

BEYOND THE SOLAR SYSTEM

Expanding the Universe in the Classroom

MEASURING SIZE FROM IMAGES STUDENT GUIDE

Name: _____ Date: _____

microObservatory

TELESCOPE ACTIVITY

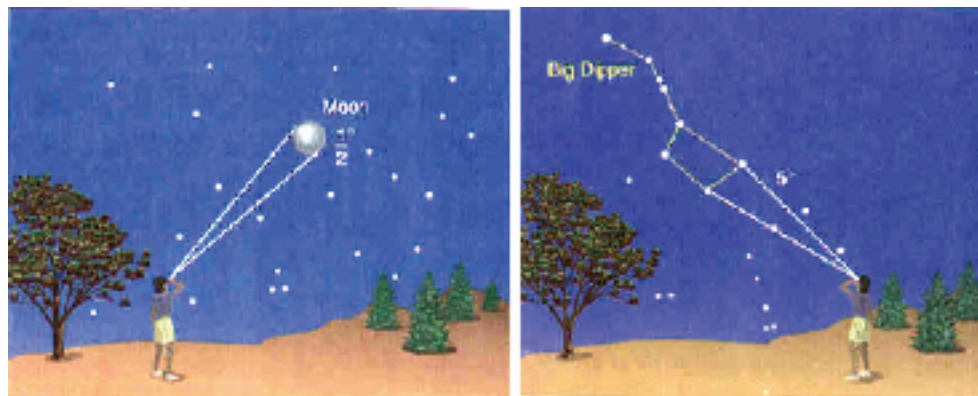
Goals

The purpose of this activity is to learn how to make measurements of angular size on images from MicroObservatory telescopes.

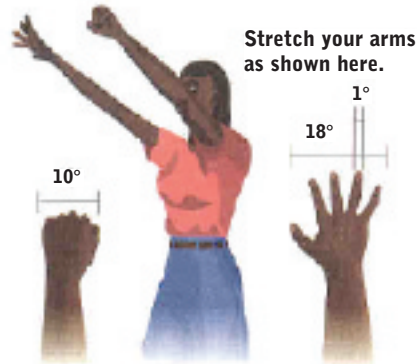
Background

While we can't take a measuring tape and directly measure actual sizes and distances of objects in the sky, we CAN measure their angles—we can measure the **angular size** of a single object, or the **angular distance** between two objects, by extending imaginary lines outward from our eyes. For example, Figure 1 shows that the angular size of the Moon is about $1/2^\circ$. The angular distance between the two pointer stars of the Big Dipper is about 5° .

Figure 1



(You can use your outstretched hand as a simple measuring device to make rough estimates of angular sizes and distances. With your arms stretched out straight in front of you, the width of your fist measures about 10° . If you move your arms upward, hand over hand, from the horizon to a point straight above you, it should take you about 9 hands to cover that 90° distance. When you hold your pinky out at arm's length, it measures about 1° .



PART I. MEASURING ANGLES FROM TELESCOPE IMAGES

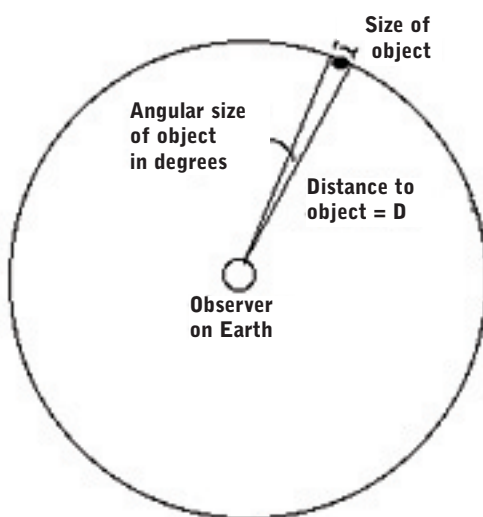
The key to using telescope images to measure distances is to realize that an object's apparent angular size is directly related to its actual size and distance from you. The farther away an object is, the smaller it appears. An object twice as far appears half as big. (This relationship holds true only for objects that take up less than 1° in your field of view, but fortunately that's true of almost all astronomical objects.)

Here is a handy fact for calculating the actual size or distance of a far away object when you can only measure its angular size: **An object with an angular size of 1° is about 57 times further away than it is big.**

The Rule of 57

Why is it that an object with an angular size of 1 degree is 57 times its own size away?

The ratio of the angular size of an object (in degrees) to a whole 360° circle should equal the ratio of the actual size of the object to the circumference of a circle at that distance from the observer.



Expressed as an equation:

$$\frac{\text{Angular size}}{360^\circ} = \frac{\text{Actual size}}{2\pi D}$$

This equation can be re-written as:

$$\frac{\text{Distance of object}}{\text{Size of object}} = \frac{360^\circ}{2(3.14)(\text{Angular size in degrees})}$$

$$\frac{\text{Distance of object}}{\text{Size of object}} = \frac{57}{\text{Angular size}}$$

THE RULE OF 57

For example, if a kite takes up 1° in your field of view and you know it is 3 feet wide, it must be $57 \times 3 = 171$ feet away from you. The same is true for any astronomical object. An object that takes up LESS than 1° will be proportionally FURTHER from you than 57 times its own size, so that the following equation always holds true:







$$\text{Distance to object} = (\text{size of object}) \times (1^\circ / \text{angular size in degrees}) \times 57$$

So, if you can measure the Moon's angular diameter, you can know how many Moon diameters the Moon is away from you. And if you already know the Moon's actual diameter, you can calculate its actual distance.

Angular size tutorial: Two methods for measuring the Moon

Here are two methods to measure the Moon's angular diameter from an image—the first uses a ruler and a hard-copy printout; the second uses the digital image file and an image-processing software program. The same procedure works for planets, gas clouds and nebulae, star clusters, and galaxies. (This method will NOT work, however, for measuring the diameters of individual stars because our telescopes are not powerful enough to resolve their tiny, tiny angular sizes!)

First, it's important to know the angular scale of the camera you use to take your images. Each of the three cameras options on the MicroObservatory telescopes give a different angular field of view, as shown by this chart:

CAMERA	FIELD OF VIEW IN DEGREES	FIELD OF VIEW (Compared to your hand at arms' length)	650x500 PIXELS IMAGE SCALE (Degrees per pixel)	MAGNIFICATION OF MOON
FINDER	$12^\circ \times 9^\circ$		1 Pixel = 1.1 arc minutes = $1.1/60$ degrees = 0.018 degrees	
MAIN ZOOMED OUT	$0.9^\circ \times 0.7^\circ$		1 Pixel = 5 arc seconds = $5/3600$ degrees = 0.0014 degrees	
MAIN ZOOMED IN	$0.45^\circ \times 0.35^\circ$		1 Pixel = 2.5 arc seconds = $2.5/3600$ degrees = 0.0007 degrees	

Method: Using a computer and Image Processing software

All the digital images created by the MicroObservatory Telescopes are composed of a grid of 650 x 500 “pixels,” or picture elements, each of which correspond to a fraction of a degree in the field of view. You can use the Image J software to measure the width of you image in pixels, and then multiply by that camera’s image scale in degrees per pixel.

In Image J

1. Open Image J
2. From the program open the Moon picture and the Moon info.
3. Go to Analyze – Set Measurements. Check Area, Perimeter, Invert Y Coordinates, and Display Label.
4. If we were going to measure in units – miles, km, etc we would next have to set a scale by drawing a line on something we know the size of then going to Analyze – Set Scale. We would then enter the size of the object the line is measuring.
5. Since we are measuring in pixels we can skip step 4.
6. Measure the diameter of the moon.

My Moon measures _____pixels in diameter.
(You may want to measure three times and take an average.)

My image is from the (circle one):

Finder 1 pixel = 0.018°	Main, Zoomed Out 1 pixel = 0.0014°	Main, Zoomed In 1 pixel = 0.0007°
----------------------------	---------------------------------------	--------------------------------------

Now, calculate the angular diameter: _____degrees

(For example, if your Moon image was from the Main Camera Zoomed Out, and it measures 350 pixels across, its angular diameter would be: 350 x 0.0014 = 0.49°)

Now that you’ve measured the angular size of your image, remember the equation from page 3:

Distance to object = (size of object) x (1°/angular size in degrees) x 57

If you knew the actual size (diameter) of the Moon, you could use you image to calculate its distance, or if you knew the Moon’s distance, you could calculate its size from your image. If you don’t know either, you can at least get a distance/ size ration:

Moon’s distance in moon diameters =
(1° divided by angular size) x 57 = _____ Moon Diameters

You can use this same technique for measuring the angular size and determining the distance or size of any object in the universe, from moon craters to distant galaxies!

MEASURING SIZE FROM IMAGES: DATA SHEET 1

Use this sheet to keep track of your calculations as you measure the angular sizes of these objects from your images. You can always calculate an object's distance/size ratio just from measuring its angular size... but if you know either its actual size or distance, you can compute the other using the "Rule of 57" equation:

$$\text{Distance to object} = (\text{size of object}) \times (1^\circ / \text{angular size in degrees}) \times 57$$

Object	Angular size (cm, or pixels)	Angular size (degrees)	Distance/size ratio	Actual size (known or calculated?)	Actual distance (known or calculated?)
MOON				3500 km. (2200 mi.)	
JUPITER				143,000 km. (85,000 mi.)	
ORION NEBULA					~1500 l.y.
CRAB NEBULA				~ 10 l.y. across	
M13 CLUSTER					~25,000 l.y.
ANDROMEDA GALAXY				Estimate: 100,000 l.y.	
WHIRLPOOL GALAXY				Estimate: 100,000 l.y.	
GALAXY NGC 253					~ 8 Million l.y.