IASI-NG Level 1 processing

How to estimate the instrument spectral response function in real-time ?

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[1] CNES, [2] Noveltis

IASI – NG level 1 processing

- From IASI to IASI-NG: innovations and new challenges
- Overview of the IASI-NG Level1 processing
- The ISRF – Estimation Model
- System performance budget

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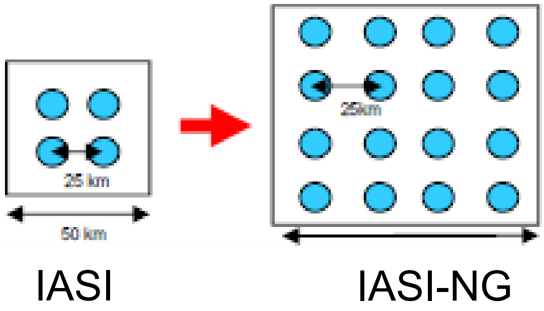
IASI-NG Level 1 main characteristics

Main figures	IASI	IASI-NG
Radiometric Resolution (NeDT)		IASI/2
Spectral resolution	0.5 cm^{-1}	IASI/2 (0.25 cm^{-1}@L1C)
Absolute Radiometric Calibration	< 0,5K	IASI/2 (<0,25K@280K)
Spectral bands	3 bands	4 bands
Number of sounder pixels per acquisition	4 pixels	16 pixels
Ground Pixel diameter	12 km	12 km
Ground sampling	25 km	25 km



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From IASI to IASI-NG: innovations and new challenges

- IASI vs IASI-NG ?

→ With great performance comes great complexity

IASI interferometer

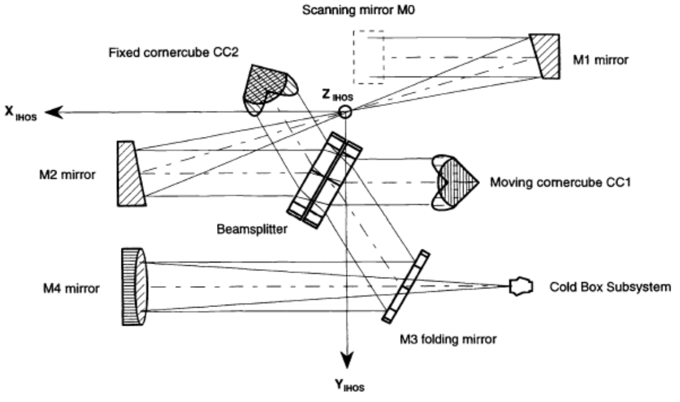
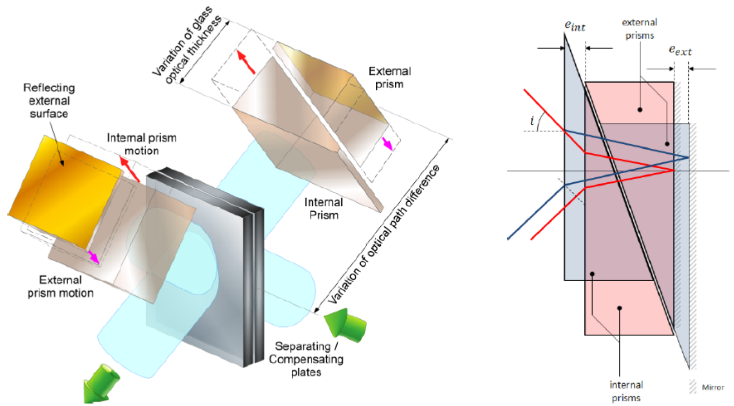


Figure 3.1-1 : IHOS optical configuration

- 4 optical components
- 1 moving corner cube
- nearly achromatic / all reflective design
- 1 laser trigs the acquisition

IASI-NG interferometer



- 6 optical components
- 4 moving prisms, simultaneously
- chromatic and <u>refractive</u> design
- 1 laser trigs the acquisition, 4 additionnal lasers for opd estimation

F. Henault, C. Buil and al. – spaceborn infrared interferometer of the IASI instrument. Proc SPIE 3437, Infrared Spaceborn Remote Sensing VI. 18/11/1998

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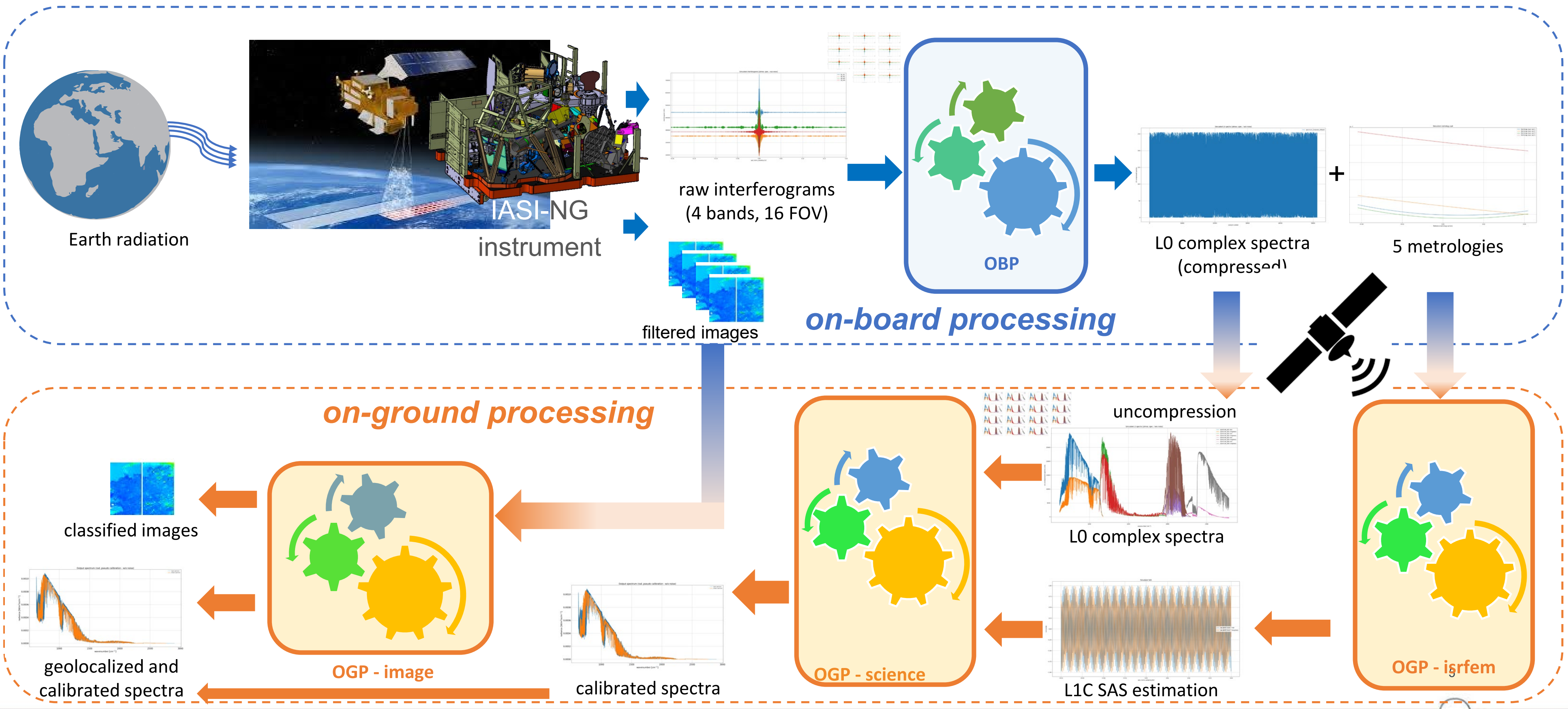
IASI-NG Level1 chain: overview



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The ISRF – Estimation Model

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The ISRF – Estimation Model

- **IASI-NG ISRF estimation principle**

  - **ISRF is estimated <u>for every set</u> of 16x4 acquisitions**

estimating the ISRF = knowing the science opd

Airbus D&S shows that the opd for every wavelength in the science band can be approximated by a linear combination of the 5 metrologies opd :

$$\mathbf{opd}(\boldsymbol{\sigma}) = \left(\mathbf{A_{cal}}(\boldsymbol{\sigma}) - \mathbf{C_0}(\boldsymbol{\sigma}, \mathbf{Z_0})\right).\mathbf{Z_0} + \sum_{i=1}^{4} \mathbf{C_i}(\boldsymbol{\sigma}, \mathbf{Z_0}).\mathbf{Z_i} + \mathbf{OFFSET}(\boldsymbol{\sigma}, \mathbf{Z_0})$$

$\mathbf{Z_{i=1..4}}$: metrologies opd
$\mathbf{Z_0}$: reference metrology opd
$\mathbf{C_{i=0..5}}$: opd coefficients

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The ISRF – Estimation Model

- **IASI-NG ISRF estimation principle**

➢ **ISRF-Estimation Model parameters - Coefficients**

$$\mathbf{opd}(\sigma) = \left(\mathbf{A_{cal}}(\sigma) - \mathbf{C_0}(\sigma, \mathbf{Z_0})\right).\mathbf{Z_0} + \sum_{i=1}^{4} \mathbf{C_i}(\sigma, \mathbf{Z_0}).\mathbf{Z_i} + \mathbf{OFFSET}(\sigma, \mathbf{Z_0})$$

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$C_{i=0..5}$: opd coefficients

They are a combination of :

Computed coefficients

- Using a numerical model of the interferometer
- Parameters of the model can be updated in-orbit using WFS

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The ISRF – Estimation Model

- **IASI-NG ISRF estimation principle**

  - **ISRF-Estimation Model parameters - Coefficients**

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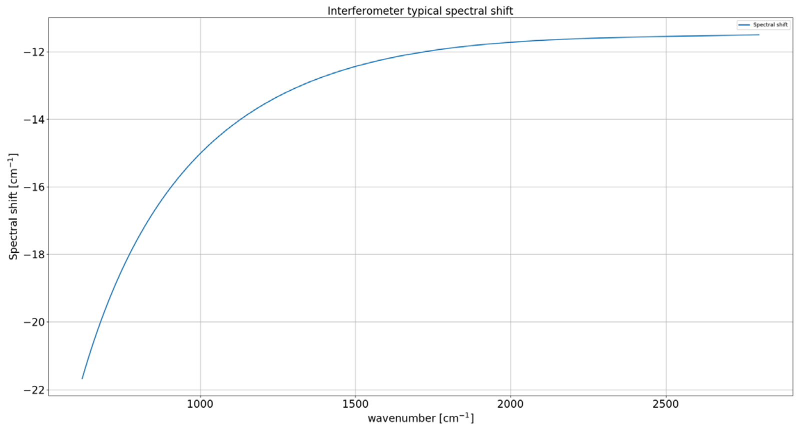
$\mathbf{Z_{i=1..4}}$: metrologies opd
$\mathbf{Z_0}$: reference metrology opd
$\mathbf{C_{i=0..5}}$: opd coefficients

They are a combination of :

Measured coefficient

- On-ground spectral shift (first guess)
- In-orbit determination using dedicated acquisitions sequences (atmospheric spectra correlation + FPI)



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The ISRF – Estimation Model

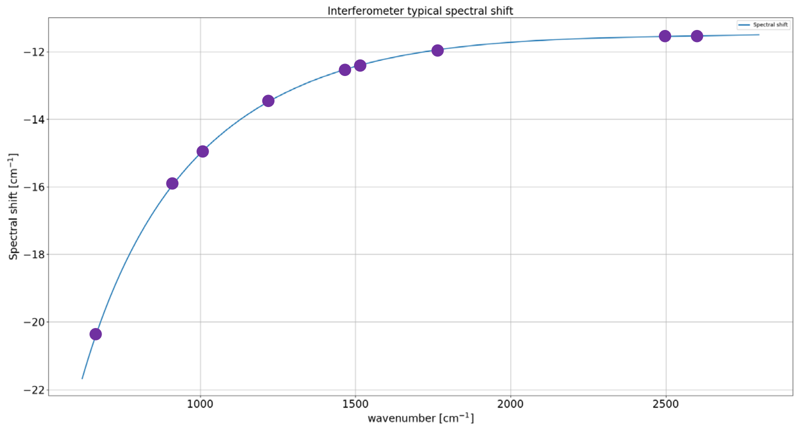
- **IASI-NG ISRF estimation principle**

➢ **ISRF-Estimation Model parameters – Coefficients – A_{cal}**

The A_{cal} coefficient is related to the spectral shift $\Delta\sigma$ throught the simple relation :

$$\mathbf{A_{cal}(\sigma) = \frac{\Delta\sigma}{\sigma}}$$

1- $\mathbf{A_{cal}(\sigma)}$ values are computed for few wavenumbers (anchor points) across the IASI-NG band using correlation between observed and modeled spectra.



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The ISRF – Estimation Model

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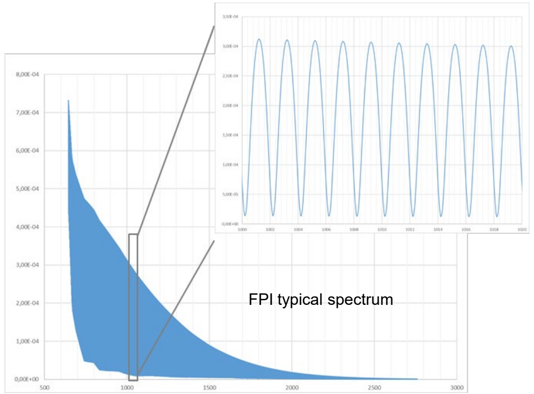
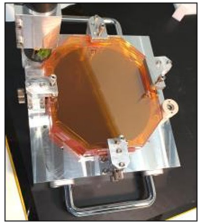
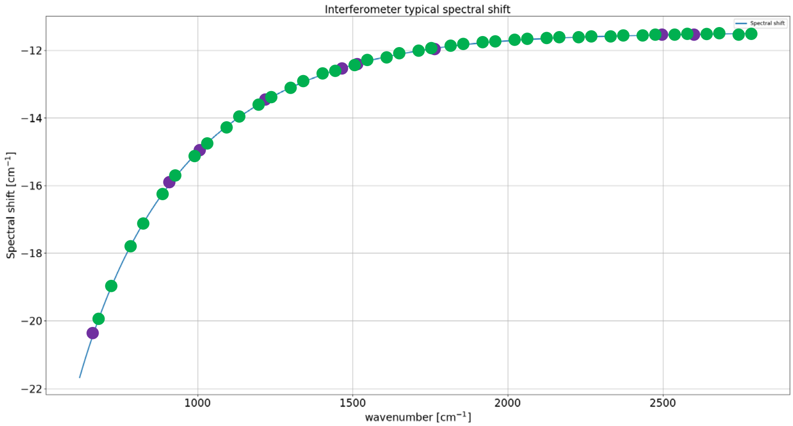


How on board calibrations will allow high level of performance during IASI-NG Mission
E. Baldit and al – Poster session – Joint EUMETSAT/AMS/NOAA conf. 2019 (Boston)



FPI plates (ZnSe)
Winlight optics



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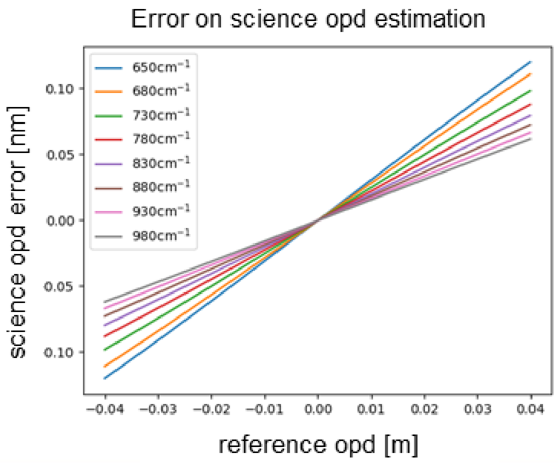
The ISRF – Estimation Model

- **IASI-NG ISRF estimation performances**

  - **Preliminary assessments of ISRF estimation model are very promising :**

Knowing the science opd = estimating the ISRF

Without defects, the opd estimation is better than few tenth of nanometers
(~ 1/1000 OPD sampling)



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The ISRF – Estimation Model

- **IASI-NG ISRF estimation performances**

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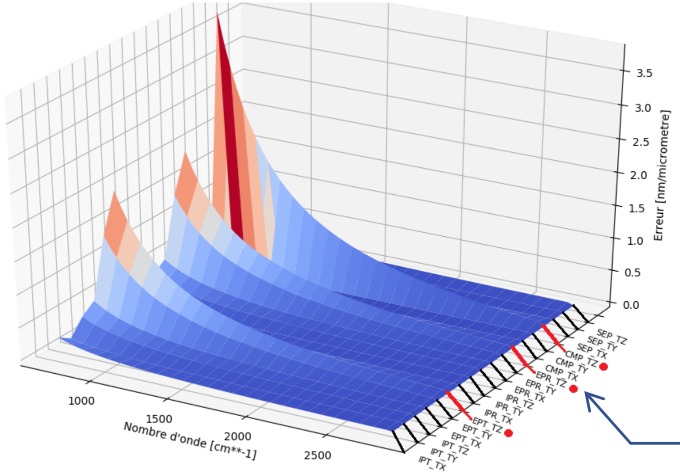
Knowing the science opd = estimating the ISRF

opd variations induced by kinematical defects are also well corrected

Sensitivity of the opd error – translation defect



6 optical components x 3 transations / rotations

Sensitivity of the opd error below :

- **3nm/µm of translation** for every component / every wavenumbers
- Movement of 1µm of the compensating plate corresponds to a worst case

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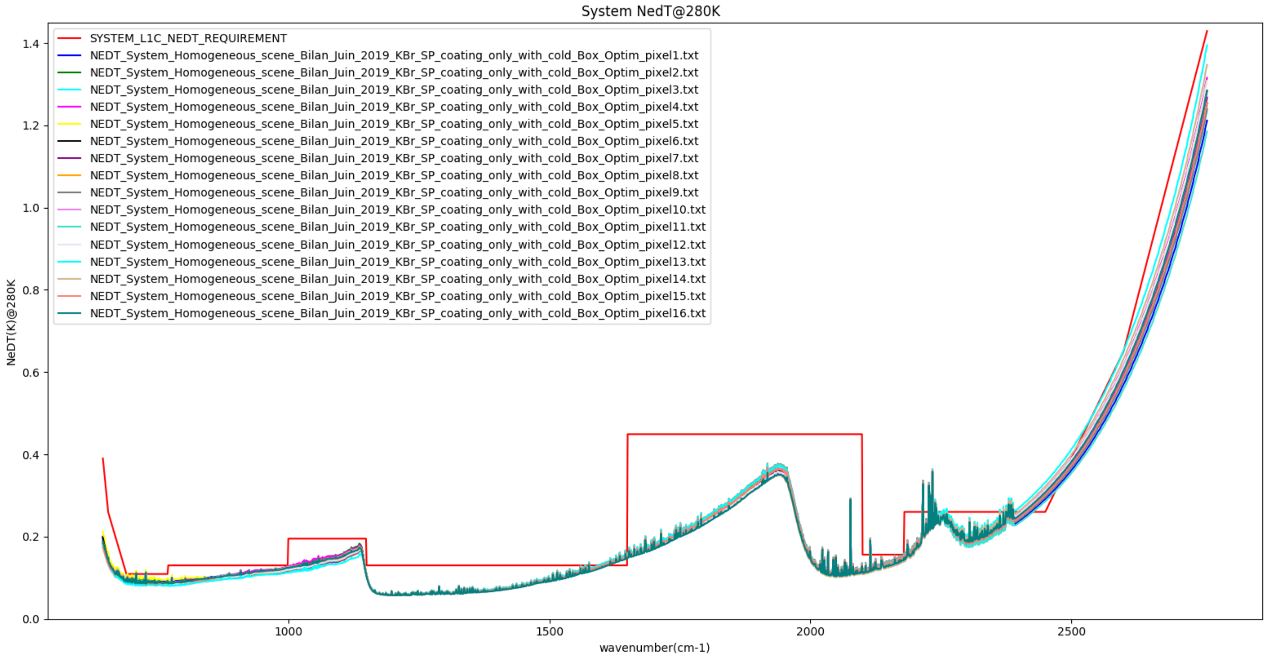
System performances budget

- The current budget of system performances shows very encouraging results in terms of
  - ✓ Geometric performances
  - ✓ Spectral performances
  - ✓ Radiometric performances



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IASI NG

Thank you …

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5th IASI Conference, 20-24 April 2020, Evian (France)

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Back-up slides

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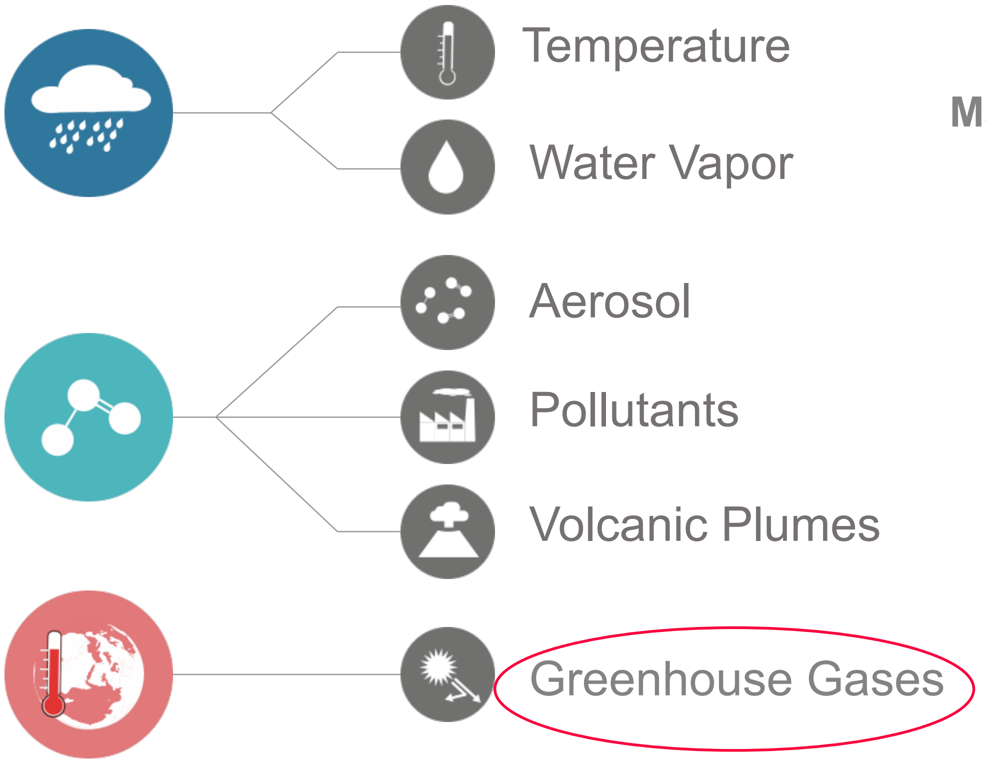
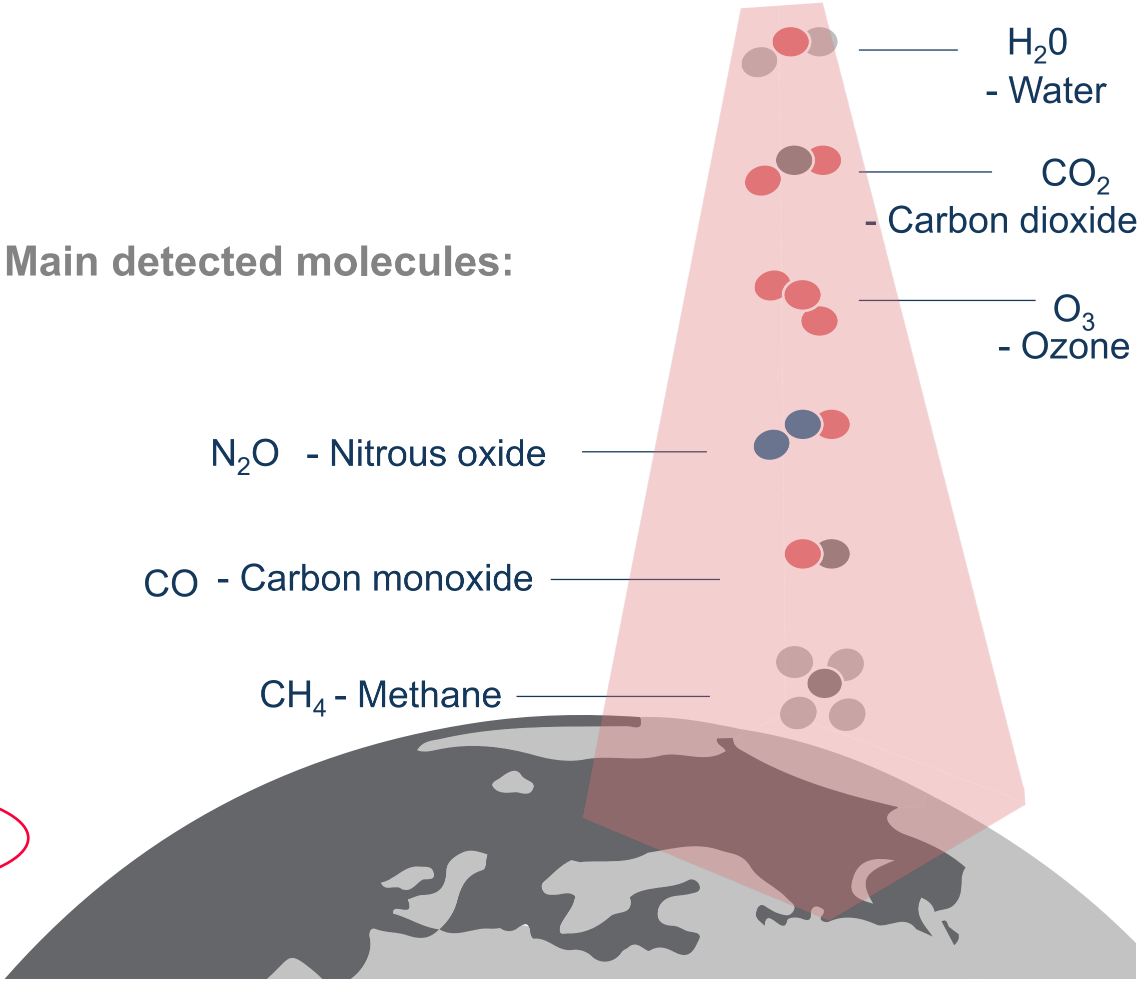
From IASI to IASI-NG: innovations and new challenges

Applications are the same:



Main detected molecules:



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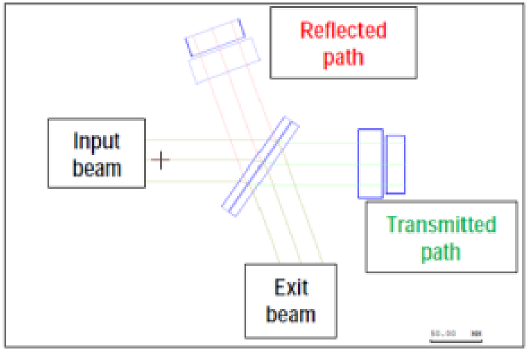
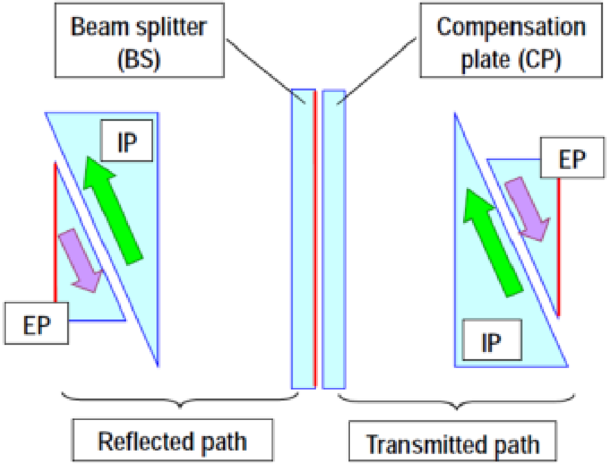
From IASI to IASI-NG: innovations and new challenges

- **To deal with the stronger requirements in terms of performances, a new instrumental concept has been proposed:**
  - ✓ The Mertz interferometer allows a field compensation (self-apodisation correction)
  - ✓ Field compensation is achieved by introducing optics with correct optical index
  - ✓ A single 'dual swing" mechanism translates two pairs of prisms proportionally and creates simultaneously the OPD change and the self-apodisation compensation

  - ✓ **The level 1 processing has been modified consequently, especially to estimate the Instrument Spectral Response Function (ISRF)**





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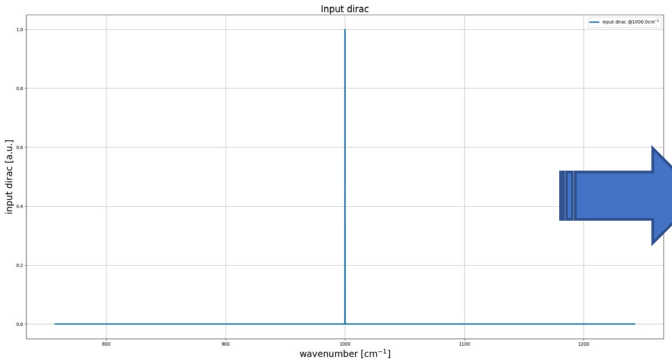
The ISRF – Estimation Model

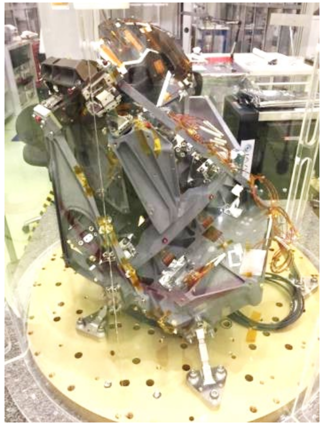
- **Why estimate the instrument spectral response function (ISRF) ?**

→ **The impact of the instrument on measured spectra**

ISRF = response of the instrument to a spectral dirac

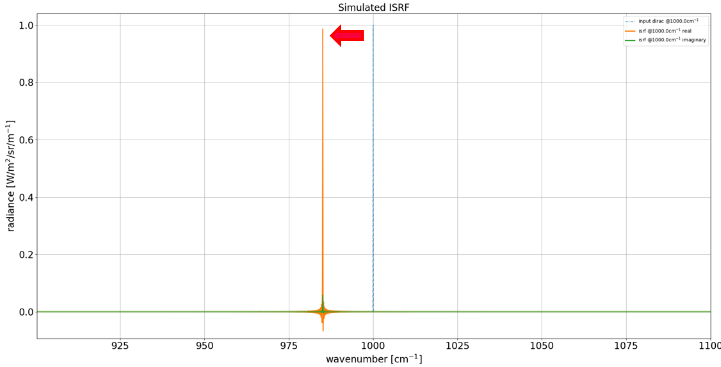


input dirac



FM1 IFM Model

(courtesy Airbus)



ISRF

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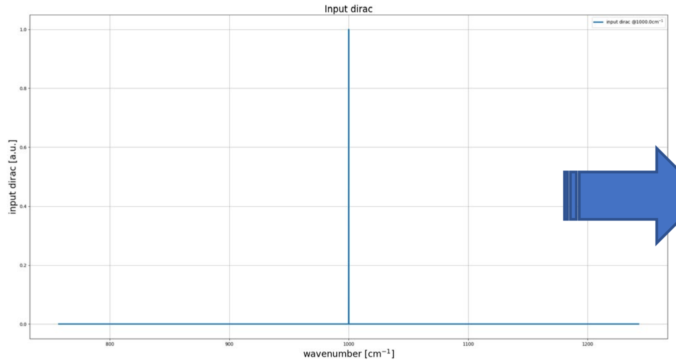

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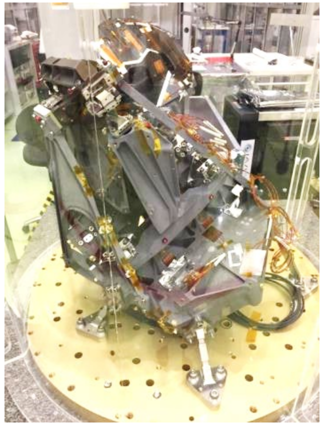

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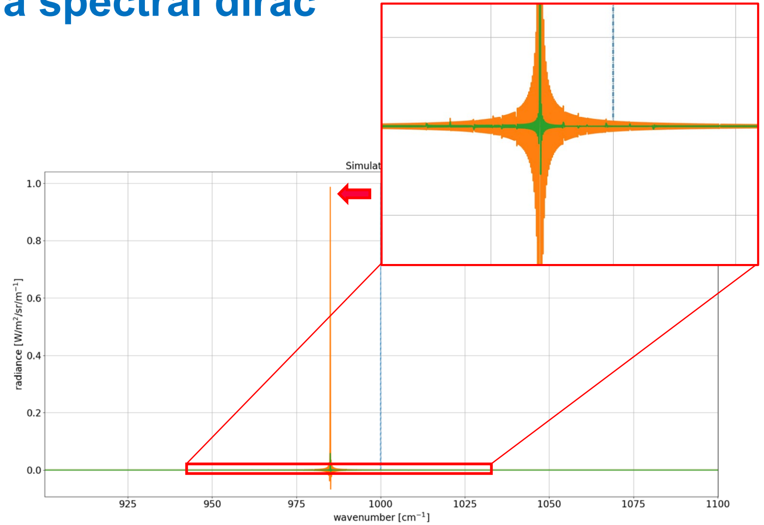

ISRF

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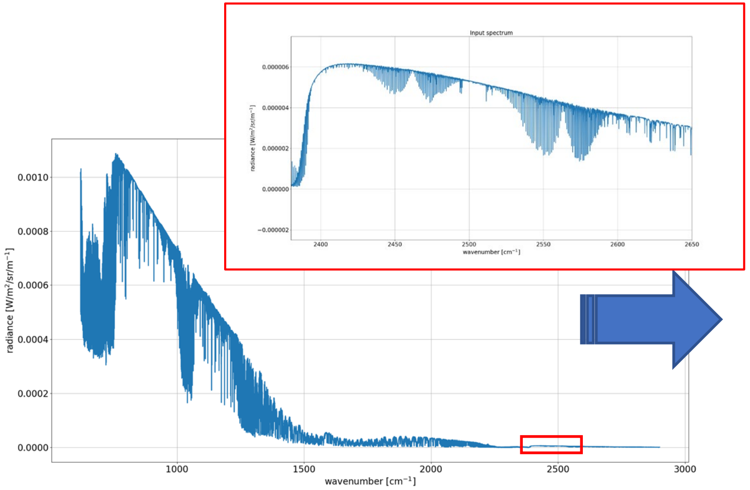
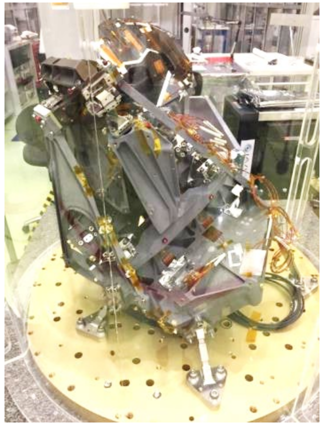
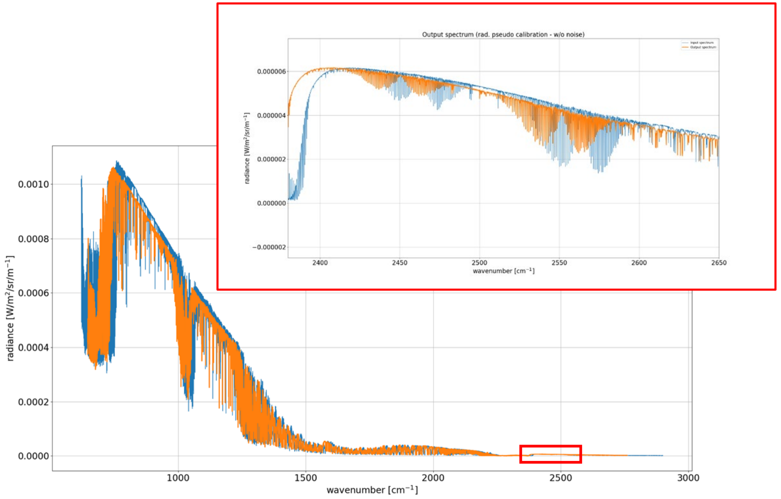


input spectrum



FM1 IFM Model
(courtesy Airbus)



output spectrum

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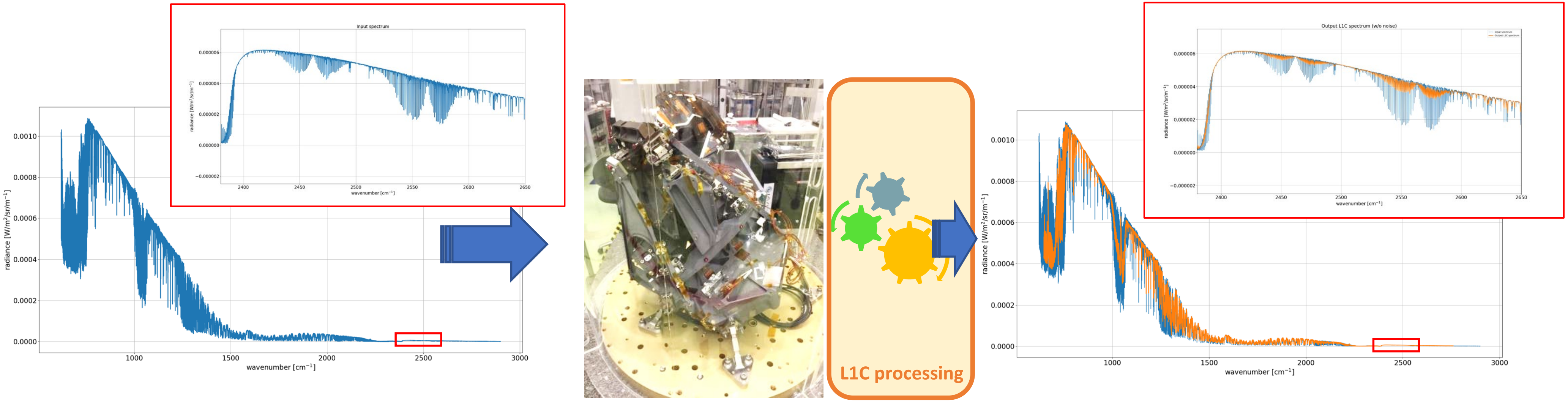

input spectrum

FM1 IFM Model

(courtesy Airbus)

output spectrum

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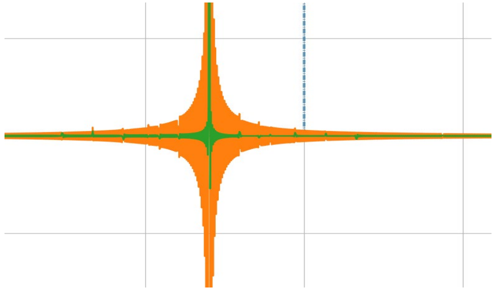
The ISRF – Estimation Model

- **IASI-NG ISRF defects**

→ **Instrument impact on ISRF can be separated into 2 main categories :**

➢ **Defects induce by the gap between the realized instrument and the ideal ones :**

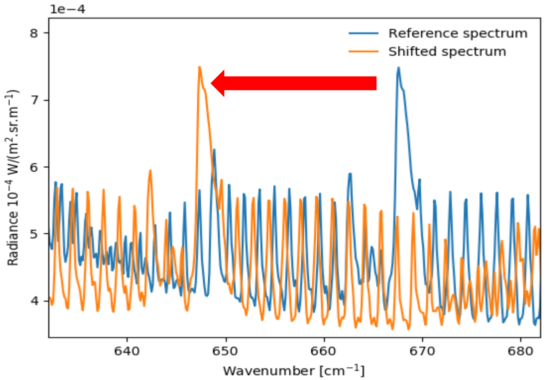
- **optics realization (MSE,…),**
- **alignments,**
- **cinematic perturbations during the stroke, …**
- **…**



➢ **Defects induce even if the instrument were ideal :**

- **variable spectral shift due to the opd chromaticity**

(~20cm^{-1}@645 and ~12cm^{-1}@2760cm^{-1})



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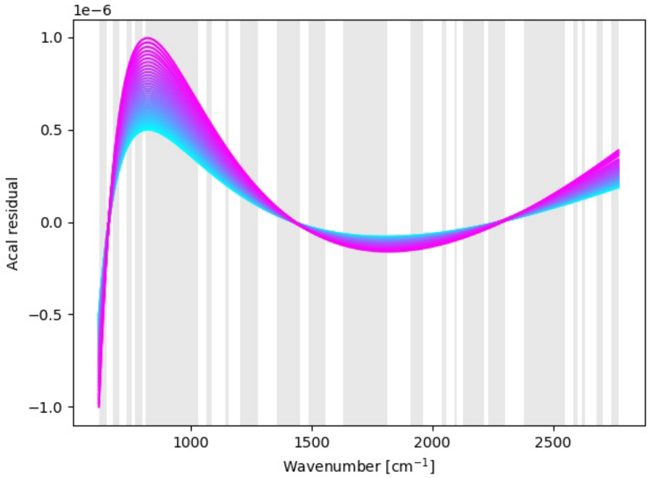
The ISRF – Estimation Model

• IASI-NG ISRF estimation performances

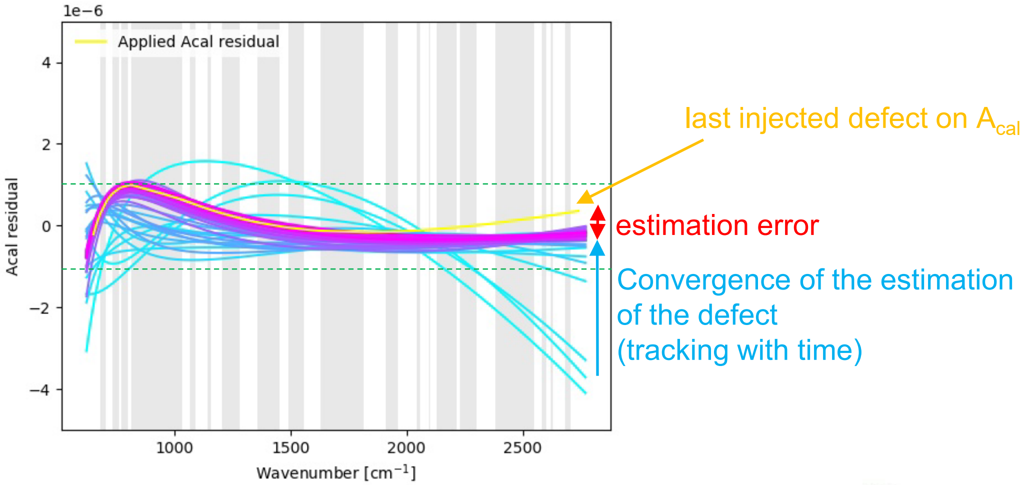
➢ **Preliminary assessments of ISRF estimation model are very promising :**

spectral shift estimation is below the **1.10^{-6}** requirements when considering around 40 tropical (night/sea) atmospheric spectra (correlated with ref. mean tropical atmos.)

Injected A_{cal} defect (linear var. with time)



A_{cal} estimation by correlation



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The ISRF – Estimation Model

- **IASI-NG ISRF estimation principle**

➢ **ISRF-Estimation Model parameters - Coefficients**

$$\mathbf{opd}(\sigma) = \left(\mathbf{A_{cal}}(\sigma) - \mathbf{C_0}(\sigma, \mathbf{Z_0})\right).\mathbf{Z_0} + \sum_{i=1}^{4} \mathbf{C_i}(\sigma, \mathbf{Z_0}).\mathbf{Z_i} + \mathbf{OFFSET}(\sigma, \mathbf{Z_0})$$

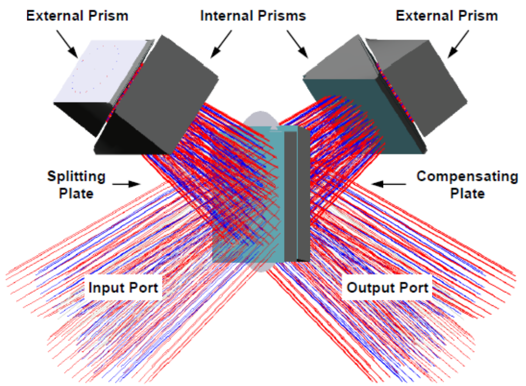
$\mathbf{Z_{i=0..4}}$: metrologies opd
$\mathbf{Z_5} = \mathbf{1}$
$\mathbf{C_{i=0..5}}$: opd coefficients

They are a combination of :

Measured coefficient :

Are expected to be updated a few times during the instrument in-orbit lifetime

dedicated acquisitions sequences (atmospheric spectra correlation + FPI)



Optical model of the interferometer

Computed coefficients

- Using a numerical model of the interferometer
- Parameters of the model can be updated in-orbit using WFS

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System performances budget

- **Synthesis of the current performances budget (compared to specifications at mission level) for the main requirements**

Description	Specified value / calculated value	Status
ISRF shift knowledge	1E10-6 / 1E10-6	compliant
ISRF shape error index	0.25% / 0.27% (parasitic contribution)	Marginally NC
Interpixel ISRF stability	1E10-4 / 3.3E10-5	compliant
Radiometric noise	See previous figure	compliant
Absolute radiometric calibration	0.25 K (O) and 0.5 K (T) / 0.24K	compliant
PSF uniformity knowledge	+/- 10 % / 14%	compliant
PSF characterization	-	No budget available
Spatial resolution	11.5 +/- 0.5 km / 11.8km	compliant
Ground sampling	3mrad / 3.2mrad	NC in worst case (compliant in typical case)
Pointing knowledge	+/- 3 mrad / 0.9mrad	compliant
Pointing accuracy	+/- 3 mrad / 0.91mrad	compliant
Pointing stability	0.1 mrad / 0.062 mrad	compliant
Sounder geolocation	1km / 949 m	compliant
Geolocation in degraded case	5km / 1108 m	compliant

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