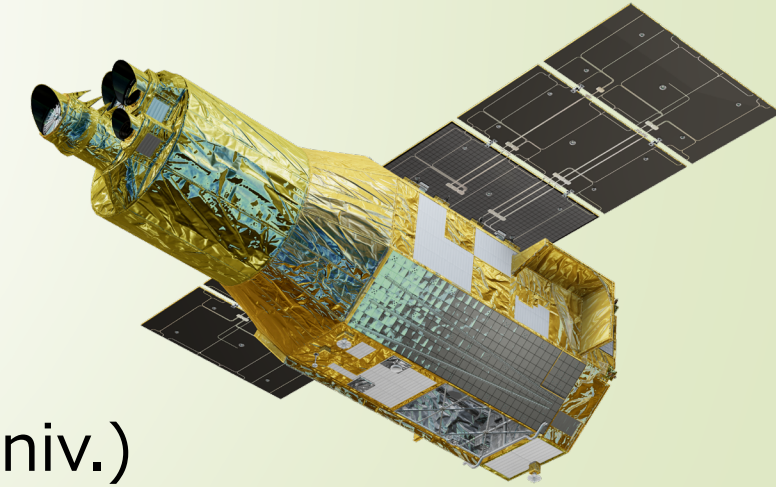
Current status and expectations for XRISM



Yutaka Fujita (Tokyo Metro. Univ.)
XRISM Project
Science Management Office

XRISM collaboration

XRISM Team Meeting (Mar. 2024 @Tokyo University of Science)

133 Science Members + 39 XRISM Guest Scientist + 27 PD + 79 Students (Feb 2024)
+ Engineers/Developers + External Science Advisory Panel

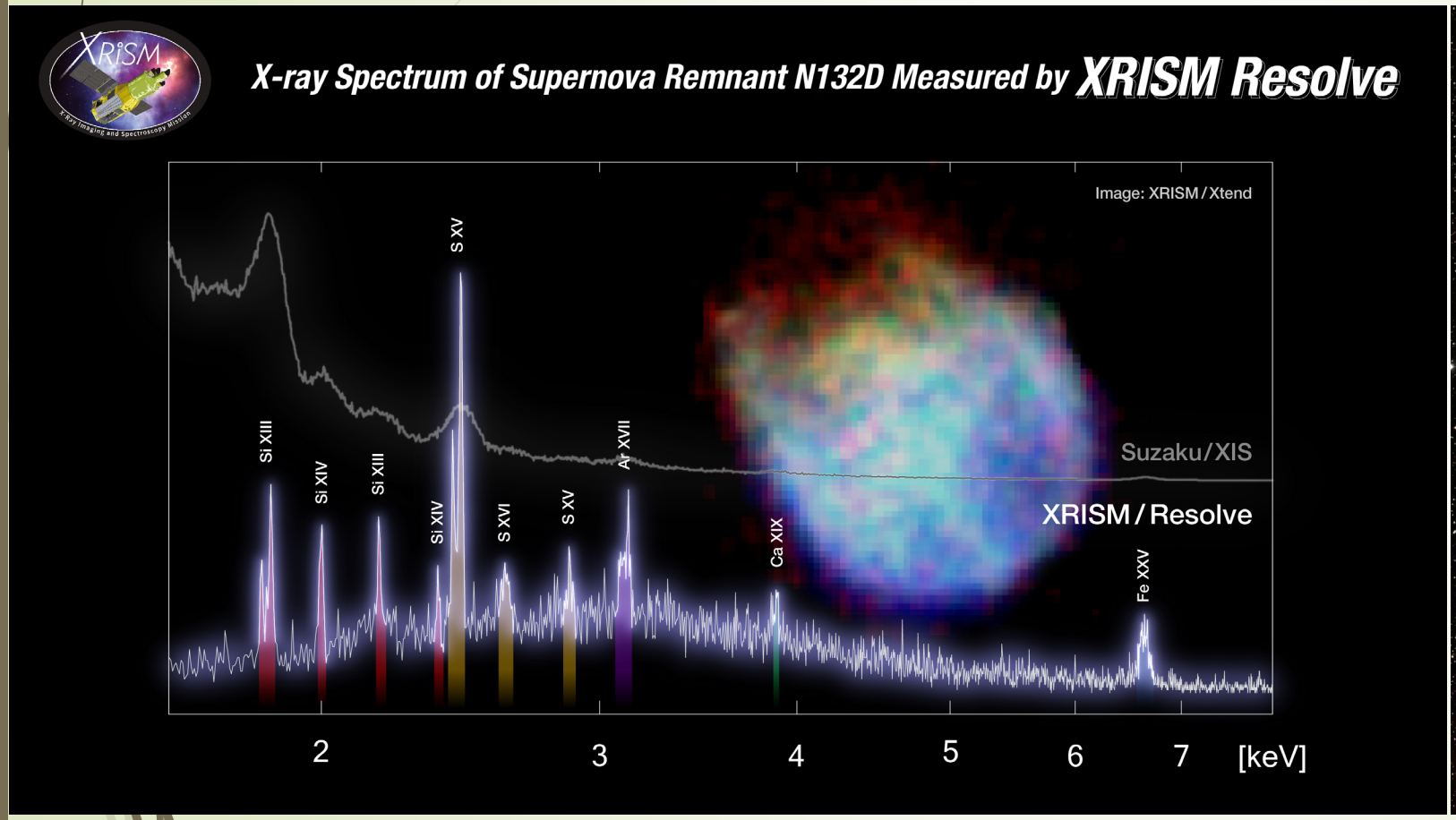
Talk Plan

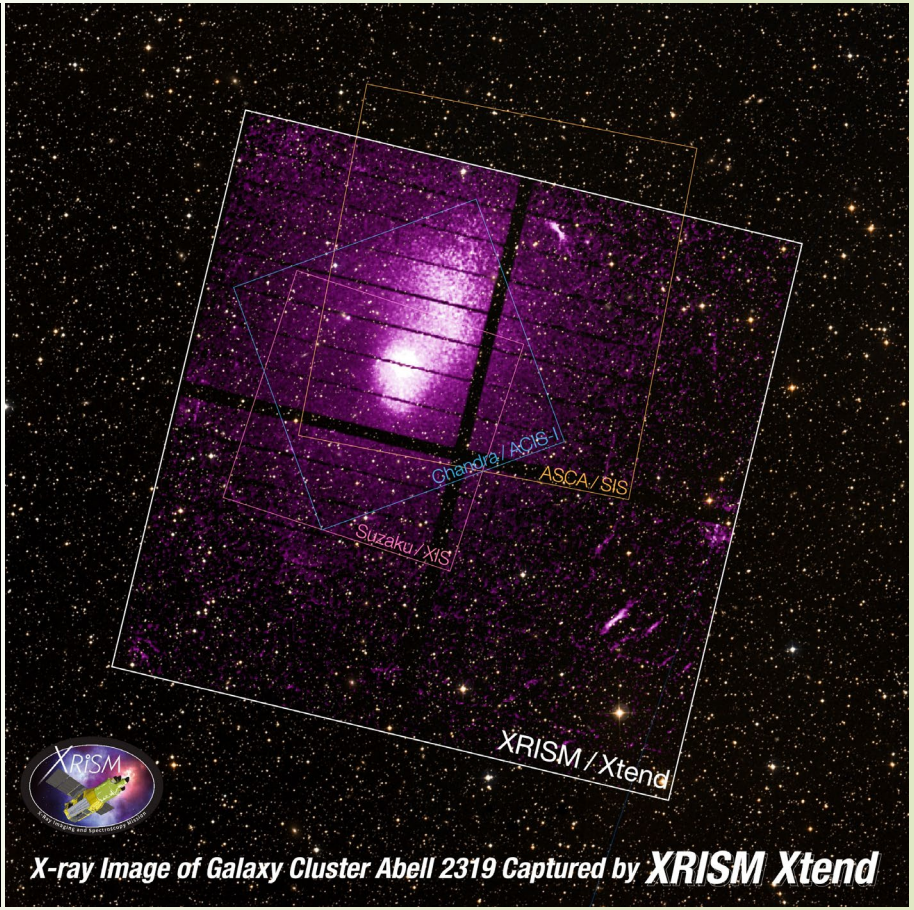
1. Introduction – the XRISM mission –
2. Mission status from Ground to the First Light
3. Collaboration with XRISM - GO program –
4. Examples of expected results

1. Introduction – the XRISM mission –

1.1 Latest figures of XRISM

2024.1.5 XRISM First Light

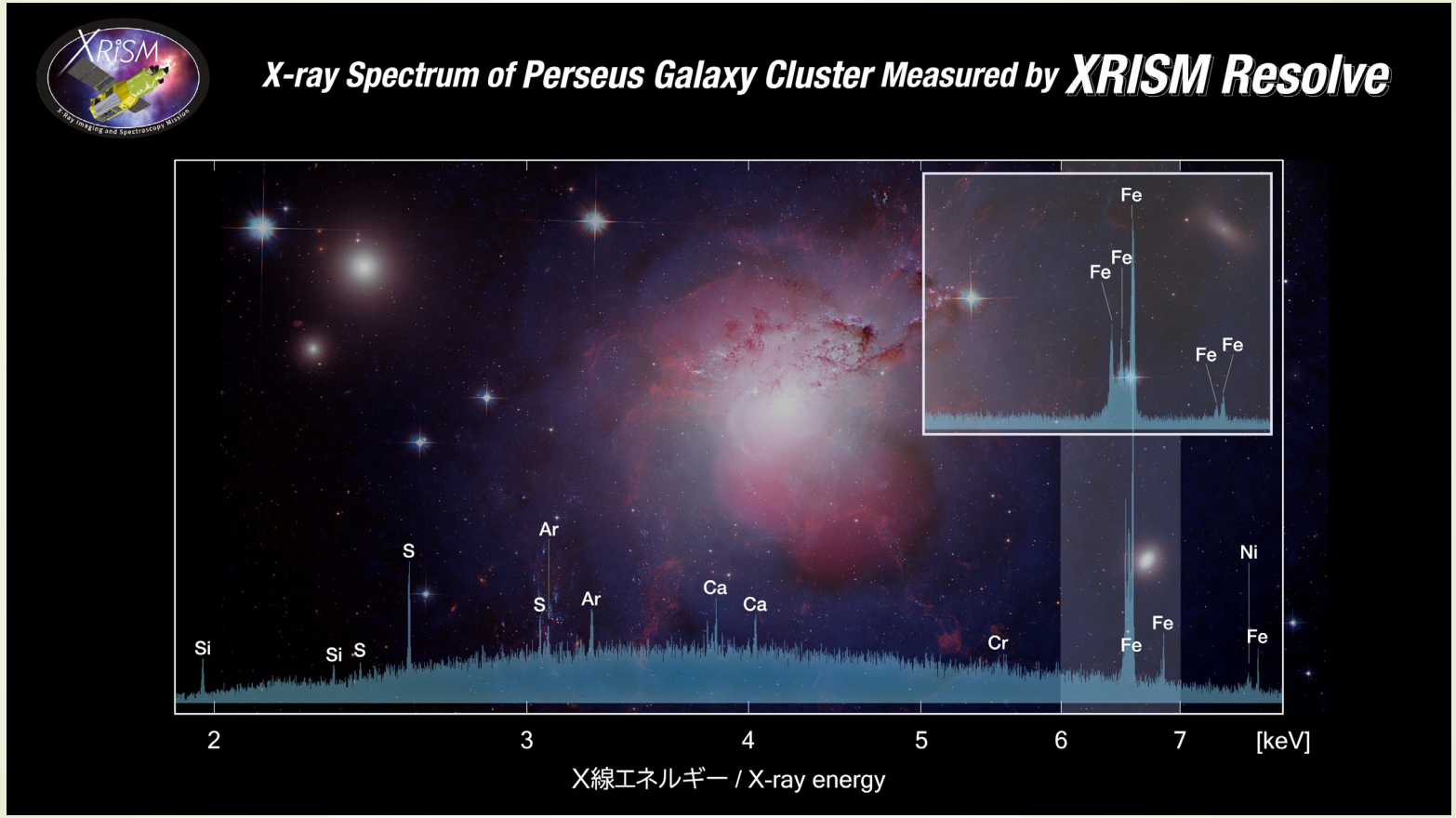




X-ray Imaging and Spectroscopy Mission
with high energy resolution and large Field of View

1.1 **Latest** figure of XRISM

2024.3.4 XRISM Early Release Data



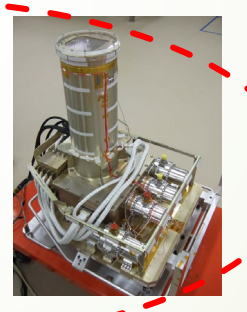
Consistent with Hitomi results

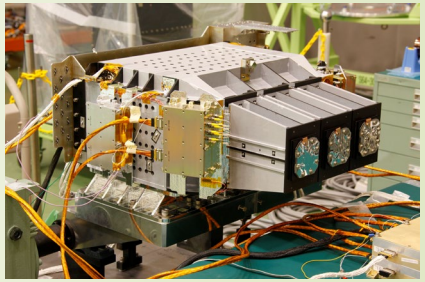
1.2 XRISM Science instruments and Spec

Recovery mission of Hitomi/ASTRO-H

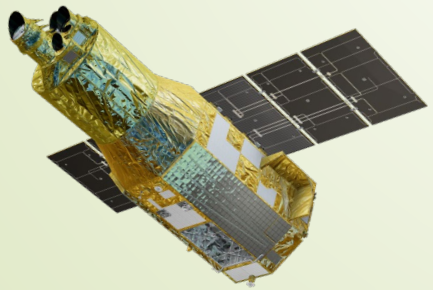
Hitomi Satellite (2016)

- Soft X-ray spectroscopy with high energy resolution (X-ray micro calorimeter)
- Soft X-ray Imaging (X-ray CCD)
- Hard X-ray Imaging (DSSD+CdTe)
- Soft Gamma-ray spectroscopy with high sensitivity (Si+CdTe)



XRISM Science Instruments



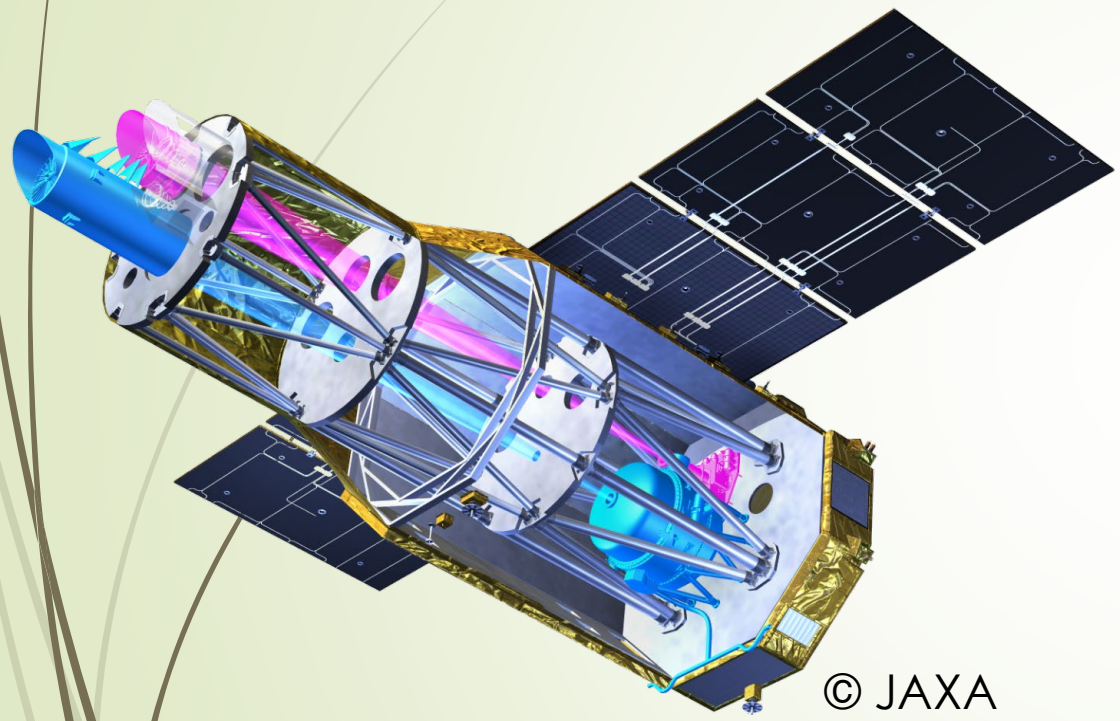
XRISM (2023-)

- X-ray micro calorimeter (Resolve)
- X-ray CCD camera (Xtend)

Quick recovery of soft X-ray spectroscopy

1.2 XRISM Science instruments and Spec (cont.)

Resolve and Xtend



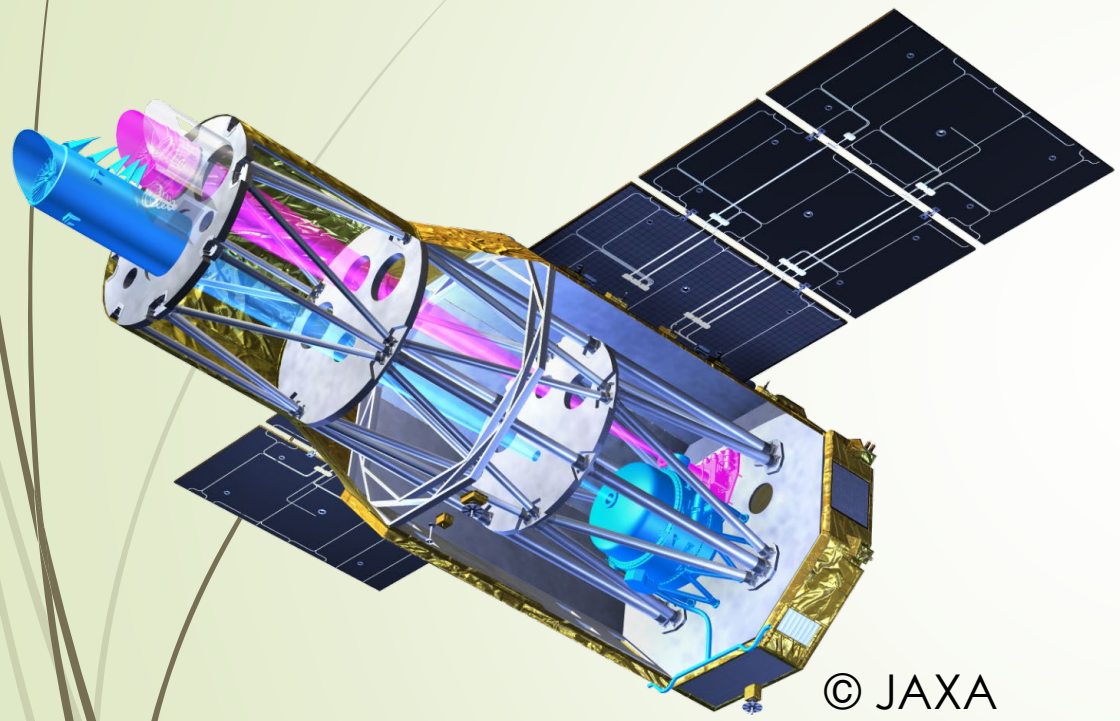
© JAXA

Parameters	Resolve	Xtend
X-ray Mirrors	Walter I optics	
Focal Length	5.6 m	
Angular Resolution	≤ 1.7 arcmin (HPD)	
Detector Technology	X-ray micro calorimeter	X-ray CCD
Effective Area	≥ 220 cm^2 @ 6 keV ≥ 160 cm^2 @1 jeV	≥ 300 cm^2 @ 6 keV
Field of View	≥ 2.9 × 2.9 $arcmin^2$	≥ 30 × 30 $arcmin^2$
Energy Range	0.3 – 12 keV	0.4 – 12 keV
Absolute Energy Scale	≤ 2 eV	-
Energy Resolution	≤ 7 eV FWHM @ 6 keV	≤ 250 eV @ 6 keV, EOL
Non-X-ray Background	≤ 2 × 10^{-3} c/s/keV/array	≤ 1 × 10^{-4} c/s/keV/$arcmin^2$ in 5-10 keV
Absolute Timing Accuracy	≤ 1 ms	-

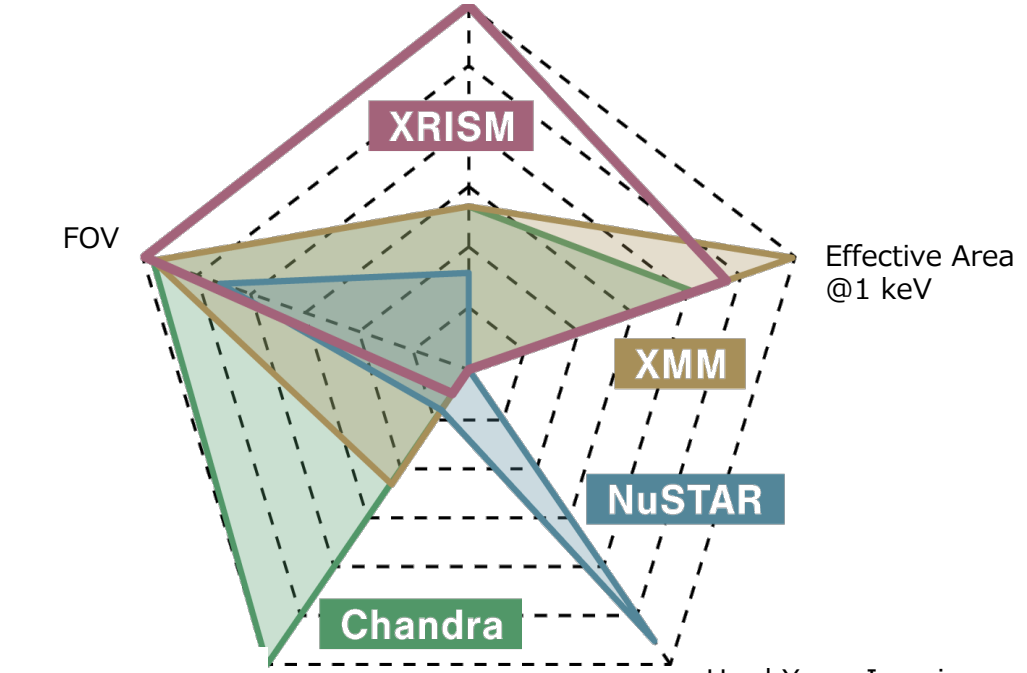
High-energy-resolution spectroscopy & large FOV imaging in keV band

1.2 XRISM Science instruments and Spec (cont.)

Resolve and Xtend



© JAXA



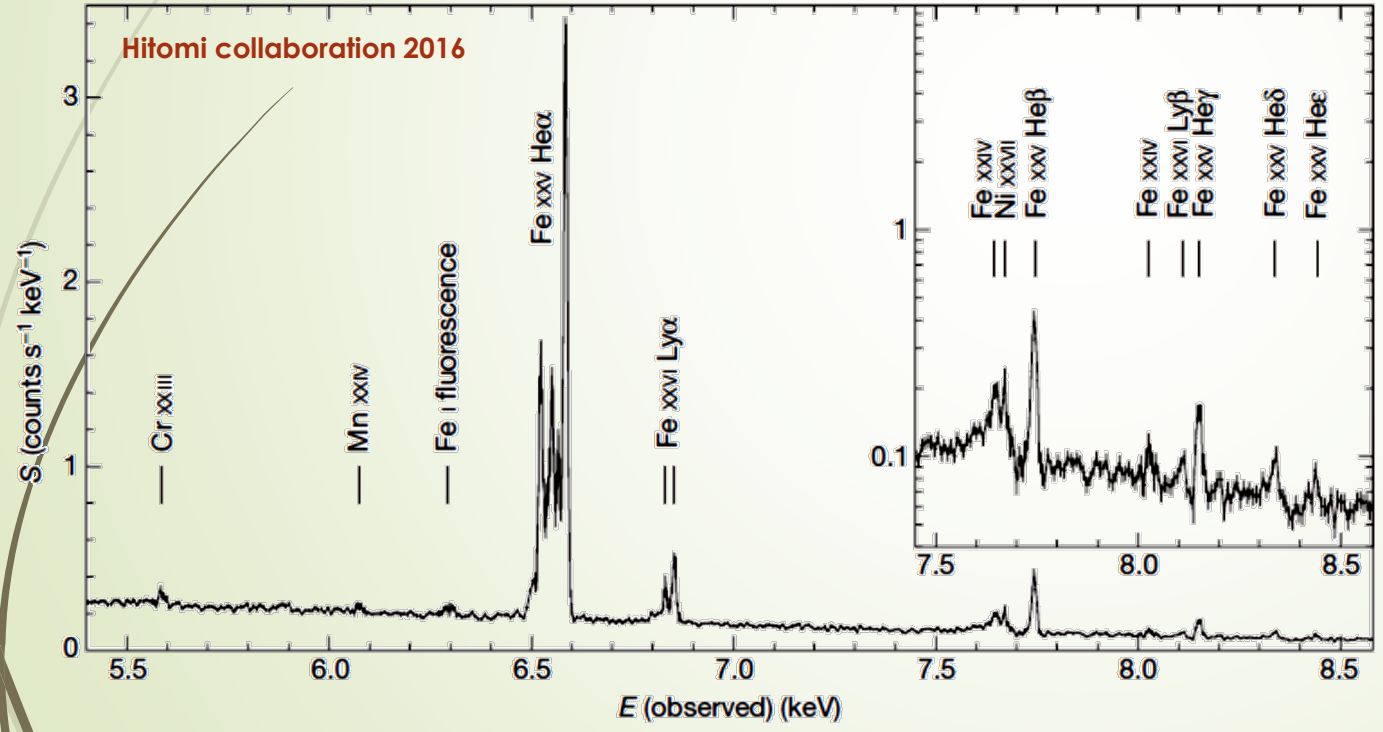
High-energy-resolution spectroscopy & large FOV imaging in keV band

1.3 What can XRISM measure ?

Three Points

1. Plasma condition and motion using X-ray lines

- High-energy-resolution X-ray spectroscopy
  → Hot plasmas in the universe (CIE plasma, PI plasma, etc)



Fe K lines from Perseus Cluster (Hitomi collaboration 2016)

- From line Intensities
  - ✓ Ion abundance
  - ✓ Plasma temperature
  - ✓ Plasma density
  - ✓ Ionization state
  - → so called, "plasma diagnostics"

- From line center & width
  - ✓ Doppler shift (red or blue)
  - ✓ Doppler broadening (random)
  - → Plasma bulk/random motion with > a few tens km/s

1.3 What XRISM can measure ? (cont.)

Three Points

1. Plasma condition and motion using X-ray lines (cont.)

- XRISM can distinguish **the satellite lines**.

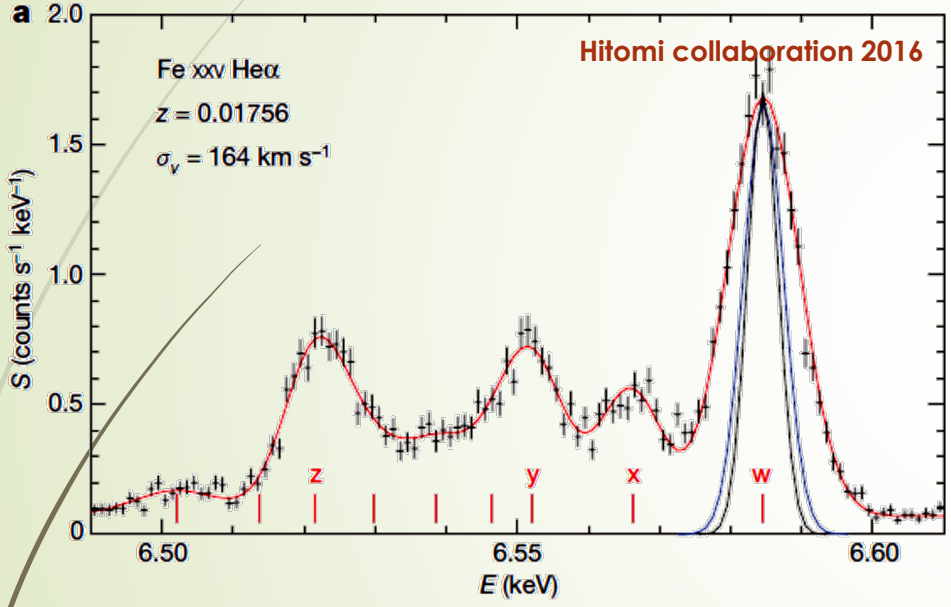
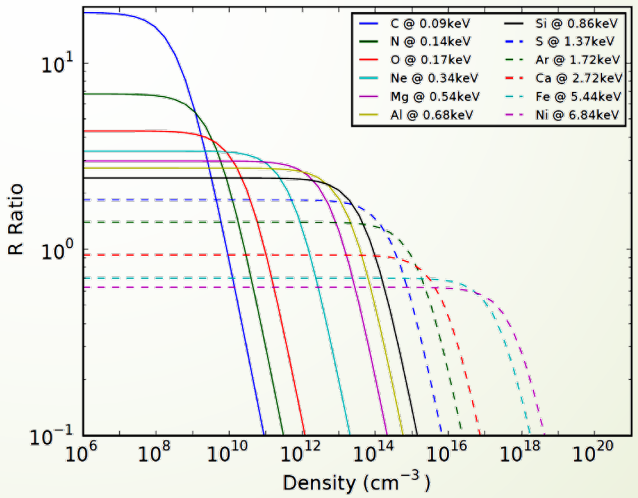


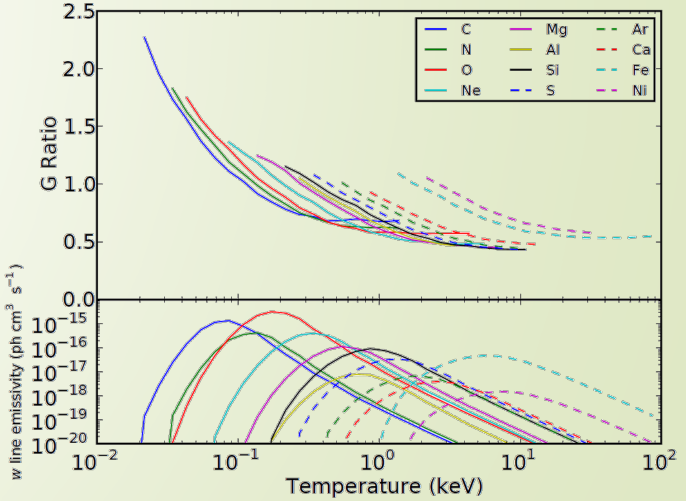
Figure 2 | Spectra of Fe xxv Heα, Fe xxvi Lyα and Fe xxv Heβ from the outer region. a–c, Gaussians (red curves) were fitted to lines with energies (marked by short red lines) from laboratory measurements in the case of He-like Fe xxv (a, c) and from theory in the case of Fe xxvi Lyα (b; see Extended Data Table 1 for details) with the same velocity dispersion (σ_v = 164 km s^{-1}), except for the Fe xxv Heα resonant line,

→ R ratio and G ratio have dependencies on the plasma density and temperature, respectively.

$$R = z/(x+y)$$



$$G = (x+y+z)/w$$



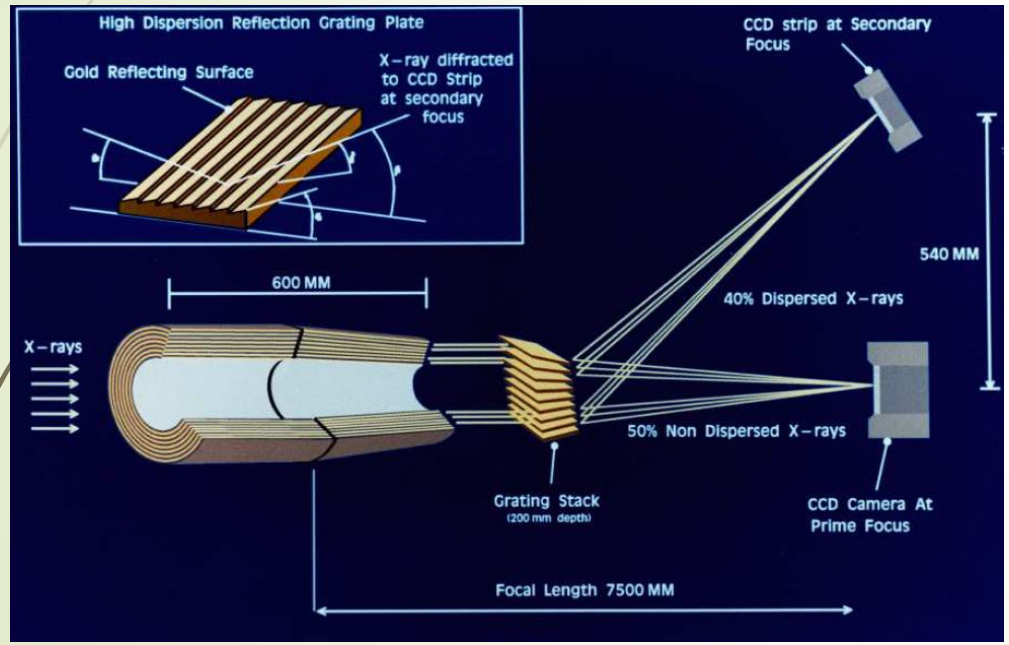
- XRISM can search for Charge Exchange lines.
  - Science Objectives: Ionization of neutral gas by Cosmic-rays etc.

1.3 What XRISM can measure ? (cont.)

Three Points

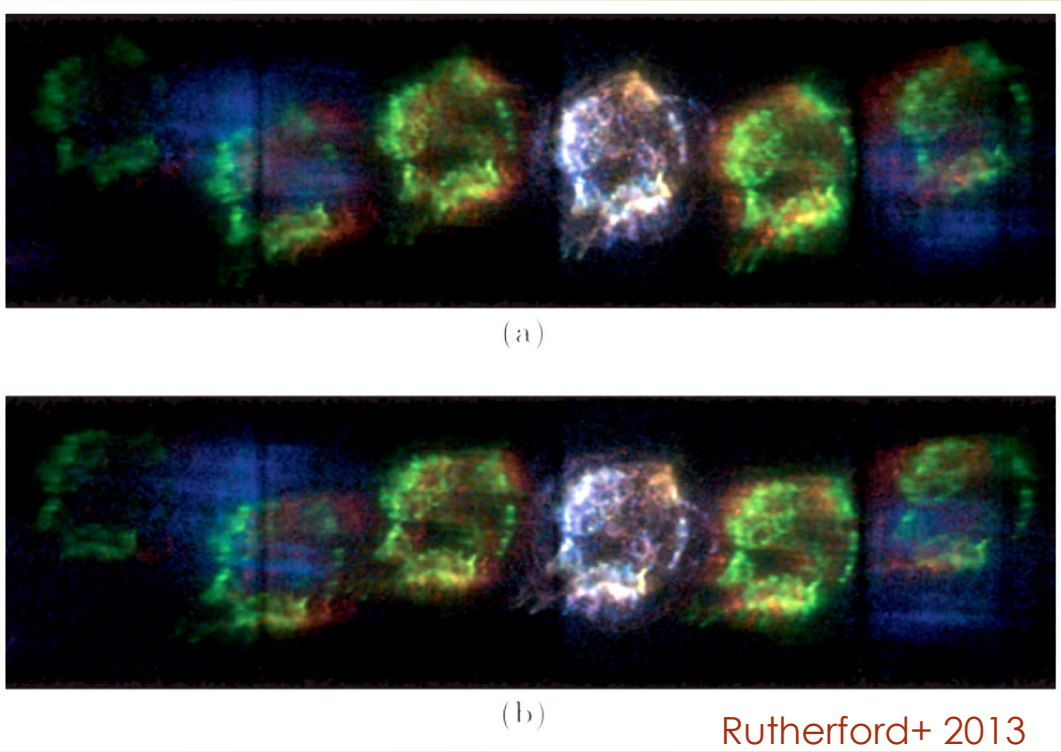
2. Spatially-resolved high-resolution X-ray spectra

Current mission: Grating optics
XMM-Newton RGS, Chandra HETG/LETG



Position ←→ Energy (wavelength)

Grating Image of Cas A with different roll angles



Rutherford+ 2013

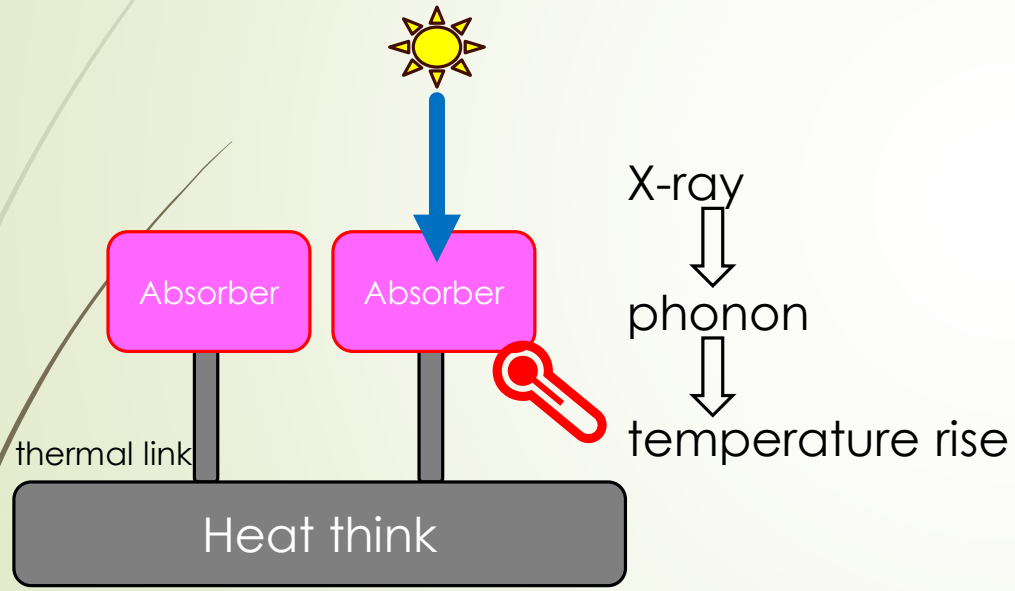
Grating optics : energy and spatial information are mixed.
→ not suitable to observe diffuse objects

1.3 What XRISM can measure ? (cont.)

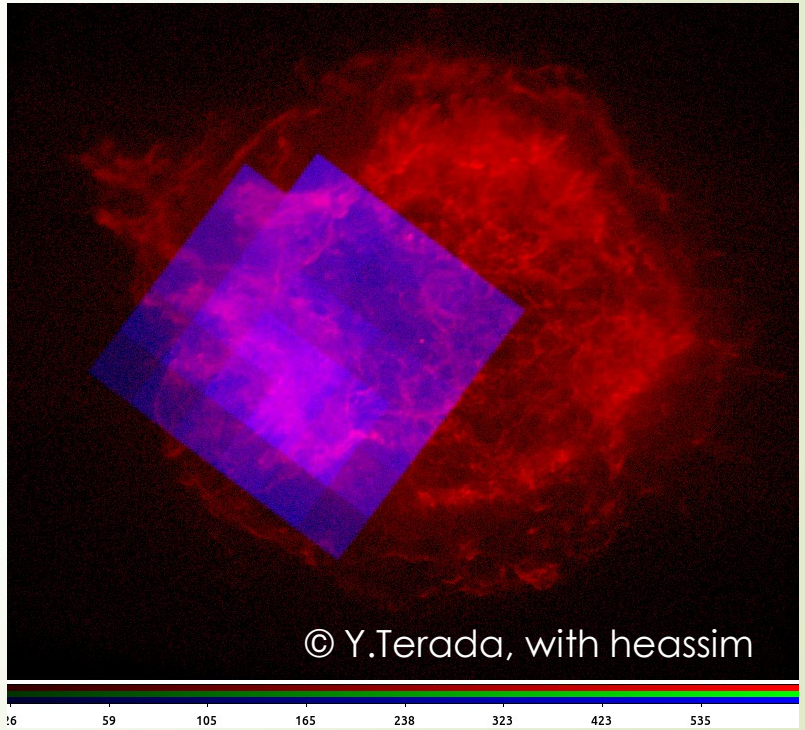
Three Points

2. Spatially-resolved high-resolution X-ray spectra (cont.)

XRISM/Resolve is the non-dispersive optics.



Cas A simulation (Blue: XRISM Resolve, Red: Chandra)

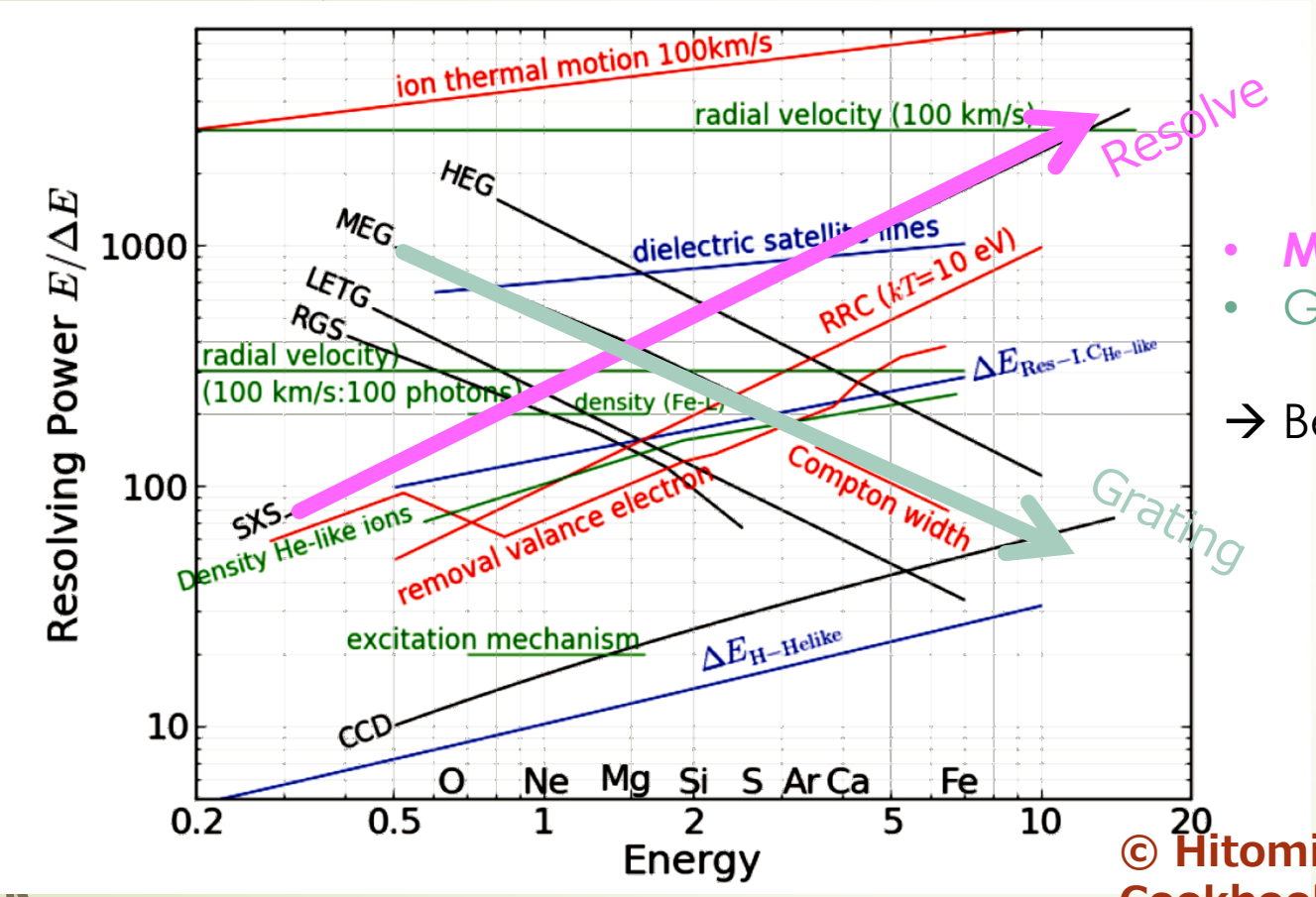


XRISM can provide pixel-by-pixel X-ray spectra.

1.3 What XRISM can measure ? (cont.)

Three Points

3. Spectroscopy especially for Fe K line band



- **Micro calorimeter:** $\Delta E \sim$ **const in** E
- Grating optics: $\Delta\lambda \sim \Delta E^{-1} \sim$ const in λ

→ Better resolving power in higher energy band

© Hitomi collaboration, AH Cookbook

Key for XRISM is the spectroscopy in Fe-K line band.

1.4 XRISM Science Objectives

3 Key points: a. Plasma diagnostics, b. Spatially resolved, c. Fe-K line band

1. Structure of the Universe and evolution of Galaxy Clusters
   i. Reveal the spatial distribution and its dissipation of thermal and non-thermal energy of the largest gravitationally bounded system - clusters of galaxies.
   ii. Directly observe the sites of their growth mechanism from both thermodynamic and kinematic aspects.
2. Circulation history of baryonic matters in the Universe
   i. Trace baryon cycles in various stages from element synthesis by stellar objects and supernovae to material dissipation in interstellar to intergalactic space
   ii. Directly observe the element abundance evolution in the cosmic structure formation.
3. Transport and circulation of energy in the Universe
   i. Reveal matter and energy feedback from galaxies and active galaxies
   ii. Observe the impacts to the coevolution of galaxies and super-massive black holes.
4. New science with unprecedented high resolution X-ray spectroscopy
   i. Develop new methods for plasma diagnostics and measurements of velocity and gravitational redshift in the spectra of matter around relativistic objects to open new horizons in X-ray astrophysics..

2. Mission status from Ground to the First Light

Spacecraft development before launch

JAXA PQR/PSR

Launch!

JAXA CDR/MOR

Verification Tests

2023

JAXA CDR

2022

JAXA PDR

Integration

Fabrication

2021

Ground Calibration

JAXA MDR/SRR
JAXA pre-project start
NASA project start / NASA CDR

Detail design

2020

Basic design

Hitomi Lessons
XARM proposal
JAXA-NASA collaboration

2019

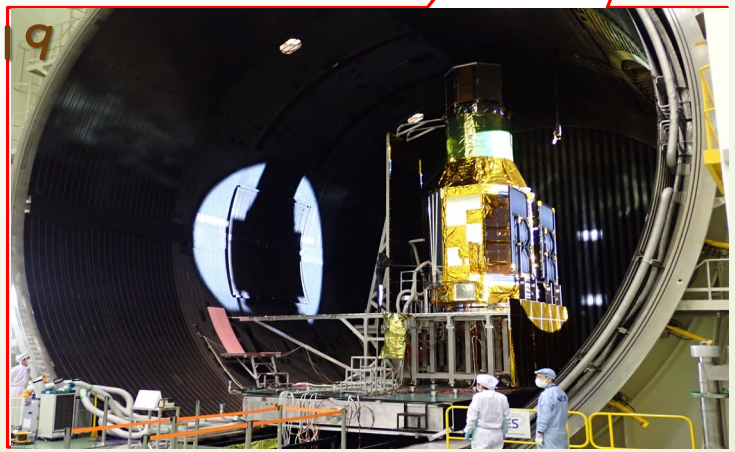
NASA-JAXA
XARM Proposal
Lessons & Close
Investigation
Hitomi Failure

2018
XARM→ XRISM

2017

2016

Ship to TNSC

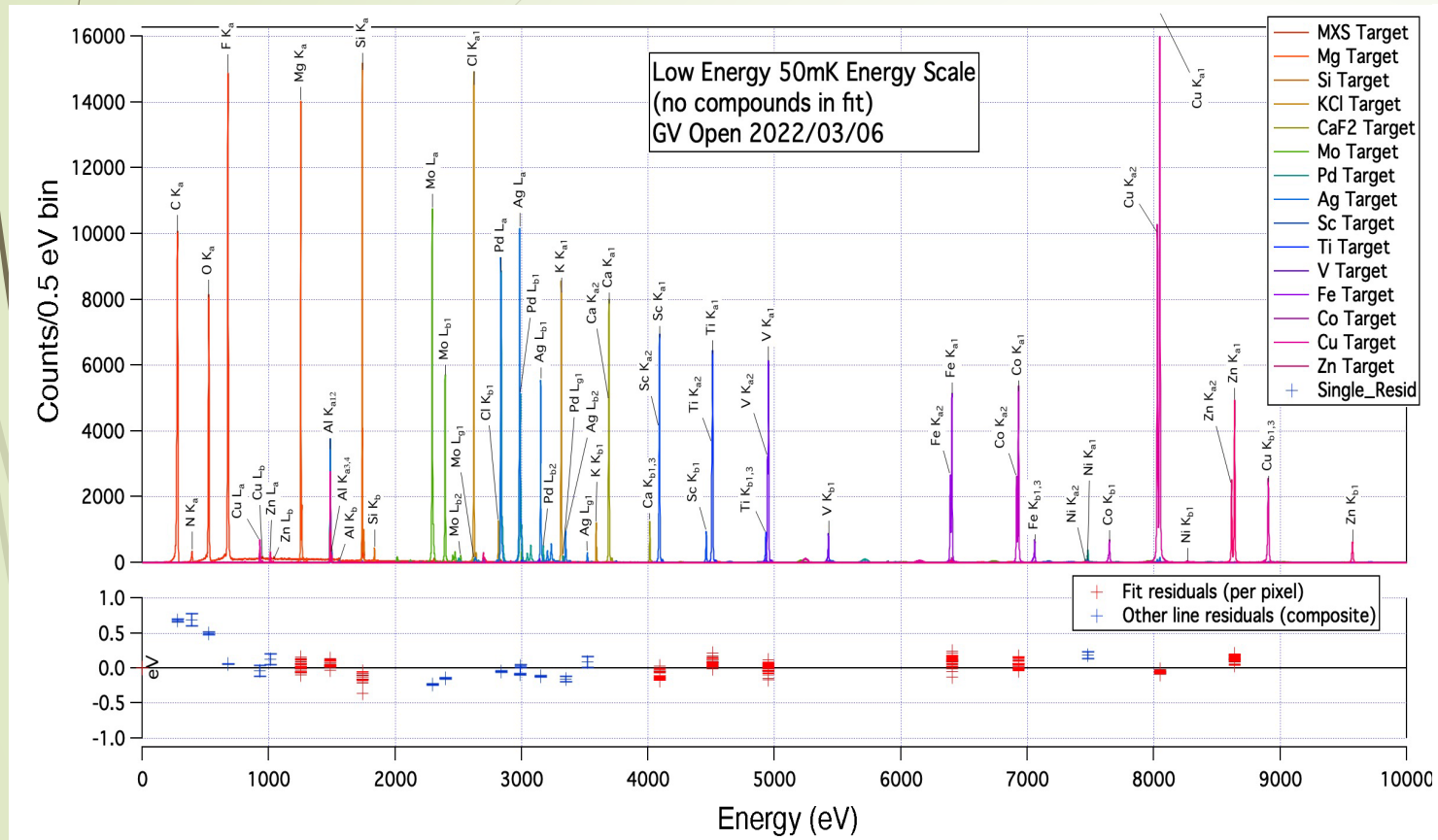


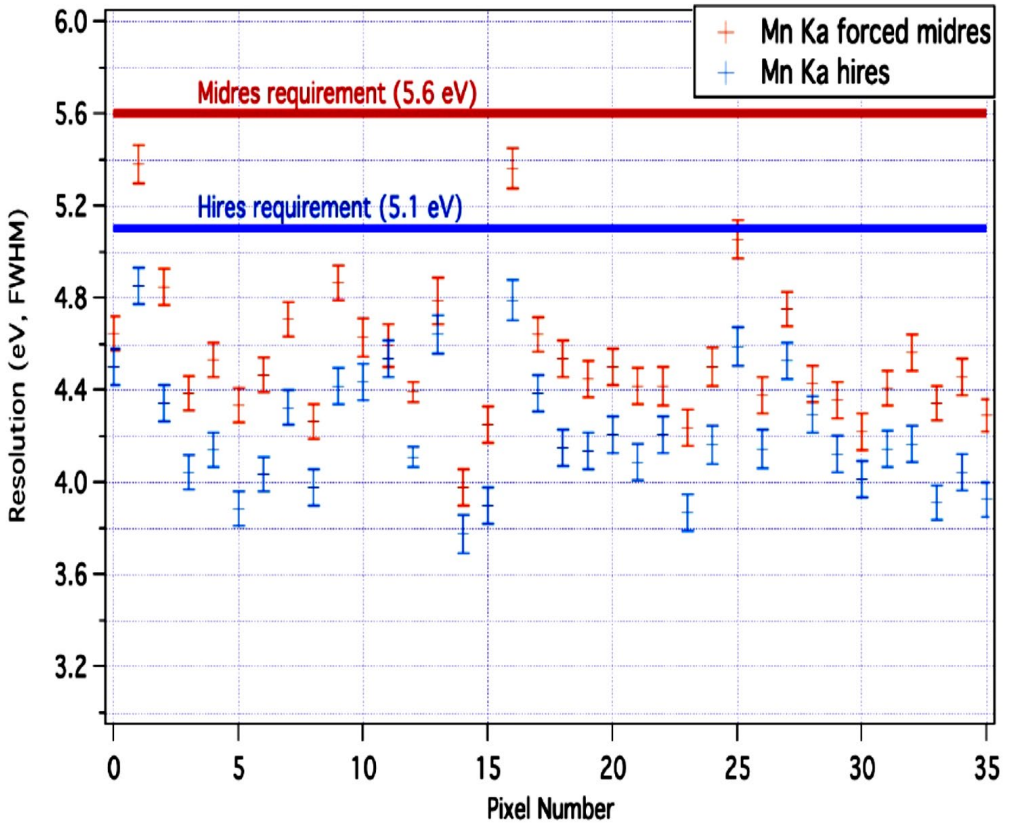
Thermal Vacuum test @TKSC

Vibration test @TKSC

Resolve performance on ground

Ishisaki et al., Proc. of SPIE 2022



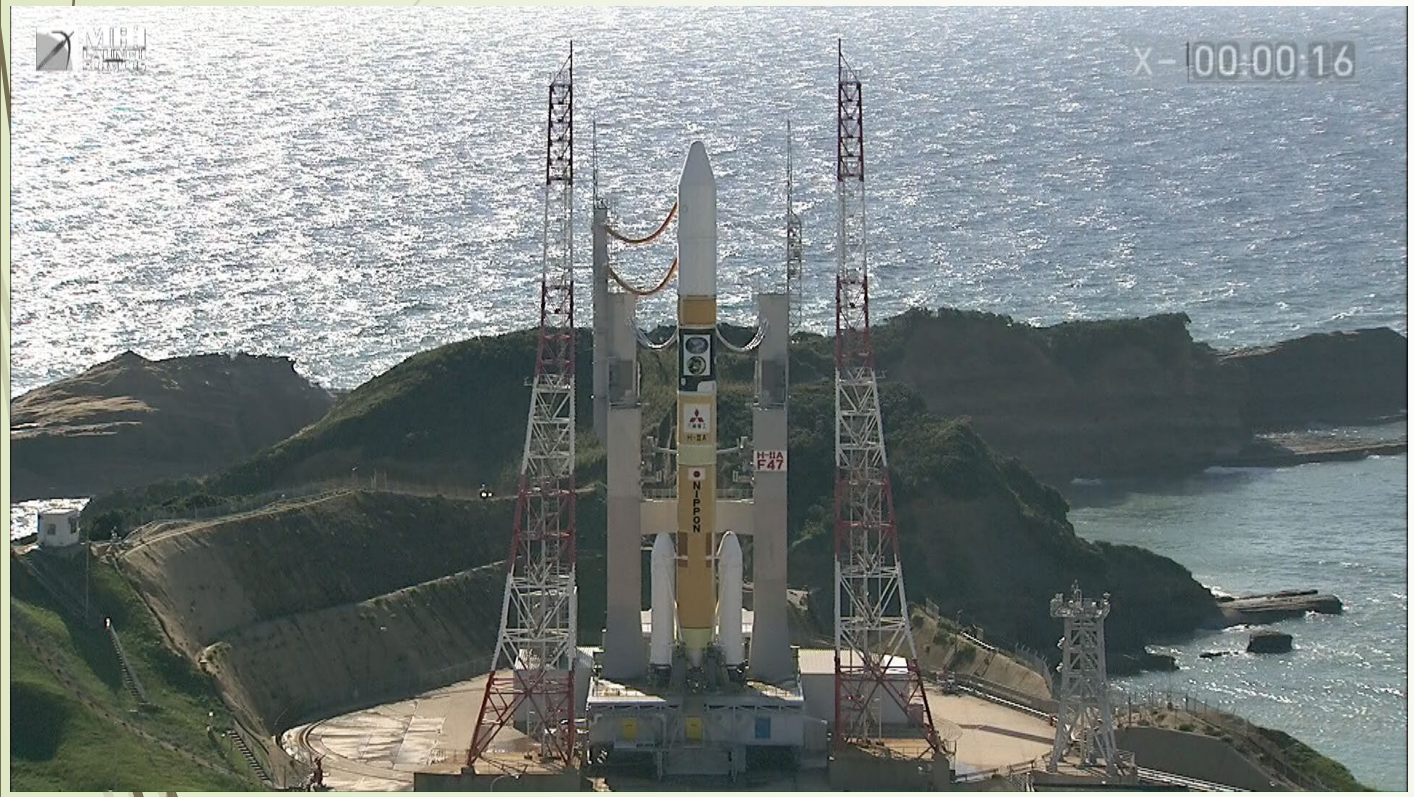


- Absolute energy scale accuracy < 2 eV in 0.3 – 9 keV band.
- Energy resolution (Hres) < 4.9 eV (amazing!)

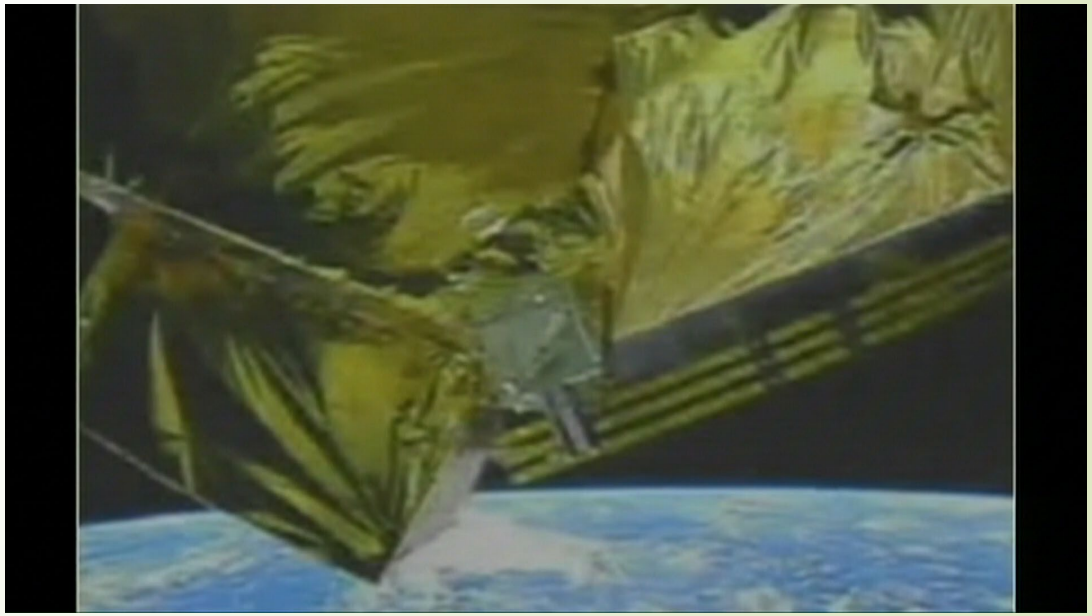
  -- both satisfy the requirement.

Launch on 7 Sep 2023

2023.9.7 8:42JST, Dual launch by H-IIA Flight 47



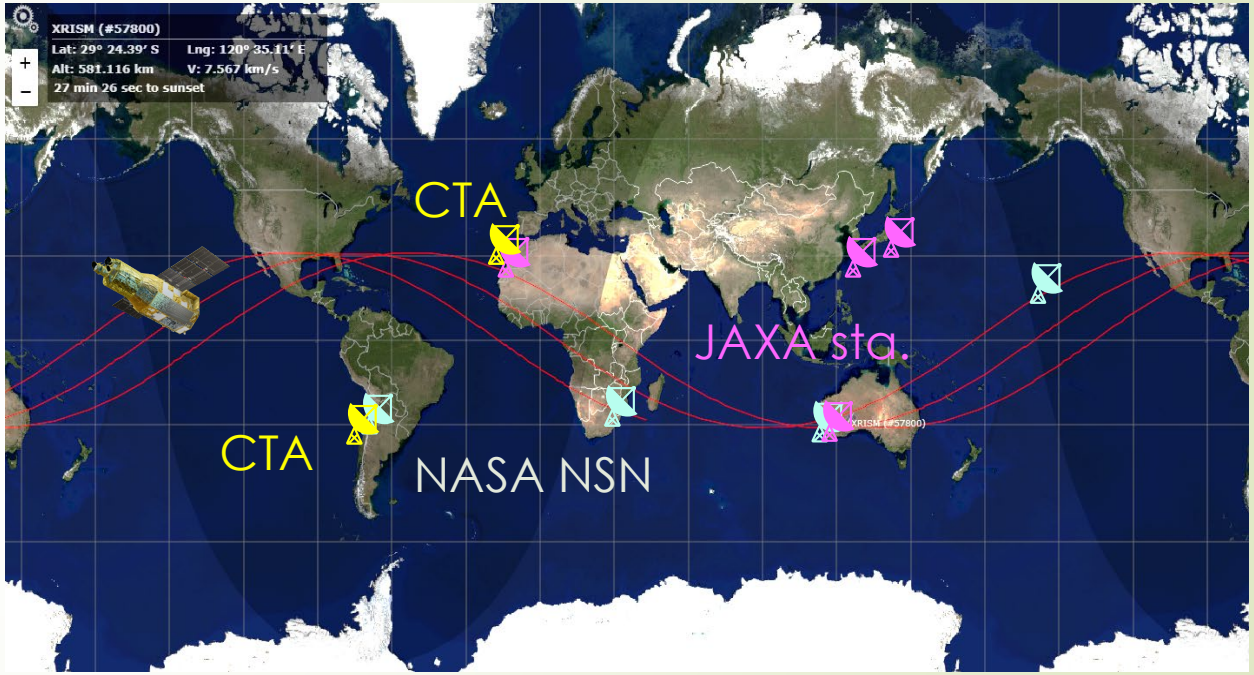
2023.9.7 8:56JST, Satellite separation



Successful launch !

Critical Operation (Y+1,2,3,4)

Soon after the launch, tracking of satellite was started and performed critical operations.



- ✓ Communication with ground stations
- ✓ Solar paddle deployment
- ✓ Launch lock release
- ✓ Attitude control system
- ✓ Resolve cooler ON

All smoothly completed.

Commissioning Operations

After the bus system commissioning (GPS, Attitude, Power Supply etc), we turn on science instruments

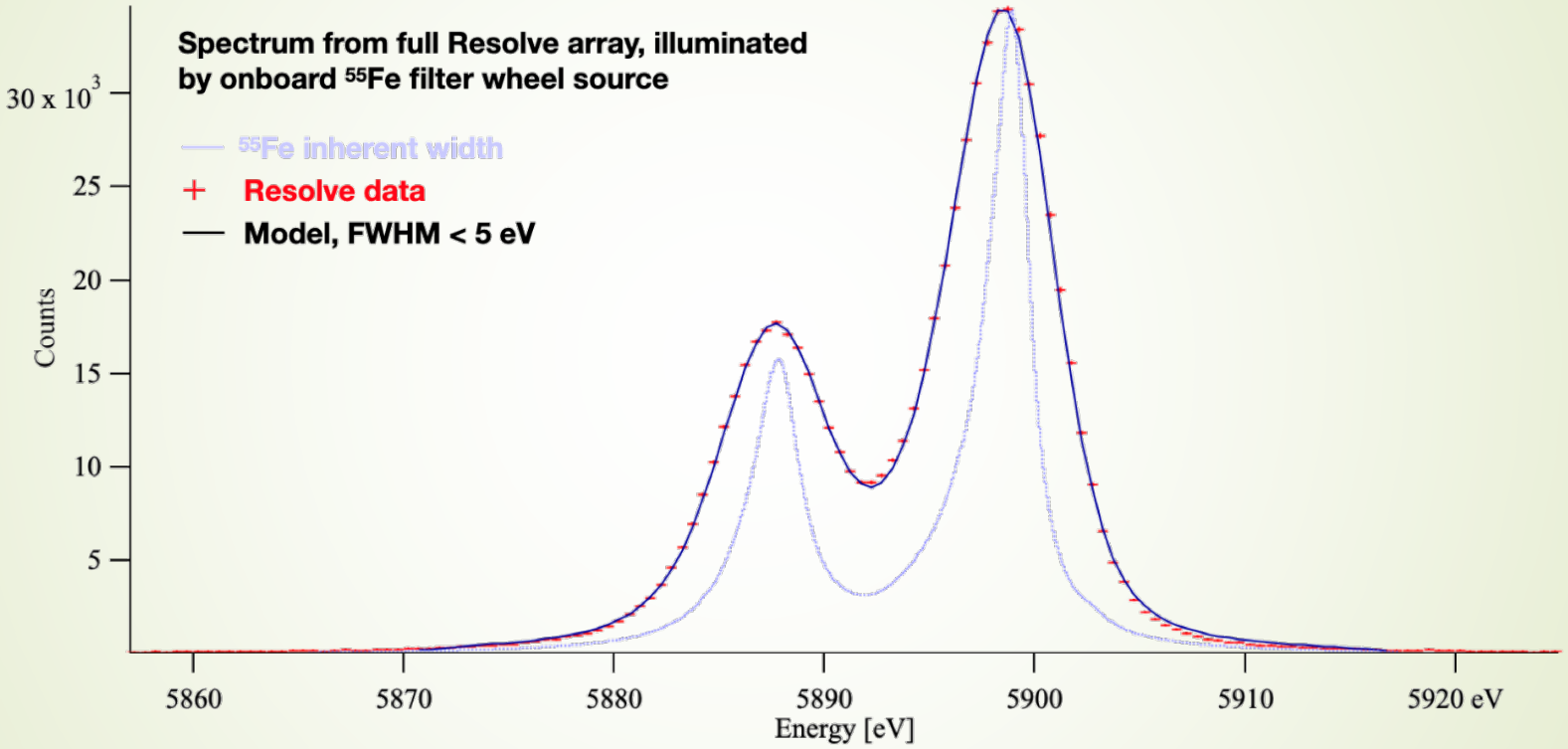
2023.10.9 Resolve 50mK achieved

2023.10.21 Xtend first detection of X-rays

At this moment, we recovered the Hitomi.

Commissioning Operations (cont.)

2023.10.20, Energy resolution check: Resolve calibration source (55Fe) in orbit



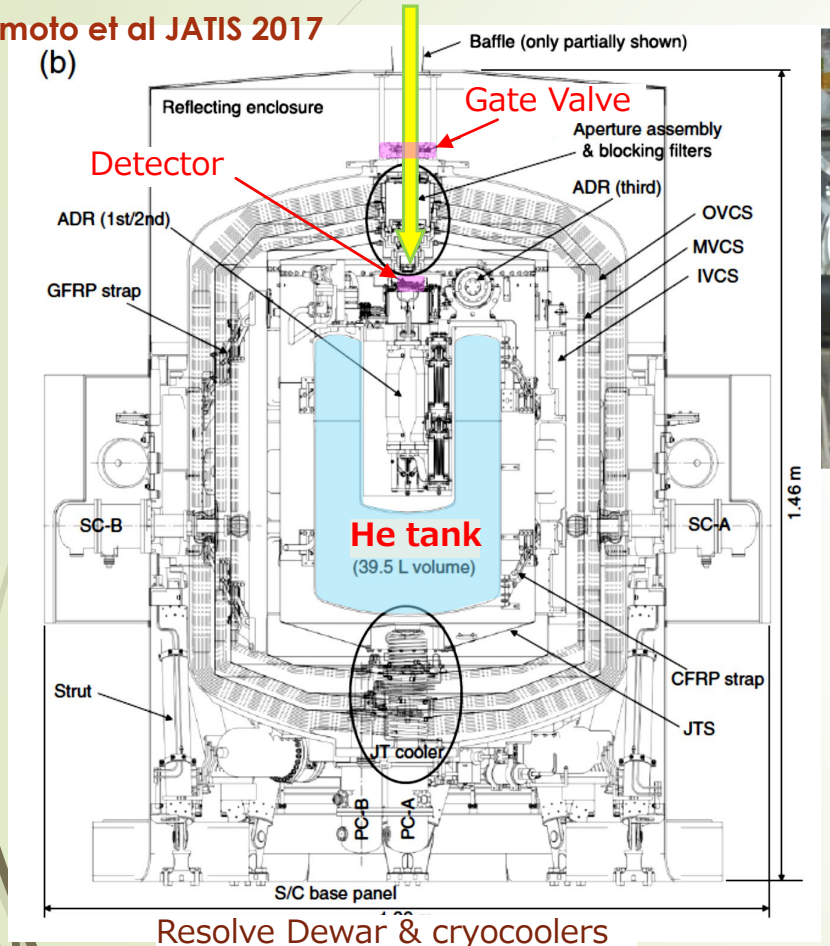
Energy Resolution < 5 eV in orbit !!
Of course, this is within the requirement on the energy resolution.

2023.10.23 Resolve MXS (Modulated X-ray source) operation, OK

Commissioning Operations (cont.)

2023.11～ Resolve Gate Valve Open operation – still ongoing

Fujimoto et al JATIS 2017



Resolve Dewar & cryocoolers

Midooka et al JATIS 2021

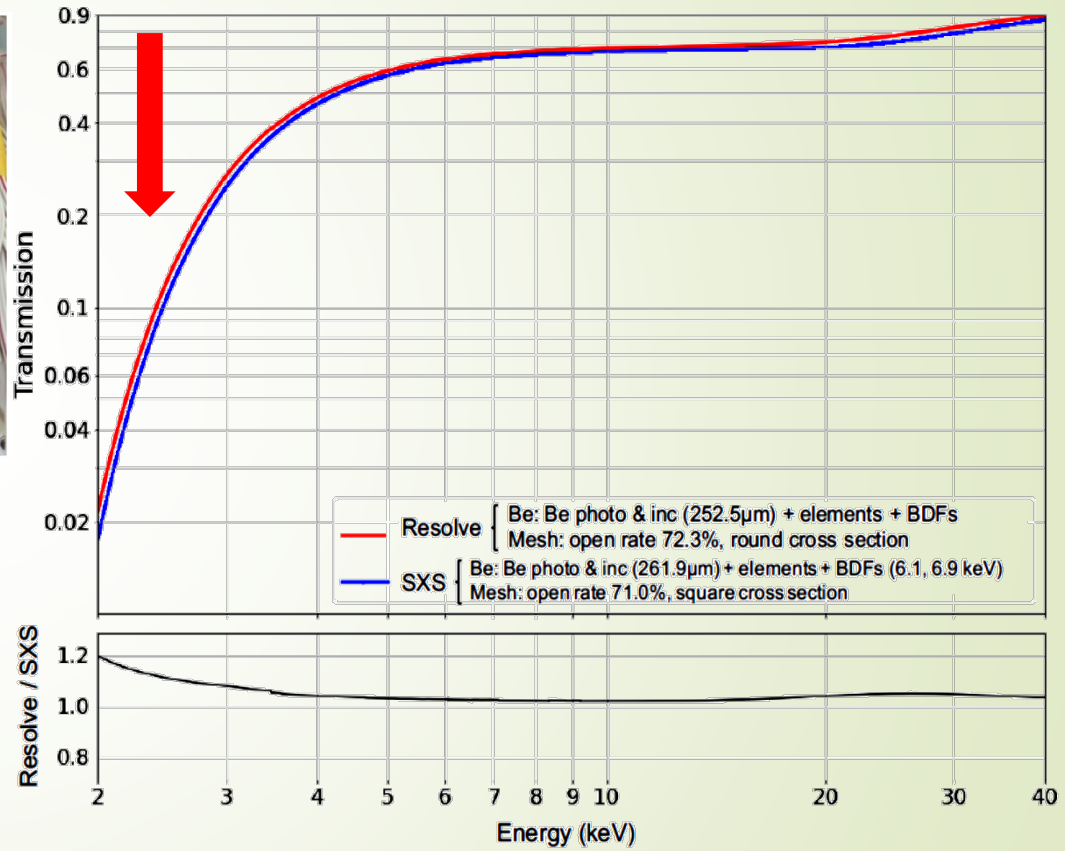
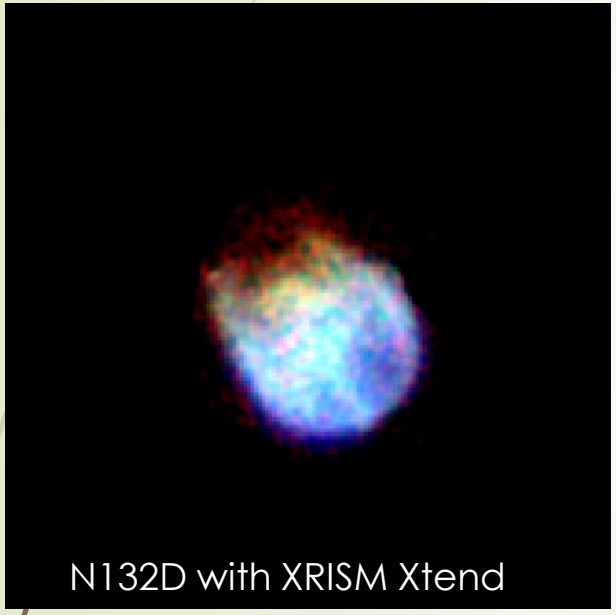


Fig 13 Comparison of the best-fit transmission models between the *Resolve* (red; this work) and the SXS (blue; CALDB ver. 20160606).

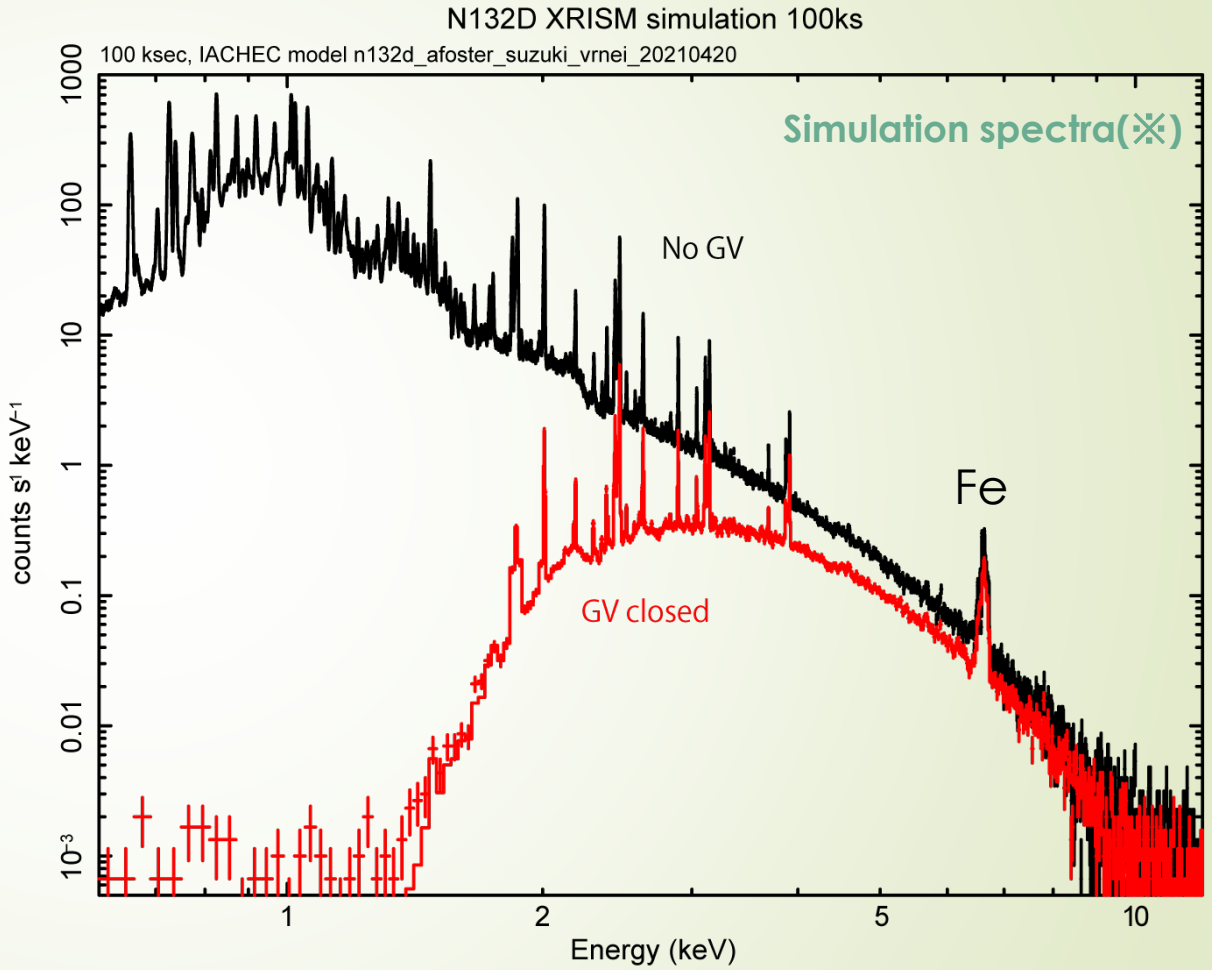
Effective area in lower energy band is not in full configuration at this moment.
We plan to keep GV Open operation during PV phase.

Commissioning Operations (cont.)

Simulated X-ray spectra with/without GV for SNR N132D →



N132D with XRISM Xtend



※ Real data with GV closed will be available soon

Detectability of lines of lighter elements is reduced?
Yes, but, science with Si – Fe K lines is still alive !

3. Collaboration with XRISM - GO program -

Nominal Operations Phase

Now it is nominal operations phase,
performance verification (PV) and Calibration Period.

PV Target, In-orbit calibration Target

https://xrism.isas.jaxa.jp/research/proposer/approved/index.html

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PV Targets

Following the successful commissioning of spacecraft and payload, XRISM will undergo a 6-months Performance Verification (PV) Phase. The goal of this phase is to showcase the XRISM transformational science, while providing the scientific community worldwide with a comprehensive set of experiments thoroughly verifying the capability of the mission to fulfill all its scientific goals.

Data of the PV phase observations are reserved to the members of the XRISM Science Team, as well as to a small number of "XRISM Guest Scientists" to be appointed by the XRISM Participating Agencies by the end of 2021. Data will be made public following the rules holding for all XRISM proprietary data.

Category	Target	Target position		Exposure (ks)	Priority	Remarks
		RA	Dec			
GC	4U 1916-053	289.699	-5.238	50	A	
GC	4U 1624-490	247.023	-49.211	50	A	
GC	GX 13+1	273.631	-17.157	30	A	
GC	Cyg X-1	299.590	35.202	100	A	
GC	SS 433	287.957	4.983	80	A	
GC	Cyg X-3	308.107	40.958	40	A	
GC	Cen X-3	170.313	-60.624	90	A	
GC	Eta Carinae	161.265	-59.684	100	A	
GC	V834 Cen	212.280	-45.288	100	A	
GC	GT Mus	174.873	-65.398	90	A	ToO

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Calibration

Target	Target position		Exposure (ks)	Notes
	RA	Dec		
1ES 0033	8.968	59.834	75	
E 0102	16.009	-72.031	60	
Perceus Cluster cal	49.951	41.512	60	
HR 1099	54.197	0.587	50	
NGC 1550	64.908	2.410	100	
Capella	79.172	45.998	258	Raster scanning over the f.o.v.
N 132D	81.258	-69.650	50	
AB Dor	82.187	-65.449	100	
Crab	83.633	22.015	78	Includes 1-degree off-axis observation, with pointing to be determined by XMA team.
Abel 1060	159.174	-27.524	100	
3C 273	187.278	2.052	150	
Abell 2029 center	227.734	5.744	10	

Some are dropped in GVC

Please check your favorite objects !

Guest Observation Program

- GO Proposal submission is now open (due: 4 April 2024).
  - Call for observations starting Aug 2024, for 1 year.
  - Pointing observation with 10 – 300 ksec exposure.
  - Time critical proposal, ToO observation with known RA, DEC.

  - See detail
    https://xrism.isas.jaxa.jp/research/proposer/announcement/index.html

- Proposal opens at JAXA (48%)/NASA(44%)/ESA(8%).
  Please submit your proposal to the country of your institute.

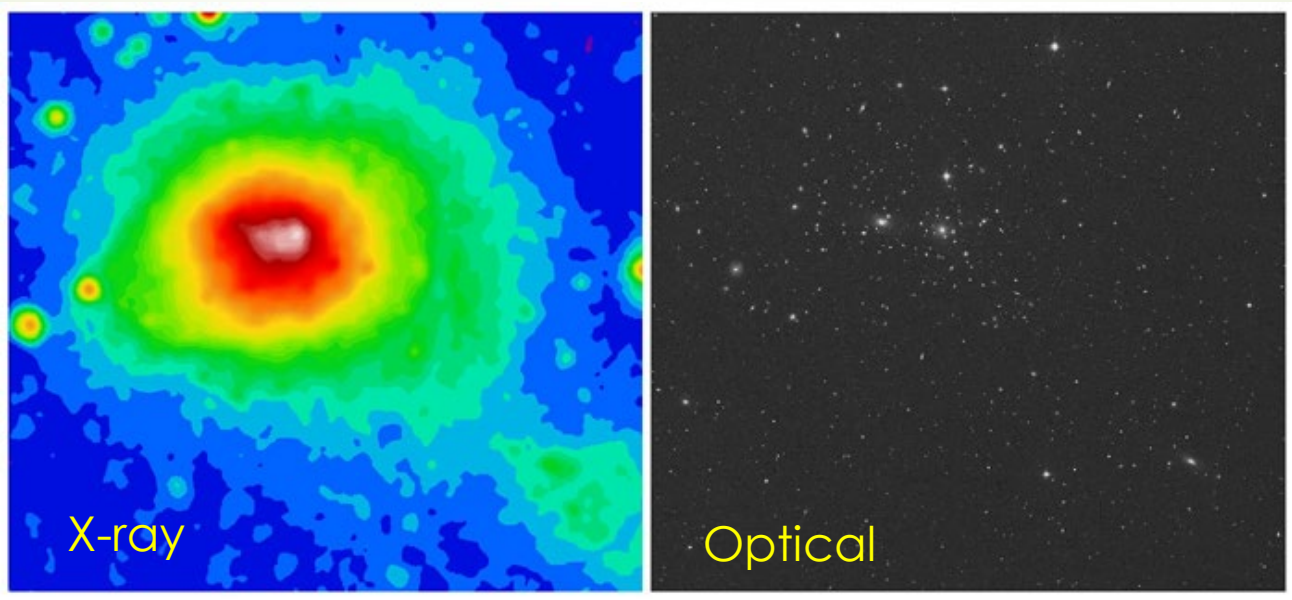
Please feel free to contact the XRISM JAXA helpdesk, if you have questions.
https://xrism.isas.jaxa.jp/research/helpdesk/format/index.html

4. Examples of expected results

- Ongoing PV observations of galaxy clusters -

Clusters of galaxies

- Most massive objects in the Universe
  - Dark matter (~80%), intracluster medium (ICM; ~15%), galaxies (~5%)
- Mass: $10^{13\text{-}15}\,M_{\odot}$
- Scale: ~Mpc
- XRISM observes the ICM
  - Diffuse
  - High temperature (~2-10 keV)
    - Not much affected by the closed Gate Valve



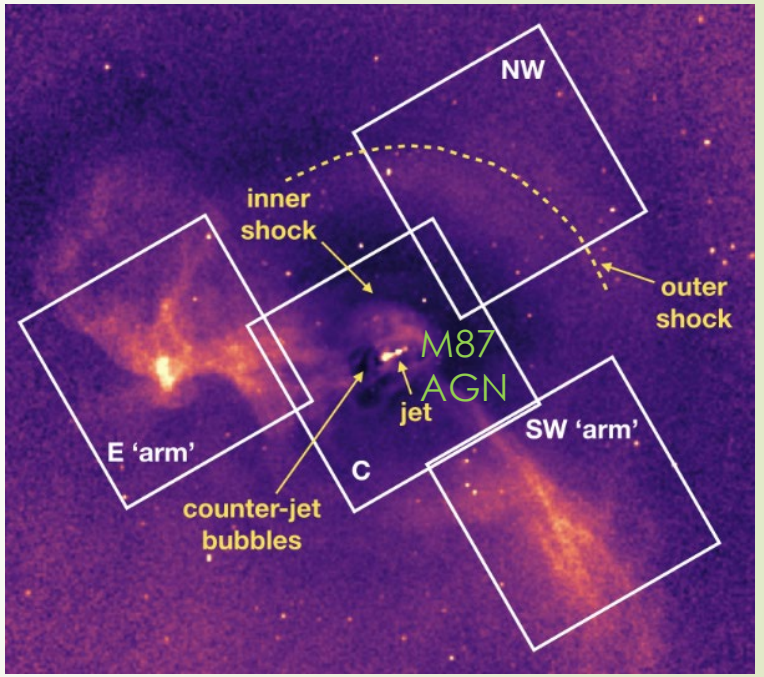
Coma cluster

NASA

Virgo cluster

- Nearby cluster
  - Large apparent size allows for spatially resolved observations
  - Complex gas Motions associated with AGN activity
    - Doppler line shift and broadening
    - AGN feedback
  - Spatial distribution of chemical composition of ICM
    - Mixing of metal-rich gas in the central galaxy (M87) with the ICM by AGN activity

Central region of the Virgo cluster

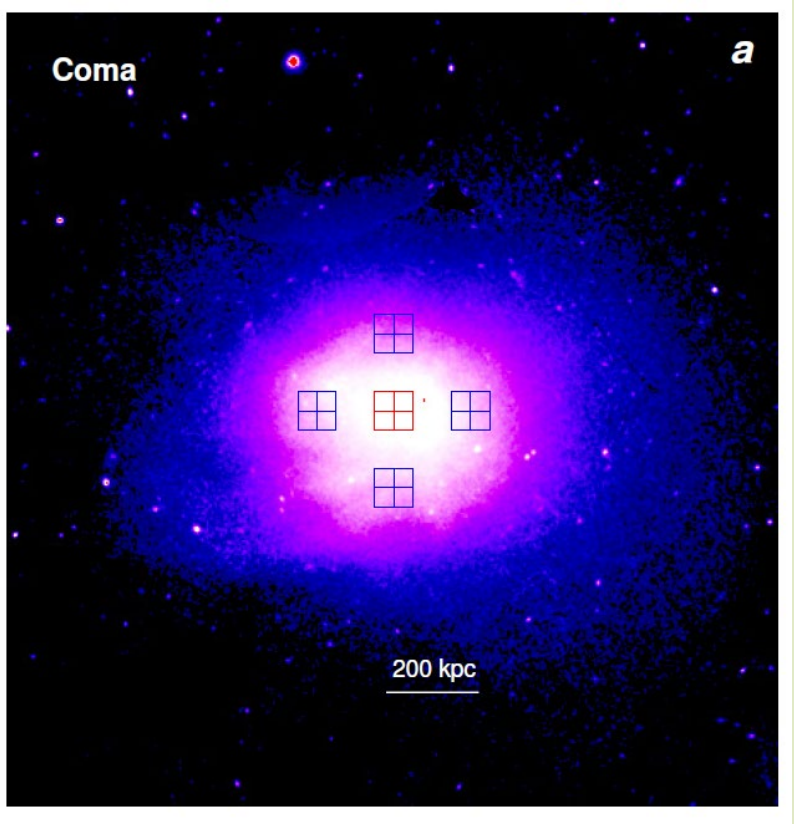


FOVs of XRISM (Resolve) on a Chandra image

Coma cluster

- Nearby massive cluster
  - Merging cluster
  - Violent gas motion is predicted
- Radio Synchrotron emission from the entire cluster
  - Turbulent acceleration of cosmic rays?
    - Electrons are accelerated in the process of being scattered by turbulence
  - We want to do more than detect turbulence
    - Energy spectrum of turbulence
    - Relationship between spatial scale and turbulence energy

Central region of the Coma cluster

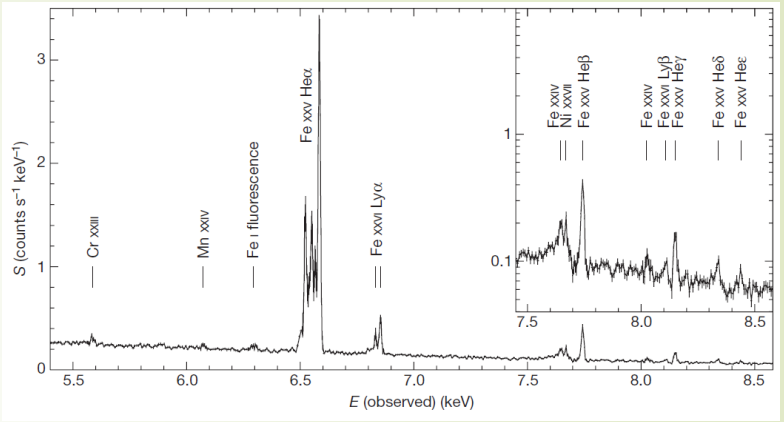


FOVs of XRISM (Resolve) on a XMM-Newton image

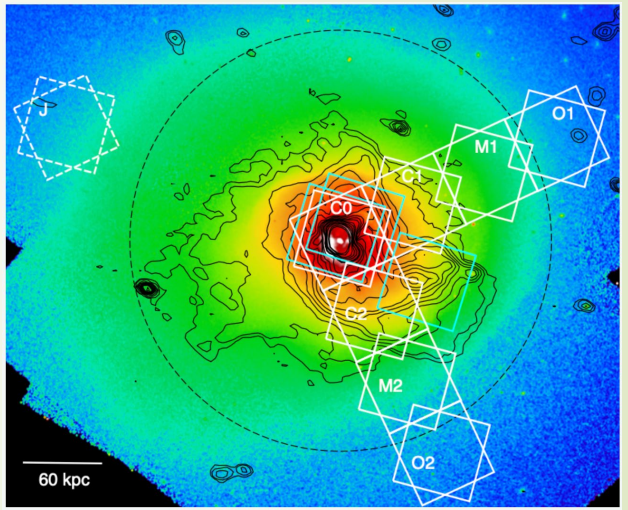
Perseus cluster

- We observed it with Hitomi, but...
  - We observed a very small portion
  - Large and bright
- There is still more to investigate
  - Origin of gas motion, turbulence
    - AGN? galaxy cluster collisions?
    - From spatial distribution of turbulence
  - Relation between cosmic ray acceleration and turbulence
    - Spatial correlation between radio emission and turbulence
  - Detailed elemental compositions
    - Type of supernova
  - Charge exchange reactions
    - Electron exchange between ions and neutrals
    - Cold gas

Hitomi collaboration (2016)



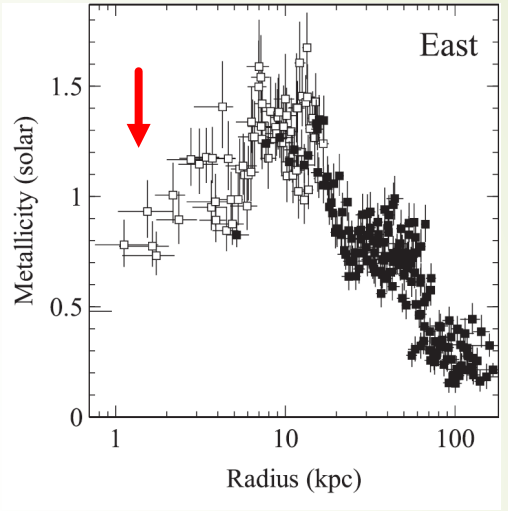
Central region of the Perseus cluster



FOVs of XRISM (Resolve) on a Chandra + radio image

Centaurus cluster

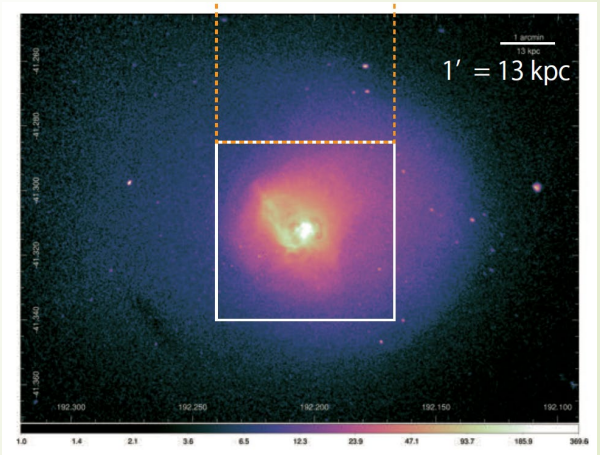
- High metal abundance
  - > 1 $Z_{\odot}$
  - Past active supernova explosions in the central galaxy
- Metal abundance drop at the center
  - Consumption by dust formation?
- Detailed metal abundance ratio observations
  - Reveals dust formation, chemical evolution, and supernova types



Metal abundance

Chandra observation (Sanders et al. 2016)

Central region of the Centaurus cluster



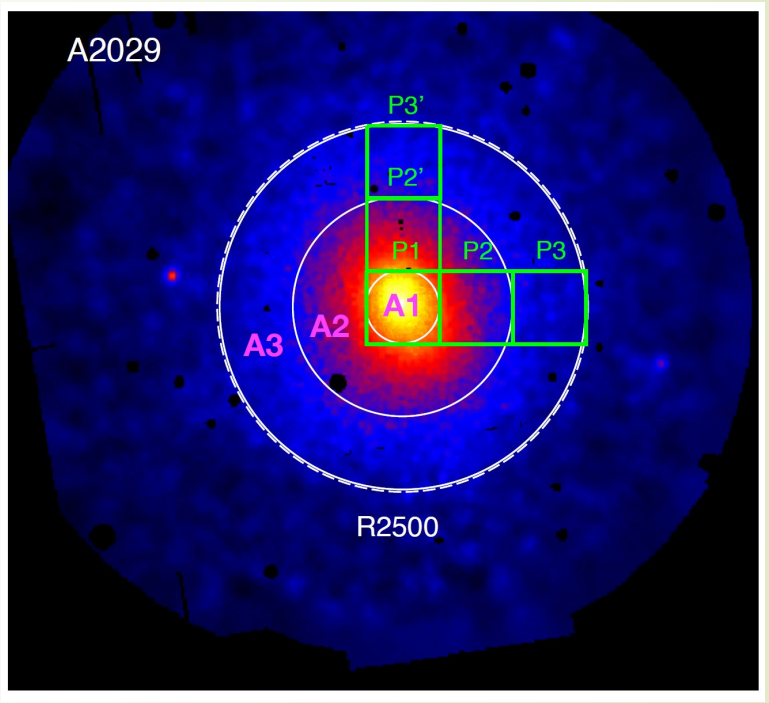
(Sanders et al. 2016)

FOVs of XRISM (Resolve) on a Chandra image

Abell 2029 cluster

- Galaxy clusters are used in cosmology
  - Cosmological parameters can be derived from the mass function
  - When determining mass in X-rays, hydrostatic equilibrium (gas is hardly moving) is assumed
    - Is this true?
- Abell 2029 is a galaxy cluster that does not seem to be merging
  - How correct is the hydrostatic equilibrium assumption?
    - Doppler shift/broadening
    - Pay particular attention to the outer edge of the cluster

Abell 2029



FOVs of XRISM (Resolve) on a XMM-Newton image

Please stay tuned!