
Report 1

MITA TEMBE

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I. INTRODUCTION

Telescopes are the most integral tool for the astronomer. This lab explores this tool and the techniques used by astronomers in order to conduct observations of the sky. Central to these techniques is an understanding of the layout of the sky, as laid out by the celestial sphere. The main purpose of this lab was to gain a working familiarity with the system of right ascension and declination, and to obtain skills in positioning an equatorial mount telescope using this system.

All of the following observations were conducted on the evening of January 20, 2014, between 7 and 10 pm (MJD 56678.5 to 56678.625), with a completely clear sky.

II. METHODS AND OBSERVATIONS

The first part of the lab was to conduct a nominal measurement of the objective diameter of the Clark 6" telescope, to determine if it matched the advertised value. A tape measure was used to first measure the outer diameter of the telescope, then used to measure the width of the inner lip supporting the lens. By subtracting twice this width, the objective diameter was determined to be $5\frac{15}{16} \pm \frac{1}{16}$ inches.

Next, the focal length of the telescope was roughly measured by using the tape measure to determine the distance between the objective lens and the eyepiece. This was measured as $86\frac{3}{4} \pm \frac{1}{16}$ inches.

The next task was to catalog the focal lengths of all the available eyepieces for the 6" telescope, as below. The following relationship was used to determine the magnification furnished by each piece, where f_t is the telescope's focal length, as measured above, and f_e is the focal length of the eyepiece:

$$m = \frac{f_t}{f_e} \quad (1)$$

Table 1: *Eyepiece Focal Lengths*

Focal Length (mm)	Magnification
40	55.09
32	68.86
26	84.75
15	146.90
12.5	176.28
12.4	177.70
9.7	227.16
6.4	344.29

As can be seen in Table 1, as the focal length of the eyepiece decreases, the magnification of the telescope increases.

The next task was to find the present latitude by measuring the declination of the telescope. First, the telescope was set in right ascension by hand so it lined up with the Meridian. Each member of the group leveled the telescope using a level and then reported the declination from the declination wheel, as in Table 2.

Table 2: *Measurement of Declination*

Trial	Person A	B	C	D
1	50°20'	50°10'	50°40'	50°20'
2	50°10'	50°30'	50°10'	50°10'
3	50°10'	50°10'	50°20'	50°20'

The error on these measurements was $\pm 1^\circ$. The average of these measurements was $50^\circ 17' \pm 9'$. Overall, it seemed that were no individuals who were significantly biased. The following relation was used to determine the latitude of McCormick Observatory:

$$lat = 90^\circ - \delta \quad (2)$$

From this relation, the latitude was experimentally determined as $39^\circ 42'$, close to the actual value of $38^\circ 2'$.

Next, the polar axis of the telescope was identified. As the Clark 6" telescope is an equatorial-mount telescope, the polar axis, by definition, points towards the North Star and parallel to the earth's rotation axis.

Next, the declination of the telescope was set to 0 and clamped. The telescope was swung in right ascension to trace the celestial equator across the sky. East was in the direction of the main dome and west was in the opposite direction. Then the declination was set to -23.5° and the telescope was swung in the same way to trace the sun's winter path through the sky. It was extremely low. By setting the declination to 23.5° , the sun's summer path was traced, which was much higher, as observed in these seasons.

Next, a method of roughly locating a star was tested. Using the 40 mm eyepiece, the edge of the telescope was visually lined up with the star Rigel. It was in fact possible to see the star in both the main eyepiece and finder using this approximate method.

Another method of finding a star was tested. First, the hour angle/right ascension dial was set to read hour angle, so that the dial read 0 when the telescope was on the meridian. The telescope was set to the declination of Betelgeuse, $05:55:10.3$. The current sidereal time was recorded as $03:48$. The following equation provided Betelgeuse's hour angle:

$$HA = LST - RA \quad (3)$$

The hour angle of Betelgeuse was calculated as $-02:07$, the negative hour angle indicating that the star had not yet crossed the meridian. By pointing the telescope to this hour angle, it was possible to see Betelgeuse through the telescope.

The following section of the lab was a short experiment to determine the relationship between eyepiece focal length and field of view.

The telescope was centered on Betelgeuse and clamped in declination. The telescope was swung in right ascension so Betelgeuse was at the eastern edge of the field of view (right side). The clock drive was turned off, and the time for the star to transit the field of view was recorded. These measurements were performed by each group member three times, as can be seen in Table 3.

Table 3: Measurement of Field of View I

Trial	Person A (s)	B (s)	C (s)	D (s)
1	2:27	2:16	2:12	2:16
2	2:45	1:51	2:14	2:42
3	2:09	2:24	2:23	2:43

The error in these times and those below was ± 2 s. The average of these measurements was $2:24 \pm 00:16$. The following relation was used to convert these transit times into field of view estimates in arcseconds:

$$FOV = 15 \cdot t \cos(\delta) \quad (4)$$

Here, the factor of 15 represents the 15 arcseconds that passes by per second of time due to earth's rotation, and the factor of cosine of the declination takes into account the distance from the equator. By this relationship, the field of view of the 40 mm eyepiece on the 6" telescope is $2142''$.

This same procedure was repeated, now with four different, higher power eyepieces. Each member measured the field of view of a different eyepiece three times, the results of which are in Table 4.

Table 4: Measurement of Field of View II

Trial	6.4 mm	15 mm	12.4 mm	9.7 mm
Person	A (s)	B (s)	C (s)	D (s)
1	15	39	42	30
2	16	36	30	36
3	15	44	23	34
Average	15.3	39.7	31.7	33.3
FOV (")	228	590	471	496

Possible sources of error in this measurement, for example the discrepancies of Person C's times, likely were inconsistencies in lining up the star with the edge of the field of view, and keeping the eye in the same position for the duration of the measurement. The relationship between the focal length of the eyepiece and the field of view in arcseconds is plotted in Figure 1. Overall, there seems to be a linear trend: the longer the focal length, the greater the field of view.

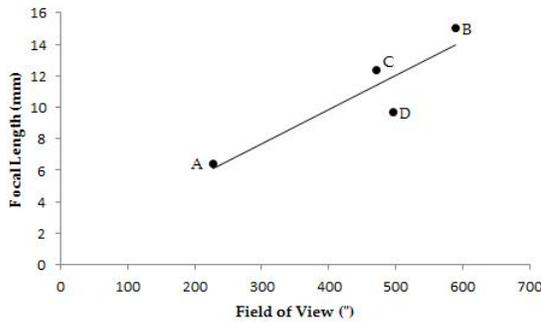


Figure 1: Focal length of the eyepiece vs. field of view in arcseconds

The preceding method of measuring the field of view can be tedious for a large field of view, for example, for the finder telescope. Another method is described below. Again using the 40 mm eyepiece, Betelgeuse was once more centered in the finder. Then the telescope was moved in only declination until Betelgeuse was at one edge of the field of view; here, the declination was measured as approximately 7° . Then the telescope was moved so Betelgeuse was on the other edge of the field of view, where the declination was measured as 11° . The difference between these two measurements is a value for the field of view for the finder telescope, 4° .

The next portion of the lab involved using the declination and right ascension of the stars Betelgeuse, Bellatrix, Rigel, and Saiph, of the constellation Orion. This method was relatively unsuccessful, mainly because reading the right ascension and declination wheels was difficult. Setting the direction of the wheel correctly was

the main issue with this part of the lab.

The final part of the lab concentrated on observing Jupiter. The telescope was pointed to the planet by eye, rather than using its coordinates. The following sketch was made of its moons in relation to the planet.

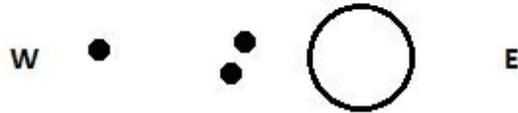


Figure 2: Sketch of Jupiter's moons as seen through the telescope

Later, the program XEphem was used to verify the observed positions of Jupiter's moons. An image from XEphem can be seen below in Figure 4. In this image, Io is I, Europa is II, Ganymede is III, and Callisto is IV. Europa, Ganymede, and Callisto were visible on the night of observation, while Io was obscured by Jupiter.

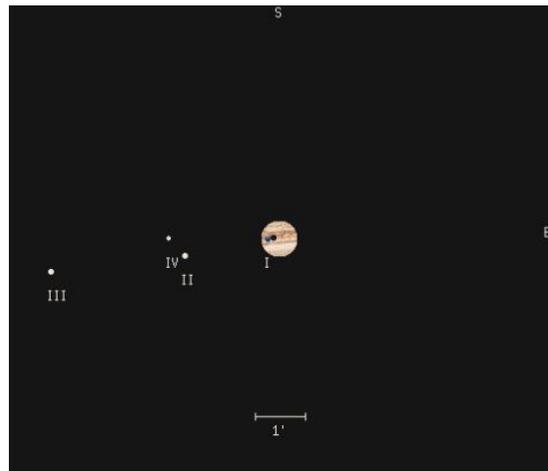


Figure 3: XEphem image of Jupiter's moons on January 20th

Using XEphem, the distance to Jupiter at the time of observation was determined as 4.253 AU (D). The physical radius of

Ganymede is 2631 km (R). The following relation was used to determine the angular size of Ganymede:

$$\theta = 2\tan^{-1}\left(\frac{R}{D}\right) \quad (5)$$

The angular size of Ganymede was calculated as $4.74 \times 10^{-4}^\circ$.

III. CONCLUSIONS

This lab resulted in greater familiarity with telescope operation and the celestial coordinate system. By conducting several measurements and using different astronomical concepts, a better understanding of the night sky was developed. Overall, the lab was successfully executed. The only portion of this lab that was confusing was the location of the stars in Orion. This likely resulted from a misunderstanding of how the right ascension and declination dials worked, and how to set these to measure the correct values. A small source of error for the entire lab may have been the capability of the telescope to move a small amount in right ascension and declination, even when it was clamped.

REFERENCES

- [1] *Ganymede: Facts and figures*. (2013, August 12). Retrieved from http://solarsystem.nasa.gov/planets/profile.cfm?Object=Jup_Ganymede&Display=Facts.

IV. APPENDIX I

Scans of hand-written lab pages.