High-speed solar wind surfs magnetic waves

The solar wind is no balmy breeze. Streaming out from the sun at speeds as high as 800 kilometers per second, this rush of charged particles exerts a profound influence on Earth and other planets. Nearly 4 decades after its discovery, solar scientists say they finally understand why the solar gale blows as hard as it does.

Observations by two spacecraft suggest that magnetic waves generated inside the sun provide the push. Charged particles—ions and electrons—gyrate about these waves and get revved up by the accompanying electric field. As the waves vibrate, they push the ions out to become the highest-speed component of the solar wind.

"These vibrating magnetic waves give solar wind particles a push, just like an ocean wave gives a surfer a ride," says John L. Kohl of the Smithsonian Astrophysical Observatory in Cambridge, Mass. Kohl's team presented the findings last week at a NASA briefing in Washington, D.C., and in the June 20 ASTROPHYSICAL JOURNAL.

Ultraviolet and visible-light telescopes on the Spartan 201 spacecraft, which flew aboard the space shuttle last fall, and the orbiting Solar and Heliospheric Observatory (SOHO) gathered the data. To measure the velocity of charged particles in the sun's outer atmosphere, or corona, each telescope recreated a solar eclipse by using a mask to block out the blinding light from the sun's surface.

The observations focused on the sun's polar regions, where the wind blows fastest. They reveal that oxygen ions stream out of the corona at 440 km/s, nearly double the speed of hydrogen ions.

That result is at odds with an earlier theory, which proposed that electrons attain high temperatures in the corona and then impart their energy to ions. If that were so, heavier ions, such as oxygen, would have lower velocities than lighter ones and none could stream out as fast as the new observations indicate.

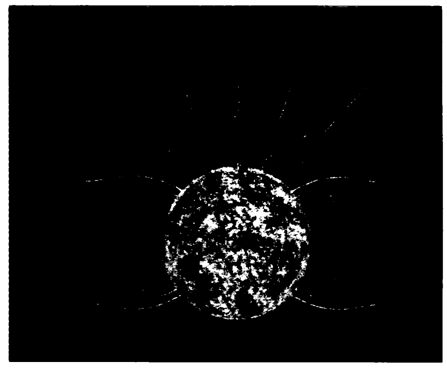
To explain the new findings, Kohl's Smithsonian colleague, Steven R. Cranmer, invokes magnetic waves. It's well known that magnetic fields loop out of the sun's corona and extend into space. Cranmer proposes that some of these waves undulate at the same frequency at which the oxygen ions gyrate about them. When the two frequencies match, something special happens.

Just as a child on a swing reaches great heights if he's pushed at the same rate at which he's moving back and forth, a particle gyrating in sync with the vibration of a magnetic wave readily absorbs energy from the wave. This allows the particle to accelerate to high speeds.

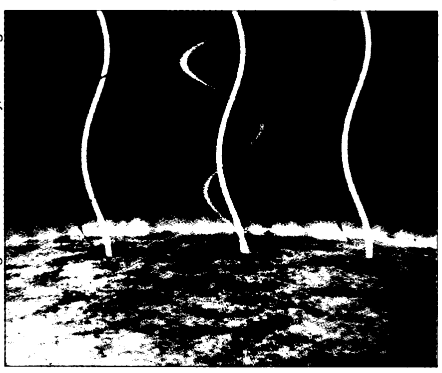
There's a variety of magnetic waves in the corona, each with a characteristic frequency. Each wave accelerates a particular type of ion that gyrates in sync with that frequency.

Previous SOHO observations prompted Kohl's team to propose this scenario several years ago (SN: 8/31/96, p. 136), but the new data make the case much more compelling, Kohl says.

Although Joseph V. Hollweg of the University of New Hampshire in Durham subscribes to the magnetic-wave scenario, he notes that the findings do not constitute a discovery of the waves themselves, just a strong hint that they exist. He adds that the observations directly show that solar-wind particles are accelerated within 1 million km from the sun's surface. "For the first time, we have a handle on what's really going on in the corona," says Hollweg. —*R. Cowen*



Magnetic waves in the sun's outer atmosphere, or corona. Ions, depicted in red and green, are shown gyrating about the waves in the polar regions.



Images: NASA/Dana Berry, AlliedSignal

Surf's up: Observations suggest that the charged particles that make up the solar wind (red and green spirals) hitch a ride on magnetic waves in the sun's atmosphere, which drive the particles into space.

Vibrating grains form floating clumps

A pile of granular material such as snow or sand can suddenly and dramatically rearrange itself in an avalanche. Shaken inside a container to form a uniform mist of particles, these materials also undergo an intriguing transformation—one that French scientists have now triggered in space.

Above a certain density of grains, this granular gas metamorphoses into a cloud containing clusters of particles. Mechanisms of such clustering may play a role in natural phenomena such as the formation of planetary rings and movement of sea-ice floes.

A new rocket-borne microgravity experiment shows that granular-gas clustering results exclusively from the energy-depleting nature of impacts between grains. Éric Falcon of the École Normale Supérieure in Paris and his colleagues report their findings in the July 12 PHYSICAL REVIEW LETTERS.

In a prior experiment on the ground, some of the same scientists observed clusters forming, but the researchers couldn't link the phenomenon exclusively to the energy-sapping collisions. Particle motions caused by up-and-down shaking of the container by a piston may have coordinated with motions caused by acceleration due to gravity to make the clusters, they say.

Now the researchers have sent briefly into space three boxes containing different numbers of tiny bronze spheres. At 150 kilometers above Earth, cameras observed the spheres during 200 seconds of shaking at nearly zero gravity. In each of the two boxes with the most particles, the experimenters saw an egg-shaped cluster surrounded by a swarm of disorganized grains.

Curiously, the eggs floated motionless in the boxes. In the earlier, ground-based experiment, the clusters bounced up and down because of the combined effects of vibrations and gravity.

As the lack of motion in the gravity-free experiment shows, "all the kinetic energy injected by the piston is dissipated by the many collisions, so there is no kinetic energy to move the [cluster] particles," Falcon explains.

The experiment is "a very beautiful example of how unmanned flights can lead to important new discoveries in physics," says Jerry P. Gollub of Haverford (Pa.) College.

Falcon contends that the new findings are helping scientists adapt to granular gases the equations describing ordinary gases, such as air. The key difference between the two types of gases is that atoms or molecules in ordinary gases collide without dissipating energy, whereas granular-gas particles lose energy via numerous paths during impacts, such as to sound and heat.

"The present experiment . . . is extremely promising because it leads to a simpler corresponding theory," agrees Stefan Luding of the University of Stuttgart in Germany. —*P. Weiss*