**The Study of the distance from the Earth to the Sun, and the Earth's Orbit around the Sun through Analyzing Photographic Images.**

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Abstract

The study of this project aims to find the distance from the Earth to the Sun and examine the orbital eccentricity of the Earth around the Sun. The investigation was conducted on the days of Aphelion and Perihelion from the Time and Date website (*1). The plan involved photographing the Sun from July 4, 2022, to May 10, 2023, using a camera with a 10-inch Dobsonian telescope. A total of 56 solar images were covered, capturing reference star images for angular distance comparisons using Stellarium Program. We used 56 solar images to measure for size using Adobe Photoshop, calculating the angular diameter by comparing with the angular distance of the reference star. The distance from the Earth to the Sun on different days and times was calculated. The study revealed that the maximum distance from the Earth to the Sun was 1.553 x $10^8$ kilometers, the minimum distance was 1.498 x $10^8$ kilometers, and the Earth's orbit around the Sun is elliptical with an eccentricity of 0.0181, showing a deviation of 8.38 percent.

Introduction

The Earth is a satellite of the Sun, and its orbit around the Sun forms an ellipse. The Earth has an average distance of 149.6 million kilometers from the Sun. The closest point to the Sun is called Perihelion, and the farthest point is called Aphelion. Due to the elliptical orbit, the apparent size of the Sun varies each day. This phenomenon inspired the researchers' interest in studying the eccentricity of the Earth's orbit around the Sun and the distance from the Earth to the Sun based on photographs of the Sun.

Method

Data Collection

1) The researcher searched for the dates and times of the Sun's closest position to the Earth (Perihelion) and the farthest position from the Earth (Aphelion) to plan the photography schedule, using the Time and Date website, 2) Captured images of the Sun from July 4, 2022, to May 10, 2023, with significant dates being July 4, 2022 (Aphelion) and January 4, 2023 (Perihelion,) and 3) Photographed reference stars.

Data Analysis

In the study, we conducted the following procedures: 1) Measured the angular distance of reference stars with Stellarium. 2) Determined the angular distance of reference stars from photographs using Adobe Photoshop. 3) Measured the Sun's size from photographs with Adobe Photoshop as Figure 1. 4) Calculated the angular diameter of the Sun, reference stars, and Earth-to-Sun distance. 5) Computed Earth-to-Sun distances on various days and times using the formula tan(ø/2) = (D/2) / R (where ø = apparent angular diameter of the Sun, D = Sun's center diameter – 1.391 x $10^6$ km, R = distance from the Earth to the Sun). 6) Calculated Earth's orbit eccentricity using eccentricity = ($R_{max}$ – $R_{min}$) / ($R_{max}$ + $R_{min}$) (where $R_{max}$ = maximum Earth-to-Sun distance, $R_{min}$ = minimum Earth-to-Sun distance).

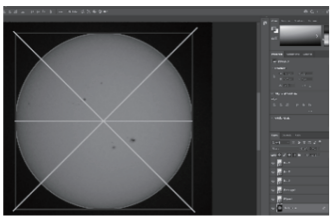

Figure 1: Measuring the Sun's size

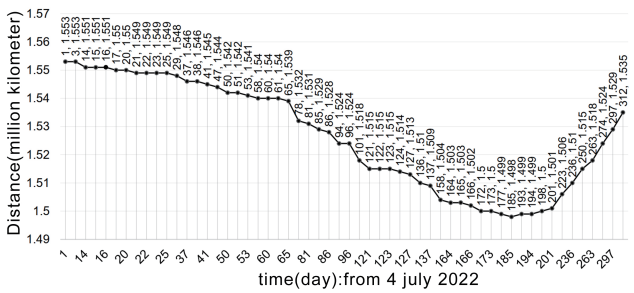


Figure 2: Graph of the distances from the Earth to the Sun related to time

Conclusion

From Figure 2 and Table 1, studying the eccentricity of Earth's orbit around the Sun and the distance from the Earth to the Sun, it is observed that the Earth's orbit forms an elliptical shape. The farthest Earth-to-Sun distance occurs at Perihelion on July 4, 2022, measuring 1.553 x $10^8$ kilometers. The closest distance, at Aphelion on January 4, 2023, is 1.498 x $10^8$ kilometers. The eccentricity of Earth's orbit around the Sun is calculated as 0.0181, resulting in a deviation of 8.38 percent.

Table 1: The Sun's angular diameter and Distance between the Earth and the Sun

| day | Date_Time | Hours since 04/07/22_00.00 | Sun' s angular diameter | Distance between the Earth and the Sun: km | day | Date_Time | Hours since 04/07/22_00.00 | Sun' s angular diameter | Distance between the Earth and the Sun: km | day | Date_Time | Hours since 04/07/22_00.00 | Sun' s angular diameter | Distance between the Earth and the Sun: km | Day | Date_Time | Hours since 04/07/22_00.00 | Sun' s angular diameter | Distance between the Earth and the Sun: km |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 04/07/22_12:24 | 12 | 0.5132 | 1.553 x $10^8$ | 41 | 13/08/22_15.13 | 975 | 0.5158 | 1.545 x $10^8$ | 96 | 07/10/22_14.48 | 2295 | 0.5231 | 1.524 x $10^8$ | 173 | 23/12/22_15.52 | 4144 | 0.5312 | 1.500 x $10^8$ |
| 3 | 06/07/22_12.15 | 60 | 0.5132 | 1.553 x $10^8$ | 47 | 19/08/22_13.29 | 1117 | 0.5163 | 1.544 x $10^8$ | 101 | 12/10/22_12.23 | 2412 | 0.5249 | 1.518 x $10^8$ | 177 | 27/12/22_15.18 | 4239 | 0.5315 | 1.499 x $10^8$ |
| 14 | 17/07/22_11.52 | 324 | 0.5140 | 1.551 x $10^8$ | 50 | 22/08/22_15.49 | 1192 | 0.5168 | 1.542 x $10^8$ | 121 | 01/11/22_12.49 | 2893 | 0.5262 | 1.515 x $10^8$ | 185 | 04/01/23_14.30 | 4431 | 0.5320 | 1.498 x $10^8$ |
| 15 | 18/07/22_15.22 | 351 | 0.5140 | 1.551 x $10^8$ | 51 | 23/08/22_11.28 | 1211 | 0.5168 | 1.542 x $10^8$ | 122 | 02/11/22_15.42 | 2920 | 0.5262 | 1.515 x $10^8$ | 193 | 12/01/23_15.01 | 4623 | 0.5317 | 1.499 x $10^8$ |
| 16 | 19/07/22_15.49 | 376 | 0.5140 | 1.551 x $10^8$ | 53 | 27/08/22_14.44 | 1311 | 0.5171 | 1.541 x $10^8$ | 123 | 03/11/22_15.15 | 2943 | 0.5262 | 1.515 x $10^8$ | 194 | 13/01/23_15.32 | 4648 | 0.5315 | 1.499 x $10^8$ |
| 17 | 20/07/22_15.27 | 399 | 0.5142 | 1.550 x $10^8$ | 58 | 30/08/22_11.58 | 1380 | 0.5175 | 1.540 x $10^8$ | 124 | 04/11/22_15.47 | 2968 | 0.5264 | 1.514 x $10^8$ | 198 | 17/01/23_15.05 | 4743 | 0.5314 | 1.500 x $10^8$ |
| 20 | 23/07/22_16.50 | 473 | 0.5143 | 1.550 x $10^8$ | 60 | 01/09/22_15.07 | 1431 | 0.5176 | 1.540 x $10^8$ | 127 | 07/11/22_16.20 | 3040 | 0.5267 | 1.513 x $10^8$ | 201 | 20/01/23_14.41 | 4815 | 0.5310 | 1.501 x $10^8$ |
| 21 | 24/07/22_16.02 | 496 | 0.5145 | 1.549 x $10^8$ | 61 | 02/09/22_16.08 | 1456 | 0.5176 | 1.540 x $10^8$ | 136 | 16/11/22_15.16 | 3255 | 0.5281 | 1.510 x $10^8$ | 223 | 11/02/23_15.02 | 5343 | 0.5292 | 1.506 x $10^8$ |
| 22 | 25/07/22_15.40 | 520 | 0.5145 | 1.549 x $10^8$ | 65 | 06/09/22_12.27 | 1548 | 0.5180 | 1.539 x $10^8$ | 137 | 17/11/22_15.42 | 3280 | 0.5282 | 1.509 x $10^8$ | 236 | 24/02/23_15.56 | 5656 | 0.5277 | 1.510 x $10^8$ |
| 23 | 26/07/22_15.47 | 544 | 0.5145 | 1.549 x $10^8$ | 78 | 19/09/22_15.09 | 1863 | 0.5201 | 1.532 x $10^8$ | 158 | 08/12/22_15.31 | 3784 | 0.5299 | 1.504 x $10^8$ | 250 | 09/03/23_16.15 | 5992 | 0.5262 | 1.515 x $10^8$ |
| 25 | 28/07/22_15.36 | 592 | 0.5146 | 1.549 x $10^8$ | 81 | 22/09/22_15.07 | 1935 | 0.5204 | 1.531 x $10^8$ | 164 | 14/12/22_15.33 | 3928 | 0.5303 | 1.503 x $10^8$ | 263 | 22/03/23_13.47 | 6302 | 0.5249 | 1.518 x $10^8$ |
| 29 | 01/08/22_17.06 | 689 | 0.5150 | 1.548 x $10^8$ | 85 | 26/09/22_15.11 | 2031 | 0.5214 | 1.529 x $10^8$ | 165 | 15/12/22_15.23 | 3951 | 0.5304 | 1.503 x $10^8$ | 274 | 02/04/23_13.11 | 6565 | 0.5231 | 1.524 x $10^8$ |
| 37 | 09/08/22_15.38 | 880 | 0.5155 | 1.546 x $10^8$ | 86 | 27/09/22_12.34 | 2053 | 0.5216 | 1.528 x $10^8$ | 166 | 16/12/22_15.29 | 3975 | 0.5307 | 1.502 x $10^8$ | 297 | 25/04/23_12.20 | 7116 | 0.5213 | 1.529 x $10^8$ |
| 38 | 10/08/22_15.07 | 903 | 0.5155 | 1.546 x $10^8$ | 94 | 05/10/22_15.20 | 2247 | 0.5229 | 1.524 x $10^8$ | 172 | 22/12/22_15.06 | 4119 | 0.5312 | 1.500 x $10^8$ | 312 | 10/05/23_12.07 | 7476 | 0.5191 | 1.535 x $10^8$ |

Reference

Puripat Tanachaiyasinwong and Thanaphon Tancharoen. (2019). Utilizing Moon Photographs for Calculating Angular Diameter, Apparent Size, and Distance from Earth to the Moon. Bang Pakok Wittayakom School, Bangkok.

Aparna Kher. (2022). Perihelion and Aphelion. Retrieved June 29, 2022, from https://www.timeanddate.com/astronomy/perihelion-aphelion-solstice.html.(*1)