ROTATION OF THE SUN 11

OBJECTIVES

After completing this exercise the student will be able to:

1. follow the linear path of a sunspot across the solar disk.
2. convert this path to a circular arc on the spherical Sun.
3. calculate the synodic and sidereal rotation period of the Sun based on sunspot observations.

STUDENT MATERIALS

mm scale
protractor
compass
calculator

LAB MATERIALS

- tracing paper

STUDENT REQUIREMENTS

This lab is to be done individually, without lab partners. Turn in **Fig. 1** and your tracing paper drawing.

INTRODUCTION

Galileo Galilei first observed sunspots and solar rotation in 1611. Since that time astronomers have determined that our Sun rotates differentially. In other words, the rotation period is slightly shorter near the equator than at higher latitudes.

In this exercise you will use a series of solar photographs to determine the average rotation rate of the Sun. These photos were obtained from the Solar and Heliosphereic Observatory (SOHO) which is a space telescope that orbits the sun directly between the Earth and the Sun. This particular series was taken during a time interval when the Earth was crossing the equatorial plane of the Sun. Therefore, the sunspots appear to move across the solar disk in straight lines. These linear displacements will be transferred to a drawing of the spherical Sun so that an angular velocity can be obtained. From this velocity the synodic and sidereal rotation periods can be calculated.

PROCEDURE

I. Tracing the Apparent Motion of Sunspots

1. On each photo of the Sun locate the north and south indicator marks. Make these marks darker, if necessary, in order to see them through the tracing paper.
2. Measure to the nearest millimeter the diameter of the Sun in the one of the photos.
3. On the tracing paper, draw a circle which has a diameter equal to the above millimeter measurement.
4. Place your circle over one of the images and trace the north and south indicator marks on your circle.
5. On one of the first few photos locate a sunspot near the eastern edge of the Sun and label it as **A**.
6. Locate spot **A** previously identified in step 5 and label it on the next four or five photos in the sequence.

7. On the first photo you labeled with sunspot **A**, carefully overlay your circular drawing onto the solar image. Be sure the center of your circle lies over the center of the Sun's image. Also be sure that your north and south markers are aligned with the solar north and south indicator marks.
8. Trace around sunspot **A** and label this position with the photograph's date. Be sure to include the fractional portion of the date.
9. Move the tracing paper to the next photo and repeat steps 7 and 8. Follow this procedure until spot **A** has disappeared around the Sun's western limb.
10. On your tracing paper use a ruler to draw a line which passes through your plotted sunspot positions. This line should begin and end on the east and west edges of the Sun (the edge of your circle). If some spot positions are not on the line check to see if you traced the correct positions.
11. On the same circle repeat steps 5 through 10 for sunspots at two different latitudes than **A**. Label them as spots **B** and **C**. You may need to start **B** and **C** on photos taken at later dates than the ones used for spot **A**. When you have finished you should have a piece of tracing paper that has one circle with three chords passing across the circle.

II. Finding the Sun's Rotation

If you examine the sunspot paths made in **part I** you will notice that they appear to move more rapidly when near the center of the Sun's disk than when near the limb. This foreshortening is caused by the fact that the Sun is spherical and the linear paths are projections onto a flat surface. In order to determine the Sun's rotation a simple graphical procedure can be used to eliminate errors caused by foreshortening. Imagine the Sun to be a globe with a circle drawn around it at the latitude of a sunspot. Slice through the globe at this latitude. Now if you look down on the Sun from above the rotation axis you should see a disk whose edge represents the circular path of the sunspot. The line drawn through the linear path of each sunspot on your tracing paper represents such a circle seen edge-on.

You will now draw such a circle from your tracing paper overlay.

1. Measure to the nearest millimeter the length of the straight line for spot **A**'s apparent motion across the solar disk. Be sure your measurement goes from the Sun's east limb to its west limb.
2. Draw a horizontal line on **Fig. 1**, for spot **A**, which is exactly this length.
3. Find the midpoint of this line and use a compass to draw a semicircle connecting the two ends. This half circle represents the Earth-facing surface of the Sun at spot **A**'s latitude, and the baseline is its projection onto a flat surface.
4. Use a ruler and transfer the sunspot positions from the tracing paper to the baseline of this semicircle. Be sure to label each position with the dates. When completed you should be able to overlay the tracing paper onto the baseline of the semicircle and get a very close match.
5. Pick two widely spaced positions for spot **A** and draw a vertical line from each position up to the semicircle representing the Sun's surface. Be sure this line makes a 90° angle to the baseline. The intersections of the vertical lines and the semicircle represent two actual positions of spot **A** at two separate times.
6. From the baseline's midpoint (the hole made by the compass) draw lines up to the semicircle which pass through both sunspot positions. These two lines will form an angle at the midpoint.
7. Use a protractor to measure the angle you just made in step 6. It may be necessary to extend the lines so that your protractor can be used properly. Record the angular measurement on your diagram.

8. Subtract the dates of the two sunspot positions to find the elapsed time between them. Record the result beside the diagram. (For spots present in both July and August, you should think of August 1st as July 32nd. Thus, August 10th would be July 41st, for example.)

9. Calculate the Sun's angular velocity, the number of degrees it rotates each day, by dividing the angular measurement by the time interval. Record this value beside your diagram.

10. Repeat steps 1 through 9 for sunspots **B** and **C**.

11. Calculate the average angular velocity of the Sun and record your answer at the bottom of **Fig. 1**.

12. To find out how long it takes the Sun to make one full rotation, its synodic period, divide 360° (the number of degrees in one rotation) by your angular velocity. Record your answer at the bottom of **Fig. 1**. If you have done things carefully you should get a synodic rotation period near 27.3 days ± 2 days.

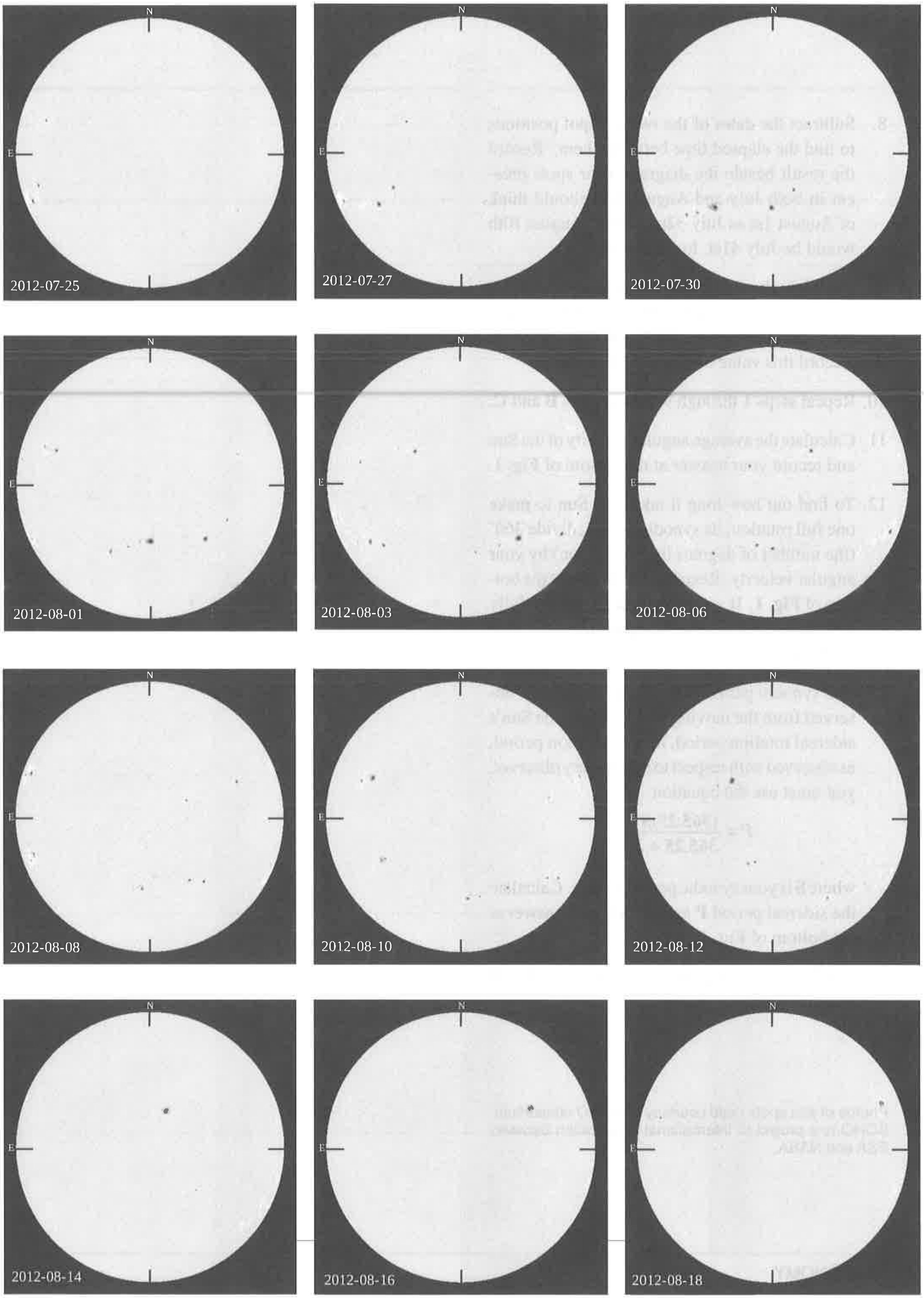
13. The synodic period is the Sun's rotation as observed from the moving Earth. To get the Sun's sidereal rotation period, its true rotation period, as observed with respect to a stationary observer, you must use the equation

$$P = \frac{(365.25)S}{365.25 + S}$$

where **S** is your synodic period in days. Calculate the sidereal period **P** and record your answer at the bottom of **Fig. 1**.

Staple your tracing paper drawing onto **Fig. 1** and turn them in together.

Photos of sun spots used courtesy of SOHO consortium. SOHO is a project of international cooperation between ESA and NASA.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2012-08-14
2012-08-16
2012-08-18

NAME: ______________________

SECTION: ______________________

TIME INTERVAL ______________________

ANGULAR VELOCITY ______________________

Spot A

TIME INTERVAL ______________________

ANGULAR VELOCITY ______________________

Spot B

Fig. 1: Conversion of each sunspot's linear path into a circular arc on the spherical sun.

TIME INTERVAL ______________________

ANGULAR VELOCITY ______________________

Spot C

AVERAGE ANGULAR VELOCITY ______________________

SYNODIC ROTATION PEROID ______________________

SIDEREAL ROTATION PERIOD ______________________

Fig. 1: (continued)