（別紙様式5）

変革を駆動する先端物理・数学プログラム（FoPM）

国外連携機関長期研修　報告書

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During this trip, I learned how to use archival data of CHIME, which is the radio telescope located in Penticton, BC, Canada, and made a code to remove aliases existing in the data.

In our previous study (Shikauchi, M., Cannon, K., Lin, H., et al. 2022), we assumed thermal noise at antenna receivers as well as a contribution from unresolved sources in the sky accounted for “noise”, i.e. anything but the target signals from short gamma-ray bursts. However, as I checked the real data taken with CHIME, I found that it suffers from “aliases”, also known as “folding noise”. It appears if there is a component with a higher frequency than a sampling one. CHIME is a radio interferometry with a large number of antenna receivers, at which signals will be correlated and Fourier transformed to get a spatial distribution with luminosities (a sky map). As a spatial separation antenna by antenna is constant, if a signal contains a higher frequency component than a spatial one defined by the separation, Nyquist condition gets broken and aliasing occurs at Fourier transformation. Then, we will see a duplicated source with the same luminosity with the true source and separated from it in a North-South direction. A feature of aliases is that a spatial separation between the true source and its alias depends on spatial frequencies, which would be problematic when data is averaged over frequencies. Over almost all the frequencies of CHIME, aliasing happens. Also, some frequency data are masked due to radio interference caused by our daily activities such as LTE band, TV band, airplanes, and so on. Which data will be masked changes day by day. Assume a pixel includes only an alias at a frequency A. Data at the frequency is included one day, but excluded the other day, and then some frequency data including A is averaged. Then, the pixel brightness will change day by day; it depends on the existence of the data at frequency A. That can be a cause of false positives.

To reduce possibilities of the false positives, I assumed that the sky observed at different frequencies is just a projection of the “true” sky, which is only one and then applied a filter based on a linear regression model to some frequency data. After applying the filter, I confirmed the brightness of aliases can be reduced to less than a few percent of that of the true sources. The derivation and the results related to the filter will be summarized to a paper and will be submitted to a journal.

Our final goal is to search for afterglow signals from short gamma-ray bursts, which have not been found yet. To that end, a precise and detailed noise model is required. I will keep working on constructing the noise model by analyzing daily data taken with CHIME. It is already known that there is a time dependence of an antenna gain, which will be considered as well.

In parallel, I will also try to estimate an upper limit of a rate of short gamma-ray burst afterglows, which can provide that of binary neutron star mergers. Here is how to derive it. First, pick up time series data of brightness in some pixels in the de-aliased sky map assuming they do not include any afterglow signals. Then, calculate a likelihood ratio, that is, a ratio of the probability of obtaining the time series data given a signal exists and that given only noise is present, and choose the maximum value. Next, inject theoretical time series data of brightness of afterglows to the pixels and calculate the likelihood ratio again. If the likelihood ratio exceeds the maximum value, the injected source will be removed. By using the information of sources considered as detectable and whose likelihood ratio does not exceed the maximum value, an upper limit of how many afterglow signals can be observed with CHIME will be derived. As we know binary neutron star mergers can induce short gamma-ray bursts (e.g. GRB 170817A), the upper limit can be translated into that of neutron star merger rate. That is an independent estimate from gravitational wave observation, and thus I am expecting it means a lot if the result is obtained. It is interesting whether the estimated rate based on CHIME and LIGO is consistent or not. More precise noise model is used for the analysis, more meaningful the result gets, but here I will try to employ simple noise model used in our previous work.

In addition, CHIME is expected to have observed GRB 170817A since one year later from the merger of

GW170817. I am going to check what a light curve of GRB 170817A looks like and whether some constraints on parameters on a relativistic jet, which can drive short gamma-ray bursts, can be placed or not.

To summarize my experiences through this program, I would like to emphasize the importance of working at a place where people enthusiastically work on things related to your work. That is because I have encountered a small chance to start a new project hidden in a casual chat. At first, a colleague and I just tried to remove aliases by taking a median value of the brightness over frequencies, which can remove outliers like aliases. While having a chat with a colleague, he told me a more statistical way to do so by using the linear regression model. If I were in Japan, he might not have told me that as he did not think it was worth chatting or emailing about that. That was a wonderful experience for me.

Also, I felt I could improve my English skill as well. In the first few months, I had difficulties in having a discussion with colleagues there. Gradually, I learned to hear what people walking along me are chatting with their friends and to reduce the time to write a paper in English. I can even think in English while discussing with colleagues. I have discussed with my supervisor in English, but realized doing "everything" in English accounted for the improvement.