

Exploding stars and stripes

March 24 2011



This image comes from a very deep Chandra observation of the Tycho supernova remnant, produced by the explosion of a white dwarf star in our Galaxy. Low-energy X-rays (red) in the image show expanding debris from the supernova explosion and high energy X-rays (blue) show the blast wave, a shell of extremely energetic electrons. These high-energy X-rays show a pattern of X-ray "stripes" never previously seen in a supernova remnant. Some of the brightest stripes can be seen on the right side of the remnant pointing from the outer rim to the interior. The stellar background is from the Digitized Sky Survey and only shows stars outside the remnant. Credit: X-ray: NASA/CXC/Rutgers/K. Eriksen et al.; Optical: DSS

The discovery of a pattern of X-ray "stripes" in the remains of an exploded star may provide the first direct evidence that a cosmic event can accelerate particles to energies a hundred times higher than achieved by the most powerful particle accelerator on Earth.

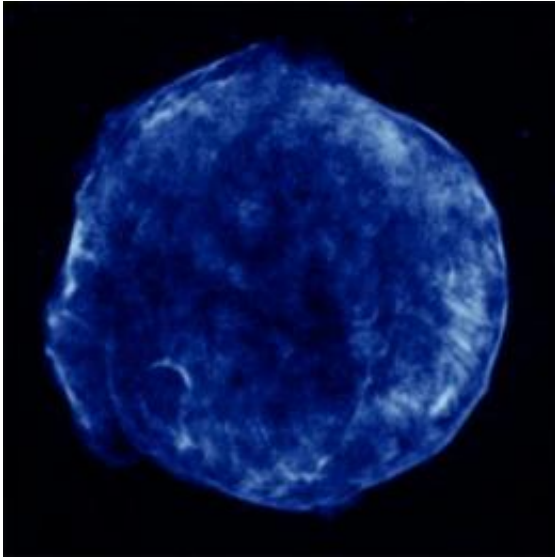
This result comes from a very long observation of the Tycho supernova remnant with NASA's Chandra X-ray Observatory. It could explain how some of the extremely energetic particles bombarding the Earth, called cosmic rays, are produced.

"We've seen lots of intriguing structures in supernova remnants, but we've never seen stripes before," said Kristoffer Eriksen, a postdoctoral researcher at Rutgers University who led the study. "This made us think very hard about what's happening in the blast wave of this powerful explosion." This latest study from Chandra provides support for a theory about how magnetic fields can be dramatically amplified in such blast waves.

In this theory, the magnetic fields become highly tangled and the motions of the particles very turbulent near the expanding supernova shock wave at the front edge of the supernova remnant. High-energy charged particles can bounce back and forth across the shock wave repeatedly, gaining energy with each crossing. [Theoretical models](#) of the motion of the most energetic particles – which are mostly protons – are predicted to leave a messy network of holes and dense walls corresponding to weak and strong regions of magnetic fields, respectively.

The X-ray stripes discovered by the Chandra researchers are thought to be regions where the turbulence is greater and the magnetic fields more tangled than surrounding areas, and may be the walls predicted by the theory. Electrons become trapped in these regions and emit X-rays as they spiral around the [magnetic field](#) lines.

However, the regular and almost periodic pattern of the X-ray stripes was not predicted by the theory.



High-energy X-rays in this image of the Tycho supernova remnant show a pattern of X-ray "stripes" never previously seen in a supernova remnant. These stripes may provide the first direct evidence that supernova remnants can accelerate particles to energies a hundred times higher than achieved by the most powerful particle accelerator on Earth, the Large Hadron Collider. The results could explain how some of the extremely energetic particles bombarding the Earth, called cosmic rays, are produced, and they provide support for a theory about how magnetic fields can be dramatically amplified in such blast waves. Credit: X-ray: NASA/CXC/Rutgers/K. Eriksen et al.; Optical: DSS

"It was a big surprise to find such a neatly arranged set of stripes," said co-author Jack Hughes, professor of physics and astronomy at Rutgers. "We were not expecting so much order to appear in so much chaos. It could mean that the theory is incomplete, or that there's something else we don't understand."

Assuming that the spacing between the X-ray stripes corresponds to the radius of the spiraling motion of the highest energy protons in the supernova remnant, the spacing corresponds to energies about 100 times higher than reached in the Large Hadron Collider. These energies equal

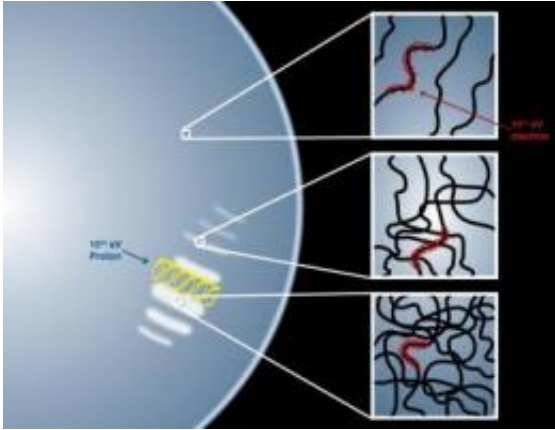
the highest energies of cosmic rays thought to be produced in our Galaxy.

Because cosmic rays are composed of charged particles, like protons and electrons, their direction of motion changes when they encounter magnetic fields throughout the galaxy. So, the origin of individual cosmic rays detected on Earth cannot be determined.

Supernova remnants have long been considered a good candidate for producing the most energetic cosmic rays in our Galaxy. The protons can reach energies that are hundreds of times higher than the highest energy electrons, but since they do not radiate efficiently like the electrons, direct evidence for the acceleration of cosmic ray protons in supernova remnants has been lacking.

These results also support the prediction that magnetic fields in interstellar space are greatly amplified in supernova remnants, but the difference between the observed and predicted structures means that other interpretations cannot be ruled out.

"We were excited to discover these stripes because they might allow us to directly track, for the first time, the origin of the most energetic particles produced in our galaxy," said Eriksen. "But, we're not claiming victory yet."



X-ray stripes are thought to be regions where the turbulence is greater and the magnetic fields more tangled than surrounding areas. Electrons become trapped in these regions and emit X-rays as they spiral around the magnetic field lines. Regions with enhanced turbulence and magnetic fields were expected in supernova remnants, but the motion of the most energetic particles -- mostly protons -- was predicted to leave a messy network of holes and dense walls corresponding to weak and strong regions of magnetic fields, respectively.
 Credit: CXC/M. Weiss

The Tycho supernova remnant is named for the famous Danish astronomer Tycho Brahe, who reported observing the supernova in 1572. Scientists think the explosion occurred when a white dwarf star grew in mass and exceeded its weight limit, forming a so-called Type Ia supernova. The Tycho remnant is located in the Milky Way, about 13,000 light years from Earth.

"[Supernova remnants](#) are our best cosmic laboratories for understanding how nature accelerates the highest energy [cosmic rays](#)," said Roger Blandford of Stanford University, a noted expert in this field who was not involved with these findings. "These careful measurements provide a very strong clue as to what actually happens at these giant shock fronts."

More information: These results were published in the February 20th, 2011 issue of *The Astrophysical Journal Letters*.

Provided by Chandra X-ray Center

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