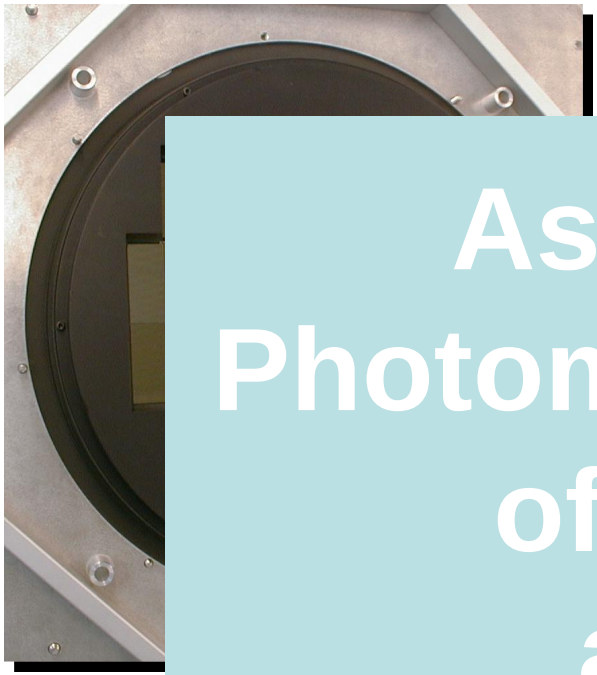
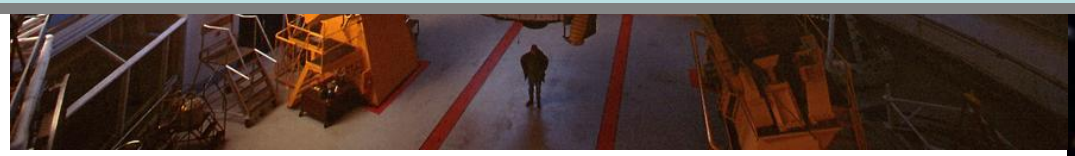
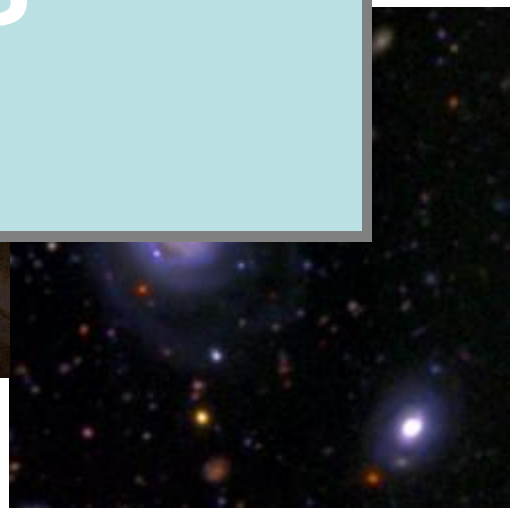


# Astrometric and Photometric calibrations of the CFHTLS at TERAPIX

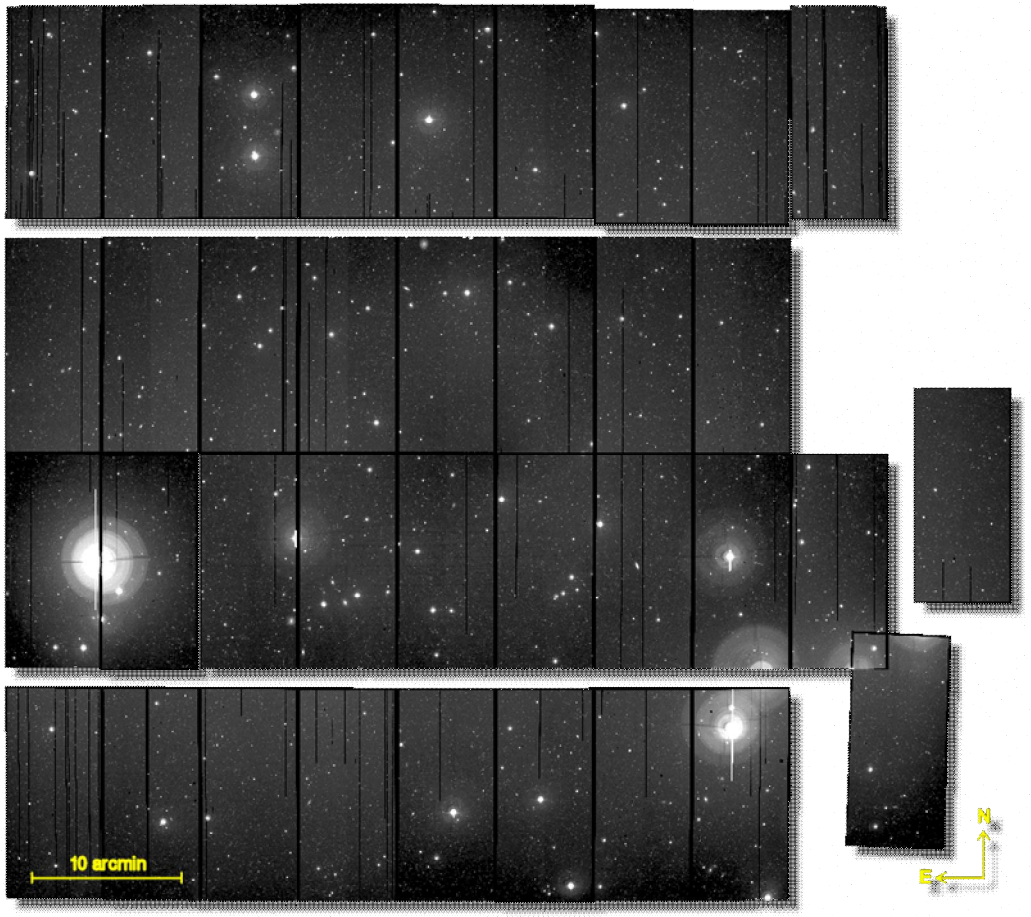
E.Bertin, (IAP & Obs. de Paris/LERMA)

# Two generation of TERAPIX calibration tools

- Calibration done on SExtractor catalogs
- T0001 release made with ASTROMETRIX (Radovich 2002) (http://www.na.astro.it/~radovich/wifix.htm )
  - Global solution, but
    - CCDs and exposures are handled one-by-one
    - Slow
- T0002 and subsequent releases made with SCAMP
  - « Fire and forget » operation:
    - `scamp *.ldac`
  - 100× faster and multithreaded
    - Currently, typically 5-20s / MEGACAM exposure on a 4-way 2.4GHz Opteron
  - Works on SExtractor catalogs extracted from any WCS-compliant image
  - Publicly released when I find the time to document it.

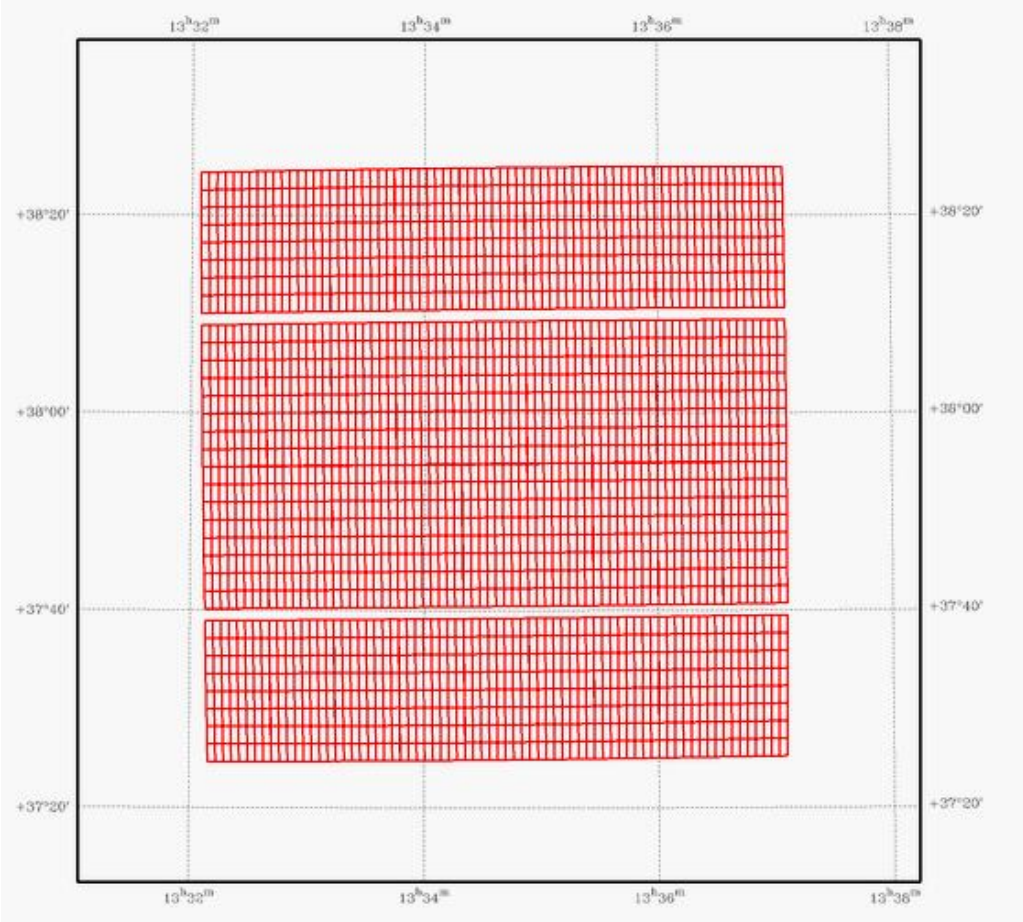
# TERAPIX and the astrometric calibration process

- CFHTLS and PI data are pre-calibrated at CFHT
  - CCDs within a MEF are astrometrically calibrated one-by-one with respect to a reference catalog (USNO)
    - Linear correction
    - Significant number (~4% of MEGACAM exposures affected) « catastrophic » errors (>20'' or wrong position angles).
    - Smaller shifts also present



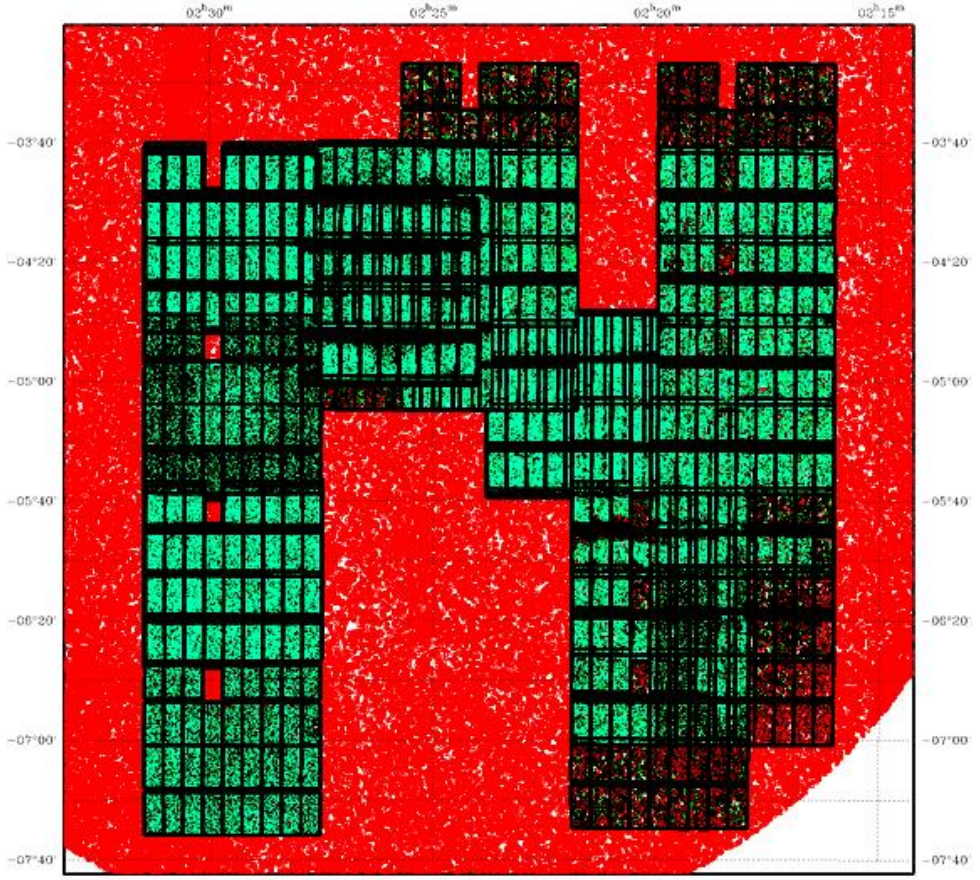
# Astrometry: what we do at TERAPIX

- TERAPIX has access to a broad range of astrometric « contexts »
  - Astrometric context defined by a combination of QRUNID and FILTER FITS keyword values
  - For each context a “median focal plane configuration” can be derived
- All astrometric calibrations are made at the MEF level
  - All internal tasks involve intermediary reprojections
  - Robustness much improved



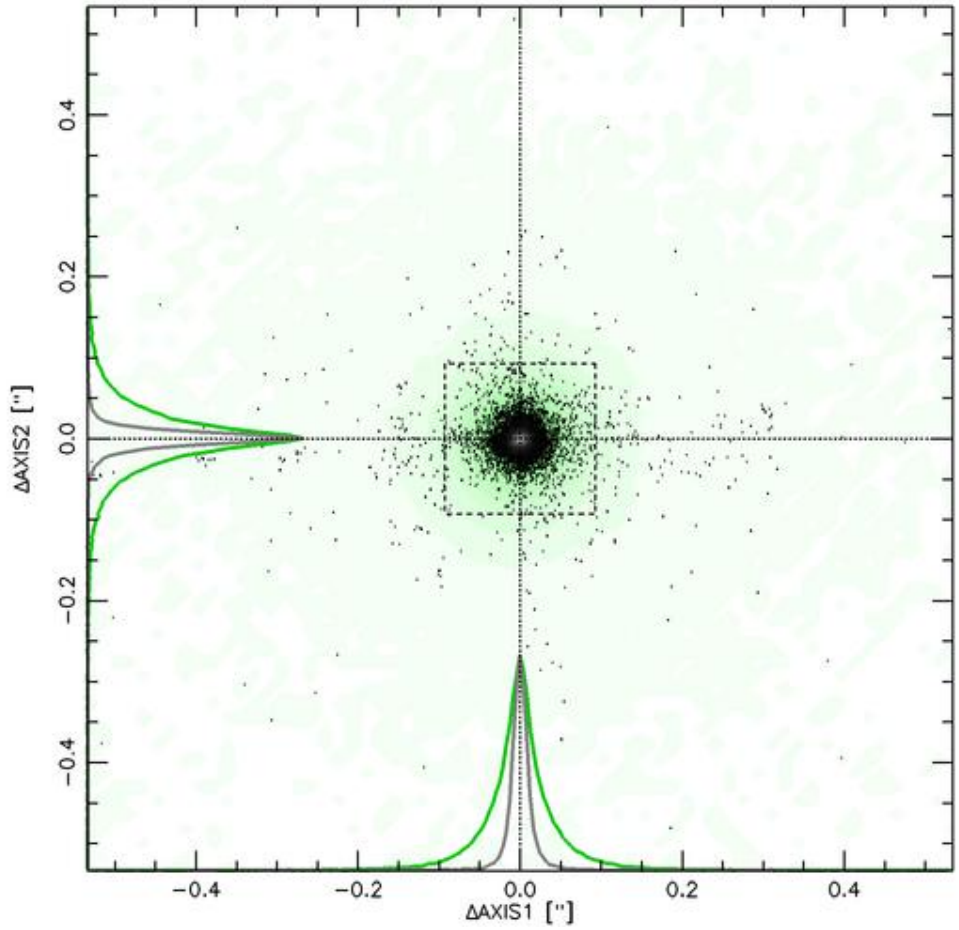
# Astrometry: calibration sequence

- Catalogs are grouped according to their positions on the sky, and their astrometric and photometric contexts.
- Focal plane configurations are fixed if necessary.
- Robust pattern matching recovers pixel scales, frame position angle, chirality and shift (up to ~ 1 deg with USNO-B1).
- « Global » solutions derived simultaneously from hundreds of exposures from different instruments and sky areas
  - 20 free parameters (3rd order polynomial) for each CCD in a given “astrometric context”
  - 6 extra free “linear distorsion” parameters common to all the CCDs, for each exposure to account for image anamorphoses due to atmospheric refraction (typically 0.12% in the visible at airmass=2) and instrumental flexures.



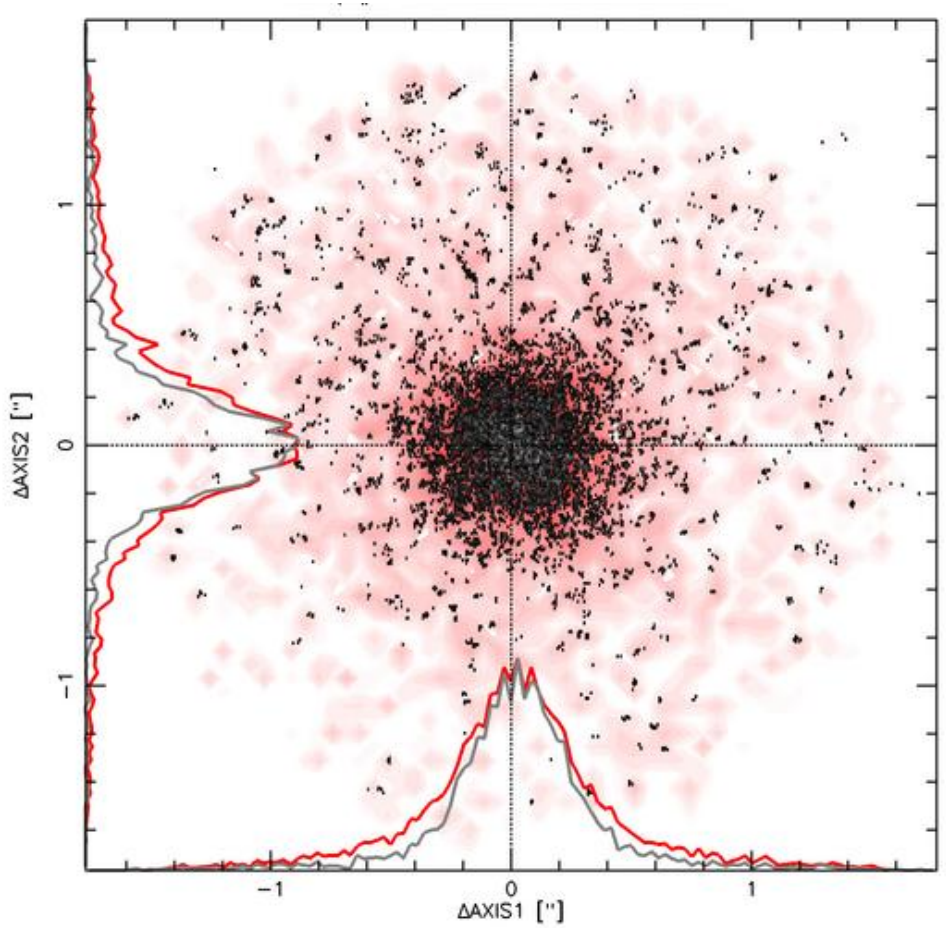
# Astrometry: what astrometric accuracy to expect with the CFHTLS

- Typical position differences in pairs of detections (including galaxies) from individual dithered exposures vary from 12 to 100 mas RMS.
- But internal accuracy on scales larger than the CCD size depends a lot on the dithering strategy
  - Small dithers provide poor constraints and falsely optimistic statistics



# Astrometry: what astrometric accuracy to expect with the CFHTLS (2)

- "Absolute" accuracy essentially depends on the reference catalog
  - With USNO-B1, the dispersion is typically 0.35" RMS.
  - Features are often seen at Schmidt plate boundaries



# Astrometry: proper motions

- Currently been implemented in SCAMP, to be featured in release T0003
  - Handled as a perturbation to the static astrometric solutions.
    - For star *i* on exposure *j*:

$$\Delta\alpha_{ij} = \lambda_{\alpha j}\Delta c_i + \mu_{\alpha i}\Delta t_j$$

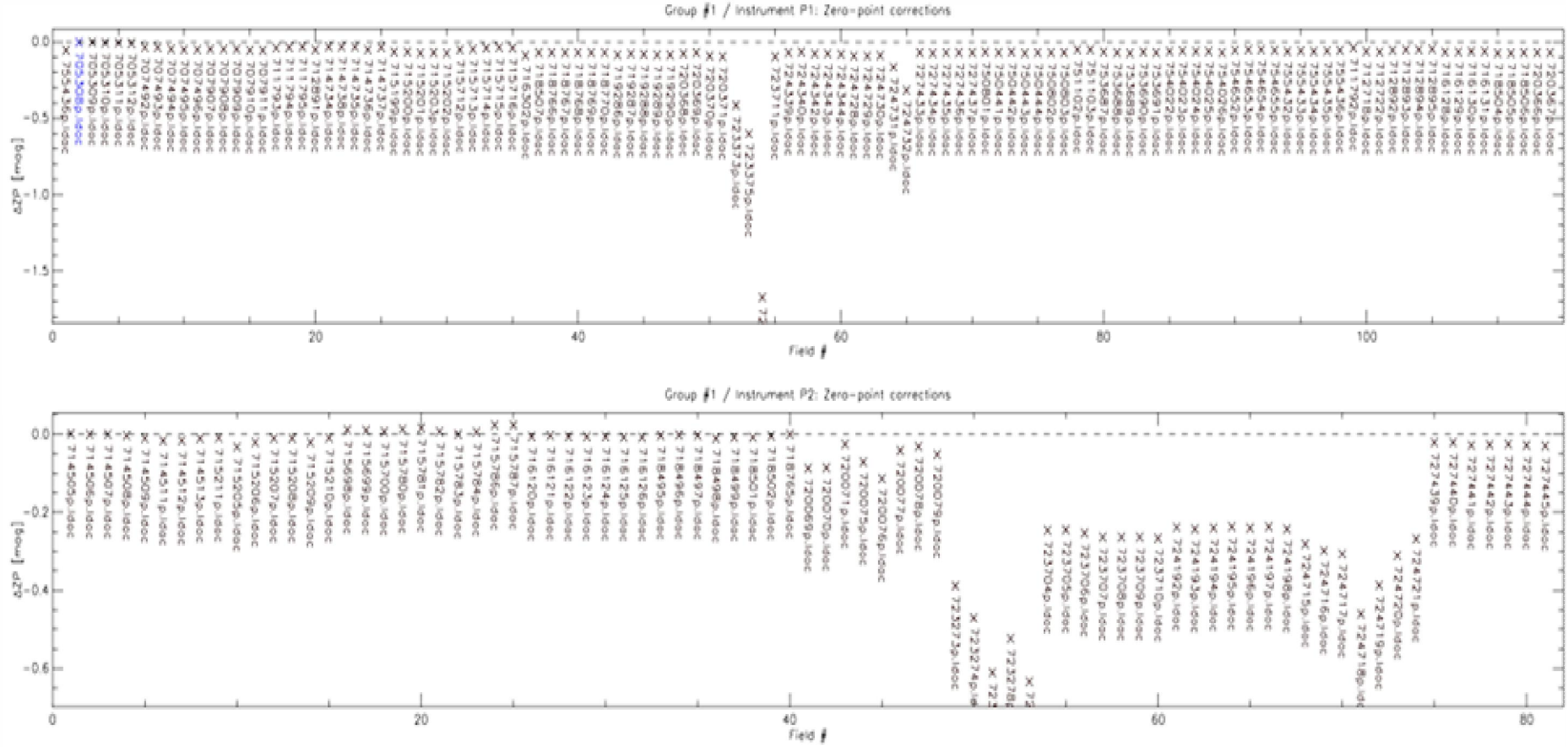
$$\Delta\delta_{ij} = \lambda_{\delta j}\Delta c_i + \mu_{\delta i}\Delta t_j$$

  - Thousands of galaxies found in individual exposures should provide a stable reference frame.
  - Proper motion accuracies at the level of 1 mas/yr or less expected.

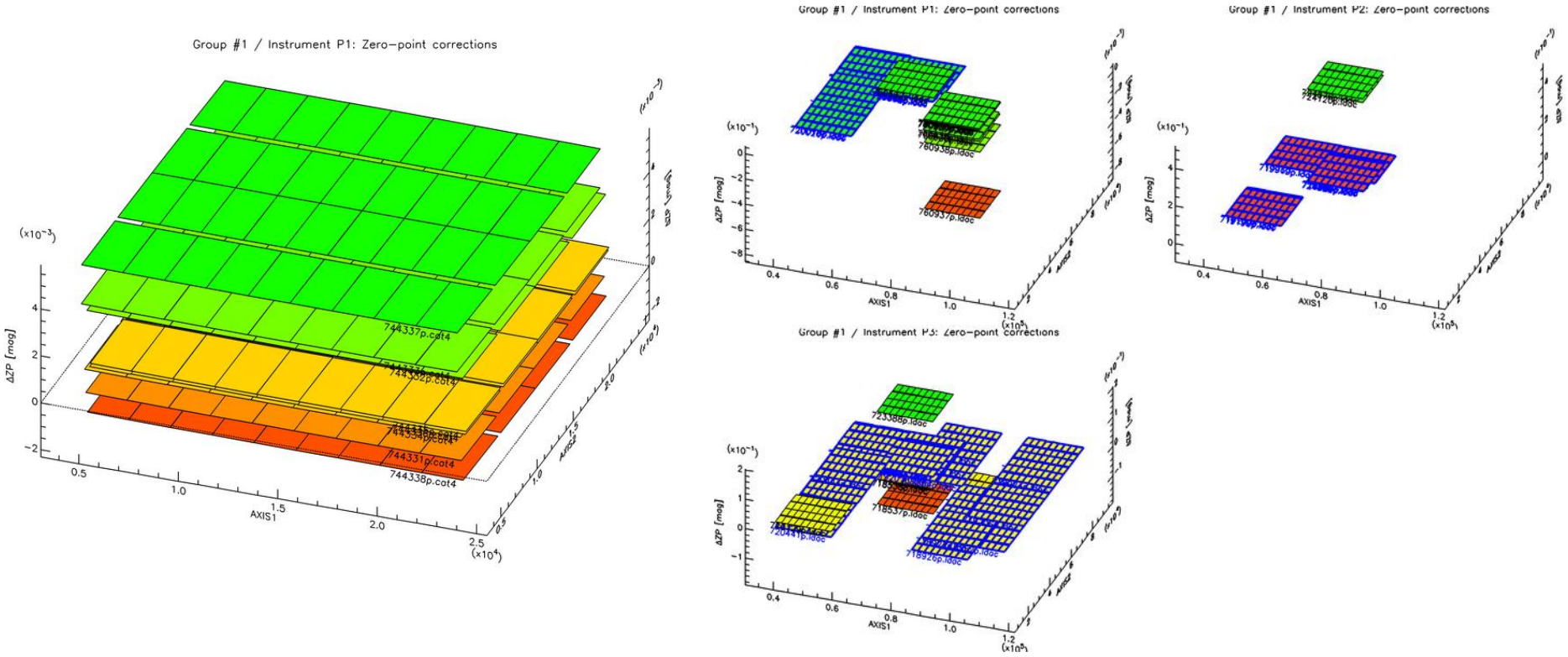
# TERAPIX and the photometric calibration process

- CFHTLS and PI data are photometrically pre-calibrated at CFHT
  - Illumination correction
  - Skyprobe
  - A photometric solution using standard stars is derived for the photometric nights of a Q-run
    - Photometric nights witinh a Q-run are supposed to be equal in terms of transparency
- At TERAPIX:
  - Exposures taken during non-photometric nights must be calibrated using overlaps
  - Exposures labelled « P » are used as photometric anchors
    - The consistency of their photometry can be checked when they overlap
  - If the dithering strategy permits it, the quality of the illumination correction can also be checked: we measure variations of 1% typically.

# Tracking photometry zero-points

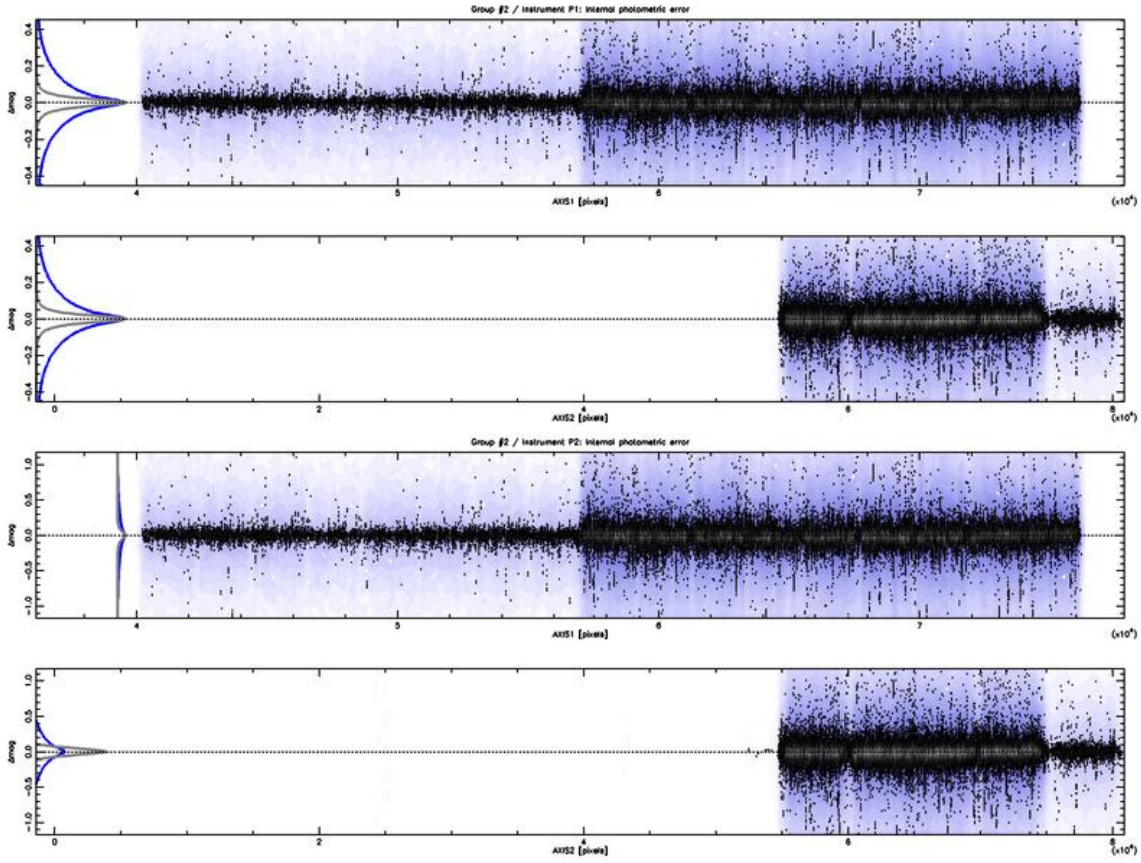


# Tracking photometry zero-points (2)



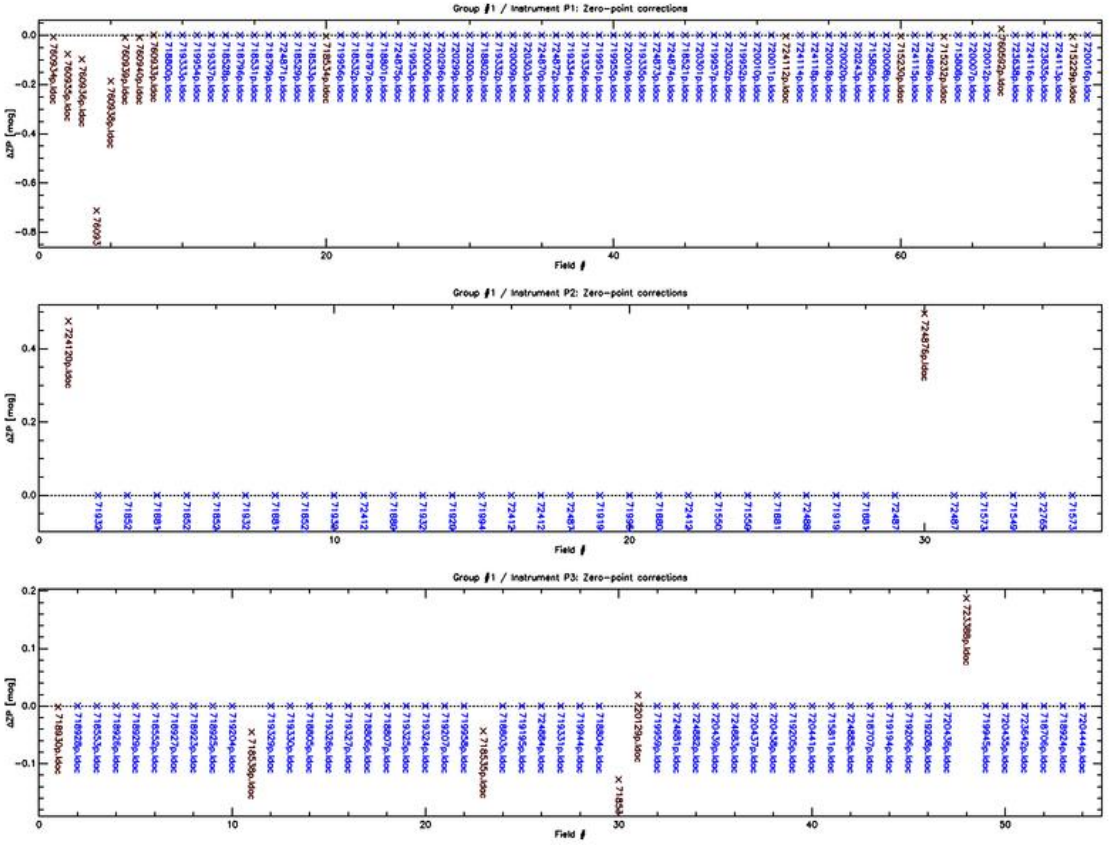
# Photometry: what photometric accuracy to expect with the CFHTLS

- Individual *relative* measurement errors are ~0.03 mag (MAG_AUTO)
- The number of overlapping sources is generally so large that the relative zero-point errors are dominated by systematics
  - Stability of the magnitude estimates
    - Seeing
    - Source profiles
  - Propagation of illumination correction errors
    - Dithering strategy
- The internal consistency of exposures qualified as “photometric” by CFHT is not very good
  - Typically ±0.02 mag



# Refining the selection of photometric fields

- Many exposures qualified as « photometric »: which one shall we keep?
  - Highest flux
  - Epoch
  - Position in the stack
  - Overlaps
- We might decide to make our own calibration using the standard star fields



# Summary

- SCAMP is now the work horse of calibration at TERAPIX
  - Fast: basically the whole CFHTLS can be recalibrated in a few days
- Appropriate dithering strategies are mandatory for reliable calibrations
- Astrometry: current issues
  - Proper motions are on the way
  - Relative weighting of the reference and detection catalogs
- Photometry: current issues
  - Better magnitude estimate for calibrations
  - Inconsistencies at the level of a few % between « photometric » reference exposures
  - Additional illumination corrections
  - The photometric calibration using standard stars may have to be redone in-house

TERAPIX

# terapix.iap.fr