Solar flare triggers energetic sunquake

Exploding a few thousand kilometers above the sun's surface, solar flares generate a tumult of X rays, beams of charged particles, and high-speed streams of ionized gas. A new study reveals that these eruptions can produce seismic waves akin to titanic earthquakes beneath the solar surface.

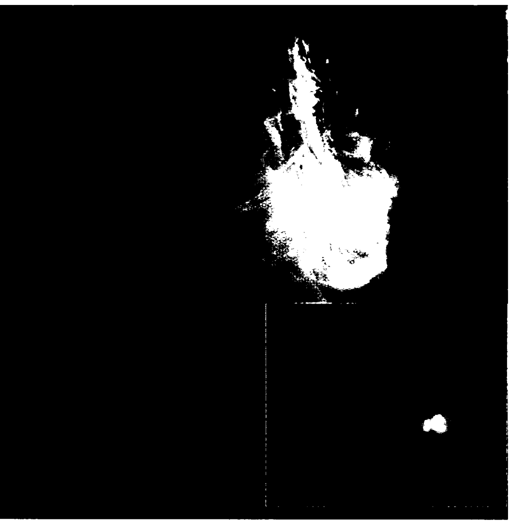
Although the finding comes from a study of only one flare, it suggests that these atmospheric explosions may offer a new way to probe the sun's interior.

Alexander G. Kosovichev of Stanford University and Valentina V. Zharkova of Glasgow University in Scotland examined a medium-energy solar flare that erupted on July 9, 1996. One minute after X-ray emissions from the flare had reached their peak, the Solar and Heliospheric Observatory (SOHO) found that a shock wave from the explosion had begun moving toward the sun. The impact of that shock—the first to be observed in association with a flare—helped generate the seismic waves that the SOHO craft detected about 20 minutes later, the researchers assert.

The waves, which resemble ripples created by a pebble cast into a pond, lasted for more than 35 minutes and were recorded by a SOHO instrument that measures the velocity of gas rising and falling at the sun's surface. Roughly 3 km in height, the waves spread about 100,000 km across the surface and penetrated an estimated 40,000 km into the sun, report Kosovichev and Zharkova in the May 28 NATURE.

They also presented the findings at a meeting of the American Geophysical Union in Boston this week.

"There's no question about the [detection]—it's there," says astronomer George H. Fisher of the University of California, Berkeley. The puzzle, he adds, is how the seismic waves were triggered.



Large photo: NASA Inset: Natl. Astronomical Obs. of Japan

Glowing gas is trapped by looping magnetic fields that extend into the sun's corona, shown in this composite of three ultraviolet images. Inset: X-ray image of a flare that triggered solar seismic waves.

According to previous models, energetic electrons and protons created by a flare heat the sun's atmosphere. Some of that heat excites the corona, or outer atmosphere of the sun, but a portion generates a shock wave that hammers the surface and produces a sunquake.

Kosovichev and Zharkova note, however, that the shock wave deduced from the SOHO data had too little energy and momentum to generate the seismic waves, which unleashed 40,000 times as much energy as the infamous 1906 San Francisco earthquake. Instead, they propose, electrons and protons from the flare struck the surface directly, contributing to the formation of the waves.

Alternatively, says Fisher, there may be some "new phenomenon associated with solar flares that we don't know about." He adds that not all flares may produce a sunquake. As the sun nears the peak of its 11-year activity cycle and eruptions become more frequent, researchers will have an opportunity to find out.

Kosovichev and Zharkova note that astronomers may want to take a closer look at other stars that have powerful flares. Such flares may trigger quakes big enough to be observed from Earth.

In a separate presentation at the geophysics meeting, Alan M. Title of the Stanford-Lockheed Institute for Space Research in Palo Alto, Calif., unveiled the latest ultraviolet images of the sun taken by the recently launched Transition Region and Coronal Explorer (TRACE) satellite. The images reveal that energy associated with magnetic fields in the sun's atmosphere is unleashed over periods of less than 20 seconds and distances of less than 700 km. Theorists will have to take these scales into account as they perfect models of how the sun's corona attains its million-degree temperature. —*R. Cowen*

Cold molecules make long-awaited debut

A dozen years have passed since physicists first trapped ultracold atoms, paving the way for atomic lasers and other advances and netting three cold-atom pioneers the 1997 Nobel Prize in Physics (SN: 10/25/97, p. 263).

All the while, researchers have dreamed of extending this rewarding means of probing atomic structure and behavior to molecules. But the lasers used to cool and trap atoms can't readily put out beams at enough different frequencies to subdue the wide variety of vibrations and energy levels that more complex particles possess.

On May 29, however, a team led by John M. Doyle of Harvard University reported the first evidence of molecular trapping at temperatures near absolute zero. His announcement followed hard on the heels of a report in the May 18 PHYSICAL REVIEW LETTERS from Pierre Pillet and his colleagues at Laboratoire Aimé Cotton near Paris describing the first detection of stable—yet untrapped—cold molecules made from cold atoms.

"The big thrill at this point is that everybody who wants to trap molecules looks at [the French group's findings] as a step closer," says Paul D. Lett of the National Institute of Standards and Technology in Gaithersburg, Md.

Lett also described the Harvard advance as "great progress, because people have wanted especially to see some general technique like this where they don't have to build a special laser system for each molecule."

While neither team has yet delivered cold molecules that are pure and confined enough for thoroughly studying their properties, both say a new era of cold molecule physics and chemistry is dawning. "We're at the birth of entirely new areas of working with cold molecules," says Doyle.

New insights into chemical reactions may arise from the study of cold, slow molecular collisions. Also on the horizon may be improved understanding of molecular energy states and, possibly, molecular lasers and Bose-Einstein condensates—collections of ultracold particles all in the same quantum state (SN: 7/15/95, p. 36; 5/25/96, p. 327).

Pillet's group was carrying out the well-established practice of photoassociating, or briefly linking pairs of atoms—cold, trapped cesium, in this case—through interaction with a photon, when they discovered frigid cesium molecules tumbling from the bottom of their trap.

"This was a little bit unexpected," says Pillet, but welcome because the molecules lasted milliseconds, signifying that they were the stable variety sought by physicists. The French group is now attempting to build a type of laser device, known as a dipole trap, to bag their quarry.

Meanwhile, Doyle's team presented spectroscopic data indicating successful trapping of more than a billion molecules of the simple compound calcium monohydride, cooled to 350 millikelvins. Reporting at a meeting in Santa Fe, N.M., of the Division of Atomic, Molecular, and Optical Physics of the American Physical Society, Doyle and his colleagues said they have dispensed with lasers altogether for trapping. Instead, they inject relatively warm molecules into frigid helium gas within a magnetic well that captures the slightly magnetically polarized molecules. Next, they plan to remove the helium and any impurities. —*P. Weiss*