Lab Report 10

Experiment (XIX)
Investigating the Surface Features of the Sun and How to Use Sunspots to Determine the Synodic and Sidereal Rotation Rate.

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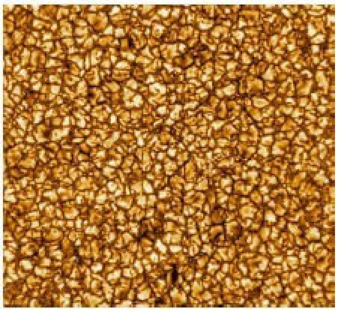
PEU 327 (Astronomy Laboratory)

Contents

1 Identifying Solar Surface Features

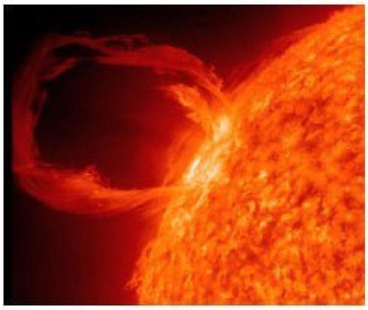
The sun is a massive ball of plasma, and can be divided approximately into 3 zones, the core (0 to 0.25 solar radii), the radiation zone (0.25 to 0.7 solar radii) and the convection zone (0.7 to 1 solar radii). The core is the innermost layer of the sun, where nuclear fusion occurs. The energy produced in the core is transported outwards through the radiation zone by radiation and then to the surface through convection. In the convective zone, hot plasma rises to the surface, cools down and then sinks back down, forming what we see as solar granulae.

Due to the plasma nature of the layers, the convective zone has differential rotation (while the core and radiation zone are thought to be rotating as a solid body). The plasma at the equator tends to rotate faster than the poles, causing the magnetic field lines to bend. The bending of the magnetic field lines tend to form pockets where the magnetic field is much stronger, in the order of thousands Gauss while normally it is around 1 to 2 Gauss on the photosphere of the sun, while MRI machines have a magnetic field strength around 10s of thousands Gauss for comparison. This bending causes the effects seen in figure 1. These effects occur as a cycle of 11 years, where the effects are at a maximum and minimum. We will explain these effects below.



1. Image One

Solar granulae

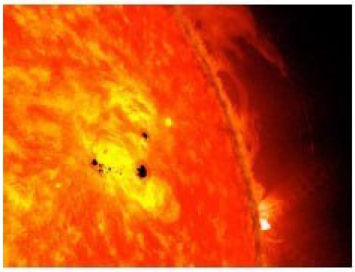


2. Image Two

Coronal mass ejections

3. Image Three

Solar flares



4. Image Four

Sunspots

Image Credits: NASA

Figure 1: Identification of Solar Features.

1.1 Solar Granulae

Solar granulae are formed due to the convection of plasma in the convective zone as described above. The brighter spots at the center of the cells are due to the hot plasma rising to the surface, while the darker spots at the edges are due to the cooler plasma sinking back down. The size of the granulae is around 1000 km, and they last for around 10 minutes before they dissipate and new ones form.

1.2 Coronal Mass Ejections (CMEs)

Coronal mass ejections (CMEs) are large expulsions of plasma and magnetic field from the sun's corona. They are formed when the magnetic field lines become twisted and snap or from instability in the magnetic field, releasing a large amount of energy. The expulsions can be seen as large loops of plasma that extend outwards from the sun's surface, and are usually accompanied by solar flares.

1.3 Solar Flare

Solar flares are sudden bursts of energy that occur when the magnetic field lines reconnect. They are usually associated with sunspots and CMEs, and can release a large amount of energy in a short period of time. They are seen as bright flashes of light in the sun's atmosphere, and can last from a few minutes to several hours.

1.4 Sunspots

Sunspots are dark spots on the sun's surface that are caused by the magnetic field lines becoming twisted and forming pockets where convection is inhibited. They are cooler than the surrounding areas (around 4000K compared to 5800K for the normal photosphere). The cooler areas then have higher wavelengths ($\lambda = \frac{2.897 * 10^{-3}}{T} \approx 724$nm) that are in the infrared region and can be seen as dark spots on the sun's surface. Figure 2 shows
The following figure contains a picture of a Sunspot taken on 06/05/2025 in Zewail City of Science and Technology, Egypt by AbdelRahman Bayoumi under the supervision of Dr. Hisham Anwer. The sunspot is faint but can be seen slightly offcenter to the bottom left (there's a red circle drawn around it).

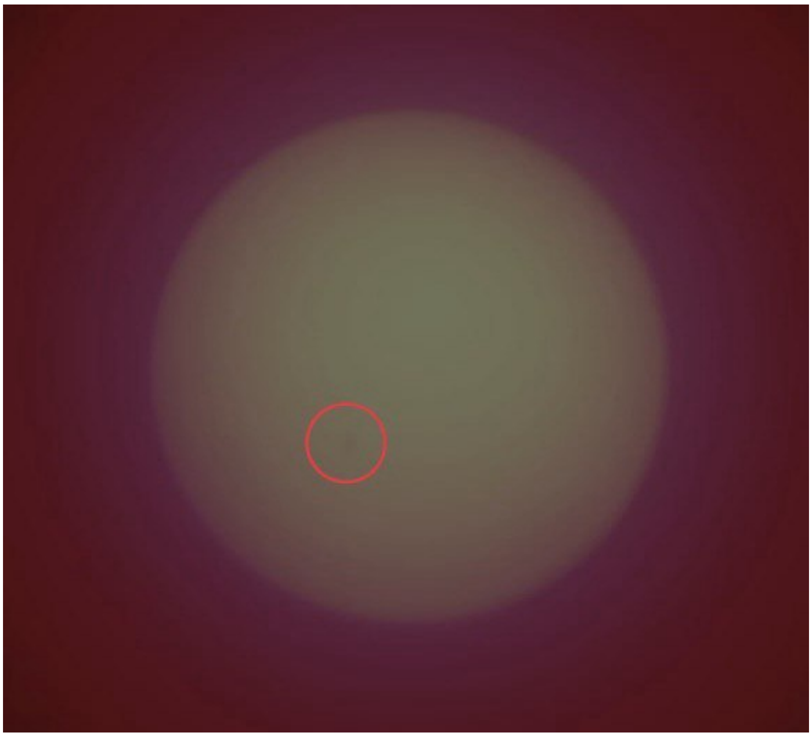


Figure 2: Sunspot taken on 06/05/2023.

2 Estimating the Sydonic and Sidereal Rotation Rates using Sunspots

2.1 Forming the tables:

The following tables (tables 1 & 2) show the longitude values of the sunspots A, B and C on the dates 22 June to 03 July. We are recording the change in the longitude values of the sunspots over the days. All values are in degrees. The longitude values are the angle between the center of the sun and the center of the sunspot, with 0 degrees being at the center of the sun.

2.2 Interpretations:

a) Question: Do all sunspots "move" around the Sun with the same rate?
Answer: No, the sunspots do not move with the same rate. The average daily change of sunspot A and B is 13.3 degrees, while the average daily change of sunspot C is 12.8 degrees. This means that sunspot C moves slower than A and B. The reason for this is that the sunspots are at different latitudes, and the sun rotates faster at the equator than at the poles. This means that sunspots at lower latitudes (A & B) will move faster than those at higher latitudes (C).

Table 1: Longitude Values of Sunspots A and B and daily changes

Sunspot A				Sunspot B			
Day	Date	Longitude	Daily change	Day	Date	Longitude	Daily change
1	June 22	-59	-	1	June 22	-75	-
2	June 23	-45	+14	2	June 23	-63	+12
3	June 24	-33	+12	3	June 24	-50	+13
4	June 25	-19	+14	4	June 25	-36	+14
5	June 26	-10	+9	5	June 26	-27	+9
6	June 27	8	+18	6	June 27	-10	+17
7	June 28	23	+15	7	June 28	5	+15
8	June 29	35	+12	8	June 29	17	+12
9	June 30	44	+9	9	June 30	26	+9
10	July 1	62	+18	10	July 1	43	+17
11	July 2	74	+12	11	July 2	56	+13
12	July 3	-	-	12	July 3	71	+15
Average daily change: +13.3				Average daily change: +13.3			

Table 2: Longitude Values of Sunspot C and daily changes

Sunspot C			
Day	Date	Longitude	Daily change
1	June 22	-59	-
2	June 23	-46	+13
3	June 24	-33	+13
4	June 25	-20	+13
5	June 26	-12	+8
6	June 27	5	+17
7	June 28	19	+14
8	June 29	31	+12
9	June 30	39	+8
10	July 1	56	+17
11	July 2	69	+13
12	July 3	-	-
Average daily change: +12.8			

The absolute latitudes of sunspot A and B are around 14 and 15 degrees respectively, while the latitude of sunspot C is around 18 degrees.

b) Question: What was the average daily rate the sunspots appear to be moving? (Average for all three spots.)
Answer: The average daily rate of the sunspots is 13.3 degrees per day for A and B, and 12.8 degrees per day for C. The average of all three spots is (13.3*3 + 12.8)/3 = 13.1 degrees per day.

c) Question: Did some spots seem to change in size or shape?
If so, explain how and why:
Answer: Spots A, B, and C did not seem to change in size or shape. This is because the

sunspots are formed by the magnetic field lines becoming twisted and forming pockets where convection is inhibited. The size of the sunspots is determined by the strength of the magnetic field, and since the magnetic field does not change significantly over a short period of time, the size and shape of the sunspots do not change significantly either. Other sunspots though are seen merging together, as they are regions of plasma, this is likely to occur when they collide.

d) Question: What is the average daily movement for Group A and Group B? This value is your angular velocity, ω. In our calculation, units for ω will be degrees/day.
Answer: The average daily movement for Group A and Group B is 13.3 degrees per day. This value is the angular velocity, ω.

e) Question: What is the Synodic rotation period of the Sun?
Answer: The synodic rotation period of the sun is the time it takes for the sun to rotate once with respect to the earth. This is given by the formula:

$$T_{syn} = \frac{360}{\omega} = \frac{360}{13.3} \approx 27.07 \text{ days} \tag{1}$$

This agrees extremely well with the value of 27.3 ± 2 days that is usually given for the synodic rotation period of the sun. The value is slightly less than the predicted value, this is likely due to the fact that the sunspots are not at the equator, and the sun rotates faster at the equator than at the poles.

f) Question: The synodic period is the Sun's rotation as observed from Earth, which means in addition to considering the Sun's rotation, the synodic period also considers the Earth's rotation. To calculate the Sun's true rotation period, the sidereal rotation period, we'll use the equation below:

$$P = \frac{T_{syn} \cdot 365.25}{365.25 + T_{syn}} = \frac{27.07 \cdot 365.25}{365.25 + 27.07} \approx 25.2 \text{ days} \tag{2}$$

Which is very close to the value of 25.38 days that is usually given for the sidereal rotation period of the sun. The value is also slightly less than the predicted value, this is likely due to the fact that the sunspots are not at the equator, and the sun rotates faster at the equator than at the poles as explained above also.