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AKARI IRC SURVEY OF THE LARGE MAGELLANIC CLOUD: AN OVERVIEW OF THE SURVEY AND A BRIEF DESCRIPTION OF THE POINT SOURCE CATALOG

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ABSTRACT

We observed an area of 10 deg^2 of the Large Magellanic Cloud using the Infrared Camera (IRC) onboard AKARI. The observations were carried out using five imaging filters (3, 7, 11, 15, and 24 μm) and the prism disperser (2 - 5 μm, $\lambda/\Delta\lambda \sim 20$) equipped in the IRC. This paper presents an outline of the survey project and also describes very briefly the newly compiled near- to mid-infrared point source catalog. The 10 σ limiting magnitudes are 17.9, 13.8, 12.4, 9.9, and 8.6 mag at 3.2, 7, 11, 15 and 24 μm, respectively. The photometric accuracy is estimated to be about 0.1 mag at 3.2 μm and 0.06 - 0.07 mag in the other bands. The position accuracy is 0.3″ at 3.2, 7 and 11 μm and 1.0″ at 15 and 24 μm. The sensitivities at 3.2, 7, and 24 μm are roughly comparable to those of the Spitzer SAGE LMC point source catalog, while the AKARI catalog provides the data at 11 and 15 μm, covering the near- to mid-infrared spectral range continuously.

Key words: infrared; survey; catalog

1. INTRODUCTION

Owing to its proximity (∼ 50 kpc; e.g., Feast & Walker, 1987) and face-on geometry, the Large Magellanic Cloud (LMC) is an ideal natural laboratory for the study of various astrophysical fields. It is located at a high Galactic latitude of $\sim -36°$, and we expect less contamination of foreground stars and less interstellar extinction. It is far enough to neglect its depth so that we can reasonably assume that objects in the LMC are all at the same distance from us. The apparent size of the LMC is ideal, for which the entire galaxy can be surveyed in a reasonable amount of time to study the material circulation processes and star-formation history in a galactic scale. Meanwhile, it is close enough to resolve and study individual objects even with relatively small telescopes. Moreover, the mean metallicity of the LMC is known to be small (∼ 1/4) compared to the solar, intriguing us to study the influence of low metallicity environments on various astrophysical phenomena.

The LMC is observed by a number of large area surveys at optical and near-infrared (NIR) wavelengths. Zaritsky et al. (2004) detected about 2.4×10^7 point sources in a $UBVI$ survey over a 64 deg^2 area of the LMC, whereas Kato et al. (2007) observed about 1.5×10^7 point sources with a JHK_s survey of a 40 deg^2 region. At mid-infrared (MIR) wavelengths, the Midcourse Space Experiment (MSX) carried out a survey over a 100 deg^2 area of the LMC (Egan et al., 2001, 2003) and detected a few thousand sources despite of the short integration time and low spatial resolution. Two recent infrared satellites, the Spitzer Space Telescope (Werner et al., 2004) and AKARI (Murakami et al., 2007), provided a capability of deep mid-infrared observations with better spatial resolutions. The Spitzer SAGE project (Meixner et al., 2006) carried out a uniform and unbiased imaging survey of a 49 $\deg^2$ area of the LMC at 4 photometric bands from 3 to 10 μm with IRAC (Fazio et al., 2004) and 3 bands at 24, 70, and 160 μm with MIPS (Rieke et al., 2004), to which the SAGE-Spec performed follow-up spectroscopic observations in the MIR and far-infrared (FIR) (Kemper et al., 2010; van Loon et al., 2010). Recently Herschel Space Observatory also observed the whole LMC with a higher spatial resolution than Spitzer in the FIR (Meixner et al., 2010). The unique features of the AKARI IRC LMC survey are described below.

2. THE AKARI IRC LMC SURVEY PROJECT

One of the primary goals of the AKARI mission was to carry out an all-sky survey with the FIS and the IRC at six bands from 9 to 180 μm (Ishihara et al., 2006; Kawada et al., 2007). As a result, the entire LMC has been mapped in the 9, 18, 65, 90, 140, and 160 μm wavebands. The MIR point source catalog at 9 and 18 μm and the FIR point source catalog at 65, 90, 140 and 160 μm have been produced from the all-sky survey observations and released to the public (Ishihara et al., 2010; Yamamura et al., 2010).

In addition to the All-Sky survey in mid- and far-infrared, AKARI carried out two large-area legacy surveys (LS) in pointing mode. The LMC survey project (PI. T. Onaka; Ita et al., 2008) is one of the two LS programs. The other is the North Ecliptic Pole survey project (PI. H. Matsuhara; Matsuhara et al., 2007). These survey areas are located at high ecliptic latitudes, where the visibility is high for AKARI's sun-synchronous polar orbit. Therefore a lot of observing time can be allocated for pointing observations in these areas together with the all-sky survey.

The AKARI Large Magellanic Cloud Survey is a NIR to MIR imaging and near-infrared spectroscopic survey toward the LMC. Compared to the contemporary SAGE survey the AKARI IRC LMC survey has the following characteristics.

- The IRC's imaging filters cover the wavelength range from 2.5 to 26 μm continuously. In particular, it has 11 μm (S11) and 15 μm (L15) imaging bands, which fill the gap between the IRAC and MIPS on board the Spitzer Space Telescope (SST). The wavelength range that S11 and L15 bands cover contains interesting spectral features such as the silicate 10 and 18 μm bands.
- One of the most significant features of the IRC is its ability to perform slit-less spectroscopy in addition to imaging. It can simultaneously obtain near- to mid-infrared (about $2-13$ μm) continuous spectra of all sources present in its large FOV of about $10' \times 10'$ within a pointing opportunity.

These features make AKARI IRC unique and complementary to the SAGE survey. Refer to Onaka et al. (2007) for instrumental details and imaging performance of the IRC. General information on the IRC spectroscopic mode, particularly on the slit-less spectroscopy, is given in Ohyama et al. (2007).

3. OBSERVATIONS

3.1. *IRC Astronomical Observing Template and Pointing Observation Sequence*

To cover a wide range of the spectral energy distribution of a celestial body, we use the AKARI IRC AOT02 observing template with a special option prepared for the LMC survey. The AOT02 with the special option yields not only imaging data at 3 (N3), 7 (S7), 11 (S11), 15 (L15), and 24 μm (L24), but also low resolution ($\lambda/\Delta\lambda \sim 20$) $2.5-5$ μm (NP) spectral data at three dithered sky positions in a pointing opportunity. Refer to Shimonishi et al. (2012) for the discussions on spectroscopic data.

As described in the IRC data user's manual (Lorente et al., 2008), one pointing observation with IRC/AOT02 produces images with 2 filters in each channel at 3 dithered sky positions. In each position, both short- and long-exposure data are taken. The net integration time for a long-exposure image is typically 133, 147, and 147 seconds for NIR, MIR-S, and MIR-L, respectively, and that for a short-exposure image is 14.0, 1.75, and 1.75 seconds, respectively.

3.2. *Mapping Strategy*

Due to the focal-plane layout of AKARI, the NIR and MIR-S channels share the same field of view (i.e., they observe the same sky position), but the MIR-L channel observes a different sky position that is offset by

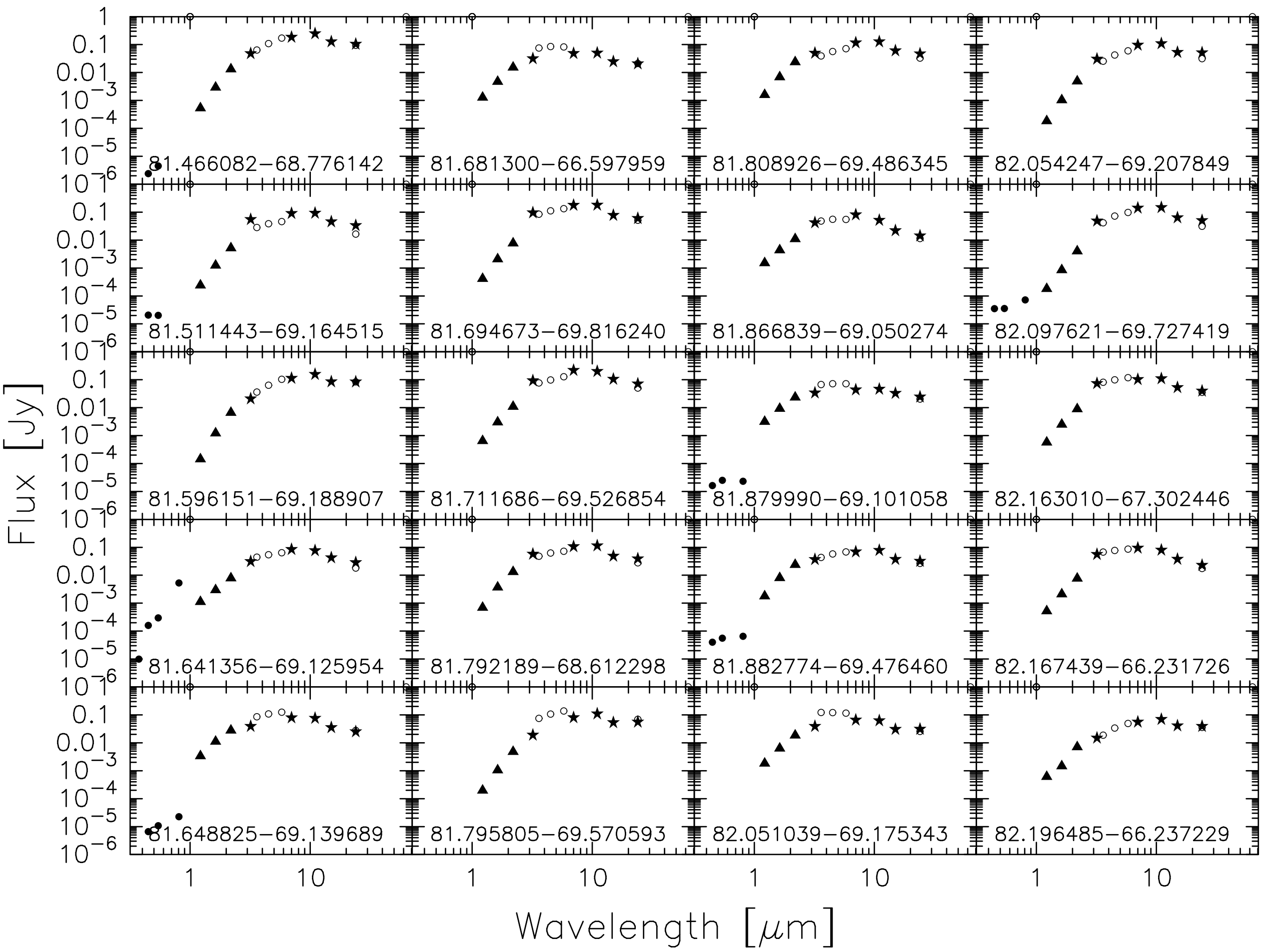

Fig. 1. Spectral energy distribution of some selected red sources in the LMC. Their equatorial coordinates are indicated in the bottom of each panel. Difference in shapes of the marks is due to a difference in photometric survey data. See text for their meanings.

25 arcmin from the NIR/MIR-S center in the direction perpendicular to the AKARI's orbit. AKARI is in a sun-synchronous polar orbit at 700 km attitude along the twilight zone, and its orbit is approximately parallel to the ecliptic meridian lines with approximately 4.1 arcmin spacing at the ecliptic plane between successive orbits. We used this feature to map the LMC effectively. Each of the IRC channels has a field of view of $10' \times 10'$ and adjacent fields are designed to overlap by $\sim 1.5'$. Since AKARI follows the Earth's yearly orbit, the telescope points at the same celestial position every six months, but the direction of the satellite movement relative to the position is rotated by 180 degrees. Thus the position of the MIR-L channel relative to the NIR and MIR-S channels is also rotated by 180 degrees in projection on the sky. Therefore, we divide the observing area into several parts to maximize the observing efficiency to map a large part of the LMC with all three channels of the IRC. Observations were carried out in three separate seasons, from 6th May 2006 to 8th June 2006, from 2nd October 2006 to 31st December 2006, and from 24th March 2007 to 2nd July 2007. Over 600 pointing observations were devoted for this project, yielding about a 10 deg^2 imaging and spectroscopic map of the main part of the LMC.

4. DATA REDUCTION

Details of data reduction are given in (Ita et al., 2008 and Kato et al., 2012), and here we briefly summarize the reduction and calibration procedures.

4.1. *Image Data Reduction*

Standard reduction processes on the imaging data, such as dark subtraction, flat-fielding, and image co-addition, are uniformly done by using the IRC data reduction toolkit version 20110304 (Lorente et al., 2008).

4.2. *Source Detection and Photometry*

We perform source detection with the IRAF/DAOFIND and photometry with the IRAF/DAOPHOT package (Stetson, 1987) on co-added images made by the reduction toolkit. The resulting instrumental signals are converted into physical units using the IRC flux conversion factors given in Tanabe et al. (2008)

4.3. *Astrometric Calibration*

The coordinates of detected sources are calculated by reference to the Two Micron All Sky Survey Point Source Catalog (2MASS-PSC; Skrutskie et al., 2006) and Spitzer SAGE LMC point source catalog (Meixner et al., 2006). The equatorial coordinates of the 2MASS-PSC are based on the International Celestial Reference System (ICRS), and so are the SAGE-PSC via the 2MASS-PSC. Hence, the equatorial coordinates of our catalog indirectly refer to the ICRS. We estimate that the overall uncertainty of our position determination is about $0.3''$ at 3.2, 7 and 11 μm and $1.0''$ at 15 and 24 μm.

5. BRIEF DESCRIPTION OF THE POINT SOURCE CATALOG

We compiled a point source catalog that lists about 6.5×10^5 sources. Refer to Kato et al. (2012) for details of the catalog compilation procedure. The point source catalog is estimated to be complete down to 14.6, 13.4, 12.6, 10.7, and 9.3 mag at N3, S7, S11, L15, and L24, respectively. Also the 10σ limiting magnitudes are 16.8, 13.4, 11.5, 9.9, and 8.5 mag at N3, S7, S11, L15, and L24, respectively. We define that the 10σ limiting magnitude is the faintest magnitude at which the mode of photometric uncertainties of the sources in catalog exceeds 0.11 mag. These limiting magnitudes are slightly worse than those of the SAGE survey, while the S11 and L15 bands fill the gap of the SAGE data with comparable sensitivities. With these sensitivities, all red giants above the tip of the first red giant branch (TRGB) and some fraction of Herbig Ae/Be stars in the LMC are expected to be detected in wavebands shorter than S11.

In Figure 1, we show spectral energy distributions of some selected red sources in the LMC. Difference in shapes of the marks is due to a difference in photometric survey data; black dots: Magellanic clouds optical photometric survey (Zaritsky et al., 2004), filled triangles: IRSF/SIRIUS near-infrared survey (Kato et al., 2007), filled stars: AKARI/LMC survey (Ita et al., 2008; Kato et al., 2012), open circles: Spitzer SAGE survey (Meixner et al., 2006). As is evident in the figure, the IRC's 11 μm (S11) and 15 μm (L15) imaging bands fill the gap between the IRAC and MIPS onboard the Spitzer. Our new AKARI catalog combined with available survey catalogs would provide us with the continuous photometric data covering from optical to mid-infrared wavelength.

6. SUMMARY

We carried out an imaging and spectroscopic survey of a 10 deg^2 area of the LMC using IRC onboard AKARI. In this paper we outline the survey, data reduction and calibration procedures. We also briefly describe the point source catalog that lists about 6.5×10^5 sources. The point source catalog will be made available to the public. The point source catalog and results from AKARI All-Sky survey together with existing radio and near-infrared ground-based observational results will provide a significant database to study the star-formation history and material circulation within a galaxy.

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