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AKARI OBSERVATIONS OF THE FLUCTUATIONS OF THE NEAR-INFRARED BACKGROUND II

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ABSTRACT

We report a spatial fluctuation analysis of the sky brightness in the near-infrared from observations towards the north ecliptic pole (NEP) by *AKARI* at 2.4 and 3.2 μm. As a follow up study of our previous work on the Monitor field of *AKARI*, we used NEP deep survey data, which covered a circular area of about 0.4 square degrees, in order to extend fluctuation analysis at angular scales up to 1000″. After pre-processing, additional correction procedures were done to correct time varying components and instrumental effects such as MUXbleed. To remove resolved objects, we applied 2σ clipping and point spread function (PSF) subtraction. We finally obtained mosaicked images which can be used for the study of various diffuse emissions in the near-infrared sky and found that there are spatial structures in the mosaicked images using a power spectrum analysis.

Key words: galaxies: high-redshift – infrared: diffuse background – methods: data analysis – stars: population III – zodiacal dust

1. INTRODUCTION

The study of spatial fluctuations in the near-infrared background is one of the useful tools to investigate various infrared components from high-redshift objects in the early universe to zodiacal light in the solar system. In particular, observations of the near-infrared background are believed to be very important for investigating the formation and evolution of the first stars of the universe, because the first stars may be massive and bright compared to subsequent generation of stars, and may leave their traces in brightness or fluctuation of brightness in the near-infrared wavelength bands. In this study, as a follow up study of our previous work on the Monitor field of *AKARI* (Matsumoto et al. 2011), we investigate fluctuations of the sky brightness in the near-infrared bands using the north ecliptic pole (NEP) deep field imaging data.

Table 1
Basic parameters of the mosaicked image of the NEP deep field

Item	2.4 μm	3.2 μm
R.A.(J2000) DEC.(J2000)	$17^h55^m24^s$	$66^\circ37'32''$
Number of pointed images	75	68
Mean observation time (min)	12.0	10.9
Remaining pixel ratio (%)	39.6	39.5

2. OBSERVATION AND DATA REDUCTION

2.1. *Observation*

The survey of the NEP deep field with *AKARI* started in 2006 May and performed about 270 pointed observations over one year period, covering nearly a circu-

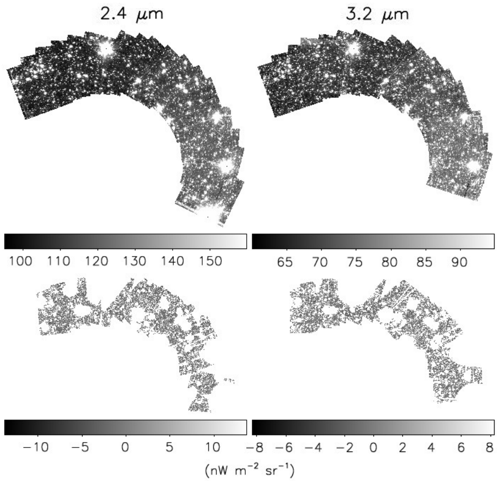

Figure 1. Mosaicked images of the NEP deep field for two bands in equatorial coordinates. Top: the selected region of the NEP deep field for the study. The lower right corner is brighter than other regions in the mosaicked image, which shows seasonal variation of zodiacal light during observation period. White color represents discrete objects. Bottom: final states of the mosaicked images. White color represents masked regions. The width and height of the mosaicked image is $36' \times 25'$ and $35' \times 23'$ for 2.4 and 3.2 μm, respectively.

lar area of 0.4 square degrees (Matsuhara et al. 2006). We used the NEP deep survey data at two wavelength bands, 2.4 and 3.2 μm. Only a portion ($\sim$30%) of the NEP deep survey area is selected to produce a reliable mosaicked image (the top panel of Figure 1) since some parts of the survey data are affected by the earthshine (Wada et al. 2007) and a planetary nebula.

2.2. *Pre-processing*

We used *AKARI* standard pipeline (Lorente et al. 2008) for most of the pre-processing of each pointed image. However, a few procedures, such as dark subtraction and flat field correction, were treated separately to improve a quality of the image.

2.3. *Additional Correction Procedures*

Pixels in the upper parts of MUXbleed-affected regions become fainter compared to those in the lower region. We identified two lines by fitting affected pixels and unaffected pixels separately. Correction for the MUXbleed problem was done by using the difference between two fitted lines. To correct for the seasonal variation of zodiacal light, we tried to fit the sky brightness by using a sinusoidal function (Pyo et al. 2012). We then subtracted the fitted function from each pointed image.

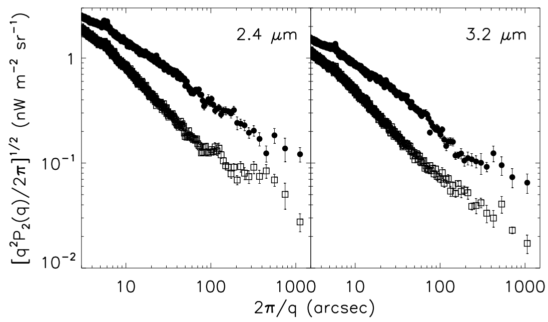

Figure 2. Fluctuation spectra obtained by two-dimensional FFT. Filled circles and open squares are fluctuation spectra of the mosaicked image and subset analysis, respectively. q and $P_2(q)$ represent angular wavenumber and power spectrum. Error bars show 1σ error.

2.4. *Source Subtraction*

In order to obtain the fluctuations in the sky brightness, we removed pixels that are affected by sources such as point or extended objects. Bright central parts of objects were masked by a clipping procedure, and relatively faint wing parts of objects were subtracted by using the Point Spread Function (PSF). Mosaicked images consisting of pointed images after data reduction procedures are presented in the bottom panel of Figure 1, and their basic parameters are listed in Table 1.

3. POWER SPECTRUM

We used a power spectrum analysis to measure the spatial fluctuations of the mosaicked image and random noise. Figure 2 shows the fluctuation spectra for the mosaicked image (filled circles) and subset analysis (open squares). Subset analysis is intended to estimate fluctuation spectrum of random noise in the mosaicked image. To perform subset analysis, the whole images were divided into two subsets. A difference of two subsets will erase persistent features in the sky and leave random noise of the mosaicked image. As shown, the mosaicked image reveals significantly larger fluctuation than that of subset analysis, which indicates that there are spatial structures in the mosaicked image.

4. SUMMARY

We studied spatial fluctuations of the sky brightness using the NEP deep survey data obtained with *AKARI* at 2.4 and 3.2 μm. In order to extend the fluctuation analysis of the Monitor field at angular scales up to 1000″, we produced mosaicked images of the NEP deep field after removing the contributions from the known point and extended sources. Mosaicked images in the bottom panel of Figure 1 can be used for the study of various diffuse emissions in the near-infrared sky. We also found that there are spatial structures in the mosaicked image using a power spectrum analysis.

Foreground diffuse components, such as zodiacal light, diffuse Galactic light, and unresolved faint galaxies at low redshift, are all candidates for inducing spatial structures in the near-infrared sky. In addition, intrahalo light (IHL; Cooray et al. 2012) and first stars in the early universe are also candidates. Seo et al. (2015) investigated spatial structures in the NEP deep field using mosaicked images in the bottom panel of Figure 1. They extended the fluctuation analysis to angular scales up to 1000″, which could provide useful constraints for the study of the background at near-infrared wavelengths.

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