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S3 New Curriculum Physics

Theme: Earth and space physics

Chapter 7 – Stars and galaxies



Stars

A **star** is a massive, glowing ball of hot gas—mostly hydrogen and helium—held together by gravity and powered by nuclear fusion at its core. Our Sun is the closest and most familiar example.

What makes a star shine?

Deep in a star's core, hydrogen atoms fuse into helium, releasing enormous amounts of energy in the form of light and heat. This process, called **nuclear fusion**, is what makes stars shine for billions of years.

The sun

- The sun is the nearest star and largest object in the solar system.
- The mass of the sun is about 330,000 times the mass of the earth.
- It is the main source of energy (light and heat) on the earth.

- The Sun's total energy output, or **luminosity**, is about 3.86×10^{26} watts of which the earth receives about 1.75×10^{17} watts.
- Sun light is used for photosynthesis

Brightness of the stars

The variation in a star's brightness—what astronomers call *stellar variability*— depends on two categories of reasons.

1. Intrinsic Variability or reasons due to star itself:

- **Pulsating stars** (like Cepheids or RR Lyrae) expand and contract rhythmically, causing their brightness to rise and fall.
- **Eruptive stars** experience flares or mass ejections that temporarily increase their luminosity.
- **Explosive events** like novae or supernovae cause dramatic, often one-time spikes in brightness².

2. Extrinsic Variability or reasons independent of the star

- **Eclipsing binaries:** Two stars orbit each other, and one periodically blocks the other from our view—like a cosmic game of peekaboo³.
- **Rotating stars:** If a star has dark spots (like sunspots), its brightness can dip as it spins and those spots come into view.
- The light from some stars takes **millions of years** to reach us, so when you look up at the night sky, you're seeing the past.

Even our own Sun varies slightly in brightness over its 11-year solar cycle—proof that the night sky is far more dynamic than it seems.

Color of the stars

The color of a star depends on its **surface temperature**—it's like a cosmic thermometer!

Star Colors and What They Mean:

- **Blue:** Hottest stars, with temperatures around 25,000 K or more. Examples: Rigel, Spica.
- **White/Blue-white:** Still very hot, around 10,000 K. Example: Sirius.
- **Yellow:** Medium temperature (~6,000 K), like our Sun.
- **Orange:** Cooler stars, around 4,000 K. Example: Aldebaran.
- **Red:** Coolest stars, about 3,000 K. Examples: Betelgeuse, Antares.

These colors come from the type of light the star emits most strongly, based on its temperature. Hotter stars emit more blue and ultraviolet light, while cooler stars glow red or orange.

Life cycle of a star:

The life cycle of a star is a cosmic journey shaped by gravity, nuclear fusion, and mass. Each stage reveals how stars are born, live, and eventually die—releasing or transforming energy along the way.

1. **Nebula (Stellar Nursery):** A star begins as a **giant cloud of gas and dust called *nebulae***. Gravity pulls the material together, and as it contracts, it heats up—marking the start of energy buildup.
2. **Protostar:** As the cloud collapses, it forms a **protostar**—a hot, dense core that glows from gravitational energy. Fusion hasn't started yet, but the temperature is rising.
3. **Main Sequence Star:** Once the core is hot enough, **nuclear fusion** begins—hydrogen atoms fuse into helium, releasing **immense energy**. The star enters its longest and most stable phase. Our Sun is currently in this stage.
4. **Red Giant or Supergiant:** When hydrogen runs out, fusion slows, and gravity causes the core to contract. The outer layers expand and cool, forming a **red giant** (for medium stars) or **supergiant** (for massive stars). Fusion of **helium and heavier elements** begins, releasing more energy.
5. **Final Stages (Depends on Mass):**
 - **Low/Medium Mass Stars:** The outer layers drift away, forming a **planetary nebula**, while the core becomes a **white dwarf**—a hot, dense remnant that slowly cools.
 - **High Mass Stars:** They explode in a **supernova**, releasing a burst of energy and scattering elements into space. The core may collapse into a **neutron star** or a **black hole**.

Neutron Stars

A **neutron star** is the collapsed core that forms when a star about **8 to 20 times the mass of our Sun** explodes in a **supernova**.

Supernova is a large explosion that takes place at the end of a star's life cycle.

Black Holes

If the original star is **more than about 20 times the Sun's mass**, the core collapse goes even further. Gravity overwhelms all other forces, and the core compresses into a **black hole**—a place in space where gravity pulls so much that even light cannot get out of it.

Black holes come in different sizes—from **stellar-mass black holes** to **supermassive ones** at the centers of galaxies.

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