Solar Viewers

Overview: You are going to start observing the Sun and tracking sunspots across the Sun using one of two different kinds of viewers so you can figure out how fast the Sun rotates.

What to Learn: Sunspots are dark, cool areas with highly active magnetic fields on the Sun's surface that last from hours to months. They are dark because they aren't as bright as the areas around them, and they extend down into the Sun as well as up into the magnetic loops.

Materials

- Tack
- 2 index cards (any size)
- Baader film from Draco Productions
  http://www.dracoproductions.net

Experiment

We're going to learn two different ways to view the Sun. First is the pinhole projector and the second is using a special film called a Baader filter. The quickest and simplest way to do this is to build a super-easy pinhole camera that projects an image of the Sun onto an index card for you to view.

If the Sun is not available, you can use images from a satellite that's pointed right at the Sun while orbiting around the Earth called "SOHO." SOHO gets clear, unobstructed views of the Sun 24 hours a day, since it's above the atmosphere of the Earth. Download the very latest image of the Sun from NASA's SOHO page (choose the SDO/HMI Continuum filter for the best sunspot visibility) and hand them out to the students to track the sunspots.
http://sohowww.nascom.nasa.gov/data/realtime-images.html

<u>Solar Pinhole Projector</u>

1. With your tack, make a small hole in the center of one of the cards.
2. Stack one card about 12″ above the other and go out into the Sun.
3. Adjust the spacing between the cards so a sharp image of the Sun is projected onto the lower paper.
4. The Sun will be about the size of a pea.
5. You can experiment with the size of the hole you use to project your image.
6. What happens if your hole is really big? Too small?
7. What if you bend the lower card while viewing? What if you punch two holes? Or three?

<u>Baader Filter</u>

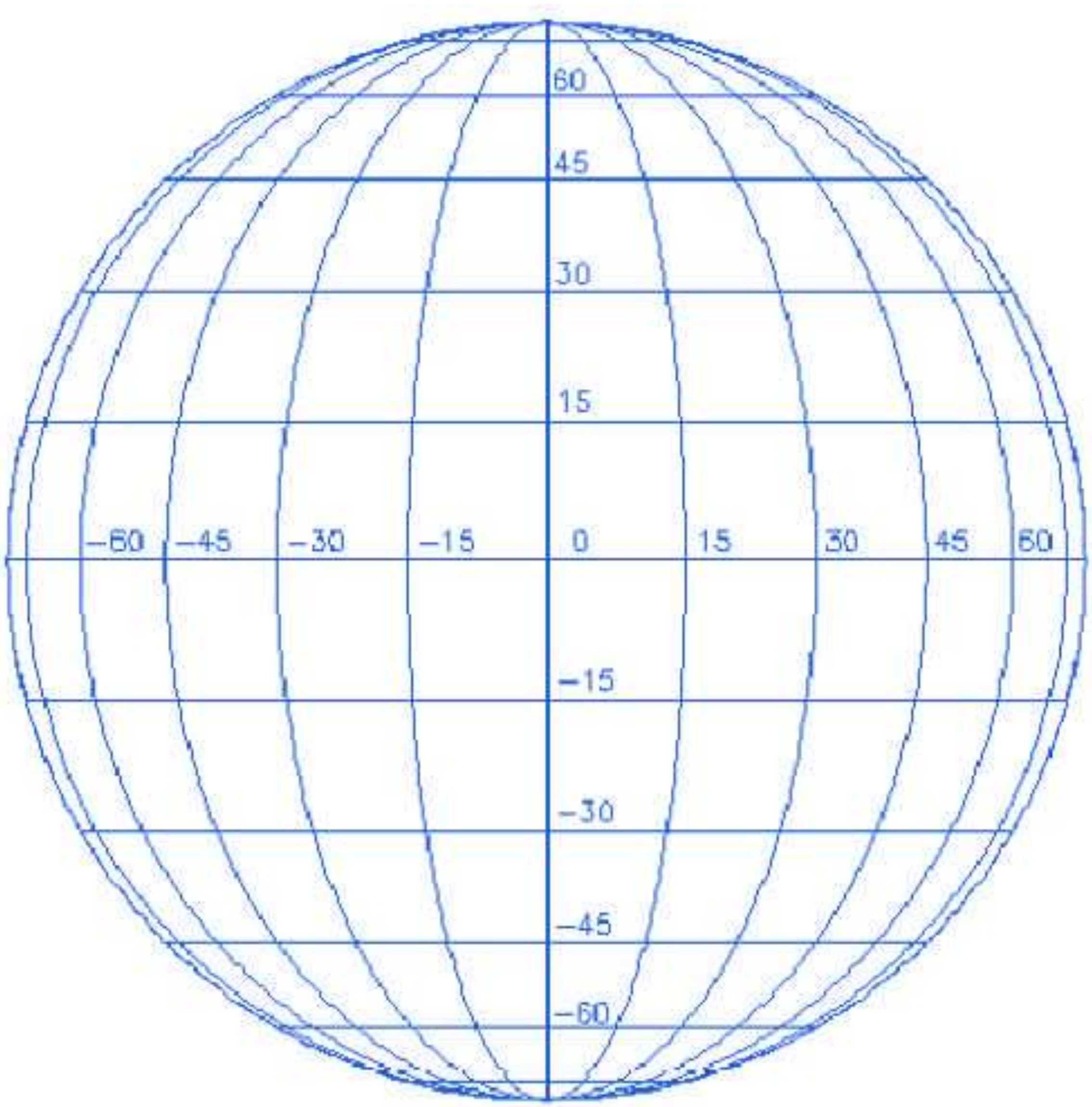
1. Using a Baader filter, you're going to look straight through the filter right at the Sun. Put the filter between you and the Sun, right up close to your eye and look *through* it. It takes a little while to get the hang of seeing the Sun through this filter, but it's totally worth it.

<u>Taking Data:</u>

1. Using either the Baader filter or the solar pinhole projector (or both), you will track the sunspot activity using the mapping grid. You will be charting the Sun for two weeks using the mapping grid.

2. Each day, step outside at the same time each day and look at the Sun using one of the two filter methods.
3. Draw what you see on the mapping grid.
4. Draw the sunspot(s) with the date of the month next to it. For example, on March 13, write a "13" right next to the sunspot picture you drew. If there's more than one sunspot, pick the largest one to track. If you'd like to track *all* of them, label them A-13, B-13, C-13…etc. The next day, label the set A-14, B-14, C-14. For multiple sunspots, use one mapping grid per day.

Mapping Grid



Solar Viewers Data Table

Sunspot (A, B, C…)	Date	Longitude

Reading

Astrophysics not only looks at nearby planets and distant stars, it also deals with the center of our solar system: the Sun. Our Sun is not quite a sphere (it's a little flat on one side), which actually made the initial calculations of Mercury's orbit incorrect when we estimated it to be a perfect ball. Our Sun is a G-type star, and recent measurements indicate that our Sun is brighter than 85% of the stars in our own galaxy. It takes light about 8 minutes to travel from the Sun to the Earth, meaning that if the Sun were to suddenly and magically disappear, we wouldn't know about it for 8 minutes.

The Sun is made of hot plasma and is 1.3 million times the size of our Earth. The Sun holds 99% of the mass of our solar system, but only has 1% of the momentum. It's 74% hydrogen and 24% helium, with trace amounts of oxygen, carbon, iron, and neon. Scientists split the incoming light into a giant 40-foot rainbow and looked for signs of which elements are burning through a special instrument called a spectrometer (you'll be building one of these in this section) to figure out the Sun's composition.

With a 15 million °C core, the Sun is not on fire, but rather generates heat by smacking protons together and getting a puff of energy through a process called nuclear fusion. We can't directly observe the core of the Sun, but we can figure out what's going on inside by watching the patterns on the surface. You'll learn more about this in the activity that covers helioseismology. The surface temperature of the Sun is about 5500°C, so it cools considerably when the gases bubble up to the surface.

The Sun rotates differentially, since it's not solid but rather a ball of hot gas and plasma. The equator rotates faster than the poles, and in one of the experiments in this section, you'll actually get to measure the Sun's rotation. This differential rotation causes the magnetic fields to twist and stretch. The Sun has two magnetic poles (north and south) that swap every 11 years as the magnetic fields reach their breaking point, like a spinning top that's getting tangled up in its own string. When they flip, it's called "solar maximum," and you'll find the most sunspots dotting the Sun at this time.

You know you're not supposed to look at the Sun, so how can you study it safely? I'm going to show you how to observe the Sun safely using a very inexpensive filter. I actually keep one of these in the glove box of my car so I can keep track of certain interesting sunspots during the week!

The visible surface of the Sun is called the photosphere, and is made mostly of plasma (electrified gas) that bubbles up hot and cold regions of gas. When an area cools down, it becomes darker (called sunspots). Solar flares (massive explosions on the surface), sunspots, and loops are all related the Sun's magnetic field. While scientists are still trying to figure this stuff out, here's the latest of what they do know…

The Sun is a large ball of really hot gas – which means there are lots of naked charged particles zipping around. And the Sun also rotates, but the poles and the equator move and different speeds (don't forget – it's not a solid ball but more like a cloud of gas). When charged particles move, they make magnetic fields (that's one of the basic laws of physics). And the different rotation rates allow the magnetic fields to "wind up" and cause massive magnetic loops to eject from the surface, growing stronger and stronger until they wind up flipping the north and south poles of the Sun (called 'solar maximum'). The poles flip every 11 years.

The Sun rotates, but because it's not a solid body but a big ball of gas, different parts of the Sun rotate at different speeds. The equator (once every 27 days) spins faster than the poles (once every 31 days). Sunspots are a great way to estimate the rotation speed.

Sunspots usually appear in groups and can grow to several times the size of the Earth. Galileo was the first to record solar activity in 1613, and was amazed how spotty the Sun appeared when he looked at the projected image on his table.

There have been several satellites especially created to observe the Sun, including Ulysses (launched 1990, studied solar wind and magnetic fields at the poles), Yohkoh (1991-2001, studied X-rays and gamma radiation from solar flares), SOHO (launched 1995, studies interior and surface), and TRACE (launched 1998, studies the corona and magnetic field).

Exercises

1. How many longitude degrees per day does the sunspot move?
2. Do all sunspots move at the same rate?
3. Did some of the sunspots change size or shape, appear or disappear?

Answers to Exercises: Solar Viewers

1. How many longitude degrees per day does the sunspot move? (About 12° per day, and when you divide 360o by 12° per day you get 30 days for a sunspot to move all the way around the Sun. But the Earth is also moving around the Sun in the same direction, but it does this at about 1o per day, so it makes the Sun seem like it's rotating less than it really is. So we need to add 1° per day to the 12, so we get 13 degrees per day, or $360^{\circ} \div 13^{\circ}$ per day = 28 days.)

2. Do all sunspots move at the same rate? (No. Sunspots at the poles move slower than at the equator, about once every 31 days.)

3. Did some of the sunspots change size or shape, appear or disappear? (Yes, all the time!)