WHIRC Report II

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1 April 2008

Introduction

During the T&E time in March, Charles and Heidi carried out a number of tests of WHIRC performance, including:

- PTC and linearity tests at detector bias values of 0.5, 0.7, 0.8, and 1.0 v.
- On-sky measurements of standard stars through the filters (0.8 v bias)

Charles has already sent around an excellent compendium of the PTC and linearity results. My results are in good agreement, but analyzed in a different way. Confirmation and independent analysis is always good.

Signal Levels

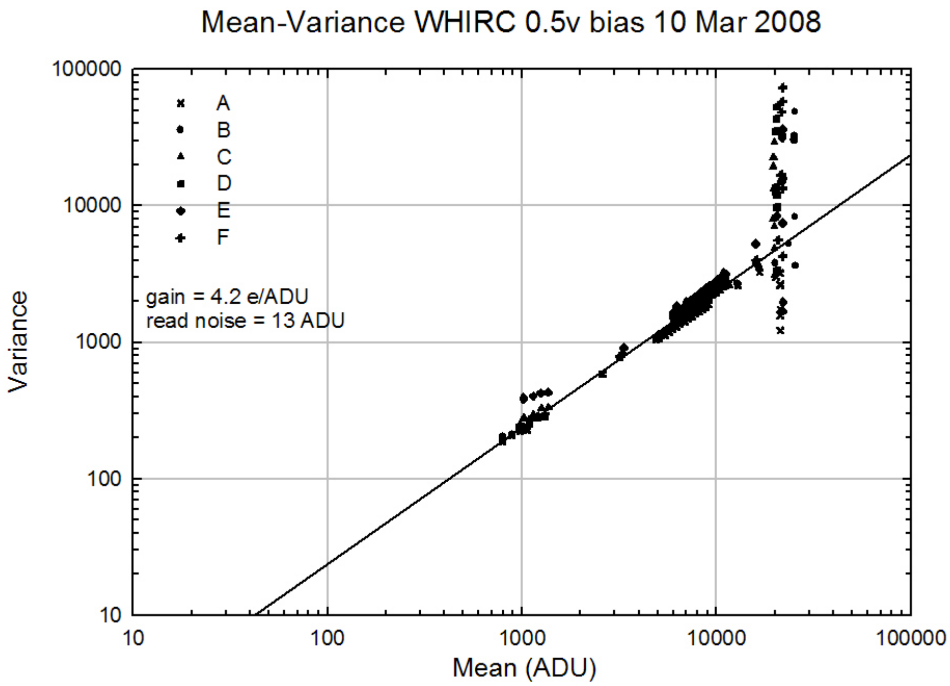
On 18 March 2008, the FS23 field was observed through all of the filters (except Pa beta) at 60s frame time in the DA4F4 mode with a detector bias of 0.8 v. These observations were taken during (unsuccessful) attempts to work with the WTTM guider, so the five images through each filter were not dithered. FS23 itself fell on a bad array pixel, which was edited using the IRAF task fixpix, which substitutes the average of the surrounding pixels for the bad value. Both FS23 and a nearby star have published JHK magnitudes (Hunt *et al*. 1998, AJ, **115**, 2594). The two stars gave equivalent flux results which generally agreed within 5%, although no attempt was made to flatfield the images; the table lists the larger of the two values. The table lists the flux levels (ADU/s) for the sky background and a mag=10.0 star for a Fowler1 mode.

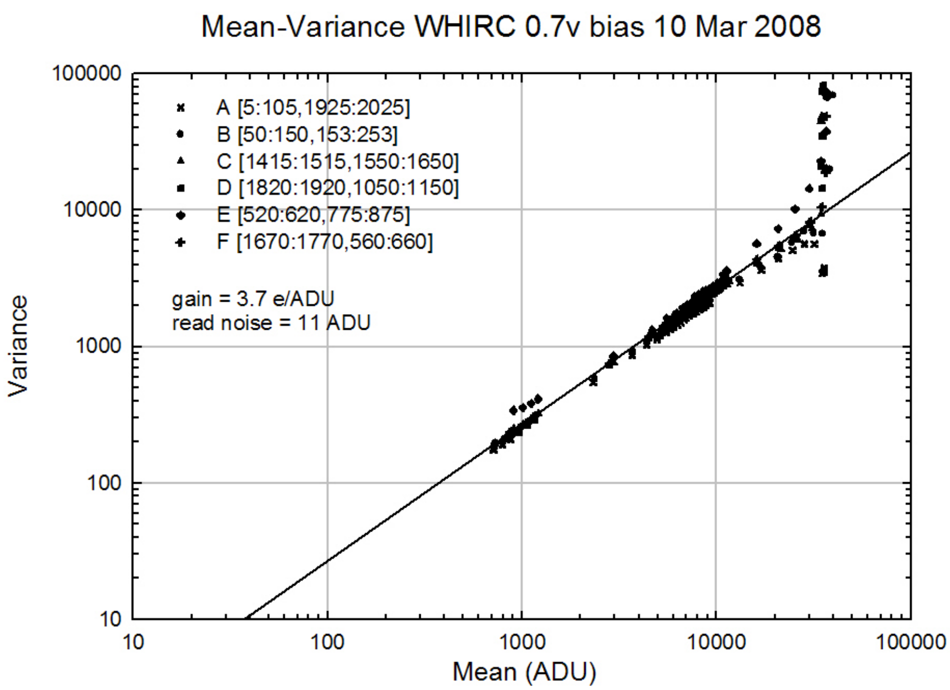
FILTER	SKY (ADU/s-pix)	10.0 mag star (ADU/s)
LOW-AIR	0.45	13200
HE_I	0.53	9350
J	5.54	177000
PA_B_4500	1.07	14300
FE II	2.03	10700
FE_II_4500	2.86	11500
H	25.32	188000
H2	2.90	7150
BR_G	3.76	7730
BR_G_4500	5.70	8630
Ks	73.73	108000
CO	7.77	5940

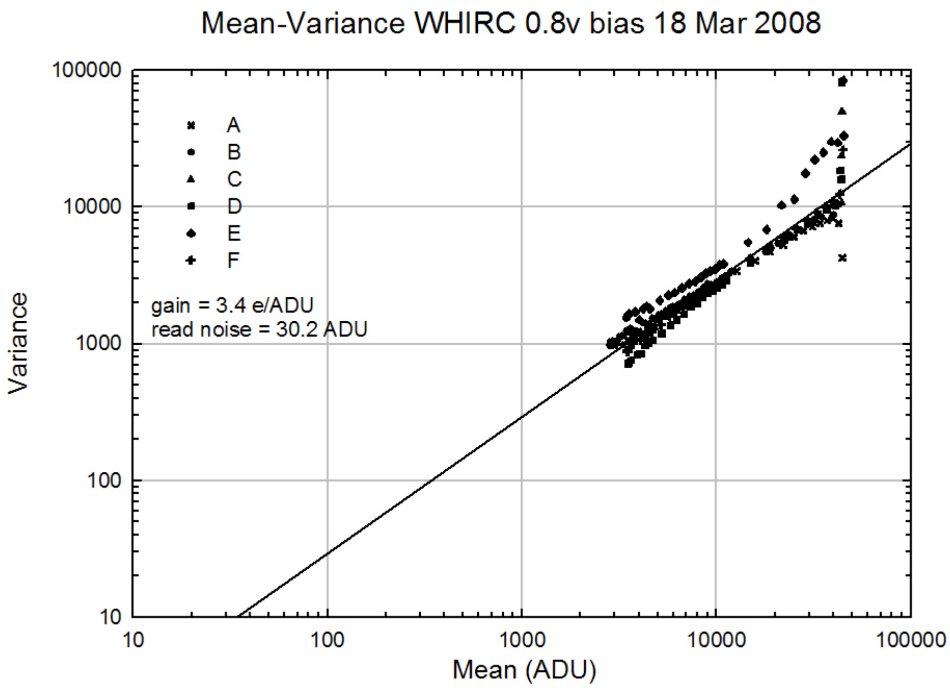
These are probably good enough to use for observing planning. For an image with FWHM = 0.5 arcsec, the <u>peak pixel</u> flux is ~ 0.03 of the integrated signal.

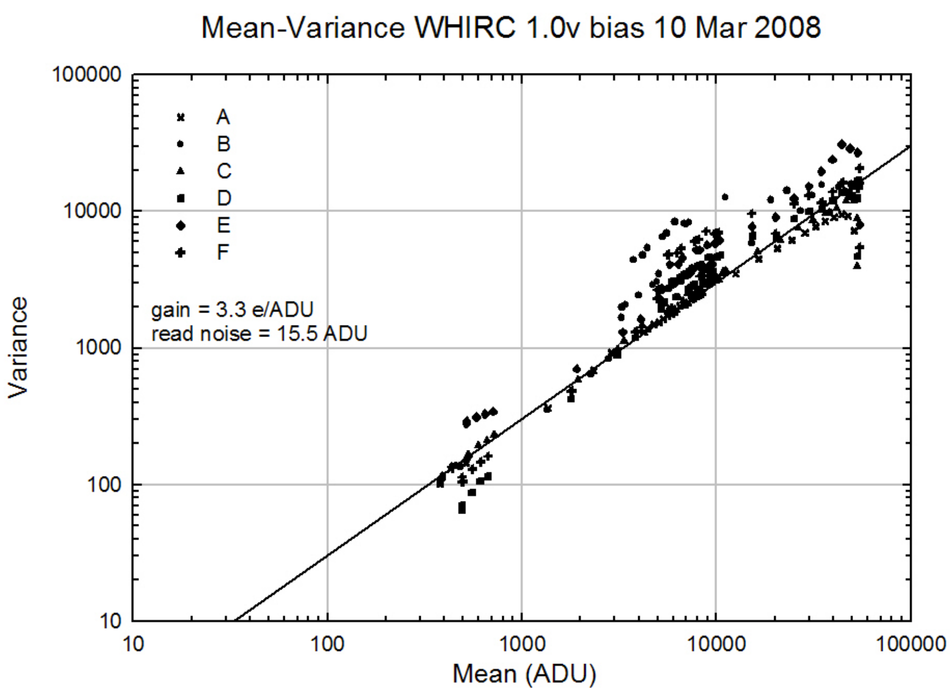
Mean-variance Analysis

The following plots show the mean-variance plots for the four bias values of 0.5, 0.7, 0.8, and 1.0 v. The darks taken at the same time as the PTC data were used to calculate the read noise. The values plotted on the ordinate are <variance – rn^2> and should yield a straight line of unity slope on the log-log plot.







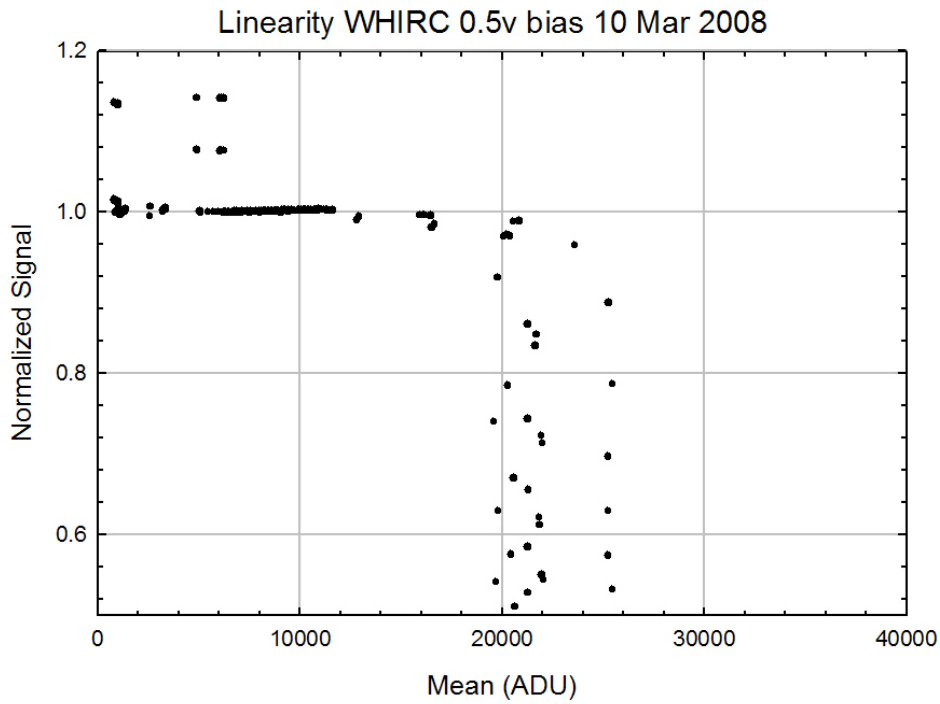


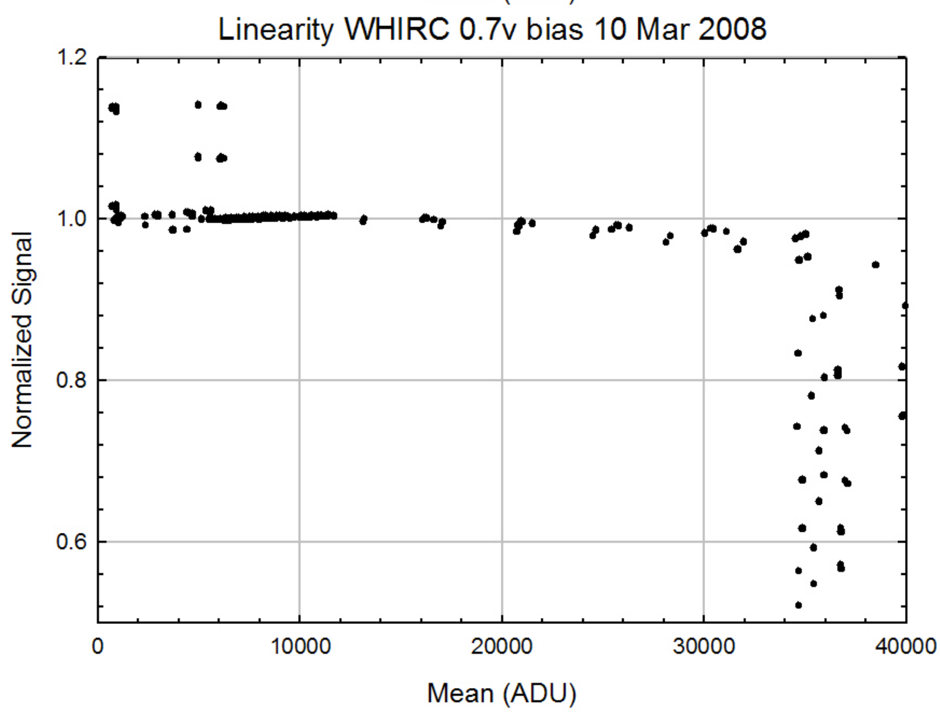
The different symbols represent different 100 × 100 subarrays distributed around the array. Except for B, these are the same subregions which Charles used in his analysis:

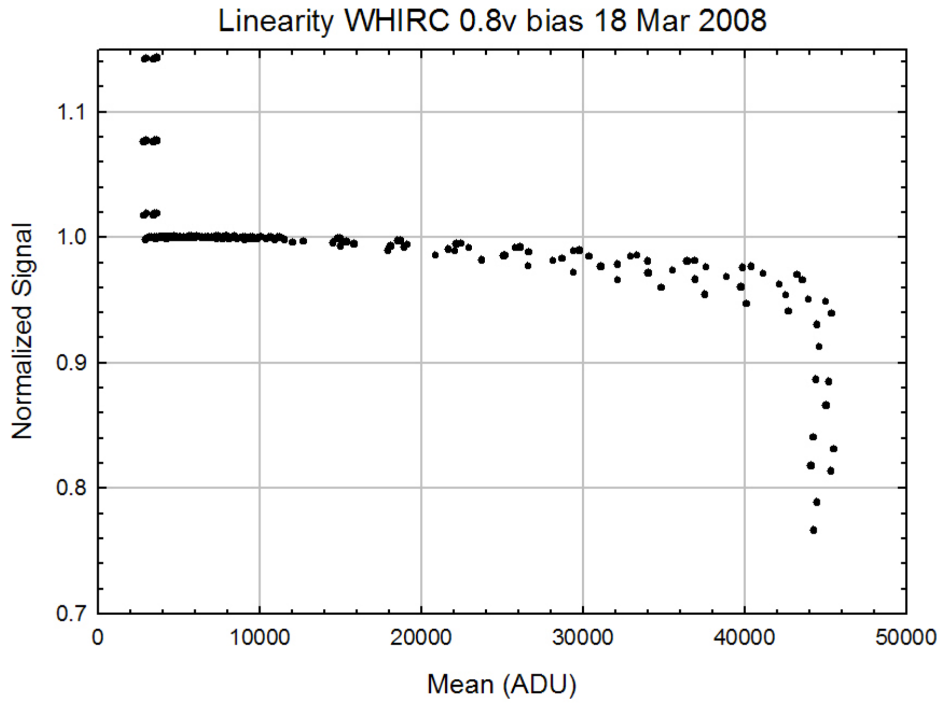
A 5:105,1925:2025
B 50:150,153:253
C 1415:1515,1550:1650
D 1820:1920,1050:1150
E 520:620,775:875
F 1670:1770,560:660

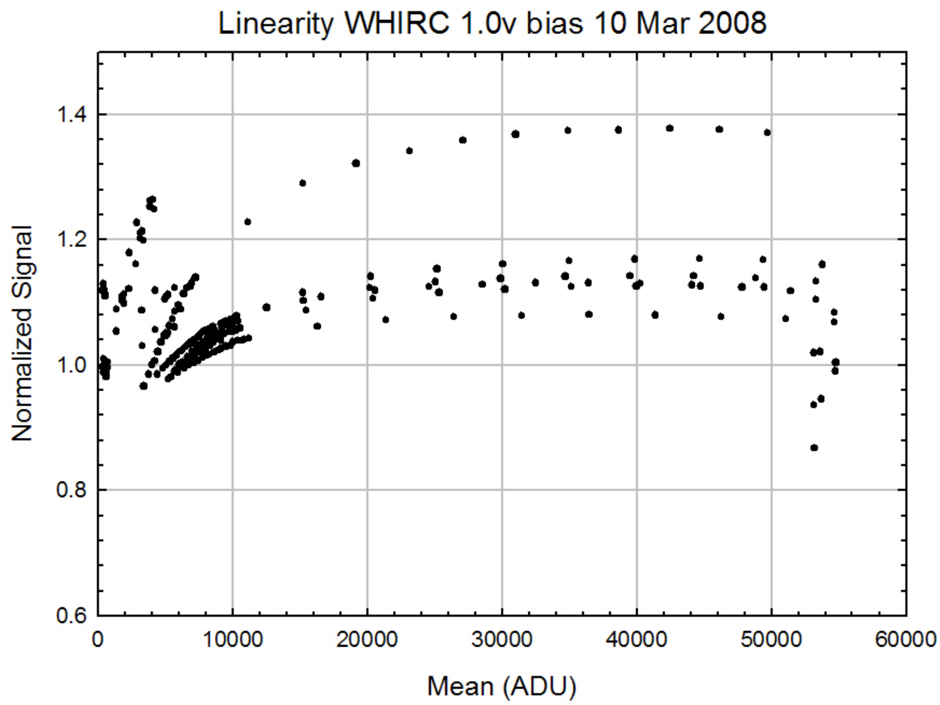
Linearity 1—Signal Linearity

The following plots are of the linearity as a function of mean signal (ADU) for the four bias values of 0.5, 0.7, 0.8, and 1.0 v. The linearity is defined as the signal flux (ADU/s) normalized to the average value between 4.2 and 5.0 s integration time. The aberrant values for short integration times probably result from the actual minimum integration time being longer than the assumed value of 3.3 s.









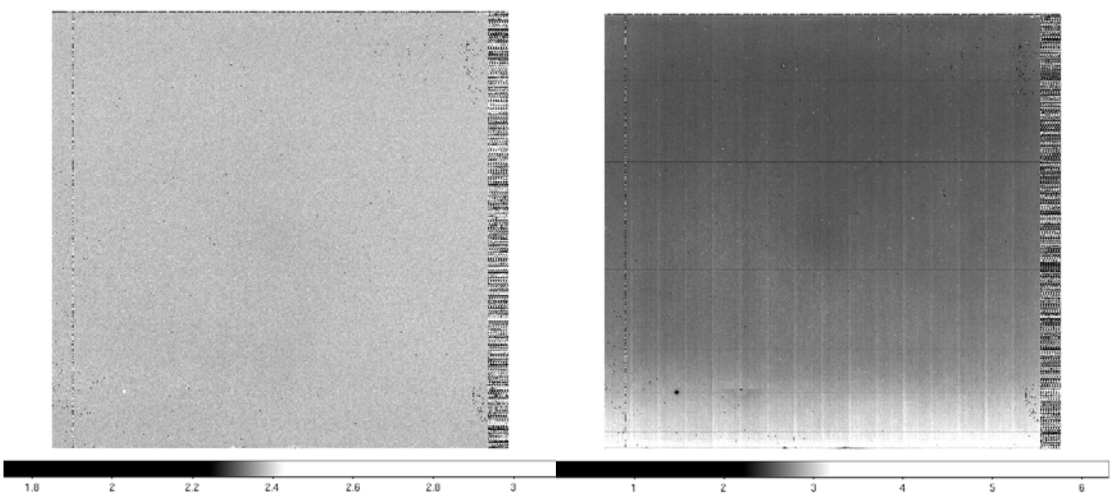
Linearity Table

Bias (v)	Gain (e/ADU)	97% FW (ADU)	97% FW (e)
0.5	4.2	19000	79000
0.7	3.7	32000	118000
0.8	3.4	40000	135000
1.0	3.3	52000	170000

The full well in the linearity table was arbitrarily defined as the signal for which the linearity dropped to 97% of its low-signal value of 1.0. For the 1.0 v bias, the behavior was sufficiently strange to be virtually scientifically useless, and the full well was defined as the roughly 97% value compared to the flat region of the curve.

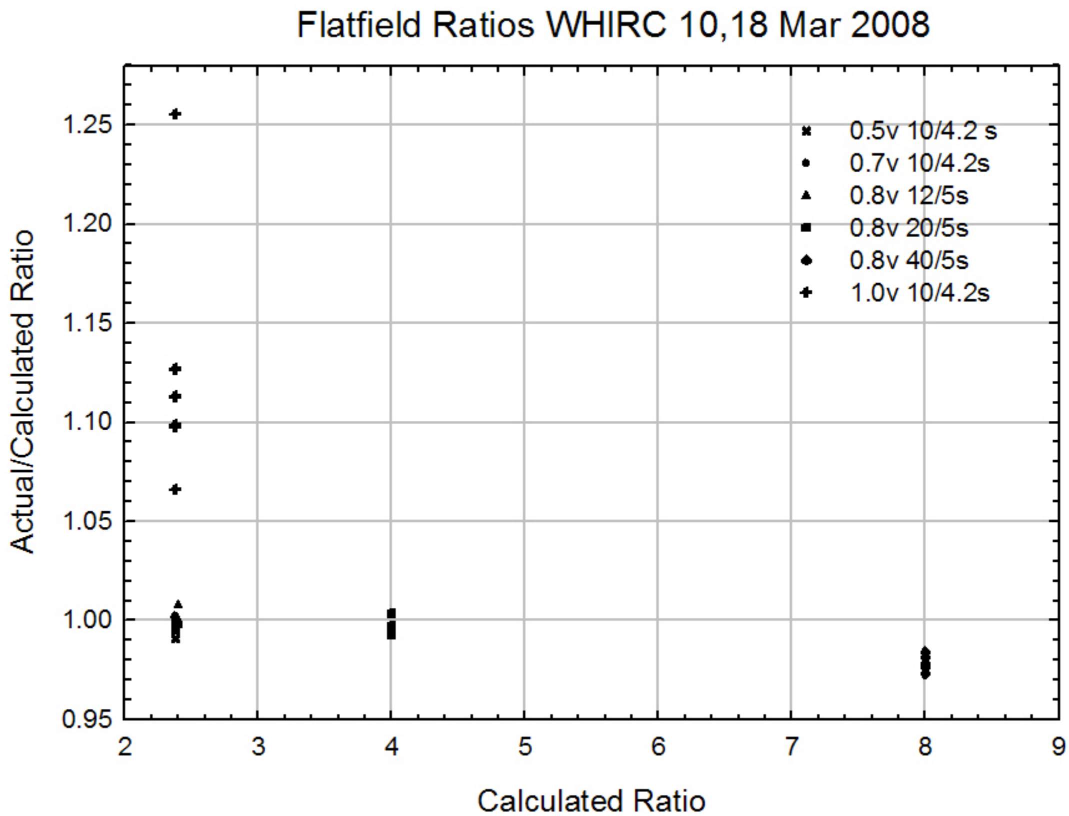
Linearity 2 – Flat Fields

The linearity plots also show a secondary aspect of linearity, the spatial variation around the array. Since the linearity curves for each of the six subregions was separately normalized to the 4.2 – 5.0 s integration time values, the scatter in the plots represents spatial variations in the linearity behavior over the array. This can be represented more clearly by simply dividing a flatfield image at one integration time by one at another time. The ratio images (below) show the same results as in the plots, but in a more dramatic fashion; in particular, the ratios (both 10 s / 4.2 s) demonstrate significant deviation in the case of the 1.0 v bias. A bias value of 1.0 v results not only in an unusual linearity behavior, but one which varies significantly around the array.



Ratio of a flafield with 10 s integration time to one with 4.2 s integration time for bias values of 0.7 v (left panel) and 1.0 v (right panel). Note the significant deviation from flatness for 1.0 v bias, even with a much larger plotting range.

The results are presented graphically below in a plot of the ratios for the six subregions of the array used in earlier analysis. The ordinate is the ratio of the observed value to that expected (the ratio of the integration times). For the data at 0.5, 0.7, and 1.0 v bias, the integration times were 10 and 4.2 s (expected ratio 2.38). For the data at 0.8 v bias, the three values plotted are the ratios of 40, 20, and 12 s to a 5 s integration. Note that the 40/5 plots fall below the expected value of 8.0 because of the rolloff in the linearity curve.

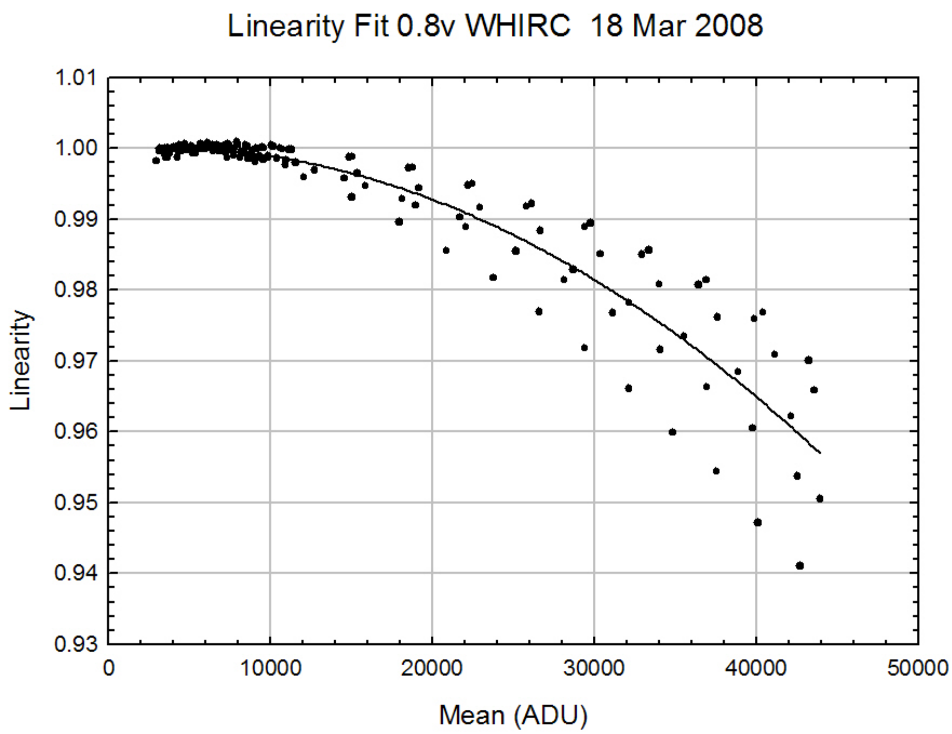


Plot of the actual/calculated flatfield ratios to those expected from the integration times. The six points for each symbol correspond to the six subregions utilized in other analyses of the array behavior. The p-p scatter is less than 2% for the 0.5, 0.7, and 0.8 v bias values, but is extremely discordant for the 1.0 v bias.

Linearity 3 – Science

While it is tempting to state that the linearity behavior limits the "useful" flux range of WHIRC, it must be noted that this type of behavior is seen in all infrared detector arrays utilizing the unit cell architecture. The potential well generated by the biasing of a pixel has an associated capacitance, which changes as the well fills, resulting in a conversion gain which is a function of well depth. As long as the behavior is stable and reasonably consistent across the array, correction for nonlinearity can be considered a part of the data reduction process, along with flatfielding and (if necessary) field distortion correction. Virtually all infrared imagers utilize this process, and there is an IRAF task irlincor, dedicated to this function. The only caveat is that the linearization procedure be carried out on the raw data, prior to any dark or sky subtraction.

As an example, consider the linearity plot for 0.8 v bias with the obviously discordant low points and the saturated points removed. A second-order polynomial fit is adequate to determine the behavior; inverting this curve provides a function which can be used for linearization of the raw data.



Linearity plot for the 0.8 v data, with a quadratic fit to the data.

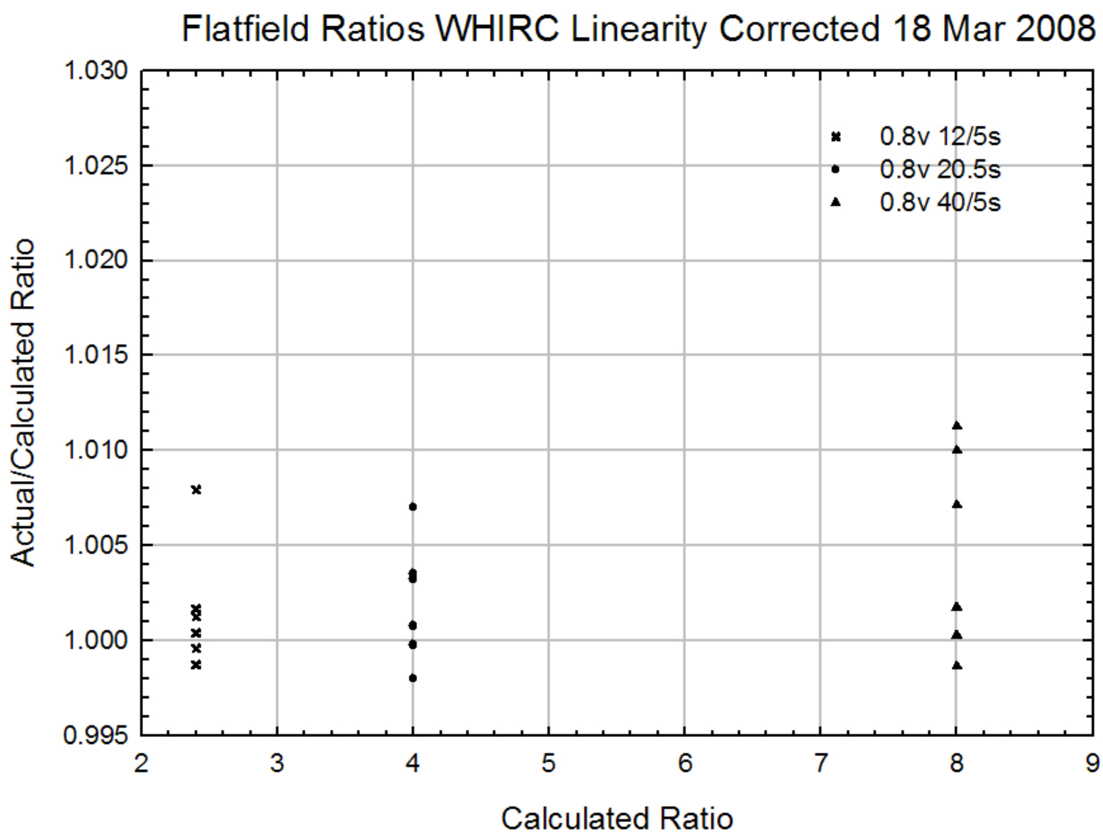
The quadratic fit in the figure is of the form $y = y_o + ax + bx^2$, where

$y_o = 0.9997$
$a = 1.7563 \times 10^{-7}$
$b = -2.6111 \times 10^{-11}$

The inverse parameters

$y_o = 1.0006$
$a = -2.3114 \times 10^{-7}$
$b = 2.8093 \times 10^{-11}$

can be used with the IRAF task irlincor to linearize the data. If the residual scatter shown in the figure represents real variations in the linearity around the array, it should be possible to consider a "linearization array" to provide better correction. This should be investigated once the operating bias voltage for the WHIRC array has been established and more calibration data can be obtained.



Plot of the actual/calculated flatfield ratios to those expected from the integration times. The six points for each symbol correspond to the six subregions utilized in other analyses of the array behavior. The data have been corrected using the IRAF task irlincor.