AST101: Our Corner of the Universe
Lab 5: Measuring Distance with Parallax

Name:

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Lab section number:

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1 Introduction

Objectives

You've learned that the amount of parallax exhibited by a celestial body, measured against the distant stars, can be used to measure how far away it is. In class we've not used this method directly; we've only argued that anything exhibiting parallax must be close to use, while anything exhibiting no parallax must be very far away.

It's true that the ancients – up until Galileo's time, at least – weren't able to observe parallax for anything further away than the Moon. With the advent of the telescope, however, it became possible to measure the parallax of nearby stars against distant stars, and thus figure out how far away the stars are for the first time.

We don't do this extensively in AST 101, since this topic involves astronomy outside the solar system and belongs properly to AST 104. However, the measurement of distance using parallax is a simple idea, and you can build the things you need to do it yourself.

You will first learn how to measure the angular sizes of things, or the angular separation between them, using a ruler held at arm's length. Then, you will use this tool to measure how the appearances of objects and groups of objects changes as you change your spatial relationship to them. In particular, this idea – that a nearby object's alignment against distant objects changes as the observer moves back and forth – is called "parallax", and is how the distance to the nearest stars (other than the Sun) is measured.

Materials

A meter-stick or a ruler.

2 Measuring angular size

Here, we are interested in measuring the *angles* that objects span in our vision. A nearby, smaller object, and a distant, larger object may both appear to span the same angle. For instance, the

Moon and Sun appear the same size to us in the sky; the Moon is smaller and closer, and the Sun is larger and more distant.

As a standard measure, an object one centimeter long held 57 cm away appears to span one degree; we call this its *angular size*. By looking at the centimeter marks on a ruler held 57 cm away from your eye, you can determine the angular sizes of things around you.

For instance, if an object's left edge lies at the 8.5 cm mark on your ruler, and its right edge lies at the 10.5 cm mark (when you hold your ruler 57 cm away), then that object has an angular size of two degrees (10.5-8.5).

Question 1: If you hold your ruler closer than 57 cm, will you overestimate or underestimate the angular sizes of things using this method? How do you know?

2.1 Heads as standard yardsticks

Measure the angular sizes of the heads of your TA and of some of your classmates, as seen from where you are sitting in class.

Question 2: What is the range of angular sizes that you measure?

Question 3: Does this tell you anything about the ranges of head-size among your peers? If not, does it give you information about anything else?

Question 4: If you observe a correlation between the distances people are from you and the angular sizes of their heads, which way does it go? Do more distant people have larger or smaller angular sizes?

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3 Parallax as a distance measure

The parallax method of distance determination involves measuring the shift of an object against a much more distant background, when viewed from two different points. For nearby objects, you may use your two eyes as the two points; for more distant objects, you will need to move. We call these two points the ends of the **baseline.** You can use your ruler held at 57 cm to measure the size of the shift, and the meter stick to measure the baseline. The Parallax Distance formula is:

$$\text{Distance from baseline to object} = 57 \times \frac{\text{separation between observing points}}{\text{parallax in degrees}}$$

Note that the distance here is inversely proportional to the parallax – this is consistent with our observation that distant objects have little parallax.

First, let's measure distances of some nearby things, using Nature's own parallax measurement: our eyes! By closing each eye in turn, you can very easily make "observations" from two different points and use the parallax formula to determine distance. How does this work?

First, choose a nearby object with a visible background that is much further away. Then:

(a) Using your left eye, identify the point on the background that lines up with your object.

(b) Using your right eye, identify a new point on the background that lines up with your object.

(c) Now, hold your ruler 57 cm from your eyes, and measure the angular separation between those two points. That angular separation is the parallax angle.

(d) Measure the distance between your eyes (or have your lab partner do it for you). This is the length of your baseline – the separation between the observation points.

(e) Use the parallax distance formula to calculate the distance to the object!

3.1 Measuring something further away

For this exercise, you will measure the distance to something further away. At your and your lab TA's discretion, you may either measure the distance to one of the lampposts near Holden Observatory, or may go to the Physics Building and measure the distance to the lampposts outside. If it is windy or cold, going to the Physics Building will let you do this from inside.

Distant buildings will serve as your background, perhaps on the other side of the Quad if you've gone to the Physics Building.

Question 5 Draw a sketch of the spatial location of the different elements involved in the parallax measurement. Indicate the baseline, the location of the lamp post and your reference points on the distant building.

Now, use your meter stick to measure out a baseline separating two convenient observing points. Stand at one point, and observe the placement of the lamp post against HBC. Use the cross-staff to find the angular separation between the lamp post and a recognizable part of the distant building. Now, move to the other observing point, and compare the angular separation of the lamp post with your reference point on the building. The difference in angular separations seen from the two points is the parallax. Use the parallax distance formula to determine the distance to the lamp post. Step outside and measure the distance to the lamp post, by pacing or using your meter stick.

Question 6

Using your previous measurements, complete the following table. Make sure that you include the appropriate units in your entries. Note that you have to repeat your measurements twice, using two different baselines.

	First measurement	Second measurement
Baseline		
Parallax		
Distance from parallax measurement		
Distance from direct measurement		

Question 7

Do your measurements using parallax and a direct method agree? What might account for any discrepancies you see?

Question 8

What is the longest observing baseline that we have access to on Earth? Give your answer in AU. Hint: When is Earth furthest from where it is now?

Question 9

The closest star other than the Sun, Alpha Centauri, is 4.2 light years away; this is 265,000 AU.

Using the parallax formula and the answer you got from Question 8 as the observing baseline, what parallax will we observe in Alpha Centauri? Given that Tycho's data measured the positions of stars with a precision of 0.03 degree, would pre-telescope astronomers have been able to observe this parallax?