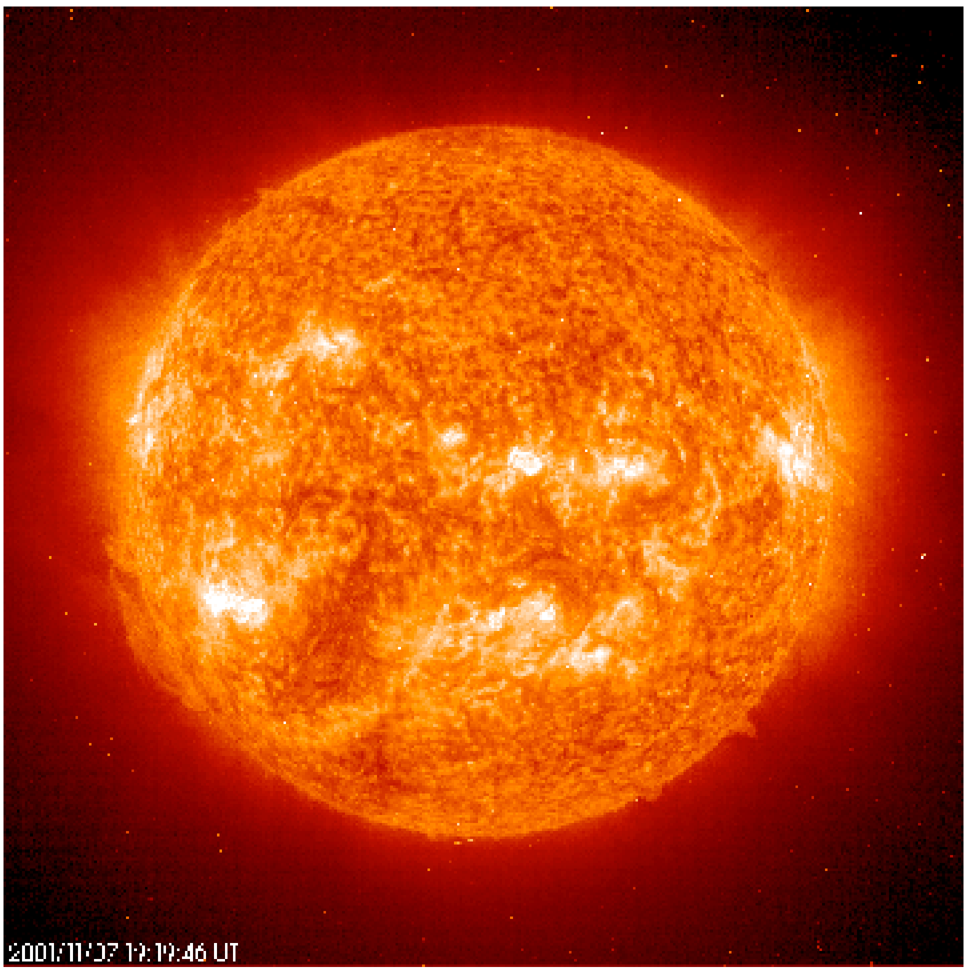
LESSON 5



MYSTERY LIGHT

Purpose: Students will develop research techniques useful for further exploration, using models developed in previous lessons. Students will design their own experiment to explore the conditions under which special beads change color. Since these beads actually change in the presence of UV light, this lesson will allow them to discover the existence of another non-visible light, ultraviolet, outside of the visible light spectrum. Students will also learn how ultraviolet light is used in science.

Benchmarks for Science Literacy:

- Scientists differ greatly in what phenomena they study and how they go about their work. **Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.** 1B/1 (6-8)
- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables), but **collaboration among investigators can often lead to research designs that are able to deal with such situations.** 1B/2 (6-8)
- **Sometimes scientists can control conditions in order to focus on the effect of a single variable.** When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns. 1B/3 (9-12)
- **Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves**; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. 4A/3(9-12)
- Accelerating electric charges produce electromagnetic waves around them. **A great variety of radiations are electromagnetic waves**: radio waves, microwaves, radiant heat, **visible light, ultraviolet radiation**, x rays, and

gamma rays. These wavelengths vary from radio waves, the longest, to gamma rays, the shortest. In empty space, all electromagnetic waves move at the same speed—the "speed of light." 4F/3 (9-12)

National Science Education Standards:
Grades 5-8

Science As Inquiry-Understanding About Scientific Inquiry

- **Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.**
- **Scientific explanations emphasize evidence, have logically consistent** arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.

Physical Science – Transfer of Energy

- The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. **The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.**

History and Nature of Science – Science as a Human Endeavor

- Science requires different abilities, depending on such factors as the field of study and type of inquiry. Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skill, and creativity--as well as on scientific habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.

History and Nature of Science – Nature of Science

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.

History and Nature of Science – History of Science

- Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.

Grades 9-12

Science as Inquiry – Abilities Necessary to do Scientific Inquiry

- COMMUNICATE AND DEFEND A SCIENTIFIC ARGUMENT. Students in school science programs should develop the abilities associated with accurate and effective communication. **These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments.**

Physical Science- Interactions of Energy and Matter

- Electromagnetic waves result when a charged object is accelerated or decelerated. **Electromagnetic waves include** radio waves (the longest wavelength), microwaves, **infrared radiation (radiant heat), visible light, ultraviolet radiation**, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.

Background:

When Johann Wilhelm Ritter heard of Herschel's work, Ritter reasoned that there might be invisible radiation on the other end of the spectrum – beyond violet. Ritter was an accomplished chemist, and he used his knowledge of chemistry to test his theory. He knew that blue light decomposed silver chloride to silver more efficiently than red light. He reasoned that non-visible light beyond blue might be even more efficient. He was right! When he exposed paper covered with silver chloride to the complete spectrum of sunlight that had passed through a prism, the silver chloride in the region beyond violet (where there was no visible light!) decomposed the fastest. From this experiment Ritter knew that there must be light beyond violet. This radiation came to be known as ultraviolet light.

If you need more background information on the electromagnetic spectrum, you might want to start with two readings that will be assigned to your students at the end of this lesson; "Electromagnetic Spectrum" and "How Astronomers Use the Electromagnetic Spectrum" on the *STP Education* website http://stp.gsfc.nasa.gov. These readings will lead you to other sources if you desire more depth.

This investigation will be very challenging for your students. The primary goal, however, is to engage them in the process of inquiry. The content goal – to discover ultraviolet light - is secondary. Your students have seen several different models for inquiry in the past lessons. There are structures provided within this lesson to help them to design a more effective procedure. And you will be available for coaching. The following information is provided to help you provide the coaching.

This investigation will use special beads that change color when exposed to ultraviolet light. The color change is fast and dramatic in strong UV light. In direct sunlight the beads will change from white or silver to a deep color (there are 6 colors available from the supplies (see Appendix): red, blue, purple, orange, yellow and copper). Normal indoor light sources such as incandescent and fluorescent do not produce sufficient UV radiation to change the beads. Depending on the filtering quality of your classroom windows, UV from sunlight may or may not penetrate. Because UV is scattered by the atmosphere in a manner similar to blue light (that is why the sky is blue), UV will come from all parts of the sky. This means that beads will change colors out of direct sunlight and even on very cloudy days. The time it takes to reach a particular deepness of color will be longer, however.

An "ideal" apparatus and procedure for this investigation have been provided for you in **A Modified Ritter Experiment: Discovering Ultraviolet Light** contained in the Appendix. You will see in the description of the apparatus for **A Modified Ritter Experiment: Discovering Ultraviolet Light**, that the top is left on the box and a small flap is cut in the top to allow viewing while still screening reflected UV light. When students separate the direct sunlight into the spectrum, and place beads in various regions of the spectrum, all beads will change color if they do not screen out reflected light. You may wish to ask questions that will lead them to discover that the beads change color even when the beads are not in direct sunlight.

The procedure for **A Modified Ritter Experiment: Discovering Ultraviolet Light** works quite well. The beads are separated by knots and the shoelace used is thick to create a knot large enough to shield each bead from reflected UV. Without this shielding the bead in the violet/blue may change color because of UV light reflected from the bead in the UV region.

Even though you still have a content goal – to discover UV light-, the experimental process is more important. The purpose and questions on the student sheet, **Mystery Light**, will help to guide their investigation. The Peer Review process will further aid the refinement of their experimental design. In addition, you will need to provide guidance and coaching. However, do not defeat the discovery process by forcing the students to perform the "ideal" experiment. Hopefully, at least one group will discover UV light. This will come out in the final presentations. In the worst case, no one discovers UV, and you can then ask questions of their procedures (for example, "Did you examine both sides of the spectrum as we did in the previous experiment?", and "Did you protect your beads from reflected light? What would happen if you covered the box and only let light in through the prism?"). You could then have the class brainstorm further adjustments and repeat the experiment with these adjustments. Alternatively, you could have the materials from **A Modified Ritter Experiment: Discovering Ultraviolet Light** on hand and do the experiment with them immediately.

Overview of Student Assignments for Mystery Light

1. **Students Investigation Procedure and Guide Questions** is a laboratory investigation that provides the problem to be solved by the investigation and leaves the design of the investigation to the student.
2. **Peer Review in the Science Classroom** (Appendix) provides a process that aids the students in the development of more effect designs for inquiry.
3. **Lab Report Format**, **Journal Article Format**, and **PowerPoint©/Webpage/Poster Presentation** (Appendix) are three different formats from which you can choose for student presentation of results of their investigation.
4. **Prediction Reflection** (Appendix) asks your students to reflect upon their process, their thinking, what went right, and what they would improve.
5. **Reading Assignment** "Electromagnetic Spectrum" and "How Astronomers Use the Electromagnetic Spectrum" on the *Solar*

terrestrial Probes (STP) Education website http://stp.gsfc.nasa.gov. Then do the activities 'Understanding Solar Spectra – Fun with Spectra' on the *SERTS (Solar Extreme-ultraviolet Rocket Telescope)* web site http://orpheus.nascom.nasa.gov/serts/.

Materials:

- 15 special (UV) beads per group
- 5 dark film canisters per group
- Equilateral **glass** prism per group
- Prism holder (optional) per group
- Tape per group
- Cardboard box per group (have available the copier paper boxes used in **Getting Hotter?**)
- **Peer Review Guidelines** (Appendix) for each student
- **Mystery Light** Student Investigation for each student
- Equipment to be determined by group
- Report guidelines for each student (**Lab Report Format**, **Journal Article Format**, and **PowerPoint©/Webpage/Poster Presentation** from Appendix or design your own).
- **Prediction Reflections** for each student
- Reading assignments for each student or assign as computer assignment

Preparation and Procedures:

1. Assign the problem as defined in **Mystery Light: Student Investigation Procedure and Guide Questions** and discuss the process. Ask your students to describe the techniques of investigation used in previous lessons. Have them describe the structure of the investigations and the strengths and weaknesses of the procedures. Ask them questions about the control of variables in earlier lessons. Also hand out **Peer Review** instructions and describe the process and the advantages of peer review in design. Assign groups, hand out materials, and tell them when their preliminary procedures are due for presentation for Peer Review. As the students take on more responsibility for the design and execution of the

investigation, your role changes as well. In this investigation you provide the questions to be answered and a new technique, Peer Review, to aid them in the design of the investigation. Be prepared to provide gentle guidance in the form of questions. For example, "How would you find out what kinds of light cause the reaction?"

2. The final student activity in this investigation is the student presentation. You may choose from a variety of formats. Evaluative criteria for three report formats are provided in the Appendix. The **Lab Report Format** is a traditional lab report with Purpose, Procedure, Errors, Data and Conclusion sections. The **Journal Article** is modeled after the format used by scientists for scientific journals. You may find a **PowerPoint©/Webpage/Poster Presentation**, also used by scientists at conferences, to be more valuable to you and your students.
3. No matter what format you choose for student presentations, you should conduct a class discussion of results and conclusions.
4. Assign a journal assignment using a modification of a **Prediction Reflection** to have your students reflect upon their process, their thinking, what went right, and what they would improve.
5. Follow the **Prediction Reflection** with a discussion of the nature of scientific research. Ask the students about their process of investigating the questions asked in the Purpose. Ask them how they might improve the process.
6. After students have completed the above assignments, extend their knowledge of light with the following applications to NASA science. Assign "Electromagnetic Spectrum" and "How Astronomers Use the Electromagnetic Spectrum" on the *STP Education* website http://stp.gsfc.nasa.gov. Then do the activities 'Understanding Solar Spectra - Fun with Spectra' on the *SERTS* (Solar Extreme-ultraviolet Rocket Telescope) web site http://orpheus.nascom.nasa.gov/serts/.

Evaluation

Students should be able to achieve a very good evaluation even if they do not discover that the light that affects the beads comes from beyond the violet. Students might lose a couple of points if they didn't determine if reflected light would affect the beads. It is a more serious omission if they did not follow the model from the previous lab to check on both sides of the visible spectrum. The primary goals are to design a thoughtful experiment appropriate to the question, to execute the experiment carefully and to interpret the evidence effectively.