# In the heart of Cygnus, NASA's Fermi reveals a cosmic-ray cocoon

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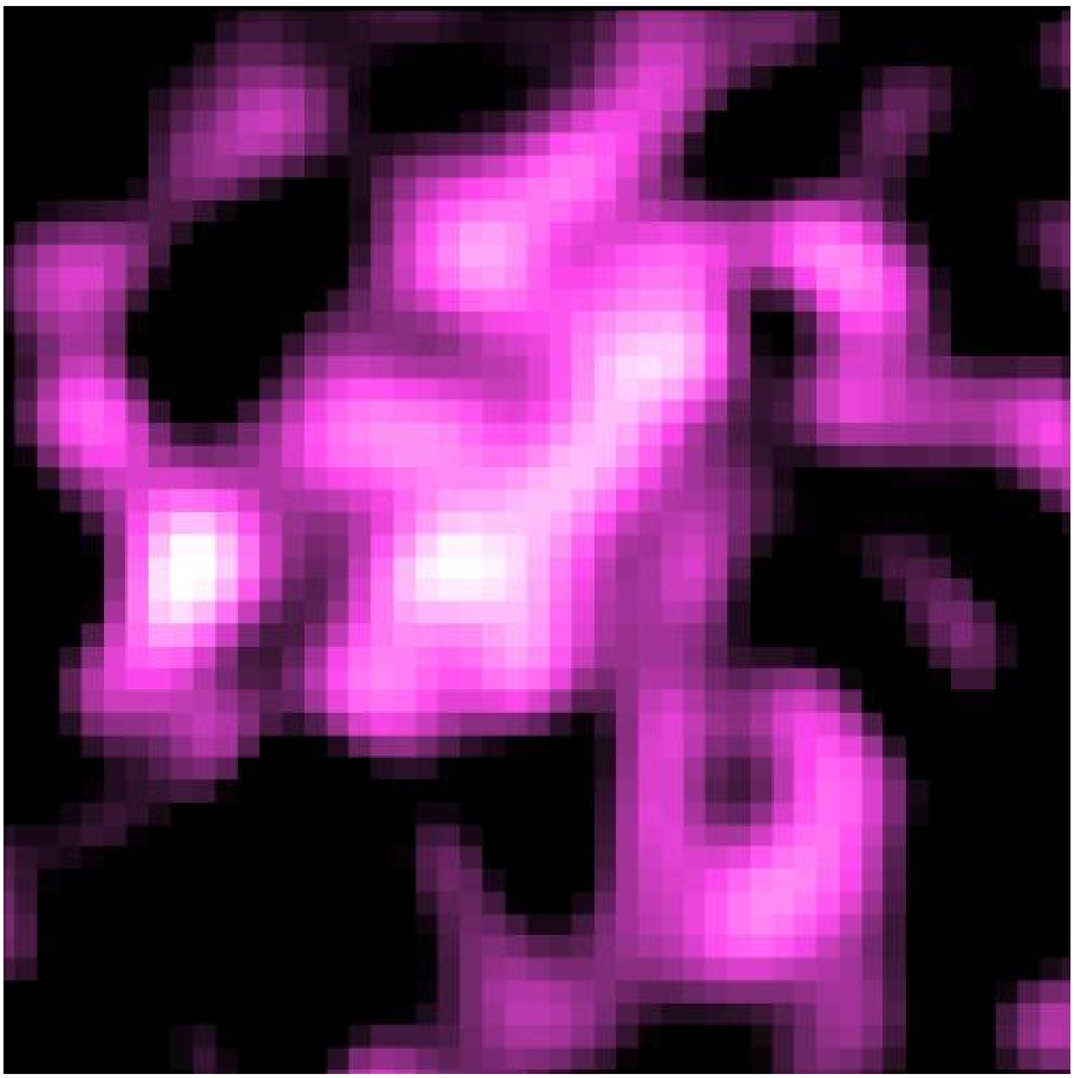


Gamma-ray emission detected by Fermi LAT fills bubbles of hot gas created by the most massive stars in Cygnus X. The turbulence and shock waves produced by these stars make it more difficult for high-energy cosmic rays to traverse the region. When the particles strike gas nuclei or photons of starlight, gamma rays result. Credit: NASA/DOE/Fermi LAT Collaboration/I. A. Grenier and L. Tibaldo

(PhysOrg.com) -- The constellation Cygnus, now visible in the western sky as twilight deepens after sunset, hosts one of our galaxy's richest-known stellar construction zones. Astronomers viewing the region at visible wavelengths see only hints of this spectacular activity thanks to a veil of nearby dust clouds forming the Great Rift, a dark lane that splits the Milky Way, a faint band of light marking our galaxy's central plane.

Located in the vicinity of the second-magnitude star Gamma Cygni, the star-forming region was named Cygnus X when it was discovered as a diffuse radio source by surveys in the 1950s. Now, a study using data from NASA's Fermi Gamma-ray Space Telescope finds that the tumult of star birth and death in Cygnus X has managed to corral fast-moving particles called cosmic rays.

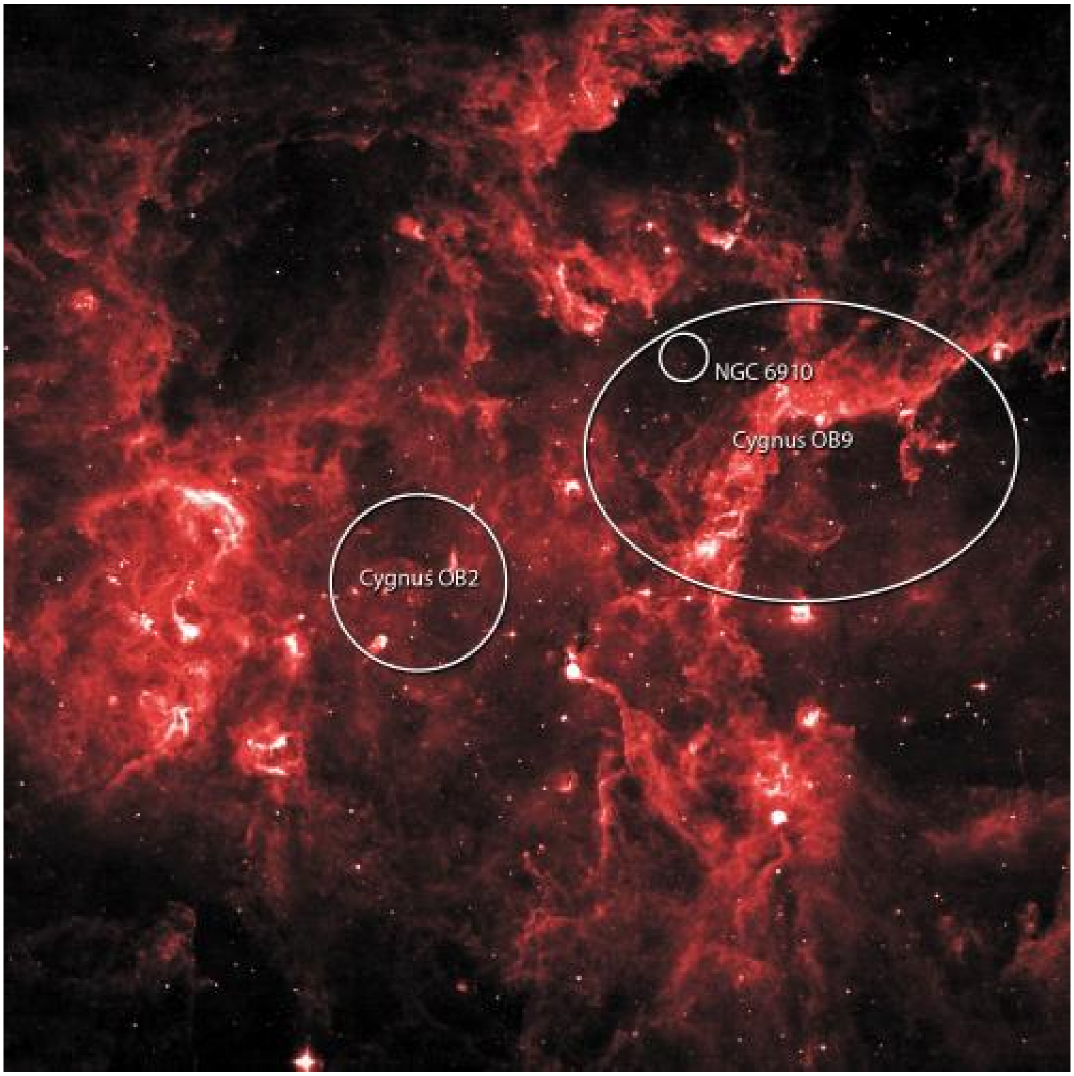
Cosmic rays are subatomic particles -- mainly protons -- that move through space at nearly the speed of light. In their journey across the galaxy, the particles are deflected by magnetic fields, which scramble their paths and make it impossible to backtrack the particles to their sources.

*Video: Tour the Cygnus X star factory. This video opens with wide optical and infrared images of the constellation Cygnus, then zooms into the Cygnus X region using radio, infrared and gamma-ray images. Fermi LAT shows that gamma rays fill cavities in the star-forming clouds. The emission occurs when fast-moving cosmic rays strike hot gas and starlight. Credit: NASA/Goddard Space Flight Center*

Yet when cosmic rays collide with interstellar gas, they produce gamma rays -- the most energetic and penetrating form of light -- that travel to us straight from the source. By tracing gamma-ray signals throughout the galaxy, Fermi's Large Area Telescope (LAT) is helping astronomers understand the sources of cosmic rays and how they're accelerated to such high speeds. In fact, this is one of the mission's key goals.

The galaxy's best candidate sites for cosmic-ray acceleration are the rapidly expanding shells of ionized gas and magnetic field associated with supernova explosions. For stars, mass is destiny, and the most massive ones -- known as types O and B -- live fast and die young.

They're also relatively rare because such extreme stars, with masses more than 40 times that of our sun and surface temperatures eight times hotter, exert tremendous influence on their surroundings. With intense ultraviolet radiation and powerful outflows known as stellar winds, the most massive stars rapidly disperse their natal gas clouds, naturally limiting the number of massive stars in any given region.




Cygnus X hosts many young stellar groupings, including the OB2 and OB9 associations and the cluster NGC 6910. The combined outflows and ultraviolet radiation from the region's numerous massive stars have heated and pushed gas away from the clusters, producing cavities of hot, lower-density gas. In this 8-micron infrared image, ridges of denser gas mark the boundaries of the cavities. Bright spots within these ridges show where stars are forming today. Credit: Credit: NASA/IPAC/MSX

Which brings us back to Cygnus X. Located about 4,500 light-years away, this star factory is believed to contain enough raw material to make two million stars like our sun. Within it are many young star clusters and several sprawling groups of related O- and B-type stars, called OB associations. One, called Cygnus OB2, contains 65 O stars -- the most massive, luminous and hottest type -- and nearly 500 B stars.

Astronomers estimate that the association's total stellar mass is 30,000 times that of our sun, making Cygnus OB2 the largest object of its type within 6,500 light-years. And with ages of less than 5 million years, few of its most massive stars have lived long enough to exhaust their fuel and explode as supernovae.

Intense light and outflows from the monster stars in Cygnus OB2 and from several other nearby associations and star clusters have excavated vast amounts of gas from their vicinities. The stars reside within cavities filled with hot, thin gas surrounded by ridges of cool, dense gas where stars are now forming. It's within the hollowed-out zones that Fermi's LAT detects intense gamma-ray emission, according to a paper describing the findings that was published in the Nov. 25 edition of the journal Science.

"We are seeing young cosmic rays, with energies comparable to those produced by the most powerful particle accelerators on Earth. They have just started their galactic voyage, zig-zagging away from their accelerator and producing gamma rays when striking gas or starlight in the cavities," said co-author Luigi Tibaldo, a physicist at Padova University and the Italian National Institute of Nuclear Physics.

The energy of the gamma-ray emission, which is measured up to 100 billion electron volts by the LAT and even higher by ground-based gamma-ray detectors, indicates the extreme nature of the accelerated particles. (For comparison, the energy of visible light is between 2 and 3 electron volts.) The environment holds onto its cosmic rays despite their high energies by entangling them in turbulent magnetic fields created by the combined outflows of the region's numerous high-mass stars.

"These shockwaves stir the gas and twist and tangle the magnetic field in a cosmic-scale jacuzzi so the young cosmic rays, freshly ejected from their accelerators, remain trapped in this turmoil until they can leak into quieter interstellar regions, where they can stream more freely," said co-author Isabelle Grenier, an astrophysicist at Paris Diderot University and the Atomic Energy Commission in Saclay, France.

The well known Gamma Cygni supernova remnant – so named for its proximity to the star -- also lies within this region; astronomers estimate its age at about 7,000 years. The Fermi team considers it possible that the supernova remnant spawned the cosmic rays trapped in the Cygnus X "cocoon," but they also suggest an alternative scenario where the particles became accelerated through repeated interaction with shockwaves produced inside the cocoon by powerful stellar winds.

"Whether the particles further gain or lose energy inside this cocoon needs to be investigated, but its existence shows that cosmic-ray history is much more eventful than a random walk away from their sources," Tibaldo added.

Fermi is providing a never-before-seen glimpse of the early life of cosmic rays, long before they diffuse into the galaxy at large. Astronomers know of a dozen stellar clusters at least as young and rich as Cygnus OB2, including the Arches and Quintuplet clusters near the galaxy's center. Energetic gamma rays are detected in the vicinity of several of them, so perhaps they also corral cosmic rays in their own high-energy cocoons.

Provided by NASA's Goddard Space Flight Center