SUN-Sational Science
There's more to LIGHT than Meets the Eye

I. Properties of Light

A. Does Light Travel in a Straight Line?
B. Refraction/Reflection

A. Does Light Travel in a Straight Line?
1. Activity: Lighting the Path of Light

Materials:
- Laser pointer (Higher power green laser works very well for this activity)
- Spray bottle with water or artificial fog

Procedure:
1. Darken classroom as much as possible.
2. Shine a laser pointer across room and discuss observations (Can you see a light on the wall? Do you see the light traveling to the wall?...)
3. Spray water mist (or artificial fog) in path of laser beam and discuss new observations. You should be able to see the light reflect off the water droplets. The probability of light reflecting off of air molecules is very small because of the small size of the molecules. However, the reflection probability rises sharply for larger particles like the water spray produces. Have students observe the laser's light path.

B. Refraction/Reflection

Reflection is the term used to describe the manner in which light "bounces" off objects. The most obvious object is a mirror, but light reflects to varying degrees off almost all objects.
Refraction is when light moves from one medium to another and as it does it changes speed (slower in a more dense medium and faster in a less dense medium), resulting in a slight change of direction, or we say that it bends.

1. Activity: The Magic Appearing Coin

Materials:
- Coin
- Water
- Non-Transparent Bowl

Procedure:
1. Put the coin in the bowl (You can use tape to secure the coin in place).
2. Walk backwards with small steps until you cannot see the coin in the bowl any longer.
3. Have someone pour water slowly into the bowl.
4. Watch the bowl from where you are standing.

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What do you see? When the bowl is empty, the edge of the bowl stops you seeing the coin. When the bowl is full, the light bends over the edge, so you can see the coin. Have you ever noticed that things at the bottom of a pool or river always look closer to the surface than they really are? This is because of the way light is bent through water and is an effect of refracted light.

2. Activity: The Disappearing (and Reappearing)

Materials:
- Coin
- Water
- Transparent Cup

Procedure:
1. Fill the transparent cup approximately 2/3 full of water.
2. Place the filled cup over top of the coin and observe.
3. Observe looking into the cup from above and then from the sides of the cup.
4. Next, lift the cup and place several drops of water on top of the coin. Replace the cup and observe.
5. Discuss how both refraction and reflection apply to making the coin disappear and then reappear in this activity.

3. Activity: Broken Straws

Materials:
- Straw or Coffee Stirrer
- Water
- Transparent Cup

Procedure:
1. Using the same cup of water as used for the activity above, have participants place a straw or coffee stirrer in the cut and rest it to one side.
2. Observe.
3. Discuss how light can be bent (refracted) because it travels faster through one medium (air) than other (liquid).

4. Activity: Laser Light in a Cup or Water Tank

(demonstrates refraction & reflection)

Materials:
- Clear glass (or clear plastic cup) of water
- Water (best to use distilled)
- Laser pointer
- Non-dairy powdered coffee creamer
- White poster board or paper, to put across the top of the container

Procedure:

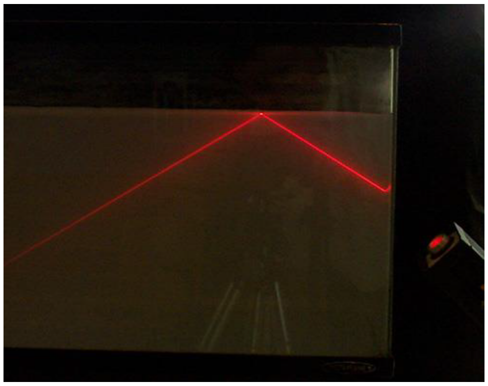
1. Explain the safety requirements for using laser lights – DO NOT shine toward anyone's face or eyes.

2. Fill a clear glass almost full of water. It is best to have the water poured the day or evening before so that there is very little turbidity (cloudy from bubbles, etc.).

3. Shine the laser pointer from the outside of the cup through the water (shine from top, side, at angles). Make observations. If desired, repeat in a darkened room.

4. Mix in a very small pinch of powdered coffee creamer (even just a few granules) and stir. If the laser light is quickly attenuated inside the glass, you have put too much coffee creamer in the water. Start over. If you can't see the light or if you can barely see it, then put in more creamer and stir. It may take some practice to get this just right.

5. Repeat shining the laser through the water (from top, side and at angles). Make observations. You should be able to see the light as more of a line travelling through the water (not just on other side of cup).



6. Make the laser reflect off the water surface: Shine the laser pointer from the outside of one side of the cup from near the bottom pointing so the light will come out through the surface of the water (see photo). You should be able to see the red path of the laser as it passes through the water. You will not be able to easily see laser light pass through clear water, but the powder adds larger masses that will scatter the laser light so you can see it. You should be able to see the light reflect off the top water surface. If you shine the laser pointer towards the other side of the cup, you may be able to see light reflected off the glass side.

7. You will not be able to see light coming out of the glass into air, because air molecules are too small to effectively scatter visible light. However, you can place a piece of white poster board over the top and sides of the cup and see the laser light shine on the white board.

8. The laser can be seen in the lower right of the photo (red spot). The path of the laser light cannot be seen until after it enters the water. The light moves to the left and is totally internally reflected at the water surface. Note the straight lines that the laser light makes inside the cup.

9. Shine the laser light so that it reflects off the water surface (from inside the water) at different angles. Use the white poster board/paper to see if light is being transmitted through the water/air interface (that is, is light being refracted?) You should easily be

able to see the laser light reflect off the surface where it enters the cup (use poster board).

10. You should be able to find an angle (called the critical angle) where, as the angle with the water surface gets smaller, all the light will be reflected from the water surface back into the container and none will be refracted out into the air. This angle should be about 40 degrees from the water surface for water and air. Smaller angles should have the light totally reflected back into the water. You will have to move the poster around on top of the cup to see the red spot, because the direction of the refracted moves dramatically with entrance angle.

II. The Visible Spectrum

Participants will conduct investigations regarding the visible portion of the Electromagnetic Spectrum.

Activity: Make (and take) a Spectroscope:

A spectroscope is an instrument used by astronomers to study the EM Spectrum as well as the correspondence of different elements and compounds to unique patterns of spectroscopic lines at different wavelengths.

Materials:

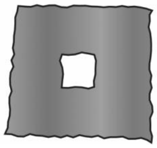
- Paper towel tubes, mailing tubes (or other tubes)
- Aluminum foil - (2 squares about 4 x 4 inches and 2 strips about 1 x 3 inches per participant; measurements are approximate and do not need to be exact)
- Masking Tape
- Diffraction Grating (1” square per participant)
- Rubber Bands (2 per scope)
- Light sources

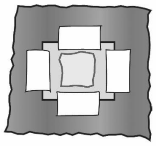
Procedure:

Construction plans:

1. The spectroscope has two ends, one for the diffraction grating (which is the end you look through) and one for a slit, which controls the entry of light into your instrument, so you can select which object to look at, and to improve the dispersion of light into a longer spectrum.

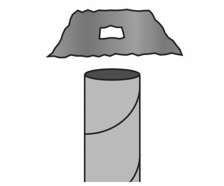
2. To assemble the diffraction grating end of the spectroscope, participants should take a piece of aluminum foil about 4x4 inches and tear or cut a small hole in the center of the foil, about the size of a nickel or a dime. The hole should be smaller than the square of diffraction grating material. The easiest way to do this is to fold the foil square in half, then half again the other direction. Cut a small square (1/4 inch) off the corner that is at the center of the foil, and unfold it to reveal a square opening approximately 1 inch x 1 inch. (NOTE: If the hole they make the first time is a little too large for the diffraction grating, the piece of foil can probably be recycled for the slit end in step 5).





3. Tape the diffraction grating over the hole, being careful not to handle the diffraction grating too much, and to tape only the

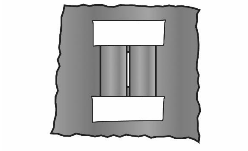
edges of the grating and not across the middle. It does not matter which side of the grating or foil is up/out.



4. Take the foil mounted grating, and put it over one end of the paper tube (with the grating over the hole) and tape the foil to the tube with masking tape or secure with a rubber band

5. Next, assemble the slit end of the scope. Students should take the other piece of aluminum foil (about 4x4 inches) and put a hole in the center of the foil as before

6. Students should take the two strips of aluminum foil and carefully fold each of them lengthwise (so the strips are now about .5x3 inches) making a sharp crease at the fold (the crease is the important part, so don't worry too much about the dimensions).



7. Take the two creased pieces of foil and lay them over the hole in the large piece of foil – the two creased edges should be next to each other but not overlapping – a gap of a few millimeters (or perhaps the width of a toothpick) is perfect. Tape the two creased pieces of foil in place over the hole (but make sure that the tape isn't covering the gap) and place the slit over the open end of the paper towel tube and wrap the aluminum foil around the tube. Do not tape foil to tube yet.

8. "Calibrate" the spectroscope by aligning the slit with the diffraction grating so that there is a wide spectrum, which will be easy to see. Hold the spectroscope so that you can look through the diffraction grating end (the plastic square should be about as close to your eye as your glasses lens or as close as you would put a microscope). Point the slit end of the spectroscope towards a light source – this can be a light in the room or if you are outside, at the sky, but not at the sun! Look for a rainbow in the spectroscope, probably a little bit off to the side or up or down (you should be able to see regular light from your source coming through the slit, but the rainbow will be off-center). While still pointing your spectroscope at the same light source, twist the slit around until the rainbow is as "fat" or "tall" as you can make it. Then, tape the foil for the slit end into position.

Using the Spectroscope:

Now that the spectroscopes are built, it's time to put them to some use – the first object students should look at (if at all possible) is a spectrum of the sun.

IMPORTANT WARNING: NEVER LOOK DIRECTLY AT THE SUN WITH THIS INSTRUMENT OR YOUR NAKED EYE.

There are a couple of ways we can see a solar spectrum without looking directly at the sun. First, we can look at the sky, which is bright from sunlight scattered off of little bits of dust in the air.

This should be possible even if it is fairly cloudy; however it may not be feasible if it is actually raining. If you are worried that even this will give students the idea that it is safe to look at the sun, you can also put a white piece of paper on the ground on a sunny day, and they can look at the paper, which will reflect the solar spectrum. If it is raining, or viewing the solar spectrum is otherwise impractical, an incandescent bulb can be substituted. You should point out that the solar spectrum (at this resolution) is a fairly uniform rainbow, showing all the usual colors (the students will usually remember and recognize ROY G BIV). Now is also a good time to point out (in conjunction with a spectrum poster) that the spectrum really extends beyond what the students can see in their spectroscopes, to "invisible light," like radio, infrared, ultraviolet, X-ray, etc. This is similar to the sound of a dog whistle. The sound a dog whistle makes is real, and with the proper kind of ears we could hear it. Radio, IR, UV, X-ray and other wavelength ranges of light are real, and with the proper kind of "eyes" or tools, we can see these other wavelengths of light.

Different colors that the students see represent different wavelengths of light, but visible light wavelengths have a very narrow range – only about 300-700 nanometers (a nanometer is a billionth of a meter) – while wavelengths of light can range longer than meters in the radio to shorter than a picometer (trillionth of a meter) for gamma rays.

Next, students should examine a light source with obvious discrete lines – most schools and other institutional buildings have bright mercury fluorescent lamps, which are ideal. If you are unsure of what kind of lamps you have, build yourself a spectroscope in advance and have a look around your home, school or neighborhood. Also, a variety of common gas emission spectra images can be found at: http://laserstars.org/data/elements/

Ask students what differences they notice between the solar spectrum and the spectrum of the artificial light. Prompt them, if necessary, with the question "Are all of the ROY G BIV colors present in this new spectrum?" For mercury fluorescent lights, there will only be a faint continuum, but there will be four or five bright lines (depending on how far red your eyes can see): 1 or 2 will be red, 1 will be green, and 2 will be blue/violet. Some colors are missing, and there are very clear lines – these lines are the fingerprint of mercury. If you see these lines, there is mercury in your light source. If you don't see them, there is little or no mercury.

This is how astronomers figure out what distant objects are made of – every atom and molecule has its own unique fingerprint, and based on the brightness of the "fingerprint," they can even tell how much of an atom or molecule is present (lots of "stuff" means bright lines, very little "stuff" means faint lines).

If time and resources permit, you can show students other light sources containing other molecules and elements (e.g. with discharge tubes) to show them what some of the other fingerprints look like. H and He lamps are good to start with since they have less complicated spectra. Regardless, you should send students home with their spectroscopes and encourage them to check out the lights in their local neighborhoods – most street lamps are either mercury or sodium lamps, and "neon" signs often contain many different elements which produce different colors (only the orange-red ones are actually neon.)

III: Seeing & "Hearing" Light Beyond the Visible Spectrum (UV & IR Light)

A. Activity: Space Radiation – Make a UV Man (or woman or dog):

_http://www.lpi.usra.edu/education/explore/space_health/space_radiation/activity_1.shtml

Overview:
Participants construct UV Man (or woman or dog) and equip him with special radiation detectors to investigate the source of ultraviolet radiation in this activity. They explore how we can protect UV Man and ourselves from being exposed to too much UV radiation.

What's the Point:
- Ultraviolet radiation comes from our Sun
- While some ultraviolet radiation is necessary, too much can harm humans (and other living organisms)
- There are ways we can protect ourselves from harmful UV radiation

Materials for each participant:
- 3 UV beads (can be found in craft store or online)
- 2 non-UV beads (regular "pony" beads)
- 3 halves of pipe cleaners or "fuzzy" sticks
- Scissors
- Various materials that will "protect" UV Man from ultraviolet radiation, for example: construction paper of different colors, foil, plastic wrap (of various colors), paper sunglasses (may be obtained from an optometrist), sunscreen (try different SPFs), masking tape, paper, cloth, etc. You may even wish to include containers of water for the children to experiment with!

Preparation:
- Locate an outdoor area close by that has both shady and sunny spots, if possible.
- Review the supporting information to prepare for the student's discussions.

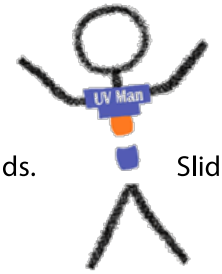
Procedure:
1. Introduce the topic of solar radiation. The students may be unfamiliar with UV radiation and its effect on skin; you may need to lead them through the discussion.
- What does our Sun provide to us? Light and heat.
- What happens when we stay outside in the Sun for too long? We get sunburned!
- What is the part of the Sun's energy that causes our skin to burn? Ultraviolet energy or radiation. This energy is invisible to our eyes and we cannot feel it, but it still affects our bodies.
- What protects Earth from much of the UV radiation? Our atmosphere blocks much of the Sun's UV light. The ozone layer in our upper atmosphere forms a protective sphere, absorbing much of the UV energy.
- How do we protect ourselves from getting burned by the Sun? We wear clothing and use sun block.

2. Invite students to construct a UV Man (or woman or dog). Explain that they will equip him with radiation detectors (UV beads) that are made from a special pigment

that is very sensitive and turns colors when exposed to the ultraviolet rays. With the help of UV Man they will investigate the source of ultraviolet radiation and how we can best protect UV Man and ourselves from it.

To construct one UV Man (or woman or dog!):

1. Form a circle at the top of one pipe cleaner half so it looks like a lollipop with the circle as the head and the “stick” as the torso.



2. Thread the beads onto his torso, alternating UV with non-UV beads. Slide all the beads toward UV Man's head

3. Fold one piece in half; these will be his legs.

4. At the crease of the legs, bend the bottom of the torso up over to attach.
5. Twist the third piece around the torso above the beads to make arms.
3. When students finish, ask them what the observe
- What color are UV Man's UV radiation detectors — the UV beads? White or creamy
- Are UV Man's radiation detectors picking up any signs of radiation in this building? No
- Do you think UV Man's radiation detectors will turn colors if he goes out into the Sun? Why or why not? Answers will vary
- Will his radiation detectors turn colors if he goes outside into the shade? Why or why not? Answers will vary.

4. Ask the students to cover UV Man’s radiation detectors with their hands so that no light can get in and the take him outside. Have them stand in the shade and uncover their UV Man. What do they observe happens to UV Man's radiation detectors? The beads become lightly colored if the children are standing in light shade, indicating that, even in the shade, there is some UV radiation reaching the detectors and our skin.
5. Ask the students to cover UV Man with their hands so that no light reaches him. Keep UV Man covered for about 1 minute while the beads change back to white. Use this opportunity to discuss their observations.

6. Let the students now take UV Man into the full Sun.
- What happens to the beads? The beads become deeply colored, reacting to the intensity of the UV radiation to which they are being exposed.

7. Return to the room and continue the discussion.
- What happened to UV Man's radiation detectors? They changed colors
- Did they change in the shade? Yes — a little.
- In the Sun? Yes — a lot!
- Where did they change the most? In the direct Sunlight.
- Was your prediction correct? Answers will vary.
- What caused UV Man's radiation detectors to change colors? The ultraviolet radiation from the Sun.
- What happened to his radiation detectors after coming back inside, and what caused it? They changed back to white because they were no longer detecting any radiation. UV radiation does not get through the building.

Some students may say light caused them to change, and others may say heat. Remind them of their observations about the beads inside; the beads were white, even though they were in the light of the room. Ask them what happened to their beads when they brought them back inside; the beads changed from a colored state in the Sun back to white in the room light. The room light does not affect the beads. If it is heat that causes the change, invite the children to hold beads in their fists; the beads do not change color when heated. They can also heat the beads with a hair dryer. The cause of the change comes from the Sun; it is from the part of the Sun's spectrum we do not see or feel directly.

- What did this experiment tell you about UV radiation and YOU? Just like UV Man, you are exposed to UV radiation when you are outside.
- How do we protect ourselves from UV radiation? Answers may include wearing clothing, using sun block, using umbrellas, or staying inside.

8. Invite the students to protect UV Man from UV radiation. Provide them with two materials to cover him or protect him in other ways. To get them started, have them make a construction paper poncho or shirt to cover the top UV bead. Have them test at least two additional ways to protect UV Man by covering him with the materials you have provided. Have them take UV Man outside again to test each material.

9. As a group, have student share their experiments and observations.

- What materials offered the best protection for UV Man? The worst? None at all?
- The Sun's rays turned UV Man colors. Do the Sun's rays ever turn you colors? Yes!
- What practical things can, and should, you do to protect yourself from UV rays? Wear protective clothing, use sunscreen, don't stay out in the Sun for extended periods, and definitely don't expect the shade to protect you! Overexposure to UV rays causes the skin to burn, sometimes badly (ouch!!). And extreme or excessive burning of the skin can lead to skin cancer.

10. Share with students that with the UV Man's help they have demonstrated the effects of the Sun's ultraviolet rays on objects (and people) on Earth.

In the next activities they will investigate a special characteristic of our planet that protects it from receiving even more UV radiation than it already does, and whether or not UV radiation is a challenge to living and working in space.

Conclusion:
Ask the group to share their thoughts about ultraviolet radiation. Where does it come from? Is it dangerous? How can we protect ourselves from it?

A little background for the Facilitator:
Light and heat are part of the spectrum of energy — or radiation — our Sun provides. We can "see" light and we can "feel" heat. But there are other types of energy that our Sun produces. Much of this energy makes up the electromagnetic spectrum. Light is part of the visible section of the spectrum and heat is part of the infrared section of the spectrum. Radio waves, microwaves, ultraviolet rays, X-rays, and gamma rays all are parts of the spectrum of electromagnetic energy — or radiation — from the Sun.

Radiation is energy that travels in waves or as particles. Radio waves, microwaves, visible light, and infrared radiation have relatively long wavelengths and low energy. But ultraviolet rays, X-rays, and gamma rays have shorter wavelengths and higher energy. This shorter wavelength is so small that these wavelengths interact with human skin, and cells, and even parts of cells — for good or for bad!
Our Sun also produces cosmic radiation. Cosmic rays are very high energy, fast moving particles (protons, electrons, and neutrinos) that can damage DNA, increasing the risk of cancer and causing other health issues. Cosmic rays have such high energy that it is difficult to design shielding that blocks them; Cosmic rays do not only come from our Sun, but from other places in our galaxy and universe.

The subject of this activity is ultraviolet — UV — radiation. Humans need UV radiation because our skin uses it to manufacture vitamin D, which is vital to maintaining healthy bones. About 10 minutes of Sun each day allows our skin to make the recommended amount of vitamin D. However, too much exposure to UV causes the skin to burn and leads to wrinkled and patchy skin, skin cancer, and cataracts.
On Earth, we are protected by our atmosphere from most UV radiation coming from the Sun. The Ozone layer absorbs much of the UV portion of the spectrum (UVB and UVC). Some still gets through (UVA and a bit of UVB). We can protect ourselves completely by covering ourselves with clothing and using sun block. Our atmosphere protects us from most of the X-, gamma-, and cosmic radiation as well.

In space there is no atmosphere to protect astronauts from UV radiation — or from X-rays and gamma rays, or even more dangerous cosmic rays. Astronauts have to provide their own protection in the form of space suits and space stations. These measures work very well for protecting against UV radiation, but the higher energy radiation is not completely blocked. Even with protective shielding, astronauts aboard the International Space Station receive a daily dosage of radiation about equal to 8 chest X-rays!

The UV-sensitive beads used in this experiment serve as UV radiation detectors. They contain a pigment that changes color when exposed to ultraviolet radiation from the Sun or from UV lights. The intensity of the color corresponds to the intensity of the UV radiation. When shielded from UV sources, or when exposed to light that does not contain UV radiation — such as indoor light bulbs — the beads remain white. The beads are designed for multiple uses, and according to the manufacturers, will change color up to 50,000 times.

B. Activity: Seeing and Hearing IR Light

http://www.sofia.usra.edu/Edu/materials/activeAstronomy/section3.pdf
Students will use a detector to hear the presence of light. Since we cannot see infrared light, we must detect it with another one of our senses. This activity leads students to "hear" infrared radiation via a photocell and speaker. Students first consider how to tell, while blindfolded, if a cow is standing in a gym. Instead of the cow analogy, the instructor could also bring objects that have distinctive sounds and smells into the classroom and ask the students to close their eyes and identify them. Using a simple photocell detector (pictured left), see what happens when they move their hand back and forth in front of it. The photocell (or solar cell), connected as shown in the image,

produces an electric current when exposed to light. Because of the way speakers are constructed, a changing current is needed to produce a sound in the speaker; a constant current will not produce a sound. When a constant light source illuminates the photocell, it produces a constant current and no sound is produced. Students should hear static, if anything, when a constant light source illuminates the photocell. When the light is continuously interrupted, or “chopped”, the current produced will continuously change and the speaker will produce a series of “pops” each time the light is chopped back on.

Next, have participants listen to a variety of IR light sources such as remotes, LEGO RCX robot, etc.

Note: You can also see IR light from TV remotes when viewed through an infrared focusing digital camera lens.

The following web site includes background information on infrared light, as well as examples of ways in which people use infrared light, e.g., in meteorology, search and rescue, and environmental monitoring. For more classroom activities involving infrared light, including the same experiment done by Sir William Herschel in 1800 in which he discovered the existence of light outside the visible spectrum, see: http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/ir_activities.html (also includes Infrared Zoo)

Additional Information of Electromagnetic Spectrum:
The sun emits energy as electromagnetic radiation. Unlike sound, such radiation requires no medium, therefore this energy is able to travel through the near vacuum of space from the sun to the earth.
Most radiant energy from the sun is concentrated in the visible and near-visible parts of the EM spectrum, and it peaks at about 500 nm. Less than 1% of solar radiation is emitted as X-rays, gamma rays, and radio waves.

Only about 25%, or about 350 W/m2, of incoming solar radiation penetrates the transparent atmosphere of the earth. The remainder is either absorbed by the atmosphere or scattered back into space. There are some latitudinal differences found on Earth. These variations are determined by time of year, by the wavelength of the energy being transmitted, and by the depth and nature of the intervening material. Terrestrial radiation is produced mainly as a result of re-radiation of solar radiation. The energy is absorbed from the sun as the sun’s spectrum but re-radiated from Earth at the much longer wavelengths associated with the temperature of Earth. The Wien displacement law, in which the wavelength is inversely proportional to the absolute temperature, provides a comparison of those peak wavelengths.

Since the sun has a surface temperature 20 times greater than that of Earth, the reradiated energy has a spectrum that peaks at a wavelength 20 times longer than the 500 nm for the sun, or at about 10,000 nm, well into the infrared. Since the atmosphere is more absorptive to such long-wavelength terrestrial radiation, the atmosphere is heated from the ground up instead of vice versa.

In addition, water vapor and carbon dioxide absorb the long wavelengths of radiation from the earth especially well, leading to the so-called "greenhouse" effect. (The temperature in real greenhouses rises mainly because the glass prevents the heated air from rising, thereby increasing the temperature inside.) Ozone, on the other hand, absorbs only very short wavelengths, mainly in the ultraviolet range, and therefore forms a shield of sorts, absorbing much of the ultraviolet radiation before it can reach the earth.

Additional Activities:
Tracking Sunspots to Determine Rotation Rate of the Sun
Using NASA images of sunspots collected over a period of time, participants will chart locations of sunspots and calculate the period of rotation for the sun. (Activity on The Sun and Space Weather disc).

Using Filters to See the Sun
An optional M&M Filter Activity is included in the lesson to demonstrate how filters work.

UV Man in Space
http://www.lpi.usra.edu/education/explore/space_health/space_radiation/activity_2.shtml