Enhancements by mapping with the ISOPHOT Interactive Analysis (PIA)

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Abstract. The Infrared Space Observatory ISO, launched by ESA in November 1995, ended its operations succesfully in April 1998. The subsequent post-operational phase, which will last for 3,5 years, is devoted mainly to re-analysis and re-calibration of the data. The ISOPHOT Interactive Analysis (PIA) is not only the main calibration tool but also the software tool of choice for the scientific analysis of data obtained with the imaging spectro-photo-polarimeter ISOPHOT. Some of the main PIA enhancements related to mapping are presented in this paper: the development of new algorithms for the obtention of ISOPHOT maps as well as a sub-package for beam profile deconvolution.

1. Introduction

The end of the ISO mission (Kessler 1996) in April 1998 due to Helium boil-off, does not mean the end of the scientific work related to the data gathered by the scientific instruments on board. This is valid for all four ISO instruments. ISOPHOT (Lemke et al 1996), the imaging spectro-photopolarimeter of the mission, covered the full ISO wavelength range ([2.5-240] μ) and was composed of several sub-instruments. The main software tool for data analysis used both for calibrating ISOPHOT as well as for producing scientific results is the ISO**P**HOT **I**nteractive **A**nalysis (PIA), referred to by several earlier ADASS conferences (Gabriel et al. 1997a, Gabriel et al. 1997b, Gabriel et al. 1997c, Gabriel et al. 1998), in which different aspects of this package and its development were presented. PIA is entirely based on the Interactive Data Language IDL. The ISO Data Centre at Villafranca, Spain, as the central place for maximising exploitation of the ISO data in a net of data centres in Europe and the USA is also in charge of the further development and maintenance of PIA.

The PIA capabilities were increased continuously during and after the operational phase of the ISO mission. One of the main reasons for it is the feed-back received from astronomers in the more than 150 scientific institutes all over the world which had the package installed. The other is the deeper understanding of the very complex ISOPHOT instrument with all its different operation modes (Heinrichsen et al. 1997) by the ISOPHOT instrument experts, who are increasing steadily reliability and accuracy of the calibration (Schulz et al. 1999, Klaas et al. 1997). The continuous improvement is reflected in new releases of the package, freely distributed to the users via the PIA homepage[1]. The homepage contains also documentation, help libraries, publications on PIA, FAQs, a mailbox for receiving bug reports, comments, etc.

Here we will concentrate only on the last improvements related to mapping with PIA. A very recent article (Gabriel & Acosta-Pulido 1999) summarize the most important enhancements of PIA in all areas in the last year.

2. Alternative mapping algorithms by PIA

A detailed description of the different ISOPHOT mapping modes can be found in the ISOPHOT Observer's Manual (Klaas et al. 1994) while the basic mapping capabilities by PIA are described in Gabriel et al. 1997c.

ISOPHOT performed mapping with all the different detector subsystems: the single pixel photometers (P1, P2, P3) in the range 2.5-100 μ with a variable aperture diameter([5-180] arcsec), the far infrared detector arrays C100 (3x3 array with a single pixel size of [43.5x43.5] arcsec^2) and C200 (2x2 array with a single pixel size of [89.4x89.4] arcsec^2) in the range 50-240 μ and the spectrometer grating array of 128 pixels in the range 2.5-11.7 μ with an entrance aperture of [24x24]arcsec^2.

Mapping was done basically using the raster capability of the ISO spacecraft. Distances between raster legs and raster points were free choosable (under certain restrictions) leading to different oversampling factors. For the long wavelength detector arrays C100 and C200 it existed also the possibility of taking advantage of the chopper for increasing the spatial resolution in a special observing mode. The spacecraft's jitter during a raster performance adds a further complication. The obtained measurements on the single sky positions are therefore in general not regularly gridded and the spatial resolution is a complex function of all the elements mentioned above and the wavelength of the used filter.

PIA offers different methods for obtaining a map from the performed observation, included in the general GUI for mapping:

A) The "full coverage" mapping algorithm

The original mapping algorithm used in PIA ("full coverage method") is based on a simple gridding function for binning the signals obtained with the individual detector pixel beams[2] at different raster/chopper positions into map pixels. Every sky position is seen several times: by an individual pixel in the normal case of oversampling and by different detector pixels when mapping with one of the detector arrays. Due to oversampling the reached spatial resolution can be better than the simple detector beam. Therefore the map pixel size (free choosable by PIA) can be smaller than the beam.

The individual contribution from a signal to a map pixel is calculated using the overlap area of beam and map pixel. The effect of co-adding the information

[1] `http://www.iso.vilspa.esa.es/manuals/PHT/pia/pia.html`

[2] With detector beam we refer to the detector pixel size in the case of an array detector, or to the aperture size in the case of a single detector pixel (P1, P2 or P3).

from the different beams into an image element is a smearing trapezoidal function which depends on the distance between beam center and center of the computed map pixel. This has a positive aspect of smoothing the noise but also the disadvantage of reducing the probability of observing point sources with low signal to noise ratio.

B) The "distance weighting" algorithm
This method is just a variation of the former one described, but instead of taking the area overlap between beam center and map pixel center for calculating the contribution, a different method is used: for a given map pixel, every contributing signal is weighted using the distance between beam center and center of the map pixel. The individual weighting factor is given by $(1 - D)^3$ with D being the distance in beam size units (the exponent 3 was found experimentally to give good results).

C) The "trigrid interpolation"
By this alternative method the central positions of all the signals from the different spacecraft pointings are used as a planar set of points, which are then Delaunay triangulated[3]. The main property of Delaunay triangulation is that the circumcircle of any triangle contains no other vertices in its interior. After having obtained the triangulation, a regular grid of interpolated values is obtained, as required by the user through his/her chosen map pixel size, by which only the nearby points are used[4]. Linear or smooth quintic polynomial interpolation can be selected. Since every sky position is generally observed several times within the raster map performance, a re-sampling is necessary prior to apply the triangulation. This is done by co-adding all signals which have beam centers within a certain radius (eg. 1/4 of the chosen map pixel size) and assigning to the co-added value a sky position, which is calculated from the average position of all contributing signals.

Both B) and C) methods reach a better spatial resolution but increase the map noise. This statement, qualitatively clear, is not easy to be quantified. Only detailed simulation studies, which take into account the very different possibilities for mapping with the diverse ISOPHOT sub-instruments and observing modes, can give an answer hereby. These studies have already started and will be conducted in the near future together with the analysis of real data for statistical comparisons of the results achieved by the different algorithms.

3. Map deconvolution

Footprint matrices have been established for the ISOPHOT filters, by folding the corresponding point spread function with the optical aperture. Their validity has been confirmed by comparison to data from very detailed raster scans. The establishment of the footprint matrices make possible a reliable deconvolution of

[3] as performed by the IDL routine TRIANGULATE, IDL Ref.Guide V5, p922

[4] as performed by the IDL routine TRIGRID, IDL Ref. Guide V5, p.925

the obtained maps, by using deconvolution techniques like maximum Likelihood method or maximum Entropy method.

Since the application of deconvolution techniques requires a high level of interaction for judgement of the obtained results, PIA has included a full GUI for deconvolution, from which the different methods can be chosen, the footprint matrix used can be displayed, start parameters for the deconvolution procedure changed and the results inspected.

An assessment of the reliability of the deconvolution procedures included in PIA is needed also by using simulated data, as described in the former section.

4. Summary

New algorithms for the obtention of ISOPHOT maps and a sub-package for their beam profile deconvolution have been developed within the framework of PIA. Their testing with simulated data as well as with a large sample of real data is necessary for a final quantitative assessment. This is facilitated through the flexibility and user friendiness of the GUI's in which they are embedded.

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