Astronomical Data Analysis Software and Systems XVI **P2-37**
ASP Conference Series, Vol. XXX, 2006
R. Shaw, F. Hill and D. Bell, eds.

Processing WIRCam/CFHT wide-field near infrared data @ 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 microns. TERAPIX can provide to any PIs with ongoing WIRCam programs astrometrically and photometrically calibrated images as well as stacks, catalogues and relevant quality assessment meta-data. 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 maps 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 depends 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 available at CFHT. Table 1 summarizes the characteristics of the detector[1].

Number of detectors	$4 = 2x2$
Pixel dimension	18 *microns*
Pixel size	0.3 *arcsec/pixel*
Detector size	2048*x*2048 *pixels*
Camera field of view	21.5 *arcminute*
Field distortion	$< 0.8\%$ in the corners
Gaps between detectors	45 *arcsec*

Table 1. Characteristics of the WIRCam mosaic.

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

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 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 advantage of CMOS detectors used in the infrared compared to optical CCDs is 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 CMOSes and therefore more prone to undersampling.

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 catalogue delivery.

2.1. Sky subtraction

In order to optimize observations a 'dithering' procedure is often used in infrared imaging: it consists in observing the object field at fixed offsets around a center position. An automatic procedure has been developed providing sky subtraction for the dithering observing mode. A median pixel to pixel combine provides an estimation of sky variations, if correct masking and normalisation are applied. In general, considering the typical exposure time of WIRCam exposures, we use only images within a thirty minute 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 0 where objects are and 1 where objects are not.
2. A specified number of images is combined using SWarp[2] to create the sky frame. The image itself is not used in the sky combine.
3. The sky frame is subtracted to the image.

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

The object masking is an essential step in the sky frame production. If not masked, objects can affect the sky measurement producing an overestimation of the background and a subsequent underestimation 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.

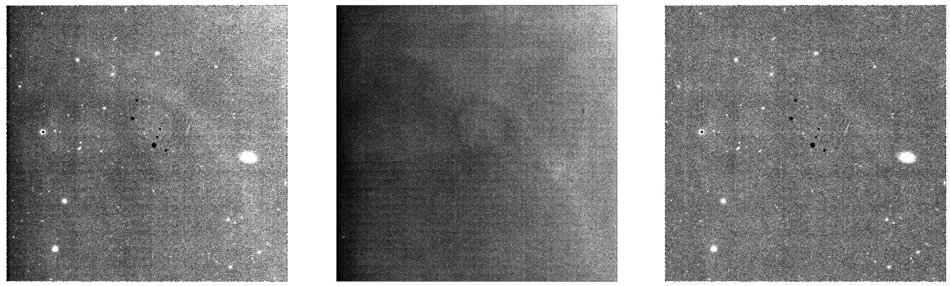

Figure 1. (from left to right) a no-sky-subtracted image, its relative sky frame, the sky-subtracted image.

2.2. Quality assessment

During this step general properties of images are computed: for example seeing, background and PSF quality. Catalogs for astrometric and photometric calibrations are extracted and weight maps generated for every image.

2.3. Astrometry and photometry

Precise astrometric calibration is required for good resampling of images, in the general case. In particular, WIRCam implements optional micro-dithering of its images: this technique allows, in principle, to construct optimally sampled composite images. To perform a correct and general resampling of images and avoid the problem of non-accurate offsets, micro-dithered or no-micro-dithered images are treated indentically 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 per second at airmass 1) with respect to 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 magnitudes. Astrometric and photometric calibration steps are done by SCAMP[3].

2.4. Artifact correction

"Guiding trails" are features of constant surface brightness which can appear around stars used for guiding. They can reach a surface brightness of $\sim 20 mag/arcsec^2$

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

in the Ks band and $\sim 21 mag/arcsec^2$ in the J band. We subtract them performing the following steps.

1. SExtractor produces a checkimage OBJECTS that WeightWatcher transforms in a weight image, having 0 where objects are and 1 where objects are not.
2. A monodimensional fit of the background is produced with SExtractor (masking objects with masks produced in previous step) in x and y directions.
3. Peaks in the background are detected using SExtractor and a checkimage 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 image.

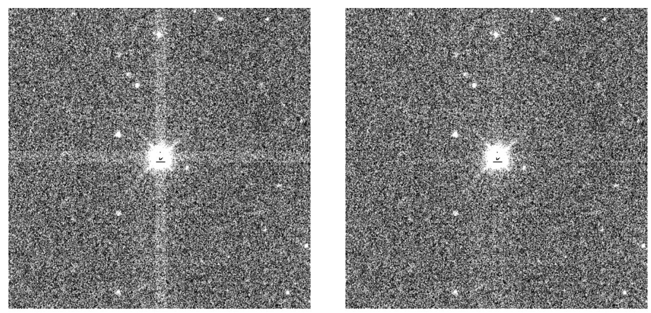

Figure 2. an example of "guiding trails" correction.

2.5. Final stacking

Images are resampled and combined using SWarp. Until present, LANCZOS2 resampling function of SWarp has been used. Higher order of Lanczos function provide in general better resampling, but for WIRCam we decide to use LANCZOS2 because of the big pixel scale ($0.3''$) with respect to the best seeing at CFHT ($\sim 0.5''$). In fact, if this optimal seeing is obtained, data are undersampled and resampling with higher order of Lanczos function will generate extended ripples around bright stars (see Bertin 2006 for more details). In practice, seeing is often worse than $0.5''$, but for good seeing LANCZOS3 or LANCZOS4 can produce artefacts around bright stars. In addition bad pixels when resampled using LANCZOS3 or LANCZOS4 functions produce a lot of artefacts. Quality assessment on the final stack is performed producing seeing and background estimations and a preliminary star galaxy separation. A catalogue is also generated, containing basic object parameters which is subsequently used for the quality assessment procedures.

References

Bertin, E. 2006, SWarp User's guide.