SCIAMACHY detectors: Calibration on-ground and in-flight

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Outline

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✦ Calibration concept
✦ Detector issues
✦ Thermal control system
✦ In-flight performance
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Instrument Introduction (I)

- **SCIA is**
  - A scanning Nadir + Limb spectrometer
  - Covering wavelengths from the UV -> VIS -> NIR at moderate resolution
  - Measuring Polarisation with broadband detectors
  - Polarisation sensitive
Calibration Concept (I)

- Calibration and/or instrument design should:
  - Not introduce air-vacuum effects (like it happened in GOME)
  - Remove detector temperature effects
  - Remove polarisation features introduced by the instrument
  - Remove effects of detector material and electronics
  - Avoid instrument features (esp. caused by dichroics) appearing in important spectral retrieval regions
  - Be able to track changes of the instrument in-flight
Calibration Concept (II)

- Calibration of SCIA consist of 4 Types of Measurements:
  - On-ground under thermal vacuum conditions ('OPTEC'), the whole instrument is put in a tank and measured for one mirror incidence angle (=reference angle) and full wavelength grid
  - On-ground under ambient conditions on component level (mirror(s) and/or diffuser combination) for selected angles and selected wavelengths (including the reference angle)
  - In-flight dark, spectral and solar irradiance measurements
  - Monitoring measurements using sun and WLS to account for long-term degradation (see previous talk by M. Wuttke)
Calibration Concept (III)

- In-flight Earth msm
- In-flight calibration (WLS, SLS, Darks, Sun)
- Monitoring
- Polarisation correction
- Radiometric correction
- Calibrated Spectrum
- Scan angle correction

in-flight Measurements
on-ground T/V conditions (instrument)
on-ground ambient conditions (component)
Calibration Concept (IV)

- Assumptions implicit in calibration:
  - Scan angle correction:
    - Polarisation dependence of mirrors/diffusers is the same in air and vacuum
    - No temperature dependence
  - Monitoring:
    - Degradation is independent of scan angle
    - Degradation does not influence polarisation sensitivity
    - Instrument didn't degrade between calibration measurements and begin of in-flight measurements
Detector issues (I)

- 2 types of detectors are employed in SCIA
  - Standard silicon detectors (Reticon):
    - for the UV/VIS range (channels 1-5)
    - read out of 1024 pixel is sequential (leading to some spatial aliasing)
    - These detectors show a 'memory effect', i.e. a read-out shows a positive or negative offset depending on the detector filling of the previous read-out
  - EPITAXX InGaAs detectors with custom designed optics and read-out electronics
    - for the NIR range (channels 6-8)
    - read out is parallel for all 1024 pixels
    - These detectors show non-linearity and bad or dead pixels (i.e. pixel that are not connected or have an anomalous behaviour (telegraph pixel, excessive noise etc.)
Detector issues (II)

Memory effect in channel 3 (in-flight measurement)
Detector issues (III)

Non-linearity (Q. Kleipool, SRON)
Detector issues (IV)

Bad & Dead Pixels in channel 7

Channel 7 dark smear, no corrections
The thermal control system

- The thermal system of SCIA:
  - A passive radiant cooler (SRC) with 2 stages that cools channels 1-6 to around 200 K and channels 7&8 to around 130 K (depending on season)
  - (Manually) controlled detector trim heaters that can raise the temperatures of the detectors up to a certain degree (power limited)
  - Optical bench temperature is controlled by an active feedback loop that holds the temperature within 17.55 +/- 0.3 °C (temperature varies over orbit) and a fail-save heater that keeps the OBM at -35°C in case of instrument shut downs
  - A heater that decontaminates the SRC; detector temperatures reach 280 K during decontamination
In-flight performance (I)

❄ Ice on channels 7&8:
  ❄ Soon after the cool-down of the instrument it was discovered that channels 7&8 lose transmission rapidly
  ❄ The reason is a (water?) ice layer developing on the lens glued on top of the detector
  ❄ Channel 7 and 8 behave very differently for an unknown reason
  ❄ The ice layer thickness can reach 230 um in channel 7 and 600 um in channel 8
In-flight performance (II)

Comparison of Decontaminations (Ch.7)

- Corrections: Dark, solar distance
- Crosses: August '02 NNDEC (86h)
- Triangles: November '02 Flash DEC (8h)
- Diamonds: December '02 NNDEC (351h)
- Asterisks: April '03 NNDEC (30h)
- Squares: May '03 NNDEC (60h)
- Circles: August '03 (375h)
- Blue Crosses: December '03 NNDEC (60+272h)
- Red Triangles: June '04 (240h)

Data adapted from work by B. Lichtenberg (09/04/2004)
In-flight performance (III)

Comparison of Decontaminations (Ch.8)

- Dark, solar distance, dGE/dT
- Crosses: August '02 NNDEC (86h)
- Triangles: November '02 Flash DEC (8h)
- Diamonds: December '02 NNDEC (304h)
- Asterisks: April '03 NNDEC (300h)
- Squares: May '03 NNDEC (60h)
- X's: August '03 (375h)
- Blue Crosses: December '03 NNDEC (66+272h)
- Red Triangles: June '04 (240h)

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Generated on Sun Oct 10 12:49:50 2004 by G. Lichtenberg (Endresmehre, Utrecht)
In-flight performance (IV)

Layer Thickness Ch. 7

Time

Wavelength/Pixelnumber

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In-flight performance (VI)

- Changes in operations and calibration necessary due to ice:
  - regular decontaminations that remove the ice
  - need of dark correction on orbital base (Ch. 8 dark signal consists largely of thermal background that is attenuated by the ice)
  - transmission correction
  - slit function correction
  - ideally: detector temperature correction (the ice on thermal couplings reduces reflectivity on the IR leading to a slow increase of detector temperature of 0.02 K/day)
In-flight performance (VII)
Slit function widening (H. Schrijver/A. Gloudemans SRON)
higher orbit number = more ice
In-flight performance (VIII)

Open points:

- Reason for different behaviour of channel 7&8
- Reason for different behaviour of channel 7 after individual decontaminations (2\textsuperscript{nd} cold trap, ENVISAT operations,...?)
- Optimisation of decontamination procedure:
  - Let the transmission be the driver for decontaminations
  - Try a rapid cool-down to trap ice on a suspected 2\textsuperscript{nd} cold trap in channel 7
The number of Bad & Dead pixel is changing:

- Increase from 55 to 90 (ch6), 280 to 380 (ch7), 180 to 275 (ch8) over the last 8000 orbits
- Reason probably radiation damage (ions)
- Consequence for calibration/retrieval:
  * Dynamic instead of static mask is needed (SRON can generate a mask per orbit)
  * Monitoring of spectral retrieval windows; if too many pixels become unusable, the windows have to be changed
- It is not yet clear if the increase will continue or if it will reach a plateau
In-flight performance (X)
Change of Bad & Dead Pixel Mask channel 8 (Q. Kleipool, SRON)
In-flight performance (XI)

Reflectance comparison UV Model/SCIA (G. Tilstra, G.v.Soest, KNMI)

![Graph showing reflectance comparison](orbit_5973_2003_sahara_state.png)
Conclusions/Summary

- The calibration of SCIA in T/V avoided GOME type problems like air-vaccum effects visible in calibrated spectra
- It is of vital importance to have in-flight calibration capabilities
- The ice layer on the detectors require a lot of adjustments in operations and data processing, after implementation of these, SCIA will reach its full potential
Lessons (I)

♦ My personal wish-list for spectrographs:
  ♦ Don't try to do everything in one instrument, UV/VIS and IR instruments have often different requirements
  ♦ Handle polarisation better (esp. for UV/VIS):
    ★ Measure polarisation on the same wavelength grid as the spectrum or
    ★ Use a polarisation scrambler
  ♦ Build in a cold trap in case of low temperature detectors (even if no problems are predicted)
  ♦ QE & detector temperature:
    ★ Automatic control of temperature or
    ★ Detector material that has a QE independent of temperature
Lessons (II)

- Have enough heater power to anneal detectors
- Measure effect of ion particle impact on detector material, not only $\gamma$-radiation
- Instrument has to be characterised in T/V
- Avoid component measurements were possible
- Allow venting of detector assembly (done in SCIA but not in GOME)