Cosmological Constrains and sensor effects
- Spurious Shear from Tree Ring on LSST CCDs -

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Precision Astronomy with Fully Depleted CCDs
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We measured tree ring effect on two types of LSST CCDs(Type 1 and 2)
using average of 25 flat images for each.
The two type CCDs come from the two different vendors.

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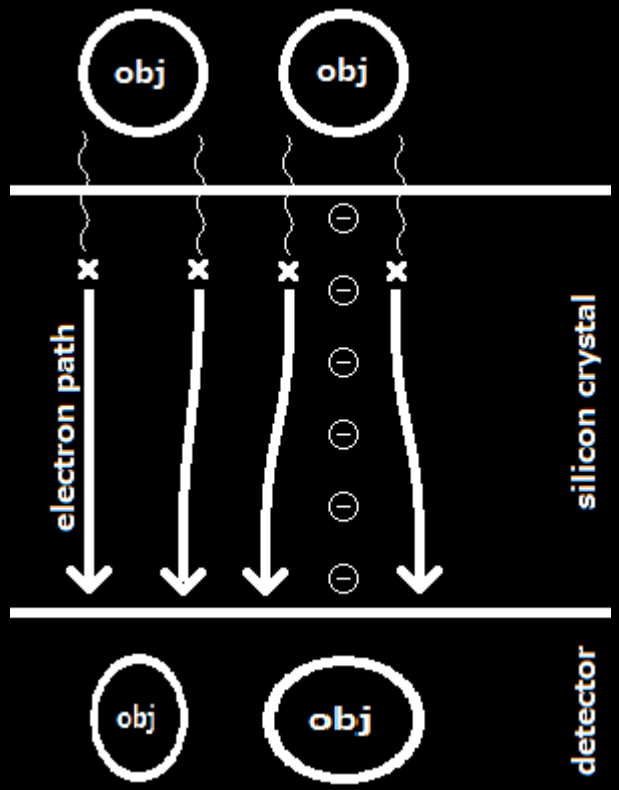
Subjects of this talk:
How we calculate spurious shear from tree ring effect.
Spurious shear and its 2-point correlation function for DES CCDs,
How we measured tree ring effect on LSST CCD (Type 1 shown in detail)
Spurious shear and its 2-point correlation function for Type 1 and 2 LSST CCDs.

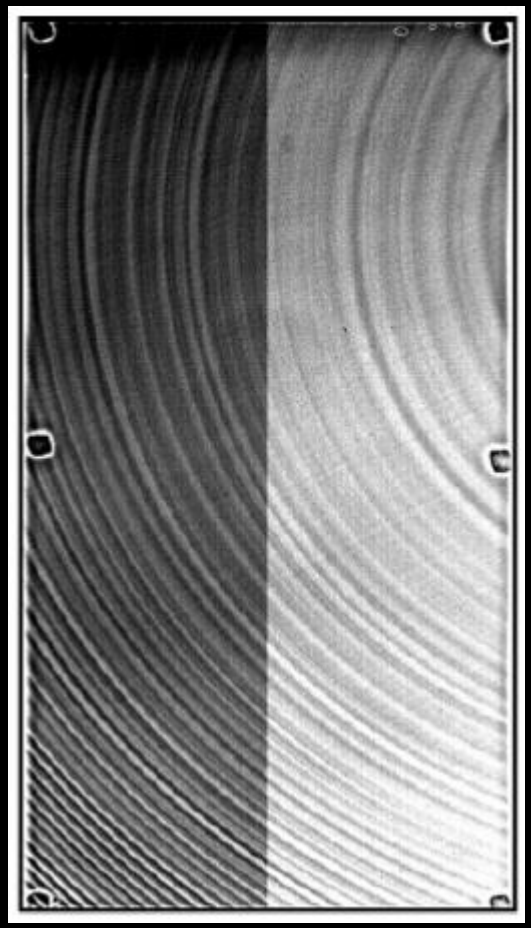
Flux Modulation by Tree Ring Effect

Impurity in the silicon layer makes additional electric field and it bends the electron path, and it makes dark and bright region in flat image and displaces and distorts object image.

The typical scale of the flux modulation is about 0.5% on DES CCD.



Bending electron path

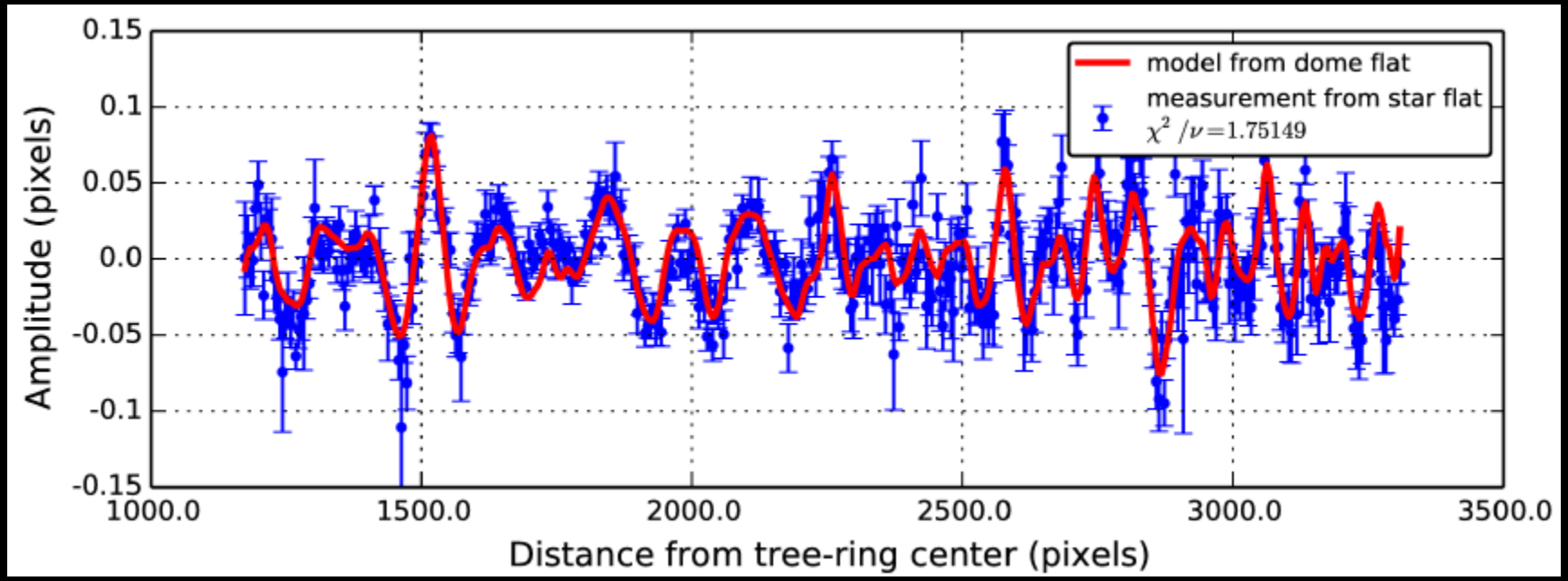


Dome flat image of DES CCD
(Andres Plazas et al., 2014)

Displacement by Tree Ring Effect

– Typical scale of the displacements is 0.1 pixel, so it is hard to measure the displacement from astrometry, but it is easy to measure the flux modulation of dome flat. Plazas made a formula which estimates the displacement from the flux modulation. – –

$$d(r) = -\frac{1}{r}\int_0^r dr' r' f(r')$$



The measured displacement and predicted displacement from flat image
(Andres Plazas et al., 2014)

Spurious Shear by Tree Ring Effect

Tree ring effect makes distortion, so it makes systematic error in weak lensing shear analysis(Spurious shear).
So we need to consider how the tree ring makes error in shear measurement.

We can calculate distortion from displacement easily,
if displacement is concentric.

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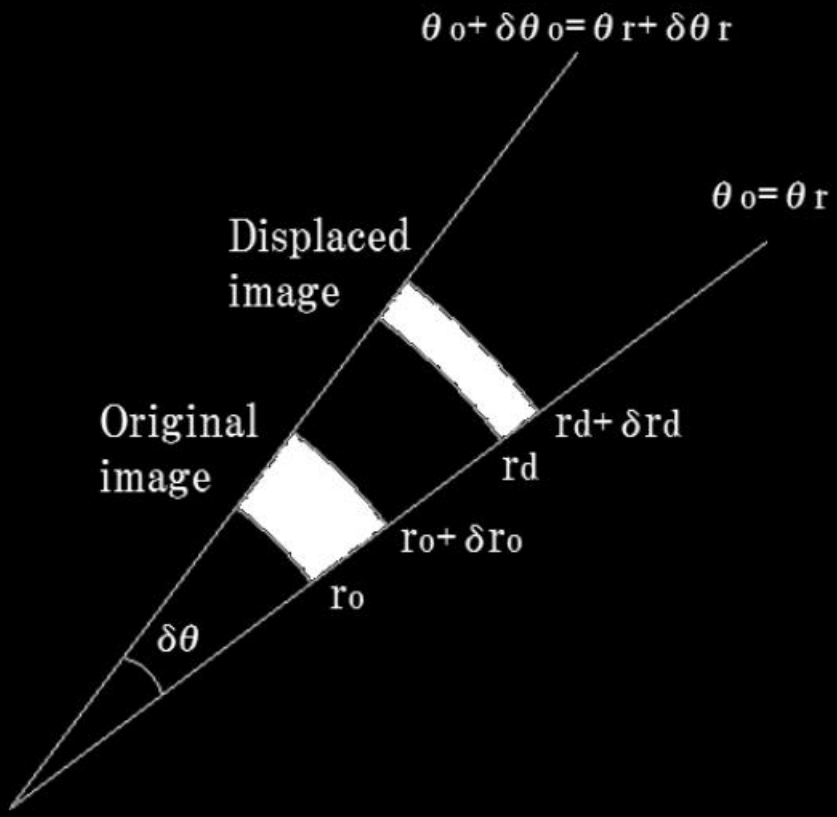
Spurious shear from tree ring is almost half of flux modulation.



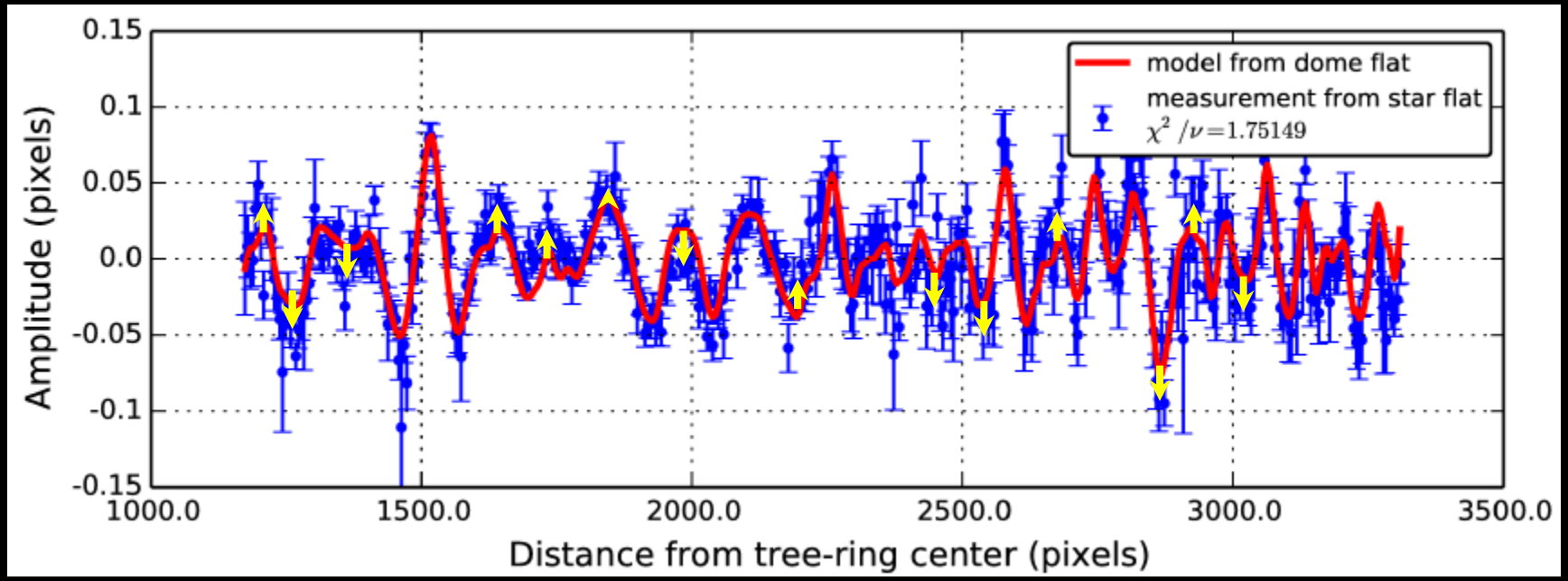
$$\kappa^{TR}(r) \equiv \frac{1}{2}\left(\frac{\partial d(r)}{\partial r} + \frac{d(r)}{r}\right) = -\frac{1}{2}f(r)$$

$$\gamma^{TR}_{rad}(r) \equiv \frac{1}{2}\left(\frac{\partial d(r)}{\partial r} - \frac{d(r)}{r}\right) = -\frac{1}{2}\left(f(r) - 2\frac{d(r)}{r}\right) \approx -\frac{1}{2}f(r)$$

Tree Ring and Residual on DES CCD

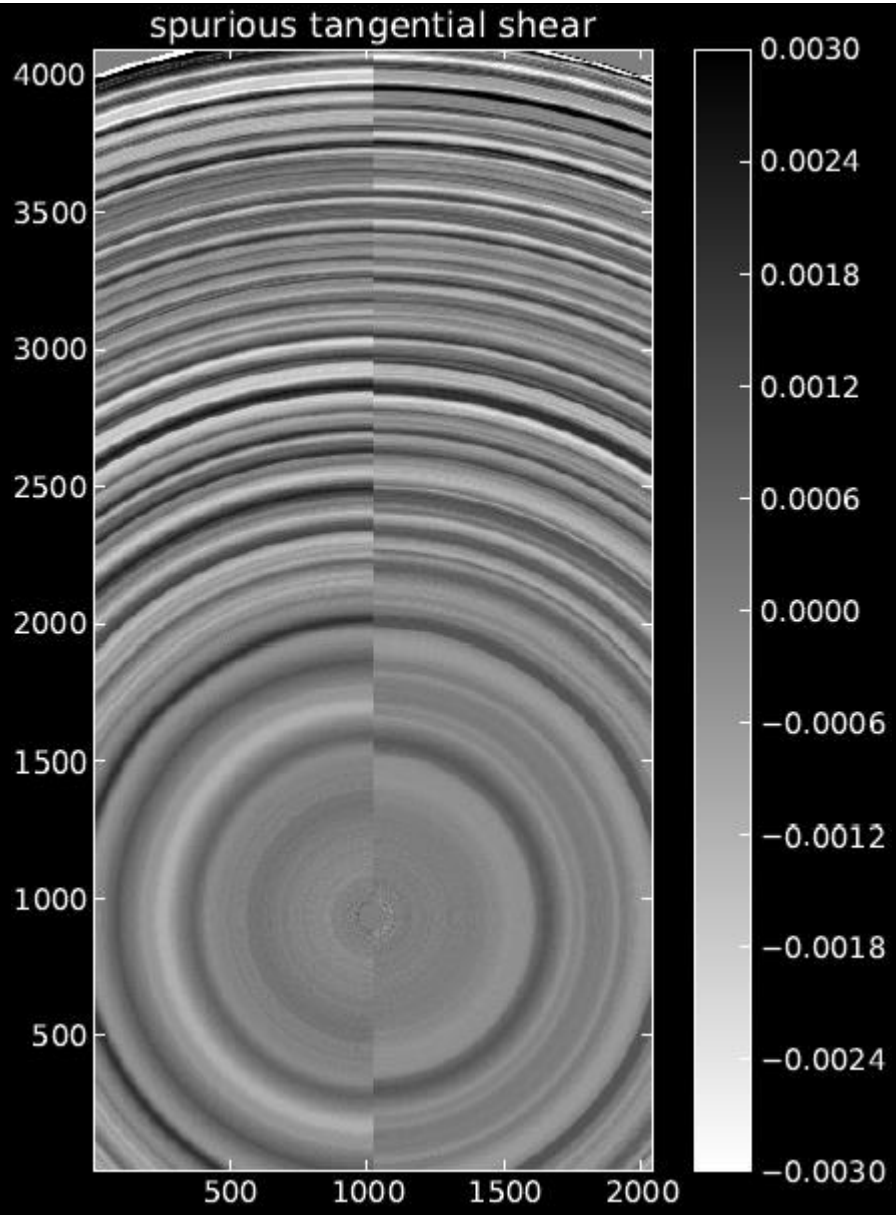
Spurious shear can be calculated from displacement,
but the displacement can be corrected by image warping using the models.
Therefore spurious shear also can be corrected by the image warping.
But there is difference slightly between measured and modelled displacement.
This differences is called “Residual”.

We consider the two spurious shear,
one is from tree ring (red line), and another is from residual(yellow arrow)

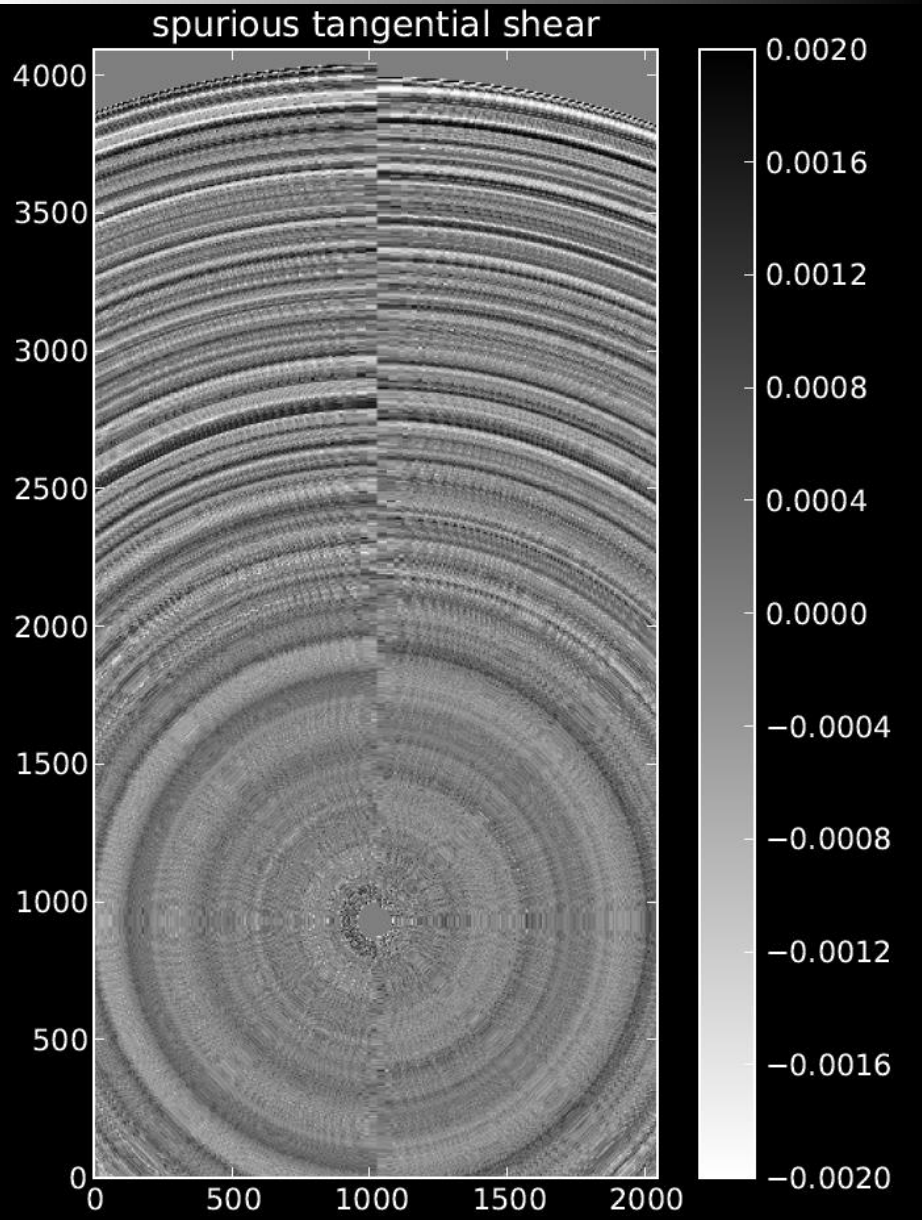


Yellow lines mean residuals from correction by model.
(Andres Plazas et al., 2014)

Spurious Shear by Tree Ring Effect on DES CCD



Spurious Shear from Tree Ring



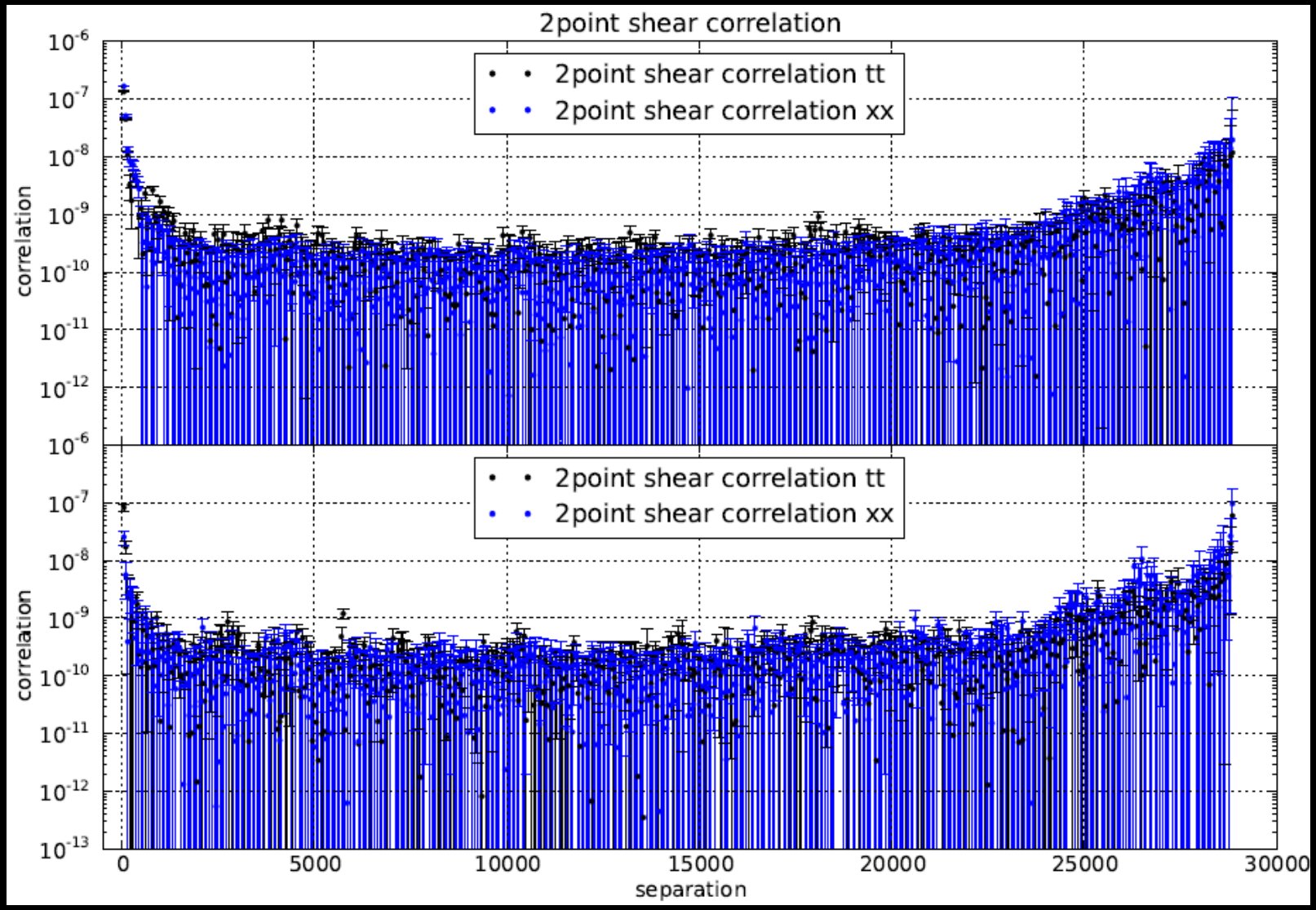
Spurious Shear from Residuals

2point correlation by the Spurious Shear on DES CCDs

2point shear correlations from the tree ring and residual in the DES focal plane.
We used flat modulation data and astrometric displacement data from star fields of 57 DES CCDs from Plazas et al. – –

Spurious shear from uncorrected tree ring

Spurious shear from Residual



The Tree Ring on LSST Type 1 CCDs

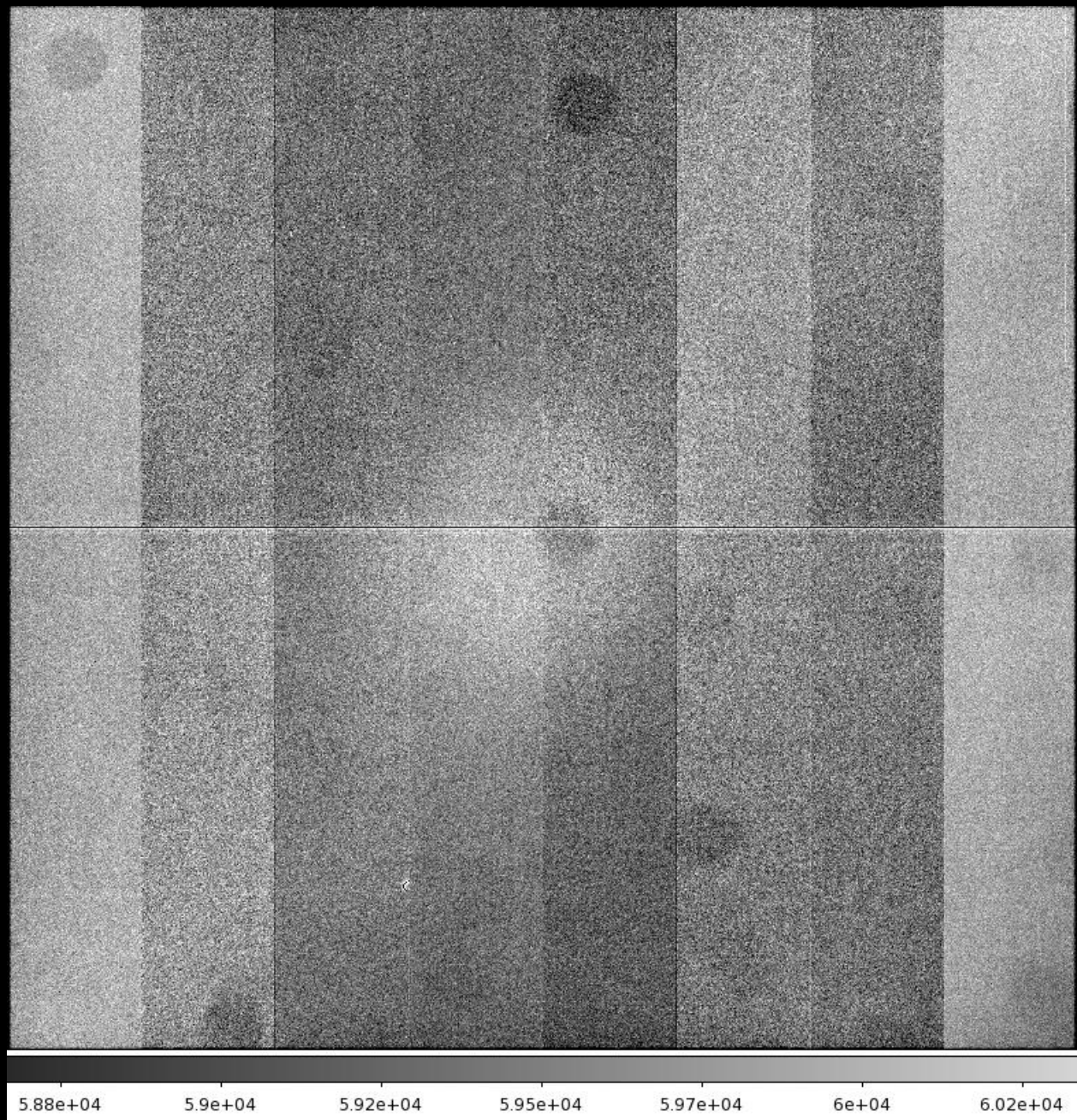
Stacked image of
Type 1 LSST CCD.

Wave length : 750nm

Stack number : 25shots

STD of flat image : 0.4%

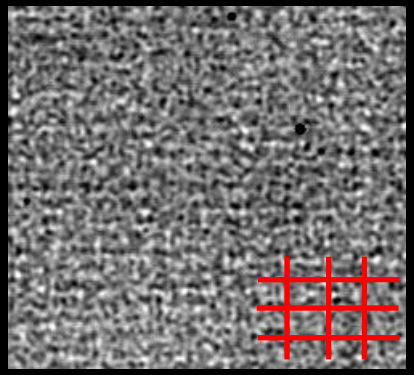
Concentric pattern is invisible
-> lower than DES CCD.
-> we corrected other effects.



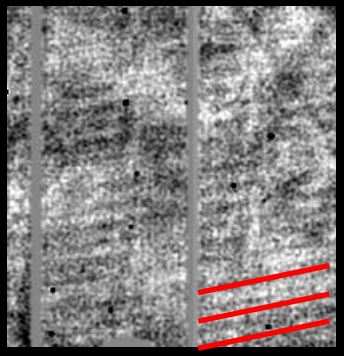
Masking and Normalization

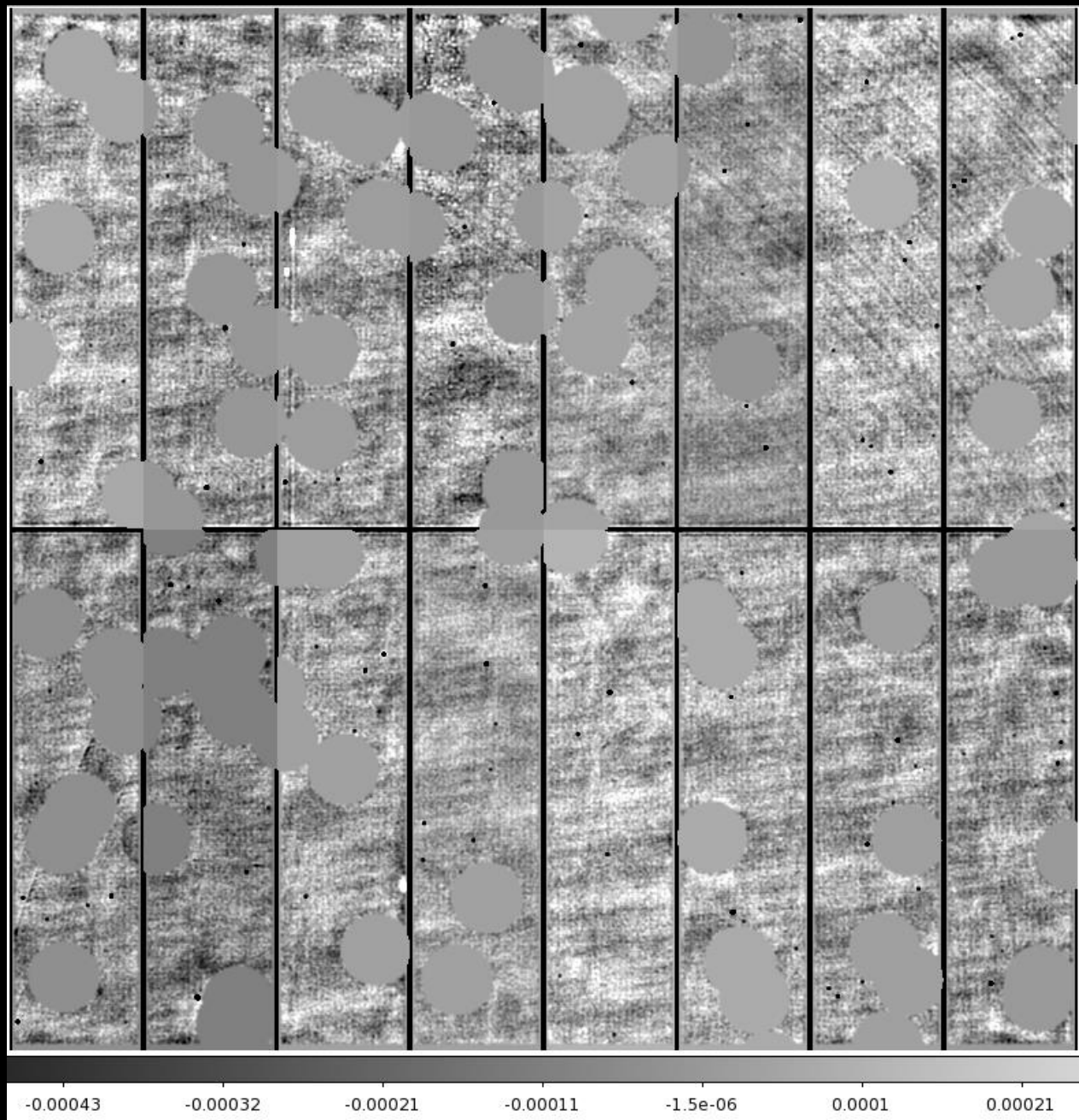
– – We can find tree ring from smoothed image. But there are some other patterns.

Grid pattern
(Pixel size variance)



Sloped pattern
(laser annealing)

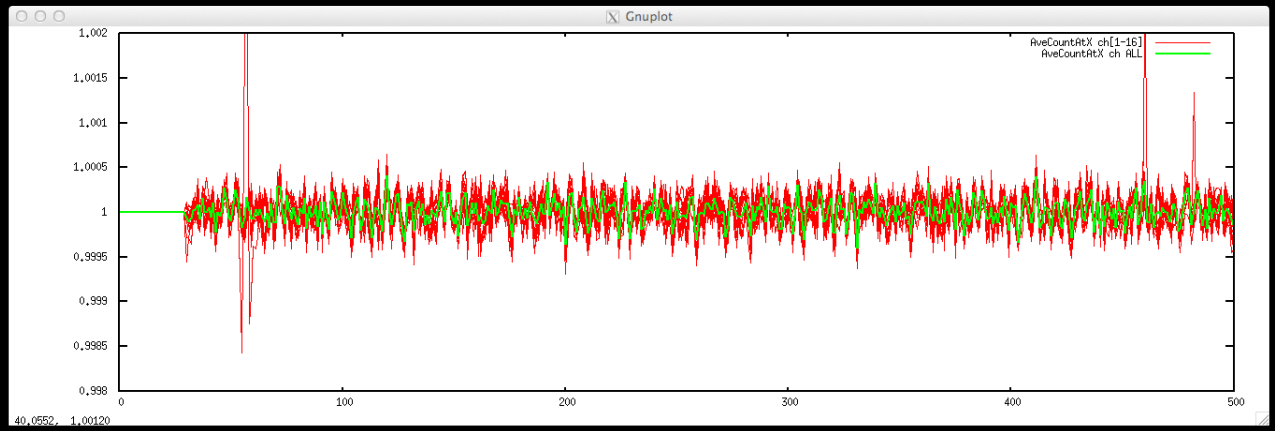




Correcting other patterns

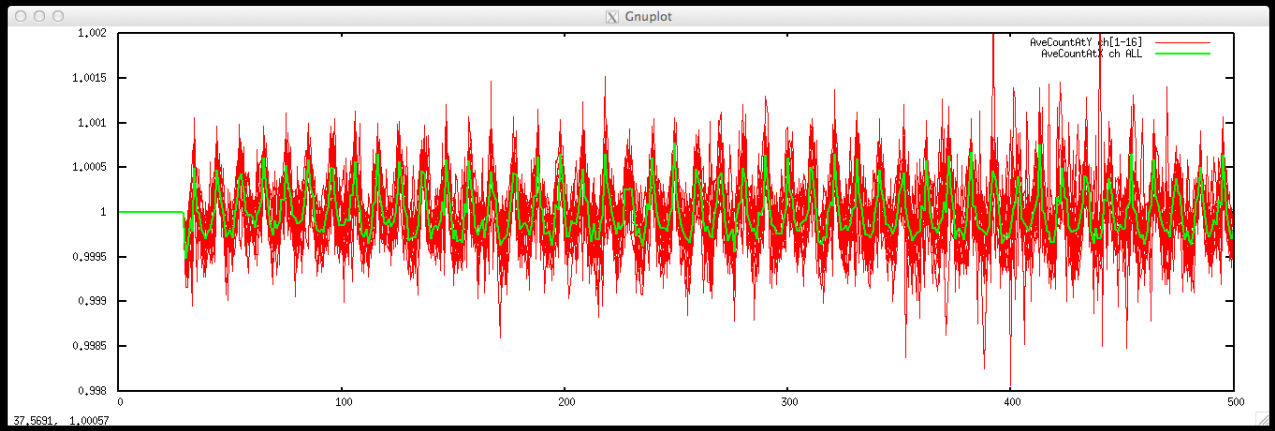
Averages of vertical lines

Almost constant



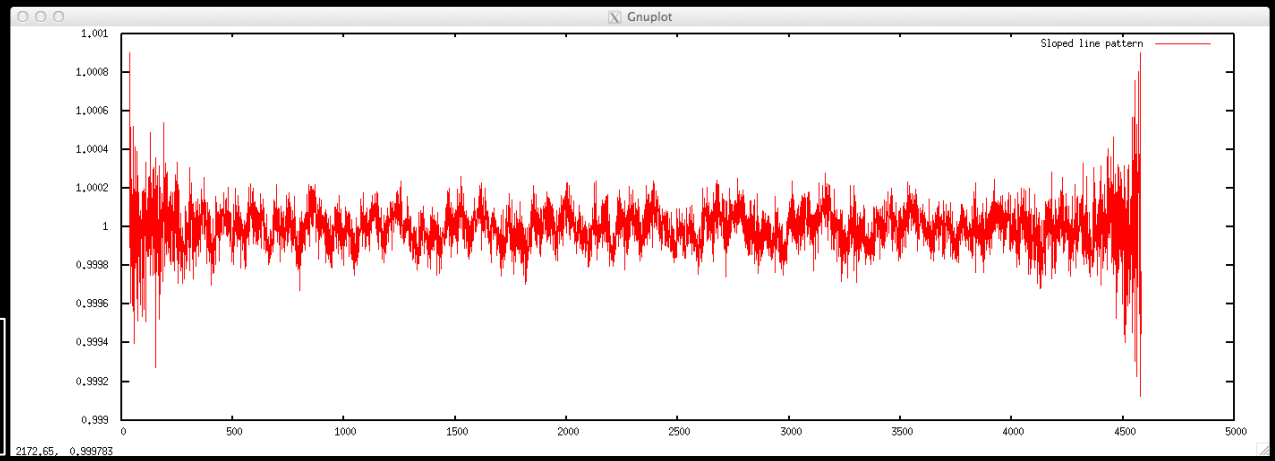
Averages of horizontal lines

Periodic peaks
Peaks : 0.05%
Period : 10 or 11 pixels



Averages of sloped lines

Periodic pattern
Peaks : 0.02%

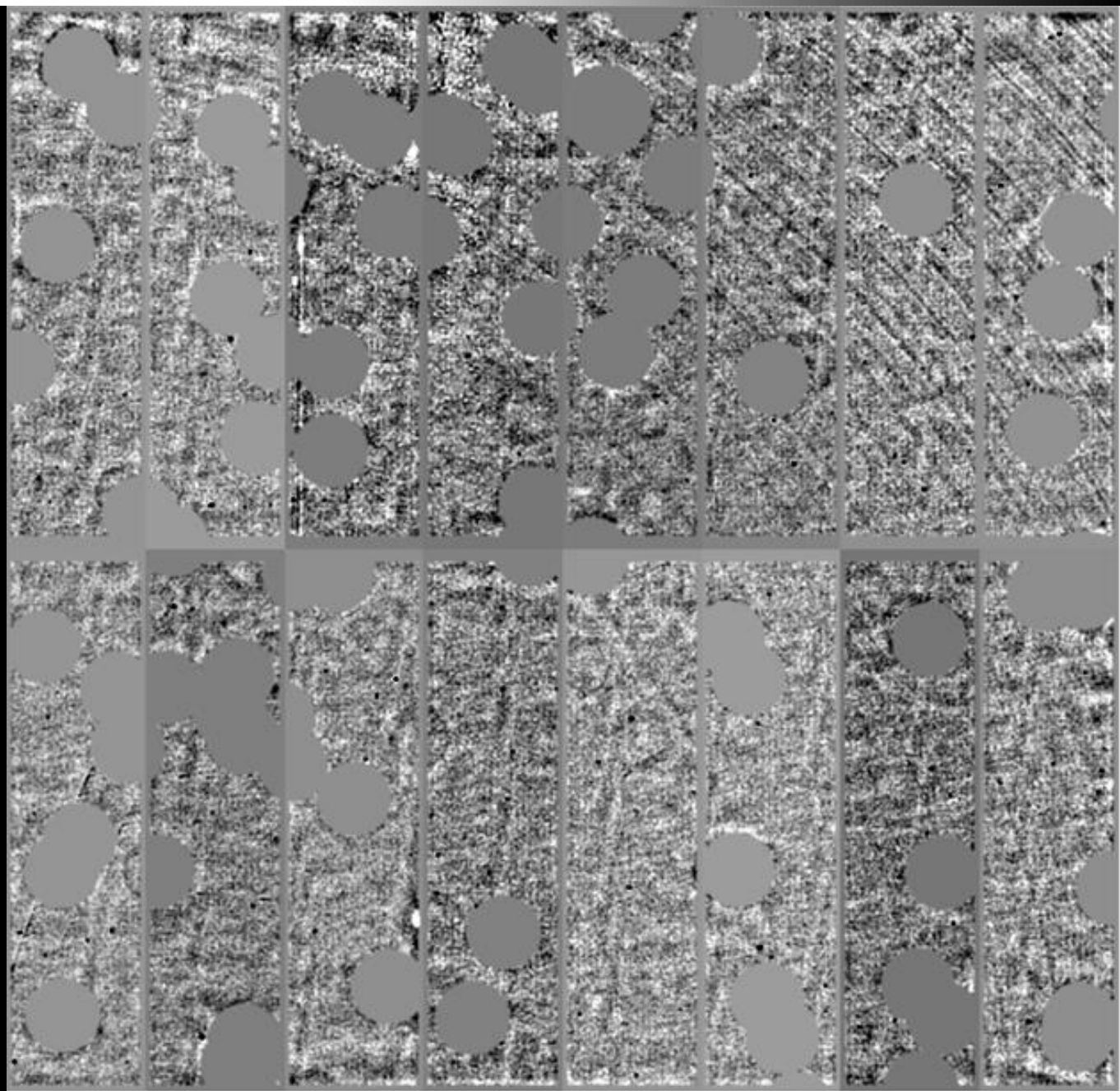


Correcting the large scale modulation in Fourier space.

LSST CCD Flat Image after All Correction

This image is a smoothed flat of type 1 CCD after all corrections.

We can see the tree ring pattern more clearly.



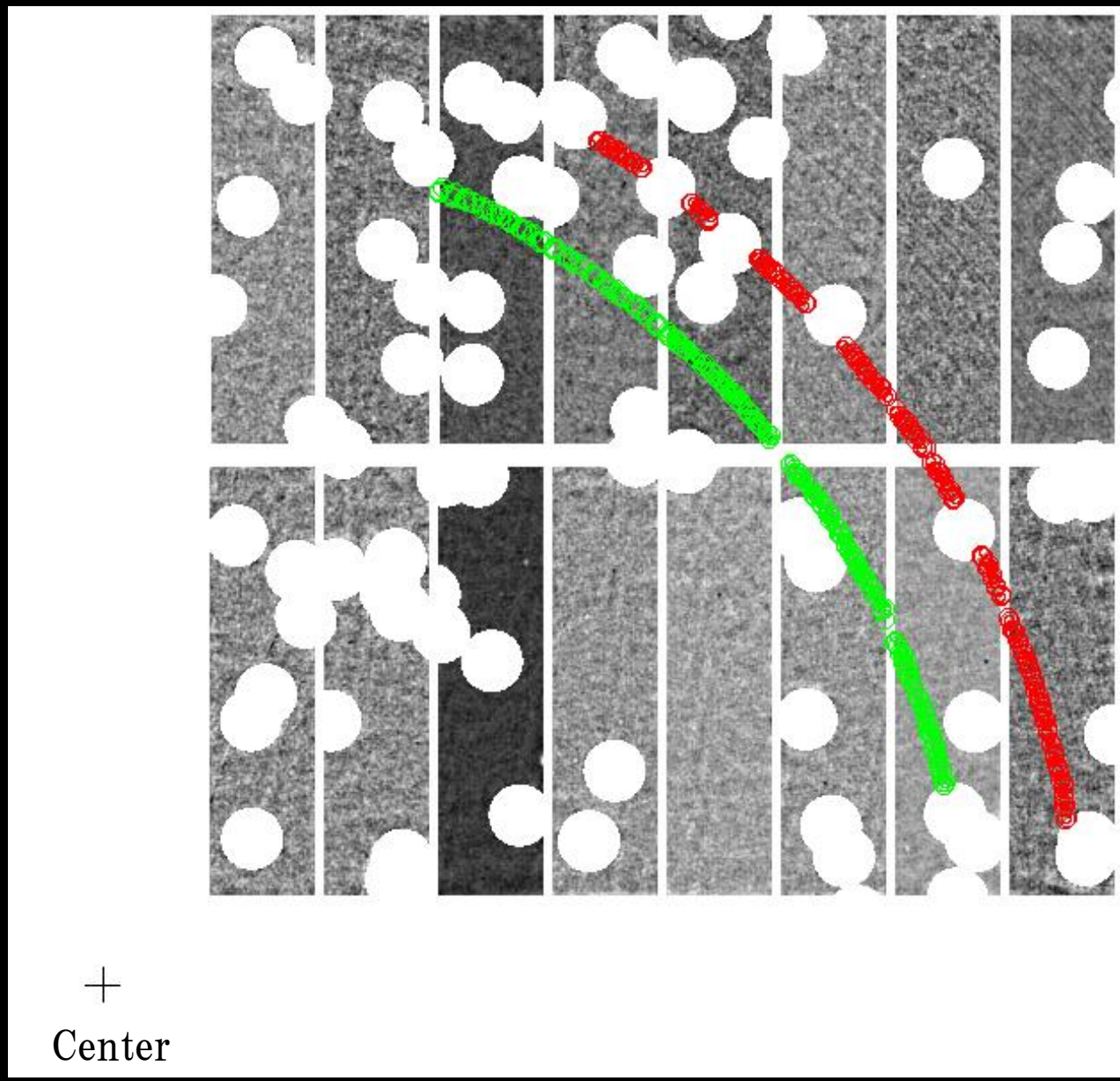
Determining Center of Tree Ring on LSST CCD

Next step is determining tree ring center.

Tree ring center is defined as making maximum peaks when averaging tree ring pattern over angle.

The position can be determined by fitting treeing line as circle.

Center : [4575, -375]



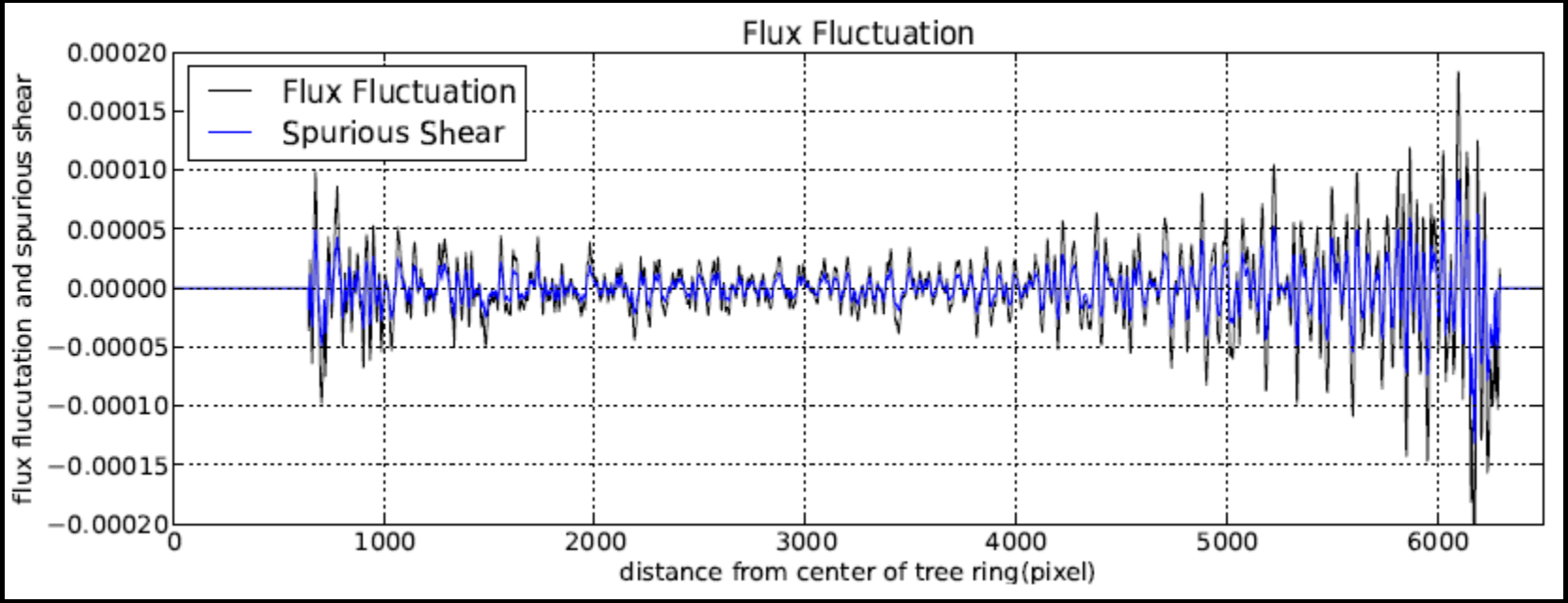
Center

Tree Ring profile on LSST CCD Type 1

Tree ring profile by averaging the pattern over angle(black line).

The typical scale of the tree ring is 0.01%

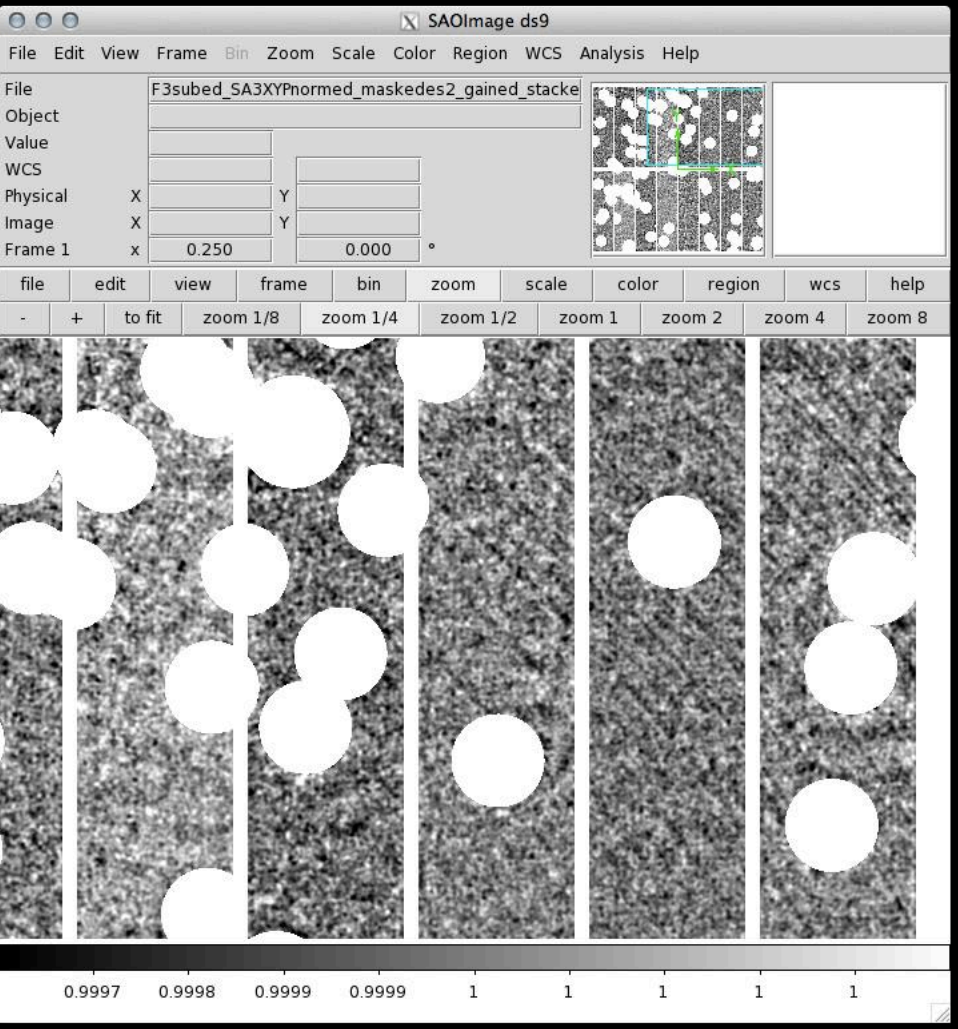
This profile is smoothed to reduce noise. –
The smoothing scale is smaller than the width of tree ring pattern,
so it does not reduce peak value so much.



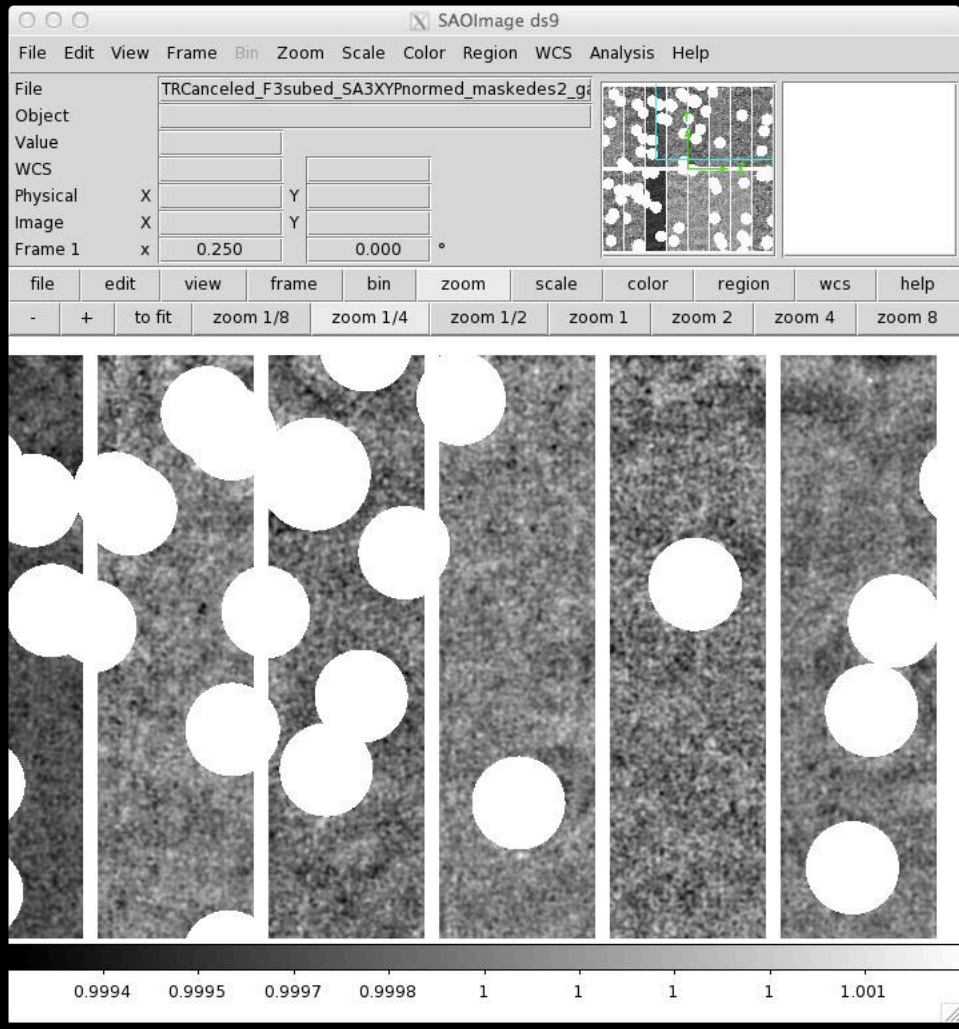
Flux modulation by the tree ring effect(Black line)

Testing Tree Ring Cancelation

Tree ring cancelation by measured profile.
Almost tree ring lines are canceled.



Before Cancelation (Smoothed image)

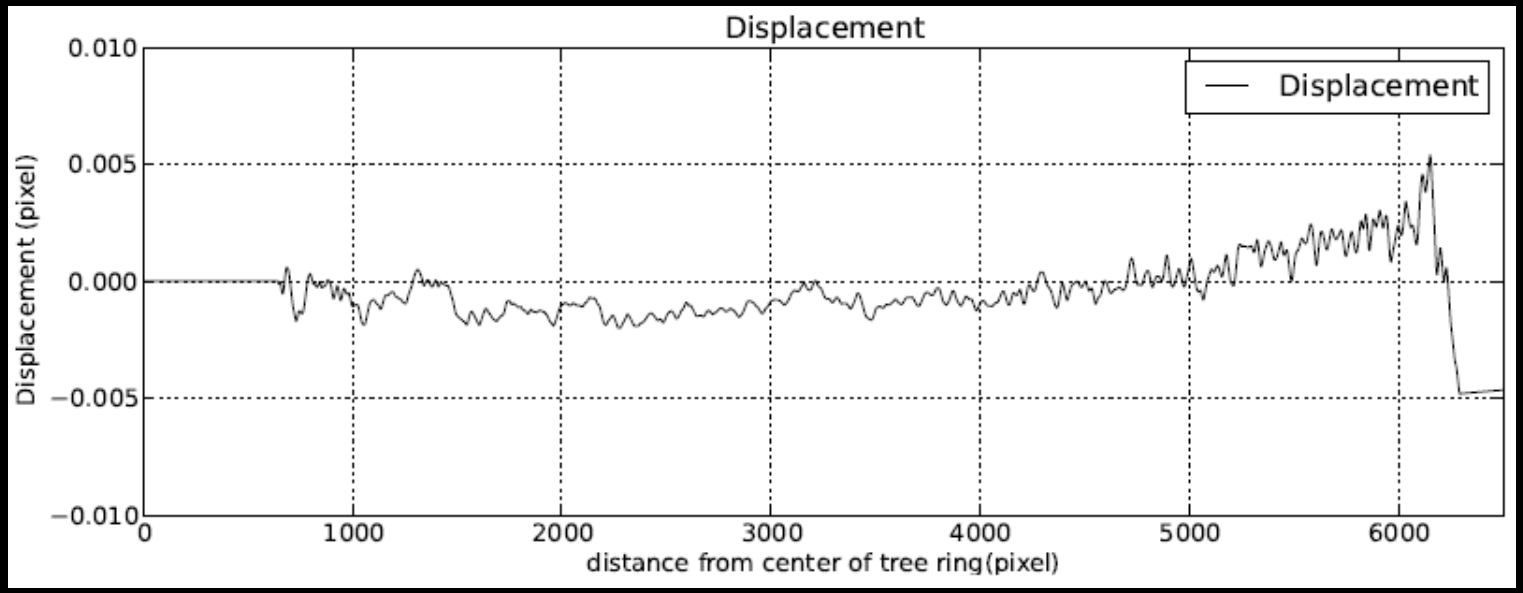


After Cancelation (Smoothed image)

Displacement and Spurious Shear from the Tree Ring

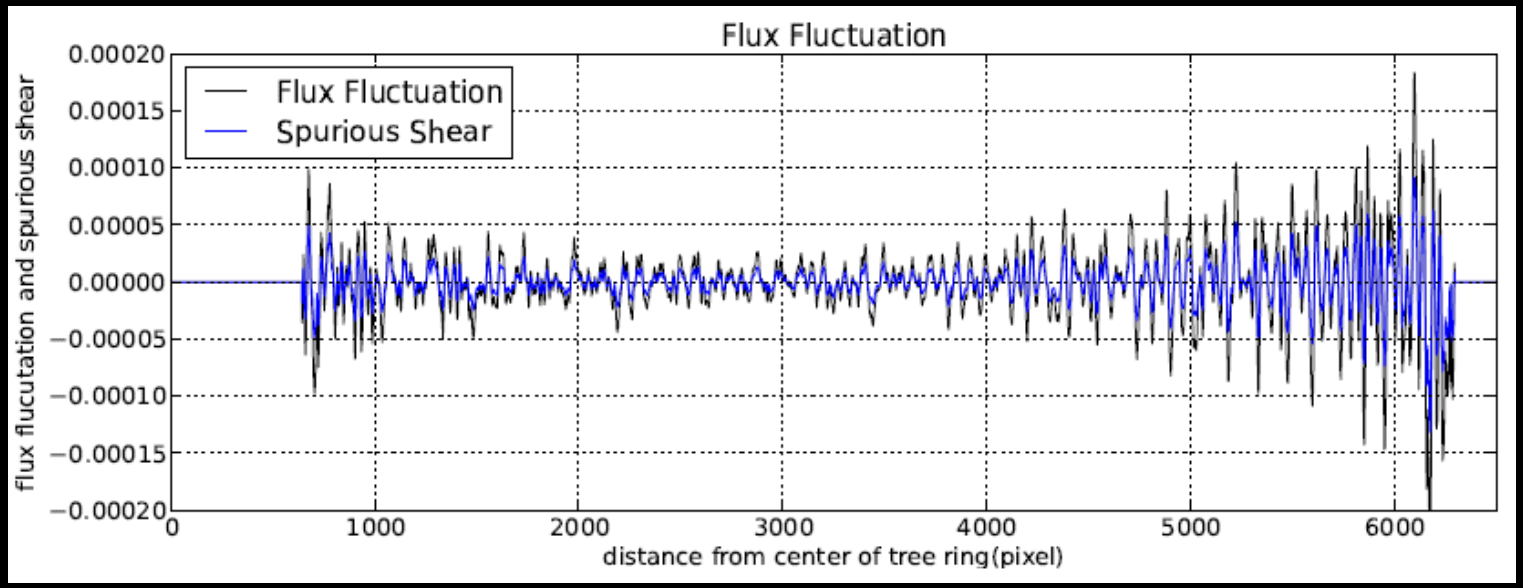
Displacement

Typical scale :
0.001 pixel



Spurious shear

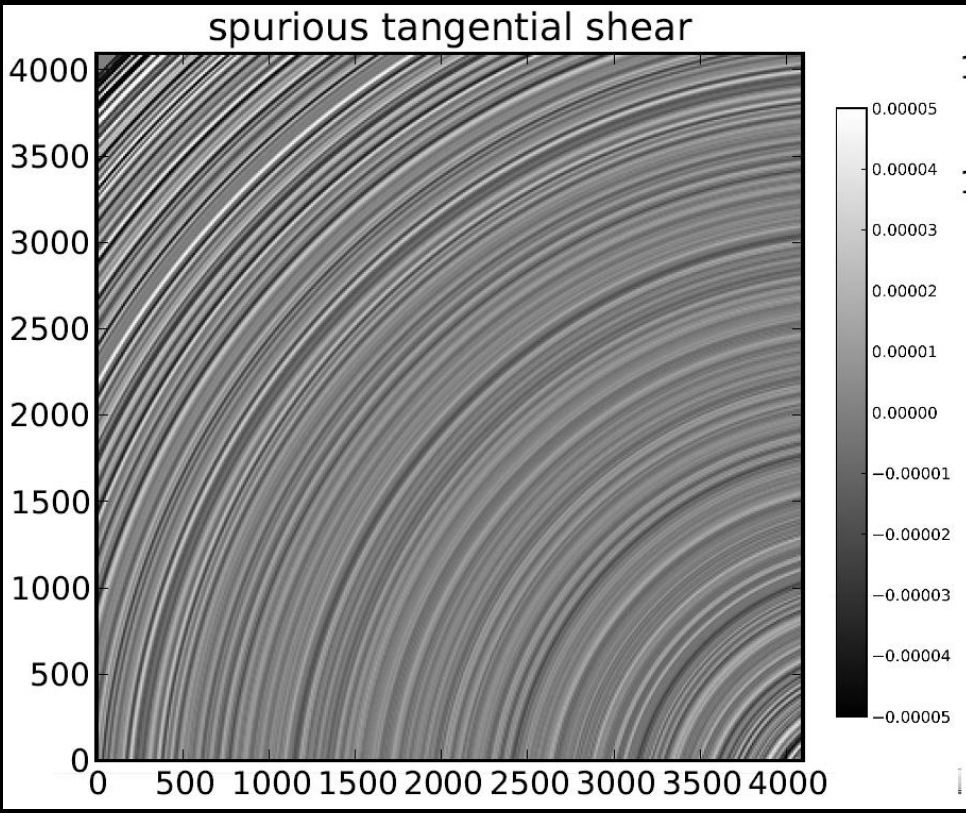
Typical scale :
0.05%



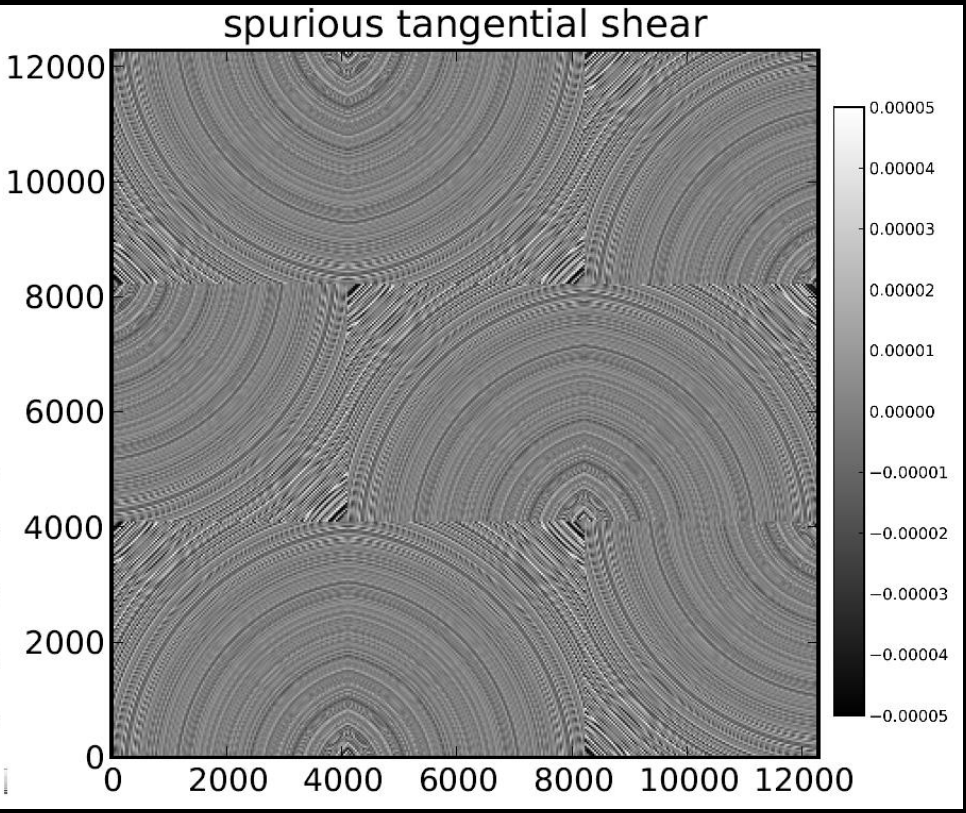
Spurious shear in LSST Type 1 CCD focal plane

Spurious shear pattern calculated from my measurement.

All LSST CCDs have a tree ring center near corner of CCD,
so we assumed all CCDs have same profile, but different orientation.
Arranged 9 CCDs into raft with varying orientations.
Arranged 21 rafts into focal plane.



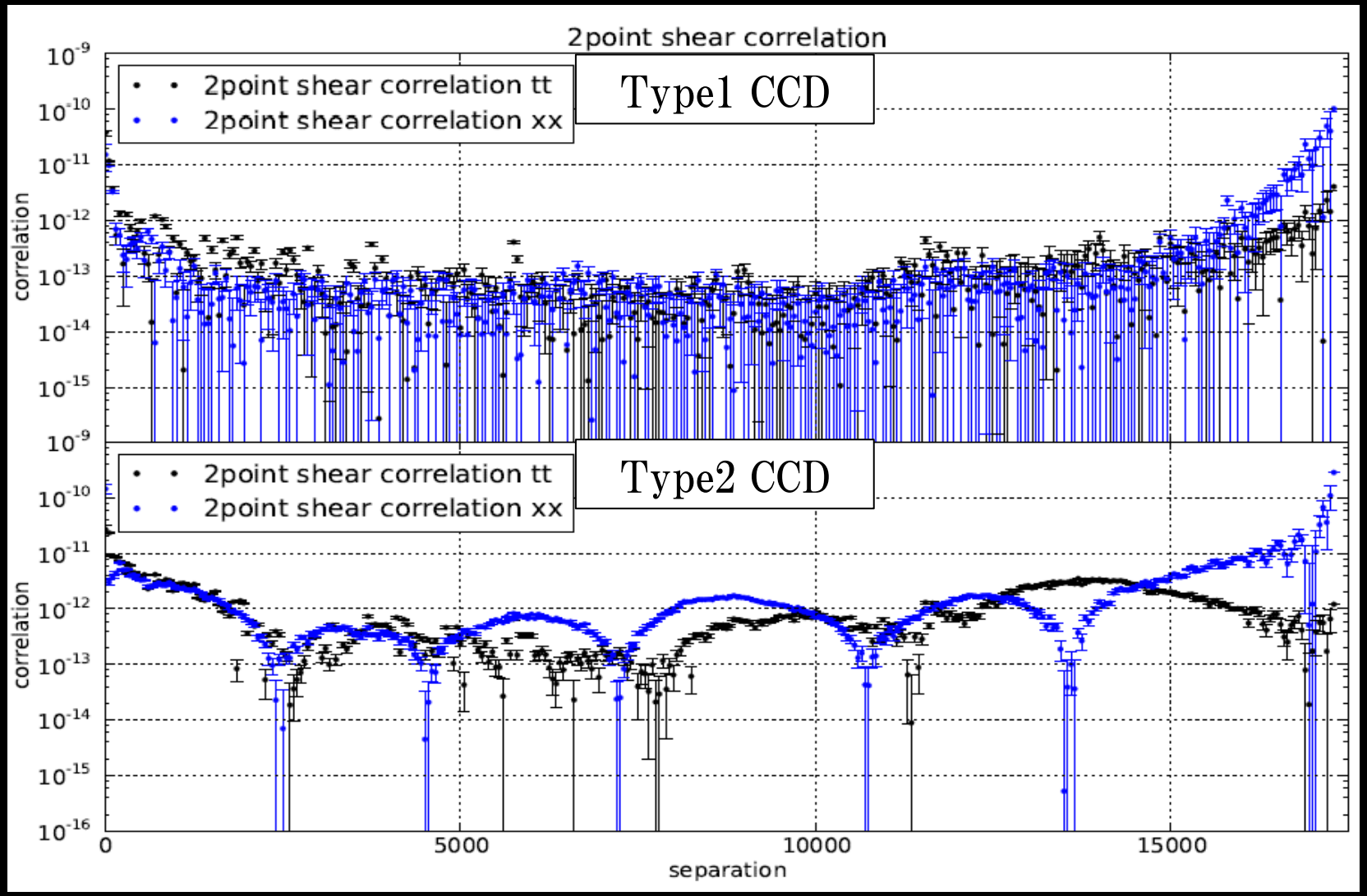
Calculated spurious shear in one CCD



Calculated spurious shear in one raft

2point shear correlation on LSST focal plane

2point shear correlations from the tree ring pattern in LSST focal plane.
The typical scale is about 10^-12 in both CCDs,
so it is small enough to neglect in measuring cosmic shear.



Conclusion and Future Works

- Conclusion -

We measured the tree ring pattern on LSST CCDs.
The typical scale of spurious shear from the tree ring pattern is about 0.005%
and 2 point shear correlation is about 10^-12,
so it is very small enough to neglect in measuring cosmic shear.
Then the effect can be reduced further by image warping correction
with displacement model calculated from flat images.

- Future Works -

In this study we measured only 2point correlation,
but Andrea Petri(Columbia) and we will calculated effect of LSST spurious shear on cosmological parameters.

We found other effects which change shapes, e.g. the pixel size variation.
The typical scale is about 0.1%, so it is 10 times larger than the tree ring effects.
So studying their effects in measuring cosmic shear is future work.