The study of factors causing inaccuracies in determining the size of the Earth using lunar eclipse photograph

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Abstract

This study aims to calculate the Earth's size through lunar eclipse photographs and explores factors contributing to inaccuracies in calculation. We collected lunar eclipse photographs with various sizes of dark shadow on the moon and clear shadow edges. Then, we found the center of the circle of the Earth's shadow in order to calculate the shadow's radius, employing trigonometry and similar triangles. We found that there are some factors affecting the result accuracy, including differences of the Earth's shadow size and position, and the variations in shadow intensity and color.

Objective

1) To calculate the Earth's radius from lunar eclipse photographs
2) To investigate the factors causing the result's inaccuracy with this method

Method

1) Capture lunar eclipse photos through a telescope with a digital camera, set the real local time at the shooting location. Capture photos that clearly show the Earth's shadow.
2) Select one lunar eclipse photo that clearly shows the Earth's shadow.
3) Open the selected photo in Adobe Photoshop and convert the image into grayscale black and white.
4) Assume that the Earth's shadow is a perfect circle. Then find the center of the Earth's shadow by drawing chords overlapping the Earth's shadow in at least 3 lines. Then draw perpendicular lines at the midpoints of each chord. According to perpendicular line drawing will pass through the center of a circle. Meaning that the intersection of these lines is the center of the Earth's shadow as shown in Fig 1.

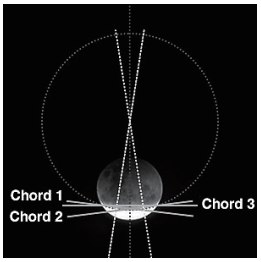

Fig. 1 : shows 2 perpendicular lines drawn from 2 chords at the bottom.

5) Define the edge of the shadow in order to make a circle with respect to the center from the previous step. As the darkest border has color codes ranging between d-c (as show in Table 1). So the first circle, as the reference circle, is created along this border.

#f1f1f1	#e3e3e3	#d2d2d2	#c0c0c0	#b1b1b1
#f8f8f8	#eeeeee	#d9d9d9	#c4c4c5	#b8b8b8

Table 1 : shows some examples of the color codes which the first letters of each code are used to define the edge of the shadow.

6) Then create 4 additional circles that have the same center as step 5. Specify the size of the newly created circles to have diameters greater and smaller than the size of the reference circle from the previous step. Approximately 10 pixels (Px), with the edge of each circle matching in the color code range b-a, c-b, e-d, and f-e respectively. So we get 5 circles with slightly different sizes since the color codes vary.

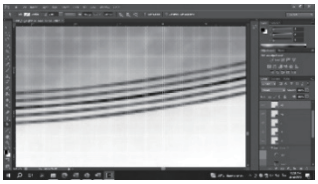

Fig. 2 : shows 5 circles created a long shadow border.

b - a
c - b
d - c
e - d
f - e

Table 2 : Show the color code ranging in each circle.

7) As each circle represents the whole shape of the Earth's shadow. So get the diameter values from the circles as in pixel units, so we get the radii of the Earth's shadow (r).
8) Use r to calculate the actual radius of the Earth (R) from the following equation.

$$tan\left(\frac{\theta}{2}\right) = \frac{R}{d+L} = \frac{r}{L}$$

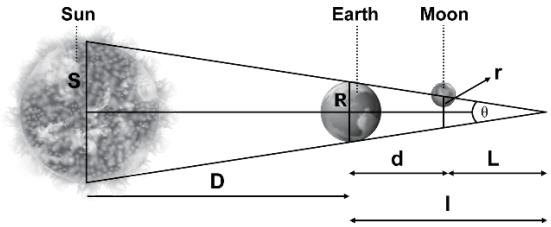

Fig. 3 : shows a diagram of a lunar eclipse.

9) Analyze the data statistically and summarize the results regarding the factors causing deviations in this method.

Conclusion

The calculation of the Earth's size from the lunar eclipse by using the similar triangle method and trigonometry can provide a result that is accurate and close to the actual size of the Earth. The average value of the Earth's radius obtained from this method is 6,328 kilometers which is 0.67% different from the Earth's actual radius. This study has found factors that may contribute to inaccuracies, including the selection of photographs with various sizes of umbra shadows. In addition, the intensity and blurriness of the shadow slightly impact the results. Meanwhile, determining the center of the Earth's shadow is a factor that has the most significant impact on the inaccuracies.

Reference

National Astronomical Research Institute of Thailand (NARIT) (Public Organization). (2020). Full Moon Eclipse Phenomenon. Chiang Mai: National Astronomical Research Institute. Retrieved from https://www.narit.or.th/