Hubble finds bizarre explosion in unexpected place

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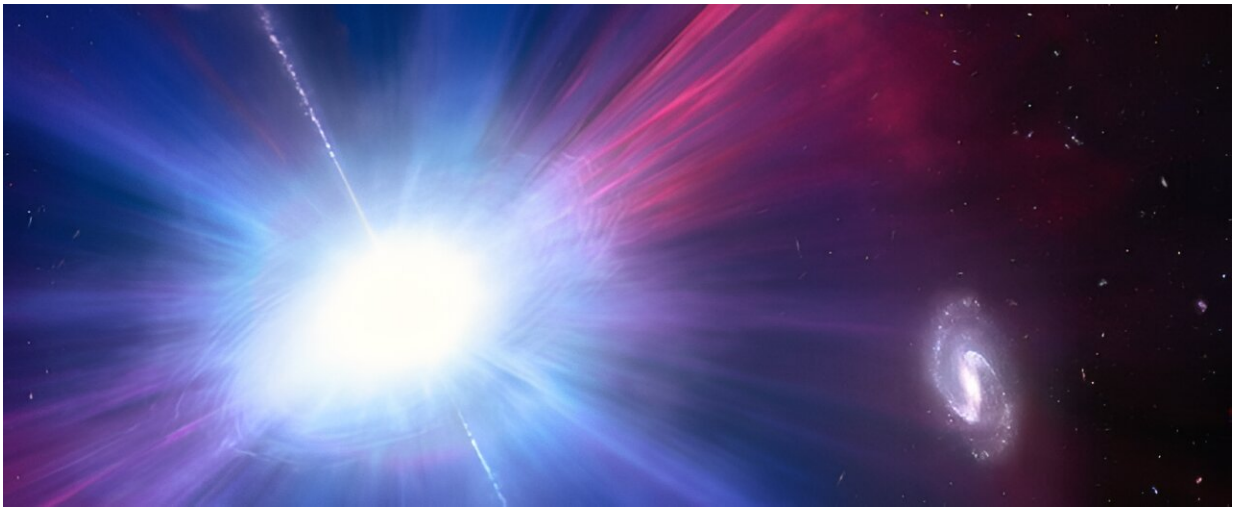


Credit: NASA, ESA, NSF's NOIRLab, M. Garlick , M. Zamani

A very rare, strange burst of extraordinarily bright light in the universe just got even stranger—thanks to the eagle-eye of the NASA/ESA Hubble Space Telescope. The phenomenon, called a Luminous Fast Blue Optical Transient (LFBOT), flashed onto the scene where it wasn't expected to be found, far away from any host galaxy. Only Hubble could pinpoint its location. The Hubble results suggest astronomers know even less about these objects than previously thought by ruling out some possible theories.

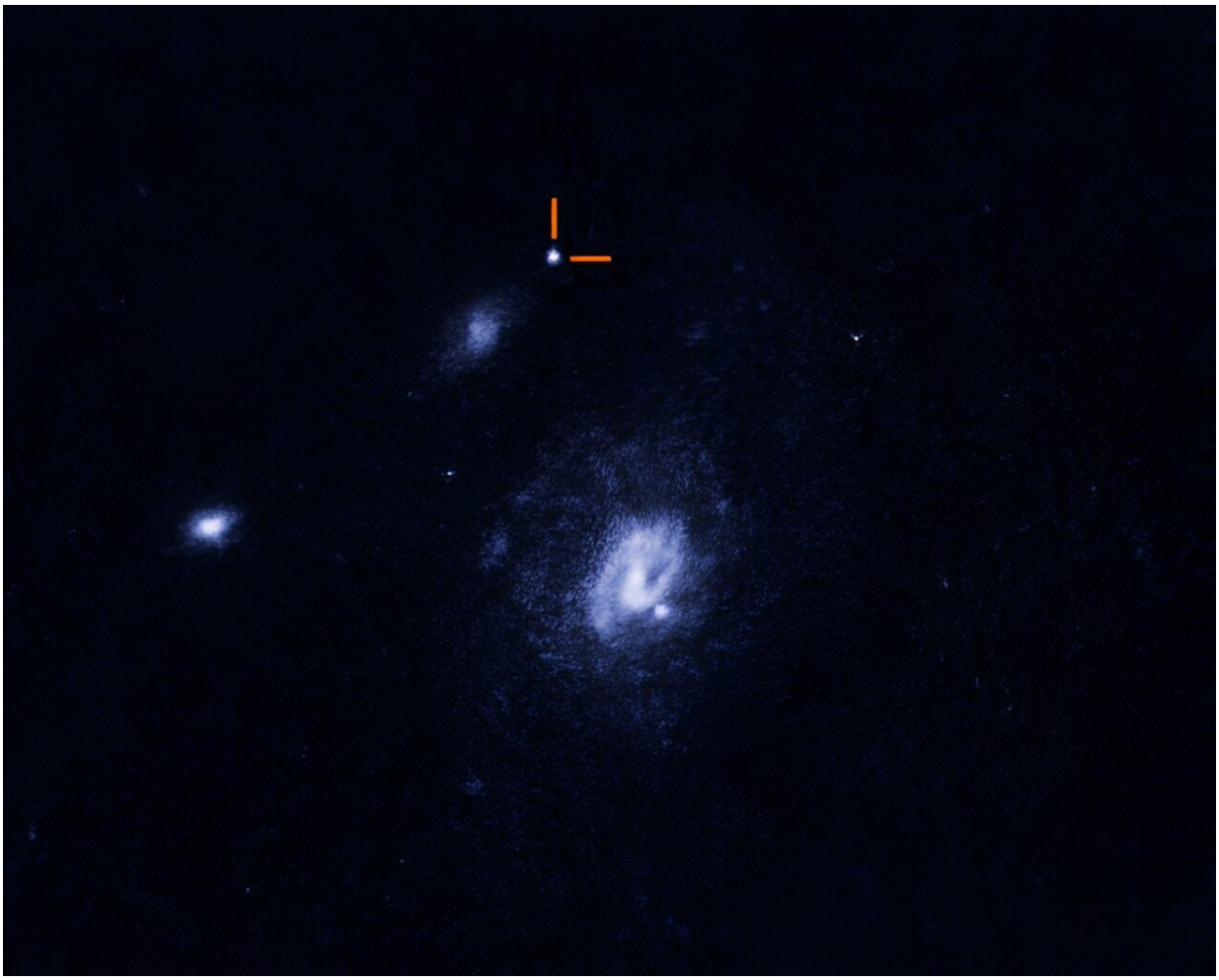
Luminous Fast Blue Optical Transients (LFBOT) are among the brightest known visible-light events in the universe—going off unexpectedly like camera flashbulbs. Only a handful have been found since the first discovery in 2018. Presently, LFBOTS are detected about once per year.

After its initial detection, the latest LFBOT was observed by multiple telescopes across the electromagnetic spectrum, from X-rays to radio waves. Only Hubble's exquisitely sharp resolution could pinpoint its location. Designated AT2023fhn and nicknamed "the Finch," the transitory event showed all the telltale characteristics of an LFBOT. It shined intensely in blue light and evolved rapidly, reaching peak brightness and fading again in a matter of days, unlike supernovae, which take weeks or months to dim.

But unlike any other LFBOT seen before, Hubble found that the Finch is located in apparent isolation between two neighboring galaxies—about 50,000 light-years from a nearby spiral galaxy and about 15,000 light-years from a smaller galaxy—a baffling locale for celestial objects previously thought to exist within host galaxies.

"The Hubble observations were really the crucial thing. They made us realize that this was unusual compared to the other ones like that, because without the Hubble data we would not have known," said Ashley Chrimes, lead author of the Hubble paper reporting the discovery. He is also a European Space Agency Research Fellow, formerly of Radboud University, Nijmegen in the Netherlands.

The study will be published in an upcoming issue of the *Monthly Notices of the Royal Astronomical Society* , and the paper is currently available on the *arXiv* preprint server.



Hubble image of a Luminous Fast Blue Optical Transient (LFBOT) This Hubble photograph shows three galaxies against the velvet-black backdrop of space. The largest is the white and blue spiral-shaped galaxy at the image center. Two smaller galaxies are whitish patches toward the left. A curious white spot near the top of the image is marked out with two perpendicular orange lines. It is the glow from some unknown object that exploded, but isn't associated with any of the galaxies.] Credit: NASA, ESA, STScI, A. Chrimes (Radboud University)

While these awesome explosions have been assumed to be a rare type of supernova (called core-collapse supernovae), the gargantuan stars that turn into supernovae are short-lived by stellar standards. Therefore, the

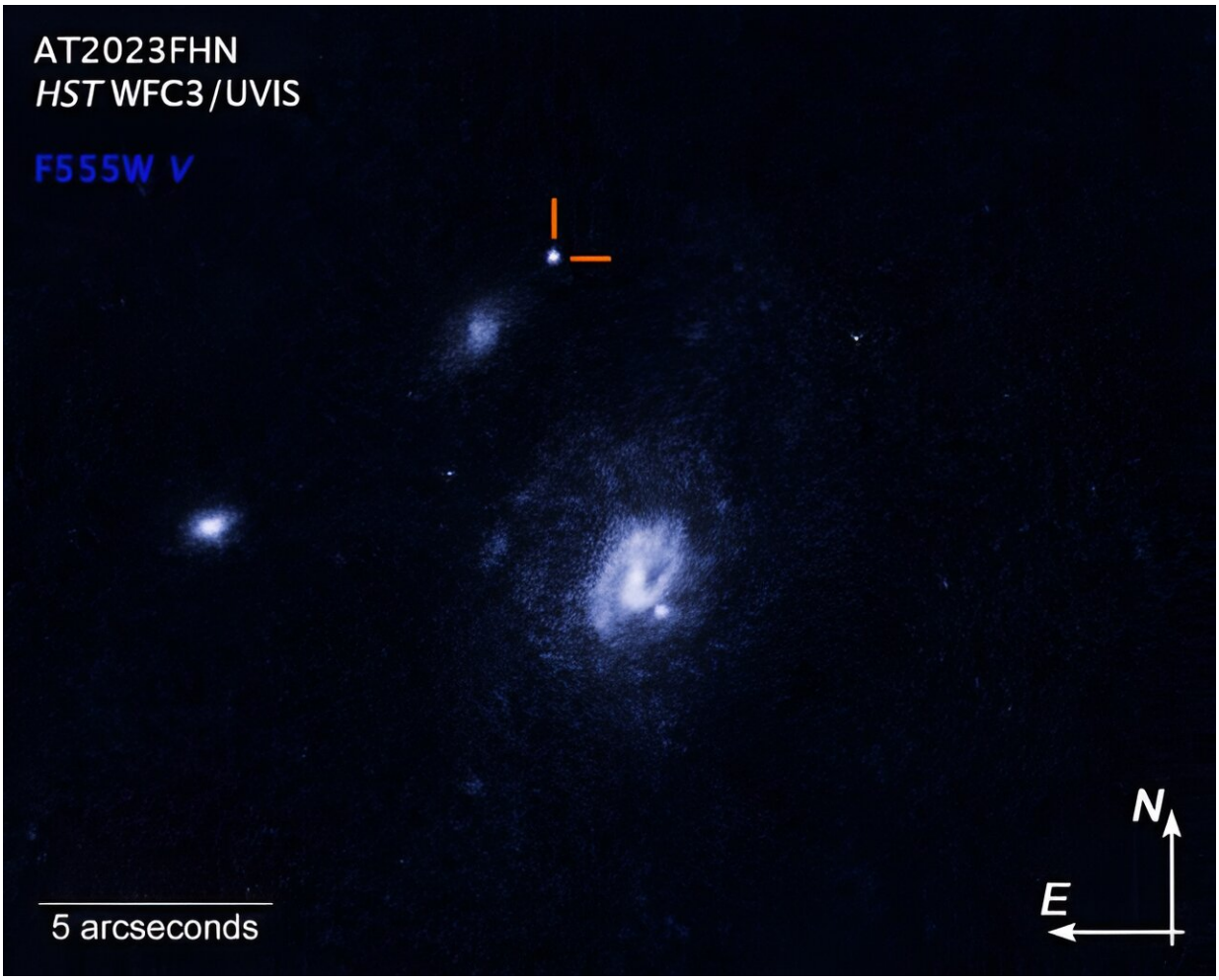
massive progenitor stars to supernovae don't have time to travel very far from their birthing place—a cluster of newborn stars. All previous LFBOTs have been found in the spiral arms of galaxies where star birth is ongoing.

"The more we learn about LFBOTs, the more they surprise us," said Chrimes. "We've now shown that LFBOTs can occur a long way from the center of the nearest galaxy, and the location of the Finch is not what we expect for any kind of supernova."

The Zwicky Transient Facility—an extremely wide-angle ground-based camera that scans the entire northern sky every two days—first alerted astronomers to the Finch on 10 April 2023. Once it was spotted, the researchers triggered a pre-planned program of observations that had been on standby, ready to quickly turn their attention to any potential LFBOT candidates that arose.

Spectroscopic measurements made with the Gemini South telescope in Chile found that the Finch is a scorching 20,000 degrees Celsius. Gemini also helped determine its distance from Earth so its luminosity could be calculated. Together with data from other observatories including the Chandra X-ray Observatory and the Very Large Array radio telescope, these findings confirmed the explosion was indeed an LFBOT.

The LFBOTs could be the result of stars being torn apart by an intermediate-mass black hole (between 100 to 1,000 solar masses). The NASA/ESA/CSA James Webb Space Telescope's high resolution and infrared sensitivity might eventually be used to find that the Finch exploded inside a globular star cluster in the outer halo of one of the two neighboring galaxies. A globular star cluster is the most likely place an intermediate-mass black hole could be found.



This Hubble photograph shows three galaxies against the black backdrop of space. The largest is the white and blue spiral-shaped galaxy at the image center. Two smaller galaxies are whitish patches toward the left. A curious white spot near the top of the image is marked out with two perpendicular orange lines. The image is labeled with the name of the white spot, coordinates and a scale marker. Credit: NASA, ESA, STScI, A. Chrimes (Radboud University)

To explain the unusual location of the Finch, the researchers are considering the alternative possibility that it is the result of a collision of two neutron stars, traveling far outside their host galaxy, that have been spiraling toward each other for billions of years.

Such collisions produce a kilonova—an explosion 1,000 times more powerful than a standard supernova. However, one very speculative theory is that if one of the neutron stars is highly magnetized—a magnetar—it could greatly amplify the power of the explosion even further to 100 times the brightness of a normal supernova.

"The discovery poses many more questions than it answers," said Chrimes. "More work is needed to figure out which of the many possible explanations is the right one."

Because astronomical transients can pop up anywhere and at any time, and are relatively fleeting in astronomical terms, researchers rely on wide-field surveys that can continuously monitor large areas of the sky to detect them and alert other observatories like Hubble to do follow-up observations.

A larger sample is needed to converge on a better understanding of the phenomenon, say researchers. Upcoming all-sky survey telescopes may be able to detect more, depending on the underlying astrophysics.

More information: A. A. Chrimes et al, AT2023fhn (the Finch): a Luminous Fast Blue Optical Transient at a large offset from its host galaxy, *arXiv* (2023). DOI: 10.48550/arxiv.2307.01771

Provided by NASA