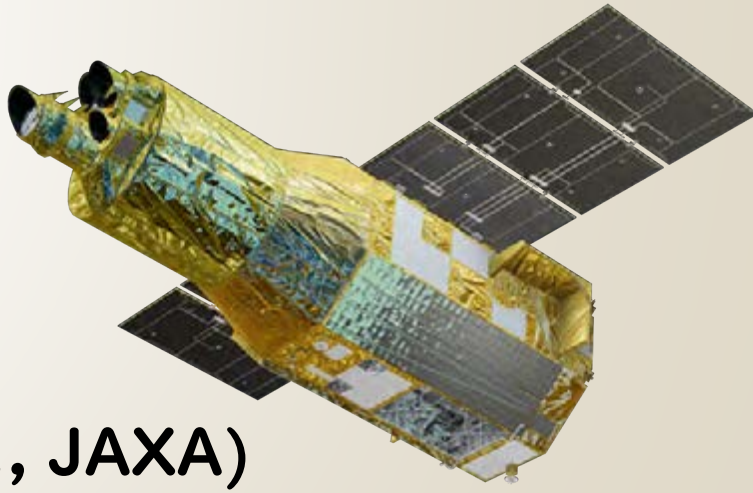
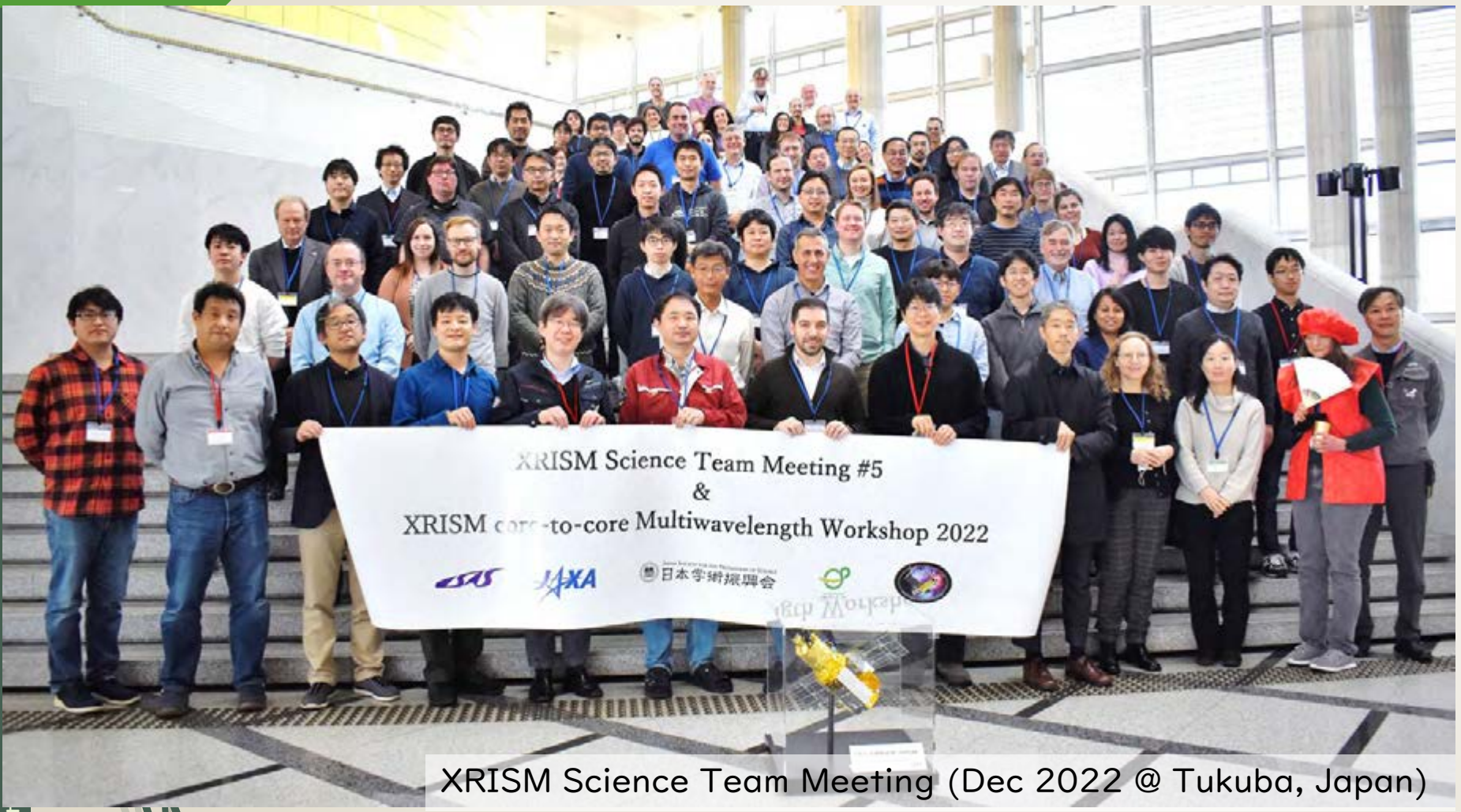
Latest status and expectations for the recently born X-ray observatory XRISM (the X-Ray Imaging and Spectroscopy Mission)



Yukikatsu Terada (Saitama Univ., JAXA)
XRISM Project,
Science Operations Team Lead

XRISM collaboration



XRISM Science Team Meeting (Dec 2022 @ Tukuba, Japan)

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

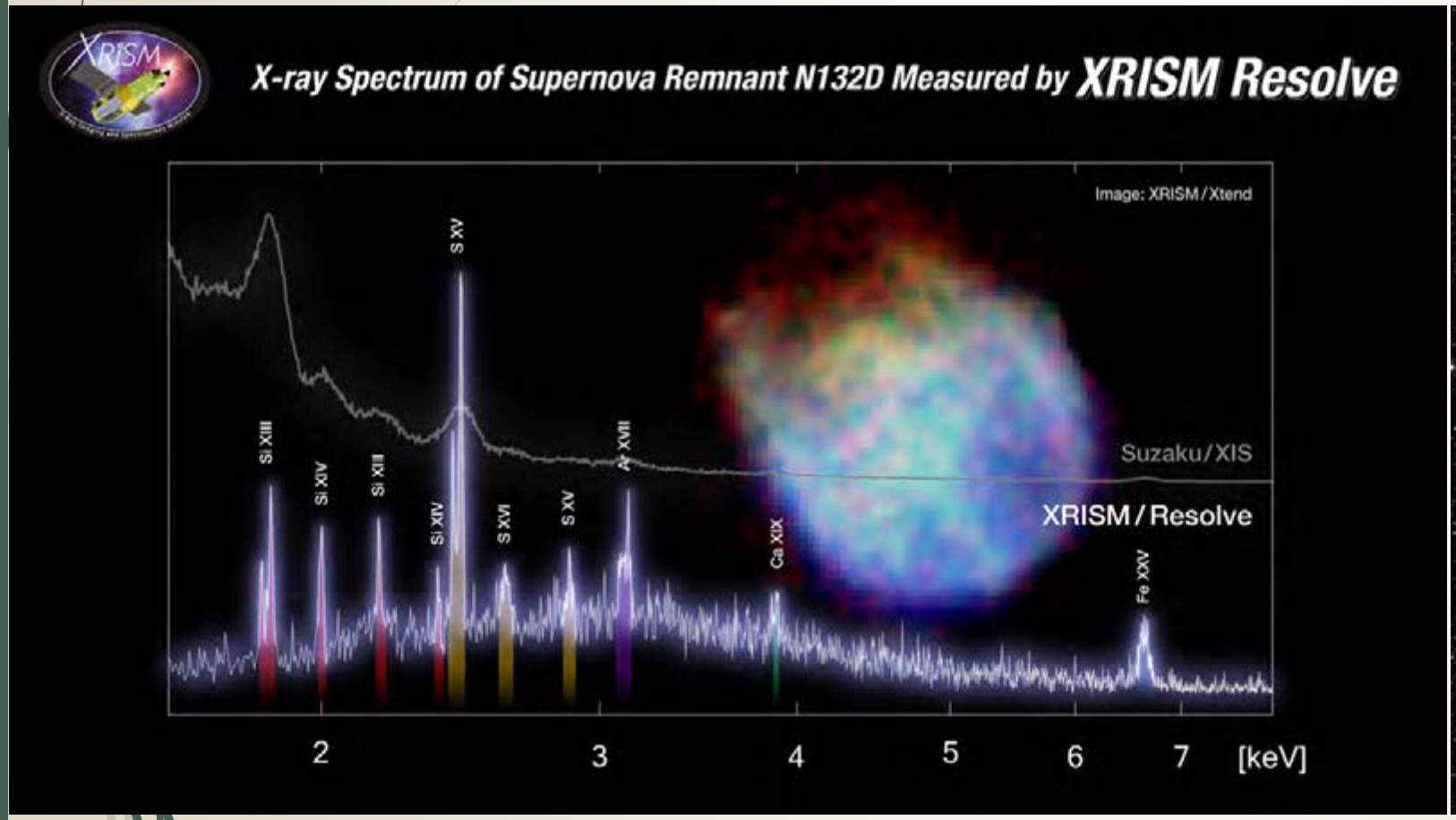
Talk Plan

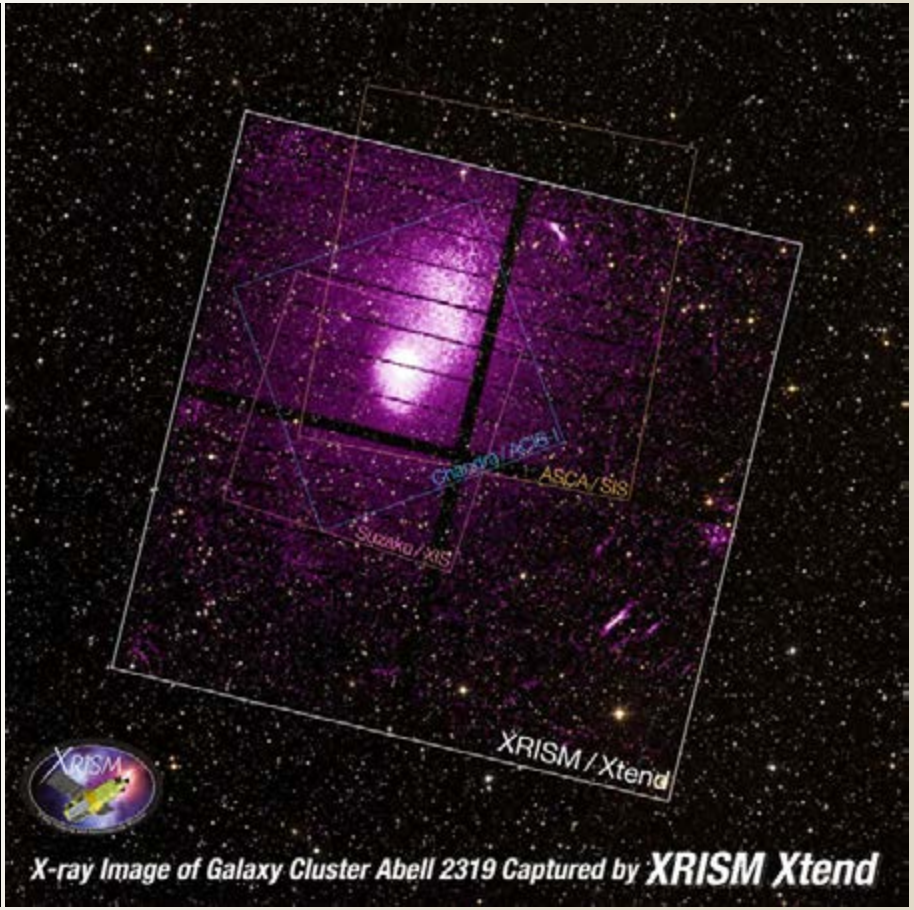
1. Introduction – the XRISM mission –
2. Mission status from Ground to the First Light
3. Collaboration with XRISM – GO program –

1. Introduction – the XRISM mission –

1.1 Latest figures of XRISM

2024.1.5 XRISM First Light

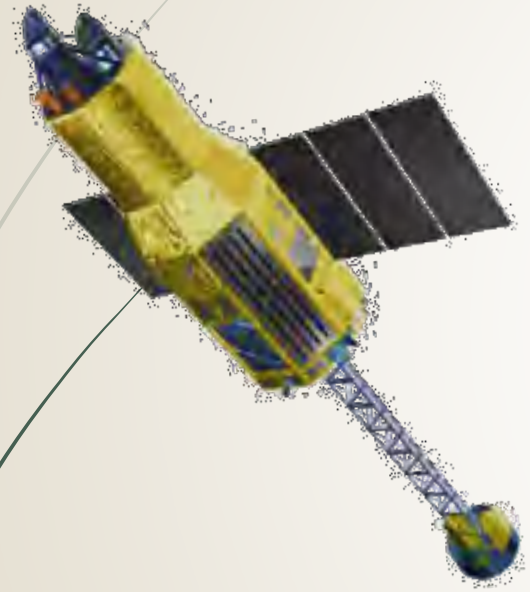




X-ray Imaging and Spectroscopy Mission
with high energy resolution and large Field of View

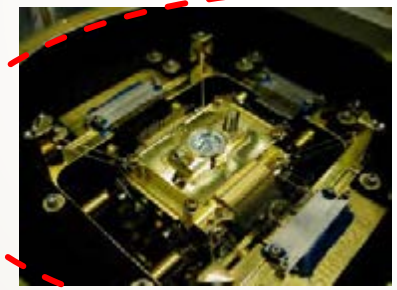
1.2 XRISM Science instruments and Spec

Recovery mission of Hitomi/ASTRO-H

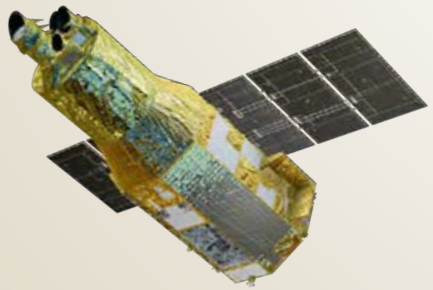


Hitomi Satellite (2016)

- 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



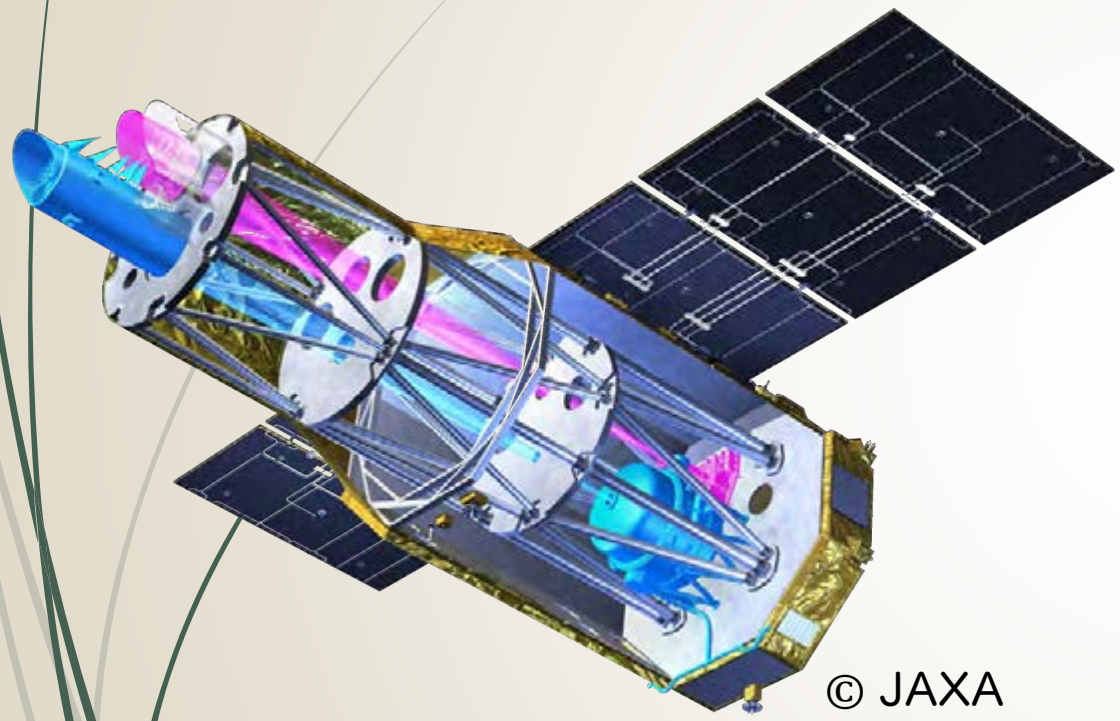
XRISM (2023-)

- 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



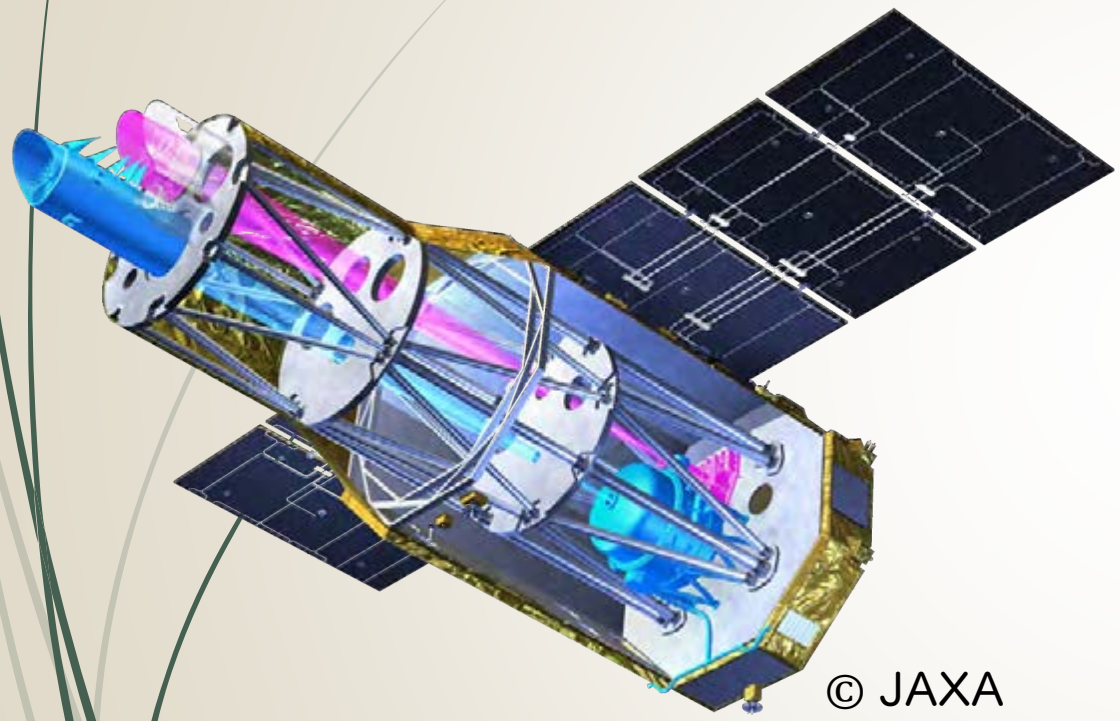
© JAXA

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



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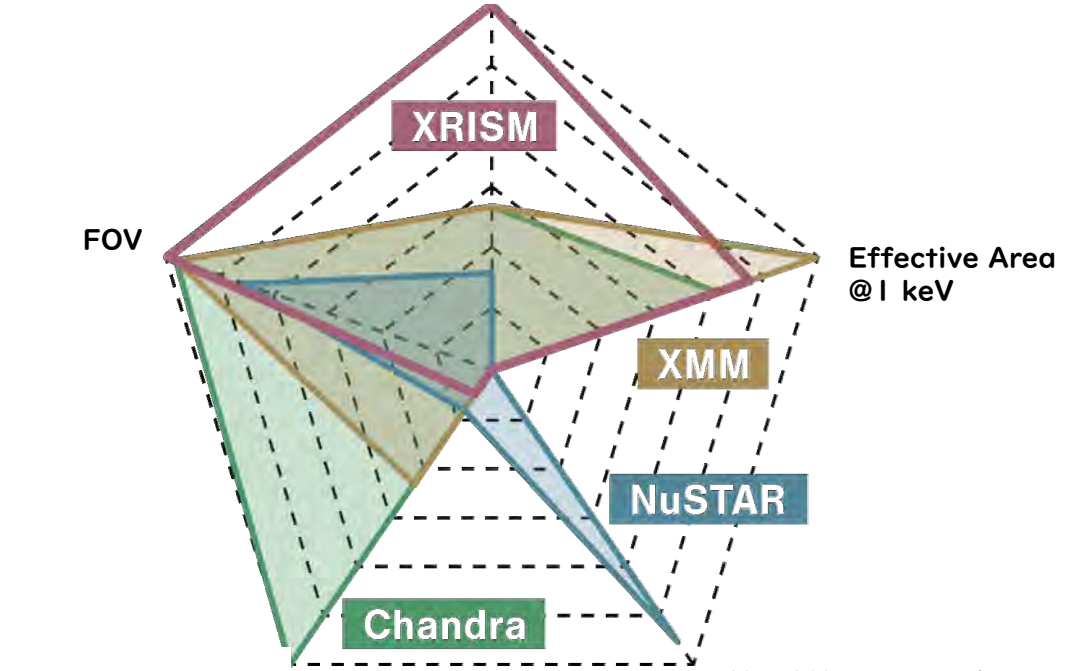
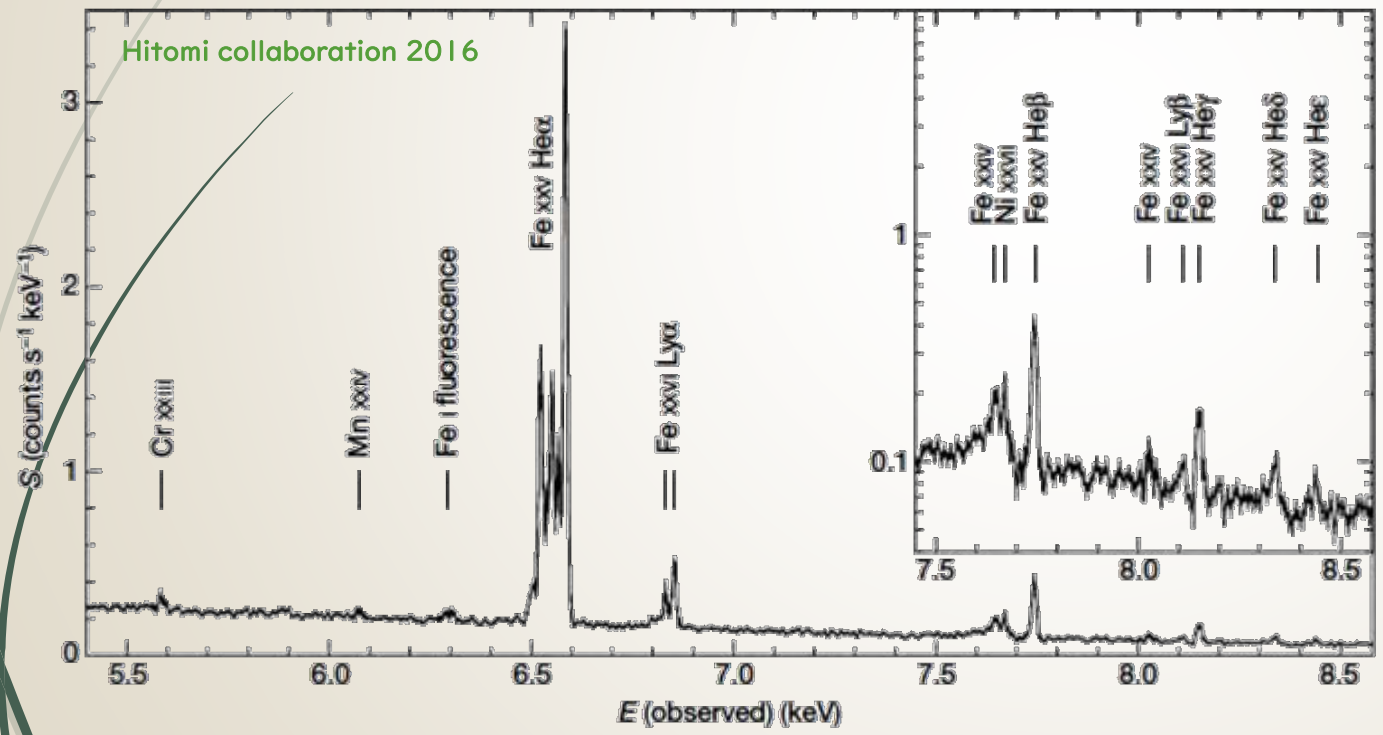


High-energy-resolution spectroscopy & large FOV imaging in keV band

1.3 What XRISM can measure ?

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 hundred km/s

I.3 What XRISM can measure ? (cont.)

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

- XRISM can distinguish the satellite lines.

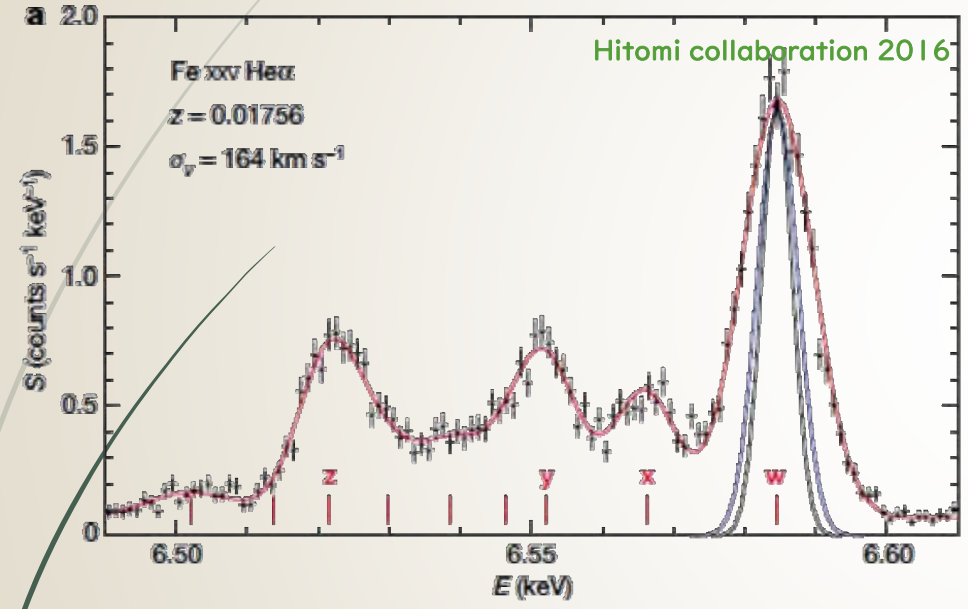
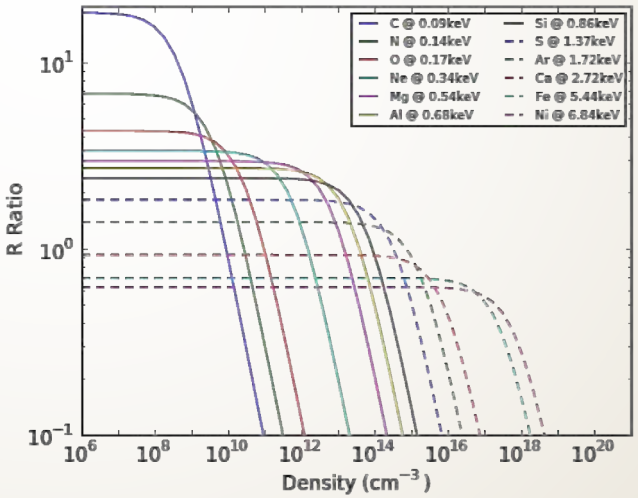


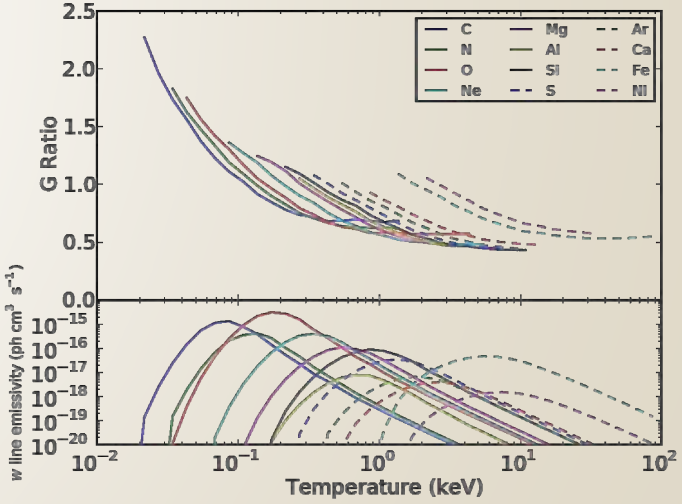
Figure 2 | Spectra of Fe xxv Heα, Fe xxvi Lyα and Fe xxv Heβ from the outer region. a–c, Gaussians (red curves) were fitted to lines with energies (marked by short red lines) from laboratory measurements in the case of He-like Fe xxv (a, c) and from theory in the case of Fe xxvi Lyα (b; see Extended 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.

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



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

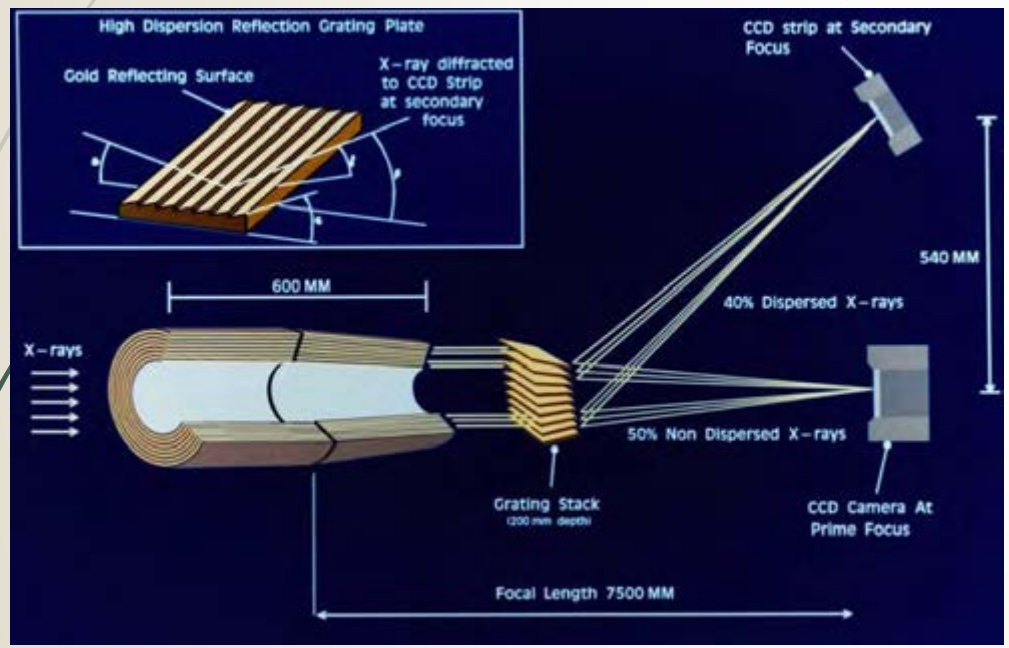


- XRISM can search for Charge Exchange lines.
  - Science Objectives: Ionization of neutral gas by Cosmic-rays etc.

1.3 What XRISM can measure ? (cont.)

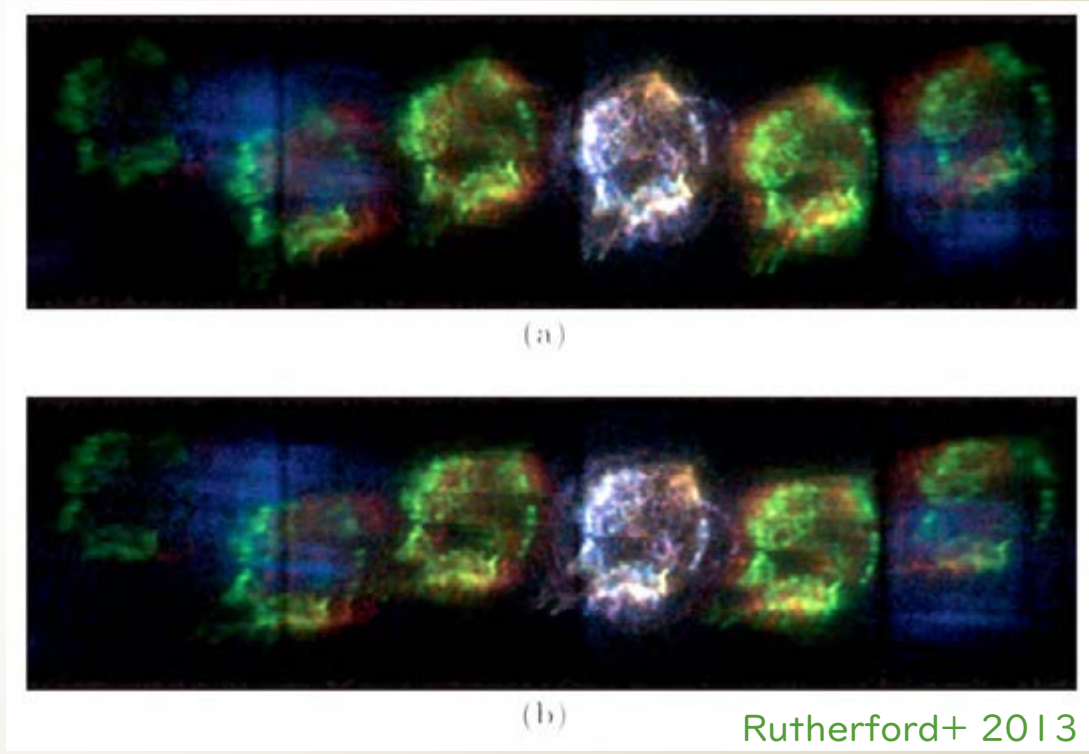
2. Spatially-resolved high-resolution X-ray spectra

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



Position ←→ Energy (wavelength)

Grating Image of Cas A with different roll angles



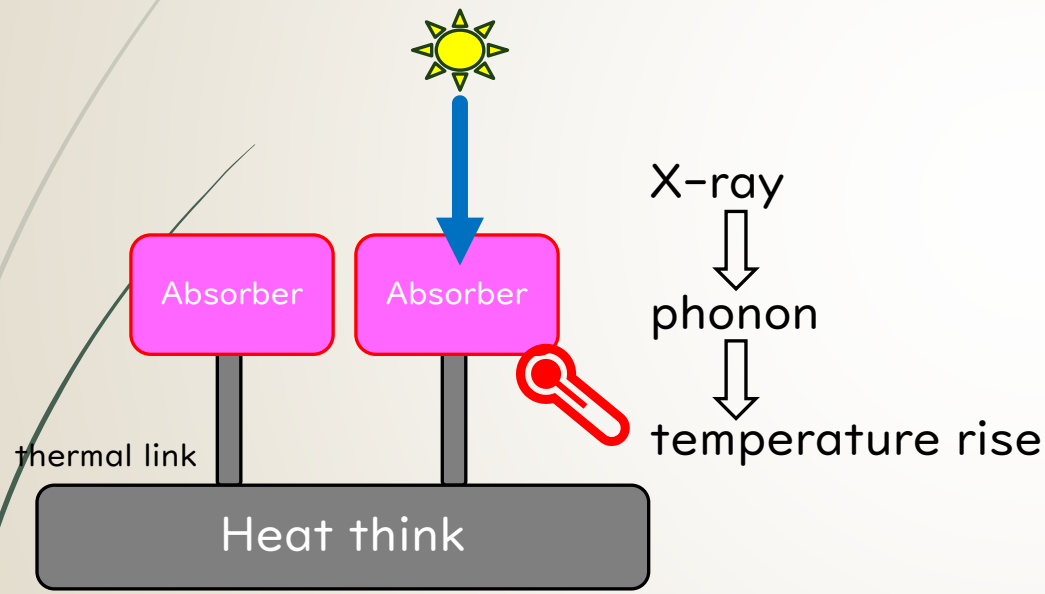
Rutherford+ 2013

Grating optics : in principle, energy and spatial information are mixed.

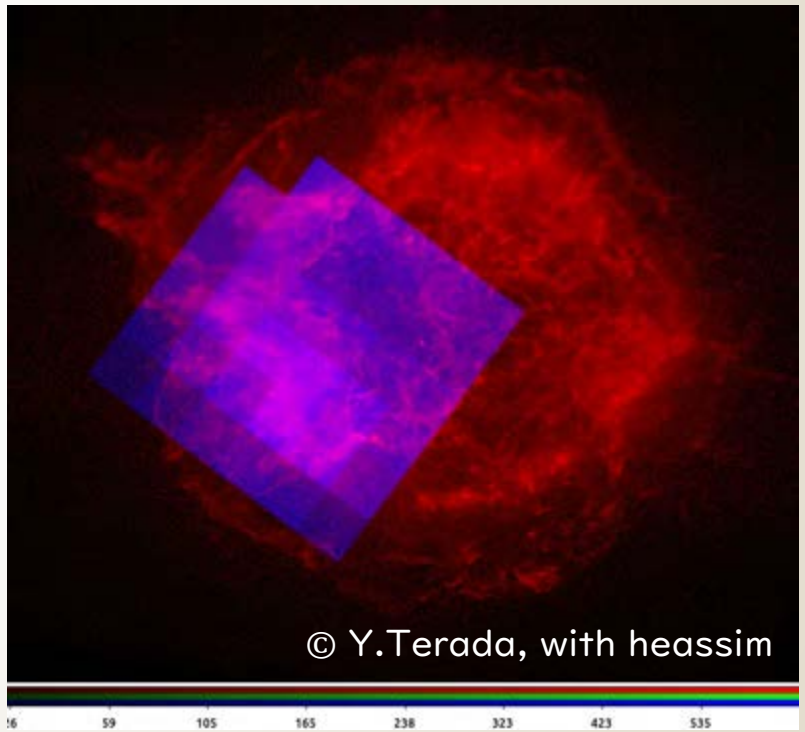
1.3 What XRISM can measure ? (cont.)

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

XRISM/Resolve is the non-dispersive optics.



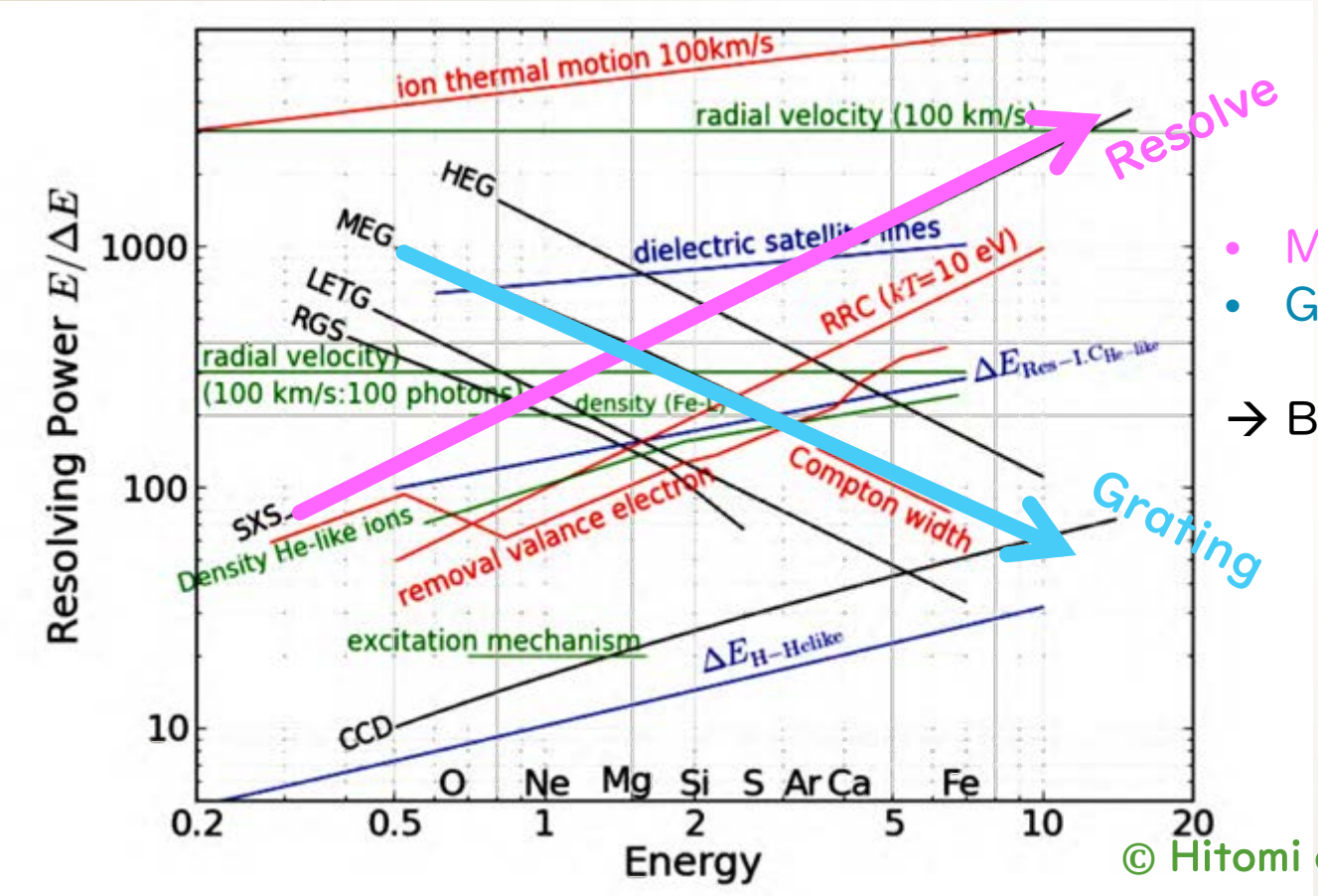
Cas A simulation (Blue: XRISM Resolve, Red: Chandra)



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

I.3 What XRISM can measure ? (cont.)

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 formation of the Universe and evolution of clusters of galaxies**
   - i. Reveal spatial distribution and their dissipation of thermal and non-thermal energy of the largest gravitationally bounded system -clusters of galaxies -
   - ii. Directly observe sites of their growth mechanism from both thermo-dynamic 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 by 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 of plasma diagnostics, and measurements of velocity and gravitational redshift shown in spectra of materials around relativistic objects to pioneer new horizon of 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

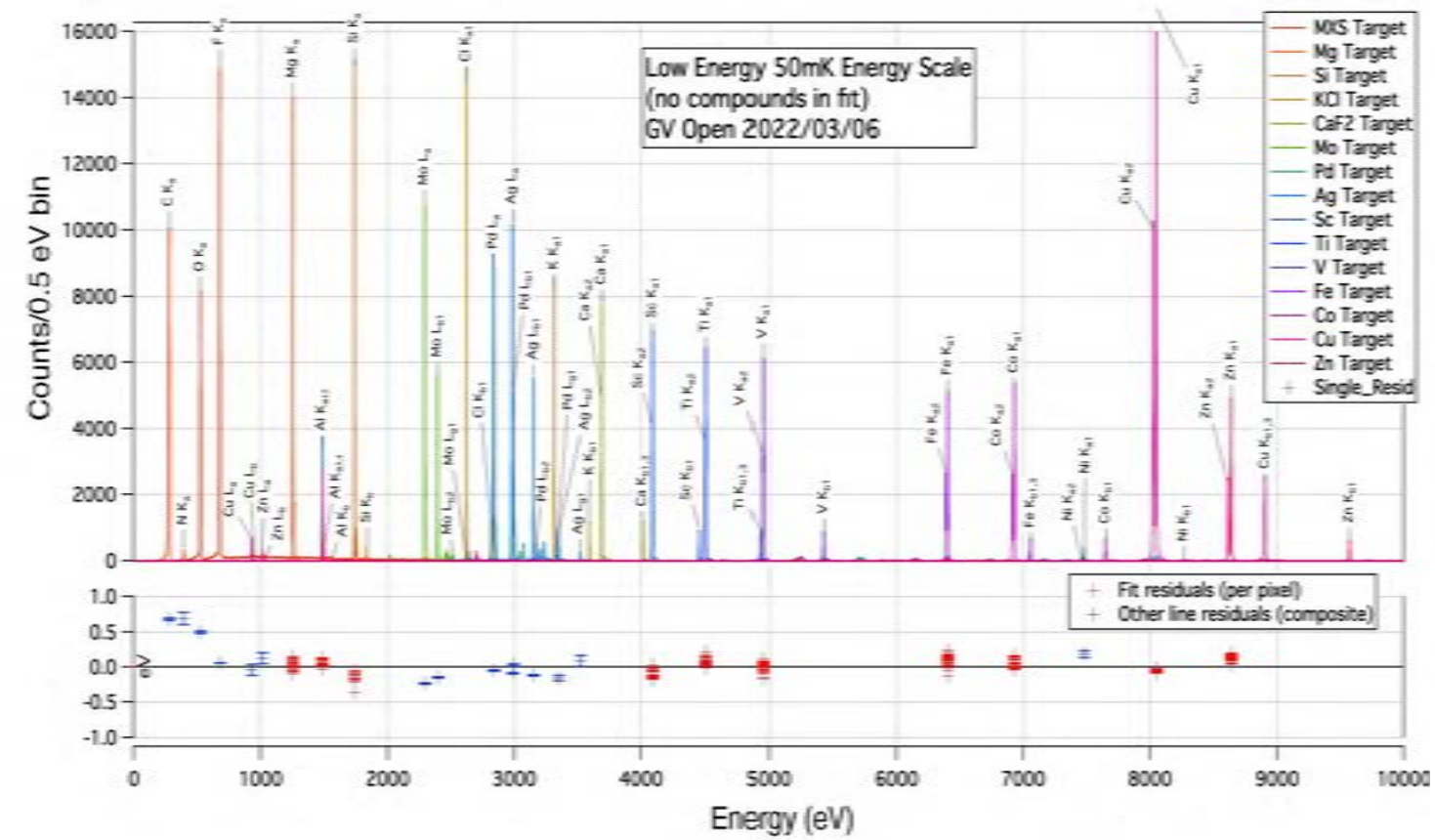
Ship to TNSC

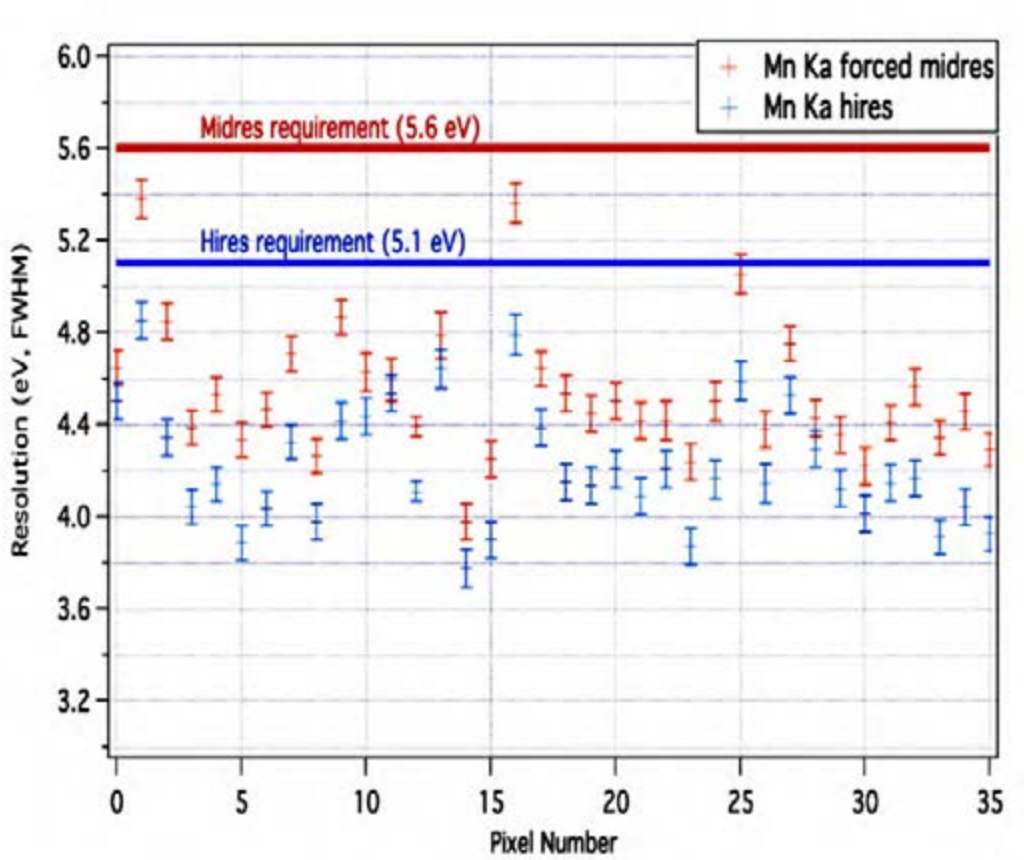
Thermal Vacuum test @TKSC

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 campaign at TNSC in 2023

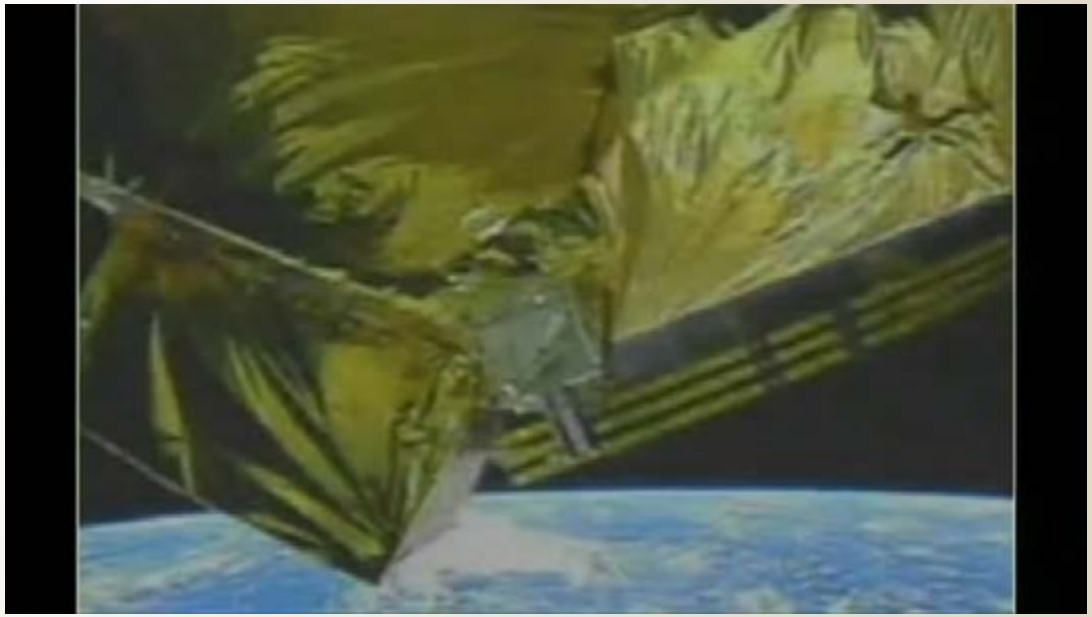
↓Recovered last weekend!!

Spacecraft was ready in Mar 2023 (Launch was delayed due to failure of the 2nd stage of HIII rocket).

Launch on 7 Sep 2023

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

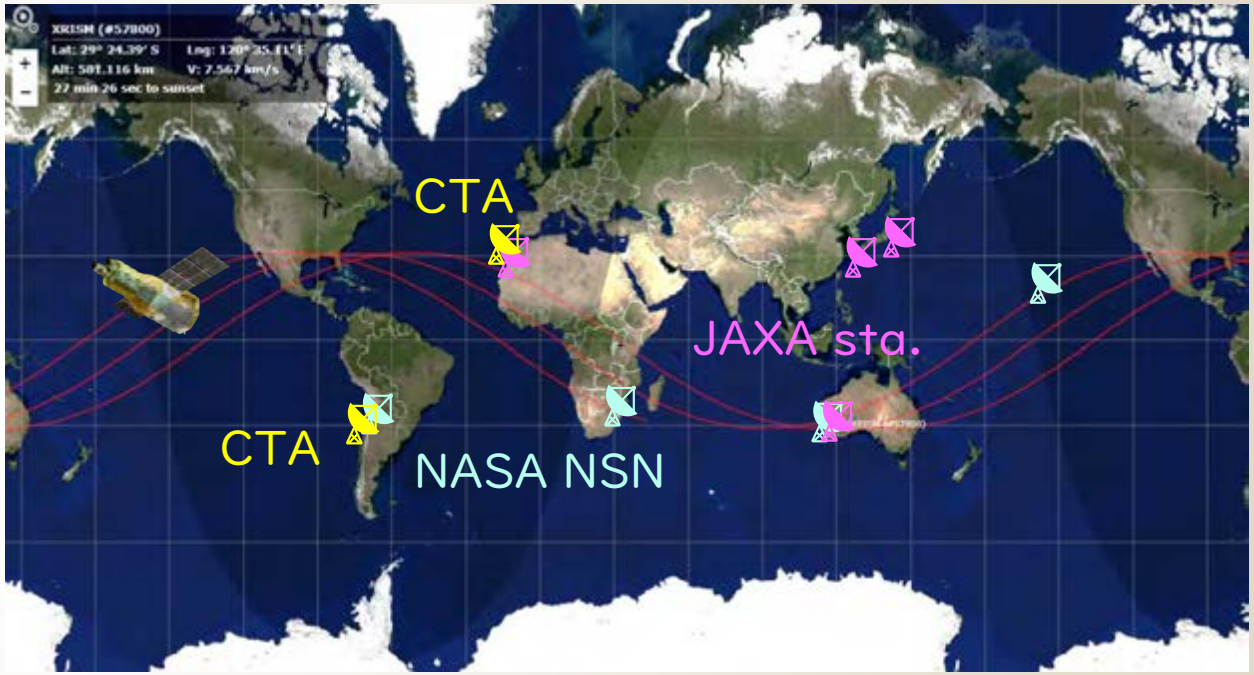
2023.9.7 8:56JST, Satellite separation



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

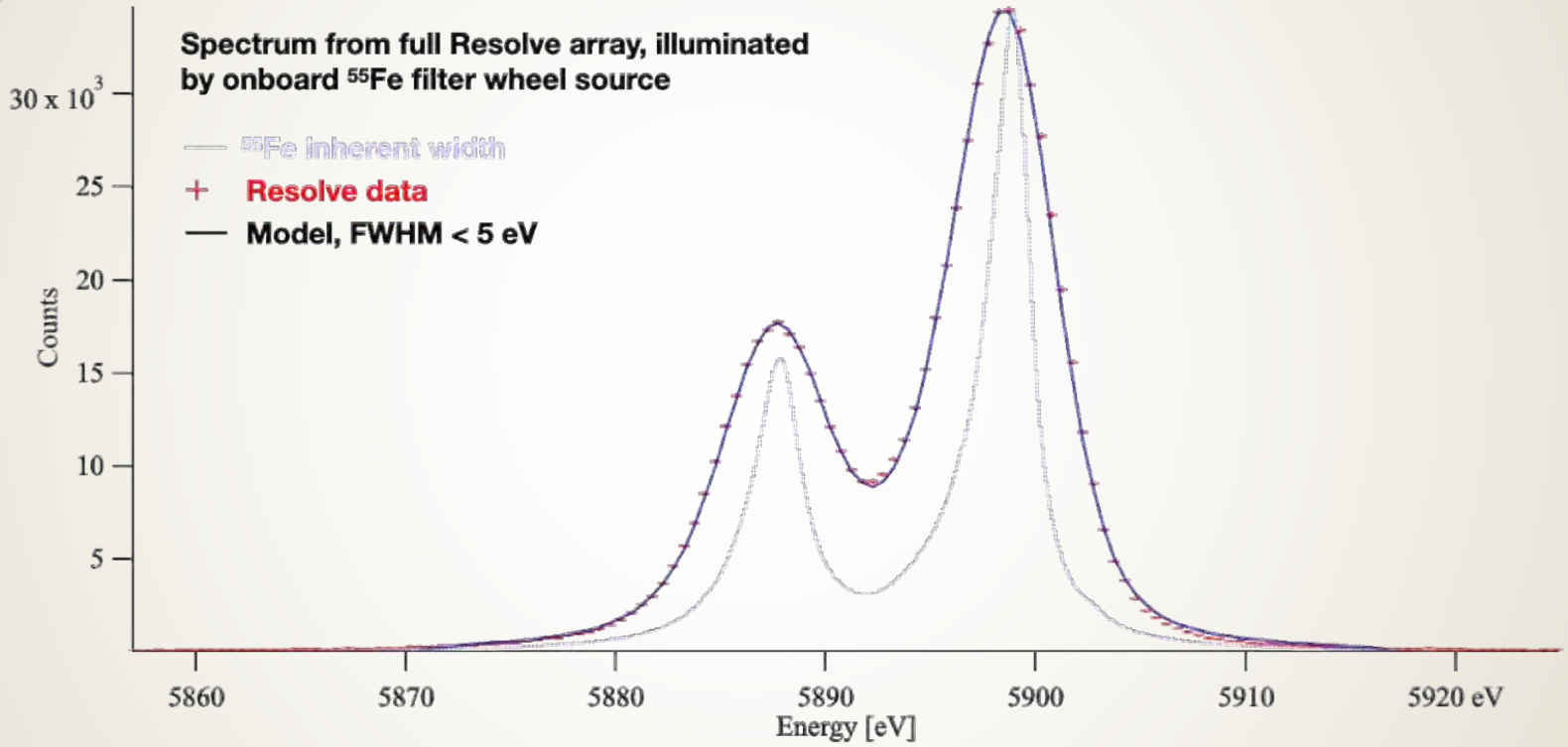
2023.10.9 Resolve 50mK achieved

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



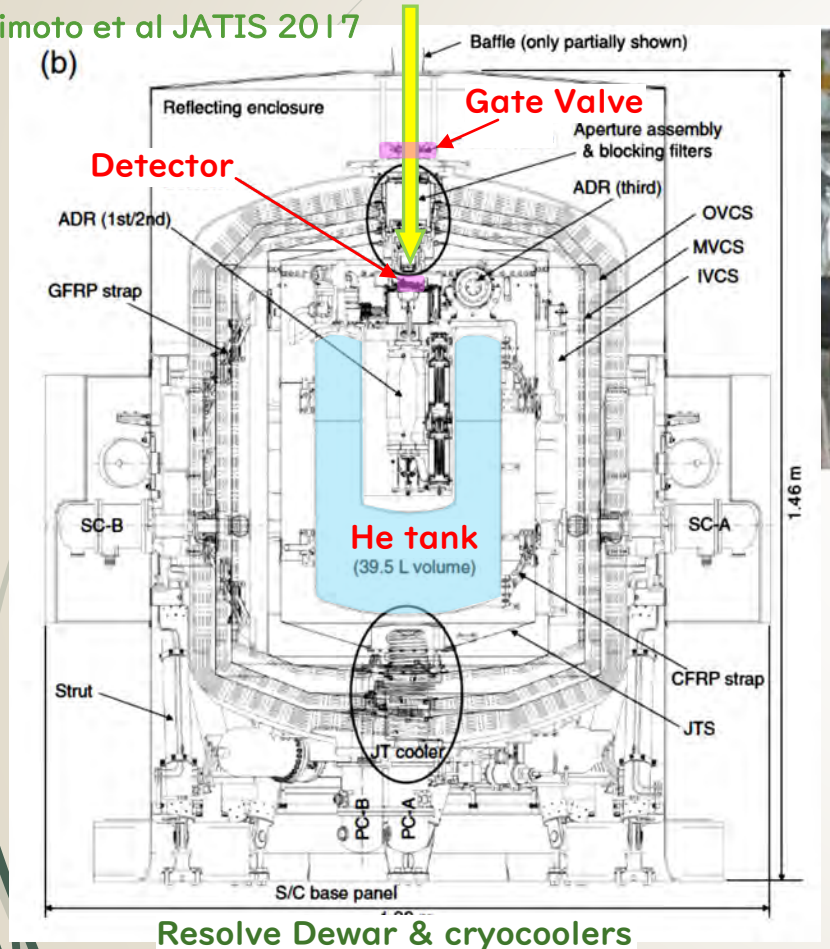
Energy Resolution < 5 eV in orbit !!
Of course, this is within the requirement on the energy resolution.

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

Commissioning Operations (cont.)

2023.11 ~ Resolve Gate Valve Open operation - on going

Fujimoto et al JATIS 2017



Resolve Dewar & cryocoolers

Midooka et al JATIS 2021

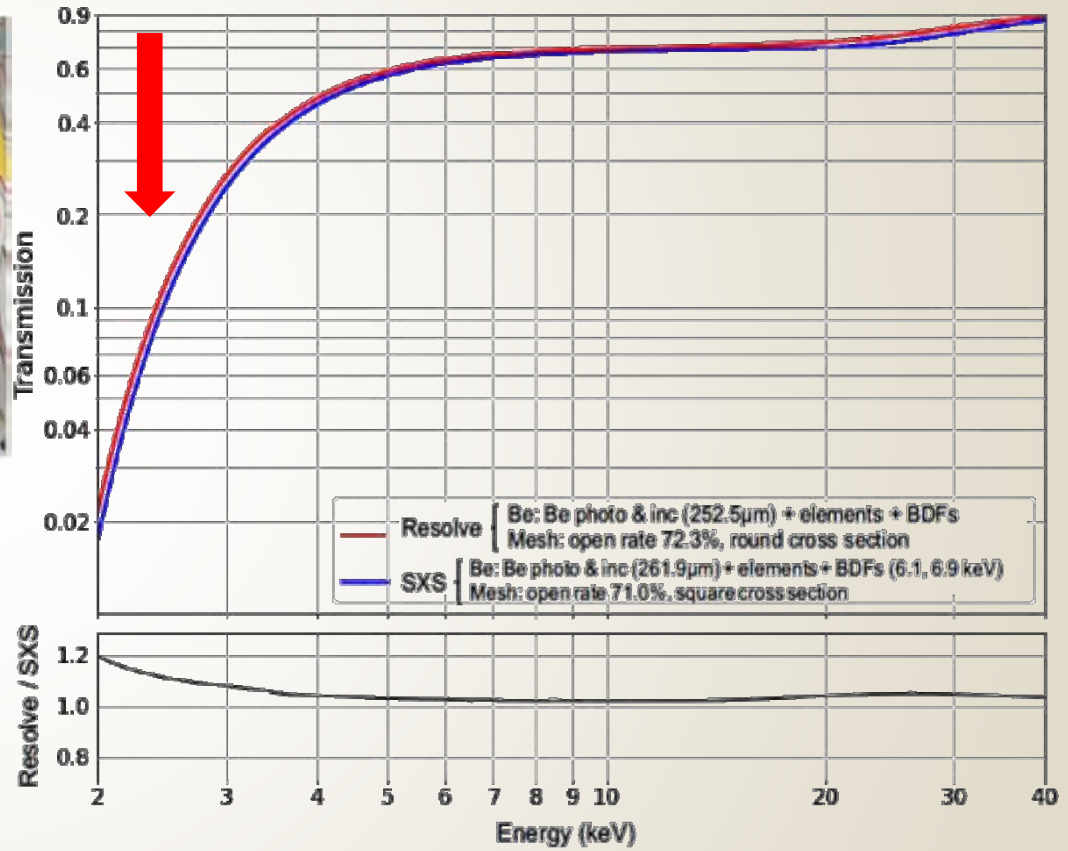
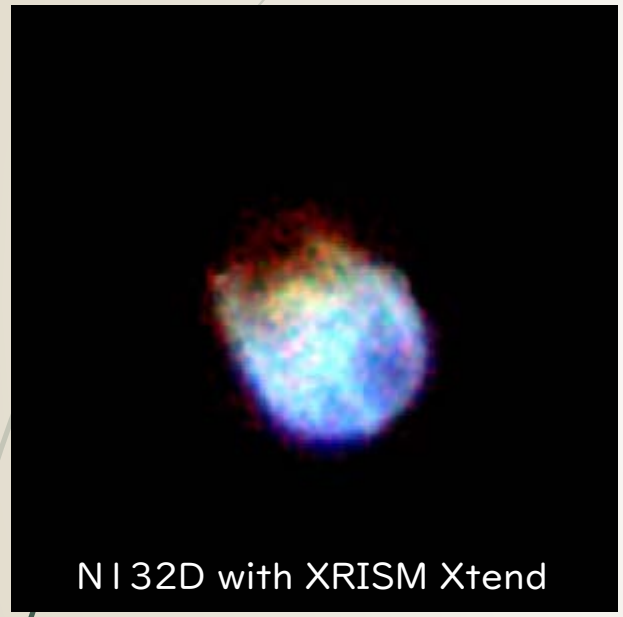


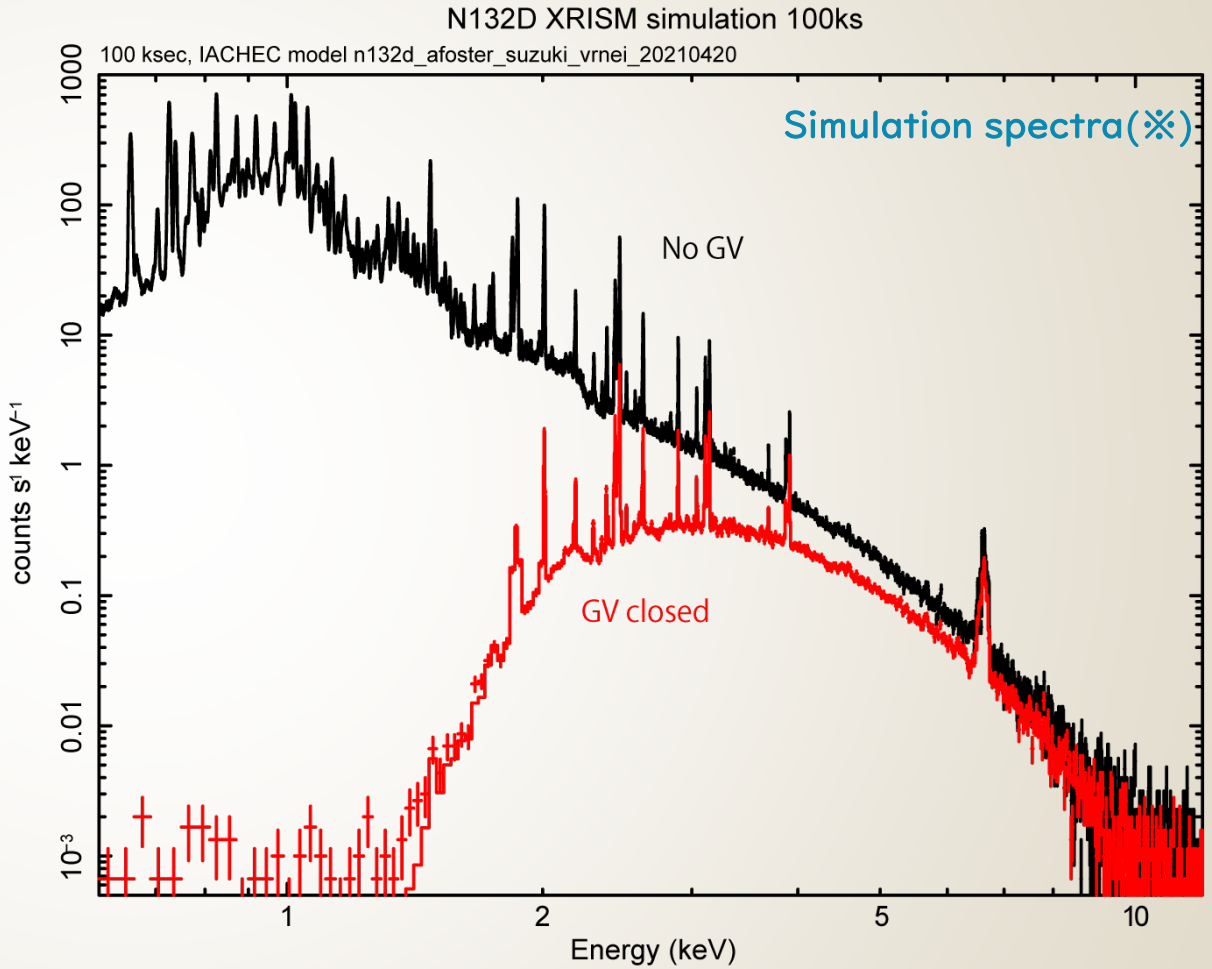
Fig 13 Comparison of the best-fit transmission models between the *Resolve* (red; this work) and the SXS (blue; CALDB ver. 20160606).

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 →





※ 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 !

Commissioning : Preparation for Science Operations

Science Operations

- Guest Observatory Program
- Observation Planning
- In-orbit calibration of instruments
- Telemetry data conversion & data calibration
- Analyses software release
- Data distribution to users / archive
- Users' support / helpdesk

✓ Preparation starts from the ground!
✓ International collaboration between JAXA&NASA.

→ Final check was completed during commissioning phase.

Ready for Nominal Operation phase.

2023.12.13 Science Operations Team, f2f meeting

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 fulfil 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

Some are dropped in GVC

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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	

Please check your favorite objects !

Collaboration during Nominal phase (PV/Cal period)

1. **Performance verification and Science discussion**
   - XRISM Science members will check the performance and science using PV (with XRISM Guest Scientists & with their PDs).
   - The output will be summarized in science paper.
   - Welcome to join the science discussion, if you are interested in ! (however, the access to the X-ray event data is not permitted)

2. **Instrument Calibration**
   - XRISM Science members perform the in-orbit calibration using PV and calibration targets.
   - The results will be public as the calibration database (CALDB), used in the analysis software.

   - International collaboration with other X-ray observatories, such as Chandra, XMM-Newton, NICER, NuSTAR, Astrosat, MAXI, Swift, INTEGRAL, Insight-HXMT, etc, under IACHEC.

Collaboration !

Guest Observation Program

- Now, Open for GO Proposal (due: 4 April 2024).
  - Call for observation starts from 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 your 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

Science Enhancement Program

JSPS core-to-core program since 2022

- Matching fund between Japan, US, and ESA
  - Saitama U/JAXA, Dr. Yukikatsu Terada
  - NASA/GSFC, Dr. WILLIAMS J. Brian
  - ESA/ESTEC, Dr. GUAINAZZI Matteo

- ☐ Funding support on Science outputs
  - Supporting travel fee to the conference on XRISM presentations.
  - Supporting paper submission fee on XRISM science and calibration.
- ☐ Young researchers' education program (long stay in US/EU)
- ☐ Organization of XRISM Science Workshop

Welcome to join this activity and enjoy XRISM data!

Thank you.