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Processing WIRCam/CFHT Wide-Field Near-Infrared Data at TERAPIX

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Abstract. The TERAPIX processing procedure for the WIRCam camera data is presented. The WIRCam camera is the latest near-infrared, wide-field facility available at CFHT. It provides wide-field imaging data in several broad- and narrow-band filters in the range 1 to 2.2 μm. TERAPIX can provide, to any PIs with ongoing WIRCam programs, astrometrically and photometrically calibrated images as well as stacks, catalogs, and relevant quality assessment metadata. TERAPIX handles pre-processed data, starting from pre-calibrated images produced by CFHT. The tools developed at TERAPIX for the WIRCam data reduction comprise the following four steps: quality assessment and weight-map production, precise astrometric and photometric calibrations, stack generation, catalogs, and final quality-assessment delivery. Specific procedures have been implemented for sky subtraction and correction of artifacts. They are known to be the most critical points in infrared data reduction. Since both depend on the observation strategy and the scientific objectives of the PIs, the TERAPIX recipes have been implemented with special attention to flexibility.

1. Introduction

WIRCam is the newest wide-field mosaic detector to be available at CFHT. Table 1 summarizes the characteristics of the detectors[1]. At infrared wavelengths large-scale sky features are much more important than in the optical: removing these features requires ad-hoc subtraction procedures which should not result in significant observational overheads. In addition, faint objects that are invisible in single exposures bias the background level estimation: these have to be masked out using a preliminary stacked image before making the definitive background subtraction. Differences between near-infrared and optical data processing arise also from different detector properties. The main advantages of CMOS detectors that are used in the infrared, compared to optical CCDs, are that their pixels are individually addressable, and that the image can be read out while signal is still being integrated. However the fact that amplifiers are integrated in the pixels makes infrared detectors potentially less uniform than CCDs over the field of view, and within the pixels themselves. Pixels are also generally physically larger in CMOS devices and therefore more prone to under-sampling.

[1]Detailed technical informations about detectors and general instrument performances can be found at `http://www.cfht.hawaii.edu/Instruments/Imaging/WIRCam/`.

Table 1. Characteristics of the WIRCam mosaic.

Module	Description
Number of detectors	$4 = 2 \times 2$
Pixel dimension	18 μm
Pixel size	$0\farcs3$ pixel^{-1}
Detector size	2048×2048 pixels
Camera field of view	$21\farcm5$
Field distortion	$< 0.8\%$ in the corners
Gaps between detectors	$45''$

2. Processing Steps at TERAPIX

The CFHT pipeline provides users with pre-processed data, i.e., de-biased, flat-fielded, and sky-subtracted images. A preliminary astrometric solution and the photometric zero-points are also provided. The reduction tools developed by TERAPIX for WIRCam perform the following operations:

- reformatting image data;
- first pass of sky-subtraction;
- quality assessment and pixel weighting;
- improved astrometric and photometric calibrations;
- preliminary stacking;
- second pass of sky-subtraction;
- correction of artifacts;
- final stacking;
- final quality assessments and catalog delivery.

2.1. Sky Subtraction

In order to optimize the observations, a dithering procedure is often used in infrared imaging: it consists of observing the object field at fixed offsets around a center position. An automatic procedure has been developed to provide sky subtraction for the dithering observing mode. A median pixel-to-pixel image combination provides an estimate of the sky variations, if correct masking and normalization are applied. In general, considering the typical exposure time of WIRCam exposures, we use only images within a 30 min time window around the image we want to subtract. Here are the steps performed by our procedure.

1. Objects are detected, and a *weight* image is built having a value of zero where objects are found, and 1 otherwise.
2. A specified number of images are combined using *SWarp*[2] to create the sky frame. The image itself is not used in the sky combination.
3. The sky frame is subtracted from the image (see Figure 1).

[2]http://terapix.iap.fr/rubrique.php?id_rubrique=49

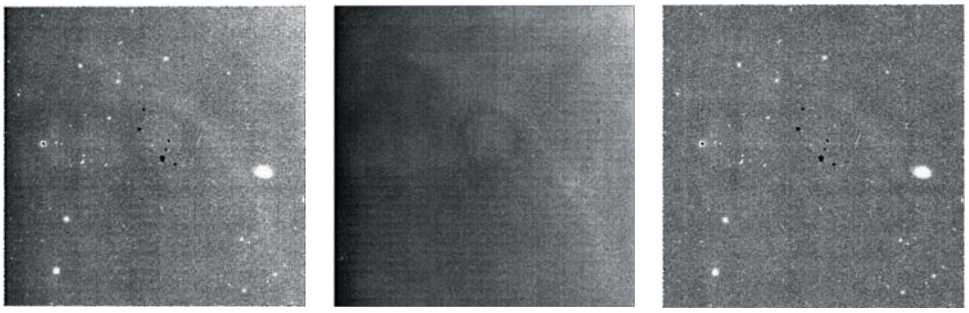


Figure 1. A non-sky-subtracted image (*left*), its relative sky frame (*center*), and the sky-subtracted image (*right*).

The object masking is an essential step in the sky-frame production. If not masked, objects can affect the sky measurement that produces an over-estimate of the background, and a subsequent under-estimate of the flux in the subtracted image. When a preliminary stack is available the weight image is obtained from it, in order to detect and mask faint objects.

2.2. Quality Assessment

During quality assessment, general properties of images are computed, e.g., seeing, background, and point-spread function (PSF) quality. Catalogs for astrometric and photometric calibrations are extracted and weight maps are generated for every image.

2.3. Astrometry and Photometry

In general, a precise astrometric calibration is required for good resampling of the images. In particular, WIRCam implements an optional micro-dithering of its images: this technique allows, in principle, constructing optimally sampled composite images. To perform a correct and general resampling of images and avoid the problem of inaccurate offsets, micro-dithered, or non-micro-dithered images are treated identically; this is why identifying spurious detections is so important. Bad pixels and defects on the detector are fixed so they are easily matched by automatic procedures, because of small offsets between real objects in the case of micro-dithering. CFHT provides for each image and extension the photometric zero-point (in ADU s^{-1} at airmass 1) with respect to the 2MASS Vega system. Overlapping sources on all exposures in a given field for a given filter are compared, and the images are then scaled to the specified zero-point of 30 Vega mags. Astrometric and photometric calibration steps are done with *SCAMP*[3].

2.4. Artifact Correction

Guiding trails are features of constant surface brightness that can appear around stars that are used for guiding. They can reach a surface brightness of $\sim$ 20

[3]http://terapix.iap.fr/rubrique.php?id_rubrique=105

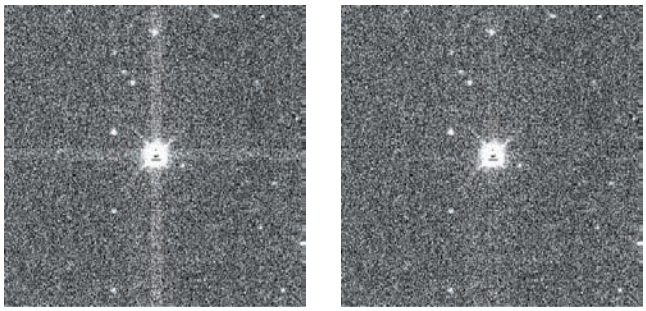


Figure 2. An example of a *guiding trails* correction.

mag arcsec^{-2} in the Ks band and $\sim$ 21 mag arcsec^{-2} in the J band. We subtract them using the following steps:

1. *SExtractor* produces a *check-image* OBJECTS that *WeightWatcher* transforms in a weight image that has the value zero where objects are found, and 1 otherwise.
2. A 1D fit of the background is produced with *SExtractor* (masking objects with masks produced in previous step) in the x and y directions.
3. Peaks in the background are detected using *SExtractor* and a check-image OBJECTS is produced.
4. The checkimages in x and y are combined using *SWarp* in a *guiding trails* image.
5. The *guiding trails* image is subtracted from the science image (see Figure 2).

2.5. Final Stacking

The images are resampled and combined using *SWarp*. In the past the LANCZOS2 resampling function of *SWarp* was used. Higher-order Lanczos functions generally provide better resampling, but for WIRCam we decided to use LANCZOS2 because of the large pixel scale ($0\farcs3$) with respect to the best seeing at CFHT ($\sim 0\farcs5$). In fact, if this optimal seeing is obtained, data are undersampled and resampling with a higher-order Lanczos function will generate extended ripples around bright stars (see Bertin 2006 for more details). In practice, the seeing is often worse than $0\farcs5$, but for good seeing LANCZOS3 or LANCZOS4 can produce artifacts around bright stars. In addition, bad pixels when resampled using the LANCZOS3 or LANCZOS4 functions produce a lot of artifacts. Quality assessment on the final stack is performed, producing seeing and background estimations and a preliminary star-galaxy separation. A catalog is also generated, containing basic object parameters that are subsequently used for the quality assessment procedures.

References

Bertin, E. 2006, *SWarp* User's Guide (Version 2.16: Paris: Observatoire de Paris)