Astronomical Data Analysis Software and Systems VIII
ASP Conference Series, Vol. 172, 1999
D. M. Mehringer, R. L. Plante, and D. A. Roberts, eds.

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 successfully 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 spectrophotopolarimeter ISOPHOT. Some of the main PIA enhancements related to mapping are presented in this paper, namely, the development of new algorithms for the creation of ISOPHOT maps as well as a sub-package for beam profile deconvolution.

1. Introduction

The end of the ISO mission (Kessler et al. 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 true for all four ISO instruments. ISOPHOT (Lemke et al. 1996), the imaging spectrophotopolarimeter of the mission, covered the full ISO wavelength range (2.5-240 μm) 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 in several earlier ADASS conferences (Gabriel et al. 1997a, 1997b, 1997c; Gabriel, Acosta-Pulido, & Heinrichsen 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, the central institution for maximising exploitation of the ISO data of a network of data centres in Europe and the USA, is also responsible for 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 the continuing development is due to the feedback received from astronomers in the more than 150 scientific institutes around the world. The other reason is due to the deeper understanding of the very complex ISOPHOT instrument and all its different operation modes by the ISOPHOT instrument experts, who are steadily increasing the 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

which are freely distributed to the users via the PIA homepage[1]. The homepage also contains documentation, help libraries, publications on PIA, FAQs, a mailbox for receiving bug reports, comments, etc.

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

2. Alternative Mapping Algorithms in 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 of PIA are described in Gabriel et al. 1997c.

ISOPHOT performs mapping for all the different detector subsystems, namely, the single pixel photometers (P1, P2, P3) in the range 2.5-100 μm with a variable aperture diameter($5''$-$180''$), the far infrared detector arrays C100 (a 3×3 array with a pixel size of $43.5''\times43.5''$) and C200 (a 2×2 array with a pixel size of $89.4''\times89.4''$) in the range 50-240 μm, and the spectrometer grating array with 128 pixels in the range 2.5-11.7 μm with an entrance aperture of $24''\times24''$.

Mapping was done basically using the raster capability of the ISO spacecraft. Distances between raster legs and raster points were freely specified (under certain restrictions) leading to different oversampling factors. For the C100 and C200 long wavelength detector arrays, the observer could also take advantage of the chopper for increasing the spatial resolution in a special observing mode. The spacecraft's jitter during a raster observation adds a further complication. The measurements of single sky positions are therefore not regularly gridded, and the spatial resolution is a complex function of all the elements mentioned above as well as the wavelength of the filter which was used.

PIA offers different methods for obtaining a map from an observation which are included in the general mapping GUI which are summarized below.

1. 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 observed 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 achieved spatial resolution can be higher than the simple detector beam. Therefore, the map pixel size (freely choosable by PIA) can be smaller than the beam.
   The contribution of the signal to a map pixel is calculated using the overlap area of beam and map pixel. Co-adding the information from the different beams into an image element results in a smearing trapezoidal function which depends on the distance between beam center and center of the computed map pixel. This has the benefit of smoothing the noise but the

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

[2] The term "detector beam" refers to the detector pixel size in the case of an array detector, or to the aperture size in the case of a single pixel detector (P1, P2 or P3).

disadvantage of reducing the probability of observing point sources with low signal to noise ratios.

2. The "distance weighting" algorithm. This method is just a variation of the "full coverage" mapping algorithm, but instead of taking the area of 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 empirically found to produce good results).
3. The "trigrid interpolation" In this method, the central positions of all the signals from the different 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 in 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, re-sampling is necessary prior to applying the triangulation. This is done by co-adding all signals which have beam centers within a certain radius (e.g., 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 methods 2) and 3) achieve higher spatial resolution but increase the noise. Although this statement is qualitatively clear, it is not easily quantified. Only detailed simulations, which take into account the very different possibilities for mapping with the diverse ISOPHOT sub-instruments and observing modes, can give an answer. 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 with data from very detailed raster scans. The establishment of the footprint matrices make possible a reliable deconvolution of the maps by using deconvolution techniques such as the Maximum Likelihood Method or the Maximum Entropy Method.

Since the application of deconvolution techniques requires a high level of interaction for judging the obtained results, PIA has included a GUI for deconvolution. Using this GUI, the different deconvolution methods can be chosen, the footprint matrix used can be displayed, initial parameters for the deconvolution can be changed, and the results can be inspected.

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[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

4. Summary

New algorithms for the creation of ISOPHOT maps and a sub-package for their deconvolution have been developed within the framework of PIA. Testing using simulated data as well as using a large sample of real data is necessary for a final quantitative assessment. This is facilitated through the flexibility of the user-friendly GUIs.

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