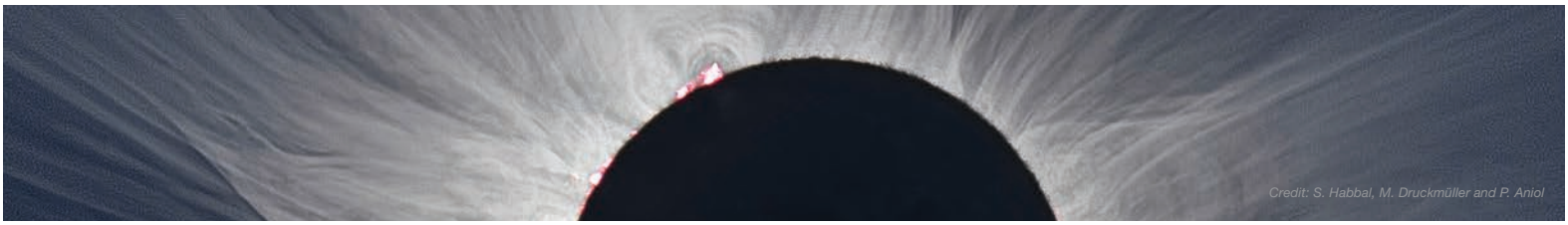
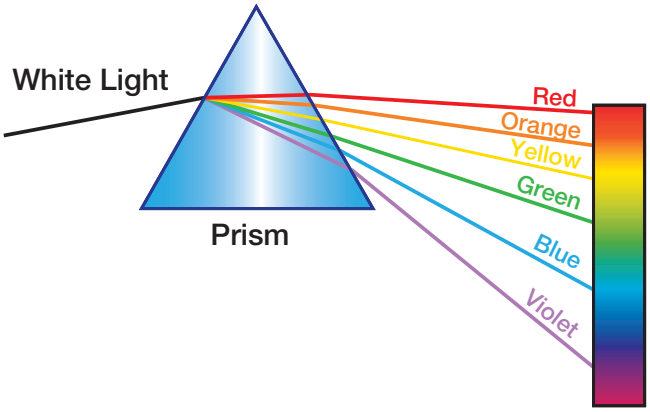


Credit: S. Habbal, M. Druckmüller and P. Aniol

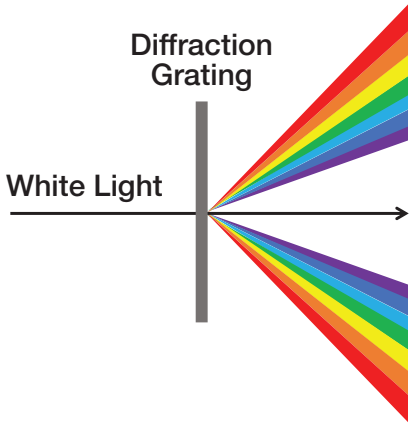
4. LET'S SEE LIGHT IN A NEW WAY: DIFFRACTION SPECTRA

What Is This About?

Most of us take our sight for granted. We see the world around us in reflected light from the sun or artificial light sources. Today, we understand that light can be composed of many colors or "wavelengths." Our eyes and brain work together to blend these wavelengths into a single color. Isaac Newton first used the word "spectrum" to describe these individual colors that can be seen when passing light through a prism. These are the familiar colors of rainbows.



Credit: NASA Space Place



Credit: E. DeVore, SETI Institute

In this activity, you will explore various light sources using a "spectroscope." The spectroscope is made with a transparent plastic film that has thousands of lines etched in it. When light passes through the etched film, it bends relative to its color or wavelength like it does through a prism. The diffraction grating spreads out the visible light, making it easy to see all the colors. For more information on the spectrum, see pages 14-15.

Materials: (you provide)

- 10 spectroscopes that participants can share
- Light sources (see next page)
- White paper to reflect sunlight

Credit: E. DeVore, SETI Institute

WARNING: DO NOT LOOK DIRECTLY AT THE SUN.
DOING SO CAN DAMAGE YOUR EYES.

To Do:

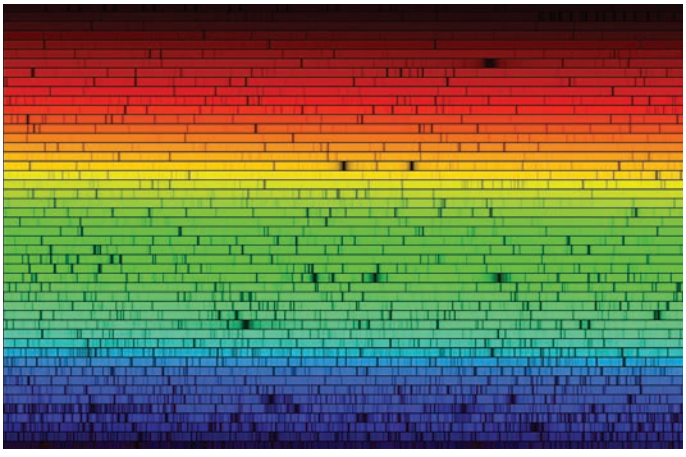
- Look at your spectroscope. Read the safety label. **DO NOT LOOK DIRECTLY AT THE SUN.**
- Look at the ends of the spectroscope.
- One end has a slit—that's the front end that you point at light sources. The other end has a small opening with a transparent piece of diffraction grating mounted in it. See page 16.
- Be careful not to touch the diffraction grating. Your fingerprints will make it work poorly.
- Look through the spectroscope at a lamp or ceiling light. What do you see?

Are All Sources of Light the Same? Check These Out!

- Incandescent (old fashioned) lamp
- Compact fluorescent lamp (CFL)
- Fluorescent lights (in the ceiling)
- A white piece of paper on the ground in sunlight. **DO NOT LOOK DIRECTLY AT THE SUN.**
- Brightly colored cars or flowers
- Neon signs
- Television and computer screens
- Stoplights
- LED lamps, flashlights, and holiday lights
- Bug lights
- Floodlights
- The moon

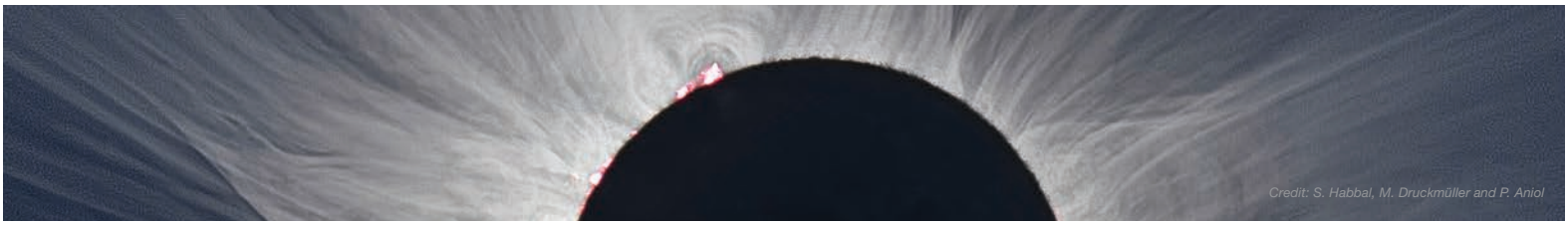
Space Science Tie-In:

Today, scientists build sensitive instruments called spectrometers to study the light from distant objects: stars, galaxies, planets, dust and gas in space. Like people, each atom and molecule shows its own unique set of fingerprints—lines in the spectrum. By studying these fingeprints—the spectrum of an object—astronomers can tell what a star or planet is made of. The spectrum can also tell us about the temperature and pressure, motion, and ultimately, the formation and evolution of celestial objects.



The spectrum of the sun

Credit: N. Sharp, NOAO/AURA/NSF



5. A LIGHT SNACK: COOKIE BOX SPECTROMETERS

What Is This About?

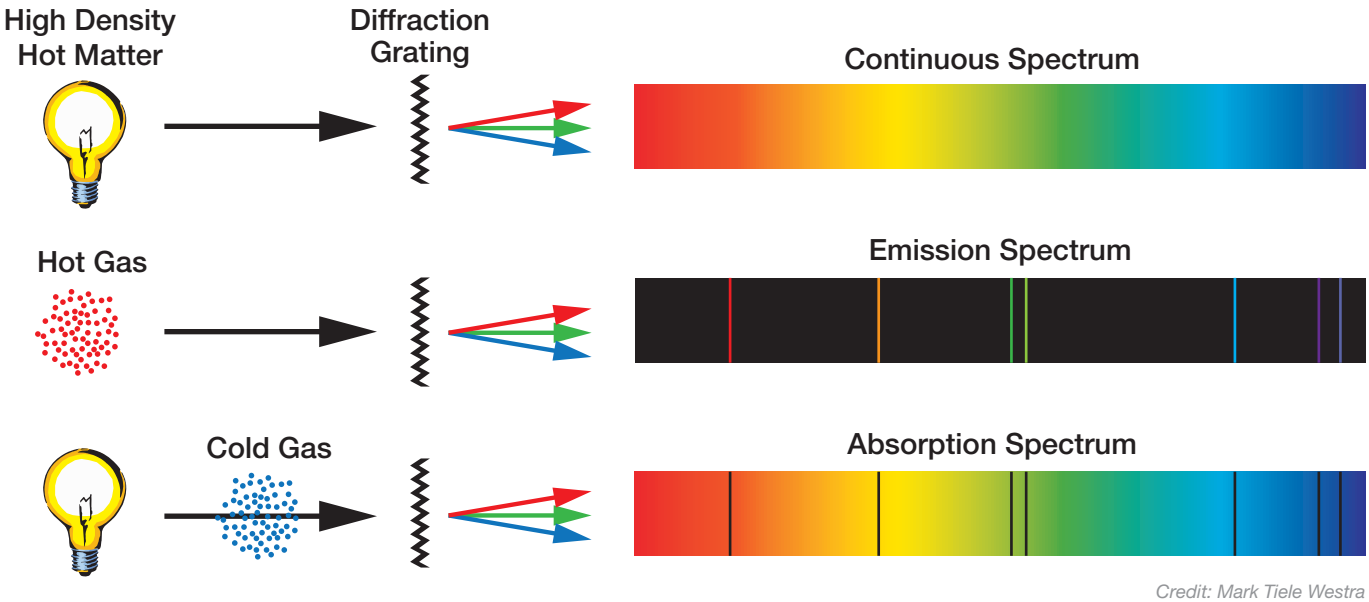
When you look at a rainbow, you are seeing the spectrum of white light from the sun. Tiny spherical raindrops refract (bend) and spread out white light into its component colors. In this activity, you will go deeper to explore the science and engineering of spectroscopy—the study of the spectrum and what it tells us about our world and the universe.

In 1665, Isaac Newton demonstrated that a prism can break light into its component colors and that a second prism can re-assemble them back again into white light. He was the first to call this the "spectrum." In 1814, Joseph Fraunhofer invented the spectroscope to study light, and discovered absorption lines in the spectrum of the sun. Helium was first discovered in the spectrum of the sun!

What Is Going On With Light?

When atoms of different materials are excited by an electric current or another source of energy, they produce a unique spectrum. Atoms of different elements have different colors in their spectra. Each atom or molecule's spectrum is unique to that element or compound, just as fingerprints are unique for every person.

Dive deeper into spectra with NASA: https://science.nasa.gov/ems



Credit: Mark Tiele Westra

The Computers:

The first spectra of stars were made with a telescope, a prism and a photographic glass plate. Beginning in 1870s, women were hired as "computers" at Harvard College Observatory to classify these stellar spectra.

Harvard computers at work circa 1890:

Henrietta Swan Leavitt seated, third from the left, with magnifying glass, Annie Jump Cannon in center also with magnifying glass, and Williamina Fleming standing, in the center, and Antonia Maury, far right.

Credit: Harvard Astronomical Plate Collection

Annie Jump Cannon studied the spectra of more than 225,000 stars as a "computer" at Harvard Observatory. She perfected the classification system we use today. She compiled the largest accumulation of astronomical information ever assembled by a single individual—the nine volume Henry Draper Catalog. She won many honors and awards in the United States and Europe during her lifetime. Today, the Annie Jump Cannon Award is presented each year by the American Astronomical Society to a North American female astronomer in the first five years after her doctorate.

Henrietta Swan Leavitt worked alongside of Cannon as a "computer." Leavitt studied variable stars—stars that dim and brighten repeatedly. She discovered the "Cepheid Variables" that allow astronomers to accurately measure distances in our galaxy, and to other galaxies. Her discovery helped other astronomers discover that the universe is expanding. Leavitt was deaf most of her career. Lauren Gunderson's play "Silent Sky" portrays these women at the dawn of modern astronomy.

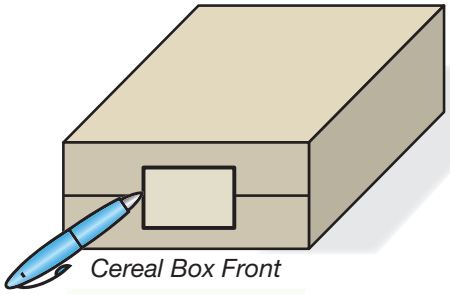
Space Science Tie-In:

Astronomers study light of all types—the electromagnetic spectrum—to understand the universe and everything in it. From the spectrum of a star, we can discover its composition, temperature, motion through space and deduce its size, mass and age. All from just light. This is true for planets, comets, moons, asteroids, gas clouds, star clusters, galaxies—everything in the universe.

Astronomers build spectrometers to launch into space or to use with ground-based telescopes to observe the spectrum of distant objects. Launching a spectrometer above the atmosphere allows us to observe high energy light sources in UV, x-rays, or gamma rays that would normally be filtered out by our atmosphere. It also allows astronomers to inspect the full infrared spectrum, much of which is filtered out by atmospheric water vapor.

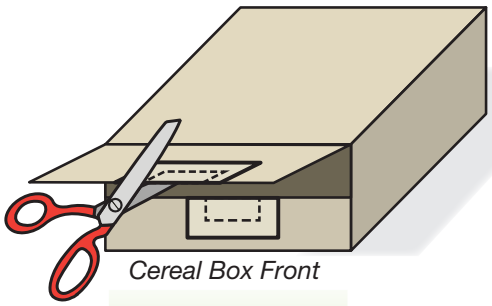
MAKING YOUR
CEREAL BOX SPECTROSCOPE

1. Select one end of the cereal box, and close the flaps. Place a diffraction grating on this end and outline it with a sharpie. This will be referred to as the front of your "Spectroscope".



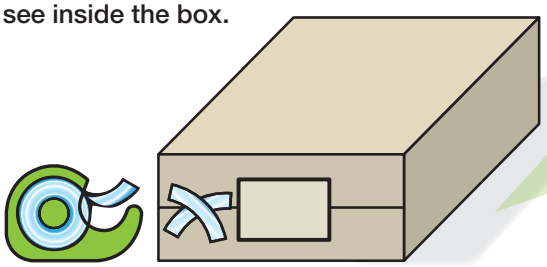
Cereal Box Front

2. Open the flaps and cut a hole smaller than the size of your outline in the cereal box.



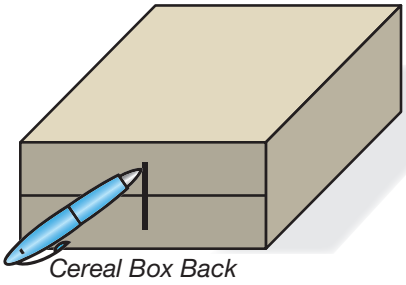
Cereal Box Front

3. Tape the cereal box flaps closed. Arrange your diffraction grating right side up (so you can read the label), then tape it over the hole you just cut. Make sure you can look through the grating and see inside the box.



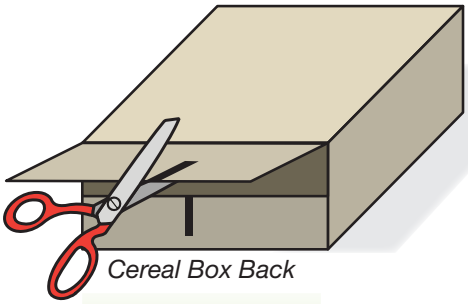
Cereal Box Front

4. Rotate the box around so you are now looking at the opposite end. (This will be the back of your "Spectroscope"). Close the two flaps and draw a line down the center (top to bottom, not side to side). The line should be directly opposite the diffraction grating, and centered.



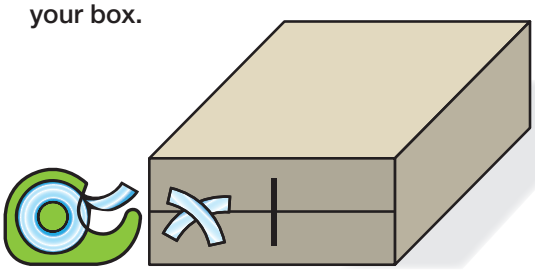
Cereal Box Back

5. Cut along the mark you just made, making a very, very narrow slit in the box.



Cereal Box Back

6. Close and tape the flaps on the back of your box.



Cereal Box Back

You're done!!

Look through the grating in your spectroscope to see the light spectrum!

Credit: NASA — The Science of the Sun—Solar Dynamics Observatory Education Unit
https://sdo.gsfc.nasa.gov/assets/docs/UnitPlanSecondary.pdf

Materials: (you provide)

- Cereal or cookie boxes, one per spectroscope
- Tape
- Scissors
- Sharpie or other pen
- Diffraction gratings, one per spectroscope*
- Black electrical tape (optional)

Cookie box spectrometer

Credit: E. DeVore, SETI Institute

*Diffraction gratings are readily available.
Search on line for "Diffraction Grating Slides."
Look for "single axis" or "linear" gratings with 500 to 1,000 lines per inch.
They cost about $1.00 each.

Scope Out the Light—Use Your Spectroscope:

- You may need to troubleshoot your spectroscope.
- If you don't see a broadband of colors, try rotating the diffraction grating 90° (1/4 turn).
- If the slit is too wide, use pieces of black electrical tape to make it narrower and crisper.

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Are All Sources of Light the Same? Check These Out!

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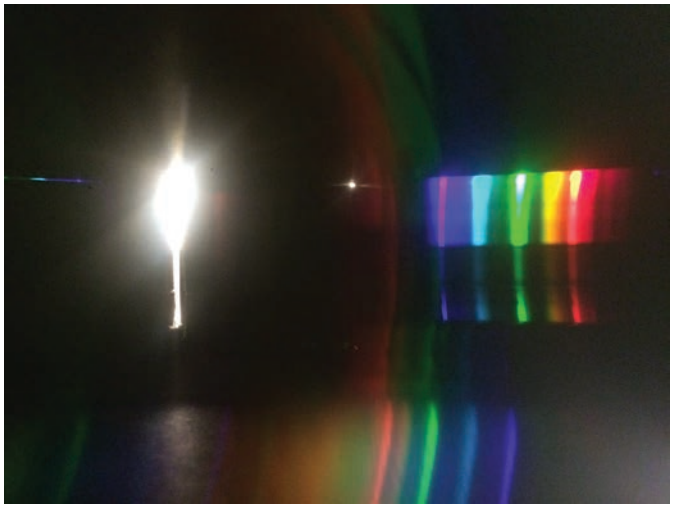

Fluorescent ceiling lamp seen through cookie box spectrometer

Credit: E. DeVore, SETI Institute