

high-speed charge-coupled device camera. "We saw that for a while nothing happened, and then slowly the action started and speeded up," says Ketterle. Many phase changes in nature happen by "relaxation," in which a system out of thermal equilibrium drops toward equilibrium almost en masse. But relaxation starts out very fast and then slows down. The accelerating pace of BEC formation implies that something different is happening, says Ketterle.

The team members believe that the BEC forms by speeding up a process of scattering. Atoms in the cooled gas want to join the condensate because it is in a lower energy state, but they need to shed some excess energy to do so. They do this by colliding with another atom outside the BEC and dumping their excess energy and momentum onto it. "One particle

takes over the energy and momentum, while the other particle jumps into the condensate," says Ketterle. And, for reasons that are not yet clear, the more atoms there are in the BEC, the more other atoms want to join, causing the process to speed up rapidly. The same principle governs stimulated emission of photons: "The probability of a photon going in a direction in which there are already photons is proportional to the number of coherent photons that are already there," explains Burnett.

Condensed-matter theorists, such as Gora Shlyapnikov of the Kurchatov Institute in Moscow and Peter Zoller of the University of Innsbruck in Austria, say that the condensate growth pattern observed by the MIT team corresponds closely to some existing formation models for BECs. "The results are very

convincing," says Zoller. Kris Helmerson of the National Institute of Standards and Technology in Gaithersburg, Maryland, says the study should have a practical effect, too. "By studying this process, you can find better strategies for the development of more intense sources for atom lasers," he says.

Whatever the long-term implications of the research, physicists are happy, for the time being, to watch in wonder. "Now when Ketterle presents their 'movie' of what is going on, you can sit back and enjoy the show," says Burnett. But he adds: "If you have seen all the elements that have gone into it to get to that place, it is really formidable."

—Alexander Hellemans

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ASTROPHYSICS

Sunquakes May Power Solar Symphony

Like a quivering gong, the sun vibrates with millions of different overtones. Although astrophysicists have long exploited this ringing to glean insights into the sun's structure, its exact cause has been a mystery. Now a paper to appear in the 1 March issue of the *Astrophysical Journal* proposes that solar tremors called "sunquakes" power this resonance with bursts of sound.

The researchers—from the New Jersey Institute of Technology (NJIT); the University of Colorado, Boulder; and the National Solar Observatory (NSO)—analyzed detailed measurements of the solar atmosphere for telltale motions caused by sound. Their findings strengthen a theory that gas plunges noisily below the solar surface. Although it's unclear how these downdrafts might generate the noise, the team detected this acoustic energy feeding one type of solar oscillation. The quakes themselves could also provide a new probe for peering beneath the sun's surface.

For decades, astrophysicists have simply attributed the sun's ringing to turbulent convection near its surface, where 1000-kilometer-wide patches of hot gas called granules bubble up from the sun's interior and slam into the solar atmosphere. A twist on this theory emerged in the mid-1980s when computer models predicted that after gas cools at the sun's surface, it forms narrow plumes that plunge at supersonic speeds toward the interior—presumably unleashing sonic booms. The plunging gas might also trigger sunquakes by sucking together neighboring granules.

The first glimpse of these powerful internal downdrafts came in 1995, when Philip Goode

of NJIT in Newark, Thomas Rimmele and Louis Strous, now of the NSO in Sunspot, New Mexico, and Robin Stebbins of Colorado observed a darkening of narrow gas lanes between granules, indicating cooling. If so, the chilled gas must fall "like a bowling ball in a swimming pool," says Stebbins.

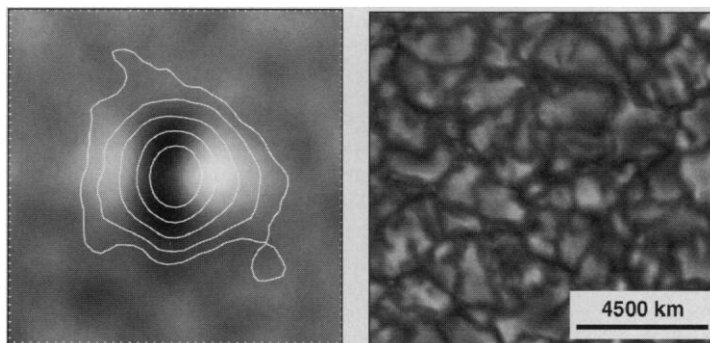
But separating the resulting quakes from background noise in the sun's turbulent atmosphere is tricky. To do so, the team clocked the speed and direction of gas flowing at two altitudes above the sun's surface—150 and 330 kilometers—by measuring the Doppler shift of light absorbed by iron ions swirling in the sun's atmosphere. The acceleration of first the lower

sarily produce a resonant tone, sound bursts on the sun's surface don't necessarily amplify solar vibrations; they have to have the right wavelength and velocity to excite the sun's natural oscillation frequencies. But the team has evidence that the quakes do excite at least one kind of oscillation, the f-mode. About 800 kilometers away from a sunquake's epicenter, "we can literally see the conversion of sound at many frequencies to sound that just belongs to the f-mode," says Goode. The team calculates that the estimated total number of quakes would have more than enough power to drive all the sun's oscillations.

The findings are "a nice illustration of a mechanism actually operating," says Peter Goldreich, an astrophysicist at the California Institute of Technology. But others are skeptical that sound bursts come from the shrieking downdrafts and thundering granules. In the composite images the team produced, the bursts aren't centered squarely on the dark lanes. That "makes me suspicious," says Tom Duvall of NASA Goddard Space Flight Center in Greenbelt, Maryland. "We don't have an explanation for that yet," acknowledges Rimmele. "We still have to investigate."

But if sunquakes are real, they might be used to probe granule structure and the local magnetic fields set up in the dark lanes, says Goode—much as seismologists on Earth detonate a charge, then study where waves resurface. Mapping this structure more finely is important because astronomers who now use oscillations to probe the sun's interior must assume that waves passing through the uppermost regions aren't much distorted. Says Phil Scherrer of Stanford University, "We're much better off if we can actually understand the surface and the sources."

—Erik Stokstad



Sunscream. Burst contour over cool gas (close-up, left) hints at solar gong.

gas layers, then the overlying ones, suggests they were shoved by a sound wave, the researchers say. To see what might be triggering the bursts, they superimposed images of the surface beneath more than 2000 sound bursts—before, during, and after an event. The composites revealed that bursts consistently emanated from the dark lanes (see figure above). Immediately after a sound's intensity peaked, the lanes would narrow, suggesting that neighboring granules were filling a void.

Just as blowing into a trumpet won't neces-