Cosmic ray riddle solved?

Physicists from Japan and the United States have discovered a possible answer to the puzzle of the origin of high energy cosmic rays that bombard Earth from all directions in space.

Using data from the Japanese/US X-ray astronomical satellite ASCA, physicists have found strong evidence for the production of cosmic particles in the shock wave of a supernova remnant, the expanding fireball produced by the explosion of a star.

Primary cosmic rays, mostly electrons and protons, travel near the speed of light. Each second, approximately 4 such particles cross one square centimetre of space just outside the Earth's atmosphere. Subsequently, collisions of these primary particles with atoms in the upper atmosphere produce slower secondary particles.

Ever since the discovery of cosmic rays early this century, scientists have debated the origin of these particles and how they can be accelerated to such high speeds. Supernova remnants have long been thought to provide the high energy component, but the evidence has been lacking until now.

The international team of investigators used the satellite to determine that cosmic rays are generated profusely in the remains of the supernova of 1006 AD - which appeared to medieval viewers to be as bright as the Moon - and that they are accelerated to high velocities by an iterative process first suggested by Enrico Fermi in 1949.

Using solid-state X-ray cameras, the ASCA satellite records simultaneous images and spectra of X-rays from celestial sources, allowing astronomers to distinguish different types of X-ray emission.

The tell-tale clue to the discovery was the detection of two diametrically opposite regions in the rapidly expanding supernova remnant, the debris from the stellar explosion. The two regions glow intensely from the synchrotron radiation produced when fast-moving electrons are bent by a magnetic field. The remainder of the supernova remnant, in contrast, emits ordinary "thermal" X-rays from hot gases such as oxygen, neon, and gaseous forms of magnesium, silicon, sulphur, and iron.

The cosmic rays appear to be accelerated in the two regions that glow with synchrotron radiation. Charged particles are accelerated to energies of 100 TeV (10^{14} electron volts) in the turbulent aftermath of the supernova explosion shock wave. In the picture first proposed by Fermi in 1949, many cosmic particles are trapped inside the supernova remnant, bouncing around and continually gaining speed in repeated encounters with the shock front.

This process probably occurs in other 'young' supernova remnants too. There is estimated to be a supernova explosion in our Milky Way galaxy about once every 30 years.

The ASCA satellite was launched from Kagoshima Space Center, Japan aboard a Japanese M-3S-II rocket on 20 February 1993.

Eclipsed neutrinos

The total solar eclipse visible in Southern Asia on 24 October provided an opportunity for an unusual physics experiment.

At face value, the levels of solar neutrinos detected on the Earth's surface are difficult to understand and suggest that perhaps the composition of solar neutrinos oscillates between different neutrino types on their journey. In this way neutrinos originating in the Sun as electron-type could convert into heavy neutrinos, which could subsequently disintegrate into an electron-neutrino and a photon.

In certain neutrino scenarios, such a photon would have an energy corresponding to that of visible light, and in principle should be detectable if there are enough of them. The problem is that they would normally be swamped by the copious photons of sunlight.

The 24 October solar eclipse provided a chance to check this out. A team led by François Vannucci, spokesman of the Nomad neutrino experiment at CERN, en route to the 'Rencontres du Vietnam' physics meeting in Ho Chi Minh Ville, set up a CCD-equipped telescope. To insure against cloud cover, a second telescope followed the eclipse in the desert of Rajastan, India, where the eclipse was to last only half as long, but the chance of cloud was minimal.

No background solar signal was seen, or, expressed in physics terms, if solar radiation has any heavy neutrino component, then less than a millionth of it disintegrates into an electron neutrino and a visible photon before it arrives at the Earth. The negative result also has implications for candidate massive, unstable neutrinos from other sources, notably a component of the missing 'dark matter' of the Universe.

The next such eclipse should be visible in North Asia in 1997, when hopefully better measurements will be made.