

Image subtraction and transient detection with LSST Software

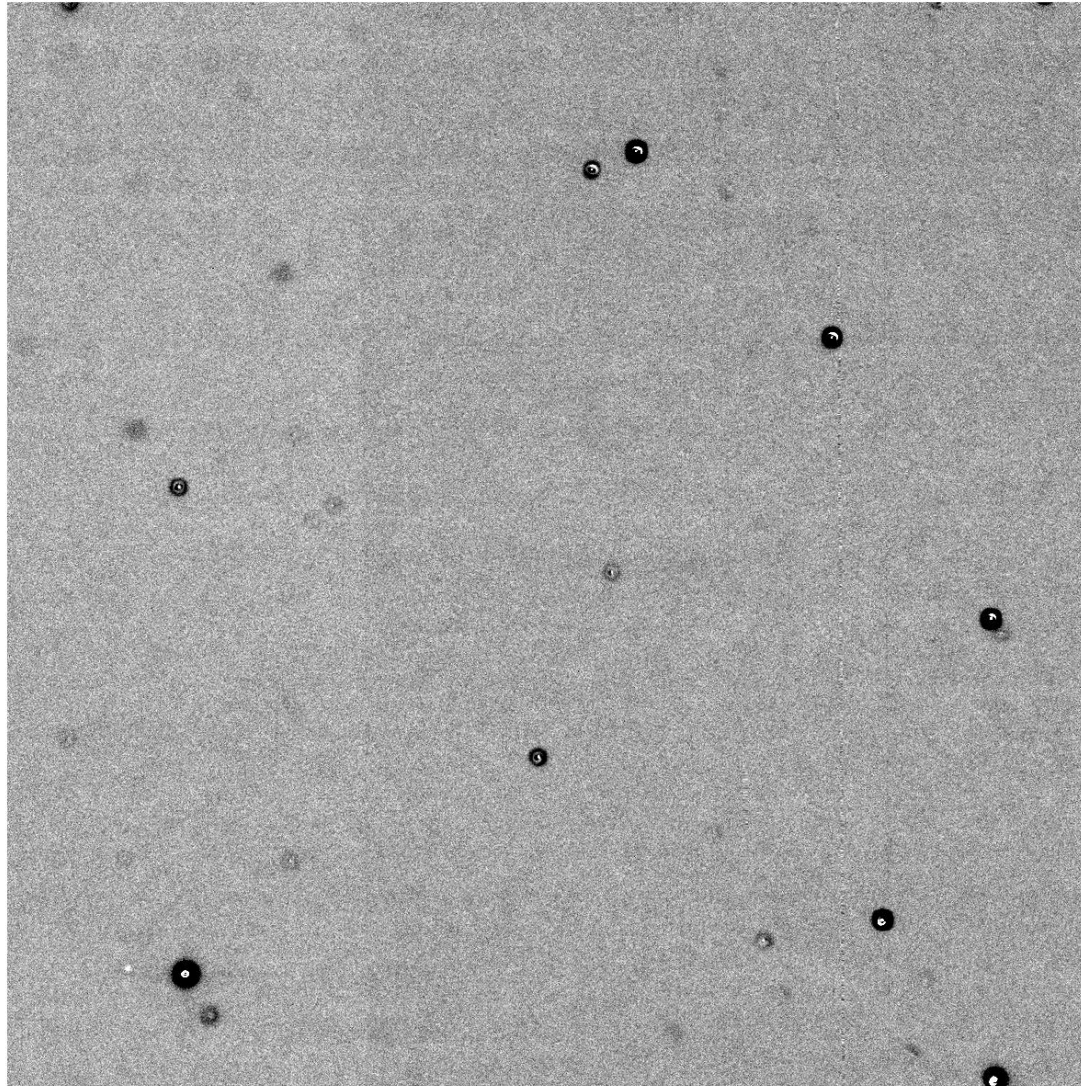
By Juan Pablo REYES GOMEZ

Supervisors: Dominique FOUCHÉZ and Marcela HERNÁNDEZ

LAST UPDATE (At Montpellier)

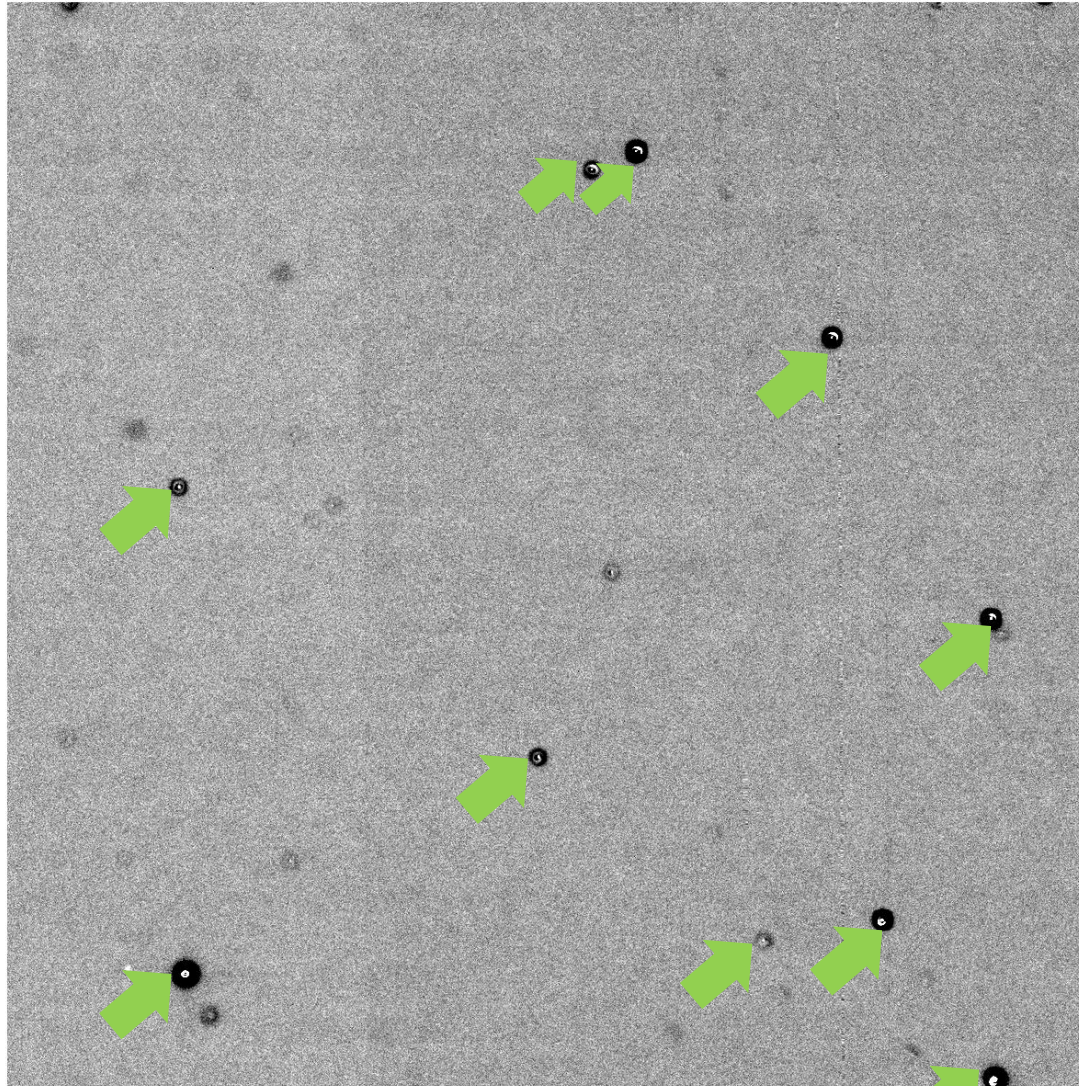
- ▶ Still plenty of artifacts on the subtracted images.
- ▶ The source of the problem was still not clear. Several hypothesis were regarded.
- ▶ A more thorough study was suggested, of course.

LAST UPDATE (At Montpellier)



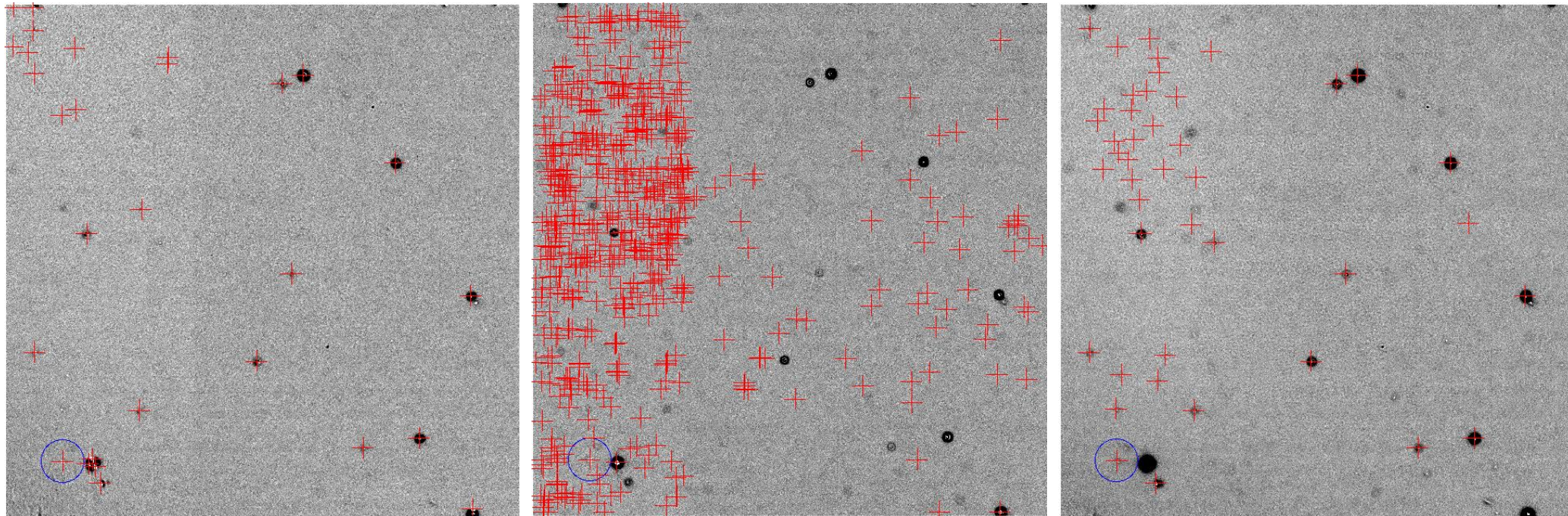
Subtraction with maximum intensity

LAST UPDATE (At Montpellier)



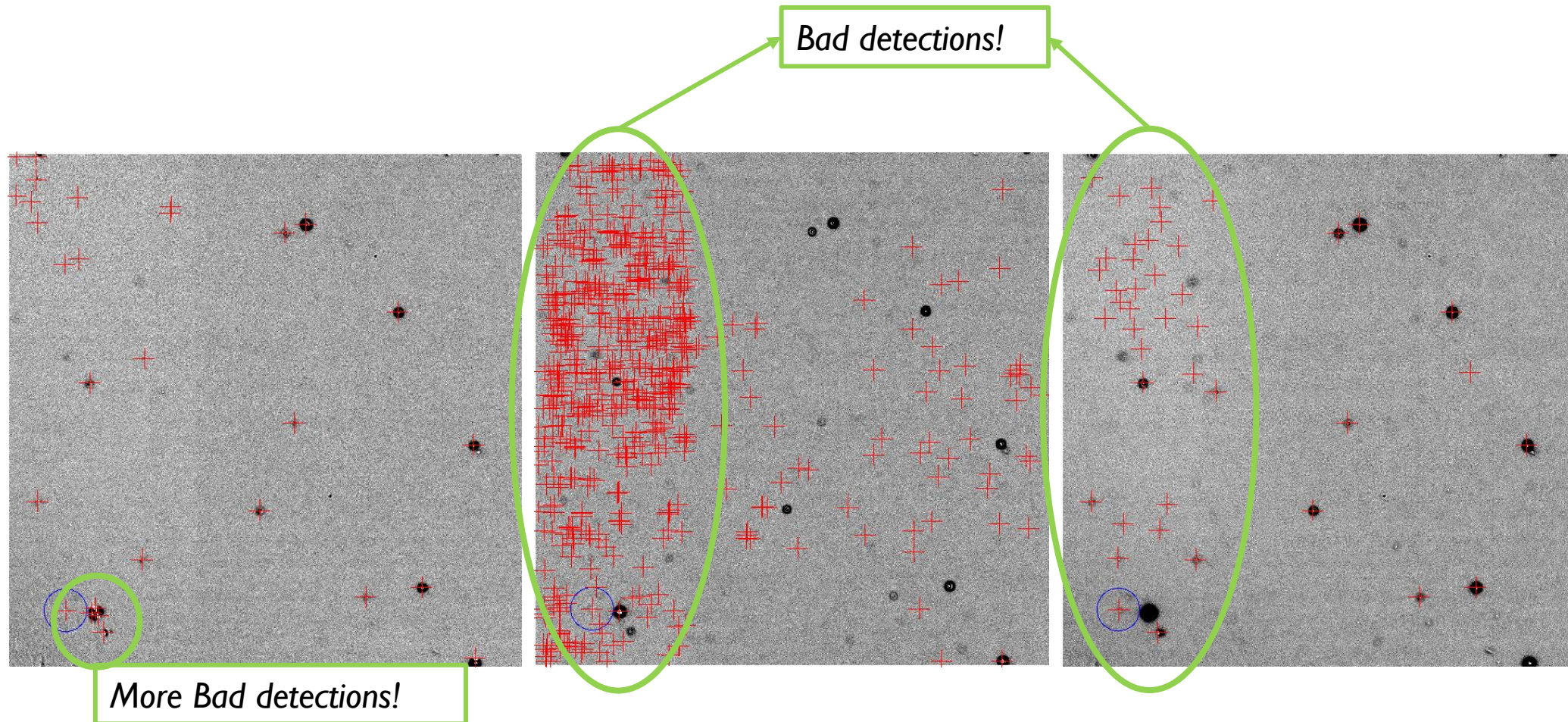
Subtraction with maximum intensity

LAST UPDATE (At Montpellier)



Subtractions from next days

LAST UPDATE (At Montpellier)



Subtractions from next days

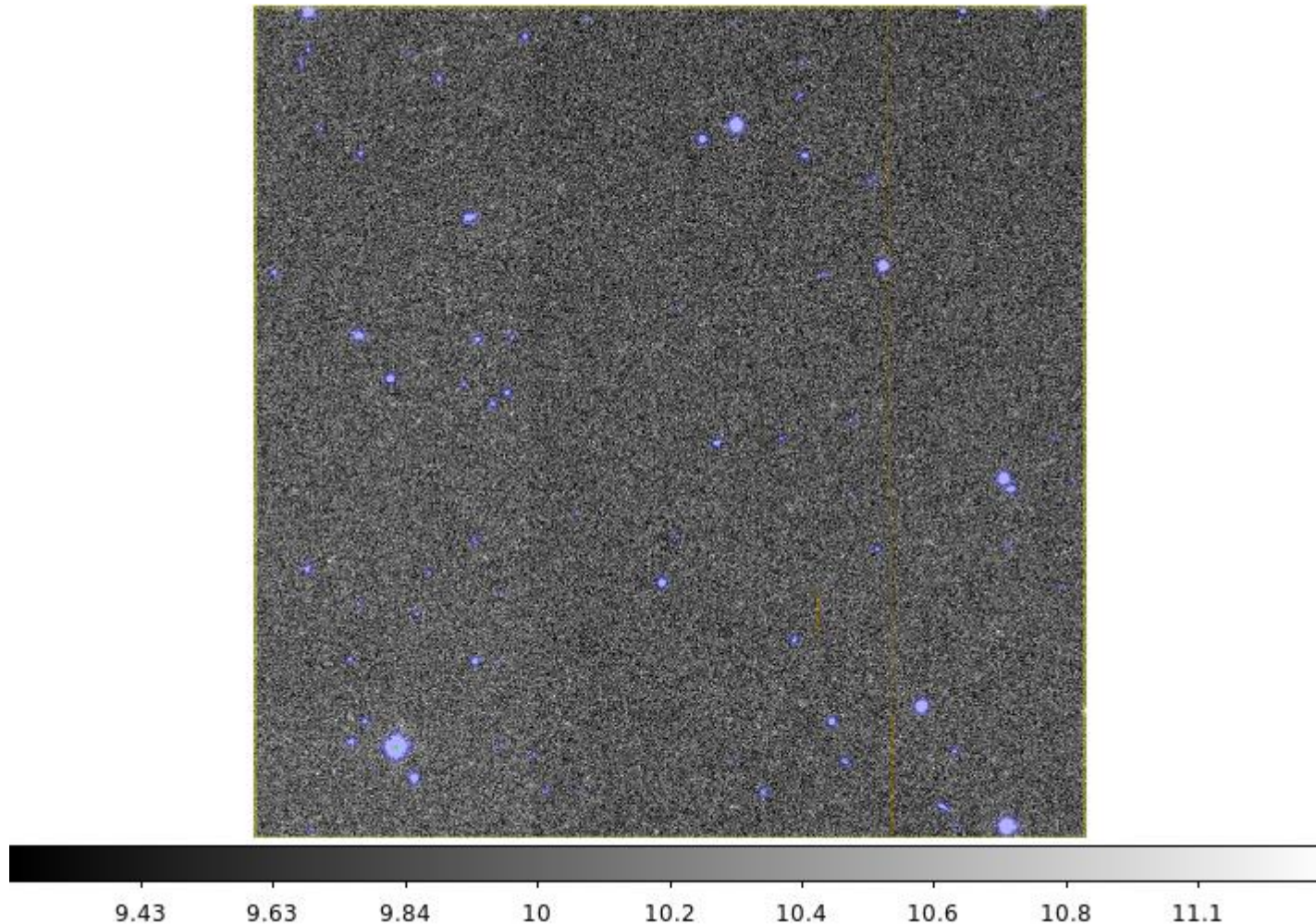
SO... WHAT'S NEW?

- Further detail onto the subtraction method has been obtained. In order to identify whether the problem lies on the PSF-matching or the Image warping, the pipeline has to be dissected.
- For the time being, data pinpoints to problems on both ends. Several question have still to be asked to the DM Team

PSF-Matching Pipeline

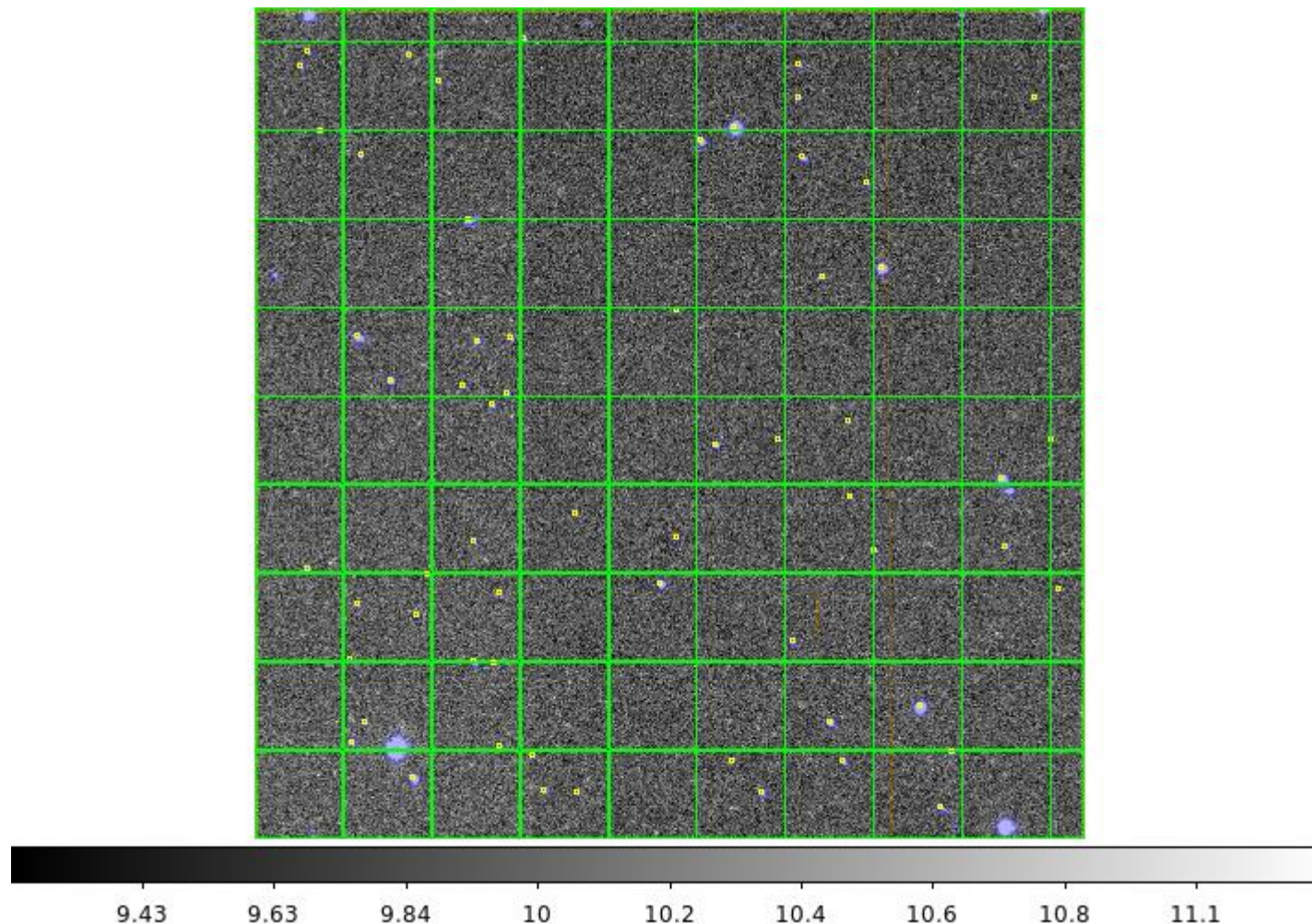
- All the different stages of the PSF-Matching have been studied. Intermediate products have been recovered.
- Last update notebook with all the intermediate images:
http://nbviewer.ipython.org/github/Daraexus/LSST_Notebooks/blob/master/Subtraction%20Pipeline%20Mail3-2015.ipynb
- Some points still remain unclear...

PSF-Matching Pipeline



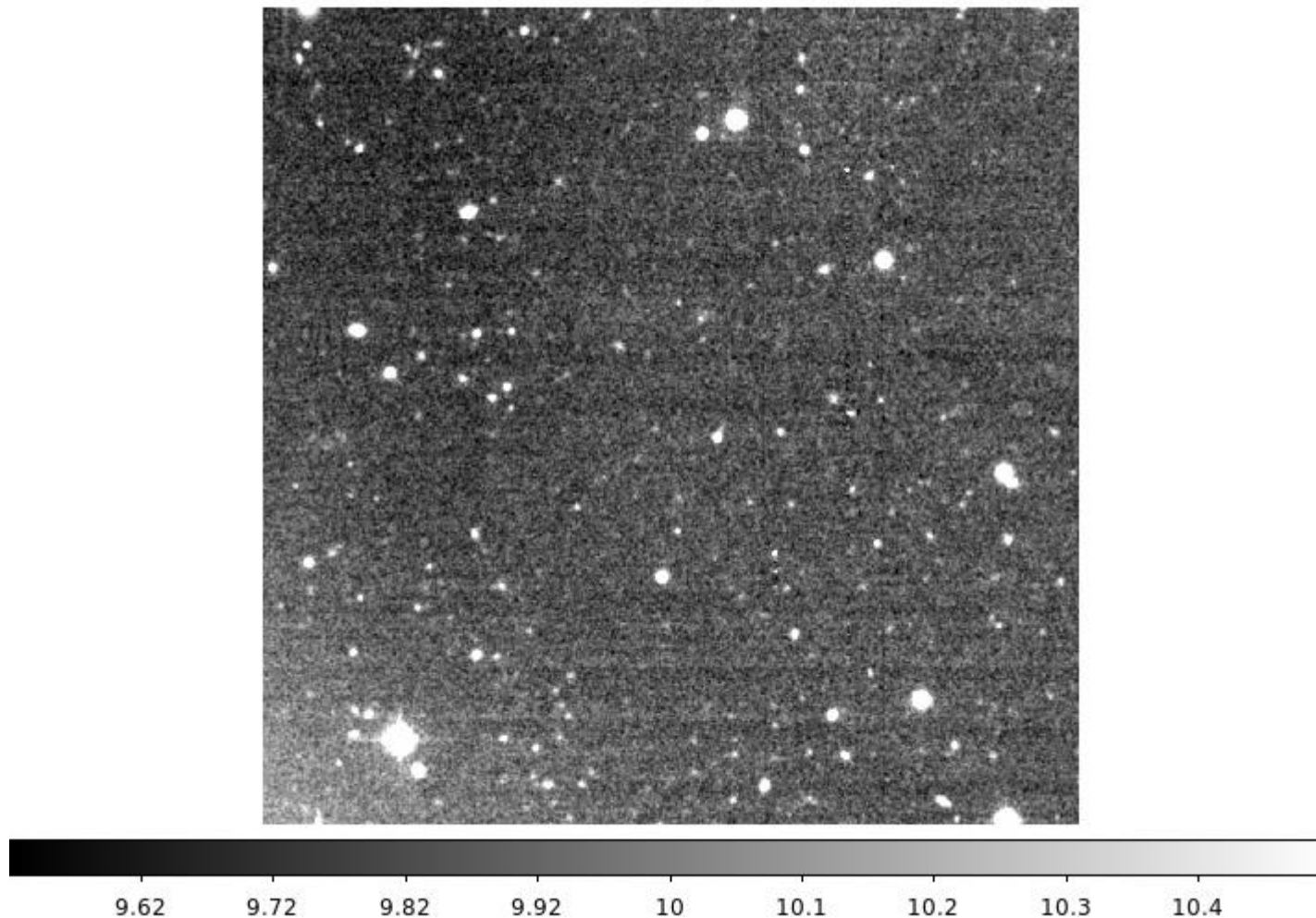
Masked Reference Exposure (Image to Convolve)

PSF-Matching Pipeline



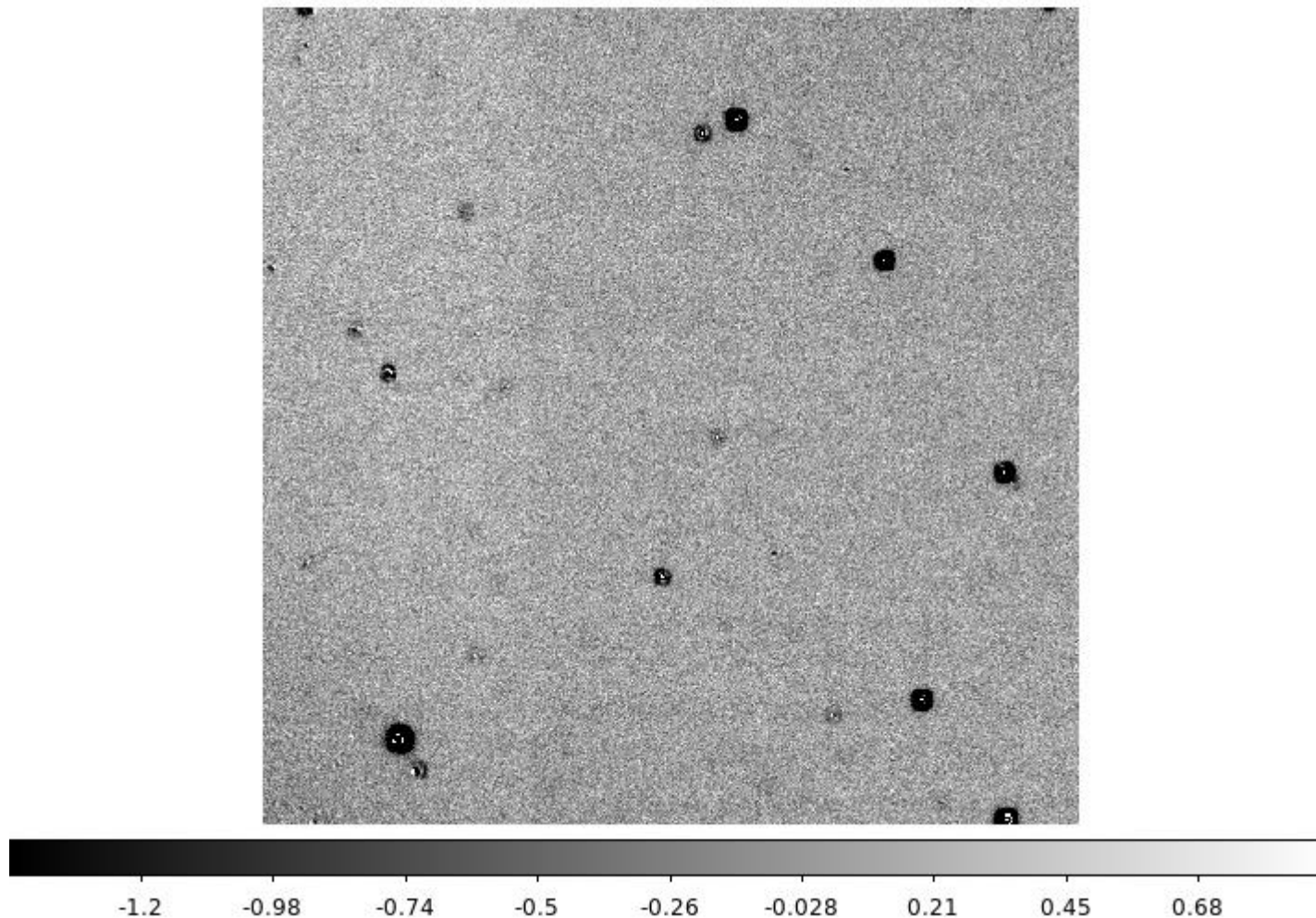
*Masked Reference Exposure with cell division for
PSF-matching kernel calculation*

PSF-Matching Pipeline



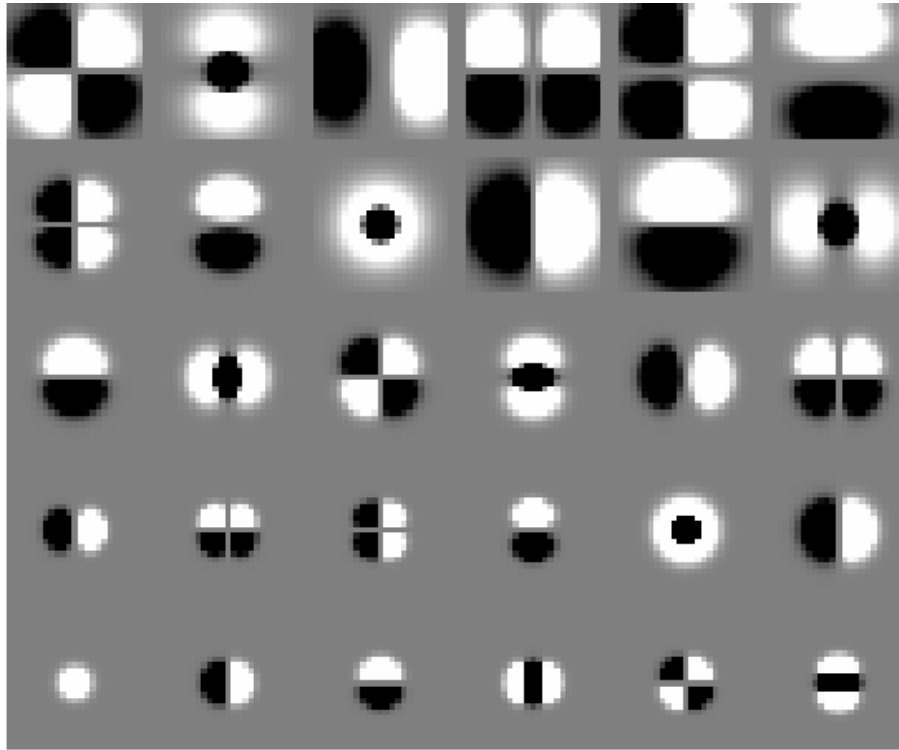
PSF-matched reference

PSF-Matching Pipeline



Final subtraction image

PSF-Matching Pipeline

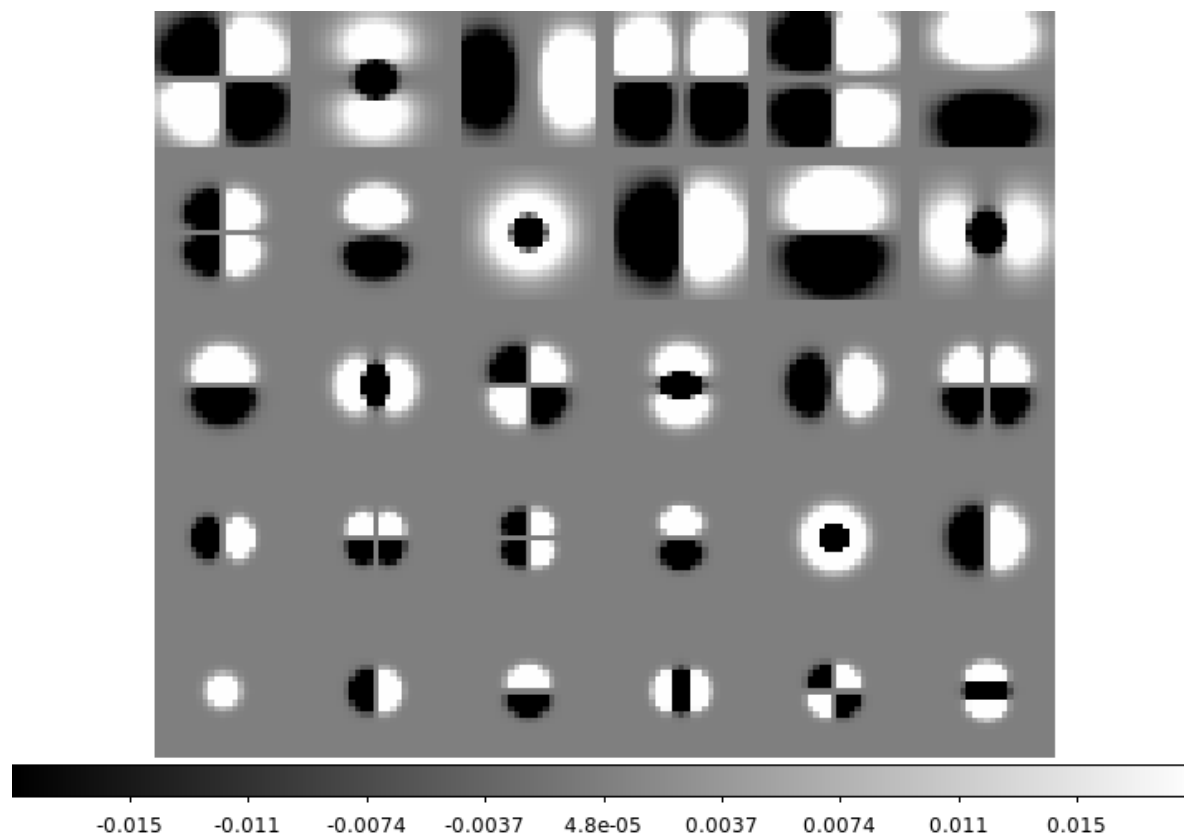


- Gaussian function basis used for the psf-matching.
- Each one represents an orthogonal sum of Gauss functions.
- nGauss is fixed at 3 by default.

$$K_i(u, v) = e^{-(u^2 + v^2)/2\sigma_n^2} u^p v^q$$

$$S(x, y) = (K \otimes R)(x, y)$$

PSF-Matching Pipeline



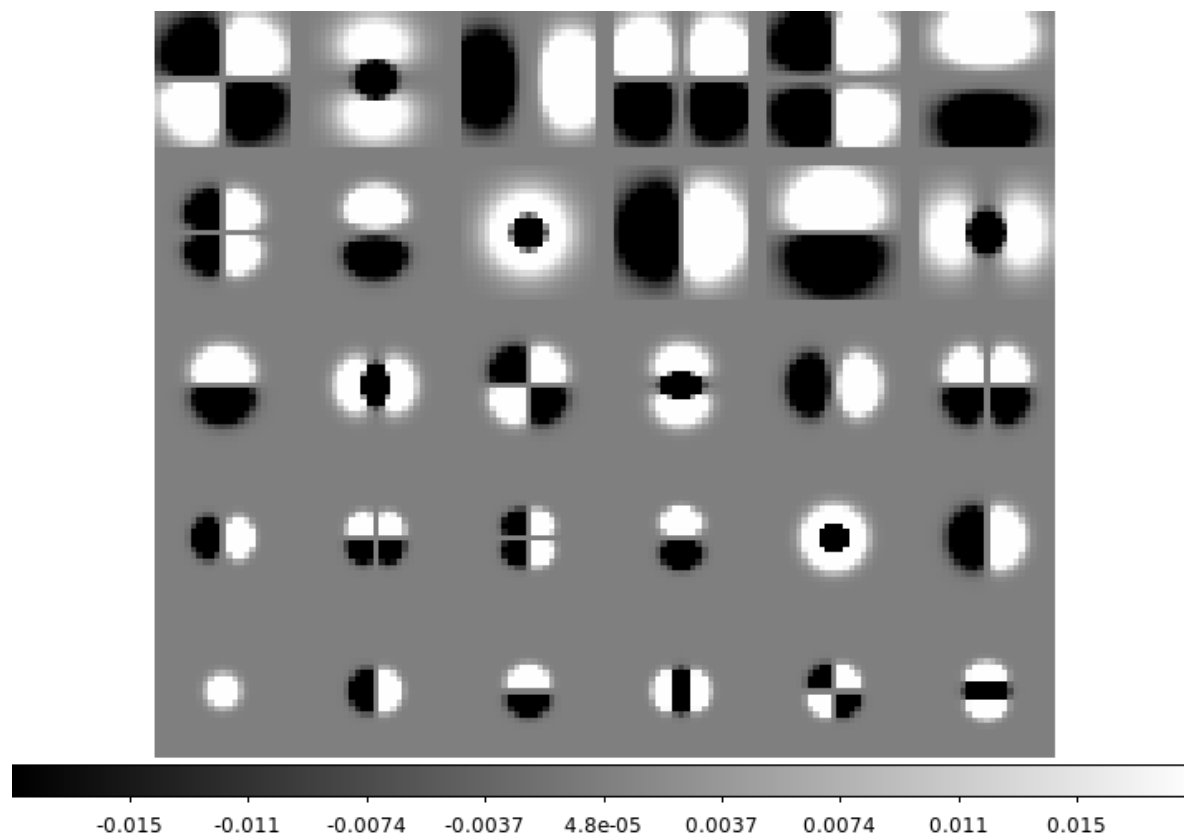
- Gaussian function basis used for the psf-matching.
- Each one represents an orthogonal sum of Gauss functions.
- nGauss is fixed at 3 by default.
- Central sigGauss is

$$\sqrt{\sigma_S^2 - \sigma_T^2}$$

$$K_i(u, v) = e^{-(u^2 + v^2)/2\sigma_n^2} u^p v^q$$

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PSF-Matching Pipeline



$$K_i(u, v) = e^{-(u^2 + v^2)/2\sigma_n^2} u^p v^q$$

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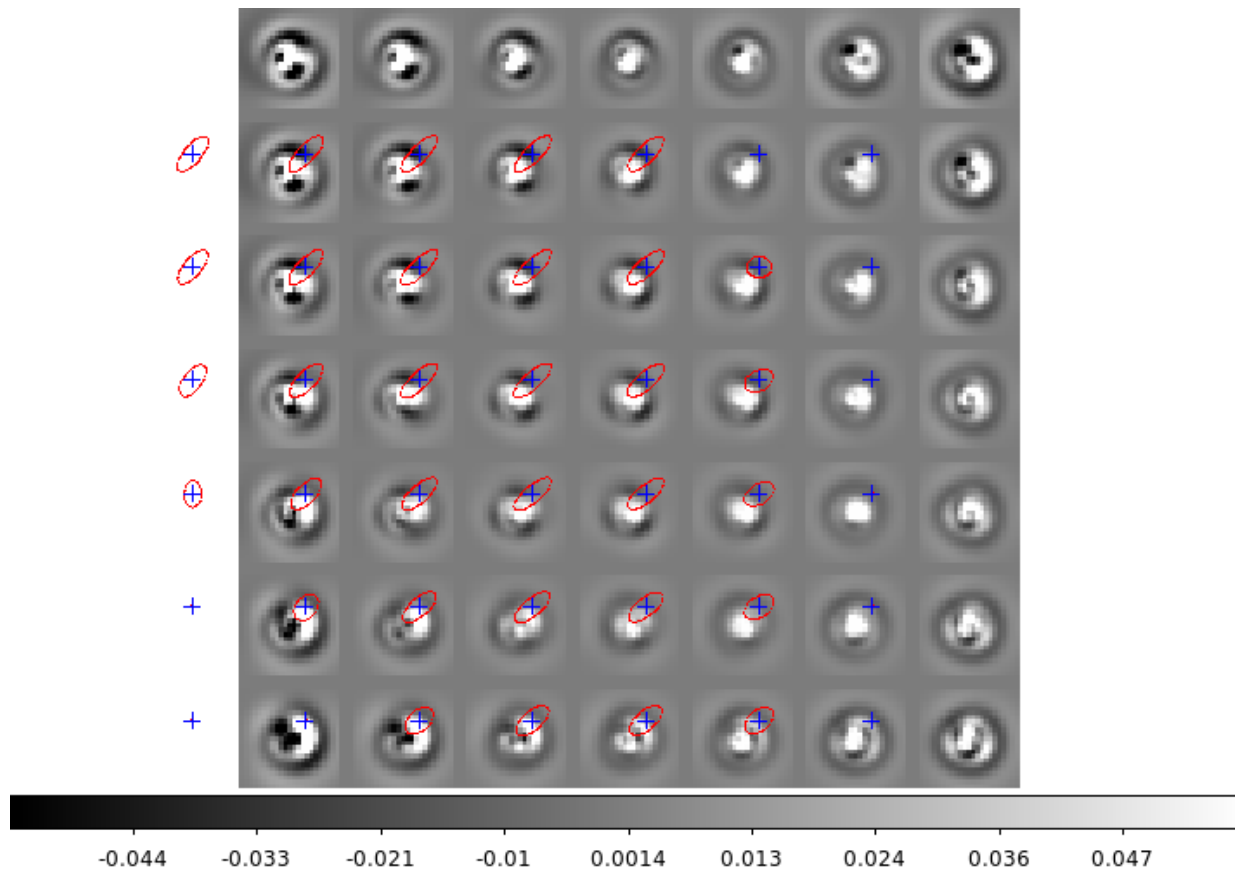
- Gaussian function basis used for the psf-matching.
- Each one represents an orthogonal sum of Gauss functions.
- nGauss is fixed at 3 by default.
- Central sigGauss is

$$\sqrt{\sigma_S^2 - \sigma_T^2}$$

- The other sigGauss are determined with

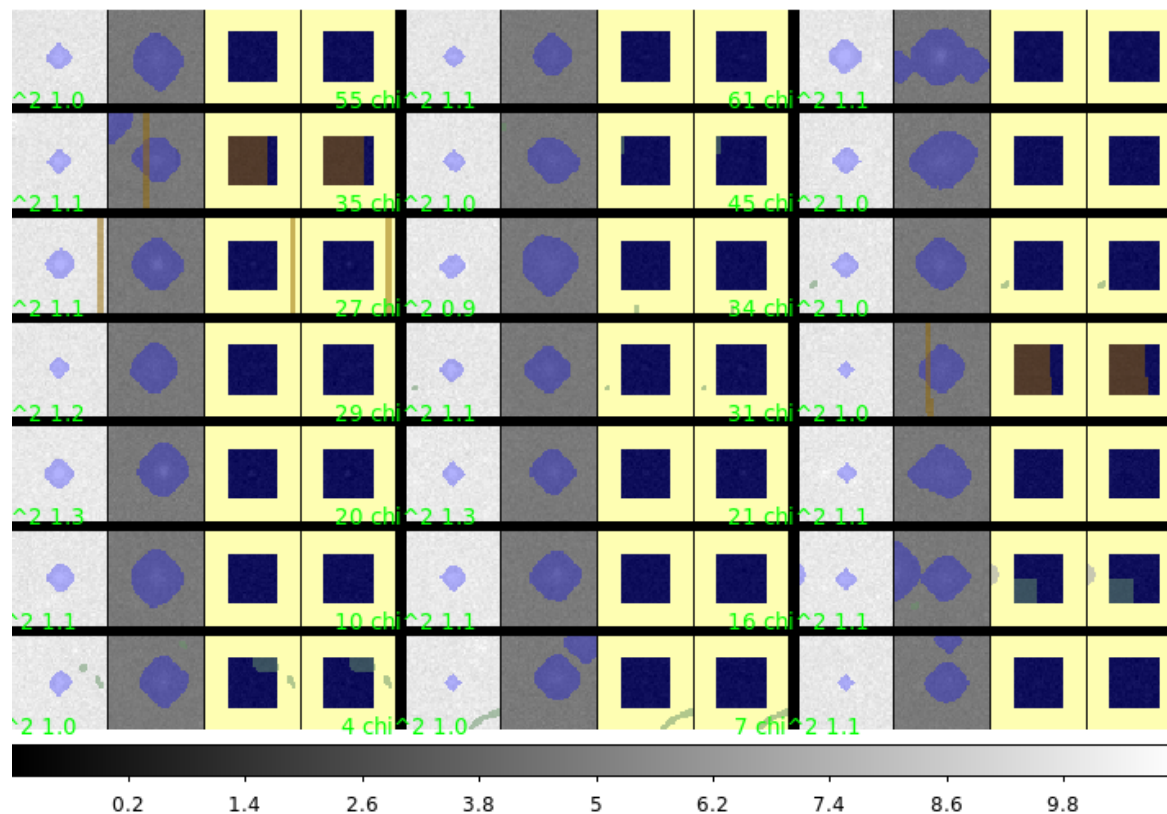
$$\sigma_{i+1} = \beta \times \sigma_i$$

PSF-Matching Pipeline



- PSF-matching cell-adapted kernel to convolve the reference exposure.

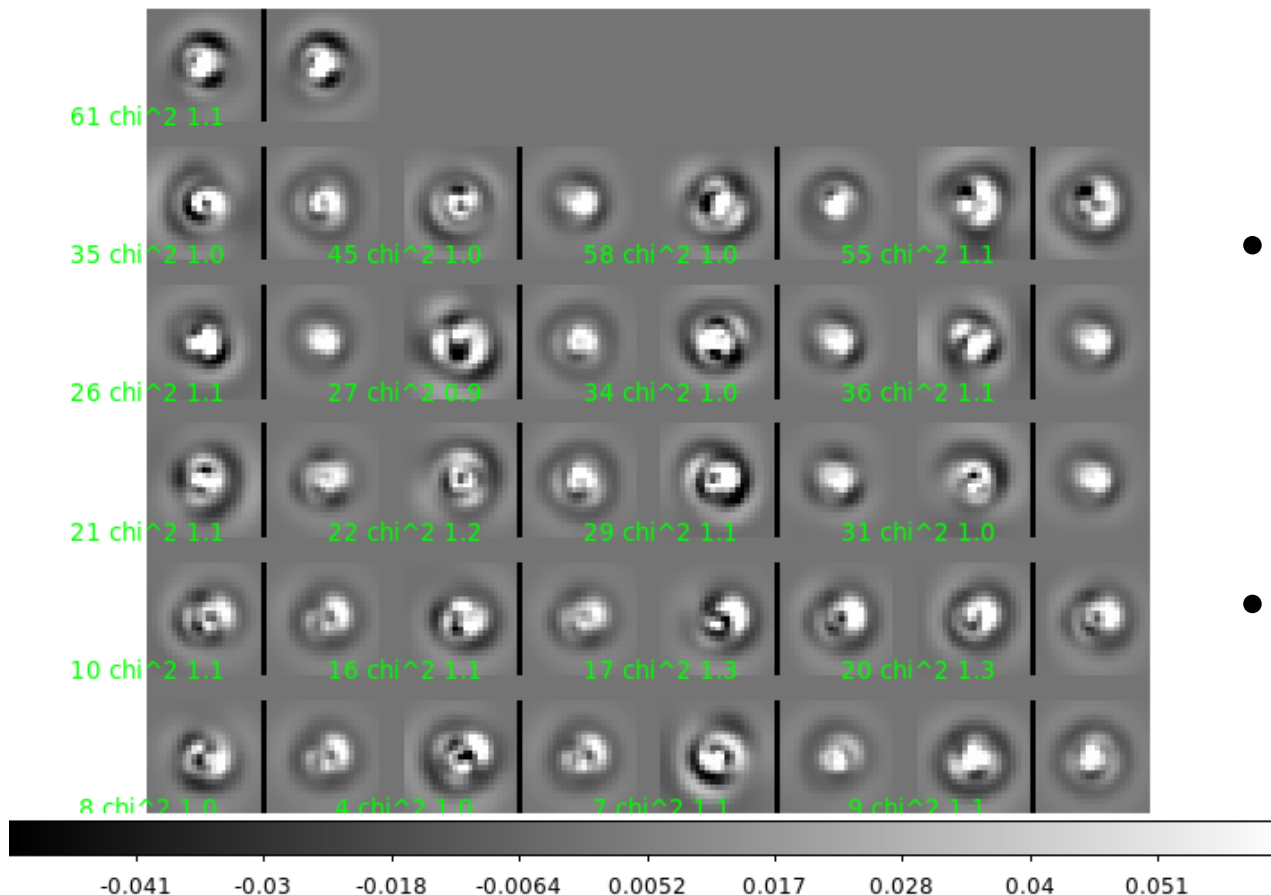
PSF-Matching Pipeline



- PSF-matching masked kernel candidates with residuals

Selection of candidates

PSF-Matching Pipeline

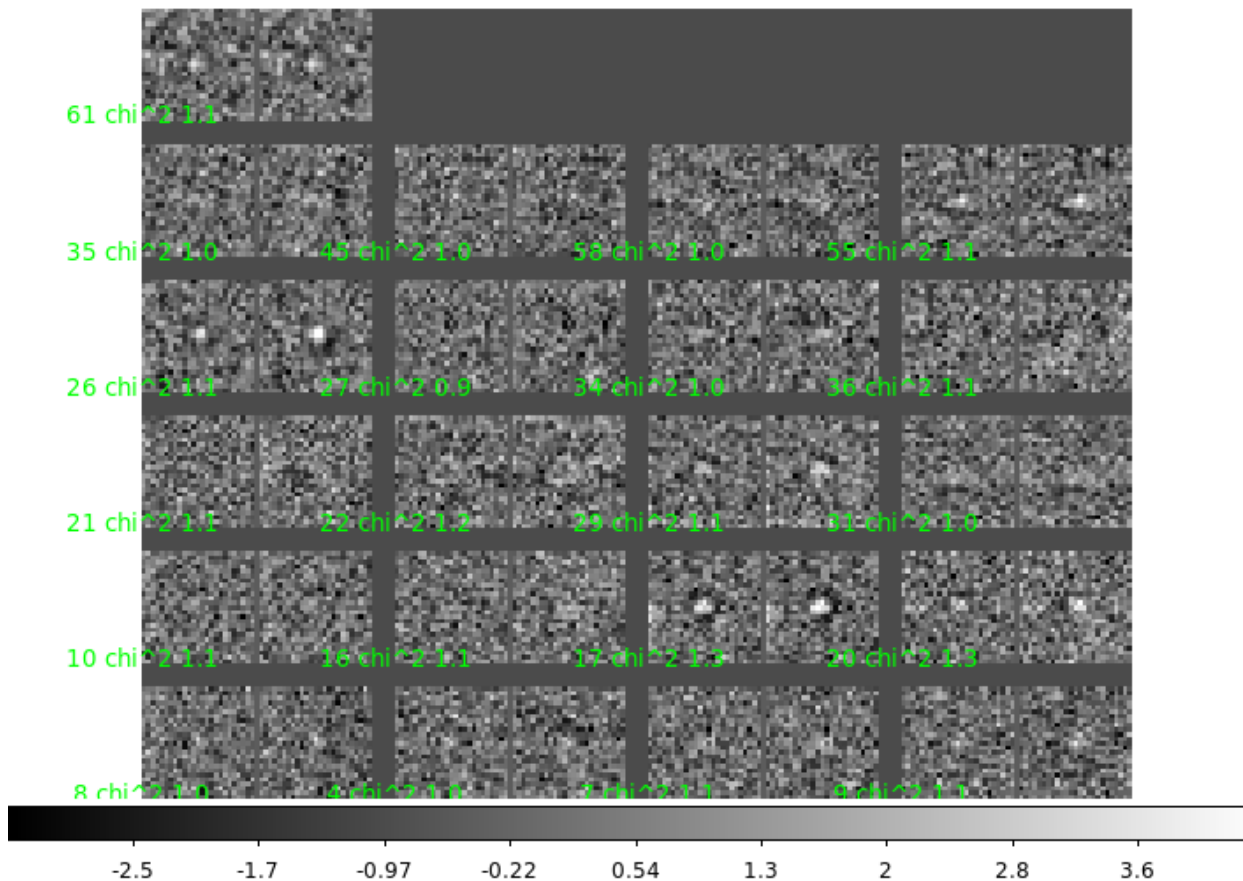


- Kernel matrix of PSF-matching candidates with χ^2 data.
- Other statistics have yet to be evaluated.

Visualization of cell-adapted candidate kernels

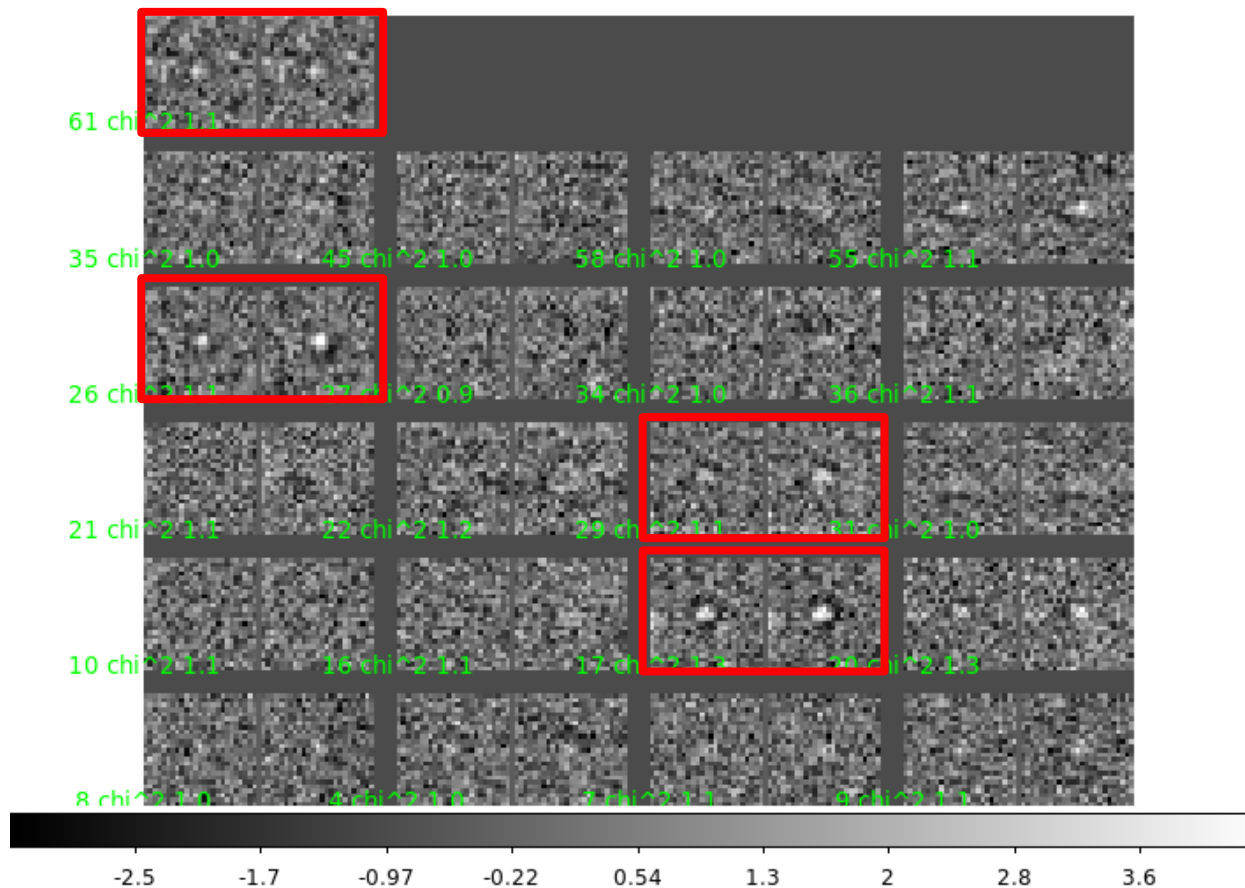
PSF-Matching Pipeline

- Residuals of PSF-matching kernel candidates.



Residual of local kernel convolutions

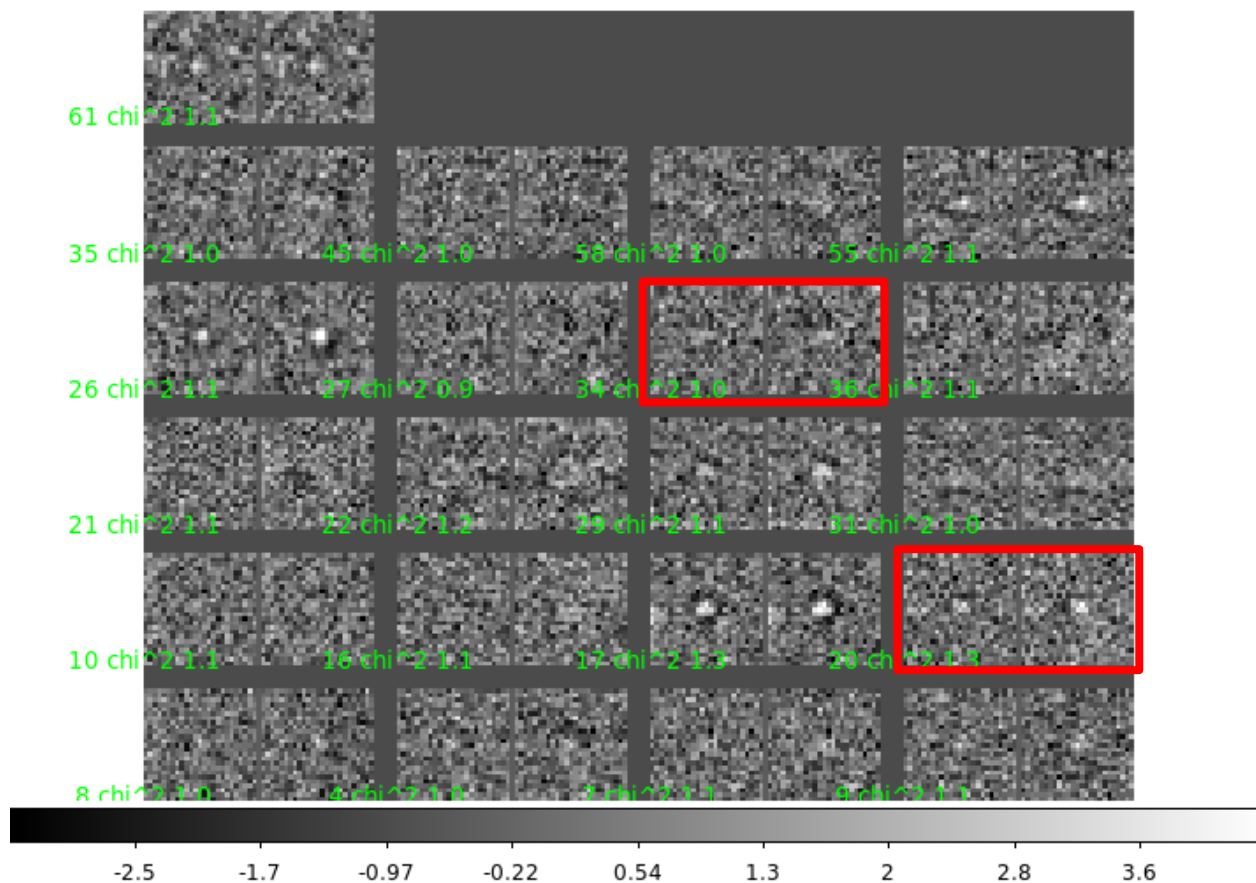
PSF-Matching Pipeline



Residual of local kernel convolutions

- Residuals of PSF-matching kernel candidates.
- Some residuals show that Gaussian sigma generates basis too big to match the PSF.

PSF-Matching Pipeline



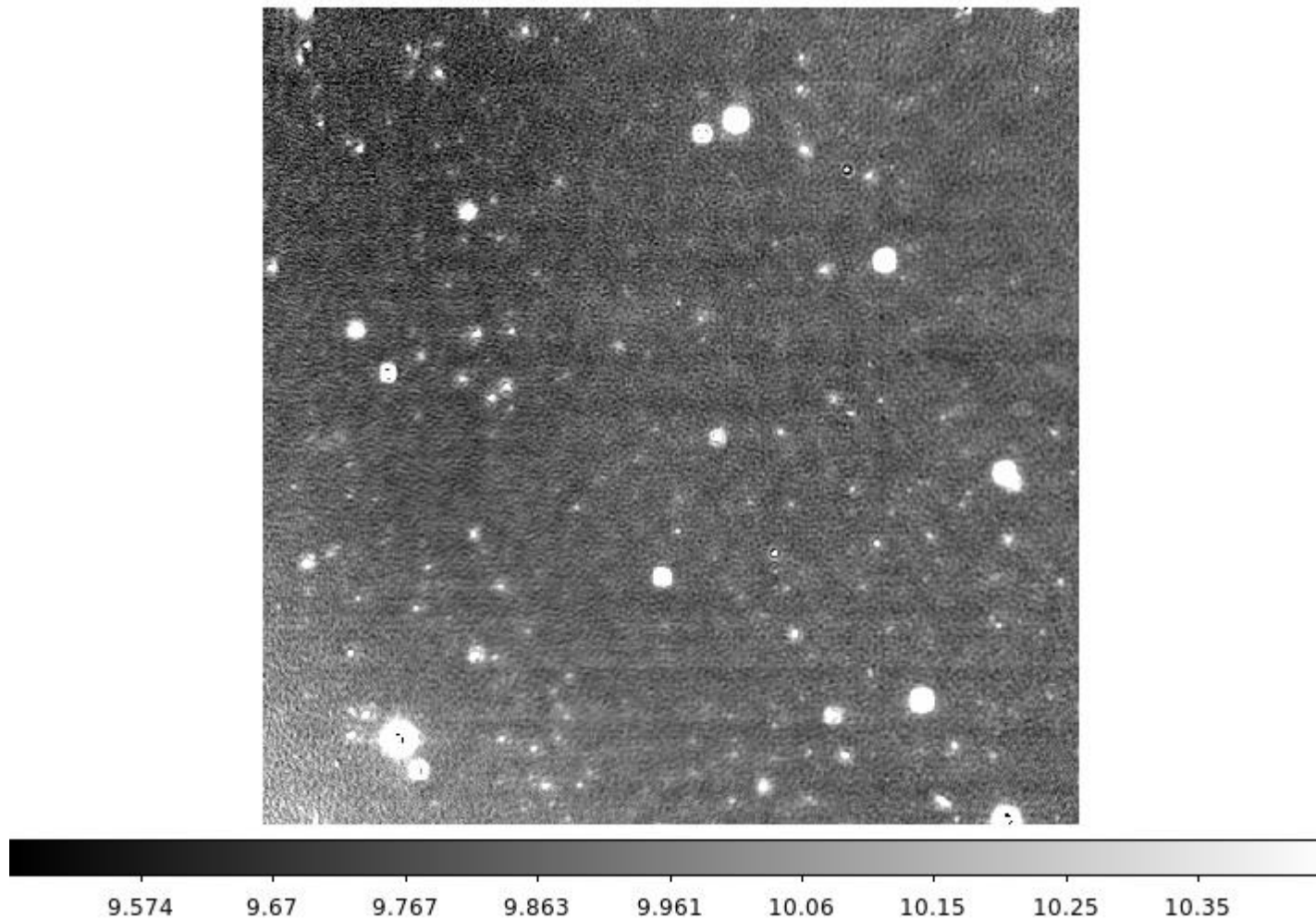
Residual of local kernel convolutions

- Residuals of PSF-matching kernel candidates.
- Some residuals show that Gaussian sigma generates basis too big to match the PSF.
- Apparently there are some “faint” dipoles as well.

PSF-Matching Pipeline

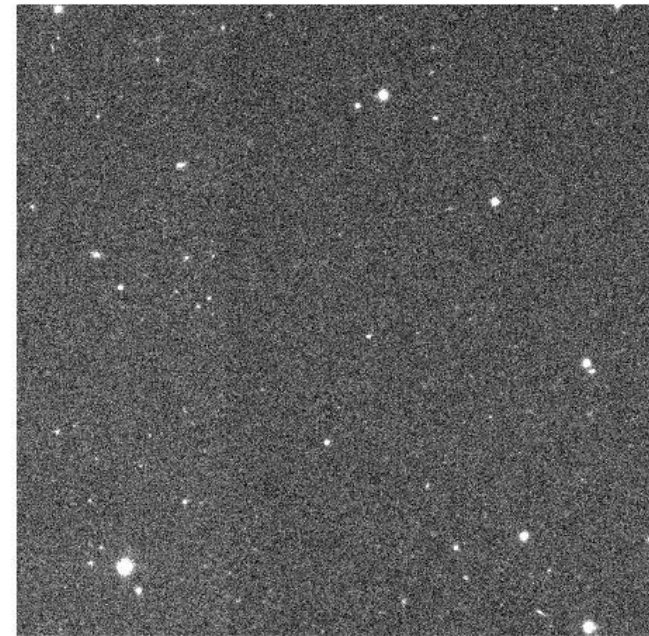
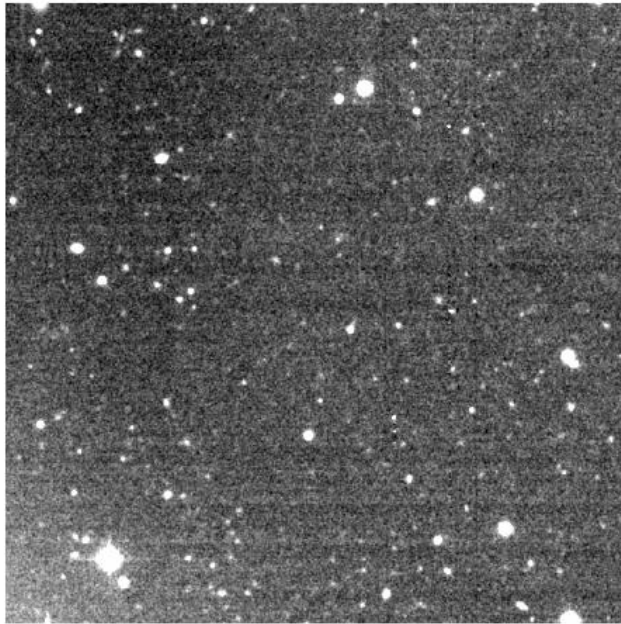
- In order to improve the understanding of the PSF-matching function, we decide to limit the number of Gaussian functions for the algorithm to one.
- Then, we measured the impact on the PSF of a single star, in order to understand how the basis choice is affecting the sources.
- Gray levels on ds9 are affecting the perception of the subtraction quality
- Pre/Post-filtering is not being taken into account.

PSF-Matching Pipeline



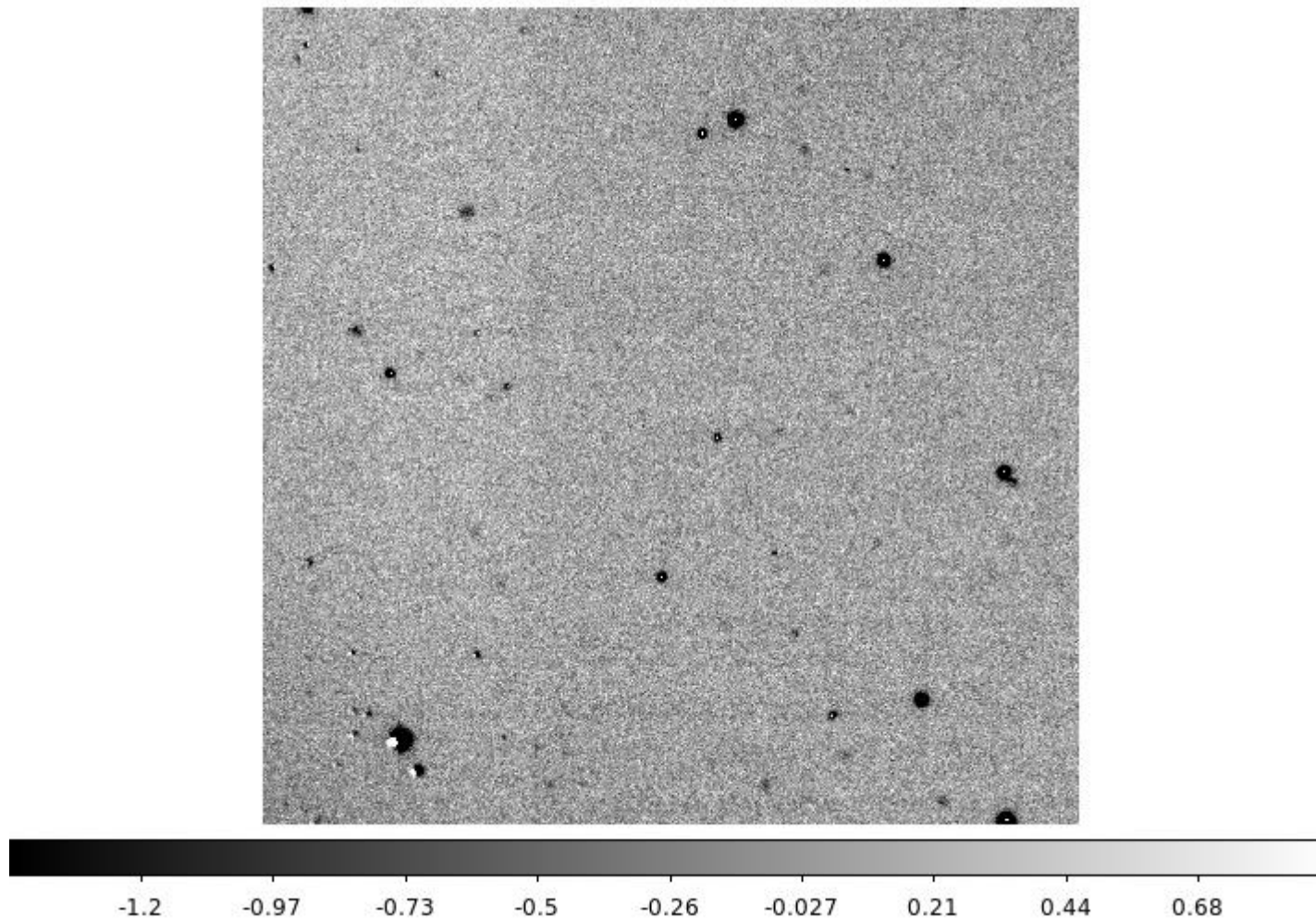
*PSF-matched reference exposure with a **single Gaussian function** as base*

PSF-Matching Pipeline



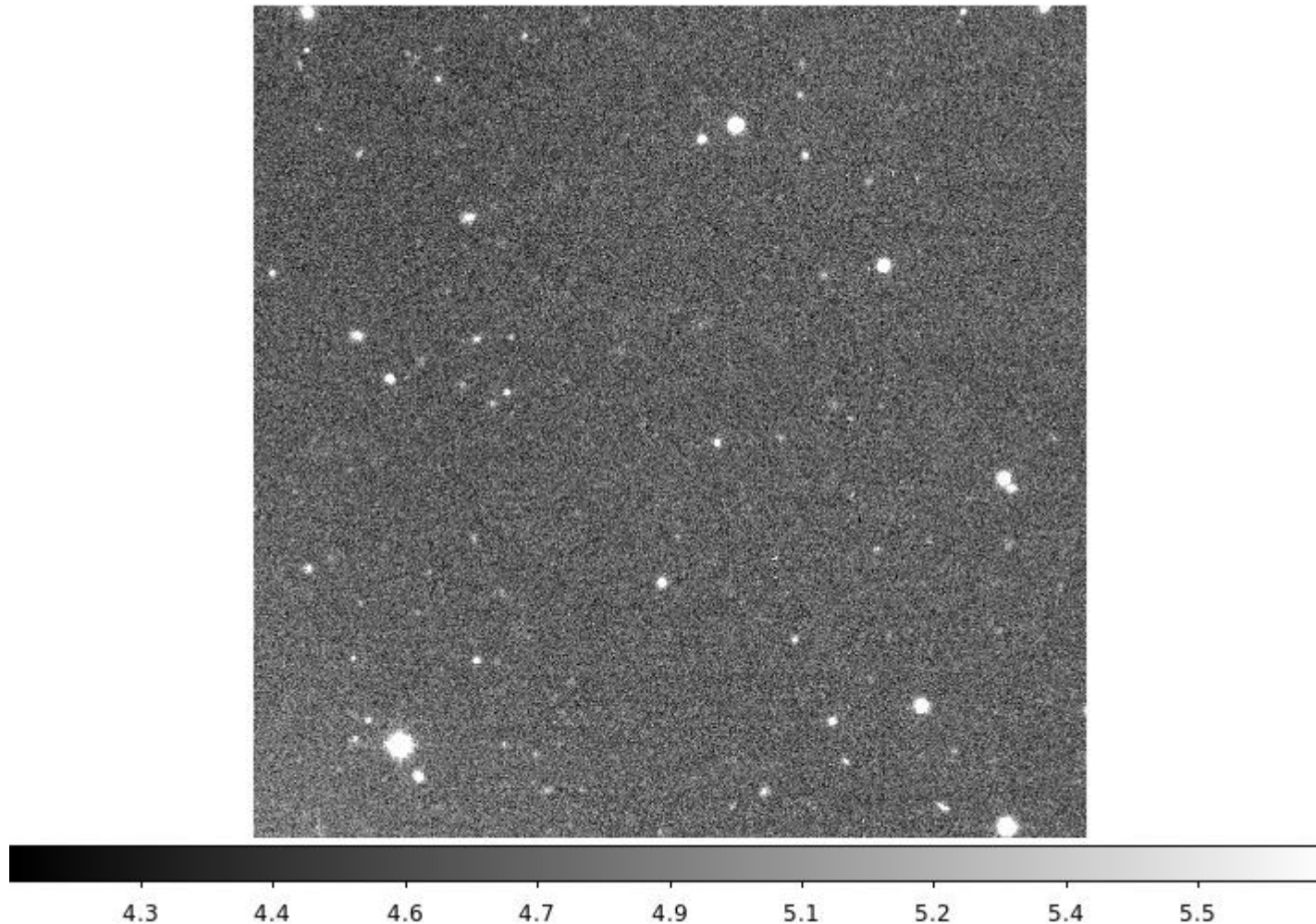
- PSF-matched exposure vs Science exposure for the subtraction. Gray levels does not correspond to the same scale for both images.

PSF-Matching Pipeline



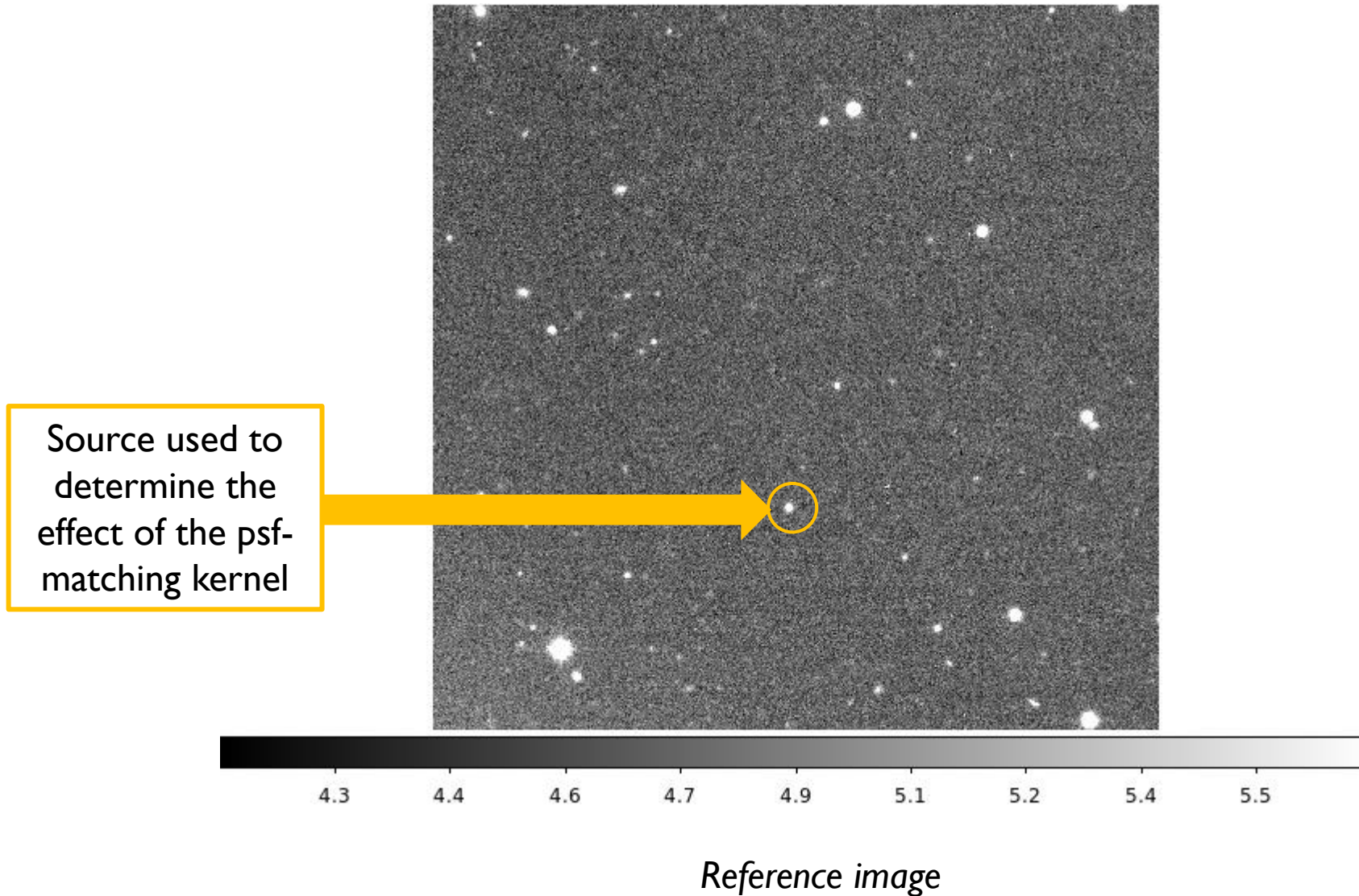
Subtracted image from PSF-matched image. Some misalignment problems seem to be present

PSF-Matching Pipeline



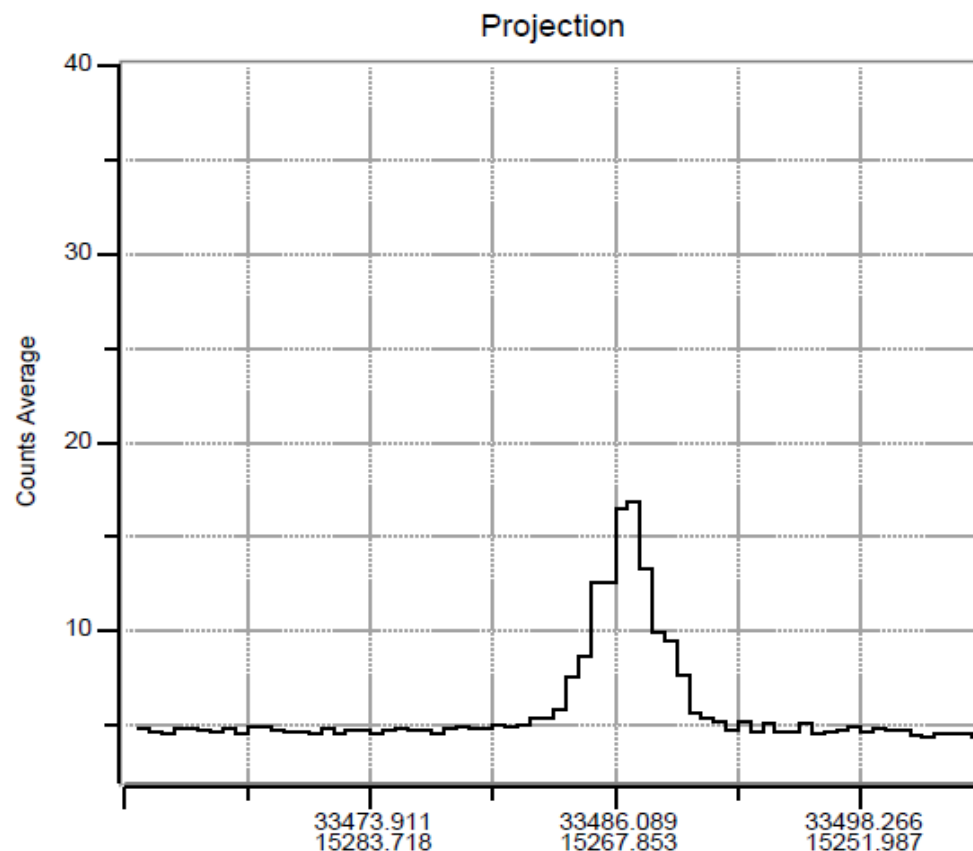
Reference image

PSF-Matching Pipeline



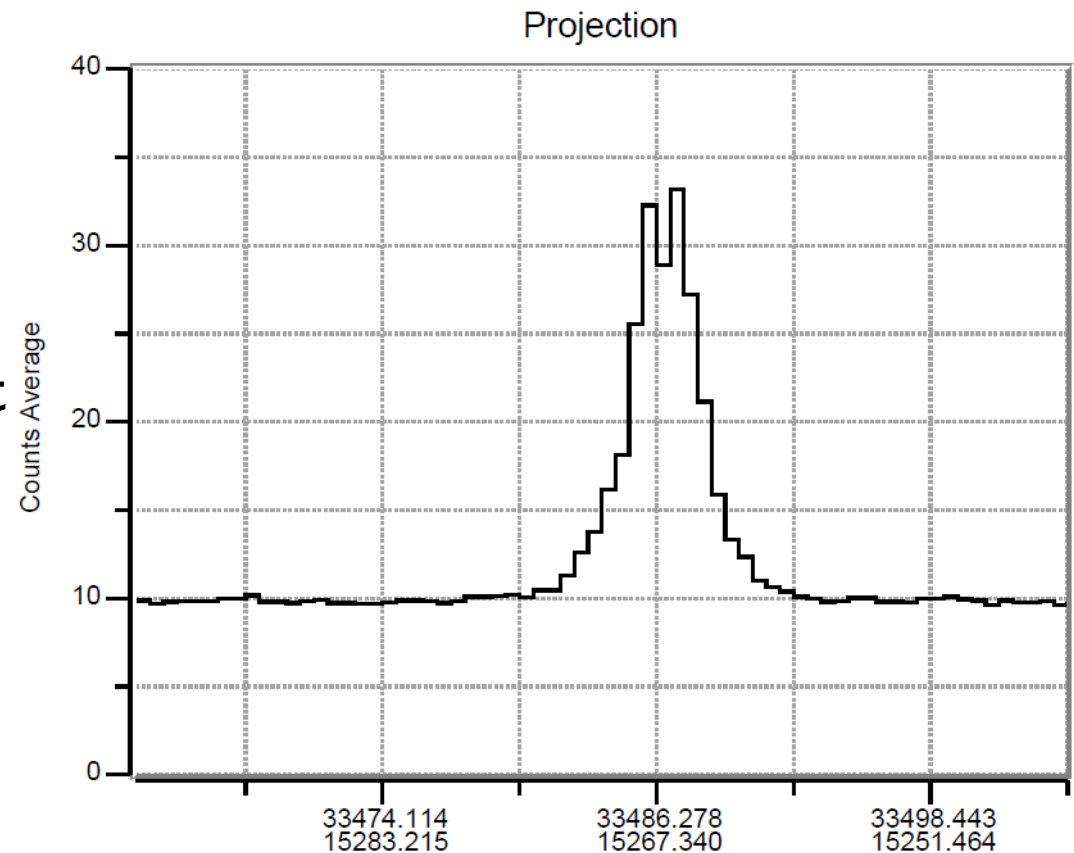
PSF-Matching Pipeline

- Using a reference source within the patch, we projected the changes on the psf due the application of the psf-matching kernel using a single Gaussian function as base.
- This corresponds to the original reference image.



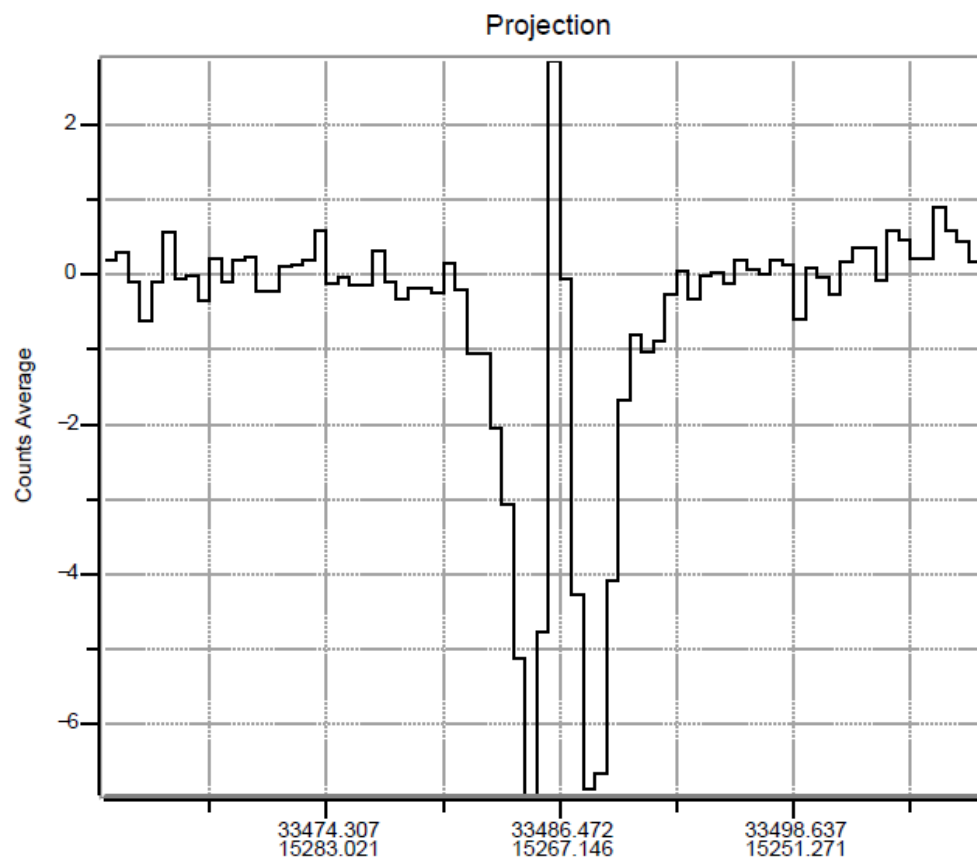
PSF-Matching Pipeline

- After applying the psf-matching kernel convolution, the resultant psf is increased in size (and is a little wider as well)



PSF-Matching Pipeline

- Subtracted image shows that most of the “black” depicted on images are the valleys around the subtraction, which are not as deeper as first imagined.

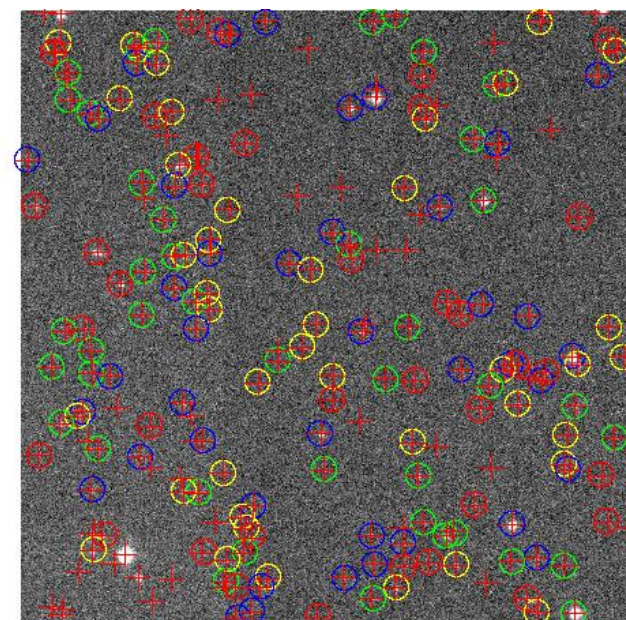
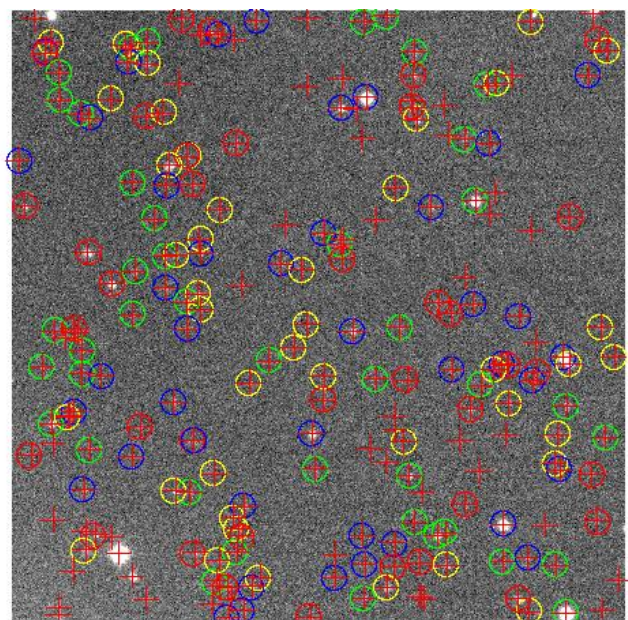


Warping Image Method

- Using the Image Registration tools within Stack, the quality of the alignment of images have been reviewed. For the time being, it seems that between two given patches to subtract, there is a slightly problem of position.
- Correction methods are being tested, in order to reduce error propagation when PSF-matching.

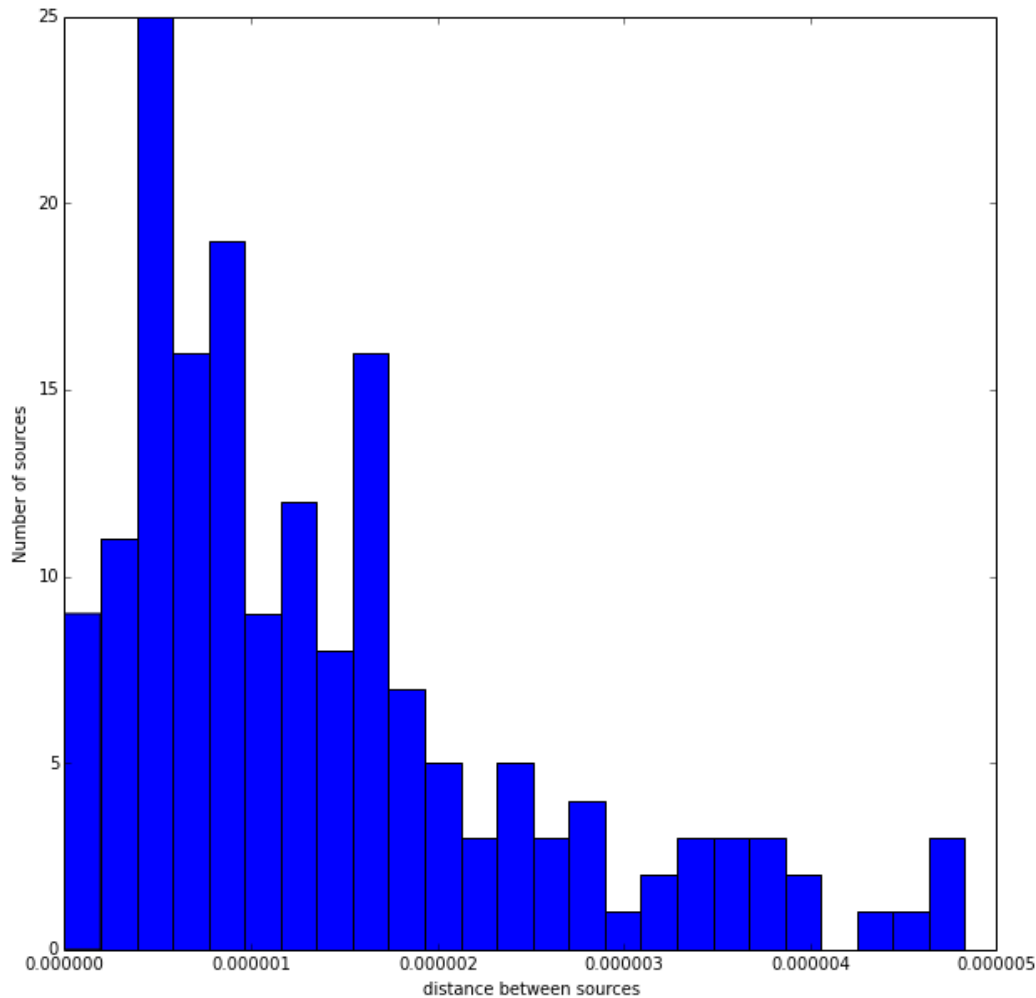
Warping Image Method

Sources were matching between the images without an external reference catalog



Source matching between both images, before attempting to correct the alignment

Warping Image Method



- Obtained distances between sources centroid on compared images.
- Despite the smallest values, Image Registration tasks finds that alignment correction is necessary.

CONCLUSIONS

- We have a more in-depth knowledge of the subtraction pipeline. We're moving forward to detect the problematic points for the algorithm.
- Image Warping does not quite work with patches: The stored WCS on patches belongs to the tract, image registering is still problematic at patch-image level (Late Winter 2013 report)
- Empiric choice of degGauss and sigGauss seems to be problematic for non-ideal non-simulated images.

CHALLENGES

- Tests over simplified simulation images with no saturation, cosmic rays or defects which influence has still not been taken into account on the current Stack version.
- Generate the kernel candidates statistics on our CFHT images (and on our patches if possible) based on the metrics defined by the Later Winter2014 report.
- Determine if the choice of PST-matching Gaussian functions fit our current set of images.