VERA C. RUBIN OBSERVATORY

LSST Camera:
Construction & Performance

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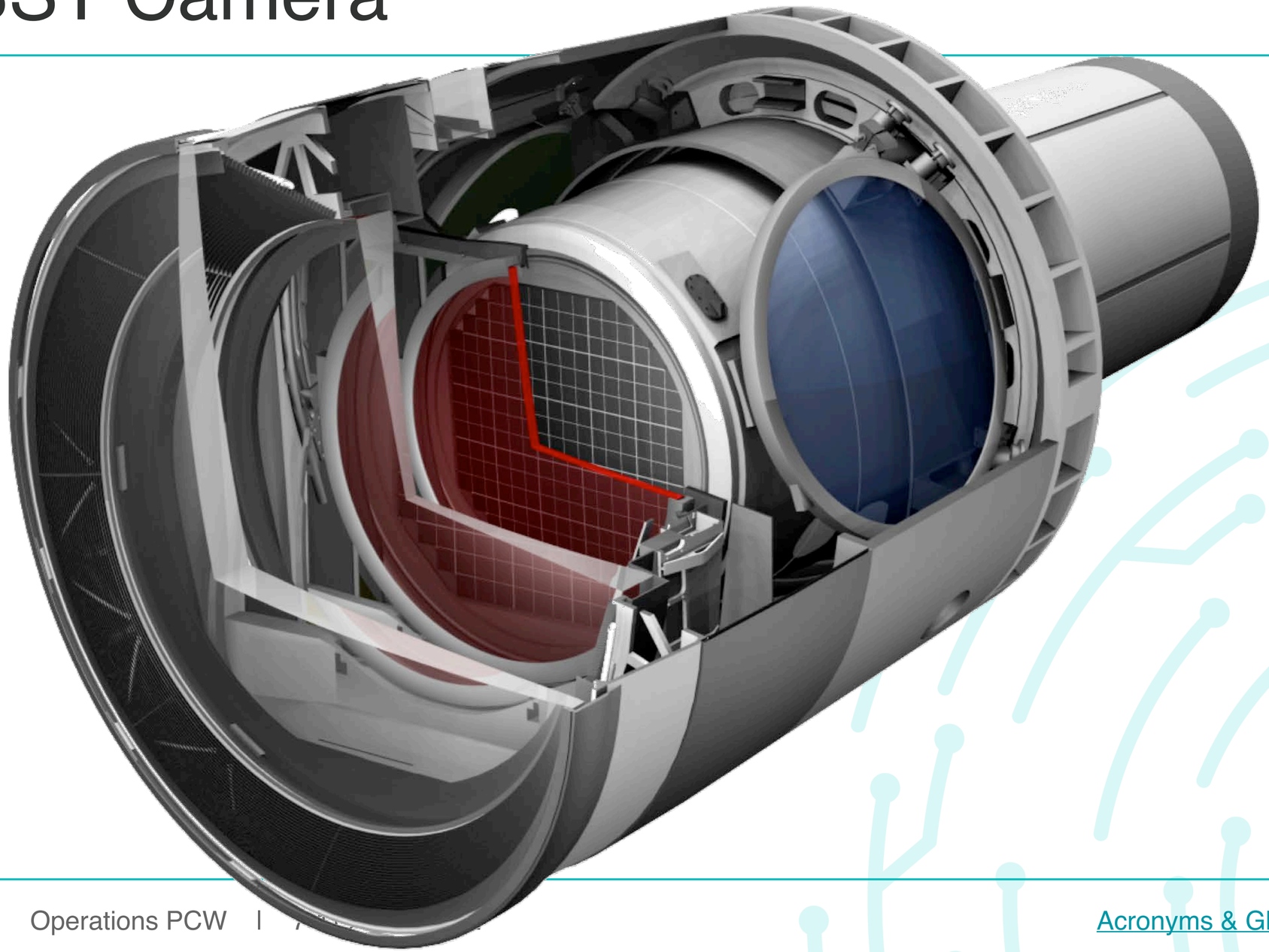
Rubin PCW, August 10 2023

NSF AURA U.S. DEPARTMENT OF ENERGY SLAC CHARLES AND LISA SIMONYI FUND FOR ARTS AND SCIENCES LSST CORPORATION

LSST Camera



Key Points of this Keynote

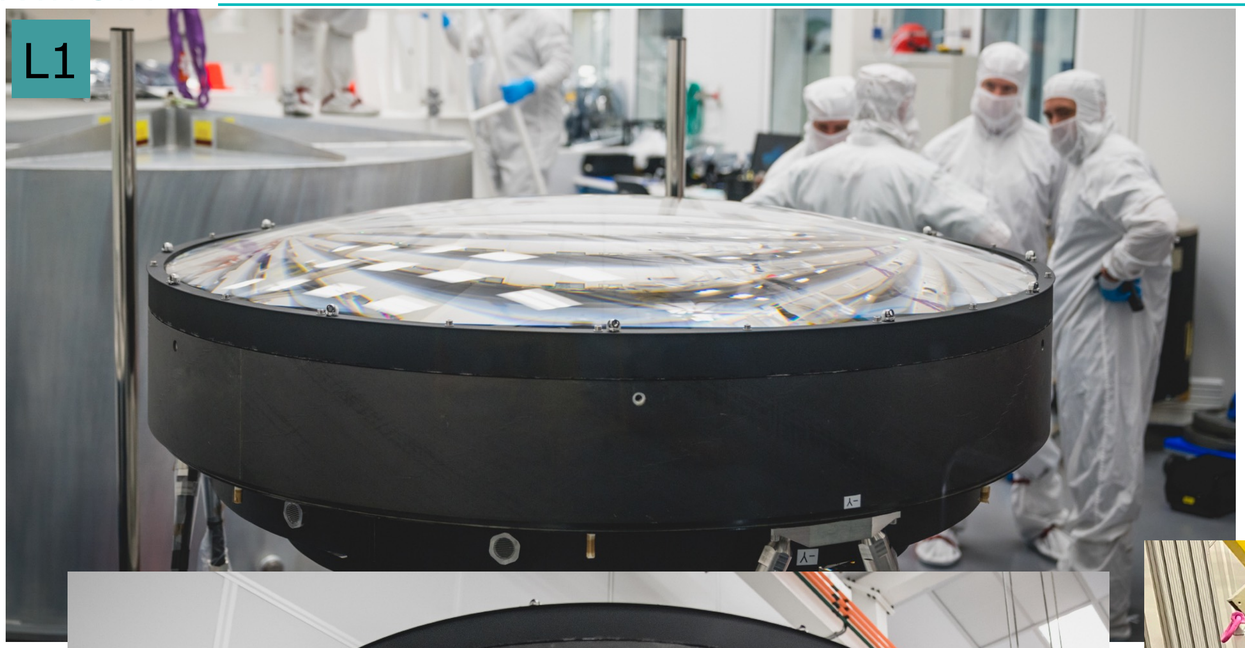
- Insight into some of the Design Drivers for the LSST Camera
  - Construction & Operational Challenges
- Performance Highlights from Laboratory Testing

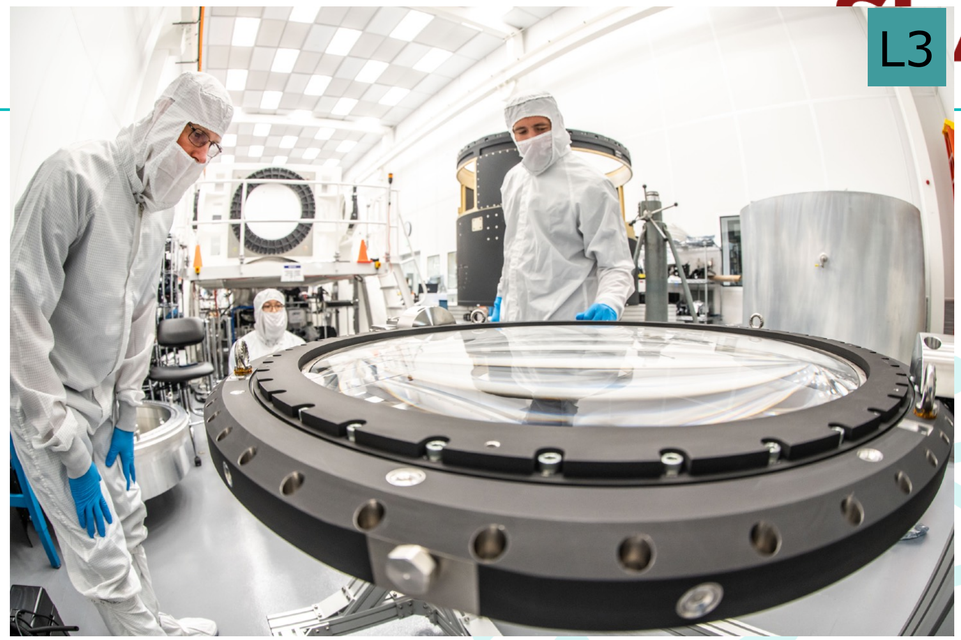
Why Does the LSST Camera need Three Lenses?

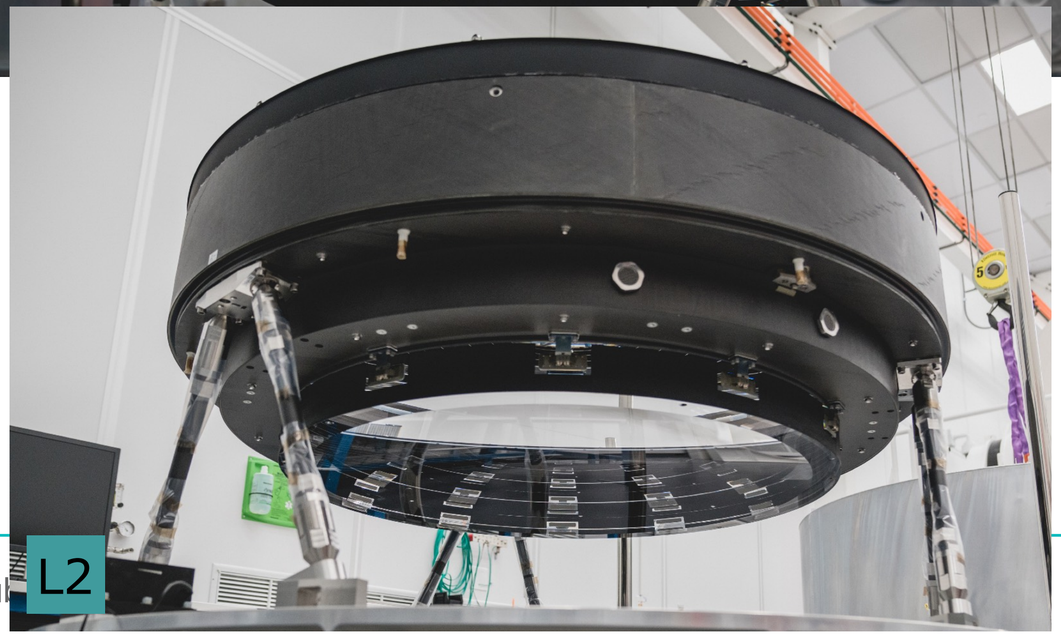
Why Does the LSST Camera have 3 lenses?

- CCDs must be cooled, typically -100°C, to avoid dark current & hot defects
- At -100°C, the CCDs must be in vacuum, behind a window
- Once there is 1 refractive element, then you need at least one more to correct chromatic aberrations
- LSST Camera design uses 3 lenses, with the vacuum window an optic, not a flat, for both chromatic correction & to optimize 3 Mirror + 3 Lens system

Lenses & Filters



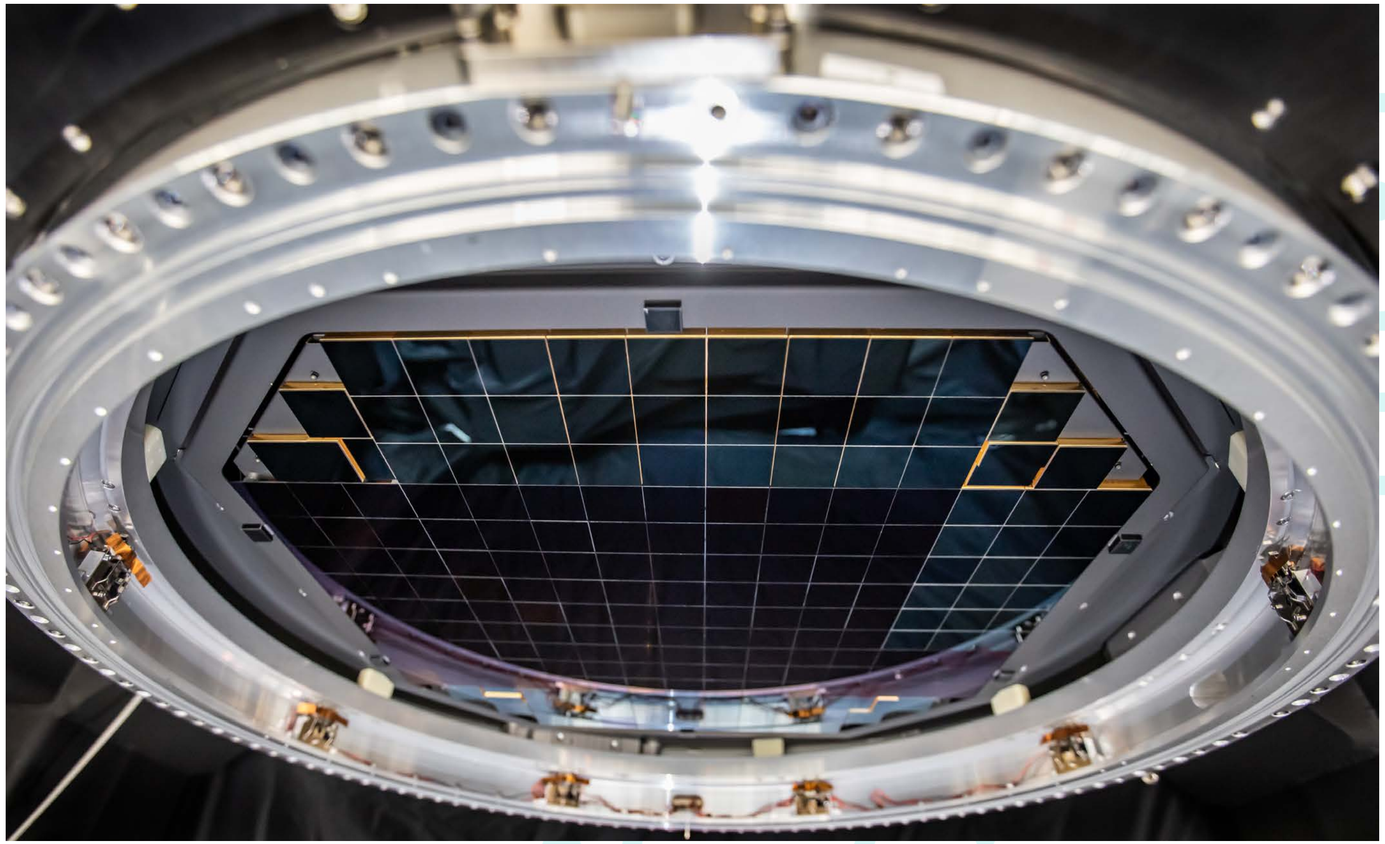




- Why do we need 3.2 Giga Pixels?
- What motivates the choice of a Plate Scale of .2”/pixel and 10 micron pixels ?

Why 3.2 GigaPixels and 0.2”/pixel?

- Science goals met with 10 square degrees Field of View
- Want at least 2 pixels to cover the very best Image Quality of 0.4” FWHM
- 10 micron pixels is a reasonable choice for CCDs

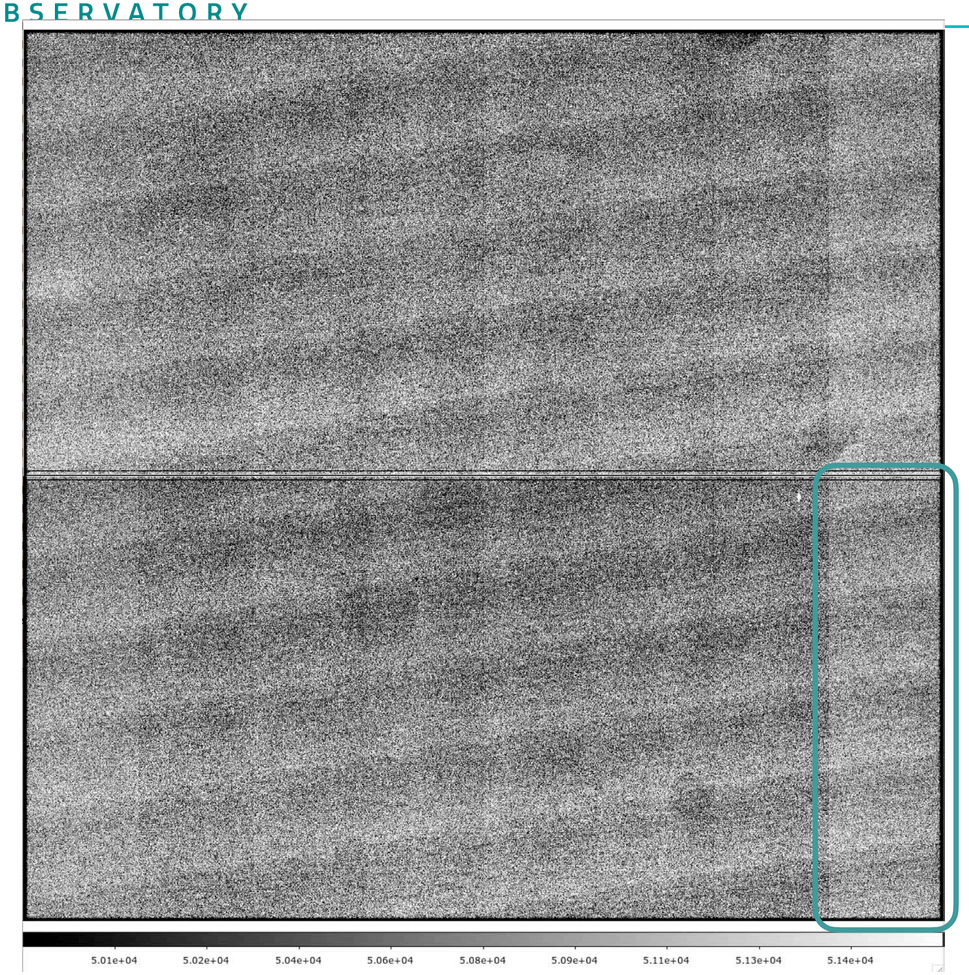


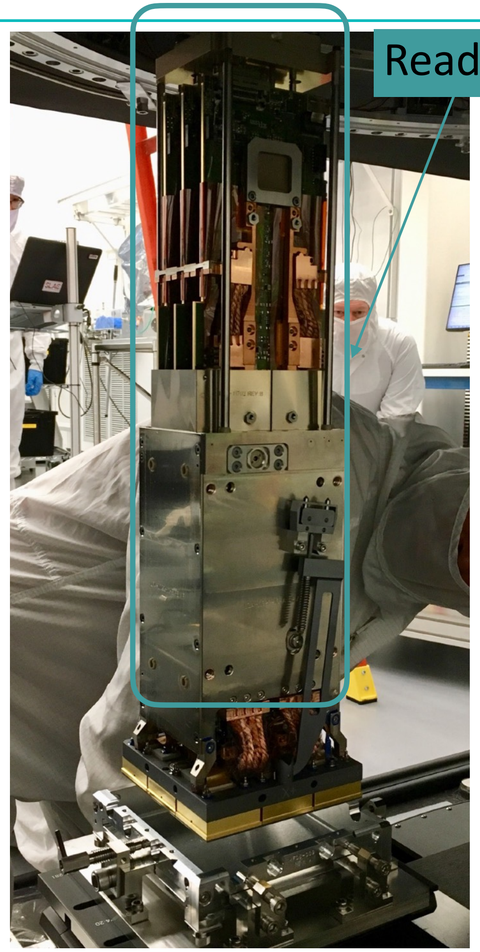
- Why does the LSST Camera have the CCD controller electronics and ADCs *inside* the Cryostat?

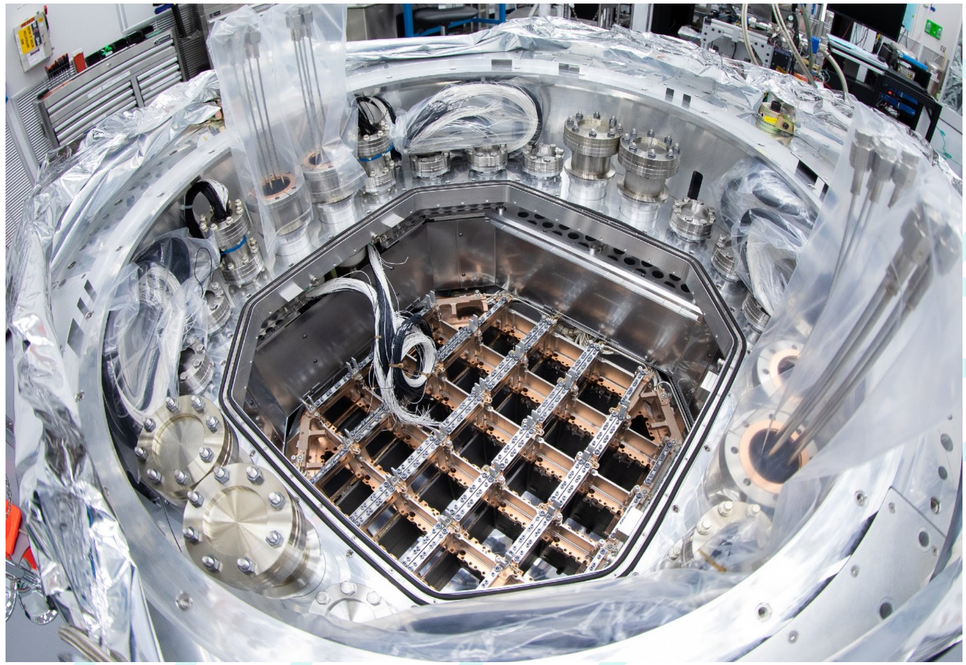
CCD Controllers in Vacuum

- Survey design, to achieve an image in every available direction every 3-4 nights, leads to 15+15 second visits
- Minimize the *dead-time* from Focal Plane readout, and 2 second readout appeared achievable
- CCD pixel readout rates pushed to 500 KHz, and then to get 2 second readout we need an amplifier for every 10^6 pixels.
- So LSST CCDs are 4k by 4k with 16 amplifier sections
- The focal plane has 189 Science CCDs plus 12 for Guiding & Wavefront sensing
- So that is 201 x 16 = 3216 analog signals
- Very difficult to bring that many analog signals out of the cryostat, while maintaining good read noise and cross-talk.

CCD & Focal Plane Requirement: 2 Second Readout



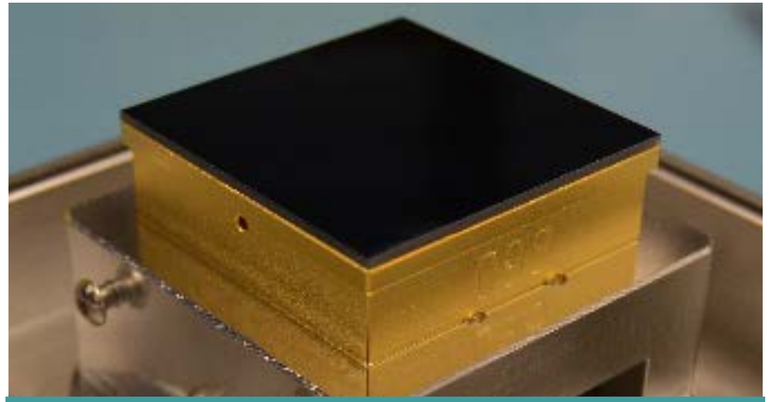




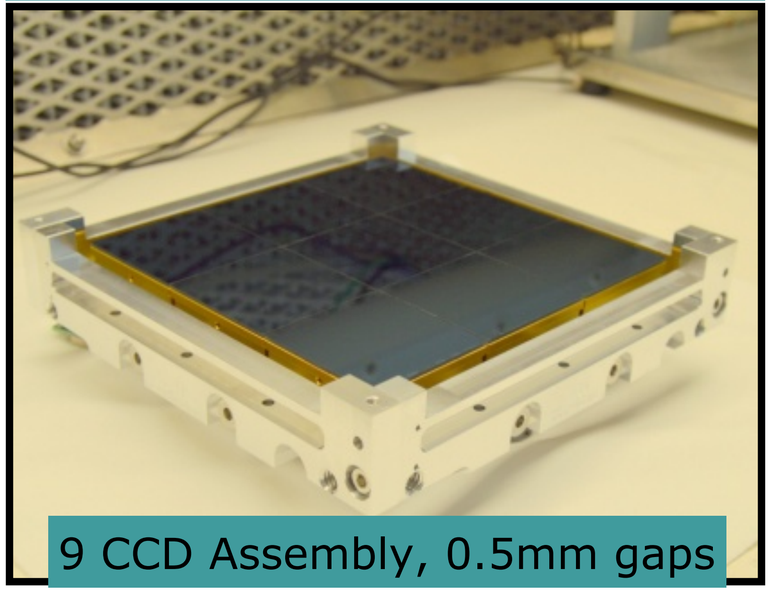
Raft = 9 CCD Subassembly

- 16 MPixels @ 0.5 MHz ➥16 Amplifier Segments
- 3216 Analog Video Channels ➥Readout Electronics in Vacuum

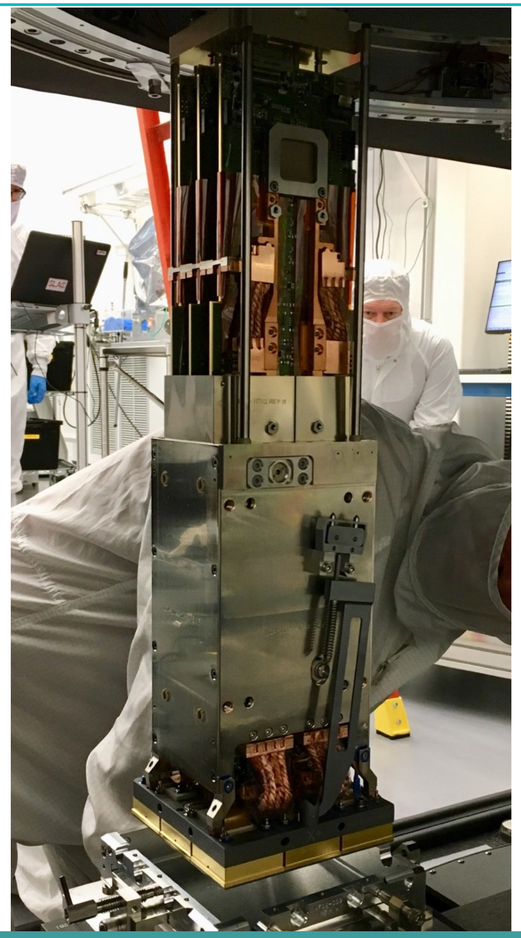
3.2 GigaPixel Focal plane



Custom 16MPix, 16 Channel CCDs

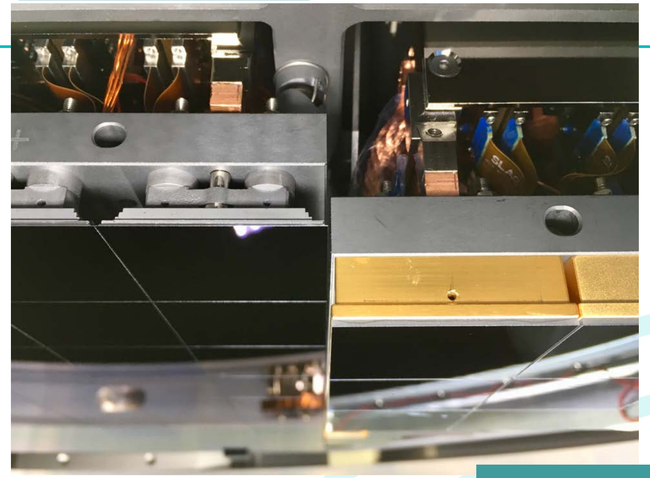


9 CCD Assembly, 0.5mm gaps

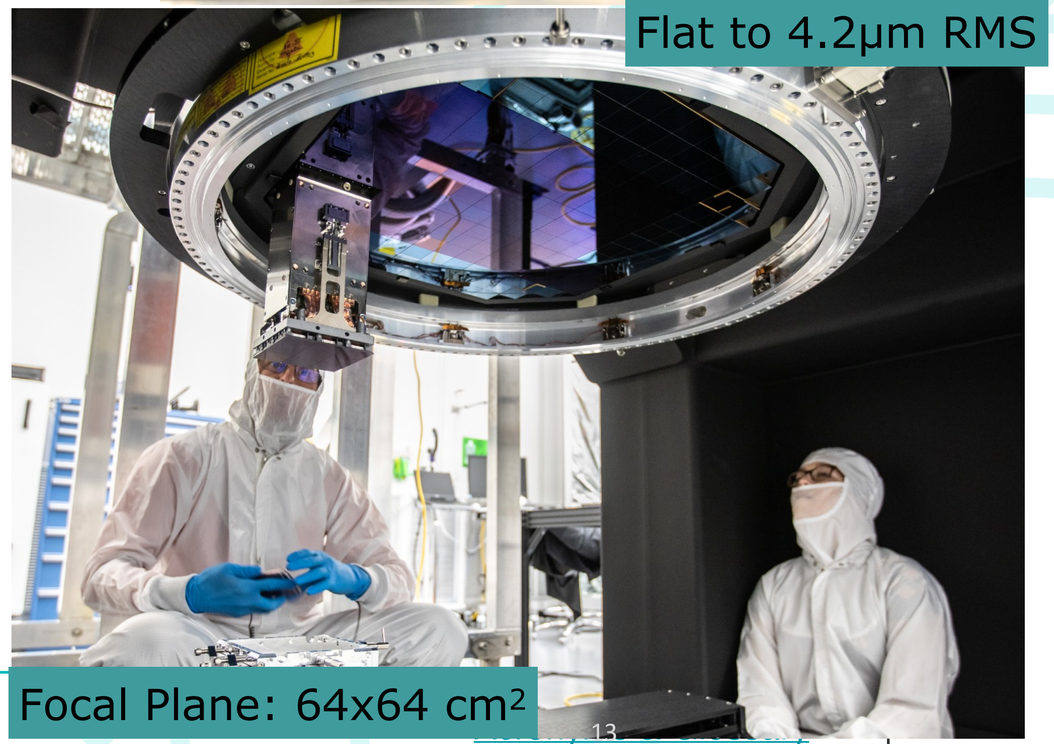


Integrated Mechanical, Thermal, Electrical package, with CCD Controllers & ADC in Vacuum

0.5mm gaps

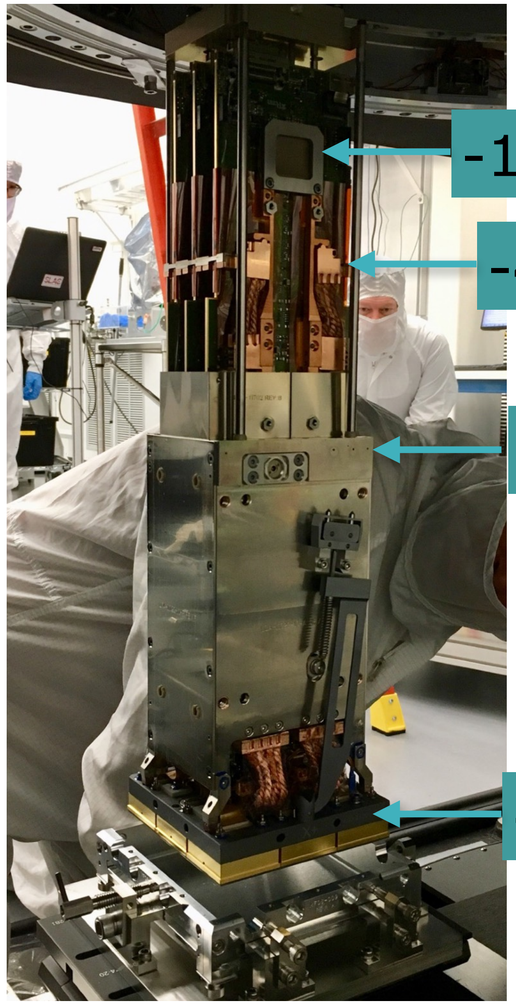


Flat to 4.2µm RMS

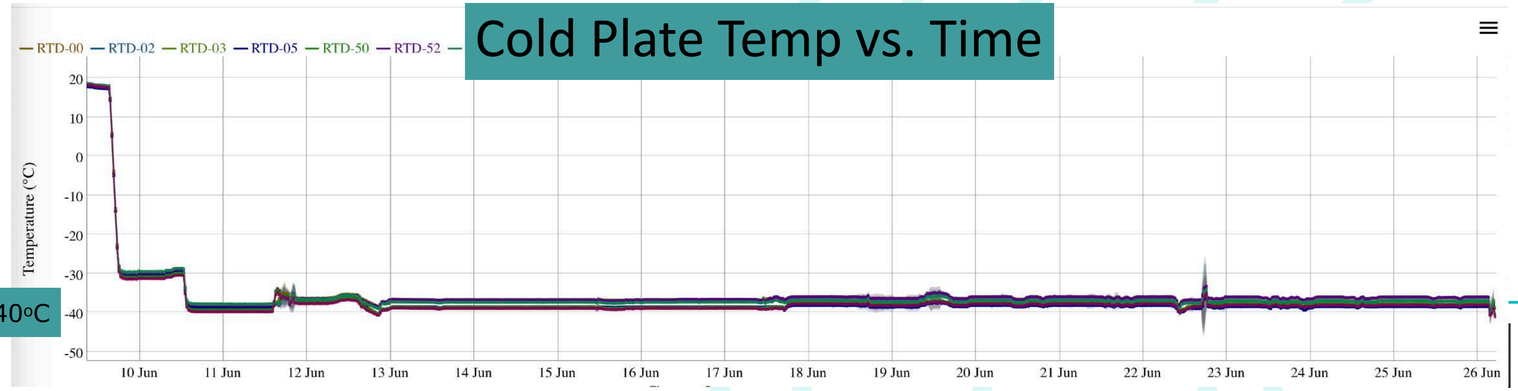


Focal Plane: 64x64 cm²

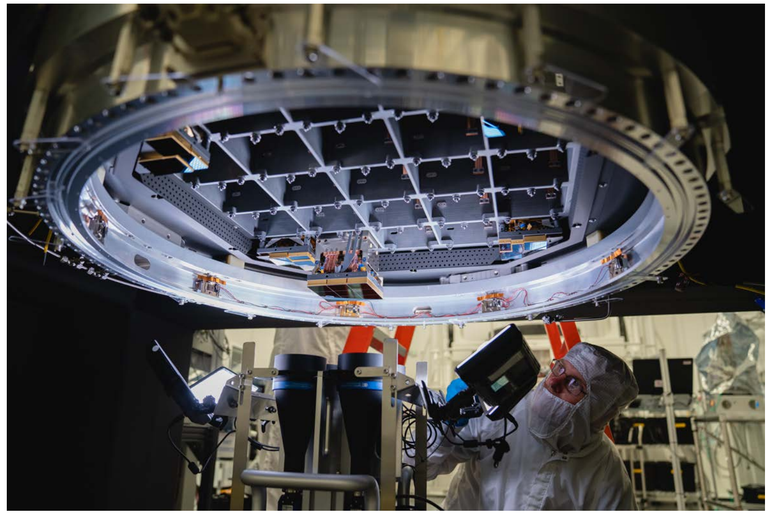
Challenges: Refrigeration

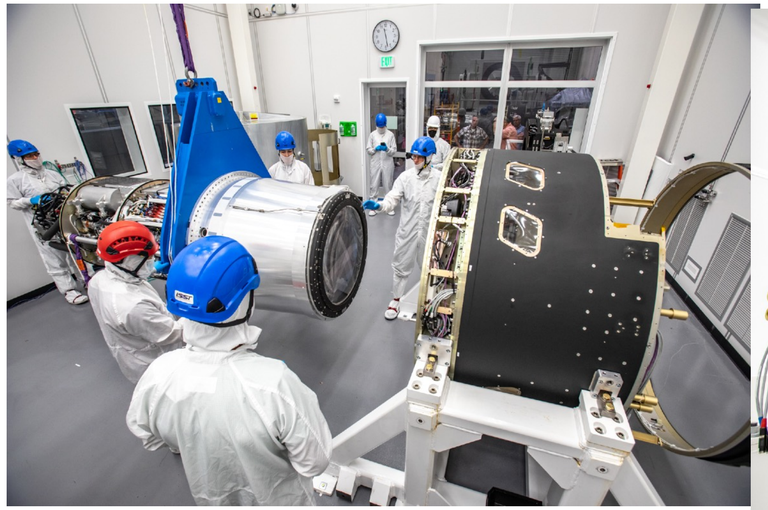
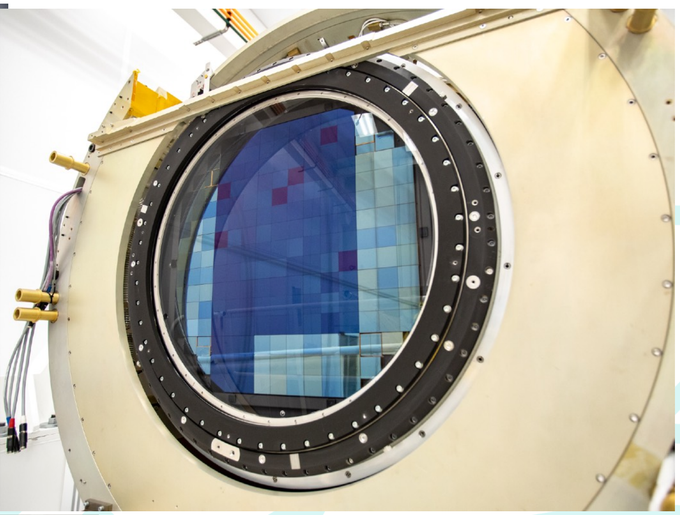
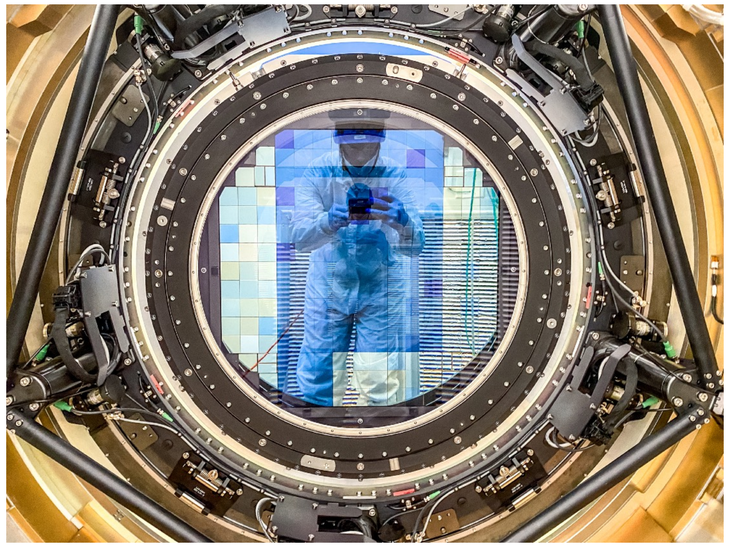


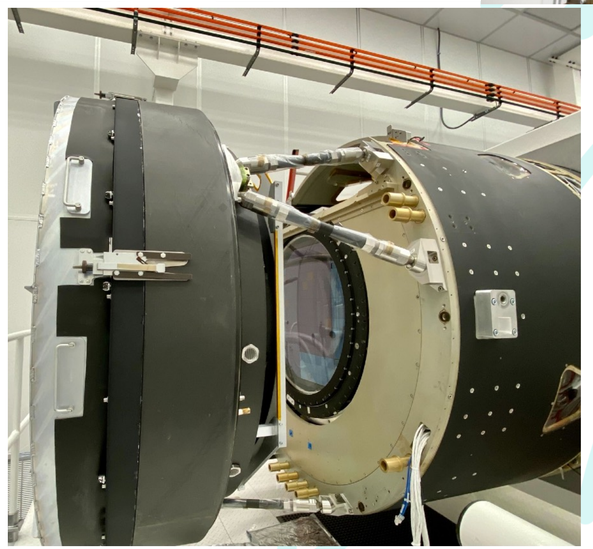
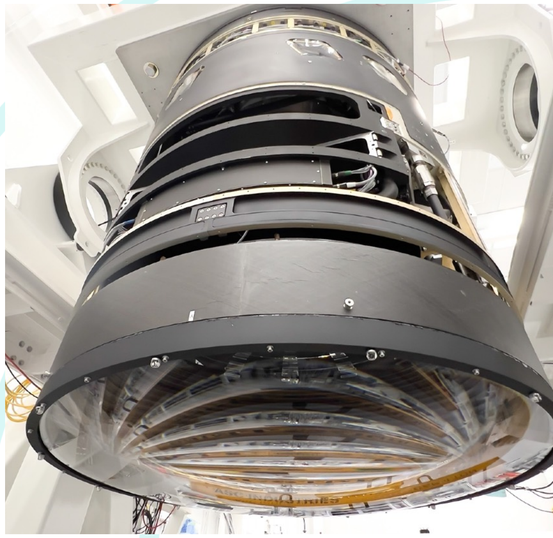
- Two Thermal zones in the Cryostat
  - Cold: 1000W at -40°C
  - Cryo: 500W at -130°C
- Cold System: conventional Vapor-Compression
  - good performance during sub-system testing
  - problems observed during Verification Testing
- new Cold System: Pumped Coolant
  - Chiller pumps -50°C Fluid to Camera
  - new Vacuum Jacketed Lines



Camera Assembly

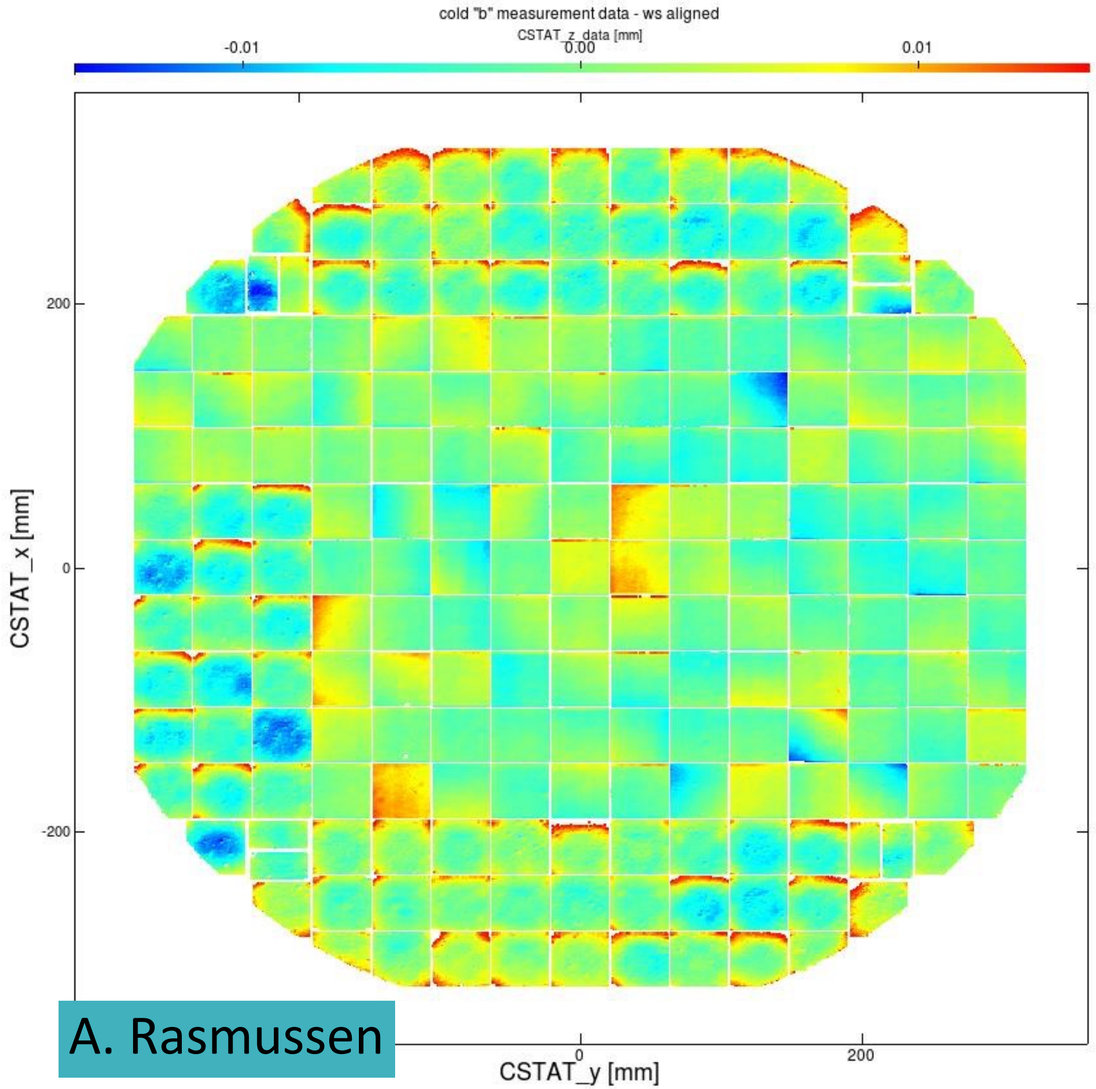


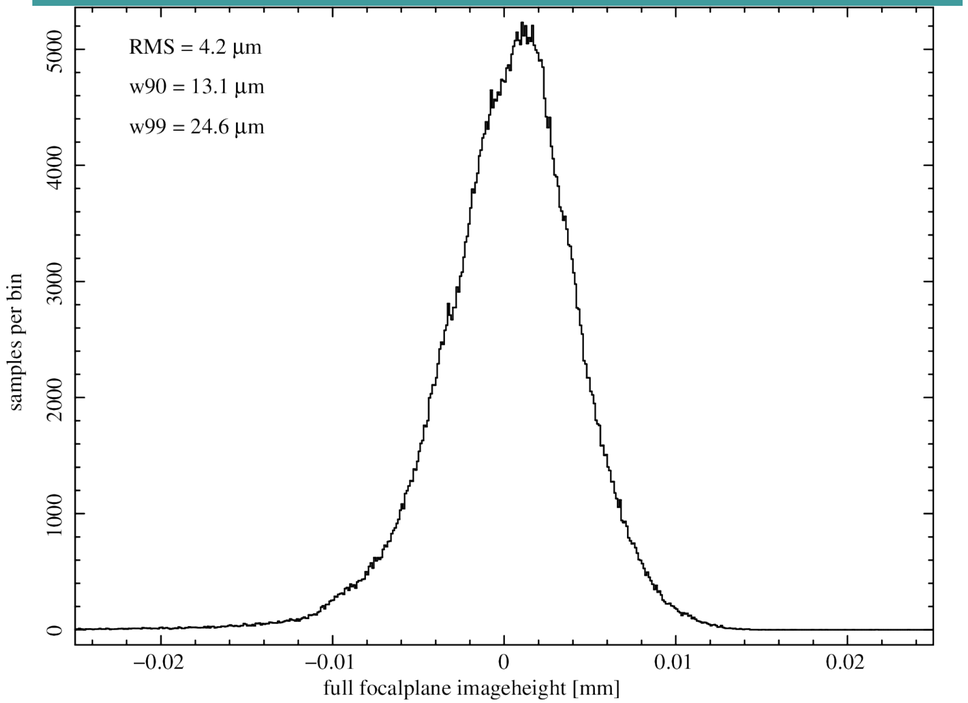

NO ENTRY
WITHOUT
LOCK-OUT
EXIT

Image Quality & Focal Plane Flatness



A. Rasmussen

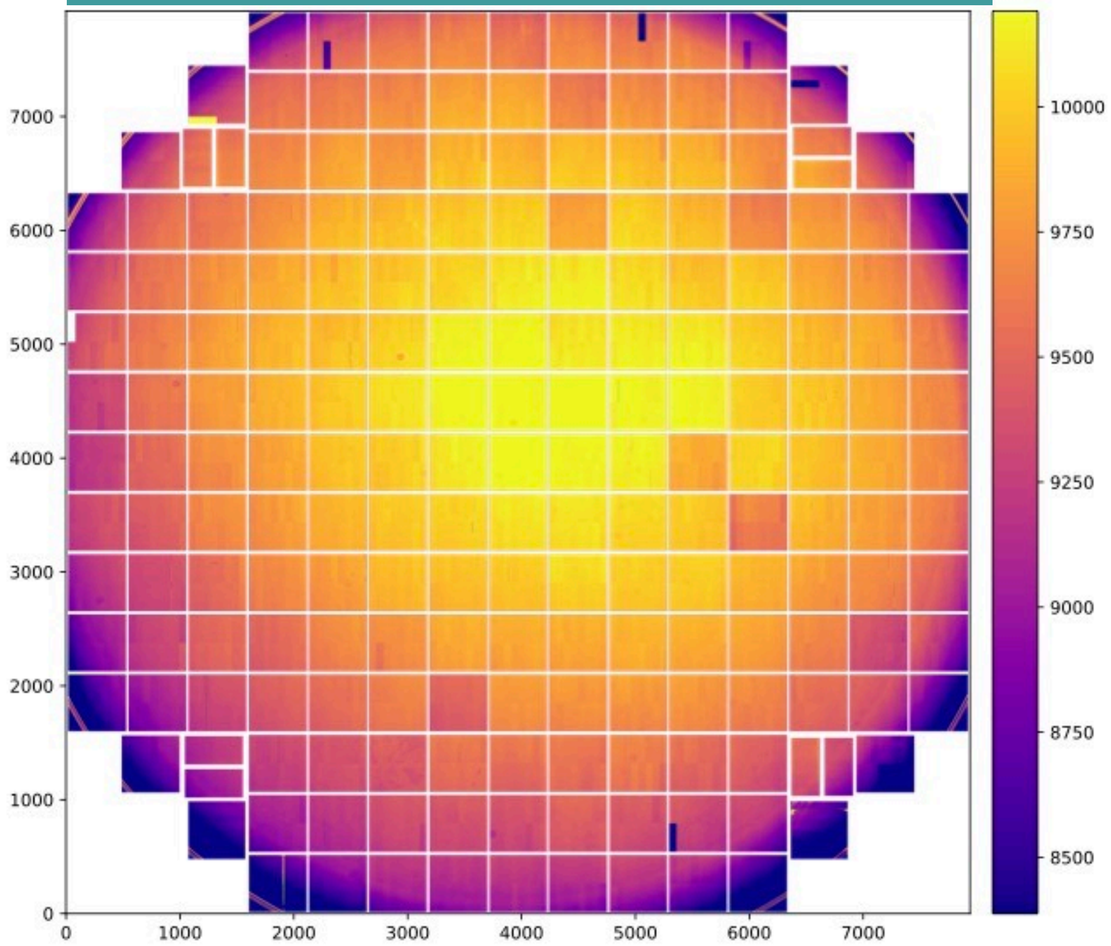
CCD Height distribution, RMS=4.2µm



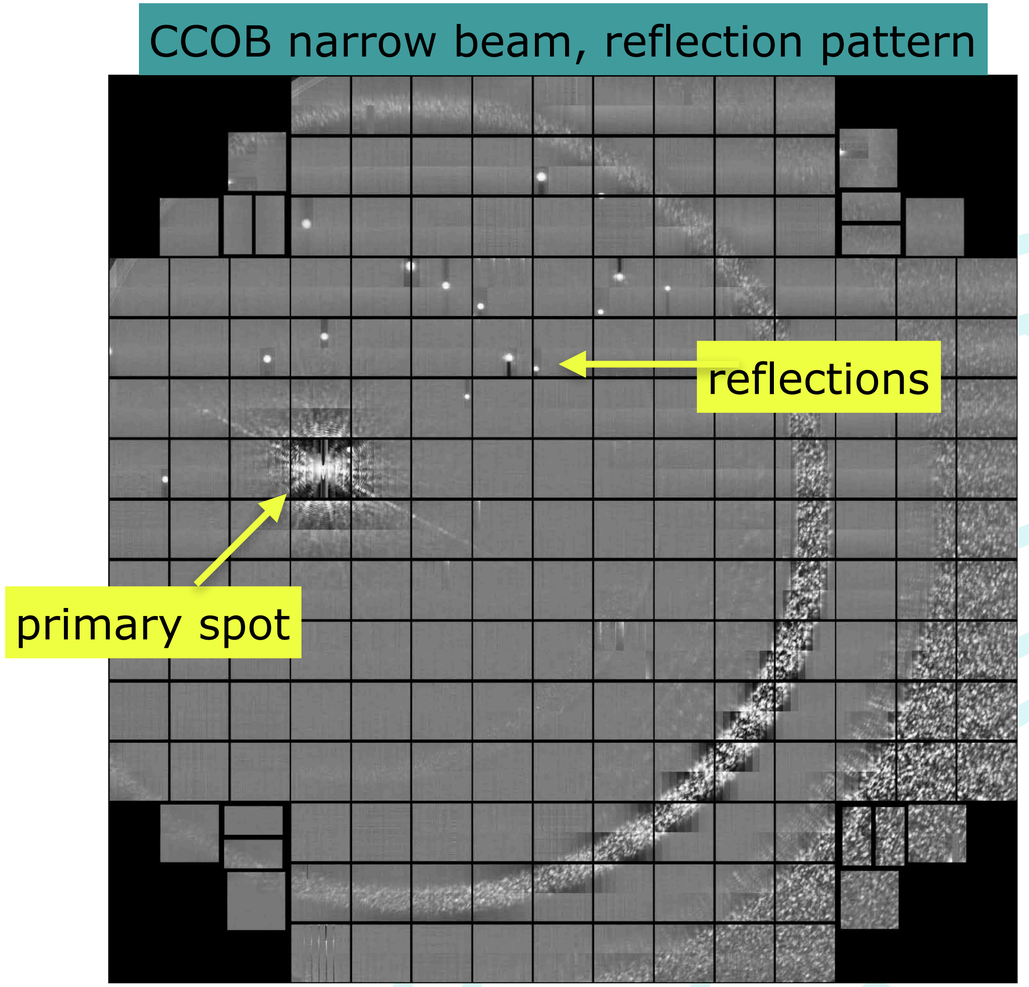
- Point Spread Function from Camera < 0.3” FWHM
  - largest contribution is diffusion in CCD ~ 0.18”
  - focal plane is flat to within 4µm RMS, ~0.05”

Electro-Optical Testing: Light sources

CCOB-wide beam: ~Flat Field, i band LED

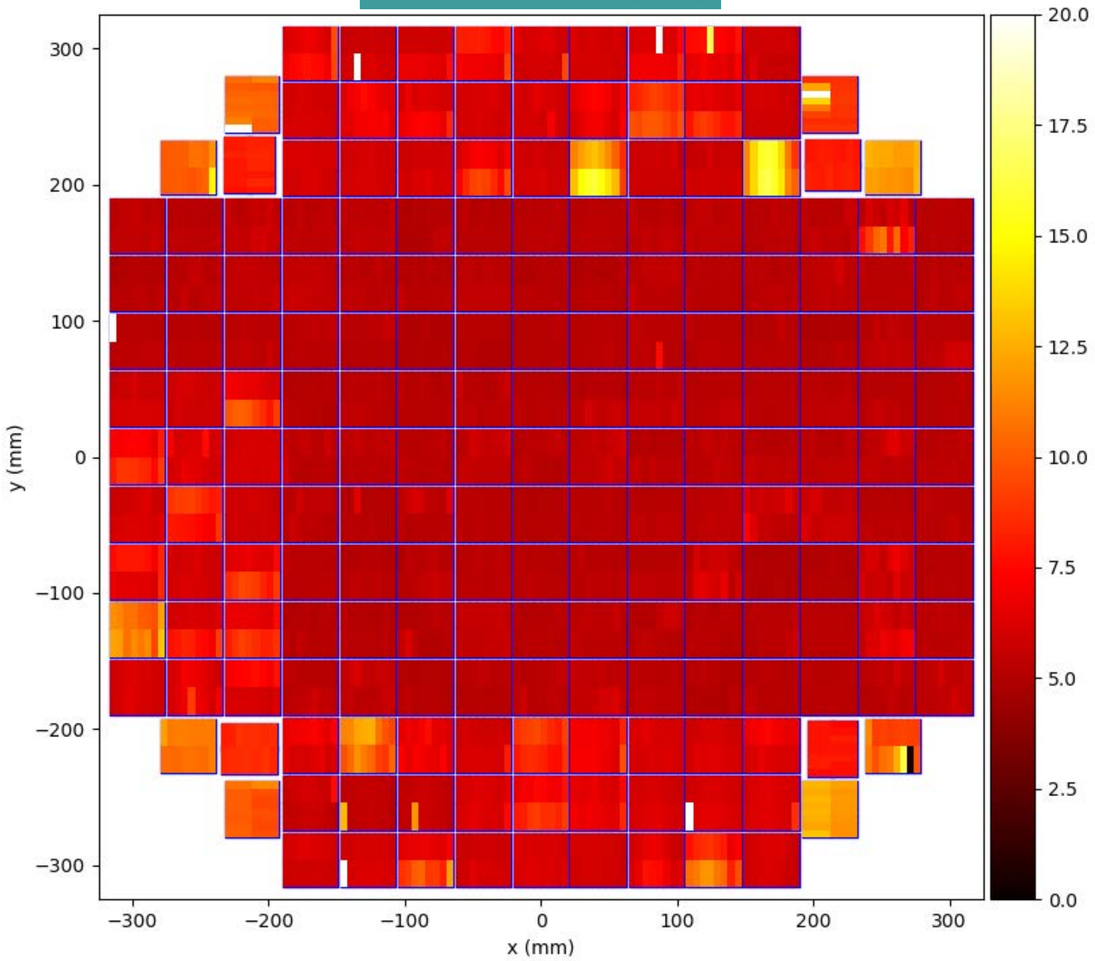


CCOB narrow beam, reflection pattern

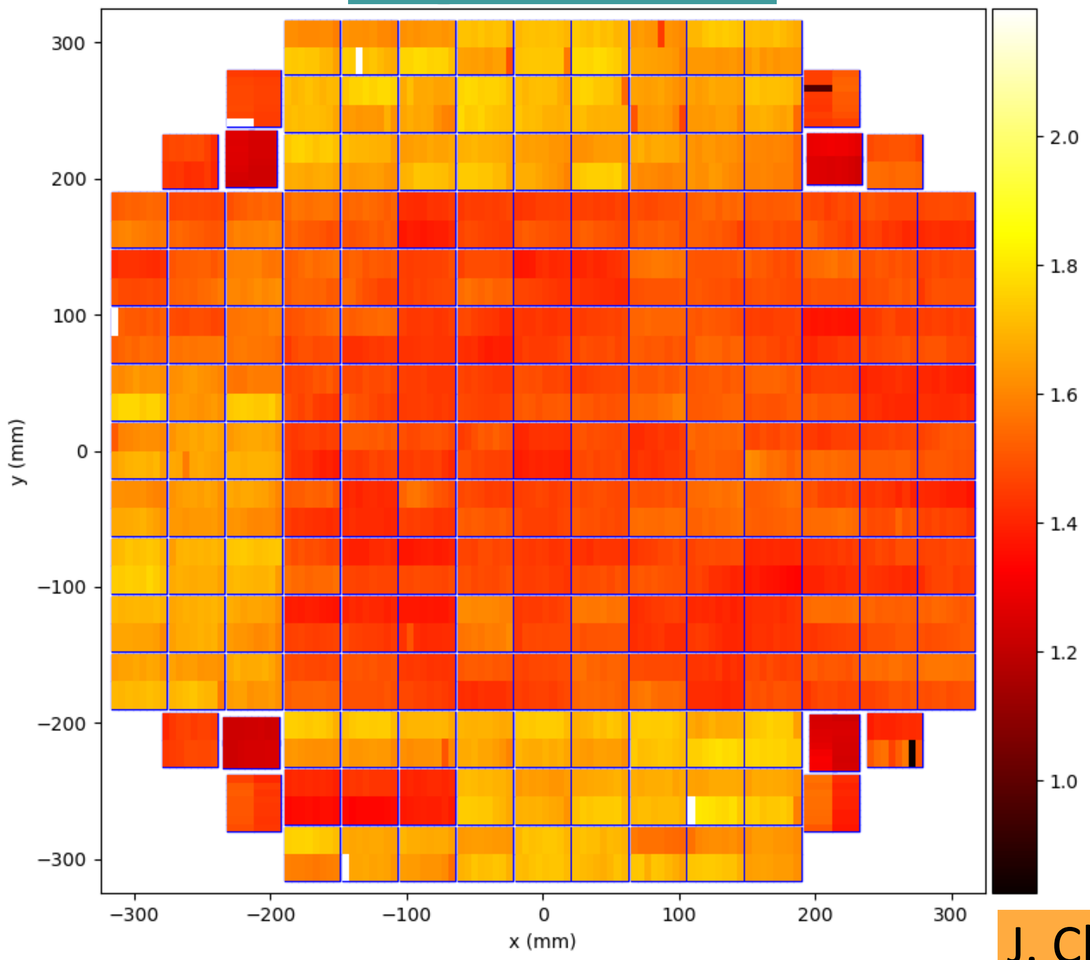


Read Noise & Photon Transfer Gain

Read Noise [e-]



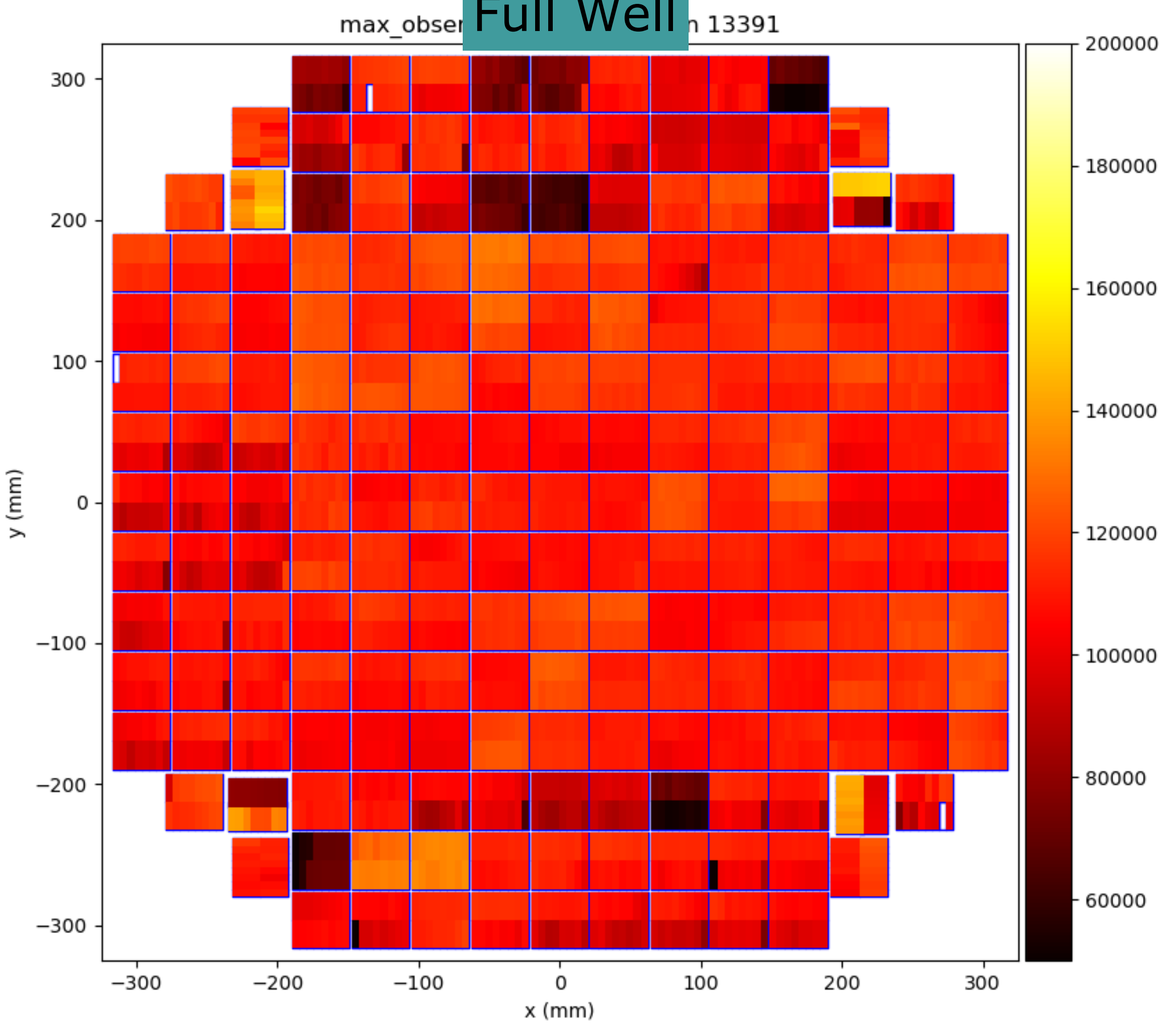
PTC Gain [e-/ADU]



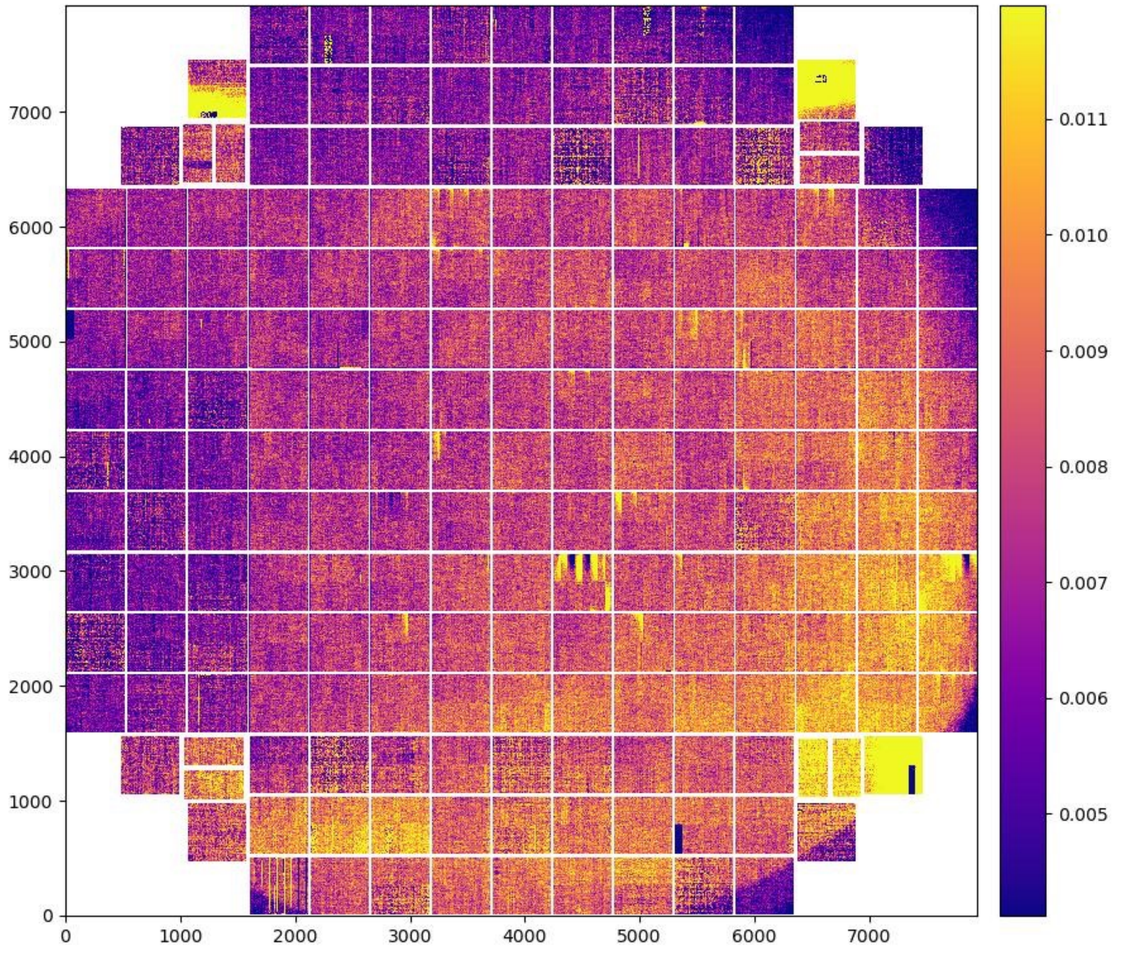
J. Chiang

Full Well and Darks

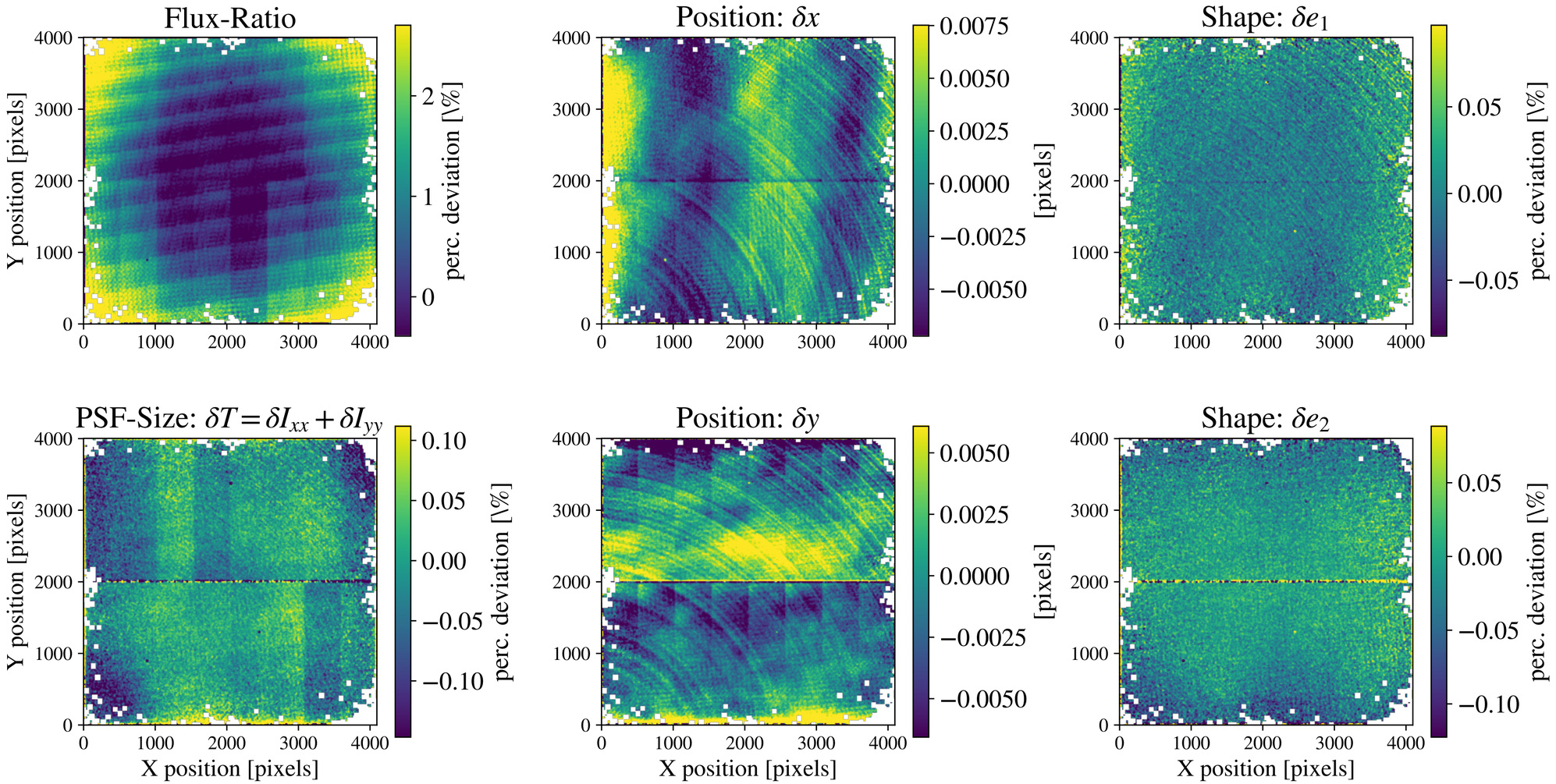
Full Well



Dark [e-/sec/pixel]

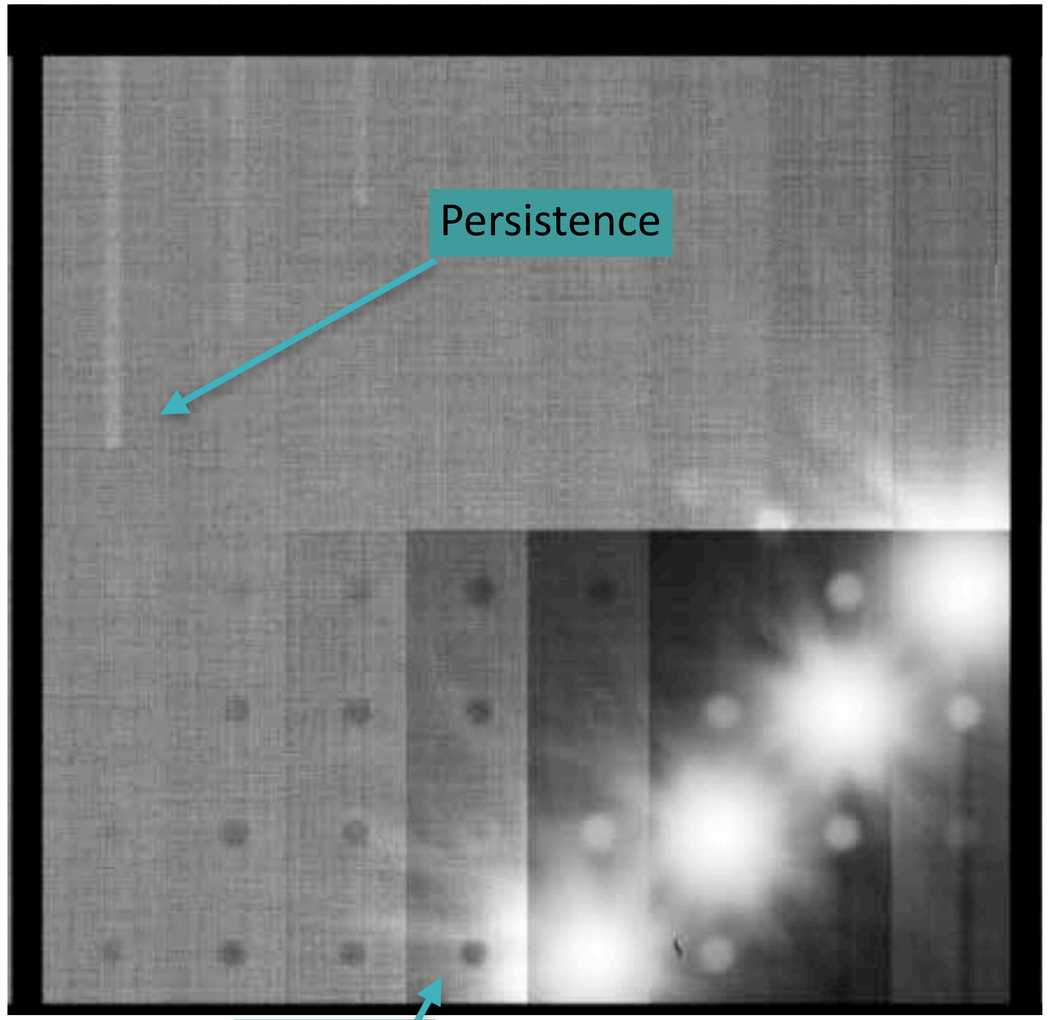


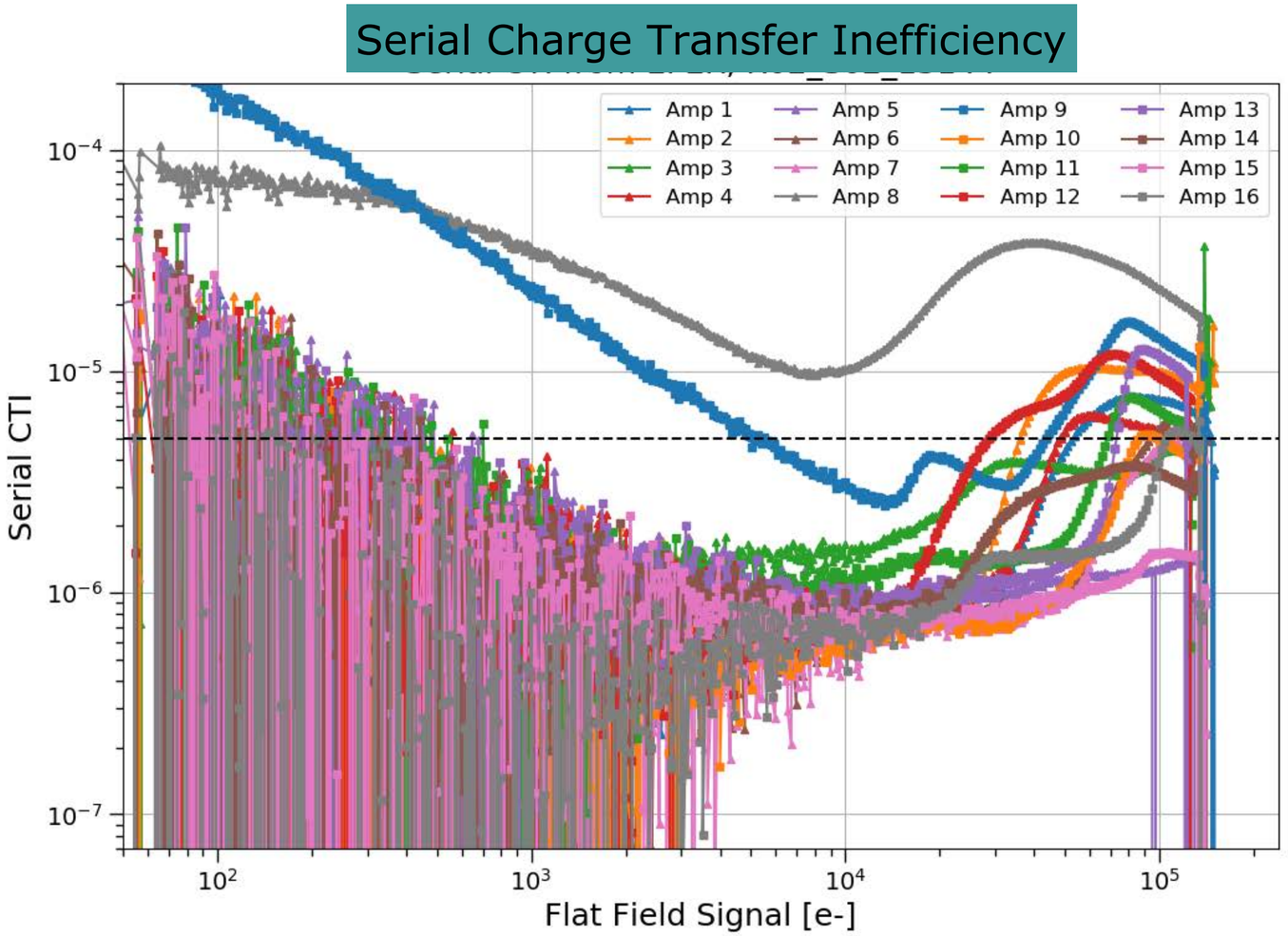
Tree Rings & Pixel Size Variations



Esteves, Utsumi et.al. 2023 https://arxiv.org/abs/2308.00919

Cross-Talk, Persistence, CTI

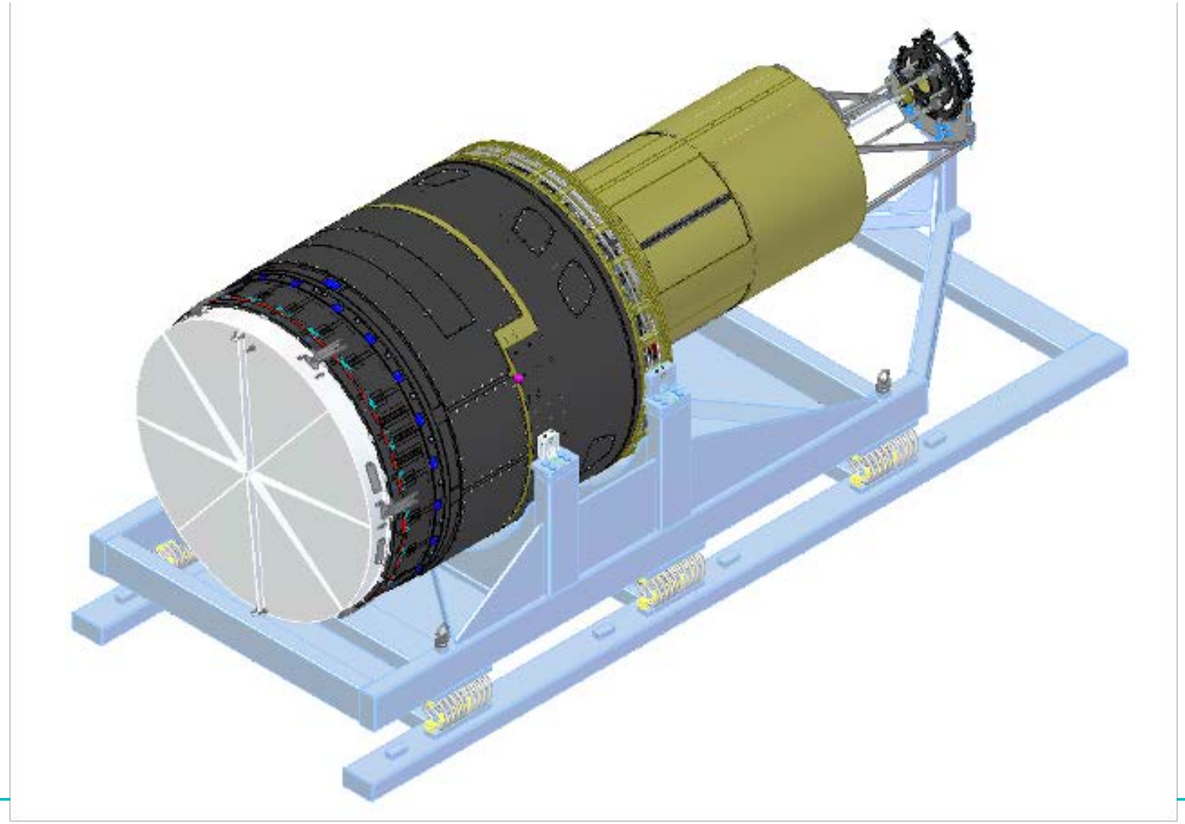




Snyder, Roodman 2020 https://arxiv.org/abs/2001.03223

Shipment to Cerro Pachon

- LSST Camera scheduled for shipment to Chile in November
  - Camera to be shipped in one piece, except filters
  - via Chartered 747



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