My, What Big Eyes You Have
JWST: The Better to See the Universe With

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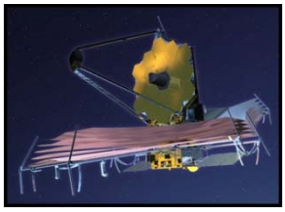

We all know that a telescope enables us to see objects that are much fainter than the human eye can see by itself. A telescope can see fainter objects because it gathers more light from a much bigger opening (telescope lens or telescope mirror) than the eye (pupil). The amount of light collected does not depend simply on the width (diameter) of the lens or mirror but instead on the entire surface (area) of the lens or mirror. For a circular shape, the area is determined by the diameter times the diameter, or diameter-squared. See Figures below.

girl scouts of southern arizona

In this activity, we use a 3/4-inch plastic counting disk (or small coin) to represent the area of the human eye. A 4-5/8-inch CD, a 9-inch paper plate, and a 12-inch pizza pan represent small, medium, and large telescope mirrors.

The pupil of the human eye can go from 2 mm to 8 mm in diameter. If we assume a typical size to be 6.5 mm, we can compare the pupil of an eye to the mirror of the James Web Space Telescope (JWST), which is 6.5 m (21.3 ft) in diameter. This means that the JWST is 1,000 times the diameter of the pupil and so its area is 1,000,000 times the area of the pupil of a human eye. If you think of the area of the pupil or the area of the JWST mirror as a bucket that can capture light, the JWST can "capture" 1,000,000 times more light than the human eye!

The diameter of the paper plate outline is nearly twice the diameter of the CD. However, the area of the paper plate outline is nearly four times the area of the CD. The diameter of the pizza pan is 2.6 times that of the CD, but the area of the pizza pan is almost 7 times greater than the area of the CD. Counting the number of disks needed to cover the surface areas allows us to see how quickly the light-gathering area increases.

The following activity will give you an idea of why astronomers build bigger telescopes in order to see fainter objects in the Universe.

Girls will *Discover* the connection between what their eyes can see and what they and astronomers can see with telescopes. They will be able to *Connect* their backyard telescopes with the greatest telescopes that scientists build and why they build them. If girls are given the opportunity to use telescopes, they can use their experience to *Take Action* to educate and inspire others to appreciate the night sky.

Figure 1: About 6.5 disks across the diameter of the CD.

Figure 2: 32 disks covering the entire area of the CD.

Figure 3: About 21 disks across the entire area of the pizza pan and 336 disks covering the entire area of the circle.

Objectives:

- To demonstrate that the bigger the telescope (the larger the mirror or lens), the more light it will gather

- To demonstrate that the amount of light gathered depends on area not diameter, i.e., twice the diameter gathers more than twice the light

Materials:

- A CD (about 4-5/8 inches in diameter), an inexpensive paper plate (9 inches in diameter), and a 12-inch disposable pizza pie pan
- A 9x12-inch or larger sheet of paper
- Disks or coins, no more than 3/4 of an inch in diameter (about 400 will complete all 3 objects)
- Plastic bags or containers, paper plates, or pie plates to hold the counters
- Simple chart to record the diameters of the three "telescope mirrors," the estimate of how many "eyes" are needed to cover the surface area, and how many "eyes" were actually needed to cover the surface area of each

Procedure:

- Trace an outline of the paper plate on the sheet of paper. (Do not work directly on the paper plate. The disks will slide off the raised plate edges.)
- Put the counters into plastic bags or containers or onto paper plates or pie pans.
- Set up one or more stations with plastic counters, a CD, the paper plate outline, and a pizza pan. Each girl or each group can have a chart for recording measurements.
- Explain that one disk represents the human eye. Have the girls brainstorm how much their eyes can see (small objects, large objects, distant objects, etc.).
- Explain that telescopes can help our eyes to see faint objects at very great distances. The size of the telescope mirror helps to determine how much we can see.
- Place a line of disks across the diameter of the CD. Count the disks and record this number (see Fig. 1)
- The CD represents a small telescope mirror. Each disk represents one "eye." Have the girls estimate how many disks will cover the CD (see Fig. 2). Record this number.
- Use the disks to cover the surface of the CD. How many "eyes" does it take to cover the CD? Record this number. How accurate were the estimates? This small "telescope mirror" would gather enough light to help us see fainter objects in the sky.
- Use the paper plate outline to represent a medium-sized telescope mirror. Place a line of disks across the diameter of the plate outline. Count the disks and record this number.
- Discuss the concept of area. The area of the paper plate outline is greater than that of the CD. Have the girls estimate how many disks will cover the paper plate outline. Record this number.
- Use the disks to cover the surface of the paper plate outline. How many "eyes" does it take to cover the paper plate outline? Record this number. How accurate were the estimates? Compared to the small "mirror," the number of disks needed to cover the area increased far more than the number of disks needed to go across the diameter.
- Use the pizza pan to represent a large telescope mirror. Follow the same procedure as above. Count how many disks fit across the diameter and record the answer. Estimate how many "eyes" it will take to cover the surface of the pizza pan, record the number, then use the disks to cover the pan, record the number, and discuss how accurate the estimates were.
- Discuss why larger telescope mirrors gather more light and help us see much fainter objects than we can see with our eyes. Emphasize the larger area of the pizza pan relative to the areas of the CD and the paper plate outline.

National Science Standards:

- Abilities necessary to do scientific inquiry; Understanding about scientific inquiry
- Light, heat, electricity, and magnetism
- Origin and evolution of the universe
- Abilities of technological design; Understanding about science and technology
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