Subaru Telescope Detects Clues for Understanding the Origin of Mysterious Dark Gamma-Ray Bursts

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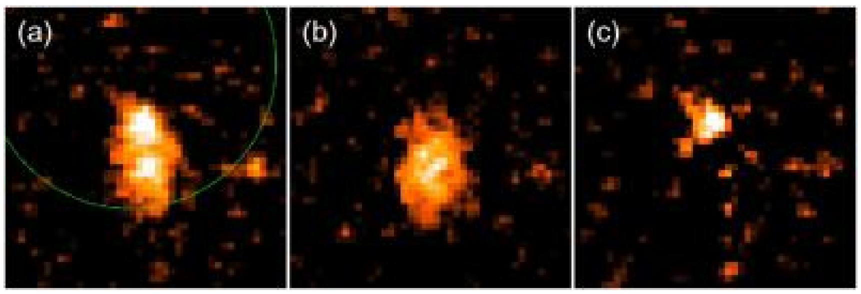

Figure 1: Afterglow of the dark GRB and its host galaxy taken with the Subaru Telescope's Multi-Object Infrared Camera and Spectrograph (MOIRCS). Image (a) was taken 9 hours after the burst. Image (b) was taken 34 hours after the burst. The afterglow seen at the upper edge of the host galaxy in (a) faded out in (b). Image (c) shows the afterglow after image (b) is subtracted from image (a). A green circle in (a) shows the uncertainty of the position of the X-ray afterglow.

(PhysOrg.com) -- A research team led by astronomers from Kyoto University, Tokyo Institute of Technology, and the National Astronomical Observatory of Japan used the Subaru Telescope to observe a dark gamma-ray burst (GRB) that provides clues for understanding the origin of dark gamma-ray bursts.

Their research is a very rare case of the detection of a dark GRB's host galaxy and afterglow in the near-infrared wavelength (Fig.1). They not only found that the host galaxy of this GRB is one of the most massive GRB host galaxies but also that a local dusty environment around the GRB significantly suppresses its afterglow. The observational results suggest a high metallicity environment (one that contains a majority of elements heavier than helium) around the GRB, a finding that is inconsistent with previous interpretations of GRBs, which associate their origin with a supernova explosion of a low-metallicity massive star (one that contains few elements heavier than helium) at the end of its life. This research suggests the possibility that GRBs classified as "dark" may originate from another mechanism such as the merger of binary stars.

Gamma-ray bursts (GRBs) are one of the most profound mysteries in current astronomy. Among the most energetic explosions in the universe, these bursts are bright flashes of enormous gamma rays that appear suddenly in the sky and usually last only several to a few tens of seconds. GRBs originate in distant galaxies far beyond the Milky Way. Their brief appearance and a quickly fading afterglow make them a challenge to research. The afterglow of a GRB can be observed in the X-ray, optical, and near-infrared wavelengths for several hours to several days. Since a gamma-ray detector cannot determine the position of the gamma-ray's source accurately, the discovery and/or identification of a galaxy by optical observations of its afterglow is necessary to examine where the GRB occurred and the nature of the environment around it. Adding to the complexity of understanding GRBs are "dark GRBs", which have extremely faint afterglows and/or cannot be detected in the optical band, are particularly elusive and have rarely been investigated, even though they may make up close to half of all GRBs.

The opportunity to know more about dark GRBs came on March 25, 2008 when a dark GRB without its optical afterglow appeared in the constellation Lyra. Only 9 hours after the burst, a research team of astronomers, primarily from Kyoto University, the Tokyo Institute of Technology, and the National Astronomical Observatory of Japan, used the Subaru Telescope, mounted with its Multi-Object Infrared Camera and Spectrograph (MOIRCS), to obtain near-infrared images of the field around the GRB and unveil its mysterious nature, the only detection of a GRB host galaxy and its afterglow in the near-infrared. The rapid observational system of the Subaru Telescope, its strong light-gathering power, and near-infrared observations with its wide-field instrument facilitated this successful discovery. Theoretical models predict much brighter GRB afterglows than the relatively faint afterglow that the team's images detected in the near-infrared wavelength. The researchers propose that their findings demonstrate that a large amount of dust around the GRB strongly suppressed the brightness of the afterglow in the optical and near-infrared wavelengths. A high-metallicity environment typically produces a very dusty environment like this. Did it do so in this case?

To explore this question, the research team followed-up their research about a year after their initial observation. They used the Subaru Prime Focus Camera (Suprime-Cam) to obtain optical images of the GRB's field that could be used to investigate the properties of the host galaxy. They successfully detected the host galaxy, this time in the optical band. This allowed them to examine various properties of the host galaxy by comparing the observed brightness of the GRB host in various wavelengths with model spectra of the galaxy. The team found that this host galaxy has a so-called "stellar mass" (the total mass of stars in the host galaxy) comparable to that of the Milky Way and is one of the most massive GRB host galaxies. More massive galaxies generally tend to show higher metallicity. The researchers calculated the expected metallicity of the host galaxy by relating its stellar mass to metallicity and found that its expected metallicity is by far the highest among metallicities previously confirmed for GRB host galaxies (Fig. 2).

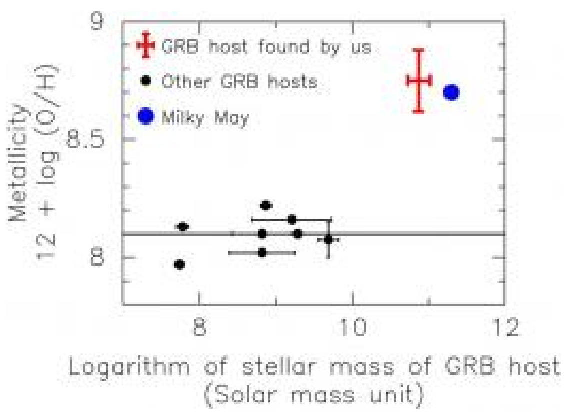

Figure 2Metallicity of GRB host galaxies compared to the stellar masses of their hosts. The black dots refer to the host galaxies from which metallicities were previously derived. GRBs are thought to occur in the environment slightly below the critical metallicity shown with the horizontal solid line. The red cross shows the expected metallicity of the host for this GRB, demonstrating a high-metallicity environment.

How, then, could they explain their findings? A low-metallicity single-star explosion scenario is a generally accepted way of explaining the origin of GRBs. Recent studies indicate that relativistic jets (a narrow stream of superhot gas moving at an extremely high speed) associated with supernovae are observed as GRBs when we see them along our line of sight. Current numerical calculations show that a low-metallicity environment is required to produce a relativistic jet when a massive star explodes as a supernova. Previous observations have shown that GRB galaxies are "light." Since lighter galaxies have lower metallicity, astronomers have inferred that a low-metallicity environment produces GRBs. Direct measurements of metallicity at the location where GRBs occurred have confirmed low metallicity. This evidence has contributed to widespread confidence in the low metallicity single-star explosion theory of GRBs' origin.

However, the low-metallicity single-star explosion scenario does not align with the current team's findings that the host galaxy of this dark GRB has high metallicity. Their findings open the possibility that dark GRBs may originate from a type of explosion process other than that of the more well-investigated GRBs. A binary-star (two stars circling each other in a systematic way) merger scenario has been proposed in the past as another possible explanation for the origin of GRBs. Since this scenario can account for the occurrence of GRBs in high-metallicity environment, the researchers point out the possibility that this dark GRB originated in a binary-star system. The team's results demonstrate that research on dark GRBs is an important key to revealing the origin of the whole population of GRBs. They may even throw light on the hypothesis that a GRB within the Milky Way may be responsible for the mass extinction that occurred on Earth about 435 million years ago during the Ordovician Period. Until now, this explanation was deemed unlikely because of the high-metallicity environment of the Milky Way.

The details of this research will be published in *The Astrophysical Journal*, in its August 2010 issue, Volume 719.

Provided by Subaru Telescope

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