

Introduction to Solar Science Learning Kit

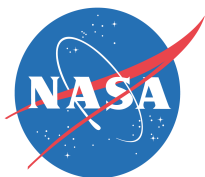
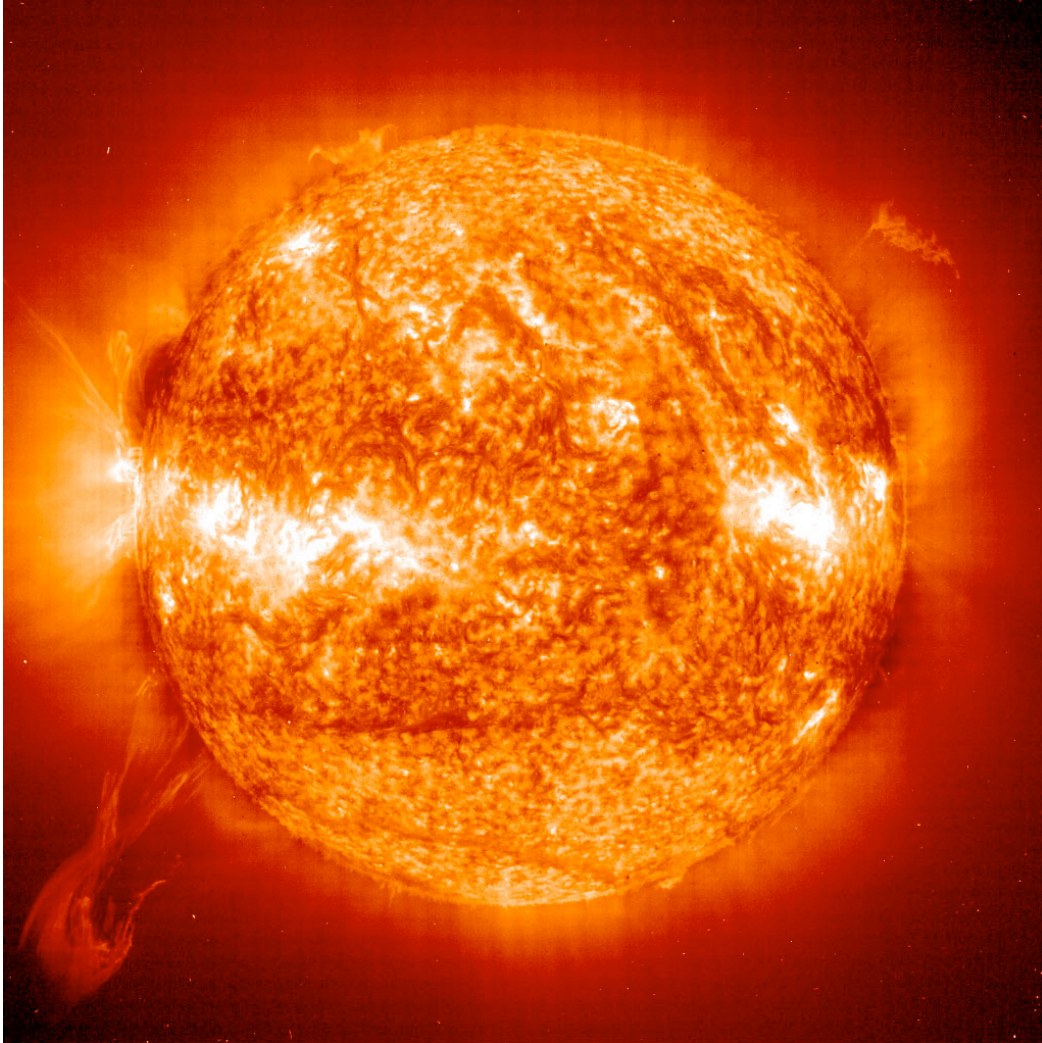
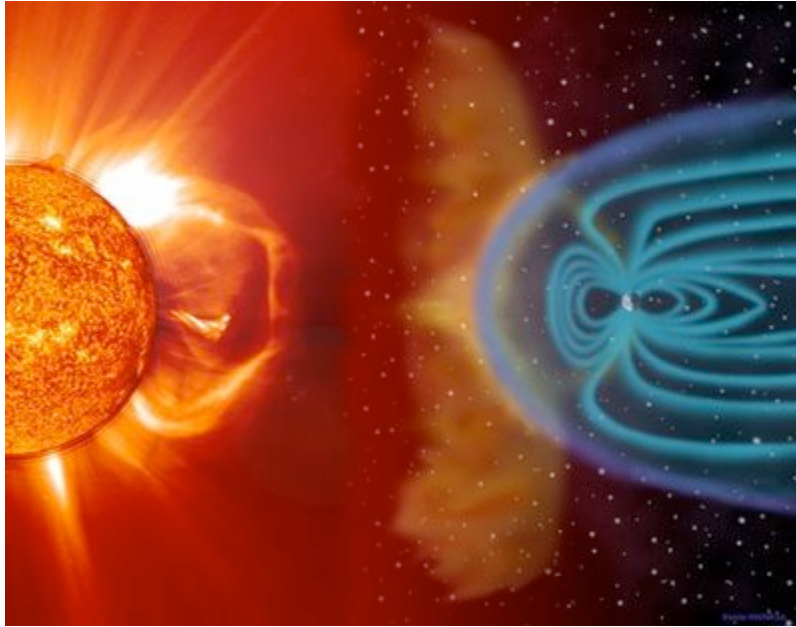


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- Introduction for Teachers
- EVE Learning Objectives and Science Standards
- Science Literacy Benchmarks
- LASP Space Weather Education website
- EVE Education website

Units

The basics of each of these units can be covered in a 45-minute period, although they can also be expanded.

1. Understanding Ultraviolet- Inquiry-based learning activities that focus on the UV band of the Electromagnetic Spectrum (including UV beads and 2 UV meters per kit with option to borrow additional meters)
2. Introduction to Solar Science- Presentations from NASA on DVD & CD
3. Examining the solar spectra- Building a Spectroscope
4. The Solar Dynamic Observatory (SDO) and Extreme Ultraviolet Variability Experiment (EVE)
5. Eyeing the Ionosphere- Using Technological Tools to Examine Atmospheric Ionization

Introduction for Teachers

Space science is by definition enormous and can be overwhelming, yet it is also inherently rich with content and can be engaging and inspiring for students. But the science is also complex and isn't always intuitive, so not all space science is necessarily "fun and games."

With this "Introduction to Solar Science Learning Kit" we have aimed to pull together a few of the resources and activities that will ideally build on the prior knowledge of students and present them with current solar science research. Moreover, we have chosen activities and information that will work in an after school program or fit in with existing science curricula.

This effort has been funded by NASA through the Extreme Ultraviolet Variability Experiment (EVE), which is part of the Solar Dynamic Observatory (SDO), which in turn is the first satellite of the "Living with a Star" mission. While part of our goal is to provide a very general overview of space science, we do want to highlight the specific research of the EVE instrument. Unlike visible and UV light, Extreme Ultraviolet and X-Rays from the sun do not penetrate to the Earth's surface because the atmosphere filters them out. Their variations therefore have to be studied from space, outside the atmosphere.

Extreme ultraviolet and X-rays, which have wavelengths from one to 250 nanometers, have an ionizing effect on the upper atmosphere, generating the aptly named "ionosphere" which plays an important role in our modern radio communications. The global electric circuit between the positively charged ionosphere and negatively charged Earth holds many mysteries that scientists are working to better understand.

In addition to the introductory materials and activities, we include supplemental resources for enrichment and further explorations. The Space Weather Compendium from LASP includes a wide range of online resources, with scope and sequence as well as relevant National Science and Mathematics Education Standards as well as Science Literacy Benchmarks. And the Sudden Ionospheric Disturbance or SID Monitor, while requiring some technical expertise and a dedicated computer, can turn a classroom into a research station monitoring changes in the ionosphere, generating data that students can analyze and share with other schools around the world.

The material in this kit builds on past efforts and experience, and will benefit from your feedback. Don't hesitate to let us know what works, what doesn't and how we can improve the kit for use in your classroom or after school program.

Sincerely,
Mark S. McCaffrey
CIRES Education and Outreach
University of Colorado at Boulder

Appendix A

EVE Learning Objectives & Science Standards

Science standards that relate to EVE and SDO project exist at all levels of formal education: Grade K-4, 5-8 and 9-12. All formal education must align within these standards in order to recruit participation from teachers and schools. High stakes science testing at the 5th grade, 8th grade and 10th grade make these grades especially interested in science that helps students meet CSAP requirements.

Following are National Science Content Standards which significantly drive what is covered in the classroom and when. Informal education (such as science centers and museums) are also relying on the standards as a way of demonstrating the relevance of the exhibits and programs to science education.

Grades K-4	Grades 5-8	Grades 9-12
Standard 1: Students understand the processes of scientific investigation and design, conduct, communicate about and evaluate such investigations.		
Standard 2: Physical Science: Students know and understand common properties, forms, and changes in matter and energy (Focus: Physics and Chemistry)		
2.1 Students know that matter has characteristic properties, which are related to its composition and structure.		
2.2 Students know that energy appears in different forms, and can move (be transferred) and change (be transformed).		
2.3 Students understand that interactions can produce changes in a system, although the total quantities of matter and energy remain unchanged.		
Standard 3: Life Science: Students know and understand the characteristics and structures of living things, the processes of life, and how living things interact with each other and their environment.		
3.1 Students know and understand the characteristics of living things, the diversity of life, and how living things interact with each other and their environment.		
3.2 Students know and understand interrelationships of matter and energy in living systems.		
Standard 4: Earth and Space Science: Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space.		
4.1 Students know and understand the compositions of Earth, its history, and the natural processes that shape it.		
4.2 Students know and understand the general characteristics of the atmosphere and fundamental processes of weather.		
4.3 Students know the structure of the solar system, composition and interaction of objects in the universe, and how space is explored.		
Standard 5: Students know and understand interrelationships among science, technology, and human activity and how they can affect the world.		
Standard 6: Students understand that science involves a particular way of knowing and understand common connections among scientific disciplines.		

CIRES Outreach will work with the EVE team and other SDO-related education and public outreach efforts to leverage existing efforts and develop effective ways of connecting the science and technologies to key audiences.

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Susan Buhr 303.492.5657 susan.buhr@colorado.edu

The kit supports these Science Literacy Benchmarks:

Accelerating electric charges produce electromagnetic waves around them. A great variety of radiations are electromagnetic waves: radio waves, microwaves, radiant heat, visible light, ultraviolet radiation, x-rays, and gamma rays. These wavelengths vary from radio waves, the longest, to gamma rays, the shortest. In empty space, all electromagnetic waves move at the same speed – “the speed of light.” AF/H3



Light from the sun is made up of a mixture of many different colors of light, even though to the eye the light looks almost white. Other things that give off or reflect light have a different mix of colors. 4F/M1

Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and X-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle data and complicated computations to interpret them; space probes send back data and materials from remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. 4A/H3

Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information. 3A/M2

Although the various forms of energy appear very different, each can be measured in a way that makes it possible to keep track of how much of one form is converted into another. Whenever the amount of energy in one place diminishes, the amount in other places or forms increases by the same amount. 4E/H1*



SPACE WEATHER EDUCATION @ LASP

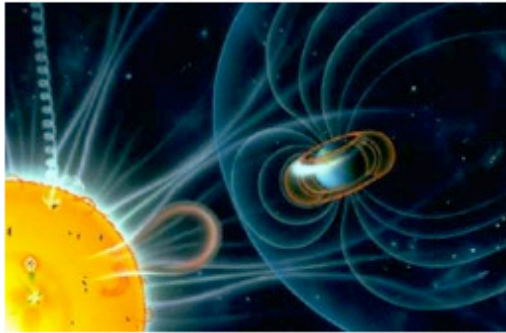


Illustration of the Sun-Earth connection showing a CME traveling toward the Earth with the solar wind. The lines are magnetic field lines.

SPACE WEATHER

As part of our education program in Space Weather, we have developed a compilation of lessons and activities from a wide variety of sources, compiling the best of the best. To aid teachers and their limited time, we take these lessons and organized them according to age groups. We've added a front page for each lesson that includes:

- Lesson summary
- Required student prior knowledge and skills
- Math and science standards (standards directly/metare stated, while standards that require teacher modification are not)
- Preparation time and in-class time
- A list of materials

In addition, we've included:

- Online resources
- Background material
- Additional lessons
- A glossary
- Tables of AAAS Benchmarks, NSES Science Standards, and NCTM mathematics standards

LESSONS

Elementary School

LESSONS

SCOPE & SEQUENCE

STANDARDS

Middle School

LESSONS

SCOPE & SEQUENCE

STANDARDS

High School

LESSONS

SCOPE & SEQUENCE

STANDARDS

FUN AND EDUCATIONAL LINKS

- LASP's [SORCE Education and Outreach](#)
- [Space Weather Center](#)
- [The Center for Science Education at the UC Berkeley Space Sciences Laboratory](#)
- [STARLAB: portable planetarium systems \(Learning Technologies, Inc.\)](#)
- [Aurora \(Your Guide to the Northern and Southern Lights\)](#)
- [Space Environment Center \(NOAA\)](#)
- [Nasa's Solar System Exploration](#)
- [The Sun-Earth Connection Education Forum](#)
- [SOHO: The Solar and Heliospheric Observatory](#)
- [Solar Max \(Your Guide to the Year of the Active Sun\)](#)


CLASSROOM RESOURCES

- [The Polar Vortex Interactive](#): Learn how energetic particles interact with Earth's magnetic field and contribute to a small amount of ozone destruction.




- [The Oases publication](#) for middle and high school students
 - Volume 1: English | Spanish
 - Volume 2: English
- [Photo Databank](#)
- [Additional Lessons](#)
- [Resources](#)

http://lasp.colorado.edu/eve/education/edu_outreach.htm



EXTREME ULTRAVIOLET VARIABILITY EXPERIMENT



Home Science Data Education News/Events Reference

EVE Education and Public Outreach (EPO)



The EVE Education and Public Outreach (EPO) program is provided by the **CU-CIRES Outreach group**. The Solar Dynamics Observatory (SDO) and the Extreme Ultraviolet Variability Experiment (EVE) project will contribute to the broad educational objectives of the NASA Living With a Star (LWS) program, to engage the public and work within the formal education system to improve the teaching of science, mathematics, and technology in the United States. Guiding scientific questions are those of the Sun-Earth Connections theme and the LWS EPO national program: Why does the sun vary? How do the planets respond to solar variability? How do the sun and galaxy interact? How does solar variability affect life and society?

The mission specific goals of the EVE EPO program described here are:


- To bring the excitement and importance of this mission and this research to multiple educational sectors (formal K 12, informal, public);
- To integrate the scientific content areas of this mission solar variability in EUV and other wavelengths, effect of solar variability on climate and technology, engineering innovations and satellite design into formal and informal educational venues;
- To contribute to the space science education and career awareness of educationally disadvantaged students;
- To engage EVE space scientists effectively in education;
- To coordinate the EVE EPO plans with NASA LWS and Sun-Earth Connections Forum;
- To peer review and evaluate our products for effectiveness and broad applicability, and to disseminate these products to the widest possible audience.

The details of the EVE EPO high school course are given in the **Classroom Experiments** link under the Education menu. For more information about the EVE EPO project please contact **Susan Buhr**.


Some useful education / outreach links:

-  [SDO EPO site at NASA GSFC](#)
-  [CU CIRES Outreach site](#)




Colorado Math, Engineering, and Science Achievement (MESA) program
St. Vrain Valley MESA program
CU Fiske Planetarium and Science Center
Colorado Project ASTRO-GEO
Space Science Institute (SSI) Education and Outreach
Stanford Solar Center - SID Monitor



Extreme Ultraviolet Variability Experiment



LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS
UNIVERSITY OF COLORADO AT BOULDER



EPO
Images & Video
Classroom Experiments
Student Q&A
EVE Fact Sheet (PDF)
Summary & Images
Quick Facts (PDF)
Space Weather Education Kit

1. Understanding Ultraviolet

Overview

Inquiry-based learning activities that focus on the UV band of the electromagnetic (EM) spectrum. 2 UV meters are provided per kit with the option to borrow additional meters from CIRES Outreach.

Ultraviolet (UV) radiation spans the electromagnetic spectrum from 400 nanometers (nm) to 10 (Extreme UV, or EUV), but only UVA (400-315) and UVB (315-280) reach the surface of the Earth because radiation below UVB is filtered out by the atmosphere. (Visible light spans from 380-750 nm, and Infrared or IR radiation runs from 750nm to 1mm.) Using UV meters or beads, students can measure the relative intensity of UV penetrating through the atmosphere, assuming it is a sunny day and there is access to outdoors to conduct the measurements. While the use of various types of light can be used with the meters and beads as a backup, having students collect data outdoors is recommended.

Learning Objectives

These activities will help students in understanding the basics of the electromagnetic spectrum with an emphasis on the ultraviolet band. Students will have the opportunity to collect and interpret data, and classify and compare findings. They will also have the opportunity to learn about the potential health impacts of UV exposure on skin and to understand the significance of the US EPA Sunwise UV Index, which on a scale of one to eleven rates the intensity of the sun's UV rays.

Materials Needed

- UV meters or UV beads
- Sunscreen
- Cloth and plastic materials

Relevant Standards and Benchmarks

Interactions of energy and matter (NSES Content Standard D, grades 9-12)

Electromagnetic waves result when a charged object is accelerated or decelerated.

Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.

Assessment

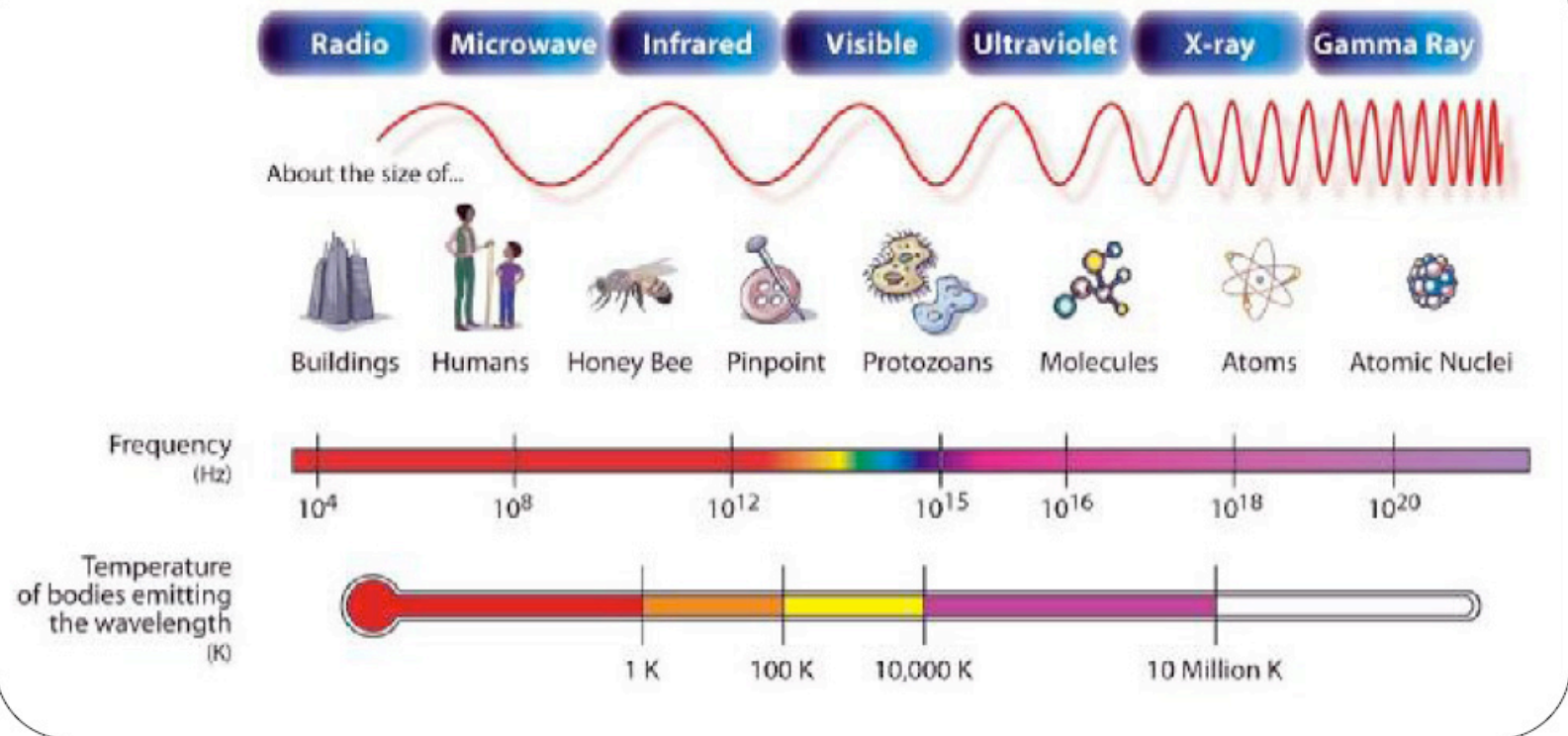
Students should be able upon completion of these activities to:

- Identify the UV band of the electromagnetic spectrum
- Collect data using the UV meters and explain the significance of the data
- Communicate the significance of the UV Index as a tool for avoiding excessive exposure to UV radiation

LAYERS OF THE SUN

There's more to light than meets the eye! Different kinds of light have different names, different wavelengths, different frequencies, and different temperatures. Use this diagram to help you match the pictures and labels of the Sun.

The Electromagnetic Spectrum



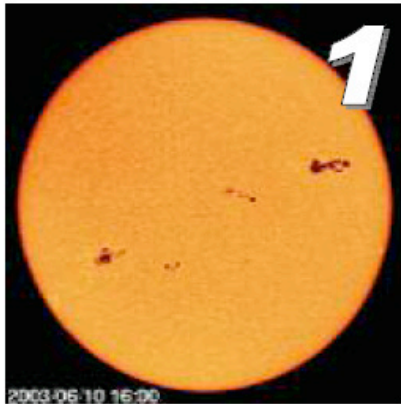
ANSWERS:

X-Ray – 4 Ultraviolet – 2 Visible Light – 1 Extreme Ultraviolet - 3

LAYERS OF THE SUN

Can you match the labels in the center with the correct pictures?

Hint: use the temperatures and the clues from the electromagnetic spectrum on the next page...



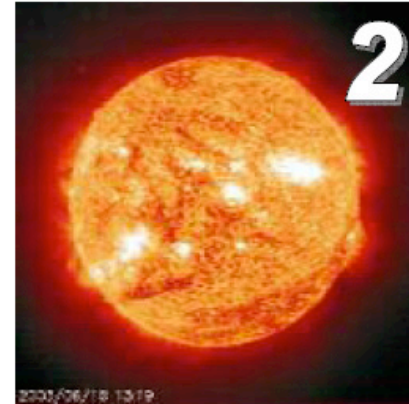
The "surface" of the Sun – the photosphere
TEMP° 10,000F, 6000Kelvin

X-RAY

Image # _____

ULTRA-VIOLET

Image # _____



The chromosphere – Just above the photosphere
TEMP° 7500F, 4000Kelvin

VISIBLE

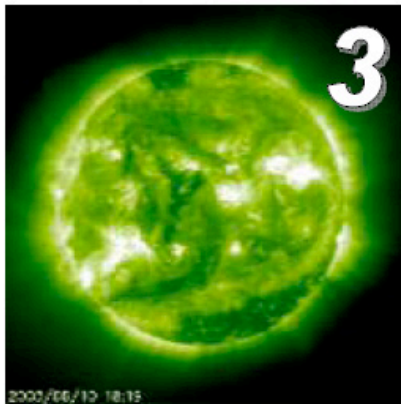
LIGHT

Image # _____

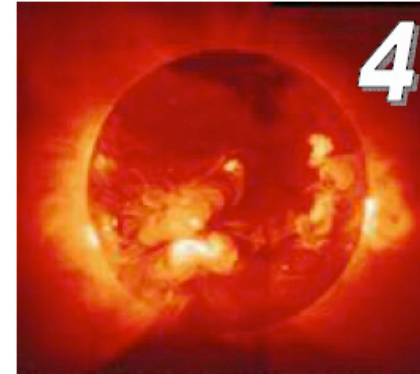
EXTREME

ULTRAVIOLET

Image # _____



The upper chromosphere
TEMP° 17,500F, 9700Kelvin



The corona – the outermost layer
TEMP° 1-2 million (F and Kelvin)

UV Meters Activities for Sunwise Meteorologist Kit

http://www.epa.gov/sunwise/doc/met_kit.pdf

Daily reporting of UV intensity data by school children will enable students to understand the scientific concepts related to ozone depletion and UV radiation. It will help them modify their outdoor behaviors to limit exposure and future incidences of adverse health effects.

This section includes instructions for operating your hand-held UV meter as well as three activities beyond entering your data on the SunWise Internet Site. Good luck with your UV monitoring efforts!

UV Meter Activities

1. What Works? Effectively Blocking UV Rays
2. Chart and Graph UV Intensity
3. Reflecting UV Radiation

Hand-Held UV Meter: Device Operating Instructions

The activities in this section require the use of an ultraviolet (UV) meter. If you choose to purchase a hand-held UV meter, several vendors can be found on the Internet. We urge you to check the open market for price, quality, and delivery terms before purchasing any items. EPA cannot endorse the products and services of these vendors.

Some hand-held UV meters measure the intensity of the sun's UV rays based upon the UV Index (UVI) scale of 1 to 11+ (low to extreme).

UV Index Values

UV Index values depict intensity levels on a 1 to 11+ scale in the following way:

Index Number	Intensity Level
< 2	Low
3 to 5	Moderate
6 to 7	High
8 to 10	Very High
11+	Extreme

What Works? Effectively Blocking UV Rays

Estimated Time

40-50 minutes

Supplies

- UV meter
- Plastic bags
- Pairs of UV and non-UV sunglasses
- Variety of sunscreens with different SPF numbers
- Variety of fabric pieces

Learning Objective

This activity will show students that different sunscreens, coverings, and sunglasses can have a real effect on UV levels. This will emphasize to students the need to wear sunscreen, while at the same time helping them distinguish the effectiveness of different types. Assess student comprehension by asking them to predict what levels of protection different materials would offer, other than the ones you've tried in the experiment.

Directions

Take the UV meter outside. Have one student check and record the unfiltered UV level. Next, have the class take turns covering the UV meter with plastic bags and applying different sunscreens on the outside of the plastic bag over the sensor area. Make sure the students apply an even amount, no thicker than you would apply on your body. Have the students check and record the UV reading and sunscreen SPF number with each sunscreen. Try this for a variety of sunscreens with different SPF numbers. Use a clean bag for each sunscreen application.

Next, try the same experiment with sunglasses. Have the class cover the UV meter sensor area with different pairs of sunglasses, and record the results. Finally, try covering the sensor with different types and colors of cloth and record the results.

Questions and Answers

- 1** What SPF number seems to be the most protective against the sun's harmful UV rays? How much of a difference did it make? Since SPF 15 filters out 93 percent of UVB radiation, and SPF 30 filters out 97 percent, there should be little noticeable difference with SPF numbers higher than 15; there should be a difference between 4 and 15.
- 2** Which pair of sunglasses filtered out the most UV rays? Were they UV sunglasses? Answers may vary. Yes, if the UV reading was low.
- 3** What kind of cloth filtered out the most UV rays? Was there any difference in similar types of cloth but with different colors? Your answers will vary. Generally, tighter weave provides greater protection.
- 4** Given what you have learned from this experiment, what precautions should you take when going outside in order to protect yourself from the sun's harmful UV rays? Answers will vary, but students might say wearing sunscreen of SPF 15 or higher, UV blocking sunglasses, and tightly-woven clothing.

Chart and Graph UV Intensity

Estimated Time

This activity should take a few minutes each day for recording data. The graphing and discussion should take 40-50 minutes once the data is collected. The entire activity could last one to two weeks, depending on how the class is divided.

Supplies

UV Meter Logbook or chart for data

Learning Objective

This activity will emphasize that harmful UV rays are present in any type of weather, not just when sunny. Students should always be SunWise, even on a cloudy day. Assess student comprehension of this message by asking the class to make a list of the clothing they wore each day of the experiment. Ask them how they would change that behavior now, knowing that there were UV rays present, even on the cloudy days.

Directions

Divide the students into pairs or groups. Each pair will take turns going outside to record the UV intensity with the UV meter and the weather conditions (sunny, cloudy, rainy, etc.) at approximately the same time each day. Students may also use the SunWise Web site, www.epa.gov/sunwise/uvindex.html, to retrieve current UV readings and past UV data.

Students should record their findings in the logbook or chart that you provide.

After all the data is recorded, instruct the students to graph and analyze the data.

Questions and Answers

1 What difference does the weather make in the UV intensity of each day? *The sun's UV rays are less affected by the weather than many students would think.*

2 On which days are the sun's UV rays the most dangerous? The least? Why? *UV rays on cloudy days, as well as sunny days, can cause damage to unprotected skin and eyes. UVB rays fluctuate with time of day and season. UVA rays are consistent throughout the day and year and can pass through clouds.*

Reflecting UV Radiation

Estimated Time

30 minutes

Supplies

UV meter Plastic bag (to protect the UV meter) A large bowl, bucket, or dishpan 1 lb. of sand 1 gallon of water Aluminum foil (enough to line the bowl)

Learning Objective

The goal of this activity is to demonstrate changes in UV intensity by comparing UV readings from direct sunlight and a variety of reflective surfaces. Assess the prior knowledge of the students by asking them to predict readings caused by the different surfaces and why they selected those values. After the activity, discuss their results. Compare their predictions with their actual results.

Directions

Take students outside on a sunny day. Choose a location that offers students proper shade coverage, but allows you to place the experiment materials in direct sunlight. Take a UV reading using the UV meter. Have students record the UV reading in the appropriate space on the chart provided, or one that they have constructed to collect data. Use the UV meter in the scenarios listed, and instruct the students to record the readings in the appropriate spaces on their chart. Remember, the UV meter is not waterproof. Don't forget to protect it with the plastic bag.

UV Meter Scenarios

- Take a reading with the UV meter facing down toward the sand.
- Take a reading with the UV meter facing up on the sand simulating sunbathing.
- Take a reading with the UV meter pointing toward the bowl of water placed in the sun.
- Take a reading with the UV meter pointing toward the aluminum foil placed in the sun.
- After your students have completed this experiment, return to your classroom to discuss the findings.

Questions and Answers

- 1 In which scenario was the UV intensity the greatest? What was the UV reading? *Answers will vary.*
- 2 In which scenario was the UV intensity the least? What was the UV reading? *Answers will vary.*
- 3 Which surface was most reflective? Which was least reflective? Why? *Answers will vary.*
- 4 What are some similarities between your behavior in the sun and the scenarios you placed the UV meter in? What are some differences? *The scenarios were designed to mimic our behavior in the sun. Differences would include the use of sunscreen, sunglasses, or protective clothing; the use of these items would add protection from the UV rays.*
- 5 List some additional scenarios you participate in; sitting inside a sun-filled room or car, for example. What do you think the UV intensity would be if the meter was placed in the same scenario? *Try it out. The answers will vary depending on whether the windows are treated to block UV rays. Car windshields generally protect against UVA and UVB, while the side windows are not as protective.*

Making a Solar UV Bracelet

Purpose: The purpose of this lesson is to introduce the concept of ultraviolet light and its practical applications to the students. Students will make a solar UV bracelet.

Background: The term “light” is often used as a generic word to describe many different forms of light such as incandescent light, fluorescent light, or sunlight, for example. However, not all light is made up of the same energy.



Sunlight is comprised of light energy that occurs at many different wavelengths. We are most familiar with light in the visible light part of the solar spectrum – visible light enables us to see the colors of the world. The visible light spectrum has wavelengths that allow us to see red, orange, yellow, green, blue, indigo, and violet (we use ROY G. BIV to remember these colors in order). Of this group, red has the longest wavelength and violet has the shortest. Light that has wavelengths that are a little shorter than violet light wavelengths is called ultraviolet light. We can't "see" ultraviolet light, but there are ways to determine if it is present.

The UV sensitive beads contain a pigment that changes color when exposed to ultraviolet light. The beads look identical when they are inside a building – they are all white. But, when you bring them out into sunlight and the ultraviolet rays of the sun hit the beads, they change color. The beads have been made with a special pigment so that they will change color in response to different wavelengths of light. Some beads will respond to “red” light, others will respond to “green” light or “violet” light. You will understand this better when you take your beads outside. Whenever the beads are “not” white, then you will know that ultraviolet light is present.

Lesson Objective: The students will make a solar UV bracelet that will detect ultraviolet light.

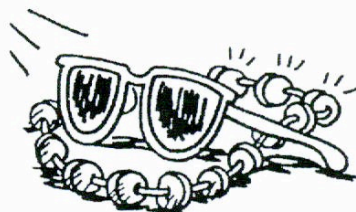
Materials: 15 Ultraviolet Light Detecting Beads (variety)
Elastic string

Procedure

1. String the beads on the elastic cord being careful that they don't fall all over the floor.
2. Connect both ends of the string together and tie a double knot. You now have a solar bracelet.
3. Put your solar bracelet on your wrist and go outside or put your hand under an ultraviolet light to see what happens.

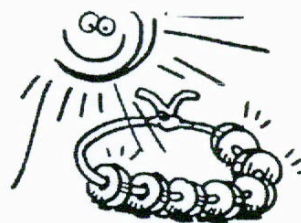
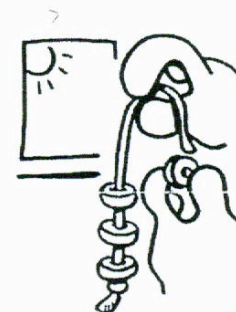
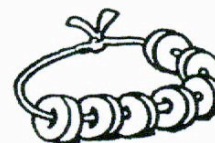
Energy Beads™

THE BEADS THAT CHANGE COLOR IN THE LIGHT OF THE SUN



Experiment Ideas with Energy Beads

- Test the ability of your sunglasses to block out ultraviolet light by covering a few beads with the lens of your sunglasses. If the beads do not change color, your sunglasses block out harmful ultraviolet light from your eyes. If not, you paid too much for that UV coating!
- Can “black light” (long wave ultraviolet light) be used to change the color of the beads? You can purchase a black light at many specialty stores or hardware stores that have a large section of light bulbs.
- Place several beads in a glass jar and expose them to direct sunlight. Do the beads change color? Test a variety of glass and plastic containers to determine which materials block out UV light.
- Test the effectiveness of your sunscreen lotion by coating several beads with lotion. Expose the beads to direct sunlight and look for any changes in color. How well does your sunscreen protect you from UV light? Test the difference between new and old sunscreen. Manufacturers suggest that you throw away old sunscreen because it does not block out harmful UV light. Do your tests support this claim?
- Test to see if the beads change color on cloudy day. If they change color, then you can see why doctors warn people to wear sunscreen even on a cloudy day.
- Make an Energy Bead mosaic by gluing the beads on to a board. Indoors the beads appear white. Step outdoors in the direct sunlight to develop your picture. Remember that your picture will only be visible in ultraviolet light!



Where to buy Ultraviolet Light Detecting Beads:



A Product of WREN Enterprises, Inc. • 3145 West Morimouth Avenue • Englewood, CO 80110 • © 2000 WREN Enterprises, Inc.

1- 800-223-9080

www.stevespanglerscience.com

<http://www.epa.gov/sunwise/>



How is the UV Index Calculated?

The U.S. National Weather Service calculates UV Index using a computer model that relates the ground-level strength of solar ultraviolet (UV) radiation to forecasted stratospheric ozone concentration, forecasted cloud amounts, and elevation of the ground. The calculation done by some other nations also includes ground observations.

The calculation starts with measurements of current total ozone amounts over the entire globe, obtained via two satellites operated by the National Oceanic and Atmospheric Administration. These data are used to produce a forecast of stratospheric ozone levels for the next day at many points across the country. A computer model uses the ozone forecast and the incident angle of sunlight at each point to calculate the strength of UV radiation at ground level. Sunlight angle is determined by latitude, day of year, and time of day ([solar noon](#)). The strength of UV radiation is calculated for several wavelengths between 290 and 400 [nm](#), the full spectrum of UV-B (290-320 nm) and UV-A (320-400 nm) radiation.

Ozone in the atmosphere absorbs (attenuates) shorter UV wavelengths more strongly than longer wavelengths. The strength of ground-level UV radiation differs significantly across the UV spectrum. As an example, UV strengths for a point might be calculated as shown in the table below. (These are hypothetical values. A National Weather Service chart shows [typical UV irradiance values](#).)

Wavelength	Strength	The next step in the calculation adjusts for the sensitivity of human skin to UV radiation. Shorter UV wavelengths cause more skin damage than longer UV wavelengths of the same intensity. To account for this response, calculated UV strength is weighted (adjusted) at each wavelength using a function called the McKinlay-Diffey Erythema action spectrum.
290nm	4	
320nm	26	
400nm	30	

Continuing with our example, the table below gives skin response weighting factors for the UV wavelengths. (These are hypothetical values for the example, not actual McKinlay-Diffey weighting factors.) We multiply the ground-level UV strength by the weighting factor to calculate the result, the effective strength of the UV radiation, at each wavelength.

Wavelength	Strength	Weight	Result
290nm	4	15	60
320nm	26	5	130
400nm	30	3	90

Next, the effective UV strength at each wavelength across the 290 to 400 nm spectrum is summed (integrated), giving a value that represents the total effect of UV radiation on skin. In our example, the total UV effect is 280 (60 + 130 + 90).

The next step of the calculation adjusts for the effects of elevation and clouds. UV intensity increases about 6% per kilometer elevation above sea level. Clouds absorb UV radiation, reducing ground-level UV intensity. Clear skies allow virtually 100% of UV to pass through, scattered clouds transmit 89%, broken clouds transmit 73%, and overcast skies transmit 31%.

For our example, let us assume that the elevation is 1 kilometer and there are broken clouds overhead. The total UV effect, adjusted 6% for elevation and 73% for clouds, would be calculated as:

$$280 \times 1.06 \times 0.73 = 216.7$$

The final step of the calculation scales the total UV effect, dividing it by 25 and rounding to the nearest whole number. The result is a number that usually ranges from 0 (darkness or very weak sunlight) to the mid-teens (very strong sunlight). This value is the **UV Index**.

For our example, the UV index would be:

$$216.7 / 25 = 8.7, \text{ rounded to } 9$$

UV Index

2 or less: Low

A UV Index reading of 2 or less means low danger from the sun's UV rays for the average person:

- Wear sunglasses on bright days. In winter, reflection off snow can nearly double UV strength.
- If you burn easily, cover up and use sunscreen.

3 - 5: Moderate

A UV Index reading of 3 to 5 means moderate risk of harm from unprotected sun exposure.

- Take precautions, such as covering up, if you will be outside.
- Stay in shade near midday when the sun is strongest.

6 - 7: High

A UV Index reading of 6 to 7 means high risk of harm from unprotected sun exposure. Apply a sunscreen with a SPF of at least 15. Wear a wide-brim hat and sunglasses to protect your eyes.

- Protection against sunburn is needed.
- Reduce time in the sun between 10 a.m. and 4 p.m.
- Cover up, wear a hat and sunglasses, and use sunscreen.

8 - 10: Very High

A UV Index reading of 8 to 10 means very high risk of harm from unprotected sun exposure. Minimize sun exposure during midday hours, from 10 a.m. to 4 p.m. Protect yourself by liberally applying a sunscreen with an SPF of at least 15. Wear protective clothing and sunglasses to protect the eyes.

- Take extra precautions. Unprotected skin will be damaged and can burn quickly.
- Minimize sun exposure between 10 a.m. and 4 p.m. Otherwise, seek shade, cover up, wear a hat and sunglasses, and use sunscreen.

11+: Extreme

A UV Index reading of 11 or higher means extreme risk of harm from unprotected sun exposure. Try to avoid sun exposure during midday hours, from 10 a.m. to 4 p.m. Apply sunscreen with an SPF of at least 15 liberally every 2 hours.

- Take all precautions. Unprotected skin can burn in minutes. Beachgoers should know that white sand and other bright surfaces reflect UV and will increase UV exposure.
- Try to avoid sun exposure between 10 a.m. and 4 p.m.
- Seek shade, cover up, wear a hat and sunglasses, and use sunscreen.

Precautions

- Use your meter to monitor only the sun's natural radiation. It should never be used to measure UV from artificial sources such as tanning beds.
- Staying in the shade does not provide complete protection from UV radiation due to the scattering effect of UV radiation.
- High temperature and humidity may lead to incorrect results. Do not leave the device in conditions of high humidity or temperature for long periods.
- The meter may fail to operate correctly if the sensor window is not kept clean. Remove dirt with a piece of soft cloth moistened in alcohol (ethanol, isopropanol). Use cleaning fluids sparingly.
- Upon leaving the factory, the meter is carefully calibrated. Improper handling (water immersion, strong shocks) may alter the meter's parameters. Handle it with care.

Your UV meter should not replace your common sense or current method of avoiding skin and eye damage by the sun.

About UV Index

The ozone layer shields the Earth from harmful ultraviolet (UV) radiation. Ozone depletion, as well as seasonal and weather variations, cause different amounts of UV radiation to reach the Earth at any given time. The **UV Index**, developed by the National Weather Service and EPA, indicates the strength of solar UV radiation on a scale from 1 (low) to 11+ (extremely high).

Every day the National Weather Service calculates the predicted UV Index for the next day in each area of the U.S. This UV Index forecast is published in mid-afternoon (Eastern time zone) at the EPA Web site. If the level of solar UV radiation is predicted to be unusually high, and consequently the risk of overexposure is greater than normal, the forecast includes a UV Alert. (You can sign up below to receive e-mail notification of UV Alerts for your community.)

For more detailed information on UV radiation and the UV index, read the factsheets that can be found in the SunWisdom section of this toolkit or logon to the SunWise website, www.epa.gov/sunwise

2. Introduction to Solar Science- Presentations from NASA on DVD & CD

Overview

Building on the UV activity, this section provides background information about solar science and space weather through the use of presentations on DVD or CD produced by NASA and its partners. These include:

- The Sun and Space Weather- NASA CD
- Space Weather- Exploring Sun-Earth Connections- NASA CD
- Colors of the Sun- Stanford Solar Center DVD

Ideally a visiting scientist can give the presentation and help set the stage for activities and field trips to follow, although with some preparation, teachers should be able to give the presentation themselves. Another option in a computer-lab setting would be for the students to work in groups to review the materials on the DVDs or CD.

Learning Objectives

These presentation materials will provide the students with an overview of the sun and its importance to life on Earth. It will also offer an introduction to space science research and the various technologies and strategies needed to measure not only radiation that researchers the Earth's surface, but other types of radiation such as Extreme Ultraviolet and X-Rays that influence the Earth system even though they don't penetrate through the atmosphere to the surface.

Materials Needed

- Computer projector and screen for presentation
- Option: Computer Laboratory

Relevant Standards and Benchmarks

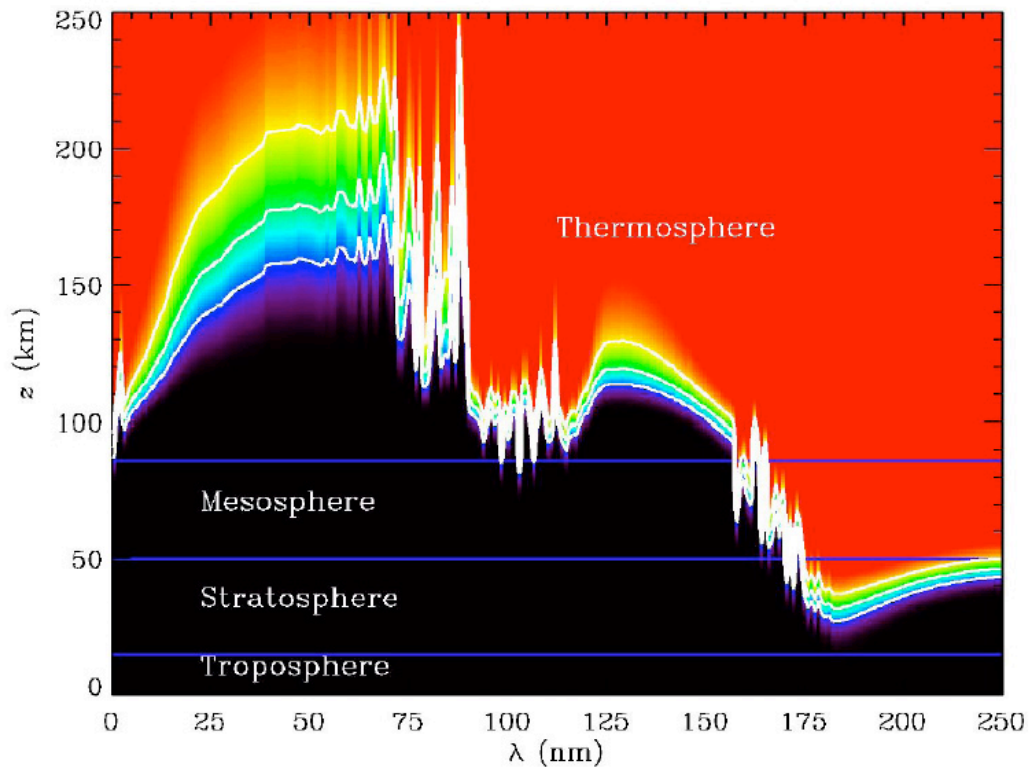
Transfer of Energy (NSES Content Standards Grades 5-8)

The sun is a major source of energy for changes on the Earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the Earth, transferring energy from the sun to the Earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Assessment

Through classroom discussion and/or team presentations, students should be able to:

- Describe the basic dynamics of the sun-Earth connection
- Convey that some radiation/light is filtering by the Earth's atmosphere and don't reach the Earth's surface



Extreme UV and X-Rays are filtered by the atmosphere and don't reach the Earth's surface, making it necessary to measure variations in them from the sun in space.

7. To find out what effect sunspots have on our space weather, visit the [Space Weather Bureau](#) and read today's solar report. Summarize today's news about the Sun in the What's Up in Space column.

8. Sunspots have been linked to both solar flares (fiery "storms" in the Sun's atmosphere) and streams of hot, charged particles that are carried away from the Sun in the solar wind. When they reach Earth's atmosphere, these particles can trigger disruptive geomagnetic storms. Look at the top of the left column and find today's reading of the solar wind. What is today's wind velocity? What is the density of protons in the solar wind?

9. Continue scrolling down the left column to today's (or the most recent) sunspot number. What is it? How does this number compare to your daily average estimate for the year 2000 in question 3?

10. Scroll further down the column to the photo of the Sun showing current active sunspots. Summarize the report of current activity (just below the photo.)

11. Keep scrolling to the current image of coronal holes. Click on the glossary link that explains them. What is the connection between coronal holes and the solar wind?

12. A bit further down the left column, you'll see NOAA forecasts for solar flares. What is the probability of medium-sized (M-class) and major (X-class) flares over the next 24 and 48 hours?

13. Finally, scroll to the geomagnetic storm forecast. Click on the glossary links explaining the three categories (active, minor storm, major storm). What is the probability of each kind of geomagnetic storm over the next 24 and 48 hours? (Give values for both mid- and high-latitudes.)

3. Examining the Solar Spectra- Building a Spectroscope

Overview

How do scientists determine the composition and measure different ranges of the electromagnetic spectra (plural of spectrum) emitted by the sun and other objects in space? On Earth where visible and UV light reach the surface without being completely filtered out by the atmosphere, spectroscopes can be used to sort visible light (~ 380 to 750 nm to the human eye) by wavelength. In space, similar tools are used to record the composition and intensity of various gases on the sun and other objects. The “Graphing the Rainbow” activity can be used to help set the stage for students building their own spectroscope.

Learning Objectives

These activities will assist students in understanding how a particular spectra corresponds to a line plot like a bar code with emission or absorption lines which is a technique used by astronomers to study the spectra from distant objects to determine what their composition is.

Materials Needed

For Graphing the Rainbow, overhead projector with transparencies of the color worksheets which are provided.

For Building a Spectroscope, cardboard spectroscopes and lenses are provided. Contact us for additional materials. For more related activities, see Project Spectra:

<http://lasp.colorado.edu/education/spectra/index.htm>

the TERC “Examine the sun at different wavelengths at: <http://tinyurl.com/7x9g4c>

and NOVA interactive “Decoding Cosmic Spectra”

<http://www.pbs.org/wgbh/nova/origins/spectra.html>

Time

One class period- 15 minutes to Graphing Rainbow and the remainder on Spectroscope

Relevant Standards and Benchmarks

Understandings About Scientific Inquiry (NSES 9-12)

Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used.

Assessment

Students will be able to:

- Recognize and describe patterns
- Interpret data
- Understand that visible light is only a small part of the electromagnetic spectrum
- Successfully construct spectroscope, experiment with different light sources, and report their findings.

Lesson Summary

This lesson introduces students to different ways of displaying visual spectra, including colored “barcode” spectra, like those produced by a diffraction grating, and line plots displaying intensity versus color, or wavelength. Students learn that a diffraction grating acts like a prism, bending light into its component colors.

Prior Knowledge & Skills

- Ability to recognize and describe patterns
- Experience interpreting data
- Visible light represents only a small portion of all light
- General understanding of energy

AAAS Science Benchmarks

The Nature of Mathematics

Patterns and Relationships

The Physical Setting

Motion

NSES Science Standards

- **Physical Science:** Transfer of Energy

NCTM Mathematics Standards

- **Geometry:** Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships
- **Algebra:** Understand patterns, relations, and functions

Colorado State Standards

- Mathematics Standards 2.1, 3.1, 3.4
- Science Standard 4

Suggested background reading

Light

Suggestion for modification

Inclusion of lessons on light and the electromagnetic spectrum will make this activity suitable for high school students.

Teaching Time: One 30-minute period

Materials

Each student needs:

- Copy of worksheet

Advanced Planning

Preparation Time: 10 minutes

1. Make one copy of student worksheet before activity.

Why Do We Care?

When passed through a prism or diffraction grating, light is broken up into its component colors. The resulting spectrum will have a characteristic pattern of light and dark that, when analyzed, reveals the composition of the light source. In this activity, students learn how a visual spectrum corresponds to a line plot, which is the way astronomers view spectra to help them determine what astronomical objects are composed of.



Graphing the Rainbow

Group Size 1

Expendable Cost per Group \$0

Engineering Connection

Understanding graphs and plots is crucial to engineering, as engineering in astronomy is driven by the need to obtain scientific data. Engineering methods are constantly improved and new types of engineering are created based upon the types of data needed to advance science.

Learning Objectives

After this lesson, students should be able to:

- Explain that light from different sources, when passed through a prism or diffraction grating, can be separated into component colors
- Explain the basic tools engineers use to view spectra
- Explain that those component colors appear in a unique pattern of bright and dark lines
- State two ways to display a spectrum
- Match a “barcode” spectrum with its corresponding line plot

Introduction / Motivation

Do you know how a rainbow is formed? It is created by light, and that light comes from the Sun. When the light passes through water droplets in the clouds, we can see the colors that light from the Sun makes that we cannot normally see with our eyes. All light makes a pattern, and today we will be exploring the patterns that are hidden in light that we cannot normally see unless we have special tools to see them. Any light source, whether it is a light bulb, a computer monitor, a star, or a planet-- when passed through a prism or a diffraction grating-- will display a unique pattern of bright and dark stripes called spectra (the plural of “spectrum”).

Prisms and diffraction gratings are tools we can use to see these patterns. Instrumentation developed by engineers can measure exactly how bright each color is, since this is a difficult thing to do with just our eyes. The instrumentation can assign a number value to the brightness that can be plotted on a graph where position on the x-axis (horizontal axis) represents color and the y-axis (vertical axis) represents brightness, or intensity.

Engineers develop instrumentation based upon the properties of light. Engineers create instrumentation to see spectral patterns of light and study the patterns to improve and develop new instrumentation. They usually use diffraction gratings. They also study the processes and the types of light that create specific spectral patterns. Engineers studying space science are interested in helping answer questions about the composition of planetary atmospheres, planetary moons, stars, and gasses within the solar system and universe.

Vocabulary / Definitions

Word	
Spectrum (plural: spectra)	The pattern light produces when passed through a prism or diffraction grating, as seen through a spectrograph
Spectrograph	A device that allows one to see a spectrum, which usually has a prism or diffraction grating inside
Diffraction	When light bends around an obstacle or through a small opening like those in a diffraction grating
Diffraction Grating	Usually a piece of film covered with very thin, parallel grooves
Continuous Spectrum	The rainbow that white light is composed in which each color is equally bright
Emission Spectrum	Bright lines that appear through the spectrograph against a dark background
Absorption Spectrum	Dark lines that appear against the continuous spectrum seen through a spectrograph
Light Source	Any object that produces light

Procedure

Background

Students should be familiar with line graphing methods and understand that graphs can be used to represent physical data. Students should have some understanding of the nature of light, i.e. rainbows are formed with light, light can be different colors, etc.

White light, like that produced by an incandescent light bulb (with electricity passing through it) is composed of all of the colors of light in the rainbow combined. It simply looks white with our eyes. A diffraction grating (or a prism) acts to break the light into its component colors. Certain colors “bend” more than others through the grating or prism, which is why the colors line up, like a rainbow.

Light passing through a cool gas will produce what is called an absorption pattern when seen through a diffraction grating or a prism, and dark lines will appear in the continuous spectrum. The dark lines are actually created by the gas absorbing the energy of the light. We can identify the gas based on the distinctive pattern of lines that appear in the spectrum. Conversely, an emission spectrum is seen as bright lines against a dark background, and is produced a hot gas emitting photons. Again, the pattern the gas creates is dependent on the type of gas. A particular hot gas shows emission lines in the exact same places that the same cool gas shows absorption lines. The pattern does not change, but whether you see an absorption or emission pattern through the grating does change depending whether the gas is hot or cool. The resulting spectrum will have a characteristic pattern of light and dark that, when analyzed, reveals the composition of the light source.

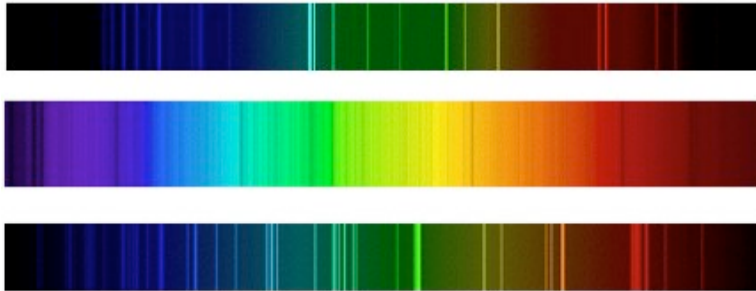


Figure 1
Emission and Absorption spectra
Source/Rights: LASP

With the Students

1. Hand out student worksheet.
2. Using the student worksheet as a guide, demonstrate how a visible light pattern can be graphically represented in different ways. An overhead projection of the second student worksheet page may be beneficial to have on hand.
3. Walk around the room to talk to individual students about the graphs from the student worksheet.
4. Ask students questions about what they see in the plots and why the pictures correspond to a specific graph on the student worksheet.

Troubleshooting Tips

Colorblind and vision-impaired children will have difficulty with this activity. Students with corrective lenses will not have difficulty. Colorblind and blind students can be paired with a student to assist them.

Assessment

Pre-Lesson Assessment

Class discussion: Ask students what they can tell you about light. Probe them for what they already know and understand.

Activity Embedded Assessment

Class Discussion: Ask students why they think the light forms rainbows or patterns when passed through a prism or diffraction grating. Note to teachers: the bending of light through a prism does not have to do with varying speeds of the colors! All colors travel at the same speed.

Worksheet: Have the students complete the activity worksheet; review their answers to gauge their mastery of the subject.

Post-Activity Assessment



Graphing the Rainbow

Think-Pair-Share activity: Ask students to discuss with a peer about what steps an engineer takes before designing an instrument that studies light. Randomly select groups to share. Discuss ideas as a class.

Graphing: Graphing and plotting are tools all engineers use. Plotting and graphing real world situations allows engineers to analyze whether a tool is working, how to design an effective tool, and can be used to create software to look at data (just like the data in this activity). Ask students to graphically represent a real-world situation, such as driving at a certain speed, at some point coming immediately to a complete stop, and then resuming that same speed. Another example could be a plot representing descending from the top of a flight of stairs to arrive at some distance at the bottom, which could be a distance vs. time plot. Perhaps, have the students represent what it would look like if they stopped on a stair for a very long time. This will establish whether they understand how graphing spectra is a representation of a real situation that occurs with light (as opposed to motion, distance, or some other variable). It will also establish whether the students can apply what they have learned in a different context from this activity. Ask students to come up with their own “real world” graphs, and ask volunteers to explain their graphs to the class.

Activity Extensions

Continue the spectroscopy unit by completing the associated activity, “Using Spectral Data to Explore Saturn and Titan” activity.

References

Fisher, Diane. “Taking Apart the Light.” “The Technology Teacher.” March (2002).

Owner

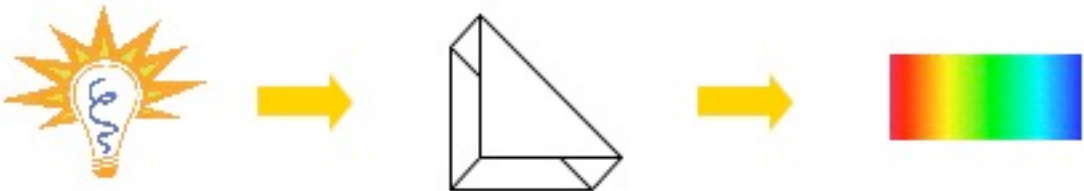
Integrated Teaching and Learning Program and Laboratory, University of Colorado at Boulder

Contributors

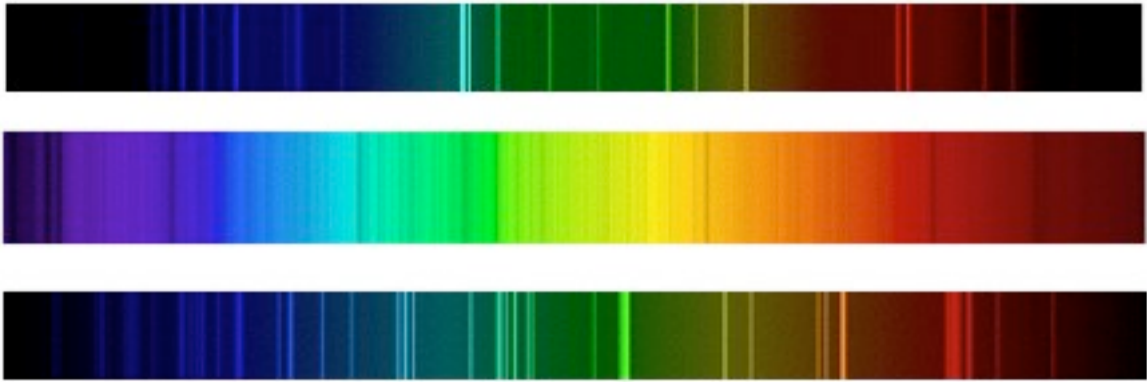
Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder

Graphing the Rainbow Student Worksheet

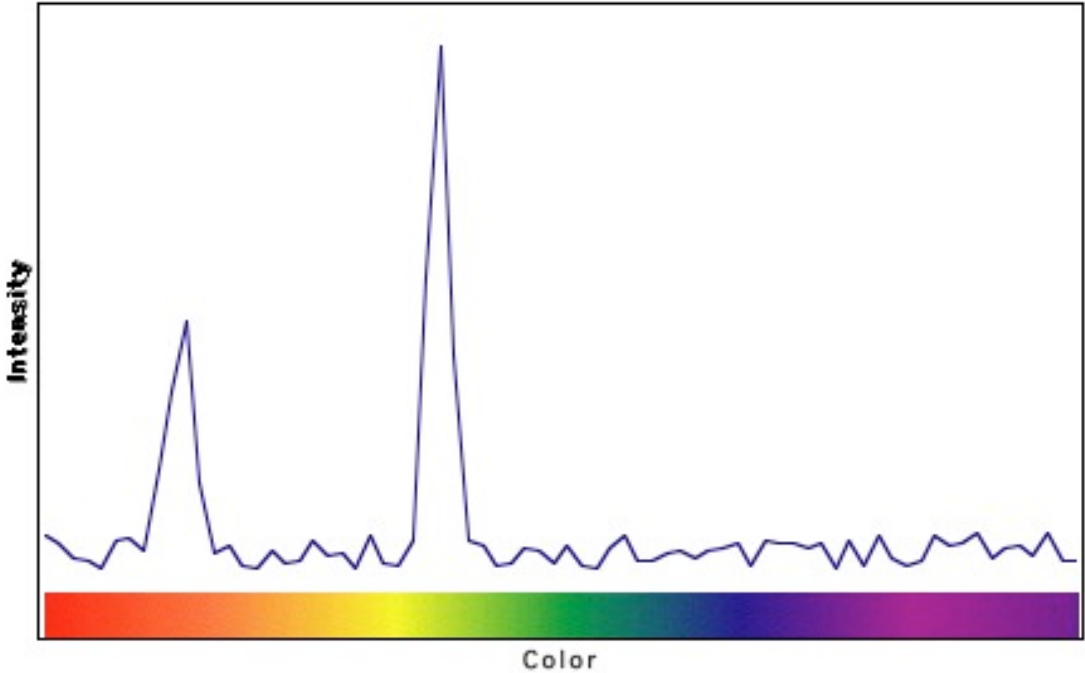
When light from any source—a light bulb, a computer monitor, a planet—passes through a prism or a diffraction grating, it produces a unique rainbow pattern.



The pattern may be mostly bright with a few dark stripes, or dark with a few bright stripes, or some combination.



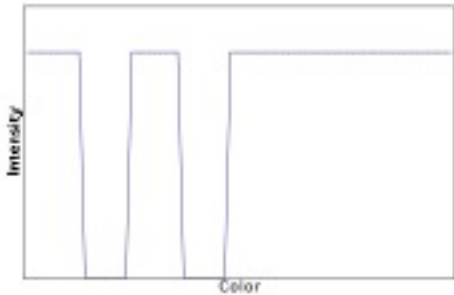
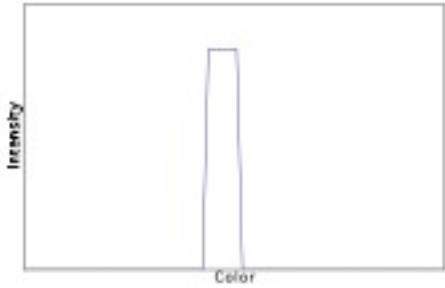
The intensity of each color of light can be plotted on a line graph like the one below.



Project
SPECTRA!

Graphing the Rainbow

Look at the following examples. Each of the spectra on the left can also be displayed as a line plot, as shown on the right. Bright colors have high intensity, as shown along the y-axis. The first spectrum is called a continuous spectrum. In a continuous spectrum, every color has the same intensity.

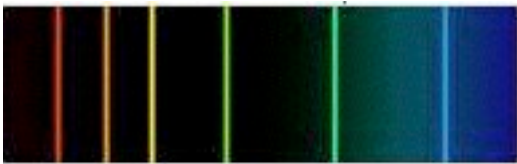
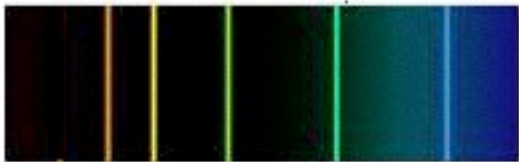
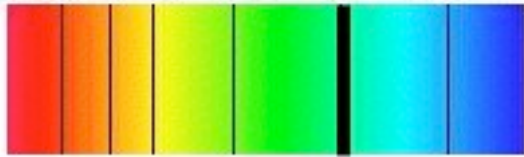


Project
SPECTRA!

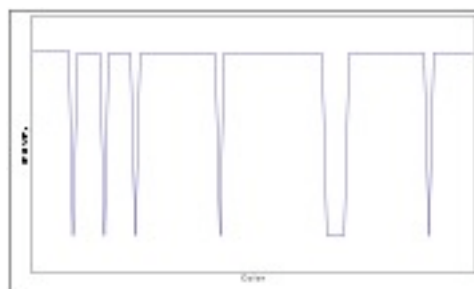
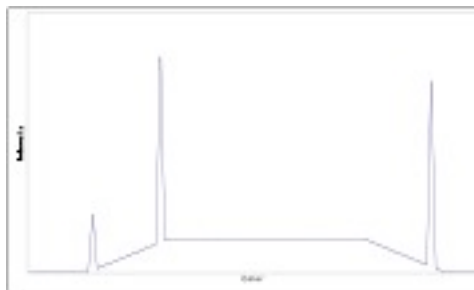
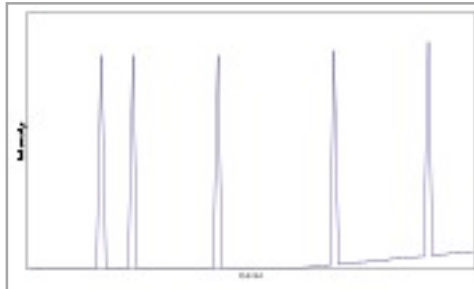
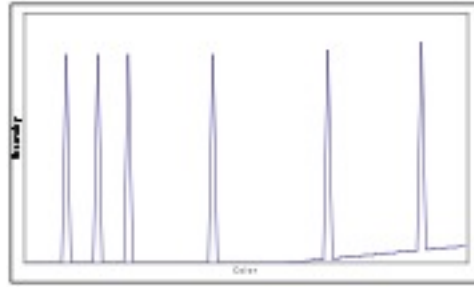
Graphing the Rainbow

Now, try matching each of the spectra from column A with its corresponding line plot from column B.

A



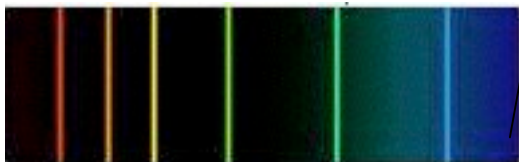
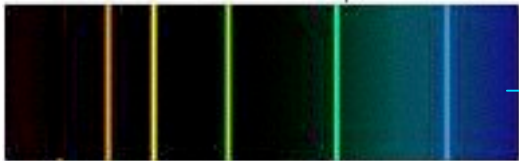
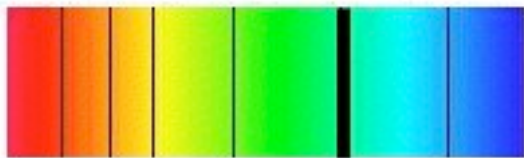
B



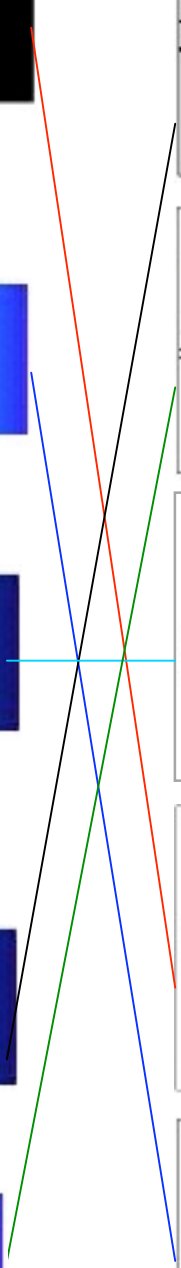
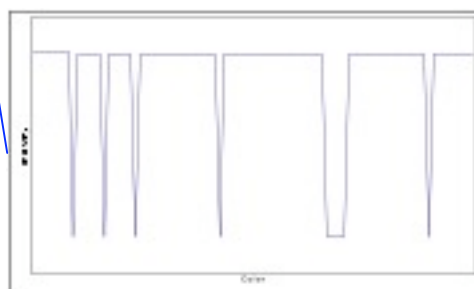
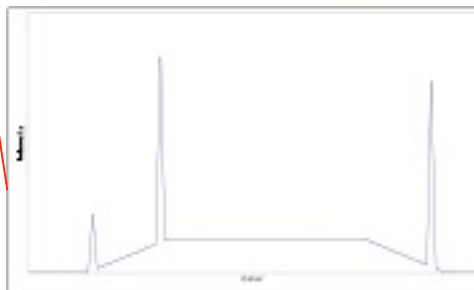
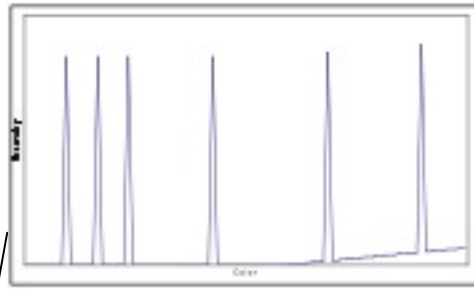
Teacher's Key: Graphing the Rainbow

Now, try matching each of the spectra from column A with its corresponding line plot from column B.

A



B





Using a Fancy Spectrograph

Middle School Grades

Lesson Summary

In this activity, students use the spectrograph and homework from the activity “Building a Fancy Spectrograph.” Students look at various light sources and make conjectures about composition.

Prior Knowledge & Skills

- Ability to recognize and describe patterns
 - Experience collecting data
 - Knowledge of the general properties of visible light
- Complete lesson:
- Building a Fancy Spectrograph

AAAS Science Benchmarks

The Nature of Science

Scientific Inquiry

The Nature of Mathematics

Patterns and Relationships

The Nature of Technology

Design and Systems

The Physical Setting

Structure of Matter

Motion

NSES Science Standards

- **Science as Inquiry:** Develop descriptions, explanations, predictions, and models using evidence
- **Physical Science:** Transfer of Energy
- **Science and Technology:** Abilities of technological design

NCTM Mathematics Standards

- **Algebra:** Understand patterns, relations, and functions

Colorado State Standards

- Mathematics Standards 3.4
- Science Standard 1, 2, 4, 5

Suggested background reading

Light

Teaching Time: One 60-minute period

Materials

Each Student Needs:

- Spectrograph from “Building a Fancy Spectrograph”
- Homework from “Building a Fancy Spectrograph”
- Colored Pencils
- Copy of directions

To Share with the Class:

- 1 Strand of multi-colored Christmas lights
- 1 Strand of clear white Christmas lights
- 1 Candle
- 1 Glow Stick
- (¼ Watt) night light with neon bulb
- 2-3 Extension cords

Advanced Planning

Preparation Time: 20 minutes

1. Have students build a simple spectrograph, using the associated “Building a fancy spectrograph” lesson.
2. Set up light sources around the room, making sure that there is distance between each source.
3. Make copies of the student pages.
4. Go over homework from “Building a Fancy Spectrograph.”
5. Go over lesson.
6. Shut off lights.

Why Do We Care?

When astronomers look at the atmosphere of a planet or body in our Solar System or beyond, they are usually able to tell what the atmosphere is made from. When light from background stars shines through the atmosphere, using a spectrograph, they can tell what is inside the atmosphere.



Using a Fancy Spectrograph

Activity Dependency “Building a Fancy Spectrograph” activity

Group Size 1 to 2

Expendable Cost per Group \$1 (initial cost, items can be reused)

Engineering Connection

Spectrographs are used both in ground- and space-based telescopes to help astronomers figure out what stars, planets, and planetary atmospheres are made of. Mechanical and electrical engineers build these spectrographs to help advance our knowledge of astronomy. Engineering of a spectrograph determines what kind of light it can analyze. For example, the materials involved affect what can be seen through the spectrograph and whether spectral lines can be seen or “resolved” at all.

Pre-Requisite Knowledge

Students should have completed the activity “Building a Fancy Spectrograph” and the homework for that lesson before completing this one. Students should have some understanding of the nature of light, i.e. rainbows are formed with light, light can be different colors, light can be obscured by physical objects, burning creates light, etc.

Learning Objectives

After this lesson, students should be able to:

- Describe that light seen through a diffraction grating shows all of the component colors of that light
- Describe that identical light sources look the same through the diffraction grating
- Explain that patterns can tell us something about what kind of light we see

Materials

Notes on Materials:

Glow sticks can be purchased at big box stores, camping supply stores, and many grocery stores, and are especially easy to find around Halloween. Glow sticks range in price from \$1-\$4.00. Make sure to get the kind that needs to be cracked to glow.

¼ watt night-lights (sometimes called 0.25 or 0.3 Watt) can be purchased at some big box stores, hardware stores, and many grocery stores, and typically cost under \$5.00.

Introduction / Motivation

Astronomers use spectrographs to figure out what the atmospheres of planets, moons, and other objects in the Solar System are made of.



Using a Fancy Spectrograph

Using the spectrographs that you built, today we are going to look at some different light sources. We will gather information about these light sources and figure out how astronomers determine what an atmosphere is made of.

Think about the spectrograph that you built. There are many factors that went into the design of this spectrograph, even though it is a very simple one. Engineers must consider all aspects of a design, from the length of the spectrograph to the angles present in the spectrograph. Often, they use computer modeling to help them design better instruments, but they also brainstorm with other engineers or read papers that engineers have written to help them come up with better ideas. Take some time to think about the components of your spectrograph, and we will discuss the limitations our simple spectrograph has, and talk about its strengths, before we begin.

Vocabulary / Definitions

Incandescent light bulb	A standard light bulb found in most households
Spectrum (plural: spectra)	The pattern light produces when passed through a prism or diffraction grating, as seen through a spectrograph
Spectrograph (also Spectroscope)	A tool that allows the components of light to be seen easily with the eye
Diffraction	When light bends around an obstacle or through a small opening like those in a diffraction grating
Diffraction Grating	Usually a piece of film covered with very thin, parallel grooves
Continuous Spectrum	The rainbow that white light is composed in which each color is equally bright
Emission Spectrum	Bright lines that appear through the spectrograph against a dark background
Absorption Spectrum	Dark lines that appear against the continuous spectrum seen through a spectrograph
Light Source	Any object that produces light

Procedure

Background

See the Background section of the activity “Building a Fancy Spectrograph” and the “Graphing a Rainbow” activity.

Here are some examples of the types of spectra you can see with different lights:

Florescent light bulbs contain mercury vapor inside and a phosphorescent coating on the glass. The bright lines are from the vapor, and the continuous spectrum is from the phosphor. Depending on the quality of the bulb, one may or may not be able to see the continuous spectrum. If the bulb is very high quality, the continuous spectrum may be all that you can see. A lower quality bulb will only produce a line spectrum.

A candle (seen at a distance) will produce a continuous spectrum.

Incandescent bulbs and holiday lights will produce a continuous spectrum.



Using a Fancy Spectrograph

Glow or light sticks will produce an emission spectrum depends on the type of dye inside. A chemical reaction causes the atoms in the dye to become excited and release photons. Even if the packaging says “neon” it is not actually neon gas that fills the tube, and the spectrum will not match that of a neon source. Students may have difficulty centering the light in the slit and will need to hold the glow stick steady several inches from the slit to observe the spectrum. It needs to be fairly dark to observe the spectrum.

A ¼ watt night-light with a neon bulb will produce a neon emission spectrum. If the night-light is the “jewel” type, it will not produce a clear spectrum so the casing will need to be removed and the connections covered with electrical tape (before plugging it in). It is preferable to get one that is not a “jewel” style, as it is difficult to remove a casing, and removal of the casing poses the risk of shock. It needs to be fairly dark to see the spectrum, and students may have to adjust their distance to the light while maintaining the light in the slit.

With the Students

1. Tell students that their job as engineers today is to establish what makes up all of the light sources that are around the room. They will be using the spectrographs that they built in the previous “Building a Fancy Spectrograph” lesson.
2. Have students rotate through the stations, spending about 5 minutes at each different light source.
3. Using their worksheets and homework from “Building a Fancy Spectrograph,” have students describe and draw the spectra of the various light sources around the room.
4. During the activity, walk around the room and ask students questions pertaining to the spectra they have drawn. Whenever possible, see if the student had used the same light sources from today’s activity in the homework for “Building a Fancy Spectrograph” and help students draw comparisons between their drawings on the homework and their drawings during today’s activity.

Safety Issues

- Students must understand fire safety as it pertains to the use of candles.

Troubleshooting Tips

Colorblind and vision-impaired children will have difficulty with this lab. Students with corrective lenses will not have difficulty. Colorblind students can be paired with a student to assist them with the activity and the homework.

Students may need assistance adjusting the position of the diffraction grating so that a spectrum appears in their spectrographs. The lid must be rotated if a spectrum is not visible.

Make sure all light sources have been tested prior to the lab to confirm that they are operational. It may be beneficial to have extra light sources in case one fails to operate.



Using a Fancy Spectrograph

Assessment

Pre-Lesson Assessment

Assessing prior knowledge: Go over homework from “Building a Fancy Spectrograph” and ask students questions pertaining to the light sources they drew. Ask them to make comparisons between their light sources and their neighbor’s light sources. Have them share their findings with the class. Highlight key concepts on the board based on their discussion.

Activity Embedded Assessment

Class discussion: Ask students what astronomers might gain from understanding the atmospheres of other planets. Reinforce the idea that without engineering technology such as spectrographs, scientists would be unable to determine what a planetary atmosphere contains. Ask students to brainstorm about the limitations and advantages of the spectrograph that they built.

Worksheet: Have the students complete the activity worksheet; review their answers to gauge their mastery of the subject.

Lesson Summary Assessment

Class discussion: At the end of this activity, students should be able to explain that light sources produce a specific pattern, and that the pattern does not change. Continuing the discussion period after the lesson is crucial. At the end of the unit, students should understand that the spectrum of a light source is different depending on what the light source is made out of, that sources that have an identical spectrum have an identical composition, and that gasses have a specific composition that can be seen by passing electricity through them or through a chemical reaction to produce light. Students can then better understand how astronomers gather information about what a body is composed of by examining light, and links can be made between this lesson and astrophysical data about the compositions of planetary atmospheres.

Activity Extension

The activity “A Spectral Mystery” can be completed if resources allow.

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Doherty, Paul. Scientific Explorations and Adventures. 1999/2000. Paul Doherty/Exploratorium: The Museum of Science, Art and Human Perception. 09/2006.

http://isaac.exploratorium.edu/%7epauld/summer_institute/summer_day9spectra/spectra_exploration.html

Fisher, Diane. “Taking Apart the Light.” “The Technology Teacher.” March (2002).

Owner

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Using a Fancy Spectrograph

Student Directions

Part 1

Student Directions: Using your homework from “Building a Fancy Spectrograph” fill in the table below. If you did not use these light sources, find one or more students who did, and share their work to complete the table.

Light Source Description	Color with Naked Eye	Draw Spectrum
Frosted Incandescent Bulb		
Incandescent Bulb		
Florescent Bulb		



Using a Fancy Spectrograph

Part 2

Bring the tables and colored pencils to the light sources around the room, and complete the tables.

Light Source Description	Color with Naked Eye	Draw Spectrum
Night Light w/ Neon Light		
Christmas Lights (white)		
Christmas Lights (colored)		
Glow Stick		
Candle		



Using a Fancy Spectrograph

1. Does the spectrum of any of the lights change if you move farther away or closer to it? Explain.

2. What do you notice about the spectrum of individual colored Christmas lights? How do the different colored light's spectra compare to one another?

3. Which spectra look exactly the same?

4. Which spectra look similar, but are not necessarily exactly the same? Explain your answer.

5. How do the spectra of the colored Christmas lights compare to the spectra of the white Christmas lights? Keeping in mind that spectra help us understand what *light* is made of explain why this is.

6. You are looking at a light through your spectrograph and you don't know what it is, but it looks the same as the nightlight spectrum:
 - a. What is the composition of the light?

 - b. How do you know?

Teacher's Key: Using a Fancy Spectrograph

1. Does the spectrum of any of the lights change if you move farther away or closer to it? Explain. *The spectrum of the lights should not change with distance unless the light source moves out of the slit. The spectrum remains the same because it does not depend upon distance, but on the composition of the light.*
2. What do you notice about the spectrum of individual colored Christmas lights? How do the different colored light's spectra compare to one another? *The Christmas lights all have a continuous spectrum, and all colors are identical to one another. Note: The colored lights may have some variation in the spectrum due to transmission through the color... red may have a darker or wider red line, for example. The color on the bulb acts like a filter, transmitting more of the color that the bulb is coated with. The students may or may not notice this, but it does not mean that the composition of the light is different (there are no emission or absorption features).*
3. Which spectra look exactly the same? *The white Christmas lights are the same as the colored Christmas lights, the frosted and unfrosted incandescent bulb, and the candle.*
4. Which spectra look similar, but are not necessarily exactly the same? Explain your answer. *The florescent bulb, the night light, and the glow stick all look similar, but they don't look the same because they all have different compositions.*
5. How do the spectra of the colored Christmas lights compare to the spectra of the white Christmas lights? Keeping in mind that spectra help us understand what *light* is made of explain why this is. *The white and colored Christmas lights look exactly the same. The light for both must also be the same, so the color in the colored lights does not effect (change) the composition of the light.*
6. You are looking at a light through your spectrograph and you don't know what it is, but it looks the same as the nightlight spectrum:
 - a. What is the composition of the light? *Neon.*
 - b. How do you know? *The nightlight's light is made from neon. If the spectrum of the nightlight is the same as the light you are looking at, it also must be neon because the pattern of the spectrum is always the same for neon light. Except a variety of responses that explain that the pattern will be the same for the two lights.*
7. How does the spectrum from the frosted bulb compare to that of the unfrosted bulb? *The two bulbs have the same spectrum.*
8. From number 7, what can you conclude about the material that makes the bulb "frosted?" *The part of the bulb that is frosted does not effect (change) the composition of the light.*
9. How is the florescent bulb different from all of the other light sources? Explain. *If the students had access to a low quality bulb, the bulb will have very sharp, bright lines (unlike any of the other sources) separated by dark spaces. These bright lines come from mercury. If you have a higher quality bulb, the spectrum should show bright lines with a fainter continuous spectrum background. It depends on the quality of the bulb.*

4. The Solar Dynamic Observatory (SDO) and Extreme Ultraviolet Variability Experiment (EVE)

Overview

Through a slideshow presentation about the Solar Dynamic Observatory and the Extreme Ultraviolet Variability Experiment (EVE), students will learn about the NASA Living With a Star Mission's Solar Dynamic Observatory and the significance of the Extreme Ultraviolet Variability Experiment, which was built in Boulder at the University of Colorado. Through an accompanying DVD, they will also learn about space science career opportunities and Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado at Boulder. Ideally, students will have a field trip to LASP and be given a tour by a scientist involved with EVE.

Learning Objectives

Through the slideshow presentation and DVD, and/or a field trip to LASP, students will learn about the technological process involved with building and testing a satellite, and what the Solar Dynamic Observatory satellite will do to measure changes in the sun's energy output. They will also be exposed to the range of job opportunities there are in space science at LASP and elsewhere, including machine operators, engineers, software experts, educators, and technicians.

Materials Needed

- Solar Dynamic Observatory slideshow presentation (CD)
- Introduction to Space Science (DVD) including All About EVE, Space Science Careers and a Tour of LASP
- Computer, overhead projector, screen and speakers
- EVE FAQ

Time

Showing the presentation and segments of the DVD can be done in one classroom period

Relevant Standards and Benchmarks

History and Nature of Science (NSES 9-12 Grades)

Science as a Human Endeavor

Individuals and teams have contributed and will continue to contribute to the scientific enterprise. Doing science or engineering can be as simple as an individual conducting field studies or as complex as hundreds of people working on a major scientific question or technological problem. Pursuing science as a career or as a hobby can be both fascinating and intellectually rewarding

Assessment

Students will also be able to:

- Describe the basic workings of a satellite and how they are built
- Understanding the variety of jobs and teamwork involved with building and operating a satellite

<http://sdo.gsfc.nasa.gov/>

The screenshot shows the NASA Solar Dynamics Observatory (SDO) website. At the top left are the NASA logo and the SDO logo. To the right is the text "Goddard Space Flight Center" and a search bar. Below this is a large banner image of the SDO satellite in space next to a close-up of the sun's surface. A navigation menu includes "Mission", "Data", "News & Resources", "Outreach", and "Gallery".

The main content area is divided into several sections:

- SDO - The Sun Now:** A large image of the sun's surface with a video player interface below it. Links for "view latest images" and "browse AIA/HMI data" are at the bottom.
- Pick of the Week:** Titled "Pick of the Week for Nov. 5, 2010" with the sub-heading "Swirling Plasma". The text describes a dynamic swirling mass of plasma. A "read more" link is provided. Below are "view more picks" and "galleries index" links, along with social media share buttons.
- SDO Mission Blog - SDO IS GO:** A blog entry titled "The Moon Gets in the Way (again)" dated "Sat, 06 Nov 2010". It features an image of the moon in a yellowish light and text explaining that the moon passes between SDO and the sun, used for spacecraft pointing. A "read more blog entries" link is at the bottom.
- SDO Interactive:** A small graphic showing the SDO satellite and the sun.
- Twitter:** A tweet from NASA_SDO: "Here comes the Sun and I say Uh-Oh!" with a link to a story about the solar cycle, dated "Mon, 08 Nov 2010".
- SDO Spacecraft:** An image of the SDO spacecraft.
- Facts:** A section titled "next fact" containing a quote from John Milton's "Paradise Lost": "There lands the Fiend, a spot like which perhaps; Astronomer in the Sun's lucent Orb; through his glazed Optic Tube yet never saw."

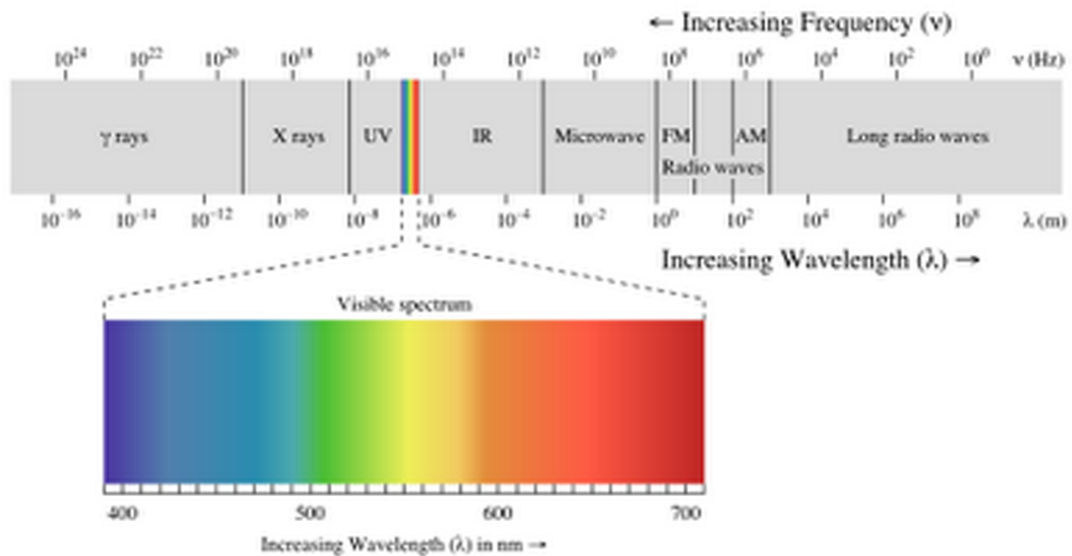


EUV FAQ

Frequently Asked Questions about Extreme Ultraviolet Radiation

What is Extreme Ultraviolet Radiation?

Extreme UV (EUV) radiation are very short wavelengths of ultraviolet light ranging from 10 to 120 nanometers (nm) in length. Longer wavelengths go up to 400 nm in the UV spectrum (UV A, or "black light") and then move into the visible, Infrared (IR), and longer-wavelength ranges of the spectrum. Wavelengths in the spectrum that are shorter than EUV are the X Rays and then Gamma Rays .



Name	Abbreviation	Wavelength range in nanometers
Ultraviolet A	UVA (black light)	400 nm - 315 nm
Ultraviolet B	UVB	315 nm - 280 nm
Ultraviolet C	UVC	280 nm - 100 nm
Extreme	EUV	121 nm - 10 nm

Why are EUV wavelengths important?

100% of the EUV light from the Sun is absorbed in the upper atmospheric layers of the Earth. Some UV radiation creates the ozone layer by breaking oxygen atoms from other molecules, causing them to form O₃, or ozone, in the stratosphere. As UV photons enter the atmosphere, they hit and deposit their energy in molecules, which heats the upper atmosphere producing the Thermosphere. Another process occurs called "ionization" also occurs in the upper atmosphere, where the energy of the EUV photons are high enough to knock electrons off from the rest of the atom. This creates the ionosphere.

What is the ionosphere?

Located throughout the thermosphere and mesosphere, the ionosphere is the region of the Earth's atmosphere that contained free, negatively charged electrons as well as the positively charged ions from where these free electrons came from. Formed from the EUV solar radiation that ionizes molecules in the upper atmosphere, it is an important component of atmospheric electricity, influencing radio waves, including AM radio and Geospatial Position System (GPS) frequencies. The ionosphere of the sunward facing part of the rotating Earth has more density than the night-side of Earth, thereby influencing radio wave transmission on a daily basis.

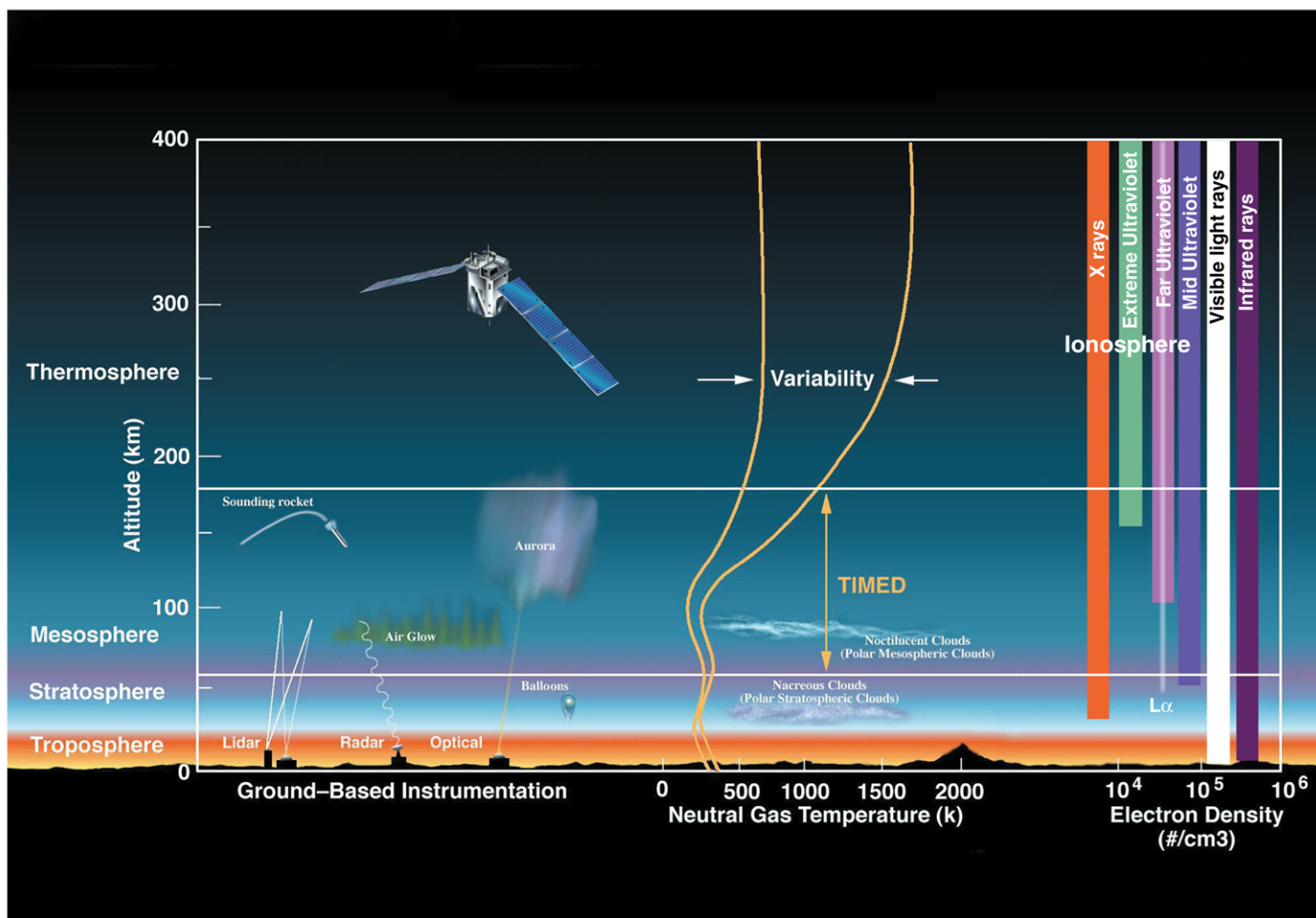
Can EUV vary in intensity?

Yes. During an 11-year period on the Sun called the Hale Solar Cycle, or also for random period of tens of minutes when a solar flare occurs on the sun, the EUV output from the Sun can increase by up to a factor of 2. The intense increase in the EUV radiation is absorbed by the particles in the atmosphere, freeing electrons, thereby increasing the density in the lower layers of the ionosphere (D and E region). The absorption of the increased EUV intensity during the solar cycle and solar flare also cause increased heating of the neutral particles in the Thermosphere and Mesosphere, which can lead to larger drag on satellites.



National Aeronautics and Space Administration
Goddard Space Flight Center

TIMED: CHARTING THE MLTI REGION

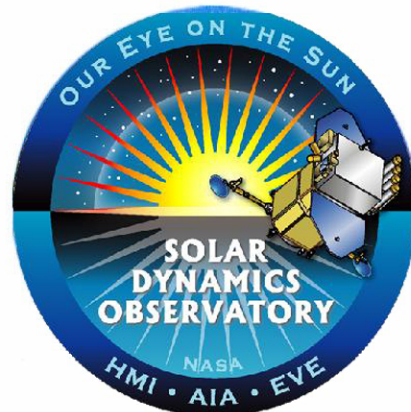


What is the Extreme Ultraviolet Variability Experiment?



The National Aeronautics and Space Administration (NASA) has been studying EUV for many years because EUV and variations caused by normal solar cycle dynamics as well as sudden disturbances triggered by solar flares can impact the Earth system. Since the radiation doesn't directly reach Earth's surface, the best place to study EUV is clearly space

itself. There have been a number of space missions which have included EUV monitors, and the most recent, the Solar Dynamic Observatory, includes the Extreme Ultraviolet Variability Experiment (EVE) that will help measure and model the solar EUV irradiance variations due to flares (seconds), solar rotation (days), and solar cycle (years). EVE has been built by the Laboratory of Atmospheric and Space Physics (LASP) at the University of Colorado in Boulder.



For More Information Visit the EVE Website: <http://lasp.colorado.edu/eve/>

5. Eyeing the Ionosphere- Using Technological Tools to Examine Atmosphere Ionization

Overview

The ionosphere is generated by ionizing radiation from the sun, specifically Extreme Ultraviolet and X-Rays, that hit the upper atmosphere, causing molecules to ionize. Fortunately for life on Earth, none of the radiation penetrates to the Earth's surface. The ionosphere, which changes throughout the day and with Earth's seasonal changes, is important to the Earth system and modern communications technologies.

Learning Objectives

These activities will engage students with modern technologies to observe different aspects of the ionosphere and can be used in preparation for the deployment of the Sudden Ionospheric Disturbance (SID) Monitor.

Materials Needed

This optional activity requires access to AM radios to observe changes in AM signals during different times of day and/or computers with Internet Access and Google Earth in order to observe current changes in the ionosphere due to solar radiation.

Time

One or more class periods. Ideally and AM Radio activity will compare night-time reception with daytime reception.

Relevant Standards and Benchmarks

Understanding about science and technology (NSES 9-12)

Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

Assessment

Students who successfully complete these activities will be able to:

- Describe in general terms the ionosphere and how it changes depending on the time of day
- Comprehend how changes in the ionosphere can impact radio communications
- Understand how technologies can be applied to monitoring changes in the ionosphere.

Introduction

Above the earth's surface, a layer of charged particles has been used, since the turn of the century, to reflect radio waves for long distance communication. Radio waves, with frequencies less than about 10 megaHertz, are reflected by the ionosphere. They are used for military and civilian 'short wave' broadcasting. The properties of the ionosphere can change dramatically with daytime transmissions being noisier than night time ones. Solar flares also change the reflectivity of the ionosphere. This AM radio project will let students detect and study some of these changes.

Objective

Students will construct an Ionosphere Monitor by using an AM radio to track solar storms and other changes in ionosphere reflectivity.

Procedure

- 1) Break the class into equal groups and have one person in each group bring an AM radio to class.
- 2) Each group creates a graph of the AM band from 540 kiloHertz to 1700 kiloHertz marked every 50 kiloHertz or so over a 1-foot span.
- 3) Remove the volume control knob and place the paper disk over the shaft, then replace the knob. Tape the disk onto the radio and mark its edge with the numbers 0-10 counterclockwise.
- 4) Have the students slowly scan through the AM band and note the location of the station on the graph. Note its loudness by the number on the disk that makes the station hard to hear.
- 5) Identify the call letters and city of each station you find.

- 6) Have the groups compare their results to create a combined master plot of the AM band. Locate the most distant station you can hear and its distance in miles from your school.
- 7) Select a location in the band on the low end between stations. Note the kinds of 'noise' you hear in a journal log for that day. Lightning storms will sound like occasional pops and crackles. Electronic noise will sound like humming or buzzing.
- 8) Changes in the ionosphere near sunset or sunrise will be heard as a sudden change in the loudness of the background noise. New distant stations may suddenly become detectable. Note the time, the location on the plot, and the city or call letters. This will take some detective work.

Materials

—An AM radio with a tuner knob and a volume control knob.

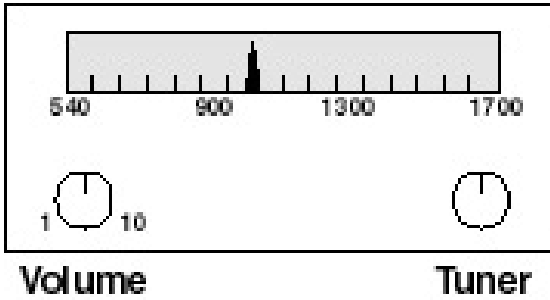
—A paper disk with a hole punched in its center to fit over the volume control.

For more things to do, advanced students may want to visit:

RadioJove at
<http://radiojove.gsfc.nasa.gov>
INSPIRE at:
<http://image.gsfc.nasa.gov/poetry/inspire>

Conclusion

Students will learn that a simple everyday device can let the listen-in to invisible changes in their environment caused by solar activity.



Note:
 On the volume control dial, you want to affix a circular scale so that when it is turned to '1', you are not very loud, and on '10' the radio is at maximum volume. When you are studying faint stations, you will typically have the volume control turned 'up' to hear them, so that the scale running from 1-10 will tell you about how loud the weak station is so that you are JUST able to hear it.

This makes a good classroom project and homework assignment (watching the changes during and after sunset). It is also a good long-term science fair project, if you also correlate solar activity with the changes in the daytime radio noise loudness, and faint station reception. Solar flares will cause short-wave 'drop outs' and impaired reception of distant radio stations during the daytime, lasting for several hours.

Sample Journal Entries:

April 5, 1997 10:45 EST Cambridge, Massachusetts

"We listened to a radio frequency setting of 610 kilo-Hertz. The noise seemed pretty steady at a loudness of 8.5, but every 10 seconds or so we heard a sharp crackle of noise. We think this was a distant thunder storm, and our TV weather report says that thunder storms were in progress in Kansas at the time."

February 6, 1997 6:00 PM EST, Dayton, Ohio:

"Sunset happened about 35 minutes ago, and I selected the same frequency we listened to at in school, to listen for the day/night changes. I can hear a faint station we did not hear in the daytime, and the background hiss is now less loud. Instead of 9.0, I have to put the volume control over to 9.5 to hear it at all. "

Online Internet resources you may find helpful:

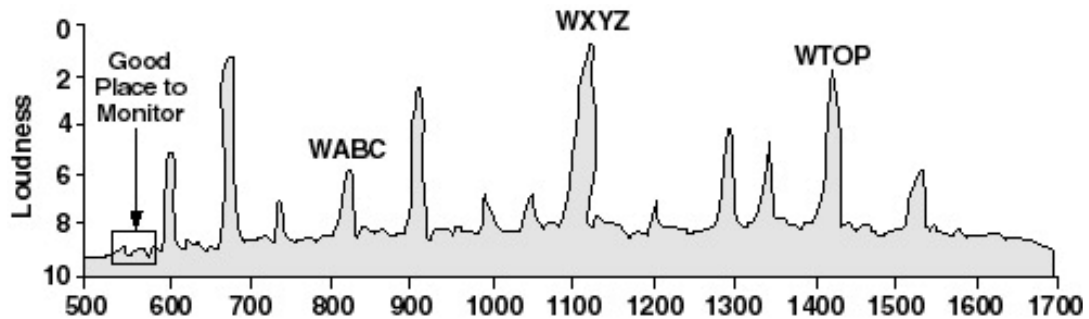
Today's Solar Activity:

<http://umbra.nascom.nasa.gov/images/latest.html>

Space Weather Forecasts:

<http://www.sec.noaa.gov/today.html>

<http://www.sec.noaa.gov/index.html>



Frequency in kiloHertz (1000 cycles per second)

$$\text{Wavelength in meters} = \frac{300,000}{\text{Frequency in kiloHertz}}$$

Teacher's Guide

Radio Waves and the Ionosphere

Introduction

When AM radio waves travel from transmitter to a receiver far away, they have to bounce off the underside of the ionosphere to reach a distant receiver. The waves lose some of their energy each time they are reflected. Although this is normally a small amount, less than 5%, it can be several times larger than this during a solar storm. When solar flares erupt, the radiation arrives at the earth 8.5 minutes later and ionizes the D-layer located just below the ionosphere closest to Earth. Radio signals passing through this layer and bouncing off the ionosphere higher up, have some or all of their intensity absorbed. If you were listening to a distant radio station, you would hear its signal suddenly 'fade-out' for 5-10 minutes.

Objective

Students will calculate the ending percentage of radio wave strength at the receiving station.

Procedure

1) Introduce the concept of radio waves in the ionosphere. Be sure to include a discussion about the waves reflecting off of the ionosphere layer and the surface of the Earth, and the impact of a solar storm on these waves. A blank transparency of the Student Page may be helpful for student visualization.

2) Explain that the radio waves normally lose about 5% each time they cross the D-layer just below the ionosphere. During solar storms, the radio waves can lose as much as 30% with each crossing of the D-layer.

3) Provide students with the examples given, and check for understanding.

4) Allow sufficient time for the students to calculate the percentages, and to determine the remaining signal strength at the

receiver's location.

5) Discuss the loss of wave strength and how that may affect communication. Some possible responses may include; mobile phone connections, AM radio station signals, and military communications.

This Lesson can conclude after the discussion, or the following additional procedure may be performed:

6) Group the students into pairs. Have them measure the given angles. Challenge each pair to vary the angle of the bounce to determine if there is an angle that will provide a stronger signal strength. For example, adjust the angle from the transmitter to a smaller degree, creating an isosceles triangle. This will change the number of bounces

Materials

- Protractor
- Calculator (if available)

to a fewer number of triangles, instead of the 8 given in the first example. By decreasing the number of bounces, the signal strength is stronger at the receiver's location. Adjusting the angle to greater than the original will increase the number of bounces required, and in turn decrease the signal strength at the receiver.

Example for one bounce with two passes through the D-layer:

Normal 5% loss:

$$100\% \times 0.95 = 95\%$$

$$95\% \times 0.95 = 90\% \text{ (Final)}$$

Solar Storm 30% loss:

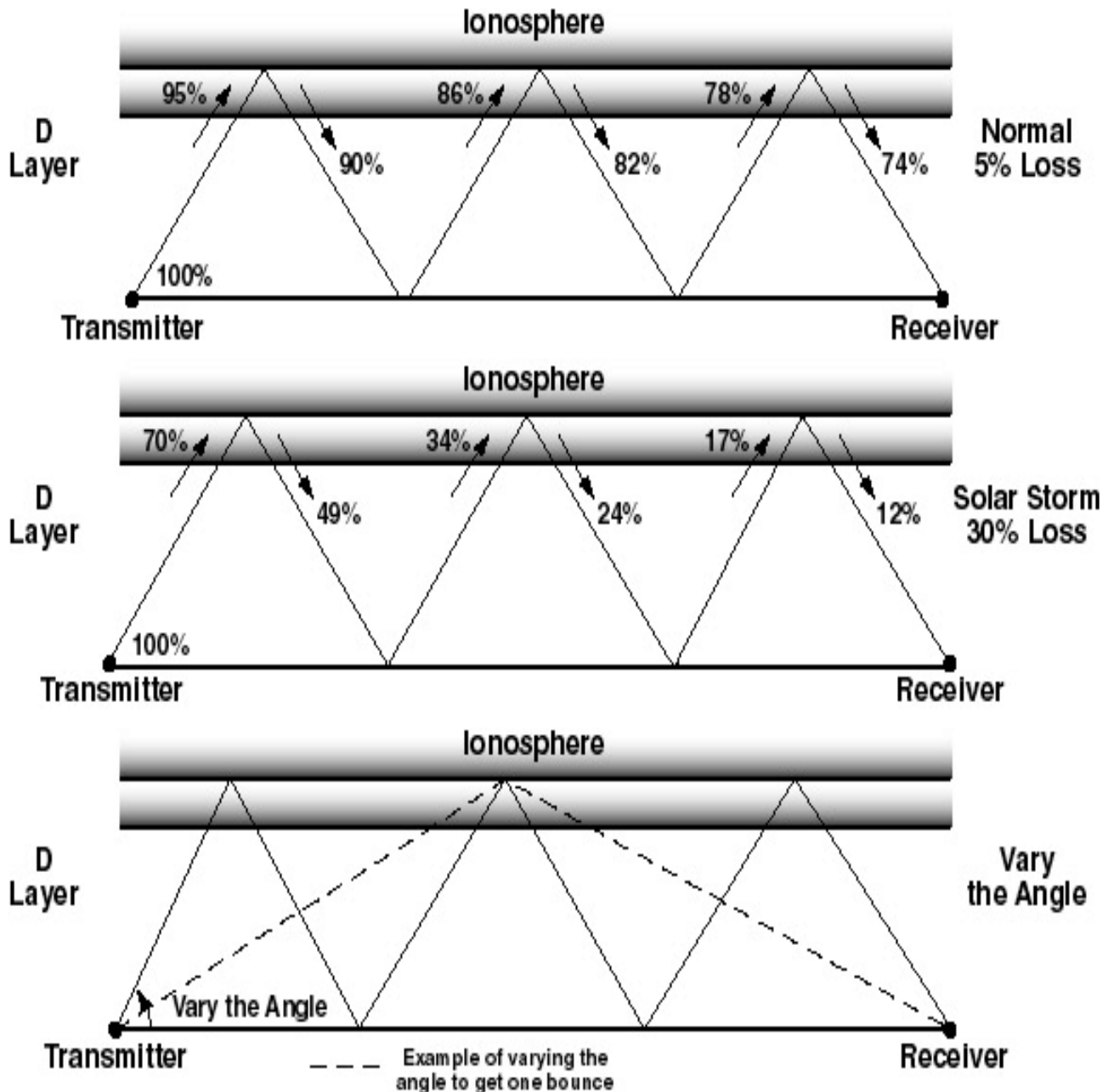
$$100\% \times 0.70 = 70\%$$

$$70\% \times 0.70 = 49\% \text{ (Final)}$$

Conclusion

Students should learn about real everyday situations that occur with our radio systems. From their discussion, they should address that during a solar flare, the radio waves lose a great amount of strength. Students should realize that solar flares greatly affect daytime long distance communication.

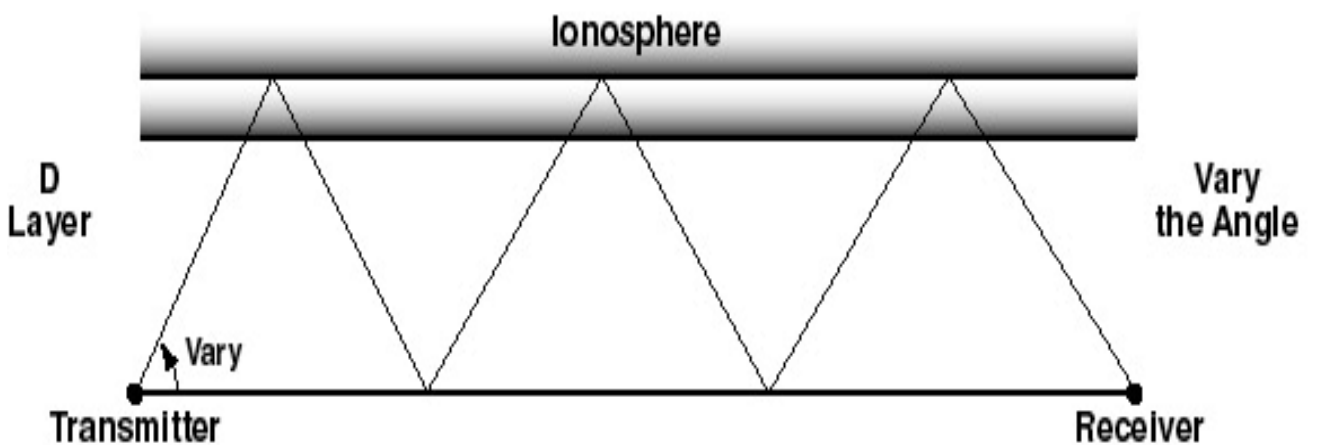
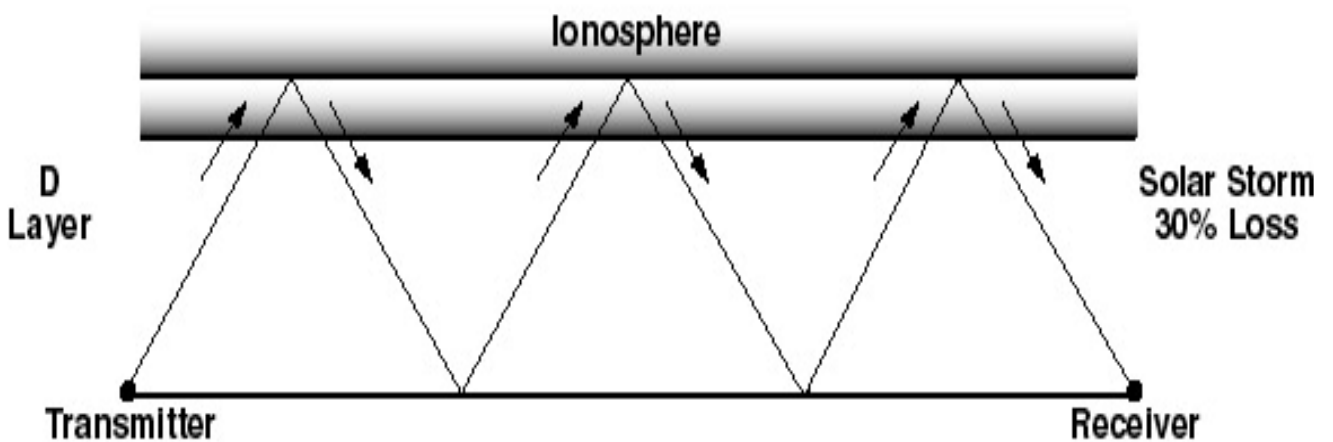
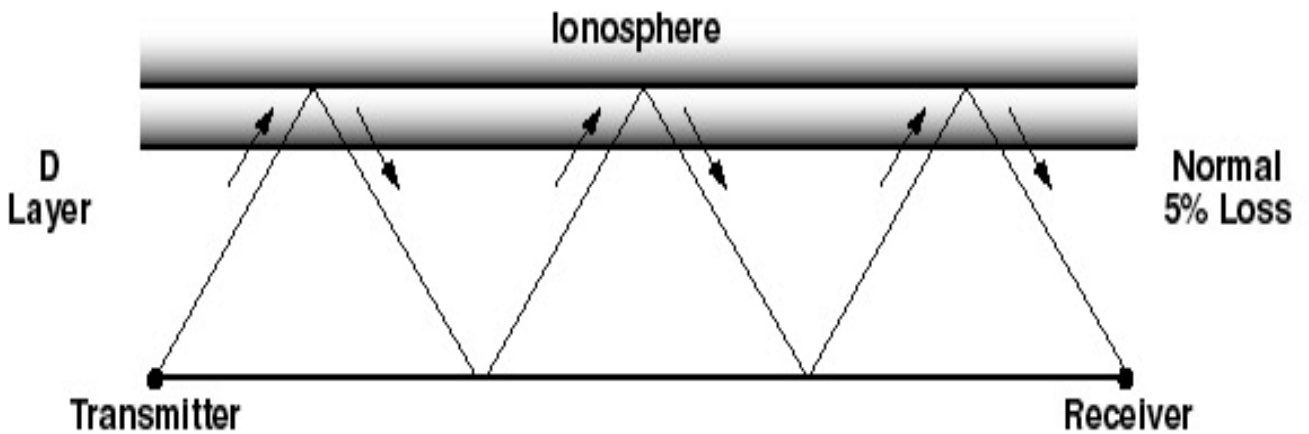
Teacher Answer Key



Radio waves travel from the transmitter to the receiver. The signal bounces from the ground, through a layer called the D-Layer, and is then reflected from the ionosphere back through the D-Layer to the ground. The waves continue to be reflected in this way until they reach the receiver. When the waves pass through the D-Layer they normally lose 5% of their strength. The loss occurs for every pass through the D-Layer, therefore, there is a 5% loss going up, and a 5% loss going down. When a solar storm occurs, the loss can be about 30%. The engineers have to adjust the angle that the signal is projected to create maximum reception by tilting their 'satellite dish'. The angle of adjustment must permit the triangles to be isosceles triangles. The wave bounces should be adjusted so that the final bounce is a direct hit to the receiver's location. If the signal is above or below the receiver's location, or to either side, there will be no reception.

Name _____

Date _____



Calculate the remaining signal strength for each bounce from the transmitter to the receiver. Determine the amount remaining at the receiver's location. Round the answers to the nearest whole number.

Today's Space Weather & Weather on Google Earth

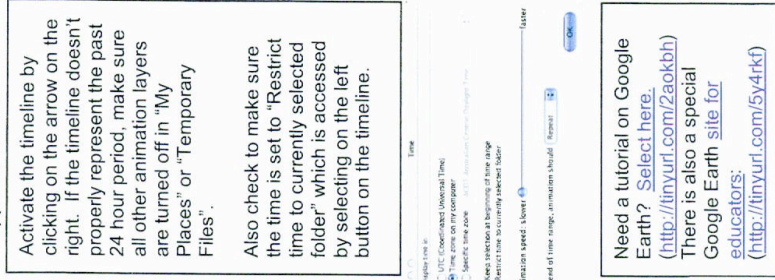
Download this [KML file](http://tinyurl.com/5y6v3o) (<http://tinyurl.com/5y6v3o>) which is an animation of the past 24 hours Total Electron Content of the ionosphere.

Once you have downloaded this file and opened it in Google Earth (ideally the [new 4.3 version](http://earth.google.com/)), you will be able to use the time slider in the upper right part of the screen to animate the file and see the changes in the ionosphere's electron concentration.

Click open the View menu in Google Earth, and turn on the "Sun" and "Atmosphere" layers by clicking each so that a checkmark appears next to the layer name.

Learning Tips

- ❖ Ionization caused by extreme ultraviolet energy and X-rays occurs in the upper reaches of the atmosphere. This energy doesn't directly reach the Earth's surface.
- ❖ Clouds and other manifestations of weather occur in the lower parts of the atmosphere.
- ❖ Short wave ultraviolet and visible light pass through the atmosphere and are absorbed at the Earth's surface, heating it up. Long wave infrared energy radiated from the surface heats the lower atmosphere,



Activate the timeline by clicking on the arrow on the right. If the timeline doesn't properly represent the past 24 hour period, make sure all other animation layers are turned off in "My Places" or "Temporary Files".

Also check to make sure the time is set to "Restrict time to currently selected folder" which is accessed by selecting on the left button on the timeline.

Need a tutorial on Google Earth? [Select here.](http://tinyurl.com/2aokbh) There is also a special Google Earth site for educators: (<http://tinyurl.com/5y4rkt>)

Turn off all layers in the "Layers" side panel by unchecking the box next to "Primary Database". Expand the Weather layer in the Layers side panel by clicking the + in the box to the left of the Weather layer. Turn on Clouds and Information by checking the box next to each. Double click the information layer, and select "download 24-hour clouds animation" in the balloon that opens in the GE display. Also select "Terrain" so you can see the land.

TEC, or Total Electron Concentration of the ionosphere is, according to the [CAPS website](http://terra1.spaceenvironment.net/~ionops/About.html) (<http://terra1.spaceenvironment.net/~ionops/About.html>) which is a joint effort between [Space Environment Technologies](http://www.spacewx.com/) (<http://www.spacewx.com/>) and [Space Environment Corporation](http://www.spaceenv.com/) (<http://www.spaceenv.com/>) "an indicator of the number of electrons that a radio signal must pass through. Maximum electron values are generally at the 200-300 km level and high TEC can indicate higher maximum altitudes with more densities," meaning less high frequency (HF) radio propagation. Changes in the ionosphere can have a major impact on radio communications especially over polar regions.

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