DECam Active Optics: Lessons for Commissioning

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Rubin Project & Community Workshop

KIPAC

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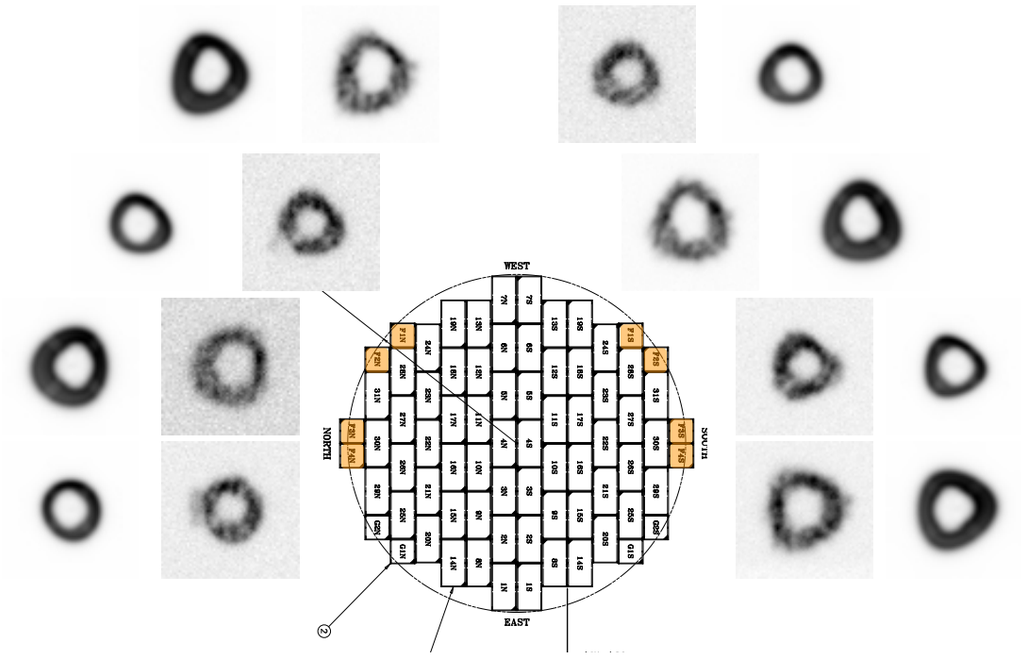
NATIONAL ACCELERATOR LABORATORY

DECam Active Optics: Overview



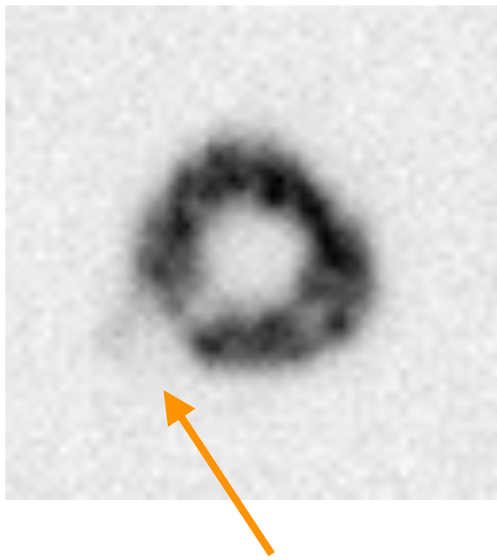
Roodman, Reil et.al. SPIE 2014

Presentation at 2019 PCW

- Wavefront sensors (8) ±1.5mm out of focus
- Forward model fit to Zernike Wavefront expansion (z4-z10)
- Roughly 20-40 Donuts fit in 7 seconds between exposures
- Camera Hexapod (5 dof) & Primary Mirror Astigmatism (2 dof):
  - LUT as a function of Alt,Az
  - simple PID loop for Active Control
- Commissioned with DECam in 2012
  - Hexpod in Active Control in 2013
  - Primary Astigmatism in Active Control in 2015-6
- Essentially problem-free operation since 2013
- ongoing study of Engineering images for PSF Estimation

DECam AOS Commissioning: Control Matrix

- Find Reference Wavefront corresponding to Optimal Alignment
  - Data Driven, using in-focus & out-of-focus images
  - Simulation would not have worked due to Donut distortions
- Command individual DOFs & measure Donut Zernike response



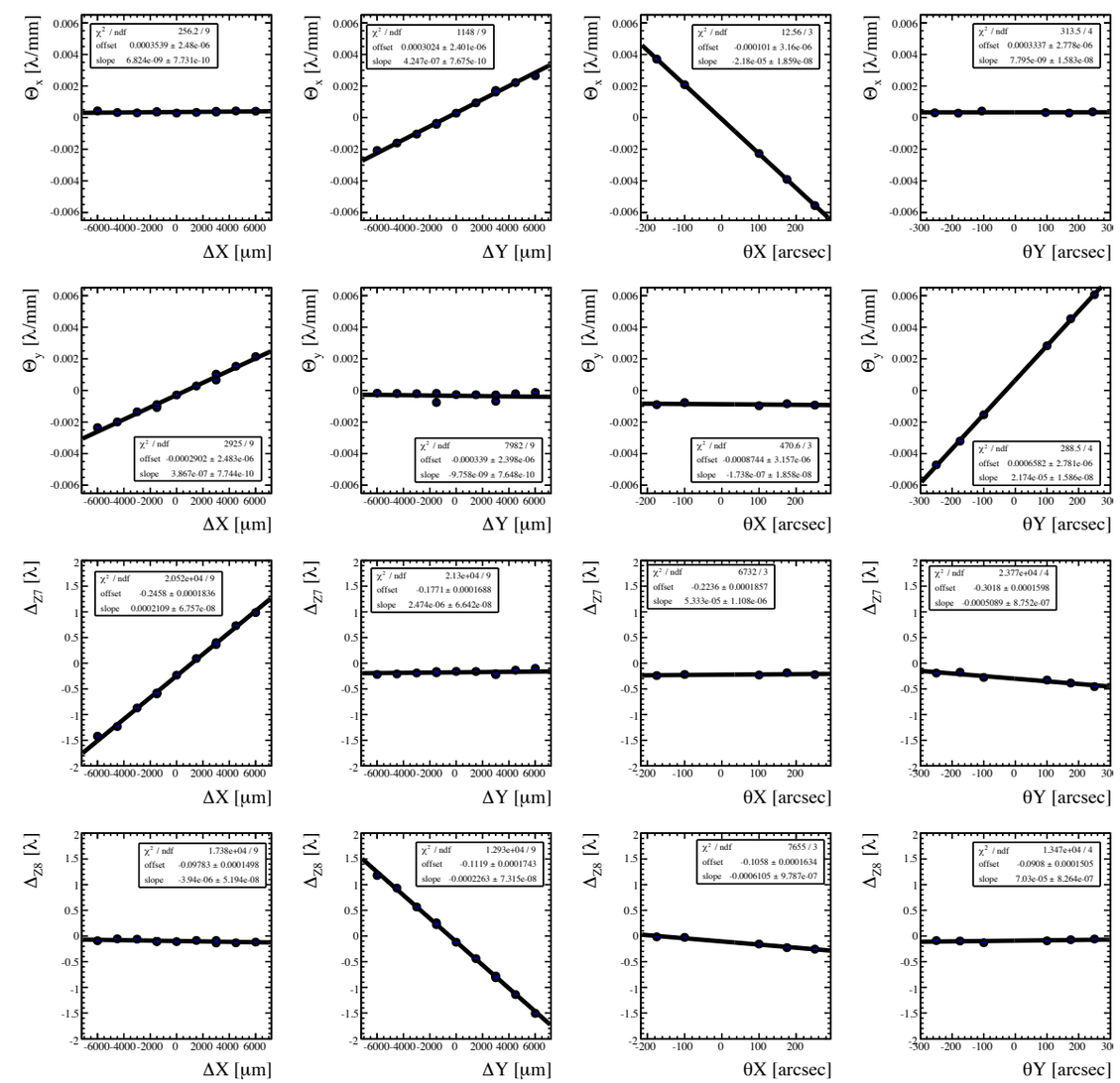
$$\frac{\partial \text{Aberration}}{\partial \text{Hexapod}} = \Delta z_7, \Delta z_8, \Theta_x(z_5, z_6), \Theta_y(z_5, z_6)$$

$$\Delta_{z_5} - \Theta_y \times x + \Theta_x \times y = \left\langle a_5(x,y) - a_5^{Reference}(x,y) \right\rangle$$

$$\Delta_{z_6} = \Theta_x \times x + \Theta_y \times y = \left\langle a_6(x,y) - a_6^{Reference}(x,y) \right\rangle$$

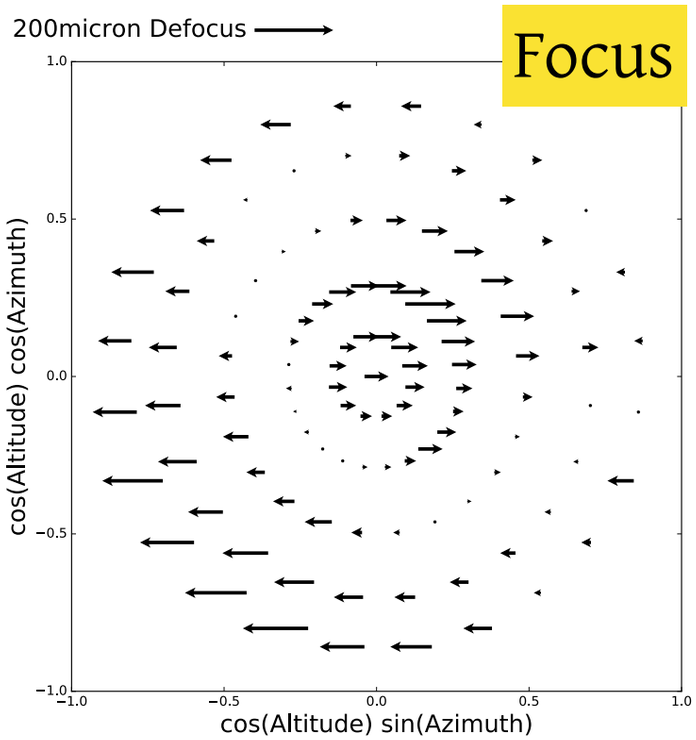
$$\Delta z_7 = \left\langle a_7(x,y) - a_7^{Reference}(x,y) \right\rangle$$

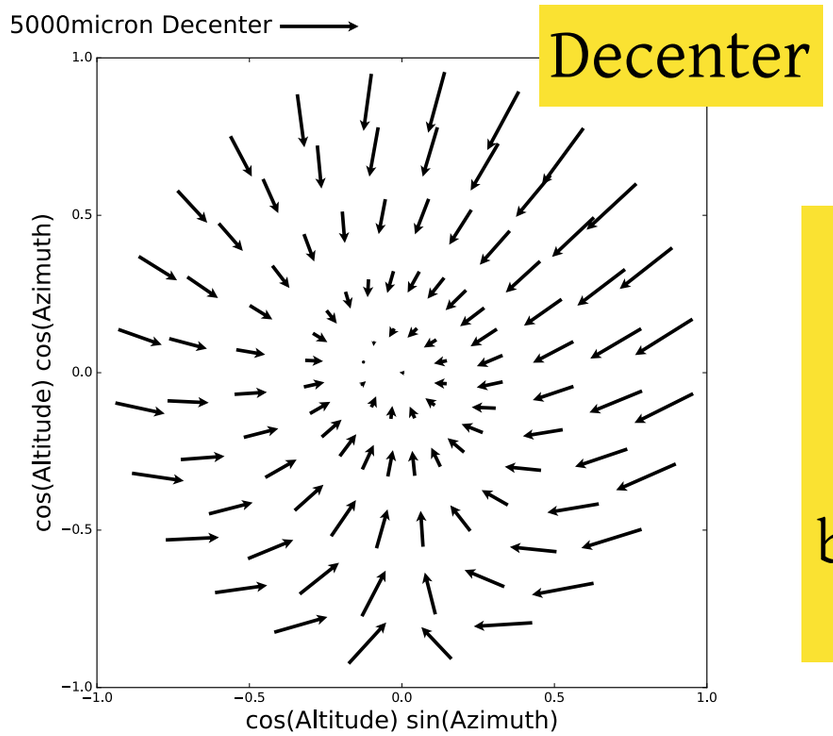
$$\Delta z_8 = \left\langle a_8(x,y) - a_8^{Reference}(x,y) \right\rangle$$



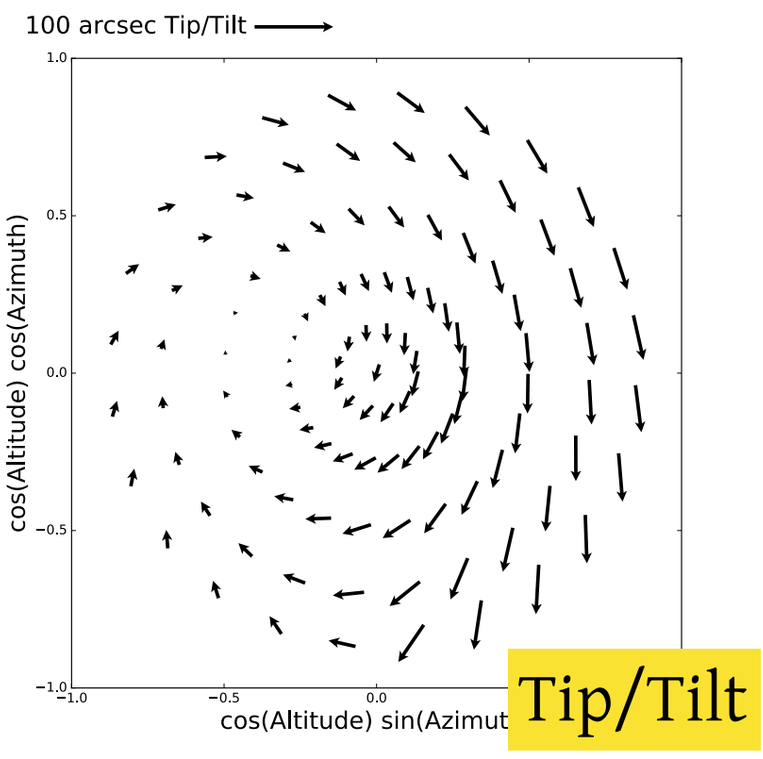
Hexapod d.o.f.

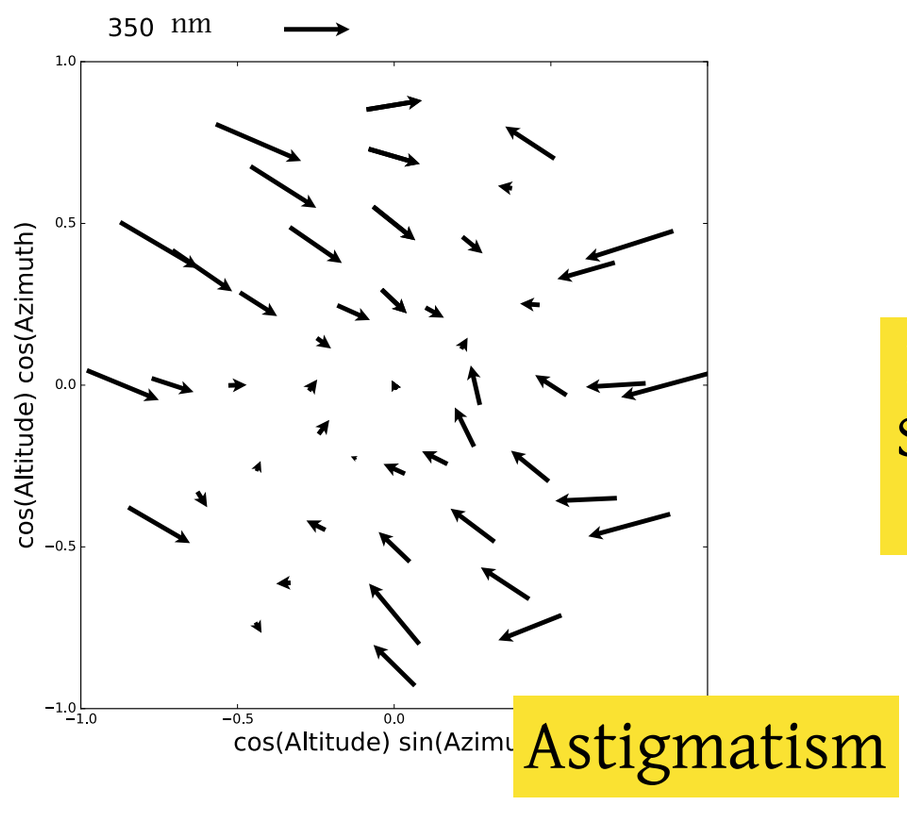
DECam AOS Commissioning: Look Up Tables





initial LUTs were from sky scans used 5 images per pointing to reduce atmospheric turbulence noise
but these LUT still had significant systematic deviations.

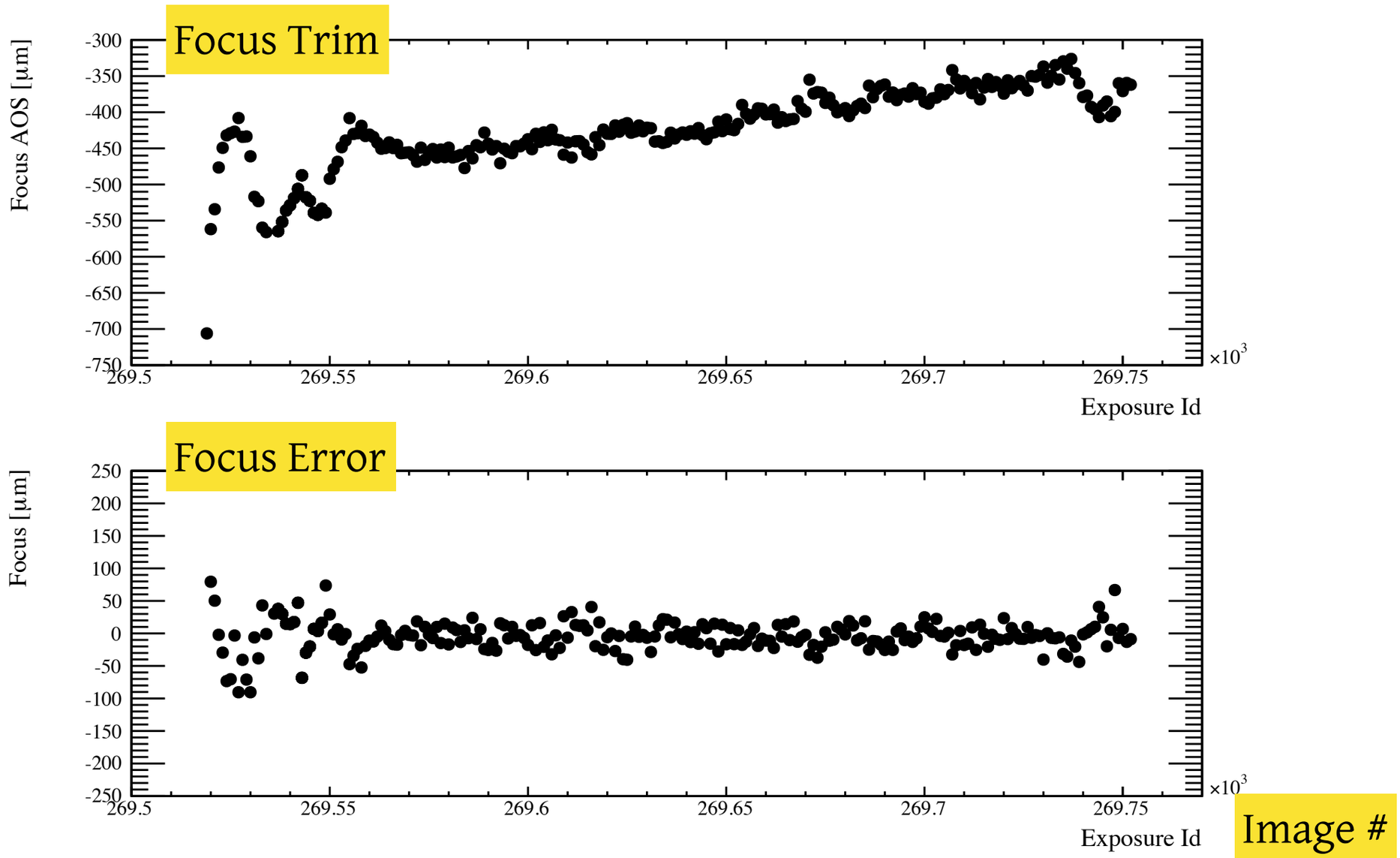




LUTs built from 3 years of Science observations, both DES & community.

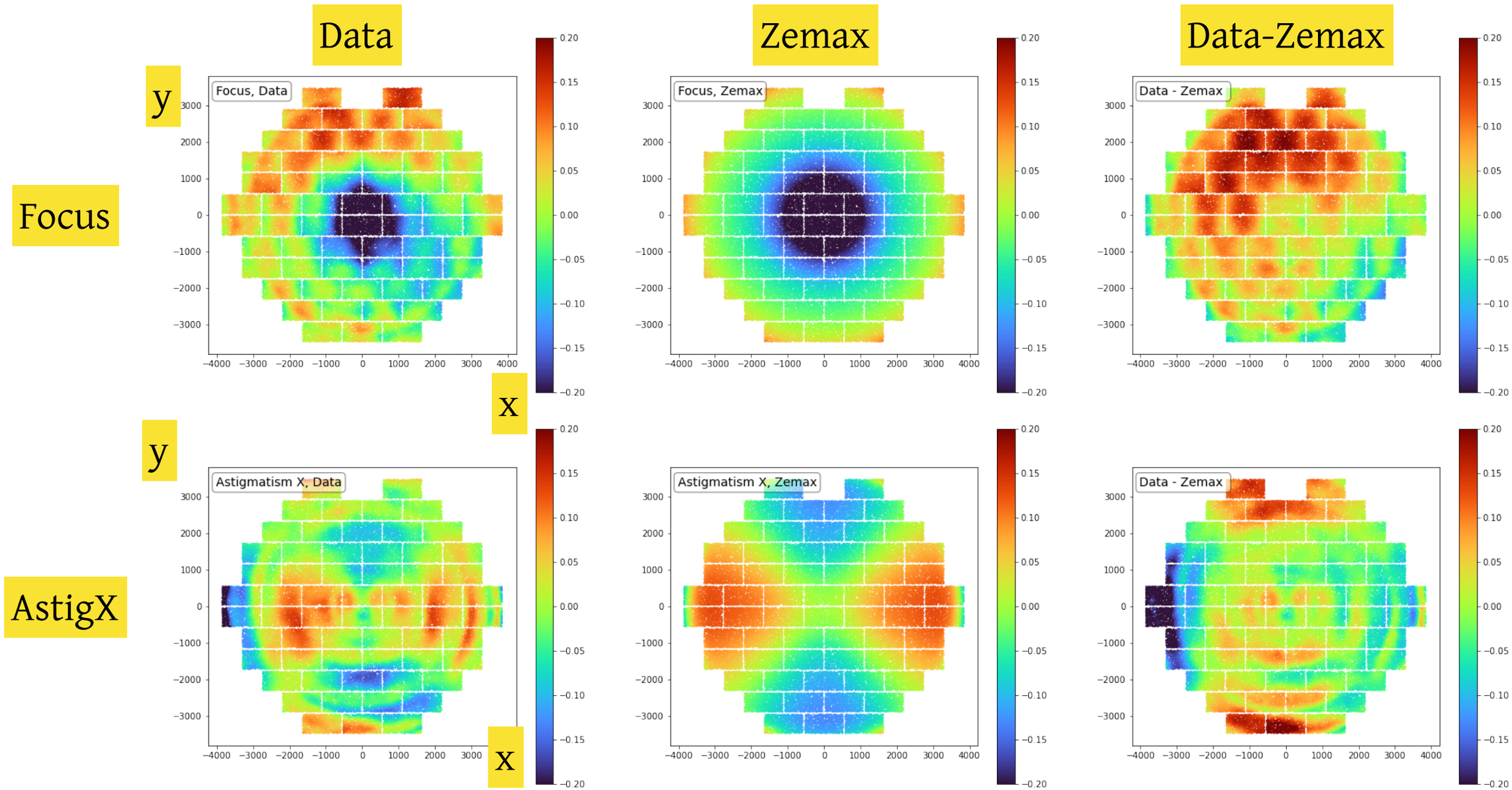
DECam AOS Commissioning: PID Loop

- Simple PID controller implemented for each DOF
- Gains optimized based on open-loop operation during Commissioning



PSF Estimation: Optics+Atmosphere in PIFF

- Uses measurement of the Optical Wavefront to estimate PSF



- Independent Check on AOS via PSF performance

Davis, Roodman, et.al. SPIE 2016 DESC PSF Presentation - 2020

Lessons for Rubin AOS

- Check individual Donut morphology both in Wavefront sensors & Science Rafts
  - ensure that all Donuts can be well modeled by Zernike expansion
- Collect Donuts across full Focal plane (intra/extra focal) in each Filter
  - 100 images at lowish gLat with only small dithers for good statistics
  - compare Wavefront performance to Zemax/Batoid model
- Measure Zernike response to each individual Hexapod, Mirror D.O.F.
  - check that measured response matrix matches model
- Seed LUT with model or Sky Scans, but update with data
  - Note: optimal Camera optical alignment requires Hexapods LUT to depend on Rotator angle
- Study open-loop (LUT only) performance of AOS
  - Tune feedback gain based on typical results
  - Donut engineering images: also provides open-loop sample with minimal changes in TMA