GATHERING LIGHT

grades K–8

Objective

Demonstrate how the size, or aperture, of a telescope determines how much light it can gather.

Introduction

Astronomers build telescopes to gather light from distant objects. The more light astronomers can gather, the more they can learn about the light's source.

The amount of light a telescope collects depends on the size of the light collector. In a **refracting** telescope, the light collector is a lens. In a **reflecting** telescope, the collector is a mirror. But in either case, the amount of light the telescope is able to collect depends on the surface area of this primary mirror or lens.

The diameter of the primary lens or mirror in a telescope is called the **aperture.** Increasing the diameter of a lens makes a big difference in how much light it collects. The surface area of a lens is proportional to the square of the aperture, which means that if the aperture doubles, the surface area becomes four times larger.

In this activity, the light collector is not a lens or a mirror, but a hole in a cardboard box. Light enters through the hole and lights up the box. Users can change the size of the hole and see how the amount of light entering the box changes. The results show why increasing the aperture of a telescope increases the amount of light it can collect.

To make the demonstration even more vivid, simple light detectors called **radiometers** can be placed in the box. Radiometers contain filaments that spin faster as more light strikes them, and the addition of moving parts makes this demonstration especially dramatic.

Background Reading for Educators

Telescopes: Super Views of Space, available at https://www.amnh.org/learn-teach/curriculum-collections/discovering-the-universe/telescopes-super-views-from-space

Developed with the generous support of
The Charles Hayden Foundation

Materials

Shoebox

4 index cards

Ruler

Scissors

Ball-point pen (not felt tip)

Black construction paper

Tape

Foam or cardboard

2 identical flashlights

Optional additional materials:

2 radiometers

Procedure

Part One: Making the Light-Collecting Box

1] Line the entire inside of the shoebox with black construction paper. Cover the foam or cardboard with black construction paper. Using the foam or cardboard, make a divider separating the shoebox into two equal portions.

2] Cover the index cards with black construction paper. Make a **5 mm** hole in the center of one index card using the tip of the ball-point pen. A second hole in another index card should be **1 cm** wide, the third **2 cm,** and the fourth **3 cm.** You will have four different index cards, each with a different sized hole.

3] Place the box on its side so that your class can see into the shoebox. Point out the two separate portions, or rooms, to your students, calling one, "Room 1," and the other, "Room 2."

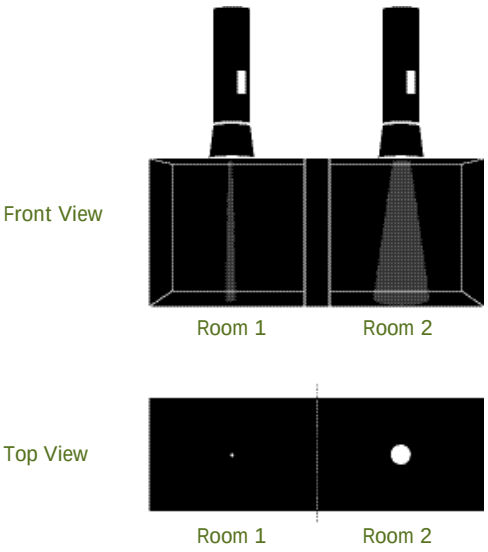
4] Poke a 5 mm hole directly above Room 1. You can make a hole this size by poking a pen through the side of the shoebox.

5] Cut a 4 cm hole directly above Room 2.

Part Two: Using the Light-Collecting Box

6] Turn off all of the lights in the classroom and draw the shades. It is essential that the flashlights are the sole source of the light entering the box.

7] Cover both holes in the box with a piece of heavy black construction paper. Place a flashlight atop each of the covered holes.
Ask: (before turning on flashlights) What do you expect to see?
Explain: No light should enter either of the rooms as the holes are covered, preventing light from passing through.



8] Remove the piece of black construction paper from the holes. Place the 5 mm index card over the hole in Room 2 so that both rooms have a 5 mm hole above them. Place the flashlights directly above each hole.
Ask: (before turning on flashlights) What do you expect to see?
Explain: The hole, or aperture, that you are passing the light through is the same for each room. Therefore the rooms should have the same brightness.

9] Now turn on the flashlights. The light in each room should be the same. You may have to adjust the positioning of the flashlight slightly so that the center of the beam is directed at the center of the room you have made.

10] Turn off the flashlight above Room 2 and change to the 1 cm index card. Place the flashlight back on top of the hole.
Ask: Doyouthinktherewillbeanydifferencein brightness between Room 1 and Room 2?
Explain: Room 2 will appear to be brighter because it now has a larger aperture.

11] Turn the flashlights on. Room 2 should be about four times brighter than Room 1. Remind the students that the light source is exactly the same in both boxes—the only difference is the size of the hole.
Explain: Compare the light in the two rooms to starlight, and the holes atop the rooms to the size of the primary mirror of a telescope. Explain that astronomers want to collect as much light as possible from stars, nebulae, and galaxies so they can observe them more clearly.

12] Replace the index card over Room 2 with the next sized aperture, once again asking your students to predict the change. Continue to the 3 cm-sized aperture, and then completely remove the index card so that the light is shining through the two holes you originally made in the box. Have the students note the difference in brightness between the two rooms.
Explain: The light-gathering ability of a telescope is directly related to the size of the collecting surface (in this case, the hole atop the box).

13] Leave both flashlights on and begin to raise them from the boxes. Lift them at the same rate, so that they are always at the same height. Have the students observe what happens to the light in the boxes as the light source gets farther away. Be sure the students tell you when Box 1 grows completely dark. When you reach that height have them compare the brightness between the two boxes.
Explain: Point out that the light sources are the same brightness, but the light from the flashlight over Box 1 cannot be seen because the hole is too small. Explain that this is why astronomers build bigger and bigger telescopes: the openings in our eyes are too small to see light from distant stars and galaxies, but telescopes with larger openings can capture enough light to make them visible.

Part Three: Optional Extension

14] Place a radiometer in each room. Hold the flashlights above the two rooms. Turn both flashlights on. Ask a student to hold the flashlights in place so that they point down through the holes.

15] As the light strikes each radiometer you will notice that each filament will spin faster as more light strikes it.
Ask: Which radiometer appears to be spinning faster?
Explain: When light strikes the radiometer the filament begins to spin. The radiometer acts as a detector for light. The faster the radiometer spins, the more light is striking it. Thus, the radiometers show that the bigger the primary lens or mirror of a telescope, the more light the telescope collects.

Meg Canlough/AMNH

Light box with radiometers.