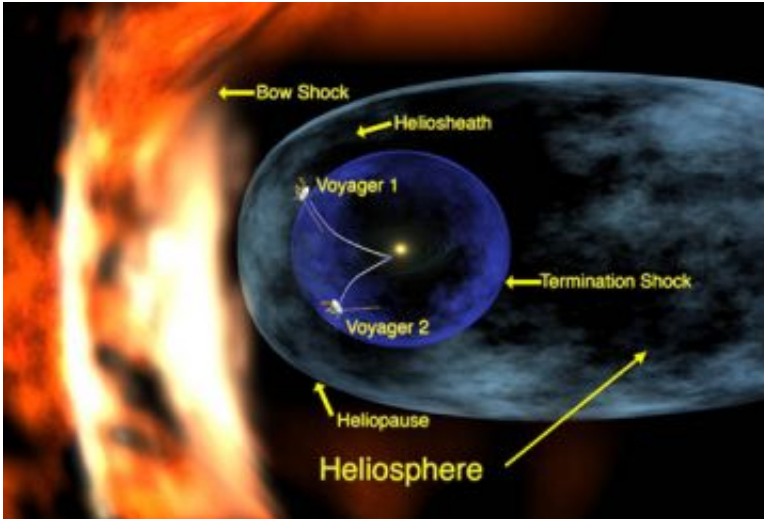


In Search of Interstellar Dragon Fire

August 20 2007



This is a diagram showing the regions of the heliosphere. It also shows the approximate locations of Voyagers 1 and 2. Voyager 1 is traveling faster and has crossed into the heliosheath. Credit: NASA/Walt Feimer

Ancient explorers set sail expecting to encounter dragons on the world's unknown oceans. NASA's twin Voyager spacecraft are searching for dragons of a different sort as they enter the boundary of our solar system – cosmic "dragons" that breathe a strange fire of high-speed atomic fragments called cosmic rays.

Just as mythical dragons were expected to inhabit stormy seas, these cosmic dragons could be found among turbulent magnetic fields powered by the colliding winds of stars, including our sun. The winds clash at the edge of our solar system, and space physicists wonder if

these dragons may be found there, or if they are even more distant in interstellar space.

"Does a great dragon, in the form of a cosmic-ray accelerator, lurk within the turbulent boundary of our solar system to breathe out the fire of cosmic rays, or do these rays arise from even more powerful dragons somewhere in deep space?" asks Dr. John Cooper of NASA's Goddard Space Flight Center in Greenbelt, Md.

Cosmic rays can cause cancer in unprotected astronauts, and a better understanding of where and how cosmic rays are accelerated will improve predictions of how many will be encountered as astronauts set sail on the new ocean of space.

This ocean is not empty. The sun exhales a thin, hot wind of electrically conducting gas, called plasma, into space at many hundreds of miles per second. This solar wind forms a large plasma bubble, called the heliosphere, in space around the Sun. Beyond the orbit of Pluto, the solar wind gradually slows as it interacts with inflowing neutral gases from interstellar space, and then abruptly drops in speed to about 30 miles per second (50 kilometers/second) at a thin, invisible boundary around our solar system called the termination shock.

A simple kitchen experiment illustrates how this shock forms. When water runs at high speed from a kitchen faucet down to the bottom surface of the sink, the water hitting this surface first flows quickly and smoothly away from the impact point, but then runs into a circular boundary with slower, more turbulent flow beyond this boundary.

In the kitchen sink experiment, the circular boundary is the termination shock. The turbulent region beyond the shock boundary corresponds to a layer in the outer heliosphere of turbulent plasma flows and magnetic fields called the heliosheath. The boundary of this turbulent layer with

the interstellar plasma environment, not so easily seen in the kitchen sink experiment because of the turbulence, is called the heliopause.

Our solar system is engulfed in a "dragon fire" of cosmic rays with a wide range of energy levels (the faster the cosmic ray, the greater its energy). Some are from known dragons like explosive flares on the sun. Astronomers believe the rays with the highest energy come from the largest dragons in the universe, including exploding stars called supernova, fast-rotating collapsed objects called neutron stars with incredibly strong magnetic fields, the heaviest collapsed stars called black holes that voraciously feed on infalling matter and spit out accelerated particles, and huge magnetic shock structures ejected far into interstellar space from these stellar sources. The energy for cosmic ray acceleration in all these sources comes from twisting, writhing motions of lower-energy charged particles in turbulent magnetic fields.

Nearer our solar system, Cooper is seeking the smaller dragons that breathe out lower energy fire, the so-called "suprathermal" cosmic rays. This suprathermal zone of fire spans a huge range in energy between that of the flowing plasma and the higher-energy cosmic rays. These suprathermal cosmic rays have been measured within the known heliosphere and theoretically modeled by Dr. Len Fisk and his collaborators at the University of Michigan.

Cooper's new idea is that similar energy distributions of such particles may be found in interstellar space. If the Voyager spacecraft eventually cross the heliopause and find this same suprathermal fire in interstellar space, it would mean that the fire breathers live outside the heliosphere.

Most space plasma scientists had expected the termination shock, traversed by Voyager 1 on December 16, 2004, to be the primary energy source for these suprathermal cosmic rays, but nothing was found. "I propose that that the fabled dragon of the termination shock breathes no

fire and is a kinder and gentler creature, more like Puff the Magic Dragon," said Cooper. "I believe that the suprathermal cosmic rays we see within our solar system instead arise from even more powerful 'dragons' somewhere in interstellar space."

Cooper suggests that the zone of fire extends higher in energy within interstellar space and that Voyager 1 measurements are gradually revealing this expanded energy range during outward movement through the heliosheath towards the heliopause. He recently presented a paper on his new theory at the 2007 International Cosmic Ray Conference at Merida, Mexico. This conference took place on the Yucatan peninsula where an asteroid impact ended the long earthy reign of real dragons, the dinosaurs, sixty-five million years ago.

Cooper's idea was surprising at first, because the magnetic field carried by the solar wind into the heliosheath was expected to deflect both the incoming interstellar plasma and the suprathermal cosmic rays away from the heliosphere on approach to the heliopause boundary. Current theory is that the suprathermal cosmic rays are found inside the solar system because they sneak across the heliopause into the heliosphere as electrically neutral atoms, which are not deflected by magnetic force. Once inside the solar system, they become electrically charged as the sun's radiation strips electrons off of them. Once charged, they feel magnetic force and are carried out of the solar system by the magnetic field embedded in the solar wind. When they reach the termination shock, they are accelerated by the clashing magnetic fields there and shot back into the solar system, where we detect them as suprathermal cosmic rays.

However, since Voyager 1 has not yet found fully definitive evidence that the termination shock accelerates cosmic rays, Cooper thinks that instead they come from interstellar space. "The magnetic 'shield' formed by the solar wind is probably not smooth. Instead, as the solar wind

crashes into the plasma found in interstellar space, it may roll and billow like a cloud, distorting the magnetic field carried with it. I believe interstellar suprathermal cosmic rays can slip between these folds to enter our solar system."

Another possibility is that the dragon lies somewhere between the termination shock and interstellar space, in the vast, teardrop-shaped region around the solar system called the heliosheath. This is where the low-speed solar wind piles up against the interstellar plasma. It forms a teardrop shape as our solar system moves through the galaxy. "However, Voyager 1 has sailed through the heliosheath for two and a half years since crossing the termination shock, and no other local acceleration source has been detected," said Cooper.

Cooper's theory will be tested again soon as the second Voyager spacecraft crosses the termination shock. "If Voyager 2 also finds no evidence of local cosmic ray acceleration as it crosses the termination shock, it will strengthen the case for more remote dragons in interstellar space, perhaps very far beyond in the galaxy, as the source of suprathermal cosmic rays," said Cooper. The first direct traces of these fiercer dragons may be found when the two Voyager spacecraft eventually cross the heliopause into local interstellar space.

Source: by Bill Steigerwald, NASA Goddard Space Flight Center

Citation: In Search of Interstellar Dragon Fire (2007, August 20) retrieved 9 April 2024 from <https://phys.org/news/2007-08-interstellar-dragon.html>

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