STUDYING STARS NEAR AND FAR
Grades 7 - 8

NJCCCS: 5.1, 5.2, 5.4

Field Trip Overview:

On your field trip, your students will be introduced to our closest star (the Sun) and the energy it emits. Activities related to the electromagnetic spectrum of light, telescope optics, and spectroscopy will demonstrate how we currently study the Sun and other stars. Students will visit our observatory where our research grade 20” Classical Cassegrain telescope is housed. Weather permitting, we will also safely view the Sun.

Background Information:

The Sun (and all the other stars) has been the source of much wonder and speculation to humanity for millennia, and one can say that we would not be here without it. Life on Earth is dependent on the energy radiated by the Sun. It helps to heat the air, water, land and organisms to create a livable temperature on Earth. It drives the weather systems and water cycles that are necessary for life to exist. Green plants and phytoplankton absorb sunlight to help them produce food (through the process of photosynthesis) to grow and become the base of the food web. Humans have strived to understand the Sun to satisfy our curiosity, know how it was created, how long it will exist and many other physical properties. The ancients likely studied the Sun (and other stars) for the practical purposes of tracking time, knowing when to plant, harvest, expect floods, travel the seas, etc.

The ancients were able to track the apparent path of the Sun (and the stars) across the sky in a very predictable way. Due to the rotation of the Earth on its axis, the Sun appears to rise in East, reach its maximum height at noon to the South (in the Northern Hemisphere), and sets in the West. Many ancient cultures built monuments and other structures that lined up with sun on the solstices and equinoxes with precision, indicating a deep understanding of the motions in the sky. Because the Earth’s axis is tilted approximately 23.5°, it causes the apparent path of the Sun to change over the course of the year, resulting in the seasons. If shaded by clouds, the Sun appears to be a perfect, unflawed circle of white light. Eventually, ancient Chinese astronomers saw dark spots (sun spots) on the surface of the Sun, which were rediscovered by Galileo, advancing our understanding of the Sun.

It wasn't until 1609 that a telescope was used to make significant contributions to our understanding of the cosmos. Galileo pointed a "spyglass" to the sky to make observations of the cosmos, and became the first person in recorded history to use a telescope and document his discoveries. It was nearly 60 years after Galileo used his refracting telescope that Isaac Newton developed a reflecting telescope, making improvements to the instrumentation used to study the sky. Newton also made significant contributions to our understanding of the properties of light and the splitting of light into its component wavelengths, or spectrum. His work set the stage for many other scientists to analyze the Sun's and other stars' spectra to unlock their mysteries. Spectroscopy (the analysis of spectra) is a key tool in astronomy because it provides a way for us to know the effective temperature, movement in space, rotation speed, size, density, and chemical composition of stars. It allowed Edwin Hubble to discover the universe is expanding and calculate the rate at which it is expanding. It has been invaluable to astronomers, allowing them to make specific measurements and quantify the characteristics of galaxies, stars and planets even though they are so far away. A continual growth of our body of knowledge has developed over time, and as Isaac Newton once wrote to a fellow scientist in 1685: "If I have seen further than certain other men, it is by standing on the shoulders of giants."

The progression of naked eye astronomy to modern astronomy involving intricate telescopes and precise instrumentation is a fascinating story of human ingenuity, creativity and achievement. It describes the development of our understanding of ourselves, the universe, our place in it, where we came from, and where we may end up. The work of many great thinkers, philosophers, scientists, mathematicians, engineers and others have led to our current understanding of the universe. Continuing the study of stars near and far will no doubt lead to new discoveries that will benefit the human race for millennia to come.

Vocabulary:

Absorption Spectrum: A pattern of dark lines across a continuous spectrum, resulting from the atom of a chemical element absorbing light and electrons jumping out to higher energy levels.

Apparent Motion of the Sun: The path of the Sun across the sky from sunrise to sunset, caused by the rotation of the Earth on its axis.

Autumnal (Fall) Equinox: The day in which the sun crosses the celestial equator moving southward; on this day there are 12 hours of daylight/darkness across the globe, it occurs on or about September 21.

Axial Tilt: The degree to which the Earth's axis (imaginary line running through the Earth from the South Pole to the North Pole) is inclined compared to the plane of the solar system (and that of the Sun). It is 23.5°.

Concave: Curved inward, like the interior of a sphere.

Continuous Spectrum: A continuous array of all the colors in a rainbow.

Convex: Curved outward, like the exterior of a sphere.

Dispersion: The breaking up and scattering of white light into the colors of the rainbow.

Electromagnetic Radiation: Changing electric and magnetic fields that travel through space (and from the Sun) and transfer energy from one place to another; examples are radio, micro, infrared, visible, ultraviolet, x-ray, and gamma ray waves.

Emission Spectrum: A pattern of bright-colored lines of different wavelengths; each chemical element has its own unique set of bright colored emission lines.

Eyepiece Lens: The lens or lens group closest to the eye in an optical instrument.

Focal Length: The distance of the focus from the surface of a lens or mirror.

Focal Point: The point at which rays of light or other radiation converge or from which they appear to diverge, as after refraction or reflection in an optical system.

Fusion: A nuclear reaction in which nuclei release energy when combining to form more massive nuclei.

Iris: The pigmented, round, contractile membrane of the eye, situated between the cornea and lens and perforated by the pupil.

Lens: 1) A piece of glass or other transparent material with opposite surfaces either or both of which are curved, by means of which light rays converge or diverge to form an image; 2) A transparent part of the eye that focuses light rays to form an image on the retina.

Light Wave: An electromagnetic disturbance that consists of rapidly changing electric and magnetic effects; transferring energy from a source (e.g., Sun) to a receiver (e.g., your eye). It can travel through the vacuum of space and does not require a medium in which to move.

Mechanical Wave: Waves which require movement through a material medium (solid, liquid, or gas); e.g., sound and water waves.

Objective Lens: The lens of an optical instrument that is the first to receive light rays from an object.

Pupil: The dark, circular opening in the center of the iris of the eye.

Reflection: The throwing or bending back from a surface.

Refraction: The turning or bending of a wave when it passes from one medium into another of different density.

Retina: A delicate, multilayered, light-sensitive membrane lining the inner eyeball and connected by the optic nerve to the brain.

Spectroscopy: The analysis of spectra (or spectrums).

Spectrum: The image or graph resulting from separating light into its component wavelengths. Spectra (pl.) could be one or all of three basic types: continuous, emission, and/or absorption.

Summer Solstice: The day in which the Sun has the most northern position of the year and has the most daylight hours; it occurs on or around June 21.

Sundial: The oldest astronomical instrument used to tell time with the apparent motion of the Sun. As the Sun moves across the sky, a shadow is cast along hour markings.

Telescope: An arrangement of lenses or mirrors or both that gathers visible light (or sensors that detect invisible radiation), permitting direct observation or photographic recording of distant objects.

Vernal (Spring) Equinox: The day in which the sun crosses the celestial equator moving northward; on this day there are 12 hours of daylight/darkness across the globe, it occurs on or about March 21.

Winter Solstice: The day in which the Sun has the most southern position of the year and has the least amount of daylight hours; it occurs on or around December 21.

References / Resources:

- Couper, H., & N. Henbest. 2007. The History of Astronomy. Firefly Books Ltd., Buffalo, NY.

- Moche, D. L. 2004. Astronomy: A Self-Teaching Guide. 6^{th} Edition. John Wiley & Sons, Inc.

- Seeds, M. A. 2001. Foundations of Astronomy. 6^{th} Edition. Brooks/Cole, a division of Thomson Learning, Inc.

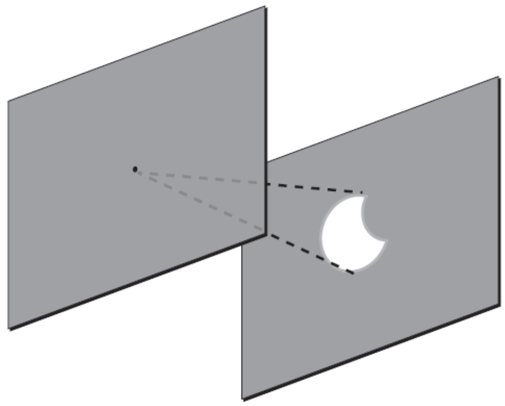
Pre-Trip Activities

1. Projecting the Sun

Classroom Activities

Activities courtesy of the Stanford Solar Center
http://solar-center.stanford.edu/observe/observe.html

Projecting the Sun



You can easily and safely observe the Sun by projecting it through a tiny hole onto a white sheet of paper. This simple device is called a "pinhole camera."

You'll need:

- **2 sheets** of stiff white paper
- **1 pin**
- **A sunny day**
- Perhaps **a friend** to help

1. With the pin, punch a hole in the center of one of your pieces of paper.

2. Go outside, hold the paper up and aim the hole at the Sun. (Don't look at the Sun either through the hole or in any other way!)

3. Now, find the image of the Sun that comes through the hole.

4. Move your other piece of paper back and forth until the image rests on the paper and is in focus (i.e., has a nice, crisp edge). What you are seeing is not just a dot of light coming through the hole, but an actual image of the Sun.

Experiment by making your hole larger or smaller. What happens to the image? What happens when you punch two holes in the piece of paper? Try bending your paper so the images from the two holes lie on top of each other. What do you think would happen if you punched a thousand holes in your paper, and you could bend your paper so all the images lined up on top of each other?

In fact, optical telescopes can be thought of as a collection of millions of "pinhole" images all focused together in one place!

You can make your pinhole camera fancier by adding devices to hold up your piece of paper, or a screen to project your Sun image onto, or you can even make your pinhole camera a "real" camera by adding film.

If you want to learn more about how light works, you can join artist Bob Miller's Web-based "Light Walk" at the Exploratorium. It's always an eye-opening experience for students and educators alike. His unique discoveries will change the way you look at light, shadow, and images!

Related Resources

Bob Miller's Light Walk
http://www.exploratorium.edu/light_walk/lw_main.html

Several sites give instructions for building more exotic pinhole cameras for observing the Sun:

Cyberspace Middle School
http://www.scri.fsu.edu/~dennisl/CMS/sf/pinhole.html

Jack Troeger's Sun Site
http://www.cnde.iastate.edu/staff/jtroeger/sun.html

CAUTION!
Don't EVER look directly at the Sun, with or without a telescope
(unless you have the proper filters).

References/Resources:
[NASA: Living With a Star]

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Post-Trip Activities

1. Make Your Own Spectroscope

Use the link below to download the template to the home-made spectroscope. It is designed to use a CD or DVD as a diffraction grating to separate light into its component wavelengths. The document includes an introduction to ozone and the atmosphere, discussing NASA's Earth-observing Aura satellite, specifically, the Tropospheric Emission Spectrometer (TES) on it. Ozone was not addressed in our program, but the spectroscope design is very nice and applicable to what was discussed on your field trip.

References / Resources:
NASA: Make Your Own Spectroscope