Study identifies a tidal disruption event that coincides with the production of a high-energy neutrino

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The intense radiation stemming from the TDE debris disk around the black hole (centre) heats surrounding dust until it begins to radiate brightly in the infrared. This process is called a dust echo. Credit: Science Communication Lab and DESY.

High-energy neutrinos are highly fascinating subatomic particles produced when very fast charged particles collide with other particles or photons. IceCube, a renowned neutrino detector located at the South Pole, has been detecting extragalactic high-energy neutrinos for almost a decade.

While many physicists have examined the observations gathered by the IceCube detector, the origin of most of the high-energy neutrinos it detected has not yet been determined. These neutrinos were detected beyond our galaxy and could result from various cosmological events.

Researchers at Deutsches Elektronen Synchrotron DESY, Humboldt-Universität zu Berlin and other academic institutes in Europe and the U.S. have recently carried out a study focusing on a specific violent cosmological event, which is referred to as AT2019fdr. Their paper, published in *Physical Review Letters*, shows that this event could be the origin of a high-energy neutrino.

"Our team has been conducting a systematic study for 3 years, where we used the optical survey telescope of the Zwicky Transient Facility (ZTF) to scan the sky region of each new high-energy neutrino that we can observe," Simeon Reusch, one of the researchers who carried out the study, told Phys.org. "Our recent paper examines a possible source for one of these neutrinos, a huge optical outburst in a very distant galaxy, which has been called AT2019fdr."

AT2019fdr, the optical outburst examined by Reusch and his colleagues, is a transient event, which means that it changes over time. The researchers studied this event in great depth, trying to determine its possible source.

Based on their analyses, they concluded that AT2019fdr was most likely a tidal disruption event (TDE). TDEs occur when a star approaches the supermassive black hole at the center of a galaxy and is close enough to be affected by it.

"As the star approaches the black hole, the gravitational pull in front of the star is much stronger than at its back, ripping the star apart," Reusch explained. "Around half of the mass of the star is then accreted around the black hole, causing the debris to shine brightly for months."

Reusch and his colleagues also tried to determine whether AT2019fdr could be the possible origin of the high-energy neutrino they observed. To do this, they teamed up with theoretical physicists who could model the source and make theoretical predictions based on their models.

"We tried to gather as much electromagnetic data on AT2019fdr as possible, spanning a wide range of wavelengths," Reusch said. "We observed the location and gathered preexisting data for it in radio, infrared, optical, UV, X-ray and gamma-ray wavelengths."

In their analysis, the researchers assessed both the AT2019fdr event and other possible sources for the high-energy neutrino they observed, all of which were situated within a reasonable proximity. Interestingly, they ruled out all sources except for AT2019fdr, due to their light curve (i.e., brightness profile over time) or due to the optical spectra they took.

"The strong dust echo we detected is in the infrared range, tying AT2019fdr to a subclass of dust echo sources in the center of galaxies," Reusch said. "The actual 'echo' is produced when the intense radiation from the TDE heats surrounding dust, which then starts to glow in the infrared range. The huge size of the system causes time delays due to light travel times, which is the reason why the peak of the dust echo is delayed with respect to the flare."

Reusch and his colleagues also observed a late-time X-ray signal with the eROSITA aboard the SRG satellite, with an extremely soft spectrum.

Overall, both their measurements and theoretical analyses point to AT2019fdr as the source of the high-energy neutrino they observed. In addition, the team's findings suggest that AT2019fdr is a TDE and not a superluminous supernova, a "regular" flare stemming from the center of the galaxy, or another type of cosmological event.

"Our findings are noteworthy, as a previous paper by our group had already identified a TDE (AT2019fdr) as the likely source of another high-energy neutrino," Reusch added. "If indeed these TDEs were both neutrino sources, they must be quite efficient in producing high-energy neutrinos. Multi-messenger studies like the one presented in our paper provide insights into cosmic particle accelerators like TDEs or AGN that are not possible based on photons alone."

In their next studies, the researchers will conduct more analyses to further validate their findings. In addition, they plan to seek for other TDEs within the large cosmological event dataset compiled by ZTF so far.

More information: Simeon Reusch et al, Candidate Tidal Disruption Event AT2019fdr Coincident with a High-Energy Neutrino, *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.221101

Robert Stein et al, A tidal disruption event coincident with a high-energy neutrino, *Nature Astronomy* (2021). DOI: 10.1038/s41550-020-01295-8