Revised calibration for near- and mid-infrared images from *AKARI*/IRC pointed observations in Phases 1 and 2

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ABSTRACT

Here we briefly overview the latest data reduction toolkit and reduced images with it that are already available online [a)]. *AKARI* performed ~4000 pointed observations over 16 months in Phases 1 and 2, when the telescope and instruments were cooled by liquid helium. Observation targets include solar system objects, Galactic objects, local galaxies, and galaxies at cosmological distances. We describe major updates on calibration processes of near- and mid-infrared images taken by the InfraRed Camera, which has nine photometric filters covering 2–27 μm continuously. The latest toolkit has been applied to data from each pointed observation to generate calibrated and stacked images. About 90% of the stacked images have a position accuracy better than $1\farcs5$. Uncertainties in aperture photometry estimated from a typical standard sky deviation of stacked images are a factor of ~ 2–4 smaller than those of AllWISE at similar wavelengths. This work has already been published as Egusa et al. (2016).

Keywords: infrared: general, methods: data analysis, techniques: image processing

1. INTRODUCTION

The InfraRed Camera (IRC; Onaka et al. 2007) on *AKARI* (Murakami et al. 2007) consists of three instruments with different observing wavelengths (NIR, MIR-S, and -L) and has nine photometric filters covering 2–27 μm continuously. The field of view (FoV) of each instrument is $\sim 10'$. The NIR and MIR-S target the same FoV, while the MIR-L FoV is $\sim 25'$ away. Angular resolutions are $\sim 4''$–$7''$, depending on wavelength.

Among several phases during the *AKARI* operation, Phases 1 and 2 denote the periods when the telescope and instruments were cooled by liquid helium. During these phases, all the instruments including the Far-Infrared Surveyor (FIS; Kawada et al. 2007) were used for scientific observations.

The duration of one pointed observation is about 10 minutes and each observation has a unique Observation ID (ObsID). An IRAF-based software package "the IRC imaging toolkit" (hereafter toolkit) is used to reduce the data from each ObsID. The astronomical observation template (AOT) indicates the observing mode, e.g., which filters were used and where the main target was. The toolkit can also be used to reduce reference images during spectroscopic observations (AOT=IRC04) and images from "parallel" observations (AOT=FIS03), where the main target is in the FoV of FIS.

Here we report a brief summary of the latest toolkit (§2) and of the results from all-data processing (§3) for Phases 1 and 2. For more detail, see Egusa et al. (2016).

2. UPDATED TOOLKIT FOR PHASES 1 AND 2

The latest toolkit is version 20150331, released on March 31, 2015. The following subsections describe major updates in this latest version.

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a) http://www.ir.isas.jaxa.jp/AKARI/Archive/Images/IRC_Images/

2.1. Dark current

For NIR, the dark model by Tsumura & Wada (2011) is adopted as a default. For MIR, a new dark frame called "neighbor dark" is created for each ObsID by combining pre-dark frames from five pointed observations taken before and after that (c.f. Egusa et al. 2013). This neighbor dark should better calibrate temporal variations in dark current than the super dark (created by combining pre-dark frames taken at the beginning of the operation) and should have higher S/N than the self dark (created by combining pre-dark frames taken within that ObsID). These neighbor dark frames are included in the archived data package for each ObsID (thus not in the toolkit).

We also introduced a new definition for hot pixels – those exceeding a certain threshold in the neighbor dark. The number of hot pixels was increasing with time even within Phases 1 and 2. The default is to mask out such hot pixels.

2.2. Flat Frame

During the first eight months of Phases 1 and 2, a noticeable pattern called "soramame" appeared in the bottom-right corner of the MIR-S FoV. As the pattern shows a temporal variation (Murata et al. 2013), we define four periods (p1, p23, p4, p5) and create a new flat of each MIR-S filter for each period.

2.3. WCS matching

Since the WCS information recorded at the time of observation is not always accurate enough, the toolkit tries to derive a solution by cross-matching detected sources in stacked images and sources in catalogs. In addition to the 2MASS catalog (Skrutskie et al. 2006) used in previous versions, the *WISE* catalog (Wright et al. 2010) is added in order to improve the matching rate at longer wavelengths.

3. RESULTS OF ALL-DATA PROCESSING

Excluding data from p1 (for which the soramame flat is less reliable) and some ObsIDs without valid data, we processed data for 3944 ObsIDs taken in Phases 1 and 2 with the latest toolkit.

For the MIR-L, we applied the "coadd L using S" (cLuS) method in addition to the standard stacking method and selected a better one. This method uses relative positional shift values between MIR-S frames to stack MIR-L frames. More than 50% of released MIR-L images are from this cLuS method and the fraction increases with wavelength. This is because fewer stars are available for stacking at longer wavelengths.

The success rate of WCS matching decreases with wavelength (due to the same reason as above) and its average is 87%. The residual of WCS matching is $\sim 0\farcs5$ for NIR and MIR-S, and $\sim 0\farcs75$ for MIR-L.

An imaging sensitivity for each filter is estimated from the standard sky deviation of stacked images from NEP observations. Periods when the Earth-shine light affected the images significantly were excluded. The sensitivity for IRC05 is ~ 2–4 times better than the AllWISE catalog for the COSMOS field (Scoville et al. 2007) at a similar wavelength (Table 1).

Again, all the raw data, processed images, and the toolkit for images taken in pointed observation carried out in Phases 1 and 2 are open to public via the *AKARI* website (see the footnote to the abstract).

Table 1. Typical 5σ sensitivity in aperture photometry from NEP observations [mJy]

AOT	$N2$	$N3$	$N4$	$S7$	$S9W$	$S11$	$L15$	$L18W$	$L24$
IRC03	0.058	0.042	0.041	0.29	0.31	0.49	0.89	0.84	1.8
IRC05	0.032	0.023	0.022	0.17	0.24	0.33	0.53	0.49	1.2
AllWISE†	...	0.054	0.071	...	...	0.73	...	...	5.0

NOTE—†: Representative wavelengths for *WISE* are 3.4, 4.6, 12, and 22 μm.

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