INTRODUCTION TO THE TELESCOPE

What will you learn in this Lab?

For a few of the labs this semester, you will be using an 8-inch Celestron telescope to take observations. This lab will introduce you to the telescope itself and some properties of a telescope. Observations will be made to illustrate the different telescope properties.

What do I need to bring to the Class with me to do this Lab?

For this lab you will need:

- A copy of this lab script
- A pencil
- Your flashlight
- Your star planisphere
- Your Audubon field guide
- A scientific calculator

I. Introduction:

In this lab exercise you will become familiar with the parts of a telescope and how to use one. You will also become familiar with some telescope properties and use observations to illustrate these properties.

Remember, telescopes are precision instruments; be careful using them. Ask your instructor for help when you are in doubt about what to do.

II. Parts of a Telescope:

Primary Mirror: This is the large mirror at the telescope's lower end which `collects' and focuses the light so that we can see fainter stars than with our `naked' eyes. ASU presently has 20 8-inch Celestron telescopes. This means the diameter of the primary mirrors are 8 inches. These are called *reflecting* telescopes.

Mounting: The mounting supports the telescope and allows it to be moved in two directions (or axes): one in the same sense as the Earth rotates (*right ascension*) and the other in a north/south direction (*declination*).

Telescope Tube: The telescope tube holds the optical parts (eyepiece, primary, and secondary mirrors for *reflecting* telescopes) in the correct position.

Clock Drive: The clock drive turns the telescope at the same rate as the Earth turns, but in the opposite direction so that the telescope stays pointed at one particular location in the sky (*i.e.,* a star).

Setting Circles: These are dials that help you tell where the telescope is pointed. There is a setting circle on the **right ascension** axis whose units are in *hours* and *minutes* of time. There is a second setting circle on the **declination** axis that reads in *degrees* and *minutes* of arc. Once the telescope is properly aligned, these setting circles can be used to point the telescope at any object whose **right ascension** and **declination** are known. Move the telescope by holding it at its base or by its tube; **never use the eyepiece as a `handle'!**

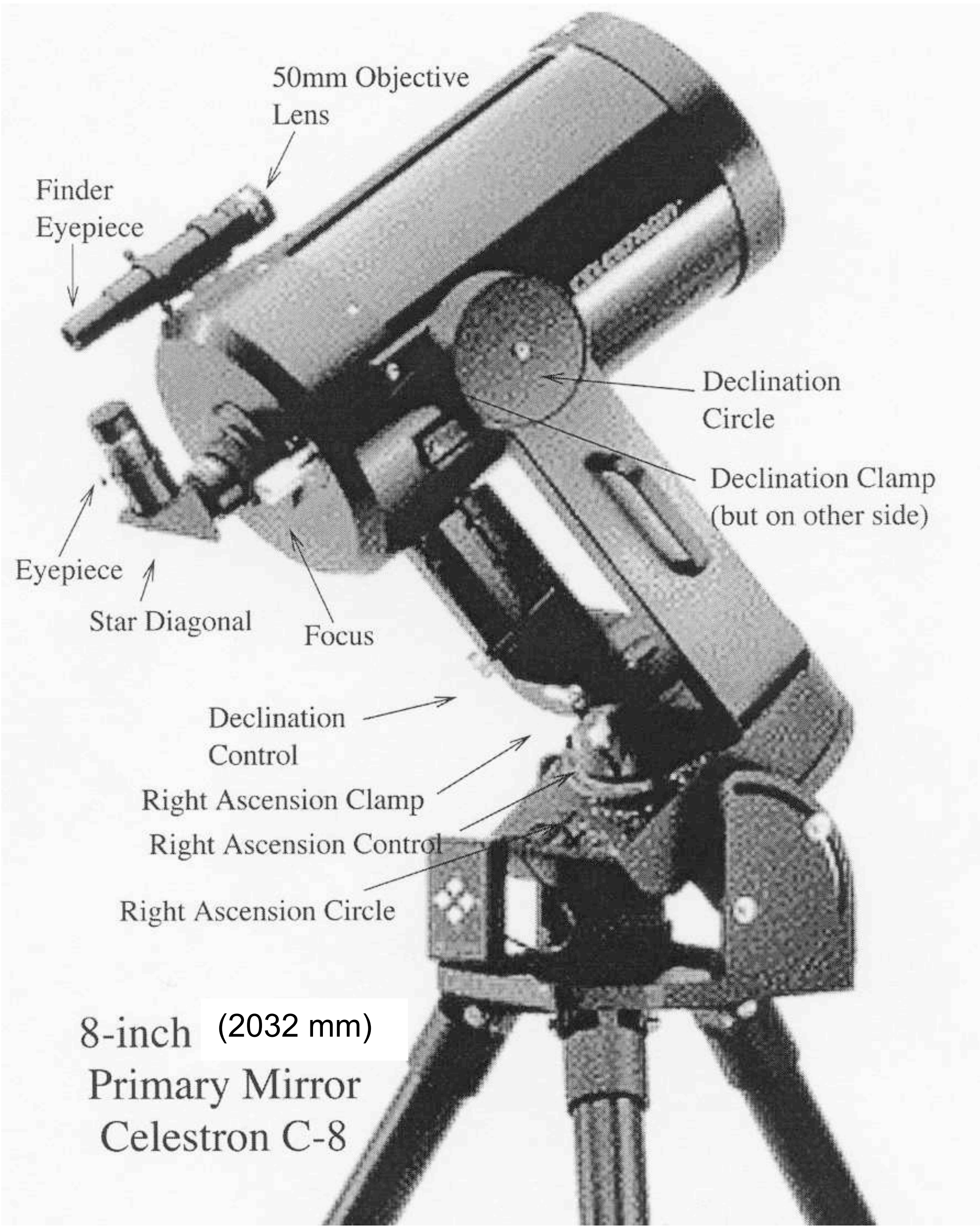
Clamps: Each telescope has two clamps, one for the **declination** axis and the other for the **right ascension** axis. These are kept locked, except when the telescope is being moved. Loosen them **before** trying to move the telescope. Once unclamped, a telescope is free to swivel in both the declination and right ascension motion. Be sure to hold the main body of the telescope tube while either of the clamps is free. Tighten the clamps after you have positioned the telescope.

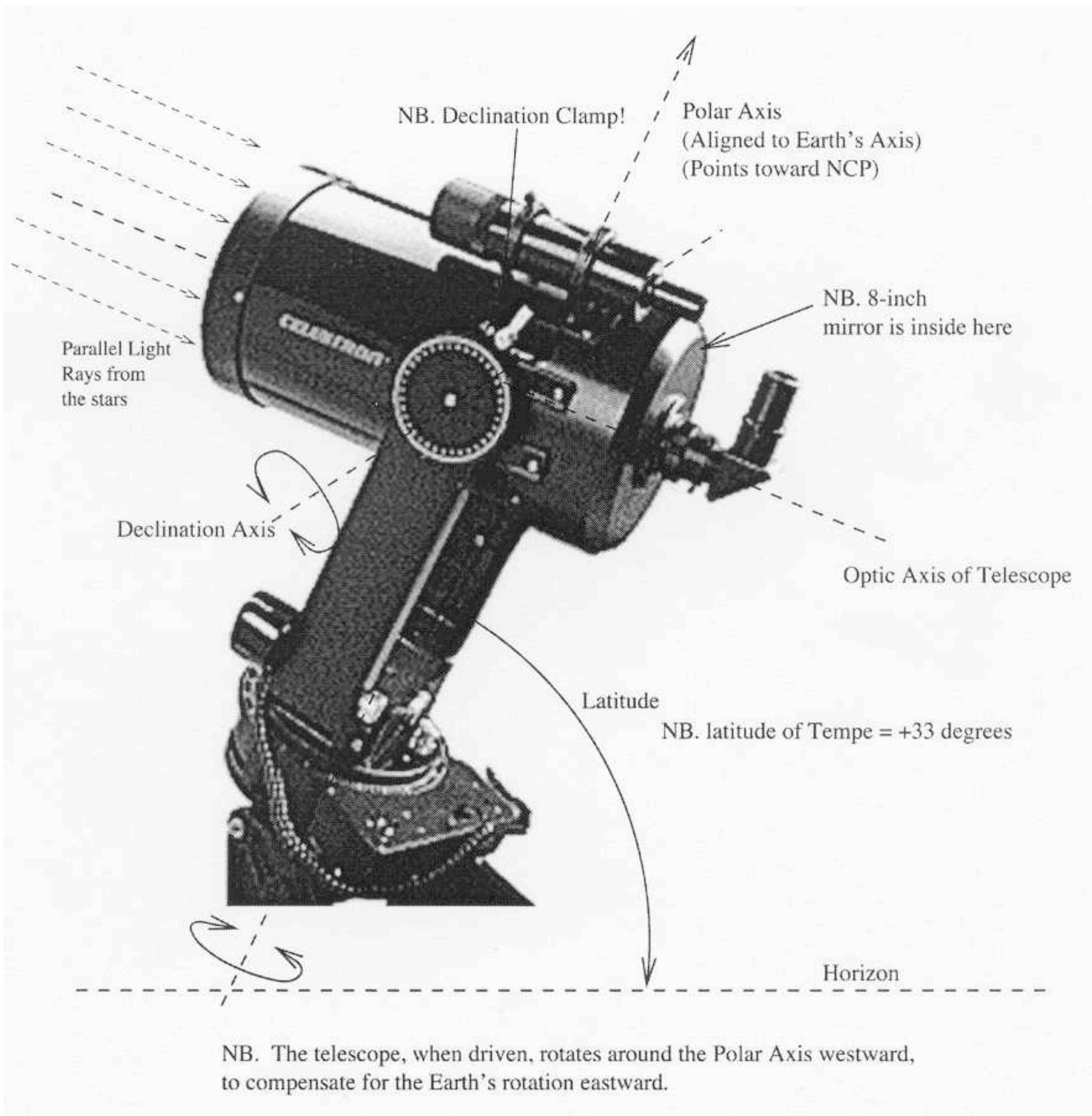
Finder Telescope: The `finder' telescope is a smaller telescope with less *magnification* and a larger *field of view*. It is attached to the side of the main telescope and `looks' in the same direction as the main telescope. The larger *field of view* makes it easy to initially locate a star in the finder telescope. Hence the name *finder*. After a star is centered on the `cross hairs' in the finder, it will also be visible in the eyepiece of the main telescope.

Slow Motion Controls: The slow motion controls help you center an object by allowing you to move the telescope slowly for small angular distances. They are mainly used for centering the object in the eyepiece of the large telescope.

Eyepiece: The eyepiece is the part you look through. Each eyepiece is identified by its *focal length*, which is stamped in white letters on the eyepiece casing (e.g., 18 mm, 25 mm, etc.).

Focus Adjustment: Once you have the star in the main eyepiece, focus on it sharply. It may help to remove your glasses. Make your focus adjustments quickly and smoothly. If you are observing faint objects, try using *averted vision*. That is, look at the object out of the corner of your eye. This works because the light detecting cells away from the center of your eyes are more sensitive than those in the center. It also will help to turn all the lights out and wait a few minutes for your eyes to become `dark adapted'.


50mm Objective Lens
Finder Eyepiece
Declination Circle
Declination Clamp (but on other side)
Eyepiece
Star Diagonal
Focus
Declination Control
Right Ascension Clamp
Right Ascension Control
Right Ascension Circle
8-inch (2032 mm) Primary Mirror Celestron C-8


NB. Declination Clamp!
Polar Axis
(Aligned to Earth's Axis)
(Points toward NCP)
NB. 8-inch
mirror is inside here
Parallel Light
Rays from
the stars
Declination Axis
Optic Axis of Telescope
Latitude
NB. latitude of Tempe = +33 degrees
Horizon
NB. The telescope, when driven, rotates around the Polar Axis westward,
to compensate for the Earth's rotation eastward.

III. Properties of a Telescope:

Light Gathering Power: The primary function of an astronomical telescope is to collect light. The *light gathering power* of a telescope is measured by the **area** of the light collector (either a lens or a mirror). A telescope's size is always specified by the **diameter** of its primary mirror. The area of a circular primary mirror is given by:

$$A = \pi(D/2)^2$$

where:

A = the area of the mirror
D = the diameter of the mirror

Thus, comparing the *light gathering power* of a 14-inch and 8-inch telescope, we find the 14-inch has 3.06 times **greater** light gathering power.

Focal Length: For a simple mirror, the *focal length* is the distance between that mirror and the place where the image is formed. In a telescope with more than one optical element (or mirror), the *effective focal length* is often longer than the telescope tube itself. It is useful to know the focal length of the telescope or eyepiece that you are using. The focal lengths of the ASU telescopes are:

focal length = 2000mm, for the 8-inch Celestron telescopes

The focal lengths of ASU eyepieces are stamped on the viewing end of each eyepiece. Typical eyepiece focal lengths are 40mm (lowest power), 24mm, 18mm, etc.

Magnification of a Telescope: The *magnifying power* of a telescope is determined by the *focal length* of **both** the telescope and the eyepiece used. A *shorter* focal length eyepiece gives *greater* magnification.

magnification of telescope = (telescope focal length)/(eyepiece focal length)

Field of View of a Telescope: The angular size of the piece of sky seen through a telescope is called its *field of view* (*i.e.,* its FoV). The size of the FoV depends on both the telescope and the eyepiece used. Since the FoV is an angle, it is measured in *degrees* (º), *arcminutes* (‘), or *arcseconds* (“). For a given telescope:

the greater the eyepiece focal length, the greater the FoV

If you choose an eyepiece with **double** the focal length, you also **double** the FoV (*i.e.,* the angular size of the area of sky you can see).

Resolving Power: The *resolving power* is the ability of a telescope to separate two close images or to see fine detail in an image. Greater magnification will not resolve two images that are closer than the resolution of a telescope. The limit, called the Rayleigh criterion, depends on the diameter of the telescope's primary mirror (D) and the color (or wavelength) of the light observed. For **visible light**, the minimum separation of two objects which can just be resolved is:

$$\alpha = 4.56/D$$

where:

α = angular separation of two stars (in *arcseconds*)
D = diameter of the telescope's primary mirror (in *inches*)

Thus:

resolving power = α = 0.57”, for the 8-inch telescopes

However, you may not actually be able to see two images this close together because of atmospheric conditions (seeing), relative brightness of the objects, etc.

Scale of a Telescope: The *scale* at the focus of any astronomical telescope is the ratio of the angular size of an object in the sky to its image size with that telescope (e.g., how large the object would look if you were to photograph it with that telescope). The scale is **constant** for a particular telescope and depends only on the **focal length** of the primary mirror. The scale is usually expressed in units of *degrees per millimeter* (º/mm) or *arcseconds per millimeter* (“/mm).

scale = 57.3º / focal length of telescope's primary mirror

scale = 206265” / focal length of telescope's primary mirror

Exercise I: Looking at the Resolving Power

Your TA will set up a light box in the corridor with 4 stars etched into a mask on the front of it. You will estimate using your naked eye from the opposite end of the corridor whether you think each star is a single or double star. Then move closer to the paper, about half the distance down the corridor. Make your estimates again. Next, return to the original position, and use a pair of binoculars and again estimate which stars are single and which double. Measure the diameter of your pupil and the diameter of the lens in the binoculars. Measure the distances from the light box to your two observation positions.

Write your observations here:

- In light of your observations, what was the limiting resolution of your eyes? Your TA will give you the linear separations of the double stars on the mask. Use a triangle to work out the angle you could resolve. Compare this to what you calculate with the Rayleigh criterion that your eye should be able to resolve. Work out what this angle is when you use binoculars. How much better are the binoculars than your eyes at resolving things?

Exercise 2: Determining the Size of the Field of View:

In this exercise, you will determine the **angular size** of the *field of view* of the 8-inch telescope. That is, how large a piece of sky can you see in the telescope? You will also find out how changing eyepieces alters the size of the *field of view*.

For this exercise, you will need to measure how long it takes for a star near the celestial equator to pass across the region viewed through the eyepiece when the telescope *drive motor* is turned off. Convert that **time** into an **angle**, which is equal to the diameter of the *field of view*.

Your TA will have the telescope pointed towards a star for you. Be sure to find out which star you are observing. You will first need to unplug the motor and watch through the eyepiece to see in which direction the star appears to 'drift'.

- Compare this direction to how the stars move through the sky when you look at it with your eyes. Is the motion in the same direction?

Then move the telescope, placing the star just outside the field of view on the eastern edge. This will cause the star to appear in the field of view when the motor is turned off.

When the star reappears in your eyepiece, start the stopwatch and record the starting time. When it passes out of view on the opposite side, stop the stopwatch and record the transit time of the star. Make a few (more than one) measurements and compute the average. Remember, this reduces your measurement error.

Convert the transit time of the star into an angular distance traveled using the conversions below. Your answer is the **size** of the field of view of this telescope/eyepiece combination.

TIME		ANGLE
24 hours	=	360º (degrees)
1 hour	=	15º (degrees)
1 minute	=	15’ (arcminutes)
1 second	=	15” (arcseconds)

Repeat these observations using a second eyepiece with a **different** focal length. Be sure to put your measurements and calculations into the data table below.

Eyepiece 1			
Time 1	Time 2	Average Time	Angle
Eyepiece 2			
Time 1	Time 2	Average Time	Angle

- Is the field of view greater with a shorter or longer focal length eyepiece?

- Would the moon be completely visible in either of the eyepieces you used (the moon is 30 arcmins in diameter)? How do you know? Be sure to show any work you did to determine your answer.

- Describe why the field of view changed when you used the different eyepieces.

- Your transit time was for a star near the celestial equator. How would the transit time change for a star at a higher declination (closer to the celestial pole)?

Exercise 3: Looking at Magnification and Light Gathering Power

For this part of the lab, you will be examining how the magnification and light gathering power changes depending on different focal lengths of the eyepieces and the telescopes. You will be observing the nebula M42, the Orion Nebula (plate 240 in your field guide) with 8-inch telescopes with different eyepieces in them, so be sure to record the telescope diameter, focal length, and eyepiece used.

- Look through each of the telescopes designated for this exercise once without recording any data. What do you see? How do the objects look?

- In which view do you see fainter stars or fainter details of M42 – with the finderscope or through the eyepiece?

- Which device has the greater light gathering power? What do you see? How do the objects look? You will need to look through the telescopes multiple times to be able to record accurate notes on what you see. Drawing a picture may help.

Next, you will be looking through the designated 8-inch telescopes, only looking at magnification differences.

- Again, record the telescope and eyepiece data, as well as comments on what you see. You will need to look through the telescopes multiple times to be able to record accurate notes. Once again, drawing a picture may help.

- When you have made observations for both light gathering power and magnification give the two telescopes a number corresponding to the faintest star you can see - these should be ordered one through three, with one corresponding to the telescope with the faintest star. Also attempt to name the faintest star you see in each case using your Field Guide. You may need to look through each of the telescopes again before you can precisely assign an order.

- How does decreasing the focal length of the **eyepiece** (but <u>not</u> the **telescope**) change the magnification of the system?

- Can you see fainter objects with a different (higher or lower) magnification?

- Calculate the magnifications for the system for each of the eyepieces you used for exercise 3.

- What differences in the appearance of the faint object did you notice between the 8-inch telescope and its finderscope? What are the causes of the differences?

Exercise 4: Looking at Resolving Power - again

For this exercise, you will be observing θ Taurus (Spring) or Mizar (Summer), with your eyes, binoculars, and an 8-inch telescope. Be sure to make careful note of what the star looks like in each of these cases.

Your first observation should be with your eyes. Use your field guide to locate the star and find it in the sky. Record the brightness and color of the star compared to the surrounding stars in the constellation. Also, record whether you think this is a single star or a double star.

Star Brightness = ____________________________
Color = ____________________________________
Single or Double? ___________________________

Next you should look at the star through the binoculars and the telescope. Again, record brightness, color and whether the star looks like a single star or a double star.

Star Brightness = ____________________________
Color = ____________________________________
Single or Double? ___________________________

- What differences in the appearance of the faint object did you notice between the 8-inch telescope and its finderscope? What are the causes of the differences?

- If the separation of two stars is 5’ 37”, which of these methods (eyes (the pupil diameter of a dark-adapted eye is 0.2 inches), binoculars, or telescope) should have resolved the stars? Did they? If not, why?

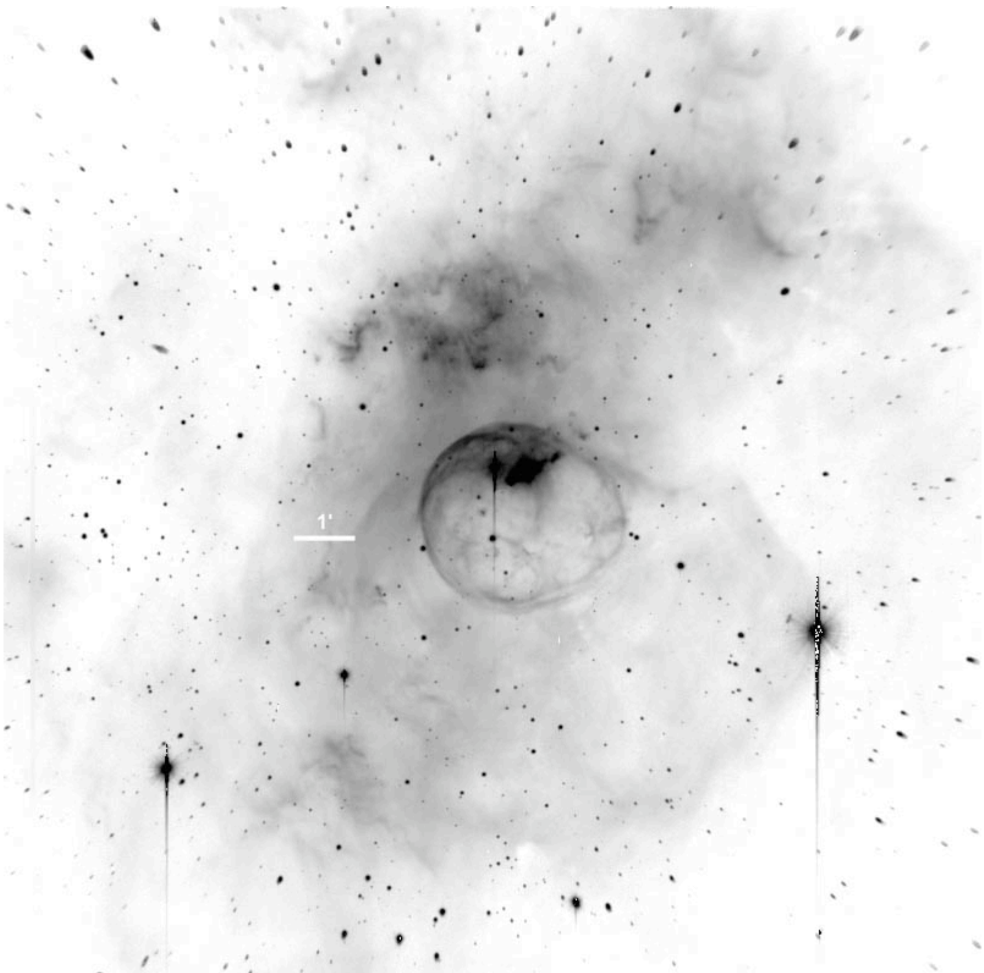
Conclusion

Indoor alternative

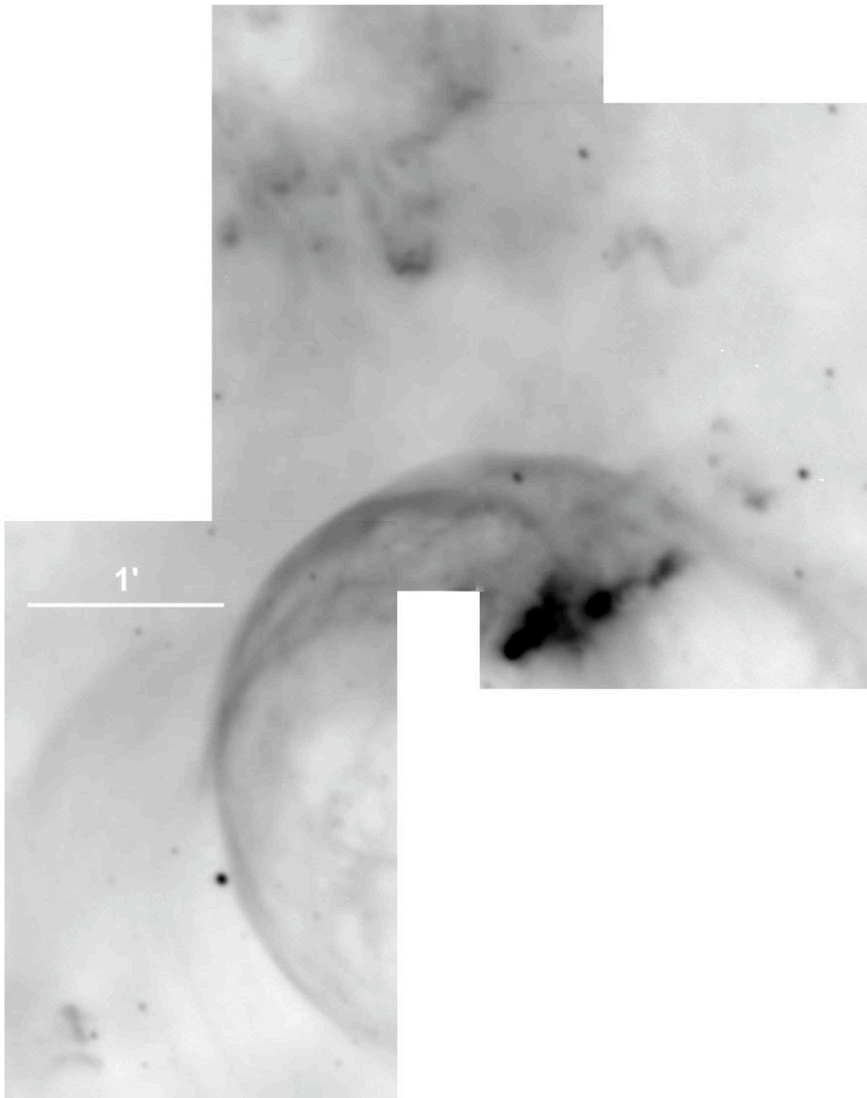
In the event of inclement weather, your TA will go over all the working parts of the telescope in the classroom so you are familiar with the use of the instrument.

(a) **FOV** – if it is actually raining this part will have to be omitted. Otherwise, your TA will set up some telescopes focused on a terrestrial light source and turn on the drive motors so the FOV moves at the same rate of motion as the sky. It is important that the light source be close to the celestial equator, and so is close to due east or due west. Complete the exercise using this configuration as detailed earlier in the lab.

(b) **Magnification & Light Gathering** – for this part of the exercise you will use two photographs taken of the same object with different telescopes. Each scope was a different **size** and because of a different focal length had a different **scale**. Here are the two photos of NGC 7635 (the Bubble Nebula):



This image was taken using the Mt. Palomar 60" telescope using a CCD camera that rendered the image at a scale of 1.2"/pixel. On the image you will see a bar that marks the length of 1 arcminute on the image at this scale.



This image was taken using the Steward Observatory 90” telescope on Kitt Peak with a CCD camera that rendered the image at a scale of 0.3”/pixel.

- Which of the telescopes gave a higher apparent magnification, or more accurately, gave a higher resolution image?

- Which one gave the widest angle shot?

- Calculate how much higher the scale is for the second picture than the first.

- Which telescope would you use to take images of a large angular diameter nebula? Why?

- Which one would you use to image a distant galaxy? Why?

- Which telescope produced a deeper image? That is, which image allows you to see the faintest structure in the nebula?

- Which telescope gives the sharpest image?

- In light of these issues, answer the same two questions above concerning which telescope you'd use to image a nebula and which a distant galaxy? Did your answer change? Why?

Resolving power – Do Exercise 1 of regular lab script.