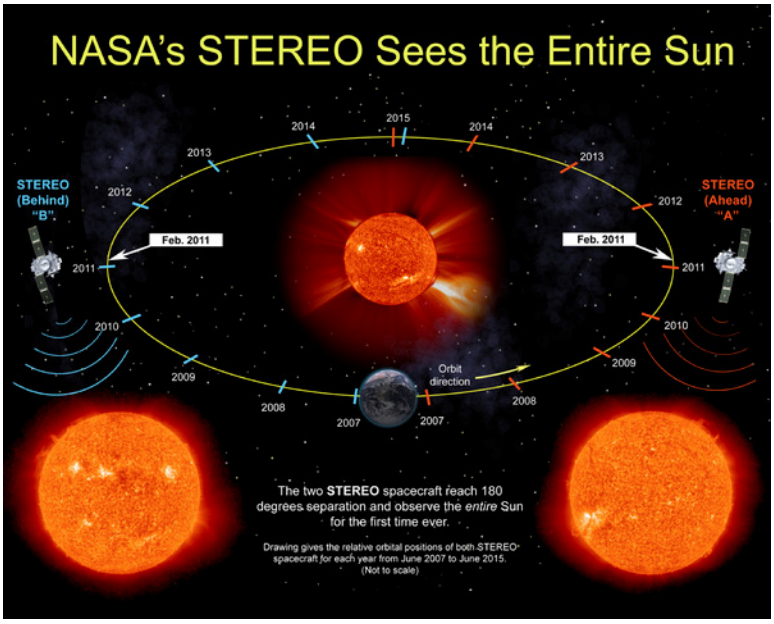
First Ever STEREO Images of the Entire Sun

These presentations give additional information on how STEREO's first ever views of the entire sun will advance the study of solar and space physics, help validate previous imaging techniques, and contribute to the accuracy and timeliness of space weather forecasts.

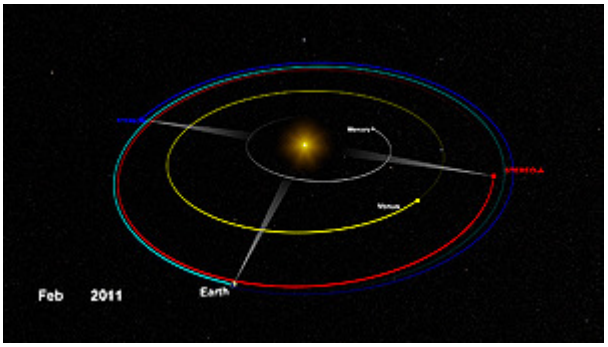


On February 6, the two STEREO spacecrafts will be 180 degrees apart and for the next 8 years the STEREO spacecrafts and SDO will be able to observe the entire 360 degrees of the Sun. Credit: NASA.

Our STEREO 360 Panel of Experts

Dr. Terry Kucera, NASA Goddard Space Flight Center
Senior Deputy STEREO Project Scientist

Today, I will tell you about the STEREO's new ability to observe the far side of the Sun – a first in human history, and how that will help us understand and predict solar activity and its effects on the entire solar system.

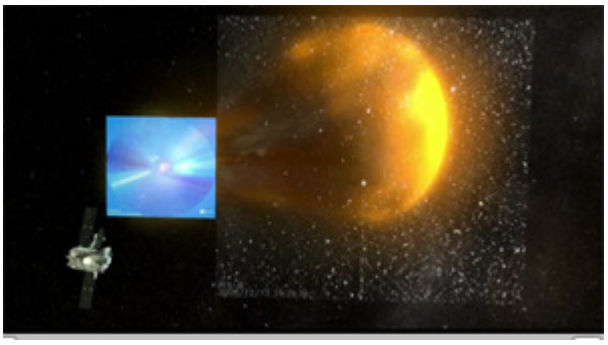


Video # 1 The STEREO mission consists of two spacecraft orbiting the Sun, one moving a bit faster than Earth and the other a bit slower. In the time since the STEREO spacecraft entered these orbits near the beginning of 2007 they have been slowly separating. In Feb. 2011 they reach the point at which they are on opposite sides of the Sun and can observe the entire far side of the Sun. Credit: NASA/Goddard Space Flight Center/Scientific Visualization Studio
http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=15504&media_id=59559661

STEREO is a two spacecraft NASA mission focused on obtaining a three dimensional understanding of the Sun and Solar activity.

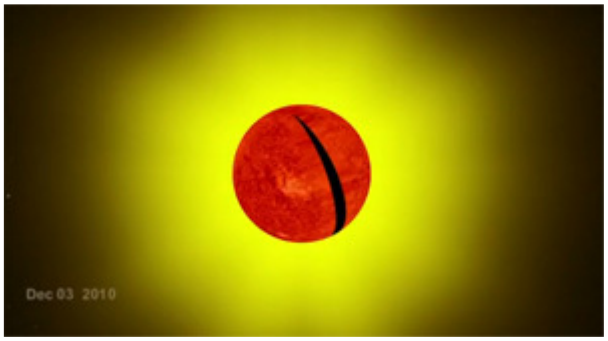
The two spacecraft were launched together on 2006 and placed in separate orbits around the Sun, one moving a bit faster than Earth and the other trailing Earth. They separate from each other at about 45 degrees a year so that now, about four years later, they are 180 degrees apart, with Earth in the center.

This means that, STEREO images now allows us to seen the entire far side of the Sun, and when combined with data from the Earth orbiting Solar Dynamics Observatory (SDO), we will be able to see the entire Sun all the time until they swing back around the Earth side of the Sun in eight years.



Video # 2 A Coronal Mass Ejection (CME) as seen by the STEREO/SECCHI imaging suite. The CME can be seen as a white structure moving out through the fields of view of the different imagers. In yellow is an animation based on a CME model. Credit: NASA/Goddard Space Flight Center/CI Labs/Walt Feimer
http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=15504&media_id=59562391

Having the two vantage points of STEREO has already given us major advances in our understanding of solar activity by allowing us to understand it in three dimensions. This activity includes coronal mass ejections (or CMEs), like those shown here in these images of the corona, the Sun's outer atmosphere, taken by STEREO. These enormous magnetic clouds blast out into the solar system at a million miles an hour and can lead to problems in many human technologies including spacecraft, communications, and GPS. These disturbances and how they affect us are referred to as "Space Weather" STEREO has allowed us to better understand their structure and how they move through space.



Video # 3 As the STEREO spacecraft have moved out on either side of Earth they have imaged more and more of the Sun's surface. This video shows how our coverage of the Sun has increased. The Sun is shown as seen by the two STEREO spacecraft and the Earth orbiting Solar Dynamic Observatory (SDO). The steadily shrinking black wedge shows the unobserved area on the Sun's far side. The data show the Sun in extreme ultraviolet light at 304 Å.
Credit: NASA/Goddard Space Flight Center/Scientific Visualization Studio
http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=15504&media_id=59565281

Now, four years after launch, the spacecraft are 180 degrees apart, which means we are able to directly image the entire Sun. In the video you see how our ability to observe the Sun as increased over the lifetime of the STEREO mission.

These data show the Sun in extreme ultraviolet light. With the observations of the two STEREO spacecraft combined. Images taken since late last spring also include images from SDO on the Earth facing side of the Sun.

Each spacecraft can see just half the Sun. At the start of the mission this was the same half, but as the spacecraft move apart our ability to see the Sun's surface has been steadily increasing, and that black wedge showing the area we can't see is now shrinking down to nothing.

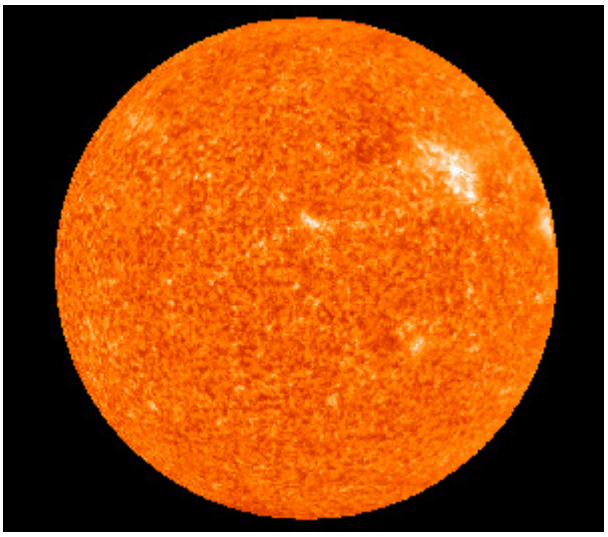
The Sun orbits at about once every 28 days, but changes on a much faster time scale, so being able to see the far side of the Sun means we can see the complete evolution of Solar activity on the surface and how it extends out into the solar system.

To give you more details about the new observations I'll hand it over to Angelos.

Dr. Angelos Vourlidas, Naval Research Lab
STEREO SECCHI Deputy Principal Investigator

I am very excited to be a part of STEREO and be part of the newest advance in heliophysics research. Our field of study just crossed another milestone, courtesy of STEREO. For the first time, we have taken snapshots of the entire atmosphere of a star! *How cool is that?!!*

To put it in perspective; before STEREO we were like a person trying to get the pulse of a city by watching through a half-open window…not an easy task. Now, STEREO has thrown wide open the window and we can watch the Sun and its activity in its full 3-dimensional glory.



Video # 4 Rotating solar sphere made from a combination of imagery from the two STEREO spacecraft, together with simultaneous data from the Solar Dynamic Observatory. This movie is made from data taken on January 31, 2011. Because the STEREO separation was still less than 180 degrees at that time, the small gap on the far side of the Sun has been interpolated over to simulate the full 360 degree view that STEREO will see. This gap will start to disappear on February 6, 2011, and will completely disappear over the next several days. The regions near the seam between the STEREO Ahead and Behind images appear stretched out because they are at the edges of the Sun in the original images. As the STEREO spacecraft continue to separate, imaging in this part of the globe will improve. Credit: NASA/Goddard Space Flight Center/ STEREO/SECCHI
http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=15504&media_id=59569421

First, let me explain what we are seeing in the video:
The red sphere is an image of the Sun taken through an the Extreme Ultraviolet filter that captures light from relatively cool parts of the atmosphere, around 80,000 degrees. Our telescopes also observe with other EUV filters sensitive to hotter temperatures. By comparing the observations from the different filters, we get information on the density and temperature of the solar atmosphere. We use colors as a visual aid to discriminate between the different filters. In the case on your screen we use the red color.

The brighter, whiter shades show regions of intense magnetic field and activity. We call them Active Regions. Darker areas are holes where the solar plasma escapes to form the solar wind. Elongated dark features are long filaments of

magnetic field which give us some of the most spectacular images when they erupt.

Each STEREO EUV telescope sees half of the Sun at a time. When we combine the 2 views, we obtain a map of the entire solar atmosphere, at 80,000 deg in this case. However, the map is not exactly perfect. Note the fuzzy stripe (looks like a seam) along a north-south line in the movie. Why is that?

Recall your time at school when you were looking at an Earth globe, say looking straight at Washington, D.C. If you glanced towards Europe which lies at the edge of the globe, you'd be hard-pressed to tell the size of the various European countries. Their shapes would appear much distorted by the projection effects at the edge of the globe.

We have the same problem here with our Solar Globe. The features at the edges of the solar sphere, as seen by each STEREO s/c appear distorted, creating two seam-like artifacts. One is on the far-side and the other on the side facing Earth. As the STEREO spacecraft rotate behind the Sun, the view of the far-side will get better (the seam will disappear) but the view of the Earth-side will get worse. We will have a growing gap there.
This would be a problem. We do care about the Earth-side since activity from those locations may affect Earth's environment.

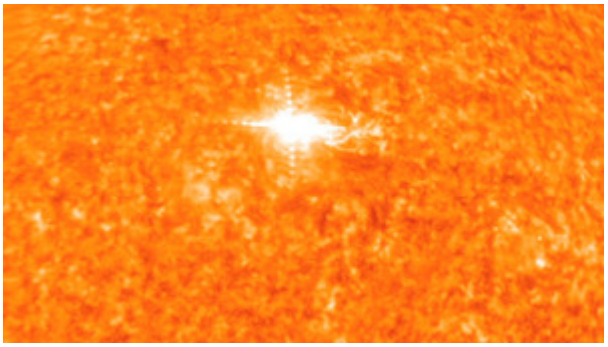
The systems approach is the power of NASA's Heliophysics Observatory.
No need to worry about that! We are able to fix this thanks to NASA's newest solar mission, the Solar Dynamics Observatory (SDO for short) which operates EUV telescopes similar to STEREO's. It is a simple matter to patch the Earth-side of the solar disk with observations from SDO and get a much more accurate image of the solar atmosphere.

This is exactly what we have done in the movie. We have created an almost perfect 360^0 deg map of the sun from the combination of 3 EUV imagers from 2 missions. At the moment, we are left with only one fuzzy edge. This will also go away over the next few months and for the next 8 years we will be treated to a continuous viewing of the entire solar atmosphere.

What will this capability do for heliophysics?
I like to think of these spherical maps as having our own magic ball! We can solve the puzzles behind the evolution and structure of the solar atmosphere, including its violent eruptions, because we will be able to observe every feature and source of activity at the same time all over the Sun and follow their connections that can extend to large distances around the Sun.

Up to now, we had to wait until an active region or filament rotated across the visible from Earth disk in order to study their properties. The problem is that the corona is highly variable, filled with regions that come and go in a matter of days

and explosions that can alter the corona landscape in a matter of hours.



Video # 5 Zoom in to solar activity visible on the far side of the Sun from the STEREO Behind spacecraft on January 13, 2011. The images show a young, fast-growing region of the solar atmosphere which creates brightening and ejection of material. These images were taken by STEREO's Extreme UltraViolet Imager (EUVI). The brightest activity comes from material at temperatures around 1.8 million degrees while the quieter parts of the images have temperatures of only 80,000 deg. This activity could not be directly seen from Earth. Because the STEREO separation was still less than 180 degrees at that time, the small gap on the far side of the Sun which would be briefly visible in the film has been interpolated over to simulate the full 360 degree view that STEREO will see. Credit: NASA/Goddard Space Flight Center/ STEREO/SECCHI
http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=15504&media_id=59571781

Now, there is no place (for the activity) to hide on the Sun! For example, take a look at the following video where we zoom in a solar region when it was at the far-side of the sun and not visible from Earth.

It started quiet enough but then, it erupted in a series of explosions and became ever more complex…BEFORE it was visible from Earth. We would have no chance to understand this violent behavior in the past. Now we can look forward to 8 years of 360 deg observations with the powerful combination of the STEREO and SDO missions. *I can hardly wait!*

But we also have to think farther ahead.

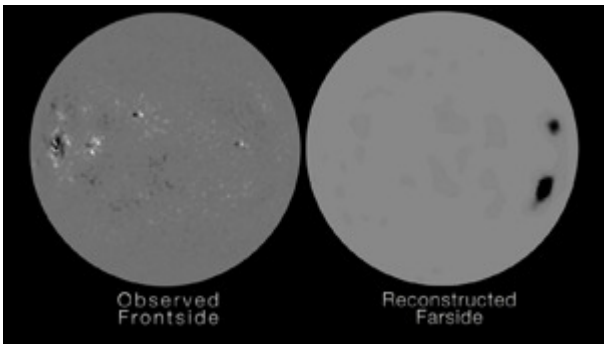
To Irene: 'But what will we do after we lose the capability to observe the far-side, Irene?'

Dr. Irene Gonzalez-Hernandez, National Solar Observatory
GONG/ NSO/NSF program scientist

Thanks Angelos!

For the last ten years we have been able to obtain limited information of the magnetic activity at the farside of the Sun by using a helioseismology technique. This technique is similar to the medical ultrasound scans that are used to image the interior of the human body. Basically, the Sun is oscillating continuously because of waves propagating in the solar interior and bouncing at the surface. Using instruments like HMI (Helioseismic and Magnetic Imager) on board of the Solar Dynamics Observatory and ground-based instruments like GONG (Global Oscillation Network Group) we can observe this wave oscillations at the surface of the Sun and compare them with a model. Deviations from the model give us information about features of interest, such as areas of strong magnetic field.

In particular, we can use this technique to calculate maps of active regions at the surface of the far-side of the Sun by observing the oscillations on the Sun's front-side.

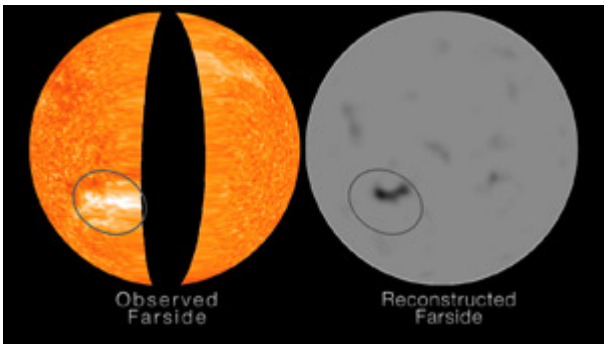


Video # 6 Active regions rotating from the observed front side of the Sun to the helioseismic reconstructed far-side and back again to the front side in October/November 2003. Large active regions were clearly visible in the helioseismic images. These particular ones were extremely active and produced the well known Halloween solar storms.
Credit: NASA/Goddard Space Flight Center/MDI/GONG/NSO/NSF/HMI
http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=15504&media_id=59574111

This video shows direct observations of the front-side magnetic field distribution and the far-side seismic reconstructions [both using MDI/SOHO data]
In this example, we can see three large active regions that appeared in 2003 rotating from the observed front-side of the Sun to the reconstructed far-side and back to the front-side. Because of the solar rotation, the active regions take approximately two week to cross the front side and get to the far side and the same time to come back.

As innovative as it has been, this helioseismic technique is limited to the detection of medium-large to very large-active regions, and you can observe in the reconstructed images that they have short-term noise due to other solar features as well as noise in the data and the analysis technique.

Direct observations of the far-side from STEREO are a huge improvement in terms of locating and following magnetic features of all sizes.



Video # 7 Farside direct observations from STEREO (left) and simultaneous helioseismic reconstructions (right). Medium to large size active regions clearly appear on the helioseismic images, however the smaller ones fall within the noise level. STEREO observations of the far-side will help calibrate and further improve the helioseismic technique. Credit: NASA/Goddard Space Flight Center/SECCHI/GONG/NSO/NSF/HMI
http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=15504&media_id=59575861

This video shows a comparison of the far-side direct chromospheric observations from STEREO and the simultaneous far-side helioseismic reconstructions. The images are from August-September 2010, before STEREO has the full view of the far-side. As you can see, the reconstructed view is able to follow the medium size active regions, however the smaller active regions fall within the noise level of these helioseismic images.

Having now the complete far-side view from Stereo give us the unprecedented opportunity to validate and improve the far-side seismic maps, so we can have continuation for space weather forecasting after the 8 years that STEREO will be observing the full far-side.

This is also a major milestone from the scientific point of view. Having both the STEREO direct observations and the helioseismic reconstructions provide us with a full picture of the magnetic field at the far-side from the photosphere and subsurface layers all the way to the corona. This is very exciting!

And now Bill will tell us how the full view of the Sun will improve Space Weather forecasting.

Mr. William Murtagh, NOAA Space Weather Prediction Center, Program Coordinator

The STEREO and SDO missions provide tremendous value to space weather operations. Space-based measurements have long provided critical measurements for space weather forecasters to alert and predict space weather storms. We have now evolved these observations to provide that full view of the Sun, an option once unheard of and indeed long desired by forecasters. Measurements from these satellites provide critical input in our efforts to meet the Nation's growing need for space weather products and services.

Visual # 8 The need for space weather services has grown significantly in past years as the technology we rely on for everyday life has become increasingly vulnerable to space weather. America's vulnerability to space weather is rising fast as our national and global critical technology infrastructure becomes more complex and dependent on advance technology. These recent advances in our technological infrastructure drive emerging space weather service needs undreamed of just a decade ago. Our advanced technological infrastructure will face challenges from the increase in solar activity and are being addressed at the highest levels of government. Credit: NOAA Space Weather Prediction Center

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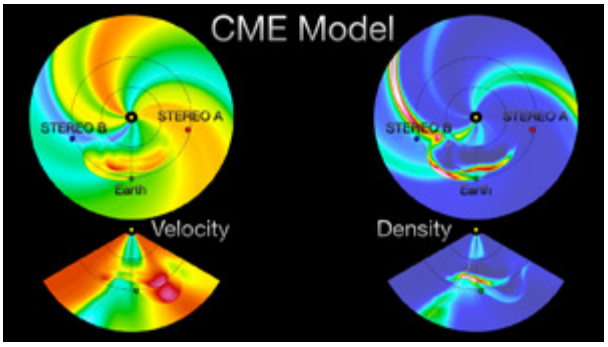
In response, NASA and NOAA are taking action to protect critical national infrastructure and ensure that the vital space weather measurements are available to meet the Nation's growing needs for space weather products.
We are currently in the rise phase of the next solar cycle. After a 4-year slumber, the Sun is now waking up and transitioning into a period of high activity where solar flares and coronal mass ejections become more frequent.

A National Academies report in January 2009 indicated that the greatest natural disaster perhaps facing the nation would be an intense geomagnetic storm. Space weather events can damage electrical grid equipment over wide geographic regions so that recovery delays become substantially longer and very costly. The academies report that the impact could be in the range of $1-2 trillion with recovery taking anywhere from 4 to ten years. That $1-2 trillion that it would take to recover amounts to nearly 50% of the 2010 Federal budget!

Airspace management needs are evolving and supporting the Next Generation Air transport System – Next Gen - is a priority in government and a hugely important initiative for our nation. NextGen is a transformation of the National Airspace System, including our national system of airports, using 21st century technologies to ensure future safety, capacity and environmental needs are met. It is our goal to provide the National Airspace System with a comprehensive weather picture in order to aid in fast and consistent decision making, enabling more effective utilization of available airspace resulting in fewer delays and re-routes. Space weather will be a key component to this decision support of NextGen.

NextGen is actually a great example of the evolving technology we are becoming more reliant on—technology that is increasingly vulnerable to space weather. NextGen will rely on the Automatic Dependent Surveillance Broadcast (ADS-B) which is GPS-based and is the future of air traffic control. Space weather events can cause GPS position errors, or even total loss of signal, both of which would render GPS useless to the aviation community.

Our lives and livelihoods depend on guaranteed access to advanced technologies, such as GPS, satellite communications, and a stable energy distribution network.



Video # 9 The critical observations from STEREO and SDO will help provide accurate and timely space weather storm warnings, and will aid greatly in our efforts to protect the technologies we have become so dependent in our daily activities. Measurements of coronal mass ejections from the STEREO spacecraft provide vital input for NOAA's space weather forecasters. Enlil is the first operational physics-based numerical space weather prediction model. Using STEREO input, the model computes the trajectory of solar storms between Sun and Earth, and provides forecasts of geomagnetic storms out to 96 hours. Credit: WSA-ENLIL Model: NOAA in partnership with AFW, AFRL (Nick Arge, WSA developer), George Mason University (Dusan Odstrcil, Enlil model developer), NASA, NSF, and NRL. http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=15504&media_id=59578031

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Through the use of STEREO and SDO, NASA and NOAA are working together in partnership, to ensure better space weather products and services, which will in turn result in new capabilities that have tangible benefits to so many critical segments of our national economy.

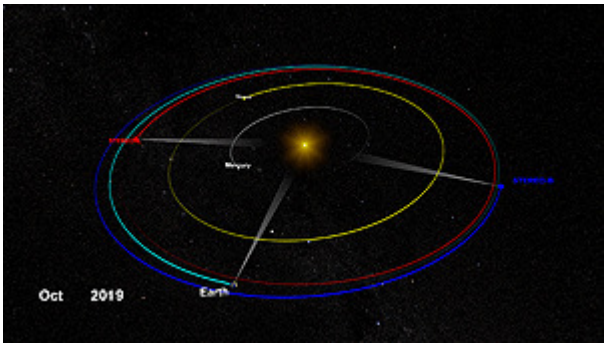
Dr. Terry Kucera, NASA Goddard Space Flight Center
Senior Deputy STEREO Project Scientist:

Conclusion

A little over 50 years ago the Luna-3 space probe returned the first images of the far side of the Moon. Now we are entering a new era in which we can see the far side of the *Sun*. We can observe *all* solar activity allowing us to understand and predict it better than ever before. We can watch the entire evolution of a solar active region and the full extent of huge sun spanning solar eruptions.

What's more, this is a key contribution to the study of space weather effects throughout the solar system. Whether we are studying aurora on Saturn, the CMEs at Mercury, or, of course, responses to solar activity here on Earth, STEREO will be working with NASA's fleet of Heliophysics spacecraft observing many different facets of our Sun and its effects on us and our solar system.

With these new observations we are now able to study the Sun and its influence on the solar system in a fully three dimensional way and we are very excited about what that will do for our understanding of solar activity and space weather.



Video # 10 The continuing orbits of the two STEREO spacecraft as they orbit on the far side of the Sun until 2019. Credit: NASA/Goddard Space Flight Center/Scientific Visualization Studio
http://www.nasa.gov/multimedia/videogallery/index.html?collection_id=15504&media_id=59582041

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