The Parallax Experiment

Firstname Lastname

Date

1. Replace the red text at the top of this page with your name and the date.

2. As you enter your work, please make sure that your answers stay red (like this). This will make them easier to see, and thus it will be easier for us to grade them accurately. To convert black text to red, highlight it and then click on the “A” symbol in the menu bar above, to the right of the “**B**”, “*I*”, and “U” symbols. Select the red square to turn your highlighted text red.

3. Delete these 3 initial instructions from this template as soon as you have followed them.

Taking Parallax Measurements

1. Estimate the distance to the horizon, or to a distant landmark in line with your measuring device and your object at Position 1, by eye.

Replace this text with your answer, leaving it in red.

Table 5.2: Direct Measurements of Distance

Distances from observer to object, in inches, to the nearest half-inch.

|  |  |  |
| --- | --- | --- |
| Position 1 | Position 2 | Position 3 |
| Replace me! | Replace me! | Replace me! |

(Distance from observer and apparatus to three foreground objects.)

2. Estimate the *uncertainty* in your measurement of the object's apparent

shift. For example, do you think your recorded measurements could be off by ten degrees? One degree? One tenth of a degree?

Replace this text.

Table 5.3: Parallax Measurements

Record angles to the nearest tenth-degree, distances to the nearest half-inch.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Angle 1 (°)[[1]](#footnote-0) | Angle 2 (°)[[2]](#footnote-1) | 2α (°)[[3]](#footnote-2) | α (°) | r/d[[4]](#footnote-3) | d (in)[[5]](#footnote-4) |
| Trial 1 |  |  |  |  |  |  |
| Posn. 1 | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! |
| Posn. 2 | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! |
| Posn. 3 | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! |
| Trial 2 |  |  |  |  |  |  |
| Posn. 1 | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! |
| Posn. 2 | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! |
| Posn. 3 | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! |
| Trial 3 |  |  |  |  |  |  |
| Posn. 1 | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! |
| Posn. 2 | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! |
| Posn. 3 | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! | Replace me! |

Dependence of Parallax on Vantage Point Separation

3. What would happen if the vantage points were farther apart? We separated our vantage points by two feet, to simulate the two astronomical units by which the Earth shifts position over a six month period. What if we had used a separation of ten feet instead? How would you expect the angular shift of the object (the difference between Angle 1 and Angle 2) to change?

Replace this text.

4. By how many degrees did the object move using the more widely separated vantage points?

Replace this text.

5. For an object at a fixed distance, how does the apparent shift change as you observe from more widely separated vantage points?

Replace this text.

Measuring Distances using Parallax

6. The apparent shift of the object is caused by looking at the object from two different vantage points. Qualitatively, what do you see changing from viewpoint to viewpoint? As a foreground object moves farther away from you, does its apparent shift increase or decrease?

Replace this text.

7. Based on your estimate of the uncertainty in the angular measurements of 2α, estimate the uncertainty in your measurements of the object distances.

Replace this text.

8. Now look at the spread in the three values for each position in the last

column of Table 5.3. Is this spread consistent with your estimated uncertainty?

Replace this text.

9. Now compare the distances that you calculated for each position using the parallax method to the distances that you measured directly at the beginning of the experiment (in Table 5.2). How well did the parallax technique work? Are the differences between the direct measurements and your parallax-derived measurements within your errors (within 2σ)?

Replace this text.

10. If the differences are larger than 5σ, can you think of a reason why your measurements might have some additional error in them? We might call this a *systematic* error, if it is connected to a big approximation in our observational setup.

Replace this text.

Table 5.5: Comparison of Average Distances

Measured and parallax-derived distances from observer to object, in inches.

For parallax distances record the average values (μ) of the three trials

and the errors (σ) calculated with the plotting tool in this form: nn.n ± n.n

|  |  |  |
| --- | --- | --- |
|  | Direct Distance |  Parallax Distance |
| Position 1 | Replace me! | μ ± σ |
| Position 2 | Replace me! | μ ± σ |
| Position 3 | Replace me! | μ ± σ |

Distances on Earth and within the Solar System

1. We have just demonstrated how parallax works on a small scale, so now let us move to a larger playing field. Use the information in

Table 5.4 to determine the angular shift (2α, in degrees) for Organ Summit, the highest peak in the Organ Mountains, if you observed it with a baseline 2*r* of not 2 feet, but 300 feet, from NMSU. Organ Summit is located 12 miles from Las Cruces. *(If you are working from another location, select a mountain, sky scraper, or other landmark at a similar distance to use in place of the Organ Summit.)* There are 5,280 feet in a mile.

If the baseline 2r = 300 feet, then r = ... feet.

The distance to the object d = 12 miles = … feet.

r/d = ….

Finding the (r/d) value in Table 5.4, α = … degrees.

The observed angular shift 2α = … degrees.

2. What about an object farther out in the solar system? Consider our near neighbor, planet Mars. At its closest approach, Mars comes to within 0.4 A.U. of the Earth. (Remember that an A.U. is the average distance between the Earth and the Sun, or 1.5 × 108 kilometers.) Let us assume we have two telescopes in neighboring states, and calculate the ratio *r/d* for Mars for a baseline of 2,000 kilometers.

If the baseline 2r = 2,000 kilometers, then r = ... kilometers.

The distance to the object d = 0.4 A.U.= … kilometers.

r/d = ….

Can we find this (r/d) value in Table 5.4? (Yes / No)

We can say that α < … degrees.

3. Create a linear plot with *r/d* values on the *x*-axis and α values on the *y*-axis, and then check the slope of a line fit through the values, for α = 0° to 80° (the complete table) and then trimming the table to contain only the points for which α is less than or equal to 2°. Include a copy of both plots in your lab report (making sure to label the axes, and to add titles). Is a straight line a good fit to either set of data (for α ≤ 80°, or just up to 2°)? What is the slope, in the linear region? Are you now comfortable using this approximation to shift between α and *r/d*?

Replace this text, and include PNG-format images of two plots.

Distances to Stars, and the Parsec

4. (a) If a star has a parallax angle of 0.25'', what is its distance in parsecs?

For a star with parallax angle α (in arcseconds) located a distance *d* (in parsecs) aways from us,

d = 1 / α = … parsecs.

(b) If a star is 5 parsecs away from Earth, what is its parallax angle in arcseconds?

For a star with parallax angle α (in arcseconds) located a distance *d* (in parsecs) aways from us,

α = 1 / d = … arcseconds.

(c) If a star lies 5 parsecs from Earth, how many light-years away is it?

d = 5 parsecs = … light-years.

Final (post-lab) Questions

1. How does the parallax angle of an object change as it moves away from us? As we can only measure angles to a certain accuracy, is it easier to measure the distance to a nearby star or to a more distant star? Why?

Replace this text.

2. Relate the experiment you did in the first part of this lab to the way that parallax is used to measure the distances to nearby stars. Describe the process an astronomer goes through to determine the distance to a star using the parallax method. What did your two vantage points represent in the experiment?

Replace this text.

3. If the angular distance between Stars *A* and *B* is 0.5 arcseconds, then how far away would you estimate that Star *P* lies from Earth?

The linear distance (length) between stars A and B is … inches (on a printed copy of Figure 5.9), which is equivalent to 0.5 arcseconds on the sky. The linear distance between stars A and P is … inches on the left image (in January) but is only … inches on the right image (in July), so star P must have shifted to the left by … inches over six months.

Between images, Star P shifts by 2α = … arcseconds on the sky.

d = 1 / α = … parsecs.

4. Astronomers like Tycho Brahe made careful naked eye observations of stars in the late 1600's, hoping to find evidence of semi-annual parallax shifts for those which were nearby and so weigh in on the growing debate over whether or not the Earth was in motion around the Sun. If the nearest stars (located 1.3 or more parsecs from Earth) were 100 times closer than they are now known to be, or if the resolving power of the human eye (0.02 degrees) was improved by a factor of 100, could he have observed such shifts? Explain your answer.

The angular shift of the nearest is star is α = 1 / d = … arcseconds.

The smallest change in angle we can see is r = 0.02 degrees = … arcseconds.

We ( can / cannot ) observe the angular shift of the nearest star by eye.

If the stars were 100 times closer, α would increase to 100 × α = … arcseconds. Or if our eyes were 100 times better, r would decrease to r / 100 = … arcseconds. In either case, we (could / could not) observe the shift by eye.

Summary (300 to 500 words)

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Extra Credit

Replace this text.

1. Landmark angle. [↑](#footnote-ref-0)
2. Foreground object angle. [↑](#footnote-ref-1)
3. 2α = Angle 1 - Angle 2. [↑](#footnote-ref-2)
4. r/d values can be looked up in Table 5.4. [↑](#footnote-ref-3)
5. d = r / (r/d), where 2r is the vantage point separation (24 inches). [↑](#footnote-ref-4)