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Mapping Using the ISOPHOT Interactive Analysis (PIA)

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Abstract. The ISO**P**HOT **I**nteractive **A**nalysis **PIA** is a full astronomical data analysis tool for data reduction and calibration of ISOPHOT, one of the instruments on board the Infrared Space Observatory *ISO*, launched in November 1995 by the European Space Agency.

This article is devoted to a description of the image processing capabilities of PIA, on the basis of the different mapping strategies with ISOPHOT. PIA offers a full graphical interface, giving the user all the informations related to the observation and data selection possibilities. Special flat fielding techniques, extraction of profiles, map rotation and convolution, point source extraction, three dimensional display, etc., are implemented in an interactive way.

1. Introduction

The ISO**P**HOT **I**nteractive **A**nalysis **PIA** is described elsewhere in this volume (Gabriel et al. 1997). It was conceived primarily as a calibration tool for ISOPHOT (Lemke et al. 1996), one of the four instruments on board *ISO*, the Infrared Space Observatory (Kessler et al. 1996). However, the software package has been developed into a full interactive astronomical analysis system for ISOPHOT data.

ISOPHOT performs infrared mapping in different modes using different detector subsystems. A detailed description of these modes can be found in the ISOPHOT Observer's Manual (Klaas et al. 1994). Mapping can be performed using one of the three single pixel photometers (P1, P2, P3) in the range 2.5–100 μm, or one of the two far infrared cameras (C100, a 3×3, and C200, a

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2×2 detector array) in the range 50–240 μm. Several filters in those ranges and apertures (in the case of the single photometers) are available.

The raster capability of *ISO*, pointing sequentially to several positions on a two-dimensional grid, makes it possible to have the combination of individual fluxes and an image of a sky region. ISOPHOT measures continuously with a fixed instrument configuration during the raster performance. The PIA mapping software basically combines the sky brightnesses measured at the different positions to an image in sky coordinates.

2. Mapping with ISOPHOT

A raster observation can have a maximum of 32×32 raster points with a maximum sampling area of $1.6\times1.6^{\circ}$. The *ISO* Observer's Manual (ISOOBS 1994) gives full information on different aspects of *ISO*'s raster observations.

There are two mapping modes possible using ISOPHOT:

- **Staring raster mode** consists of several staring observations on a regular grid. It is possible to oversample. The single ISOPHOT photometers can be used with different raster points separated by a minimum of $8''$ (during the first year of the *ISO* mission this was $13''$). For the long wavelength array detectors, the minimum separation is $15''$ (1/3 of a C100, 1/6 of a C200 pixel).
- **Chopped raster mode** can be used with the long wavelength detector arrays, in order to achieve a high spatial resolution, while optimizing the observation time. In this case, data are taken in chopper steps of $15''$ in the spacecraft Y-direction. This also allows observing the same celestial position during several raster pointings, therefore making possible the elimination of transients in detector response.

3. Mapping using PIA

As input for mapping processing, PIA uses ISOPHOT data which has been reduced to the level of sky brightness (in MJy/sr) for each raster (and chopper) step and per detector pixel, together with the associated pointing information per raster point. All these data, corresponding to one measurement, are contained in an element of the so called AAP (astrophysical application) data structure. A description of the data reduction from the raw telemetry to this level as done by PIA can be found in Gabriel et al. (1996).

On this level, we must deal with data derived from a measurement: an array of measured brightnesses, their uncertainties, associated sky positions and corresponding observation times of these positions. PIA calculates the positions of the individual detector pixels at different raster/chopper positions during the raster measurement. After this calculation, the values of the detector signals are binned into map pixels. A simple gridding function is applied, which is a trapezoidal function, i.e., the geometric overlap of detector pixel and map pixel is used as the contributing part of the measured detector brightness to the map pixel. For the final image computation, PIA uses the coverage and the time of coverage of all the contributing signals for normalization.

PIA produces three kinds of maps for each measurement:

- A **brightness map**, computed from either mean values, median values, or first or third quartile values, depending on the user's selection. The unit is [MJy/sr].
- An **uncertainty map**, processed from the uncertainty array in the AAP data. The unit is [MJy/sr].
- An **exposure map**, which is the map of exposure times for each map point in [s]. The exposure time is the total of all exposure times from the contributing detector signals, corrected for the map pixel size.

3.1. Options for Producing a Map

PIA allows a free choice for the image binning, although there is a "natural" choice, given by the level of oversampling reached in the observation. The pointing taken for the image computation is given by the measured positions, which can differ slightly from the planned ones.

For data obtained with one of the detector arrays, there is also the possibility of selecting/deselecting detector pixels to use only part of the data, or obtaining maps from individual detector pixels. This may help judge the quality of parts of the map, reveal flat fielding problems, etc.

Flat fielding of the detector arrays is in principle given, since measurements of the internal fine calibration sources are performed before and after the raster source measurement. Nevertheless, the possibility of using an additional flat fielding technique is given. If this option is chosen, individual maps are produced for every detector pixel and the central, common region of the maps taken for obtaining flat fielding factors.

3.2. Displaying a Map

Once the map is produced, the PIA graphical interface offers several possibilities for enhancing the quality of the image display. Starting from a Map Display Window, several context sensitive menus allow changing the color tables, interpolating image pixels, zooming every map region with different zoom factors, setting cut values, overplotting contours to the map, obtaining profiles, extracting flux values and positions from the map, and extracting possible point sources.

It is also possible to obtain a three-dimensional surface from the map, using an interface allowing rotation about each axis and super-position of contours.

3.3. Map Transformations

PIA includes the option of convolving a map to a given spatial resolution. To facilitate comparisons between maps obtained in different wavelengths, conversion to the resolution of every PHT-filter is available. A two-dimensional Gaussian approximation to the point spread function is used for the convolution.

Maps can be also rotated by PIA to every angle with respect to the RA-DEC plane.

3.4. Input/Output

The main input for mapping with PIA is the AAP data, resulting from the reduction of a raster measurement. All of the mapping capabilities just described may be applied to these data.

Several additional formats can be used both as input to and output from the PIA imaging software:

- Internal format data, for use within PIA in a future session.
- FITS format (FITS 1993), providing an interface to basically every other package for instrument independent image processing, and to PIA itself.
- PostScript output to a file or printer, and GIF output to a file.

4. Further PIA Development on Mapping

The very simple trapezoidal gridding function used for obtaining an image by PIA will be complemented with enhanced imaging methods. Using the redundant information from a single detector pixel should lead to better spatial resolution. The same redundant information will be used for modeling detector response transients during an observation. Flat-fielding may also be enhanced by taking a user defined area (preferably a background area) for computing the flat-fielding factors. Measured point spread profiles will be used for image convolution and for point source extraction.

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