New method detects emerging sunspots deep inside the sun, provides warning of dangerous solar flares

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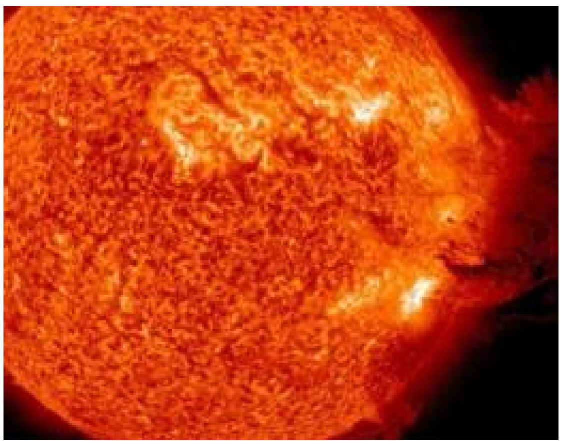

This photo, released by NASA's Earth Observatory in June 2011 and taken from Nasa's Solar Dynamics Observatory shows the Sun unleashing an M-2 (medium-sized) solar flare. Scientists said Thursday they can now better predict when sunspots will erupt, offering earlier warning of magnetic disruptions that can cut power and interrupt communications on Earth.

Viewed from the technological perspective of modern humans, the sun is a seething cauldron of disruptive influences that can wreak havoc on communication systems, air travel, power grids and satellites – not to mention astronauts in space.

If disruptions such as solar flares and mass eruptions could be predicted, protective measures could be taken to shield vulnerable electronics before solar storms strike.

Now Stanford researchers have developed a method that allows them to peer deep into the sun's interior, using acoustic waves to catch sunspots in the early stage of development and giving as much as two days' warning.

Sunspots develop in active solar regions of strong, concentrated magnetic fields and appear dark when they reach the surface of the sun. Eruptions of the intense magnetic flux give rise to solar storms, but until now, no one has had luck in predicting them.

"Many solar physicists tried different ways to predict when sunspots would appear, but with no success," said Phil Scherrer, a professor of physics in whose lab the research was conducted.

The key to the new method is using acoustic waves generated inside the sun by the turbulent motion of plasma and gases in constant motion. In the near-surface region, small-scale convection cells – about the size of California – generate sound waves that travel to the interior of the sun and are refracted back to the surface.

The researchers got help from the Michelson Doppler Imager aboard NASA's Solar and Heliospheric Observatory satellite, known as SOHO. The craft spent 15 years making detailed observations of the sound waves within the sun. It was superseded in 2010 with the launch of NASA's Solar Dynamics Observatory satellite, which carries the Helioseismic and Magnetic Imager.

Using the masses of data generated by the two imagers, Stathis Ilonidis, a Stanford graduate student in physics, was able to develop a way to reduce the electronic clutter in the data so he could accurately measure the solar sounds.

The new method enabled Ilonidis to detect sunspots in the early stages of formation as deep as 65,000 kilometers inside the sun. Between one and two days later, the sunspots would appear on the surface. Ilonidis is the lead author of a paper describing the research, published in the Aug. 19 edition of *Science*.

The principles used to track and measure the acoustic waves traveling through the sun are comparable to measuring seismic waves on Earth. The researchers measure the travel time of acoustic waves between widely separated points on the solar surface.

"We know enough about the structure of the sun that we can predict the travel path and travel time of an acoustic wave as it propagates through the interior of the sun," said Junwei Zhao, a senior research scientist at Stanford's Hansen Experimental Physics Lab. "Travel times get perturbed if there are magnetic fields located along the wave's travel path." Those perturbations are what tip the researchers that a sunspot is forming.

By measuring and comparing millions of pairs of points and the travel times between them, the researchers are able to home in on the anomalies that reveal the growing presence of magnetic flux associated with an incipient sunspot.

They found that sunspots that ultimately become large rise up to the surface more quickly than ones that stay small. The larger sunspots are the ones that spawn the biggest disruptions, and for those the warning time is roughly a day. The smaller ones can be found up to two days before they reach the surface.

"Researchers have suspected for a long time that sunspot regions are generated in the deep solar interior, but until now the emergence of these regions through the convection zone to the surface had gone undetected," Ilonidis said. "We have now successfully detected them four times and tracked them moving upward at speeds between 1,000 and 2,000 kilometers per hour."

One of the big goals with forecasting space weather is achieving a three-day warning time of impending solar storms. That would give the potential victims a day to plan, another day to put the plan into action and a third day as a safety margin.

Provided by Stanford University