

University of Applied Sciences Northwestern Switzerland

STIX on Solar Orbiter

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LESIA-Paris Observatory

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RPW

SPP FIELDS

Joint RPW/FIELDS/S-WAVES Consortium meeting

Monday 6th November 2017

Meudon, France

STIX

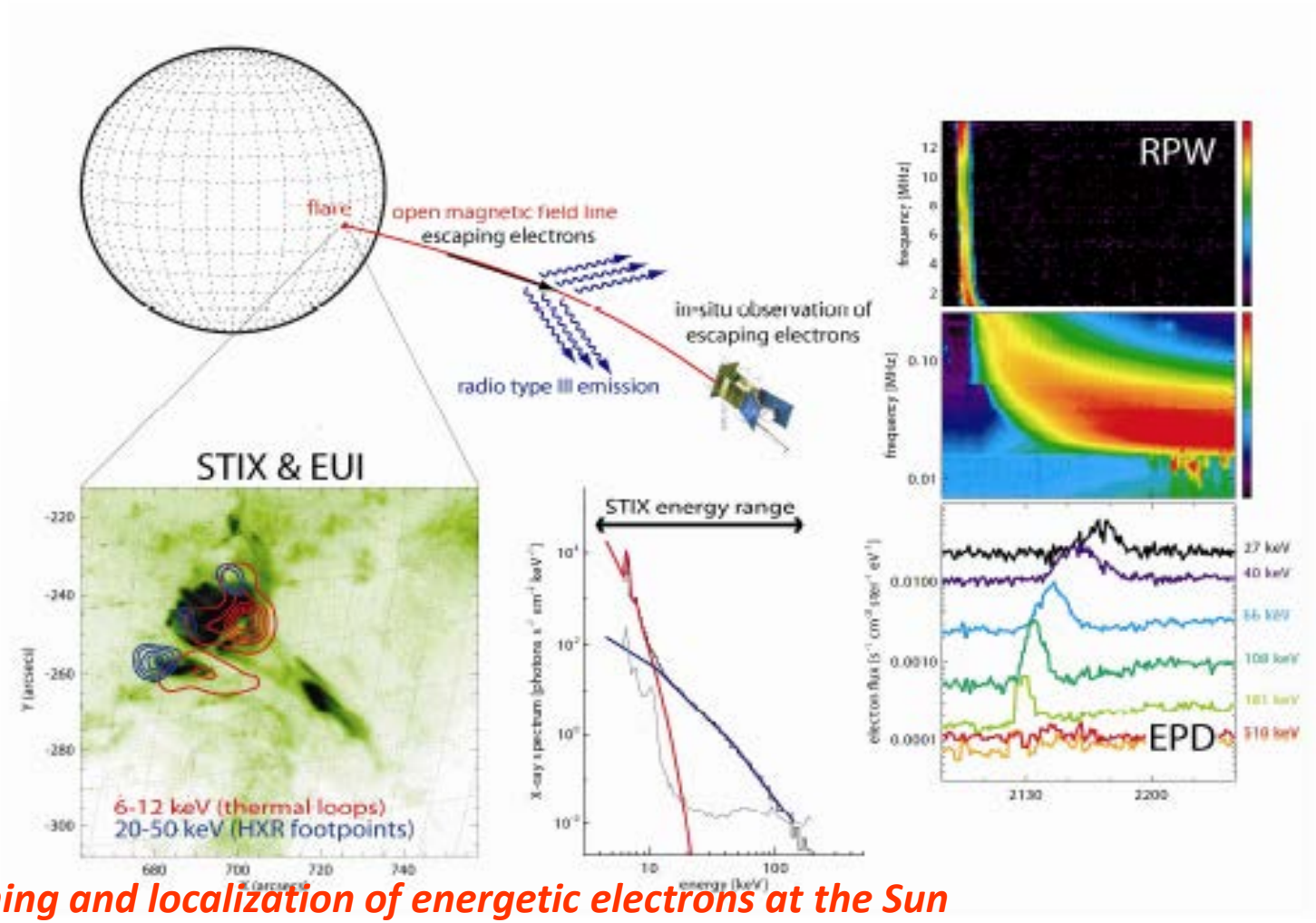
- Imaging spectroscopy of thermal & non-thermal X-rays

High-energy link between surface and in situ observations

- Science Role:
  - Timing, spectra and location of accelerated electrons at Sun
    ➔Link between in-situ and imaging instrumentation

Energy range	4 – 150 keV
Energy Resolution	1-15 keV (energy dependent)
Effective area	6 cm2
Finest angular resolution	7 arcsec
Image placement accuracy	<4 arcsec
Field of view	2 degrees (full sun at perihelion)
Time resolution (variable)	>= 0.1 second

Why an X-ray spectro-imager on Solar Orbiter?

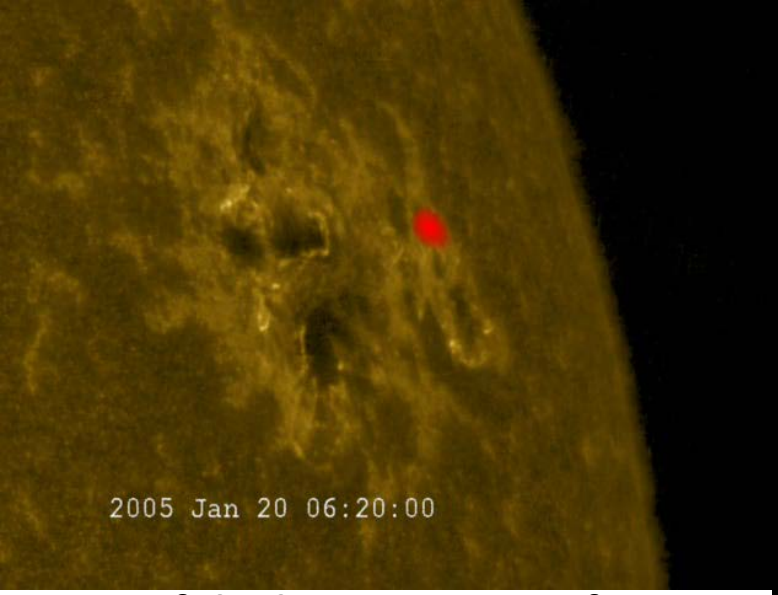


-Timing and localization of energetic electrons at the Sun

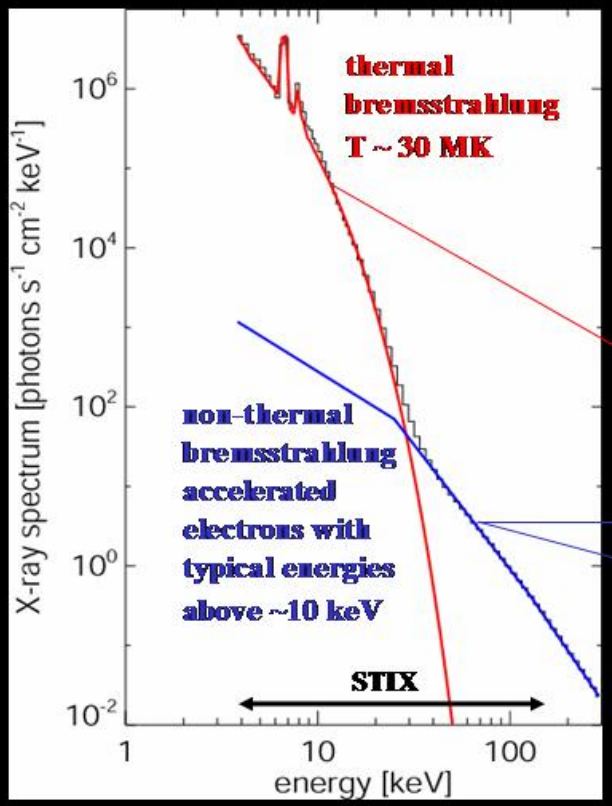
--Energy spectra and number of energetic electrons at the Sun

- Energetic particles at the Sun and in the interplanetary medium

- Magnetic connectivity between the Sun and the spacecraft

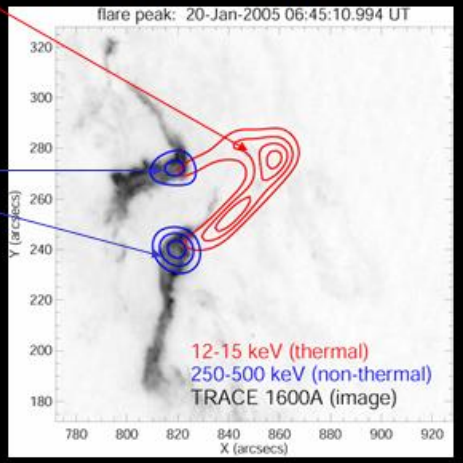


One of the key questions of solar orbiter



HXR emission of a solar flare

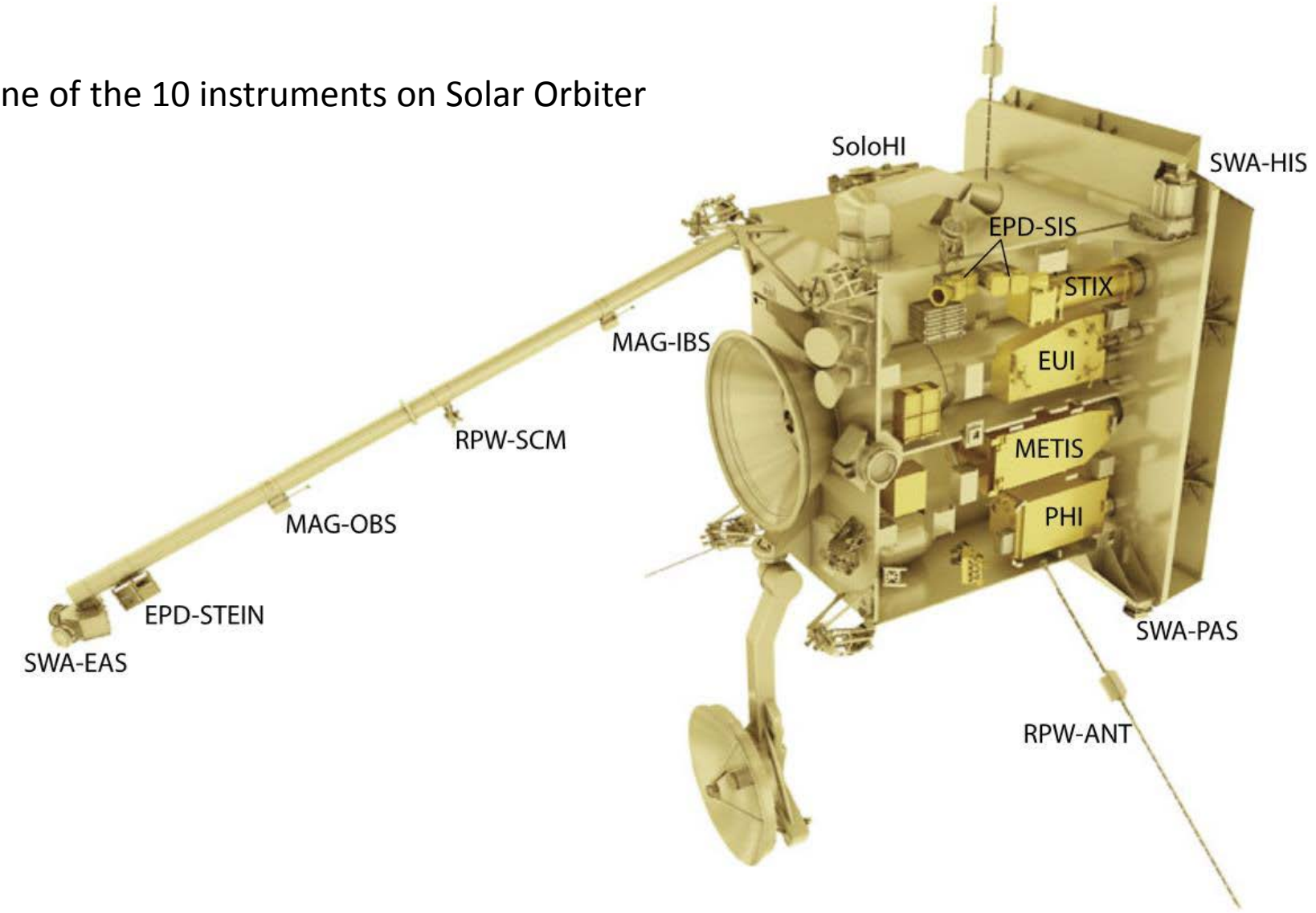
- STIX energy range: 4-150 keV
- simultaneous imaging and spectroscopy



Acceleration and transport of energetic particles in the heliosphere?

HXR imaging-spectroscopy (number, energy spectra) thermal and non-thermal electrons in the solar atmosphere

One of the 10 instruments on Solar Orbiter



PI: Sam Krucker, FHNW

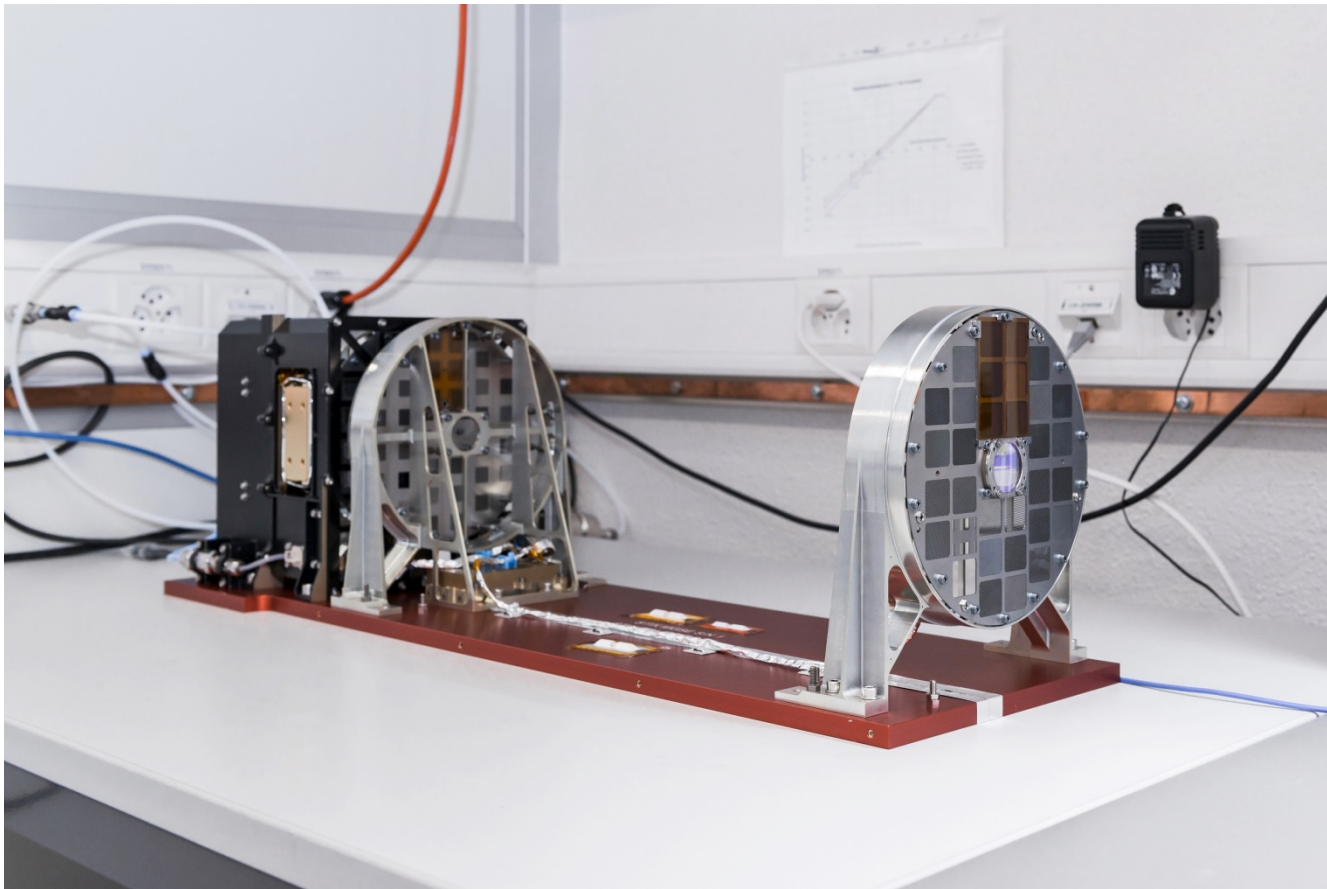
STIX instrument and collaboration

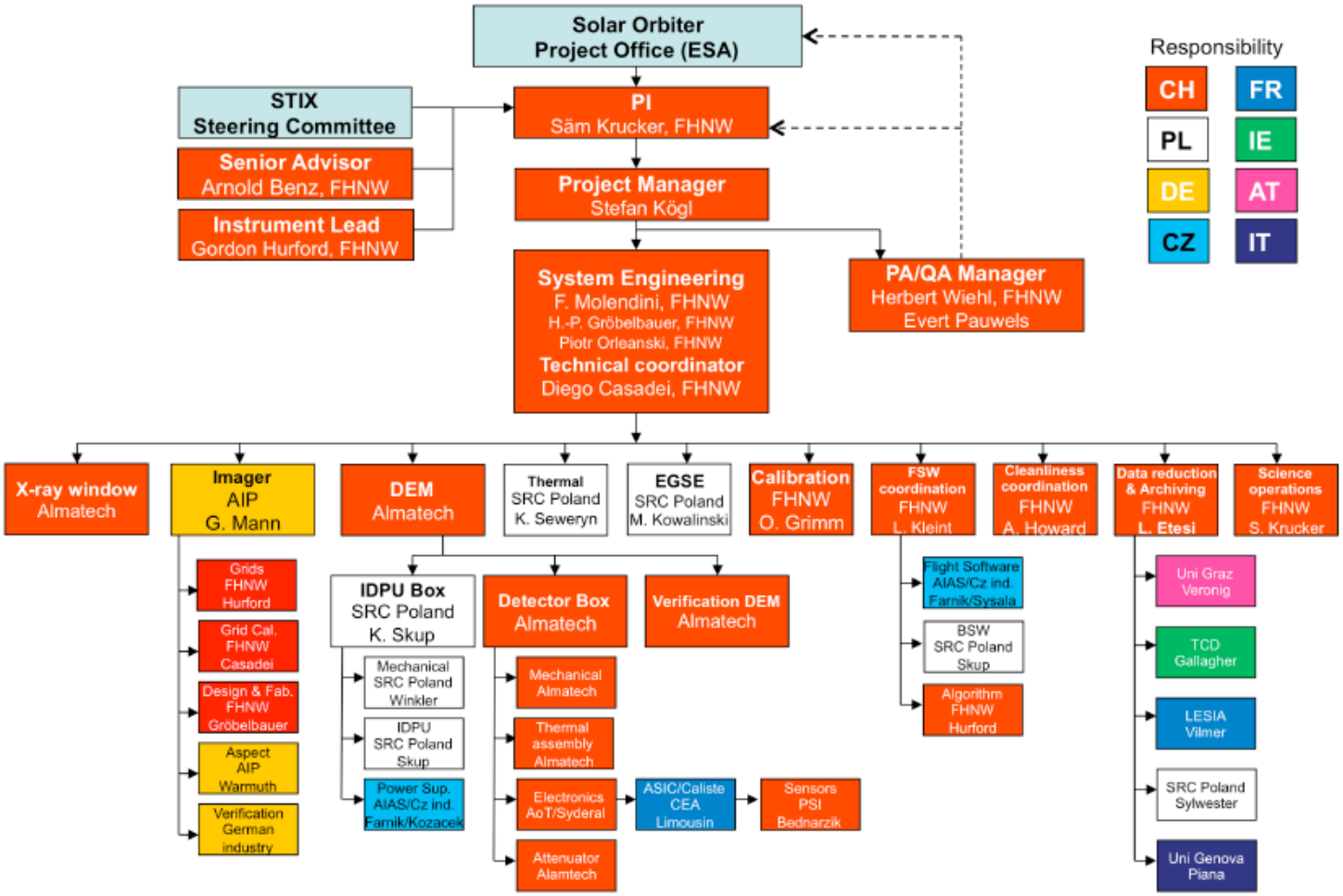
Hardware:

- Switzerland (FHNW, Almatech, PSI)
- France (CEA)
- Poland (CBK – Warsaw & Wroclaw)
- Czech Republic (ESC, ASI)
- Germany (AIP)

Analysis Software

- FHNW
- Paris Observatory
- Uni Graz
- Trinity College Dublin
- CBK-Wroclaw
- Uni Genoa




Solar Orbiter
Project Office (ESA)
STIX
Steering Committee
Senior Advisor
Arnold Benz, FHNW
Instrument Lead
Gordon Hurford, FHNW
PI
Säm Krucker, FHNW
Project Manager
Stefan Kögl
System Engineering
F. Molendini, FHNW
H.-P. Gröbelbauer, FHNW
Piotr Orleanski, FHNW
Technical coordinator
Diego Casadei, FHNW
PA/QA Manager
Herbert Wiehl, FHNW
Evert Pauwels
Responsibility
CH
FR
PL
IE
DE
AT
CZ
IT
X-ray window
Almatech
Imager
AIP
G. Mann
DEM
Almatech
Thermal
SRC Poland
K. Seweryn
EGSE
SRC Poland
M. Kowalinski
Calibration
FHNW
O. Grimm
FSW coordination
FHNW
L. Kleint
Cleanliness coordination
FHNW
A. Howard
Data reduction & Archiving
FHNW
L. Etesi
Science operations
FHNW
S. Krucker
Grids
FHNW
Hurford
Grid Cal.
FHNW
Casadei
Design & Fab.
FHNW
Gröbelbauer
Aspect
AIP
Warmuth
Verification
German industry
IDPU Box
SRC Poland
K. Skup
Detector Box
Almatech
Verification DEM
Almatech
Mechanical
SRC Poland
Winkler
IDPU
SRC Poland
Skup
Power Sup.
AIAS/Cz ind.
Farnik/Kozacek
Mechanical
Almatech
Thermal assembly
Almatech
Electronics
AoT/Syderal
ASIC/Caliste
CEA
Limousin
Sensors
PSI
Bednarzik
Attenuator
Alamtech
Flight Software
AIAS/Cz ind.
Farnik/Sysala
BSW
SRC Poland
Skup
Algorithm
FHNW
Hurford
Uni Graz
Veronig
TCD
Gallagher
LESIA
Vilmer
SRC Poland
Sylwester
Uni Genova
Piana

STIX Spectrometer/Telescope for Imaging X-rays

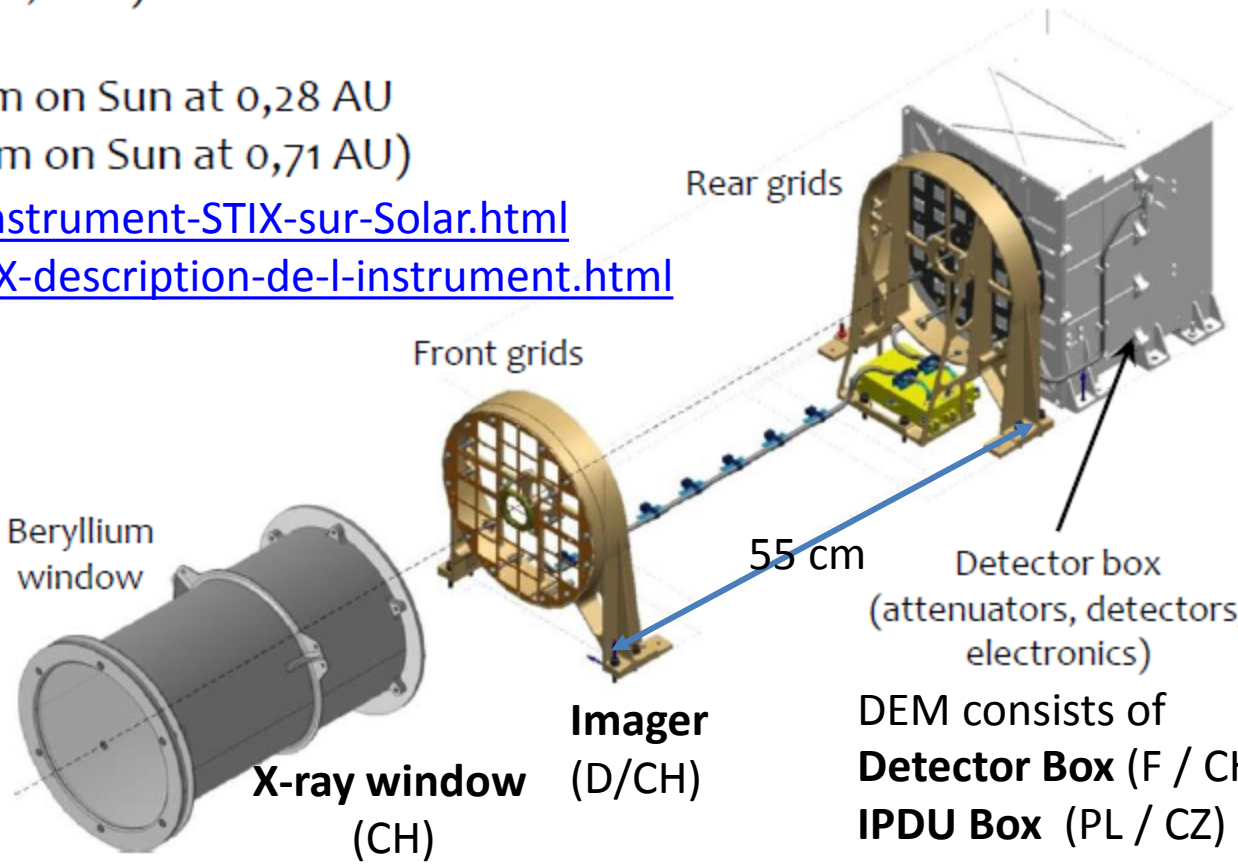
PI Säm Krucker, FHNW, Switzerland

Spectroscopy 4-150 keV
Spectral resolution 1 keV @ 6 keV
32 scientific energy bands

7 kg
8 watts
700 bits/s

32 detectors (CdTe, Caliste-SO, CEA)
30 collimators for imaging
7" spatial resolution (1400 km on Sun at 0,28 AU
3600 km on Sun at 0,71 AU)

http://www.lesia.obspm.fr/L-instrument-STIX-sur-Solar.html
http://www.lesia.obspm.fr/STIX-description-de-l-instrument.html



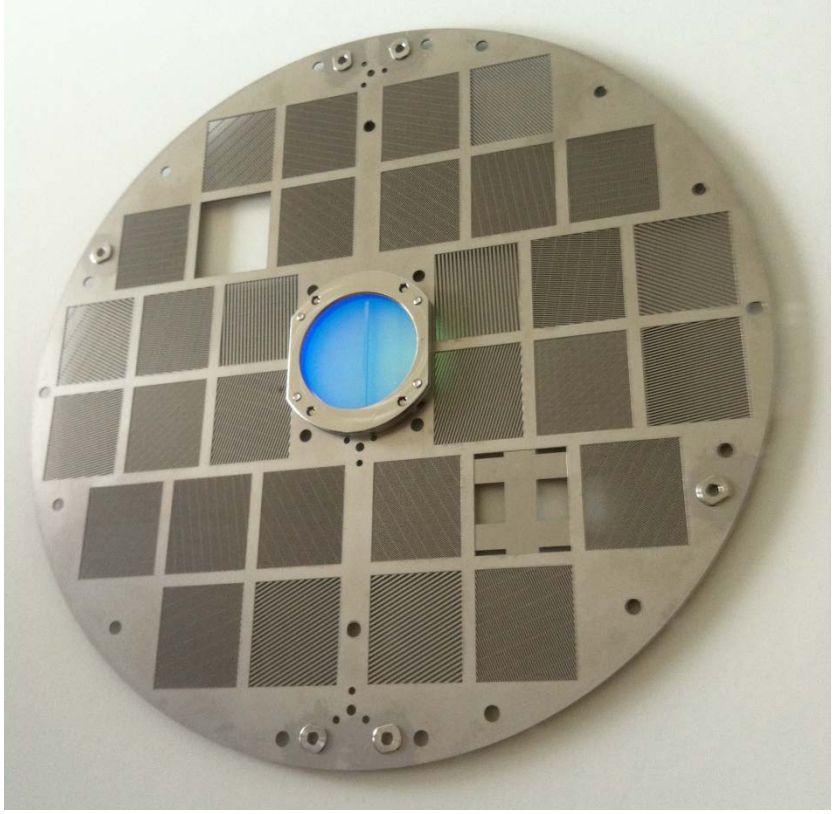
X-ray window (CH)

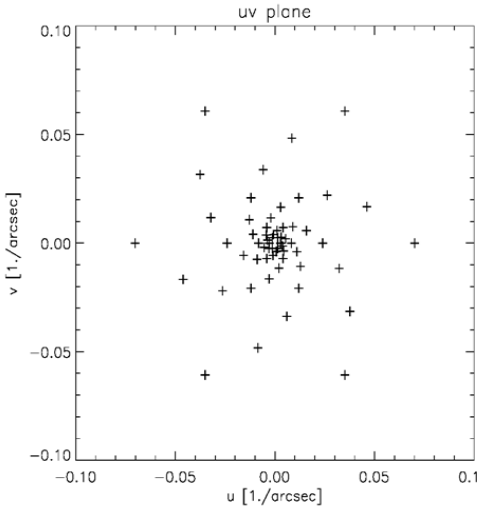
Imager (D/CH)

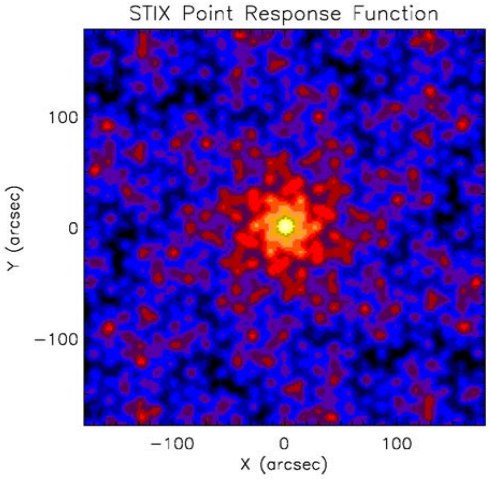
DEM consists of
Detector Box (F / CH)
IPDU Box (PL / CZ)

Imager

- 32 subcollimators measure 30 Fourier components (+background and coarse flare location)
- ‘Twin Mount design has front and rear grids separately mounted to s/c panel
- Stacked grids of 400 micron thick tungsten
- Periods from 38 microns to 1 mm
- Measures 10 spatial frequencies from 7 to 180 arcsec FWHM in 3 spirals

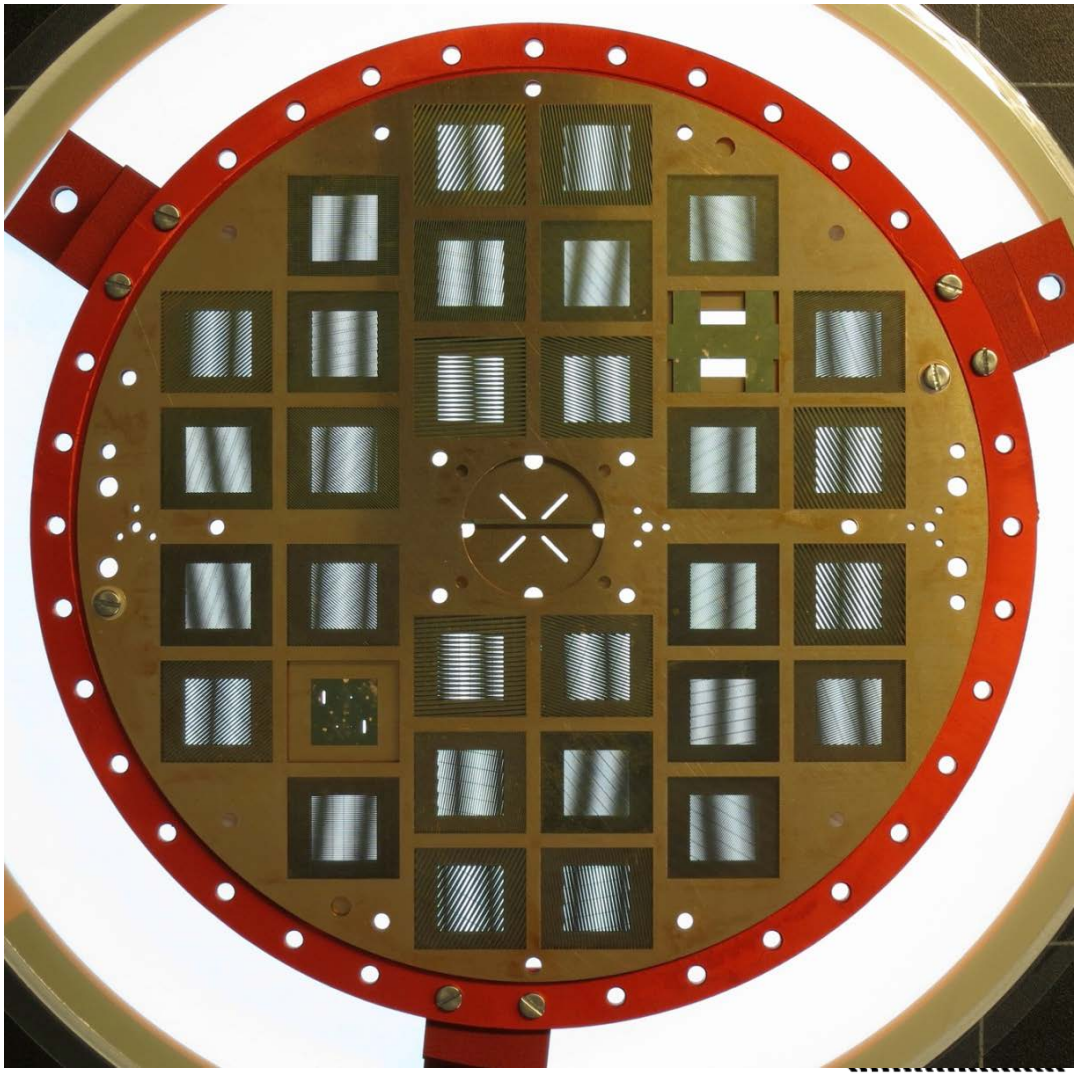






Visibility Measurement

(from Hurford presentations)

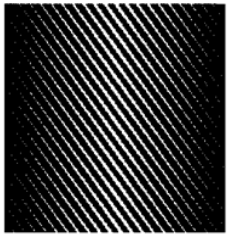


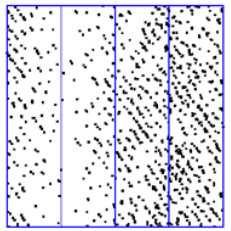
Superimposed STM grids

Front and rear grids have slightly different pitch and/or orientation

➔ X-ray Moire pattern that can be measured with a coarsely pixelated detector

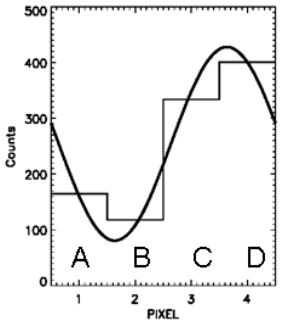
➔ Pixel sums and differences redundantly measure total flux, and complex visibility



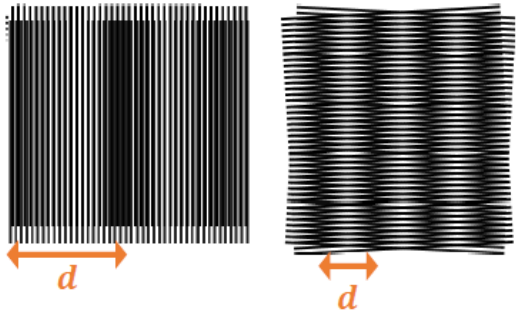


*Real (V) = C - A
*Imag (V) = D – B
**Flux = A+B+C+D
**Check: A + C = B + D

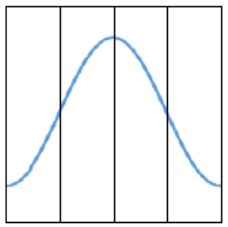
* Independent of background
**Independent of source morphology



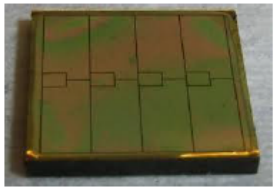
STIX

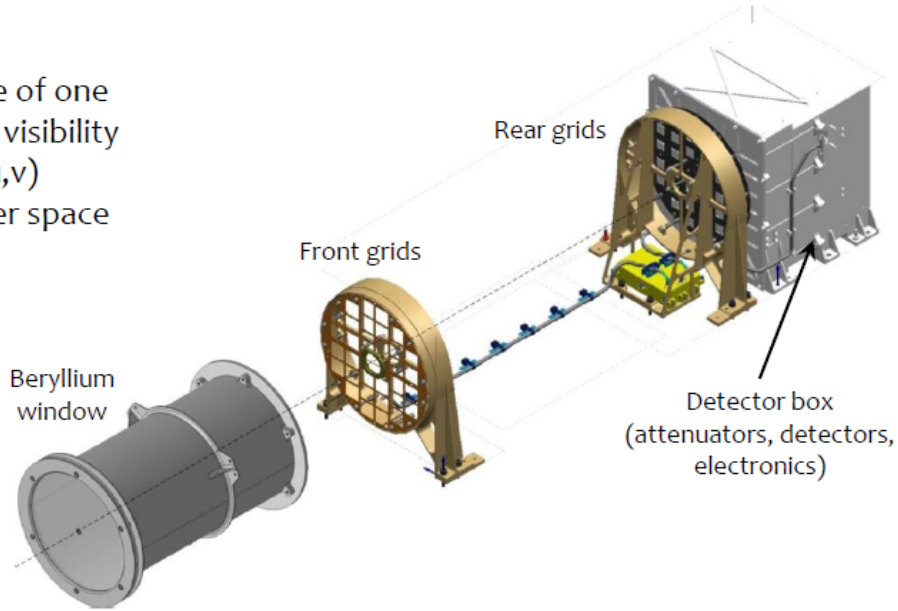


Moire pattern

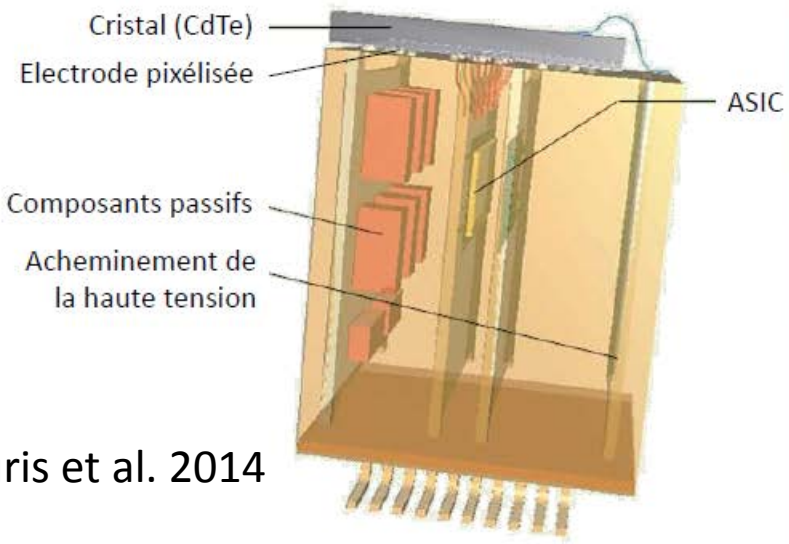


Measure of one complex visibility V(u,v) In Fourier space



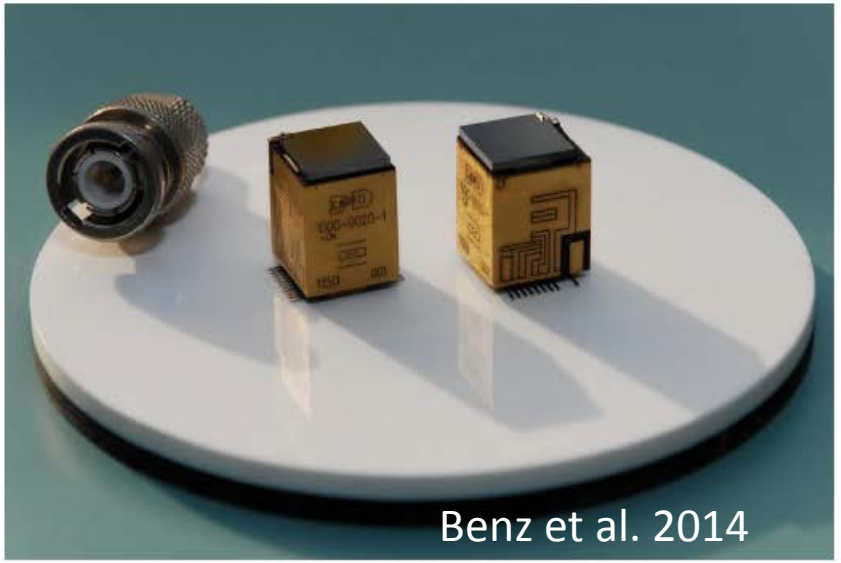


STIX Detectors

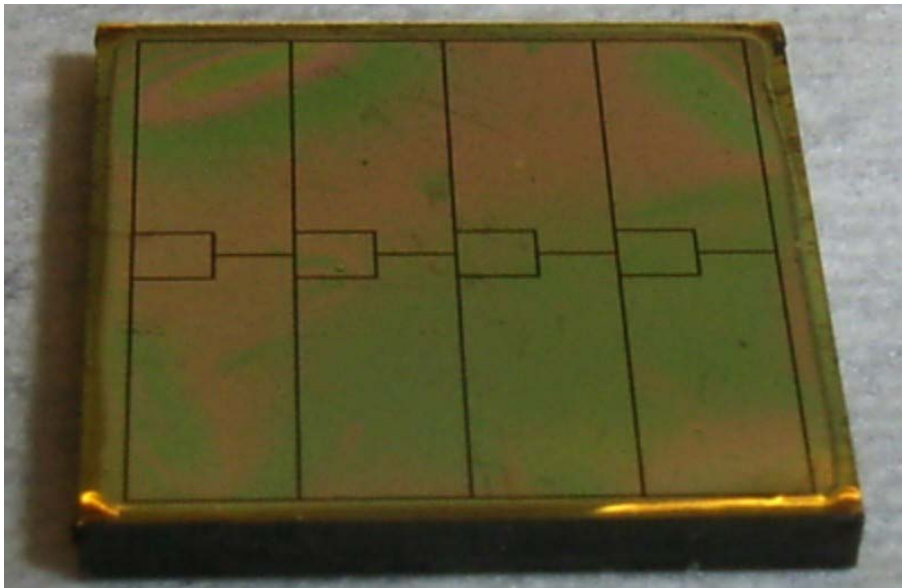


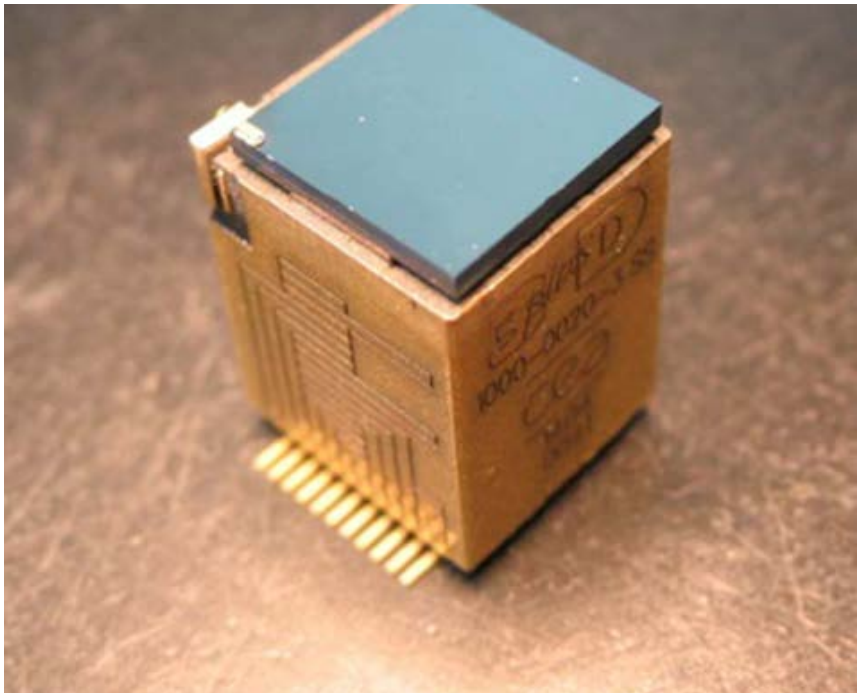
Meuris et al. 2014

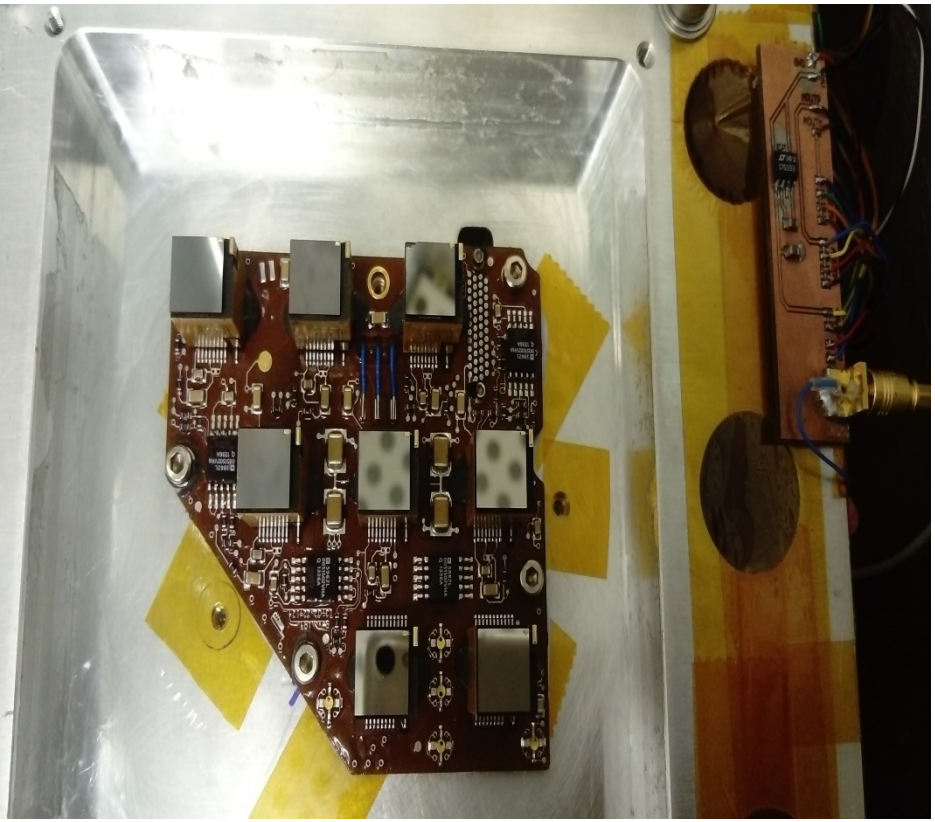
Vue par transparence du Caliste-SO



Photographie de deux Caliste-SO

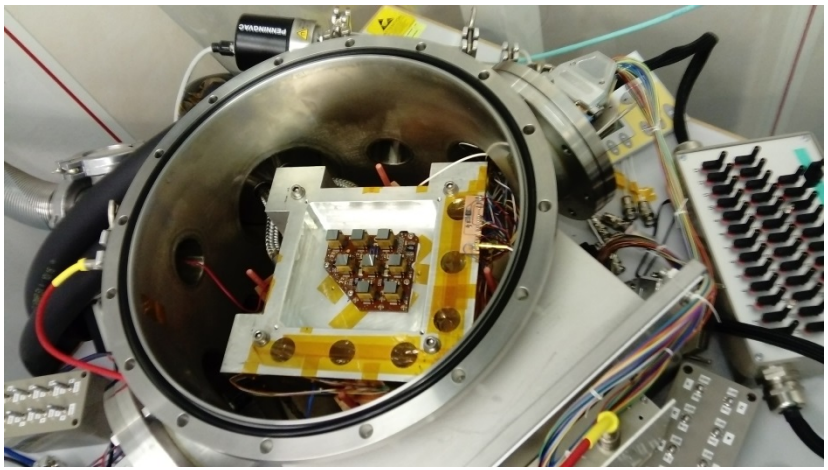




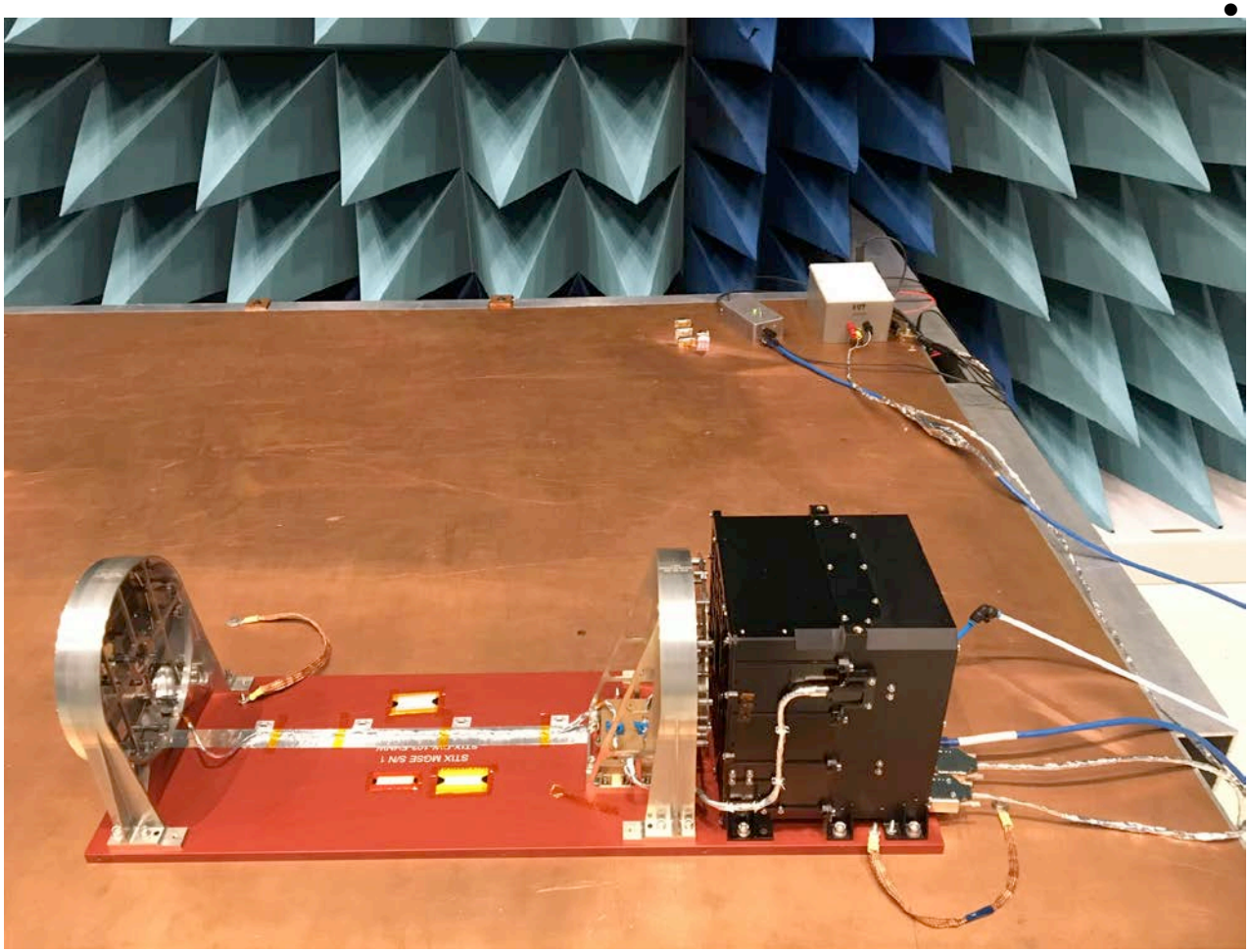


A quarter of a focal plane in the clean room at CEA

(courtesy A. Meuris)



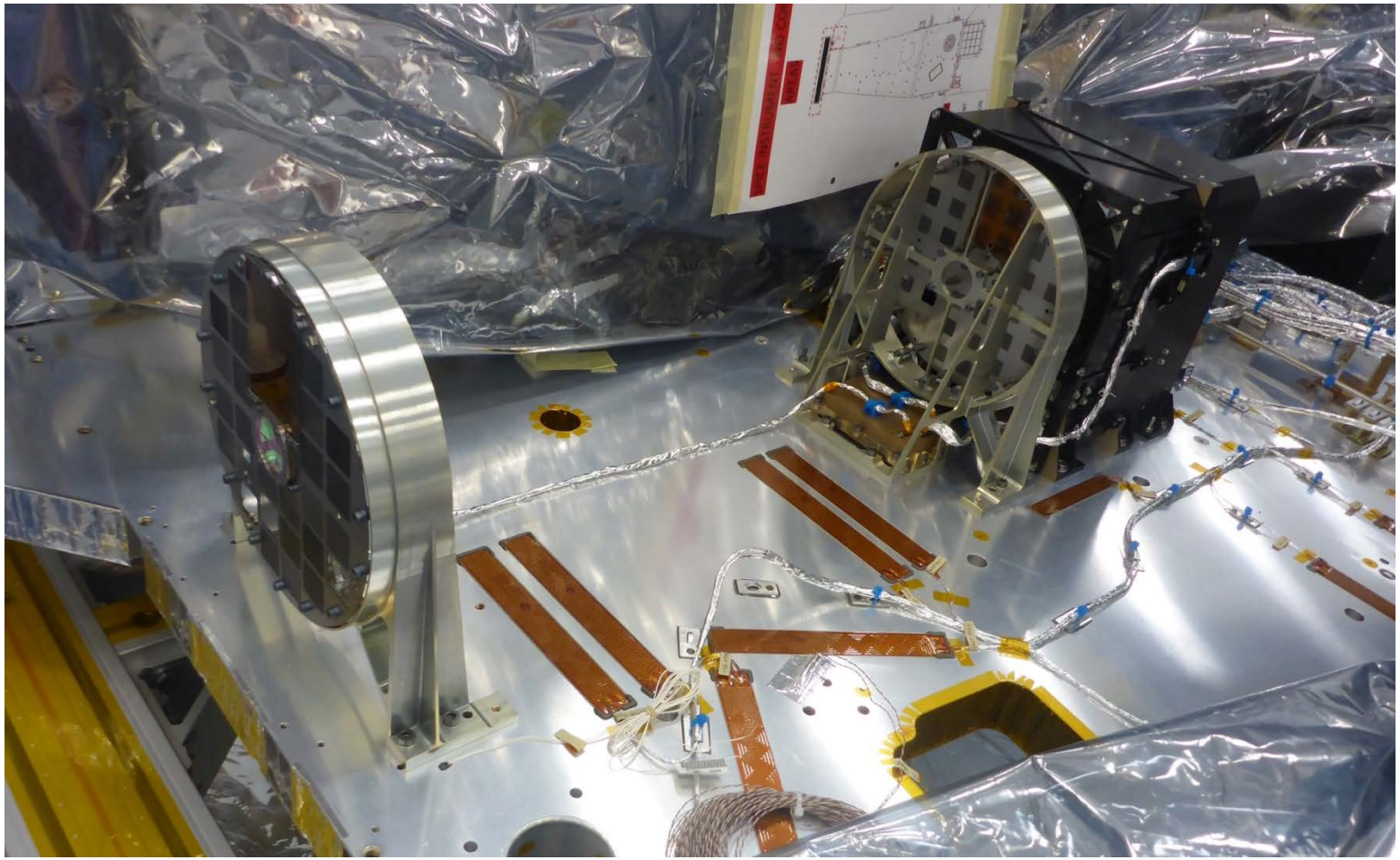
EMC testing @ ESTEC



- **Successful completion of EMC tests on May 19**

(from S. Krucker

STIX integrated on spacecraft panel (August 24)



STIX compared to RHESSI

Item	STIX	Compared to RHESSI
Imaging	30 Fourier components 7-180 arcsec angular resolution	Fewer Fourier components Affects imaging of complex sources Better *spatial* resolution at perihelion
Spectroscopy	4 – 150 keV 1+ keV FWHM resolution 32 energy channels Variable time resolution to 0.1 s	No gamma rays Similar resolution , fewer channels Less pileup. No time modulation ➔better light curves
Sensitivity & Throughput	6 cm2 Up to 600,000 ph/sec	Similar at perihelion, Imaging down to A1 ~3x larger
Data handling	Transmits accumulated counts or visibilities Long term (months) on-board storage Automated & ground-selected time-energy bins	Not photo-by=photon but "scientifically-lossless" Retains flexibility for time, energy , & imaging options.
Rate Control	1 moveable attenuator Dynamic reduction in Aeff	2 moveable attenuators Should handle up to X30 without saturation
Observing	20% duty cycle minimum In 10 day blocks	RHESSI: 55% with hourly gaps.

G. Hurford RHESSI Workshop 2015

STIX Operations and Data Products

- Schedule
  - 2 year cruise phase (limited observing?)
  - 5 year primary mission
  - 3 year extended mission
- STIX Observing will be ‘campaign-oriented’ (viz preplanned) in 3 10-day windows/orbit.
  - Additional observing time will be available?
- STIX has single observing mode
  - Flexibility is provided through on-board rate control, data selection, analysis options
- Self-calibrating (energy, metrology, aspect…)
- Catalog of calibrated data products (spectra, light curves, images) will be more extensive than RHESSI
- Support for joint analyses with other instruments

Quick Look Data

- 50 bits/s
- Transmitted daily
- Contents
  - Spatially-integrated light curves - 5 energy ranges, 4s time resolution
  - Full resolution, spatially-integrated spectra -32 s time resolution
  - Coarse flare location
  - Background data, calibration data, aspect data, status, housekeeping data, etc

Table 1. Default Usage of Quick Look Telemetry

Packet Type	Default Parameters	Primary Data Rate (Excl. Overhead)	One Packet Contains	Average Data Rate (bps)
Light Curves	4s, 5 energies, RCR, Trigger	7 bytes/4s	582 4s samples	14.1
Background	8s, 5 energies, Trigger	6 bytes/8s	680 8s samples	6.0
Det. Spectra	32s, 32 energies, Trigger	33 bytes/32s	113 32s samples	9.1
Variance	4s	1 byte/4s	4091 4s samples	2.0
Flare Flag & Location	Flare Status, X,Z, 8s	3 bytes/8s	1362 8s samples	3.0
Flare/TM Mgmt	Flare start and end times, volume, analysis status	1 packet (300 flares) / 20 hours	~300 flares	0.5
Calibration Spectra	5 subspectra, 32 det., 8 pixels. 20 hour integration	1280 subspectra / 20 hours	61 64-point Subspectra (21 packets per calibration)	9.6
TOTAL				**44.3**

Bulk Science Data

- 600 bits/s
  - Drives the data handling strategy
  - Supports several hundred selected images /hour

- Delay in transmission will range from ~1 day to many weeks

- Transmitted data is typically pixel accumulations or uncalibrated visibilities

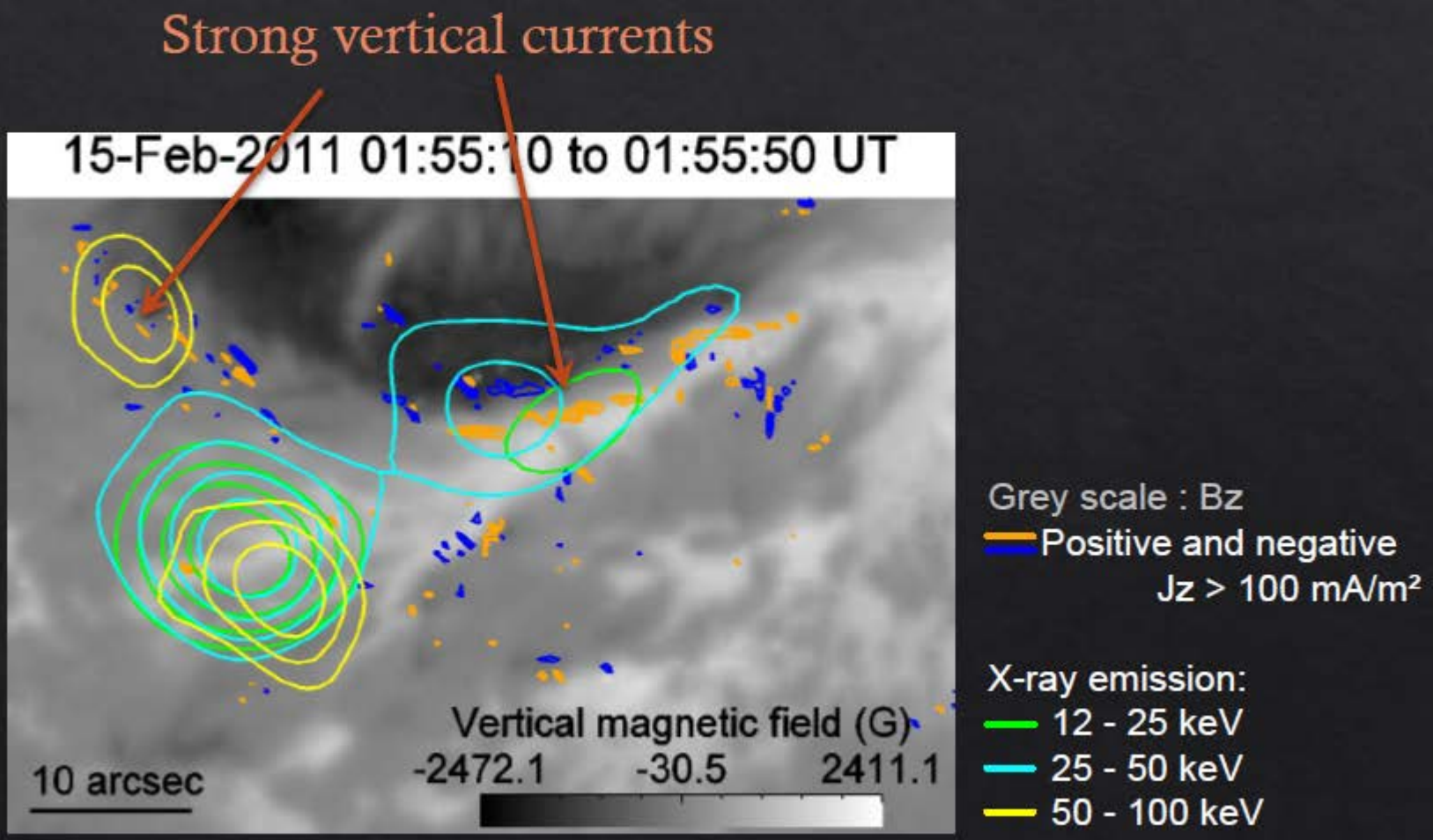
- Further custom data averaging on ground (images, light curves, spectra)

STIX Science

- Improved light curves compared to RHESSI at higher time resolution (to 0.1s)
  (both spatially integrated and imaged)
- Partially-occulted flare studies (with spectrometers in the sun earth direction) to study link between chromospheric and coronal sources as a function of time and energy
- Directivity

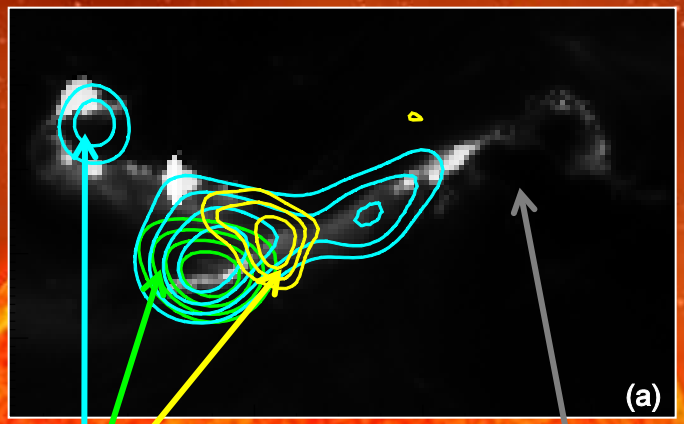
- Collaborative studies with other on-board instruments and Solar Probe
- Magnetic connectivity
- Electron path from the sun to the IP medium
- Thermal and non thermal electrons associated with CME onsets
- Microflares

Spatial correlation between X-ray emission sites and strong photopheric electric currents



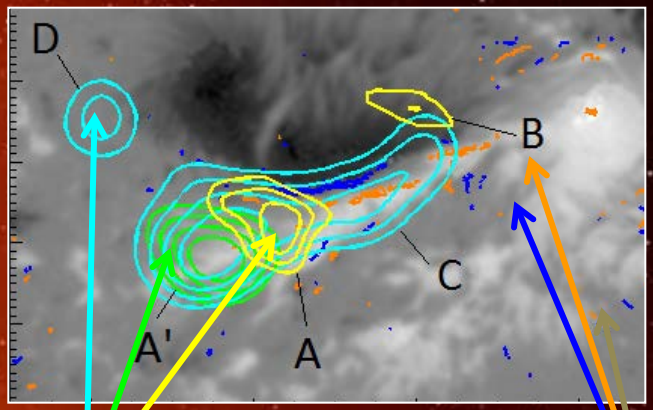
Musset et al (2015)

Emissions X, champs magnétiques et courants électriques: Observations avec Solar Orbiter



STIX

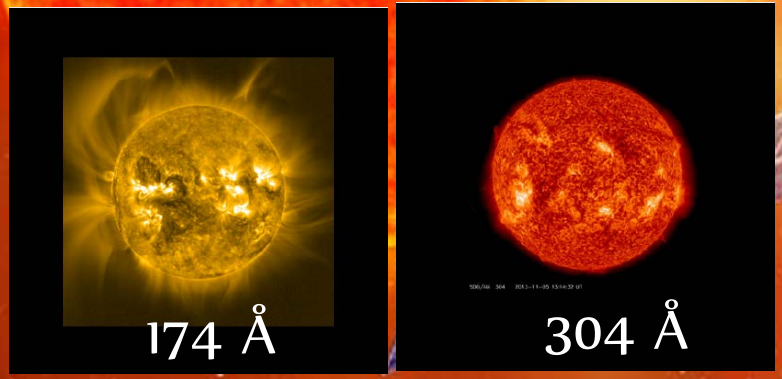
EUI



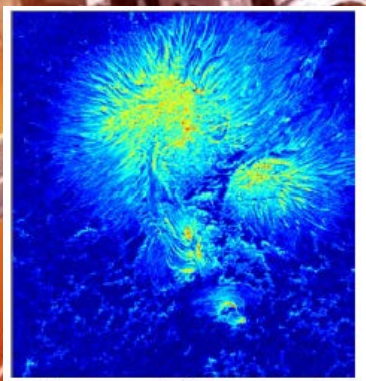
STIX

PHI

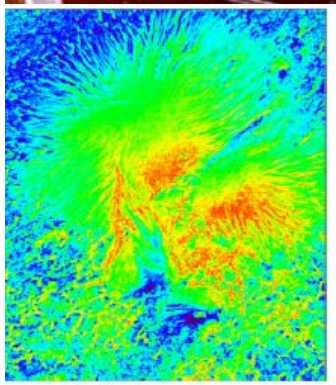
Instrument EUI



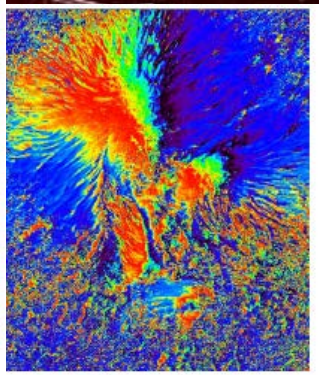
Instrument PHI



LOS magnetic field strength

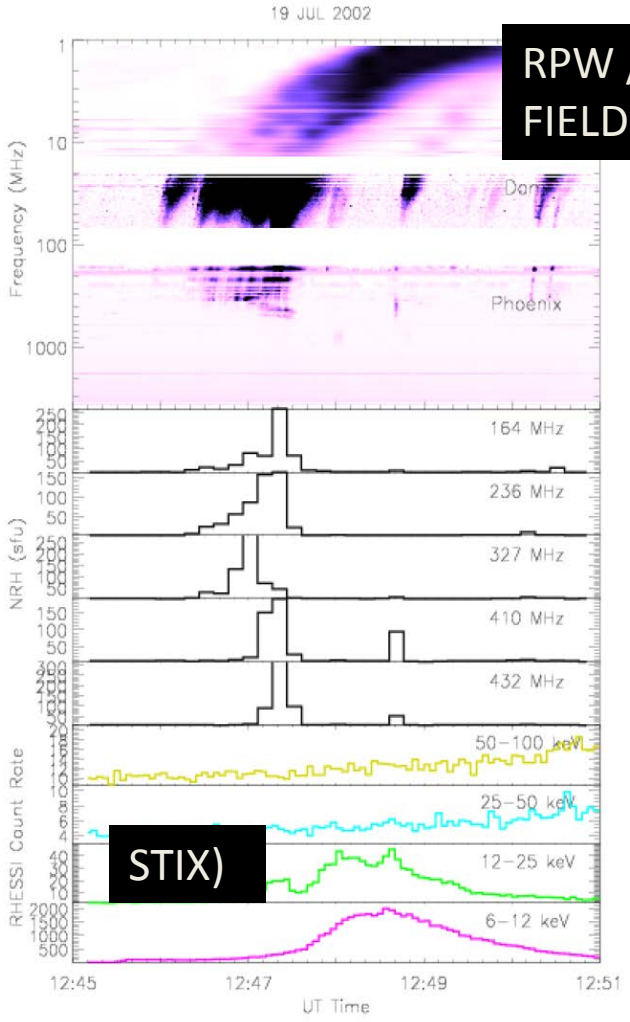


magnetic field inclination



magnetic field azimuth

Electron beams in the corona to the IP medium in the Solar Orbiter-Parker Solar Probe era



More to be learnt in the future using
radio/X-ray instruments aboard Solar Orbiter
or radio instruments aboard Parker Solar Probe
in combination with ground-based NRH, LOFAR, MUSER
images of radio bursts
and ground-based radio spectrographs
and ground based radio imaging spectroscopy (SKA?)

Comparison with electron measurements (EPD) of escaping electrons

