Lab 4 - Solar Rotation submitted

Exploring the Night Sky (University of Victoria)

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Lab 4 -Solar Rotation

Objective

This lab consisted of simple observations of pictures of sunspots of the Sun. As the sunspots traversed the Sun in the 8 pictures, it was clear that the Sun rotates on an axis. The rate at which the sunspot travels was used to calculate the Sun's rotational speed.

Introduction

The Sun is a star. It was formed around 4.6 billion years ago from a swirling cloud of gas and dust. The high velocities of these clouds left the Sun in a spin; this is due to the law of conservation of angular momentum. Today, the spin is slower and visible from Earth. Using the proper technologies, pictures of the Sun can be taken over time and compared to find the rate of its rotation.

However, the Sun looks like a homologous mixture of white-yellow burning gases. Luckily, there are imperfections on the Sun called sunspots; interruptions in the Sun's inner dynamics that warp the magnetic field and are cooler and visibly darker than the rest of the star. They can last weeks upon the Sun's surface, making them an aid to finding the rotation of the Sun. Observation of sunspots can be traced back in history to Ancient China and Greece, to Galileo Galilei, and to today's astronomers.

Procedure

First, I was given the tools required to trace the pictures of the Sun. With the compass and tracing paper, I traced out the picture of the Sun as seen in Figure 1. The right-angle lines are the corners of the picture for lining up. This helped to avoid errors.

There were 8 pictures of the Sun taken in 8 consecutive days in May 2016. Through the days, there was a sunspot traversing the equator. For each day, I traced the sunspot on the same diagram as I had traced the Sun. Then, I took a cross-section of the Sun; a line drawn straight through the path of the sunspot. Because the path was on the equator, the cross-section was equal to the Southern hemisphere of the Sun. Next, to find the center of the cross-section, I folded the tracing paper in half so as to match the East and West sides of the Sun together. With this center point and a protractor, I calculated the displacement of the sunspot through the 8 days. The angles calculated were then used to fill out Table 1.

Observations

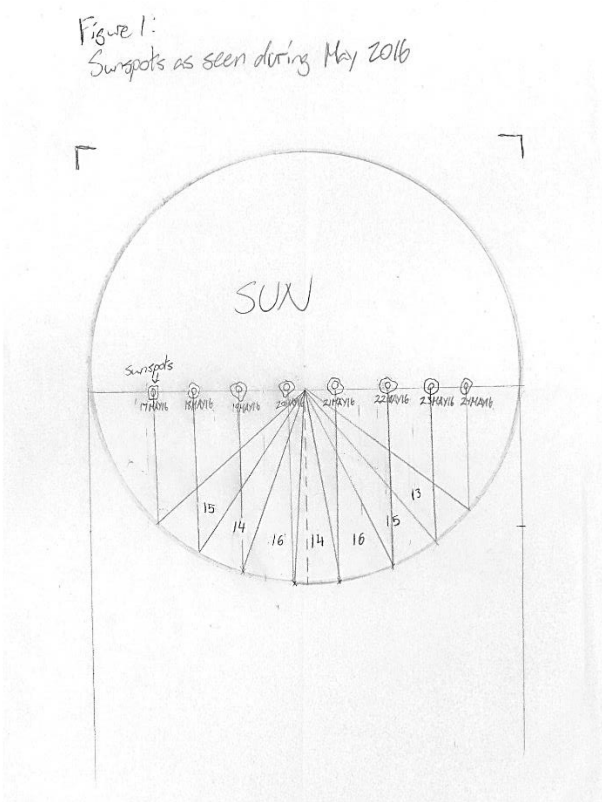

Table 1 - Face-on view of the Sun. One sunspot is traced over 8 days, producing a straight line traversing the photosphere. If the sunspot's path was lower or higher than the equator, a semicircle of the latitude, called a cross-sectional view, would have been drawn. This sunspot was very close to the equator, so the cross-sectional view would have just been the southern hemisphere. This is why the angular displacement is measured in the southern hemisphere in this diagram.

Date (DDMMYY)	**Change in Angle (°)**	**Synodic Period (days)**
17/05/16	Start	
18/05/16	15	24.0
19/05/16	14	25.7
20/05/16	16	22.5
21/05/16	14	25.7
22/05/16	16	22.5
23/05/16	15	24.0
24/05/16	13	27.7
	Ave. Peroid & Uncertainty	24.6 ± 1.89

Table 2 - Angular displacement of a sunspot over 8 days in May 2016. Average period and uncertainty (standard deviation) were calculated in Microsoft Excel 2016. Calculation can be found in this hyperlink: *https://d.docs.live.net/46fc47ff00d93f91/Documents/UVic%20Summer%202018/ASTR%20101/Tutorial/Lab%204%20-%20Solar%20Rotation%20excel.xlsx*

Answers

1. Sun Ø = 1 392 500km = 15.9cm in Figure 1. Earth Ø = 12 756km.

Find Earth's diameter (Ø) in cm.
% of Earth Ø in comparison to Sun Ø in Figure 1 = $\frac{12756km}{1392500km}$ = 0.00916 x 100 = 0.92% of Sun's diameter.
Earth Ø cm in Figure 1 = 0.92% of 15.9cm = 0.00916 x 15.9 = **0.146cm**

Find Sunspot diameter in km.
Average Sunspot Ø = $\frac{\sum \ individual\ sunspot\ Ø}{8\ sunspots}$ = 0.6cm
% of Sunspot compared to Sun = $\frac{0.6cm}{15.9cm}$ = 0.0377 x 100 = 3.77%
Sunspot Ø in km = 3.77% of 1 392 500km = 0.0377 x 1 392 500 = **52 547.17km**

The sunspot studied in this lab has a diameter about 4X the diameter of Earth.

2. The assumption that the sunspots are in a fixed spot on the Sun can be checked by looking at the diagram in Figure 1. Because sunspots are found on the most visible layer of the Sun, the photosphere, they are an aid to tracking the rotation. With the observations in Figure 1, it is clear that the sunspot traverses the images in a straight path. This indicates that it is fixed on the star's surface.
   In addition, scientists can assume the sunspots are fixed on the surface as they are caused by an interruption of the inner workings of the Sun.
3. The sunspot observed in this lab is found very near the equator, where the Sun's rotation is ~26 days. Because the Sun experiences differential rotation – the rotation at the poles is much slower – it affects the interpretation of my measurements. For the purposes of this lab and report, I measured the speed of rotation of the Sun's equator.
4. The observation of sunspots contradicted Ptolemaic cosmology. The Sun was seen as a perfect celestial body with no flaws. In some cultures and religions, the Sun was the embodiment of a god (e.g. Horus in Egypt, or God's Sun/Son). When sunspots were found by astronomers, it went against the belief that our star was without impurities. This put to question whether the Sun was a god; before the scientific renaissance, astronomers were persecuted for questioning its religious standing.
5. With the Earth moving along its orbit for the 8-day period, the results of the measurements of the sunspots are affected. The pictures used in this lab were most likely taken in a synodical fashion; each time the camera on the Earth was in the same position facing the Sun as the day before. As discussed in Question 3, the equator rotates about every 26 days. But this is the synodic period in relation to the Earth. To get a proper calculation of the motion of the sunspot, I have to convert my numbers from synodical to sidereal. For this, I found the conversion $\frac{1}{P} = \frac{1}{E} + \frac{1}{S}$, where P is the sidereal period, S is the synodical period, and E is the Earth's orbital period. I am looking for P, which in this case is the sidereal of the Sun's equator. I will take my synodical period average that was calculated in Table 1, 24.6 days, and plug it in as S. E will equal 365.20 days. Therefore,

$\frac{1}{P} = \frac{1}{365.20} + \frac{1}{24.6} = \frac{389}{8760}$. Multiply both sides by P, and divide out the fraction for P = $\frac{1}{389/8760}$ = **22.5 days.** The sidereal period of the Sun's equator is 22.5 days.

Discussion

I was surprised when it turns out my calculations done in Table 1 were not entirely correct. They were the synodic period of the Sun's rotation and not the sidereal period, which I discovered is the truest calculation of the Sun's rotation. In Question 5, I recalculated the average period and found that it was about 2 days less than the synodical.

In history, the Sun was seen as a source of light, warmth, and energy. It was known to early humans as a giver life. Like many other bodies in the sky, night or day, the Sun was given many embodiment names; in Egypt, it was the old god Ra; the Ancient Chinese believed it was part of a yin-yang balance with the Moon and was known as Taiyang. In many cultures and religions, people thought of the Sun as a perfect celestial body that provided life. This was contradicted with the discovery of sunspots. They were viewed in Ancient China, but were thought to be mere shadows on the star's surface. When Galileo turned his telescope to the Sun – rather unwisely, mind you – he found that they were not shadows, but rather imperfections on a god-like body. This, among other astronomical discoveries, angered entire congregations and governments.

Thankfully, with the science and technology of recent history, we know that the Sun is perfect in a different way; it is a normal sized star in the middle of its 8 billion-year lifespan. It will be around to provide light and warmth to Earth for the rest of humankind's existence.

Conclusion

Through this lab, I was able to calculate the synodical and sidereal periods of the equator of the Sun. This shows me how fast the Sun is rotating on its axis. This lab also introduced me to two new tools in calculating the uncertainty of measurements.

Works Cited

"Sidereal vs. Synodic Motions." *Kepler's Laws - Planetary Orbits - NAAP*, Astronomy Education at the University of Nebraska-Lincoln, astro.unl.edu/naap/motion3/sidereal_synodic.html.

"Formulas - Synodic and Sidereal Periods." *AstronomyOnline.org*, Astronomy Online, astronomyonline.org/Science/SiderealSynodicPeriod.asp.

Joseph, Peter, director. *Zeitgeist: The Movie--The Greatest Story Ever Told*. Sideways Film, 2007.

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.	Acceptable content. Most calculations present, but some details missing. Units	Excellent content. All calculations included. Units and significant figures present	5

		No detailed calculations at the end of the report.	and significant figures use inconsistent.	in all calculations.	
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