LAB # 8 Measuring Astronomical Distances

OVERVIEW

The universe contains various types of objects and astronomers want to know where they are with respect to one another.

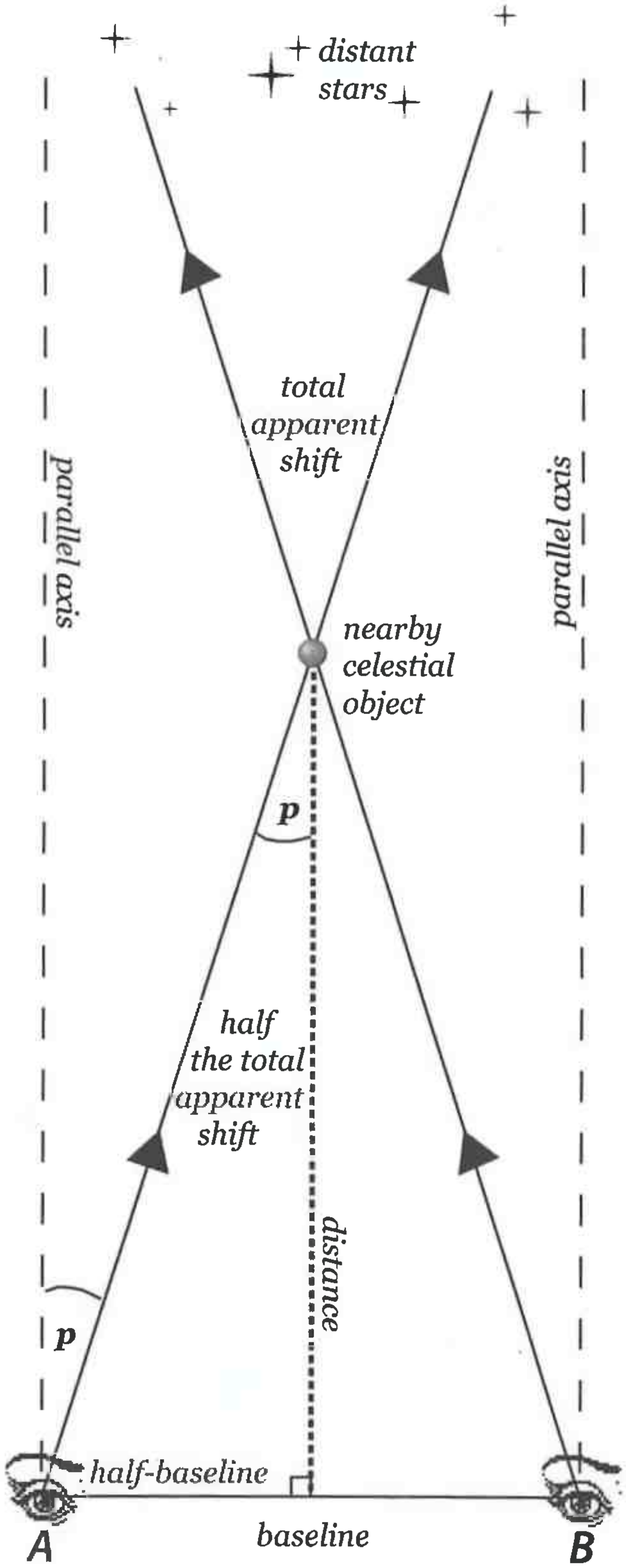
If you want to find out the distance to a star, you can't do it by putting meter sticks end on end as you could do if you were measuring the distance to a nearby building. What can you do? Use the method pigeons and chickens use when they bob their heads back and forth in order to judge the distances of things around them. That method involves observing **parallax**, which is the apparent shift of a nearby object with respect to very distant objects due to the change in position of the observer.

The word parallax is derived from the term parallel axes. These axes are illustrated in the diagram at right.

Let's say you look at a celestial object from viewpoint A and note where the object is in relation to distant stars. Then you move to viewpoint B and do the same. The object will appear to have moved. The closer the object is to you, the more it will appear to have shifted.

Distance AB is called the *baseline*. Note the right triangle with sides ***distance*** and ***half-baseline***. Also note that angle ***p*** is half the total apparent shift of the object. In this triangle, the following is true:

$$\textit{tangent of angle } p = \frac{\textit{half-baseline}}{\textit{distance}}$$

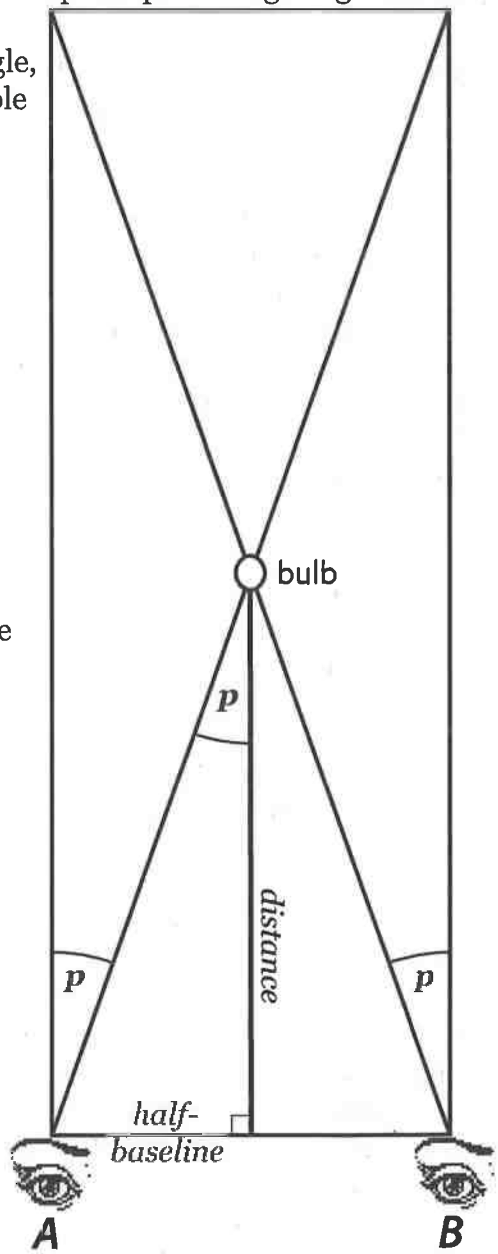


In this lab you are asked to measure the distances to several objects using the parallax method: the distance to a light bulb in the lab room, to the Moon, and to two nearby stars.

PROCEDURE

Part 1: Finding the distance to a light bulb.

First, measure the baseline in cm at the end of the lab table and enter it in the space below. Divide the value by two to get the half-baseline. Then place the protractor printed on the last page of this lab at the corner of the lab table and set up the plastic sighting device so that you can measure the angle ***p***. Your instructor will show you how to use the device. After recording the angle, repeat the measurement from the other corner of the table and find the average of the two angles.



- Baseline = _________ cm
- Half-baseline = ________ cm
- Viewpoint A: Angle ***p(A)*** =_______ degrees
- Viewpoint B: Angle ***p(B)*** =_______ degrees
- Average ***p*** = _______ degrees

Now find the parallax distance using

Tangent of Angle ***p*** = Half-baseline/Parallax distance

or

$$\text{Parallax distance} = \frac{\text{Half-baseline}}{\text{Tangent of Angle } p}$$

= _____________________________ cm

(find the tangent value in the table below)

Now measure the actual distance from the midpoint of the baseline to the bulb using a meter stick.

- Actual distance (stick to bulb) = _______cm
- Find the percent difference between the actual value and the one found using parallax.

$$\frac{|(\text{Actual distance - Parallax distance})|}{\text{Actual distance}} \times 100 = \_\_\_\_\_\%$$

angle (deg)	5	6	7	8	9	10	11	12	13	14	15	16	17
tangent	0.09	0.11	0.12	0.14	0.16	0.18	0.19	0.21	0.23	0.25	0.27	0.29	0.31

Part 2: The distance to the Moon.

Look at the two photographs of the Moon below taken from two different places on Earth. Note that the Moon's image is shifted. This shift can give you the parallax if you know the scale of the photographs. Tear off the millimeter paper ruler on the bottom of page five.

- Measure the length of the white bar in the left photograph. Length of bar = _____ mm
- Find the *scale factor*: angular length of bar/length of bar = __________ degree per mm

Measure the ***horizontal*** distance in mm between a bright star and the Moon's limb (edge) in each photograph and find the difference between these values.

- Photo 1: _____ mm • Photo 2: _____ mm • Difference = ___ mm

Convert this distance on the photographs to the actual one in the sky using the scale factor.

- Difference x *scale factor* = _______________ degrees

This angle equals ***2p***, so divide it by two to get ***p***. ***p*** = ______ degrees

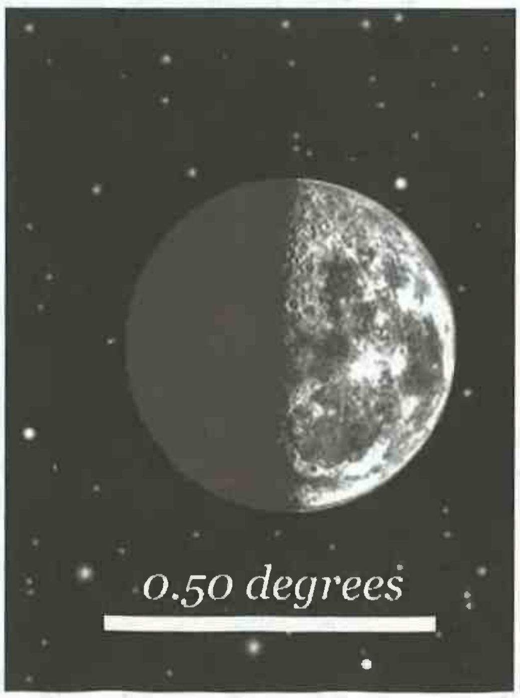
Using a baseline of 200 kilometers, compute the Earth-Moon distance.

- Parallax distance = Half-baseline/Tangent of angle ***p*** = ____________________ km

angle (deg)	0.010	0.012	0.014	0.016	0.018	0.020
tangent	0.00017	0.00021	0.00024	0.00028	0.00031	0.00035

The actual mean distance is about 384,000 kilometers. Find the percent difference between the actual distance and the one found using parallax.

- (|(Actual distance - Parallax distance)| / Actual distance) x 100 = ___ %



Part 3: The distance to two nearby stars.

Every six months the Earth moves to the opposite side of its orbit. Nearby stars will appear to have moved relative to distant ones. In the simulated star field below, find two shifted stars.

• Measure the length of the white bar in the left photograph. Length of bar = _______ mm

• Find the *scale factor*: angular length of bar/length of bar = _________arc seconds per mm
(There are 3600 arc seconds in one degree.)

Measure the *horizontal* distance in mm from each star to the right edge of each of the photos.

Star 1: • Photo 1: _______mm • Photo 2: _______mm • Difference = _____mm

Star 2: • Photo 1: _______mm • Photo 2: _______mm • Difference = _____mm

Convert this distance on the photographs to the actual one in the sky using the *scale factor*.

Star 1: • Difference x *scale factor* = _________________________ arc seconds

Star 2: • Difference x *scale factor* = _________________________ arc seconds

Each of these angles equals ***2p***, so divide each of them by two to get ***p***.

Star 1: ***p*** = __________arc seconds **Star 2:** ***p*** = _________ arc seconds

Using a half-baseline of one **Astronomical Unit (AU)**, compute the distance in **parsecs (pc)**.
(A star that has a parallax of one arc second is one parsec distant.)

Use this relationship: $\boxed{D(\text{pc}) = 1/p(\text{arc sec})}$

Star 1: • Distance in parsecs = 1/***p*** in arc seconds =_______ parsecs

Star 2: • Distance in parsecs = 1/***p*** in arc seconds =_______ parsecs

Which star is the more distant one? _______________

QUESTIONS

1) Complete the following table using the relationships described in this lab.

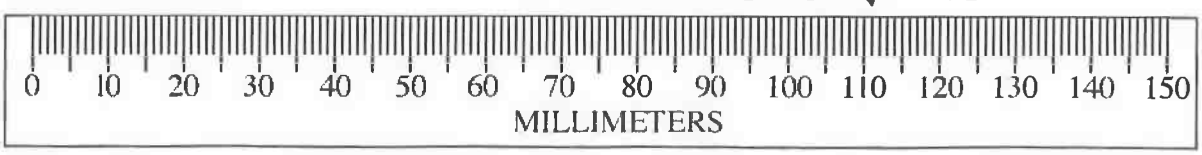
Star	*p* (arc seconds)	Distance (parsecs)
Alpha Centauri	0.77	
Vega		7.5
Capella	0.083	
Sirius		2.6
Betelgeuse		222

2) If we can't measure the parallax of a star, how can we find the distance to it? Look on the Internet or in your textbook under Cosmic Distance Ladder. Select one method and summarize it in the space below.

3) Most nearby stars in the sky are observed to move in oval paths in the course of a year. Stars at the ecliptic poles appear to move in nearly circular paths. Stars along the ecliptic simply move back and forth. Explain briefly why this is the case.

TEAR ALONG BROKEN LINE, THEN

FOLD THIS EDGE OVER



PROTRACTOR FOR MEASUREMENT OF ANGLE *P*