Astrometric shifts in LSST CCDs

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• Astrometric shift at the edge

• Modeling the physics of the CCD

• Tree rings and flat fielding

• Correction methods vs. masking?

Dithering stars a few microns at a time





<u>A</u>strometry ~10 pixels from edge are badly biased, but in a measurable, modelable, and <u>correctable</u> way



Shown for multiple different segments of the CCD along bottom & top Configuration: V bb = -60, V scup=+19, filter=r



Simulation setup: side view



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Edge shift depends on knobs & operation \rightarrow opportunity to minimize edge cuts





Edge systematics correlate galaxy shapes



Correlations computation cred: James Jee

Flat fielding doesn't help



Flat vs no flat... enhanced



Flat vs no flat... enhanced



Tree rings in ITL flat field image



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Tree rings in astrometry

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Scatter plot of Y astrometric error field, ~3 million data points .001 pix stat noise, edges and tree rings easily detected

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Lessons from lab & simulations



- 1. Astrometry is strongly dependent on camera operation
- 2. Turning knobs on camera varying e.g. back bias, scupper, serial voltages varies electron transport \rightarrow optimize?
- 3. Poisson simulation confirms physical interpretation and informs correction algorithms
- 4. Flat fielding only hides the problem
- 5. Without correction, these will imprint on position & shear correlation functions

You too can hack this data!!



- Data from Davis/SLAC beam simulator is available for download, through SLAC data repository & NCSA
 Raw pinhole array images, flats [~100 GBs of FITS]
- Catalogs are also available
 - both detection level [~1GB of FITS_LDAC]
 - and post-processing [~3MB of .txt]
- Code [~1MB of .ipynb's] available

Astrometry with pinhole grid



Residuals are error on grid shift between two dithers:

Astrometric error = Measured position - Predicted position

Predicted positions determined by median of ~1000 pinholes



Where I left off @ Oxford '16: "Bamboo" seen in earlier device plagues entire CCD, not just edges





Similar bamboo/stepper issue seen in X/Y direction, but astrometry systematic periodicity in Y direction was 10 times X dir. Shown for different segments. Configuration: V_bb = -60; V_scup=+19, filter=r

Poisson simulation of tree rings

Tree Rings: Amplitude = 1.00, Angle = 38.00 degrees, Period = 46.00 microns

Variable doping pattern reproduces pixel displacements similar to tree rings





UC Davis beam simulator setup



The LSST beam simulator assembly. **A**: camera and cryogenic dewar, **B**: LSST f/1.2 beam simulator optics and input mask, **C**: Illuminating sphere, **D**: precision X/Y/Z stage.

Electron paths at edge, from Poisson simulation



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