

<p style="text-align: center;"><b>Aperture Size and Resolution</b> Observational Astronomy</p>
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Name: \_\_\_\_\_

## **Introduction**

Telescope aperture sizes range from that of the humble spyglass up to the 8- to 10-meter giants used in modern astronomical research. Why do astronomers need such large instruments? How does a telescope's diameter affect its performance?

Two things that characterize telescope performance are *resolution* and *light-gathering power*. Resolution refers to the smallest details you can make out. Light-gathering power refers to how much light the telescope can collect from an object. Resolution depends on telescope diameter because of the wave nature of light (diffraction limits resolution), and light-gathering power depends on telescope diameter because more mirror area can collect more light.

## **Pre-test**

1. Which factor do you think is the main reason for building larger ground-based telescopes — resolution or light-gathering power? Write down what you think.

## Binary Stars

You will investigate resolution and light-gathering power by observing *binary stars*. These are two stars in the same system which appear quite close together in the sky. Some apparent binaries are only *optical doubles*, which means they appear together in the sky but are not gravitationally linked in any way and could be at totally different distances. Binaries range from being visible to the naked eye all the way to being so closely bound that only indirect methods can detect them. Because they appear so closely together in the sky, binary stars can be used to test the resolving power of a telescope.

## Finding Mizar

You will be using the small telescopes on the roof for this activity. You will be using fairly high magnification and narrow field of view, so you should probably use an equatorial mount for ease of tracking. Make sure you are comfortable with moving the scope, focusing, and tracking before you move on.

The binary star you will be observing tonight is called Mizar, or  $\zeta$  Ursae Majoris. Located in the middle of the handle of the Big Dipper, Mizar itself is part of an optical double with the fainter star Alcor. If you have good eyesight, you should be able to make out Alcor with your unaided eyes (Figure 1).

Find Mizar and Alcor in the finderscope, then view them with a low power (long focal length) eyepiece. Once you have them in the field of view, switch to a higher power eyepiece and re-focus. You will have to keep adjusting the scope to track them. Increase the magnification until you can split the two components of Mizar. You will probably still see Alcor in the eyepiece (Figure 2).

1. Make a note of the telescope/eyepiece combination you are using to split the components of Mizar, and sketch what you see in the eyepiece.

## Altering the aperture

Now you will alter the aperture of the telescope and see how that affects the image of the binary star.

**2.** Place a supplied dark paper or cardboard mask with a smaller circular aperture at the end of the telescope while another observes. Make a note of any changes in the image in terms of resolution and brightness.

**3.** Repeat for a mask with a square aperture. Again, note any changes in the image.

**4.** Now, while looking through the eyepiece, start covering the aperture with a sheet of dark paper or cardboard by sliding it in from the edge until the aperture is almost fully covered. How does the resolution and brightness of the image change?

## Conclusions

5. When you altered the telescope aperture, which did you seem to affect more — resolution or light-gathering power?

6. Did the shape of the aperture seem to matter? If it didn't, why do you think astronomers still use circular telescopes?

7. Which factor is the main reason for building larger ground-based telescopes — resolution or light-gathering power?

The standard way to quantify the resolution of a telescope is with the *Rayleigh criterion*. Derived from a consideration of diffraction effects, the Rayleigh criterion states that the limiting angular resolution of an optical system of diameter  $D$  is approximately  $1.22 \cdot \frac{\lambda}{D}$ , where  $\lambda$  is the wavelength of light being used.

8. Using a wavelength of 500 nm, calculate the Rayleigh limit of the telescope you used tonight.

9. Given that atmospheric turbulence can sometimes limit the *seeing* to 4 arcseconds in Troy, does diffraction or the atmosphere limit your resolution tonight?

### **Extra**

If you have time after completing the rest of this activity, try observing some of the other telescopic binary stars listed in the third section of Table 1. Figures 3-6 show you where they are in the sky, and Figures 7-12 should aid you in finding them. Record which ones you succeed in resolving.

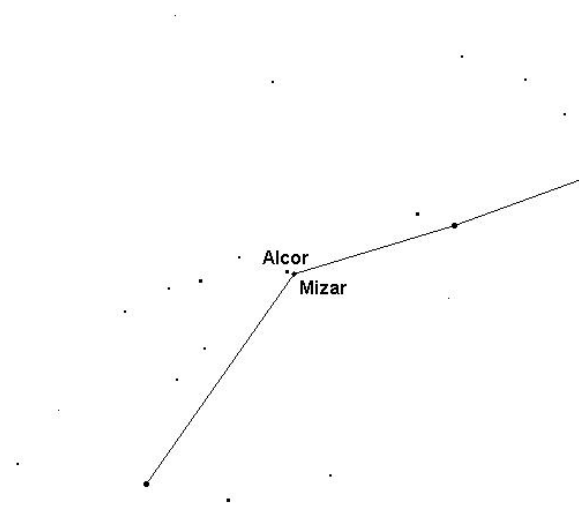


Figure 1: Looking more closely at the handle of the Big Dipper. Mizar and Alcor are labeled. (Image from <http://www.fourmilab.ch/yoursky>.)

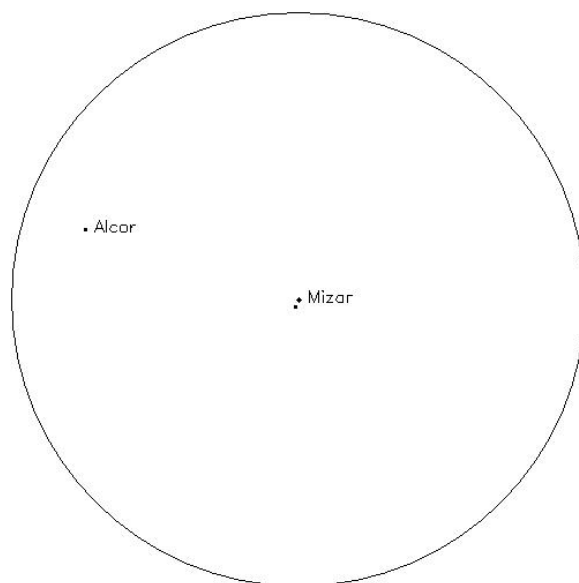


Figure 2: A 30' field of view centered on Mizar. Both Mizar A and Mizar B are visible. (Image from <http://www.fourmilab.ch/yoursky>.)

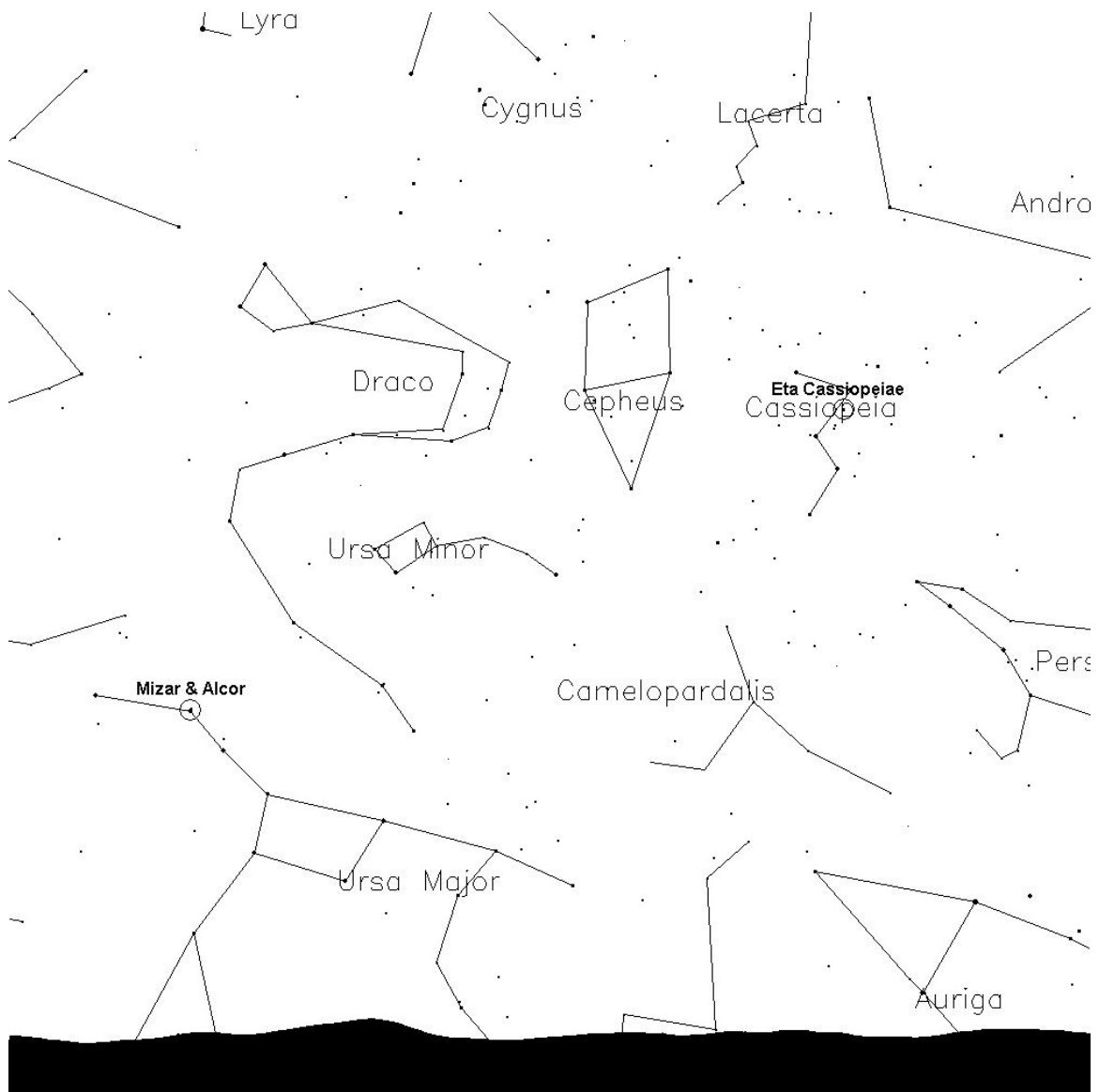


Figure 3: Looking north at 9pm on October 1st. (Image from <http://www.fourmilab.ch/yoursky>.)

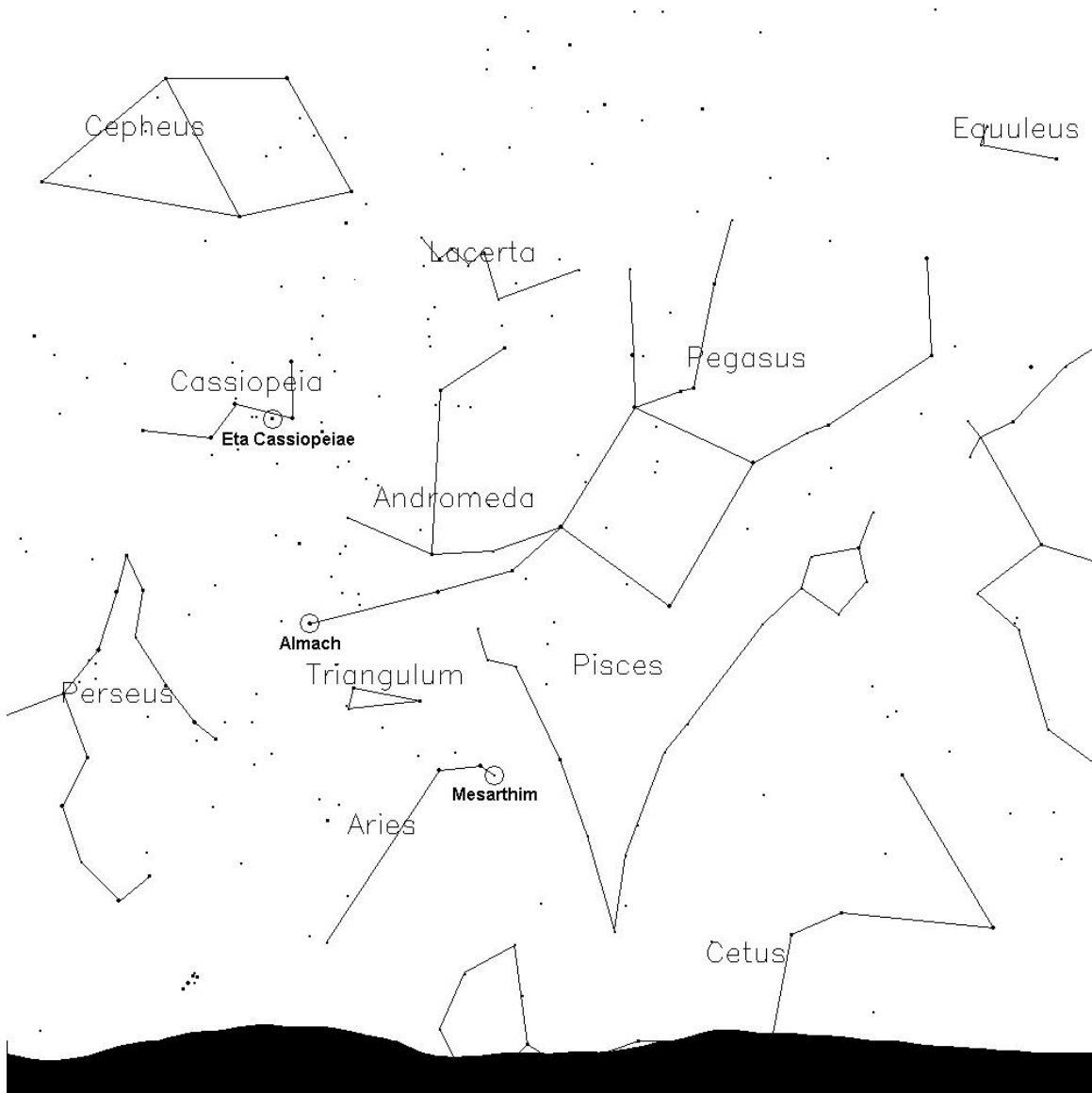


Figure 4: Looking east at 9pm on October 1st. (Image from <http://www.fourmilab.ch/yoursky>.)

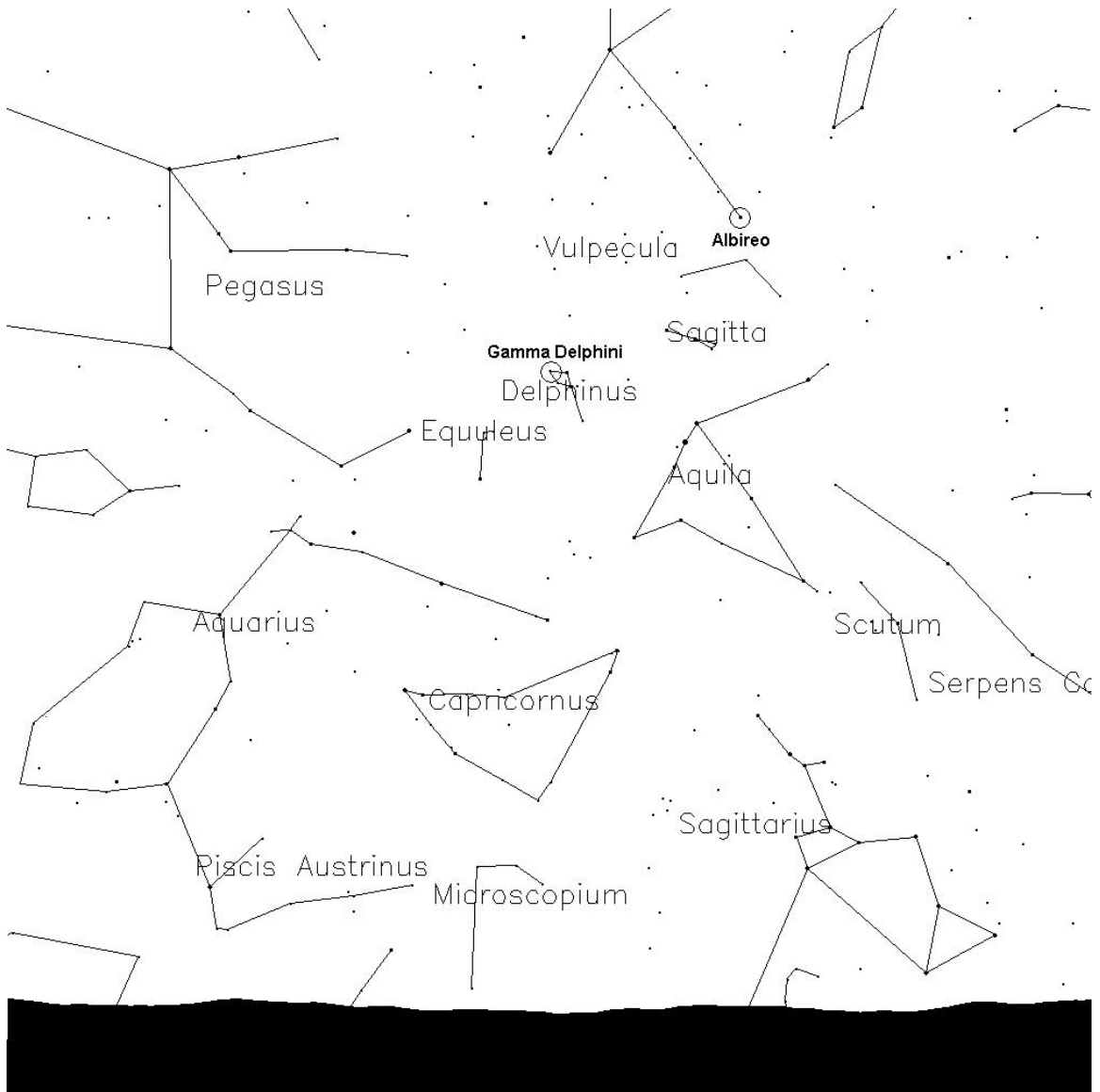


Figure 5: Looking south at 9pm on October 1st. (Image from <http://www.fourmilab.ch/yoursky>.)

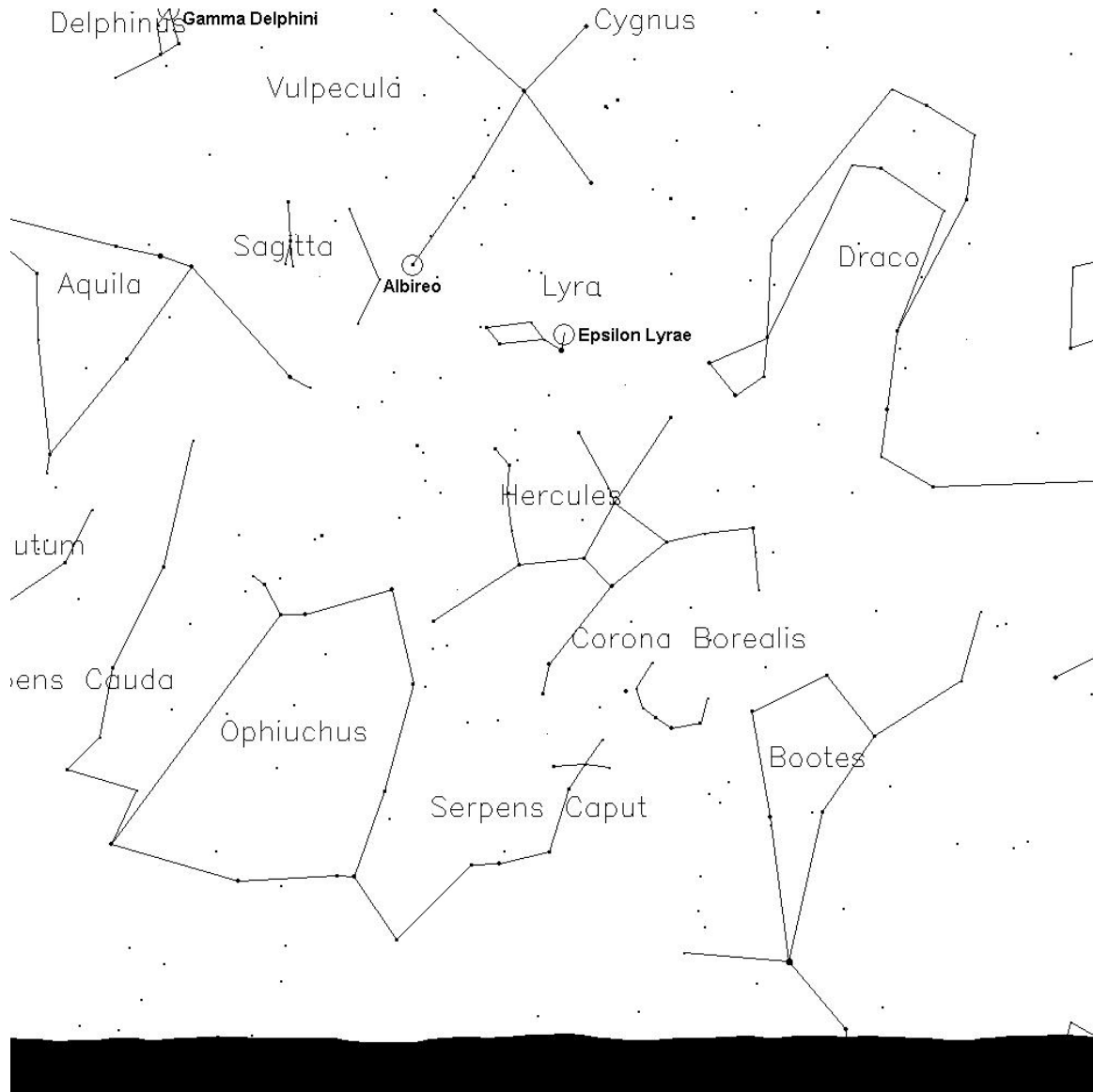


Figure 6: Looking west at 9pm on October 1st. (Image from <http://www.fourmilab.ch/yoursky>.)

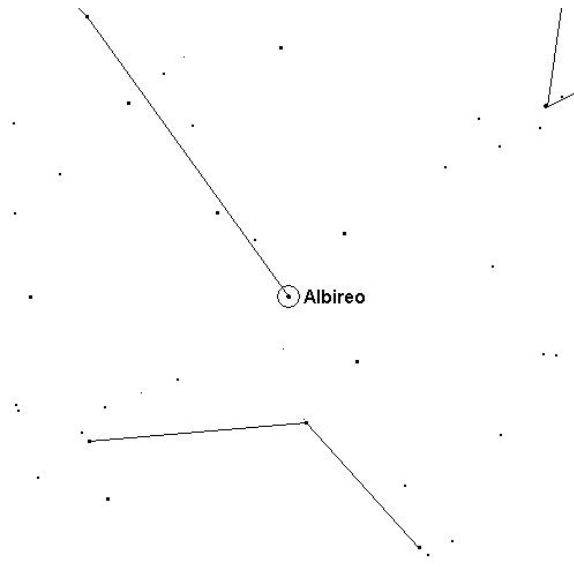


Figure 7: Looking more closely at Cygnus. (Image from <http://www.fourmilab.ch/yoursky.>)

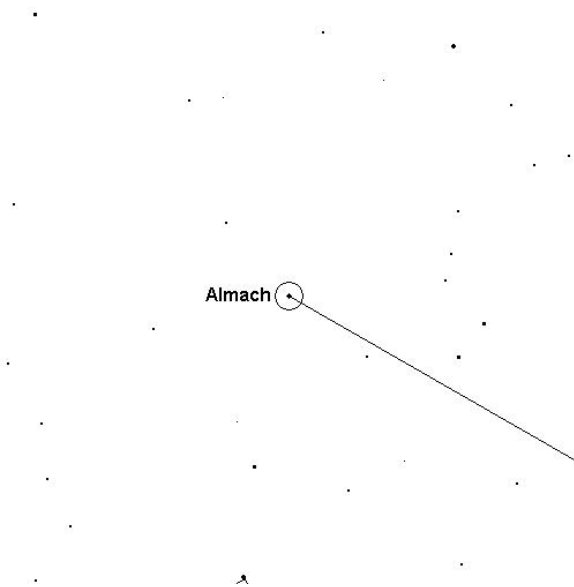


Figure 8: Looking more closely at Andromeda. (Image from <http://www.fourmilab.ch/yoursky.>)

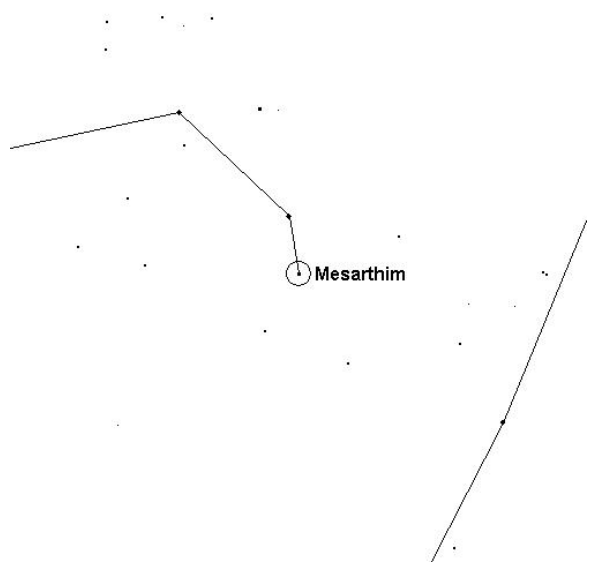


Figure 9: Looking more closely at Aries. (Image from <http://www.fourmilab.ch/yoursky>.)

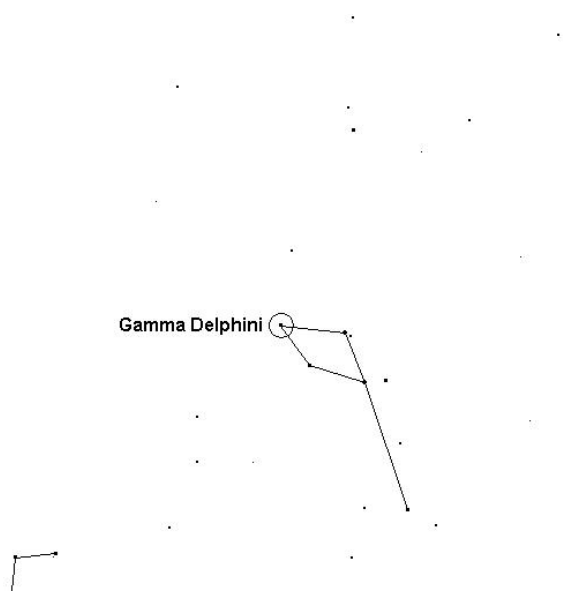


Figure 10: Looking more closely at Delphinus. (Image from <http://www.fourmilab.ch/yoursky>.)

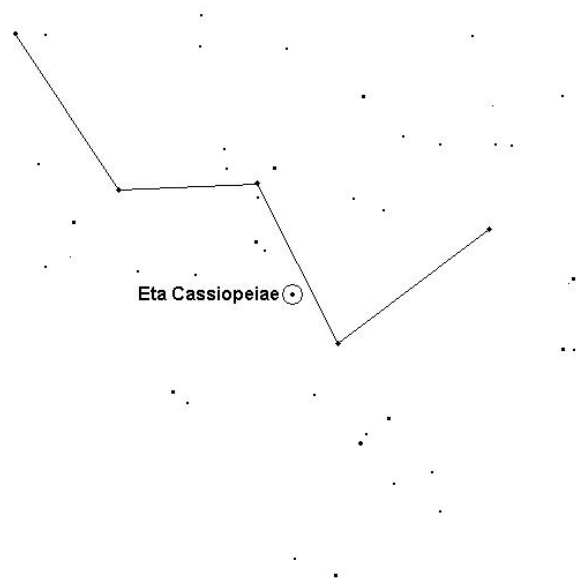


Figure 11: Looking more closely at Cassiopeia. (Image from <http://www.fourmilab.ch/yoursky>.)

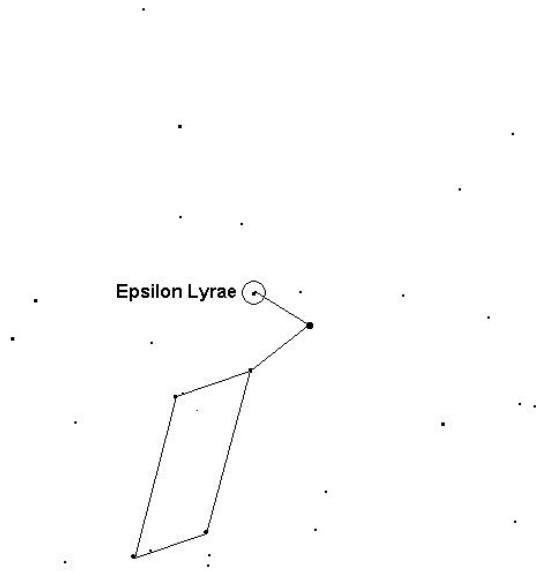


Figure 12: Looking more closely at Lyra. (Image from <http://www.fourmilab.ch/yoursky>.)

<b>Name</b>	<b>Separation</b>
Mizar/Alcor ( $\zeta/80$ Ursae Majoris)	11' 47''
Algedi ( $\alpha$ Capricorni)	6' 20''
$\epsilon$ Lyrae	3' 28''
Dabih ( $\beta$ Capricorni)	3' 25''
Albireo ( $\beta$ Cygni)	34''
Mizar ( $\zeta$ Ursae Majoris)	14''
Almach ( $\gamma$ Andromedae)	10''
Mesarthim ( $\gamma$ Arietis)	9''
$\gamma$ Delphini	9''
$\eta$ Cassiopeiae	9''
$\epsilon$ Lyrae (2)	2''

Table 1: A list of some binary systems. The top group is visible with just good eyesight, the second group is visible in binoculars and low power eyepieces, and the third group requires medium to high power eyepieces.