The Sun

9th-12th grades (14 to 18 years), 40 to 60 minutes

Notice

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Objectives

Students will learn:

- That the sun is the closest star to Earth, just the right distance away to support life on our planet;
- That the sun's energy comes from nuclear fusion, and we receive this energy in the form of light and heat;
- That light from the sun hits the earth's surface at different angles throughout the year due to Earth's axial tilt, and this axial tilt causes the seasons;
- That Earth's atmosphere scatters light from the sun, which makes the sky blue and prevents us from seeing other stars during the day;
- Facts about some interesting solar phenomena: solar flares, sun spots, solar wind/aurora borealis, etc.;
- That the sun is about 4.5 to 5 billion years old; and
- That the sun will run out of hydrogen fuel in about 5 billion years, which will cause it to change radically and result in the total destruction of Earth.

Materials needed

- Flashlight
- Light and laser pointers
- **OPTIONAL**: A large copy or several small copies of the periodic table of the elements
- **OPTIONAL:** A large copy or several small copies of the Hertzsprung-Russell diagram
- Digitarium® planetarium system set for the current date at a time when the sun is easily visible, with atmospheric effects and landscape turned on

I. Introduction *(5 to 10 minutes)*

A) Inform students that you'll be learning about the sun today. What do they already know about the sun? *[If no one mentions it, point out that the sun is the closest star to Earth—only about 93 million miles/150 million kilometers away; that it provides energy in the form of light and heat; and that it is just the right distance from Earth to support life.]*

B) Ask students where the sun's energy comes from *[nuclear fusion]*. Discuss the basic process of nuclear fusion: Lighter elements combine or fuse into heavier elements. First hydrogen atoms fuse into helium atoms; next helium atoms fuse into carbon atoms; then carbon atoms fuse into oxygen; etc. *[If you have a periodic table, point to these elements on the table.]*

C) Inform students that you'll be going inside the planetarium to learn more about the sun. Review rules and expectations, then enter.

II. The Sun and Earth's Atmosphere *(5 minutes)*

A) Inform them that they're seeing the sky as it would look at about ____ am/pm, and point out the date and time bar so they know where to find the sky time. What do they notice? Where is the sun? Can they tell their directions using the sun? What part of the sky (north, south, etc.) is the sun in at the moment? *[If they cannot figure out the directions, reverse time to just after sunrise, and ask students in what direction the sun rises in order to determine which way is which. Point out the directions, then display the cardinal points.]*

B) Why is the sky blue? Because Earth's atmosphere—the layers of gases surrounding our planet—scatter sunlight . *[If time allows, discuss how different wavelengths of visible light travel through our atmosphere—i.e., why the sky is blue instead of red.]* This scattering of light prevents us from seeing other stars during the day. Let's turn off the atmospheric effects to show the sun against the stars. What do the students notice about the sun now that the atmospheric effects have been turned off? *[It looks smaller; it has a halo; there are other stars in the background, etc.]*

C) **OPTIONAL:** If time allows, discuss the relevance of the zodiac constellations. See the Astrology: Fact or Fiction? lesson for more details.

D) There are many legends about the sun from different parts of the world. Share one or two with students before moving on. *[See our resources webpage for ideas.]*

E) Other effects of Earth's atmosphere are beautiful sunsets and sunrises. Let's turn the atmospheric effects back on, then travel forward in time until after the sun rises tomorrow morning... *[As you watch the sunset and later the sunrise, discuss why we see those colors. You may want to stop time at some point during the night to discuss how the stars twinkle because of Earth's atmosphere.]*

III. Features of the Sun *(10 to 15 minutes)*

A) Let's take a closer look at the sun. *[Select and zoom in on it.]* What do you notice? *[If no one mentions sun spots, be sure to point those out.]* What are sun spots? They are cooler areas on the sun's surface—cooler being a relative term. Sun spots are only about 4,000 degrees Celsius, while the surface temperature of the sun is about 5,500 degrees Celsius.

What causes sun spots? Intense magnetic activity, which inhibits convection. Convection is heat transfer due to the movement of molecules. How many of you have ever boiled a pot of water on the stove? What happens to the water as it is heated? *[The heated water moves to the top of the pot.]* That is convection in action.

B) Share some other “fast facts” about the sun:

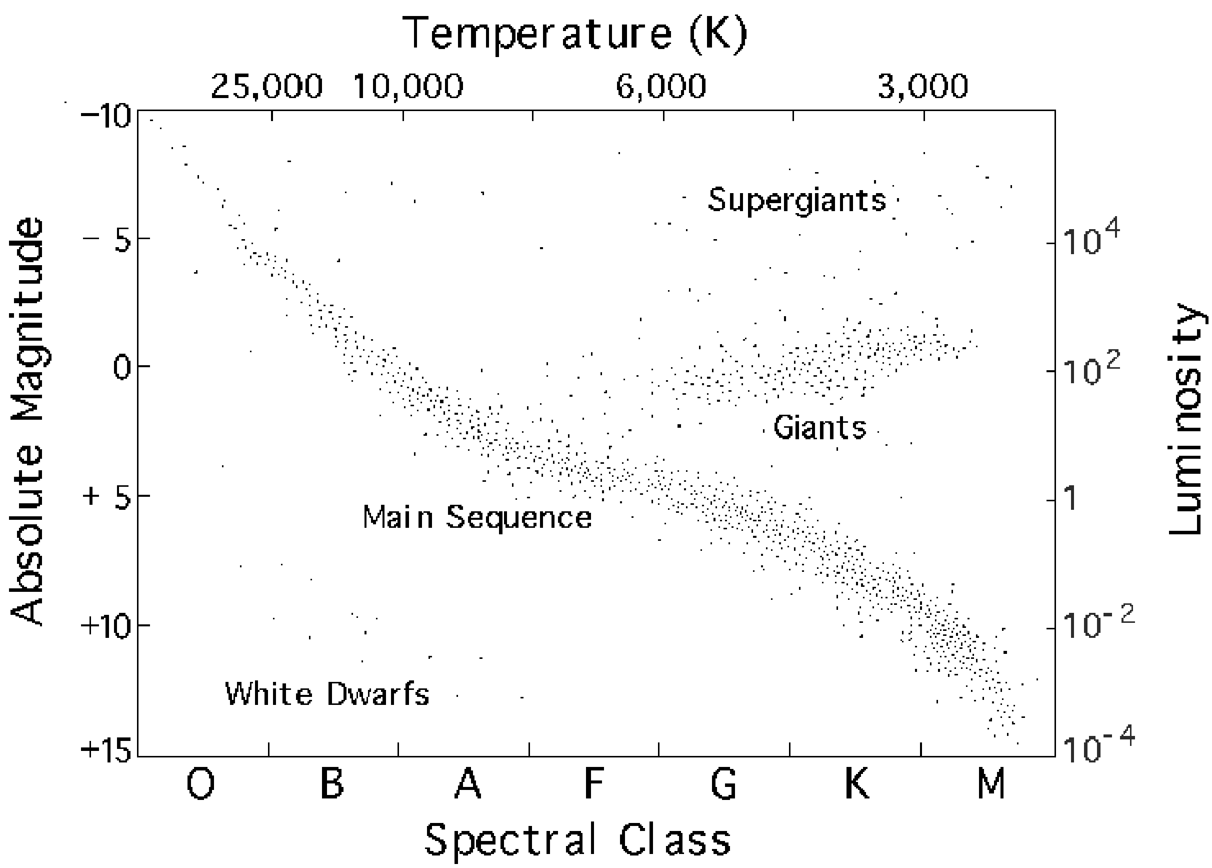
- Its diameter is about 870,000 miles (1.4 million km).
- The sun contains 99.8% of the mass of the solar system.
- The sun's magnetosphere extends beyond Pluto. What is the magnetosphere? A.k.a. the heliosphere, the sun's magnetosphere is the vast region around the sun which is permeated by the solar wind (the flow of energetic charged particles from the solar corona into the interplanetary medium) and the weak interplanetary magnetic field.
- As we discussed earlier, the sun's energy comes from nuclear fusion. Each second about 700,000,000 tons of hydrogen are converted to about 695,000,000 tons of helium and 5,000,000 tons of energy in the form of gamma rays. As it travels out toward the surface, the energy is continuously absorbed and re-emitted at lower and lower temperatures so that by the time it reaches the surface, it is primarily visible light. For the last 20% of the way to the surface the energy is carried more by convection than by radiation.

C) How old is the sun? About 4.5 to 5 billion years old. How do we know the age of the sun? Primarily through radioactive dating of the oldest meteorites. Most scientists think that the solar system formed as one unit, so the age of the sun should be close to the age of the meteorites. Another piece of evidence for this age estimate comes from our home planet, Earth, and the age of the oldest rocks found here—which are about 4.6 billion years old.

Since its birth the sun has used up about half of the hydrogen in its core. It will continue to radiate "peacefully" for another 5 billion years or so (although its luminosity will approximately double in that time). But eventually it will run out of hydrogen fuel and will be forced into radical changes. These changes will result in the total destruction of the Earth and probably the creation of a planetary nebula, such as the Ring Nebula in Lyra, M27/Dumbbell Nebula in Vulpecula, the Egg Nebula in Cygnus, or M97/Owl Nebula in Ursa Major *[select and zoom in on at least one of these nebulae]*.

If desired, share the basics of stellar evolution for a star similar in size to the sun. Use the Hertzsprung-Russell (HR) diagram to discuss where the sun is in this process:

Hertzsprung-Russell Diagram



source: NASA (imagine.gsfc.nasa.gov/docs/science/know_l2/stars.html)

See http://cass.ucsd.edu/public/tutorial/StevI.html for stellar evolution background information.

IV. Movements and Structure of the Sun *(10 to 15 minutes)*

A) Does the sun rotate? Let's speed up time to find out... Is the sun rotating? How can you tell? The outer layers of the Sun exhibit differential rotation: at the equator the sun's surface rotates once every 25.4 days; near the poles one rotation takes as much as 36 days. This is because the Sun is not a solid body like Earth. The differential rotation extends considerably down into the interior of the sun, but its core rotates as a solid body.

B) Does the sun revolve? Yes, it revolves around our galaxy, the Milky Way, on an almost circular orbit at a speed of about 137 miles/second (220km/second). It takes about 230 million years for the sun to complete one revolution.

C) As seen from Earth, does the sun travel the same path through the sky every day of the year? Why not? Because Earth is tilted about 23.5 degrees on its axis, so light from the sun hits the earth's surface at different angles over the course of a year. This tilt is the reason why we experience seasons. *[If time allows, do the sun prediction and path* *activity from the 6th-8th grade Solstices and Equinoxes lesson.]*

D) Discuss the structure of the sun, using the image of the sun's layers from the lesson media or community website.

V. Solar Phenomena *(10 to 15 minutes)*

A) Discuss solar flares: A sudden, rapid, and intense variation in brightness. A solar flare occurs when magnetic energy that has built up in the solar atmosphere is suddenly released. Radiation is emitted across virtually the entire electromagnetic spectrum, from radio waves at the long wavelength end, through optical emission to x-rays and gamma rays at the short wavelength end. The amount of energy released is the equivalent of millions of 100-megaton hydrogen bombs exploding at the same time! The first solar flare recorded in astronomical literature was on September 1, 1859. Two scientists, Richard C. Carrington and Richard Hodgson, were independently observing sunspots at the time, when they viewed a large flare in white light. *[The above text is from hesperia.gsfc.nasa.gov/sftheory/flare.htm]*

Show some images of solar flares *[available on the Digitalis lesson media and community website]* to supplement this discussion.

B) Solar prominences: Clouds of solar gas held above the sun's surface by the sun's magnetic field. Sometimes the prominences become unstable, erupt, and rise off of the Sun in just a few minutes or hours. Scientists have not yet determined the cause of solar prominences, although they do know that the cause is somehow related to the sun's magnetic field.

C) Solar eclipses: Ask students if any of them have ever witnessed a solar eclipse, when the moon passes between the earth and the sun and partly or fully blocks out the sun. If so, what do they remember about the event? Do they remember where they were and when they saw it?

There are between two and five solar eclipses each year. There are four types of solar eclipses:

- A **total eclipse** occurs when the sun is completely obscured by the moon. The intensely bright disk of the sun is replaced by the dark silhouette of the moon, and the much fainter corona is visible. During any one eclipse, totality is visible only from at most a narrow track on the surface of the Earth. Simulate a total eclipse using the following settings: Date: July 22, 2009. Latitude: 22.72N; longitude: 75.83E; time zone: Asia/Calcutta; start time: approximately 5:30 am local time. Zoom in on the sun with moon enlargement OFF for the best results. *[Note: Digitarium system users can download a total solar eclipse script from the StratoScripts section of the Digitalis community website to simulate this eclipse.]*
- An **annular eclipse** occurs when the sun and moon are exactly in line, but the apparent size of the moon is smaller than that of the sun. This causes the sun to appear as a very bright ring. Because the moon's orbit around Earth and Earth's orbit around the sun are ellipses rather than exact circles, the apparent sizes of the sun and moon change. Simulate an annular eclipse using the following settings: Date: January 15, 2010. Latitude: 1.6N; longitude: 69.3E; time zone: Asia/Karachi; start time: approximately 9:30 am local time. Zoom in on the sun with moon enlargement OFF for the best results. *[Digitarium system users can download an annular eclipse script from the StratoScripts section of the Digitalis community website to simulate this eclipse.]*
- A **hybrid eclipse** is an intermediate stage between a total and annular eclipse. At some points on the surface of the earth it is visible as a total eclipse, whereas at others it is

annular. Hybrid eclipses are rather rare. *[Note: Digitarium system users can download a hybrid solar eclipse script from the StratoScripts section of the Digitalis community website.]*

- A **partial eclipse** occurs when the sun and moon are not exactly in line, and the moon only partially obscures the sun. This phenomenon can usually be seen from a large part of the Earth outside of the track of an annular or total eclipse. However, some eclipses can only be seen as a partial eclipse, because the umbra never intersects the Earth's surface. Simulate a partial eclipse using the following settings: Date: January 4, 2011. Latitude: 64.7N; longitude: 20.8E; time zone: Europe/Helsinki; start time: approximately 9:30 am local time. Zoom in on the sun with moon enlargement OFF for the best results. *[Note: Digitarium system users can download a partial solar eclipse script from the StratoScripts section of the Digitalis community website to simulate this eclipse.]*

D) Aurora borealis (a.k.a. the northern lights) and aurora australis (a.k.a. the southern lights): Ask students if they have ever witnessed this. If so, what do they remember? What causes this beautiful phenomenon? High energy electrons from the sun striking atoms and molecules of gases in Earth's upper atmosphere. *[From asahi-classroom.gi.alaska.edu/suncnnx.htm:]*

> When viewed from space, the aurora appears as a bright oval around both the geomagnetic pole(S) in the Northern hemisphere and the geomagnetic pole (N) in the Southern hemisphere. The auroral oval [...] [is] shaped by Earth's magnetic field.
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> The solar wind -- streams of charged particles flowing from the sun -- is deflected by Earth's magnetic field. Earth's magnetic field is in turn compressed by the solar wind and distorted into a comet-shaped cavity known as the magnetosphere. The magnetic fields can intermingle creating a complicated flow pattern within the magnetosphere.
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> The streams of charged particles that produce the aurora come from the corona, the outermost layer of the sun's atmosphere. The corona is exceedingly hot, measuring more than one million degrees. The high temperature causes hydrogen atoms to split into protons and electrons. The resulting gas of charged particles is called plasma, which is electrically conductive. The solar plasma is so hot that it breaks free of the sun's gravitational force and blows away from the surface in all directions. The movement of this plasma is called solar wind. The intensity of the solar wind and the magnetic field carried by it change constantly. When the solar wind blows stronger, we see more active and brighter aurora on Earth.

Show some images of aurorae *[available on the Digitalis lesson media and community website]* to supplement this discussion.

VI. Conclusion *(5 minutes)*

A) Ask the students what they learned about the sun today, being sure to review the major lesson concepts: the sun is the closest star to Earth; the sun rotates on its axis; etc.

B) Emphasize that students should NEVER observe the real sun without eye protection, not even during a solar eclipse. Share some strategies for safely observing the real sun: pinhole viewers; solar telescopes; etc.