The Sun — Experiment AS07

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Group 49

Lab Section

Objective

- Part A: Scale Model
- Part B: The Proton-Proton Chain
- Part C: The Sun's Rotational Period

Materials

Calculator

Ruler

Procedure

Part A: Scale Model

Most everyone has seen a Hoberman Sphere even without knowing what it's called. It's a popular kids' toy from the early 90s that can shrink and grow by pushing/pulling on it thanks to its scissor-like action joints. Below is a picture of a 48-inch diameter version belonging to the Physics Department at ODU. (Most kids owned a much smaller version.) The second largest one in existence resides at the Liberty Science Center in New Jersey and is 18 feet across when fully expanded.

In this section, we are going to scale down the Sun to the size of our Hoberman Sphere. From here, we'll see how big the solar system is in on scales more relative to what we deal with every day. Provided on the next page is a table with the diameter for each planet (in kilometers).

First, convert the size of the Hoberman Sphere to centimeters. You can do this by multiplying it's diameter by 2.54 inches/cm

Diameter of the Hoberman Sphere: 121.92 cm

To scale everything down, we must convert the real-world sizes to our scale model sizes. Since we are using the Sun as our starting point, we need to know that the Sun's diameter is 1.3927 x10^6 km.

We must then create a Scale Factor in order to scale down all of the real-world sizes.

$$Scale\ Factor = \frac{(Hoberman\ Sphere\ diameter\ in\ centimeters)}{1.3927\ \times\ 10^6\ kilometers}$$

What is your Scale Factor?

Scale Factor: 8.754 x 10^-5

As you calculate the scaled sizes for the planets, enter that value in the table below.

Here is an example of the calculations you will need to do:

The diameter of Mercury is 4.879 x10^3 km. To scale this down just like we did for the Sun, we would then calculate

$$(Scale\ Factor) \times\ (4.879\ \times\ 10^3\ km)\ = 0.43\ cm$$

Object	Diameter (km)	Scaled Diameter (cm)	Real World Object of Similar Size
Sun	1.3927×10^{6}	121.92 cm	Large exercise ball
Mercury	4.879×10^{3}	.43 cm	Width of table saw blade
Venus	1.210×10^{4}	1.06 cm	Bouncy ball
Earth	1.276×10^{4}	1.12 cm	Bouncy ball
Mars	6.794×10^{3}	.59 cm	Width of table saw blade
Jupiter	1.430×10^{5}	12.52 cm	Shot put
Saturn	1.205×10^{5}	10.55 cm	Soft ball (fast pitch)
Uranus	5.112×10^{4}	4.46 cm	Ping Pong ball
Neptune	4.953×10^{4}	4.34 cm	Ping Pong ball
Dwarf Planets			
Pluto	2.370×10^{3}	.21 cm	BB
Ceres	9.50×10^{2}	.083 cm	Mechanical pencil lead
Haumea	1.960×10^{3}	.171 cm	15 Sheets of paper
Makemake	1.900×10^{3}	.166 cm	14 sheets of paper
Eris	2.326 x10+	.002 cm	Human hair

(Be careful to note the value of the exponent in each case.)

Haumea and Makemake are also more oblate than spherical, but this at least gives us an idea of their sizes.

Part B: The Proton-Proton Chain

Open the *Classaction* program you previously installed. Choose *Sun and Solar Energy*, *Animations*, and then ***Proton-Proton Animation***. Watch the animation and answer the following questions.

1. In your own words, write the steps of the proton-proton chain. Be thorough and explain each step of the fusion process.

The proton-proton chain is how hydrogen becomes helium via fusion and releases energy. We start with a total of 4 H protons. In separate chains two hydrogen protons fuse together and release a positron and a neutrino. This same process happens simultaneously on the sperate chain. Now we have H2 with a proton. This proton/neutron then fuses with an additional H proton and releases a gamma ray. Same process happens in separate chain. We now have 2 He3 and those will fuse together releasing 2 H protons and leaving a stable He element.

2. If the Sun puts out $3.8x10^{26}$ Joules of energy per second, use $E = mc^2$ to calculate how much mass is lost by the Sun every second. (*c is the speed of light and is approximately $3x10^8$ m/s*)

M= 4.2 * 10^9 kg

3. Convert the mass loss from kilograms to tons. (1 ton = 907 kg)

4.63 * 10^6 tons.

4. When converting hydrogen to helium in the core of the Sun, the mass-energy conversion is 0.7%. This means that when hydrogen is fused into helium, 0.7% of the mass of the protons involved is lost and converted to energy. Divide your answer for #2 by 0.007 to find the amount of mass of hydrogen that is converted into helium each second in the Sun. Also write this value in tons.

6.615*10^8 tons

5. If a single fusion reaction releases $4.3x10^{-12}$ Joules of energy, then how many reactions are occurring in the core of the Sun each second? (*Hint: Compare the total output of energy to the output for a single reaction.*)

8.88*10^37 reactions

6. If the Sun is 75% hydrogen and has a mass of 1.99×10^{30} kg, how many more years can the Sun theoretically live at its current fusion rate? (*Hint: Find the total amount of the Sun that is hydrogen and compare with the mass loss per second found in #4. Be sure to convert seconds to years at the end of your calculations using 1 year = 3.15×10^{7} s.)*

7.904*10^10 years.

Part C: The Sun's Rotational Period

Four centuries ago, Galileo observed sunspots on the surface of the Sun by projecting an image of the Sun on a screen. He then deduced that the Sun rotates because the spots moved across its face over many days. The Sun is not a solid body but made of gas. Because of this, Sun does not rotate with one period. It is actually in *differential rotation*, with regions at different latitudes rotating with different periods. This activity uses modern images of sunspots to estimate the Sun's rotation period and also the size of sunspots.

1. On the next few pages of the lab are images of the Sun taken on multiple days as. There is also a grid showing latitude and longitude that is overlaid on the images.

2. Inspect the images with the grid overlay so that you can determine the latitude and longitude for the major sunspot group. Each vertical and horizontal line equal 10° latitude and longitude, respectively.

3. Estimate how far the sunspot group moves between day one and day two by subtracting the smaller longitude from the larger. Record this longitude change in the table below. Estimate this number to the nearest whole degree.

4. Repeat this process for the next few days, up to day four, and record your results.

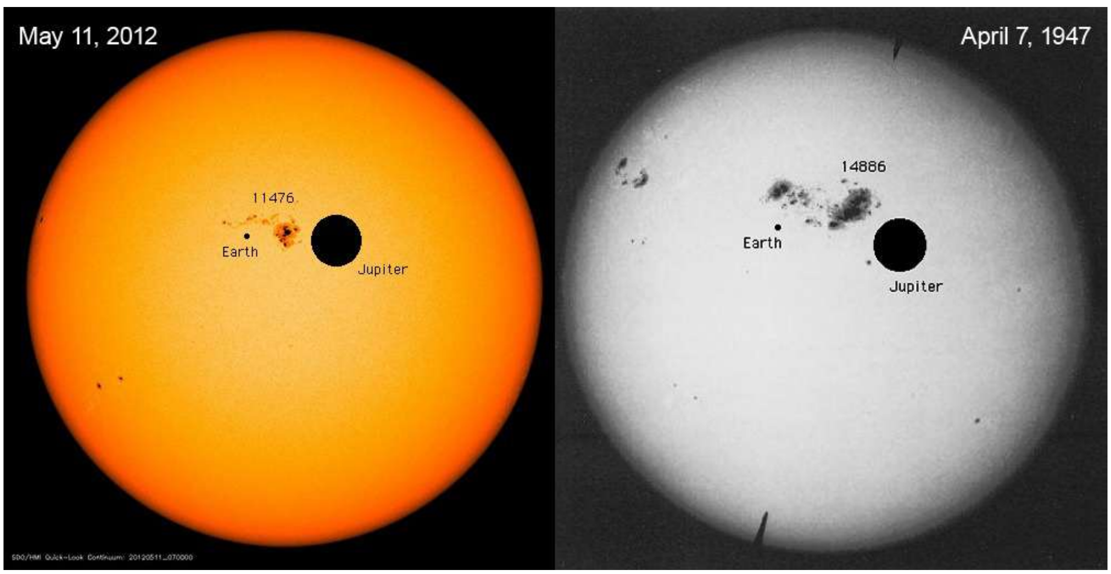
5. The Earth revolves around the Sun at a rate of 360 degrees in one year (365 days) or an average motion of about 1° per day. Since Earth revolves around the Sun in the same direction as the Sun rotates, our motion seems to chase after the sunspots. Thus, the apparent movement of sunspots is less than the real rotation by about 1° per day. Therefore, you must compensate for the orbital motion of the Earth by adding 1° to your compared apparent daily motion.

6. Let us assume that sunspots are features who's position on the Sun does not change very much over the course of a solar rotation. Use the following proportion to calculate the Sun's *period of rotation* (in days):

$$\frac{Corrected\ longitude\ change}{1\ day} = \frac{360°}{X\ days}$$

7. Find the average rotational period and record it in the table below. Calculate to the nearest tenth of a day.

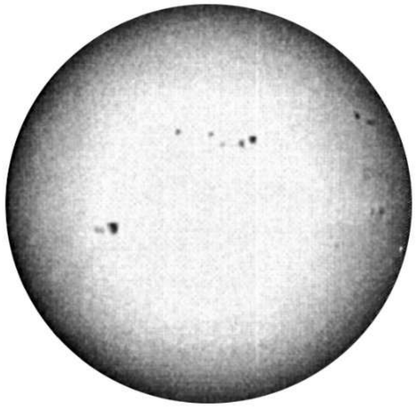
	Longitude of Sunspot Group	Change in Longitude (Ex: Day 2 – Day 1)	Corrected Longitude Change	Period of Rotation (Solve for "X")
Day 1	30			
Day 2	18	12	13	27.7
Day 3	2	16	17	21.2
Day 4	10	12	13	27.7
Average Rotational Period = 25.3				



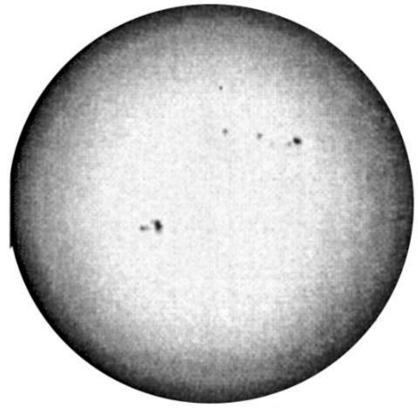
A large sunspot can sometimes be 20 times larger than the Earth.
Image on the left courtesy of NASA's Solar Dynamics Observatory, and the one on the right is courtesy of the Carnegie Institution of Washington and shows the largest sunspot ever captured on film.

8. The diameter of the Sun is about 860,000 miles. Using a ruler, hold it up to your computer screen and measure the size of the sunspot group on the pictures provided, and then set up a ratio similar to that in step 7 to determine the size of the sunspot group in miles.

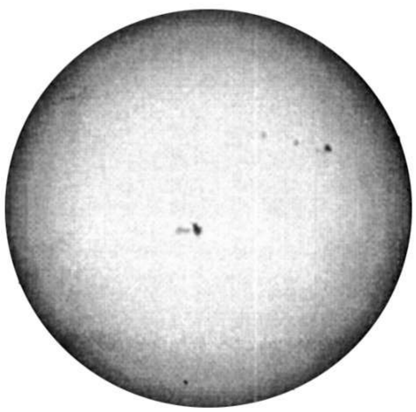
3”= 860,000 miles
Left picture- 3/860000= (¼)/X
X=71,666 miles
Right picture 3/860000 = (¾)/x
X=215000 miles



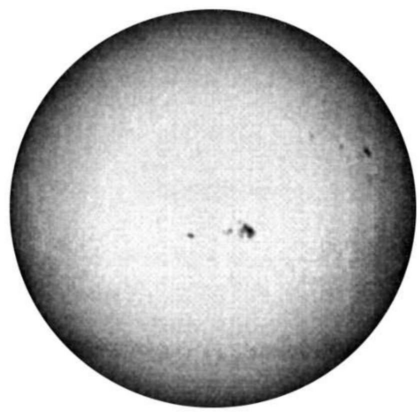
Day 1



Day 2

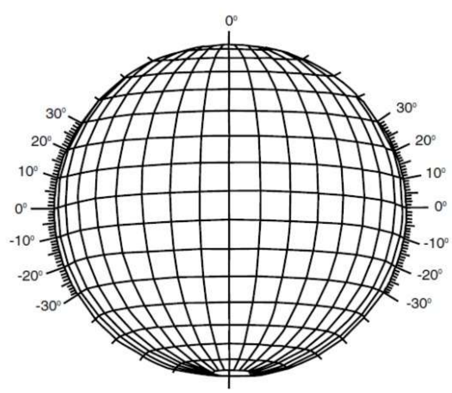


Day 3

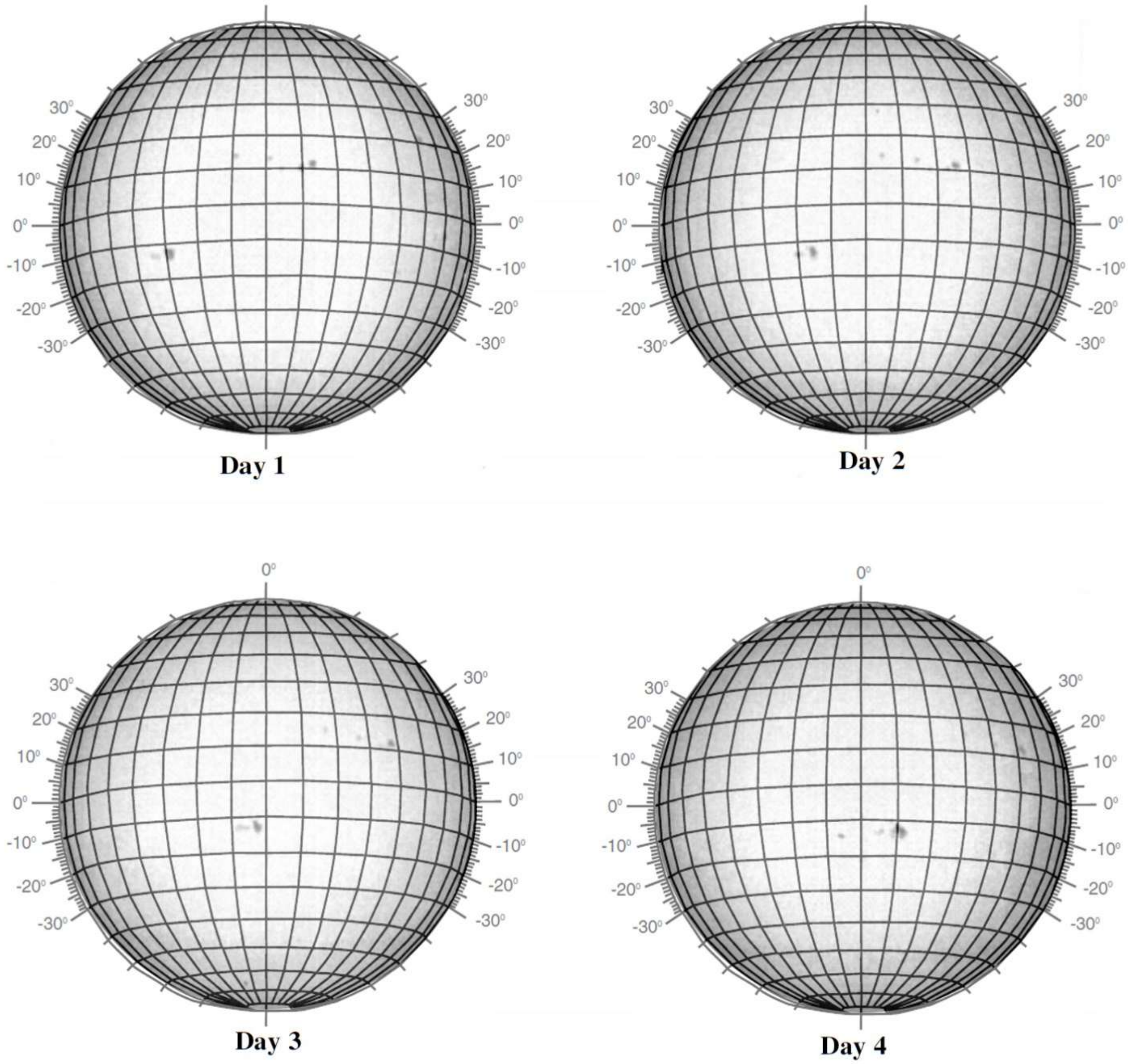


Day 4

Sunspots can be used to determine how long it takes the Sun to rotate about its axis. These visible images were taken by the Japanese Yohkoh spacecraft, during February 12th through the 15th, 1996.



NOTE: Each horizontal or vertical line = 10^0 latitude or longitude, respectively.



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