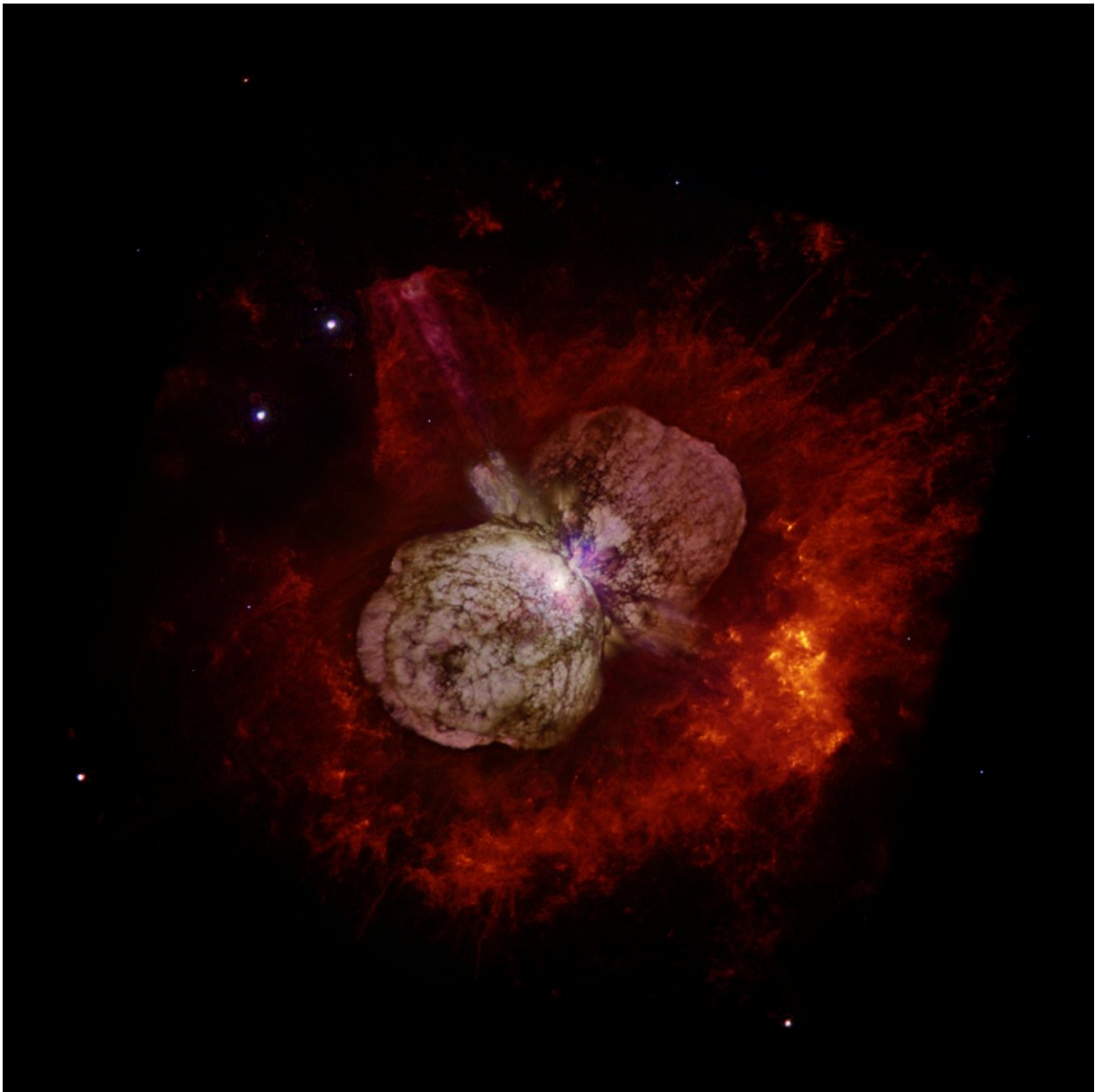


NuSTAR mission proves superstar Eta Carinae shoots cosmic rays

July 3 2018, by Francis Reddy



Eta Carinae's great eruption in the 1840s created the billowing Homunculus Nebula, imaged here by Hubble. Now about a light-year long, the expanding cloud contains enough material to make at least 10 copies of our Sun.

Astronomers cannot yet explain what caused this eruption. Credit: NASA, ESA, and the Hubble SM4 ERO Team

A new study using data from NASA's NuSTAR space telescope suggests that Eta Carinae, the most luminous and massive stellar system within 10,000 light-years, is accelerating particles to high energies—some of which may reach Earth as cosmic rays.

"We know the blast waves of exploded stars can accelerate [cosmic ray particles](#) to speeds comparable to that of light, an incredible [energy boost](#)," said Kenji Hamaguchi, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and the lead author of the study. "Similar processes must occur in other extreme environments. Our analysis indicates Eta Carinae is one of them."

Astronomers know that cosmic rays with energies greater than 1 billion electron volts (eV) come to us from beyond our solar system. But because these particles—electrons, protons and atomic nuclei—all carry an electrical charge, they veer off course whenever they encounter magnetic fields. This scrambles their paths and masks their origins.

Eta Carinae, located about 7,500 light-years away in the southern constellation of Carina, is famous for a 19th century outburst that briefly made it the second-brightest star in the sky. This event also ejected a massive hourglass-shaped nebula, but the cause of the eruption remains poorly understood.

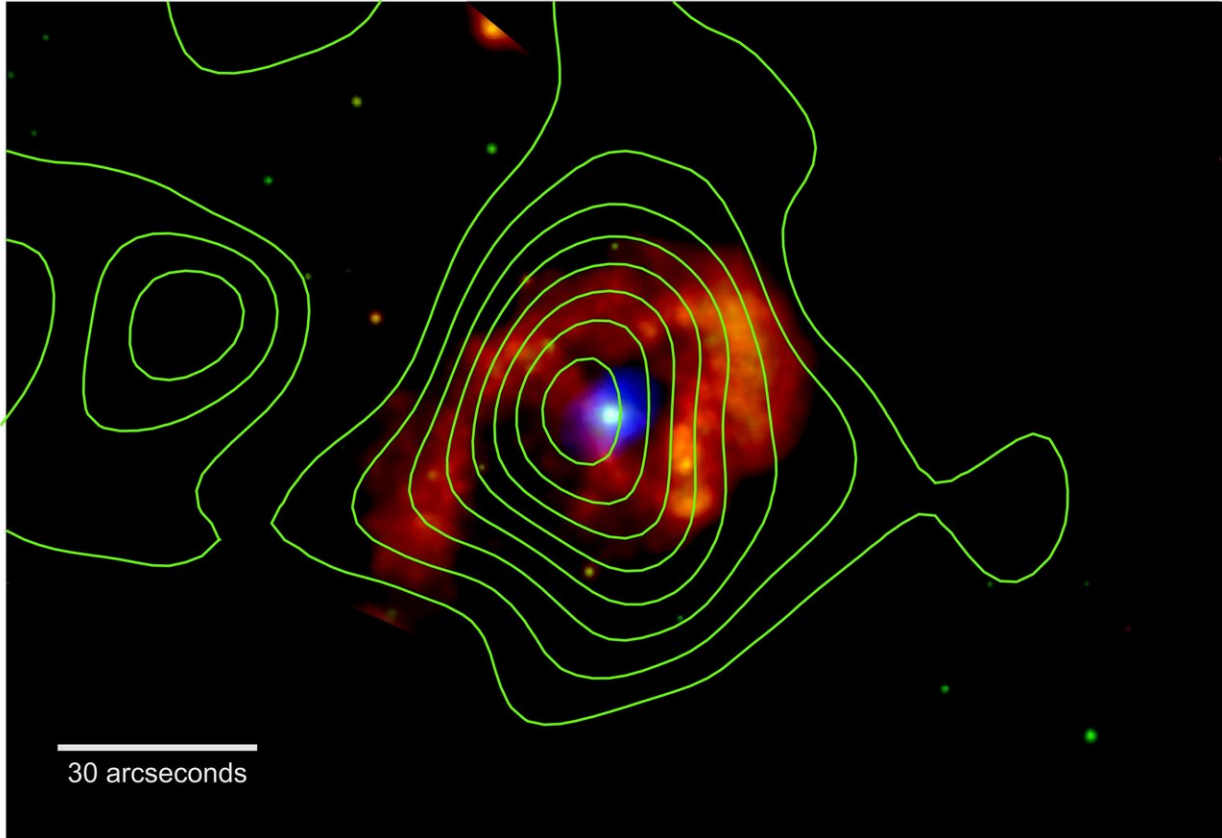
The system contains a pair of massive stars whose eccentric orbits bring

them unusually close every 5.5 years. The stars contain 90 and 30 times the mass of our Sun and pass 140 million miles (225 million kilometers) apart at their closest approach—about the average distance separating Mars and the Sun.

"Both of Eta Carinae's stars drive powerful outflows called stellar winds," said team member Michael Corcoran, also at Goddard. "Where these winds clash changes during the orbital cycle, which produces a periodic signal in low-energy X-rays we've been tracking for more than two decades."

NASA's Fermi Gamma-ray Space Telescope also observes a change in [gamma rays](#)—light packing far more energy than X-rays—from a source in the direction of Eta Carinae. But Fermi's vision isn't as sharp as X-ray telescopes, so astronomers couldn't confirm the connection.

To bridge the gap between low-energy X-ray monitoring and Fermi observations, Hamaguchi and his colleagues turned to NuSTAR. Launched in 2012, NuSTAR can focus X-rays of much greater energy than any previous telescope. Using both newly taken and archival data, the team examined NuSTAR observations acquired between March 2014 and June 2016, along with lower-energy X-ray observations from the European Space Agency's XMM-Newton satellite over the same period.



Eta Carinae shines in X-rays in this image from NASA's Chandra X-ray Observatory. The colors indicate different energies. Red spans 300 to 1,000 electron volts (eV), green ranges from 1,000 to 3,000 eV and blue covers 3,000 to 10,000 eV. For comparison, the energy of visible light is about 2 to 3 eV. NuSTAR observations (green contours) reveal a source of X-rays with energies some three times higher than Chandra detects. X-rays seen from the central point source arise from the binary's stellar wind collision. The NuSTAR detection shows that shock waves in the wind collision zone accelerate charged particles like electrons and protons to near the speed of light. Some of these may reach Earth, where they will be detected as cosmic ray particles. X-rays scattered by debris ejected in Eta Carinae's famous 1840 eruption may produce the broader red emission. Credit: NASA/CXC and NASA/JPL-Caltech

Eta Carinae's low-energy, or soft, X-rays come from gas at the interface

of the colliding stellar winds, where temperatures exceed 70 million degrees Fahrenheit (40 million degrees Celsius). But NuSTAR detects a source emitting X-rays above 30,000 eV, some three times higher than can be explained by shock waves in the colliding winds. For comparison, the energy of visible light ranges from about 2 to 3 eV.

The team's analysis, presented in a paper published on Monday, July 2, in *Nature Astronomy*, shows that these "hard" X-rays vary with the binary orbital period and show a similar pattern of energy output as the gamma rays observed by Fermi.

The researchers say that the best explanation for both the hard X-ray and the gamma-ray emission is electrons accelerated in violent shock waves along the boundary of the colliding [stellar winds](#). The X-rays detected by NuSTAR and the gamma rays detected by Fermi arise from starlight given a huge energy boost by interactions with these electrons.

Some of the superfast electrons, as well as other accelerated particles, must escape the system and perhaps some eventually wander to Earth, where they may be detected as [cosmic rays](#).

"We've known for some time that the region around Eta Carinae is the source of energetic emission in high-energy X-rays and gamma rays", said Fiona Harrison, the principal investigator of NuSTAR and a professor of astronomy at Caltech in Pasadena, California. "But until NuSTAR was able to pinpoint the radiation, show it comes from the binary and study its properties in detail, the origin was mysterious."

More information: Kenji Hamaguchi et al. Non-thermal X-rays from colliding wind shock acceleration in the massive binary Eta Carinae, *Nature Astronomy* (2018). [DOI: 10.1038/s41550-018-0505-1](https://doi.org/10.1038/s41550-018-0505-1)

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