# S from the Sun Coronal Mass Ejections



Particles are blasted from the Sun ...

Some plunge through Earth's magnetosphere ....

And make bright northern lights ....

### Robins, Splitter, Lot and Treatme

The second where he done to be party the study which any said the second second second second second the de surger in the state of t we have a watch to say specify them. And NAME ADDRESS OF ADDRESS Name of Academic and Academic and

the state of the second s the local lines and the local line and infertions. make don't have a first showing and showing the products in the local data in the local products of the local sector of the local sect the design of the second second second The same state of an in the low other and the same

> The state of the state of state 1 and 1 and 1 and 1 the second statements from some diversion state and we also have in the other have been been a second



and the second sec -----

internet in the second second in some shall of secthe other property in the local data of the local of the local data and the local data an

the R. and start for fars and in contrast limit. And in the lattice of the link. Name of the West Associate and the state of the second state of the secon streams to their terminant of an intelling that and the training . I willing out strain, it was bet prime, but and part and story date in fast \$100mg costs for from on the product of the barriers states. and the second design is an even of second second of the man fare of second loads, the state of some States and Street and Street and

#### Thursday Not.

the state of the local state of the state of speeds to show a Westerney to her and i passing to be all the tracks of server. The protocol is protocol of the life of source in the server as it is a server and the server ant - report of the largest distribution into an other states i distance in the states of the states of the states manual spinster wird also has some insue billings ofte up to manual an in-

print with the characteristic to the second second second second second out only "since matches the age by the second reader the second s department of the second second



the last of the la

Station little optimized for successive stations the summer of the star of the same same way a strength and share the same sold the set of the state of the set of the set of the set of the set of the in the local day in the second of the second second

the role and the party of Materia and the of these provides an own the first of the second s No. of Lot & Lot &

supported in the statement of the statem -

"In such the "Average databased CORP. OF A 44 I Report to a party in the same same that training the state of the state the second second second and which is the provide spite of spice sectored and sectored have been and they want the Rowsell We start sector wanted from page 1, page 1-4 and the standard states and and status in the same of the same of the last of the most desire one walk strength in the spatial limit. Such that and the prove second -



and the second second second second strategy of the second second

the description of some had not been added as the solution of the solution of In the same ways that in the second state in the the production of their descent from the cost of the seca far shear word in the paper survive student from

and the second sec server to be a construction in the server in the server in and Trading to Dive a province of the A real reality of the designment day in these of reality. sugar and the set of the

and that both particle internation of the of the lighting his section where he doe not a fact over the parts of their detection or in the "selection ingenand of some city days to be and some in-



And in the second second in

the second second second second

the first of the same of the second second

and the second data is in some

had described the same of some barries

second states in the second states and states

Internal to be internal to particular

the second se

-----

the state of the s

the state of the state of the and set of educations of the Contractor State State.

make the other that the state of

contribute, do have a relationed of the state of state fraction."

A R AND AND A the start starting in the start of the start is not in the

the same strength advantation for an include of the not be the other subscripts of the spring one way. Spring in the other states which the state of the s IN COLUMN 2 (1971) & IN COLUMN IS AND, PLOTED.

transition of the second representation of the second the same is to be it is a set of his to be there a print sum of a first bit of the second state of the print

the latter wanted in a little state of the state of the and there are a summing off, the

## STORMS from the SUN

### Normal Phone

-

many series and a series of

.

and the second second

Contractor of the second and the second second THE R. P. LEWIS CO., LANSING MICH., NAME AND ADDRESS OF TAXABLE AND phone and the second se The second in the local second second second

the ball is proved to information where is strained control minimum of it control much. Multiple 4 which is \$2.00 to \$1.00 because \$1.00 because grades

the set degree and it is the in-insalesh tray test o read little to any the York and the first second diaments with the state of the second second and a second sec particular of the second second second second your or list opposition and starts into Arrest strategy in an and the second strategy in the second Watching to a destine of the standard strends.

the second of the second start of the second start -The second second second



NUMBER OF STREET, AND ADDREED & D. D. MILL. to the pair processory one other study and prove download Non-Service of the Adult is a reader of such makes place Average over the statement and

manufacture and a difference Dance of sile or other and a local de sere and the state of a lot of the tion of press later man and compare total states that second r berring the same in a state of the second sec dates, do line to make a street of the print water and the meritagi a billay for available. Non, arta-ballar avita-

thead the second state and a list and these in such that the such that the

#### Second the Includes.

in the stimulation of the same same a summer of a second state of the conversion of the last of gas, in other Physics and the same a desired at the solution.



When provide an instantoning law to show that show the second state of the second state of the second state and from a plant. "An other had a ball to the local state of the second se and show I there is a buildened of the state of the

the state of the state of the state of the state of the

NAME AND ADDRESS OF TAXABLE



which the the stand that he had been



Concernance of the second pair parts, thing, from.

broad and the problem therease the states as a state of the state and the local first serve "for a province on the fait in some sets The second with the standington. Without splits with process strength in a state of the state of the name when the set, have already independent of the Court manage has says over an a got as an internal (MC). 1.815

#### Elsekton, Rissant, and Rissanter's

And the built second terms on the second state of the prime concernment the second state is A CONTRACTOR and the set of the second s and a second second and a second seco 200 200 200 200 1

AND REAL TRADE IN \*\*\*\* delivered and produced Character in the same in the second second The lot of the lot of the second of Construction in second state and will service and the service of the service the design of party of these last in some these second a little of the second interfaces and the largest in the second second second second time of the second seco The company and out on her

The Party of the statement of the



the surged of some in surgery which "Sector Contract in the state of the sector of the to have the standing down in south 1 of the Automatic Property and the well dependences on all out first \$1.00 mills MANUAL PROPERTY AND ADDRESS OF which the part of the state of the local state of the sta instructions and instruction which said ing the print of a party courts of the last the winds of which have be trains a set in station and some first the second second

right a shirt of the part of the they wanted to be a set of the se Children and south the Westman Property of owner be been wetting the second second -

#### Make Some Other from Carrie Compositions

Taken to short it such that the plate of the last has been determined on the ------In this way when or waters and work had a

contrastive contrastive and in contrastive data help the shirt is sub-1 if has a set in a since the property of the state of th training over 1700 that regist an annual figs and the second in part, the the lot is a state of the lot of manufacture accession larger.

State of Concession, Name A characterized with the second state of the second state of the that shall be a straight of the shall be seen as the second sectory and indefine the residue managed across press where In set is sense in and in the set of the lot set of the second of Includes that is sufficiently to have

And in the local division of the local divis Statement of the local data and the The second second second company particular in the contract of the second of some space of the second tran of \$2. but the original \$2. \$1 and its second, general

Lond Rooms-Huge Street been and the ball and a strength of the the state of the Income and South Prop. Proc.

The second secon



### Measure the Manual of a Constant Man Lawrence

window Transmission and compared of a discovery spin-Not not the internet of the standard of the state. designation of the same pair of the local state and the ball Name of Actual Property of Street, Str structure with the or which which a data which of the

National Sciences of product on the same in starts if their all the re-many in a the basis in the same size in vices incase one. We primerate his course a place. then to be represented in the second second and an other reason was so to be a bridge tor other strength and in the and the state of the set of the set. Second was chosen one be the state of a first 176 for an it was rank. To starting advectory of the design of the order of the function of Resident from storage 2 th William in an about to be success.

a same in the part of a real of the second data Said & All and 14 house a to see 1 house ----

and the second s

the in-many law is to pay the law a set tage, pays cover it can be that the property is an it should be colored and the state of preside all date the state of the state of the based of the standard of the based of the standard of the An other stands for her high a 14, and a second second second



#### Parket Station of Longel

that is she want to be a submit of a serie to see the set the strength of the state of the strength of the state of the strength of the sectory' "read-double, and a context of bollowing its full start at the state of the state of the state of the "In such as the life Advantage" But an other that is your a straight of a loss and a fact the second

The second se

#### WARA Recommendant Test Principality of

the last state of the last state of the last investigate property and the restriction of and the second s

Statistics in succession and the second s

#### the state in the second s

COLUMN PROPERTY. suprovision



No. B..... the state of the s





former contents of the ferrors of the And street of the local division of and the second of

> And the second sec and the second second

and the second se

San and a special second

And the lot of the last state of the

and which was a district in the other

the second se

A LOCAL DESIGNATION

A REAL PROPERTY OF A REAL PROPER

and a second second

and the other states and the states

OCCUPATION PROPERTY AND

and the same state is the same



And the second s

The state of the second state of the second state of

CALCULATION AND ADDRESS

comparison of the second second sent said while a shift but a sale of our an at the land, in small 18, 70 million has a state of a little state all the last state of any ball is with index of spin-of. The balls of "Second in case of a company and in and in form the second second second second second All residues that reports the two republic and and the set was been and be shown in the set of the seath fully a little billing proving the black for and the strategy of the second state of the second state service which that any property of the dead the important

the set to be under housest setting it have a situation of a start port of the lattice is in the posterior Wagnets include on other time and only one of the local control of factory considered they believe that or its street and the Research Constraints of the Research of the second Appl. of parts of Witness many in her. same a second represent, to the second to a second the subject interface the second s replace the sector statute is a sector of their per-

1111

summer of the local division of the local di which advants in the second

# **Bubble, Bubble, Toil and Trouble**

Looking at the sky, you would think the Sun is static, placid, constant. From the ground, the only features that seem to change are where and when the Sun will appear: will clouds block its rays today? Will it rise at 6:30 or 7:30 a.m.? But while our Sun does give us a steady stream of warmth and light, it also has weather that is turbulent and dynamic, provoking the cosmic equivalent of winds, clouds, waves, precipitation, and storms.

The Sun is a huge thermonuclear reactor, fusing hydrogen atoms into helium and producing million degree temperatures and intense magnetic fields. Near its surface, the Sun is like a pot of boiling water, with bubbles of hot, electrified gas—actually electrons and protons in a fourth state of matter known as plasma circulating up from the interior, rising to the surface, and bursting out into space. The steady stream of particles from the Sun is known



A close-up of the Sun (shown in ultraviolet light) reveals a mottled surface, bright flares, and tongues of hot gas leaping into space.

as the solar wind.



Though they look like burns in the face of the Sun, sunspots are actually much cooler than the rest of the surface.

Blowing at 800,000 to 5 million miles per hour, the solar wind carries a million tons of matter into space every second (that's the mass of Utah's Great Salt Lake). It's

not the mass or speed, however, that makes the solar wind potent. In fact, the solar wind would not even ruffle the hair on your head because there are too few particles in the breeze (our air is millions of times denser than the solar wind). Instead, it is the energy stored in the plasma and the magnetic fields associated with that plasma that allow the wind to shape and impact Earth's protective magnetic shield in space (the magnetosphere). Though less than 1% of the solar wind penetrates the magnetosphere, that's enough to generate millions of amps of electric current in our atmosphere and to cause occasional magnetic storms in the space around Earth.

If the character of the solar wind is like that of the winds on Earth—mild, steady, and global—then sunspots and solar flares are like lightning and tornadoes—potent, but only over a small area. Sunspots are dark splotches on the Sun caused by the appearance of cooler (3000 degrees Celsius) areas

amidst the roiling gases on the surface (6000 degrees C). These areas are cooler because much of their energy is tied up in intense magnetic fields that are 1000 times stronger than the magnetic field of Earth.

On the other hand, solar flares appear as explosive bright spots on the surface of the Sun. Flares occur when magnetic energy built up in the solar atmosphere near a sunspot is suddenly released in a burst equivalent to ten million volcanic eruptions. Radiation—including radio waves, X rays, and gamma rays—and charged particles may strike the Earth following a solar flare (though most of the particles are deflected by Earth's magnetic field). The strongest flares occur just several times per year, while weaker flares are relatively common, with as many as a dozen a day during the Sun's most active periods.



The use of an occulting disk—the orange and white circle in the center of the photo—allows scientists to see the solar wind streaming away from the Sun

# **Hurricane Sol**

One of the most important solar events from Earth's perspective is the coronal mass ejection (CME), the solar equivalent of a hurricane. A CME is the eruption of a huge bubble of plasma from the Sun's outer atmosphere, or corona. The corona is the gaseous region above the surface that extends millions of miles into space. Thin and faint compared to the Sun' surface, the corona is only visible to the naked eye during a total solar eclipse. Temperatures in this region exceed one million degrees Celsius, 200 times hotter than the surface of the Sun.

How the corona can be so much hotter than the surface remains a mystery to scientists, but most suspect that it has to do with the complicated magnetic fields that burst from the interior and extend above the surface in



When scientists see a faint halo around the Sun (expanding around the disk), they know a coronal mass ejection is headed for Earth.

great arches and loops. The buildup and interaction of these magnetic loops—which can stretch over, under, and around each other—seems to supply the energy to heat the corona and produce the violent explosion of a CME.

According to some of the newest observations and theories, the larger and higher magnetic loops of the Sun's field are believed to hold down the newer, smaller fields emerging from the surface. They also tie down the hot plasma carried by those fields. Much like a net holding down a helium balloon, this network of magnetic loops restrains the plasma and magnetic fields trying to rise into the corona. This causes tremendous energy to build. Eventually,

some of the overlying magnetic loops merge and cancel each other, cutting a hole in the magnetic net and allowing the CME to escape at high speed.

Researchers compare this process to that of filling helium balloons. If you inflate a balloon without holding it down, it will slowly drift upward. But if you hold the balloon down with a net, you can generate a lot of force when you fill it, causing it to push upward. Once you remove the net, the balloon shoots skyward.

Once it escapes the Sun's gravity, a CME speeds across the gulf of space at velocities approaching one million miles per hour (400 km/sec), with the fastest CMEs accelerating to 5 million mph. A typical CME can carry more than 10 billion tons of plasma into the solar system, a mass equal to that of 100,000 battleships. The

energy in the bubble of solar plasma packs a punch comparable to that of a hundred hurricanes combined.

Just hours after blowing into space, a CME cloud can grow to dimensions exceeding those of the Sun itself, often as wide as 30 million miles across. As it ploughs into the solar wind, a CME can create a shock wave that accelerates particles to dangerously high energies and speeds. Behind that shock wave, the CME cloud flies through the solar system bombarding planets, asteroids, and other objects with radiation and plasma. If a CME erupts on the side of the Sun facing Earth, and if our orbit intersects the path of that cloud, the results can be spectacular and sometimes hazardous.



The bubble of plasma in a CME expands and grows more potent until it escapes from the magnetic and gravitational energy of the Sun.

# **Storm Front**

Coronal mass ejections occur at a rate of a few times a week to several times per day, depending on how

active the Sun may be. And because of the size of the plasma clouds they produce, the odds say Earth is going to get hit by a CME from time to time. Fortunately, our planet is protected from the harmful effects of the radiation and hot plasma by our atmosphere and by an invisible magnetic shell known as the magnetosphere. Produced as a result of Earth's own magnetic field, the magnetosphere shields us from most of the Sun's plasma by deflecting it into space.

But some energetic particles do enter the magnetosphere from time to time, funneling in near the North and South Poles, where the magnetic field is weakest and the magnetosphere is partially open to space. The rain of plasma into our magnetosphere can induce magnetic storms, alter Earth's magnetic field as measured on the ground, and produce the phenomena known as auroras.



A computer simulation of the magnetosphere shows how a CME cloud can compress our magnetic field and increase its intensity.

Many things

can happen in the magnetosphere during a magnetic storm because a lot of energy is being dumped into the system. When impacted by plasma from space or even from the far reaches of the magnetosphere, the electrons, protons, and oxygen ions of Earth's Van Allen radiation belts become denser, hotter, and faster. Due to their motion, these particles produce as much as a million amperes of electrical current, a jolt of power that can decrease the strength of Earth's magnetic field. Some of the current flows along Earth's magnetic field lines and into the upper atmosphere. The passage of electric current through the upper atmosphere and the loss of electrons and protons from the magnetosphere can cause the atmosphere to warm and expand, increasing the density at high altitudes.

Finally, some of the excited particles in the radiation belts can plunge into the upper atmosphere, where they collide with oxygen and nitrogen. These collisions—which usually occur between 40 and 200

miles above ground cause the oxygen and nitrogen to become electrically excited and to emit light (fluorescent lights and televisions work in much the same way). The result

is a dazzling dance of green, blue, white, and red light in the night sky, also known as aurora borealis and aurora australis ("northern and southern lights"). Auroras can appear as colorful, wispy curtains of light ruffling in the night sky, or sometimes as diffuse, flickering bands. Either way, they tell us that something electric is happening in the space around Earth.



Seen here over Alaska, auroras are native to the far northern and southern lands. The most powerful magnetic storms can bring auroras all the way to Texas.



Though they grow more intense when a CME hits Earth, auroras are present every day.

## Seeing the Invisible

Auroras are a visible sign of the magnetic mayhem in our atmosphere, but beyond that, the human eye can't detect much of what we call space weather. That's because most of the material flowing from Sun to Earth is too small, too diffuse, or too dim—when measured against the background of space or the brightness of the Sun—to



The orbits of ISTP's satellites allow scientists to see the Sun-Earth system from many angles.

register in the visible portion of the spectrum.

For instance, since the corona is only visible to the naked eye during an eclipse, scientists must use an occulting disk—which blocks out the light from the solar surface to create an artificial eclipse—to detect what the Sun is spitting into space. Some of the most important recent advances in understanding and tracking coronal mass ejections have come from cameras that photograph the corona and detect the plasma of a CME as it heads toward Earth.

In order to see the invisible, space physicists rely on telescopes that detect visible light, ultraviolet light, gamma rays, and X rays. They use

receivers and transmitters that detect the radio shock waves created when

Polar

a CME crashes into the solar wind (the equivalent of a sonic boom in space). They employ particle detectors to count ions and electrons, magnetometers to record changes in magnetic fields, and cameras to observe the auroral patterns over the whole Earth.

All of these instruments and many others are the tools of the hundreds of scientists participating in the International Solar-Terrestrial Physics (ISTP) program, a global effort to observe and understand our star and its effects on our environment. An armada of more than 25 satellites carry those instruments into space, and together with

ground-based observatories, they allow scientists to study the Sun, the Earth, and the space between them. Individually, the spacecraft contributing to ISTP act as microscopes, studying the fine detail of the Sun, the solar wind, and the boundaries and internal workings of Earth's magnetic shell. When linked together with each other and the resources on the ground, they act as a wide-field telescope that

sees the entire Sun-Earth environment.

The spacecraft of ISTP principally, Wind, Polar,

Geotail, and the Solar and Heliospheric Observatory—allow physicists to observe all the key regions of Earth's space. They study the interior of the Sun, its surface and corona, the solar wind, and Earth's magnetosphere, including the auroral regions and Van Allen radiation belts. Orbiting as far as one million miles and as close as a few hundred miles from Earth, the spacecraft of ISTP make coordinated, simultaneous observations of the Sun and activity in the magnetosphere. Working together with ground observatories, these spacecraft can now for the first time ever—track CMEs and other space weather events from cradle to grave. Someday, they might even be able to predict the arrival and effects of CMEs.



ISTP includes spacecraft from NASA, the European Space Agency, Japan's Institute for Space and Astronomical Science, and Russia's Space Research Institute.



SOHO



# **Blackouts, Burnouts, and Bummers**

Aside from bright auroras, there are other less benevolent effects of the connection between Sun and Earth. In fact, bright auroras are merely a visible sign that the balance of electrical and magnetic energy in Earth's magnetosphere has been upset. With the average CME dumping about 1500 Gigawatts of electricity into the

atmosphere (double the power generating capacity of the entire United States), big changes can occur in our space. Those changes can wreak havoc on a world that has come to depend on satellites, electrical power, and radio communication—all of which are affected by electric and magnetic forces.

For the satellites dancing in and out of the radiation belts and the solar wind, CMEs and magnetic storms can be perilous. For instance, a series of flares and coronal mass ejections in March 1989 produced a potent magnetic storm. After the particles and energy from the Sun bombarded the Earth, more than 1500 satellites slowed down or dropped several miles of altitude in their orbits due to increased drag.

But atmospheric drag isn't the only effect CMEs can have on satellites. When excited and accelerated by a storm, high-



The effects of magnetic storms—what scientists call space weather—extend from the ground to geostationary orbit and beyond.

energy electrons can degrade the solar panels used to power satellites and can upset and even shut off computers on a spacecraft. The increased flow of electricity in Earth's space also can cause electrical charge build up on the surface of a spacecraft. That charge can eventually be released as a damaging spark (a spark not unlike the



Magnetic storms, like this one seen in ultraviolet light, can wreak havoc on radio communications and electric power stations.

one you get when you touch metal or a friend after you drag your feet on a carpet). In 1994, two Canadian satellites were shut down when each was electrically shocked during magnetic storms; as a result, telephone service across Canada was disrupted for months. Similarly, in January 1997, an American satellite went dead just hours after a CME struck the magnetosphere. The loss of that satellite disrupted television signals, telephone calls, and part of a U.S. earthquake monitoring network.

Magnetic storms also play havoc with radio signals, which are bounced off Earth's ionosphere (the outermost layer of our atmosphere, made up mostly of plasma) as a sort of natural relay station. In March 1989, listeners in Minnesota reported that they could not hear their local radio stations, but they could hear the broadcasts of the California Highway Patrol. In the extreme, magnetic storms can completely wipe out radio communication around Earth's North and South Poles for hours to days. On the ground, magnetic storms can affect the strength of Earth's magnetic fields. Changes in magnetic fields can produce surges in power lines and strong electrical currents in gas and oil pipelines. The extra current can cause pipelines to corrode and deteriorate faster than they would naturally; in power lines, the extra electricity can burn out transformers and cause brownouts and blackouts. During the March 1989 storm, a transformer burned up at a power plant in New Jersey, and a whole system was blown out at a power station in Quebec, leaving 6 million people without electricity for hours, some for months.

Since so much modern information is relayed by satellites and other advanced technology—from automated teller machines and broadcast signals to the Global Positioning System and disaster warning systems—CMEs pose a natural and technological hazard to life on Earth.



These images from SOHO (left) and Polar (right) show particles from the Sun bombarding the satellites. SOHO sees the solar wind in the first image, then a snow of protons accelerated by a CME. Polar looks down on the aurora and Earth's dayglow before the protons smack the camera.

# **Make Your Own Sun-Earth Connections**

Thanks to the Internet, it is easy for you to keep up with the latest observations and breakthroughs in the study of Sun and Earth. In fact, anyone who can access the World Wide Web can study the Sun, Earth's magnetosphere, and interplanetary space, because that is where ISTP scientists receive and share their data.

Many of the observations made by ISTP are available within hours to days after they are made, allowing you to witness science in action. In particular, every time a CME lifts off the Sun and heads toward Earth, you can watch the storm develop by viewing some of the same images and data sets that space physicists are using. So don't wait for science to show up in your textbooks or magazines—look over a scientist's shoulder and watch it happen.

### **Mission to Geospace**

To learn more about how and why physicists study the space around Earth, go to http://www-istp.gsfc.nasa.gov/istp/outreach. The site includes easy to read articles and primers; a place to question and read about real scientists; activities, images and movies; and an extensive library of news items and articles about the latest and greatest discoveries from our neighborhood in space.

### **SOHO Explore**

To learn more about the Sun as seen through the keen eyes of the Solar and Heliospheric Observatory, go to http://seal.nascom.nasa.gov/ explore/. The site includes exercises, glossaries, activities, and lessons in solar science, as well as information about a poster called "New Views of the Sun" and a place to get all your Sun questions answered.

### Live Storms from the Sun

Every time the Sun spits a CME in Earth's direction, scientists track it online at http://www-istp.gsfc.nasa.gov/istp/events/

### **International Solar Terrestrial Physics Program**

To see the same raw, unedited data and images that ISTP scientists view, visit

the low and a set and a set list of the set of the set







# Measure the Motion of a Coronal Mass Ejection

Activity: Calculate the velocity and acceleration of a coronal mass ejection (CME) based on its position in a series of images from the Large-Angle Spectrometric Coronograph (LASCO) instrument on SOHO. Materials: ruler, calculator, and a set of CME images from the LASCO instrument on SOHO. You can use the ones here or gather another set from http://sohowww.nascom.nasa.gov/gallery/LASCO/las001.gif

**Background:** 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 Sun's 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:

actual distance of feature from Sun<br/>diameter of the Sun (1.4 million km)=position of feature as measured on image<br/>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:  $v = (s_2 - s_1) / (t_2 - t_1)$ , where  $s_2$  is the position at time,  $t_2$ ;  $s_1$  is the position at time,  $t_1$ . The acceleration equals the change in velocity over time; that is,  $a = (v_2 - v_1) / (t_2 - t_1)$ , where  $v_2$  is the velocity at time  $t_2$ ;  $v_1$  is the velocity at time  $t_1$ . You can record your results in a table.

Universal Time	Time Interval	Position	Avg. Velocity	Avg. Acceleration
8:05				
8:36				
9:27				
10:25				
11:23				

### **Further Questions and Activities**

• 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.

• 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?



### **NASA Resources for Educators**

### NASA's Central Operation of Resources for Educators

(CORE) was established for the national and international distribution of NASA-produced educational materials in audiovisual format. Educators can obtain a catalogue and an order form by one of the following methods:

- NASA CORE Lorain County Joint Vocational School 15181 Route 58 South Oberlin, OH 44074
- Phone (440) 774-1051, Ext. 249 or 293
- Fax (440) 774-2144
- E-mail nasaco@leeca.esu.k12.oh.us
- Home Page: http://spacelink.nasa.gov/CORE

### Educator Resource Center Network

To make additional information available to the education community, the NASA Education Division has created the NASA Educator Resource Center (ERC) network. ERCs contain a wealth of information for educators: publications, reference books, slide sets, audio cassettes, videotapes, telelecture programs, computer programs, lesson plans, and teacher guides with activities. Educators may preview, copy, or receive NASA materials at these sites. Because each NASA Field Center has its own areas of expertise, no two ERCs are exactly alike. Phone calls are welcome if you are unable to visit the ERC that serves your geographic area. A list of the centers and the regions they serve includes:

AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY NASA Educator Resource Center Mail Stop 253-2 NASA Ames Research Center Moffett Field, CA 94035-1000 Phone: (415) 604-3574

CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT NASA Educator Resource Laboratory Mail Code 130.3 NASA Goddard Space Flight Center Greenbelt, MD 20771-0001 Phone: (301) 286-8570

CO, KS, NE, NM, ND, OK, SD, TX ISC Educator Resource Center Space Center Houston NASA Johnson Space Center 1601 NASA Road One Houston, TX 77058-3696 Phone: (281) 483-8696

FL, GA, PR, VI NASA Educator Resource Laboratory Mail Code ERL NASA Kennedy Space Center Kennedy Space Center, FL 32899-0001 Phone: (407) 867-4090

KY, NC, SC, VA, WV Virginia Air and Space Museum NASA Educator Resource Center for NASA Langley Research Center 600 Settler's Landing Road Hampton, VA 23669-4033 Phone: (757) 727-0900 x 757

IL, IN, MI, MN, OH, WI NASA Educator Resource Center Mail Stop 8-1 NASA Lewis Research Center 21000 Brookpark Road Cleveland, OH 44135-3191 Phone: (216) 433-2017 AL, AR, IA, LA, MO,TN U.S. Space and Rocket Center NASA Educator Resource Center for NASA Marshall Space Flight Center P.O. Box 070015 Huntsville, AL 35807-7015 Phone: (205) 544-5812

MS NASA Educator Resource Center Building 1200 NASA John C. Stennis Space Center Stennis Space Center, MS 39529-6000 Phone: (601) 688-3338

NASA Educator Resource Center JPL Educational Outreach Mail Stop CS-530 NASA Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena, CA 91109-8099 Phone: (818) 354-6916

CA cities near the center NASA Educator Resource Center for NASA Dryden Flight Research Center 45108 N. 3rd Street East Lancaster, CA 93535 Phone: (805) 948-7347

VA and MD's Eastern Shores NASA Educator Resource Lab Education Complex - Visitor Center Building I-1 NASA Wallops Flight Facility Wallops Island, VA 23337-5099 Phone: (757) 824-2297/2298 **Regional Educator Resource Centers (RERCs)** offer more educators access to NASA educational materials. NASA has formed partnerships with universities, museums, and other educational institutions to serve as RERCs in many states. A complete list of RERCs is available through CORE, or electronically via NASA Spacelink at http://spacelink.nasa.gov

NASA On-line Resources for Educators provide current educational information and instructional resource materials to teachers, faculty, and students. A wide range of information is available, including science, mathematics, engineering, and technology education lesson plans, historical information related to the aeronautics and space program, current status reports on NASA projects, news releases, information on NASA educational programs, useful software and graphics files. Educators and students can also use NASA resources as learning tools to explore the Internet, accessing information about educational grants, interacting with other schools which are already on-line, and participating in on-line interactive projects, communicating with NASA scientists, engineers, and other team members to experience the excitement of real NASA projects.

Access these resources through the NASA Education Home Page: http://www.hq.nasa.gov/education

NASA Television (NTV) is the Agency's distribution system for live and taped programs. It offers the public a front-row seat for launches and missions, as well as informational and educational programming, historical documentaries, and updates on the latest developments in aeronautics and space science. NTV is transmitted on the GE-2 satellite, Transponder 9C at 85 degrees West longitude, vertical polarization, with a frequency of 3880 megahertz, and audio of 6.8 megahertz.

Apart from live mission coverage, regular NASA Television programming includes a Video File from noon to 1:00 pm, a NASA Gallery File from 1:00 to 2:00 pm, and an Education File from 2:00 to 3:00 pm (all times Eastern). This sequence is repeated at 3:00 pm, 6:00 pm, and 9:00 pm, Monday through Friday. The NTV Education File features programming for teachers and students on science, mathematics, and technology. NASA Television programming may be videotaped for later use.

For more information on NASA Television, contact: NASA Headquarters, Code P-2, NASA TV, Washington, DC 20546-0001 Phone: (202) 358-3572 NTV Home Page: http://www.hq.nasa.gov/ntv.html

How to Access NASA's Education Materials and Services, EP-1996-11-345-HQ This brochure serves as a guide to accessing a variety of NASA materials and services for educators. Copies are available through the ERC network, or electronically via NASA Spacelink. NASA Spacelink can be accessed at the following address: http://spacelink.nasa.gov

