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ISOPHOT far-infrared survey in the Lockman hole: First report[0]

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The ISOPHOT data presented in this paper was reduced using PIA, which is a joint development by the ESA Astrophysics Division and the ISOPHOT consortium led by the Max Planck Institute for Astronomy (MPIA), Heidelberg.

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Abstract. An ISOPHOT C_160 (174 μm) map covering approximately a $22' \times 22'$ area in the Lockman Hole is presented. Preliminary data reduction with the PIA (PHOT Interactive Analysis) package shows many spots in this area. If these spots are point sources, the map is confused by galaxies. Bright spots appear to be point sources at the flux level of 100 mJy when the COBE data is used for flux scaling. No significant extended structures in the brightness distribution common to IRAS 100 μm observation are found, and no IRAS point sources are cataloged in this area. Optical counterparts of bright 174 μm sources are faint or invisible on Palomar Sky Survey I E plates.

1. Introduction

In 1991, members of a Japanese group led by H. Okuda met at ISAS and agreed to dedicate one third of the ISAS guaranteed time to search for high redshift objects with the Infrared Space Observatory (ISO; Kessler et al. 1996). As part of this program, two $40' \times 40'$ fields were surveyed at the ISOPHOT C_90 (95μm) and C_160 (174 μm) bands in the Lockman Hole where the HI column density is minimum over the entire sky. Each field is made up with four sub-fields, each of which covers approximately a $22' \times 22'$ area. Pilot observations with AOT (Astronomical Observation Template) PHT32 executed on March 28, 1996 (rev. 132) indicated that PHT22 was superior to PHT32 for faint source detection toward this direction with low background radiation and virtually free from cirrus confusion. Preliminary data reduction shows that 95μm data are seriously affected by detector drifts and special routines are required to clean such systematic noise, while 174 μm data are already clean and the sensitivity is probably limited by statistical noise of data samples. This article presents a C_160 (174 μm) PHT22 map for sub-field LHNW4.

The basic strategy of this program is: 1) to extract the diffuse cosmic background emission which cannot be resolved by ISO by covering $40' \times 40'$ areas matching with the COBE beam; 2) to study luminosity evolution of starburst galaxies and dust-enshrouded quasars by emphasizing observations at the C_160 (174 μm) band, because the energy peak of high redshift counterparts should shift into this band.

2. Observations

LHNW4 was surveyed at the C_160 band with C200 which is a 2×2 stressed Ge:Ga array on May 29, 1996 (rev. 198). The linear size of the array is $184''$ and that of each detector is $89.4''$ (Lemke et al. 1996). The Airy disc is $146''$ at 174 μm. A 27×14 PHT22 raster mapping was made with a raster step size of $46''$ in the satellite Y-axis and $92''$ in the Z-axis; $46''$ and $92''$ are a quarter and half of the array size respectively. The integration time per raster point is 16 seconds, providing four integration ramps with 127 non-destructive readouts each. The TDT (Target Dedicated Time) of ISO is 8,900 sec.

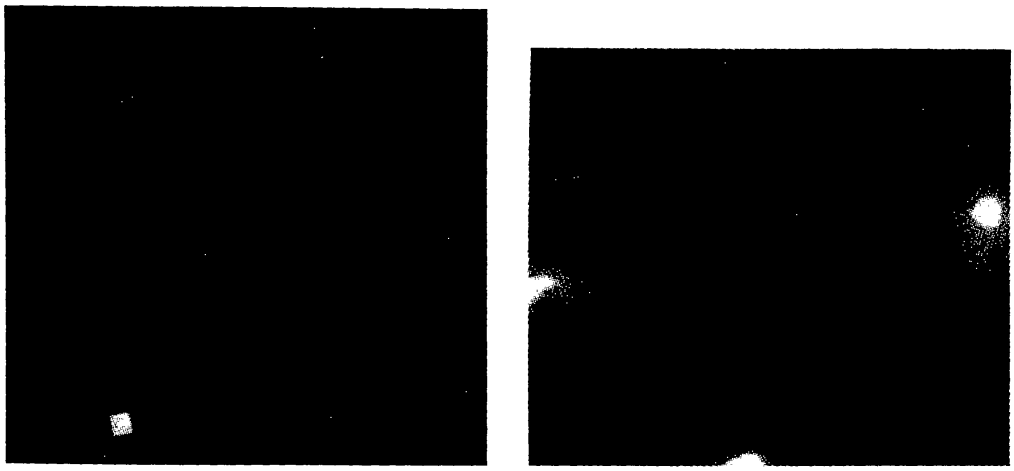

Figure 1. **Left:** ISOPHOT C_160 (174 μm) map of Lockman Hole sub-field LHNW4 which was taken with AOT PHT22. North is up and east to the left. The linear size of the map is 23.8′ from side to side. The scale is 23″ × 23″ per pixel, while the 2 × 2 detector array has dimensions 184″ × 184″ and the step size in rastering is by 46″ and 92″ in the satellite axis directions. The map appears confused probably by galaxies and the detection limit is tentatively estimated to be 30 - 50 mJy. The surface brightness measured by COBE is 2.79 MJy sr^{-1} at 160μm (Reach 1996). Signal to noise ratio per pixel is about 100, where noise only includes the statistical error of data samples and signal includes zodiacal light contribution to the surface brightness. **Right:** IRAS 100 μm map with FRESCO (Full RESolution Survey COaddition) Processing provided by IPAC. The sub-field observed by ISO is enclosed by box. The surface brightness across the IRAS map ranges from -0.2 to 0.1 MJy sr^{-1} with zodiacal contribution subtracted, and its standard deviations to each pixel is about 0.3.

The PIA package was used for data reduction with the default flat-fielding. The calibration files supplied with PIA ver. 5.4 were used. Flux calibration was made by scaling to the COBE value 2.79 MJy sr^{-1} at 160μm (Reach 1996).

3. Discussion

Figure 1 compares the ISO 174 μm map of LHNW4 with the IRAS 100 μm map. The pixel size is 23″ × 23″ on the ISO map, while that is 15″ × 15″ for IRAS. The IRAS map is a FRESCO (Full RESolution Survey COaddition) processed product supplied from IPAC. Signal to noise ratio per detector on the ISO map is about 100, where noise only includes the statistical error of data samples and signal includes zodiacal light contribution to the surface brightness. The surface brightness across the IRAS map ranges from -0.2 to 0.1 MJy sr^{-1} with the zodiacal contribution subtracted, and its standard deviations to each pixel is about 0.3. Thus, IRAS shows no significant cirrus emission in this region

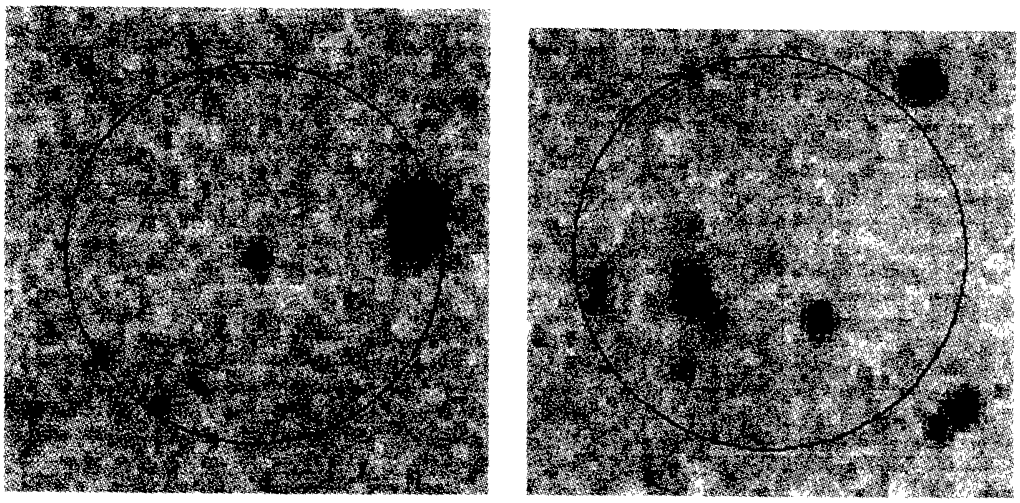

Figure 2. Examples of possible optical counterparts of ISO 174 μm sources at the flux level of 100 mJy, which were searched on the Palomar Sky Survey I E Plates. ISO source positions are at the center of the circle and the diameter is $92''$, where the detector size is $89.4'' \times 89.4''$.

and variation in surface brightness across the IRAS map is probably caused by statistical fluctuation. No IRAS point sources are cataloged in this field.

Many spots are present on the ISO map. The brightness of bright spots deviates from the mean value by 20%. These spots are probably 100 mJy level point sources. If faintest spots are real and point sources, then the detection limits would be at the level of 30 - 50 mJy. The real detection limits may be higher than this value, because the map appears to be confused by these spots.

Possible optical counterparts of ISO 100 mJy level point sources were searched by using the Digital Sky Survey data, which is in fact the Palomar Sky Survey I E plate data. Optical counterparts are usually very faint, and in some cases no optical counterparts are found. Examples of optical counterparts are shown in Figure 2. 100 mJy 174 μm point sources with no optical counterparts on the Palomar Sky Survey may be consistent with Arp 220 with the luminosity scaled down by a factor of 1,000 or with high redshift version of such objects.

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Part 7. Preliminary Results of the ISO