National Aeronautics and Space Administration

FROM QUESTIONS TO DISCOVERIES

exploration

Exploring with Light and Color

Educator Materials

"From the time of our birth,
it is our instinct to explore.

To map the lands, we must explore.
To chart the seas, we must explore.
To make new discoveries, we must explore."

—Neil Armstrong

Introduction

This booklet contains instructions for implementing activities that were presented May 8, 2007 to Queen Elizabeth at the Goddard Space Flight Center.

The first lesson, entitled *Light Exploration*, includes four activities designed to pre-assess and extend student knowledge of light and color. Students observe a prism demonstration, observe light with diffraction grating, and observe the effects of filters upon light. Students extend their knowledge by examining and recording the emission spectra of four different gases, and apply their knowledge by explaining why light is an important tool for studying and learning about the universe.

The second lesson, entitled *Galaxy Exploration*, features the Hubble Ultra Deep Field and involves the classification of deep field objects based upon observed properties such as color and shape. This lesson also includes four activities and provides an opportunity for students to participate in the same process used by scientists when studying and classifying objects in the universe. The process skills used in this activity are observing, comparing and contrasting, and classifying.

The lessons included in this booklet are supported by resources such as the *From Questions to Discoveries Student Workbook*, a glossary, and background about the Hubble Space Telescope. In addition, the student workbooks include background information about light and galaxies in a resource called Q & As, and information about common light and galaxy misconceptions in a resource called Myths vs. Realities. These resources can be used to build student background knowledge, can serve as content reading resources, can provide topics for additional research, or can be used to address student misconceptions.

These lessons are written for classroom use and designed for students in grades six through eight. They can be implemented in their entirety as written, or implemented at the teacher's discretion.

These activities developed by Space Telescope Science Institute 2008.
For more information, please contact: **amazing-space@stsci.edu**
or find more resources online at **http://amazing-space.stsci.edu**

Contents

Light Exploration:

What is the relationship between **light** and **exploration**?

Big Question

What is the relationship between light and exploration?

Background

This series of activities is designed to introduce the idea that light carries information; both about what produced the light and what the light has traveled through. By separating visible light into a spectrum, it is possible to see its component colors. These components can reveal information about the object from which the light emanates. **Activity 1** incorporates a prism demonstration to probe students' prior knowledge about light. **Activity 2** demonstrates how filters absorb specific colors or wavelengths of light. **Activity 3** examines the light produced by certain elements and demonstrates how each element has its own unique emission spectrum, thus revealing the chemical composition of the object that produces the light. **Activity 4** includes a discussion of how astronomers utilize different types of light for studying objects in the universe.

National Education Standards

Project 2061 Standards
The Physical Setting: Motion

By the end of the 8th grade, students should know that:

- 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.

Learning Outcomes

Students will:

- Observe that electromagnetic radiation exists beyond what we can see with our eyes.
- Observe that visible light can be separated into component colors.
- Observe how filters absorb specific colors or wavelengths of light.
- Observe and record emission spectra for different gases/elements.
- Relate the significance of the electromagnetic spectrum to astronomy.

continued...

Prerequisites

Before attempting to complete this lesson, students should:

- Have a general understanding of the visible light spectrum.
- Know that light can be reflected, refracted, or absorbed by an object.

General Misconceptions

Students may think:

- The electromagnetic spectrum consists of only visible light.
- All radiation is harmful.
- The primary colors of light are identical to the primary colors of pigments.
- Filters change the color of light.

Activity 1: Exploring Visible Light

Learning Outcomes

Students will:

- Observe that electromagnetic radiation exists beyond what we can see with our eyes.
- Observe how visible light can be separated into component colors.

Materials

- *From Questions to Discoveries Student Workbook* (one per student)
- Prism
- Flashlight
- Box for displaying the spectrum (a shoebox or similarly sized cardboard box works best)
- **Optional:** Computer or laptop with an Internet connection and/or the *Amazing Space* CD

Procedure

Engage students by showing them the prism and asking if anyone knows what it is or what it does. Call on a few volunteer students to share their ideas. Have students refer to the "student directions" provided on page 2 of the *From Questions to Discoveries Student Workbook*. **Optional:** Students may record responses to these questions during the activity.

Use the flashlight and prism to display the visible light spectrum/rainbow inside the box. Do this by putting the prism on the top edge of the side of the box that is facing you while students gather around the other side of the box to observe. Hold the prism in place with one hand while shining the light from the flashlight through the prism with the other hand. A rainbow-colored arc or spectrum should appear inside the box. If the spectrum is not apparent or is very spread out, try turning or rotating the prism slightly until a more visible spectrum is achieved.

Elicit students' ideas about light with prompts such as:

- Describe when and where you have observed something similar to this before.
- Explain what you are seeing and why.
- Explain what light is, or tell what you know about light.
- Have you ever heard of the electromagnetic spectrum? Tell what it is, and identify its parts.

continued...

Activity 1: Exploring Visible Light continued

If necessary, explain to students what a prism is and how it works. Explain that the visible light from the flash light is a small portion of the electromagnetic spectrum, composed of component colors/wavelengths (red, orange, yellow, green, blue, and violet). The prism helps us see the component colors by dispersing the light.

Note: This demonstration works best with practice and in a low-light environment. If the spectrum in this demonstration proves difficult to achieve, another option includes demonstrating the above principle using a computer or laptop. Log onto the *Amazing Space* Web site at **http://amazing-space.stsci.edu/resources/explorations/**, or use the *Amazing Space* CD to access the Online Exploration "Star Light, Star Bright." Select the activity "Catch the Waves." By clicking on "Activate," the above principle can be demonstrated for students electronically.

Activity 2: Exploring Filters

Learning Outcomes

Students will:

- Observe that electromagnetic radiation exists beyond what we can see with our eyes.
- Observe how filters absorb specific colors or wavelengths of light.

Materials

- *From Questions to Discoveries Student Workbook* (one per student)
- Incandescent light bulb w/socket and clamp
- Stand or box for attaching the clamp
- Extension cords
- Diffraction glasses (one pair per student)
- Red and blue gel filter sheets (cut into approximately 5-by-7-inch rectangles, one rectangle of each color per student)

Safety Tip

Take appropriate safety precautions when using extension cords. Be sure extension cords are either taped down or connected well outside of walking areas and pathways.

Procedure

Have students refer to the "student directions" provided on page 3 of the *From Questions to Discoveries Student Workbook*. **Optional:** Students may record responses to these questions during the activity.

Attach the socket clamp with the light bulb in place to a stand or box so that the light bulb is at a safe distance from students but still easily seen. Caution students not to stand too close or touch the light when it is turned on. Turn on the light and ask students to describe what they see. Provide each student with a pair of diffraction glasses, and ask them to look at the light again while wearing the glasses. Engage the students in a discussion of what they are observing by asking questions such as:

- What do you see?
- Have you seen a similar pattern before?
- Can you explain what you are observing and why?
- How is this similar to, and different from, what you observed during the prism demonstration?

continued...

Activity 2: Exploring Filters continued

Next, provide each student with a piece of red and blue gel filter. Before students use the filters, have them make predictions about what they think they will see or what they think will happen while using the filters. While the students are wearing the diffraction glasses, ask them to look at the light through the blue filter first, and then the red filter. This works best if students look at the light while they pass each filter in front of their glasses. Further discussion questions and prompts include:

- What do you notice when you use the blue filter? Describe what you see.
- What do you notice when you use the red filter? Describe what you see.
- Compare what you observe with your predictions.
- What is a filter? Explain how a filter works, or what it does.
- Predict what you would see if you used a green-colored filter.

If necessary, explain what filters are and how they work. Filters change the way the light appears by absorbing some colors/wavelengths of light, while allowing others to pass through. This concept is related to how Earth's atmosphere blocks or "filters out" some of the wavelengths of the electromagnetic spectrum.

Activity 3: Exploring Emission Spectra

Learning Outcomes

Students will:

- Observe that electromagnetic radiation exists beyond what we can see with our eyes.
- Observe and record emission spectra for different gases/elements.

Materials

- *From Questions to Discoveries Student Workbook* (one per student)
- Hydrogen, neon, argon, and helium discharge tubes
- Power supplies for the tubes (4)
- Diffraction glasses (one pair per student)
- Crayons or colored pencils (one pack per student)
- Extension cords
- Power strip

Safety Tips

Be aware that the power supplies are high voltage and take appropriate precautions when using them. Caution students to not touch the discharge tubes or power supplies.

Take appropriate safety precautions when using extension cords and power strips. Be sure cords are either taped down or connected well outside of walking areas and pathways.

Procedure

Have students refer to the "student directions" provided on page 4 of the *From Questions to Discoveries Student Workbook*. **Optional:** Students may record responses to these questions during the activity.

Locate a central location for setting up the power supplies and discharge tubes so they are at a safe distance from students but easily seen. When presenting the power supplies and discharge tubes to students, explain to them that one tube contains a small amount of neon gas; another, hydrogen gas; the third, helium; and the fourth, argon. When turned on, the gas will glow. Be sure to caution students not to touch the power supplies or tubes.

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Activity 3: Exploring Emission Spectra continued

Turn on the power supplies and have students look at the glowing gases, and take note of what they observe. Next, turn on each power supply (starting with the neon gas) one at a time, and have students put on their diffraction glasses and observe each gas. Follow this procedure with the remaining gas tubes. **Note:** Do not leave the power supplies on for extended periods of time.

- Have students use crayons or colored pencils to record what they see through their glasses when they look at each gas. Space to do this is provided on page 5 of the *From Questions to Discoveries Student Workbook*. Encourage students to do their best when recording color, line size, and line spacing.
- Direct students to label each drawing with the name of each corresponding gas.
- Challenge students to compare what they see when looking at the different gases and determine why they appear different when observed with diffraction glasses.

Discussion questions and prompts include:

- Explain why you think the lines and colors look different for each gas.
- Predict what you would see if you observed another gas, such as oxygen. Would it look like the ones you just observed? Explain why or why not.
- Explain how you think astronomers use emission lines similar to the ones you observed to learn about objects in the universe.

If necessary, explain to students that they are observing emission spectra. Each element has its own unique spectra. By analyzing a celestial object's emission spectra (and absorption spectra), astronomers can determine important characteristics, such as the object's chemical composition or the chemical elements in its atmosphere.

Activity 4: How Light is Used as a Tool

Learning Outcomes

Students will:

- Relate the significance of the electromagnetic spectrum to astronomy.

Materials

- *From Questions to Discoveries Student Workbooks* (one per student)
- Electromagnetic spectrum poster (available from the Space Telescope Science Institute's Office of Public Outreach)

Procedure

Have students refer to the "student directions" on page 6 of the *From Questions to Discoveries Student Workbook*. **Optional:** Students may record responses to these questions during the activity.

Display the electromagnetic spectrum poster prominently for students to see. Explain to students that the large image on the poster is the center of the Whirlpool Galaxy (M51). Also explain that the images at the bottom of the poster show the Whirlpool Galaxy (M51) in different types of light (or different wavelengths).

- Ask students to find a feature in the M51 image that is visible in all or several types of light. Have students explain what they think this means.
- Ask students to find a feature in the M51 image that is visible in only one or a few types of light. Ask students to explain what they think this means.

If necessary, explain to students that light is an important tool for studying and learning about the universe. Astronomers must use all types of light to learn as much as they can about objects in space, because some objects or features can only be detected in certain types of light. For example, the "radio image" of M51 shows an area just outside the galaxy that is detectable only at radio wavelengths, whereas the galaxy's core is detectable in all types of light.

Time for Reflection

Have students think about and summarize some of the new ideas they have learned during this lesson. Ask students to turn to page 7 in their workbooks and answer the questions found on that page.

Galaxy Exploration:

How is light used to explore the **universe**?

Big Question

How is light used to explore the universe?

Background

This series of activities is designed to reinforce the idea that astronomers learn about objects by analyzing the light they emit over great distances. Astronomers also can learn about objects by classifying them based upon observed properties and characteristics. **Activity 1** probes students' prior knowledge about the universe. Students observe an image of the Hubble Ultra Deep Field (HUDF) and formulate questions about what they see in the image. During **Activity 2**, students independently classify select objects in the HUDF. During **Activity 3**, students compare their classifications in cooperative groups and develop a team classification system for the HUDF objects. **Activity 4** reinforces the scientific process when students compare their team results with astronomers' results. Students learn from this activity that often scientists do not always agree or get the same results. They, however, must be able to support their results with evidence.

National Education Standards

National Council of Mathematics Standards

- In grades 6-8 all students should formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.

Project 2061 Standards
Habits of Mind: Critical Response Skills

By the end of the 8th grade, students should:

- Be aware that there may be more than one good way to interpret a given set of findings.

Learning Outcomes

Students will:

- Generate questions that can be answered using scientific inquiry.
- Compare and classify galaxies and stars.
- Use a table to organize and display data.
- Determine the characteristics used by astronomers to classify galaxies and stars and compare their findings with astronomers' findings.

continued...

Prerequisites

Before attempting to complete this lesson, students should:

- Be familiar with charts and tables.
- Have skills in comparing and contrasting.
- Know that galaxies are composed of stars and are outside the Milky Way.

General Misconceptions

Students may:

- Have an understated idea of the size of the universe.
- Not have an awareness of the vastness of the universe and the number of celestial objects it contains.
- Not realize that most galaxies cannot be seen without the aid of a telescope.

Activity 1: Exploring the Hubble Ultra Deep Field (HUDF)

Learning Outcomes

Students will:

- Generate questions that can be answered using scientific inquiry.

Materials

- *From Questions to Discoveries Student Workbook* (one per student)
- Chart paper and marker

Procedure

Begin by identifying ideas students have about the universe.
Discussion prompts include:

- Identify objects that can be found in the universe.
- Identify something in the universe that is bigger than the Earth.
- Identify something in the universe that is smaller than the Earth.
- Explain how scientists use light as a tool for studying the universe.

Have students refer to the "student directions" on page 15 in the *From Questions to Discoveries Student Workbook* and examine the HUDF image provided on page 16. **Optional:** Students may record responses to the questions found on page 15 during the activity.

Have students generate questions about what they see in the HUDF image. Record these questions on chart paper as students share them aloud. This activity can be conducted using the Think-Pair-Share strategy. Students first generate questions independently, and then share their questions with a partner before sharing them out loud with the class. Possible questions include:

- What are the objects?
- How many objects are there?
- Why are the objects different colors?
- Why are the objects different shapes?
- How big are the objects?
- How far away are they from us?

Activity 2: Classifying Deep Field Objects

Learning Outcomes

Students will:

- Compare and classify galaxies and stars.

Materials

- *From Questions to Discoveries Student Workbook* (one per student)
- Hand lenses

Procedure

After students generate questions about the image, have students refer to the "student directions" on page 17 of the *From Questions to Discoveries Student Workbook*.
Optional: Students may record responses to these questions during the activity.

Next, have students refer to the HUDF image provided on page 18. Students should take note of the numbered objects if they have not already done so. Ask students to describe the numbered objects and predict what they might be. Challenge students to devise a way of grouping or classifying the objects based upon observed similarities in their characteristics. Each student should create their own unique categories, and sort the 16 numbered objects into their categories accordingly. Space to do this activity is provided on page 19. Students may use hand lenses to help them examine the objects more closely. Grouping strategies may include:

- By Color
- By Shape
- By Size
- By Location

After students have completed this task, ask for volunteers to share and explain their groupings with the class.

Activity 3: A Team Classification System

Learning Outcomes

Students will:

- Use a table to organize and display data.

Materials

- *From Questions to Discoveries Student Workbook* (one per student)

Procedure

Have students refer to the "student directions" provided on page 20 of the *From Questions to Discoveries Student Workbook*. **Optional:** Students may record responses to these questions during this activity.

Explain that the objects in the HUDF image are galaxies and stars. Challenge students to locate the stars and the galaxies in the image.

Then ask students to preview the chart provided on page 22. Explain that the classification scheme astronomers use to group objects in the universe is based upon shape and color. Also explain that there are three main types/shapes of galaxies: spiral, elliptical, and irregular. An explanation of galaxy types is provided for students on page 21 of the *From Questions to Discoveries Student Workbook*. To check whether students understand the galaxy types, ask for a few volunteers to identify examples of each galaxy type in the numbered HUDF image.

Determine a strategy for grouping students, and arrange them into cooperative groups/teams. Have students share their individual classifications with their teams. Ask them to arrive at a consensus, and complete the team classification chart on page 22. After students have completed this task, ask that a reporter from each team share and explain his or her team's groupings.

Note: The group sharing process can be facilitated by providing each team with an overhead transparency of page 22 to complete so that results can be more easily and visually shared.

Activity 4: Understanding the Scientific Process

Learning Outcomes

Students will:

- Determine the characteristics used by astronomers to classify galaxies and stars and compare their findings to astronomers' findings.

Materials

- *From Questions to Discoveries Student Workbook* (one per student)
- Astronomers' Chart (one copy per student)

Procedure

Have students refer to the "student directions" provided on page 23 of the *From Questions to Discoveries Student Workbook*. **Optional:** Students may record responses to these questions during the activity.

Provide each student with a copy of the Astronomers' Chart. (The answer key is on page 19 of this booklet.) The students should still be in their working groups. Ask them to compare their team results with the astronomers' results. They also should discuss any similarities and/or differences they notice. Have students share their observations in a class discussion. Discussion prompts include:

- Explain how your teams' results are similar to the astronomers' results.
- Explain how your teams' results are different from the astronomers' results.
- Explain why you think differences exist between your team's results and the astronomers' results.

Emphasize during the discussion that often scientists do not always agree and that it is common to have different results, or more than one possible answer, for a scientific question. What is more important is the process of scientific inquiry and providing evidence for your results.

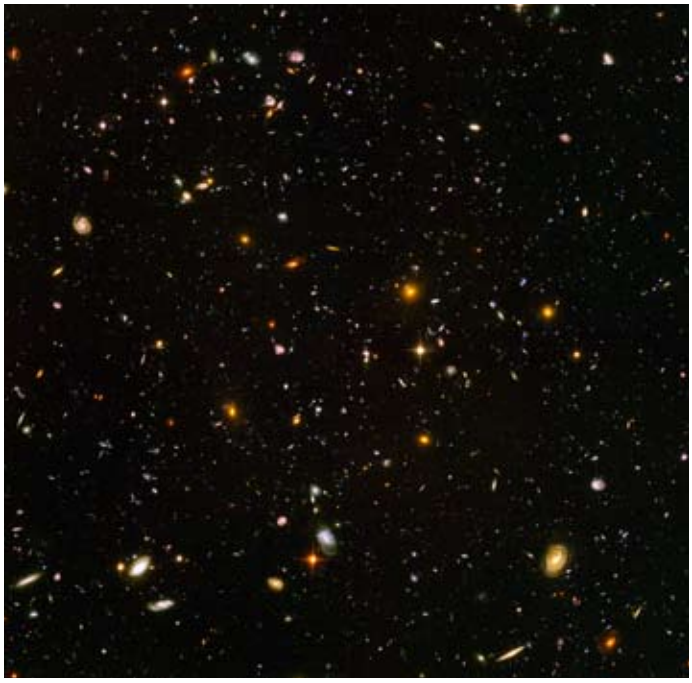
Time for Reflection

Have students think about and summarize some of the new ideas they have learned during this lesson. Ask students to turn to page 24 in their workbooks and answer the questions found on that page.

Note: An online version of this lesson, entitled "Hubble Deep Field Academy," is available at the *Amazing Space* Web site at **http://amazing-space.stsci.edu/resources/explorations**.

The Hubble Ultra Deep Field

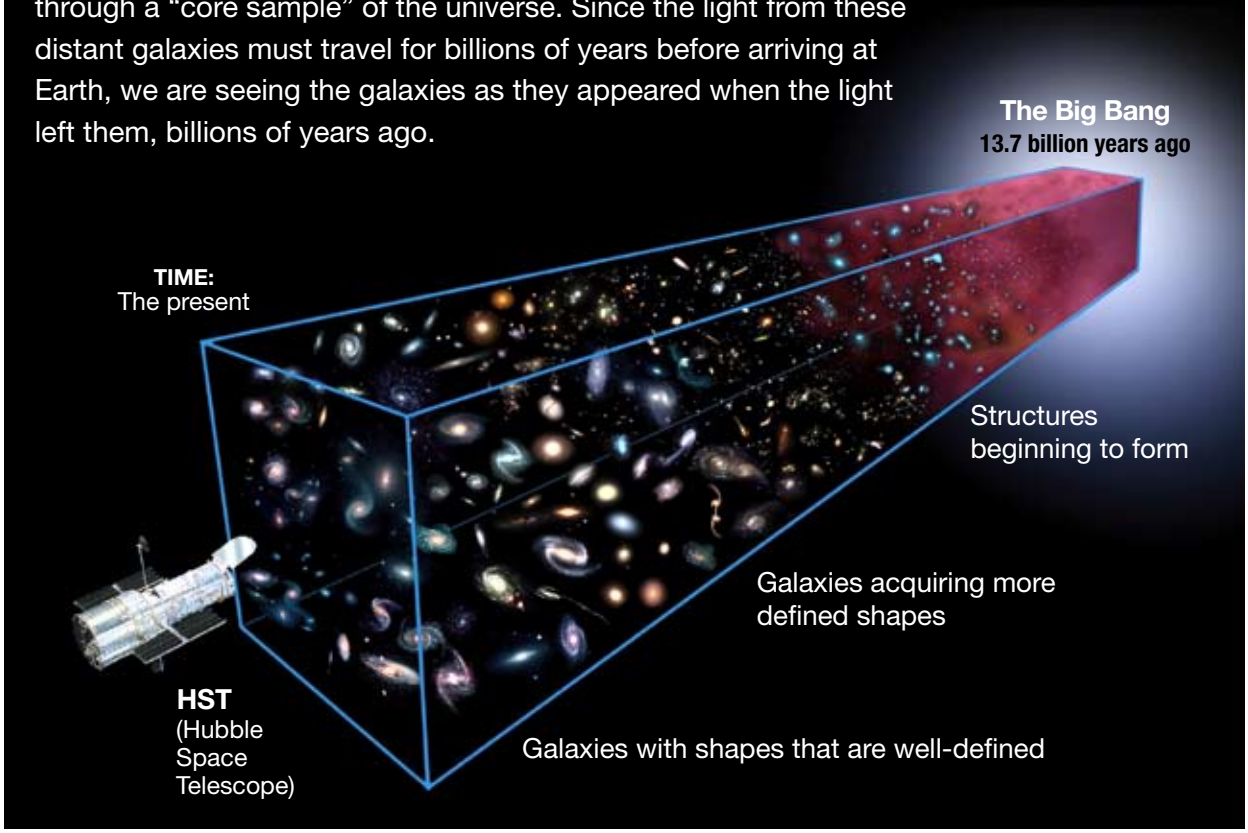
The Hubble Ultra Deep Field (HUDF) is the deepest visible-light portrait of the universe ever achieved by humankind. This image reveals nearly 10,000 galaxies. Some formed shortly after the universe itself was born.



NASA, ESA, S. Beckwith (STScI), and the HUDF Team

HUDF reveals stages of galaxy formation

In the Hubble Ultra Deep Field image, HST looked back in time, through a "core sample" of the universe. Since the light from these distant galaxies must travel for billions of years before arriving at Earth, we are seeing the galaxies as they appeared when the light left them, billions of years ago.



NOTE: The elongated box representing time and distance is not to scale.

STScI Graphic, Ann Didyk

Astronomers' Chart

		Object Shape				
						IRREGULAR
Object Color	BLUE	10				9
	WHITE	5		13	6, 8	14
	YELLOW	12		15	11, 16	3
	RED	1		2, 4	7	

Glossary

Barred Spiral Galaxy:

A type of spiral galaxy that has a "bar" of stars and interstellar matter, such as dust and gas, slicing across its center. The Milky Way is thought to be a barred spiral galaxy.

Blue Star:

Blue stars are very hot and young. Sirius (Alpha Canis Majoris) is an example of a blue star.

Color:

The visual perception of light that enables human eyes to differentiate between wavelengths of the visible spectrum, with the longest wavelengths appearing red and the shortest appearing blue or violet.

Constellation:

A geometric pattern of bright stars that appear grouped in the sky, and which are named after gods, heroes, animals, and mythological beings by ancient astronomers.

Data:

Collected acts, statistics, or information about something being observed, investigated or studied.

Disk:

The disk is a pancake-shaped structure composed primarily of young and middle-age stars, with abundant gas and dust. Some old stars are also present. It surrounds the bulge in a spiral galaxy. The disk in the Milky Way is 100,000 light-years across and 2,000 light-years thick.

Electromagnetic Spectrum:

The entire range of wavelengths of electromagnetic radiation, including radio waves, microwaves, infrared light, visible light, ultraviolet light, X-rays, and gamma rays.

Elliptical Galaxy:

A galaxy that appears spherical or football-shaped. Elliptical galaxies are comprised mostly of old stars and contain very little dust and "cool" gas that can form stars.

Emit:

To send out or give off. The sun emits radiation, some of which we can feel as heat and some of which we can see as light.

Gamma Rays:

The part of the electromagnetic spectrum with the highest energy; also called gamma radiation. Gamma rays can cause serious damage when absorbed by living cells.

Hubble Space Telescope:

An automated telescope that orbits above Earth's atmosphere and is operated jointly by the National Aeronautics and Space Administration and the European Space Agency. Its primary mirror is 2.4 meters (94.5 inches) wide. The telescope contains an array of instruments capable of carrying out a variety of high-quality astronomical observations in ultraviolet, optical, and infrared wavelengths.

Image:

The appearance of an object, as is produced by reflection from a mirror or refraction by a lens.

Infrared (IR) Light:

The part of the electromagnetic spectrum that has slightly lower energy than visible light, but is not visible to the human eye. Just as there are low-pitched sounds that cannot be heard, there is low-energy light that cannot be seen. Infrared light can be detected as the heat from warm–blooded animals.

Irregular Galaxy:

A galaxy that appears disorganized and disordered, without a distinct spiral or elliptical shape. Irregular galaxies are usually rich in interstellar matter, such as dust and gas. The Large and Small Magellanic Clouds are examples of nearby irregular galaxies.

Light-Year:

The distance traveled by light in a full year, equal to some 10 trillion kilometers (or about 6 trillion miles).

Milky Way:

The specific galaxy to which the Sun belongs, so named because most of its visible stars appear overhead on a clear, dark night as a milky band of light extending across the sky. The Milky Way is a spiral galaxy.

Observation:

In science, an observation is a fact or occurrence that is noted and recorded. The Hubble Space Telescope is a tool astronomers use to make observations of celestial objects.

Orbit:

The act of traveling around a celestial body; or the path followed by an object moving in the gravitational field of a celestial body. For example, the planets travel around, or orbit, the Sun because the Sun's gravitational field keeps them in their paths, or orbits.

Radiation:

The process by which electromagnetic energy moves through space as vibrations in electric and magnetic fields. This term also refers to radiant energy and other forms of electromagnetic radiation, such as gamma rays and X-rays.

Radio Waves:

The part of the electromagnetic spectrum with the lowest energy. Radio waves are the easiest way to communicate information through the atmosphere or outer space.

Red Star:

These are old stars because they have a cooler temperature and a red color. Betelgeuse (Alpha Orionis) is an example of a red star.

Reflection:

Reflection occurs when light changes direction as a result of "bouncing off" a surface like a mirror.

Refraction

Refraction is the bending of light as it passes from one substance to another. Here, the light ray passes from air to glass and back to air. The bending is caused by the differences in density between the two substances.

Satellite:

A man-made object that orbits Earth, the Moon, or another celestial object.

Spiral Arms:

Spiral arms are waves that develop in the disk of a spiral galaxy. They are like the ripples that appear on a pond after tossing a stone into it. Spiral arms contain blue and luminous new stars that are born there. They make the spiral pattern visible.

Spiral Galaxy:

A galaxy made up of a disk, spiral arms, and a bulge at its center. The size of the disk and the bulge vary. The galaxy is composed of a mixture of old and young stars as well as loose interstellar matter.

Star:

A huge ball of gas held together by gravity. The central core of a star is extremely hot and produces energy. Some of this energy is released as visible light, which makes the star glow. Stars come in different sizes, colors, and temperatures. Our Sun, the center of our solar system, is a yellow star of average temperature and size.

Ultraviolet (UV) Light:

The part of the electromagnetic spectrum that has slightly higher energy than visible light, but is not visible to the human eye. Just as there are high-pitched sounds that cannot be heard, there is high-energy light that cannot be seen. Too much exposure to ultraviolet light causes sunburns.

Visible Light:

The part of the electromagnetic spectrum that human eyes can detect; also known as the visible spectrum. The colors of the rainbow make up visible light. Blue light has more energy than red light.

X-Rays:

The part of the electromagnetic spectrum with energy between ultraviolet light and gamma rays. X-rays are used in medicine to detect broken bones and cavities in teeth. Astronomers can detect X-rays from exploding stars and black holes.

Yellow Star:

These stars are middle-aged and not extremely cool nor hot for a star. Earth's Sun is an example of a yellow star.