Elusive matter found to be abundant far above Earth

January 24 2012

(PhysOrg.com) -- Cold plasma has been well-hidden. Space physicists have long lacked clues to how much of this electrically charged gas exists tens of thousands of miles above Earth and how the stuff may impact our planet's interaction with the sun. Now, a new method developed by Swedish researchers makes cold plasma measurable and reveals significantly more cold, charged ions in Earth's upper altitudes than previously imagined.

At these lofty elevations, storms of high-energy charged particles — space weather — roil the atmosphere, creating auroras, buffeting satellites, and sometimes wreaking havoc with electronic devices and electric grids on Earth. The new evidence of abundant cold (i.e. low-energy) ions may change our understanding of this tumultuous space weather and lead to more accurate forecasting of it, scientists say. The finding might also shed light on what's happening around other planets and moons — for instance, helping explain why the once robust atmosphere of Mars is so wispy today.

"The more you look for low-energy ions, the more you find," said Mats André, a professor of space physics at the Swedish Institute of Space Physics in Uppsala, Sweden, and leader of the research team. "We didn't know how much was out there. It's more than even I thought."

The low-energy ions are created in the ionosphere, a region of the upper atmosphere where solar energy can sweep electrons away from molecules, leaving atoms of elements like hydrogen and oxygen with positive charges. Actually detecting these ions at high altitudes has been extremely difficult.

Now that has changed, making it apparent that low-energy ions abound in the distant reaches where Earth's atmosphere gives way to outer space. Researchers knew the ions were present at altitudes of about 100 kilometers (60 miles), but André and his colleague Chris Cully looked much higher, between 20,000 and 100,000 km (12,400 to 60,000 mi). While the concentration of the previously hidden cold ions varies, about 50 to 70 percent of the time the particles make up most of the mass of great swaths of space, according to the researchers' satellite measurements and calculations. And, in some high-altitude zones, low-energy ions dominate nearly all of the time. Even at altitudes around 100,000 km — about a third of the distance to the moon — the team detected these previously elusive low-energy ions.

Finding so many relatively cool ions in those regions is surprising, André said, because there's so much energy blasting into Earth's high altitudes from the solar wind — a rushing flow of hot plasma streaming from the sun, which stirs up space-weather storms.

This hot plasma is about 1,000 times hotter than what André considers cold plasma — but even cold is a relative term. The low-energy ions have an energy that would correspond to about 500,000 degrees Celsius (about one million degrees Fahrenheit) at typical gas densities found on Earth. But because the density of the ions in space is so low, satellites and spacecraft can orbit without bursting into flames.

The researchers' new findings have been accepted for publication in *Geophysical Research Letters*, a journal of the American Geophysical Union.

For decades, space physicists have struggled to accurately detect low-energy ions and determine how much of the material is leaving our atmosphere. The satellite André works on, one of four European Space Agency CLUSTER spacecraft, is equipped with a detector with thin wire arms that measures the electric field between them as the satellite rotates. But, when the scientists gathered data from their detectors, two mysterious trends appeared. Strong electric fields turned up in unexpected regions of space. And as the spacecraft rotated, measurements of the electric field didn't fluctuate in the smoothly changing manner that André expected.

"To a scientist, it looked pretty ugly," André said. "We tried to figure out what was wrong with the instrument. Then we realized there's nothing wrong with the instrument." Unexpectedly, they found that cold plasma was altering the structure of electrical fields around the satellite. Once they understood that, they could use their field measurements to reveal the presence of the once-hidden ions.

It's a clever way of turning the limitations of a spacecraft-based detector into assets, said Thomas Moore, senior project scientist for NASA's Magnetospheric Multiscale mission at the Goddard Space Flight Center in Greenbelt, Maryland. He was not involved in the new research.

As scientists use the new measurement method to map cold plasma around Earth, they could discover more about how hot and cold plasmas interact during space storms and other events, deepening researchers' understanding of space weather, André said.

The new measurements indicate that about a kilogram (two pounds) of cold plasma escapes from Earth's atmosphere every second, André said. Knowing that rate of loss for Earth may help scientists better reconstruct what became of the atmosphere of Mars, which is thought to once have been denser and more similar to Earth's. The new cold plasma results might also help researchers explain atmospheric traits of other planets and moons, André suggested.

And closer to home, if scientists could develop more accurate space weather forecasts, they could save satellites from being blinded or destroyed, and better warn space station astronauts and airlines of danger from high-energy radiation. While low-energy ions are not responsible for the damage caused by space weather, they do influence that weather. André compared the swaths of ions to, say, a low-pressure area in our familiar, down-to-Earth weather — as opposed to a harmful storm. It is a key player, even if it doesn't cause the damage itself. "You may want to know where the low-pressure area is, to predict a storm," André noted.

Improving space weather forecasts to the point where they're comparable to ordinary weather forecasting, was "not even remotely possible if you're missing most of your plasma," Moore, with NASA, said. Now, with a way to measure cold plasma, the goal of high-quality forecasts is one step closer.

"It is stuff we couldn't see and couldn't detect, and then suddenly we could measure it," Moore said of the low-energy ions. "Now you can actually study it and see if it agrees with the theories."

More information: "Low-energy ions: A previously hidden solar system particle population", *Geophysical Research Letters*.

Provided by American Geophysical Union