

The Expanding Universe

Instructional Objectives

After viewing the program and participating in accompanying activities, the student will be able to:

1. explain the importance of cepheid variables to astronomers,
2. explain how the redshift is an indicator of recession velocity, and
3. state an analogy to explain why we can perceive all the other galaxies to be moving away from us and yet not be at the center of the universe.

Synopsis

This program begins with "HST Data Stream" with Dr. Eric Chaisson. Eric shares with us the meaning of the images we see from HST.

The program outlines the development of the notion of an expanding universe and provides that the phenomenon is a reality. Henrietta Leavitt's observation of cepheid variables and their relationship to establish a standard celestial ruler are demonstrated. The succeeding discoveries by Edwin Hubble are explained, as well as the phenomenon of redshift. An analogy using a raisin yeast cake shows how the earth can have all the other galaxies receding from it and not be the center of the universe.

"The People Behind the HST" highlights the role of the Head of Academic Affairs at the Space Telescope Science Institute. The students are shown the importance of the dissemination of HST information to astronomers around the world and to the academic community, to which this position is responsible. The Head of Academic Affairs shares his perspective on science and on the role of adventure in science.

Vocabulary

Absolute Brightness - Apparent brightness a star would have at a distance of 10 parsecs.

Apparent Brightness - A measure from earth of the observed light flux received from a star or other object.

Cepheid Variable - Relatively rare star that belongs to one of two classes of yellow super-giant pulsating stars. The brighter cepheids always have longer periods of light fluctuation.

Fluctuation Period - The period of time, usually given in days, it takes a cepheid variable to complete one cycle from very bright to dim to very bright. Most cepheids have periods in the range of 3 to 50 days.



Nebula - Cloud of interstellar gas or dust.

Parsec - The distance of an object that would have a stellar parallax of one second of arc; 1 parsec = 3.26 light-years.

Recession Velocity - The speed and direction of movement of a star or object away from the observer on earth.

Redshift - A shift to longer wavelengths of the light from remote galaxies, presumed to be produced by a Doppler shift.

Spectral Pattern - Each particular element and compound, when in gaseous form, produces a characteristic pattern of dark (absorbing) or bright (emitting) lines. Detailed study of spectral lines can indicate a star or object's temperature, pressure, turbulence, physical state of the gases, and strength or existence of magnetic and electric fields, as well as the approach or recession of the star.

Previewing

Discuss with the students the earth's position in the solar system, the solar system's position in the galaxy, and the galaxy's position in the universe. Emphasize the difference between where we have learned we are located and where from earth it seems we are located.

Ask the students to share what they believe the universe to be like. Are stars and galaxies floating in space, colliding, or perhaps moving closer together or farther apart?

This program shows students one of the important contributions of Edwin Hubble, for whom the HST is named. Share some background on his life with the students.

Postviewing

Ask students to describe what the information the HST brought us represents to scientists.

Ask students to explain why cepheid variables are important to astronomers.

Ask students to describe redshift and give a common example of the Doppler effect on sound.

Ask the students to explain the role one's point of view can have on perception and interpretation of an observation. (Beginning this discussion now will aid understanding of later concepts.)

Ask the students how astronomers receive and use information about the HST discoveries.

Active Involvement

Provide students with the data from Hubble and Humanson on the approximate distances of clusters of galaxies and their radial velocities. Have the students chart these values. Explain the concept of "directly proportional."

Have the students hypothesize about why we cannot feel that the earth is moving. Ask students to remember when they feel motion in a car or boat.

Record the location of new images from HST on your map of the sky.

Bibliography

For high school readers:

Chaisson, Eric. *The Cosmic Dawn*. New York: W.W. Norton & Co., 1981.

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For middle school readers:

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A production of



MARYLAND STATE DEPARTMENT OF EDUCATION
MARYLAND INSTRUCTIONAL TECHNOLOGY • INTEC

11767 Bonita Avenue
Owings Mills, Maryland 21117
(301) 356-5600

Major funding provided by

MARTIN MARIETTA

and
U.S. Department of Education

Office of Educational Research and Improvement
Fund for the Improvement and Reform of Schools
and Teaching

Dwight D. Eisenhower National Mathematics and
Science Program

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Vacancy

Heather White (Student Member)

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See for Yourself: Experiments/Projects



Raisin Yeast Cake

MATERIALS:

- Hot buttermilk (2 c.)
- Light brown sugar (3 Tbls.)
- Margarine (3 Tbls.)
- Salt (2 tsp.)
- Unbleached white flour sifted (5 c.)
- Sugar (1/2 tsp.)
- Warm water (1/4 c.)
- Active dry yeast (2 Tbls.)
- Raisins (1 1/2 c.)
- Four glass bowls
- Four small loaf pans
- Ruler
- Graph paper

DIRECTIONS:

Mix hot buttermilk, brown sugar, margarine, and salt in a large bowl. Mix yeast with warm water and (1/2 tsp.) sugar. Let stand until froth appears. Add to the first mixture. Slowly add 2 c. flour to buttermilk mixture, using an electric mixer set at low speed for 1 minute, then increase speed to medium and beat for 2 minutes, or beat vigorously by hand for 300 strokes. Add raisins. Add enough of remaining flour so that dough rolls away from the sides of the bowl. Place on a floured board and knead

for 10 minutes. Separate the dough into 4 equal parts. This much may be done ahead of time and the dough refrigerated.

Give one portion of the dough to each observation group. Place the dough in a greased bowl covered with plastic wrap. Observe the dough at the start.

1. Draw a diagram of the location of the raisins you can see. Estimate the distance as closely as possible between several pairs of raisins. Choose one raisin to represent earth.
2. At five minute intervals, sketch the dough again and measure the distance between the selected raisins. Be sure to label each observation.

When you have finished your observations, the dough can be punched down and placed in greased pans, covered with plastic wrap. Let it rise again for about an hour (If necessary this could be another group's observation time.). Brush with milk and bake in a preheated oven at 350° F for 35-40 minutes.

1. What is the relationship between raisins that were next to each other at the start and raisins that were farther apart at the start as the dough rose?
2. Chart and graph your observations.
3. What conclusions can you draw?

Cepheid Variables

MATERIALS:

- Telescope or binoculars
- Information from AAVSO
- Star charts
- Graph paper

DIRECTIONS:

To get started observing and recording data from cepheid variables, you should write to the American Association of Variable Star Observers (AAVSO). Their address is 187

Concord Avenue, Cambridge, MA 02138. AAVSO will be able to send you information on variable star observation. The AAVSO will be able to send you articles and pamphlets on how to start your observations. Your data can then be sent in to AAVSO after the first of every month. In this way your data will be added to all the other observers of the variable stars you share.

Absorption and Emission

MATERIALS:

- Light bulb in a working socket (a lamp or other source)
- Helium or other non-toxic gaseous source
- Feather (or diffraction grating)
- Darkened room

DIRECTIONS:

Set up the lamp and gas source so that the light will travel through the gas (see diagram 1). Darken the room. Look through the feather to the gaseous cloud from a position between the light and the cloud (Position A).

1. Draw or record your observations of the spectrum.

Look through the feather to the gaseous cloud at a 90° angle to the light directly opposite the gaseous cloud (Position B).

2. Draw or record your observations of the spectrum.

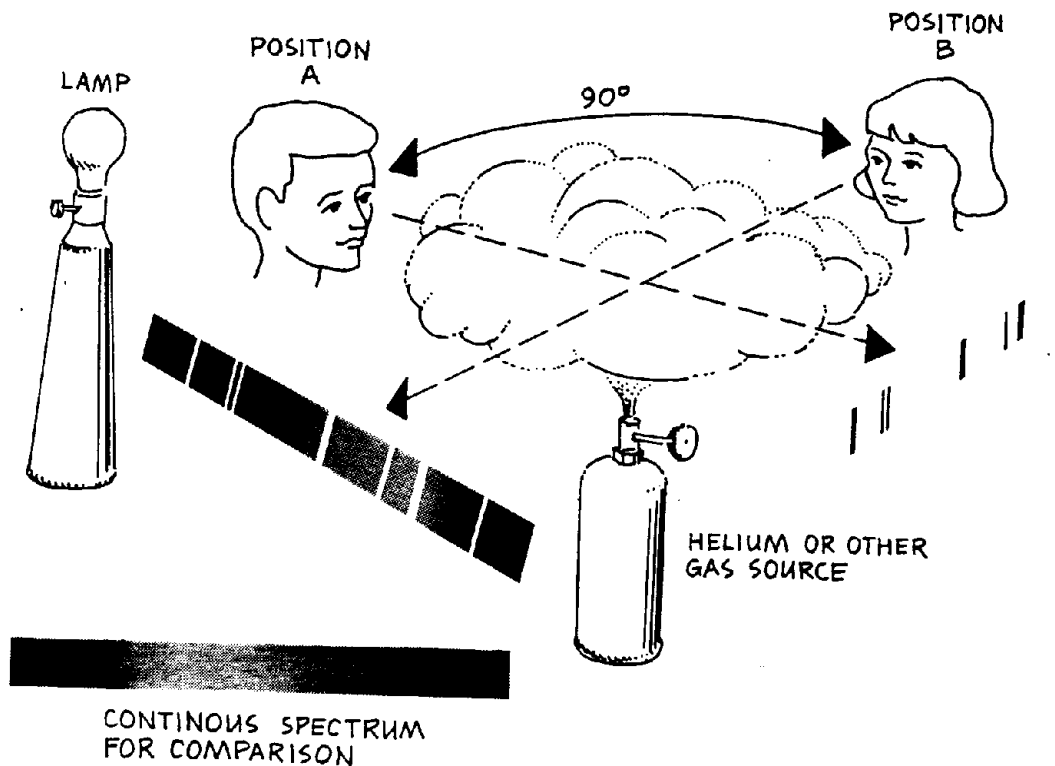
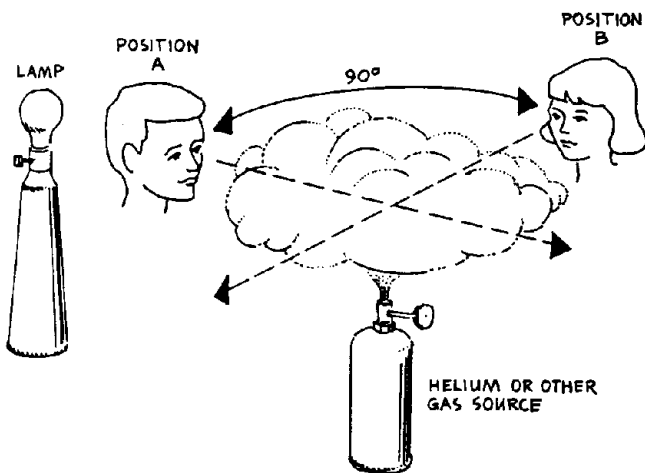
A bright line or emission spectrum appears as a pattern or series of bright lines; it is formed from light in which only certain discrete wavelengths are present. A dark line spectrum or absorption spectrum consists of a series or pattern of dark lines (missing wavelengths) overlaid on the continuous spectrum of a source of white light.

The atoms in the gas cloud produce absorption lines in the continuous spectrum of the white light source when viewed from Position A, but produce emission lines (of the light they reemit) when viewed from Position B (see diagram 2).

3. Use your knowledge of absorption and emission lines to explain why this is the case.

We can observe the reemitted light as emission lines only if we can view the absorbing atoms from a direction from which no light with a continuous spectrum is coming. An example of this occurs when we look at gaseous nebulae.

4. How is the ability to view these spectra related to the findings of Hubble and Humason?



Science Career Profile

DR. COLIN NORMAN

Head of Academic Affairs
Space Telescope Science Institute
and Professor of Physics and Astronomy
at The Johns Hopkins University
Education: B.E. Engineering
Ph.D. Astrophysics



Chief Responsibilities

As Head of Academic Affairs, Dr. Colin Norman is responsible for the science research environment at the Science Institute. He also disseminates Hubble Space Telescope data and information to astronomers and other members of the academic community. Colin's organization is the source of data from the HST for astronomers all over the earth.

The Academic Affairs Division is a team that carries out the sharing of information with scientists. There is a vital role in the progress of science. In an effort to bring the information to all of the scientific community, the division also runs a large visitor program for graduate students and postdoctoral students.

A Typical Day

Colin's days vary based upon the demands and challenges the particular day presents. He attends meetings, collaborates with other scientists, and communicates with his division personnel. Colin responds to his electronic mail on a daily basis and keeps in touch with the Science Institute and astronomers and physicists outside the Science Institute. Through these communications he is able to keep himself and those who depend on him informed.

Colin makes an effort to attend colloquia or talks given by other specialists to keep up to date in his field and to encourage a science research environment at the Science Institute. He shares his expertise through the publication of scientific papers, by teaching college classes, and by giving talks.

Career Viewpoint

Colin grew up in Australia and has traveled to the Republic of China and the U.S.S.R. He has studied in England, where leading scientists influenced his career choice.

Colin says he "encourages scientists to do frontier studies in astrophysics." To be a good scientist, Colin believes you have to have doubt. Actually doing astronomical research is not at all like astronomy that is taught in the classroom. Everything must be tested. In astronomy, scientists can only observe the universe; they cannot manipulate it. There are no variables to be altered and observed and measured.

Colin believes going into space and exploring the universe is one of the truly great intellectual and physical adventures left. Being an astronaut is one way to combine intellectual and physical adventure with a scientific field. Colin challenges students to strive to be part of this adventure.

Content Consultants for STARFINDER - Program 4

Eric Chaisson
Space Telescope Science Institute
Operated by AURA for NASA

Harry Neuman
Parkville High School
Baltimore, MD

Teacher's Guide

Writers
Pat Murphy
Barbara Bourne

Editor
Kate Harrison

Illustrator
Robert Jones

Logo Design
Dave Weaver

Graphic Design
Bob Lindler
The Design Co-op

Typesetting
Blue Heron Typesetters