AKARI Large Area Survey of the Large Magellanic Cloud*

Takashi Onaka[1], Yoshifusa Ita[2], Daisuke Kato[1], Takashi Shimonishi[1], Ituski Sakon[1], Yoshikazu Nakada[3], Toshihiko Tanabé[3], Hidehiro Kaneda[4], Takehiko Wada[4], Aiko Kawamura[5], Bon Chul Koo[6], Hidenori Takahashi[7], Motohide Tamura[2], and Tetsuo Hasegawa[2]

ABSTRACT

We present the results of the large area survey observations of the Large Magellanic Cloud (LMC) with the *AKARI* infrared satellite. In addition to the all-sky survey observations at 9, 18, 65, 90, 140, and 160 μm, about a 12 deg^2 region of the LMC has been observed in pointed observations with the Infrared Camera (IRC) on board *AKARI* at 3, 7, 11, 15, and 24 μm bands. Together with these imaging observations, 2–5 μm low-resolution slit-less spectroscopy was also carried out for the same area. These data, particularly the 11 and 15 μm imaging and near-infrared spectral data, complement the *Spitzer* SAGE observations and provide significant information to the various fields of the LMC research. The near-infrared spectroscopic survey is demonstrated to be very efficient in the study of the nature of detected sources. We present an overview of the *AKARI* LMC observations together with some early results.

Subject headings: galaxies: ISM — infrared: galaxies — infrared: ISM — ISM: dust, extinction — Magellanic Clouds

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[1]Department of Astronomy, Graduate School of Science, University of Tokyo, Tokyo 113-0033, Japan

[2]National Astronomical Observatory of Japan, Tokyo 181-8588, Japan

[3]Institute of Astronomy, Graduate School of Science, University of Tokyo, Tokyo, 181-0015, Japan

[4]Institute of Space and Astronautical Science (ISAS), JAXA, Kanagawa 229-8519, Japan

[5]Division of Particle and Astrophysical Sciences, Graduate School of Science, Nagoya University, Nagoya 464-8602, Japan

[6]Department of Physics and Astronomy, Seoul National University, Seoul 151-742, Korea

[7]Gumma Astronomical Observatory, Gunma 377-0702, Japan

1. Introduction

AKARI (formerly known as ASTRO-F) is a Japanese satellite mission dedicated to infrared astronomy (Murakami et al. 2007). It has a light-weight telescope with a silicon-carbide primary mirror of 685 mm in effective diameter (Kaneda et al. 2007) together with two on-board instruments, Far-Infrared Surveyor (FIS; Kawada et al. 2007) and Infrared Camera (IRC; Onaka et al. 2007). The telescope as well as the on-board instruments are cooled by 179-liter superfluid liquid helium and mechanical coolers on board (Nakagawa et al. al 2007). *AKARI* was launched on 2006 February 21 (UT) and brought into a sun-synchronous polar orbit of an altitude of 700 km by the JAXA M-V-8 rocket. The aperture lid was opened on 2006 April 13 and until 2007 August 26, when the liquid helium was exhausted, *AKARI* carried out all-sky survey observations at 9, 18, 65, 90, 140, and 160 μm. Together with the all-sky survey, deep imaging and spectroscopic observations from near- to far-infrared have also been performed with IRC and FIS in the pointing mode, in which the telescope was pointed at a given position of the sky for about 10 min.

A survey observation of about a 12 deg^2 region of the Large Magellanic Cloud (LMC) was performed with IRC in the pointing mode as one of the *AKARI* large area survey programs in addition to the all-sky survey observations (Matsuhara et al. 2005; Ita and Onaka 2007). In this report we present an overview of the *AKARI* LMC survey and its early results.

2. *AKARI* LMC Observations and Early Results

IRC consists of three channels; NIR, MIR-S, and MIR-L (Onaka et al. 2007). Each channel has a field-of-view of about $10' \times 10'$. The NIR and MIR-S shares the same field-of-view by virtue of a beam splitter, whereas the MIR-L observes the sky about $25'$ away from the NIR/MIR-S field-of-view. The NIR channel operates from 1.8 to 5.5 μm, the MIR-S works in 5.4–13.1 μm, and the MIR-L covers 12.4–26.5 μm. All the three channels are operated simultaneously. Each channel is equipped with three filters for imaging observations, two dispersive elements (prism or transmission grating) for spectroscopic observations and the shutter for the dark measurement.

Fig. 1 shows the area observed by IRC in the pointing mode. Each square indicates a field-of-view of the NIR channel. Observation positions of the LMC were arranged so as to observe the targeted area with the three cameras. The observations were made from 2006 May to 2007 July. The observed area is smaller than the *Spitzer*/SAGE survey area (Meixner et al. 2006), but it covers most of major regions of the LMC. The IRC observations were carried out with the 3, 7, 11, 15, and 24 μm imaging bands (see Onaka et al. 2007).

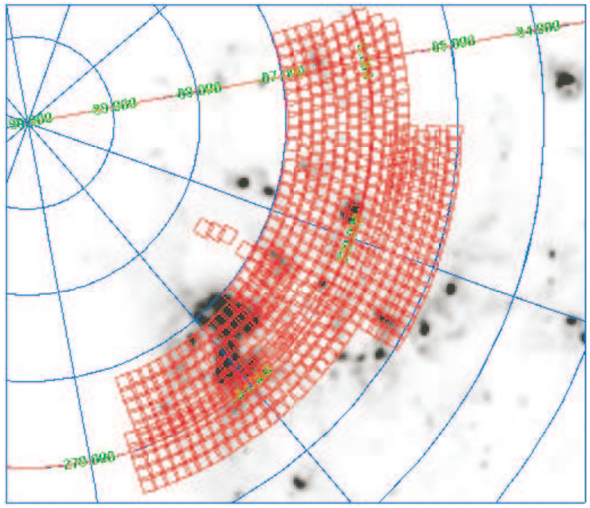

Fig. 1.— Area of the LMC observed with IRC

In addition near-infrared low-resolution slit-less spectroscopy ($R \sim 20$) was performed for the same 12 deg^2 region in 2–5 μm with the prism spectroscopic mode of IRC (NP; Ohyama et al. 2007). The relative spectral responses of the IRC observations of the LMC as well as those of the all-sky observations are shown in Fig. 2 together with typical spectra of an oxygen-rich Mira variable and a Galactic cirrus cloud.

The *AKARI* all-sky survey provides 6-band photometric data over the entire LMC from the mid-infrared to far-infrared, which allow us to study diffuse emission from the interstellar medium (ISM) in the LMC with a much higher spatial resolution and a better sensitivity than *IRAS* and *COBE* observations (cf. Sakon et al. 2006). IRC pointing observations of the LMC include 11 and 15 μm band imaging, which fills the gap between the IRAC and MIPS bands and complements the *Spitzer* SAGE data. In particular, the 11 μm data together with the 15 μm data will be important for the estimation of the silicate band strength in mass-losing stars.

The near-infrared (NIR) slit-less spectroscopy provides flux-limited spectroscopic survey of point sources in the LMC, adding a new dimension to the *AKARI* LMC survey data. Fig. 3 shows an example of the IRC NIR slit-less spectroscopy image. Based on the imaging data taken at 3 μm band, the zero point of the wavelength scale is determined and the spectrum of a point source is extracted (Ohyama et al. 2007). Examples of thus derived spectra are shown in Fig. 4. Fig. 4a indicates the spectrum of a HII region, where hydrogen recombination lines dominate in addition to the unidentified infrared (UIR) emission band at 3.3 μm. Due to the low spectral resolution, the UIR band is possibly blended with Pfδ. Fig. 4b shows the spectrum of a dusty carbon star. C_2H_2 and HCN bands around 3.0 and 3.7 μm are

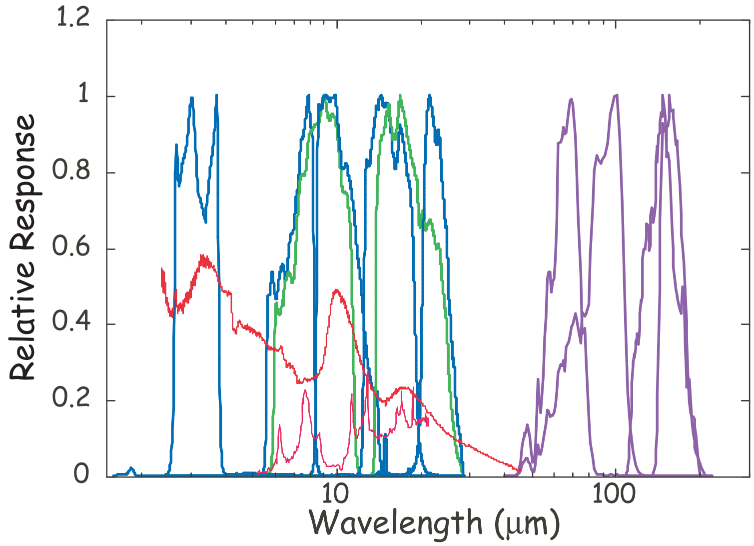

Fig. 2.— Relative response of the imaging filter bands used for the *AKARI* LMC observations. The blue lines indicate those used with the IRC pointing observations, and the green and purple lines indicate those employed in the all-sky survey mode. The thick solid line in the upper left corner indicates the spectral range of the low-resolution spectroscopy. The red lines show typical spectra of an oxygen-rich Mira variable (upper line) and a Galactic cirrus cloud (lower line).

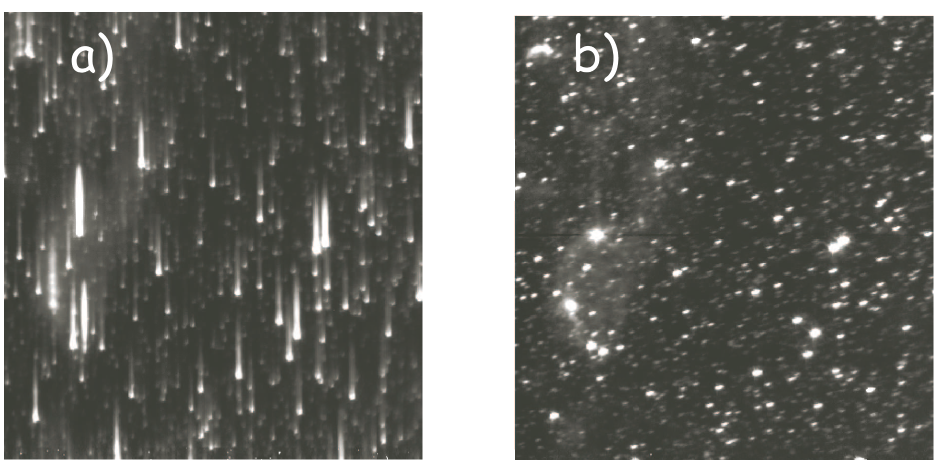

Fig. 3.— Slit-less spectroscopy image (a) and the corresponding 3 μm image (b). The image size is about $9' \times 10'$.

clearly seen. Finally the spectrum of a young stellar object (YSO) is shown in Fig. 4c. It is characterized by the presence of H_2O (3.1 μm) and CO_2 (4.3 μm) ice bands, which is the first clear detection of the 4.3 μm CO_2 band in extragalactic sources (Shimonishi et al. 2008).

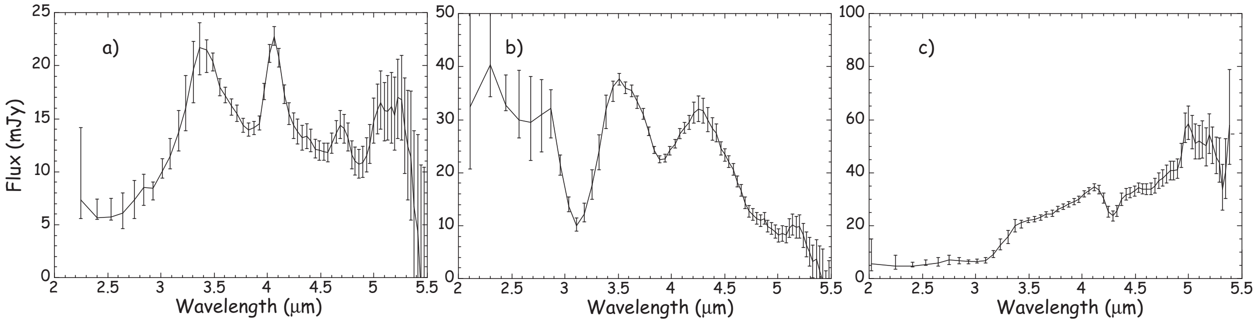

Fig. 4.— Example of the NIR spectra taken with the IRC slit-less spectroscopy mode. (a) HII region, (b) dusty carbon star, and (c) young stellar object.

These data enable us to investigate the ice chemistry in a low metallicity environment of the LMC (e.g. Gerakines et al. 1999; Watanabe & Kouchi 2002). Fig. 4 clearly demonstrates that the NIR spectroscopy is quite efficient in distinguishing YSOs from dusty evolved stars and correctly classifying the detected objects. As indicated in Fig. 4, IRC NIR spectroscopy can detect sources of the flux down to $\sim 1\,$mJy in the NIR with a sufficient signal-to-noise ratio (Ohyama et al. 2007).

3. Summary and Future Plan

Needless to say, the LMC is a unique object for the study of various astronomy fields because of its proximity and face-on geometry. Survey observations provide a systematic and coherent dataset since all the objects are located nearly at the same distance from us. The *AKARI* survey takes an advantage of this uniqueness as well as their good locations on the sky for the visibility. It provides 3, 7, 11, 15, and 24 μm imaging and 2–5 μm low-resolution spectroscopy data of about a 12^{2} region of the LMC, significantly improving our understanding of various fields of cutting-edge astronomy, including star-formation, interstellar chemistry, mass-loss process of the late stage stellar evolution, and mass and energy return from SNRs. The *AKARI* LMC survey imaging data are now in the process of data reduction and the first point source catalog is planned to be prepared in 2008. It will be released to the public in 2009.

AKARI NIR spectroscopic capability is unique and provides a significant dataset for the study of the nature of detected sources. However, as indicated in Fig. 3, source confusion becomes serious in several crowded fields. After the exhaustion of liquid helium, the telescope and the on-board instruments of *AKARI* are kept cold ($\sim 40\,$K) by the mechanical coolers and the NIR channel of IRC continues observations. During the post-liquid helium mission it is now planned to make duplicated spectroscopic observations with a different position angle to remove contamination from faint sources and significantly increase the reliability of the spectroscopic survey data.

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