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New Tools for the Analysis of ISOPHOT P32 Mapping Data in PIA

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Abstract. The Infrared Space Observatory AOT P32 is a dedicated mapping mode combining the raster capability of *ISO* with the chopping capability of the ISOPHOT instrument for obtaining images in the far infrared, maximising the spatial resolution. We present diffraction limited maps of the Crab Nebula at 60 and 100 μm, as an illustration of a new tool for the P32 data analysis, integrated within the ISOPHOT Interactive Analysis (PIA).

1. Introduction

The Astronomical Observation Template (AOT) P32 was one of the observational modes (Heinrichsen, Gabriel, Richards, & Klaas 1997) defined for the instrument ISOPHOT (Lemke et al. 1996) on board the Infrared Space Observatory (*ISO*; Kessler et al. 1996). It tried to solve the question of observing extended structures with large detector pixels in the far infrared by a high sky registration and redundancy. The non-linear response of the Ge:Ga detectors affects the calibration of such a mode to a large extent, making the correction of those transient effects one of the most difficult tasks in the ISOPHOT data analysis.

2. The Challenge: Mapping in the Far Infrared

Obtaining photometric maps of extended sources in the far infrared (50–200 μm) is challenging because of the typical large sizes of the detector pixels involved in addition to the diffraction effects in this wavelength regime. The ISOPHOT detector arrays used in the far infrared were PHT-C100 (a 3×3 array of $46'' \times 46''$) and PHT-C200 (a 2×2 array of $92'' \times 92''$). Mapping in a finite time with a good (Nyquist) sampling therefore requires special observation techniques.

3. The Way: ISOPHOT's AOT P32

In addition to using *ISO*s capability of performing raster observations and the array structure of ISOPHOT's long wavelength detectors, the Astronomical Observation Template P32 used the focal plane chopper of ISOPHOT to rapidly modulate the satellite effective pointing, in steps of a third of the detector pixel pitch, on timescales ranging down to $\sim$0.15 sec. The result is very good sky registration, with the oversampling and redundancy necessary for the best achievable spatial resolution.

The chopper deflection is up to $\pm$90 arcsec in the Y-spacecraft direction, in 15 and 30 arcsec steps respectively for the C100 and C200 detectors. The arrays are on the Y-Z spacecraft plane and the total number of positions seen by a chopper sweep is therefore 13 for C100 and 7 for C200. Every sky position is therefore registered three times in the Y-spacecraft direction within a chopper cycle by a detector pixel and its neighbour pixels. The raster steps in Y and Z directions (with different user defined oversampling factors) also ensure a uniform coverage and high redundancy.

4. The Main Problem: Detector Transients

The ISOPHOT C200 (Ge:Ga stressed) and especially the C100 (Ge:Ga) photoconductor detectors have a complex non-linear response as a function of illumination history on timescales of $\sim$0.1–100 sec, depending on the absolute flux level as well as the flux changes involved (Acosta, Gabriel, & Castañeda 2000). The P32 observation mode, with its high frequency flux modulation, as described above, is in principle always in a non-stabilized state. Under- and overshooting signal effects, caused by a short term "hook" response, complicate the calibration of observations performed in this mode.

5. The Solution: P32_Tools Package

This package, originally developed at Max-Planck Institut für Kernphysik by one of us, is a collection of IDL routines, which:

- solves the non-linear optimisation problem for the set of sky brightnesses illuminating the detector on the grid of sky sampling (arbitrary source morphology),
- optionally solves for detector starting state,
- optionally solves for detector model parameters (through self-calibration), which by default are predetermined.

A complete set of diagnostic plots, images, and text information is produced, which enables the user to assess the quality and reliability of the data treatment.

5.1. Detector Model

The signal to every time is given by the sum of two components: $S = S_1 + S_2$ with a slow S_1 and a fast S_2 part:

$$S_1 = (1-\beta_1)S_\infty(1-e^{-t/\tau_1}) + S_{01}e^{-t/\tau_1} \tag{1}$$

$$S_2 = \beta_2 S_\infty (1 - e^{-t/\tau_2}) + S_{02} e^{-t/\tau_2} \tag{2}$$

The prediction of a change in photocurrent after a flux change is known as the "jump condition":

$$S_{01} = \beta_1 (S_\infty - S_{\infty p}) + S_{1p} S_{02} = S_{2p} \tag{3}$$

with p as the index for the previous flux level.

5.2. Determination of Parameters

The "default" parameters determination was performed using

- starting exposures of internal calibrators for slow components
- standard celestial calibration sources for fast components, exploiting the redundancy
- illumination dependency in parametrisation of βs and τs.

6. The Results

P32_Tools is already giving very good results, both for point sources and extended objects, although it is still in a testing and enhancement phase.

The nature of the problem, together with the fact that disturbances from cosmic ray hits are difficult to handle in an automatic way in this observation mode, require highly interactive work on the data.

7. The Integration within PIA

P32_Tools has been fully integrated within PIA (Gabriel, Acosta-Pulido, Heinrichsen, Morris, & Tai 1997; Gabriel & Acosta-Pulido 1999) for a better and easier access to all the capabilities already given. This also allowed us to make use of PIA's graphical data handling. Graphical menus for driving processing and parameter handling, display of results and information were specially developed, but wide use is made of already existent PIA tools.

8. An Example, FIR images of the Crab Nebula

P32 observations of the Crab Nebula have been preliminarily reduced with the P32_Tools package. These observations were performed with the aim of trying to understand the origin of the "InfraRed Bump" discovered by IRAS. A comparison of the obtained images at 60 μm and 100 μm using the default PIA processing (Figure 1), and the ones obtained using the P32_Tools package (Figure 2) show a remarkable improvement in angular resolution, indicating that the "Infrared Bump" probably arises from compact line emitting structure superposed on the smooth synchrotron emission.

There is a good correlation between the drift corrected P32 maps and an [O III]λ5007 emission map of the Crab Nebula taken with the Goddard Fabry-Perot Imager (Lawrence et al. 1995). The P32 maps are largely tracing oxygen. Prominent oxygen fine structure emission lines are present in the nebula at 52 μm ([O III]), 63 μm ([O I]) and 88 μm ([O III]), as observed by the spectra

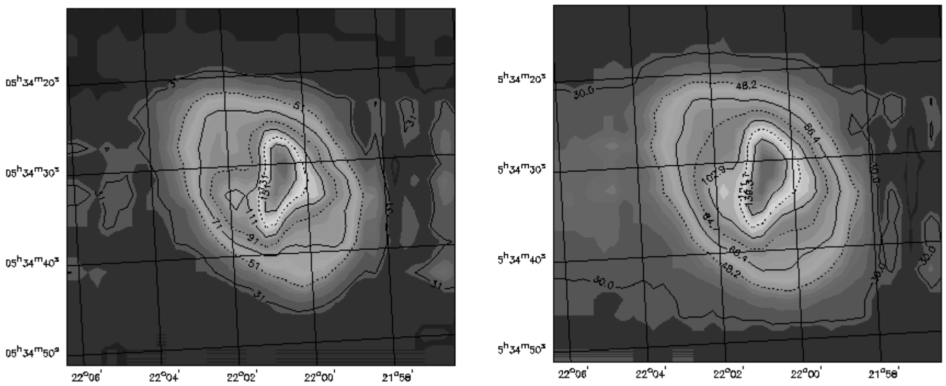

Figure 1. Crab Nebula maps obtained by PIA plain processing

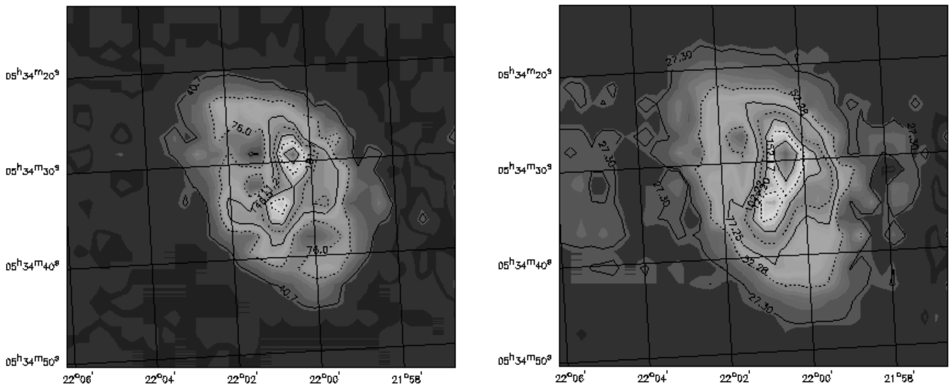

Figure 2. Crab Nebula maps obtained by P32_Tools processing

taken with the ISO-LWS spectrometer in both wavelength regions covered by the ISOPHOT C100 60 μm and 100 μm broadband filters.

References

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