CdTe detectors in space: hard X-ray spectral performance on-board the INTEGRAL and the Solar Orbiter missions

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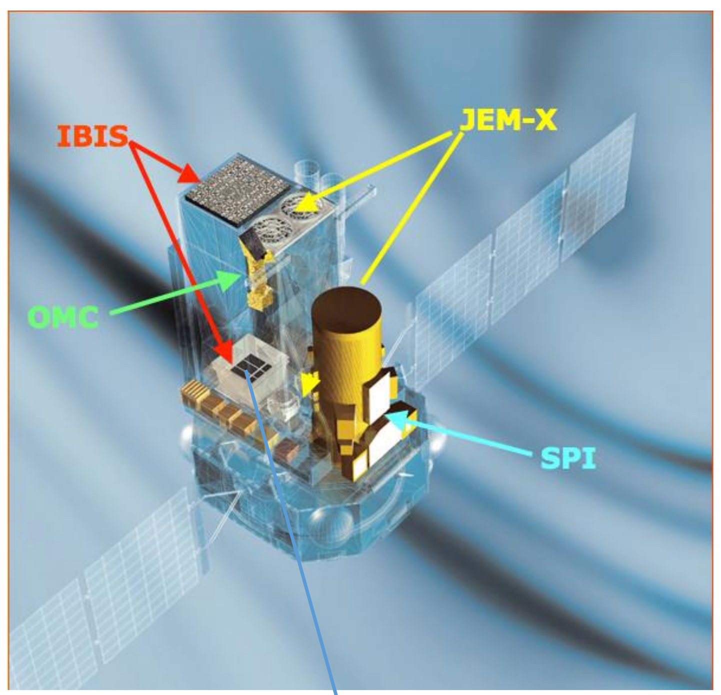
INTEGRAL

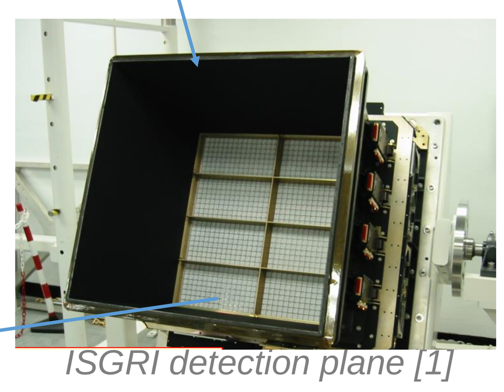
20 years in orbit

Launch date: 17 October 2002
Highly excentric orbit: Perigee 9.000 km, Apogee: 153.000 km; inclination 51.6°
Orbital period: 72 hours

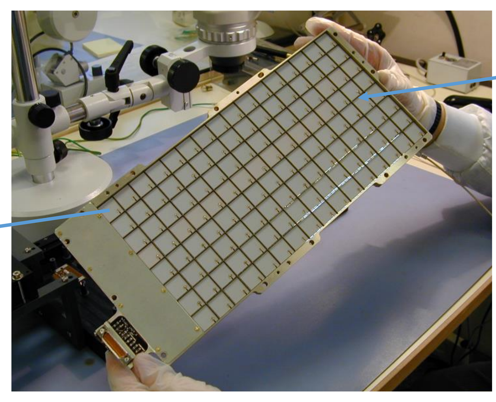


IBIS (Imager on board the INTEGRAL satellite)
3,4 m coded mask telescope, 700 kg
2 focal planes: ISGRI (15 keV – 1 MeV) and PICsIT (175 keV – 10 MeV)

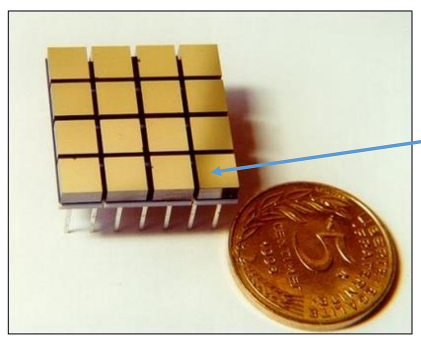
ISGRI (INTEGRAL Soft Gamma-Ray Imager) [1]
16384 monopixel crystals of 4 mm × 4 mm ×2 mm with platinum ohmic contact (2048 cm²)



ISGRI detection plane [1]



One of the 8 ISGRI modules



One polycell, the detection elementary unit

Bad pixels

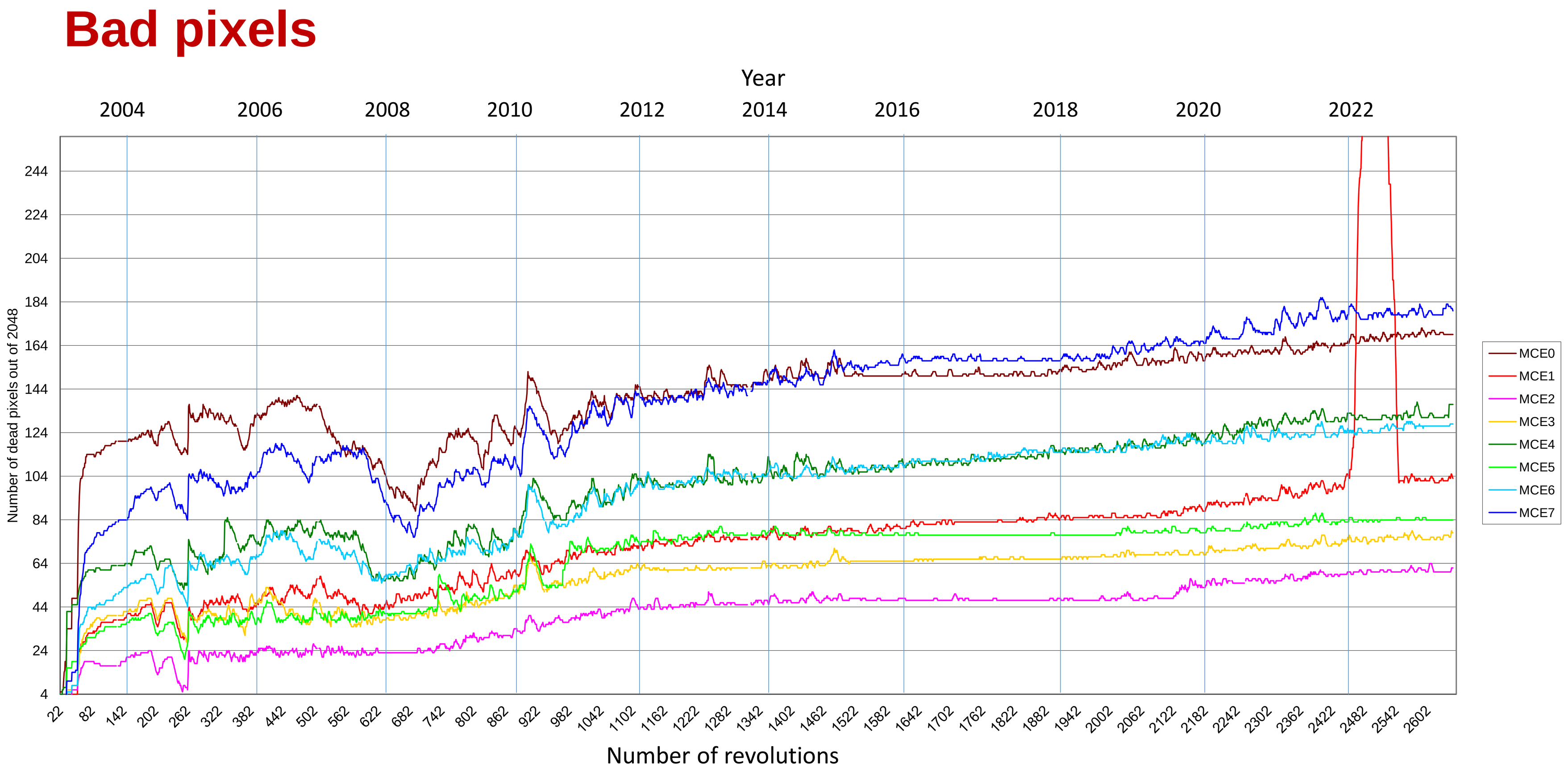


Fig. 1. Number of switched-off pixels for each module because judged as dead or noisy.

The fraction is bad pixels is not much affected by the operation in space: it is 3 % at launch and 6 % 20 years later.

Gain loss

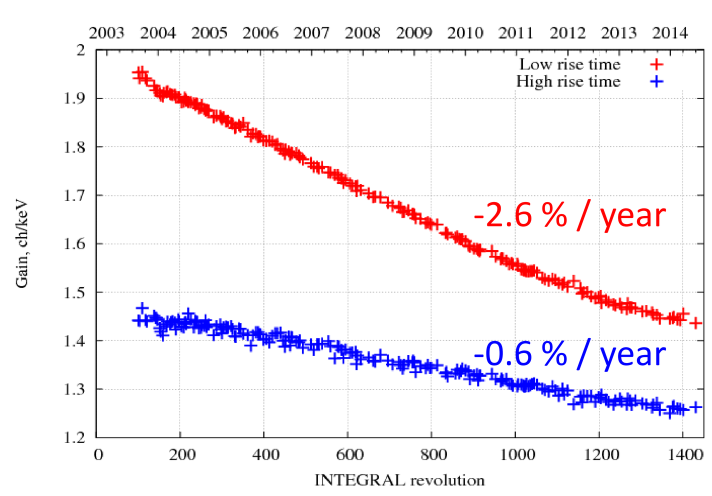


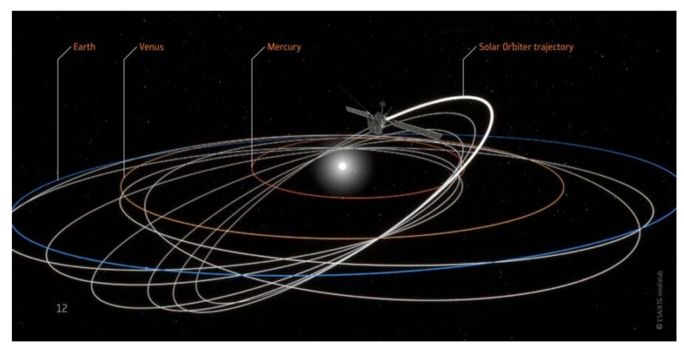
Fig. 2. Gain measured on board ISGRI.

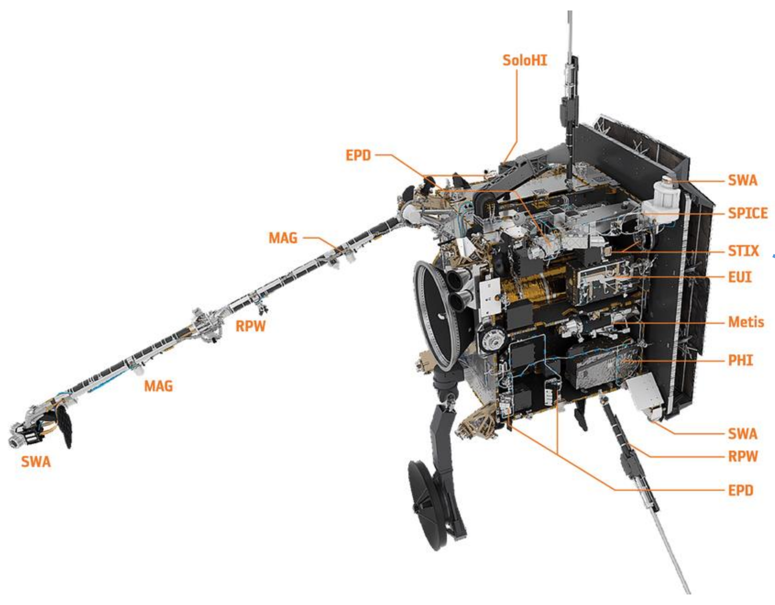
The gain of the short rise-time pulses is strongly linked to the electron mobility and lifetime and the gain of the long rise-time pulses is related to the hole mobility and lifetime. From the measurement technique in ISGRI and other ground protons tests [3], we demonstrate that **radiation damage only affects the electron mobility**.

SOLAR ORBITER

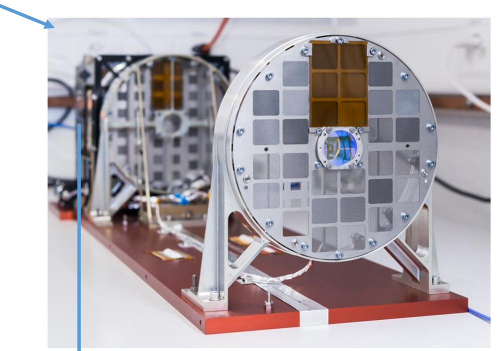
3 years of cruise around the Sun

Launch date: 9 February 2020
Orbit as close as 0.28 UA

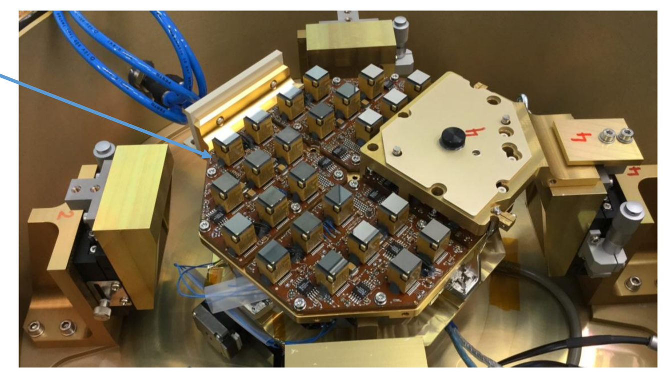




STIX (Spectrometer Telescope Imaging X-rays) [2]
Fourier telescope, 7 kg
32 collimators pairs, 32 Caliste-SO CdTe detectors



Caliste-SO
1 mm-thick 12-pixel Schottky CdTe detector in a hybrid component with low-noise front-end ASIC IDeF-X HD



Bad pixels

No bad pixel is noticed (out of 384) after 3 years in orbit. This great success is due to:

- The guard rings protecting from surface leakage current of the cutting edges
- A better handling of the crystals during tests and integration, based on INTEGRAL feedback experience.

Energy calibration

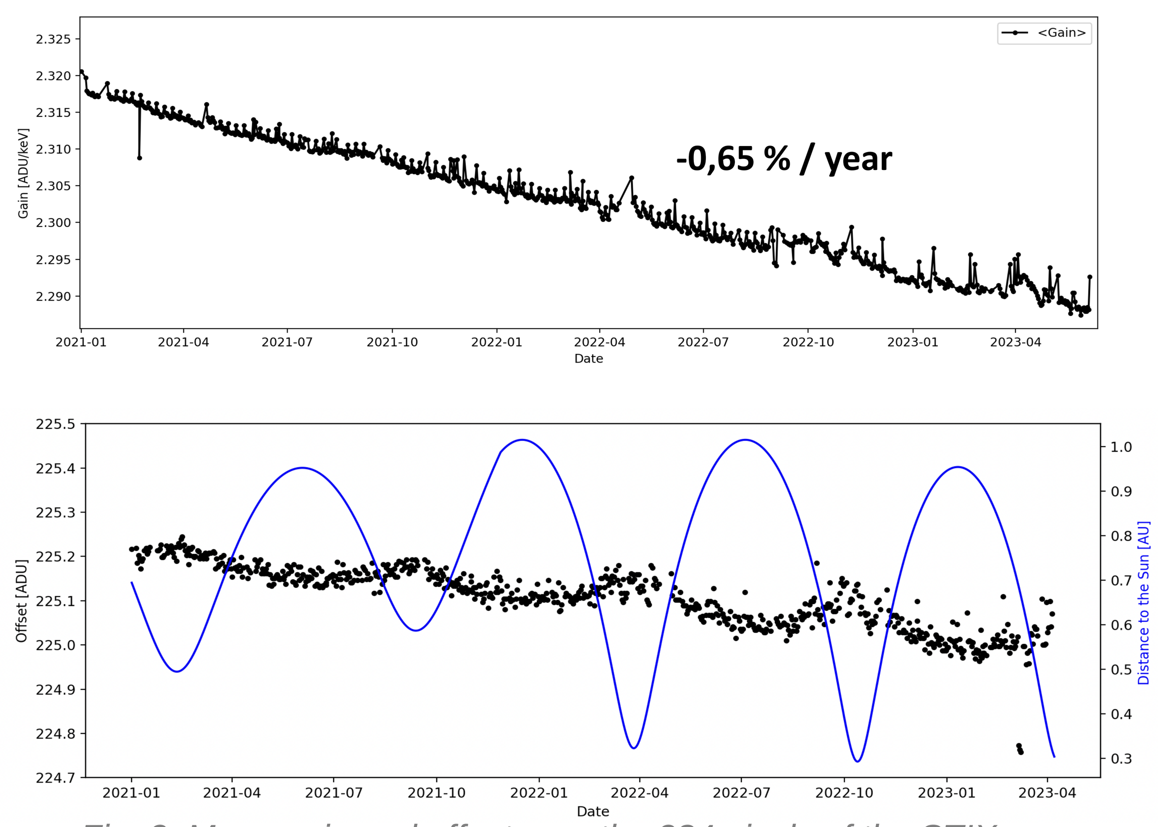


Fig. 3. Mean gain and offset over the 384 pixels of the STIX detection plane.

The gain decrease is 4 times slower than in INTEGRAL.

The offset is remarkable stable thanks to the baseline holder of the ASIC (unvariant with the detector leakage current). The remaining fluctuations (within 0.1 %) is anti-correlated with the distance of the spacecraft to the Sun (effect of power supplies).

Energy resolution

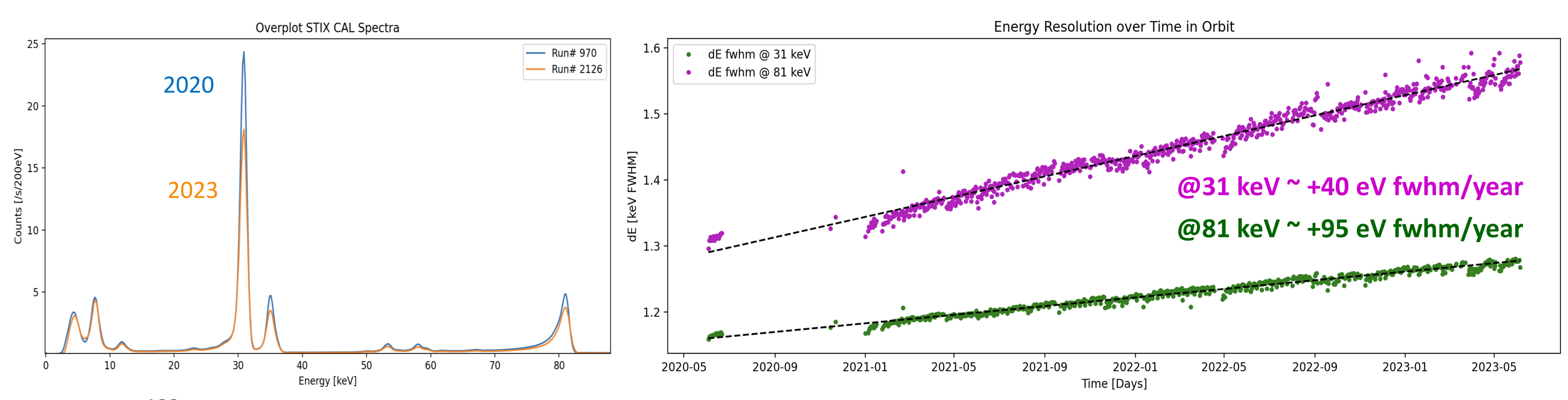


Fig. 4. ^{133}Ba Calibration source sum spectrum taken in 2020 and 2023. Evolution of energy resolution measured on the two main lines of the calibration sources.

The spectral response (energy resolution and left tailing of the lines) is remarkably stable, suggesting that the CdTe Schottky detectors have no degradation of hole transport properties or leakage current.

CONCLUSIONS

Displacement damage dose in space causes a **gain loss** in CdTe detectors for both missions due to a **decrease of electron mobility**.
The damage is less severe on-board Solar Orbiter than INTEGRAL despite a similar radiation environment.
The high-Z material shielding ISGRI to reduce the instrument background and improve the sensitivity (crucial for astrophysics) is likely to generate damaging secondary neutrons [4].

[1] F. Lebrun et al., A&A 411, L141–L148 (2003)
[2] S. Krucker et al., A&A 642 A15 (2020)
[3] O. Grimm et al., NIM-A 972 (2020) 164116.
[4] O. Limousin et al., NIM-A 747 (2015) 328.