Module 1: What are the features of the Sun?

Activity B: Observing the Sun

Overview

Did you know Galileo first discovered sunspots over 400 years ago in 1612? Galileo used the newly invented telescope to safely view the Sun by projecting its image onto paper. During his observations, Galileo saw dark spots that moved across the surface of the Sun. Galileo's critics believed the Sun was "perfect" so the dark spots could not be on the Sun but instead said they were small planets that circled around the Sun. How could Galileo prove his discovery was correct?

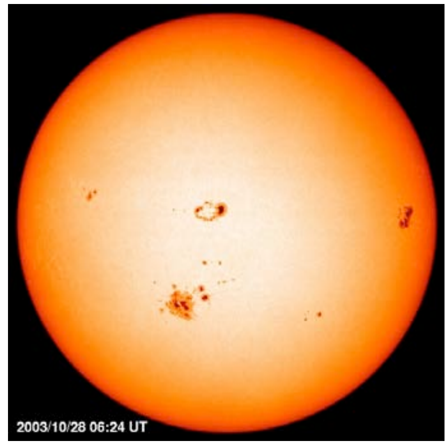


Image: NASA

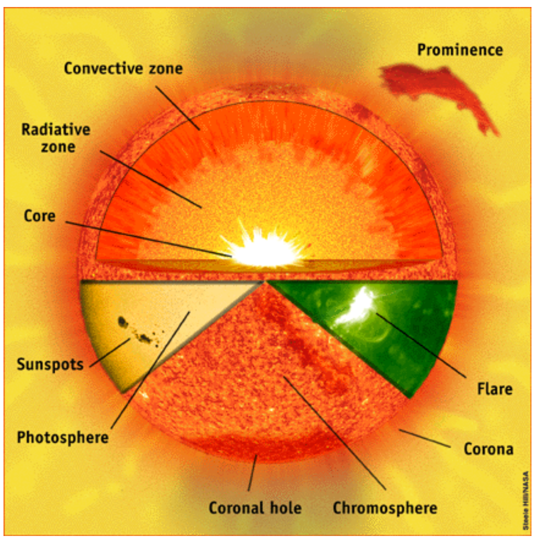


Image: NASA

What are sunspots, how and where are they formed, and what do they tell us about the Sun? How can Galileo's claim be tested? In this module you will investigate and observe sunspots firsthand to find out the answers to these and other sizzling solar questions!

Team Goal

Your goal is to test Galileo's claim and observe sunspots over a period of time to determine the relationship between sunspots and the Sun.

Materials

- Computer with Internet access
- 1 "Galileo's Claim" lab sheet
- 1 "Solar Latitude & Longitude Grid" data sheets
- 14 "Daily Sunspot Observations" data sheets
- 1 "Tracking Sunspot Movement" data sheet
- 1 "Tracking Sunspot Movement" Graph
- Printer (shared)
- Copier (shared)
- Ruler
- Pencil
- Eraser
- Calculator

Engage & Explore!

1. BUILD Knowledge:

Gain understanding of the SDO Mission

Watch these NASA and NOVA Sun Lab videos for an introduction to the Solar Dynamics Observatory (SDO) and how space telescopes help us understand and learn more about our Sun.

Intro to SDO Video
SDO Science Overview Video
Solar Space Telescopes Video

2. APPLY Learning:

Self-test on the science of sunspots

Take the Stanford Solar Center's online Sunspot Quiz to test your Solar IQ! This knowledge is useful for Module 2B "Solar Activity & Magnetism".

Sunspot Quiz

3. DEMONSTRATE Ability:

Student-scientist research to test Galileo's claim

(Adapted from Stanford Solar Center's activity "Are Those Sunspots Really on the Sun?")

Each of these completed module resources will be used as artifacts for your team's Module 4 SDO Exploration Museum 3-D Solar Exhibit. Prior to starting your sunspot investigation, review and research the following to help build your expertise as a solar scientist:

- What are latitude and longitude lines; which one has a vertical orientation and which one has a horizontal orientation? Latitude and longitude lines can be "drawn" on the Sun similar to how latitude and longitude lines are shown on a map or globe of Earth.
- What is an HMI Intensitygram image and how is it created?
- How are sunspots identified on an HMI Intensitygram of the Sun?
- What do the darker and lighter colors on an HMI Intensitygram solar image indicate?

Introduction:
Using NASA's Solar Dynamic Observatory (SDO) website and actual solar data, observe sunspots like Galileo did and discover what he learned about the Sun by studying sunspots! As a scientific team, you will investigate and determine the relationship between sunspots and the Sun. During this investigation your student-scientist team will:

- Investigate Galileo's claim that sunspots are on the Sun's surface and not in orbit around the Sun.
- Collect and analyze SDO HMI Intensitygram sunspot images for 14 days as scientific evidence.
- Collect and analyze any changes in the shape, size, number, latitude, longitude, and location of sunspots as scientific evidence.
- Respond to discussion questions based upon your team's analysis of the evidence.
- Using the evidence, provide scientific reasoning about Galileo's claim that sunspots are on the surface of the Sun and not objects that orbit around the Sun.

Part 1: Galileo's Claim
First, discuss what your team already knows about sunspots.

Next, read and discuss your team's thoughts on Galileo's claim about sunspots:

Sunspots are located on the surface of the Sun and are not objects that orbit in space around the Sun.

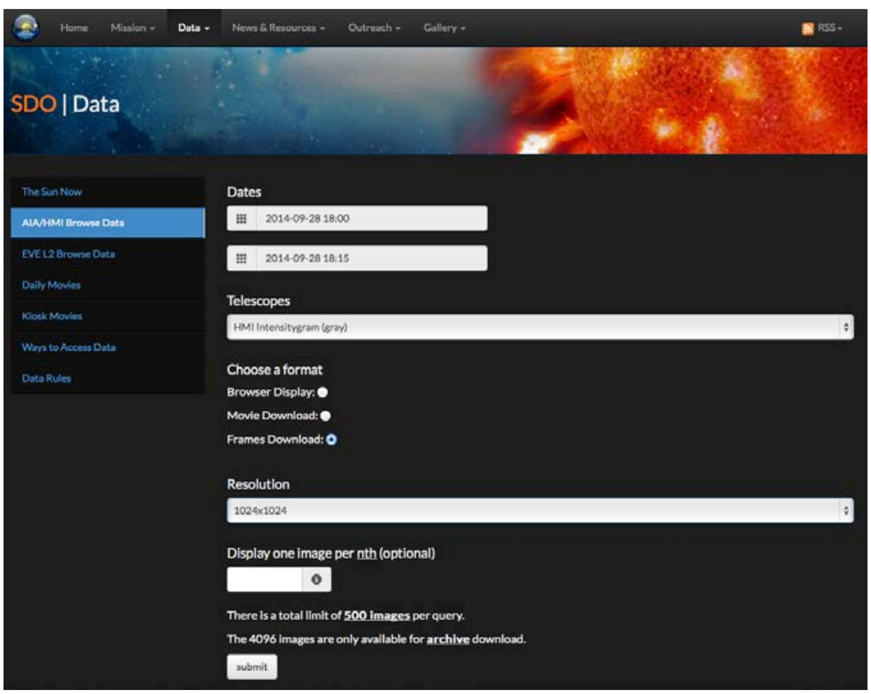
On the "Galileo's Claim" lab worksheet, write your team's ideas on how you can test Galileo's claim that sunspots are located on the Sun's surface and do not orbit around the Sun.

Part 2: Collect and Assess Sunspot Evidence
Sunspot Observation Tips:

- It is very important that scientists collect and record data accurately!
- Most (but not all) sunspots appear in groups, so we will call all sunspots **sunspot groups**, even in cases where there is a single sunspot.
- When measuring sunspots, measure only the large "blotches" and don't measure the much smaller "dots" or the spread-out areas that look like lace.
- Start with the current day's image. Record the necessary solar data on your team's "Daily Sunspot Observations" and "Solar Latitude & Longitude Grid" data sheets.
- If you have less than two weeks available for research or if there are not any substantial sunspots in recent images, use solar images from a previous 14-day period of time that have sunspots.

A) Sunspot Image Collection:

1. Each day, navigate to the Solar Dynamics Observatory "The Sun Now" webpage (http://sdo.gsfc.nasa.gov/data/). In the left sidebar, click on "AIA/HMI Browse Data" tab.
2. Dates: In the first date field, select a day as a start date and a time that day (e.g. 28 September 2014, 18:00). In the second date field, select the same date and a time 15 min. later than the start time (e.g. 28 September 2014, 18:15).
3. Telescopes: Scroll down and select the "**HMI Intensitygram (gray)**" image of the Sun (NOT the HMI Intensitygram (orange) or HMI Magnetogram).
4. Choose a format: Select "Frames Download".
5. Resolution: Choose 1024x1024.
6. Submit: Click the "Submit" button. Your image will be saved as a zip file in downloads labeled "(number)hmii.tar". Click on this zip file and the information will be available in downloads via a folder labeled "data", which contains multiple sub-folders. The "img" sub-folder contains an hmii.jpg file of the solar image. Rename the file by using the correct image date as the saved file name (e.g. "Image_11_05_13" is the file name for the HMI Intensitygram on Nov. 5, 2013). If you receive an error message, check that the date and time selected are correct (it may be necessary to try different dates/times to get a solar image).
7. Print the image; write the date and time range on it



B) Sunspot Data Recording:
Follow these steps to record SDO sunspot image data for a 14-day period of time. Keep track of up to five of the same sunspot groups over the two-week period. Identify and track the major sunspot group(s) as follows:

1. Use each day's SDO HMI Intensitygram solar image to identify and plot major sunspot groups. Accurately monitor up to five of the same sunspot groups for two weeks.
2. On the "Solar Latitude & Longitude Grid" data sheet, locate the latitude and longitude coordinates and sketch a picture of each sunspot group and label each sunspot group with its name and observation date (e.g. SG 1, Date 9/28/14).
3. On the "Daily Sunspot Observations" data sheet, record the date, latitude, longitude, and location (distance of center of sunspot group from the left edge of Sun in 0.0 cm.) for each sunspot group.
4. Record any observed changes for each sunspot group (change in size, shape, increase (new) or decrease (loss) of sunspot groups). Check all work!

C) Sunspot Data Analysis:
Use the recorded information from the "Daily Sunspot Observations" data sheet to complete the "Tracking Sunspot Movement" data sheet. Next, use the "Tracking Sunspot Movement" data sheet to make a "Tracking Sunspot Movement" graph to visually represent your sunspot data.

1. On the "Tracking Sunspot Movement" data sheet, record the date each sunspot group is first observed, the date it is last visible on the Sun, and the distance the sunspot group is located from the left edge of the Sun on each of these two dates.
2. Create a "Tracking Sunspot Movement" line graph to show the same sunspot groups' change in distance over time. On the x-axis, label it "Observation Date" and list the dates for Day 1 through Day 14.
3. On the y-axis, label it "Observed Sunspot Location (cm)" and use a suitable, incremental scale.
4. For each sunspot group, use the "Tracking Sunspot Movement" data sheet to plot the day the sunspot group is first observed (x coordinate) and its observed location on that date (y coordinate) and do the same to plot the last day the same sunspot is visible and its location on the Sun.
5. Draw a line between each sunspot group's starting and ending points to show its movement across the Sun over time.
6. Include a title, origin, and key on the graph.

D) Discussion Questions:
Write your team's responses to the following questions in the "Galileo's Claim" lab sheet. State specific data from your team's SDO "HMI Intensitygram (gray)" solar images, "Solar Latitude & Longitude Grid", "Daily Sunspot Observations", "Tracking Sunspot Movement" data sheets, and "Tracking Sunspot Movement" graph to provide supporting scientific evidence for your answers.

1. Were there any changes in the shape, size and/or number of the sunspot group(s) during your investigation or did the sunspot(s) remain the same the entire time?
2. Do sunspot groups stay stationery (in the same place) or do they move? If they move, which direction do sunspots move horizontally across the Sun's disc (visible face of the Sun)? Do sunspots move vertically up or down on the Sun's disc?
3. Do sunspots only appear and disappear on the solar limb (edge of the Sun's disc) or do sunspots appear and disappear anywhere within the Sun's disc?
4. Discuss and decide if your scientific evidence supports Galileo's claim that sunspots are features on the Sun's surface and that they are not objects in space that orbit around the Sun. Give three specific examples of evidence that support your team's decision.

Part 3: Concluding Statement - Claims, Evidence and Reasoning

Based upon your team's analysis of the SDO HMI Intensitygram solar images, "Solar Latitude & Longitude Grid", "Daily Sunspot Observations", "Tracking Sunspot Movement" data sheets, and "Tracking Sunspot Movement" graph, write a concluding statement on Galileo's claim about sunspots. Refer back to the Part 2 "Collect and Assess Sunspot Evidence" section to write your team's statement. Use your scientific evidence to provide reasoning in response to Galileo's claim. Follow these prompts to complete your statement:

1. First, restate Galileo's **claim** regarding sunspots in relation to the Sun.
2. Second, state whether your team's scientific **evidence** does or does not support Galileo's claim.
3. Third, provide scientific **reasoning** that explains why your evidence does or does not support Galileo's claim about the relationship between sunspots and the Sun. Use specific evidence from your data to support your claim, such as patterns in the data, measurements including units, visual evidence, etc.
4. Ensure that you use complete sentences with correct capitalization, punctuation, spelling, and grammar when writing your conclusion.
5. Re-read and edit your concluding statement to ensure your team effectively communicates the science you learned!

Super, you are now Sunspot Specialists!