JOHNS HOPKINS
UNIVERSITY
Applied Physics Laboratory
Laurel MD 20723-6099

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To: S. L. Murchie

From: L. M. Howser

Subject: Measurement of Brightness Samples with the CRISP Sensor

Reference: [1] L. M. Howser, 'Responsivity Results for the CONTOUR Spectrograph,' A1F(2)02-U-079, November 2002.

Summary

One reference and three oxide brightness samples were measured during the calibration of the CONTOUR spectrograph. The data from the CRISP sensor are compared with externally-measured calibration spectra. This comparison shows a good correspondence between the CRISP data and the calibration spectra. The analysis also shows that using the dark rows in the image to estimate and remove system scatter effects improves the accuracy of the measurements.

Introduction

The CONTOUR Remote Imager and Spectrograph (CRISP) is one of the instruments on the CONTOUR spacecraft. The IR spectrograph contains a 256x256 HgCdTe array. The array is illuminated through a slit that provides a two-dimensional image. One dimension of the image is spatial, with a field-of-view of about 0.86°. The other image dimension is spectral, measuring the IR spectrum from 800 nm to 2500.

As an assessment of the accuracy of the CRISP sensor, images of four brightness samples were collected during the sensor calibration. The reflectance of each of these samples was also recently measured by John Mustard (at Brown University) in support of NASA. A comparison of the CRISP measurements and the Brown/NASA measurements is provided in this memo.

These brightness data were also used to determine the effect of scatter in the CRISP sensor. The top 10-12 rows of the CRISP image are not illuminated by the external source. Reference [1] shows that these 'dark' rows can be used to estimate the scatter in the system. The data in the dark rows of the brightness sample images are used to study the effect of scatter.

CRISP Test Conditions

The four brightness samples observed by the CRISP sensor were: SRS_099, WCS_EO, WCS_HO, and WCS_DO. In all, fifteen images were collected of each sample: three images each at frame rates of 1, 2, 3, 4, and 5 Hz. These data were collected during the test sequence: CSBMH_HS3. SRS_099 is a sample with about 99% reflectance across most of the

CRISP waveband. The remaining three samples are oxides. Each of the oxides has a significant drop in reflectance somewhere in the CRISP waveband.

Comparison of Brightness Samples

The same four brightness samples were measured by the CRISP sensor and at Brown/NASA. However, because of different illumination, test equipment windows, etc., the measurements could not be compared directly. Instead of a direct comparison, the ratios of the oxides to the 99% standard were compared. By performing this ratio, most of the differences in test condition are removed.

The reflectance data received from Brown/NASA are shown in the top of Figure 1. This figure shows that the 99% sample has uniform reflectance out to about 2000 nm. After 2000 nm the reflectance starts to roll off. The ratio of the oxides to the 99% standard is shown in the bottom of the figure.

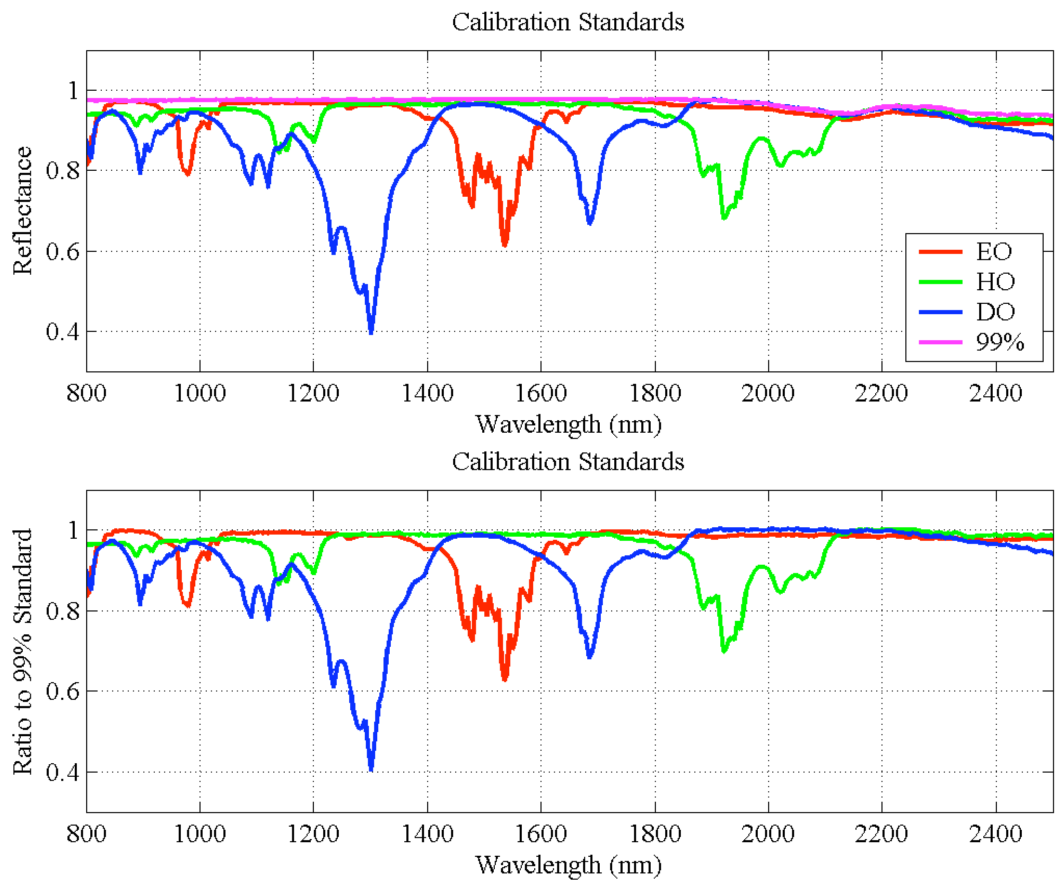

Figure 1: Plots of reference calibration data received from Brown/NASA. The reflectance of the 4 samples is plotted in the top of the figure. The ratios of the oxides to the 99% standard are plotted in the bottom of the figure.

The ratio calculations are not as straight forward for the CRISP data. Samples of the CRISP images are shown in Figure 2. One image is shown for each of the four brightness samples. In this figure, three images at the same frame rate have been averaged together (to reduce noise), and the average background image was subtracted. (The background image was collected with no external illumination entering the sensor.) The dark rows are shown in the top of each image.

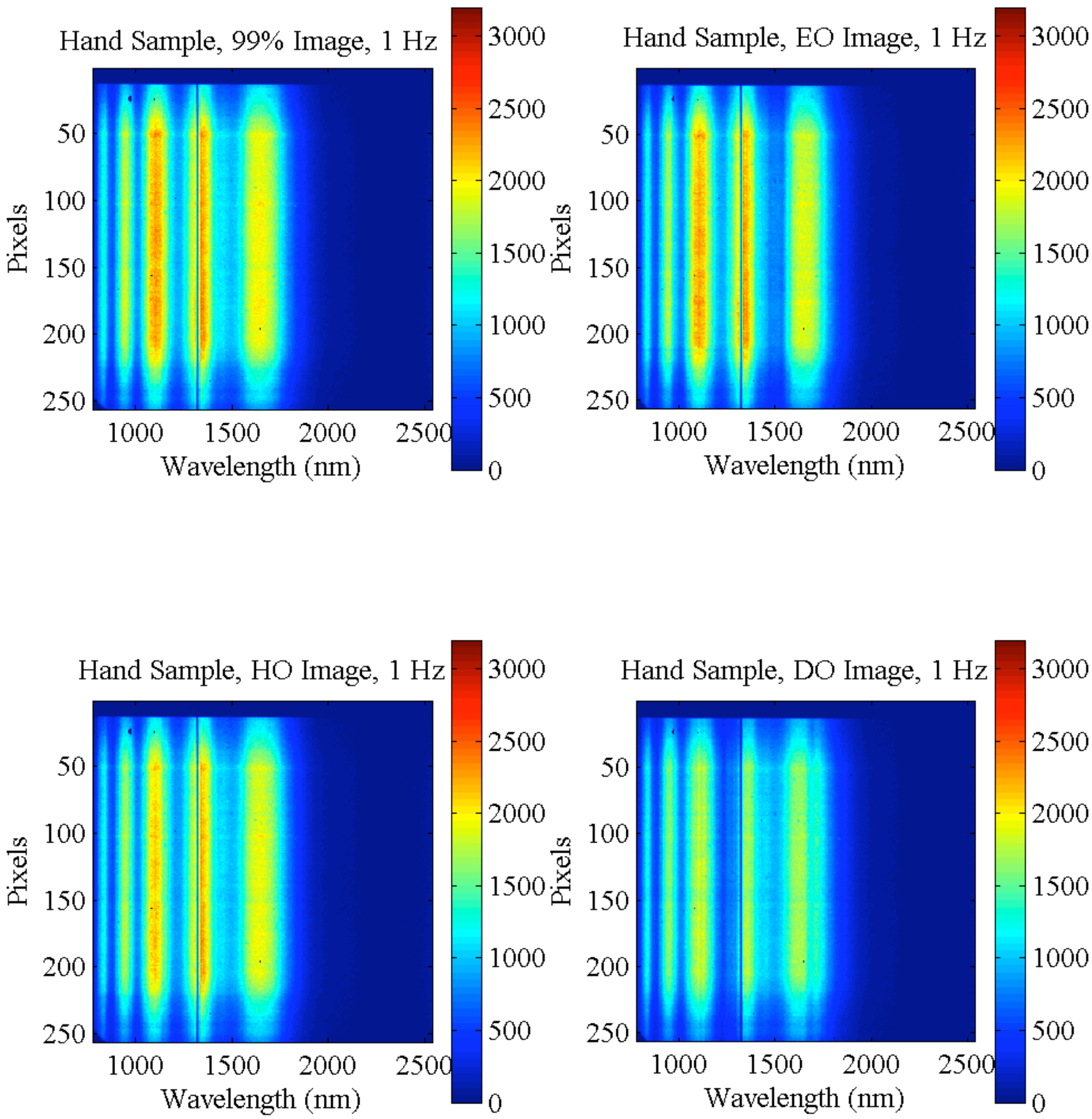

Figure 2: Example of CRISP brightness sample images. One example is shown of each of the brightness samples. These are all 1 Hz images that have had the background image subtracted.

Two different calculations of the oxide/99% ratio were computed. The steps of the first computation were:

1) average 3 frames from same brightness sample and frame rate,
2) subtract (averaged) background image from #1 average,
3) divide oxide images from #2 by 99% image in #2,
4) scale the ratio data to match the Brown/NASA data at 1 wavelength, and
5) compute mean and standard deviation of center 50 rows of the ratio images (#4).

Statistics were computed from the central rows of the image because the brightness samples did not fill the field-of-view of the sensor. The images in Figure 2 show that the signal rolls off at the top and bottom of the image.

The original ratio data, without the scaling in step #4, were slightly lower than the Brown/NASA data (<5%). These discrepancies were attributed to differences in the measurement of the samples. To overcome these test differences, a single wavelength was chosen that was near the peak signal for each brightness sample. The ratio of the Brown/NASA data to the CRISP data was computed at that wavelength. All of the CRISP ratio data were then scaled by the Brown/CRISP ratio. (Thus, on average, all of the CRISP ratios were boosted by 1-2% to better match the Brown/NASA data.)

Previous tests showed that scatter in the CRISP sensor could slightly degrade the resulting images. Thus, in addition to removing the background image, it was desirable to estimate and remove the remaining scatter. The sensor scatter was measured using the data in the dark rows. As mentioned previously, the top 10-12 rows of the CRISP sensor are not illuminated. However, the signals in these rows increases slightly as the scene intensity increases. Figure 3 shows this data. The top plot shows a single row from the 'EO' image at all frame rates. The bottom plot shows the signal from the 'dark' rows of the same EO images. (A low-pass filter was applied to the dark signal to reduce noise.) These plots show that as the scene intensity increases, the signal in the dark rows also increases. However, the spectra in the dark rows do not match the spectra in the scene.

The dark row signals were used to estimate the scatter in the sensor. To do this, the following steps were executed:

1) average top rows of CRISP image (rows 2-7),
2) create a 'dark image' from the average rows (replicate the average dark row to a 256x256 image), and
3) low-pass filter the dark image (7x7 filter template).

Once the dark image was created, it was used in the calculation of the ratios.

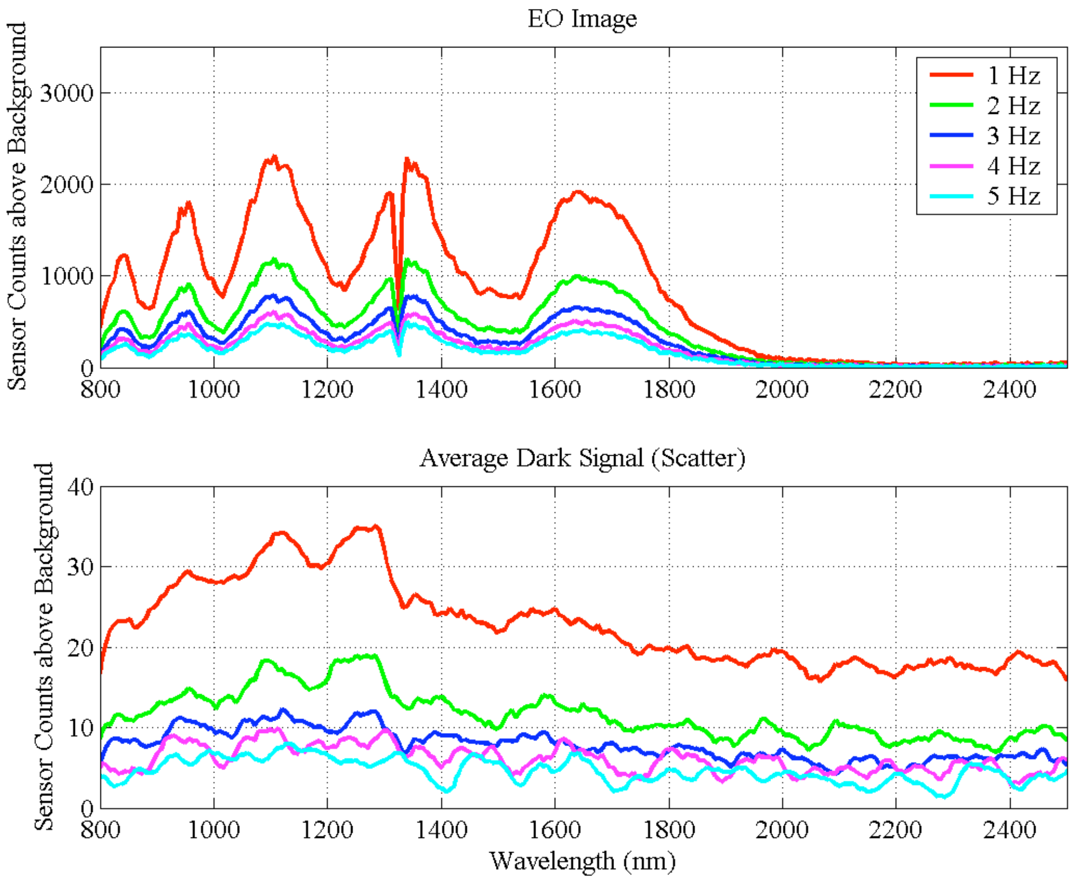

Figure 3: Estimate of system scatter using the dark rows. The top of the figure shows a single row from the EO image for all frame rates. The bottom plot shows the corresponding data from the image 'dark rows'. These plots show: 1) the average signal in the dark rows increases with the average scene intensity, and 2) the spectra in the dark rows do not match the spectra in the scene. For these reasons, the dark rows are used to estimate the system scatter. Note that above 1900 nm there is very little signal in the EO image.

The steps of the second method of computing the oxide / 99% ratios were:

1) average 3 frames from same brightness sample and frame rate,
2) subtract (averaged) background image from #1 average,
3) **subtract dark image from #2 difference image,**
4) divide oxide images from #3 by 99% image in #3,
5) scale the ratio data to match the Brown/NASA data at 1 wavelength, and
6) compute mean and standard deviation of center 50 rows of the ratio images (#5).

So, the only difference between the two computations is the subtraction of the dark image estimate of scatter.

Figures 4-6 show the resulting ratios from both calculation methods. In all three plots, above about 1900 nm the match to the calibration standard (Brown/NASA data) gets poor. The plot in Figure 3 showed that above this wavelength there was very little signal, thus the noise becomes significant. The average CRISP ratio is shown in these plots. The standard deviation is plotted in black for wavelengths above 1800 nm. In all three cases, both ratio calculation methods match the Brown/NASA data well when there is significant signal. The data with the dark signal removed appears to match the standard slightly better when there is reduced signal (only out to about 2100 nm). The Brown/NASA data were at a higher resolution than the CRISP data (.5 – 3 nm versus 7 nm), explaining why some of the spikes in the standard calibration curve appear to be smoother in the CRISP ratios.

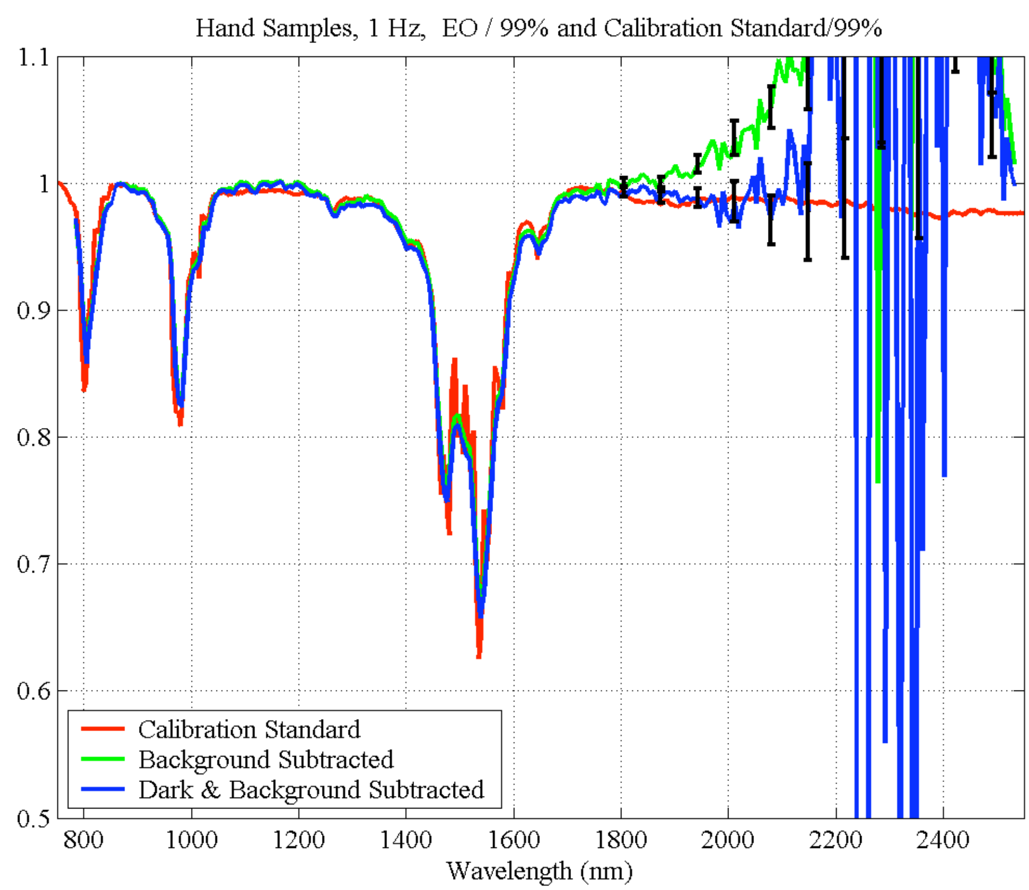

Figure 4: Resulting ratios for the EO brightness sample. Both the 'background' and 'dark + background' data are a good match for the calibration standard data out to 1800 nm. Between 1800 and 2100 nm, the 'dark + background' data are a better fit.

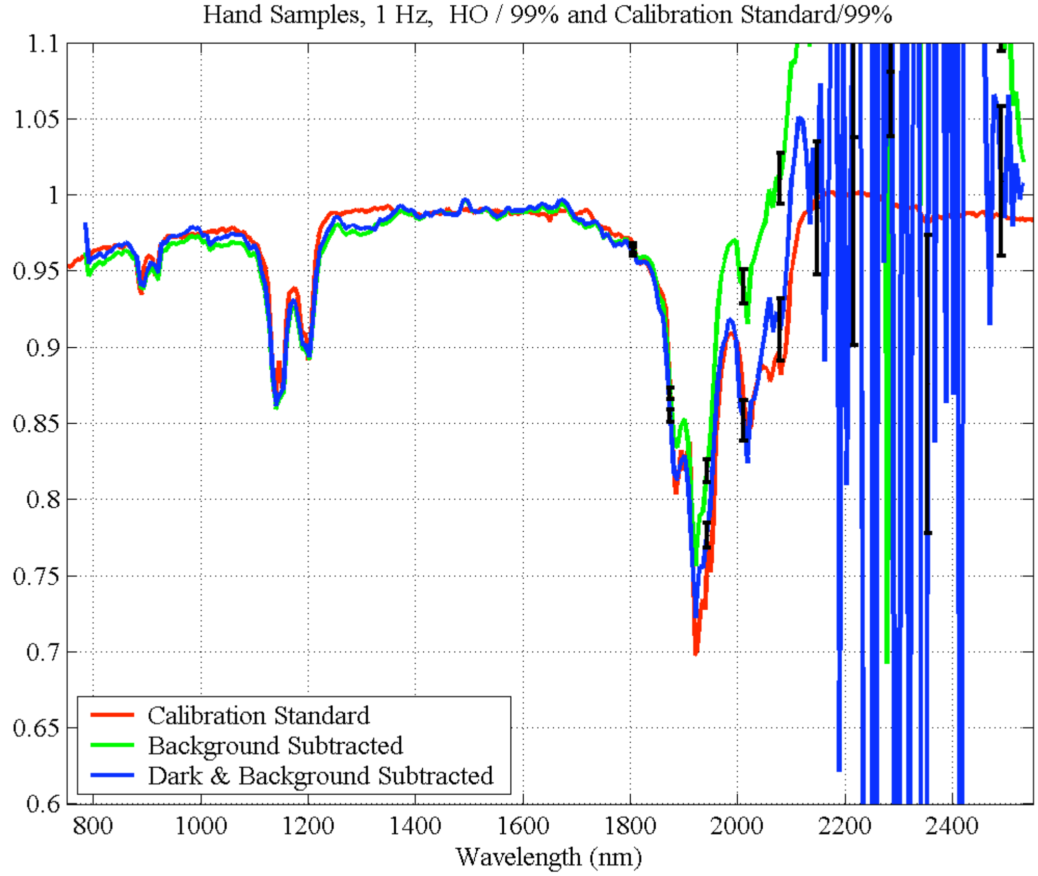

Figure 5: Resulting ratios for the HO brightness sample. Both the 'background' and 'dark + background' data are a good match for the calibration standard data out to 1900 nm. Between 1900 and 2100 nm, the 'dark + background' data are a better fit.

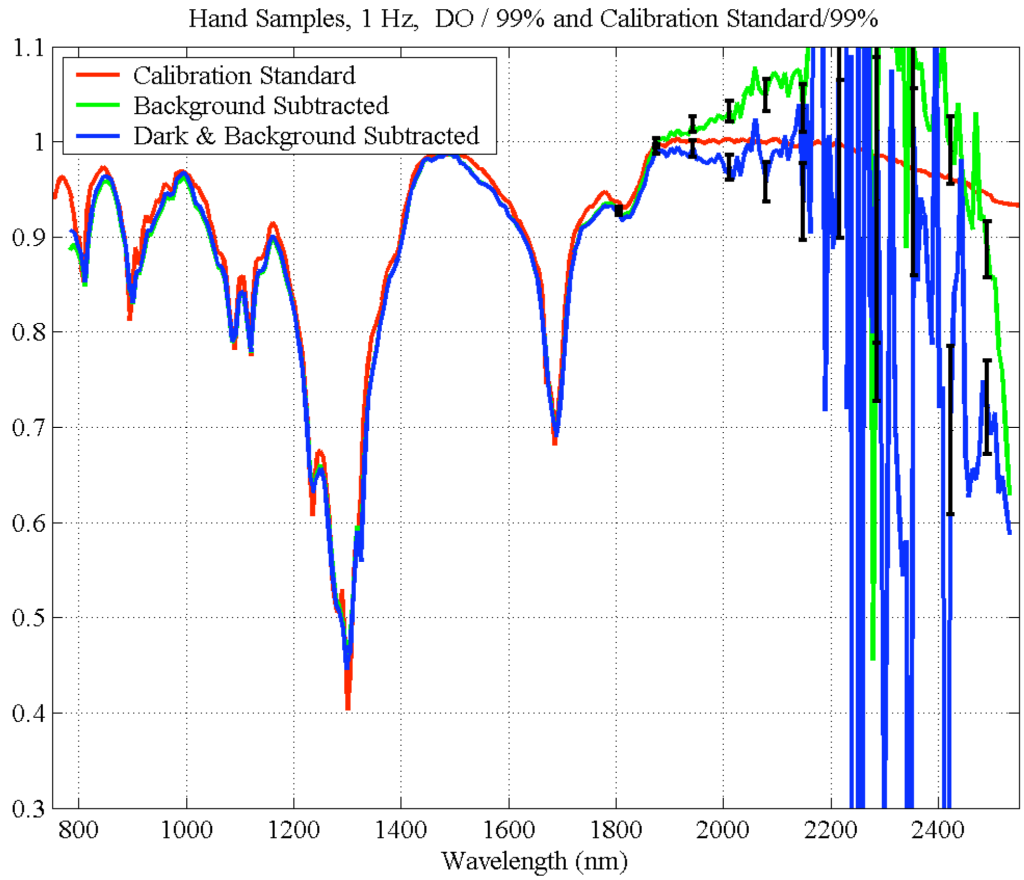

Figure 6: Resulting ratios for the DO brightness sample. Both the 'background' and 'dark + background' data are a good match for the calibration standard data out to 1900 nm. Between 1900 and 2100 nm, the 'dark + background' data are a better fit.

Conclusions

The CRISP measurements of the brightness samples have been compared to the Brown/NASA calibration data. These comparisons show a good match between 800 and 1900 nm. Beyond 1900 nm, there was little signal in the CRISP data, causing the noise to be significant. The calculation using the dark rows to estimate and remove the system scatter provides a better match to the calibration data.

L. M. Howser

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