

The ASTRO-H project



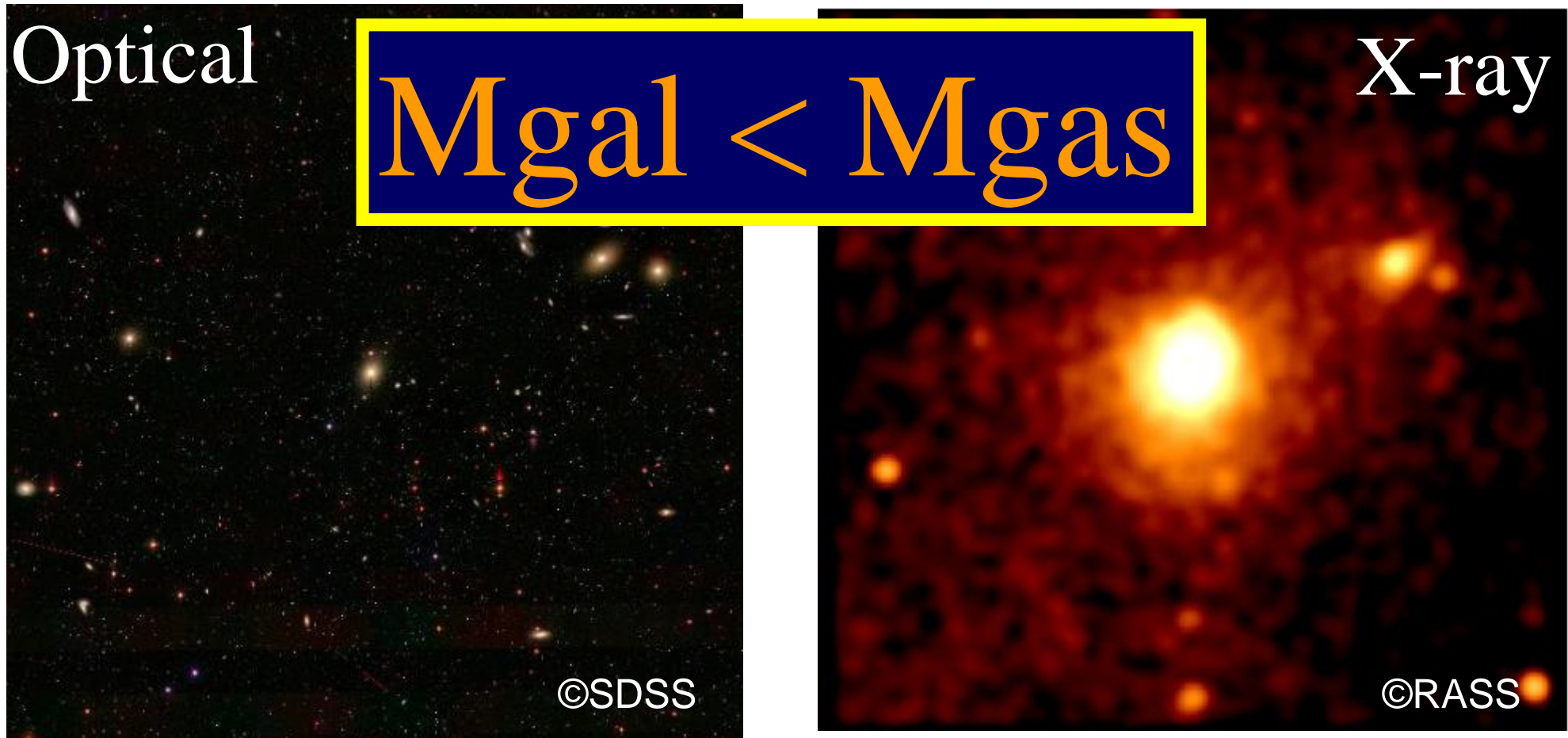
Hironori MATSUMOTO (Nagoya University)

On behalf of the ASTRO-H team

Outline

- ASTRO-H System
 - Precise Soft X-ray Spectroscopy
 - Soft X-ray Telescope (SXT) + Soft X-ray Spectrometer (SXS)
 - Hard X-ray Imaging system
 - Hard X-ray Telescope (HXT) + Hard X-ray Imager (HXI)
 - Soft Gamma-ray
 - Soft Gamma-ray Detector (SGD)
 - Soft X-ray Imaging
 - SXT + Soft X-ray Imager (SXI)
- Athena project
- Summary

X-ray Universe



Cluster of galaxies

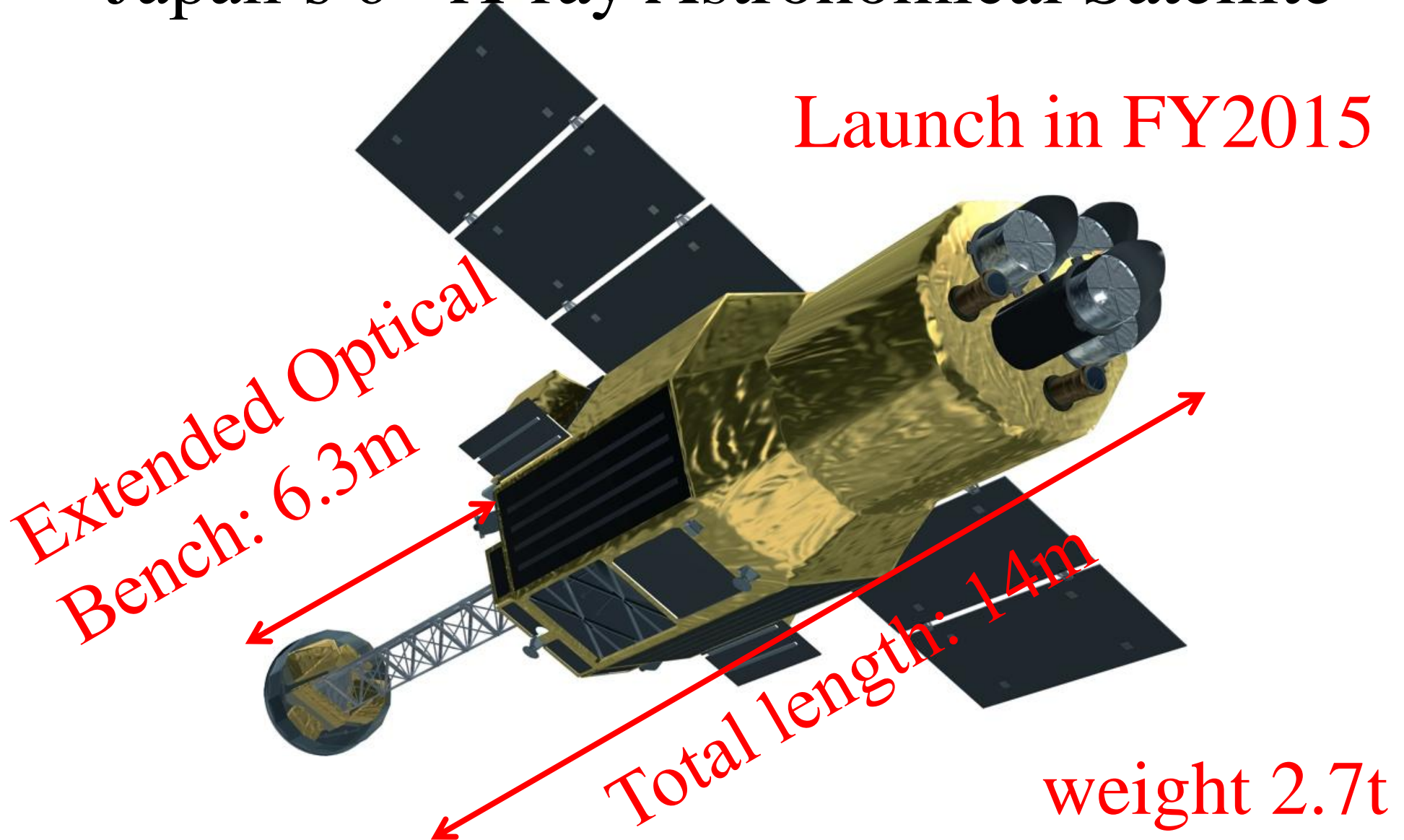
hot gas

We would overlook real face without X-rays.

ASTRO-H Satellite

Japan's 6th X-ray Astronomical Satellite

Launch in FY2015



International collaboration

More than 160 scientists from Japan/USA/Europe



JAXA
NASA
Aoyama Gakuin U.
U. of Cambridge
CEA/DSM/IRFU
CfA/Harvard
Chubu U.
Chuo U.
Columbia U.
CSA
Dublin Institute for
Advanced Studies
Durham U.
Ehime U.
ESA
U. of Geneva
Gunma Astronomical
Observatory
Hiroshima U.
JHU

Kanazawa U.
Kochi U. of Tech.
Kobe U.
Kogakuin U.
Kyoto U.
LLNL
U. of Manitoba
U. of Maryland
Miami U.
U. of Michigan
MIT
U. of Miyazaki
Nagoya U.
Nara Women's U.
Nihon Fukushi U.
Nihon U.
NIMS
Osaka U.
RIKEN
Rikkyo U.

Rutgers U.
Saint Mary's U.
Saitama U.
Shibaura Inst. Tech.
SRON
Stanford U./KIPAC
STScI
Toho U.
Tokyo Inst. Tech
Tokyo
Metropolitan U.
Tokyo U. of Sci.
U. of Tokyo
U. of Tsukuba
Waseda U.
U. of Waterloo
U. of Wisconsin
Yale U.

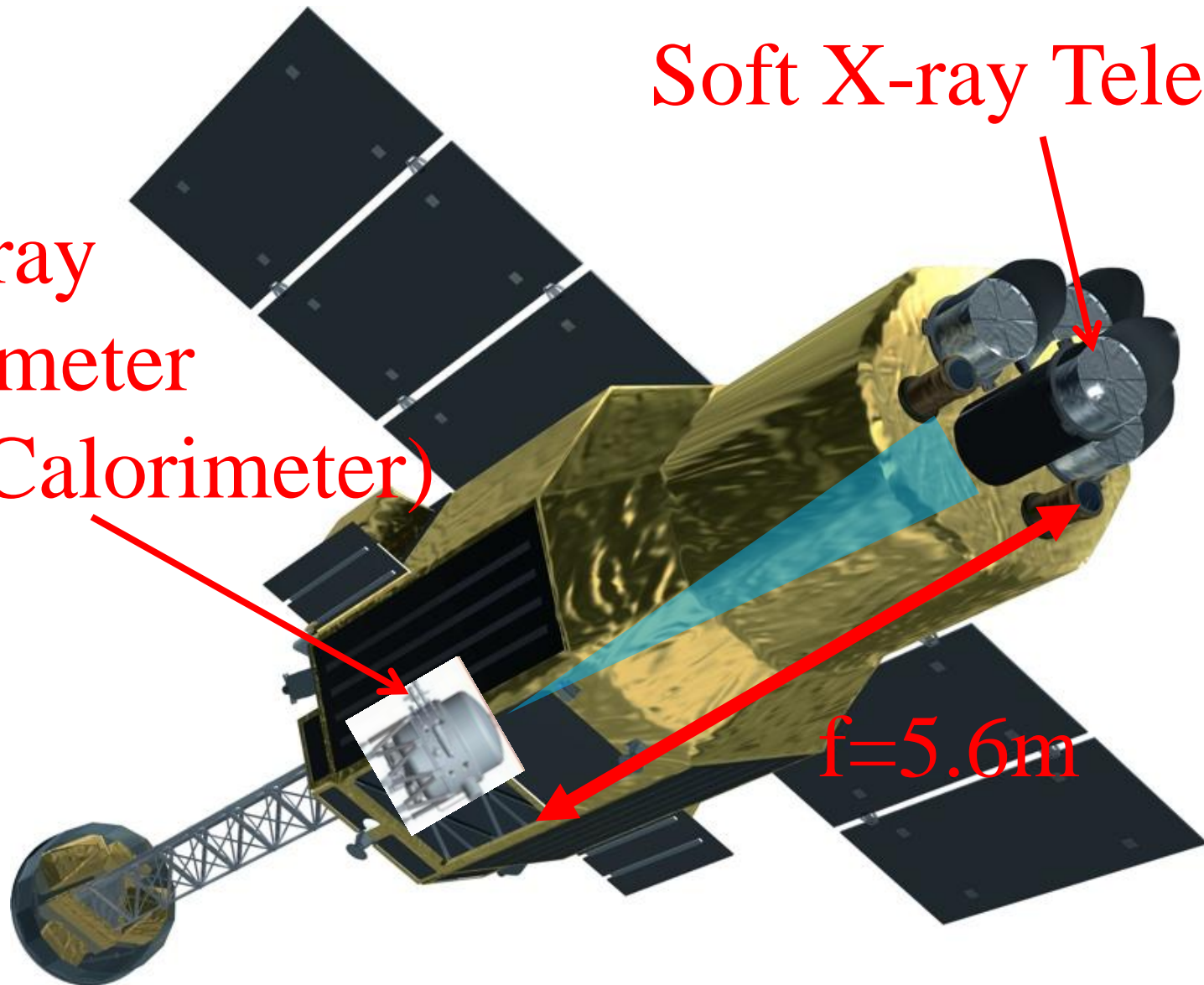


2011.7.18

SXT + SXS (0.3—12keV)

Soft X-ray Telescope

Soft X-ray
Spectrometer
(X-ray Calorimeter)



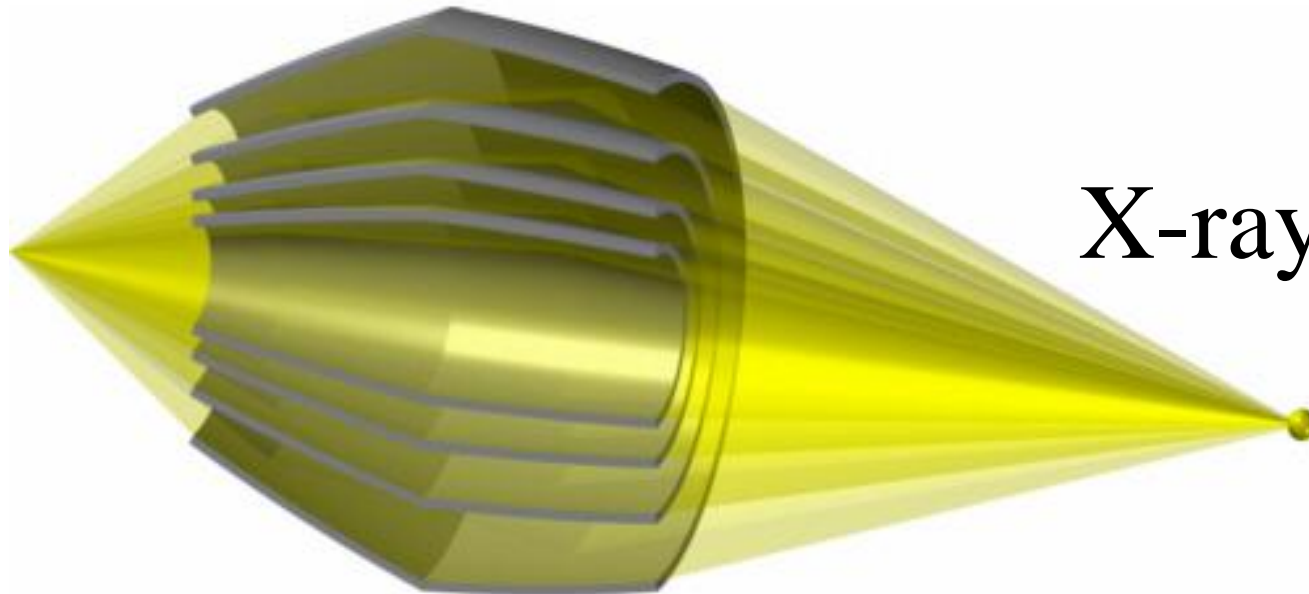
$f=5.6\text{m}$

Principle of X-ray Telescope

Wolter-I Grazing angle optics

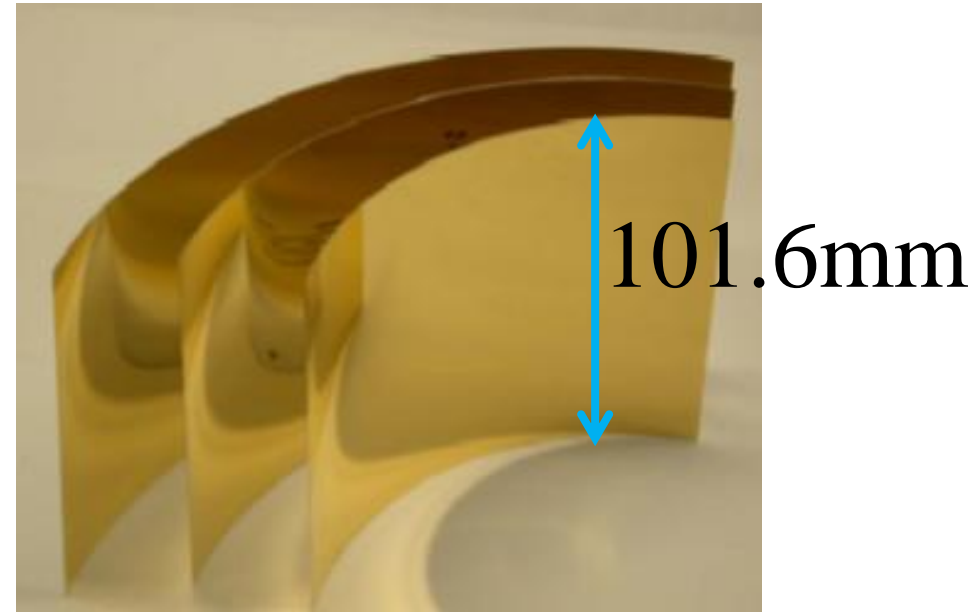
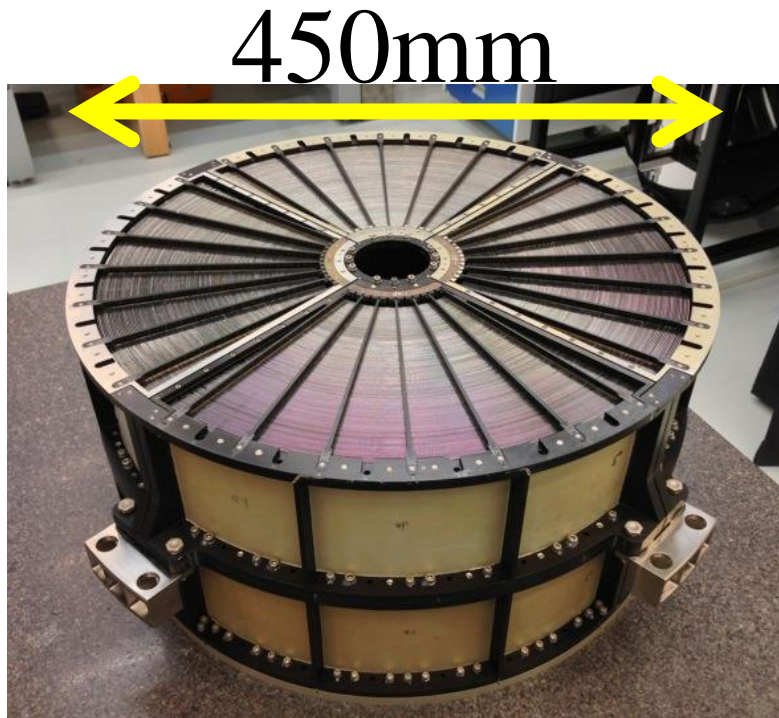
“Year ring” of foils

focus



X-ray source

Soft X-ray Telescope (SXT)



SXT-1 FM

203 nested shells

Au-coated Al foils

Total reflection

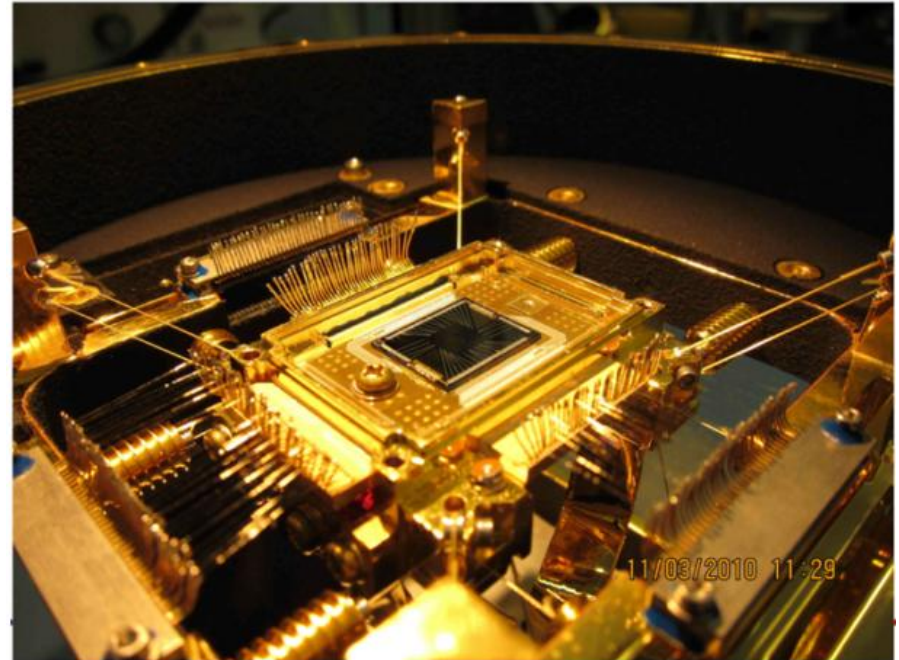
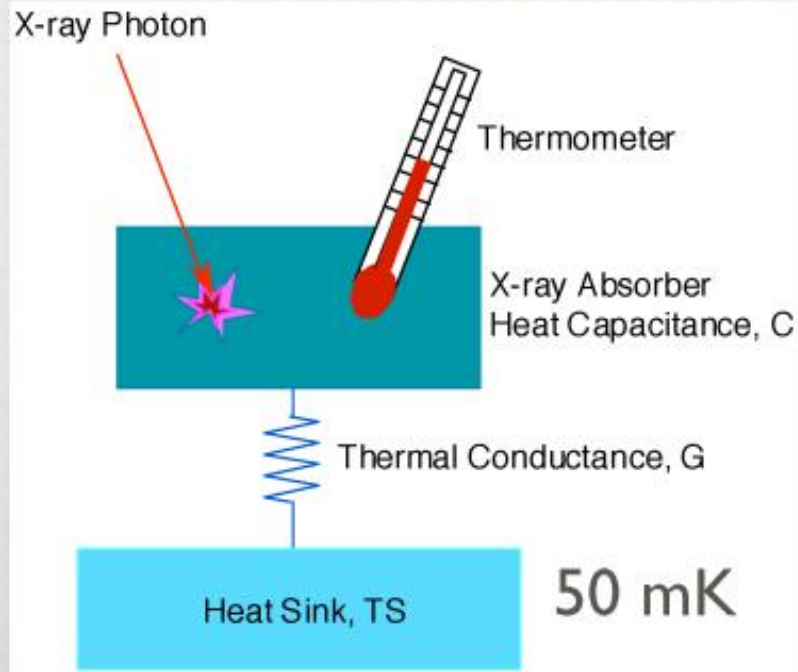
Angular resolution ~ 1.3'

Soft X-ray Spectrometer (SXS)

Microcalorimeters

High quantum efficiency

Imaging capability



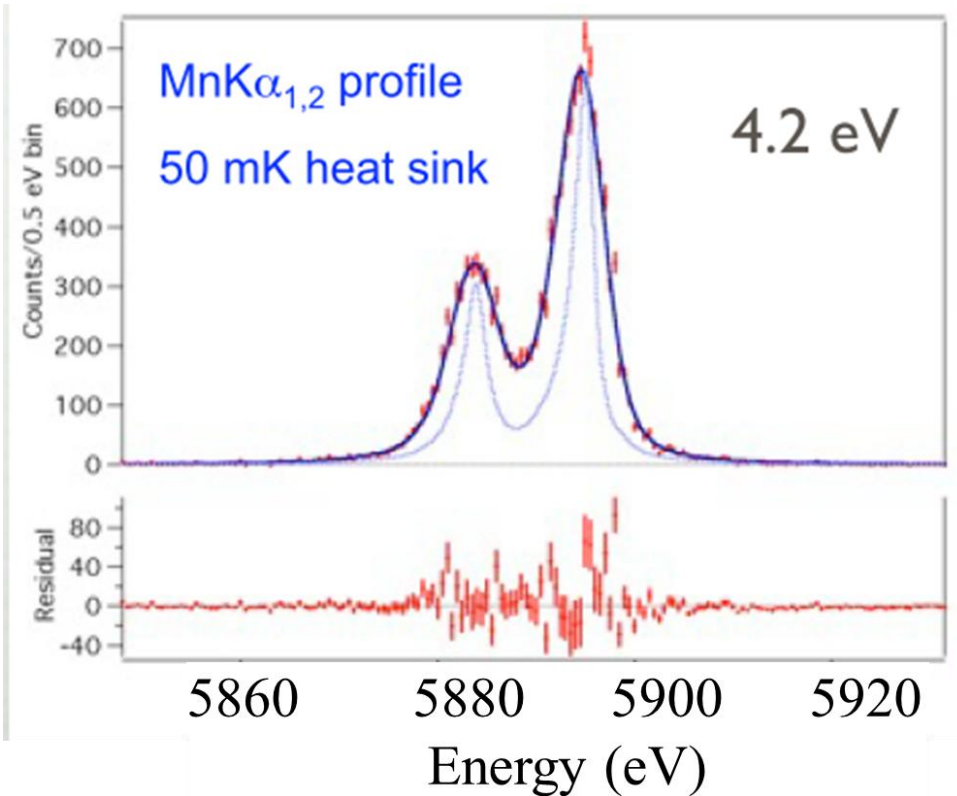
$$\Delta E < 7\text{eV}$$

(goal $< 4\text{eV}$)

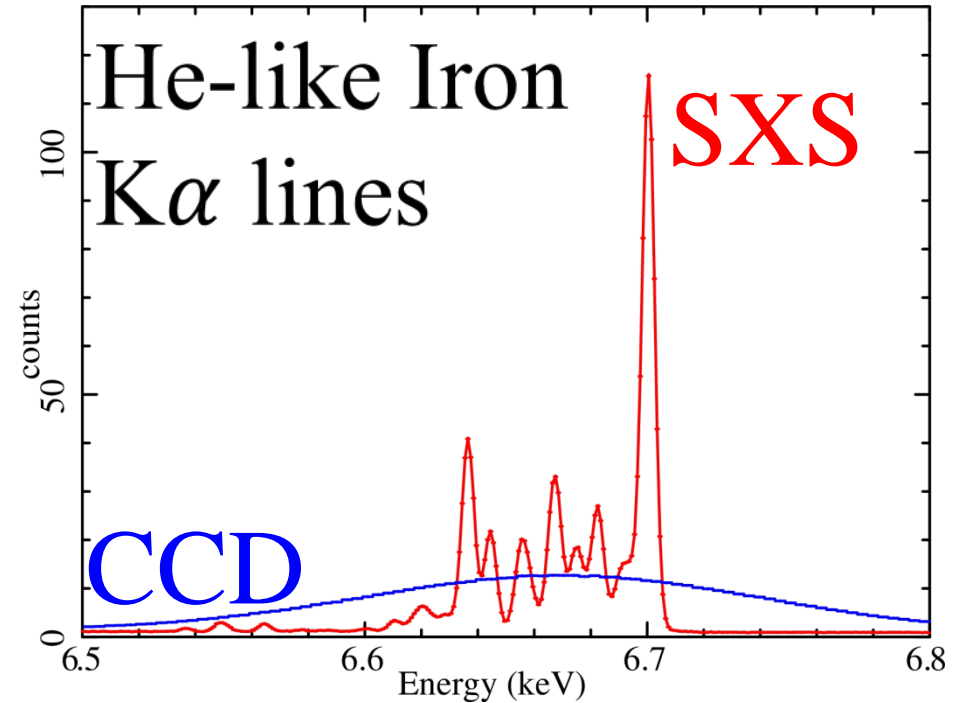
High-energy resolution even for spatially extended objects (cf. gratings)

SXS Energy resolution

Ground Experiment



Simulation



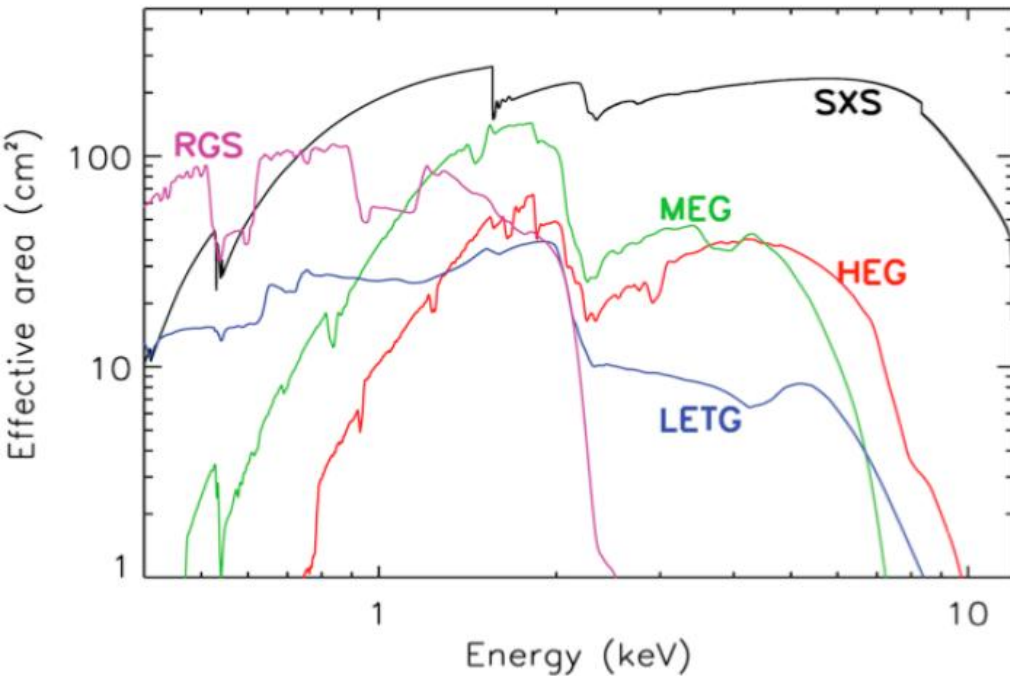
SXS can distinguish fine structures

→ Measure physical parameters of plasma directly.

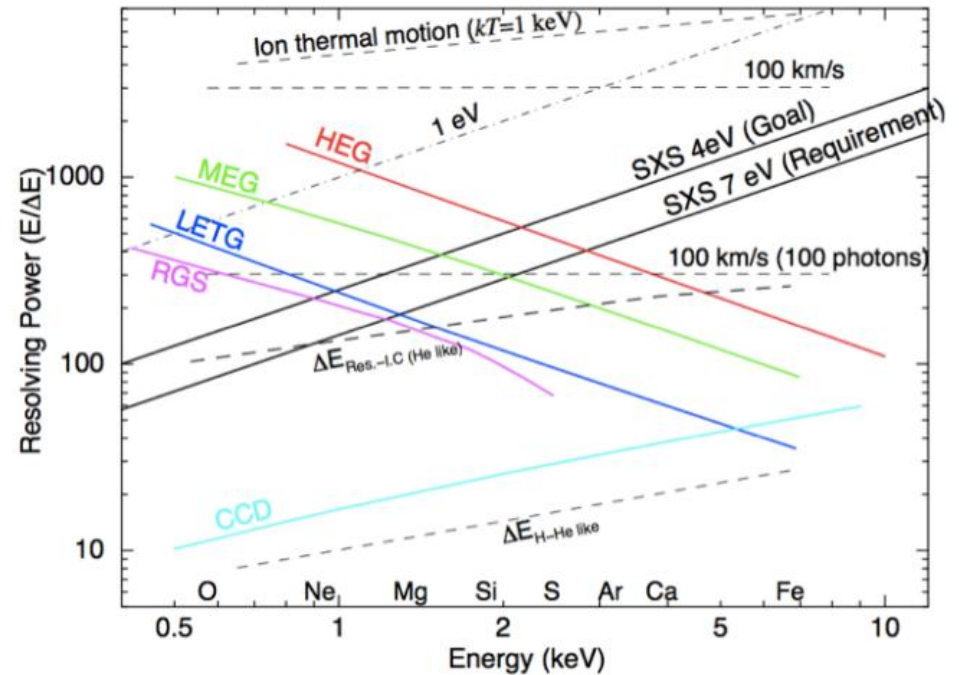
SXT+SXS vs other gratings

210cm²@6keV
for micro-calorimeter

Effective Area



E resolution



Good for dim objects & high-energy X-rays

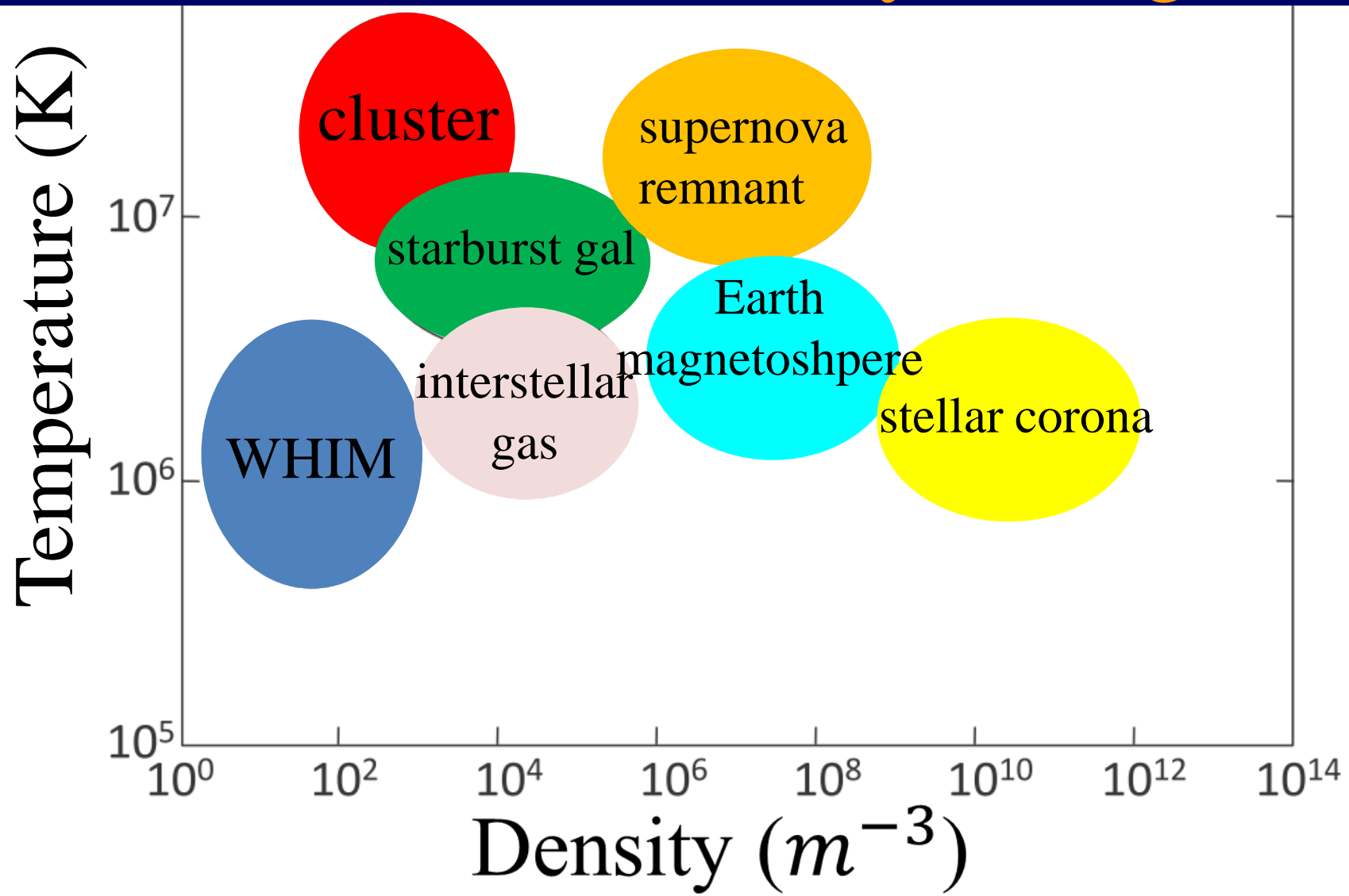
SXS+SXT

High-energy resolution
for spatially extended
objects for the first time!

Plasma spectroscopy!

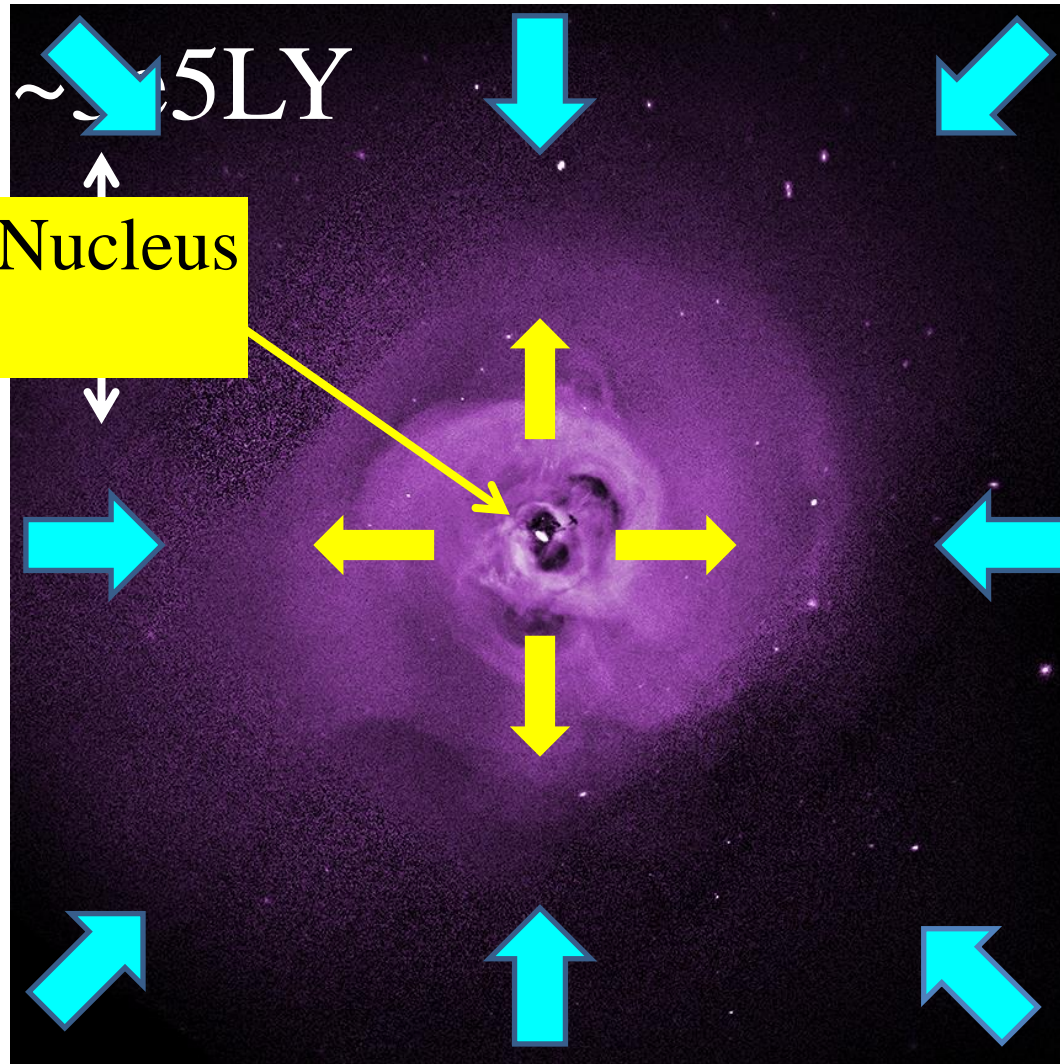
Plasma in the universe

Most can be observed only through X-rays



Perseus cluster

falling down
from outskirts

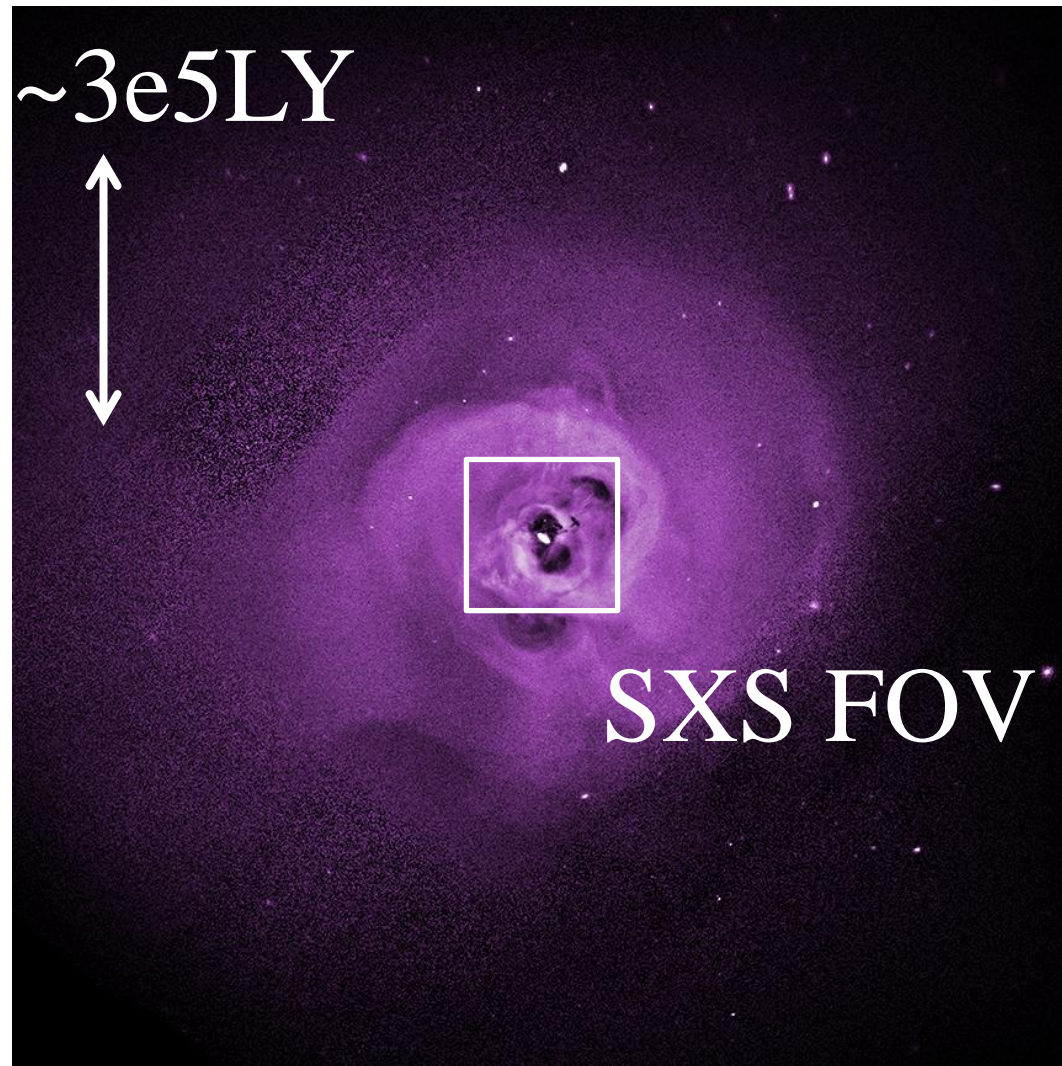


Active Galactic Nucleus
(Black hole)

Feedback
by jets etc.

How chaotic? How much energy stored?

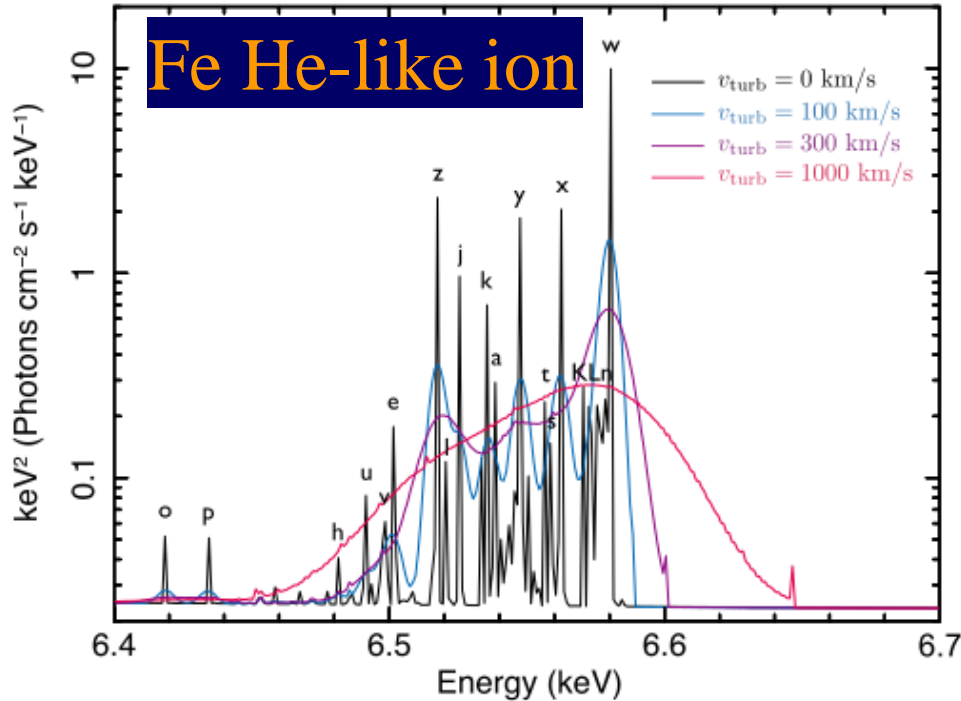
Perseus cluster



Reveal gas dynamics

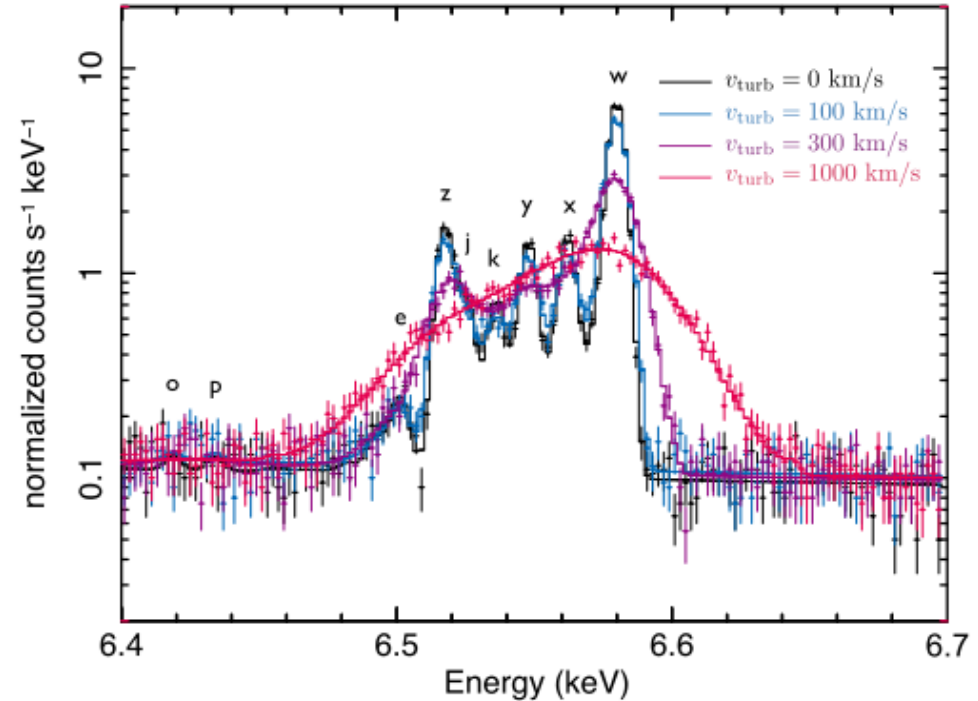
Theoretical model

Perseus model spectrum (wabs*bapec)



SXS simulation

Perseus simulated spectrum (wabs*bapec)



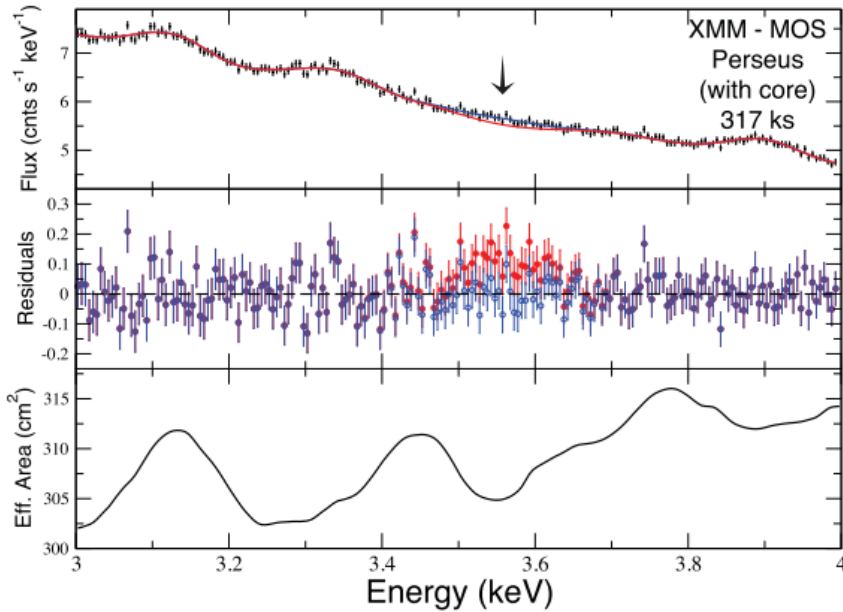
Line center → bulk motion

Line width → turbulence

Line ratio → temperature, density etc.

3.5keV Dark Matter line?

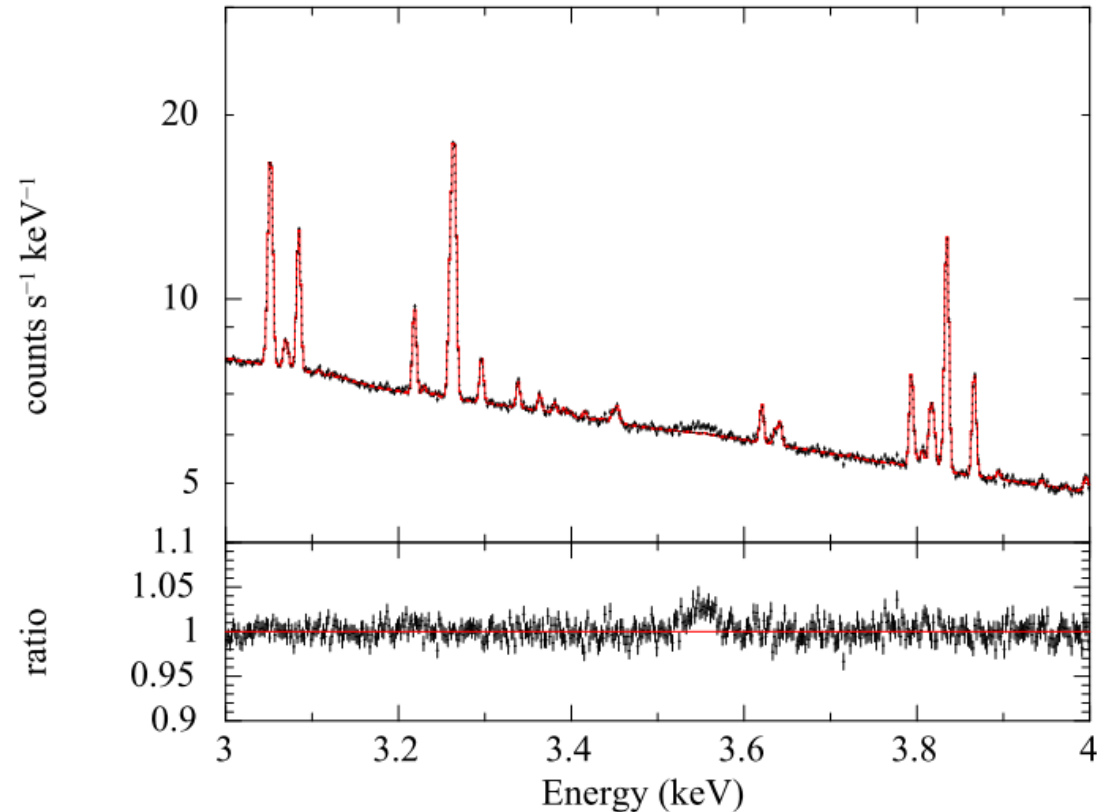
3.5keV line? DM?



Bulbul et al. 2014

SXS simulation

APEC(4keV)+Line(3.55keV, sigma=15eV), 1Msec

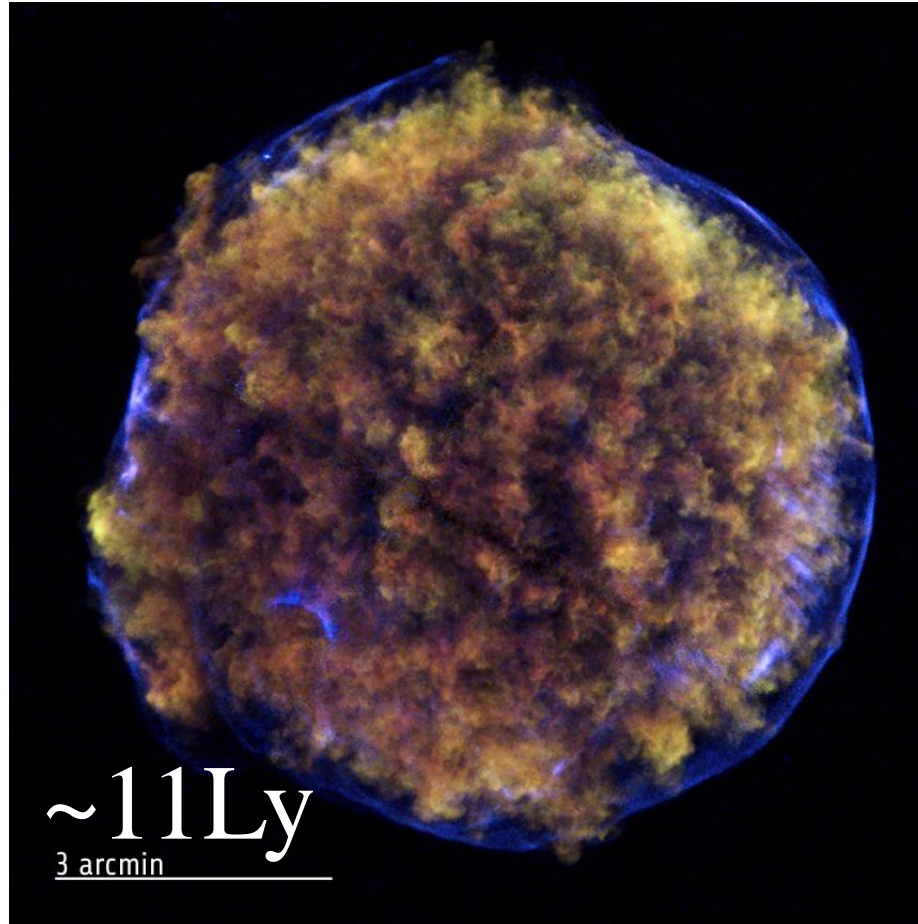


But no line was seen in Suzaku data
(Tamura et al. submitted to PASJ)

Supernova Remnant

Typically $E_{tot} \sim 10^{51}$ erg.

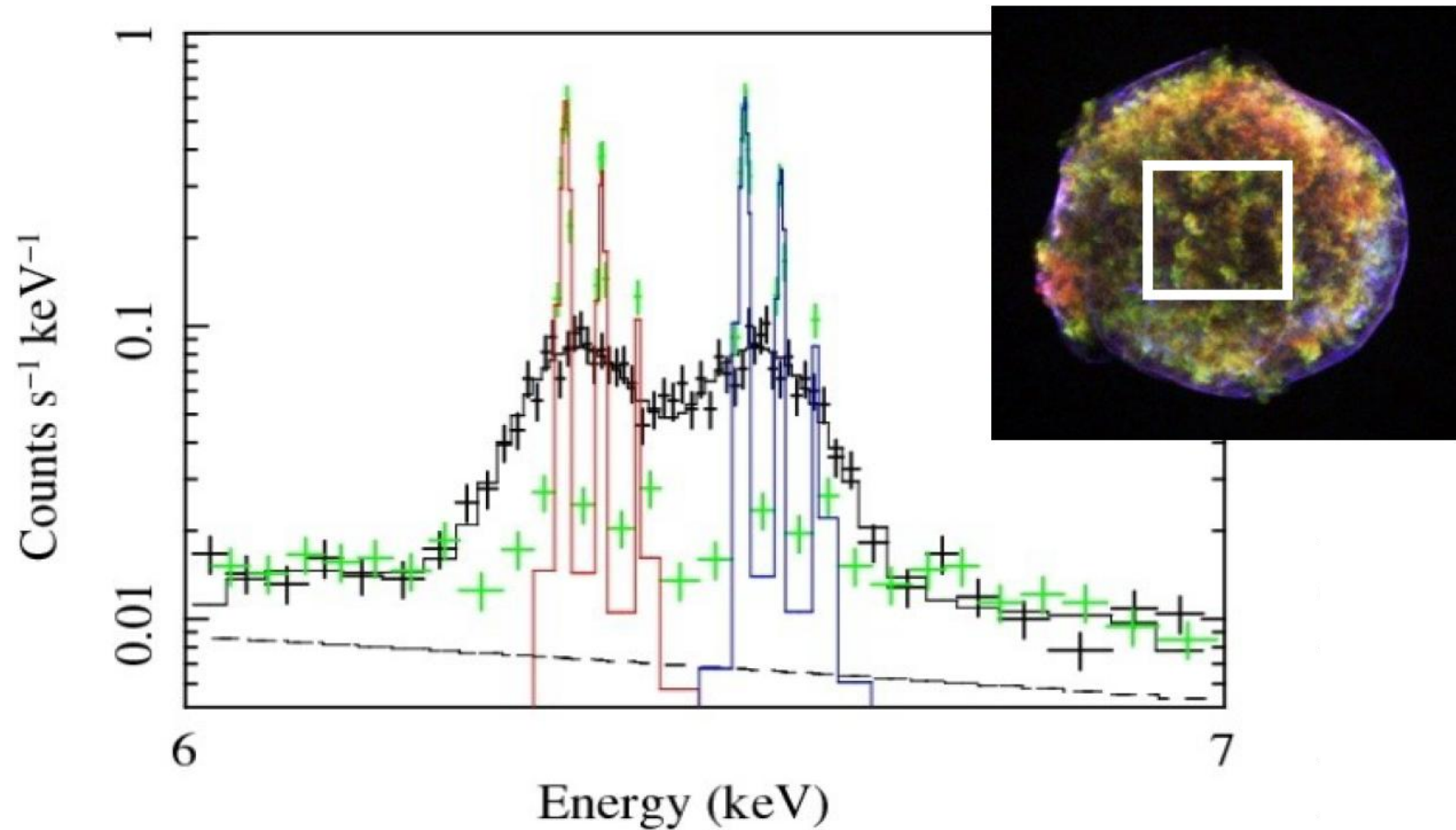
e.g. Tycho



Only emission from electrons can be seen. $E \sim 10^{49}$ erg
Where is the 99% of the total energy?

Energetics of supernova remnants

Tycho SNR center

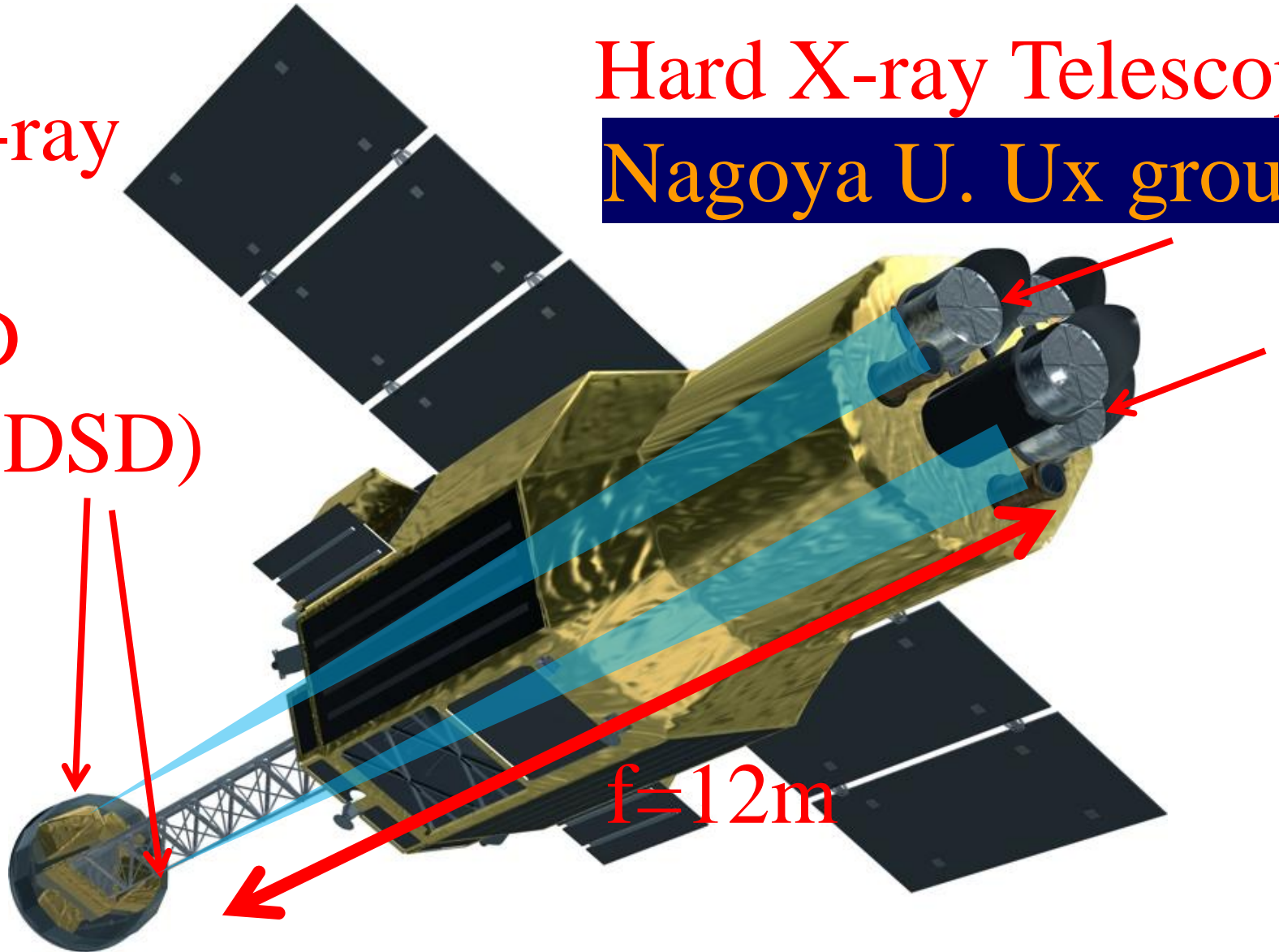


Ion expansion speed, temperature

HXT + HXI (5—80keV)

Hard X-ray Telescope
Nagoya U. Ux group

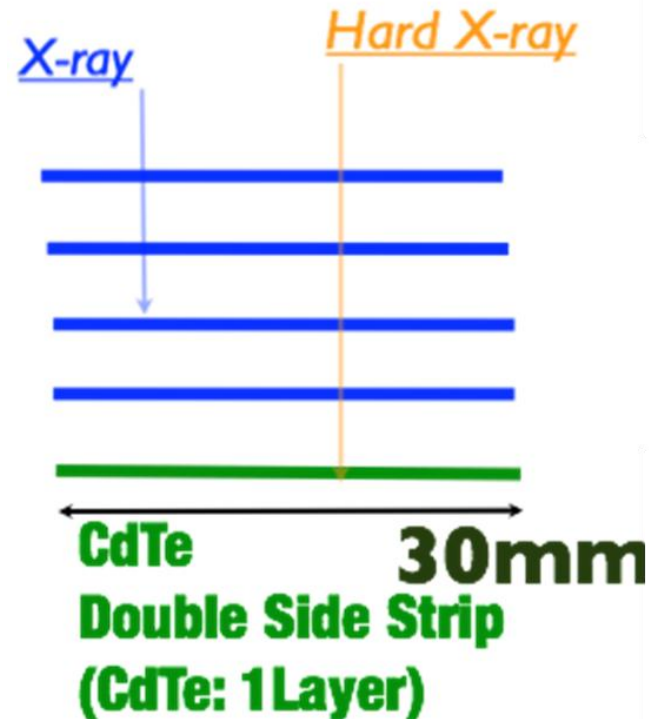
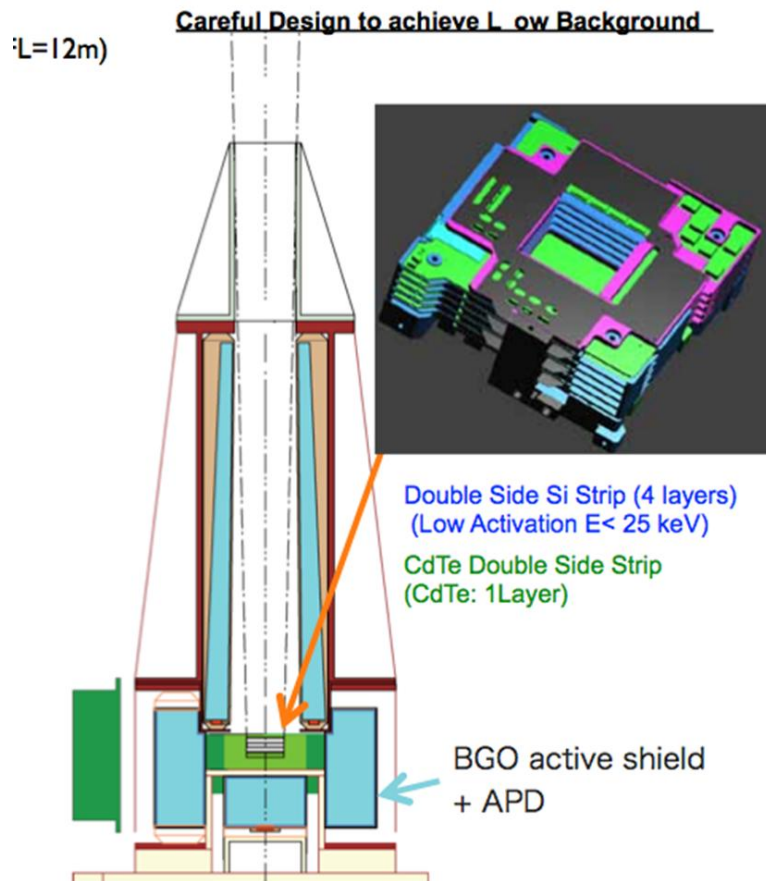
Hard X-ray
Imager
(Si DSD
+ CdTe DSD)



Hard X-ray Imager (HXI)

$E < 20 \text{ keV}$: Double-sided Si Strip Detector

$E > 20 \text{ keV}$: Double-sided CdTe Strip Detector



FOV: $9' \times 9'$

Hard X-ray Telescope

45cm



49cm



Thin-foil mirror (t0.22mm)

Pt/C multilayer

Bragg Reflection

E=5—80keV

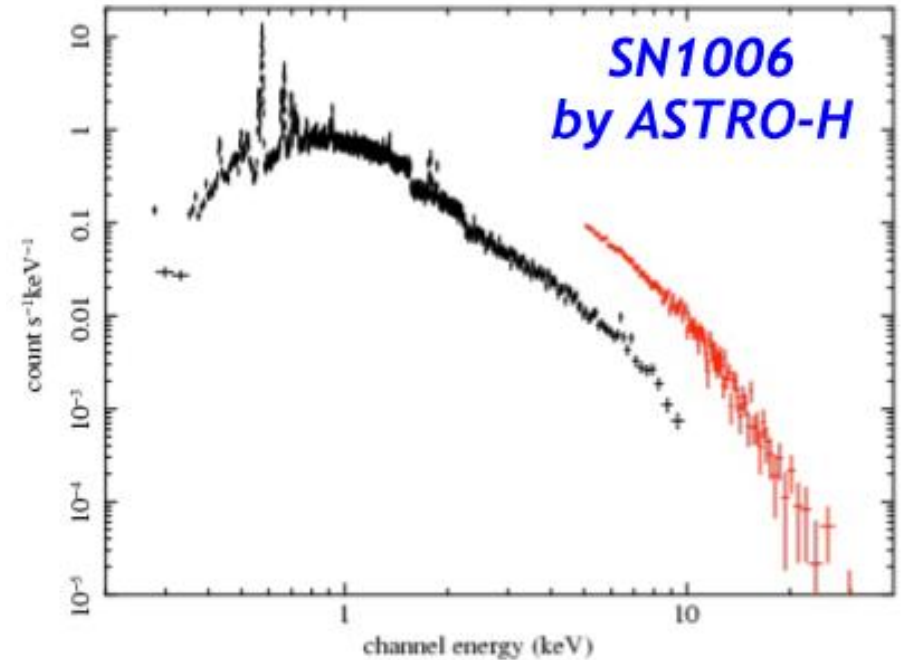
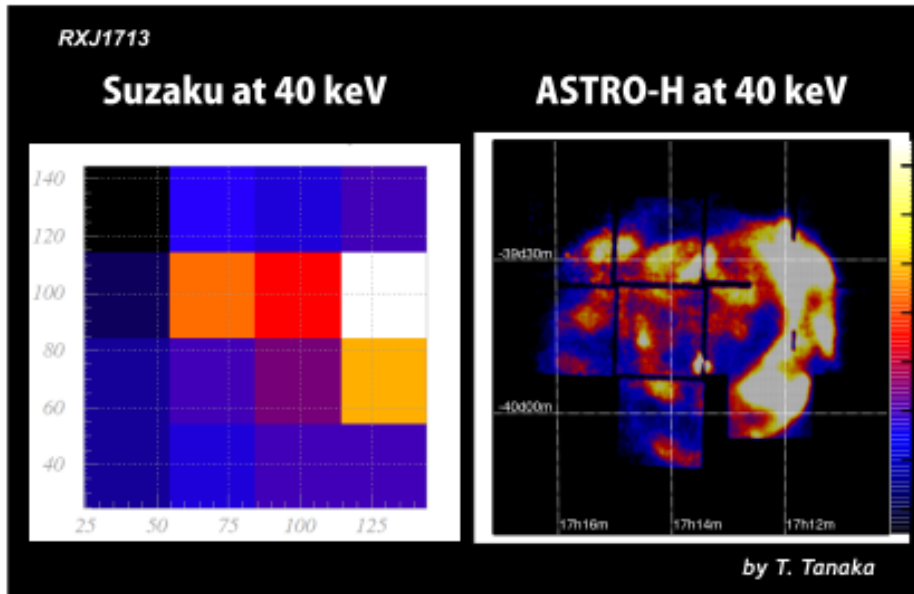
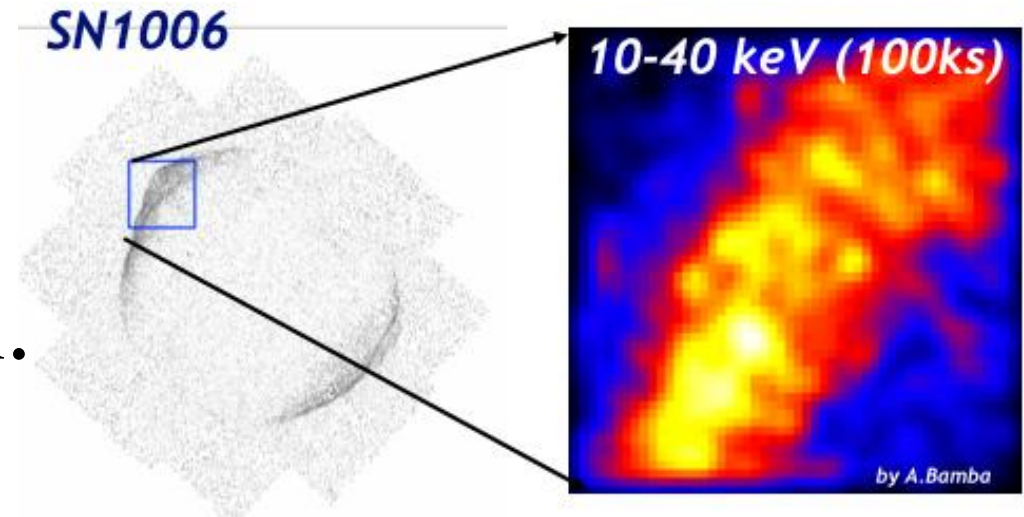
HXT-1 FM

213 nested shells

Ang. Res. ~ 1.9'

SNRs seen with HXI

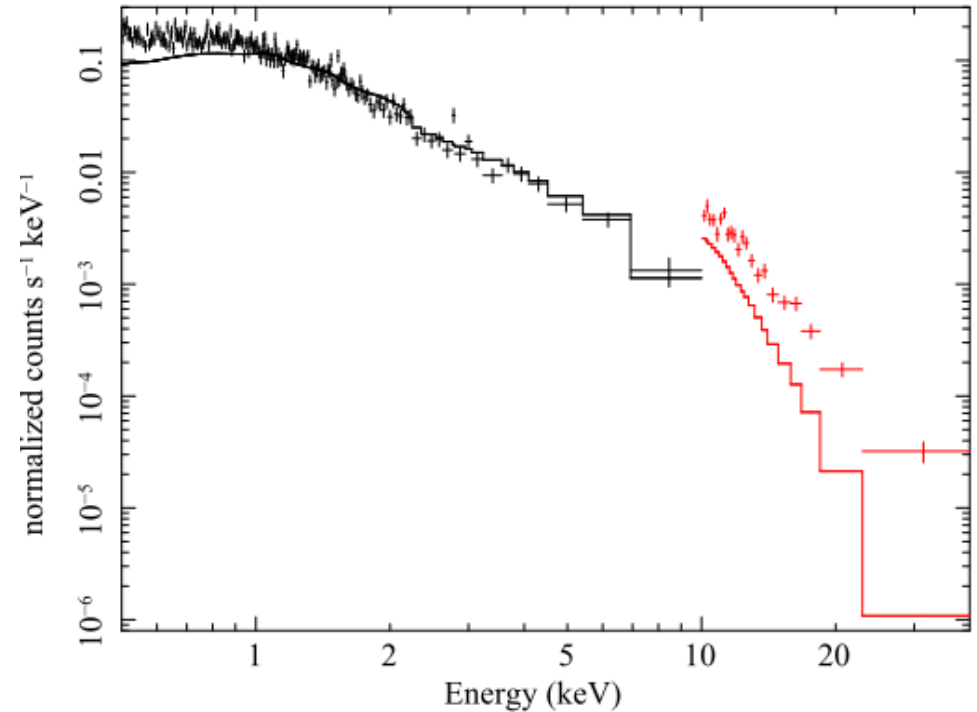
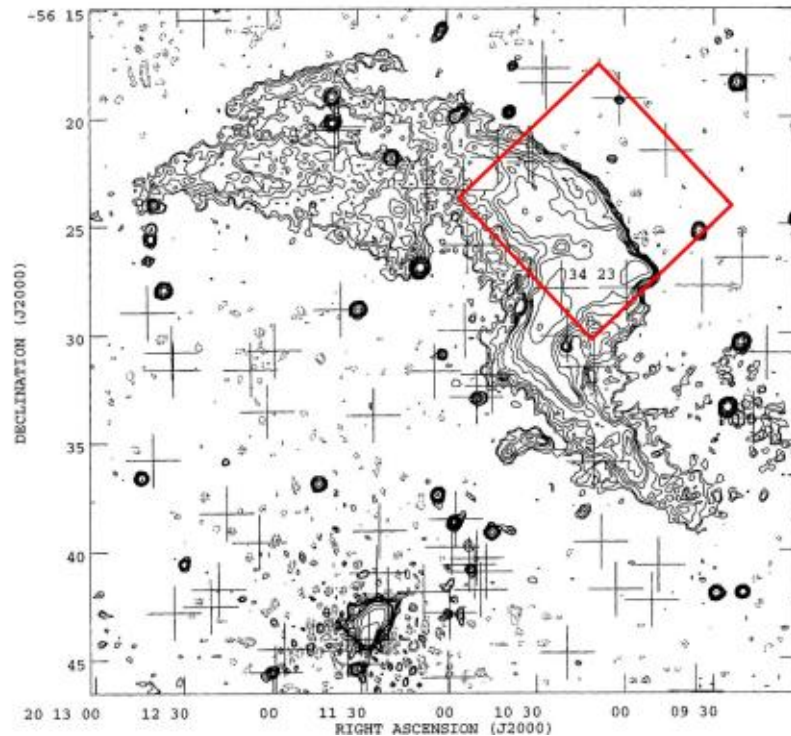
Clarify the mechanism of particle acceleration.



Clusters of galaxies

A3667

Radio emission



Relativistic electrons (\sim GeV)

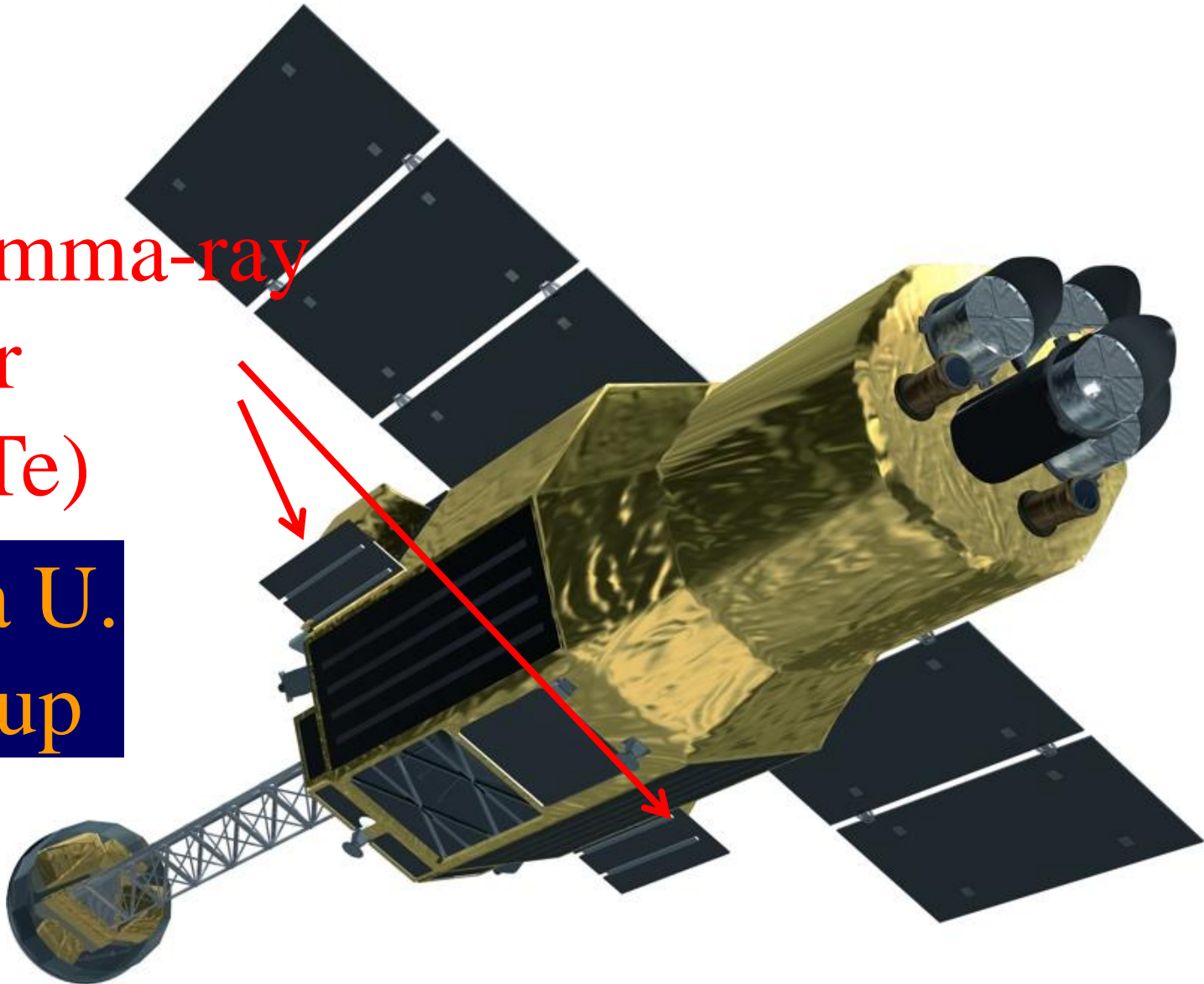
If high E electrons ($>$ TeV) exist, hard X-rays can be seen.

(Inverse Compton of CMB)

SGD (10—600keV)

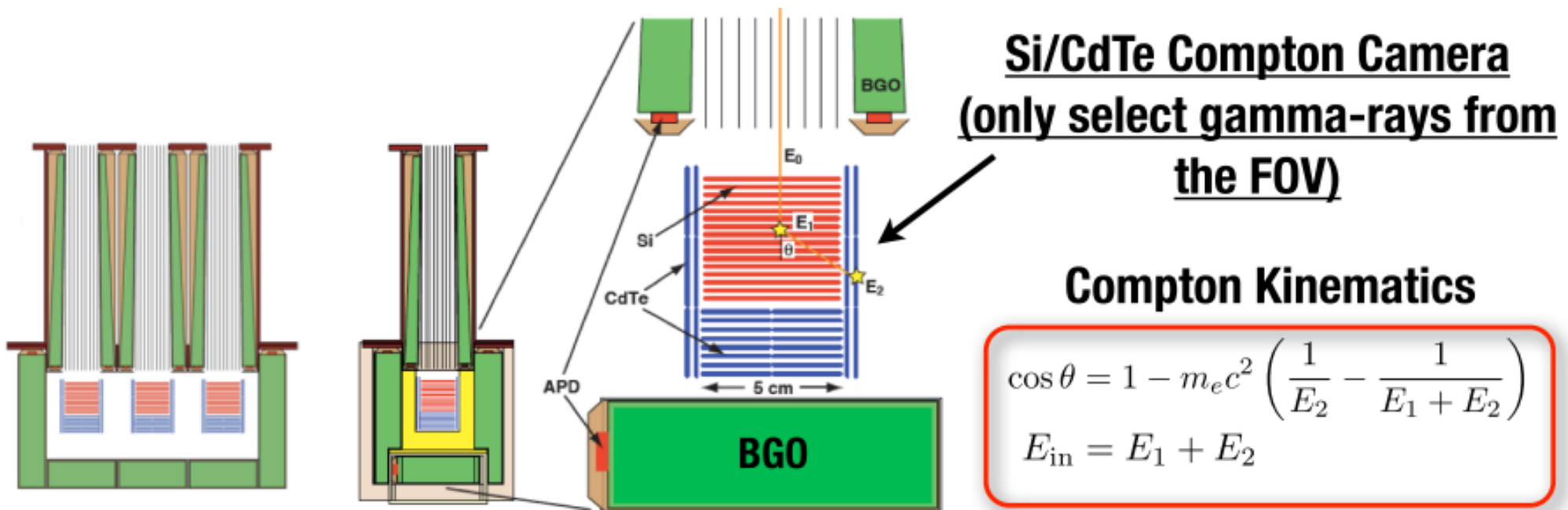
Soft Gamma-ray
Detector
(Si+CdTe)

Nagoya U.
CR group

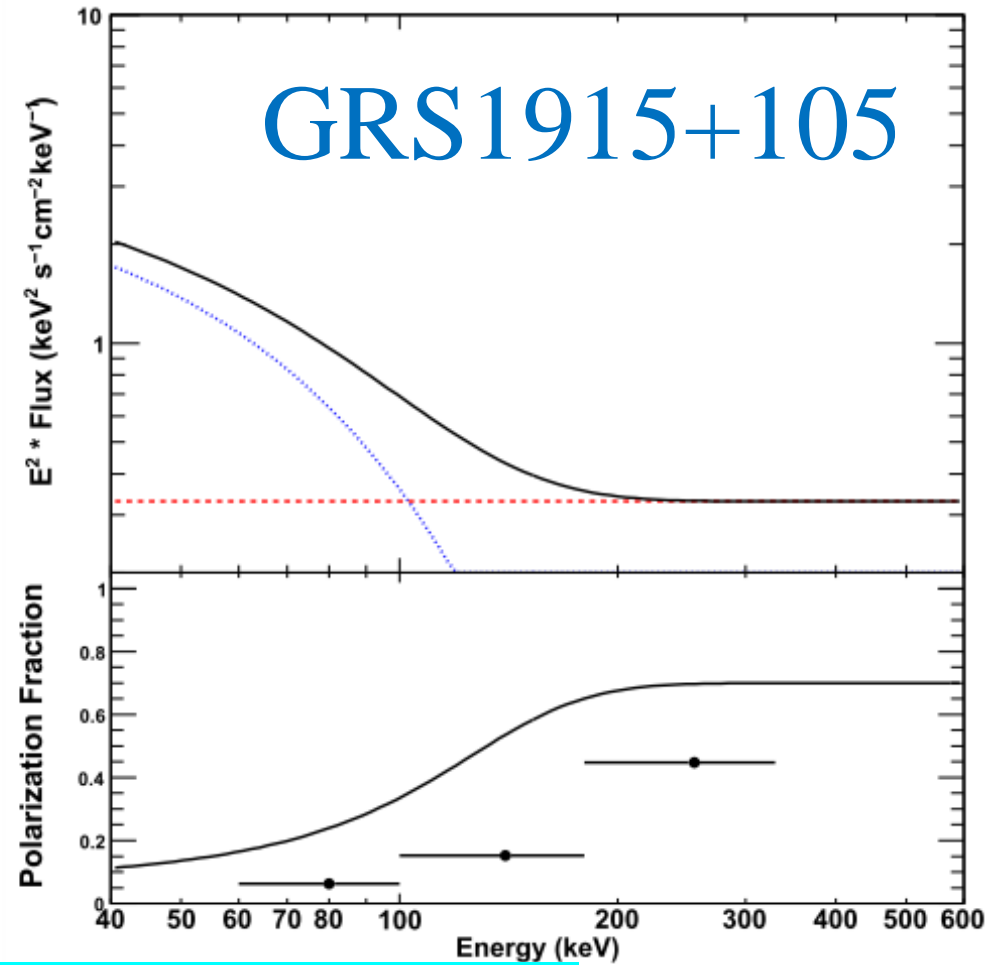
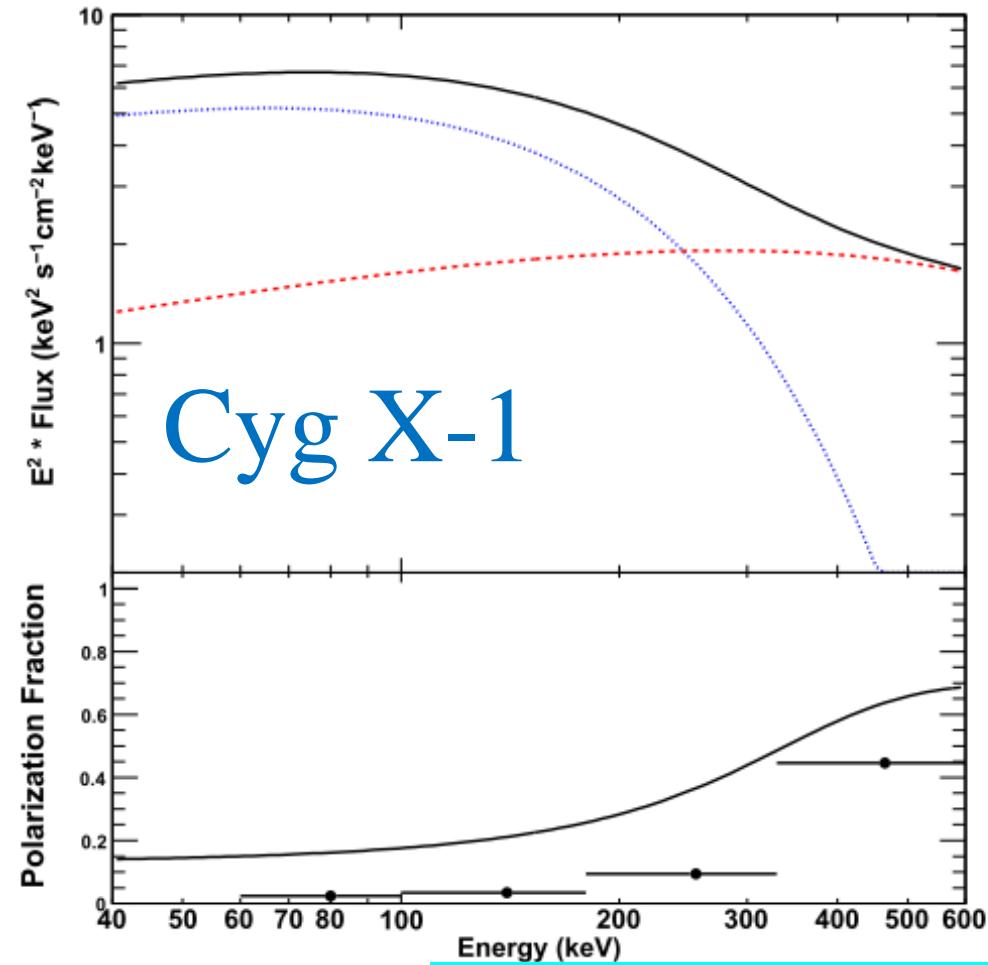


Soft Gamma-ray Detector (SGD)

- Si/CdTe Compton Camera
- Active shield of BGO



BH binary with jet

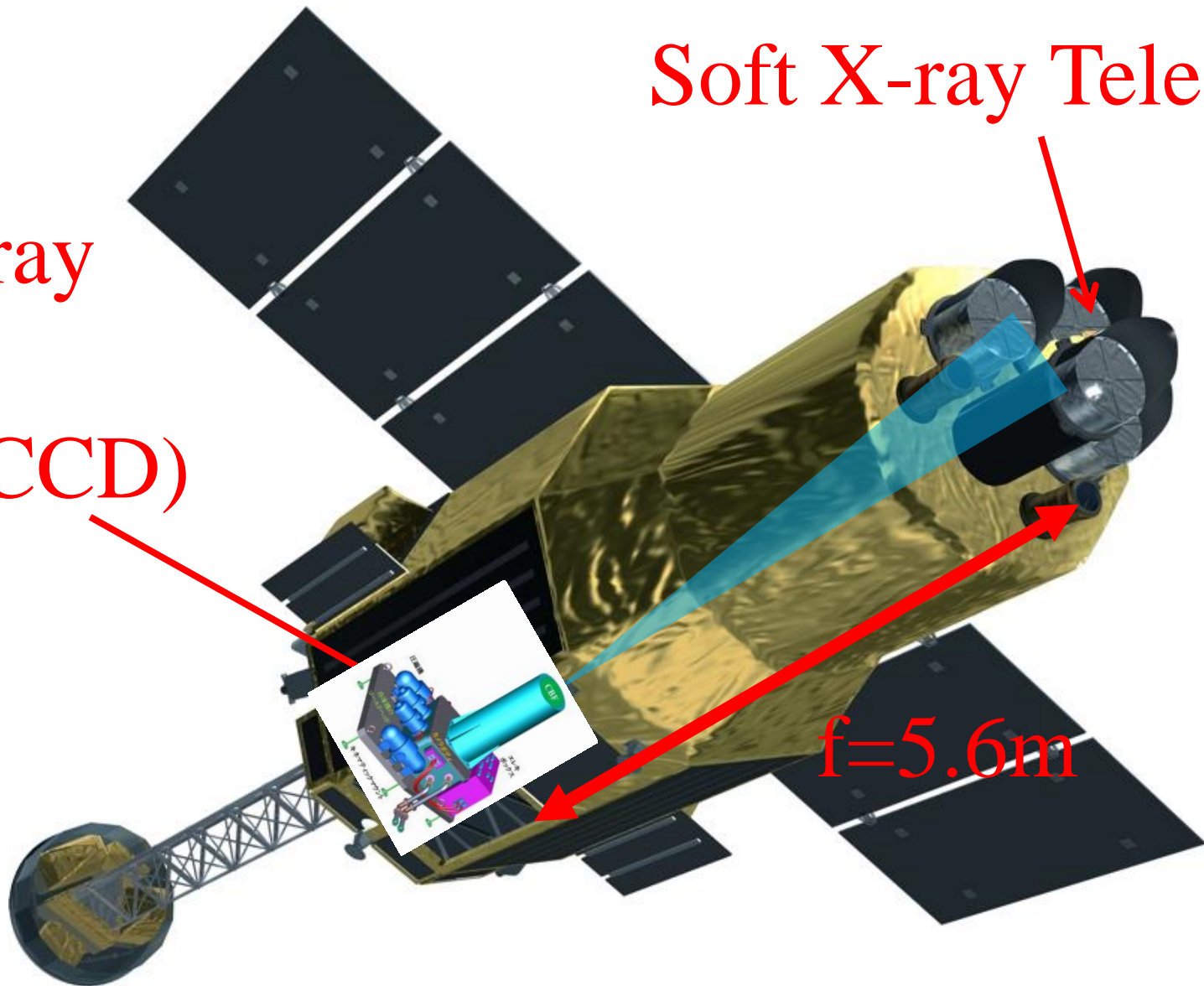


Polarization will be detected

SXT + SXI (0.3—12keV)

Soft X-ray Telescope

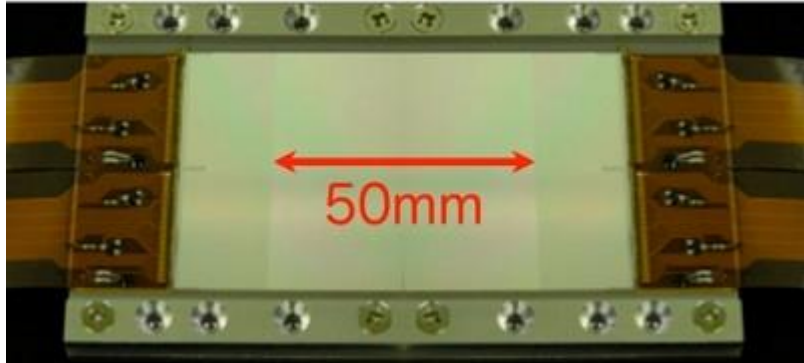
Soft X-ray
Imager
(X-ray CCD)



$f=5.6\text{m}$

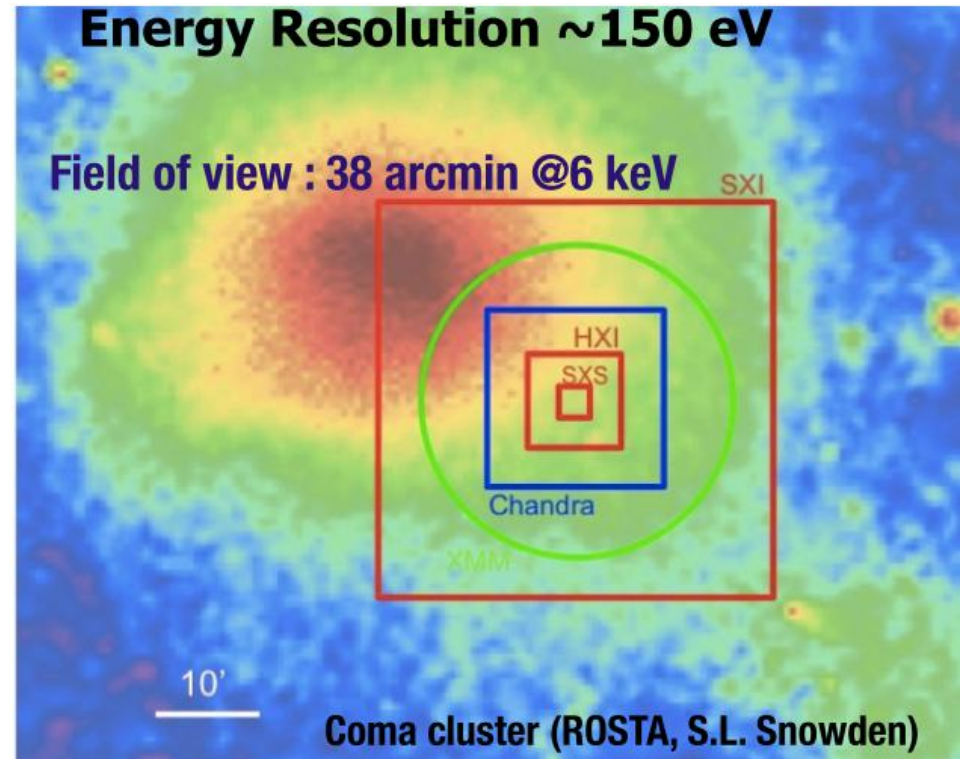
Soft X-ray Imager (SXI)

Pch X-ray CCD



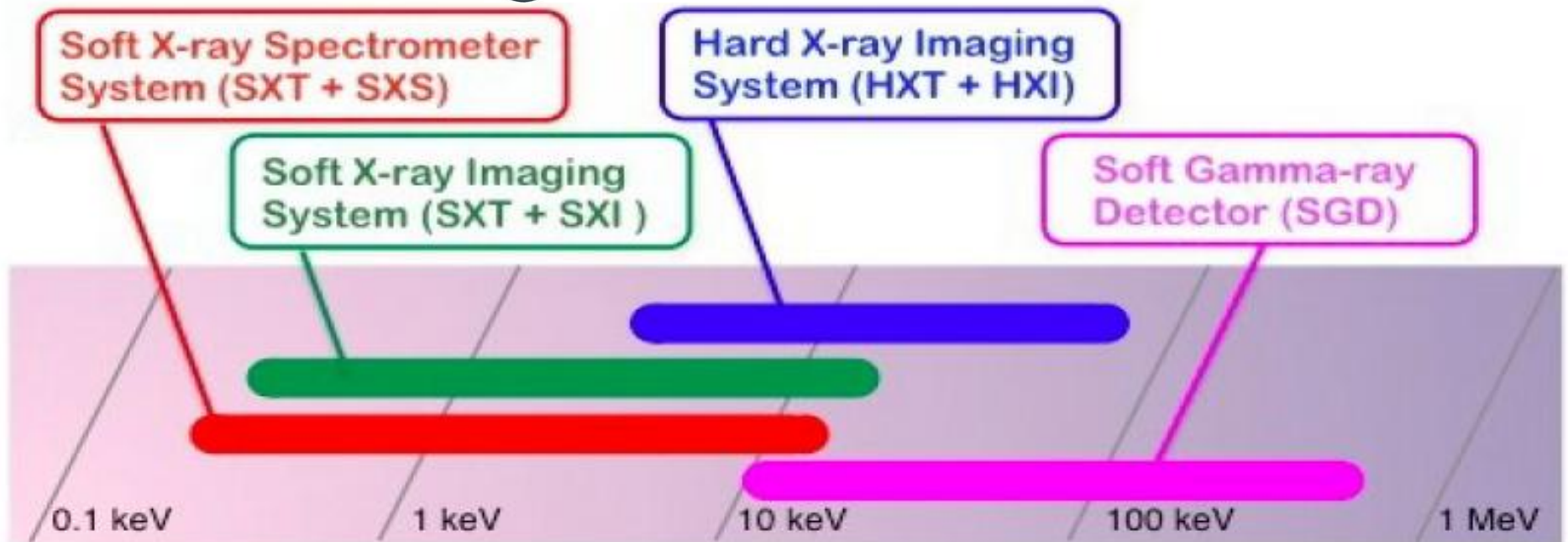
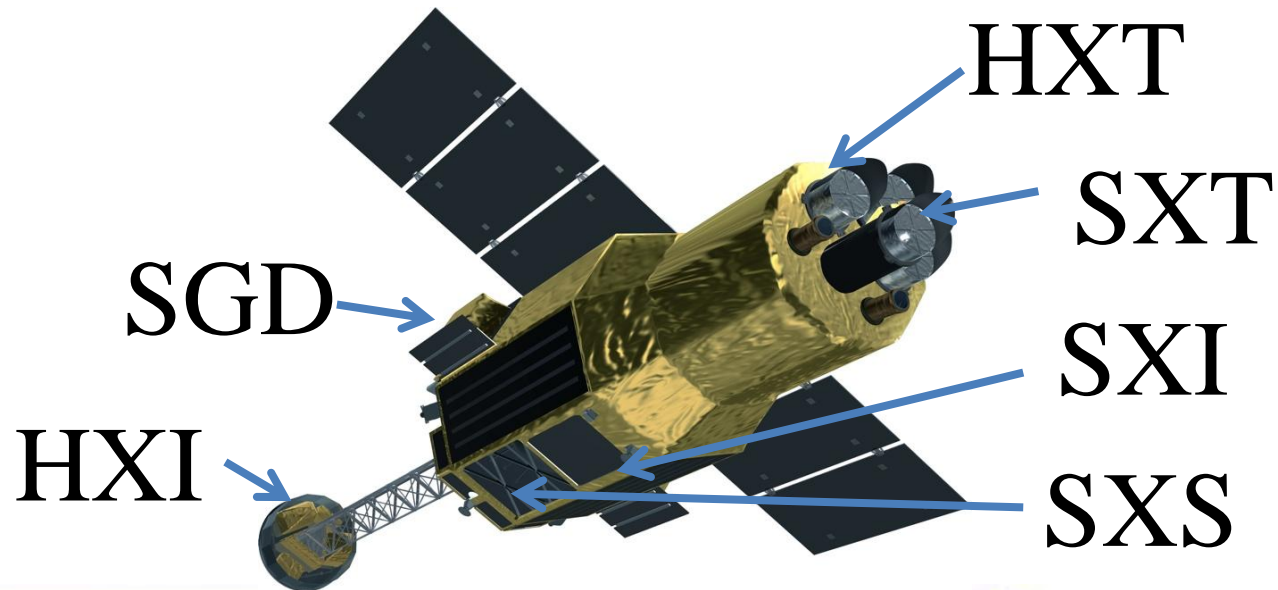
Thick depletion layer
~200 μ m

Moderate ΔE
(~150eV@6keV)

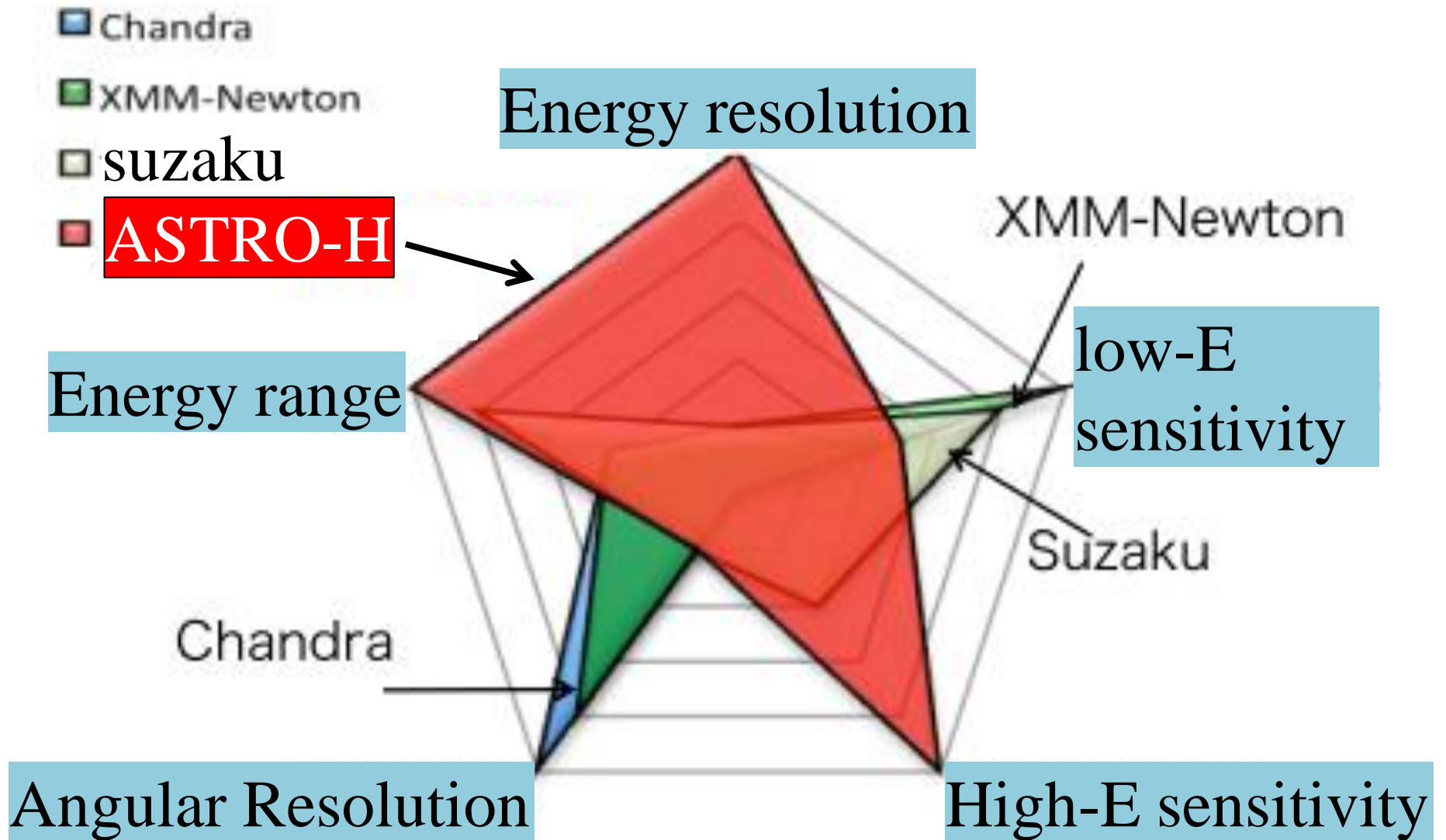


Largest FOV
38min X 38min

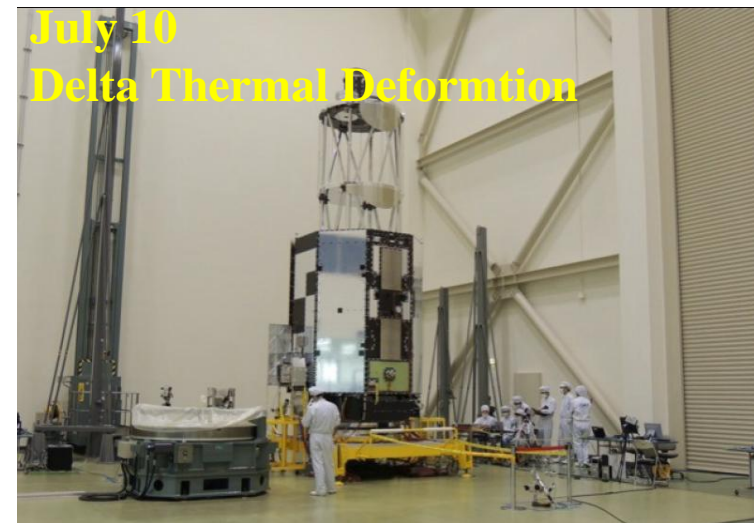
Wide energy range (0.3—600keV)



ASTRO-H vs other observatories



ASTRO-H under test



final integration test is now going on!

Summary

- ASTRO-H carries four instruments
 - SXT + SXS, SXT+SXI, HXT+HXI, SGD
 - Wide energy range
 - High energy resolution
 - High sensitivity in high-E X-rays
 - Wide FOV
- Many science topics can be addressed
- ASTRO-H will be launched in FY2015

Visit <http://astro-h.isas.jaxa.jp/index.html.en>

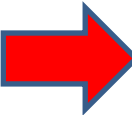
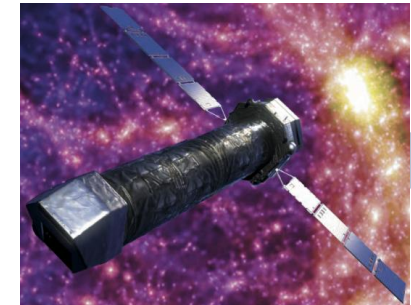
Flagship mission in X-ray astronomy

14 2015 16 17 18 19 2020 21 22 23 24 25 26 27 28 29 2030



ASTRO-H(2015~)

Athena(2028~)



Only small/medium
missions

eROSITA (2016~),
NICER(2016~) etc.

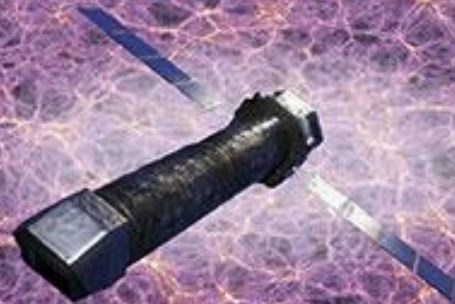
Europe Athena project

June 27, 2014

Athena is approved as L2 mission

ATHENA

THE ASTROPHYSICS OF THE
HOT AND ENERGETIC
UNIVERSE



HOW DOES ORDINARY MATTER
ASSEMBLE INTO THE LARGE SCALE
STRUCTURES THAT WE SEE TODAY?

HOW DO BLACK HOLES GROW
AND SHAPE THE UNIVERSE?

Europe's next generation **X-RAY OBSERVATORY**

<http://the-athena-x-ray-observatory.eu/>

<http://www.cosmos.esa.int/web/athena>

ESA cosmic vision (2015-2025)

<http://sci.esa.int/cosmic-vision/>

Four themes

- 1) Planets and Life, 2) The Solar System
- 3) Fundamental Laws, 4) The Universe

ESA missions

L1: JUICE (2020~)

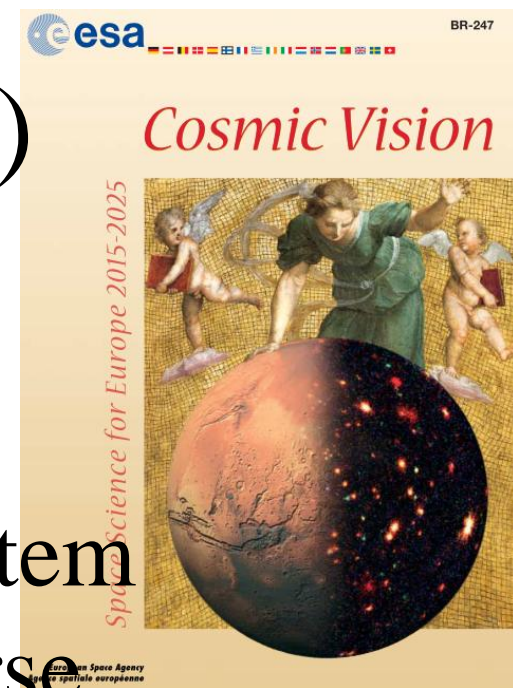
L2: Athena (2028~)

L3: gravitation (2034~)

M1: Solar Orbiter (2017~)

M2: Euclid (2020~)

M3: PLATO (2024~)



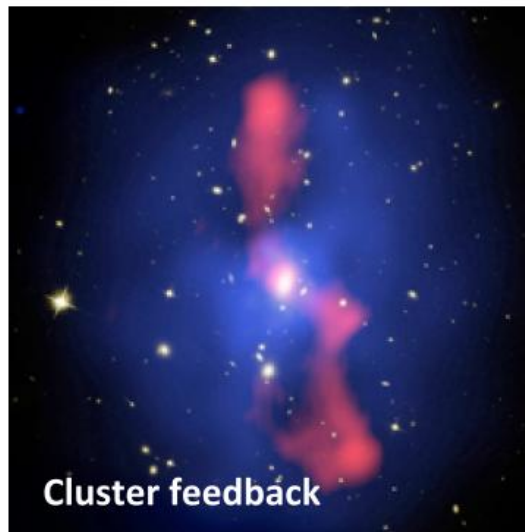
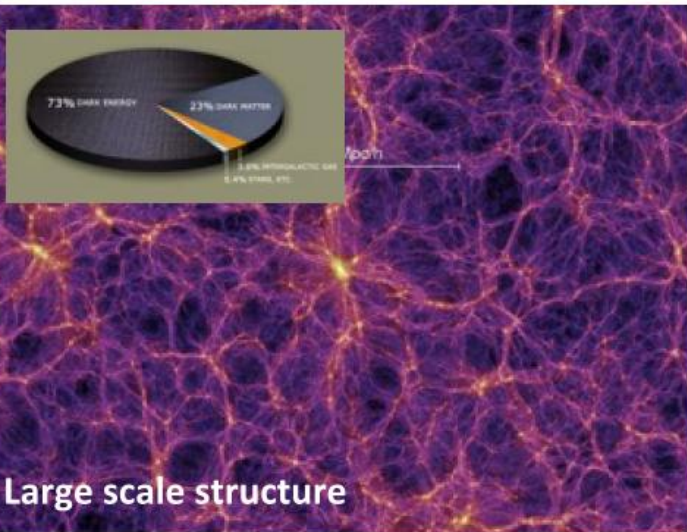
Athena Scientific Objectives

- Hot Universe

- How does ordinary matter assemble into the large scale structures that we see today?

- Energetic Universe

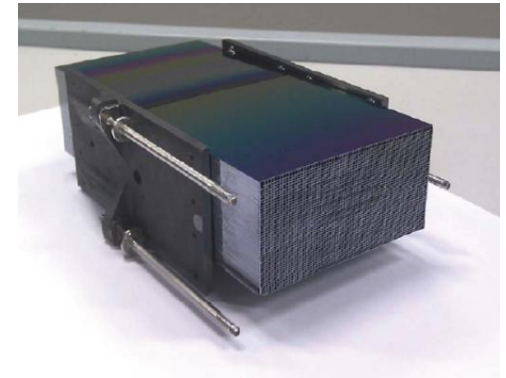
- How do black holes grow and shape the universe?



Athena

L2 orbit Ariane V
M < 5100kg
Power ~ 2500W
Life > 5 yrs

XRT Si Pore Optics

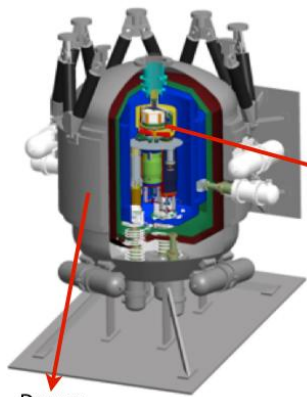


PSF ~ 5"
 $S \sim 2m^2 @ 1keV$

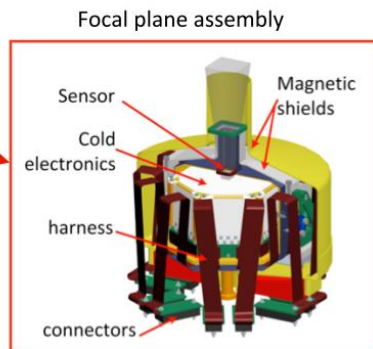
Xray Integral Field Unit

TES calorimeter

$\Delta E \sim 2.5eV$

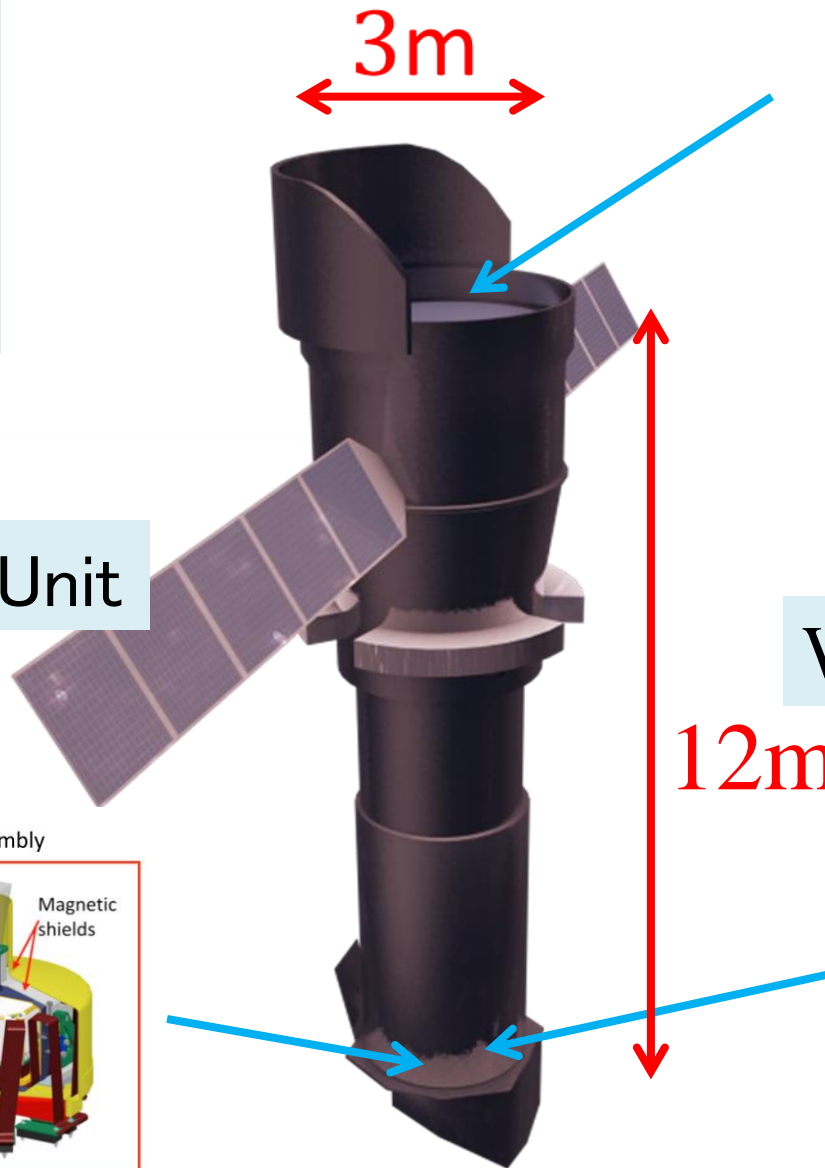


Dewar



Focal plane assembly

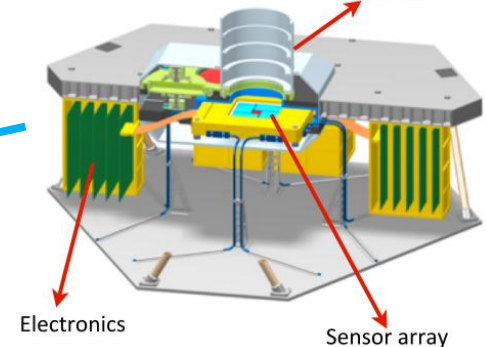
Sensor
Cold electronics
harness
connectors
Magnetic shields



Wide Field Imager

DEPFET

FOV ~ 40' ^{Baffle}

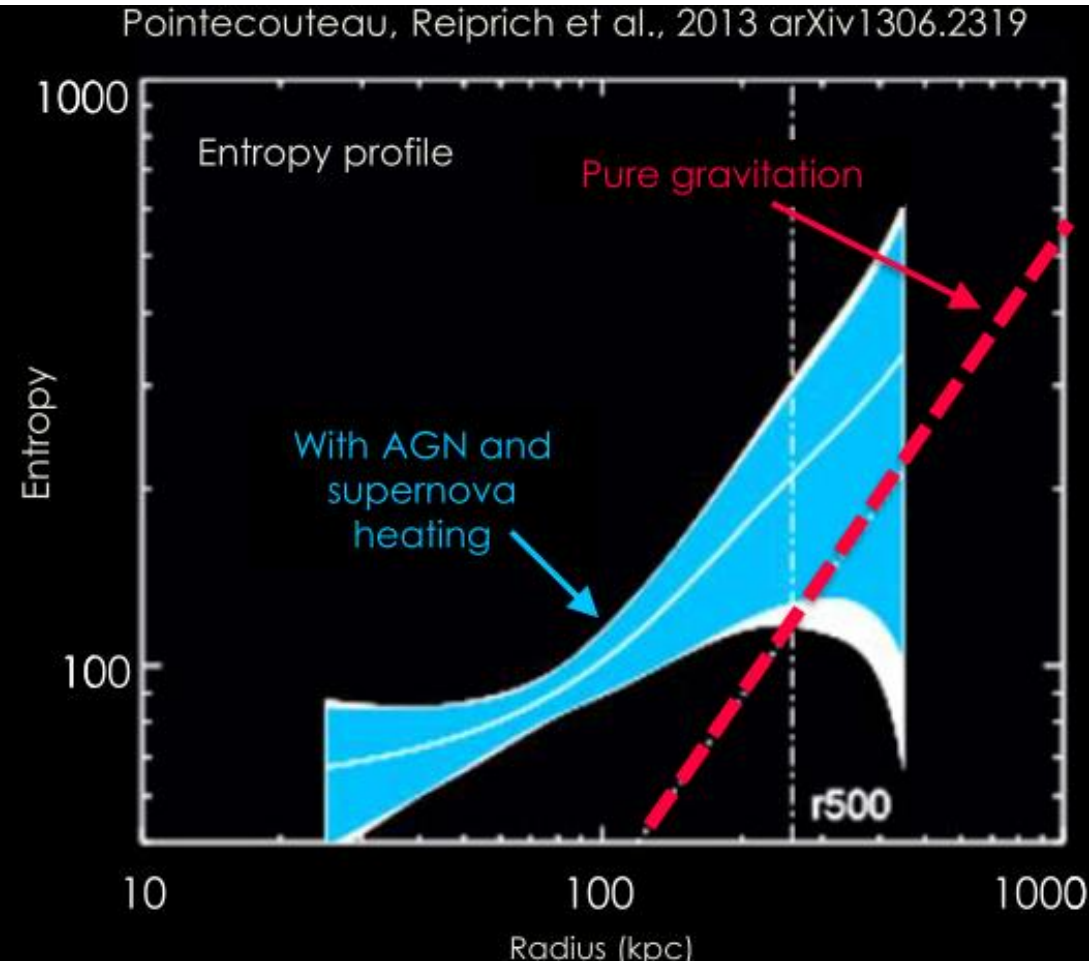
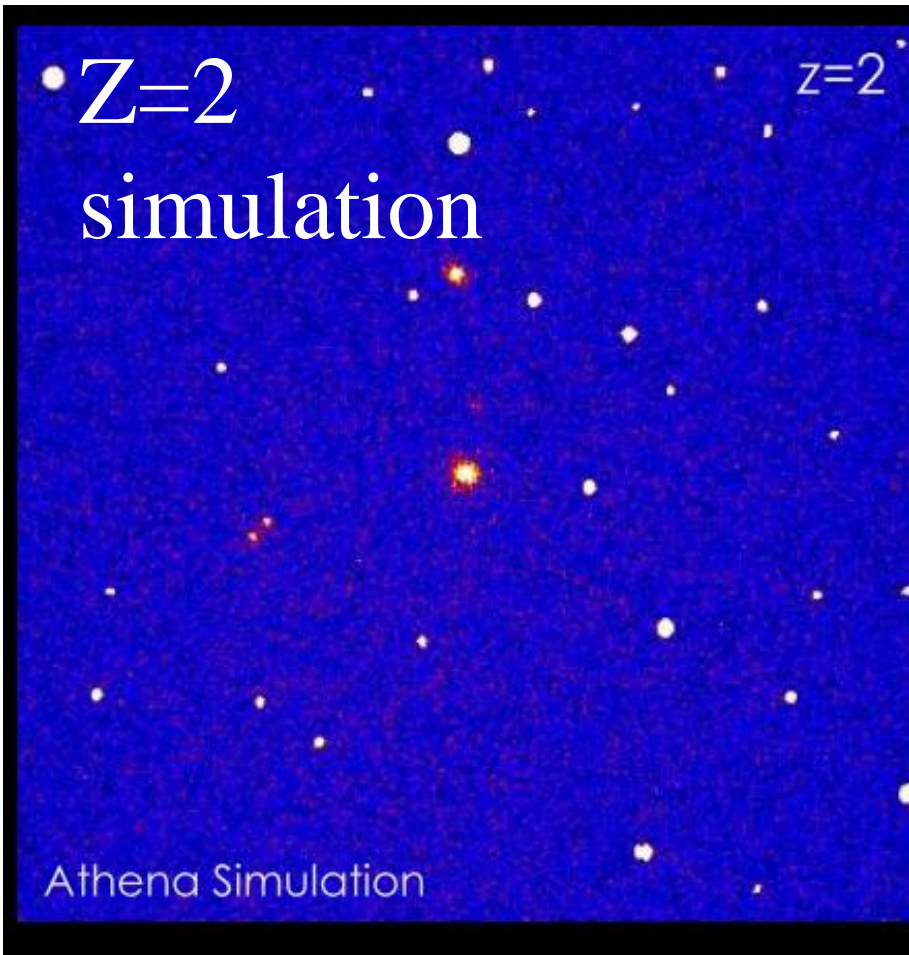


Electronics

Sensor array

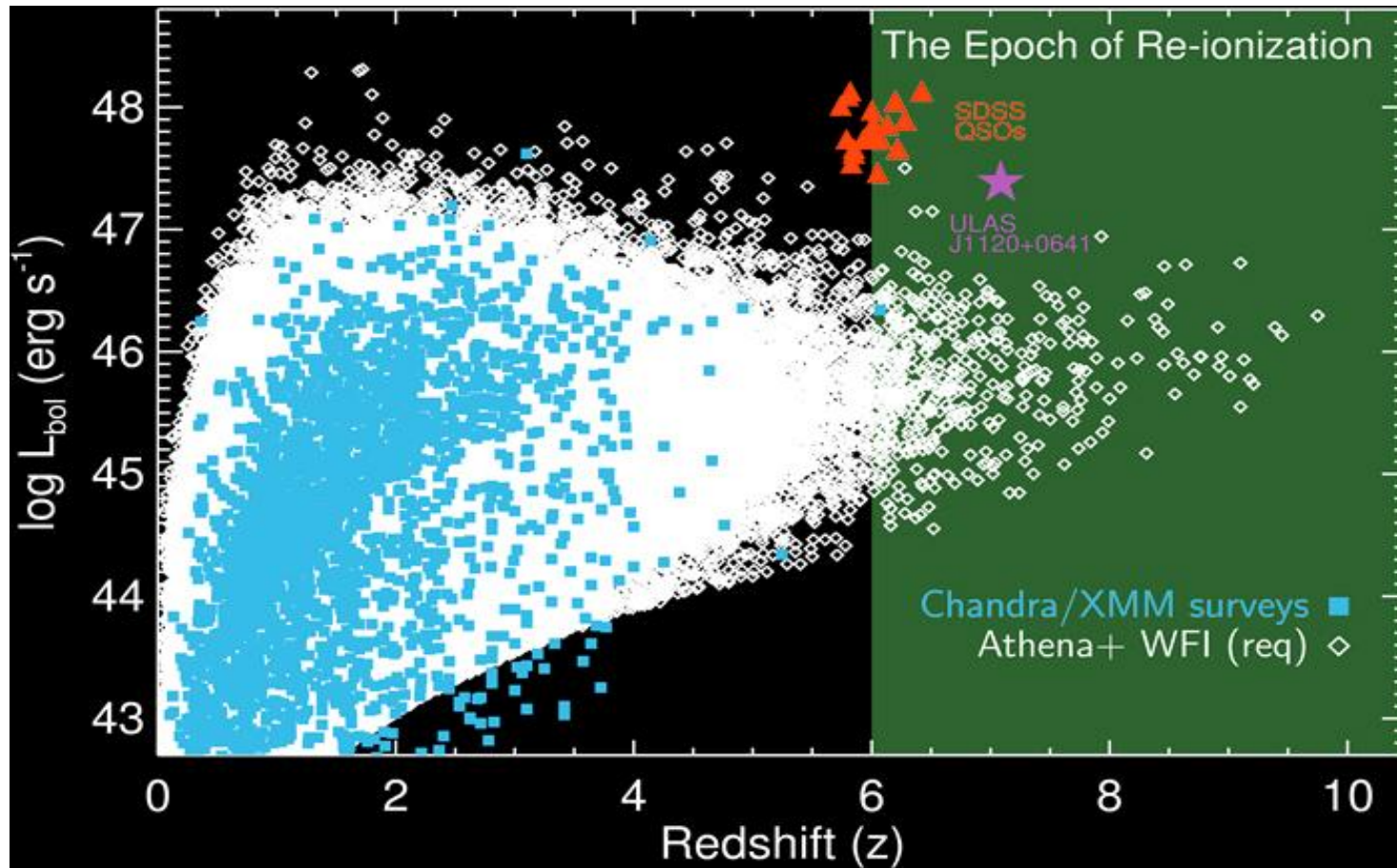
Hot Universe

How and when was the energy of ICM produced?



Energetic Universe

How do black holes grow and shape the universe



Discovery of High- z AGN

Japan's participation

- 高エネルギー宇宙物理学連絡会(高宇連; High-Energy Astrophysics Association in Japan) supports Athena.
 - Athena WG in ISAS
 - Chair: H. Matsumoto (Nagoya U.)
 - HM joins to the Athena Science Study Team
 - Europe (8) + USA(1) + Japan (1; HM)
- Athena team expects to collaborate with Japan
 - Japan's cryogenic technique is the best.
 - Suzaku, ASTRO-H, SPICA, ...
 - Expertise through many successful X-ray missions