IASING science data processing overview

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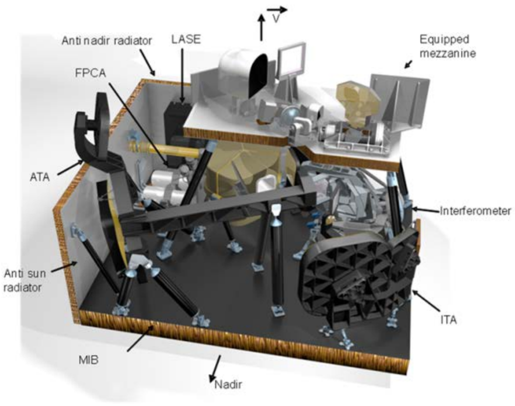
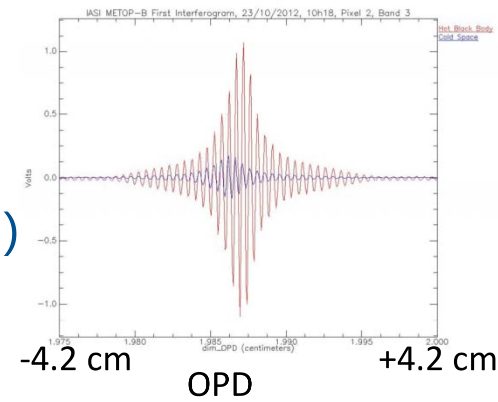
Introduction



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

- Interferogram = Fourier Transform (Spectrum)

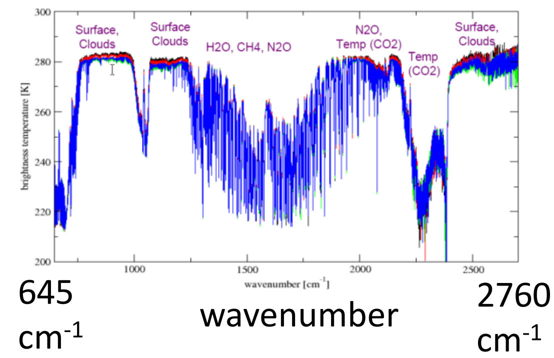
Note : all these data are sampled data, not continuous !



- Users work with L1C spectrum

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

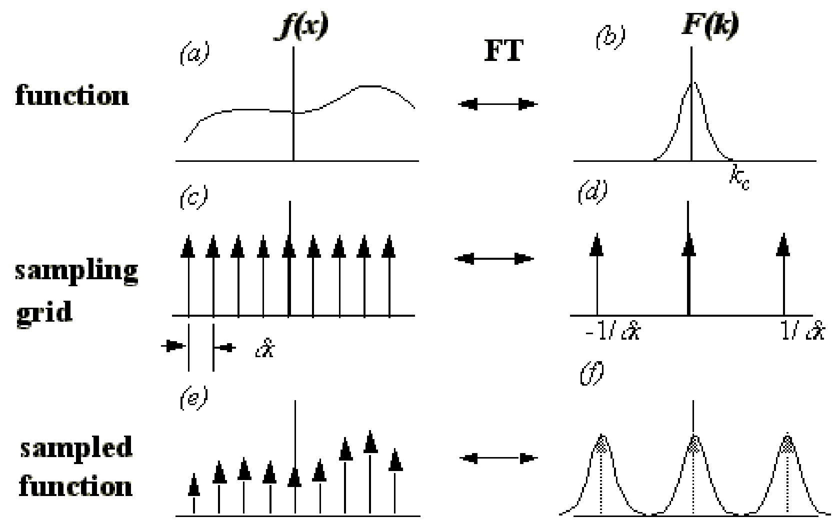
- L1C spectrum
  - fully calibrated (spectral and radiometry)
  - a unique ISRF for all channels of all spectra
  - geo-localized
  - performance requirement : Radiometry = IASI / 2, Spectral = IASI/2, geometry = IASI



On-board / on-ground processing sharing is mainly driven by telemetry data rate allocated to IASI-NG on MetOp-SG (6Mb/s for science data in average)

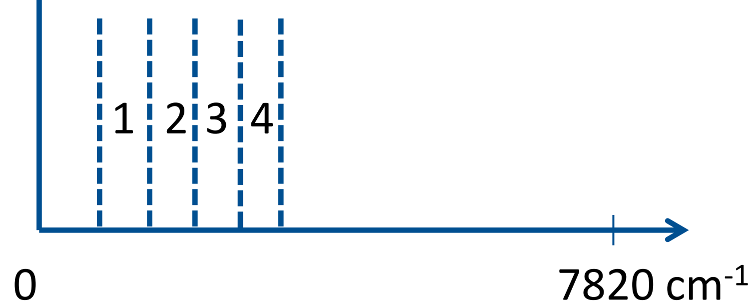
On-board processing objectives

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



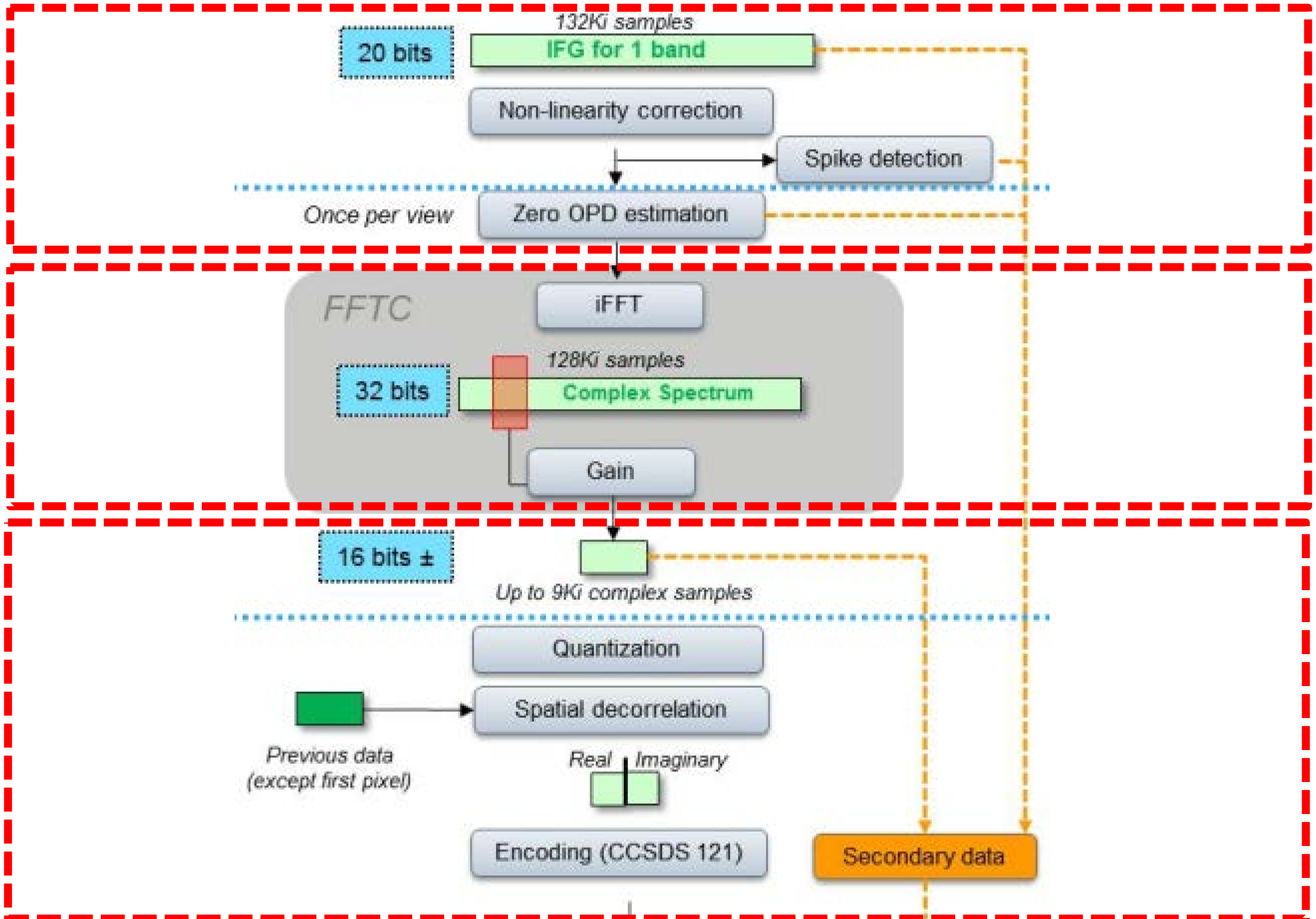
- The logic of the design becomes then more obvious
  - ✦ Preserve the information content by keeping the Fourier transform reversible in the useful spectral band and with respect to imperfections we may want to correct on ground
  - ✦ Be compliant with computation time and telemetry data rate.
  - ✦ 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)

Preprocessing

(to avoid spectral aliasing introduced by discreet FT and loss of information)

1st level of compression

1) FFT of interferogram
2) Frequency truncation to useful band
(+ interbands + ghost + spikes + monitoring frequencies)

Data rate / 20-25

2nd level of compression

"conventional compression"

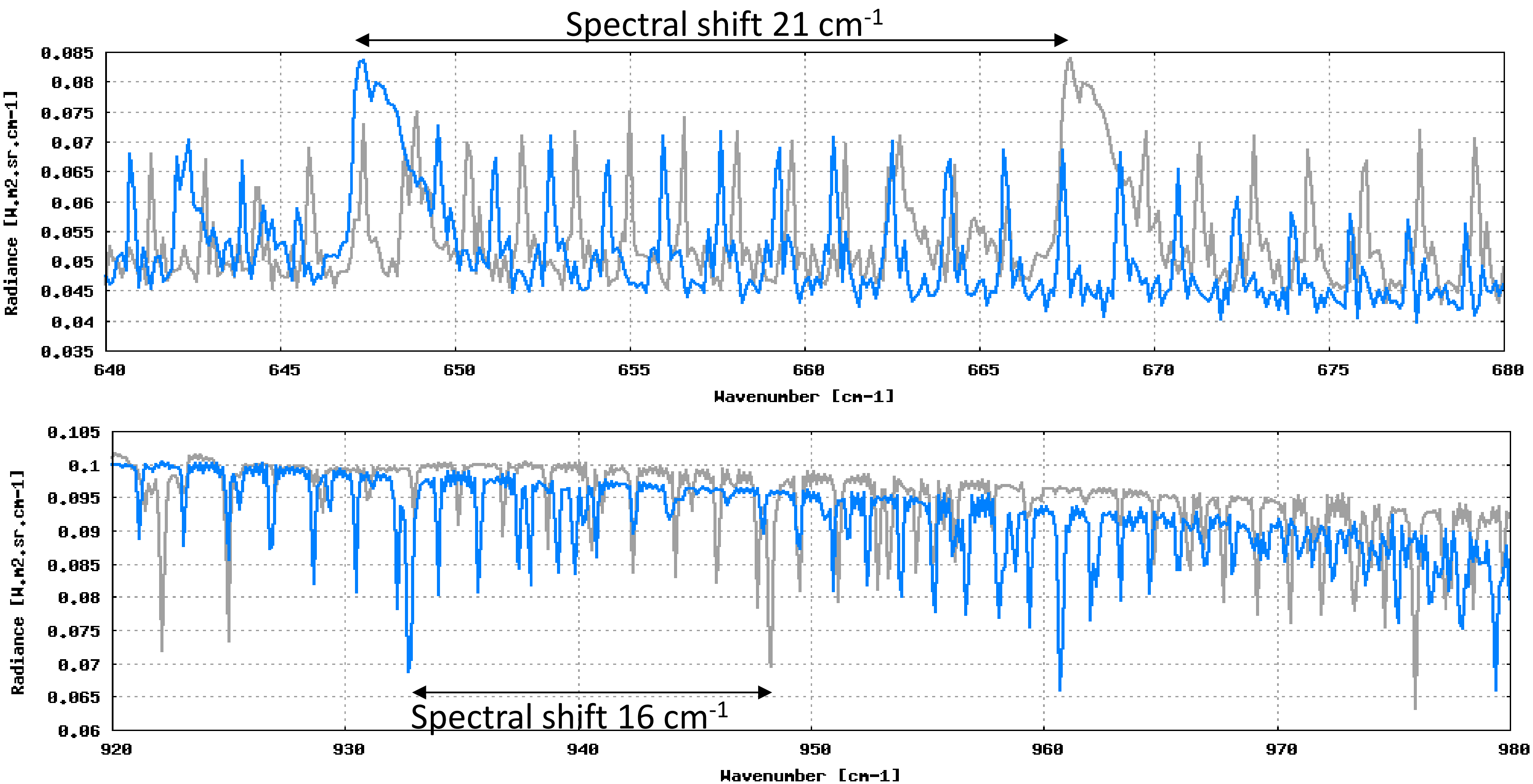
Quasi-loss less (quantization 0.5% noise increase)

Data rate / 2-3

Space segment output

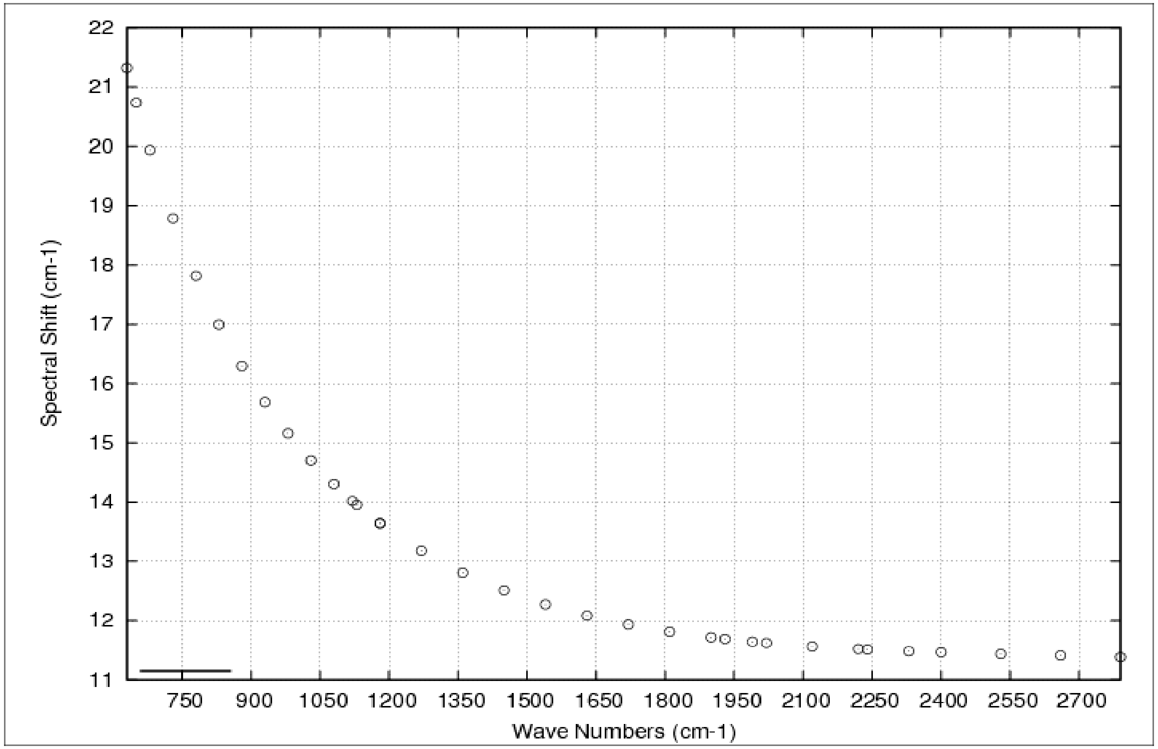
Grey: Atmospheric input spectrum (Opd_{Max} = 4.2 cm, SRF = Cardinal sine)

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 L1 processing



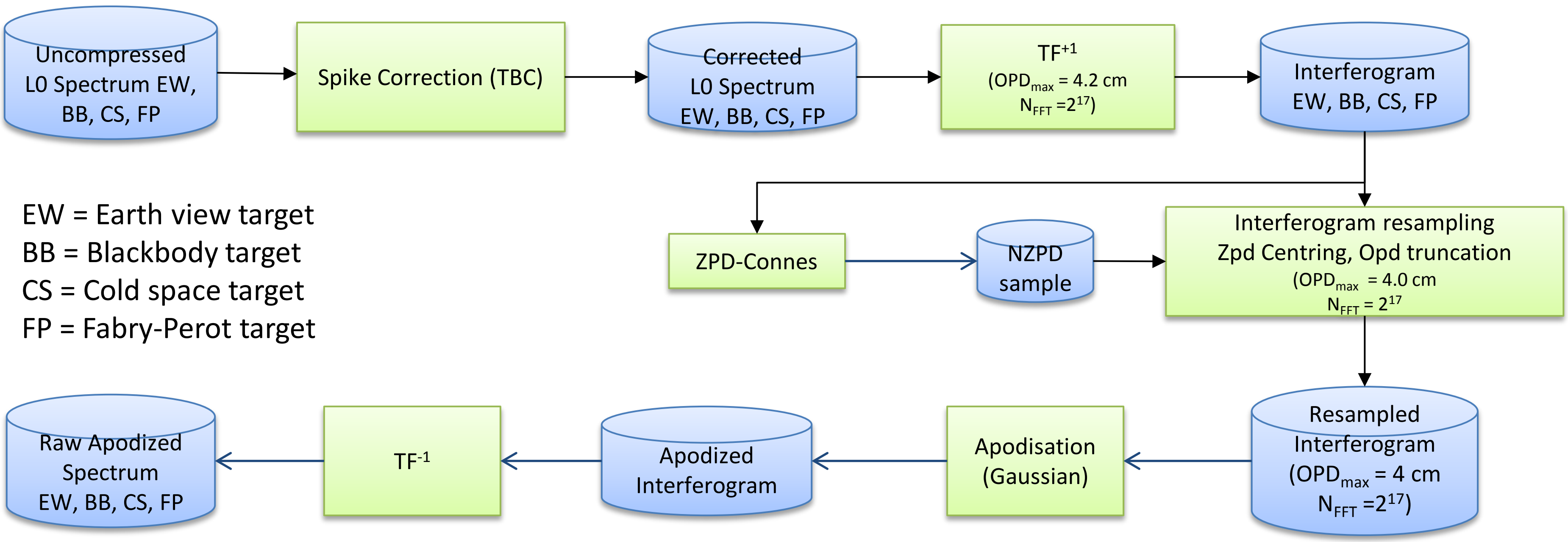
On-ground processing objectives

- Provide atmospheric spectra fully calibrated (spectral and radiometry) and geo-localized
- A unique ISRF for all channels of every spectrum
  - ✦ The objective is to facilitate spectra simulation by RT models (user friendly approach)
- To provide additional geophysical characteristics of the scene (at pixel and sub-pixel scale) in order to help with the exploitation of IASI-NG spectra.
- Make the processing in near real time (more than 1 million spectra per day !)

On-ground processing: pre-processing

Pre-processing is mainly done in the interferogram space

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

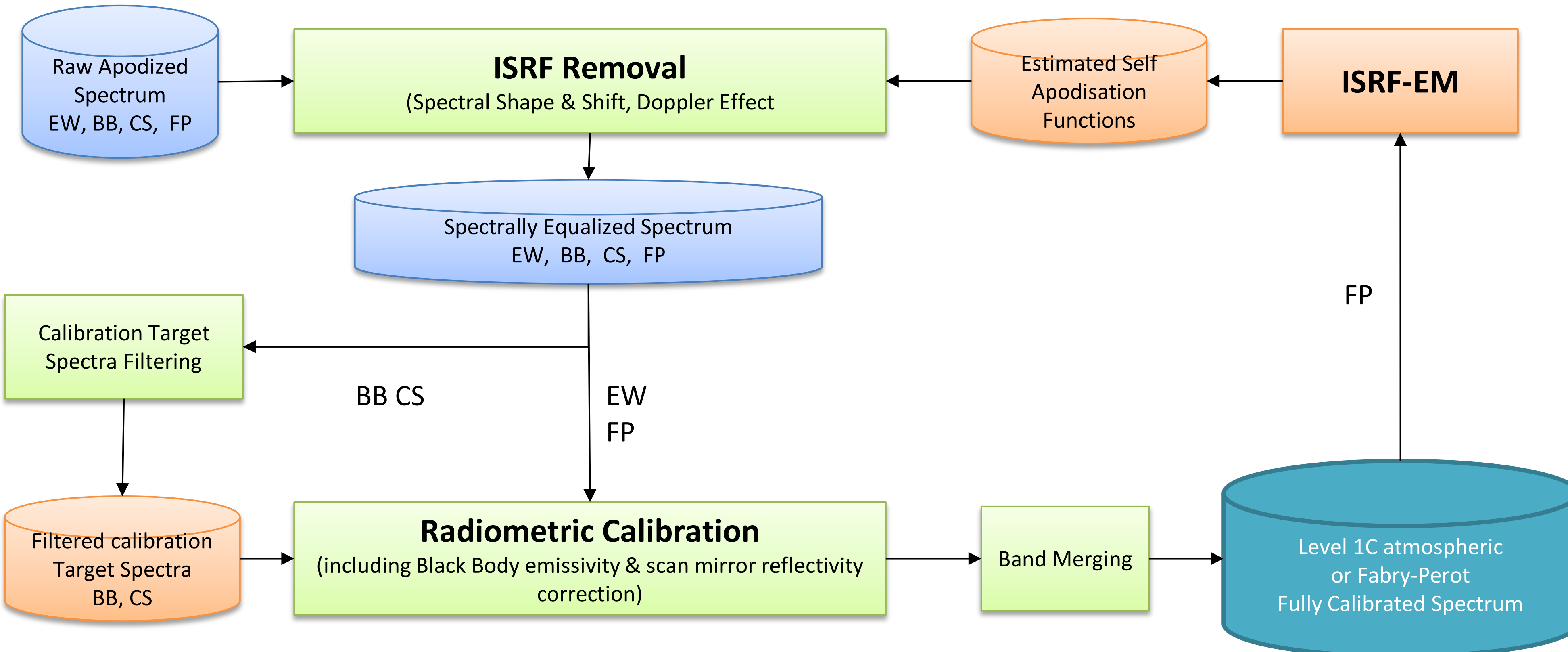


L0 and Apodized Raw spectra: reduced to the useful spectral band and complex, intermediate interferograms: real

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)



Instrument removal principle
(spectral calibration, ISRF deconvolution, L1C apodisation)

Illustration for a monochromatic wave

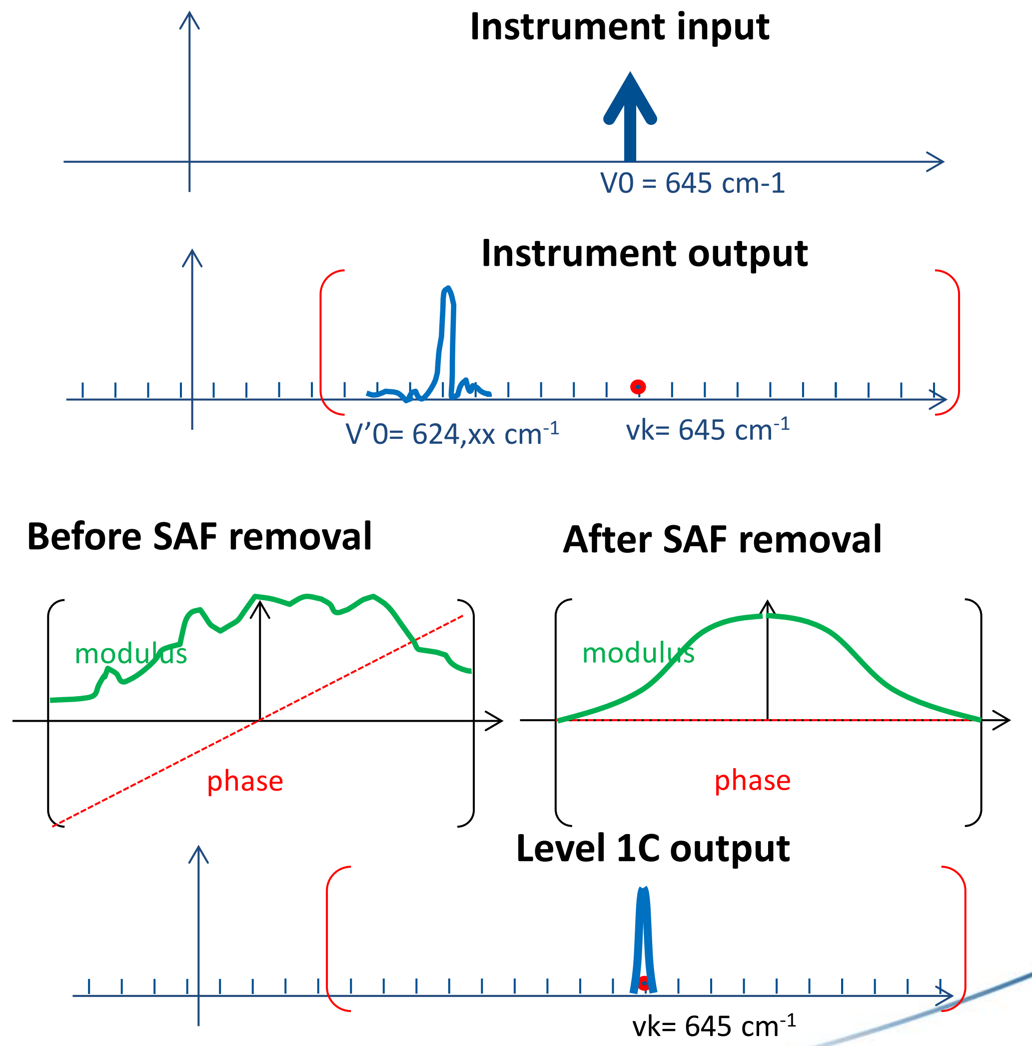
Monochromatic wave at 645 cm^{-1}

Left: Estimated Instrument Transfer Function (SAF) at 645 cm^{-1}

Right: Final Level 1C Instrument Transfer Function (equalized and apodised)

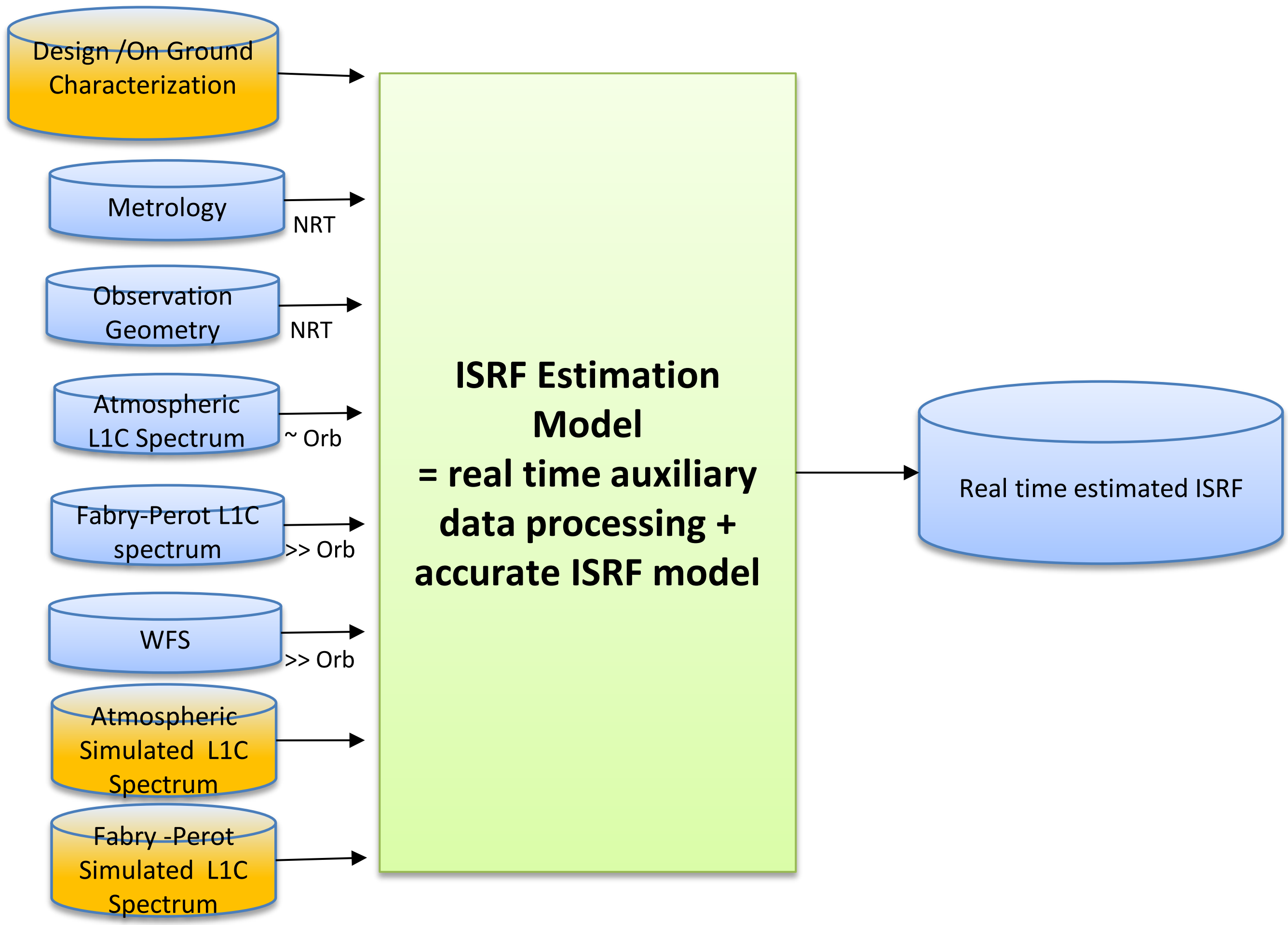
Here we are in the interferogram space. Easier for deconvolution / convolution

Final Level 1C spectrum sample at 645 cm^{-1}



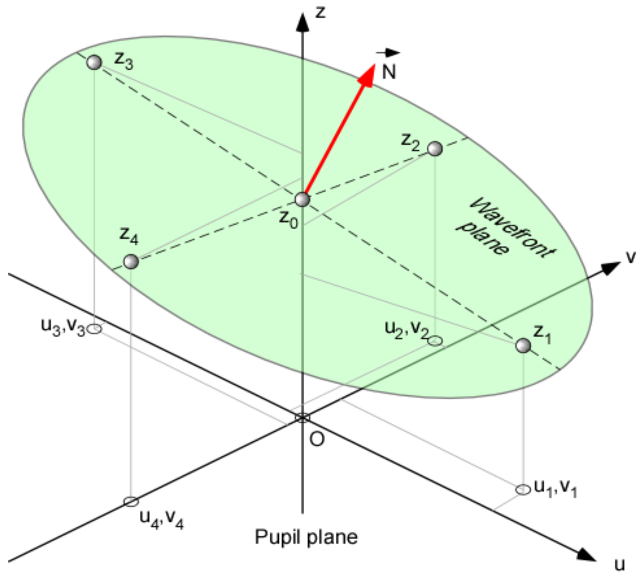
ISRF-EM overview

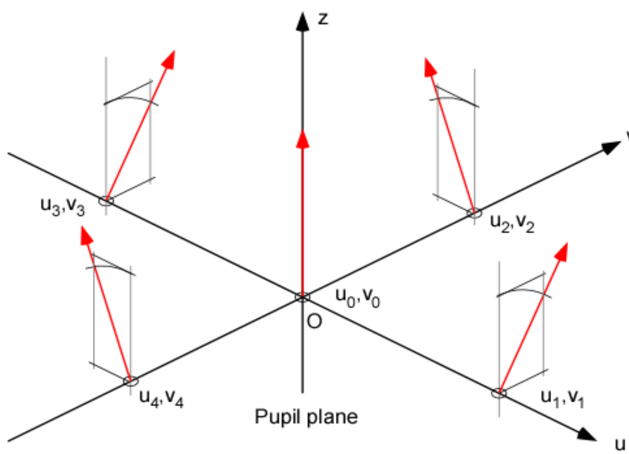
The quality of the ISRF removal relies on an accurate ISRF model + on-ground and in-flight characterisations of input parameters of this model



Enhance off-axis metrology (new with respect to IASI 1st generation)

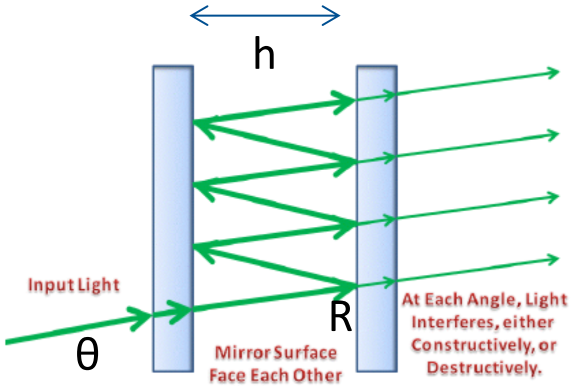
The interferometer baseline design includes in addition to the on-axis metrology four additional laser beams

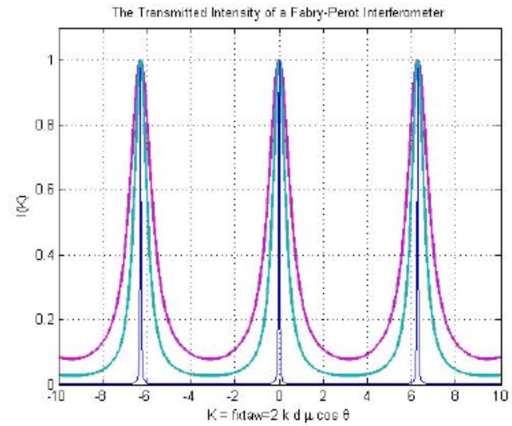




- The on-axis beam z_0 provides the nominal OPD including µvibration effects
- The difference between z_2&z_4 provides the tilt around u
- The difference between z_1&z_3 provides the tilt around v
- The mean value of z_1, z_2, z_3 and z_4 compared to z_0 provides the air/glass ratio
- The difference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

Fabry-Perot device (new with respect to IASI 1st generation)



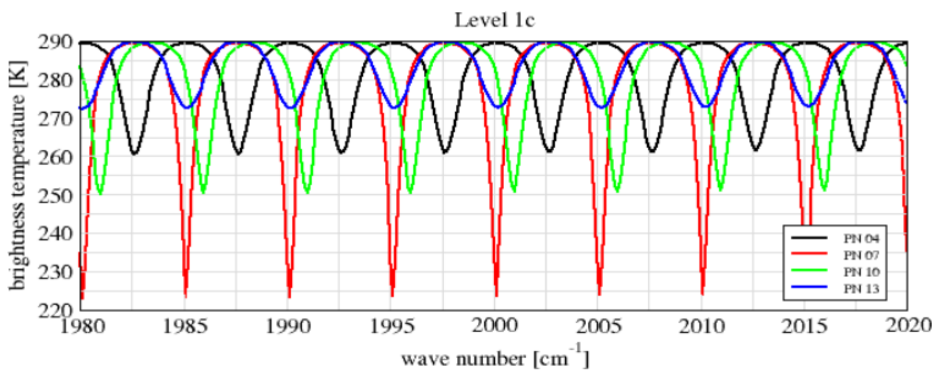


$$Tr_{FPI-0}(\nu) = \frac{1}{1 + F \cdot \sin^2(2\pi \cdot h \cdot \cos\theta \cdot \nu)}$$

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

- 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)



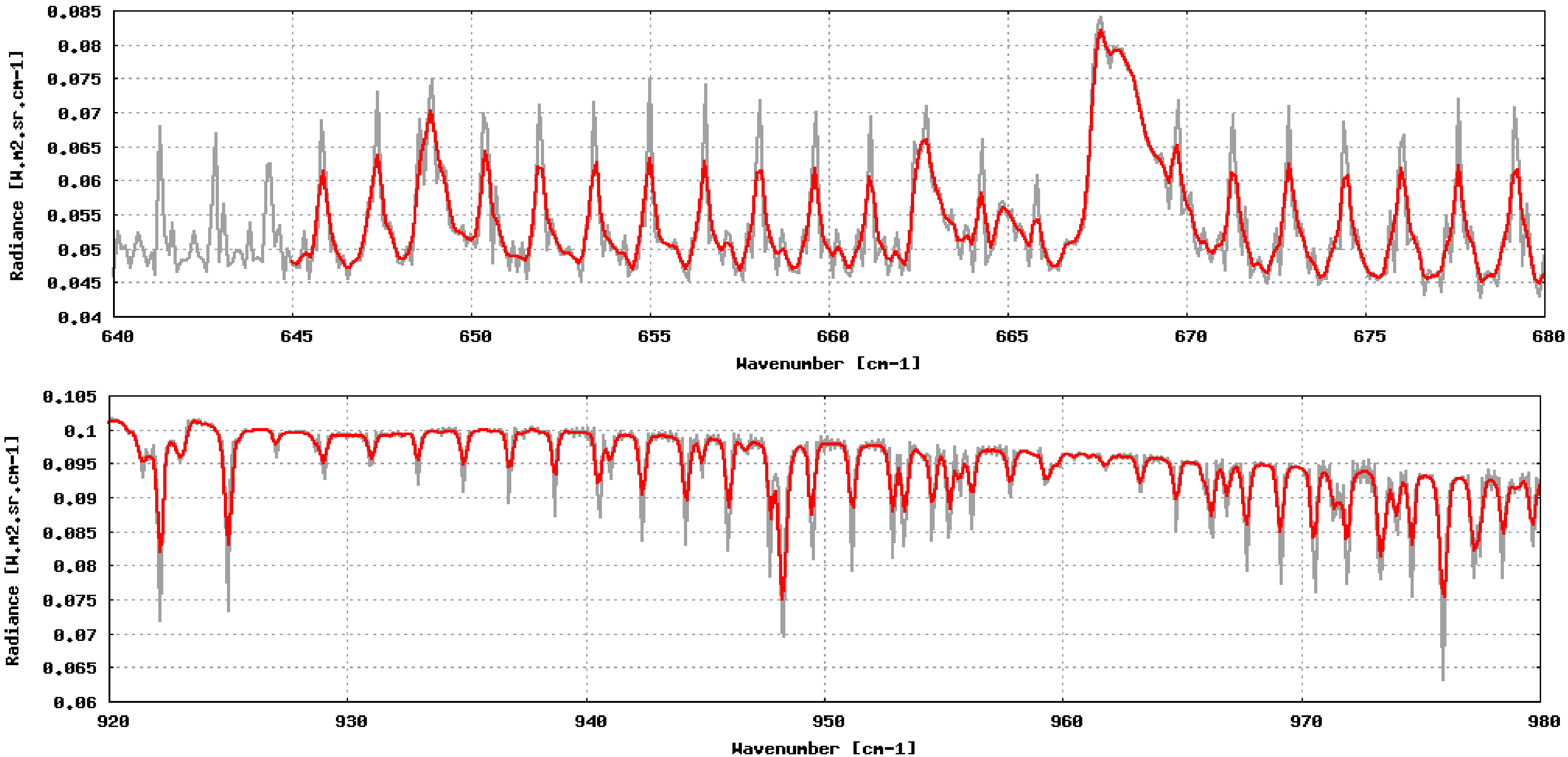
FPI level 1c spectra in the spectral range 1980-2020 cm^{-1} for detectors 4, 7, 10, and 13

- Main advantages
  - it creates a regular spectral pattern that is easy to model
  - additional calibration device with respect to IASI, where atmospheric spectral signatures are the only calibration source.

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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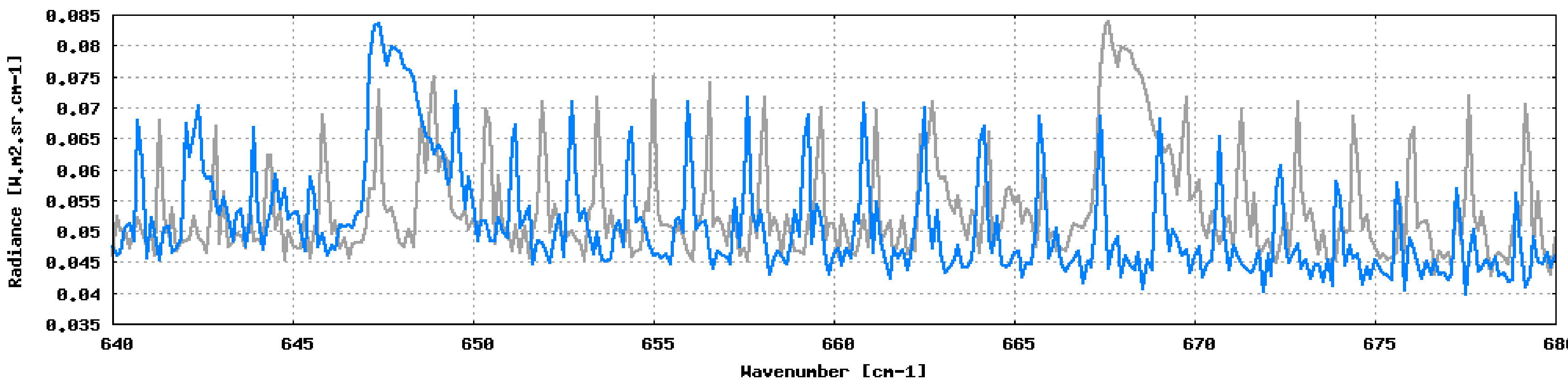

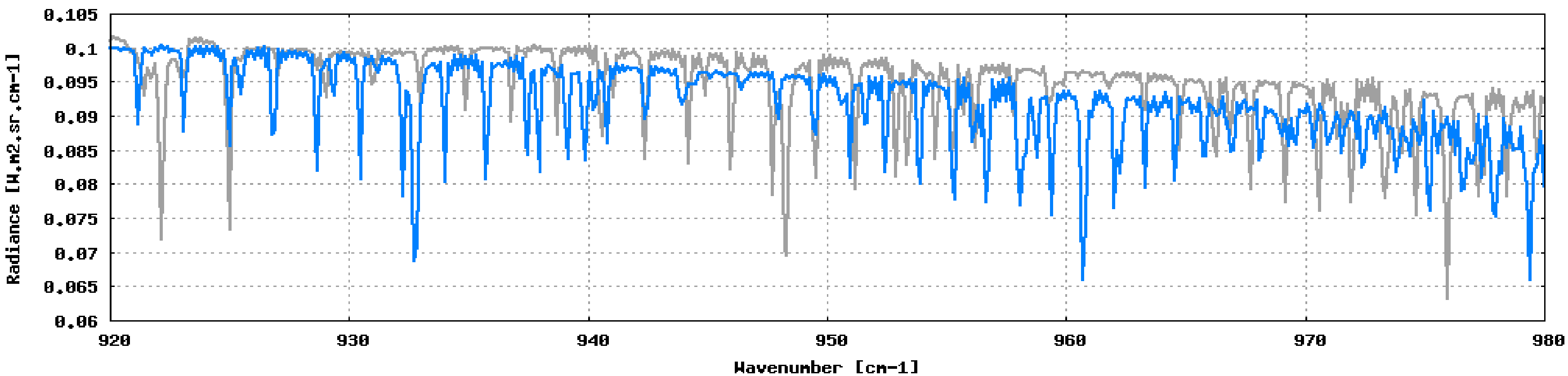

Conclusions

- Main principles of science data processing and corresponding in-flight auxiliary instrument devices have been defined
  - » IASING has been imagined as a system including an instrument, an on-board and on-ground processing. L1C performances relies on the complementarity and mastering of these 3 components.
  - » New devices on-board to ensure the knowledge of instrument state : Fabry Perot, 5 beams laser metrology, Wave Font Sensor
  - » New capabilities for on-ground correction of instrumental artefact
    - » We put in the science telemetry both imaginary and real parts of the spectra.
    - » Additional datarate to monitor out of band signal (spike & µvibration correction, Non Linearity monitoring)
  - » Today a changing phase black body could not be accommodated within the instrument which means that there is no direct in-flight monitoring of absolute radiometric calibration. However a SI traceability of BB temperature has been asked during the development.
- On-board processing prototype is available
- On-ground processing prototype will be available by mid of 2017
- A scientific validation of algorithms has started (see Adrien's poster #14p.03) based on simulated test orbits provided by EUMETSAT