Telescopes

Light and Lens

NG Artifact – James Webb display in Great Observatories

Standards: 5- ETS1.B; 5-ETS1.C; MS-ETS1.B; MS-ETS1.C; MS-PS2.B; MS-PS4.A; MS-PS4.B; MS-ESS1.A; MS-ESS1.B

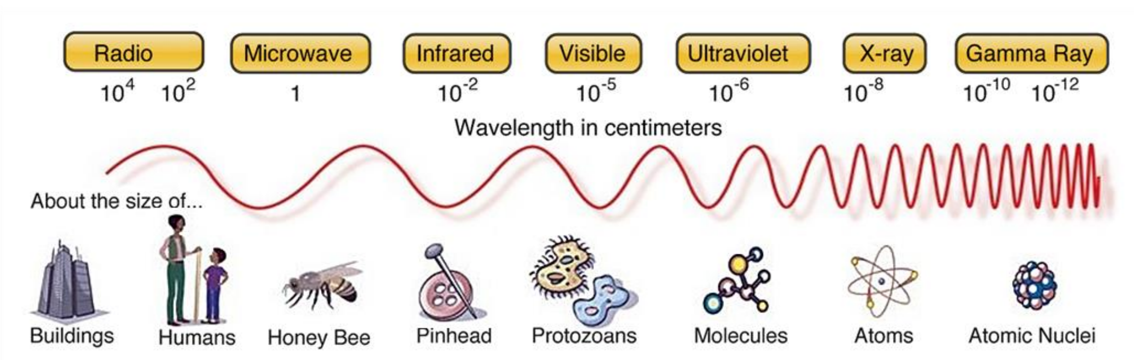
Objectives: The student will:

1. Discuss the wave/particle nature of light.
2. Investigate the effects of lenses and mirrors on light.
3. Apply the principles of refraction to create a simple telescope.

Background:

Light is energy that consists of particles called **photons**, moving through the universe in a **wave** pattern. This energy is created in the universe by processes such as fusion in the center of glowing stars, collisions of cosmic bodies, and even pulsars and black holes. Energy is not all generated at the same levels however, depending on the event, the energy released can be very high, very low, or anywhere in between. We call this range of energy the **electromagnetic spectrum.**

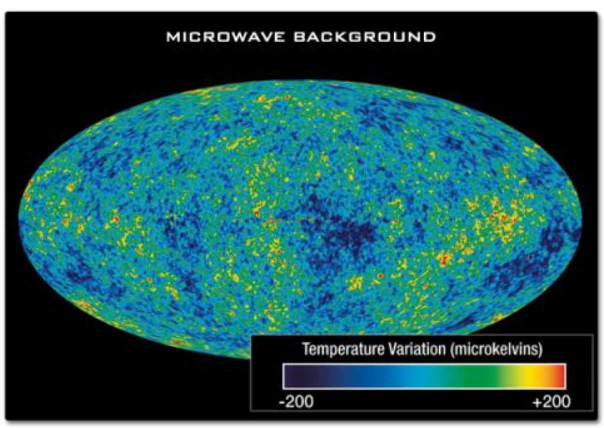
The image below shows that the energy and the wavelength are inversely proportional – the higher the energy, the shorter the wavelength. What we call 'visible light' or what the human eye can perceive, is actually only a small part of the energy from the universe.



We use tools like the **lenses** and **mirrors** in **telescopes** to study energy and light from distant objects. If scientists want a full picture of what is going on, they must use tools that can 'see' in all ranges of wavelengths. NASA has many telescopes that are looking out, deep into space so that we can learn what is out there, and where it came from.

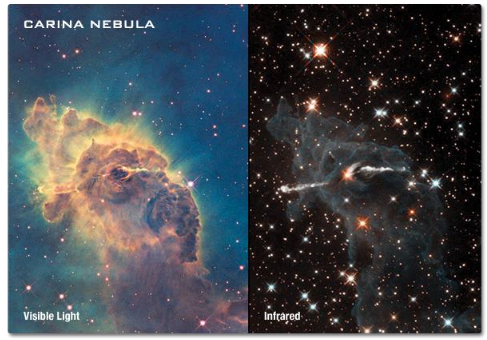
- The lowest energy and longest wavelength emissions come in the form of radio waves. These waves can range in size from the length of a water bottle to the size of the earth! To detect these waves from space, we use radio telescopes. Since radio waves are longer than optical waves, radio telescopes are made differently than the telescopes used for visible light. Radio telescopes must be physically larger than an optical telescopes in order to make images of comparable resolution. Radio telescopes use dishes and a receiver to gather radio waves, and computers to analyze the waves and put it into a form that we can see.

- The next most energetic waves are microwaves. Most people are familiar with microwaves because of their use in the kitchen, but microwaves are also used in weather radars, cell phones, and GPS systems. **Astronomers** are interested in microwaves because of their presence in all areas of the universe, telling us the story of the origins of the cosmos. This is called the Cosmic Microwave Background Radiation, and it was mapped by a microwave telescope called COBE. (Cosmic Background Explorer)

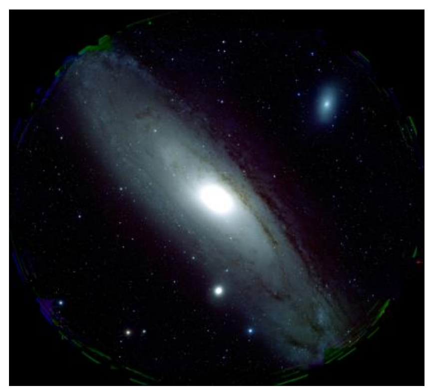


- Infrared is a little higher energy than microwaves, we can't quite see them, but we can feel them as heat. Humans and animals emit energy in infrared waves and this energy can be detected with infrared cameras and goggles. Infrared telescopes such as NASA's Spitzer space telescope can detect infrared energy from objects too cool or too far away to be seen with an optical telescope. The picture below shows the new baby stars being formed in the

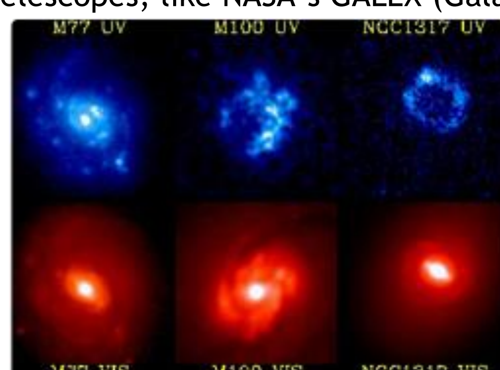
Carina Nebula that can't be seen otherwise. Spitzer was retired in early 2020 and will soon be replaced by the James Webb Telescope.



- Visible light is that energy that we can see. Our eyes have sensors that act as receivers for these waves. Light can be manipulated, bent, and even broken into its individual colors with the use of mirrors, lenses, and **prisms**. Optical telescopes use different combinations of these tools to gather visible light from space. Visible light telescopes range from small models that people use in their back yard to the Giant Magellan Telescope scheduled to come online in 2029 and even space-based telescopes. The GMT will have a resolving power ten times greater than the Hubble Space Telescope. However, Hubble has the advantage of being above the **atmosphere**, which means that there is no distortion or obstacles to prevent deep space viewing. You can see the difference in the images below, the first is from Hubble, while the second is from the Subaru observatory, a Japanese operated optical telescope located in Hawaii.



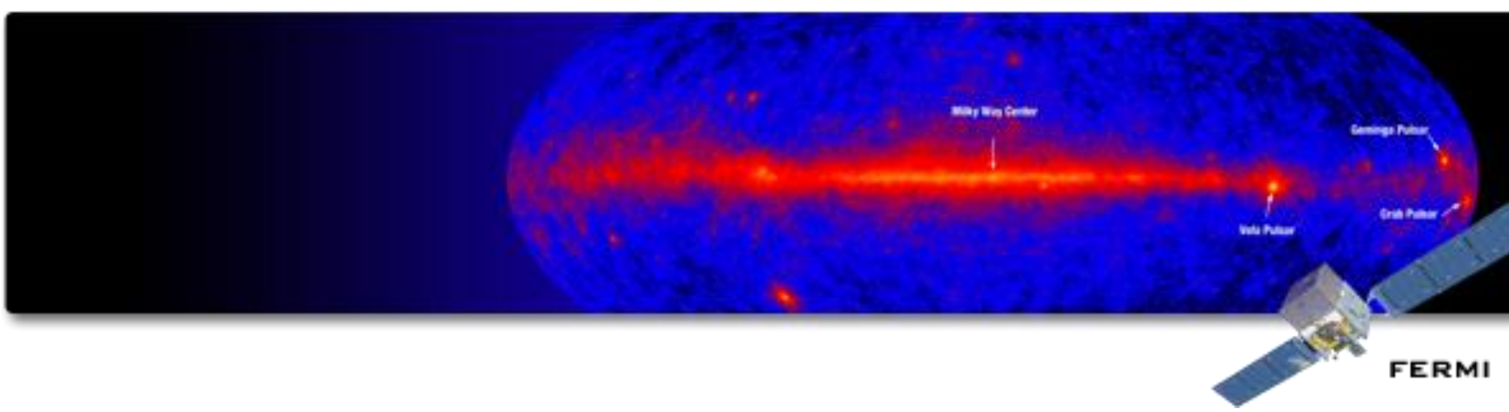
- Ultraviolet or UV light is more energetic than what we see. (It is interesting to note that some insects and birds can see light in the UV range.) Much of the UV light that comes our way does not make it through the earth's atmosphere, making space-based telescopes necessary to observe the universe in this wavelength. Many of the solar telescopes have UV sensors as well as optical telescopes, like NASA's GALEX (Galaxy Evolution Explorer), which



used UV data to study new, hot stars in crowded galaxies. In the image below you can see the individual stars clearly in UV (top picture), unlike in visible light on the bottom.

- X-rays are familiar to most people because of their use in the medical field, but astronomers are interested in what they reveal as well. X-rays are much more energetic than UV light waves, and have a much shorter wavelength, some as small as the size of an individual atom. X-rays are emitted by some of the most powerful cosmic events, such as supernovas and black holes. In addition, our sun produces X-rays in its outermost layers, and studying the sun in the X-ray part of the spectrum reveals new insight to its structure and behavior.

- Gamma rays have the smallest wavelengths and the most energy of any wave in the electromagnetic spectrum. We can't capture, refract or reflect them as we do in typical telescope because they pass right through the material the telescope is made from! We use sensors that 'see' the results of the gamma rays instead. We know that they come in short energetic bursts, from the the hottest and most energetic objects in the universe, such as neutron stars and pulsars, supernova explosions, and the regions around black holes. The image below is the Milky Way galaxy imaged in gamma radiation by the Fermi Space Telescope.



<u>Vocabulary</u>:

- <u>Astronomy/Astronomers</u> -The science of/ a scientist who observes and studies planets, stars, and galaxies.
- <u>Atmosphere</u> - The gases held by gravity around Earth and around other planets. "Atmosphere" can also be used to talk about gases around stars.
- <u>Concave</u> – lenses or mirrors that curve inward, away from the viewer (like a cave goes in).

- Convex – lenses or mirrors that curve outward, toward the viewer.
- Electromagnetic Spectrum – The name for all the different kinds of light and energy in the universe. This includes radio waves, microwaves, infrared radiation, visible light, ultraviolet light, X-rays, and gamma rays.
- Focus – the point that an image becomes clear, or light becomes directed at a single point.
- Hans Lipperhey – The inventor of the first telescope. It was a refracting scope that used lenses.
- Isaac Newton – The inventor of the first reflecting telescope, one that uses mirrors.
- Lenses – a piece of glass or other transparent material that can be used to bend light.
- Mirrors – a surface that reflects a clear image or beam of light.
- Photons – a single particle of light or energy.
- Prisms – a piece of glass or other transparent material that can be used to break light into its spectrum of colors.
- Reflection – the act of bouncing back light or energy.
- Refraction - The turning or bending of any wave, such as a light or sound wave, when it passes from one medium into another of different optical density.
- Telescope – A device which creates a larger image of a far away object.
- Wave - A way energy moves from one place to another.

Supplies:

Bending and breaking light:

- Pencil
- Glass
- Water
- Card stock (white)
- Scissors
- Flashlight
- Tape

Mirrors vs. Lenses:

- Flashlight
- Glass of water from previous activity
- Print out of image or picture (you may use the ones at the end of the lesson plan if you wish, they are a Snelling chart, NASA image of an energetic galaxy, and **Hans Lippershey** and **Sir Isaac Newton)**
- Magnifying glasses of different sizes (2)
- Metal Spoon (this will act as a concave/convex mirror)
- Small Mirror
- White paper
- Pencil

Building a telescope:

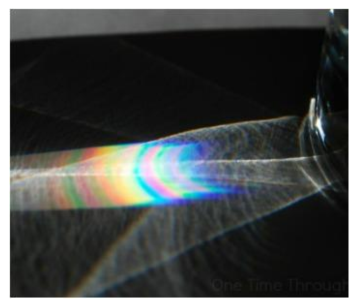
- Empty paper towel roll
- Magnifying lenses from previous activity

- Ruler
- Scissors
- Tape
- Pencil and paper

Procedures:

Since telescopes depend on the manipulation of light to see things that are far away, the first activity will be showing that light can be bent and broken. The bending of light is called **refraction**.

1. Fill a clear glass halfway with water.
2. Drop the pencil in the water. Observe from all sides. Discuss what you see and why. Remember light travels in a wave pattern, and it will not travel through water the same way it travels through air. How does this explain what you see?
3. This shows that light can be bent, now we are going to use water to break light into its components. Place the glass on a piece of white card stock and fill it the rest of the way with water.
4. Cut another piece of cardstock in half. Then cut a slit in the middle of one of the pieces. (See picture for reference)
5. Tape the piece of cardstock so that light shining through the slit can hit the surface of the water.
6. Shine the flashlight through the slit onto the water. You may have to adjust your angle until a rainbow appears on the cardstock under your glass. (Photos found at http://onetimethrough.com/how-to-make-rainbows-at-home/)
7. The different colors of light you see on the cardstock are the different wavelengths of light that comprise what we call visible light.



Some telescopes use lenses to capture and manipulate light (refracting telescopes), while others use mirrors (reflecting telescopes). In this investigation, you will use different surfaces to see how light and images can be manipulated.

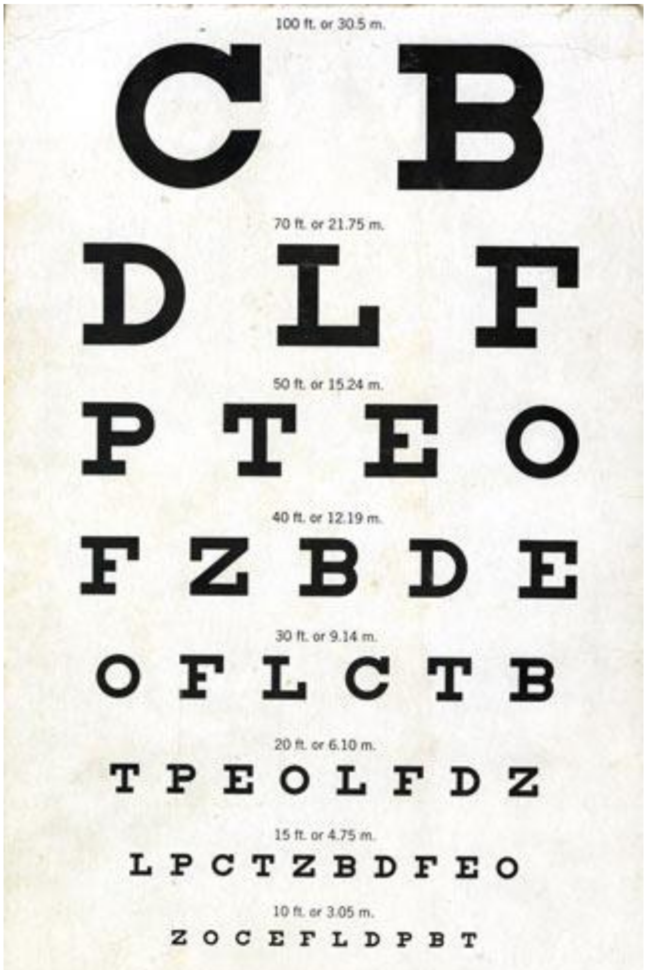
1. This is an investigation of **reflection** and refraction. Give each student at least 2 lenses, a flat mirror and a spoon (that will act as a **convex**/**concave** mirror)
2. Using the lenses first, have the students look at the images you have printed out. Move the lenses closer to and farther away from the images. Have them make observations and answer questions about the images. (ex: whether or not they are right side up, or upside down, are they larger or smaller than the original, do they appear blurry or clear, etc.)
3. Have the students work together to shine a flashlight through the lens and onto the white paper. As they move the lens back and forth in the beam, what happens to the light on the paper? Can they focus the beam into a clear circle?
4. Now have the students conduct an investigation with mirrors. Using the spoon, have them look at the back (the convex part). What does their reflection look like? Ask the same questions that they discussed in the first part of the activity (whether or not they are right

side up, or upside down, are they larger or smaller than the original, do they appear blurry or clear, etc.)

5. Flip the spoon and repeat with the convex side.
6. Have the students work together to shine a flashlight onto the surfaces of the spoon and reflect it onto the white paper. As they move the spoon back and forth in the beam, what happens to the light on the paper? Can they focus the beam into a clear circle?

Finally, you will use the lenses to create a telescope of sorts.

1. Students will work in pairs for this activity
2. Use one of your printed images and the two magnifying lenses. Put the image a little distance away from the students.
3. One of the students will hold the bigger magnifying glass between themselves and the image. As they look through it, the image will look blurry.
4. Have then place the second magnifying glass between their eye and the first magnifying glass. They will look through both lenses at the image and move the second glass forward or backward until the image comes into sharp **focus**. Have the second student mark the location of the lenses when the image comes into focus. Also note what is different about the image.
5. The second student will measure the distance between the two magnifying glasses at the focal points and write the distance down.
6. If your students struggle with scissors, you can help them with the following cuts: cut a slot in the cardboard tube near the front opening about an inch (2.5 cm) away from the end. <u>Do not cut all the way through the tube</u>. This slot should be able to hold the large magnifying glass.
7. Have the students look at the distance that they measured as the focus length (step 5). They should cut a second slot in the tube that same distance from the first slot. This is where the second magnifying glass will go.
8. Place the two magnifying glasses in their slots (big one at front, little one at back) and secure them with tape.
9. The students may trim off any excess tube if they wish. Also, if each student is making their own telescope, have them switch roles and build the telescope for the second student at this time.
10. Check to see that it works by looking at the printed image. You may have to adjust the lenses slightly to get the exact distances between the two glasses right so that the image comes to a focus.



Credits:

https://science.nasa.gov/ems/05_radiowaves

https://science.nasa.gov/ems/06_microwaves

https://science.nasa.gov/ems/07_infraredwaves

https://science.nasa.gov/ems/09_visiblelight

https://asterisk.apod.com/viewtopic.php?t=31909

https://science.nasa.gov/ems/10_ultravioletwaves

https://science.nasa.gov/ems/11_xrays

https://science.nasa.gov/ems/12_gammarays

https://science.howstuffworks.com/question568.htm#:~:text=To%20make%20a%20simple%20telescope,duct%20tape

http://onetimethrough.com/how-to-make-rainbows-at-home/

https://www.aao.org/eye-health/tips-prevention/eye-chart-facts-history (eye chart)

https://www.nasa.gov/feature/goddard/2020/quasar-tsunamis-rip-across-galaxies

https://spaceplace.nasa.gov/glossary/en/

https://starchild.gsfc.nasa.gov/docs/StarChild/glossary_level1/glossary_text.html