Gamma-ray telescopes measure diameters of distant stars

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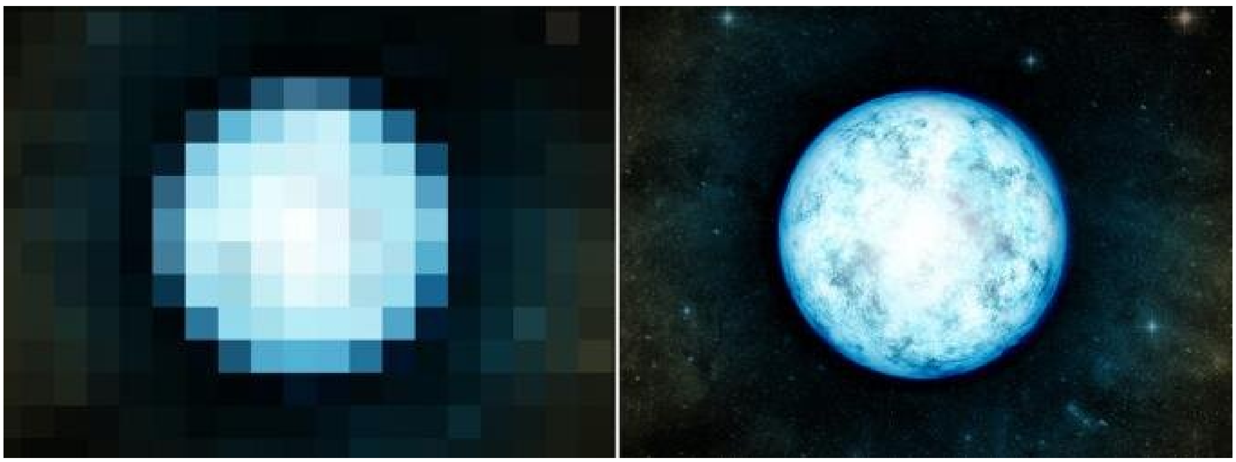

Adding more telescopes at greater distances can improve the angular resolution of Stellar Intensity Interferometry up to the capability to image stellar surfaces (artist's concept). Credit: CfA, M. Weiss

By reviving a technique capable of combining specialized gamma-ray telescopes to one giant virtual instrument, scientists have measured the diameters of individual stars hundreds of light-years away. The team used the four VERITAS telescopes (Very Energetic Radiation Imaging Telescope Array System) in the US as one combined instrument to determine the size of Beta Canis Majoris—a blue giant star located 500 light-years from the sun—and Epsilon Orionis—a blue supergiant star located 2,000 light-years from the sun. The Stellar Intensity

Interferometry technique, demonstrated for the first time nearly 50 years ago, could be a secondary use for other gamma-ray observatories as well, including the upcoming Cherenkov Telescope Array (CTA). The team led by astronomers from the Harvard & Smithsonian Center for Astrophysics (CfA) and the University of Utah and including scientists from DESY report their findings in the journal *Nature Astronomy*.

"A proper understanding of stellar physics is important for a massive range of astronomical fields, from exoplanet studies to cosmology, and yet they are often seen as point sources of light due to their great distances from Earth," said Nolan Matthews from the University of Utah. "Interferometry has been widely successful in achieving the angular resolution needed to spatially resolve stars and we've demonstrated the capability to perform optical intensity interferometry measurements with an array of many telescopes that in turn will help to improve our understanding of stellar systems."

Usually, the VERITAS telescopes monitor the sky for faint blue flashes of Cherenkov light that are produced when gamma rays from the cosmos hit Earth's atmosphere. However, these observations are limited to dark moonless hours. The team used time during which VERITAS cannot perform its normal observations in December 2019. "Modern electronics allow us to computationally combine light signals from each telescope. The resulting instrument has the optical resolution of a football-field-sized reflector," said Principal Investigator David Kieda from the University of Utah. "This is the first demonstration of the original Hanbury Brown and Twiss technique using an array of optical telescopes."

The team observed both stars for several hours. The measurements resulted in angular diameters of 0.523 milliarcseconds for Beta Canis Majoris and 0.631 milliarcseconds for Epsilon Orionis. A milliarcsecond is about the size of a two-eurocent coin atop the Eiffel Tower in Paris as seen from New York. "The measured values for both stars are in good agreement with previous measurements with the same technique made with the Narrabri telescopes in the 1970s," said DESY scientist Tarek Hassan who was involved in the analysis of the VERITAS measurements. The Narrabri telescopes were the first instruments performing stellar measurements using Stellar Intensity Interferometry and were operating from 1963 to 1974. The VERITAS team demonstrated both improvements to the sensitivity of the technique and its scalability using digital electronics.

The scientists have proven that dozens of telescopes could be combined using modern electronics. This could prove an interesting option for the future Cherenkov Telescope Array. It will be the world's largest gamma-ray observatory. CTA will feature gamma-ray telescopes in three size classes, DESY is responsible for the medium-sized telescopes. "CTA will employ up to 99 telescopes with kilometer baseline in the southern hemisphere and 19 telescopes with several hundred-meter baselines in the Northern hemisphere," explained Hassan. "Performing Stellar Intensity Interferometry measurements with the future CTA would allow us to study stars with unparalleled angular resolution."

Intensity interferometry could not only enable scientists to determine the diameters of stars, but also to image stellar surfaces, and to measure the properties of systems like interacting binary stars, rapidly rotating stars, or the pulsation of Cepheid variables, among others.Having previously measured the apparent diameter of some very small stars in the sky using the asteroid occultation method, the new study is one more indicator that gamma-ray telescopes, and their scientists, are more than meets the eye.

More information: A. U. Abeysekara et al. Demonstration of stellar intensity interferometry with the four VERITAS telescopes, *Nature Astronomy* (2020). DOI: 10.1038/s41550-020-1143-y

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