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Data Analysis and Simulations of Spectroscopic and Continuum Mapping with the ISOPHOT Interactive Analysis (PIA)

C. Gabriel

ISO Data Centre, ESA Astrophysics Division, Villafranca del Castillo, Spain

J. Acosta-Pulido

Instituto de Astrofísica de Canarias, La Laguna, Spain

M. Hur

Infrared Processing and Analysis Center, Pasadena, USA

Abstract. The ISOPHOT Interactive Analysis (PIA) is the software tool of choice for the scientific analysis of ISOPHOT data. It is used in more than 200 astronomy institutes all over the world and it has been continuously upgraded during and after the operational phase of the ISO mission. Special enhancements concerning the analysis of imaging spectrophotometry data as well as the inclusion of a raster data simulation package within the PIA capabilities are discussed here.

1. Introduction

The Infrared Space Observatory [ISO] (Kessler et al. 1996) observed the infrared sky for more than 28 months until April 1998. One of the activities of ESA's ISO Data Centre (IDC) in Villafranca, Spain (see Arviset et al. 2000), during the ISO post-mission phase is the maintenance and further development of some of the scientific data analysis packages specially developed for calibration and data reduction of the instruments on board. One of these packages is the ISO**P**HOT **I**nteractive **A**nalysis (**PIA**), referred to by several earlier ADASS conferences (e.g. Gabriel et al. 1997a, 1997b, 1998). The continuous effort in understanding the behaviour of the complex ISOPHOT instrument (Lemke et al. 1996), ISO's imaging spectro-photopolarimeter, results in new calibration and data processing strategies, which are reflected in PIA upgrades. They should help to maximize the scientific outcome of the ISOPHOT observations.

This paper deals with the enhancements in the PIA capabilities concerning imaging spectrophotometry, as well as with a PIA associated package for simulation of mapping observations.

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2. Mapping with PHT-S

The ISOPHOT sub-instrument PHT-S (Klaas et al. 1997) offered unique capabilities of imaging spectrophotometry in the MIR. PHT-S is a fast low-resolution grating spectrometer ($\Delta\lambda/\lambda < 100$) covering the wavelength ranges 2.4-4.8 μ and 5.8-11.8 μ with 128 Si:Ga simultaneously measuring detector pixels. The entrance aperture of the spectrometer is [24x24]arcsec^2.

One of the ISO observing modes included the possibility of spacecraft raster while using PHT-S, thus providing bi-dimensional spectrophotometry across a region on the sky. The product of such an observation is basically a flux data cube with two axes as the sky positions and the third one as the wavelength.

In order to be able to exploit the scientific contents of such an observation mode to the maximum, special tools for 3D spectroscopy were developed within PIA. It is possible to slice the cube into images giving the flux spatial distribution at a certain wavelength interval. The direct extraction of the spectrum at any desired sky position is also possible. There is also an animation which shows images in order of increasing wavelength. All these capabilities are embedded into context sensitive graphical user interfaces in order to facilitate work with big and complex datasets.

3. The PIA Mapping Simulation System

The variety and complexity of the observing modes used by ISOPHOT (Heinrichsen et al. 1997) together with the instrumental features due to the hazardous conditions of infrared detectors in space, make the assessment and scientific interpretation of the obtained data difficult. The basic mapping capabilities of PIA were described in Gabriel et al. (1997c), while different methods for pixel co-addition and deconvolution methods were discussed in Gabriel (1999). In the last paper we concluded that simulations were needed in order to quantify several aspects of the image data analysis, including the different data corrections and mapping algorithms which can be used within PIA for obtaining the final images.

Meanwhile, we have developed a mapping simulation system within PIA, capable of generating sky images with several point/extended sources on a flat or variable background and simulating what ISOPHOT would have recorded under certain instrument and spacecraft raster configurations.

This system should help to test several aspects of the image data analysis:

1. To find out which are the detection limits and confusion levels for the different cases, both with respect to instrument configuration and sky characteristics,
2. To test the different mapping and correction algorithms in relation to different observation configurations, with the aim of (1) improving the data analysis; and (2) giving recommendations to the users,
3. Increasing the reliability of the obtained results by real observations,
4. To test the validity of the theoretical and experimental beam profiles, as used for the data correction.

While all the above mentioned points are mostly of interest for calibrators and instrument specialists, it is very important that a general observer be able to simulate his/her observation by matching the selected observing mode. This requires a high degree of user friendliness in the package and free distribution to ISOPHOT users.

3.1. Basic Outline of the Simulation System

The system is divided into three main stages:

1. *sky simulation:* a portion of the sky as well as a number n of sources with their respective positions in the sky, brightnesses and sizes (circular and bar structures are included) are defined. The choice between a flat or a gradient background is also included. Convolution with the footprint of a given filter yields an image of the convolved sky in addition to the pure sky. These images, together with the parameter set used to create them, are the products of this portion of the simulation that can be saved as data entities for reuse at any time;
2. *observing mode specification:* the observing mode is defined together with the raster parameters (number of raster legs and points per leg, distance between legs and points, central position of the raster). Both the orientation of the raster on the sky as well as the orientation of the spacecraft on the sky are necessary for establishing the exact positioning of the (square) detectors (and hence the "measured" flux) on the sky at any step of the observation. The result is a PIA data structure which can be used within the PIA environment as any real observation, e.g. deriving the corresponding image;
3. *instrumental effects:* the expansion of every spatially "measured" point into a time series of signals, as would have been recorded by a real observation, is done together with the inclusion of instrumental effects, like the transient behaviour of the ISOPHOT detectors (Acosta-Pulido, Gabriel & Castañeda 1999), the effects produced by cosmic rays, different detector pixel response and a random noise contribution. The product, a PIA data structure (on a lower level of data reduction), can also be ingested into PIA for virtually simulating the data analysis.

The parameters included in all three stages of the simulation system are kept in configurable tables, so that changes can be easily done from dedicated GUIs. The model for the transient behaviour (by default the so called "offset exponential function" as explained in the PIA User's Manual[1], see also Acosta-Pulido, Gabriel & Castañeda 1999) can be replaced by any other model function.

3.2. The GUI

The PIA map simulation system includes a widget based graphical user interface, with dedicated menus for each of the three parts of the system, as referred to in the former section. Visualization of the created sky images with superimposed raster and detector pixel positions is also reachable from the main menu. The visualization tools attached to this GUI are common to the PIA mapping system. These offer the user the main IDL capabilities of image display and manipulation from comprehensive menus.

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

3.3. Distribution

The PIA map simulation system is distributed in compiled form (IDL savefile) as an individual sub-package obtainable from the PIA homepage[2]. However, it runs under PIA, and has to be started from the PIA prompt.

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