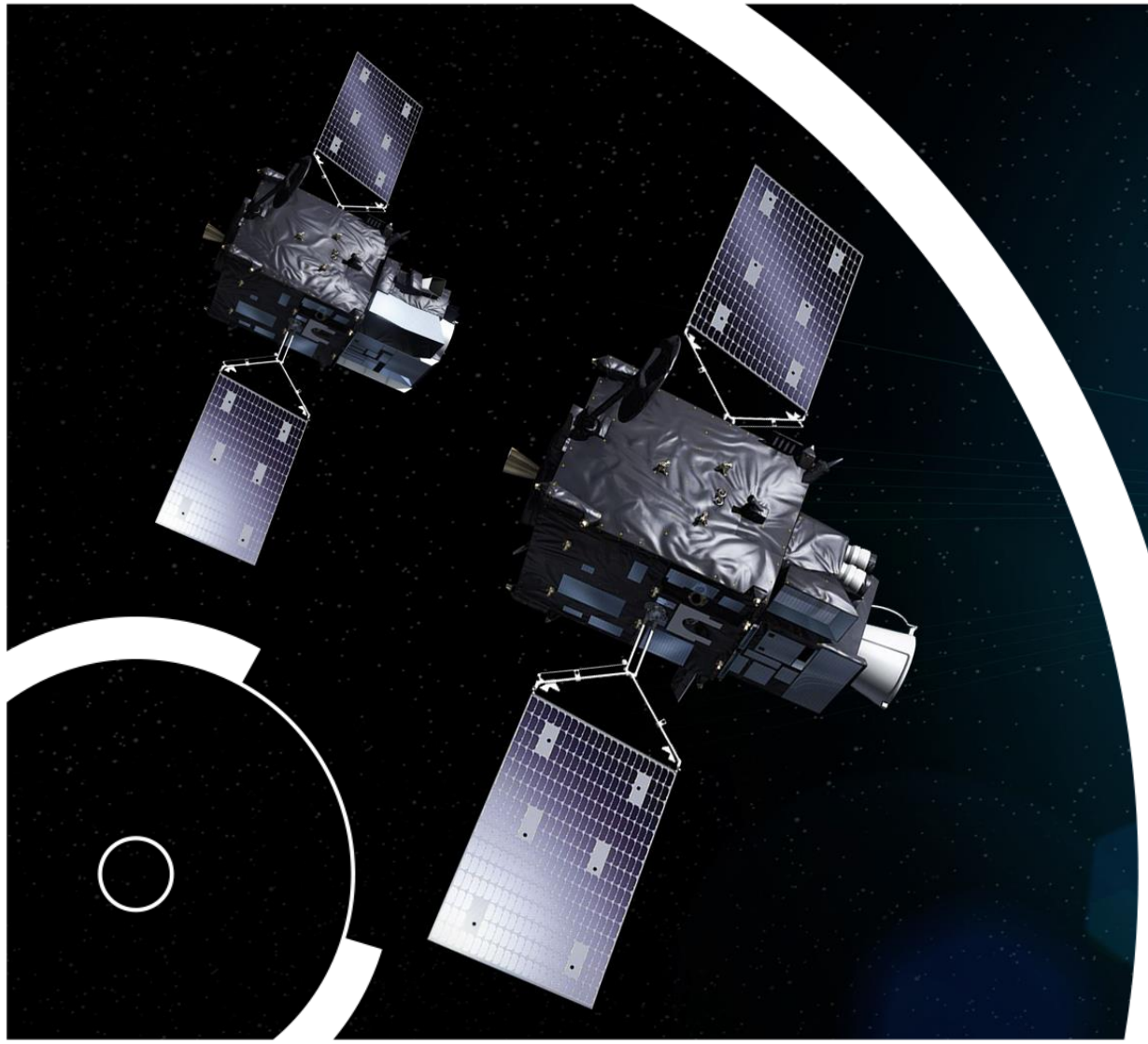

Calibration Ringing and its correction in MTG-S IRS

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Agenda

Calibration Ringing in Fourier Transform spectrometer,

Application to IRS LWIR band:

- **Definition**
- **Correction**
- **Discussion**
- **Summary**

Definition

- **Measurement**: $L1A(\nu) = ($ *Scene:* $\boldsymbol{Sp(\nu)}$ $\times$ *Instrument transmission:* $\boldsymbol{R(\nu)}$ $) \otimes$ *Spectral Response Function:* $\boldsymbol{SRF(\nu)}$

- **Radiometric calibration**:

$$L1A_r(\nu) = \frac{EV(\nu) - DS2(\nu)}{BB(\nu) - DS1(\nu)} \times \Gamma(\nu, T_{BB})$$

- **Radiometric calibration**:
  - Same transmission for the four views (back optics)
  - The BB spectrum is flat at the scale of the SRF,

$$\rightarrow \boxed{L1A_r(\nu) = \frac{[(Sp_{atm} \times R) \otimes SRF](\nu)}{[R \otimes SRF](\nu)} \neq [Sp_{atm} \otimes SRF](\nu)}$$

  - The product still depends on the instrument,
  - The radiometric calibration “works” only if the transmission R is also flat at the scale of the SRF.

Definition

- **SRF distortion**:

(Dussarrat et al. *arXiv:2111.08574*, 2021)

  - The SRF is distorted:

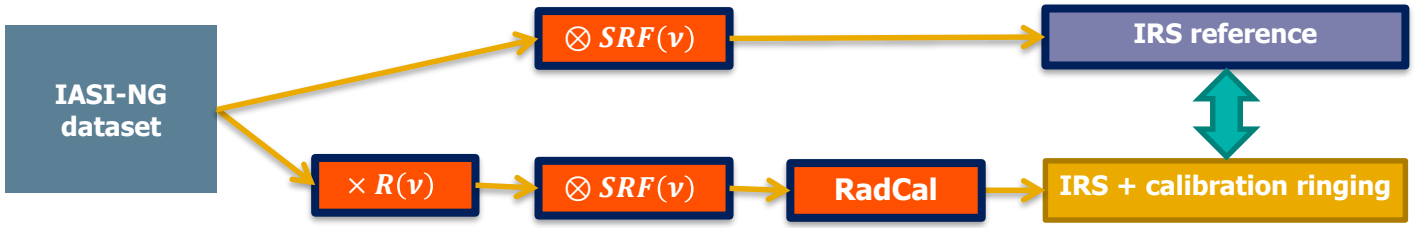
$$\widetilde{SRF}_{\nu_0}(\nu) = \frac{R(\nu_0 - \nu)}{[R \otimes SRF](\nu_0)} \times SRF(\nu)$$

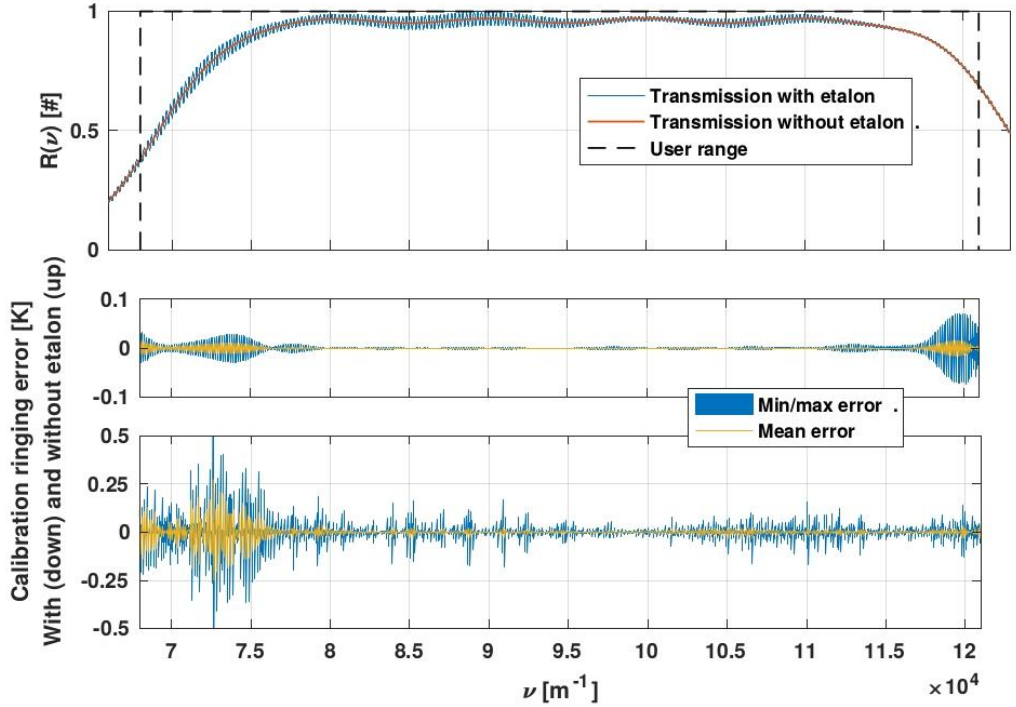
  - The calibrated product at ν_0 depends on the local behaviour of the transmission around ν_0.
  - **NB**: That is why the industry provides the SRFs including the distortions for all channels and pixels. Therefore the data can be well interpreted anyway !

  - **However, it is not reasonable for most users to account for this distortions in their applications (in the RT-models for example)**
  - If we neglect the distortions in the data application, it leads to a radiometric error called the: **Calibration Ringing.**

Calibration Ringing: Example IRS

- **Example of calibration ringing**:
  - In the context of MTG-S IRS LWIR band
    - Low finesse etalon in a protective layer producing a transmission modulation: few %, etalon frequency: $\mathrm{f} \sim 0.4cm$
  - Using a IASI-NG simulation dataset as a high-resolution proxy for IRS, we compute the expected error:





- No calibration ringing expected in MWIR (not shown)
- Etalon is dominating the error,
- Calibration ringing < 100mK bias for > 800cm^{-1}
- Maximum error: 500mK at 720cm^{-1} (TBC)

Calibration Ringing Mitigation / Correction

- **Radiometric Transfer Function (RTF) Uniformisation - IRS**:
  - We look for a "direct" post-correction, multiplying the product by $f_{corr}(\nu)$:

$$L1B(\nu) = L1A_r(\nu) \times f_{corr}(\nu) = [Sp_{atm} \otimes SRF](\nu)$$

  - We use a high-resolution guess of the atmospheric spectrum $Sp_{ref}(\nu)$:

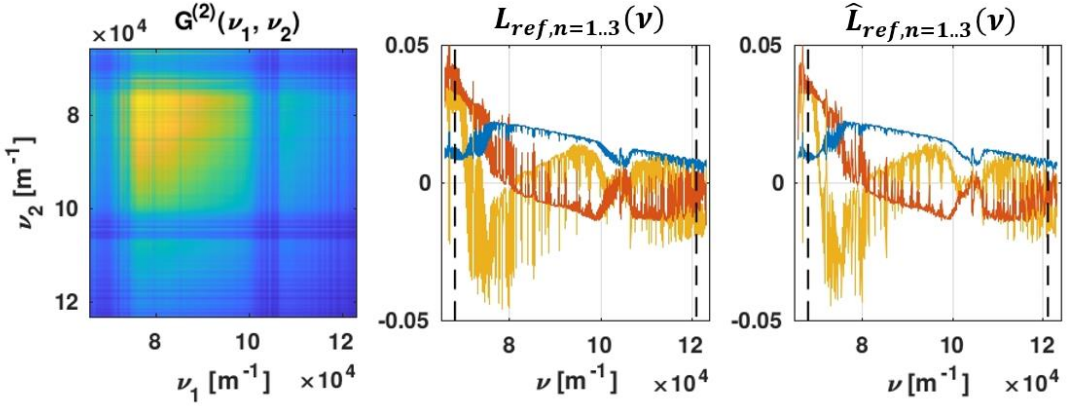
$$L1B(\nu) = \overbrace{\frac{[(Sp_{atm} \times R) \otimes SRF](\nu)}{[R \otimes SRF](\nu)}}^{L1A_r(\nu)} \times \overbrace{\frac{[R \otimes SRF](\nu) \times [Sp_{ref} \otimes SRF](\nu)}{[(Sp_{ref} \times R) \otimes SRF](\nu)}}^{f_{corr}(\nu)} \cong [Sp_{atm} \otimes SRF](\nu)$$

    Required high-resolution guess equivalent maximum OPD: $> 0.8cm + 2f \sim 1.6cm$

  - The high-resolution guess is performed using a principal component decomposition.

Calibration Ringing Mitigation / Correction

- **Radiometric Transfer Function (RTF) Uniformisation - IRS**:
  - We define a high resolution basis and its IRS-resolution counterpart:



  - The PC scores are computed and used to define the guess:

$$PC(n) = \sum_{\nu_0} L1A_r(\nu_0) \times \hat{L}_{ref,n}(\nu_0) \quad \rightarrow \quad Sp_{ref}(\nu) = \sum_{n} PC(n) \times L_{ref,n}(\nu)$$

  - Finally the correction vector is computed:

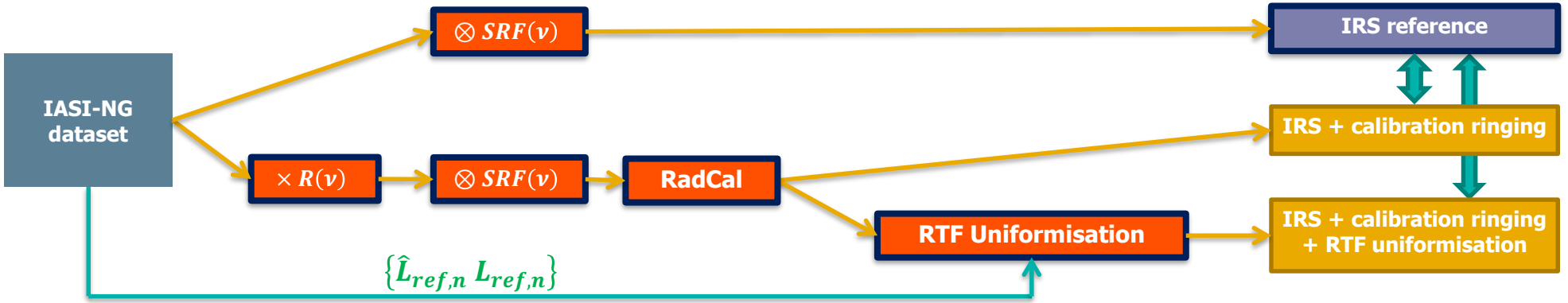
$$f_{corr}(\nu) = \frac{[R \otimes SRF](\nu) \times [Sp_{ref} \otimes SRF](\nu)}{[(Sp_{ref} \times R) \otimes SRF](\nu)}$$

From the DS1 and BB calibration views

High-resolution interpolation of $[R \otimes SRF](\nu)$
Accurate if etalon frequency $f < MOPD$: Ok

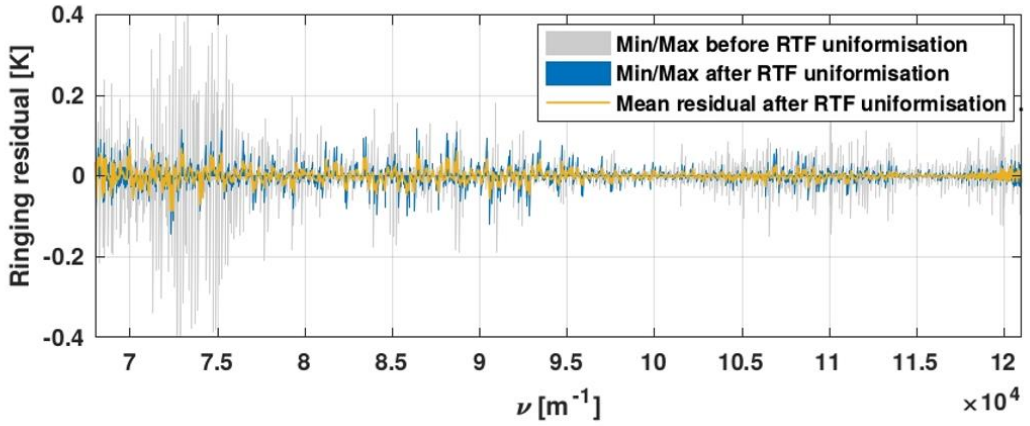
RTF Uniformisation Simulation

- **Results**:
  - A IASI-NG simulation dataset is used to compute the two PC basis (orbit nb 1) and the IRS measurements as proxy (orbit nb 2).



  - Using 10 PCs, we decrease the maximum error from 500 to 100mK.

  - The efficiency is intrinsically limited since we cannot perfectly guess a high-resolution spectrum from only low-resolution measurements.



Discussion

- **Instead of the RTF Uniformisation, can we account for the SRF distortions in the data application, in the RT-models for example ? Yes but no.**
  - The etalon properties depend on the pixel and wavenumber, therefore one should use many high-resolution SRFs,
  - One set of RTTOV coefficients for every pixels and channel in the LWIR ?! It seems out of reach for most of us !

- **Can the RTF uniformisation impact some species retrieval ?**
  - The RTF uniformisation is planned to be applied only at the beginning of LWIR band of IRS, in the CO2 band.
  - The PC basis could be produced using real measurements as IASI-NG to avoid potential model biases.
  - **To be discussed !**

- Transmission variations at the scale of the SRF should be corrected at hardware level if possible in the next generation of instruments ! **And IASI-NG ?**
  Most likely a forgotten effect since it had no impact on IASI (~flat RTF) !

Summary

- The Radiometric Transfer Function “fast” spectral variations are not properly cancelled at the radiometric calibration step.
- The residual is called the Calibration Ringing.®
- Its impact is computed by the industry for information but not accounted in the radiometric budget
- Calibration ringing could have an impact on IRS (~500mK error max < 800cm^{-1}) for the users not using the SRFs per pixel and channel including the distortions. **TBC**

  NB: Nonetheless, the IRS performance should remain excellent !
- Calibration ringing cannot be corrected by simple bias correction or standard uniformisation.
- **For IRS LWIR band, EUM in collaboration with Spascia has developed a post-correction using high resolution guesses, ready for launch in IDPF-S v2.**

  → RTF Uniformisation : 500mK error max to 100mK max

Thank you!

Questions are welcome.