**Lab [Number] – [Title of Lab]**

[Author names]

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[Course and section] – [Due date]

**ABSTRACT**

[*Write your abstract here.*]

1. **Introduction**

Astronomers use a wide variety of methods to determine the distances of astronomical objects. These methods are arranged in something called the cosmic distance ladder, in which methods of determining distances of close objects help determine distances of farther objects. Similar to a real ladder, the success of higher rungs of the cosmic distance ladder depend on the stability of the lower rungs. In astronomy, one of the lowest rungs, and therefore, one of the most fundamental methods, is stellar parallax.

Parallax is the apparent movement of an object due to the angle of observation. Typically, astronomers use the Earth’s position at opposite points in its orbit as the two observation points, as observed in Figure 1 below.

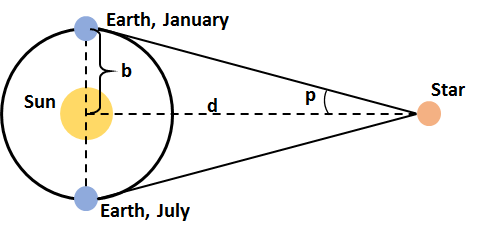
By knowing the size of the Earth’s orbit and measuring the angle the star appears to move relative to ‘stationary’ background stars (that is, stars that do not visibly move,) one can calculate the distance to a star *d* by using simple geometry:

Figure 1: Stellar Parallax from Earth’s Orbit

where *b* is the observer baseline (half the distance between observation points) and *p* is the parallax angle (half of the observed angular distance traveled), as illustrated in Figure 1. The greater the parallax angle, the closer an object is to the observer.

Though parallax can theoretically be measured from any two points in space, astronomers often use the Earth’s orbit about the Sun as a baseline, which results in a particular form of the above equation:

[*Give the parallax equation for Earth-orbit observations, followed by a definition of variables*]

In this lab, we [*briefly state the purpose of the lab: include what values you ultimately calculated and what was done with this data*].

1. **Methodology**

The data we used for our analysis consisted of [*describe the data you were given*]. In each image, we identified the star that was a good candidate for a parallax measurement, [*define which stars were able to be used for parallax*.] We assumed that [*list any assumptions made*].

The first step in the analysis of each pair was to find the plate scale of the images. In order to do this, we [*describe method used to measure this.*]

Then, we measured the apparent distance each star moved between the two images by [*describe method used for measurement*.] The apparent movement that we measured in illustrated in Figures 2 and 3 [*for this, you can use the images given to use as a start, but you might want to mark them to show your measurements*].

Figure 3: Ending image of [*data set*] with parallax motion

Figure 2: Starting image of [*data set*]

With the plate scale and apparent distance traveled by each star, we could then determine the parallax angle by [*describe how to find parallax angle*.] Finally, we were able to calculate the distance to the star, using the equation defined in the introduction.

This process was repeated for all 10 data sets. Additionally, we combined the entire class’s data for Star 1 by [*how did you combine the data?*].

For some of the images, [*describe an issue/issues found in the data*]. To deal with this problem, we [*discuss any variations in the data and how you dealt with them*].

1. **Analysis**

The most significant source of uncertainty in this lab was [*list largest source of error (instrumental)*]. We quantified this uncertainty by [*describe how you defined values for this uncertainty, and whether it ever changed*].

In order to determine the uncertainty of the plate scale , we used the uncertainty of the [*what device/method?*] and propagated the error using the equation

where [*define variables*].

Similarly, we found the uncertainty in the calculated parallax angle by using [*describe method of finding uncertainty*]:

[*Give equation and define variables*]

Finally, we propagated the uncertainty of the object distance by using [*describe method of finding uncertainty]:*

[*Give equation and define variables*]

The values measured from each pair of images is recorded in Table 1, and the calculated values of parallax angle and distance in Table 2. The difference between our distances and that of the Hipparcos data is shown in a residual plot in Figure 4.

For the collective class data, the distance to Star 1 was [*distance, error*]. Class measurements for Star 1 are shown in Figure 5. For this class-wide data set, we determined the error of the average object distance for Star 1 by [*explanation of uncertainty*], as shown in the equation

Table 1: Measured Values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Data Set | Plate Scale s (arcsec/mm) | Plate Scale Error σs (arcsec/mm) | Apparent Separation a (mm) | Apparent Separation error σa (mm) |
| 1 |  |  |  |  |
| 2 |  |  |  |  |
| 3 |  |  |  |  |
| 4 |  |  |  |  |
| 5 |  |  |  |  |
| 6 |  |  |  |  |
| 7 |  |  |  |  |
| 8 |  |  |  |  |
| 9 |  |  |  |  |
| 10 |  |  |  |  |

Table 2: Calculated Values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Data Set | Parallax Angle p (arcsec) | Parallax Angle Error σp (arcsec) | Object Distance d (pc) | Object Distance Error σd (pc) |
| 1 |  |  |  |  |
| 2 |  |  |  |  |
| 3 |  |  |  |  |
| 4 |  |  |  |  |
| 5 |  |  |  |  |
| 6 |  |  |  |  |
| 7 |  |  |  |  |
| 8 |  |  |  |  |
| 9 |  |  |  |  |
| 10 |  |  |  |  |

Figure 4: Residuals with Hipparcos Data

Figure 5: Class Measurements of Star 1 Distance

1. **Discussion**

In general, our calculated distances were [*close/far*] to the Hipparcos data. The most accurate measurement was of [*Which star?*], with a distance of [*distance, error*]. The most precise measurement was of [*which star?*], with a distance of [*distance, error*]. The least accurate and least precise measurements were [*star x*] and [*star y*], respectively, with distances of [*distance, error*], and [*distance, error*]. These measurements [*do/don’t seem plausible, and explain why*]

Our class measurement of Star 1’s distance was [*distance, error*]. This [*agrees, disagrees*] with the given value for this star, [*value*]. To improve the uncertainty of this measurement, we could [*give method to improve error*].

The biggest contribution to the discrepancy between our data and the Hipparcos data is [*describe and explain largest source of error*]. To minimize this error in the future, we could [*think of a method to possibly decrease your error*]. Additionally, [*list any other sources of error (explain random or systematic), and assumptions*].

[*Discuss any strange data and how you dealt with it*]

[*Answer any other questions from the handout*]

[*Discuss whether your results support or refute the data from the Hipparcos satellite*]

[*Briefly recap your main finding(s) and why they are important/significant*]