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Ray Tracing: Energetic cosmic rays linked to giant black holes

Ron Cowen
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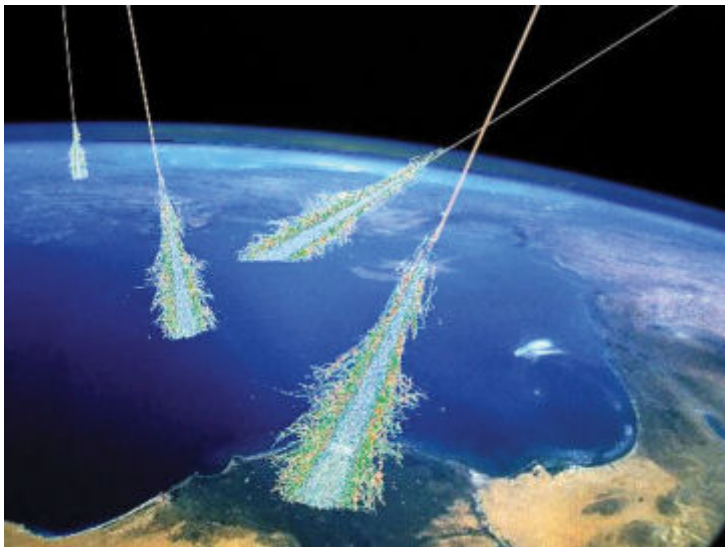
Imagine a single proton smashing into Earth's atmosphere with as much punch as a fast-pitch baseball. For decades, scientists have suspected that protons and other particles with such huge energies, known as ultra-high-energy cosmic rays, arise in the tumultuous surroundings of giant black holes at the centers of galaxies.



CATCHING SOME RAYS. Illustration shows air showers generated by the highest-energy cosmic rays, the most energetic particles known in the universe.

Now, the sprawling Pierre Auger Observatory in Argentina has found the first solid evidence linking these exceedingly rare cosmic rays—the most energetic particles in the universe—to supermassive black holes in nearby galaxies.

"This is a landmark finding for both cosmic-ray physics and astrophysics," says Auger researcher Paul Mantsch of the Fermi National Accelerator Laboratory in Batavia, Ill. Mantsch and a vast team of researchers from 17 countries describe the findings in the Nov. 9 *Science*.

In the study, the observatory recorded 27 cosmic rays with energies greater than 57 billion billion electron volts (eV). The team found that 20 of these 27 ultra-energetic rays came from points in the sky coinciding with the known locations of active galactic nuclei (AGN). Mantsch and his colleagues say there is less than a 1 percent chance that the alignment between the cosmic rays and the AGN is merely random. The AGN all lie relatively close to the Milky Way, no more than 326 million light-years away.

In AGN, black holes feed on swirling disks of gas and dust. As this material spirals into the abyss, it heats up and emits energetic radiation. In addition, AGN typically shoot out enormous jets of high-speed gas. The jets might blast some cosmic rays to

energies millions of times as great as those created in the most powerful accelerators on Earth. But "we don't really know" the acceleration mechanism, cautions Mantsch. The Auger facility, which opened in 2004, detects the cascade of secondary particles generated when cosmic rays smack into Earth's upper atmosphere. This cascade, known as an air shower, can spread over an area as large as 40 square kilometers by the time it reaches Earth's surface. The observatory includes some 1,600 water tanks—particle detectors that scintillate when particles from the shower pass through—spread over 3,000 km^2, along with 24 ultraviolet telescopes that record the faint light generated by the shower as it speeds toward Earth's surface.

Lower-energy cosmic rays may arise from supernova remnants within the Milky Way, but such particles are so easily deflected by magnetic fields that their direction of arrival provides almost no information on where they originate. In contrast, the ultra-high-energy cosmic rays travel nearly in straight lines from their source. The most energetic cosmic rays are also the rarest. They strike a square kilometer of Earth about once per century and require an observatory as vast as Auger to find them.

The close coincidence between the cosmic-ray directions and AGN locations suggests that most of the energetic cosmic rays are protons that have traveled through relatively weak intergalactic magnetic fields en route to Earth, says Mantsch.

Cosmic-ray astronomer Trevor Weekes of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., says that the study is significant but adds that he's a bit surprised that more of the energetic rays aren't associated with the most powerful nearby AGN. The new findings, he says, make a compelling case for building a second Auger observatory in the Northern Hemisphere.