# Module 1: What are the features of the Sun?

Activity B: Observing the Sun

## Overview

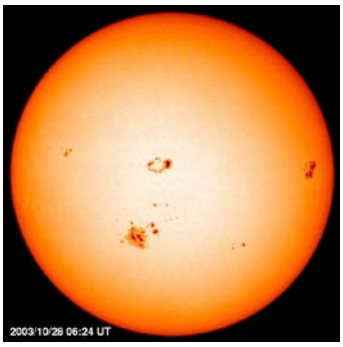



Image: NASA

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 Sun. He claimed sunspots were located on 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?

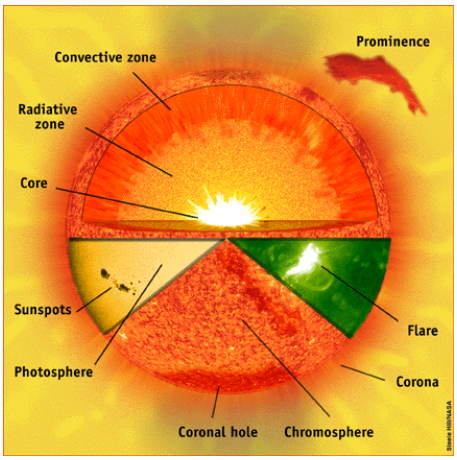



Image: NASA

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!

**Teacher Overview**

All modules in the *SDO Project Suite* are student-led activities, which means the role of the teacher is to support student learning rather than directly lead it. The objective of Solar Module 1 is to provide students with a fundamental understanding of the Sun's structure and function. The focus of Module 1B is to enable student-scientist teams to incorporate actual solar images and data to research sunspots and understand their relationship to the Sun.

**Objectives**

Students will be able to:

- Acquire current solar images from the Internet and record the latitude and longitude coordinates of sunspot groups.
- Calculate and plot apparent sunspot movement and describe changes in the size, shape, and quantities of sunspot groups.
- Determine whether sunspots are features on the surface of the Sun, or objects in orbit around the Sun.

**Essential Vocabulary**

- Coordinate
- Orbit
- Latitude
- Longitude
- Mean (average)
- Solar Disc
- Solar Limb
- Sunspot/Sunspot Group

## 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 sheet
- 14 "Daily Sunspot Observations" data sheets
- 1 "Sunspot Movement" Graph
- Printer (shared)
- Copier (shared)
- Ruler
- Pencil
- Eraser
- Calculator

**Module Lesson**
Time: 2 block periods/4 class periods total to introduce & conclude lesson, plus 10 consecutive days to download & print current HMI Intensitygram solar image (10-15 min./day)

Materials: per team

- Computer with Internet access
- 1 "Galileo's Claim" lab sheet
- 1 "Solar Latitude & Longitude Grid" data sheet
- 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

Teacher Prep:

- Bookmark "Intro to SDO" video, "NOVA Sun Labs: Solar Space Telescopes video, and "The Sun Now" Internet links on computer(s)/Smart Board
- Make team copies of "Galileo's Claim" lab sheets, "Solar Latitude & Longitude Grid", "Daily Sunspot Observations", "Tracking Sunspot Movement" data sheets, and "Tracking Sunspot Movement" graph
- Prepare remaining materials

## 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

**Student Engage/Explore Activities**

**1. BUILD Knowledge:**

**Gain understanding of the SDO Mission**

Each team views the introductory video to learn about the Solar Dynamic Observatory (SDO), what we are learning from SDO, and why SDO is important to us on Earth. Also, students gain insight as to how space telescopes collect and transmit images that students will be collecting, recording, and analyzing as data to test Galileo's claim that sunspots are on the Sun's surface and not objects orbiting around the Sun.

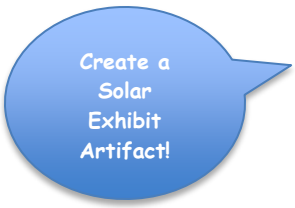
Intro to SDO Video
SDO Science Overview Video
Solar Space Telescopes Video

**2. APPLY Learning:**

**Self-test on the science of sunspots**

Each student in each team individually takes the online Stanford Solar Center "Sunspot Quiz" to test their understanding of sunspots and their relation to the Sun. This quiz provides instant "re-teaching" of concepts if students choose an incorrect response. This knowledge is useful for Solar Module 3 B. "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?

**3. Demonstrate Ability:**
**Student-scientist research to test Galileo's Claim**

Student teams follow the instructions in the Solar Module 1B Student Guide and record their information for the "Galileo's Claim" lab sheet using the "Daily Sunspot Observations", "Solar Latitude & Longitude Grid", and "Tracking Sunspot Movement" data sheets and graph, as required.
(Inspired by Stanford Solar Center's activity "Are Those Sunspots Really on the Sun?")

Prior to starting their sunspot investigation, teams review the following concepts and information:

- Review latitude and longitude lines & coordinates
- Learn about HMI Intensitygram solar images
- Understand how to identify sunspots on an HMI Intensitygram

**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.

Procedure:
Student-scientist teams utilize NASA's Solar Dynamic Observatory (SDO) "The Sun Now" webpage to access real-time HMI Intensitygram solar images to study current sunspots. During this five-part investigation, teams apply the scientific method process to investigate and determine the relationship between sunspots and the Sun in order to:

- Test Galileo's claim that sunspots are on the Sun's surface and not in orbit around the Sun.
- Download, print, and review SDO HMI Intensitygram sunspot images for consecutive 14 days.
- Record and analyze any changes in the shape, size, number, latitude, longitude, and location of sunspots. Track the movement of sunspots on the Sun's surface.
- Answer discussion questions based on analysis of data to provide evidence for the patterns presented in the data.
- Apply scientific evidence and reasoning in response to Galileo's claim that sunspots are on the surface of the Sun and not in orbit around the Sun.

Part 1: Galileo's Claim
Before starting their scientific investigation of sunspots, teams discuss Galileo's scientific claim:
*Sunspots are located on the surface of the Sun and are not objects that orbit in space around the Sun.*

Next, each team writes down ideas on how to test Galileo's claim that sunspots are located on the Sun's surface and do not orbit the Sun. Students may know that sunspots are on the Sun's surface but do not know how to prove this scientific fact.

## 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 2 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:

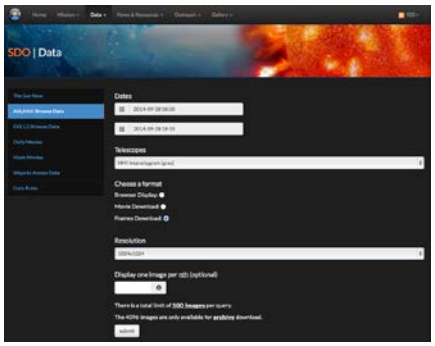
1. Each day, navigate to the Solar Dynamics Observatory "The Sun Now" webpage (http://sdo.gsfc.nasa.gov/data/). In the left sidebar, click on "AIA/HMI Browse Data" tab.
2. Dates: In the first date field, select a day as a start date and a time that day (e.g. 28 September 2014, 18:00). In the second date 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.

Part 2: Collect and Assess Sunspot Evidence

Review the Sunspot Observation Tips with students. Use a pre-printed SDO HMI Intensitygram image that highlights examples of each tip.

SDO Daily Sunspot Image
For a consecutive 14-day period of time, teams follow detailed steps to collect and record sunspot data from SDO HMI Intensitygram solar images. Teams will observe the current day's solar image and identify each of the major sunspot group(s). Next, students record and plot the following data for each sunspot group on their team's "Daily Sunspot Observations" and "Solar Latitude & Longitude Grid" data sheets.

If time or computers are limited, have a pre-printed and laminated set of daily SDO HMI Intensitygram solar images for a two-week period of time available for student teams to use. Teams may use the same two-week image set or each team may use a different two-week image set for comparing and contrasting solar variability.



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.

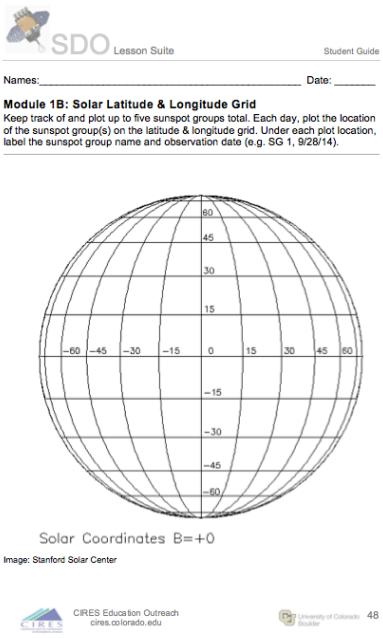
Part 2: Collect and Assess Sunspot Evidence

Sunspot Data Collection

Each day after reviewing the current SDO HMI Intensitygram image, teams plot and sketch each major sunspot group on the "Solar Latitude & Longitude Grid". Next, teams complete each section on the "Daily Sunspot Observation" data sheet. Provide an example image and data sheet.

Sunspot Data Analysis

Sunspot groups do not appear or disappear on the Sun's disc at the same so it is important to explain to students that they must carefully note which day of observation sunspot groups appear and note which day of observation the same spot is no longer visible. Also, it is important that the distance each sunspot group is from the left limb (edge) of the Sun is accurately measured (from the Sun's left edge to the center of the sunspot group to the nearest 0.1 cm.). Sunspot groups change their size, shape, numbers, and location due to the effects of solar activity and the Sun's rotation.



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**Module 1B: Solar Latitude & Longitude Grid**

Keep track of and plot up to five sunspot groups total. Each day, plot the location of the sunspot group(s) on the latitude & longitude grid. Under each plot location, label the sunspot group name and observation date (e.g. SG 1, 9/28/14).



Solar Coordinates B=+0

Image: Stanford Solar Center

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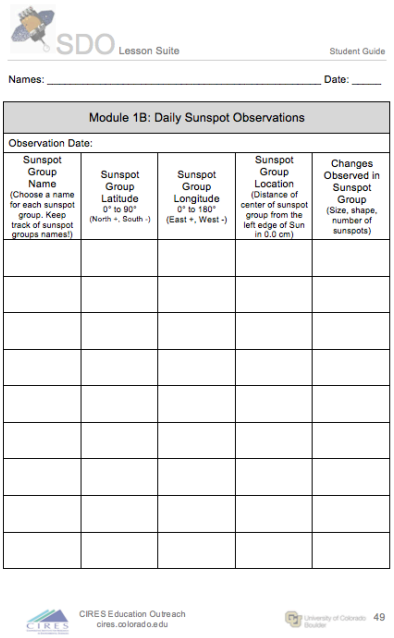

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Names: _____ Date: _____

| Module 1B: Daily Sunspot Observations | | | | |
|---|---|---|---|---|
| Observation Date: | | | | |
| Sunspot Group Name (Choose a name for each sunspot group. Keep track of sunspot groups names!) | Sunspot Group Latitude 0° to 90° (North +, South -) | Sunspot Group Longitude 0° to 180° (East +, West -) | Sunspot Group Location (Distance of center of sunspot group from the left edge of Sun in 0.0 cm) | Changes Observed in Sunspot Group (Size, shape, number of sunspots) |
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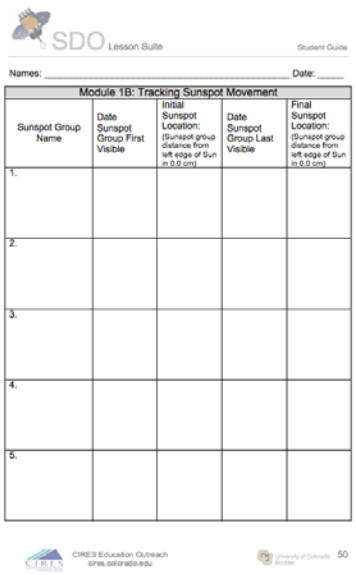
D) Discussion Questions:
Write your team's responses to the following questions in the "Galileo's Claim" lab sheet. State specific data from your team's SDO "HMI Intensitygram (gray)" solar images, "Solar Latitude & Longitude Grid", "Daily Sunspot Observations", "Tracking Sunspot Movement" data sheets, 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 2: Collect and Assess Evidence
Discussion Questions
Student teams critically evaluate their data to provide scientific evidence about Galileo's claim. Student teams review the evidence presented in the SDO HMI Intensitygram solar images, "Solar Latitude & Longitude Grid", "Daily Sunspot Observations", "Tracking Sunspot Movement" data sheets, and "Tracking Sunspot Movement" graph to answer the discussion questions. Remind students to support their responses with specific evidence from their data. Due to the direction of the Sun's rotation, sunspots appear to move from left to right across the Sun's disc. Sunspots also "migrate" toward the Sun's equator over time, they do not always remain at set latitudes. Since sunspots can "appear" and "disappear" based upon solar activity, they do not have a set "life span". Also, the size, shape, and number of sunspots continually change during the solar cycle.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Names: _____ Date: _____

Module 1B: Tracking Sunspot Movement

| Sunspot Group Name | Date Sunspot Group First Visible | Initial Sunspot Location: (Sunspot group distance from left edge of Sun in 0.0 cm) | Date Sunspot Group Last Visible | Final Sunspot Location: (Sunspot group distance from left edge of Sun in 0.0 cm) |
|---|---|---|---|---|
| 1. | | | | |
| 2. | | | | |
| 3. | | | | |
| 4. | | | | |
| 5. | | | | |

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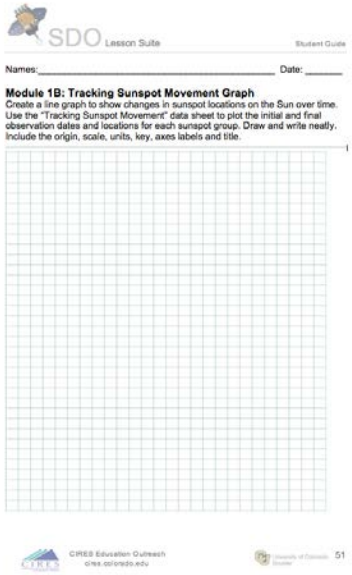
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**Module 1B: Tracking Sunspot Movement Graph**

Create a line graph to show changes in sunspot locations on the Sun over time. Use the "Tracking Sunspot Movement" data sheet to plot the initial and final observation dates and locations for each sunspot group. Draw and write neatly. Include the origin, scale, units, key, axes labels and title.

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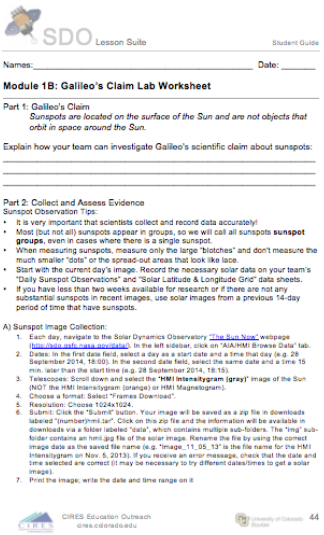
## Part 3: Concluding Statement - Claims, Evidence and Reasoning

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!

Part 3: Concluding Statement - Claim, Evidence and Reasoning
Students will develop their skills in scientific reasoning by addressing Galileo's claim with specific evidence from their investigation on sunspots. Scientific communication is a vital part of developing and expressing an understanding of scientific concepts. The "Galileo's Claim" lab sheet provides student teams with a format to synthesize the sunspot investigation.



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**Module 1B: Galileo's Claim Lab Worksheet**

Part 1: Galileo's Claim
*Sunspots are located on the surface of the Sun and are not objects that orbit in space around the Sun.*

Explain how your team can investigate Galileo's scientific claim about sunspots:

Part 2: Collect and Assess 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, 16:00). In the second date field, select the same date and a time 15 min. later than the start time (e.g. 28 September 2014, 16:15).
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)hmi.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

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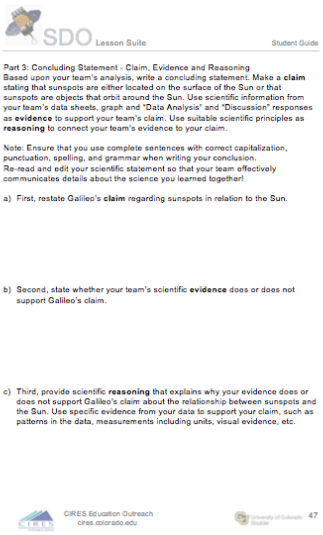

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Part 3: Concluding Statement - Claim, Evidence and Reasoning
Based upon your team's analysis, write a concluding statement. Make a **claim** stating that sunspots are either located on the surface of the Sun or that sunspots are objects that orbit around the Sun. Use scientific information from your team's data sheets, graph and "Data Analysis" and "Discussion" responses as **evidence** to support your team's claim. Use suitable scientific principles as **reasoning** to connect your team's evidence to your claim.

Note: Ensure that you use complete sentences with correct capitalization, punctuation, spelling, and grammar when writing your conclusion.
Re-read and edit your scientific statement so that your team effectively communicates details about the science you learned together!

a) First, restate Galileo's **claim** regarding sunspots in relation to the Sun.

b) Second, state whether your team's scientific **evidence** does or does not support Galileo's claim.

c) 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.

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***Super, you are now Sunspot Specialists!***

**Differentiation/Extension**

- If you were Galileo, how would you mathematically prove sunspots are actually on the Sun? (http://solar-center.stanford.edu/sunspots/gClaim.html)

- Write and illustrate a storyboard to compare and contrast the pathway of a sunspot and planet in relation to the Sun using these resources:
  Orbiting the Sun: Venus Transit of the Sun
  NASA SDO: Three Years of the Sun
  SDO: Year 4

- NASA Solar Math
  Grade Level 3-5, p. 26
  Grade Level 6-8, p. 53
  Grade Level 9-12, p. 67

**Internet Resources**

How to Safely View the Sun Video
Observing the Sun
Pinhole Camera
Solar Surface Videos
Draw a Sunspot Map
Create a Sundial
Journey into the Sun: SDO
NASA Space Weather Media Viewer: "The Sun" Videos #3-4
NASA Space Weather Media Viewer: Visualizations "The Sun"