MEASURING THE DIAMETER OF THE SUN

OBJECTIVES

The objectives of this activity are intended to meet the following course goals:

1. Students will learn basic astronomical laboratory skills and understandings.
2. Students will learn how to make basic astronomical observations.
3. Students will become scientifically literate about the nature of science in general and astronomy specifically.

After completing this activity the student will be able to:

1. Use a pinhole to form an image of the Sun.
2. Use a meter stick to make measurements in mm or cm.
3. Calculate the diameter of the Sun from measurements of the image diameters formed by a pinhole.
4. Perform basic unit conversions from mm to cm to km, etc.

STUDENT MATERIALS

lab manual
pencil
calculator
ruler

LAB MATERIALS

The instructor should provide the following items:
meter sticks
pin hole
white copier paper
stiff cardboard
thumbtacks

STUDENT REQUIREMENTS

The student will turn in all data tables and answers to the questions at the end of the lab.

INTRODUCTION

Measuring the diameter of the Sun depends on some basic trigonometry and knowing the distance to the Sun. To determine the distance to the Sun requires knowing the distance to the moon and the angle the moon makes with the Sun and Earth (the Moon's elongation) and a little trigonometry. To know the diameter of the Moon requires knowing the diameter of the Earth and measuring the time it takes the Moon to travel through the Earth's shadow during a lunar eclipse. The early Greek astronomers Eratosthenes and Aristarchus preformed all these measurements. You can read more about them in your astronomy textbook. Today astronomers can use light travel time to determine the distance to the Sun to be about 150,000,000 kilometers (km).

In the lab activity you are going to use a pinhole to estimate the Sun's diameter as shown in Fig. 1. When sunlight is allowed to pass through a pinhole it will produce an image of the sun on a screen. Tree leafs also act like tiny moving pinholes and sunlight shinning through tree leafs produces little tiny images of the sun that dance around on the ground. The size of the image produced by a pinhole depends only on the distance of the pinhole from the screen. The farther away the pinhole is from the screen the larger the image. Tall trees produce large images of the Sun and short trees make smaller images of the Sun. It can be seen from Fig. 1 that the height, h, of the pinhole above the screen determines the diameter, d, of the image on the screen. By shining sunlight through a pinhole and using a little geometry of similar triangles it can be seen that the ratio of the image diameter and screen height is the same ratio as the diameter of the Sun, D, is to the distance of

the Sun. In other words the *image diameter/image distance = Sun's diameter/Sun's distance*. Therefore,

$$d/h = D/150,000,000km \qquad \textbf{Eq. 1.}$$

From these simple relationships the diameter of the Sun can be estimated.

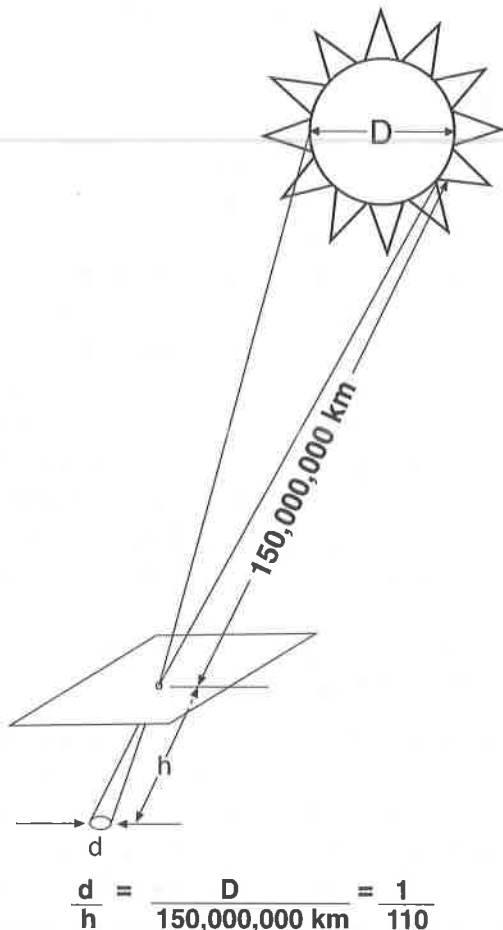$$\frac{d}{h} = \frac{D}{150,000,000 \text{ km}} = \frac{1}{110}$$

Figure 1: Projection of a solar image using a pinhole.

PROCEDURE

To complete this lab activity it is best to work in small groups of three students.

One student will need to hold the pinhole. Another student will need to hold and adjust the screen. The third student will need to measure the distance between the pinhole and screen, and to record this data. Each student in the group should take turns doing each job.

1. You will be provided with a pinhole, or you will construct a pinhole using materials provided by your instructor.

2. Use page 22-4 as your screen. Using a straight edge and the mm rulers on the page, draw three pairs of lines. Each pair should be somewhere between 2mm and 10mm apart. This distance is "d" on page 22-3.

3. Use thumbtacks to fasten the screen to a piece of cardboard. This will allow the screen to be held flat with out blowing around in the wind.

4. Take the pinhole, screen, and a meter stick outside and project an image of the Sun onto the screen as shown in Fig. 1.

5. Adjust the separation between the pinhole and screen until image of the Sun exactly fills the distance between the two lines on the screen. Make sure that the image of the sun is round by making sure the pin hole and screen are lined up with the sun. Record the distance between the two lines in mm as "d" in Table 1.

6. Use the meter stick to measure the mm height of the pinhole above the screen. It is important that the screen height and image size are measured using the same units so that you can take ratios.

7. Each student in the group should repeat steps 5 and 6 at least three times. Please take turns holding the pinhole, screen, and measuring the screen height until the each student has made 3 measurements. Record your screen heights in Table I in mm. Therefore a group of three students should have 9 individual measurements recorded in Table I.

8. Return to the lab room to complete this activity.

DATA COLLECTION AND ANALYSIS

TABLE I

Trial #	Student Name	d (mm)	h (mm)	d/h
1				
2				
3				
4				
5				
6				
7				
8				
9				
	Avg. d/h =			

QUESTIONS

1. Use the average value of d/h and Eq. 1 to calculate the diameter of the Sun. Be sure to show your work, round off your answers, and to place the proper distance units on your answer.

2. The actual diameter of the sun is about 1,390,000 km. Use this value to calculate the percent error for your answer.

$$percent\ error = \frac{|actual - yours|}{actual} \times 100$$

3. List three things that produced errors in your measurements.

a)

b)

c)