Introduction to Astronomy

AST 101

Parallax experiment

Lehman College

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1 Introduction

As you have seen in the lecture, parallax is a phenomenon that occurs when you look from different places at objects that are at different distances from you. If some of these objects are very far, they can be taken as a fixed background and used to measure the distance to the nearby object without having to go there.

While this has only limited applications on your daily life, it is a very useful technique to measure the distance to nearby stars, by observing where they are within the background of distant, *fixed* stars, as we look at them at different times of the year (because the Earth is at a different location at different times of the year). You can see an illustration of this in the figure below.

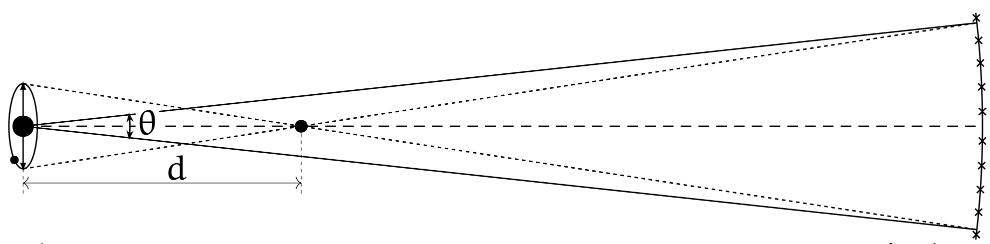

Figure 1

In this experiment, you will recreate a smaller version of this, by using your phone camera as a telescope, and observing a nearby object move through a background of fixed, distant objects.

2 Description of the experiment

By looking at the diagram above, we can identify three entities:

the solar system is the observation point, where the Earth is located, and it needs to move in a direction perpendicular to the line of observation;

the source is a more or less nearby star, to which we want to measure our distance;

the fixed stars are very far away stars that, for that reason, don't seem to move around even when the Earth moves within the solar system.

In your experiment, these three items will be replaced as follows

the solar system → desk with ruler and phone: a ruler will be placed on a desk, perpendicular to the line of observation. This will allow you to know how much your phone moves.

the source → dot on window: you will make a small dot with a sharpie on a window, which will represent the *star* that you want to measure the distance to.

the fixed stars → distant buildings: these buildings are so far away compared to the dot on the window, that they barely move when you move the phone just a few inches.

3 Procedure

NOTE: Do not change the zoom setting on your phone. If you do so across different measurements, they will not make sense!

3.1 Calibration

The first thing we need is to be able to measure angles with your phone camera. To figure out what is the angle seen by your camera, you will need two rulers and your phone, to set up something like what is shown on the pictures in Fig. 2.

1. Set a long ruler on the desk, with the centimeter scale facing up;
2. take the short ruler and put it vertically on top of the other one, around the center;
3. place your phone facing down on top of the short ruler, with the camera almost on top of it, and take a picture of the long ruler;
4. record the length of the short ruler as L_s below:

   L_s = _____ cm

5. in the picture, find out what are the numbers on the ruler all the way to the left and all the way to the right of the picture; record them as x_L and x_R below:

   x_L = _____ cm $\qquad$ x_R = _____ cm

6. calculate the distance seen on the long ruler as $L_l = x_R - x_L$ and record it below:

   L_l = _____ cm

7. find the angle covered by your phone (θ_p) using the trigonometric relation

$$\theta_p = 2 \arctan\left(\frac{L_l/2}{L_s}\right),$$

   and record it below:

   θ_p = _____ $^\circ$

Figure 2

3.2 Pictures against fixed background

Now, you are ready to take the parallax measurements, as shown in the pictures in Fig. 3:

1. place your phone vertically on the desk in front of the ruler and pointing towards the window;
2. locate the point on the window that plays the role of the star,
3. move your phone left or right until it is right on top of a distant object in the background that is easily recognizable to use as reference point. Without moving from that position,
   a) take a picture,
   b) read the position of the left edge of your phone on the ruler, and record it below as x_1
4. now, move your phone to the side until the same dot is on top of a **different** distant object in the background that is easily recognizable. Again, without moving from that position,
   a) take a picture,
   b) read the position of the left edge of your phone on the ruler, and record it below as x_2

   $x_1 =$ _____ cm $\qquad$ $x_2 =$ _____ cm

5. calculate the distance between the two points,

   $$x = |x_2 - x_1|,$$

   and record it below:

   $x =$ _____ cm

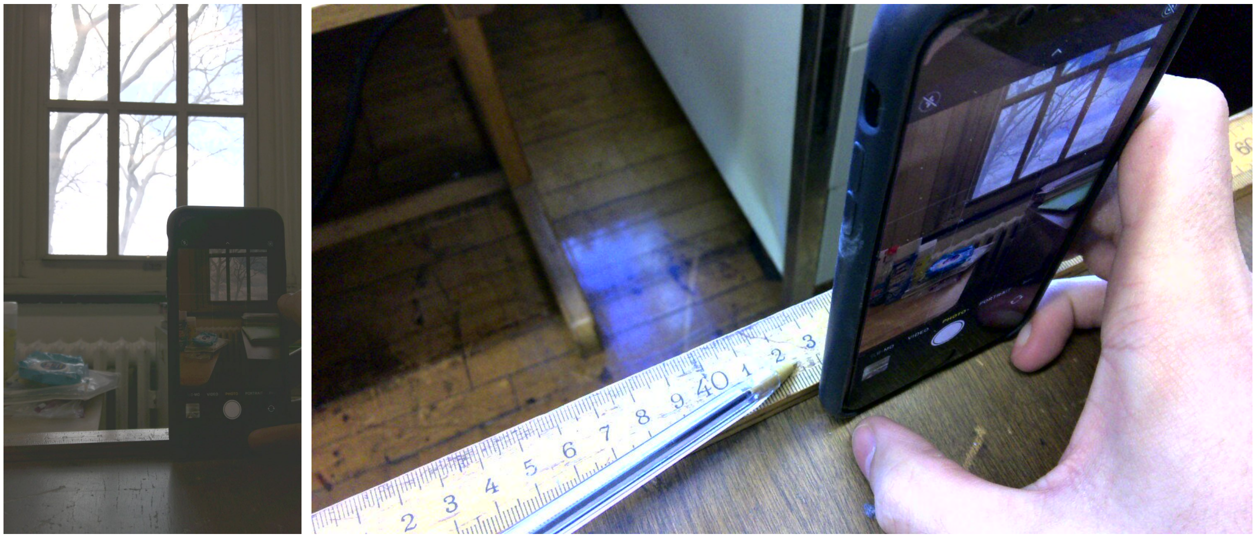

Figure 3

3.3 Obtaining the angle

You can now use the previous pictures to measure the angle between the two background points:

1. Carefully observe the two photos taken before and identify the two points that you used as reference;

2. choose one of the two pictures, making sure that both reference points are visible;

3. with the ruler utility in the photo edition tool (iPhone, see Fig. 4), find the distance between those two points and record it as s_{ref}:

   s_{ref} = ______

4. with the same tool, find out how wide the whole picture is, and record it as s_{pic}:

   s_{pic} = ______

5. find what fraction of the total picture separates the two reference points using

   $$f = \frac{s_{ref}}{s_{pic}}$$

   and record it below:

   f = ______

6. if the reference points take a fraction f of the screen, and the screen covers an angle θ_p, which you found before, the angle between the reference points is $\alpha = f \times \theta_p$. Calculate this number and record it below:

   $\alpha =$ _____ $^\circ$

Figure 4

3.4 Calculating the distance

Finally, with all the numbers you obtained and the parallax formula, you should be able to obtain the distance between your phone (the Earth) and the dot on the window (a star).

1. Calculate the distance from the phone to the window using the following equation

$$d = \frac{x}{2\tan(\alpha/2)},$$

   and record it below:

   $d =$ _____ cm

2. use a ruler to measure the actual distance and record it below:

3. $d_{true} =$ _____ cm

4. compare both numbers.

Notice that steps 2 and 3 above are the steps that one can't do in astronomical observations: we can't use a ruler from the Earth to a distant star, so only the parallax method is available to figure out how far it is.