What Lies Beneath a Sunspot

Using techniques similar to medical ultrasound diagnostics, scientists have peered inside the Sun and discovered what lies beneath sunspots, planet-sized dark areas on the surface of our star. Sunspots are surprisingly shallow, say researchers, and they lie on top of swirling hurricanes of electrified gas (plasma) big enough to swallow the planet Earth.

The new research, gathered from the Michelson Doppler Imager (MDI) onboard the Solar and Heliospheric Observatory (SOHO), will deepen our understanding of stormy areas on the Sun — called “active regions” — where sunspots appear. Powerful explosions from magnetic active regions can trigger beautiful auroras on Earth and affect high-technology systems such as satellites, power grids, and radio communications.

Sunspots have fascinated people since the early 1600’s when Galileo’s observations of them contradicted the common belief that heavenly objects like the Sun were flawless. Sunspots have remained a mystery for nearly 400 years. At first glance, it seems they should rapidly disappear. Instead, they persist for weeks or more.

Astronomers have long known that sunspots are regions where magnetic fields become concentrated. Yet anyone who played with magnets as a child has felt how magnetic fields of like polarities repel each other. Likewise, the strong magnetic fields of sunspots should naturally repel each other, causing the sunspot to quickly dissipate. Indeed, observations show that surface material clearly flows out of the spots.

What then makes sunspots so long-lasting? How do they remain intact for weeks and months? A team of scientists had to look beneath the surface of the Sun to find the answer.

Alexander Kosovichev and Junwei Zhao of Stanford University, along with Thomas Duvall of NASA’s Goddard Space Flight Center, used MDI’s unique ability to probe the happenings just below a sunspot’s surface — and for the first time they have clearly observed inward-flowing material.

“We discovered that the outflowing material was just a surface feature,” said Zhao. “If you can look a bit deeper, you find material rushing inward, like a planet-sized whirlpool or hurricane. This inflow pulls the magnetic fields together.”

The Sun is a humming ball of sound waves launched by turbulent convective motions in our star’s outer layers. “The waves we monitor [using MDI] have a period of about 5 minutes,” says Phil Scherrer of Stanford University, principal investigator for the MDI instrument. “That’s roughly the turn-over time of the California-sized bubbles that appear as granulation of the photosphere.” Solar granulation is what excites the Sun’s internal sound waves.

The material above the plug cools and becomes denser, causing it to plunge downward as fast as 3,000 miles per hour, according to the new observations. That draws the surrounding plasma and magnetic field inward toward the sunspot’s center. The concentrated field promotes further cooling, and as that cooling plasma sinks it draws in still more plasma, thereby setting up a self-perpetuating cycle. As long as the magnetic field remains strong, the cooling effect will maintain an inflow that makes the structure stable. Outflows seen right at the surface are confined to a very narrow layer.

Since the magnetic plug prevents heat from reaching the solar surface, the regions beneath the plug should become hotter. A June 1998 observation provided evidence for this. “We were surprised at how shallow sunspots are,” said Kosovichev. Below 3,000 miles the observed sound speed was higher, suggesting that the roots of the sunspots were hotter than their surroundings, just the opposite of conditions at the surface.

“The cool downward flows dissipate at the same depth where the hot upward flows diverge,” said Duvall. “With these data one cannot get a sharp enough picture to really explain the details. Until now we’ve looked down at the top of sunspots like we might look down at the leaves in treetops. For the first time we’re able to observe the branches and trunk of the tree that give it structure. The roots of the tree are still a mystery.”

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For further images go to: http://science.nasa.gov/headlines/y2001/ast07nov_1.htm

An artist’s concept of hidden gases swirling beneath a sunspot.
The capability to double the pressure limits in fusion devices by spinning the fuel will have broad application to a range of approaches to fusion energy. These results will increase the emphasis on developing methods to spin the fusion fuel in a fusion power source. The DIII-D research team expects this advance could ultimately allow the design of more economical fusion power sources and reduce the time required to develop and deploy reliable sources of fusion energy.

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