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Sunspots

Introduction and Background

Sunspots are temporary phenomena on the photosphere of the Sun that appear visibly as dark spots compared to surrounding regions. They are studied under Heliophysics; a branch of physics which also includes solar flares and coronal mass ejections. They are formed at certain points where the Sun's magnetic field inhibits convection, thus reducing the surface temperature at that point (approximately 3000-4500K). Prototypical Sunspots come in pairs with opposite magnetic polarity. [1] As luminance varies rapidly with temperature, they appear dark compared with the surrounding material, which is approximately 5780K. Although they appear as dark spots, they are still very bright; if a Sunspot was isolated from the surrounding photosphere it would be brighter than the moon. [2]

Sunspots expand and contract as they move across the surface of the Sun, and can vary in size from as small as 16 kilometres to as large as 160,000 kilometres in diameter; the larger ones being visible from Earth without the aid of a telescope. [3] Their occurrence can be used to help predict space weather and the conditions of satellite communications.

The Sunspot itself consists of a central umbra, which is the darkest part, where the magnetic field is approximately vertical, and a surrounding penumbra, which is lighter, where the magnetic field is more inclined.

At Sunspots, secondary phenomena such as solar flares and coronal mass ejections may occur. Most solar flares and coronal mass ejections originate in magnetically active regions, mainly around visible Sunspot groupings. [4]

The earliest observations of Sunspots date back to 364 BC, but were not observed telescopically until 1610. At present, Sunspots are observed with land-based and Earth-orbiting solar telescopes.

GONG Solar Telescope

The Global Oscillation Network Group (GONG) is a community-based program to conduct a detailed study of solar internal structure and dynamics using helioseismology (the study of propagation of wave oscillations in the Sun). GONG has developed a six-station network of extremely sensitive and stable velocity imagers located around the Earth to obtain 24-hour a day observations of the Sun. [5]

We used images taken from a telescope that is a part of the GONG network. The telescope is on the island of Tenerife, an island within the Canary Islands. Images were taken using an H-alpha filter so the Sunspots were more visible and therefore easier to track.

A hydrogen-alpha filter is an optical filter designed to transmit a narrow bandwidth of light generally centered on the H-alpha wavelength (656.28nm). [6] The filters produce interference effects that filter out any wavelengths except at the necessary band. [7]

Target and Dataset

The target of this project is to determine the rotation period of the Sun using the data from the GONG solar telescope, and also to investigate the Sunspot counts over a hundred year period and determine if there are any patterns.

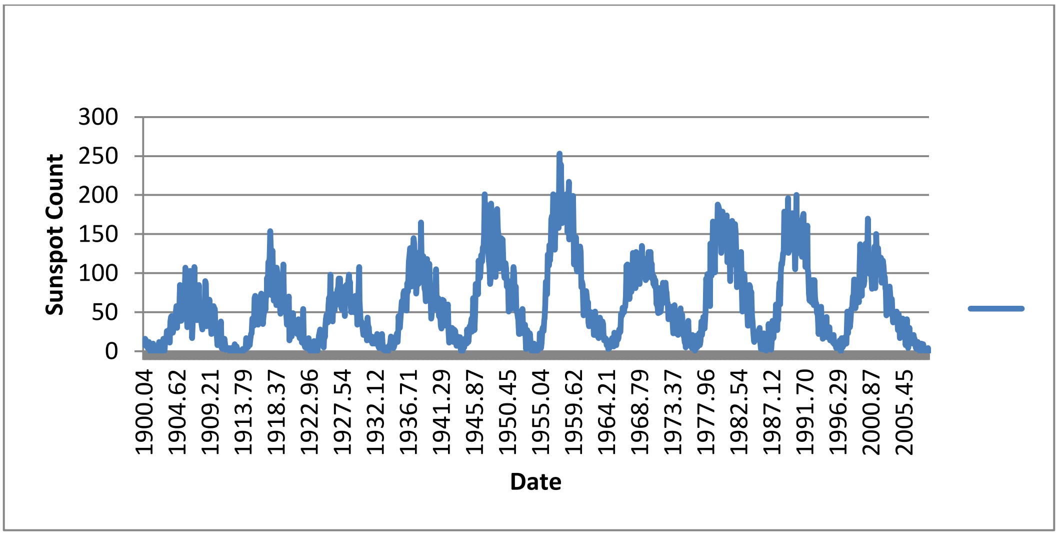

Figure 1 shows the number of Sunspots recorded at various times between 1900 and 2008.

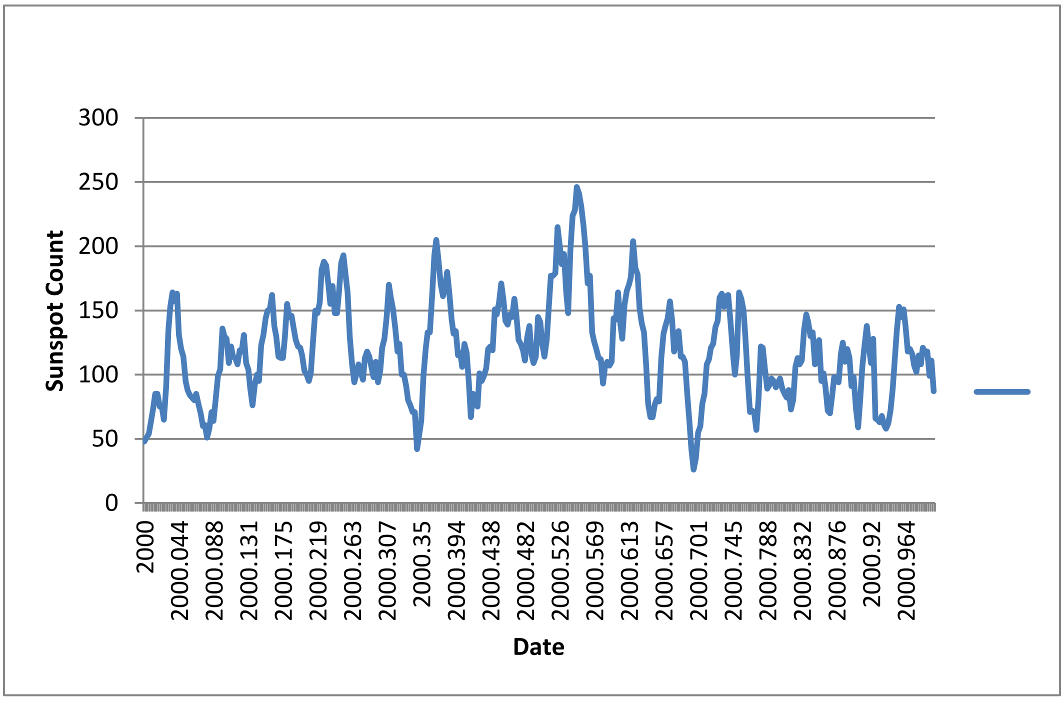

Figure 2 shows the Sunspot count across the year 2000.

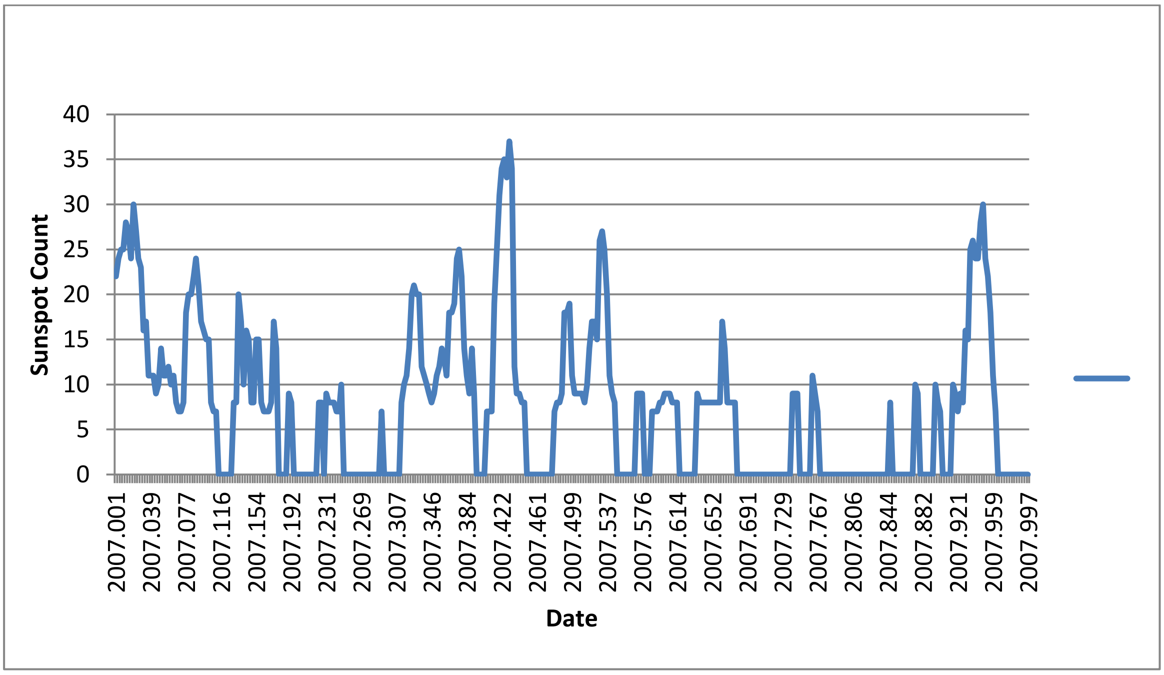

Figure 3 shows the Sunspot count across the year 2007.

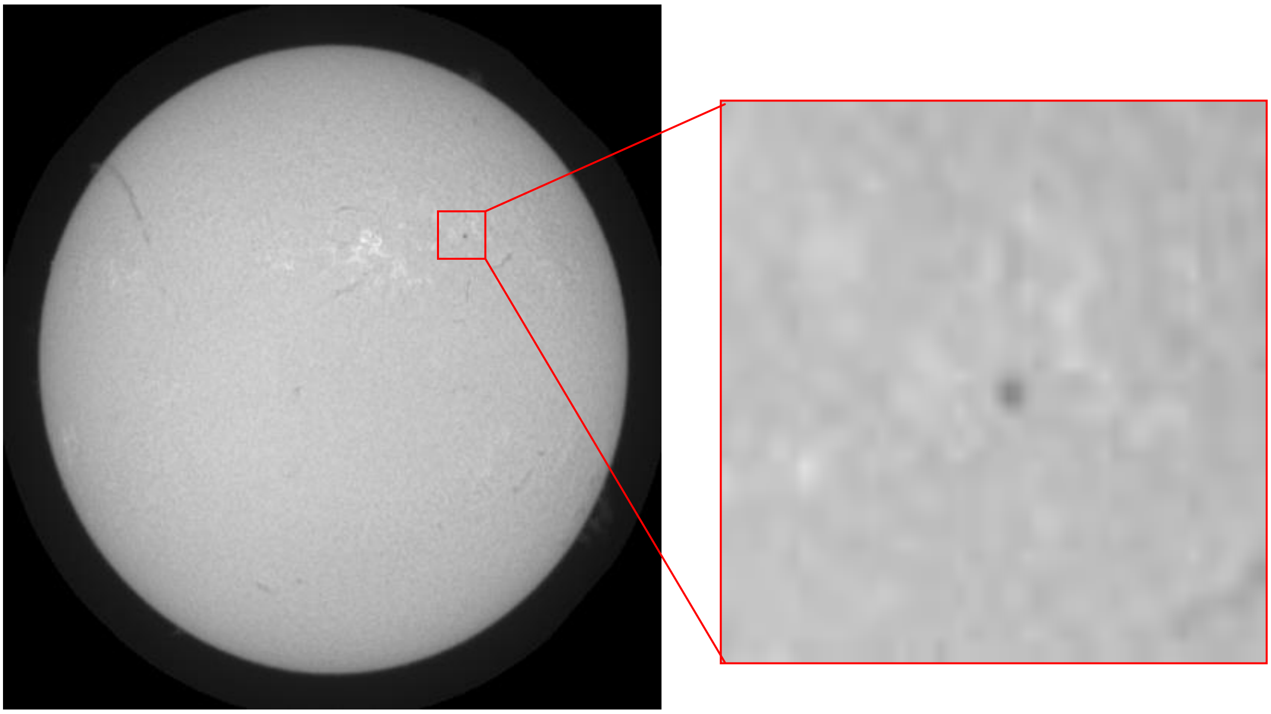

Figure 4 shows a sunspot on the sun

Method of Analysis

Using the data for the Sunspot readings between 1900 and 2008, we imported the results into Excel and were then able to produce a graph which clearly showed the pattern across the 108 year period. We worked out the length of each cycle by analysing the data to find the lowest and highest number of Sunspots, and therefore calculated an average length of the cycle – 11.6 years. Using the same process, we produced graphs for the Sunspot readings across the year 2000 and the year 2007, thus allowing us to compare these patterns.

We were asked to work out the rotation period using formulas for angular momentum and velocity. To do this we had to look at several images of the Sun taken using an H-alpha filter on a telescope that is part of the GONG network, using the ds9 program.

$$\phi = \tan^{-1}\left(\frac{x}{\sqrt{R^2 - x^2 - y^2}} \right)$$

This is the formula we used to calculate the angle of rotation of the Sunspots.

To work out the time it would take for a Sunspot to complete one full rotation we had to calculate the angle at which the Sunspot spins on the Sun's axis as well as the speed it travels.

To work out the angle at which the Sunspot was moving relative to its poles we had to map out the Sun on axis to gain values for X and Y so we could use the formula.

We had to work out the angle of each of the different positions of the Sunspots as it moved. From this we worked out the difference between these angles to give a value of the velocity of the Sunspot in degrees/day.

From all of the values we calculated for the angular velocity we worked out the average velocity that the Sunspot was moving.

We then worked out the time it would take for the Sunspot to complete one full rotation by dividing 360 by the average angular velocity of the Sunspot.

Results

A Sunspot cycle lasts for 11 years on average, although this can range from approximately 9 to 14 years. Each peak represents the solar maximum of the cycle; the point of highest Sunspot activity. Figure 1 represents the 10 Sunspot cycles between 1900 and 2008. From 1900 to the 1960s, the solar maxima trend of the Sunspot count has been upward; the cycle between 1954 and 1964 giving the highest solar maximum, with a total of 253 Sunspot counts. From the 1960s to the present, the solar maxima trend has diminished overall. [8]

This trend across a Sunspot cycle occurs because the Sun circulates a hot, electrified gas called plasma between the Sun's equator and its poles, acting as a sort of conveyor belt. When Sunspots formed earlier in the cycle begin to decay, a magnetic imprint is left on the plasma. This plasma is carried with the magnetic imprints towards the poles and then back inside the Sun, distorting the Sun's magnetic fields. This causes the magnetic fields to intensify, and therefore form more Sunspots. [9]

The number of Sunspots counted in 2000 (Figure 2) was consistently greater than the number counted in 2007 (Figure 3). This suggests that in 2000 the cycle was nearing the solar maximum, whereas in 2007 the cycle was coming to an end and thus the number of Sunspot readings was lower. This is supported by the information in Figure 1 which shows there is a solar maximum at 2000.54, where 170 Sunspots were recorded.

We calculated the angle of rotation and the rotation period for one full rotation for three Sunspots at different latitudes. The full rotation time of the Sunspot shown in Figure 4 (closest to the equator) was approximately 24.02 days as the Sunspot travelled on average 14.99 degrees per day. The other results were:

Sunspot 2: An estimate of 27.07 days to complete one full rotation as it was travelling at an approximate of 13.29 degrees per day.

Sunspot 3 (furthest from the equator): An estimate of 28.29 days to complete one full rotation as it was travelling at an approximate of 12.72 degrees per day.

Conclusion

From our graphs we can conclude that an average Sunspot cycle lasts for approximately 11 years. Within these 11 years, the amount of Sunspots fluctuates, ranging from a solar minimum to a solar maximum. Across each year, there are also fluctuations in the amount of Sunspots counted, and the reason for this is unknown. Overall, the amount of Sunspots' increases or decreases depending on which stage of the cycle it is at.

From our calculations we determined that the Sunspot with the highest latitude (furthest from the equator) travelled the slowest, as it has the smallest angular velocity. We found that, as the latitude decreases, the angle of velocity increases; therefore it takes less time for a Sunspot to complete a full rotation.

References

[1] http://www.esrl.noaa.gov/gsd/outreach/education/sam1/Activity10.html

[2] http://image.gsfc.nasa.gov/poetry/workbook/Sunspot.html

[3] http://articles.adsabs.harvard.edu//full/1989QJRAS..30...59M/0000060.000.html

[4] https://en.wikipedia.org/wiki/Sunspot#cite_note-3

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[7] http://www.olympusmicro.com/primer/java/filters/interference/index.html

[8] http://sidc.oma.be/html/wolfaml.html

[9] http://science.howstuffworks.com/Sunspot2.htm