AKARI Mid-Infrared All-Sky Survey

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ABSTRACT

AKARI is the first Japanese astronomical infrared satellite mission orbiting around the Earth in a sun-synchronous polar orbit at the altitude of 700 km. One of the major observation programs of the *AKARI* is an all-sky survey in the mid- to far-infrared spectral regions with 6 photometric bands. The mid-infrared part of the *AKARI* All-Sky Survey was carried out with the Infrared Camera (IRC) at the 9 and 18 μm bands with the sensitivity of about 50 and 120 mJy (5σ per scan), respectively. The spatial resolution is about $9.''4$ at both bands. The 9 μm band probes the UIR bands effectively, whereas the 18 μm band traces the thermal emission from warm dust grains. We present an overview of the mid-infrared all-sky survey and report some initial results to demonstrate its great potential in the study of star-forming regions in our Galaxy.

Subject headings: infrared : large area survey — reflection nebula : individual (IC 4954/4955) — open clusters : individual (Roslund 4)

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1. Introduction

More than two decades have passed since the Infrared Astronomical Satellite (*IRAS*) carried out an all-sky survey for the first time in the infrared with four broad bands centered at 12, 25, 60, and 100 μm (Neugebauer et al. 1984). Later, the Midcourse Space Experiment (*MSX*) surveyed the regions of the sky confused to *IRAS*, such as the Galactic plane and the Magellanic Clouds, as well as those areas not observed by the *IRAS* mission. *MSX* had higher sensitivity and spatial resolution (18$''$) than *IRAS*, with four broad bands at 8.28, 12.13, 14.65, and 21.34 μm, and two narrow bands at 4.29 and 4.35 μm (Price et al. 2001).

AKARI is the first Japanese satellite mission dedicated to infrared astronomical observations (Murakami et al. 2007). It was launched on 2006 February 22 (JST) and successfully brought into a sun-synchronous orbit at an altitude of 700 km. It has a Ritchey-Chretien type cooled telescope with a primary-mirror aperture size of 685 mm (Kaneda et al. 2007) together with two scientific instruments on board: the Infrared Camera (IRC) that covers the spectral range 2–26 μm (Onaka et al. 2007) and the Far-Infrared Surveyor (FIS) that operates in the range 50–180 μm (Kawada et al. 2007). The scientific instruments and the telescope are cooled down by super-fluid liquid helium and mechanical coolers. One of the major objectives of the *AKARI* mission is an all-sky survey in four far-infrared (FIR) bands with FIS and two midinfrared (MIR) bands with IRC, which surpasses the *IRAS* survey in sensitivity, spatial resolution, and spectral coverage.

2. Observations and Data Reduction

The *AKARI* All-Sky Survey observations were carried out from May 8 2006 to August 26 2007 during the life time of the cooling medium (liquid helium). More than 90% of the entire sky was observed at least twice during this period.

In the all-sky survey, the IRC is operated in the scan mode (Ishihara et al. 2006a), in which the data of only two rows in the detector arrays are taken with a cross-scan width of about 10$'$. The scan speed is about 216$''$ s^{-1}. The output signals of every four adjacent pixels are binned together to reduce the data down-link rate, and the virtual pixel scale is 9.$''$36 × 9.$''$36 in the survey mode. A second confirmation is enabled by independent data sets taken by the two separated rows, which allow one to efficiently reject high-energy ionization particle events, and largely improves the reliability of source detection. The data of two bands were taken simultaneously with different channels of the IRC which observe sky positions separated by about 20$'$ in the cross-scan direction (Onaka et al. 2007). Figure 2 shows the relative spectral response of the two bands, S9W and L18W.

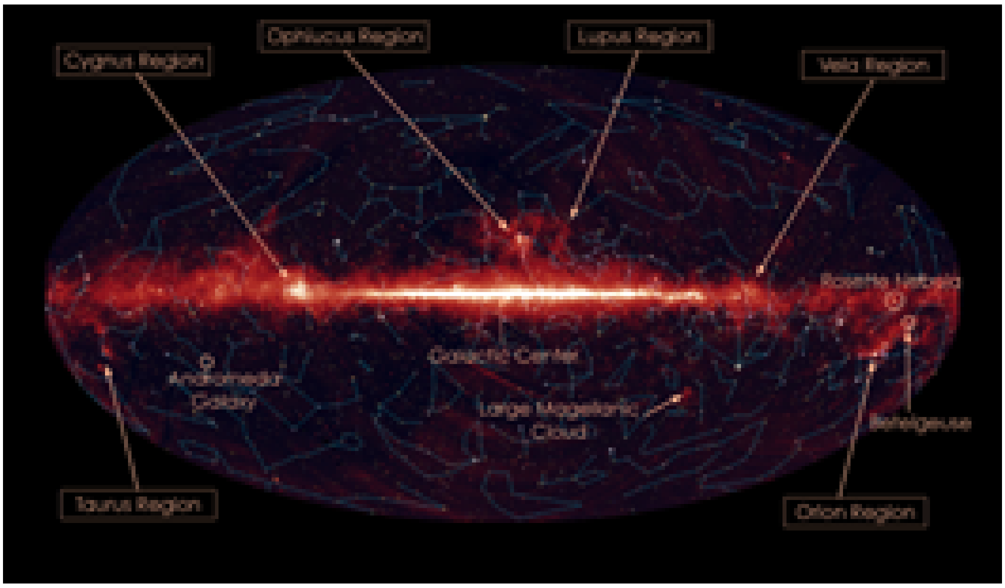

Fig. 1.— 9 μm all-sky map obtained by *AKARI*/IRC. More than 90% of the sky is covered more than twice. Zodiacal light was removed in a simple way.

Data are reduced automatically by pipeline software to create a map. The pipeline process includes a linearity correction, a flat correction, a reset anomaly correction, a removal of the stray light, source extraction, rejection of high-energy particle events by the second confirmation, a position determination using identified objects, coaddition of the images obtained by the two rows, and map construction.

The pointing reconstruction is carried out with the data of the focal-plane star-sensor by the European Space Astronomy Center (ESAC). Source associations of the IRC survey data are carried out first with the *IRAS* and *MSX* data based on the pointing reconstruction information and the position of the IRC survey is determined. A goal of the accuracy of the position determination is about 1″.

The flux calibrations of point sources in the all-sky survey data are carried out based on a large number of detections of hundreds of stars in the standard star networks consists of K and M-giants (Cohen et al. 1999, 2003; Ishihara et al. 2006b). Fainter standards for the IRC are taken from a set of far-UV to MIR calibrators built by Cohen to support the calibration of *Spitzer* IRAC, from which the IRAC routine standards are drawn (Reach et al. 2005). The flux accuracy is estimated as 7% for the S9W band and 15% for the L18W band for point sources at the present calibration stage.

The sensitivity of the IRC all-sky survey is limited by detector noise (Ishihara et al. 2006a). The noise performance in orbit has been confirmed to be about the same as pre-

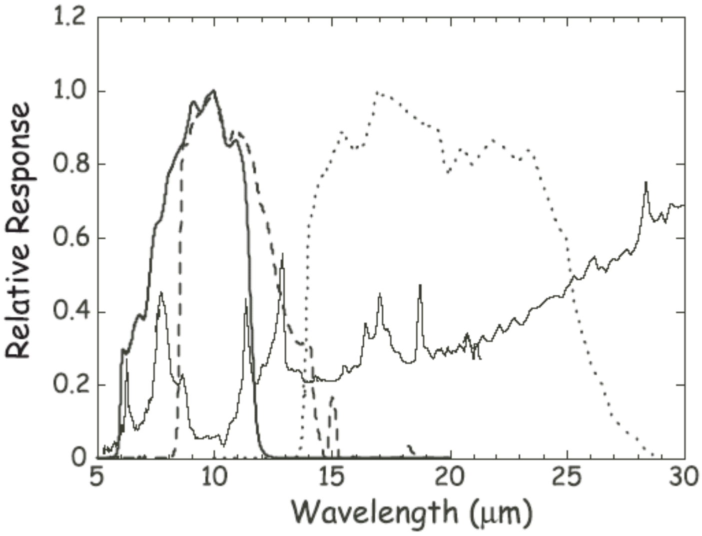

Fig. 2.— Relative band response of the S9W (thick solid line) and L18W (thick dotted line) in units of electron/energy normalized at the peak. An interstellar cirrus spectrum at (l,b) = (355.2, +0.02) taken with *Spitzer*/IRS is also shown as a reference by the thin solid line. It is in units of Jy, but arbitrarily scaled.

flight data. Based on the observations of standard stars and the measured noises, the 5σ sensitivity in orbit has been estimated to be about 50 mJy and 120 mJy for the S9W and L18W bands, respectively. Comparison of the sensitivity, the spatial resolution and the sky coverage with other wide-area survey projects are shown in figure 3.

The *AKARI* all-sky survey data will be released to the public. The first *AKARI* point-source catalog of the IRC all-sky survey, together with that of the FIS all-sky survey, is planned for preparation one year after the end of the survey and will be released to the public after a one year proprietary period for *AKARI* team members.

3. Review of the initial result from the observations

In this section we present one of the first results of a star-forming region that have been derived from the preliminary processing of the data (Ishihara et al. 2007).

IC 4954 and IC 4955 are the reflection nebulae located in the Vulpecula constellation on the galactic plane around (l, b) = (66.96, -1.26), associated with the young open cluster Roslund 4 (Roslund 1960). The heliocentric distance and the age of this cluster were estimated based on the analysis of isochrones as about 4–10 Myr and 2–2.9 kpc by Racine

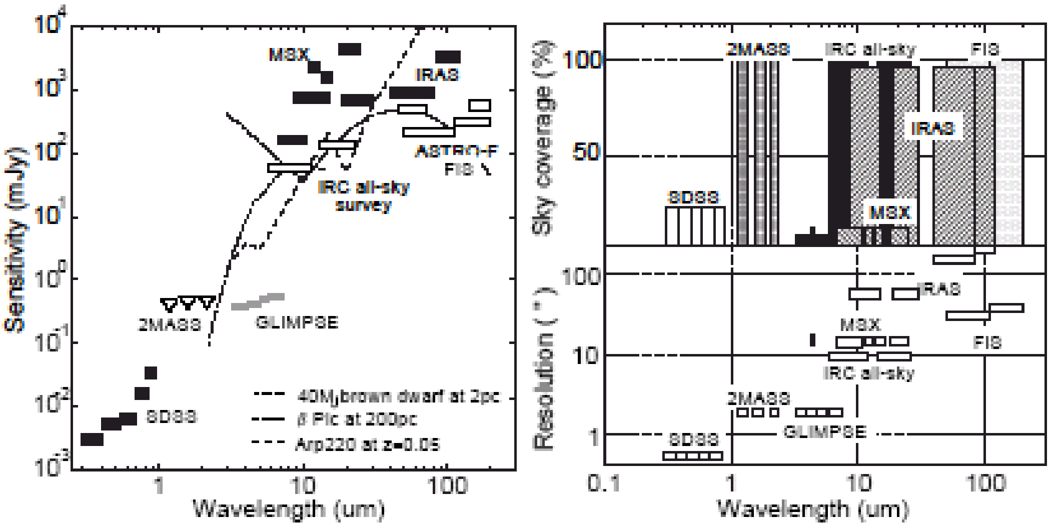

Fig. 3.— Sensitivity for point sources (left) and spatial resolution and sky coverage (right) of the *AKARI* mid-infrared all-sky survey observation in comparison with other wide area survey projects.

(1996), Phelps (2003) and Delgado et al. (2004).

We observed the IC 4954/4955 region with both on-board scientific instruments, IRC and FIS during the performance verification phase from 2006 April 24 to May 8, with the purposes of the confirmations of the instruments. In this report we highlight the discussions based on the mid-infrared survey data.

Color images of IC 4954/4955 in the optical, mid-infrared, and far-infrared are shown in figure 4. The difference in the spatial distribution between S9W and L18W images is remarkable. Figure 2 shows the relative spectral response of the S9W and L18W bands. Also plotted by the thin solid line is an interstellar cirrus spectrum taken with *Spitzer*/IRS for a reference. The S9W band includes the major UIR bands at 6.2, 7.7, 8.6, and 11.2um, except for the 12.7um band, and is not affected by continuum emission longer than 12um. In the L18W the UIR 17um complex is included and the main contributor is the continuum emission longer than 15um. The line emissions from ionized species is insignificant compared to the UIR band emission. The S9W image shows arc-like structures clearly and the emission in L18W is stronger inside the arcs, as indicated by red. Most of the regions highlighted by red color are associated with B type stars, which are supposed to act as heating sources of the region. We surmise that the red regions are directly heated by B type stars, and are probably associated with ionized gas, whereas the arcs represented by white color in figure 4 are PDRs surrounding them, which are characterized by strong UIR emissions in the S9W

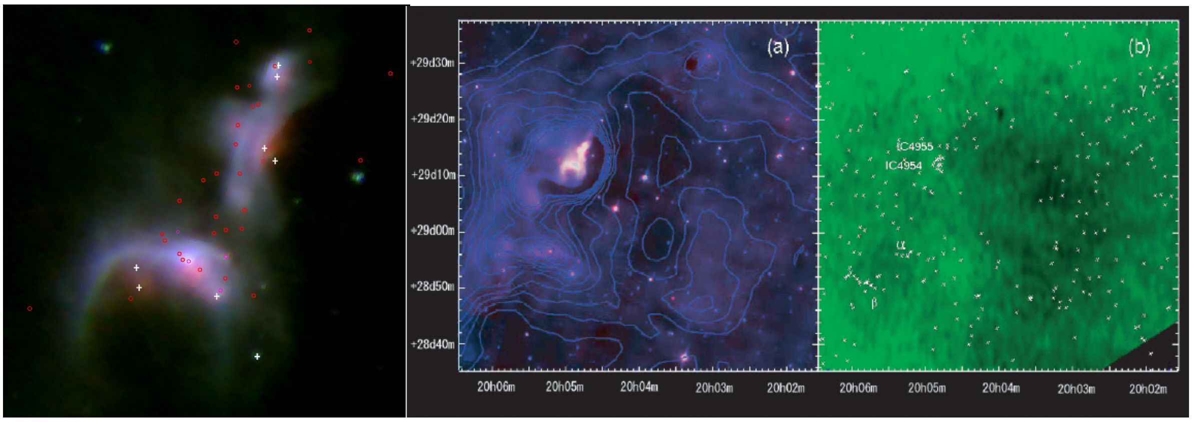

Fig. 4.— (Left) Mid-infrared two-color image made from the S9W (blue) and L18W (red) images taken with the *AKARI*/IRC. Optically known early-type stars are indicated by the white crosses (Delgado et al. 2004; Merrill et al. 1942). Red ($H-K>0.9$ and $J-H>0.9$) sources selected from the 2MASS catalog are shown by the red circles. (Center) Color image made from the S9W and L18W all-sky survey data of *AKARI*/IRC around IC 4954/4955. The contours indicate the ISSA 100 μm intensity. (Right) CGPS HI 21 cm map integrated over the velocity range of 0–30 km s^{-1}. The crosses indicate red sources selected from the 2MASS catalog.

(cf., Onaka et al. 2004). The strength of the incident radiation field estimated based on the projected distance at the arcs are comparable with those of typical PDRs (cf., Mizutani et al. 2004). The observed color variation is well accounted for by the increasing contribution from thermal dust emission. It further indicates that the UIR-band dominating infrared bright regions are always located in the north-east side, suggesting the presence of high-density regions in this side.

To investigate the origin of the IC 4954/4955, mid-infrared maps of the surrounding region of about $1^\circ \times 1^\circ$ at 9 and 18 μm were investigated from the all-sky survey data (center pannel of Figure 4). It indicates that there is a cavity of low mid-infrared emission centered around (RA, Dec) = (20h03m,+29d00m) and that the IC 4954/4955 region is located on an edge of the cavity of the 10 pc radius. Such structures are commonly seen in galactic bubbles (Churchwell et al. 2006).

The presence of the cavity is confirmed by the HI 21 cm data of the region obtained from the Canadian Galactic Plane Survey (CGPS). The HI intensity integrated over 0–30 km s^{-1} is shown in the right pannel of figure 4, which clearly supports the presence of a low-density cavity around the center of the map. The velocity range of HI gas in this region was estimated based on the plot of intensity vs. velocity in good agreement with that of CO emission (6.19 km s^{-1}; Leisawitz et al. 1989). YSO candidates of the region are also plotted by crosses. They were selected from the 2MASS catalog based on the criteria, $H - K > 0.9$, $J - H > 0.9$ and $13.5 < K < 15.0$. YSO candidates seem to be located on the edge of the cavity. It is most clearly seen in the eastern edge, which includes the IC 4954/4955 region.

Though the progenitor candidates of the cavity were not found in the star catalogs, the X-ray maps and the radio continuum maps, this cavity may have been created by supernovae or O-type stars. Since SNRs disappear in the time scale of 1 Myr and the age of the cavity must be older than 4 Myr, based on the age of Roslund 4, it is not unexpected that there is no direct sign for the progenitor. The Cepheus bubble (Patel et al. 1998) is also thought to be formed by O-type stars or supernovae, but shows no direct hint of them.

The present *AKARI* observations have revealed another bubble of small scale, which seems to trigger past (4–15 Myr old) star-formation in IC 4954/4955. It also indicates current star-formation in the region, which is triggered by stars of the second generation. The present observations indicate triggered star-formation over the three generations in a different spatial scale in the IC 4954/4955.

4. Summary

AKARI Mid-Infrared All-Sky Survey was performed with the two mid-infrared band centerd at 9 and 18 μm, with the spatial resolution of about $9.''4$, with the 5σ sensitivity of 50 and 120 mJy, respectively. *AKARI* Mid-Infrared All-Sky Survey substantially improves the MIR dataset of the *IRAS* survey of two decades ago and provides a significant database for studies of various fields of astronomy. Its potential in studying star-forming regions is demonstrated by an initial result.

This work is based on observations with *AKARI*, a JAXA project with the participation of ESA. The contribution from the ESAC to the pointing reconstruction is greatly acknowledged. We also thank M. Cohen for helping us in the flux calibration, T. Muller for providing us the fluxes of asteroids at the observing times. This work is supported in part by a Grant-in-Aid for Scientific Research on Priority Areas from the Ministry of Education, Culture, Sports, Science and Technology of Japan and Grants-in-Aid for Scientific Research from JSPS.

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