The Brighter-Fatter Effect and Photon Transfer

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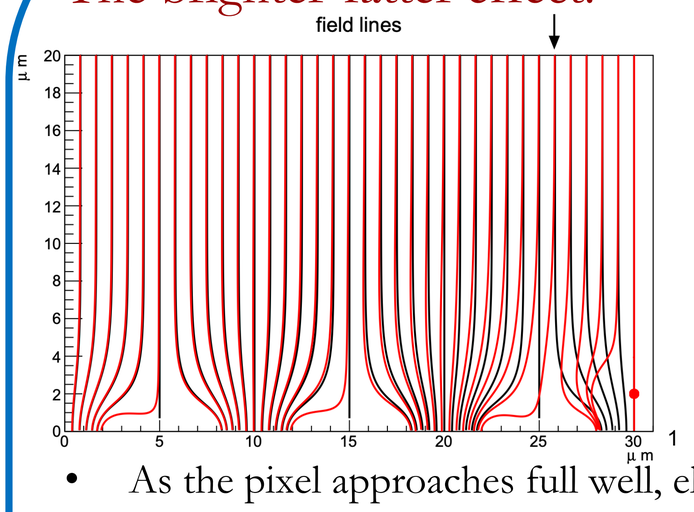
Research Question

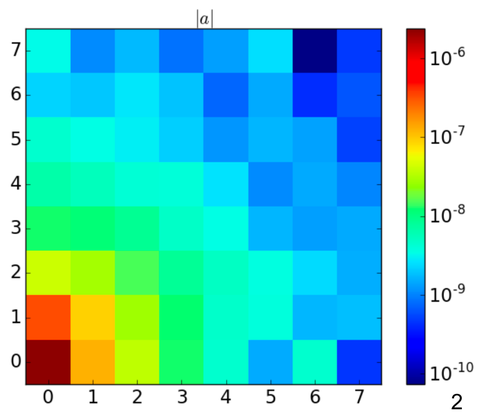
How does the Photon Transfer curve depend on the Brighter-Fatter effect for different combinations of means of pixels?

Background

The brighter-fatter effect:



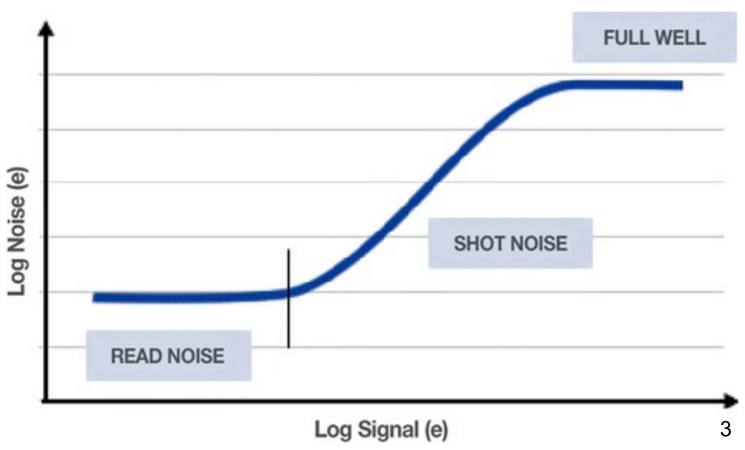
1



2

- As the pixel approaches full well, electric field lines are deflected away from the pixel
- Any electron released by a photon will have a higher probability of being trapped in adjacent pixels
- Causes a decrease in variance of pixels as brightness is increased
- When observing stars: brighter stars are wider/fatter (brighter-fatter effect)

The photon transfer curve:



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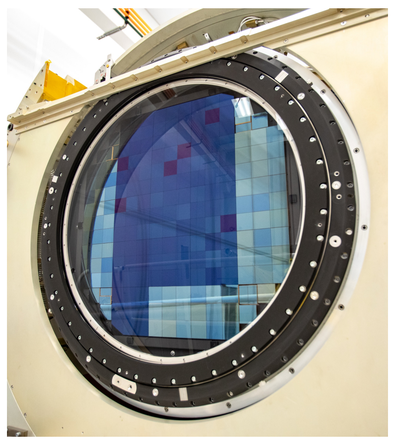
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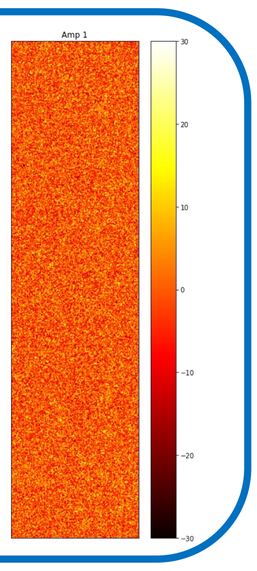
$$C_{00} = \frac{1}{2g^2 a_{00}} [\exp(2a_{00}\mu g) - 1] + n_{00}/g^2$$ 5

- The photon transfer curve plots the noise (variance) against the mean signal of the image
- Can fit the equation above where C_{00} = variance, g = gain, a_{00} = how much of an impact the electrons in the well have on any released photoelectron, μ = mean signal, n_{00} = read noise

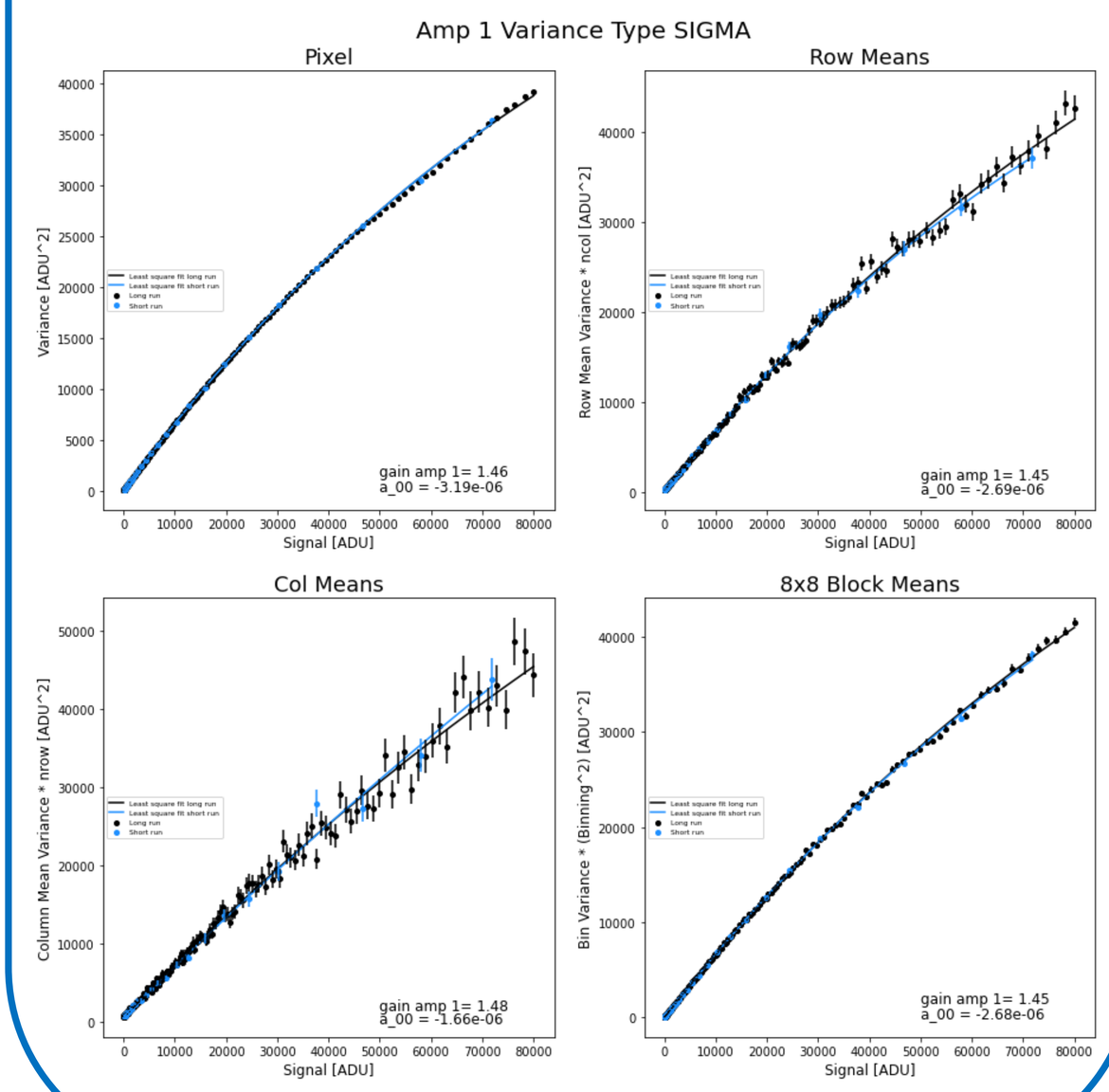
Methodology

- Take the the variance, row mean variance, column mean variance, and binning variance vs the mean signal of each flat pair
- Fit the data to the equation that describes the photon transfer curve and determine the a_{00} parameter for each amplifier
- This new a_{00} will encompass the a_{00}'s from all the individual pixels in the mean



Results

- Found that the column means deviate from the best fit line quite significantly
- Row means also deviate from best fit line, although not as much
- Expect the 8x8 binned a_{00} to be about 1/8 of the pixel a_{00}
- The a_{00} values of the 8x8 binned values disagree with expectations, and are about the same as the pixel a_{00}
- The scaled variance of the column means is higher than the scaled variance of all the other mean types



Discussion and Conclusions

- Must refine these models of the brighter-fatter effect because the PSF of stars will vary from the PSF of galaxies
- Determine why the 8x8 block mean has larger a_{00} values than expected
- Investigate the column means and why they deviate so far from the fit
- Include more parameters in the fit that may have a smaller impact than the a_{00} term.
- Examine how these results can be applied to the LSST image correction algorithm
- Run code on a PTC run of ~350 images instead of 41

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[1]Antilogus, P., Astier, P., Doherty, P., Guyonnet, A., & Regnault, N. (2014). The brighter-fatter effect and pixel correlations in CCD sensors. *Journal of Instrumentation*, *9*(03). https://doi.org/10.1088/1748-0221/9/03/c03048
[2, 5]Astier, P., Antilogus, P., Juramy, C., Le Breton, R., Le Guillou, L., & Sepulveda, E. (2019). The shape of the photon transfer curve of CCD sensors. *Astronomy & Astrophysics*, *629*. https://doi.org/10.1051/0004-6361/201935508
[3]Kreysar, D. (2017, December 1). *Understanding CCD camera resolution and dynamic range*. Fierce Electronics. Retrieved August 1, 2022, from https://www.fierceelectronics.com/components/understanding-ccd-camera-resolution-and-dynamic-range