Light

Science

The electromagnetic spectrum is the full range of electromagnetic radiation and their wavelengths. All the various forms of radiation are present in the world around us, however only the visible light region of the spectrum is detectable by the human eye and the different

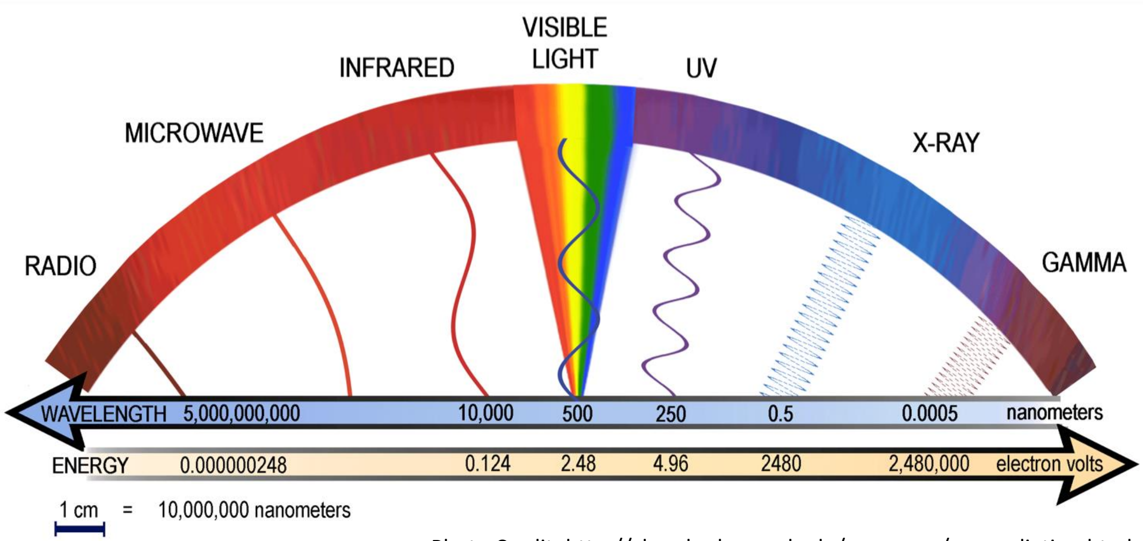


Photo Credit: http://chandra.harvard.edu/resources/em_radiation.html

wavelengths are seen as the colors of the rainbow. Some regions of the spectrum are more commonly known than others; radio waves are used to transmit songs and shows over the radio, microwaves are used to vibrate the water molecules in food and heat it up, UV or ultraviolet waves radiate from the sun and can cause damage to a person's skin and eyes, and X-rays are used often in the medical field to see a person's bones through their skin. The less commonly known portions are infrared and gamma rays. Gamma rays have the shortest wavelength of the electromagnetic spectrum and can penetrate a variety of different surfaces, so are commonly used for sterilization in the food industry as well as used for medical imaging and cancer treatment. Infrared can be separated into three groups, far infrared (far-IR), mid infrared (mid-IR), and near infrared (near-IR). Far-IR is given off by hot bodies and is used for sensing heat and thermal images, mid-IR is considered the "finger print" region because it's used often to differentiate compounds, and near-IR is similar in property to visible light and can be captured with certain cameras. Near-IR also has a unique relationship to vegetation and has imaging applications in agriculture and invasive species management.

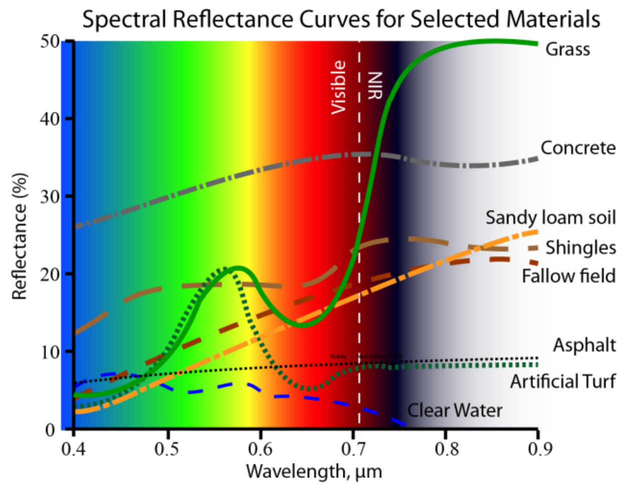


Photo Credit: Andy Henry, Wayne RESA

When these forms of electromagnetic radiation interact with matter and transfer energy, it's called absorption. Different types of matter absorb energy in unique ways and have distinct absorption spectra. Matter also has reflectance spectra, or emissions, the opposite of absorption spectra, which depicts the energy reflected off matter after it has absorbed the energy. The following image depicts examples of reflectance spectrum that depict how much energy is reflected by the various materials at each wavelength of light. It shows that grass reflects in the green and yellow region of the visible range and to a greater degree in the Near-IR. Conversely, asphalt reflects in similar amounts across the different wavengths. Reflectance and absoprtion are also often depicted by the full rainbow where some color bands are amplified or diminished. The following image shows the full spectrum, an absoprtion, and an emissions spectrum.

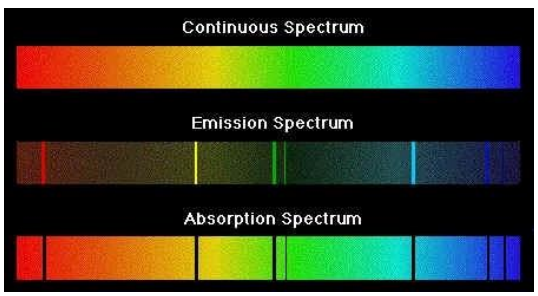


Photo Credit: https://thecuriousastronomer.wordpress.com

One way this is applied is in the study of plants. During photosynthesis, plants absorb and reflect colors in different quantities. Red and blue are mostly absorbed and used in food production, whereas the green is only partially absorbed and almost no near-IR light is absorbed. The higher reflectance of green compared to blue and red is why plants appear green to the human eye. Similarly, because near-IR is almost entirely reflected by vegetation, plants apprear bright white when viewed through an infrared filter. This phenomenon makes it possible to observe and study plants using near-IR cameras.

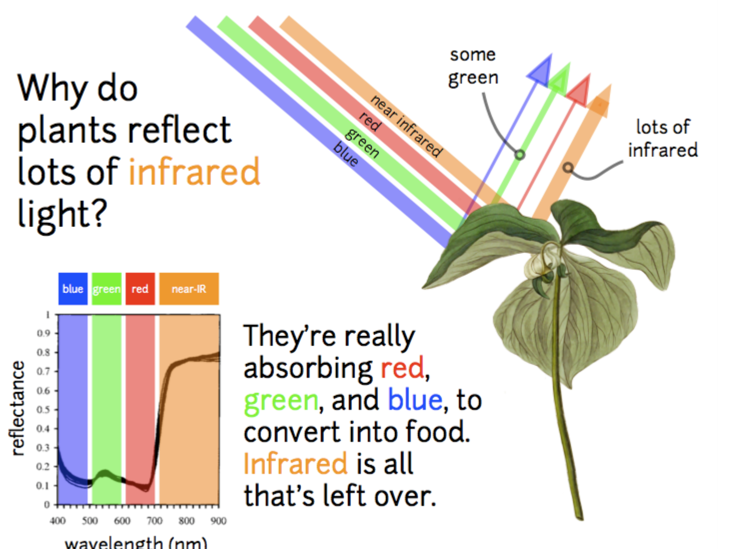


Photo Credit: Jeff Warren, Public Labs

NASA Research

Light is important in a lot of the research NASA conducts because an object's light absorption spectrum provides valuable information about it's composition, temperature, movement, etc. Because our universe is so expansive, one of the ways in which NASA gathers information on distant bodies is using it's absorption spectrum. In particular, when scientists study the sun or distant stars they measure the absorption spectra that depicts the full rainbow of colors with certain areas of dark bands caused by the absorption of light from specific chemicals. Because each chemical has a unique absorption spectra scientists can then identify which chemicals caused the dark bands and the chemical make up of the star. The following example shows the absorption spectra of a star and the chemicals that correspond to the dark bands. Similarly, scientists use absorption spectra to determine if a star is moving towards or away from us. If a star is moving towards us the light wavelengths will be squished and compressed giving a blue shift to the absorption and if the star is moving away the wavelengths will be elongated giving a red shift.

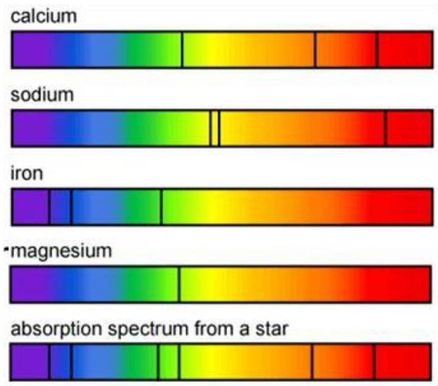


Photo Credit:
https://colganscience.weebly.com

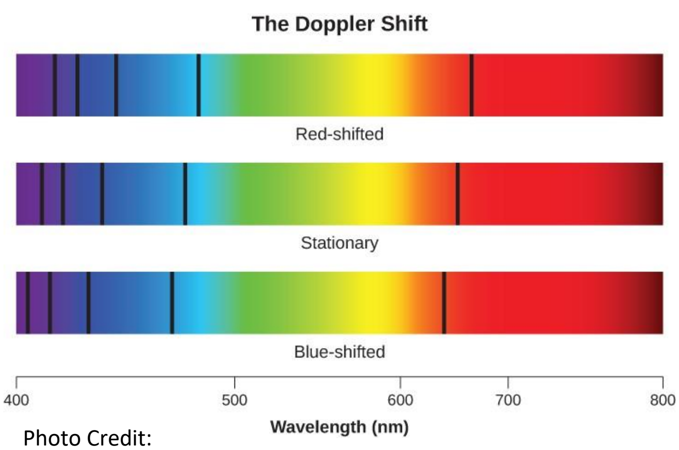
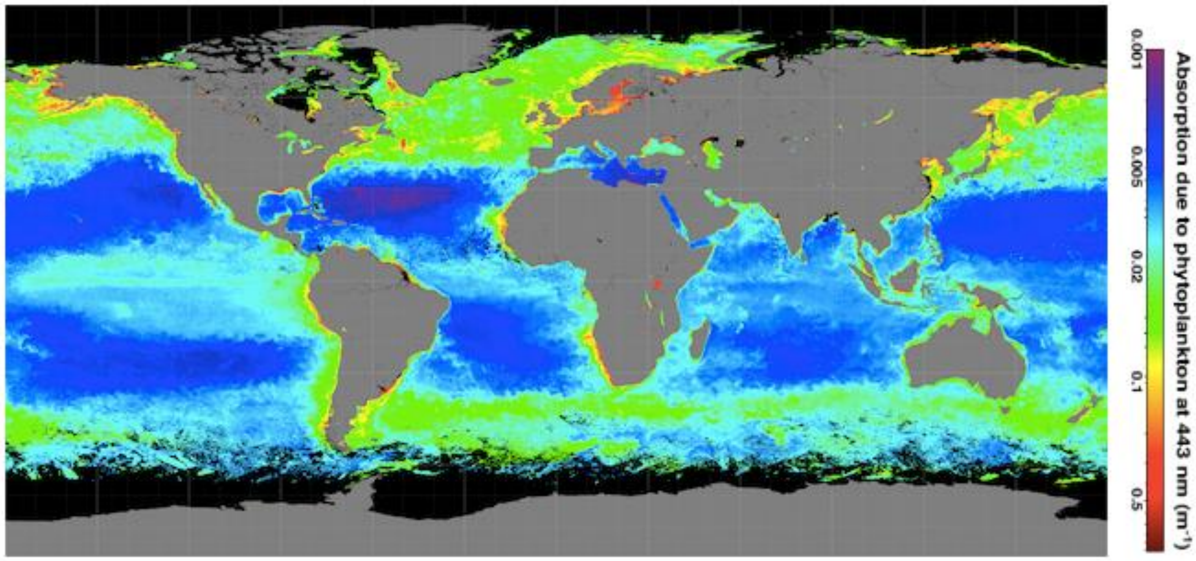


Photo Credit:
https://courses.lumenlearning.com/astronomy/chapter/using-spectra-to-measure-stellar-radius-composition-and-motion/

NASA scientists use light to study the earth as well. One example is the use of absoprtion spectra to study the ocean and more specifically, phytoplankton. Ocean color satellites orbit the earth and collect various readings about the ocean including absoption spectra at specific wavelengths. The different wavelengths of light can be used in algorithms to calculate concentrations of different types of phytoplankton for use in monitoring diversity and specific population types. This research is important because photoplankton produce a large portion of earth breathable oxygen and also because they are the bottom of the food chain in the ocean so any major changes in phytoplankton populations would have much larger global ramifications.



MODIS Aqua seasonal composite of phytoplankton absorption at 443 nm for Spring 2014

Photo Credit: https://oceancolor.gsfc.nasa.gov/atbd/poc/

AREN Technologies

In addition to the science that NASA conducts to monitor the solar system as well as earth systems, smaller NASA organizations like AREN operate closer to the surface. AREN stands for AEROKATS and ROVER Education Network, and is an education and outreach organization that engages students and life long learners in their local environments. Within AEROKATS (Advancing Earth Research Opportunites using Kites and Atmospheric/Terrestrial Sensors) participants use a kite based platform to collect scientific data and images from an aerial persepctive. In order to collect the data we mount aeropods with various instrumentation and attach them to kites that can fly up to 500ft. Aeropods (following figure) are a stick with a camera/sensor on one end, fins that keep it stable

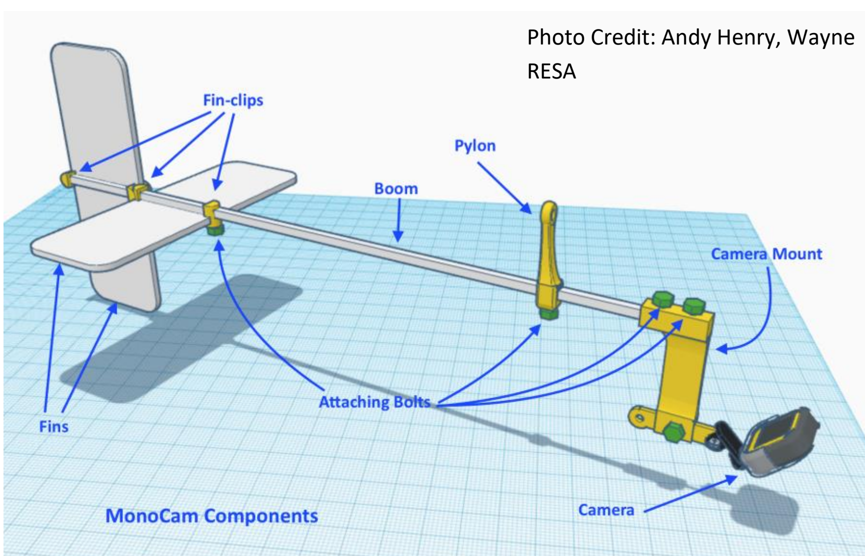
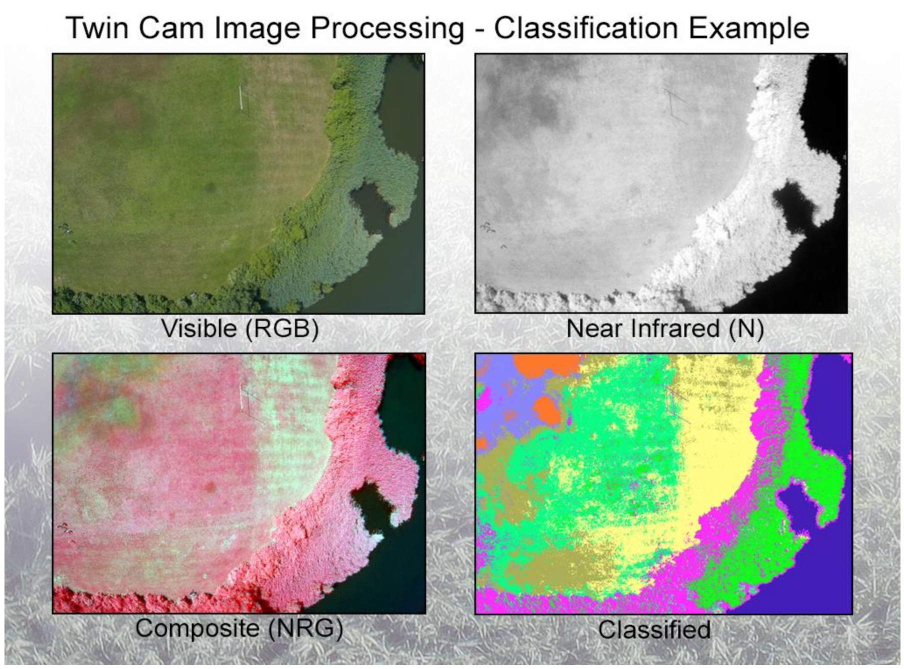


Photo Credit: Andy Henry, Wayne RESA

and directionally oriented with the wind on the other end, and a a connector in the middle that attaches it to a kite. Because aeropods are primarity 3D printed, they can be outfitted with a variety of instrumentation.

One instrument in paritcular is the TwinCam that mounts a color camera side by side with a near- IR camera. The cameras are arranged together in order to capture near simultaneous images of the same study area. With a RGB (red green blue) color image and a near-IR image we can learn a lot about vegetation because of the unique nature in which light interacts with plants. By replacing either the red or blue band in the RGB image with the near-IR imagewe create a composite image. That image can be further processed in image software, like MultiSpec, to create calssified images that detail different vegetation types. The following image shows an example of a classified image where the different plant types are differentiated from each other as well as differentiated from the water and the dirt patches seen in the RGB image. Classification images provide valuable information about vegetation with applications in the field of agriculture and invasive species monitoring and mitigation.

Photo Credit: Andy Henry, Wayne RESA



Objective

Introduce the concept of the electromagnetic spectrum, light absorption, and their significance in vegetation and the objects around us. Encourage the students to experiment and observe the light spectra from different objects and document their observations. Further expand the activity into a design challenge to exercise their new knowledge of light and spectroscopes.

Overwiew

Students will construct their own spectroscope and calibrate it to see the light spectrum. They will collect data from viewing various objects through the spectroscopes including drawing the color bands. Discuss and analyze the results in groups or 3 or 4. In the next step, students will design a new spectroscope in those same groups to improve on one aspect of the old design.

Time

Construction: 1 hour

Data recording: One reading takes 10 minutes

Design challenge: 2 hours

Age Group

Most appropriate for 5-8 grade level

Materials

Part 1

- Cardboard tube, roughly 1x9”
- Two circular stickers or thick tape, at least 1.5”
- CDs
- Rulers
- Scissors
- A variety of leaves
- White paper
- Source of bright light
- Crayons or markers
- Spectroscope diagram and data sheet
- Optional: Tic Tac containers

Part 2

- Addition of variety of spectroscope materials (boxes,

Preparation

- If under a time constraint or working with younger children, consider making the cuts to the cardboard tubes beforehand.
- Cut CDs into quarters.
- Organize students into groups of 3 or 4.
- Lay out the materials for each student.
- Pass out the spectroscope diagram as well as the data sheet.

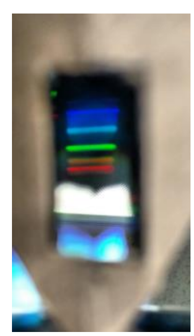
Instructions

1. Flatten the carboard tube so it's easier to cut. Measure the width of the tube and make draw a square that size. Make sure to leave at least 1cm space from the end.
2. Draw a diagonal starting from the top left to the bottom right. And mark the halfway point of the diagonal. Cut along the diagonal to the halfway point leaving a roughly 2mm gap for the CD.

3. Measure one centimeter from the diagonal cut towards the center of the tube. Draw a rectangle .5cm tall and 2cm wide. Cut out the rectangle to make a 1x2cm viewing slot at the top of the tube. Unflatten the tube and mold back to original shape.

4. Center one sticker over the end closest to the cuts and cover hole to block out light. If the sticker is not opaque enough to block out light, blacken with a marker.

5. Cut the other sticker in half and place both halves on the opposite end of the cardboard tube so that there is a 1mm gap between the stickers creating a slit. Make sure the slit is horizontal to the table with the viewing hole facing up.
6. Insert the CD piece in the 45 degree slot, and test the spectroscope by pointing the slit end towards a light and looking through the viewing hole. NEVER look directly at the sun!! You should see a spectrum. Adjust the position of the sticker halves if not seen.



7. Take an initial observation with an open spectroscope and record on data sheet.

8. Cut a green leaf, white paper, and other assorted objects into strips large enough to cover the slit and record more observations on the data sheet. Be creative! Consider adding liquids to a tic tac container and viewing through spectroscope.

Collecting and Recording Data

After the spectroscope is set up, one data point should be collected with nothing covering the slit. Students will continue to experiment with other materials in front of the slit and observing how the light spectrum changes. Data should be recorded on the data sheet for future analysis. Date, Time, and Object observed are straightforward. Under "Draw Spectrum" students should use the crayon provided to draw what they see through the spectroscope and then describe which colors are more predominant and which are dimmed in the "Describe Spectrum" section. In the "Additional Observations" section we ecourange students to include more details about the observation and anything that stands out to them.

Technology

To briefly summmarize the machanics of this type of spectroscopes, the light enters the narrow slit on one end of the tube and the diffraction grating separates it out into the full spectrum of color much like a prism. While light may seem white or yellowish, it's actually a combination of different colors of the electraomagnetic spectrum. When light comes through the split and diffraction grating, it spreads the light out into the different wavelengths so that you can see each color individually. When different light sources or light through different objects is viewed with the spectroscope, they show different spectra. Some bands may be more prominent and some maybe be diminished.

Operations

A couple skills to emphasize throughout this activity are teamwork and communication where each person has an equal voice. One suggested way to emphaze these skills is to create groups of 3 or 4 to discuss their findings after they've had a chance to use their spectroscopes and fill their data sheets. The students can discuss together what they saw and how the light spectrum changed depending on what they viewed and to analyze the results to better understand the forces at work in created the different spectra. This also gives the students a chance to brain storm other objects to use with the spectroscopes and collect more data.

Some suggested questions to encourage creativity and critical thinking: How were the spectra different depending on light source? What causes the difference in light spectra? Did you notice any difference if you doubled up objects viewed through the spectroscope, both same and different objects? How do spectra differ between two people's scopes viewing the same object? What could cause those differences? What might the spectra look like if you viewed sunlight through the atmosphere on a different planet?

Part 2: Design Challenge

Once the students have created their spectroscopes and have had a chance to analyze the light spectra with different objects, we encourage the activity be taken a step further to incorporate a design challenge. The students will remain in their groups of 3 or 4 and be given the choice of several objectives. The goal is for each group to improve on one aspect of the spectroscope design. Options include: create a brighter spectrum, create a higher resolution spectrum, make the spectroscope pocket size, incorporate their cellphones so they can capture pictures of the spectrum, or create a spectroscope that can fit over their heads. The students will be supplied with a variety of materials, in addition to the material required for the original spectroscope, to complete their objectives. Some suggested materials are boxes, cereal boxes, card stock, duct tape, small mirrors, etc. It's important for the students to first brainstorm and draw out their design ideas and have them approved by the instructor before they start working towards building the spectroscopes. Once they've has a chance to build their scopes and make improvements each group should present to the class what they tried to achieve their objective and the results as well as their final product.

Data Sheet

Date	Time	Object Observed	Draw Spectrum

_______ _____ _____________ ______________________________________

Describe Spectrum ____

Additional Observations ____

_______ _____ _____________ ______________________________________

Describe Spectrum ____

Additional Observations ____

_______ _____ _____________ ______________________________________

Describe Spectrum ____

Additional Observations ____

_______ _____ _____________ ______________________________________

Describe Spectrum ____

Additional Observations ____

_______ _____ _____________ ______________________________________

Describe Spectrum ____

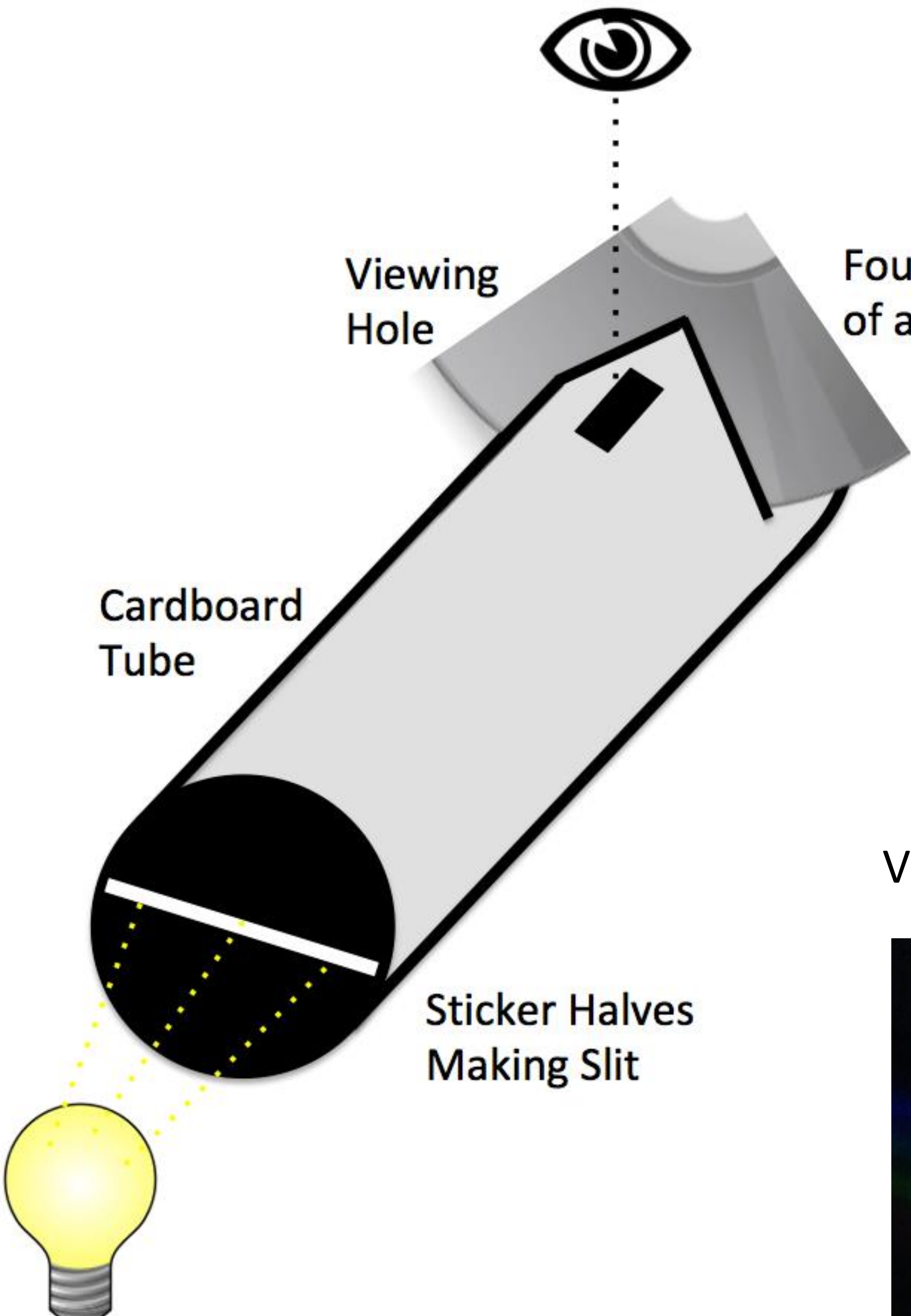
Additional Observations ____

_______ _____ _____________ ______________________________________

Describe Spectrum ____

Additional Observations ____

Spectroscope Diagram



View Through Hole