These Alfvén waves would impede incoming cosmic particles, says Balogh: "It's like trying to walk through mud."

Detailed analysis of these same waves, and of the composition of the solar wind, could unravel the mysteries of the processes that accelerate the solar wind. Some theorists have speculated that magnetic waves close to the sun add momentum to charged particles leaving the corona, while others have proposed that the sun's magnetic field acts like the constricted neck of a rocket nozzle, from which material is ejected at high velocity. Data from Ulysses should reveal the relative importance of these two processes. "That will have to be sorted out by doing a lot of careful modeling," says U.S. Ulysses project scientist Edward Smith of the Jet Propulsion Laboratory in Pasadena, California.

While the data already gathered by Ulysses will keep the modelers busy for years, the mission is far from over. After reaching its highest southerly latitude of 80.2 degrees on 13 September, Ulysses is now swooping toward the sun's north pole, and will pass over it about 1 year from now. And beyond that, mission scientists hope the project will be continued for a second orbit of the sun. ESA is already in favor, and although NASA hasn't yet made a firm commitment, the signs are positive. The proposal is to keep Ulysses in action until 2001, when the sun will be at its most active. The sun's magnetic field will then be highly disordered, and coronal mass ejections will be daily events. Understanding this turbulent environment will test the skills of mission scientists to the limit, but they are eager for the challenge. Indeed, after waiting 7 years to get Ulysses off the ground, they are anxious to wring as much data from the spacecraft as possible. "Not continuing the mission would be really crazy," says Balogh.

–Peter Aldhous

ASTRONOMY

A Constant Star Suddenly Flares Up

Stars, although they blow up once in a while, have a reputation for dependability: Shakespeare's Cassius described himself as "constant as the Northern star," and sailors still use the predictability of stellar positions to steer their courses. For astronomers, one of the most enduring emblems of stellar steadfastness has been the x-rays given off by so-called hot stars, whose surface temperatures range from 10,000 to 60,000 degrees kelvin. Day after day, year after year, these celestial objects seem to generate an unvarying amount of x-rays.

Now one of these reliable hot stars has shown some startlingly erratic behavior. On page 1689, two astronomers at the Max Planck Institute for Extraterrestrial Physics in Munich report that Zeta Orionis, the leftmost star in Warrior's belt of the famed Orion constellation, suddenly displayed a dramatic burst in x-ray brightness over the span of 2 days in 1992. In contrast to the variable x-ray emissions of stars like our sun, "we had never seen a flarelike event on [a hot star]," says one of the investigators, Jürgen Schmitt. Astronomers are now scrambling to explain the blast, a complex task made more difficult because they've never been sure how these stars generate x-rays at all.

Schmitt and colleague Thomas Berghöfer spotted the x-ray eruption earlier this year, when they were studying observations taken by the German x-ray satellite ROSAT. According to one of ROSAT's instruments, Zeta Orionis' production of "hard," or high-energy, x-rays rose by 30% over a period of 48 hours in late September 1992. When next observed in February 1993, the star's hard x-ray production had decreased but was still higher than before the flare. At the same time, its output of "soft" or low-energy x-rays was up by 20%. By September 1993, both hard and soft x-ray emissions had returned to their constant ways.

Until astronomers figure out how these stars generate x-rays in the first place, they will be hard put to explain Zeta Orionis' flare-up. The basic quandary is that only gases heated to millions of degrees emit x-rays, yet the surface temperatures of stars such as Zeta Orionis do not approach that mark. Nor do hot stars have the immense magnetic fields that allow cooler sunlike stars to produce x-rays; the magnetic fields trap and condense pockets of gas, heating them to sufficient temperatures for x-ray emission. "We're not really sure where the x-rays come from," says Michael Corcoran, who studies hot stars at the National Aeronautics and Space Administration's Goddard Space Flight Center in Maryland.

JOHN SANFORD/PHOTO RESEARCHERS

Erratic emissions. Zeta Orionis *(leftmost of three-star group near top of photo)* loosed an unexpected blast of x-rays in 1992.

More than a decade ago, a few astronomers did put forth a theory about these x-rays: The answer, they said, was blowing in the wind. Hot massive stars can generate huge stellar winds, which are waves of gaseous material streaming off the surface. The speed of these stellar winds often varies, so there should be times when a fast-moving gust overtakes a slower moving breeze. When they collide, the theory holds, resulting shock waves could heat gases to millions of degrees. This mechanism can also be reconciled with the consistency of x-ray emission. "There just has to be lots and lots of little shocks to keep the x-rays constant," explains theorist Stan Owocki of the Bartol Research Institute in Delaware.

Berghöfer and Schmitt argue that their x-ray flare stems from an abnormally large shock wave. In a model they developed to match the ROSAT data, Zeta Orionis at some point puffs out a relatively slow-moving dense shell of gas, one that after 2 days is moving at 570 kilometers per second (km/s). The stellar wind then returns to normal, a smooth stream of less dense gas traveling at 1600 km/s. This quicker gas catches up to the dense slow shell, Schmitt explains, and the collision creates a shock wave that propagates outward at 1000 km/s and generates x-rays as it heats the gases. As the shock wave extends, adds Berghöfer, it should lose energy and start to generate more soft x-rays than hard, as the resulting lower temperature gases would produce lower energy radiation.

Although Berghöfer and Schmitt's conjecture fits the satellite observations, other hot-star modelers argue that the data are just too limited to conclude that the event was caused by a propagating shockwave. A crucial problem, says Owocki, is that ROSAT only caught the initial x-ray rise and didn't keep observing Zeta Orionis to establish a decaying curve, which would be much stronger evidence for a cooling shock wave. As a result, Schmitt, Berghöfer, and other astronomers plan to step up their monitoring of Zeta Orionis and similar hot stars, hoping this eruption—unique to date—won't be unique for long.

–John Travis