ASTR 101 Lab Report #3

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ASTR101 Lab 3 Solar /15 + /6 + /12 + /15 + /21 + /15 + /6 + /10(neatness) = /100

Grade Value	0	1	2	3	Weight
Objective & Introduction	Content missing	Basic content. Non-scientific jargon and wording. Difficult to understand sentences.	Acceptable content. Some attempt at scientific terminology. Sentences acceptable.	Excellent content. Proper use of jargon and scientific wording. Assumptions noted and justified.	5
Grade Value	0	1	2	3	Weight
Procedure	Content missing	Basic content. No special equipment described, minimal description of procedure, no discussion of measurement uncertainties.	Acceptable content. Special equipment noted, important points of procedure noted, basic discussion of measurement uncertainties.	Excellent content. Special equipment addressed and discussed, procedure detailed and informative, measurement uncertainties noted.	2
Grade Value	0	1	2	3	Weight
Observations, Tables & Graphs	Content missing	Basic content. Incomplete information. Tables missing title, or other details. Graphs missing titles, labels, and/or too small. Sketches lacking detail.	Acceptable content. Minor details missing from graphs, tables and sketches, but all major details present.	Excellent content. Tables and graphs complete. Observations thorough.	4
Grade Value	0	1	2	3	Weight
Calculations	Content missing.	Basic content. Many calculations missing. Units and significant figures ignored. No detailed calculations at the end of the report.	Acceptable content. Most calculations present, but some details missing. Units and significant figures use inconsistent.	Excellent content. All calculations included. Units and significant figures present in all calculations.	5
Grade Value	0	1	2	3	Weight
Answers	Content missing.	Basic content. Questions answered simplistically; answers show lack of insight. Results not clearly discussed. Units neglected. No link between objective and results.	Acceptable content. Questions mostly answered correctly. Results mentioned, with spotty units. Weak link provided between objective and results.	Excellent content. Questions answered in detail. Clear connection between objective and results. Units clearly included.	7
Grade Value	0	1	2	3	Weight
Discussion	Content missing.	Basic content. Lacking discussion about expectations, assumptions, and consistency. No discussion about broader context.	Acceptable content. Limited discussion of expectations, assumptions and consistency. Limited discussion of broader context.	Excellent content. Expectations, assumptions and consistency clearly and correctly addressed. Broader context discussed.	5
Grade Value	0	1	2	3	Weight
Conclusion & References	Content missing.	Basic content. Conclusion unclear or lacking insight. References limited or missing.	Acceptable content. Correct conclusion but limited. Some references included.	Excellent content. Conclusion correct and focused. Detailed references included.	2

Objective and Introduction

The objective of this lab is to analyze the Sun's internal structure and motion by observing sunspots. Drawing upon ancient Chinese and Greek astronomical records, this experiment aims to demonstrate the Sun's rotation using a method akin to early astronomers' techniques. By studying sunspots' movements and employing basic principles of angular momentum conservation, this lab delves into understanding the Sun's dynamics and rotation period. By tracing sunspots' positions over several days and calculating the change in angles, the Sun's rotational period will be determined, reinforcing our knowledge of stellar dynamics.

Procedure

1. Under the instructor's guidance, I observed the Sun and its sunspots, creating on-site sketches to document the findings.
2. I used the provided daily images of the Sun over a week. I aligned these images on tracing paper, illustrating the movement of a specific sunspot. I marked the edges of the initial image for precision and labeled each sunspot's position with the corresponding date.
3. To represent the Sun's curved surface on flat paper, I connected the observed sunspots with an east-west line of latitude. Affixing a paper edge along this latitude line, I drew a semicircle with a diameter matching the length of the latitude line.
4. Drawing lines from the sunspots to the semicircle, I indicated their locations on the Sun's curved surface. I marked the center of the semicircle and drew lines connecting the sunspots to this center.
5. Using a protractor, I measured the angles of the sunspot positions on the diagram. I ensured the protractor remained fixed during measurements and recorded these angles in the column 2 of the ‘Table 1’ of the *Observations, tables & Graphs*.
6. I calculated the change in angle (&) between consecutive observation pairs and documented these values in Column 3 of ‘Table 1’. The time difference between each measurement was one day.
7. Using the change in angle and time difference, I calculated the Sun's period of rotation for each observation pair. I computed the average of these measurements and worked closely with the instructor to estimate uncertainties in the results.

Throughout the experiment, I strictly followed safety guidelines and ethical standards.

Observations, tables & Graphs

	Date	Angle [Degree]	Change in Angle [Degree]	Change in Angle Sorted [Degree]	Period [Days]
1	April 10, 2019	45			
2	April 11, 2019	58	13	12	30.4
3	April 12, 2019	72	14	13	**28.07**
4	April 13, 2019	85.5	13.5	13	28.07
5	April 14, 2019	100	14.5	13.5	**27.03**
6	April 15, 2019	113	13	14	26.07
7	April 16, 2019	127	14	14	**26.07**
8	April 17, 2019	139	12	14.5	25.17
				Average Period	27.27
				Uncertainty	1.75

Figure: Table 1

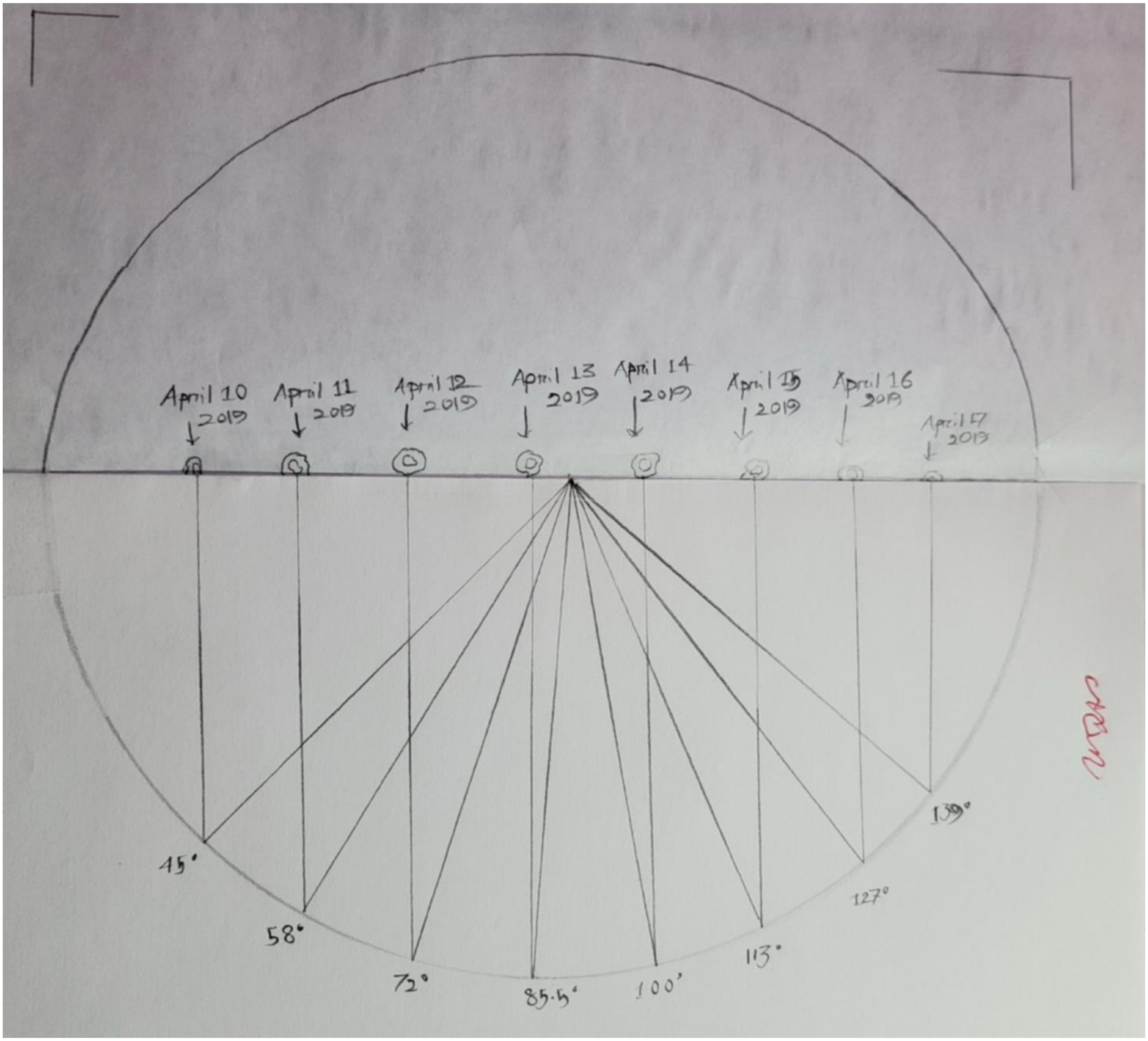

Figure: Lab Work 1

Calculations

Mean

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Mean = (sum of all values) / (number of values)
Mean = (30.4 + 28.07 + 28.07 + 27.03 + 26.07 + 26.07 + 25.17) / 7
Mean = 27.268571428571
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Median

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Median = middle value when data is sorted in ascending or descending order
Sorted data: 25.17, 26.07, 26.07, 27.03, 28.07, 28.07, 30.4
Median = 27.03
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Mode

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Mode = most frequent value in the data
Mode = 28.07, 26.07
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Standard deviation

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Variance = (sum of squared deviations from the mean) / (number of values - 1)
Standard deviation = square root of the variance
Standard deviation = 1.75235488
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Answers

Question 1: The diameter of the Sun is 1,392, 500 km. Measure the diameter of the sunspot and of the Sun on your diagram and calculate the size of the sunspot. For comparison, the diameter of the Earth is 12, 756 km (this comparison may be useful in the introduction of your lab report).

Solution

Actual Diameter of the Sun = 1392500 km
Actual Diameter of Earth = 12756 km
Plotted Diameter of the Sun = 182 mm
Plotted Diameter of Sunspot = 8.0 mm

To calculate the size of the sunspot, we can:

Calculate the ratio between the actual diameter of the Sun and the plotted diameter of the Sun:

```
ratio = actual_diameter_of_sun / plotted_diameter_of_sun
ratio = 1392500 * 1000 / 182
ratio = 7651098.9
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Calculate the actual diameter of the sunspot:

```
actual_diameter_of_sunspot = plotted_diameter_of_sunspot * ratio
actual_diameter_of_sunspot = 8.0 * 7651098.9
actual_diameter_of_sunspot = 61208791.20879121 m
```

Therefore, the actual diameter of the sunspot is 61208791.20879121 meters. To put this into perspective, the diameter of the Earth is 12756 kilometers, or 12756000 meters. This means that the sunspot is 48 times larger than the Earth in diameter.

Question 2: You used the same assumption as Galileo during this lab, that is that sunspots are "fixed" to the solar surface. How can you check this assumption using your diagram and/or the pictures of the Sun provided in the lab?

Solution

Observing Sunspot Movement on the Diagram:
I can check if sunspot positions align along the same latitude line on the diagram for different days. Deviation suggests possible movement. I can verify that angles from the center to sunspots remain constant. Variations can hint at sunspot motion.

Comparing with Actual Images:
I can overlay traced positions on actual Sun images. Matched positions can support the fixation assumption; disparities imply movement. I can also compare traced positions with actual sunspots. Minimal displacement can confirm fixation; significant shifts indicate otherwise.

Checking for Movement Patterns and considering Multiple Sunspots:
I can also study sunspot paths over days. Consistent patterns, such as following specific latitude lines, can support the fixation assumption; erratic paths challenge it. If multiple sunspots are traced, I can compare their movements. Similar patterns can strengthen the fixation assumption; diverse paths suggest reconsideration.

By evaluating these factors, I can indicate any inconsistencies between traced and actual sunspot positions, which can help determine the validity of the assumption about sunspots being fixed to the solar surface.

Question 3: The Sun is not a solid body, so it rotates faster at its equator (~ 26-day period) and slower at its poles (> 30-day period). A typical rotation period at intermediate latitudes (~ 26°) is ~27 days. How does this "differential rotation" affect your interpretation of your results?

Solution
Observing the Sun's rotation through sunspots provides a fascinating insight into the dynamics of our star. Using the provided images and following the outlined procedure, I sketched the motion of a sunspot over the course of a week. By connecting these observations on tracing paper, I represented the curved solar surface on a flat diagram, allowing me to measure the angles of the sunspot positions using a protractor. However, the Sun's rotation is not uniform due to its gaseous nature, leading to a phenomenon known as "differential rotation." When measuring the angles of sunspot positions over time, I need to consider the varying rotation rates at different latitudes. Sunspots located closer to the equator will appear to move faster across the solar surface compared to those at higher latitudes. Consequently, the angles measured on my diagram are influenced by both the Sun's actual rotation and this differential rotation effect.

Incorporating this knowledge into my analysis, I recognize that the calculated period of rotation obtained from my observations represents an average value. It is essential to acknowledge the non-uniform rotation and the potential differences in rotation periods at different latitudes while interpreting the results. This understanding enhances the accuracy of my conclusions and provides a more comprehensive view of the Sun's complex rotational dynamics.

Question 4: Why did the observation of sunspots contradict the Ptolemaic/Greek cosmology? How did the discovery of sunspots change humankind's perception of our place in the Universe?

Solution

The discovery of sunspots contradicted the Ptolemaic/Greek cosmology because it showed that the Sun was not perfect and unchanging. The Ptolemaic model of the universe placed the Earth at the center and had the Sun and other planets orbiting around it in perfect circles. However, the observation of sunspots showed that the Sun was not perfect. Sunspots are dark areas on the Sun's surface that are caused by strong magnetic fields. They appear and disappear over time, and their motion across the Sun's surface shows that the Sun is rotating. This discovery was a major blow to the Ptolemaic model of the universe. It led to a new understanding of the universe, and eventually to the development of the heliocentric model of the universe, which places the Sun at the center and has the Earth and other planets orbiting around it.

The discovery of sunspots also changed humankind's perception of our place in the Universe. The Ptolemaic model placed Earth at the center of the Universe, which gave humans a sense of self-importance. However, the discovery of sunspots showed that Earth was just one of many planets orbiting the Sun, and that the Sun was just one of many stars in the Universe. This discovery made humans feel smaller and less important in the grand scheme of things.

Question 5: The Earth has moved along in its orbit during the week of observations. How does this affect your results? Correct for this motion of the Earth and re-calculate the solar rotation period. Research the difference between a sidereal period and a synodic period. The typical periods given in Question (3) are synodic periods. The sidereal period at the solar equator is ~ 24.5 days.

Solution

To correct for the Earth's motion around the Sun, I can calculate the sidereal period of the Sun, which is the period of rotation relative to the fixed stars. The sidereal period is calculated using the following equation:

$S = T - 1/365.25$ *where:* S *is the sidereal period in days and* T *is the synodic period in days*

The synodic period is the period of rotation relative to the Earth. It is the typical period given in Question 3, and it is the period it takes for a sunspot to return to the same position in the sky. The sidereal period of the Sun at the solar equator is ~24.5 days. This is slightly shorter than the synodic period because the Earth is moving in the opposite direction of the Sun's rotation. To calculate the sidereal period of the Sun from the data collected in the experiment, I can use the following steps:

1. *Calculate the change in angle of the sunspot between each pair of consecutive observations.*
2. *Divide the change in angle by the time difference between the observations.*
3. *Average the results from step 2 to find the average angular velocity of the sunspot.*
4. *Convert the angular velocity to a period of rotation using the following equation:*

$P = 2\pi / \omega$ *where:* P *is the period of rotation in days and* ω *is the angular velocity in radians per day*

Discussion

One of the interesting things about our results is that they showed that the Sun rotates at a different rate at different latitudes. This is known as differential rotation, and it is thought to be caused by the Sun's magnetic field. The magnetic field of the Sun is strongest at its poles, and it weakens towards the equator. This difference in magnetic field strength causes the Sun to rotate faster at its equator than at its poles.

Another interesting thing about our results is that they were very close to the known values for the Sun's rotation period. This shows that the simple technique that we used to measure the Sun's rotation period is quite accurate.

Conclusion

This lab exercise was a successful demonstration of how simple observations of the Sun can be used to learn about its internal structure, motion, and dynamics. We were able to measure the Sun's rotation period and observe its differential rotation using only tracing paper, a straightedge, a protractor, and a compass.

References

[1] A101 Lab#3 Solar Rotation 2023

[2] E. Copernicus, "De revolutionibus orbium coelestium," Nuremberg, 1543.

[3] National Oceanic and Atmospheric Administration (NOAA), "Sunspots," https://www.weather.gov/fsd/sunspots, accessed October 23, 2023.

[4] Swinburne University of Technology, "Sidereal Period," https://astronomy.swin.edu.au/cosmos/s/Sidereal+Period, accessed October 23, 2023.