

Science Highlight

Proof: Cosmic Rays Come from Exploding Stars

A recent study confirms what scientists have long suspected: Cosmic rays – energetic particles that pelt Earth from all directions – are born in the violent aftermath of supernovas, exploding stars throughout the galaxy.

Clues from a Space Telescope

The study was led by scientists at the Kavli Institute for Particle Astrophysics and Cosmology, a joint SLAC/Stanford institute. Sifting through four years of data from NASA's Fermi Gamma-ray Space Telescope, they found the first unambiguous evidence of how cosmic rays are born.

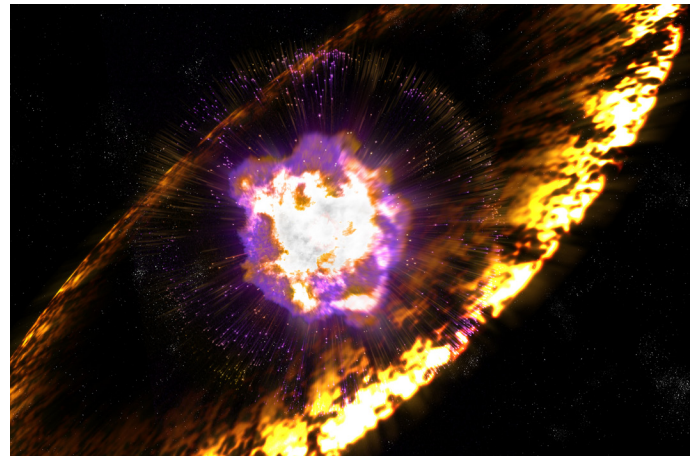
Reporting in the journal *Science*, the team identified two ancient supernovas whose shock waves accelerated protons to nearly the speed of light, turning them into what we call cosmic rays.

When these energetic protons collided with static protons in gas or dust, they gave rise to gamma rays with distinctive signatures, giving scientists the smoking-gun evidence they needed to finally verify the cosmic-ray nurseries.

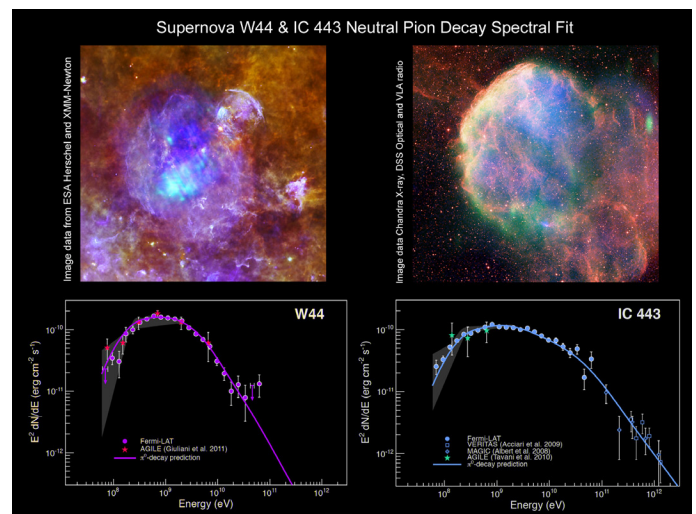
Energetic Protons

Protons make up 90 percent of the cosmic rays that hit Earth's atmosphere, triggering showers of particles that reach the ground and exposing air travelers to radiation. Scientists have theorized that two of the most likely sources for the protons are supernova explosions within our Milky Way galaxy and powerful jets of energy from black holes outside the galaxy.

“The energies of these protons are far beyond what the most powerful particle colliders on Earth can produce,” said Stefan Funk, astrophysicist with the Kavli Institute and Stanford University, who led the analysis. “In the last century we’ve learned a lot about cosmic rays as they arrive here. We’ve even had strong suspicions about the source of their acceleration, but we haven’t had unambiguous evidence to back them up until recently.”



When stars explode, the supernovas send off shock waves like the one shown in this artist's rendition, which accelerate protons to cosmic-ray energies through a process known as Fermi acceleration. (Greg Stewart/SLAC)



Finding evidence for the acceleration of protons has long been a key issue in efforts to explain the origin of cosmic rays. This pair of spectra from two supernova remnants, shown here with data from various satellites and wavelengths, is the “smoking gun” that researchers have been looking for. Observations with the Large Area Telescope – the main instrument on the Fermi Gamma-ray Space Telescope – fit neatly with predictions of neutral pion decay. (NASA/DOE/Fermi LAT Collaboration; Chandra X-ray Observatory; ESA Herschel/XMM-Newton)

That's because the positively charged protons are deflected by any magnetic field they encounter along the way, so tracing them back to their source is impossible. But researchers using Fermi's main instrument, the Large Area Telescope, were able to approach the problem straight on through gamma-ray observations.

A Trail Points Straight Back

When protons that are trapped and accelerated in supernova shock waves hit slower-moving protons, the collision can create particles called neutral pions. The pions, in turn, quickly decay into gamma-ray photons, the most energetic form of light. Unaffected by magnetic fields, the gamma rays travel in a straight line and can be traced back to their source. And the gamma rays from this particular process come in a distinctive range of energies.

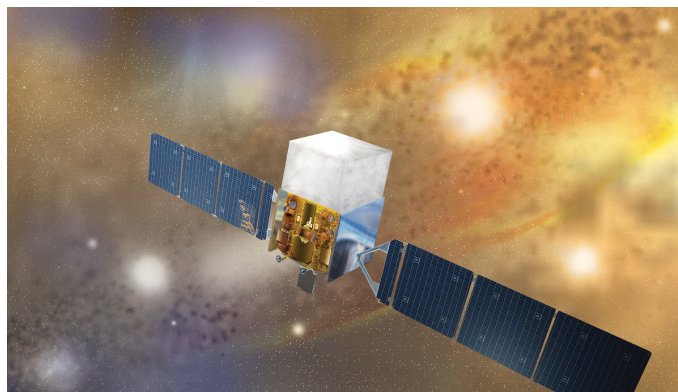
Fermi researchers analyzed data from two supernova remnants thousands of light years away. Both turned out to be strong sources of gamma rays, but not at energies below what neutral pion decay would produce. This was the observational proof scientists had been looking for.

A Theory Confirmed

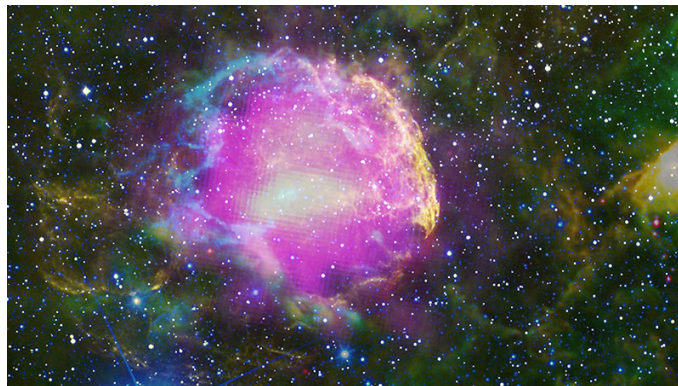
"Until now, we had only theoretical calculations and common sense to guide us in the belief that cosmic rays were generated in supernova remnants," said Jerry Ostriker, an astrophysicist from Columbia University who was not involved in the study. "The direct detection of pion-decay signatures in supernova remnants closes the loop and provides dramatic observational evidence for a significant component of cosmic rays."

As humans spend more time high up in and above the atmosphere, many questions remain to explain the way cosmic rays affect life here on Earth and the fundamental processes that control their origins and acceleration. The next step in this research, Funk said, is to understand the exact details of the acceleration mechanism and also the maximum energies to which supernova remnants can accelerate protons.

*Citation: M. Ackermann et al., Science, 14 Feb 2013
(10.1126/science.1231160)*



Fermi Gamma-ray Space Telescope is an international project launched by NASA in 2008 to observe the universe in gamma rays. These high-energy rays bring us invaluable information about the extreme events that blasted them into space, such as black holes and exploding stars. SLAC managed construction and assembly of Fermi's main instrument, the Large Area Telescope, whose observations were used in this study.
(NASA E/PO; Sonoma State University; Aurore Simonnet)



Supernova remnant IC 443, also known as the Jellyfish Nebula, is one of two supernova remnants identified as cosmic ray nurseries in this study. This image is actually a composite of several images taken in different wavelengths of light.
(NASA/DOE/Fermi LAT Collaboration; Tom Bash and John Fox/Adam Block/NOAO/AURA/NSF; JPL-Caltech/UCLA)