NASA missions find 'jetlets' could power the solar wind

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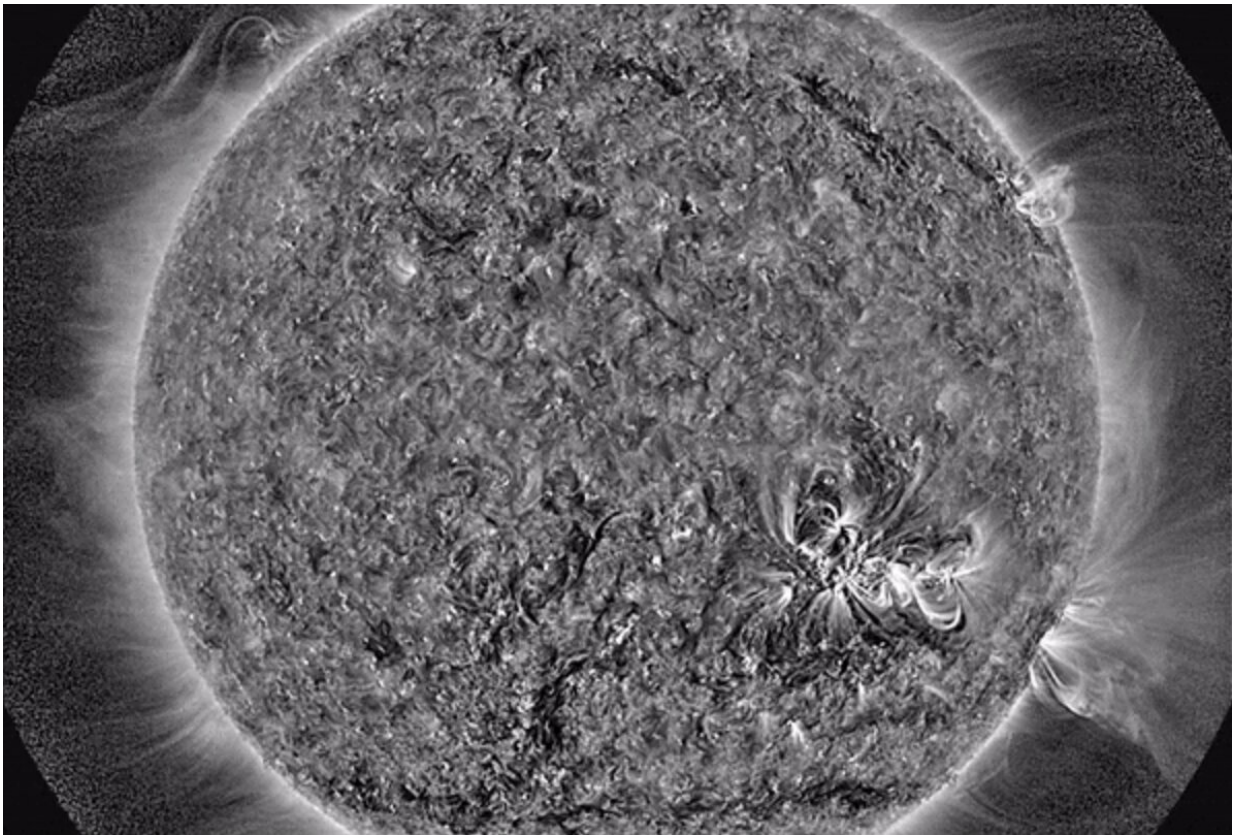

NASA's Solar Dynamics Observatory shows small-scale jetlets at the base of the solar corona, or the Sun's upper atmosphere. Jetlets can be seen emanating from the surface of the Sun. The observations were made over the course of approximately 10 hours on April 28, 2021. Credits: NASA/SDO

Scientists with NASA's Parker Solar Probe mission have uncovered significant new clues about the origins of the solar wind—a continual stream of charged particles released from the Sun that fills the solar system.

Observations from multiple space and ground-based observatories show the solar wind could be largely fueled by small-scale jets, or "jetlets," at the base of the corona—the Sun's upper atmosphere. This finding is helping scientists better understand the 60-year-old mystery of what heats and accelerates the solar wind.

"This new data shows us how the solar wind gets going at its source," said Nour Raouafi, the study lead and the Parker Solar Probe project scientist at the Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland. "You can see the flow of the solar wind rising from tiny jets of million-degree plasma all over the base of the corona. These findings will have a huge impact on our understanding of the heating and acceleration of the coronal and solar wind plasma."

Understanding the solar wind is fundamental to our understanding of our solar system and others throughout the universe—and is the primary science goal of the Parker Solar Probe mission. Made of electrons, protons, and heavier ions, the solar wind courses through the solar system at roughly 1 million miles per hour.

When the solar wind interacts with Earth's magnetic field, it can create stunning auroras as well as disruptions in GPS and communications systems. Over time, the solar wind, and stellar winds in other solar systems, can also affect the composition and evolution of planetary atmospheres—even influencing planets' habitability.

Strength in numbers

At Earth, the solar wind is usually a constant breeze. Scientists have therefore been looking for a steady source at the Sun that could continually power the solar wind. However, the new findings—accepted for publication in the *Astrophysical Journal* and published on *ArXiv*—show the solar wind might be largely energized and fueled by individual jetlets that are intermittently erupting into the lower part of the corona. Though each jetlet is relatively small—just a few hundred miles long—their collective energy and mass could be enough to create the solar wind.

"This result implies that essentially all of the solar wind is likely released intermittently, becoming a steady flow in much the same way that the individual clapping sounds in an auditorium become a steady roar as an audience applauds," said Craig DeForest, a solar physicist at the Southwest Research Institute in Boulder, Colorado, and coauthor on the new paper. "This changes the paradigm for how we think about certain aspects of the solar wind."

Jetlets, which were first observed over a decade ago, are known to be caused by a process known as magnetic reconnection, which occurs as magnetic field lines become tangled and explosively realign. Reconnection is a common process in charged gases called plasmas and is found across the universe from the Sun to near-Earth space to around black holes. In the solar corona, reconnection creates these short-lived jets of plasma that pass energy and material into the upper corona, which escape across the solar system as the solar wind.

To study the jetlets and magnetic fields, scientists primarily used observations from the Solar Dynamics Observatory (SDO) and the Geostationary Operational Environmental Satellite-R Series' Solar Ultraviolet Imager (GOES-R/SUVI) instrument, as well as high-resolution magnetic field data from the Goode Solar Telescope at the Big Bear Solar Observatory in California.

The whole study was driven by a phenomenon first observed by Parker Solar Probe called switchbacks—magnetic zig-zag structures in the solar wind. The combination of observations from many viewpoints, along with the high resolution of those views and Parker Solar Probe's up-close observations, helped the scientists understand the collective behavior of the jetlets.

"Previously, we could not detect enough such events to explain the observed amount of mass and energy streaming from the Sun," said Judy Karpen, coauthor on the paper and heliophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "But the improved resolution of the observations and meticulous data processing enabled the new findings."

The observations showed that jetlets are present in the lower solar atmosphere across the entire Sun. This makes them a tenable driver for the constant solar wind, as opposed to other phenomena that wax and wane with the 11-year cycle of solar activity, such as solar flares and coronal mass ejections. Furthermore, the scientists calculated that the energy and mass produced by the jetlets could provide most, if not all, of the amount of energy and mass seen in the solar wind.

A breakthrough decades in the making

The solar wind was first proposed in the late 1950s by the visionary scientist Eugene Parker, namesake of the Parker Solar Probe. In 1988, Parker proposed the corona could be heated by "nanoflares," tiny explosions on the solar atmosphere. Parker's theory eventually became a leading candidate to explain the heating and acceleration of the solar wind.

"The tiny reconnection events we observed are, in a way, what Eugene Parker proposed over three decades ago," Raouafi said. "I am convinced

that we are on the right path toward understanding the solar wind and coronal heating."

Continued observations from Parker Solar Probe and other instruments such as NASA's Polarimeter to Unify the Corona and Heliosphere, or PUNCH, and the Daniel K. Inouye Solar Telescope, will help scientists confirm whether jetlets are the main source of solar wind.

"The findings make it much easier to explain how the solar wind is accelerated and heated," DeForest said. "We're not finished with the puzzle yet, but this is a major step forward for understanding a central mystery of solar physics."

Parker Solar Probe was developed as 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 Applied Physics Laboratory designed, built, manages, and operates the spacecraft.

More information: Nour E. Raouafi et al, Magnetic Reconnection as the Driver of the Solar Wind, *arXiv* (2023). DOI: 10.48550/arxiv.2301.00903

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