Palomar Prime-Focus Infrared Camera (PFIRCAM)

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Abstract. In a joint effort between engineers and scientists at the Jet Propulsion Laboratory and the California Institute of Technology, a near-infrared (0.8 - 2.6 μm) direct imaging system has been developed and integrated into the Caltech Palomar Observatory detector series. The camera system has been tested and operated in a science mode at the prime-focus (f/3.3) of the Hale 5-m Telescope. This paper outlines the system components and performance, including discussion of the detector linearity.

Key words: Instrumentation; Linearity.

1. PFIRCAM System Components and Performance

The system parts include a double-walled LN_2 dewar containing the array, optics and filter wheels, electronic components (pre-amplifier, A/D converter, bias and timing, and high speed data transfer), and computer control ("highspeed data receiver, array test software, cpu, etc.).

The infrared array is a matrix of 256 x 256 photodiodes formed by ion implantation into a layer of HgCdTe grown on a sapphire substrate (Rockwell's NICMOS III). The pixel size is 40 x 40 μm, corresponding to a plate scale of 0.54″× 0.54″, giving a total field of view ~2.3′× 2.3′. The overall camera system resolution is 11 electrons/DN with a dynamic range ~170,000 electrons subject to a read noise ~ 50 electrons. At prime focus (f/3.3) on the Hale 5-m Telescope the 10% limiting magnitudes are K ~16.7, H ~ 17.9, and J ~18.8 in 60 second exposures.

2. PFIRCAM Linearity

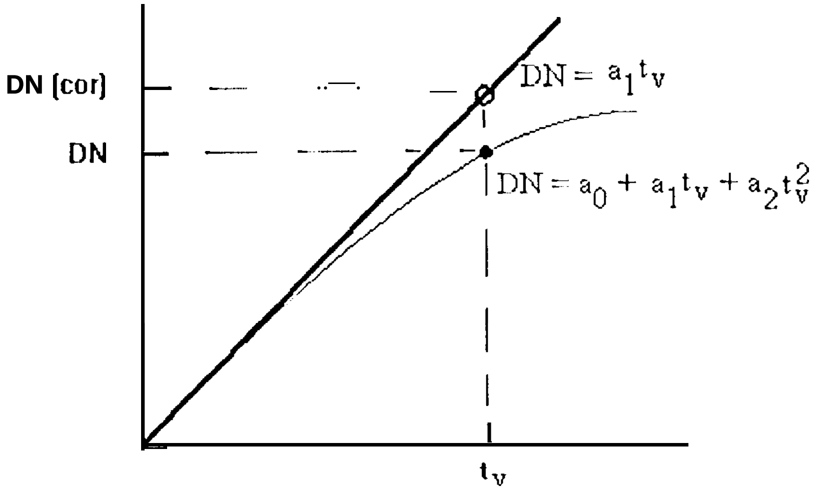
The NICMOS III detector behaves nonlinearly at all flux levels, in a pixel-to-pixel dependent fashion. In order to model the detector response we obtained multiple signal images of the Hale 200″ mirror cover. A typical pixel response includes a linear region followed by rollover and saturation. The linear regime may be characterized by the quadratic

$$DN = a_0 + a_1 t + a_2 t^2; \quad DN < a_3 \qquad (1)$$

where t is the integration time. In this fit the various terms are to be interpreted as: a_0 the zero bias level, a_1 the quantum efficiency or sensitivity, a_2 the non-linearity or saturation, and a_3 the dynamic range.

The fitting procedure follows four steps: (1) form (t,DN) pairs for each pixel; (2) eliminate pixels with DN > 95% of the saturation threshold; (3) perform quadratic least-squares fit; (4) residuals are computed for each point; data where the residual exceeds 2σ are eliminated and the fit is recalculated.

The basic procedure to linearly rectify PFIR CAM science data is sketched below.



The observed DN and a_i polynomial coefficients are used to compute a "virtual" exposure time needed to match the calibration linear-sequence data. Accordingly, we must solve for t_v in the quadratic

$$DN(obs) = a_0 + a_1 t_v + a_2 t_v^2 \tag{2}$$

where the solution we seek is the smallest positive root; t_v is then multiplied by quantum efficiency a_1 to give the linearized data:

$$DN(cor) = a_1 t_v \ . \tag{3}$$

If $DN(obs)_{i,j} > a_3$, then pixel (i,j) is flagged as saturated and set to some constant lower threshold.

For very large data sets it may be necessary to further optimize the computational pipeline by solving the quadratic using a series expansion. The smallest positive root has the solution

$$t_v = \frac{a_0(-a_1 + \sqrt{a_1^2 - 4a_0a_2})}{2} - \frac{a_0^2 DN}{\sqrt{a_1^2 - 4a_0a_2}} + \frac{a_0^3 DN^2}{(a_1^2 - 4a_0a_2)^{3/2}} + O(DN^3) \ , \tag{4}$$

i.e.,

$$t_v = a_0' + a_1' DN + a_2' DN^2 + O(DN^3) \ . \tag{5}$$