The ScaRaB instrument on Megha-Tropiques

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ScaRaB

ScaRaB-MT: third model of ScaRaB

At the beginning, ScaRaB : French-Russian-German joint Mission

ScaRaB-1 on METEOR 3/7

Launch : at Plesetsk, January 25th ,1994
Data : February 24th, 1994 to March 6th, 1995
Failure due to the electrical slip ring

ScaRaB-2 on RESURS 01/4

Launch : at Baïkonour, July 10th,1998
Data : November 1998, March, 1999
Failure due to the data transmitter

ScaRaB-MT: French-Indian joint Mission

Launch : schedule on early 2011

ScaRaB follow-on ? New design

Outline

1) ***The Instrument***

2) ***Detector Characterization***

3) ***Preflight Calibration***

4) ***In-flight Calibration***

5) ***ScaRaB follow-on***

1) The Instrument

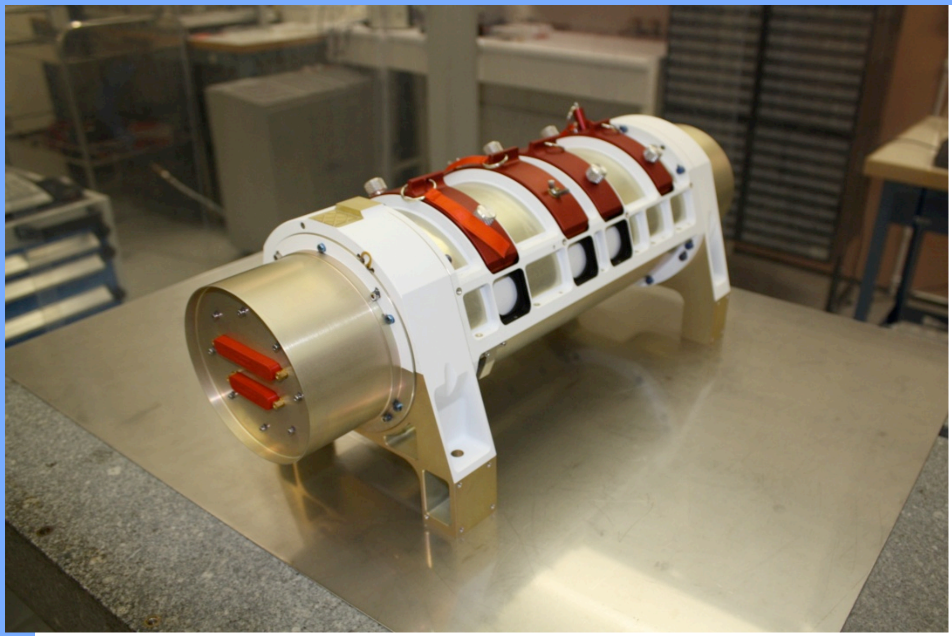
2) Detector Characterization

3) Preflight Calibration

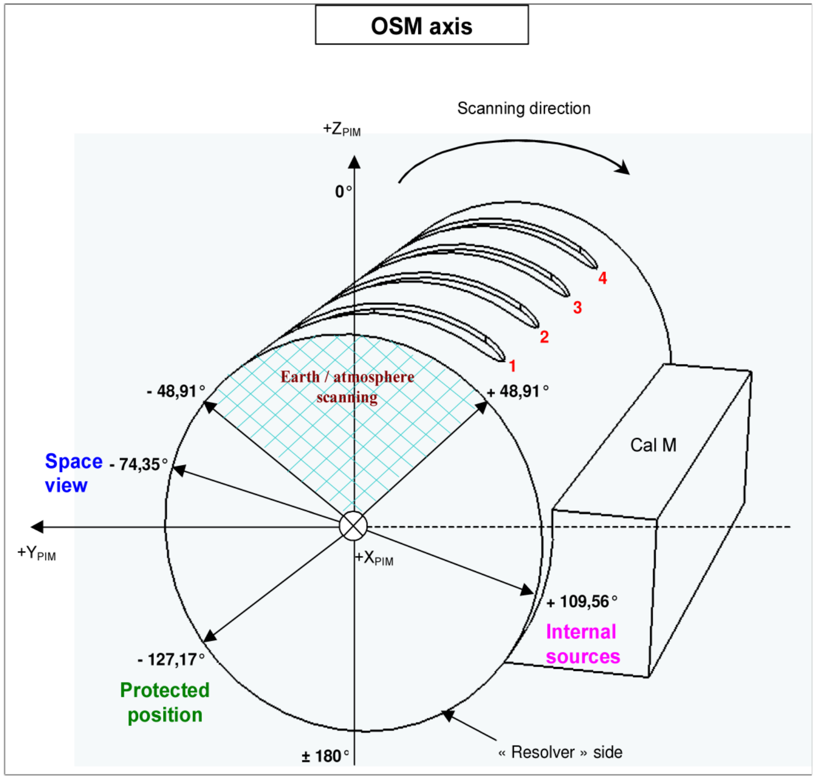
4) In-flight Calibration

5) ScaRaB follow-on

The Instrument



ScaRaB-MT without the CALM



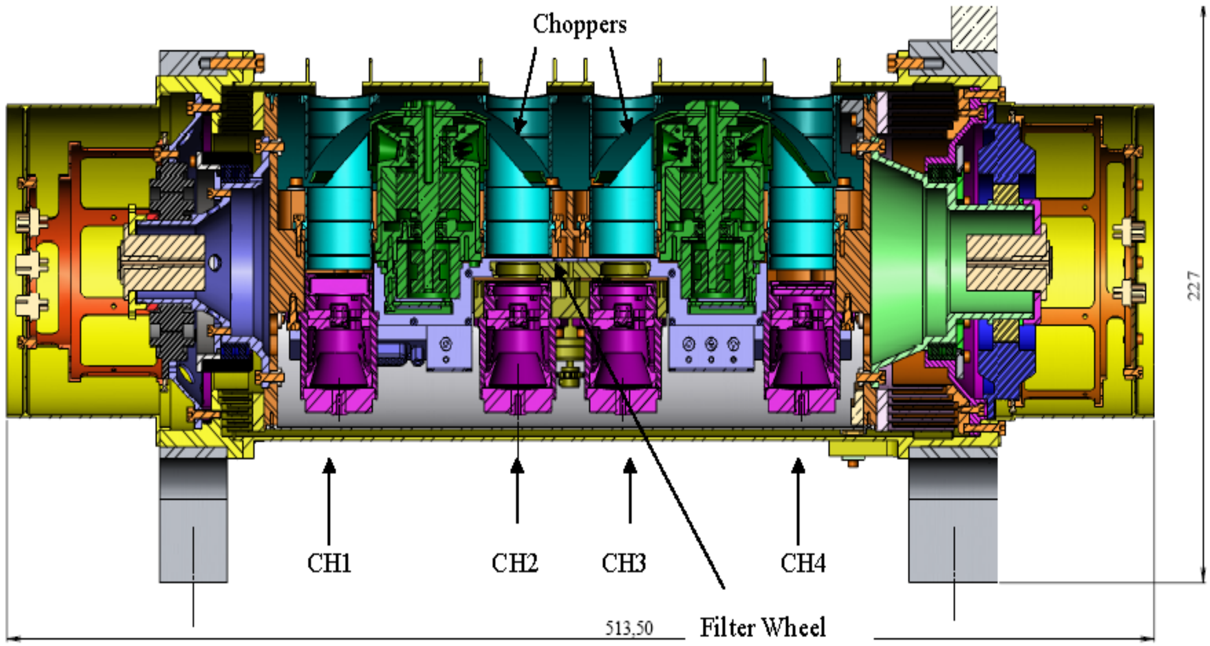
Cross track scanning

2 main channels (# 2 & 3, broad band)
2 auxiliary channels (# 1 & 4 narrow band)
Calibration Module

40 km resolution at nadir

ScaRaB MT

The Instrument



2 main parts : Stator : (grey and yellow part)

Rotor : 4 Telescopes

2 spherical Choppers

Filter wheel

The Instrument

Channel	Description	Spectral Interval	Filter
1	VIS (visible)	0.55 – 0.65 µm	Interferential
2	SW (or solar)	0.2 – 4 µm	Silice filter
3	T (total)	0.2 – 100 µm	No filter
4	IR (Infrared)	10.5 – 12.5 µm	Interferential

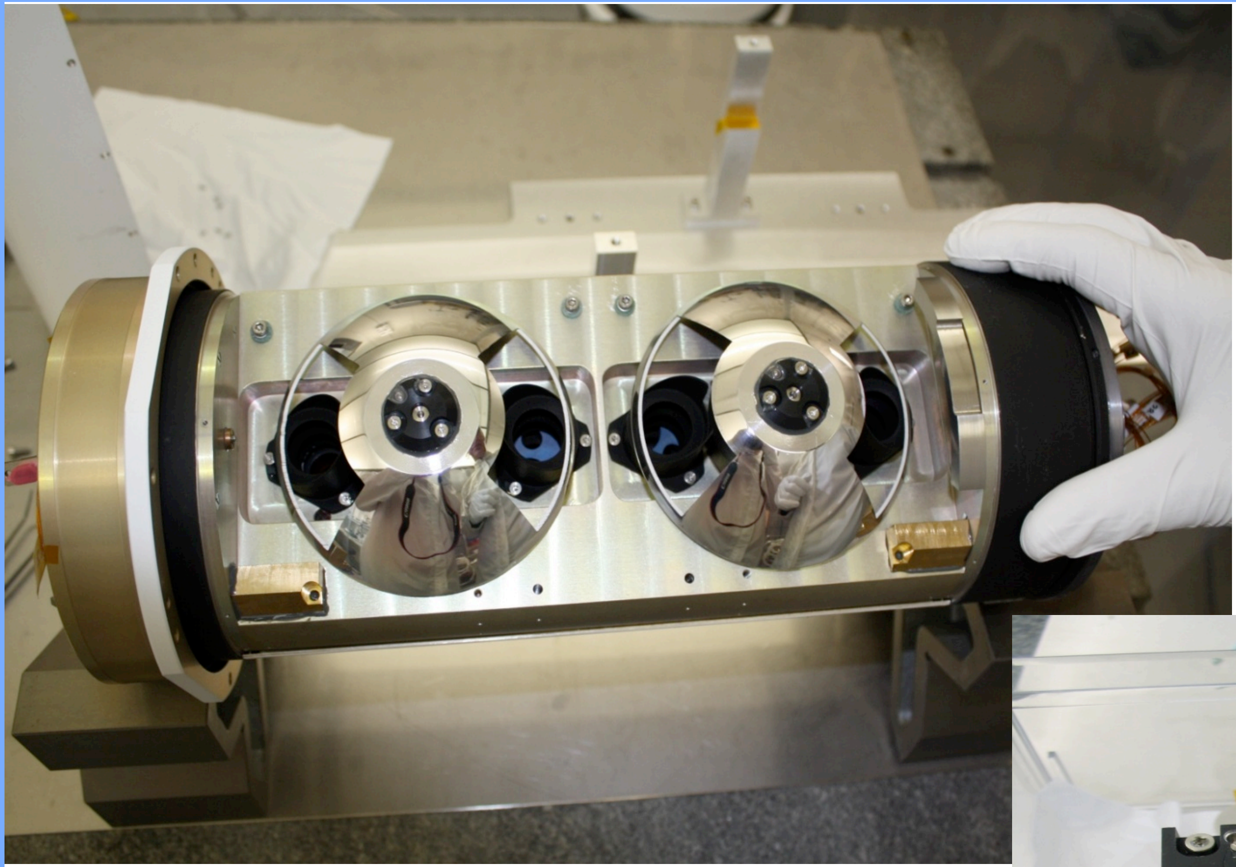
The main goal is the measurement of the two components of Radiative Budget at the top of the atmosphere

1. The solar radiation reflected by the surface/atmosphere system (SW)
2. The thermal infrared radiation emitted by the system (LW)

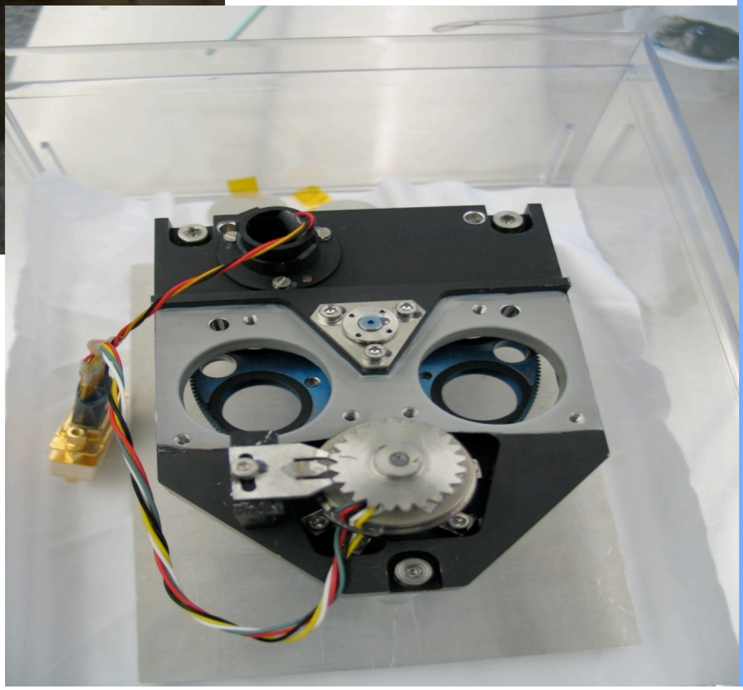
$$L_{LW} = L_{TOTAL} - A' \times L_{SW}$$

where A' : the relative SW/LW response in the Total channel

The Instrument

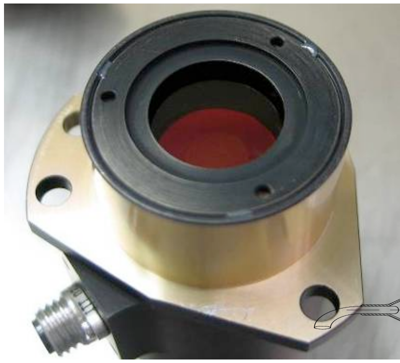


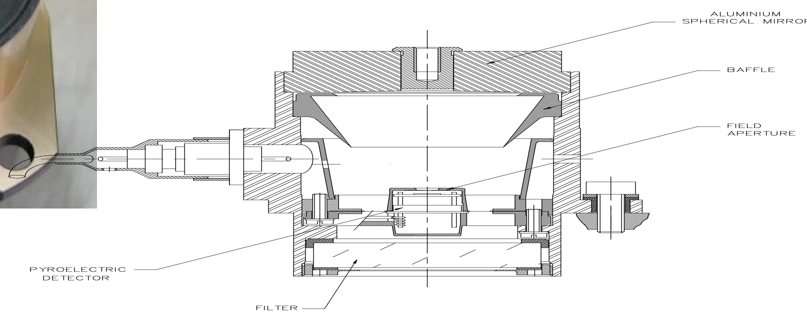
Opened ScaRaB with the 2 choppers

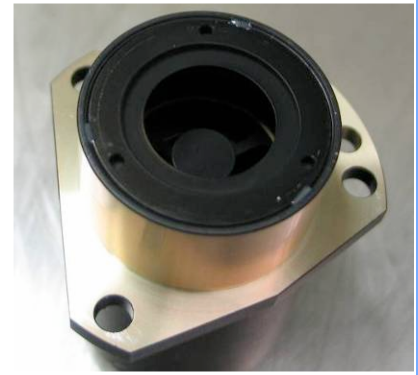


Filter wheel

The Instrument



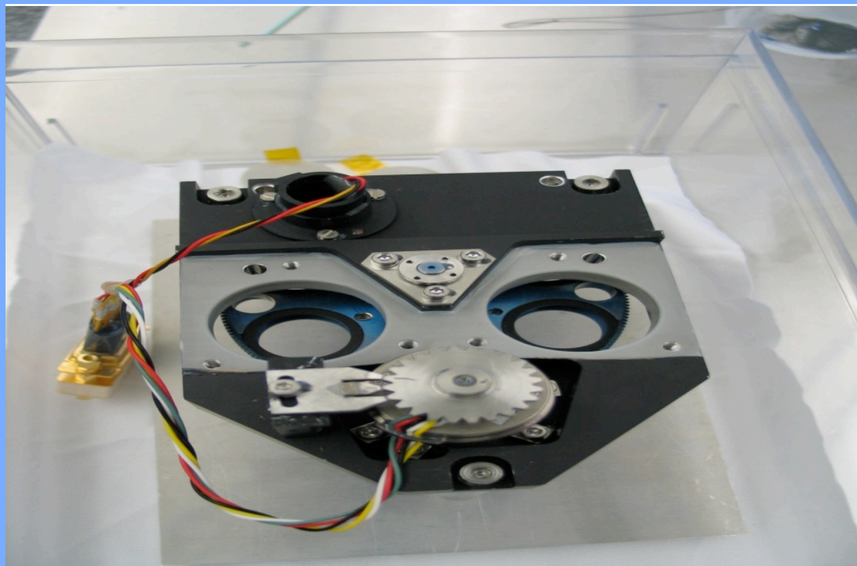




Each telescope is essentially based on:

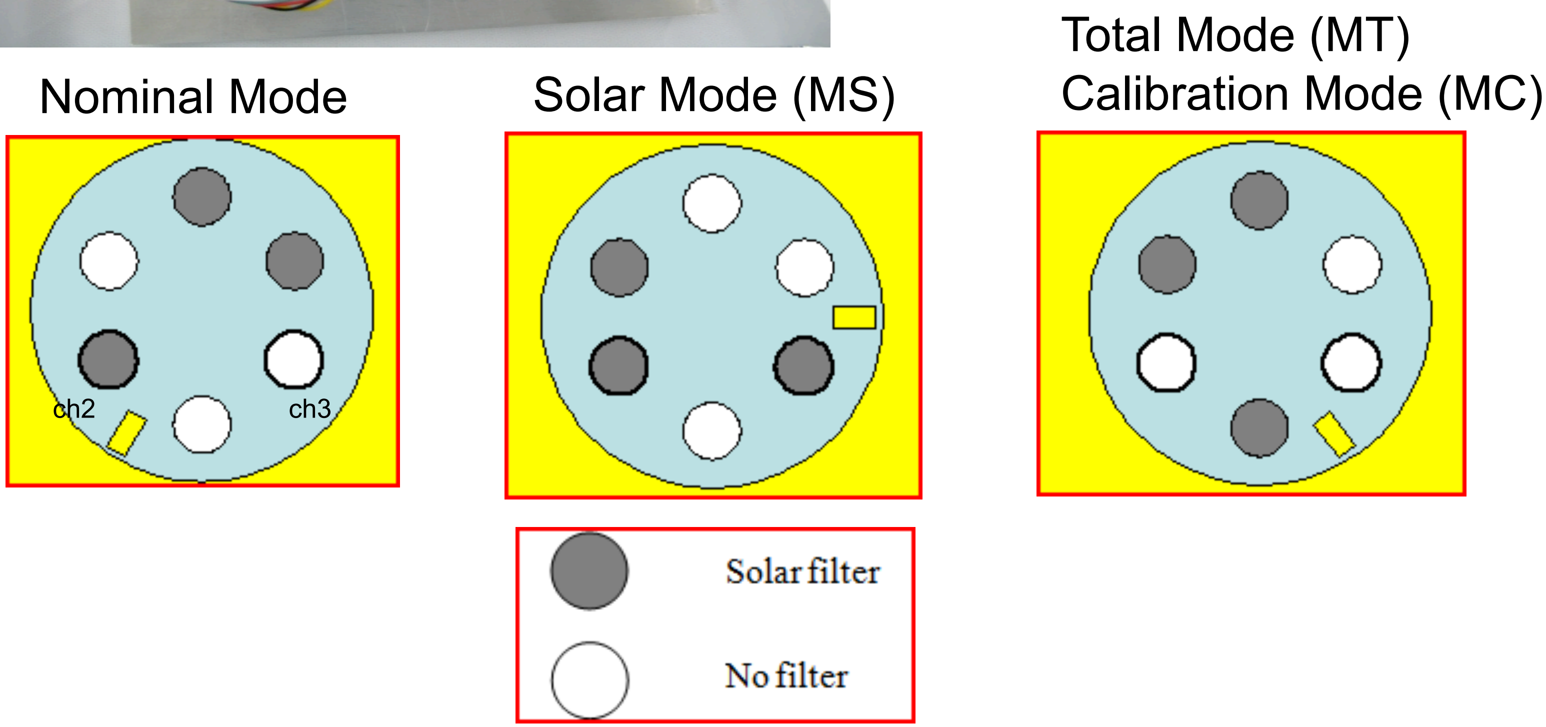
- Pyroelectric detector
- Aluminium spherical mirror
- Filter or no

The Instrument

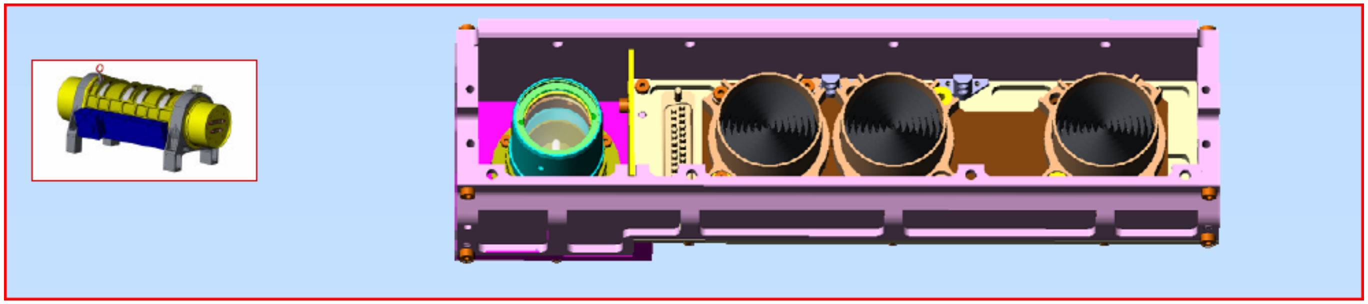


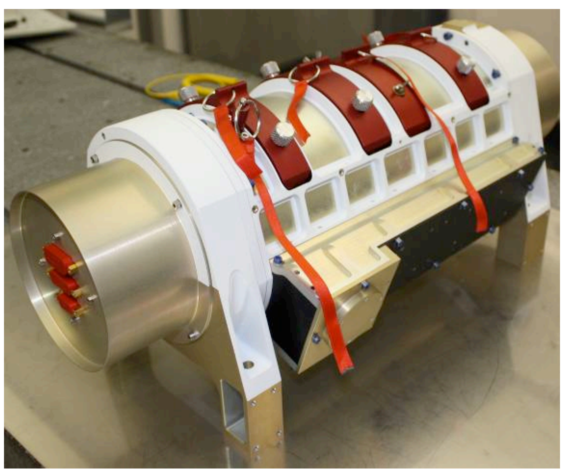
ScaRaB-MT has a new filter design:

The fused Silica filter (SW channel) is now on the filter wheel instead of being on the telescope



The Calibration Module (CALM)





ScaRaB-MT with the CALM

- Lamps for the channel 1
- 3 blackbodies simulators in front of the Channel 2, 3, 4

According to measurements carried out at Laboratoire National de Métrologie et d'Essais (F78, Trappes) the emissivity of the three new blackbodies was estimated to be 0.997 (+/-0.002) between 2 and 14 µm from measurements of their directional reflexion factor.

ScaRaB MT

1) The Instrument

2) Detector Characterization

3) Preflight Calibration

4) In-flight Calibration

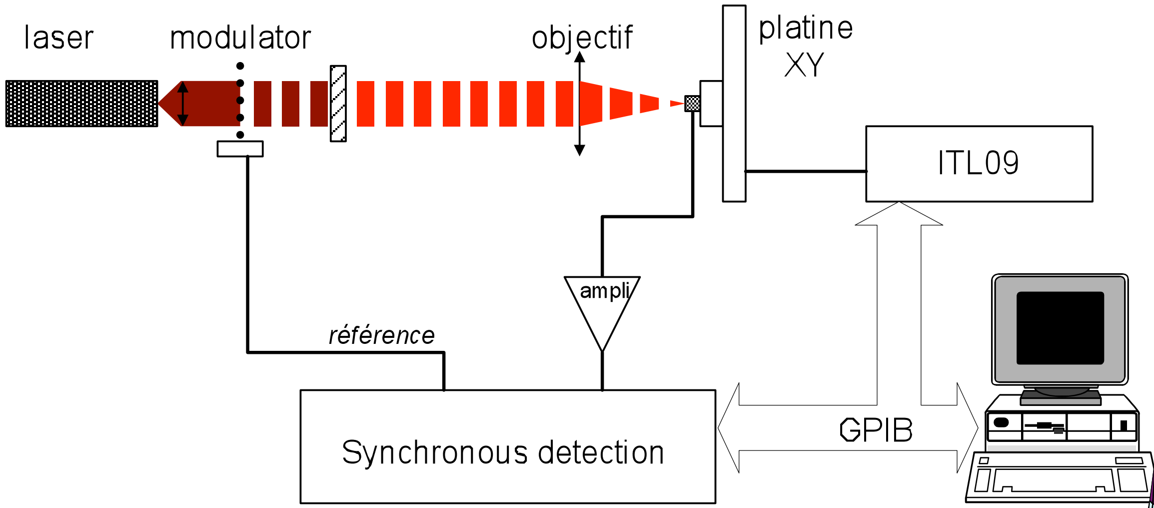
5) ScaRaB follow-on

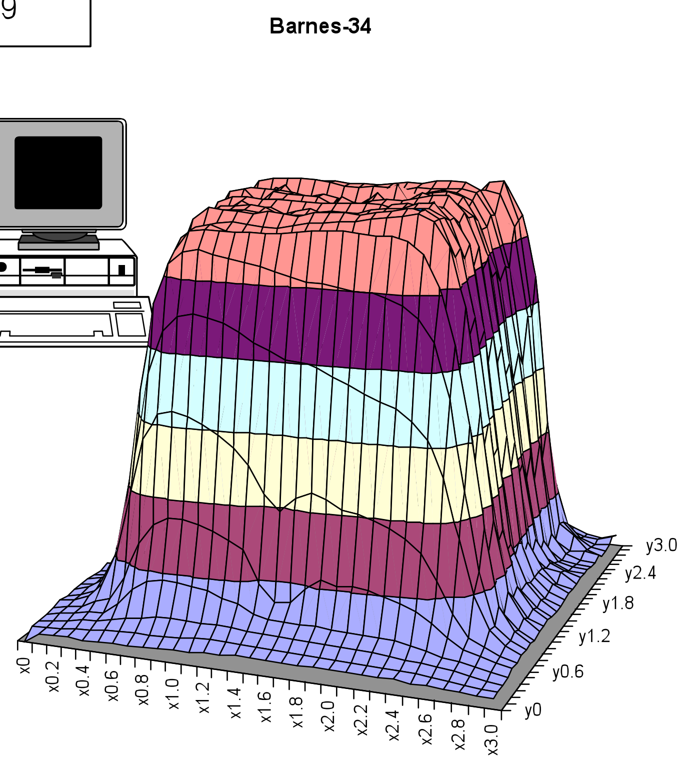
The detector characterization has been done by The Technical team at LMD.

- spatial response for each detector
- spectral response for each detector

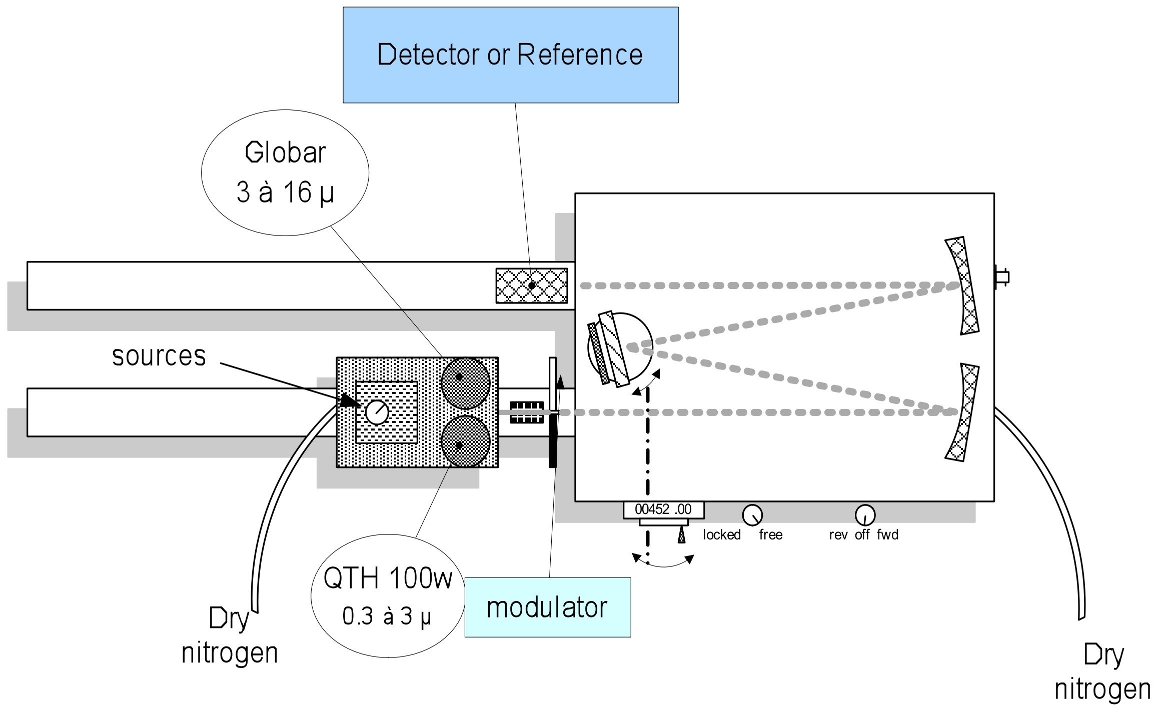
Reference:
MT-V1-6-2-7-1: Mesure de champs de vue de ScaRaB-MT
MT-V1-6-2-7-2: Réponse spectrale des canaux de ScaRaB-MT

Detector Spatial Response



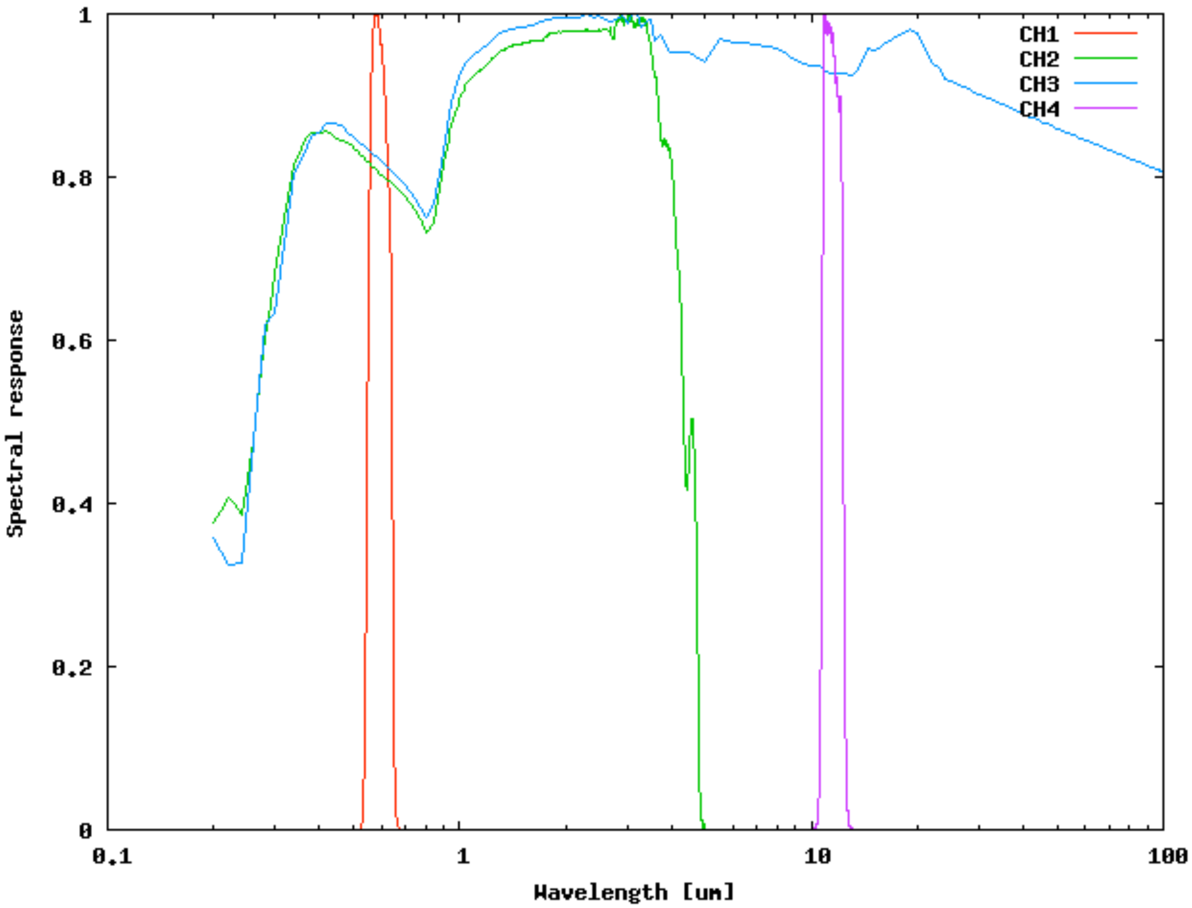


Spectral Response



Detector Characterization

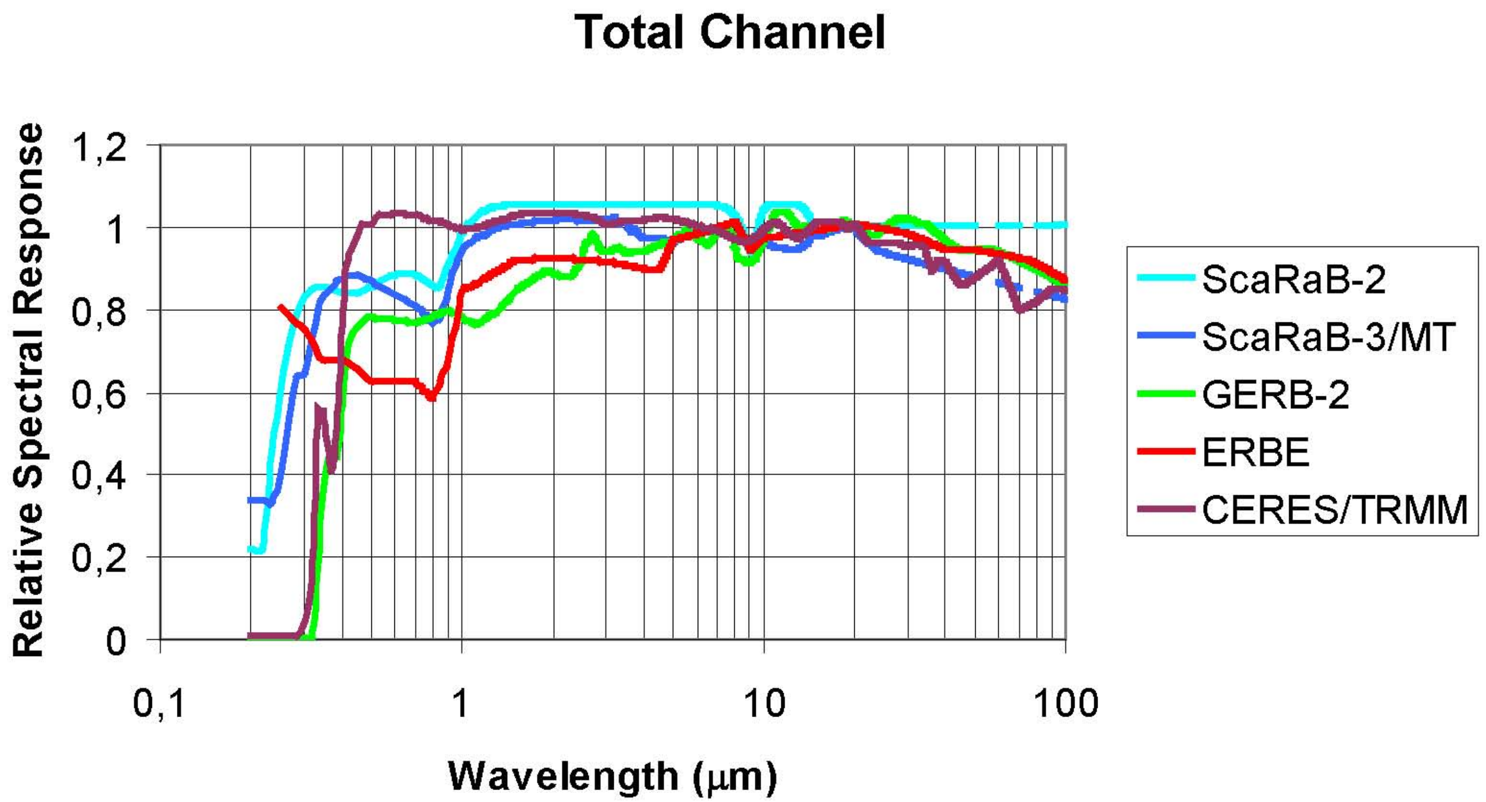
Spectral Response for the 4 channels



ScaRaB MT

Detector Characterization

Spectral Response of channel 2-3 and the others Mission



ScaRaB MT

1) The Instrument

2) Detector Characterization

3) *Preflight Calibration*

4) In-flight Calibration

5) ScaRaB follow-on

PreflightCalibration

Calibration concept

$$L_K^f = \int_0^\infty L(\lambda) r_K(\lambda) d\lambda$$

$$G_K = \frac{N_K}{L_K^f}$$

L_K^f Filtered radiance for channel k

$L(\lambda)$ Unfiltered radiance

$r_K(\lambda)$ Spectral response for channel k

G_K Gain for channel k

N_K Numerical output for channel k

The key points of pre flight calibration is to have a good first guess of :
A' and G_k to obtain climate accuracy data

Gain for the SW channel :

Gsw = G2 with the silica filter defined by ($r_2(\lambda)$) and $t_{filter}(\lambda)$

$$L_{sw}^f = \int_0^\infty L(\lambda) r_2(\lambda) t_{f\,ilter}(\lambda) d\lambda$$

Preflight Calibration

The Pre-flight calibration has been done by the CNES project Team
With: Nadia Karrouche, Alain Rosak, Thierry Trémas

The calibration report will be available very soon

SW calibration using Integrating Sphere at CNES

Gain G1 for channel 1
Gain G2 for channel 2, Gsw using the silica filter
Ratio G2/G3 in SW domain
Ratio G1/G2

A' relative SW/LW response in SW domain

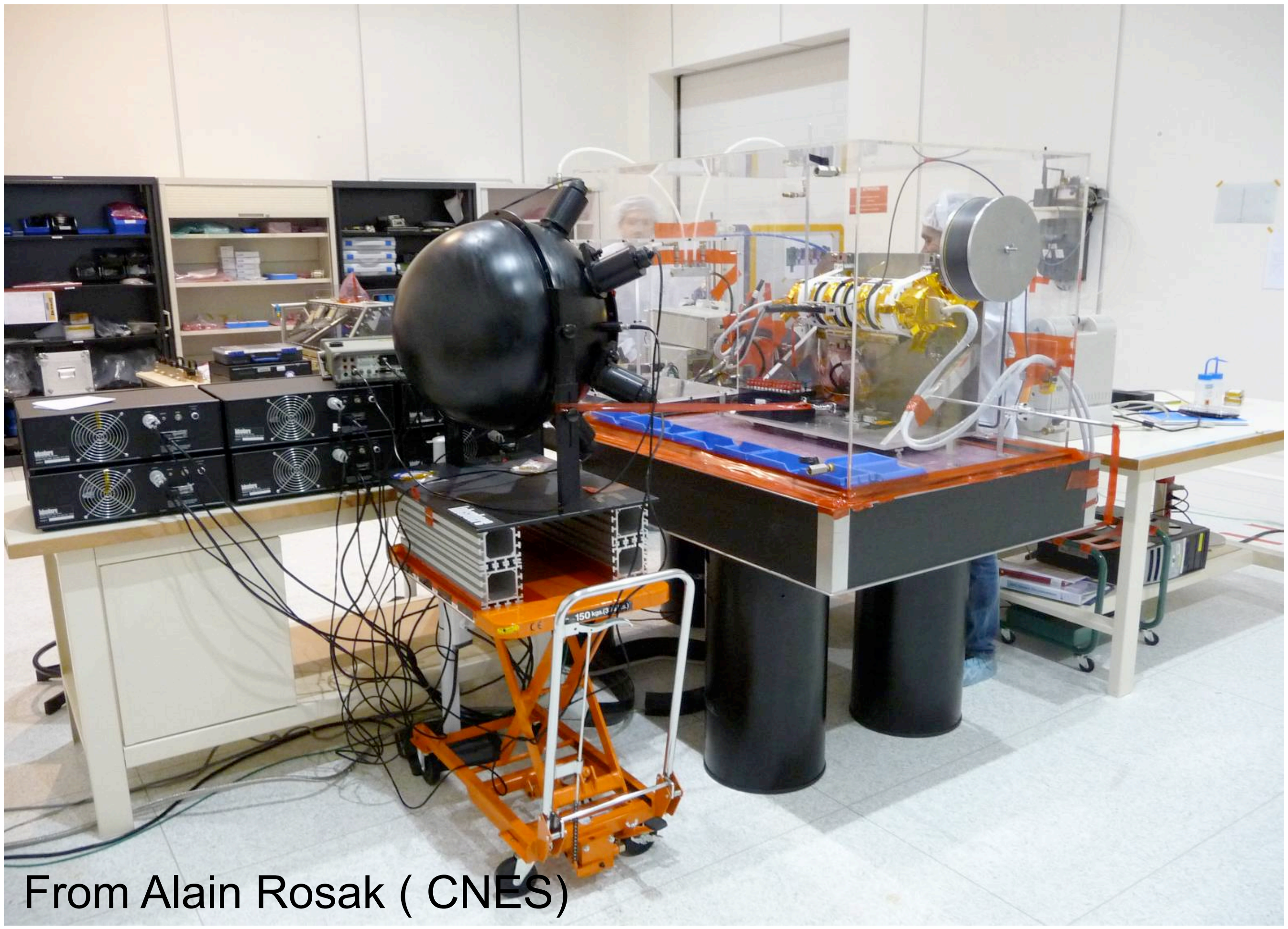
LW calibration using thermal vacuum at INTESPACE

GAIN G2 for channel 2 without the silica filter
GAIN G3 for channel3
Ratio G2/G3 in LW domain
Gain G4 for channel 4

A' relative SW/LW response in LW domain

PreflightCalibration

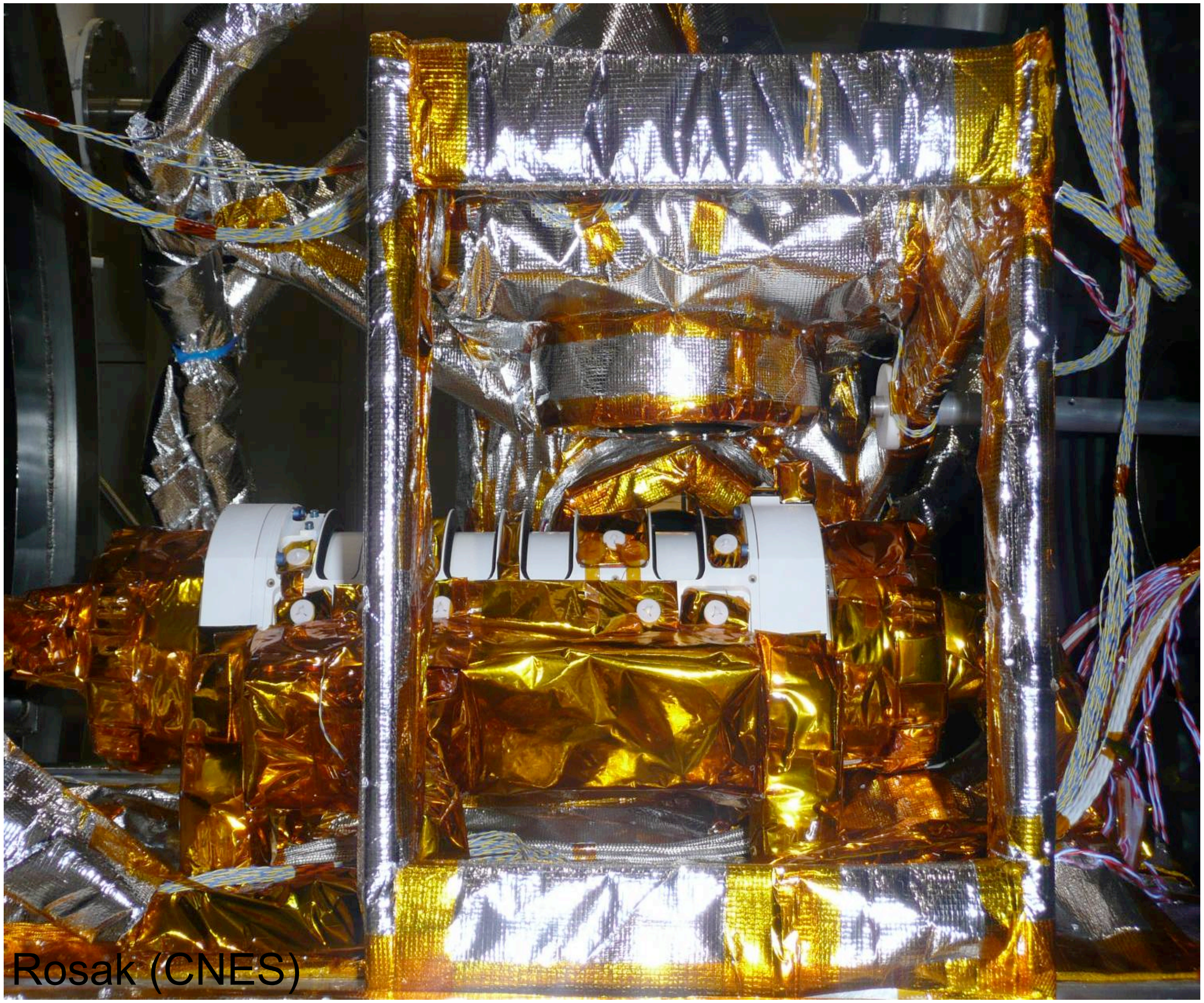
Integrating Sphere for SW calibration



From Alain Rosak (CNES)

LW calibration

Thermal vacuum



From Alain Rosak (CNES)

PreFlight Calibration

Cold BB = -196°C

LW calibration

emissivity
>0.9993
(paint 0.97)

Température
<>0.05°

Range Warm BB:
-50° / +50°

From Alain Rosak (CNES)

ScaRaB MT

1) The Instrument

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3) Preflight Calibration

4) In-flight Calibration

5) ScaRaB follow-on

Within the new design of ScaRaB-MT*

The silica filter (SW domain) is now implemented on the filter wheel

1.C-mode (calibration mode)

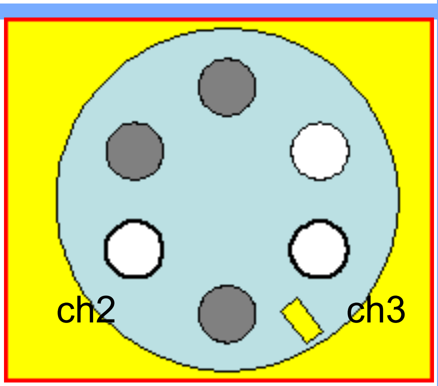
2.T-mode (Total mode)

3.S-mode (Solar mode)

- Geophysical cross-calibration

* Viollier, M., and P. Raberanto, 2010: Radiometric and Spectral Characteristics of the ScaRaB-3 Instrument on Megha-Tropiques: Comparisons with ERBE, CERES, and GERB. J. Atmos. Oceanic Technol., 27, 428–442

1.C-mode (calibration mode)



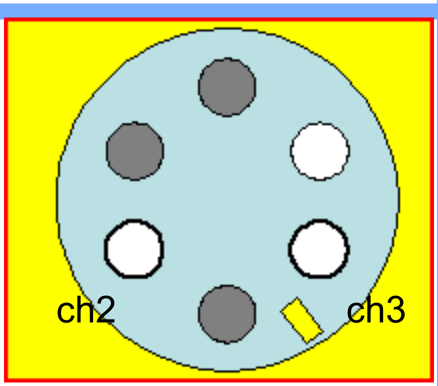
No filter in front of channel 2 and channel 3

The detectors are looking for the calibration module (CALM)

Purpose:

check gain stability using internal blackbodies
and lamp (G1, G2, G1/G2, G3, G4, G2/G3)

2. T-mode (Total mode)



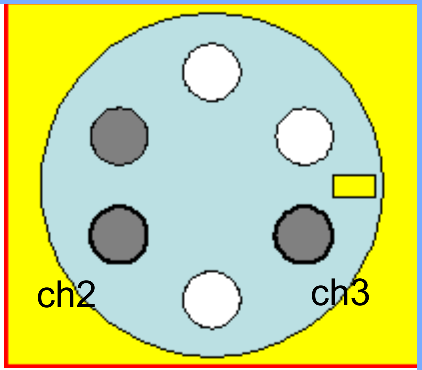
No filter in front of channel 2 and channel 3

The detectors are scanning like as nominal mode

Purpose:

Compare measurements from geophysical scenes obtained from channel 2 and channel 3 as total channel

3. S-mode (Solar mode)



Silica Filter in front of channel 2 and channel 3

The detectors are scanning like as nominal mode

Purpose:

Compare measurements from geophysical scenes obtained from channel 2 and channel 3 as solar channel

InFlight Calibration

- Only one lamp is kept (for channel VIS)

- Blackbodies (emissivity > 0.994) for channels T,IR

- The SW calibration now consists in in-flight direct intercomparisons of both SW and T channels over terrestrial scenes and on-board scene by switching the solar filter.

- These inter-comparisons also allow to detect long term drift of the relative spectral responses of the SW and total channels in the SW domain.

Another calibration method:

Geophysical cross-calibration method allow to simplify the original calibration system in the SW domain*

- **Analysis of very cold bright daytime cloud scenes over tropical convective regimes**
- **for which the TW signal is dominated by SW reflection**
- **and the residual LW component can be estimated independently from the IRW radiance (channel 4)**

Actually, the satellite was delivered in India

* *Duvel, J.-Ph., and P. Raberanto, Ageophysical cross-calibration approach for broadband channels: Application to the ScaRaB experiment, 2000, J. Atmos. Oceanic Technol. 17,1609-1717*

ScaRaB MT

1) *The Instrument*

2) *Detector Characterization*

3) *Preflight Calibration*

4) *In-flight Calibration*

5) *ScaRaB follow-on*

ScaRaB follow-on

ScaRaB follow-on ? New design

Requirements:

. the 2 broadband channels (SW, Total) (cross-track scanner)

Sampling grid 40×40km (Nadir)
Pixel IFOV typ. 40×40km
NEdL< 0.5 Wm-2sr-1
ΔL < 1.5 Wm-2sr-1
Registration (pointing knowledge) 0.1pixel
Channels coregistration: 98%
On-board calibration : deep space, blackbody simulators

. an imager in the infrared window (8-12 µm) for the Scene Identification

image frame sampling 1×1 km
Frame IFOV: 64×64 km
NEdT< 0.5 K ΔT < 1 K
Coregistration with radiometer:98%

Reuse of existing design/principle

.To minimise development cost
.To minimise risks
.To provide proven performances
.Potential design/performances heritage:

ScaRaB radiometers from (FM1, FM2, Megha-Tropiques)
IRW imager from IASI, CALIPSO

ScaRaB follow-on

The uncooled IR imager for IASI is considered as good starting point for designing the same function on TOA:

Detector

320×240 µbolometer array
Sodern design based on U3000A device
but is no more in product catalogue of DRS (formerly Boeing)

Image acquisition

Specific readout operation: fast array readout except for the 64×64 area of interest
Five 64×64 frames are acquired per cycle,
the first one is discarded (bolometer thermal stabilisation),
the 4 remaining ones are valid the output is the average over 1, 2 or 4 frames
Signal integration time: 111 µs (line readout period)

Frame period:	216/5 = 43 ms	23Hz
Image period:	216 ms	4.6 Hz

Constraints

- Typical µbolometer constant time in the 10 ms range leads to a 30 ms settling time (95% of scene change)
In case of continuous ACT scan,(e.g.360°/6s => 698 km/s) the image shift during 30 ms is 21 km
The image is blurred, 1 km resolution is not achieved
- for the scanner detector, for the typical frame of 60Hz, scan drift for 16,66s : 12km

→ **The ScaRaB continous scan shall be replaced by step and stare operation**

ScaRaB follow-on

But the Step & stare operation is not compatible of large inertia linked to ScaRaB-like rotor

Estimated rotor inertia for a scaled down ScaRaB: 0.025 kgm^2

Estimated max torque for 50 step&stare steps, over 80°in 4s : 22 N.m

Available typical mechanisms: ≤1N.m !

The mobile part shall be minimised

Baseline configuration: static radiometer and imager + scanning mirror

tilting scan mirror

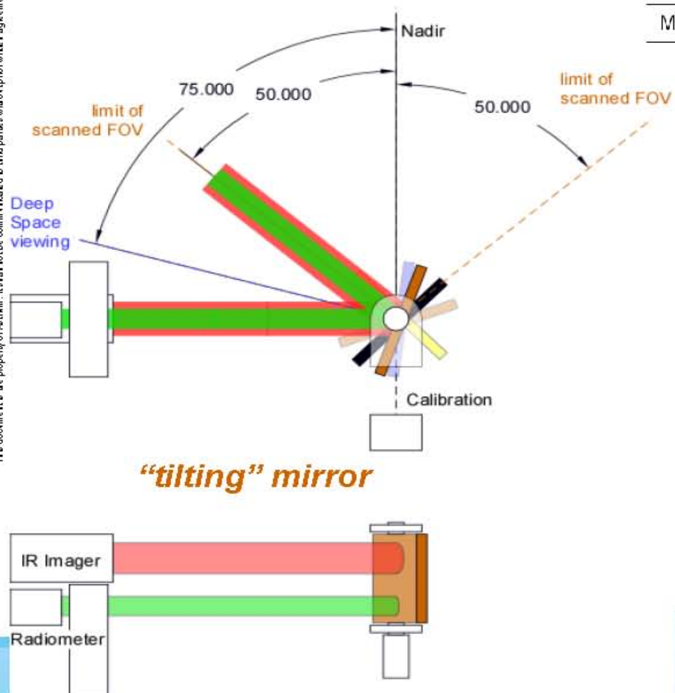
rotating scan mirror

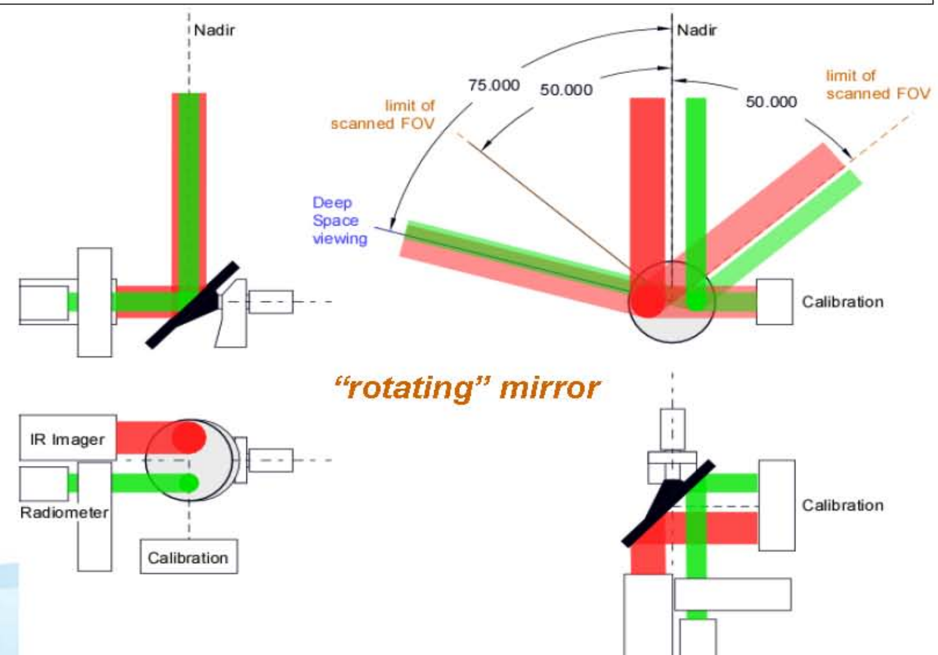
→rotating configuration selected for the present TOA baseline

Alternative scanning options with a mirror

- **"Rotating mirror" selected, despite field rotation**

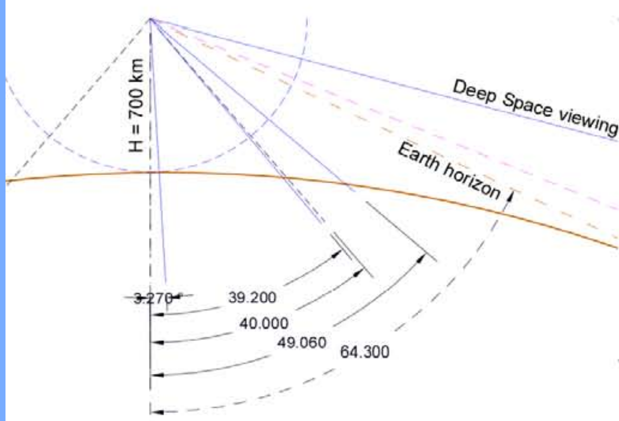
	"tilting mirror"	"rotating" mirror	
Scan pointing angle	α	α	-75° to +50°, plus access to calibration target
Scan mechanism angle	α/2	α	
Incidence on scan mirror	Variable di = dα/2	Constant typ. 45°	Important radiometric issue
Field rotation	No	Yes = α	See specific discussion
Beam foot print on mirror	Constant centring variable width	Variable position constant size	Minor radiometric issue
Motor axis	in mirror plane	along beam axis	
Mirror size			Similar

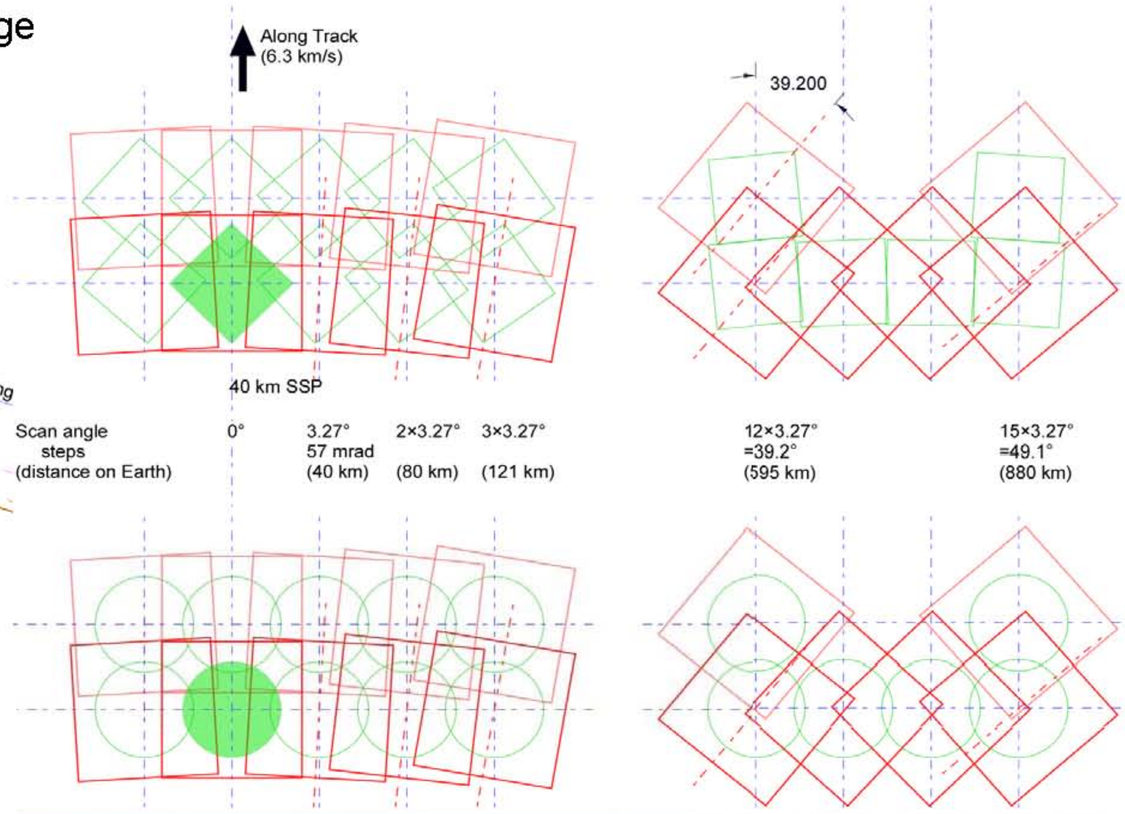




Field rotation with the selected scan configuration

- The radiometer and imager IFOV remain registered (centred & aligned)
- Rotation of the imager sampling grid does not prevent from achieving the "declouding" function
- A 45 km circular IFOV is recommended for the radiometer (instead of 40 km square)
  - Uniform (angular) coverage over the swath
  - Isotropic & uniform MTF





Polarisation rotation with the selected scan configuration

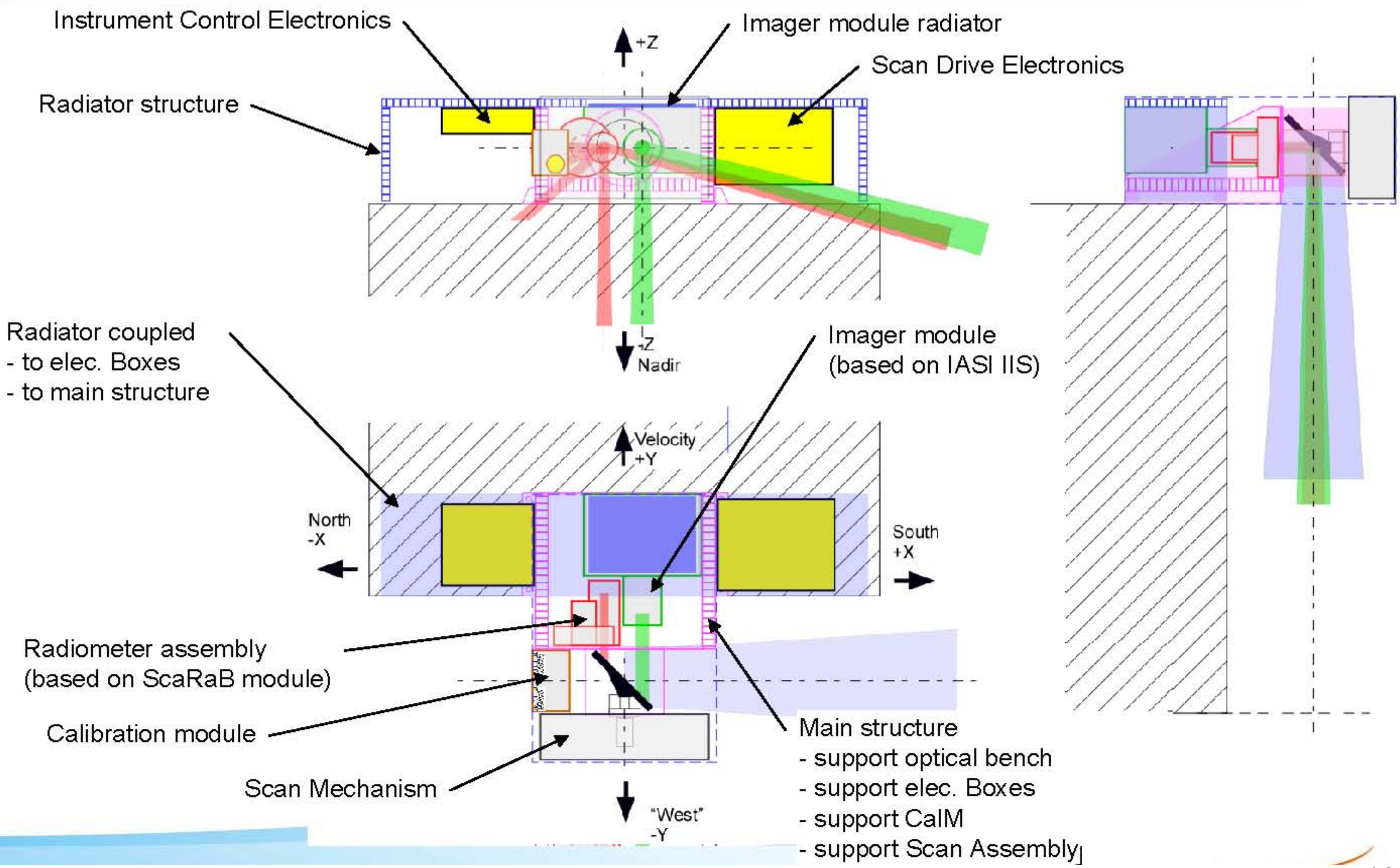
- **The beam incidence on the scan mirror is constant whatever the scan position**
  - The reflectance is constant
  - The 45° incidence generates a polarising effect (depending of the coating and of the wavelength)
    - The polarising ratio is constant
    - But the polarising direction with respect to the scene varies

  ➯ this can leads to radiometric error when observing a polarised scene (solar reflected range for example)
- **It will be difficult to design a non polarising coating over the full 0.2-4 µm range**
- **But the polarising effect can be cancelled by design :**
  - 2 identical mirrors are mounted on the scan mechanism
  - They are encountered successively by the incident beam, at 45° incidence for both, but their incidence planes are crossed at 90°
  - Thus the polarising effect of one mirror is compensated by the second one
  - This is equivalent to a 90° folding system, but in the 3D space

Baseline instrument principles

- **Radiometer function trough a single ScaRaB-like "telescope" module**
  - Pyroelectric detector + spherical metal mirror
  - Chopper wheel + Reference blackbody
  - But only one module for TW and SW channels
    (4 positions chopper wheel : open/close × with/without Silica filter)
- **Imaging function through a IASI-like IR imager (µbolometer array)**
- **Step & Stare scanning over the Earth range (±50°, 30 steps)**
  + acquisition toward Deep Space (dark calibration at each scan cycle)
  + acquisition toward Calibration Module (BB source and Sun diffuser)
- **Scan through a rotating mirror**
  - Constant incidence but rotating field
  - Radiometer and imager beams separated in the pupil, but co-aligned
- **Self-operating instrument,**
  - with minimised number of interfaces with platform
  - No image memory (use of µwave Radiometer memory)

Overall configuration



This configuration is the first design of a ScaRaB follow-on

but further studies have to be done :

- . polarisation
- . detail design
- . …

Thank YOU