Liceo Scientifico Statale

"Alfred Nobel"

SCHOOL-WORK ALTERNATION (PCTO)

SOLAR ROTATION PERIOD

BORRIELLO CLAUDIA, ESPOSITO ROBERTA, IENGO MATTIA, MAGLIULO CLAUDIA, NOCERINO FRANCESCO PIO, RUSSO CIRO.
LICEO SCIENTIFICO A.NOBEL, TORRE DEL GRECO, NAPLES, ITALY

ABSTRACT

We are going to present and discuss a simple experiment aimed to measure the rotation period of the Sun through the observation of sunspots. Sunspots are regions of the photosphere which have a low temperature (about 3700 K) when compared to surrounding areas (about 5700 K). Because intense magnetic activity also makes them noticeably darker, they can facilitate acquisition of data about the sun's activity. Our goal is to measure the solar rotation period by observing their movement. As it is known, the Sun rotates on its axis and, being part of the photosphere, sunspots will also move in a circular motion. We made all our measurements using the software JHelioviewer[1] and, with the data we obtained, we made a two-dimensional map of the sunspots' positions. Lastly, we calculated the angular frequency and subsequently found the solar rotation period.

KEY WORDS: Sun: Sunspots -Sun: Rotation period

INTRODUCTION

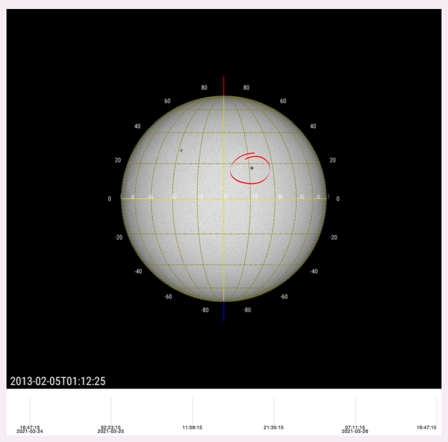
It is well known that the sun is not a static body. It is involved in a plurality of physical processes, including a rotation motion around its own axis. Our starting point are the sunspots; this event was observed for the first time in 1610 by Galileo Galilei, later described in the treaty *"Istoria e dimostrazioni intorno alle macchie solari"*[2]. These discoveries challenged both the conception of the sun as a perfect star and the immutability of the heavens, theories strongly supported by the Aristotelians.

Our observations have been conducted with the use of open-source imaging software JHelioviewer, an advanced program made by ESA JHELIOVIEWER TEAM, based on JPEG 2000 compression standards and used globally. It grant us access to data from different space observatories, one of them being NASA's SDO[3] wish we have chosen for our experiment.

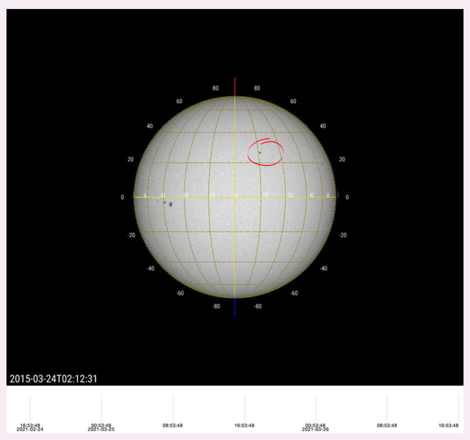
GOALS: **Looking for an accessible but efficient way to calculate the rotation period of the sun, starting from the data given by Jhelioviewer, and using dynamics laws to get a result.**

ANALYSIS AND OBSERVATION

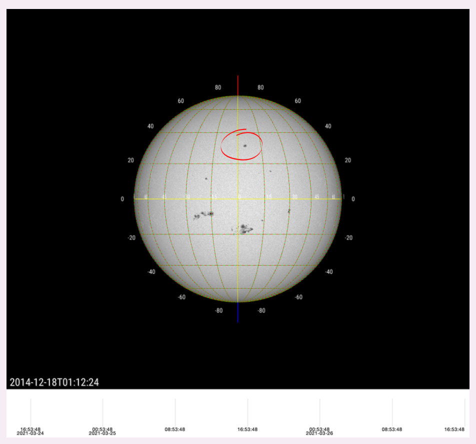
For precision's sake, we decided to observe three sunspots. They were chosen based on their latitude: not too close to the equatorial line, nor to the polar regions. For each one of them, we measured their latitude *y* and longitude *x*, along with their displacement. We repeated this operation once every day, for a total of 12 days.



LATITUDE 15°



LATITUDE 23.5°



LATITUDE 30°

There is an issue regarding the interpretation of this data: although we are looking at the Sun in a two-dimensional representation, it is obviously a sphere: this causes sunspots closer to the edge to appear as if they travel a shorter distance than those closer to the centre. To find an accurate trajectory, we drew a line over the images which approximately passes through each position the sunspot has been in. Having done that, we marked the semi-sphere whose diameter is the aforementioned line. Then, for each position, we have drawn a line perpendicular to the diameter: their intersection with the semi-circle shows the sunspots' actual locations. This procedure has been repeated for each sunspot. (Fig.1)

When making measurements on JHelioviewer, we are actually measuring the projection of the circular motion on the diameter. That is how we find our *x* (that is the longitude *φ*). (Fig.2)

If AB is the diameter, *β* is the arc angle and *R* the radius, then according to trigonometry:

$x = R\cos\beta$

$x = R\cos(\omega t+\alpha)$ being $\omega = \beta/t$ the sunspots' angular velocity being and α the phase constant.

$x/R = \cos(\omega t+\alpha)$

$\arccos(x/R) = \omega t+\alpha$

If: $y = \arccos(x/R)$ then: $y = \omega t+\alpha$

The graph of this function is a straight line with a slope *ω*. (Fig.3)

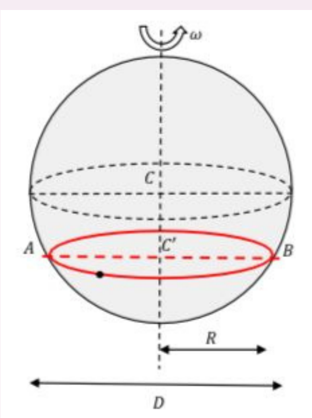


FIG.1

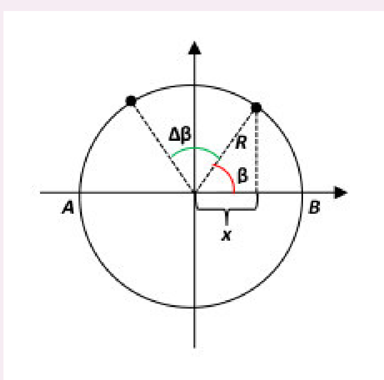


FIG.2

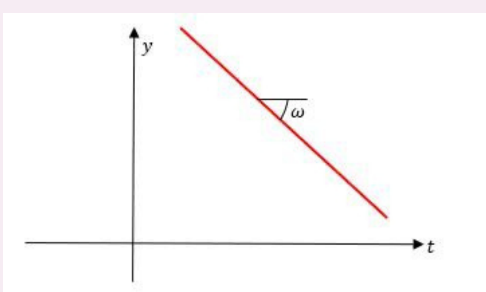


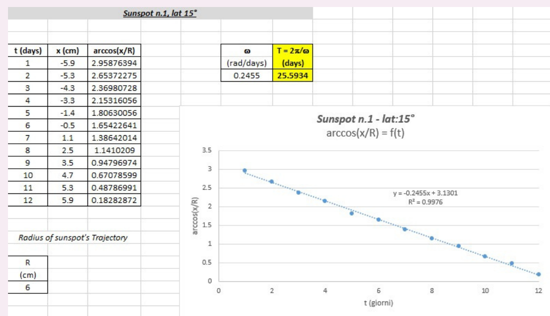
FIG.3

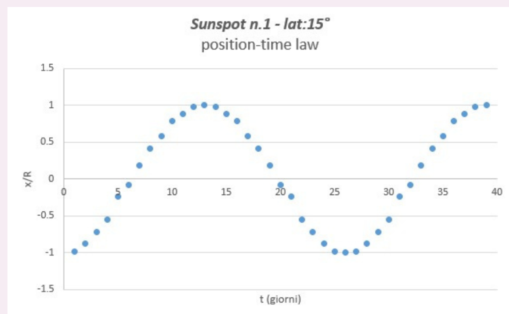
We then recall that the period of a circular motion equals $T=2\pi/\omega$. From this simple formula we get the Sun's period of rotation.

DATA

1st SUNSPOT:

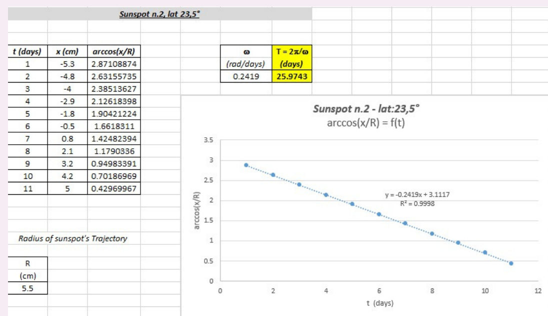
DAYS OBSERVED: 28/01/2013 - 9/02/2013 → JULIAN DATES: 2456320.5 - 2456332.5

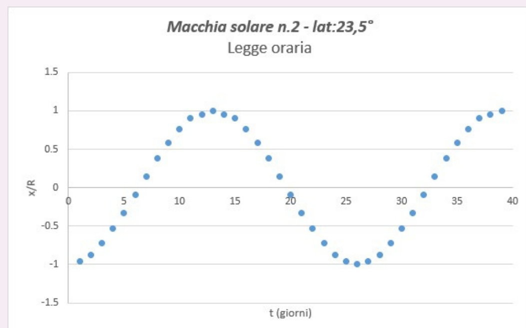




2nd SUNSPOT:

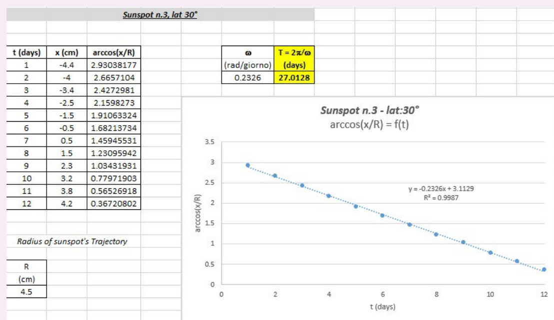
DAYS OBSERVED: 17/03/2015 - 28/03/2015 → JULIAN DATES: 2457098.5 - 2457109.5

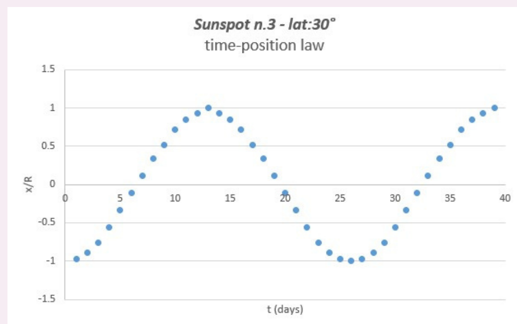




3rd SUNSPOT:

DAYS OBSERVED: 11/12/2014 - 23/12/2014 → JULIAN DATES: 2457002.5 - 2457014.5





RESULTS AND COMMENT

The experiments have yielded the following results:

Sunspot at φ = 15°: T=25.5934 days|Sunspot at φ = 23.5°: T=25.97343 days|Sunspot at φ = 30°: T=27.0128 days

Our measurements have an error which is dependent on the resolution of the images taken from JHelioviewer.

What is evident from our data is that the soalr rotaion is not constant but instead differential, and it varies with latitude (more specifically, it increases ad latitude increases).

This empirical relationship is called differential rotation law, and it is usually written as follows(Polijancic)[4]:

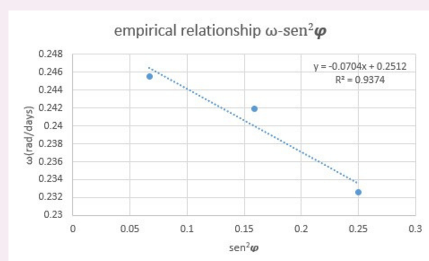
$\omega(\varphi) = A + B\,sen^2\varphi$ where φ is the heliographic latitude and A, B are parameters of the solar rotation, which we know to be differential. If φ = 0, A is the equatorial angular velocity of the Sun.

Using Excel, we can make a linear interpolation of our data. The resulting equation describes the variation of the angular velocity (and therefore of the synodic period)

We can formulate an empirical equation based on our data: $\omega = A + B \times sen2\varphi$.

We can make a linear fit with said equation:

φ(°)	Sen² φ(°)	$\omega(\frac{rad}{days})$
15	0.066987	0.2455
25.5	0.159001	0.2419
30	0.25	0.2326



A = 0.2512 rad/days

B = - 0.0704 rad/days

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[2]"Istoria e dimostrazioni intorno alle macchie solari" di Galileo Galilei: http://strangepaths.com/wp-content/uploads/2007/04/N0003355.pdf
[3]Archivio delle immagini HMI Intensity di SDO: https://sdo.gsfc.nasa.gov/data/aiahmi/
[4]Poljančić Beljan, I. et al., Astronomy & Astrophisycs 606, A72 ,2017
inoltre: "The Spinning Sun" (sito dal quale abbiamo tratto spunto per il lavoro di ricerca):
http://www.mso.anu.edu.au/~jerjen/researchprojects/spinningsun/spinningsun.html
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C. Isabel Ribeiro; Sunspots on a rotating Sun (articolo da cui abbiamo preso spunto per l'esperienza): https://www.scienceinschool.org/content/sunspots-rotating-sun