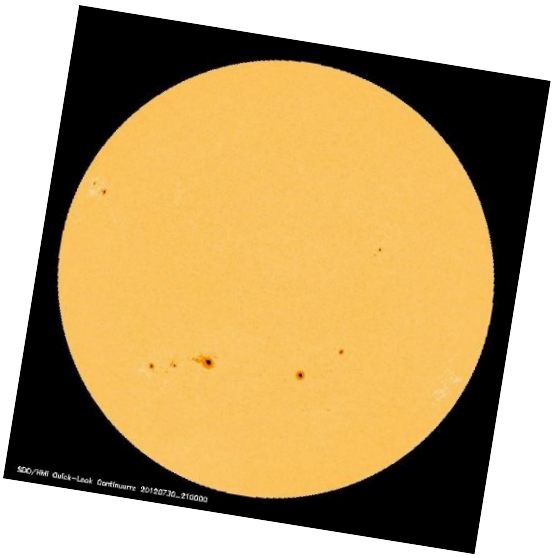
Exploring the Sun

FRONTIERS

Does the
Sun rotate?

Orientation Phase

Orienting and Asking Questions



Have you ever heard of sunspots? Do you know what they are?

The first recording of an observation of sunspots was made by the Chinese around 800 B.C. Thomas Harriot, in England, was the first to observe them with a telescope in December 1610. Later, Galileo Galilei and other astronomers studied them and reached some very interesting conclusions.
Most people have never observed sunspots.

As you know, looking directly at the Sun with the naked eye damages your sight and might even blind you. To observe sunspots, you have to use projected images or use protective filters. You can also access images taken with land-based or Earth-orbiting solar telescopes. And these can be spectacular!
You can discover a lot about our Sun exploring the images.

We usually assume that the Sun radiates steadily, predictably, every day, like a "quiet" star.
Watch this amazing video... [*NASA/Goddard*

https://www.youtube.com/watch?v=GrnGi-q6iWc
Magnificent Eruption [NASA Goddard]

Discuss with your colleagues if you think the Sun is always "quiet".

Provide Contact with the content and/or provoke curiosity

What are the sunspots and why is it important to study them?

The sunspots are regions in the solar surface that are darker than the surrounding photosphere (the surface of the Sun), reflecting a difference between their temperature (about 3000 K) and the surrounding surface temperature (about 5770 K). They are still very hot and would appear very bright on their own if they didn't have a so much hotter surface background.

Sunspots are cooler than the surroundings because the magnetic field in the sunspot is stronger and inhibits convection, preventing the hot gas from deeper inside the sun to come to the surface. Since the transfer of energy by convection is less efficient in the sunspot, these are not as hot as the surroundings.

Two different zones may be detected in a sunspot: the dark centre, called the umbra, and the lighter border, the penumbra. The following picture shows details of a sunspot.

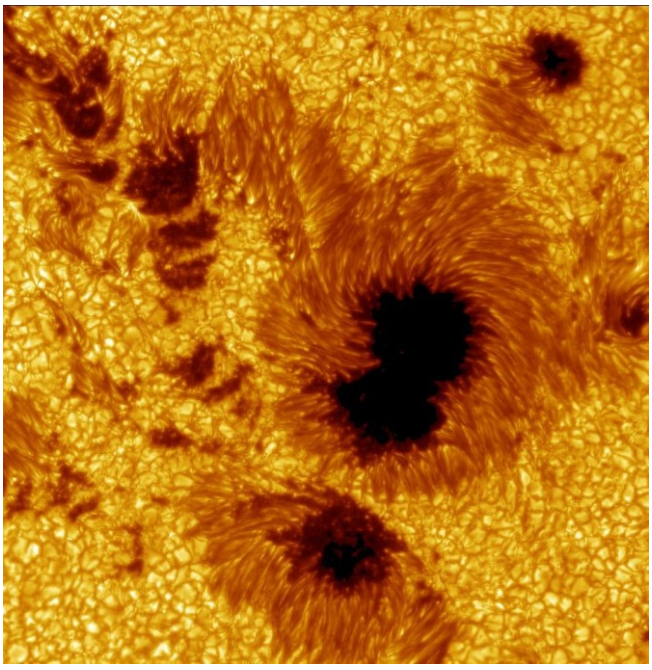


Figure 1 Sunspots taken with the Swedish Solar Telescope. [SST/Royal Swedish Academy of Sciences]

The appearance of sunspots may last between a few days and a few weeks, sometimes even months. But groups of sunspots and their active regions tend to last weeks or months. The number of sunspots visible on the Sun's surface

increases and decreases in a regular cycle of about 11 years, called the Solar Cycle.

The sunspot's analysis is a very important aspect of the study of the phenomena occurring on the surface of the Sun. Sunspots are associated with other activity on the Sun – for instance, the strong magnetic fields of the sunspots can generate solar flares or even generate storms of energetic particles into planetary space. These can affect the Earth and its near-space environment.

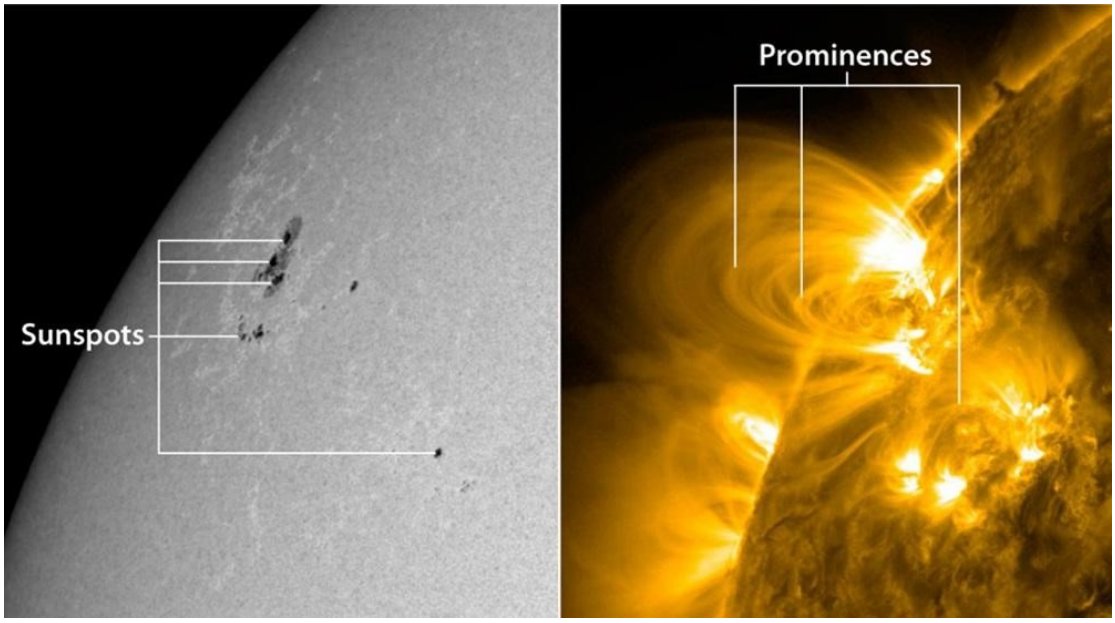


Figure 2. Sunspots are the direct manifestations of the Sun's complex magnetic field. The magnetic fields can suspend material in arches of gas, called prominences. [NASA/SDO]

The Sun is essential for life on Earth and is part of our daily life. It is so important for us but we don't think a lot about it.

Can you guess how the size of the Sun compares with the size of the Earth? And have you ever wondered what motions does the Sun have?

Discuss with your colleagues and write down your ideas:

1. How many Earths fit along the diameter of the Sun?
2. How many Earths can you put inside the Sun?
3. Does our Sun rotate around itself, like the Earth and the other planets?

Would you like to become a solar scientist for a day and discover exciting features about the Sun, our star?

Your challenge is to use images of the Sun to investigate how we discover if the Sun rotates or not. You will have access to images that are used by professional astronomers to study the Sun!

Teacher Guidelines:

Exploratory Phase

Question or Statement

Define Goals and/or questions from current knowledge

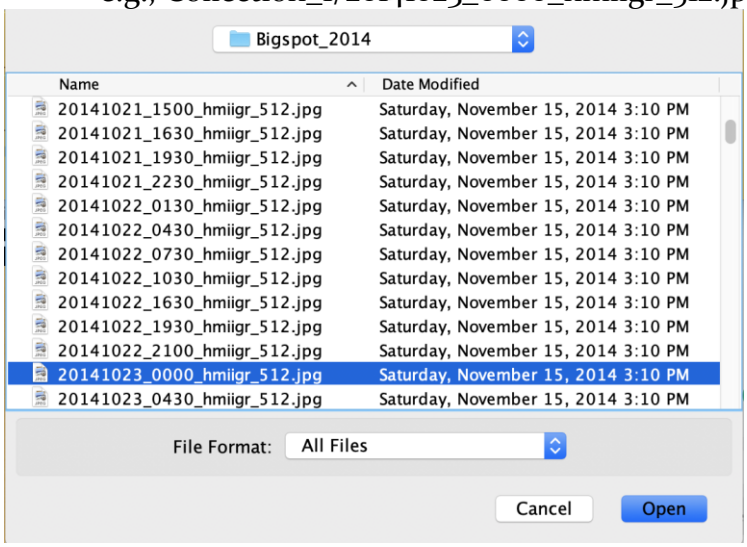
Image Analysis - SalsaJ software

To analyze the solar images, let's start by making you an expert on image processing, just like astronomers. You will learn how to use a software called **SalsaJ** (Such a lovely software for Astronomy in Java).

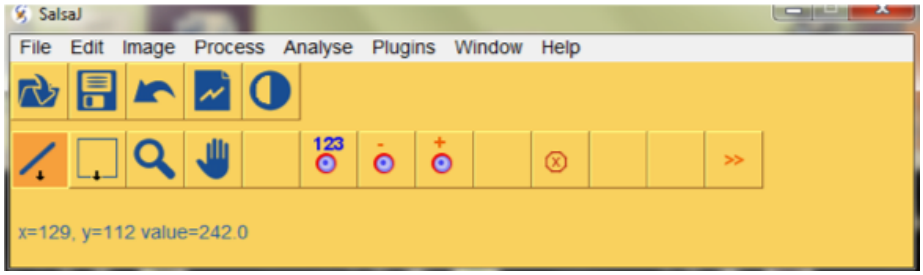
You can find SalsaJ here. Install it on your computer.
Download the following images of the Sun:
Collection_1
Collection_2
Collection_3
These are collections of images taken with the SOHO and SDO satellites that allow you to see the photosphere of the Sun.

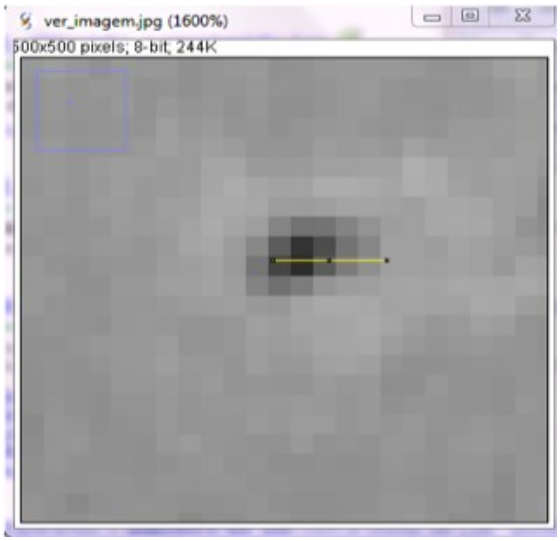
Measuring Sunspots

- Open SalsaJ
- Use (**Open**) to open an image from the downloaded collections, e.g., Collection_1/20141023_0000_hmiigr_512.jpg:

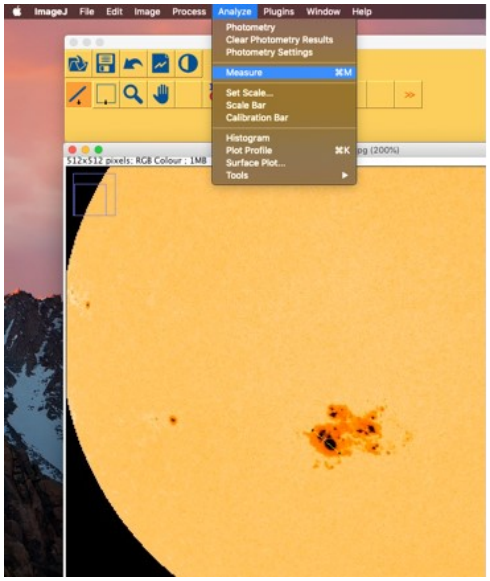


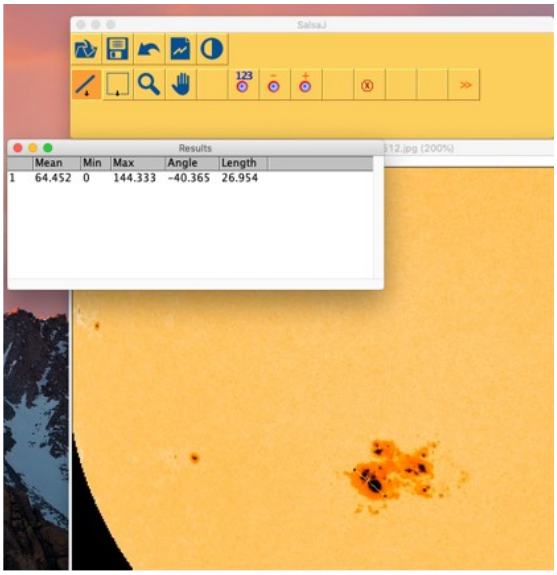
- Use (**Scrolling tool**) to select a sunspot and zoom in using the (**Magnifying glass**).
- Use (**Straight line selection**) to draw a line that crosses the sunspot, from where you think the spot starts to where you think it ends.





- Measure the diameter of the sunspot in pixels using the measurement tool in SalsaJ as shown in the image:





- Now, considering that the Sun's equatorial diameter is approximately 1 390 600 km, find the size of the spot you have measured. Repeat the procedure for a few sunspots and compare their sizes to the size of our planet (the Earth's equatorial diameter is 12760 km). Fill the table with spot 1, spot 2, etc., size in pixels, in kilometers, and comparison with Earth's size.

Spot Number	**Size (pixels)**	**Size (km)**	**Size (Earth's diameter)**

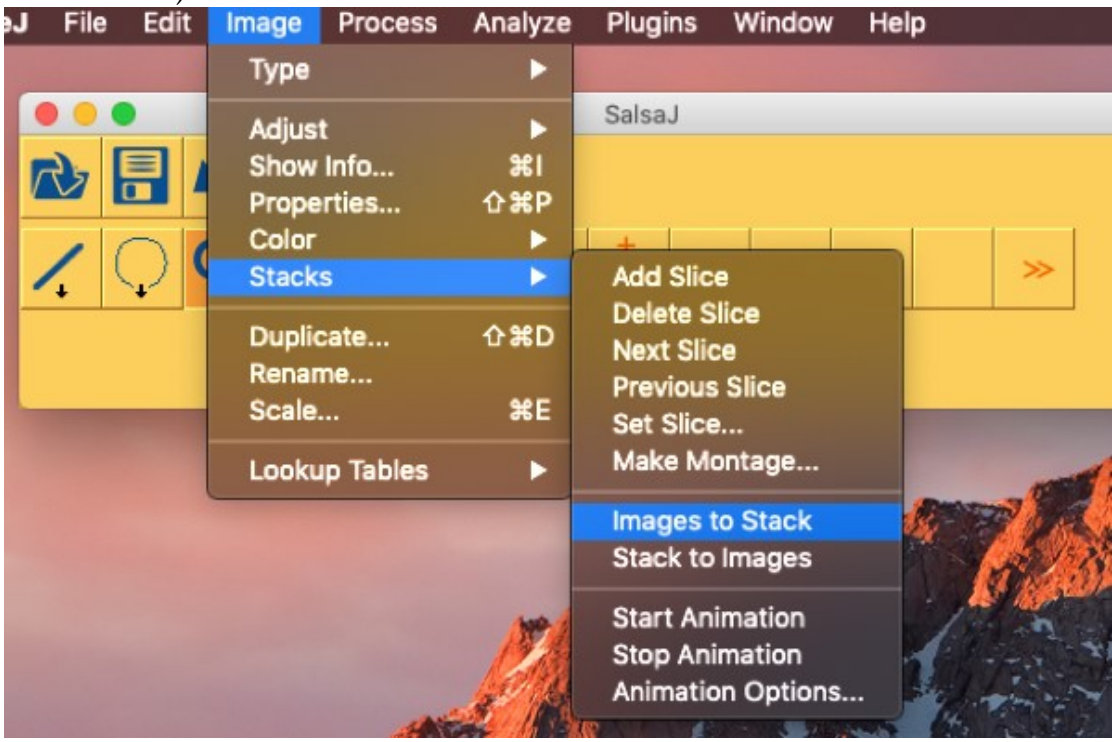
Surprised with the results? Did you expect the sunspots to be as big as our Earth, or even bigger? By the way, can you now answer the question "How many Earths can you fit along the diameter of the Sun?"

Animations with Salsa J

Let's learn how to produce an animation from a collection of images.

- Close all images you have opened with SalsaJ. Now open with SalsaJ four images from the data you downloaded, eg:
  - Collection_1/20141023_0000_hmiigr_512.jpg
  - Collection_1/20141023_0000_hmiigr_512.jpg

    - Collection_1/20141023_0000_hmiigr_512.jpg
    - Collection_1/20141023_0000_hmiigr_512.jpg
- Make sure that these are the only images opened with SalsaJ.
- Select the options Stacks (from the Image menu) and then (Image to Stack).



- Use again the same menu to start your animation: **Image – Stack – Start Animation.**

Now you are all set to start your exploration!

Teacher Guidelines: Remember that is very important for the students to explore their own misconception. Don't induce them to provide the right answer. Let them

Generation of Hypothesis or Preliminary Explanations

Exploring the Sun's features

Explore the collection of images provided in the links above. For each collection, start by observing the changes along the sequence of images. The image name has information on the date and time of the observation. You can make animations like the one you did above.

Discuss with your colleagues what you think is happening in the different collections of images. What features do you think you are observing and what happens when time goes by? Do you think you can tell something about the Sun's motion by analyzing these images? Write down your observations and hypothesis.

Evidence

New Evidence
Let's observe now another collection of images.
Collection 4
Analyze these images. What do you think is different in this new collection?

Discuss with your colleagues - do you want to review your initial hypotheses?

Teacher Guidelines:

Plan Investigation

Discuss with your group and explore ways to distinguish between something passing in front of the Sun and something that might be at its surface (the photosphere).

Perform Investigation

With your colleagues, think of how you can investigate what is happening in each set of images. If they depict different situations, how can you tell what is happening in each one?

To support your investigation, explore other images from the observatories:
SDO Archives: https://sdo.gsfc.nasa.gov/data/
You can also make online animations with the SOHO Movie Theater (choose image type *hmiigr*).

Remember that SalsaJ can help you analyze the different images.

Plan and conduct your investigation. Take notes of what you observe and gather data to support your hypotheses.

Analysis and Explanation

Analysis: Analyse evidence to discover a possible answer

Now that you have performed your investigation, analyze and interpret your data.

Explanation: Formulate an explanation based on the analysis of your evidence

What can you say about the sunspots and the solar rotation? Do you think sunspots give evidence that the Sun is rotating?

Formulate an explanation based on the analysis of your evidence.

Consolidation Phase

Connect

Connect explanation with current scientific knowledge

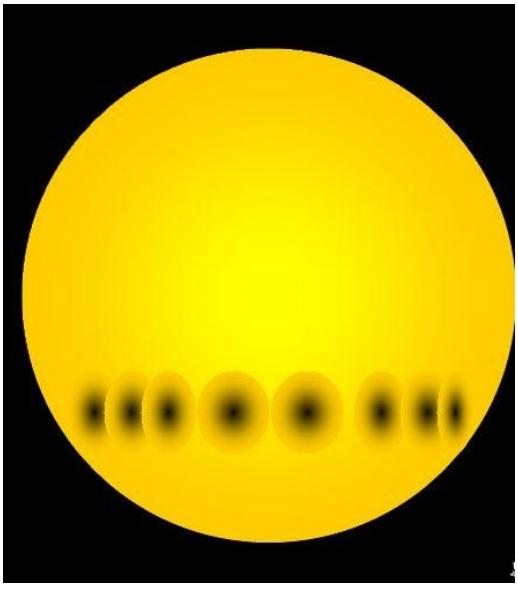
You started with images of the Sun (Colection_!, Collection_2, Collection_3) where you can see sunspots - some bigger, some smaller, some lasting longer than others. With the animations, you observed them moving, giving the impression that the Sun was rotating. This is what Galileo Galilei observed and argued that the sun rotated. But how could he justify that the sunspots weren't satellites moving around the Sun?

Galileo observed that the shape of the sunspots became foreshortened, or compacted, as they approached the edge of the visible sun. He argued that this would only happen if the spots were like flat objects on the surface of the sun, and were turning their edges to Earth as the Sun rotated. This would not happen if the sunspots were spherical planets or moons passing in front of the sun. So Galileo concluded that the spots must be on the surface.

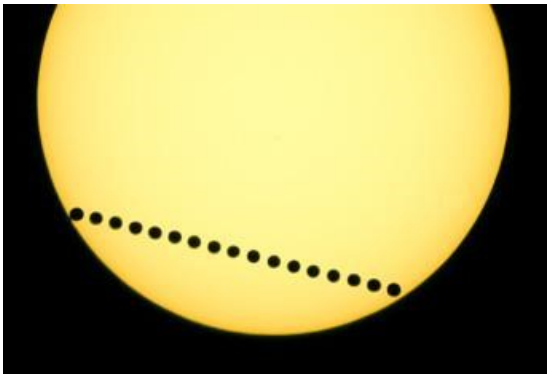
[Taken from:
http://cse.ssl.berkeley.edu/segwayed/lessons/sunspots/history3.html]

You were then given images (Collection_4) depicting a transit of Venus! Did you notice the differences that Galileo mentioned? Were you able to distinguish the two situations?

The image below shows (in an exaggerated manner) what happens when it is indeed something at the surface of the Sun (from Swinbourne Online Education),



a nd this is an illustration of how the transit looks like



You can simulate Galileo's observation yourself by taping a coin to a globe, and rotating the globe. How does the shape of the coin appear to change?

Discuss with your colleagues how close you were to Galileo's claims. Did you have new ideas? Present your results to the whole classroom.

Well done, today you were in Galileo Galilei's shoes!

Communicate

Communicate and justify your explanation

Discuss with your colleagues how close you were to Galileo's claims. Did you have new ideas? Present your results to the whole classroom.

Well done, today you were in Galileo Galilei's shoes!

Reflect

Reflect on what you have learned from the learning process

Review your learning process while exploring the Sun:

- What are the main concepts that you have learned?
- Which competencies did you improve or acquire?
- How do you feel about the activity?
- What would you do differently?
- What would you like to know more about the Sun?

Teacher Guidelines: In the next activity students will have the opportunity to calculate the rotation of the Sun (part II) and estimate the activity cycle of the Sun while comparing the change in our climate. They will be invited to discuss climate change in depth.