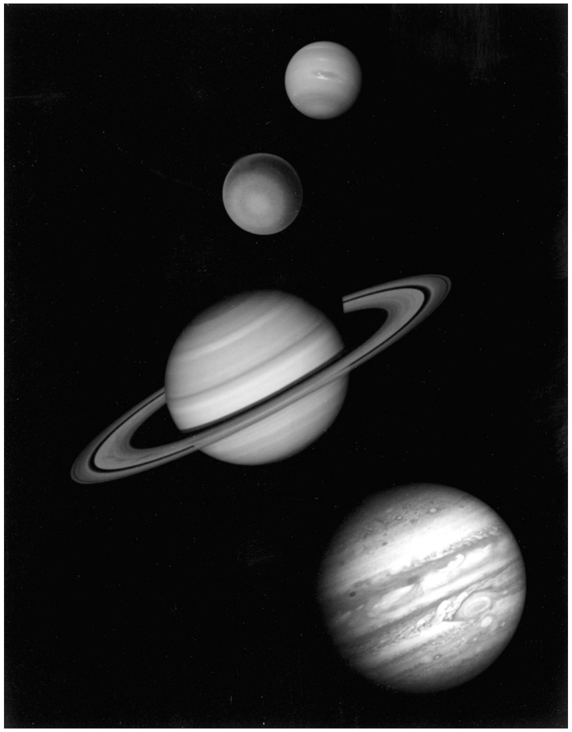
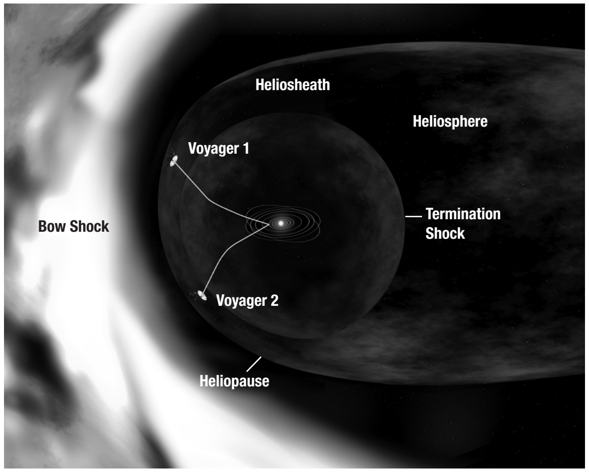
Voyager Mission Profile

The twin Voyager 1 and 2 spacecraft continue exploring where nothing from Earth has flown before. Launched in 1977, they each are now more than three times farther away from Earth and the Sun than is Pluto. The Voyagers are involved in a mission to characterize the far outer heliosphere, the distant solar wind, and the interaction between the two. This phase of the mission has allowed us to explore the most distant reaches of our heliosphere and allowed us to take the first tentative steps in the transition regions between that region dominated by the Sun and interstellar space.

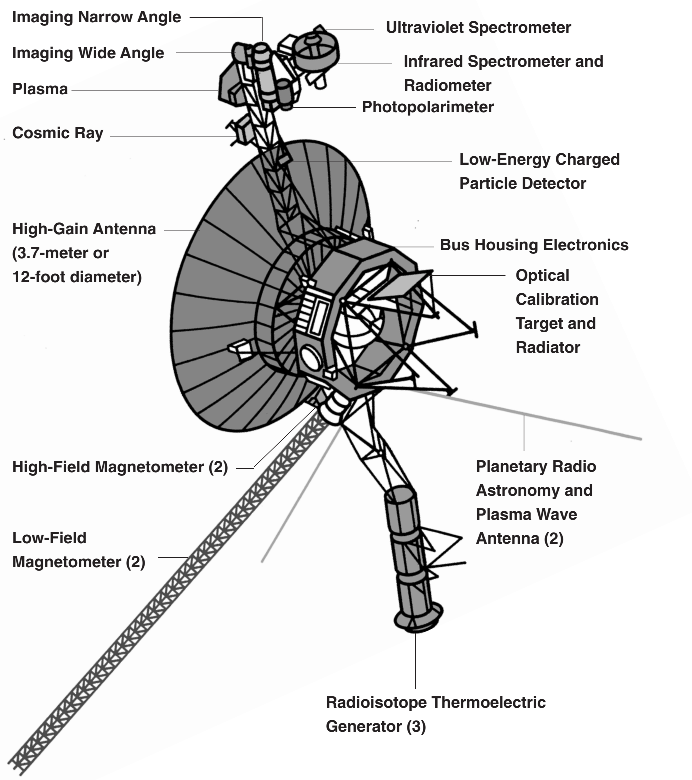


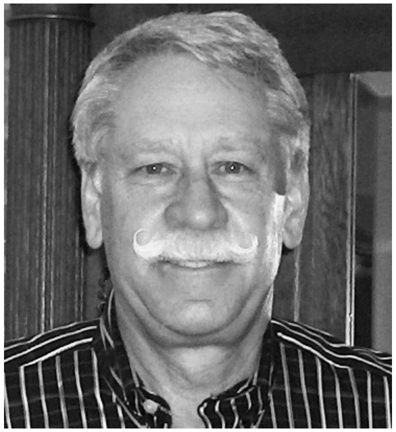
Voyager 1 and Voyager 2 have crossed the termination shock — where the solar wind is slowed abruptly due to the interaction with interstellar gas. Voyager 1 crossed the shock in December 2004 and Voyager 2 crossed in August 2007. Both spacecraft are sending information about their surroundings through NASA's Deep Space Network.

The Voyager spacecraft are on a unique exploratory mission. The two spacecraft are exploring regions of space never before encountered, building on the legacy of one of NASA's most successful and productive missions. The Voyager Interstellar Mission (VIM) is critical for meeting several science objectives of NASA's Heliophysics System Observatory. The Voyagers are the only components of the observatory that are, for now and in the foreseeable future, making measurements in the farthest region of the heliosphere. As such, the mission addresses directly a number of "Challenges." For example, "Understanding the global structure of the space carved out of the interstellar medium by the Sun, the distribution of magnetic fields and matter throughout the solar system and the interaction of the solar atmosphere with the local interstellar medium"and "Understanding the basic physics in processes observed in solar and space plasmas."



The Voyager Spacecraft





Since 1994, Dr. Alan C. Cummings has been a Co-Investigator on the Voyager Cosmic Ray Subsystem (CRS) experiment. The CRS instrument measures the energy spectrum of electrons and cosmic ray nuclei and uses three independent systems — a high-energy telescope system (HET), a low-energy telescope system (LET), and an electron telescope (TET). Dr. Cummings participated in the design of the LETs and had the parts built in South Pasadena. He was responsible for testing all the detectors that went into the LETs and assembled and tested each one of the eight telescopes (four on each Voyager). He was the last person under the shroud checking the aluminum windows covering the apertures once the spacecraft was on the rocket.

Dr. Cummings is a Senior Scientist and Member of the Professional Staff at the California Institute of Technology, and has been analyzing Voyager data since the twin spacecraft launched in 1977.

When asked what scientific discoveries surprised him the most about the Voyagers, Dr. Cummings replied, "There have been, and continue to be, many surprises, but the first big surprise for me was Jupiter's moon Io. It was all black and orange and looked like a poorly made pizza. That astounded me."

Dr. Cummings graduated from Rice University in 1966 with a B.A. in physics. He attended Churchill College, Cambridge, England, as a United States Winston Churchill Foundation Fellow and received his Ph.D. from Caltech. In addition to his scientific pursuits, Dr. Cummings is an avid tennis player and birdwatcher. He has led a weekly bird walk on the Caltech campus since 1986.

After completing her Ph.D. at the University of Sao Paulo in Sao Paulo, Brazil, Dr. Merav Opher came to the U.S. in 1999 for a postdoctoral position at the plasma group in the physics department at UCLA. Dr. Opher's parents are New Yorkers who immigrated to Israel and then to Brazil, causing her English to be very rudimentary; it was mostly learned from books.

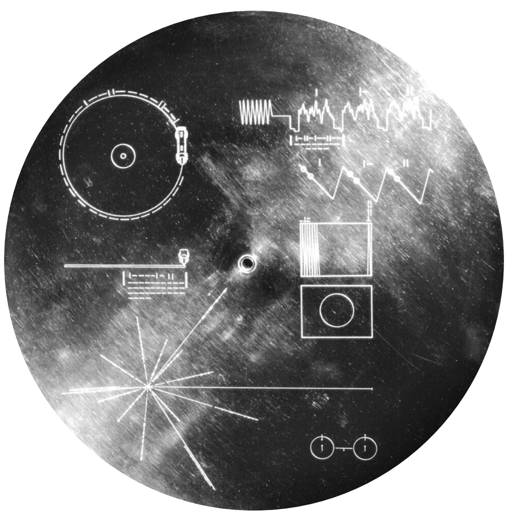
Dr. Opher came to the Jet Propulsion Laboratory in 2001 to begin another postdoctoral position and became involved with the Voyager mission. When asked about her academic life, she commented, "I wandered from plasma effects in the early universe to the edge of the solar system. I like to think my emigrant experience from different countries and academic fields gives me a different outlook in science."

Dr. Opher was most intrigued by two phenomena: how few women worked in space science when she entered the field and how large the age gap was between newcomers like herself and the established names in the field. She finds that one of the romantic aspects of the Voyager Science Team meetings is seeing these two distinct generations in a room poring through the newest data from the spacecraft now at an especially exciting region — the edge of our solar system.

Dr. Opher is also an Associate Professor in the Department of Physics and Astronomy at George Mason University in Fairfax, Virginia, and moves to the Astronomy Department of Boston University in January 2011.

A Message to the Universe

Flying aboard Voyagers 1 and 2 are identical "golden" phonograph records, carrying the story of Earth far into deep space. The 12-inch gold-plated copper discs contain greetings in 54 different languages, samples of music from different cultures and eras, natural and human-made sounds from Earth, and 117 pictures explaining ourselves and the planet Earth. They also contain electronic information that an advanced technological civilization could convert into diagrams and photographs. The cover of each gold-plated aluminum jacket, designed to protect the record from micrometeorite bombardment, also serves a double purpose in providing the finder a key to play the record. The explanatory diagram appears on both the outer and inner surfaces of the cover, as the outer diagram will be eroded in time. Some of the scenes and sounds from the Voyager Golden Record can be viewed and heard at the Voyager project website at **http://voyager.jpl.nasa.gov**. Voyager 1 flew past Jupiter in March 1979 and Saturn in November 1980, before heading out of our solar system. Voyager 2 surveyed Jupiter in July 1979, Saturn in August 1981, Uranus in January 1986, and Neptune in August 1989.



Standards

National Science Education Standards–National Research Council Addressed by Voyager Activities

Mathematical Standards

Source: Principles and Standards for School Mathematics, National Council of Teachers of Mathematics, Reston, VA (2000)

Activity — Voyager 1 and 2: Where Are You?

Grades 6–8

Measurement — Understand measurable attributes of objects and the units, systems, and processes of measurement.

Number Operations — Understand meanings of operations and how they relate to one another.

Communication — Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.

Geometry — Specify locations and describe spatial relationships using coordinate geometry and other representational methods.

Activity — Where Is Voyager Going?

Grades 6–8

Representation — Use representations to model and interpret physical and mathematical phenomena.

Connections — Recognize and apply mathematics in contexts outside of mathematics.

Geometry — Use visualization, spatial reasoning, and geometric modeling to solve problems.

Number Operations — Compute fluently and make reasonable estimates.

Science Standards

Source: National Science Education Standards, National Research Council, Washington, D.C. (1999)

Activity — Voyager 1 and 2: Where Are You?

Grades 6–8

Earth and Space Science

- The Earth is the third planet from the Sun in a system that includes the Moon, Sun, and seven other planets and their moons.

- Most objects in the solar system are in regular and predictable motion.

- Gravity is the force that keeps planets in orbit around the Sun and governs the rest of the motion in the solar system.

Activity — Where Is Voyager Going?

Grades 6–8

Science and Technology

- Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as distance.

- Technology provides tools for investigations, inquiry, and analysis.

Learning Objectives: Students will appreciate the great distances between the planets and their comparable sizes, view the solar system in three dimensions in a useful scale, and visualize the paths of the Voyager spacecraft and their present distances and positions.

You Will Need: An open area with 120 meters of space (like a football or soccer field), meter sticks or measuring tape, 5 × 7 index cards, markers, calculators, balls of string (300 meters or 1000 feet), a plastic sandwich baggie per team, cardboard cut to fit in sandwich baggie, Popsicle sticks, glue, and a 360-degree protractor (you will provide a Sun model).

For the first part, 10 teams of three students each are suggested. Students will choose roles to play for their team. Each team should be assigned one of the planets, Pluto, and each of the Voyager spacecraft.

Part A: The Hypothesis

Out in the Field: This activity will work best if the students are first able to make some predictions. Tell the students: "We are going to make a scale model of the solar system, including the Sun and the two Voyager spacecraft. We are going to locate the Sun in the corner of the field." Take them to the site — point out where the Sun will be (but don't use your scale model yet). Ask each team to discuss where they think their object would be on the field in this scaled system. Then, have a member of each team stand where the group has placed the object they were assigned. If possible, you might have the students leave some sort of marker where they think their object would be. One team member should take a 5 × 7 index card and draw dots to show where each of the objects is thought to be.

Back in the Classroom: If there's time, each group could make a brief presentation on why they think their object is where it is.

Part B: Inside Activity: Making a Scale Model of Objects in the Solar System

Give the students a copy of the *Planetary Data Table* giving distance and diameter information. Tell them the solar system needs to be fitted to the field you chose to construct the model and that they need to make a model of their planet the same scale. They will use a scaling factor for this. This number is 1 meter = 125,000,000 kilometers. They will need to divide each of the distances and the diameter for their object by this number. The answers will come out in meters. If the calculators you use won't allow you to use numbers this large, leave off the last 3 zeros on all the numbers you use. The ratio will be the same as if the actual number was used. The calculations should be written on the *Student Data Table*.

Each group should be given a 5 × 7 card, which they will use as a placard for their object. They should write the actual distance from the Sun and the scaled distance from the Sun on one side of the card. They should attempt to draw the scaled planet on the other side in the approximate center of the card. They should use a ruler to accurately measure the diameter (in the case of all the terrestrial planets, this diameter will be only a tiny portion of a millimeter (impossible to draw that small). They can use the smallest "dot" from a pencil to approximate the size.

Using markers, they should write the name of their object across the top portion of the card in large letters. They must take a piece of string and measure it, getting its length to the correct scaled distance, then carefully coil the string around a piece of cardboard and place in the baggie. You will make the Sun, which has a scaled diameter of 11 millimeters. Make a card for the Sun, label it "Sun," color it yellow, and glue it to a Popsicle stick. You will need the 360-degree protractor around the Sun (see "Part C: Back to the Field" below). You will need to photocopy the 360-degree protractor on panel 5.

Part C: Back to the Field

In placing the cards on the field, the planets drawn on the cards need to be placed the same distance off the ground (at the start). Cards will be glued to a Popsicle stick. Mercury can be placed about a centimeter above the others (because it is 7 degrees above the plane of the other planets). Pluto can be placed about 1 meter above the plane of the planets (because it is 17 degrees above the plane of the planets).

The planets need to be positioned close (in scale) to where they really are (in space). To do this, place the Sun in the following manner (see the *Out in the Field* diagram on panel 5). On a football field, place it on the right hand side of one goal line. On a standard-size soccer field, place it about 12 meters up on the right hand side from the goal line. On any other type of field, you need about 12 meters of space behind you and the most space in front and off to the left. Place the 360-degree protractor around the Sun with 0 degrees (360 degrees) towards the far end of the field (football field/soccer field: align 0 degrees with the sideline).

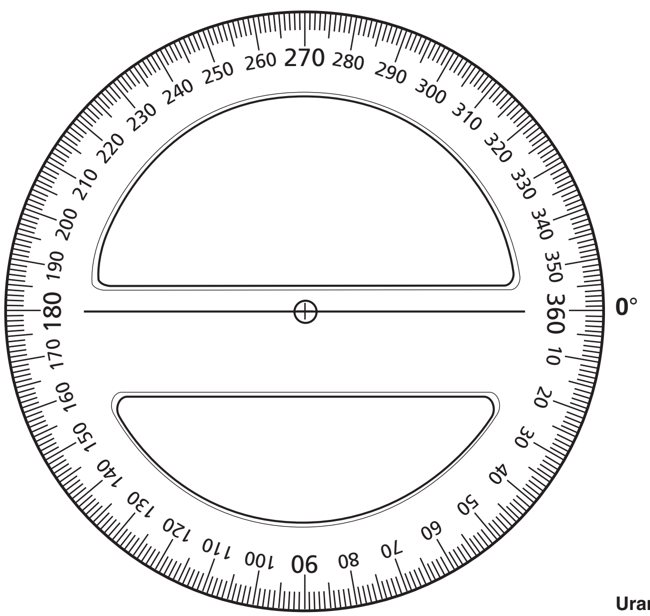
Tell each student team their angle. Student teams should use the protractor around the Sun. They should take the string out of the baggie. Then, one team member will stand at the protractor holding on to the end of the string. The second team member will find the angle of degrees on the protractor. The third team member, holding the other end of the string, will walk the length of the string in the direction that the protractor was pointing. The second team member will try to keep the string going on a "true path." The inner planets will be clustered very close to the Sun. Jupiter will be slightly behind and off the field. Saturn will be directly behind on the sideline. The outer planets and the Voyagers will be a ways out on the field.

continued on panel 5

When the string is laid out, the Popsicle stick/index card should be held at the far end of the string. After all objects have been placed in the "correct" spots on the field, one team member should return to the Sun with the index card from Part A, turn the card over, and draw the positions as they now appear.

Extensions

How fast are the objects moving? Is it possible to scale the speed of the objects and compare their movement? Students can research other interesting data about each planet/object and prepare a report to the class.



Planetary Data Table

Planet or Object	Average Distance from the Sun, kilometers	Student Class Data, meters	Diameter, kilometers	Teacher: Scaled Distance on Playing Field, meters
Sun	—	—	1,390,000	—
Mercury	57,910,000		4,880	0.45
Venus	108,200,000		12,103.6	0.9
Earth	149,600,000		12,756.3	1.2
Mars	227,940,000		6,794	1.8
Jupiter	778,330,000		142,984	6.2
Saturn	1,429,400,000		120,536	11.5
Uranus	2,990,504,000		51,118	24
Neptune	4,502,960,000		49,532	36
Pluto	4,558,312,000		2,274	36.5
Voyager 2	13,957,730,613		—	111
Voyager 1	17,165,601,070		—	137

Out in the Field

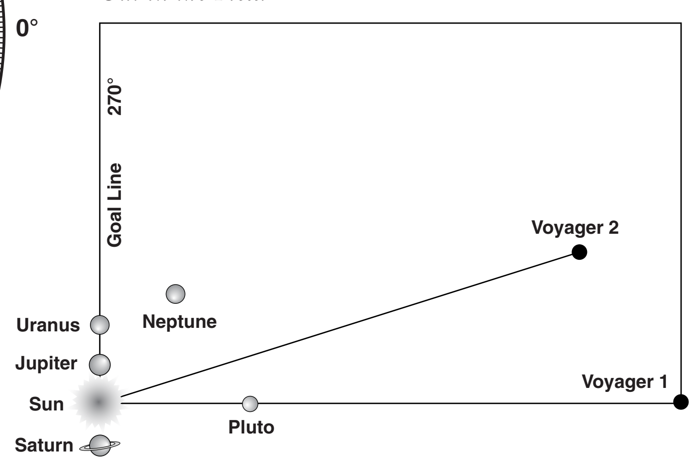


Table Notes

- These are the present distances from the Sun. Because of Pluto's erratic orbit, it has recently moved from its position of being closer to the Sun than Neptune, and is now slightly farther from the Sun than Neptune; therefore, at the present time, it's comparatively close to the same distance.
- Mercury, Venus, Earth, and Mars: These are average distances from the Sun. They can be placed anywhere in their orbits (but at their correct distances from the Sun) because their positions change so greatly month to month. The outer planetary positions relative to the Sun were accurate as of August 2002 (Voyager's 25th anniversary). If you wish to place any planets in more exact positions, check at http://www.heavens-above.com/ for the daily planetary positions.
- To compute the angles on the field using the protractor, look up the object locations in the units called right ascension (RA) at http://www.heavens-above.com/planetsummary.asp?lat=0&lng=0&loc=Unspecified&alt=0&tz=CET. The formula for conversion is: RA hours × 15 and subtract 90. For example, if the location of Uranus is 24 hours RA, 24 × 15)–90 = 270 degrees.

Sources

http://www.heavens-above.com/planets.aspx?lat=0&lng=0=Unspecified&alt=0&tz=CET

http://voyager.jpl.nasa.gov/mission/weekly-reports

This activity will build on the ideas developed in the "Voyager 1 and 2: Where Are You?" activity to demonstrate that the distances between stars are great and that the two Voyager spacecraft will travel very far.

Part A: Scale Models

For this part of the activity, a photocopier that can "photo-reduce" is helpful. In "Voyager 1 and 2: Where Are You?" the scale of the solar system was reduced so that it (and the Voyagers' present positions) would fit on a standard football/soccer field. Students made a visual scale model of the Voyager–solar system set up on a 5 × 7 card. One of these cards should be borrowed from one student and photo-reduced enough times to make the Voyager–solar system the size of a period, 3 millimeters in diameter. This could be done with the students watching; however, if not, save all the "in-between" reductions to show the students. If a copier is not available, simply make a dot on a paper and describe how this now represents the Voyager–solar system (which is actually one light-day in diameter). So 3 mm/light-day is the scale of this activity, with a light-day [the diameter of our Voyager–solar system] becoming the basis of our measure (1 m = 1 light-year). Voyager 1 is heading toward the constellation Ophiuchus [OFF-ih-YOU-kus]. It contains many stars — some are listed in the *Star Data Table*. Distances are in light-years (LY).

Star Data Table

Star Name	Distance, LY	Degrees	Star Name	Distance, LY	Degrees
72 Ophiuchi	82	345	70 Ophiuchi	16.6	346
Gamma Ophiuchi	94.8	347	Cebalrai	82	352
Rasalhague	46	354	44 Ophiuchi	83.7	356
Xi Ophiuchi	56.7	357	36 Ophiuchi	19.5	359
Kappa Ophiuchi	86	3	Eta Ophiuchi	84	0
Epsilon Ophiuchi	108	13			

Table Notes

- How stars are named is an interesting topic. Sometimes stars are given Greek letter first names with the constellation name second (e.g., Gamma Ophiuchi). A number followed by the constellation name may also be used (e.g., 72 Ophiuchi).
- The "degrees" were assigned to place the stars on the field. They were calculated using 1 degree = 4 minutes of right ascension (a unit of astronomical measure). Eta Ophiuchi was assigned 0 degrees because it is approximately in the middle of the constellation. The other stars are "placed" right or left of Eta Ophiuchi using the degree calculation from their right ascension.
- Each group should now be assigned a star. Give the students the Star Data Table of distance and location information. Tell them their star needs to be fitted to the field you chose to construct the model. They will use a new scaling factor for this. This number is 1 meter (or 1,000 millimeters) = 1 light-year [3 mm/light-day × 365 days/yr = 1000 mm/light-year=1 meter/light-year]. With this scale, the number of light-years of distance will be equal to the number of meters from the Voyager spacecraft and our solar system.
- Each group should be given a 5 × 7 card, which they will use as a placard for their star. They should write the actual distance from our solar system in light-years. Using markers, they should write the name of their star across the top portion of the card in large letters. They should also make a dot on the card to represent their star (note: on this scale, even the largest stars would be microscopic dots). They must take a piece of string and measure it, getting its length to the correct scaled distance, then carefully coil the string around a piece of cardboard, and place in the baggie.

Part B. Back Outside

Place the card with the dot representing the Voyager–solar system in one corner of the soccer/football field. Place the 360-degree protractor (from the last activity) around the card with 0 degrees pointed towards the far opposite corner of the field. Tell each student team their angle. Student teams should use the protractor around the Voyager–solar system dot. They should take the string out of the baggie. Then, one team member will stand at the protractor holding on end of the string. The second team member will find the angle of degrees on the protractor. The third team member, holding the other end of the string, will walk the length of the string in the direction that the protractor was pointing. The second team member will try to keep the string going on a "true path."

When the string is laid out, the index card with the star information should be held at the far end of each string. After all the stars have been placed in the "correct" spots on the field, one team member should return to the Sun with a new index card and draw the positions as they now appear. (Note: for the purposes of this activity, the stars have been placed according to their angles <from side-to-side> and scaled distances from our Sun. They have not been placed in their proper angles up and down. This was done because of the impracticality of the height placement. The stars form a "fan" in the model. In real life, they would be above and below the plane they are in. This should be pointed out to the students). An illustration of the constellation Ophiuchus can be found at **http://www.heavens-above.com/**.

Extensions

This model is a spatial representation of the area in space where the Voyager 1 spacecraft is headed. Students might be interested in calculating the length of time for Voyager to come near each of the stars in Ophiuchus. They can use the following calculation: Voyager 1 has traveled about 12.5 billion kilometers in 25 years, representing approximately 0.001 light-years. Figure out the ratio to calculate the total time (25 years × 1000 = years to travel 1 light-year).

How large is the solar system? What do the distances between each planet look like? How could the solar system be measured so that the distances between each planet can be visualized? Where are Voyagers 1 and 2 in relation to our solar system? In what direction are they headed? Your class, working as a team will be able to map these answers using a playing field and a little bit of math!

Materials Needed per Team

• Part A: 5 × 7 index card, pencil, activity sheet.
• Part B: 5 × 7 index card, paper, calculator, pencil, metric ruler with millimeter markings, black marker, copy of *Planetary Data Table,* 100 meters of string, scissors, re-closable baggie, cardboard, activity sheet.
• Part C: index card from Part A, index card from Part B, meter stick or measuring tape and a metric ruler with millimeter markings, Popsicle stick, class protractor (on field), baggie with string, activity sheet.

Team Members

(fill in student's name on the line next to his/her job)

• **Materials Engineer (ME):** ______________________

Tasks: Reads list of materials, finds materials and brings them to the team, cleans up, and returns all materials after each part of the activity is done, helps with tasks if asked by the Experimental Specialist.

• **Experimental Specialist (ES):** ______________________

Tasks: Reads the procedures for Parts A, B, and C; performs the experiment and directs others to help if necessary; completes the Student Data Table with information from the Data Processing Statistician.

• **Data Processing Statistician (DPS):** ______________________

Tasks: Computes numerical information, helps with tasks, and gives information to the Experimental Specialist.

Procedure

Part A: Hypothesis

1. Your team will be assigned an object in the solar system. Our object is

____

2. Your team will be going outside to the playing field. Bring a 5 × 7 index card and a pencil.

3. Once outside, you will be making a class hypothesis as to how the solar system and the two Voyagers are arranged within the playing field area. Your teacher will take you to the spot where the Sun will be stationed. Some background information/directions will be given.

4. Look out over the field and decide where you think your object should be located. The team should walk to that location.

5. After each team has decided where its object should be placed within the area, one member of your team should take the index card, go stand where the Sun is located, and plot (draw a dot) approximately where each object is located using your pencil. Make sure all groups have been plotted on your card. This is your team's hypothesis of how the solar system is arranged using the scale of the playing field.

Part B: Inside Activity — Making a scaled model of the objects in the solar system

1. ME: Gather materials listed for Part B.

2. Using the table, find your object from Part A. These numbers need to be adjusted to fit within the playing field. The DPS will calculate the new numbers for your object.

3. The scaling factor you will be using is 1 meter = 125,000,000 km (1 m/125,000,000 km).

4. DPS: Using a calculator, divide the distance your object is from the Sun by the number 125,000,000. ES: Record this number on the back of a 5 × 7 index card. Label the answer "Distance from the Sun in Meters." Also include the actual distance in kilometers as recorded on the table. *HINT: If your calculator won't allow you to use numbers so large, leave off the last 3 zeros on all the numbers you use. The ratio will be the same as if the actual number was used. The calculations should also be written in the* Student Data Table.

5. Do the same calculations for the diameter of your object (if it is a planet). Record the number on the back of the index card and label the diameter in meters. Make sure to include the actual diameter in kilometers as recorded on the table. Also record these numbers in the *Student Data Table.*

6. On the other side of the index card, make a scaled drawing of your object. Use the metric ruler. Round to the nearest millimeter (3 spots to the right of the decimal point). *HINT: If your diameter is less than 1 millimeter, make your drawing the smallest "dot" using a pencil.*

continued on panel 8

7. With a thick black marker, print the name of your object across the top portion of your card in very large letters. Carefully go over your drawing with a thin black marker. Be careful not to change the size of the picture.

8. Measure out a piece of string that is equal to the distance of your object from the Sun in meters. Cut the string, wrap it around the piece of cardboard, and put it carefully in the baggie. Label the baggie with the name of your object using masking tape and pencil.

Part C: Back to the Field

1. Gather the materials needed for Part C.
2. Glue your card to the Popsicle stick with the stick on the "calculation side" of the card. Try to keep from covering the information on that side of the card.
3. DPS: Go to your teacher and write down the angle of degrees for your planet's place in its orbit on the handle of the Popsicle stick.
4. Find the protractor/Sun on the field. Take the string out of the baggie. One team member will hold the protractor. The third team member, holding the other end of the string, will walk the length of the string in the direction that the protractor was pointing. The second team member will try to keep the string going on a "true path."
5. When the string is laid out, the Popsicle stick/index card should be held at the far end of the string.
6. After all objects have been placed in the "correct" spots on the field, one team member should return to the Sun with the index card from Part A, turn the card over, and draw the positions as they now appear.

Conclusions

- Look at the two index card drawings.

  Were they the same? ____________ (yes/no)

- How many drawings could be seen from the Sun's position? ____________________________
- Which ones?

  ____

  ____

- Which objects were the farthest out?

  ____

  ____

- Do you know how long it took for these objects to get there? ____________________________
- Voyager 2 was launched on August 20, 1977. How long has it taken to travel to its current position?

  ____

  ____

- Voyager 1 was launched on September 5, 1977. How long has it taken to get to its current location?

  ____

  ____

Student Data Table

Name of object

____

Average distance from the Sun in kilometers

____

Scaled distance from the Sun
(1 m/125,000,000 km of distance from the Sun)

______________________________ meters

Scaled diameter of object
(1 m/125,000,000 km of diameter)

______________________________ meters

Is Voyager 1 lost now that it has left the solar system? Towards what is it heading? Using several common items, some math, and a playing field, your class will discover where Voyager 1 is going and the distance that must be covered to get there.

Materials Needed per Team

Part A: 5 × 7 index card, pencil, black marker, string, meter stick with centimeter markings, table of information on stars, piece of cardboard, re-closable baggie, glue, Popsicle stick.

Part B: 5 × 7 index card with the name of your star on it (on the Popsicle stick), a blank 5 × 7 index card, a pencil, the baggie with the cardboard and string inside. Your teacher will supply a protractor.

Procedure

Part A

1. Your teacher will show you a series of photocopies taken from one index card made during the "Voyager: Where Are You?" activity. This is the new scale for this next activity. It will be called Voyager–solar system. It will take 1,000 Voyager–solar systems to equal 1 meter. This meter also equals 1 light-year. What is the unit of measure that makes up the Voyager–solar system?

   ____

2. Voyager 1 is heading toward the constellation Ophiuchus [OFF-ih-YOU-kus]. Your teacher will give you one of the stars to work with that make up this constellation.
   Our group's star is ________________________

3. Gather the materials needed for Part A.

4. Using the table, find your star. The "Distance in Light-Years" number needs to be adjusted to fit within the playing field used in the next part of the activity.

5. The scaling factor you will be using is 1 meter = 1 light-year.
6. Write the name of the star in large letters using a marker across the top of the index card. Write the actual distance from our solar system in light-years underneath the star's name. Glue this card to a Popsicle stick.
7. Using a meter stick, measure a piece of string that will represent the correct scaled distance. Cut the string.
8. Carefully coil the string around the piece of cardboard, and place it in the baggie. Label the cardboard with the name of the star.

Part B

1. Gather the materials listed for Part B.
2. Meet on the playing field where directed to meet.
3. The teacher will place the Voyager–solar system card at that spot.
4. A 360-degree protractor will be placed in the same area.
5. Your teacher will tell you the angle of your star from the Voyager–solar system dot.

   Our angle is ______________ degrees.
6. One team member will take the string and cardboard out of the baggie while standing at the protractor.
7. The second team member will find the angle of degrees on the protractor and stand there. This member will also try to keep the string going straight as the string is unrolled. This member should also hold onto the blank index card and the pencil.
8. The third team member, taking the cardboard with the string wrapped around it and the index card with the star's name on it, will walk the length of the string, unwrapping as you go.
9. When the string is completely laid out, the index card with the name of the star on it should be held at the end of the string.
10. Once all the stars have been laid out, the second team member should draw the positions of all the stars on the playing field using the blank index card to represent the playing field.
11. Listen to your teacher for final instructions before going back to the classroom.

Conclusions

- Look at your index card that represents the constellation Ophiuchus. Does it look like the drawing on your activity sheet? ______________ (yes/no)

Why do you think this is so?

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- The "dot" by the protractor represents where the Voyager spacecraft is now. It has taken 25 years to cover that distance. Look at your index card with all the stars drawn on it. Estimate how long it might take to reach the closest star in the constellation. (How many "dots" would it take to get there?)

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EW-2010-09-012-JPL
JPL 400-1431 10/10