

Calculation of the Instrumental Line Shape (ILS) in PROFFAST

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ILS in PROFFAST

Background:

- Any spectrally resolving technique has limited spectral resolution.
- The measured spectrum is interpreted as a “smeared” copy of the irradiated / monochromatic spectral scene.
- Quantitatively, the measured spectrum is generated by convolving the irradiated spectrum with the ILS.

ILS in PROFFAST

Background:

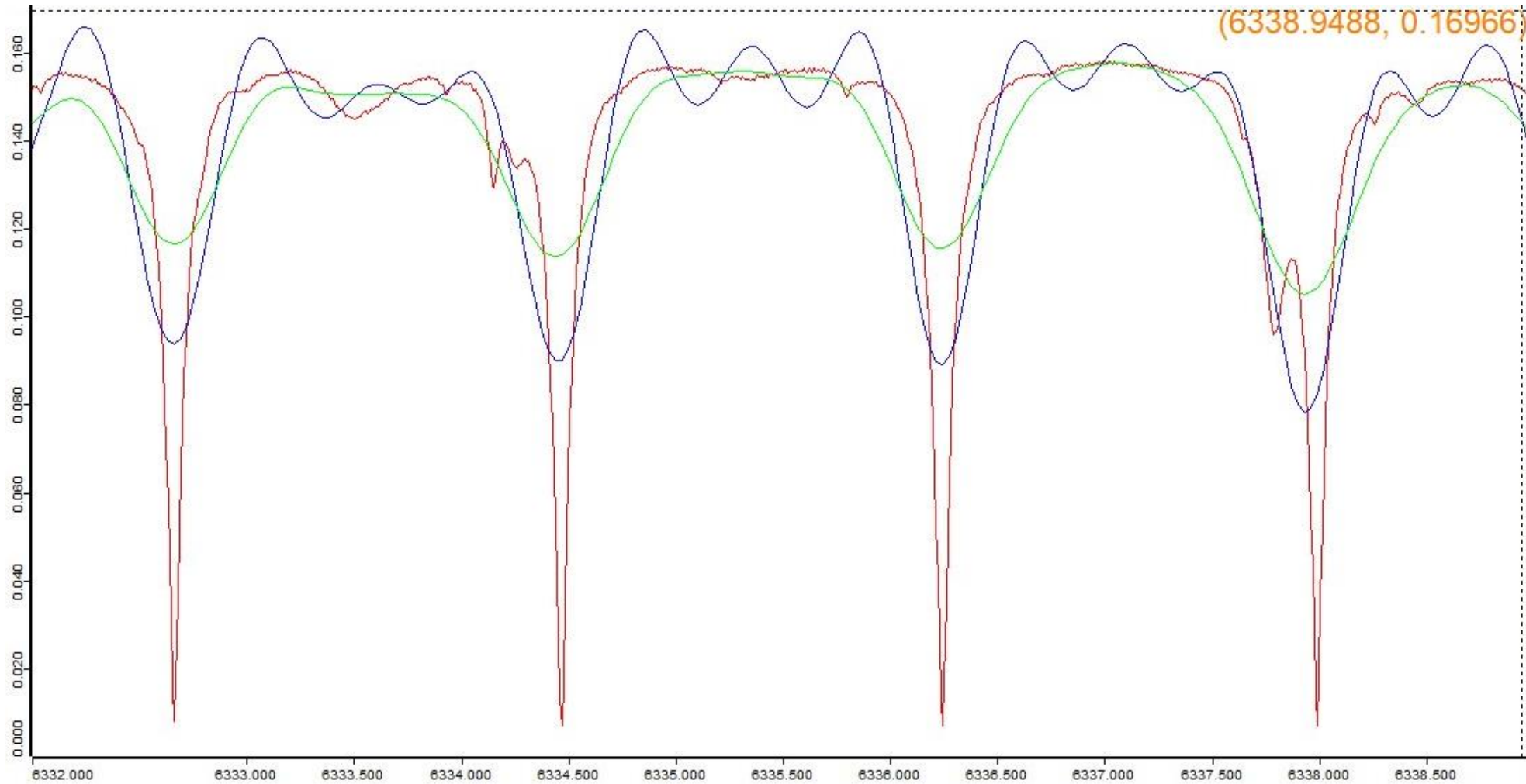
- For an FTS, the claim $S_{meas} = S_{irr} \otimes ILS$ is well justified (interferogram truncation + FT convolution theorem).
- The “raw” ILS of an FTS is not too pleasant (boxcar $\rightarrow$ sinc).
- We can numerically modify the ILS by multiplication of the IFG with a smooth weighting function (“numerical apodisation”).
- Because the IFG is zero beyond max path difference (MPD), a spectrum sampled with grid spacing $\Delta\nu = 1/(2 \cdot MPD)$ preserves all spectral detail available in the measurement.

ILS in PROFFAST

Background:

- A real-world FTS shows self-apodisation, representable as convolution of the spectrum with a boxcar ($\Delta\nu \approx 0.5 \cdot \nu \cdot \alpha^2$)
 - This result assumes an evenly illuminated circular FOV (α is the max. inclination of a ray supported by the interferometer).
 - Note that the smearing is $\sim\nu$, so the ILS kernel of the FTS becomes wavenumber-dependent.
 - Note that for an irradiated monochromatic line at ν_0 , the boxcar-convolved line in the measured spectrum spans the interval $[\nu_0 - \Delta\nu, \nu_0]$, so the spectral calibration is affected.

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EM27/SUN ILS:

- Because the EM27/SUN has low resolution, we use a NBM numerical apodization to avoid excessive sidelobes.
- The self-apo of the EM27/SUN is pretty small: $\Delta\nu [8000 \text{ cm}^{-1}] \approx 0.023 \text{ cm}^{-1}$ (compare with required sampling $\Delta\nu \approx 0.28 \text{ cm}^{-1}$).
- Each individual EM27/SUN has little imperfections, generating deviations from the ideal ILS. This is taken into account by a 2-parameter model for the modulation efficiency.
 - This parameterisation is approximative.
 - The overall bias in the linear MEA ($\text{MEA} \approx 0.983$) is believed to be an artefact of the analysis of the open path measurement.
 - The ν -dependence of the correction is unknown.

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PROFFAST implementation:

- The ILS operations are performed in the spectral domain.
- The ILS including NBM apo and the instrument-specific ME correction is tabulated in INVERS for each MW.
- The pre-calculated tabulated x-sections and solar spectrum are sampled with grid spacing $\sim \nu$: $\Delta\nu = 0.002\text{cm}^{-1} \cdot (\nu/4000\text{cm}^{-1})$.
- The self-apo boxcar has a constant width in grid spacing units of this non-equidistant spectral grid.
- A boxcar is numerically awful, so a $\cos^2(x)$ smearing is used.
- By adjusting the width to a whole multiple of the monochromatic grid spacing, the convolution can be performed on a coarser grid.

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PROFFAST implementation:

- The radius of the $\cos^2(x)$ kernel amounts to ≈ 4.7 grid steps.
- By adjusting the width to a whole multiple of the monochromatic grid spacing (5), the convolution can be performed on the coarser grid.

Critics:

- The boxcar becomes a $\cos^2(x)$ shape
- The adjustment to a whole multiple generates a rounding error
- The convolution between an equidistant and non-equidistant grid is complex.

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Critics:

- The boxcar becomes a $\cos^2(x)$ shape.
Acceptable approximation due to interferogram truncation.
- The adjustment to a whole multiple generates a rounding error.
The residual broadening could be included in the ILS kernel.
- The convolution between an equidistant and non-equidistant grid is complex.
Yes (an additional equidistant x-section grid might be introduced ...).