National Aeronautics and
Space Administration

Educational Product	
Educators and Students	Grades 5–12

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PLANETQUEST

THE SEARCH FOR ANOTHER EARTH

Activities for Students

JET PROPULSION LABORATORY

The Search for Another Earth

In 1995, a Swiss team of scientists discovered a planet half the mass of Jupiter orbiting a star 48 light-years from Earth. Today, dozens of other planets have been found outside of our own solar system—some as close as 15 light-years and some as far as 200 light-years away. Some scientists believe that there are thousands of other systems waiting to be discovered.

The extrasolar planets we have discovered so far are giants, like Jupiter and Saturn, many orbiting close to their stars. We don’t expect them to support life as we know it. But these same planetary systems might also contain smaller, terrestrial planets.

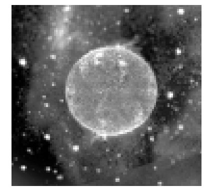
The “holy grail” for planet searchers is a planet closer to the size of Earth, orbiting its star at a constant distance similar to the distance between the Sun and Earth. Why? Because this is the type of planet that is most likely to contain signs of life. If we found water, carbon dioxide, and ozone in the atmosphere, we would be even closer to finding life. But how do we find these smaller planets and determine whether there could be life on them? That is the PlanetQuest mission.

Contents

To find another Earth, we need instruments more sensitive and more precise than any that have ever been built, instruments that will let us see farther and more clearly into the universe. These visionary technologies will let us learn more about other planetary systems and discover what they may contain. NASA has combined its planet-searching missions into the Navigator Program.

With new technology, the giant Keck telescopes in Hawaii will capture the first images of gas giants outside of our solar system. The Space Interferometry Mission (SIM) will launch a virtual telescope into space capable of detecting evidence of planets just slightly larger than Earth. NASA will also launch the Terrestrial Planet Finder (TPF), a sophisticated mission that will build upon the legacy of all planet-searching missions that have gone before it. This breakthrough mission will send back the first photographs of nearby planetary systems, helping us analyze their atmospheres and taking us even closer to our goal of finding another Earth.

The PlanetQuest website and other PlanetQuest educational and outreach activities will continue to bring these exciting missions to an ever-expanding audience.



Scientists have already discovered more than 100 planets outside our solar system!

http://planetquest.jpl.nasa.gov

Math and Science Activities

L e a r n i n g b y D o i n g

NASA's planet-searching missions will rely on advanced mathematics to understand and interpret data. In fact, mathematical analysis and tools are an integral part of NASA's entire space program. Here is a chance for your students to experiment with some of the same techniques and concepts that NASA scientists will employ.

This package contains a set of four activities for students in grades 5 through 12. There are separate "Teacher Pages" and "Student Pages" for each activity that provide lists of materials and instructions on how to proceed. These hands-on activities are designed to help your students see how measurement and computation in mathematics can be used in real-world applications.

Each of these activities has been coordinated with the National Council of Teachers of Mathematics (NCTM) standards to enhance the following learning objectives:

DIRECTION AND DISTANCE IN SPACE
Students will investigate distance and direction, and conceptual bridges will be presented to help students understand the size and scale of the universe.

MEASURING AND ATTRIBUTES OF OBJECTS
Using "representation methods," familiar objects will be used as scale-appropriate objects in the measurement of interplanetary and interstellar distances.

USE OF DISCRETE QUANTITIES INVOLVING NUMBERS, DECIMALS, AND POWERS OF TEN
Using NASA data, students will calculate to scale, interstellar distances. Also, using representative objects, they will model the measure of distances whose scale make them impossible to measure by direct means.

USE OF TEAM APPROACH
Discussion, experimentation, and consensus are critical skills for students attempting to develop a mathematical plan to solve a problem.

AFTER COMPLETING THESE ACTIVITIES, YOUR STUDENTS WILL BE ABLE TO:

1. Use measuring instruments (rulers, protractors) and simple materials to represent distance between planets and stars.
2. Integrate the conception of distances represented by familiar objects to the use of mathematical computation to both quantify and realize the vast distances used by astronomers.
3. Plan an investigation using data and prompts provided and execute measurements and data analysis with a team of peers.

Looking for Planets Without Seeing Them

Materials You Will Need

- *Students: Notebook paper, pencil*
- *Drinking straws*

ACTIVITY

Let's make a model of a star and planet. Your teacher will prepare the model, and you will observe what happens to the star and planet.

QUESTIONS FOR THE STUDENTS

1 What do you think the golf-ball-size clay at the end of the drinking straw is supposed to be?

2 What does the marble-size lump of clay at the other end of the straw represent?

3 When your teacher turns the model, watch the big lump of clay. Does it stay in one place or does it move?

4 Now observe the turning model from across the room. Can you see the "wobble"?

5 Hold a drinking straw vertically at arm's length between your eye and the little spinning solar system. Can you see the wobble now?

NASA's Space Interferometry Mission is like that drinking straw you are using to observe the little solar system. It will help us see the wobble of stars with planets that are very far away.

Looking for Planets Without Seeing Them

Materials You Will Need	Time Required
• *Strong piece of string* • *Drinking straws* • *Soft clay*	• *One hour*

FOR THE TEACHER

First make a little solar system model from a string, drinking straw, and clay. As you do the activity, ask the students questions about the model. [Teacher hints are in brackets.]

Tie one end of a piece of string around a drinking straw, allowing the knot to slide back and forth along the straw. Put a golf-ball-size lump of clay around one end of the drinking straw. Ask the students: What do you think the clay is supposed to be? [a star] Put a marble-size lump of clay around the other end of the straw. Ask the students: What does this lump of clay represent? [a planet]

Hang the model up so it can spin freely. GENTLY turn the model. Have the students watch the big lump of clay [the star]. Ask the students: Does it stay in one place or move? [It moves slightly. Students may be disappointed that the motion is not greater, but this is close to the slight motion of a star with an orbiting planet.] Have them observe from across the room. Ask the students: Can you see the "wobble"? [It will be more difficult to see.] Hold another drinking straw vertically at arm's length between your eye and our little spinning solar system. [The vertical straw simulates the measuring instruments on the SIM spacecraft.] Ask the students: Can you see the wobble now? [It should be easier to see.]

For the rest of the activity, the students will follow your instructions as you read the following script. Discuss with the students how planets behave and how we will use space missions to find distant planets. [Teacher hints are in brackets.]

Have the students write down this list of objects: STAR, MOON, COMET, METEOR [shooting star], PLANET [other than Earth], BLACK HOLE, GALAXY, AIRPLANE. Ask them: Imagine the night sky and circle the names of objects you have seen in the night sky with your eyes [not pictures]. [Students may pick any or all of these objects.]

Ask the students: If one of the things you picked was PLANET, please share with the class what you saw and why you decided it was a planet. Did the planet you saw look different than the other bright lights in the dark sky? Here are some hints: Did the light from the planet twinkle, or shine like a flashlight? If you watched several nights, did the planet stay near the same stars every night? [It may have moved a little.] Could you see the color of the planet? [Mars sometimes appears to have a slightly red color.] Could you see its shape? [Not without a telescope or binoculars; with them, Saturn has an oblong shape.]

The planets of our solar system are near Earth. If Earth is the size of a grain of rice, Mars is another rice grain about 4 meters (20 feet) away. A nearby star is a grapefruit as far as New York is from Los Angeles. If that "grapefruit" star had its own planets, they would be rice grains as well. Imagine trying to see a rice grain that is 6,000 km (3,500 miles) away.

The Space Interferometry Mission (SIM) cannot "see" the planets of nearby stars. How can it help us know if other stars besides our own Sun have planets around them? [SIM has to measure something that indicates that a planet is present.] Have you ever been with a friend who suddenly found they had an insect inside their clothing? Did you see the insect right away? [Probably not; it was inside the clothing or too small to see from a distance.] Did your friend quietly explain to you about the insect in their clothing? [doubtful] Did your friend yell? [probably] Did your friend do anything else? [wiggle or jump] Did your friend move around? Can you show the class what a person does who has an insect in their clothing? [As appropriate, students mime the wiggling.]

Stars that have planets orbiting them are like people with insects in their clothing. They "jump around" a little. Astronomers call this slight motion "wobble." SIM cannot see planets directly, but SIM's very accurate measurement of where stars are located can help it see stars that wobble and change their positions.

Ask the students: Why do you think stars with planets wobble, but stars without planets do not? Do planets stay in one place or move? [They move around.] How do planets move? Does the motion make a shape? [nearly circular] Is there a force that helps planets move this way? [yes] What is that force called? [gravity]

Measure a Tree

Materials You Will Need

- *Pencil and clipboard or other hard surface (such as a book) to write on in the field*
- *Long piece of string*
- *Meterstick*

What is the tallest object you can measure with a meterstick? A fence? The ceiling? Have you ever disagreed with someone about the height of a tree or building? If you work as a team, you can measure the height of any object!

THE TEAM MEMBERS AND THEIR JOBS

- *Math Magician:* Stands between the measuring being done and the object to be measured, holding the end of a string on top of her or his head.
- *Line Sighter:* "Sights" using a string to line up the top of the Math Magician's head with the object to be measured.
- *Meterstick Master:* Uses a meterstick to measure many meters and parts of meters and adds them together into a total (the total may have decimals); gives data to the Inspector/Recorder.
- *Inspector/Recorder:* Reads directions, inspects work being done, and records data from the Meterstick Master. Also gets equipment, and takes a pencil and the Height Data Table to the field with a clipboard or other item to write on.

DIRECTIONS FOR MEASURING A TREE

1. The Inspector/Recorder picks a place to measure the tree. It should be a place where the Line Sighter can lie on the ground and have a clear view of the tree.
2. The Math Magician chooses a place to stand and holds the end of a long string on top of his or her head.
3. The Line Sighter takes the other end of the string and moves to a place where she or he can lie down and still see the top of the Math Magician's head lined up with the top of the tree. Use the string pulled tight to help you "sight" these two and line them up. You many have to move several times.
4. The Meterstick Master now measures the distance on the ground (not the string) between the Line Sighter's eye and the feet of the Math Magician. Without moving the meterstick, read the measurement and tell the Inspector/Recorder (it should be a number that has decimals for the small parts of a meter measured). Do not remove the meterstick!
5. The Meterstick Master continues on toward the tree, measuring until the tree is reached. Read the measurement and tell the Inspector/Recorder the total distance between the Line Sighter's eye and the base of the tree.
6. The Meterstick Master measures the height of the Math Magician and tells the Inspector/Recorder.
7. The Math Magician leads the team in the analysis of the data collected and designs a mathematical plan to compute the height of the tree. Suggestions: Make a drawing of the measuring experiment as seen by someone watching from the side. Show the position of each person and draw lines to show what the Line Sighter was looking at.
8. What is a ratio? Can it help solve this problem? On your drawing, write down the data you collected. Circle the object whose height you want to measure. Write out a mathematical plan (equation) and fill in the data numbers. Compute the height of the tree using your plan. Does the answer make sense? (Is the height too short, or too tall?)
9. If you think you need to try again, that is OK. Ask other teams for help after several attempts, but be sure to take your work with you so they know what you were thinking about. Put your team's agreed-on computed answer for the height of the tree on the Class Height Data Table. Compare your answer with answers from the other teams. Do you agree or disagree?

The Space Interferometry Mission will measure stars that are very far away. The SIM astronomers are using a spacecraft and calculations like these to measure distances in the universe.

Height Data Table

Distance from Line Sighter's eye to the Math Magician's feet	*meters*
Distance from Line Sighter's eye to the base of the tree	*meters*
Height of the Math Magician	*meters*
Computed height of the tree	*meters*

Measure a Tree

UPON COMPLETION OF THIS ACTIVITY, STUDENTS WILL BE ABLE TO

- Use mathematical problem solving to measure inaccessible objects
- Use data sets with one variable
- Employ ratios to compare similar triangles

NCTM STANDARDS

Grades 6–8

- *Data Analysis:* Students collect, organize, and represent data sets that have one variable and identify relationships of the data collected. Students will know various forms of display of data sets.
- *Understanding Numbers:* Students will demonstrate ways of representing numbers, relationships among numbers, and number systems.

Grades 9–12

Mathematics as Problem Solving, Algebra, Mathematical Connections, and Mathematics as Communication.

Notes on Materials You Will Need

- *Metersticks (2 per team if possible), or a long tape measure.*
- *One ball of string per team (enough to stretch from the Line Sighter to the top of the Math Magician's head).*

Time Required

- *One hour*

COOPERATIVE TEAMS

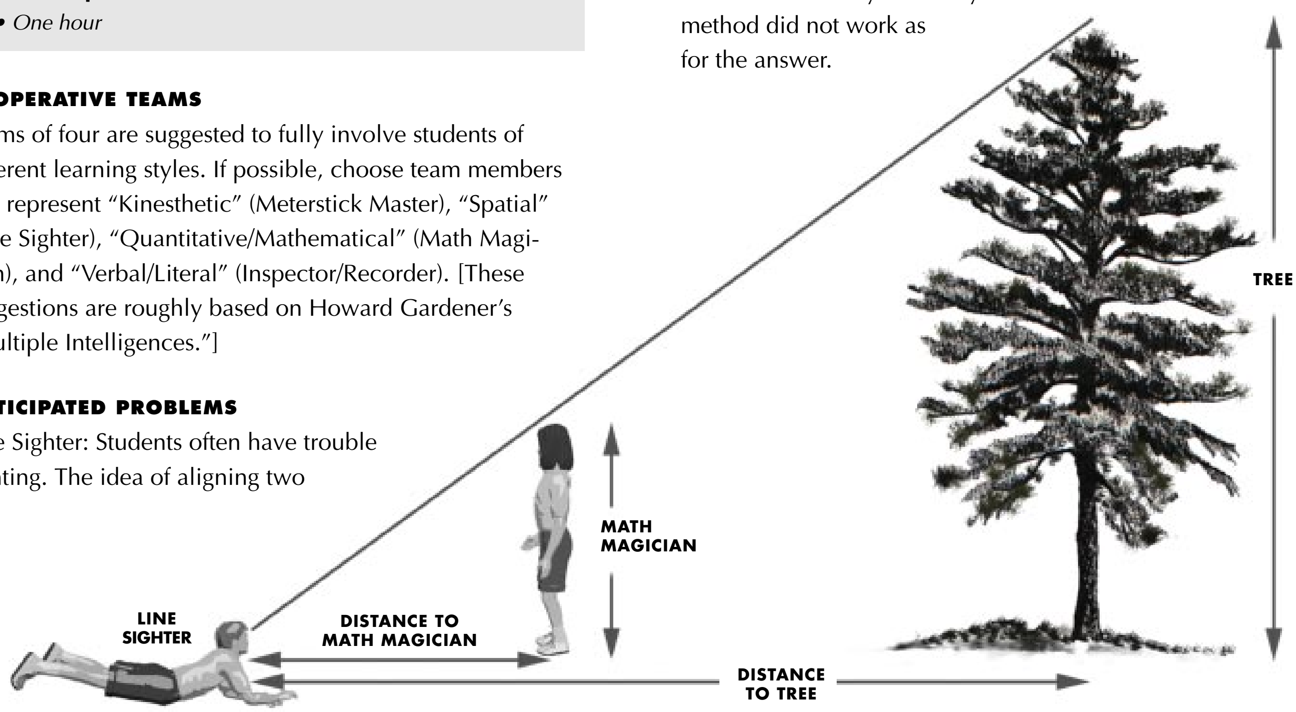
Teams of four are suggested to fully involve students of different learning styles. If possible, choose team members that represent "Kinesthetic" (Meterstick Master), "Spatial" (Line Sighter), "Quantitative/Mathematical" (Math Magician), and "Verbal/Literal" (Inspector/Recorder). [These suggestions are roughly based on Howard Gardener's "Multiple Intelligences."]

1 **ANTICIPATED PROBLEMS**

Line Sighter: Students often have trouble sighting. The idea of aligning two objects so they seem superimposed is conceptually foreign. If students are having trouble with this concept, try using two pencils held upright with erasers on top, one close to the eye and one at arm's length. Have them align the two erasers with a distant object. Or — even better — if a mirror is available, have them align the pencils by looking at themselves in the mirror where they see their eyes as well as the reflected pencils.

2 The Meterstick Master must be able to make successive measurements of a long distance with one or two metersticks by going end to end and keeping track. This student must also be able to measure decimal portions of meters and express the final measurement in one number that includes decimals. Example: Student measures 5 full metersticks and an additional 40 centimeters. This is 5.40 meters.

3 Final display of the data on a Class Height Data Table: The intent is to encourage students to explore the design of a mathematical plan to solve the problem (students are often more concerned with getting the "right answer" and avoiding embarrassment). Have teams discuss their methods before posting data on the Class Height Data Table. Have a discussion about interesting mathematical plans that gave results that did not make sense. As much praise should be shown for analysis of why a method did not work as for the answer.



Measure Earth

Eratosthenes was the first to take the measure of his known universe, which was Earth. Listen to the story as your teacher reads it.

On a separate piece of paper, write the answers to these questions:

HOW TO MEASURE EARTH

1 Make a mathematical plan to find out how many pieces of "Earth pie" there are if each piece is 7.12 degrees and a full circle is 360 degrees.

2 What did Eratosthenes conclude about the shape of Earth?

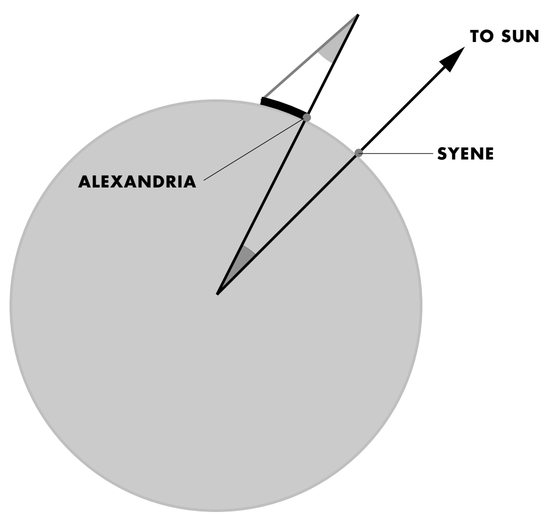
3 How did the angle of the obelisk shadow help Eratosthenes measure Earth?

4 What are two possible methods that Eratosthenes used to measure the distance from Syene to Alexandria?

5 How far was that distance?

6 Make a mathematical plan to measure the distance around Earth using units of stadia.

7 Now calculate the size of Earth using the information that Eratosthenes had.



Measure Earth

UPON COMPLETION OF THIS ACTIVITY, STUDENTS WILL BE ABLE TO

- Use parallel lines and segments of circles to measure Earth
- Use relationships among numbers

NCTM STANDARDS

Grades 6–8

- *Data Analysis:* Students collect, organize, and represent data sets.
- *Identify Variables:* Explore relationships among numbers and number systems.
- *Develop Understanding of Large Numbers:* Use bench-marks to understand magnitude — Understand and appropriately use various relationships for large numbers (e.g., exponential, scientific, and calculator notation).

Grades 9–12

Students use theorems involving the properties of parallel lines cut by a transversal — Investigate the properties of circles — Use and measure sides, interior, and exterior angles of triangles — Classify figures and solve problems — Understand the notion of angles and how to measure them.

DIRECTIONS FOR THE TEACHER

Read the story of Eratosthenes with the students. Stop the story when you come to places where an activity or calculation is suggested. You may wish to make and project a transparency of the illustrations.

Time Required • *One hour*

THE STORY OF ERATOSTHENES

A scientific writer, poet, and astronomer, Eratosthenes [Err/a/tos/the/neez] lived more than 2,000 years ago in Egypt (276 BC to 194 BC). He is the first person known to have calculated the circumference of Earth.

Eratosthenes knew that there was a deep well in Syene in Egypt. People walked down circular steps to get into the well to get water. It was very dark on the steps when people were walking down. But on one day a year (June 21st), the sunlight at noon shone all the way down to the bottom of the well. He noticed that his own shadow was very "short" on that day, only covering his feet but not the ground nearby. Eratosthenes went to another city in Egypt — Alexandria. On that same day of the year, sunlight did not reach the bottom of wells. And he noticed that his shadow was "longer."

Look at the illustration of the student. She has placed clay on two places on a globe and put sticks in the clay so they are perpendicular to the surface of the globe. Notice that one stick has a very small shadow but the other stick has a longer shadow. What does Earth do to the sticks so that one of them has a longer shadow?

Eratosthenes observed the shadow of a tall obelisk (the Washington Monument in Washington, D.C., is an obelisk). He figured out a way to measure the angle of the shadow from the top of the obelisk. The angle was 7.12 degrees. He divided the degrees in a whole circle (360 degrees) by the angle he measured in Alexandria. He found there were 50 pieces of "pie." The distance between Syene and Alexandria was about 1/50th of a circle.

Eratosthenes made two observations:

1. The difference in the shadows and the amount of light shining down the wells is because Earth is round (not flat).
2. The angle of the obelisk is very important. What do you think it told Eratosthenes?

The diagram shows that this angle is the same as the angle between the two cities, Syene and Alexandria, measured from the center of Earth. Like pieces of pie, the angle of the obelisk in Alexandria is the angle between that city and Syene. How many "Eratosthenes pie pieces" are needed to make a whole Earth?

Eratosthenes had one last problem to solve: How long was the outer edge of one piece of "pie" on Earth's surface? One story says he paid someone to walk from Syene to Alexandria, measuring with a rod, which is similar to a meterstick but marked in units called *stadia*. He found that the distance between Syene and Alexandria was 5,000 stadia, about 800 km. (In a similar fashion, you could measure the length of your classroom with a meterstick, turning it end over end. Then, knowing how many classrooms are in your hall, you could calculate the length of the hall.) Another story said that Eratosthenes knew that caravans of camels went from Syene to Alexandria in 50 days and traveled at the rate of 100 stadia a day.

Eratosthenes now knew the distance from Alexandria to Syene and the number of those lengths (pieces of "Earth pie" to go once around Earth. He multiplied the two together (50 x 5,000) and concluded that Earth was 250,000 stadia around. In modern measure, that is 40,000 km. Today, using new instruments, we know that Earth is 41,670 km around. Do you think Eratosthenes did a pretty good job? Do you think that Columbus knew about the experiment carried out by Eratosthenes?

Measure the Galaxy

Materials You Will Need *(For each team)*
- *About one tablespoon of uncooked rice*
- *Ruler or meterstick with millimeter markings*
- *Calculators*
- *15 meters of string*
- *Glue stick*

Work as a team, and check each box when the task is completed.

Distances in space are very hard to imagine. Since few people walk between cities, it is even hard to imagine the distance between two widely separated places. Try to imagine a trip from your house to the next town. ☐ Can you imagine walking to the next town with a meterstick, stopping to measure every meter of your journey? ______ (yes or no) Now try to imagine the distance to the Moon, to another planet, or to a star. Science fiction movies make it seem easy to travel in space. But what would it be like to actually try to travel to another star?

THE TEAM MEMBERS AND THEIR JOBS

- *Materials Engineer:* Reads list of materials, finds materials and brings them to the team, cleans up, and returns all materials after the experiment is completed.
- *Experimental Specialist:* Reads the "Directions for Measuring the Galaxy" and performs the experiment; completes the Student Data Table with information from the Data Processing Statistician.
- *Data Processing Statistician:* Computes numerical information and gives information to the Experimental Specialist.

DIRECTIONS FOR MEASURING THE GALAXY

1 Imagine that Earth is only as big as a grain of rice. Mathematicians call this technique "changing the scale." Using the Student Data Table, compute the number of rice grains ("mini- Earths"), if placed beside each other in a row, needed to go from here to the Moon. ☐ Hint: To do this, you need to know that Earth is about 13,000 km in diameter.

Consult the Student Data Table to find the distance from Earth to the Moon. Using this information, discuss and design a mathematical plan to change the distance from Earth to the Moon into rice grains laid in a row. Write down your plan. Check your plan with your teacher. ☐ Compute the number of rice grains in this scale that show the distance from Earth to the Moon. Write this number in your table.

2 Draw a line and try to lay this many grains of rice on it, side by side so that each rice grain touches its neighbor. All the rest of the computations will use the scale of one rice grain = one mini-Earth.

3 Using your mathematical plan, compute the number of rice grains needed to measure the distance to the other planet. Try laying out the rice grains (mini-Earths) to represent the distance from Earth to Mars. Check this with your teacher. ☐ Write this number in the Student Data Table. Would you like to count this many rice grains? ______ (yes/no) Would you like to lay out that many rice grains in a row? ______ (yes/no)

4 Measuring length instead of counting: Try changing rows of rice grains into measures of length. (An average coarse rice grain is 1 millimeter in diameter.) Look at the ruler or meterstick, and find the length called millimeters. Draw two dots that are 1 millimeter apart. Show your teacher. ☐ This is the size of a rice grain (mini-Earth). Draw four more dots along a line, each dot 1 millimeter farther away from the last. Using your ruler, draw a straight line through all five dots. Show your teacher. ☐ This represents five rice grains lined up.

5 We need to make a new mathematical plan to change a certain number of rice grains in a row into millimeters of length. Write down your plan and show it to your teacher. ☐ How many millimeters of rice grains are needed to measure the distance from Earth to Mars in rice grain (mini-Earth) units? Write this answer in the Student Data Table and check it with your teacher. ☐ Measure a length of string this long and stretch it out. This is how many rice grains are needed, lined up, to measure the distance from Earth to Mars. On this scale (one rice grain = one mini-Earth), Pluto is over 400 meters (4 soccer fields) away. On this scale, the distance to Sirius — a nearby bright star — is a line of rice grains stretching from Los Angeles to New York City! You can see that distances in the universe are very hard to imagine. SIM is going to measure them!

Student Data Table

Distance from Earth to:	*In Reality (km)*	*In Rice Grains*	*Length Rice Grains Occupy*
Moon	*384,000*		
Mars	*78,000,000*		
Sun	*150,000,000*		
Pluto	*5,900,000,000*		
Sirius	*81,000,000,000,000*		

Measure the Galaxy

UPON COMPLETION OF THIS ACTIVITY, STUDENTS WILL BE ABLE TO

- Convert the scale size of an object using ratio manipulation
- Calculate distances using large numbers

NCTM STANDARDS

Grades 6–8

- *Data Analysis:* Concept of scale (Earth is reduced to rice-grain scale) — Concept of representations of large numbers — Relationship of large numbers (cosmic distances) to a small scale (rice grains) — Exponential and calculator notation.
- *Understanding Numbers:* Students will demonstrate ways of representing numbers, relationships among numbers, and number systems.

Grades 9–12

Analysis using large numbers — Create benchmarks to understand magnitude — Compute using representations for large numbers (e.g., exponential, scientific, and calculator notation).

NOTES ON THE ACTIVITY

Teams of three are suggested. Distances in space are very hard to imagine. We suggest reading the student sheet aloud, stopping to complete activities and calculations as they occur. Time should also be allowed for group discussion to create their "mathematical plans." Alter the plan if it leads to incorrect solutions and/or analyze results of the computation.

Notes on Materials You Will Need

- *Rice grains about 1 mm in diameter the short way. If this size is unavailable, tapioca could be substituted.*
- *Hand lenses or forceps may be useful but are not obligatory.*
- *String, 15 meters long. The string is to show the distance from Earth to the Sun using the scale of one Earth = one grain of rice.*
- *Glue stick (optional)*

Time Required

- *One hour*

NOTES ON THE MATHEMATICAL PLANS

Depending on age appropriateness, it is hoped that students will be able to think about the challenge of converting distances between celestial objects into the scale of rice grains representing the size of Earth.

1 The mathematical plan to convert the distance from Earth to the Moon should include finding the distance to the Moon in kilometers (km) and dividing by the diameter of Earth in km: 384,000 km /13,000 km per Earth diameter = 29.5 Earth diameters (rice grains).

2 After the students draw the line, it may help to have them go over the line with a glue stick. This will keep the rice grains from moving around during placement.

3 The mathematical plan for calculating the number of rice grains (mini-Earths) to show the distance to Mars is the same as for the Earth-to-Moon problem. This may be a time to introduce scientific notation: 78,000,000 km / 13,000 km = 6,000 rice grains. A discussion about the time needed to lay out 6,000 rice grains might lead to seeing the need for an easier method of measuring scale distances.

4 This activity begins to make the connection between the size of rice grains and millimeters.

5 The mathematical plan for changing the Earth-to-Mars distance from rice grains into millimeters (mm) of length is: one rice grain = 1 mm of length. Therefore, 6,000 rice grains x 1 mm per rice grain = 6,000 mm. If students are proficient in conversion in the metric system, have them change the 6,000 mm into either centimeters or meters. Then have them measure a length of string this long and lay it out in the classroom, perhaps crossing their rice grains of the Earth-to-Moon distance. A discussion of relative distances in the solar system may lead to interest in computing distances to other planets, the Sun, or nearby stars.

Student Data Table

Distance from Earth to:	*In Reality (km)*	*In Rice Grains*	*Length Rice Grains Occupy*
Moon	*384,000*	*29.5*	*2.95 cm*
Mars	*78,000,000*	*6,000*	*6 m*
Sun	*150,000,000*	*11,500*	*11.5 m*
Pluto	*5,900,000,000*	*454,000*	*454 m*
Sirius	*81,000,000,000,000*	*6,200,000,000*	*6,200 km*

A good example is Dr. Ann Wehrle, a member of the SIM Science Team, who leads a project to investigate black holes in galaxies.

Ann does strategic planning for the SIM mission, which includes, among other things, deciding how and when the spacecraft will be used by scientists. She explains what the scientists need to the engineers designing and building SIM, such as the desire for larger mirrors to study fainter objects. Part of her job involves explaining the SIM spacecraft design to other astronomers at national and international astronomy meetings.

Dr. Ann Wehrle, SIM science team member.

Ann's favorite recent activity was arranging the use of seven astronomical spacecraft to point simultaneously at a single quasar undergoing a bright flare. Her collaborators were from many countries around the globe, led by a small group of women who realized that international cooperation would result in a unique, unprecedented experiment.

Throughout her school career, math and physics were Ann's favorite subjects. She loved reading science fiction and watching *Star Trek*. In library books on astronomy, she saw images of planets and galaxies photographed with large telescopes like the 200-inch-diameter telescope on Palomar Mountain. As a professional astronomer, she now has her own images of galaxies from the same telescope. Astronomy is fun because you discover new things about how the universe works, and you do things no one has ever done before. You also get to travel a lot, especially to other countries and to mountaintops to use big telescopes.

The most important characteristics you need to be a scientist are the abilities to do math, to explain things well, and to be persistent. For both boys and girls, it's important to excel at math and science, and to take the initiative in finding opportunities to explore. There are many exciting ways to explore the universe — for a start, visit the PlanetQuest website at ***http://planetquest.jpl.nasa.gov*** for information on space missions and news about the latest discoveries. Your community may have a planetarium or science museum to visit, and you might also check into star-gazing events (often free) organized by a local astronomy club. Go outside and enjoy the night sky!

SUGGESTED ACTIVITY

Discuss how you think mathematics are used in space missions. You might start by thinking about what you want a mission to do — for example, the SIM spacecraft will measure the distances to stars and the positions of the stars in the sky, and the measurements must be extremely accurate. SIM will have computers, mirrors, sensors, and many other parts, and will have a very large structure.

One part of Ann's work involves working with the teams that will develop the design for the flight system. Then they will build, assemble, and test the system. If you were on the team, how would you use mathematics to design a spacecraft to measure distances to stars? Would you use mathematics in assembling the spacecraft? What kinds of problems might you encounter that can be solved by using mathematics?

Math is a powerful tool that anyone can use. Computer programmers use it — can you think of other jobs needed for space missions that use mathematics?

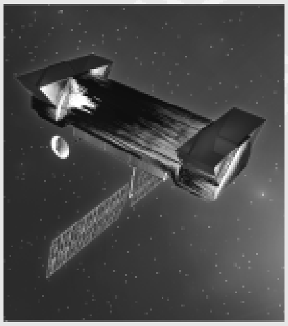
Missions

Over the next 15 years, NASA is embarking on a bold series of missions to find and characterize new worlds. These will be the most sensitive instruments ever built, capable of reaching beyond the bounds of our own solar system.

THE KECK INTERFEROMETER

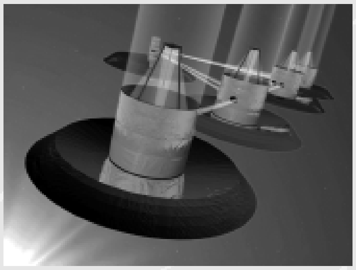
The Keck Interferometer will combine the light of the world's largest optical telescopes, extending our vision by a quantum leap. Using a technique known as interferometry, Keck will study dust clouds around stars where planets may be forming. It may also provide the first direct images of giant planets outside our solar system.

THE SPACE INTERFEROMETRY MISSION



The Space Interferometry Mission (SIM), scheduled to launch in 2009, will measure the distances and positions of stars several hundred times more accurately than any previous observations. SIM's precision will allow us to determine the distances to stars throughout the galaxy and to detect evidence of planets just slightly larger than Earth.

TERRESTRIAL PLANET FINDER



Terrestrial Planet Finder, anticipated for launch in 2012, will be capable of detecting and characterizing Earth-like planets around as many as 200 stars up to 45 light-years away. The project will look for the atmospheric signatures (such as water, carbon dioxide, and ozone) of habitable or even inhabited planets.

Other projects related to NASA's search for new worlds:

THE LARGE BINOCULAR TELESCOPE INTERFEROMETER (LBTI)

Two 8-meter class telescopes on Mount Graham, Arizona, will be linked to create an infrared interferometer capable of imaging distant galaxies and other faint objects over a wide field of view.

THE INTERFEROMETRY SCIENCE CENTER

Support for all of the missions listed on this page is provided by the Interferometry Science Center (ISC), a science operations and analysis service sponsored by the Origins theme and operated by the California Institute of Technology. The ISC facilitates timely and successful execution of projects that use interferometry, a key technology in the Origins Program.

http://planetquest.jpl.nasa.gov

For more information on the quest for extrasolar planets, visit:

http://planetquest.jpl.nasa.gov

For additional NASA educational materials, visit Spacelink and the Teacher Resource Directory:

http://spacelink.nasa.gov

http://teachspacescience.stsci.edu

For more information, contact:

Rhonda Jones
Telephone: (818) 354-1562
E-mail: Rhonda.R.Jones@jpl.nasa.gov

Jenny Tieu
Telephone: (818) 393-4765
E-mail: Jenny.Tieu@jpl.nasa.gov

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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