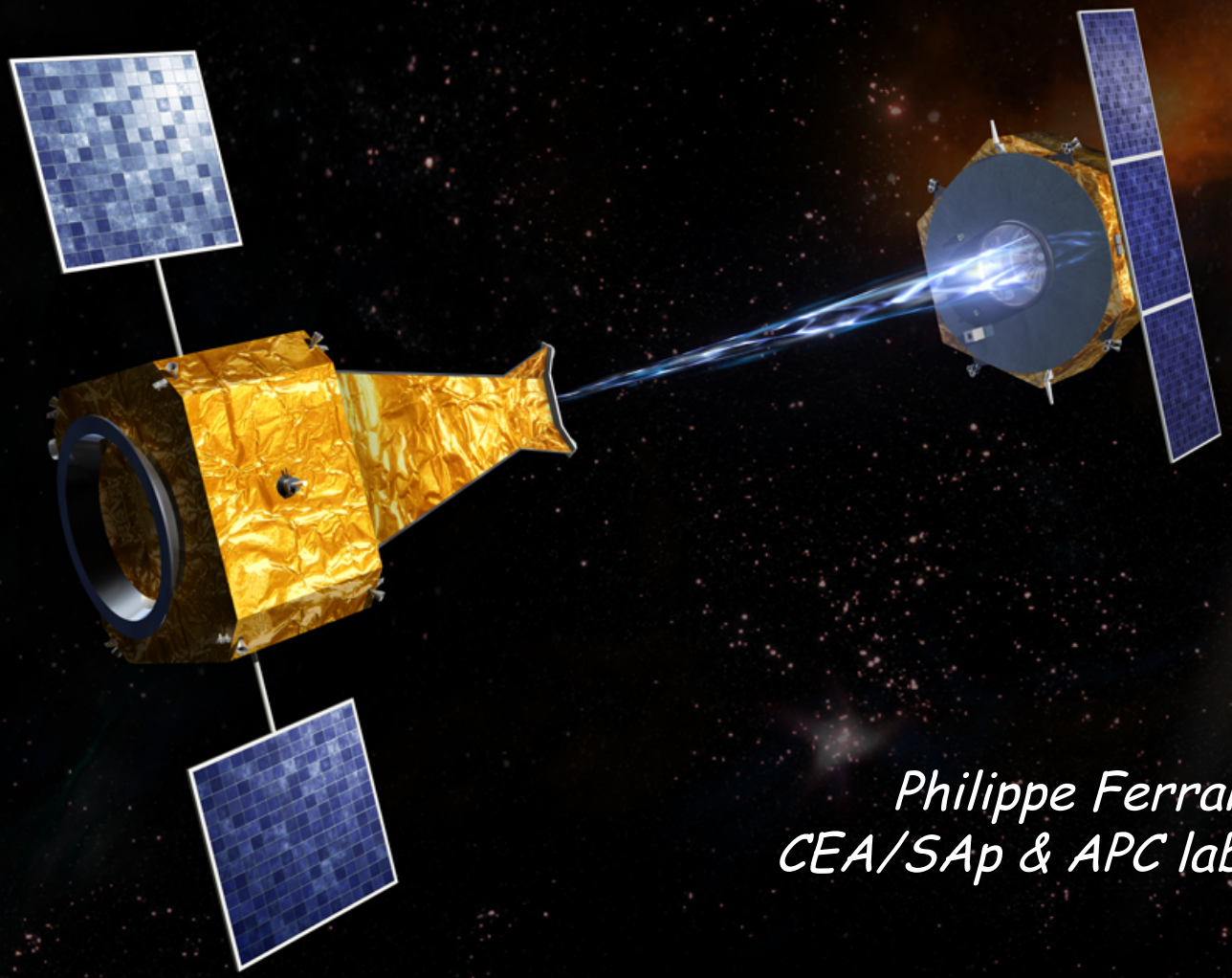
From Simbol-X to new hard X-ray missionS



Hard X-rays focusing

Philippe Ferrando
CEA/SAp & APC laboratory

The Simbol-X collaboration

F, It, D : historical

+ (late '08-09) Spain, Poland, Belgium, Switzerland

- End '01 : First ideas and discussions CEA/Saclay & O.A. Brera
- End '03 : CNES call for ideas for formation flight
- Mid '04 : Selection of 4 missions for assessment phase (phase 0)
- End '05 : Selected for phase A, implemented jointly by CNES & ASI
- Beg.'08 : Start phase B (part)
- Sept. 08 : Partial withdrawal of ASI
- March 09 : Definitive cancellation by CNES

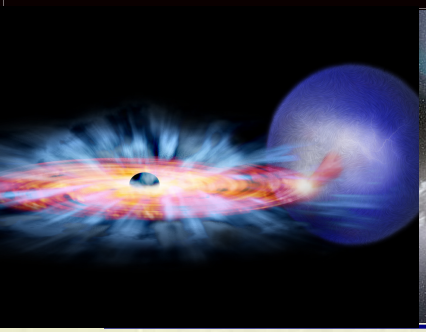
20-40 keV / ISGRI

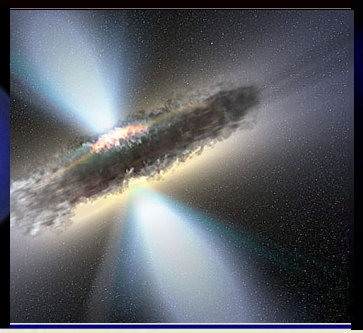
Importance of the hard X-ray domain

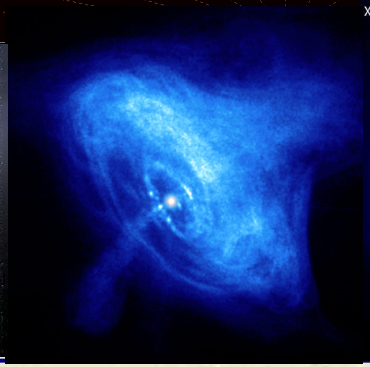
Matter under extreme conditions, particularly around black holes

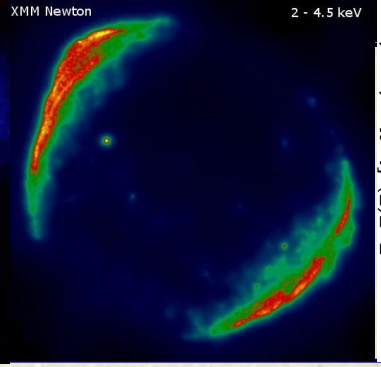
Non thermal emissions dominating over thermal

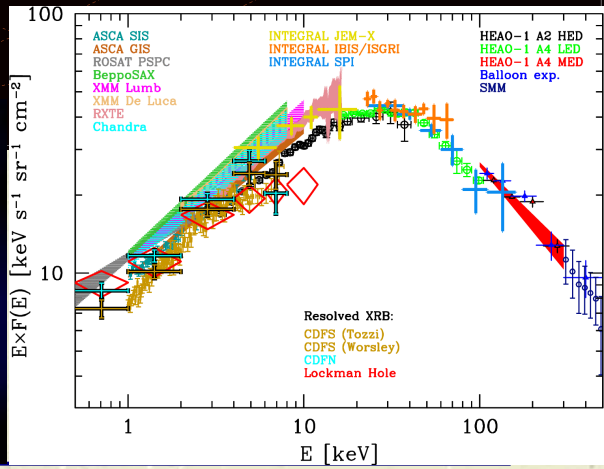
Overall Universe emission dominated by accretion onto SMBH











Goal (in 2002) : hard X-rays at the "XMM" level

Hard X-rays

IGR/ISGRI (2002, coded mask)

- 15 keV – 1 MeV
- sensitivity : ~ 0.3 mCrab
- angular resol. (FWHM) : 0.2°
- catalog of 421 sources

Simbol-X (2014, focusing)

- 0.5 – 80 keV
- sensitivity : ~ 0.5 μ Crab
- angular resol. (FWHM) : 8"

Soft X-rays

UHURU (1970, collimator)

- 2 – 20 keV
- sensitivity : ~ 1 mCrab
- angular resol. (FWHM) : 0.5°
- catalog of 339 sources

XMM-Newton (1999, focusing)

- 0.1 – 15 keV
- sensitivity : ~ 0.1 μ Crab
- angular resol. (FWHM) : 6"
- catalog of ~ 200,000 sources

Simbol–X core science objectives

I - Black Holes Physics

- Resolve ~ 50% of the Cosmic X-ray Background where it peaks at 30–40 keV
- Understand SgrA* and its environment
- Constrain the physics of accretion flows onto solar mass and super massive Black Holes

II - Particle acceleration mechanisms

- Constrain acceleration processes in relativistic jets of blazars
- Probe acceleration mechanisms in the strong fields of pulsars
- Measure and map the full non thermal electron spectrum in SNR shocks
- Measure and map the controversial non-thermal emission in clusters of galaxies

Simbol-X top level scientific requirements

Energy band : ⌘ 0.5 to > 80 keV

ΔE : < 150 eV @ 6 keV

< 1.3 keV @ 68 keV

Eff. area : 1000 cm² @ 2 keV

300 cm² @ 30 keV

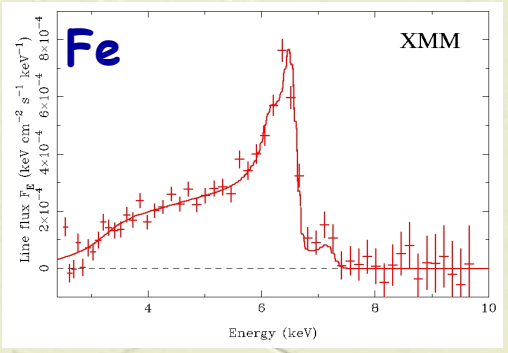
100 cm² @ 70 keV

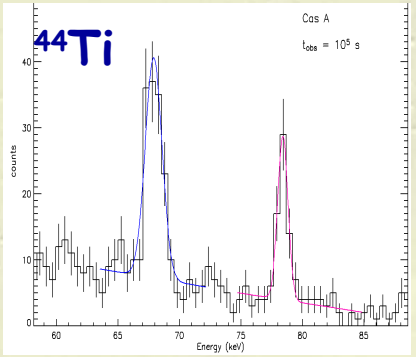
Δθ (HPD) : < 20 arcsec (30 keV)

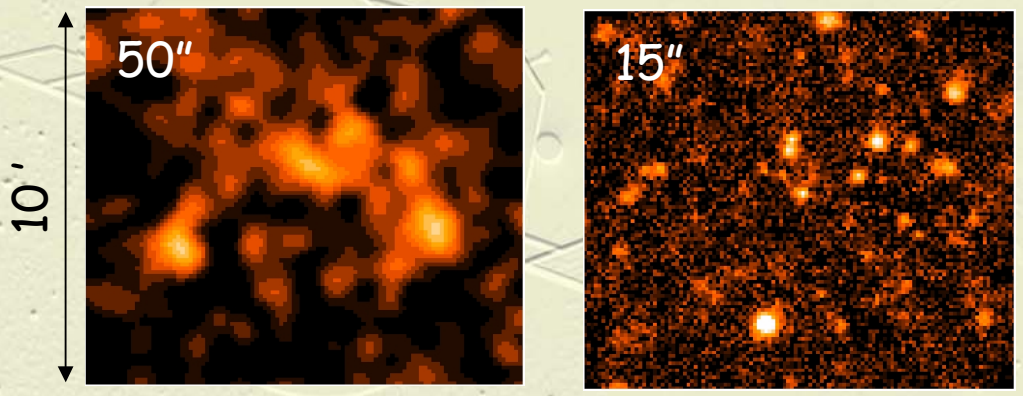
FOV : > 12 arcmin

Attitude reconst. : ± 3 arcsec

Δt : < 100 microsecondes





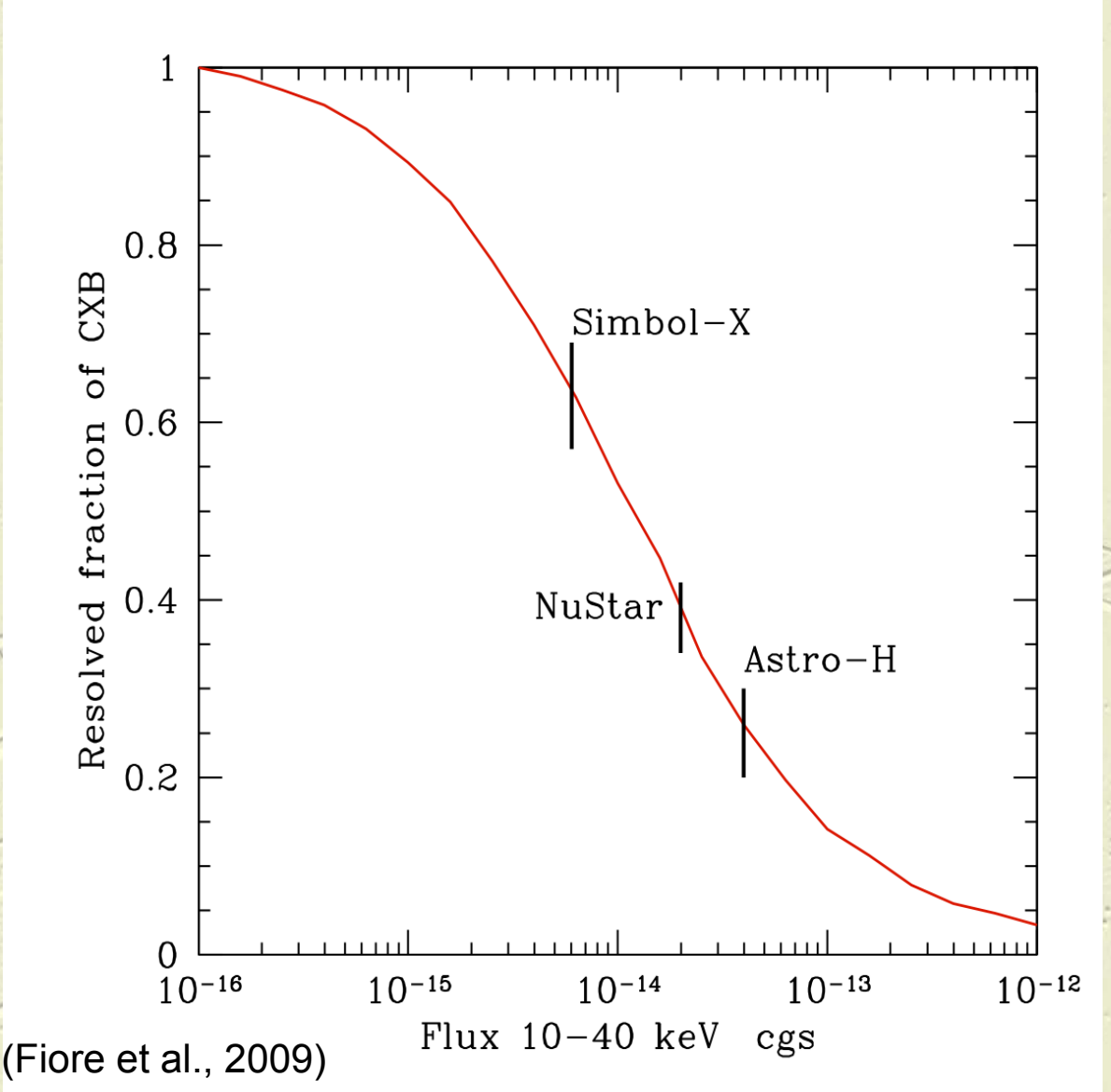


Continuum sensitivity [1 Ms, 3 σ] : < 6 10^{-15} cgs [10-40 keV]

Line sensitivity : < 3 10^{-7} ph/cm²/s @ 68 keV

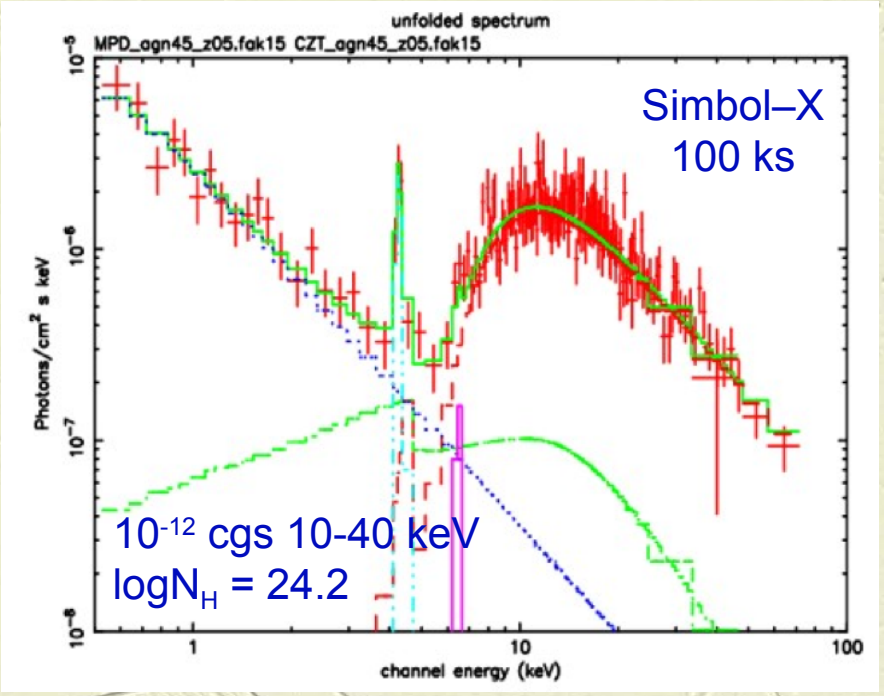
Mission duration : 3 years + provision for 2 additional years

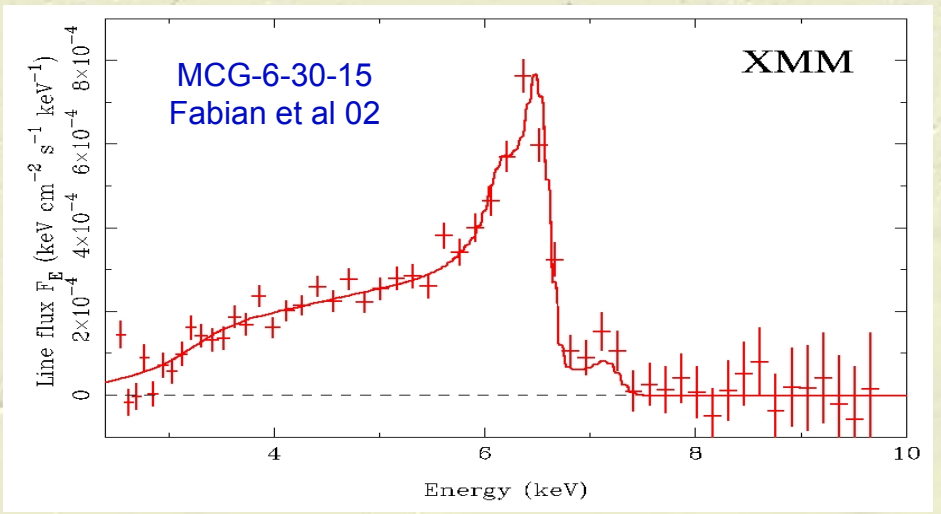
Science with angular resolution and sensitivity : resolving the CXB

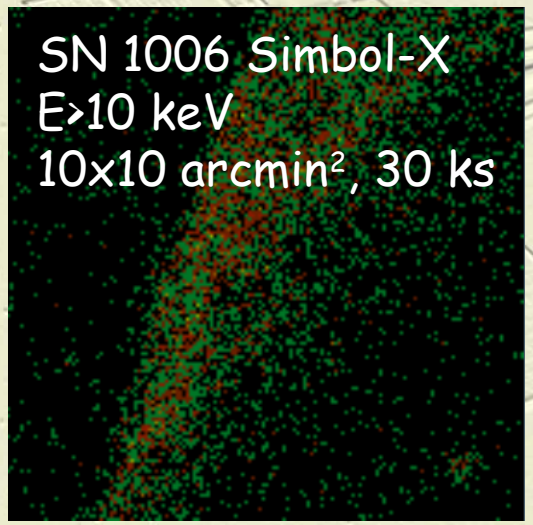


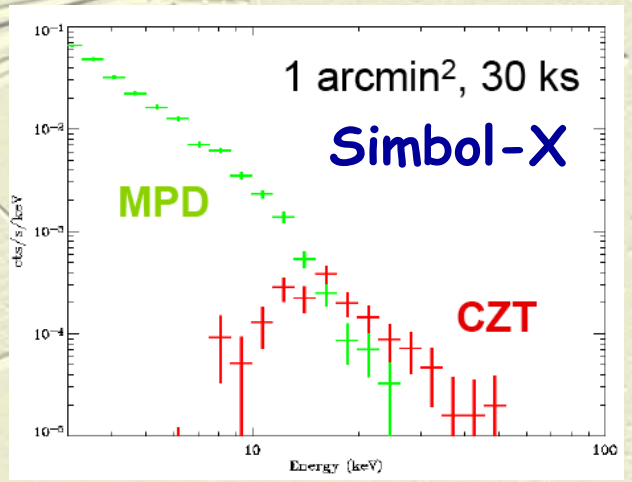
(Fiore et al., 2009)

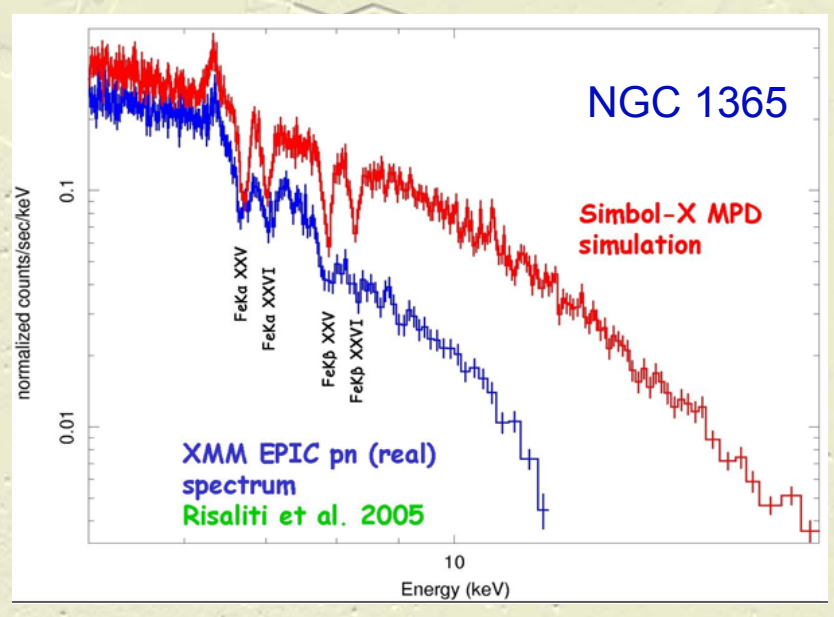
Simbol-X : also a lot of science from spectral capabilities



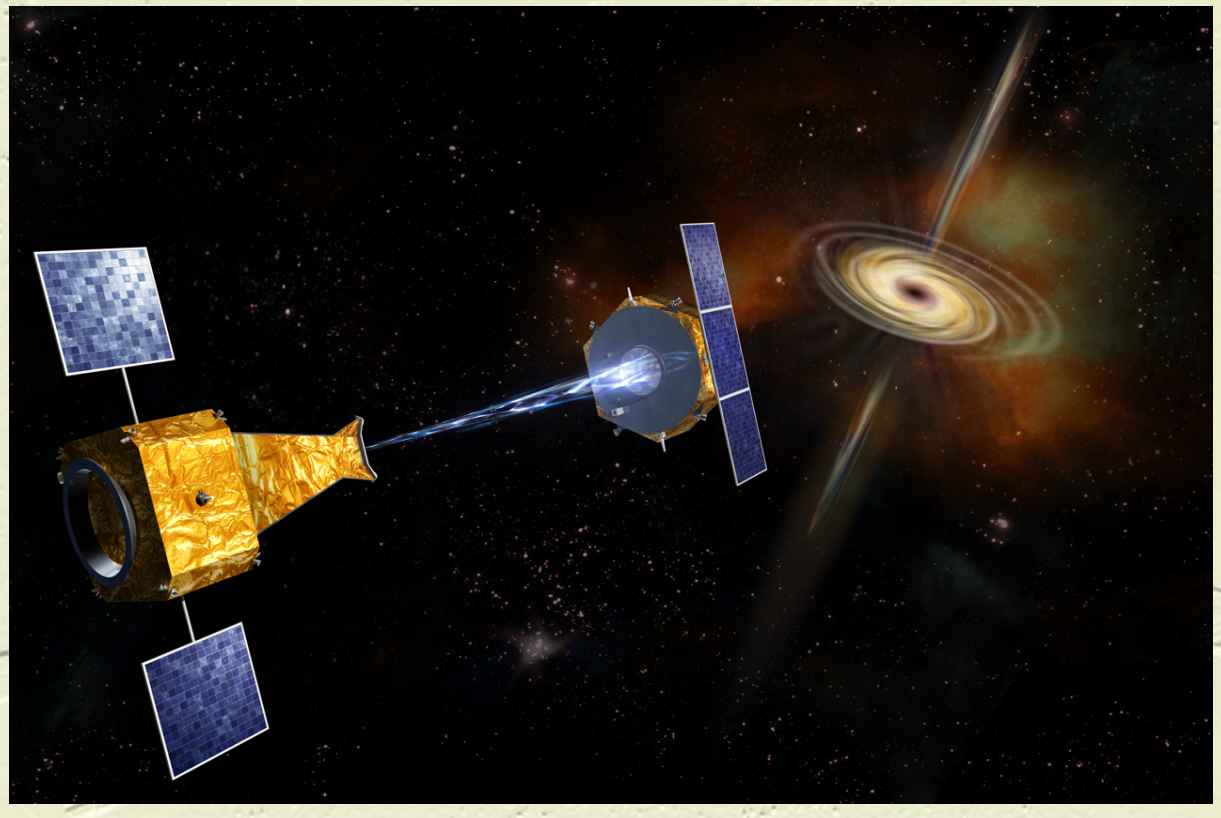








Simbol-X technological challenges (and success)



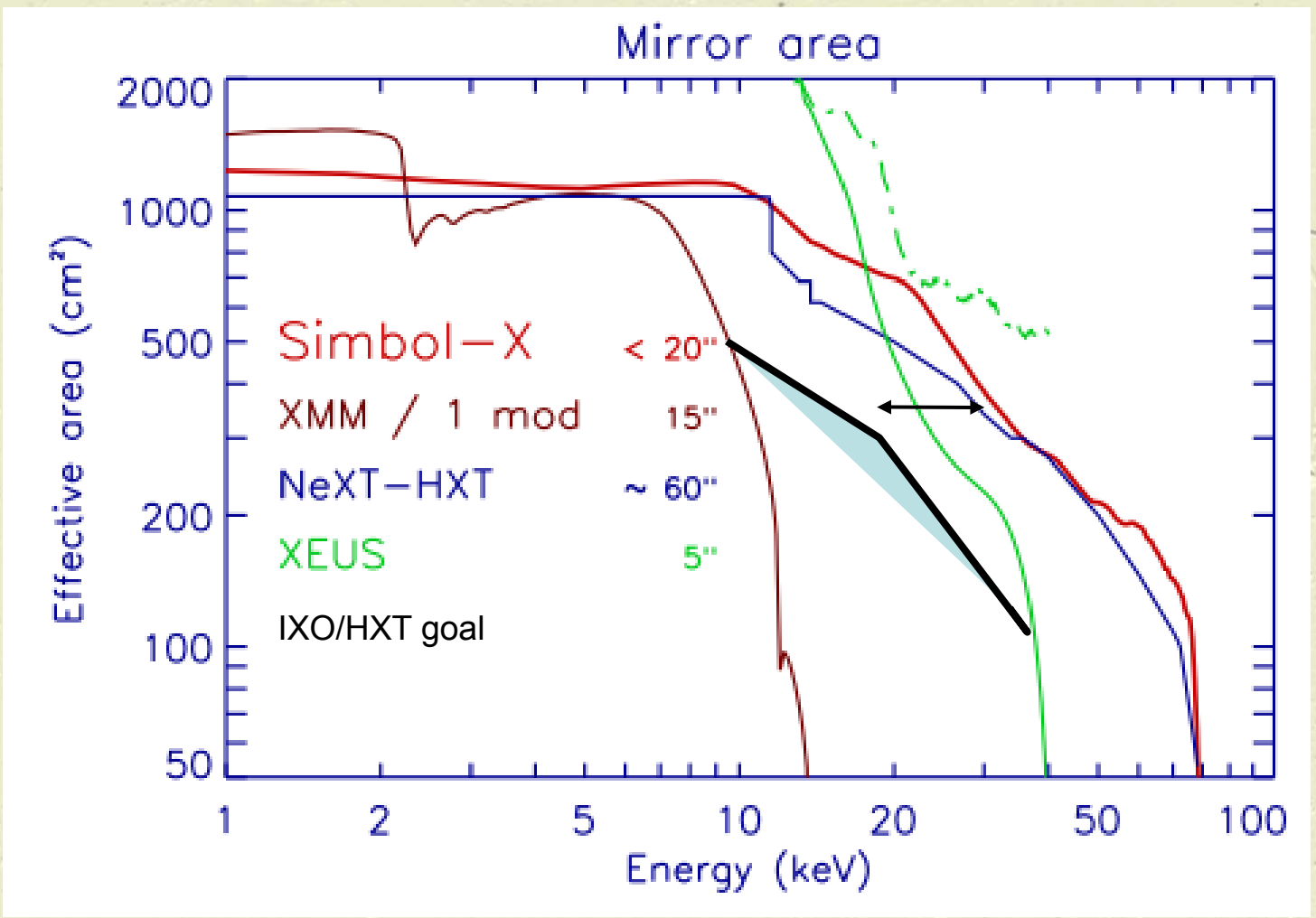
Detectors

Optics

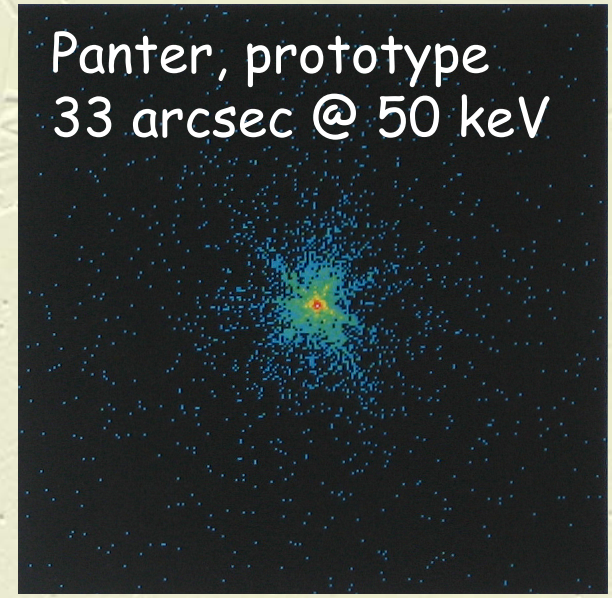
Formation Flight

Optics (INAF/O.A. Brera, see Giovanni's talk)

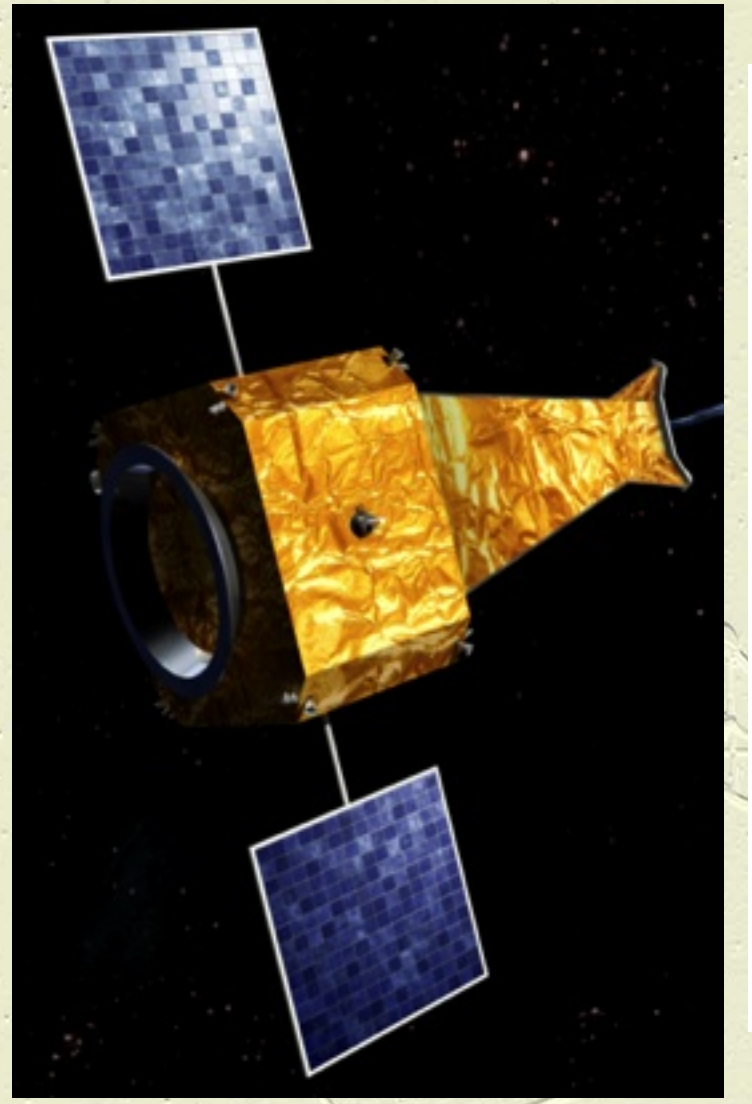
Extension of XMM technology + multi-layer

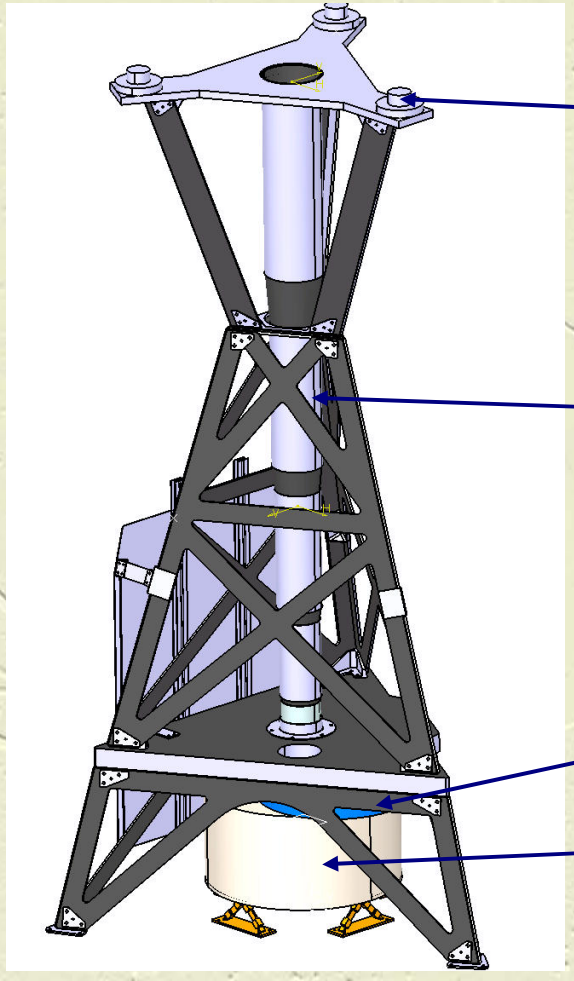


100 shells
Pt/C multi-layer
Max diam. 70 cm
Min diam. 29 cm



The detector payload (CNES + F+D labs)





(Antennas for formation flight)

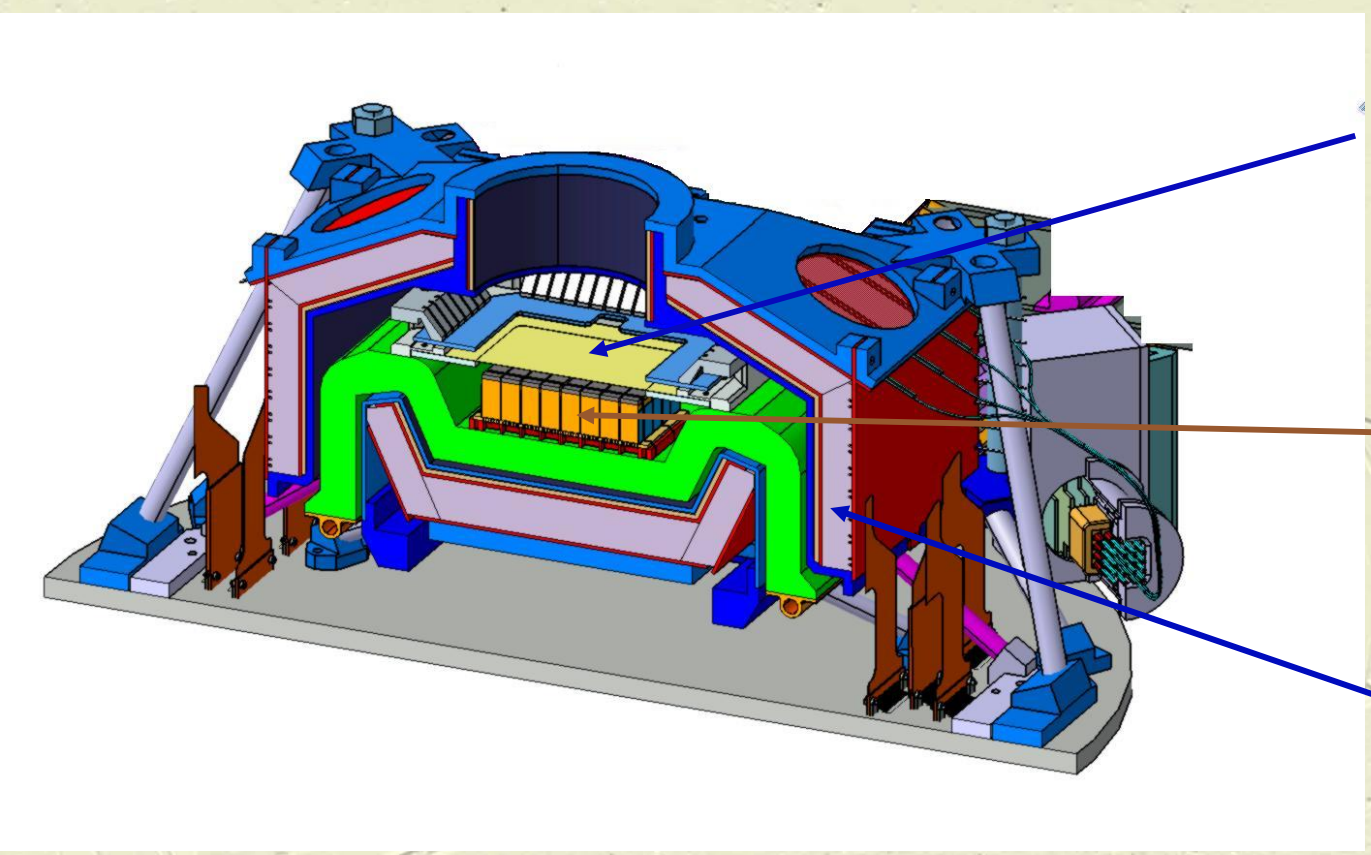
Collimator

Calibration wheel

Focal plane assembly

(one possible tower configuration, CNES)

The focal plane assembly (F+D, led by CEA)



Low energy detector
(450 µ m Silicon)

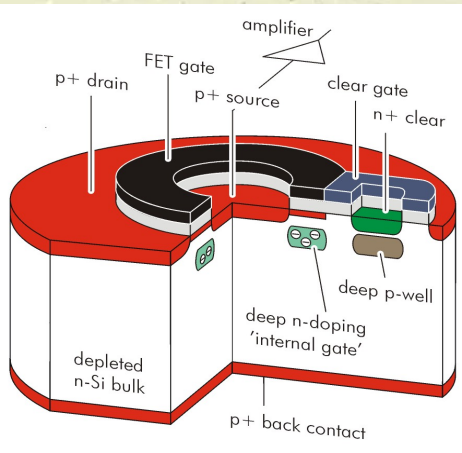
High energy detector
(2 mm Cd(Zn)Te)

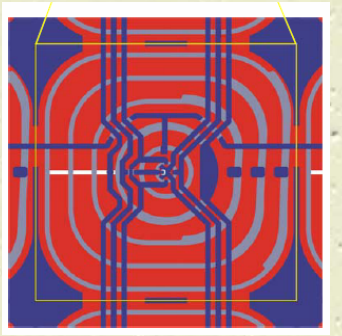
Active and passive
shielding

- Spectro-imaging system 0.5-100 keV, fast reading
- Full size : 8x8 cm2, 128x128 pixels of 625 µ m
- Operation at ~ -40°C

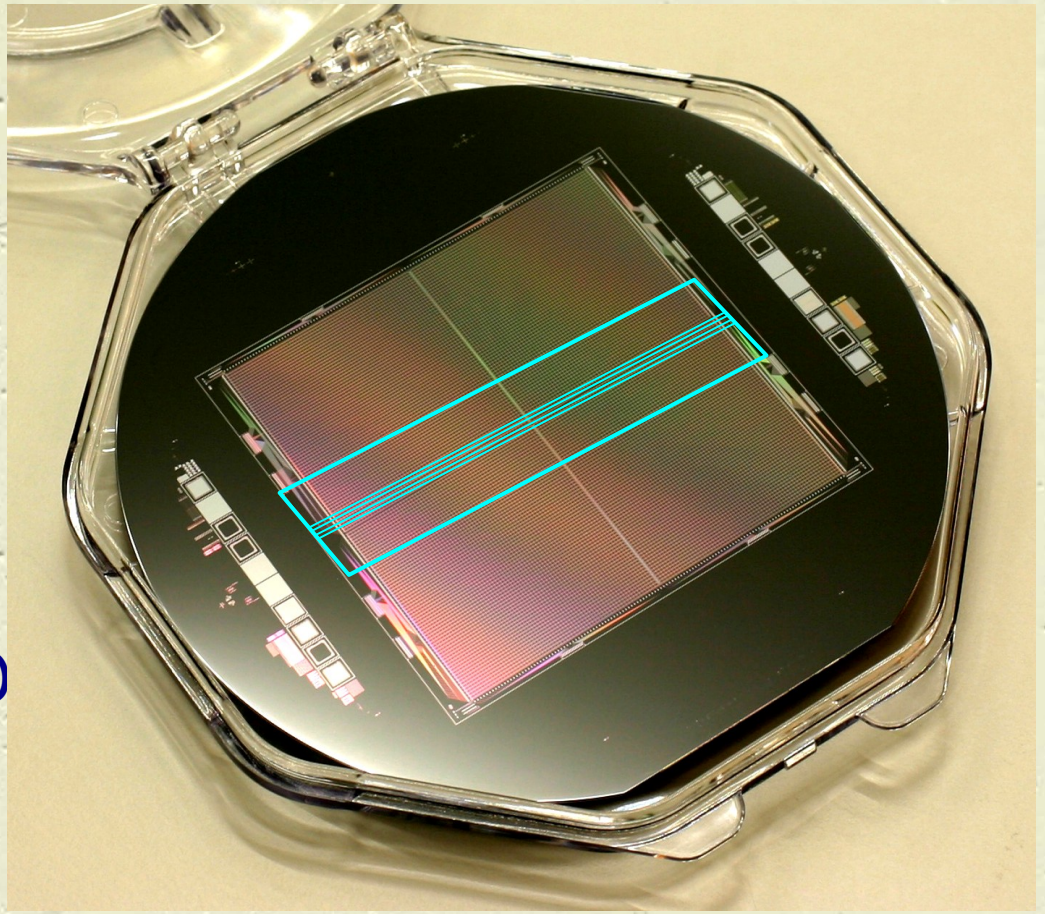
Low energy detector (MPE/IAAT)

Macro Pixel Detector with integrated DEPFET





625 µm²



- Low power consumption
- Internal amplification
- Active Pixel Sensor type
- 100 % filling factor
- Adjustable pixel size (50 µ m to 1 mm)
- Fast, parallel readout possible

  Simbol-X : 128 µ s full frame

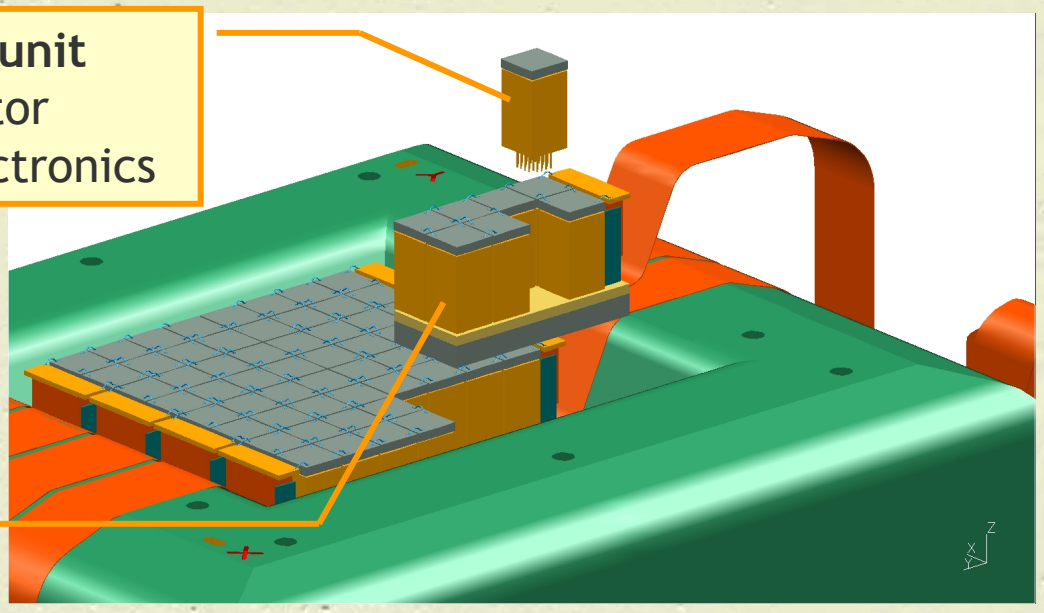
  32 µ s window

(Lechner et al, 2009)

High energy detector (CEA Saclay)

- 64 elementary detection units of 256 pixels grouped in 8 sectors and placed side by side.

Elementary detection unit
256-pixel CdTe detector
256-channel front-end electronics



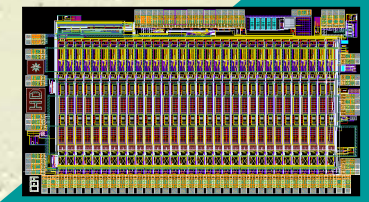
1 Sector

- **Challenge: to minimize inter-module and inter-sector space** (detector layout, cutting path, mechanical tolerance)
  - **Homogenoeus repartition of dead zones**: 1 pixel pitch per module
    1 line missing every 16 lines

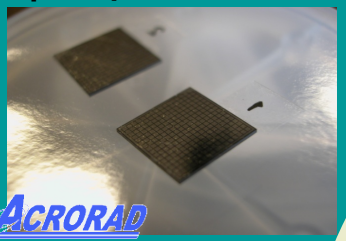
(Meuris et al., 2009)

Caliste design and fabrication

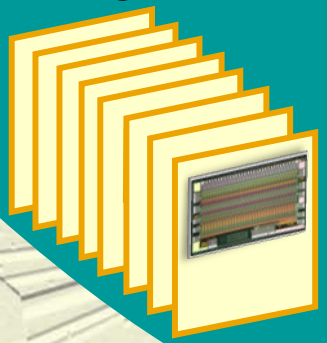
IDeF-X HD ASIC
32 analog channels



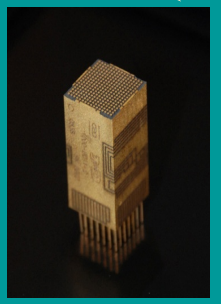
Cd(Zn)Te 256-pixel detector
(625 µm pitch, 0.5 or 1 mm thick)



Mounting on PCB

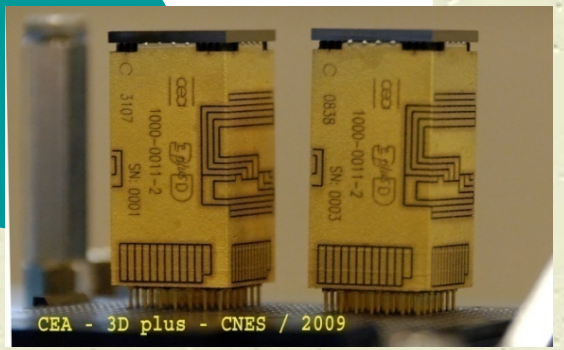


8 ASIC Stacking

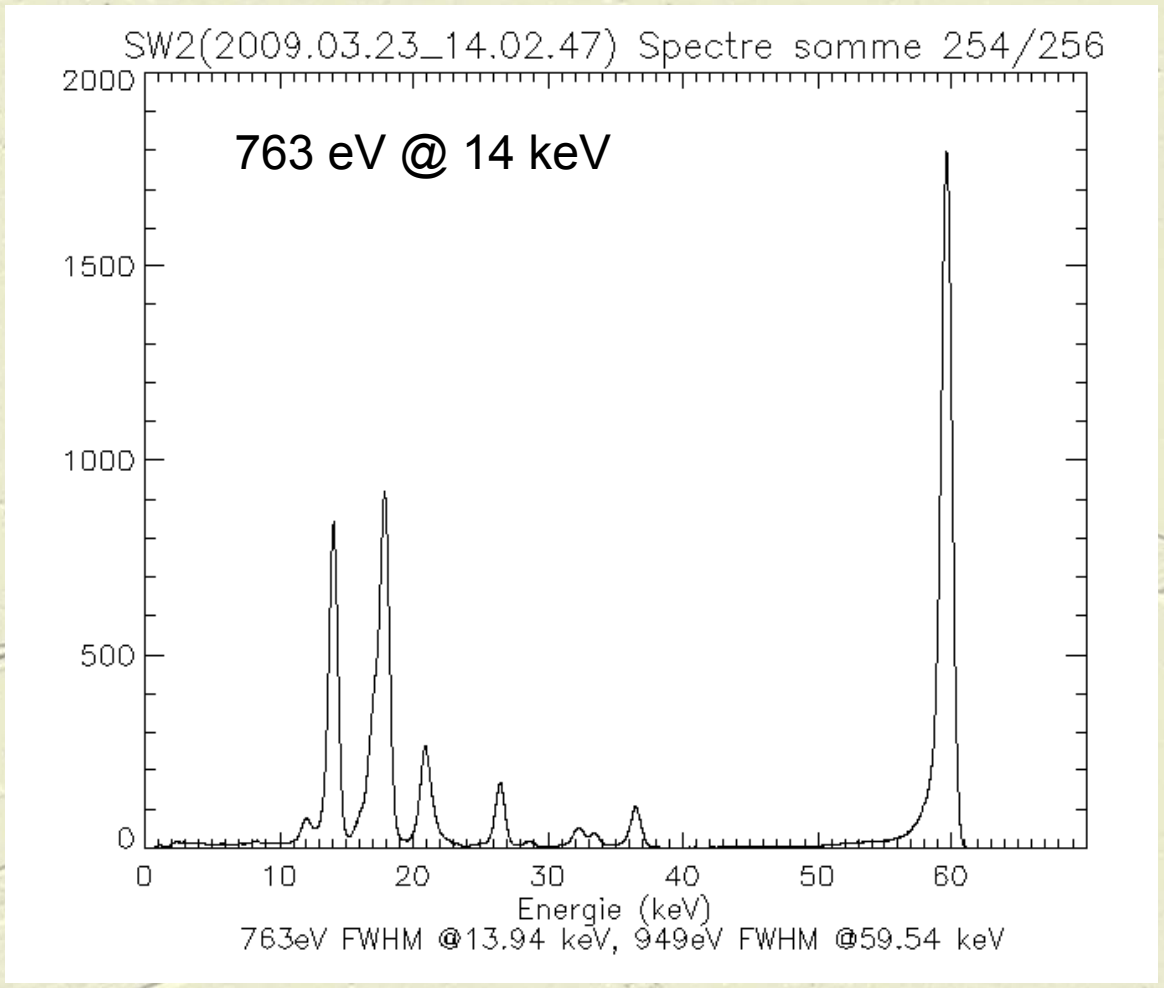


Electrical body
with a 4 x 4 PGA

Caliste 256 V2

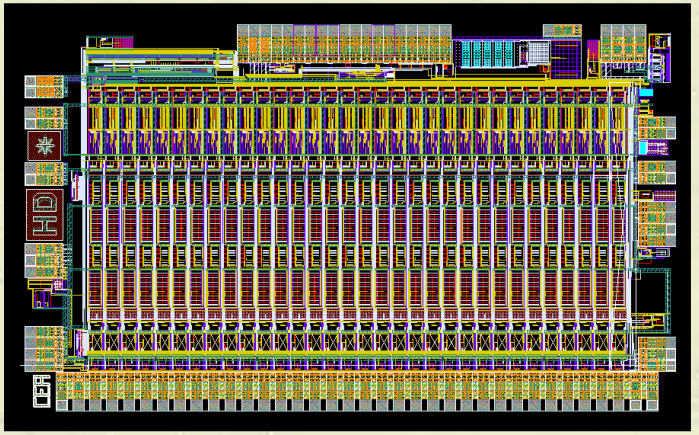


Caliste : demonstrated performances

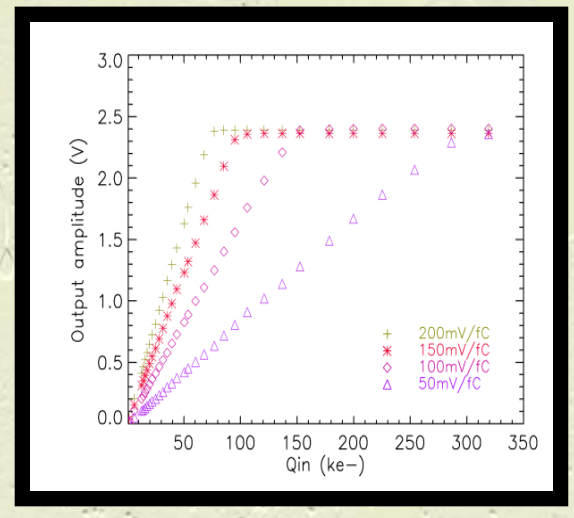


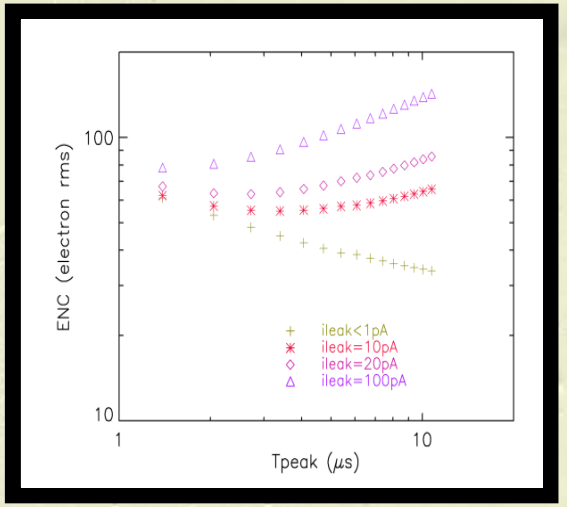
Idef-X HD : produced and OK

- I/F ok
- Noise ok
- Linearity and dynamic range ok
- Power ok
- Thermal sensor ok



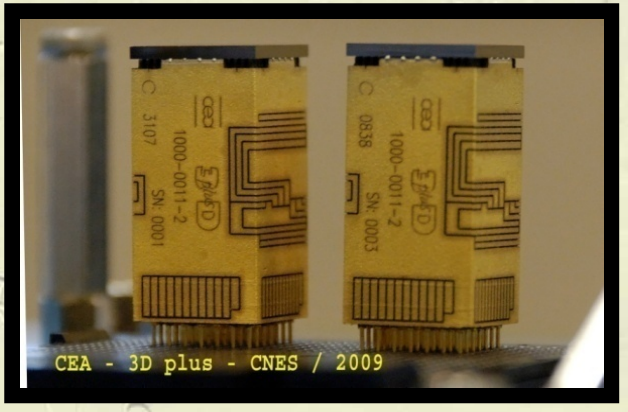
PARAMETER	VALUE
CHIP SIZE	3500 µm × 5800 µm
TECHNOLOGY	AMS 0.35µm
POWER CONSUMPTION	27mW (850 µW/channel)
GAIN	50,100,150,200 mV/fC
	250 ke⁻ (1.1 MeV for CdTe) at 50 mV/fC
DISCRIMINATION THRESHOLD	90 e⁻ to 3.6 ke⁻
PEAK TIMES (5%-100% OF SHAPED SIGNAL)	0.7 µs to 10.7 µs (16 values)
TEMPERATURE SENSOR DYNAMIC RANGE	-50°C to +30°C
RESOLUTION	0.5°C

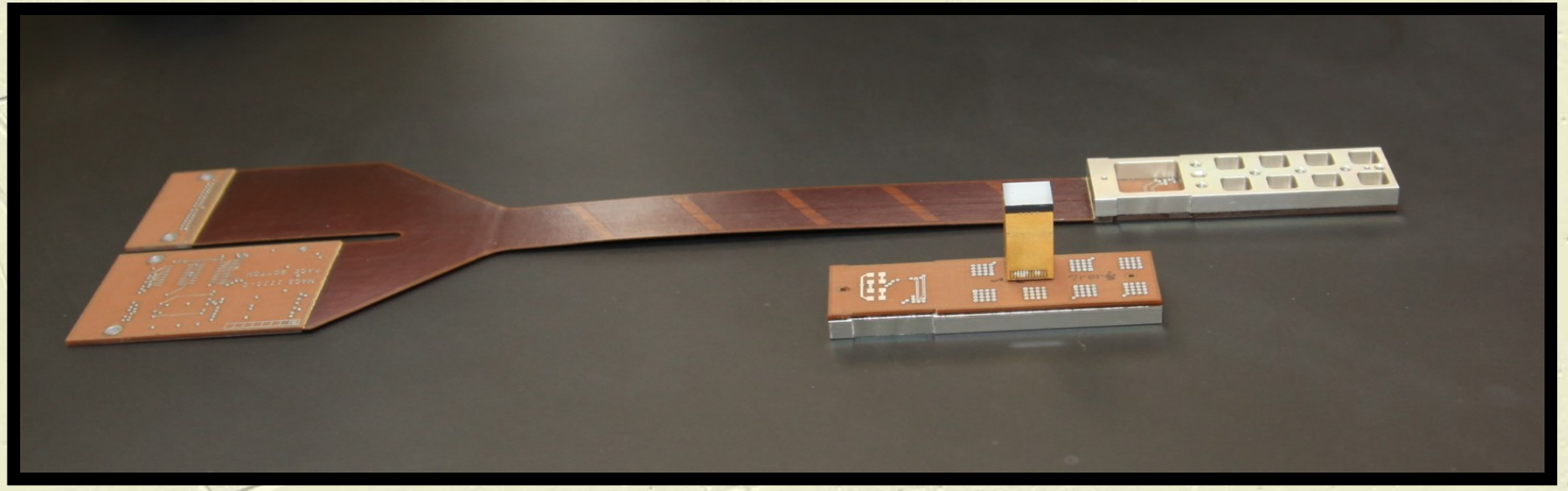




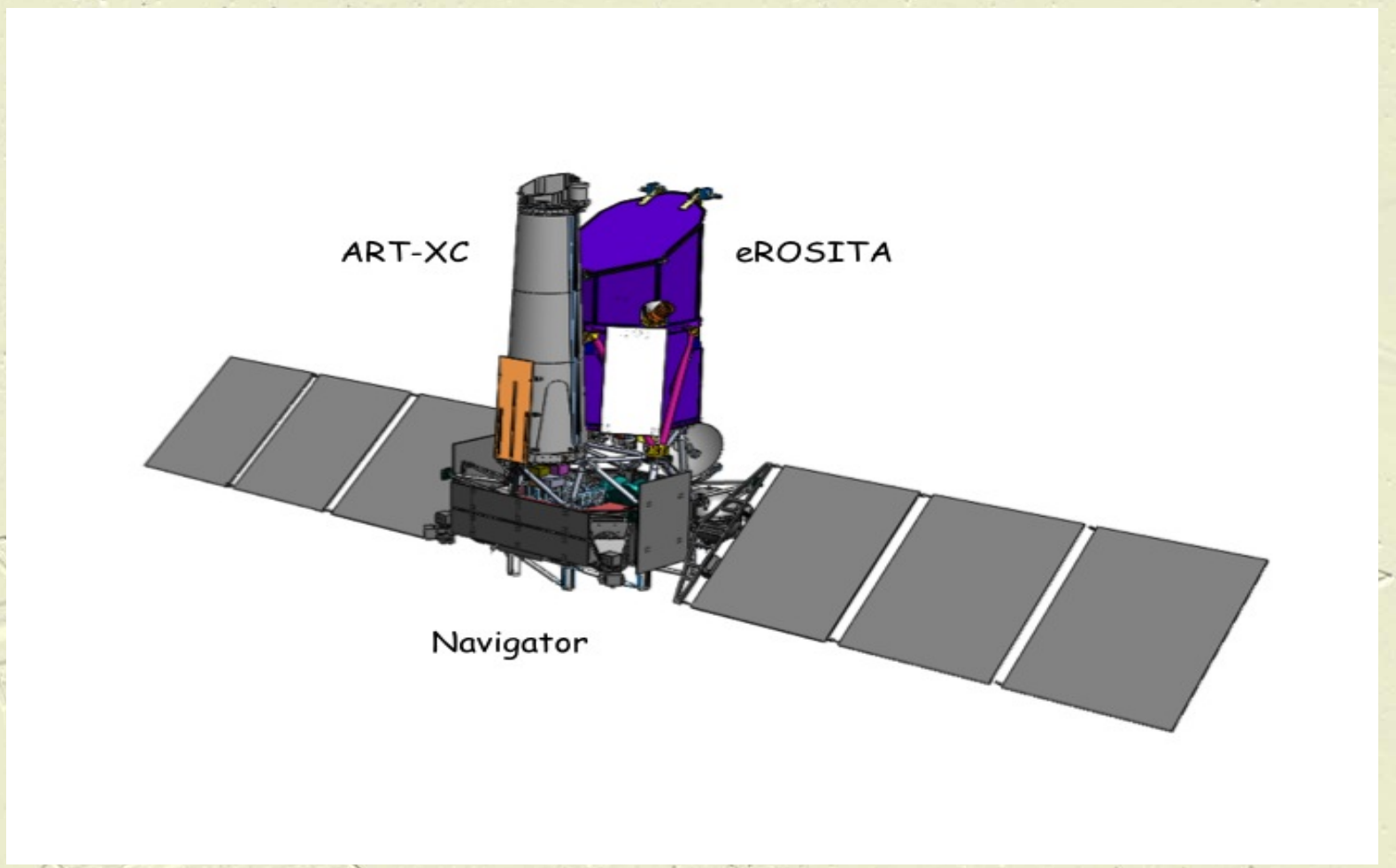
MACSI : 8 Caliste to a single detection unit

- MACSI kicked-off at CEA
- Caliste V2 kicked-off in industry
- IDeF-X HD tests ok
- Flex-Rigid PCB's first prototypes ok
- 3D Design just finished



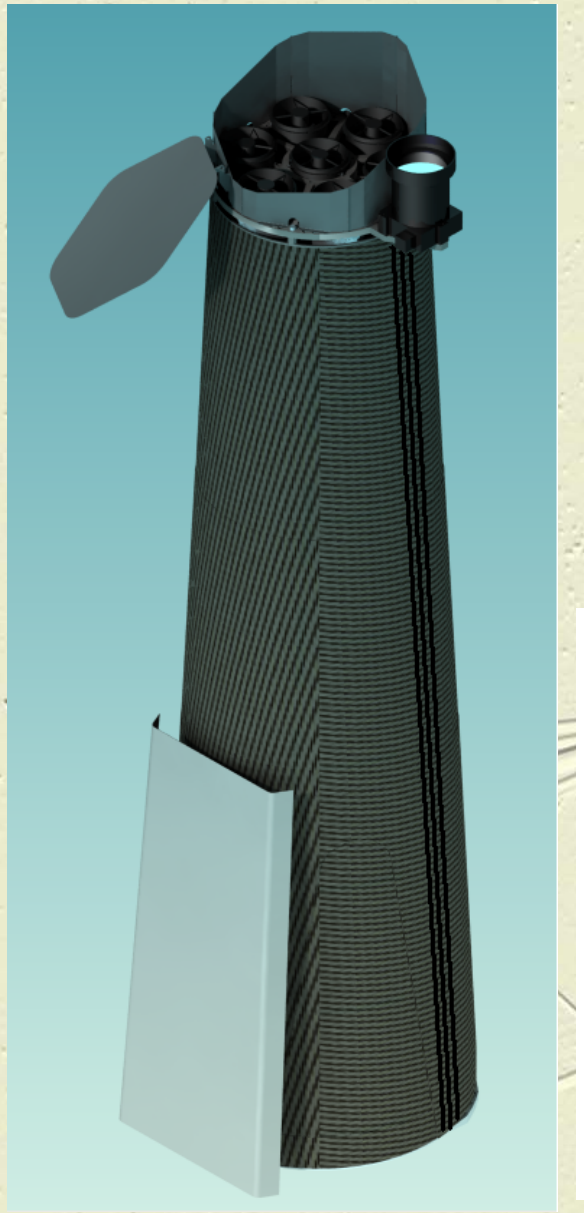


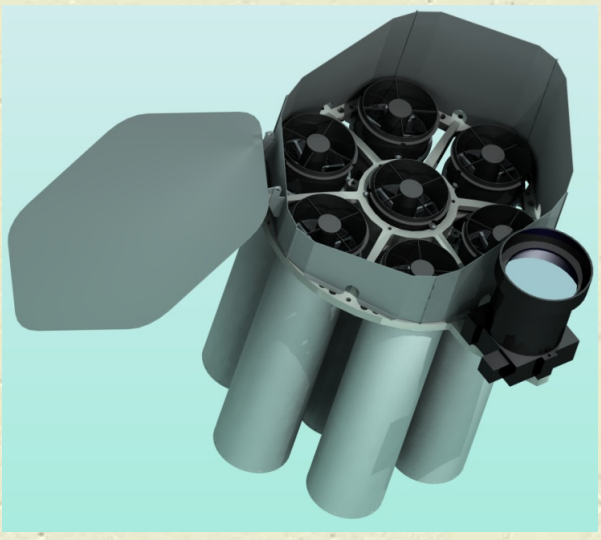
MACSI : flying on Spectrum Roentgen Gamma ?

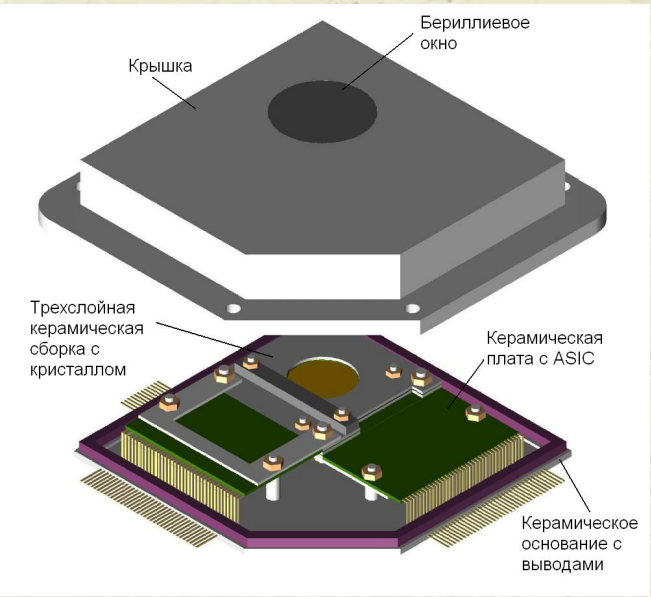


- Discussion on-going since end of January for F to participate to ART-XC

The ART-XC Hard X-ray instrument

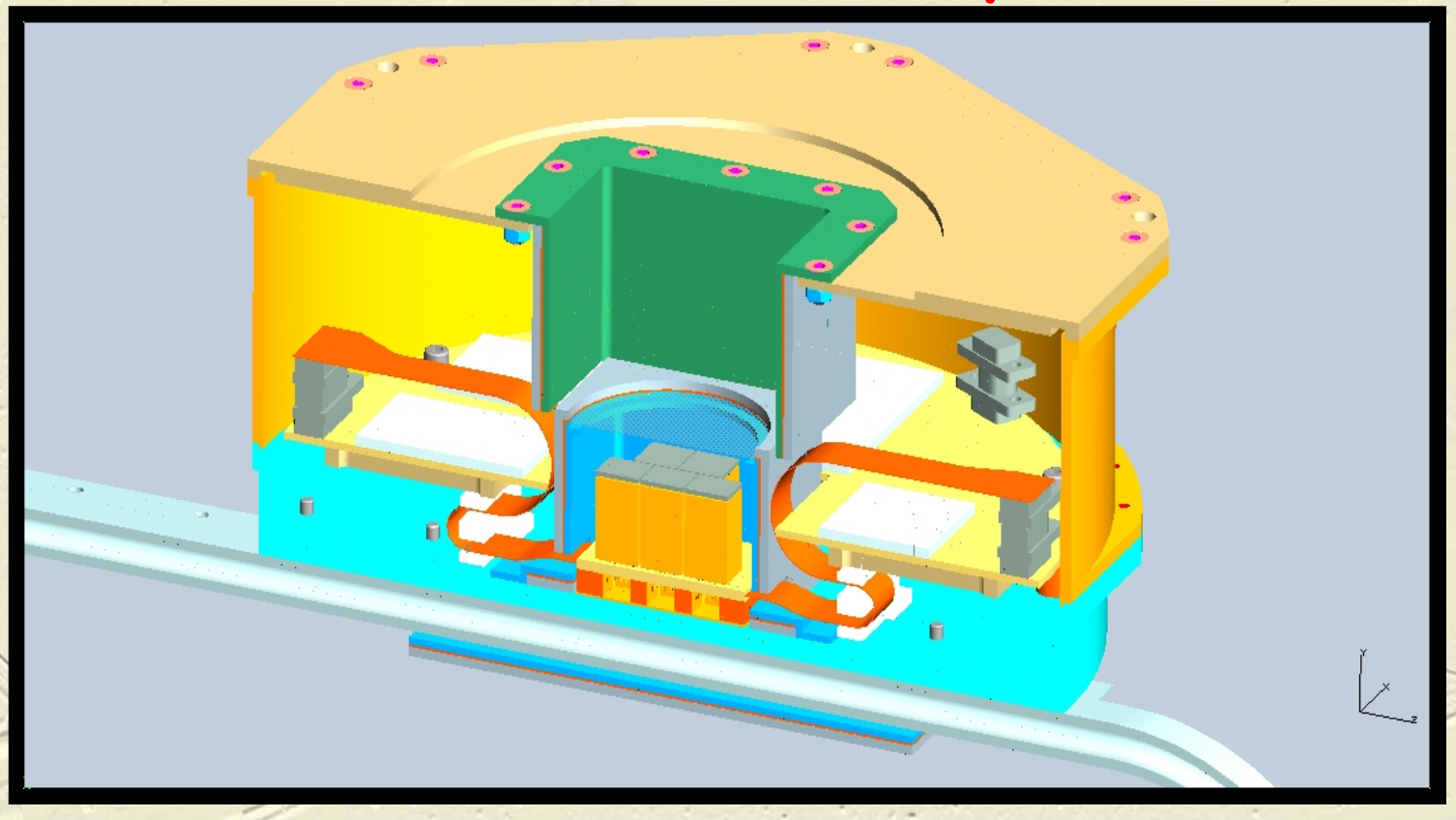






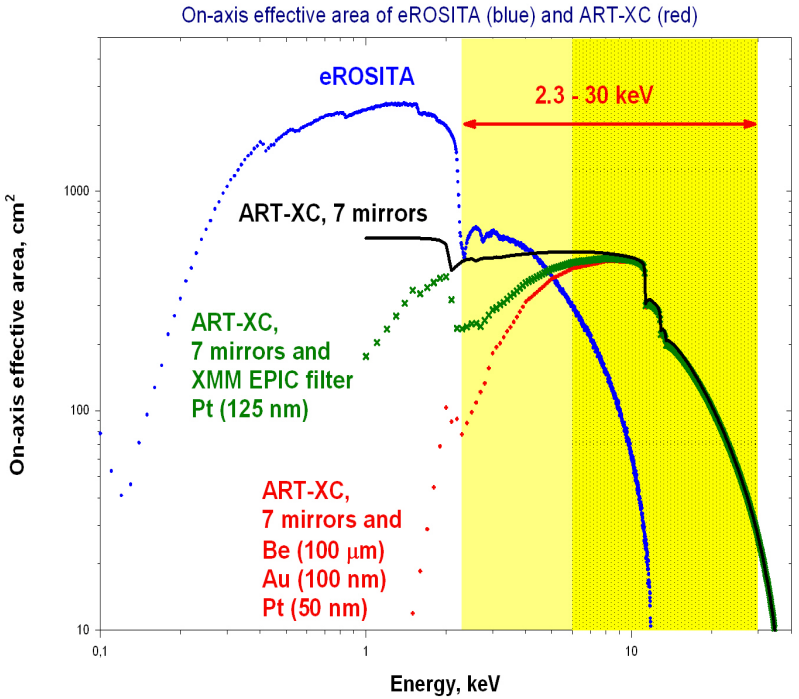
- 7 telescopes (28 shells)
- Resolution : 1 arcmin
- Field of view : 32 arcmin
- Focal length 2.7 m
- Emax : ~ 30 keV
- Built in Sarov, and by MSFC
- 7 focal planes
- Stripped CdTe (Acrorad)
- Commercial ASICS
- Threshold : 6 keV
- ΔE : 1.4 keV (goal)

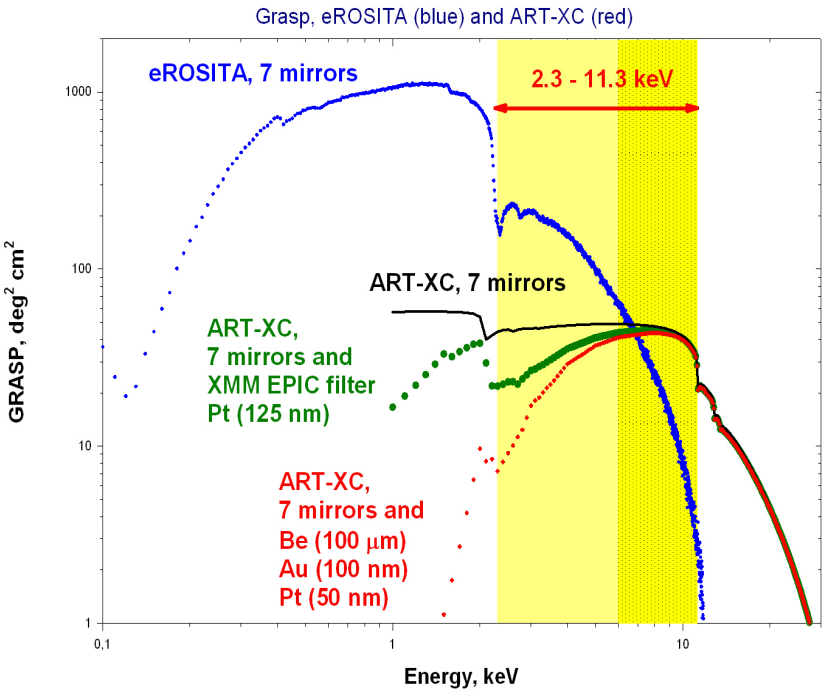
The French Focal plane



- Same mechanical I/F as IKI detector and simplifies cooling on ground
- Low threshold : 2 keV & Excellent energy resolution (< 1 keV)
- Shielding : passive, also inherited from Simbol-X (design and simulations).

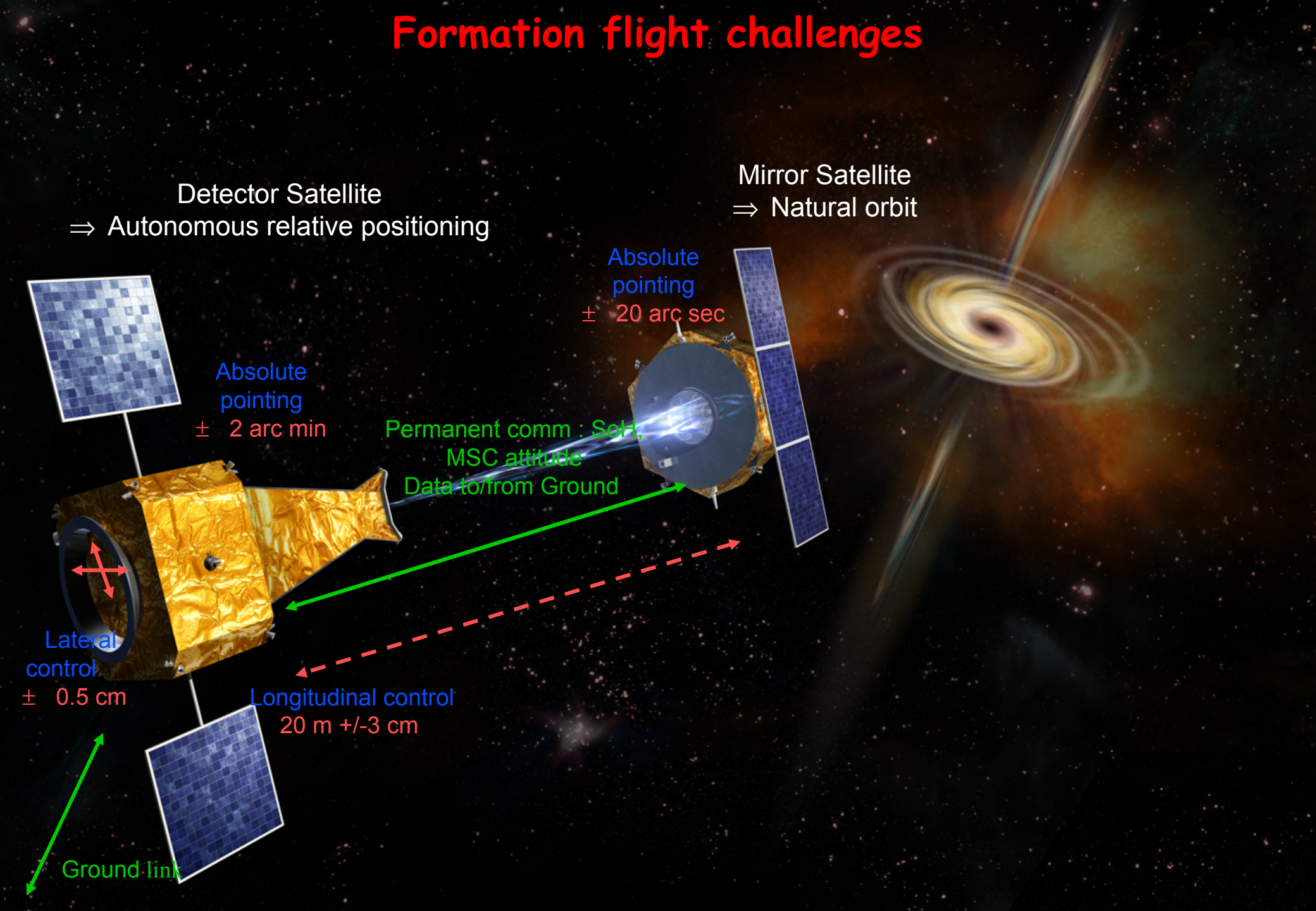
The ART-XC science gain with Caliste



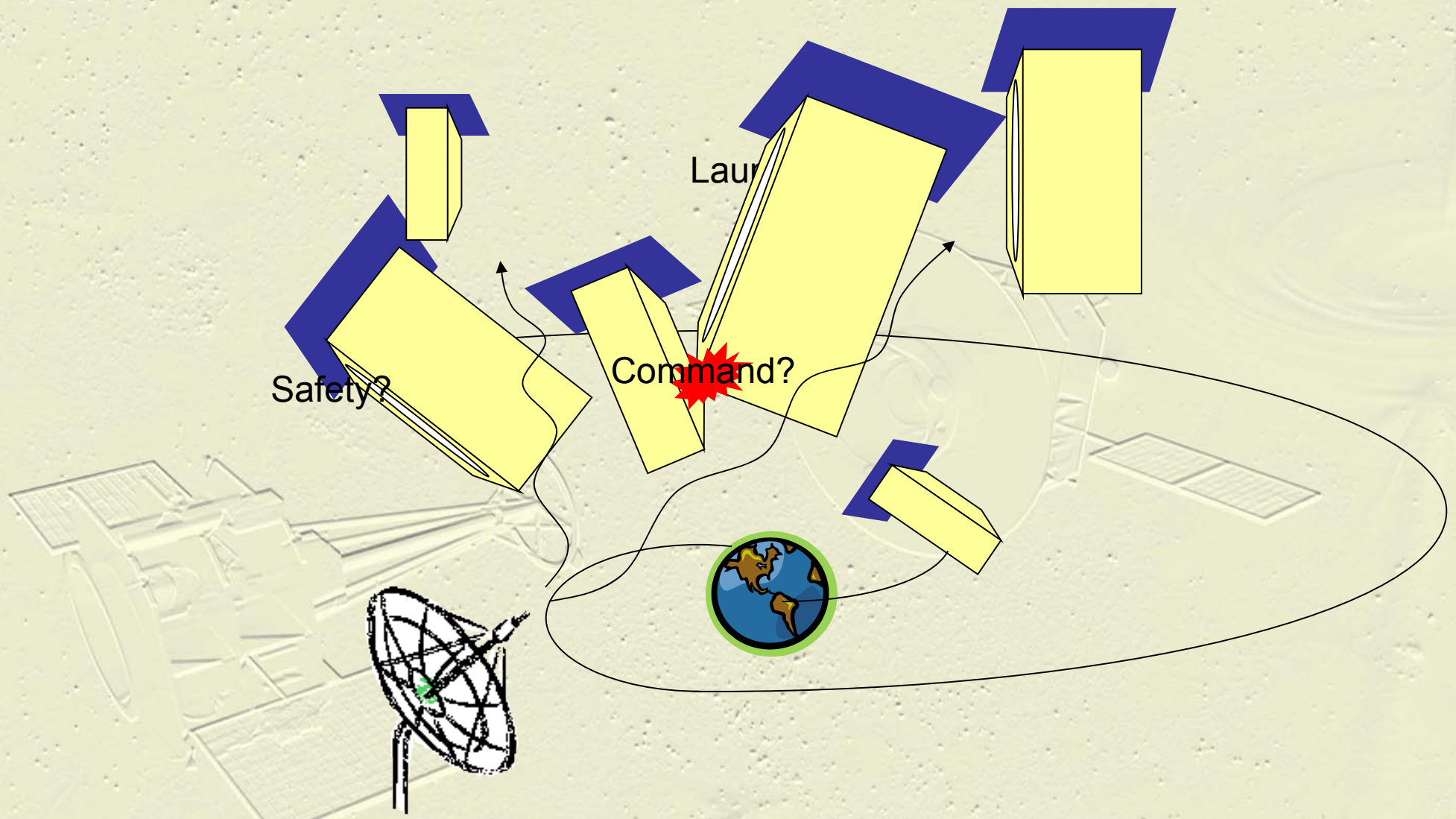


- Status (France) : proposal sent to CNES
  examined in September, decision end of year

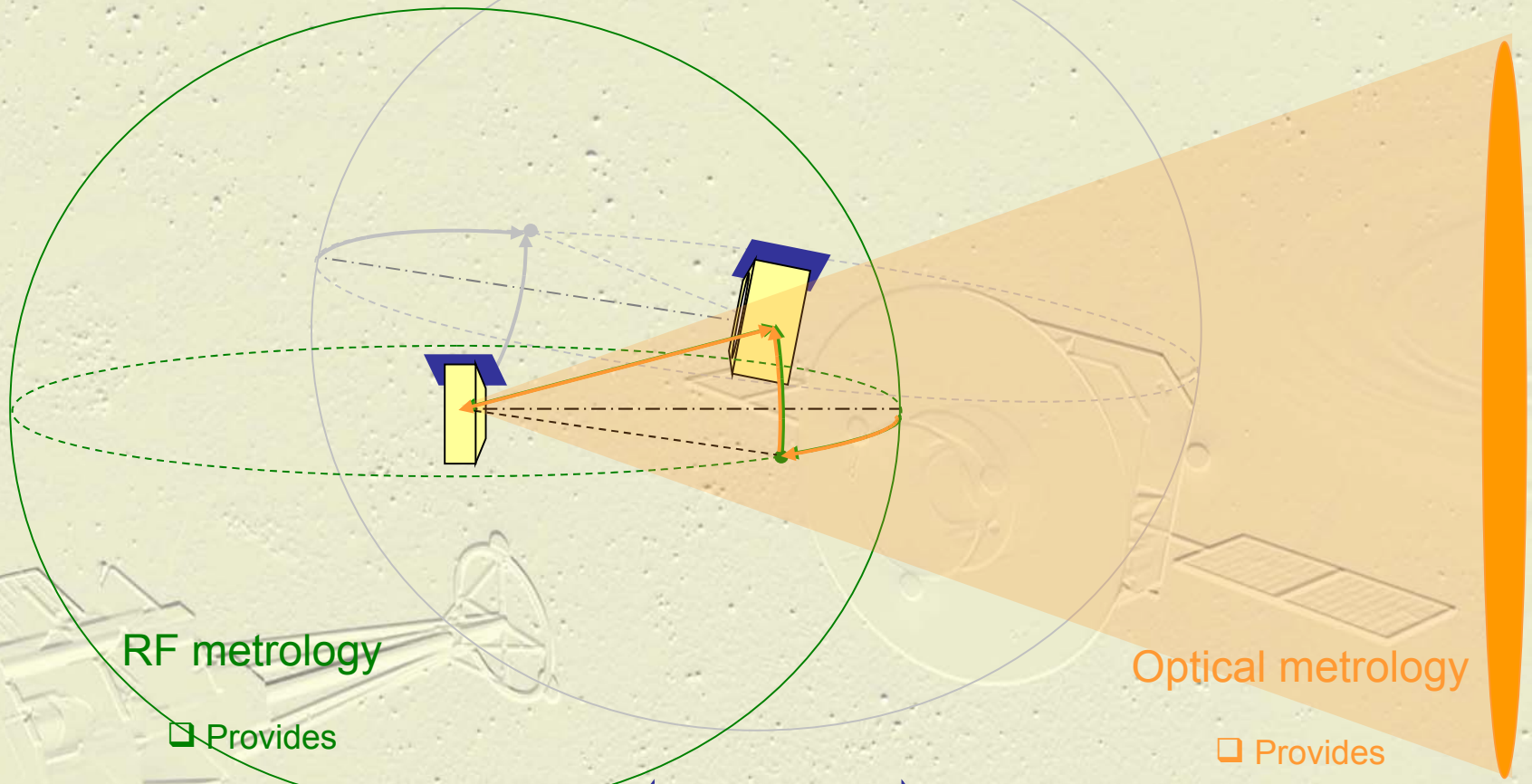
Formation flight challenges



Formation flight challenges : system



Formation flight challenges : metrology



RF metrology

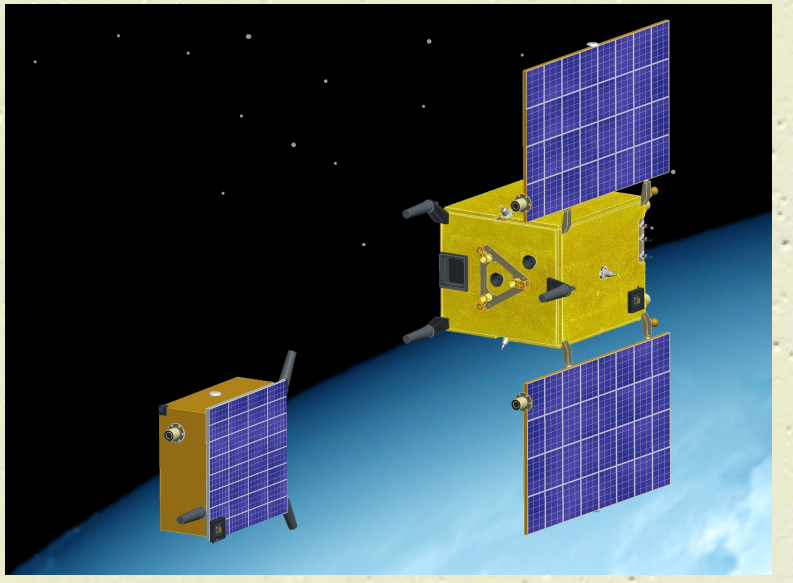
- ❑ Provides
  - • Intersatellite range
  - • Aspect angles (azimuth+elevation)
- ❑ Omnidirectionnal
- ❑ Available on each satellite
- ❑ Operational range 3 m – 30 km

2 independent &complementary metrologies

Optical metrology

- ❑ Provides
  - • Intersatellite range
  - • Aspect angles (azimuth+elevation)
- ❑ Field of view ≥ 3°
- ❑ Available on the detector satellite
- ❑ Operational range 20 m ± ε

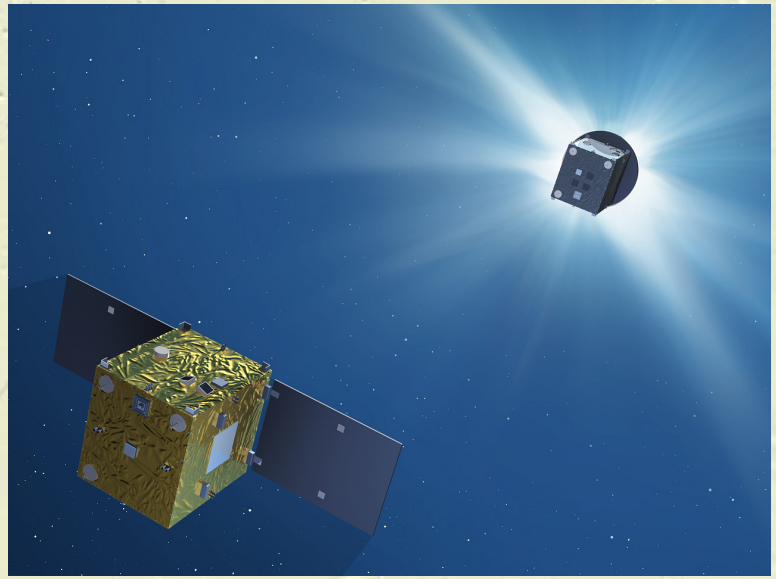
Formation flight : no more a challenge (at this level)



Prisma mission (Sweden)
with Radio Freq. Metrology
from F + Spain

Launched June 15

Separation and Form. Flight
Tests in August



Proba-3 (ESA) - Phase B (tbc)

Science mission, with solar coronograph

Focal length : 150 m
Control : within a few mm

Full operational Form. Flight

From Simbol–X to which hard X-ray mission(S) ?

- Increase SRG performances - Uses Caliste developments

but, although interesting, mission not as performant as Simbol–X in pointing mode (eff. area, angular resolution, highest energy reached)

- NHXM (see Gianpiero's talk) - Uses Optics and (possibly) Caliste developments

same spectro-imaging performances as Simbol–X but in 2018, largely after NuSTAR and Astro-H

gain : angular resolution (CXB, Galactic Centre)

same effective area as NuSTAR, and Astro-H

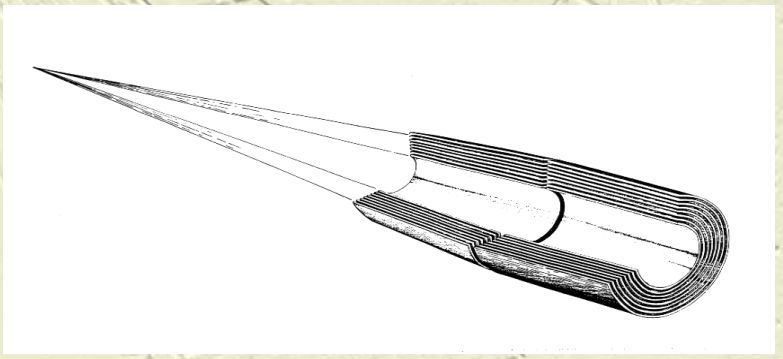
A mission with a really large area in Hard X-rays ?

- Number of photons :

  - a very important parameter when fitting spectra, and for timing studies (variability, but also QPO's)

  - the very important parameter when there is no confusion problem (AGN's, Galactic binaries, even extra-galactic if reasonable imaging), and as long as there is a reasonable focusing

- The way to go : the « initial » Simbol-X way :



$$A_{eff} \approx F^2 \times \theta_c^{\,2} \times R^2$$

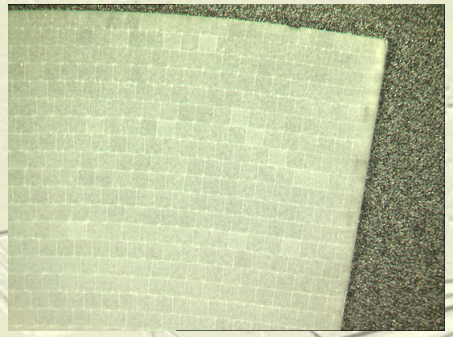
(G. Pareschi)

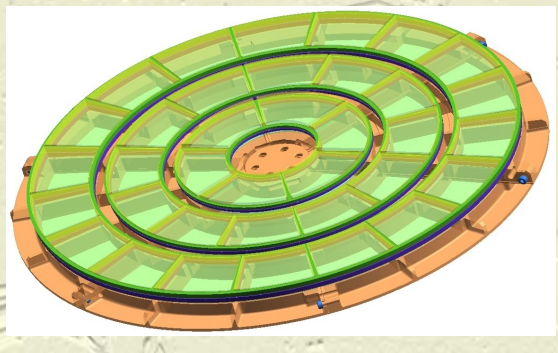
F x 3 ➔ A_{eff} x 10

A possible mission concept : optics

- Aim at : > 10 times current effective area @ 30 keV (5000 cm2 range) keeping low energy response
- Keep focusing, but with moderate angular requirements (~ 1-2 arcmin)

-> Use low mass optics

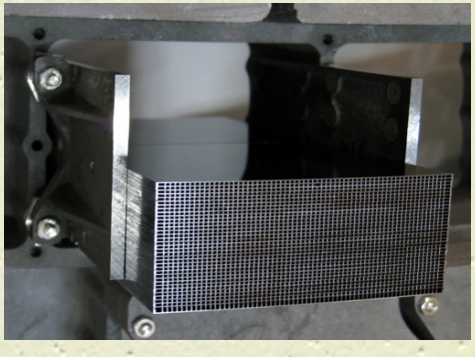




MIXS-T on BepiColombo

MCP optics
- a few 10's kg/m^2
- Ir coating demonstrated

Slumped Glass
5" HEW
~270 kg/m^2

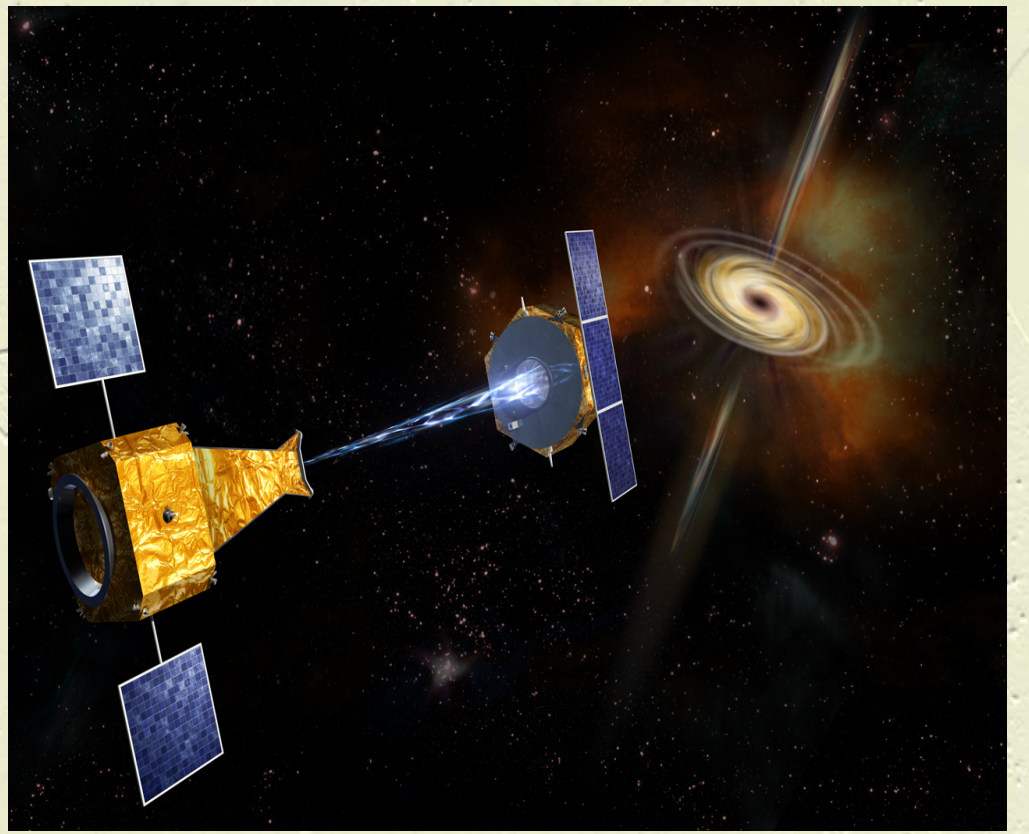


Si-HPO
5" HEW
~200 kg/m^2

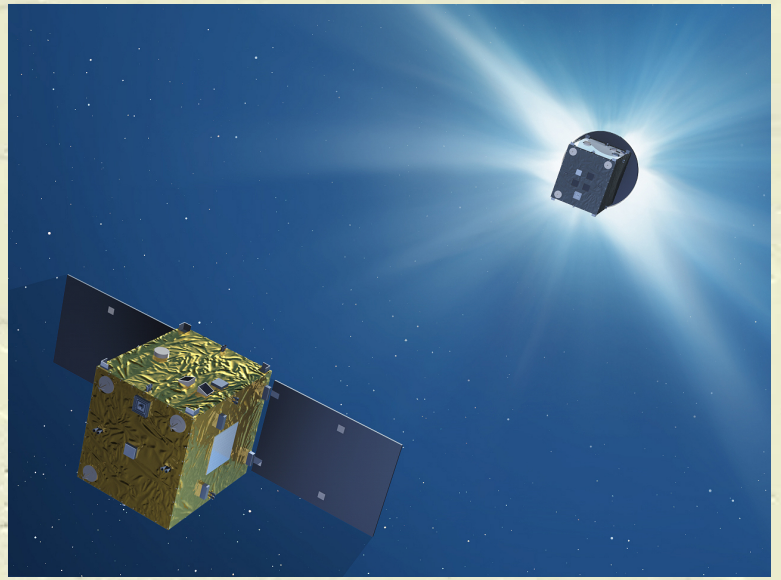
A possible mission concept : the focal length

- Use Formation Flight, with ~ 100 m Focal Length

Build on Simbol-X studies

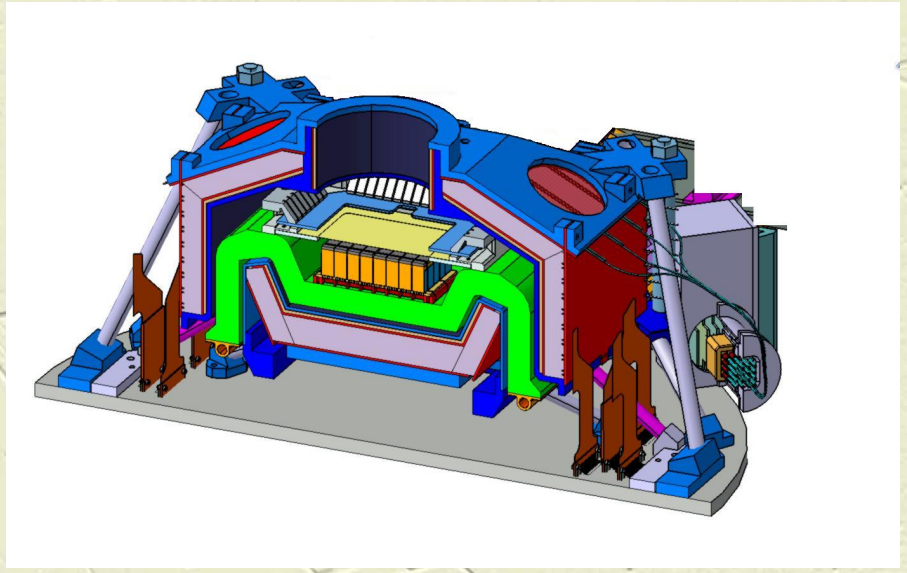


and on high TRL technology

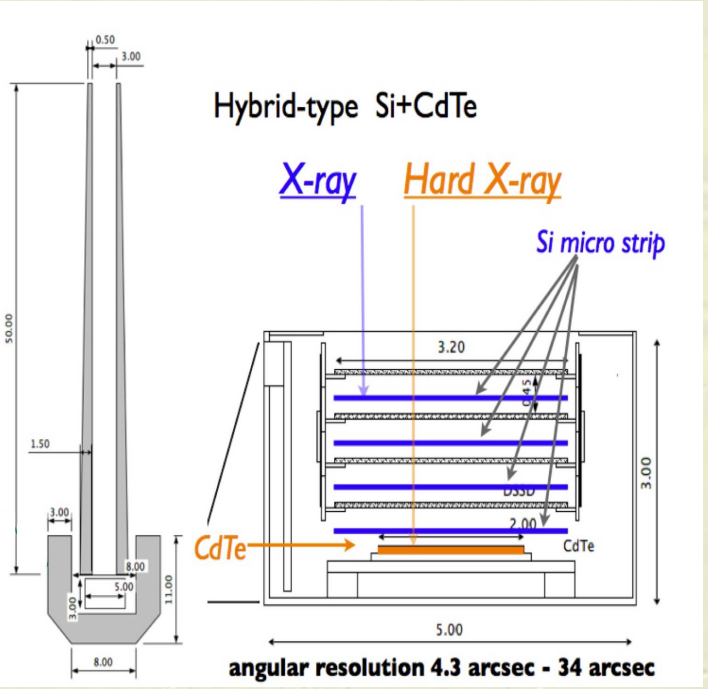


A possible mission concept : detector payload

- Spectro-imaging - Good spectral resolution at Fe line
- Polarimetric capabilities (Compton)



e.g. Simbol-X type



or Astro-H HXI type

Thank you