The Period of Rotation of the Sun

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Abstract

The rotation of the Sun has been studied by means of the apparent movement of 5 different sunspots over 11 days. Five different values for the Synodic and the Sideral period of rotation of the Sun have been calculated from longitudinal positions of sunspots obtaining the final value for each from their means. The synodic period obtained by susnpots near the equator is (27.3 ± 0.3) *days while the obtained for sunspot at latitude* > 20 *degrees is* (28.46 ± 0.04) *days. The sideral period obtained by susnpots near the equator is* (25.4 ± 0.2) *days.*

1. Introduction

Sunspots have been observed since many years before Galileo Galilei but he was the first to recorded the sunspots and observe how they move as the Sun rotated. This was a clear evidence that the Sun rotated, seen not only how these spots move, but they appear and disappear due to the spherical form of the Sun.

The period of rotation of the Sun can be measured by means of the move of these sunspot studing how its positions changes over the time. Nevertheless, a discrepancy between the periods measured from spots near the equator and the periods measured from spots further away the equator has been observed and explained as a consequence that the Sun is not a Solid body.

However, this period of rotation of the Sun, called *Synodic Period*, measured from the earth it is not exactly the period of rotation of the Sun due to the own rotation of the earth and due to its oibit around the Sun. For that reason the *sidereal Period* is defined as the ”true” rotation period of the Sun, which it is take respect to the distant stars.

2. Methods

In this experiment the CLEA program *The Period of Rotation of the Sun* has been used to record the position of sunspots from 11 pictures of the Sun taken by the GONG solar telescopes.

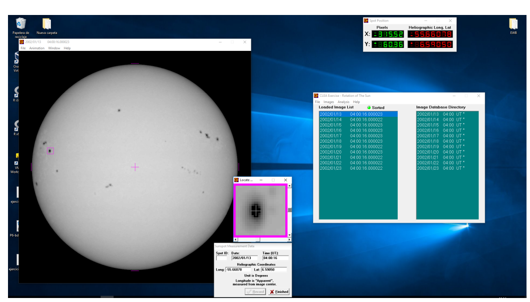

Figure 1: *The CLEA program The Period of Rotation of the Sun used in the experiment with a picture of the Sun.*

This program allows to obtain, save and plot the position of a certain point by means of its longitude and latitude coordinates. The positions on Heliographic Coordinates are given by the longitude and the latitude, measered in degrees. The latitude corresponds to the ”height” over the Equator, been 0^o for the equator, positive above it and negative under it; of the Sun and the longitude runs right down the middle of the solar disk and take positive values to the rigth and negative to the left.

Once the program has been started, the 11 pictures of the Sun of the GONG solar telescopes have been opened. The program provides these pictures by its own and characterize each one by their date and time of acquisition.

When the first picture is opened, the longitude and latitude of each sunspot can be measured just by select the sunspot, as it is shown in Figure 1. The program also allowed to identify each sunspot by an ID so all the measurements are recorded with its ID, its Julian dates and its longitude and latitude.

In this experiment five different sunspots have been measured, 4 of them near the equator and 1 at latitude > 20 degrees, for each picture, repeating all the measurements each time.

All the calculus have been done by a code script [1]

3. Results

In Figure 2 shows the 5 differents sunspot measured with its correspondent label. All the pictures used were taken between January 13^{th} and January 23^{rd} of 2002.

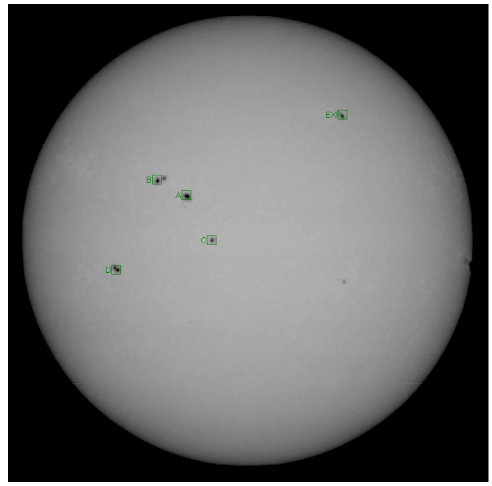

Figure 2: *Image of the Sun with the 5 sunspot used to obtain the synodic period of the Sun. Sunspots A, B, C and D are approximately at latitudes < 10 degrees while sunspot Esp is at latitude > 20 degrees.*

Measurements have been taken from 11 differents pictures of the Sun in differents days. However, sunspot C disappear in the last one so it was only possible to take 10 measurements. Similarly, only 7 measurements have been taken for sunspot Esp. All the measurements taken are shown in the appendix A.

In Figure 3 latitudes are plotted versus time of each sunspot.

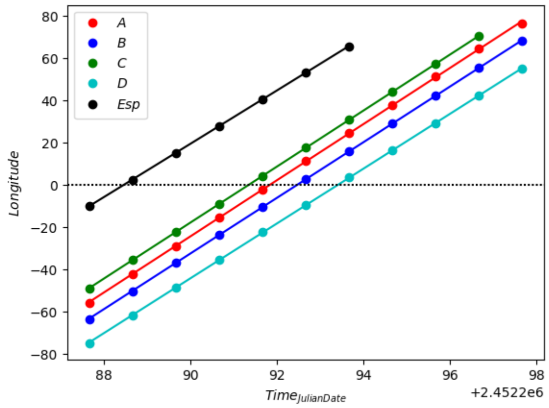

Figure 3: *Latitudes versus time for each sunspot. The black one corresponds to sunspot at latitude > 20 degrees. Values have been adjust by linear regression, slopes are shown in Table 1.*

Slopes shown in Table 1 represent how many degrees the Sun rotates per day.

$Sunspot$	$Slopes/^o \cdot days^{-1}$	$\sigma/^o \cdot days^{-1}$
A	13.31	0.04
B	13.20	0.01
C	13.283	0.017
D	13.00	0.02
Esp	12.647	0.019

Table 1: *Slopes of each sunspot obtained by linear regression with its standard deviation σ.*

Synodic period of rotation of the Sun can be obtained by divide the 360^o degrees of the sphere over slopes $Synodic_{period} = \frac{360}{Slope}$. Synodic periods of each sunspot are shown in Table 2.

$Sunspot$	$P_{Synodic}/days$	$\sigma_{P_{sync}}/days$
A	27.04	0.08
B	27.28	0.02
C	27.10	0.03
D	27.69	0.05
Esp	28.46	0.04

Table 2: *Synodic period of rotation of the Sun, $P_{Synodic}$ for each sunspot with its standard deviation $\sigma_{P_{sync}}$.*

In order to obtain an unique value for the synodic period the mean of all the obtained values has been calculated with its standard deviation.

$$\bar{P}_{synodic} = \sum_{N} P_{synodic_N} = (27.5 \pm 0.5) \text{ days} \quad (1)$$

However, due to discrepancy between values obtained for sunspot at latitudes < 10 and the value obtained from the Esp sunspot at latitude > 20 degrees, $\bar{P}_{synodic}$ is calculated again but without Esp's value.

$$\bar{P}_{synodic} = \sum_{N-1} P_{synodic_N} = (27.3 \pm 0.3) \text{ days} \quad (2)$$

Sidereal period of rotation od the Sun can be calculated from synodic period with following equation.

$$P_{sidereal} = (P_{synodic} \cdot 365.25)/(P_{synodic} + 365.25) \quad (3)$$

In order to obtain an unique value for the sidereal period of rotation of the Sun, the former method used for synodic period has been followed, obtaining first the sideral period for each sunspot, and then, the mean value with and without Esp's value.

In Table 3 appear all sidereal periods obtained from synodic periods of Table 2 by equation 3.

Sunspot	$P_{sideral}/days$
A	25.17
B	25.38
C	25.23
D	25.74
Esp	26.41

Table 3: *Sideral period of rotation of the Sun, $P_{sideral}$ for each sunspot calculated by the equation .*

$$\bar{P}_{sidereal} = \sum_{N} P_{sidereal_N} = (25.6 \pm 0.5) \text{ days} \tag{4}$$

$$\bar{P}_{sidereal} = \sum_{N-1} P_{sidereal_N} = (25.4 \pm 0.2) \text{ days} \tag{5}$$

4. Conclussions

The position (latitude and longitude) of 5 sunspots have been measured from 11 pictures of the Sun took at different days, been able to observe how susnpots move over time due to the rotation of the Sun.

Latitude magnitud does not change a lot over the time but for sunspot B some important fluctuations have been observe. These fluctuations along latitude could also affect the longitude measurements.

The period of rotation of the Sun has been obtained from the longitude values obtaining first the synodic period for the 4 sunspot near the equator (27.3 ± 0.3 days) and for the sunspot at latitude < 20 degrees (28.46 ± 0.04 days). This discrepancy between the values is not possible if the Sun were a solid body and agree with the theory and it is called differential rotation. The sidereal period obtained for the near equator susnpots is (25.6 ± 0.5) days.

The errors obtained from the standard deviation of the means are one order of magnitude bigger than obtained from the standard deviation of the linear deviation. This discrepancy shows that although the logitude of the sunspot evolves as a linear function, the slopes , and so the periods, obtained vary for each sunspots. However, this error is also very good been around 2%. When the values from the sunspot at latitude < 20 degrees are not considered for the mean, the standard deviation also decrese.

References

[1] `https://github.com/Jaimedgp/python_utilities/blob/master/P1-Astronomy.py`.

A. Tables with all measurements

$Time_{JulianDate}$	$Longitude_A$	$Latitude_A$
2452287.66685	-55.65453	6.55383
2452288.66685	-42.2863	6.5937
2452289.66685	-28.8823	6.64063
2452290.66685	-15.50355	6.67726
2452291.66685	-2.01846	6.70327
2452292.66685	11.37515	6.62191
2452293.66685	24.77242	6.60149
2452294.66685	38.04959	6.41166
2452295.66685	51.31593	6.29824
2452296.66685	64.83209	6.62467
2452297.66685	76.66677	6.57176

Table 4: *Longitude and latitude of sunspot A in function of the time, in Julian date, at each picture of the Sun measured.*

$Time_{JulianDate}$	$Longitude_B$	$Latitude_B$
2452287.66685	-63.34676	11.23107
2452288.66685	-50.18665	11.08985
2452289.66685	-36.88429	10.9511
2452290.66685	-23.58993	10.87732
2452291.66685	-10.41042	10.75143
2452292.66685	2.80314	10.59884
2452293.66685	16.0277	10.33038
2452294.66685	29.2019	10.09961
2452295.66685	42.40231	10.01009
2452296.66685	55.40194	10.0055
2452297.66685	68.5707	9.97334

Table 5: *Longitude and latitude of sunspot B in function of the time, in Julian date, at each picture of the Sun measured.*

$Time_{JulianDate}$	$Longitude_C$	$Latitude_C$
2452287.66685	-48.83466	-4.97057
2452288.66685	-35.5057	-4.77817
2452289.66685	-22.32334	-4.60597
2452290.66685	-9.04038	-4.51789
2452291.66685	4.19704	-4.45484
2452292.66685	17.66659	-4.46922
2452293.66685	31.04852	-4.5463
2452294.66685	44.35606	-4.5057
2452295.66685	57.51859	-4.40233
2452296.66685	70.43497	-4.44667

Table 6: *Longitude and latitude of sunspot C in function of the time, in Julian date, at each picture of the Sun measured.*

$Time_{JulianDate}$	$Longitude_D$	$Latitude_D$
2452287.66685	-75.09	-10.39144
2452288.66685	-61.52851	-10.6506
2452289.66685	-48.42289	-10.90289
2452290.66685	-35.34592	-11.11281
2452291.66685	-22.33181	-11.18763
2452292.66685	-9.39826	-11.38654
2452293.66685	3.61386	-11.52341
2452294.66685	16.5406	-11.55453
2452295.66685	29.43427	-11.62974
2452296.66685	42.40014	-11.70924
2452297.66685	55.16223	-11.70424

Table 7: *Longitude and latitude of sunspot D in function of the time, in Julian date, at each picture of the Sun measured.*

$Time_{JulianDate}$	$Longitude_{Esp}$	$Latitude_{Esp}$
2452287.66685	-10.06711	28.79832
2452288.66685	2.59907	28.69309
2452289.66685	15.32213	28.81208
2452290.66685	27.96642	28.7478
2452291.66685	40.68168	28.52958
2452292.66685	53.31627	28.61809
2452293.66685	65.70861	28.58446

Table 8: *Longitude and latitude of sunspot Esp in function of the time, in Julian date, at each picture of the Sun measured.*