Current Status of B04: DM search utilizing novel X-ray detectors

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with
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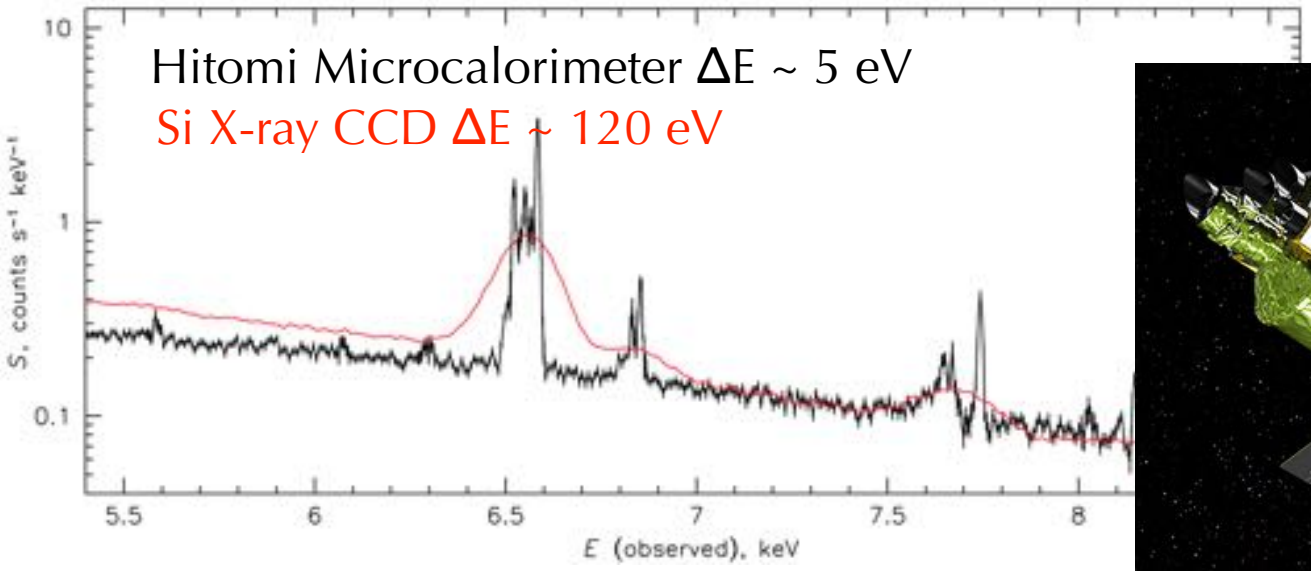
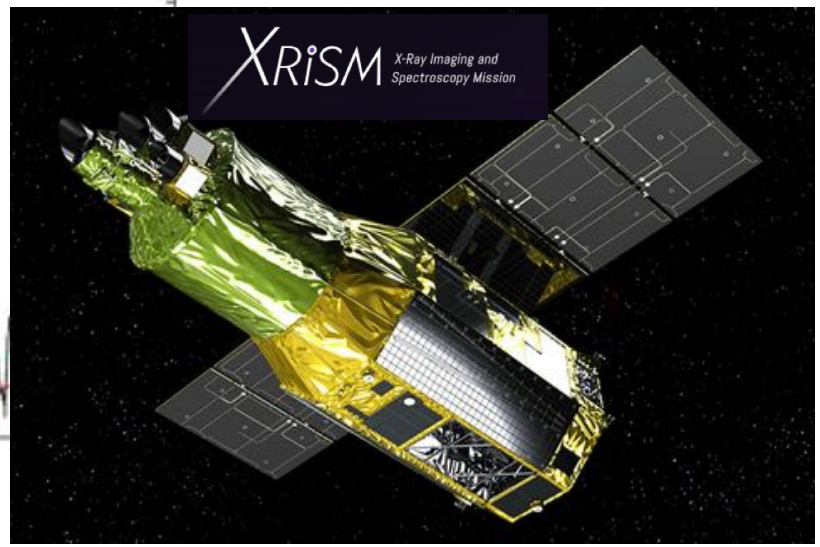
Overview

- Strategy and Structure of B04
- Status Report
  - Overview
  - Development status of TES micro-calorimeters with 57Fe for solar axion search　by Y. Yagi
  - Development of Microwave SQUID Multiplexer for Multi-pixel X-ray TES Readout by F. Hirayama
  - DM search by astronomical observation in X-ray by N. Uchida

High resolution spectroscopy in X-ray

Around Fe^{+24} K-line from Perseus cluster of galaxies

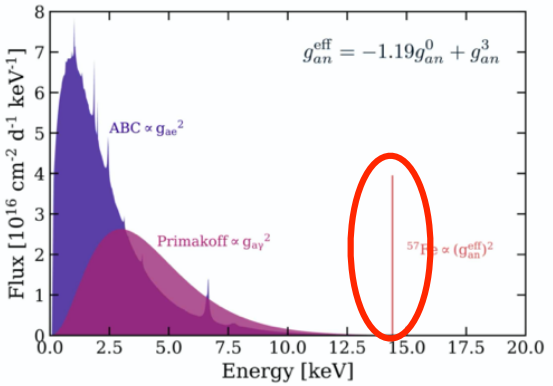




Energy resolution increased dramatically by micro-calorimeters !

⇒ Update astrophysical search of DM by XRISM

New method to search DM/new particles on ground ? ex. Solar actions from 57Fe interaction ?



(From XENON1T web page)

Structure

Astrophysical search

Particle physics search

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(2021 Jul~)

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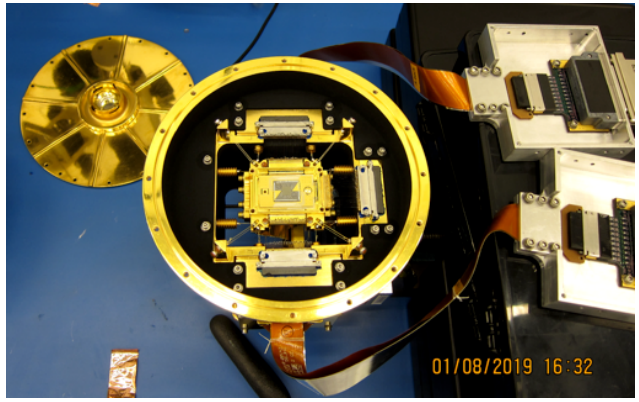
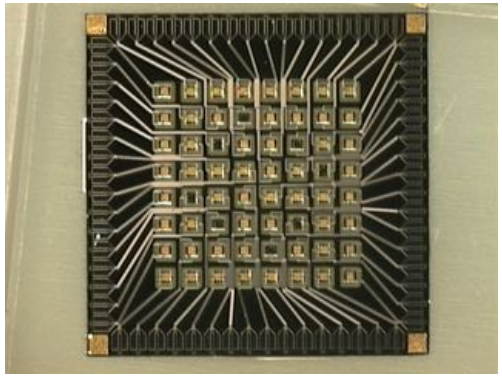
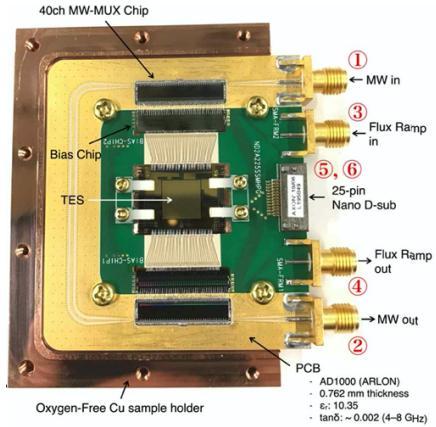
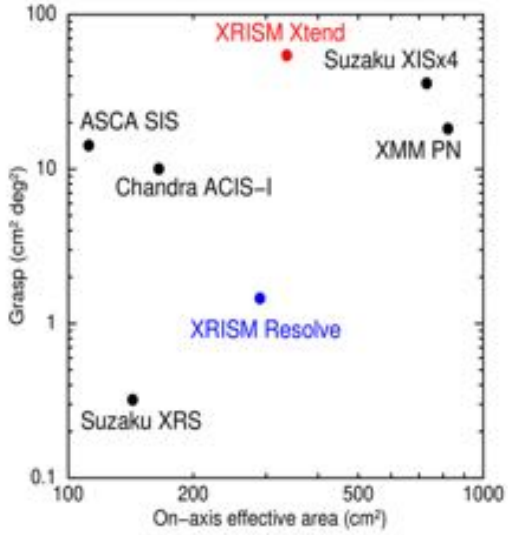


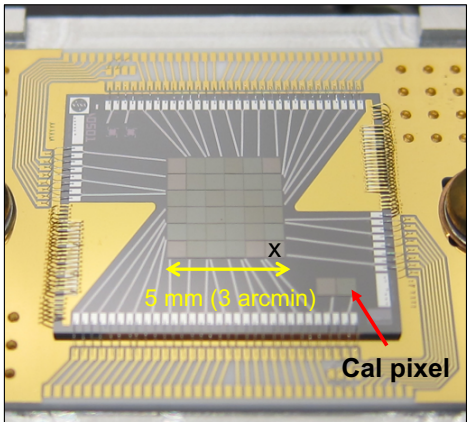


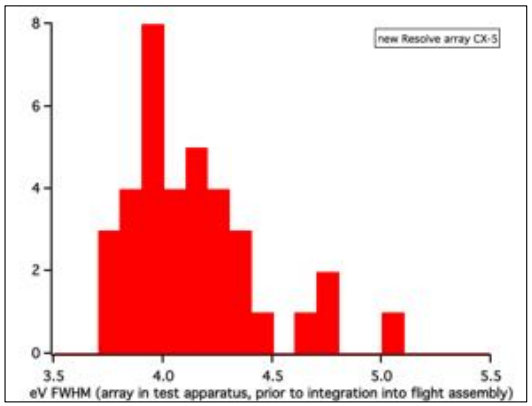


XRISM

Instrument	FOV/pix	ΔE (FWHM @6keV)	Energy band
Resolve (XMA+ μcalorimeter)	2.9' □ / 6 x 6 pix	7 eV (goal 5 eV)	0.3 – 12 keV
Xtend (XMA + CCD)	38' □/ 1280 x 1280pix	< 250 eV at EOL (< 200 eV at BOL)	0.4 – 13 keV



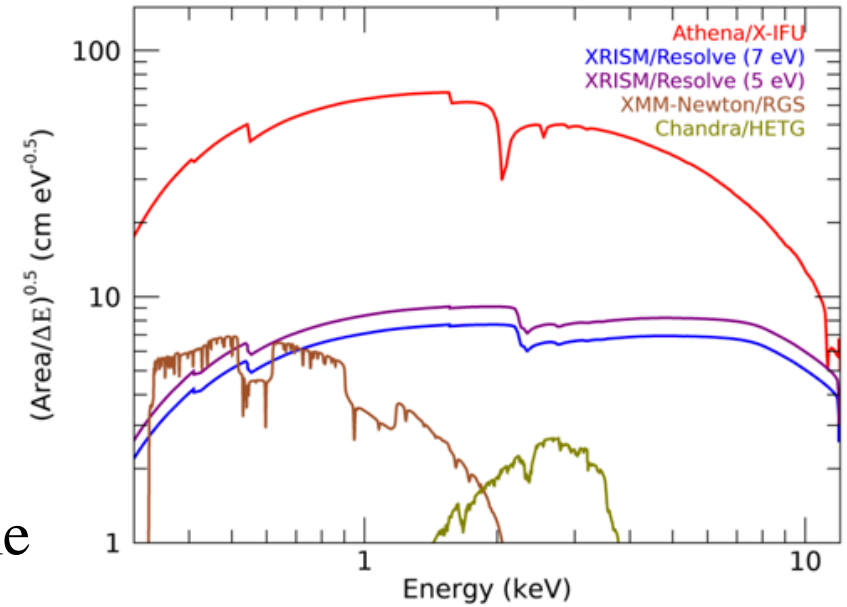




$$\text{S/N} \propto \frac{FAT}{\sqrt{BAT\Delta E}} \propto \sqrt{\frac{A}{\Delta E}}$$

F : Flux, B : Background
A : Area, T : Exposure time

FoM for weak lines from point sources



Sterile ν ?

DM shall concentrate on clusters of galaxies and galaxy core.

(3.55-3.57)±0.03 keV line from clusters of galaxies (Bulbul+2014)

No feature with Hitomi (Astro-H) (Hitomi Collaboration 2017)

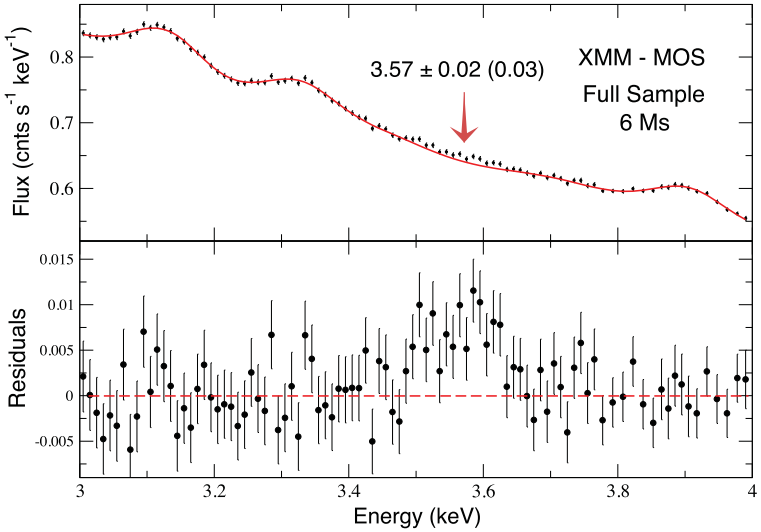
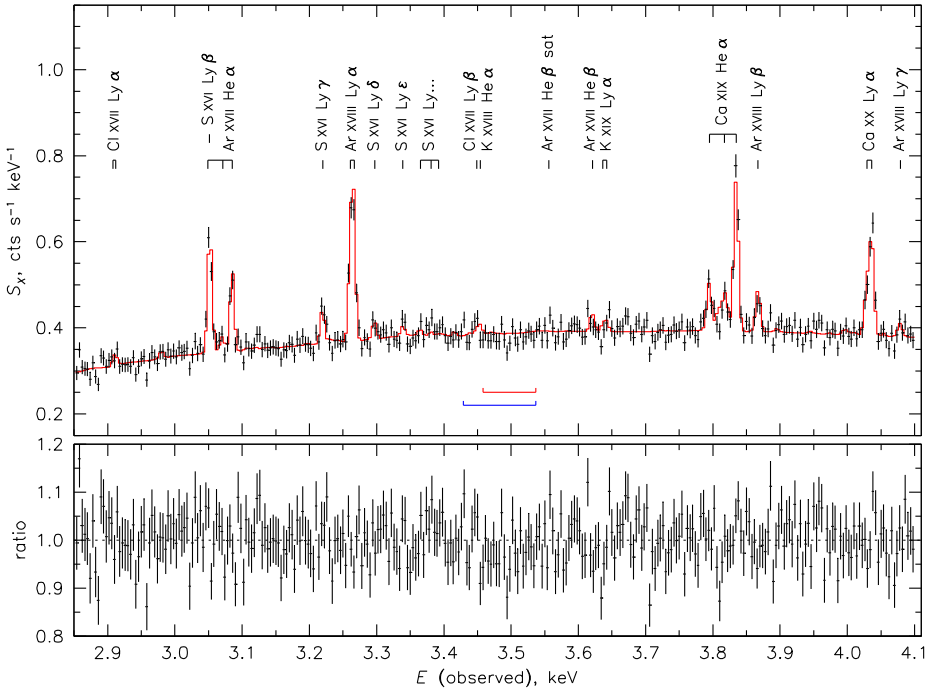


Figure 6. 3–4 keV band of the stacked *XMM-Newton* MOS spectrum of the full sample. The spectrum was rebinned to make the excess at ∼3.57 keV more apparent.



This might be confirmed by XRISM in many objects.

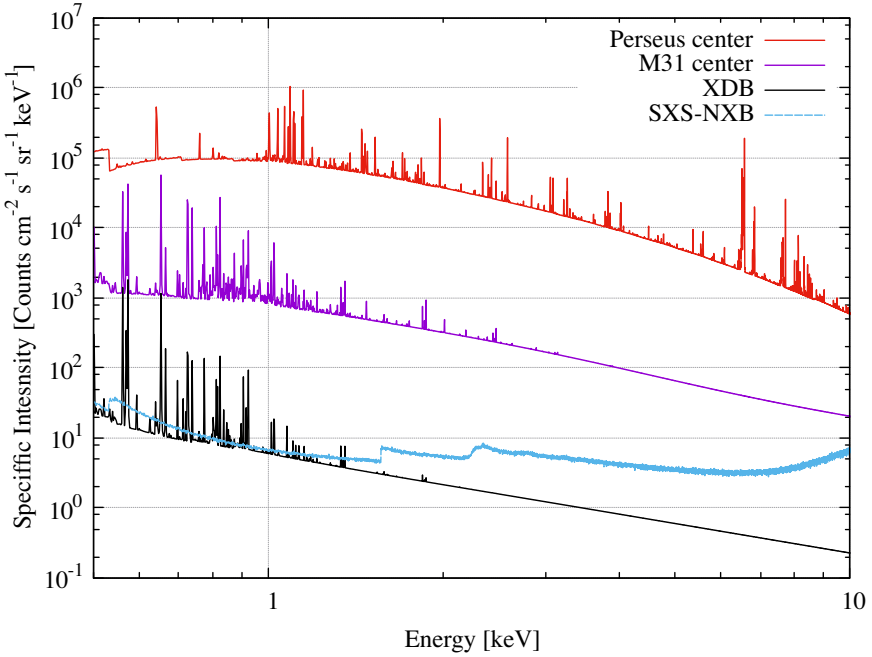
Signals from DM

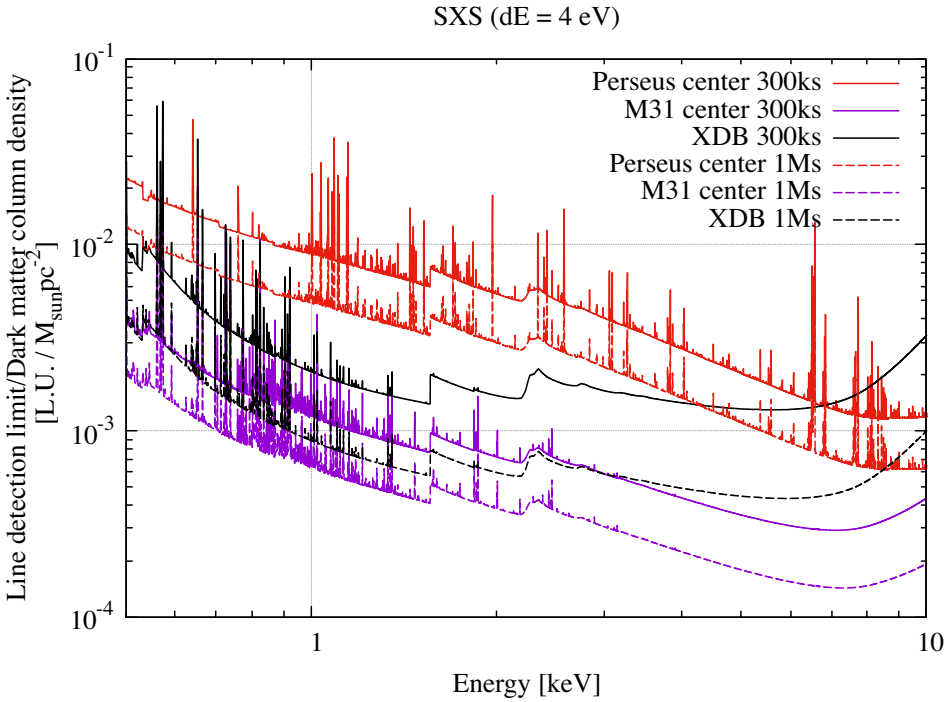
$$\mathrm{S/N} \propto \frac{SA\Omega T}{\sqrt{BAT\Delta E}} \propto \sqrt{\frac{A\Omega}{\Delta E}}$$

S : SurfaceBrightness, B : Background

If $\rho_{DM} \propto \rho_{Baryon}$, $S \propto \rho_{DM}, B \propto \rho^2_{baryon}$

Selection of targets is very important !



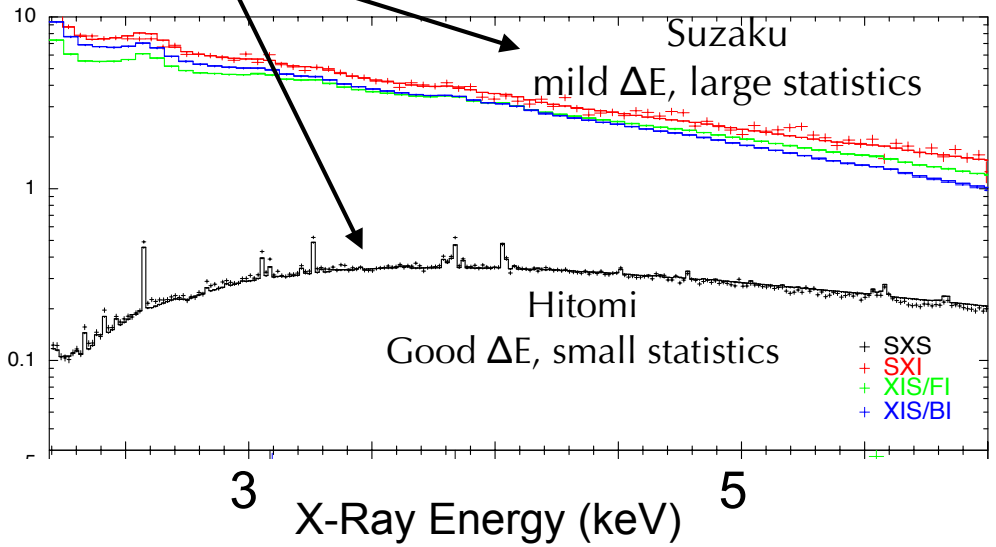


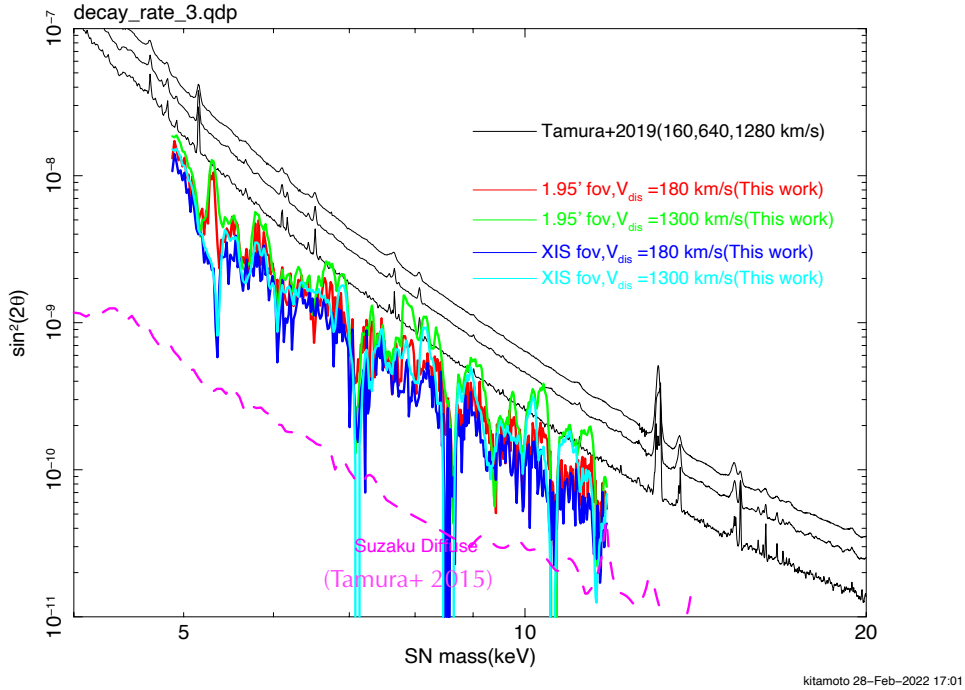
Galaxies seems better, but still need long exposure.
New strategies, techniques are being searched for.
(Ex. usage of magnetars, by Uchida)

Joint analysis of Suzaku and Hitomi

- Dark Matter search in the Perseus cluster with Simultaneous Analysis of Hitomi and Suzaku archival data (Fukuichi, Kitamoto, & Tamura 2022 to be submitted)
  - Joint X-ray spectroscopic search using large grasp & deep Suzaku(CCD) + high energy resolution Hitomi (calorimeter; short exposure) data.
  - A factor of ~2 sensitivity increase for a faint line or absorption emission in the 2-6 keV band.
  - A pilot study for XRISM observations of various dark matter objects.

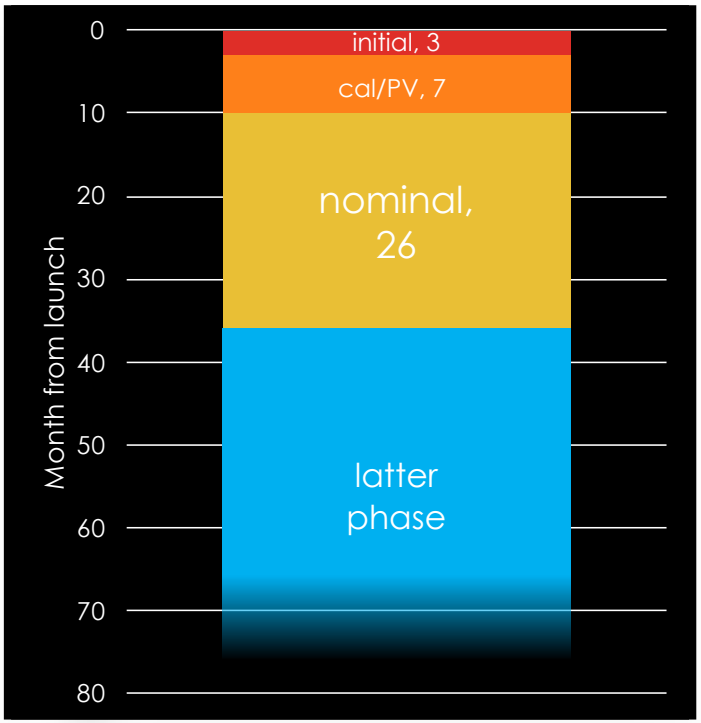
Different data with different response are combined together



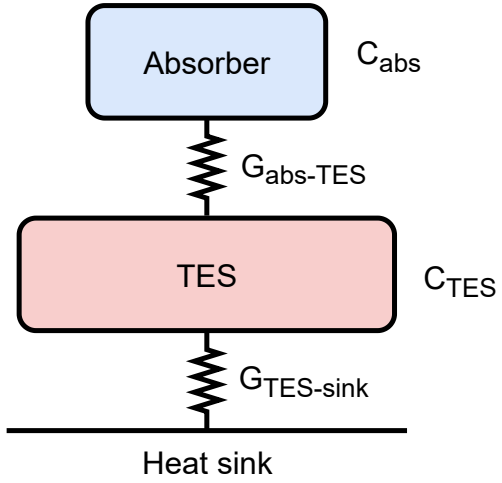


News from XRISM

- Resolve is now under test at Tsukuba Space Center. It will be delivered to S/C on April, and the launch is scheduled in FY2022.
- Target list in PV phase is now open at https://xrism.isas.jaxa.jp/research/proposer/approved/pv/index.html
- XRISM Guest Scientist Program (TBD) is planned.
  Guest Scientists nominated from 3 agencies (JAXA,NASA,ESA) can join a PV target team to enhance science production.
- Job opening for Project Researchers from FY2023 is planned.

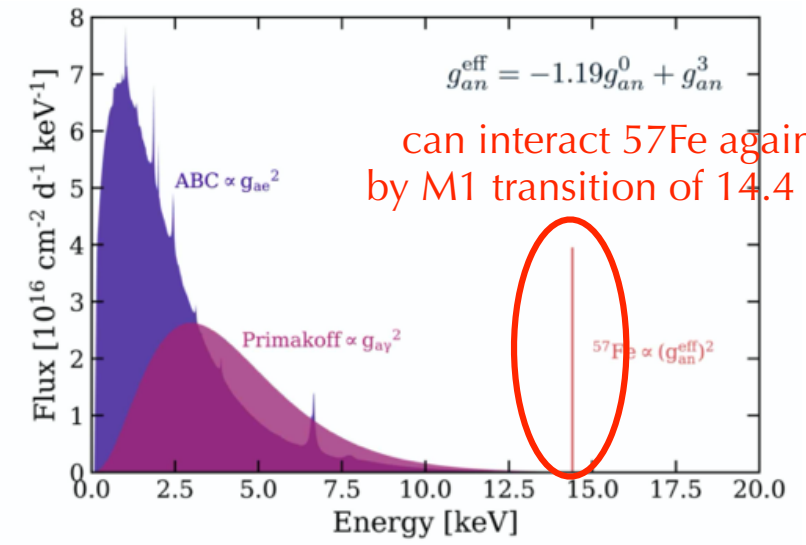


Axion search by TES microcalorimeter

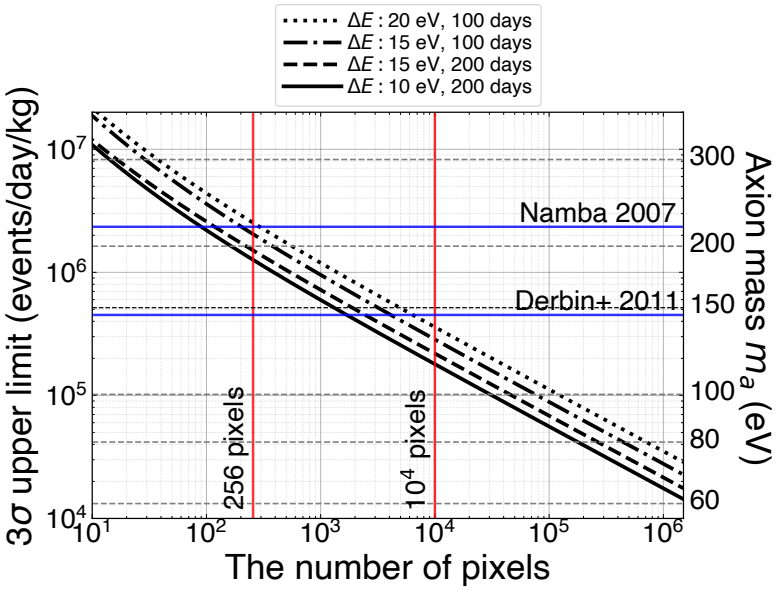


Microcalorimeters senses energy deposit in "absorber" as heat. They are used as X-ray spectrometers and as optical photon counters.

If there's some reaction by DM to radiate energies in absorber, it can be a new detection channel.
⇒ Fe 57 to catch Solar axions !



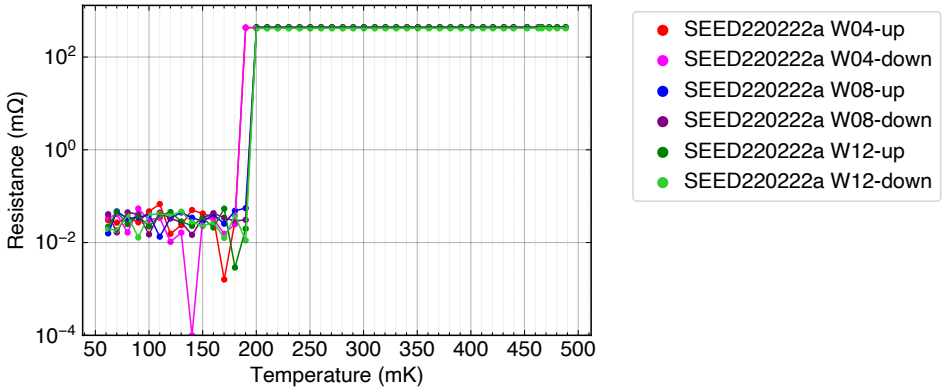
(From XENON1T web page)



Yagi+ 2022, submitted

New Instrument at ISAS

New vapor deposition equipment (Apr/2021) for Ti/Au bi-layor for TES by Henkaku funding.



Fabrication of TES has started !

CR at ISAS Build.D

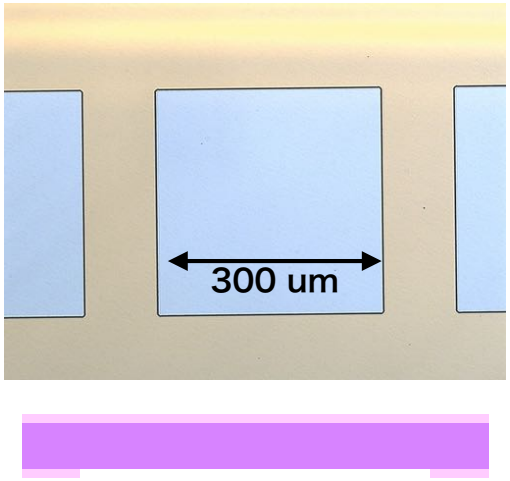
also QUP ISAS satellite

In-house TES fabrication at ISAS

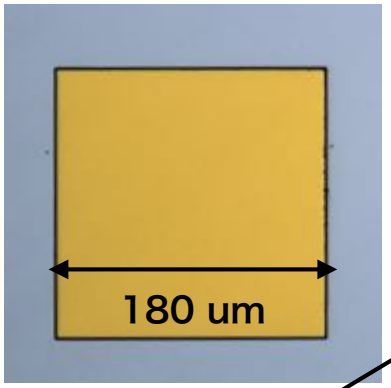
SiNx/SiO2
t1.0/0.5 um

Si t 300um

Remove SiNx, SiO2 on backside

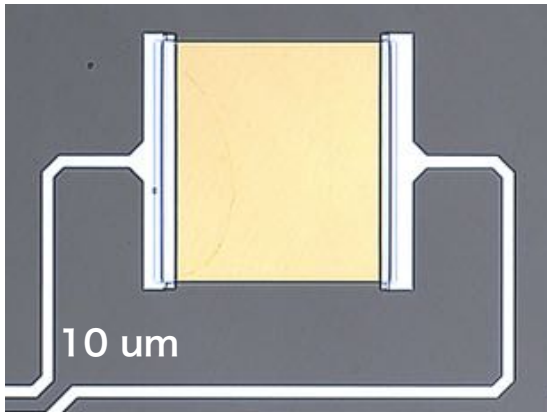


Deposit TES bilayer & etch

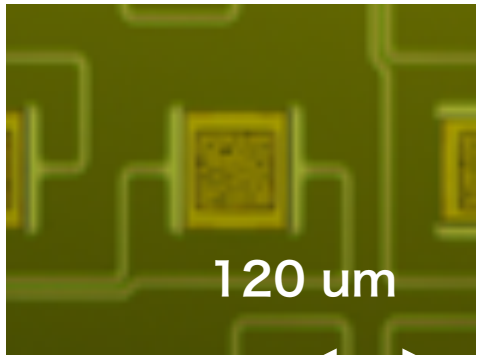


Ti/Au
40/90nm

Al wiring

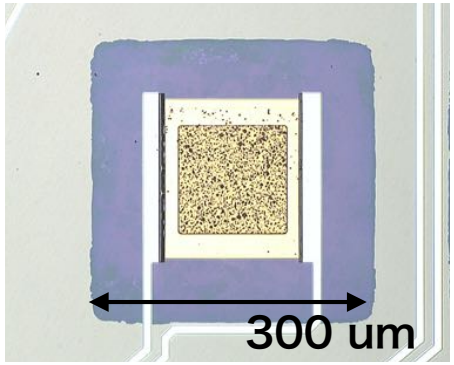


Au absorber

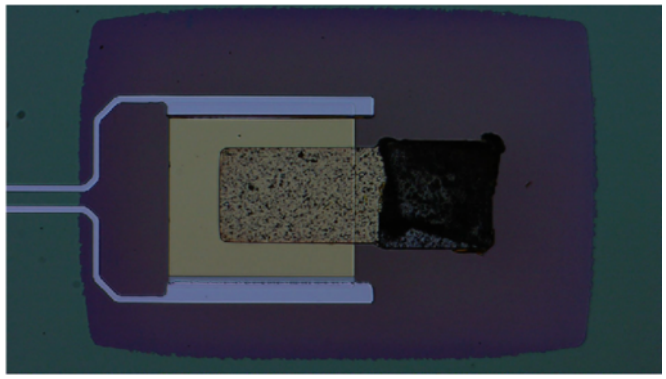


Normal absorber are directly attached on the TES

membrane



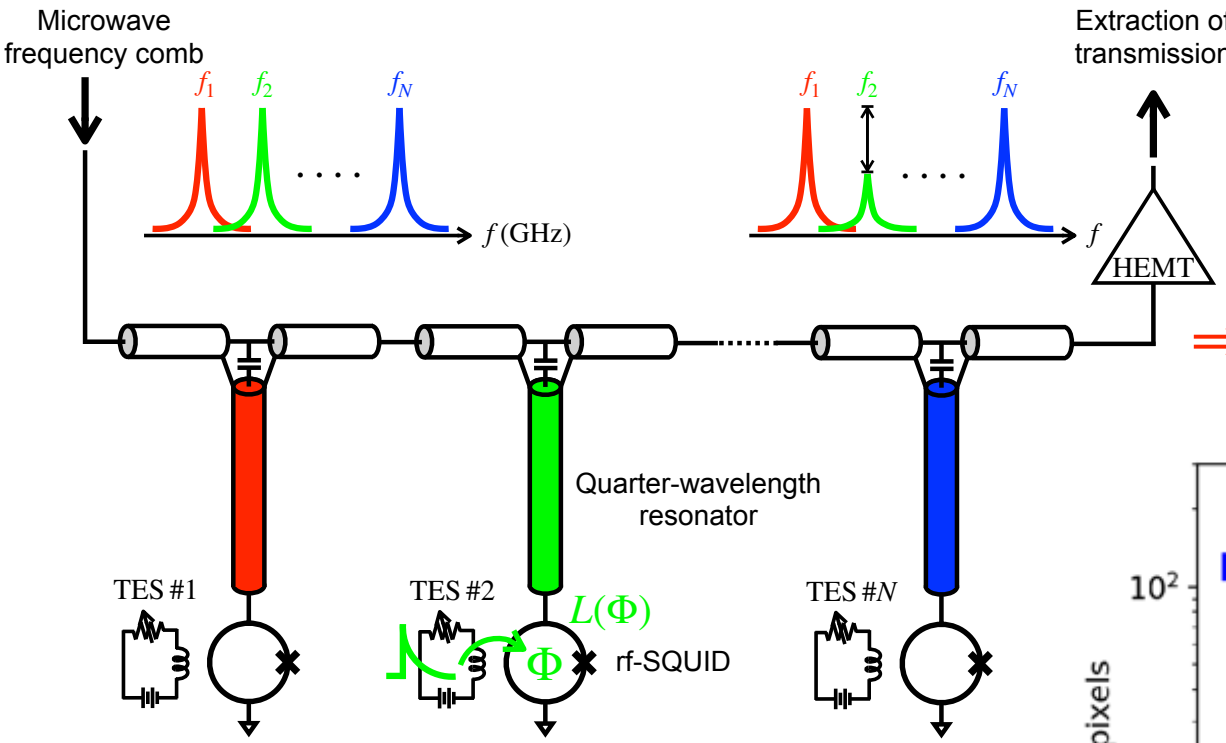
New Test Patterns



Fe57 absorber is offset from TES to avoid direct magnetic field on TES sensor.

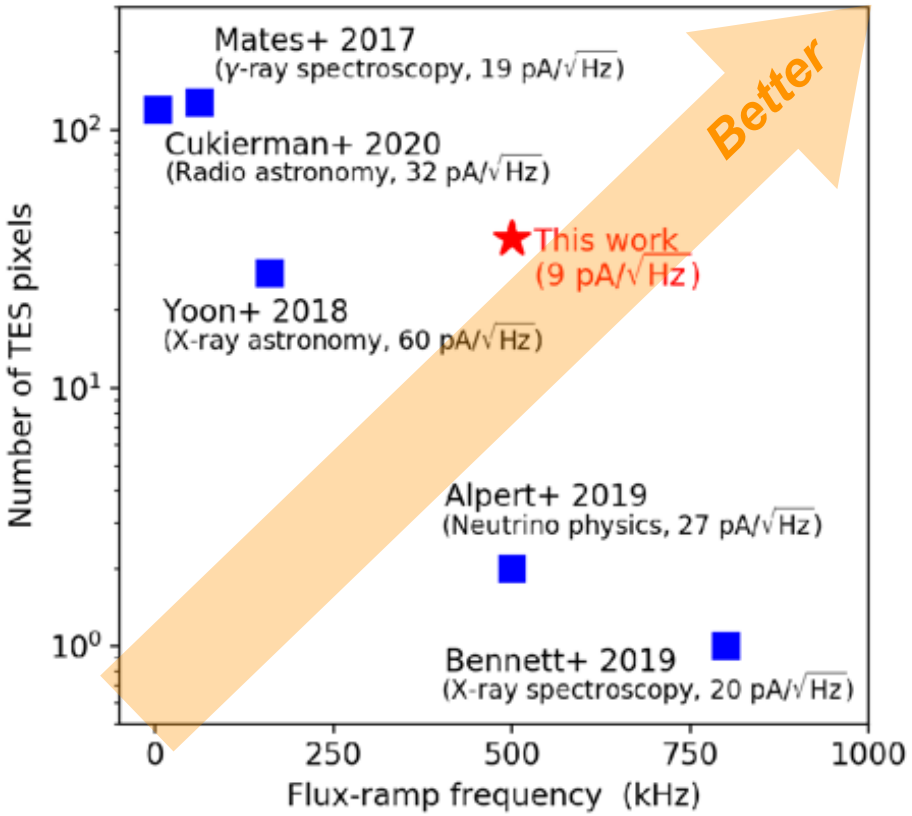
(Details shown by Yagi)

GHz multiplexing



We have succeeded 38 signal readout /channel.

⇒Increasing the No. of pixels
(details by F. Hirayama)



Typical rise time of TES is >μsec.
Current major multiplexing method (TDM/FDM) use ~MHz bandwidth. Microwave technology can expand the array format.

(Nakashima+ 2021)