Hubble finds telltale fireball after gamma ray burst

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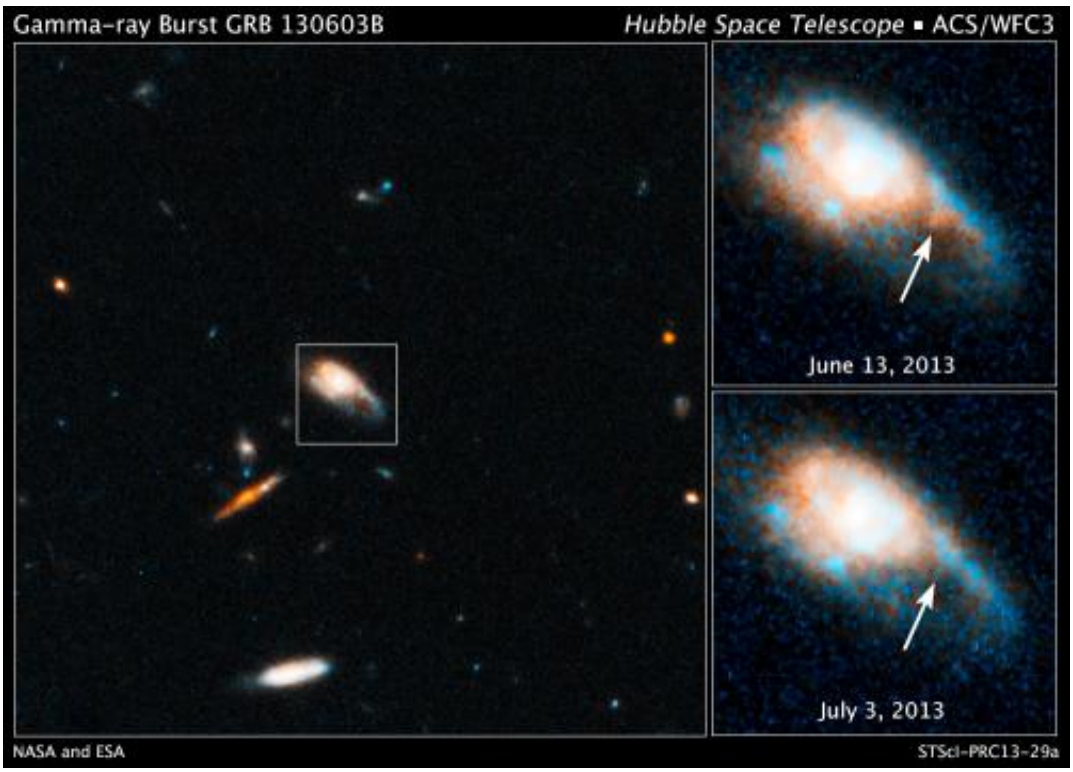

These images taken by NASA's Hubble Space Telescope reveal a new type of stellar explosion produced from the merger of two compact objects. Hubble spotted the outburst while looking at the aftermath of a short- duration gamma-ray burst, a mysterious flash of intense high-energy radiation that appears from random directions in space. Short-duration blasts last at most a few seconds. They sometimes, however, produce faint afterglows in visible and near-infrared light that continue for several hours or days and help astronomers pinpoint the exact location of the burst. In the image at left, the galaxy in the center produced the gamma-ray burst, designated GRB 130603B. The galaxy, cataloged as SDS J112848.22+170418.5, resides almost 4 billion light-years away. A probe of the

galaxy with Hubble's Wide Field Camera 3 on June 13, 2013, revealed a glow in near-infrared light at the source of the gamma-ray burst, shown in the image at top, right. When Hubble observed the same location on July 3, the source had faded, shown in the image at below, right. The fading glow provided key evidence that it was the decaying fireball of a new type of stellar blast called a kilonova. Kilonovas are about 1,000 times brighter than a nova, which is caused by the eruption of a white dwarf. But they are 1/10th to 1/100th the brightness of a typical supernova, the self-detonation of a massive star. Credit: NASA, ESA, N. Tanvir (University of Leicester), A. Fruchter (STScI), and A. Levan (University of Warwick)

(Phys.org) —NASA's Hubble Space Telescope has provided the strongest evidence yet that short-duration gamma-ray bursts are triggered by the merger of two small, super-dense stellar objects, such as a pair of neutron stars or a neutron star and a black hole.

The definitive evidence came from Hubble observations in near-infrared light of the fading fireball produced in the aftermath of a short gamma-ray burst (GRB). The afterglow reveals for the first time a new kind of stellar blast called a kilonova, an explosion predicted to accompany a short-duration GRB.

A kilonova is about 1,000 times brighter than a nova, which is caused by the eruption of a white dwarf. Such a stellar blast, however, is only 1/10th to 1/100th the brightness of a typical supernova, the self-detonation of a massive star.

Gamma-ray bursts are mysterious flashes of intense high-energy radiation that appear from random directions in space. Short-duration blasts last at most a few seconds, but they sometimes generate faint afterglows in visible and near-infrared light that continue for several hours or days.

The afterglows have helped astronomers determine that GRBs lie in distant galaxies. The cause of short-duration GRBs, however, remains a mystery. The most popular theory is that astronomers are witnessing the energy released as two compact objects crash together. But, until now, astronomers have not gathered enough strong evidence to prove it, say researchers.

A team of researchers led by Nial Tanvir of the University of Leicester in the United Kingdom has used Hubble to study a recent short-duration burst in near-infrared light. The observations revealed the fading afterglow of a kilonova explosion, providing the "smoking gun" evidence for the merger hypothesis.

"This observation finally solves the mystery of the origin of short gamma-ray bursts," Tanvir said. "Many astronomers, including our group, have already provided a great deal of evidence that long-duration gamma-ray bursts (those lasting more than two seconds) are produced by the collapse of extremely massive stars. But we only had weak circumstantial evidence that short bursts were produced by the merger of compact objects. This result now appears to provide definitive proof supporting that scenario."

Astrophysicists have predicted that short-duration GRBs are created when a pair of super-dense neutron stars in a binary system spiral together. This event happens as the system emits gravitational radiation, tiny ripples in the fabric of space-time. The energy dissipated by the waves causes the two objects to sweep closer together. In the final milliseconds, as the two objects merge, the death spiral kicks out highly radioactive material. This material heats up and expands, emitting a burst of light. This powerful kilonova blast emits as much visible and near-infrared light every second as the Sun does every few years. A kilonova lasts for about a week.

In a recent science paper Jennifer Barnes and Daniel Kasen of the University of California, Berkeley, and the Lawrence Berkeley National Laboratory presented new calculations predicting how kilonovas should look. They predicted that the same hot plasma producing the radiation will also act to block the visible light, causing the gusher of energy from the kilonova to flood out in near-infrared light over several days.

An unexpected opportunity to test this model came on June 3 when NASA's Swift Space Telescope picked up the extremely bright gamma-ray burst, cataloged as GRB 130603B, in a galaxy located almost 4 billion light-years away. Although the initial blast of gamma rays lasted just one-tenth of a second, it was roughly 100 billion times brighter than the subsequent kilonova flash.

The visible-light afterglow was detected at the William Herschel Telescope and its distance was determined with the Gran Telescopio Canarias, both located in the Canary Islands.

"We quickly realized this was a chance to test Barnes' and Kasen's new theory by using Hubble to hunt for a kilonova in near-infrared light," Tanvir said. The calculations suggested that the light would most likely be brightest in near-infrared wavelengths about 3 to 11 days after the initial blast. The researchers needed to act quickly before the light faded, so they requested Director's Discretionary Observing Time with Hubble's Wide Field Camera 3.

On June 12-13 Hubble searched the location of the initial burst, spotting a faint red object. An independent analysis of the data from another research team confirmed the detection. Subsequent Hubble observations three weeks later, on July 3, revealed that the source had faded away, therefore providing the key evidence it was the fireball from an explosive event.

"Previously, astronomers had been looking at the aftermath of short-period bursts largely in optical light, and were not really finding anything besides the light of the gamma-ray burst itself," explained Andrew Fruchter of the Space Telescope Science Institute in Baltimore, Md., a member of Tanvir's research team. "But this new theory predicts that when you compare near-infrared and optical images of a short gamma-ray burst about a week after the blast, the kilonova should pop out in the infrared, and that's exactly what we're seeing."

In addition to confirming the nature of short GRBs, the discovery has two important implications. First, the origin of many heavy chemical elements in the universe, including gold and platinum, has long been a puzzle. Kilonovas are predicted to form such elements in abundance, spraying them out into space where they could become part of future generations of stars and planets.

Second, the mergers of compact objects are also expected to emit intense gravitational waves, first predicted by Albert Einstein. Gravity waves have not yet been discovered, but new instruments under development may make the first detections within a few years. "Now it seems that by hunting for kilonovas, astronomers may be able to tie together the events giving rise to both phenomena," Tanvir said.

The team's results will appear online on Aug. 3 in the journal *Nature*.

More information: *Nature* paper (PDF)

Provided by NASA