

FROM THE GROUND UP!

Measuring Size from Images: A wrangle with angles and image scale

Purpose:

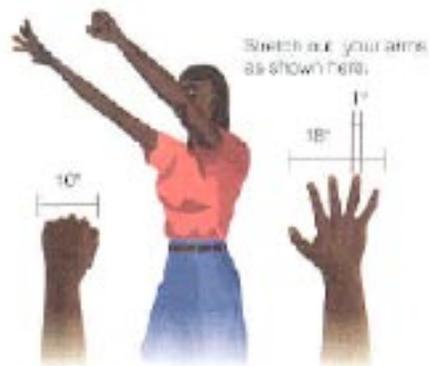
To learn how to make measurements of angular size on images from MicroObservatory telescopes.

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 2 objects, by extending imaginary lines outward from our eyes. For example, Fig 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° .

Fig 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 arms' length, it measures about 1° .

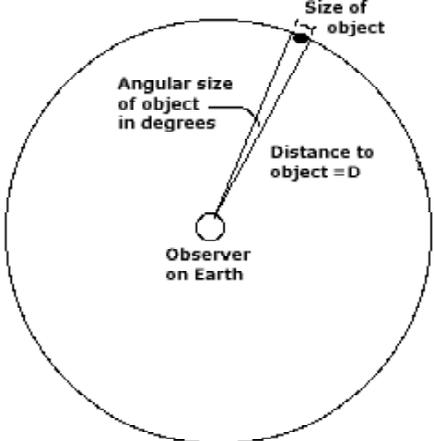


Measuring angles from telescope images.

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 further 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 degree 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 degree 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 degree will be proportionally FURTHER from you than 57 times its own size, so that the following equation always holds true:

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

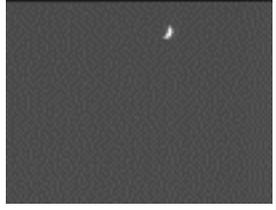
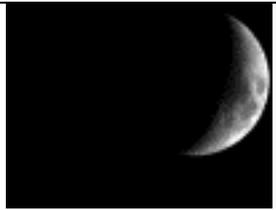
So, if you can measure the moon's angular diameter, you can know how many moon diameters the moon is away from you. And if you already know the moon's actual diameter (see Eclipse activity for a way of figuring this out from scratch), you can calculate it's actual distance.

* The word size is somewhat vague, since it can refer to an object's area or volume or weight, as well as to its diameter, length, width or height. The angular size of an object is directly related to its linear width, height, length or diameter, NOT to its area or volume.

Angular size tutorial: 2 methods for measuring the moon

Here are 2 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 3 cameras options on the MicroObservatory telescopes give a different angular field of view, as shown by this chart:

CAMERA	FIELD OF VIEW IN DEGREES	F.O.V. Compared to your hand at arms' length	650X500 PIXELS IMAGE SCALE (Degrees per pixel)	MAGNIFICATION OF MOON
FINDER	12° x 9°	10° 	1 Pixel = 1.1 arc minutes = 1.1/60 degrees = 0.018 degrees	
MAIN ZOOMED OUT	0.9° x 0.7°	1° 	1 Pixel = 5 arc seconds = 5/3600 degrees = 0.0014 degrees	
MAIN ZOOMED IN	0.45° x 0.35°	0.5° 	1 Pixel = 2.5 arc seconds = 2.5/3600 degrees = 0.0007 degrees	

Method 1. Using a ruler and image printout

(you may need to use "landscape" to fit your image on one page)

Measure the width and height of the image rectangle:

Width of image printout _____ (cm.)

Height of image printout _____ (cm.)

Now calculate the scale of your image in degrees per centimeter by dividing the angular width or height of your image field-of-view (see above chart) by its measured height or width. For example, if your printout of a **finder** image is 8 cm. x 6 cm., the scale would

be 12 degrees divided by 8 centimeters, or 9 degrees divided by 6 cm., or 1.5 degrees per cm. If the moon in this image was 1/2 cm (5mm) in diameter, its angular size would be .5 cm. x 1.5 degrees per cm. = .75 degrees.

My image is from the (circle one):

Finder
(12°x9°)

Main Zoomed Out
(.9°x.7°)

Main Zoomed In
(.45°x.35°)

The scale of my image printout is _____ degrees per cm.

Now you can calculate the angular diameter of the moon in your image:

My moon measures _____ cm. in diameter
(you may want to measure 3 times and take an average)

Calculate the angular diameter: _____ degrees

Method 2. Using a computer and image processing software

All the digital images created by the MicroObservatory Telescopes are composed of a grid of 650x500 "pixels," or picture elements, each of which correspond to a fraction of a degree in the field of view. You can use an image processing program to measure the width of your image in pixels, and then multiply by that camera's image scale in degrees per pixel (see chart) to get an angular size.

You'll need:

- A downloaded file of your image in FITS format. (Find your image in the MicroObservatory archive; click and hold on the "Save as FITS file" option just above your image; choose "Save as SOURCE" rather than as TEXT.)
- An image processing software program such as ImageJ or SIP

In Image J:

• Open your file:	File: Open...
• Select straight line tool	Click on line selection tool in ImageJ window, then click on image
• Specify length of moon to be measured	Click and hold while dragging mouse from one edge of moon to other (you may have to estimate where greatest diameter is)
• Measure size of moon in pixels	Analyze: Measure... then click in ImageJ info window to see length

My moon measures _____ pixels in diameter
(you may want to measure 3 times and take an average)

My image is from the (circle one):

Finder
(1 pixel = .018°)

Main Zoomed Out
(1 pixel = .0014°)

Main Zoomed In
(1 pixel = .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:
 $350 \times .0014 = .49^\circ$)

Now that you've measured the angular size of your image by either method, remember the equation from page 1:

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 your 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 ratio:

Moon's distance in moon diameters =

$$1^\circ \div \text{angular size in degrees} \times 57 = \text{_____ moon diameters}$$

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!

