University of Waterloo

PHYS270L

The Eccentricity of the Moon

Experiment #4

Authors:
William Ngana
20533462

Waterloo, ON

Date Performed: March 19, 2018 - March 22, 2018
Date Submitted: April 1, 2018

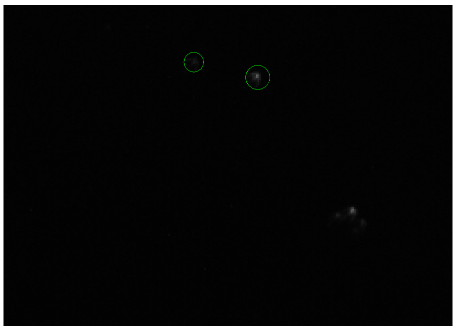
1 Purpose

The purpose of this experiment was to determine the radius and the Eccentricity of the Moon based on images captured from a telescope.

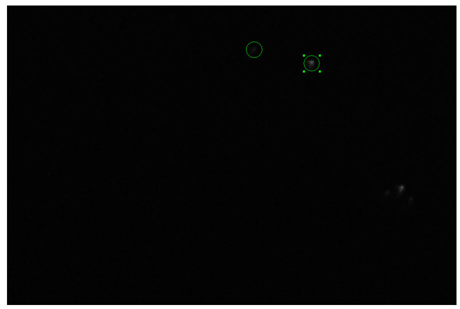
2 Experimental Results and Analysis

2.1 Part B: Data reduction

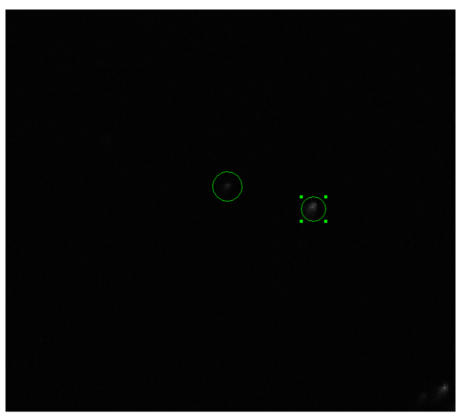
In this part of the lab we are calibrating the images so that we can accurately determine the radius later on. For this we look a the position of stars in the calibration pictures that were taken on the day. The reference stars that i am looking at are going to be the double star separated by 52.5 arcseconds.



(a) March 19



(b) March 20



(c) March 22

Figure 1: Calibration plots for each of the days

From this using DS9 we were able to determine the x separation and the y separation for each Day and using this we can determine the plate scale of the telescope which will have unites of arsecs per pixel. using this we can determine the plate scale of the telescope which will hae unites of arsecs per pixel.

Day of year	Δ x	Plate Scale (arcsec/pixel)
March 22 2018	35	1.5
March 19 2018	35.75	1.47
March 20 2018	34.25	1.53

Table 1: table of the separation of each on each day

2.2 Part C: Data Analysis

2.2.1 Apparent size of the Moon

This portion of the lab we used the images that we captured to try an determine the apparent size of the moon. This was done by using the DS9 software to open the .fit files that we got from the observing portion of the lab. Then we found the edges of the moon and recorded the X and Y values. The lab manual suggested that we plot 7 points at least, for my graph I plotted 15 points who's X and Y values are below.

X (±15)	Y (±15)
780	104
817	115
847	125
922	159
988.5	201
1095.5	289
1139	338.5
1174	392
1202.5	437.5
1216.5	465
1236.5	509
1280.5	720
1280.5	773
1278.5	821.5

Table 2: Table of the x and y position of the edge of the moon taken March 22 at 19:57

From this the initial graph that you get is

The next part we needed to guess at what the radius and the x0 and y0 point of the

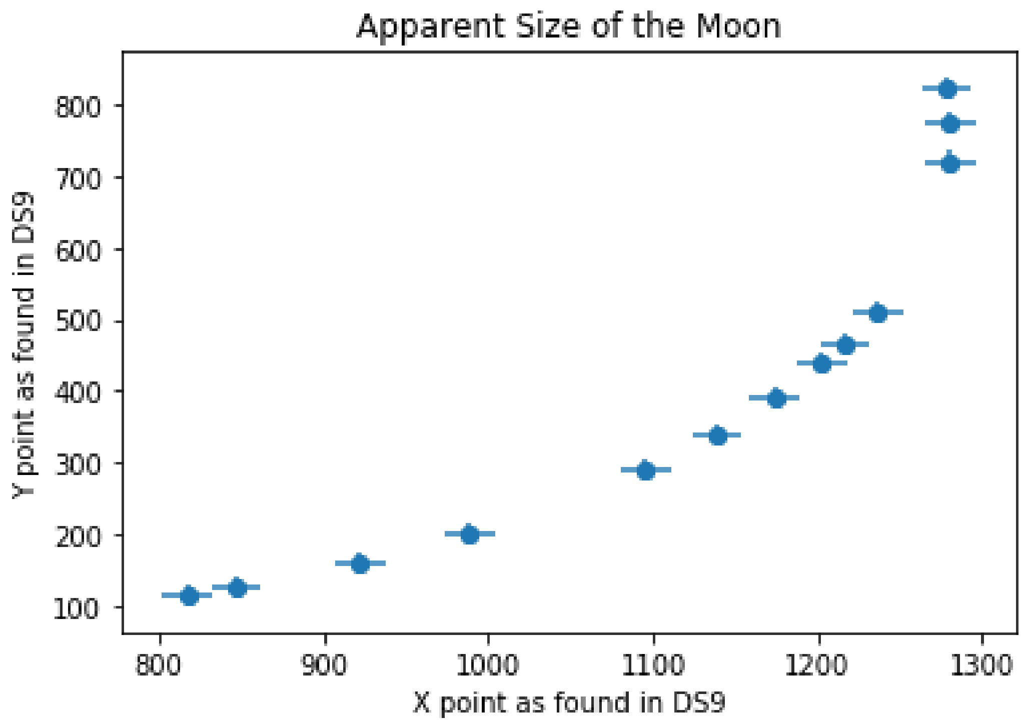


Figure 2: Raw plot of the x an y position the edge of the moon taken March 22 at 19:57

moon would be based on the plot that we had. My initial guesses for them were $x0 = 620$, $y0 = 700$ $r = 600$, and using the parametric equation of a circle which is

$$x = x0 + r\cos(\theta) \tag{1}$$

$$y = y0 + r\sin(\theta) \tag{2}$$

where θ goes from 0 to 360. For this part I wrote a python script that allowed me to plot out the resulting circle on top of the original plot of the points found above.

Next we fine tuned this circle so that the residual

$$\Sigma[(x_i - x_0)^2 + (y_i - y_0)^2 - r^2]^2 \tag{3}$$

is a close to zero as possible. Again for this I wrote a python script using the scipy.optimize.minimize function which allows me to minimize the residual function. The resulting plot is below, with a r,x_0, y_0 values of 670.89394826, 610.60327528, 753.43597485 respectfully.

From there I repeated the same steps for 2 other images taken on different days and tabulated the results.

2.3 Orbit of the Moon

This part of the lab we determine the eccentricity of the orbit of the moon. To do that the first thing that we have to do is calculate the angular position of the Moon for each of the

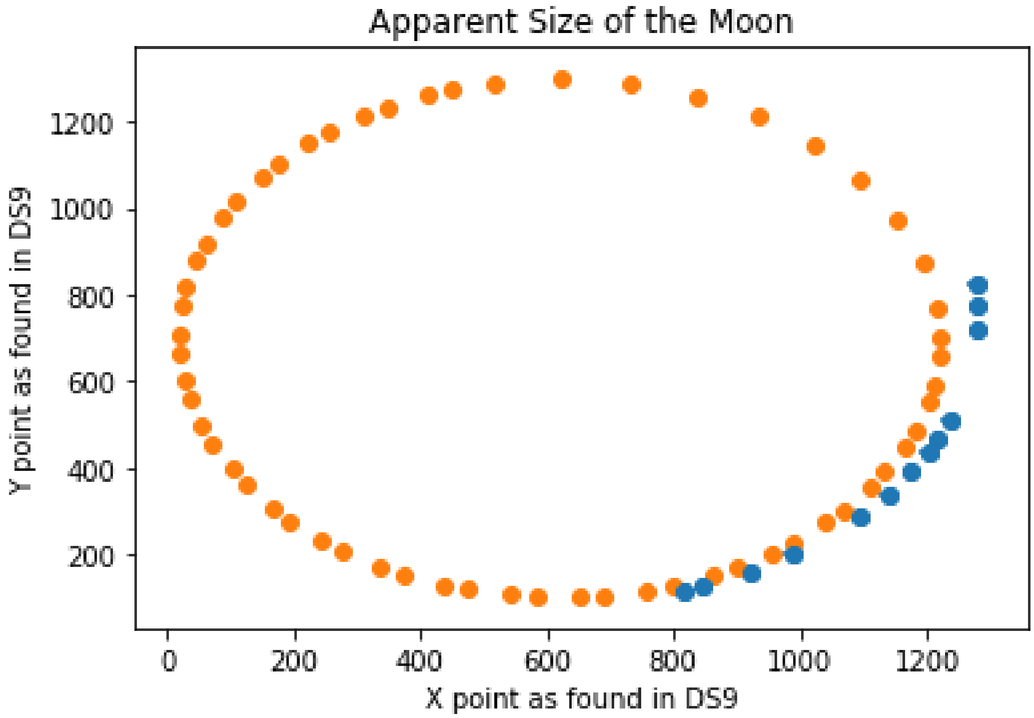


Figure 3: Plot with initial fit

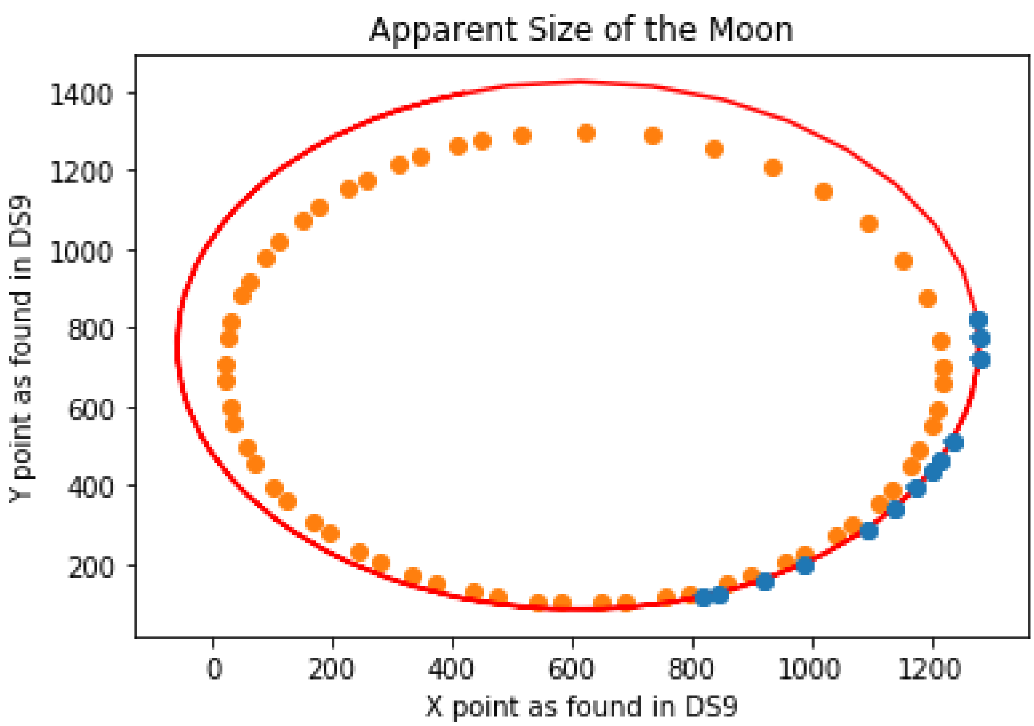
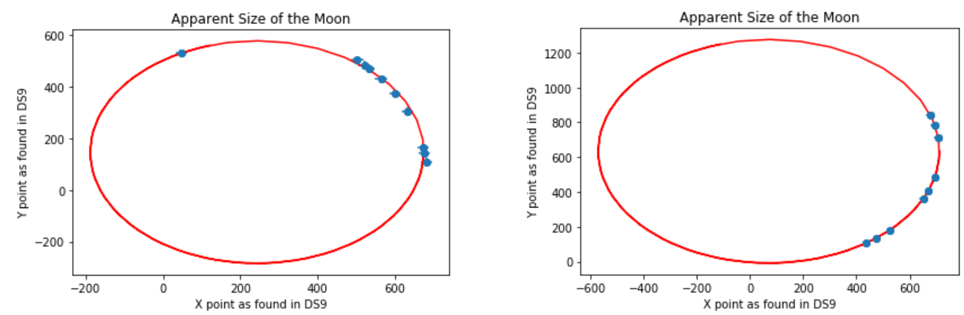


Figure 4: Plot fully optimized with the residual function

Day	radius(± 15)	converted radius (km)
March 22 2018	670.89	1006.335
March 19 2018	413.43	607.11
March 20 2018	642.87	983.59

Table 3: Radius of the moon compiled over 3 days



(a) Optimized for March 19 (b) Optimized for March 20

Figure 5: Optimized plots for other 2 days

images analyzed. This is done by looking at the what fraction of the anomalistic month the data was taken. From the background information we know that the anomalistic month is 27.55 days. And in the time period that we are viewing the moon the perigees are going to be on Feb 27 at 15:00 and Mar 26 at 17:00. That means for the first image Ngana0322 1957 taken on March 22 at 19:57 the fraction would be

$$\frac{23.21}{27.55} = 0.842 \tag{4}$$

Then you multiple it by 360 to get the degrees

$$0.842 * 360 = 303.29 \tag{5}$$

The table below is the result of all the other calculations of angle

Day of year	Day in anomalistic month	angular position(degrees)
March 22 2018	23.21	303.29
March 19 2018	20.22	264.22
March 20 2018	21.24	277.55

Table 4: Table of the angular position of the moon at different days

From that point we had to convert the polar coordinates to Cartesian and plot results then, similar to what was done in the earlier section we fit an ellipses to the points and from that determined what a and b where.

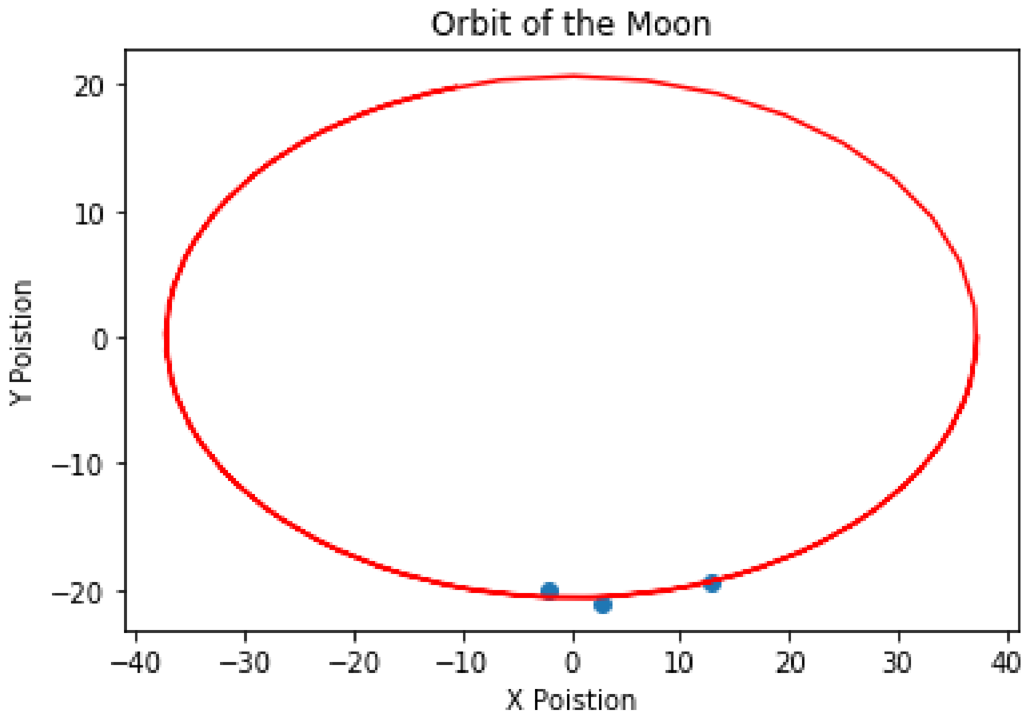


Figure 6: Plot of the orbit of the moon

From this a = 37.295 and b = 20.654. Using the equation

$$e = \sqrt{1 - \frac{b^2}{a^2}} \tag{6}$$

$$e = \sqrt{1 - \frac{(20.654)^2}{(37.395)^2}} = 0.8326 \tag{7}$$

2.4 Questions

3 Conclusion