National Aeronautics and
Space Administration

Educational Product	
Educators & Students	Grades 5–12

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Educational Brief

CASSINI SCIENCE INVESTIGATION

Monitoring the Sun's Corona

Objective

To learn how spacecraft use the relative positions of the Sun, Earth, and a spacecraft to study the Sun's outer region, called the corona.

Time Required: 1 hour

Saturn System Analogy: Cassini's Radio Science Subsystem

Keywords: Corona, Plasma, Solar Conjunction

MATERIALS

1. Shared Effect Demonstration

- Laser pointer. *The laser pointer will serve as the transmitted signal.*
- Clear plastic food wrap. *Wrap that is wrinkled and has many layers is recommended, mounted on a coat-hanger or cardboard frame for easy handling. The food wrap will serve as the coronal plasma. Transparent packaging tape can also be used.*
- Projection screen or a large sheet of white paper. *The projection screen or white paper will serve as the signal receiver.*
- Two large binder clips

2. Direct Analog Demonstration

- High-intensity AA or AAA flashlight with a removable reflector that uses a grain-of-wheat size bulb. *The flashlight should be able to stand in view of the students so that the tiny, brilliant filament is visible. The flashlight will serve as part of the transmitter.*
- Separate pieces of transparent red and blue filter material. *This can be a candy wrapper, cellophane gift wrapping material, colored food wrap, or commercial photographic filter material. The filter material will also serve as part of the transmitter.*

One of the giant antennas in NASA's Deep Space Network.

- Clear plastic food wrap. *Wrap that is wrinkled and has many layers is recommended, mounted on a coathanger or cardboard frame for easy handling. The food wrap will serve as the coronal plasma. Transparent packaging tape can also be used.*

3. Hybrid Demonstration

- Overhead projector. *The projector serves as part of the transmitter.*
- Projection screen or a large sheet of white paper. *The projection screen or white paper will serve as the signal receiver.*
- Opaque cardboard or paper to completely cover the projector top
- Ruler; tape measure; fine-point pencil
- Transparent red and blue filter material. *This can be a candy wrapper, cellophane gift wrapping material, colored food wrap, or commercial photographic filter material. The filter material will also serve as part of the transmitter.*
- Clear plastic food wrap. *Wrap that is wrinkled and has many layers is recommended, mounted on a coathanger or cardboard frame for easy handling. The food wrap will serve as the coronal plasma. Transparent packaging tape can also be used.*

Discussion

On many space missions, a spacecraft observed from Earth can be seen to travel behind the Sun. This spacecraft–Sun–Earth alignment is called solar conjunction. During solar conjunction, the increased distance from Earth and the interference of solar radio emissions seriously degrade the quality of transmitted information — known as telemetry — from a spacecraft to Earth, where NASA's Deep Space Network antennas receive the information. During solar conjunction, scientists have the opportunity to study the Sun's outermost layer, called the corona.

The corona is composed of plasma, a "gas" of atoms broken down into negatively charged electrons and positively charged ions. The corona is the source of the solar wind, a stream of plasma that blows out from the Sun at speeds from 300 to 1600 kilometers per second (200 to 1000 miles per second). The solar wind is so strong and far-reaching that it can be detected by spacecraft flying beyond Pluto.

Telemetry from a spacecraft is transmitted back to Earth via radio waves. When in solar conjunction, these radio waves must pass through both the corona and solar wind. The electrified nature of the corona and solar wind can distort the signal before it reaches Earth. Over a period of a few days, radio waves from a spacecraft in solar conjunction may pass through plasma that is dense enough and variable enough to noticeably affect reception. (This phenomenon can be compared to the way water waves distort the view of objects on the floor of a swimming pool or to the twinkling of stars caused by Earth's atmosphere.) By analyzing variations in the telemetry data from a spacecraft in solar conjunction, scientists can study the corona and solar wind. For example, if a spacecraft can transmit at two widely different radio frequencies, scientists can assess the density variation of electrons in the plasma through which the telemetry signal passes. In the two-color demonstrations described below, the ratio of frequencies for red and blue is less than half of the ratio for the radio frequencies used. Thus, this optical demonstration will not easily display the differences in the signals seen with radio waves.

Background

The bending of light and radio waves by a medium depends on the refractive index of the medium and the thickness of the refracting (bending) layer. Radio signals from a spacecraft in solar conjunction traverse millions of kilometers of very low refractivity solar plasma while the light waves in these demonstrations traverse very thin layers of plastic with more refractivity.

The physics of the light-plastic and radio-plasma interactions are not the same. But these demonstrations using light present results that are analogous to the real investigations researchers do. The physics of the interactions (not just the results) are analogous for radio studies of planetary atmospheres, during which the radio signals pass through a planet's atmosphere on their way to Earth (a geometric condition called an occultation).

Procedure

Three methods using visible-light sources illustrate the effects of solar plasma on spacecraft-transmitted radio waves. In the Direct Analog Demonstration, the flashlight serves as the "spacecraft" and the students are the "receivers" of the Deep Space Network.

Shared Effect Demonstration

Darken the room, if possible. Project the laser beam toward the screen using one binder clip as a stand and the other clip to hold the laser's switch in the "ON" position (no specific distance from laser to screen is required). The projected laser light will look like a "clean" point of light.

CAUTION: BE CAREFUL NOT TO SHINE THE LASER BEAM INTO ANYONE'S EYES. EYE DAMAGE CAN RESULT.

Pass the plastic wrap across the laser beam. Observe how the laser beam is broadened, distorted, bent, and scattered. Move the plastic wrap across the beam and at different distances from the laser pointer. Observe how the laser beam changes due to the variations in the density and position of the plastic wrap.

Direct Analog Demonstration

With the flashlight bulb exposed (remove the reflector assembly), wrap the colored filter material around the flashlight so that the emitted light is colored. The combination of the filter and light serves as the spacecraft sending radio signals. Have the students observe the emitted light as you pass the plastic wrap between the students and the bulb. Students will notice the distortion of the light. Switch colored filters and repeat. Are there noticeable differences in the distortion of red and blue light? The light rays from the flashlight should traverse the same strip of plastic wrap if possible.

Hybrid Demonstration

Punch a small (less than 5 millimeters), sharp-edged circular hole in the middle of the cardboard projector cover. Tape a color filter over the hole. A colored spot will be projected onto the screen. Have the students observe the colored spot. Pass the plastic wrap over the hole. Students will notice the distortion of the image of the hole. Switch colored filters and repeat. Are there noticeable differences in the distortion of the image of the hole? The light beam from the projector should traverse the same strip of plastic wrap if possible.

Extension

These demonstrations can be quantified using a solar cell and a multimeter. Record the voltage at specific, repeatable points where light from the source passes through the plastic. Several vendors offer light-measuring photometry systems that acquire data and plot it under computer control. Such systems can be adapted for the measurements in this activity. Computerized data acquisition is common in many laboratories.

Science Standards

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

12. Understands the nature of scientific inquiry.

LEVEL I (GRADES K–2)

Knows that learning can come from careful observations and simple experiments.

Knows that tools (e.g., thermometers, magnifiers, rulers, balances) can be used to gather information and extend the senses.

LEVEL 2 (GRADES 3–5)

Knows that scientists use different kinds of investigations (e.g., naturalistic observation of things or events, data collection, controlled experiments), depending on the questions they are trying to answer.

Plans and conducts simple investigations (e.g., formulates a testable question, makes systematic observations, develops logical conclusions).

Uses appropriate tools and simple equipment (e.g., thermometers, magnifiers, microscopes, calculators, graduated cylinders) to gather scientific data and extend the senses.

LEVEL 3 (GRADES 6–8)

Designs and conducts a scientific investigation (e.g., formulates hypotheses, designs and executes investigations, interprets data, synthesizes evidence into explanations, proposes alternative explanations for observations, critiques explanations and procedures).

LEVEL 4 (GRADES 9–12)

Designs and conducts scientific investigations (e.g., formulates testable hypotheses; identifies and clarifies the method, controls, and variables; organizes, displays, and analyzes data; revises methods and explanations; presents results; receives critical response from others).

Knows that, when conditions of an investigation cannot be controlled, it may be necessary to discern patterns by observing a wide range of natural occurrences.

Uses technology (e.g., hand tools, measuring instruments, calculators, computers) and mathematics (e.g., measurement, formulas, charts, graphs) to perform accurate scientific investigations and communications.

***Teachers** — Please take a moment to evaluate this product at* http://ehb2.gsfc.nasa.gov/edcats/educational_brief.
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.

Student Worksheet — Monitoring the Sun's Corona

Procedure

The teacher will set up and describe the three demonstrations for you.

Shared Effect Demonstration

- Project the laser beam onto the screen. Observe how the beam looks on the screen.
- Pass a piece of plastic wrap across the laser beam. Observe how the beam is affected by the plastic wrap.
- Try this at different distances from the laser and observe the effect.
- What role does the distance of the plastic wrap "plasma" from the laser play in distorting the beam?

Direct Analog Demonstration

- Wrap a piece of colored filter material around the flashlight bulb — don't let the bulb melt the filter.
- Pass the plastic wrap across the beam of light. Observe how the light source is distorted.
- Repeat this by passing the plastic wrap at different distances across the beam of light and with the other colored filter. What role does the distance of the plastic wrap "plasma" from the flashlight play in distorting the beam? Is more distortion seen with one color or the other? Why or why not?

Hybrid Demonstration

- Punch a small, sharp-edged circular hole in the middle of the cardboard cover.
- Tape the colored filter material over the hole.
- Pass the plastic wrap across the beam of light. Observe how the image is distorted.
- Repeat this after changing the colored filter. Is more distortion seen with one color or the other? Why or why not?