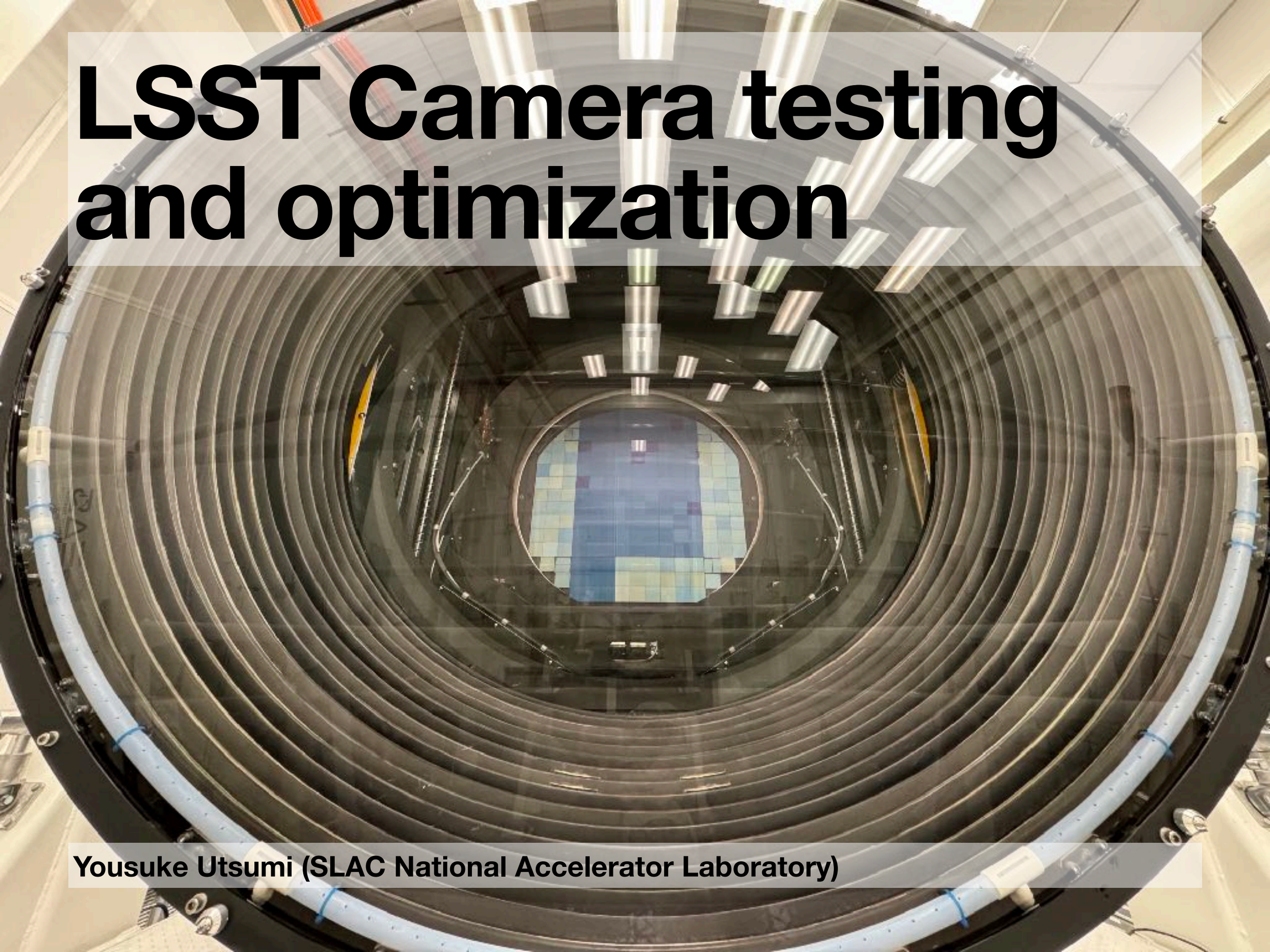
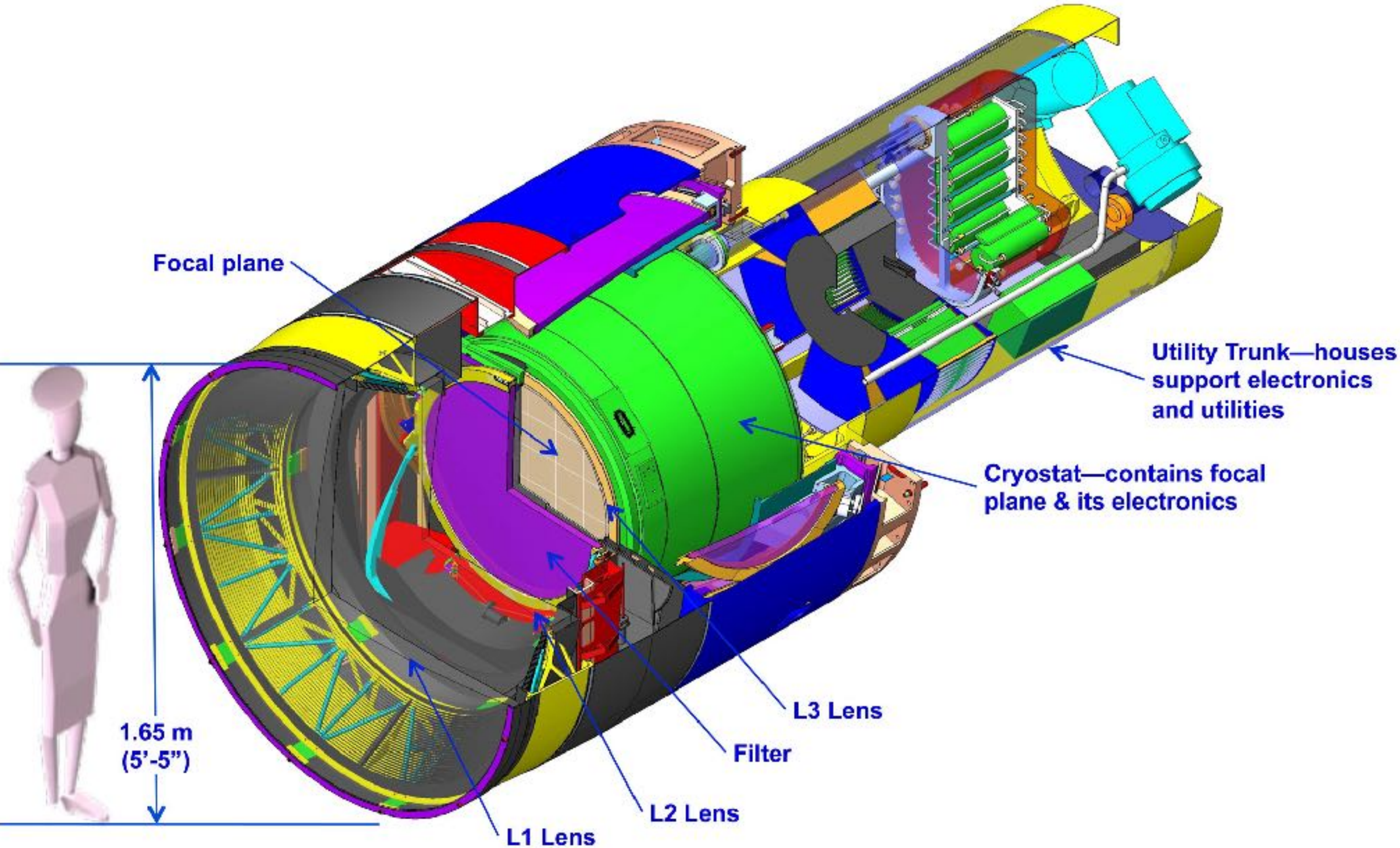
LSST Camera testing and optimization



Yousuke Utsumi (SLAC National Accelerator Laboratory)

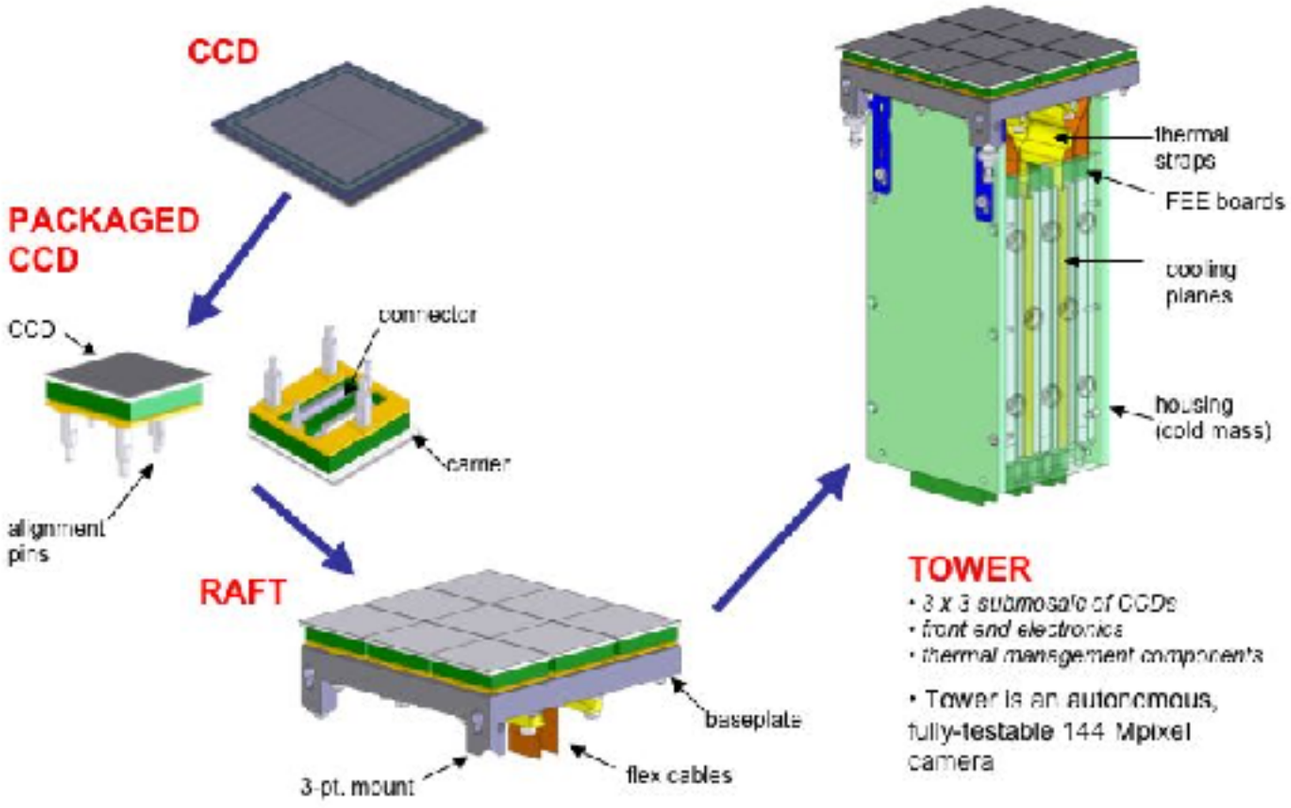
2024-1-17 © Jacqueline/SLAC

Camera being constructed at SLAC



Camera ¾ Section

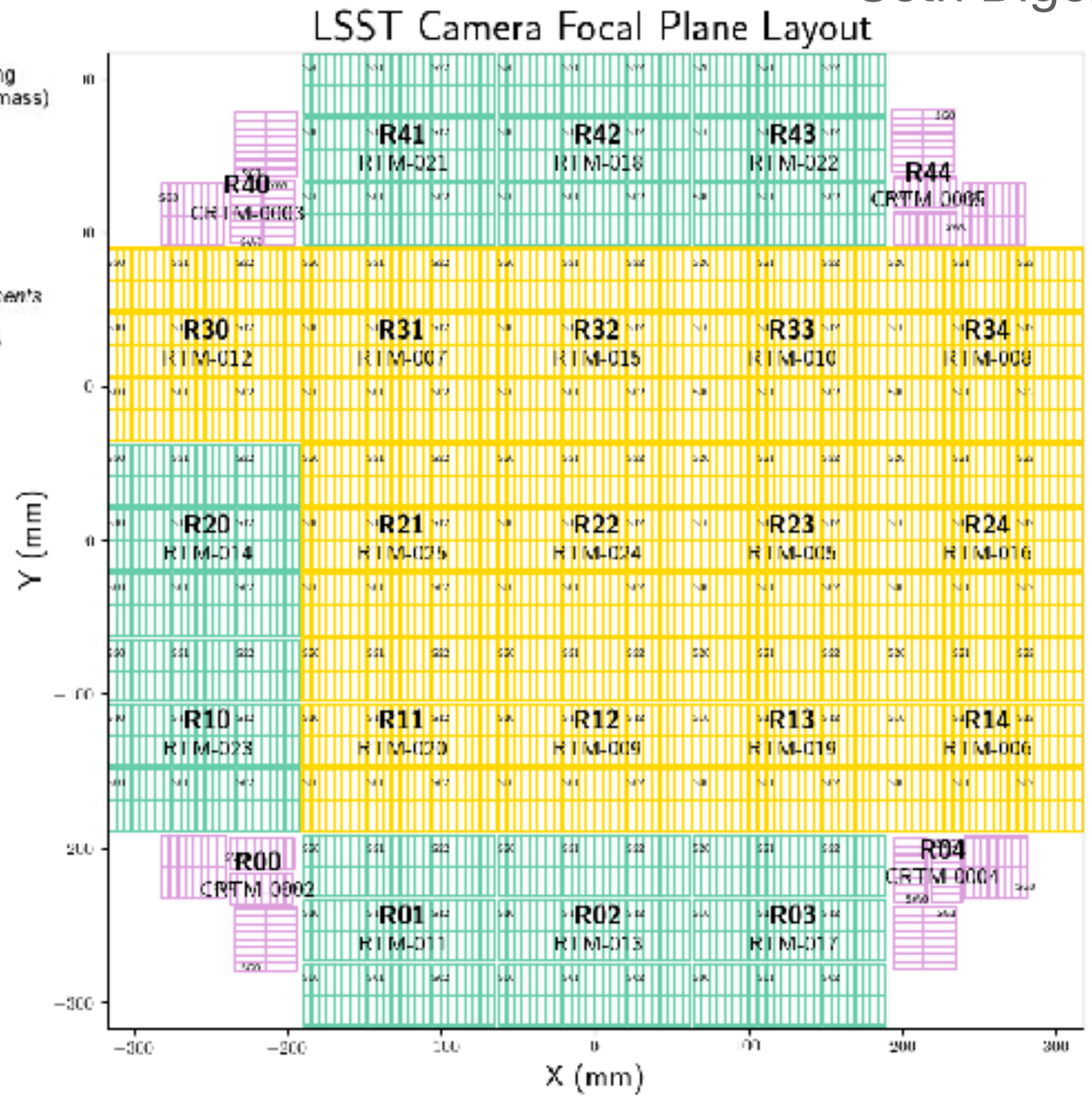
Raft & Focal plane



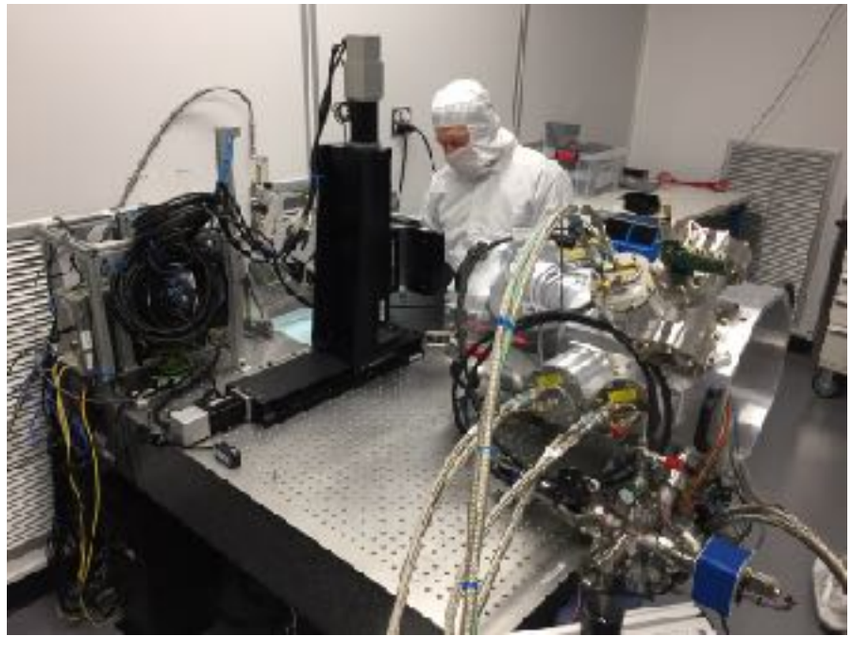
- 4k x 4k 10um² px CCD sensors segmented by 16 channels enabling 3Gpixel readout in ~2sec
- **BNL** constructed Science Rafts and **SLAC**:
  - Corner Rafts
  - Testing, Characterization, Integration
- Bias and Clock voltages and patterns are customizable

- 21 Science **Rafts**
  - E2V and ITL
- 4 Corners **Rafts**
  - ITL

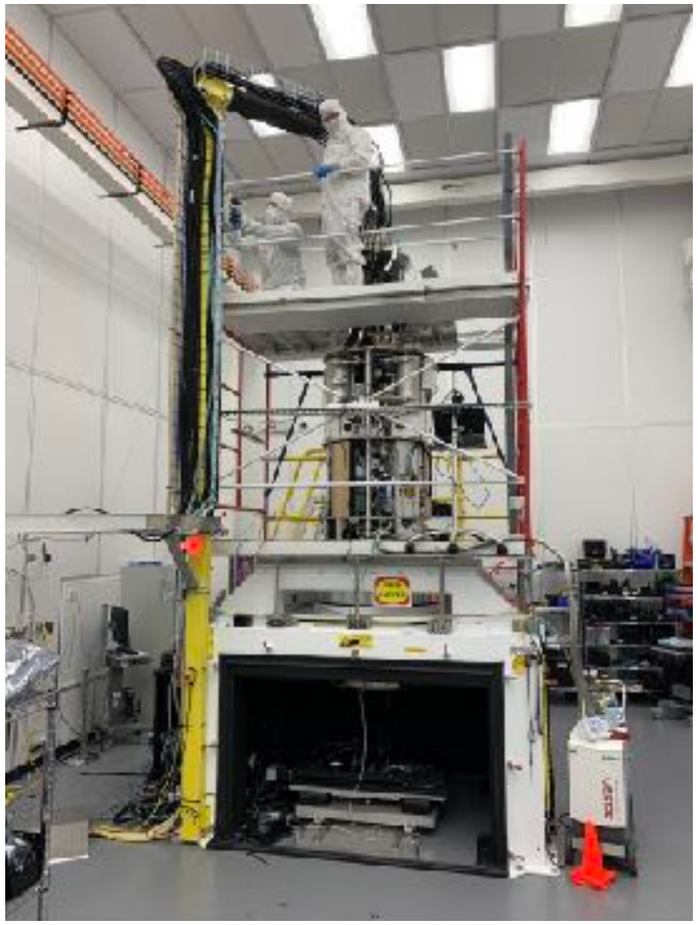
Seth Digel



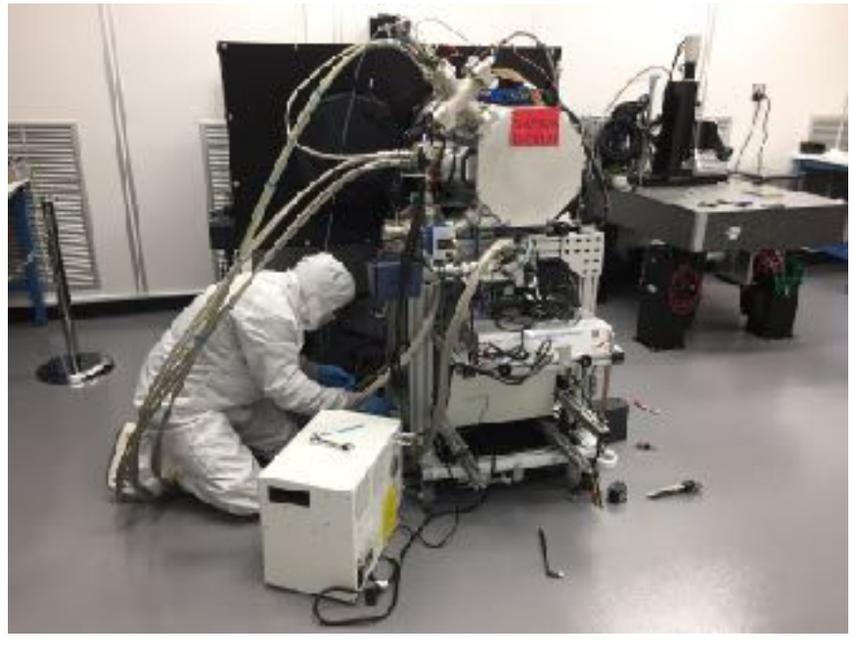
TS5 (Metrology; see Andy Rasmussen's poster)



Bench of Optical Testing



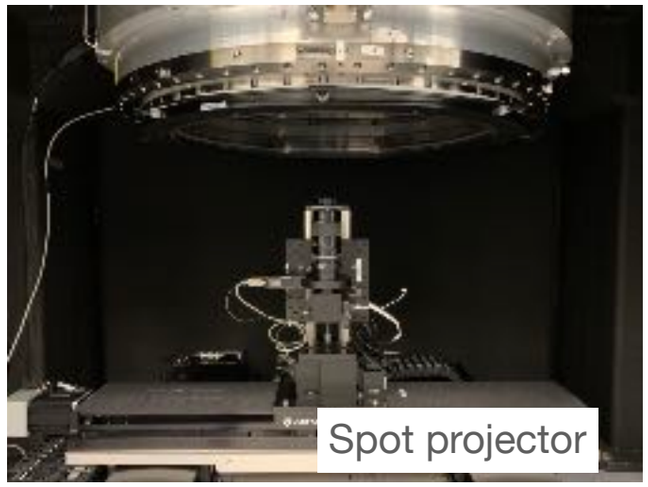
TS8 (Electro Optical Testing)

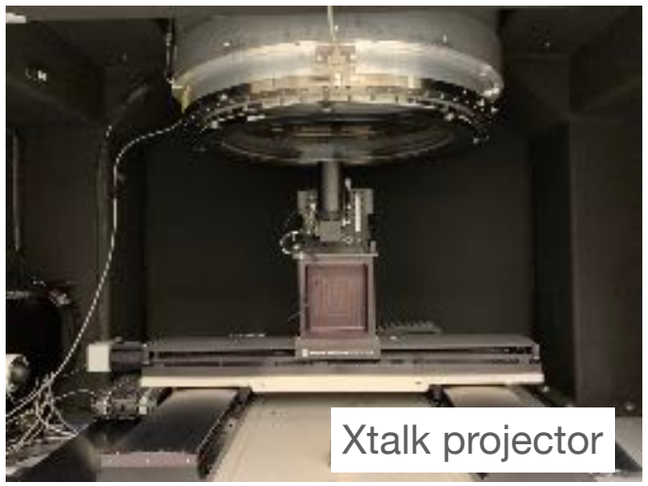


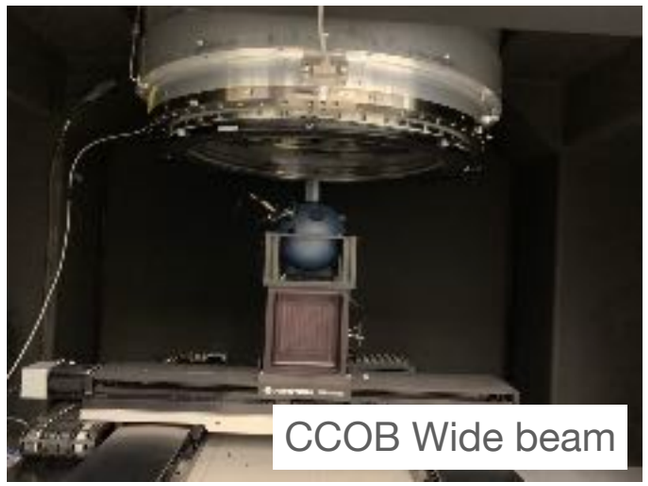
Camera Calibration Optical Bench

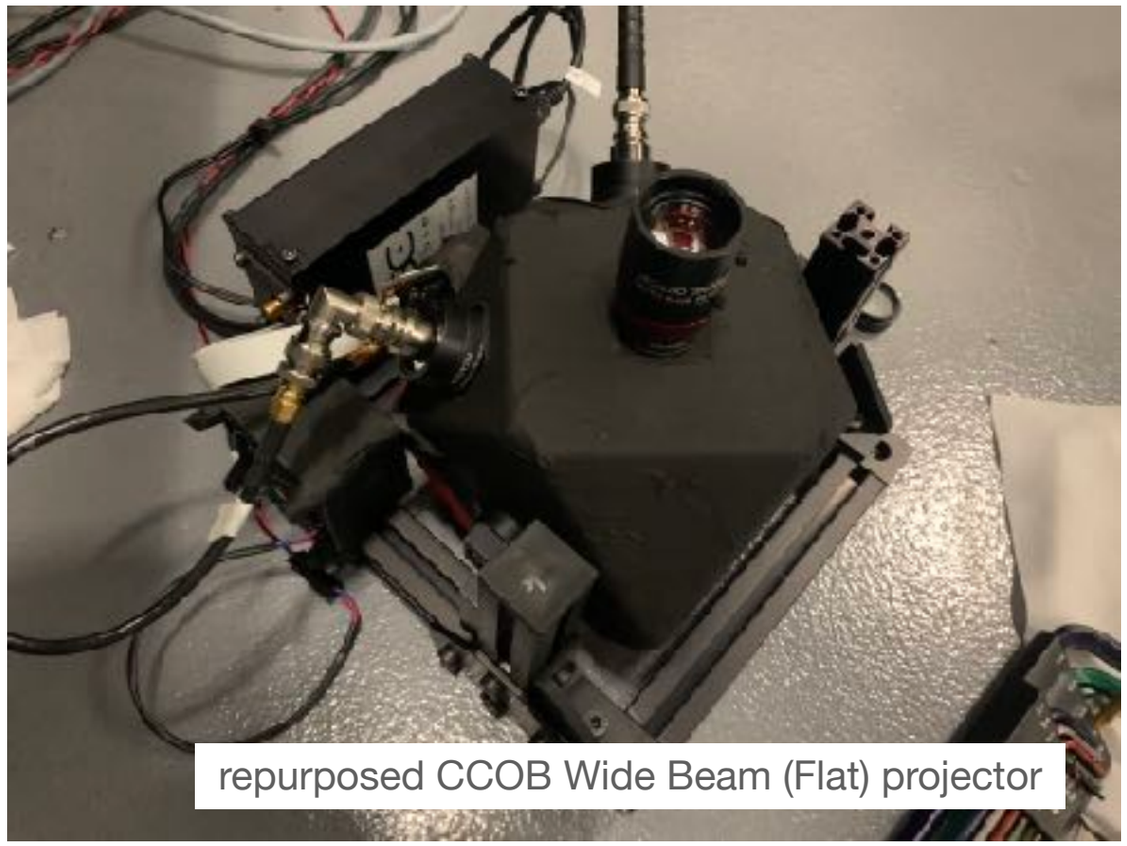
Extensive Camera testing…


Flat projector

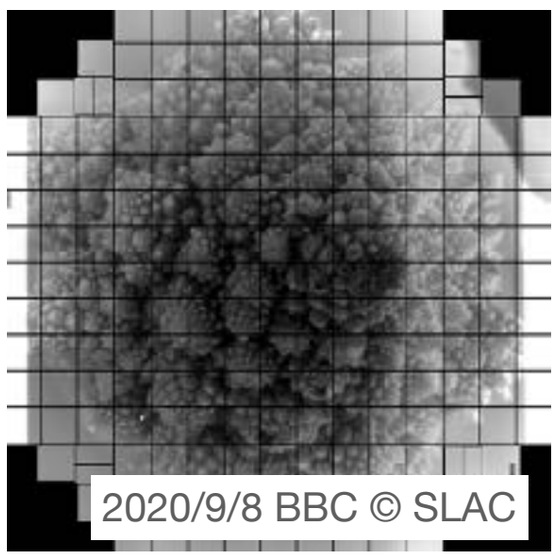

Spot projector

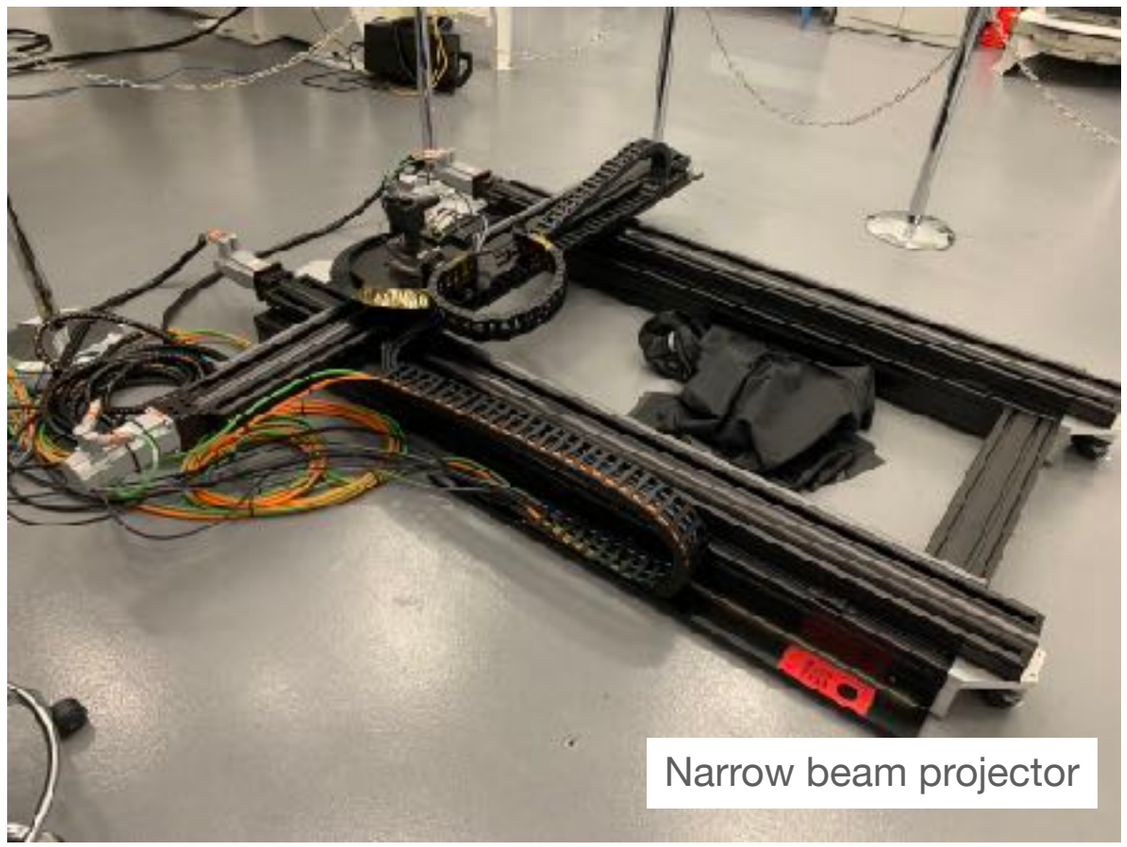

Xtalk projector


CCOB Wide beam


repurposed CCOB Wide Beam (Flat) projector

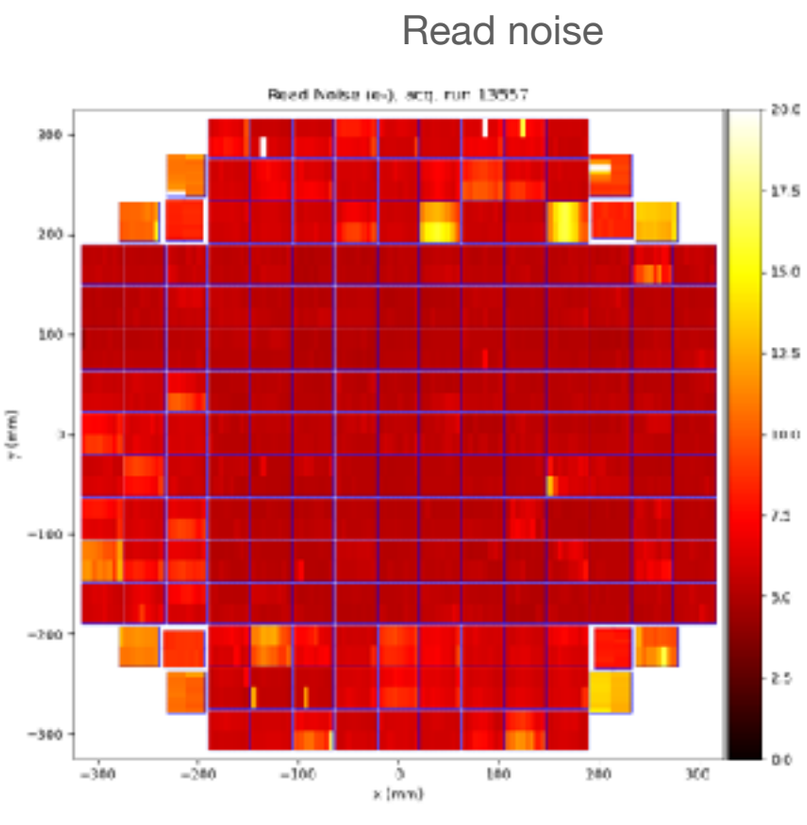

Pinhole Projector © Jacqueline/SLAC

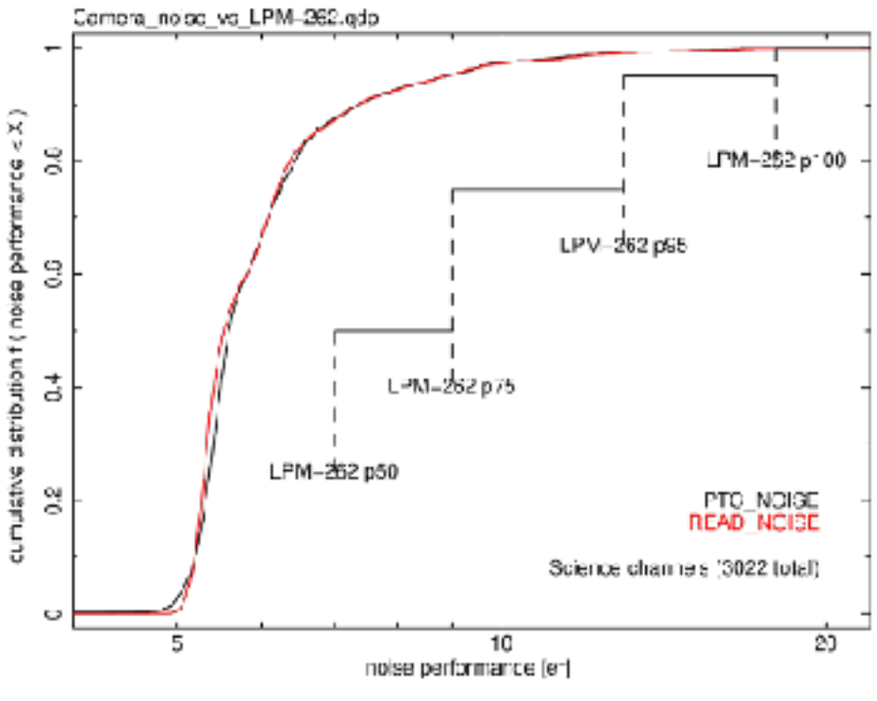

2020/9/8 BBC © SLAC

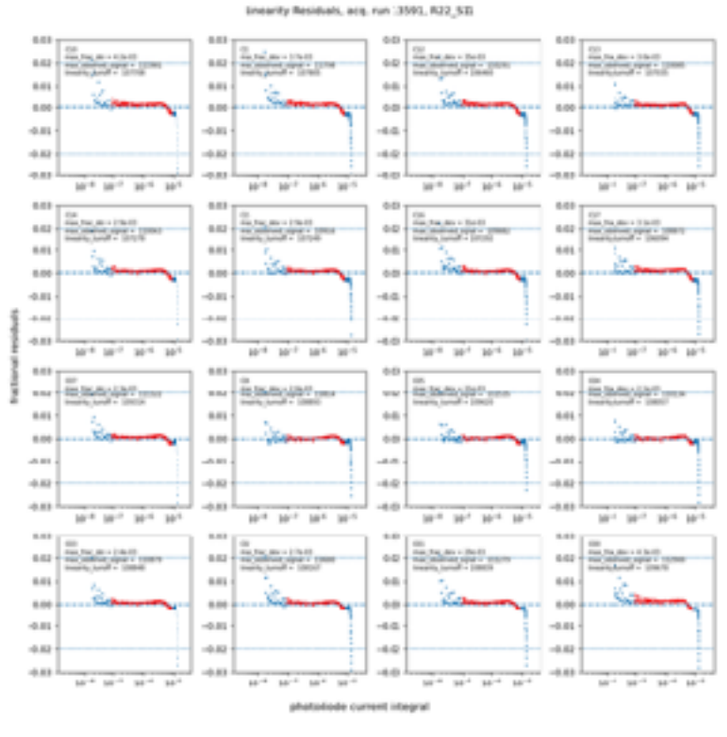

Narrow beam projector

Testing

- Noise, Dark, Serial Charge Transfer Inefficiency, Linearity, Bias structure, Defects (see Sean MacBride' poster), Brighter Fatter (see Alex Broughton's talk), Throughputs (see Aaron Roodman's poster) by wavelengths
- Jim Chiang's automated software "eotools" characterized the focal plane
  - Total ~1000 plots (20 focal plane level / 5 sensor level)

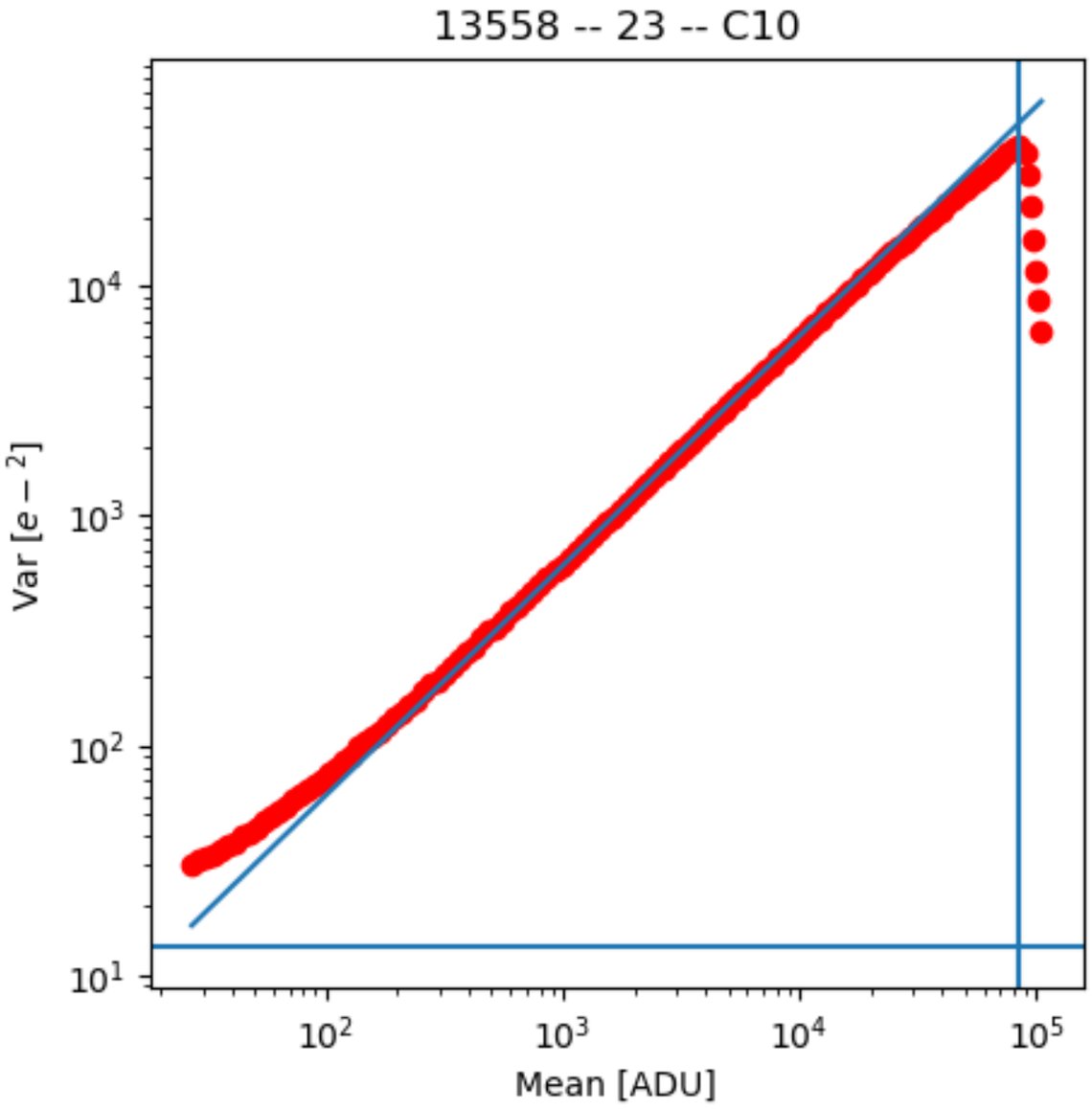




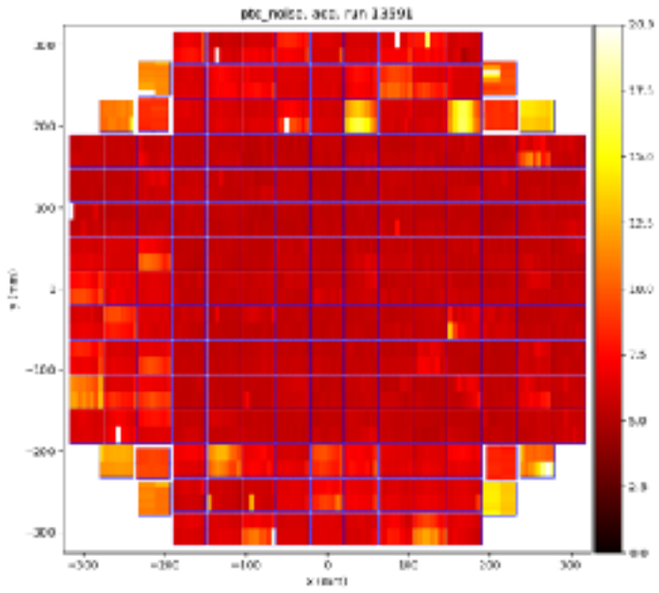


LCA-19634

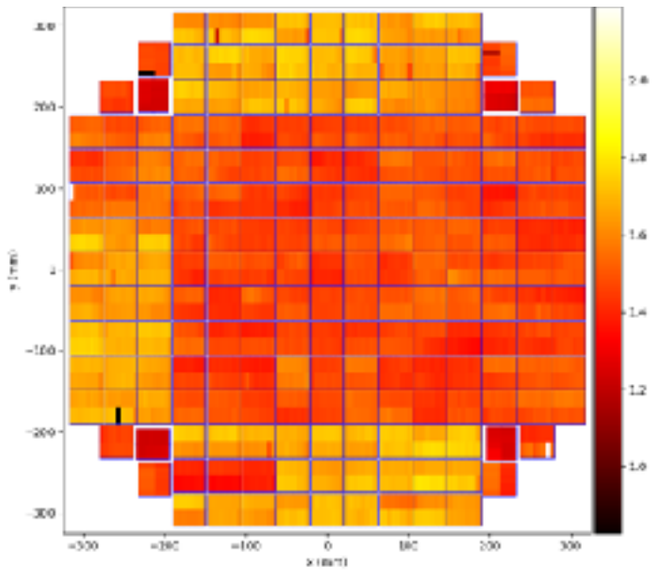
Characterizing **P**hoton **T**ransfer **C**urve



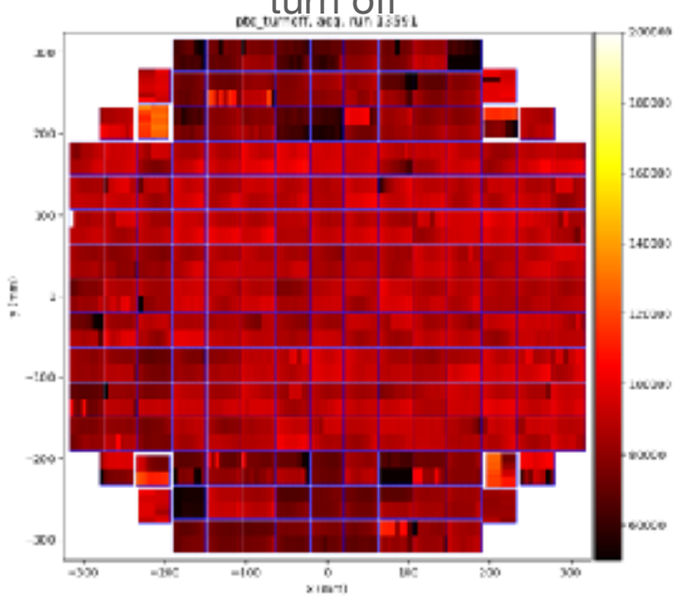
noise



gain



turn off

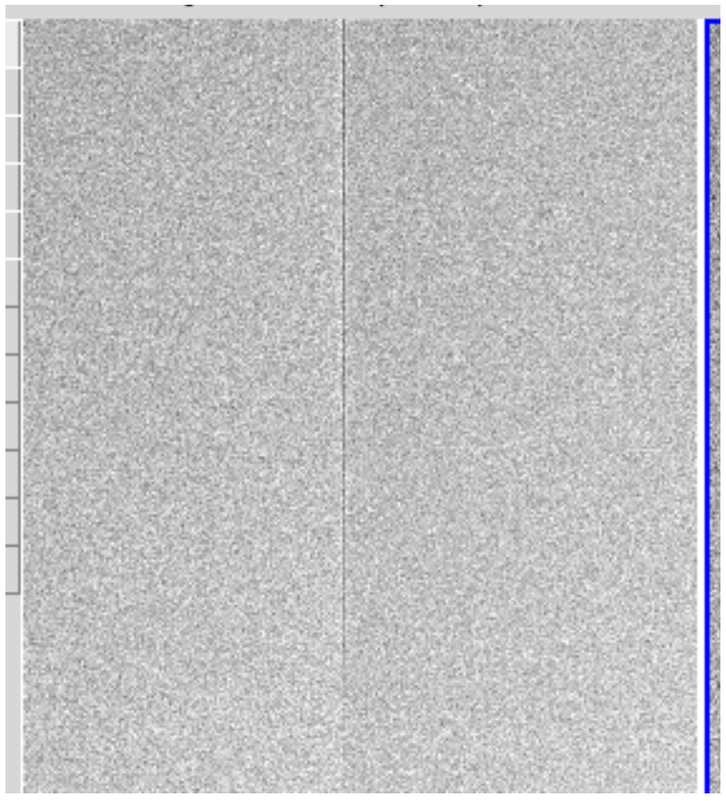


- ~400 samplings in flux
- Dynamical response of CCDs: noise, gain, “full well”
- Deviation from the straight line is “Brighter Fatter” effect (Alex Broughton’s talk)

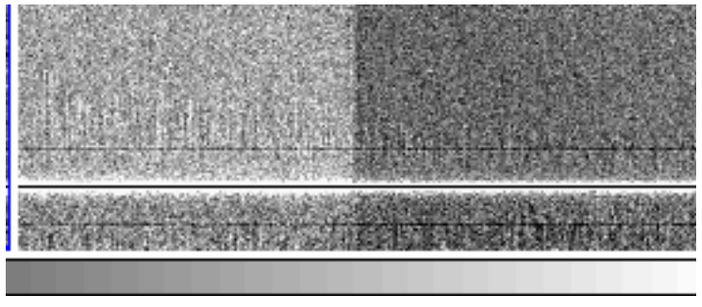
Optimization targets

Tearing (e2v)

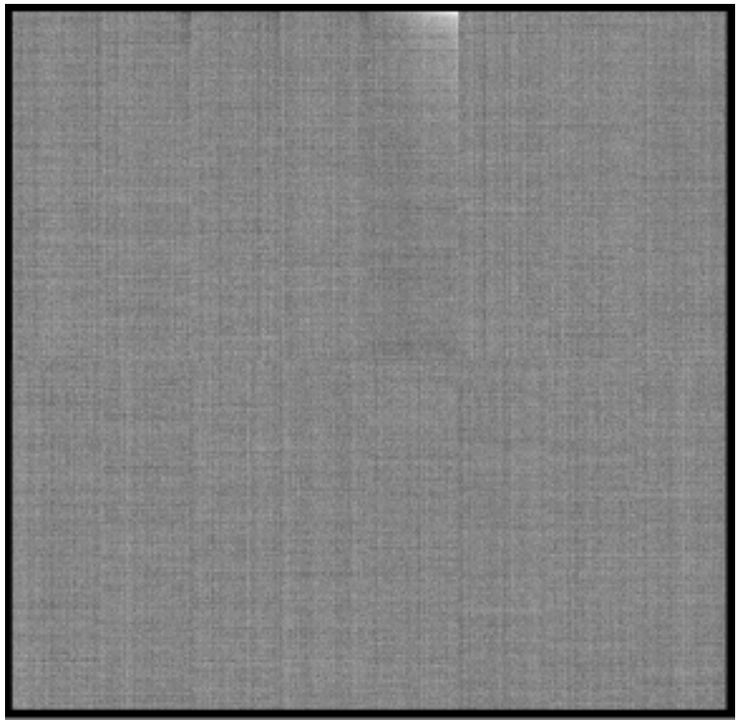
Divisadero, R13/S11



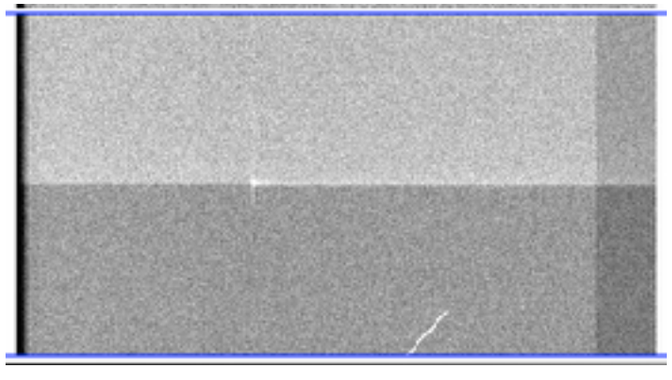
Classical, R14/S22



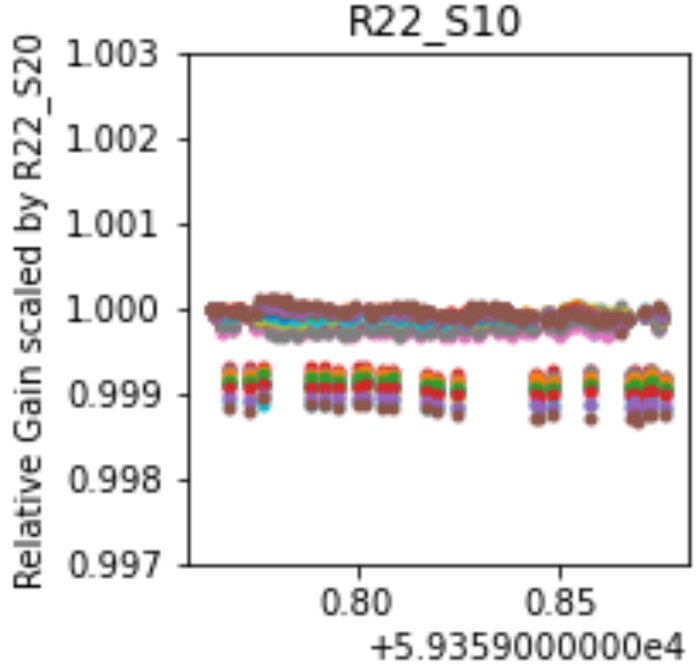
Bias instability (e2v)



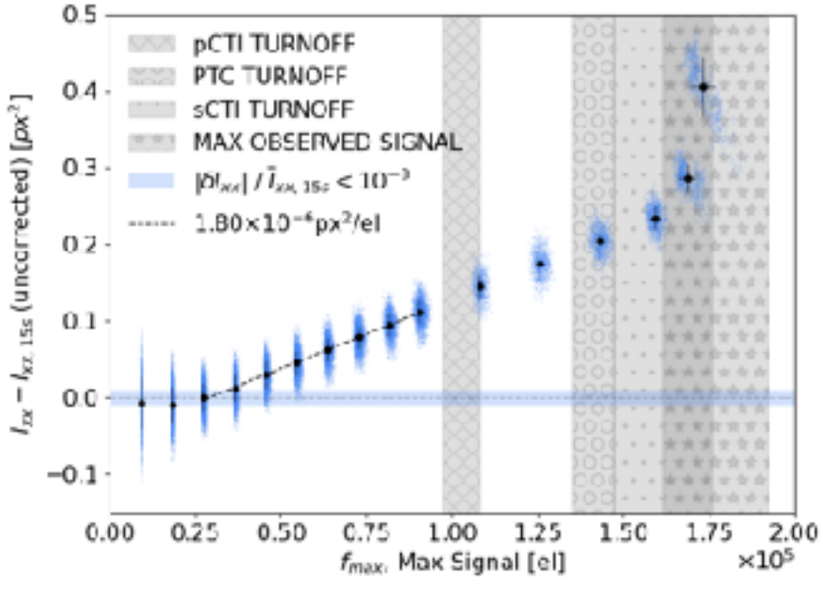
Bias shift (both)



Gain instability (ITL)



Brighter Fatter effect (both)

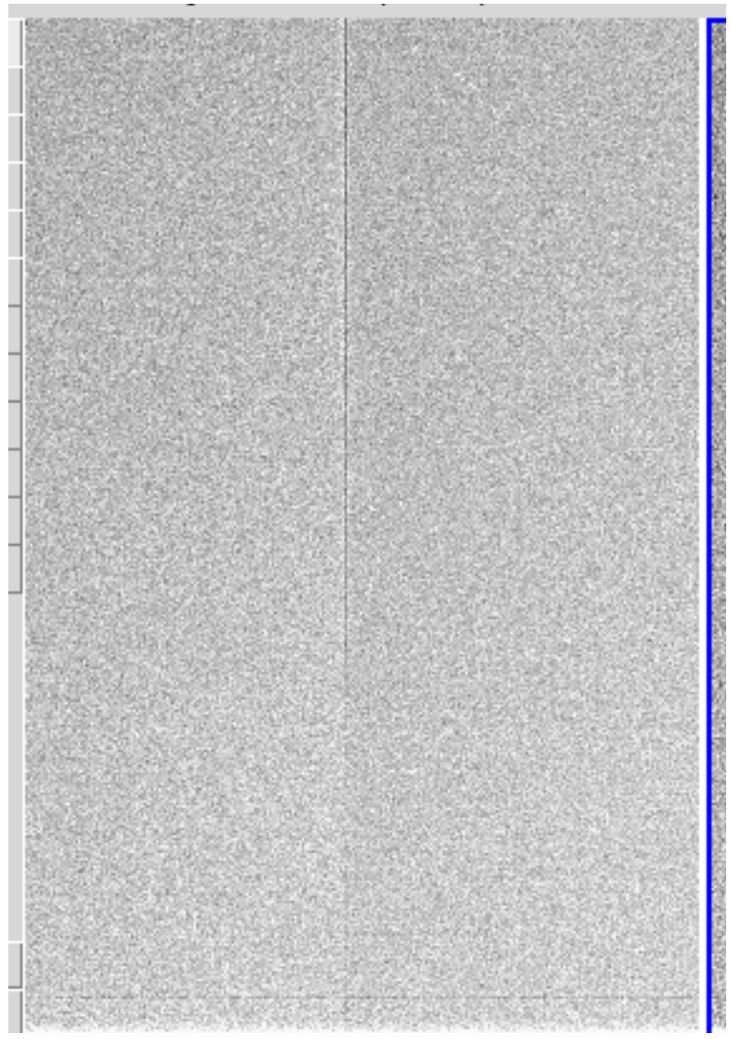


Broughton et al. (submitted)

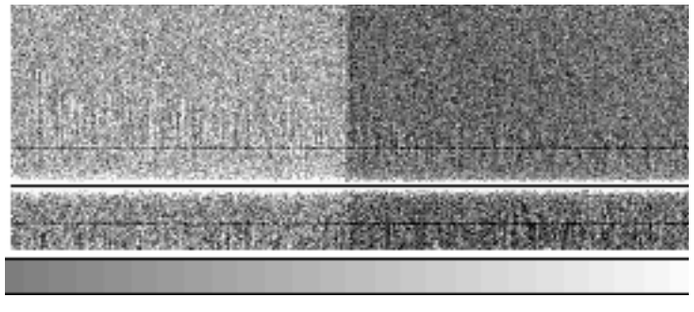
Tearing (E2V)

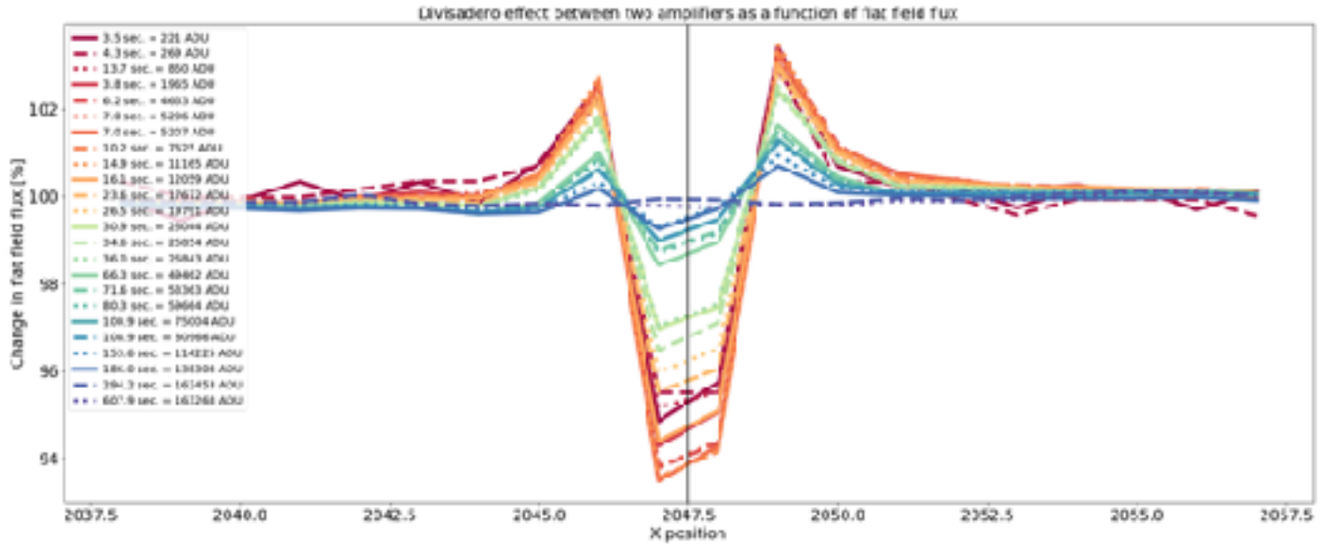
- Juramy et al. (2019) reported “Tearing” in e2v devices
- “Nonuniform distribution of holes in the channel stops between sensor columns.”
- **Mitigation**
  - Making all parallels low for 3ms before an exposure
  - Unipolar voltages (P+/P-)=(9,0)-> Bipolar voltages (P+/P-)=(3.6,-6)
  - **Row-by-row gain variation** of ~0.2%
    - Tweaking RD mitigated the effect
  - Lowering parallel clocking from 9.6V to 9.3V
- Could be mitigated by “pinning” condition

Divisadero, R13/S11

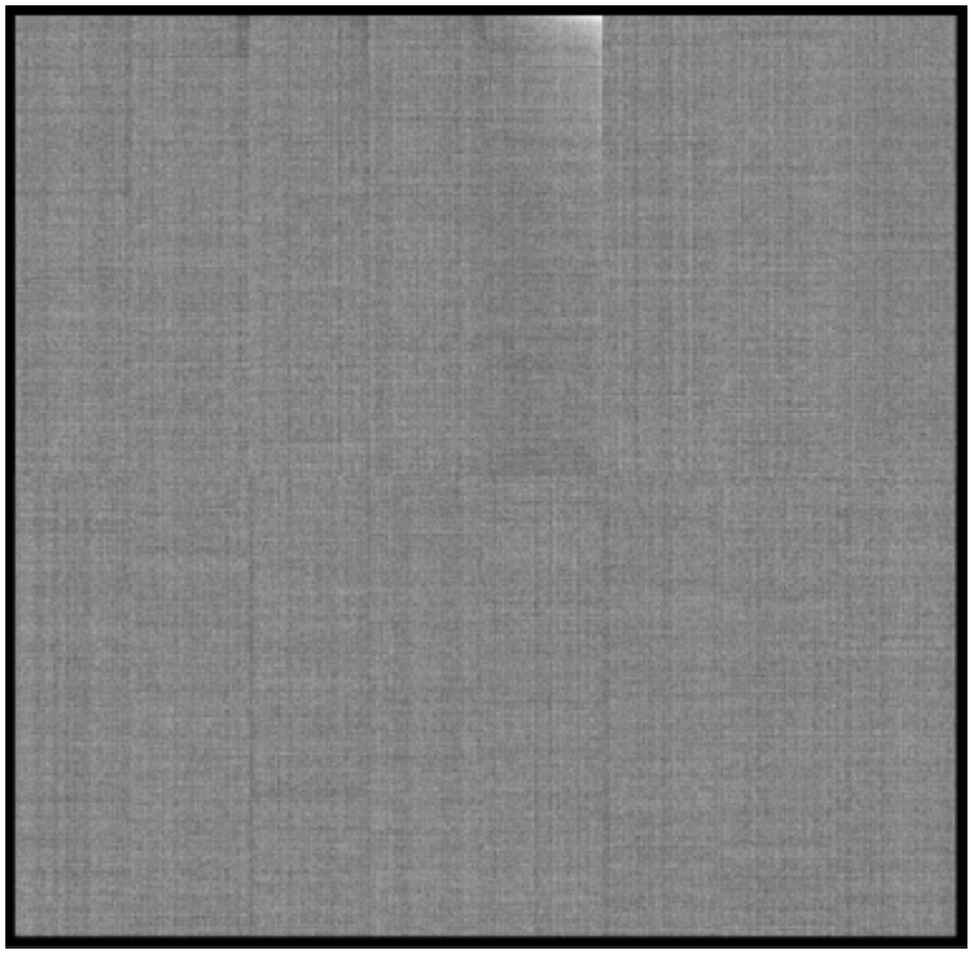


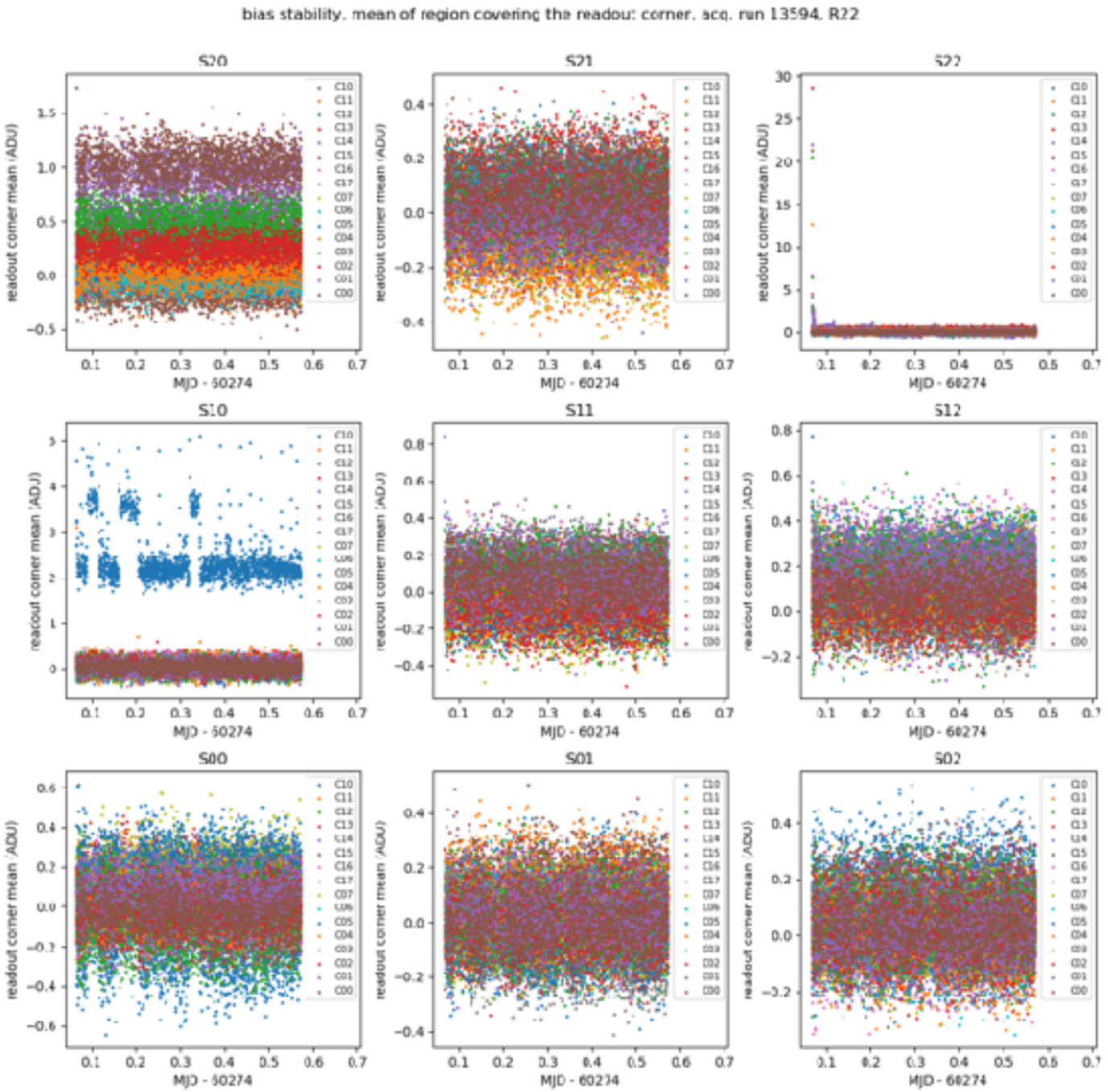
Classical, R14/S22





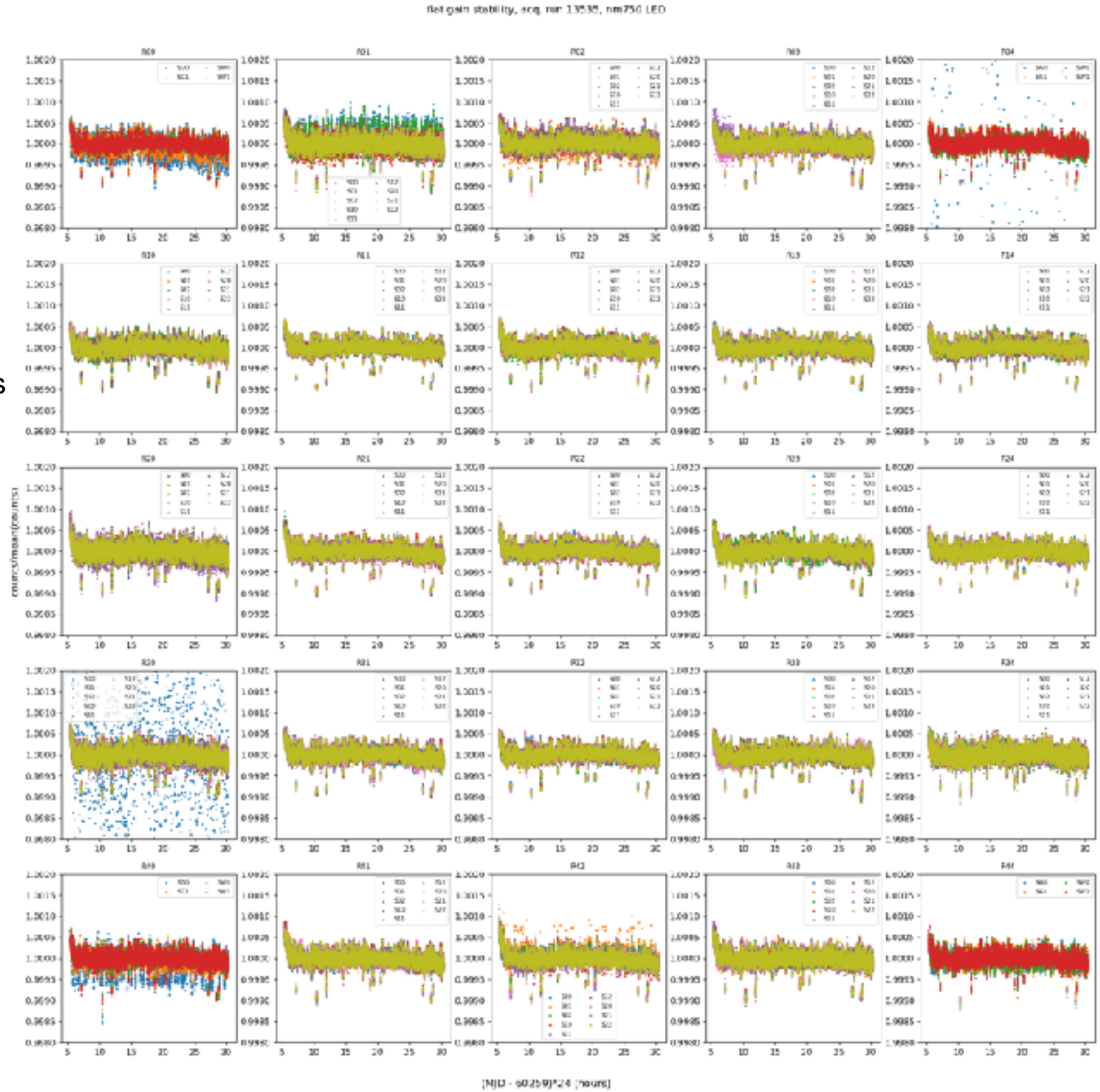
Darks with realistic cadence





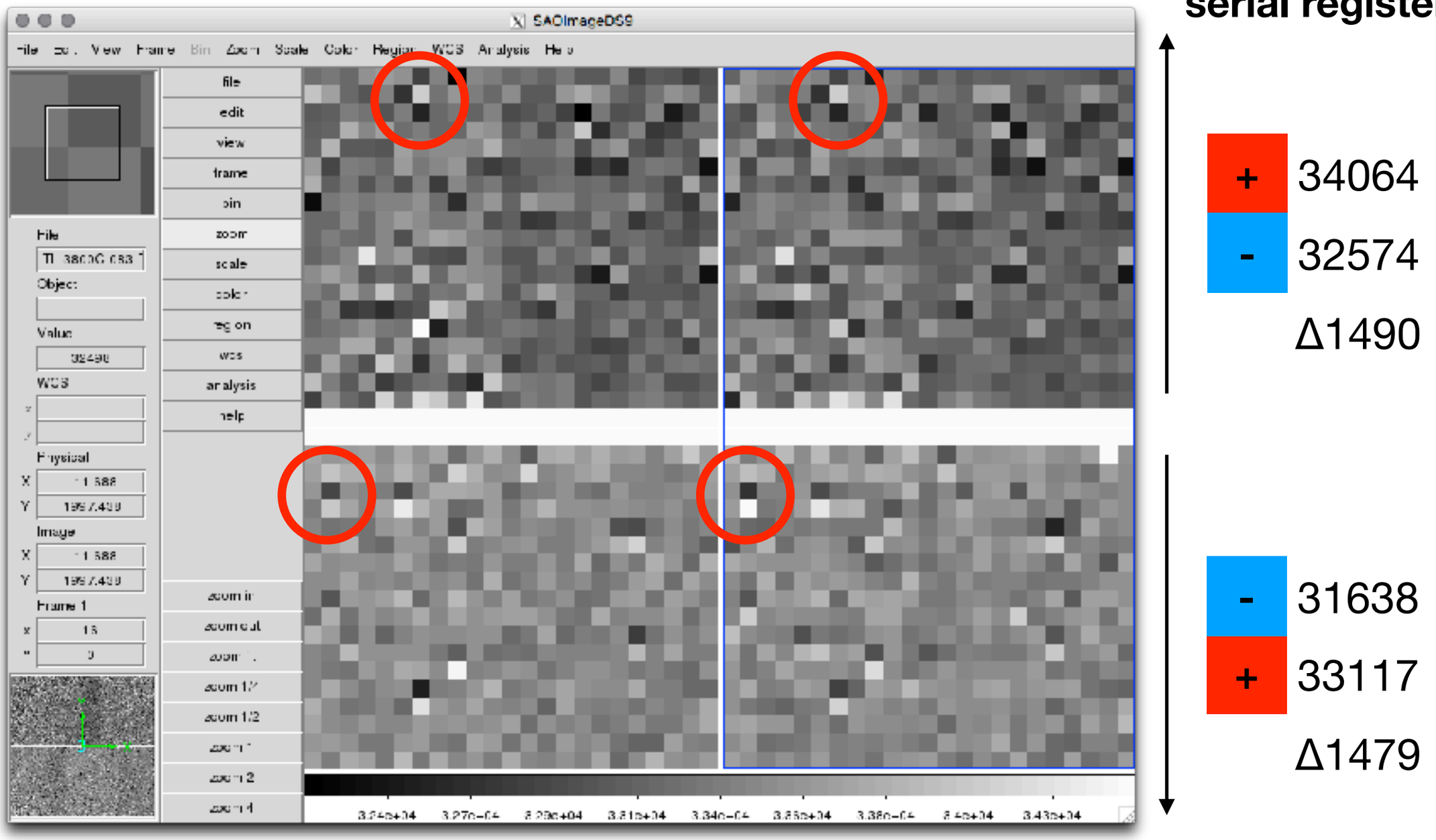
- ~1800 darks were acquired
- A few ADU bias instability at the readout corner is present
- No clear driver have been understood

Gain stability (ITL)



- 1130 images were collected over ~24hours
- Stable within 0.1% over 24 hours
- dG/G ~ 0.06%/degC
- The cold plate temp is very stable
- Tweaking OD (one of bias voltages) improved gain stability

Dipoles (ITL)



serial register

\+ 34064

\- 32574

Δ1490

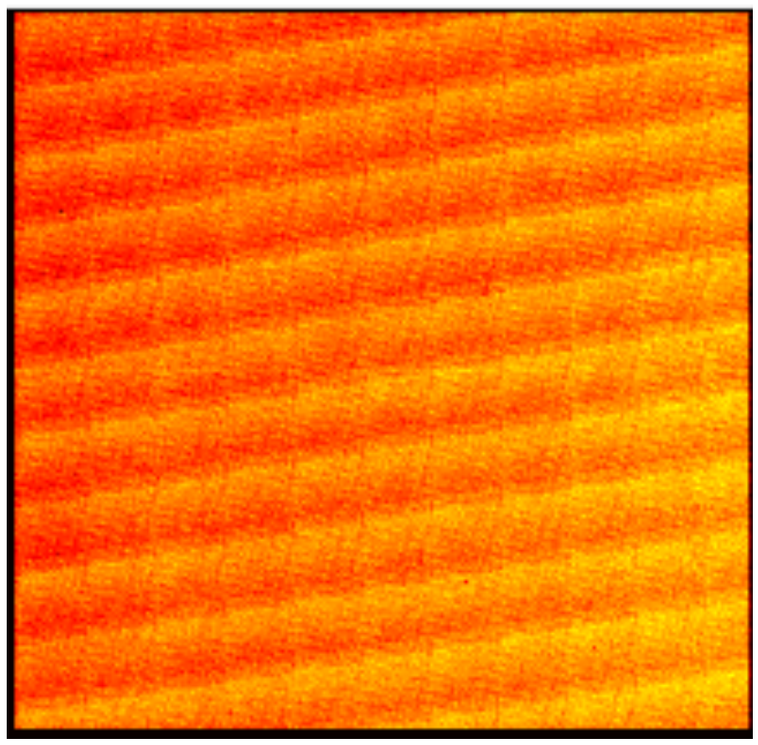
\- 31638

\+ 33117

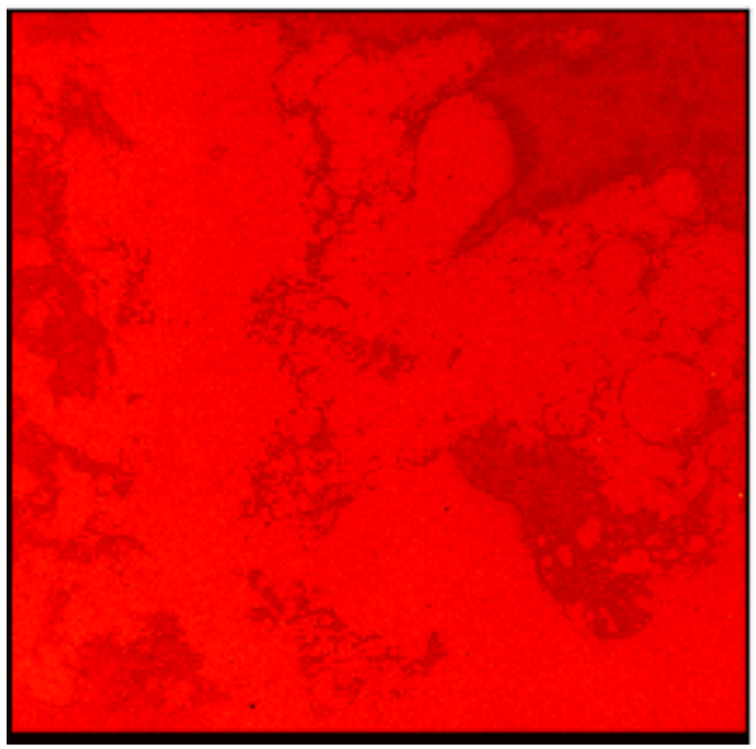
Δ1479

Changing the number of Hi parallel phases during integration removed this
Charges stuck between low phases could explain this effect

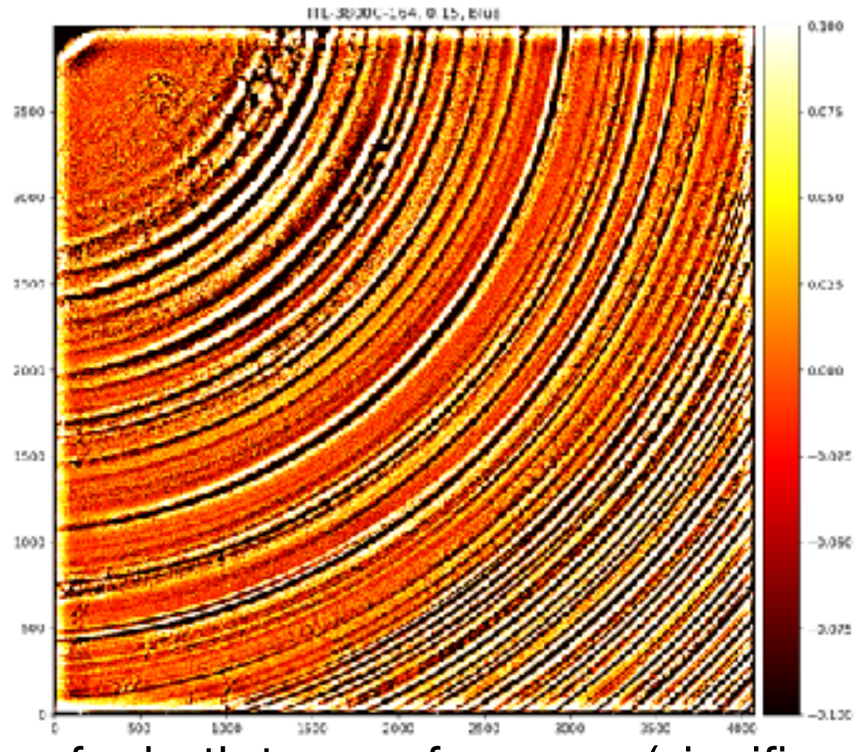
Features in flat images



Laser annealing pattern in blue for e2v

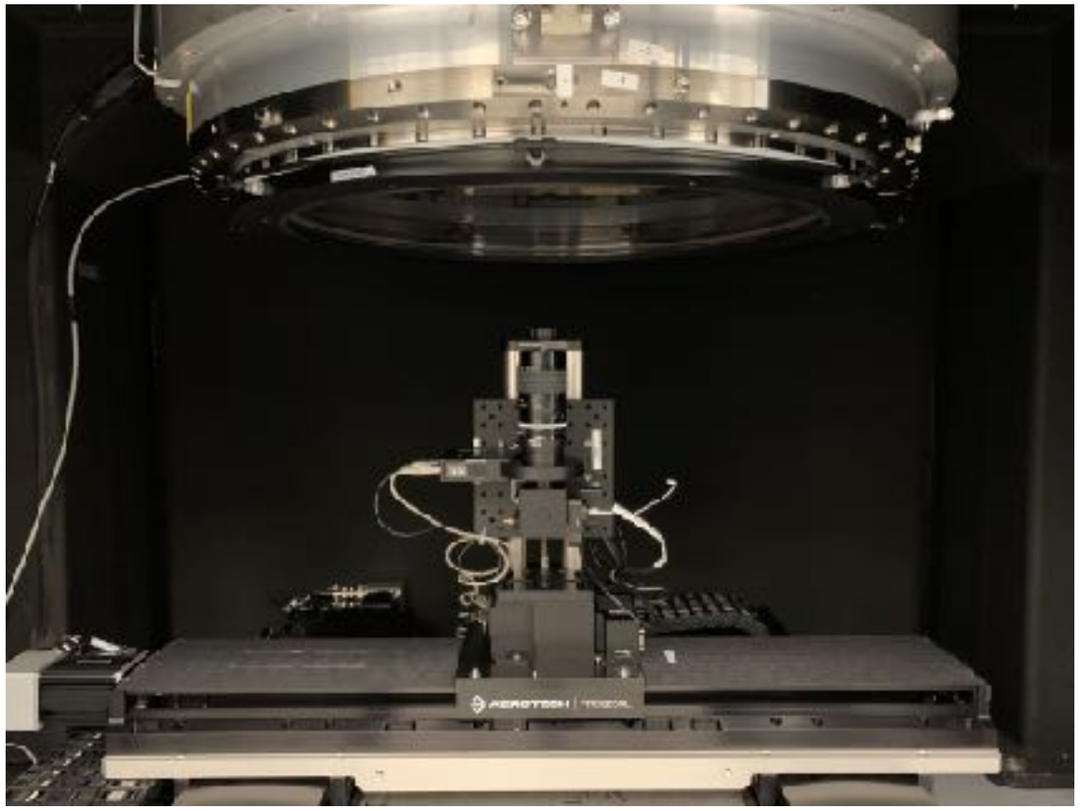


“Coffee stain” — chemical finish pattern in blue? for ITL

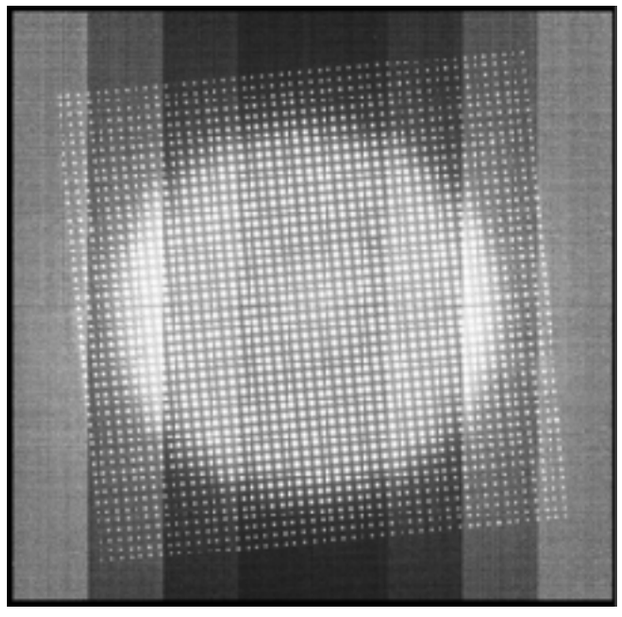


Tree-rings for both types of sensors (significantly enhanced; HV off; see Zhuoqi Zhang’s poster)

Studies by spot projectors

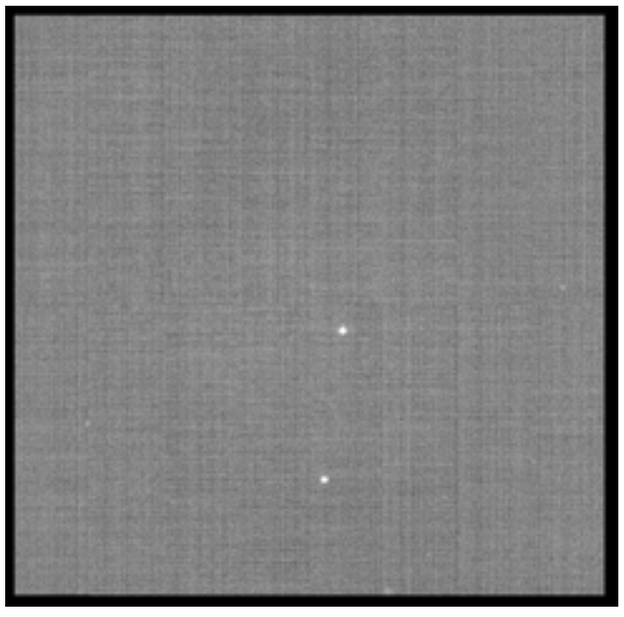


grid



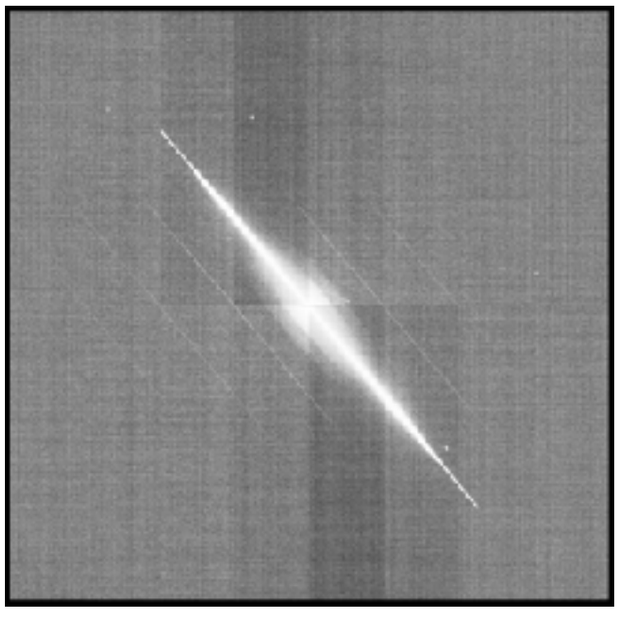
Sensor response to measurement

spot



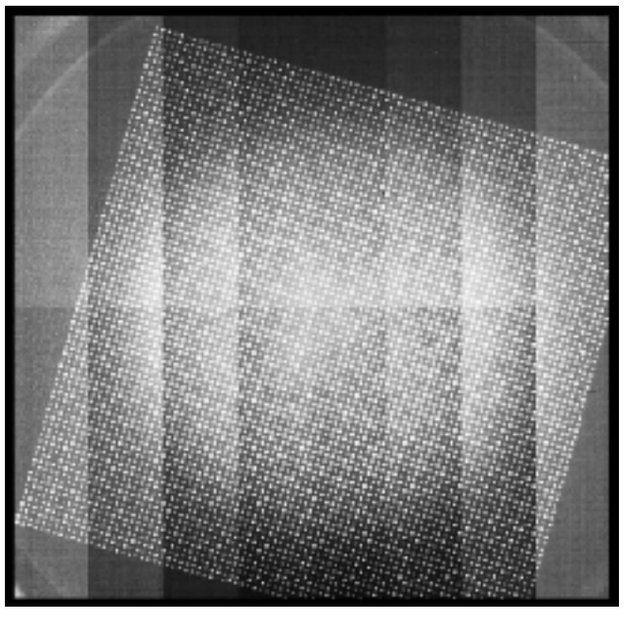
Sensor response to measurement

streak



Xtalk

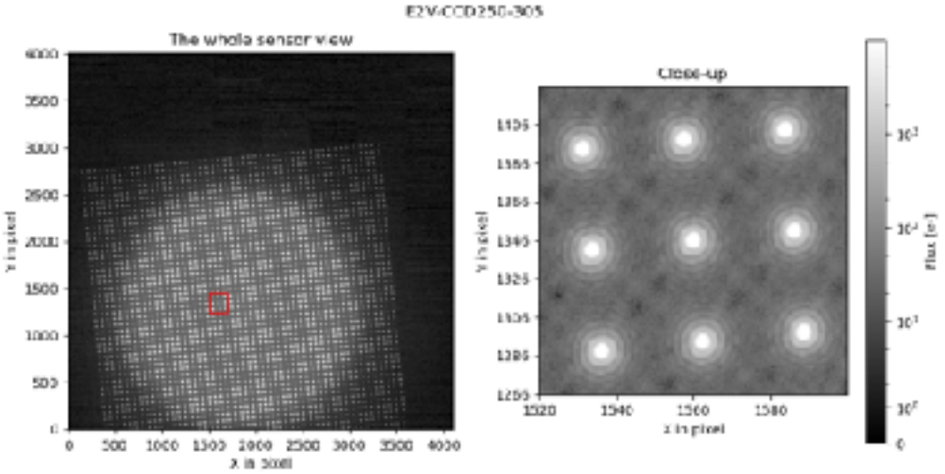
ellipses

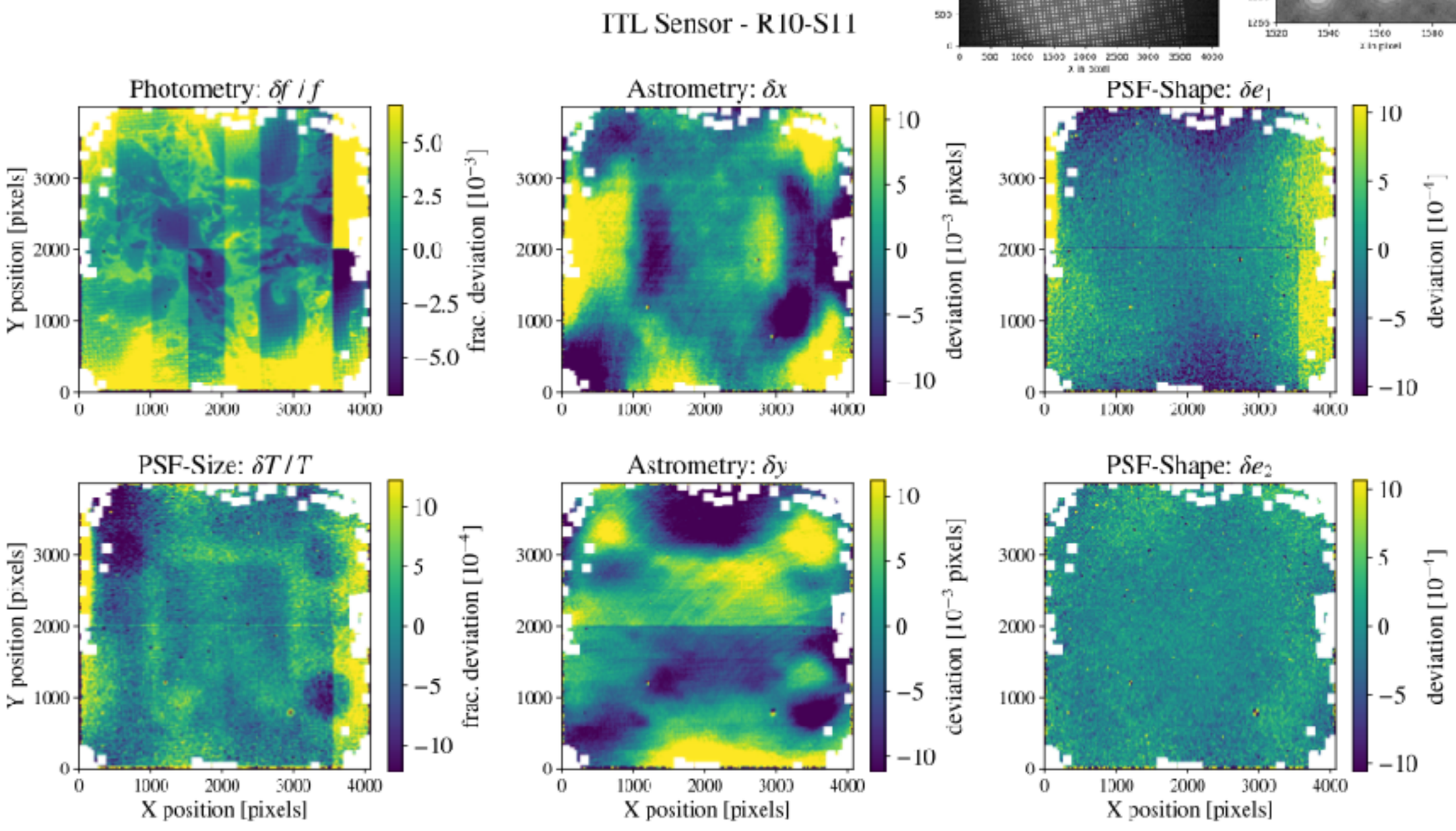


Xtalk

Spot measurements

2000 images of 2400 spots were collected



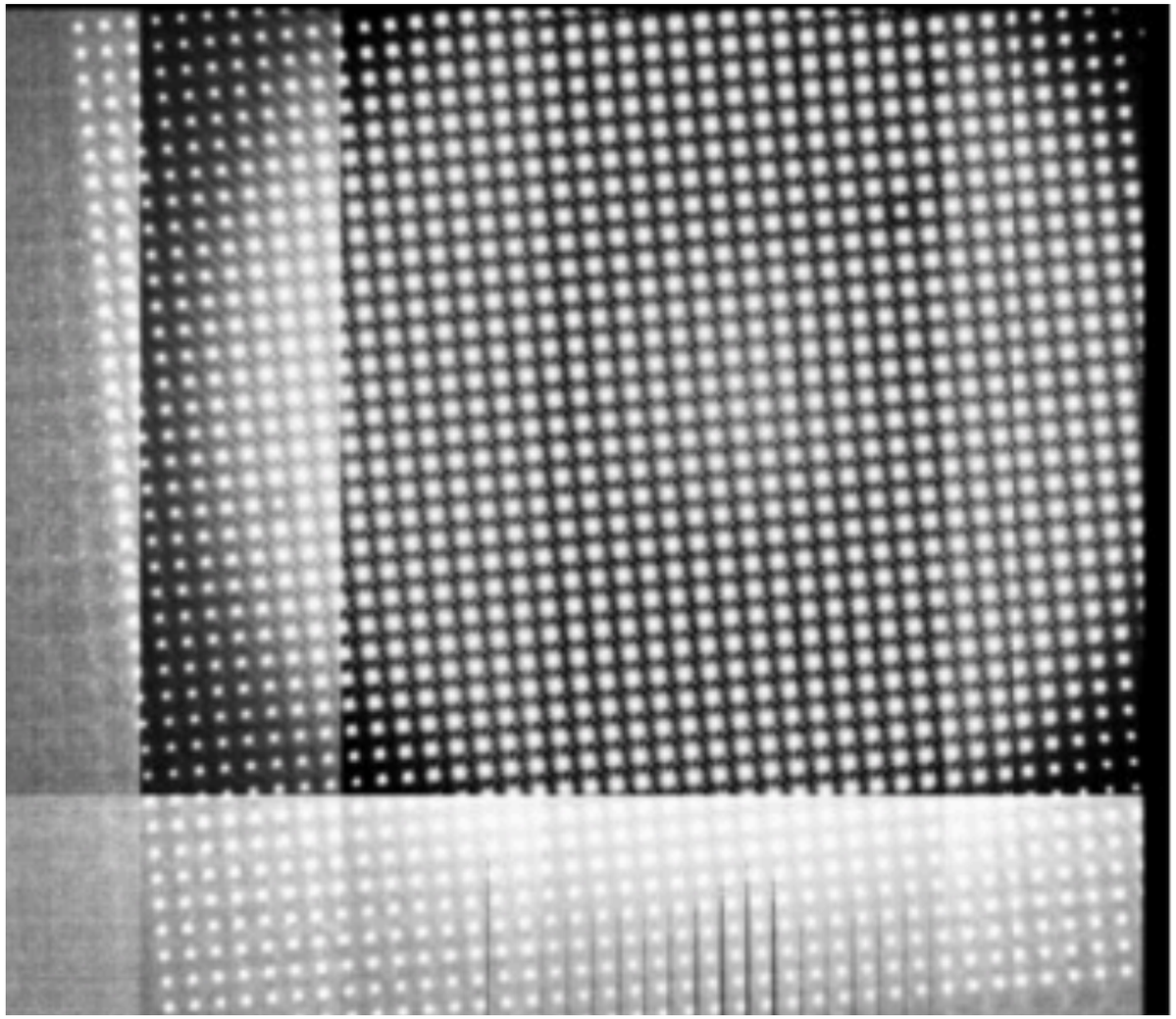


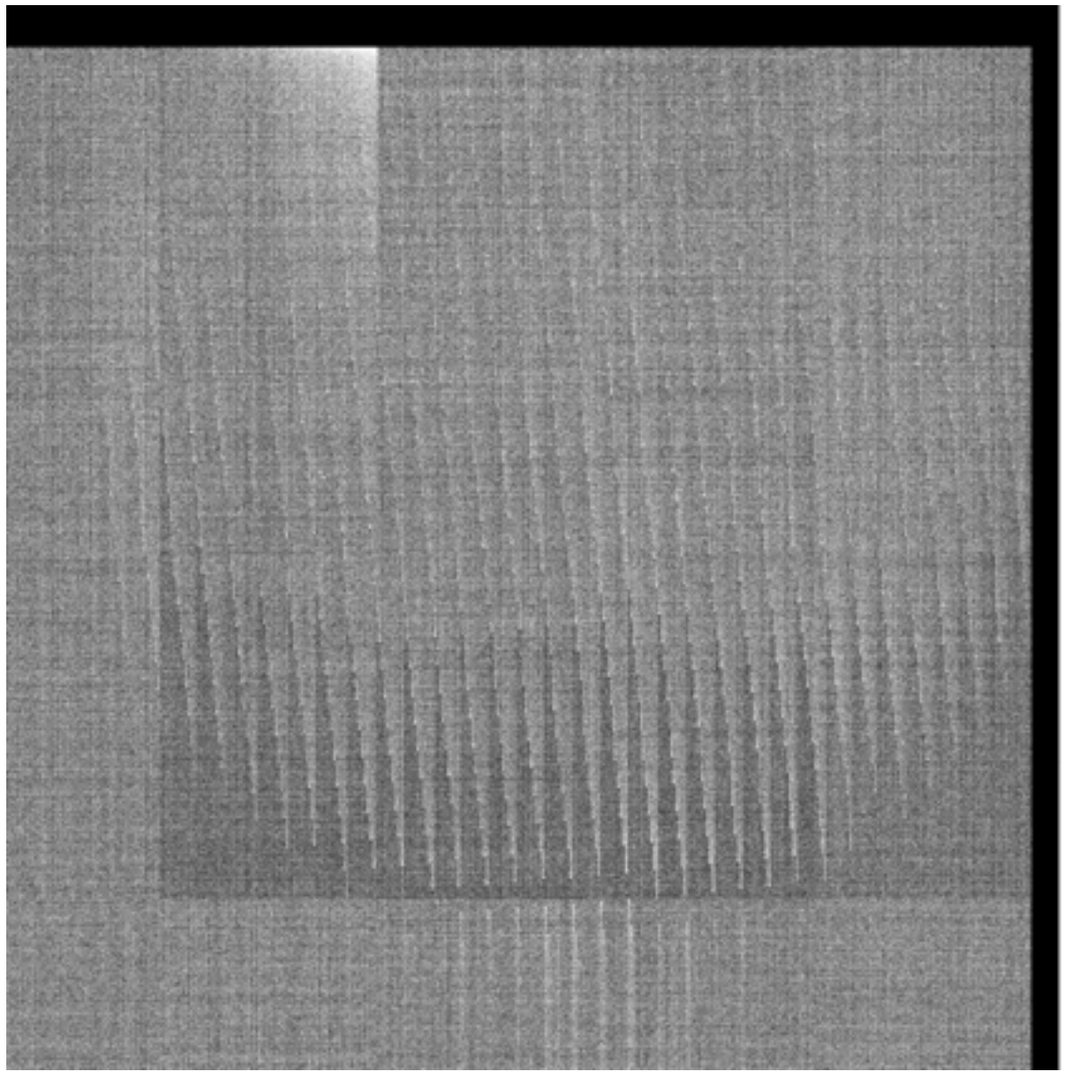
- **Laser annealing** / **Coffee stain** pattern have impact on flux

Esteves et al. (2023)

- **Tree-ring** has some effect on measurements — lateral electric field shifts (generally as small as 0.01% level)
- Midline breaks / Stress from back support structure

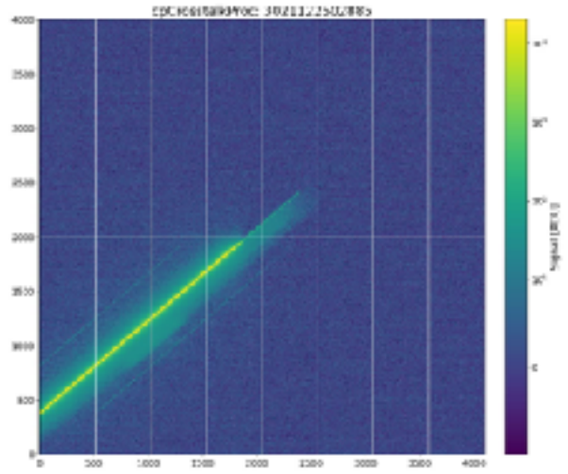
Persistence

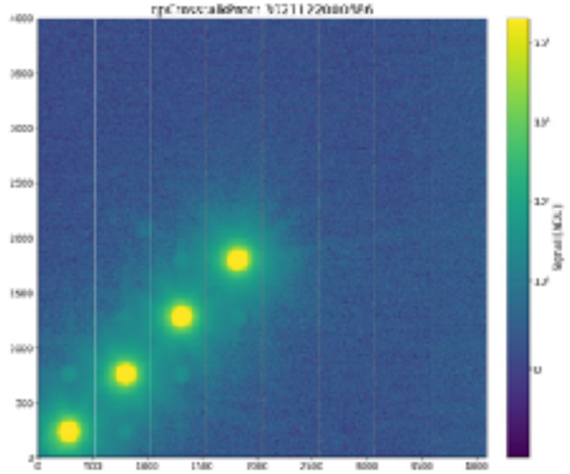


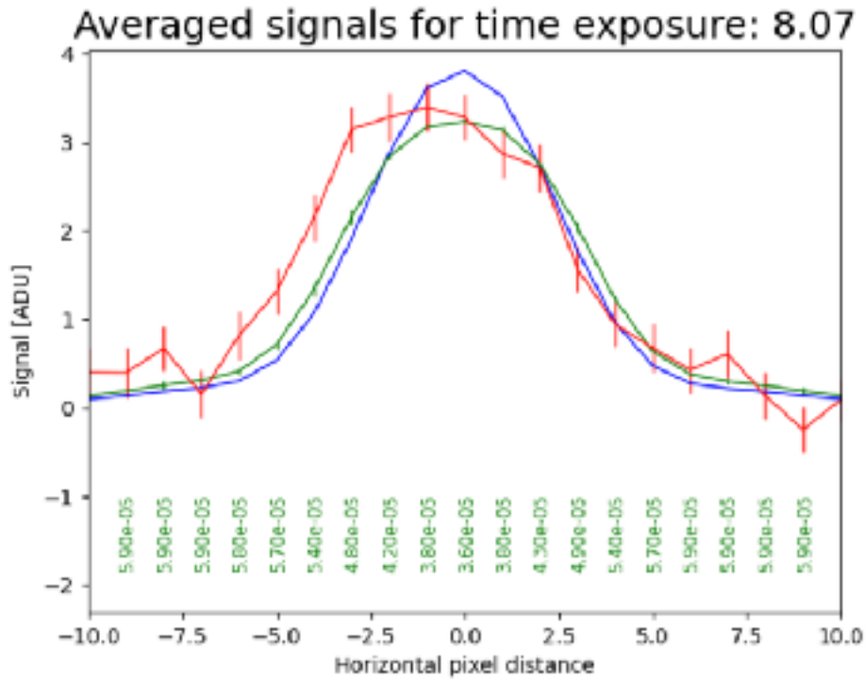


- Charges appeared to be trapped at interface at Si-SiO2
- Doherty et al. (2014) narrowing parallel swing to 8V eliminate the persistence
- Mitigations:
  - “Pinning condition” — flooding surface state by holes (safety concern by the vendor)
  - Make FW_blooming < FW_surface — by paying penalty of loosing full well

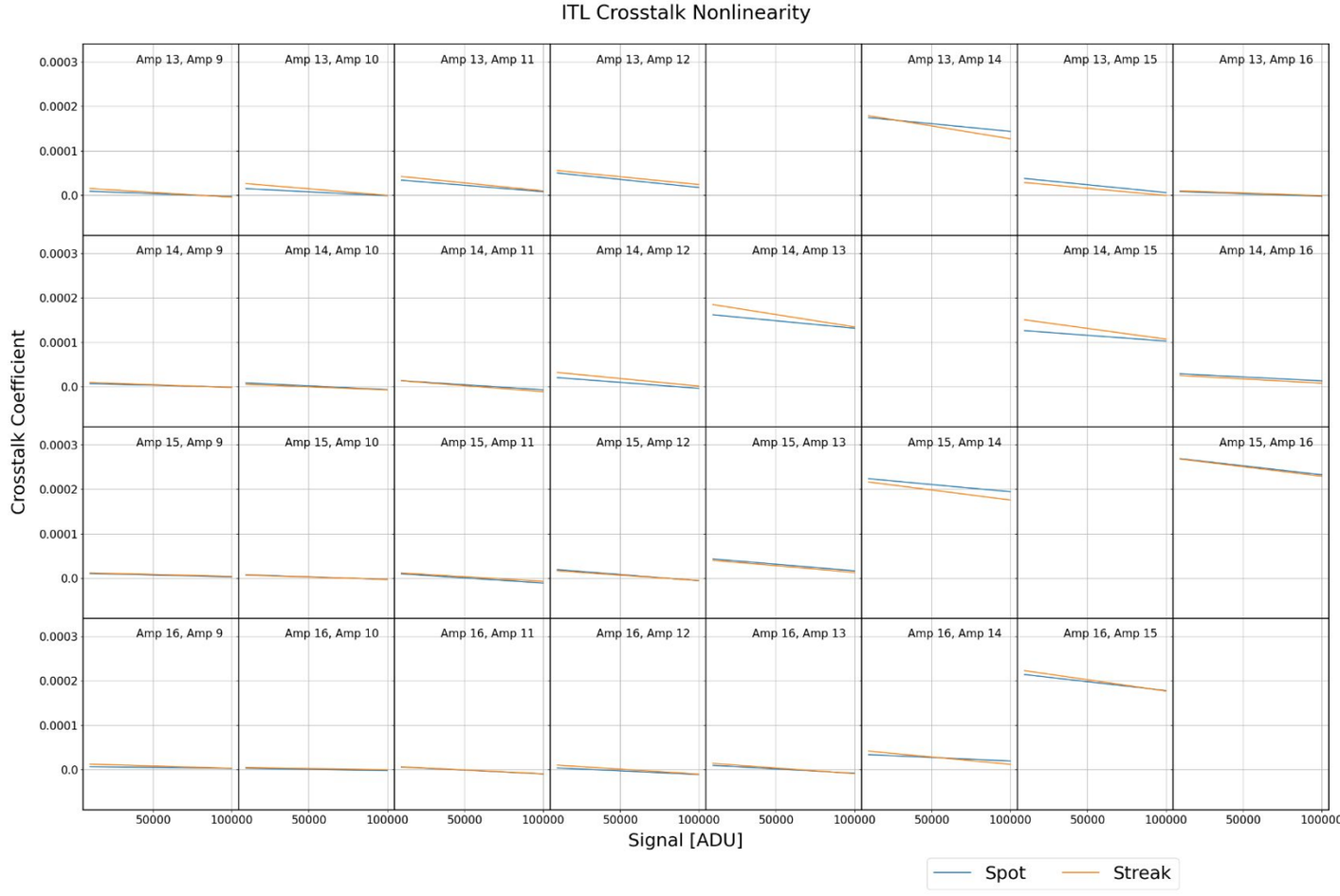
X talk study



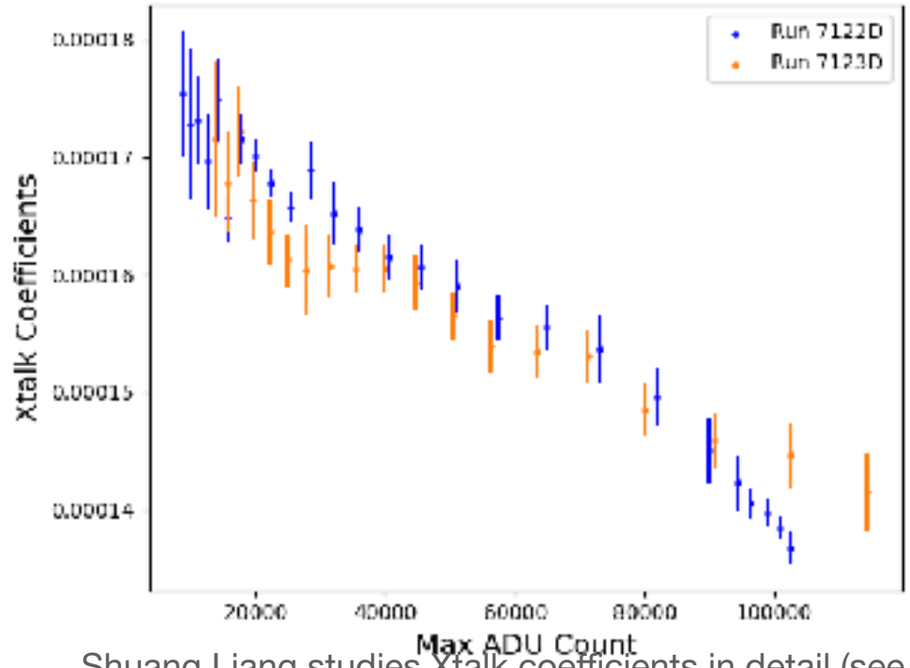




B. Guachalla Confirmed P. Astier's delayed X talk component.



Adam Snyder & Andrew Bradshaw derived Xtalk coefficients for all sensors from different methods using **spots** and **streak** based on **model fit** and **pixel basis**



Shuang Liang studies Xtalk coefficients in detail (see his and Daniel Polin's posters)

- Low Xtalk thanks to the distance between CCD and Read out electronics
- Presence of Non-linear component
- Delayed component

Summary

- **Extensive Electro-Optical testings were performed**: Biases; Darks (realistic cadence); Flats (Uniform illumination) by wavelengths and by flux; Structured illuminations
    - Large numbers of images to increase S/N
- Detailed studies of sensor response to measurement and X-talk
    - **Laser annealing / Coffee stain:** QE effect (correctable by flat fielding)
    - **Treering:** Lateral electric field shift (not correctable by flat fielding)
    - **X-talk**: non-linearity and delayed components
- **e2v features**: Tearing mitigation is mitigated / Persistence — Study is underway at UCD
- **ITL features:** Dipoles / Gain instability are mitigated