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 the 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, 1996). It was conceived primarily as a calibration tool for ISOPHOT (Lemke, Klaas et al, 1996), one of the four instruments on board the Infrared Space Observatory (Kessler, Steinz et al, 1996). However, the software package has been developed further to the level of 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] μ, or one of the two far infrared cameras (C100, a 3x3, and C200, a 2x2

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detector array) in the range [50-240] μ. Several filters in those ranges and apertures in the case of the single photometers are available.

The raster capability of ISO, pointing sequentially on 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 on the different positions to an image in sky coordinates.

2. Mapping with ISOPHOT

A raster observation can have a maximum of 32 x 32 raster points with a maximum sampling area of 1.6 x 1.6 square degrees. 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: it 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 arcsec (during the first year of the ISO mission this was 13 arcsec). For the long wavelength array detectors the minimum separation is 15 arcsec (1/3 of a C100, 1/6 of a C200 pixel sidelength).
- chopped raster mode: the ISOPHOT chopping capability 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 is taken in chopper steps of 15 arcsec 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 responsivity.

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) per raster (and chopper) step and per detector pixel, together with the associated pointing information per raster point. All this data corresponding to one measurement is 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 by Gabriel et al, 1996b.

On this level, we have basically to deal with the 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, which are:

- a **brightness map**, computed from either mean values, median values, first or third quartile values, depending on the users 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, thus using only part of the data, or obtaining maps from individual detector pixels. This may help for judging the quality of parts of the map, 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 give the possibility of 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, extracting possible point sources.

It is also possible to obtain a three-dimensional surface from the map, using an interface allowing for rotation on all axes and super-imposition of contours.

3.3. Map transformations

PIA includes the option of convolution for converting a computed map to a given spatial resolution. For making possible comparisons between maps obtained in different wavelengths, the choice of the conversion parameter associated with the resolution of every PHT-filter is given. For the convolution a two-dimensional gaussian approximation of the point spread function is used.

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

3.4. Input / Output

The main input for mapping using the PIA is given by the AAP data, resulting from the reduction of a raster measurement. In this case the full capability of mapping processing as described above is given.

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

- Internal format for use within PIA in a future session.
- FITS format (FITS, 1990) building an interface to basically every other package for instrument independent image processing. Can be also used as input into PIA.
- Postscript output to a file or printer and GIF output to a file.

4. Further PIA development on mapping

The very simple gridding trapezoidal function used for obtaining an image by PIA will be complemented by enhanced imaging methods, which using the redundant information from a single detector pixel should lead to a better spatial resolution. The same redundant information will be used for modelling detector responsivity transients during an observation. Flat-fielding has also to 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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