

Pace bowlers of the cosmos

The source of very high energy cosmic rays battering the earth may have been located, says S. Ananthanarayanan.

A team of scientists in 90 institutes, worldwide have found that these most energetic particles of the universe come from super heavy black holes, according to a report by the Pierre Auger Collaboration of scientists, to be published in the journal *Science* on 9th Nov.

Cosmic rays

Cosmic rays were discovered in 1912, when Victor Hess found that ionizing radiation increased as the experimenter ascended in a balloon. It looked like there was some kind of radiation that was entering the atmosphere from outer space. The 'rays' are now understood as consisting of particles, mostly the so called 'alpha particles, or nuclei of the helium atom, along with protons, electrons and some other atomic nuclei.

Cosmic rays rarely reach the surface of the earth (and a good thing that) because they interact with the atmosphere and decay. They are usually detected by 'showers' of energetic products of the collision of cosmic rays with atoms of oxygen or nitrogen. Pierre Auger, a French scientist, discovered these showers in 1938.

Energy spread

A good part of the cosmic rays striking the earth seem to come from the sun, from the thermonuclear reaction going on out there. These are relatively low energy cosmic rays. More energetic are the particles that come from neutron stars, supernovae and black holes within our own galaxy. Till the 1950s, when we developed high energy particle accelerators, cosmic rays were the only source of high energy particles for experiments in nuclear science.

But there are cosmic rays with much higher energy than what man-made accelerators can produce. As there are few events in our own galaxy that can create such high energies the general explanation for such cosmic rays is that they come from extragalactic sources. In fact there is a theoretical study, known as the *Greisen-Zatsepin-Kuzmin limit* (GZK limit), which says that a particle with more than about ten million times the energy of the most powerful man-made accelerator would interact with components of the cosmos and slow down. Such particles, if produced more than 163 million light years from the earth, should then never reach the earth. And then, there are no known sources of such particles nearer than that distance. Hence ultra high energy particles should not be detected at all!

Paradox

Yet, in 1991, the University of Utah's Fly Eye observatory observed a cosmic ray particle with energy of a 100 million times that of the fastest man-made particle (10 to the power of 20 electron Volts). This single particle, if it should survive the atmosphere, would strike a person

with the force of a pace bowler's cricket ball! Numerous such events, of ultra high energy particles, have been observed since then. How these particles could be detected on the earth, when theoretically they should not get so far, has been a mystery.

Pierre Auger Project

This was conceived in 1996 by an international group of scientists, to create a pair of fifty million Dollar observatories in Argentina and Utah. The project is ambitious, with a 1,200-square-mile grid of 1,600 large, instrumented water tanks - which detect particles from air showers - and four sites with a total of 24 telescopes that detect faint fluorescent flashes in the sky when a cosmic ray particle triggers an air shower.

The project has been collecting data, from its own facility and from others, since 2004. In the study reported in *Science*, the Auger collaboration reports seventy seven cosmic rays observations with ultrahigh-energies above 40 billion billion electron volts, or 4 times 10 to the 19th power electron volts. Of the twenty seven most energetic events - those with energies above 57 billion billion electron volts - twenty come from the direction of the known locations of some of the three hundred and eighteen *active galactic nuclei* within the Auger Observatory's field of view.

If the cosmic rays were coming randomly from all directions, only five or six would correlate with the known locations of the active galaxies. It is thus statistically highly likely that these particles have actually come from active galactic nuclei.

Active galactic nuclei (AGN)

AGNs are the ultimate in black holes. Black holes are large stars that have collapsed under their own weight and are so massive that they suck in all matter and even the light that they emit - hence their name. AGNs are super massive black holes - million of times more massive than the sun, which exert such forces on matter around them that the matter emits high energy radiation, gamma rays and ultra violet light. It is estimated that many galaxies contain super-massive black holes,

Such radiating cores of large galaxies are known as *Active Galactic Nuclei* and they are considered to be able to create the super high energy cosmic ray particles that now defy the theory that they cannot be seen near the earth!

The Pierre Auger group seems to have discovered that there must be AGNs within the GZK limit, which, in cosmic terms, is the near neighbourhood of the earth!
