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

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Gamma-ray bursts (GRBs) are one of the most profound mysteries in current astronomy. A low-metallicity single-star explosion scenario is generally being accepted as a explanation of the origin of GRBs in theory[1] and observation[2]. However 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. Only 9 hours after the burst, we used the Subaru Telescope, mounted with its Multi-Object Infrared Camera and Spectrograph (MOIRCS), to obtain nearinfrared 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 (Figure 1). 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 our images detected in the near-infrared wavelength. We propose that our 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, we followed-up our research about a year after our initial observation. We 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. We successfully detected the host galaxy, this time in the optical band. This allowed us 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. We found that this host galaxy has a stellar mass 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[3]. We 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[4].

How, then, could we explain our findings? A lowmetallicity single-star explosion scenario does not align with the current our findings that the host galaxy of this dark GRB has high metallicity. Our findings open the possibility that dark GRBs may originate from a type of explosion process other than that of the more wellinvestigated GRBs. A binary-star merger scenario [5] 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, we point out the possibility that this dark GRB originated in a binary-star system. Our results demonstrate that research on dark GRBs is an important key to revealing the origin of the whole population of GRBs.

We may even throw light on the hypothesis[6] 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[7].

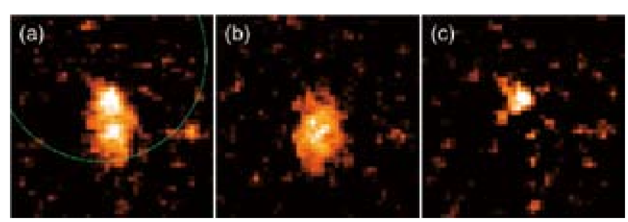

Figure 1: Afterglow of the dark GRB and its host galaxy taken with the Subaru Telescope's MOIRCS. Image (a) was taken 9 hours after the burst. Image (b) was taken 34 hours after the burst. Image (c) shows the afterglow after image (b) is subtracted from image (a). A green circle in (a) shows the uncertainty of the position of the X-ray afterglow.

References

[1] Woosley, S. E., Bloom, J. S.: 2006, *ARA&A*, **44**, 507.
[2] Modjaz, M., et al.: 2008, *AJ*, **135**, 1136.
[3] Erb, D. K., et al.: 2006, *ApJ*, **644**, 813.
[4] Hashimoto, T., et al.: 2010, *ApJ*, **719**, 378.
[5] Nomoto, K. I., et al.: 1995, *Phys. Rep.*, **256**, 173.
[6] Melott, A. L., et al.: 2004, *IJAsB*, **3**, 55.
[7] Stanek, K. Z., et al.: 2006, *AcA*, **56**, 333.