XDEP workshop — February 5-6 2024

Commercial CMOS sensors for soft X-ray astronomy

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Outline

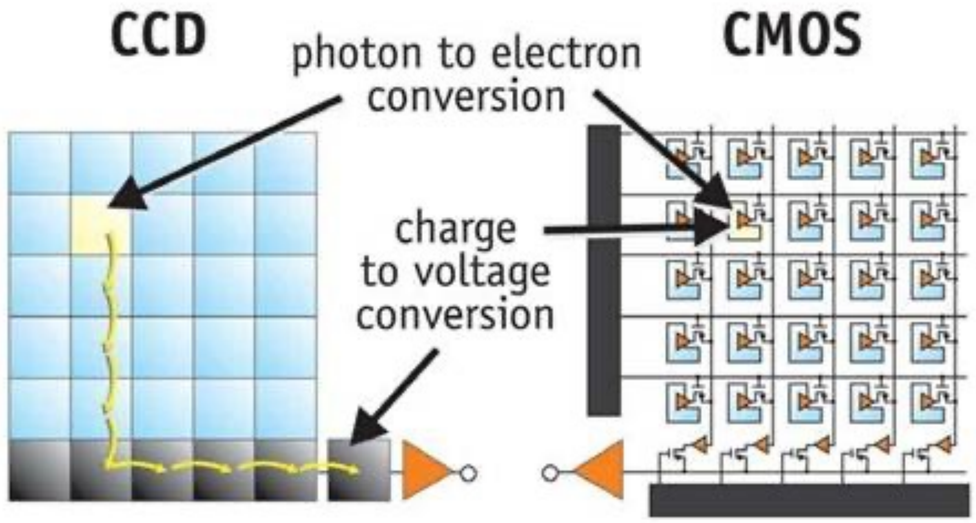
I. Brief introduction

II. Performance and soft X-ray response of the Sony IMX290

III. Per-pixel gain calibration of the Sony IMX290

CMOS sensors

- Active-pixel sensors (APS) where each pixel:
  - photodiode + active circuit
- Two major categories:
  - hybrid (HAPS)
  - monolithic (MAPS)

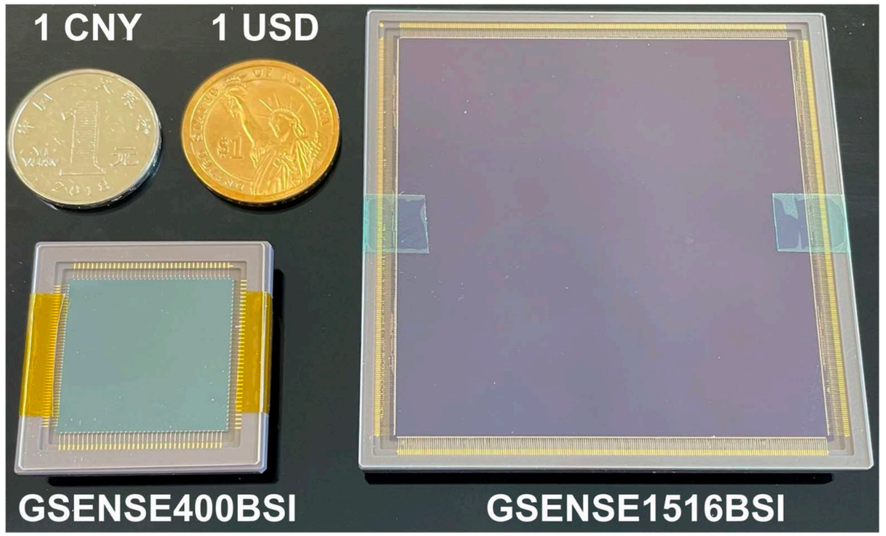


X-ray CMOS Pros	X-ray CMOS Cons
Very high frame rate	Lack of experience/heritage
No charge transfer inefficiency (CTI)	Per-pixel gain and noise variation
Low power consumption	Image lag
Region of interest (ROI)	Thin sensitive volume low QE at E > 3 keV
Higher radiation tolerance	
Can be operated at room temperature	

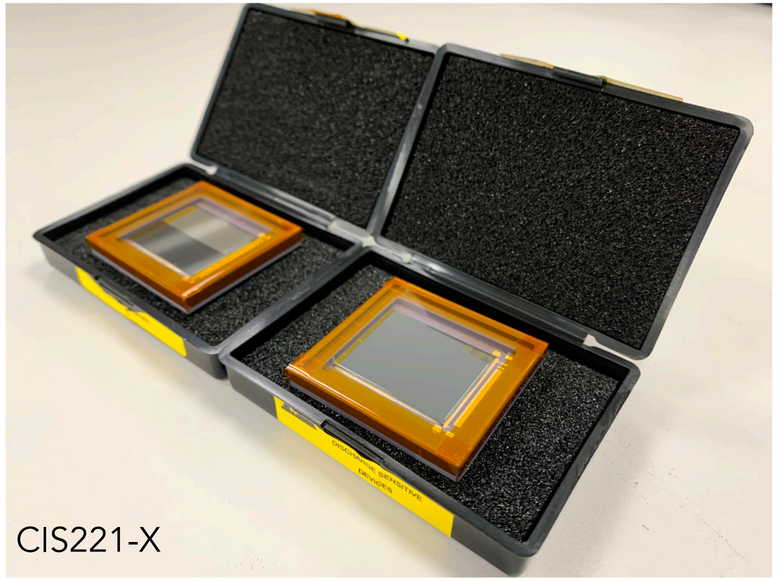
X-ray CMOS for space astronomy

- Missions in operation using X-ray CMOS:
  - Einstein probe (Yuan+18)
  - LEIA (Ling+23)

- Mission concepts employing X-ray CMOS sensors:
  - THESEUS (Amati+21)
  - HiZ-GUNDAM (Yonetoku+20)
  - FOXSI3 (Ishikawa+18)
  - Lynx X-ray observatory (Gaskin+19)



Wu+22

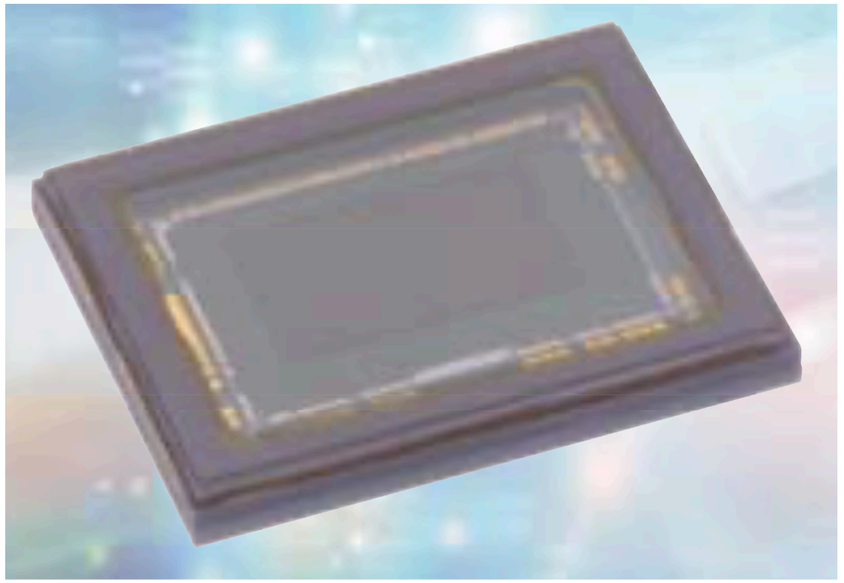


Townsend-Rose+23

Commercial CMOS sensors for X-ray imaging

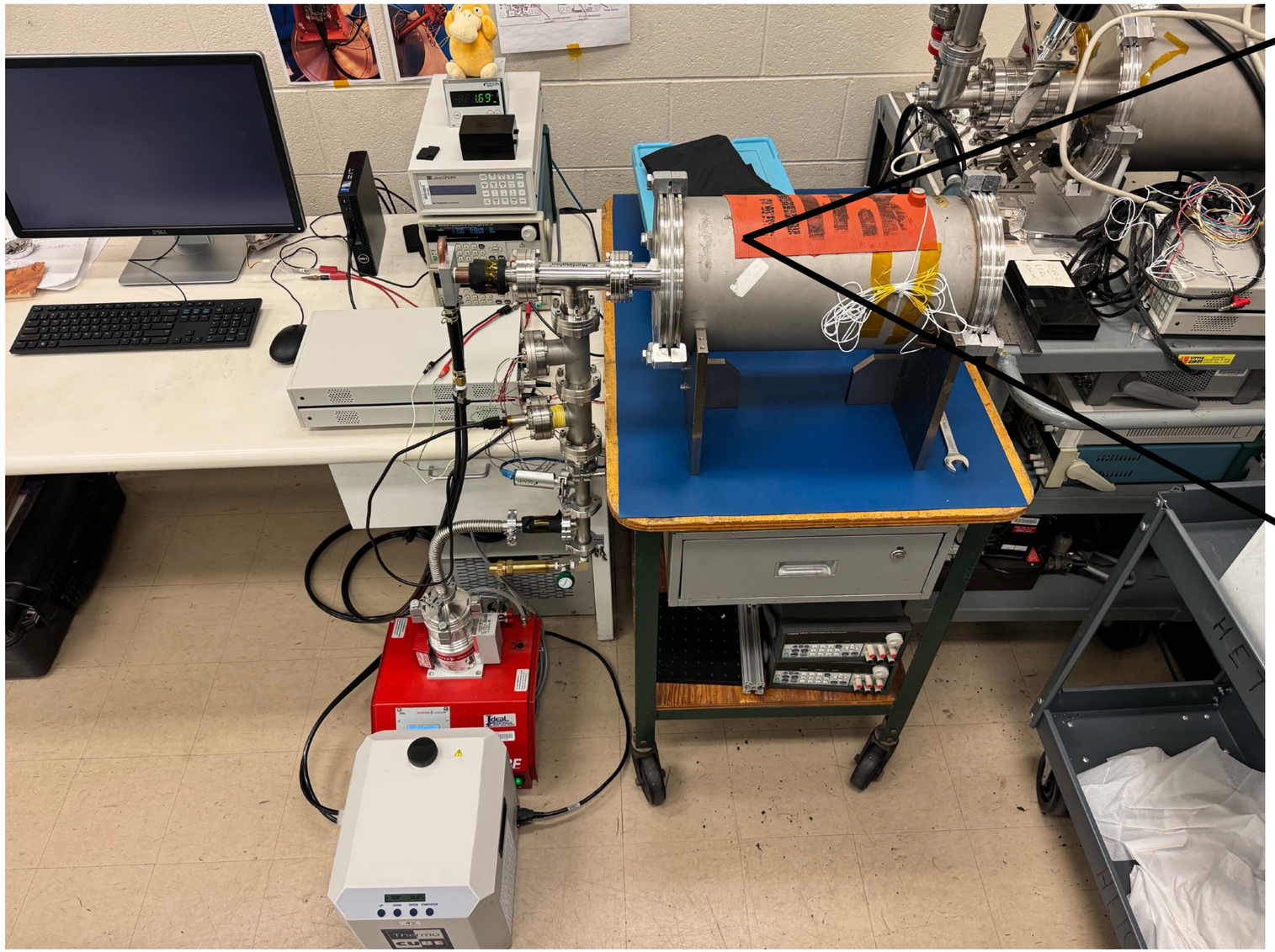
- Commercial CMOS, optimized for optical light, some of them = promising for X-rays
  - low cost → small satellites
  - small pixels → towards diffraction limited X-ray optics

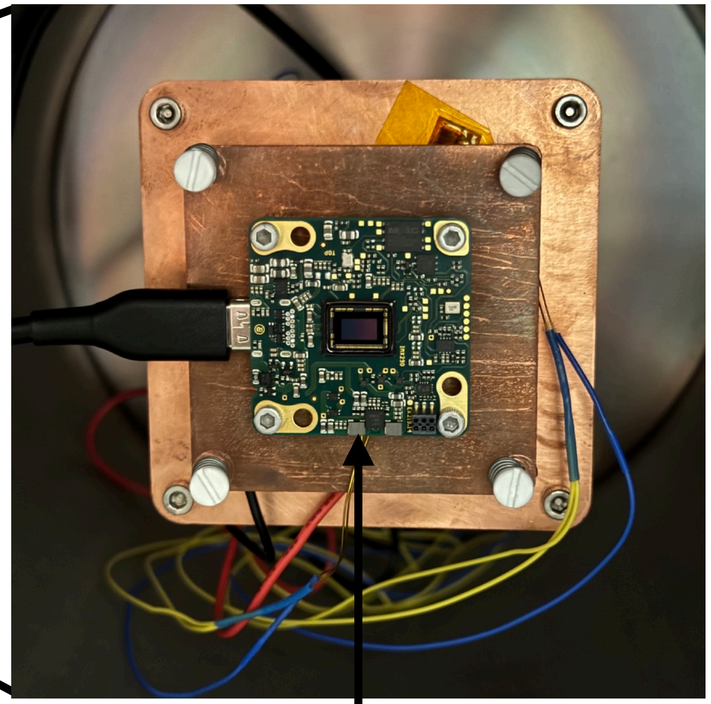
- Sony CMOS IMX290LLR:
  - STARVIS I series
  - **backside illuminated** sensor
  - monolithic active pixel sensors
  - number of pixels: 1936 x 1096 of **2.9 µm**
  - image area: 5.6 x 3.2 mm
  - frame rate: up to 120 fps
  - exposure time: up to 120 seconds
  - consumption: 0.9 - 1.5 W



Credit: Sony

Setup overview

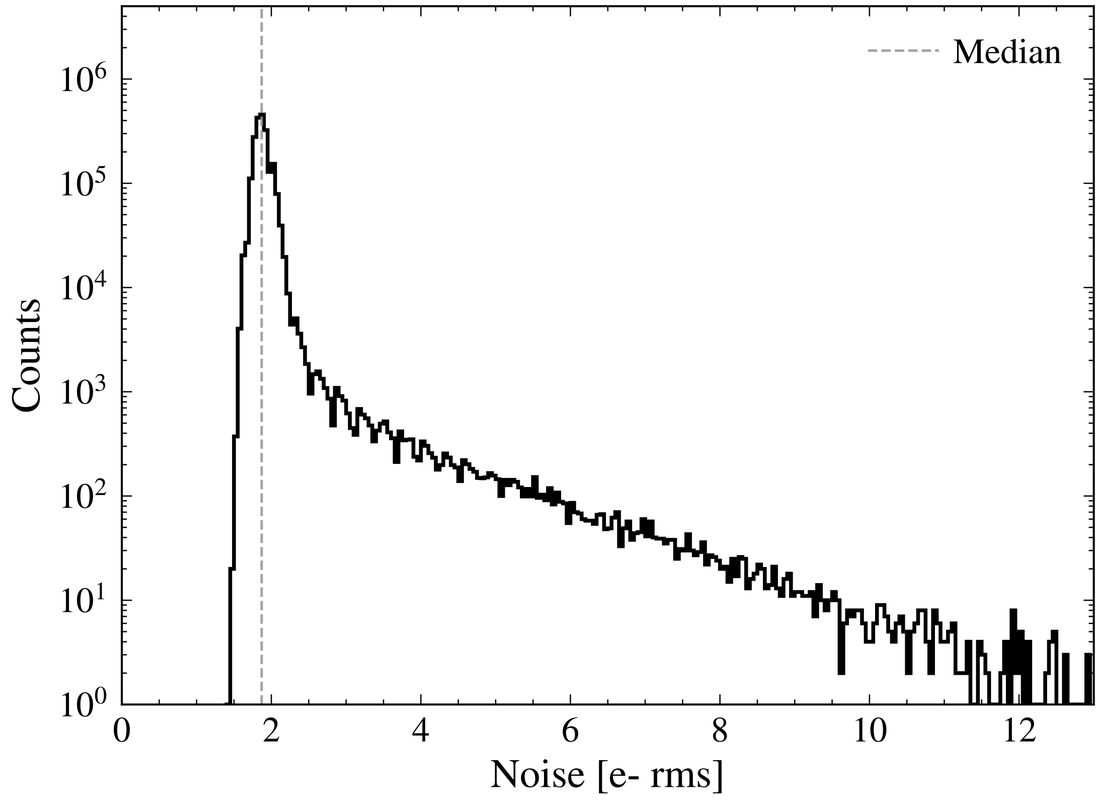


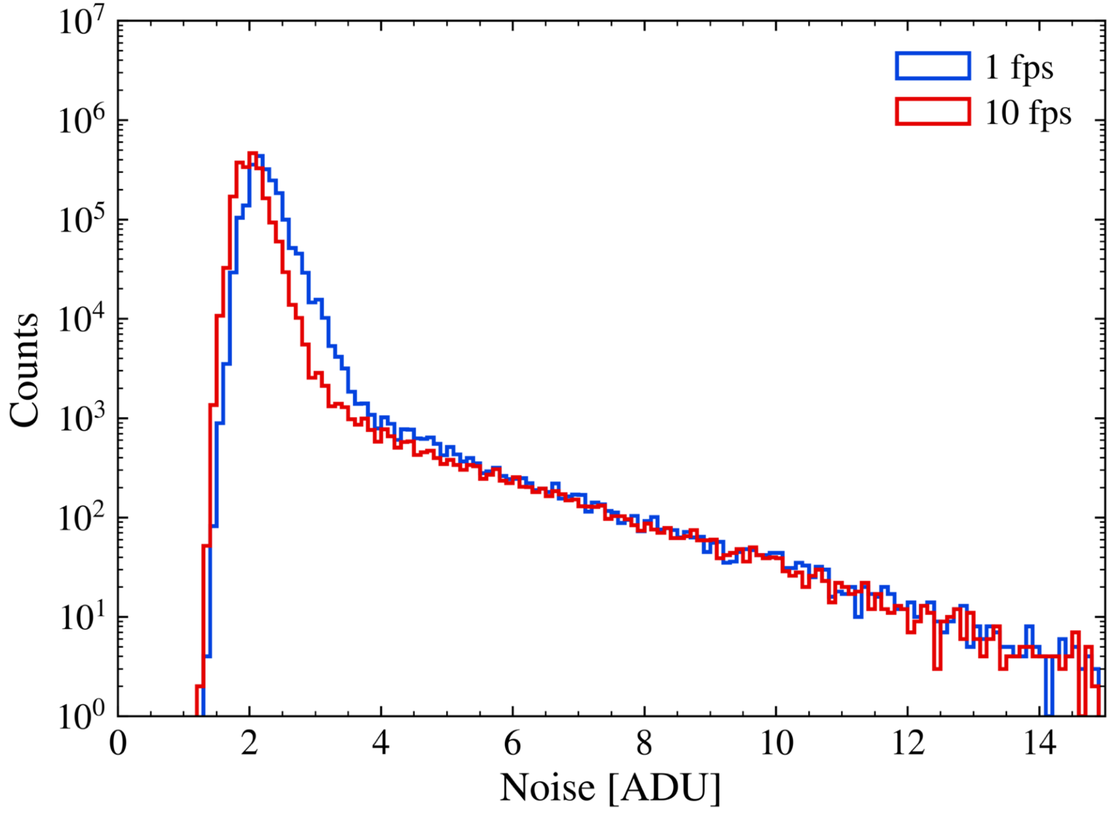


IDS UI-3862LE-M camera

Per-pixel noise

- At room temperature (~26°C):
  - Low noise = median equivalent noise charge ~**1.9 e- rms**
  - no significant different between 1 vs 10 fps → suggests negligible dark current at room temp
  - extending tail → random telegraph signal (RTS) noise of the source follower

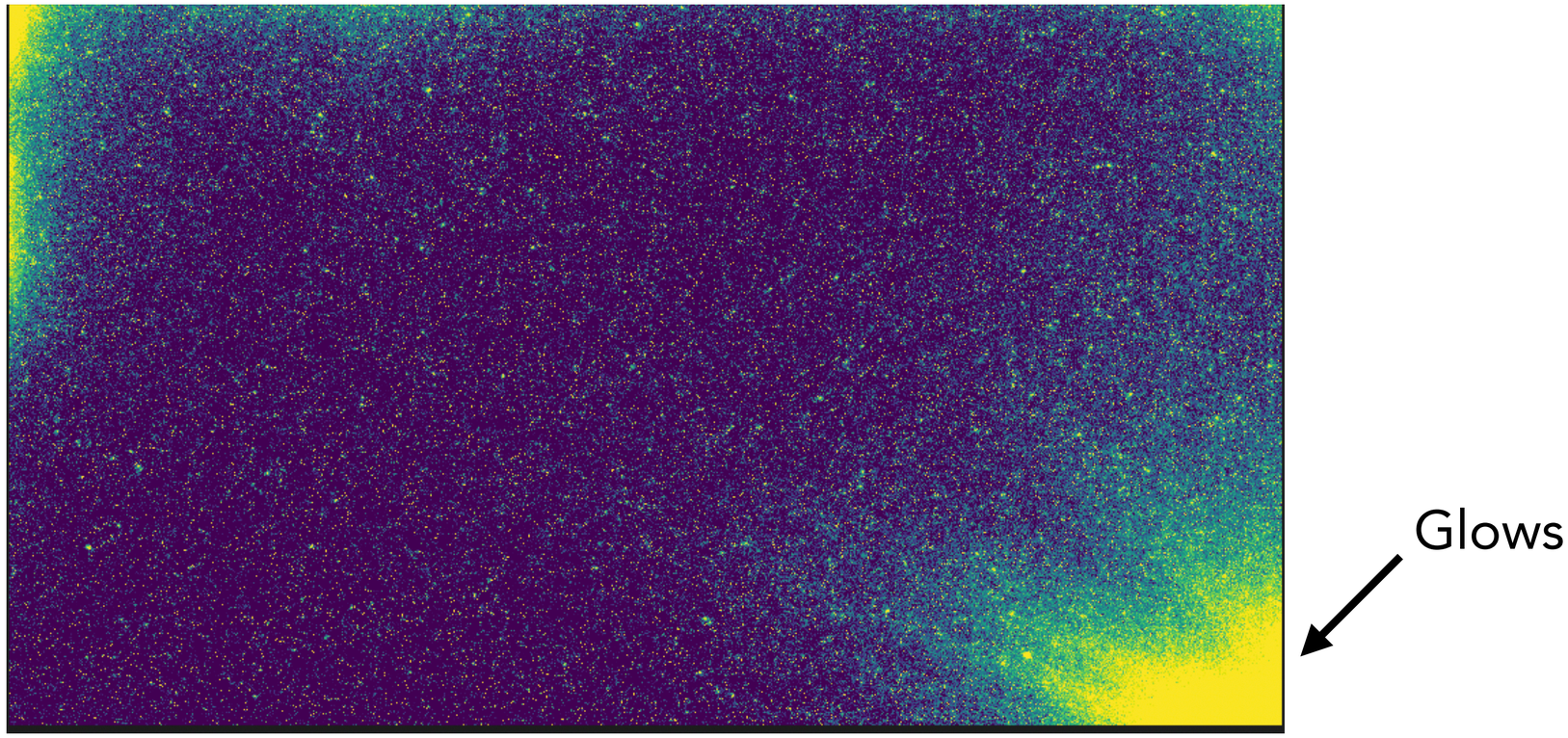




Long exposure measurements

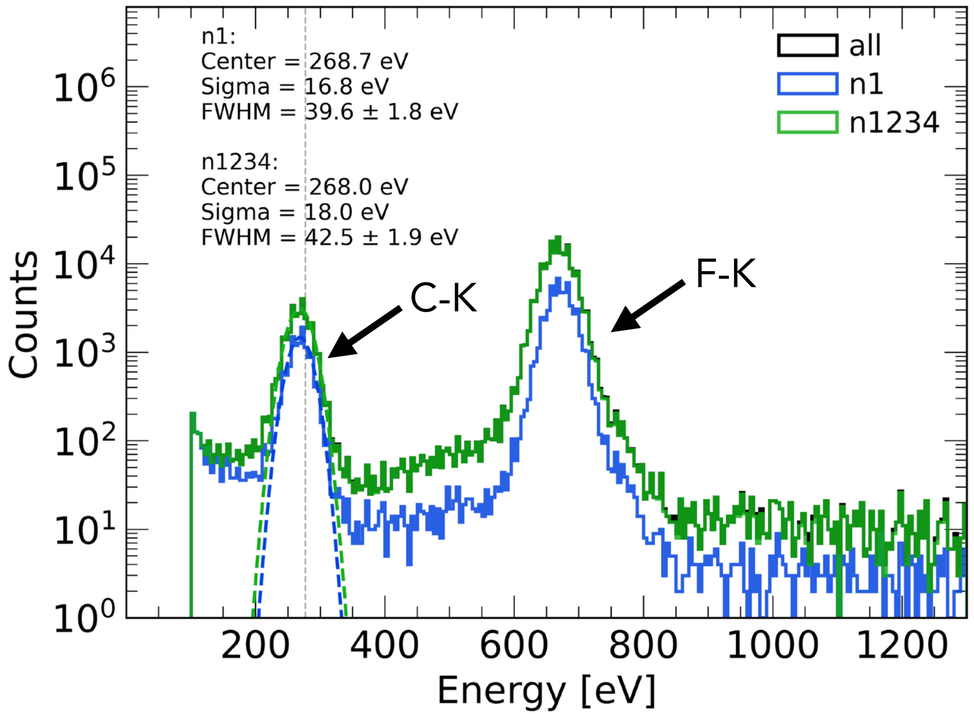
- Sensor exposure time up to 120s
- Glows visible in the corners for long exposures:
  - likely produced by onboard support circuits and processors generating heat and NIR light

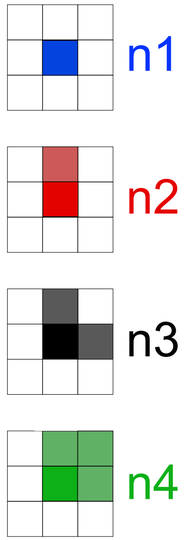
Stack of 120 images with 120s exposure

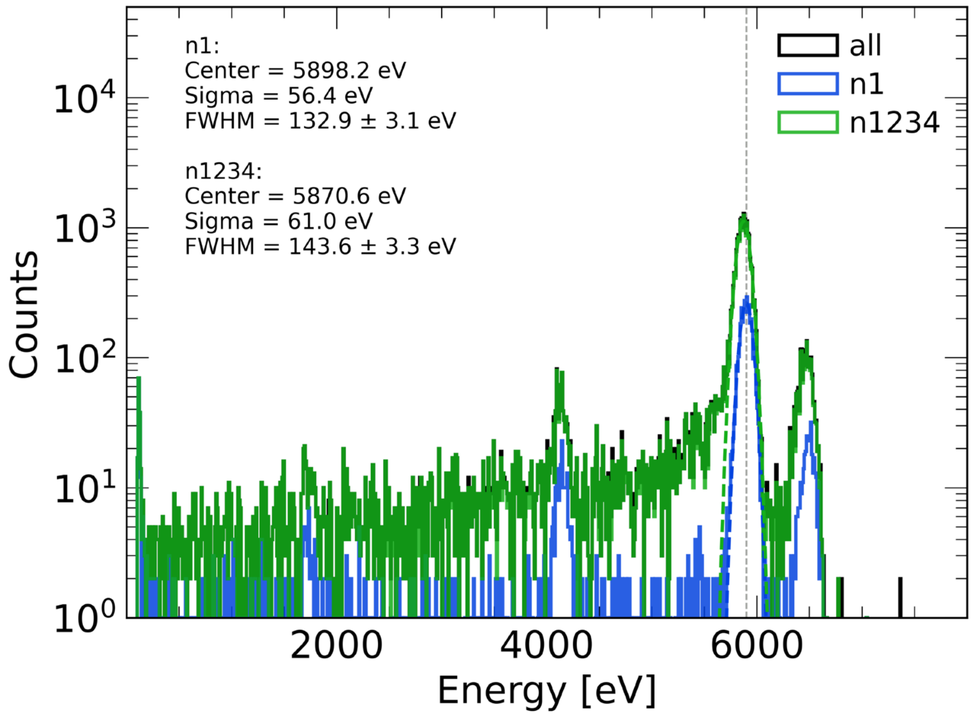


Radioactive sources testing

- Preliminary tests once the cover glass removed:
  - Po210 (+teflon) and Fe55 radioactive sources
  - confirmed X-ray detection from 277 eV to 6.4 keV (see also Tammes+20)

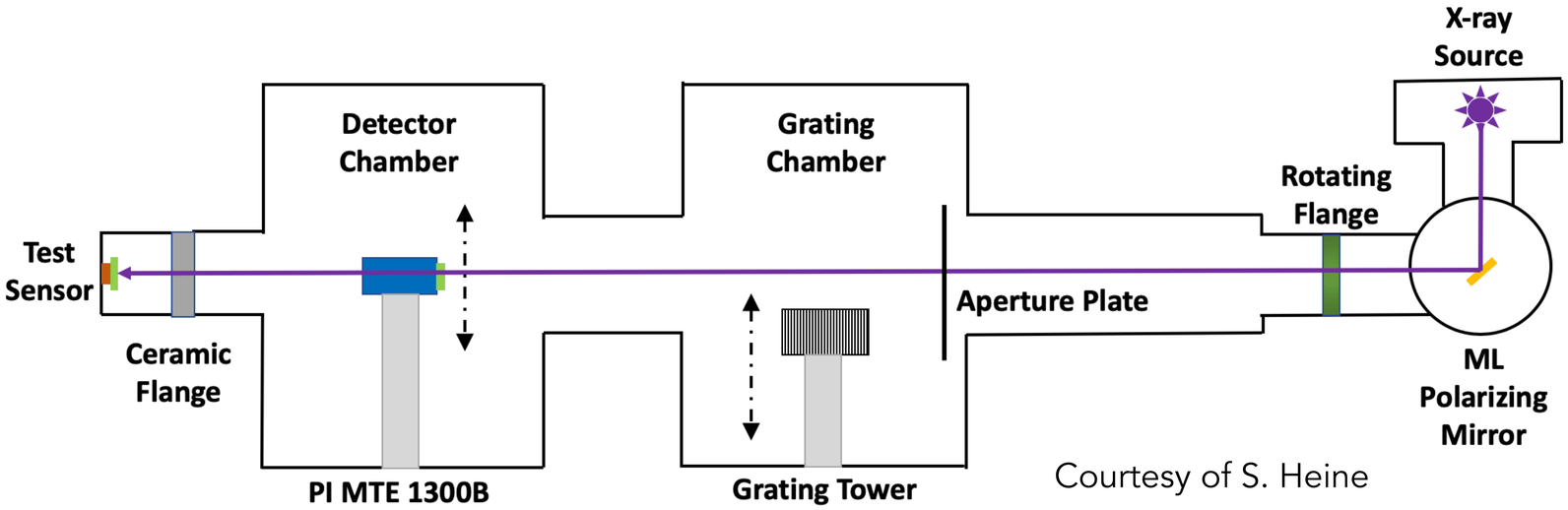






MIT polarimetry beamline

- Beamline re-purposed from original use as a calibration facility for Chandra HETG gratings
- About 20m long with 3 chambers
- X-ray tube with interchangeable anodes + Bragg reflector:
  - monochromatic energy line
  - from 183 eV (B-K) to 705 eV (Fe-L)



Courtesy of S. Heine

Soft X-ray performance

- X-ray photons detected down to 183 eV
- Possible optical light contamination from the X-ray source
- Energy resolution comparable or better than for the best BI CCDs