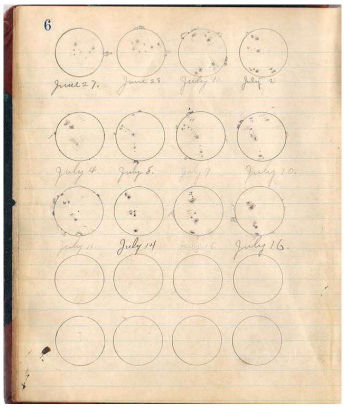
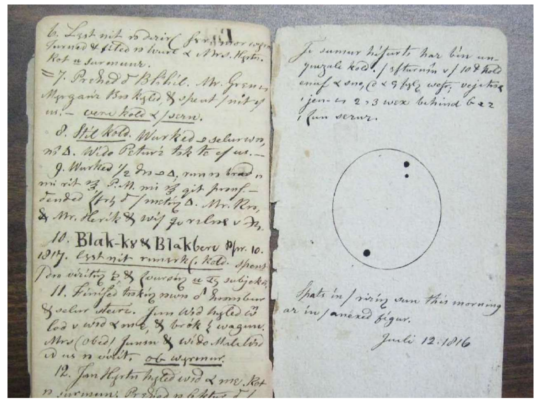
THE PAST, PRESENT AND FUTURE OF THE PARKER SOLAR PROBE

by John O'Neal, 2018

Way back in 1858 we didn't know a lot about the Sun. Solar Physics was still in it's infancy, but we were taking the first tentative steps in attempting to understand the Sun. People around the globe were watching the sun and observing it's features.

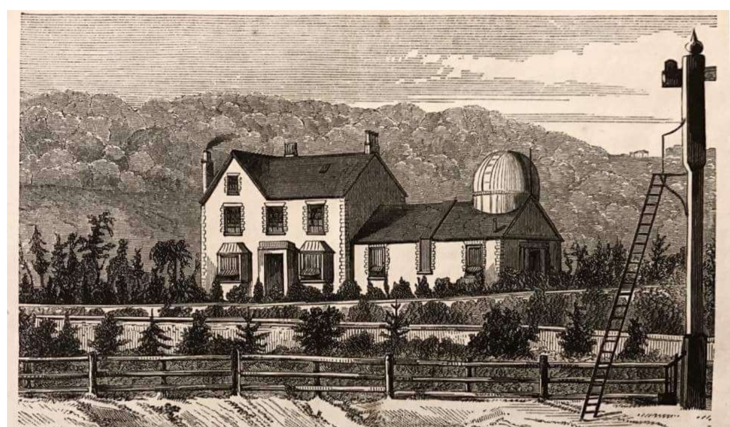




Sunspots were being studied and counted and it seemed like every country and astronomer had their own unique system for counting spots. Some forward thinking astronomers were in communication with each other and trying to develop classification systems for recording data in a systematic and standardized format to level the playing field, so sunspot data was uniform and could be shared amongst astronomers across social and political lines.

This engraving depicts the private observatory of the wealthy English amateur astronomer Richard C. Carrington (1826-1875). Attached to his country estate, Redhill Observatory was located just outside of London. This illustration is the title page picture of Carrington's 1857 book, "A Catalogue of 3,735 Circumpolar Stars Observed at Redhill in the Years 1854, 1855, and 1856...."

Carrington was an accomplished sunspot observer who determined that the sun rotates at different speeds depending on latitude.



Redhill Observatory from the South-East.

Carrington's REDHILL OBSERVATORY near London

But his most memorable observation occurred on September 1, 1859. His colleague, Richard Hodgson shared in history's first observation of a solar flare. On Thursday, September 1st, 1858, Richard C. Carrington, Esq. was observing the sun in his 4 1/2-inch Simms filtered white light refracting telescope. The Sun was projected onto a glass plate with an apparent diameter of about 12 inches.

Suddenly, two patches of intensely bright, white light broke out in the active region he was studying. Mr. Carrington at first thought his filter had failed and that direct unfiltered light was coming through. He moved the scope in RA and noted that the bright areas moved with the sun.

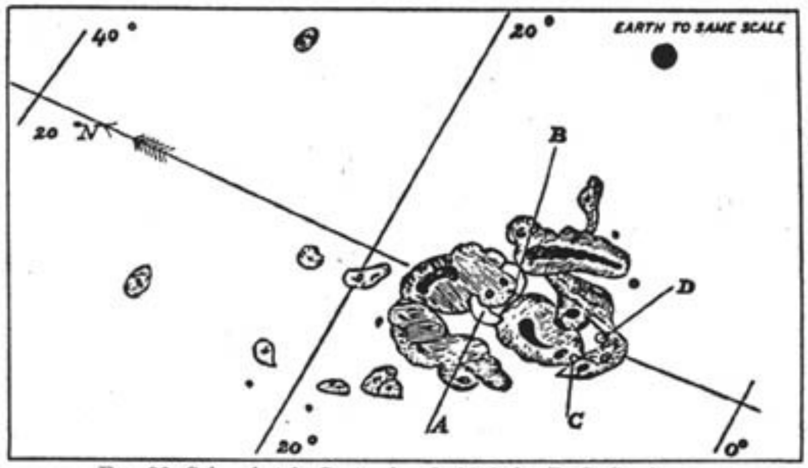


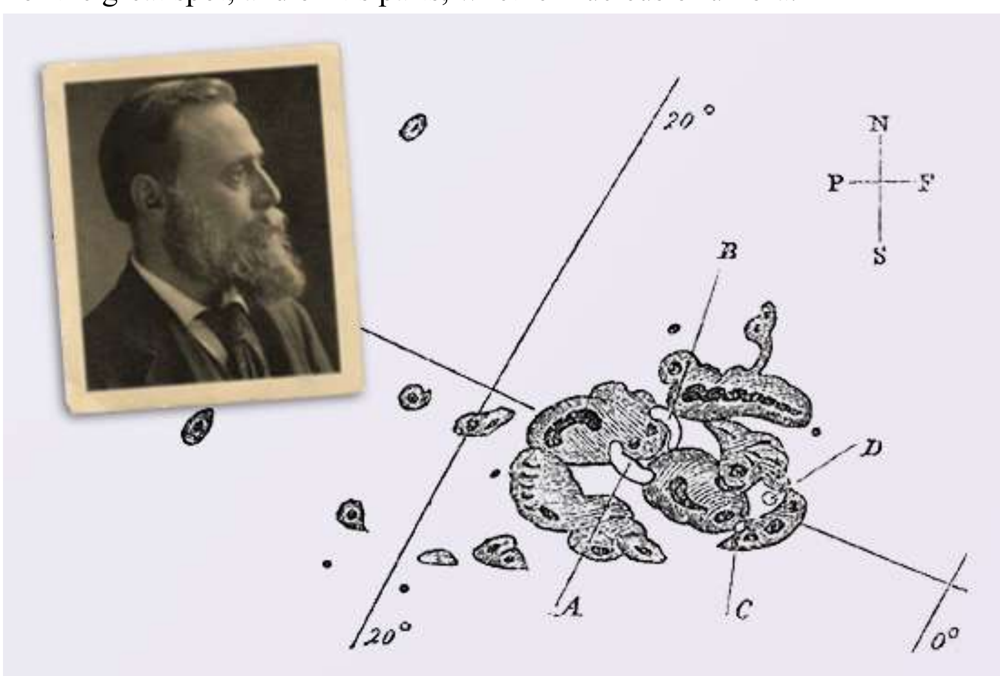
FIG. 36. Solar sketch, September 1, 1859, by R. C. Carrington

He recorded the time and ran to get another observer to confirm what he was seeing. He returned to the scope within 60 seconds, to find the flare greatly diminished and shortly thereafter all trace was gone.

The first trace of the flare was at 11h 18m and the last trace was recorded at 11h 23m GMT. So, in a mere 5 minutes the two patches of bright light traversed a space of about 35,000 miles

Mr. Carrington wrote that,

"The impression left upon me is, that the phenomenon took place at an elevation considerably above the general surface of the sun, and, accordingly, altogether above and over the great group in which it was seen projected. Both in figure and position the patches of light seemed entirely independent of the configuration of the great spot, and of it's parts, whether nucleus or umbra."

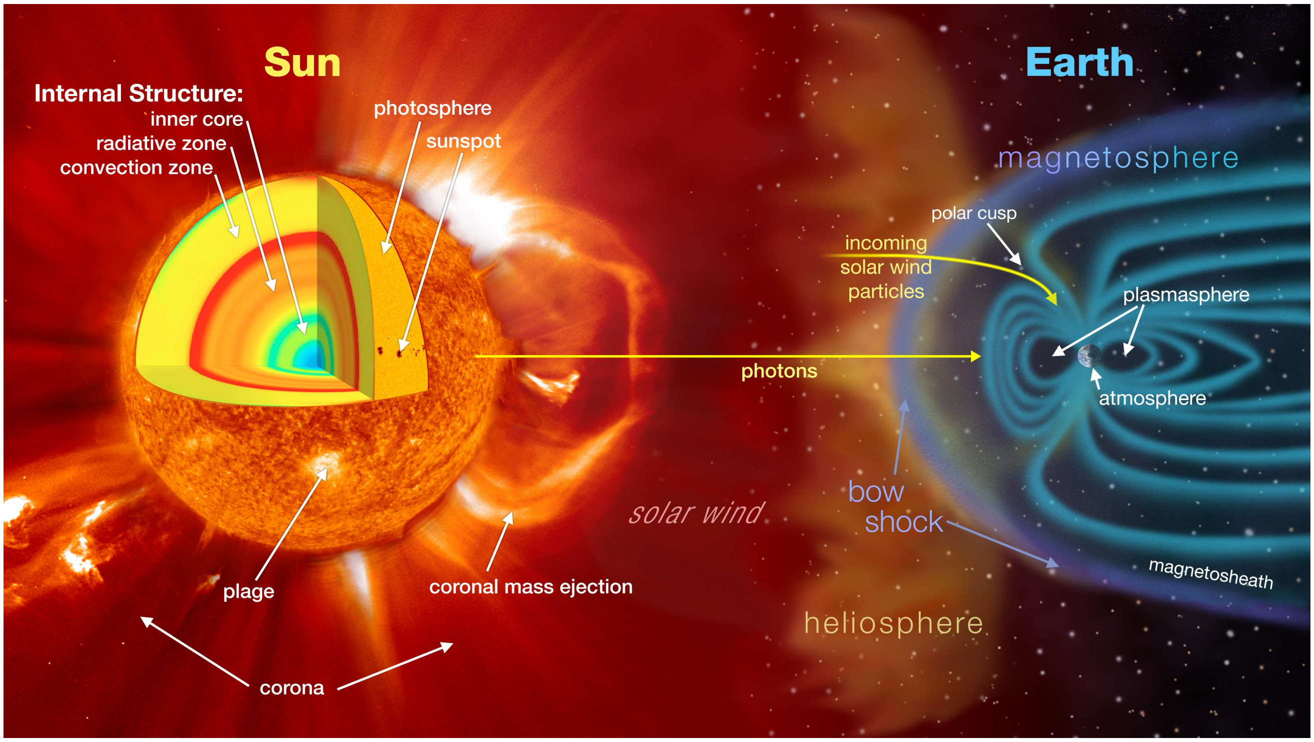


Mr. Carrington exhibited at the November Meeting of the Royal Astronomical Society with complete diagrams of the sun at the time of the flare. He also reported that at four hours after midnight there commenced a great magnetic storm, which subsequent accounts established to have been as considerable in the southern as in the northern hemisphere.

In 1859 our understanding of the sun was minimal.

We had no idea at that time that the chromosphere of the sun even existed. All solar astronomers could see was the photosphere, the layer of the sun where granulation and sunspots takes place.

No one had ever seen a solar flare before because they only exist, for the most part, in the unseen chromosphere. Observing flares in white light is an extremely rare occurrence.



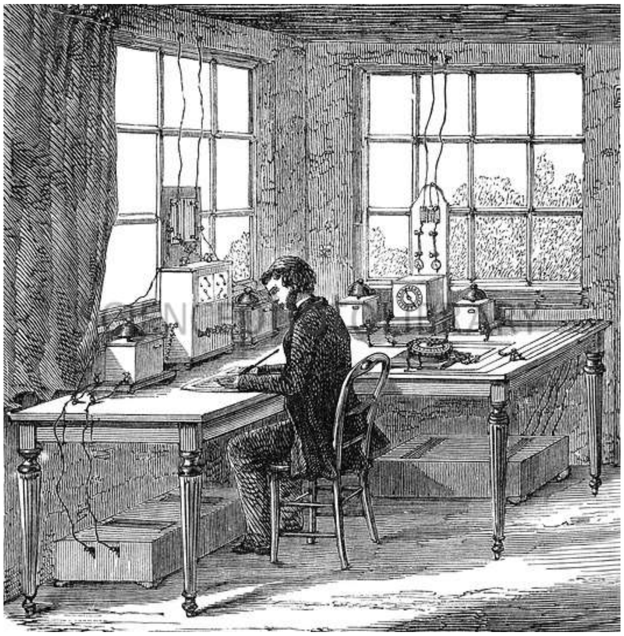
NASA Spaceweather illustration

So, for Carrington to say that it appeared that the flare emanated from a place above the chromosphere, and for him to surmise that the following aurora were somehow related, was a leap of faith, but a leap based on observation and an astute awareness of his subject matter, and arrived upon by the very same keen observational skills that led him to deduce that the sun rotated at differing speeds dependent on latitude.

The only real technology the existed in 1859 was the Morse or telegraph system for sending coded messages along wires to remote locations and to other population centers of the world.

There are considerable reports of damages to the system, with reports of wires and telegraph poles and stations burning down to telegraph operators getting mild shocks to fully electrocuted. Operators reported multi colored dancing aurora like wisps of color following the wires.

Telegraphy or Morse code works by transmitting a carrier wave and then interrupting the carrier in short or long bursts. These breaks in the carrier were interpreted on the other end as dots and dashes and skilled operators converted the bursts into their respective alpha numeric counterparts.



Many operators reported that they removed the batteries and that some mysterious power extant in the ether powered their equipment during the magnetic storm that followed the flare.

So, it takes no stretch of the imagination to extrapolate that an event such as this would play havoc in our globally wired and interconnected world of today.
The second important part of our story takes place in 1958.

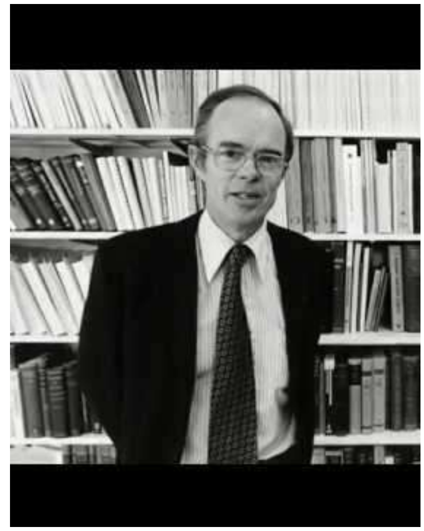
On October 24th, 1958 the National Academy of Sciences created the "Simpson's Committee" to study the sun and space-weather and it's effects on our modern electrical infrastructure.

Even with the very limited electrical grid of 1958 it was recognized that a large Carrington type event could be devastating. The committee recommended that we continue to study space-weather and that we send a probe to the sun.

Unfortunately, in 1958 the technology just didn't exist to undertake such a task. There were no computers. Radio technology was insufficient to communicate across such a large expanse and sending a rocket to the Sun, recording data, then retrieving the rocket was totally beyond our technological means at the time. We would need to wait for some major advances in technology to bear fruit before seriously considering pulling the trigger on a solar probe…

Also, in 1958 another part of our backstory was unfolding. There was a young physicist named Eugene Newman Parker, who proposed a number of concepts about how stars, including our sun gives off energy.

He called this cascade of energy the solar wind, and he described an entire complex system of plasmas, magnetic fields and energetic particles that make up this phenomenon. Parker also theorized an explanation for the super-heated solar corona, which is hotter than the surface of the sun itself, contrary to what was expected by the known laws of physics.



Much of his pioneering work, which has been proven by subsequent spacecraft, defined a great deal of what we know today about the how the Sun–Earth system interacts.

But at the time of publication in 1958 Mr. Parker's views were looked at by some as totally erroneous. Two of the editors who read his paper scoffed and refused to publish it and advised him to go to the library and read some books about the sun before submitting any more articles. Fortunately the third editor realized the importance of the paper and overrode the others and the paper was published. You can download and read a copy of this important document by googling the title in the graphic below.

DYNAMICS OF THE INTERPLANETARY GAS AND MAGNETIC FIELDS*

E. N. PARKER

Enrico Fermi Institute for Nuclear Studies, University of Chicago

Received January 2, 1958

ABSTRACT

We consider the dynamical consequences of Biermann's suggestion that gas is often streaming outward in all directions from the sun with velocities of the order of 500–1500 km/sec. These velocities of 500 km/sec and more and the interplanetary densities of 500 ions/cm^3 (10^{14} gm/sec mass loss from the sun) follow from the hydrodynamic equations for a 3×10^6 °K solar corona. It is suggested that the outward-streaming gas draws out the lines of force of the solar magnetic fields so that near the sun the field is very nearly in a radial direction. Plasma instabilities are expected to result in the thick shell of disordered field (10^{-5} gauss) inclosing the inner solar system, whose presence has already been inferred from cosmic-ray observations.

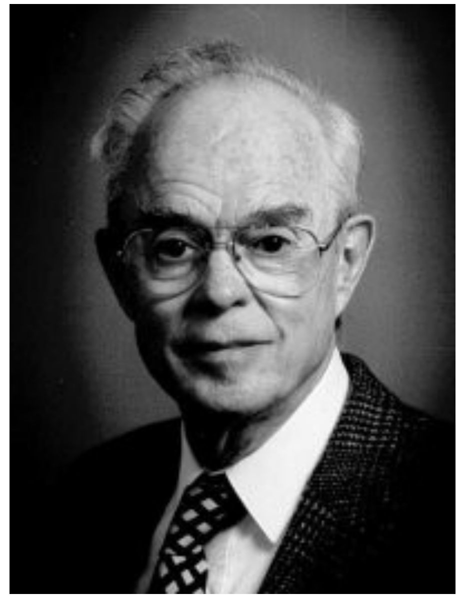
I. INTRODUCTION

Biermann (1951, 1952, 1957*a*) has pointed out that the observed motions of comet tails would seem to require gas streaming outward from the sun. He suggests that gas

Front Page of Dr Eugene Parker's Paper, published in 1958

I feel that Mr. Parker’s paper was important for two reasons...

First, for the science it contained. It was revolutionary in it’s time, it was controversial and as we said earlier it has withstood the scrutiny and testing of many other scientists over time and is still pertinent today.



And second, because it started a long overdue conversation. It opened up a door for communication and got people talking about solar wind and nanoflares and space weather and the like.

As a result, NASA has named the first mission to fly a spacecraft directly into the sun’s atmosphere in honor of Prof. Eugene Parker.

Mr.. Parker was honored May 31, 2017 at a public celebration on campus that included colleagues and students from U of Chicago and leaders from NASA and the Johns Hopkins University Applied Physics Laboratory.

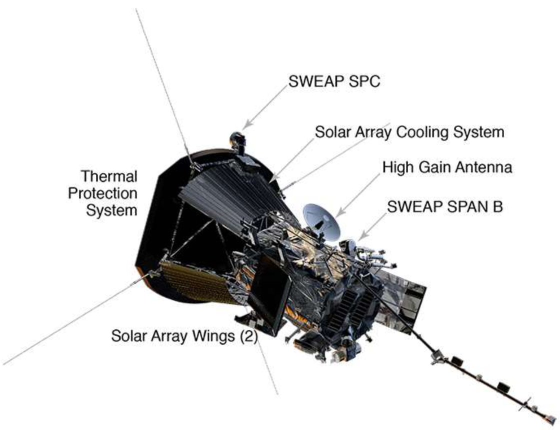
“This marks the first time a NASA spacecraft has been named for a living individual, and I am very excited to be personally involved,” said Thomas Zurbuchen, associate administrator for NASA’s Science Mission Directorate in Washington, D.C.

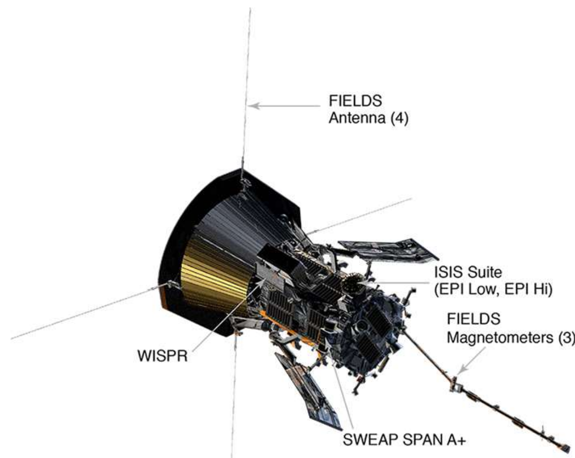
Zurbuchen also presented Parker with NASA’s distinguished public service medal, one of its highest honors

The solar probe cost NASA US$1.5 billion to build. While 1.5 billion dollars might seem a bit excessive at first blush, consider that damage estimates to our infrastructure from a current Carrington type event could exceed $15 TRILLION US Dollars and it could take as long as 2 decades to recover from the adverse effects of a Carrington type storm in the US alone.

Understanding the weather patterns on the sun and their effects on the Earth is the first step in building accurate and reliable space weather models and using them to predict adverse weather effects on the sun in time to prepare and to mitigate their effects here on Earth. Looking at the cost that way justifies the expenditure.

The Parker Solar Probe is a scientific and mechanical masterpiece of human innovation and design and will conduct experiments in one of the harshest environments we've ever sent a probe into. And, as an added bonus will further our knowledge of how all stars work and how stars and planets throughout the universe inter-react with each other.

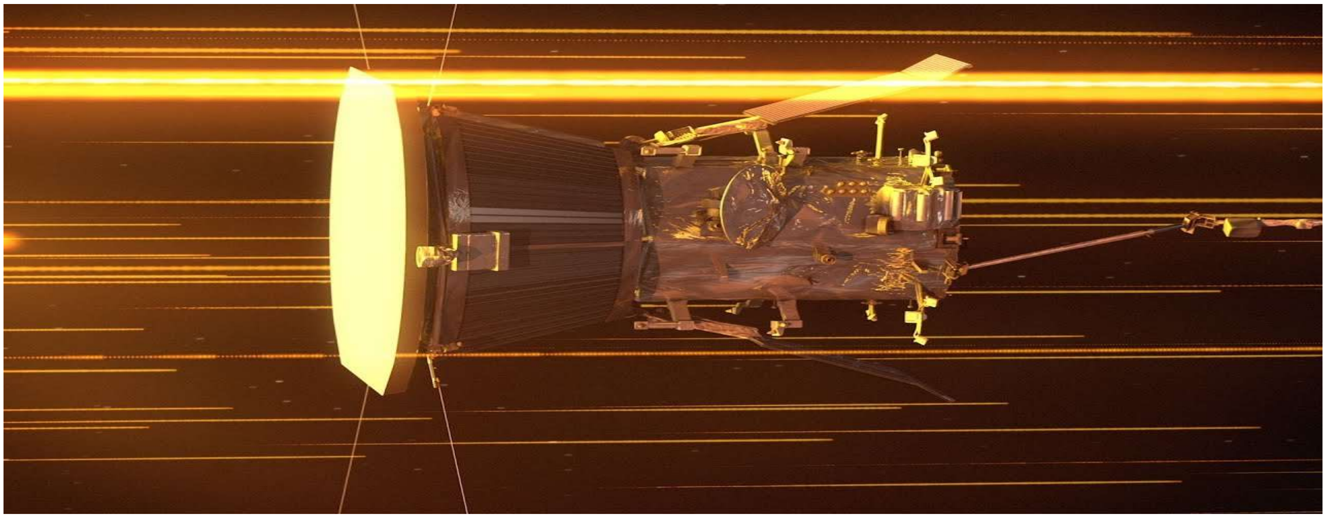




At closest approach, Parker Solar Probe will be hurtling around the sun at approximately 450,000 miles per hour! In a car it would take 2h 47m or 10,020 seconds to drive from Philadelphia to Washington, D.C. In an airplane it would take one hour or 3,600 seconds to fly from Philadelphia to Washington, D.C. 45,000 mph is fast enough to get the Parker Solar Probe from Philadelphia to Washington, D.C., in one second.

The physical size of the craft is similar to the van that Scooby Do and his cohorts puttered around the country in during their Saturday morning adventures in cartoon land.

At closest approach to the sun, while the front of Parker Solar Probe' solar shield faces temperatures approaching 1,400° Celsius,the spacecraft's payload will be near room temperature. 1,400° Celsius = 2,252° Fahrenheit at which point copper wires and their plastic insulation & solder connections all melt.



The eight-foot-diameter heat shield will safeguard everything within its umbra, the shadow it casts on the spacecraft. At Parker Solar Probe's closest approach to the Sun, temperatures on the heat shield will reach nearly 2,500 degrees Fahrenheit, but the spacecraft and its instruments will be kept at a relatively comfortable temperature of about 85 degrees Fahrenheit.

The heat shield is made of two panels of superheated carbon-carbon composite sandwiching a lightweight 4.5-inch-thick carbon foam core. The Sun-facing side of the heat shield is also sprayed with a specially formulated white coating to reflect as much of the Sun's energy away from the spacecraft as possible. The heat shield itself weighs only about 160 pounds — here on Earth, the foam core is 97 percent air.

Dorothy O'Neal and I and our close friends, Pamela and Randy Shivak were afforded a unique opportunity to view the launch from the Banana Creek Launch Viewing Site. We were given passes to the Kennedy Space Center, and we were permitted to attend the Press Briefings held daily before the launch.

We were able to hear the late breaking news and updates on launch progress. We didn't get an opportunity to sit down and talk with our heroes, but it was great to be in the same room and see Dr. Nikki Fox and Dr. Eugene Parker and other prominent NASA officials.

We owe a debt of gratitude to our friend, David Wexler, who played a significant role in facilitating our acquisition of the launch passes. David got the tickets from the SHINE (Solar Heliospheric and Interplanetary Environment) conference for grad students and professionals, who arranged this special treat with NASA.

So, after traveling to Cape Canaveral, Florida with Harvey the RV in tow we arrived 2 days before the launch and setup camp at Jetty Park Campground.

We spent the next two days viewing the Space Center, taking bus tours and press briefings, and visiting the local tourist traps in the area. And finally we went back to the Space Centar at Midnight to board buses for our exclusive trip to the launch site.

I thought we were going to be 3 miles from the launch site so I brought along a 300mm lens to shoot the launch. But, alas, upon arrival & much to my chagrin I was informed that we were actually 8.5 miles from the launch pad.

The rocket was a tiny speck on the launch pad at such a far distance. And then, after waiting there until ~3:29am, with 1:58 seconds left on the countdown clock the launch was scrubbed.

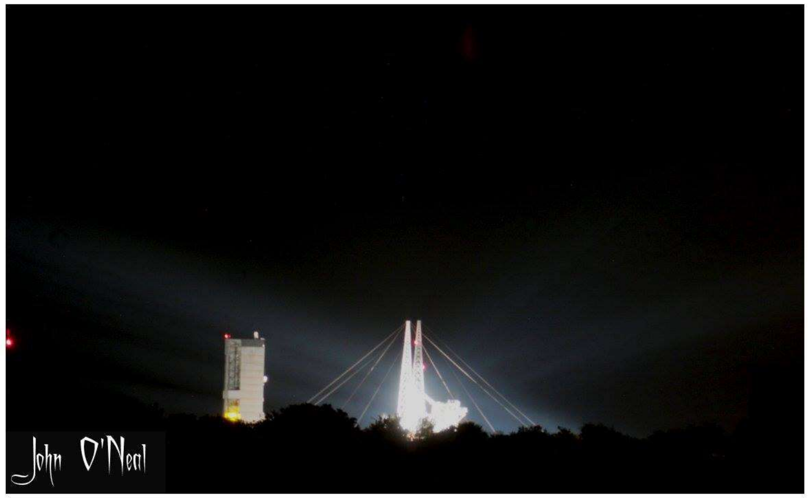
I was tired and exhausted, but vowed to return with much more magnification on the next attempt.

And so it was, at midnight, the following night, August 12th, 2018 we returned to Kennedy Space Center and dutifully boarded our bus, but this time I left the 300mm lens at home and brought along my Meade ETX80 at 1,250mm focal length. Much better!!!!

Now the rocket was much than a speck on the horizon. I could even see the guy wires and lightning protection towers.

And that morning at 3:31am on August 12th, 2018 we witnessed the shock & awe of a ULA Delta IV Heavy lifting the Parker Solar Probe on the first airborne part of it's journey to touch our closest star, the Sun.

I captured 3 still images with this camera and lens of the liftoff sequence.



I also brought along a Canon 40D with a Samyung 8mm Fisheye lens to attempt a “Streak” image.

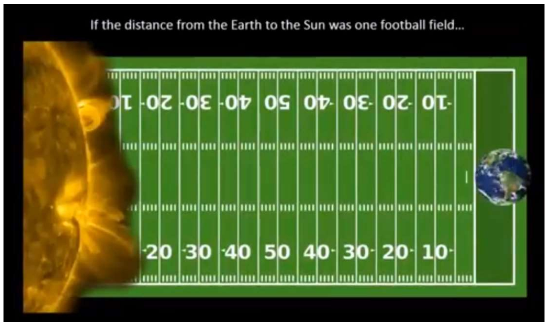
I had done my due diligence before leaving home and had read about how to shoot streak images, but everything I studied was from people shooting at a 3 mile distance or closer. At triple that distance I would be seeing much more sky and a lot less rocket, so I knew my exposure parameters were going to change dramatically.

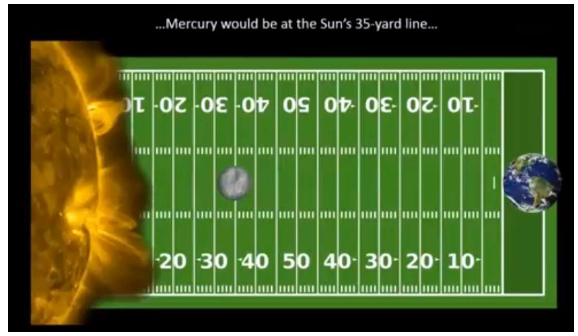
I practiced taking photos the night before at different setting and after several trial images determined that I should shoot 5 minute exposures at f/20 using an ISO 100 setting. This kept the sky dark, while allowing a bright streak while keeping the streak and lights in the background from blooming.

I was upset about the clouds during the launch, but after seeing the result and the breaks in the streak, I’m not so upset after all. I think it provides a dramatic effect to the image.

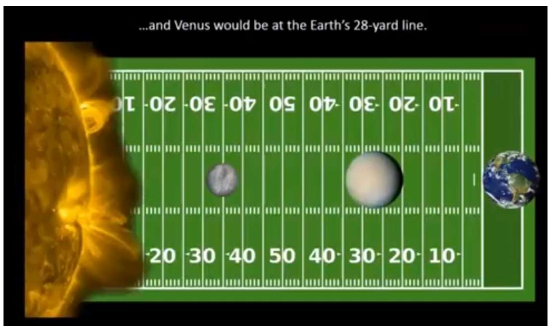
You can clearly see the rocket leave the pad, pass through several cloud bands, reach altitude and start moving down range in this image.

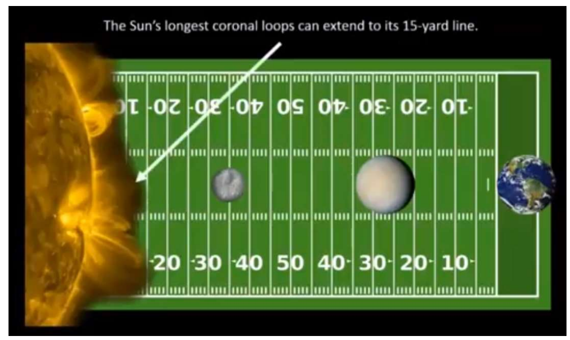
We all know that the sun is at the center of the solar system, that Mercury is 33m miles from the Sun, Venus is 66m miles and the Earth is 93 m miles.





Let's round off these numbers and relate them to yards on a football field.



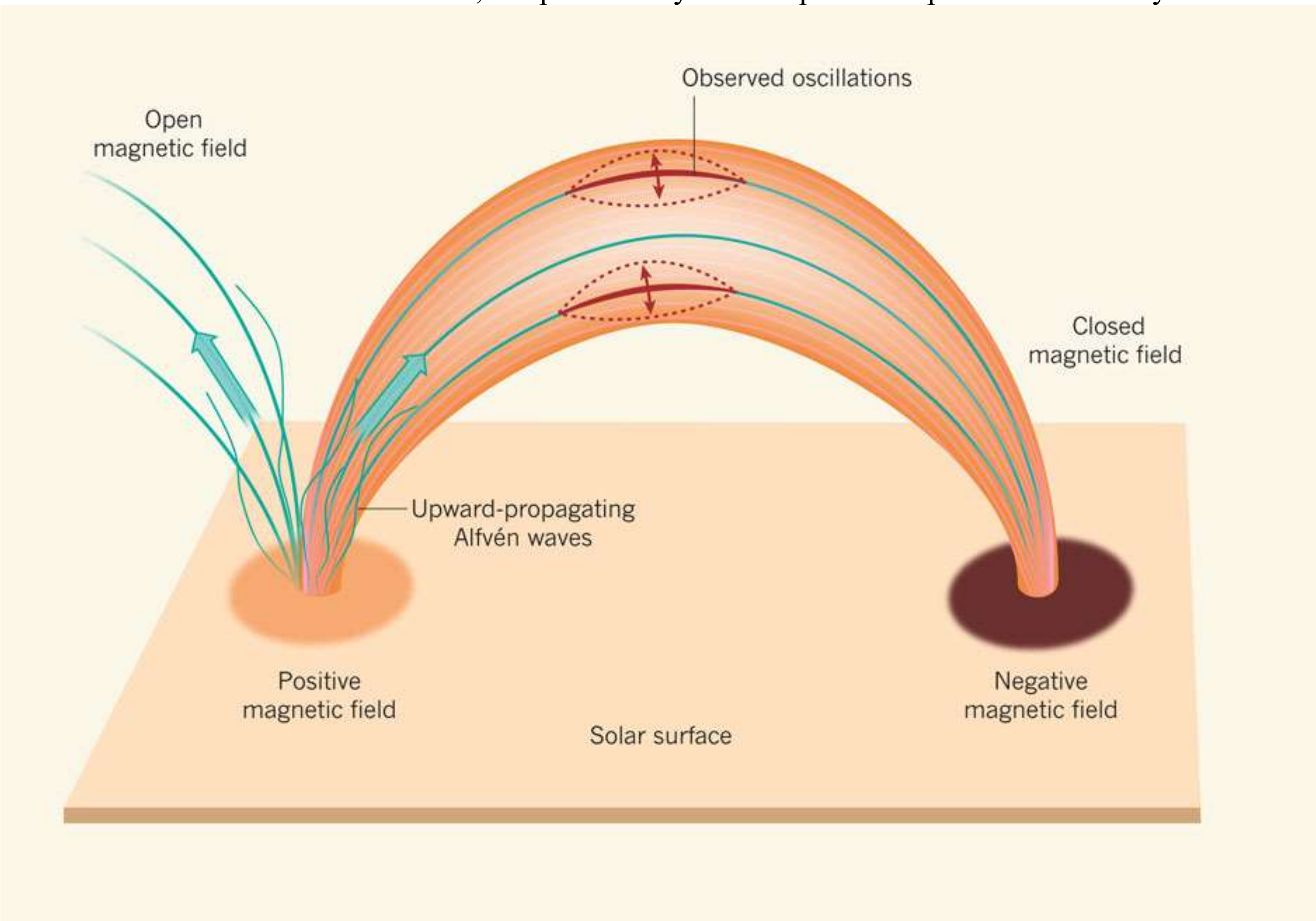


That would put the Sun's surface on the Zero yard line, Mercury on the 33 yard line, Venus on the 66 yard line and The Earth on the 100 yard line.

The closest we have ever been to the sun is on the 29 yard line with the Helios 2 probe. The Solar Chromosphere that we want to study only extends outward to the 15 yard line.

The Parker Solar Probe will study the atmosphere by flying right through it on the 4 yard line in our example.

The Parker Solar Probe will be the first mission to ever pass the ALFVEN POINT. Within this boundary, Alfven Waves, oscillations of charged particles and the magnetic field lines they travel along, tie the solar wind to the sun's surface, but particle beyond this point escape into the solar system.



Imagine a guitar string being plucked. The diameter, length and tension of the string determines the frequency at which it vibrates. Alfven waves travel along the Alfen point's "string" and are propelled by the diamater, length and tension of the magnetic force within.

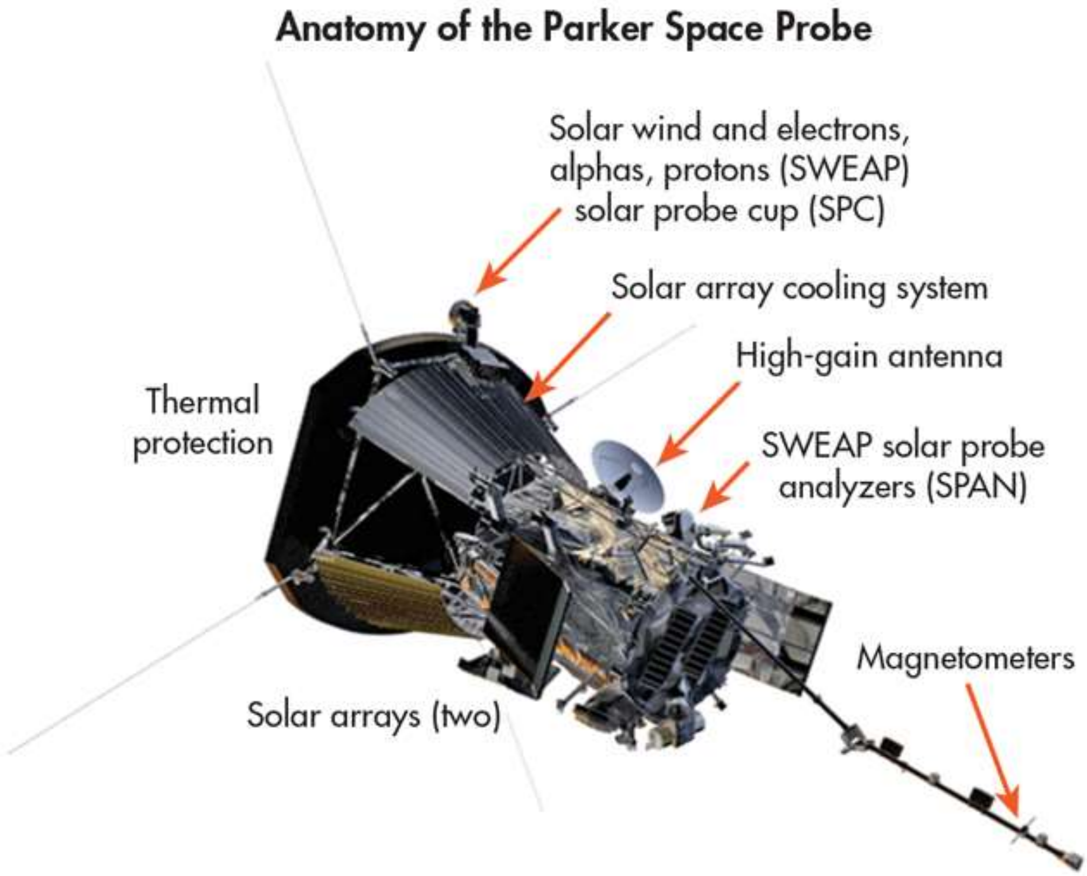
So, being inside the Alfven point is going to offer unheralded opportunities to study Alfven waves up close and personal and learn exactly how these mysterious waves move plasma around and perhaps even tell us what role they may play in heating the solar corona.

The Parker Solar Probe has three detailed science objectives:

Trace the flow of energy that heats and accelerates the solar corona and solar wind.

Determine the structure and dynamics of the plasma and magnetic fields at the sources of the solar wind.

Explore mechanisms that accelerate and transport energetic particles.



There is a fleet of instruments uniquely constructed to perform these scientific experiments. Each instrument compliments the other three to enhance the data and reinforce the others.
Just over a month into its mission, Parker Solar Probe has returned first-light data from each of its four instrument suites. These early observations – while not yet examples of the key science observations Parker Solar Probe will take closer to the Sun – show that each of the instruments is working well.

The instruments work in tandem to measure the Sun's electric and magnetic fields, particles from the Sun and the solar wind, and capture images of the environment around the spacecraft.

"All instruments returned data that not only serves for calibration, but also captures glimpses of what we expect them to measure near the Sun to solve the mysteries of the solar atmosphere, the corona," said Nour Raouafi, Parker Solar Probe project scientist at the Johns Hopkins University Applied Physics Lab in Laurel, Maryland.

The mission's first close approach to the Sun will be in November 2018, but even now, the instruments are able to gather measurements of what's happening in the solar wind closer to Earth.

Let's take a brief look at each of the four instrument suites...

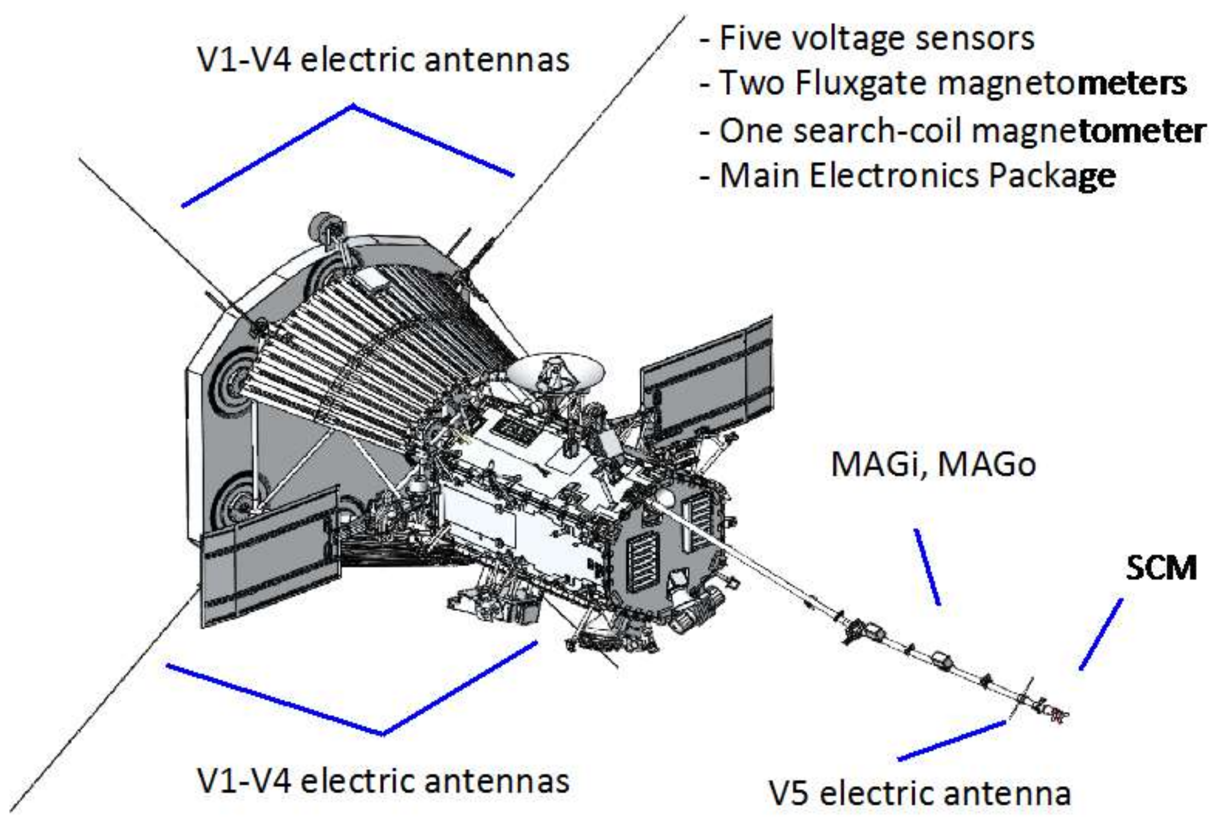
FIELDS

The FIELDS instrument suite aboard Parker Solar Probe captures the scale and shape of electric and magnetic fields in the Sun's atmosphere. These are key measurements to understanding why the Sun's corona is hundreds of times hotter than its surface below.

FIELDS' sensors include four two-meter electric field antennas — mounted at the front of the spacecraft, extending beyond the heat shield and exposed to the full brunt of the solar environment — as well as three magnetometers and a fifth, shorter electric field antenna mounted on a boom that extends from the back of the spacecraft.

Data gathered during the boom deployment measured a sharp drop in the magnetic field as the boom extended away from the spacecraft — illustrating the very reason such sensors need to be held out far from the spacecraft.

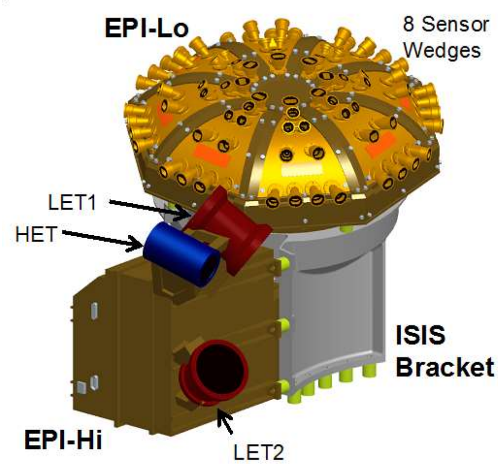
In early September, the four electric field antennas on the front of the spacecraft were successfully deployed — and almost immediately observed the signatures of a solar flare.
"FIELDS is one of the most comprehensive fields and waves suites ever flown in space, and it is performing beautifully," said principal investigator Stuart Bale, of the Space Sciences Laboratory at the University of California, Berkeley.



ISʘIS (pronounced "ee-sis" and including the symbol for the Sun in its acronym) measures high-energy particles associated with solar activity like flares and coronal mass ejections.

ISʘIS' two Energetic Particle Instruments cover a range of energies for these activity-driven particles: EPI-Lo focuses on the lower end of the energy spectrum, while EPI-Hi measures the more energetic particles. Both instruments have gathered data under low voltage, making sure their detectors work as expected. As Parker Solar Probe approaches the Sun, they will be fully powered on to measure particles within the Sun's corona.

EPI-Lo's initial data, shows background cosmic rays, particles that were energized and came rocketing into our solar system from elsewhere in the galaxy. As EPI-Lo's high voltage is turned on and Parker Solar Probe gets closer to the Sun, the particles measured will shift toward solar energetic particles, which are accelerated in bursts and come streaming out from the Sun and corona.

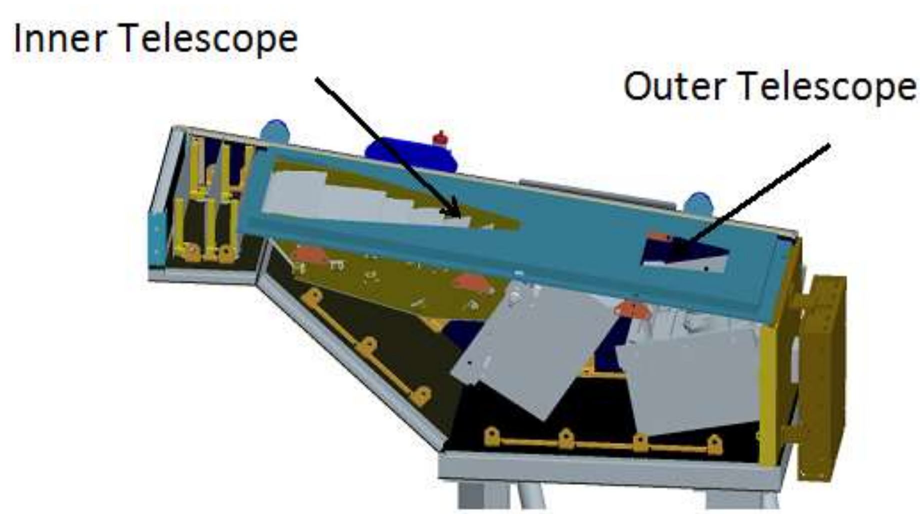


Data from EPI-Hi shows detections of both hydrogen and helium particles. Nearer to the Sun, scientists expect to see many more of these particles — along with heavier elements — as well as some particles with much higher energies, especially during solar energetic particle events.

"The ISʘIS team is delighted with instrument turn-on so far," said David McComas, Professor of Astrophysical Sciences at Princeton University and principal investigator of the ISʘIS instrument suite. "There are a few more steps to go, but so far everything looks great!"

WISPR (Wide-field Imager for Solar Probe)

As the only imager on Parker Solar Probe, WISPR will provide the clearest-yet glimpse of the solar wind from within the Sun's corona. Comprising two telescopes, WISPR sits behind the heat shield between two antennae from the FIELDS instrument suite. The telescopes were covered by a protective door during launch to keep them safe.



WISPR was turned on in early September 2018 and took closed-door test images for calibration. On Sept. 9, WISPR's door was opened, allowing the instrument to take the first images during its journey to the Sun.

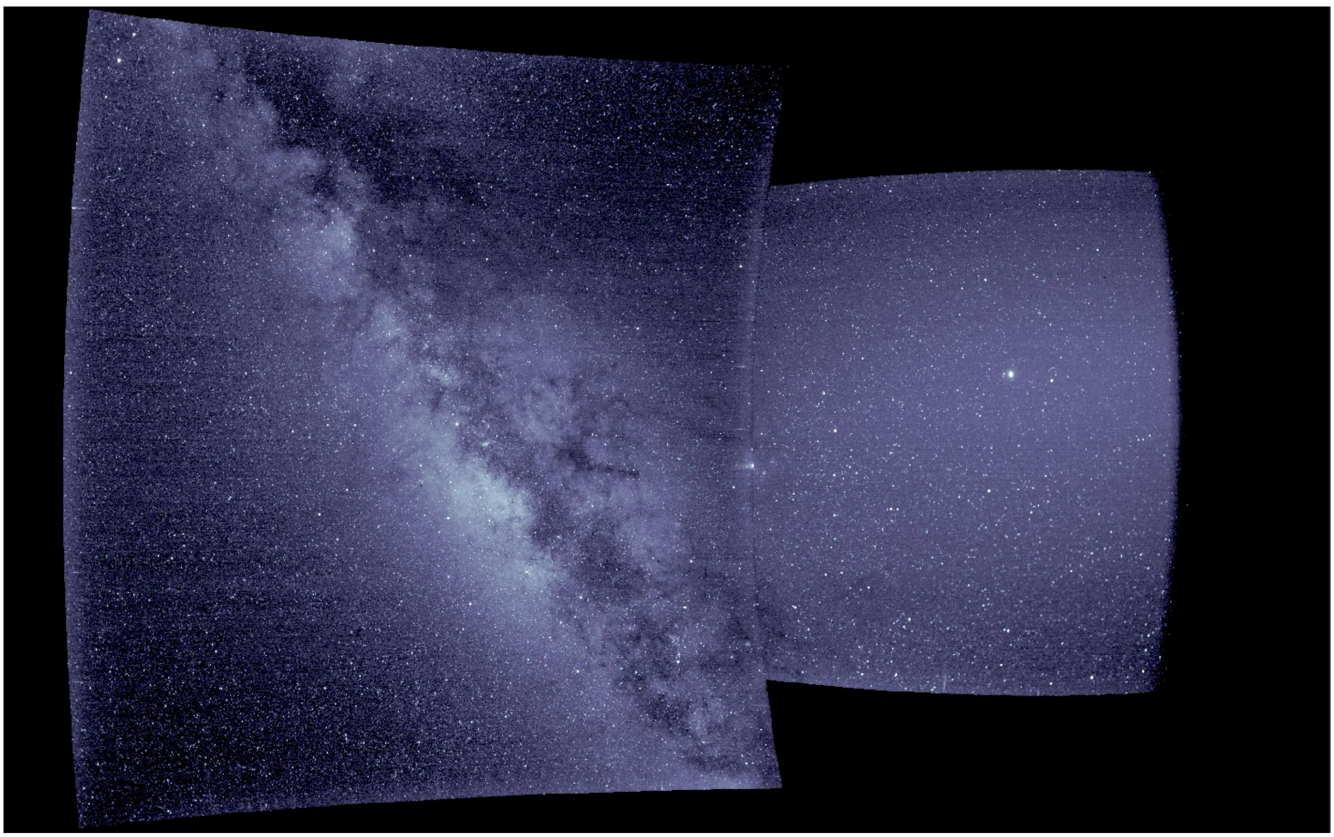
The right side of this image — from WISPR's inner telescope — has a 40-degree field of view, with its right edge 58.5 degrees from the Sun's center.

The left side of the image is from WISPR's outer telescope, which has a 58-degree field of view and extends to about 160 degrees from the Sun.

There is a parallax of about 13 degrees in the apparent position of the Sun as viewed from Earth and from Parker Solar Probe.

Russ Howard, WISPR principal investigator from the Naval Research Laboratory, studied the images to determine the instrument was pointing as expected, using celestial landmarks as a guide.

"There is a very distinctive cluster of stars on the overlap of the two images. The brightest is the star Antares-alpha, which is in the constellation Scorpius and is about 90 degrees from the Sun," said Howard.



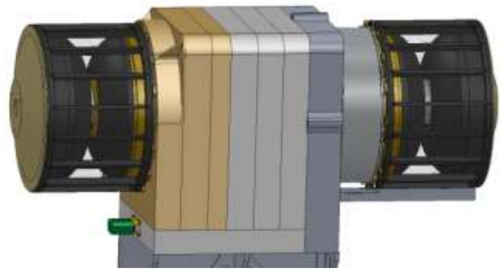
The Sun, not visible in the image, is far off to the right of the image's right edge. The planet Jupiter is visible in the image captured by WISPR's inner telescope — it's the bright object slightly right of center in the right-hand panel of the image.

"The left side of the photo shows a beautiful image of the Milky Way, looking at the galactic center," said Howard.

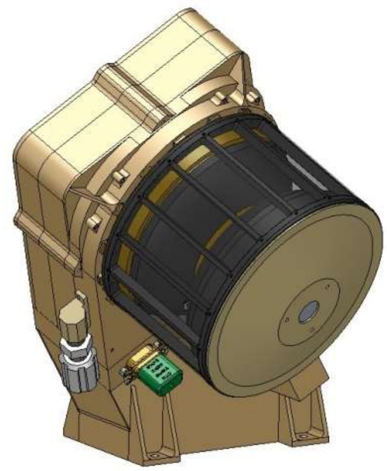
As the spacecraft approaches the Sun, its orientation will change, and so will WISPR's images. With each solar orbit, WISPR will capture images of the structures flowing out from the corona.

SWEAP (Solar Wind Electrons Alphas and Protons)

The SWEAP suite includes three instruments: Two Solar Probe Analyzers measure electrons and ions in the solar wind, while the Solar Probe Cup sticks out from behind Parker Solar Probe’s heat shield to measure the solar wind directly as it streams off the Sun. After opening covers, turning on high voltages and running internal diagnostics, all three instruments caught glimpses of the solar wind itself.



Because of Parker Solar Probe’s position and orientation, the science team expected that Solar Probe Cup would mostly measure background noise at first, without picking up the solar wind. But just after the instrument was powered on, a sudden, intense gust of solar wind blew into the cup. As the spacecraft approaches the Sun, such observations will be Solar Probe Cup’s bread and butter — and will hopefully reveal new information about the processes that heat and accelerate the solar wind.



The two Solar Probe Analyzers (SPAN) also caught early peeks of the solar wind. During commissioning, the team turned the spacecraft so that SPAN-A — one of the two SPAN instruments — was exposed to the solar wind directly. It captured about 20 minutes’ worth of data, including measurements of solar wind ions and electrons .

“SWEAP’s solar wind and corona plasma instrument performance has been very promising,” said Justin Kasper, principal investigator of the SWEAP instrument suite at University of Michigan. “Our preliminary results just after turn-on suggest we have a set of highly sensitive instruments that will allow us to do amazing science close to the Sun.”

The Solar Probe Cup sticks out from behind Parker Solar Probe’s heat shield to measure the solar wind directly as it streams off the Sun.

This brave little sensor is NOT be protected by the Solar Shield. He will be buffeted by everything the sun can throw at it. Energetic particles charged electrons & ions and superheated plasma will all assault this sensor. It will feel the force of Coronal Mass Ejections and will bear the brunt of the Solar wind.
To complete the science objectives and it’s mission, the Parker Solar Probe will make 7 Venus fly-by’s and 24 orbits around the sun over the course of 6 years and 11 months.

VENUS FLYBY & PEREHELION SCHEDULE **2018** September 28, 2018: Venus Flyby #1 November 1, 2018: Perihelion #1 **2019** March 31, 2019: Perihelion #2 August 28, 2019: Perihelion #3 December 22, 2019: Venus Flyby #2 **2020** January 24, 2020: Perihelion #4 June 2, 2020: Perihelion #5 July 6, 2020: Venus Flyby #3 September 22, 2020: Perihelion #6 **2021** January 13, 2021: Perihelion #7 February 16, 2021: Venus Flyby #4 April 24, 2021: Perihelion #8 August 5, 2021: Perihelion #9 October 11, 2021: Venus Flyby #5 November 16, 2021: Perihelion #10	**2022** February 21, 2022: Perihelion #11 May 28, 2022: Perihelion #12 September 1, 2022: Perihelion #13 December 6, 2022: Perihelion #14 **2023** March 13, 2023: Perihelion #15 June 17, 2023: Perihelion #16 August 16, 2023: Venus Flyby #6 September 23, 2023: Perihelion #17 December 24, 2023: Perihelion #18 **2024** March 25, 2024: Perihelion #19 June 25, 2024: Perihelion #20 September 25, 224: Perihelion #21 November 2, 2024: Venus Flyby #7 December 19, 2024: Perihelion #22 First Close Approach **2025** March 18, 2025: Perihelion #23 June 14, 2025: Perihelion #24

But then what?
Is the mission over?

Fortunately the craft is designed with built in Artificial Intelligence and can make course corrections and maintain it's course over the years. So long as fuel holds out the Parker Solar Probe will continue to correct it's orbit and continue to gather data.

To learn more about the PARKER SOLAR PROBE follow these links…

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