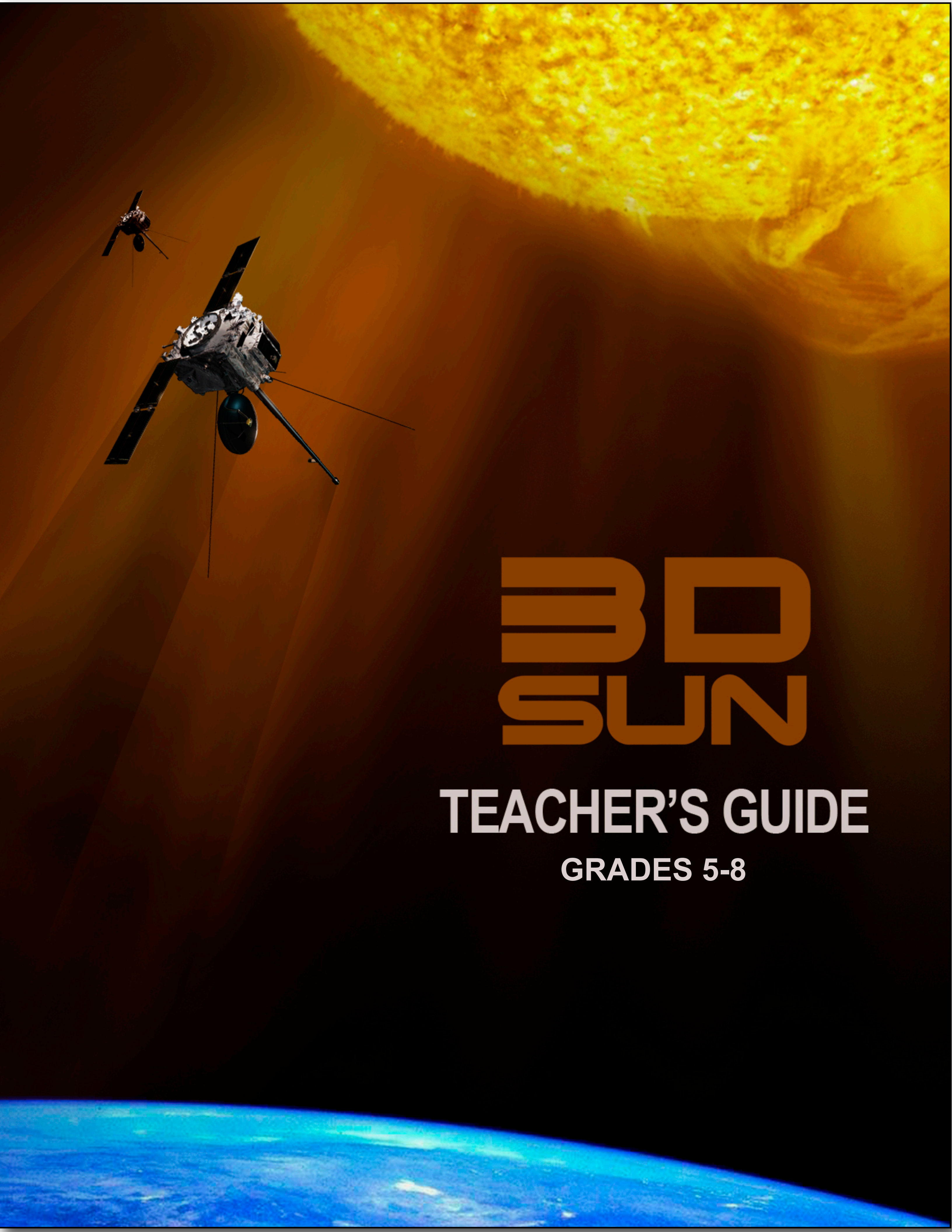


3D SUN

TEACHER'S GUIDE

GRADES 5-8

About the film

It's not safe to look at the sun without a special solar filter. 3D SUN gives audiences the chance to see the sun up close in dazzling, high-definition 3D. Stand above the arctic circle and witness the most brilliant auroras on Earth. Take a ride on a solar blast from sun's surface to Earth's Magnetosphere. Witness the most powerful explosions in the solar system - equal to the force of a billion megaton nuclear bombs.

In October, 2006 NASA launched twin spacecraft from a single rocket in Florida – spacecraft that would, for the first time in the history of space exploration, capture space-born, high-definition 3D images of the sun. In 3D SUN, the leading NASA scientists from the mission unveil these images and take us behind the scenes, to tell the story of the sun and why WE CAN'T LIVE WITHOUT IT.

3D SUN is a Melrae Pictures production in association with K2 Communications, and was developed with the support of *National Aeronautics and Space Administration*, Science Mission Directorate, Heliophysics Division.

Teacher's Guide

3D sun provides an ideal platform for teaching important Earth, space and sun concepts and their relevance to our daily lives. The guide is designed primarily for grades 5-8.

Key areas covered in the guide include:

- Sun science basics
- Coronal mass ejections (CMEs)
- Space weather
- Solar flares
- Interplanetary magnetic field
- Solar eclipse
- Space exploration technologies
- 3D technology

The appendix contains activity supplements as well as a listing of Internet resources for additional lessons and further study.

National Science Education Standards

The exercises in this teaching guide address a wide variety of the NSTA Science standards, including:

- ✓ Earth & Space Science
- ✓ Science as Inquiry
- ✓ Unifying Concepts
- ✓ Physical Science
- ✓ Science & Technology
- ✓ Science in Personal & Social Perspectives

Table of Contents

The sun in 3D

Why Seeing the sun in 3D is Important in Forecasting

The thrills! The chills! Soon you'll be able to see for the first time ever, in dazzling three dimension ... the sun. Imagine solar prominences looping out into space for thousands of miles. Now picture a billion megaton blast of solar plasma flying toward Earth and the effect it would have on astronauts, satellites in orbit, airplanes, and power grids, which are vulnerable to such a burst. Now you're starting to see why we need a better understanding of that powerful and dynamic star.

The Solar TErrestrial RElations Observatory (STEREO) mission will help provide the big picture by using two nearly identical spacecraft to image the sun and track its activity in high definition 3-D. Particularly crucial will be its observations of coronal mass ejections, or CMEs, the most powerful explosions in the solar system. Related to solar flares (scientists still don't really know which comes first), CMEs can pack the force of a billion megaton nuclear bombs.

"In terms of space weather forecasting, we're where weather forecasters were in the 1950s. They didn't see hurricanes until the rain clouds were right above them; in our case, we can see storms leaving the sun but we have to make guesses and use models to figure out if and when it will impact Earth," said Dr. Michael Kaiser, Project Scientist for STEREO at NASA Goddard Space Flight Center.

There's a strong fleet of satellites observing the sun right now, but even with missions like SOHO (Solar Heliospheric Observatory), which images the sun every 10 to 15 minutes, scientists still can't definitively say if a CME is coming toward Earth or traveling away from it—for that we need to see the third dimension.

"When you're trying to figure out what really makes a CME go, knowing where it is in space is crucial. At this point we don't quite know where it is, how fast it's traveling, or how one structure interacts with another," said Dr. Terry Kucera, Deputy Project Scientist for the mission.

"If you only saw stuff with one eye you lose the ability to judge perspective and depth," said Dr. Alex Young,a NASA scientist. "Basically we're looking at the sun with one eye. With STEREO,we're finally going to have the ability to gain this extra dimension,or this depth perception we didn't have before."

STEREO's spacecraft are just as unique and groundbreaking as its mission. It marks the first time that two spacecraft will launch on the same rocket, and then swing around the moon to get into separate orbits. Once there, STEREO 'A' flew ahead of the Earth and STEREO 'B' flew behind it. When the solar arrays are deployed, the spacecraft will be about the length of a large school bus.

Building two spacecraft at the same time "requires twice the amount of effort, but isn't that much harder with the right team," said Jim Adams, the Deputy Project Manager. Each STEREO observatory has a total of 16 instruments,all of which have been assembled in labs throughout the world. The instruments were delivered to The Johns Hopkins Applied Physics Lab for assembly and initial testing,and then went to NASA Goddard Space Flight Center for final testing. STEREO was launched on October 25th, 2007 from the Cape Canaveral Air Force Station in Florida.

Besides improving space weather forecasting and understanding for Earth systems,STEREO is also an important key to understanding the sun's influence throughout the solar system. Here on Earth we're protected by the atmosphere and magnetic fields from the sun's radiation. But as NASA gears up to send astronauts to the moon and beyond, we're going to need a better understanding of the dangerous solar particles accelerated by shock waves from CMEs. One of the biggest mysteries confronting scientists: why does one CME produce a major storm and another one does not?

"To some degree,we're getting knocked around and seeing bits and pieces. With STEREO,we'll get a chance to step back and see a CME from the outside in all its glory. ... We're not just going to see CMEs coming toward us,but we'll see how they move through the solar system," said Young.

Activity: See the sun in 3D

Prep time: less than 10 minutes
Duration: 50 minutes
Objective: to view 3D images of the sun on the STEREO website
Materials: oaktag (sturdy poster board or foamcore), clear tape, scissors, sheets of red & blue acetate (available at art supply store), pattern for glasses (see appendix), computers with Internet connection

Background - How does 3D work?

Most human beings use what is known as binocular vision to perceive depth and see the world in 3D. The binocular vision system relies on the fact that we have two eyes, which are approximately 3 in apart. This separation causes each eye to see the world from a slightly different perspective. The brain fuses these two views together. It understands the differences and uses them to calculate distance creating our sense of depth and ability to gauge distance.

A simple way to understand this principle is to hold your thumb up at arms length and close one eye. Then try closing the other eye. As you switch between open eyes you should see your thumb "jumping" back and forth against the background. To see how much of a difference the binocular vision system makes, have a friend throw you a ball and try to catch it while keeping one eye closed.

Activity One: Make your own 3D glasses

Color filter glasses are one of the oldest methods of viewing 3D images or movies. The system works by feeding different images into your eyes. The different color filters allow only one of the images to enter each eye, and your brain does the rest. There are two color filter systems: Red/Blue and Red/Green.

Steps

1. Cut out the sample pattern (including eye holes) for your 3D glasses and tape the sides to the center section. You now have your stencil for the actual glasses.
2. Trace the stencil on the oaktag or sturdy poster board. Cut the glasses out making sure to also cut out the eye holes.
3. Tape the red (left) and blue (right) acetate pieces to cover the eye holes. Make sure to cut the acetate pieces a little larger than the opening for the eyes. DO NOT get tape on parts of the acetate visible through the eye hole.

Hints

- You can decorate the glasses using any materials on hand. Encourage students to be as creative as possible!
- The pattern provided is just one possible style. Vary the outer shape of the glasses to make them unique.
- Take a picture of the whole class wearing their glasses. Or, even better, Use the class wearing their glasses as the subject of your 3D photo!

Activity Two: View the sun in 3D!

Make copies of the article on the previous page and have students visit the following website address:

http://stereo.gsfc.nasa.gov/gallery/3dimages.shtml

Once there, they will be able to view 3D still images and movies of the sun taken by the orbiting STEREO observatories.

Discussion questions

1. Why is it important for scientists to be able to view 3D images of the sun?
2. What are Coronal Mass Ejections and why is understanding them relevant to our modern lifestyle?
3. What is unique about the STEREO spacecraft?
4. How is Earth protected from the sun's radiation?

STEREO Science Basics

Corona

The corona is the Sun's hot, thin outer atmosphere. From Earth it is most easily seen during a total solar eclipse in which the Sun's bright disk is covered by the Moon, revealing the much fainter corona.

The highly structured corona is shaped by the Sun's complex magnetic field, and is very active, exhibiting coronal mass ejections and flares among other solar magnetic phenomena. The corona is so hot at over a million degrees celcius that it produces ultraviolet light and X-rays.

STEREO's SECCHI imaging suite shows us the corona in two ways. Its coronagraphs imitate a solar eclipse in space by covering the disk of the Sun with an occulting disk (or fake moon), so that we can see scattered light from the corona. The SECCHI Extreme-Ultraviolet Imager (EUVI) lets us observe the ultraviolet light produced by the corona.

Coronal Mass Ejections

A billion tons of matter traveling at a million miles an hour, these giant magnetic structures blast off the Sun into the solar system and can create major disturbances in Earth's magnetic field, resulting in the beautiful aurora but also problems with spacecraft and power systems. They are also a source of Solar Energetic Particles (SEPs), which are a hazard to astronauts.

Although CMEs are huge and powerful, they are very thin and spread out, with just a few particles per cubic centimeter. Much of the power they have to affect us comes from their magnetic fields, which are part of the interplanetary magnetic field, and can disturb the magnetic field of Earth. It usually takes a CME two to four days to reach Earth, although extremely fast ones have been known to reach here in just over a day.

Understanding what causes CMEs and how they move through the solar system is one of the chief goals of the STEREO mission. The CMEs are imaged by the different telescopes in the SECCHI instrument suite. The actual material in CMEs is measured as they pass the spacecraft using the IMPACT and PLASTIC instruments, and IMPACT measures their magnetic fields. The SWAVES instruments observe radio signals produced by shock waves formed as the CMEs plow through the solar wind.

Solar Wind

The Sun's super hot atmosphere expands out into the solar system flowing past Earth and the other planets. In fact, you could say that Earth is inside the outermost layer of the Sun.

This flow is called the Solar Wind and it consists mostly of hydrogen, with some helium and small amounts of heavier elements. It is exceedingly thin - just a few particles per cubic centimeter, and moves at velocities from 200 to 800 km/s, or even faster if you count the fastest CMEs which can move outwards at over 1000 km/s (two million mph). However, this is still far slower than the speeds of solar energetic particles which can shoot out at over 100,000 km/s, about one-third of the speed of light.

The solar wind varies in time and location, with higher speed, lower density streams flowing out of areas known as coronal holes, where the Sun's magnetic field opens out into the solar system. The solar wind carries the Sun's magnetic field outwards to form the interplanetary magnetic field (or IMF). The area which is affected by the solar wind and IMF extends beyond the orbit of Pluto and is know as the heliosphere.

The STEREO PLASTIC and IMPACT instruments sample the solar wind as it passes by the two spacecraft.

Solar Flares

Solar flares are bright, explosive events that take place in the Sun's lower corona. They can be associated with CMEs, but are not the same thing. Scientists will use the SECCHI imaging instruments aboard STEREO to improve our understanding of how flares are related to CMEs.

Although most of what is called a solar flare occurs relatively low in the Sun's atmosphere, flares do release charged particles which travel along the magnetic field lines of the interplanetary magnetic field (IMF). Electrons emitted in this way by flares produce radio waves detected by the SWAVES instruments and allow researchers to map the IMF.

Activity: Measure the Motion of a Coronal Mass Ejection

Prep time: less than 10 minutes
Duration: 30 minutes
Objective: Calculate the velocity and acceleration of a coronal mass ejection (CME) based on its position in a series of images
Materials: ruler, calculator, and a set of CME images (in appendix)

Background - How does 3D work?

An important part of space weather research is to measure the velocity of CMEs and their acceleration as they leave the Sun. This is done by tracing features in the CME and measuring their positions at different times. In the sequence of images shown on the right, you can see a CME erupting from the Sun on the right side of the coronagraph disk. The white circle shows the size and location of the Sun. The black disk is the occulting disk that blocks the surface of the Sun and the inner corona. The lines along the bottom of the image mark off units of the Sunís diameter.

Procedure

Select a feature of the CME that you can see in all five images--for instance, the outermost extent of the cloud, or the inner edge. Measure its position in each image. Your measurements can be converted to kilometers using a simple ratio:

$$\frac{\text{actual distance of feature from sun}}{\text{diameter of sun (1.4 million kms)}} = \frac{\text{position of feature as measured on image}}{\text{diameter of sun as measured on image}}$$

Using the distance from the Sun and the time (listed on each image), you can calculate the average velocity. Velocity is defined as the rate of change of position. Using the changes in position and time, the velocity for the period can be calculated using the following equation: $v = (s2 - s1) / (t2 - t1)$, where s2 is the position at time, t2; s1 is the position at time, t1. The acceleration equals the change in velocity over time; that is, $a = (v2 - v1) / (t2 - t1)$, where v2 is the velocity at time t2; v1 is the velocity at time t1. You can record your results in a table.

Further Questions & Activities

1. Select another feature, trace it, and calculate the velocity and acceleration. Is it different from the velocity and acceleration of the other feature you measured? Scientists often look at a number of points in the CME to get an overall idea of what is happening.
2. How does the size of the CME change with time? What kind of forces might be acting on the CME? How would these account for your data?

Universal time	Time Interval (t)	Position (s)	Avg. Velocity (V0)	Avg. Acceleration (a)
8:05				
8:36				
9:27				
10:25				
11:23				

Magnetism & Solar Wind

A NASA story of STEREO/IMPACT

There are many scientists who want to understand more about the Sun. They know that the Sun is a fiery ball of gas that gets so hot that gas flies out from the Sun at very high speeds. Many of the electrons in the Sun's atoms have enough energy to leave the atoms. These new particles are called ions. These ions and electrons are flowing from the Sun and together they are known as the solar wind. The ions and electrons dance in the Sun's magnetic field. Scientists discovered that the solar wind and its magnetic field flow together out past Mercury, past Earth, and continue out past Pluto. Because the magnetic field is threaded throughout the solar system, we call it the interplanetary magnetic field, that is the magnetic field found between (inter) the planets (planetary).

Scientists have also noticed that the Sun goes through different cycles, just like moody people who are calm and quiet some days but other days, they explode with anger. But of course the Sun doesn't have emotions to drive its cycles! Physical principles, such as magnetic and electric forces, drive its cycles. During the Sun's active cycle, parts of the Sun will explode, sending out even more solar wind and magnetic fields than it typically sends out.

What happens to the solar wind and magnetic fields that the explosions send flying out into space? Well, sometimes the explosive solar wind will flow by Earth, where we all live. Luckily Earth has a magnetic field and a thick layer of atmosphere, which protect all living creatures on Earth from the particles and radiation that can come from such solar explosions. But when astronauts are up in space, sometimes the magnetic field isn't strong enough to protect them and they have to remain in their space vehicles, such as the space station. Scientists asked themselves: "What triggers these explosions?" How do these explosions flow out and away from the Sun? How do these explosions make ions and electrons go so fast?"

How are the scientists going to answer these questions? Well, they have studied the solar explosions while sitting (or standing) on Earth using telescopes. They named these explosions coronal mass ejections. Scientists like to give names to specific types of events so that everyone knows what they are talking about using only a couple of words. That is efficient. NASA scientists like to make it even easier by making an acronym out of the name. An acronym is made with the first letter of each word in the name. What acronym would you use for the term: interplanetary magnetic field? What does the acronym NASA stand for? NASA scientists made a Coronal Mass Ejection into an acronym too: a CME.

With just one satellite, scientists can only measure magnetic fields at one point in space, and that's just what they have done. And with one satellite at a time, they have discovered many things about the Sun. But really, scientists need to measure the interplanetary magnetic field and the solar wind at more than just one point. Two instruments studying the Sun from two different places will help them understand better how the explosions move outward. So, several scientists proposed to put up two satellites at the same time. These two satellites would be able to take photographs of the Sun from two perspectives, and instruments on the satellites would measure the Interplanetary Magnetic Field in two locations. If we converted the data into sound and listened through headphones, the data could come out in stereo! And so, this mission was named STEREO, which is short for Solar Terrestrial Relations Observatory. As they say, "Two ears are better than one!" The reviewers at NASA, who are other space scientists, said: "Yes! These are good science questions and a feasible mission. Let's do it!" And the U.S. Congress agreed to pay for it. And so instruments and a satellite are being built for the NASA STEREO mission in order to study the Sun's explosions. And now you too can be a part of this mission.

We never really answered the question: "How are the scientists going to measure the interplanetary magnetic field?" This is what you are going to answer in the next activities centered on electromagnetism. First, you have to remember what you know about magnetic fields and how to measure them. Then you have to design a model experiment that could work on a spacecraft to measure the interplanetary magnetic field. And then you have to create your design, test it, and share your design and model with your fellow scientists and engineers, that is — your fellow students. This is exactly what scientists and engineers working on the STEREO/IMPACT NASA mission have had to do.

Activity: Match Magnetic Activity & Active Regions

Prep time: less than 10 minutes
Duration: 20 - 40 minutes
Objective: to match ultraviolet and magnetic solar images
Materials: copies of “Magnetism & Solar Wind” article (on previous page), magnetic/solar images page (in appendix), computers & Internet connection (optional)

Background - Magnetism & the solar wind

Have students read the article on the previous page which introduces the Interplanetary Magnetic Field and the solar wind and describes their significance to life on Earth and human space exploration.

Activity One: Match the ultraviolet and magnetic solar images

This is a fun activity that calls for matching up pairs of images of the Sun. This can be done online or printed out and done in a class or small group setting. Each pair was taken about the same time on a given day, but the pairs were taken from five different days over the past few years. Images 1-5 reveal areas of strong magnetic activity on the Sun's surface, in which the black indicates one pole of magnetic attraction and white the other. Images A-E show activity above the Sun's surface in extreme ultraviolet light in which areas of more intense activity appear lighter. These regions of intense activity, where magnetic forces are connecting, breaking apart and reconnecting, are often the sources of solar storms. Many of these areas would appear as sunspots in "white light" or simply filtered images of the Sun.

You will find that the magnetic images match up very closely with the ultraviolet images. See if you can find the pairs of images taken on the same days.

Steps

1. Review the images on the “Magnetic/solar image set” page in the appendix, or view the images online at “**http://stereo.gsfc.nasa.gov/classroom/matching/matching_activity.shtml**”
2. (Optional) After you have completed the activity, view a short movie (**http://stereo.gsfc.nasa.gov/classroom/matching/fiveyears.mpg**) to see how active regions (seen here by the SOHO spacecraft in a different wavelength of UV light) and magnetic areas match up as the Sun rotates.

Solution Key

The solution is:

- A - 3
- B - 4
- C - 5
- D - 2
- E - 1

Space Weather

Space Weather

Space weather happens when a solar storm from the Sun travels through space and impacts the Earth's magnetosphere. Studying space weather is important to our national economy because solar storms can affect the advanced technology we have become so dependent upon in our everyday lives. Energy and radiation from solar flares and coronal mass ejections can:

- Harm astronauts in space
- Damage sensitive electronics on orbiting spacecraft…
- Cause colorful auroras, often seen in the higher latitudes…
- Create blackouts on Earth when they cause surges in power grids.

Understanding the changing Sun and its effects on the solar system, life, and society is a main goal of NASA's Heliophysics research program. Many NASA missions focus on the Sun and its interactions with Earth. Current missions include SOHO, ACE, IMAGE, SORCE, and Cluster. Future missions include STEREO and Solar Dynamics Observatory.

Solar Cycle

The changing Sun produces sunspots and solar storms over an 11-year cycle of activity, which is driven by the reversal of its magnetic poles over this time period. Solar storms (coronal mass ejections and flares) occur most often and more powerfully during its period of solar maximum. The next period of solar maximum is due around 2011.

Solar Storms

There are two kinds of solar storms, often related to each other: coronal mass ejections (CMEs) and solar flares. A flare occurs when magnetic energy builds to a peak near the Sun's surface and explodes. This intense, fast-paced event results in an intense burst of light, including X-rays, in the Sun's lower atmosphere. A much larger storm, a CME erupts when magnetic field lines snap, sending billions of tons of material into space at millions of miles per hour. The cloud expands to over 30 million miles by the time it reaches Earth. Both flares and CMEs can result in additional high speed particles being shot out into the solar system at close to the speed of light.

Impact From Space

One beautiful sign of the space weather at the Earth is the aurora. When the CMEs from the sun interact with the Earth's own protective magnetic shield, its magnetosphere, the magnetosphere becomes disturbed. This ultimately causes charged particles to flow down along magnetic field lines into the polar regions where they hit the atmosphere and create the bright aurora. If viewed from high above Earth, these regions appear as ovals. Images taken by astronauts in the space shuttles show the depth of aurora. Other impacts from space weather include short-circuiting power grids that cause blackouts, disrupting communications, damaging satellites, and endangering astronauts with radiation.

Aurora

Aurora appear from Earth as shimmering, dancing lights in the night sky. Only 100 years ago did scientists discover that the Sun was ultimately the cause of these mysterious lights. Although green is the most common color, red and yellow hues are also observed. The most powerful displays occur when large clouds of particles from CMEs slam into our magnetosphere, but the constant outpouring of solar particles (called the solar wind) can cause them as well. Aurora are most visible at latitudes near Earth's poles."

Image Gallery

Visit **http://stereo.gsfc.nasa.gov/spaceweather/spaceweather.shtml** to view breathtaking images of the phenomena described above

Activity: Crossword Puzzle About the Sun and Sun-Earth Connections

Prep time: less than 10 minutes
Duration: 20 - 40 minutes
Objective: to learn about the Sun and Sun-Earth connection by completing a crossword puzzle
Materials: copies of crossword puzzle and questions (in appendix)

STEREO Spacecraft

Twin Observatory Design

The STEREO mission includes two nearly identical spacecraft designed, built and operated by APL for NASA Goddard Space Flight Center, which manages the mission. The twin observatories each carry two instruments and two instrument suites for a total of 16 instruments per observatory. The scientific instruments come from institutions around the world, including the Naval Research Laboratory; the University of California at Berkeley; the university of New Hampshire; and the Paris Observatory. Onboard each spacecraft, six operational subsystems support the instruments and instrument suites. The subsystems include: command and data handling, radio frequency communications, guidance and control, propulsion, power, and thermal. Each of the two solar-powered, 3-axis-stabilized spacecraft have a launch mass — including propellant — of approximately 1,412 pounds (642 kilograms). The spacecraft will communicate with the APL-based mission operations center via NASA's Deep Space Network. illustrating deployment of the twin observatories' panels shortly after the spacecraft
separate from the launch vehicle.

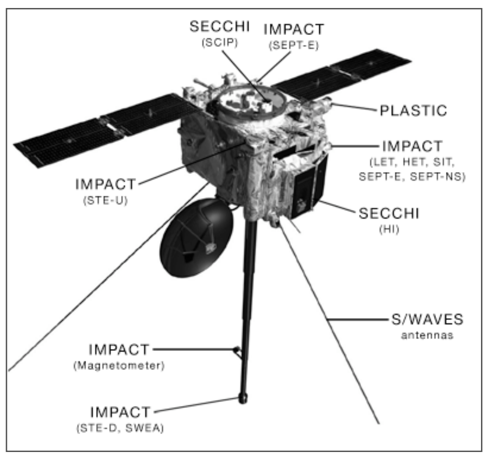
Design Challenge

The significant number and wide range of instruments onboard each of the twin observatories is notable for spacecraft of their size. The significant challenge facing spacecraft designers was coupling the large number of instruments and their differing fields of view with their competing design requirements to ensure successful science observations.

More like fraternal than identical twins, the instruments onboard the "nearly identical" observatories are positioned a bit differently on each spacecraft to ensure the high-gain dish antennas remain pointed at Earth for command and telemetry, and the instruments remain pointed at the sun. Neither observatory has to be rotated to accommodate instruments' viewing angles. The "B" observatory's main structure is a little thicker so that it can support the weight of the "A" observatory during launch. (The "A" observatory is the one that will be placed "ahead" of Earth in its orbit around the sun; "B" will be placed "behind.") The "B" observatory will retain a portion of the separation fitting or ring used to connect the two spacecraft during their ride into space.

Instrument Suites

The Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) is a suite of remote-sensing instruments consisting of an extreme ultraviolet imager, two white-light coronagraphs, and a heliospheric imager. These instruments will study the 3-D evolution of coronal mass ejections — the most energetic eruptions on the sun and primary cause of major geomagnetic storms — from their origin at the sun's surface through the corona and interplanetary medium to their eventual impact at Earth. The principal investigator for the SECCHI instrument suite is Russell Howard of the Naval Research Laboratory. The In situ Measurements of PArticles and CME Transients (IMPACT) investigation provides measurements of the solar wind electrons, interplanetary magnetic fields, and solar energetic particles. IMPACT comprises seven instruments including a solar wind electron analyzer, a magnetometer, and an array of particle detectors measuring the energetic ions and electrons accelerated in coronal mass ejection (CME) shocks and in solar flares. IMPACT's principal investigator is Janet Luhmann of the university of California, Berkeley.



Create Your Own STEREO Observatories

INSTRUCTIONS: Adult supervision suggested. Follow steps A – G to complete the STEREO Observatory A and repeat to complete STEREO Observatory B. Please read all instructions before starting. Estimated time: 1 hour.

MATERIALS NEEDED: Scissors, hole punch, tape or glue.

A. DISH
1. Cut out a dish.
2. Bring A-1 and A-2 together with the dark gray flap in back of A-2. Tape this in place and set aside.

B. RING TO HOLD DISH
1. Cut out a ring.
2. Tape flap B-1 behind B-2 to form a ring. This will hold the dish onto the STEREO body at G-5.
3. Tape one set of 4 (folded out) tabs of ring to bottom of dish, centering ring on the bottom side of the dish and set aside.

C. SOLAR PANELS
1. Cut out 2 solar panels (both are identical) and set aside.

D. IMPACT BOOM HOLDER
1. Cut out the IMPACT boom holder and fold the flaps down.
2. Punch out red circle D-3 with the hole punch.
3. Go to E. IMPACT Boom and assemble.
4. Tape D-1 flap under D-2. This forms a cylinder. Fold over both caps and insert flaps and tape them into the cylinder and set aside.

E. IMPACT BOOM
1. Cut out the IMPACT boom. Starting on the E-1 side, roll this into a tight cylinder (wrap around a pencil or coffee stirrer to shape). Tape together.
2. Insert this IMPACT boom cylinder into the D. IMPACT Boom Holder at D-3. Tape dark gray flaps to the inside of the IMPACT boom holder.

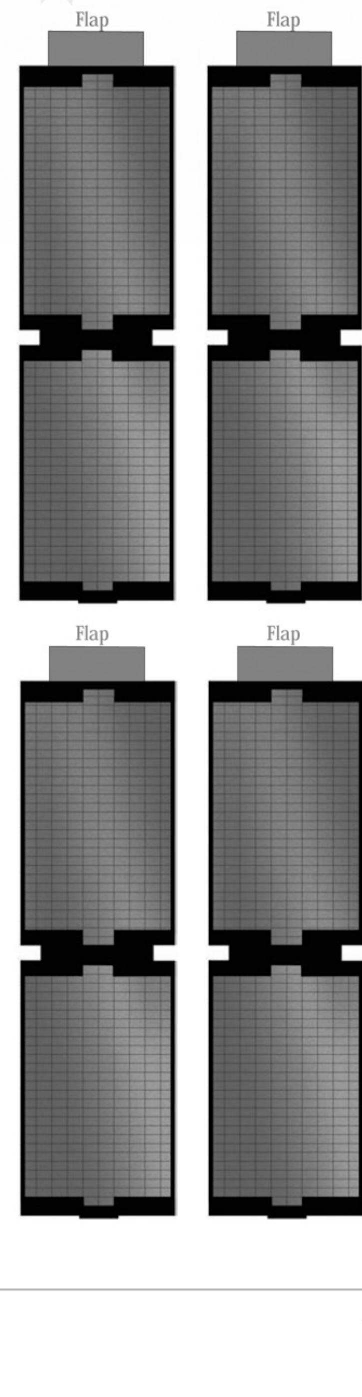
F. S/WAVES ANTENNAS
1. Cut out 3 S/WAVES antennas. Fold these in half lengthwise and tape so that they lie flat. Fold gray flap at blue line.

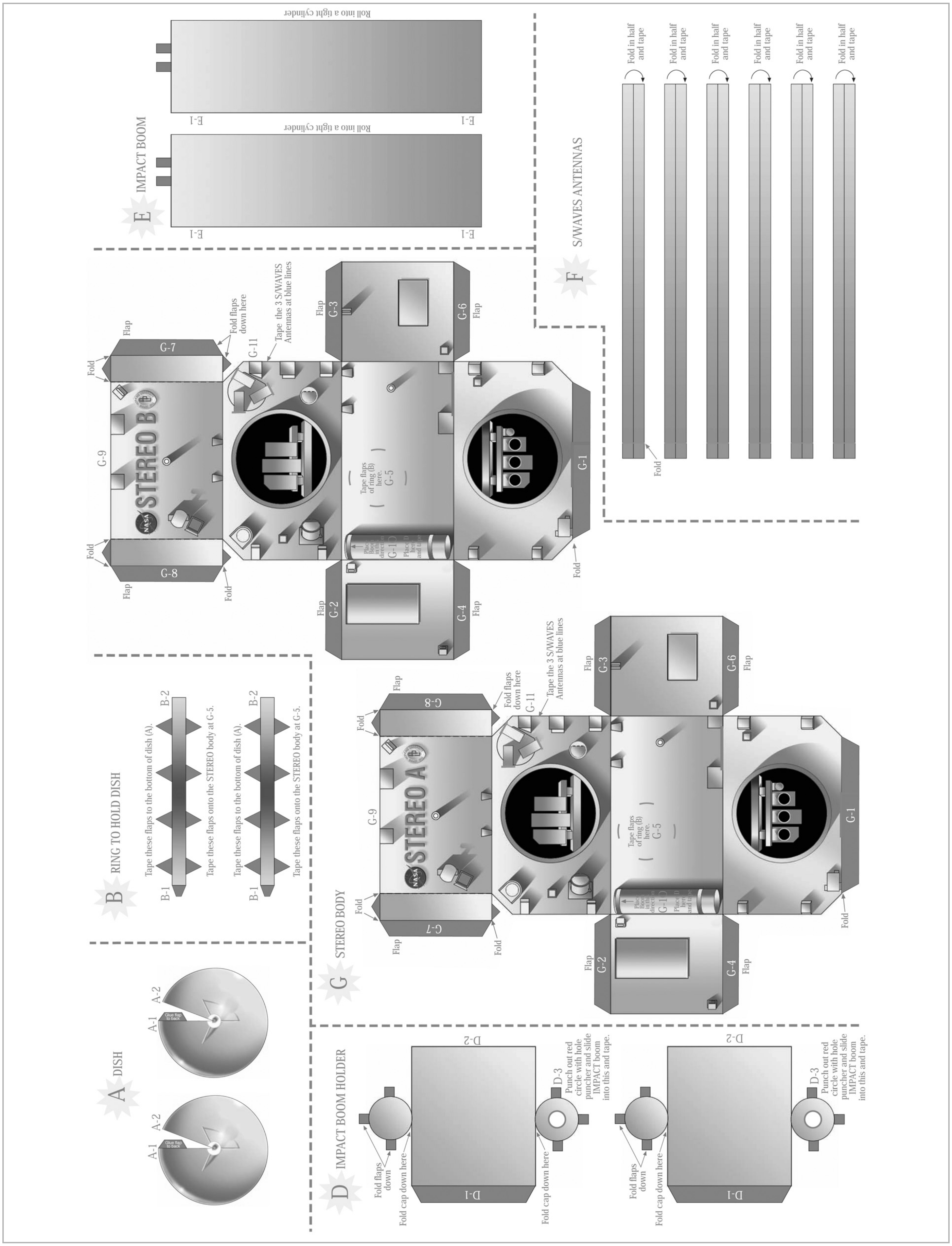
G. STEREO BODY
1. Cut out entire STEREO body. Score all interior black lines so they fold easily. Fold all the dark gray flaps down. Cut all red lines with scissors (be sure not to go beyond the red line).
2. Attaching the Solar Panels (C): Insert and tape the flap of 1 of the Solar Panels (C) into the G-1 cut red line you previously cut. Insert and tape the second solar panel in the red line previously cut near the G-6 flap. Both solar panels are positioned opposite each other with blue side up.
3. Attaching the IMPACT Boom (E) and IMPACT Boom Holder (D): Tape the assembled IMPACT Boom and Holder on top of G-10. See G-10 arrow for position of the boom.
4. Attaching the Dish (A) and Ring (B): Tape the 4 flaps of the Ring (B) over the 4 blue lines at G-5.
5. Attaching the S/WAVES Antennas (F): Tape each of the 3 S/WAVES Antennas (F) gray flaps to the blue lines at G-11.
6. Bring flap G-1 to G-9 and tape flap under G-9.
7. Fold over G-2 and G-4 panel to meet with G-7 and tape.
8. Fold over G-3 and G-6 panel to meet with G-8 and tape.

To learn more, visit: http://stereo.jhuapl.edu.

Congratulations! You have successfully built your own twin observatories.

C SOLAR PANELS





A DISH
A-1
A-2
Glue flap to back
B RING TO HOLD DISH
B-1
B-2
Tape these flaps to the bottom of dish (A).
Tape these flaps onto the STEREO body at G-5.
D IMPACT BOOM HOLDER
D-1
D-2
D-3
Fold flaps down
Fold cap down here
Punch out red circle with hole puncher and slide IMPACT boom into this and tape.
E IMPACT BOOM
E-1
Roll into a tight cylinder
F S/WAVES ANTENNAS
Fold in half and tape
Fold
G STEREO BODY
STEREO A
STEREO B
NASA
G-1
G-2
G-3
G-4
G-5
G-6
G-7
G-8
G-9
G-10
G-11
Flap
Fold
Fold flaps down here
Tape the 3 S/WAVES Antennas at blue lines
Tape flaps of ring (B) here.

Fun Facts About The Sun

1. The Sun is just one of hundreds of billions of stars in our galaxy, the Milky Way.
2. Only about a billionth of the total energy emitted by the Sun reaches Earth.
3. If we could harness all the sunlight that reaches Earth in a single day, it could meet the entire planet's current energy needs for 30 years!
4. The energy in the gas that powers your car came from the Sun. Gasoline comes from oil, which is what we call a fossil fuel. Fossil fuels come from plants and animals that lived millions of years ago, and they got their energy from the Sun.
5. Because of the solar wind*, the Sun loses over 50 billion tons (50 trillion kilograms) of material per day.
6. The Sun's corona* can rip open and spew as much as 20 billion tons of material into space. These explosions are known as coronal mass ejections (CMEs), the hurricanes of space weather. If a CME heads toward Earth, it can endanger spacecraft and astronauts.
7. A solar flare releases enough energy in two hours to meet Earth's present energy needs for 10,000 years!
8. The element helium was first discovered on the Sun!
9. The gas in the Sun rotates (or spins) about 10 days faster at its equator than around the poles.
10. The Sun makes up about 99% of the stuff in the whole Solar System*.
11. Earth has its own protective force field! Earth’s magnetic field and atmosphere shelter us from tremendous explosions of energy and dangerous radiation from the Sun.
12. There are places on Earth, near the north and south poles, where when the Sun is in the sky 24 hours a day near the peak of summertime (midnight sun), and below the horizon all day in wintertime.
13. Some sunspots* are as much as 20 times wider than Earth!
14. It takes light from the Sun about 81/2 minutes to travel to Earth. This means that from Earth we can only know what happened on the Sun 81/2 minutes ago. Light travels through space at a whopping 186,000 miles per second (300,000 kilometers/second)!
15. Energy from the Sun’s core* takes about 150,000 years to reach the photosphere* (visible surface). That means the light you see today was produced in the core when humans were still in the stone age!

Activity: Make a Scale Model of the Solar System

Prep time: less than 10 minutes
Duration: 30 - 50 minutes
Objective: to make a scale model of the solar system using play-doh
Materials: 3 lbs. of play-doh, pens, paper, rulers

Activity Procedures

Earth/Moon

1. Have students predict and make models of the size and distance of the MOON in relation to the EARTH.
2. Divide the Play-doh into 50 equal sized balls (as equal as possible). Choose an average sized ball and set it aside. Squash the other 49 back together. You now have the EARTH and MOON compared in size by volume.
3. Now comes the relative distance. The distance between the EARTH and the MOON should be equal to 30 EARTH diameters.
4. Have students compare their original model with the scale model they just created. Get them to think about why they thought that before. (NOTE: the misconception of the relative size and distance between the EARTH and the MOON is due to perspective which comes from the photographs we have all seen of both. In order to get both the EARTH and the MOON in the same photo, one has to take a photo of them one in front of the other and slightly off to one side.

Earth/Moon/Mars

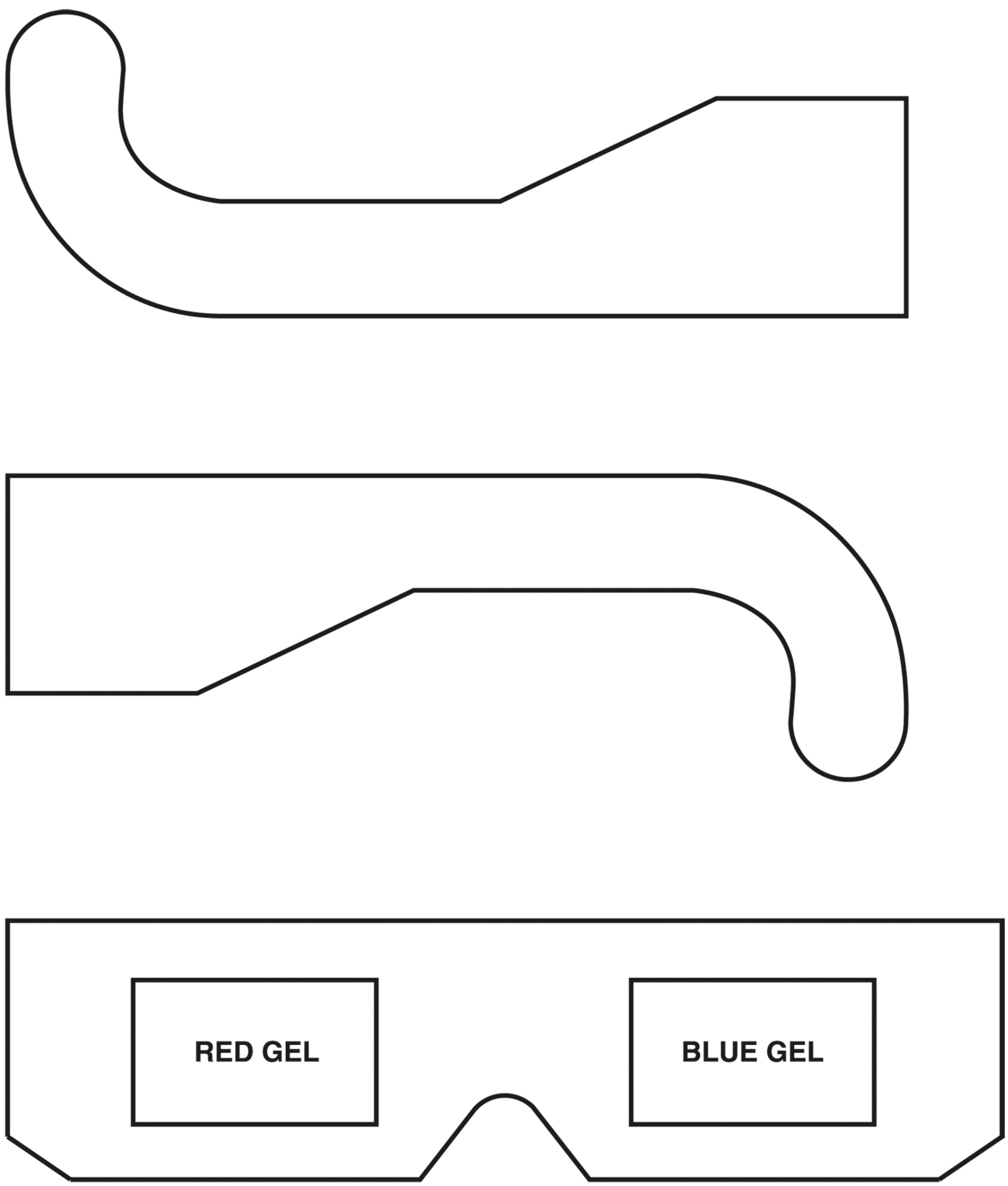
1. Divide your Play-doh in half. One half is the EARTH.
2. Make seven balls out of the other half. One ball is MARS.
3. Take another one of the seven balls and divide it into seven. One of those is the MOON.
4. You can also do scales with this model...but MARS is far! If you used 3lbs of Play-doh for this model, the distance between EARTH and MARS would be 7 city blocks!

Solar System

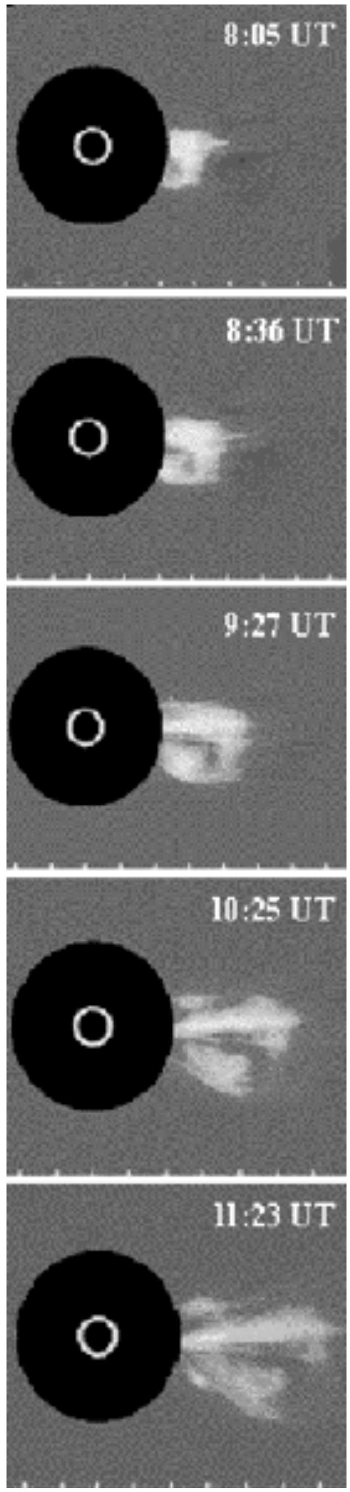
1. Write the name of each of the nine planets on separate pieces of paper. Spread the labeled papers out on a table. This is where you will be placing the Play-doh to make each of the planets.
2. Make 10 equal balls. Squash 6 of them together...this will be JUPITER. Place the ball on the paper labeled JUPITER. Take another 3 and squash them together...this is only part of SATURN (you will add to SATURN two more times before the activity is over). Place the ball on the paper labeled SATURN.
3. Divide the ball of Play-doh that is left into 10. Squash 5 of them together and add them to SATURN. Take 2 and squash them together...this is NEPTUNE. Place the ball on the paper labeled NEPTUNE. Take another 2 and squash them together...this is URANUS. Place the ball on the paper labeled URANUS.
4. With the ball that is left, make 10 equal sized balls. Squash 9 of them together...add them to SATURN. SATURN is now complete!
5. Divide the remaining ball into 2. 1 is EARTH. Place the ball on the paper labeled EARTH.
6. Now is when things get tricky! Divide the ball that is left into 10. 9 of them make up VENUS. Place the ball on the paper labeled VENUS.
7. Make 10 balls out of the 1 that is left. Use 9 to make create MARS. Place the ball on the paper labeled MARS.
8. Divide the ball of Play-doh that is left into 10. 9 of them make up MERCURY (Place them on the paper labeled MERCURY) and the one left is PLUTO! Place the ball on the paper labeled PLUTO.

Why isn't the Sun included in this activity? The Sun is so much larger than all of the planets that if you use a 3lb tub of Play-doh to make the 9 planets, it would take 980 tubs to make the Sun!

Appendix: pattern for 3D glasses



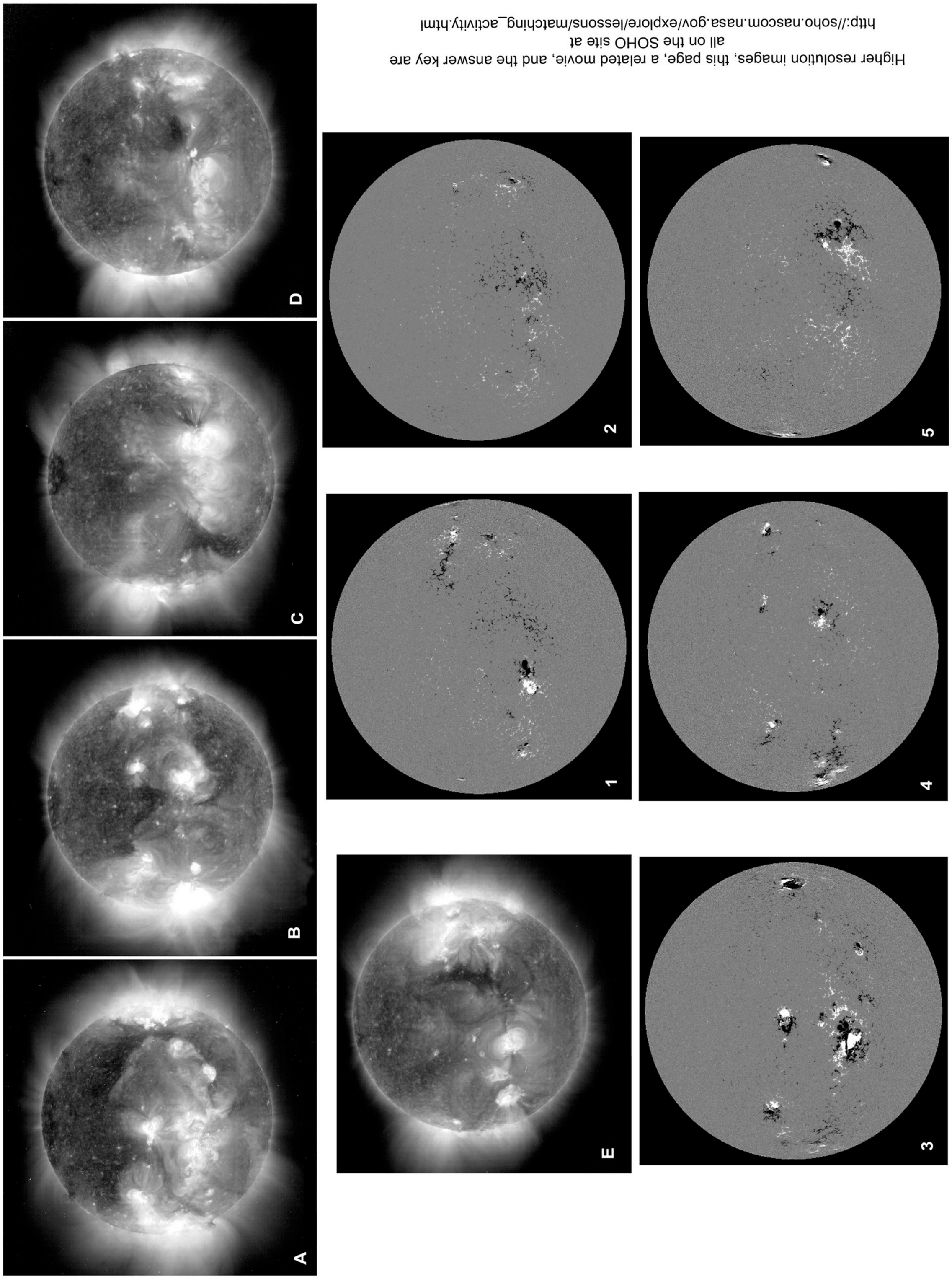
Appendix: CME image set



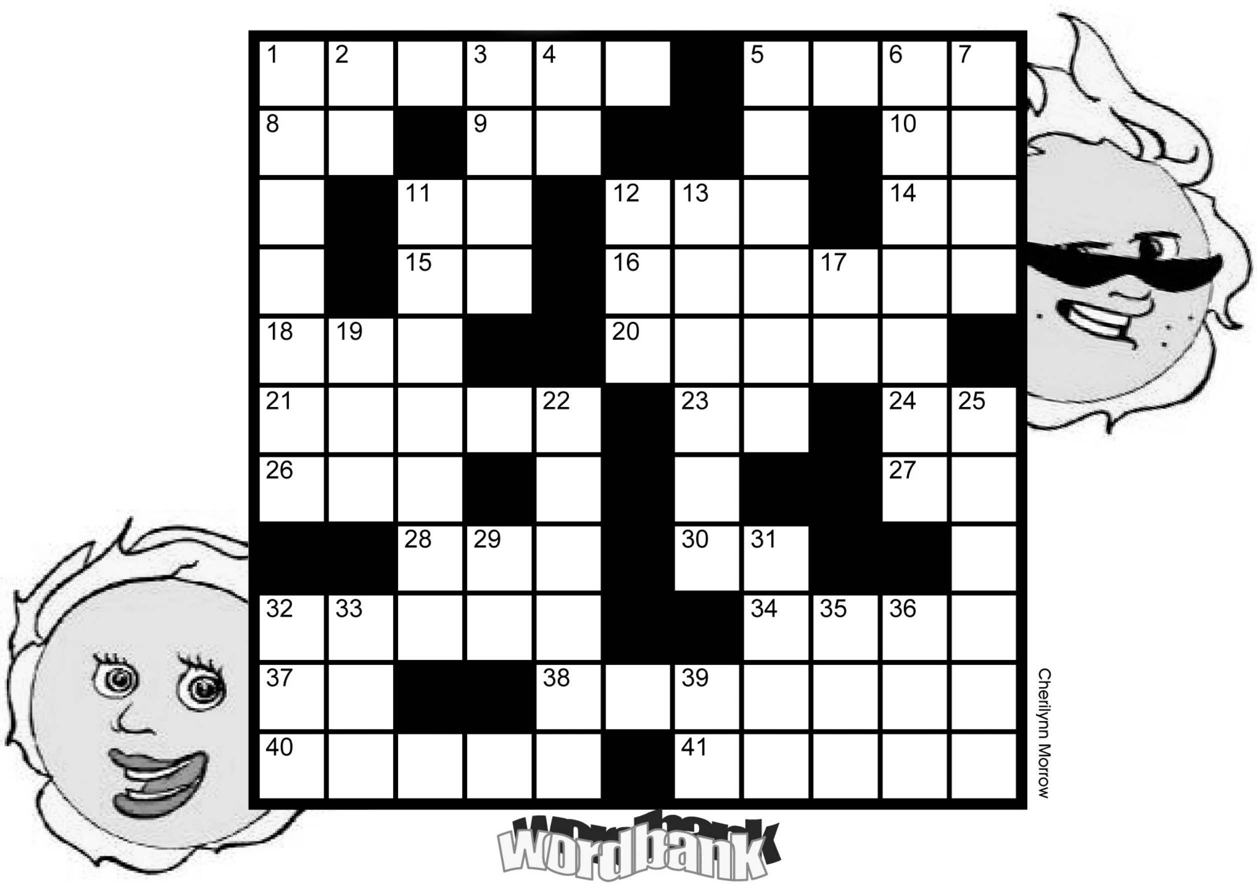
Appendix: Magnetism/solar image set

Matching the Ultraviolet and Magnetic Solar Images

Higher resolution images, this page, a related movie, and the answer key are all on the SOHO site at http://soho.nascom.nasa.gov/explore/lessons/matching_activity.html



Appendix:Crossword Puzzle



SUNSPOT ECLIPSE CME EQUATOR AURORA
AUTUMN WINTER SUMMERS SPRING
SUNSET STAR SUN

Appendix: Crossword Puzzle

ACROSS

1. Season for robins, daffodils, and tulips

5. Earth's rotation makes the Sun appear to rise in the east and set in the _ _ _ _.

8. United States (abbr) [HINT: "abbr" means "abbreviation". For example, the abbreviation for "National Aeronautics and Space Administration" would be "NASA", and the abbreviation for "feet" would be "ft"]

9. The Wizard of _ _.

10. University of Hawaii (abbr). This university operates telescopes that observe the Sun.

11. Extra-Terrestrial (abbr)

12. Person who roots for a sports team

14. Third note on a major musical scale [HINT: Remember the song in The Sound of Music?]

15. State on the western coast of the US that has the Golden Gate bridge, redwood trees, and Hollywood (abbr)

16. Season of falling leaves

18. A pen _ _ _ is a buddy to whom you write letters and who writes letters to you.

20. A very thin folded or rolled pancake, as in a _ _ _ _ _ suzette -- a famous French dessert.

21. Funny papers = C _ _ _ _ _.

23. State on the west coast of the US with California to the south of it and Washington to the north of it (abbr) [HINT: Look at a map or atlas if you need it to help you]

24. Room (abbr)

26. Money you leave on your table at a restaurant if the service has been good

27. Fifth note on a major musical scale

28. The _ _ _ is our star. Earth intercepts only 1 billionth of the energy it puts out, but this is enough to support plant and animal life.

30. Quiet _ _ a mouse.

32. Board game with a king, queen, 2 bishops, 2 knights, 2 rooks, and 8 pawns

34. Large, low-pitched brass instrument, often seen in marching bands

37. Greek letter for M [HINT: If you do not know this one, try the cross words first (32 and 33 DOWN) to see if they help you]

38. The North Pole is at 90 degrees north latitude where it is very cold. The _ _ _ _ _ _ _ _ is at 0 degrees latitude where it is very warm.

40. Country with large, stone pyramids. People there used to worship a sun god named Ra.

41. Trick or _ _ _ _ _!

DOWN

1. Dark patch on the Sun. There are more of them during times of maximum solar activity (Solar Maximum*). Solar Maxima occur about every 11 years. The last one was in 2001.

2. Letters to use when you want to add a note at the bottom of a letter to a friend

3. Small amount (same as Greek letter for I) [HINT: If you do not know this one, try the cross words first (1, 9, 11, and 15 ACROSS) to see if they help you discover the answer.]

4. Country in the southern hemisphere that is famous for flightless birds called Kiwis (abbr)

5. Season for sledding and ice skating

6. Times of year for vacations

7. Pizza can have thick or _ _ _ _ crust.

11. When the Moon blocks light from the Sun, we call this a solar _ _ _ _ _ _ _.

12. Friday Afternoon Club (abbr)

13. _ _ _ _ _ _ borealis. Another name for the Northern Lights caused by the Sun's activity.

17. The Sun appears to come _ _ at sunrise, and go down at sunset.

19. In French, "une amie" is a female friend. So a male friend would be "un _ _ _".

22. Opposite of "sunrise"

25. Famous 18th century musical composer who wrote "The Magic Flute" and "The Marriage of Figaro": Wolfgang Amadeus _ _ _ _ _ _.

29. Same as 8 ACROSS.

31. The Sun is a _ _ _ _. It is the only one in our solar system*, but it is one of over 100 billion in the Milky Way galaxy!

32. Coronal Mass Ejection (abbr). This is a storm from the Sun that can cause especially bright auroras* or power outages on Earth.

33. Kiss and a _ _ _ for someone you love

35. Group of Native American people living in parts of Utah, Colorado, and New Mexico

36. _ _ _ constrictor -- a Brazilian snake

39. Universal Time (abbr). This is the time at Earth's prime meridian -- the zero line of longitude that passes through Greenwich, England. If it is midnight in New York then it is five hours later, or 5am, in Greenwich. At this time, astronomers would write 0500 UT no matter where in the world they were observing.

Links for Further Study

- Glossary: http://sohowww.nascom.nasa.gov/classroom/glossary_middle.html
- Corona
  - U. Michigan Solar-Heliospheric Research Group: Corona; http://solar-heliospheric.engin.umich.edu/hjenning/Corona.html
  - Windows to the Universe: Corona; http://www.windows.ucar.edu/tour/link=/sun/atmosphere/corona.html
- Solar wind
  - Windows to the Universe: Solar Wind; http://www.windows.ucar.edu/tour/link=/glossary/solar_wind.html&edu=mid
  - NASA/MSFC Solar Physics: The Solar Wind; http://science.msfc.nasa.gov/ssl/pad/solar/sun_wind.htm
- Coronal Mass Ejection (CME)
  - ISTP: Storms from the Sun; http://www-istp.gsfc.nasa.gov/istp/outreach/cmeposter/html.html
  - Windows to the Universe: Coronal Mass Ejections; http://www.windows.ucar.edu/tour/link=/sun/cmes.html
- Solar flares
  - NASA/GSFC Solar Physics: Solar Flare Theory Page; http://hesperia.gsfc.nasa.gov/sftheory/
  - RHESSI: Solar Flares; http://hesperia.gsfc.nasa.gov/hessi/flares.htm
- Interplanetary Magnetic Field (IMF)
  - Windows to the Universe: The Interplanetary Magnetic Field; http://www.windows.ucar.edu/cgi-bin/tour_def/glossary/IMF.html
  - IMAGE: Interplanetary Magnetic Field (IMF); http://pluto.space.swri.edu/IMAGE/glossary/IMF.html
- Solar Energetic Particles (SEPS)
  - Cosmicopia: Solar Energetic Particles; http://helios.gsfc.nasa.gov/sep.html
  - Windows to the Universe: The Arrival of High Energy Solar Protons; http://www.windows.ucar.edu/spaceweather/build_storm2.html
- Space weather
  - Windows to the Universe: Space Weather; http://www.windows.ucar.edu/tour/link=/space_weather/space_weather.html
  - SpaceWeather.com; http://spaceweather.com/
- STEREO learning center (http://stereo.gsfc.nasa.gov/classroom/classroom.shtml)
- STEREO links (http://stereo.gsfc.nasa.gov/links.shtml)
- STEREO websites:
  - http://www.nasa.gov/stereo/
  - http://stereo.gsfc.nasa.gov/
  - http://stereo.jhuapl.edu/