Signal-Dependent Interpixel Capacitance in HgCdTe Detector Arrays for NEOCam

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The Near-Earth Object Camera (NEOCam)

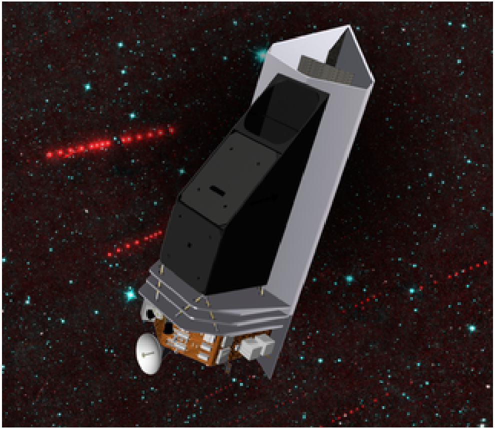
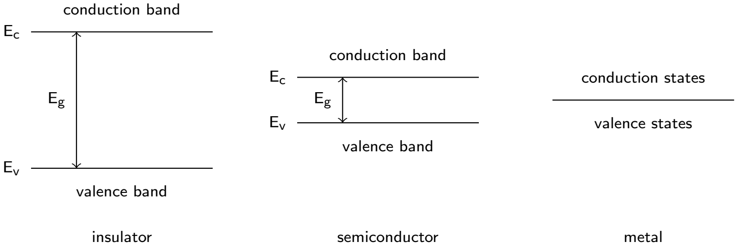


Figure: A rendering of the NEOCam spacecraft.

Image credit: NASA/JPL-Caltech

Semiconductors



$Hg_{1-x}Cd_xTe$ (mercury cadmium telluride, or MCT) is a semiconductor that is used for the detection of infrared photons. The bandgap of HgCdTe can be tuned by varying the parameter x in the formula for the compound.

Diagram recreated from Rieke (2002)

Interpixel Capacitance

$$\boxed{V[i,j] = \frac{Q[i,j]}{C[i,j]}}$$

Interpixel capacitance (IPC) is a coupling between pixels on an IR detector array that causes signal deposited in one pixel to be measured in neighboring pixels.

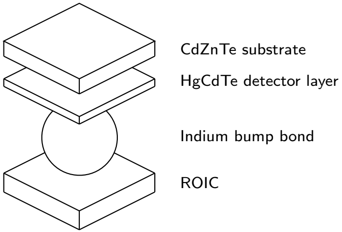


Figure: A simplified deconstruction of a pixel in an infrared array for NEOCam (not to scale).

Kannawadi et al. 2016

Figure adapted from Donlon et al. 2017

Motivation

Recent developments in performance analysis of IR detector arrays for JWST's NIRCam have noted that IPC is **signal-dependent**.

Project Goal

Write an algorithm that summarizes the effect of IPC on the pixels in a particular array and develops a correction that can be applied to images taken with that array.

IPC Correction

We determine the relationship between the coupling coefficient and signal strength using **hot pixels** in dark exposures.

Dark current is the current measured in a pixel when the array is not being illuminated.

We must ensure that the hot pixels are viable for analysis. That is,

- they are isolated,
- they are not saturated, and
- their four nearest neighbors have signals that are sufficiently symmetric.

Calculating the Coupling Coefficient, α

We can calculate the coupling coefficient α for each hot pixel.[1]
This relation assumes zero background illumination.

$$\alpha = \frac{\langle Neighbor \rangle - \ LocalMedian}{4 \cdot (\langle Neighbor \rangle - \ LocalMedian) + (Center - LocalMedian)}$$

[1] Donlon et al. 2018

IPC Correction

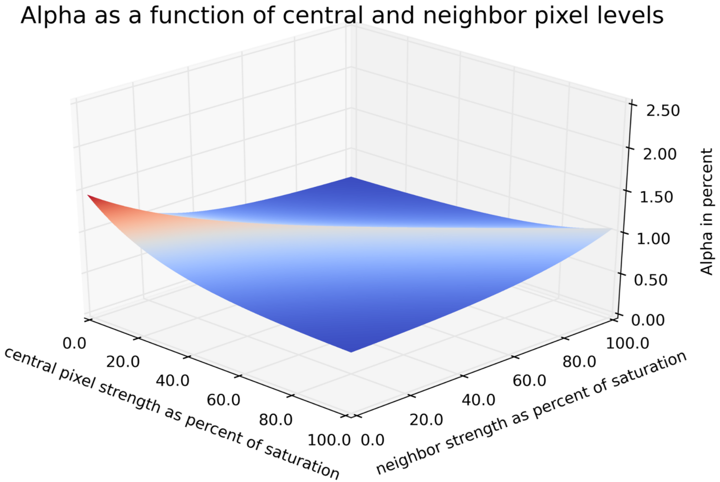


Figure from Donlon et al. 2018

α as a function of Signal Strength

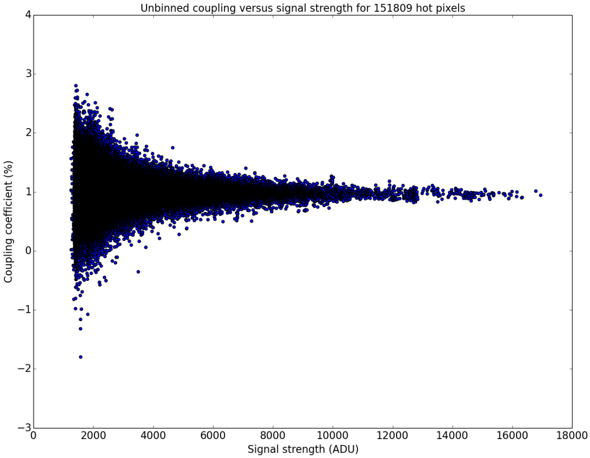


Figure: Distribution of coupling versus signal strength for H2RG-18481.

α as a function of Signal Strength

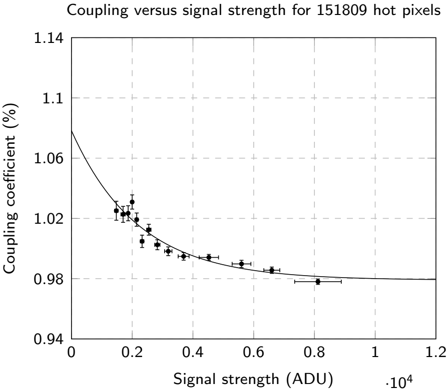


Figure: Averaged coupling versus signal strength for H2RG-18481.

$$\alpha(S) = A \cdot \exp\left(-\frac{S}{B}\right) + \alpha_\infty$$

$$A = 0.0992 \pm 0.0543$$

$$B = 2202.9 \pm 2105.4$$

$$\alpha_\infty = 0.979 \pm 0.0184$$

Measuring the Correction

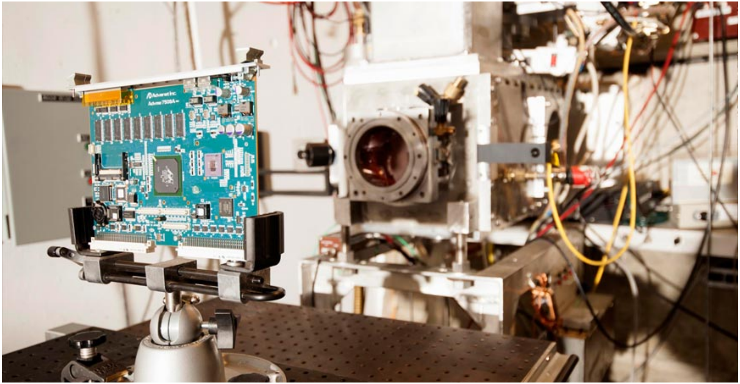


Figure: A circuit board in the cyclotron's beam at UC Davis' Crocker Nuclear Laboratory.

Image credit: CNL

Measuring the Correction

Array	Pixels/hit (orig.)	Pixels/hit (corr.)
H1RG-17346	23.0	20.8
H1RG-17354	16.7	13.2

Table: A summary of the average number of pixels per proton hit measured before and after the new IPC correction. The beam energy for these observations was 12 MeV, and the detector bias was 150 mV.

Measuring the Correction

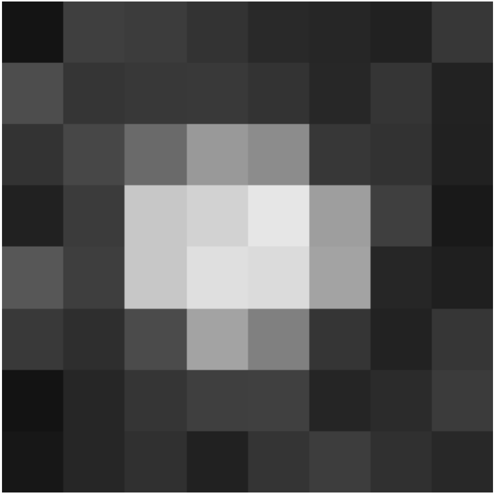


Figure: Close-up of a hit before the correction is applied.

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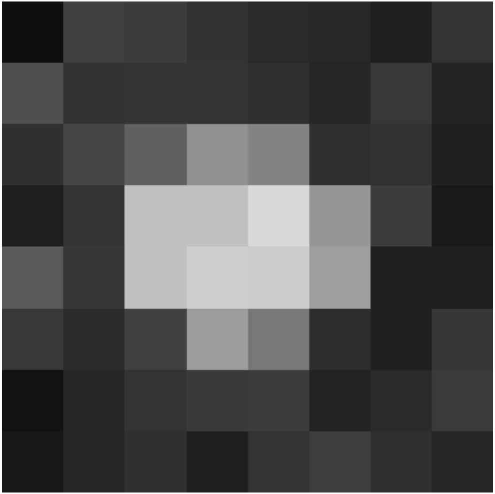

Figure: Close-up of a hit after the correction is applied.

Conclusions and Future Work

- An algorithm to correct for signal-dependent IPC, given the assumption that there is zero background strength in an image, has been successfully developed.
- More data under different background strengths are needed to characterize and correct for the dependence of IPC on neighbor pixel strength.
- Exploration of the functional forms produced by several different arrays will provide insight on how the coupling changes in similar arrays.

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