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The ISOCAM Parallel Mode Survey

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Abstract. During most of ESA's ISO mission, the mid-infrared camera ISOCAM continued to observe the sky mainly around 6.7μm with a pixel field of view of 6″ in its so-called "parallel mode" while another instrument was prime.

This permitted an serendipitous survey of limited areas of the infrared sky, with varying depth and wavelength per field due to the different instrumental configurations used and the highly variable time spent per pointed observation.

Dedicated calibration, data reduction and source extraction methods were developed to analyse these serendipitously recorded data: 37000 individual pointings, taken during 6700 hours of observation. Using sophisticated merging algorithms, over 42 square degrees of the sky — roughly one per mille of the celestial sphere — are currently being processed and catalogued.

For the final catalogue around 30000 distinct point sources are expected. Their mid-infrared flux goes down to 0.5 mJy. Sources observed with the most sensitive instrumental configuration have a median flux of 2.7 mJy outside the galactic plane, and a median flux of 6.3 mJy inside the galactic plane.

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1. Overview of the ISOCAM Parallel Survey

During most of ESA's Infrared Space Observatory (ISO) mission (Kessler et al. 1996), the mid-infrared camera ISOCAM (Cesarsky et al. 1996), continued to observe the sky in its so-called "parallel mode" while another of the three instruments (LWS, ISOPHOT or SWS) was prime, during both normal pointed observations and satellite slews between targets (Siebenmorgen et al. 1996).

In parallel mode, routine use was made of broad band filters centred around 6μm with the $6''$ pixel field of view (PFOV). As only a restricted telemetry band-width was available, 12 readouts with 2.1 seconds integration time were accumulated on board and down-linked as one image every 25 seconds. Depending on the prime instrument, ISOCAM observed the sky $12'$–$17'$ from the prime target. In order to avoid saturation of the detector, the optical configuration was adapted to the expected flux level of field sources using one of several modes.

Effectively, this permitted an serendipitous survey of limited areas of the infrared sky: Around 9700 hours of data were taken in the ISOCAM parallel mode; out of these 400 hours were used for calibration measurements, with ISOCAM in dark configuration.

For the work on the ISOCAM parallel catalogue only pointed observations lasting longer than 100 seconds were considered, i.e., such that at least four ISOCAM parallel readouts view the same part of the sky with the same instrumental configuration. Additionally, 617 hours of observation time had to be excluded for various reasons. Consequently 37000 pointings, representing in total 6700 hours of observation time, or 72% of all ISOCAM parallel data taken in pointed mode, could be processed. This makes the ISOCAM parallel survey the ISOCAM programme with by far the longest observing time. With an observed area of approximately 42 square degrees, it yields a sky-coverage double as large as any other ISO proposal for this wavelength range. Compared to IRAS (Beichman et al. 1988), areas covered by ISOCAM parallel are surveyed with up to 500 times more sensitivity, and a 50 times higher spatial resolution.

2. Status of the Point Source Catalogue

Dedicated data reduction and source extraction techniques, combined with major calibration, simulation and verification efforts, had to be developed to generate a catalogue of mid-infrared point sources candidates from data taken in the ISOCAM parallel survey (Ott 2002).

The deglitching methods are based on improved sigma-clipping algorithms, adapted for ISOCAM observations and its temporal glitch distribution, and were particularly efficient to deglitch ISOCAM parallel data down to four readouts. Major calibration efforts led to the generation of 11 master flat-fields, which enabled the detection of true sources close to the array borders and significantly reduced the number of spurious detections at the same area.

The source extraction method is based on an iterative, multi-step "search and destroy" algorithm, that combines source detection with classification into point and extended sources. This technique was particularly powerful to detect point sources in crowded areas and within extended sources, without missing any significant sources.

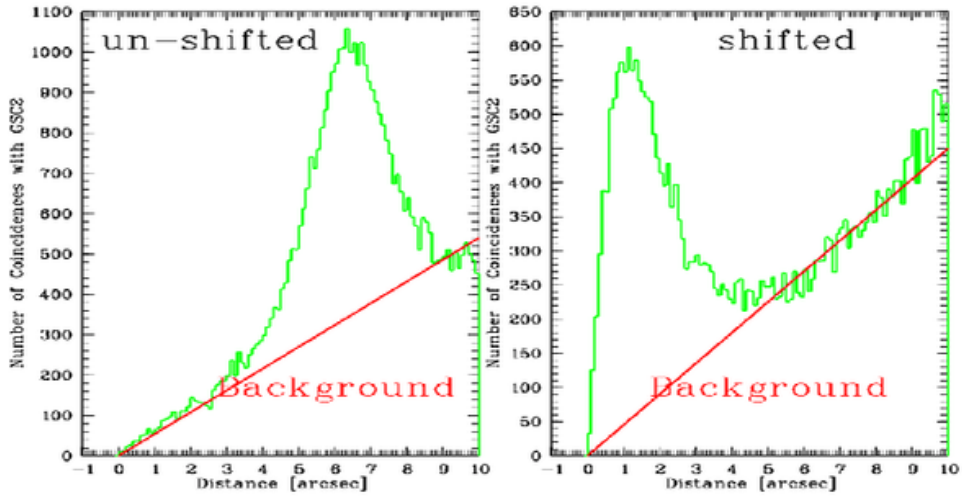

Figure 1. Position coincidence between ISO and optical sources before **(left)** and after **(right)** astrometric correction for the lens-wheel jitter. For the corrected coordinates the peak of the distribution is $\approx 1.3''$, i.e., the magnitude of ISO's pointing error, and not at $\approx 6.5''$ as seen for sources without correction

A variety of simulations, performed at different flux levels, covered all aspects of the data processing. These validated the algorithmic approach, and permitted to predict the flux and positional accuracy of the extracted sources, and the completeness limits for each pointing of the ISOCAM parallel survey.

Major efforts were spent on quality checks and source classification. Over 74000 source candidates and 24000 individual pointings were eye-balled. The manual classification of source candidates is used to determine the cut-off parameters in order to statistically clean the detected source candidates.

Sources found in pointings which are characterised by a high number of readouts are accepted for the final catalogue if they are compliant with the cut-off parameters. This method isn't sufficient for sources detected in pointings with a small number of read-outs. Therefore, such sources are only accepted if they show a distance coincidence with sources known from optical (Guide Star Catalogue II), or near infrared (2MASS, k-band) observations.

Due to the lens-wheel jitter, which leads to an astrometric shift of ± 1 PFOV (e.g., $\pm 6''$ for most observations), direct merging is not possible, as there are sources which are observed several times and might be interpreted as independent sources, or two independent sources might be wrongly identified as one source. The final merging is based on ISO-ISO distance coincidences as provided in Figure 2 (left).

Currently we are in the process to merge multiple detected sources into unique sources. We hope to complete the merging, and the simulation of bias effects, and an additional completeness estimate on the whole catalogue end 2002, so that the catalogue can be published and released to the community spring 2003.

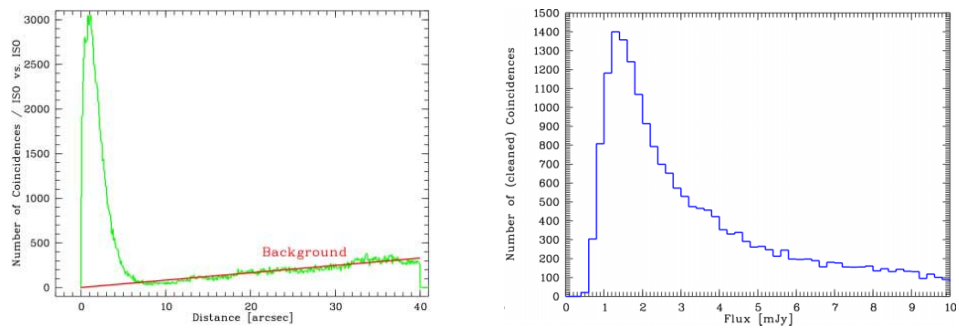

Figure 2. **Left:** Position coincidence between ISO / ISO sources **Right:** Flux distribution of ISOCAM parallel LW2 point sources.

3. Description of the Catalogue

For the final catalogue, we expect 30000 unique point sources, and a reliability of at least 99%. The detection threshold is limited by the flat-field noise. Using the most sensitive instrumental configuration (the broad band filter LW2, covering a wavelength range between 5–8.5μm, and 6″ PFOV), sources with a flux down to 0.5 mJy can be detected. The median flux of sources outside the galactic plane (galactic latitude outside $\pm 20°$) is 2.7mJy. The vast majority of these sources are new detections in the infrared. 30 square degrees are mapped completely down to 4 mJy, while 0.4 square degrees could be mapped completely down to 1.0 mJy.

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