New physics theory resolves mystery of anomalous cosmic rays

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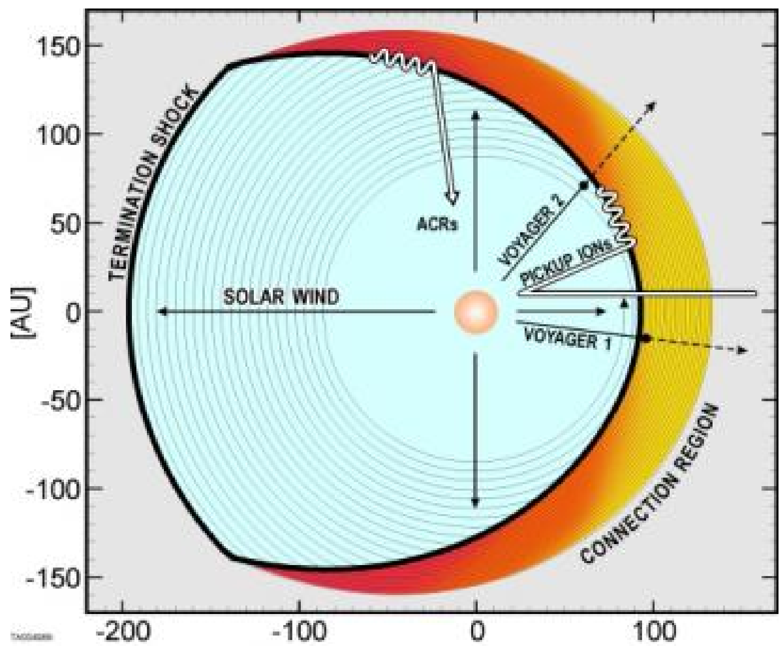

This schematic diagram cuts through the termination shock at the equator. Inside the termination shock, the magnetic field line spirals out and connects to the shock. Also shown are the approximate positions of Voyager 1 at the “nose” of the termination shock and Voyager 2 farther back.

When Voyager 1 finally crossed the "termination shock" at the edge of interstellar space in December 2004, space physicists anticipated the long-sought discovery of the source of anomalous cosmic rays. These cosmic rays, among the most energetic particle radiation in the solar system, are thought to be produced at the termination shock -- the boundary at the edge of the solar system where the million-mile-per-hour solar wind abruptly slows. A mystery unfolded instead when Voyager data showed 20 years of predictions to be wrong.

A new theory published in the February 17 issue of the *Geophysical Research Letters* by Dr. David McComas of Southwest Research Institute and Dr. Nathan Schwadron of Boston University explains why the energization of anomalous cosmic rays is almost entirely absent where Voyager passed through the blunt nose of the termination shock. While the shape of the shock was formerly thought to be unimportant, the new theory explains how this shape is the major factor in particle energization.

McComas and Schwadron say that understanding the role of the termination shock's shape in the energization of anomalous cosmic rays may be a stepping stone to understanding the influence of shock shapes for energization of particle radiation throughout the cosmos. Shocks energize many forms of this dangerous particle radiation, which pose significant hazards to astronauts on space missions, such as future manned missions to the Moon and Mars.

"Models showed we should see the source energy spectrum of anomalous cosmic rays at the termination shock," says McComas, senior executive director of the SwRI Space Science and Engineering Division. "We were pretty sure we knew what we'd see, but when we got there it wasn't what we expected and it clearly was not the source of the anomalous cosmic rays."

Researchers were uncertain where the termination shock would even be found, but they knew there would be a jump in magnetic fields, a deceleration of plasma and other signs.

"It's like walking across a field when you don't know where the edge of the property is," says McComas. "You know you're at the boundary when you finally see the fence."

The shape of the termination shock wasn't thought to be important, so most researchers treated it as being circular, with the magnetic field from the solar wind spiraling out and piercing through it at a single point. McComas and Schwadron showed that acceleration of anomalous cosmic rays can be easily explained by including a more realistic termination shock shape.

"In fact, the termination shock couldn't be circular because the solar system is moving through the galaxy, which would create more of a flattened egg shape," says Schwadron. "A flattening of the nose of the termination shock leads to a time dependant acceleration process."

The production of anomalous cosmic rays requires a connection to the termination shock (the point where it's pierced by the magnetic field line) and the ability for energetic particles to reside near that connection for up to about a year. Using the new model, simple calculations showed particles could remain at a connection point for about 300 days, further evidence of a valid model.

Voyager 1 didn't see the energetic anomalous cosmic rays when it crossed the termination shock.

"The 20-million-electron-volts-per-particle helium that we saw was less than 10 percent of what was predicted. Similarly, we saw only 5 percent of what was predicted for 4-million-electron-volts-per-particle oxygen," says McComas. "We weren't off by 5 or 10 percent, we were off by factors of 10 and 20."

The new model shows that particles can indeed be accelerated at the termination shock, but not at the nose where Voyager crossed it.

"The particles don't get accelerated up to the highest energies until the field line has moved a long way out and its 'feet' have moved back along the sides of the termination shock," says McComas. "This means the source of the energetic anomalous cosmic rays must be on the flanks."

The Voyager 2 spacecraft is also moving out of the solar system, making single-point measurements as it travels. It is expected to pass the termination shock, farther back from the nose, within the next 2–3 years.

"The explanation given here provides predictions that Voyager 2 should observe a larger jump in energetic particle fluxes and a more unfolded anomalous cosmic ray spectrum as it crosses the termination shock," says Schwadron.

The Interstellar Boundary Explorer (IBEX) spacecraft, scheduled to launch in the summer of 2008, will be the first to make global images of the interactions around the termination shock. At that time, researchers will be able to view global interactions at the termination shock's nose, flanks and tail. Combined with data from Voyagers 1 and 2, these observations will enable researchers to understand the global interaction of the solar system with the galaxy for the first time.

"Even without IBEX, this is a big step in understanding what's going on at the termination shock," says McComas. "We really feel that our answer to this mystery is just too simple to be wrong."

SwRI leads the IBEX science mission for NASA. The Goddard Space Flight Center manages the Explorer Program for the Science Mission Directorate.

The paper, "An Explanation of the Voyager Paradox: Particle

Acceleration at a Blunt Termination Shock," is available in the February 17 issue of the *Geophysical Research Letters*.

Source: Boston University