Technical Justification

1. Observation Strategy

As of Aug 2019, the previous JCMT large program over the NEP region (M17BL007; NEP: Extragalactic JCMT Survey of the North Ecliptic Pole) is 48 % complete in terms of the proposed observing time. The central $\sim 0.6\,\mathrm{deg}^2$ area centered on the *AKARI* NEP-deep was covered by the SCUBA-2 Cosmology Legacy Survey (S2CLS; Geach et al. 2017) beforehand with a sensitivity of $\sigma_{\rm rms} = 1.0$–$1.2\,\mathrm{mJy/beam}$. Therefore the observation strategy of the M17BL007 was to increase the area by adding additional visits when going around the circumference of the existing S2CLS area (see Fig. 1 in the Science Justification section). In the overlapping regions, we combined the S2CLS 850-μm data with the newly obtained data, in order to increase the sensitivity. Due to this strategy, now the overlapping $0.4\,\mathrm{deg}^2$ region goes slightly deeper than in S2CLS, to achieve $\sigma_{\rm rms} = 1\,\mathrm{mJy/beam}$ and the deepest part has a sensitivity as deep as $\sigma_{\rm rms} = 0.92\,\mathrm{mJy/beam}$ (Fig. 3). The survey also increased the $\sigma_{\rm rms} = 1.2\,\mathrm{mJy/beam}$ area by a factor of 1.5, and added much shallower $850\,\mu$m data over a wider ($1.8\,\mathrm{deg}^2$) area.

In order to complement the planned *Euclid*-deep field survey and the TolTEC Large Structure survey on the NEP region, we propose to: (1) obtain "deep" 850-μm images near the confusion limit for a limited small area; and (2) complete the previous program M17BL007 in the outer region, which would not otherwise be completed by the end of 2019.

NEPSC2-Deep The planned *Euclid*-deep field coverage is slightly offset from the pole, yet the previous S2CLS and NEP3, 4, and 5 regions (already observed as a part of M17BL007) are well-centered in the *Euclid*-deep field and has the deepest 850-μm data. With the existing $\sigma_{\rm rms} = 0.92\,\mathrm{mJy/beam}$ data (the deepest), the addition of $\sigma_{\rm rms} = 1.7\,\mathrm{mJy/beam}$ data will result in a final $\sigma_{\rm rms}$ of $0.8\,\mathrm{mJy/beam}$, which is essentially the SCUBA-2 850-μm confusion limit. To go even deeper, pushing the noise level to be $\sigma_{\rm rms} = 0.5\,\mathrm{mJy/beam}$, i.e., to reach an equivalent sensitivity to the TolTEC survey at 1.1 mm, we need additional $\sigma_{\rm rms} = 0.8\,\mathrm{mJy/beam}$ data to combine with to the existing $0.92\,\mathrm{mJy/beam}$ data (on regions marked as thicker lines in Fig. 1). The declination of the NEP field is relatively high at 66.5 deg. With the PONG1800 recipe, if the observations are made in weather band 2 ($\tau = 0.05$–0.08), the observing time needed to reach $\sigma_{\rm rms}$ of $0.8\,\mathrm{mJy/beam}$ is **98.56 hrs** including overheads. With this strategy, we would obtain a 0.5 deg diameter region ($= 0.8\,\mathrm{deg}^2$) of unprecedented depth in 850-μm continuum imaging.

NEPSC2-Wide The TolTEC survey is planned to obtain a $\sim 100\,\mathrm{deg}^2$ map, therefore we will not attempt to cover the entire $100\,\mathrm{deg}^2$, but focus on the most important $\sim 4\,\mathrm{deg}^2$ where deep 3.6- and 4.5-μm images are available (Fig. 1). To finish the tiling around the NEP region, we need 10 additional PONG1800 observations with a depth of $1.7\,\mathrm{mJy/beam}$ rms. The M17BL007 program was carried out in weather band 3 condition, which has more chance of being observed during the summer seasons when the target (NEP) visibility is the best. In band 3 ($\tau = 0.08 - 0.12$) weather, with the PONG1800 recipe, the necessary time to reach $1.7\,\mathrm{mJy}$ rms is **40.11 hrs** $\times$ **10** $=$ **400 hrs**. Considering that the last pointing of M17BL007 will not be completed by the end of this year due to the decreasing visibility (pointing marked as purple color in Fig. 1), **an additional 20 hrs** is required to complement the insufficient exposure.

The total time request is 100 hrs in band 2, and 420 hrs in band 3. We plan to give higher priority to NEPSC2-Deep, and update the mosaic by combining newly obtained data with the previously existing data right after the new data are obtained. If the sensitivity requirement is met earlier than expected, we will modify or revise the MSBs to allow efficient mapping over this field with as homogeneous a depth as possible.

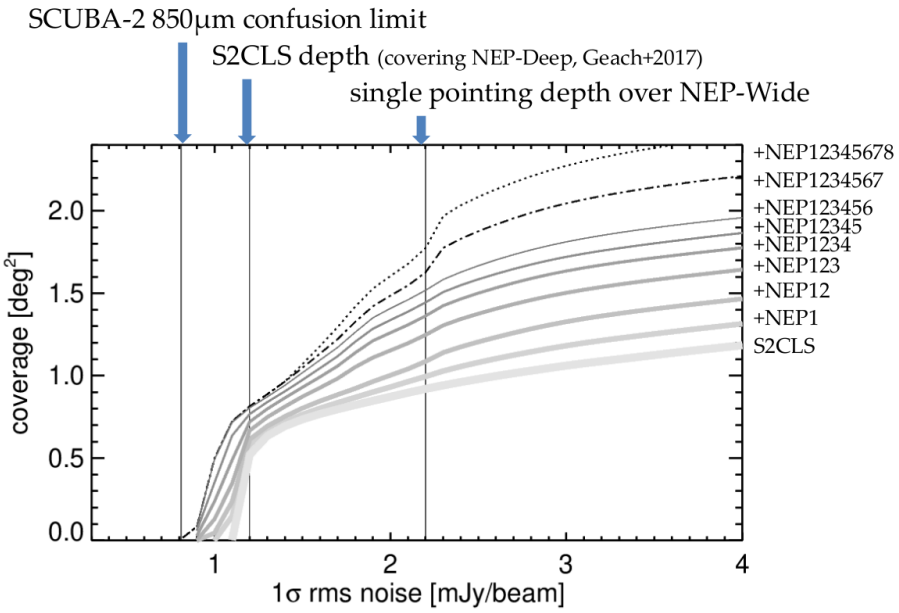

Figure 3: Progress of the NEP survey in terms of the survey depth and area coverage (as of July 2019).

2. Project Management Plan

The *AKARI* NEP survey team has been a long-term collaboration between astronomers in the EAO region and those outside of the EAO. During the period of the previous large program M17BL007, we had three face-to-face meetings (in Jan 2018, Jun 2018, and Jun 2019) to discuss the status of the SCUBA-2 data and the possible applications, in close connection with the other ancillary data sets over this field. There is also a regular telecon to discuss science with the multi-wavelength NEP data across the broad NEP collaboration, and sometimes we discuss the SCUBA-2 NEP program in this telecon. Unfortunately, the data acquisition progress was very slow before 2019, therefore we do not have any papers published yet. Instead there was a pilot study on 850 μm sources in the *AKARI* NEP-deep field published by Seo et al.(2018). Several science talks (talks in the regional astronomical society meetings and colloquiums) using SCUBA-2 850-μm data on the NEP field have been or are being scheduled in different EAO regions (KR, TW, and JP).

2.1. Membership

This proposal is an extension of the previous JCMT Large Program M17BL007, NEP. The total number of members involved in M17BL007 is $\sim$ 70 as of Aug 2019, including members from all regions and participating institutions – Korea, Taiwan, Japan, China, UK and Canada. The previous member statistics showed that there were more senior researchers than junior astronomers involved in this program, but this is because the actual number of junior members (including graduate students and postdocs) has not been updated since our last submission of the project plan. We now have a number of new students and postdocs heavily involved with SCUBA-2 NEP data reduction and who are handling multi-wavelength data over the NEP field, i.e., potential users of the SCUBA-2 850 μm data. Once the extension proposal is approved, we plan advertise to the wider community that we are actively seeking participation of additional new (junior) members. Basically the membership is open to the entire JCMT community.

2.2. Data Reduction Management

As in the case of M17BL007, members in the KNU and KASI (both in region KR) will lead the data reduction activities, allowing graduate students and postdocs participating in this program ample

opportunity to contribute. We have been satisfied with the data reduction using the generic pipeline with the blank field recipe. The FCFs have been monitored during the two years of the previous observing periods, resulting in less than 5 % variation from the standard FCF value. Applying single, standard FCF value to all observation and deriving FCF separately for different observations based on the calibrators produced ~ 2 % difference in the measured flux densities of the detected sources. Once the new FCF values (in terms of observing condition factors) are released in late 2019, we will check its relevance for the derived flux densities of the 850-μm sources and any effects on the multi-wavelength usage.

The mosaic image produced, as well as the blind source catalog, is being distributed using the team-accessible data servers hosted by KASI. The mosaic image of the individual PONG1800 maps and the entire mosaic image of the growing field of view are provided. Multi-wavelength source catalog updates will be led by members in NTHU (TW). De-convolution of the 850-μm images with higher resolution TolTEC data (that will be obtained later in 2020) will be led by UK members.

2.3. Publication Plan

A selected list of potential papers based on or contributed to by the SCUBA-2 NEP data is presented below. Some of the projects can only be done once the observations are completed, while the previous M17BL007 program is only less than 50 % complete and there is little chance of updating the progress, as the target visibility becomes limited towards winter - this is another reason demanding completion of the SCUBA-2 850-μm survey over the NEP.

We are currently searching for a better way to share ideas on publication, such as migrating from e-mails to wiki access; however, the system is not in place yet. The basic policy would be that any members interested in particular projects may participate or lead the project, while adjustment should be made consensus discussions if conflicts arise. Any papers using the produced 850-μm mosaic and source catalog should acknowledge the use of SCUBA-2 data and cite the relevant papers.

- 850 μm mosaic image and catalog (blind and band-merged) of the NEP-Wide: Data release paper (this will be prepared after the completion of the survey; a separate paper from the deeper addition of 850-μm data near the center is also planned).
- Dusty star-forming galaxies at $z > 5$ (this will require the completion of the "NEPSC2-Deep" part of the survey and the LMT/TolTEC 1.1–2.0 mm map of higher resolution).
- Dust properties of high-z star-forming galaxies selected in the rest-frame UV and optical (this will require the completion of the survey to ensure enough number statistics).
- Mid-IR to mm spectral energy distributions of $z < 0.3$ IR-luminous galaxies.
- Dust-obscured AGN and hidden star-formation rates.
- Cluster and proto-cluster searches around submm sources.
- Clustering of 850-μm sources (this will be done after the completion of the survey).
- Star formation and cluster environments as a function of redshift (this will be done after the completion of the survey, considering the spatial scales to probe for high-z galaxy clusters.)
- NEP supercluster environments and galaxies (the NEP supercluster at $z = 0.087$ covers more than 3 deg^2, therefore the completion of the survey is essential to work on this topic).
- Dust-to-gas ratios of star-forming galaxies (we have submitted ancillary JCMT heterodyne observations R19BP004 for a pilot study; in local Universe this can be done once the heterodyne data are obtained, and will be extended to $z > 1$ once the *Euclid*-deep data become available.)