Investigating Icy Worlds
From Exploring Ice in the Solar System

Photometry and Spectroscopy

Background understanding needed to complete this module:

- Students should have had an introduction to the electromagnetic spectrum and the concepts of wavelength and frequency.
- The electromagnetic spectrum encompasses a continuous range of frequencies or wavelengths of electromagnetic radiation.
- The electromagnetic spectrum is traditionally divided into regions of radio waves, microwaves, infrared radiation, visible light, ultraviolet rays, X-rays, and gamma rays.
- Electromagnetic radiation from space is unable to reach the surface of the Earth except at a very few wavelengths, such as the visible spectrum, radio frequencies, and some ultraviolet wavelengths.
- Wavelengths in the electromagnetic spectrum vary in size from very long radio waves, the size of buildings, to very short gamma-rays, smaller than the size of the nucleus of an atom.

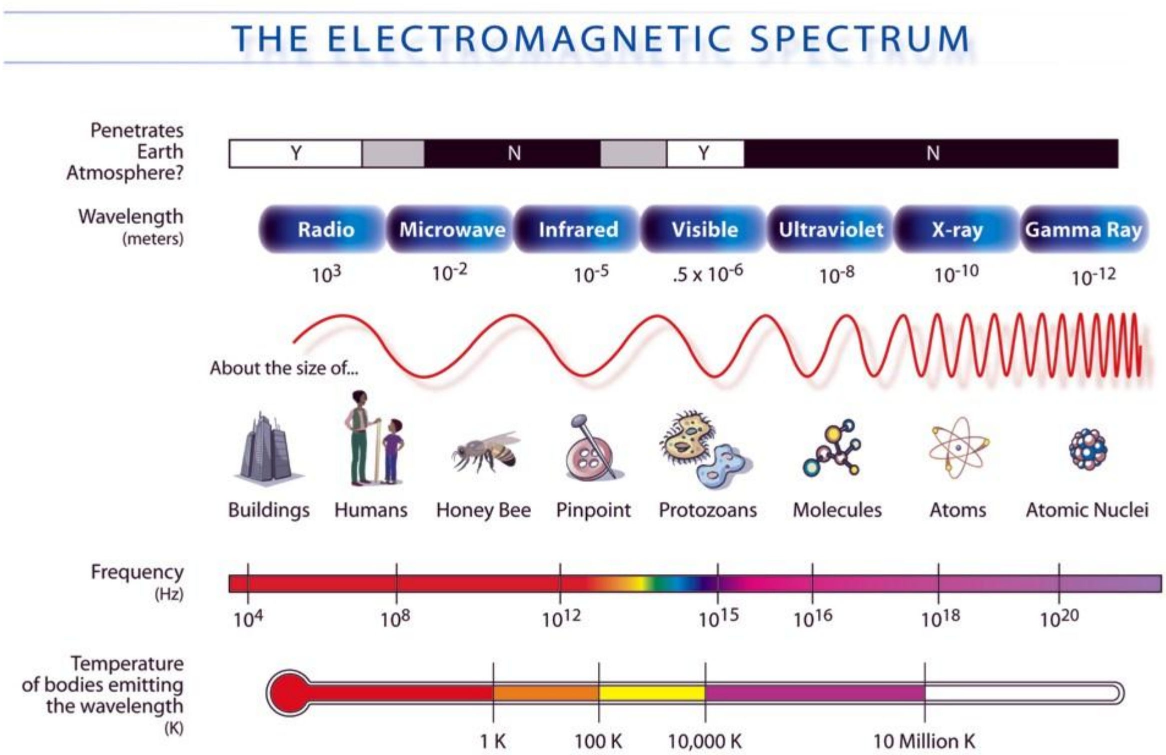


Image credit: http://mynasadata.larc.nasa.gov/ElectroMag.html

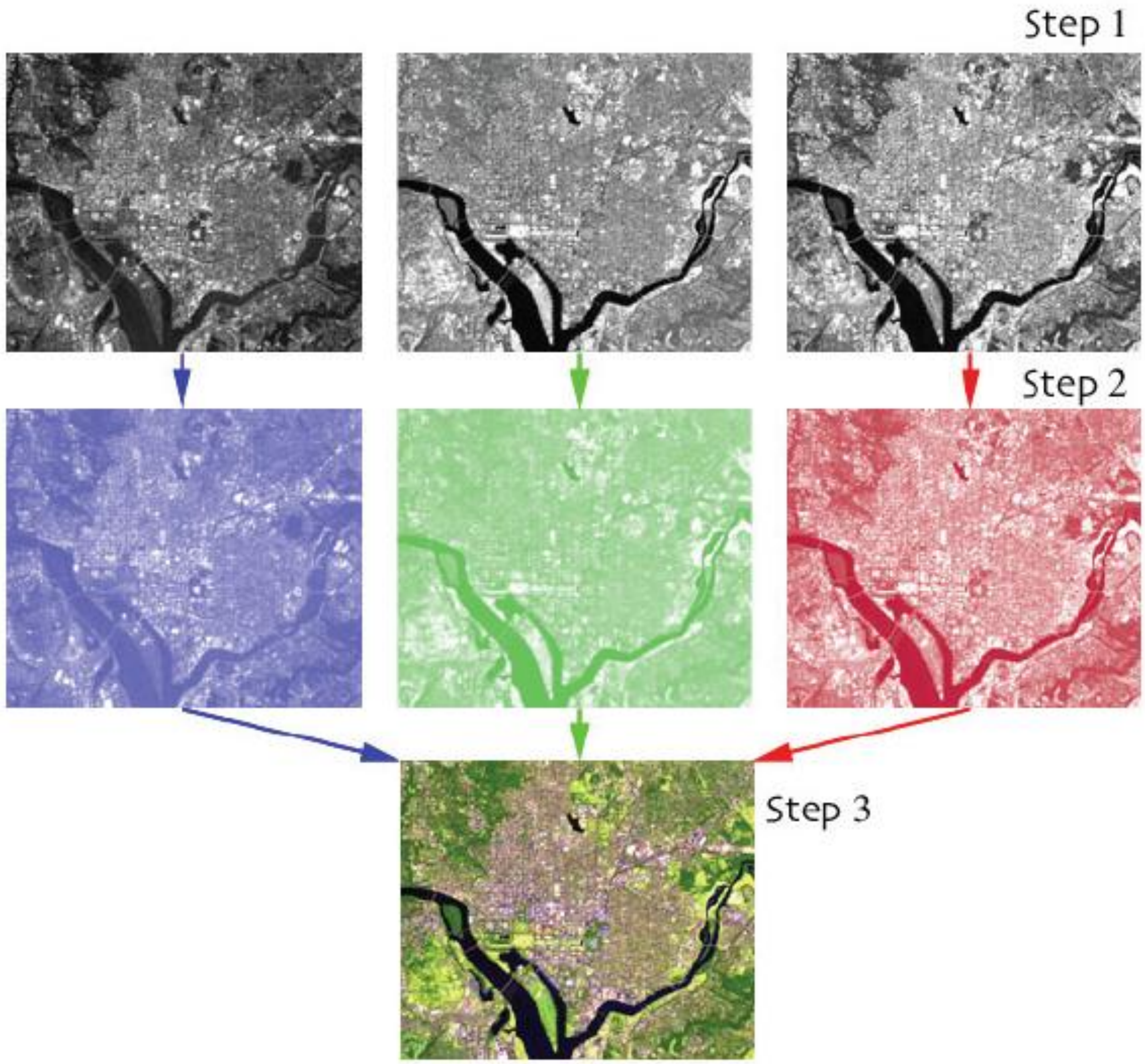
Light photometry is the art and science of extracting information from light. The Earth receives incidents light (sunlight) from the Sun. Objects such as planets, moons, clouds, ice, and water absorb and reflect different amounts of light. The ratio of the amount of reflected light compared to the sunlight is called **albedo**. Albedo values range from 0.0 (completely dark, the material reflects no light) to 1.0 (very bright, the material reflects all light). The higher the albedo of an object or a material, the more light it reflects (and the less light it absorbs). For example, the planet Earth has an albedo of 0.38, which means that Earth reflects 38% of the sunlight it receives back out into space.

Spectroscopy is a technique that measures how much of a particular wavelength of light is emitted (or "given off") by an object each second. Stars emit light; planetary objects reflect light. Since different elements and compounds absorb or emit light in characteristic patterns, scientists can use these patterns to tell what the surface of an object is made of. Scientists use spectrometer to observe these patterns over a very wide range of wavelengths, from gamma rays and X-rays into the far infrared.

Charge-coupled devices (CCD), used with spectrometers, are sensitive digital instruments used to observe objects in greater detail, by changing light into charged signals that read as pixels. These pixels are the photometric data that scientists examine to infer what the surface looks like and what the object is made of.

NASA uses **remote-sensing satellites** to learn more about the planets in our Solar System. These satellites are able to provide a global view of a planet, whereas a lander or a rover is only able to gather data in its immediate area. Unlike a lander or a rover, a satellite cannot pick up surface material to analyze. Instead, satellites use different band (wavelengths of light) to aid scientists in determining compositions. The images collected have different contrast (light and dark) areas. With the use of computers, it is possible to assign "false color" to the black and white images taken by the satellite. The three primary colors of light are red, green, and blue.

The following figure, from NASA's Landsat Program, is an example of how a color image is created. The image was taken in three different bands, each band is a different primary color, then combine to create a "false color image".



Earth-observing satellites collect data on our oceans, ice caps, continents, weather, and even the chemical make up of our atmosphere. Depending on what an instrument on the satellite is measuring, the data may be collected by looking straight down at the surface, or off on an angle. By collecting data over long periods of time, scientists are able to look for patterns, more easily make predictions, and sometimes even observe drastic changes that may occur on or above the Earth over time.

Standards

BENCHMARKS:
Grades 6-8
4B The Earth

- The benefits of the Earth's resources-such as fresh water, air, soil, and trees-can be reduced by using them wastefully or by deliberately or inadvertently destroying them. The atmosphere and the oceans have a limited capacity to absorb wastes and recycle materials naturally. Cleaning up polluted air, water, or soil or restoring depleted soil, forests, or fishing grounds can be very difficult and costly.
- The Earth is mostly rock. Three-fourths of its surface is covered by a relatively thin layer of water (some of it frozen), and the entire planet is surrounded by a relatively thin blanket of air. It is the only body in the solar system that appears able to support life. The other planets have compositions and conditions very different from the Earth's.
- Because the Earth turns daily on an axis that is tilted relative to the plane of the Earth's yearly orbit around the Sun, sunlight falls more intensely on different parts of the Earth during the year. The difference in heating of the Earth's surface produces the planet's seasons and weather patterns.
- Climates have sometimes changed abruptly in the past as a result of changes in the Earth's crust, such as volcanic eruptions or impacts of huge rocks from space. Even relatively small changes in atmospheric or ocean content can have widespread effects on climate if the change lasts long enough.
- The cycling of water in and out of the atmosphere plays an important role in determining climatic patterns. Water evaporates from the surface of the Earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the ocean.

4C Processes that Shape the Earth

- Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the Earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms.

4D Structure of Matter

- All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.

4F Motion

- 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.
- Something can be "seen" when light waves emitted or reflected by it enter the eye—just as something can be "heard" when sound waves from it enter the ear.

NSES:
Grades 5-8
CONTENT STANDARD A: Science as an Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard D: Earth and Space Science

- Understanding of Structure of the Earth system
- Understanding of Earth's history
- Understanding of Earth in the Solar System

Resources:

- Electromagnetic Spectrum: http://science.hq.nasa.gov/kids/imagers/ems/index.html
- Imagine the Universe, EM write-up http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html
- What is Ultraviolet Light?: http://solar-center.stanford.edu/activities/uv.html
- What's the frequency, Roy G. Biv?: http://imagine.gsfc.nasa.gov/docs/teachers/lessons/roygbiv/roygbiv_cover.html
- Content modified from *Exploring Ice in the Solar System,* Chapter 11: *Investigating Icy Worlds*: http://www.messenger-education.org/teachers/MEMS_CompPlanetology.php

Photometry Activity

Modification of *Exploring Ice in the Solar System*, Chapter 11: *Investigating Icy Worlds*: http://www.messenger-education.org/teachers/MEMS_CompPlanetology.php

MATERIAL:

Light Sources

For each group of six students:

- 4 Flashlights:
  - Red light or red vellum paper in front of the flashlight.
  - Blue light or blue vellum paper in front of the flashlight.
  - Green light or Green vellum paper in front of the flashlight.
  - White light flashlight.
- Laser
- Mid-wave UV lamp

Containers:

- Possible types of containers. A **minimum of 3 containers is needed.**
  - Aluminum deep steam table pans (1/3 to 1/2 size pans work well for ice and liquids)
  - Aluminum trays (quarter-sheet-cake trays work well)
  - Round aluminum cake pans or 8"x8" brownie pans work for small freezers

Investigation Material

You will need to freeze the containers with
Choose one type of material from each column for a total of at least three different objects that will be investigated.

Pan 1:

Add water and a couple of handfuls of ice cubes to the water. Place in the freezer. Some of the ice will melt before the entire pan becomes frozen.

Pan 2:

Add water to a pan. Before putting in the freezer, add about 7 dime size pieces of white paper towels or paper. Push them to the bottom. Another option is to use clear decorative marbles/rocks

Pan 3:

Add water to a pan, next place in the freezer. Before setting out the pan of ice, sprinkle a thin layer of one of the following:

- Coca*
- Chocolate Milk*

- Baby powder
- Dirt
- Sand *
- Flour *
- Cake mix
  *A sifter works well for creating a think layer.

Extras Pans – Optional:

- When the ice is partially frozen break it up and add either a little water with food coloring or juice to provide some color
- Instead of water, place Tonic Water in the pan and freeze.

PREPARATION

Assure that students have an understanding about light sources

Set out at least four different pans of material to be investigated by the entire class. Students will be viewing the pans as a satellite would. Choose one of the pans containing solid material. Holding the pan up and tilt it forward slightly so that everyone can see inside it. Ask that students to imagine that the material inside pan is the surface of the Earth, as seen through a telescope viewfinder. You might have students cup their hands together as if they were looking through a telescope. Questions to ask the students:

Why is the pan visible?
Where is the light source?
In the Solar System, where does light come from?

Remind students that there are wavelengths of light that our eyes cannot see, such as infrared, ultraviolet, gamma-rays, X-rays, and radio waves. Some satellite instruments are able to collect light from these other wavelengths.

Students will gain a better understanding of how scientists use different wavelengths of light to determine the compositions of unknown materials in the following hands-on activity. This activity will be presented as a ‘think, pair, share, activity’. Students will practice making observations, interpreting their data, and supporting their interpretations with the evidence. To do this, they will use different colored flashlights to investigate a variety of materials you would find on the Earth.

PROCEDURES

This lesson is a *think-pair-share* activity. Using remote sensing techniques (i.e. looking at different angles and without touching the pans or the materials within them), each student will make observations and take measurements of four pans containing different materials.

Remind students not to look at the laser and UV flashlight directly or shine it in another persons’ eyes. Take a few minutes distribute the different colored flashlight (red, white, yellow, blue, laser, UV) to the students. The students will be split both into an interpretation group, consisting a complete set of the different lights, and an observation group based on individual flashlight colors (i.e. all red flashlights will work together). The interpretation groups will analyze and interpret the information collected by the observation groups. Each observation group will be ‘expert’ in analyzing the material using a particular light source. Make the room as dark as possible to allow students to view the material by their assigned light source.

Give students approximately 5 minutes to examine each pan. All students should take notes as to what their observations are for they are a liaison to their interpretation group. After all pans have been viewed, students will spend 5 minutes interpreting their observations back in their interpretation groups. Their interpretation may consist of:

- What were they able to see or not see, depending on a particular light source?
- What light source provided the most information for each or all the pans?
- What the material in the pans might be?

After the groups have discussed their individual findings, pair different interpretation groups together to compare their results. They should spend 5 minutes comparing their findings. Do they agree? Why or why not?

At the conclusion of the paired group analyses, the teacher should facilitate a discussion on their observations and results. The following are some questions to ask:

- Are they using their observations to support their interpretations?
- What happened as they gathered more data (from other groups)?
- What differs among the groups?
- Why did we provide different light sources?