

Using Spectral Data to Explore Saturn and Titan

Middle grades

Lesson Summary

Students compare known elemental spectra with spectra of Titan and Saturn's rings from a spectrometer aboard the NASA Cassini spacecraft. They identify the elements visible in the planetary and lunar spectra.

Prior Knowledge & Skills

- Identifying patterns
- Nature of light

AAAS Science Benchmarks

The Physical Setting

The Earth

Energy Transformations

The Nature of Science

Scientific Inquiry

NSES Science Standards

- **Science as inquiry:** Abilities necessary to do scientific inquiry
- **Physical science:** Transfer of energy
- **Earth and space science:** Earth in the solar system, Structure of the earth system
- **Unifying concepts and processes:** Evidence, models and explanation

NCTM Mathematics Standards

- **Data analysis and probability:** Develop and evaluate inferences and predictions that are based on data

Teaching Time: One 45-minute period

Materials

Each student will need:

- A copy of the "Using Spectral Data" handout

Advanced Planning

Preparation Time: 20 minutes

1. Copy handouts
2. Review lesson plan

Why Do We Care?

The Ultraviolet Imaging Spectrograph (UVIS), which recorded the data used in this activity, is one of the instruments currently orbiting Saturn aboard the Cassini spacecraft. UVIS spectra show the intensity of ultraviolet light emitted by or reflected off an object over a range of light wavelengths. Astronomers use the distinctive pattern of peaks and valleys in each spectrum to uncover the chemical makeup of objects in the Saturn system, like its rings and moons.

Suggested background reading

The Instruments on UVIS

Cassini Mission to Saturn

Cassini Spacecraft and Huygens Probe

Cassini-Huygens Mission to Saturn

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Activity Dependency Graphing the Rainbow

Group Size 1

Expendable Cost per Group \$0

Engineering Connection

The instruments aboard Cassini were engineered to gather data about Saturn and Saturn's moons and rings. Mechanical and electrical engineers build these instruments to help advance our knowledge of planetary science.

Pre-Requisite Knowledge

Students should have some understanding of the nature of light i.e. rainbows are formed with light. Students should be familiar with graphical representations of data, such as line plots.

Learning Objectives

After this lesson, students should be able to:

- Explain that spectral data correlates to chemical compositions
- Match plots of real data to experimentally known data
- Describe how scientific data relates to scientific discovery

Introduction / Motivation

Show students the PowerPoint, "Spectrographs" from the CDrom

In 1997, NASA launched the Cassini spacecraft, the first spacecraft to orbit Saturn. Since June 30th of 2004, Cassini has been sending back images and data from Saturn, its rings, and its Moons, including Saturn's largest moon, Titan. Engineers collaborated with scientists to create instrumentation that sits onboard Cassini. Mechanical, electrical, and aerospace engineers made sure the components of Cassini work properly and could withstand the launch and rigors of space travel. The spacecraft needs to be able to communicate with people on Earth, operate in very cold and harsh conditions, and be able to travel in the right direction! All of these things require appropriate engineering to make sure the spacecraft is healthy, going the right way, and able to send data back to Earth.

Cassini carries 12 different science instruments, including optical and microwave cameras and spectrometers. One of these instruments is the Ultraviolet Imaging Spectrograph (UVIS). Spectrographs measure the wavelengths and intensities of light coming from objects in space. Every chemical element emits light at a characteristic set of light wavelengths. By looking at the spectral 'fingerprints' of an object, like those generated from UVIS data, scientists can determine what the object's chemical composition is.

Today, you will look at two spectra from the Ultraviolet Imaging Spectrograph (UVIS) that traveled to Saturn aboard the Cassini spacecraft. After you look at these

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images on the first page, on the second page, you will find the known spectra of four elements, hydrogen (H), helium (He), nitrogen (N) and krypton (Kr).

Match the patterns of peaks and valleys you see in the known spectra with those you see on the spectra from UVIS to determine what elements UVIS is seeing in Saturn's rings and on Titan. Enter your answers on the worksheet provided.

Vocabulary / Definitions

Word	Definition
Spectrum (plural: spectra)	The pattern light produces as can be seen through a spectrograph
Spectrometer (also Spectroscope, Spectrograph)	A tool that allows the components of light to be seen easily with the eye.
Titan	A moon of Saturn that has an incredibly thick atmosphere.
Microwave	A type of light that can be detected with a Microwave camera.
Ultraviolet	A type of light that can be detected with an ultraviolet detector.

Procedure

Background

See also background from the "Graphing a Rainbow" Activity.

It is highly recommended that you read the following articles:

<http://www.pbs.org/wgbh/nova/titan/atmosphere.html>

http://planetquest.jpl.nasa.gov/science/finding_life.html

Light is sometimes what scientists call the electromagnetic (E-M) spectrum, of which visible light is only a small portion. Other types of E-M radiation include Gamma Rays, X-Rays, UV, infrared, microwave and radio. Light can be thought of as both a wave and a particle in all cases. The more energetic the particle of light, the shorter wavelength, and hence, smaller frequency, it will have. Gamma rays are the most energetic, and radio are the least.

Spectral patterns of a gas can be shown on a plot such that the x-axis is the wavelength of the light, and the y-axis is the intensity of the light. Plotted in this way, scientists can determine if laboratory measurements of a gas match with data obtained elsewhere because every element has a unique signature. In this activity, students will compare the spectral lines in Titan's and Saturn's atmosphere with laboratory measurements of spectra.

Titan has a thick atmosphere consisting mostly of nitrogen, similar to the Earth's. The gravitational properties of a large moon like Titan are very different from those of a debris field like the rings. Titan's gravity captures atoms like nitrogen that would

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otherwise escape to space. Unlike Titan's atmosphere, Earth's atmosphere contains oxygen, mostly a result of photosynthesis. Before there were plants, we did not have oxygen in our atmosphere (see figure 1). We might speculate that Titan has no plant life (at least as we know it) because Titan's atmosphere lacks oxygen.

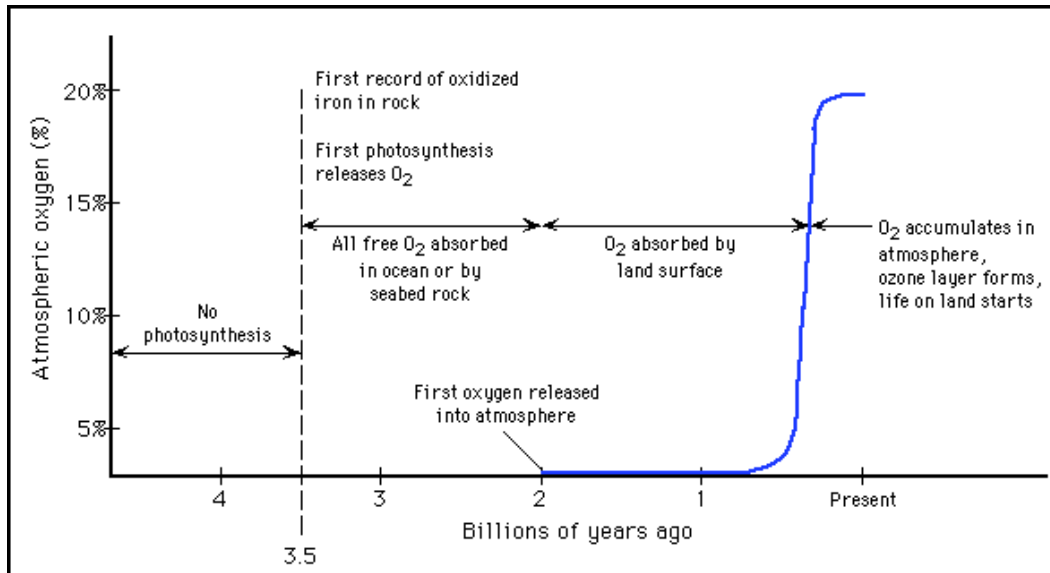


Figure 1

This is a timeline that describes when the Earth obtained its oxygen atmosphere and why. Two billion years ago, the first oxygen was released into the atmosphere.

Image file path: <http://eesc.columbia.edu/courses/ees/slides/life/oxygen2.gif>

Source/Rights: Columbia University, NY

Troubleshooting Tips

Severely vision-impaired and blind children will have difficulty with this activity. Students with corrective lenses will not have difficulty. Students can be paired to assist them with the activity.

Assessment

Pre-Lesson Assessment

Assessing prior knowledge: Ask students what they can tell you about light. Probe them for what they already know and understand. Ask students if they are familiar with any engineered devices that people use as tools to help them determine values that they cannot "see" i.e. thermometers, barometers, radon detectors, x-ray machines, etc.

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Post-Introduction Assessment

Class discussion: Ask students why they think instrumentation is needed to get this type of data, and for what the data could be used. Ask students how they think engineers develop instrumentation. It is important to honor creative answers.

Post-Activity Assessment

Review answers to questions aloud.

Activity Extensions

Complete the “Building a Fancy Spectrograph” activity.

References

Fisher, Diane. “Taking Apart the Light.” “The Technology Teacher.” March (2002).

Owner

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Contributors

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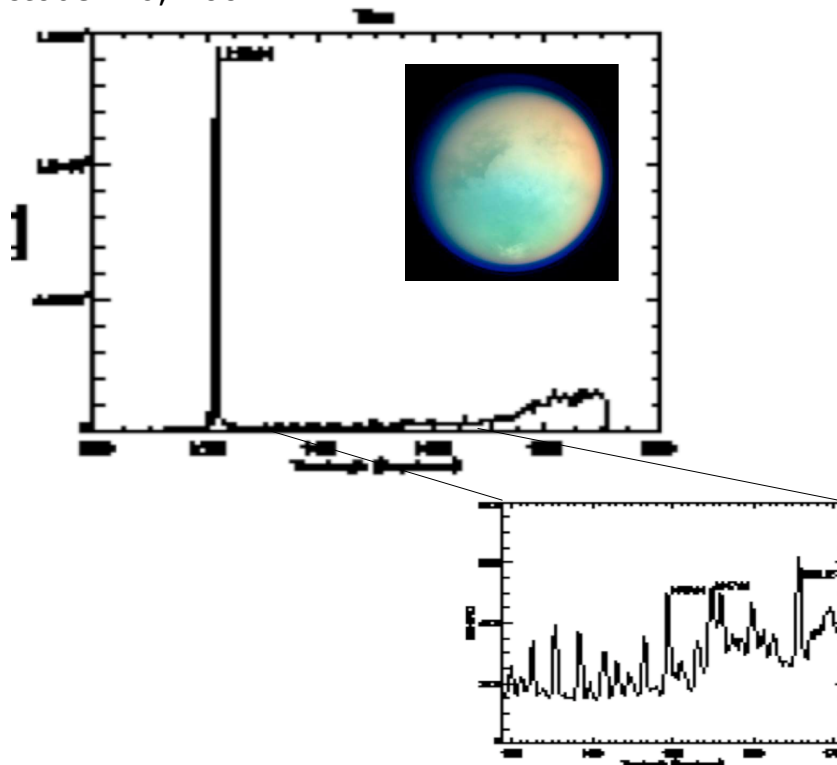
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Students Directions

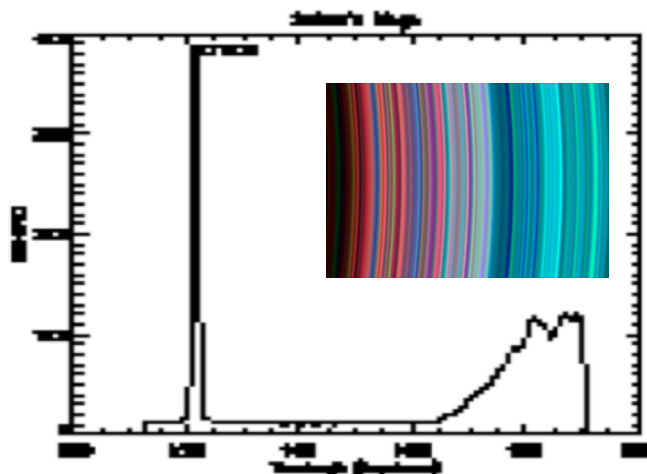
Name _____

Directions: Look at the data on page one and two. Page one shows the spectra of Titan and Saturn's rings. Page two shows known spectra of specific elements. Compare both pages and determine what elements are present in Titan's atmosphere and in Saturn's rings and answer the questions on page three.

a) Titan, October 26, 2004

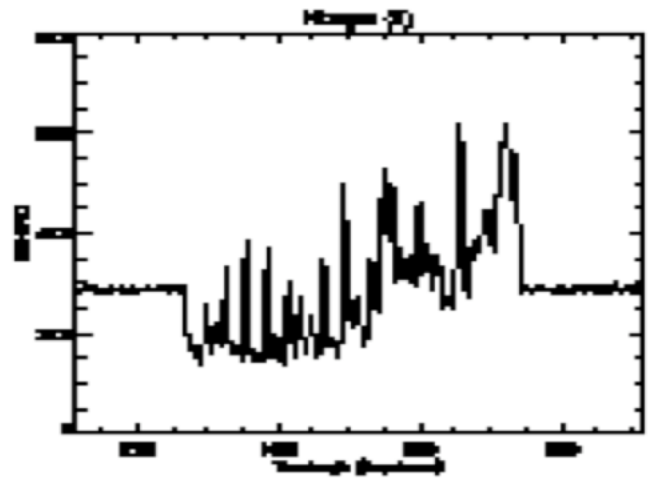
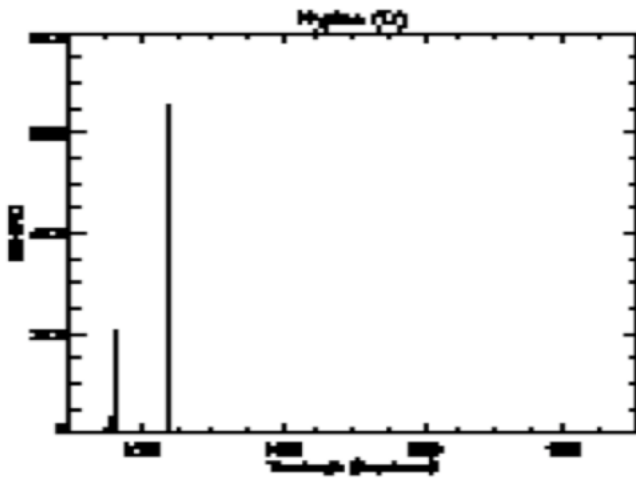
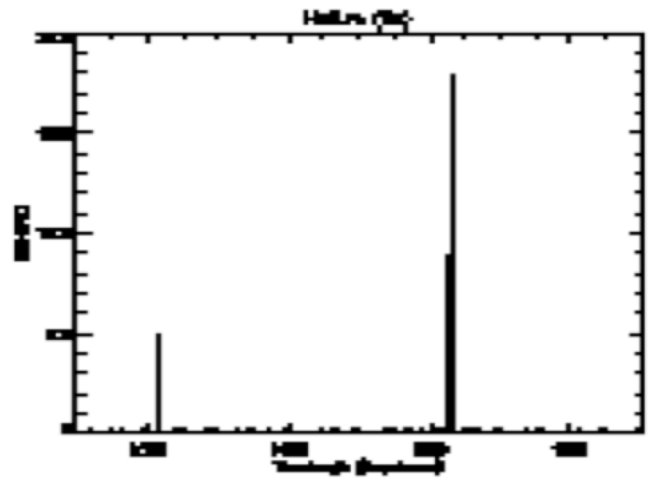
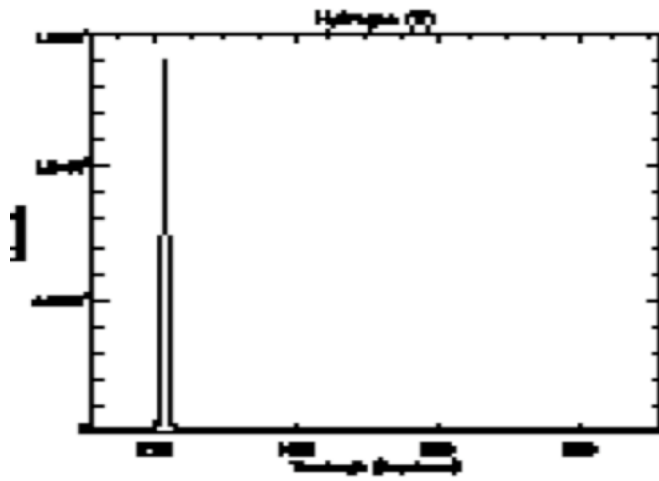


b) Saturn's rings, June 30, 2004



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Known Spectra



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Worksheet

1. Elements present in spectrum (a), Titan, are:

2. Elements present in spectrum (b), Saturn's rings, are:

3. Why is hydrogen so abundant in these spectra? (Hint: What do you know about the structure of hydrogen and about its abundance in the universe?)

4. Why do you think nitrogen is present in the spectra from Titan but not in the spectra of Saturn's rings?

5. Using the tables below, compare and contrast the composition of Titan's atmosphere and Earth's atmosphere. What are some reasons these differences might exist?

Titan

Nitrogen	95%
Methane	3%
Argon	2%

Earth

Nitrogen	78%
Oxygen	21%
Argon	1%

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Answer key

1. Hydrogen and nitrogen
2. Hydrogen
3. Hydrogen is the simplest and most abundant element in the universe, so we expect to find it in high concentrations throughout the solar system. The hydrogen signature in the ring spectra, however, actually comes from hydrogen present in interplanetary space. The light shines through the rings and isn't actually emitted by the rings themselves. *Supplemental question:* What techniques could scientists use to remove the signature of interplanetary gas from their data? *Answer:* Scientists can compare the spectrum of "empty" space to the spectrum of the object being observed and subtract off the interplanetary "background."
4. Titan has an atmosphere. The gravitational properties of a large moon like Titan are very different from those of a debris field like the rings. Titan's gravity captures atoms like nitrogen that would otherwise escape to space. *Fun Fact:* Nitrogen isn't always visible in Titan's spectrum: it can be seen only during a Titanian aurora, when electrons from the sun become trapped in Saturn's magnetic field and hit Titan's upper atmosphere. This energizes the nitrogen atoms and causes them to emit light.
5. Earth's atmosphere reflects its inhabitants, as well as complex chemical processes. Oxygen is present in Earth's atmosphere as a result, among other things, of photosynthesis, the process that plants use to breath. It uses carbon dioxide and gives off oxygen as a by-product. The oxygen in the atmosphere forms our protective ozone layer that shields us from incoming solar radiation.