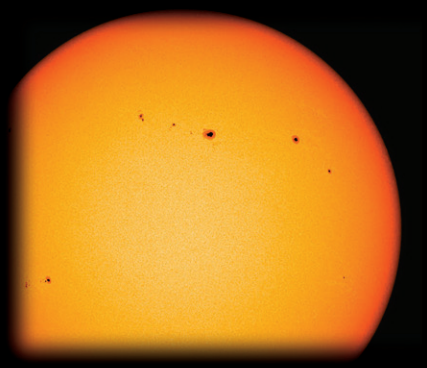
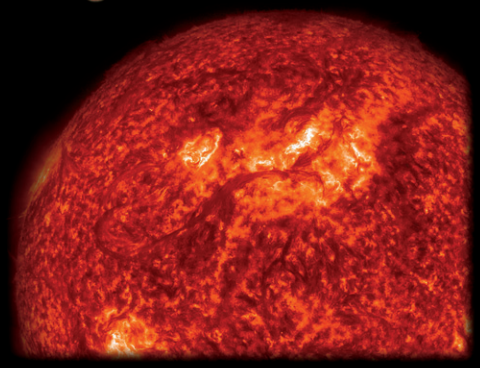
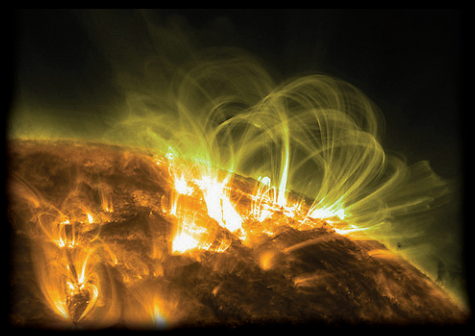
National Aeronautics
and Space Administration

Tracking a Solar Storm

Interface Region Imaging Spectrograph

An Educator Guide for the IRIS Mission Challenge Activity

Educator Guide	
Educators	Grades 6–12

EG-2013-01-002-ARC

Tracking a Solar Storm: An Educator Guide for the IRIS Mission Challenge Activity is available in electronic format only. A PDF of this publication may be accessed at the following address: **http://irischallenge.arc.nasa.gov/**

TRACKING A SOLAR STORM

An Educator Guide for the IRIS Mission Challenge Activity

This publication is in the public domain and is not protected by copyright.
Permission is not required for duplication.

Updated September 2013

Table of Contents

About this Guide and Challenge Overview 6

Objectives, Materials, and National Science Standards 7

Engage 8

Explore 9

- The Sun 9
- Solar Storms 11
- Solar Cycle 13
- Auroras 14
- Solar Missions 16
- Instruments 18
- People 20

Explain 21

- Gather Materials 21
- Collect and Analyze Data 22
- Produce a Space Weather Report 24
- Share Your Space Weather Report 25

Glossary 26

Acknowledgments

Rebecca Green, the Collaborative
Tracking a Solar Storm IRIS Challenge Educator Guide Developer

Linda Conrad, the Collaborative
Tracking a Solar Storm IRIS Challenge Coordinator

Special thanks to our IRIS mission subject matter experts, mission specialists, and content reviewers/contributors:

Bart De Pontieu, Lockheed Martin Solar and Astrophysics Laboratory
IRIS Mission Science Lead

Debbie Scherrer, Stanford Solar Center
IRIS Mission Education & Public Outreach Lead

John Marmie, NASA Ames Research Center
IRIS Mission Assistant Project Manager

Special thanks to the NASA Goddard Space Flight Center-based team that produced the Space Weather Action Center website and associated educational materials on which this challenge was based.

Elaine Lewis, ADNET Systems Inc.
NASA Sun-Earth Day Team Education Specialist

Troy Cline, ADNET Systems Inc.
NASA Sun-Earth Day Team Education Technologist

ABOUT THIS GUIDE

The purpose of this educator guide is to provide background information on a list of topics relevant to the *Tracking a Solar Storm* challenge. In addition to the printed information, this guide includes a list of web resources and web-based videos that you and your students can explore for more in-depth information. Also featured are recommended supplemental activities, such as building a spectroscope and math connections, and a glossary defining key terms appearing in **boldface** type. At the end of the guide are instructions for setting up a space weather station, collecting space weather data, and putting together a space weather report. Finally, in this guide, temperatures are given in degrees Celsius, and distances are given in miles.

The scope and sequence of how you carry out the challenge activity is up to you, the educator. Depending on the time available, you can decide if you want your students to work together as a class, in small teams, or individually and whether or not you want to explore all or some of the topics and activities. This guide simply outlines all of your options.

Important: Throughout the challenge, students will have the opportunity to research and explore several subtopics including the effects of space weather on Earth, past and present solar missions, scientific instruments, and a variety of people and careers involved in carrying out a mission. Much of this information is housed on the ***IRIS Challenge website*** in the form of videos, images, bios, and external web links. Pay close attention to the **yellow callout boxes** located at the end of each section as these point to recommended web resources such as engaging videos, intriguing images, and well-written articles that will provide a wealth of information to your students beyond what this guide offers.

CHALLENGE OVERVIEW

Tracking a Solar Storm is a challenge activity associated with NASA's **I**nterface **R**egion **I**maging **S**pectrograph (IRIS) mission that launched on June 27, 2013. IRIS is a solar mission that will study the dynamics of the **interface region** of the Sun's atmosphere, allowing us to understand the processes powering it. The interface region is the area between the Sun's surface (the photosphere) and upper atmosphere (the corona). From its Sun-synchronous orbit, the IRIS spacecraft will trace the flow of energy and plasma from the photosphere through the chromosphere and into the corona using an ultraviolet telescope and imaging spectrograph. The IRIS Challenge is designed to help students learn about the Sun's anatomy, the space weather it generates, and why studying the Sun is an important human endeavor. Much like meteorologists study Earth's atmosphere and track and predict the effects of its weather, the IRIS Challenge will guide students to study solar activity, track a magnetic "storm" on the Sun, and predict its effect on Earth.

OBJECTIVES

Upon completing this challenge activity, students will be able to:

- Identify major regions and features of the Sun by using key terminology such as photosphere, chromosphere, corona, sunspot, solar flare, solar prominence, coronal mass ejection, solar wind, and aurora.
- Describe three or more ways in which a solar storm can impact human life on Earth.
- Build a small spectroscope and use it to observe spectra of different light sources.
- Give an oral (video) or written (slide show) space weather report that includes key terminology, solar activity data, and a prediction of a solar weather event's effect on Earth.
- Name and describe three or more careers associated with NASA's IRIS mission.

MATERIALS

This is a general list of materials that students will need to complete the challenge activity:

- Notebook for listing key vocabulary terms, recording data, and scripting the space weather report.
- Access to the Internet for doing research, watching videos, gathering solar images, and collecting solar and auroral data.
- Access to a mobile device with free solar and auroral data apps.
- Digital camera or video camera (smartphones or tablets with these features will do).
- Access to software for creating a space weather report in either slide show form (PowerPoint, Keynote) or video (iMovie, iPhoto, Garage Band, etc.).
- If students produce a video weather report, then they will need a place to upload and post the video online such as a classroom website or You Tube channel.
- If students do the optional Build a Spectroscope activity, then you will need to order a class set of spectroscope kits from the Stanford Solar Center (see page 23) and have a variety of light sources.

NATIONAL SCIENCE STANDARDS

The activities in *Tracking a Solar Storm* are correlated with the following National Science Standards for Grades 5-8:

Unifying Concepts and Processes
- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement

Science As Inquiry
- Abilities necessary to do scientific inquiry
  - Design and conduct a scientific investigation
  - Use appropriate tools and techniques to gather, analyze, and interpret data
  - Develop descriptions, explanations, predictions, and models using evidence
  - Think critically and logically to make the relationships between evidence and explanations
- Communicate scientific procedures and explanations
- Use mathematics in all aspects of scientific inquiry
- Understandings about scientific inquiry

Physical Science
- Properties and changes of properties in matter
- Transfer of energy

Earth and Space Science
- Earth in the solar system

Science and Technology
- Understandings about science and technology

Science in Personal and Social Perspectives
- Natural hazards
- Science and technology in society

History and Nature of Science
- Science as a human endeavor
- Nature of science

ENGAGE

Open the lesson with a class discussion on storms. During the discussion, have students record in a notebook weather terminology that their classmates commonly use such as "severe," "forecast," and "warning." These types of words and phrases will be useful later in the challenge as students prepare their **space weather** reports.

- *Who has been in a storm?*
- *What was it like? (Describe the sights and sounds. Was there wind, rain, hail, snow?)*
- *Did you have any advance warning that the storm was coming, such as a TV weather report, a radio announcement, or a siren?*
- *How did you prepare for the storm?*
- *Was any property damaged? Were you without power?*
- *What impact did the storm have on your family's short term or long term plans?*

We know storms on Earth are full of powerful forces that can damage property, ruin crops, and disable the power grid through flooding, lightning-induced fires, high winds, large hail, and heavy snow and ice. They can cause people to change travel plans, to be stranded by delayed or canceled flights, to suffer without heating or air conditioning, or to be displaced from their home for days or weeks. But what about storms that occur outside of Earth's atmosphere?

Our Sun is a medium-sized star located in the center of our **solar system**. It is a spinning ball of hot gases that drives our winds and supports life on Earth by providing necessary light and heat. But in addition to influencing vital systems on our home planet, the Sun also generates space weather. As Earth's atmosphere heats and cools, warm moist air masses mix with cool dry air masses causing traditional storms to develop. Similarly, conditions on the Sun's surface and atmosphere are constantly changing, causing powerful **solar storms** to erupt. The energy of these storms is carried by the solar wind 93 million miles to planet Earth where it affects humans in a variety of ways, including interference in communication systems, satellite failure, power outages, and cosmic ray exposure to human space travelers.

Wrap up the discussion by informing students that in the *Tracking a Solar Storm* challenge, they will learn about the anatomy of our Sun, the life span and effects of a solar storm, and the people, tools, and space missions currently studying the Sun's activity. Then they will take on the role of space weather meteorologists by tracking the Sun's activity and predicting the effects of a solar storm on Earth.

Close the discussion by showing students the nine-minute video, *Solar Storms: Why We Care,* hosted by astronomer Sten Odenwald.

Recommended Web Video

Solar Storms: Why We Care
A Talk with Astronomer Sten Odenwald (9:15)

This video is on the challenge website listed as "Solar Storms, part 1" http://irischallenge.arc.nasa.gov/videos/irisvid1.html

Recommended Music

"The Sun Song"
by The Chromatics (2:45)

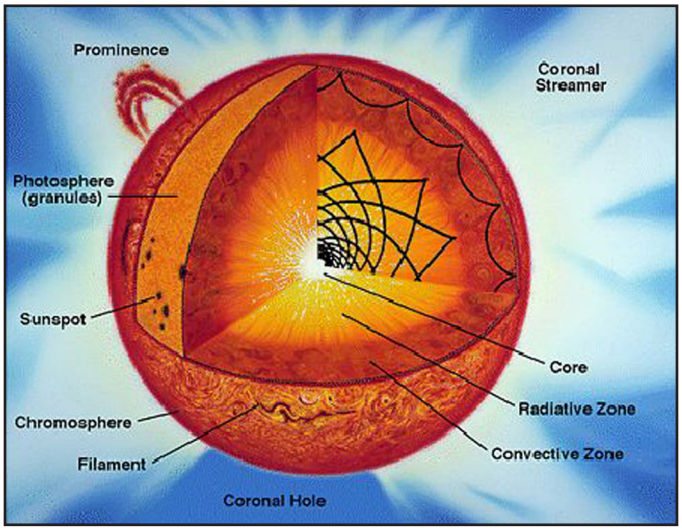
http://venustransit.nasa.gov/2012eclipse/chromatics.php

EXPLORE

During this portion of the challenge, students will acquire knowledge about the Sun, solar storms and their effect on Earth (including the auroras), current solar missions, science instrumentation, and the people who support these missions. You may choose for your students to explore all these topics one by one as a class or, instead, divide them into small groups, assign each group a single topic, and then have them report back to the class on what they learned.

The Sun

Our Sun is a massive, multi-layered, turbulent ball of hot gases that measures 865,000 miles across and makes up about 99% of all the mass in our solar system. At the **core**, where nuclear fusion converts hydrogen to helium, temperatures reach 15 million degrees Celsius (°C). Energy slowly travels from the core through the radiative zone to the convective zone before reaching the Sun's surface and atmosphere.



Moving from the core of the Sun to the surface, the temperature drops from 15 million°C to 5,000°C. Then a strange thing happens. As we move farther out into the Sun's atmosphere, the temperature dramatically increases again, first to 20,000°C in the chromosphere and then to millions of degrees in the corona.

Just as Earth's atmosphere is layered, the Sun's atmosphere is divided into three regions. The lowest region is the **photosphere**, which is the visible surface that we see. The photosphere is much cooler than the core with a temperature around 5,500°C. The middle region is the **chromosphere**, which is only visible during a solar eclipse. In the chromosphere, temperatures begin to rise again to around 20,000°C as energy moves further outward to the uppermost **plasma** layer of the solar atmosphere, the **corona**. The corona extends far into space and is shaped by the Sun's magnetic field. Just like the chromosphere, the corona is only visible with the unaided eye during eclipses. It is here in the hot corona, where temperatures range between 1 to 10 million °C, that the charged particles can no longer be contained by the Sun's gravitational field and thus escape as the **solar wind**. The solar wind streams off the Sun in all directions at speeds of about 1 million miles per hour forming the **heliosphere**, which is the bubble of charged particles surrounding the entire solar system.

The Sun is a dynamic star with moving and flowing gases and ever-changing features such as sunspots, prominences, filaments, and flares. **Sunspots** appear as dark spots on the Sun's photosphere and indicate temperatures a few thousand degrees cooler than the surrounding surface. They are associated with intense magnetic fields and often occur in groups, forming and dissipating over periods of days or even weeks. The occurrence of sunspots tends to be concentrated between 15-30 degrees latitude both north and south of the solar equator. Solar **prominences** and **filaments** are high loops of bright, hot plasma that follow the twisted path of magnetic fields. These impressive features are anchored in the photosphere where sunspots occur and extend thousands of miles high into the corona. Solar **flares** are giant, violent explosions that produce a flash of light and eject billions of energetic particles out of

the Sun and into space. Flares often produce a **coronal mass ejection**, or CME, which is an enormous magnetic ball of plasma that breaks free of the Sun's corona and travels through space at several million miles per hour upon the solar wind.

Recommended Web Resources

1. Sun. National Geographic. http://science.nationalgeographic.com/science/space/solar-system/sun-article/ [Be sure to check out the interesting "sun stats" and interactive animation.]

2. Our Star: The Sun. American Museum of Natural History. http://www.amnh.org/education/resources/rfl/web//starsguide/our-star.html

3. Solar Storm FAQs. NASA Sun-Earth Connection. http://www.nasa.gov/mission_pages/sunearth/spaceweather/index.html [Check out questions 2-5 and questions 9-11.]

4. Solar Physics. NASA Marshall Space Flight Center. http://solarscience.msfc.nasa.gov [The left menu bar points to numerous topics on solar structure, features, and activity.]

5. The Sun's Corona. NASA's Imagine the Universe! http://imagine.gsfc.nasa.gov/docs/science/mysteries_l1/corona.html

6. Coronal Weather Report: Solar Flares and Coronal Mass Ejections. The Center for Science Education at the UC Berkeley Space Sciences Laboratory. Part of the Living With a Star Project. http://cse.ssl.berkeley.edu/coronalweather/CMEsFlares/

Recommended Web Video

Space Weather Questions Part 1 (2:55) Solar Storm FAQs. NASA Heliophysics Sun-Earth Connection.

http://www.nasa.gov/mission_pages/sunearth/spaceweather/index.html#q3

Fun Fact!

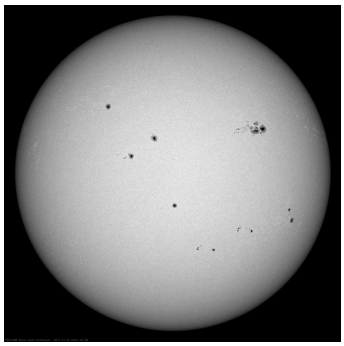
Our sun is white.

The Sun is actually white, which is how human eyes see or interpret all colors mixed together. All stars have a color, which is determined by their surface temperature. Since our Sun has a surface temperature of around 10,000°F, its apparent color is white. In comparison, hotter stars are bluer and cooler stars are redder.

So why does our Sun sometimes appear to be yellow, orange, or red? Well, when the Sun is low on the horizon during sunrise and sunset, the sunlight must pass through a greater amount of Earth's atmosphere. All that atmosphere filters out the short wavelength **light** (violet, blue, green) and allows only the long wavelength colors (red, orange, yellow) to pass through. The same holds true when the atmosphere is laden with dust or smoke.

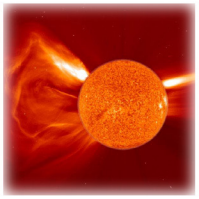
Check out these links to better understand why our Sun is white:

- http://solar-center.stanford.edu/SID/activities/GreenSun.html
- http://www.universetoday.com/18689/color-of-the-sun/
- http://en.wikipedia.org/wiki/Stellar_classification



This image represents how the Sun looks through a telescope above Earth's atmosphere.

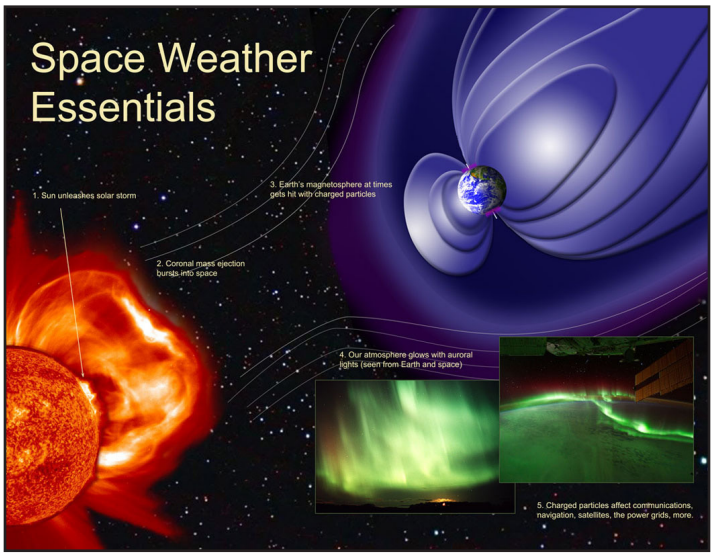
Different cultures choose to represent the Sun with different colors. For example, in the United States school children often color the Sun yellow whereas students in southeast Asia choose orange and Japanese students choose red.



Solar Storms

In our solar system, **space weather** is driven by the Sun's activity. One aspect of space weather that scientists study is **solar storms**, which are the result of solar flares and coronal mass ejections (CME). When powerful flares and CMEs occur, billions of tons of hot, charged particles are blasted millions of miles per hour through our solar system's **interplanetary space**, impacting anything in its path including planets, moons, asteroids, satellites, and spacecraft.

Luckily Earth's magnetic field creates a **magnetosphere** that protects our planet's inhabitants from most of the particles that the Sun emits, including those of solar storms. The Earth's **atmosphere** serves as a second layer of protection by absorbing the higher levels of radiation. Because of these two barriers, very little of the energy from solar flares and CMEs actually reaches Earth's surface.



This image illustrates the sequence of events in the life of a solar storm.

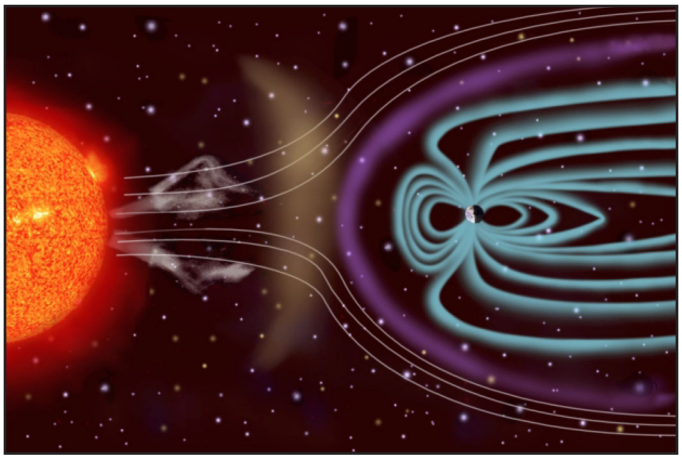
The flash of a solar flare travels at the **speed of light**, taking about 8 minutes to reach Earth 93 million miles away. This is the first signal that a solar storm is headed our way. The solar particles travel at a slightly slower speed, taking 20-30 minutes to reach our planet. The CME travels even slower, taking 1-4 days to reach Earth. When a **solar storm** impacts Earth, the strength of our planet's magnetic field is reduced for six to twelve hours. The magnetic field gradually recovers over a period of several days, but during this weakened period, dramatic **auroras** occur and strong electrical currents travel along Earth's surface. In contrast to providing a lovely nighttime light show, these strong currents can disrupt electric power grids, interfere with high-frequency radio communications and Global Positioning System navigation, expose astronauts to increased radiation, and damage important equipment on orbiting satellites.

So what relevance do the various impacts of solar storms have in the lives of everyday people? Imagine a massive CME strikes Earth causing interference or damage to communications, weather, and military satellites orbiting our planet. Now brainstorm a list of ways that people might be affected. What would that mean for you if you were streaming a movie to your TV or downloading music to your mobile device? How would it impact weather forecasters? What about military operations?

Think also about air traffic. Many international flights, such as those traveling from New York City to Hong Kong, follow a polar route where pilots must use high-frequency radio to communicate with air traffic control. If a massive solar storm were to strike Earth during this time, then many flights would be grounded, delayed, or canceled, ruining family vacation plans and inconveniencing or stranding travelers.

Now, imagine this same storm causes a major power outage that affects millions of people? What if there are freezing weather conditions and those people lose the ability to heat their homes or cook hot food? What if the weather is very hot and they have to go without air conditioning for several days? How would a large-scale power outage affect commuters, hospital patients, and the elderly?

Finally, think beyond the immediate day-to-day happenings on Earth and imagine how a barrage of solar particles would impact people living and working in space outside the protection of Earth's atmosphere and magnetosphere. How might a storm affect their bodies? What if it disabled their spacecraft or life support systems?



This image illustrates a coronal mass ejection approaching Earth and how the solar wind shapes Earth's magnetosphere.

Solar storms impact Earth quite often, and some have been major enough to cause significant problems like those listed above. In September 1859, solar astronomer Richard Carrington of England witnessed a solar flare that caused telegraph systems around the world to malfunction. Likewise, in March 1989, a solar flare caused short-wave radio interference and the resulting CME led to a 12-hour power grid failure in Quebec, Canada that left millions of people without power, many of whom were stuck in elevators, grid locked on city streets, or stranded in subway systems. All these scenarios reinforce the importance of studying and tracking space weather so that we can be prepared for future solar events.

To learn more about solar storms and their impact on Earth, have students visit the five recommended websites and watch the three engaging videos that talk more about CMEs, auroras, space weather, and the 1989 Blackout.

Fun Fact!

Solar storms can interfere with animal navigation.

Solar storms can disrupt man-made navigational equipment, but they can interfere with an animal's ability to navigate as well. Homing pigeons can navigate hundreds of miles very accurately by sensing Earth's magnetic fields. Likewise, ocean life such as whales and sea turtles also use magnetic fields to orient themselves. However, when heightened solar activity results in the form of a geomagnetic storm, Earth's magnetic fields can be distorted causing these types of animals to become disoriented and lost.

Check out these links to learn more about the effects of geomagnetic storms on animals:

- http://solar-center.stanford.edu/solar-weather/pigeons.html
- http://en.wikipedia.org/wiki/Geomagnetic_storm

Recommended Web Videos

1. Coronal Mass Ejection (4:45)
SOHO Classroom Students & Teachers Activities: An Explanatory Video About the Production of Auroras. http://soho.nascom.nasa.gov/classroom/nordlys_english.mp4

2. Space Weather Questions Part 2 (3:27)
Solar Storm FAQs. NASA Sun-Earth Connection. http://www.nasa.gov/mission_pages/sunearth/spaceweather/index.html#q17

3. 1989 Blackout (9:34)
A Talk with Astronomer Sten Odenwald.
This video is on the challenge website listed as "Solar Storms, part 3" http://irischallenge.arc.nasa.gov/videos/irisvid3.html

Recommended Web Resources

1. A Super Solar Flare. NASA Science: Science News. http://science.nasa.gov/science-news/science-at-nasa/2008/06may_carringtonflare/

2. The Day the Sun Brought Darkness. News Topics: Earth. Feature March 13, 2009. http://www.nasa.gov/topics/earth/features/sun_darkness.html

3. Solar Storms Can Cause Power Grids to Fail at Lower Latitudes. Earth Sky Blog, Human World. September 24, 2012. http://earthsky.org/human-world/solar-storms-can-cause-power-grids-to-fail-at-lower-latitudes

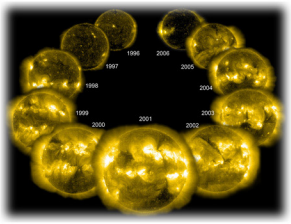
4. Space Weather Center activities. http://www.spaceweathercenter.org/activity_page/01/01.html

5. This Is What 670 Million People Without Power Look Like: Pictures from a Blacked Out India. Zero Hedge, News. July 31, 2012. http://www.zerohedge.com/news/what-670-million-people-without-power-look-pictures-blacked-out-india [Note: This event was not caused by a solar storm, but the story does illustrate the effect of a major power outage.]

Fun Fact!

It takes 8.3 minutes for a photon to travel from the Sun's surface to Earth.

It takes only 8 minutes and 20 seconds for a **photon** of light to travel from the Sun's photosphere to Earth. In contrast, it takes between 10,000 and 170,000 years for a photon to travel from the Sun's core to the surface! To learn about the complicated journey of a photon, read the "Ancient Sunlight" article on NASA's Sun Earth Day: Living in the Atmosphere of the Sun website. http://sunearthday.nasa.gov/2007/locations/ttt_sunlight.php



Solar Cycle

About every 11 years our Sun completes a **solar cycle** caused by its changing magnetic field. During this period, solar activity heightens for what is called the **solar maximum** and then ebbs significantly for what is called the **solar minimum**. During a solar maximum, sunspots are large, long-lasting, and nearly always present. The occurrence of flares and CMEs also is greatly increased. In contrast, during a solar minimum, sunspots are small, short-lived, and very infrequent and overall activity on the sun is relatively quiet. Counting sunspots is how scientists monitor the 11 year solar cycle.

This series of images shows the Sun approaching Solar Maximum over a three year period.

Notice how the Sun is relatively quiet in early 1997 and then is much more active in late 1999.

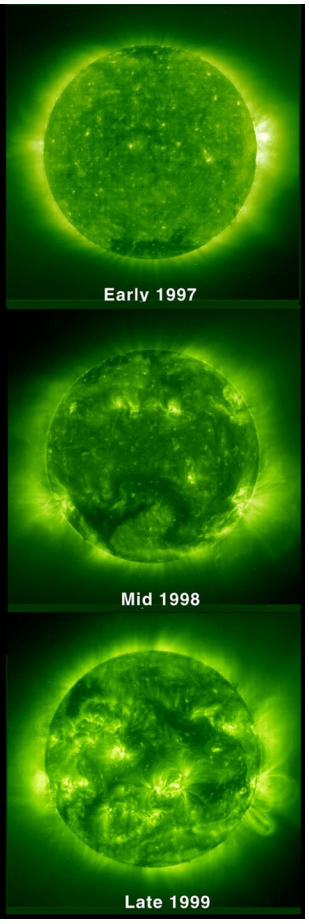


Image credit: NASA SOHO, Extreme Ultraviolet Imaging Telescope

Recommended Web Video

What Is the Solar Cycle? (1:44) NASA Space Weather Media Viewer Videos: "The Sun" (video #4). http://sunearthday.nasa.gov/spaceweather/#

Recommended Web Resources

1. The Sun in Action: The Sunspot Cycle. Solar Science. NASA Marshall Space Flight Center Solar Physics. http://solarscience.msfc.nasa.gov/SunspotCycle.shtml

2. A Complete Solar Cycle from SOHO. Astronomy Picture of the Day. Featured December 3, 2007. http://apod.nasa.gov/apod/ap071203.html

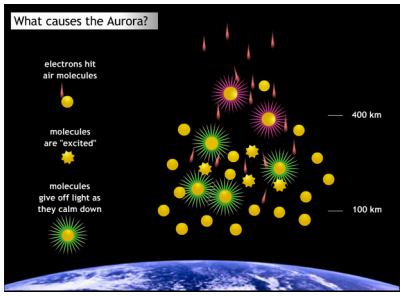
3. Solar Activity Heats Up. NASA Science: Science News. April 14, 2011. http://science.nasa.gov/science-news/science-at-nasa/2011/14apr_thewatchedpot/

4. Solar Activity. NASA Solar Dynamics Observatory: News and Media Resources. http://www.nasa.gov/mission_pages/sdo/news/solar-activity.html

Unusual auroral occurrence 40 miles northwest of Oklahoma City, OK in October 2003. Photo credit: Dave Ewoldt

Auroras

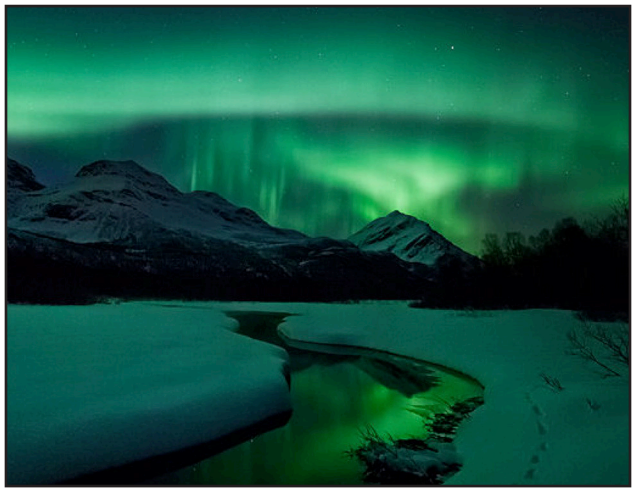
The aurora borealis (northern lights) and aurora australis (southern lights) are lovely phenomena that exemplify solar activity's effect on the Earth – or what we refer to as the Sun-Earth connection. The **auroras** are the result of a domino effect between the solar wind, Earth's protective magnetosphere, and Earth's upper atmosphere. As the solar wind impacts Earth, much of the **plasma** is deflected by Earth's magnetic field, yet some of the electrically charged particles penetrate the magnetosphere and travel along electric currents to Earth's upper atmosphere. Here, the charged particles collide with oxygen and nitrogen atoms, transferring their energy to these gases. These energized gases, in turn, become excited and move around rapidly. As the oxygen and nitrogen atoms begin to settle down and return to their normal state, they re-radiate the energy in the form of **light**. It is the emitted **photons** of light that we see as the auroras.



Auroras generally occur at altitudes between 60 and 200 miles, and the colors vary from green to red to violet. The color of the aurora depends on which gas is being excited and to what magnitude. Oxygen emits a greenish or reddish light whereas nitrogen emits a bluish or purplish light. Both gases also emit ultraviolet light that can be detected by special cameras but not the human eye.

Auroras can occur day or night, but the auroral light is overpowered by the Sun's light and, therefore, is only visible in the dark hours. Auroras usually occur in ring-shaped areas circling Earth's magnetic poles. The

rings expand and contract based on the intensity of the solar wind, which is heightened by solar flares and CMEs. Auroras are commonly seen at the high northern latitudes of central Canada, Alaska, Greenland, Iceland, and Scandinavia and the southern latitudes of Antarctica. On rare occasions, they have been seen in the northern hemisphere as far south as Florida or Texas and in the southern hemisphere as far north as Argentina, Chile, New Zealand, and Australia.



Lovely auroral display near Tromsø, Norway, during the spring equinox (March 20, 2012). Photo credit: Ole C. Salomonsen

Recommended Web Resources

1. Auroras: Sun-Earth Connection. NASA THEMIS Mission: Understanding Space Weather. April 25, 2006. http://www.nasa.gov/mission_pages/themis/auroras/sun_earth_connect.html

2. Auroras Over North America. NASA Earth Observatory. October 10, 2012. http://earthobservatory.nasa.gov/IOTD/view.php?id=79373

3. OVATION Aurora Forecast. NOAA Space Weather Prediction Center. http://helios.swpc.noaa.gov/ovation/

Fun Fact!

Auroras occur most often near the equinoxes.

Equinox means equal night and is the period during the year in which day and night are of equal length. An equinox occurs twice a year when the tilt of Earth's axis is even with the Sun, meaning that the center of the Sun is aligned with Earth's equator. The vernal equinox marks the first day of spring in mid-March, and the autumnal equinox marks the first day of autumn in mid-September. During those times, due to the Sun-Earth alignment, the solar wind strikes Earth at a greater intensity increasing the likelihood of auroral activity. Auroral activity also increases during the solar maximum of the solar cycle when there is a greater frequency of sunspots, flares, and CMEs.

Recommended Web Videos

1. Space Weather and Earth's Aurora (4:45) An Explanatory Video About the Production of Auroras. This video is on the challenge website: http://irischallenge.arc.nasa.gov/videos/irisvid14.html

2. Flying Through a Geomagnetic Storm (3:22) NASA Missions: Sun-Earth. News & Media Resources. http://www.nasa.gov/mission_pages/sunearth/news/aurora-underfoot.html

3. Substorm and Aurora (0:49) NASA Missions: THEMIS. News & Media Resources. "THEMIS Celebrates Five Years of Watching Aurora and Space Weather." February 17, 2012. http://www.nasa.gov/mission_pages/themis/news/five-years.html

4. NASA Space Weather Media Viewer. Videos: "Aurora" (videos #1-8). http://sunearthday.gsfc.nasa.gov/spaceweather/#

Solar Missions

For well over a decade, NASA has studied the Sun and the space weather it creates through a variety of missions. Below is a brief description of ten such missions, most of which are currently in operation.

SOHO - Launched in December 1995, the Solar and Heliospheric Observatory (SOHO) studies the Sun from its deep core to the outer corona, including the solar wind. The SOHO mission is a project of international collaboration between the European Space Agency and NASA. The spacecraft is outfitted with twelve scientific instruments including two spectrometers. http://soho.nascom.nasa.gov/

TRACE - Launched in April 1998 and functional through June 2010, the Transition Region and Coronal Explorer (TRACE) used an imaging telescope to study the behavior of the Sun's looping magnetic fields and its superheated upper atmosphere by capturing high resolution images of the photosphere, transition region, and corona. http://science.nasa.gov/missions/trace/

RHESSI - Launched in February 2002, the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI)uses x-ray and gamma ray imaging spectroscopy to explore the physics of particle acceleration and explosive energy release in solar flares. http://hesperia.gsfc.nasa.gov/rhessi2/

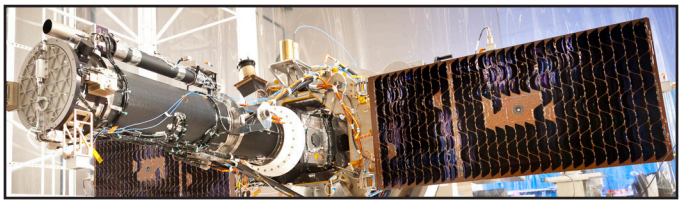
Hinode - Launched in September 2006, Hinode is measuring the solar magnetic fields and determining how energy influences the dynamics and structure of the Sun's upper atmosphere. The Hinode mission is a multi-nation endeavor between the Japan Aerospace Exploration Agency, NASA, and the United Kingdom's Particle Physics and Astronomy Research Council. http://solarb.msfc.nasa.gov/

STEREO - Launched in October 2006, the Solar Terrestrial Relations Observatory (STEREO) is a pair of identical spacecraft, STEREO A and STEREO B, that orbit the sun, one ahead of Earth and the other trailing. Together these observatories are exploring the causes and mechanisms of coronal mass ejections and how they evolve. Through 3-D images, the STEREO mission provides scientists with a better view of how solar storms begin and helps them trace the flow of energy and matter of these storms as they move from the Sun into space. http://stereo.gsfc.nasa.gov/

THEMIS - Launched in February 2007, the Timed History of Events and Macroscale Interactions during Substorms (THEMIS) mission utilizes a set of five identical probes to study the onset of solar substorms and how they trigger auroral eruptions. http://www.nasa.gov/mission_pages/themis/main/index.html

SDO - Launched in February 2010, the Solar Dynamics Observatory (SDO) studies the solar atmosphere and investigates how the Sun's magnetic field is generated and structured. The instruments aboard SDO are examining where the sun's energy comes from, how the inside of the Sun works, and how energy is stored and released in the sun's atmosphere. http://sdo.gsfc.nasa.gov/

Van Allen Probes - Launched in August 2012, the Van Allen Probes mission is using two spacecraft to study how Earth's Van Allen Radiation Belts behave during solar storms. Data will help scientists and engineers design more robust satellites and safer spacecraft as well as stronger safeguards for communication systems on Earth. http://www.nasa.gov/mission_pages/rbsp/main/index.html



IRIS Spacecraft, Photo Credit: Lockheed Martin

IRIS - Launched on June 27, 2013, the Interface Region Imaging Spectrograph (IRIS) spacecraft is orbiting 400 miles above Earth studying the region of the Sun's atmosphere between the photosphere and corona. In this dynamic place, solar activity raises temperatures from 10,000°F at the surface to millions of degrees in the upper atmosphere. Scientists are curious to know why solar temperatures steadily cool from the core to the photosphere yet rise again from the photosphere to the corona. Outfitted with an ultraviolet **telescope** and high-resolution imaging **spectrograph,** the IRIS spacecraft will trace the flow of heat, energy, and **plasma** through the chromosphere and **transition region**. The high-resolution images and spectra obtained by IRIS, coupled with advanced computer models, will help scientists better understand the mystery of how stellar atmospheres are energized. The science conducted by the IRIS mission will complement the efforts of the Solar Dynamic Observatory (SDO). Where SDO monitors the solar surface (photosphere) and outer atmosphere (corona), IRIS will monitor the **interface region** in between. Together they will explore how the solar atmosphere works and impacts Earth, thus helping forecasters better predict space weather events.

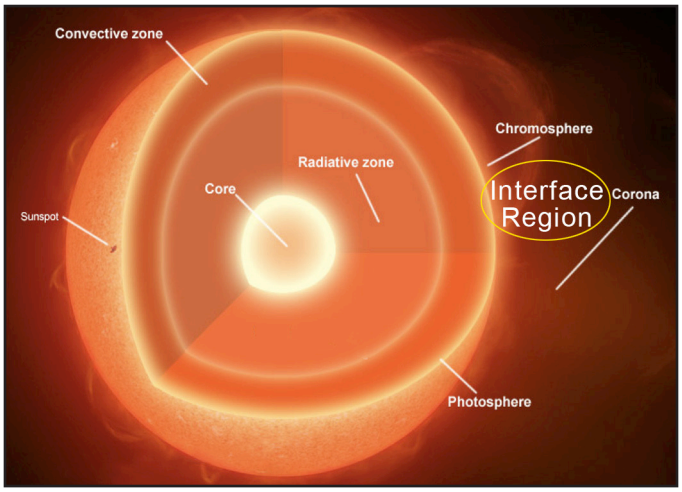


Illustration showing the interface region of the Sun's atmosphere.

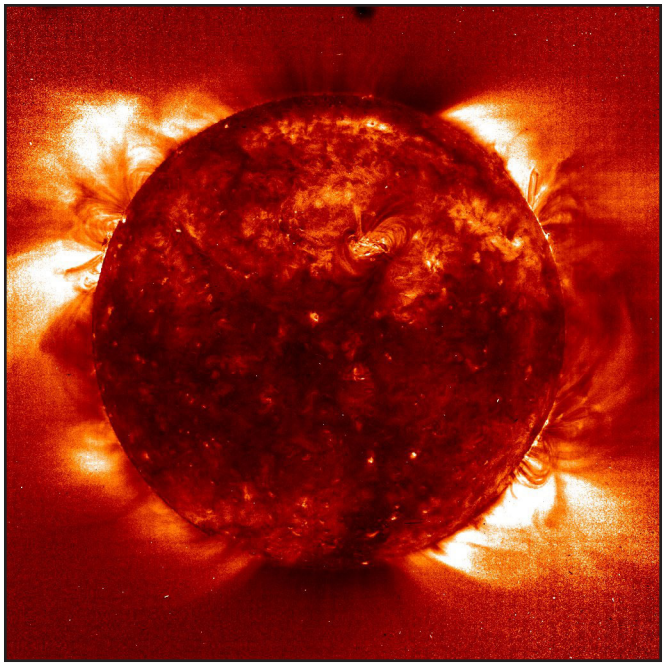
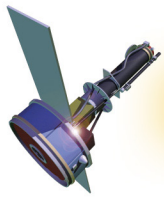


Image of the Sun as seen through an extreme ultraviolet imaging telescope Credit: NASA SOHO, September 1997

The IRIS mission is a joint effort between multiple institutions. Lockheed Martin Solar and **Astrophysics** Laboratory is primarily responsible for the mission, having built the multi-channel spectrograph and being in charge of overall integration. Montana State University assisted in the development of the spectrograph, and the Smithsonian Astrophysical Observatory provided the UV telescope. Another division of Lockheed Martin built the spacecraft. NASA is providing help through two of its centers: Goddard Space Flight Center, which oversees program management, and Ames Research Center, which is responsible for mission operations and ground station data systems. Orbital Sciences Corporation will launch the spacecraft from Vandenberg Air Force Base in California aboard a Pegasus XL rocket. Ground stations at Wallops Flight Facility in Virginia, Svalbard, Norway, and Fairbanks, Alaska will track and receive data from the IRIS instruments. The University of Oslo is providing downlinks, data archiving, and numerical simulations, and Stanford University will collect the science data, format it, archive it, and make it available to the science community. http://www.nasa.gov/mission_pages/iris/index.html



Instruments

The Sun is too far away for us to study up close in person. Luckily, there are scientific methods of studying the Sun from a distance. Two scientific instruments commonly used to study the Sun are telescopes and spectrographs. NASA's IRIS mission will utilize both as it studies the Sun's atmosphere. Specifically, the IRIS spacecraft will be outfitted with a 20 cm ultraviolet telescope and an imaging spectrograph. So what exactly are these instruments and how do they work?

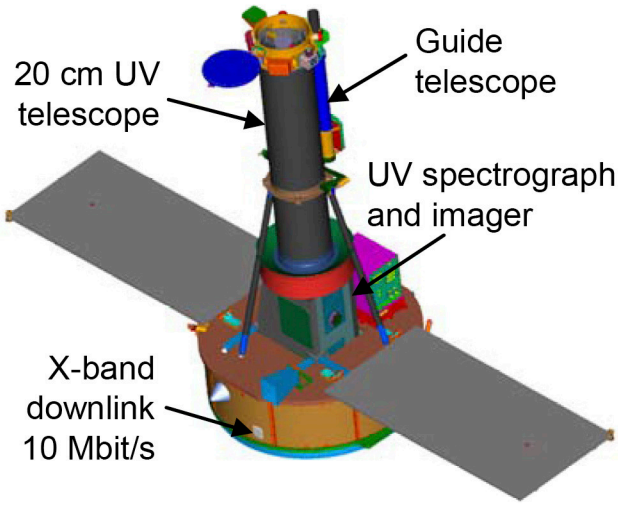
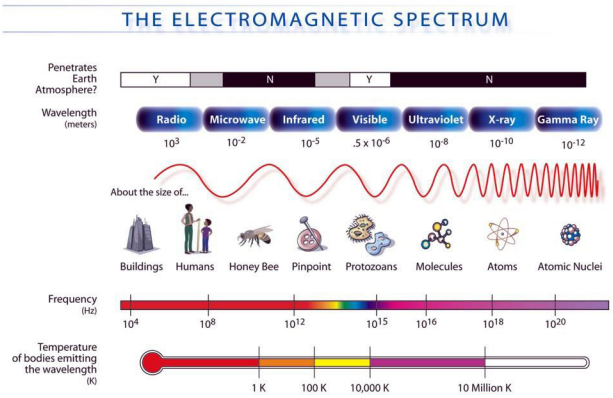


Illustration of the IRIS spacecraft instruments

The Sun emits **electromagnetic radiation** (light) that travels as waves throughout **interplanetary space**. By studying the **light** emitted by the Sun, we can learn about its temperature, density, movement, magnetic fields, and chemical composition. Light has a range of wavelengths, and one way scientists learn information is by analyzing a specific wavelength. Scientists call the wavelengths of light a **spectrum**. At one end of the electromagnetic spectrum are gamma rays which are comprised of high-energy **photons** that have short wavelengths with high frequency. Next in line are x-rays followed by **ultraviolet light**. Visible light, which the human eye can perceive, is sandwiched between the ultraviolet and infrared regions of the spectrum and can be broken down into the colors of the rainbow. Following the visible light portion of the spectrum are infrared light and then microwaves. Finally, at the other end of the spectrum, are radio waves which are made up of low-energy photons characterized by long wavelengths with low frequency.

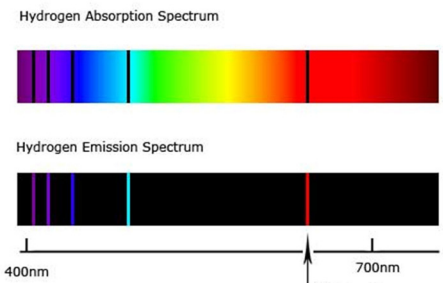


A **telescope** detects light, including wavelengths outside the visible light portion of the electromagnetic spectrum. This instrument lets humans see features and details beyond what their eyes allow. By using filters to block out certain wavelengths of light while allowing other wavelengths to pass through, scientists can detect specific types of information. For example, one filter allows us to see variations in temperature while another filter helps us measure how fast the gases on the Sun are moving. A polarizing filter gives us information about the Sun's magnetic fields, and different color filters help us see light from specific chemical elements. The telescope on the IRIS spacecraft will be looking at the Sun through an ultraviolet (UV) filter, meaning that only UV light will be allowed to pass through. Since Earth's atmosphere blocks much of the Sun's UV energy, this type of observation must be made from space.

A **spectrograph** (or spectroscope) is an instrument that analyzes the light emitted from objects like stars and nebulae as well as light reflected from objects like planets and moons. A spectrograph works by letting light pass

through a narrow slit and then, using a diffraction grating, disperses the light into its progression of wavelengths, or colors. This forms a spectrum that we can look at, which acts like a fingerprint identifying the unique properties of the light source (e.g. the Sun).

An object that is glowing because it is hot essentially will give off a continuous spectrum showing all of the visible colors of the rainbow from red to violet. A good example of this is the surface of the Sun, or photosphere. However, gas being energized by that hot source will emit a spectrum that consists of individual lines, each a specific color that represents a specific wavelength of light.



When the energized gas is viewed against a dark background, the re-emitted wavelengths will show up as an emission line spectrum (or bright line spectrum). A good example of an emission line spectrum is the solar atmosphere, or chromosphere, when viewed at the edge of the Sun. This emission line spectrum arises because different types of atoms and molecules absorb very specific wavelengths of light when light passes through them. These atoms and molecules then re-emit those same wavelengths in random directions. When a thermal source is viewed through a gas, the atoms and molecules in the gas will absorb certain wavelengths, resulting in a bright continuous spectrum showing a series of dark absorption lines where specific wavelengths have been absorbed. This is called an absorption line spectrum. When scientists view the chromosphere at the edge of the Sun (with dark space behind it), the chromosphere shows an emission line spectrum. In contrast, when they view the chromosphere against the Sun's bright disk, it shows an absorption line spectrum.

Atoms and molecules emit and absorb light at specific wavelengths, leaving a unique pattern of lines (a fingerprint) on the spectrum. This makes it possible to detect their presence in distant objects like the Sun. By studying the pattern of the spectrum and its graph, called a spectrogram, scientists can detect the different elements in the atmosphere of the object at which they are looking.

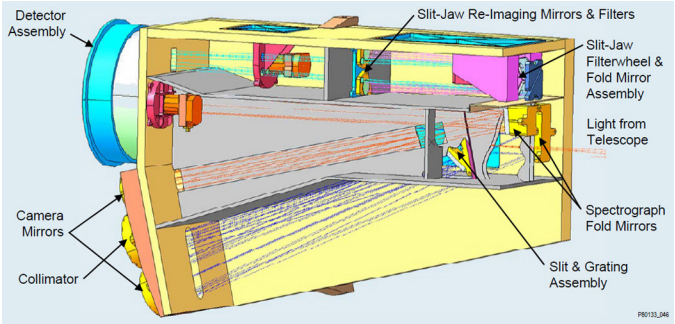


Illustration of the IRIS spectrograph

NOTE: Young students might enjoy the *Tales from Stanford Solar* comic book titled, "What Color is the Sun?"

Recommended Web Videos

1. Colors of the Sun (13:00)
Stanford Solar Center.
A video describing the use of telescopes and spectrographs in solar astronomy. http://solar-center.stanford.edu/colors/qt.html

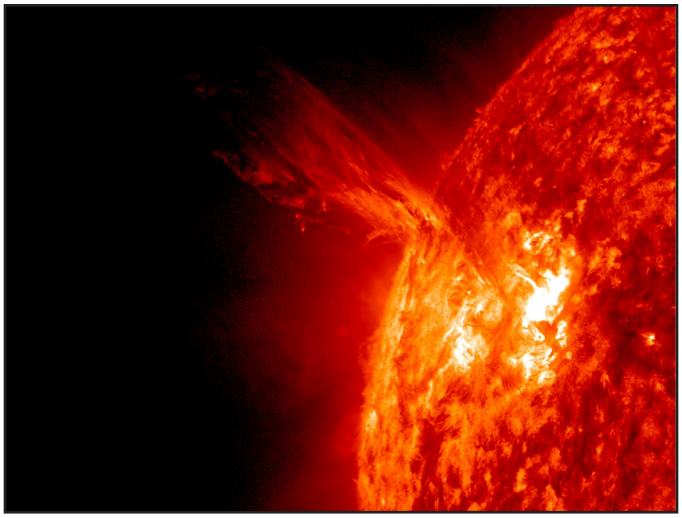
2. Inside Solar Storms: The View from the Hinode Satellite (9:54)
This video is on the challenge website listed as "Solar Storms, part 2" http://irischallenge.arc.nasa.gov/videos/irisvid2.html

3. Infrared: More Than Your Eyes Can See (7:00) NASA Jet Propulsion Laboratory.
A video describing the use of infrared light to study the universe. http://www.spitzer.caltech.edu/video-audio/145-ask_ir-Infrared-More-Than-Your-Eyes-Can-See

Recommended Web Resources

1. Introduction to The Electromagnetic Spectrum. Mission: Science. NASA Science Mission Directorate. 2010. http://missionscience.nasa.gov/ems/01_intro.html

2. Infrared Spectroscopy: What is Spectroscopy. Cool Cosmos: Infrared Astronomy. http://coolcosmos.ipac.caltech.edu/cosmic_classroom/ir_tutorial/spec.html



Solar flares June 27-29, 2012.

Image credit: NASA.
Solar Dynamic Observatory web gallery

People

It takes a broad mix of people with a variety of skill sets to run a mission. To start, an assortment of engineers are needed to design, build, and assemble the spacecraft. Electrical engineers work on the solar cells that power the spacecraft computers. Mechanical engineers figure out how to build the spacecraft so it doesn't break apart during the violent launch. Thermal engineers design cooling and heating mechanisms to protect the craft from the extreme hot and cold environment in space. Computer programmers and software engineers must write code that will control the instruments and spacecraft and allow them to communicate and relay data back to Earth. Next, program managers must oversee all parts of the project and make sure that everyone on the team is doing their job and staying on schedule. Financial specialists must track the money that is being spent and make sure that materials are purchased and people are paid. Scientists must decide what needs to be studied, how to study it, and how to interpret the data. Outreach specialists are in charge of informing the public about the mission and explaining its purpose and value. To learn about some of the talented people supporting the IRIS mission, visit the Bios section of the challenge website: http://irischallenge.arc.nasa.gov/iris_bios.html

People often bring more than traditional job skills to the work that they do. For example, the IRIS mission's Assistant Project Manager, John Marmie, is an engineer with strong project management skills, meaning that he understands both the technical and business aspects of running a mission. But in addition to these left-brain skills, he also has creative talents. One of John's hobbies is writing songs and playing music. He has found a way to blend his job skills and hobby by creating songs about the NASA missions that he supports. Most recently, John added an IRIS song to his music collection. You can listen to this song as well as John's other space exploration-themed music for free on his *Curiosity* album on Google Play.

Recommended Music

"IRIS" by John Marmie (3:27) Google Play. John Marmie. Curiosity album. November 11, 2012 https://play.google.com/store/search?q=john+marmie

EXPLAIN

The Sun is currently entering a solar maximum, making 2013 a good year for both the IRIS mission and for observing active sunspots, flares, and CMEs. Now that your students have acquired a basic understanding of the Sun and the way in which its activity affects Earth, they will spend the next few weeks monitoring space weather and predicting its effects on our planet. This portion of the challenge will culminate in a space weather report given to the class in the form of a video or presentation.

As the teacher, you can decide if you want to divide your class into small teams or complete the project as a whole class. If divided into teams, each group can either complete the entire weather study from start to finish, meaning you will have a weather report for each team, or each group can take on a particular topic to study, meaning that the teams will share their findings with the rest of class and generate one final weather report.

NOTE: The format for the Tracking a Solar Storm portion of this challenge has been adapted from the well-established NASA Sun-Earth Day Space Weather Action Center activity. If you would like to conduct this challenge activity in greater depth, then you can download the Space Weather Action Center instructional guide along with the student-friendly flip charts and data collection sheets from the website below.

http://sunearthday.nasa.gov/swac/

1. GATHER MATERIALS

- Data Collection notebook(s)
- Computer with Internet access to these websites:
  - NASA Space Weather Action Center Data: http://sunearthday.nasa.gov/swac/data.php
  - NASA Space Weather Media Viewer: http://sunearthday.gsfc.nasa.gov/spaceweather/#
  - NOAA Space Weather Prediction Center: http://www.swpc.noaa.gov/
    - » Alerts/Warnings
    - » Space Weather Now
    - » Today's Space Wx
    - » Data and Products
  - SOHO Space Weather: (*for advanced students*) http://sohowww.nascom.nasa.gov/spaceweather
  - Space Weather: http://www.spaceweather.com
  - Geophysical Institute Aurora Forecast: http://www.gi.alaska.edu/AuroraForecast

- Mobile device with any of the following free apps:
  <u>iTunes and Google Play:</u>
  - Ideum: **NASA Space Weather Media Viewer (Sun Viewer)**
  - NASA Heliophysics Division: **3D Sun**
  - SELab Inc: **SWx Monitor (SWx)**
  - Utah State University USTAR: **Space Weather Center Free (SpaceWx)**
  - ASTRA: **Solar Dynamics Observatory (SDO)**
  - ASTRA: **Space Weather (SWA)**
  - Tinac Inc: **Aurora Forecast (Aurora Fcst)**

  <u>iTunes only:</u>
  - Concentric Sky: **Astronomy Picture of the Day (APOD)**

  <u>Google Play only:</u>
  - Tomasso: **Solaris Alpha**

- Presentation software (PowerPoint, Keynote...) <u>*or*</u> video equipment (smartphone, digital camera, tablet computer...) and the ability to upload video files to the computer.

- Video editing software, e.g. iMovie (*optional*)
- Music capability, e.g. iTunes/Garage Band (*optional*)

2. COLLECT AND ANALYZE DATA

On a routine basis (daily or weekly), utilize the suggested websites and apps to collect data regarding the Sun's activity. Record the data in a data collection notebook, making note of key information such as dates, location of activity on the Sun, intensity or magnitude of solar events, changes in solar activity compared to previous observations, sources of information/data, terminology, etc. In particular, students should monitor:

- Sunspot activity.
- If a solar flare or CME occurs within the observed active sunspot region.
- The magnitude of the solar flare or CME.
- Whether or not the flare or CME is directed toward Earth.
- The effects of an Earth-directed flare or CME (e.g. heightened auroral activity).

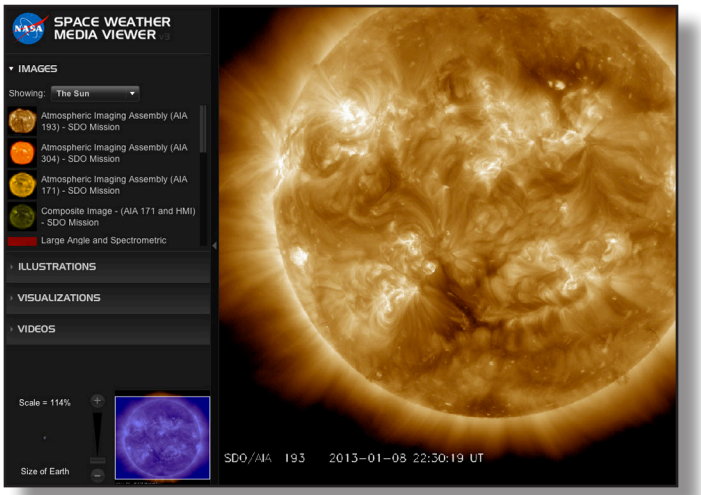
TIPS FOR COLLECTING AND ANALYZING DATA:

- Students should **not** observe the Sun directly with their naked eyes as this can damage their eyesight.

- To enhance their final space weather report, students should capture images (screenshots from apps and websites or already existing imagery) that represents the solar activity they are observing.

- When collecting data from the GOES Solar X-ray Flux Monitor on the NOAA Space Weather Prediction Center website (http://www.swpc.noaa.gov/today.html), use the solar x-ray activity scale along the side of the graph to determine the power of the solar storm. The scale has five levels: A, B, C, M, and X. Each level is 10 times more powerful than the previous level, such that level B is 10 times more powerful than level A, level C is 10 times more powerful than level B, and so on.
  - Levels A and B indicate that aurora sightings are only possible in higher latitudes.
  - Level C indicates that aurora sightings are possible further south.
  - Levels M and X indicate that aurora sightings are possible as far south as Texas or Florida!

- The Sun-Earth Day Space Weather Action Center (SWAC) website's **Space Weather Media Viewer v3** is a valuable all-in-one resource full of helpful illustrations, visualizations, and videos as well as current images representing real-time data of the Sun.



http://sunearthday.gsfc.nasa.gov/spaceweather/#

Students can collect data from this website on a variety of topics (the Sun, Auroras, the solar wind, the magnetosphere, etc) by toggling the drop down menu in each section of the viewer.

To help students collect data in a systematic fashion, you can have them focus on these four categories:

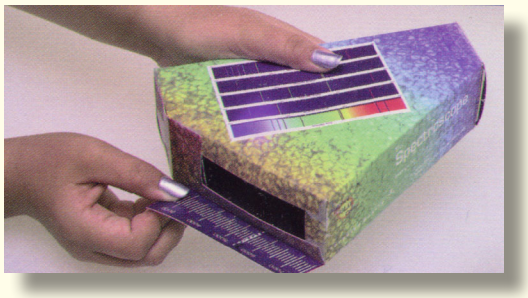
- Sunspot regions
- Storm Signals
- Magnetosphere
- Auroras

http://sunearthday.nasa.gov/swac/data.php

Flip charts & Data Collection Sheets are available for each of the four categories on the SWAC website:
http://sunearthday.nasa.gov/swac/
Resources for each category can be found on the SWAC Space Weather Data page at:
http://sunearthday.nasa.gov/swac/data.php

SPECTROSCOPY ACTIVITY

One of main instruments aboard the IRIS spacecraft is a spectrograph. Students can better understand the value of this tool by building their own spectroscope in class. The Stanford Solar Center website features a "Build Your Own Spectroscope" activity designed for elementary and middle school classrooms (grades 2-4 and 5-8). This activity is an easy and fun way for students to explore & observe the nature of light in a hands-on fashion. Materials include study guides, PowerPoint presentations, videos, and spectroscope kits, all of which are accessible from the website: http://solar-center.stanford.edu/activities/cots.html



Each kit includes enough materials to make 45 spectroscopes. There is no cost for the kit; however, you must pay a $7.00 shipping fee. Orders are placed online at: http://solar-center.stanford.edu/posters/posters_spec_bulk.html

NOTE: It can take *several weeks* to process orders, so plan ahead and order early. To expedite processing, type "IRIS Challenge" on the second optional address line of the online order form (see URL above).

MATH ACTIVITIES

Activity 1: Distances in our solar system are so great that it becomes cumbersome to measure distances in miles or kilometers. Instead, distances are measured in astronomical units, or AU. One AU is defined as the mean distance between the Earth and the Sun, or 149,597,870,700 meters.

1 AU ≈ 150,000,000 kilometers

1 AU ≈ 93,000,000 miles

Given the distance chart below, have your students participate in a unit conversion activity by calculating how many AU each planet is from the Sun. Students can round their answers to the nearest one hundredth.

Planet	Avg distance from Sun (mi)	Avg distance from Sun (km)
Mercury	36,000,000	57,910,000
Venus	67,200,000	108,200,000
Earth	93,000,000	149,600,000
Mars	141,600,000	227,940,000
Jupiter	483,600,000	778,330,000
Saturn	888,000,000	1,429,400,000
Uranus	1,784,000,000	2,870,990,000
Neptune	2,798,600,000	4,504,000,000

Activity 2: A light year is the distance that light can travel in a vacuum in one Earth year (365.25 days). One light year is equal to 5,878,625 million miles or 63,240 AU. To put this distance into perspective, have your students calculate the following:

If 1 AU equals 1 inch, then how many inches represent 1 light year? Next, convert these inches to miles. Answer:

1 AU = 1 inch
1 light year ≈ 1 mile

3. PRODUCE A SPACE WEATHER REPORT

After students have collected sufficient data and images, they will summarize their findings in the form of a weather report. The report can be presented as a video or a slide presentation and either can be broken down into a series of brief daily or weekly weather newscasts or produced as one all-encompassing weather report summarizing solar activity and outcomes spanning a longer time period.

Depending on the Sun's activity, student weather reports may include information on sunspot activity, solar events (flares, filaments, prominences, and CMEs), and auroral occurrences.

Recommended Web Resources

1. NOAA Space Weather Scales. NOAA Space Space Weather Prediction Center. http://www.swpc.noaa.gov/NOAAscales/index.html#GeomagneticStorms

This website shows three scales that will help students write their weather reports:
- Scale for Geomagnetic Storms
- Scale for Solar Radiation Storms
- Scale for Radio Blackouts

2. The Geophysical Alert Message "WWV Broadcast": Sample Messages. NOAA Space Weather Prediction Center. http://www.swpc.noaa.gov/Data/info/WWVdoc.html

This website will help students use proper terminology when writing their report.

3. A Traveler's Guide to the Aurora Borealis. Geophysical Institute. http://www.gi.alaska.edu/AuroraForecast/TravelersGuide

Students should begin organizing their report by writing a script. If working in teams, students can establish roles so that everyone can participate. For example, one student may serve as the news anchor, another may be the space meteorologist, and a third may be a reporter in the field with one or two eye witnesses. Other roles may include camera operator and cue card holder. The following sample script is an adaptation from page 18 of the *Space Weather Action Center Educator's Instructional Guide v4*:

> **Anchor:** *Good evening, this is [anchor name] bringing you a Space Weather Report for [month, day, year].*
>
> *This just in, a large sunspot, number AR1598, erupted with an M-class level 9 solar flare yesterday and is likely to cause communications disruption here on Earth.*
>
> *Giving us the latest update on this solar activity is our space meteorologist, [meteorologist name].*
>
> **Space Meteorologist:** *Thank you, [anchor name]. Yes, this very active sunspot released a major flare on Tuesday and is likely to continue emitting flares over the next few days. Energy from this flare is fast approaching Earth and is expected to spark a strong Kp=7 geomagnetic storm. X-ray emissions are likely to cause an R3 radio communications blackout, resulting in possible low-frequency radio navigation problems and intermittent loss of HF radio contact for about an hour. Auroras are likely to be seen as far south as Oregon and Illinois.*
>
> *Following this event, space weather for the next 24-48 hours is predicted to be moderate. Geomagnetic storms reaching the G2 level are likely and expected. Back to you, [anchor name.]*
>
> **Anchor:** *Thank you, [meteorologist name]. In the field with us today we have [reporter name] reporting from Fairbanks, Alaska. [Reporter name}, tell us what preparations are going on in your area and what you expect to see over the next couple of nights.*

Reporter: *Good evening, [anchor name]. I just spoke to staff at the Fairbanks airport and long haul flights out of there are having to modify their flight plans to avoid the radiation hazard posed to high-flying aircraft. They're hoping to avoid major delays or cancellations.*

On a brighter note, however, forecasted conditions for viewing the aurora are excellent here in northern Alaska with dark, clear skies expected and temperatures hovering around 14ºF. Many folks are likely to venture 17 miles outside Fairbanks on Cleary Summit where past auroral sightings have resulted in bright green ribbons of light dancing in waves across the sky. This latest geomagnetic storm is certain to bring yet another great photo opportunity for photographers in the region. Back to you, [anchor name.]

Anchor: *Thank you, [reporter name]. We will continue to keep you informed of any breaking developments. I'm _____ bringing you today's Space Weather Report. Thanks for watching.*

ART ACTIVITY

In contrast to hard facts and data, science can have an artistic side, too. One example of this is in the work of members of the Solar and Heliospheric Research Group. Listen to this audio interview to learn how composer Robert Alexander and space science research fellow Jason Gilbert teamed up to make music from celestial data.

The Sound of Solar (7:51)
Living on Earth: Public Radio International's Environmental News Magazine. Air Date: Week of March 5, 2010.

http://www.loe.org/shows/segments.html?programID=10-P13-00010&segmentID=7

As students put together their space weather reports, have them select and incorporate music that represents the dynamic activity of the Sun. The music can be used during the opening, closing, or transition portions of their weather report newscast. Some students may even choose to create their own "spacey" music using software such as Garage Band.

4. SHARE YOUR SPACE WEATHER REPORT

Once students have produced their weather report, we encourage them to share their video or slide presentation with their peers as well as with the greater IRIS Challenge community.

Options for sharing a video:

- Upload the video to your personal teacher/classroom website.
- Upload the video to You Tube (requires a free Google account). Common video formats supported by You Tube include:
  - .MOV
  - .MPEG4
  - .AVI
  - .WMV

  Next, email the URL of the website or the You Tube link where the video is posted to the Challenge Coordinator so that it can be linked to the Student Reports section of the *Tracking a Solar Storm* challenge website.

Options for sharing a slide presentation:

- Upload the presentation to your personal teacher/classroom website.
- Save the slide presentation as an Adobe PDF and email the PDF file to the Challenge Coordinator so that it can be posted on the *Tracking a Solar Storm* challenge website. (Only PDF files will be accepted.)

GLOSSARY

Astrophysics – A branch of astronomy dealing principally with the physics of stars, stellar systems, and interstellar material.

Aurora – Light radiated in the sky as energetic electrically charged particles from the magnetosphere travel along Earth's magnetic field and collide with atoms in Earth's upper atmosphere. Auroras occur mostly in the higher latitudes near the polar regions. Those occurring near the North Pole are called "Aurora Borealis." Those occurring near the South Pole are called "Aurora Australis."

Chromosphere – The middle, or transition, layer of the Sun's atmosphere. It is reddish in color and is only visible to the naked eye during a total solar eclipse.

Core – The central, innermost region of the Sun where its energy is produced by the fusion of hydrogen into helium. It is the hottest part of the Sun with a temperature near 27,000,000°F.

Corona – The third, or outermost, layer of the Sun's atmosphere that is comprised of plasma and is the source of the solar wind. The corona is only visible to the unaided eye during a total solar eclipse or through special filters or via x-ray cameras aboard satellites.

Coronal Mass Ejection (CME) – A massive burst of hot plasma expelled from the Sun beyond the corona and accelerated through interplanetary space as solar wind.

Electromagnetic radiation – Energy emitted and absorbed by charged particles that exhibits a wave-like behavior as it travels through space. Listed from shortest to longest wavelength, the electromagnetic spectrum includes gamma rays, x-rays, ultraviolet light, visible light, infrared light, microwaves, and radio waves.

Filament – See *prominence*.

Flare – A sudden, intense, bright flash caused by a violent, rapid outburst of gas on the Sun's surface. Flares usually occur in the vicinity of active sunspots and are the result of a build up of magnetic energy in the solar atmosphere that is suddenly released.

Heliosphere – The bubble of charged particles emanating from the Sun and carried by the solar wind throughout the space surrounding the entire solar system.

Interface region – The portion of the Sun's atmosphere between the surface (photosphere) and the corona.

Interplanetary space – The space between the planets, which is filled with the solar wind, the interplanetary magnetic field, cosmic rays, and dust. This term is often used interchangeably with "heliosphere."

Interstellar space – The space between the stars within a galaxy.

Magnetosphere – The region of space in which the magnetic field of an object (e.g., Earth) deflects a stream of charged particles (e.g., the solar wind).

Photon – The smallest unit of electromagnetic energy (light). Photons are generally regarded as particles with zero mass and no electric charge.

Photosphere – The first, or innermost, layer of the Sun's atmosphere. It is the "surface" of the Sun that we visibly see.

Plasma – A state of matter similar to gas in which the individual atoms are ionized (charged).

Prominence – A large, bright, loop-shaped cloud of relatively cool dense plasma anchored in the photosphere and extending outward into the Sun's corona. When viewed from the top down, such that it appears as a darker feature against the brighter background of the Sun, a prominence is referred to as a filament.

Solar – Of or relating to the Sun.

Solar cycle – An irregular cycle, averaging about 11 years in length, during which the number of sunspots and their associated outbursts increases and then decreases and the polar magnetic field of the Sun reverses. The months during the solar cycle when sunspot numbers reach a maximum is known as the *solar maximum*. In contrast, the months during the solar cycle when sunspot numbers reaches a minimum is known as the *solar minimum*.

Solar storm – a massive barrage of particles from the Sun's atmosphere carried by the solar wind due to an intensive solar outburst such as a solar flare or a coronal mass ejection.

Solar system – a star (e.g. the Sun) and all the planets and other celestial bodies that revolve around it.

Solar wind – A stream of charged particles ejected from the Sun's upper atmosphere (corona) and spread in all directions throughout interplanetary space. Like the Sun, the solar wind is composed mostly of hydrogen and travels at a speed of 400 km/sec, reaching Earth in 4-5 days.

Space Weather – A collection of processes and events driven by solar activity which can affect interplanetary space, including planets, moons, natural and manmade satellites, etc.

Spectrograph (Spectroscope) – A scientific instrument that measures the spectrum of light by separating incoming light into its various colors (or wavelengths). Extra or missing colors indicate details about the source of the light such as chemical composition, temperature, involvement with magnetic fields, and movement toward or away from the observer. Most astronomy is done with spectrographs attached to telescopes.

Spectrum – The distribution of energy emitted by a radiant source (e.g. the Sun), arranged in order of wavelengths.

Speed of light – The speed at which electromagnetic radiation moves through the vacuum of space. It is defined as 299,792,458 meters per second (186,000 miles per second).

Sunspot – An active region on the Sun's photosphere that is intensely magnetic, cooler, and darker in color. Sunspots tend to be associated with violent solar outbursts of various kinds.

Telescope – A scientific instrument that magnifies distant objects by using an arrangement of lenses and/or mirrors to collect and focus electromagnetic radiation, making the object easier to observe.

Transition region – The region of the Sun's atmosphere between the chromosphere and corona.

Ultraviolet light – Electromagnetic radiation at wavelengths shorter than the violet end of visible light. Earth's atmosphere blocks the transmission of most ultraviolet light.

Visible light – Electromagnetic radiation that is visible to the human eye.