Astronomers unveil 'heart' of Eta Carinae

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An international team of astronomers has imaged the Eta Carinae star system in the greatest detail ever. Eta Carinae is a colossal binary system that consists of two massive stars orbiting each other. It is found almost 8,000 light years from Earth within the Carina Nebula, a giant star-forming region in the Carina-Sagittarius Arm of the Milky Way.

The images enabled the astronomers to observe unexpected new structures in the binary system, including a region between the two stars in which extremely high-velocity stellar winds are colliding.

"With these observations, we were able to map the zone in which the two stellar winds collide and make sure we genuinely understand the basic parameters of the binary system," said Augusto Damineli, Full Professor at the University of São Paulo's Institute of Astronomy, Geophysics & Atmospheric Sciences (IAG-USP) in Brazil.

Damineli has studied mysterious phenomena involving Eta Carinae for more than 20 years with FAPESP's support and is one of the three Brazilian authors of the paper published by *Astronomy & Astrophysics*.

The other two are Mairan Macedo Teodoro, a researcher at NASA's Goddard Space Flight Center, and José Henrique Groh de Castro Moura, a professor at Trinity College Dublin in Ireland.

According to the researchers, the Eta Carinae binary pair are so massive and bright that the radiation they produce rips atoms off their surfaces and spews them into space. This expulsion of atomic material is referred to as stellar wind.

The raging winds from Eta Carinae are much faster and denser than the solar wind streaming off our own Sun. They collide violently in the zone between the two stars at speeds that can reach 10 million km per hour.

The combined effect of the two stellar winds as they smash into each other at extreme speeds is to create temperatures of millions of degrees and intense deluges of X-ray radiation.

The central area where the raging winds collide is so comparatively tiny that telescopes in space and on the ground have not been able to image them in detail - until now.

Utilizing an advanced new imaging technique called infrared long baseline interferometry, which combines light beams collected from the same astronomic object by several telescopes to analyze it in great detail, the researchers were able to observe the turbulent collision zone for the first time.

They did this with the Astronomical Multi-Beam Recombiner known as AMBER, an instrument currently installed on the Very Large Telescope Interferometer (VLTI) at the European Southern Observatory's Paranal Facility in Chile's Atacama Desert.

They used three of the VLT's four auxiliary telescopes, each with a diameter of 1.8 m and mounted on tracks so that they can move up to 200 m apart.

Image sharpness increases with telescope separation, so the astronomers were able to achieve a tenfold increase in resolving power compared with one of the VLT array's main telescopes, delivering for the first time direct images 50,000 times finer than human vision of both the wind that swirls around Eta Carinae's primary star and the wind collision zone between the two stars.

Using the Doppler effect, which enables astronomers to calculate precisely how fast stars and other astronomical objects are moving toward or away from Earth, they obtained images of the stellar winds at different velocities, measuring velocities and densities to compare them with a computer model of the collision.

"The images we obtained via the Doppler effect show the stellar winds colliding at different velocities," Damineli said. "So we were able to use them to reconstruct the shape of the walls of the cavity formed by the collision shockwave from its apex to the most distant regions."

The researchers also observed in the images an unexpected fan-shaped structure where the raging wind from the smaller, hotter star crashes into the denser wind from the larger of the pair.

The wind from the secondary star is less dense but much fiercer than the wind from the primary star, reaching velocities of 3,000 km per second, they estimated.

On the basis of these stellar wind velocities, they hope to be able to create more accurate computer models of Eta Carinae's internal structure and increase their understanding of how extremely massive stars lose mass as they evolve.

"Because light from the secondary star is 200-300 times weaker than light from the primary, we couldn't see it directly with AMBER," Damineli said. "We should be able to do so with GRAVITY, a new VLTI instrument due to come on stream soon."

GRAVITY is an interferometric instrument operating in the K band and combining four telescope beams. Its higher resolution will enable the astronomers to obtain interferometric images of astronomic objects with even greater precision and over a wider range of wavelengths.

According to Damineli, they may succeed in tracking Eta Carinae's secondary star from point to point along its 5.5-year orbit and plotting its ellipse.

"When we've done that we'll at last be able to 'weigh' the secondary star. Mass is a star's most fundamental parameter," he said.

Provided by FAPESP

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