SCIAMACHY Calibration Lessons Learned

G. Lichtenberg, S. Slijkhuis and many more

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Outline

1. Intro
2. Calibration Team
3. The Instrument
4. Calibration Concept
5. What?
6. Summary
7. Additional Slides

Introduction

- This is not a blame game: there were always reasons for the decisions made
- Hindsight is easy: some things were just unknown
- No great revelations: most things here are no-brainers (or so you would think)
- In the following we present generic, high level lessons that can be applied to any spectrometer

Calibration Team

In no particular order!

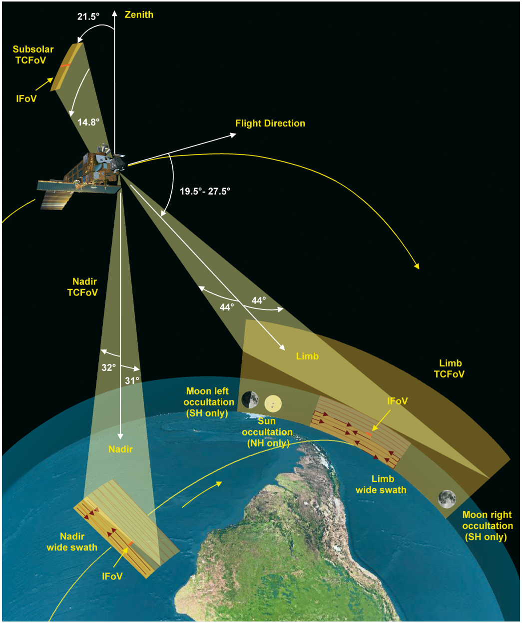
Institutions: SRON, TPD/TNO, DLR-IMF, IUP Bremen, ESA, KNMI

People (I could remember): R. Snel, J.M. Krijger, R. Hoogeveen, Q. Kleipool B. Ahlers, G. Otter, H. Visser, C. Schrijvers, M. Dobber, R. Soffer, M. te Plate S. Noel, K. Bramstedt, P. Liebing, R. de Beek, M. Wuttke, J. Skupin, H. Bovensmann, J. Burrows J. Frerick. P. Lützow-Wentzky, R. Mager S. Slijkhuis, G. Lichtenberg, M.Gottwald, E. Krieg P. Stammes, G. Tilstra, . . .

Reminder: The Instrument

- Measurement Principle: 2 scanning mirrors & 1-dim photodiode arrays, Polarisation with broadband PMDs
- Observation Modes:: Nadir, Limb, Occultation
- Targets: Earth, Sun, Moon (& Venus)
- Spectral Range: 213 - 1773 nm, 1934 - 2044* nm, 2259 - 2386 nm in 8 channels
- Spectral Resolution: 0.22 - 0.56 nm, 1.48 nm (ch. 6)
- Detectors Passively cooled RETICON (UV/VIS) and EPITAXX InGaAs (SWIR)
- Calibration: WLS, SLS, backside of scanner modules with diffusers

Modes



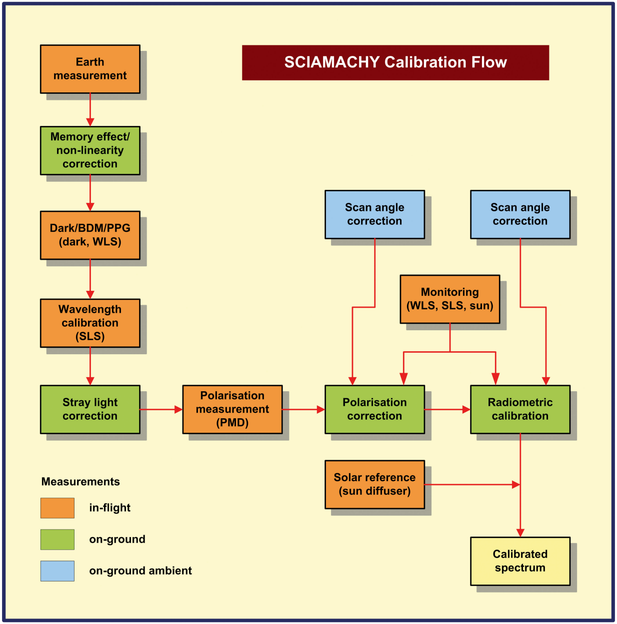
21.5°
Zenith
Subsolar TCFoV
IFoV
14.8°
Flight Direction
19.5°- 27.5°
Nadir TCFoV
44°
44°
Limb
Limb TCFoV
32°
31°
Moon left occultation (SH only)
Sun occultation (NH only)
IFoV
Nadir
Limb wide swath
Moon right occultation (SH only)
Nadir wide swath
IFoV

Calibration Concept - on-ground

- Special SCIA needs:
  - (a range of) scan angles had to be measured
  - no polarisation scrambler or fixing of observed polarisation
- There was no T/V tank available to measure all needed angles in vacuum ⇒ combined ambient & T/V calibration
  - Ambient measurement on the scanner (combination) with a number of incidence angles and wavelengths
  - Assume this covers the geometric dependencies of the whole instrument
  - Measure a reference incidence angle in T/V and ambient
  - get the angle dependency from ambient measurements and the absolute values from T/V
- Measure polarisation sensitivity for s/p and -45/45
- Mathematically the Mueller Matrix formalism was used

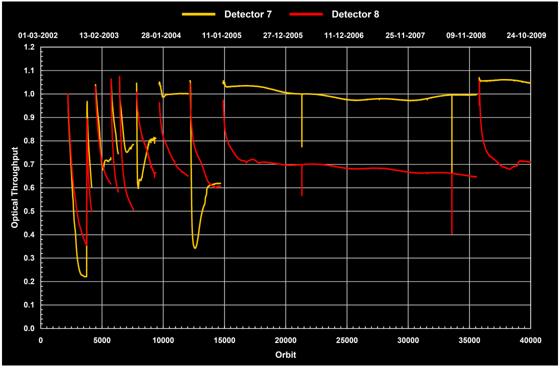
Calibration Concept - in-flight

- Dark: 5 measurements into deep space (250km TH) to derive darks for all ITs
- Spectral: Sun and SLS measurements
- Degradation:
  - Use Sun over mirror and WLS in different light paths
  - Sun was observed in Limb mode (Nadir & Limb mirror and Extra mirror), subsolar (Nadir mirror)
  - Observe Moon
  - The combination of all measurements allowed to characterise the individual light path degradation


SCIAMACHY Calibration Flow
Earth measurement
Memory effect/ non-linearity correction
Dark/BDM/PPG (dark, WLS)
Wavelength calibration (SLS)
Stray light correction
Polarisation measurement (PMD)
Polarisation correction
Radiometric calibration
Scan angle correction
Scan angle correction
Monitoring (WLS, SLS, sun)
Solar reference (sun diffuser)
Calibrated spectrum
Measurements
in-flight
on-ground
on-ground ambient

Source: SRON

Not enough photons



Source: IUP Bremen

- ENVISAT carbon fibre frame outgassed water
- Venting was (partially) blocked (MLI ENVISAT + MLI SCIA)
- Detectors cool down to 140 - 200 K
- ⇒ Ice
- Lesson: Detector should not be the coldest surface
- Recovery: Decontamination scheme

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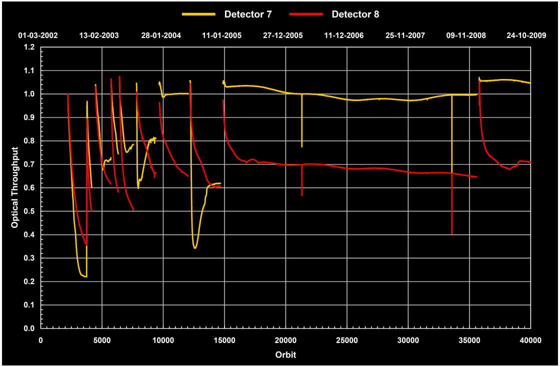

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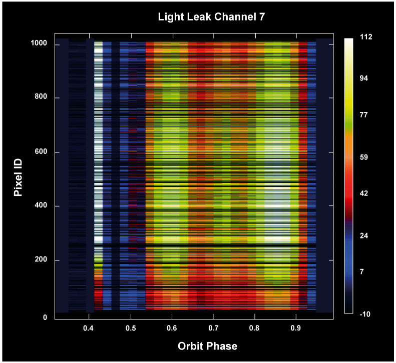

Source: DLR-IMF/SRON

- The housing of channel 7 is not light tight
- Light from an unknown place falls on the detector
- Tests for light tightness were done but only in ambient
- SWIR detector noise under ambient conditions was too high to discover the leak (if it was there and did not happen during launch)
- Position of light leak could not be identified with certainty
- Lesson: no shortcuts
- This is the one case which we did not recover from (yet)

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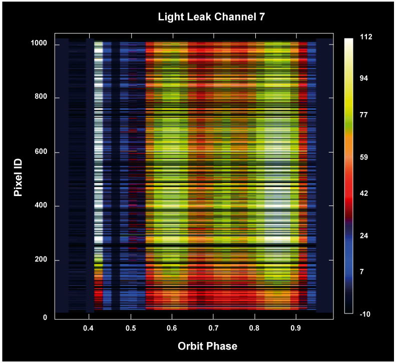

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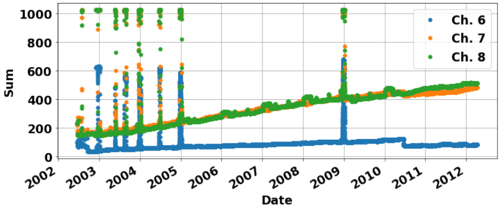
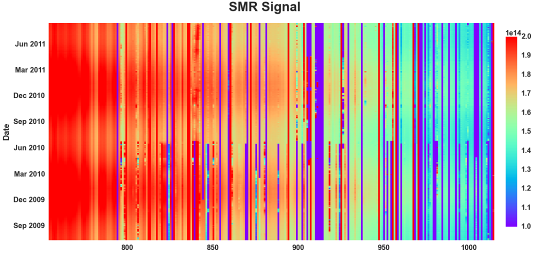
Pixels go bad/die/resurrect





- SWIR Detectors are EPITAXX detectors with a light detecting InGaAs layer on top of a InP substrate
- The doting of the InGaAs layer was changed to get sensitivity at longer wavelengths
- ⇒ Lattice mismatch between InGaAs and substrate
- ⇒ Sensitivity to proton impact damaging pixels
- Solution: Monitor all pixels with various measurements
- Lesson: Monitoring concept, Calibration goes on

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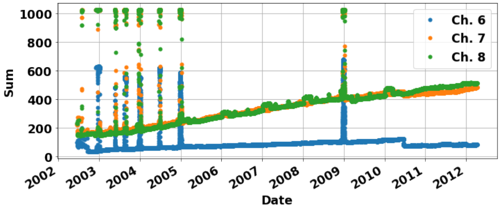

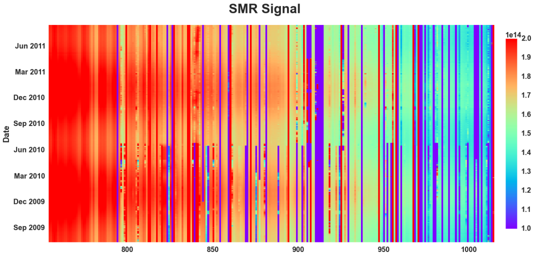

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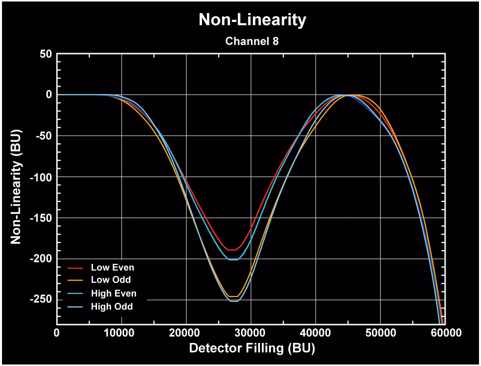

Source: SRON

- On-ground measurements of the NL were done but hampered by an instable light source
- Only one average per multiplexer NL was derived, but commissioning phase measurements showed that this is not sufficient
- Incorporation of more on-ground measurements and a re-analysis led 14 new curves
- NL correction was checked with on-ground data
- Lesson: redundant measurements, availability of on-ground data is needed

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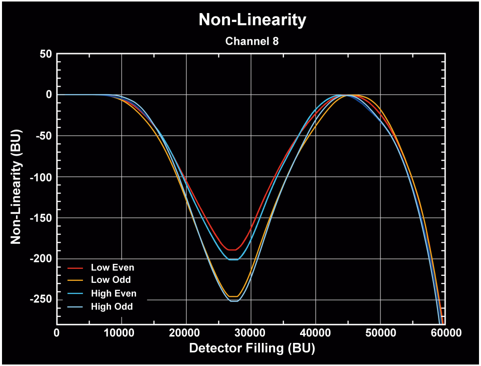

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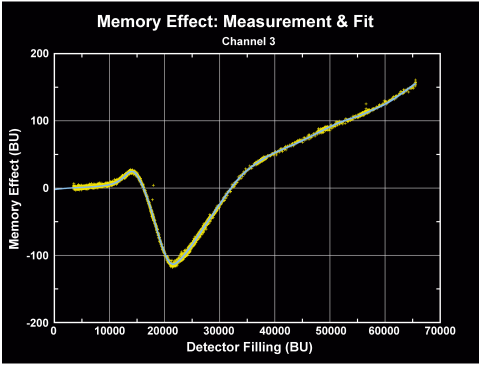
Unexpected Detector Behaviour (II)



Source: SRON

- The memory effect correction was measured on-ground
- Measurements for one channel were taken (scaled for ch. 1) for all channels, reason not entirely clear from documentation
- Key data derivation was not described in detail
- In-flight measurements could be defined to measure the MEC
- Analyses resulted in dedicated curves for each channel and the discovery of a saturation effect (which was seen but not investigated before)
- Lesson: Document everything, no short cuts, keep the instrument flexible

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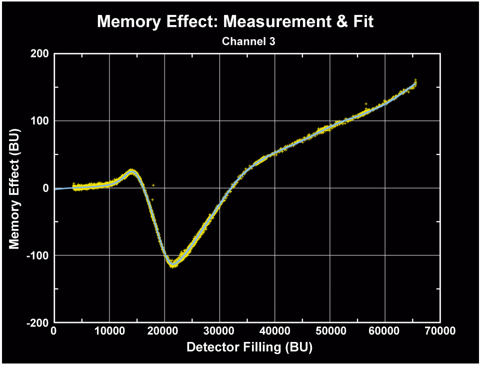

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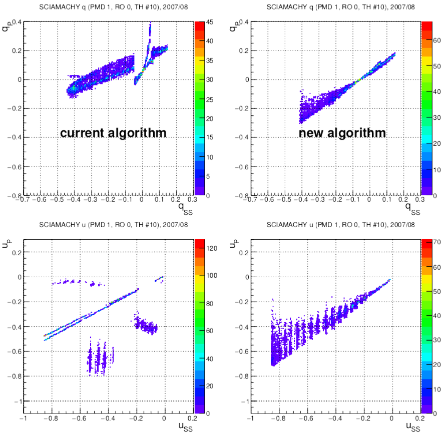
Radiance & Polarization (I)

Radiometric

- first comparisons showed a significant difference between expected and measured (ir)radiances
- this required a major re-analysis and led to the re-calculation of key data
- the exact set-up of measurements could not always recovered
- in order to recover, all redundant measurements were needed (FEL lamp with different geometries, sphere measurements)

Radiance & Polarisation (II)



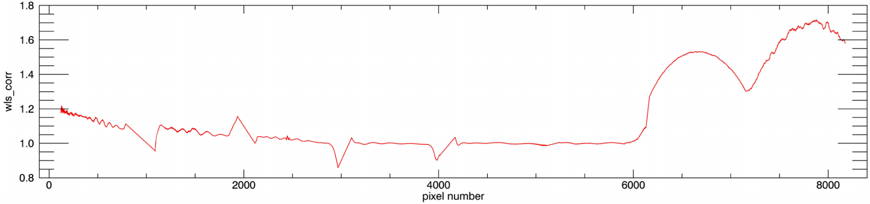
Source: IUP Bremen

- The polarisation correction is a combination of on-ground calibration, in-flight PMD measurements and theoretical assumptions
- The instrument showed an unexpected polarisation phase shift
- The initially used polarisation key data were not consistent with each other
- The reference frame for the polarisation data had to be newly derived, because from the measurement logs it was not clear
- Left: L01 V8 and V9 polarisation calculation (V9 used completely revised correction)

Radiance & Polarisation (III) - Lessons

- Redundant measurements
  - Radiometric: different distances in a given config and different set-ups (e.g. FEL & Sphere)
- Documentation!
- Quick looks and pre-analysis
- Use L01 processor already in on-ground calibration (Formats, Algorithms)
- Polarisation: Either
  - measure polarisation on same spectral resolution as science channels
  - scramble it
  - or fix it

On-ground → In-flight

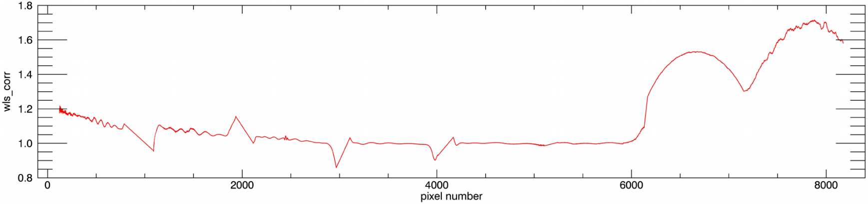


Source: IUP Bremen

- There will be always a difference between the on-ground calibration and the first in-flight measurements
- The longer the storage the more likely are larger changes
- In SCIA the internal WLS was used to correct the effect
- For the correction we also had to take into account a 97K higher lamp temperature (micro-gravity effect)

- Lessons:
  - Incorporate on-ground → in-flight in calibration scheme (using internal light sources)
  - Do this measurement as early as possible to have a proper reference point and avoid ageing effects of the light source

On-ground $\rightarrow$ In-flight



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Summary

1. Document. Each. And. Every. Step.
2. Redundant measurements are mandatory (and not "nice to have")
3. There are no short cuts
4. Quick looks + first analysis on-site are essential
5. Calibration goes on (and on) ⇒ access to on-ground calibration data
6. Do not neglect the technical stuff (data formats, analysis S/W)
7. Develop an integrated calibration concept for on-ground, in-flight and monitoring
8. Have a flexible instrument operation concept (even if not needed during nominal operation)
9. Fight for your calibration time

Channels & PMDs

Channel	Range/Resolution	PMD	Range
1	214 - 334/0.24 nm		
2	300 - 412/0.26 nm	A	310 - 365 nm
3	383 - 628/0.44 nm	B	455 - 415 nm
4	595 - 812/0.48 nm	C	610 - 690 nm
5	773 - 1063/0.54 nm	D,45	800 - 900 nm
6	971 - 1773/1.48 nm	E	1500 - 1635 nm
7	1934 - 2044/0.22 nm		
8	2259 - 2386/0.26 nm	F	2280 - 2400 nm

Mueller Matrix

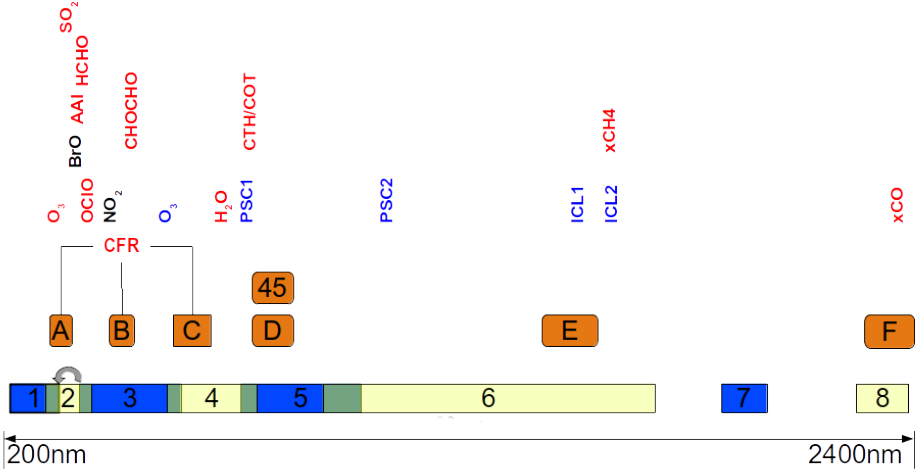
- Mueller Matrix

$$\begin{pmatrix} S \\ Q \\ U \\ V \end{pmatrix}_{det} = \begin{pmatrix} M_{II} & M_{IQ} & M_{IU} & M_{IV} \\ M_{QI} & M_{QQ} & M_{QU} & M_{QV} \\ M_{UI} & M_{UQ} & M_{UU} & M_{UV} \\ M_{VI} & M_{VQ} & M_{VU} & M_{VV} \end{pmatrix} \cdot \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}_0$$

- (I, Q, U, V): Stokes Vector

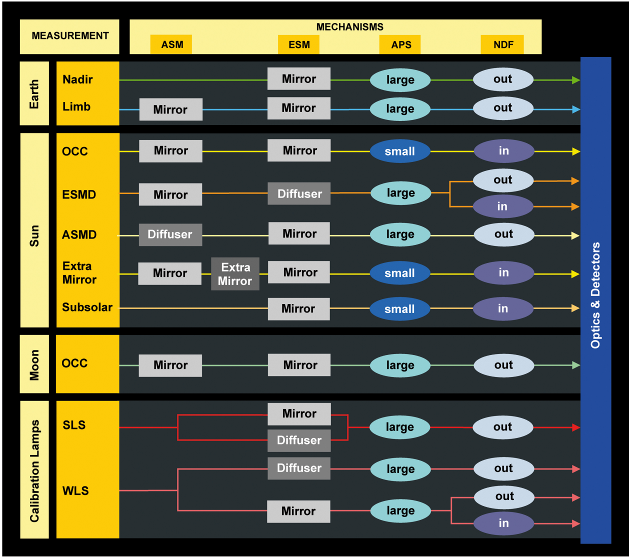
SCIAMACHY Wavelength Bands & Products (to scale):

- 8 Science Channels (1024 pixels), Resolution 0.2 - 1.48 nm
- Broadband: 6 PMD A -F (p) and 1 PMD +45°



Colours: Nadir, Limb, Both
CFR/TH/OT: Cloud Fraction/Top Height/Optical Thickness
ICL: Ice Cl.; NCL: Noctilucent Cl.; PSC: Polar Stratosph. Cl.

Calibration Concept - in-flight



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