Flat Fields from Ground Test Data
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This is a summary of how we derived flat fields for each of the MVIC arrays from ground test data (optical test #2). We include more information than is probably necessary for longevity.

Reduction Method

The array was illuminated by an integrating sphere. The integrating sphere did not illuminate the whole field so observations were taken at different positions (FARRIGHT, RIGHT, CENTER, LEFT). The intensity of the integrating sphere was also varied to match a given array (CH4, P1, RED, PAN…).

For each mode of observations (pan frame, pan 1, pan 2 and color) and each illumination level, we stitched together the observations to cover the whole field. We excluded data with low signal levels and saturated levels.

For the TDI observations, we collapsed the observations to one-dimension by taking the median of each column. The 1-D median dark signal was removed from the data. Then the data were scaled to unity in the range where the signal was highest. The result from this step for one mode, exposure time, and light level are shown in Figure 1.

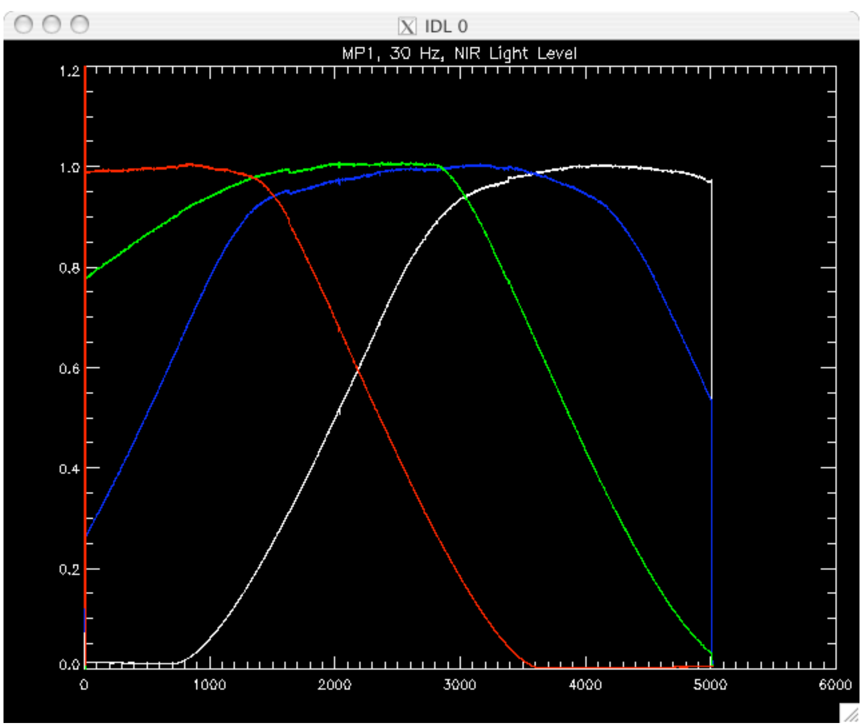

Figure 1: The individual contributions for each lamp position are displayed.

The lamp setting indicated by 'FARRIGHT' is red, 'RIGHT' is green, 'CENTER' is blue and 'LEFT' is white. You will notice that the lamp position is opposite the display in the Figure. We confirmed the correct orientation for each observation mode by decoding the high speed header embedded in the data.

In order to construct a flat field we had to remove the low order curvature from the collapsed image. We fit a third order polynomial to the section of each data that would be used in the composite flat field (see Figure 2) to model the curvature without removing any real pixel-to-pixel variation and removed the curvature.

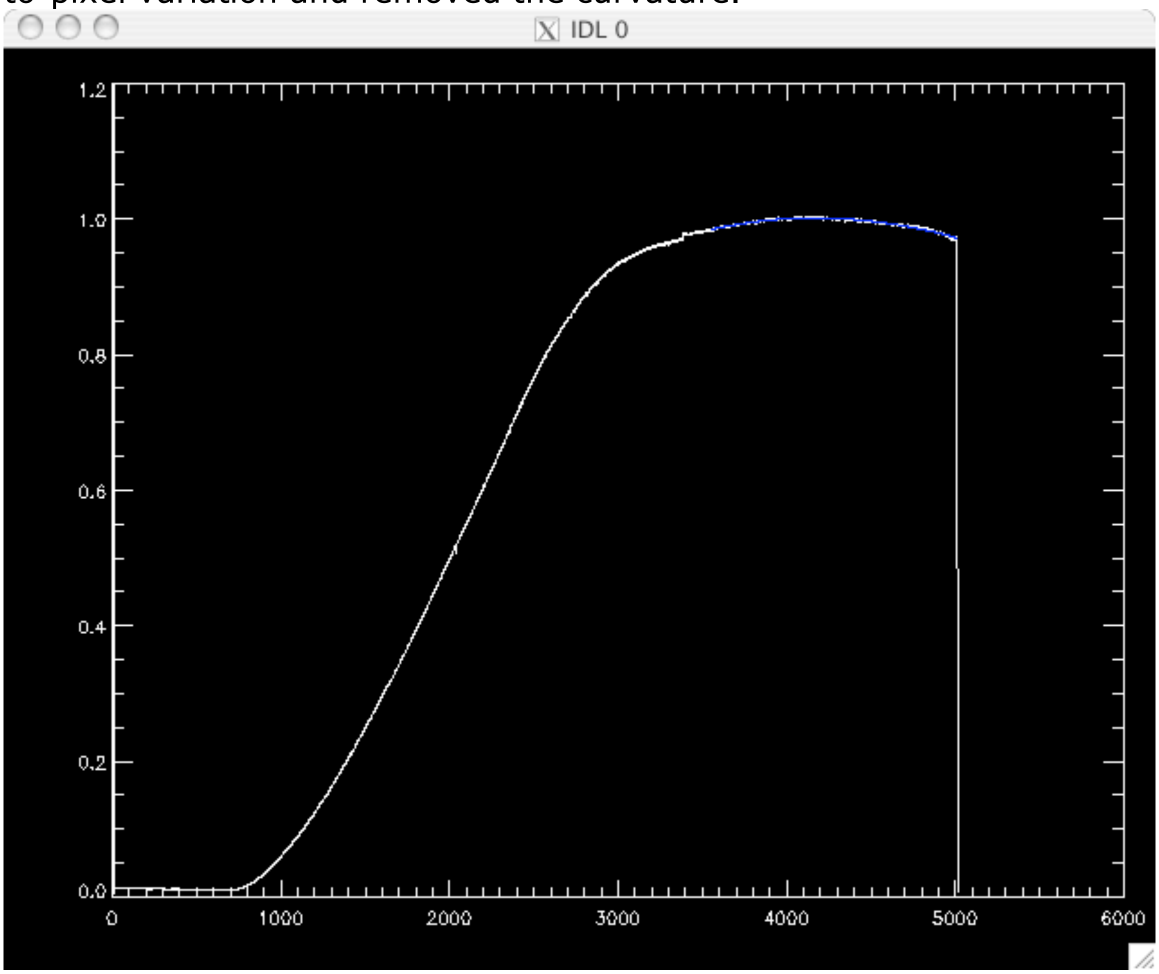

Figure 2. The 1-D dark subtracted flat field data (white) and our third-order polynomial model (blue line).

Next we combine the useable segments of each lamp position to give the resulting flat field for the given observing mode, integration time and lamp level. The result for this example is given in Figure 3.

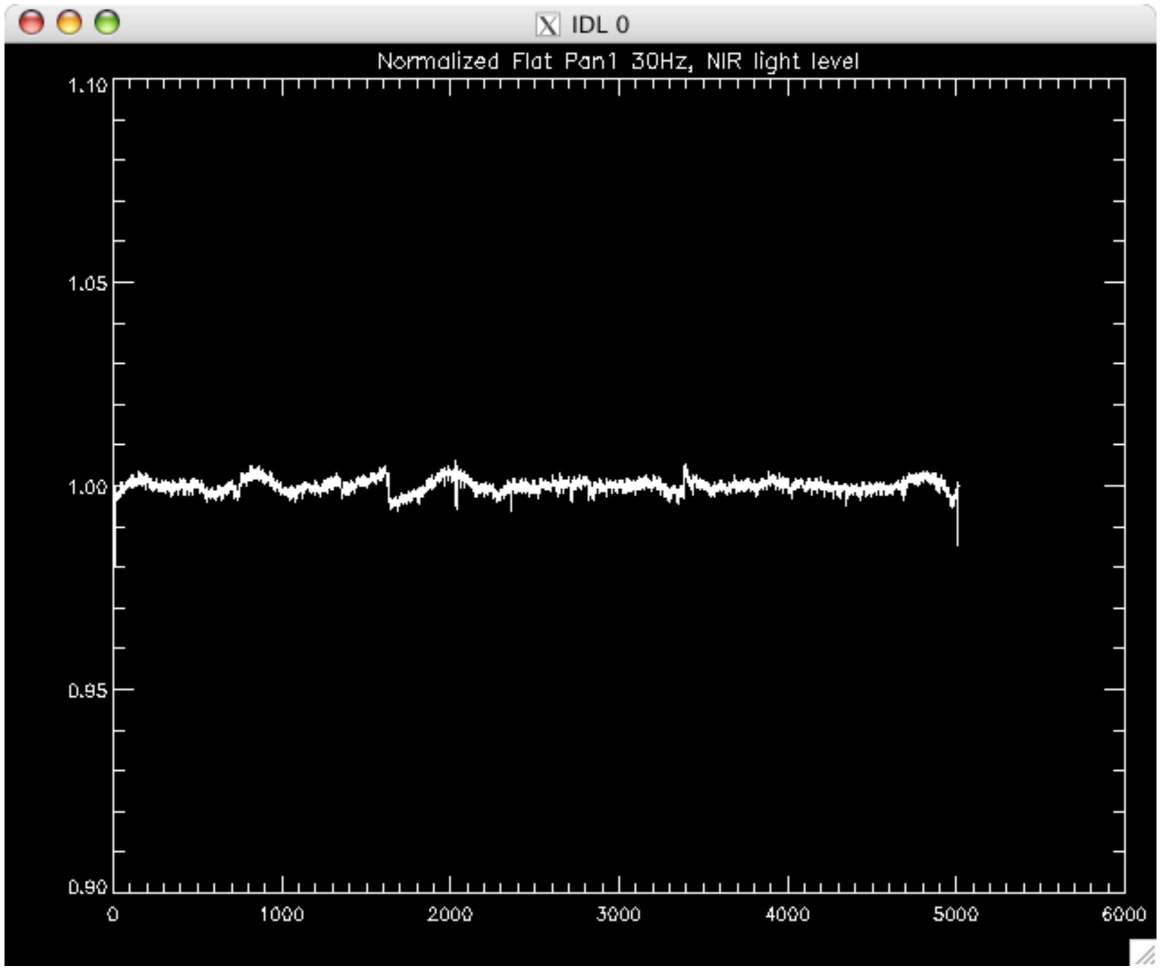

Figure 3. The normalized flat field for the pan 1, 30Hz, NIR light level observations

For each observing mode (pan frame, pan 1, etc.), we have observations from OT2 at different exposure times and integrating sphere settings. We constructed the flat field for each observing mode from the median of the images with good light levels. Below is a list of which flats went into each median flat

Pan1: Pan1_flat.fits
MP1_15Hz_NIRLL.FITS
MP1_30Hz_CH4LL.FITS

Pan2: Pan2_flat.fits
MP2_15Hz_NIRLL.FITS
MP2_30Hz_CH4LL.FITS

Color, Filter 0: MCL_0_flat.fits
MCL_15Hz_P1LL_0.FITS
MCL_30Hz_P1LL_0.FITS

MCL_15Hz_REDLL_0.FITS
MCL_30Hz_REDLL_0.FITS

Color, Filter 1: MCL_1_flat.fits
MCL_15Hz_BLUELL_1.FITS
MCL_30Hz_BLUELL_1.FITS
MCL_15Hz_REDLL_1.FITS

Color, Filter 2: MCL_2_flat.fits
MCL_15Hz_NIRLL_2.FITS
MCL_30Hz_P1LL_2.FITS
MCL_54p9Hz_P1LL_2.FITS
MCL_30Hz_NIRLL_2.FITS

Color, Filter 3: MCL_3_flat.fits
MCL_30Hz_P1LL_3.FITS
MCL_15Hz_P1LL_3.FITS

TDI Results

The resulting flat fields for each array are shown in Figure 4.

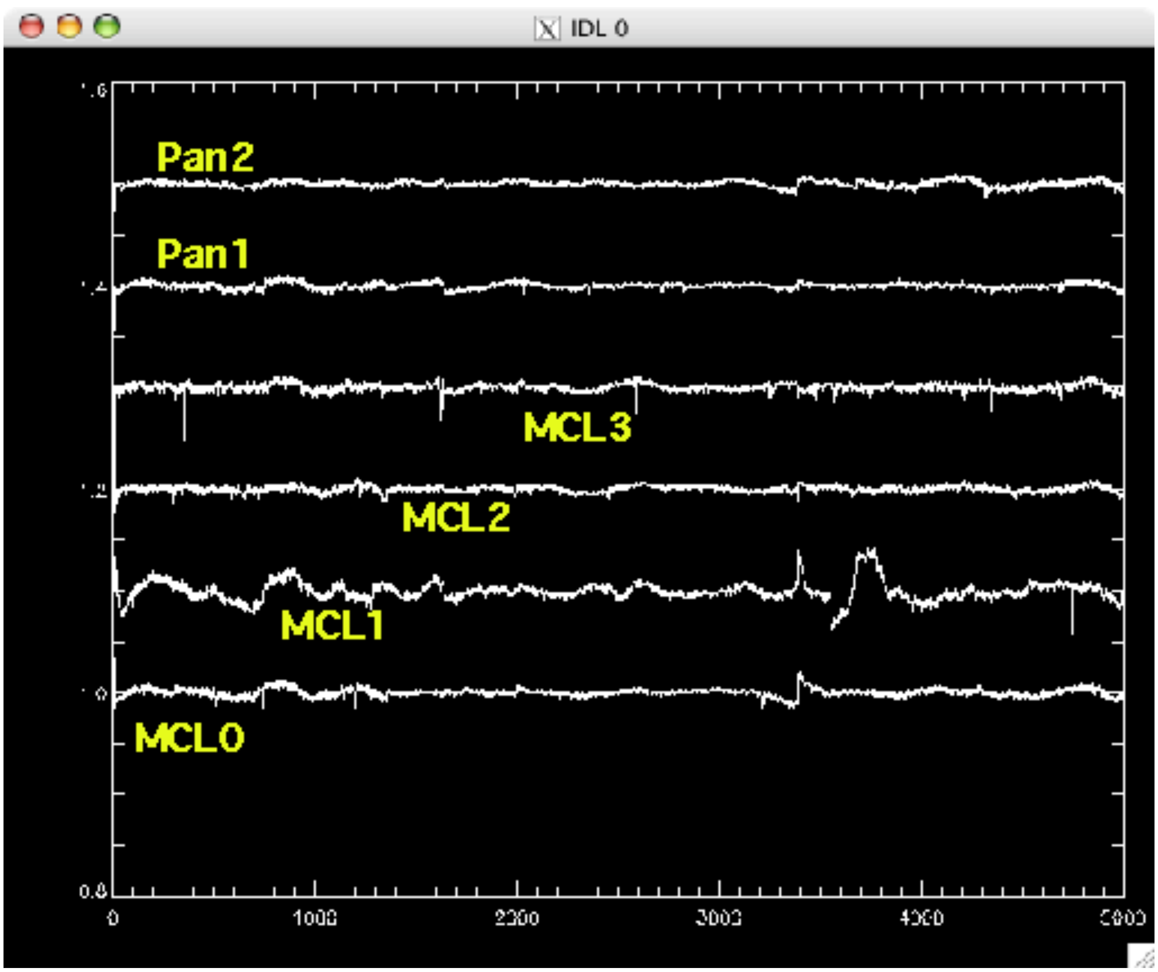

Figure 4. The median flat field for each of the TDI arrays. The flat are normalized to a mean value of unity, but are offset for display purposes. For the MVIC color TDI: 0=Red, 1=Blue, 2=NIR, 3=CH4.

TDI Discussion

The discontinuities seen near column numbers 1700 and 3400 in each of the TDI channels are a result of real differences in sections of the detector. The arrays were pieced together from 3 segments and those discontinuities indicate the different sections of the CCD that have different QE.

The MCL1 flat field (Blue filter) shows different structure than the other flats. We have re-examined the data that went into this flat field and the variation in the signal is seen in the raw data. It is not an artifact of the reduction (it is not due to the polynomial fit).

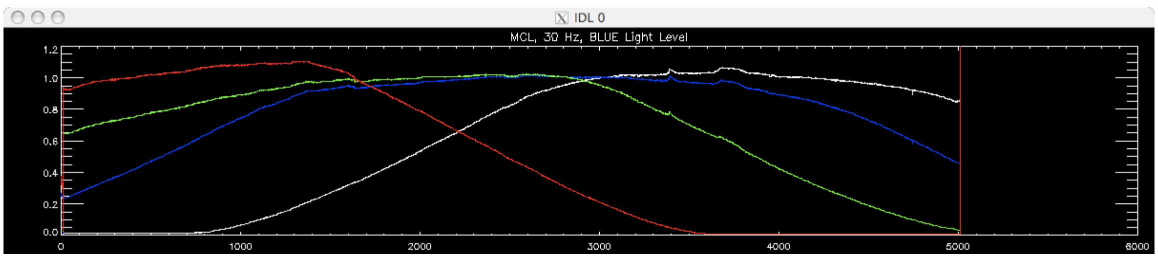

Figure 5. The 1-D individual lamp positions that made up the blue filter flat field. The feature near column 3700 is seen in all the images with flux in that region.

Error estimate

Next we will discuss the error analysis. The formal error from the scatter of the individual flats that went into the mean flat is much less than 1% (0.002). The contribution of systematic errors from stitching together the different images to construct a flat is much larger than the formal error. I would give a conservative estimate of the error in these flat fields at 2% from looking at the curvature of the segments where the different illumination patterns met.

Pan Frame Flat Field

Finally, we discuss the pan frame array. For this mode a 2-D flat field is needed. The integrating sphere did not fully illuminate the pan frame array in either dimension (row or column). As in the TDI cases, we have stitched together different integrating sphere positions to cover the columns of the detector. Unfortunately we did not have data to cover the lowest 46 rows of the detector, see Figure 6.

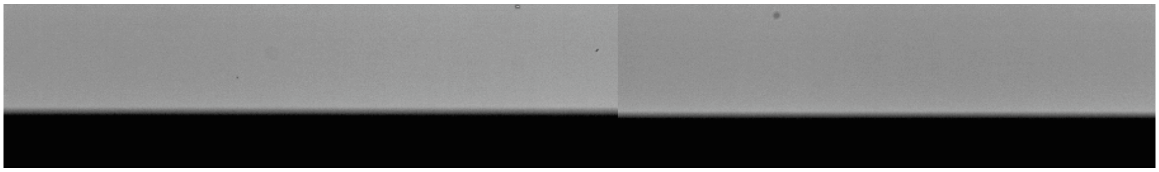

Figure 6. An extracted segment of the pan frame flat field. The lowest 46 rows are dark. The discontinuity near the middle of the figure is the center of the array. Each side of the array goes to a different A2D converter. Also, seen in the figure are some minor blemishes and a dust donut.

The lowest 46 rows are filled with the value 1.0 in the final normalized flat field.

I am assuming an error in the flat field equal to 2% for each pixel (using the same argument as above for the TDIs).

The flat fields are available on ralphlxsrv (in /raid/OT2/NormalizedFlatFields) and will be incorporated into the MVIC pipeline next week.