Investigating the Sun-Earth-Moon System Name:_____Block:_____

Rotation of the Sun

Earth rotates on its axis in 24 hours, defining a period of time we call one day. Other planets take different amounts of time to rotate once on their axes, a fact that results in "days" that range from 10 hours (Jupiter) to 243 Earth days (Venus). What about the Sun? In this activity, you will explore the rotation rate of the Sun by examining a time series of solar images.

Part 1: A Rough Estimate of the Sun's Rotation

1. To help you prepare, read FYI: *Sunspots*.

   As you read use the spaces below to write down any information you find especially interesting. Also define the bold terms used in the text. If you run across any other words that you don't know the meaning of, write those down and ask your teacher to help you with them.

Word/Term	Definition
Sunspot	
Umbra	
Penumbra	
Solar Cycle	
Solar Minimum	
Solar Maximum	
Coronal Mass Ejections (CMEs)	
Extra space for additional words or interesting information.	

2. In what ways do sunspots help us learn more about the magnetic field of the Sun?

3. In what ways does the solar cycle of activity on the Sun's surface pose potential concerns for activity on the Sun?

FYI Sunspots

When the sun is viewed through a solar telescope, dark spots can be observed on its surface. These continuously changing dark regions are called **sunspots**. Sunspots can be quite small (1500 km in diameter), or can reach sizes of up to 50,000 km (Figure 2-5). The inner part of a sunspot is very dark and is called the **umbra**, the Latin word for shadow. The lighter region surrounding the umbra is known as the **penumbra**. Sunspots tell us a lot about the sun, including its rotation rate and changes in its strong magnetic field.

The dark sunspots indicate regions of cool gas—or at least cooler than the surrounding hot gas—near the surface of the sun. Typically the gas would mix quickly, so cooler regions would not last long enough to be observable. The fact that sunspots commonly occur in pairs led astronomers to look at magnetic fields as a factor in sunspots. One explanation is that the magnetic field lines bunch up at certain regions on the sun and create small magnetic loops near the sun's surface, where each end of the loop is a magnetic pole (Figure 2-6).

Sunspots provide evidence of dramatic changes in the sun's magnetic field. The sun's entire magnetic field flips every 11 years, taking a total of 22 years to return to its original orientation. This 22-year cycle is called the **solar cycle**. At the beginning of a new solar cycle, sunspots appear mainly at high solar latitudes, close to the sun's north and south poles. As the magnetic field changes its orientation, sunspots form closer to the sun's equator, and then return to the poles. Within the cycle, there is one 11-year period that has high activity, called the **solar maximum**, and one with low activity, the **solar minimum**. During the solar maximum the sun is very active; it has many sunspots, solar flares, and **coronal mass ejections** (called "**CMEs**"), which can affect life here on Earth. For centuries it has been known

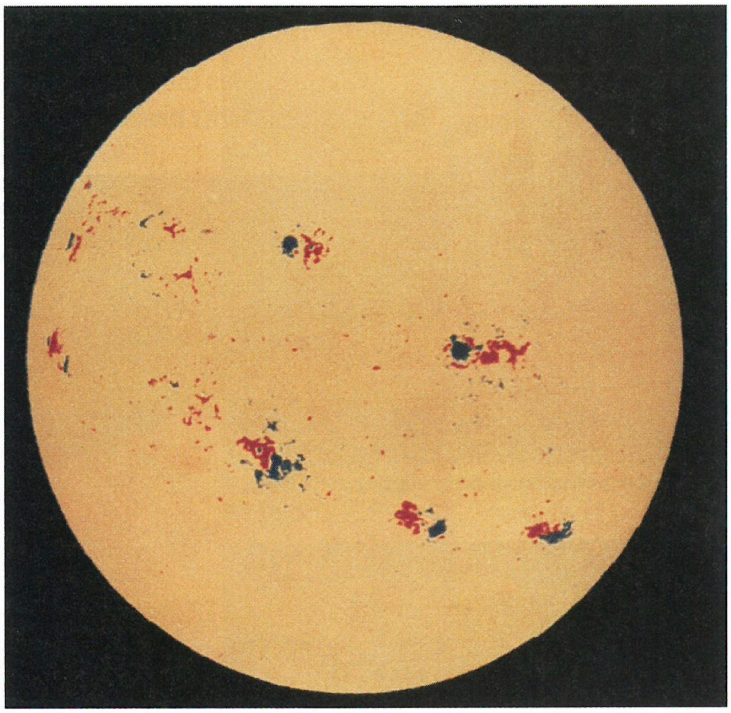


Figure 2-5: Color-enhanced image of sunspots

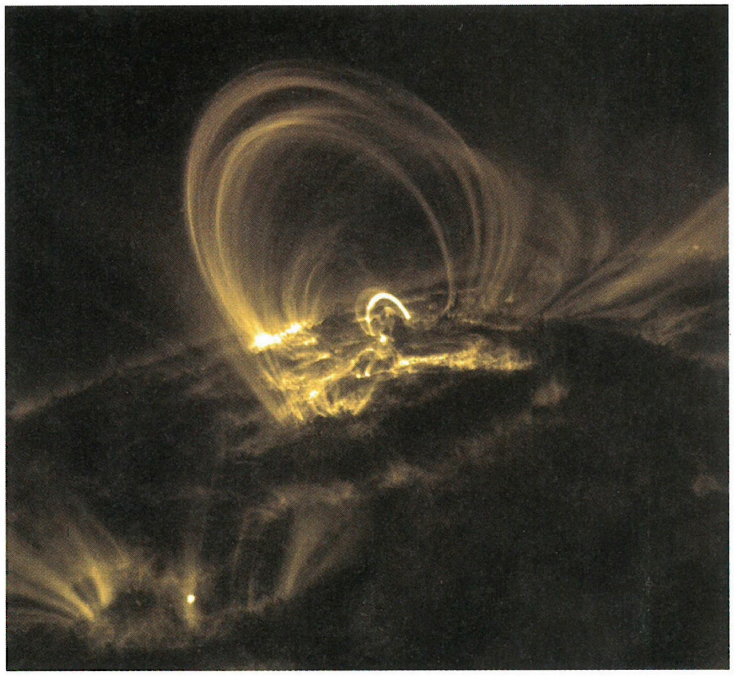
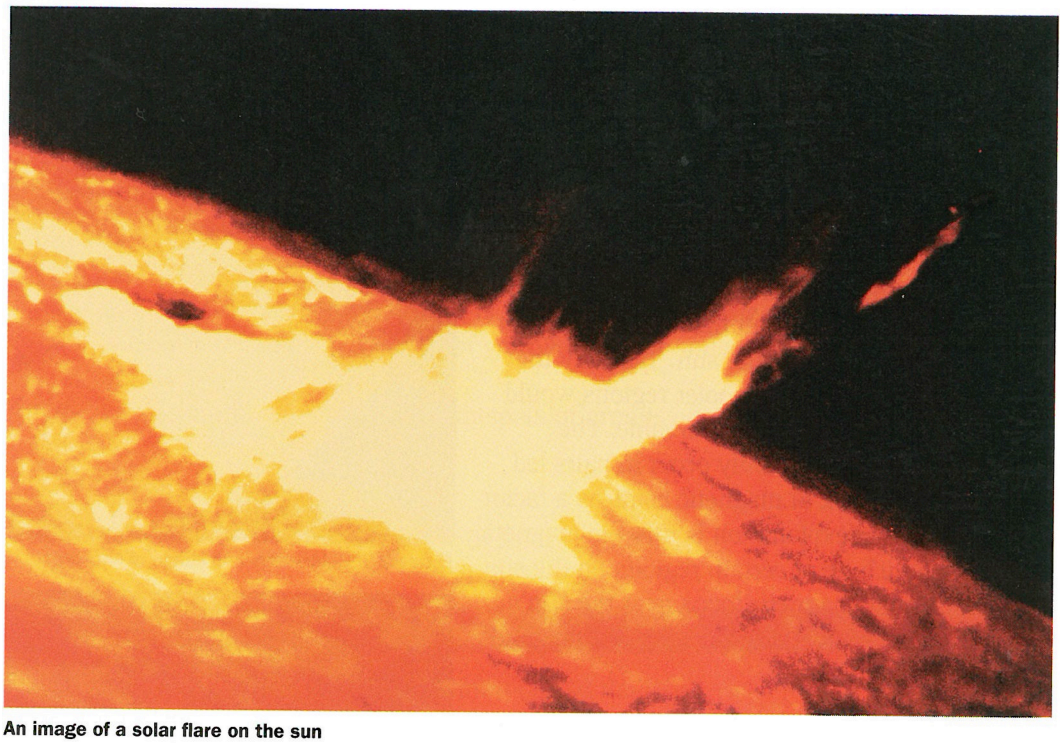


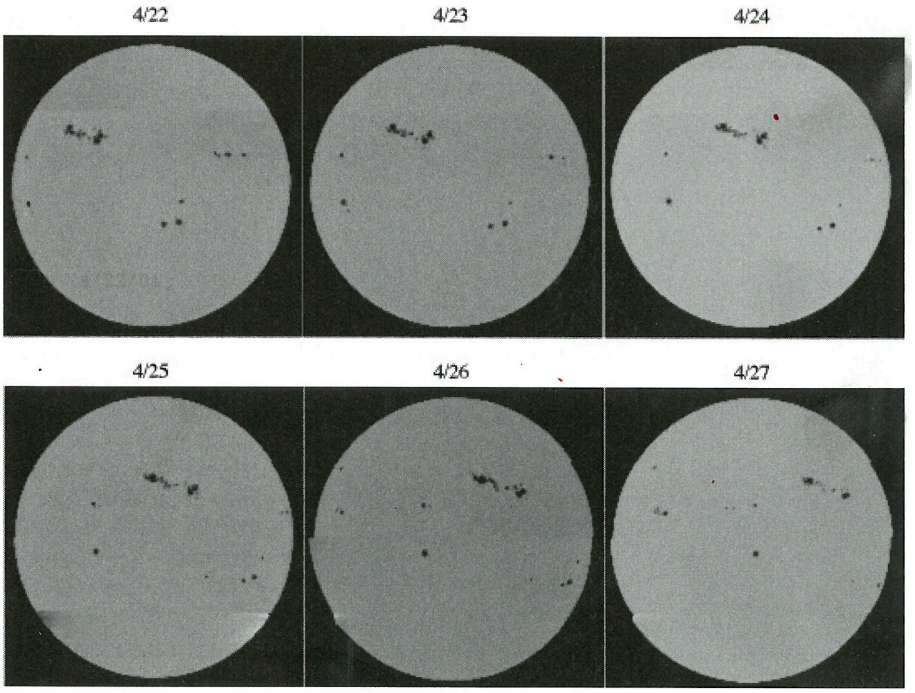
Figure 2-6: Image of solar material tracing out magnetic loops on the sun's surface

that the solar cycle has an impact on Earth's weather, and in the modern era, solar activity can seriously influence electrical devices and communication systems. Solar storms can send huge waves of electrical energy surging along power lines, shorting circuits and burning out equipment. A solar storm in 1989 caused a blackout in Quebec, and coils in a transformer station in Salem, New Jersey melted and caught fire, causing a regional power outage. There is always concern about the effect of CMEs on orbiting satellites and astronauts who are exposed to the elements of outer space during space walks.



An image of a solar flare on the sun

4. Examine the six solar images below. The black splotches you see in the images are sunspots. Their motion across the disk of the Sun will allow you to determine the Sun's approximate rotation rate.
5. Based on the dates printed above each of the images (take between 4/22/2001 and 4/27/2001), estimate the rotation rate of the Sun in days. Write down your estimate below and compare with a classmate.



Estimated rotation rate of the Sun: One rotation every _____ days.

Part 2: What is the Rotation Rate of the Sun?

1. Go to the class website and find the link: Rotation of the Sun-Data Center Link
2. Play the animation
3. Collect sunspot data
    a. Select a group of spots or a single spot that you can track over a significant portion of the solar disk as the Sun rotates.
    b. Turn on the grid and use the solar latitude and longitude values to measure the latitude and longitude of the sunspot or sunspot group you selected.
    c. Use the appropriate buttons to step through the images one at a time. For each date, record the latitude and longitude of the sunspot or sunspot group you selected. Use the data table below to record your latitudes and longitudes.

Date	Solar Latitude	Solar Longitude

4. Calculate the solar rotation rate.
    a. Calculate the angular velocity of your sunspot or sunspot group by dividing the total change in longitude of your spot(s) by the change in time.
        - For example, if you sunspot moved a total of 45° in longitude over a period of 3 days, the angular velocity of your spot would be 45°/3 days = 15°/day.
    b. Divide your calculated angular velocity into 360°.
        - Since one full rotation of the Sun is 360°, the rotation rate of the Sun is 360° divided by the angular velocity of your sunspot or sunspot group.

5. Record the rate of solar rotation you calculated here:_____.

6. Add your rotation rate and the latitude (how far north or south of the Sun's equator) to the class data chart.

7. Calculate an average rotation rate for the Sun based on adding the measurements and dividing by the total number of measurements. Record the average below:

Pause and Reflect

8. Did everyone measure the same rotation rate of the Sun?

9. Does the rotation rate of the Sun vary by latitude (north or south of the equator)?

10. Where were the fastest rotation rates?

11. Where were the slowest rotation rates?