Drive-by Science

A series of quick activities for
informal science events

Why is the sky blue, why are sunsets orange, and what color is the Sun?

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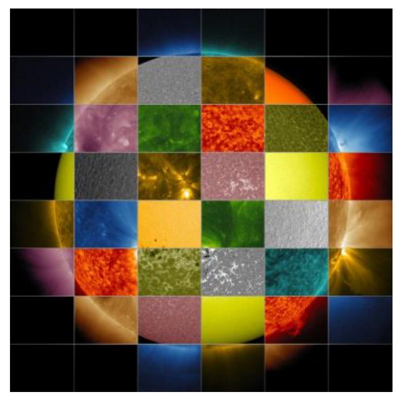
Introduction



In this activity, participants will explore questions such as "What color is the Sun", "Why is the sky blue?", "Why are sunsets orange", and "Why are oceans and lakes blue?".

The activity includes a demonstration to show why the sky is blue and why sunsets and sunrises are orange. Participants will address any misconceptions they had, and go away contemplating further challenges.

Target Audience:	**Materials Needed:**	**Activity Time:**
• Informal science events • Visits to NASA centers • Other public events where time is limited	• Clear plastic or glass container that can hold water • Water • Milk, powdered cream, cedar oil, or isopropyl alcohol • Copies of the imagery provided • Pinhole camera or 2 sheets of white paper plus a nail (*optional*)	~15 minutes **Age Group:** Age 8 to adult

Learner Goals:

- Participants will learn that the Sun appears white to human eyes, but white color is composed of all the colors of the rainbow.
- Participants will learn why the Sun appears orange at sunrise and sunset.
- Participants will learn why the sky is blue.
- If there is time, participants will learn why oceans and lakes appear blue
- Participants will be encouraged to address misconceptions and to investigate for themselves.

Process:

1. Set up your materials on a table at the start of the science event. Set up some signs that advertise your activities (some provided).

2. Begin by asking participants what color they think the Sun is. Accept all answers. Hopefully, there will be more than one suggested color.

3. Ask participants to be scientists and suggest ways to investigate how they might determine the color of the Sun. They might come up with ideas such as these:
   - Glance up at the Sun in the middle of the day. (Do **not** stare and **never, ever look at the Sun through a telescope or binoculars without the proper filters**!)
   - Observe what color the clouds are, or the Moon, since both shine by light from the Sun.
   - Collect photographs taken of the Sun, both from Earth and from space.
   - Observe sunlight reflecting off the walls of a white building, or a piece of white paper.
   - Project an image of the Sun through a pinhole camera or a SunSpotter™ telescope.
   - Look at some pictures of the analemma, which show the Sun at the same time of day throughout a year.
   - Look at images of the Sun taken by observatories both on the ground and in space.
   - Observe the Sun's corona (atmosphere) during a total solar eclipse.
   - Google the question.
   - Ask a scientist (though scientists are often subject to the same misconceptions that other people are).
   - *… and so on*

4. Have participants investigate, perhaps by looking at the Sun projected through a pinhole camera to determine the color of the Sun. If your time is very limited, or the Sun is not out, or you are inside, you can provide the set of sample data following. Hopefully, the participants will determine that the Sun is intrinsically white.

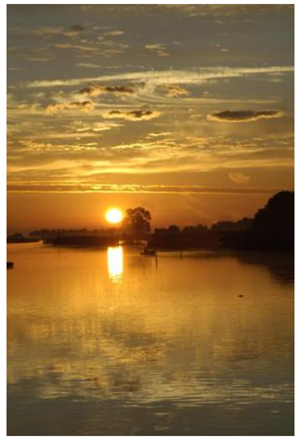
5. Now explain that you are going to demonstrate or model (using a jar of water, milk, and a flashlight) how the sky is blue and the sunset orange. The demo is described below.

6. To understand the blue sky-orange sunset phenomenon and model, participants should be familiar with the concept that light can be thought of as waves. It is the Sun's light (waves) trying to get through Earth's atmosphere that causes the blue sky and orange sunsets. To help participants understand, use discussion and the imagery we have provided.

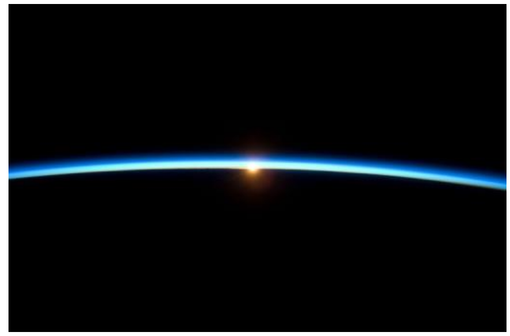
7. If there is time, ask the participants why they think the ocean is blue, or why a lunar eclipse looks red. We've included signs to help them understand. Or, allow participants to further explore these questions on their own.

Sample data for investigating the color of the Sun

Sunrise



Sunset



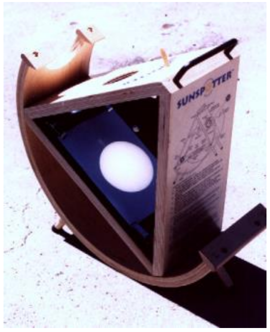
Sunrise seen through Earth's atmosphere

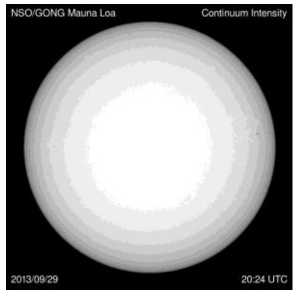
Sun at mid-day

Sun from space shuttle

Total solar eclipse

Sun from ISS

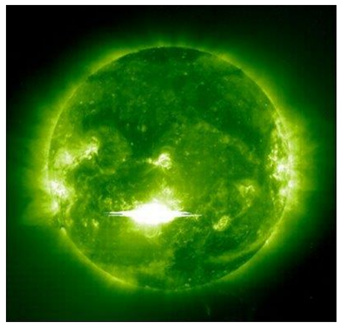

SunSpotter™ image

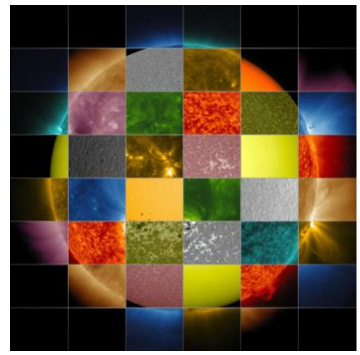


Solar image in visible light from GONG, a ground-based telescope


Projected image of Sun


Solar image taken in EUV from SDO/AIA


ESA/NASA SOHO, image taken in EUV


NASA SDO, images taken in several wavelengths

Analemma

Blue sky, orange sunset demo

Materials Needed:

Clear plastic or glass container (can be spherical or box-shaped

Water

Strong flashlight

Milk or powdered creamer (cedar oil or isopropyl alcohol can also be used)

Process:

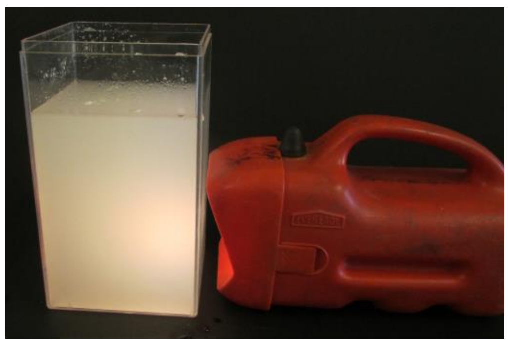
1. Fill the container with water. This will simulate a small amount of clear atmosphere. Shine a strong (white light) flashlight through it. The image should exit the water as white.

Hence, with a small amount of clear water, all the wavelengths making up white light pass straight through, and no separation of color is observed.

2. Add a small amount of milk or powdered cream to your water and stir until dissolved. This will simulate the molecules in the Earth's atmosphere.

← Now, when white light is passed through the suspension, the light is observed to be yellow-orange.

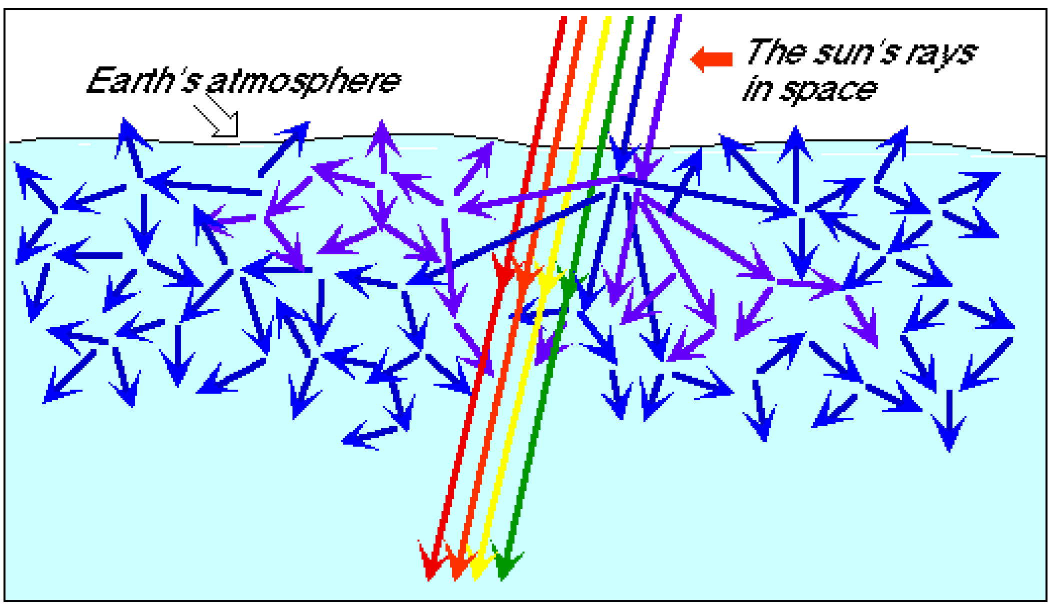
Light of a blue color → is observed to come from the side of the container. *Photo doesn't accurately depict the blue.*



The scattered blue light models the Earth's sky, where short wavelength blue colors have been scattered by air molecules (oxygen and nitrogen, primarily). This is called Rayleigh scattering.

The orange color models sunrises and sunsets, when sunlight must travel a much greater distance through the atmosphere than when the Sun is overhead. This results in a greater amount of scattering which removes more and more of the shorter-wavelength colors, leaving reds, oranges, and yellows.

For the setting or rising Sun to be red, small foreign particles must be present in the atmosphere to scatter light along with the atmospheric molecules. This frequently happens during times of fire or volcanic eruptions.



Blue light being scattered by Earth's atmosphere

For more, see:
http://www.physicscurriculum.com/light.htm
https://www.youtube.com/watch?v=gUgDtWANJ18
http://www.esrl.noaa.gov/gmd/grad/about/redsky/

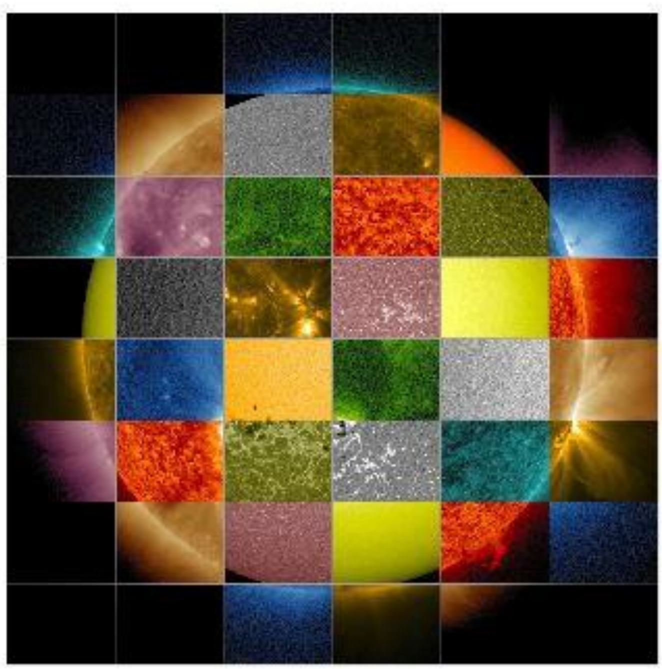
Potentially useful signs and imagery

Following is a collection of imagery that you might find useful. Some presenters have the question on the front of the paper, and then people must turn it over to find the answer. Or the signs can be used a discussion-starters. Or ????

Our collection includes:

- What Color is the Sun?
- Light as waves
- Why is the sky blue?
- Why is the sunset orange?
- Why is the ocean blue?
- Why does a lunar eclipse look reddish?

What color is the Sun?



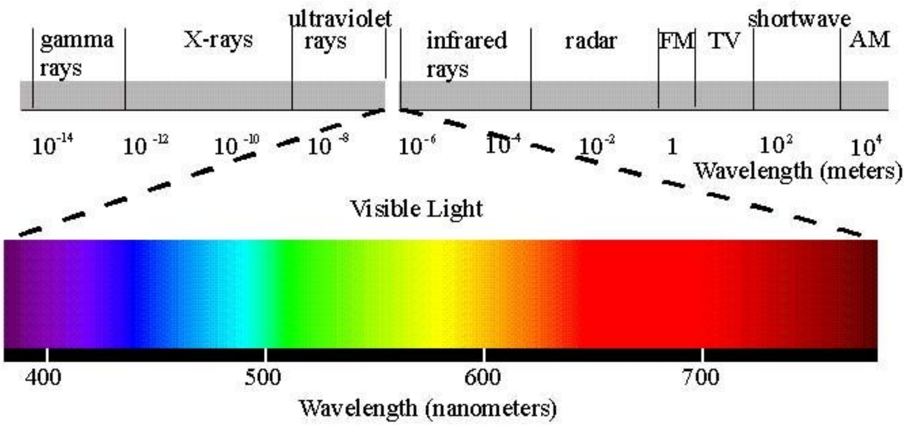
White light-- that is, sunlight -- is made up of all the colors of the rainbow.

Our eyes see this as white!

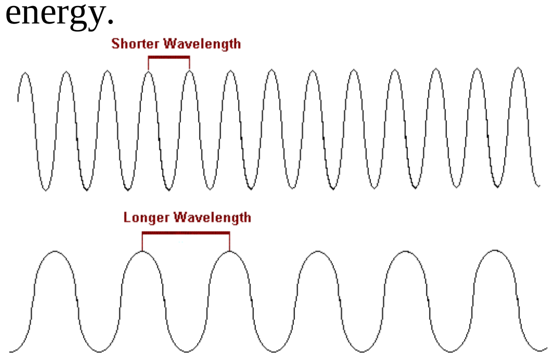
So, the Sun is white!

Light as Waves

Light is a form of energy. All forms of light are part of the same phenomena: the electromagnetic spectrum. Our eyes can detect only a small amount of this energy, that portion we call "visible light." Radio waves, X-rays, microwaves, gamma rays, and the rest all have longer or shorter wavelengths than visible light, but otherwise are the same phenomena.



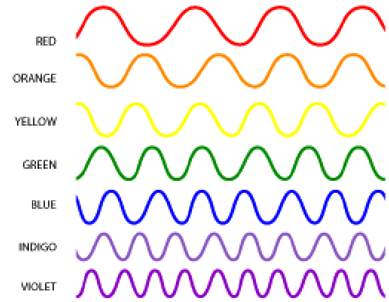
All forms of electromagnetic radiation make characteristic patterns as they travel through space. Each wave has a certain shape and length. The distance between peaks (high points) is called wavelength. The shorter the wavelength, the greater the energy in the smallest possible “chunk” (i.e. photon) of light at that wavelength. The longer the wavelength, the lower the energy.



The colors in our sky come from the Sun. The Sun’s light is white, but sometimes the colors can be separated out, as in a rainbow. To help understand this, light can be thought of as waves.

Colors have wavelengths. Just like waves at the beach[1] can be large or small, different colors have different wavelengths that can be large or small -- or anything in between.

[1] Ocean waves are a good way to describe light waves to younger children. However, the analogy is not complete.



short wavelength ←-- long wavelength

Like these big waves, the colors **red** and **orange** have long wavelengths.

Like these small waves, the colors **blue** and violet have short wavelengths.

When little ocean waves hit big rocks, they get scattered in all directions.

When big waves hit these same rocks, they roll right over them!

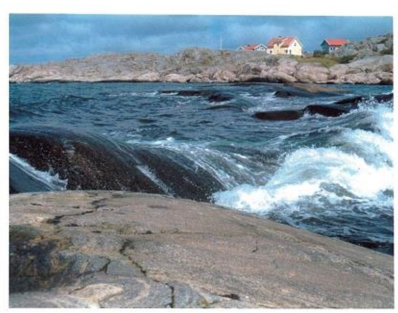
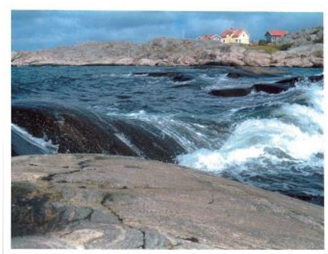


Image from http://andreasrossevold.blogspot.com/2012/01/why-is-sky-blue.html

Our Blue Sky

When sunlight hits the Earth's atmosphere, the air molecules act similarly to the rocks with the ocean waves.

When the Sun is high in the sky, some of the short wavelength light (blue & violet) gets scattered out by the air molecules, like the small ocean waves, leaving blue light bouncing around in the upper atmosphere.



The other colors have long enough wavelengths that they slide past the molecules in our air and reach the ground.

Hence our sky appears blue!

(Though violet is even a shorter wavelength than blue, are eyes are not very sensitive to violet light, so the blue overwhelms it.)

See also http://andreasrossevold.blogspot.com/2012/01/why-is-sky-blue.html

Our orange sunrises and sunsets

The sunset is orange for a similar reason to why the sky is blue.

White sunlight at mid-day goes through very little atmosphere (about 30 km), hence most colors (other than some of the blue and violet) get through and the Sun looks white.

However, at sunrise or sunset, sunlight must go through a great deal of the Earth's atmosphere (about 320 km). Many of the colors are scattered away and mostly the red, orange, and yellow (long wavelengths) get through.

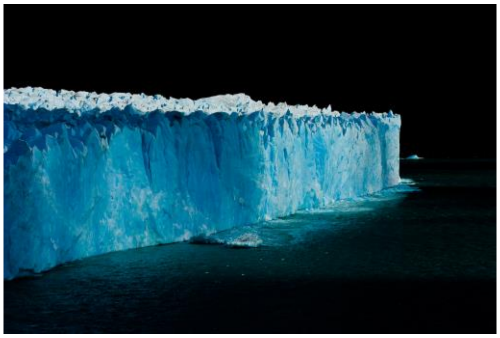
Why is the ocean blue?

Why is water blue?

While relatively small quantities of water appear to be colorless, water's tint becomes a deeper blue as the thickness of the observed sample increases. The blue hue of water is an intrinsic property and is caused by selective absorption and scattering of white light and the absorption of reddish wavelengths. Impurities dissolved or suspended in water may give water different colored appearances.

The blue color of water may be seen with the naked eye by looking through a long tube filled with purified water. In the image to the right, a 3 m long by 4 cm diameter aluminum tube was used, with a Plexiglass™ window expoxied to the ends of the tube.

The color of water can also be seen in snow and ice as an intense blue color scattered back from deep holes in fresh snow. Blue to blue-green hues are also scattered back when light deeply penetrates frozen waterfalls and glaciers.



This, and more information, written by Charles L. Braun and Sergei N. Smirnov, is available at: http://www.dartmouth.edu/~etrnsfer/water.htm

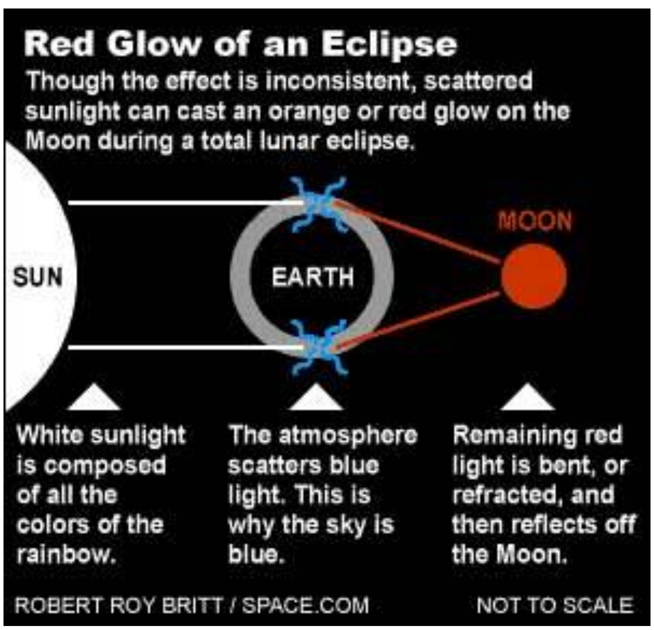
Water images from Braun & Smirnow

Although when you pour water into a glass, it looks clear -- water is actually blue, when you look through enough of it!

So the ocean and lakes are inherently BLUE! That color can be affected by the depth of the water, algae, pollution, runoff from agriculture or a storm, or reflections from the sky.

Why does a lunar eclipse look red?

The Moon turns red during a lunar eclipse for similar reasons to why sunrises and sunsets are orange and red – light gets refracted (bent and scattered) through Earth's atmosphere!



The Earth is larger than the Sun in the sky as seen from the Moon, so it blocks all direct sunlight from hitting the Moon during a lunar eclipse. But, since we have an atmosphere, some sunlight just grazes the Earth, is bent through our atmosphere, and ends up hitting the Moon. Our atmosphere scatters blue light more effectively than red light, so some of the same long-wavelength red light that you see at sunrise or sunset continues on into space and colors the Moon.