ASTRO 1050
LAB #9: Parallax and Angular Size-Distance relations

ABSTRACT

Parallax is the name given to the technique astronomers use to find distances to the nearby stars. You will calibrate their own measuring device and use this device to estimate sizes and distances to objects. This technique will then be applied to astronomical objects.

Materials

Meter stick, paper, index cards, pencil, calculator

Excercises

A. Review of angular size and using angular size to find distance

It should seem somewhat intuitive that the closer an object is, the larger it appears... that is, the closer it is the larger its angular size. The relation between the distance of an object, D, the size of the object, L, and the angular size, α, is given by:

$$\alpha[\text{radians}] = \frac{LinearSize[\text{m}]}{Distance[\text{m}]} = \frac{L}{D}. \tag{1}$$

Or in degrees, since there are 57.3 degrees in a radian:

$$\alpha[\text{degrees}] = 57.3 \times \frac{L}{D} \tag{2}$$

You can use these in combination to find the angular size, distance or linear size of other objects around you.

B. Calibrating an index card as a measuring device

Your objective will be to measure the distance to a nearby object in Laramie using this relation, and later, using the *parallax* method. First, we'll need to calibrate an angular measuring tool, an index card held at arm's length, so that you can use it to measure angles.

You will use the card, in a similar way (but more precise) than when using your hands as measuring devices to measure the angular size of things around you.

Your objective is to delineate your index card into 1 degree segments *when you hold the card at arm's length*.

- First have a partner measure the distance from you eye to the card (when your arm is outstretched).
- Distance from eye to card, D: _______ cm
- Compute the linear size, L, on the card which will cover (subtend) 1 degree.
- **Linear size on card, L = $\alpha \times$ D / 57.3 = _______cm (compute to nearest 0.1 cm.)**
- Finally, use a ruler to carefully make small marks across the long side of the card every L (cm) which are 1 degree in separation when held at arms length.

C. Finding the size of a nearby object

Using your newly calibrated angular measuring device, measure the angular size of the chalkboard, top to bottom, from the back of the room. Also measure the distance from where you stand to the chalkboard. Be sure to measure as precisely as you are able (to about 0.01 m or 1 cm).

Angular size, α[degrees]: _______

Distance to board, D[m]: _______

Now compute the size of the chalkboard, $L_{computed}$:

$$L_{computed}[\mathrm{m}] = \frac{\alpha[\mathrm{degrees}] \times D[\mathrm{m}]}{57.3} = \underline{\qquad\quad}\ \mathrm{m} \tag{3}$$

Next, directly measure the size of the chalkboard with your meter stick

$$\mathrm{L}_{direct} = \underline{\qquad\quad}\ \mathrm{m} \tag{4}$$

Compare the two measurements, via finding the percent error:

$$\text{Percent error} = \frac{L_{direct} - L_{computed}}{L_{direct}} = \underline{\qquad\quad} \tag{5}$$

What do you think is the major source of error? How could it be reduced?

D. Finding the distance to a star cluster

Online (at physics.uwyo.edu/∼shawns/astro1050_2.html) is a picture of a globular star cluster. A scale bar is shown that gives an *angular* size for reference, and let's say that you know most globular clusters are about 2 parsecs in diameter (i.e. the actual linear size $L = 2$ pc).

How far away is the cluster? (Show your calculation in the space below.) D = _______ pc.

E. Measuring distances with parallax

Parallax is the name given to the technique astronomers use to find distances to the nearby stars. Hold your thumb at arm's length and look at it using only one eye. Now try the other eye. What happens? The "jump" that your thumb appears to make against the more distant objects in the background is caused by observing your thumb from two different vantage points; that is, along two different lines of sight.

Now hold your thumb close to your nose and observe it with one eye. Now use the other eye. What do you notice? The amount of "jump" is much different than before. By measuring the amount of the jump, and by knowing the distance between your eyes, you could measure the distance to your thumb!

Astronomers do much the same thing. They measure the apparent "jump" of a nearby star against the background of much more distant stars. The two vantage points are on opposite sides of the earth's orbit around the sun, as shown in the picture. The distance between the two vantage points is called the *baseline*, B. The amount of the jump is called the *parallax angle*, p. Another way to say this is that the angular size of the parallax jump is p.

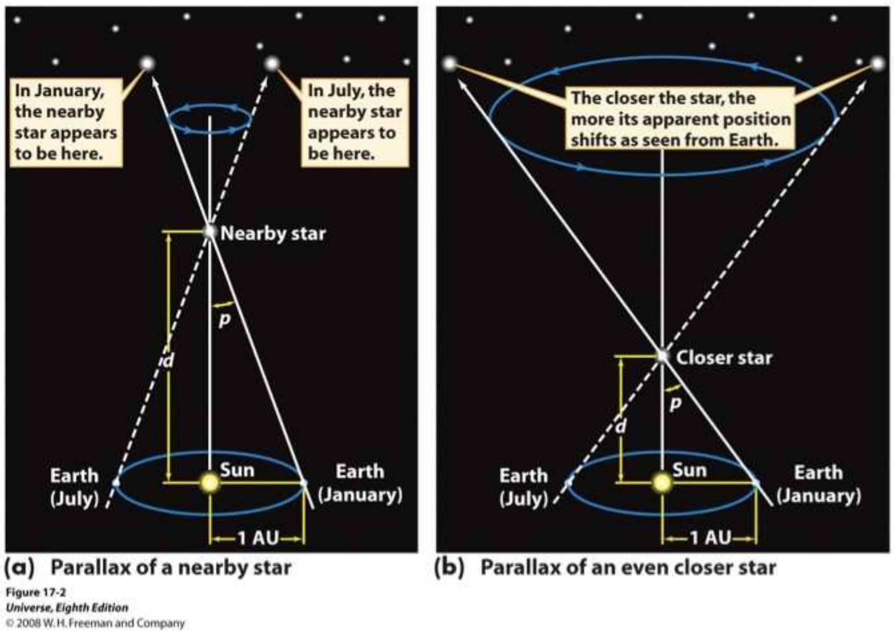

Fig. 1.—: Parallax

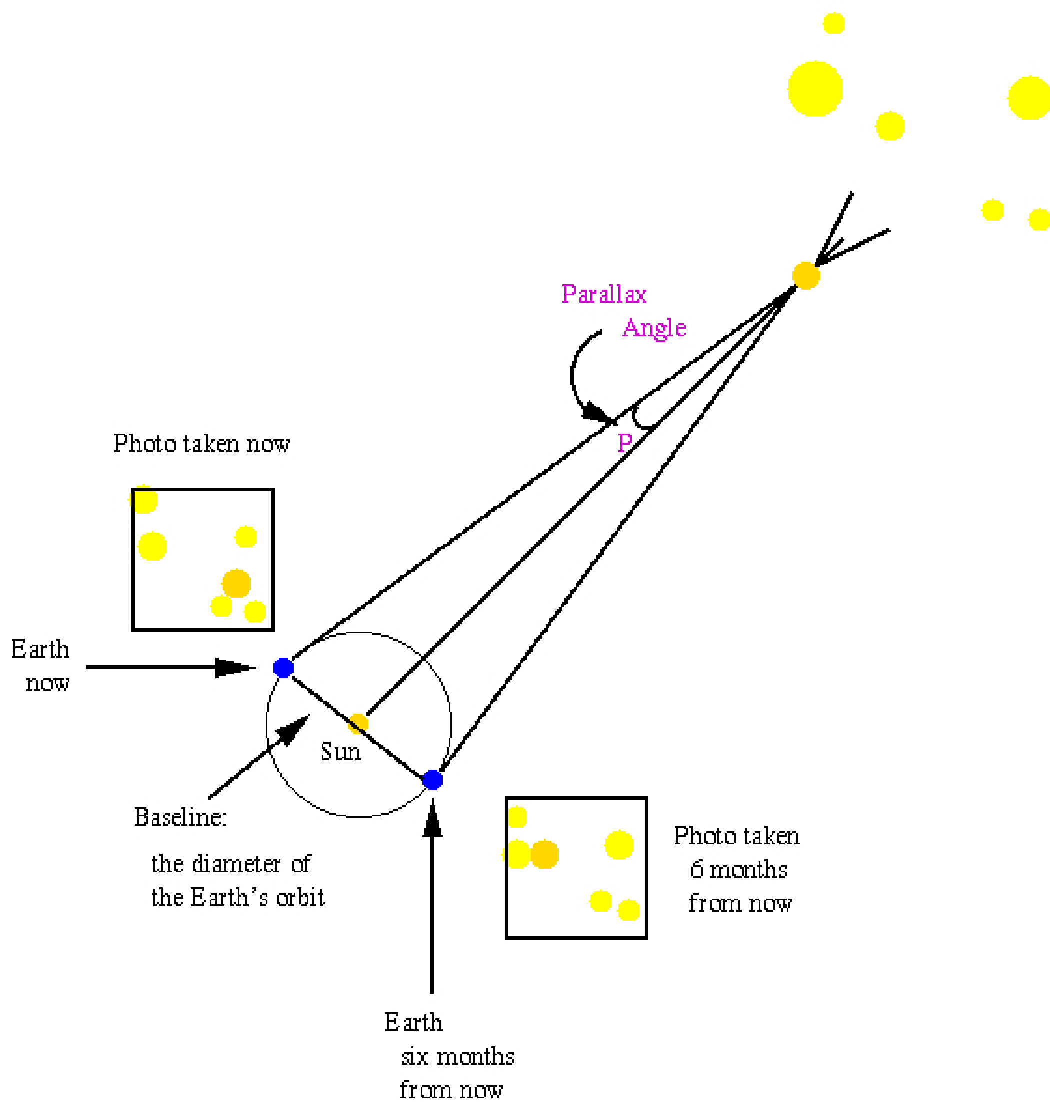

Fig. 2.—: Parallax

For small angles, we say:

$$p[\text{radians}] = \frac{B[\text{m}]}{d[\text{m}]}. \tag{6}$$

Therefore the distance is,

$$d[\text{m}] = \frac{B[\text{m}]}{p[\text{radians}]} = 57.3 \times \frac{B[\text{m}]}{p[\text{degrees}]} \tag{7}$$

Or, since there are 3600 arcseconds in a degree, this can then be written,

$$d[\text{m}] = 206265 \times \frac{B[\text{m}]}{p[\text{arcsec}]}. \tag{8}$$

And for cases where the baseline is 1 AU (in astronomy observations are made with this as the baseline) then,

$$d[\text{pc}] = \frac{1}{p[\text{arcsec}]}, \tag{9}$$

just like the book says in Chapter 17. This is the simplest form of the parallax equation- but be careful! It ONLY applies when the correct units are used (just like with Kepler's third law) and the baseline is 1AU!

Now, let's go outside and make some measurements of an object!

1. We will be measuring the distance to the smokestack near the train tracks in West Laramie.

2. First, establish your baseline. That is, pick two locations, separated by at least 10 meters where you have a clear view of your object. Measure the baseline length and record it here.

   Baseline length, B = _______ m

3. Now draw a picture of your object and the background (mountains, buildings...) from location 1. Pay particular attention to where your target object falls against the background scenery. The point where your object falls against the background scenery is called *reference point 1.* Then move to location 2 and sketch the scene. Pay particular attention to where your target object falls against the background scenery. The point where your object falls against the background scenery is called *reference point 2.*

View from location 1

View from location 2

4. Now stand at one end of your baseline and measure the *angular distance between background reference point 1* and *background reference point 2* using your index card as you practiced in the classroom. Record this angular distance, p. Do this several times to get a good estimate.

   Angular shift (parallax), p = _______ degrees

5. Finally, compute the physical distance to your object using the parallax formula.

d [m] = 57.3 × B [m] / p [degrees] = _______ m

Record some results from your other classmates.
Student 1 (you): Distance = _______ m
Student 2: Distance = _______ m
Student 3: Distance = _______ m
Student 4: Distance = _______ m
Student 5: Distance = _______ m
Student 6: Distance = _______ m
Student 7: Distance = _______ m
Student 8: Distance = _______ m

Average Distance: _______ m

6. How accurate do you think your estimate is? Are you within 5 meters? 10 meters? 100 meters?

7. Does taking the average of many students' measurements give you a better estimate of the TRUE distance?

8. What do you think contributes most to the error or uncertainty in your measurement?

9. Do you think there are any advantages to using a LARGE baseline versus a SMALL baseline? Why?

F. Extension to stars

If you were to measure the distance to the nearest star using as a baseline the radius of the earth's orbit, what angular shift, i.e., parallax, would you expect to measure?

Parallax: _______ arcsec

Could you measure such an angle with your pinky or notecard? Why or why not?