Tree-rings in the LSST Camera

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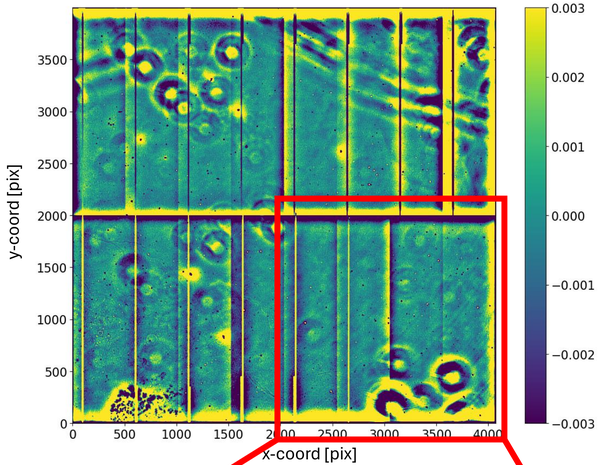
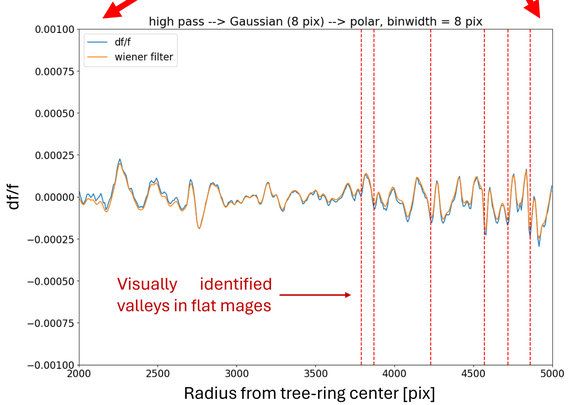
Tree-rings

Tree-rings are circular variations in effective pixel-size in the CCD (due to fluctuating doping concentration in the silicon). Tree-rings can directly impact flux measurement and propagate into photometry, astrometry, and shape measurements.

Measuring tree-rings

Measuring tree-rings can be hard. See e.g. dome flat from the auxiliary telescope. We applied following steps: high pass filter → Gaussian smoothing → masking → convert to polar coordinates. However, tree-rings are still hard to spot.

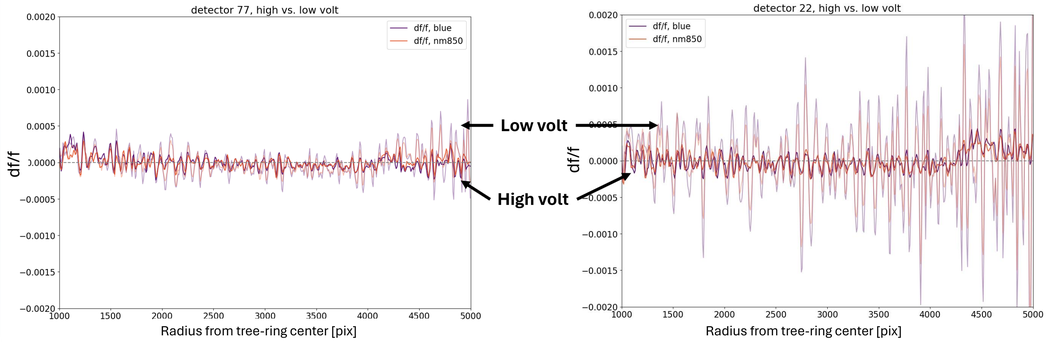




High vs. Low Voltage Flat Images

Is there a way to better measure tree-rings?

Instead of using flat images taken with normal operating (50 V) back bias, we can use a 0 V back bias. Since electrons are reads out by diffusion with 0-Volt, signal to noise of tree-ring is enhanced.

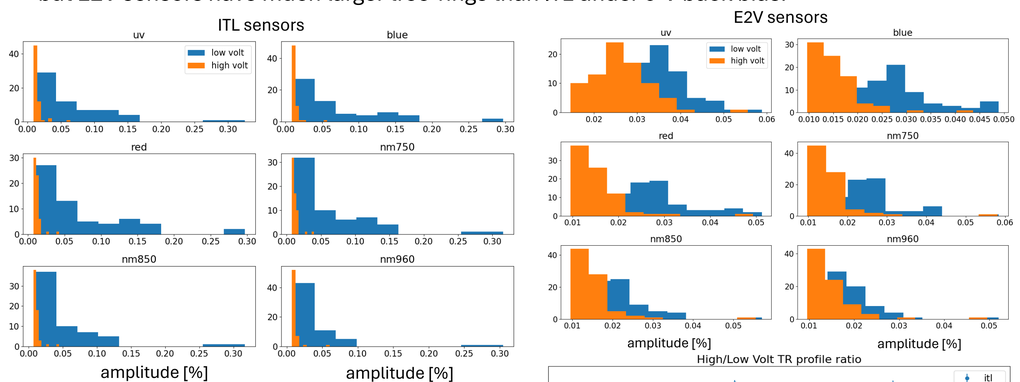


This improves the tree-ring center measurements, but how about tree-ring amplitudes?

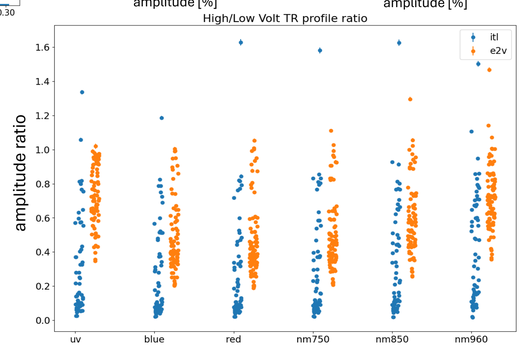
Statistics on Tree-ring Amplitudes

We measure the tree-ring amplitude (root-mean-square of the radial profile of flux fluctuation) from ~150 CCDs from both ITL and E2V vendors. We find that:

- Tree-ring amplitudes are consistent among ITL and E2V sensors in high-volt images ($\lesssim 0.05\%$), but E2V sensors have much larger tree-rings than ITL under 0-V back bias.

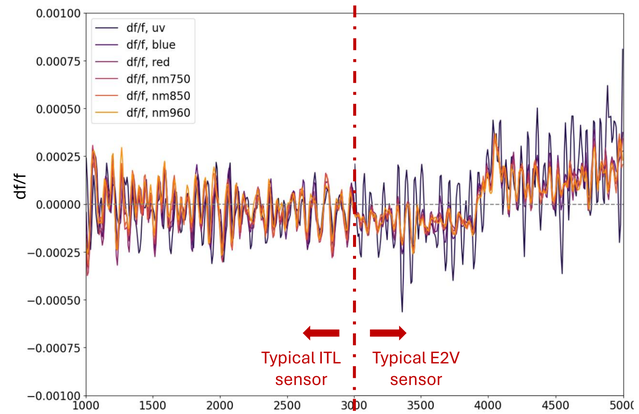


- We see a large scatter in the ratios between tree-ring amplitudes under high vs. low voltage back biases flat images. This scatter presents a difficulty in estimating the tree-ring profiles using the 0-V back bias flat images. Further studies of systematics and noise in flat images may be needed.



Wavelength Dependence

We observe wavelength dependence in the summary statistics for tree-ring amplitudes. This is due to that photons of longer wavelengths are converted to electrons deeper into the silicon layer, where doping concentration variation is smaller. The wavelength dependence varies between vendors.



Conclusions

1. 0-V back bias can enhance tree-ring signatures in flat images, which can be used to measure tree-ring centers.
2. However, due to large scatter in amplitude ratios between the low and high voltage flat images, inferring tree-ring amplitudes from low-voltage images may require more studies on noise/systematics.
3. Compared to DECam (tree-ring amplitude ~1%), the tree-rings in LSSTCam (with amplitude $\lesssim 0.05\%$) are small.
4. We discovered slight wavelength dependence of tree-ring amplitudes in ITL sensors. E2V sensors have significant larger tree-ring amplitudes in the UV band in particular.

References

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