# COR-1B Final Assembly Tests September 2004

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September 21, 2004

This is a report on the result of the measurements made of the COR-1B instrument as part of the final assembly procedure, during September 2004 in the COR-1 clean room facility in Building 5.

## 1 Focus

To measure the instrument resolution, an Air Force 1951 resolution test target was placed at the eyepiece location of a Meade telescope. To take the difference between nitrogen and vacuum focus into account, the target was moved back by a measured distance from the Meade's infinity focus.

Measurements were made at the following six locations on the detector, relative to the center of the CCD:

| Location | X (mm) | Y (mm) |
|---|---|---|
| A | 0 | 7 |
| B | 0 | 12.5 |
| C | -5 | -5 |
| D | 5 | -5 |
| E | -9 | -9 |
| F | 9 | -9 |

At each of the above points, measurements were made at 5 focus positions on the Meade telescope, centered around the nominal position of 8.7 mm, and at ±1.5 mm and ±3 mm. Because of vignetting problems, points A and B were done with the Meade telescope at one location, and the rest of the points were done with another location of the Meade telescope.

Figure 1 shows a sample Air Force Target image, taken at full 13.5×13.5 $\mu$m resolution. Group 4-4 corresponds to the Nyquist frequency, while 3-4 would be the Nyquist frequency for 2×2 binning.

To characterize the data, the contrast of group 4-1 was analyzed. This group has bars which are very close to 1.5 pixels wide. The results are shown in Figure 2. No dependence was found on polarizer position.

The results for all the positions except C and D are consistent with the position of best focus being close to nominal focus. Positions C and D, however, suggest a best focus position when the Meade telescope is +1.5 mm off of nominal focus. (An offset of 1.5 mm on the Meade telescope corresponds to a 0.6 mm shift at the FPA.) When all the measurements are averaged together, the highest average contrast is at the nominal focus position.

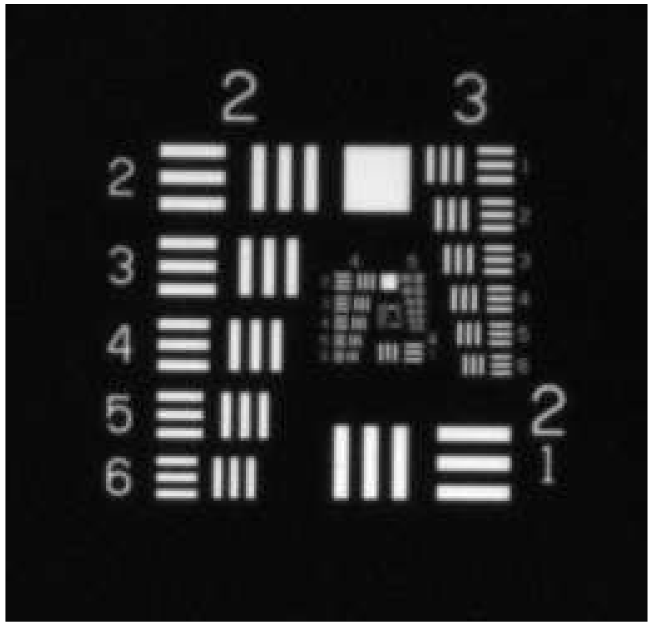


Figure 1: Sample image of Air Force 1951 resolution test target. This image has been rotated by 90° and reflected to make the lettering more readable.

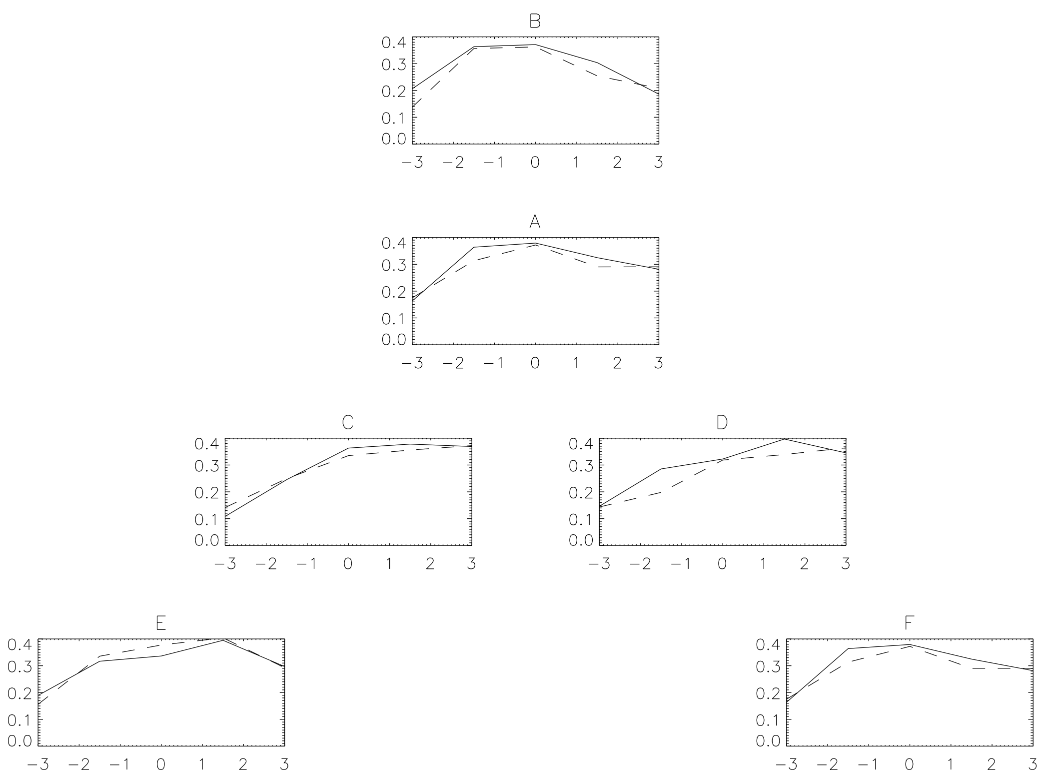


Figure 2: Contrast values as a function of Meade focus for several positions on the detector. Solid lines are for vertical bars, dashed for horizontal bars.

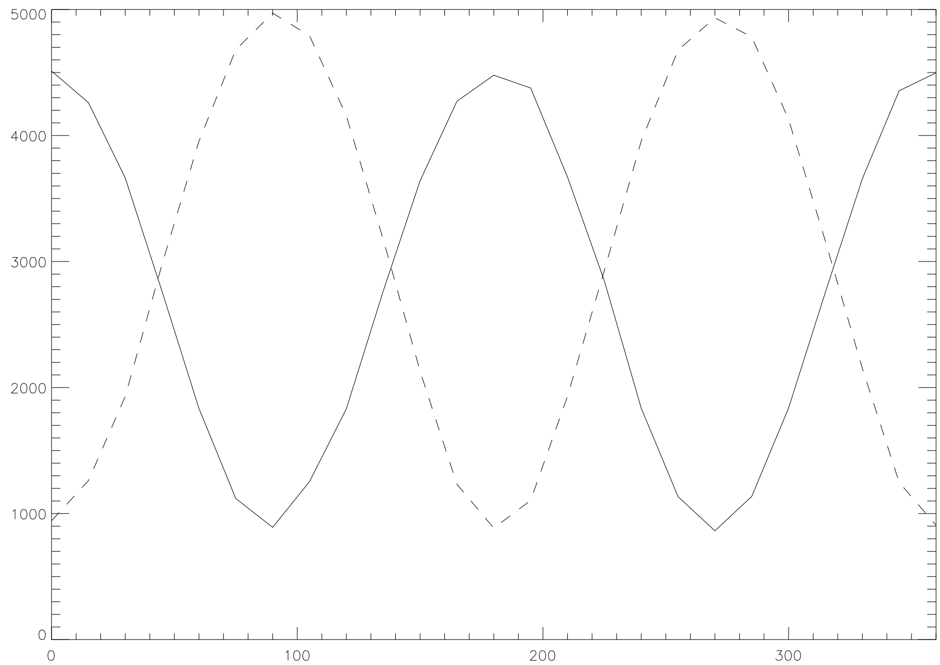


Figure 3: Relative response of the instrument as a function of polarizer angle to light polarized vertically (solid line), and horizontally (dashed line). The light levels were not identical for the two measurements.

## 2 Polarization angle

To calibrate the angle of the polarizer, the instrument was exposed to diffuse light polarized vertically, and then by light polarized horizontally. For each, the procedure STEP15 was run, to measure the response stepping every 15°. The results are shown in Figure 3. Fitting the function

$$y = A\cos^2(\phi - \phi_0) + B$$

to these curves gives an offset $\phi_0$ of $0.07 \pm 0.22$ and $1.50 \pm 0.24$ degrees respectively. Averaging these two results together gives $0.79 \pm 1.01$ degrees, which is consistent with zero. This corresponds to $0.32 \pm 0.40$ steps of the hollow core motor.

Note that the curves in Figure 3 do not go all the way to zero. This is because the amount of dark current in the images that use the shutter is higher than for those that don't. The reason for this is because of the extra delay involved in sending the commands to the shutter mechanism. Most of the delay comes from creating windows on the GSE computer to display each command as it's executed.

## 3 Polarizer wedge

Measurements of the Air Force resolution target, made every 15°, can be used to derive the amount of image motion as a function of polarizer position. The results are shown in Figure 4. This test

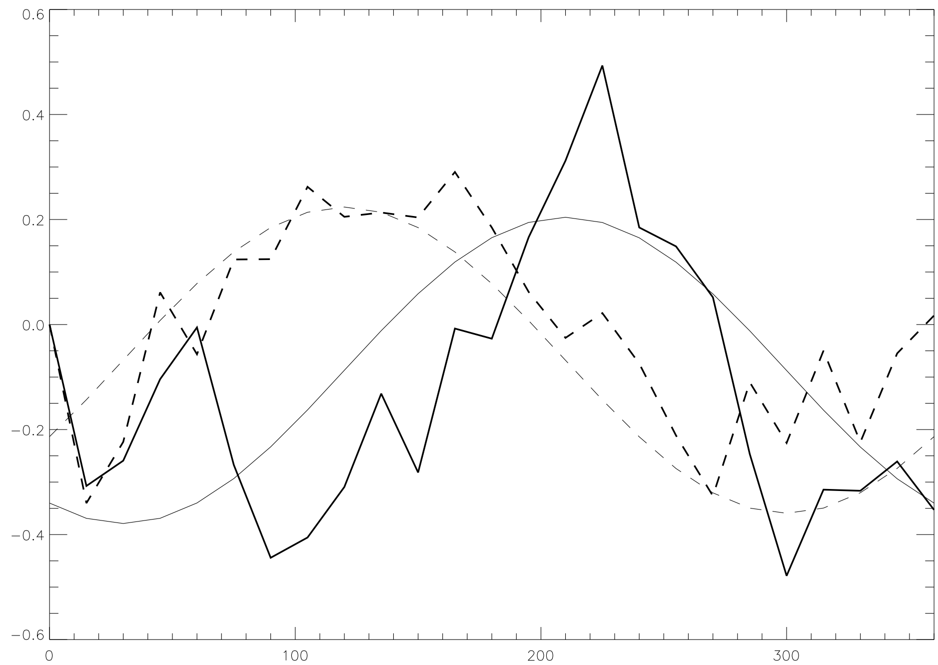


Figure 4: Target position as a function of polarizer angle, relative to the position at 0°, in the X (solid) and Y (dashed) directions. Also shown are the curves representing the fitted circle.

shows that the target image makes a small circular motion with a radius of 0.29 pixels (3.9 $\mu$m, 1.1 arcsec), *anti*-rotating with a phase angle of 210°.0. (In other words, the image rotates clockwise as the polarizer angle increases, which is the opposite sense from COR-1A. The phase is measured counter-clockwise from the $+x$ axis.)

# 4 Focal plane mask

Figure 5 shows the results of the focal plane mask test, using the NRL "Sun bucket" to mimic the Sun. To remove thermal effects and ambient light, an identical data set taken with the lamp turned off was subtracted. The appearance and light levels are similar to those seen with COR-1A. There is no evidence of the bright rings around the edge of the occulter making it past the focal plane mask.

# 5 Flat field

To measure the flat field, a bright, diffuse light source was placed directly in front of the diffuser window in the COR-1 door. The results, which are essentially identical to those found for COR-1A, are shown in Figure 6.

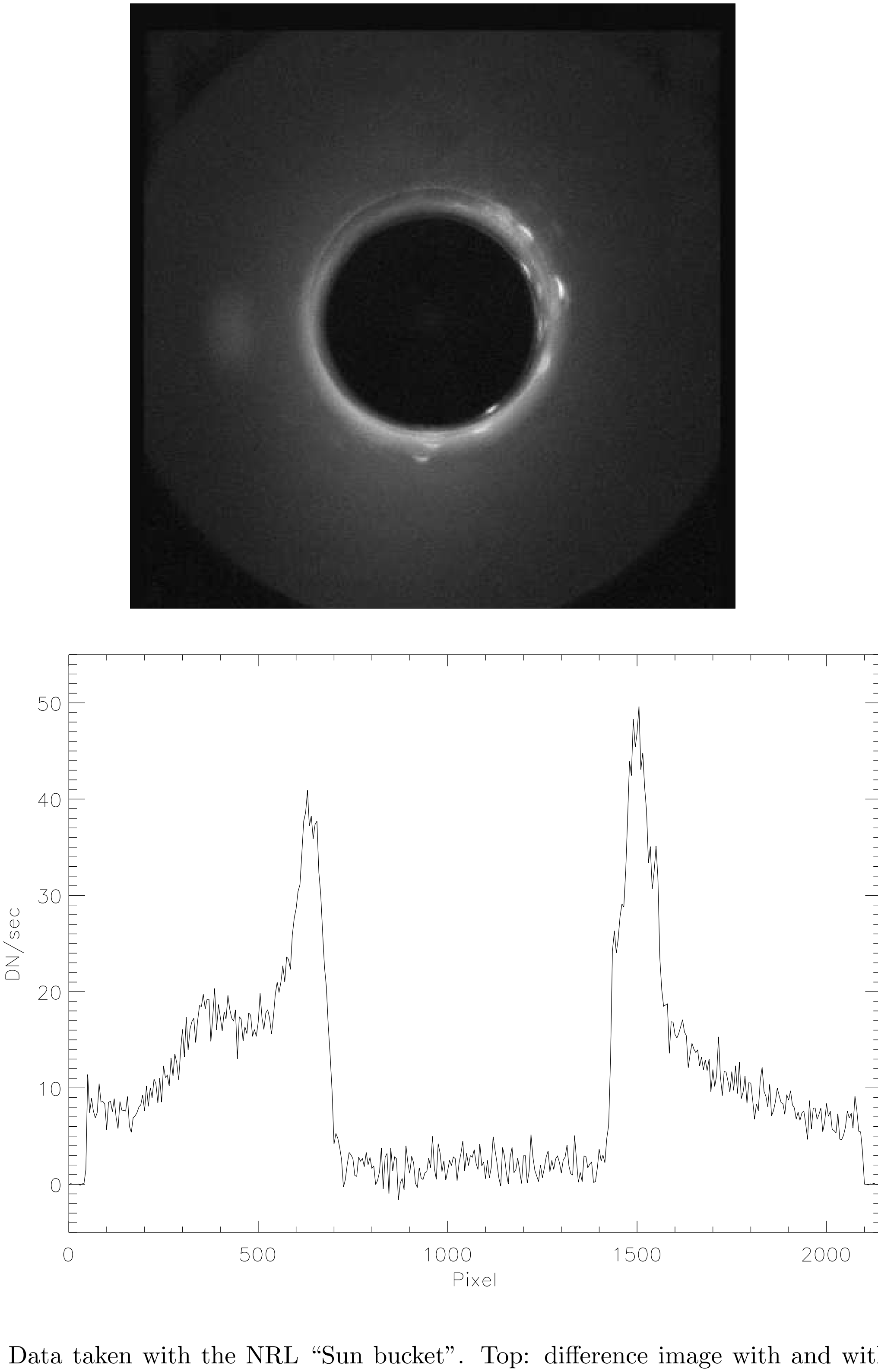


Figure 5: Data taken with the NRL “Sun bucket”. Top: difference image with and without the source turned on. Bottom: vertical trace through the image, in DN/sec.

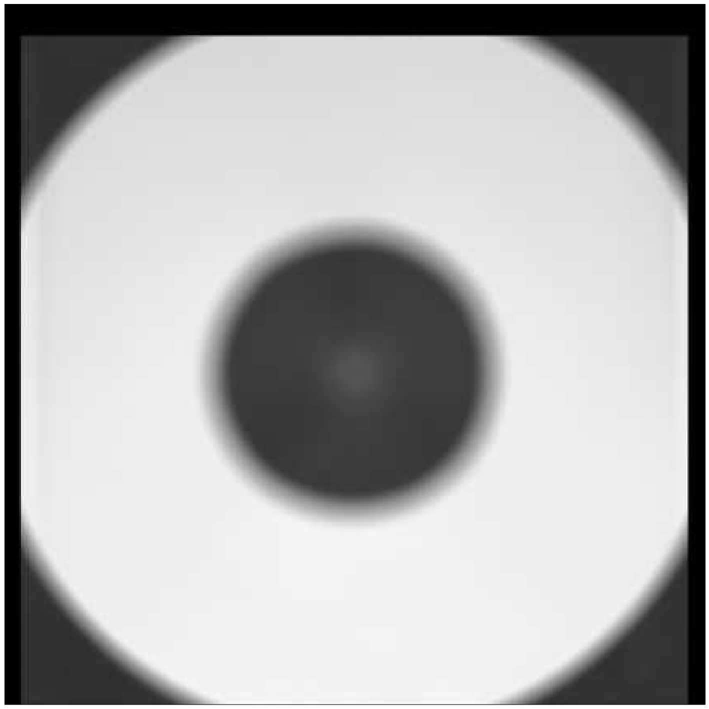

Figure 6: Instrument flat field.

## 6 Exposure time test

The procedure EXPTIMETEST takes a series of exposures ranging from 0.1 to 10 seconds, together with the associated dark images. Intercomparing the resulting images allows the accuracy of the exposure times to be explored.

Two keywords in the FITS headers are related to the exposure times. The keyword EXPCMD contains the commanded exposure time, while EXPTIME contains the measured exposure time, based on the motion of the shutter mechanism. For dark images, EXPTIME is calculated using a different algorithm, and is not reliable. Figure 7 shows the difference between the measured and commanded exposure times. The results are somewhat different from those for COR-1A, but in both cases the differences are small. (These results should not be confused with repeatablility, which was not addressed by this test—see Section 7.)

Figure 8 shows the relationship between the exposure time and the measured signal in the detector. The signal was derived by subtracting the average signal in the complete shadowed areas of the detector from that in the completely unshadowed area. The associated dark image was subtracted from each image before processing. From 0.1 to 2 seconds, the instrument behaves linearly. After that, the instrument starts to saturate, mostly due to thermal noise from the room temperature CCD. A straight line fit to the first five points is also shown. The fit doesn't go quite through the origin, which may be because of the differences in dark current between shuttered and unshuttered exposures (see Section 2), or because the lamp wasn't completely steady.

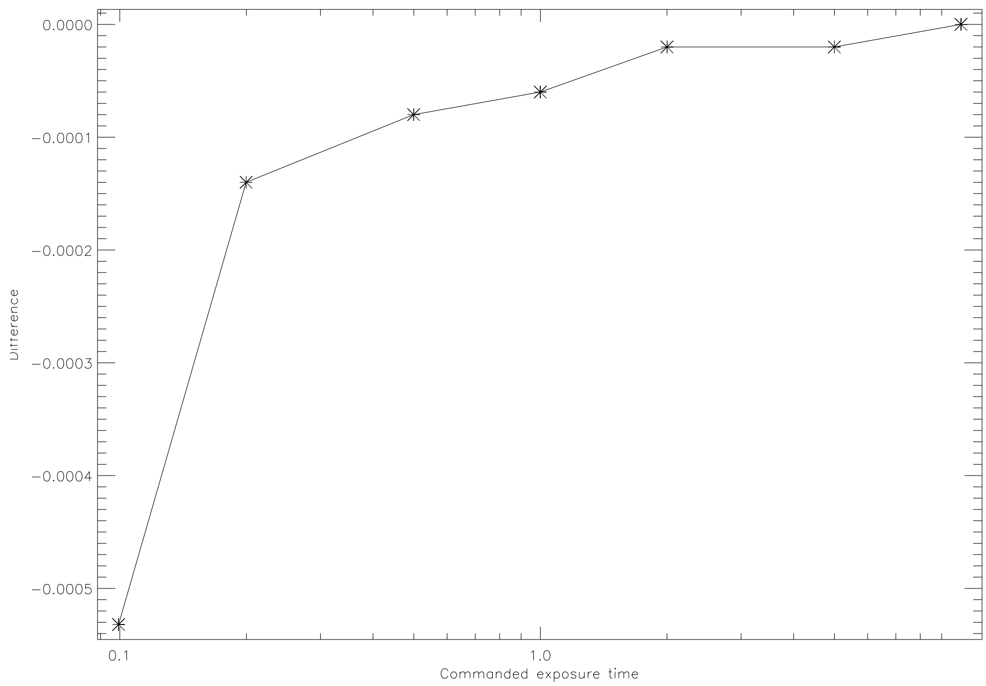


Figure 7: Difference between measured and commanded exposure times.

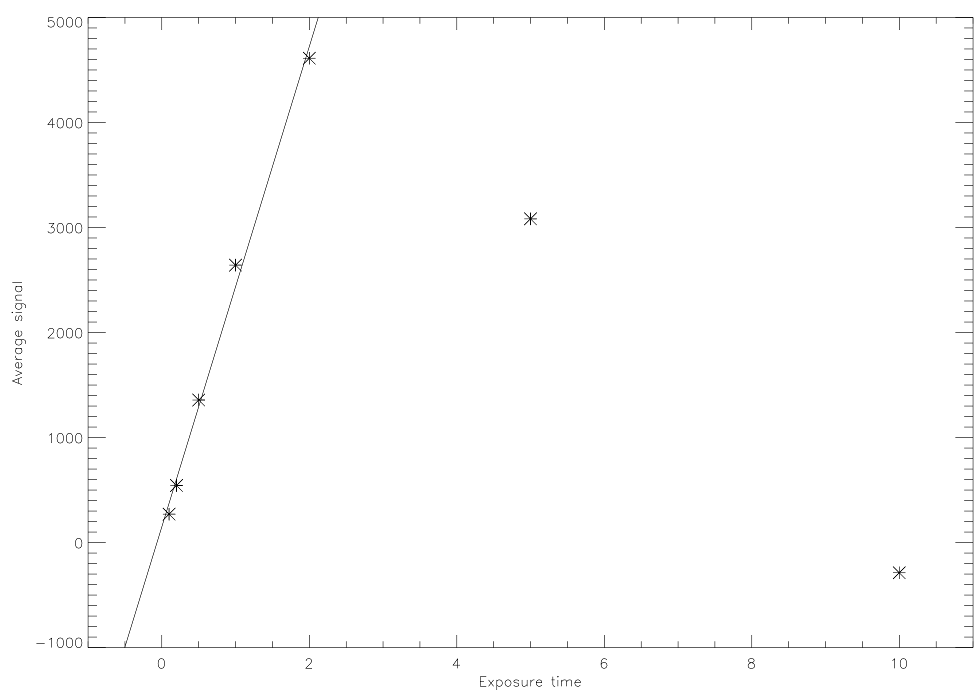


Figure 8: Comparison between measured signal and exposure time. The exposure times above 2 seconds are affected by saturation in the detector.

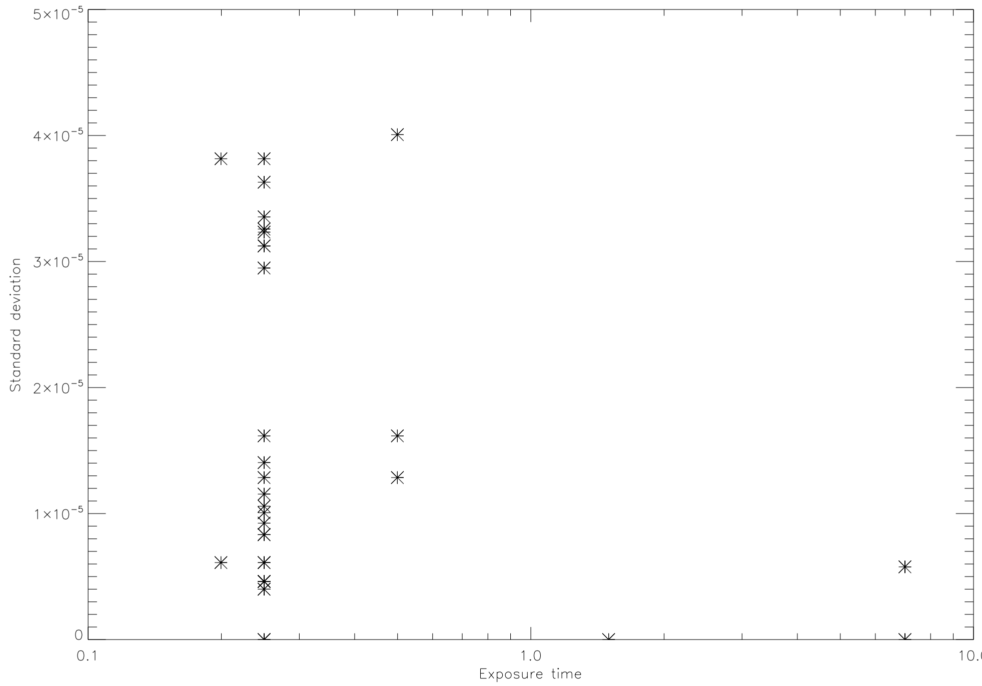


Figure 9: The RMS deviation of exposure times for each run of PBSERIES, plotted against the average exposure time.

# 7 Exposure repeatability

The primary testing of exposure repeatability was performed on the shutter mechanism before it was delivered to the COR-1 team. However, some information on repeatability can be gleaned from the EXPTIME values in the various FITS headers. To explore the question of exposure repeatability, the exposure times were read in from all the runs of the sequence PBSERIES. Figure 9 shows the standard deviations from each sequence of three images, plotted against the exposure time. The exposure times are highly repeatable.