Lab Report

Measuring the Proper Motion of LHS 352

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PRA2023 - Astronomical Observing Techniques

May 11, 2023

1 Objective

In this experiment, the goal is to learn how to use a network of telescopes (iTelescope.net) and standard astronomy software (Topcat, AstroImageJ, Cartes du Ciel) together to study the characteristics of a star. First targets are found by filtering an astronomical catalogue. Then the telescope is programmed to observe and the outputs are analyzed and compared to earlier observations from prior surveys (POSSI and POSSII) to estimate the proper motion and position angle of the chosen target. Lastly the experimental results can be compared to accepted results from the initial catalogue.

2 Procedure

The procedure for this lab involved many steps: A target was found by filtering the Luyten Half-Second catalogue (LHS); Cartes du Ciel was used to understand where the target was best visible from on Earth; the appropriate telescope was found and programmed to perform the observation; the results were measured in AstroImageJ; the measurements were finally analyzed in a python script. (Note: by convention all equatorial coordinates are given in J2000)

2.1 LHS Catalogue Filtering

The revised Luyten Half-Second catalogue includes 22 features of 4470 observations (Bakos, Sahu, and Nemeth 2002). To pick a target, the catalogue was filtered to only include observations brighter than the 12th magnitude, those that were visible at night and with a proper motion greater than $1 arcmin/year$. The Topcat software allowed us to reduce the catalogue to a total of 37 possible target visible from the Siding Spring Observatory in Australia. This observatory was chosen for its timezone, because while we were setting up the experiment, the sun was beginning to set for that observatory. The target visible from this telescope were estimated using its coordinates 31° 16' 24" S and 149° 03' 52" E. Meaning for this time of year (mid April 2023) the visible declinations were be in the range -90° to 30° and the visible right ascensions were be between 120° and 240°. The target LHS 352 was chosen as it met all of these criteria and was not too bright. Furthermore this star had observations from both POSSI and POSSII surveys on the The STScI Digitized Sky Survey, meaning this would yield better accuracy in the analysis.

2.2 Cartes du Ciel

Cartes du Ciel, also referred to as Skychart, allowed us to visualize the target in the Siding Observatory sky and to learn about some of its characteristics. The most important one for our purposes is its transit. According to this chart, LHS 352 transited at 23h37m23s +48°29' on the 22nd of April when the measurement was taken. This guaranteed that the target would indeed be visible from the chosen telescope which had a minimum target elevation of 35° North.

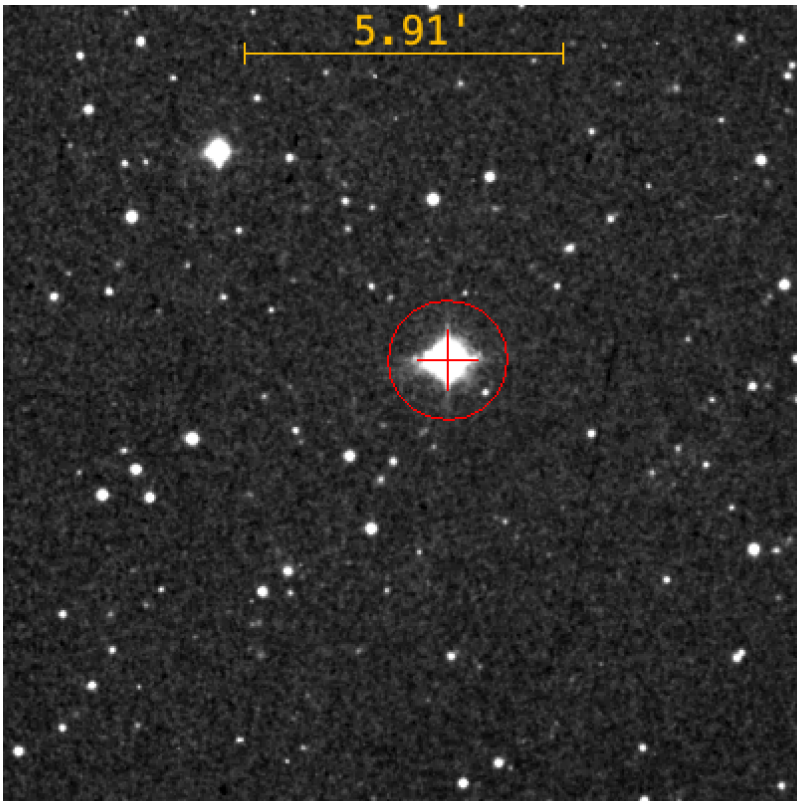

Figure 1: Observation of LHS 352 from POSSI survey.

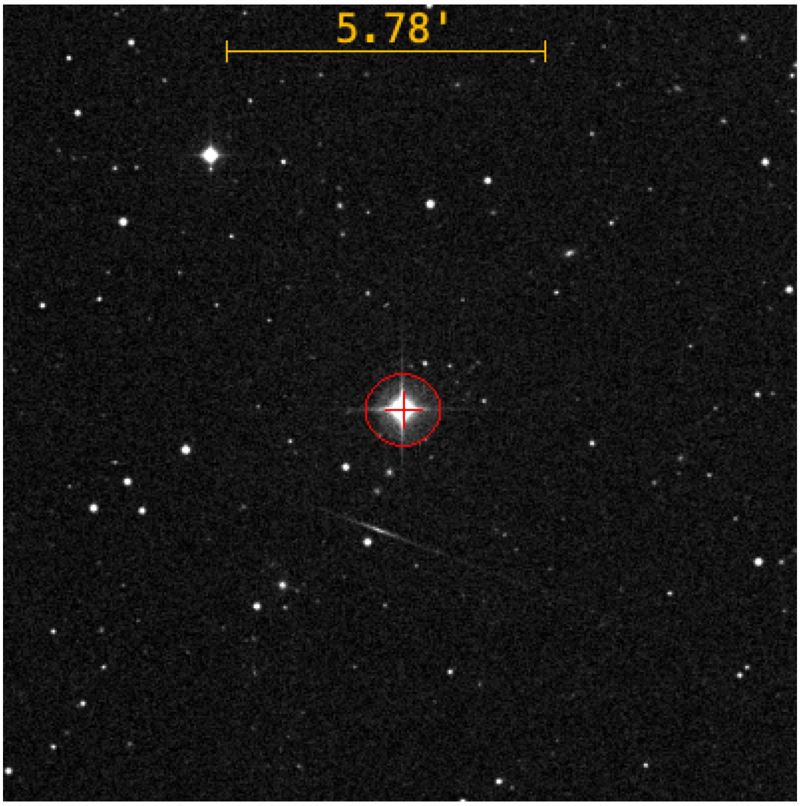

Figure 2: Observation of LHS 352 from POSSII survey.

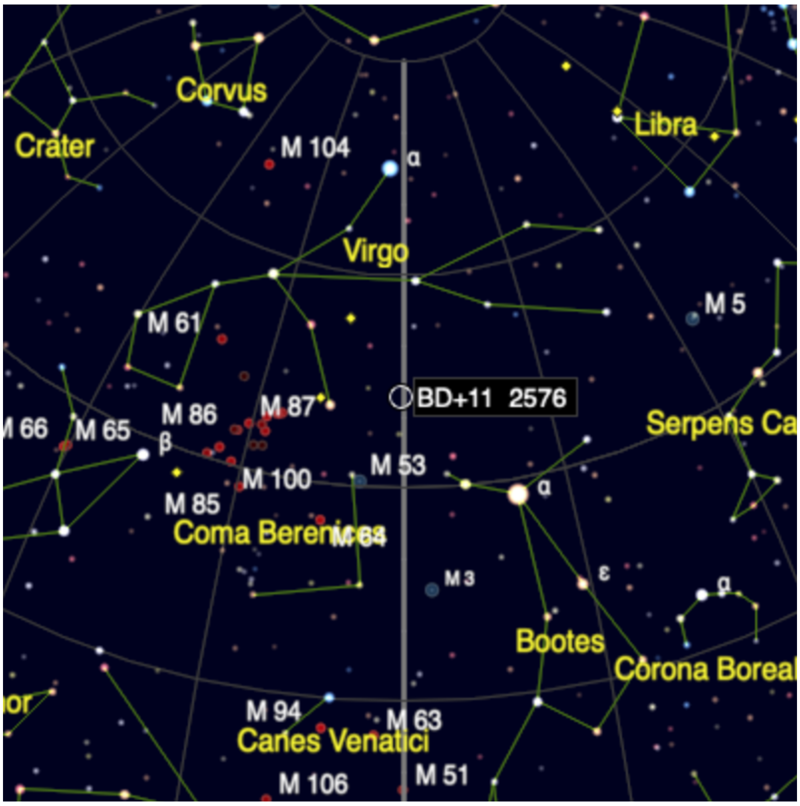

Figure 3: LHS 352 (BD+11 2576) in the Asutralian sky on Cartes du Ciel at time of observation.

Location Information

Observatory: iTelescope.Net at Siding Spring Observatory Australia - MPC Q62
Telescope: 0.43-m f/6.8 reflector + CCD
Timezone: UTC +10:00 New South Wales, Australia Daylight savings time is observed.
Minimum Target Elevation: Approx 35° EAST & NORTH, 45° WEST, 35° SOUTH

South 31° 16' 24" **East** 149° 03' 52"
Elevation: 1122m **MPC** Code Q62

Figure 4: Technical Information of T32 Telescope

Target	Red Exp.	Blue Exp.	Green Exp.	Lum. Exp.	RA	DEC
LHS 352	60s	60s	60s	60s	13:29:59.85	10:22:38.1
LHS 344	60s	60s	60s	60s	13:04:57.38	-52:26:36.7

Table 1: Plan given to telescope T32

2.3 T32 Telescope Programming

Since the minimum observing time allowed on the iTelescope network is 15 minutes, we decided to group up and plan two observations in the same plan. The plan thus included instructions to observe LHS 352 during transit and LHS 344 also during transit. We paired up according to which targets would be visible from the same locations and whose transit were close together. To select the telescope, some parameters had to be carefully identified. Since LHS 352 transits at a Zenith of around 50°, the minimum target elevation had to be below 50°; LHS 344 on the other hand had a Zenith 68° which was less of a constraint. Ultimately the telescope T32 was chosen for its specifications (see figure XXX) and because it was free in the next day to perform the observation. Table 1 shows the plan given to the telescope.

3 Data

The data collected by the telescope T32 consists of 4 fit files of the red, green, blue, and luminance channels over 60 seconds each. The field of view of the image is 43.2 x 43.2 arcmin with a resolution of 4096 x 4096 pixels. Figure 5 shows the red channel fit files processed through AstroImageJ, all fit files are available on GitHub. More specifications of the scope are available in figure 6.

Figures 1 and 2 show LHS 352 in the red channel from POSSI and POSSII respectively. Only the red channels were available on the Digitized Sky Survey, thus for a more accurate comparison, the red channel from the T32 telescope was used for analysis.

Table 2 shows a collection of essential data for further analysis, including the exact date and location where the measurements were taken, and the location of the target on the celestial sphere.

Table 3 shows the data collected using AstroImageJ from the POSSI and POSSII surveys as well as from the image collected for this lab from the T32 scope. The table contains only the relevant information for the upcoming analysis, namely the image source, the time of

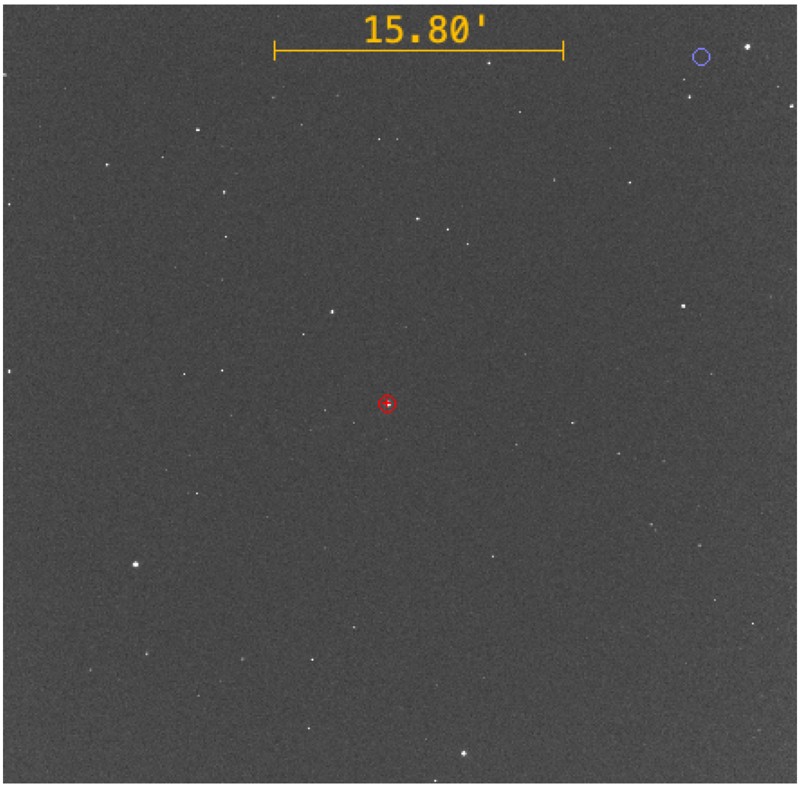

Figure 5: Red channel observation of LHS 352 with T32 telescope.

Instrument Package

CCD: **Moravian G4 16000**
QE: 60% Peak
Gain: 1.6 e-/ADU
Full Well: ~100,000 e- (ABG)
Dark Current: ~0.05 e-/pixel/sec. @ -15° C
Pixel Size: 9um Square
Resolution: 0.63 arcsec/pixel
Sensor: KAF-16803
Cooling: -15° C default
Array: 4096 x 4096 pixels
FOV: 43.2 x 43.2 arcmin
Filters:
Astrodon E-Series Luminance Red, Green, Blue
Astrodon 5nm Ha, SII, OIII
Astrodon Johnson/Couisins V, Ic
Position Angle: 90°

Figure 6: Specifications of the T32 instrument. See more on iTelescope

Date	Latitude	Longitude	RA	DEC
21/04/2023	31° 16' 24" S	149° 03' 52"E	13:29:59.85	10:22:38.1

Table 2: Coordinates of observations and target.

Label	J.D.-2400000	RA	DEC
POSSI	35242.703067	13.498984	10.390593
POSSII	50550.878877	13.499870	10.378123
T32	60057.074424	13.500420	10.370666

Table 3: Data collected from all 3 images of LHS 352 for analysis.

	POSSI	POSSII	T32
POSSI	–	0.0180°	0.0290°
POSSII	0.0180°	–	0.0110°
T32	0.0290°	0.0110°	–

Table 4: Angular separation between each pair of observations

the observation in Julian Days -2400000 and the measured RA and DEC of LHS 352.

The RA and DEC coordinates for the POSSI and POSSII images, which came from the Digitized Sky Survey, were already plate solved. However, the image taken with the T32 was not. Thus, plate solving was done in AstroImageJ with a key from nova.astrometry.net.

4 Analysis

4.1 Angular Separation

The first step to calculate the Proper Motion of LHS 352, is calculating the angular separation between LHS 352 in two images separated in time. The angular separation d between two points in the sky with equatorial coordinates $(\alpha_1, \delta_1)$and(α_2, δ_2) represents the angle at the origin between them and is given by the expression:

$$cos d = sin\delta_1 sin\delta_2 + cos\delta_1 cos\delta_2 cos(\alpha_1 - \alpha_2) \tag{1}$$

where $(\alpha_1, \delta_1)$and(α_2, δ_2) are given in decimal degrees. However, for $d \approx 0°$or$d \approx 180°$, the following expression yields more accurate results:

$$d = \sqrt{cos^2\delta \cdot \Delta\alpha^2 + \Delta\delta^2} \tag{2}$$

For the sake of repetition and homogeneity, a short function was written in python to calculate the angular separation d in decimal degrees from a pair of equatorial coordinates using equation 2. See the GitHub repository for more details. The angular separation between each pair of observation is recorded in table 4. Each angle can then be divided by the difference in time between each observation to get the proper motion.

4.2 Proper Motion

The proper motion (oftentimes denoted μ of an object, in our case LHS 352, is the apparent angular motion of a star across the sky with respect to more distant stars (Pogge 2006). In effect, it represents the angular separation per unit time $\mu = \frac{d}{\Delta t}$ where d is the angular separation calculated above and Δt is the difference in time. For the sake of convention, d is

	POSSI	POSSII	T32
POSSI	–	1.551	1.541
POSSII	1.551	–	1.524
T32	1.541	1.524	–

Table 5: Proper motion between each pair of observations (in arcsec/year)

	POSSI	POSSII	T32
POSSI	–	175.93°	175.87°
POSSII	175.93°	–	175.78°
T32	175.87°	175.78°	–

Table 6: Position angle between each pair of observations

multiplied by 3600 to get the result in arcsec. Similarly to the angular separation calculation, a python function was defined and used to calculate the proper motion from each pair of observations. The time between each images was calculated by taking the difference in Julian Days from table 3, and converting them to Julian Years by dividing by 365.25. Table 5 shows the proper motion estimated from each pair of measurements in arcsec/year. The average of all three measurements yields: 1.538 arcsec/year.

4.3 Position Angle

The last metric of interest in this lab is the position angle of LHS 352. The position angle of an object in the sky is the angle between the Celestial North Pole and the imaginary line of motion through the East. This can be easily measured using the equatorial coordinate system. It only takes two points to calculate the position angle. For two set of coordinates $(\alpha_1, \delta_1)$and(α_2, δ_2), the position angle θ is derived using:

$$\theta = 180° - atan\frac{\Delta\alpha}{\Delta\delta} \tag{3}$$

Table 6 shows the position angle from each pair of observations. The average of all three pairs of measurements is 175.86°. Finally the angle can be visually verified by looking at the scatter plot of the three observations in figure 7. The motion of LHS 352 seems to be mainly North to South with a slight shift towards the equatorial East.

5 Conclusion

In conclusion, thanks to the iTelescope network and the abundant astronomical software, we estimated the proper motion and position angle of LHS 352. The accuracy of these results are yet to be investigated. Thankfully, the results from this lab can be compared to the data in the Revised LHS catalogue. In the LHS catalogue, LHS 352 is recorded having a proper motion of 1.525 arcsec/year, which results in a 0.85 percent error. However, its position angle is recorded as 134.2° which yields a 31 percent error.

Overall, the proper motion was successfully estimated using the described methods with a very low percent error. Yet the position angle measurement is off by over 30 percent.

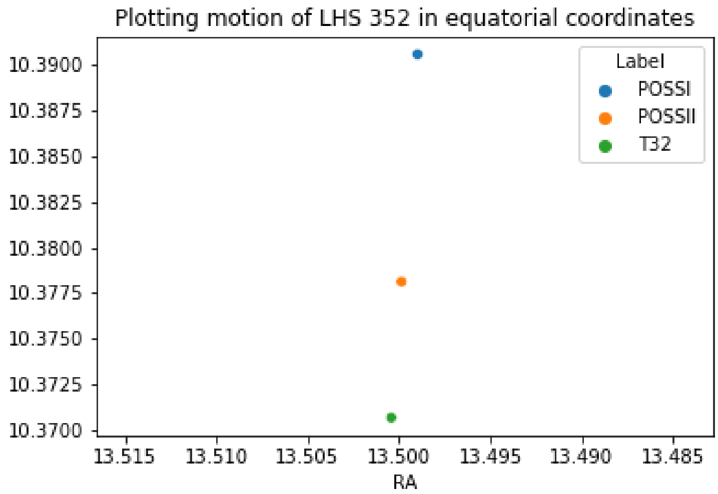

Figure 7: Scatter plot of LHS 352 positions from POSSI, POSSII and T32 observations.

The explanation for this is not evident; originally it was hypothesised that the equation to calculate θ was wrong, but using the position angle function from the AstroPy package gave similar results. Moreover, figure 7 clearly shows, in an orthonormal set of axes, that the angle of motion is close to vertical, i.e 180°.

Ultimately, the objective of becoming familiar with astrometry and the relevant software was accomplished, albeit with some errors. The concepts of equatorial coordinates, proper motion and position angle were used to quantify the accuracy of measurements done using remote telescope observation.

References

Bakos, Gaspar A., Kailash C. Sahu, and Peter Nemeth (July 2002). "Revised Coordinates and Proper Motions of the Stars in the Luyten Half-Second Catalog". In: *The Astrophysical Journal Supplement Series* 141, pp. 187–193. DOI: 10.1086/340115. (Visited on 02/17/2023).

Pogge, Richard (Jan. 2006). *Lecture 6: Motions of the Stars*. www.astronomy.ohio-state.edu. URL: https://www.astronomy.ohio-state.edu/pogge.1/Ast162/Unit1/motions.html.