

The Sun

BINARY STARS

Purpose: This lab has 5 primary purposes:

1. To familiarize yourself with the appearance of multiple star systems.
2. To learn to detect stellar colors.
3. To practice with the magnitude system.
4. To practice planning an observing session and using your setting circles.
5. To begin to learn how astronomers determine star ages.

Introduction

Two-thirds of all stars are part of multiple star systems, where two or more stars are born at the same time from the same gas cloud. Only about 30% of all stars are single, like the Sun. The distances between companion stars ranges from less than 10 million miles (0.1 AU), to over 10,000 AU. Similarly, the time it takes stars to orbit each other varies from a few hours to a million years or more! For reference: one Astronomical Unit (AU) is defined to be the average distance between the Earth and the Sun. (How many miles is that?)

The nearest star to our Sun, Alpha Centauri, is a triple star system and is the third brightest star in the sky; however it can only be viewed from the southern hemisphere. The brightest (and largest) star in this triplet system (the A component) is a G-star, very similar to our Sun but about 30% more luminous. The next brightest star (the B component) is an orange K-star that orbits the G-star at a distance of about 20 AU in a period of 80 years. For reference, 20 AU is about the distance from Earth to Uranus. The smallest companion, and the one closest to Earth, is called Proxima Centauri and is a tiny red dwarf that is 10,000 AU from the first two, and takes about 500,000 years to orbit the other two! From a planet in a 1 AU orbit around the brightest star, one would see two blazing suns: one, slightly brighter than our Sun and yellowish in color, and the other a much fainter orange star, but still about 100 times brighter than our full Moon. The 2nd star would easily be visible in the day time and you could easily read by its light at night. From this fictional planet, tiny Proxima would be a deep red star four times fainter than the stars in the Big Dipper!

Through a telescope, multiple stars appear in a variety of brightnesses, colors, and separations. There are four types of binaries as viewed from Earth:

1. Spectroscopic Binaries - These stars orbit so closely to each other that they appear as a single star even through the best telescopes on Earth. Their binary character is revealed in their spectra, which reveal absorption lines from two different stars that are regularly Doppler blueshifted and redshifted as they orbit each other. We will not examine any of these for obvious reasons.
2. Eclipsing Binaries - These stars are also too close to be seen separately through a telescope. As viewed from Earth, they reveal their binary nature when one star passes in front of the other. When this eclipse occurs, the total light from the star system drops, which is detected from Earth. The star Algol, in Perseus, is a fine example.
3. Visual Binaries – These are binary systems that are visible as two stars through a telescope. The separation is usually at least 10 AU, and typically over 100 AU. The positions and the distance between the pair can be seen to move over a period of decades or centuries. By measuring the period and the separation, the mass of the system can be calculated. Sometimes one or more of the stars is also a spectroscopic binary. These visual binaries are the subject of this lab.
4. Optical Doubles - These are not true binary stars. Rather, they are a chance alignment of two stars that are actually very far apart from each other and are not orbiting each other at all.

Requirements:

1. **BEFORE COMING TO CLASS**: see step 1 in directions.
2. Sketches of 8 binary systems through the 17mm eyepiece (unless you ask to use a different eyepiece). Center stars in the eyepiece before sketching. At least 2 pairs should be separated by 10" or less. Separations of 2" or less will require good observing conditions and high magnification. Sketches should include:
 - a. [½ pt each] An indication of north and west (as done in the FOV lab, see page **Error! Bookmark not defined.**).
 - b. [1 pt each] Notes on magnitudes (i.e. brightness) and colors for both stars.
 - c. [1 pt each] Identify which star is brightest as "A", and which is the faintest "B" (There may be ties.)
 - d. [1 pt each] Note the separation angle (in arcseconds), and position angle of the pairs on the sketch itself. Position angle is the clockwise angle between the line pointing north and the line *from A to B*. Position angles range from 0° to 360°.
 - e. [½ pt each] Note whether or not you can see the binary star system without a telescope. (In other words, after finding it in your telescope, can you point out that binary star?)
3. The completed table on page 3. (You need only fill in 8 rows, total.)
4. Answers to the questions below.

Directions:

1. Plan your observations before you come to the telescope, just like real astronomers. Pick 8 stars from the list below that you want to observe, plus a couple of back-ups. Make sure Cor Caroli (Spring) or Alberio (Fall) is on your list. Pick a bright pair to observe first.
2. Set up your telescope and polar align it and calibrate the RA wheel.
3. Point the telescope at Cor Caroli (Spring) or Alberio. Make the notes listed above and fill in the observation sheet. Make a mental note of the separation of the components. Make your sketch to scale, so that your large circle encompasses the entire field of view. **Repeat this observation for the 40mm and 17mm eyepieces.** You will only need to sketch this one star through two eyepieces.
4. **Questions to keep in mind:** How does the star appear in your finder scope? Through your low power eyepiece? How does each star appear through your highest power eyepiece?
5. Move to the next star. If the next binary is faint, find a bright nearby star first to reset your R.A. circle. Then go to the binary star. Try to find the star in the 40mm eyepiece, but once you find it, switch to the 17mm.
6. Repeat steps 3-5 for the next star.

Questions:

For all of the questions below, "redder" and "bluer" refer to the position in the rainbow. Reddest is the color red, followed by orange, yellow, green, blue, indigo, and violet (ROY G BIV). Note that white-colored objects can appear white for two reasons: they are yellow like our Sun, or they are faint and cannot be detected by the color-sensitive cones in our eyes (i.e. they are so faint that they are only seen in black and white).

1. [1.5 pts] For Cor Caroli/Alberio, was the redder star brighter than the bluer star? What does this mean about what evolutionary stage the red star is in? Explain. (See next question.)
2. [2 pts] Based on color/magnitude differences, which stars are in their giant phase and which are still on the main sequence? When referring to a star, make sure that you note if you are talking about the A component or the B component. Hints: 1) for stars we can see in this class, the only way a red star can be more luminous than a bluer one is if the red star is a giant or supergiant. 2) Red stars that are fainter than bluer ones are probably on the main sequence. All blue stars are probably on the main sequence because non-main sequence blue giants are very short lived, so there's only a very small chance of seeing one before it dies.
3. [1.5 pts] Describe three reasons why the two stars could appear to be very close to each other.
4. [2 pts] In what ways is the Sun a typical star? How is it unusual? (List at least 2 answers for each.)
5. [1 pt] What can measuring the period of a binary star tell us if we already know the distance to the star? Explain how you would compute your answer.

6. (Optional) Summarize your experience with this lab. What did you learn? Was it fun? What changes would you suggest?

Spring Binary Stars	RA	Dec	Separ. (")	Magnitudes (A & B)	Pos. Angle Estimate	Color A	Color B	Star system visible to eye
Cor Caroli (α Canes Venatici)			19"	2.9, 5.6				
Castor (α Geminorum)								
Rigel (β Orionis)								
β Monoceri								
Izar (ϵ Boötes)								
Rasalgeti (α Herc.)								
ξ Boötes								
π Boötes								
24 Coma Bernices								
Algeiba (γ Leonis) [in Leo]								
Porrina (γ Virginis) [Virgo]								
ζ Coronae Borealis								
Mizar (ζ Ursa Majoris)								
ν Dracronis								
Polaris (α Ursa Minoris)								

Completely fill in 8 rows.

Some stars may not be visible when the lab is performed. Ask the instructor for suggestions.

Fall Binary Stars	RA	Dec	Separ. (")	Magnitudes (A & B)	Pos. Angle Estimate	Color A	Color B	Star system visible to eye
Alberio (β Cygni)	19h 31m	+28	34" (4400 AU!)	3.1, 5.1				
ϵ_1 Lyrae (see below)	18h 44m	+40	2.6" (165 AU)	5.1, 6.0				
ϵ_2 Lyr (208" from ϵ_1)	18h 44m	+40	2.3" (150 AU)	5.1, 5.4				
61 Cygni								
γ Andromedae								
Rasalgeti (α Herc.)								
ζ Aquarii								
γ Arietis (in Aries)								
η Cassiopeiae								
ι Cassiopeiae								
\omicron Capricorni								
γ Delphini								
β Cephei								
57 Aquilae								
ν Dracronis								
Polaris (α Ursa Minoris)								

Extra Credit: [2.5 pts] If the Sun had a tiny red dwarf companion (much less massive than the Sun) at the same distance as the separation of the two stars in Alberio, how long would it take to orbit the Sun? (Hint: use Kepler's 3rd law). How long would it take to move 1 degree with respect to the stars?