Very high energy gamma-ray emission from a radio galaxy

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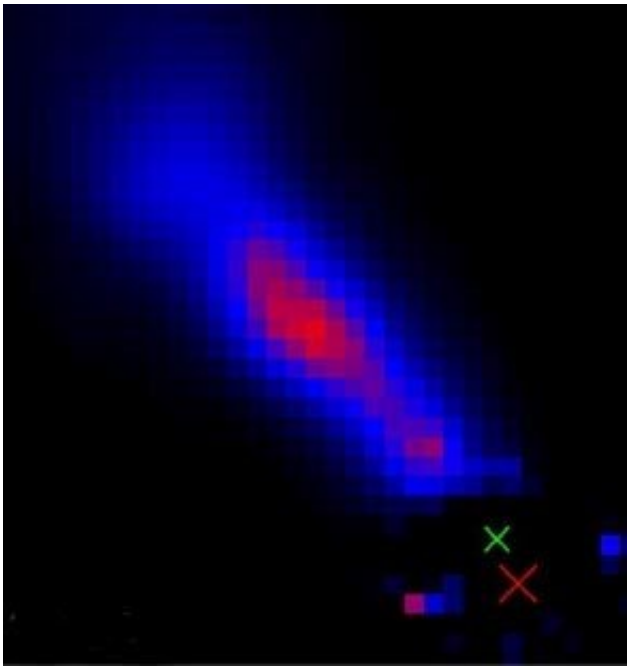

A Hubble image of the radio galaxy 3C264 and its jet (the light from the galaxy itself and its inner disk have been subtracted to make it easier to see the jet). The red cross marks the location of the supermassive black hole AGN (the green cross marks the location of a jet feature). The image is about one thousand light-years across. Astronomers have detected variable, very high energy gamma-ray emission from the supermassicve black hole nucleus of this galaxy. Credit: NASA/Archer et al., 2020

Giant elliptical galaxies, the oldest known large galactic structures in the universe, have no spiral arms and little or no current star formation

activity, but their central supermassive black holes are often active galactic nuclei (AGN). While nearly all galaxies host a supermassive black hole in their nuclei, most nuclei are not AGN. Astronomers think that giant ellipticals formed in the early universe, less than a billion years after the big bang, after a phase of rapid star-formation, and then evolved to become even larger through galaxy mergers and accretion of gas from the intergalactic medium. The same accretion helps feed the AGN that drive the ejection of powerful jets of rapidly moving charged particles. The particles emit strongly at radio frequencies, making these objects bright targets for radio telescopes, and many of these galaxies were first discovered in radio surveys.

VERITAS, the Very Energetic Radiation Imaging Telescope Array System, is a CfA observatory consisting of four 12-m telescopes located at the Fred L. Whipple Observatory at Mt. Hopkins, Arizona. VERITAS is designed to study gamma ray photons, each one packing approximately hundred million times the energy of the highest energy X-ray photon seen by the Chandra X-ray Observatory. CfA astronomers Wystan Benbow, Michael Daniel, Pascal Fortin, Gareth Hughes, and Emmet Roache, together with a large team of colleagues, used VERITAS to search for gamma-ray photons from the AGN in radio-bright, old elliptical galaxies. They and other astronomers realized that the same AGN-produced jets of charged particles that radiate at radio wavelengths can, because they are moving at speeds close to that of light, produce gamma-ray emission when its particles interact with low energy photons. This emission is particularly bright if those jets are being observed nearly face-on.

The astronomers used VERITAS to study the AGN in the elliptical galaxy 3C264 during 2017—2019. They discovered very high energy gamma-ray emission in early 2018 and realized this emission must be variable. The emission made this AGN, located about three hundred million light-years from Earth, the most distant very high energy gamma-

ray emitting AGN of only four known with jets that are not observed face-on. They followed up this discovery with a large campaign of observations by a variety of multi-wavelength telescopes: Swift, Fermi-LAT, Chandra X-ray Observatory, and Hubble in space, and optical and radio observations on the ground using the Kitt Peak robotically controlled telescope, the Very Long Baseline Array, and the Very Large Array. The team's complex multi-wavelength data and analysis program allowed them to determine that 3C264 is probably similar to the famous (and very much closer) galaxy M87 and its jet; M87 contains the supermassive black hole that was imaged last year. Only about two hundred very high energy gamma-ray sources have been discovered so far, including both AGN and non-AGN. The new results on 3C264, as one of only four known non face-on AGN in elliptical galaxies, expand our knowledge of AGN jets and their underlying physics. The team is continuing to monitor the source: four bright knots are seen in the radio jet and two are expected to collide in the next few years, with some fireworks expected when this happens.

More information: A. Archer et al. VERITAS Discovery of VHE Emission from the Radio Galaxy 3C 264: A Multiwavelength Study, *The Astrophysical Journal* (2020). DOI: 10.3847/1538-4357/ab910e

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