Title of lesson plan
A Star Is Born

Length of lesson
Two class periods

Grade level
9–12

Subject area
Astronomy/Space

Credit
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Objectives
Students will understand the following:

1. Since we cannot watch a star evolve through its entire lifetime, astronomers use their knowledge of a star's behavior at various stages of its life to piece together a picture of the star's entire life.

2. The most important factor in how a star evolves and eventually dies is its initial mass. (It is assumed that the students already possess background information concerning how stars of different masses evolve—solar mass stars, such as the Sun; low-mass stars 0.8 or less than the Sun's mass; and higher-mass stars.)

Materials
Only research materials are required for this activity. You might want to have a selection of sources on hand in the classroom, but students should go to the library or the Internet for additional research.

- Reference materials on stellar evolution, including, if possible, examples of images taken by the Hubble Space Telescope of stars in different stages of development

- A computer with Internet access

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Procedure

1. Ask your students how they think astronomers can make inferences about the life of a particular star, from its birth to its death, taking into consideration that it is impossible to observe a star's evolution through its entire lifetime.

2. Make sure students understand that because a star's initial mass largely determines how the star will behave at various stages of its life, observing a star at any of those stages can give astronomers information about the star's initial mass and, therefore, about how the star was born, will evolve, and will die.

3. Tell the class that they will be dividing into teams to do research on a star's life. Each team will focus on one aspect of the stellar evolution of a particular star.

4. Assign each of 7 teams a star at a particular stage of stellar evolution: protostar (e.g., the Eagle Nebula, a stellar nursery); protoplanetary disk and stellar system in formation (e.g., Orion Nebula); cluster of young stars (e.g., the Pleiades); middle-aged, normal star (e.g., the Sun); cluster of older stars—red giant (e.g., Betelgeuse); dying stage—supernova, planetary nebula, white dwarf (e.g., Supernova 1987A); end-stage of a star—black dwarf, black hole, neutron star (e.g., Cygnus X-1).

5. Tell students to keep track of the sources for their facts so that they or other interested classmates can go back to those sources for further information.

6. Encourage students to include visuals in their reports.

7. Have teams report their findings to the class through a poster session, sharing of photographic or printed sources, PowerPoint presentation, or some other format of the students' own choosing.

8. After each team's report, have team members lead a whole-class discussion on what could be inferred about earlier and later stages of the star's development based on information about the star at the stage of stellar evolution the team has researched. What can they infer about the star's initial mass? (For example, our Sun will never become a black hole because it has too little mass, and therefore too little gravity. Rather, it will expel a ring of gas rich in heavier elements as a planetary nebula and then contract to become a white dwarf.)

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Adaptations
Instead of having team members act as discussion leaders, at the end of each report, ask the class specific questions they can answer by making inferences about earlier and later stages of the star's evolution based on information they have learned from the report.

Discussion questions

1. Explain how the Hubble Space Telescope's discoveries have improved our understanding of stellar evolution.

2. Debate whether manned space missions should be scheduled during times of increased solar activity. Is space exploration worth the risk of exposing humans to harmful radiation?

3. Discuss what you would expect to see if you were observing a newly forming planetary system. How would the material be distributed? What events would you expect to see on the forming protoplanets?

4. Discuss the 2 possible explanations of why Venus rotates retrograde and hypothesize and debate alternative explanations.

5. Analyze how astronomers came to the conclusion that Neptune's Great Dark Spot didn't just shift from the southern hemisphere to the northern hemisphere.

6. Our Sun is like a giant thermonuclear reactor, generating an incredible amount of energy each second. Fortunately, this violent maelstrom is well contained. Explain how Einstein's famous equation, $E=mc^2$, relates to the Sun's energy production. Describe what you think would happen if all the Sun's mass were instantly converted to energy.

Evaluation
You can evaluate your students on their reports using the following 3-point rubric:

- **Three points—**Report well researched; information clearly and logically organized; presentation interesting and lively; discussion session well organized

- **Two points—**Report adequately researched; information sufficiently organized; presentation dull; discussion session disorganized

- **One point—**Report insufficiently researched; information inadequately organized; presentation poorly prepared; discussion session disorganized

You can ask your students to contribute to the assessment rubric by determining a minimum number of facts to be presented in a report and setting up criteria for an interesting and lively presentation.

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Extension

Inner Circle

The 3 largest terrestrial planets, Earth, Venus, and Mars, share a common heritage in terms of their location in the solar system, composition, and age; however, the path each of these planets took on its evolutionary track is very different. Divide the class into 3 teams with the assignment to research and present their findings on how their individual planet evolved to its current state. The teams' combined research should make it apparent that many factors played a role in the appearance of each of the 3 planets and the conditions surrounding each one. Be sure students address the following factors:

1. The planet's orbital characteristics
2. Development and composition of an atmosphere
3. Rotation rate
4. Surface conditions
5. Development of life

You might also initiate a discussion about terraforming, or altering an existing planet's conditions to allow it to become more Earthlike. How could terraforming be accomplished on a planet such as Mars or Venus? Should it be done at all? Would terraforming provide an option for survival when the Sun becomes a red giant?

Stellar Scripts

Have students write an article on how life on Earth would change as the Sun evolves from its present state to its red giant phase, and eventually to a white dwarf. Encourage them to include the effects on Earth's environment, society, and technology and on human evolution.

Suggested readings

Stars and Atoms: From the Big Bang to the Solar System
Stuart Clark. Oxford University Press, 1995.
The concepts and ideas of modern astronomy and cosmology are presented in this clearly worded book, which is supplemented with illustrations, charts, and tables. Read and learn about the universe and its fate, the big bang, galaxies and quasars, stars, and planets.

The Story of Astronomy
Lloyd Motz and Jefferson Hane Weaver. Plenum Press, 1995.
Trace the evolution of the great astronomical ideas from their birth as pure speculations in the minds of the great ancient Greek astronomers to the reality of present-day astronomy. Read about Kepler, Tycho Brahe, Galileo, Newton, Gauss, and Einstein, and the relationship between astronomy and physics.

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Web links

Star Formation

Simple explanations of star formation, enriched with colorful diagrams and related Internet links, make this Web site an excellent primer on stellar evolution.
http://zebu.uoregon.edu/~js/ast122/lectures/lec14.html

The Life Cycles of Stars

This is a NASA-sponsored Web site of teacher-made activities relating to "The Life Cycles of Stars."
http://imagine.gsfc.nasa.gov/docs/teachers/lifecycles/SC_title2.html

Vocabulary

supernova

The explosion of a very large star in which the star may reach a maximum intrinsic luminosity one billion times that of the Sun.

Context:

Eta Carinae will soon collapse and explode violently, ending its years as a supernova.

nebulae

Clouds of gas or dust in interstellar space.

Context:

Blasted out from the dying star, this gas and dust can form fabulous clouds called nebulae.

corona

The tenuous outermost part of the atmosphere of a star (like the Sun).

Context:

In the Sun's corona, the temperature shoots up another 2 million degrees above that of the already scorching surface.

cosmic rays

Extremely high-energy, short-wavelength particles such as protons, neutrons, and atomic nuclei that originate outside the solar system.

Context:

Harmful cosmic rays stream through space, but they're deflected by the Sun's magnetic field.

equilibrium

A state of balance between opposing forces or actions. In the Sun, this refers to the balancing of inward-pulling gravitational forces with outward-pushing pressure.

Context:

After about a billion years, the Sun reached equilibrium.

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prograde
A direction of rotation or revolution that is counterclockwise as viewed from the north pole of a planet.
Context:
The Earth has what is called prograde rotation (spin).

retrograde
A direction of rotation or revolution that is clockwise as viewed from the north pole of a planet.
Context:
On Venus the spin is retrograde. Although all the planets orbit the Sun in the same direction (counterclockwise), the spin on Venus is backwards from that of Earth and most of the other planets.

greenhouse gas
An atmospheric component that promotes the **greenhouse effect** (the conversion of solar radiation into longer wavelengths, its absorption by the planet's surface, and reradiation as heat).
Context:
Carbon dioxide, a greenhouse gas, remained in Venus's warming atmosphere, trapping heat from the Sun.

gas giant
One of the outer planets of the solar system (Jupiter, Saturn, Uranus, and Neptune), which are composed of various amounts of hydrogen, helium, methane, and other gases.
Context:
Jupiter marks the start of the gas giants—massive planets that formed from the lightest chemical elements in the outer portions of the solar system.

Academic standards

Grade level
6–8

Subject area
Space science

Standard
Understands essential ideas about the composition and structure of the universe and Earth's place in it.

Benchmarks
- Knows that the Sun is the principle energy source for phenomena on Earth's surface (e.g., winds, ocean currents, the water cycle, plant growth).
- Knows characteristics and movement patterns of the 8 planets in our solar system

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(e.g., planets differ in size, composition, and surface features; planets move around the Sun in elliptical orbits; some planets have moons, rings of particles, and other satellites orbiting them).

- Knows that the planet Earth and our solar system appear to be somewhat unique, although similar systems might yet be discovered in the universe.
- Knows characteristics and movement patterns of asteroids, comets, and meteors.

Grade level
9–12

Subject area
Earth science

Standard
Understands basic features of Earth.

Benchmarks
Knows how life is adapted to conditions on Earth (e.g., force of gravity that enables the planet to retain an adequate atmosphere, intensity of radiation from the Sun that allows water to cycle between liquid and vapor).

Grade level
9–12

Subject area
Space science

Standard
Understands essential ideas about the composition and structure of the universe and Earth's place in it.

Benchmarks

- Knows the ongoing processes involved in star formation and destruction (e.g., stars condense by gravity out of clouds of molecules of the lightest elements; nuclear fusion of light elements into heavier ones occurs in the stars' extremely hot, dense cores, releasing great amounts of energy; some stars eventually explode, producing clouds of material from which new stars and planets condense).
- Knows common characteristics of stars in the universe (e.g., types of stars include red and blue giants, white dwarfs, neutron stars, and black holes; stars differ in size, temperature, and age, but they all appear to be made up of the same elements and to behave according to the same principles; most stars exist in systems of 2 or more stars orbiting around a common point).
- Knows ways in which technology has increased our understanding of the universe (e.g., visual, radio, and X-ray telescopes collect information about the universe

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from electromagnetic waves; computers interpret vast amounts of data from space; space probes gather information from distant parts of the solar system; accelerators allow us to simulate conditions in the stars and in the early history of the universe).

Grade level
9–12

Subject area
Physical science

Standard
Understands energy types, sources, and conversions, and their relationship to heat and temperature.

Benchmark

- Knows that nuclear reactions convert a fraction of the mass of interacting particles into energy (fission involves the splitting of a large nucleus into smaller pieces; fusion is the joining of 2 nuclei at extremely high temperature and pressure) and release much greater amounts of energy than atomic interactions.

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