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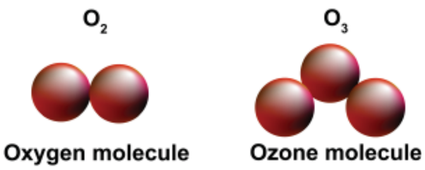
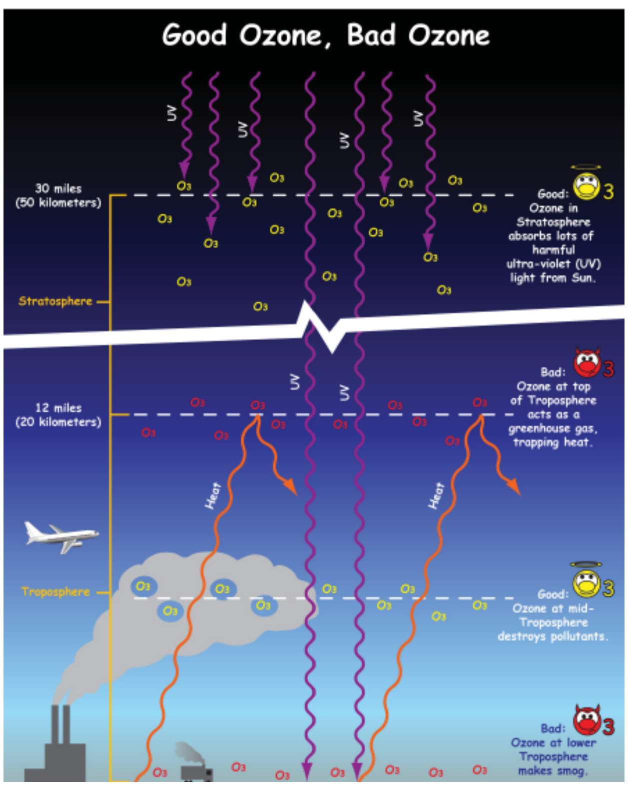
Evil-doer or Do-gooder: Getting the Goods on Ozone

Like the Dr. Jekyll and Mr. Hyde character of Robert Louis Stevenson's curious novel, ozone has two personalities. Sometimes it is the good guy, sometimes the bad.

Ozone is one of the gases in Earth's atmosphere. It is a cousin of the oxygen molecule on which we depend for life. The oxygen molecule is two oxygen atoms bound together. The ozone molecule is three. That extra atom makes a big difference. Although ozone can play "good" roles in the atmosphere, you don't want to breathe it!



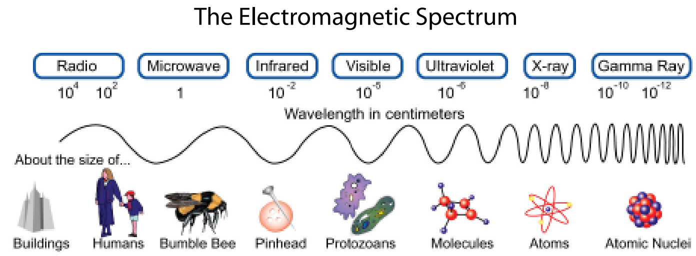
Ozone hangs out at different altitudes in the atmosphere. Whether it acts like Jekyll or Hyde depends on where it is.



Depending on the altitude where ozone resides in the atmosphere, it either plays helpful or harmful roles with respect to life at the surface.

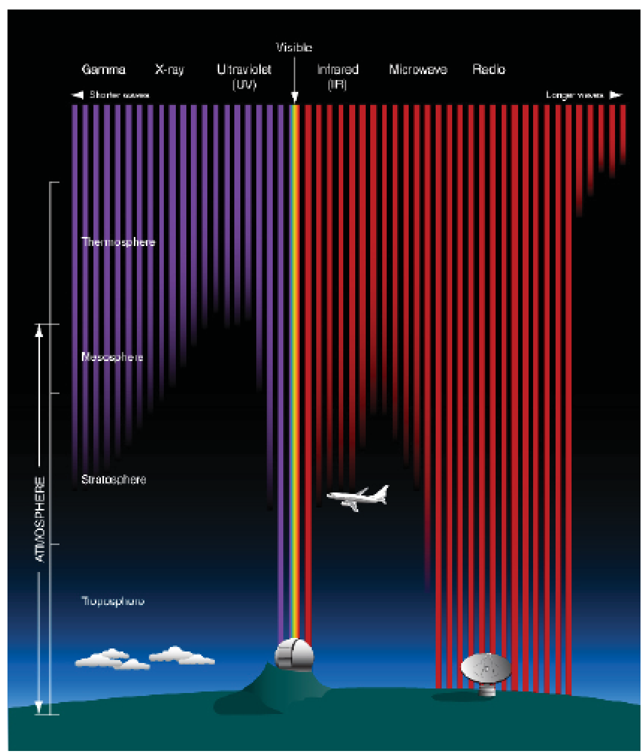
The "Parts" of Sunlight

Remember that light travels in waves. Different colors of light have different wavelengths. For example, red light waves are longer than blue light waves. White light is made up of all the wavelengths mixed together. Even light from the Sun or a light bulb contains many different wavelengths.



Ozone, the Good

Now, ozone in the stratosphere is good. By absorbing much of the ultraviolet (UV) portion of sunlight, it protects us and other living things from the bad things UV can do, such as cause skin cancer, cataracts (clouding of the lens inside the eye), damage to crops, and other problems.



Earth's atmosphere has "windows" that allow certain parts of the electromagnetic spectrum through, while absorbing, scattering, or reflecting other parts of the spectrum.

Ozone, the Bad

However, lower in the atmosphere, at the top of the troposphere (around 12 miles up), ozone acts like a greenhouse gas, trapping heat from Earth and preventing it from escaping into space. Up to a point this is okay, but too much ozone just adds fuel to the global warming fire.

More Ozone, the Good

You may be getting the idea that the way ozone behaves in the atmosphere is really complicated. You would be right. At mid-troposphere (around 4-7 miles high), ozone helps to clean pollutants out of the atmosphere.

More Ozone, the Bad (and Ugly)

Pollutants from cars and industry combine in sunlight to produce ozone down here where we breathe and grow crops. It doesn't take many ozone molecules mixed with the air to damage our lungs, our crops, and cause other problems.

Sorting it out

Atmospheric scientists want to better understand complicated ozone chemistry: how the (good) ozone layer in the stratosphere varies throughout the year and around the world; how the (bad) ozone concentrations vary in the lower troposphere over cities; where this ozone goes over time. Does it rise into the altitude where it helps clean up pollutants? Or does it rise to the altitude where it acts like a greenhouse gas?

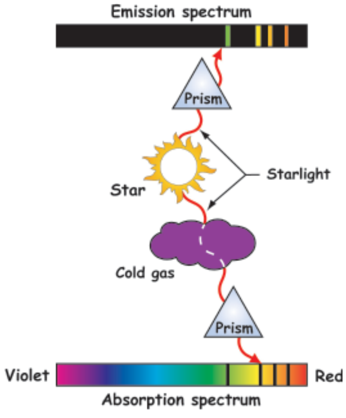
One of the instruments on NASA's Earth-observing Aura satellite is the Tropospheric Emission Spectrometer (TES). One of TES's main jobs is to create 3-D profiles of the ozone concentrations all over the world.

Just what is a spectrometer (spek-TROM-et-er)? A spectrometer is an instrument that uses light to identify the chemical composition of matter. A spectrometer can analyze any light to determine what elements are glowing or burning to produce the light. A spectrometer can also observe the light passing through a gas to determine what's in the gas.

How it Works

How does a spectrometer identify substances just by looking at light? Remember the electromagnetic spectrum shown earlier, with wavelengths ranging from tiny, high-energy gamma rays and x-rays through UV, visible, infrared, microwaves, and finally the long, low-energy radio waves.

Atoms and molecules in solids, liquids, or gases produce or change light in ways that are unique to each substance. When very hot, each substance emits a unique color of light of an exact wavelength. For example, hot sodium street lights are yellow and mercury athletic field lights are blue. When vaporized, or in the form of a gas, each absorbs that unique color of light, of an exact wavelength. In other words, every atom or molecule leaves a unique "fingerprint" as its spectrum.



The implications of this fact for technology are great! All we have to do is separate the light into its various colors and see what colors are especially bright (in the case of a light source), or what colors are missing (in the case of light that has passed through a gas).

A spectrometer (or spectroscope) can do just that. Emission spectrometers analyze the spectrum of light emitted from some source, and absorption spectrometers look for missing, or absorbed colors in the spectrum of light that has passed through a gas or vapor.

Make Your Own Spectroscope

It's easy to make your own spectroscope* and observe the different spectra emitted by different types of light. With blank (or unwanted) CDs and DVDs almost as cheap and plentiful as paper plates, they make ideal *diffraction gratings* for your spectroscope. A diffraction grating works similarly to a prism, splitting the light into its component wavelengths.

A DVD will give you a higher resolution instrument, splitting the light into 1350 spectral lines per mm. A CD will give you 625 lines per mm.

Tools You Will Need:

Box, X-acto® or matte knife
Straight edge
Ballpoint pen (preferably dry, to score fold-lines)

Materials:

Poster or paperboard, matte black on both sides, 8-1/2" x 11", 2 pieces
Matte black construction paper, 8-1/2" x 11", 1 piece
Tacky Glue, or quick drying Tacky Glue
Transparent tape
One DVD and /or one CD
Panels for lens-slit:
One obsolete credit card or *opaque* plastic container lid (such as from a coffee can or soft butter tub), cut into two 10 x 30-mm panels. (If the plastic is not completely opaque, blacken one side with a marker pen.)

Construction:

A pattern for the spectroscope body, view shade and disk mask can be downloaded from **http://spaceplace.nasa.gov/en/educators/spectroscope.pdf**. Otherwise, either redraw or enlarge the pattern drawings here. It is important that the 100-mm-scale (a tad under 4 in.) on your printed pattern be accurate. There will also be a construction paper viewing tube, for which you do not need a pattern.

Glue just the corners of the pattern pages to the poster board (for the body) and construction paper (for the view shade and disk mask). Score all dashed fold-lines with the ballpoint pen. Carefully cut the openings for disk slots, view-windows, and lens-slit.

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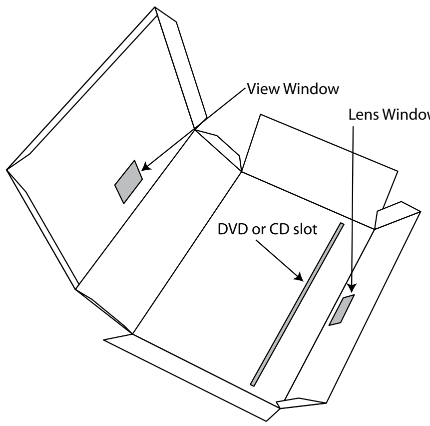
* This design is adapted from "A DVD Spectroscope: A Simple, High-Resolution Classroom Spectroscope," by Fumitaka Wakabayashi and Kiyohito Hamada, *Journal of Chemical Education*, Vol. 83 No. 1, January 2006.

Cut the perimeter lines. Fold up or down on scored lines, per drawing, and then crease them.

Assembly:

1. Install the lens slit in the spectroscope body:

Place the body piece so all folds are upward (this is the inside of the body).



At the lens slit window, glue one slit panel (opaque plastic piece or credit card half) in place to cover half the lens slit window. Use a little piece of poster board as a spacer for the slit, and glue the second slit panel to cover the other half of the window. The slit should be 0.5 mm wide.

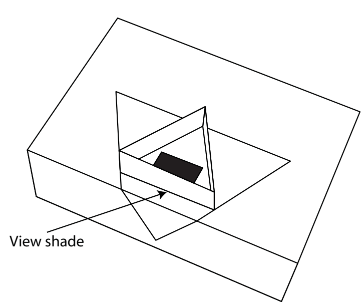
When glue is dry, remove the spacer. To further secure the slit panels, use transparent tape on their outer edges. Avoid covering the open slit.

2. Fold and glue body:

Apply glue to tabs on the side indicated, and then press them in place, one at a time.

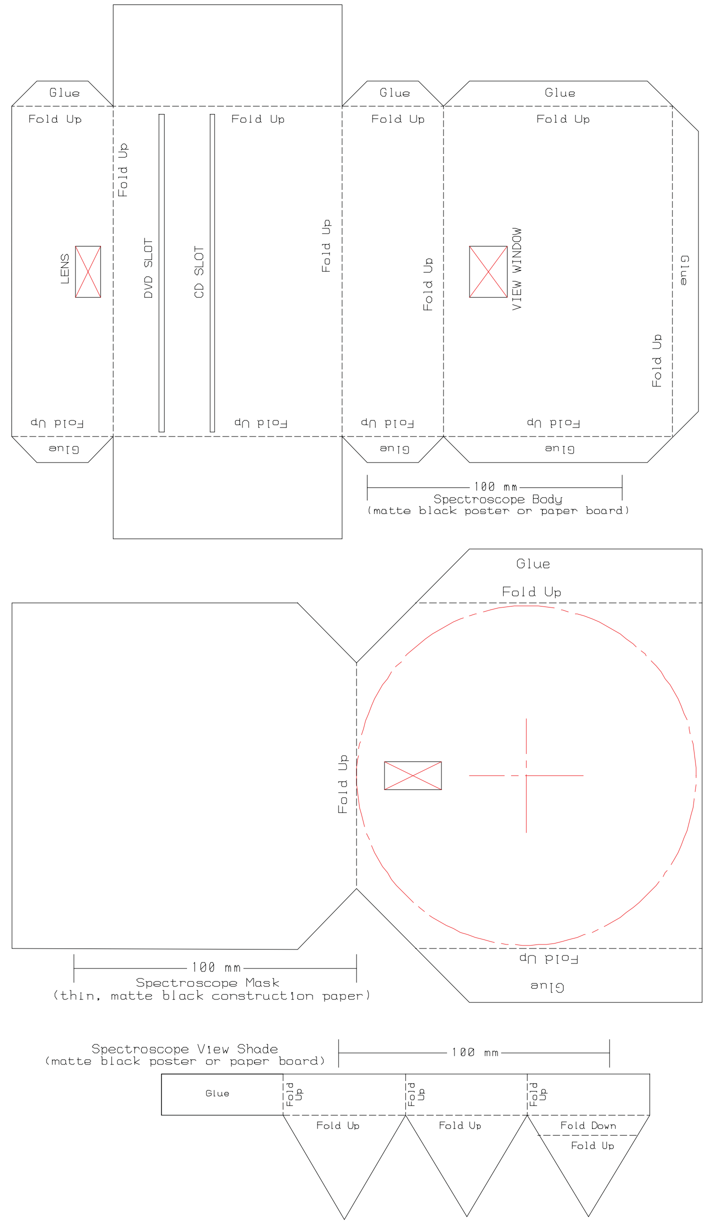
3. Assemble and install view shade:

Fold it to shape, then apply glue to the end strip and press it in place. When dry, glue it onto the spectroscope body so that the view window is centered within the walls of the triangular shade.



4. Make and install viewing tube:

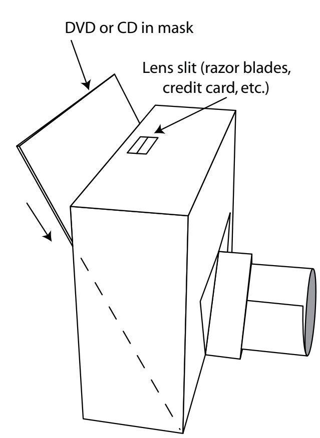
Cut a piece of black construction paper to 50 x 200 mm (2” x 8”). Roll it snugly into a cylinder 50 mm long and about 20 mm (0.8”) in diameter. Place the cylinder into the view shade and let it uncoil in place.



Scaled patterns for spectroscope. Either scale these up, or download full-scale patterns from spaceplace.nasa.gov/en/educators/spectroscope.pdf.

5. Assemble disk mask:

Fold the scored lines per the pattern, then crease them. Apply glue to tabs, fold, and press in place.



Operation:

Place a DVD or CD disk in the mask, with the unlabeled side toward the mask window.

On the spectroscope body, select the upper slot for a DVD, the lower one for a CD. With window side up, insert the masked disk downward through that slot, snugly into the lower front corner edge.

Point the slit toward a light source. Look through the viewing tube to see the spectral lines. The viewing tube prevents distortions from light entering view window. Look at the spectra from different sources of light, such as fluorescent light, incandescent light, LED light, candlelight, etc. Take the spectroscope outside and look at the sky. You may be able to see black absorption lines. These are called Fraunhofer lines. They can be caused by either absorption of certain wavelengths of light by cool gas in the atmosphere or by gases in the Sun.

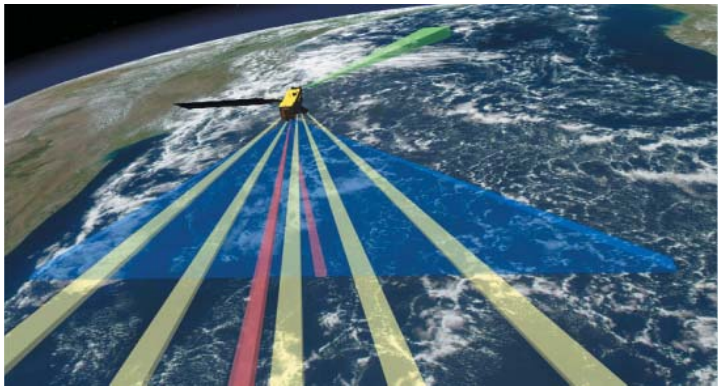
You can use a camera to make spectrographic photos. Remove the viewing tube and place the camera close to the view window. You may also be able to connect a digital camera to a computer to display the spectrum on the computer screen for everyone to view at once.

Back to the Ozone

The Tropospheric Emission Spectrometer (TES) senses infrared light. We don't see infrared light, but we do feel it as heat. As sunlight warms Earth's surface, Earth radiates the energy back toward space as infrared light. TES separates the infrared light into a very finely resolved (highly detailed) spectrum. The spectrum shows the particular "fingerprints" of ozone at different altitudes. Remember, if you are an ozone molecule (or anything else!) the higher you go, the less air is above you, so the less air pressure you will experience. TES is so sensitive, it can detect the very tiny differences in the fingerprint wavelengths of ozone that reside at different atmospheric pressures and different temperatures. Vertical temperature variations are not so straightforward as pressure variations, but they are known.

The Aura satellite carrying TES orbits near Earth's poles. As Earth rotates beneath TES, the instrument passes over each point on Earth at the same local time each day. This kind of orbit is called a sun-synchronous orbit. TES points straight down, so it can detect the concentrations of ozone at different levels in the atmosphere all the way to the ground. It also looks sideways at an angle through the atmosphere, which gives an even better reading of the ozone layers, but does not "see' all the way to the ground.

TES also measures other gases pertinent to global warming and air pollution, including carbon monoxide, methane, and water vapor. In a research mode, TES has also measured methanol, ammonia, and carbon dioxide. The information TES provides will help us make choices based on sound science, to the benefit of our country and the world.



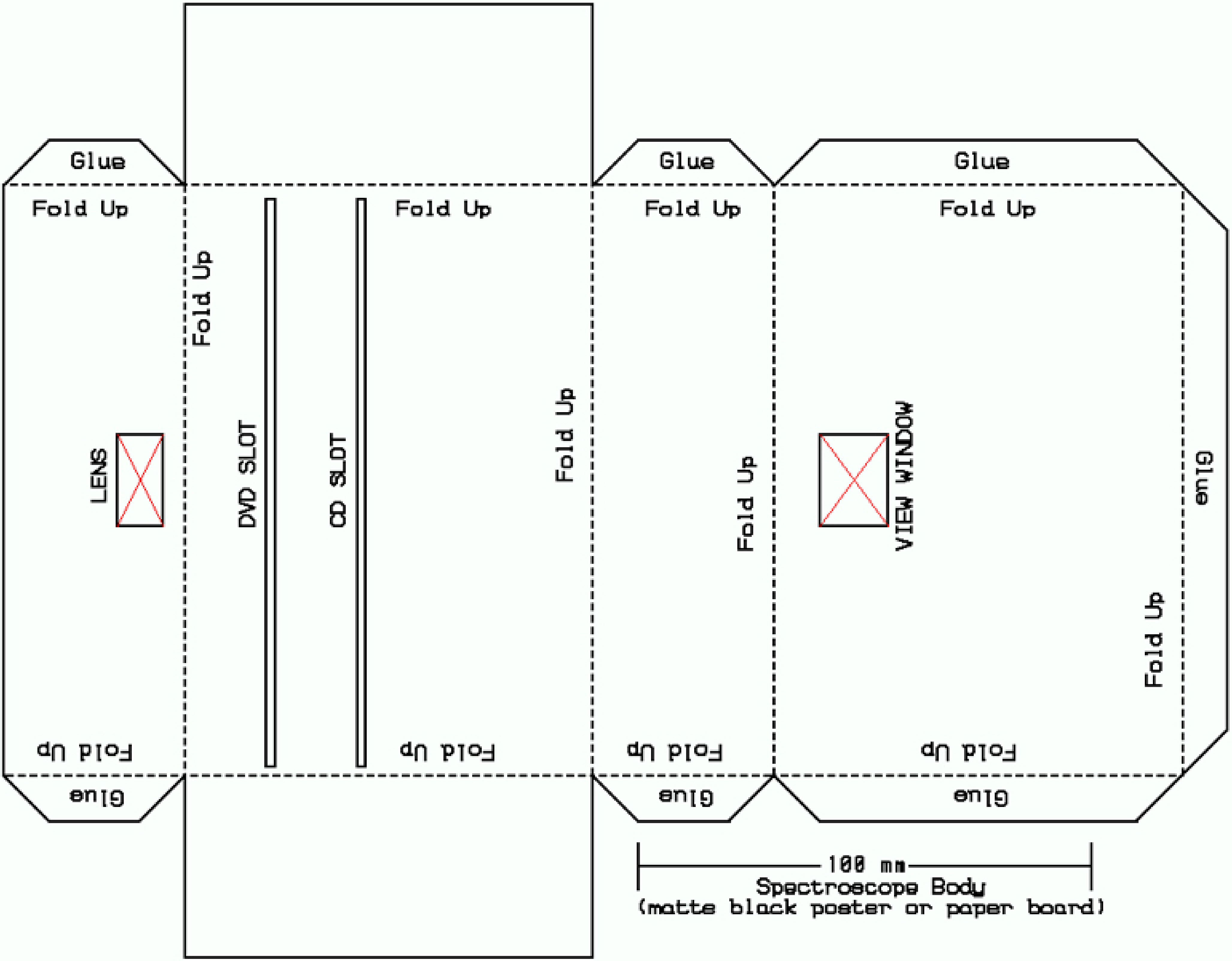
In this artist's rendering of the Aura spacecraft, the fields of view for TES are shown in red.

Discussion Questions

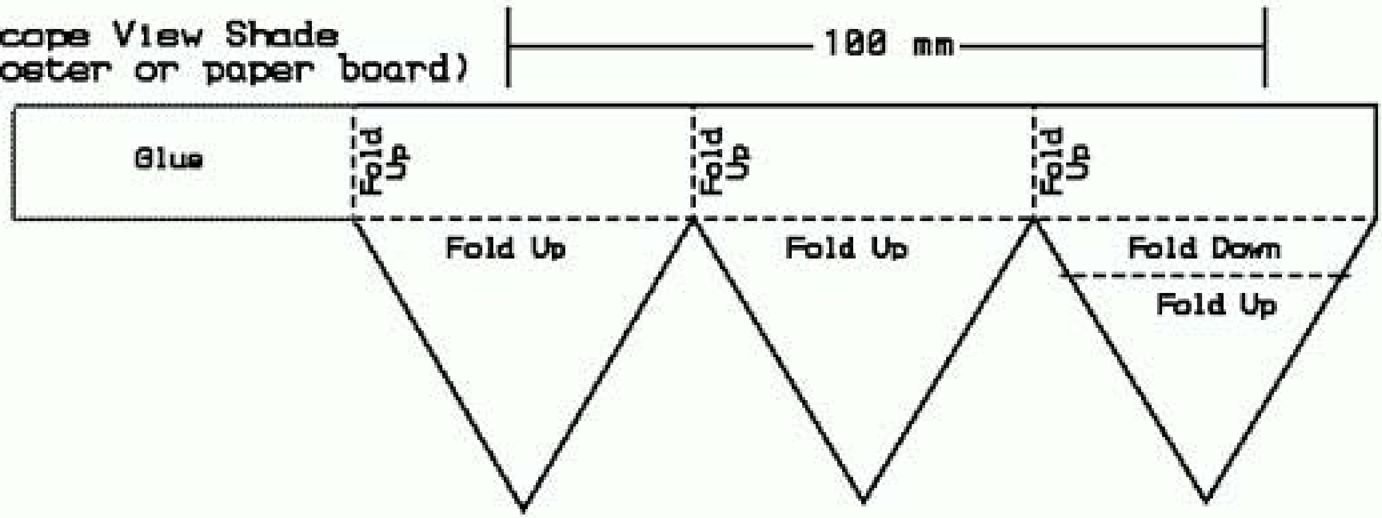
1. Why is it important for the TES instrument to be able to distinguish between ozone in the stratosphere and ozone near Earth's surface?
2. Why should we care if there is a big "hole in the ozone"?
3. What is the difference between emission spectroscopy and absorption spectroscopy?
4. Why do some of the spectra you see in the spectroscope have bright lines in certain colors?

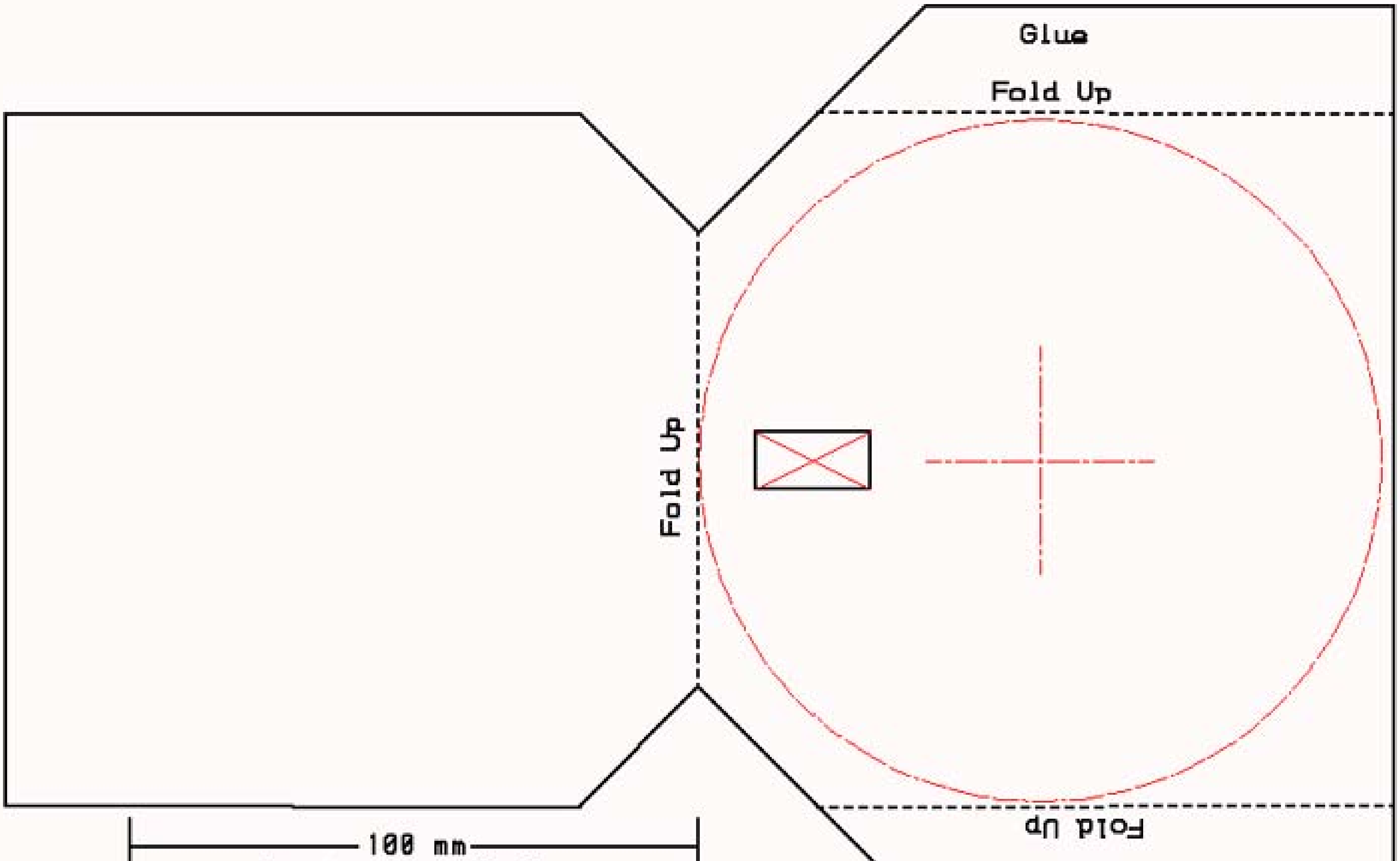
You can find out more about greenhouse gases and make your own greenhouse gas molecules out of gumdrops at http://spaceplace.nasa.gov/en/kids/tes/gumdrops.

This article was written by Diane K. Fisher, writer and designer of The Space Place at ***spaceplace.nasa.gov****. Alexander Novati did the illustrations. Spectroscope design help came from Mr. Gene Schugart, a consultant in educational product development. The article was provided through the courtesy of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, under a contract with the National Aeronautics and Space Administration.*


Glue
Fold Up
LENS
DVD SLOT
CD SLOT
VIEW WINDOW
100 mm
Spectroscope Body
(matte black poster or paper board)

Spectroscope View Shade
(matte black poster or paper board)





Spectroscope Mask
(thin, matte black construction paper)