
D. Thermal energy
The answer is C. Dark energy explains the accelerated expansion of the universe.
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