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LHS252: Measuring Distance to High Proper Motion Stars

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ABSTRACT

Finding distances in space requires extremely accurate measurements. We present the method used to calculate the distance to star LHS252, a M-class star in the outer banks of the Milky Way Galaxy. Using triangulation, creating imaginary triangles to employ geometry given certain lengths and angles, we determine that LHS252 is 28.94 parsecs away. It's parallax angle from Earth is 0.0345 arc seconds.

1. INTRODUCTION

It is important to understand the methods of calculating distance to celestial bodies, besides our Sun, so that astronomers can make inferences about the observed body's properties of true size, energy, luminosity, and apparent brightness. While we may have the apparent magnitude of stars, the flux of energy viewed by the observer, in order to calculate the absolute magnitude and luminosity, finding the most accurate distance is necessary. Besides triangulation, employing the use of parallax angles, there exist other methods of calculating distance that are more appropriate for approximating distances not believed to be in our galaxy. Within our solar system, radar or sonar direct imaging is very efficient, and the standard candles method is ideal for far away stars whose neighbors' light magnitudes are known **?**. Although there exist more methods of calculating distance, in this paper we will focus on the use of parallax.

Triangulation takes into account the apparent displacement of a celestial body to create triangles from the observer's different points of view. The best way to measure parallax angles is by making observations from two perspectives with the maximum possible distance between them. On Earth, the maximum distance attainable to view stars are at opposite points in the Earth's orbit about the Sun. Even then, with a distance of about one Astronomical Unit (AU) away from the Sun, the angle measured to the star being observed is minuscule. Additionally, one must take into account the perspective of the ecliptic plane, plane of Earth's orbit about the Sun, its ecliptic coordinates, the varying distances between the Earth and the Sun, and the proper motion of the star. Proper motion is the apparent motion of a body from the point of view of the observer, measured in angle per year and also known as angular velocity.

Due to the vast implications of calculating distances to stars, we must verify our data and processes are reliable. In section 2, we describe the data we collected: from where, when, and how each bit is used. In section 3, we analyze the data collected to actually make use of it, creating models and graphics to display our steps. Finally, in section 4, we explain the results and our interpretation of the results.

2. DATA

LHS252 was observed from the Palomar Transient Factory (PTF) on 51 separate dates ranging from March 2009 to March 2017, at each observation noting the right ascension and declination. Right ascension (R.A.) and declination (Dec.) are the coordinates used to describe a location on the celestial sphere. We plot these 51 observed coordinates to view the star's progression across the sky, resulting in Figure 1. Note that the data is not plotted in a straight line; this is most likely caused by infrequent observation times. In other words, there is more time in between some observations than others. Ideally, the distance in time between observations should be the same; however the data should not be greatly affected.

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3. ANALYSIS

Now, we must show the residual motion in R.A. and Dec.; removing the proper motion in each coordinate. To make things simpler, we save the star's information in a python dictionary containing: name, epoch of observation, R.A., Dec., proper motion for R.A., and proper motion for Dec. and create a function to predict the position of the star at a specified time (epoch). After predicting the position of the star, we find the angular separation between the prediction and the actual observation. Finally, we graph the R.A. residual and Dec. residual versus time, as shown in Figures 3 and 2, respectively.

Since parallax is a measure of angular change, it is important to calculate the R.A. and Dec. factors to create a location. In doing this, we must also account for the rise and run over the ecliptic plane, not just the mere trigonometry. The resultant R.A. and Dec. parallax factors should be of the form:

$$F_\alpha = R\sin(A-\alpha)\cos D$$

$$F_\delta = R[\sin D\cos\delta - \cos D\sin\delta\cos(A-\alpha)]$$

such that...

- F_α is the R.A. Parallax Factor
- F_δ is the Dec. Parallax Factor
- R is the current distance from the Earth and the Sun
- A is the R.A. of the Sun
- D is the Dec. of the Sun
- α is the R.A. equatorial coordinate
- δ is the Dec. equatorial coordinate

The star's elliptic motion is shown in Figure 4.

Using the least-squares fitting method, we now find the best-fit parameters. These parameters include the parallax angle, proper motion in R.A, proper motion in Dec., and the coefficients for both R.A. and Dec.... they all equal one. After creating the functions to create the Y and X matrix, we can use the equation:

$$p = [X^T * X]^{-1} * [X^T * Y]$$

to solve for

$$Y = Xp$$

As one may notice we first need to multiply by the transpose of X since X and Y are not of the same dimensions.

Now we must use the solved parameters to create an R.A. and Dec. model using the respective equations: $\delta = \mu_\delta t + \delta_0$ $\alpha = \mu_\alpha t + \alpha_0$ such that t is the specified time variable.

The output of these model values produce the Figure 5.

4. CONCLUSIONS

We present observed data from the Palomar Transient Factory and use it to practice predicting where the star LHS252 will be. LHS252 is a high proper motion body with a parallax angle of 0.0345 arc seconds. As demonstrated in the analysis, we replicated the steps an astronomer would to calculate he distance to a relatively nearby star using parallax angles and the method of triangulation. To replicate this process for other stars is fairly simple if provided with the data. The next step is to learn how to use other methods computationally to calculate distance to an even farther celestial body.

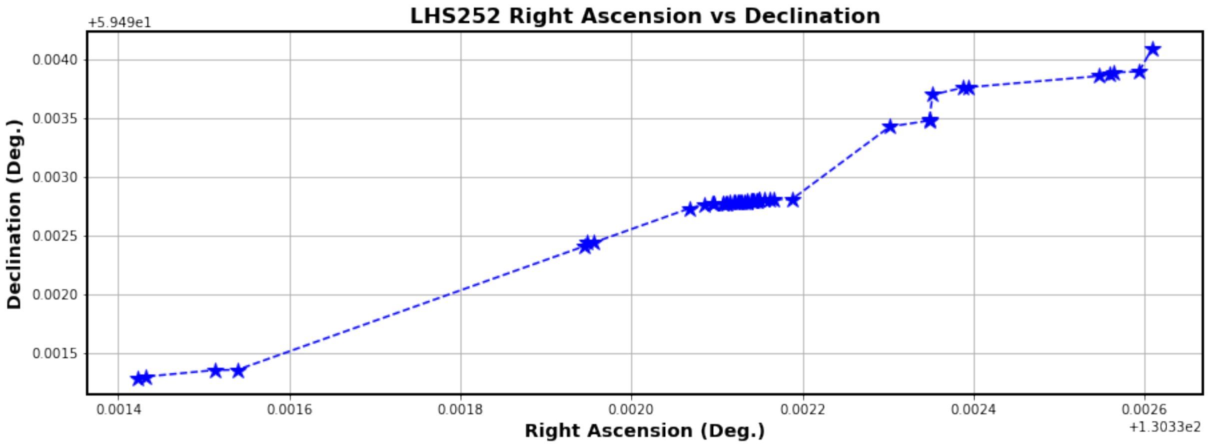

Figure 1. Initial plot of LHS252's motion.

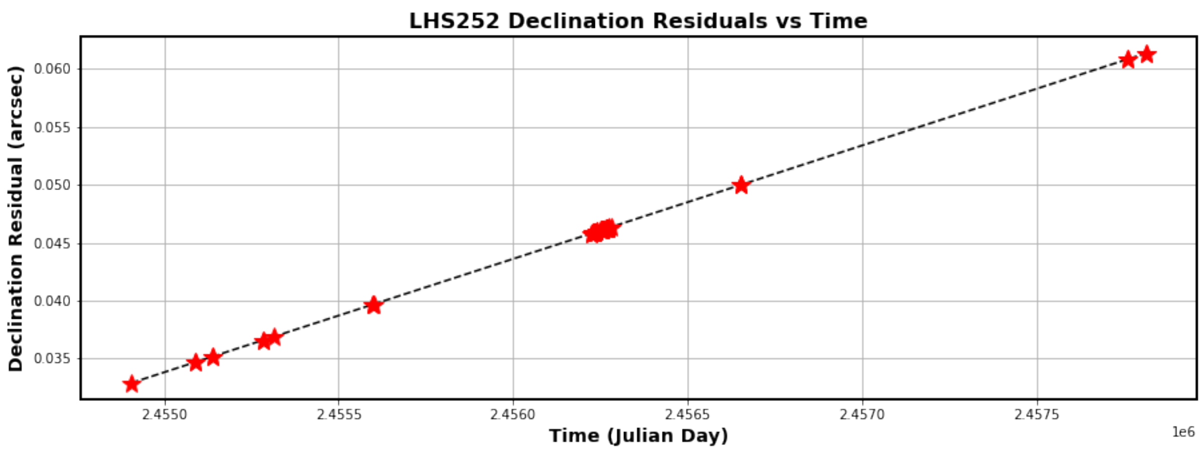

Figure 2. Plot of LHS252's Declination Residuals vs. Time

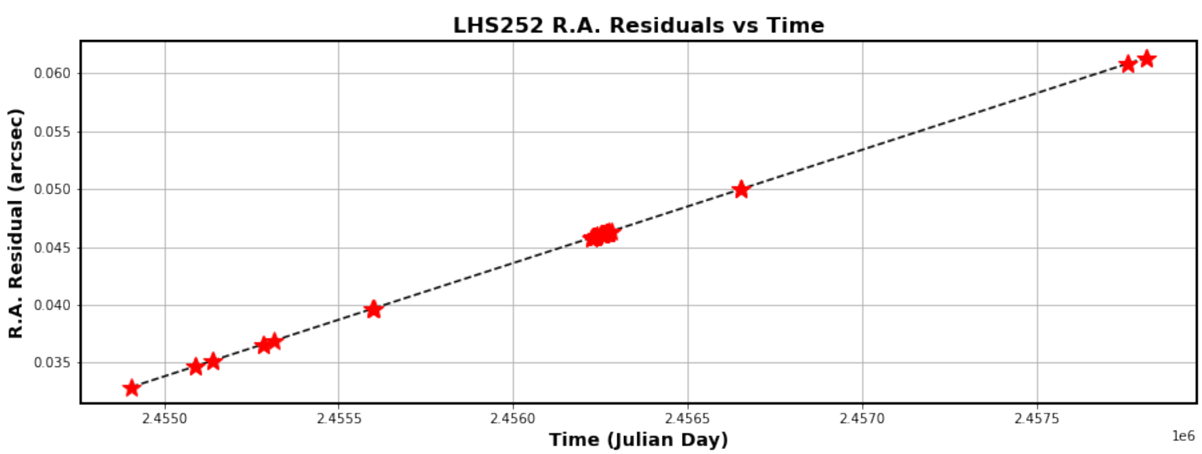

Figure 3. Plot of LHS252's Right Ascension Residuals vs. Time

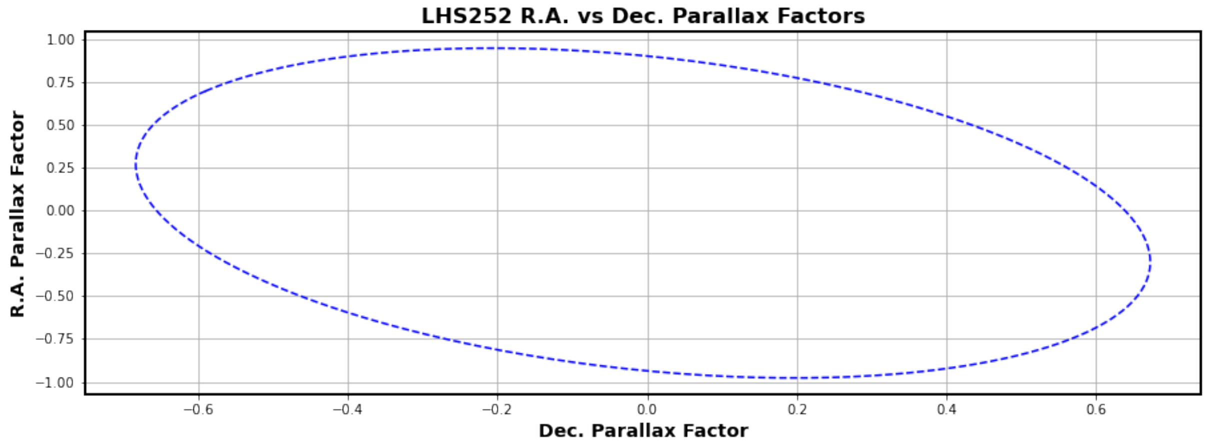

Figure 4. Plot of LHS252's Right Ascension vs. Declination Parallax Factors

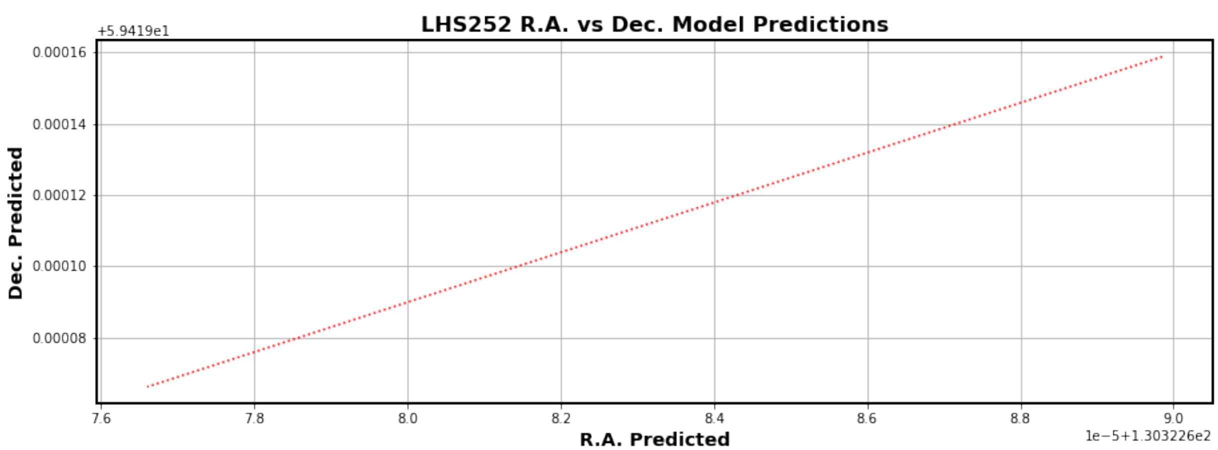

Figure 5. Plot of LHS252's Model Predictions