Calibration of the Pollution Spectrometer using an Integration Sphere

Version: 10.3.2022

How Demetra process the images

Demetra is using “additive method” during the processing the pictures. It means that:

- All pixels in y-direction (after the geometrical correction) located in the working area are summed together. Each observation uses its own working area. So, the higher is the working area, the higher is the output signal. The height of the working area is shown in the program.
- Signals from individual pictures are summed together. So, the higher is the number of processed images, the higher is the output signal. The total exposure time (the sum of individual exposure times) is shown in metadata of the processed pictures.
- In the “Scale” phase of the processing, the signal is scaled down to the values of the order 1. The scaling coefficient is shown in the processing log.
- The flat-field levels have no effect on the output signal. Flat-fields with the maxima of 20000 ADU and 30000 ADU give the same output signal (the same product of the output signal and the scaling coefficient, to be more precise).

Radiometric calibration

Following parameters will be used during the calibration:

H_S – height of the working area (measured spectrum)
H_R – height of the working area of the reference (integration sphere)
T_S – total integration time of the measured spectrum
T_R – total integration time of the reference (integration sphere)
S_S – scaling coefficient of the measured spectrum
S_R – scaling coefficient of the reference (integration sphere)
V_S – value of the measured spectrum
V_R – value of the spectrum of the reference (integration sphere)
L_R – spectral radiance of the reference (integration sphere)
C_S – calibration (multiplication) coefficient for the transformation of the measured spectrum to the spectral radiance

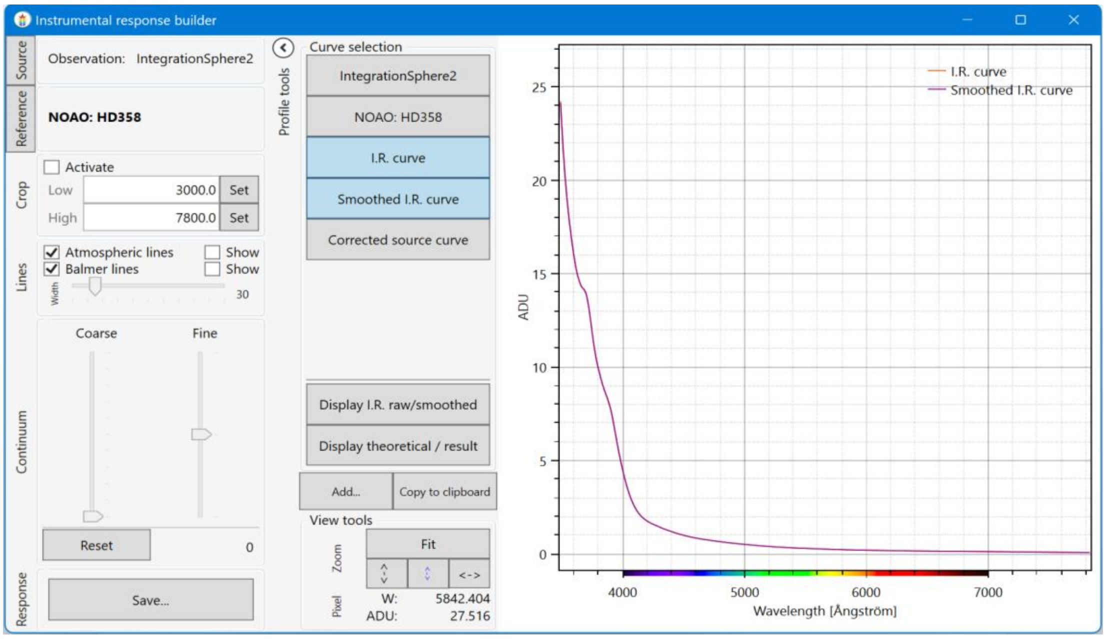
The process is as follows:

1. Construction the instrument response curve

- Measure the spectrum of the integration sphere by the pollution spectrometer (use more pictures to suppress the noise, use flat-fields, darks, biases and wavelength calibrations). Typical exposure time is 2s (maximum signal about 35000 ADU – ca 1/2 of the maximum range of 65535 ADU.
- Replace the spectrum of any reference star (e.g. HD358) in ISIS database – folder ‘C:\Users\Public\Documents\Demetra\SpectrumReferenceDatabase\isis_database_v7’ by

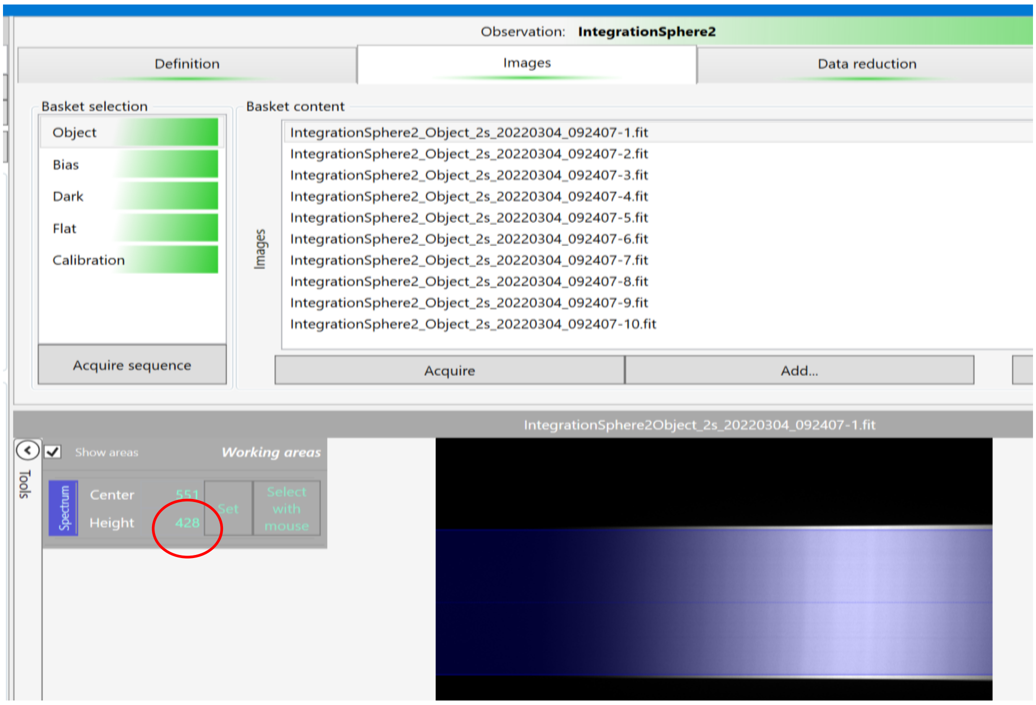
the spectrum taken by the USB650 spectrometer (spectral radiance vs. wavelength in angstroms) - see ‘Calibrating the integration sphere using USB650 spectrometer’.

- In Demetra (Tools/Construct response curve) use this star (e.g. HD358) as a reference star and use the measured spectrum of the integration sphere as the source. Then follow the instructions (smooth the curve – “Continuum” sliders) and save it in FITS format to disk:

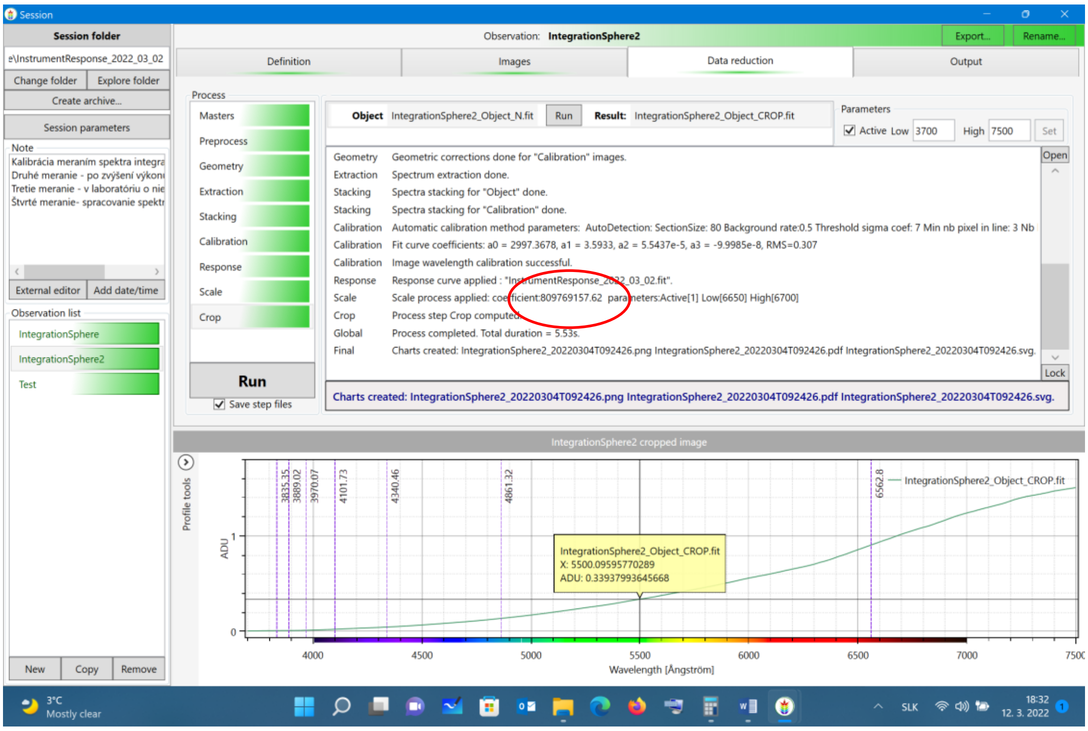


2. Finding the scaling coefficients of the reference (integration sphere)

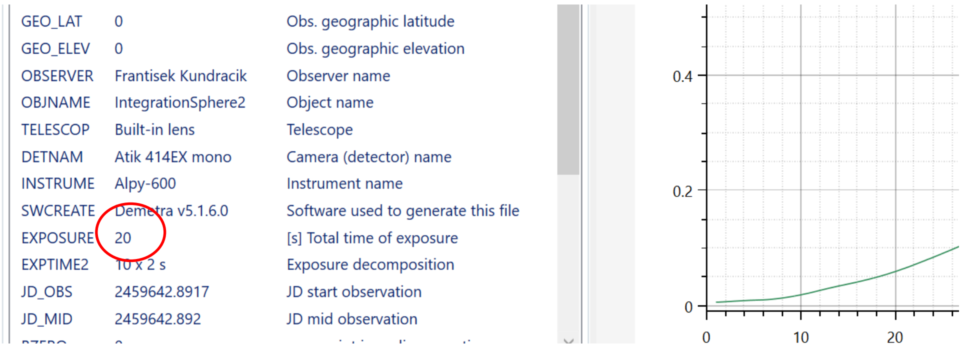
- In Demetra, open the observation of the integration sphere and process it using the Instrument Response curve found in previous step.
- Read the height H_R of the working area by double-click of any input image (**H_R = 428** in our example):



- After the Data reduction is done, read the scaling coefficient S_R applied by Demetra (**S_R = 809 769 157.62** in our case). Then double-click the final cropped image and read the value of the output signal at 550 nm (**V_R = 0.33937** in our case)



- Right-click the final cropped image and select “Open in FIT viewer”. Then read the total time of exposure (**T_R = 20 s** in our case)



- Open the radiometrically calibrated spectrum “integration_sphere _final.dat” of the integration sphere (see “Calibration of the integration sphere”) and read the real spectral radiance (**L_R = 9.582e-4** in our case) at 550 nm:

…

5480	9.384E-04
5490	9.484E-04
5500	9.582E-04
5510	9.682E-04

…

3. Finding the scaling coefficients of the measured spectrum

- Open the measured spectrum in Demetra and process it using the same Instrument Response curve as in previous step:

- Write down following coefficients:

***H_S* = 433, *S_S* = 122 799.94, *T_S* = 300 s**

4. Finding the calibration coefficient of the measured spectrum

The calibration coefficient can be found as:

$$L_S = C_S V_S = \frac{H_R}{S_R}\frac{T_R}{V_R}L_R\frac{S_S}{T_S H_S}V_S$$

For our case

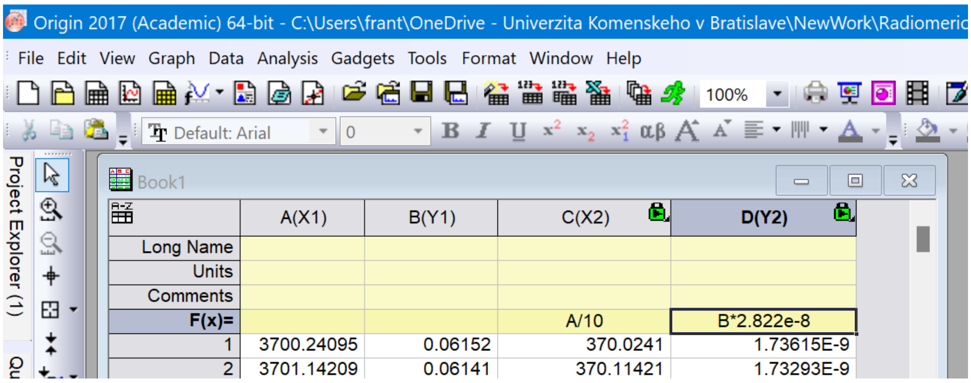
$$C_s = \frac{428}{809\,769\,157.62}\frac{20}{0.33937}9.582\text{x}10^{-4}\frac{122\,799.94}{300\text{x}433} = 2.822\text{x}10^{-8}$$

As an example, the highest peak has the value of V_S = 6.185 ADU and its spectral radiance is 6.185 x $2.822\text{x}10^{-8}$ = $1.745\text{x}10^{-7}$ W/m2/sr/nm

5. Creating the picture of calibrated spectrum

- Open the "spectrum_template.opj" file in OriginLab
- Copy the content of the spectrum (*.dat file) and paste it into the first two columns.

- Modify the equation in column D (multiply by 2.822e-8 in our case):



- Palette should be linearly mapped from 3700 to 8200 (if changed):