Calibration Description: OSIRIS-REX Visible and Infrared Spectrometer (OVIRS)
Amy Simon, March 3, 2019
Version 2.0
Changes: updated calibration step order

Introduction

OVIRS is a point spectrometer that operates from 0.4 to 4.3 microns. All pixels see the same 4-mrad spot projected onto the target. The spectrum is made using 5 linear variable filter segments to cover the full spectral range. Each filter segment spans 512 pixels in the wavelength dimension. Readout is done over a predetermined number of rows, or region of interest (ROI) in each filter, typically 32 rows per segment, and then are not required to be contiguous. With dark pixel rows, a full frame is 512x180 pixels. Typically, the pixels are summed onboard in SuperPixel (SP) mode to reduce data volume. The normal operating mode sums 8 pixels (also called SP=8) of the same wavelength, after removing any known bad pixels. This results in 512x23 pixels, including 3 dark rows, in the Level 0 product. *If data are summed onboard in any mode other than SP=8, they will be further summed on the ground before pipeline processing, after removing bad pixels*. All Level 2 data arrays will be 512x20.

The ground calibration pipeline converts the Level 0 data to physical units. Several processing and calibration steps are performed on the raw data to produce a Level 2 spectrum:

1. Multiply by the bad pixel map to adjust the sums for the numbers of pixels included in the SP.
2. Subtract the background level
3. Calculate and remove out-of-band contribution
4. Convert to radiance units

Description of the OVIRS Pipeline is provided in the SPOC-OVIRS Interface Control Document, UA-ICD-9.4.4-1004. Derivation of the calibration files is described in the instrument description paper (Reuter et al. 2018, *Space Science Reviews* **214**, 54, DOI:10.1007/s11214-018-0482-9) and the first inflight calibration paper (Simon et al. 2018, in prep).

1. SuperPixel Sum Adjustment

As pixels have been summed onboard to create SP sum ($SPS_{i,j}$), but are not averaged, the counts at Level 0 do not reflect the actual count values. To determine data number ($DN_{i,j}$), $SPS_{i,j}$ are corrected for the number of pixels using the corresponding bad pixel map ($BPM_{i,j}$). In flight, all science data use the 115K BPM.

$$DN_{i,j} = SPS_{i,j} * \frac{8}{BPM_{i,j}}$$

2. Background Subtraction

Background levels are dependent on the detector temperature. Blocks of deep space spectra in the same SP mode, similar detector temperature, and acquired close in time, are used to calculate the average background level (Deep Space Calibration File), $B_{i,j}$. Corrected counts, $C_{i,j}$, are produced by subtracting the average background frame.

$$C_{i,j} = DN_{i,j} - \frac{1}{n}\sum_{1}^{n} B_{i,j}$$

3. Out-of-Band Correction

The last correction is to remove out-of-band signal, long wavelength photons that appear as signal in the short wavelength segments. This is performed in multiple steps:

- Convert $C_{i,j}$ to photon radiance, $P_{i,j}$, in photon/s/cm^2/sr/um, by multiplying b the radiometric coefficient, $R_{i,j}$ and dividing by integration time, t, and photon energy, $E_{i,j}$:

$$E_{i,j} = h * \frac{c}{\lambda_{i,j}}$$

Where h is the Planck constant, c is the speed of light and $\lambda_{i,j}$ is the wavelength of pixel (i,j):

$$P_{i,j} = \frac{R_{i,j} * C_{i,j}}{t * E_{i,j}}$$

- Integrate photon radiance from 2.8 to 3.9 um, S, using trapezoidal rule. Note: here the rows, j, to sum over are those in the 3rd filter segment (rows 53-84 in a full frame, rows 8 to 11 in SP=8, before dark pixel rows are removed):

$$S = \iint P_{i,j}\, di\, dj$$

- Multiply sum by Out-of-Band Correction File, $OB_{i,j}$, for each pixel, convert back to counts and subtract out-of-band counts from background-subtracted counts for final corrected counts, $CO_{i,j}$:

$$CO_{i,j} = C_{i,j} - S * OB_{i,j} * E_{i,j}$$

4. Radiance Unit Conversion

Corrected counts are converted to radiance units, $I_{i,j}$, in W/cm^2/sr/micron by first dividing by exposure time, t, to get counts/s. They are then multiplied by the Radiometric Conversion File, $R_{i,j}$:

$$I_{i,j} = \frac{CO_{i,j}}{t} * R_{i,j}$$