

# SIFTI, a sounder based on a new instrument concept: static Fourier transform interferometry

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## Outline

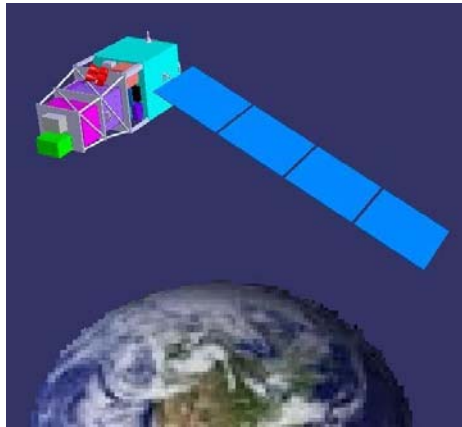
- **Programmatic**
- **Mission & requirements**
- **Heritage**
- **Principle of static FTS**
- **Tricky items and solutions**
- **Advantages**
- **Conclusion**

- **Candidate mission: TRAQ (TRopospheric Air Quality) (\*)**
  - ◆ **ESA's Earth Explorer Mission**
  - ◆ **To date, running a phase 0 among 6 challengers**
  - ◆ **Launch foreseen ~ 2015**
  
- **SIFTI: phase A started March 2007**
  - ◆ **CNES / Thales Alenia Space - France cooperation**
  - ◆ **2 year long :**
    - optimisation of specification w.r.t mission & techno, concepts optimisation
    - preliminary definition, budgets, performances

→ feasibility
  
- **Development of an infrared breadboard of SIFTI**

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# SIFTI mission



Global Air Quality



Atmospheric pollution



O<sub>3</sub> & CO atmospheric sounding



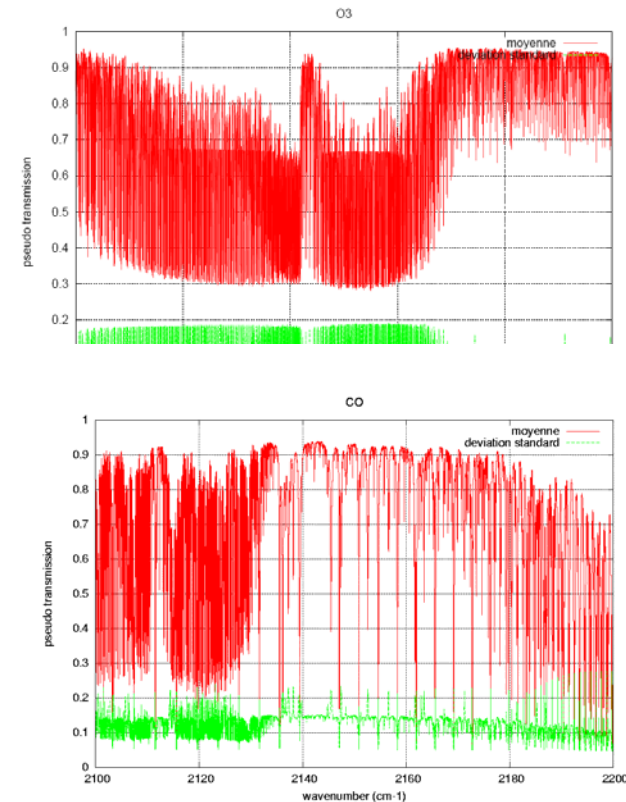
Spectrometer



Interferometer



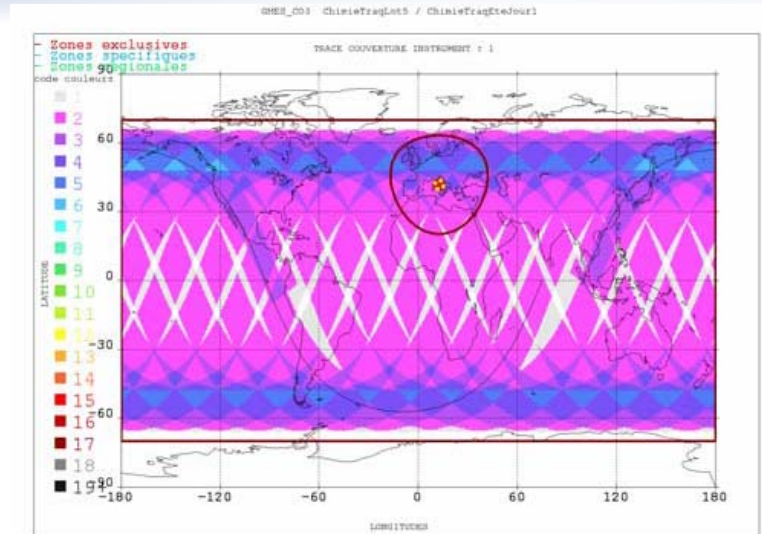
Static Interferometer



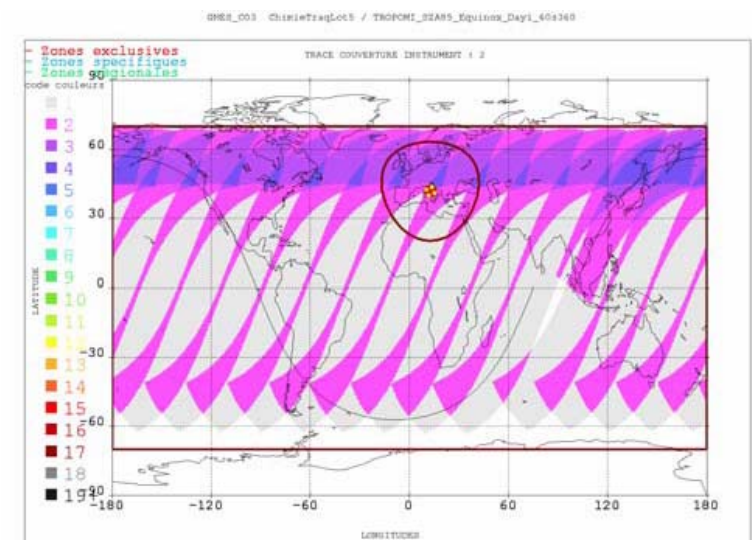
Species	Spectral range	Instrument
Aerosols	UV-VIS-SWIR	OCAPI
O <sub>3</sub>	UV-VIS	TROPOMI
NO <sub>2</sub>	UV-VIS	
H <sub>2</sub> CO	UV-VIS	
SO <sub>2</sub>	UV-VIS	
O <sub>3</sub>	TIR	SIFTI
CO	TIR + SWIR ?	

## Static Infrared Fourier Transform Interferometer

- Proposed by CNES for TRAQ proposal, August 2005
  
- To maximise earth global coverage and local repeatability
  - drifting orbit, inclined 54°
  - 76 day basic cycle
  - local time drifts by 19 mn per day
  - from 0 to 5, then 5 to 0, passes during day time above a given continent
  - one pass every 99 mn
  - periods of 18 days with 5 passes during day time, at solstices
  - earth global coverage between [-55° ; +55°] latitudes every day
  
- “Exploration” mission → cost reduction:
  - ✓ only one satellite
  - ✓ small type satellite



SIFTI daily coverage



TROPOMI coverage during one day, at equinox, around the day 15

Species	Product	DOFS	Absolute Uncertainty	Spectral range (cm <sup>-1</sup> )	SNR spectre total	NEDT (mK)	$\delta\sigma$ non apod. (cm <sup>-1</sup> )	max OPD (cm)	2 × 1000 pts interferogram SNR
O <sub>3</sub>	Strato profile [12 – 50 km]	4	1 - 4 %	[1030 – 1070] (9.71 – 9.35 μm)	650	80	0.0625 (R = 8500)	8	11000
	Tropo profile [0 – 12 km]	2.3 (*)	10 – 30 %						
CO	Tropo profile [0 – 12 km]	2.5 (*)	6 – 12 %	[2140 – 2180] (4.67 – 4.59 μm)	200	120	0.0625 (R = 17000)	8	4500
	Column [0 – 12 km]	1	3 – 15 %	[4270 – 4300] (2.34 -2.32 μm)	90 ?	TBD	0.075 (R=29000)	8	TBD
CH <sub>4</sub>	Tropo profile [0 – 12 km]	TBD	0.4 – 2.5 %	[4270 – 4300] (2.34 -2.32 μm)	90 ?	TBD	0.075 (R=29000)	8	TBD

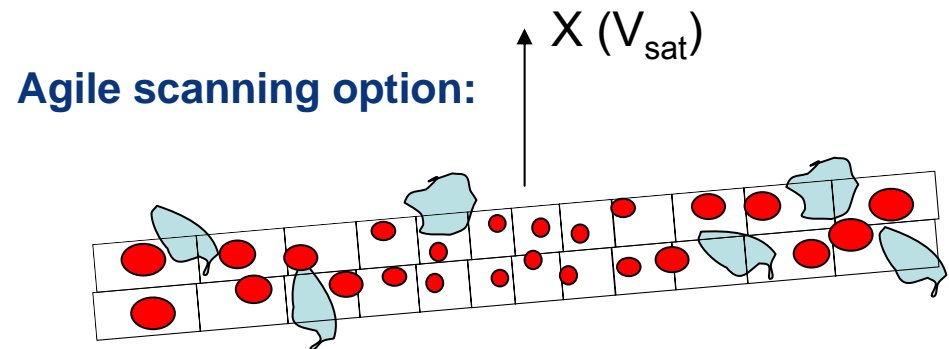
(\*) 1 point in the boundary layer

■ Geometric requirements:

Spatial resolution = 10 km @ nadir

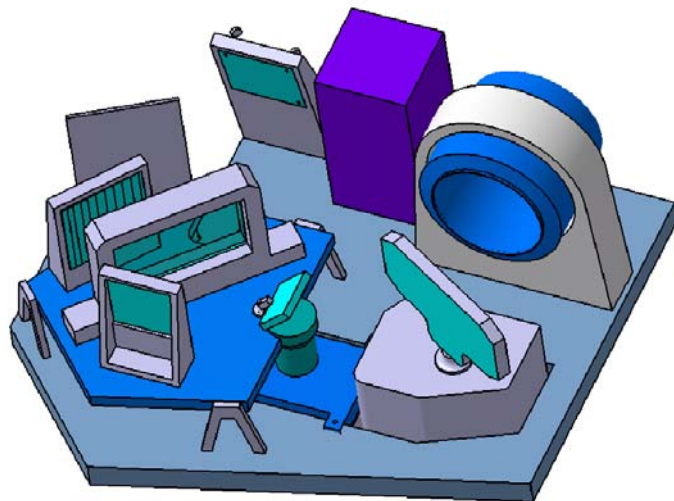
Spatial sampling = 43 x 43 km<sup>2</sup> @ nadir  
to 70 x 70 km<sup>2</sup> @nadir

swath = 1700 km



• = pixel SIFTI

- Wedged mirror interferometer (SIT) studied at CNES end of 80'
- CNES patent in 1998 for the facet mirror interferometer principle, and its applications to atmospheric sounding from space
- studies of an instrument dedicated to CO<sub>2</sub> sounding, beginning of 2000'
- Development of a breadboard for CO<sub>2</sub> interferometer



SIFTI Phase 0 concept

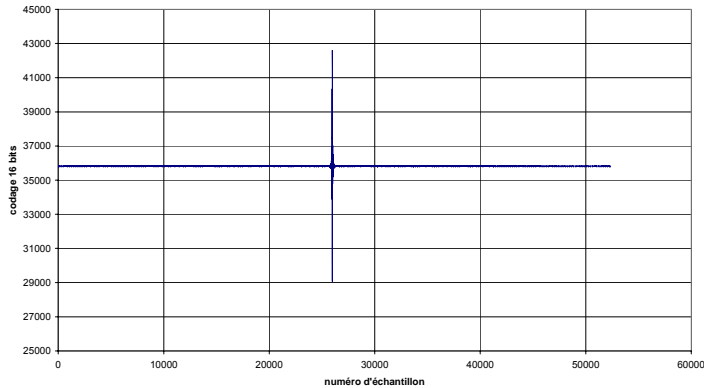
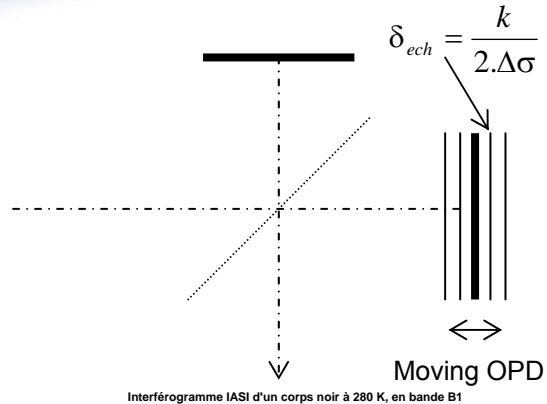


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CNES R&T: CO<sub>2</sub> breadboard

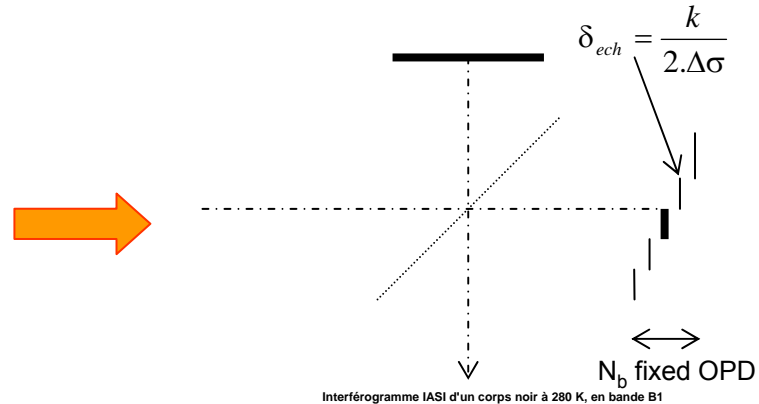
- Preliminary studies (phase 0) and proposal of SIFTI for ESA's Earth Explorer call for Ideas, 2005
- CNES / labs joint science group set up in 2006 ("GST")
- Performance models and instrument specifications
- SIFTI industrial phase A started March 2007 with TAS-F
- SIFTI breadboard in CNES labs

## Dynamic interferometer

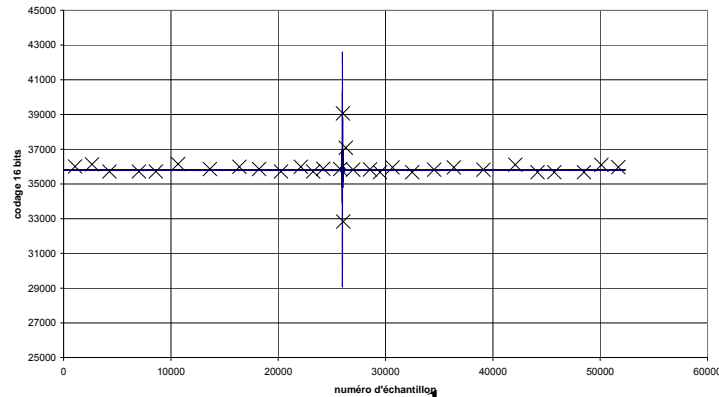


$$\delta x_{sample} = \frac{1}{2 \cdot \sigma_{max}}$$

## Static interferometer



$MOPD = 1/d\sigma_{apod}$



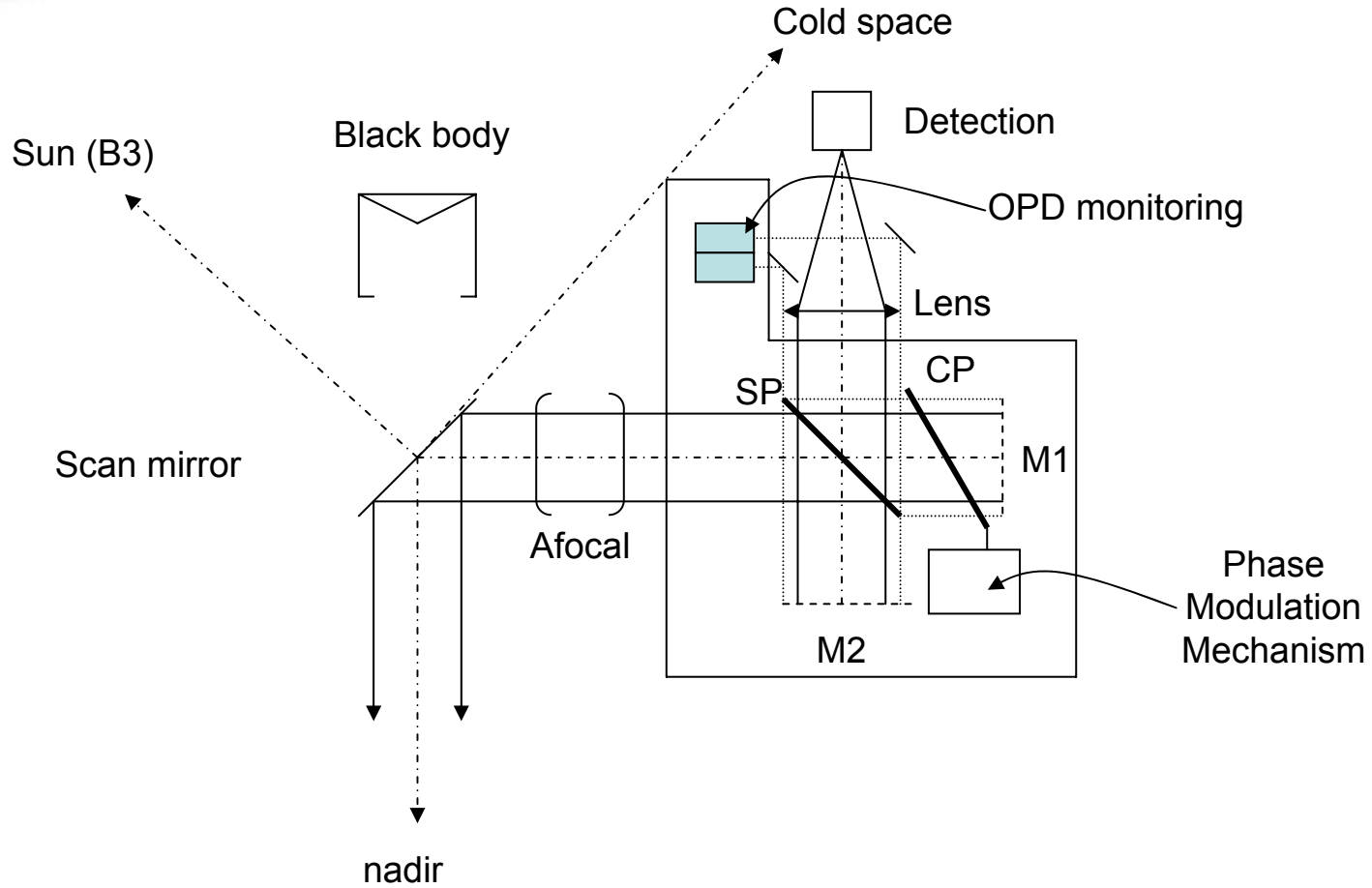
$$\delta x_{sample} = \frac{1}{2 \cdot (\sigma_{max} - \sigma_{min})}$$

## Under-sampled interferograms

→ limited number of spectral channels vs narrow spectral bands : generalised Shannon theorem



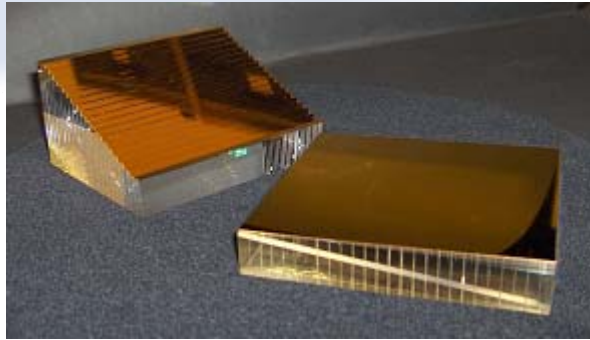
# SIFTI instrument lay-out



# Tricky items

Item	Criterion	Specification	Impact	Solution
Filter technology	Slope rate: $\Delta B_{ut}(90\%)/\Delta B_{tot}(1\%)$	<i>272 nm/511 nm @ 9.52 <math>\mu m</math></i> <i>54 nm/120 nm @ 4.53 <math>\mu m</math></i>	Free spectral range	3 spacer interference filters
	Rejection	< 0.1%	Aliasing	Blocking coatings
	Spectral Non-uniformities	< 0.2 %	Spectral discrepancies in interferogram	CNES R&T
Facet mirror technology	Facet size Step regularity & tilt, assembling	3 x 3 mm <sup>2</sup> $\pm 2 \mu m$ $\lambda/30$ RMS on 3 x 3 mm <sup>2</sup>	Instrument throughput Contrast Point Spread Function	Re-sampling algorithm Molecular bonding
Detectors	AR coatings onto detector	< 2 % (TBC)	Detector – filter ghost	R&T CNES (TBC)
Coatings	AR on plates	< 1 %	Ghost interferograms	Signal processing
Thermal stability	Slow biases	< 10 <sup>-4</sup> (TBC)	Noise	Phase Modulation Mechanism (TBC)
Phase Modulation Mechanism (if any)	Induced microvibrations	As few as possible	Contrast	Self compensated mechanism
Image quality	Deconvolution of diffraction & blur	< 10 <sup>-4</sup> (TBC)	Discrepancies in ILS	Calibration + Deconvolution of diffraction & blur
Interferogram sampling	Knowledge of OPD position	< 10 nm	Discrepancies in ILS	OPD monitoring device
Detectors	PRNU	< 10 <sup>-3</sup> (TBC)	Discrepancies in ILS	Calibration
SNR	Temporal noise	11000 (B1) ; 4500 (B2)	NE $\Delta T$	Phase A study

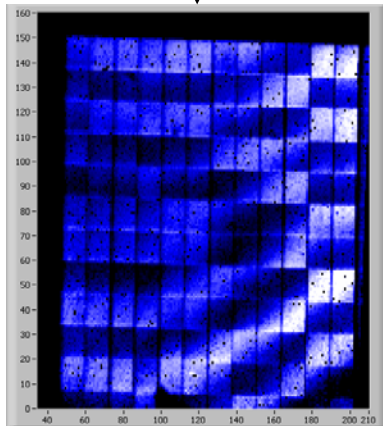
- **A simplified mechanism:**
  - **20  $\mu\text{m}$  vs. 4 cm range**
  - **robustness**
  
- **Less sensitive to gain noise:**
  - **reduced noise bandwidth**
  - **reduced impact of vibrations**
  
- **Intrinsic reduction of data rate**



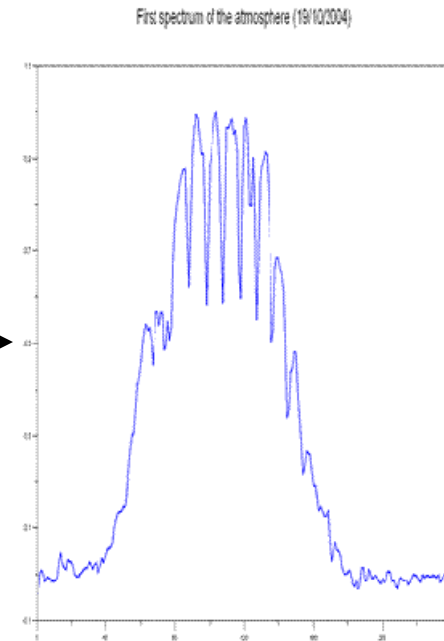
Stepped mirrors (CNES R&T)



Breadboard in action



2D interferogram



CO<sub>2</sub> spectrum

- Solutions to tricky items
  - ghosts reduced by design (stray light, rejection...)
  - calibrations
- ...
- A validation program including:
  - ◆ 2 year industrial phase A,
  - ◆ breadboard
  - ◆ set of R&T actions

to reach:

**a specialized / optimised sounder**  
**high performances**  
**a robust on-board concept**