IRTS Far-infrared Photometer (FIRP) Explanatory Supplement

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This document is intended to provide minimal information which would be needed to use the FIRP data. This is still **'under construction'** and is subject to change without notice. Users of the FIRP data are advised to check the web site where you got this document for a revised version.

1 Instrument

The Far Infrared Photometer (FIRP) on-board the Infrared Telescope in Space (IRTS) is a four-band photometer which is optimized to observe diffuse sky emission at sub-mm wavelengths. The FIRP was capable of doing absolute photometry at 4 wavelengths (150, 250, 400, 700 μm) simultaneously with the beam size of 0.5 degrees. The Ge composite bolometers were used with the AC-biased bridge circuit followed by cold J-FETs and low- noise lock-in amplifiers as the readout electronics. The bolometers were cooled down to 300mK using the ^{3}He closed cycle refrigerator that was specially designed to work at zero-gravity environment. The lifetime of ^{3}He refrigerator per one cycle was approximately seven days (Freund et al. (1996)). Absolute photometry was established with the use of internal cold shutter as well as 2K cooled telescope. In addition, the focal plane instruments were covered by an radiation shield which was also cooled down to around 2K to block the thermal radiation from the warmer part of the inside of the cryostat. Relative responsivity change was able to be monitored by turning on the internal calibrator periodically.

Further description for the FIRP instrument is appeared in Lange et al.(1994).

2 Observation

Observations started on 1995 March 30, and terminated on 1995 April 24, when the liquid ^{4}He ran out. Three ^{3}He condensations were performed during the observation. While these condensation period which was about 1 day per one cycle, the detectors had no response to the incident light. From Apr.6 to Apr.9, the FIRP was turned off to eliminate the electrical interference to the other focal plane instruments. Therefore the FIRP observation were separated into three periods.

1. Mar.30 - Apr.5
2. Apr.10 - Apr.18
3. Apr.19 - Apr.24

As a result of this, the FIRP data did not cover the whole sky regions which were observed by IRTS.

3 Data reduction

The basic strategy of the data reduction is described in Hirao et al. (1996a,b) although some minor changes were applied when building the datasets released this time. It must be mentioned that the results are consistent despite the changes.

Further description of the data reduction will be presented in the next version.

4 Calibration

4.1 Responsivity change

The relative changes of the responsivity of the bolometers were monitored by turning on the internal cal lamp periodically. As a result, the responsivity of the bolometers were stable overall except $\sim$2% changes, which occurred about one day before the ran out of 4He, due to the change of still temperature of $\sim$5mK (Hirao et al. 1996a).

4.2 Absolute calibration

Due to narrow coverage of the sky and short observation period, it was unable to observe any objects (such as the planets) suitable for absolute calibration of the 150, 250, 400 μm channels. We decided to use the COBE/DIRBE 140, 240μm data for the absolute calibration of the 150, 250 μm channels. Since the passbands of the DIRBE and the FIRP are similar, this should give reasonable results. In case of the 700 μm channel, cosmic microwave background radiation is dominant at high galactic latitude region and we used this to determine the voltage to signal conversion factor. For the 400μm channel, no reliable calibration method was found. Therefore the scaling factor for this channel was determined from the interpolation of the 250μm data and the 700μm data at the galactic plane.

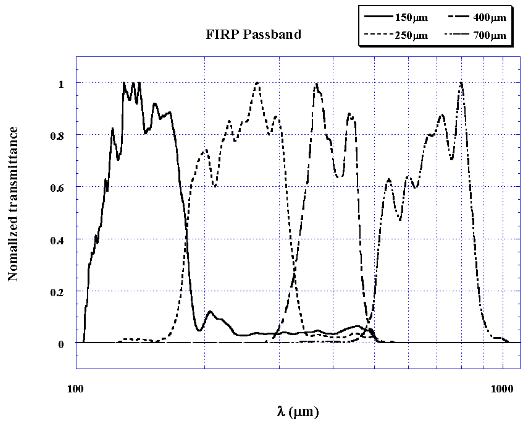

Figure 1: The passbands of FIRP.

4.3 Color correction

The brightness data in the data products, I_ν, are expressed in W/m^2/Hz/sr at fixed nominal frequencies, assuming the source spectrum is νI_ν = constant. If the source spectrum is different from this assumption, a color correction must be applied. This is the IRAS convention and further explanation is given in the "IRAS Catalogs and Atlases Explanatory Supplement" p.VI-27 and "COBE/DIRBE Explanatory Supplement" p.58 section 5.5.

4.4 Passband

The passbands for each channels was measured in the laboratory before launch. The measured data is given in the section 6.

5 Data Products

The FIRP data are available in sky map formats. The data products give the sky brightness as observed. By the time of writing this document, most of the 250 μm data and some of the 400 μm and 700 μm data are opened to public. The rest of the data, except the degraded and scientifically meaningless ones, will be available as soon as they will be ready.

5.1 Mission Average Sky Maps

All of the sky brightness data, except the degraded data, are averaged into each pixel for each of the channel. Standard deviation and the number of the samples coadded are also provided for each pixel. The absolute calibrations were done as described in the Section 4.2.

The brightness data , I_ν, are expressed in W/m^2/Hz/sr at fixed nominal frequencies, assuming the source spectrum is νI_ν = constant. If the source spectrum is different from this assumption, a color correction must be applied (See Section 4.3).

5.1.1 Available area

Below is the list of the available area for the each channels. Most of the 250μm data is available. For the 400μm, only the galactic plane data is opened. For the 700μm, all the data is opened.

- 150μm: `None`
- 250μm: `NS01-NS10,NS15-NS26,NS28-NS30,NS33-NS37,SS17-SS21,SS44-SS45`
- 400μm: `NS19-NS21,SS18-SS19`
- 700μm: `All`

5.1.2 Formats

The averaged sky brightness data, the standard deviation and the number of the samples coadded are stored as FITS images. Therefore three FITS files are provided for each region. The filenames are in a format of

`(instrument)-(wavelength)-(region No.)-(raw,err,smp).fits`.

"raw", "err"[1] and "smp" represent the calibrated sky brightness, standard deviation and the number of the samples, respectively. Below is an example of the filename for the FIRP 250 μm data at SS44 region.

```
firp-250-ss44-raw.fits     - Sky brightness -
firp-250-ss44-err.fits     - Standard deviation -
firp-250-ss44-smp.fits     - number of samples -
```

[1] The error data is not available for the time of writing this document.

5.1.3 Pixelization

The time-ordered data includes sky brightness value and position data in Galactic coordinates for each position. The position data were converted to pixel coordinates using the Gnomonic projection. The Galactic coordinates at the center of each map are given in their FITS header (CRVAL1, CRVAL2). Each pixel correspond to approximately $0.2^\circ \times 0.2^\circ$. List 1 and List 2 are the C functions for Galactic coordinates to pixel coordinate conversion, pixel coordinates to Galactic coordinates conversion, respectively. These functions are based on the description in the IRAS Explanatory Supplements (1997).

List 1: The C function to make a conversion from Galactic coordinates to pixel coordinates

```
int lb2linesamp(double ll, double bb, double ll0, double bb0,
double scale, double *line, double *sample)
/*
  scale:  number of pixels per degree in the map
  ll, bb:  Galactic coordinates of a given position
  ll0, bb0:  Galactic coordinates of the map center

  All angle unit must be in radian.
*/
{
  double A, F;

  A = cos(bb) * cos(ll - ll0);
  F = scale * (180/kPI)/(sin(bb0) * sin(bb) + A * cos(bb0));
  *line = -F * (cos(bb0) * sin(bb) - A * sin(bb0));
  *sample = -F * cos(bb) * sin(ll - ll0);
}
```

List 2: The C-function to make a conversion from pixel coordinates to Galactic coordinates

```
int linesamp2lb(double line, double sample, double scale,
double ll0, double bb0, double *ll, double *bb)
{
  double X, Y, D, B, XX, YY;
```

```
    X = sample/(scale * 180/kPI);
    Y = line/(scale * 180/kPI);
    D = atan2(sqrt(X*X + Y*Y), 1);
    B = atan2(-X, Y);
    XX = sin(bb0) * sin(D) * cos(B) + cos(bb0) * cos(D);
    YY = sin(D) * sin(B);

    *ll = ll0 + atan2(YY, XX);
    *bb = asin(sin(bb0) * cos(D) - cos(bb0) * sin(D) * cos(B));
    /*
      NOTE:  The arctangent functions for B and ll must be
             four-quadrant arctangents.
    */
  }
```

5.1.4 FITS Header

The example FITS header is presented. Currently, some keywords are not set properly as listed below.

- `CDELT3` keyword in all fits files is incorrect.
- `BSCALE, BZERO, BUNIT` keywords are not set properly in `firp_*_err.fits` file and in `firp_*_smp.fits` file.

```
SIMPLE  =                    T / Standard FITS format
BITPIX  =                   32 / 32 bit Integer
NAXIS   =                    3 / # OF AXES
NAXIS1  =                   64 / Number of positions along axis 1 for FIRP
NAXIS2  =                   64 / Number of positions along axis 2 for FIRP
NAXIS3  =                    1 / Number of positions along axis 3
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format defined in Astronomy and
COMMENT   Astrophysics Supplement Series v44/p363, v44/p371, v73/p359, v73/p365.
COMMENT   Contact the NASA Science Office of Standards and Technology for the
COMMENT   FITS Definition document #100 and other FITS information.
BSCALE  =         1.396800E-25 / TRUE=TAPE*BSCALE+BZERO
BZERO   =         0.000000E+00
BUNIT   = 'W/m**2/sr/Hz'       / INTENSITY (I-LAMBDA) FOR CONTINUUM
BLANK   =          -2147483647 / TAPE VALUE FOR EMPTY PIXEL
CTYPE1  = 'GLON-TAN'           / GALACTIC LONGITUDE (Gnomonic Projection)
CRVAL1  =         4.500000E+01 / L AT ORIGIN (DEGREES)
```

```
CRPIX1  =                   32 / SAMPLE AXIS ORIGIN (PIXEL) for FIRP
CDELT1  =        -2.000000E-01 / COORD VALUE INCR DEG/PIXEL for FIRP
CTYPE2  = 'GLAT-TAN'           / GALACTIC LATITUDE (Gnomonic Projection)
CRVAL2  =        -3.000000E+00 / B AT ORIGIN (DEGREES)
CRPIX2  =                   32 / LINE AXIS ORIGIN (PIXEL) for FIRP
CDELT2  =        -2.000000E-01 / COORD VALUE INCR DEG/PIXEL for FIRP
CTYPE3  = 'WAVE    '           / WAVELENGTH OF BAND CENTER
CRVAL3  =         2.500000E-04 / WAVELENGTH IN METERS
CRPIX3  =                    1
CDELT3  =         0.000000E+00 / BAND WIDTH
CUNIT3  = 'm       '           / UNIT OF WAVELENGTH
DATAMAX =         2.188450E-17 / TRUE VALUE
DATAMIN =         1.385665E-19 / TRUE VALUE
DATE-FIT= '2001-06-11'         / FITS CREATION DATE (YYYY-MM-DD)
DATE-MAP= '2001-06-11'         / MAP CREATION DATE (YYYY-MM-DD)
DATE-BGN= '1995-03-29'         / IRTS MISSION START
DATE-END= '1995-04-25'         / IRTS MISSION End
ORIGIN  = 'ISAS    '           / INSTITUTION
TELESCOP= 'IRTS    '           /
INSTRUME= 'FIRP    '           /
CHANNEL =                    3 / CHANNEL NUMBER OF EACH INSTRUMNENT
OBJECT  = 'SS-19   '           / (SS=SOUTH-SCAN, NS=NORTH-SCAN)-(Map Number)
PROCESS = '01      '           / FITS FILE VERSION
VERSION = '0001    '           / IRTS_LAN (ORIGINAL DATA SET) VERSION
COMMENT
HISTORY
END
```

5.2 Time-Ordered data

The time-ordered data is still in preparation. The release data is not fixed yet.

6 Miscellaneous Data

6.1 Passband

The laboratory measurement data of the passband will be available in the electrical format. Those who need the data right now, please contact irts_help@ir.isas.ac.jp

References

[1] *COBE Diffuse Infrared Background Experiment (DIRBE) Explanatory Supplement version.2.3* (1998), Hauser,M.G. et al., eds. *COBE Ref. Pub. No. 98-A*, (Greenbelt, MD: NASA/GSFC), available in electronic form from the NSSDC.

[2] Hirao,T. et al., "Flight performance of the Far-Infrared Photometer (FIRP)" (1996a), *Proc. SPIE*, **2817**, 276.

[3] Hirao,T. et al., "Submillimeter Observations of the Galactic Plane by the IRTS" (1996b), *PASJ*, **48**, L77.

[4] *IRAS Explanatory Supplement* (1997), Beichman,C.A. et al., eds. (http://www.ipac.caltech.edu/ipac/iras/iras.html).

[5] Lange,A.E. et al., "The Far-Infrared Photometer on the Infrared Telescope in Space" (1994), *ApJ*, **428**, 384.