Calibration plans for the Soft X-ray Imager's CCDs on SMILE

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International Astronomical Consortium for High Energy Calibration

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Centre for Electronic Imaging

- The CEI is a research centre within the Open University, UK.
- Expertise in X-ray spectroscopy and the effects of radiation damage for space applications.
- Have previous experience working on Gaia, Euclid, JUICE and XMM Newton missions.

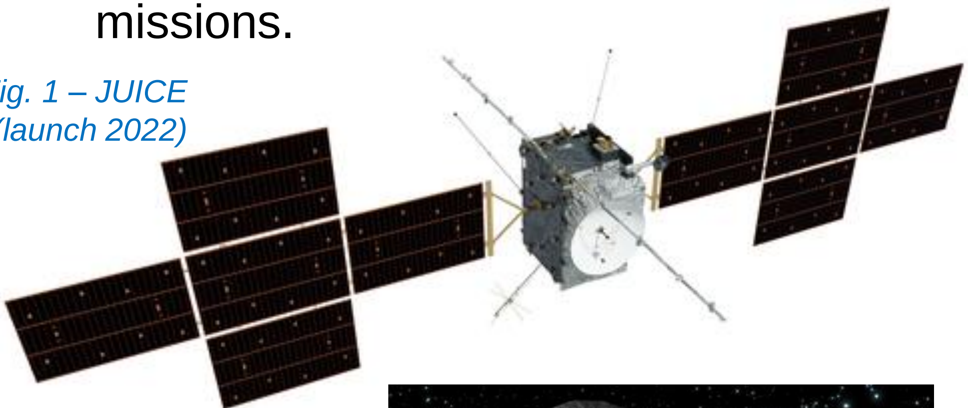

Fig. 1 – JUICE (launch 2022)

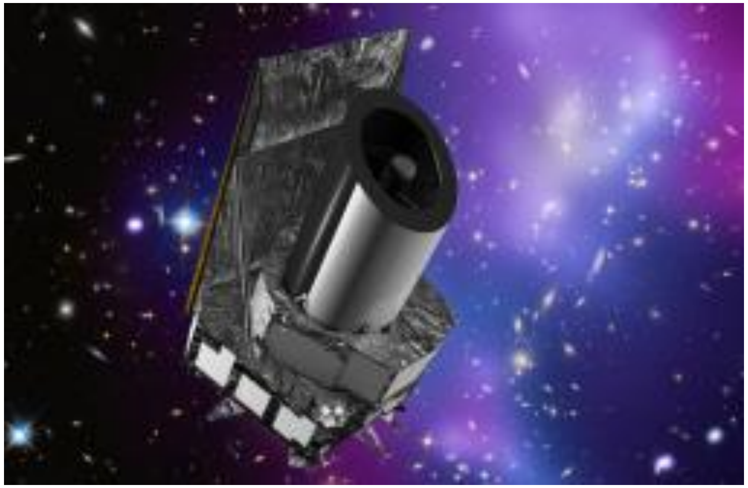

Fig. 2 – Euclid (launch 2021)

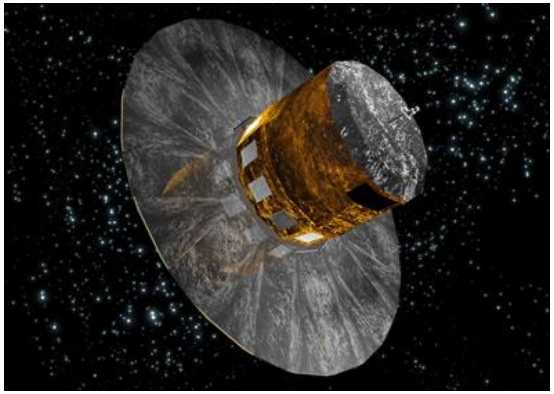

Fig. 3 – Gaia (launched 2013)

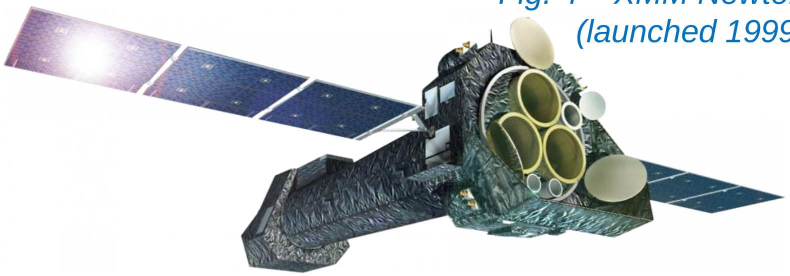

Fig. 4 – XMM Newton (launched 1999)

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SMILE - Solar-wind Magnetosphere Ionosphere Link Explorer

- SMILE is a collaborative space mission between the European Space Agency (ESA) and the Chinese Academy of Sciences (CAS)
- Will combine soft X-ray imaging of the Earth's magnetopause and magnetospheric cusps whilst simultaneously imaging the Northern Aurora using ultraviolet.

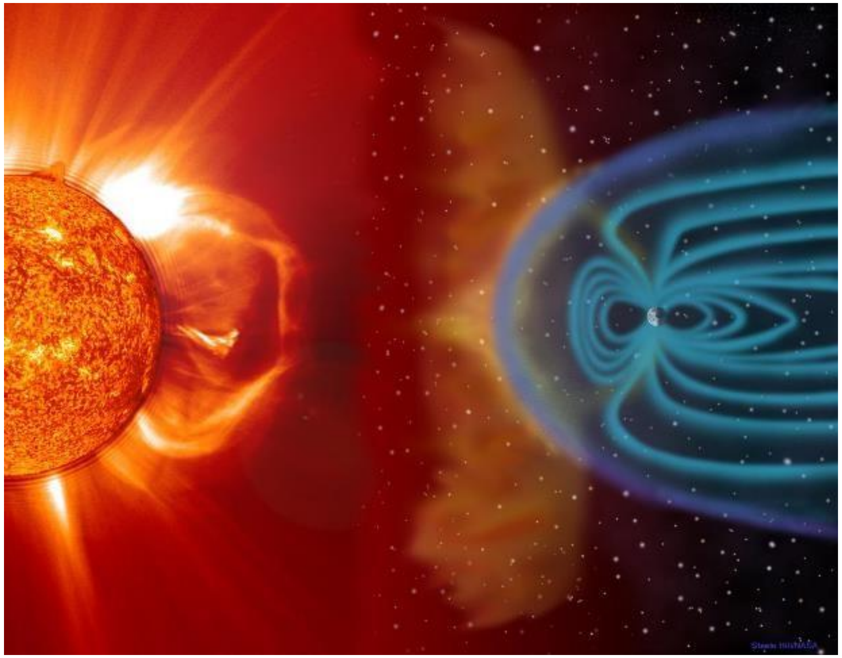

Fig. 5 - A visualisation of the Sun-Earth interaction

- Due for launch 2021.
- Instruments include:

Soft X-Ray Imager (SXI);
Ultra-Violet Imager (UVI);
Light Ion Analyser (LIA);
Magnetometer (MAG).

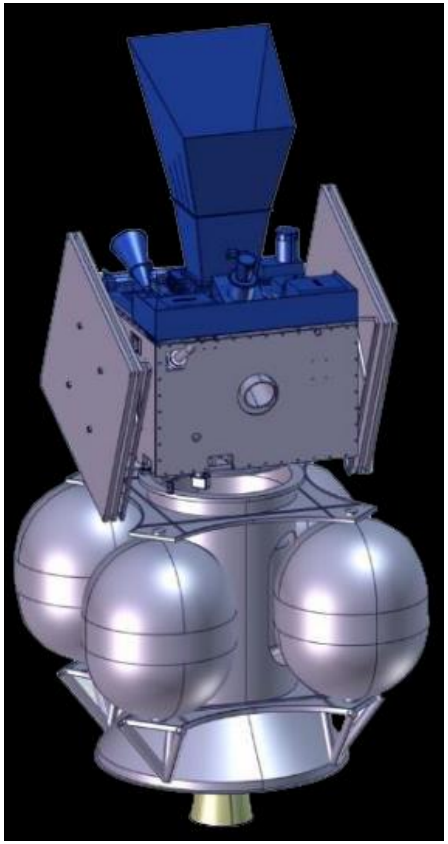

Fig. 6 - Preliminary SMILE design concept

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The Soft X-Ray Imager (SXI)

- The Soft X-Ray Imager (SXI) is being led by the University of Leicester with contributions from institutions in the UK and overseas.
- SXI will take spectral images of the Earth's magnetosphere which will enable researchers to observe the dynamical properties of the dayside magnetospheric boundaries within the soft X-ray range, between 0.2 and 2 keV.
- Silicon Micro-Pore Optics (MPOs) are used to focus the X-rays onto a focal plane of two large-area Charge-Coupled Devices (CCDs) where the X-rays are directly detected.
- Operation and image processing are carried out in the Front End Electronics (FEE), located under the focal plane.

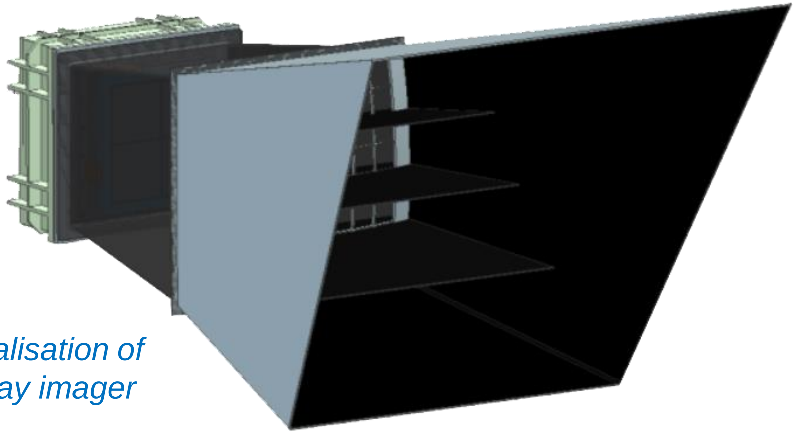

Fig. 7 - Visualisation of the Soft X-Ray imager

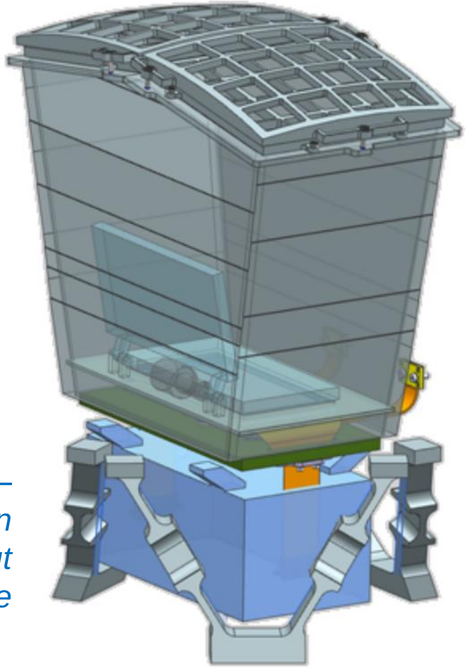

Fig. 8 – Visualisation of SXI without optical baffle

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Charge-Coupled Devices (CCDs)

- The SXI CCDs have been developed to optimise the soft X-ray sensitivity throughout the mission lifetime.
- CCD370 manufactured by Teledyne-e2v in the UK.
- 6x6 pixel binning to be used in operation.
- 6 x manufactured including devices for calibration, radiation damage, electronics testing, flight model and spares.
- Adapted from PLATO CCD 270s - same electrical interface.
- CCD380 to be used for calibration.

Property	Units	Value
Sensitive silicon thickness	μm	16
Native pixel size	$\mu m \times \mu m$	18×18
Image area size	pixels	4510 columns $\times$ 3791 rows
	mm $\times$ mm	81.18×68.24
Store area size	pixels	4510 columns $\times$ 719 rows
Responsivity	μV electron^{-1}	~ 7
Output nodes	-	2
Serial registers	-	1

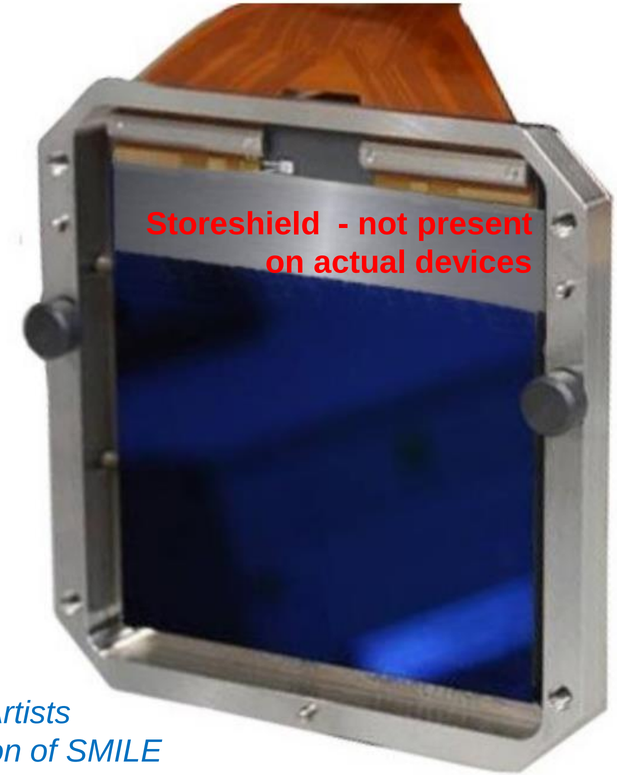

Fig. 9 – Artists impression of SMILE CCD370

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Open University Activities

- Modelling of the scale and types of radiation effects incident on the CCDs due to the mission orbit and instrument design.
- Minimising CCD damage and instrument background by optimising the design of CCD radiation store shield that is in close proximity to the detectors.
- Characterising the CCD behaviour in a mission-like radiation environment and developing correction algorithms for the radiation effects.
- Understanding the radiation background and its effect on images collected by the detectors.
- Calibration of the CCDs with soft X-rays to understand their response to different energy X-rays.
- Development and test of data processing algorithms for the on-board Event Detection Unit to identify soft X-rays observed in the images and reject background cosmic events.

CCD calibration plan - ground

Initial calibration will be done with CCD380 using PTB beamline at Bessy-II in Berlin.

- Response Matrix Function (RMF) describes the probability that a photon of a given energy is assigned to a particular detector channel.
- RMF can be determined by collecting a spectral response when a detector is exposed to each of a range of different photon energies.
- Quantum Efficiency (QE) to be determined for a range of different energies.
- PTB-EUV provides tuneable monochromatic beamline (50eV – 1950eV) and calibrated photodiode for above measurements.
- Possible repeat measurements on irradiated detector.

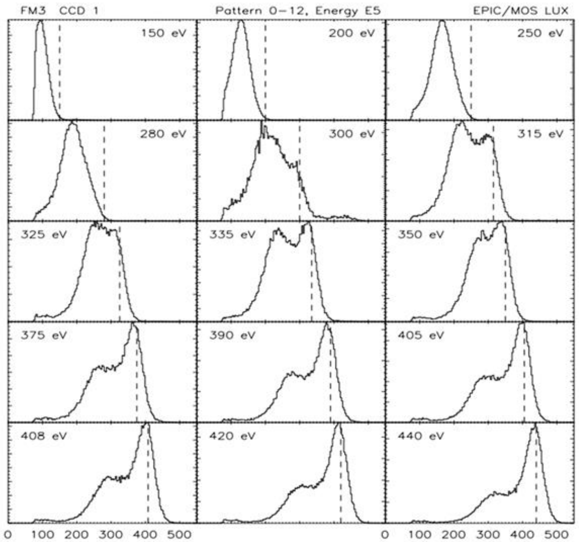

Fig. 10 -Example of RMF from EPIC camera on XMM-Newton (Sembay 2004)

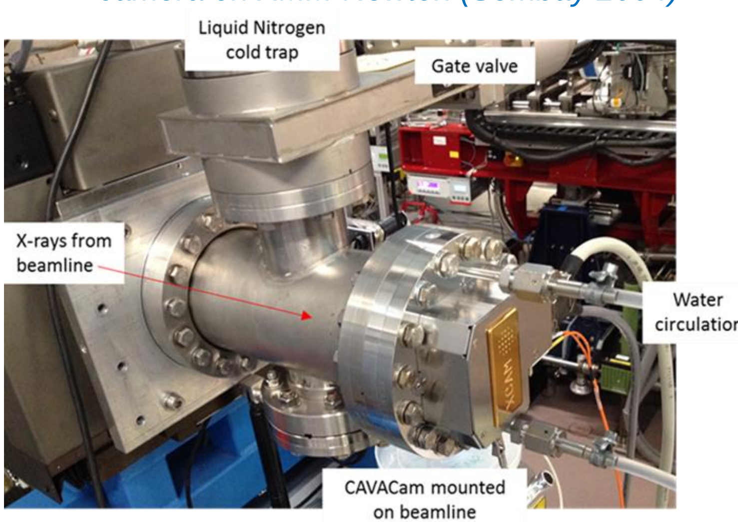

Fig. 11 - Experimental setup from a previous campaign.

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CCD calibration plan - ground

Further calibration will be conducted on the CCD370 flight model using a specially constructed soft x-ray calibration system within the OU laboratory

- Variation across whole detector area
- Tuning charge spreading models for the flight detectors
- Dark current
- Defect pixels
- Noise
- Charge injection structure uniformity
- Clock optimisation
- Full well capacity and linearity
- Charge transfer efficiency
- Charge to voltage conversion factor (CVF)
- Trap pumping – defect identification

Fig 12. - Cryogenic test chamber within OU laboratory.

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CCD calibration plan – in flight

- ^{55}Fe calibration source, with an aluminium target, will be implanted within the structure of the Radiation Shutter Mechanism (RSM).
- Will produce manganese and aluminium k-shell emission at around 5.9 and 1.49 keV.
- Distribution and specification of sources are to be decided but will be positioned so that CCDs are illuminated when shutter is closed.
- Aluminium K-shell fluorescence will also be induced by the external radiation environment on the instrument throughout orbit.

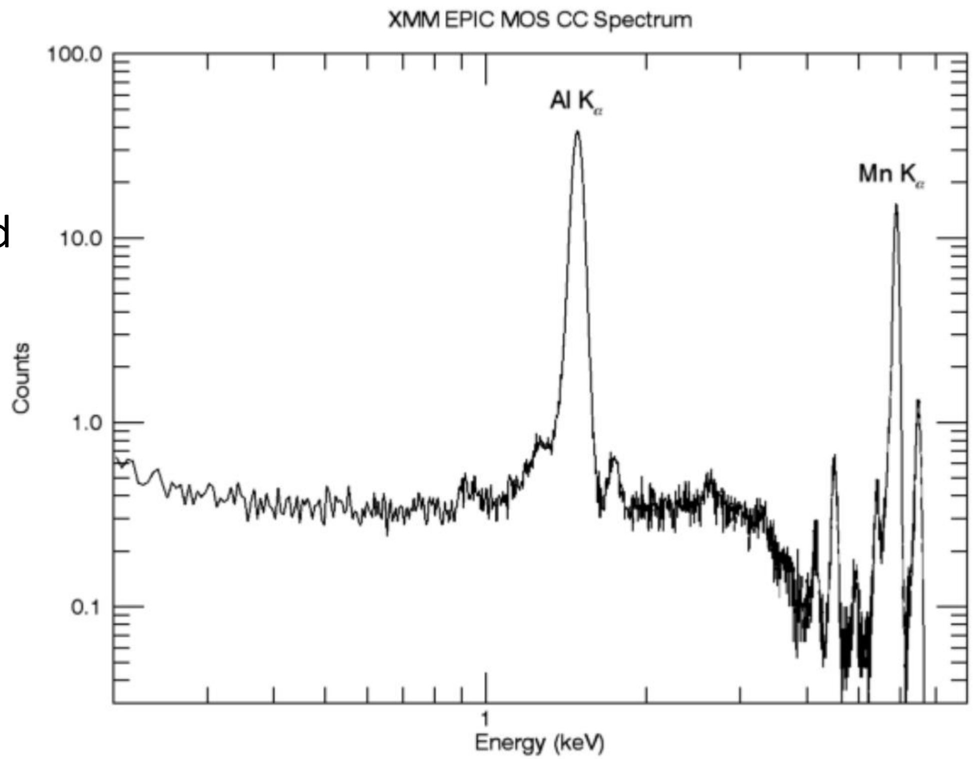

Fig. 13 - Example of on-board calibration source spectrum from an XMM-Newton EPIC MOS X-ray camera..

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Summary

- CCD380 - BESSY II – PTB campaign
  - RMF and QE measurements using tuneable X-ray source
  - Tuneable X-ray source 50 eV to 1900
  - possibly repeat measurements on irradiated sensor
- CCD370 Flight Models
  - OU Lab soft X-ray source for whole device calibration
  - Variation across whole detector area
  - Tuning charge spreading models for the flight detectors
  - Dark current, defect pixels, CVF, noise, defects, etc.
- CCD370 In-fight calibration
  - ^{55}Fe source on shutter mechanism (6 keV)
  - Al and Mn K_α fluorescence from ^{55}Fe and celestial sources

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