Precision Astronomy with Fully Depleted CCDs 2014 Summary

Tony Tyson

The connection to science

Rachel Mandelbaum

Model errors in shapes as a multiplicative bias, additive term:

$$\gamma_{meas} = (1+m)\,\gamma_{true} + c$$

(Ideally m=c=0)

Cosmic shear (shear-shear correlation):

$$\langle \gamma_{meas}\,\gamma_{meas} \rangle = (1+m)^2 \langle \gamma_{true}\,\gamma_{true} \rangle + 2\,(1+m)\langle c\,\gamma_{true} \rangle + \langle c\,c \rangle$$

Calibration bias

Additive term (diagnosable with star-galaxy cross-correlations)

The connection to science

Rachel Mandelbaum

Model errors in shapes as a multiplicative bias, additive term:

$$\gamma_{meas} = (1+m)\,\gamma_{true} + c$$

(Ideally m=c=0)

< 3E-3

< 3E-4

Cosmic shear (shear-shear correlation):

$$\langle \gamma_{meas}\,\gamma_{meas} \rangle = (1+m)^2 \langle \gamma_{true}\,\gamma_{true} \rangle + 2\,(1+m)\langle c\,\gamma_{true} \rangle + \langle c\,c \rangle$$

Calibration bias

Additive term (diagnosable with star-galaxy cross-correlations)

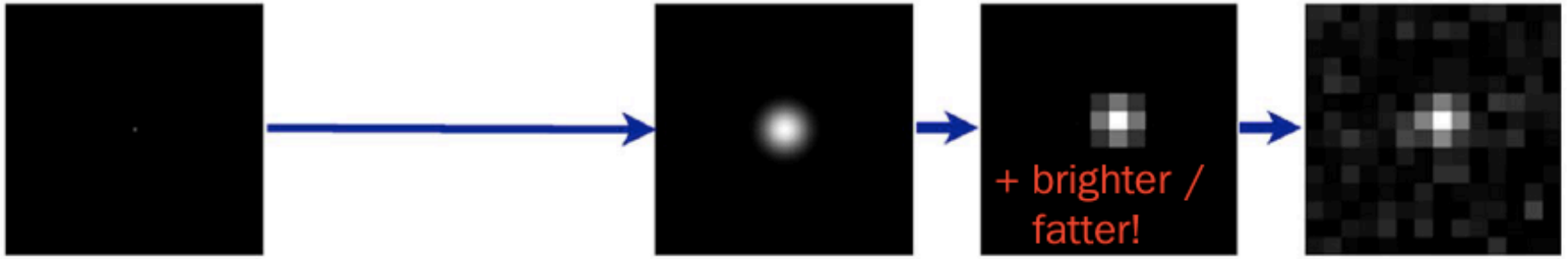
Examples of where systematics come in

- Chromatic effects: PSF for stars is different from that for galaxies, or even within different parts of the same galaxy.
- Brighter-fatter effect: PSF for bright stars is fatter than that for the galaxies.
- Tree rings, edge distortion: astrometry (a remapping that isn't a convolution)
- Cosmic rays: basic measurement issue
- Defects can lead to coherent selection effects

Galaxies: Intrinsic galaxy shapes to measured image:

Intrinsic galaxy (shape unknown) | Gravitational lensing causes a ***shear (g)*** | Atmosphere and telescope cause a convolution | Detectors measure a pixelated image | Image also contains noise

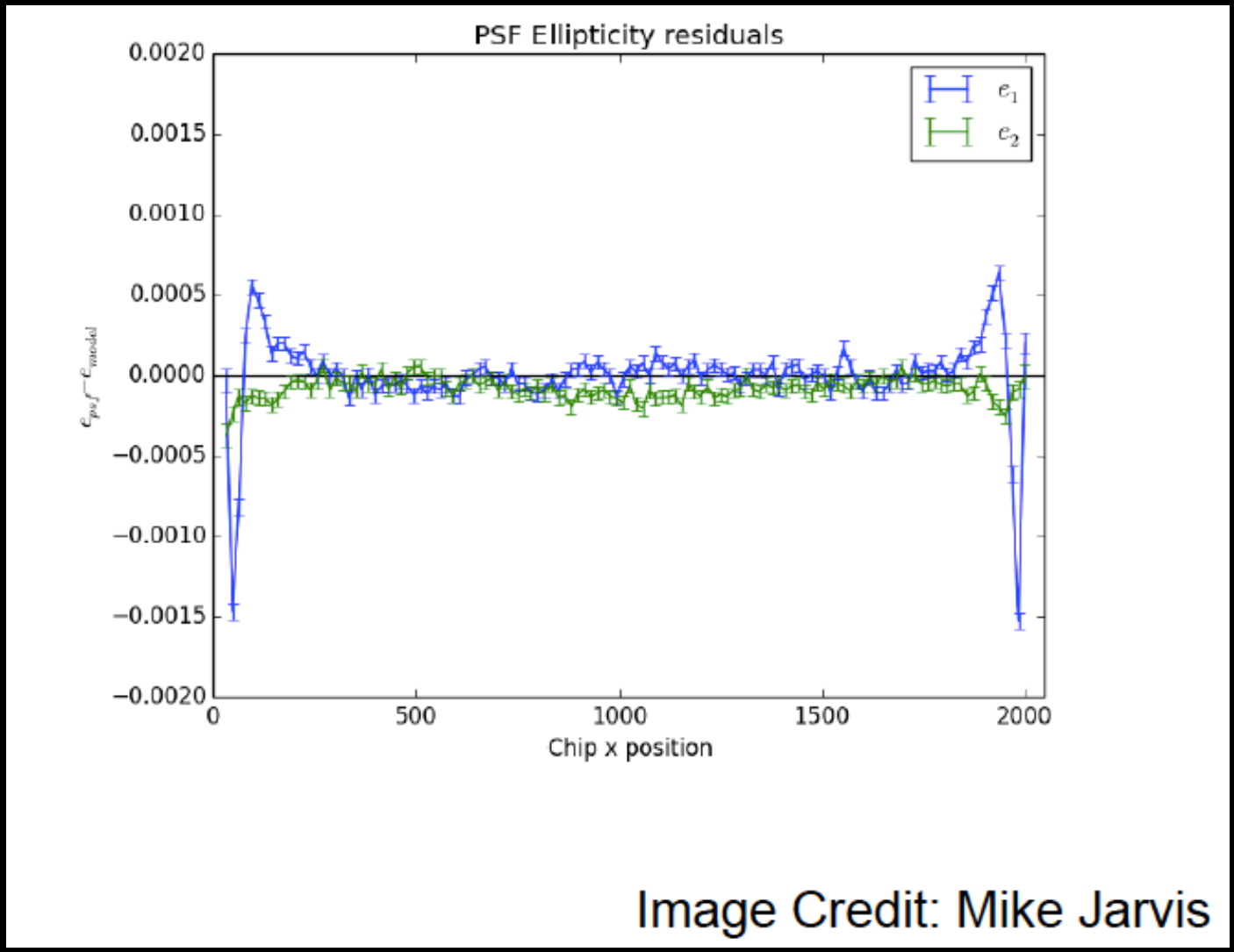
Stars: Point sources to star images:



Intrinsic star (point source) | Atmosphere and telescope cause a convolution | Detectors measure a pixelated image | Image also contains noise

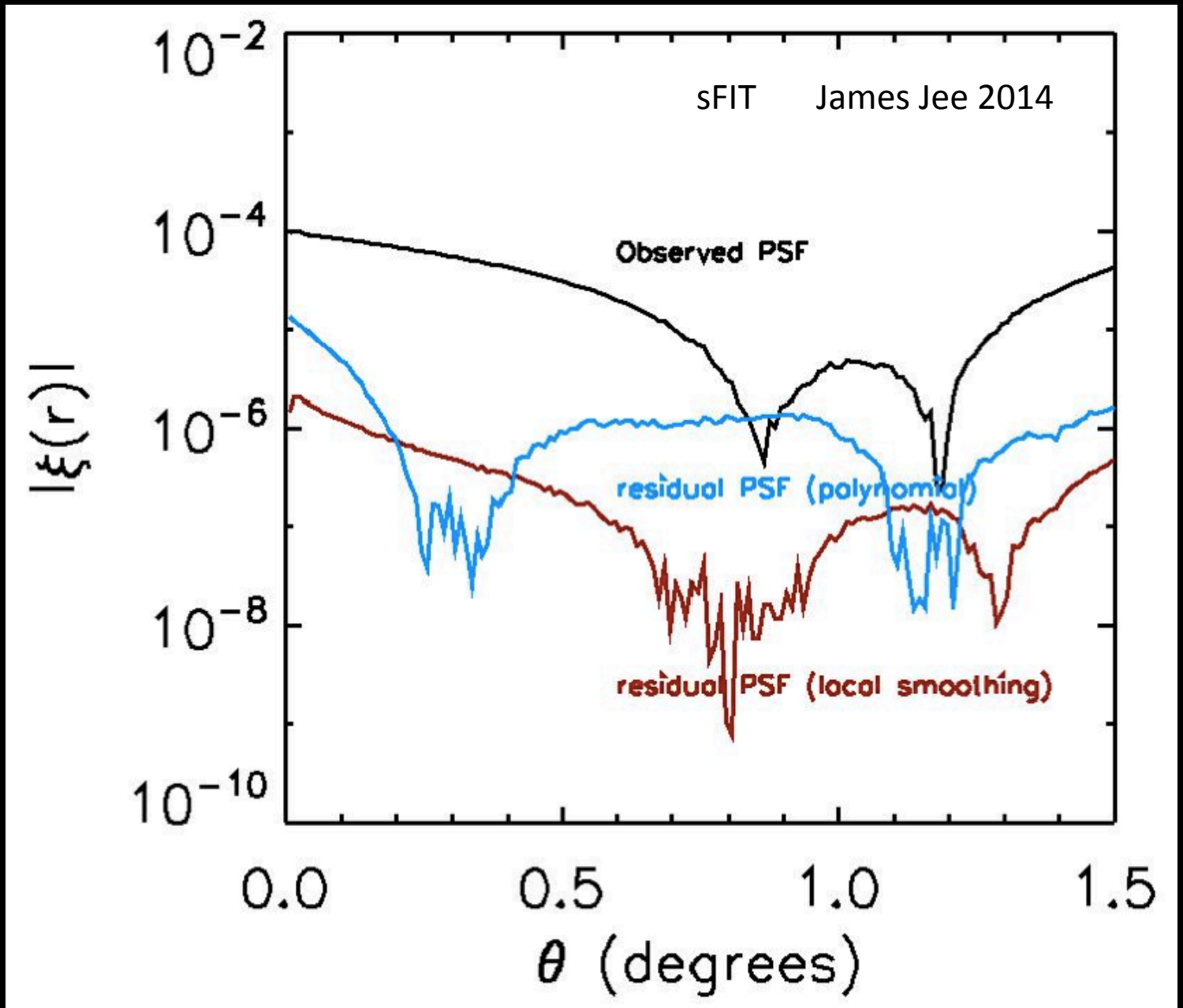
Source: Bridle et al. 2009

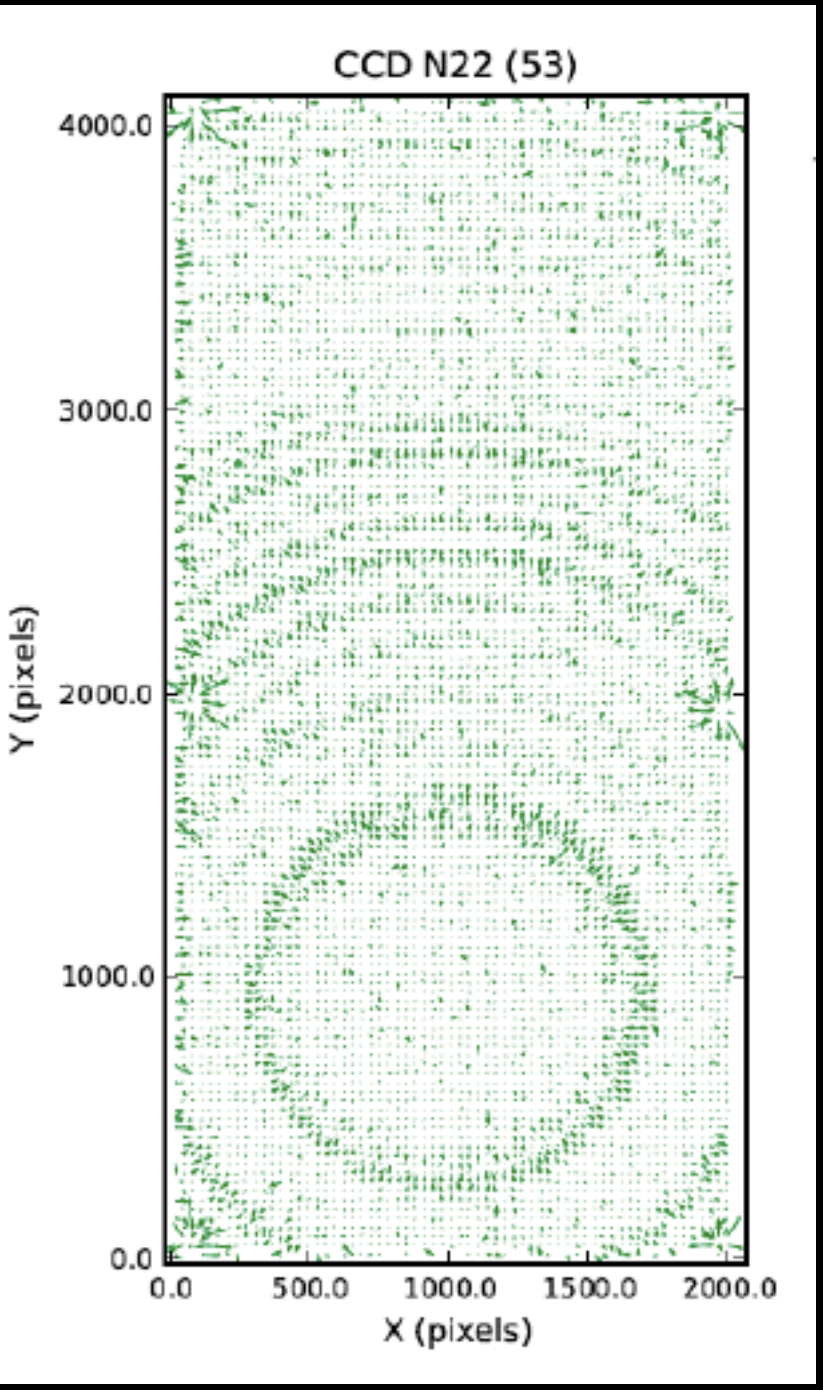
DES PSF modeling

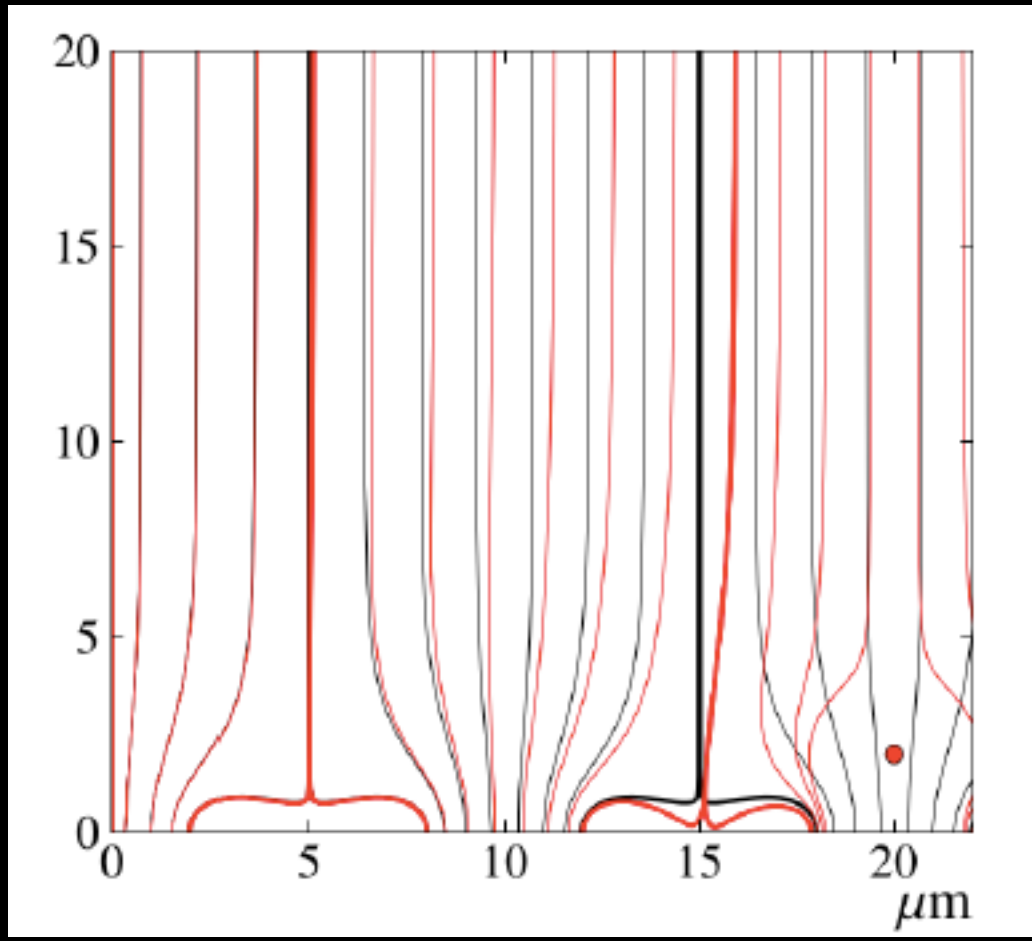


Bob Armstrong

GREAT3 shear estimation challenge

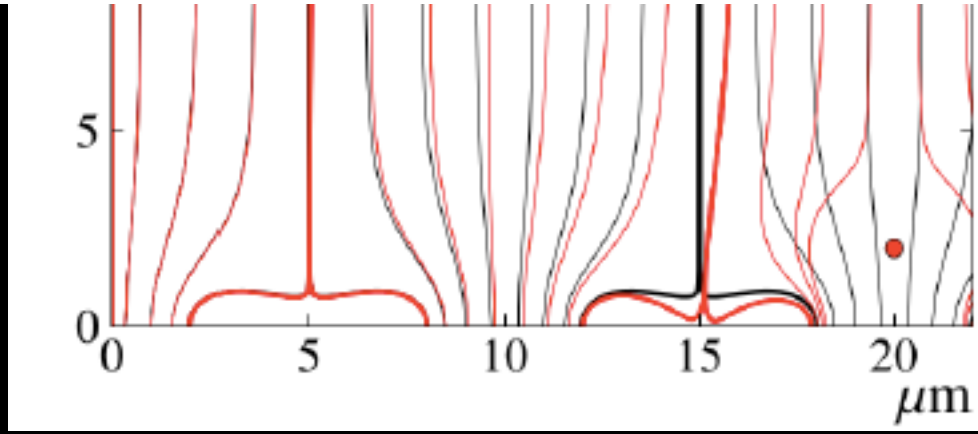






Pierre Astier

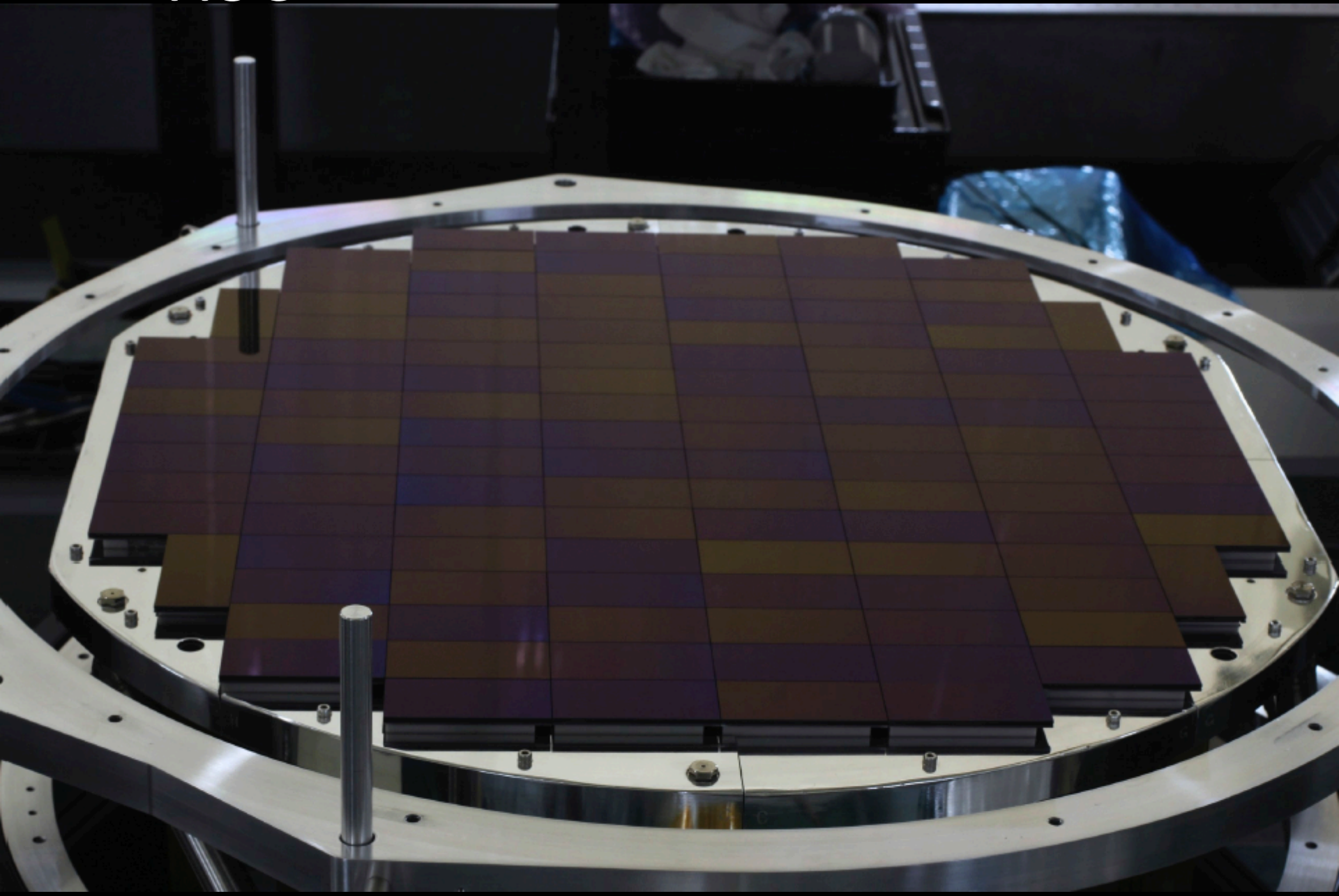
- The stored charge pattern distorts the average drift lines
- It also decreases the drift electric field, and hence increases lateral diffusion (S. Holland).

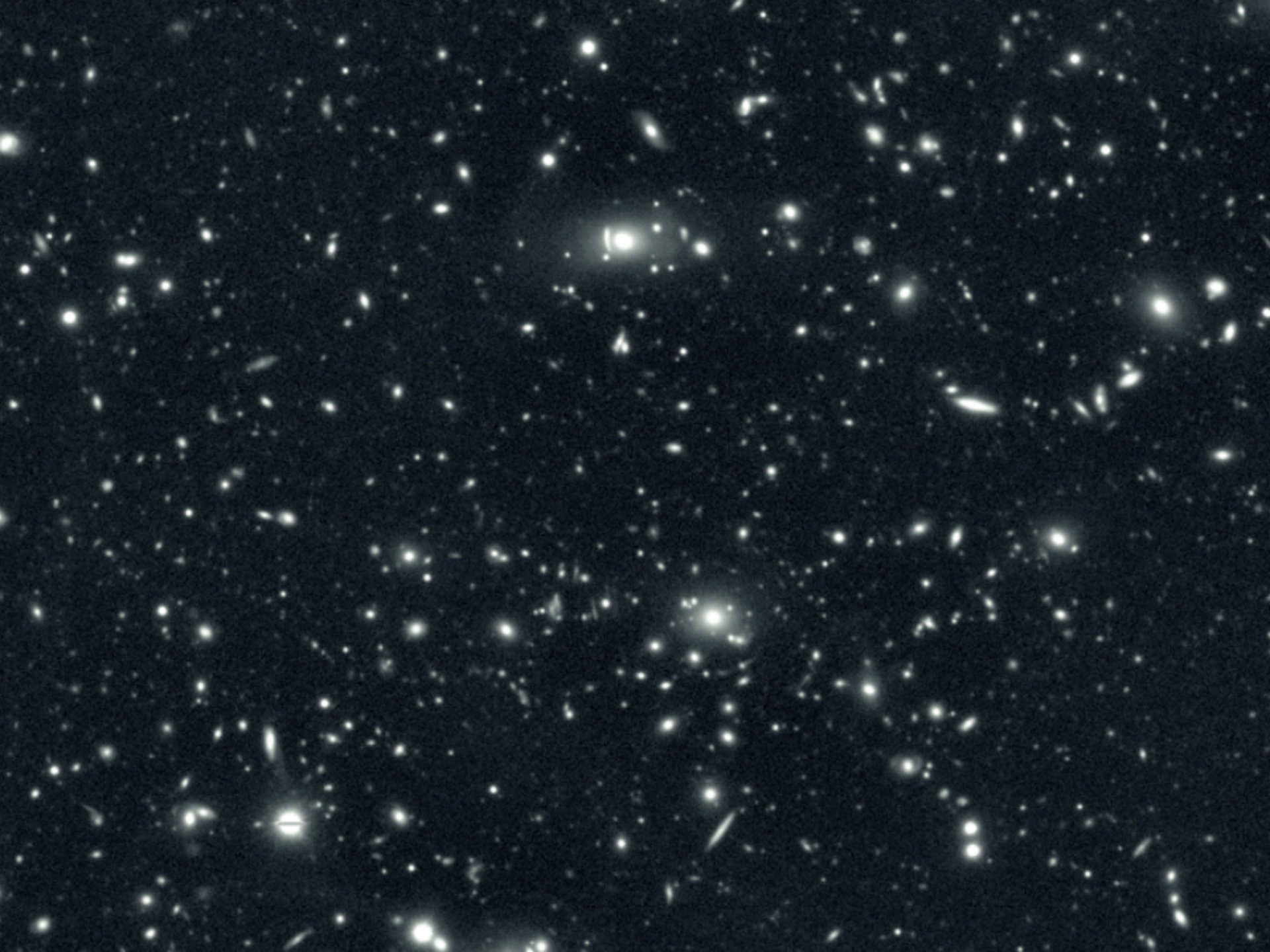


Pierre Astier

HSC

Satoshi Miyazaki

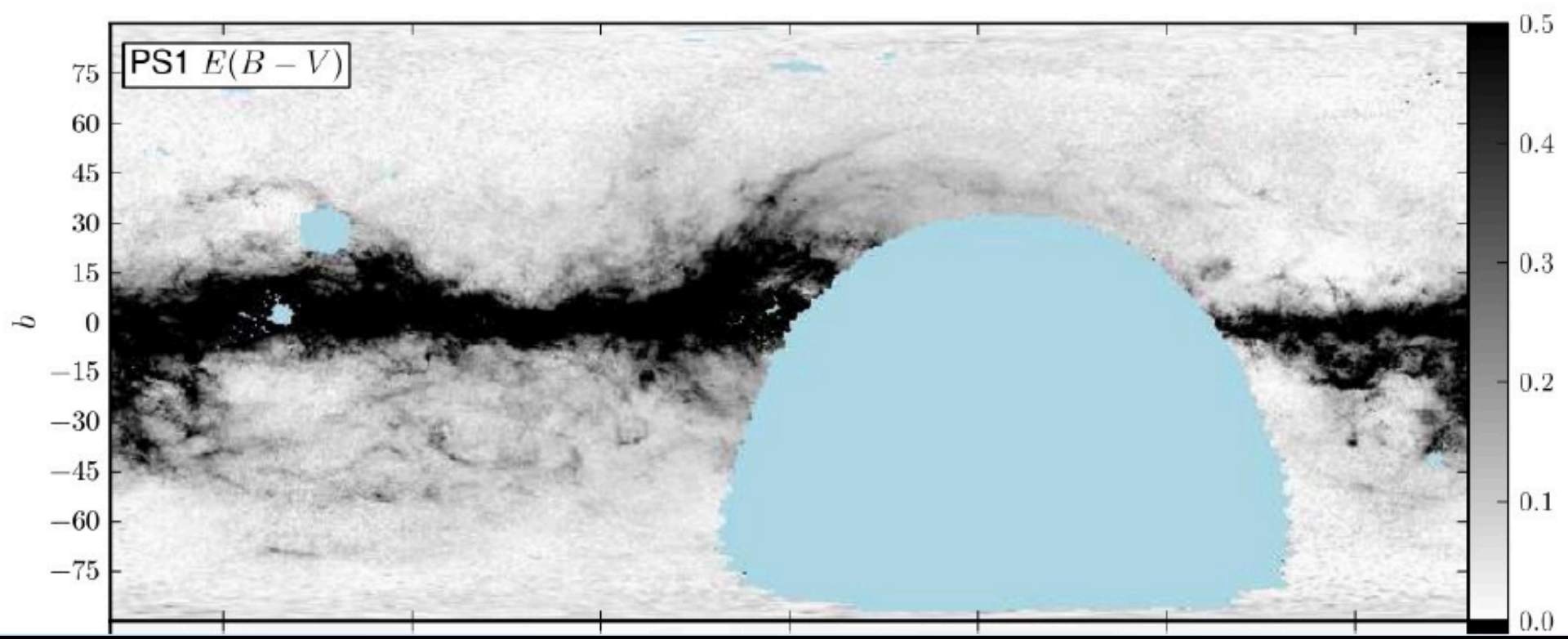




PanSTARRS

Gene Manier

3D Dust map

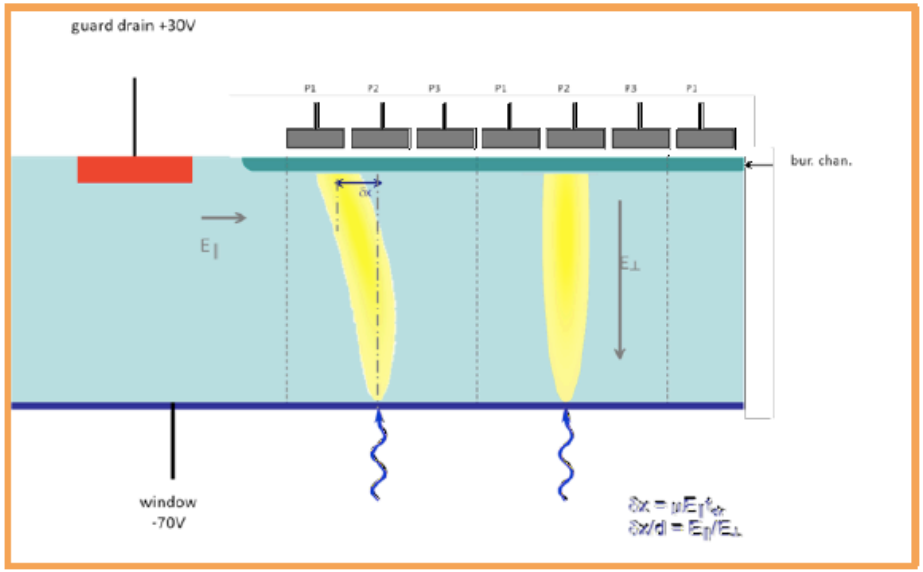


2.8 bilion objects

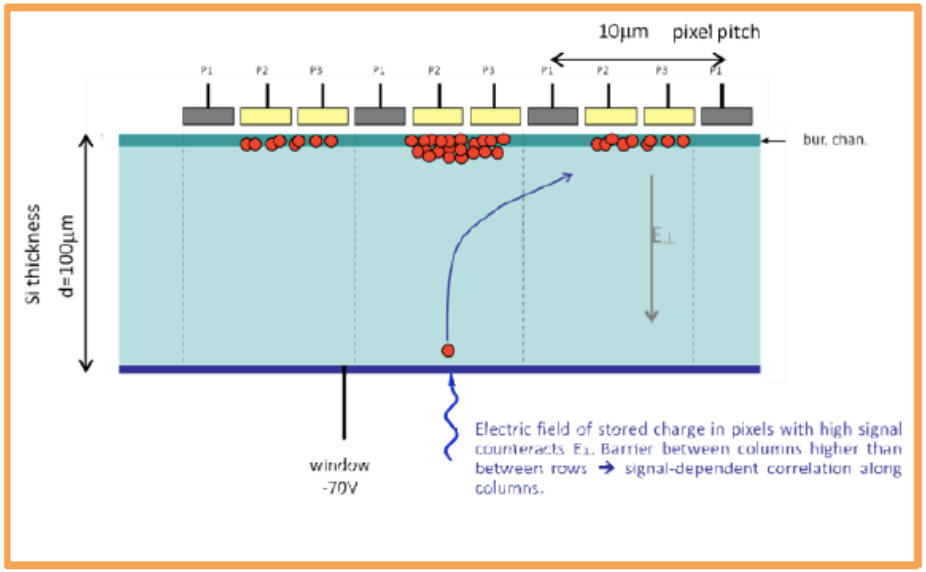
LSST sensors

Andrei Nomeroski

Static : edge effects, tree-rings



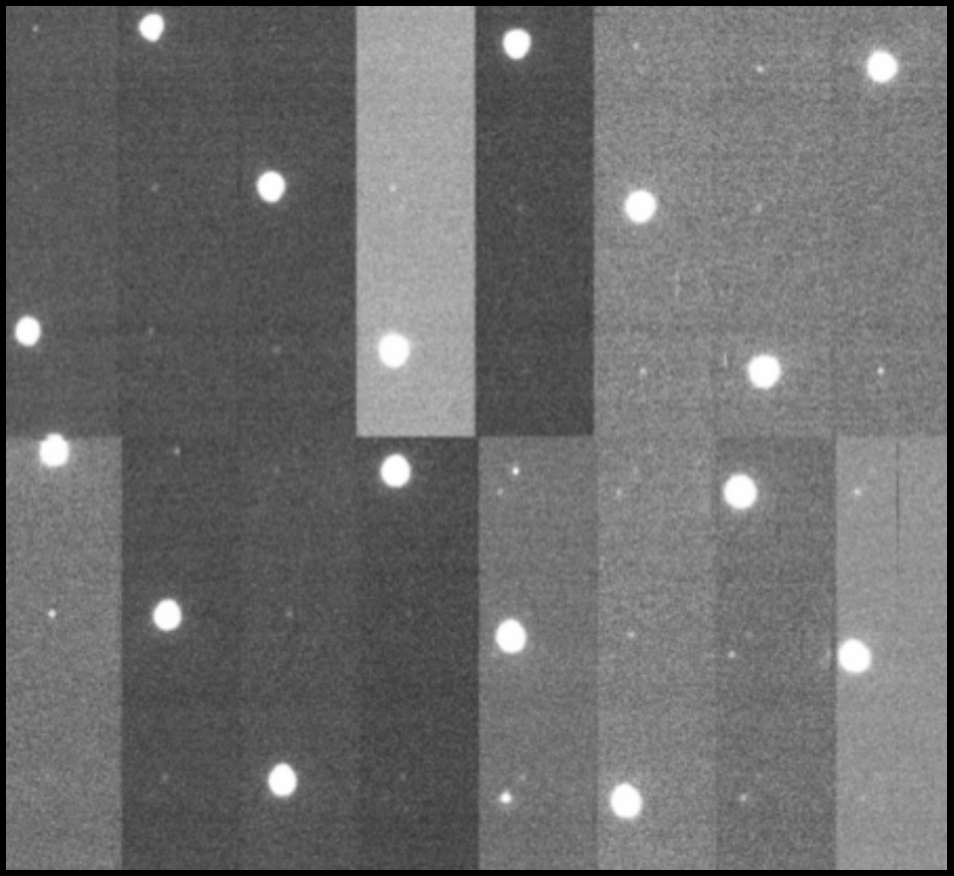
"Dynamic" : brighter-fatter effect



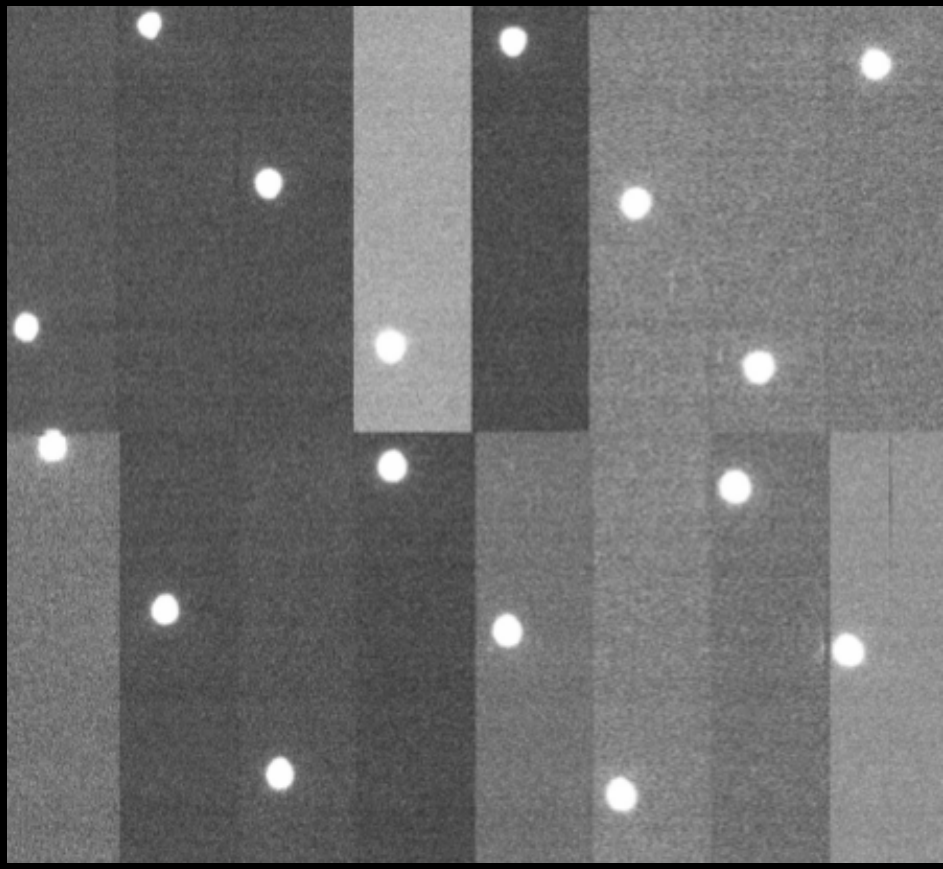
Crosstalk

Paul O'Connor

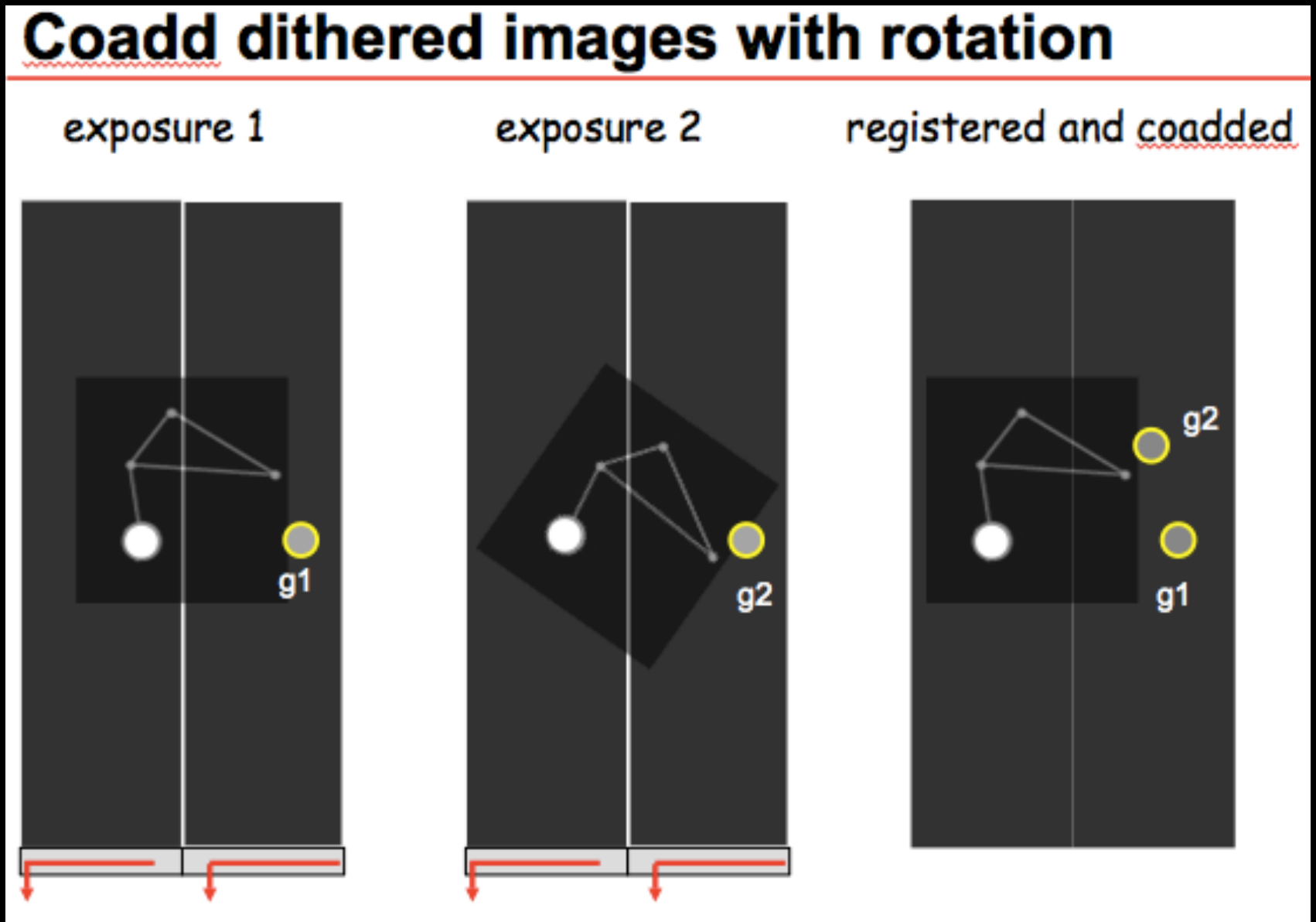
Before correction



After correction



rotation


Coadd dithered images with rotation
exposure 1
exposure 2
registered and coadded
g1
g2
g2
g1

DECam

Daniel Gruen

- brighter-fatter effect independent of photon rate

- Flat field pixel covariance is lot dependent

Euclid CCDs

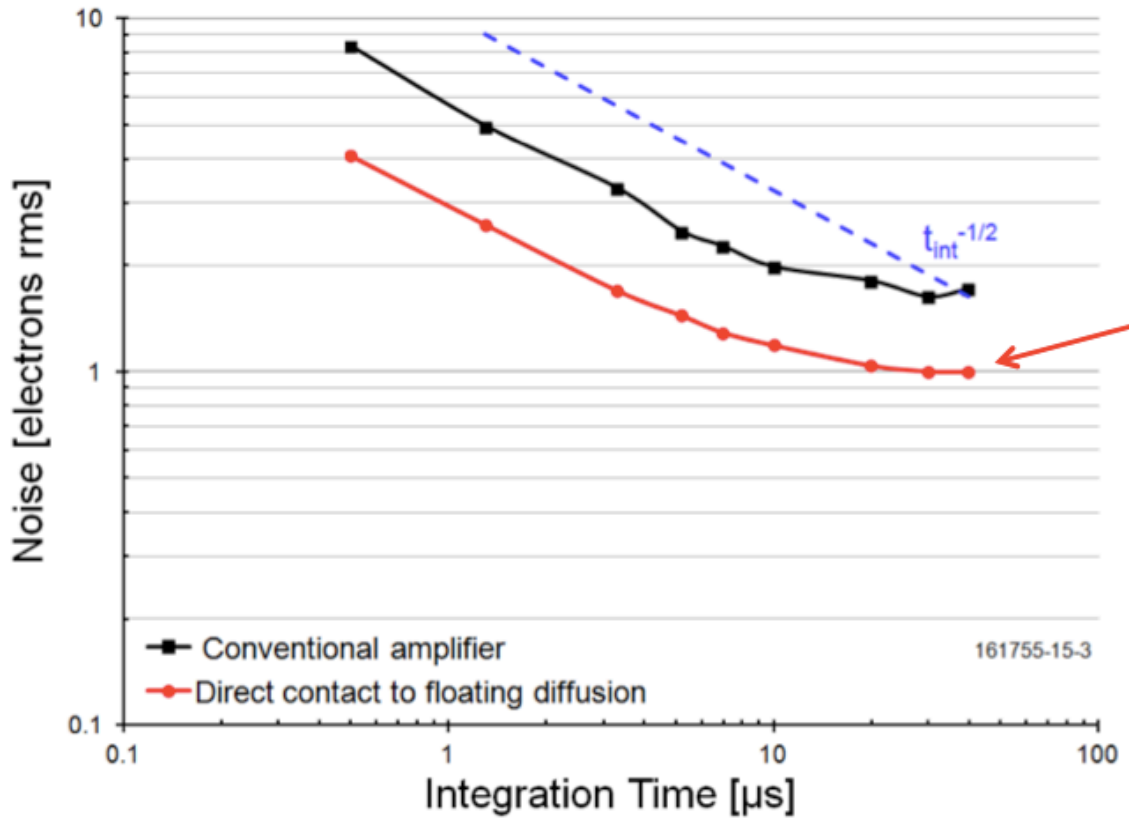
Douglas Jordan

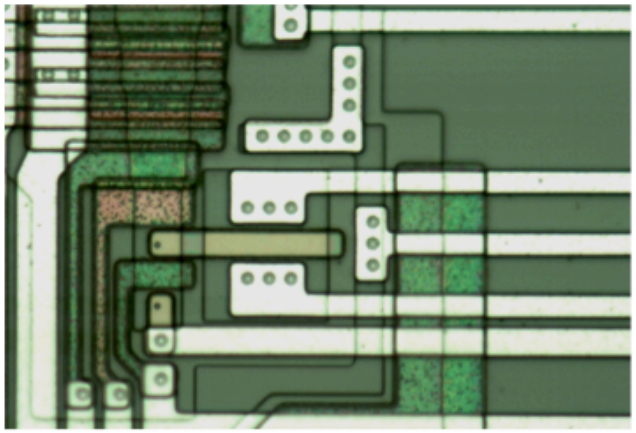
- Radiation induced traps act on a particular volume so it follows that by reducing the interaction volume, one could reduce the frequency of traps → Build the device with a thinner register channel.

- Introduce a charge injection structure to fill traps with a “fat zero” prior to readout.

DESI CCDs

Steve Holland

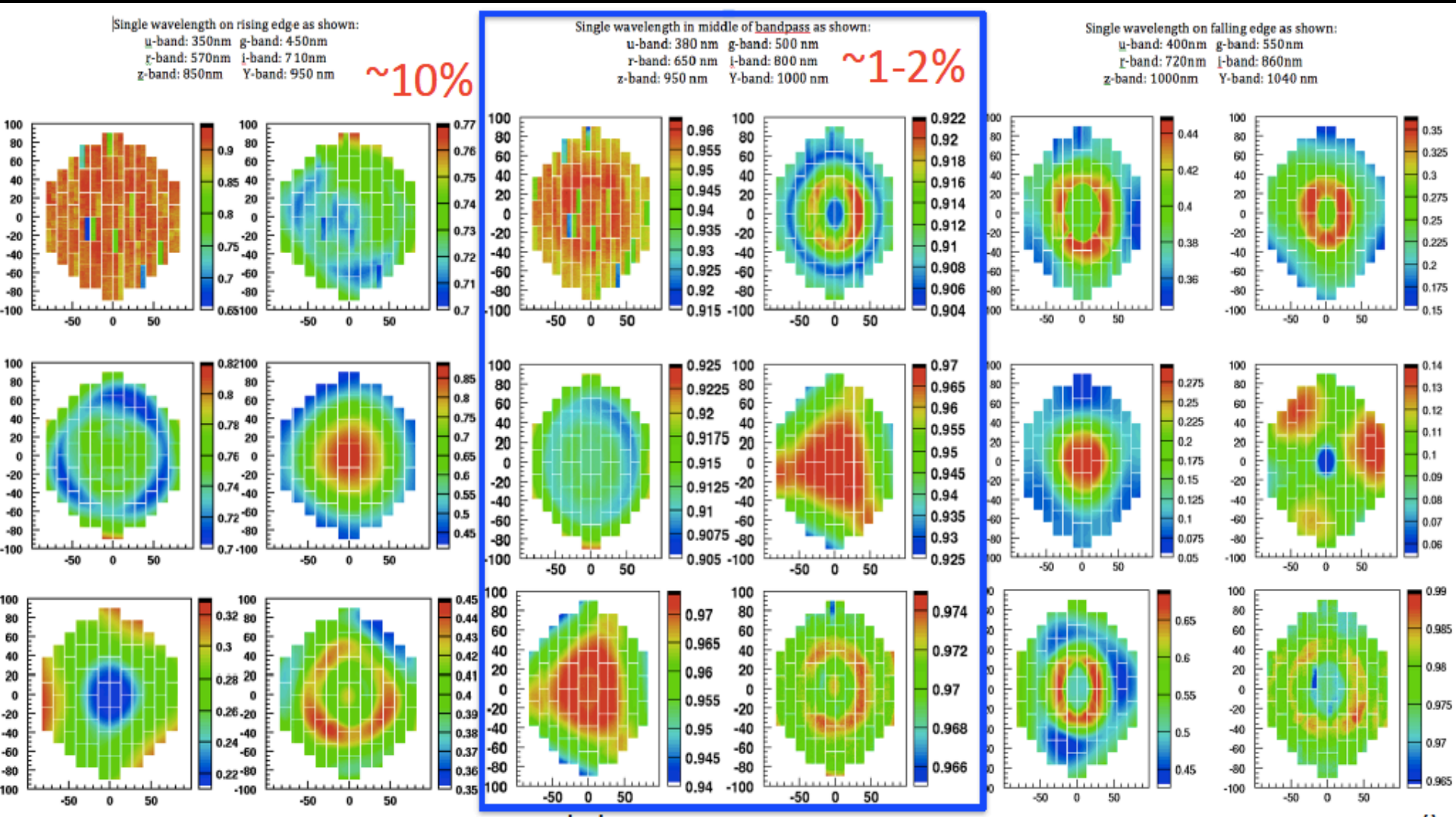




Ghosts

- CFHTLS Nicolas Regnault
- DEC William Wester

Filter edges matter



Astrometric & photometric calibration

Robert Lupton

The number of detected counts $C_{raw,b}$ from an astronomical source with flux F_ν in band b is

$$C_{raw,b} \propto \int_0^\infty F_\nu(\lambda) S^{atm}(\lambda) S_b^{sys}(\lambda)\, d\lambda/\lambda$$

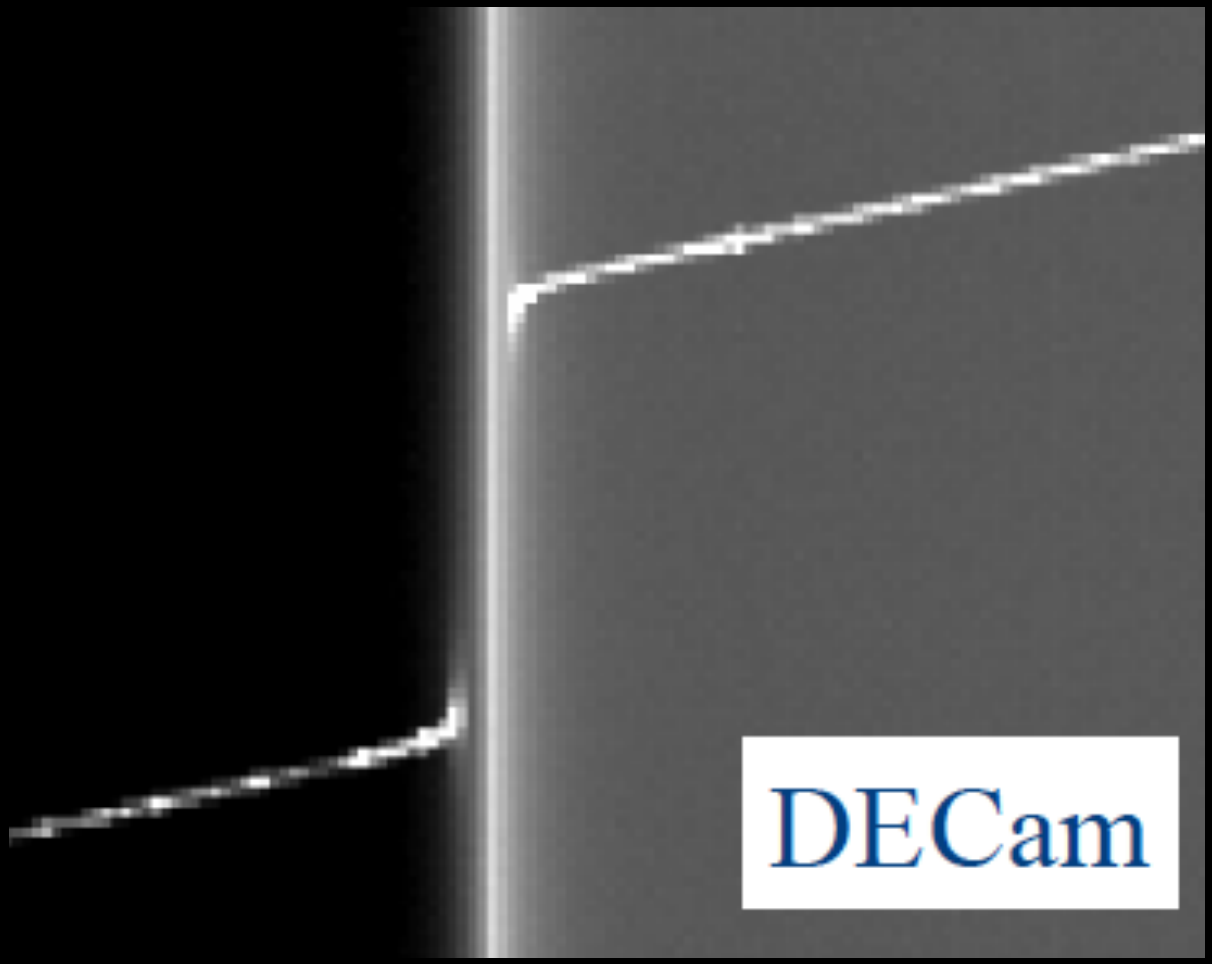
where "detected" means photons which are measured as part of the object, as opposed to those spread out over the focal plane by scattering and ghosting.
We are interested in S^{atm} and S_b^{sys}, the probabilities of a photon passing through the atmosphere and through the telescope/camera and being detected.
We need to find

$$C_{std,b} \equiv \int_0^\infty F_\nu S_{std,b}\, d\lambda/\lambda$$

given $C_{raw,b}$ (where $S_{std,b}$ is some average $S^{atm} S_b^{sys}$).

Uses clever projection system designed by Chris Stubbs

CCD characterization with muons



Merlin Fisher-Levine

- How do you characterize the uncertainty in your estimate of the PSF? Can you predict the posterior and marginalize for science?
- This will depend on how well your basis set can model the PSF.
- Quite a bit of recent work in this area (see Schneider et al. 2014)
- Need to consider computational feasibility.

Probablistic graphical model of shear inference

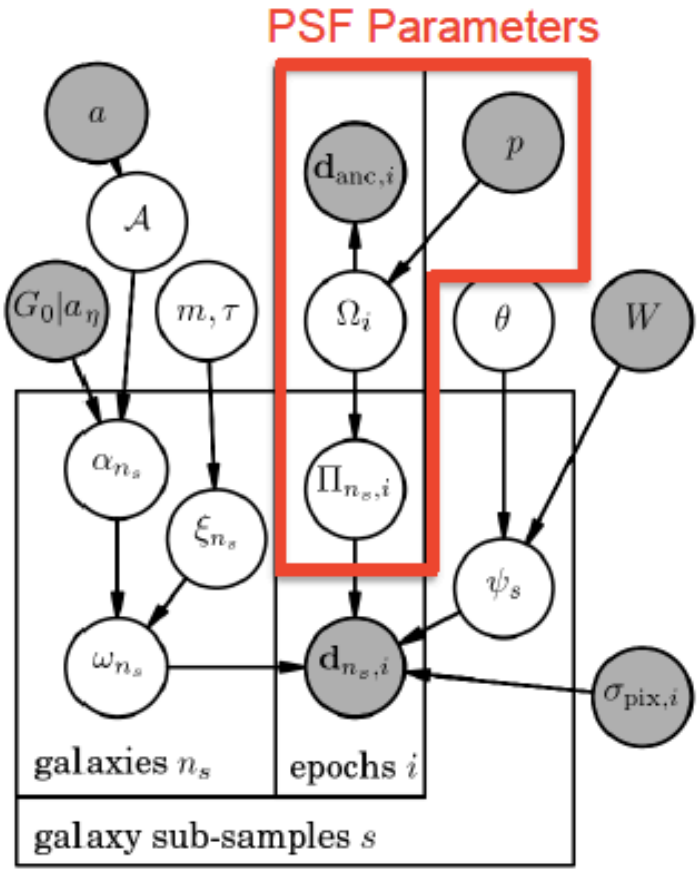
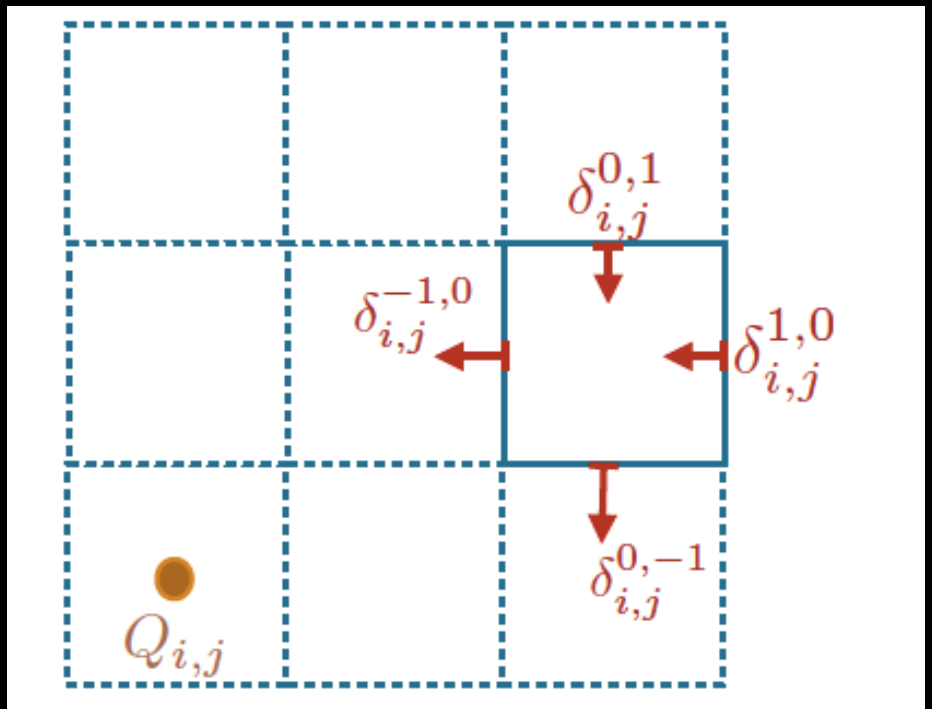
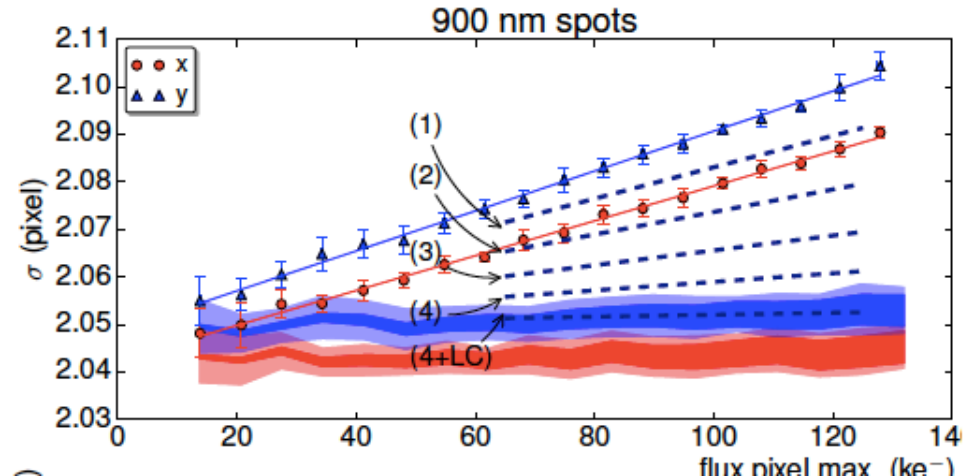


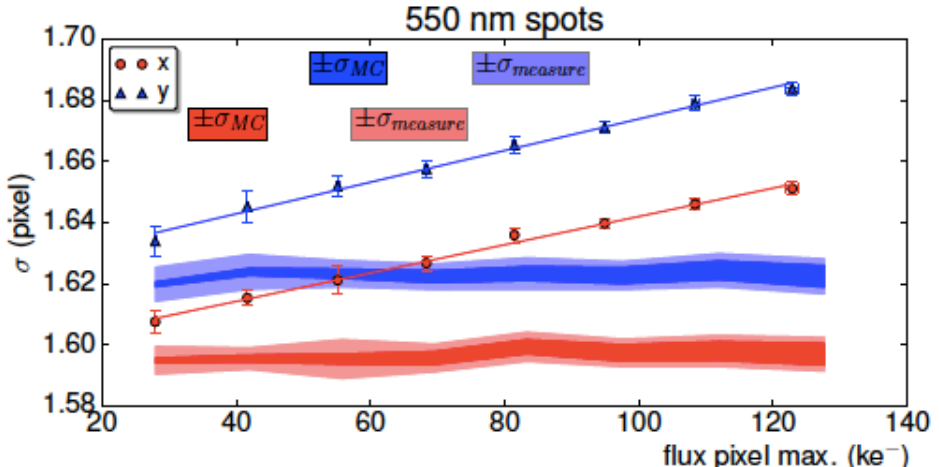
Image Credit: Schneider et. al. 2014

Electrostaic model BF effect

Augustin Guyonnet

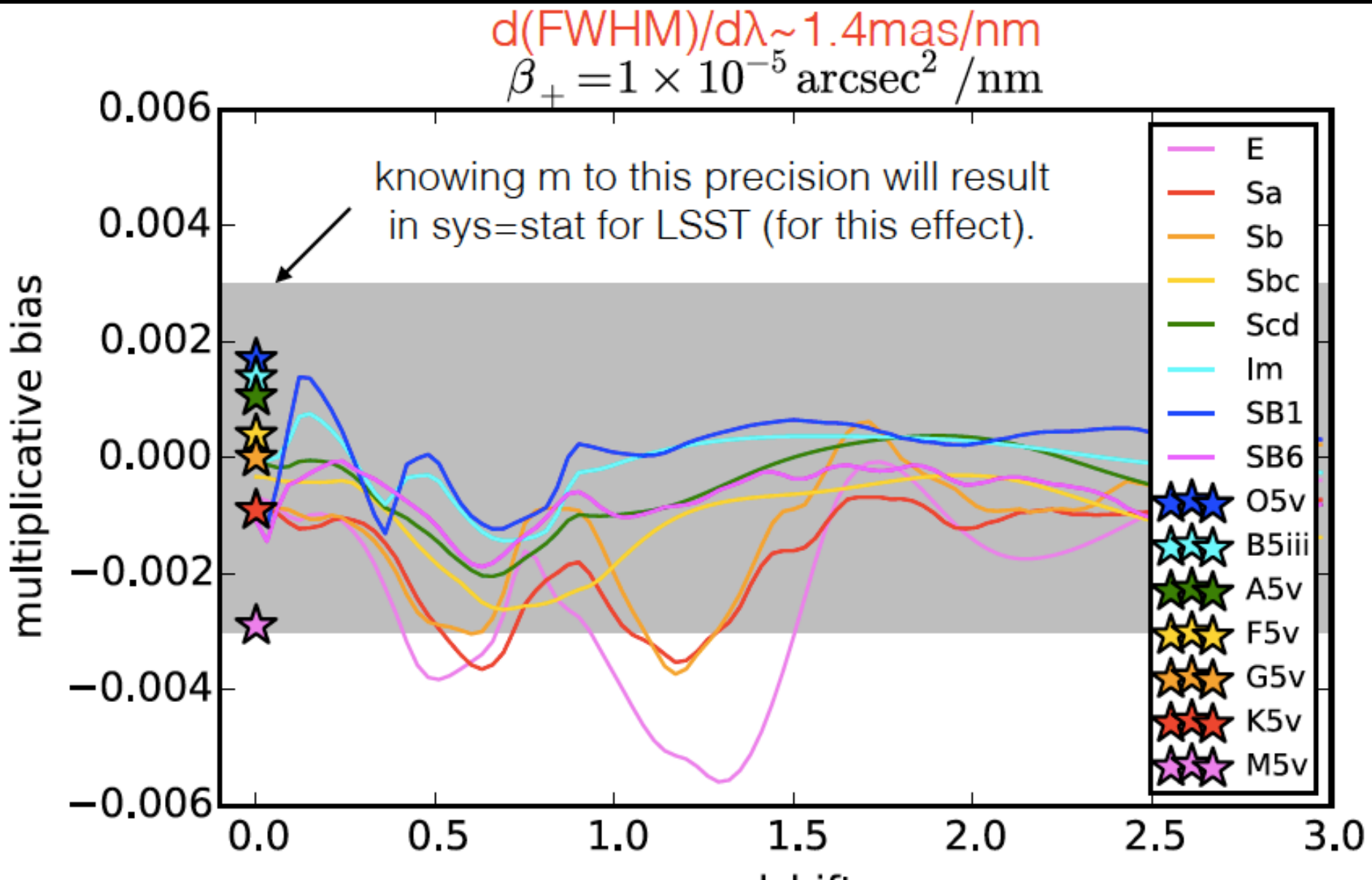






PSF chromaticity

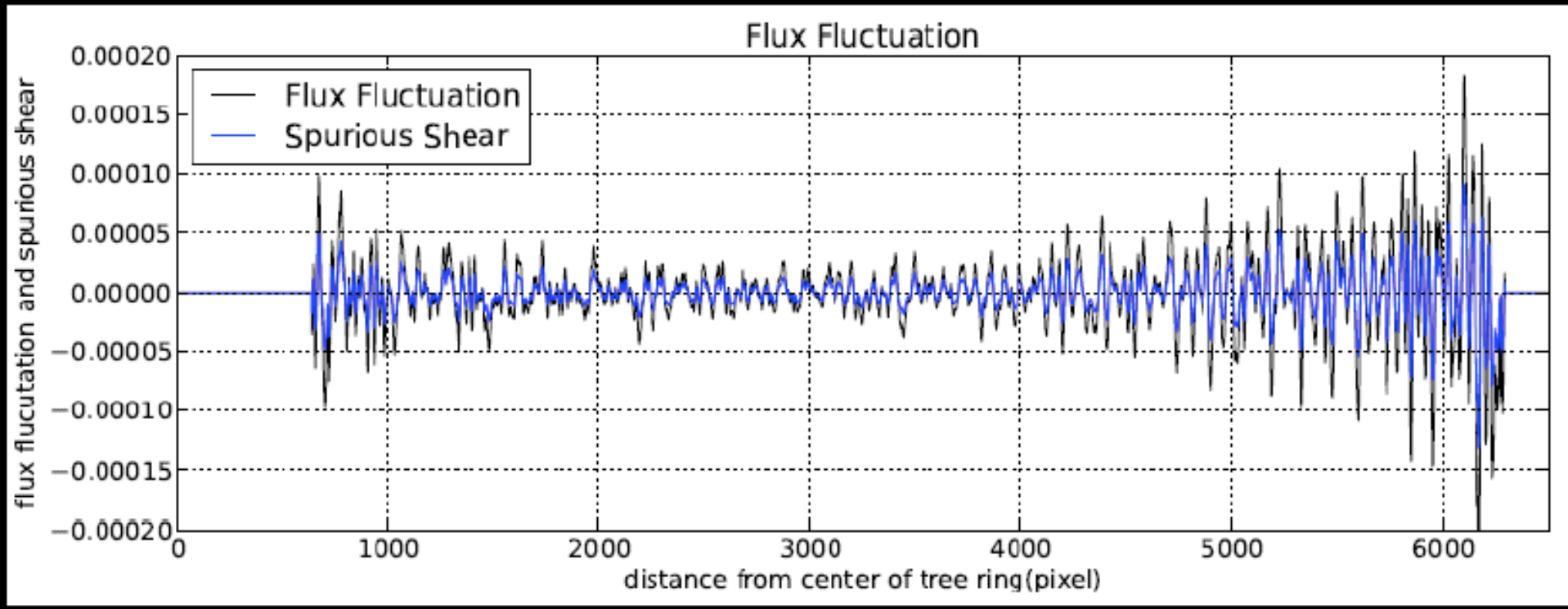
Josh Meyers



Tree ring spurious shear

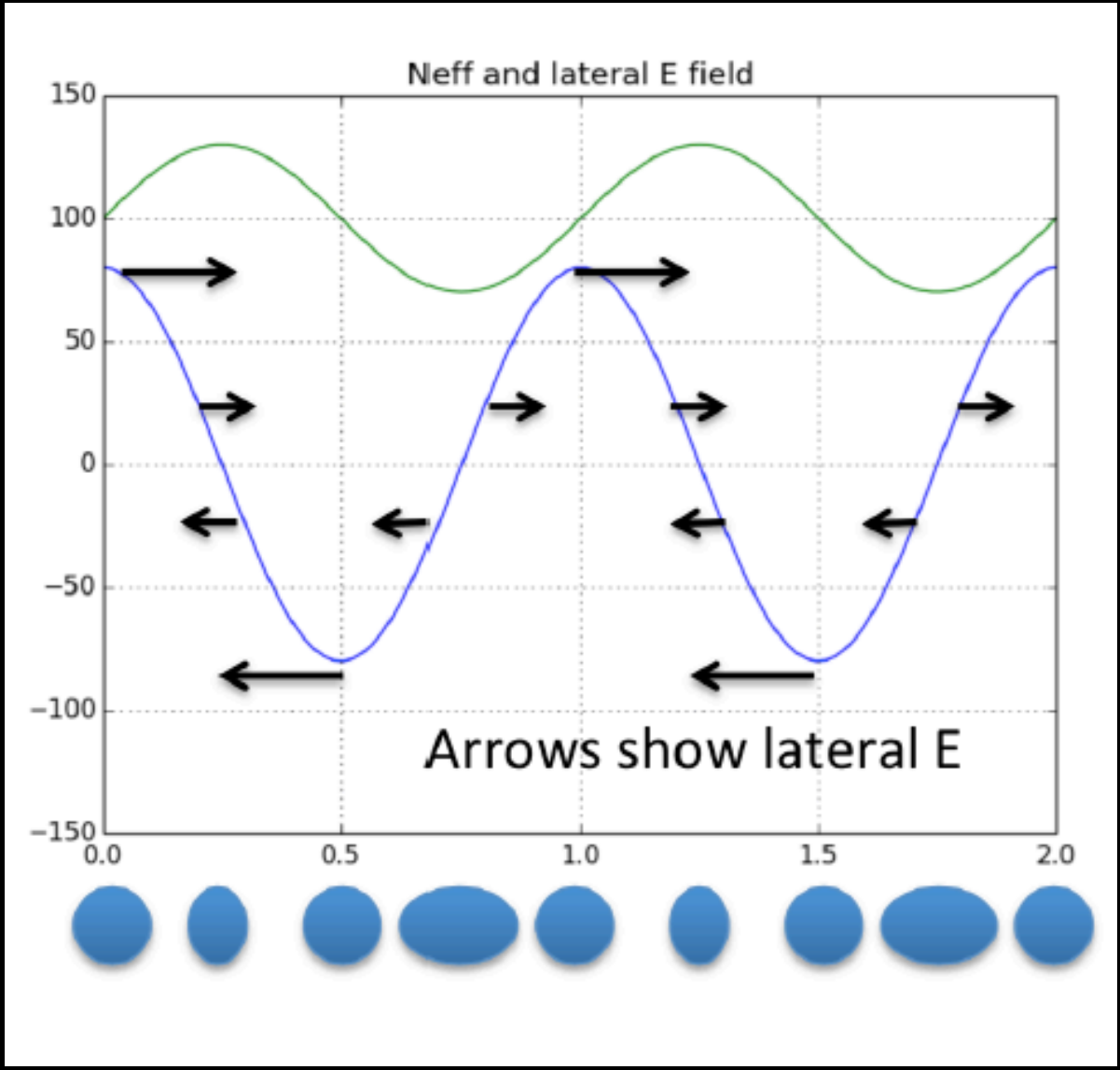
Yuki Okura

- LSST CCD2 corrected using Plazas model



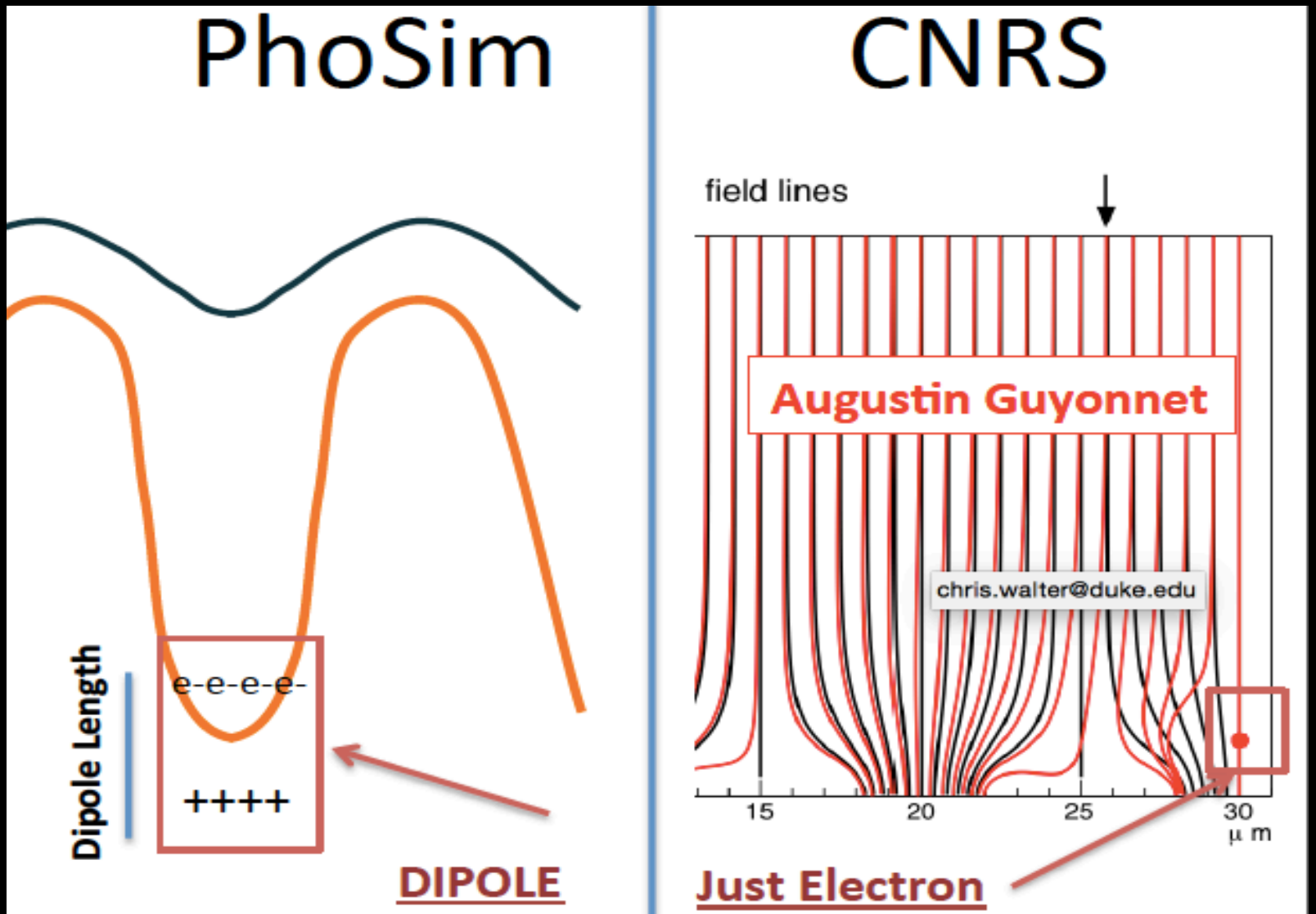
Phosim CCD simulations

Chris Walter



model as dipole or potential from gate voltage plus space charge?

Chris Walter

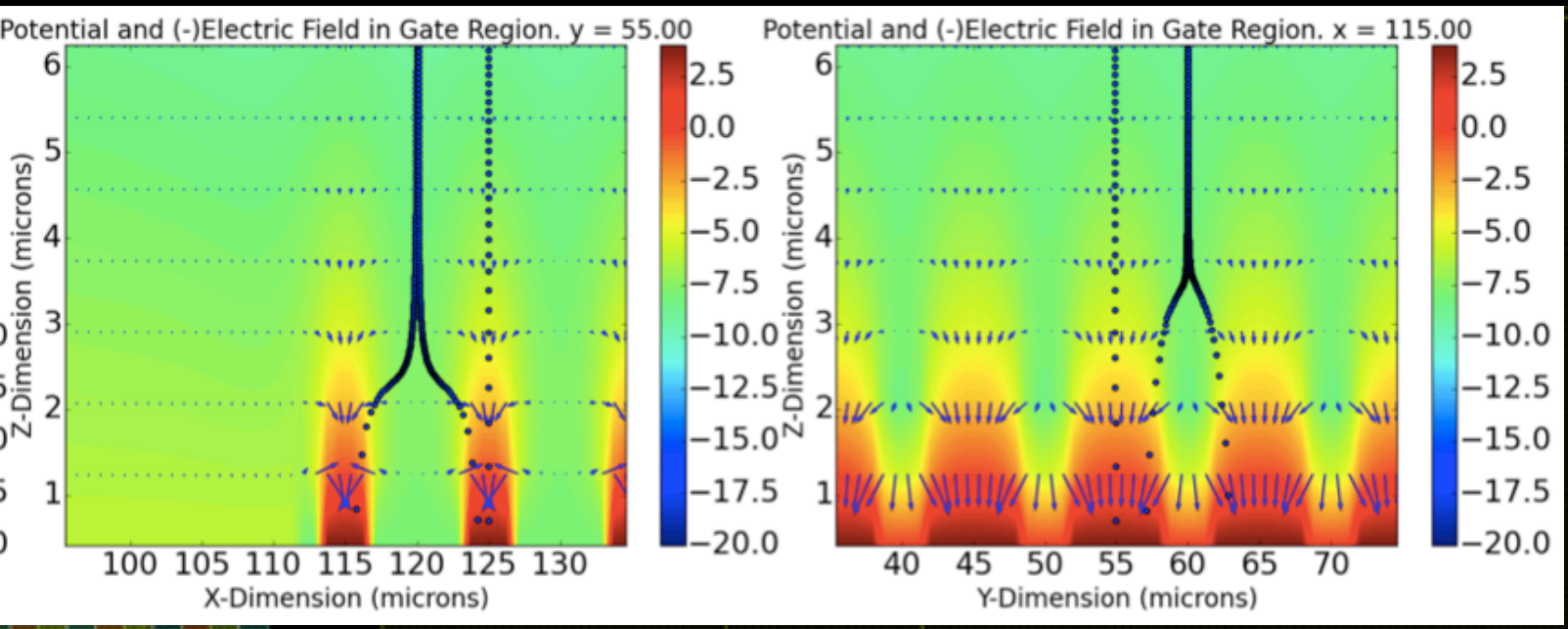


Use all information

- Many of the current efforts on CCD systematics reduction rely on observational data from telescope operations.

- We should certainly use everything we can know about these CCDs from lab measurements, taken under realistic conditions.

Use known information



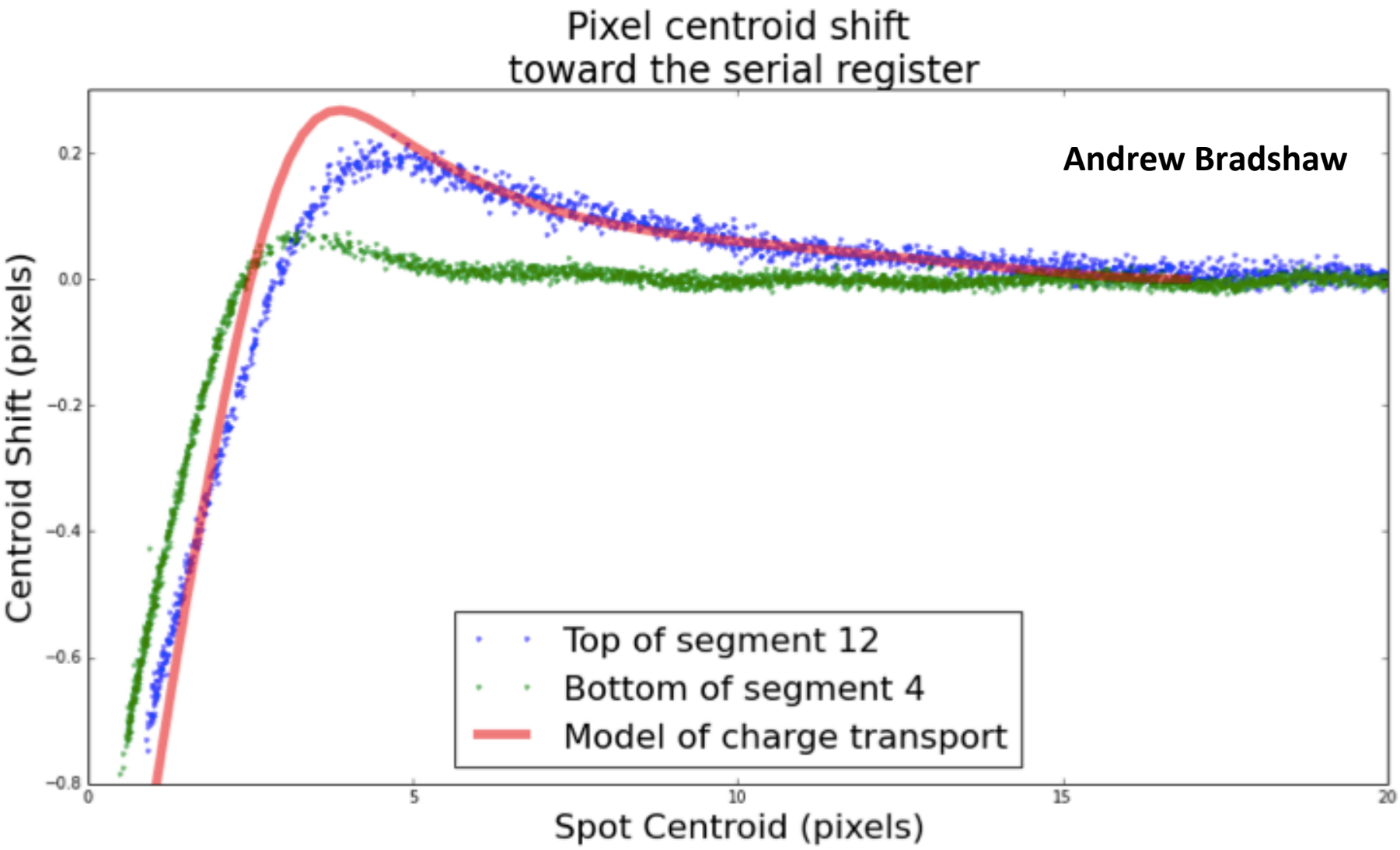
Craig Lage

Known geometry and voltages

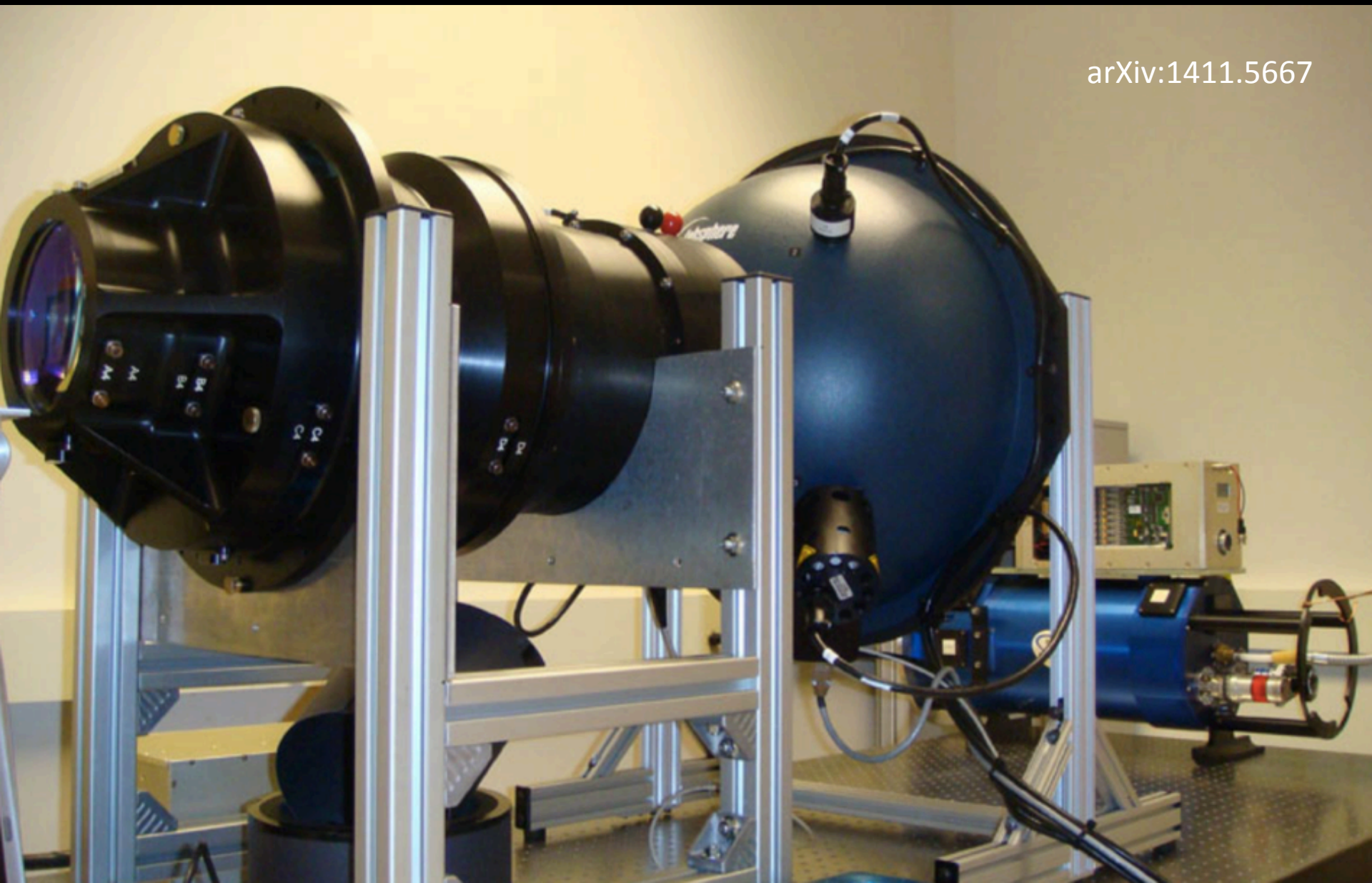
Vserial_lo

Vparallel

Use known information



LSST f1.2 beam simulator Illuminates full CCD.

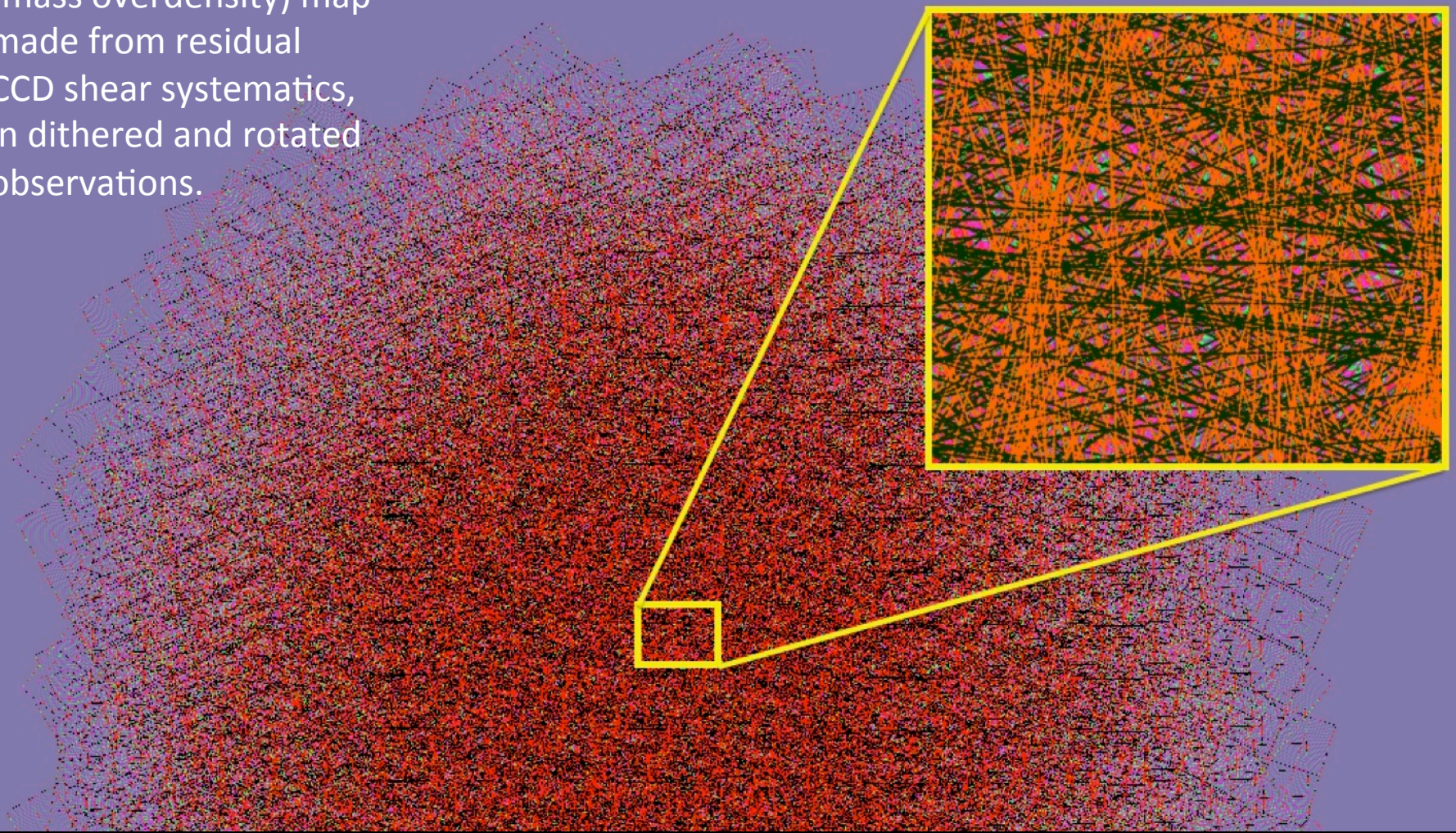


Characterization priorities

- Sub-pixel studies
- Study CCD effects vs sky background
- All vs wavelength
- Find copy of Jackson
- Further develop models of charge transport
- Explore clock and bias voltages, settling times
- Null tests; confirm removal of PSF systematics
- Undertake lab simulated observing
- Can we measure the science signals?
- What is the residual error?

What if we don't correct for systematics? Simulated LSST survey with only CCD effects on

- κ (mass overdensity) map made from residual CCD shear systematics, in dithered and rotated observations.



Two Nobel prize nominations

- Chris Stubbs: for discovery of variable electron charge.

- Steve Holland: for operation at -150K without inverting population

Most memorable comment

"Phosim doesn't have to be correct, but it shouldn't be wrong"

Robert Lupton