A binary star as a cosmic particle accelerator

July 1 2020

Using the High Energy Sterescopic System H.E.S.S., astrophysicists have identified colliding stellar winds from the double star Eta Carinae as a new type of source of very high-energy (VHE) cosmic gamma radiation. Credit: DESY, Science Communication Lab

With a specialized telescope in Namibia a DESY-led team of researchers has proven a certain type of binary star as a new kind of source for very high-energy cosmic gamma-radiation. Eta Carinae is located 7500 lightyears away in the constellation Carina (the ship's keel) in the

Southern Sky and, based on the data collected, emits gamma rays with energies all the way up to 400 gigaelectronvolts (GeV), some 100 billion times more than the energy of visible light. The team headed by DESY's Stefan Ohm, Eva Leser and Matthias Füßling is presenting its findings, made at the gamma-ray observatory High Energy Stereoscopic System (H.E.S.S.), in the journal *Astronomy & Astrophysics*. An accompanying multimedia animation explains the phenomenon. "With such visualizations we want to make the fascination of research tangible," emphasizes DESY's Director of Astroparticle Physics, Christian Stegmann.

Eta Carinae is a binary system of superlatives, consisting of two blue giants, one about 100 times, the other about 30 times the mass of our sun. The two stars orbit each other every 5.5 years in very eccentric elliptical orbits, their separation varying approximately between the distance from our Sun to Mars and from the Sun to Uranus. Both these gigantic stars fling dense, supersonic stellar winds of charged particles out into space. In the process, the larger of the two loses a mass equivalent to our entire Sun in just 5000 years or so. The smaller one produces a fast stellar wind traveling at speeds around eleven million kilometers per hour (about one percent of the speed of light).

A huge shock front is formed in the region where these two stellar winds collide, heating up the material in the wind to extremely high temperatures. At around 50 million degrees Celsius, this matter radiates brightly in the X-ray range. The particles in the stellar wind are not hot enough to emit gamma radiation, though. "However, shock regions like this are typically sites where subatomic particles are accelerated by strong prevailing electromagnetic fields," explains Ohm, who is the head of the H.E.S.S. group at DESY. When particles are accelerated this rapidly, they can also emit gamma radiation. In fact, the satellites "Fermi," operated by the US space agency NASA, and AGILE, belonging to the Italian space agency ASI, already detected energetic gamma rays of up to about 10 GeV coming from Eta Carinae in 2009.

"Different models have been proposed to explain how this gamma radiation is produced," Füßling reports. "It could be generated by accelerated electrons or by high-energy atomic nuclei." Determining which of these two scenarios is correct is crucial: very energetic atomic nuclei account for the bulk of the so-called Cosmic Rays, a subatomic cosmic hailstorm striking Earth constantly from all directions. Despite intense research for more than 100 years, the sources of the Cosmic Rays are still not exhaustively known. Since the electrically charged atomic nuclei are deflected by cosmic magnetic fields as they travel through the universe, the direction from which they arrive at Earth no longer points back to their origin. Cosmic gamma rays, on the other hand, are not deflected. So, if the gamma rays emitted by a specific source can be shown to originate from high-energy atomic nuclei, one of the long-sought accelerators of cosmic particle radiation will have been identified.

"In the case of Eta Carinae, electrons have a particularly hard time getting accelerated to high energyies, because they are constantly being deflected by magnetic fields during their acceleration, which makes them lose energy again," says Leser. "Very high-energy gamma radiation begins above the 100 GeV range, which is rather difficult to explain in Eta Carinae to stem from electron acceleration." The satellite data already indicated that Eta Carinae also emits gamma radiation beyond 100 GeV, and H.E.S.S. has now succeeded in detecting such radiation up to energies of 400 GeV around the time of the close encounter of the two blue giants in 2014 and 2015. This makes the binary star the first known example of a source in which very high-energy gamma radiation is generated by colliding stellar winds.

"The analysis of the gamma radiation measurements taken by H.E.S.S. and the satellites shows that the radiation can best be interpreted as the product of rapidly accelerated atomic nuclei," says DESY's Ph.D. student Ruslan Konno, who has published a companion study, together with scientists from the Max Planck Institute for Nuclear Physics in Heidelberg. "This would make the shock regions of colliding stellar winds a new type of natural particle accelerator for cosmic rays." With H.E.S.S., which is named after the discoverer of Cosmic Rays, Victor Franz Hess, and the upcoming Cherenkov Telescope Array (CTA), the next-generation gamma-ray observatory currently being built in the Chilean highlands, the scientists hope to investigate this phenomenon in greater detail and discover more sources of this kind.

Thanks to detailed observations of Eta Carinae at all wavelengths, the properties of the stars, their orbits and stellar winds have been determined relatively accurately. This has given astrophysicists a better picture of the binary star system and its history. To illustrate the new observations of Eta Carinae, the DESY astrophysicists have produced a video animation together with the animation specialists of the award-winning Science Communication Lab. The computer-generated images are close to reality because the measured orbital, stellar and wind parameters were used for this purpose. The internationally acclaimed multimedia artist Carsten Nicolai, who uses the pseudonym Alva Noto for his musical works, created the sound for the animation.

"I find science and scientific research extremely important," says Nicolai, who sees close parallels in the creative work of artists and scientists. For him, the appeal of this work also lay in the artistic mediation of scientific research results: "particularly the fact that it is not a film soundtrack, but has a genuine reference to reality," emphasizes the musician and artist. Together with the exclusively composed sound, this unique collaboration of scientists, animation artists and musician has resulted in a multimedia work that takes viewers on an extraordinary journey to a superlative double star some 7500 light years away.

More information: Detection of very-high-energy γ-ray emission from the colliding wind binary η Car with H.E.S.S., *Astronomy & Astrophysics* (2020). DOI: 10.1051/0004-6361/201936761

R. White et al. Gamma-ray and X-ray constraints on non-thermal processes in η Carinae, *Astronomy & Astrophysics* (2020). dx.doi.org/10.1051/0004-6361/201937031

Provided by Deutsches Elektronen-Synchrotron

Citation: A binary star as a cosmic particle accelerator (2020, July 1) retrieved 25 April 2024 from https://phys.org/news/2020-07-binary-star-cosmic-particle.html