IASING science data processing overview

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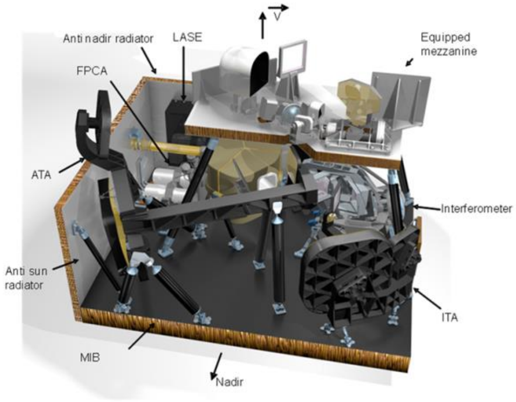
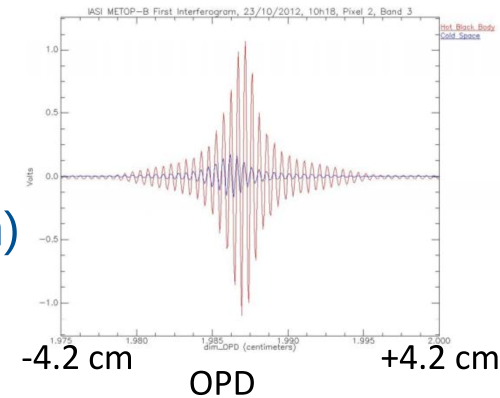
Introduction



- IASI-NG instrument measures interferogram (not spectrum !)

- Interferogram = Fourier Transform (Spectrum)

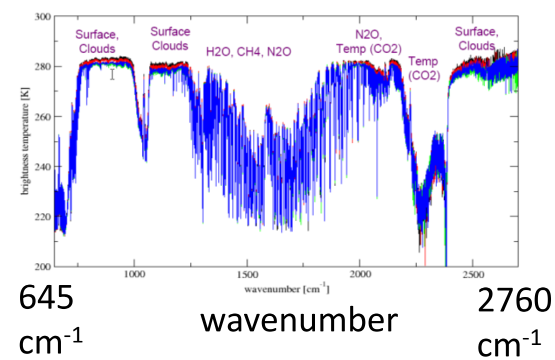
Note : all these data are sampled data, not continuous !



- Users work with L1C spectrum

(+ additional information like flags, cloud fraction,….)

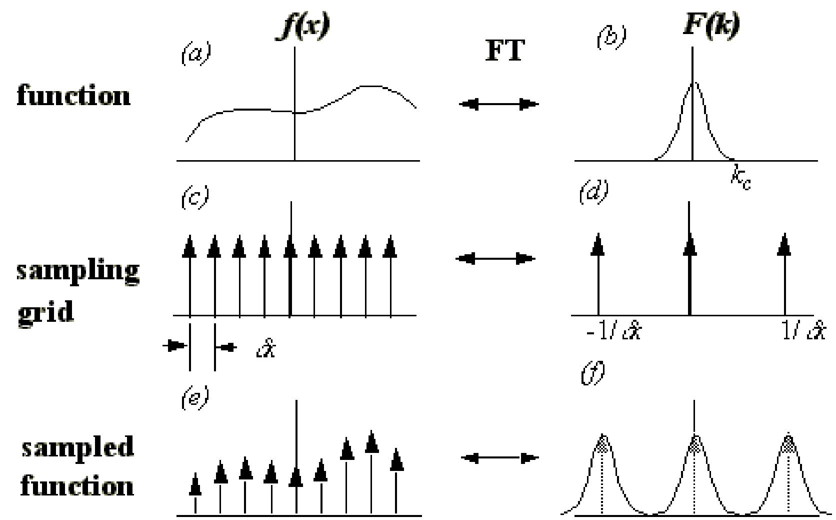
- L1C spectrum ("user friendly approach")
  - fully calibrated (spectral and radiometry)
  - a unique ISRF for all channels of all spectra
  - a sounding is a geo-localized point
  - performance requirement : Radiometry = IASI / 2, Spectral = IASI/2, geometry = IASI



On-board/ground sharing is driven by TM allocated (6 Mb/s in average, excluding a sub-set of full measured interferogram verification data.)

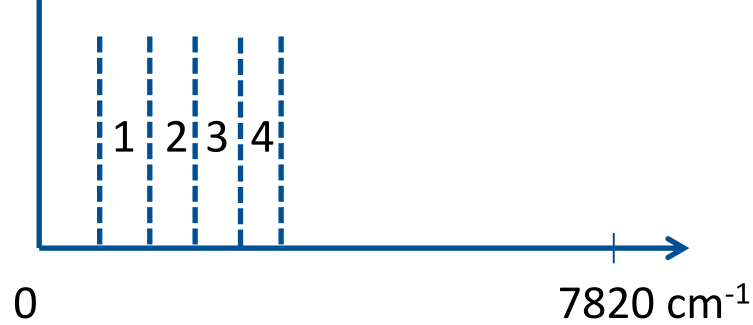
On-board processing objectives

- As long as interferogram acquisition and sampling is done properly (Shannon criteria respected and anti-aliasing filter), all the meaningful information is contained in $[0, \nu_s/2]$, where ν_s is the wavenumber associated to the sampling frequency ($\nu_s/2 \sim 7820\ cm^{-1} = 1.2788\ \mu m$)



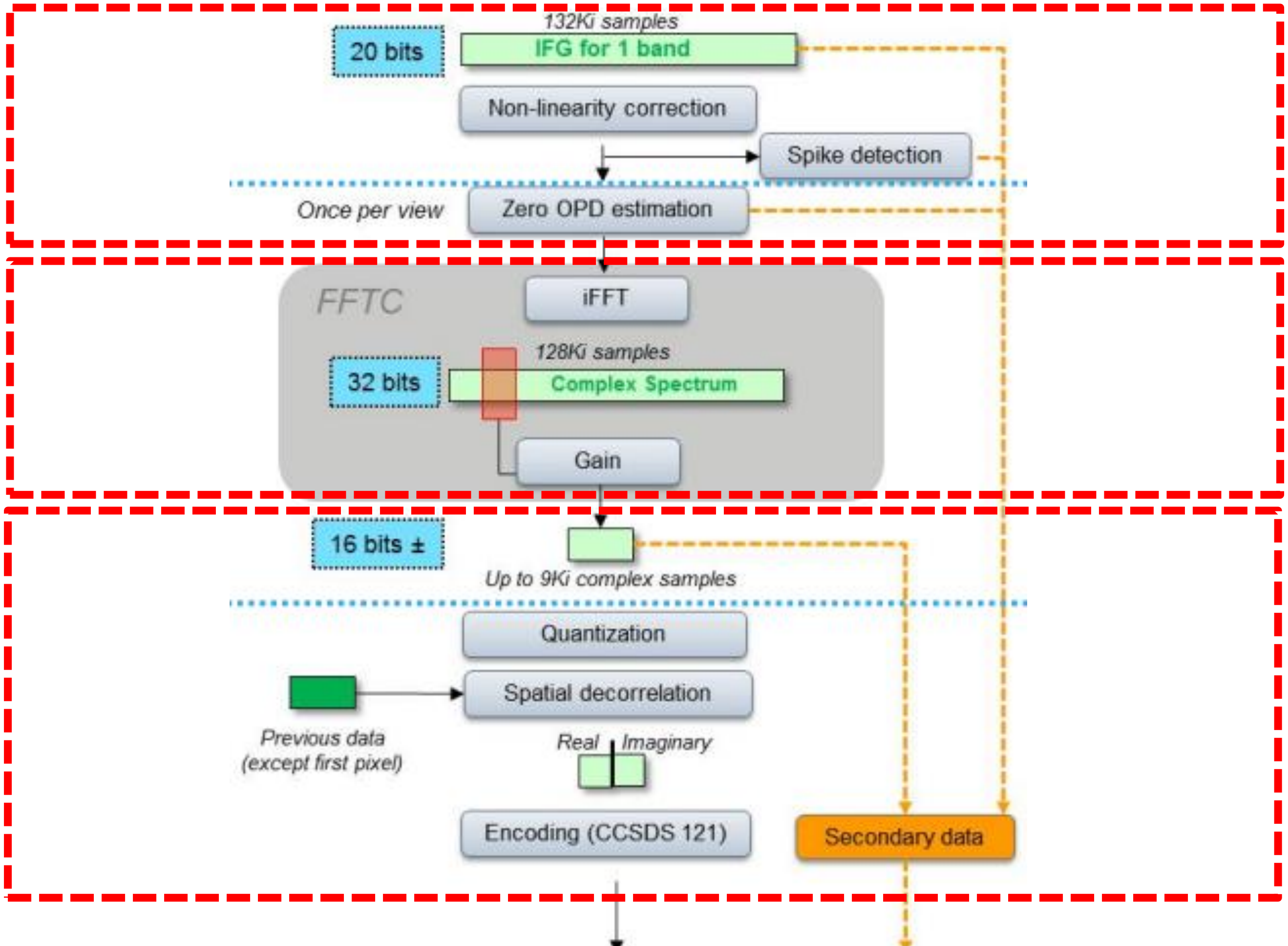
- The logic of the design becomes then more obvious
  - ✦ Preserve the information content by keeping the Fourier transform reversible in the useful spectral band and with respect to instrument artifacts we correct on ground
  - ✦ Be compliant with computation time and telemetry data rate.
  - ✦ The data flow is compressed from 200 Mb/s to 6 Mb/s !

Spectral bands	Lower limits (cm-1)	Upper limits (cm-1)
1	645	1180
2	1180	1940
3	1940	2300
4	2300	2760



On-board processing of science data

16 (pixels) x 4 (bands) sampled interferograms



16 (pixels) x 4 (bands) compressed complex spectra
(real + imaginary parts)

<u>Preprocessing</u>
(to avoid spectral aliasing introduced by discreet FT and loss of information)

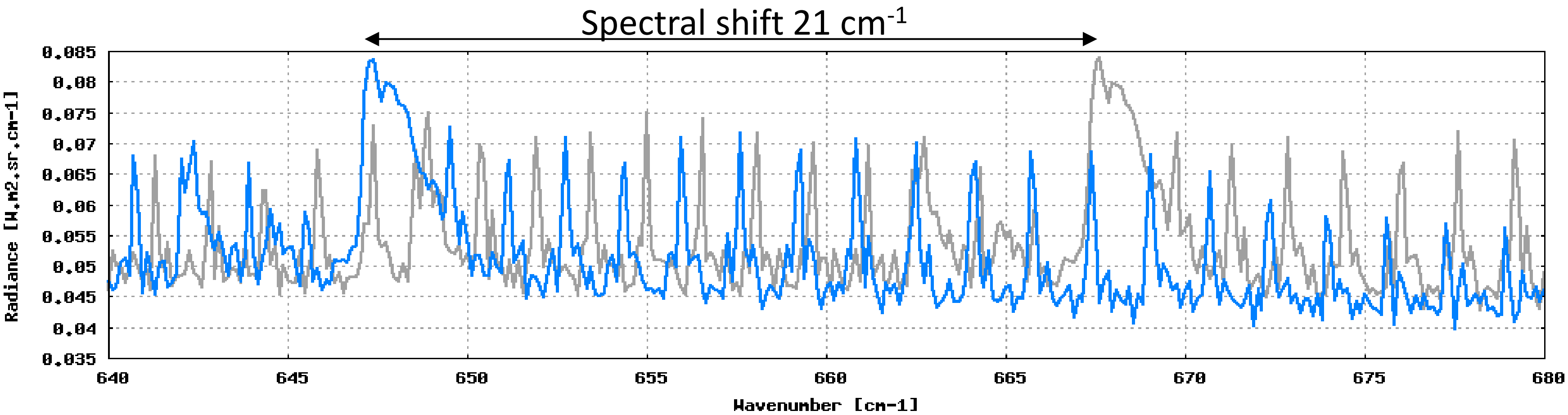
<u>1st level of compression</u>
1) FFT of interferogram
2) Frequency truncation to useful band
(+ interbands + ghost + spikes + monitoring frequencies)
Data rate / 20-25

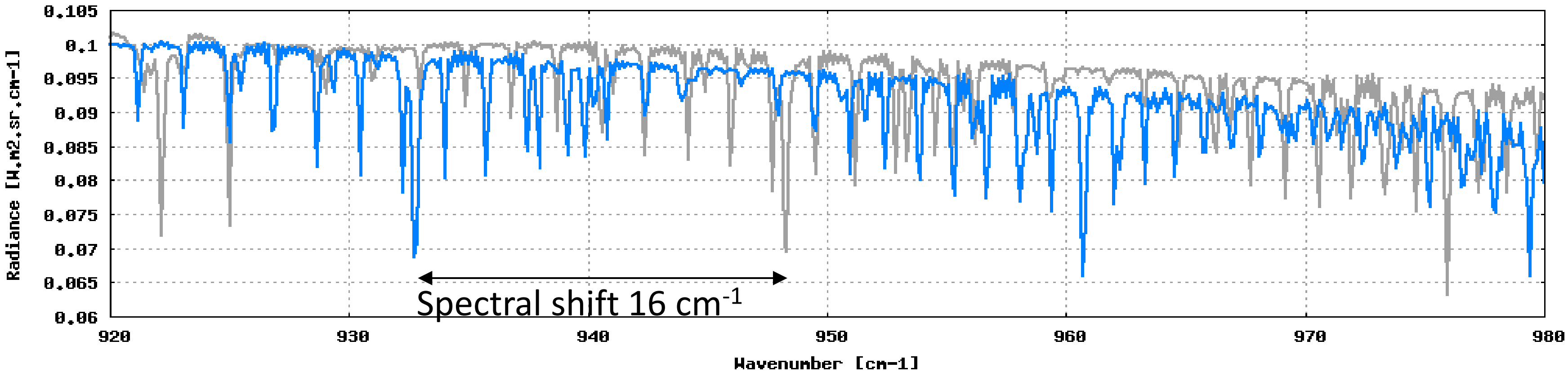
<u>2nd level of compression</u>
“conventional compression”
Quasi-loss less (quantization 0.5% noise increase)
Data rate / 2-3

Space segment output

Grey: Atmospheric input spectrum (Opd_{Max} = 4.2 cm, SRF = Cardinal sine)

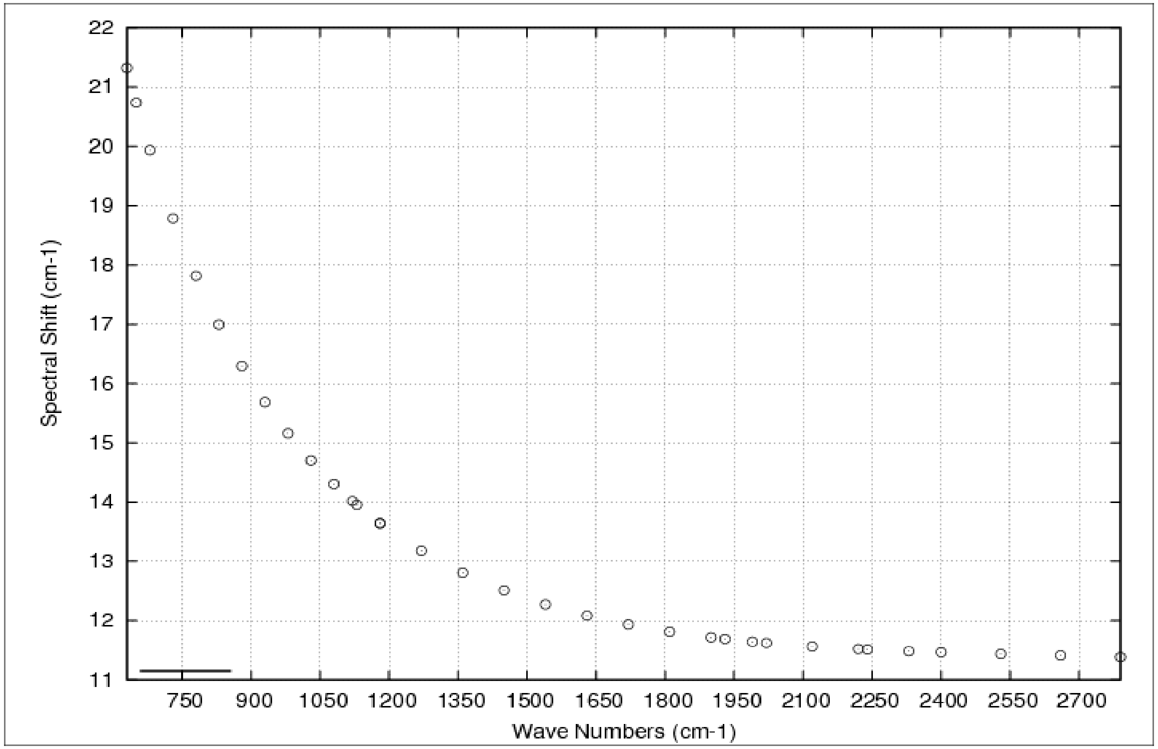
Blue: L0 spectrum space segment output (real part, Opd_{Max} = 4.2 cm, SRF = Nominal instrument, Background at 80 K)





Instrument chromatic spectral shift

- The field compensation within the interferometer is compulsory in order to achieve NedT and spectral resolution requirements
- This field compensation introduces a large chromatic effect (up to 21 cm^{-1} @645cm^{-1})
- This is a new feature with respect to IASI first generation
- It is corrected by the L1 processing



On-Ground Processing: objectives

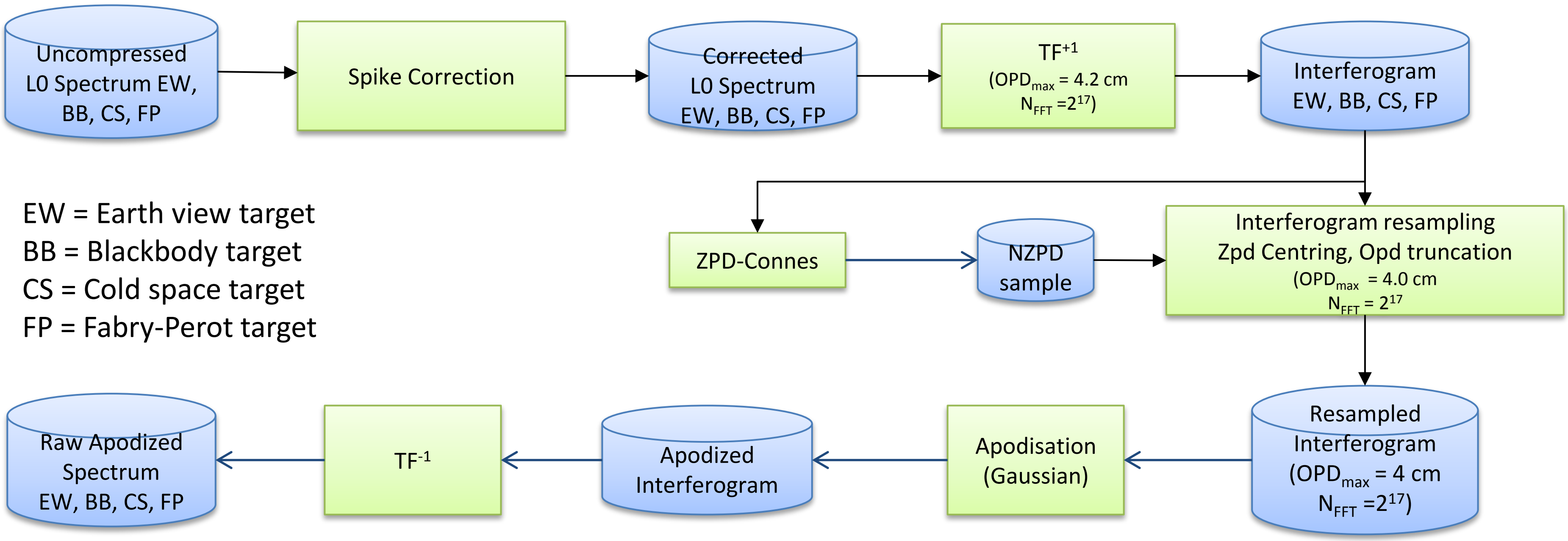
- Objectives
  - ✦ Providing atmospheric spectra fully calibrated (spectral and radiometry) and geo-localized
  - ✦ Performing ISRF removal (de-convolution). The variable ISRF with respect to channel, pixel and time is replaced by a single and standard spectral response function.
  - ✦ Providing additional geophysical characteristics of the scene (at pixel and sub-pixel scale) in order to help with the exploitation of IASI-NG spectra.
  - ✦ Making the processing in near real time (more than 1 million spectra per day !)

- The main design drivers are
  - ✦ ISRF Estimation Model reliability and accuracy
  - ✦ Radiometric, spectral and geo-location performances
  - ✦ Computing time

On-Ground Processing: pre-processing (overview)

Pre-processing is mainly done in the interferogram space

Operations: Spike Correction, Direct Fourier Transform, Interferogram Resampling (centered on ZPD), Interferogram Apodisation and Inverse Fourier Transform

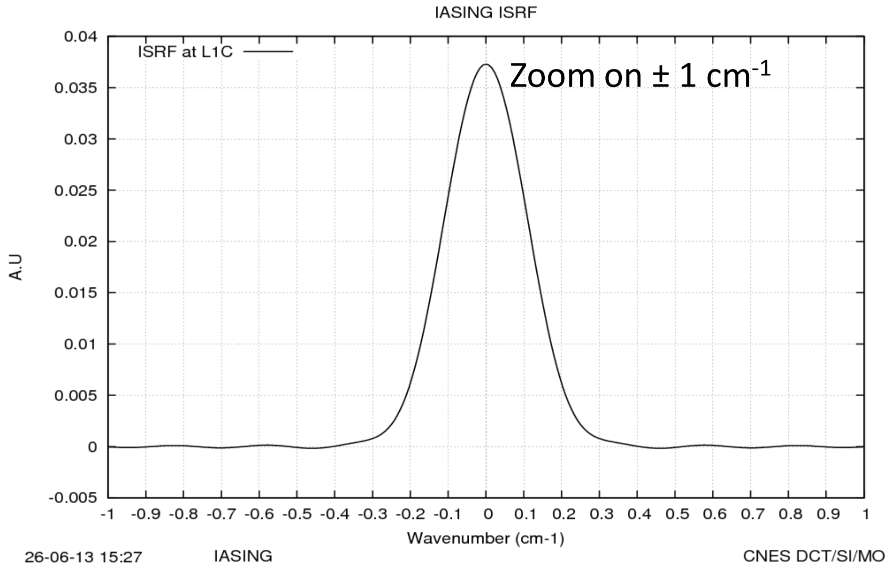


EW = Earth view target
BB = Blackbody target
CS = Cold space target
FP = Fabry-Perot target

L0 and Apodized Raw spectra: reduced to the useful spectral band and complex, intermediate interferograms: real

On-Ground Processing: pre-processing (apodisation)

- Numerical apodisation $I_{ap}(x) = I(x) A_p(x)$
- Truncated Gaussian: FWHM 0.25 cm^{-1} & sampling 0.125 cm^{-1} (OPD$_{max}$=4 cm)

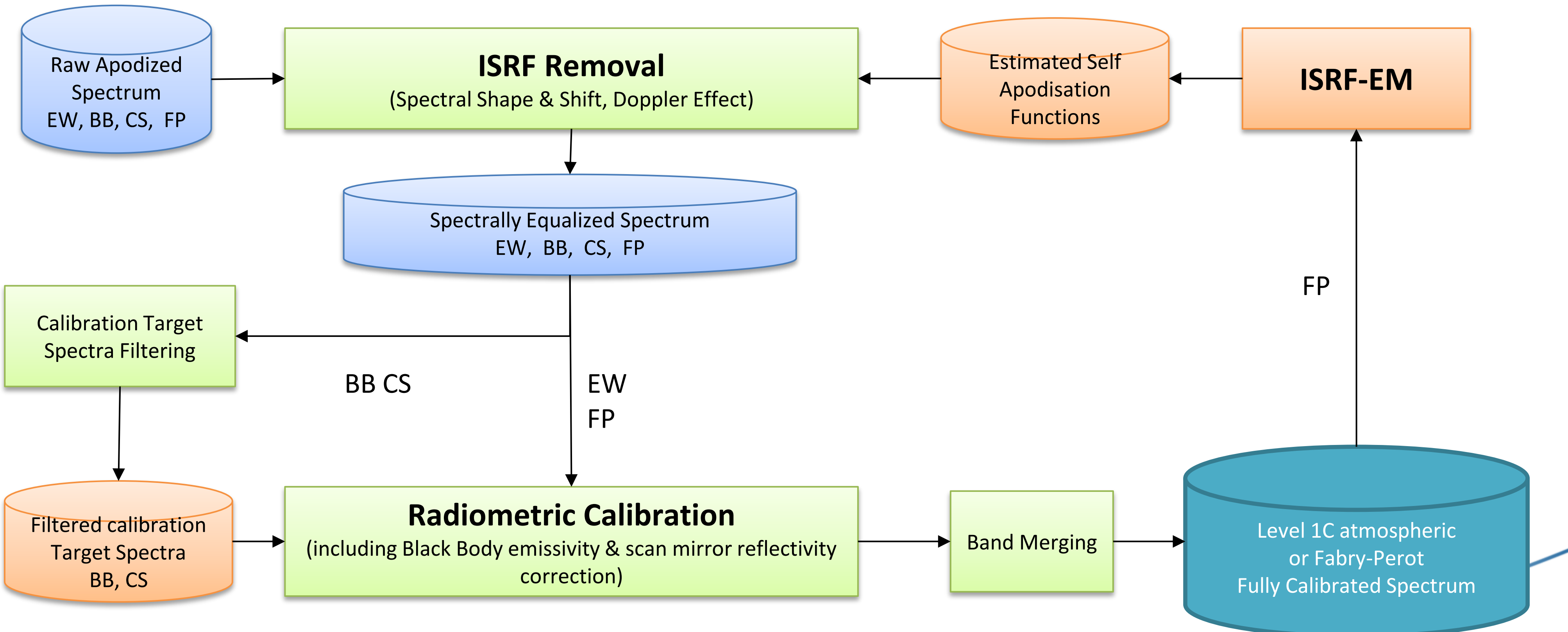


- Fully reversible
- Can be changed easily (note that improving spectral resolution increases the noise)
- Making the apodisation before or after the ISRF removal has no impact on spectral performances as long as the apodisation function is symmetric
- Making apodisation and spectral calibration before the radiometric calibration is compulsory to achieve performance

On-ground processing: spectral and radiometric calibration

Main-processing is done in the spectrum space

- Self Apodisation Functions: complex
- Equalized Spectra: complex
- Level 1C Spectra:
  - Real Part disseminated to the users
  - Imaginary Part delivered to the Technical Expertise Center (TBC)



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ISRF removal

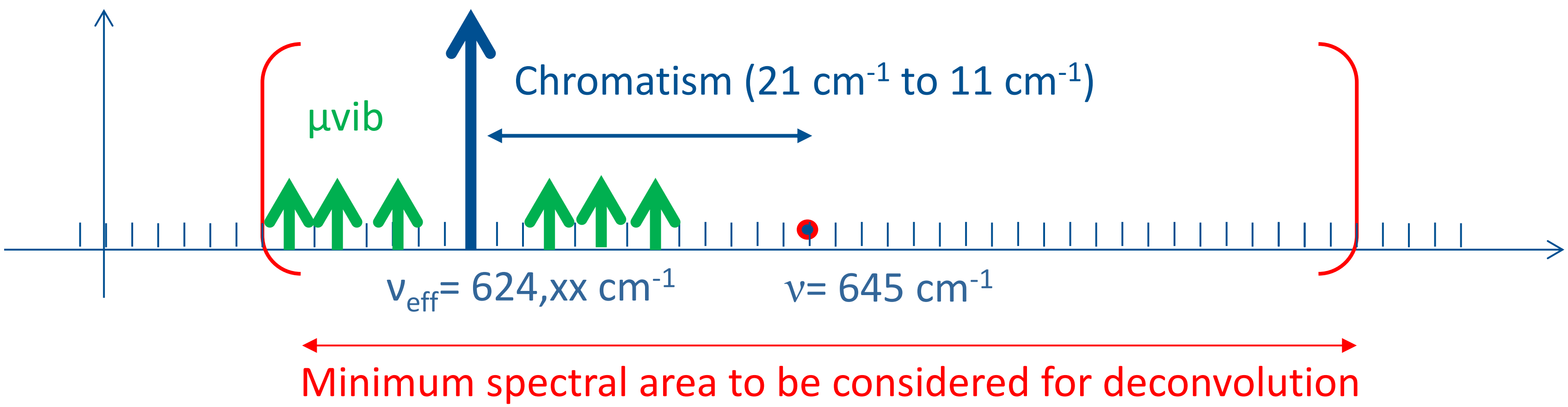
- Spectral calibration objectives

✦ Correcting from the ISRF centroid shift and shape for each wavenumber

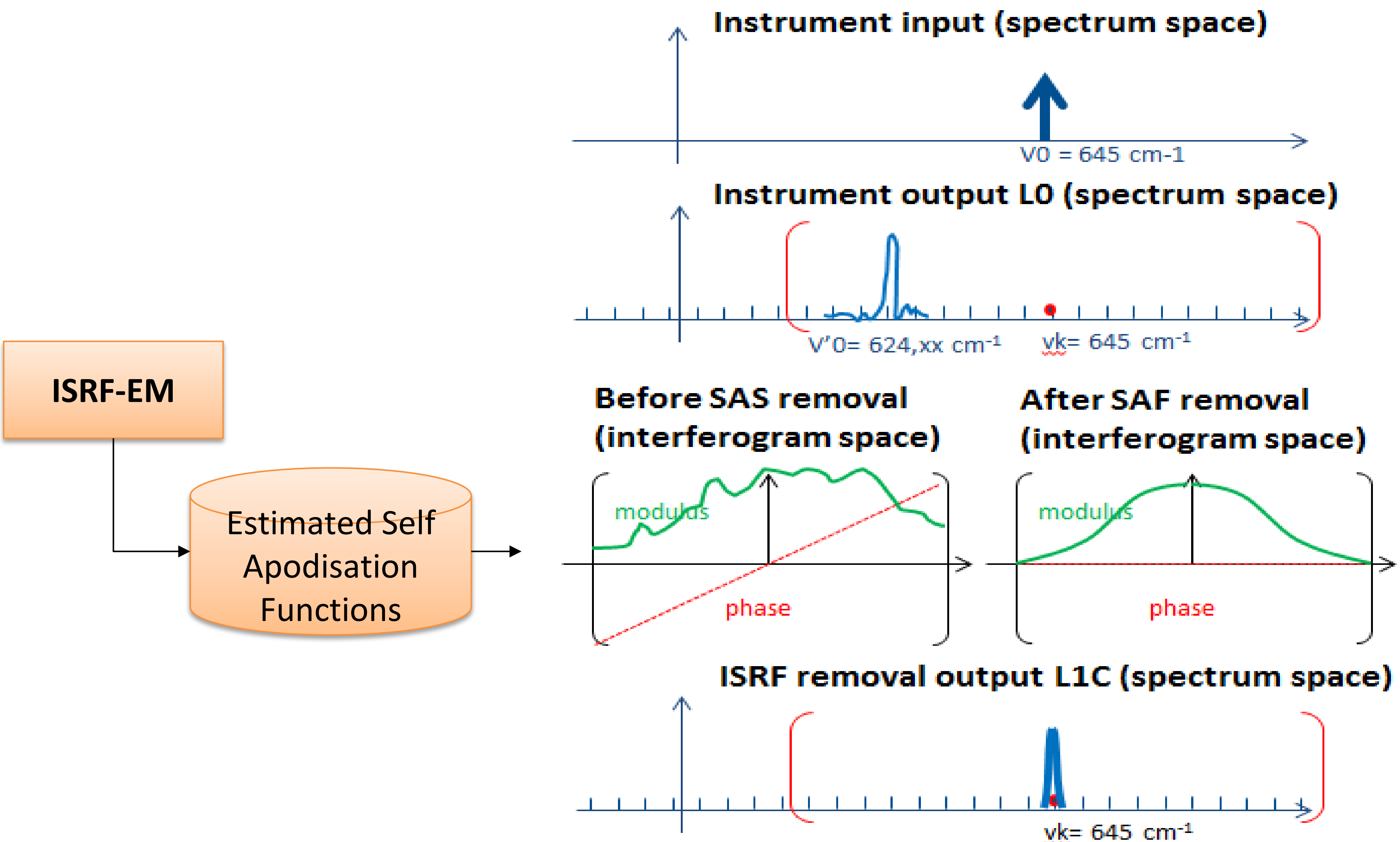
- Spectral calibration principle

✦ Monochromatic local deconvolution of the ISRF. As convolution (resp. deconvolution) is a product (resp. division) in the interferogram space, it makes mathematical operations easiest and reversible.

✦ “short FFT” of typically ±512 or 1024 samples save a huge amount of computing time

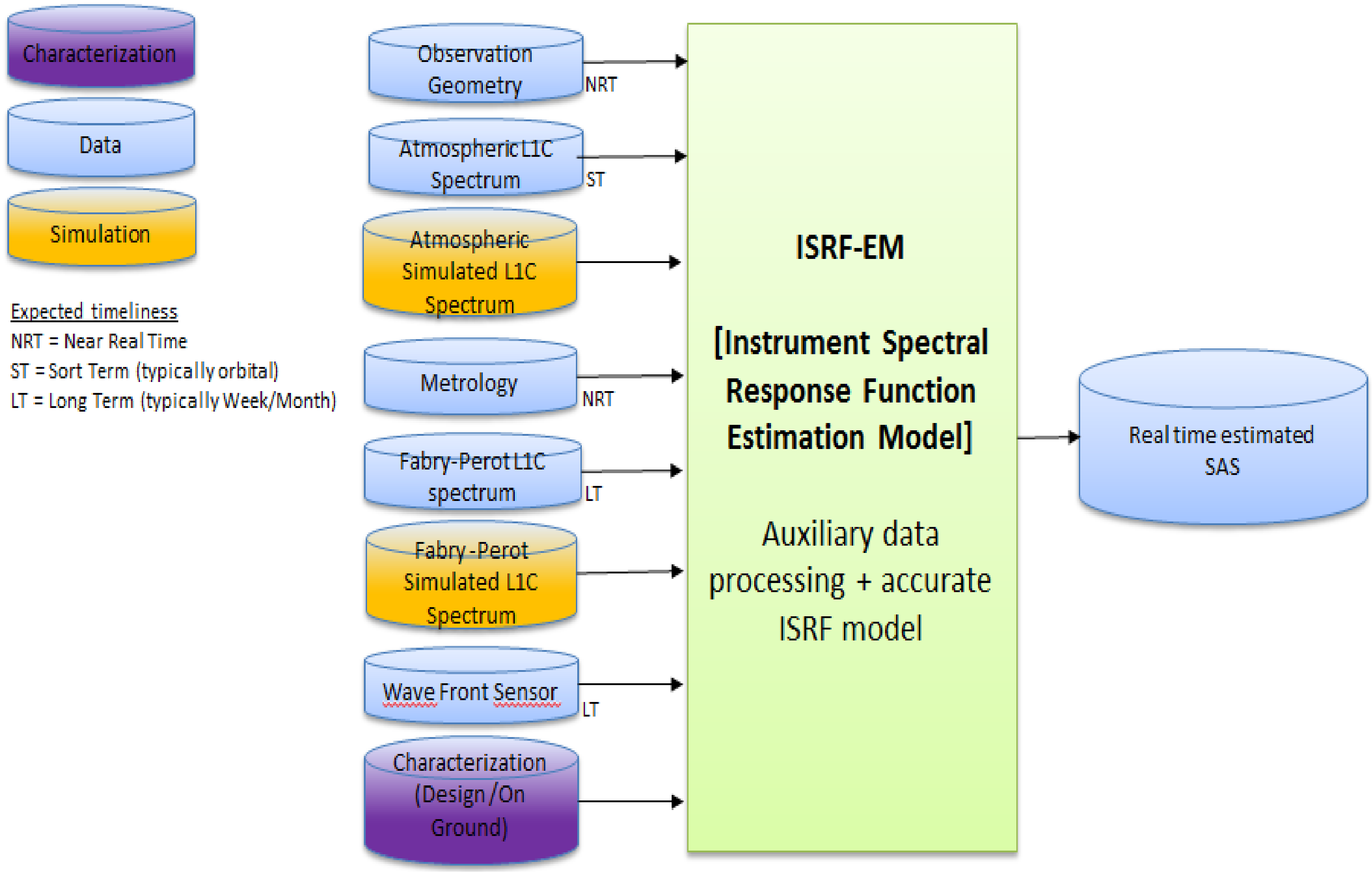


ISRF removal



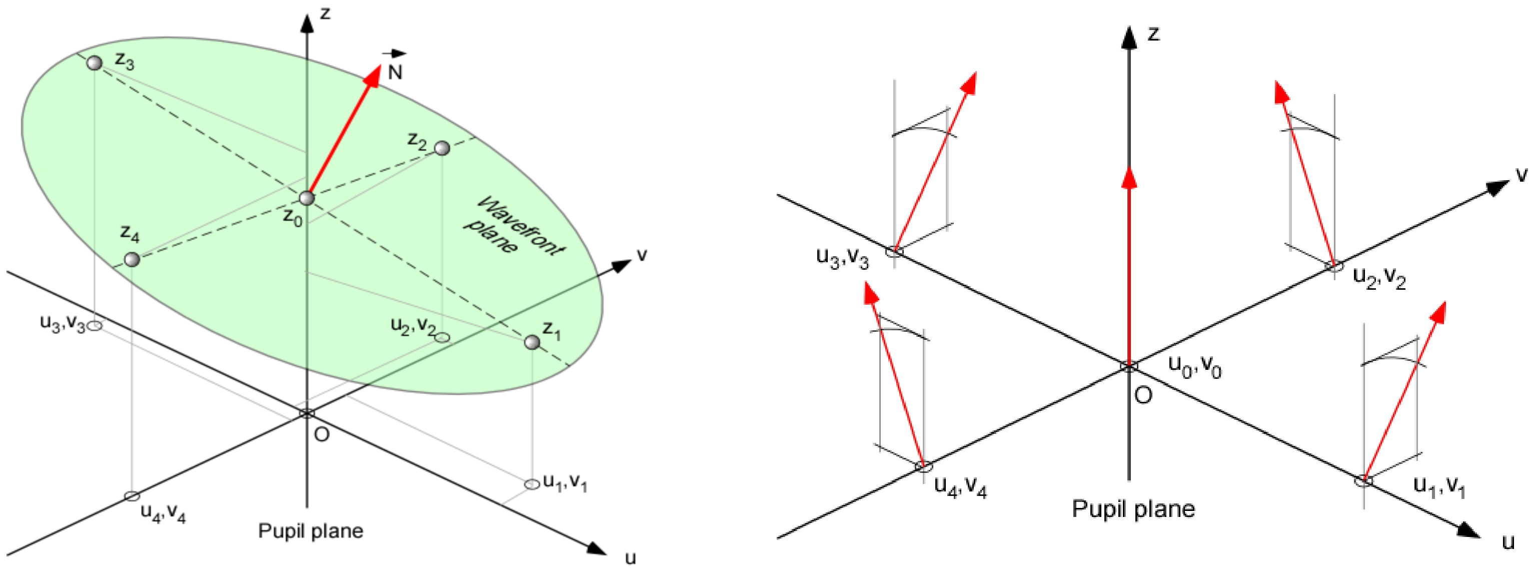
ISRF-EM objectives

The quality of the ISRF removal relies on an accurate ISRF model + on-ground and in-flight characterisations of input parameters of this model



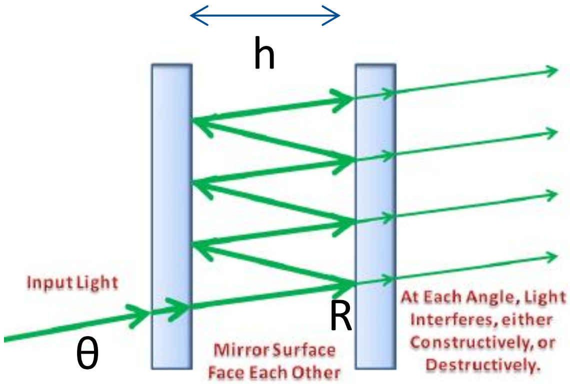
ISRF-EM Parameter Estimation (Metrology)

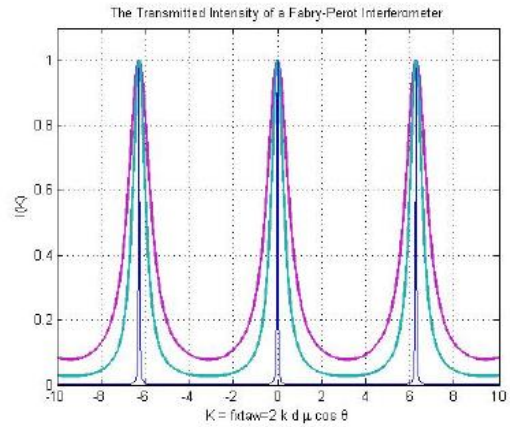
The interferometer baseline design includes 5 laser beams



- The on-axis beam z_0 provides the nominal OPD including µvibration effects
- The difference between z_2&z_4 provides the tilt around u
- The difference between z_1&z_3 provides the tilt around v
- The mean value of z_1, z_2, z_3 and z_4 compared to z_0 provides the air/glass ratio
- The difference between the mean value of z_2&z_4 and the mean value of z_1&z_3 provides the prism gap

ISRF-EM Parameter Estimation (Fabry Perot)

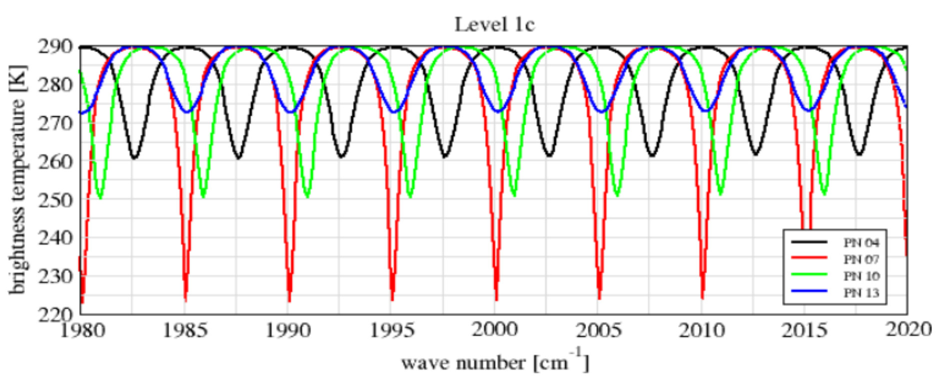




$$Tr_{FPI-0}(\nu) = \frac{1}{1 + F \cdot \sin^2(2\pi \cdot h \cdot \cos\theta \cdot \nu)}$$

$$F = \frac{4 \cdot R}{(1-R)^2}$$

- The interferometer baseline design includes a FP device to monitor in-flight IASI-NG spectral calibration (mainly KBr refractive index in the whole spectral domain)
- Signal = reflection of the hot parts of the instrument (including field effect integration and SRF convolution)



FPI level 1c spectra in the spectral range 1980-2020 cm^{-1} for detectors 4, 7, 10, and 13

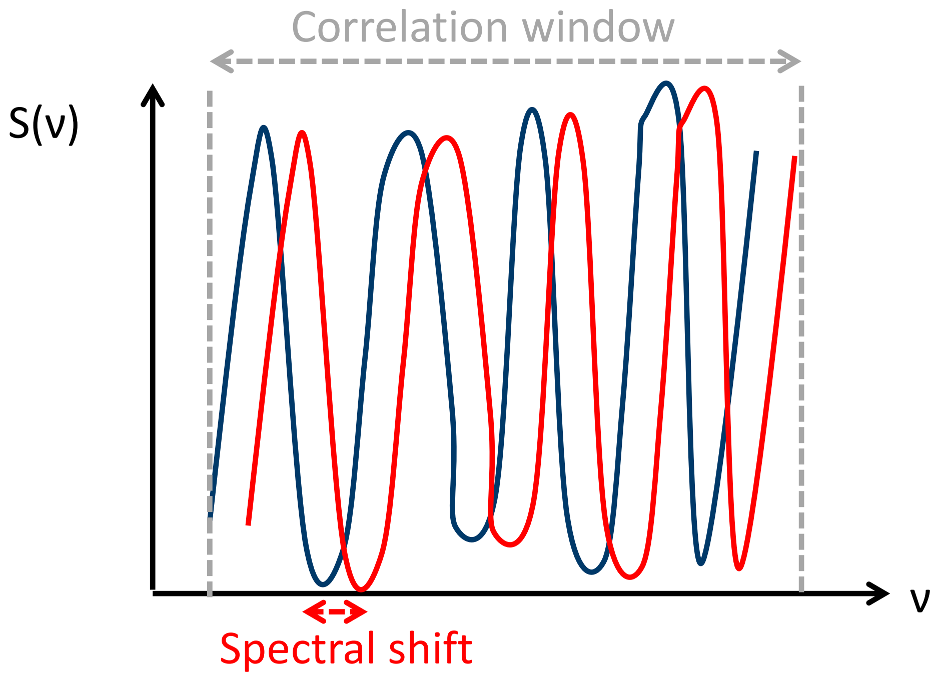
- <u>Main advantages</u>

✦ it creates a regular spectral pattern that is easiest to model than the atmosphere in the whole spectral range

=> Accurate monitoring of spectral calibration

ISRF-EM Parameter Estimation (Fabry-Perot)

- Absolute spectral shift is measured through the recognition and accurate location of well-defined patterns in the atmospheric spectrum. It has a strong heritage from IASI first generation.



Measured spectrum
Simulated spectrum

Fabry-Perot direct model input parameters tuning using a set of anchor wavenumbers

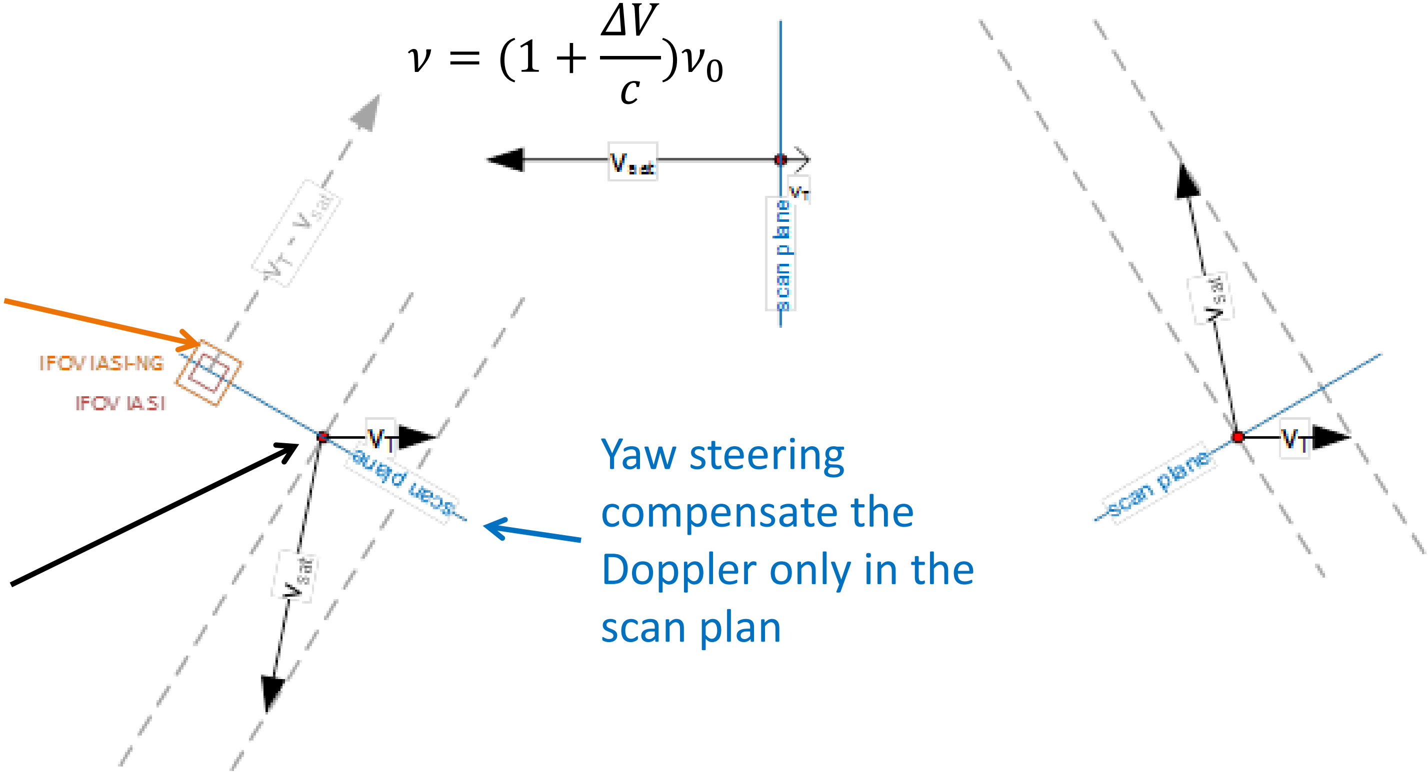
- Algorithms are based on searching for the maximum of correlation between a measured and simulated spectrum (RTM)

ISRF-EM Parameter Estimation (Doppler shift)

$$\nu = (1 + \frac{\Delta V}{c})\nu_0$$

Earth rotation and FOV spatial extension (max at the edge of the swath)

LOS stabilization during acquisition (max at nadir)



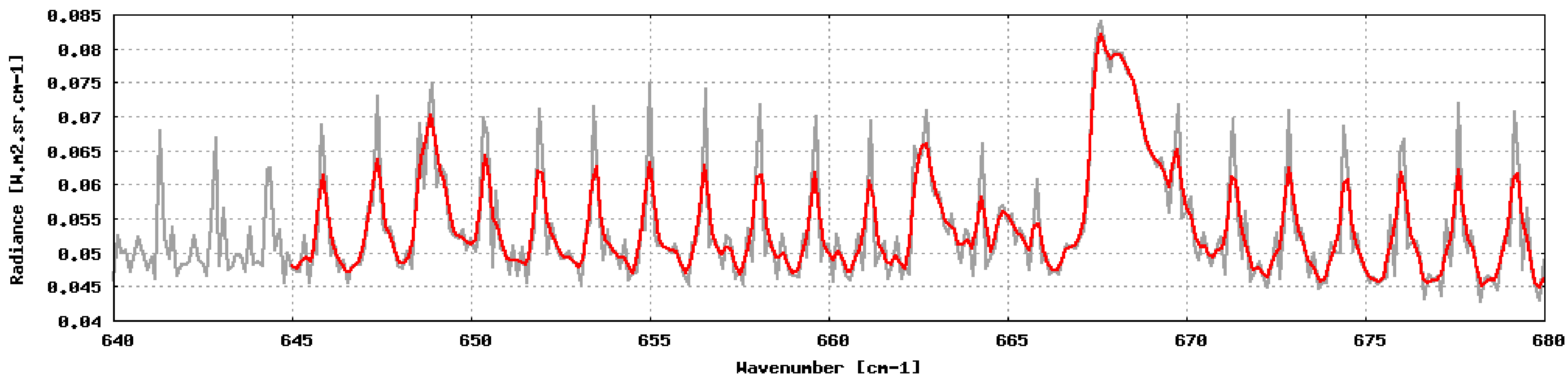
Yaw steering compensate the Doppler only in the scan plan

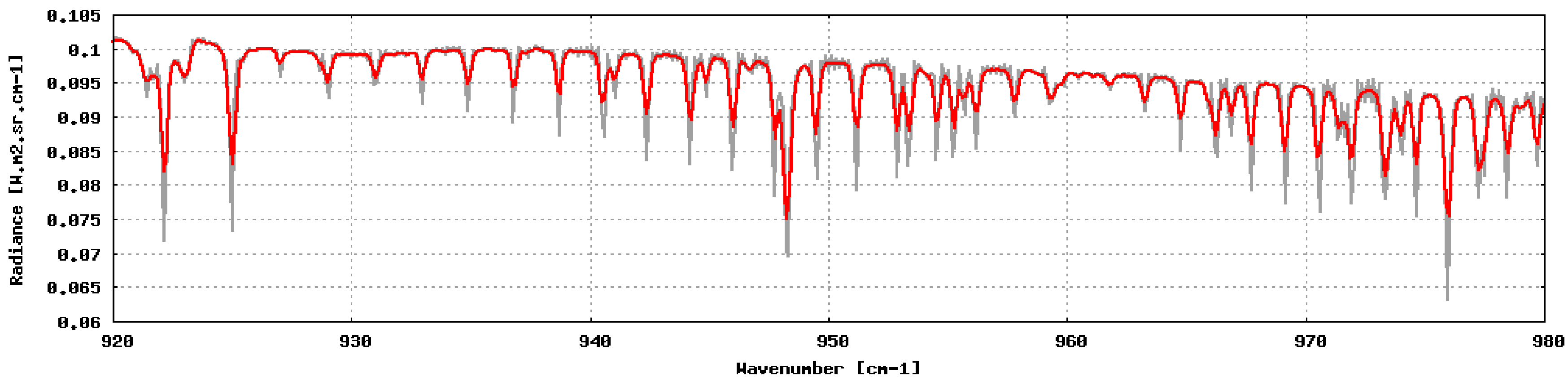
- Residual Doppler shift is not negligible with respect to IASI-NG spectral shift performance (whereas it was the case for IASI)
- Correction using a polynomial variation of SAF phase with respect to v (expected linear)

$$v_{Dop}(x) = V_{Dop}(@ZPD) + a_{Dop}(1) \cdot x + \sum_{k=2}^{N_D} a_{Dop}(k) \cdot x^k$$

Ground segment output

Black: Atmospheric input spectrum (Opd$_{Max}$ = 4.2 cm, SRF = Cardinal sine)
Red: L1C spectrum L1 processing output (real part, OPD$_{Max}$ = 4 cm, SRF = L1C)





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Space segment output

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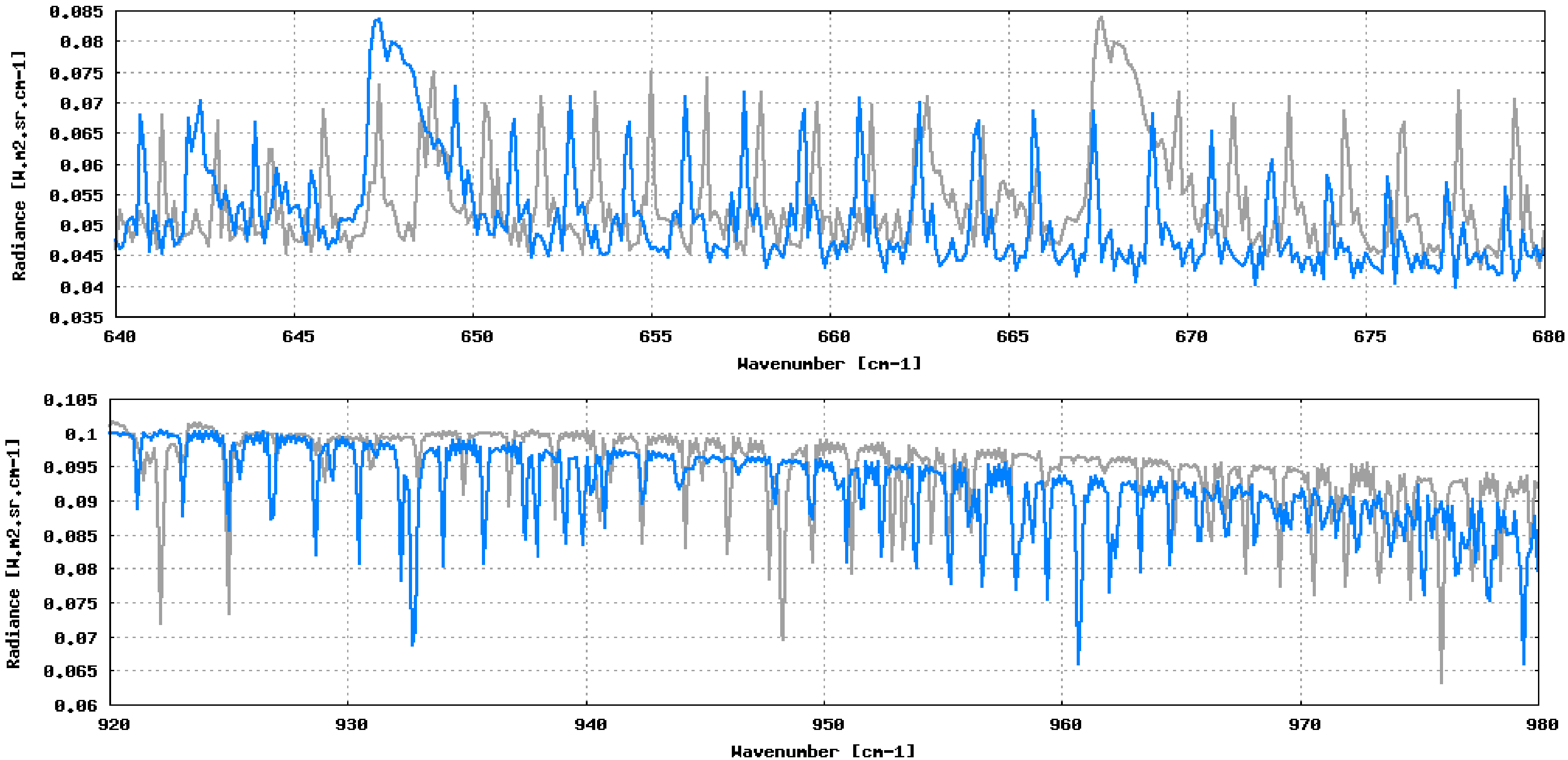

Conclusions

- Since the beginning IASI-NG has been thought as a system including an instrument (INS), on-board processing (OBP), on-ground processing (L1C POP), processing parameters initialisation/monitoring/update (IASTEC).
  - » L1C performances rely on the complementarity and mastering of these 4 components. One fails, all fail !
- OBP_Science (and auxiliary data processing): defined and prototyped
  - » First validation done by ADS
- OGP_Science: defined and prototyped
  - » Scientific validation of algorithms has started (see Adrien's poster #139)
- OGP_Image: "IASI-like" version has been defined and prototyped
  - » Some improvement with respect to IASI are on-going
  - » Expected to be completed by the end of 2016
- OGP_ISRFEM: roughly defined and not prototyped yet
  - » Preliminary expected by Q1 2017
- OGP_TEC : expected by Q2 2018