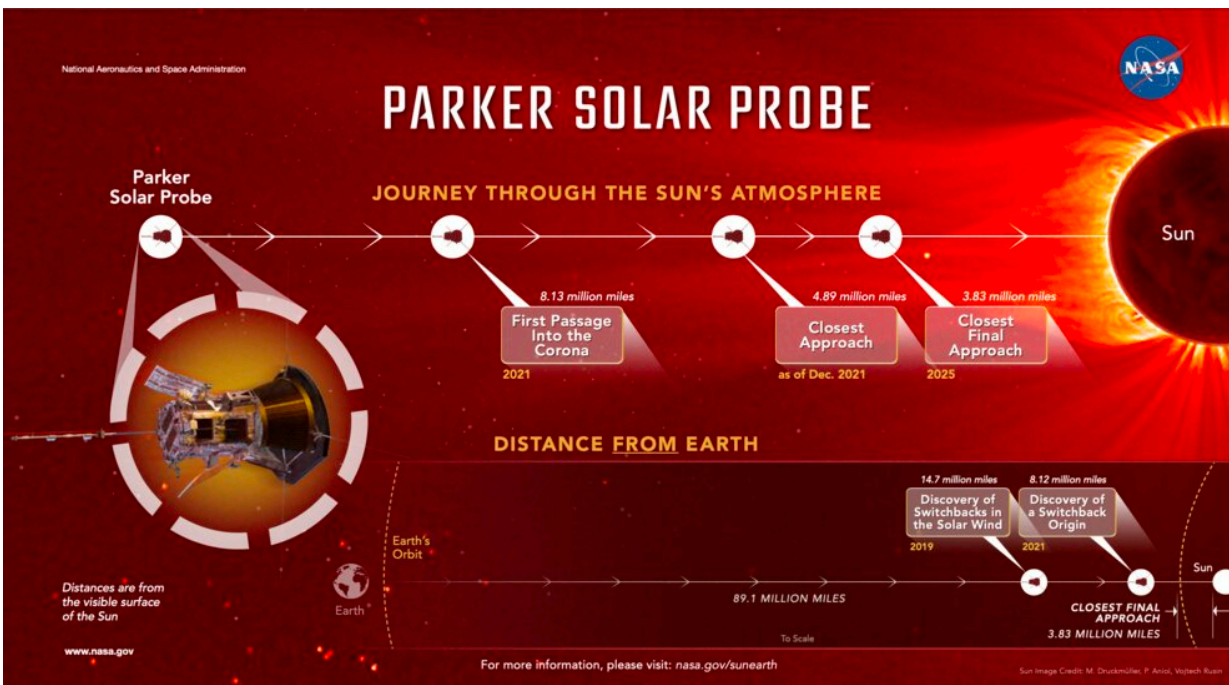


NASA enters the solar atmosphere for the first time, bringing new discoveries

December 14 2021, by Mara Johnson-Groh



As Parker Solar Probe ventures closer to the Sun, it's crossing into uncharted regimes and making new discoveries. This image represents Parker Solar Probe's distances from the Sun for some of these milestones and discoveries. Credit: NASA's Goddard Space Flight Center/Mary P. Hrybyk-Keith

For the first time in history, a spacecraft has touched the Sun. NASA's Parker Solar Probe has now flown through the Sun's upper atmosphere—the corona—and sampled particles and magnetic fields

there.

The new milestone marks one major step for Parker Solar Probe and one giant leap for solar science. Just as landing on the Moon allowed scientists to understand how it was formed, touching the very stuff the Sun is made of will help scientists uncover critical information about our closest star and its influence on the solar system.

"Parker Solar Probe "touching the Sun" is a monumental moment for solar science and a truly remarkable feat," said Thomas Zurbuchen, the associate administrator for the Science Mission Directorate at NASA Headquarters in Washington. "Not only does this milestone provide us with deeper insights into our Sun's evolution and its impacts on our solar system, but everything we learn about our own star also teaches us more about stars in the rest of the universe."

As it circles closer to the solar [surface](#), Parker is making new discoveries that other spacecraft were too far away to see, including from within the solar wind—the flow of particles from the Sun that can influence us at Earth. In 2019, Parker discovered that magnetic zig-zag structures in the solar wind, called switchbacks, are plentiful close to the Sun. But how and where they form remained a mystery. Halving the distance to the Sun since then, Parker Solar Probe has now passed close enough to identify one place where they originate: the solar surface.

The first passage through the corona—and the promise of more flybys to come—will continue to provide data on phenomena that are impossible to study from afar.

"Flying so close to the Sun, Parker Solar Probe now senses conditions in the magnetically dominated layer of the solar atmosphere—the corona—that we never could before," said Nour Raouafi, the Parker project scientist at the Johns Hopkins Applied Physics Laboratory in

Laurel, Maryland. "We see evidence of being in the corona in [magnetic field](#) data, solar wind data, and visually in images. We can actually see the spacecraft flying through coronal structures that can be observed during a total solar eclipse."

Closer Than Ever Before

Parker Solar Probe launched in 2018 to explore the mysteries of the Sun by traveling closer to it than any spacecraft before. Three years after launch and decades after first conception, Parker has finally arrived.

Unlike Earth, the Sun doesn't have a solid surface. But it does have a superheated atmosphere, made of solar material bound to the Sun by gravity and magnetic forces. As rising heat and pressure push that material away from the Sun, it reaches a point where gravity and magnetic fields are too weak to contain it.

That point, known as the Alfvén critical surface, marks the end of the solar atmosphere and beginning of the solar wind. Solar material with the energy to make it across that boundary becomes the solar wind, which drags the magnetic field of the Sun with it as it races across the [solar system](#), to Earth and beyond. Importantly, beyond the Alfvén critical surface, the solar wind moves so fast that waves within the wind cannot ever travel fast enough to make it back to the Sun—severing their connection.

Until now, researchers were unsure exactly where the Alfvén critical surface lay. Based on remote images of the corona, estimates had put it somewhere between 10 to 20 solar radii from the surface of the Sun—4.3 to 8.6 million miles. Parker's spiral trajectory brings it slowly closer to the Sun and during the last few passes, the spacecraft was consistently below 20 solar radii (91 percent of Earth's distance from the Sun), putting it in the position to cross the boundary—if the estimates

were correct.

On April 28, 2021, during its eighth flyby of the Sun, Parker Solar Probe encountered the specific magnetic and particle conditions at 18.8 solar radii (around 8.1 million miles) above the solar surface that told scientists it had crossed the Alfvén critical surface for the first time and finally entered the solar atmosphere.

"We were fully expecting that, sooner or later, we would encounter the corona for at least a short duration of time," said Justin Kasper, lead author on a [new paper](#) about the milestone published in *Physical Review Letters*, and deputy chief technology officer at BWX Technologies, Inc. and University of Michigan professor. "But it is very exciting that we've already reached it."

Into the Eye of the Storm

During the flyby, Parker Solar Probe passed into and out of the corona several times. This is proved what some had predicted—that the Alfvén critical surface isn't shaped like a smooth ball. Rather, it has spikes and valleys that wrinkle the surface. Discovering where these protrusions line up with solar activity coming from the surface can help scientists learn how events on the Sun affect the atmosphere and solar wind.

At one point, as Parker Solar Probe dipped to just beneath 15 solar radii (around 6.5 million miles) from the Sun's surface, it transited a feature in the corona called a pseudostreamer. Pseudostreamers are massive structures that rise above the Sun's surface and can be seen from Earth during solar eclipses.

Passing through the pseudostreamer was like flying into the eye of a storm. Inside the pseudostreamer, the conditions quieted, particles slowed, and number of switchbacks dropped—a dramatic change from

the busy barrage of particles the spacecraft usually encounters in the solar wind.

For the first time, the spacecraft found itself in a region where the magnetic fields were strong enough to dominate the movement of particles there. These conditions were the definitive proof the spacecraft had passed the Alfvén critical surface and entered the solar atmosphere where magnetic fields shape the movement of everything in the region.

The first passage through the corona, which lasted only a few hours, is one of many planned for the mission. Parker will continue to spiral closer to the Sun, eventually reaching as close as 8.86 solar radii (3.83 million miles) from the surface. Upcoming flybys, the next of which is happening in January 2022, will likely bring Parker Solar Probe through the corona again.

"I'm excited to see what Parker finds as it repeatedly passes through the corona in the years to come," said Nicola Fox, division director for the Heliophysics Division at NASA Headquarters. "The opportunity for new discoveries is boundless."

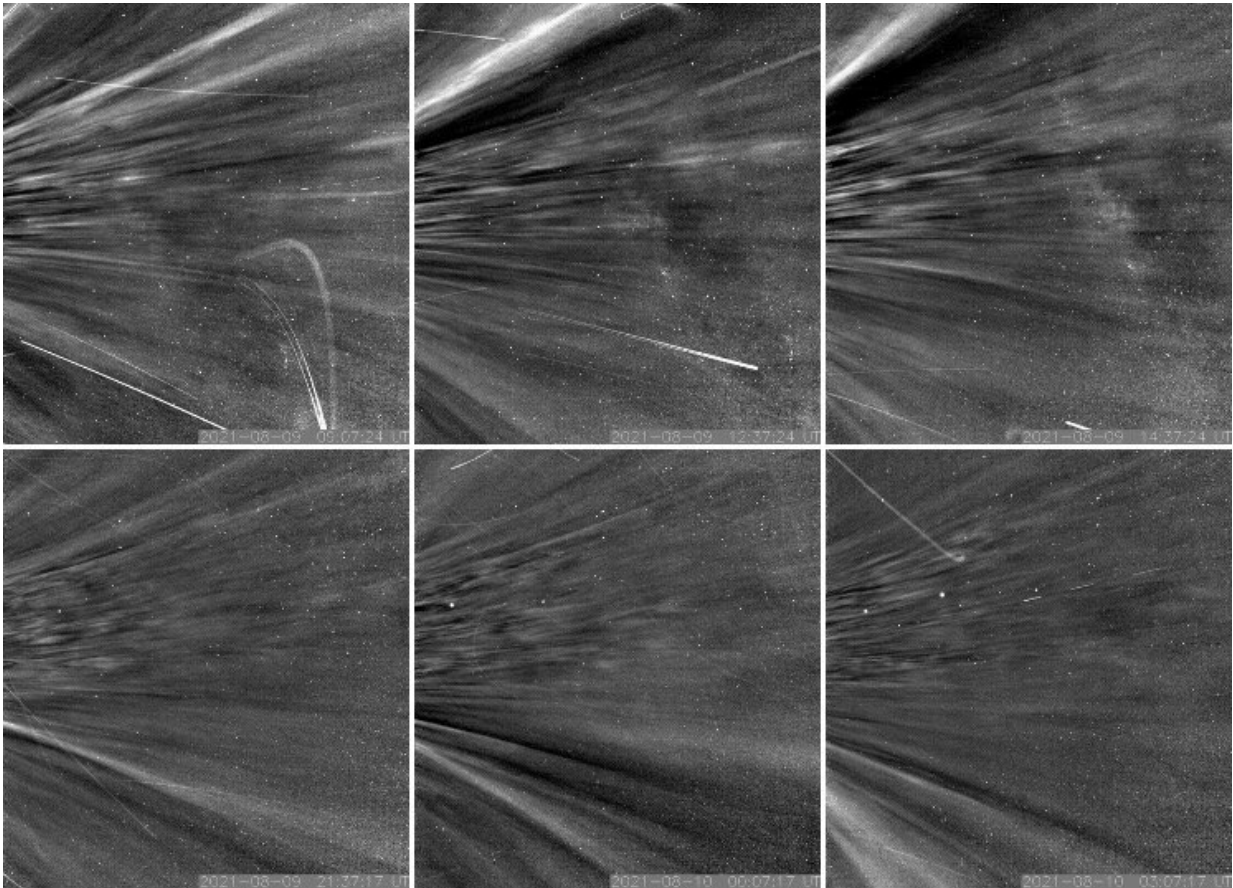
The size of the corona is also driven by solar activity. As the Sun's 11-year activity cycle—the solar cycle—ramps up, the outer edge of the corona will expand, giving Parker Solar Probe a greater chance of being inside the corona for longer periods of time.

"It is a really important region to get into because we think all sorts of physics potentially turn on," Kasper said. "And now we're getting into that region and hopefully going to start seeing some of these physics and behaviors."

Narrowing Down Switchback Origins

Even before the first trips through the corona, some surprising physics was already surfacing. On recent solar encounters, Parker Solar Probe collected data pinpointing the origin of zig-zag-shaped structures in the solar wind, called switchbacks. The data showed one spot that switchbacks originate is at the visible surface of the Sun—the photosphere.

By the time it reaches Earth, 93 million miles away, the solar wind is an unrelenting headwind of particles and magnetic fields. But as it escapes the Sun, the solar wind is structured and patchy. In the mid-1990s, the NASA-European Space Agency mission [Ulysses](#) flew over the Sun's poles and discovered a handful of bizarre S-shaped kinks in the solar wind's magnetic field lines, which detoured charged particles on a zig-zag path as they escaped the Sun. For decades, scientists thought these occasional switchbacks were oddities confined to the Sun's polar regions.



As Parker Solar Probe passed through the corona on encounter nine, the spacecraft flew by structures called coronal streamers. These structures can be seen as bright features moving upward in the upper images and angled downward in the lower row. Such a view is only possible because the spacecraft flew above and below the streamers inside the corona. Until now, streamers have only been seen from afar. They are visible from Earth during total solar eclipses. Credit: NASA/Johns Hopkins APL/Naval Research Laboratory

In 2019, at 34 solar radii from the Sun, Parker discovered that switchbacks were not rare, but common in the solar wind. This renewed interest in the features and raised new questions: Where were they coming from? Were they forged at the surface of the Sun, or shaped by some process kinking magnetic fields in the solar atmosphere?

The new findings, in press at the *Astrophysical Journal*, finally confirm one origin point is near the solar surface.

The clues came as Parker orbited closer to the Sun on its sixth flyby, less than 25 solar radii out. Data showed switchbacks occur in patches and have a higher percentage of helium—known to come from the photosphere—than other elements. The switchbacks' origins were further narrowed when the scientists found the patches aligned with magnetic funnels that emerge from the photosphere between convection cell structures called [supergranules](#).

In addition to being the birthplace of switchbacks, the scientists think the magnetic funnels might be where one component of the solar wind originates. The solar wind comes in two different varieties—fast and slow—and the funnels could be where some particles in the fast solar wind come from.

"The structure of the regions with switchbacks matches up with a small magnetic funnel structure at the base of the corona," said Stuart Bale, professor at the University of California, Berkeley, and lead author on the new switchbacks paper. "This is what we expect from some theories, and this pinpoints a source for the solar wind itself."

Understanding where and how the components of the fast solar wind emerge, and if they're linked to switchbacks, could help scientists answer a longstanding solar mystery: how the corona is heated to millions of degrees, far hotter than the [solar surface](#) below.

While the new findings locate where switchbacks are made, the scientists can't yet confirm how they're formed. One theory suggests they might be created by waves of plasma that roll through the region like ocean surf. Another contends they're made by an explosive process known as magnetic reconnection, which is thought to occur at the

boundaries where the magnetic funnels come together.

"My instinct is, as we go deeper into the mission and lower and closer to the Sun, we're going to learn more about how magnetic funnels are connected to the switchbacks," Bale said. "And hopefully resolve the question of what process makes them."

Now that researchers know what to look for, Parker's closer passes may reveal even more clues about switchbacks and other solar phenomena. The data to come will allow scientists a glimpse into a region that's critical for superheating the corona and pushing the [solar wind](#) to supersonic speeds. Such measurements from the corona will be critical for understanding and forecasting extreme space weather events that can disrupt telecommunications and damage satellites around Earth.

"It's really exciting to see our advanced technologies succeed in taking Parker Solar Probe closer to the Sun than we've ever been, and to be able to return such amazing science," said Joseph Smith, Parker program executive at NASA Headquarters. "We look forward to seeing what else the mission discovers as it ventures even closer in the coming years."

Parker Solar Probe is part of NASA's Living with a Star program to explore aspects of the Sun-Earth system that directly affect life and society. The Living with a Star program is managed by the agency's Goddard Space Flight Center in Greenbelt, Maryland, for NASA's Science Mission Directorate in Washington. The Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, manages the Parker Solar Probe mission for NASA and designed, built, and operates the spacecraft.

Provided by NASA's Goddard Space Flight Center

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