SPICA deep cosmological survey: from AKARI to SPICA

Conference or Workshop Item

How to cite:

Shirahata, M.; Matsuura, S.; Matsuhara, H.; Takagi, T.; Oyabu, S.; Wada, T.; Nakagawa, T.; Kawada, M.; Takeuchi, T. T.; Hatsukade, B.; Kohno, K.; Pearson, C. P.; Serjeant, S. and White, G. (2009). SPICA deep cosmological survey: from AKARI to SPICA. In: EDP Sciences 04012/1-0412/4.

Version: Version of Record

Link(s) to article on publisher's website:
http://dx.doi.org/doi:10.1051/spica/200904012
http://spica.edpsciences.org/index.php?option=com_toc&url=/articles/spica/abs/2009/01/contents/contents.html

SPICA Workshop, 04012 (2009)
DOI:10.1051/spica/200904012

SPICA DEEP COSMOLOGICAL SURVEY : FROM AKARI TO SPICA

M. Shirahata[1], **S. Matsuura**[1], **H. Matsuhara**[1], **T. Takagi**[1], **S. Oyabu**[1], **T. Wada**[1], **T. Nakagawa**[1], **M. Kawada**[2], **T.T. Takeuchi**[3], **B. Hatsukade**[4], **K. Kohno**[4], **C. P. Pearson**[5,6,7], **S. Serjeant**[7], and **G. White**[7,5]

[1]Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), Sagamihara, Kanagawa 229-8510, Japan
[2]Graduate School of Science, Nagoya University, Nagoya, Aichi 464-8602, Japan
[3]Institute for Advanced Research, Nagoya University, Nagoya, Aichi 464-8601, Japan
[4]Institute of Astronomy, University of Tokyo, Mitaka, Tokyo 181-0015, Japan
[5]Space Science and Technology Department, CCLRC Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire OX11 0QX, UK
[6]Department of Physics, University of Lethbridge, Alberta, T1J 1B1, Canada
[7]Department of Physics and Astronomy, Faculty of Science, The Open University, milton Keynes, MK7 6AA, UK

ABSTRACT

On the basis of the results of the AKARI far-infrared deep surveys, we propose a multi-wavelength far-infrared deep cosmological survey with SAFARI on SPICA. We have carried out a far-infrared deep cosmological survey with AKARI, and successfully obtained the galaxy counts and new limits on the absolute brightness of the cosmic far-infrared background. These results provide strong constraints on evolutionary scenarios, and suggest the necessity for a new model to explain galaxy evolution. Thanks to the excellent sensitivity and spatial resolution of SPICA/SAFARI, we will be able to resolve the cosmic infrared background into individual objects with 3 times or more higher spatial resolution than that of AKARI, and will also be able to conduct infrared photometry and spectroscopy on those objects. The far-infrared deep survey with SPICA/SAFARI will be an ideal opportunity to reveal the origin of the cosmic far-infrared background residual brightness and fluctuations. These observation will allow us to reveal the star formation history in the early Universe without the uncertainty of dust attenuation, which is essential if we are to understand the process of galaxy formation.

Key words: Galaxies: evolution – Cosmology: observations – Missions: SPICA

1. INTRODUCTION

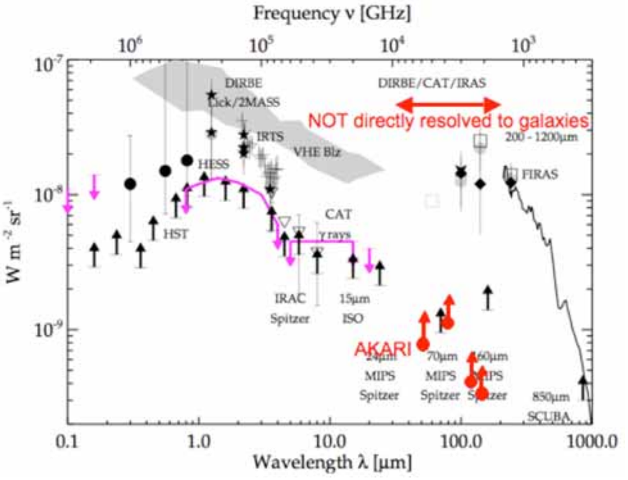

Figure 1. The absolute brightness of the CIB, compared with the integrated flux of resolved galaxies (Dole et al. 2006).

Since the Cosmic Infrared Background (CIB) was discovered with the COBE satellite (Puget et al. 1996; Hauser et al. 1998), it has been known that a large fraction of the radiation energy in the Universe is released at far-infrared wavelengths. The main source of the far-infrared background has been thought to be the re-emission of UV light absorbed by dust in star-forming galaxies at high redshift. Up to now, many efforts have been made to resolve the CIB into individual galaxies through deep surveys with infrared space telescopes such as ISO, Spitzer and AKARI. However, only 10–30% of the CIB has been resolved into individual galaxies, and main bulk of the CIB is still remains unknown (See Figure 1).

By using the excellent sensitivity and high resolution of SPICA, we will be able to resolve the CIB into individual objects, and reveal the origin of the cosmic far-infrared background brightness and fluctuations.

2. SCIENTIFIC OBJECTIVES

The scientific objectives of this program are as follows.

2.1. SOURCE COUNTS FOR INFRARED GALAXIES

Since SPICA has a large cooled telescope (3.5 m, 6 K), its sensitivity will be at least 2 orders of magnitude better than that of Herschel, and its spectral resolution is at least 3 times greater than that of AKARI and Spitzer. With the projected sensitivites for point sources, SPICA has a

Proceedings of the *“SPICA Joint European Japanese Workshop”*, 6–8 July 2009, Oxford, United Kingdom
(Edited by A. M. Heras, B. M. Swinyard, K. G. Isaak, & J. R. Goicoechea)

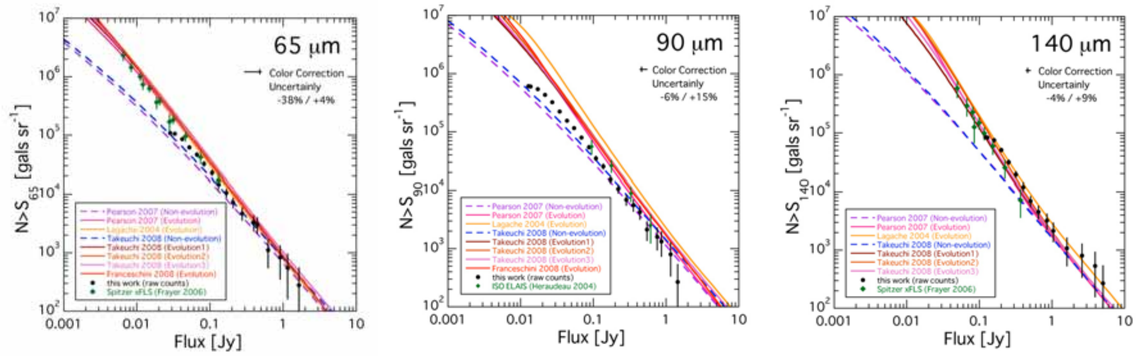

Figure 2. Integral galaxy counts measured in the AKARI Deep Field South at 65, 90, and 140 μm *(Shirahata et al. 2009)*

capability to resolve 90% and 60% of the CIB at 70 μm and 160 μm, respectively (Dole et al. 2004).

Galaxy number counts are useful to constrain the evolutionary scenario of galaxies. We have carried out a deep cosmological survey at four far-infrared wavelength bands (65, 90, 140, and 160 μm) with the FIS instrument (Kawada et al. 2007) onboard the AKARI satellite (Murakami et al. 2007). In order to minimize the contamination from the Galactic cirrus emission, we selected an extremely low cirrus density region on the whole sky – near the South Ecliptic Pole – as a survey field (AKARI Deep Field South: ADF-S). The brightness of the cirrus emission in this field is less than 0.5 MJy sr^{-1} at 100 μm (Schlegel et al. 1998), which means that this field provides the best cosmological window to the high-redshift Universe. This survey is particularly unique in having continuous wavelength coverage across four photometric bands including wavelengths not well explored by previous missions, and contiguous mapping over an area of large extent. We have successfully detected almost 2000 galaxies down to $\sim$10 mJy at 90 μm, and measured infrared colors for about 500 sources. As shown in Figure 2, the AKARI results indicate the necessity of multi-band galaxy number counts, especially around wavelengths of 100 μm (Shirahata et al. 2009). Thus, multi-wavelength galaxy counts at projected SPICA/SAFARI sensitivities will be a powerful tool to discriminate between different galaxy evolution scenarios.

2.2. PROPERTIES OF DETECTED INDIVIDUAL GALAXIES

In order to reveal what kind of galaxies dominate the CIB, the measurement of the spectral energy distributions (SEDs) of detected sources are very important. The AKARI extra-galactic deep surveys have discovered examples of pure-starburst ULIRGs (Takagi et al. 2007, 2009, Figure 3) and extremely red objects which show evidence of co-evolution of both the obscured AGN and starburst components (Matsuhara et al. 2009, Figure 6). We will be able to statistically detect significant numbers of these galaxies beyond redshifts of $z > 3$ with SAFARI and the mid-infrared MIRACLE instrument multi-band imaging.

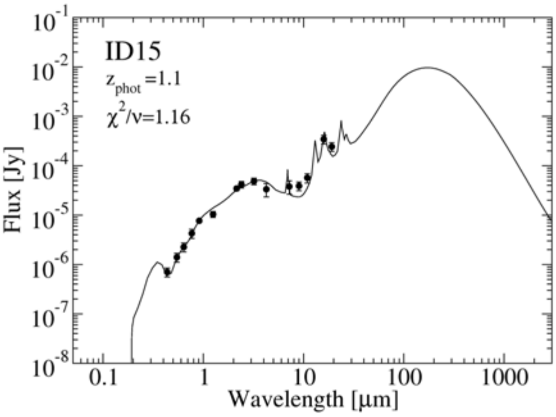

Figure 3. SED of pure-starburst ULIRG at z$\sim$1 discoveried by Takagi et al. (2007, 2009).

Moreover, we have the possibility to detect dust-obscured (i.e., IR-luminous) galaxies at z=4–10, which would be key targets in probing the high-redshift universe to the epoch of reionization.

2.3. STACKING ANALYSIS

Stacking analysis with other wavelength data is a useful method with which to investigate the properties of the unresolved sources. Since the galaxy confusion limit at mid-infrared wavelengths is much lower than that at far-infrared wavelengths, a far-infrared stacking analysis using the mid-infrared images as a reference will be less hampered by confusion. On the other hand, because the cosmic sub-mm background can be almost completely explained by distant sub-mm galaxies, stacking analysis for the sub-mm galaxies reveals information on the distant universe.

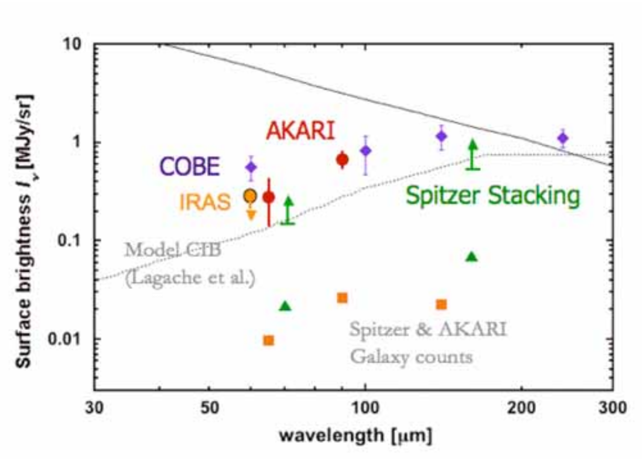

Figure 4. The CIB brightness measured by AKARI compared with the previous CIB limits (Matsuura et al. 2009).

2.4. The absolute brightness of the CIB

The results from the AKARI far-infrared deep survey, also provided new limits on the absolute brightness of the CIB (see Figure 4), and also found a signature of galaxy clustering at angular scales of 10–30 arcmin (Matsuura et al. 2009). With the aim of detecting the signatures of the first stars at the re-ionization epoch of the Universe, we will evaluate the far-infrared background fluctuations in an effort to reveal their origin through detailed analyses through detailed analysis such as multi-wavelength correlation.

3. SPICA Deep Survey

We propose a deep multi-wavelength far-infrared survey making use of the unique capability of the SAFARI instrument on SPICA, to obtain statistically significant samples of sources to clearly detect CIB fluctuations on angular scales of up to a degree. In order to measure the SEDs of detected galaxies and the absolute brightness of CIB, a low-resolution spectro-photometric imaging mode ($\Delta\sigma \sim 10$ cm^{-1}) is desired. The required detection limit is ~300 μJy (5-sigma). To avoid contamination from Galactic cirrus, a low HI-column density region should be selected for the survey. The required survey area needs to be larger than $2{\times}2$ deg^2 if we are to be able to investigate large-scale structure at z=1–3. Follow-up imaging with MIRACLE filter bands will also be necessary.

Figure 5 shows the predicted performance of SAFARI and MIRACLE on SPICA, compared with the SED template of ULIRGs at various redshifts. The results of the estimation of the galaxy confusion limit (Takeuchi et al. 2009) and IR cirrus confusion limit (Miville et al. 2007) are also shown. It can be seen that SPICA/SAFARI will have the sensitivity in low-resolution spectro-photometric imaging mode to detect dusty ULIRGs in the distant dusty universe out to z=3. In addition, SPICA/MIRACLE should detect the PAH and silicate features of such ULIRGs, which provide important clues into the properties of dusty ULIRGs.

In order to achieve this observation, there will be requirements for the SPICA mission and the SAFARI instrument. Figure 6 shows the expected brightness of the CIB compared with the thermal emission from the telescope and the baffle. Since the absolute brightness of the CIB is weak, and the emission diffuse, we not only have to cool the telescope to low temperatures, but also the baffle. In order to achieve an absolute measurement with high accuracy, we also need a cold shutter in order to accurately subtract the detector dark current and calibration lamps to calibrate and correct for detector sensitivity.

Acknowledgements

We express our gratitude to all members of the AKARI project and SPICA project. This research is based on discussions within the SPICA task force of the Japanese community of optical and infrared astronomers. This work is partly supported by JSPS grants (16204013 and 19540250). M. Shirahata thanks the Daiwa Anglo-Japanese Foundation for supporting a visit to Oxford to participate in this work.

References

Dole, H., Le Floc'h, E., Pérez-González, P. G., et al. 2004, ApJS, 154, 87

Dole, H., Lagache, G., Puget, J.-L., et al. 2006, A&A, 451, 417

Hauser, M. G., Arendt, R. G., Kelsall, T., et al. 1998, ApJ, 508, 25

Kawada, M., et al. 2007, APJS, 59, S389

Lagache, G., Dole, H., Puget, J.-L., et al. 2004, ApJS, 154, 112

Matsuhara, H., Wada, T., Oyabu, S., et al. 2009, proceedings of the AKARI conference, ASPCS, submitted

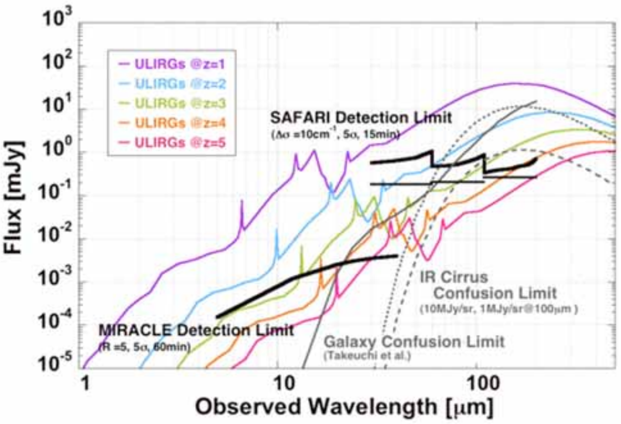

Figure 5. The predicted performance of SAFARI and MIRACLE on SPICA, compared with the SED template of ULIRGs at various redshift.

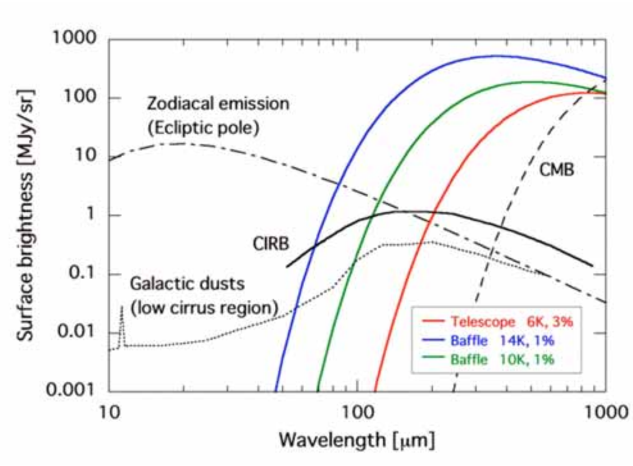

Figure 6. The expected brightness of the CIB compared with the thermal emission from the telescope and the baffle.

Matsuura, S., Shirahata, M., Kawada, M., et al. 2009, proceedings of the AKARI conference, ASPCS, submitted

Miville-Deschenes, M.-A., Lagache, G., Boulanger, F., et al. 2007, A&A, 469, 595

Murakami, H., et al. 2007, APJS, 59, S369

Pearson, C., Jeong W-S., Matsuura, S. et al. 2007, Adv.Space Res. 40, 605

Puget, J.-L., Abergel, A., Bernard. J.-P., et al. 1996, A&A, 308, 5

Schlegel, D. J., Finkbeiner, D. P., & Davis, M. 1998, ApJ, 500, 525

Shirahata, M., Matsuura, S., Kawada, M., et al. 2009, proceedings of the AKARI conference, ASPCS, submitted

Takagi, T., Matsuhara, H., Wada, T., et al. 2007, PASJ, 59, S557

Takagi, T., Matsuhara, H., Oyabu, S., et al. 2009, A&A, submitted

Takeuchi, T. T., Ishii, T. T., & Murata, K. L. 2010, in preparation