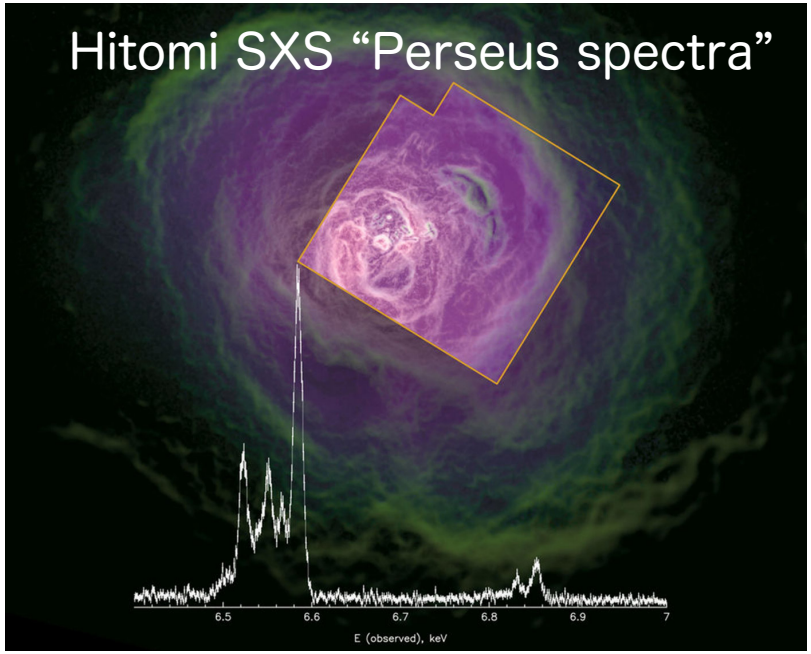
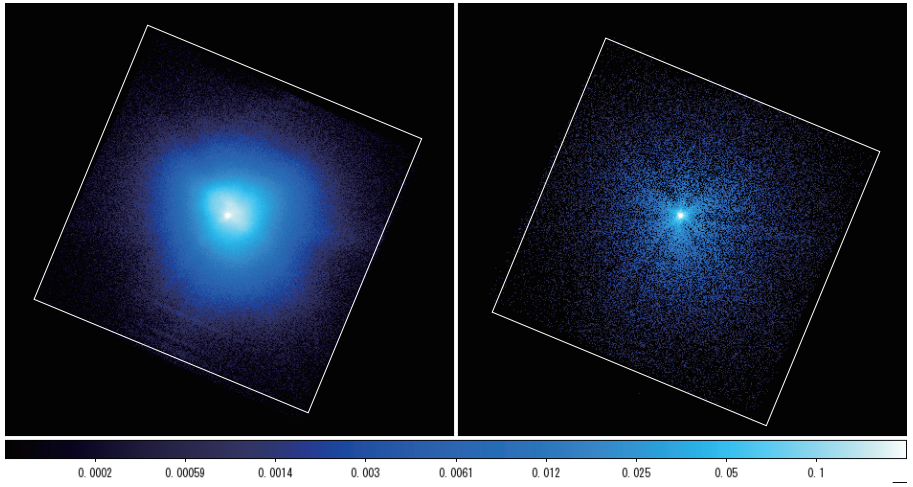
High-resolution X-ray spectroscopy with XARM and future mission candidate FORCE for hard X-ray/wide-band imaging spec.

Kazuhiro Nakazawa
on behalf of the XARM team and the FORCE WG

Vision for XARM and future hard X-ray



Hitomi HXI “Crab image”



- Early recovery of high-resolution X-ray spectroscopy
  → the XARM mission *Talk-1*
- hard X-ray/soft gamma-ray road-map
  - HXI science only partly covered *by NuSTAR*

  →candidate “HXI recovery”: *FORCE* (late 2020 – 2030).
  Hard-band coverage in Athena/Lynx era *Talk-2*
  - SGD science uncovered → under consideration

Talk-1: XARM

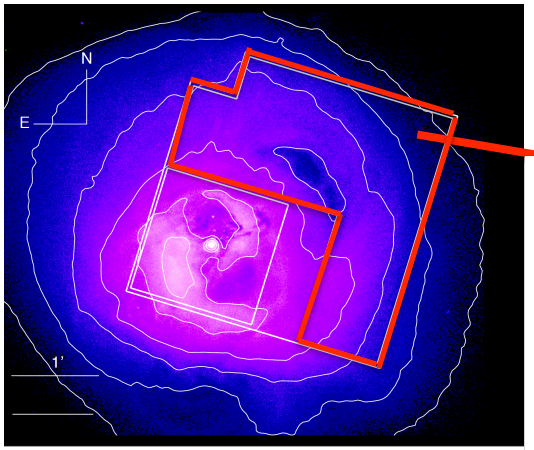
-the X-ray Astronomy Recovery Mission-

The Power of high-resolution X-ray spectroscopy

with 2 month operation.

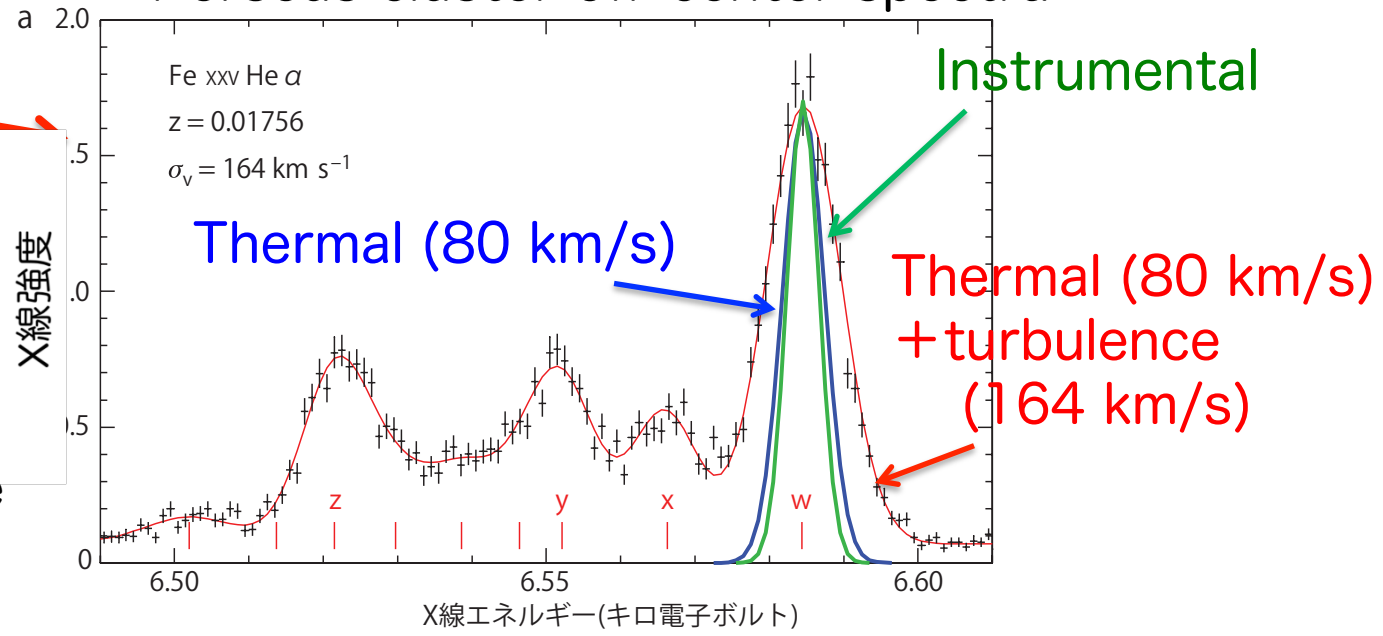
1: The quiescent intracluster medium (*Nature* 2016)

Plasma subsonic kinetic mosion



Chandra X-ray image and Hitomi SXS FoV

Perseus cluster off-center spectra



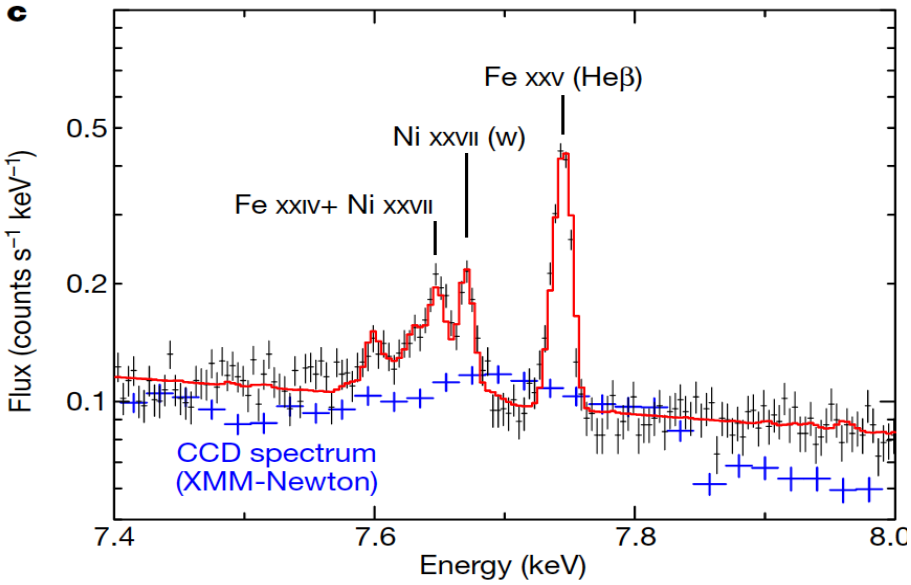
- First clear determination of turbulence motion
- low sub-sonic even in AGN-ICM interaction region

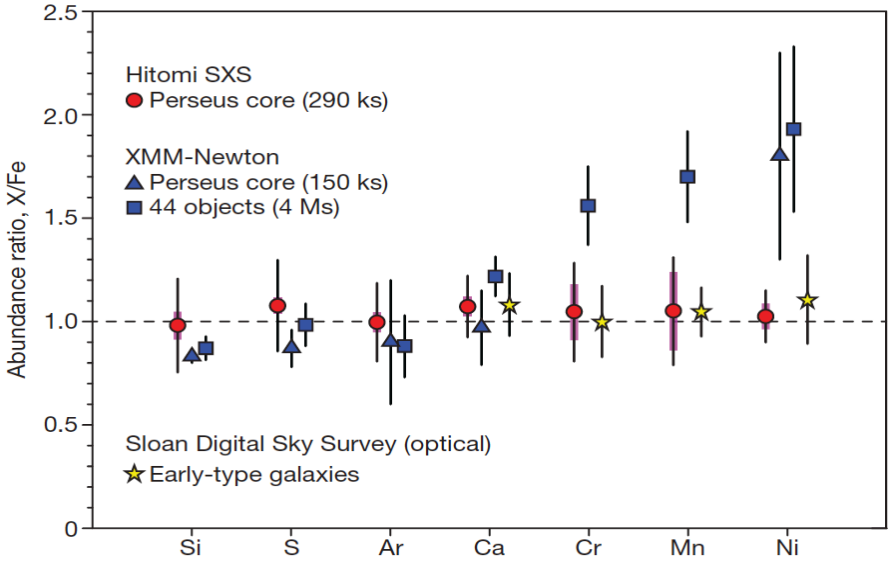
The Power of high-resolution X-ray spectroscopy

2nd nature!!

2: Solving the Ni over-abundance problem (*Nature* 2017)

Metal flourescence line diagnostics





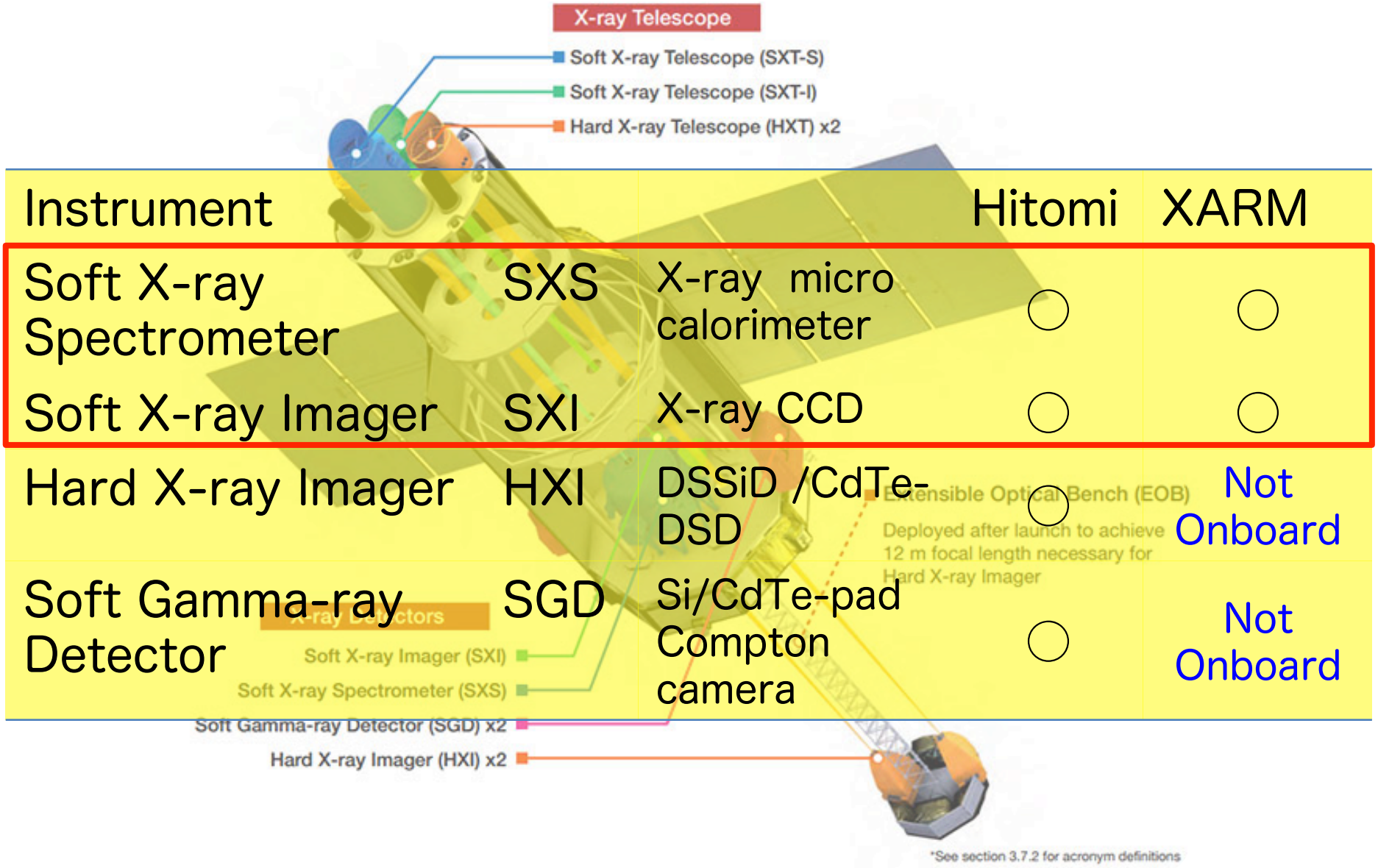
- First resolved the Fe-Kb and Ni-Ka emission
- Cluster Fe-Ni abundance is consistent with Solar

→ Well-averaged metal abundance ratio?

XARM Science Objectives

- **structure formation of the Universe and evolution of clusters of galaxies**
  - thermal, non-thermal and their dissipation mechanisms in clusters of galaxies → how clusters evolve?
- circulation history of baryonic matters in the Universe
  - trace baryon cycles and metak distribution history in the universe → how metals distributed?
- transport and circulation of energy in the Universe
  - reveal matter and energy feedback by galaxies and active galaxies → BH-Gal. co-evolution
- new science with unprecedented high resolution X-ray spectroscopy
  - pioneer new horizon of X-ray astrophysics with plasma diagnostics, graviational-redshift measurement, etc…

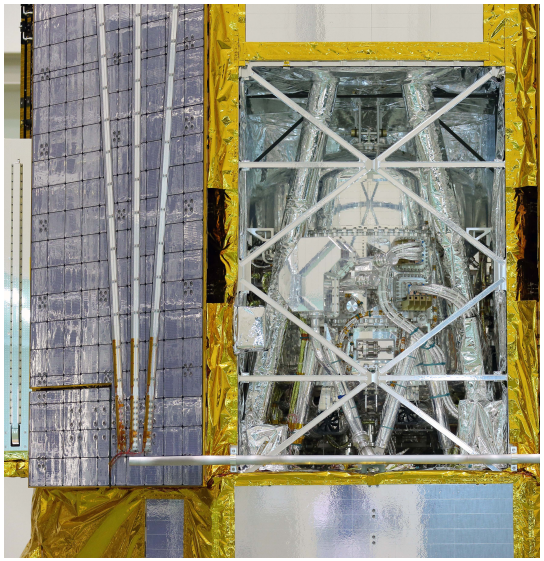
XARM compared with Hitomi

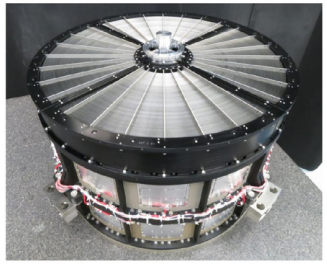


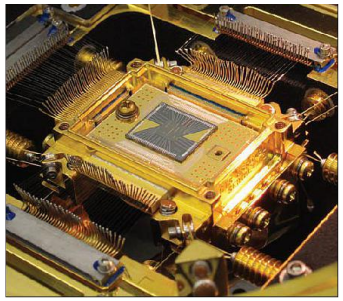
Instrument			Hitomi	XARM
Soft X-ray Spectrometer	SXS	X-ray micro calorimeter	○	○
Soft X-ray Imager	SXI	X-ray CCD	○	○
Hard X-ray Imager	HXI	DSSiD /CdTe-DSD	○	Not Onboard
Soft Gamma-ray Detector	SGD	Si/CdTe-pad Compton camera	○	Not Onboard

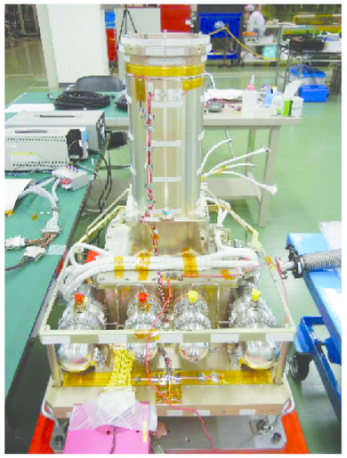
two XARM instruments

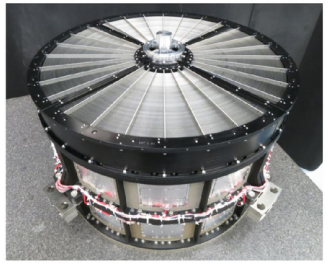
Instrument	FOV/pix	ΔE (FWHM @6 keV)	band
Resolve (XMA + X-ray microcalorimeter)	2.9' □ / 6 x 6 pix	7 eV (goal 5 eV)	0.3 – 12 keV
Xtend (XMA + X-ray CCD)	38' □/ 1280 x 1280 pix	< 250 eV at EOL (< 200 eV at BOL)	0.4 – 13 keV

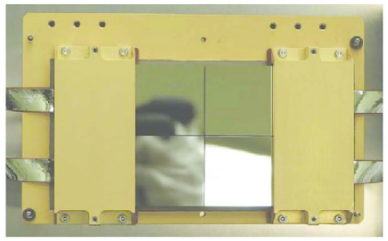












two other sub-teams

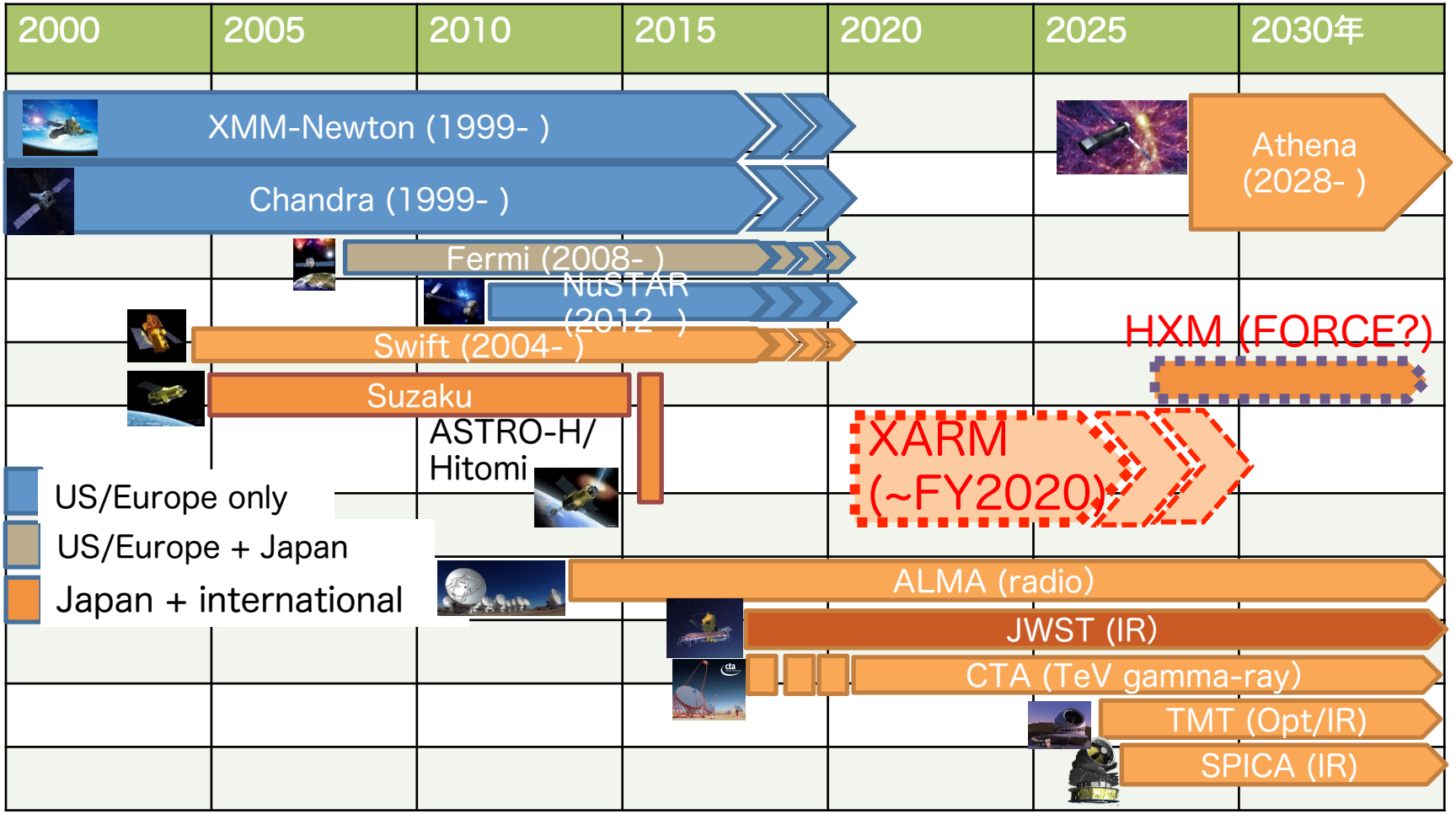
Science Operations Team

Science Management Office

XARM Science Team and Observation program Concept

- Science Team:
  - data-rights to all PV data
  - scientists of the sub-teams + ~dozen "Participating Scientists" by JAXA,NASA,ESA.
- "PV phase collaborating scientists" : *new!*
  - data-rights only to a specified PV targe
  - appointed ~1 year before the launch
- Guest Observer Program:
  - After start-up & PV phase, Guest Observation program starts

XARM Time Frame



Status

The XARM team (now ~100 members from JP+US+ESA)

PM: H. Maejima, PE: K. Toda (JAXA), PI: M. Tashiro (Saitama U./JAXA),
NASA PM: L. Reichenthal, SE: J. Lobell, co-PI: R. Kelley (NASA)
Resolve (Calorimeter): R. Kelley (NASA) + Y. Ishisaki (TMU)
Xtend (CCD): K. Hayashida (Osaka)
Science Operation Team: Y. Terada (Saitama)
Science Team Lead: to be appointed soon

Integrated team of
engineer
sicentists

Key Mile stones / Schedule

- ✓ 2016/10 Preparation-team stand up
- ✓ 2017/4 Mission Definition Review/System Requirement Review
- ✓ 2017/11 Pre-Project start
- ✓ 2017/11 Critical Design Review at NASA for *Resolve*
- ✓ ~2018/4 (planned) Project start
- ✓ ~FY2020 (planned) Launch

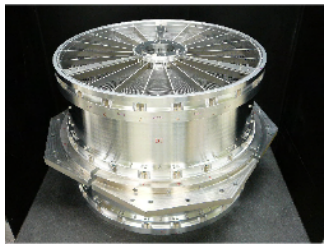
Project now actively ongoing to recover high-resolution X-ray spectroscopy

Talk-2

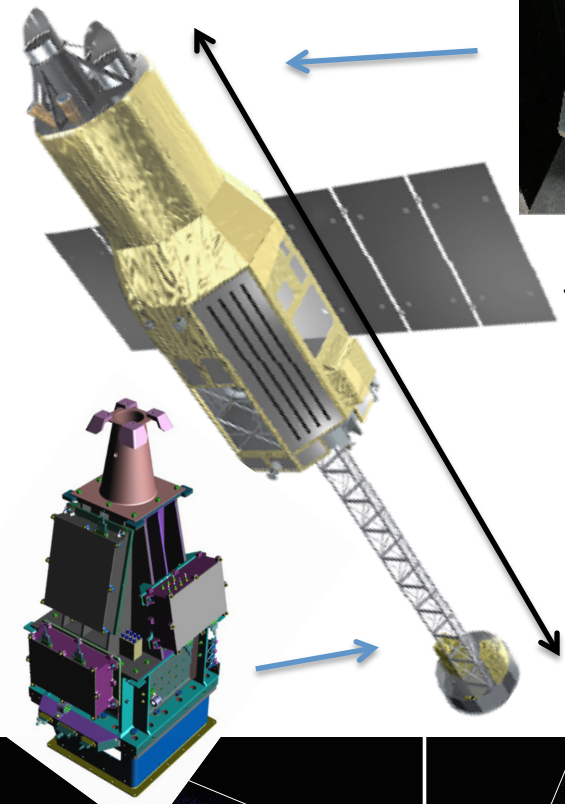
the FORCE mission proposal

- Focusing On Relativistic universe and Cosmic Evolution -

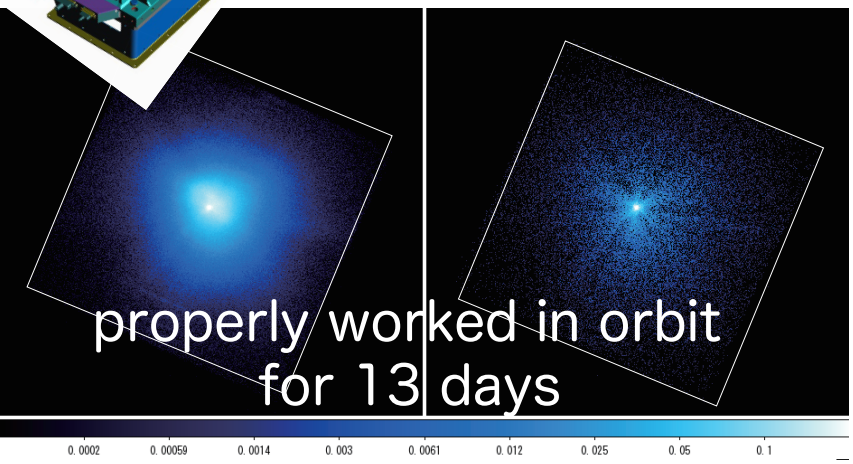
The power of Hitomi Hard X-ray Imager

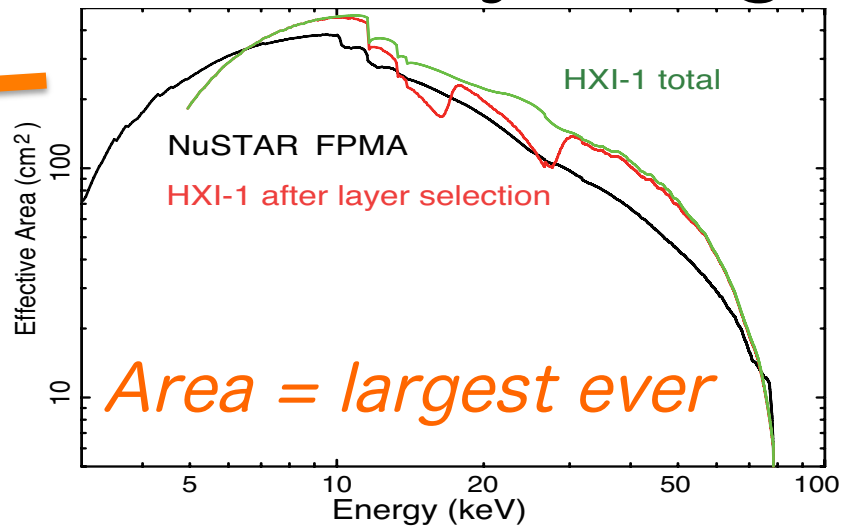


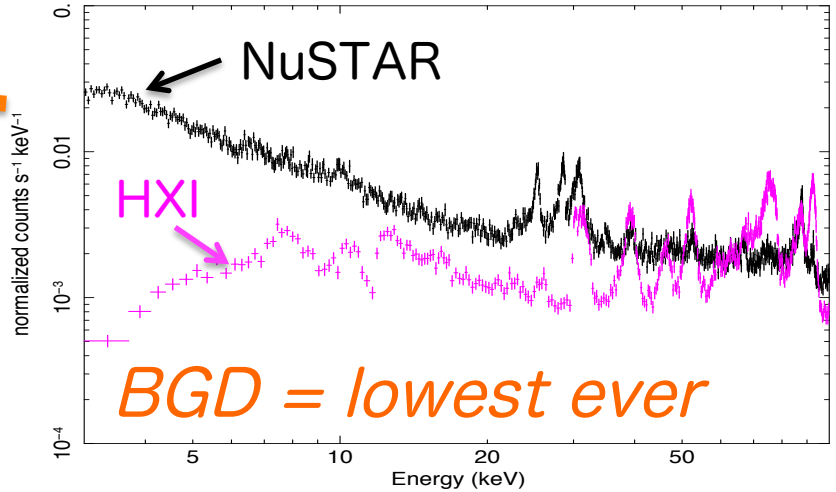
Hard X-ray Telescope



Hard X-ray Imager



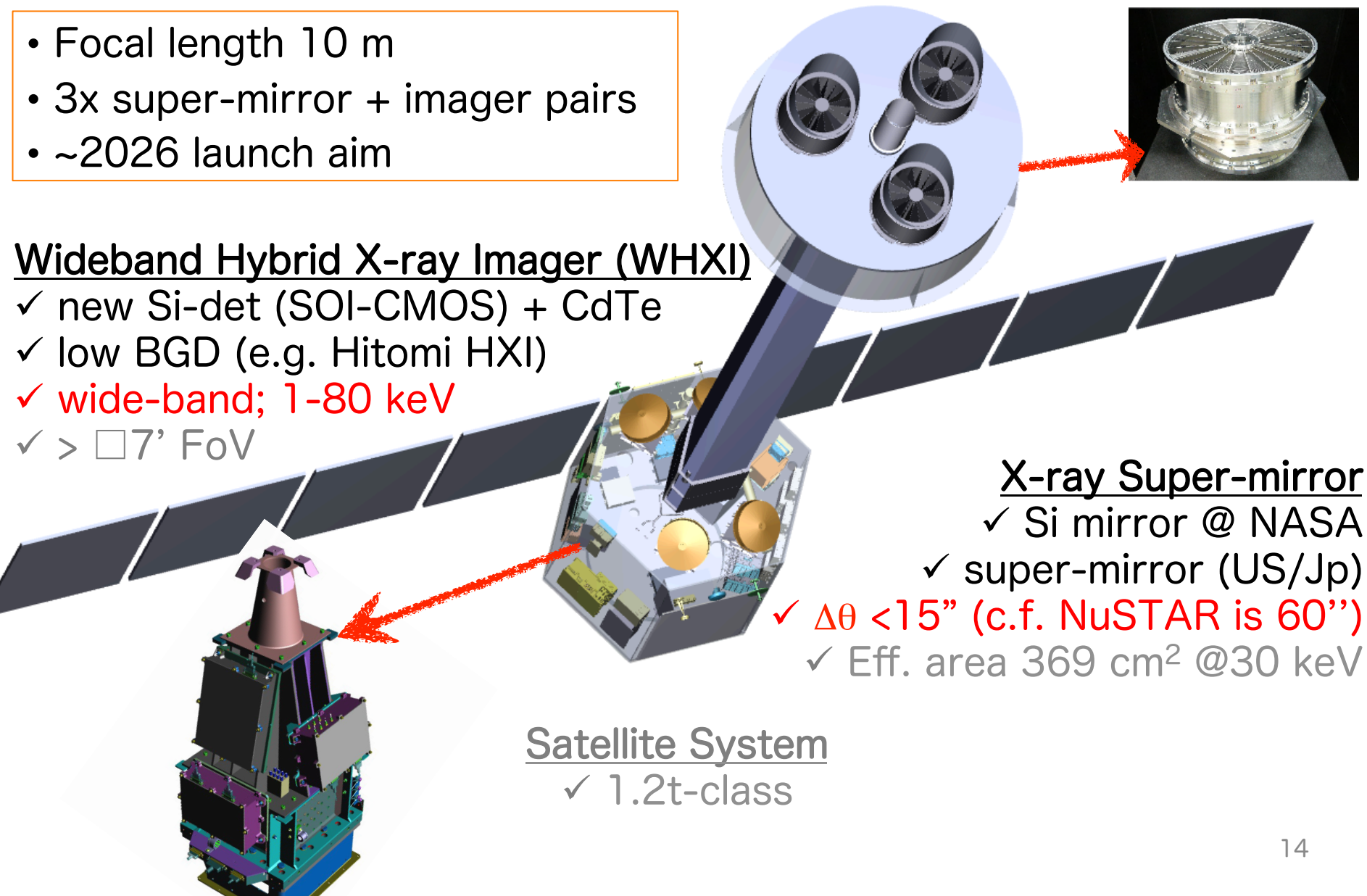




x4-5 better sensitivitiy than NuSTAR for extended sources

FORCE Conceptual Design

- Focal length 10 m
- 3x super-mirror + imager pairs
- ~2026 launch aim

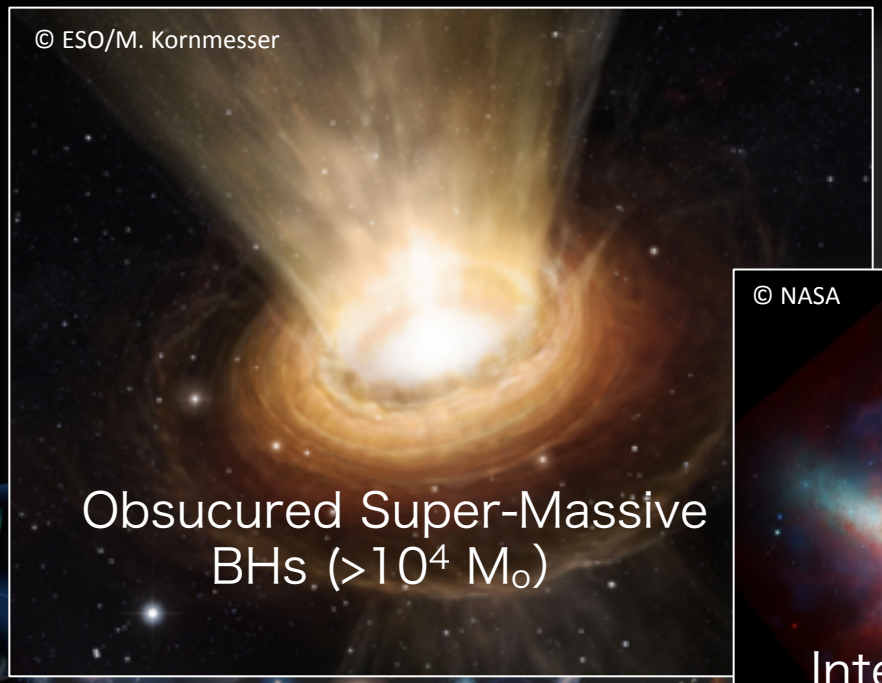


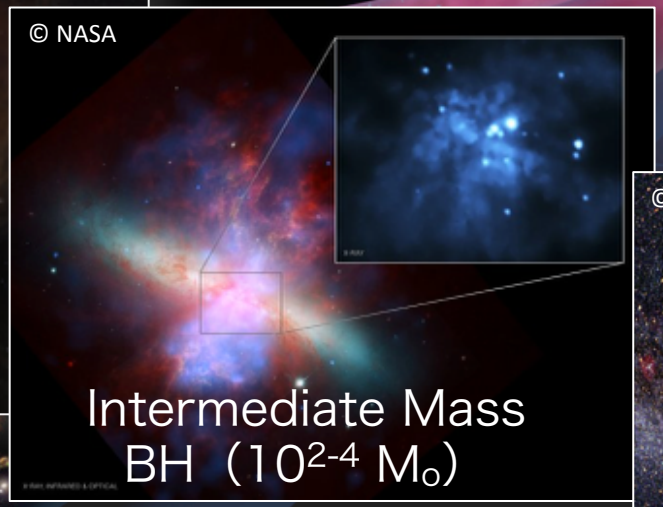
Wideband Hybrid X-ray Imager (WHXI)
✓ new Si-det (SOI-CMOS) + CdTe
✓ low BGD (e.g. Hitomi HXI)
✓ wide-band; 1-80 keV
✓ > □7' FoV

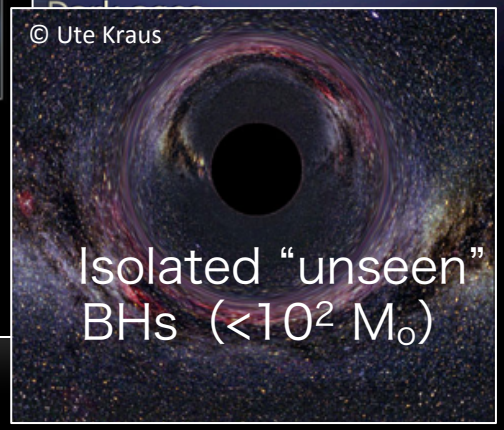
X-ray Super-mirror
✓ Si mirror @ NASA
✓ super-mirror (US/Jp)
✓ $\Delta\theta$ <15" (c.f. NuSTAR is 60'')
✓ Eff. area 369 cm^2 @30 keV

Satellite System
✓ 1.2t-class

Main Science Objective







Big Bang

Afterglow light pattern

Recombination

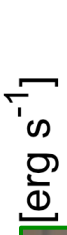
Resolving the number of "Missing BHs",

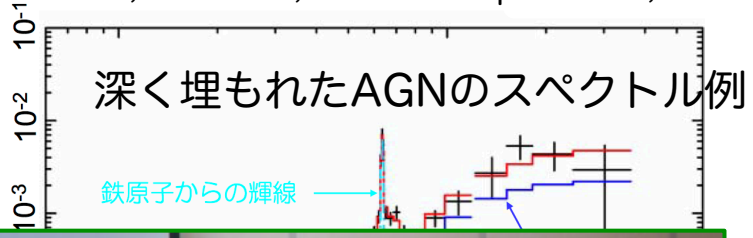
to understand the cosmoligical evolution history of stars, galaxies and clusters.

Importance of 1-80 keV band

- Hard X-rays see “true AGN Luminosity”, apart from SF
- Complementary to IR + ALMA survey

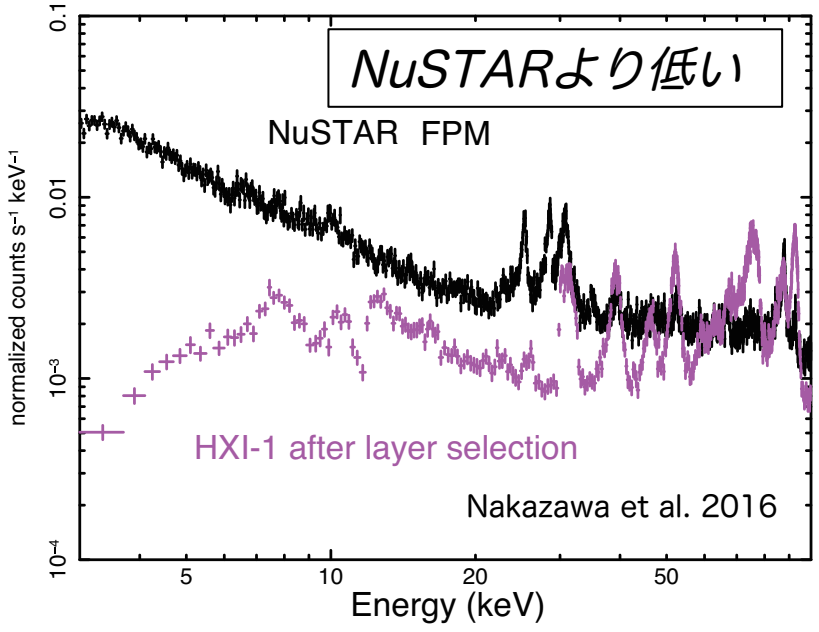
Kawamuro, Ueda+16, Perez-Beaupuits+ 11, etc…

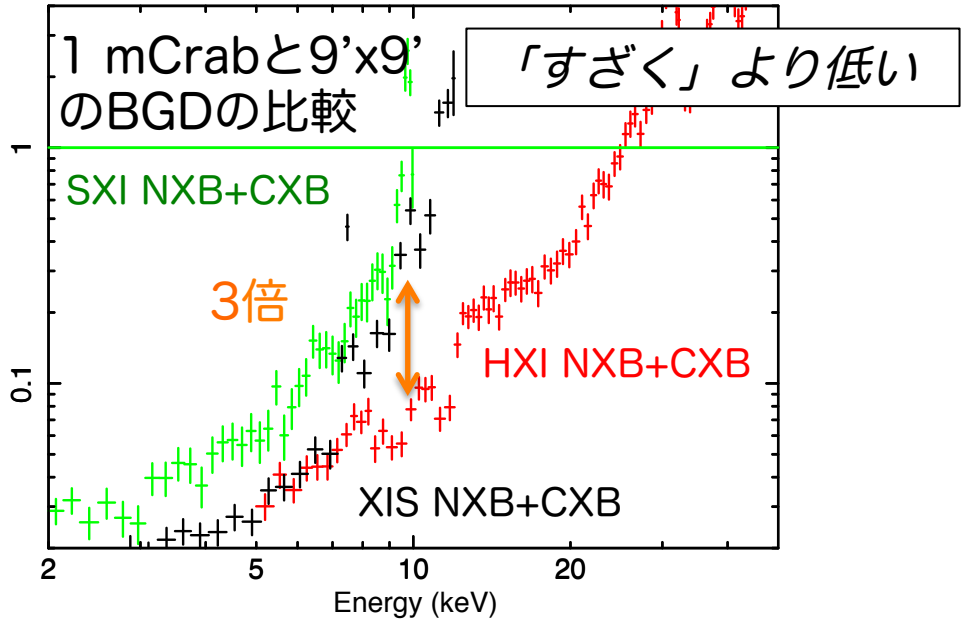




Ovservatory Science : e.g. Diffuse

The lowest BGD of Hitomo HXI can be “halved” @ 10 keV
→ FORCE cab be ideal for “extended hard X-ray source”

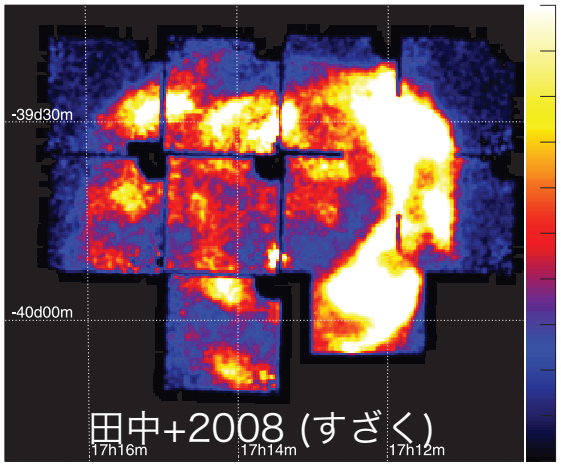




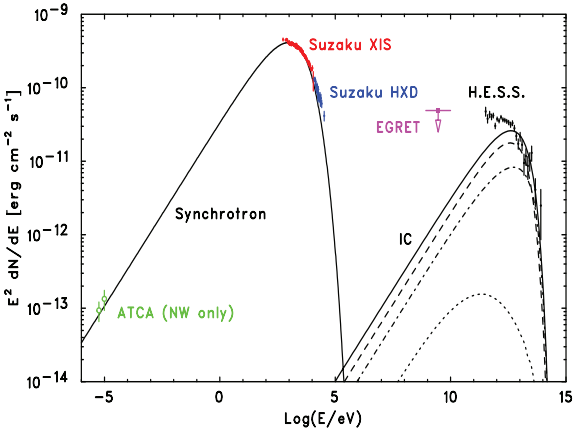
Ovservatory Science : e.g. Diffuse

The lowest BGD of Hitomo HXI can be “halved” @ 10 keV
→ FORCE cab be ideal for “extended hard X-ray source”

Particle Accelleration in SNR

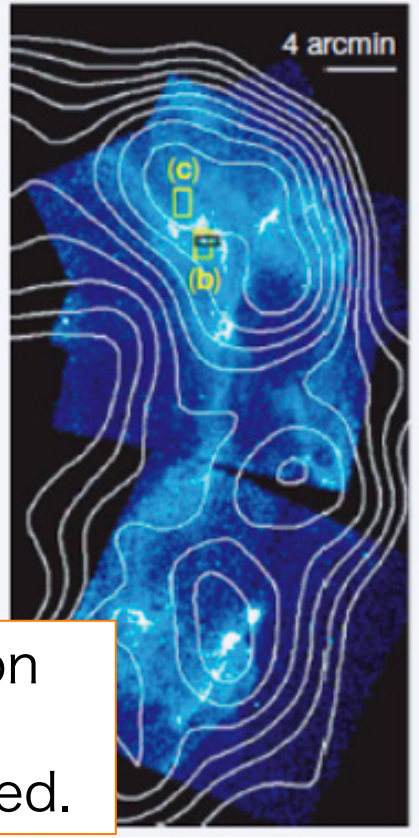


1. Cutoff of synchrotron emission cooling? escaping? aging?
2. Local B amplification, with good resolution imaging



New science field, in collaboration with radio, IR-optical, gamma, neutrino, and GW shall be persued.

内山+2007

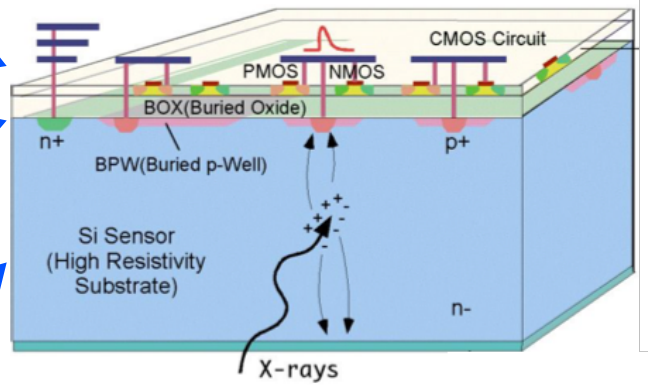


Improved performance of SOIPIX

CMOS (low ρ Si)

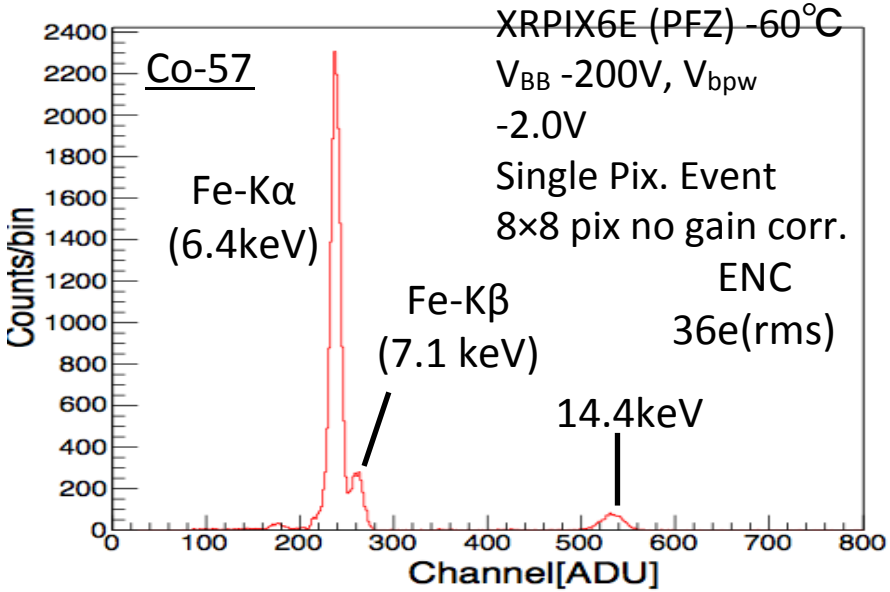
Insulator (SiO2)

Sensor (high ρ Si)



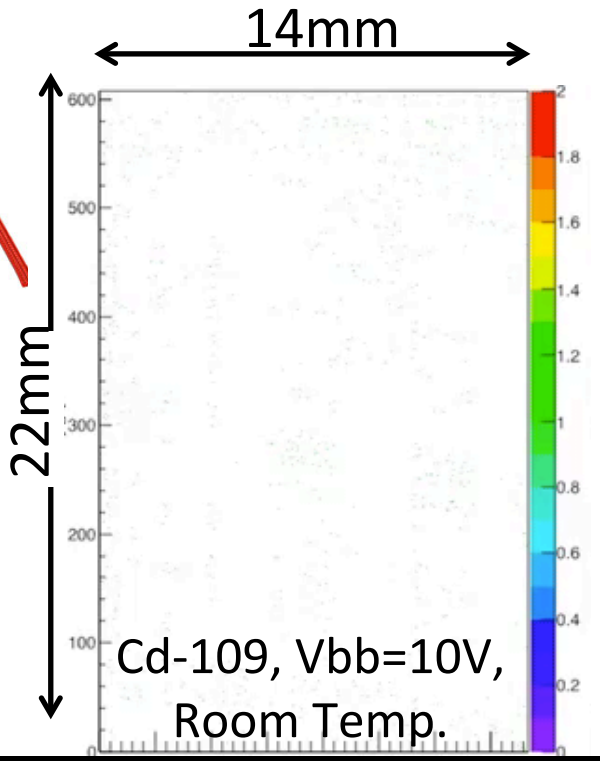
- Each pixel has its own trigger and analogue readout.
- Time resolution ~1 μsec and through-put >1kHz (e.g. anti-coincidence for low BGD)
- BI with depletion >200 μm

Event-Driven readout mode



Fe-Kα, Kβ are resolved

Tsuru et al.



Event rate > 500Hz is Confirmed

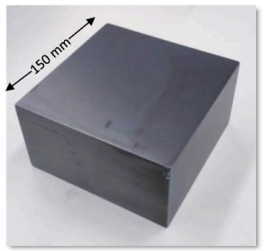
Initial results from Si-mirror (NASA)

Riveros et al. 2014,15,16,17

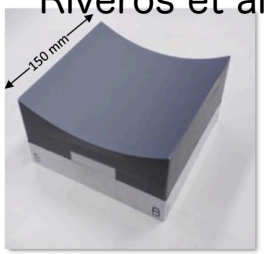
Key technology

- Si optics (NASA/GSFC PI. W. Zhang) + multi-layer (Jp/US)
- Si optics 1-pair w/o multi-layer →

  $\Delta\theta$ = 3''.4 HPD is demonstrated.
- Tests with multi-layer on-going

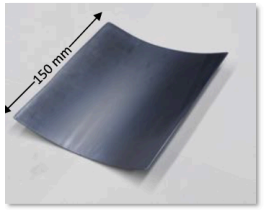


Monocrystalline silicon block

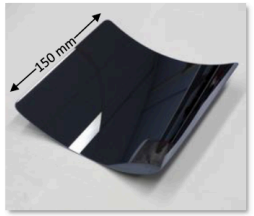


Conical form generated

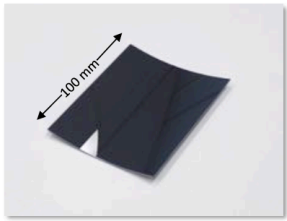
Light-weighted substrate



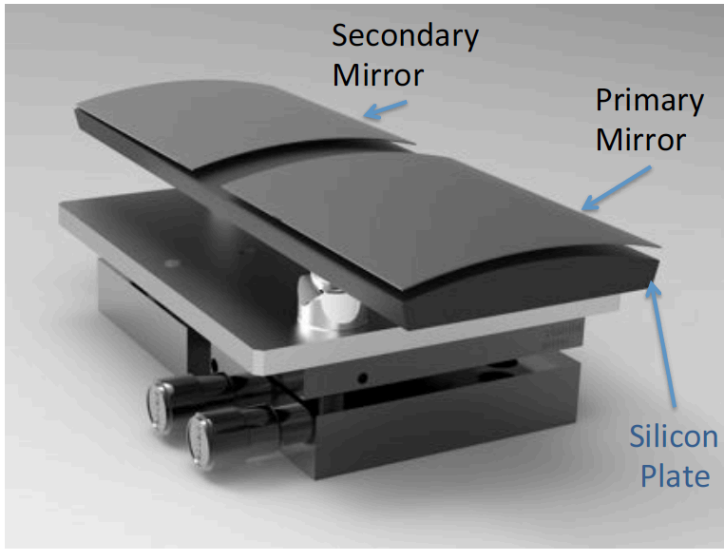
Etched substrate



Polished mirror substrate

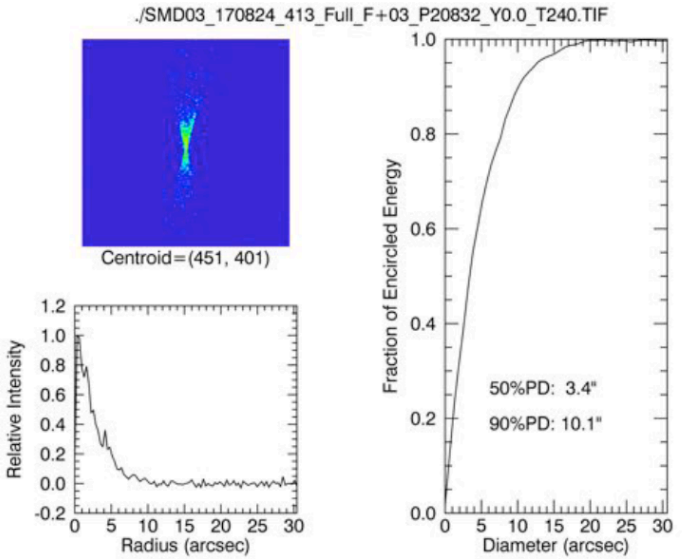


Trimmed mirror substrate



Two uncoated mono-crystalline silicon mirrors aligned and bonded on a silicon platform

Chan et al. 2017



Full illumination with Ti-K X-rays (4.5 keV)

Summary

- FORCE mission is a candidate hard X-ray/wide band (1-80 keV) probe with 10”-15” mirror
- Main goal is to count the numbers of “mission BHs”, SMBH, IMBH, and isolated-Stellar Mass BH
- Also with its very low BGD, a good hard X-ray (8-20 keV) diffuse source observation can be done
- Aiming at 2026 launch, preparation is actively on-going.

【参考1】

スケジュール案

	AO	締切	審査	Phase A1	年数	打上	備考
小型4	2018.8	2018.11	2019.2	1	5	2025.3	
（小型5）	2018.8	2018.11	2019.2	2.5	5.5	2027.3	
小型5	2020.2	2020.5	2020.8	1	5.5	2027.3	