ASTRO 100/G – Experiment 3

Distance Modulus & Parallax

Links to Lectures 5, 6, 17, A1 and A3

Name: ID: UPI/Username:	**Grade** /10

Introduction

This lab is about measuring distances using **parallax**, **apparent magnitudes**, **absolute magnitudes** and the **distance modulus**. The first part of this lab involves coming to understand how parallax works. Then you'll use parallax to calculate the distance to a star in the night sky, then from this and the apparent magnitude you will calculate the absolute magnitude, i.e. how bright the star really is.

At the end of this lab, students will be able to:

- **Describe** what is the phenomenon of parallax and how it is used to calculate distances.
- **Explain** how parallax is used to calculate absolute magnitudes of stars.
- **Explain** how the colour and magnitude of a star are related to its temperature and distance.

Understanding Parallax

First let us look at the most basic way to measure distance to stars: parallax. Getting the distance for a star is important because without this we have no way to know how intrinsically bright the star is.

To see the effect of parallax, hold your hand out at arms length, and then look through your fingers as you close one eye then the other. You should see that what you can see between your fingers changes (as long as the background is very far away). This is because your eyes are about 10 cm apart and have a slightly different viewing angle on the gaps between your fingers. This is shown as a diagram at the top of the next page.

1. (2 marks) Fill in the table below, via the following steps:
   (a) Stand approximately two metres away from one of the scales your demonstrator has put up nearby.
   (b) Take the metre ruler, put one end just in front of your nose, and point it towards the scale.
   (c) Ask your lab partner to hold a pen halfway along the metre ruler.
   (d) Open then close one eye at a time and see how the pen moves against the scale. Use the scale to measure the relative apparent shift of the pen to the scale.
   (e) Write down your measurement on the table on the next page. Repeat this measurement with the pen 25cm away from your eye, and 1m away from your eye.
2. (1 mark) Based on your measurements above, is parallax easier to detect for objects nearer or distant to you? **Nearer – bigger shift.** .
3. (1 mark) At some distance past the end of the ruler, the pen will appear to effectively be stationary. Perform an experiment to figure out what that distance is. *Hint: the person with the ruler should remain stationary.*

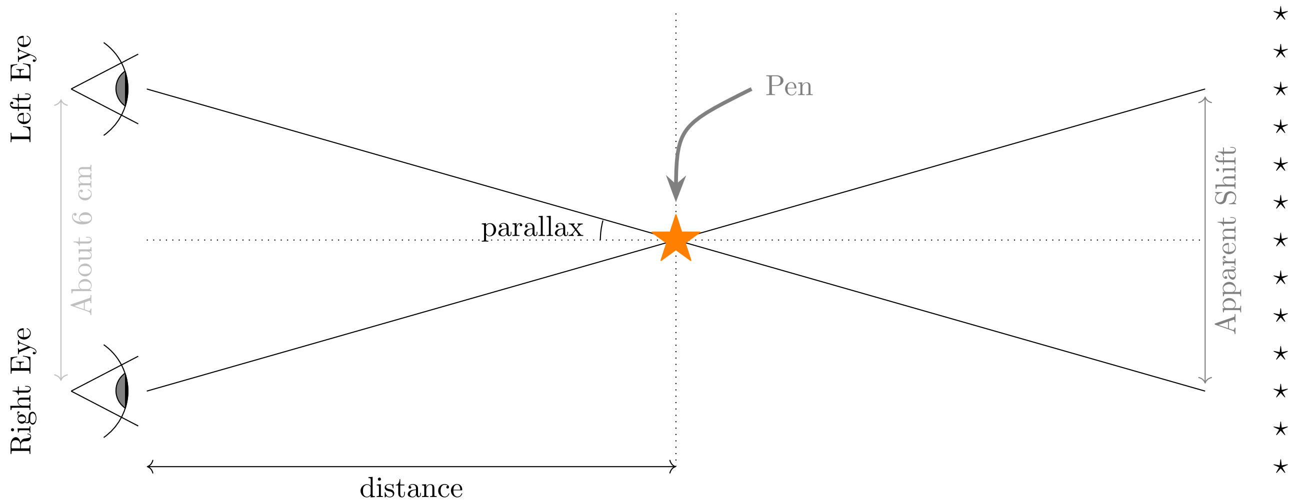
   The pen appears to be stationary at a distance of **Around 2 meters - depends on the student** from my eyes.

Pen Distance	Apparent Shift
25cm	
50cm	
1m	

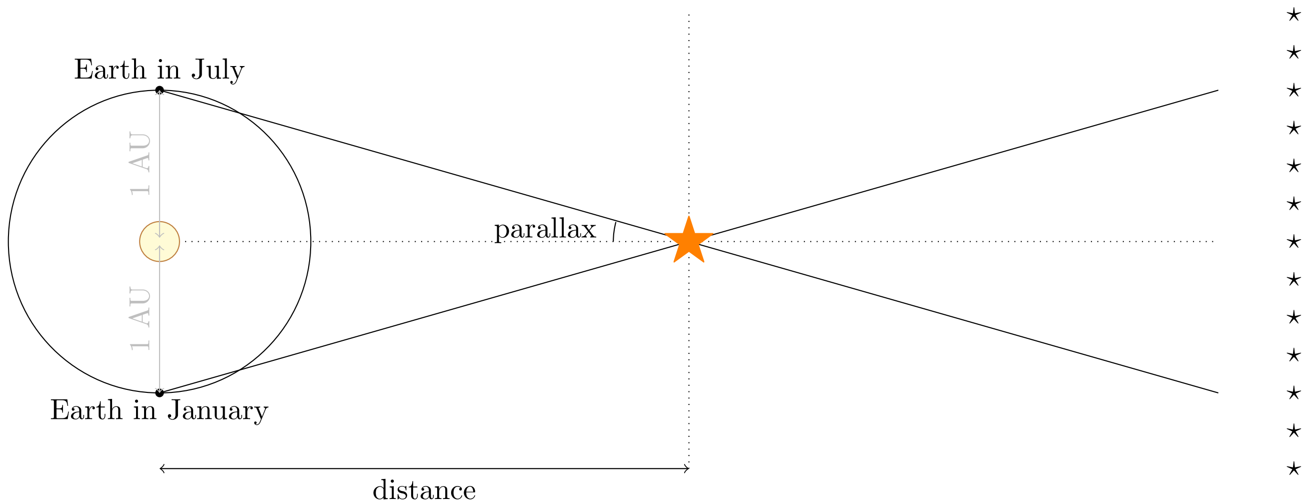
Measuring Stellar Parallax

In Question 3 you will have found a maximum distance to produce an observable parallax. This distance will be determined by your eyesight and the distance between your eyes, as shown in the picture below. As the pen gets further away, the apparent shift will shrink. The relationship between the distance between your eyes, distance to the star, and parallax, is

$$\text{distance to star} = \frac{\text{distance between eyes}}{2 \times \text{parallax}} .$$



But stars are much further away than this distance. Instead, the position of a star can be measured at different times in the Earth's orbit around the Sun. If we repeat the measurements of a star's position 6 months apart, during which time the Earth will have moved 2 AU from its initial position relative to the Sun, and a nearby star will appear to have moved, as shown in the picture below (not to scale – normally the distance to the star is *much* greater than the radius of the Earth's orbit). Effectively, the "distance between your eyes" is now 2 AU instead of about 6 cm.



If we measure parallax in arcseconds, then the distance in parsecs is given by

$$\text{distance} = \frac{1}{\text{parallax}} \ ,$$

which is the same as the equation at the top of the page, just where the distance between eyes is 2 AU. There are 3,600 arseconds in 1 degree (which is the angular size of a thumb held at arms length away).

4. Here, we will briefly look at the star Proxima Centauri, the closest star to our solar system.

   (a) (1 mark) Proxima Centauri is 1.302 parsecs away. What is the largest value of parallax that Proxima Centauri will have, as seen from Earth? Give your answer in arcseconds.

   Solution:

$$1.302 = \frac{1}{\text{parallax}} \implies \text{parallax} = \frac{1}{1.302} \approx 0.76\text{''} \quad (1)$$

   (b) (1 mark) **Comment** on your answer. Convert this parallax into degrees. How easy or hard would it be to measure this change in position?

   Solution: 0.000213 degrees. Hard to measure the quality of this answer, but look for evidence that they are thinking about parallax and telescopes rather than quality of the telescope

Parallax and Stellar Properties

In this section, we will **compute** some of the useful information about a star, given parallax and magnitude measurements that were collected earlier.

There are some important numbers which tell us information about the star:

- **Apparent Magnitude** – how bright the star appears in the sky in yellow light. Larger (i.e. more positive) magnitudes correspond to dimmer stars, and smaller (more negative) magnitudes to brighter stars.
- **B-V** – a number that tells us the colour of the star. The more negative the number the bluer the star, the more positive the redder the star. This is linked to the temperature of the star – remember, astronomers can't use taps, because bluer stars are hot but red stars are cool.
- **Parallax** – an angle that tells us how much the star moves on the sky as the Earth orbits the Sun. This is the most basic way we can measure distance.
- **Absolute Magnitude** – how bright the star would be if it was 10 parsecs away from us. This tells us about the *intrinsic* (or actual) brightness of the star.

To fill out the table for Putara and Matariki below, follow steps 5-7, then answer question 8.

5. Calculate the **distance** in parsecs to each star.
6. (1 mark) Now work out the distance modulus of the star. This is the factor we subtract from the apparent magnitude that takes into account the distance to give us the absolute magnitude. This is how bright the star would look at if it was at 10 parsecs. This is just the standard distance assumed for all stars. To calculate the distance modulus we use the equation:

$$\text{DM} = 5\log(\text{distance}) - 5\ .$$

(see Assignment 1 and Lecture 6)

7. Now calculate the absolute magnitude. Subtract the distance modulus from the apparent magnitude:

$$\text{absolute magnitude} = \text{apparent magnitude} - \text{DM}$$

Star Name	Apparent Magnitude	B-V	Parallax (arcsec)	Distance (parsec)	Distance Modulus	Absolute Magnitude
Autahi	-0.74	0.15	0.0106	$\frac{1}{0.0106} = 94.34$	$5\log 94.3 - 5 = 4.87$	$-0.74 - 4.87 = -5.61$
Matariki	2.87	-0.09	0.00809	123.61	5.46	-2.59
Putara	0.42	1.55	0.00655	152.67	5.92	-5.50

8. (2 marks) **Compare** the surface temperatures and intrinsic brightnesses of each star.
   (a) Which star has the cooler surface temperature (and why)?
   (b) Which star is intrinsically brightest (and why)?

Solution: Putara is coolest - low B-V $\therefore$ redder $\therefore$ cooler.

Autahi is brightest - smaller absolute magnitude.

You are now finished. Please hand your sheet to the demonstrator for marking.