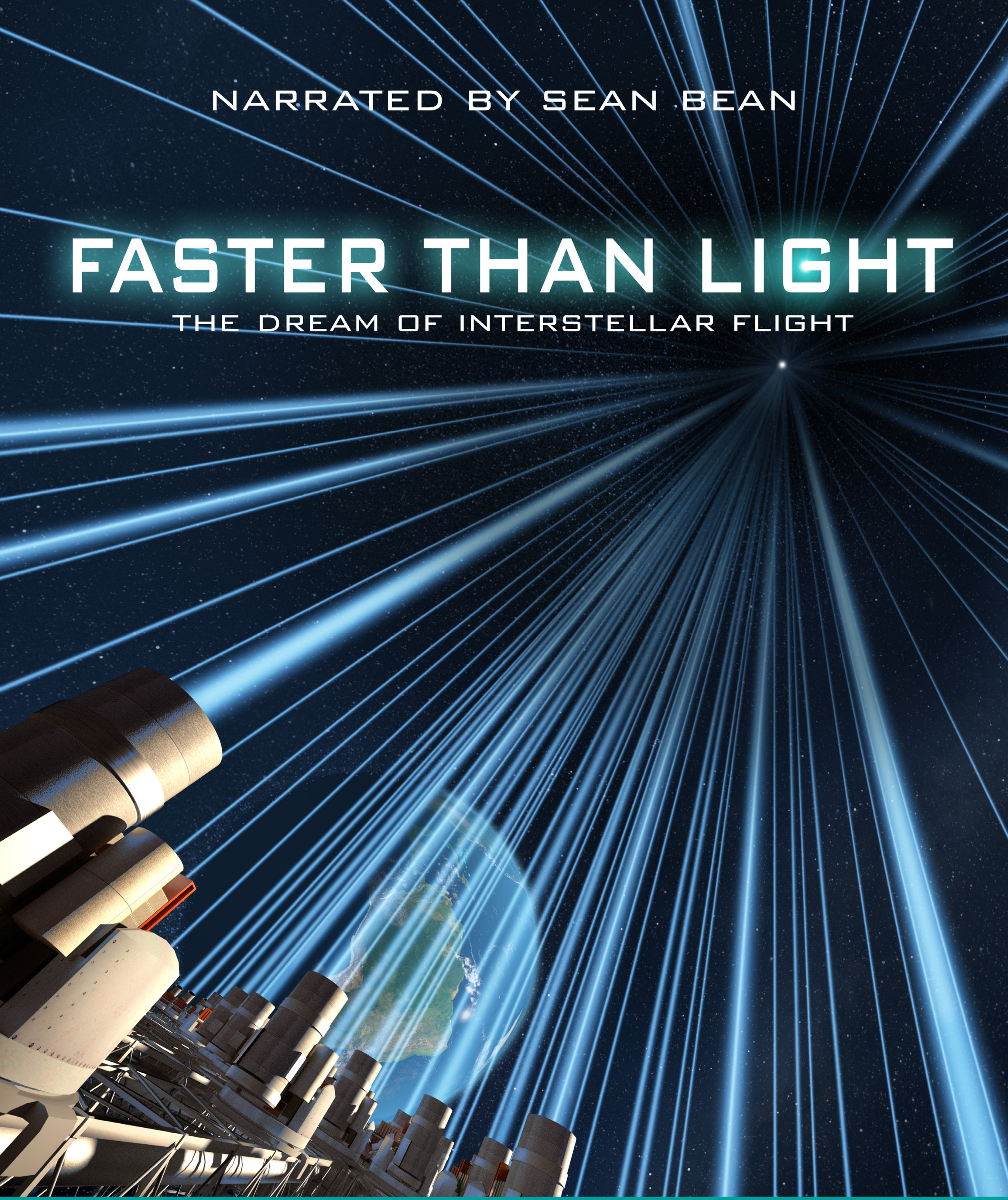

NARRATED BY SEAN BEAN

FASTER THAN LIGHT

THE DREAM OF INTERSTELLAR FLIGHT

EDUCATOR GUIDE

Narrated by Sean Bean

FASTER THAN LIGHT

THE DREAM OF INTERSTELLAR FLIGHT

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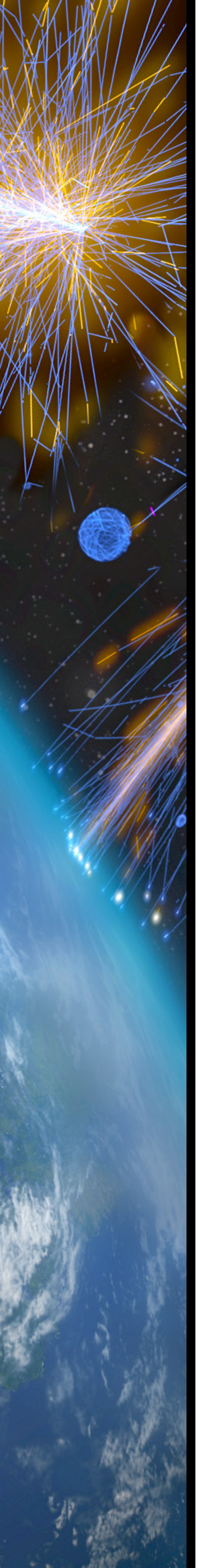


About This Guide

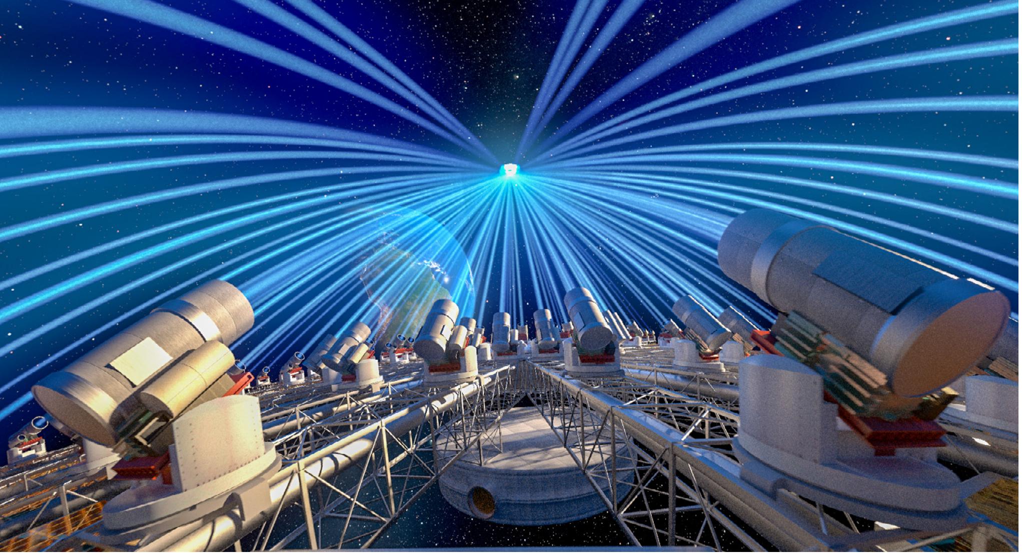
This Educator Guide is designed for use with students in grades 7–12 in conjunction with a viewing of the planetarium show. It supplements the documentary by offering classroom resources that address and reinforce the topics covered in the show, including: spaceship design, long-distance and interstellar space travel, and space exploration. The guide includes content overview, three inquiry-based labs, experiments, activities and related reference guides.

Faster Than Light: The Dream of Interstellar Flight was designed for fulldome theaters in museums, planetariums, and science centers. It features narration by actor Sean Bean. The show was produced by Spitz Creative Media, Mirage3D and Thomas Lucas Productions, Inc. This project is supported by the Commonwealth of Pennsylvania and the Pennsylvania Film Office.

The movie is distributed by Spitz, Inc. (http://www.spitzinc.com), Mirage3D (www.mirage3d.nl) and Evans & Sutherland (www.es.com).

This Educator Guide was written by David Dundee, Astronomer, and Lynn Avery, Educator, of the Tellus Science Museum in Cartersville, GA.

AntiMatter Shower *(left):* One possibility for interstellar travel fuel is antimatter, which is created when cosmic rays collide with our atmosphere. Visualization by Spitz Creative Media



SECTION I
Overview

Laser Cannons *(left):* When lasers converge on a solar sail, they can propel it to space the way winds propel a sailboat. Visualization by Spitz Creative Media

EDUCATOR'S NOTES

Faster Than Light: The Dream of Interstellar Flight

The impulse to strike out into the unknown, to see what's over the horizon… is as old as humanity. Today, a whole new horizon beckons. Scientists now believe that our galaxy is filled with solar systems, including up to 9 billion Sun-like stars with planets similar to Earth.

Astronomers are racing to find habitable worlds, including any that might exist in the neighborhood of our Sun. But if we find one, how will we ever get there? How long will it take? What rocket designs might one day conquer the voids of space?

Faster Than Light: The Dream of Interstellar Flight dazzles audiences with virtual rides aboard spacecraft of the future. These craft are based on whole new technologies designed to achieve ultra-high speeds, using exotic next generation rocket fuels and breakthrough concepts in physics. How far can our technology take us?

SECTION II
Education Goals

Antimatter Space Probe *(left):* Other than our own Sun, the star that's closest to Earth is Proxima Centauri, located only 4.2 light years away. Visualization by Spitz Creative Media

EDUCATOR'S NOTES

Next Generation Science Standards (NGSS)

Middle School Standards

Physical Science

PS2.A: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's Third Law). (MS PS2 1)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS PS2 2)

PS2.B: Types of Interactions

- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass (e.g., Earth and the sun). (MS PS2 4)
- Forces that act at a distance (electrical, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, a magnet, or a ball, respectively). (MS PS2 5)

PS3.C: Relationship Between Energy and Forces

- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS PS3 2)

ETS1.A: Defining and Delimiting an Engineering Problem

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (secondary to MS PS3 3)

EDUCATOR'S NOTES

ETS1.B: Developing Possible Solutions

- A solution needs to be tested and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (secondary to MS PS3 3)

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS PS4 2)
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS PS4 2)
- A wave model of light is useful for explaining brightness, color, and the frequency dependent bending of light at a surface between media. (MS PS4 2)
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS PS4 2)

Earth Science

ESS1.A: The Universe and Its Stars

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS ESS1 1)
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (MS ESS1 2)

ESS1.B: Earth and the Solar System

- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS ESS1 2), (MS ESS1 3)
- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. (MS ESS1 1)
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. (MS ESS1 2)

EDUCATOR'S NOTES

High School Standards

Physics

PS2.B: Types of Interactions

- Newton's Law of Universal Gravitation and Coulomb's Law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS PS2 4)
- Forces at a distance are explained by fields (gravitational, electrical, and magnetic) permeating space that can transfer energy through space. Magnets or electrical currents cause magnetic fields; electrical charges or changing magnetic fields cause electrical field. (HS PS2 4), (HS PS2 5)

Earth Science

ESS1.A: The Universe and Its Stars

- The star called the sun is changing and will burn out over a life span of approximately 10 billion years. (HS ESS1 1)
- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS ESS1 2), (HS ESS1 3)
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS ESS1 2)
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (HS ESS1 2), (HS ESS1 3)

ESS1.B: Earth and the Solar System

- Kepler's Laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS ESS1 4)

ESS1.B: Earth and the Solar System

- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary to HS ESS2 4)

EDUCATOR'S NOTES

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS ETS1 3)
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical, and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS ETS1 4)

Main Questions and Answers About Interstellar Travel

Why do we want to travel faster than the speed of light?

The distances between solar systems within our galaxy are so vast, they are almost beyond comprehension. In order to reach any destination and return in the lifetime of a human astronaut, we have to find a way to reach extreme speeds.

The closest star system to our sun, Alpha Centauri, is more than 4 light years away. Traveling at the speed of light (186,000 miles per second), a round trip would take us 8 years. The fastest spacecraft we have today would take hundreds of thousands of years at its top speed of about 0.05% the speed of light.

Why would future spacecraft be different from current ones?

To build spacecraft that would go a significant percentage of the speed of light, we will have to reinvent the whole idea of a spacecraft engine. Rocket fuels of the present, either solid or liquid in form, just don't provide enough energy to go that fast. To get a sense of how impractical they are, a conventional rocket of today simply can't carry enough fuel to accelerate to even a few percent the speed of light.

Today's rockets are so inefficient that they must rely on the gravity of the planets as a sling shot to get where they're going. Scientists are looking for answers on the cutting edge of physics, and in technologies we have not yet invented. Sound impossible? Well, who can really say how far, and how fast, the human imagination will one day take us?

SECTION III

Inquiry Based Labs, Experiments and Activities

Looking for Life *(left)*: Ultimately, our goal is to find a planet outside our solar system that is hospitable to life. Visualization by Spitz Creative Media

EDUCATOR'S NOTES

All About Galaxies

This first activity is a Galaxy Mobile appropriate for any age and comes from a NASA website: https://spaceplace.nasa.gov/galactic-mobile/en/ For middle schoolers, the patterns may be used. High schoolers may wish to research and draw their own galaxy shapes.

Overview:

A galaxy is a grouping of stars. All but a few stars in the universe live in galaxies. Our sun is just one of at least 200 billion stars in our own Milky Way Galaxy.

With our best telescopes, we can look deep into space and see billions of galaxies. Galaxies come in all different shapes. Some are spiral-shaped, like our own Milky Way. Some are like a circle, while others seem to have no particular shape at all.

How did the galaxies get to be such a variety of shapes?

Well, we don't know. But with the Galaxy Evolution Explorer spacecraft, or GALEX, we learned a lot about stars and galaxies.

GALEX was launched into orbit around Earth on April 28, 2003. It used advanced instruments to peer outward, deep into the universe. It collected data that is helping astronomers piece together the story of how stars and galaxies are formed and how they change over billions of years.

The GALEX mission ended on June 28th, 2013 after a very successful ten years of observing the varied galaxies and other mysterious objects that make up our universe.

Galaxy Mobile

Make your own collection of beautiful galaxies. Suspend them on a mobile so they turn and sparkle in the wind. Here's how:

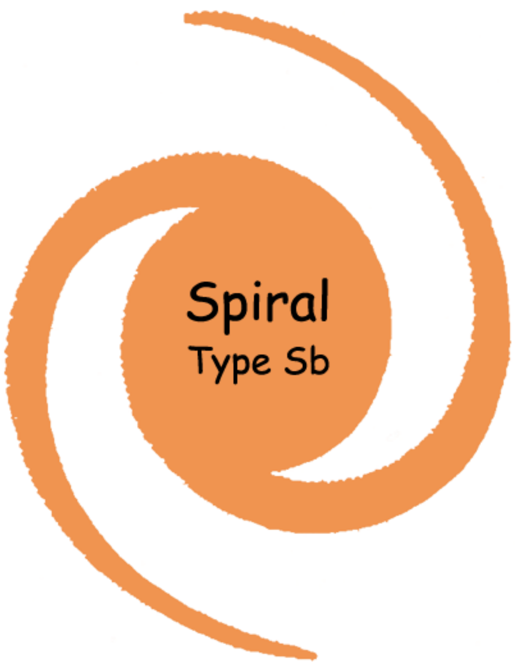
What you need:

- 12" (family size) or 7" (individual size) round cardboard from frozen pizza box. (Or cut circle from a cardboard box.)
- 4 large sheets (11" x 17") black construction paper
- Glitter—gold, silver, red, orange, yellow, blue, purple, or any other colors you like
- White glue
- Paintbrush, about 1/4 to 1/2 inch wide
- Scissors
- Thread (black is best) or fine nylon fishing line
- Small, 4-holed button
- Large, sturdy sewing needle
- 16 sequins or very small beads, black is best (optional)
- Tape measure or yard (meter) stick
- Pattern for galaxies.

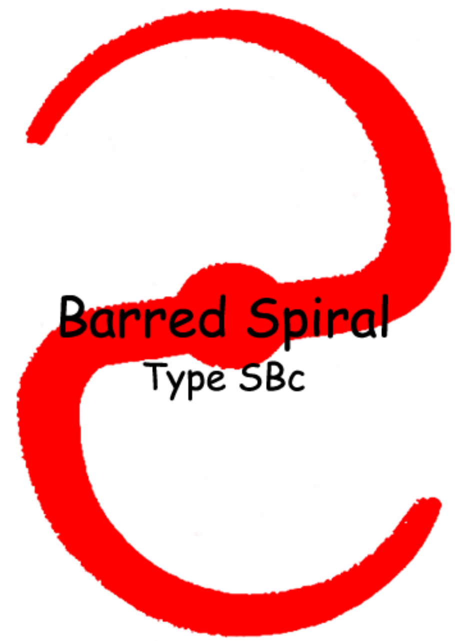

Spiral
Type Sa


Spiral
Type Sc

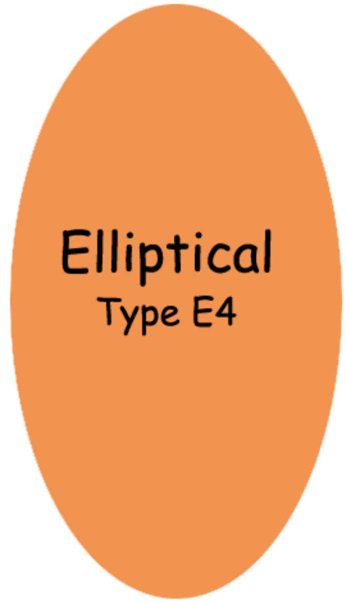

Barred Spiral
Type SBb

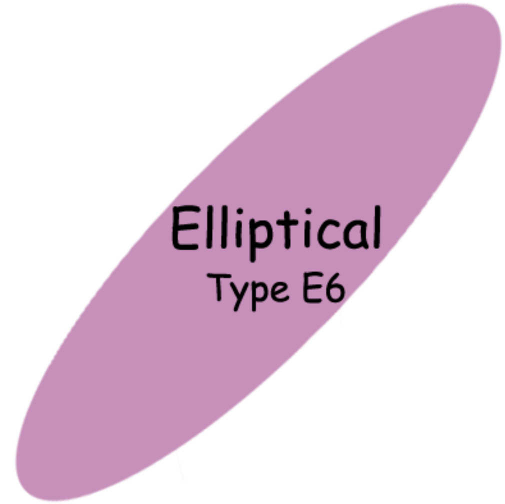

Spiral
Type Sb

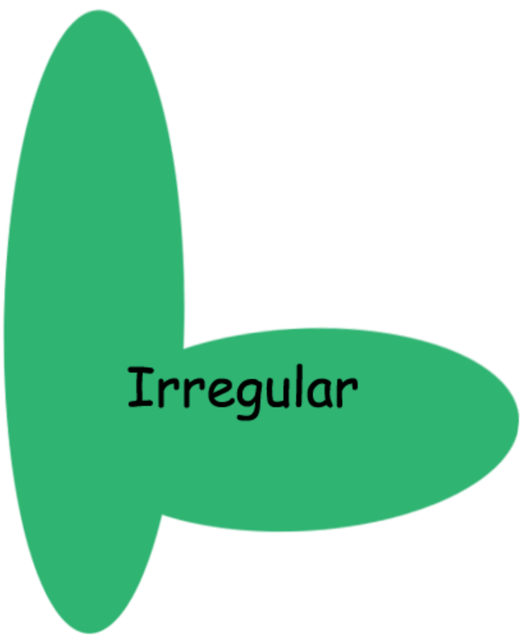

Barred Spiral
Type SBb(s)


Barred Spiral
Type SBc


Elliptical
Type E0


Elliptical
Type E4


Elliptical
Type E6


Irregular


Irregular

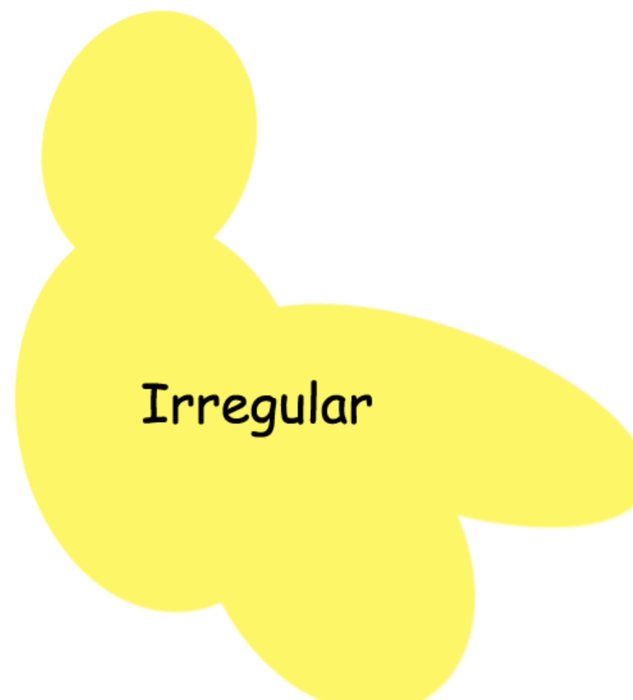

Irregular

Fig. A

Fig. B

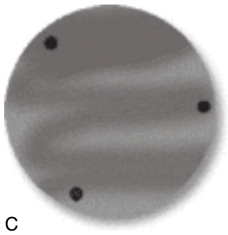


Fig. C

Fig. D

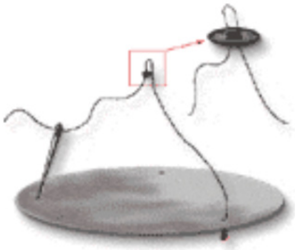


Fig. E

First, make the galaxies:

1. Print out the patterns for the galaxies.
2. Cut the galaxy patterns apart on the dotted lines.
3. Use the patterns (pages 14–15) to cut each galaxy out of construction paper. If you are making a "family size" mobile, use all 12 galaxies. For an "individual size" mobile, use only 9 galaxies. Here's one way to cut out the galaxies:

   First cut out a small square of construction paper a little larger than the pattern paper. **(Fig A.)** Tape the edges of the pattern to the construction paper so it doesn't slip when you cut. Now, cut out the galaxy, cutting through both the pattern and the construction paper.
4. Now decorate the galaxies with glitter. Imagine each speck of glitter is a star!

   Use the brush to spread the glue on one side of one galaxy. Sprinkle one or two colors of glitter on each. Remember, galaxies are brighter in the center (where the stars are younger and hotter), becoming fainter at the edges or on the spiral arms.
5. When you have decorated one side, set the galaxy on something it won't stick to when the glue is dry! (Like a cookie sheet, for example.)
6. When you have decorated one side of each galaxy, let the glue dry. Then turn them over and decorate the other side. Be sure to leave them laying flat until the glue is completely dry. Otherwise, the spiral arms will droop. (If they do, when they are dry you can set a heavy book on them for a while.)

While you wait for the glue to dry . . .

Make the frame for the mobile:

7. Use the round pizza cardboard as a pattern to draw a circle in the center of each of two pieces of construction paper. If the paper is big enough, cut the two paper circles a little larger than the cardboard.
8. Glue the paper circles to the top and bottom of the cardboard. **(Fig B.)** If the paper circles are large enough, glue their edges together so the edge of the cardboard is also covered.

   Note: Instead of covering the cardboard with paper, if you wish, you can paint both sides of the cardboard with flat black spray paint.
9. Make three pencil marks equally spaced around the edge of the circle, about 1 inch in from the edge. **(Fig C.)**
10. Cut a length of thread about 2 feet long. Thread the needle, and either tie a fat knot in the end or tie a sequin or small bead to the end (include only one strand of thread). **(Fig D.)**
11. Poke the needle through one of the pencil marks on the edge of the cardboard circle. Pull the thread through to the knot, sequin, or bead.
12. Take the 4-holed button and poke the needle up through one hole in the button and down through another. **(Fig E.)**

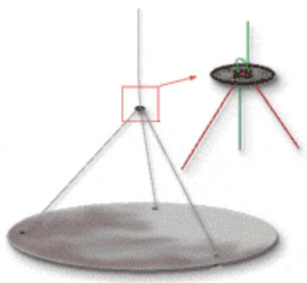


Fig. F

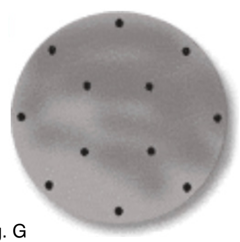


Fig. G

13. Now poke the needle back down through another pencil mark on the circle (since the mark will be on the wrong side of the circle, you'll have to poke the needle up the other way first just to mark the hole).
14. Unthread the needle and tie a fat knot, sequin, or bead in the end of the thread.
15. Now, cut a length of thread about 3 feet long and rethread the needle. Again, tie a fat knot, sequin, or bead in the end. Poke the needle up through the remaining pencil mark on the circle. **(Fig F.**) (Knots, sequins, or beads should all be on the same side.)

    Poke the needle up through one of the remaining holes in the button and then down through the last hole. Unthread the needle and tie a loop in the end of the thread for hanging the mobile from the ceiling.

Hang the galaxies from the mobile frame:

16. Make pencil marks on the bottom of the cardboard circle where you will be attaching each galaxy. For a 12-inch mobile, you could put eight evenly spaced around the edges and four evenly spaced in the center area. **(Fig G.**) For a smaller mobile, you could put six around the edges and three in the center.

For each galaxy:

17. Cut a length of thread and thread the needle. Tie a knot, sequin, or bead to the end. Draw the needle through the center of the galaxy. Now poke the needle through one of the marks on the circle. Adjust the length of the thread so the galaxy hangs nicely, then cut the thread and tie a knot, sequin, or bead in the end.
18. Make the galaxies hang at different levels, so they can turn freely without hitting each other.
19. Hang your Galactic Mobile from the ceiling. Notice that you can adjust the thread going through the button to make the circle hang level.
20. Listen to the "Oh's" and "Ah's."

EDUCATOR'S NOTES

Space Travel

Make a Spacecraft

The second activity is Make a Spacecraft, a three to four-day space activity for students that will challenge their design, art, and engineering skills as well as their general knowledge of space and can be adapted for any age. The idea is a combination from two sources: the Sciencekids website at http://www.sciencekids.co.nz/lessonplans/space/makeaspaceship.html and the Nasa website at https://spaceplace.nasa.gov/classroom-activities/en/

Day 1

Overview:

- Man-made objects that are designed for use in space are complex engineering feats that take a lot of design and planning. Examples include such things as the International Space Station, spaceships and satellites.
- Most spacecraft have parts that do certain jobs:
    - something that houses the electronics
    - something to keep the electronics warm in the cold of space, like a space blanket
    - something to supply electrical power to the electronics, like solar panels
    - some instruments to make and record measurements and pictures
    - some way to navigate the spacecraft, like thrusters to keep it on course

Make a Spacecraft Lesson Plan

Objective:

Students will design and build a spacecraft incorporating specific features, using their own materials from home.

Teacher Materials:

- Pictures of various spacecraft including their name, country of origin, and purpose, graph paper per group, rubric per group

Procedure:

- Read and discuss the overview above. Have several pictures of the space station, spaceships, exploration spacecraft, and satellites to show students. Discuss their names and purposes. Display the pictures where everyone can see them.
- Explain that working individually or in teams of up to 4, their task is to design and build their own spacecraft, space station or satellite. Hand out the rubric so everyone knows the criteria for their craft. Their group will need to determine what features will be added to make their creation safe as it travels in space.
- Determine the type of craft and its purpose.

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- Plan the design on graph paper before you start building. Decide on what materials will be used to make your space station, spaceship or satellite.
- Determine who will be responsible for bringing what materials by the following day.
- Some materials your group may wish to use are K'Nex, Legos, cardboard boxes, juice boxes, straws, egg cartons, tin foil, soft drink bottles, milk cartons, newspaper, paper bowls, Frisbees, cotton swabs, popsicle sticks, cardboard tubes, shoe boxes, Saran Wrap, clay, paper clips, etc.

Day 2 and 3 (if needed)

Build it! Try to follow your original design as much as possible but it's ok to make changes as you go. Use rubric to make sure you have all necessary components.

Day 4

When you've finished, display your finished spacecraft to others in the class and answer any questions they might have regarding your project.

Evaluation

This rubric could be used or modified for this lesson.

Name and Type of Spacecraft: ____ ___/10

Names of Designers: ____ ___/10

How was spacecraft chosen? ____ ___/10

Graphic Design Changes Explained____________________________________ ___/10

Use of Materials ____ ___/10

All components of spacecraft made at school ___________________________ ___/10

Power Source ____________________ Heat Source ______________________ ___/10

Instruments ______________________ Computers ______________________ ___/10

Navigation capability ____ ___/10

Presentation ____ ___/10

Modifications:

This project could have a written component added. A paper with all the information presented in the rubric could also be assigned.

EDUCATOR'S NOTES

Space Exploration

Strange New Planet

The last activity, Strange New Planet, comes from Explore Space Science Activities at https://www.lpi.usra.edu/education/explore/beyondEarth/activities/newPlanet.shtml and in this simulation of space exploration, participants plan and carry out five missions to a "planet" and communicate their discoveries to their family or a friend.

Overview

- Scientists plan space exploration missions based on previous scientific knowledge and investigations. Different kinds of investigations answer different kinds of questions.
- Space missions are scientific investigations that involve observing and describing planets, asteroids, and moons. Sample return missions allow scientists to collect and analyze specimens.
- Space scientists use technology, such as telescopes and robotic spacecraft, to help them make better observations. Robotic spacecraft may fly by or orbit a planet, or they may investigate the surface (landers and sample return missions).
- Scientists and engineers often work in teams with different individuals doing different things that contribute to the results. The team members work together to gather and analyze data, and they use that data to plan future investigations.

Materials

Facility needs:

- A (30' x 6' or larger) hallway or open space
- A stool, pedestal, or stand

For the facilitator:

- Craft and food items for constructing one or more "planets," each constructed from:
  - 1 (4–8") Styrofoam© ball
  - 1 (1-lb.) container of modeling clay or case of Play-Doh© in a variety of colors, to depict features
  - A selection of "planet" surface features: cotton balls or gauze, felt, toothpicks
  - "Life" (optional): whole cloves, or small green leaves from a plant such as thyme
- Glue or tape
- 2–4 markers of different colors
- 1 measuring tape
- 1 roll of masking tape
- 1 permanent marker

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For each audience of 10–15 participants:

- 1 or more "telescopes on Earth," each constructed from
  - 1 cardboard or rolled paper tube, 1 (5" × 5") blue cellophane square,
  - 1 rubber band
- 1 or more additional cardboard or rolled paper tubes to serve as the "telescope in space"
- 5–7 observation sheets, printed on cardstock
- 5–7 pencils and/or colored pencils

Optional: 5–7 flag stickers, 5–7 toothpicks for "planting" the flag, 1 set of walkie-talkies for the group to share

Preparation

Create a "planet" using the craft and/or food materials. Decorate the planet with beads, stickers, sequins, candy, marbles, scents (optional), etc., to make the object interesting to observe. Some of these materials should be placed discreetly so that they are not obvious upon brief or distant inspection. Features might include:

- Cotton-ball or gauze "clouds"
- White patches of "ice"
- Indented craters
- "Rifts" cut into the surface
- "Volcanos" or "mountains"
- A "moon" grape attached with toothpicks
- Cloves, small green leaves, or other signs of "life."

Prepare a hallway or large, open area with the "planet" elevated at one end on a pedestal or stool. Leave a clear path around the "planet" for the participants to walk in a complete circle ("orbit") around them from a distance of about 2 feet.

Using tape and a marker, provide labels on the floor for where observers should stand at each stage of exploration. Space the labels out so over a distance of about 20 feet (measurements are approximate):

- Telescope on Earth (20 feet from the "planet")
- Telescope in Space (21 feet from the "planet")
- Space Probe (10 feet from the "planet")
- Orbiter (2 feet from the "planet")
- Lander (next to the "planet")

Create a "mission control" area at the farthest point from the "planet" (with seating, if desired).

Make at least one "telescope on Earth" by attaching a blue cellophane square to one end of a paper towel tube of rolled piece of paper using a rubber band. If multiple

EDUCATOR'S NOTES

teams will view the "planet" at the same time, make one "telescope on Earth" and one "telescope in space" for each team. (Alternatively, provide time during the activity for the participants to make their own "telescopes.")

Optional: If the walkie-talkies will be used, test them beforehand for battery strength and to set them to the clearest channel.

Activity

1. **Share ideas and knowledge.**

   Frame the activity with the main message: Exploration allows us to build new knowledge on the discoveries of others.

   Brief participants on their mission: to plan and carry out the exploration of a new "planet" as if they are looking through a telescope from Earth or traveling to the planet as a space probe, orbiter, lander, or sample return mission.

   - One person from each team will serve as an "observer."
   - Remaining team members will stay at "mission control" and use the observation sheets and pencils to record what they learn from the observers at each stage of exploration.
   - Optional: Have the group take turns using the walkie-talkies to report back observations to "mission control." Begin with a demonstration on how the walkie-talkies work.

2. **Guide the participants as they plan, then carry out, the following five stages of exploration.**

   Team members will take turns being the "observer," who will look at the "planet" from each marker and report the "planet's" colors, shapes, and textures to mission control. Teams use this information to decide together on how best to proceed at the next stage of exploration. *(Optional: use walkie-talkies to incorporate technology into this process). After each step, each team must have and report out scientific questions in order to continue with a new mission; NASA never sends a mission without science questions they want answered.*

   a. Telescope observations: Observers look through cellophane-covered tubes to study the "planet" as it would appear from Earth-based telescopes.

      Observers look through tubes (without cellophane) to study the planet as it would appear from Earth orbit.

      Ask the participants to consider how the blue cellophane represents the Earth's atmosphere and discuss what effect the Earth's atmosphere would have on our ability to see details on the planet's surface.

   b. Space probe: Observers view the "front" side (the side they just viewed from a distance) of the "planet."

   c. Orbiter: Observers walk around the "planet" in a circle (orbit) at a distance of 2 feet.

EDUCATOR'S NOTES

d. Lander:

- Each team uses their prior observations to decide where they would like to send a lander and what feature(s) they would like to examine.
- Observers mark their "landing site" by planting a toothpick, with a flag sticker attached, onto their chosen site. Observers then study only that spot for up to about five minutes.

e. Optional: Sample return mission:

- Each team uses their prior observations to decide what sample they would like to collect.
- Observers return to the "Lander" marker to collect one sample (a tiny pinch) from the "planet." They bring the sample back to mission control for examination in a scientific laboratory.

3. Have the participants describe what they discovered by exploring the model planet, based on their observations.

Conclusion

Draw on the participants' discoveries to summarize the experience, and encourage teams to talk with each other. Prompt conversation with questions such as:

- What did you first observe through the "telescopes"? How did the blue cellophane affect what you saw?
- How did your understanding of the "planet" and its features change with each stage of exploration?
- What evidence can each team provide to argue that there is — or is not — life on the "planet"?
- How did talking to your teammates help you decide what you were seeing and what to look for during the next stage of exploration?
- How did your drawings — your scientific understanding — change as you learned more?
- What questions will you be able to answer based on your sample?
- What real planet would you like to explore?

APPENDIX A
Glossary of Terms

Antimatter
Matter composed only of antiparticles, especially antiprotons, antineutrons, and positrons.

Climate
The composite or generally prevailing weather conditions of a region—such as temperature, air pressure, humidity, precipitation, sunshine, cloudiness, winds—throughout the year, averaged over a series of years.

Cosmic Rays
A radiation of high penetrating power that originates in outer space and consists partly of high-energy atomic nuclei.

Friction
Surface resistance to relative motion, as of a body sliding or rolling. The rubbing of the surface of one body against that of another.

Fusion
Also called nuclear fusion. A thermonuclear reaction in which nuclei of light atoms join to form nuclei of heavier atoms, as the combination of hydrogen atoms to form helium atoms.

Galaxy
A large system of stars held together by mutual gravitation and isolated from similar systems by vast regions of space.

Meteor
A meteoroid that has entered the Earth's atmosphere. A transient fiery streak in the sky produced by a meteoroid passing through the Earth's atmosphere.

Orbit
The curved path, usually elliptical, described by a planet, satellite, spaceship, etc., around a celestial body, such as the sun.

Sensor
A mechanical device sensitive to light, temperature, radiation level, or the like, that transmits a signal to a measuring or control instrument.

APPENDIX B
Additional Resources on the Web

http://www.sciencekids.co.nz/lessonplans/space/makeaspaceship.html

https://spaceplace.nasa.gov/classroom-activities/en/

https://spaceplace.nasa.gov/galactic-mobile/en/

https://www.jpl.nasa.gov/edu/teach/activity/stem-activities-for-families/

https://www.lpi.usra.edu/education/explore/beyondEarth/activities/newPlanet.shtml

https://www.lpi.usra.edu/education/explore/LifeOnMars/activities/MarsFromAbove/CarvingChannels/

https://www.lpi.usra.edu/education/explore/mars/surface/craters/

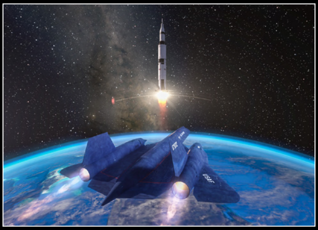
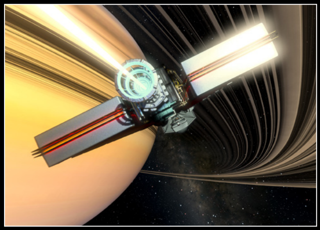
https://www.lpi.usra.edu/education/explore/solar_system/activities/bigKid/planetPull/

https://www.nasa.gov/

https://www.jpl.nasa.gov/edu/

FASTER THAN LIGHT!

THE DREAM OF INTERSTELLAR FLIGHT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