Evolution of A Star

Instructional Objectives

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

1. describe and sequence the stellar evolutionary process from gas cloud to black dwarf, neutron star, or black hole, and
2. identify the sun as a star and describe its place within the evolutionary process.

Synopsis

Program 11 opens with Dr. Eric Chaisson sharing some of the latest information received through the "HST Data Stream."

Building on information presented in Program 10, "Science Links" traces the evolution of the stellar process from the earliest stages of gravitational attraction between the hydrogen atoms and dust particles in the vast expanses of space to the various forms stars may take as their existences draw to a close.

The beginning stages of our sun are used to introduce the evolutionary process. Hydrogen and dust particles were slowly drawn together by their mutual gravitational attraction. Heat and pressure built as increased gravity drew these elements closer, causing hydrogen atoms to fuse and emit tremendous explosions of heat and light. Eventually the inward pull of gravity was sufficiently balanced by the outward push of energy, coming in the form of heat and light, and our sun became a stable star. A star like our sun will remain in this stable state for billions of years.

Eventually, however, the core of the star uses up its supply of hydrogen and other elements that it has produced during its thermonuclear stages. Usually a star will puff up as a red giant before its life cycle draws to a close. Viewers are presented with black dwarfs, neutron stars, and black holes as the final stages for various sizes of stars.

The program concludes as it opened, with the continuity of the evolutionary cycle of a star—stellar gasses and light released by supernovas eventually coming together to form new stars.

Laura Danly, a NASA Hubble Fellow based at the Space Telescope Science Institute, will be featured in "The People Behind the HST." As a researcher studying the interstellar medium, she talks about the task of conducting research and interacting with the larger scientific community.

Vocabulary

Black Dwarf - The final stage of smaller stars.

Black Hole - The final stage of the largest stars. The mass is

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compacted into an extremely small volume, causing its gravitational field to become so strong that nothing, not even light, can escape from it.

Core - The central region of a planet, star, or galaxy.

Dry Ice - A coolant made up of solidified carbon dioxide.

Dwarf Star - Any star comparable to or smaller in size thar our sun.

Giant Star - Any star much larger in size than our sun.

Helical Structure - Shaped into a helix, or spiral pattern. In R Aquarii, the plasma in the nebula is twisted around by magnetic fields into a helix, or spiral pattern.

Hertzsprung-Russell (H-R) Diagram - A plot of absolute magnitude against spectral type for a group of stars.

Interstellar Medium - The sparse gas and dust between the stars.

Luminosity - The rate of electromagnetic energy released from any object, sometimes called the absolute brightnes

Main Sequence - A diagonal region on the Hertzsprung-Russell Diagram in which most stars fall. These stars are generally stable stars, those whose inward gravitational pull is counterbalanced by the outward pressure created by fusion reactions.

Nebula - An area of ionized, interstellar gas (plasma).

Neutron Star - An extremely compact ball of neutrons formed from the central core of a collapsed star. Neutron stars have the mass of a star but a size that is smaller than a planet.

Nova - A star that rapidly brightens while expelling a smal fraction of its matter, after which it slowly fades back to normal.

Plasma - The fourth state of matter. A highly energized state of matter in which all atoms are ionized; a mixture of free electrons and free atomic nuclei.

R Aquarii - A binary, or double star system in the constellation Aquarius, comprised of a red giant and whit dwarf star. As the white dwarf orbits the red giant, it pulls away some of the material of the red giant, causing tremendous outbursts of energy. R Aquarii was originally studied by Edwin Hubble.

Red Giant - An aging star, larger and cooler than our sun.

Star - A gaseous object, held together by its own gravity, and so hot that its core releases energy by fusing lighter nuclei to heavier nuclei.

Stellar Evolution - The changes experienced by stars as they originate, mature and age.

Supernova - An explosive death of a massive star whose tremendous energy output causes its expanding gas and dust to glow brightly for weeks or months thereafter.

White Dwarf - An old, dim star, much smaller and hotter than our sun.

Previewing

Write vocabulary words on the board and define for students.

Ask students if they can name our nearest star. Through questions and discussion, make sure that all students realize that the sun is the star closest to earth.

Draw attention to the dust particles that are visible in a shaft of sunlight. Discuss whether they have any gravitational influence on one another.

Review the process of fusion energy presented in Program 10.

Discuss the fact that colors change with temperature. If possible, show pictures of molten iron, which turns from black to red to white. The color red represents a cooler temperature than white. Blue is hotter than white.

Have students rub their hands together and feel the heat. Have them continue to rub faster and faster and make note of increased heat with increased movement.

Postviewing

Discuss the latest findings of the Hubble Space Telescope.

Discuss the career of a scientific researcher. Why is it important to science to have people who spend their careers doing research?

Have students list some topics that they feel they might like to research.

Help students use a star map so that they can locate the Pleiades in the night sky. This subconstellation can be viewed with binoculars. The Pleiades cluster is so young (about 60 million years old) that some of the gas and dust cloud, or interstellar medium, from which the stars originated can still be seen.

Have students look for news clippings about Supernova 1987A. The Hubble Space Telescope's faint object camera captured a visible image of this on August 23, 1990. Astronomers were surprised by a ring of hydrogen rich material that was emitted by the star 10,000 years ago. For more information, replay STARFINDER'S "HST Data Stream" segment, Program 7.

Using a rheostat switch, observe the color changes of a light bulb filament as it increases in brightness.

Active Involvement

Place a balloon on a cold soda bottle and put the bottle in a pan of warm water. As the contents of the bottle warm and expand, the balloon should inflate. Use this as a springboard for discussion of how the gasses of a star expand. Relate this to a red giant.

Have students do research on various topics of interest related to stellar evolution. A variety of interdisciplinary presentation styles can be used to report back to the class.

- Some students can make a two or three dimensional time line showing the probable evolution of our closest star, the sun. The project should emphasize color and size proportions.
- Have students research the ancient records of the 1054 A.D. supernova that left the Crab Nebula in the constellation of Taurus. Have them try to discover how many civilizations left documentation of the mysterious explosion in the sky. They should make copies of the pictorial representations.
- Some students may wish to investigate the mysterious black hole, perhaps using Cygnus X-1 as an example. Challenging words to look for include "escape velocity," "event horizon," "hyperspace," "implosion," "Schwarzchild radius," "singularity," "white hole," and "wormhole."

Display a Hertzsprung-Russell Diagram in your classroom. These are easily found in most astronomy books. Identify the Main Sequence and discuss the relationship between brightness and temperature. Locate the sun on the Main Sequence. Chart the evolution of a small star as it ages.

Bibliography

For high school readers:

Abell, George. *Exploration of the Universe.* New York: Holt, Rinehart and Winston, 1969.

Herbst, Judith. *Sky Above and Worlds Beyond.* New York: Atheneum, 1983.

Menzel, Donald H. and Jay M. Pasachorr. *A Field Guide to Stars and Planets.* Boston: Houghton Mifflin Co, 1983.

For middle school readers:

Fisher, David E. *The Creation of Atoms and Stars.* New York: Holt, Rinehart and Winston, 1979.

Gallant, Roy A. *Fires in the Sky.* New York: Four Winds Press, 1978.

Kaufman, William J. *Stars and Nebulas.* San Francisco: W.H. Freeman and Co., 1978.

See For Yourself: Experiments/Projects

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The Main Sequence

The Hertzsprung-Russell Diagram

▶ MATERIALS:

- Hertzsprung-Russell Diagram (reproduced from this page)
- red pen or pencil
- blue pen or pencil

There are two main factors with which to compare stars—their spectral type, which represents their color/temperature, and their absolute magnitude, a measure of their brightness. Scientists use a chart, called the Hertzsprung-Russell, or H-R Diagram, to compare stars according to these factors. This chart shows that most stable stars lie along one diagonal, referred to as the Main Sequence.

Spectral Class

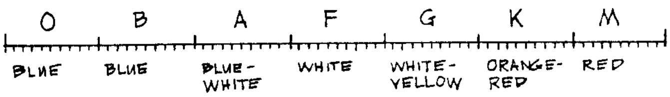
1. Think about the visible color changes you would see as a metal, such as iron, was heated.

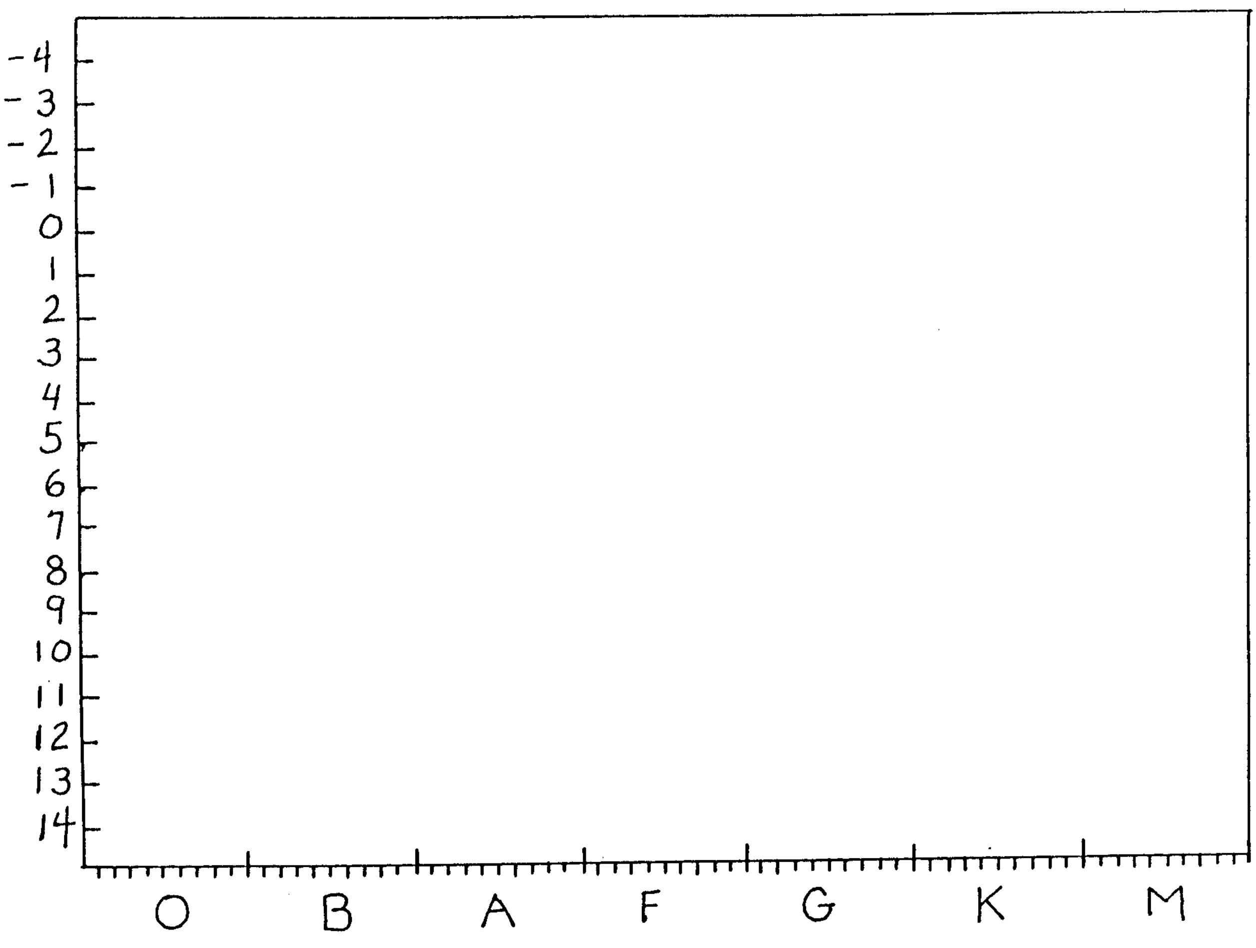
a. What color is cool iron?

b. As it gets hotter, such as when a stove burner is at its hottest, it turns what color?

c. If it were to get even hotter, to the point of melting, it actually turns white. What do you think a scientist could tell about a star by determining its color?

2. Astronomers use the letters O, B, A, F, G, K, and M to categorize the color and temperatures of the stars. O represents the hottest temperatures and M represents the coolest. Use the information on the chart below to determine which would be hotter, a spectral type A star or a type G star? Type B or type K?





HERTZSPRUNG-RUSSELL DIAGRAM

3. Each spectral type is further broken down into subclasses, so that a star halfway between F and G would be called an F5 star. Where would A2 fall along the line?

Absolute Magnitude

4. You have learned that stars are formed by clouds of gases drawn together by mutual gravitational attraction. If the original gas clouds that formed two stars were of different sizes, what differences would there be in the resulting masses of the two stars?

b. Larger stars have more hydrogen atoms colliding than do smaller stars, and therefore will emit more energy in the form of heat and light. Consequently, these stars will be brighter. What, then, can scientists tell about the size of a star if they can determine its brightness?

c. Scientists have developed a scale of brightness called absolute magnitude based on how bright a star would appear if it were observed from a distance of 32.6 light years. The lower the number, the brighter the star. Which would be brighter, a star with an absolute magnitude of -6.2 or a star of +2.8?

The Main Sequence Stars

5. Reproduce the sample Hertzsprung-Russell (H-R) Diagram on this page and plot some of the stars that fall along the main sequence.

a. Plot our sun on the H-R Diagram. The spectral type of our sun is G2. (Remember, the 2 after the G represents 2/10, or 1/5, of the way along the G line) The sun's absolute magnitude is 5. Plot the intersection of the two factors and indicate the sun's location on the chart with an S.

b. These are some of the brightest stars that fall on the Main Sequence and their approximate spectral types and absolute magnitudes. Use a blue pen or pencil to plot them on your H-R Diagram.

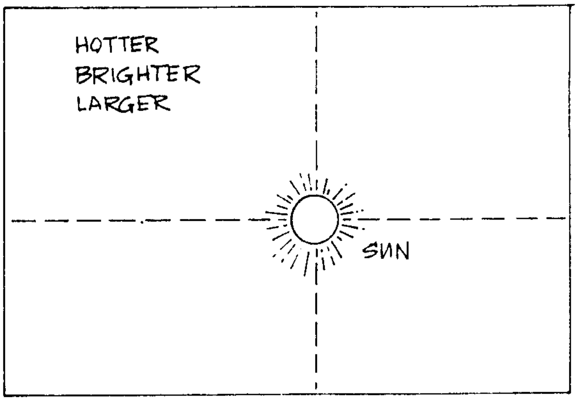
STAR	SPECTRUM	ABSOLUTE MAGNITUDE
Achernar	B5	-1.6
Canopus	F0	-4.6
Fomalhaut	A3	+2.1
Sirius	A1	+1.4
Spica	B2	-2.2
Vega	A0	+0.5

c. These are some of our nearest stars that fall along the Main Sequence and their approximate spectral types and absolute magnitudes. Plot them on your H-R Diagram with a red pen or pencil.

STAR	SPECTRUM	ABSOLUTE MAGNITUDE
Barnard's Star	M5	+13.2
Kapteyn's Star	M0	+10.8
Lalande 21185	M2	+10.5
Procyon	F5	+2.8
Ross 154	M5	+13.1
Ross 248	M6	+14.8
Sirius	A1	+1.4
Wolf 424A	M6	+14.4

d. Describe the relationship of our sun to some of the brightest stars.

e. Describe the relationship of our sun to some of our nearest stars.



f. Just by seeing where a star falls along the Main Sequence, you can determine if it is hotter or cooler than our sun (indicated by spectral type). You can determine if it is brighter or dimmer than our sun (indicated by absolute magnitude) and therefore if it is larger or smaller than our sun. Use what you have learned so far to indicate these three factors (hotter/cooler; brighter/dimmer; larger/smaller) in each section of the diagram. The first section has been completed for you. A star that fell in this section of the H-R Diagram would be hotter, brighter and bigger than our sun.

Red Giants and White Dwarfs

6. Go to your school or public library and find the spectral types and absolute magnitudes of some red giants and white dwarf stars. Using different color pens or pencils, plot them on your H-R Diagram. What can you determine about these groups of stars?

Stellar Evolution and the H-R Diagram

7. Go to the library and research how the evolutionary cycle of one star will travel along a specific path on the H-R Diagram. Compare the path of a smaller star with that of a larger star.

Science Career Profile

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LAURA DANLY
Researcher; NASA Hubble Fellowship
Space Telescope Science Institute
Education: B.A Physics
Ph.D. Astronomy

Chief Responsibilities

Laura Danly's academic background, her skills as a researcher, and her knowledge of the interstellar medium, or gases between the galaxies, have earned her a NASA Hubble Fellowship. This position provides her a unique opportunity to do research in one of the most exciting scientific environments available today, the Hubble Space Telescope Science Institute.

Although you might think Laura's job as an astronomer would primarily be one of viewing the stars at night, she actually spends most of her time reading, thinking, writing, and speaking—usually during the daylight hours! Laura's main responsibilities take place in four steps.

1. **Propose an experiment.** A researcher must first identify a problem, and then propose an experiment. In order to do this, Laura must read and study a great deal so she will know what other research has already been done on the subject. She must match the problem to the proper instrumentation. For example she might need to determine what would be the best observational technique—optical or radio telescope; land based telescope or space observatory.
2. **Carry out an observation.** After the problem and methods have been identified, it is time actually to go to the observatory, sit at the controls, point the telescope, and collect the data.
3. **Reduce and analyze data.** Whether collected on tape or disk, there will be a tremendous amount of data to sort through. In order to get any meaning from these raw data, they must be reduced to a meaningful form and manageable amount. The resulting data are then analyzed. Laura enjoys the amount of creativity needed to look at the final data and ask, "What does this mean; how does this fit into what we already know?" To search for trends, she might set up a graph or chart to compare one characteristic with another.
4. **Communicate results.** Finally, it is time to write up her results and share this new information with other scientists and the general public. She will publish articles and give talks. Hopefully, the results that this research produces will give rise to new questions and pave the way for new research.

A Typical Day

Each day is different for Laura, but she usually begins by logging on to her computer and checking her electronic mail. This is a quick way for her to keep in contact with scientists at the Institute and around the world. In one hour, she might read and respond to electronic messages from Great Britain, Germany and Japan. Fortunately for Laura, most scientists around the world use English to communicate their messages.

Laura also keeps up contacts with other scientists through phone calls and letters. By building and maintaining relationships with others in her field, she not only gains friendships, she creates a list of colleagues with whom she can discuss complicated questions.

The rest of the day is spent on the various stages of her research. Reading, writing, computing, and sometimes just thinking are all part of the process.

The Space Telescope Science Institute provides many ways for astronomers to keep up on the latest scientific research. Lectures and talks are given daily, and informal discussions take place over coffee or luncheons. Laura attends about three lectures a week, and may even be the featured speaker two or three times a year.

Laura travels about once a month. She might travel to an observatory anywhere in the world, or she might attend a scientific meeting or conference. Several times a year, she delivers scientific talks at universities or science conferences.

Career Viewpoint

Laura believes that being able to communicate is the key to scientific exploration. Although math and science skills are important, speaking and writing skills are necessary to communicate ideas and discoveries.

She sees science as a surprisingly personal field. It is a collection of individual ideas that make up the big picture. A scientist may never know in his or her own lifetime whether or not an idea was right or wrong, so it is important to trust in, explore, and fight for your own vision.

The Educational and Public Affairs Office of the Space Telescope Science Institute has compiled a *Glossary of Astronomical Terms for the Hubble Space Telescope.* Teachers interested in receiving the glossary, or a color poster of the Electromagnetic Spectrum, may send a written request to:

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