

Noise Modeling using Photon Transfer Curves

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$$\langle I \rangle_i = G\eta \langle P \rangle_i + ped$$

$$\begin{aligned}\sigma_i^2 &= \sigma_{SHOT}^2 + \sigma_{FANO}^2 + \sigma_{READ}^2 \\ &= G^2 \eta^2 \langle P \rangle_i + G^2 \eta F + \sigma_{READ}^2 \\ &= \left(G (\langle I \rangle_i - ped) + G^2 F \right) \eta + \sigma_{READ}^2\end{aligned}$$

Charge Collection Issues: $\eta \rightarrow \eta_E, \eta_E < \eta$

$$\langle I \rangle_i = G\eta\langle P \rangle_i + ped$$

$$\sigma_i^2 = \left(G(\langle I \rangle_i - ped) + G^2 F \right) \eta_E + \sigma_{READ}^2$$

Need to measure $\sigma_{READ}^2, ped, G, \eta_E$

$$\langle I \rangle_{BOX} = G\eta\langle P \rangle_{BOX} + ped$$

$$\sigma_{BOX}^2 = \left(G(\langle I \rangle_{BOX} - ped) + G^2 F \right) \eta_E + \sigma_{READ}^2 + \sigma_{FIXED}^2$$

$$\sigma_{dI,BOX}^2 = \left(G(\langle I \rangle_{BOX} - ped) + G^2 F \right) \eta_E + \sigma_{READ}^2$$

$$dI \equiv \frac{I_2 - I_1}{\sqrt{2}}$$

$$\eta_E = \frac{\sigma_{EUV}^2 - \sigma_{READ}^2}{G(\langle I \rangle_{BOX} - ped) + G^2 F} \quad [\text{e-/phot}]$$

$\lambda > 400nm :$

$$\sigma_{RED}^2 = G(\langle I \rangle - ped) + \sigma_{READ}^2$$

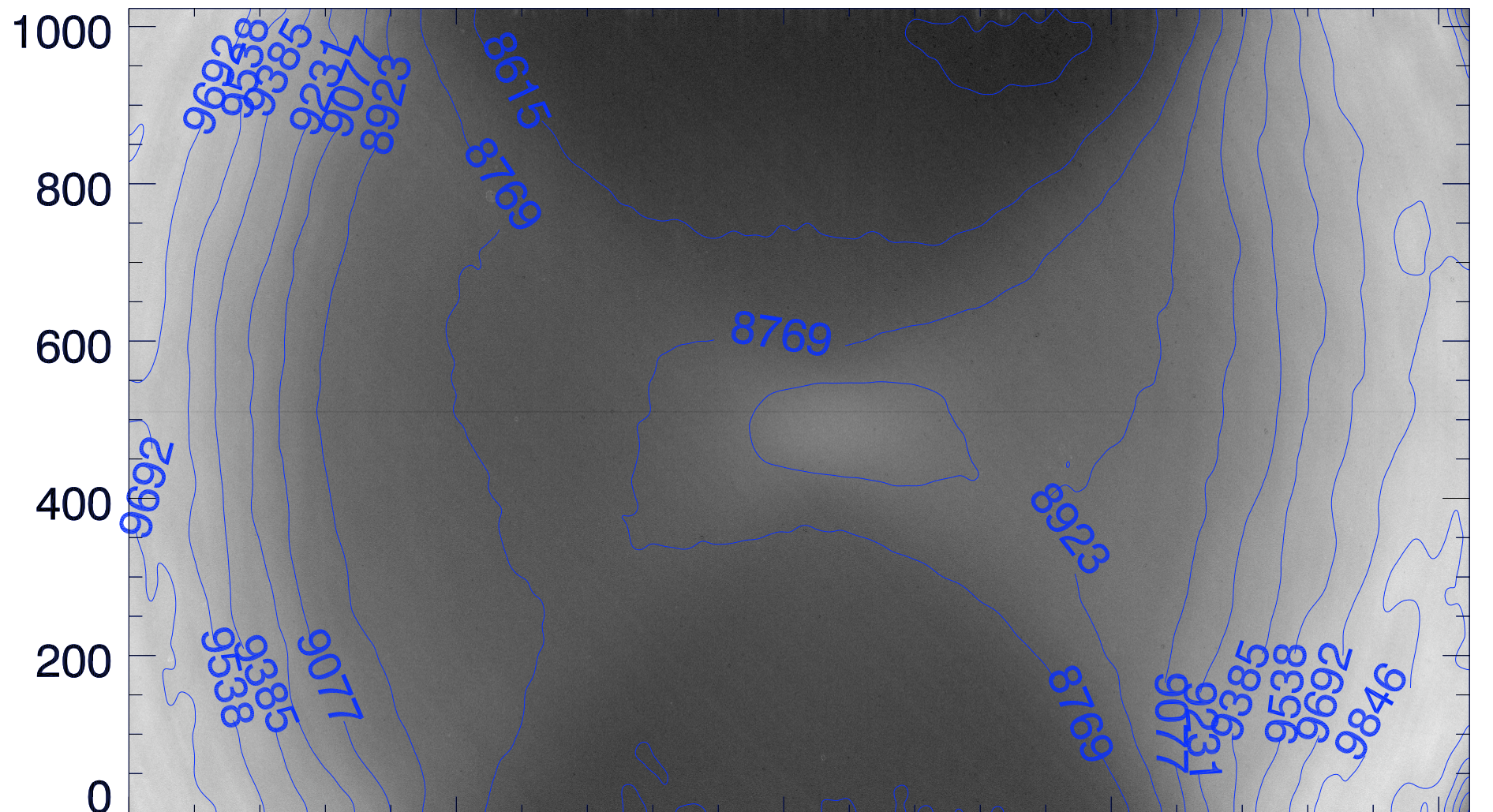
$$G = \frac{\sigma_{RED}^2 - \sigma_{READ}^2}{\langle I \rangle - ped} \quad [\text{DN/e-}]$$

σ_{READ}^2, ped measured from bias images
(dark current at room temp)

G is temperature dependent.

Procedure

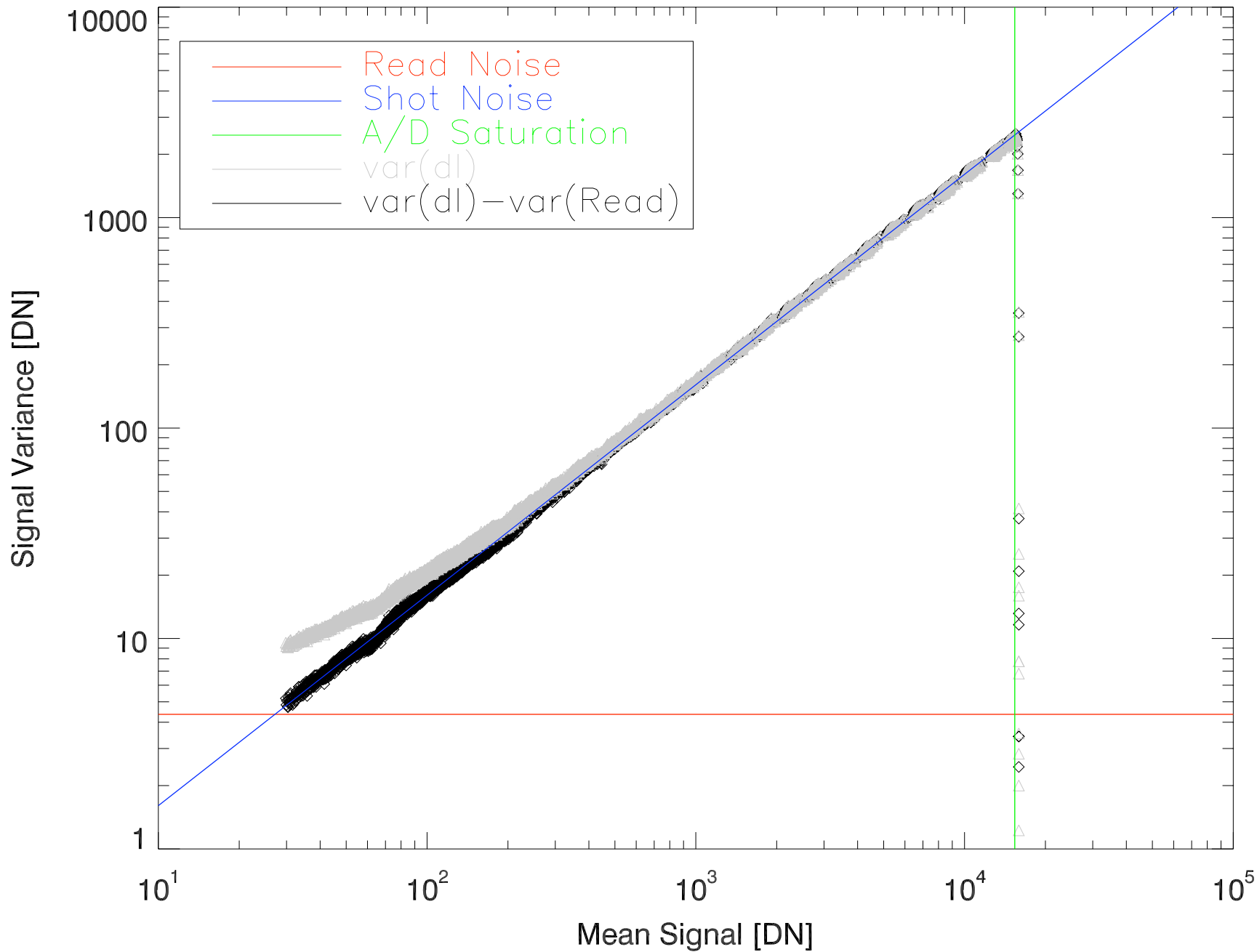
- Expose CCD's to pulsed 635 nm LED
- Vary exposure level from dark to A/D saturation
- Two images at each exposure level
- Difference same exposure images
- Compute $\sigma_{dI,BOX}^2, \langle I \rangle_{BOX}$ for many locations on CCD
- Plot on log-log scale



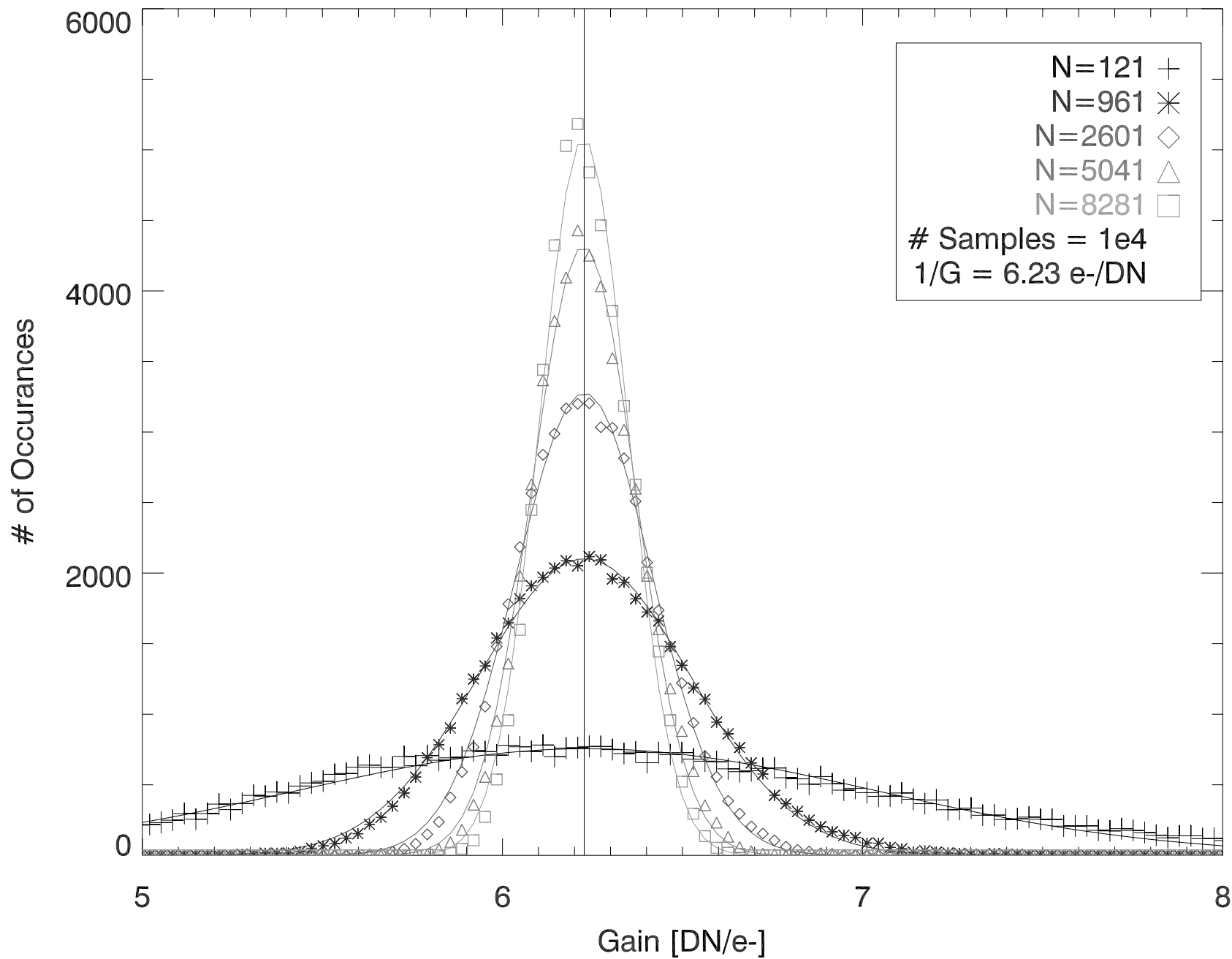
0 500 1000 1500 2000

m=-1, <I> = 9011 DN, t_exp = .192 s

m=-1 Photon Transfer Curve



m=-1 Gain Histogram



Results

	1/G [e-/DN]	RMS Read Noise [e-]	Min Full Well [ke-]
m = -1	6.23	13.00	95.7
m = 0	6.40	13.22	99.9
m = +1	6.25	14.08	98.1

TO DO

- Cooled (vacuum) red light photon transfer
- Measure effective quantum yield in EUV
 - ➔ noise model
- PTC – Flatfield Connection

Thanks

Pat Lokken

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Jake Plovanic

Charles

Norm

Bo

Larry

References

- Janesick, J. (2001). *Scientific Charge-Coupled Devices*. SPIE Press.
- Janesick, J. (2007). *DN \rightarrow λ* . SPIE Press.