Subtracting dark spectra

Technical Note

Abstract

In many cases it is advisable to subtract a dark spectrum from a measured spectrum to obtain a proper measure of your signal. In this short technical note, we explain why it is important to subtract dark spectra and when it is better not to do so.

Jord Prangsma
Application Specialist

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Subtracting dark spectra

Often it is advisable to subtract a dark spectrum from a measured spectrum. In practice this means that every measurement is made in a pair. In each pair one measurement is done with the light source on and one measurement is done with the light source off. The signal of interest is the difference between these two measurements (See Figure 1).

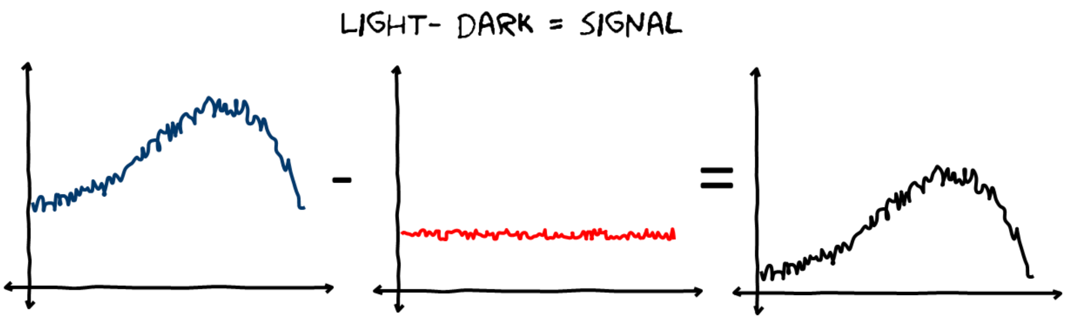

Figure 1, schematic description of dark subtraction

There are three main reasons to subtract a dark measurement:

1. It removes the baseline from the measurement.
2. It removes the dark current contribution from the measurement.
3. It can in also be used to get rid of background light.

Thus by subtracting the dark measurement you get closer to observing the real signal you are interested in.

The baseline originates from a voltage that is added to the signal to allow a correct conversion of the analog signal to a digital signal by the electronics. This baseline is thus not a real signal and can in fact often be set by the user. The baseline is not always stable in time; it can show fluctuations and drift for instance due to temperature changes.

Contrary to the real signal that originates from electrons absorbing one photon, the dark current of the detector originates from electrons that acquire energy in a thermal process. Dark current therefore rises if the temperature rises (See also our Technical Note on cooled detectors). The dark current contribution is accumulative; it rises linearly with integration time. To remove the dark current contribution it is thus important to use the same integration time for dark and light measurements and also it is important to have the temperature of the detector the same in both measurements.

Background light is also removed when using dark subtraction. To have that work properly the background has to be the same in dark and light measurement. Obviously for the best signal to noise ratio it is always better to have no background light.

A suitable dark measurement is always measured at the same conditions as the real measurement. It therefore should e.g. have the same integration time and detector temperature. Often, the closer in time the two spectra are taken the better reference the dark measurement forms. If there are several minutes in between two spectra for instance, the detector temperature can already have changed, changing the dark current. Also for some electronics the baseline can be subject to substantial drift over time see for instance Figure 2 that illustrates the drift of the average dark signal just after startup of the detector.

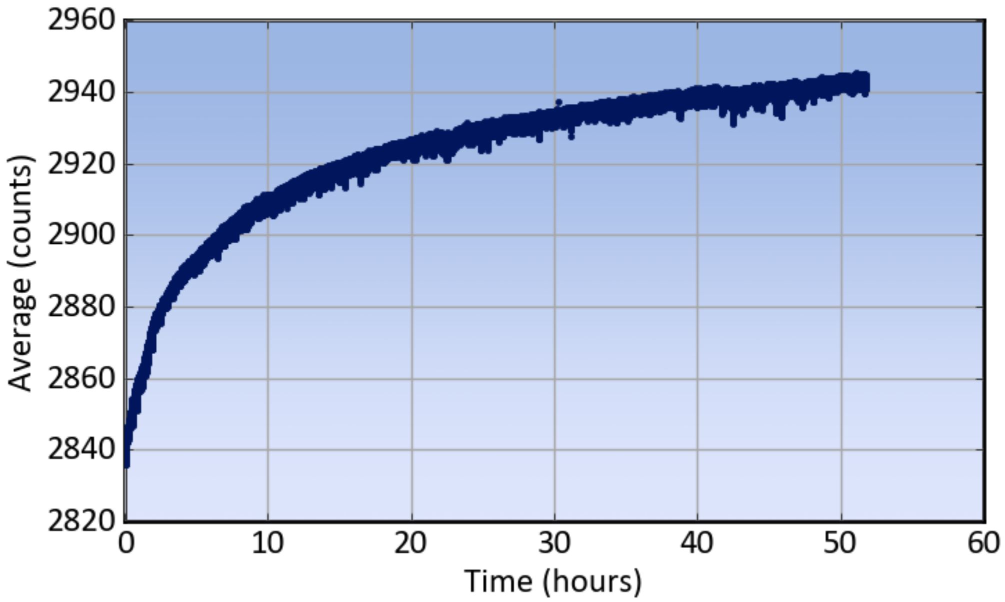

Figure 2, an example of the baseline drift over time for a linear array detector [1]

When not to subtract a dark spectrum

Subtracting a dark spectrum adds noise because both the measurement and the dark spectrum have an independent noise contribution. If the change in dark current and baseline over time are very low it can thus be advantageous not to subtract a dark measurement. As general rule subtracting dark spectra gives improvement if the baseline drift b_{drift} is larger than the additional noise due to subtracting:

$$b_{drift} > (\sqrt{2} - 1)\sqrt{n_{dark\ current}^2 + n_{read}^2 + n_{baseline}^2}$$

Where the baselined drift can be measured by subtracting the average of subsequent dark spectra, and $n_{dark\ current}$, n_{read} and $n_{baseline}$ are the noise contributions to dark measurements and can be obtained by measuring the noise in of several subsequent fast measurements (fast enough to exclude effects of drift). There are of course also practical circumstances in which it might be impossible to block the light source and take a dark measurement.

References

[1] This particular measurement was done with a Hamamatsu S10420 detector with VERSAPIC USB controller electronics.