Processing WIRCam/CFHT wide-field near-infrared data @ TERAPIX

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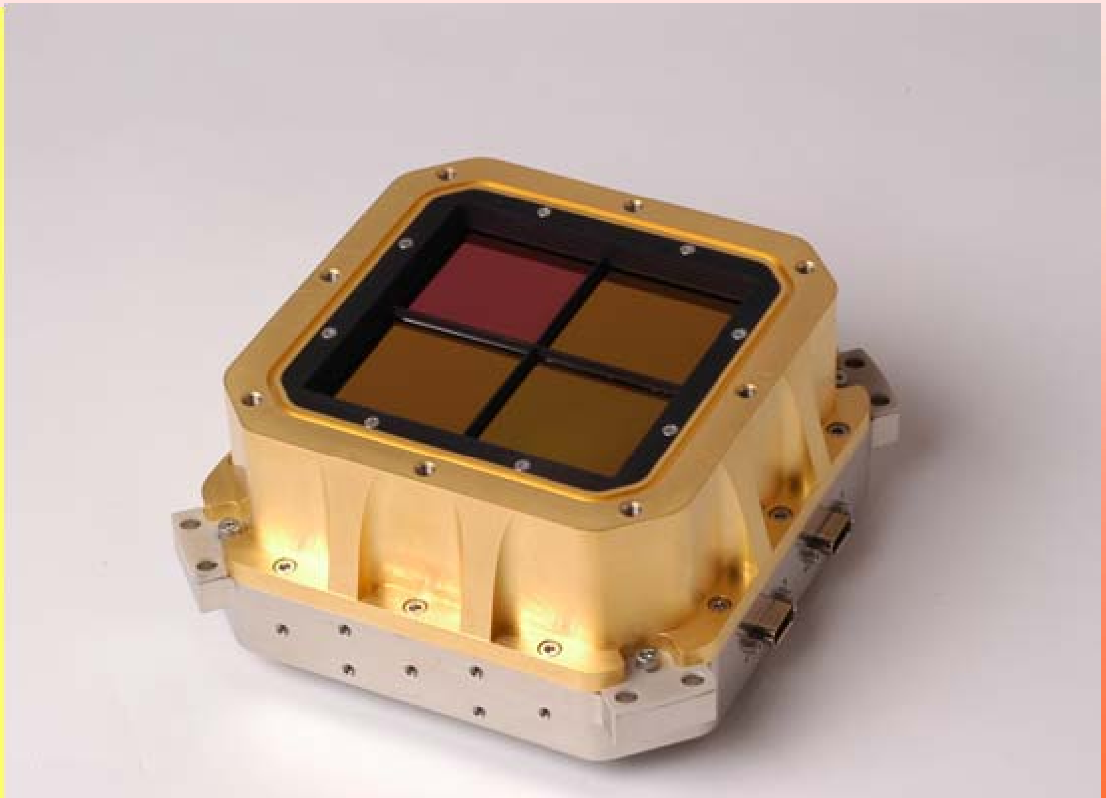
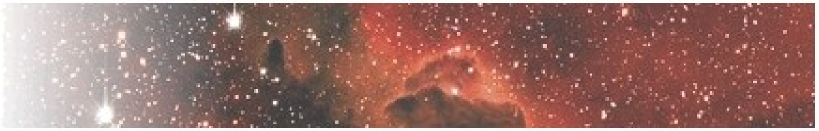


WIRCam detectors:
credits to Gerry Lupino, GL Scientific

CFHTLS french users meeting
Nov 6-7, 2006, IAP, Paris



Near-infrared vs. optical observations I.

Detector properties: APS-CMOS vs. CCD

- Data are accessed by row and column not by shifting rows and reading serially.

- Photosites are individually addressable, the image can be read out while signal is still being integrated.

- Amplifier characteristics make CMOSs less uniform all over the field and in the pixel itself.

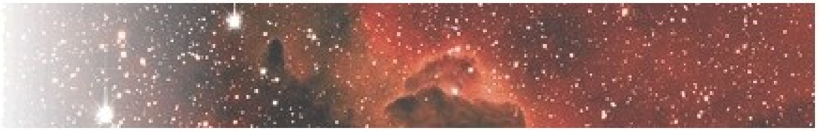
- Bigger physical dimension of pixels often produces undersampled data.

Near-infrared vs. optical observations II.

Processing strategy

- Large scale sky features are more obvious than in optical images: they require ad-hoc subtraction procedures compatible with no observational time loss at the telescope.

- Faint objects invisible in single exposures enhance the background level: they have to be masked out using a preliminary stacked image, in a more refined sky subtraction procedure.



WIRCam @ CFHT I.

Number of detectors	4 = 2 x 2
Pixel dimension	18 microns
Pixel scale @ center of the field	0.306 (arcsec / pixel) (sampling step is 0.15 arcsec with microdithering)
Detector size (pixels)	2040 x 2040 active pixels (2048 x 2048 with reference pixels)
Camera field of view	21.5 arcminutes
Field distortion	<0.8% in the corners
Gaps between detectors	45 arcsec
Available filters	from 1000nm to 2200nm

Processing steps @ TERAPIX

- image datacube splitting if necessary;
- first pass sky-subtraction;
- quality assessment and weight map production;
- precise astrometric and photometric calibrations;
- first stack generation;
- second pass sky-subtraction;
- artifact correction;
- final stack generation;
- catalogs and final quality assessment delivery.

Why datacubes @ CFHT?

- Because of the large number of background photons at longer wavelengths, near-infrared detectors saturate faster than optical detectors: exposure time is shortened and the number of exposures around the same coordinates is increased.

- The dithering or micro-dithering observation strategy (adopted to optimize sky-subtraction procedures) produces lots of images with small offsets around a central position.

In both cases datacubes were preferred for archiving reasons as a unique header can describe several images.

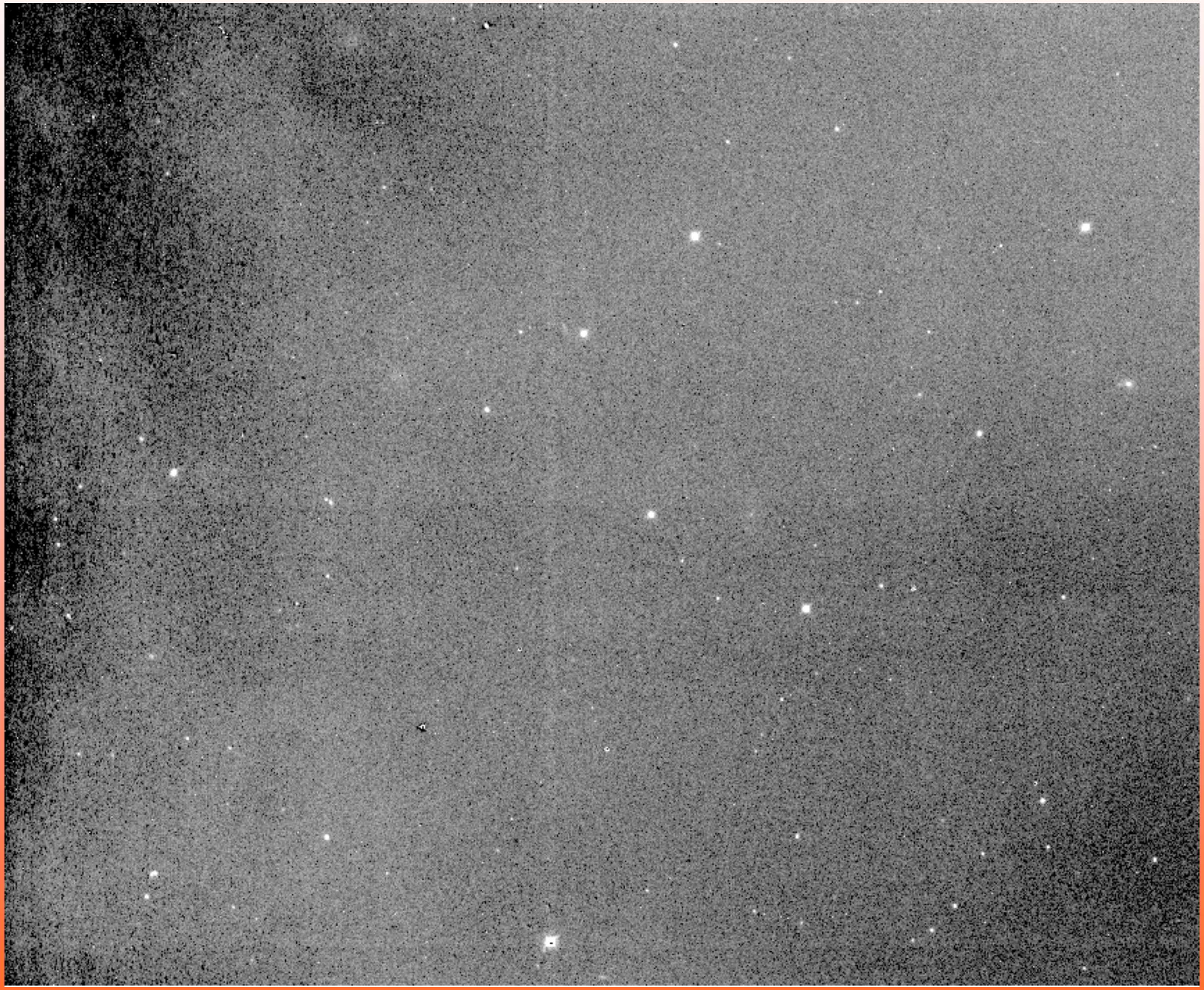
Why slicing @ TERAPIX?

- TERAPIX software is not compatible with datacubes!

- There is no three-dimensional information in CFHT datacubes. Every slice is actually an image with changing seeing, sky features, photometric quality and zero-points: quality assessment has to be performed before any medianing or combining.

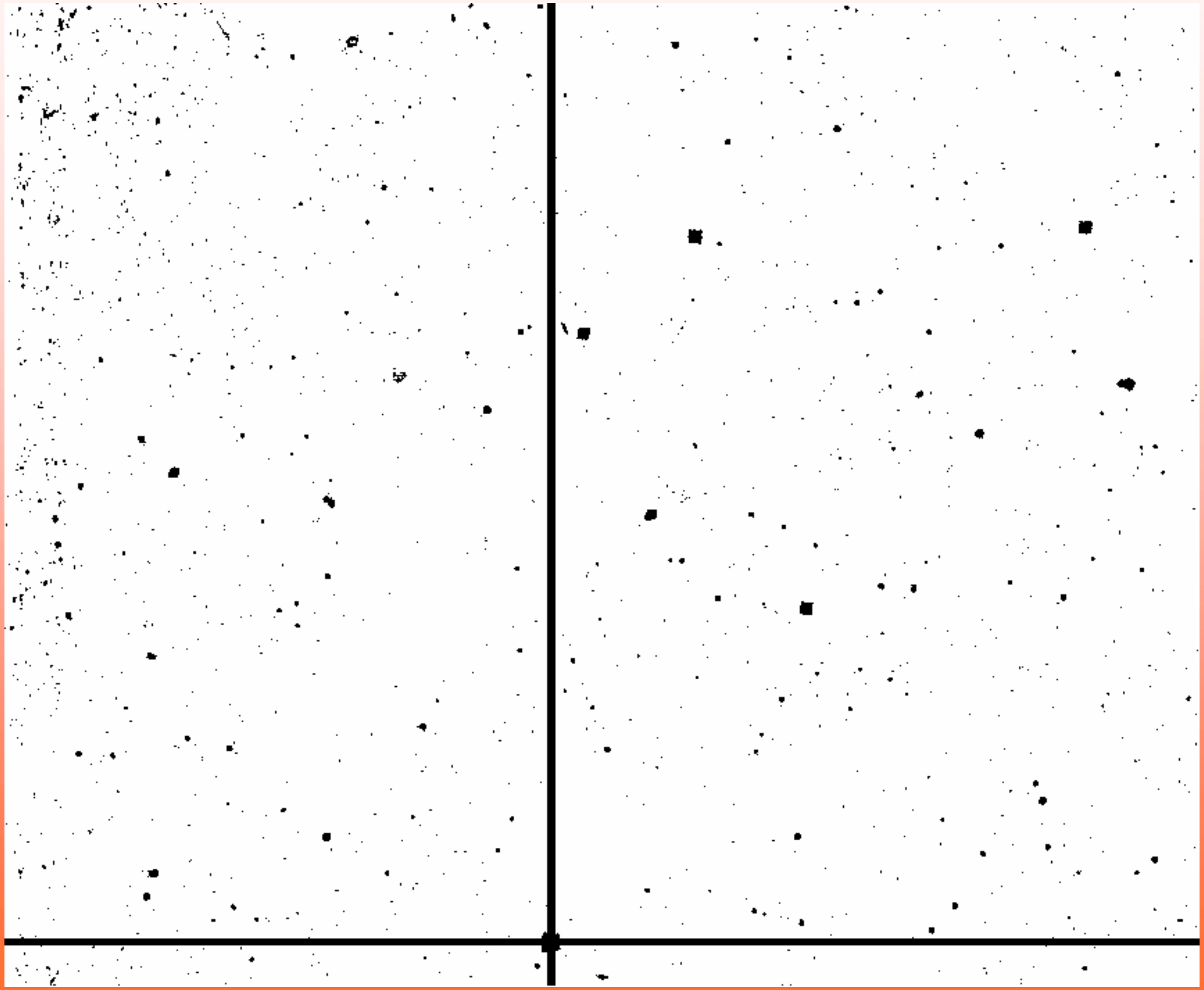
- In the micro-dithering case, the PSF is affected by pixel-to-pixel combine, more or less depending on image seeing: the TERAPIX software tools can perform astrometry precisely enough to resample and stack images with half a pixel of displacement.

First pass sky-subtraction: mask production



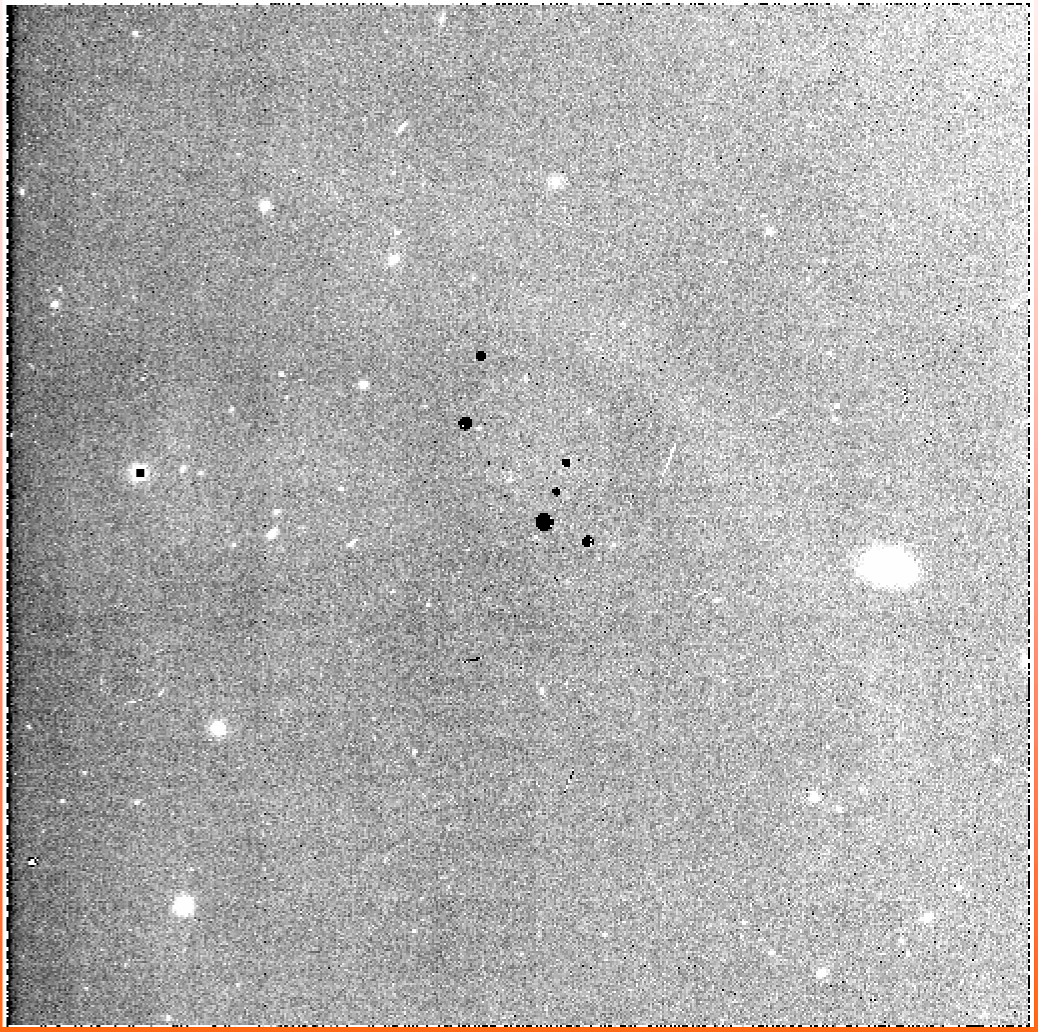
- Input Image ->
SExtractor ->
CHECKIMAGE
OBJECTS

First pass sky-subtraction: mask production



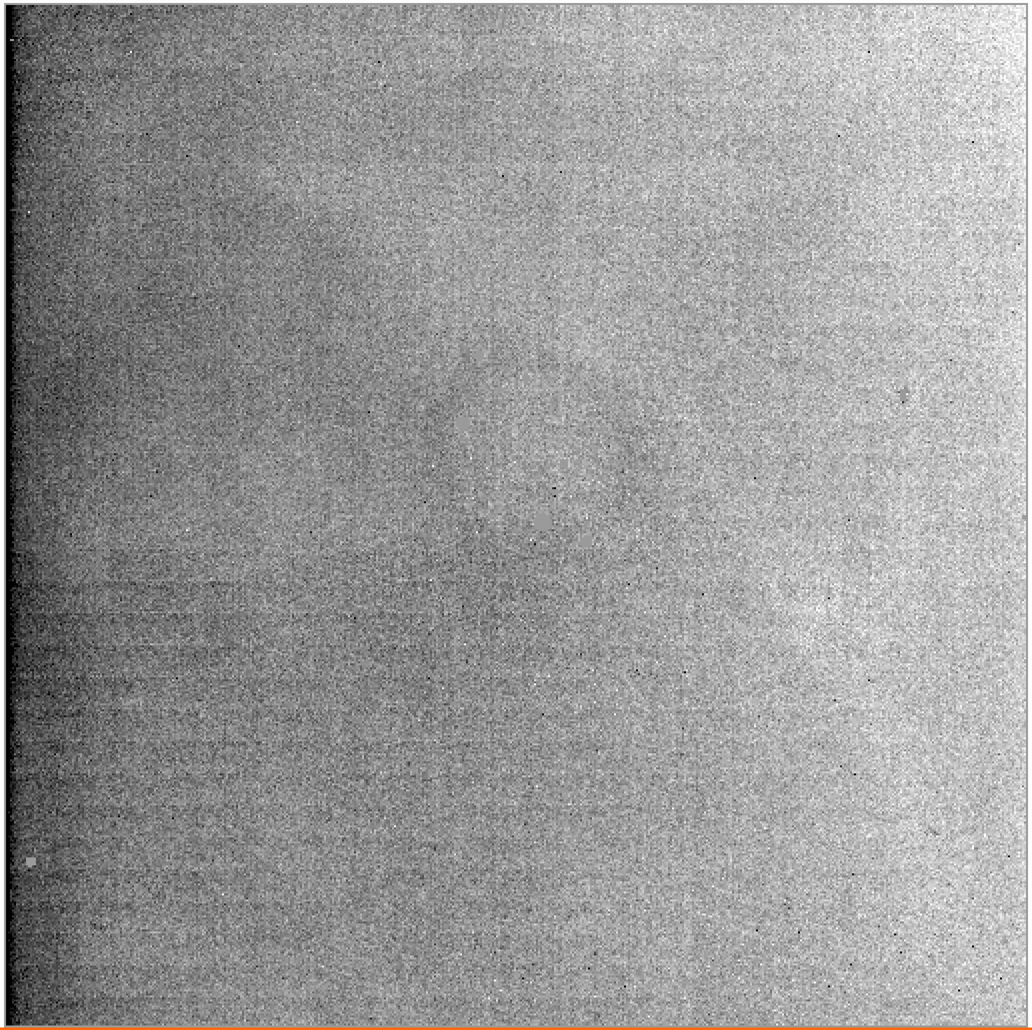
- Input Image -> **SExtractor** -> CHECKIMAGE OBJECTS
- --guide-on: option for guide trails masking (cf. artifact correction)
- Bad Pixel Mask + CHECKIMAGE OBJECTS-> **WeightWatcher** -> Output Mask

First pass sky-subtraction: sky frame production and subtraction



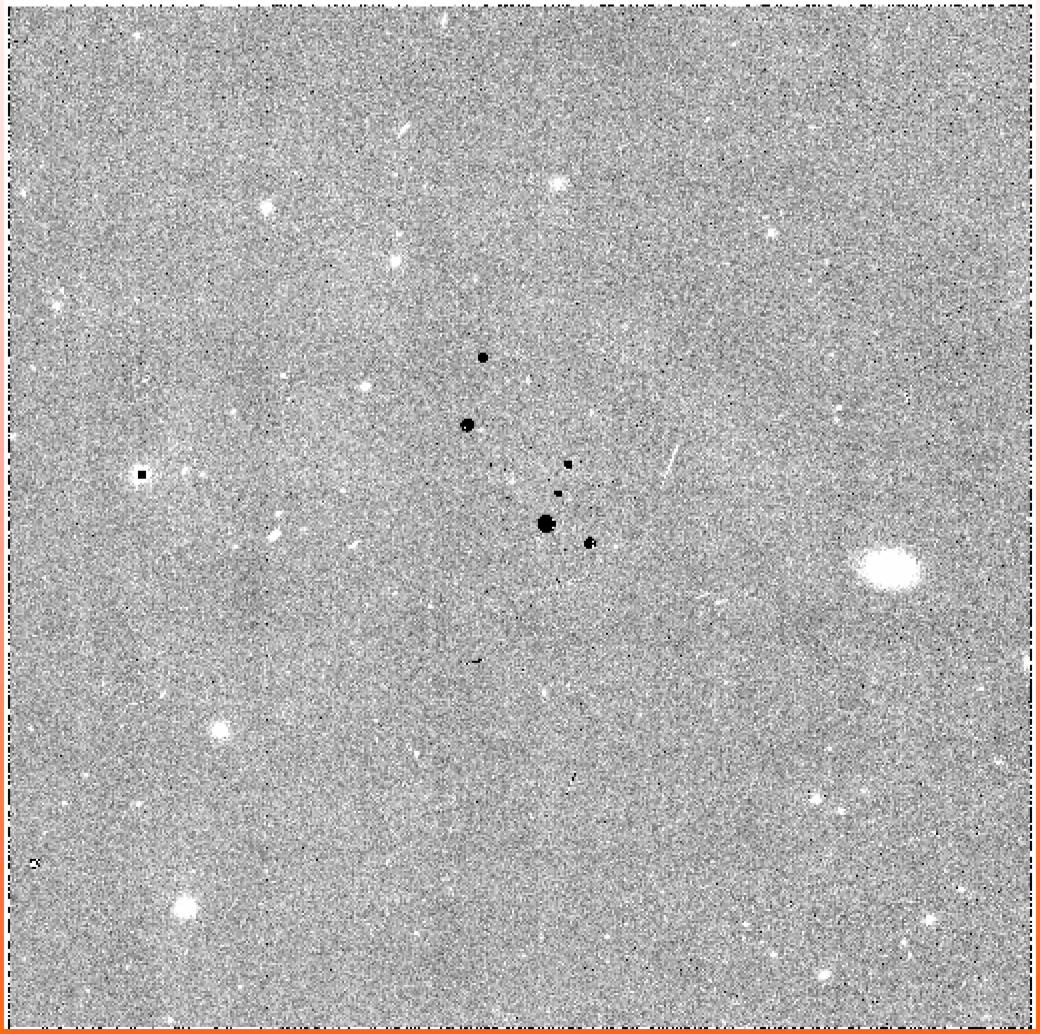
- *N* Input Images -> **SWarp** -> Sky Frame

First pass sky-subtraction: sky frame production and subtraction



- *N* Input Images -> **SWarp** -> Sky Frame

First pass sky-subtraction: sky frame production and subtraction



- *N* Input Images -> **SWarp** -> Sky Frame
- Input Image + Sky Frame -> **SWarp** -> Subtracted Image

Quality assessment: using QualityFITS

QualityFITS is a pipeline software. We use it to

- run SExtractor for identifying hot pixels;
- run WeightWatcher to produce weight maps;
- run SExtractor to produce the catalogs for astrometric and photometric calibrations;
- run PSFEx to build a PSF model;
- plot histograms of the background as well as preliminary star and galaxy counts.

All this information is summarized in a webpage.

Hot pixel and cosmic ray identification

WHY?

Precise astrometric calibration is required for proper alignment of the images, especially if micro-dithering is used (as often with WIRCam). The positions of bad pixels and defects remain the same on the detector and are easily matched by automatic procedures because of the small micro-dithering offsets.

HOW?

- ❑ A non-linear filter has been generated once for all using machine learning (EyE).
- ❑ The detection of bad pixels is performed using SExtractor (-FILTER Y –FILTER_NAME wircam.ret).

Weight maps and catalog production.

Using WeightWatcher for weight maps:

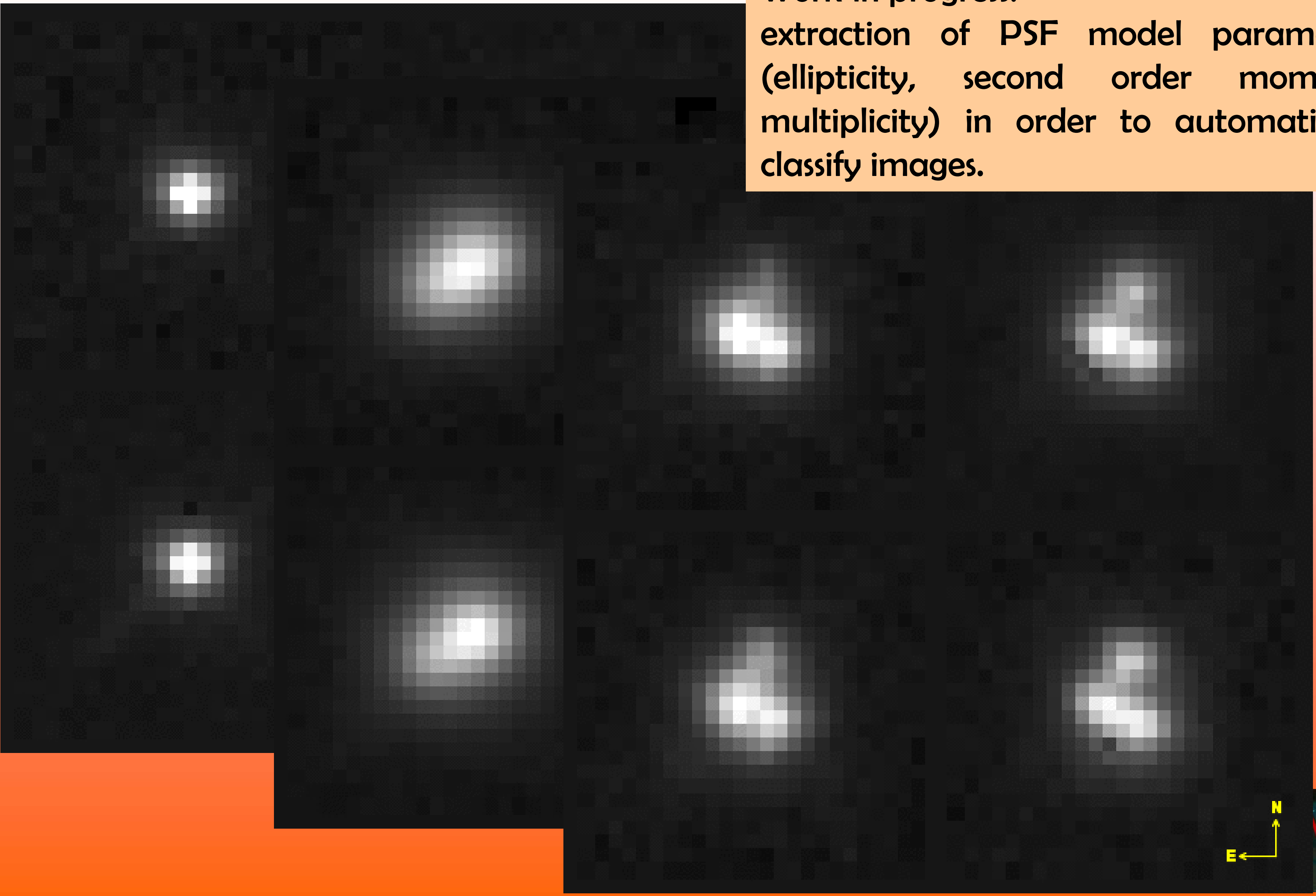
- CFHT provides flats and bad pixel masks used in the detrending phase;
- hot pixels and cosmic rays flagged;
- edge regions strongly affected by bad pixels masked with ds9 .reg files.

Using SExtractor for catalogs:

- weighted detections;
- parameters optimized to eliminate spurious detections:
  - ✓ INTERP_TYPE NONE.

PSF quality estimation.

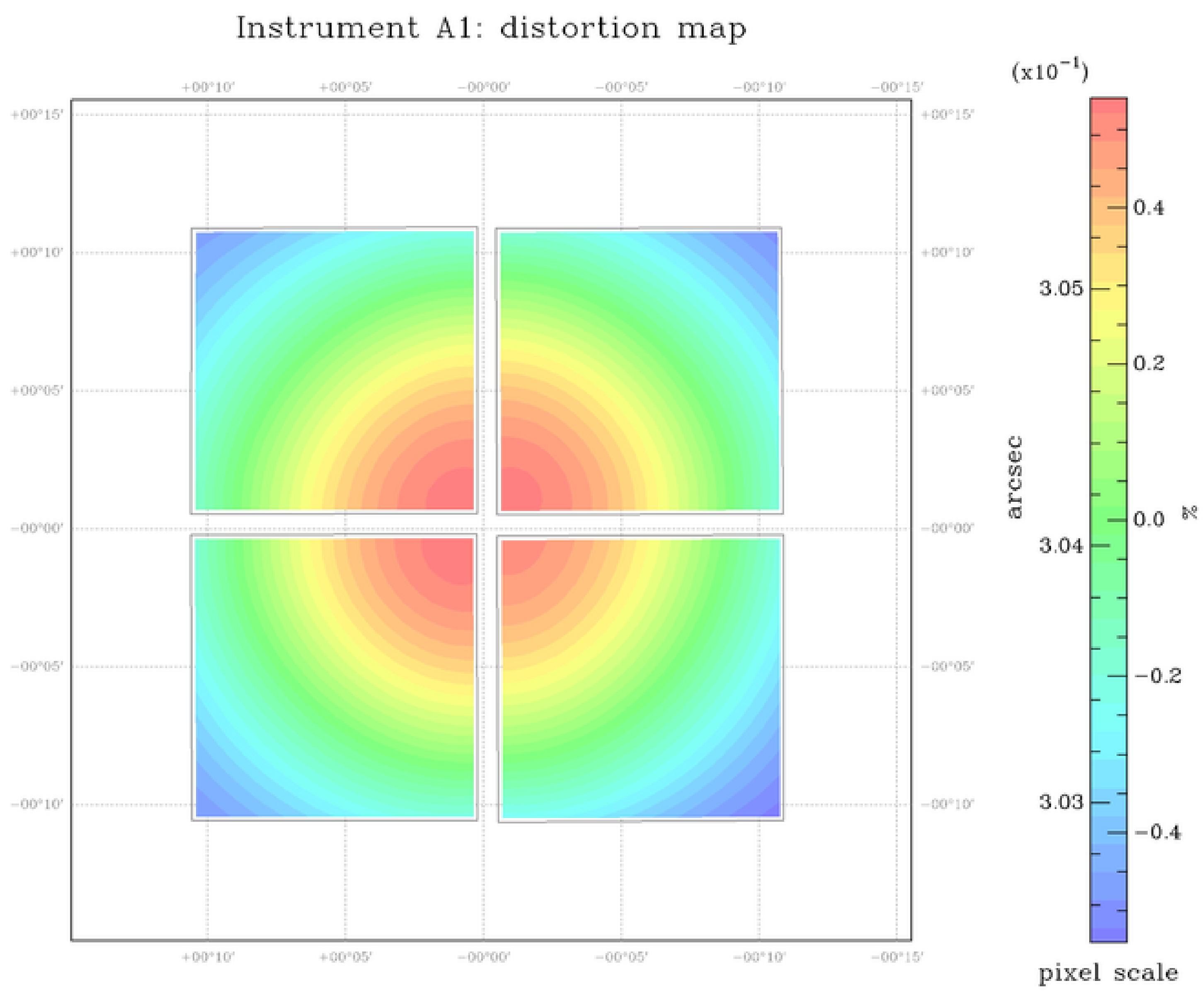
Work in progress:
extraction of PSF model parameters (ellipticity, second order moments, multiplicity) in order to automatically classify images.



Astrometry I.

Using SCAmP:

- the CFHT QSO team has provided us with a stellar astrometric field. A model of the WIRCam field was produced, and used as starting point for all images.
- 2MASS astrometric reference catalog (if PIs have no specific requests) and fourth degree polynomial solution.
- WIRCam can be considered an astrometrically stable instrument.

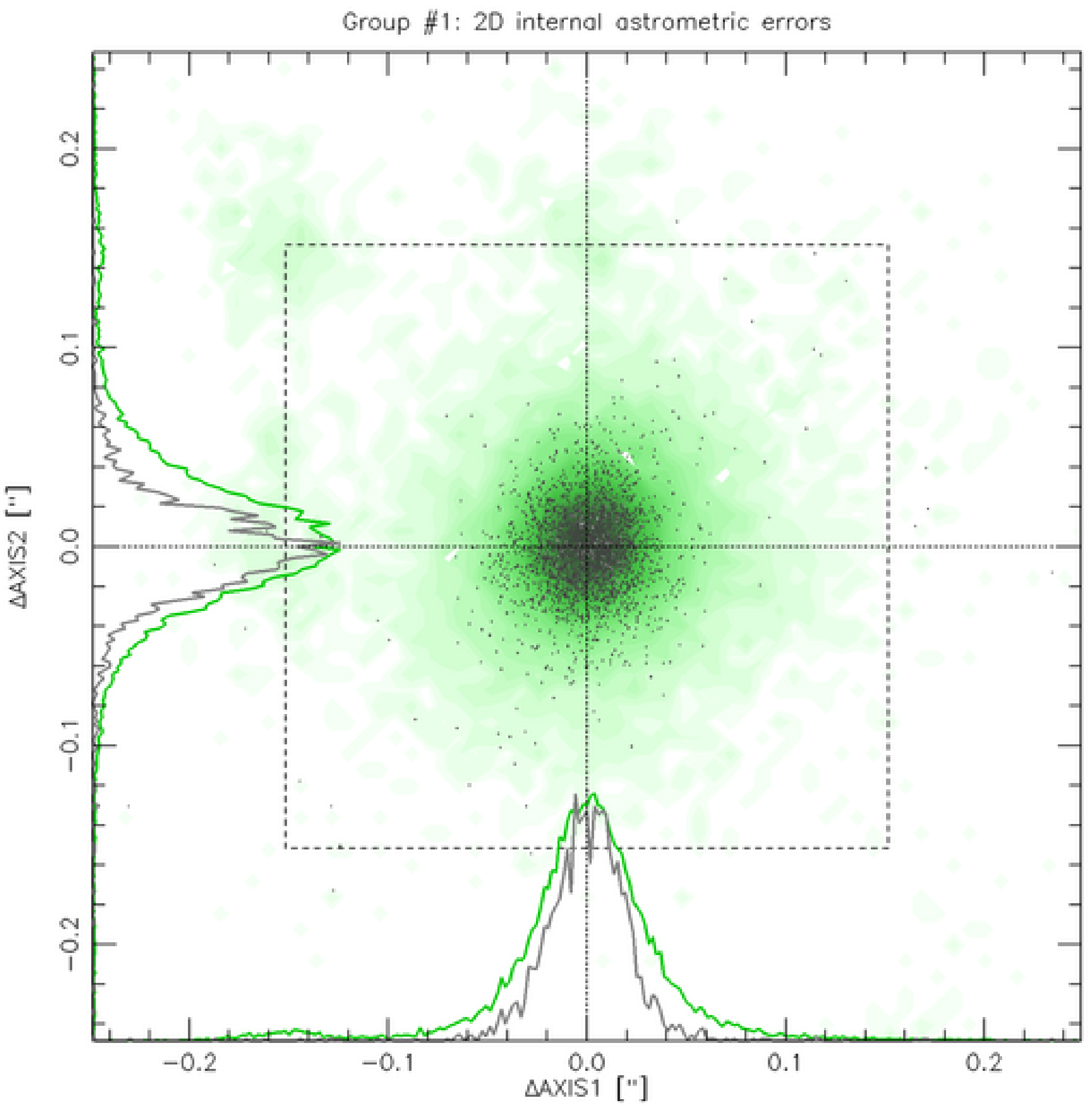


Instrument A1: distortion map
+00°10'
+00°05'
-00°00'
-00°05'
-00°10'
-00°15'
+00°15'
(x10^{-1})
0.4
0.2
0.0
-0.2
-0.4
%
3.05
3.04
3.03
arcsec
pixel scale

Astrometry II.

Using SCAmP:

- The pairwise internal error (repeatability*sqrt(2) for high S/N sources) within a micro-dithered datacube is about 18 mas rms.
- Typical values for the (pairwise) residuals of the astrometric solution go from ~30 mas (a few tens of exposures) to ~90 mas (several thousands of exposures) rms internal, and 130 mas rms with respect to reference catalog.


Group #1: 2D internal astrometric errors
ΔAXIS2 ["]
0.2
0.1
0.0
−0.1
−0.2
−0.2
−0.1
0.0
0.1
0.2
ΔAXIS1 ["]

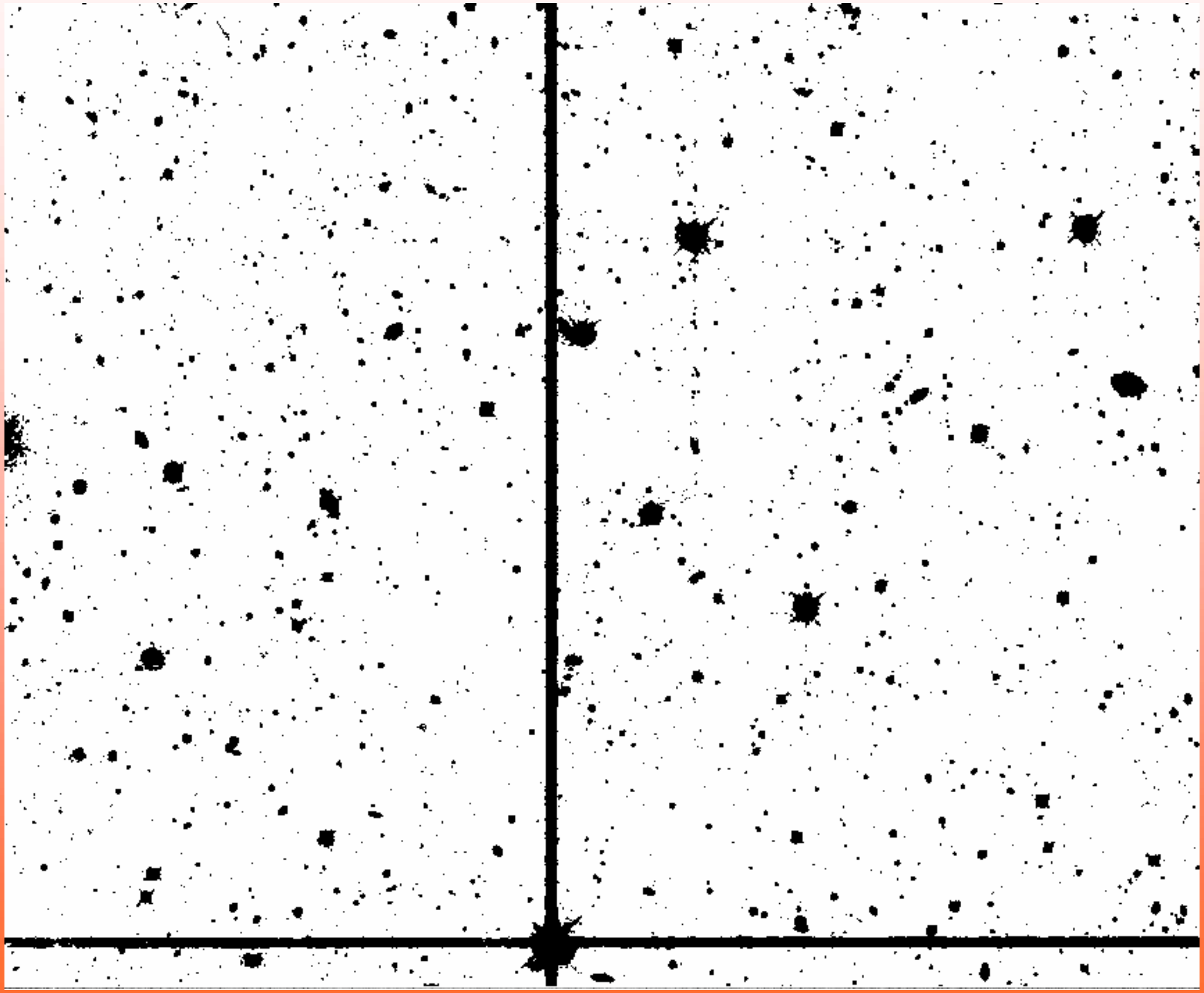
Photometry

Using SCAmP:

- The CFHT photometric calibration is based on 2MASS, for 2MASS-like filters: zero-points for every detector and every image are provided to TERAPIX.
- SCAmP matches the detected sources and rescales the fluxes relative to an arbitrary (30) zero-point: the magnitude system is instrumental Vega because of the 2MASS calibration.
- Typical values for the (pairwise) residuals of the photometric solution are ~0.2 magnitude internal.
- But final (after coaddition) photometry directly compared with the 2MASS catalog gives a 0.1 mag rms dispersion.

After astrometric and photometric calibration a preliminary stack is produced

Second pass background subtraction

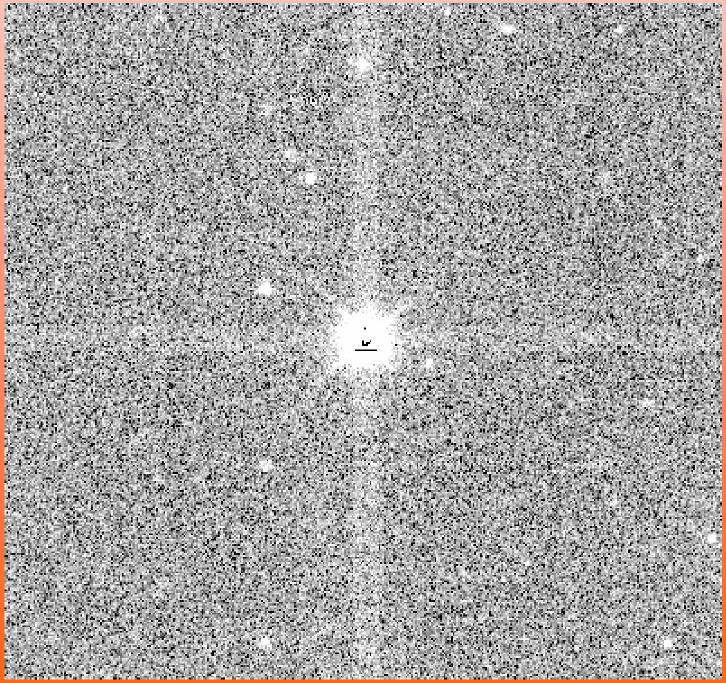


- First Stack -> **SExtractor** -> CHECKIMAGE OBJECTS
- CHECKIMAGE OBJECTS + astrometric solution (.head) -> **Swarp** -> OBJECTS reprojected
- Bad Pixel Mask + OBJECTS reprojected-> **WeightWatcher** -> Output Mask

Correction of artifacts:

We call 'guiding trails' the constant remanences appearing around stars which are used as guiding stars.

They can reach a surface brightness of ~20mag/arcsec^2 in the Ks band and ~21mag/arcsec^2 in the J band.



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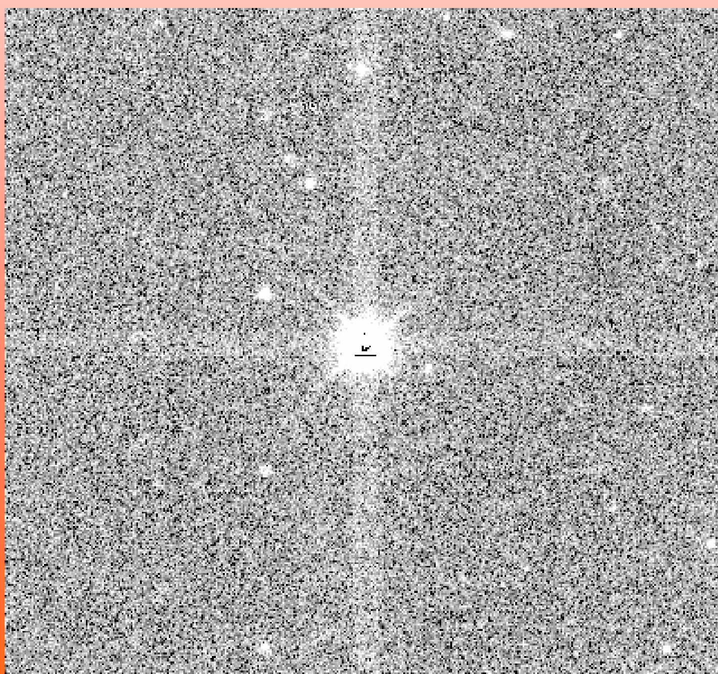
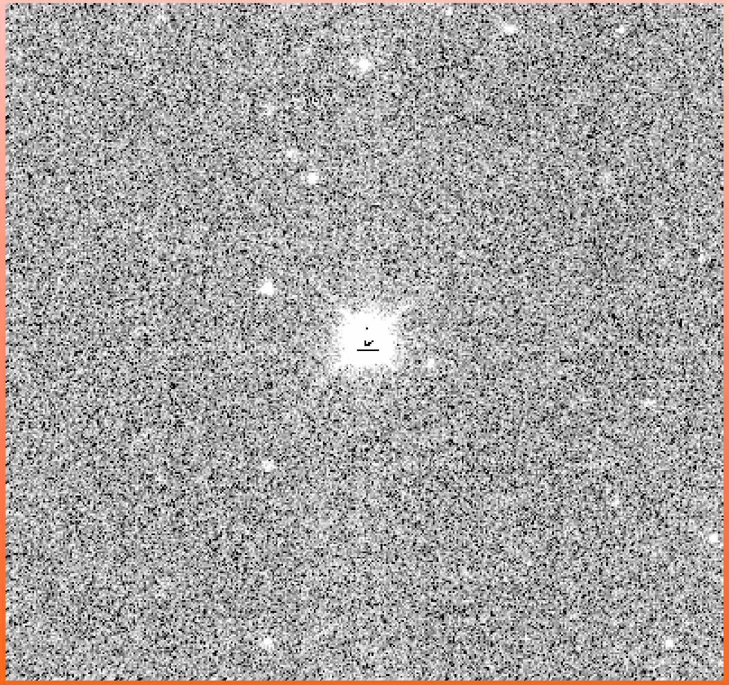
They can reach a surface brightness of ~20mag/arcsec^2 in the Ks band and ~21mag/arcsec^2 in the J band.



[redacted]



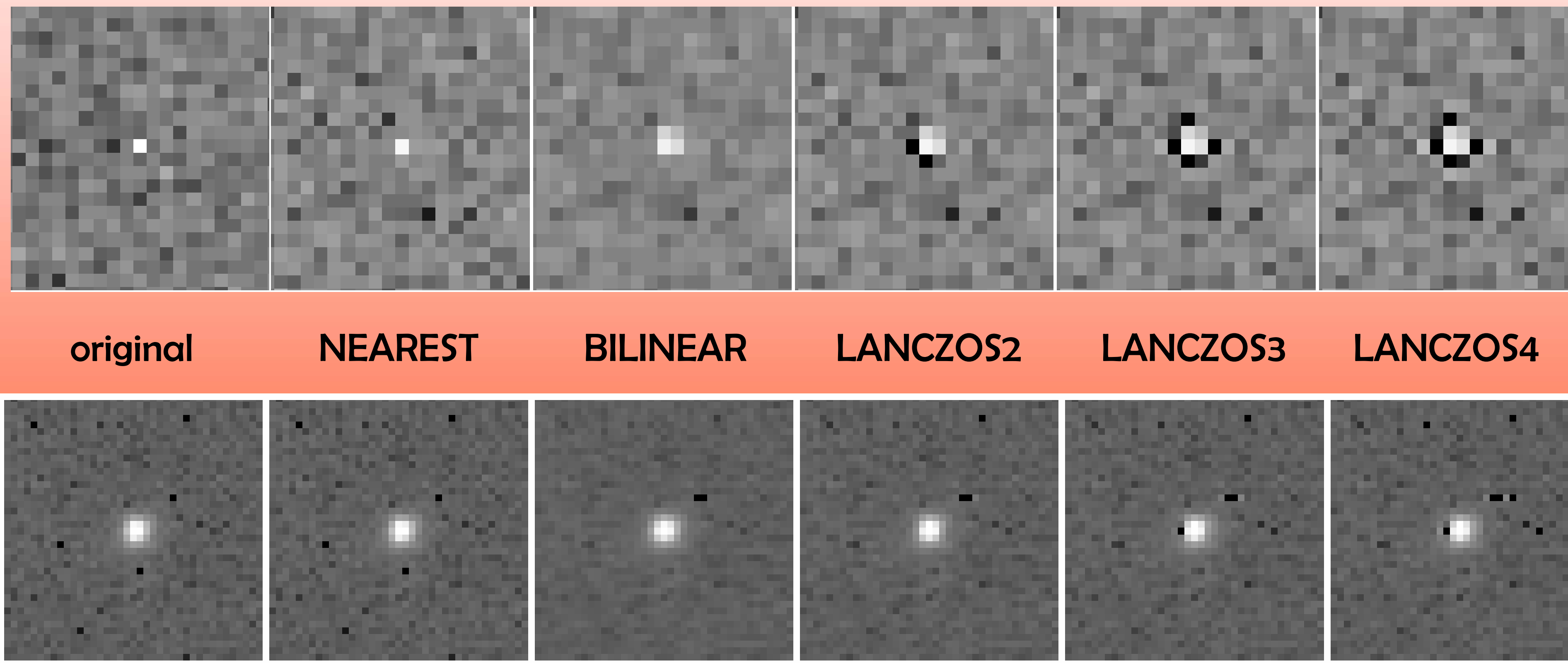
[redacted]

They can reach a surface brightness of ~20mag/arcsec^2 in the Ks band and ~21mag/arcsec^2 in the J band.

Stacking

Using SWarp:

RESAMPLING_TYPE LANCZOS2, in order to avoid strong resampling defects caused by under-sampled data.



Final products

- Stacked images (effective field of view, magnitude zero-points), the weight and flag images, the ds9 .reg ASCII files.
- Catalog containing basic object parameters.
- Quality assessment (using qualityFITS), background and PSF quality.
- Astrometric and photometric quality assessment plots: astrometric solution scatter plots, photometric solution scatter plots, galaxy counts plot.
- χ^2 image and merged catalog, if more than one filter is processed.