Molecular Gas in the Host Galaxies of Long-duration Gamma-ray Bursts. B. Hatsukade\(^1\), K. Ohta\(^2\), K. Kohno\(^3\), K. Nakanishi\(^4\), Y. Tamura\(^3\), A. Endo\(^2\), T. Hashimoto\(^5\), \(^1\)National Astronomical Observatory of Japan (bunyo.hatsukade@nao.ac.jp), \(^2\)Kyoto University, \(^3\)University of Tokyo, \(^4\)Delft University of Technology, \(^5\)National Tsing Hua University.

Introduction: Long-duration gamma-ray bursts (GRBs) have been shown to be associated with the explosions of massive and short-lived stars (e.g., [1]), and are expected to trace galaxies with ongoing star formation. Because GRBs are bright enough to be observable in the cosmological distances (e.g., [2], [3]), they are expected to be a new tool to probe the star-forming activity in the distant universe (e.g., [4], [5]). However, whether GRBs can be used as an unbiased tool to trace star formation in the universe is still a subject of debate. To establish the link between GRBs and star-forming activity, it is necessary to understand the properties of GRB host in terms of molecular gas, which is the fuel of star formation. While molecular hydrogen has been detected in absorption in the spectra of GRB afterglows (e.g., [6]), the detected column density probes only one sight line in front of the GRB. In order to measure the molecular gas content, molecular lines need to be detected in emission.

After numerous unsuccessful searches of CO line emission ([7], [8], [9], [10], [11]), which is a tracer of molecular gas, we successfully detected in two GRB hosts for the first time among GRB hosts ([12]). A third detection of CO emission in a GRB host was reported ([13]). However, only a handful of GRB hosts have been observed with CO, and only three of them have a CO detection. In order to understand the properties of GRB hosts, it is necessary to increase the number of GRB hosts with CO observations.

Observations and Results: We conducted CO observations toward 10 GRB hosts at \(z = 0.1-2.5\) by using Atacama Large Millimeter/submillimeter Array (ALMA). This is the first CO survey for GRB hosts, providing the largest sample with CO observations. We selected the targets with high star-formation rates (SFRs) in literature in order to obtain tight constraint on molecular gas mass. Our observations provide molecular gas properties in GRB hosts with high star-forming activity. The targets have been studied at multi-wavelengths, allowing us to compare their physical quantities (such as SFR, stellar mass, star formation efficiency, and gas consumption timescale) with other galaxy populations.

The ALMA data were recently delivered and we obtained preliminary results. We successfully detected CO emission in 6 GRB hosts \((z = 1-2)\). This triples the sample size of GRB hosts with CO detection. The molecular gas mass of the hosts ranges \(5 \times 10^9 - 9 \times 10^{10} \, M_{\odot}\) by assuming a Galactic CO-to-H\(_2\) conversion factor. We found that the hosts with CO detection at \(z = 1-2\) have a star-formation efficiency similar to normal star-forming galaxies at \(z \sim 1-2\). This is in contrast to the previous results, where GRB hosts at \(z < 1\) show higher star-formation efficiency compared to local star-forming galaxies. The similarity between the GRB hosts and normal star-forming galaxies at \(z \sim 1-2\) suggests that GRB occur in normal environments at the redshift range and can be an unbiased tracer of star forming activity in the universe.