ASTRO 101 – M.M. Montgomery

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Solar Flare and CME Hands-On Lab
LWS Heliophysics Summer School 2013

Target Audience: Undergraduate Pre-Service Teachers

Concepts Learned: Flares, CMEs, Frozen-In Flux, Magnetic Fields, timescales, size scales

Methodology: Hands-on modeling of a solar flare and CME using an orange, straws, and a banana

Delivery: Lab Report

Materials: An orange and a banana; clear bendable straws; black Sharpee fine point marker, paper, pencil, scissors

Assessment: Predictions and conclusions in lab report

Reference Texts:

1. Heliophysics I Plasma Physics of Local Cosmos, Chapter 8

2. Heliophysics II Space Storms and Radiation: Causes and Effects, Chapter 5

Usage: Review CME.ppt prior to assigning this hands-on lab

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Introduction

The Sun produces transient events such as solar flares and Coronal Mass Ejections (CMEs). The number of events changes from a minimum to a maximum to a minimum on an 11-year solar cycle, a cycle that maps to the number and locations of sunspots on the Sun.

The Big Questions

In visible light images of the sun,

- what does a sunspot look like?
- what does a solar flare look like?
- what does a CME look like?

Other questions we will answer are:

- What does frozen-in mean and what is frozen in to what?
- When does a CME occur relative to the solar flare event?
- When will a CME's photons and charged particles reach Earth relative to when they were emitted from the Sun?

Pre-Assess Through Drawing and Question

Using paper and a pencil, draw to scale a cartoon of the Sun (i.e., the photosphere), sunspots, a solar flare, and a CME. Also locate on your drawing the relative location of Earth. Label the celestial objects.

On your drawing, label the time of the solar flare t=0. Predict a time relative to 0 when the CME will occur and label the CME with that time. Don't forget to include time units like seconds, minutes, hours, or days.

What is your prediction? ______________________________________

Predict a time relative to 0 when the photons from the flare reach Earth and label that time near your drawing of Earth.

What is your prediction? ______________________________________

Predict a time relative to 0 when the charged particles (i.e., electrons) reach Earth and also label that time near your drawing of Earth.

What is your prediction? ______________________________________

Predict a time relative to 0 when the CME reaches Earth and also label that time near your drawing of Earth.

What is your prediction? ______________________________________

Give your drawing a proper title.

Part I - Modeling a Solar Flare and CME

You will be building a model of a solar flare and CME relative to the size of the Sun. *Italics* represent action items for you to perform hands-on during this lab exercises. Answer the questions given as you complete the hands-on tasks.

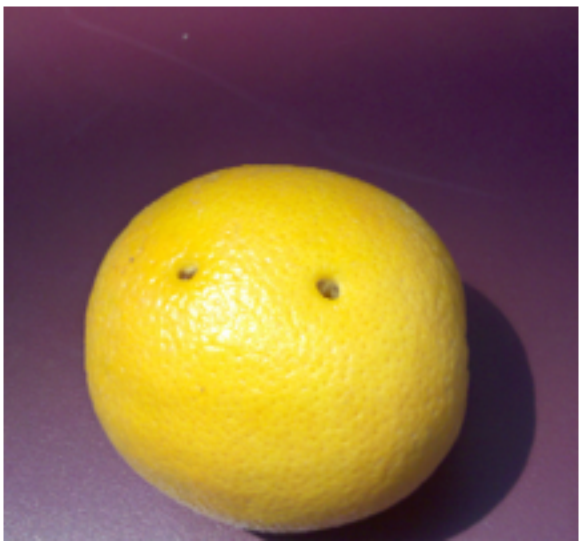
a) *Put an orange on a flat table like that shown below.* The orange represents the Sun.

Choose a whole number between 0 and 11, inclusive, to represent a specific year of the 11-year sunspot cycle.

1. What year did you choose? ______________________________

b) Discuss with your lab partner where a sunspot pair is located on the surface of the Sun for your chosen year of the 11-year sunspot cycle.

Using your Sharpee, mark the location on your orange with two dots to represent your sunspot pair. Using one end of a straw, poke a hole through each spot on your orange, being sure to penetrate through the rind and into the pulpy area of the orange as shown below.



2. For the sunspot pair shown in the picture above, decide whether the distance between the spots is an acceptable value relative to the diameter of the orange. Should the spots be closer? Further apart?

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Answer: Spots should be closer.

3. Light can be emitted (e.g., light bulb), absorbed, transmitted (e.g., a glass window pane), or reflected (e.g., a mirror). Of these four, which explains why the sunspots on your orange appear dark?

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Answer: Reflection - not enough light is reflecting from the holes, hence the holes look dark.

4. Of the four choices given in the previous question, which explains why sunspots appear dark in visible light images of the Sun's photosphere? ____

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Answer: Emitted – not enough light is emitted from sunspots. One could also argue, based solely on the color black, that the sunspot could be absorbing the energy from the hotter, deeper interior and not re-emitting it in visible light, but ultimately 'emission' is still the best choice.

5. If temperature is an indicator of color where violet V in the rainbow of colors ROYGBIV is warm and red R is cool, what temperature is the color of the sunspots relative to rest of the Sun's photosphere? Answer using either 'hotter' or 'colder' and using one letter of the ROYGBIV (e.g., hotter than I, colder than G, etc.). ______________

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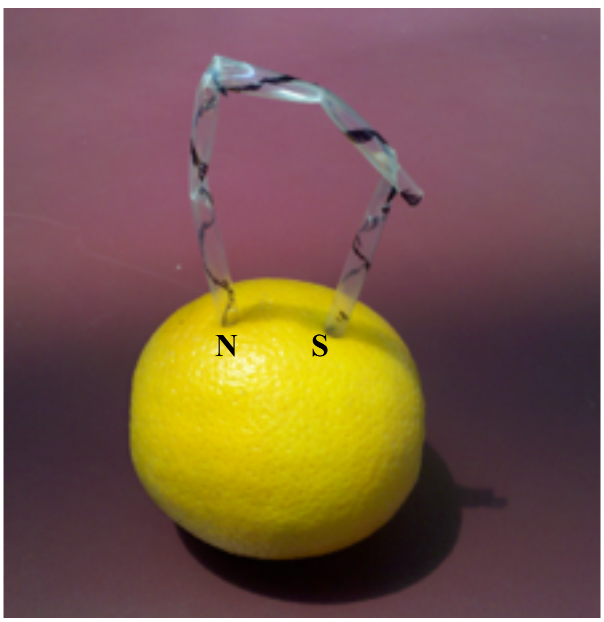
Answer: The poked holes appear black and sunspots on the Sun also appear black in visible light images of the Sun. Sunspots are cooler regions than the surrounding areas of the photosphere. Thus the correct answer is 'colder than R' as black is colder than red.

c) *Using your Sharpee, label one spot 'N' and the other 'S' on your orange to represent the north and south magnetic poles of the sunspot pair (i.e., like a bar magnet).*

While rolling a clear plastic straw on the table, drag your Sharpee pen from one end of the straw to the other end. The net result should be a straw that, when held vertically, looks like a barbershop pole.

Bend the straw and place both ends through the sunspots on the orange and into the pulpy area as shown below:



6. What does the straw represent about the Sun in the image shown above of a model Sun? (*Hint:* One footpoint is labeled S whereas the other footpoint is labeled N. The location of a footpoint is where one end of the clear plastic straw meets a sunspot). _________________

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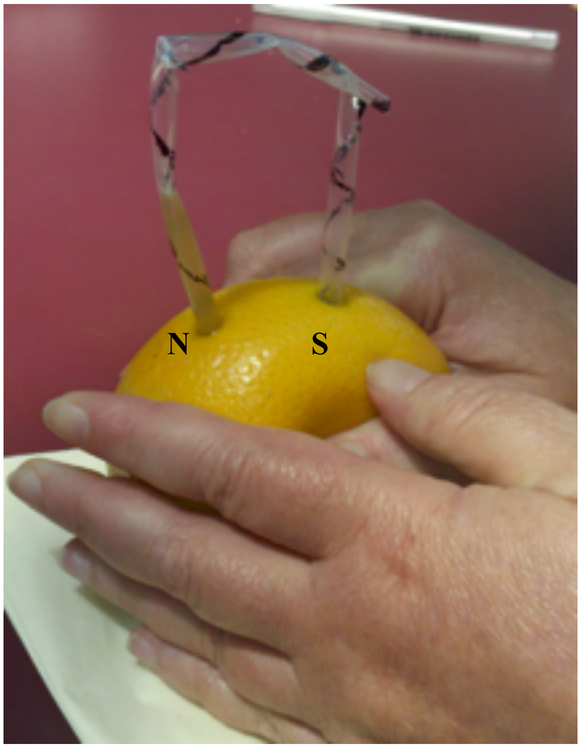
Answer: The magnetic field line(s) of the Sun.

d) *Squeeze the orange so the juice flows up through the straw. Using your cell phone or other camera, take a picture like the one shown:*



The juice represents the Sun's plasma (that is, charged particles such as electrons). Where the juice moves, the straw remains with it.

Move the juice-filled straw around. Where the straw moves, the juice remains with it.

Add a second, similarly drawn straw into the same sunspots to make two loops side-by-side (not shown).

7. Explain the concept of 'frozen-in' with regards to the juice in each straw. ____

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Answer: The juice in each straw is frozen-in to that same straw and each straw is frozen-in to the juice within that straw (i.e., juice can flow along each straw but not cross through one straw and into the other straw).

8. Explain the concept of ‘frozen-in’ with regards to the Sun. _______

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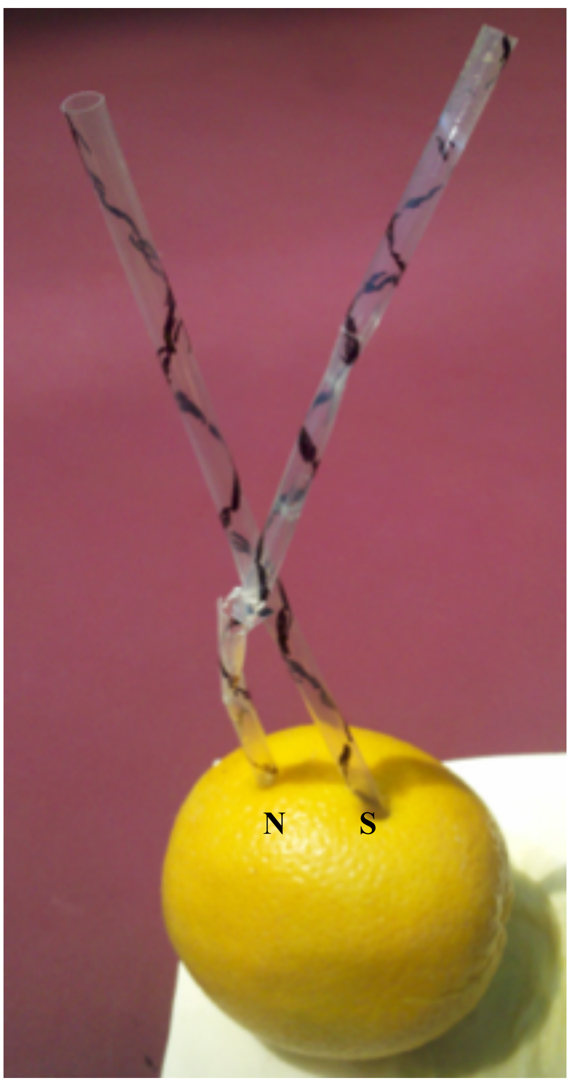
Answer: Each straw represents a magnetic field line of the Sun that exits a S pole and enters a N pole. The juice represents the plasma of the Sun. The magnetic field lines of the Sun and the Sun’s plasma are frozen-in to each other. Wherever the magnetic field lines move, the plasma moves with them. The plasma can move along magnetic field lines but not cross from one magnetic field line to another.

d. *Using scissors, cut the straws at the top of the loop* (see below):



Squeeze the orange again so the juice flows up through and squirts out of the straws.

9. What solar event is represented by the breakage of the straw and the immediate emission of juice away from the orange? __________

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Answer: A solar flare

10. If the Earth is located below the table in the above image, will Earth be in the path of this solar event? How do you know? ________

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Answer: No, the solar flare plasma (i.e., spitting juice from orange) is away from the Sun and in a straight-line path that is not in the direction of Earth as Earth is located under the table.

e. *Take your banana and put it above the breakage in your straws. Squeeze the orange so the juice is once again flowing out of the straws. Using your cell phone or other camera, take a picture.*

11. The banana represents a bubble of plasma being emitted awhile later, after the breakage and emission of plasma has occurred. What solar event does the banana represent? ________________________

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Answer: A CME

12. What else besides a bubble of plasma is emitted during this solar event? (*Hint:* plasma travels really slow, much slower than the speed of light *c.*) ____

Answer: Light

13. Which travels the fastest through space and arrives at Earth first – the plasma bubble or your answer to the previous question? How do you know? ____

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Answer: The light as this particle is lightest and travels at the speed of light whereas the charged particles in the plasma are heavier and travel at speeds much slower than the speed of light.

14. In the space below, form a chronological scenario of a CME and a solar flare. Use the pictures you took in this lab in your explanation. Explain how these solar events may impact Earth based upon Earth's location in the solar system and the path of the solar events. If Earth is impacted, explain which particle hits Earth first and why.

Answer: A plasma loops breaks at the top of the loop, light and charged particles are emitted during this solar flare event. Later, a CME bubble is emitted as well as the light associated with the CME solar event. If Earth is in the path of the solar flare or CME, then Earth will be impacted. The light from either the solar flare or CME event will arrive first as light travels at the speed of light. The charged particles will hit Earth at a later time as charged particles are heavier than photons and thus travel much slower than the speed of light.