The Spectrometer Telescope for Imaging X-rays (STIX) on board the Solar Orbiter mission

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An instrument optimized for solar flare observation

STIX achieves 2 major goals of Solar Orbiter:

(1) Understanding the acceleration of electrons at the Sun and their transport into interplanetary space;
(2) Determining the magnetic connection of the Solar Orbiter back to the Sun.

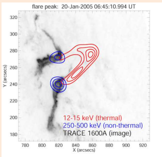


Fig 1: Observation of solar flares requires X-ray images resolved in energy and time (RHESSI image).

- Thermal emission: Electron bremsstrahlung in coronal loop (T ~10 MK);
- Non-thermal emission: bremsstrahlung of energetic electrons at the footprints of the loops.

STIX provides imaging spectroscopy of solar X-ray emissions with **unprecedented spatial resolution and sensitivity** near perihelion.

PERFORMANCE

Energy range: 4-150 keV
Effective area: 6 cm²
Field of view: 2°
Finest angular resolution: 7 arcsec
Image position accuracy: 4 arcsec
Energy resolution (FWHM):
- 1 keV at 6 keV
- 15 keV at 150 keV

Time resolution (stat limited): ≥ 0.1 s

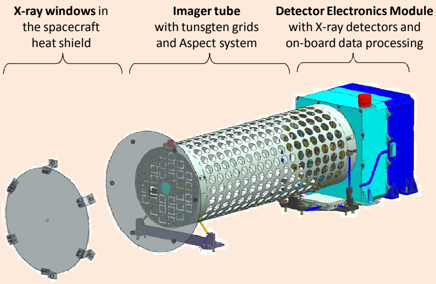


Fig 2: Instrument overview.

SYSTEM PARAMETERS

Mass: 5 kg
Power: 4 W
Volume: $76 \times 22 \times 22$ cm³
Temperature:
- Feedthrough: +270°C
- Spacecraft: +50°C
- CdTe Detectors: –20°C

STIX is based on a Fourier-transform imaging technique (see Poster 8443-130) using:
- An imager with 32 subcollimators,
- An spectrometer with 32 CdTe X-ray detectors, one behind each subcollimator.

The X-ray windows

- Prime element in the instrument thermal control (reflecting and reradating optical and infrared solar flux);
- **Allow observations down to 4 keV** but absorb intense flux of low energy X-rays during intense flares (detector live time issue).

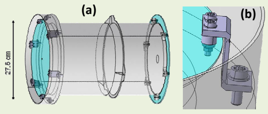


Fig. 3a: STIX X-ray windows and feedthrough.

Fig. 3b: Front window, 2 mm–thick beryllium screwed to decoupled springs.

The imager

- **1 subcollimator** = **2 tungsten grids** at opposite ends of the Al tube = **1 visibility** measurement (a specific 1D spatial Fourier component of the source distribution).

> Alternating, equispaced slits and X-ray opaque slats on each grid.
> Moiré pattern on the detector due to slightly different pitch or orientation between front and rear grids

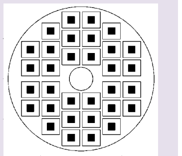
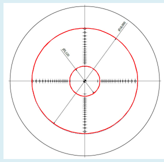


Fig. 4: Layout of the front grid assembly with the 32 subcollimators (open rectangles) and the Aspect lens. The solid squares represent the detectors located behind the grids.

The Aspect system

- On the front: Silica Lens (3 cm ∅, f = 55 cm);
- On the rear: 80 apertures arranged in a cross-shaped pattern, 4 photodiodes (UVG10).



The optical image produced by the lens on the rear grid will change during the orbit (Sun image ∅ between 5.1 and 18 mm, red circles) and in case of off-pointing.

Fig. 6: Arrangement of apertures in the rear grid.

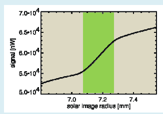


Fig. 7: Total signal as a function of the solar image size (selection).

Transition when the image covers an additional diode

Increase due to solar limb darkening

- **Reduces pointing uncertainty from 2 arcmin (S/C) to 4 arcsec.**

Thermal design

Design must answer strong thermal constraints.

- Imager painted in black to limit temperature gradients (grid distortion)
- Top coating of Be windows and reflective layer on the Aspect lens.
- DEM front-end boards coupled to cold finger and thermally isolated from the enclosure by MLI for detector performance.

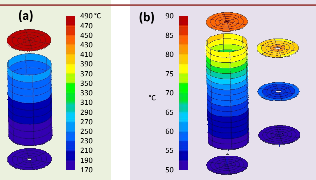


Fig 5: Temperature profiles in the hot operational case.
(a) Feedthrough with windows.
(b) Imager tube.
(c) Detector Electronics Module.

The Detector Electronics Module

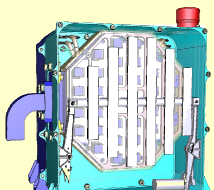
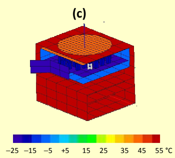
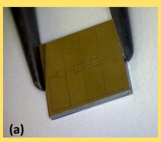


Fig 8: STIX Detector Electronics Module (DEM) showing the Detector Box (front cover removed), the attenuator, the thermal enclosure of the cold unit (transparent) with the spacecraft cold element on the left and the Caliste-SO units. The IDPU Box is the rear part, with connectors to the S/C on the back side.



Caliste-SO spectrometers: design and first results

- **Al Schottky CdTe** detectors with anode patterned by PSI;
- **IDeF-X HD** low noise low power analog front-end ASIC designed by CEA /Irfu;
- **Space-qualified packaging** of the electrical body with 1 ASIC, passive parts and a SOP bottom interface by 3D Plus company; hybridization by polymer bump bonding.
- Spectral characterization of prototypes:
  - **Energy resolution (FWHM) at 14 keV: 1.3 keV (large pixels) and 0.9 keV (small pixels).**
  - **Low-level threshold: 3.4 keV (large pixels) and 2.4 keV (small pixels).**



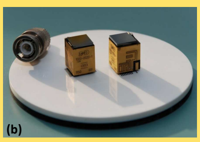


Fig 9:
(a) 10×10 mm² Pixel Al-Ti-Au/CdTe/Pt detector sample.
(b) Prototypes of Caliste-SO ($12 \times 14 \times 17$ mm³).

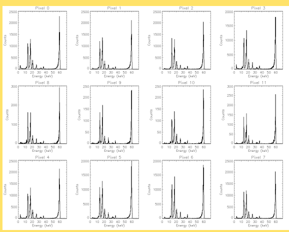


Fig 10: ²⁴¹Am spectra with the 12 pixels of the first Caliste-SO prototype at –30°C,–200V. Large pixels #0 to #7, Button pixels #8 to #11.

The STIX DEM is divided into 2 sub-units connected by ~200 wires.

The Detector Box contains:

- A removable **attenuator** to reduce the count rate of low energy photons during intense events;
- **32 spectrometer units**: Caliste-SO front-end hybrids with CdTe pixel detectors for photon counting and energy measurement;
- Sealed ^{133}Ba **calibration sources** of low activity (<100 Bq).

The IDPU (Instrument data processing unit) Box contains:

- 16 **Analog-to-digital converters** (12-bit);
- **Two redundant FPGA** (Actel RTAX) for readout and control electronics;
- 3 **memories**: PROM for start-up software, 128 MB RAM for operations or data buffer, 16 GB Flash memory to archive scientific data for months;
- Low and high voltage **power supplies**;
- The **flight software** including the application software for:
  - ✓ flare detection (**trigger to other Solar Orbiter instruments**),
  - ✓ data selection and compression (adaptive algorithms),
  - ✓ real-time data analysis (quick-look data accumulation, live-time measurement, coarse flare location),
  - ✓ long-term background count accumulation for on-ground detector calibration.

Conclusions

- **Indirect imaging concept heritated and improved** from successful Yohkoh and RHESSI missions;
- **New concept of X-ray detectors** with pixel CdTe sensors, full-custom front-end ASICs and an innovative hybridization technique;
- Caliste-SO prototypes demonstrate the technological feasibility and satisfying performance in phase B; CdTe pixel samples by PSI have now still better leakage current characteristics.
- The modularity of the STIX concept makes it attractive for use in future solar hard X-ray instruments and opens the possibility of **stereoscopic hard X-ray observations**.

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