

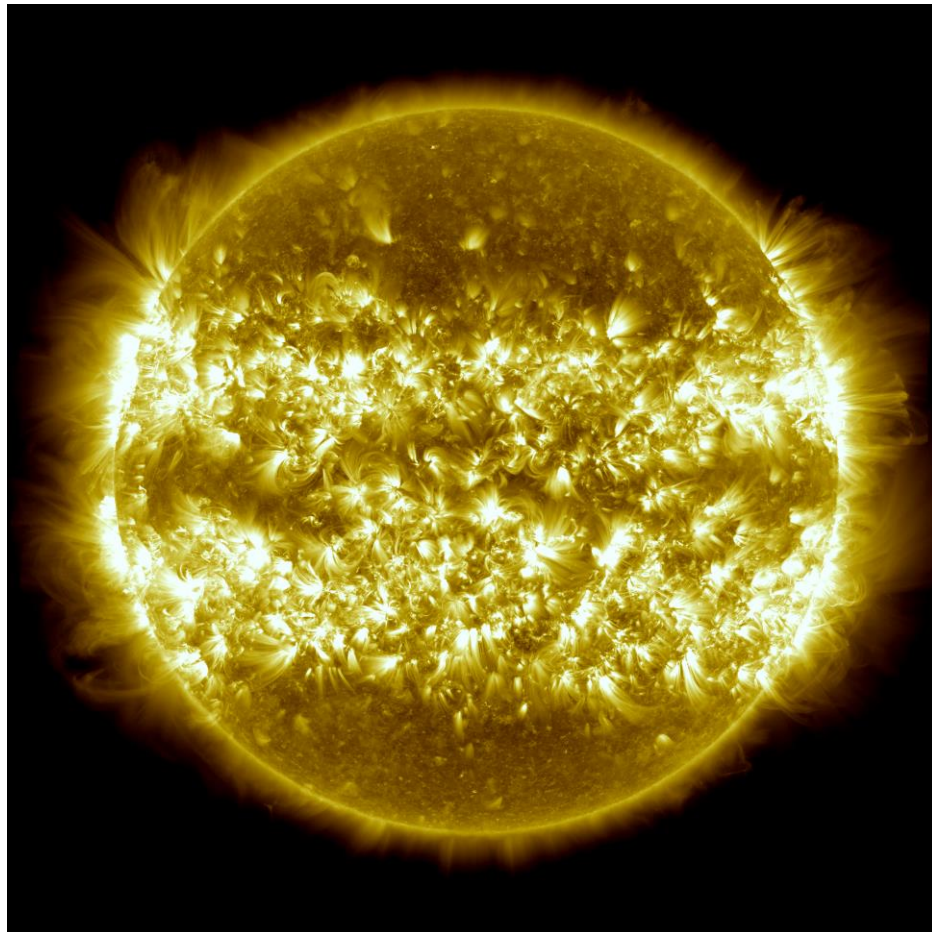


# NASA's Solar Dynamics Observatory Data in the Classroom

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*Scott Hildreth, Shannon Lee, Timothy Dave*

*Chabot Community College, Hayward, CA*

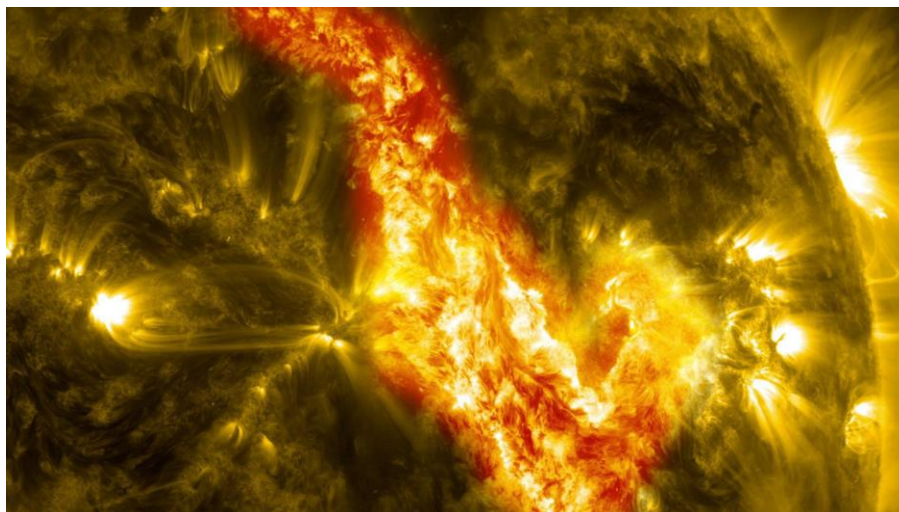


A collaborative project between Chabot Community College, the Stanford Solar Center, and NASA's Solar Dynamics Observatory Education and Public Outreach Team.



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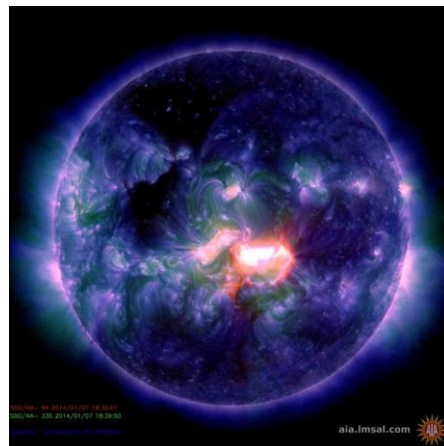
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*A hands-on laboratory developed by Scott Hildreth,  
Shannon Lee, Timothy Dave*

*Chabot Community College, Hayward, CA*

## About the Labs

### The Process of Science



Historically, people tracked and monitored astronomical objects with their eyes. Then telescopes showed us light we could not see with our eyes. Observations originally had to be recorded by making sketches by hand, as Galileo did of the four moons of Jupiter, our Moon, and sunspots on the Sun. More recently we attached cameras to the eyepieces to make photographs. But still, we mostly gathered and analyzed only the visible light from astronomical objects.

As technology has advanced we now launch satellites above our atmosphere to observe celestial objects in many wavelengths of light, and collect that light using computerized telescopes that transmit their data digitally back to Earth. We again use computers to analyze the data to do our science investigations. In this activity students will access and use authentic astronomical data, taken recently from NASA's Solar Dynamic Observatory (SDO) spacecraft, to do research on sunspots and solar activity as part of a collaborative Stanford University, NASA, and Chabot Community College project for citizen science.

## Introduction

There are many stars that dot the night sky but the most important star is the one that we see during the day - our Sun. Most organisms on Earth depend on the Sun for survival. While it is necessary for our existence, the Sun may also be our undoing. Our modern way of life depends on technology, and the more technology-dependent we become the more vulnerable we are to the Sun's outbursts.

On March 13 1989, an estimated 6 million people in the region of Quebec Canada lost power for 9 hours. This extensive blackout was caused by the Sun. A massive eruption of plasma, called a *coronal mass ejection*, had occurred on the Sun and eventually impacted Earth. These eruptions and other solar activity are actually quite common. We call this connection between solar activity and its impact on Earth "*space weather*".

## Our Data

NASA's **Solar Dynamics Observatory** (SDO) -- a solar space telescope launched in February 2010, circles in geosynchronous orbit about 22,000 miles above the surface of the Earth. SDO includes three scientific instruments: the Atmospheric Imaging Assembly (AIA), the Helioseismic and Magnetic Imager (HMI), and the Extreme-ultraviolet Variability Experiment (EVE). For this lab we will be using authentic, near-real-time data from SDO's AIA and HMI instruments to observe sunspots, flares, solar eruptions, and other forms of solar activity.

- SDO - <http://sdo.gsfc.nasa.gov>
- AIA - <http://aia.lmsal.com>
- HMI - <http://hmi.stanford.edu>
- EVE - <http://lasp.colorado.edu/home/eve>



## Objectives

From this laboratory, students will be able to:

- Create movies using real data from AIA and HMI to observe sunspots and solar flares.
- Explore the connection between solar activity and space weather.
- Use different types of data to generate and test a hypothesis about solar activity.
- Collaborate with other students to explore data and their hypotheses.
- Present their results in a scientifically appropriate manner.

## Overview of the Activities

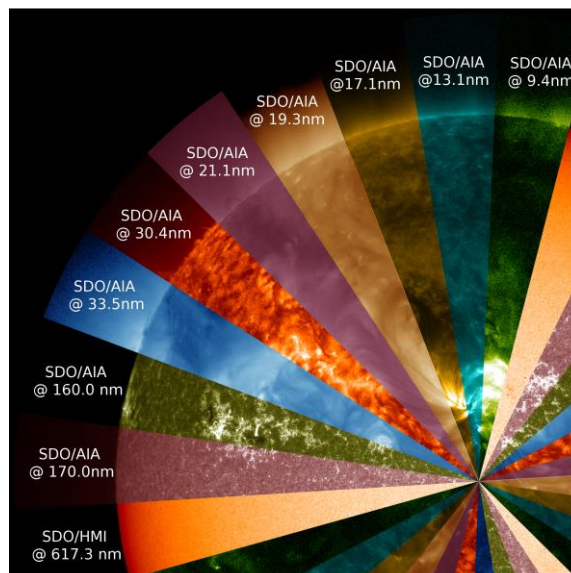
The laboratory requires access to the internet and is expected to cover at least 2 lab periods of 3 hours each. The process includes:

1. Students observe an online video, *Journey to the Sun*, produced by KQED Quest in conjunction with the SDO mission team. As the students watch the video, they answer questions about the SDO mission and its data.
2. To begin their research, students view a series of 6 short videos of actual solar activity, extracted from SDO data. Students again answer questions as they observe the various



forms of flares, prominences, coronal mass ejections, and other forms of solar activity they encounter.

3. Students go to the online database of near-real-time solar data from SDO, select solar active regions that are of interest to them, and create their own videos from still imagery. After recording their observations, student teams develop at least one research question to explore further based upon the data they have seen.
4. Using an online application called **Helioviewer**, students compare additional imagery and data from various solar spacecraft to explore the research question they have developed, and generate their research results.
5. Student teams are asked to present their results to the class either in oral presentations or posters.
6. Formative assessment is embedded in the activities. After the laboratory is completed, students are also asked complete a final summary assessment to determine the value of the workshop to them and give educators suggestions for improvement.



## Part 1: Background Material

**Intro Video:** <http://www.youtube.com/watch?v=fqKFQ7z0Nuk>

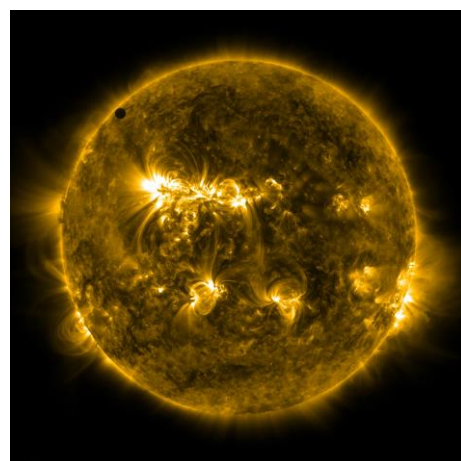
The SDO mission is a groundbreaking venture into solar science. As we progress into the social media age, science is being promoted to the public on many different levels. We will need some information about the SDO mission before we can begin analyzing data. We will take advantage of a YouTube video called “**Journey to the Sun**”, produced by KQED Quest, to provide students with information useful in our lab. As they watch the video there will be questions students will need to answer to guide them. Suggest to students that they pay close attention and pause the video frequently so that they don’t miss important information. The video is available at:

<http://tinyurl.com/journeyintothesun>

or

<http://www.youtube.com/watch?v=fqKFQ7z0Nuk>

Divide students into teams of 2 or 3. As they watch the video, students should complete the questions on the Quest Worksheet.



## Solar Dynamics Observatory Laboratory – Quest Worksheet

Designed to accompany video at <http://www.youtube.com/watch?v=fqKFQ7z0Nuk>

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Lab Partners: \_\_\_\_\_

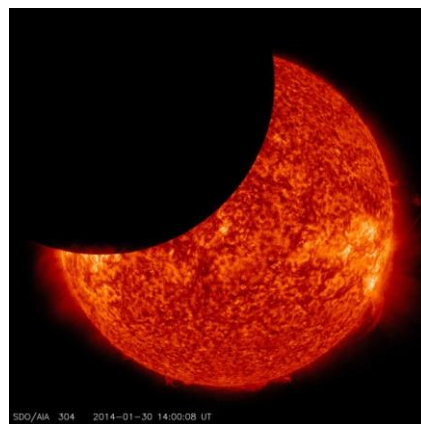
Video questions:



- 1) What is the resolution for SDO? \_\_\_\_\_
- 2) What do we call the extension of the Sun's atmosphere into the solar system?  
\_\_\_\_\_
- 3) Describe a difference between *coronal mass ejections* and *solar flares*  
\_\_\_\_\_  
\_\_\_\_\_
- 4) How will SDO help us deal with "*space weather*"?  
\_\_\_\_\_  
\_\_\_\_\_
- 5) How are *sunspots* and space weather connected?  
\_\_\_\_\_  
\_\_\_\_\_
- 6) How long is the *solar cycle*? What is changing during the cycle?  
\_\_\_\_\_  
\_\_\_\_\_
- 7) The AIA instrument measures light in what range of light? What region of the Sun emits this radiation?  
\_\_\_\_\_  
\_\_\_\_\_
- 8) What does the HMI instrument measure?  
\_\_\_\_\_  
\_\_\_\_\_
- 9) How much of the Sun does each pixel on the camera represent?  
\_\_\_\_\_
- 10) *Helioseismology* studies the inside of the Sun by using what kind of waves?  
\_\_\_\_\_
- 11) What do the black and white colors on the magnetic map of the Sun represent?  
\_\_\_\_\_  
\_\_\_\_\_
- 12) How often does HMI take a *picture* of the Sun? How often does it make a *full map* of the Sun?  
\_\_\_\_\_

## Part 2: Directed Introductory Student Activity

Your students will look at intriguing video collections of data from the instruments aboard SDO and answer questions about what they observe:



1. **Video 1 - A compilation of data from the 1<sup>st</sup> year of SDO operation.** These will show a sampling of the forms taken by solar activity.  
[http://www.youtube.com/watch?v=U\\_MKL\\_fjDLo&feature=youtu.be](http://www.youtube.com/watch?v=U_MKL_fjDLo&feature=youtu.be)
2. **Video 2 – Students observe an active region in three different wavelengths of light side by side.** <http://www.youtube.com/watch?v=BVDsQkuRt-c&feature=youtu.be>
3. **Video 3 - One solar rotation worth of images in white (i.e. visible) light,** showing sunspots as they move with the rotation of the Sun.  
<http://www.youtube.com/watch?v=oInoNnPsxCA&feature=youtu.be>
4. **Video 4 - Data from a portion of the same dates as video 3 with the active regions labeled.** Students focus on one in particular, where they observe details of the changes of active region. <http://www.youtube.com/watch?v=Nnwqkm6rL4M&feature=youtu.be>
5. **Video 5 - Shows one particular flare seen by SDO in different wavelengths of light.**  
[http://www.youtube.com/watch?v=6MWL\\_gQVWQk&feature=youtu.be](http://www.youtube.com/watch?v=6MWL_gQVWQk&feature=youtu.be)
6. **Video 6 – A video of a solar flare as observed by SDO and NASA’s Fermi Gamma-ray Space Telescope.** <http://www.youtube.com/watch?v=sQ3MuftUbMc&feature=youtu.be>

Have your students complete the following 6 worksheets as they observe the videos.





**Video 1 Worksheet:** <http://tinyurl.com/SDOyear1>  
[http://www.youtube.com/watch?v=U\\_MKL\\_fjDLo&feature=youtu.be](http://www.youtube.com/watch?v=U_MKL_fjDLo&feature=youtu.be)

This is a sampling of data from both the AIA and HMI instruments for the first year that SDO was in operation. **Prominences** are clouds of material magnetically supported in the Sun's atmosphere. They can last for weeks or months and sometimes erupt. When they do, the glowing gas will *look* like water flowing from a hose into the Sun's atmosphere. **Flares** are seen as bright bursts of energy that last for only a few seconds on the video. You can also see **sunspots** as they evolve over time and cross the solar surface. Sunspots look like very dark patches on the surface, almost like solar acne. The black and white imagery shows magnetic fields on the Sun.

In the video, notice that the Sun is imaged in different colors, each representing a different frequency of ultraviolet light and temperature. Try to identify which parts of the video are showcasing the different types of solar activity. Note the time on the video when each feature appears.

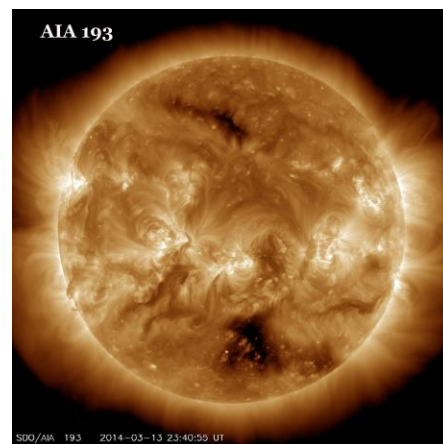
**Prominences:** video times \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_

**Solar flares:** video times \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_

**Sunspots:** video times \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_

**Unknown features:** video times \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_

Now view the following website <http://sdo.gsfc.nasa.gov/data/>. Here we can see the data from the Sun *today*. Each image has been labeled with important information. At the top you will see “AIA” and then a number (like AIA 193). This tells you the AIA instrument took the data and that the wavelength of light in that image is 193 *angstroms*. The figure on the right is an example. All the AIA images are taken in extreme ultraviolet light (EUV). The HMI images are in visible light. All images are artificially colored.



Compare and contrast the different wavelength images. Specifically comment on which of the images seems the most “active”, which of the images seem the most “quiet”? Also mention what criteria you are using to differentiate quiet from

active.

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- 1) For any of the AIA wavelength channels, click on each of the numbers (4096, 2048, 1024, 512) directly underneath the image. Each is a hyperlink. What is the difference between the numbers?

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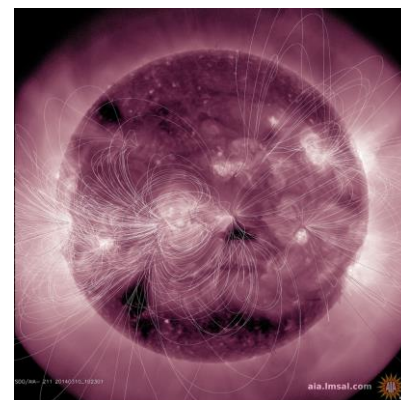
- 2) For any of the AIA wavelength channels, click again on each of the numbers labeled with “PFSS” underneath the image. PFSS stands for Potential Field Source Surface model, and the lines you see are approximated magnetic field lines. What do you notice about the number of lines, and the “density” of lines (how many are packed into a small region) you see coming from particular features on the Sun?

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(You can read more about PFSS models and these lines at Young, C. A. (2010, Oct 10) “Magnetic Field Lines Galore (SDO Pick of the Week).” The Sun Today.

<http://www.thesuntoday.org/current-observations/magnetic-field-lines-galore-sdo-pick-of-the-week/>



- 3) Each wavelength represents a different region and temperature on the Sun. Let’s explore that in more detail. [http://en.wikipedia.org/wiki/Solar\\_Dynamics\\_Observatory](http://en.wikipedia.org/wiki/Solar_Dynamics_Observatory) and <http://aia.lmsal.com/public/instrument.htm> list the AIA wavelength, region, and temperature. What region of the Sun and temperature do images taken with wavelength 193 Å represent?

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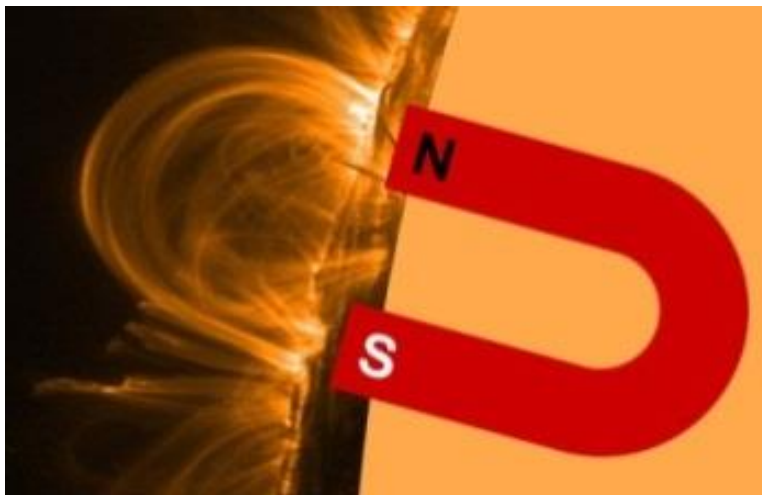
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**Video 2 Worksheet:** <http://tinyurl.com/activeregion>  
<http://www.youtube.com/watch?v=BVDsQkuRt-c&feature=youtu.be>

An **active region** is an area on the Sun where the magnetic fields are stronger than the surrounding area. **Sunspots** are visible manifestations of active regions. Active regions are also responsible for solar eruptions like **flares**, **prominences**, and **coronal mass ejections**. In this video we see an active region in three different wavelengths of light, side by side.

The image to the right is a conceptual rendering of an active region. The area under the active region can be represented by a bar magnet with a north and south pole. Charged particles are trapped along the magnetic field lines and create unstable glowing loops above the active region.

Image credit: Windows to the Universe  
 original artwork by Randy Russel using an image from NASA's TRACE spacecraft.



What features of the Sun are *uniquely* visible in each of the three frames of the video?

- a. Orange (AIA 304 Å, Chromosphere, 50,000 K)

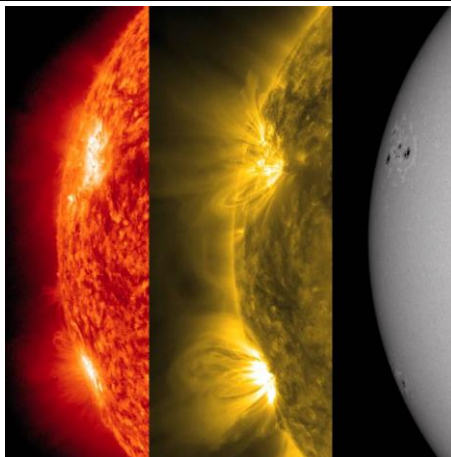
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- b. Yellow (AIA 171 Å, Corona, 630,000 K)

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- c. Black and White (HMI intensitygram, Photosphere, 5,000 K)

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**Video 3 Worksheet:** <http://tinyurl.com/onerotation>  
<http://www.youtube.com/watch?v=oInoNnPxcA&feature=youtu.be>

Now let's focus our attention on sunspots. This video is one solar rotation worth of images in white light/visible light<sup>1</sup> (photosphere: 5,000 K). The Earth rotates on its axis once every 24 hours (one day). The Sun also rotates on its axis but it takes much longer than one Earth day.

1. How long (in Earth days) is one solar rotation (at the equator)?

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2. How many active regions can you count on the Sun in this solar rotation?

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3. Do you think this is a time of high solar activity or low solar activity? Explain why.

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4. Are there any active regions that you believe would be more likely to cause a solar eruption than others? Explain!

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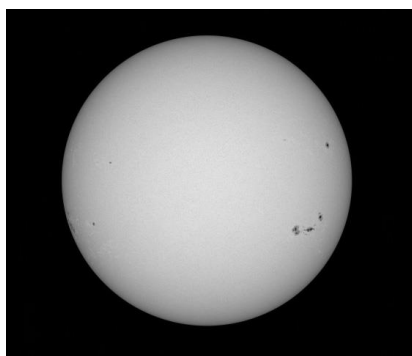
5. How could you check this hypothesis?

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<sup>1</sup> The color is unretouched since the Sun is white.



### Video 4 Worksheet: <http://tinyurl.com/largesunspot>

(<http://www.youtube.com/watch?v=Nnwqkm6rL4M&feature=youtu.be>)

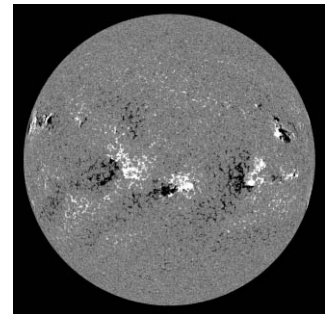
**Active regions** on the Sun are carefully labeled and catalogued. Each sunspot group is given an active region number. This may seem a simple categorizing task but as sunspots evolve they can shrink, grow, split or disappear altogether. Video 4 is data from the same dates as video 3 (but only a few days instead of the full solar rotation). Here



the active regions are labeled and we can focus on one in particular, region AR1339 on 6 November 2011. The video will show you many details about this active region.

1. Pause the video at the **5 second** mark. How large is the sunspot group, in terms of our planet's diameter? (In other words, how many "Earth's" **across** is this sunspot group?)  
\_\_\_\_\_
2. How many Earth's **tall** is this sunspot group?  
\_\_\_\_\_
3. Area is calculated by multiplying length times width. Multiply your answers from the previous two questions. Approximately how many Earth's in area is AR 1339?  
\_\_\_\_\_

The next portion of the video deals with magnetic fields. Sunspots are really pairs of magnetic poles. When you get a large group of sunspots it can be very hard to separate them. HMI scientists use white for positive magnetic fields, i.e. the field is pointing into the Sun. Black indicates negative, where the field is pointing out of the Sun. Draw a quick sketch of a frame from the video and label the negative and positive polarity of the main magnetic fields.



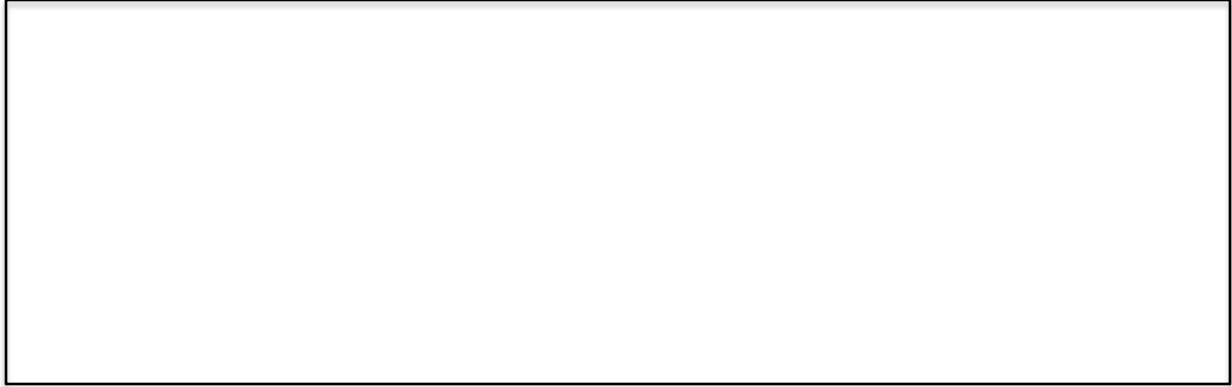
## SDO Data in the Classroom

The last portion of the video looks at sunspot evolution data. Watch carefully to see if the sunspots rotate.

4. Is it easier to see the large spots or the small spots rotate?

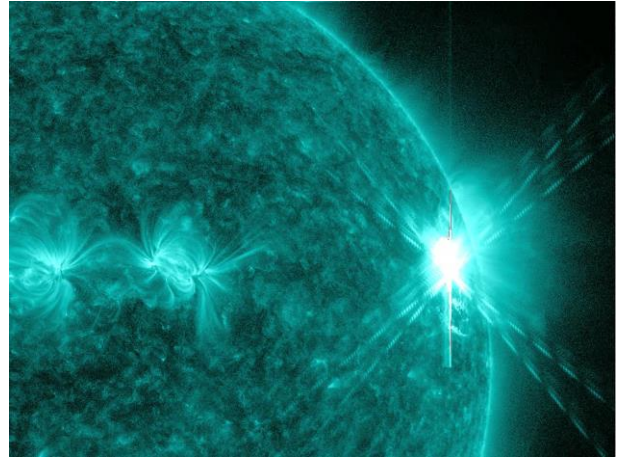
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5. Choose one or two spots to watch and draw them in the box below, indicating with arrows which way the sunspots are rotating.



**Video 5 Worksheet:** <http://tinyurl.com/X1flare>  
 ([http://www.youtube.com/watch?v=6MWL\\_gQVWQk&feature=youtu.be](http://www.youtube.com/watch?v=6MWL_gQVWQk&feature=youtu.be))

**Solar flares** are the most energetic and violent eruptions in our solar system. During solar maximum they can occur very frequently and can have a significant impact on our daily lives. X-ray radiation is shot out from the Sun and, if aimed towards Earth, can destroy satellites and harm astronauts. Solar flares are classed based upon their intensity: B and C flares are the weakest and least energetic, M flares are fairly strong and can cause us some worry, X class flares are the most powerful and dangerous. (See <http://spaceweather.com/glossary/flareclasses.html>)



The video shows one particular flare seen by SDO in different wavelengths of light. After watching the video please answer these questions to guide your observations.

1. Does the flare emanate from an active region (sunspot) or does it emanate from a “quiet” place on the Sun? How can you tell?  


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2. Compare and contrast the appearance of the flare with the other bright places on the Sun at that time? What makes the flare so different?  


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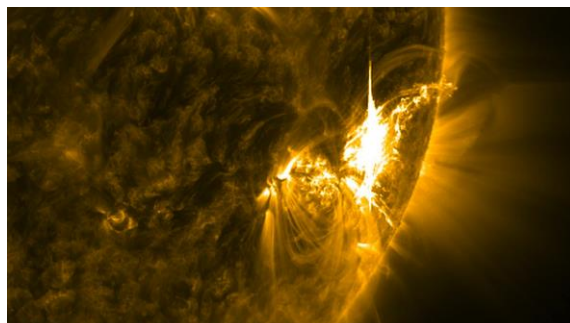
  


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3. Is the flare just a flash of light? Do you see anything else occurring in that region?  


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**Video 6:** <http://tinyurl.com/gamma-flare>  
(<http://www.youtube.com/watch?v=sQ3MuftUbMc&feature=youtu.be>)

We have been observing and trying to predict the occurrence of solar flares for many years but they can still surprise us. SDO is not equipped to detect gamma rays from the Sun, mostly because the Sun doesn't usually produce much gamma radiation. There are other telescopes in space sensitive to gamma ray wavelengths. We can get very useful and informative observation data when telescopes work together to observe the same event.



After watching the video, please answer the following questions:

1. Do you think it would be cost effective to build and launch a gamma ray telescope that only looks at the Sun? Provide reasoning to support your argument.

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2. After all your research that you have done so far in this lab, what topic do you find most interesting? If you were asked to choose one topic to continue researching what would you choose and what questions would you like to explore further? (As a reminder, we have learned about SDO, temperature and wavelength, prominences, sunspots and active regions, and flares. You also can choose a topic not on this list that you find interesting.)

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## Part 3: Access to Live Data

Now that we have some background knowledge of the Sun we can start to explore ways to make movies of our own using the same data! First we need to find an “active day” on the Sun as a starting place. We already know from the previous YouTube videos that November of 2011 was particularly active (with lots of large sunspots). But there have been more recent dates that are also interesting.

### iSolSearch locates solar activity and allows you to develop research questions

- 1) We will go to the online database for the Lockheed Martin Solar and Astrophysics Laboratory (LMSAL) and use their **iSolSearch** tool to access an SDO database of solar activity: <http://www.lmsal.com/isolsearch>
- 2) Once there, we need to restrict ourselves to a few hours of solar data to see the results clearly. On the upper left, enter **2014-02-25T00:00:00** in the *Start Date* box and **2014-02-25T04:00:00** in the *End Date* box. Next, restrict the visible event types to only **active regions** and **flares**; to do this quickly, CLEAR all of the preselected event types, and then check Active Regions and Flares. Then, hit *Search*. Your screen should now look like this (ignore the far right column for now):

The screenshot displays the iSolSearch web interface. The top navigation bar includes links: HEK home, Recently reported events, Search Events, Search Data, Request AIA Data, API, and Contact Us. The main interface is divided into several sections:

- Search Filters (Left):**
  - Start Date:** 2014-02-25T00:00:00
  - End Date:** 2014-02-25T04:00:00
  - Choose Event Types:** (all / invert / common / clear)
    - ☒ Active Region
    - ☐ CME
    - ☐ Coronal Cavity
    - ☐ Coronal Dimming
    - ☐ Coronal Hole
    - Size > 1
    - % of surface area
    - ☐ Coronal Jet
    - ☐ Coronal Rain
    - ☐ Coronal Wave
    - ☐ Emerging Flux
    - ☐ Eruption
    - ☐ Filament
    - ☐ Filament Eruption
    - ☐ Filament Activation
    - ☒ Flare
    - ☐ Loop
    - ☐ Oscillation
    - ☐ Sigmoid
    - ☐ Spray Surge
    - ☐ Sunspot
    - ☐ Topological Object
    - ☐ Plage
- Search Results (Center):** A Carrington Map showing the Sun's disk with various active regions and flares marked. The map is labeled with "Disk" and "Carrington Map".
- Search results (Right):**
  - Search results (export):** A list of search results including Active Regions (AR) and Flares (FL) with their IDs (e.g., 1.AR, 2.AR, 3.AR, 4.AR, 5.AR, 6.AR, 7.AR, 8.AR11990, 9.AR11981, 10.AR11982, 11.AR11986, 12.AR11987, 13.AR11989, 14.GOE5 X4.9 Flare, 15.AIA Flare, 16.AIA Flare, 17.AIA Flare, 18.HEK Flare, 19.AIA Flare, 20.AIA Flare, 21.AIA Flare, 22.AIA Flare, 23.AIA Flare, 24.AIA Flare, 25.AIA Flare, 26.AIA Flare, 27.AIA Flare, 28.AIA Flare, 29.AIA Flare, 30.AIA Flare, 31.AIA Flare, 32.AIA Flare, 33.AR, 34.AR, 35.AR, 36.AR, 37.AR, 38.AR).
  - 1. AR: ActiveRegion:** A detailed view of the first result, showing a thumbnail image of the Sun, a movie player, and metadata:
    - Start: 2014-02-24T21:23:12
    - End: 2014-02-25T01:23:12
    - Location: -923.58, -181.16
    - Coord Sys: UTC-HPC-TOPO
    - Observatory: SDO
    - Instrument: AIA
    - Channel: AIA 171, AIA 193
    - FRM: SPoCA
    - Archived: 2014-02-25T02:15:09
    - Area: 19100 Mm2
    - URL: [OBS\\_DATAPREPURL](#), [SSW Movie Menu](#), [SDO Movie](#), [SSW Context Image](#), [SSW Context Thumbnail](#), [Helioviewer.org](#), [HEK event summary](#), [VOEvent XML](#), [Get SDO Data](#)

To the right of the image you have a list of search results. If you mouse over the spots on the Sun you should see the particular event (active region) highlighted on the right. If you click on one (either on the Sun or in the list) you can get some links to appear on the far right. Some active region results will have more useful data than others, and some will have movies. Those are the most useful to you.

- 3) If you click on result “**1. AR**”<sup>2</sup>, you should see the data menu pictured above on the right. Click on the picture at the top to enlarge it. If you click on the *Movie* hotlink just below the image, you’ll see a brief movie of the event, in this case a very large solar flare.
- 4) Click on **SSW Movie Menu** for “1.AR”. You will see some movies that you can explore in different video formats (JavaScript, Flash, MPEG). Try each one and be patient for loading times. Also check out the **SDO Movie** link.
- 5) Pick a few different **active regions** from the Results column. Some will and some will not have movies. When there is one, click on the SSW Movie Menu, and from there view the FLASH or JavaScript representations of the event. Record your observations briefly, and with your team, develop at least one research question to explore further based upon the data you have seen. An example is done below. In iSolSearch, the active region number is not given, so you will need to identify your event by the time and location.

### EXAMPLE: SDO Recording of observations for one event:

**Location of Event:**

Start: **2014-02-24T21:23:12**

End: **2014-02-25T01:23:12**

Location: **-923.59, -181.16**

**Data Viewed** (JavaScript Movie, Flash Movie, etc.): **Flash Movie**

**Observations** (*Did you notice patterns, loops, whorls, structures, events like a flare or sudden brightening of the image? Try to be as specific about what you see, and when it occurred, as possible.*)

**Visible active region with many loops of glowing gas flowing from apparently one sunspot to another.**

**Research question to explore further:**

**Was the large flare associated with a coronal mass ejection?**

Now, develop your own observations and research questions by looking for other AR numbers that link to a movie. Feel free to try different dates.

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<sup>2</sup> The numbers in the right side table are made in response to the query. So if more days specified then you get different numbers. And if more people have submitted entries to the database the numbers can change.

**iSolSearch Observation #1**

**Location of Event:**

Start:

End:

Location:

**Data Viewed** (JavaScript Movie, Flash Movie, etc.):

**Observations** *(Did you notice patterns, loops, whorls, structures, events like a flare or sudden brightening of the image? Try to be as specific about what you see, and when it occurred, as possible.)*

**Research question to explore further:**

**iSolSearch Observation #2**

**Location of Event:**

Start:

End:

Location:

**Data Viewed** (JavaScript Movie, Flash Movie, etc.):

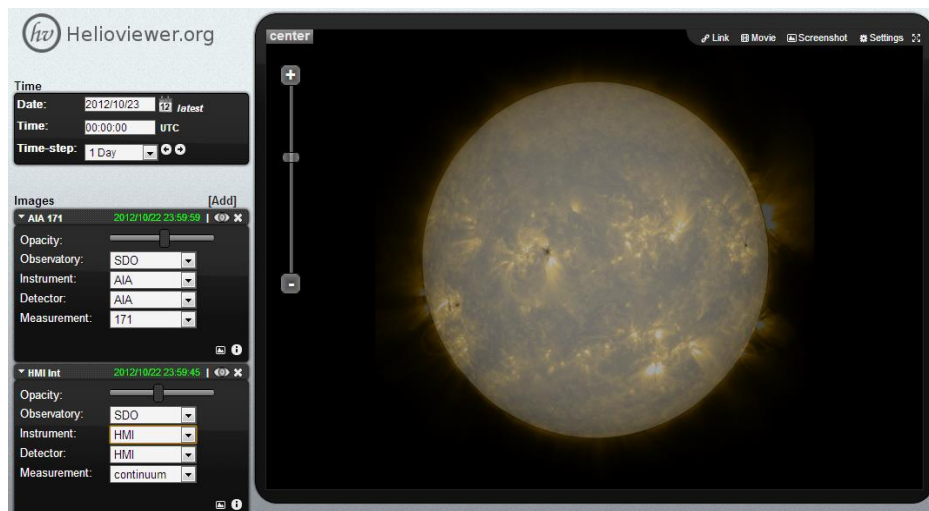
**Observations** *(Did you notice patterns, loops, whorls, structures, events like a flare or sudden brightening of the image? Try to be as specific about what you see, and when it occurred, as possible.)*

**Research question to explore further:**

## Use Helioviewer to generate videos and research your questions

To answer your questions, you'll need to get more data of the area you selected. You can do that quickly, with low-resolution data, using a tool called Helioviewer, available at [www.helioviewer.org](http://www.helioviewer.org), but you can also get there directly from iSolSearch.

- 1) For the Active Region in iSolSearch that generated your question, use the menu in the right window to go to Helioviewer.org.
  - a. Helioviewer should have automatically included the date and time of your event. If not, in the **Time** box on the upper left, enter the *Date and Time* for the event you chose. Leave a *Time-step* of 1 Day.
  - b. In the **Images** box (below Time), there should be a list of image observation sources. They should include AIA 171 and HMI Int. Using the pull-down menu for HMI Int, make sure Observatory is set to SDO, Instrument is set to HMI (the Helioseismic and Magnetic Imager instrument), the Detector is set to HMI, and Measurement is set to continuum. (You can learn more about HMI's role in the Solar Dynamics Observatory mission at <http://www.youtube.com/watch?v=vSSs7-O5IqY>).
  - c. Later you can come back and check additional sources such as SOHO, STEREO A or B, PROBA2, or YOHKOH. This will create additional observation sets.

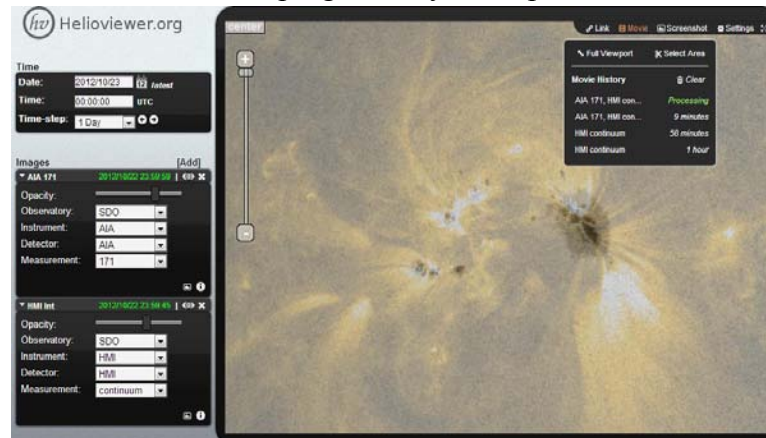


- d. You can toggle the images from each instrument using the “**eye**” symbol. Try that now, and notice how the HMI continuum data overlays the AIA Far Ultraviolet range. Try varying the “**opacity**” of the HMI data from minimum (so that only the AIA data is visible) to maximum (so that the HMI data is visible). Select an opacity mid-way so that you can see both the visual surface of the sun’s photosphere (the continuum layer) and the AIA features.

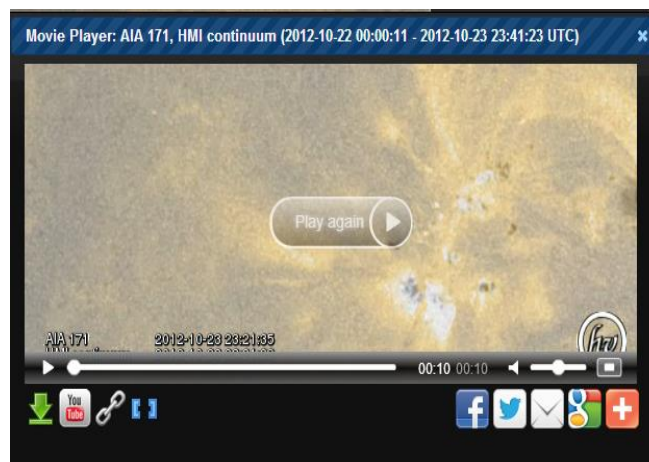


- 2) Click on **Movie** in the upper portion of the image box, and then **Select Area**. Move the default box, or draw a box around an area of interest, making it small enough to enclose the region (you might want to make it longer to the right). Use the zoom features if you wish. Click **OK**, select a movie duration of **2 days**, then click OK. The movie will be processed, and returned to your computer browser in a matter of a one to many minutes. (*You are accessing actual data of the Sun with your request, in real time, for the area YOU want to study! This movie is uniquely your own.*)

Click on the Movie button to track the progress of your clip.



On busy days, it may take a long time to generate your movie, so be patient. Once the movie is returned, it will show up in a small window, which you may have to click. You will also see buttons that allow you to watch the movie, post it to YouTube if you have an account, or access it from a link



- 3) Carefully observe your movie and record your observations. In particular, what did you notice about *the resolution* (detail) in the movie you obtained with Helioviewer compared to that linked in iSolSearch?

### Helioviewer Observation #1

**Event:** \_\_\_\_\_

**Data Viewed** (AIA/HMI bands)\_\_\_\_\_

**Movie URL created:** \_\_\_\_\_

**More Observations** (*Did you notice patterns, loops, whorls, structures, events like a flare or sudden brightening of the image? Try to be as specific about what you see, and when it occurred, as possible.*)

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**Resolution** (compared with original SDO movie clip) Better? Worse? Which had more detail?

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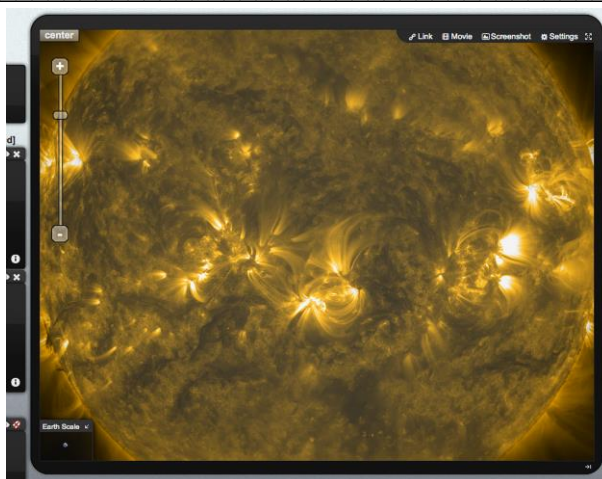
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- 4) With your first movie exported, you may or may not yet have useful information to help with your question. **But you can now begin to investigate!** You could view the same area with different wavelengths of the AIA instrument, or view the magnetograms from the HMI instrument to look for correlations in active regions with magnetic field motions. Return to the initial **Helioviewer.org** screen, and adjust the **Images** window according to what you want to view next, create another movie, and record your observations below. Briefly, what is your goal for next part of data acquisition and analysis, i.e. **what would you like to gather or explore further?**

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**Helioviewer Observation #2****Event:** \_\_\_\_\_**Data Viewed** (AIA/HMI bands) \_\_\_\_\_**Movie URL created:** \_\_\_\_\_

**More Observations** *(Did you notice patterns, loops, whorls, structures, events like a flare or sudden brightening of the image? Try to be as specific about what you see, and when it occurred, as possible.*

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- 5) **Did your repeated exploration help to give you more answers to the question(s) you asked about this particular active region?** Why or why not?

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- 6) **Based on your work so far, what would you like to research next?** For example, you might want to follow this particular active region in time, or, see how it looks one solar rotation later (or earlier) to explore how these active regions evolve over time. Or, you might want to zoom in tighter and with more data resolution.

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**jHelioviewer goes even farther**

It is quite possible that you will need more detailed data to investigate your questions, or you might need to play with other image settings. Additional more powerful data image analysis tools are available online to accomplish this, but they require programs to be downloaded to take advantage of more computer processing power. One such tool is “**jHelioviewer**” available at <http://jheliviewer.org/>. In a lab setting, it may have been downloaded to your computer already

## SDO Data in the Classroom

(or, you can download<sup>3</sup> it yourself for free.) jHelioviewer can be a useful tool but expect it to be slower than Helioviewer.

- 7) Start up this application, input the date and time (any time you want) for your observations, **ADD layers** for the AIA and HMI instruments as you did before, adjust the speed of the playback in the Movie Controls area, and use the Adjustments window to explore



contrast, color, and opacity for each layer. After you have created a movie you find interesting, export it (using the FILE menu command) to your desktop.



- 8) The next step is up to you – you can continue to explore the data from any previous date, or look at the current day's solar weather, and investigate some of the sunspots, flares, and active regions going on today. As you do this, record what you access, your observations, and any questions or hypotheses you have generated as a result of your research.

<sup>3</sup> Note: sometimes iHelioviewer has trouble being downloaded.



**jHelioviewer Observation****Date/Time of Observation** \_\_\_\_\_**Active Region #** \_\_\_\_\_ **Data Viewed** (JavaScript Movie, Flash Movie, etc.) \_\_\_\_\_**Tool(s) Used** (*check all that apply*)☐ HEK   ☐ Helioviewer   ☐ jHelioviewer   ☐ The Sun Today   ☐ \_\_\_\_\_ (other)**Observations** (*Did you notice patterns, loops, whorls, structures, events like a flare or sudden brightening of the image? Try to be as specific about what you see, and when it occurred, as possible.*)

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**Research Question(s) to Explore Further?**


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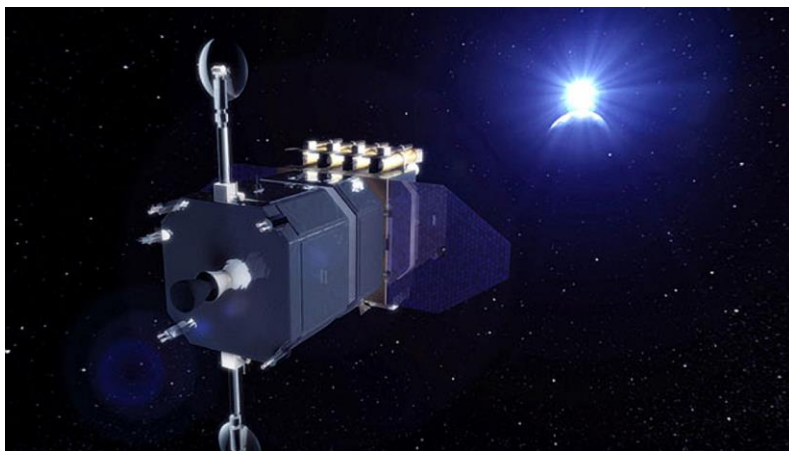


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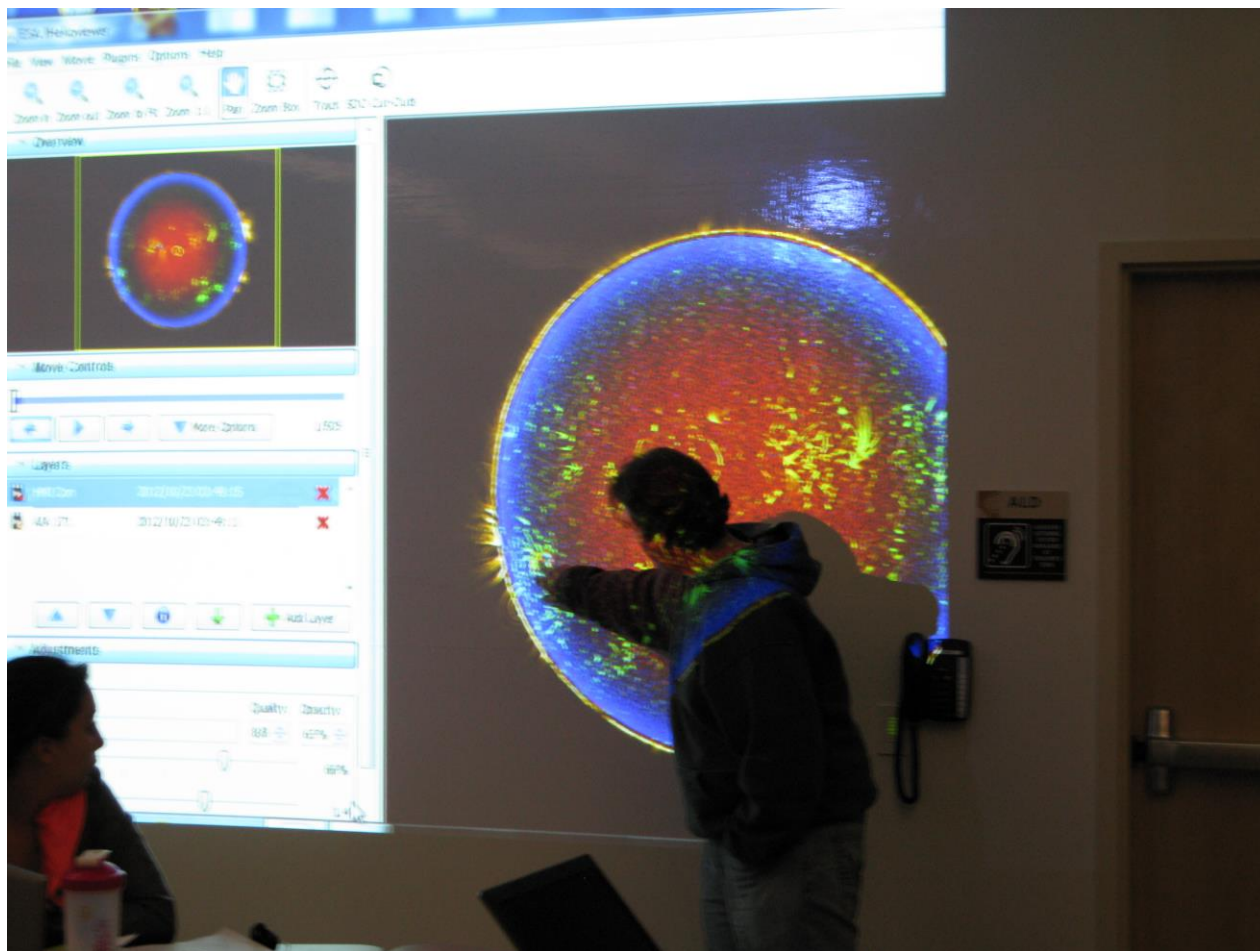
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Up to this point, all of the data you have had access to has been “binned down”. This means that instead of giving you the full possible resolution for an image they have given you less data to work with (an analogy would be diluting a solution). There are many reasons to do this but the biggest is that full images of the Sun with SDO have so much data in them they would take a very long time to download. A movie would take even longer! There are additional ways to request more detailed data. Please see your professor if you wish to pursue this step for additional credit!



## Finalization and Summative Assessment

At the end of the lab, student teams should be expected to present their results to the class either in an oral report or a poster.



Formative assessment is embedded with each of the activities. However, it is valuable for you to ask students about their experiences with these labs. What did they find most significant? How much did they help students understand the process of scientific data analysis? How would they like to have the lab changed or extended? Below is a possible feedback form.

## Student SDO Laboratory Feedback Form

*Use more pages if you wish*

From this two-week exercise, what are the some of the most significant things you have learned about the Sun?

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From this two-week exercise, what are the some of the most significant things you have learned about the process of data analysis that solar astronomers go through?

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What would you have liked to do with this activity that you were not able to do, or not given enough time to do?

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What would you keep, and what would you change overall, in this lab activity?

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## Additional Resources

This document is available online at

<http://www.chabotcollege.edu/faculty/shildreth/sdo/>

and <http://solar-center.stanford.edu/activities/SDO/Chabot.pdf>

Using Solar Dynamics Observatory Data to do REAL science - A Community College Astronomy Lab Activity – PowerPoint Presentation for the Astronomical Society of the Pacific Cosmos in the Classroom, July 2013

[http://solar-center.stanford.edu/activities/SDO/SDO\\_Astronomy\\_Lab\\_Presentation\\_7\\_22\\_2013.ppt](http://solar-center.stanford.edu/activities/SDO/SDO_Astronomy_Lab_Presentation_7_22_2013.ppt)

### Final Project Report

[http://www.chabotcollege.edu/faculty/shildreth/sdo/sdo\\_final\\_report.pdf](http://www.chabotcollege.edu/faculty/shildreth/sdo/sdo_final_report.pdf)

### Resources and Software Links used in the lab:

<http://sdo.gsfc.nasa.gov/data/> - The Solar Dynamics Observatory Website

<http://www.lmsal.com/hek/> - Lockheed Martin Solar and Astrophysics Laboratory (LMSAL) Heliophysics Events Knowledgebase (HEK).

<http://www.lmsal.com/isolsearch> - online tool to search HEK

<http://www.helioviewer.org> - Helioviewer online data browsing and movie export site (ESA/NASA funded site and tool)

<http://jhelioviewer.org/> - jhelioviewer software (downloadable)

[http://www.lmsal.com/get\\_aia\\_data/](http://www.lmsal.com/get_aia_data/) - Retrieve cutouts of AIA and HMI data, rather than full disk images.

<http://jsoc.stanford.edu/ajax/lookdata.html> - JSOC "Lookdata" (Advanced Web-based search)

### Video Clips used in the current version of the Lab:

Pre-lab/Intro Video: <http://www.youtube.com/watch?v=fqKFQ7z0Nuk> - Journey into the Sun KQED QUEST program

Background Video #1: [http://www.youtube.com/watch?v=U\\_MKL\\_fjDLo&feature=youtu.be](http://www.youtube.com/watch?v=U_MKL_fjDLo&feature=youtu.be) - Solar Dynamics Observatory - Year One

Background Video #2: <http://www.youtube.com/watch?v=BVDsQkuRt-c&feature=youtu.be> - Active Region example from 2011

Background Video #3: <http://www.youtube.com/watch?v=oInoNnPsscA&feature=youtu.be> - One complete Solar Rotation of Sunspots

Background Video #4: <http://www.youtube.com/watch?v=Nnwqkm6rL4M&feature=youtu.be> - Large Sunspot AR1339 November 2011

Background Video #5: [http://www.youtube.com/watch?v=6MWL\\_gQVWQk&feature=youtu.be](http://www.youtube.com/watch?v=6MWL_gQVWQk&feature=youtu.be) - NASA SDO X1-class Flare July 2012

Background Video #6: <http://www.youtube.com/watch?v=sQ3MuftUbMc&feature=youtu.be> - NASA Fermi & SDO - Fermi Detects the Highest-Energy Light from a Solar Flare

Also of use:

[http://en.wikipedia.org/wiki/SDO\\_AIA\\_temperatures](http://en.wikipedia.org/wiki/SDO_AIA_temperatures) - Wikipedia page about SDO AIA instrument wavelength regions correlated with temperatures

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Student photographs courtesy of Scott Hildreth. Unless otherwise noted, all other imagery courtesy NASA.