UV-Vis remote sensing instruments - From L0 to L1

Alexander Cede

LuftBlick, Austria

NASA/Goddard Space Flight Center, USA

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From photons to digital number

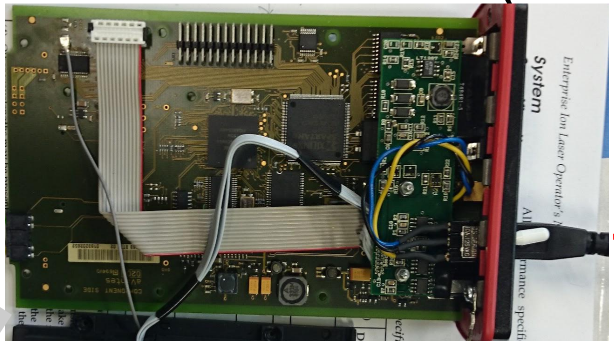
What do we want to measure?

Spectral Irradiance [W/m^2/nm] =

Energy received per time interval (J/s=W) per area (m^2) per wavelength interval (nm)

Telescope

Readout electronics (ROE)



Spectrometer

Fiber optics

What do we get?

A digital number (DN)

L0 to L1 correction steps

These is a “typical” set of correction to be applied in the L1 processing. The order does not necessarily have to be the same in all instruments. The examples here are for a “non-imaging” system, but the basics also apply to imaging systems.

From front (telescope) to back (readout electronics)

1. Dark correction
2. Non-linearity correction
3. Latency correction
4. Flat field correction
5. Conversion to count rates
6. Temperature correction
7. Stray light correction
8. Sensitivity correction
9. Wavelength correction

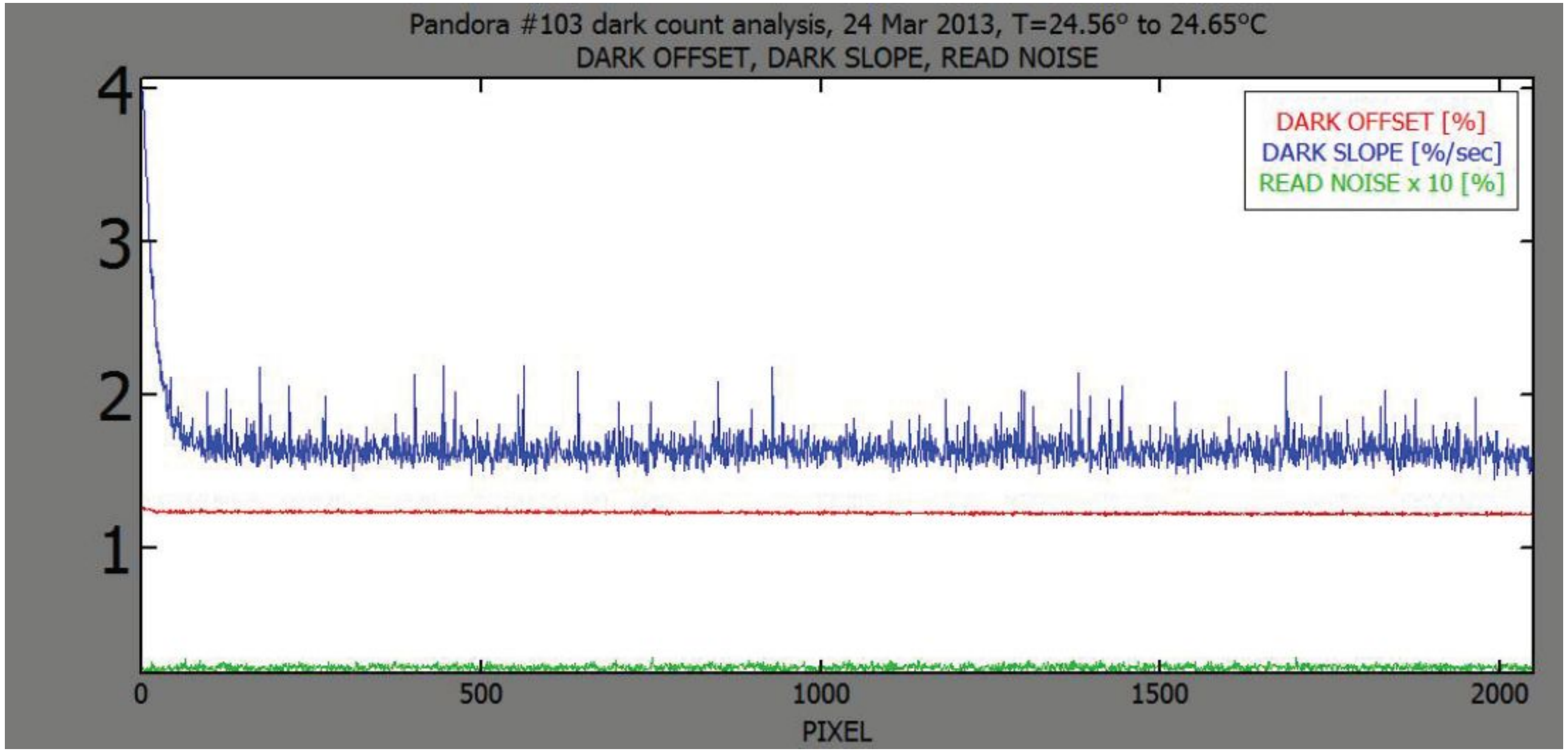
From back (DN) to front (Radiance)

Dark correction

Dark Signal = Dark Offset + Dark Slope

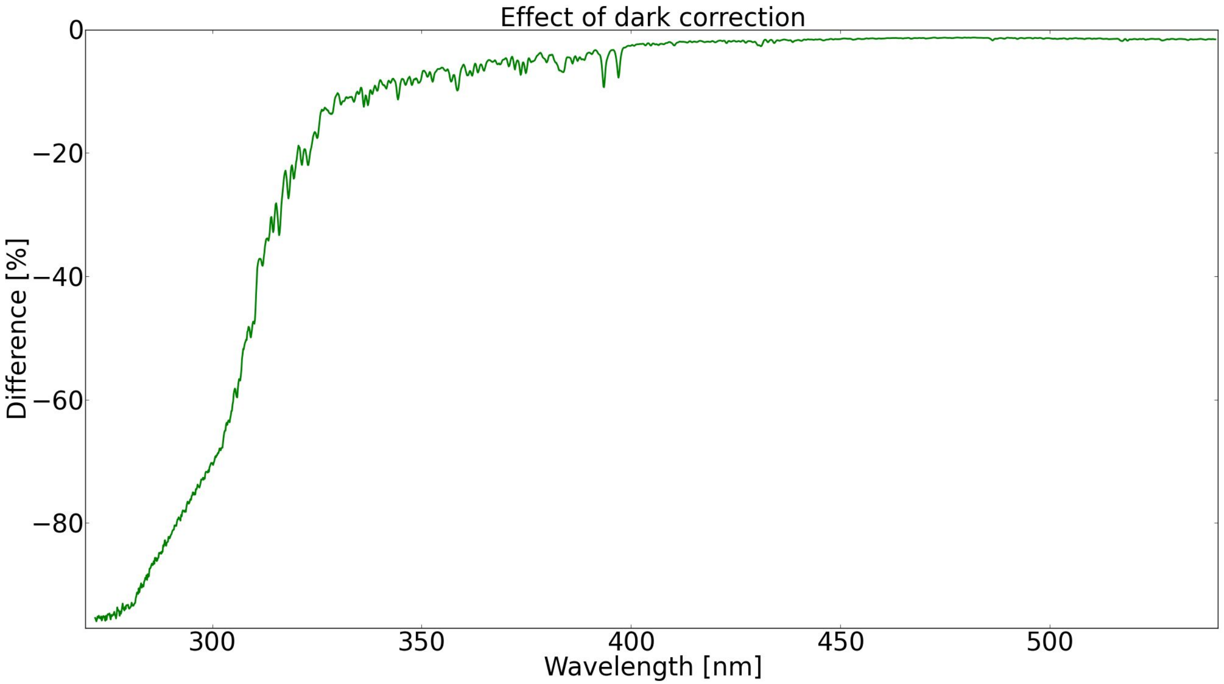
Mostly from ROE

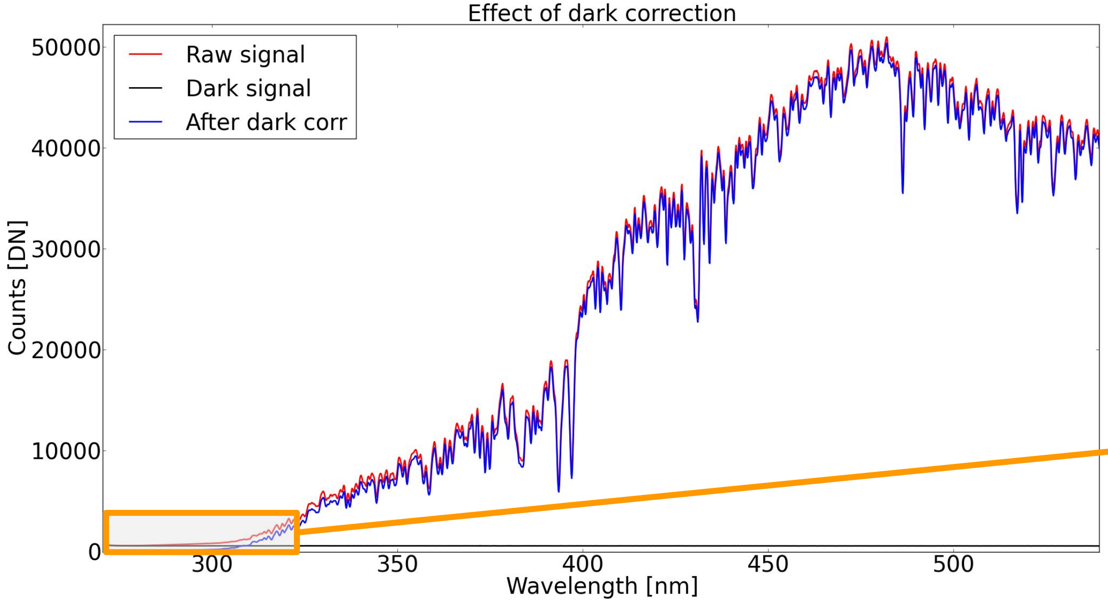
Mostly from thermal electrons

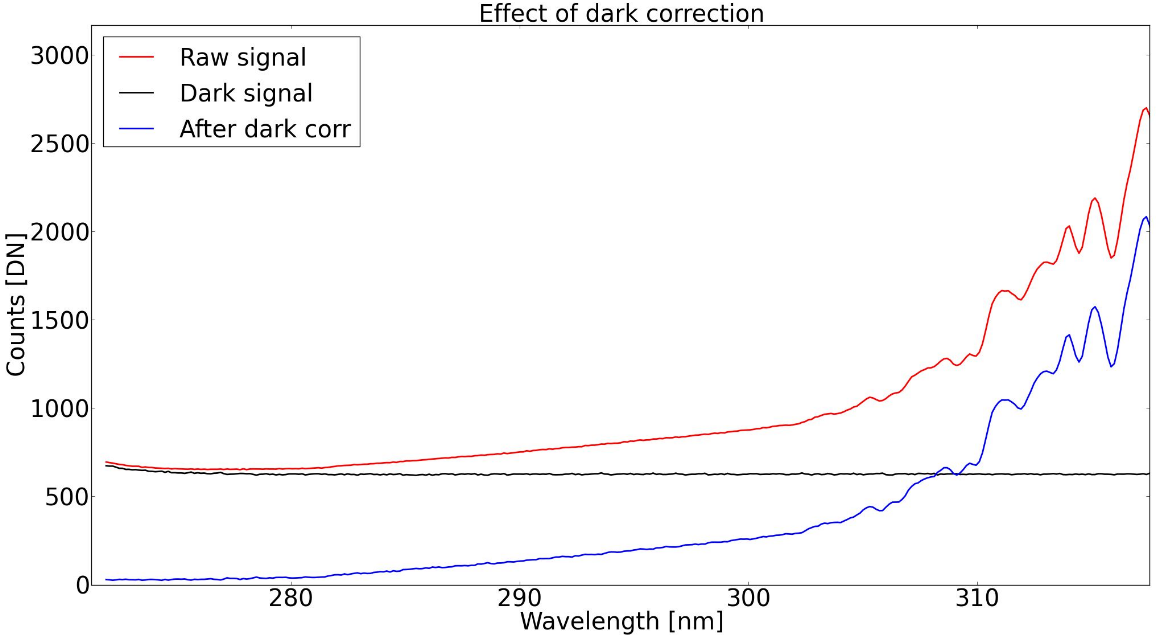


Effect of Dark correction

Spectrum shown in this presentation is direct sun at noon (SZA=56°) on 17 Oct 2019 at Innsbruck.



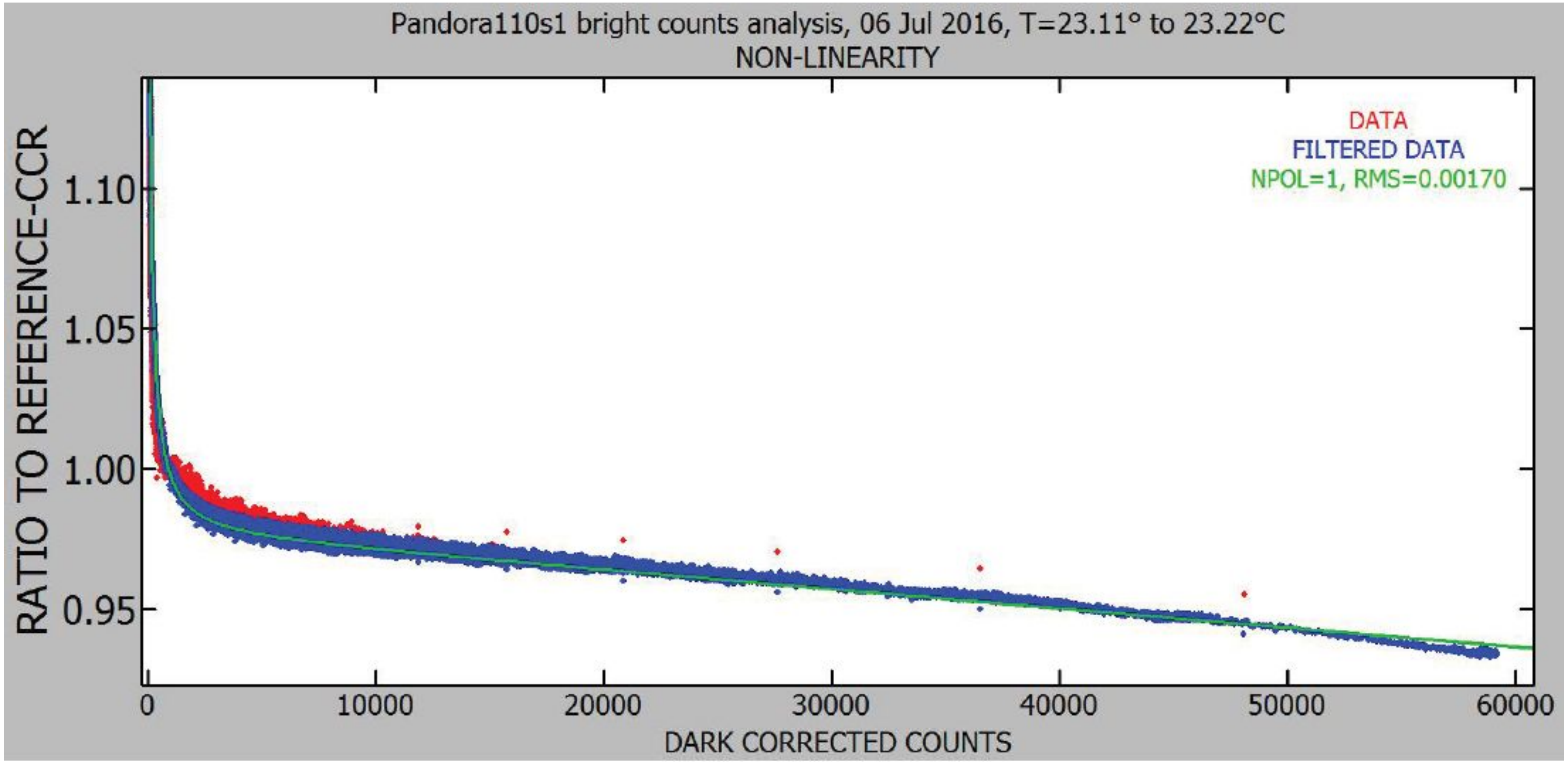




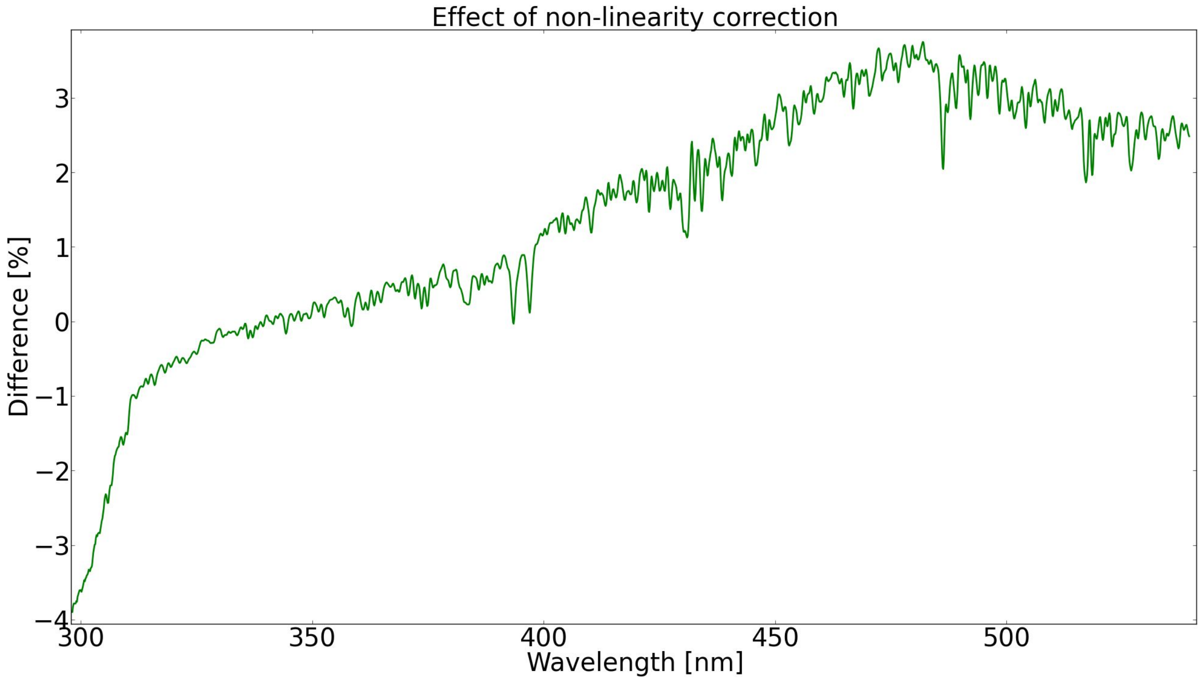
Non linearity

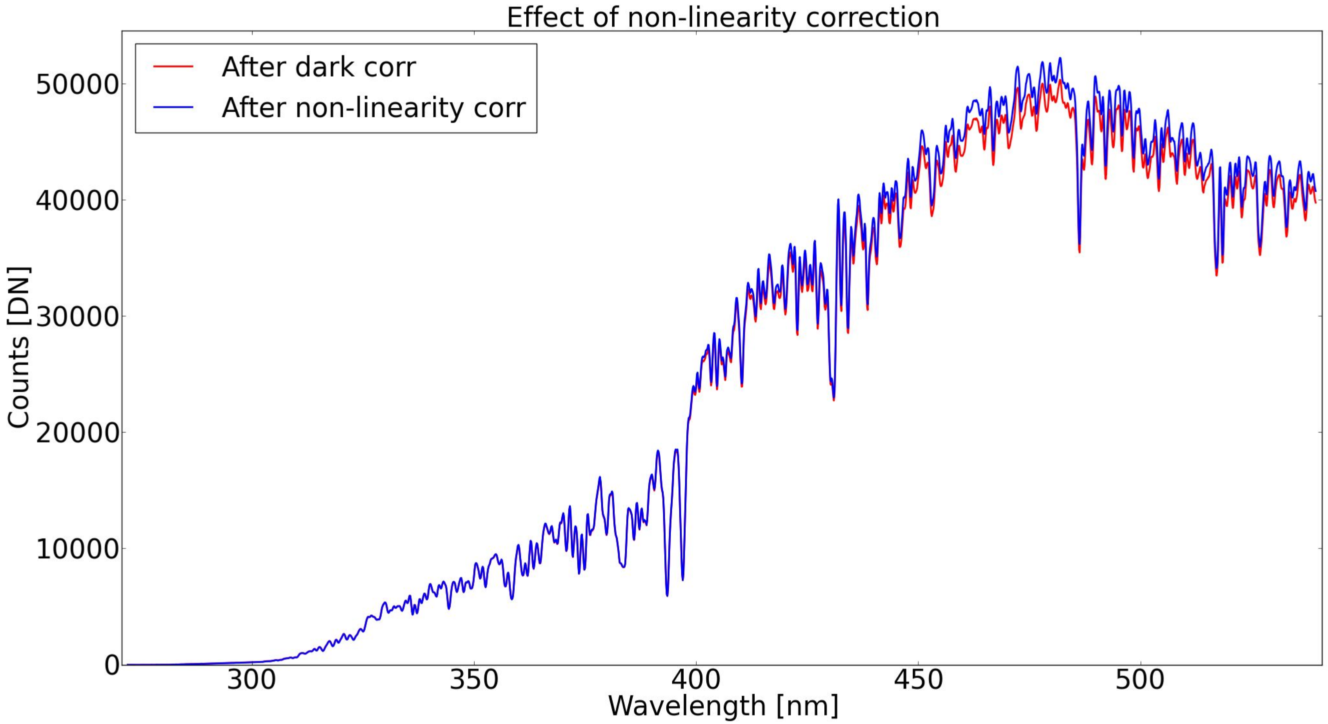
“A doubled input does not give a doubled output”

Mostly due to ROE



Effect of Non-linearity correction





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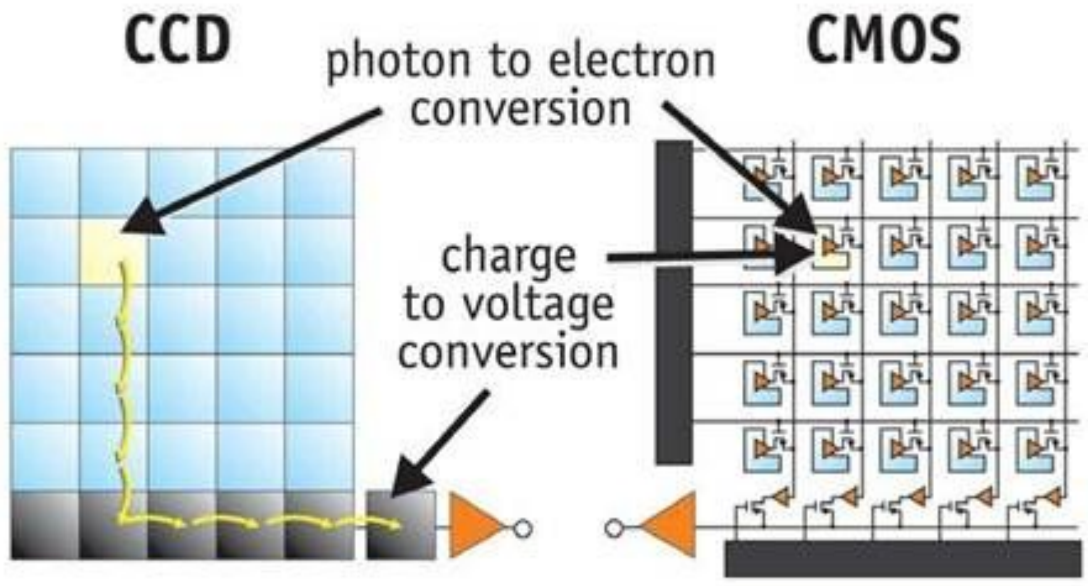
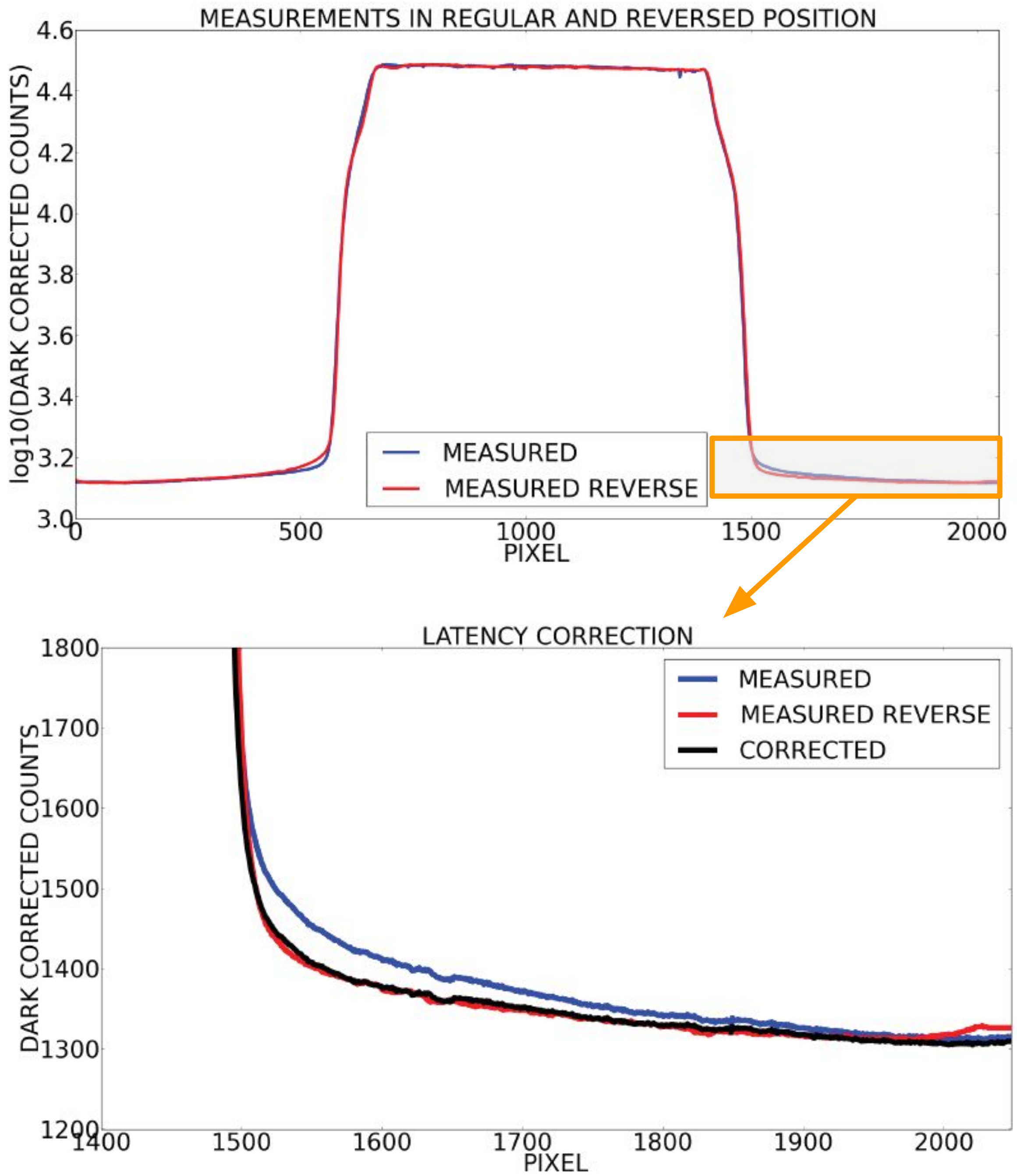
Latency

- Latency effects in the ROE of CCD detectors cause the readings in a pixel to be influenced by the readings in the previously read pixels.
- E.g. if there are many subsequent high readings followed by very low readings, then the first low readings are biased high, since a residual charge from the previous readings is still in the ROE capacitor.
- This is not a problem for CMOS detectors.

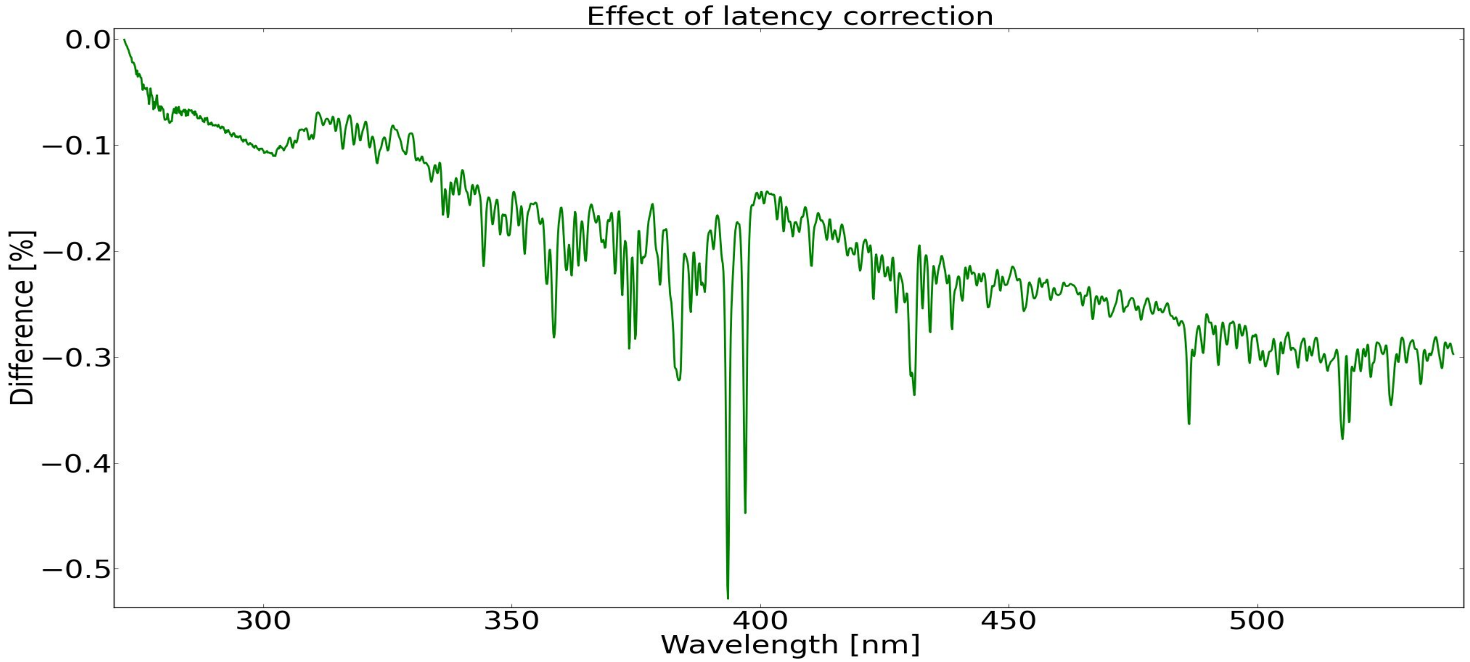


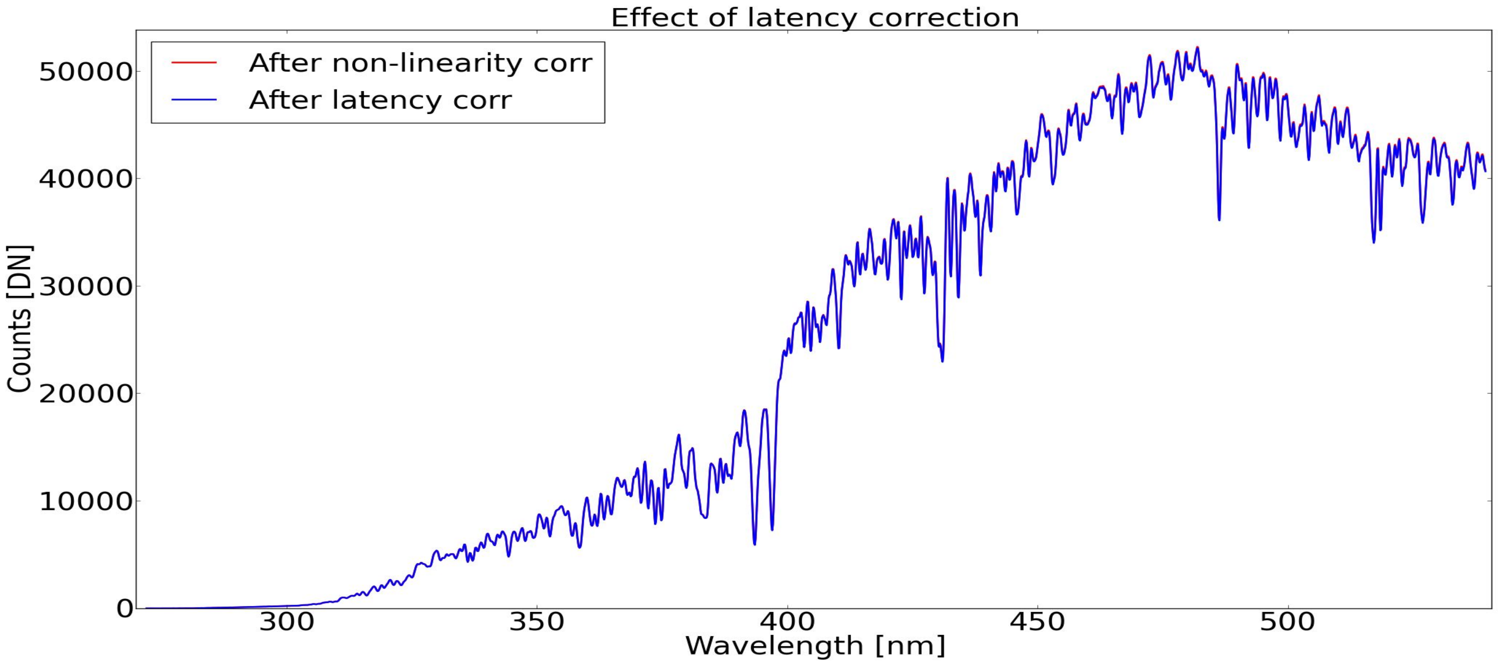
Latency

- Latency calibration is very difficult in case the CCD can only be read from one point, therefore it is most often not done.
- It actually affects the spatial component for imaging systems more than the spectral one (e.g. biased MODIS data near clouds).



Effect of latency correction





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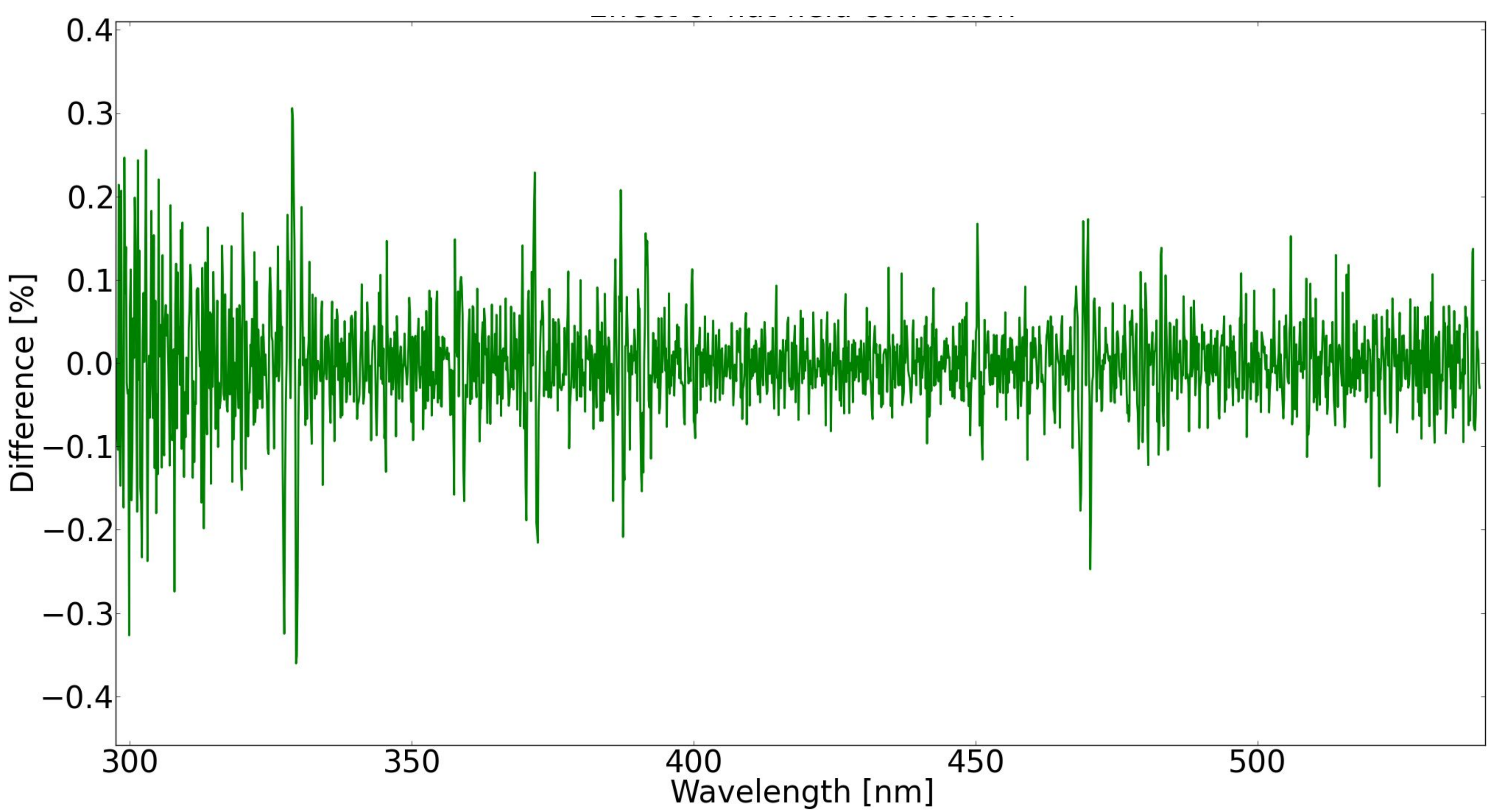
Pixel response non uniformity

"What is the difference in the signal if every pixel gets exactly the same input?"

For single pixels the PRNU is actually an effect of about ±1%. Here is is reduced since for this CCD 64 single pixels are averaged in the reading.



Conversion to count rates

In this correction step the data are divided by the integration time, which changes their unit from

"counts" or "DN"

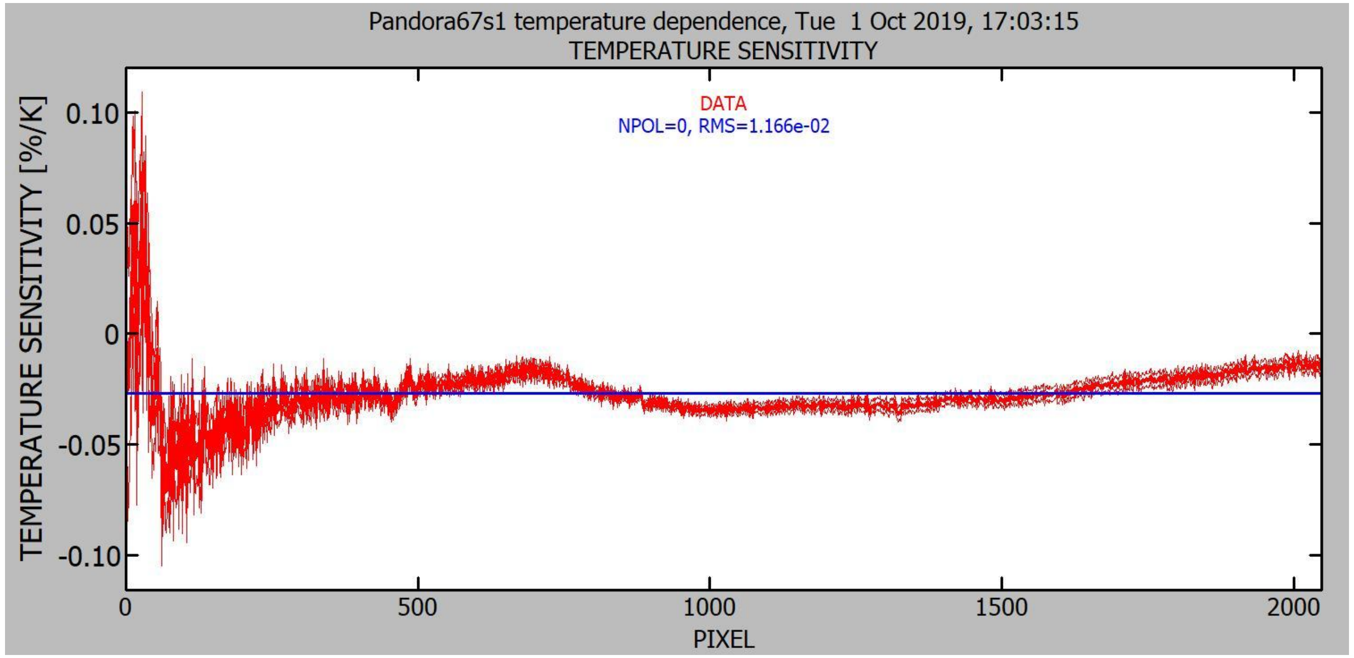
to

"counts/s" or "DN/s".

Note that sometimes the “nominal integration time” is not necessarily the “true” integration time and an integration time correction needs to be applied.

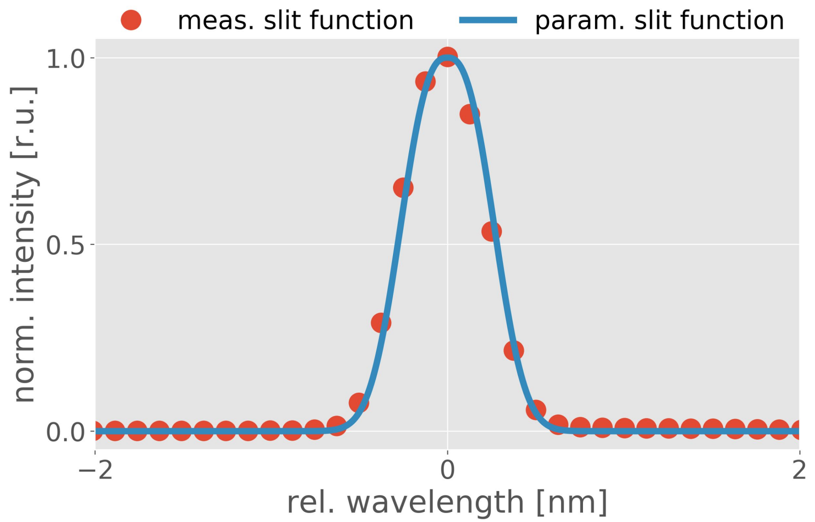
Temperature correction

- The quantum efficiency of a detector as well as the performance of the ROE In general depend on the temperature.
- This is one of the reasons spectrometers are usually temperature-stabilized.
- The effect is usually rather uniform across the wavelengths, i.e. a correction of X%/°C is applied to the data.

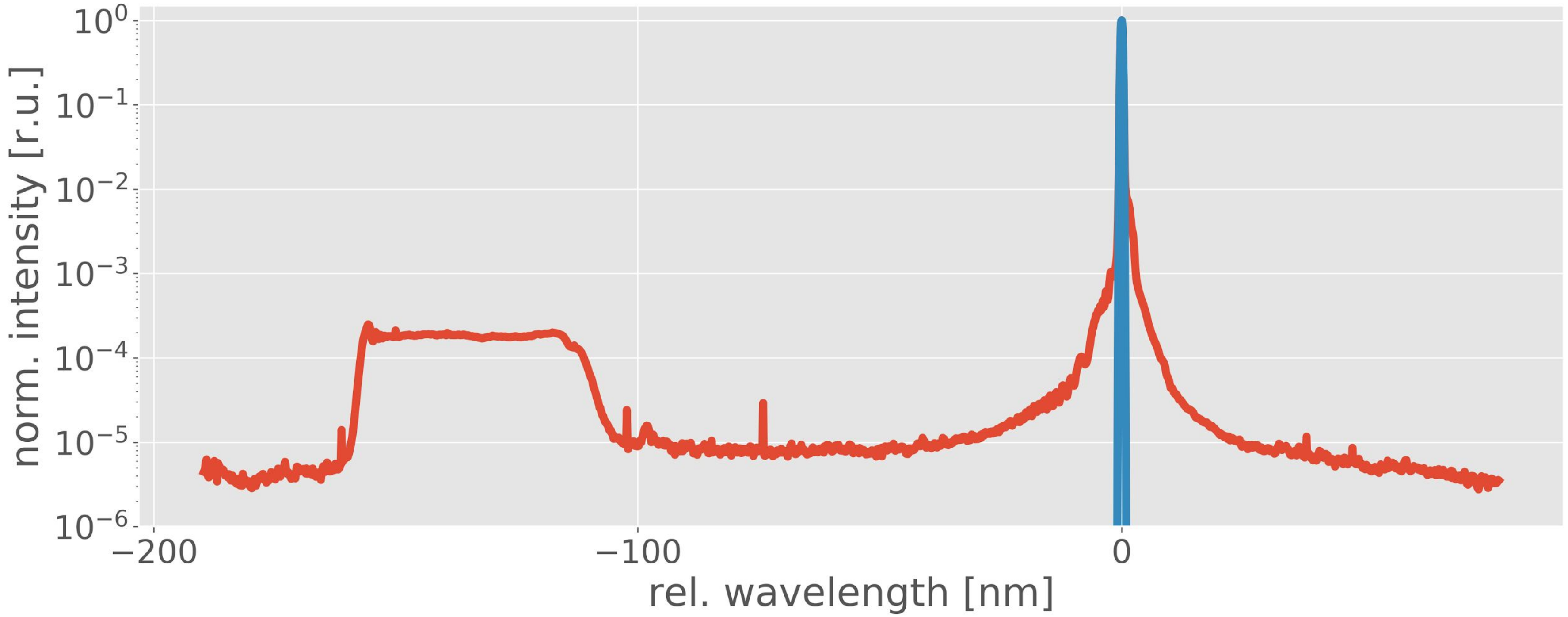


Stray light correction

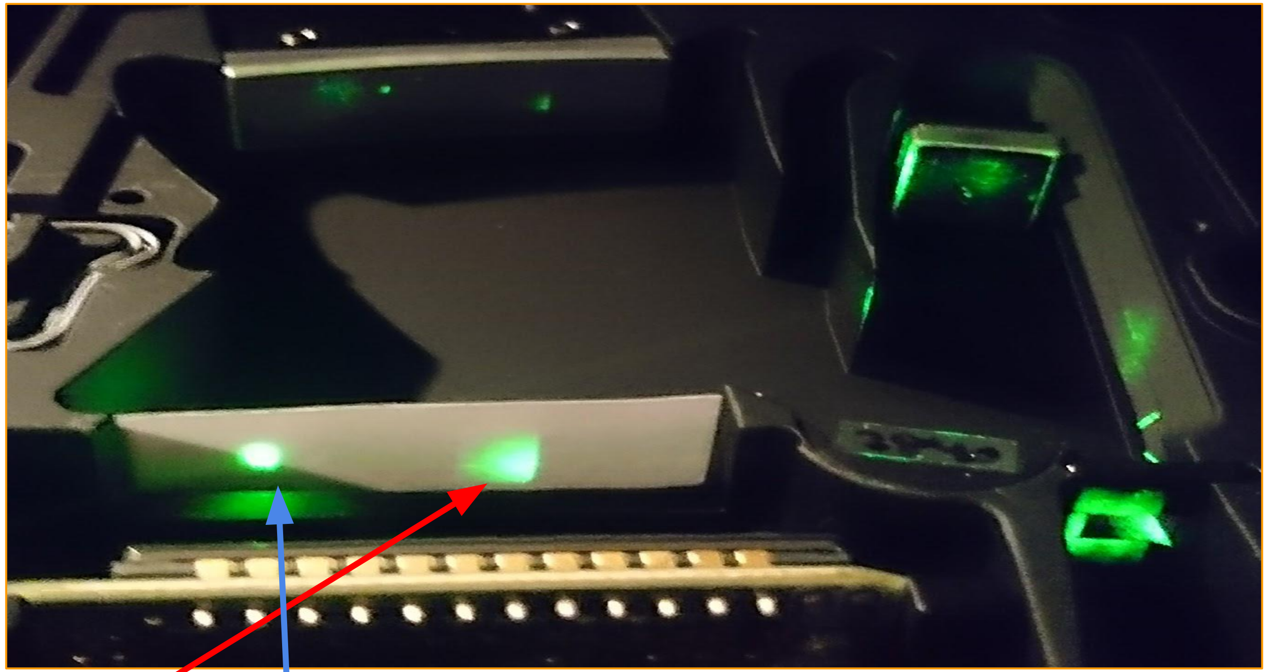
“Not all photons necessarily end up where they should.”

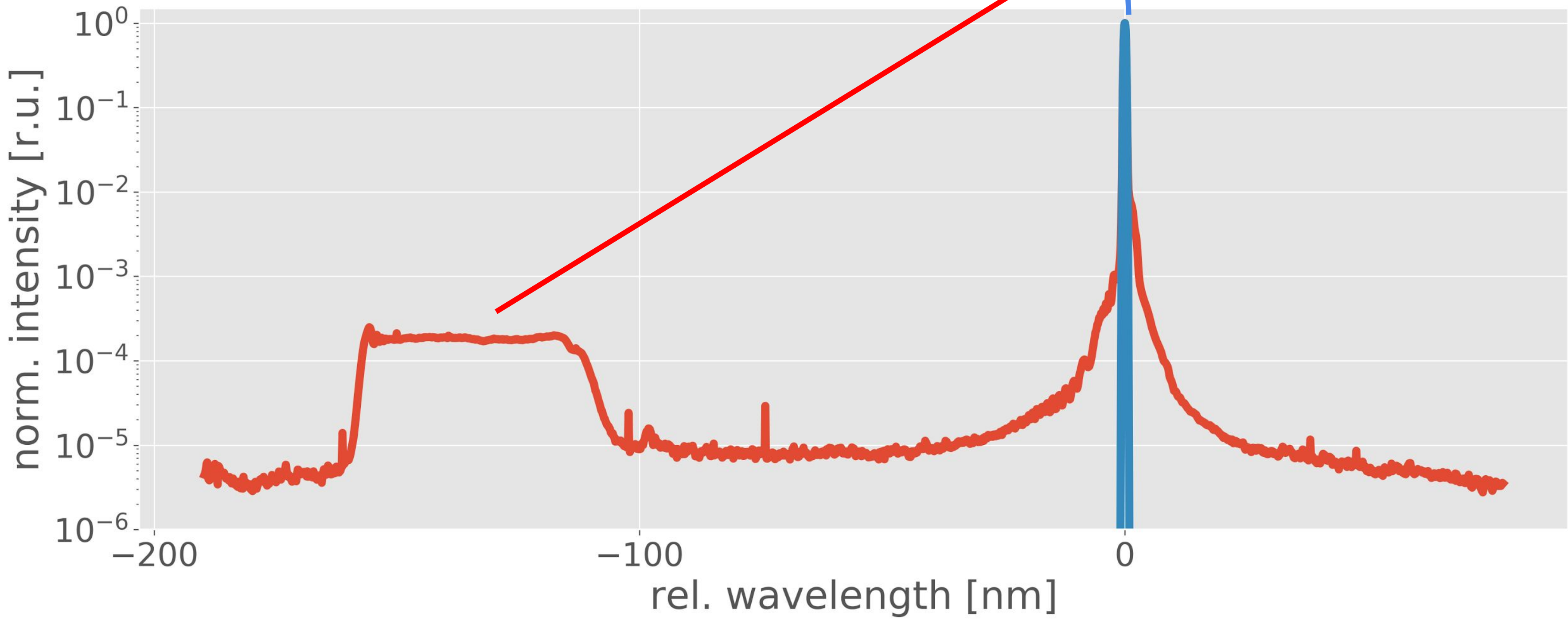


Slit function looks tame on the linear scale, but reveals all kind of structures on the log scale → spectral stray light

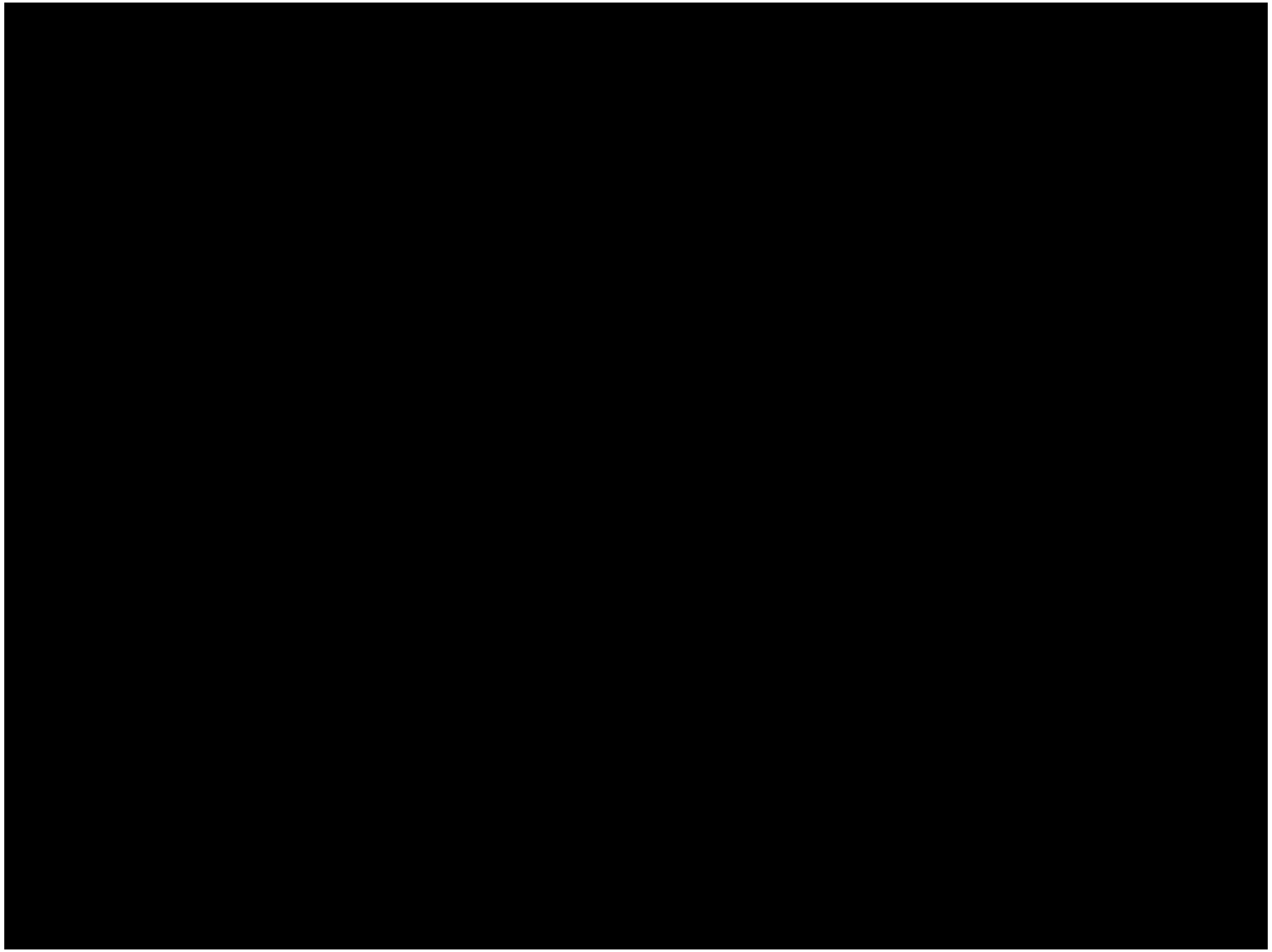


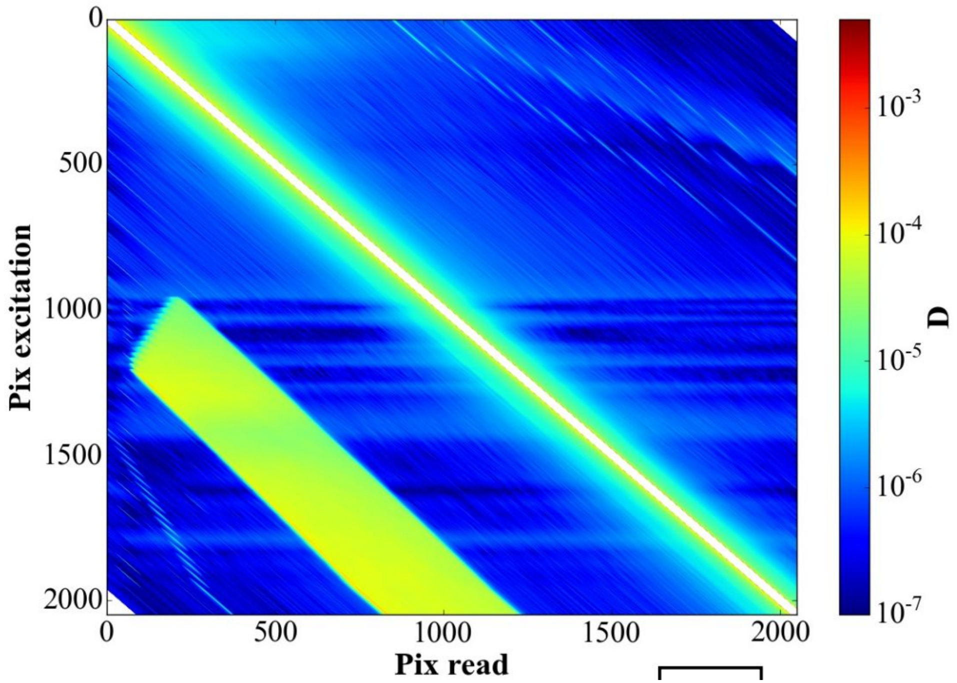
Stray light correction





Full slit function

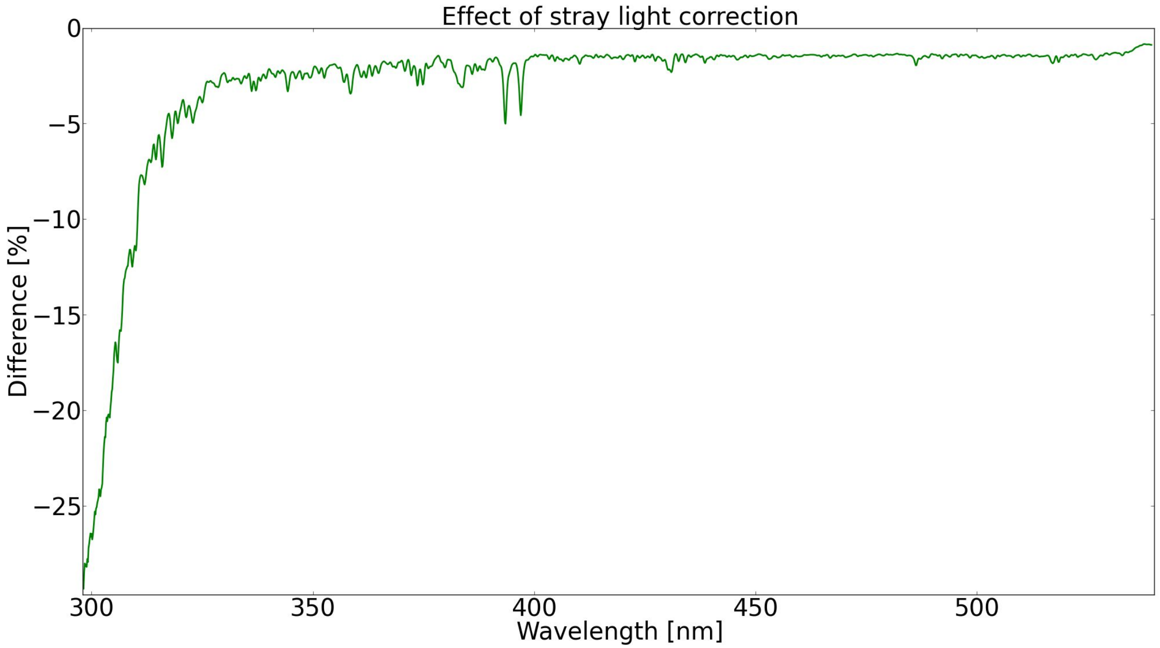


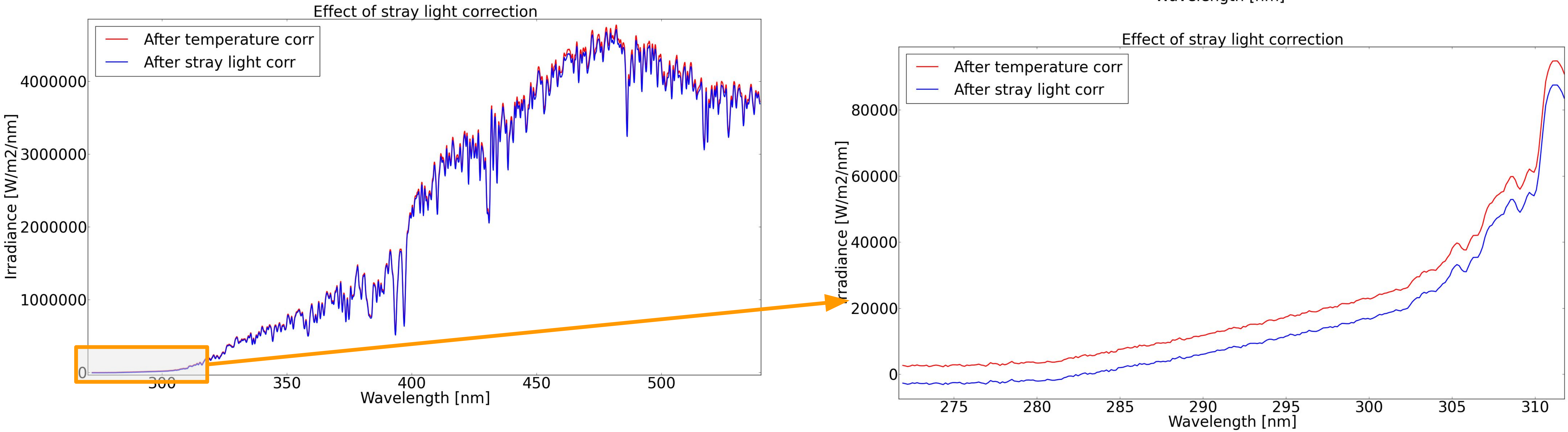


Video compiled and thankfully provided by

- Julian Gröbner and
- Natalia Kouremeti

Effect of Stray light correction





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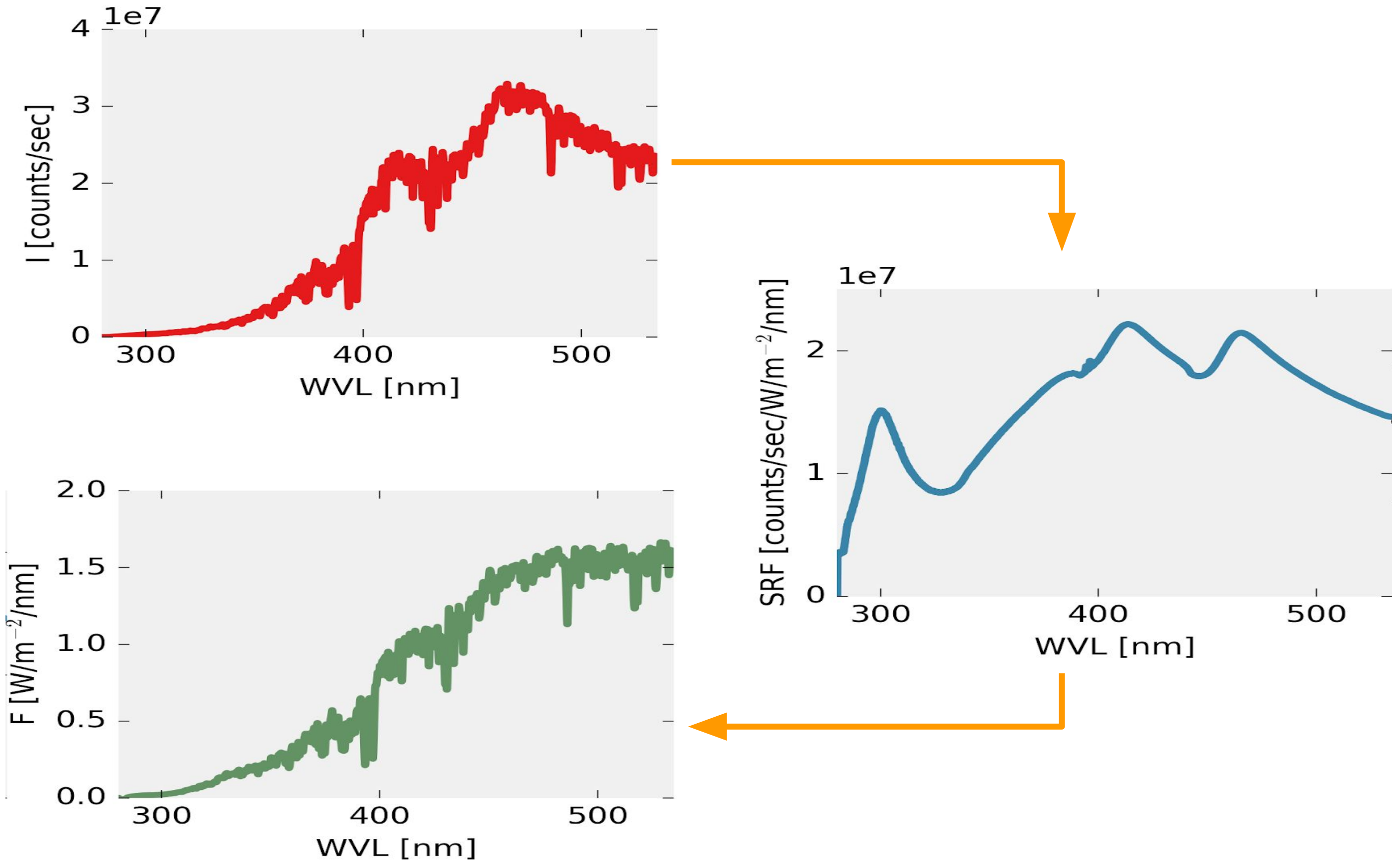
Spectral Sensitivity

"What is the effect of all optical elements on the signal at each wavelength?"

Each optical element "applies" a certain change to the signal. The instrument sensitivity is a combination of all the transmissions and is mainly a combination of

- Filter transmission
- Fiber transmission
- Grating efficiency and
- Detector efficiency



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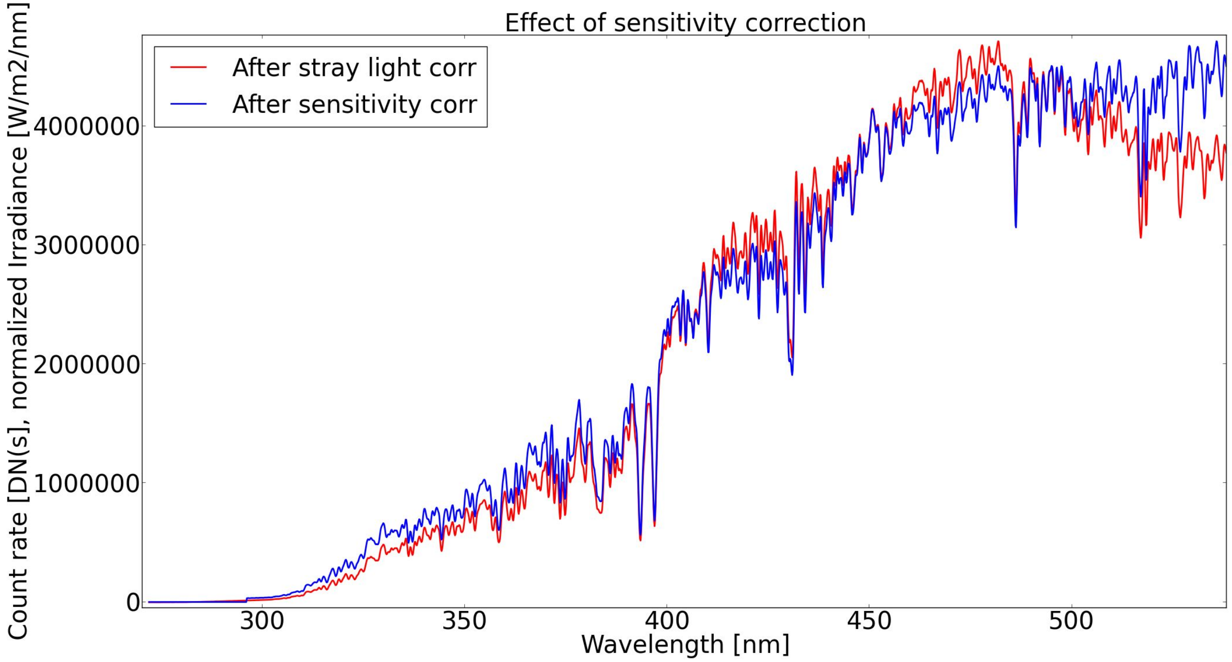
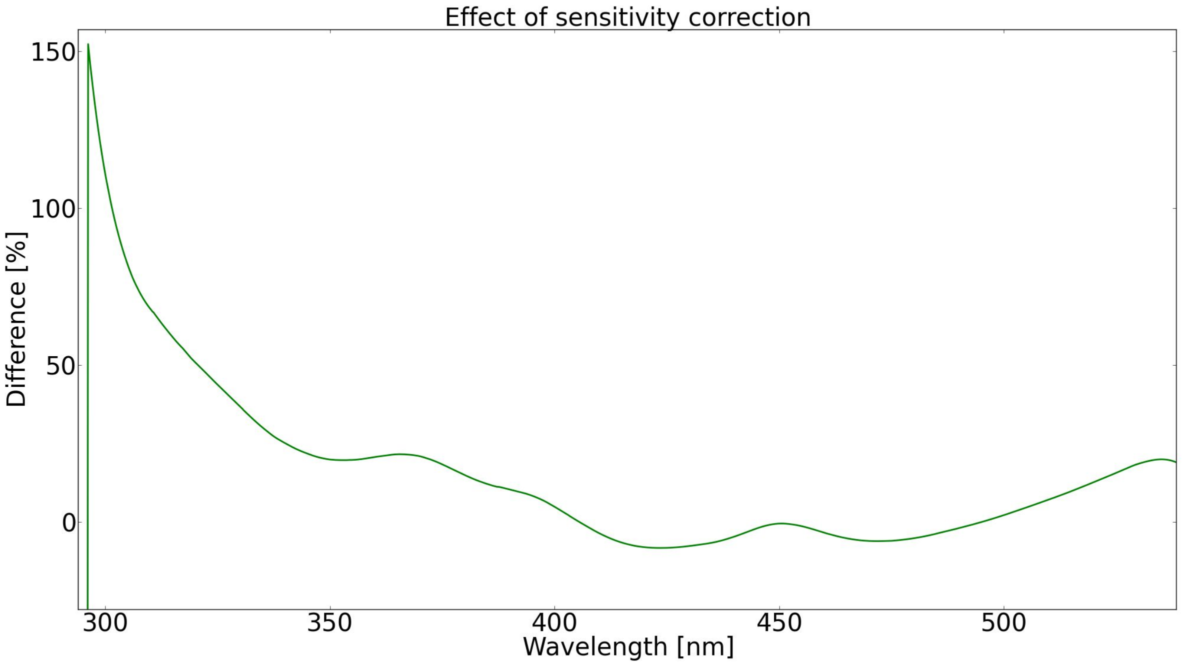
Effect of Sensitivity correction

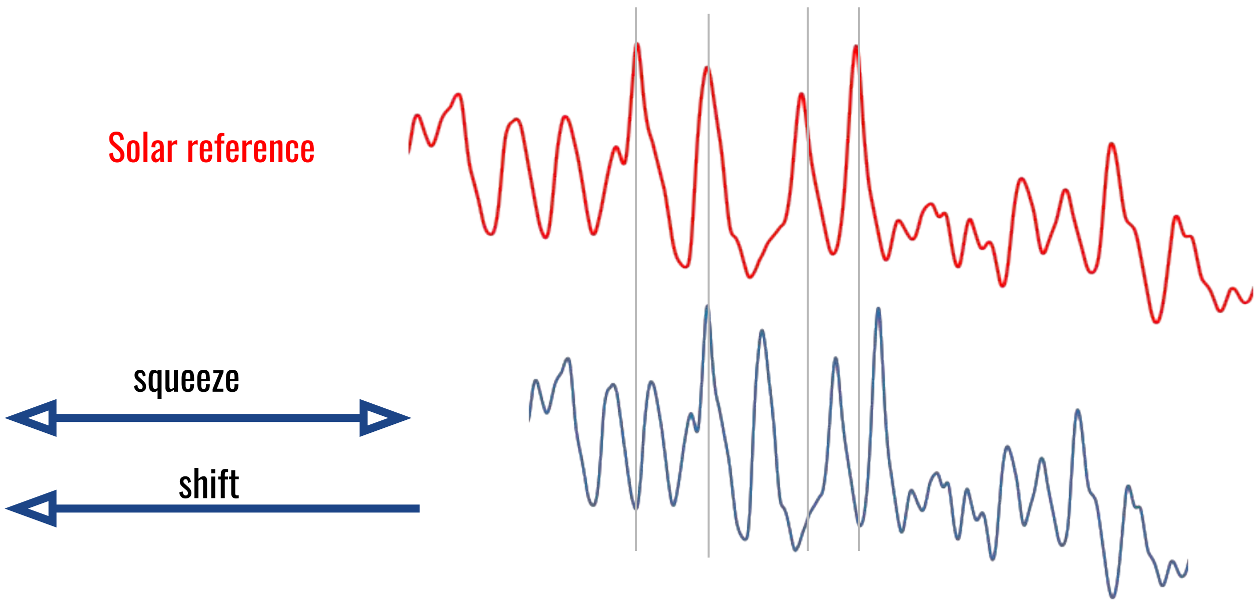




Wavelength correction

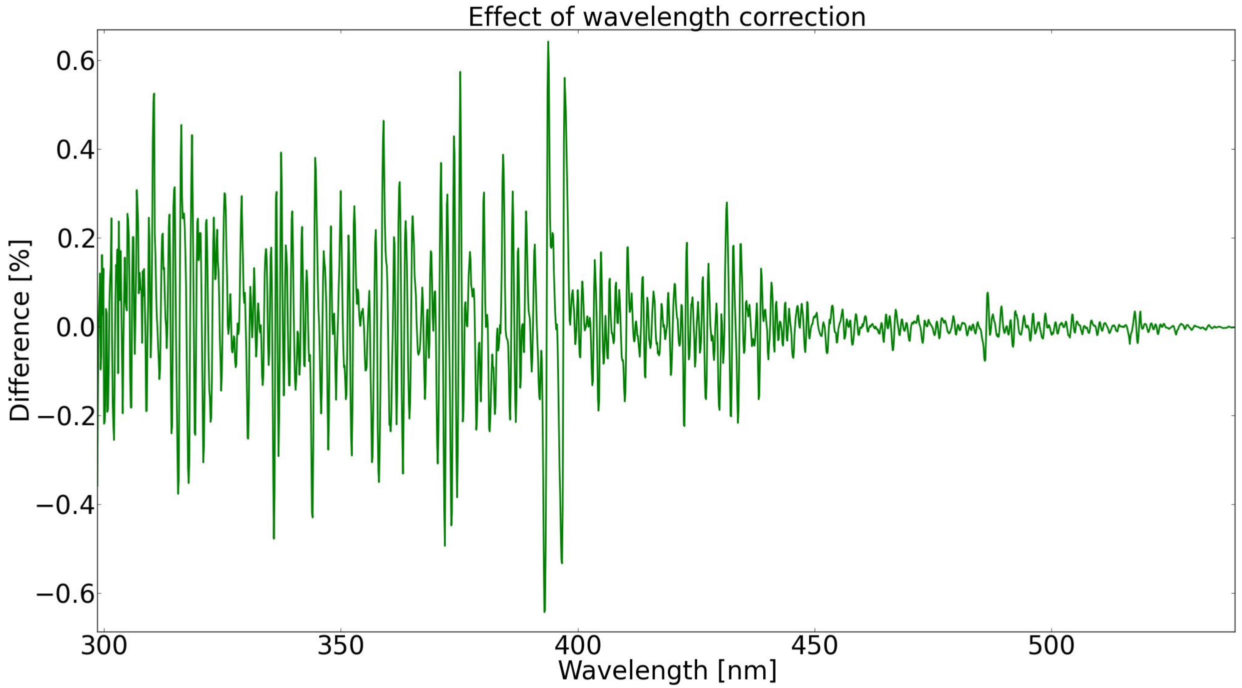
"What has the spectrum been if there was no wavelength change?"

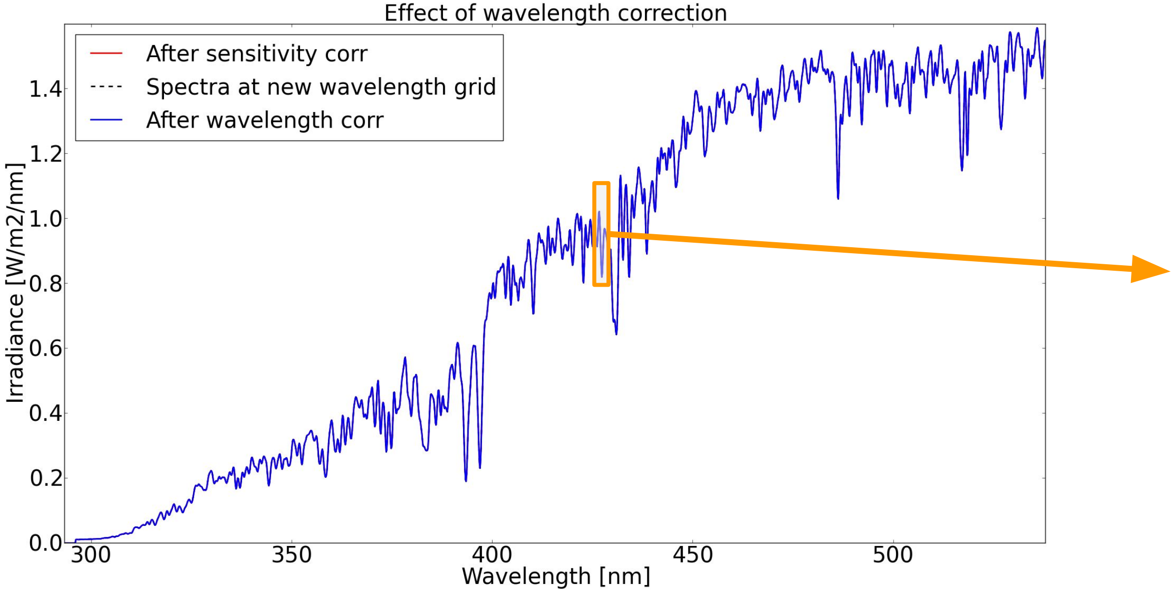
- By comparing the data to the solar Fraunhofer lines, one can determine a wavelength change of the spectrum relative to the nominal wavelength grid.
- If needed for the L1 data, one can do a "Wavelength adjustment" of the measured data in some way.
- Note that the input for spectral fitting is usually NOT adjusted for wavelength change, since this effect is taken into account in the fitting process.

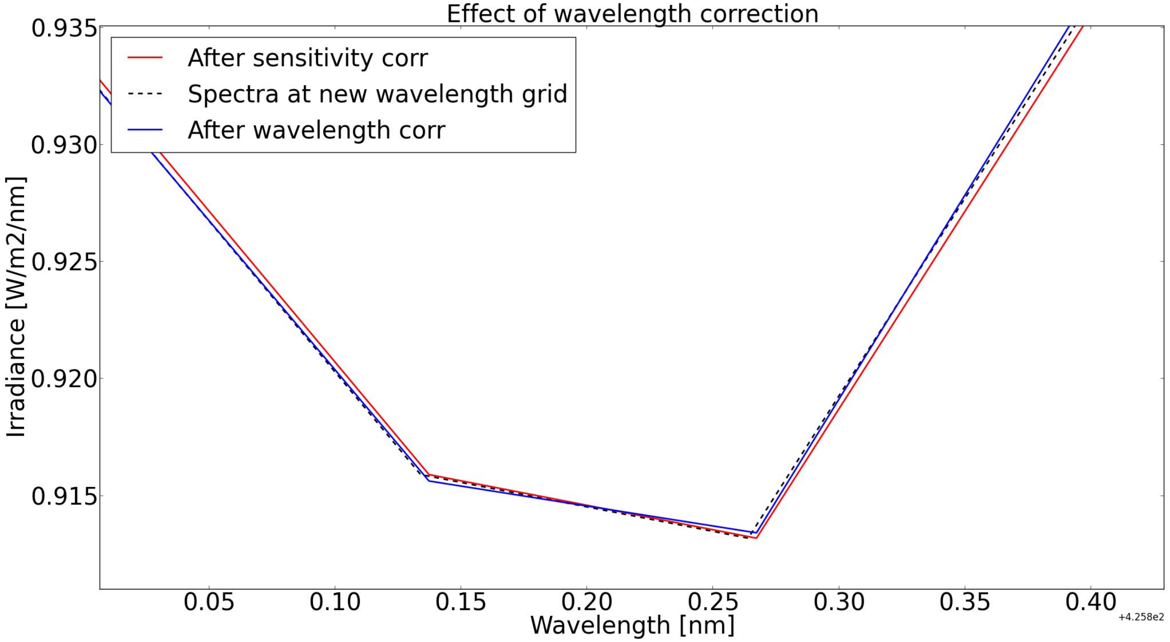


Effect of Wavelength correction

Here the wavelength shift was about 0.01nm.







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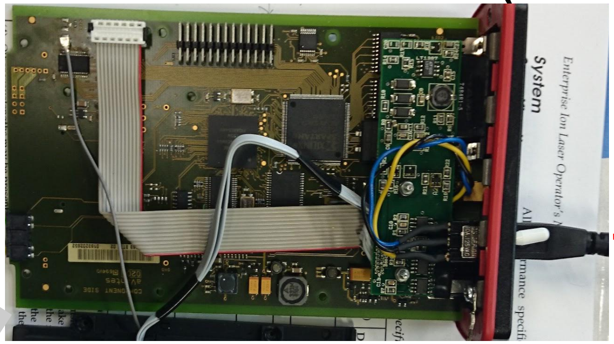

Spectrometer

After having applied all correction steps, the L1 data are the best estimation for the spectral (ir)radiances. Contact me (alexander.cede@luftblick.at) if you want more material on this subject ...

What do we get?

A digital number (DN)