

Observational Exercise  
Angular Sizes and Scales, and Distances  
to Planets or Nebulae

In the course this exercise, you will use a six inch Newtonian telescope to determine the angular field of view of the telescope through each of several eyepieces. You will then use that information and similar techniques to determine the angular size of at least one astronomical object (a planet, extended nebula, or in desperation, the moon). That information, in turn, can be used to calculate the distance to your object at the time of your observation, provided that the object's true diameter is known.

I. Finding the Scale of Telescope/Eyepiece System  
Observing an appropriate star

If you look at a celestial globe, you will notice that the common astronomical coordinate system resembles latitude and longitude. Instead of degrees longitude, we use a coordinate named right ascension. It is measured in hours, such that at the equator, one hour is equivalent to  $15^\circ$ , so that full turn of the earth ( $360^\circ$ ) is 24 hours ( $15 \times 24 = 360$ ). This comes as no great surprise, since the entire celestial sphere turns fully in one sidereal day. You can also appreciate that this coordinate system is necessarily linked with time measurement.

Procedure:

You will need to find one of the stars on the list below, selected because they are near the celestial equator. Please note the correction factor associated with each star.

Star	Correction factor	Star	Correction factor
fall		spring	
Gamma Peg	0.9654	Procyon	0.9958
Rigel	0.9897	Regulus	0.9780
winter		summer	
Betelgeuse	0.9917	Spica	0.9813
Sirius	0.9578	Altair	0.9881
		Arcturus	0.9441

(In case you're interested, the correction factor is just the cosine of the declination coordinate.)

Acquire your star in the finder of the telescope and insert the longest focal length eyepiece (40 mm).

You may want to have a partner help you with this step and you will need a stop watch or the darkroom timer with luminous dial, or the WWV-UT clock radio. You are going to measure the field of the eyepiece by turning off the telescope drive, and timing the passage of your star cross the diameter of the field. The drive may be turned off by unplugging the cord, or disconnecting the clutch from the motor drive (the clamp screw on the right ascension circle). You will want to

be sure that your star does in fact pass across the full diameter of the eyepiece field.

a) Note in your notebook, the eyepiece, whether you are using a right-angle prism, and its orientation.

b) Note the time of passage,  $\Delta t$ , in minutes or seconds.

c) Note the direction of drift of the star. The point of noting this is that obviously you have now determined at least one direction when you use this particular eyepiece assembly--the direction the star drifts towards is West.

Now, you want to convert your time measurements,  $\Delta t$ , to angular measurements,  $\Delta\alpha$  either arc-minutes or arc-seconds (1/60th of an arc mm.).

$$\Delta\alpha (") = 15 \times \text{factor} \times \Delta t (\text{seconds})$$

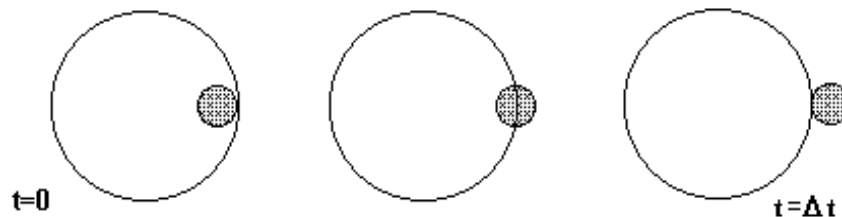
$$\Delta\alpha (') = 15 \times \text{factor} \times \Delta t (\text{minutes})$$

Repeat these measurements for all of the eyepieces, making a table in your notebook that notes the time of the star's passage and the computed angular size of the eyepiece field. Do this for the 40, 20, and 12.5 mm eyepieces.

## II. Angular Size of an Extended Object

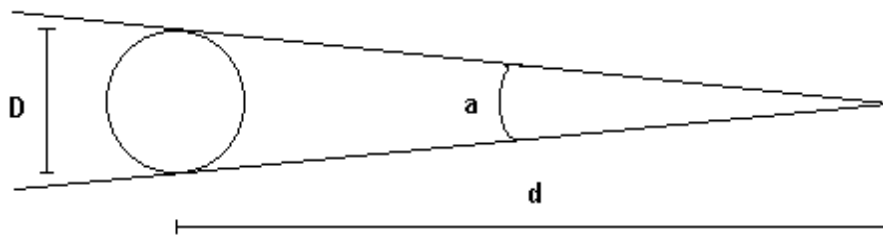
Find a major planet (Mars, Jupiter, Saturn or its rings), the Orion Nebula, Ring Nebula, or the Moon, if all else fails. You will now measure the object's angular size in two ways. Select an eyepiece that gives the largest yet clearest view of the object.

Measure the angular size of your object by letting it drift off the west edge of the field (again, by turning off the drive).



You should show the time for the planet to drift its diameter, the correction factor (supplied by your instructor, the cosine of the declination of the object), and the computed angular size, as well as the details of your calculations.

The angular size of an object is related very simply to its diameter and its distance. In the sketch below,  $d$  is the object's distance from the viewer,  $D$  is the object's true diameter. You will want to express both in the same units. Obviously, the larger the distance, the smaller the angular diameter of the object, noted  $a$  in the sketch.



The most appropriate unit for angles is the radian; the angular measure of one full circle is expressed as  $360^\circ$  or  $2\pi$  radians, a much more natural unit. The principal advantage of using radians is then the simplicity of the relation between  $a$ ,  $d$  and  $D$ :

$$a = D/d$$

The immediate disadvantage is that we must convert arc-seconds or arc-minutes to radians:

$$a = \frac{\Delta\alpha(^{\circ})}{206265(^{\circ}/rad)}$$

or

$$a = \Delta\alpha(^{\circ}) \times \frac{60''}{1'} \times \frac{1rad}{206265''}$$

which determines  $a$  in radians from a measure in arc-minutes.

- a) Note your object in your notebook
- b) its angular size, from previous section
- c) compute its angular size, in radians

Now, you may compute the object's distance, if the true diameter is known by inverting the relation to solve for  $d$ :

$$d = D/a$$

Whatever units you use for  $D$ , you will get your distance  $d$  in the same units. Here are some diameters in various, but appropriate units:

Moon	3476 km
Mars	6800 km
Venus	12,112 km
Jupiter	143,000 km
Saturn	121,000 km
Orion Nebula	12 LYr
Ring Nebula	1.7 LYr

d) Note the distance of your object.

If you work on a nebula, don't be surprised if your distance varies with an accepted value; the edges of a diffuse object such as these may be difficult to see, and vary apparently from night to night.

Data:

**Be sure to include appropriate units.**

<u>Eyepiece</u>	<u>Star</u>	<u>Correction Factor</u>	<u><math>\Delta t</math></u>	<u>Field of View</u>
40mm	_____	_____	_____	_____
20mm	_____	_____	_____	_____
12.5mm	_____	_____	_____	_____
<u>Object Name</u>	<u><math>\Delta t</math></u>	<u>Angular Size</u>	<u>Diameter</u>	<u>Distance</u>
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Calculations (Show all calculations in the space below.):