

A detailed 3D rendering of the Hitomi X-ray telescope satellite in space. The satellite is a complex structure with a central cylindrical body wrapped in gold thermal insulation. It has several large, flat solar panel arrays extending from its sides. At the top, there are several circular instruments, likely X-ray detectors. The background is a dark space with some faint light trails and stars.

Early results of the Hitomi satellite

Hiro Matsumoto

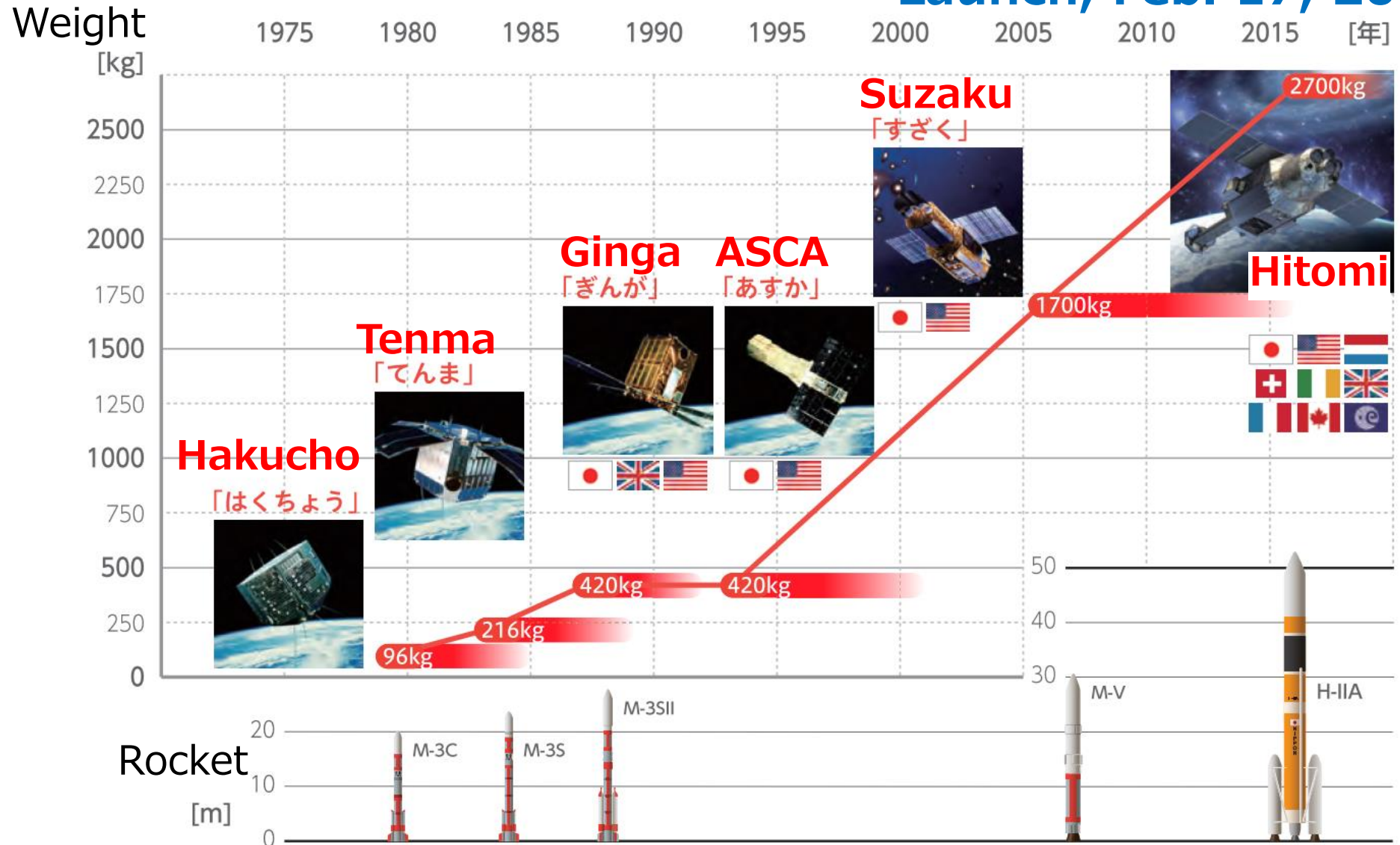
**Ux group & KMI
Nagoya Univ.**

Outline

- Hitomi instruments
- Early scientific results
 - DM in Perseus
 - Turbulence in Perseus
 - others

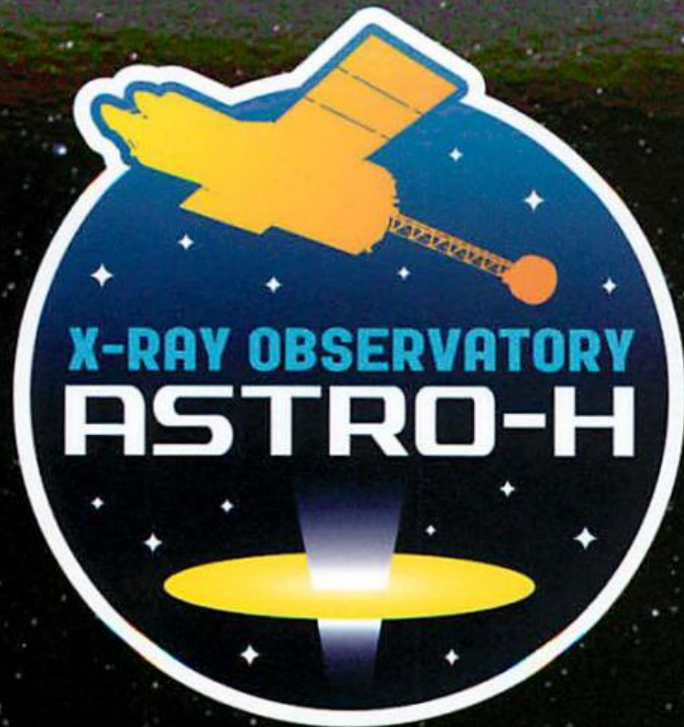
Japanese history of X-ray satellites

Launch, Feb. 17, 2016



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.

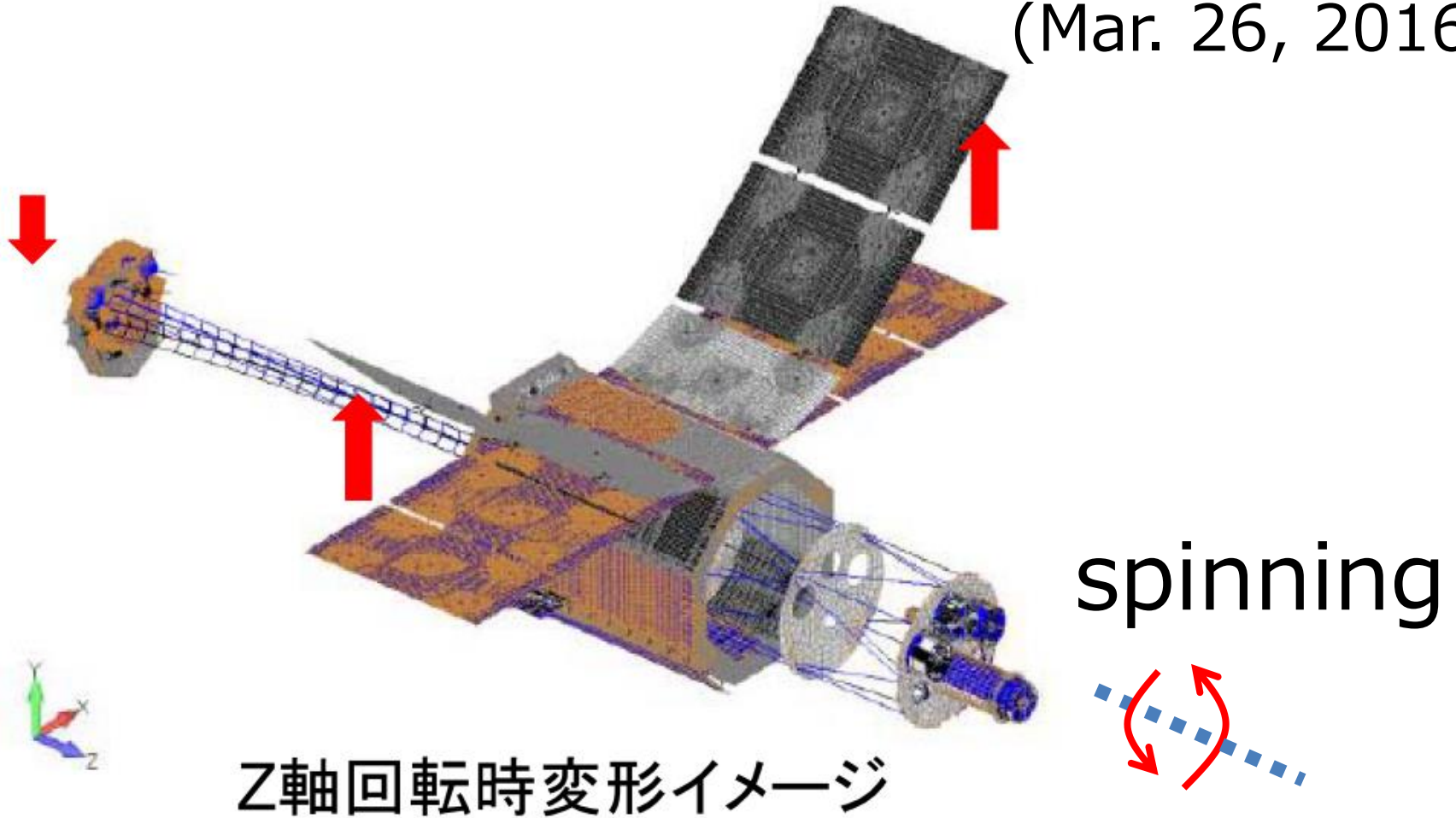


2011.7.18

Attitude anomaly

→ Loss of communication

(Mar. 26, 2016)



Gave up recovery (Apr. 28, 2016)

Hitomi Obs. List

Target		Date
Perseus	Cluster of galaxies	Feb. 25—27, 2016 Mar. 4—8, 2016
N132D	Supernova remnants	Mar. 8—11, 2016
IGR J16318-4848	Pulsar wind nebula	Mar. 11—15, 2016
RXJ 1856-3754	Neutron star	Mar. 17—19, 2016 Mar. 23—25, 2016
G21.5-0.9	Pulsar wind nebula	Mar. 19—23, 2016
Crab	Pulsar wind nebula	Mar. 25, 2016

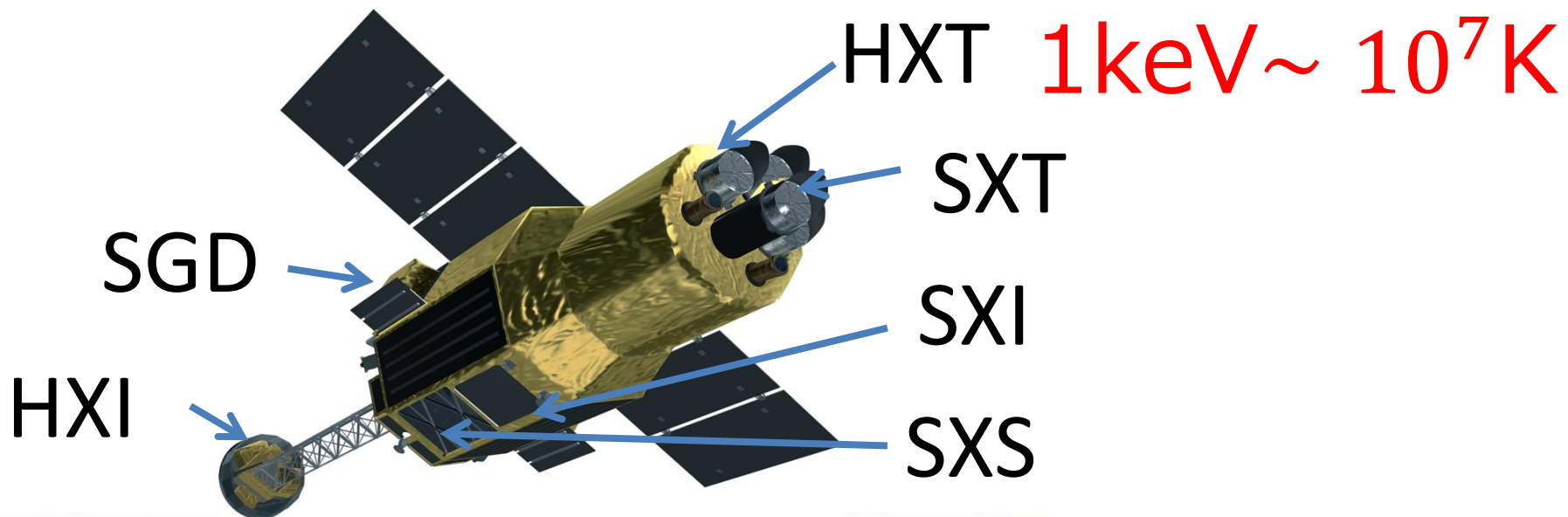


Scientific Instruments

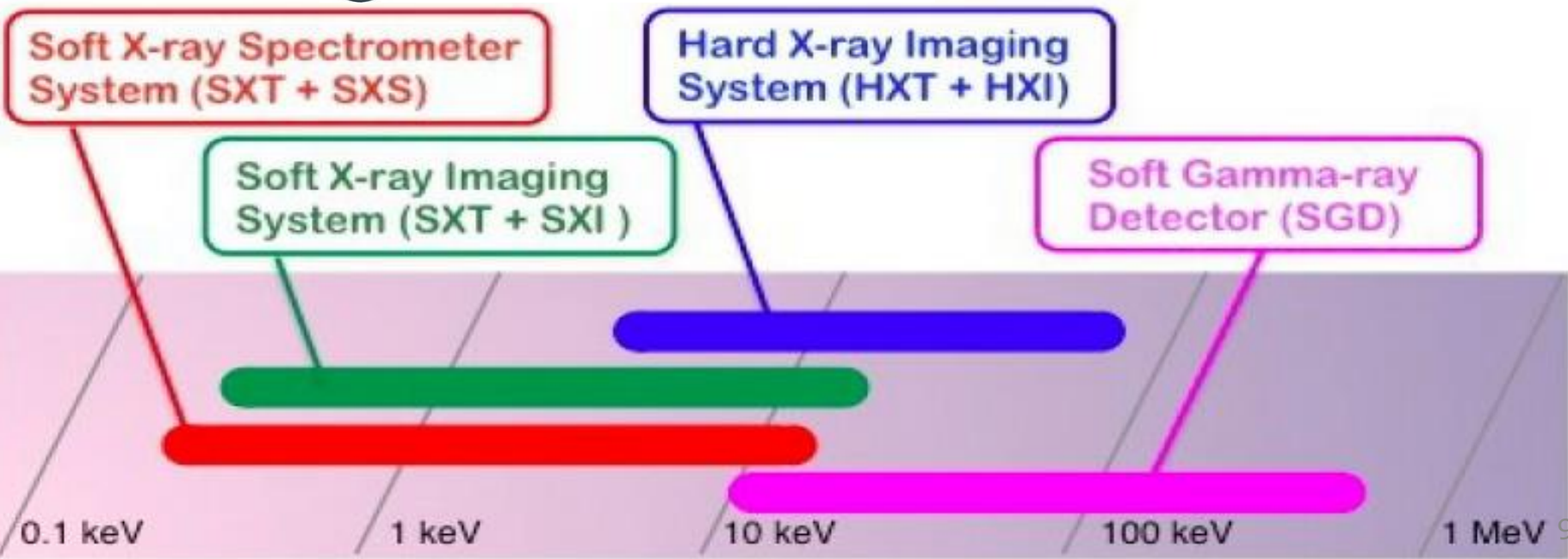
4 systems

Name	X-Ray Telescope	
SXS	Soft ($E < 10\text{keV}$)	Micro-calorimeter
SXI	Soft ($E < 10\text{keV}$)	CCD
HXI	Hard ($E < 80\text{keV}$)	Si/CdTe
SGD	---	Si/CdTe (Compton)

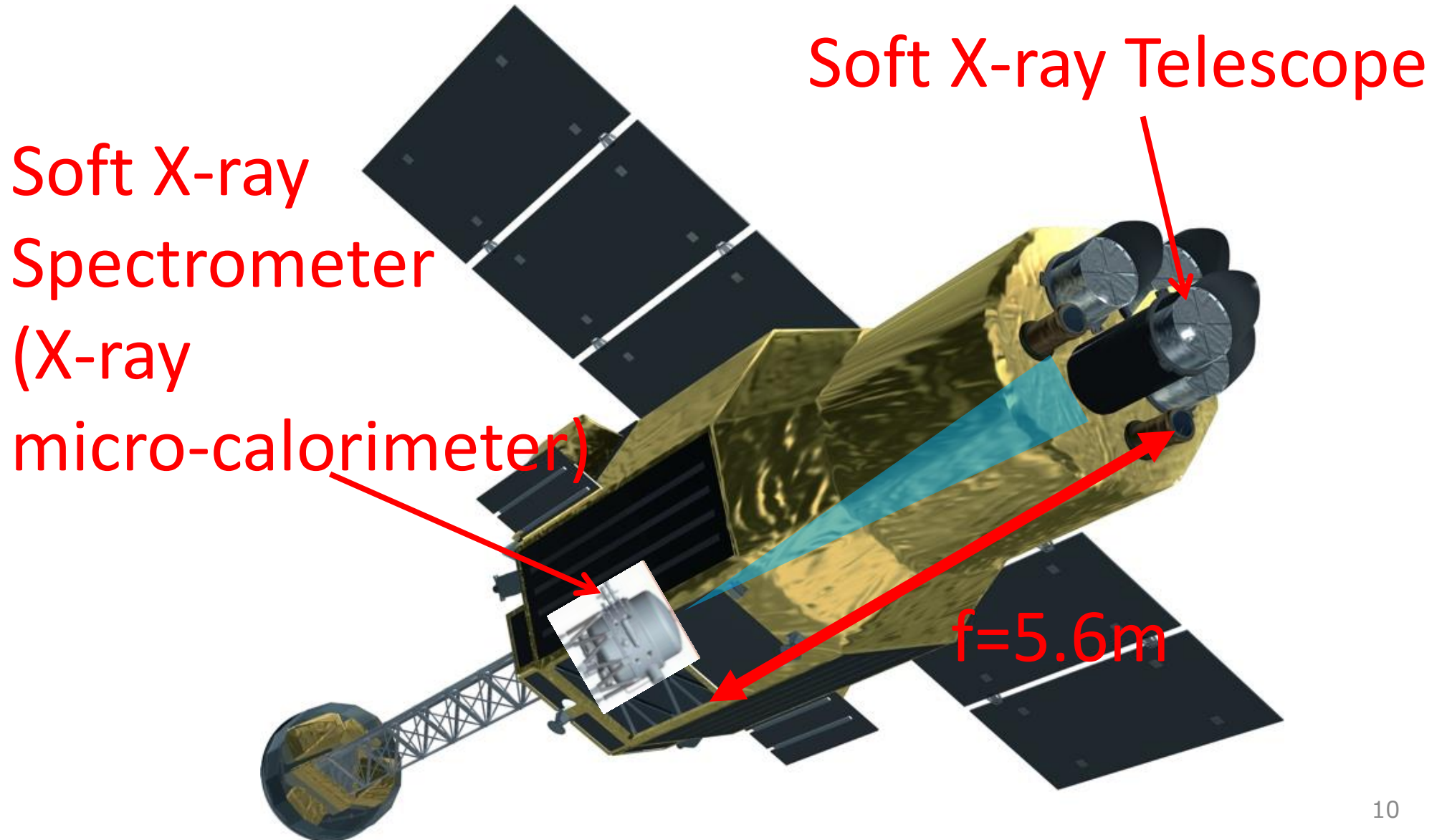
Wide energy range (0.3–600keV)



HXT 1keV ~ 10⁷ K



SXT + SXS (0.3–12keV)

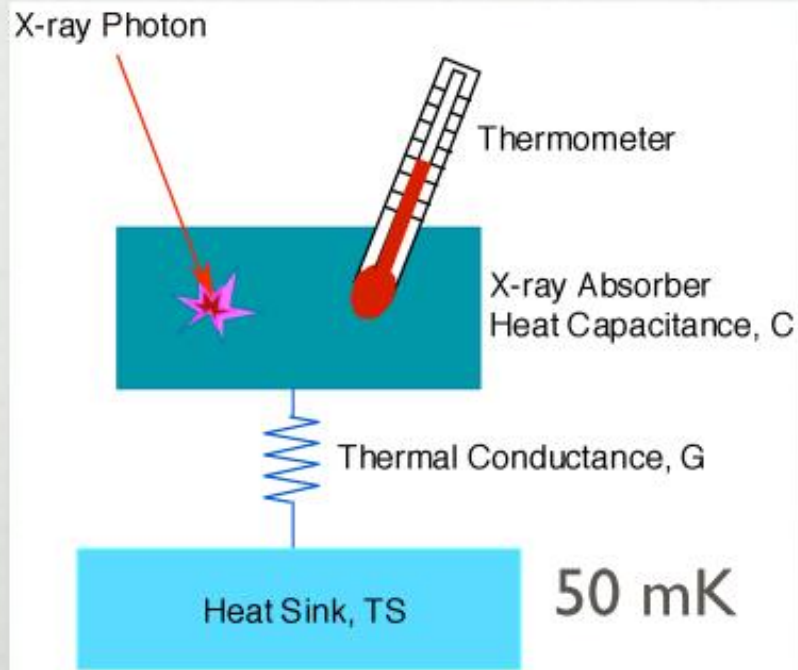


Soft X-ray Spectrometer (SXS)

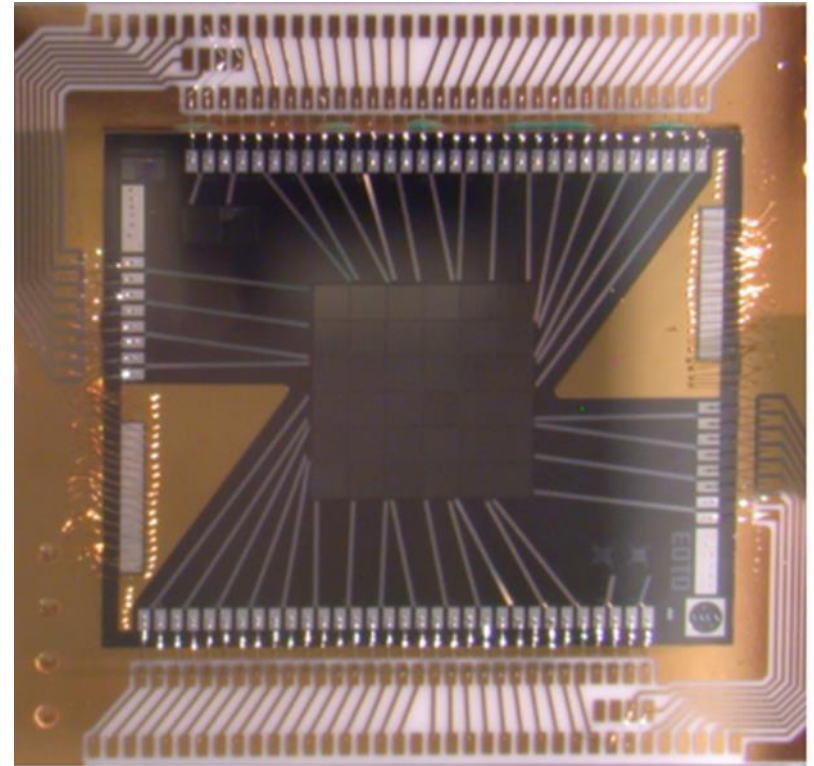
Microcalorimeters

High quantum efficiency

Imaging capability

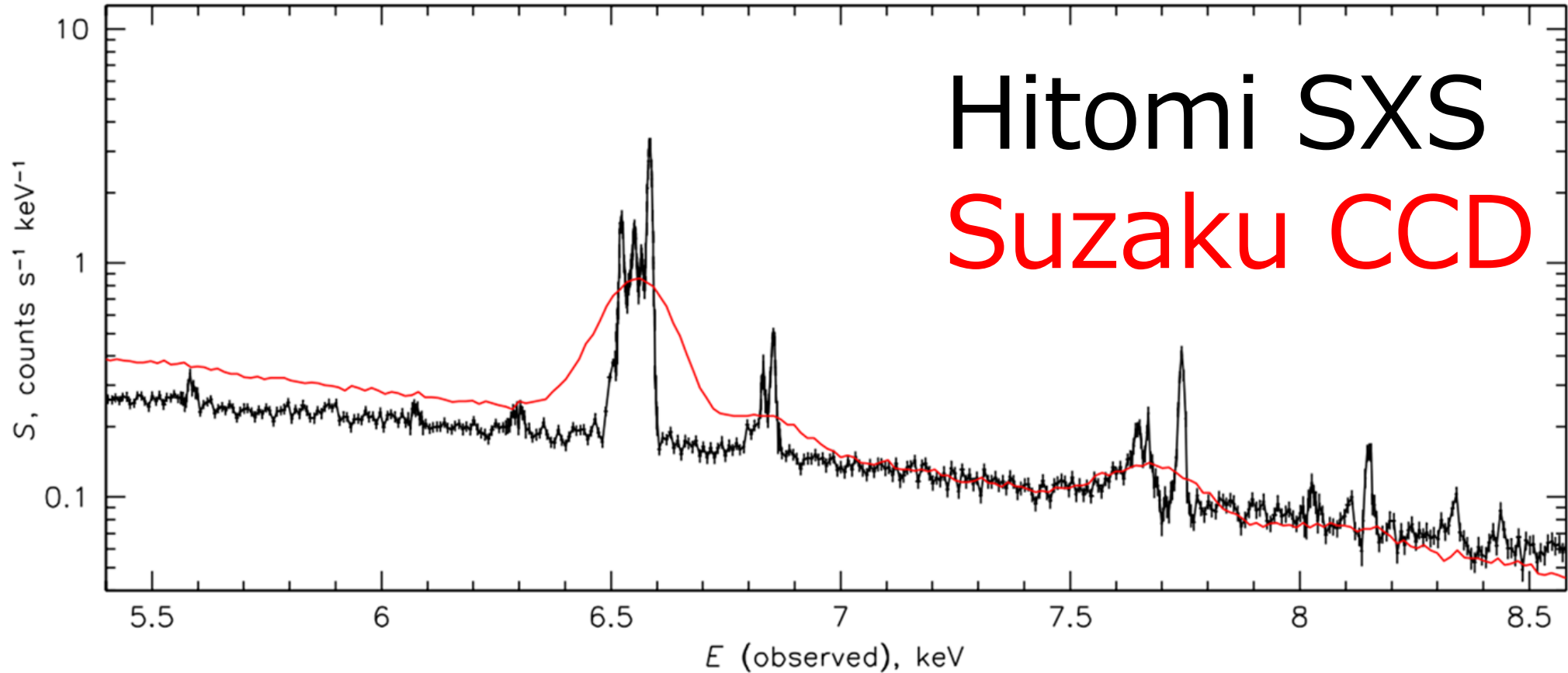


$$\Delta T \propto h\nu$$



FOV: $3' \times 3'$
 6×6 pix

Energy Resolution

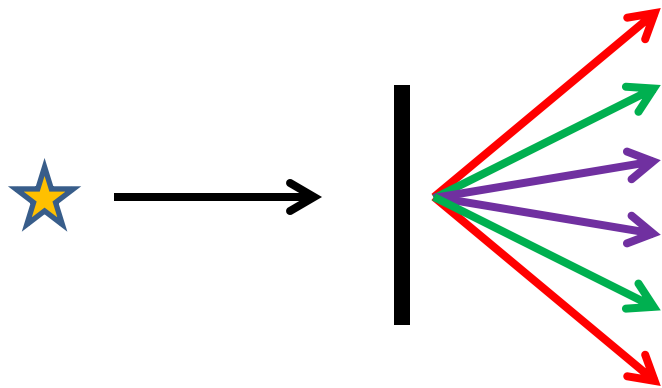


$$\Delta E = 5 \text{ eV} @ 6 \text{ keV}$$

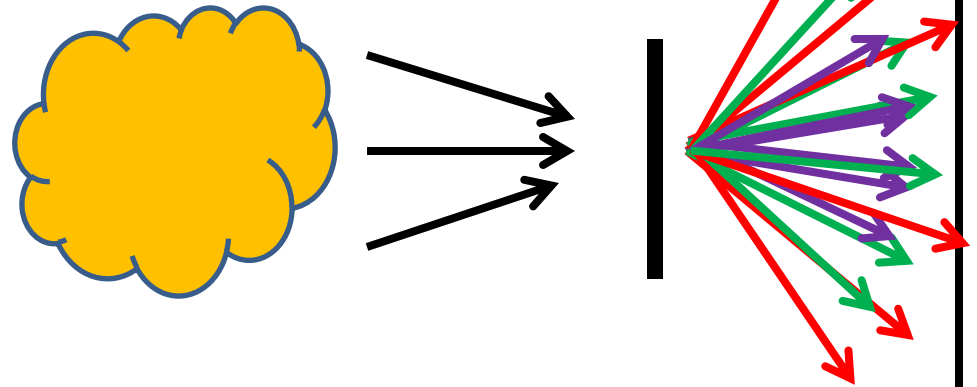
(cf. CCD $\Delta E = 130 \text{ eV}$)₁₂

Before Hitomi: gratings

Point source



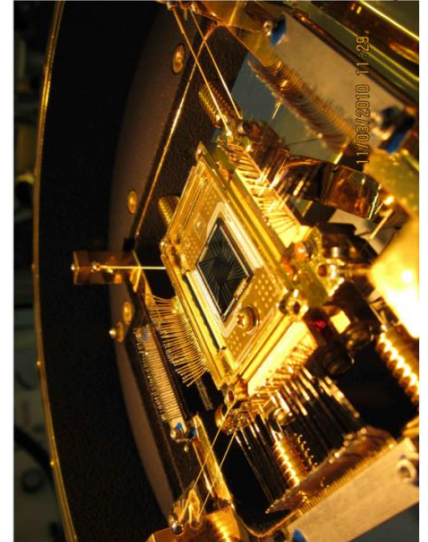
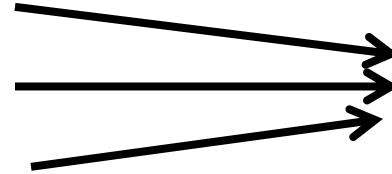
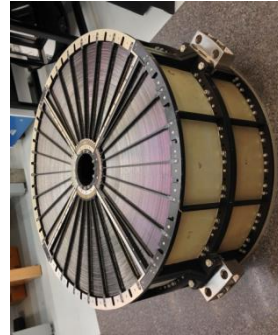
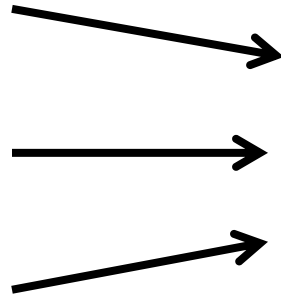
Extended



Not good for extended objects

X-ray microcalorimeter

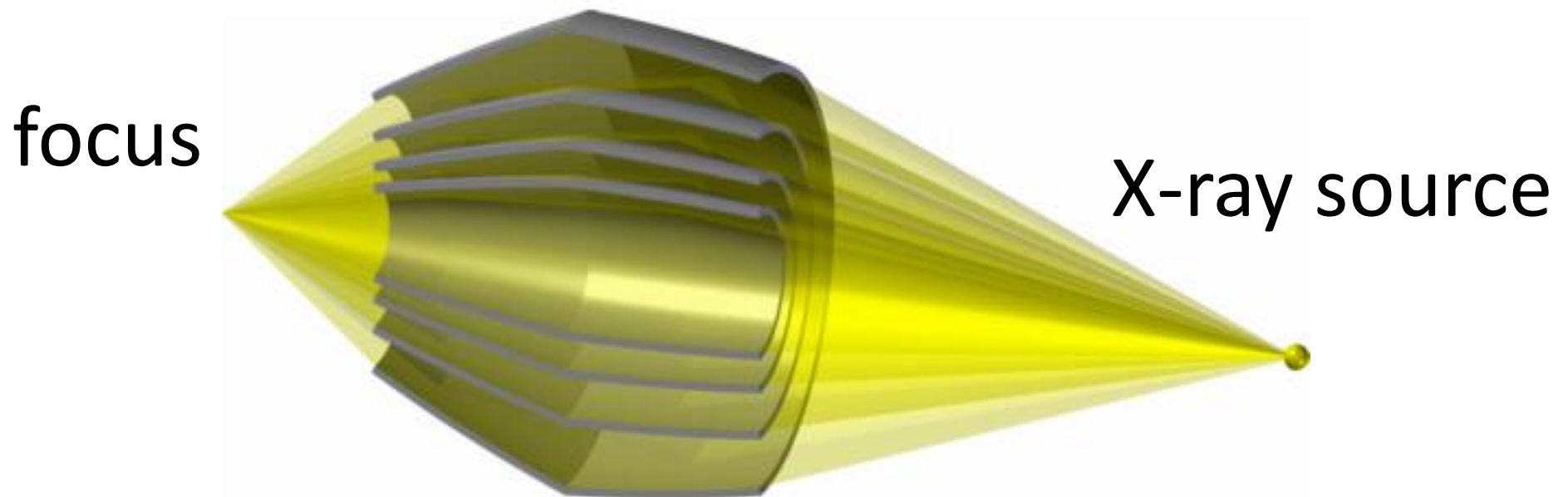
Extended



Non-dispersive type.
Spatial extension doesn't matter.

X-Ray Telescope (SXT, HXT)

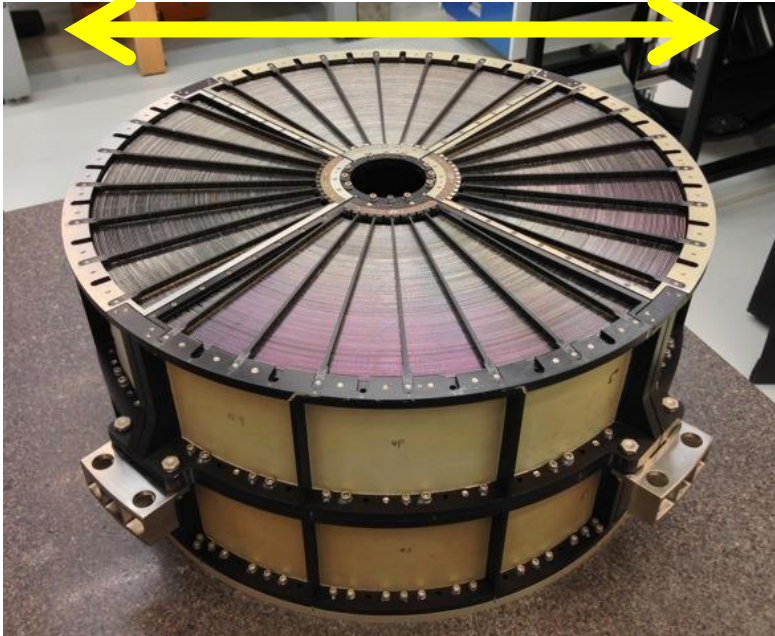
Wolter-I optics



“Annual ring” of foils

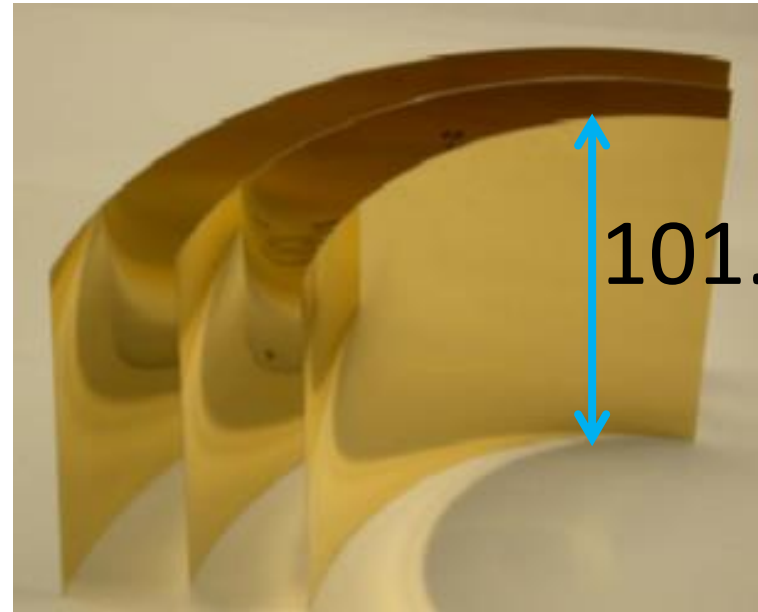
Soft X-ray Telescope (SXT)

450mm



SXT-1 FM

203 nested shells

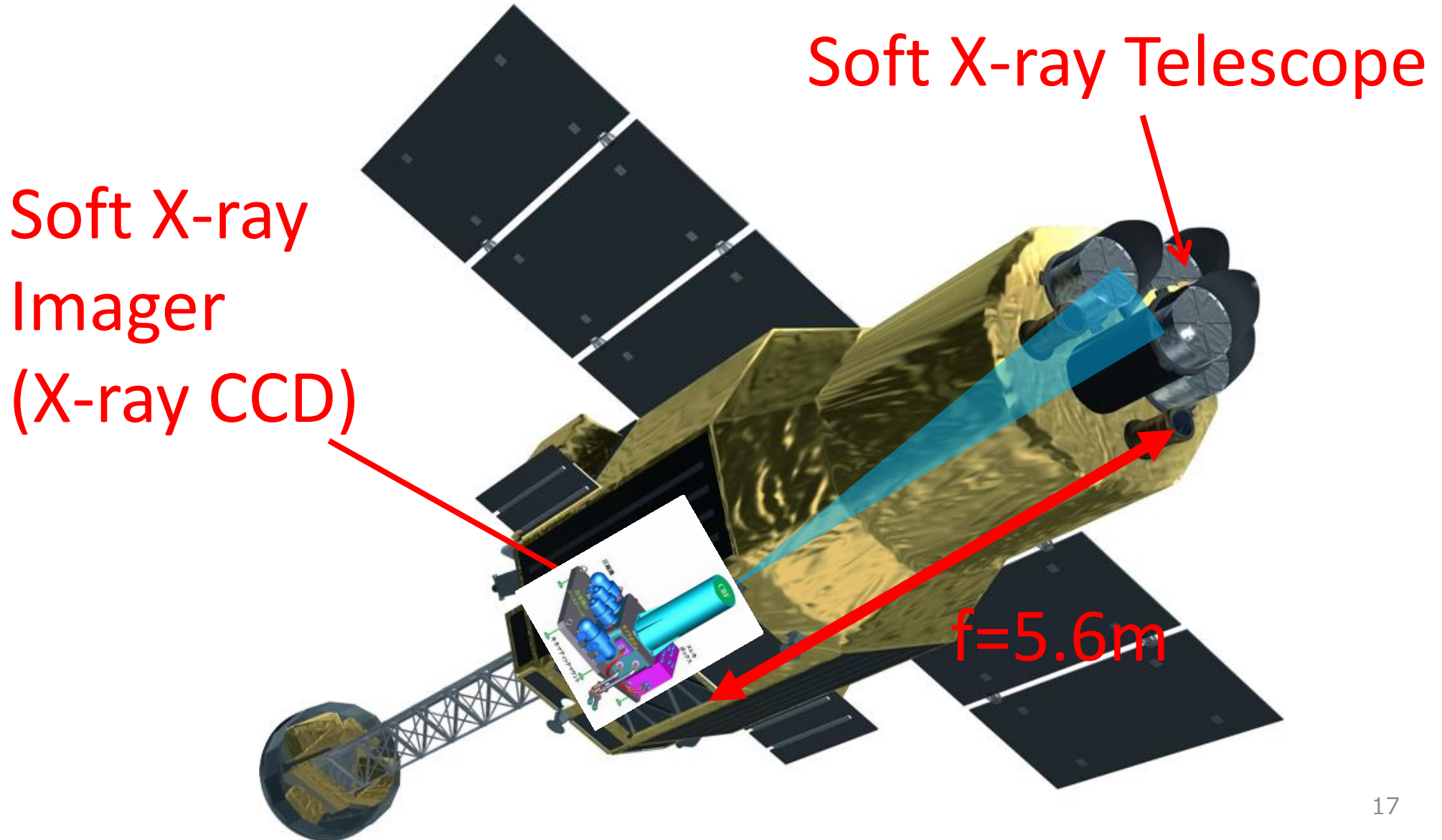


Au-coated Al foils

Total reflection

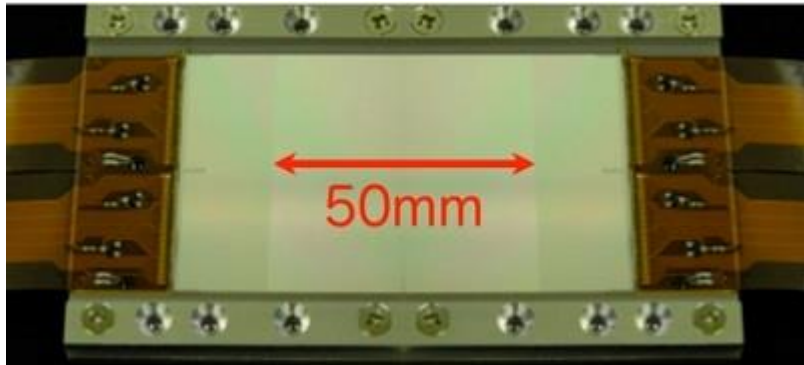
Angular resolution ~ 1.3'

SXT + SXI (0.3–12keV)



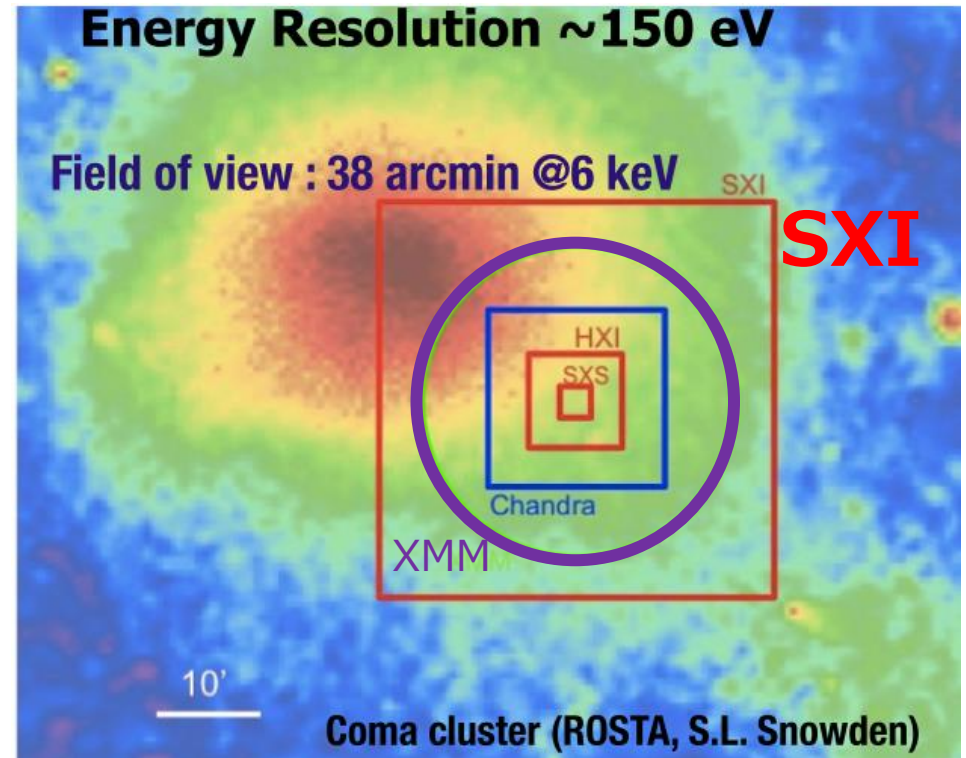
Soft X-ray Imager (SXI)

Pch X-ray CCD



Thick depletion layer
~200 μm

Moderate ΔE
(~150eV@6keV)

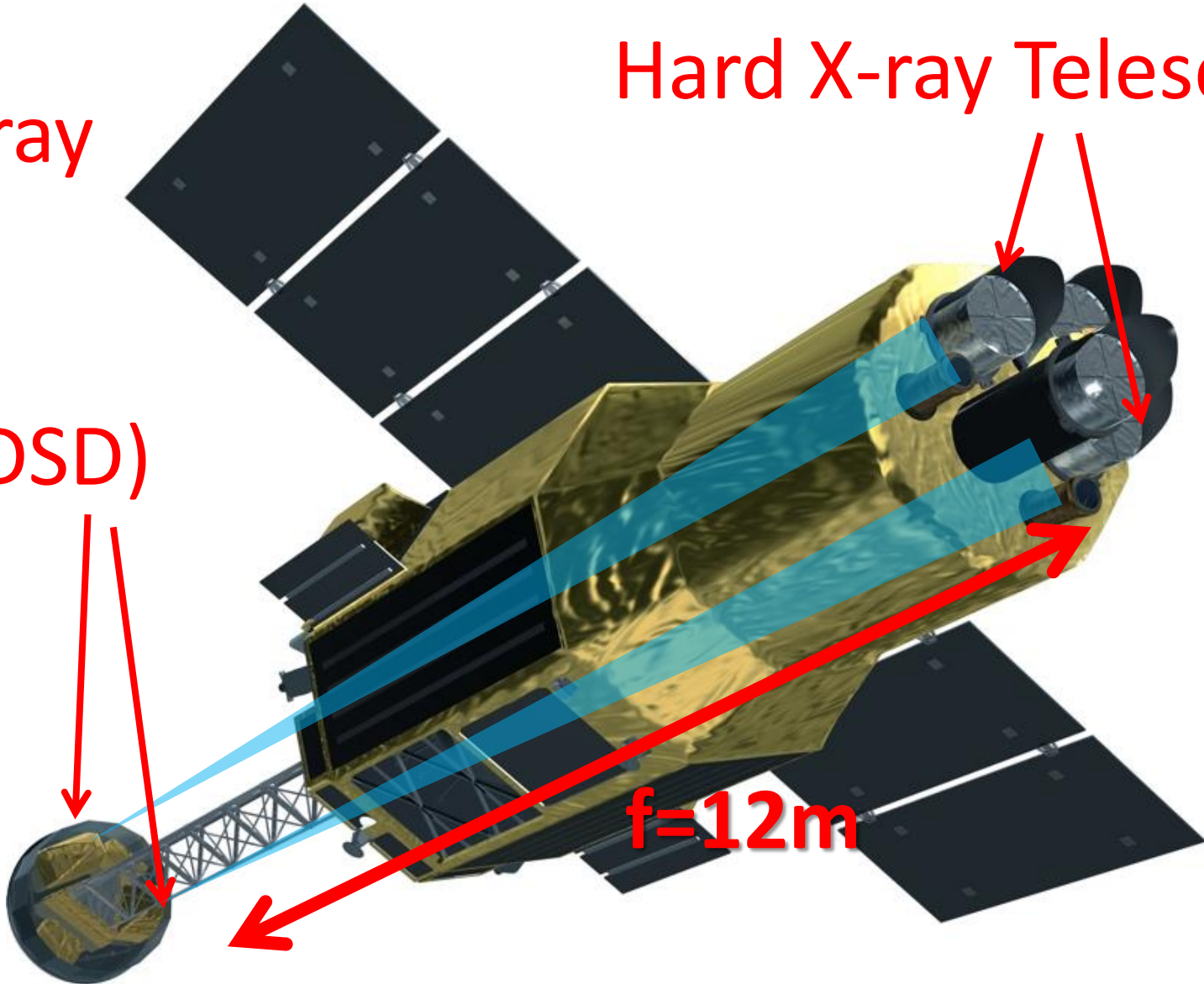


Largest FOV
38' \times 38'

HXT + HXI (5–80keV)

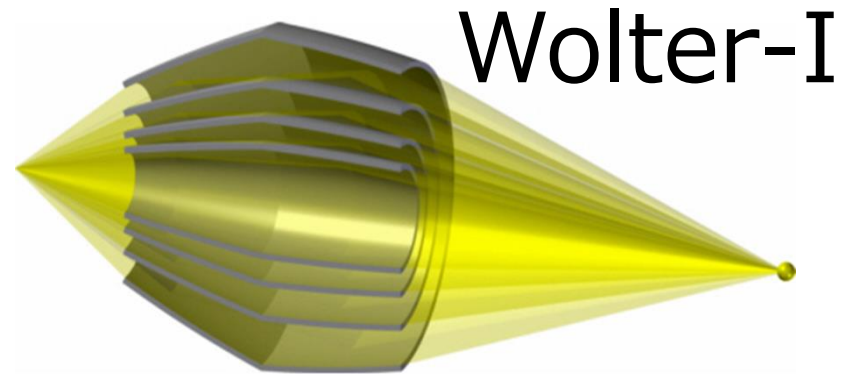
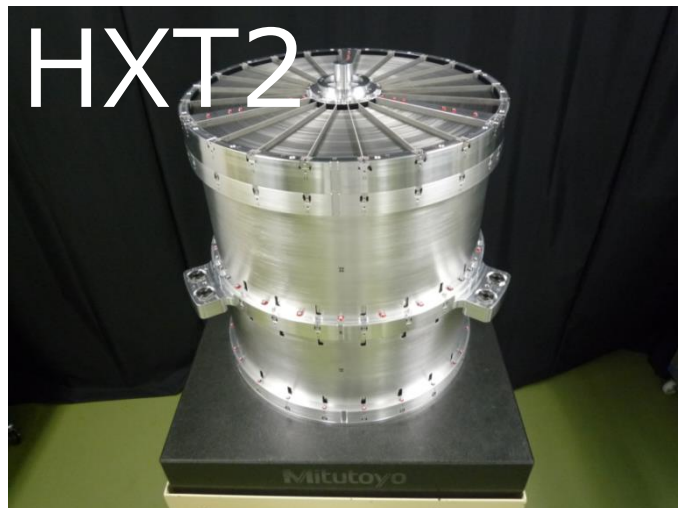
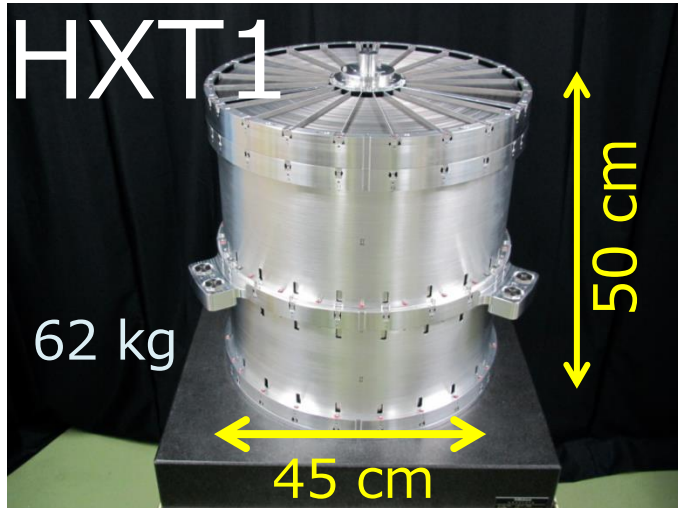
Hard X-ray
Imager
(Si DSD
+ CdTe DSD)

Hard X-ray Telescope



Hard X-ray Telescope (HXT)

Made in Nagoya U.

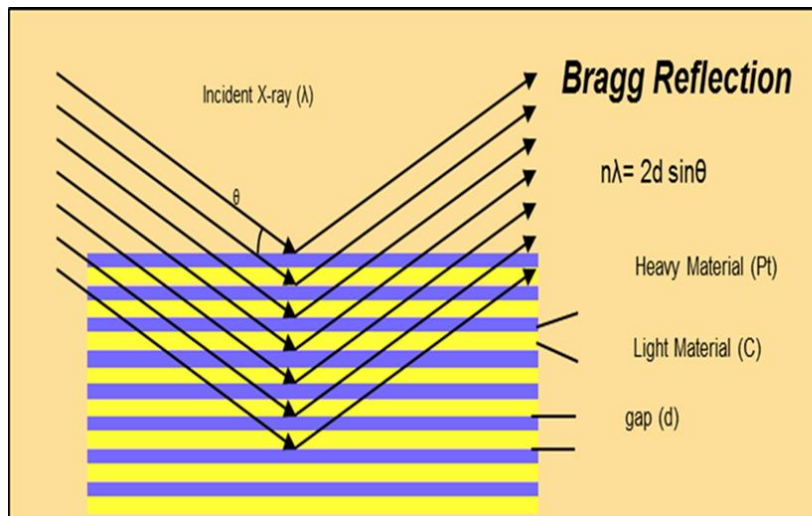
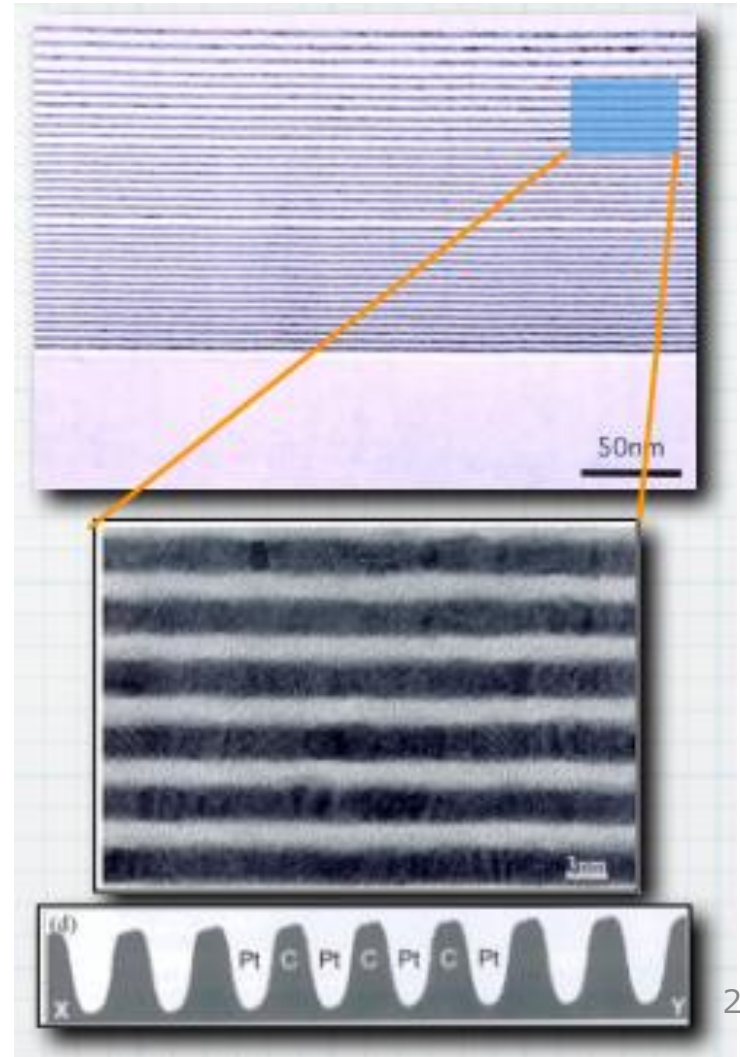


1278
reflectors

HXT mirror

Pt & C multilayer

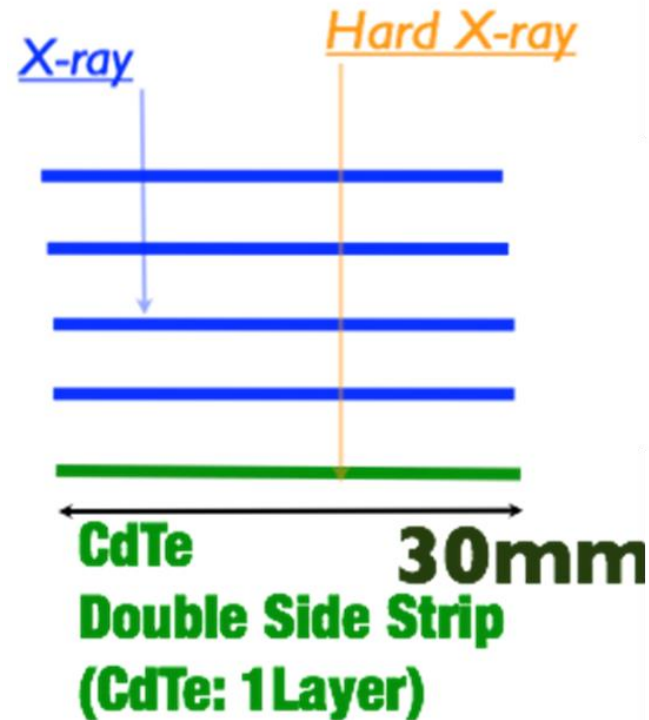
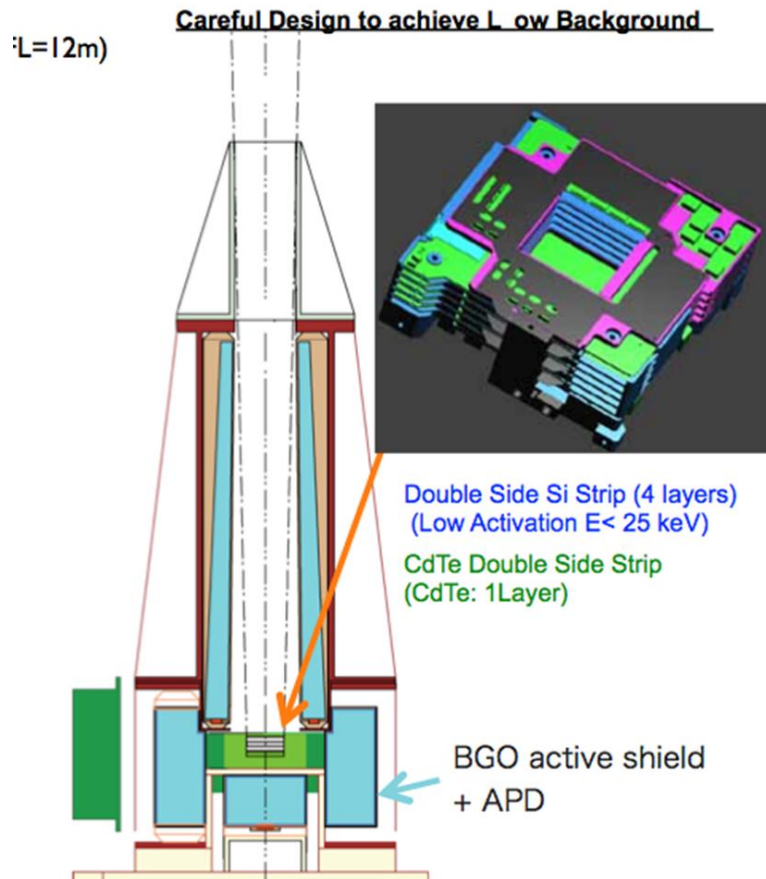
Thin-foil mirror (t0.22mm)



Hard X-ray Imager (HXI)

$E < 20$ keV: Double-sided Si Strip Detector

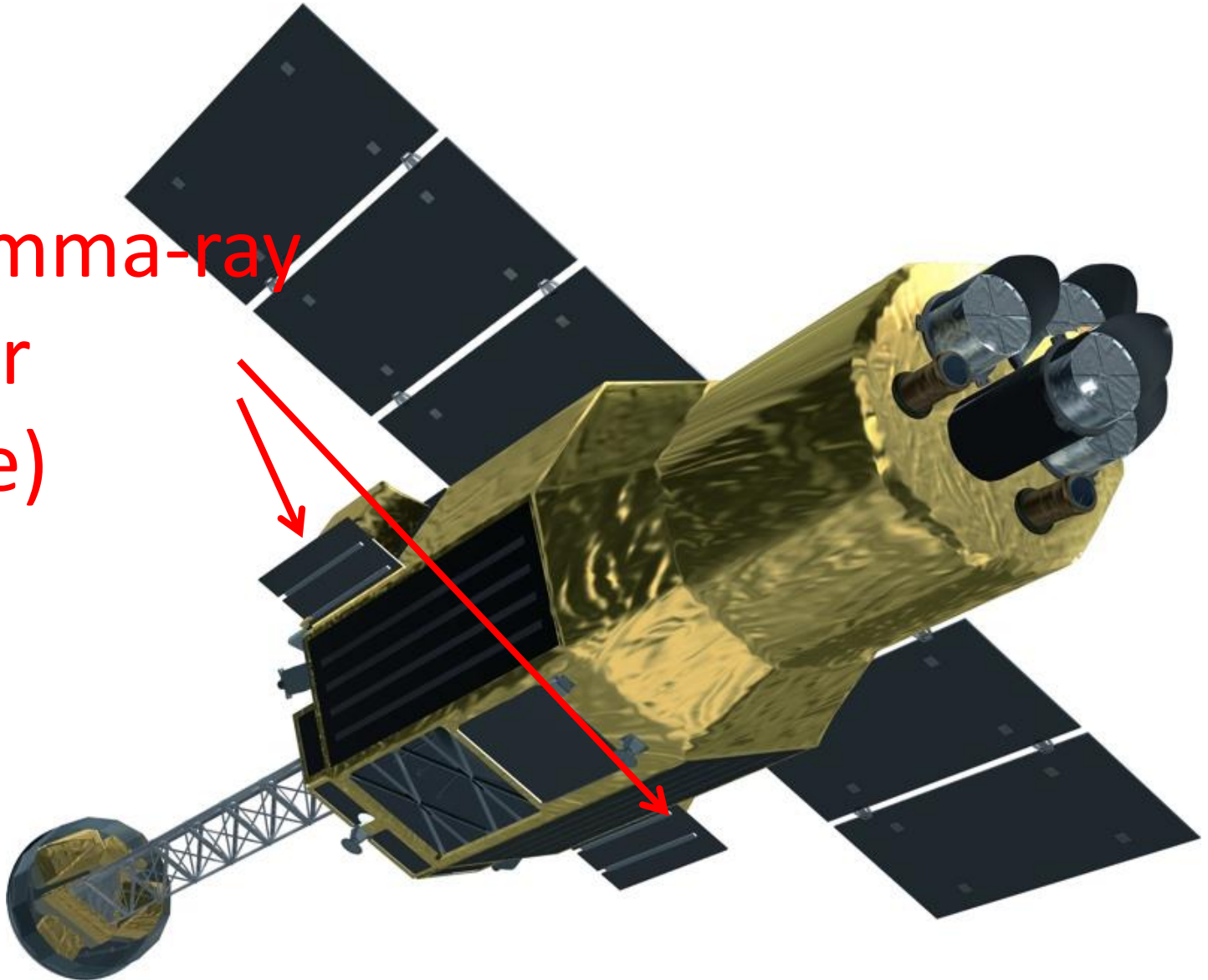
$E > 20$ keV: Double-sided CdTe Strip Detector



FOV: 9' × 9'

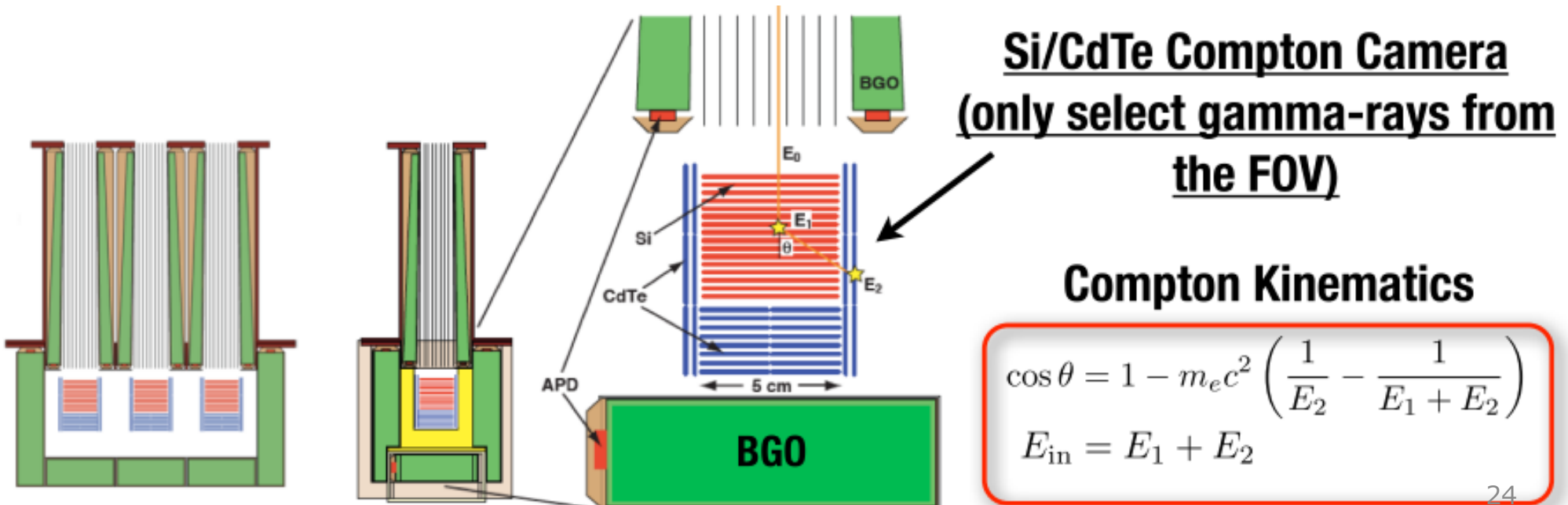
SGD (10–600keV)

Soft Gamma-ray
Detector
(Si+CdTe)



Soft Gamma-ray Detector (SGD)

- Si/CdTe Compton Camera
- Active shield of BGO

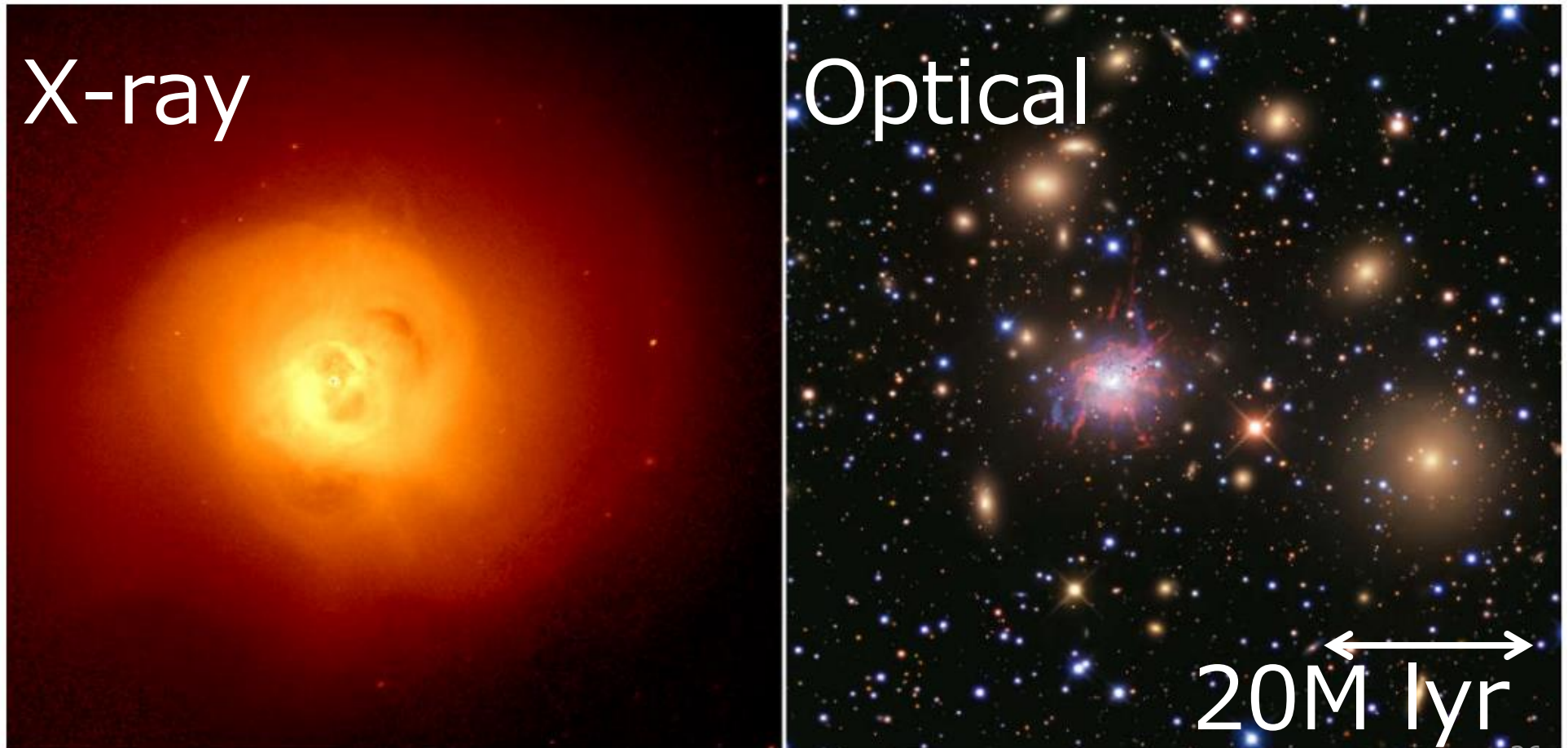


A detailed illustration of a satellite in space. The satellite features a central instrument package wrapped in gold thermal insulation, with several circular sensors or antennas protruding from its top. Two large, rectangular solar panel arrays are extended from the sides. The background shows the dark void of space with a few distant stars and a faint, glowing horizon line at the bottom, suggesting the satellite is in orbit above a planet's atmosphere.

Scientific Results

X-ray vs Visible

Perseus cluster of galaxies

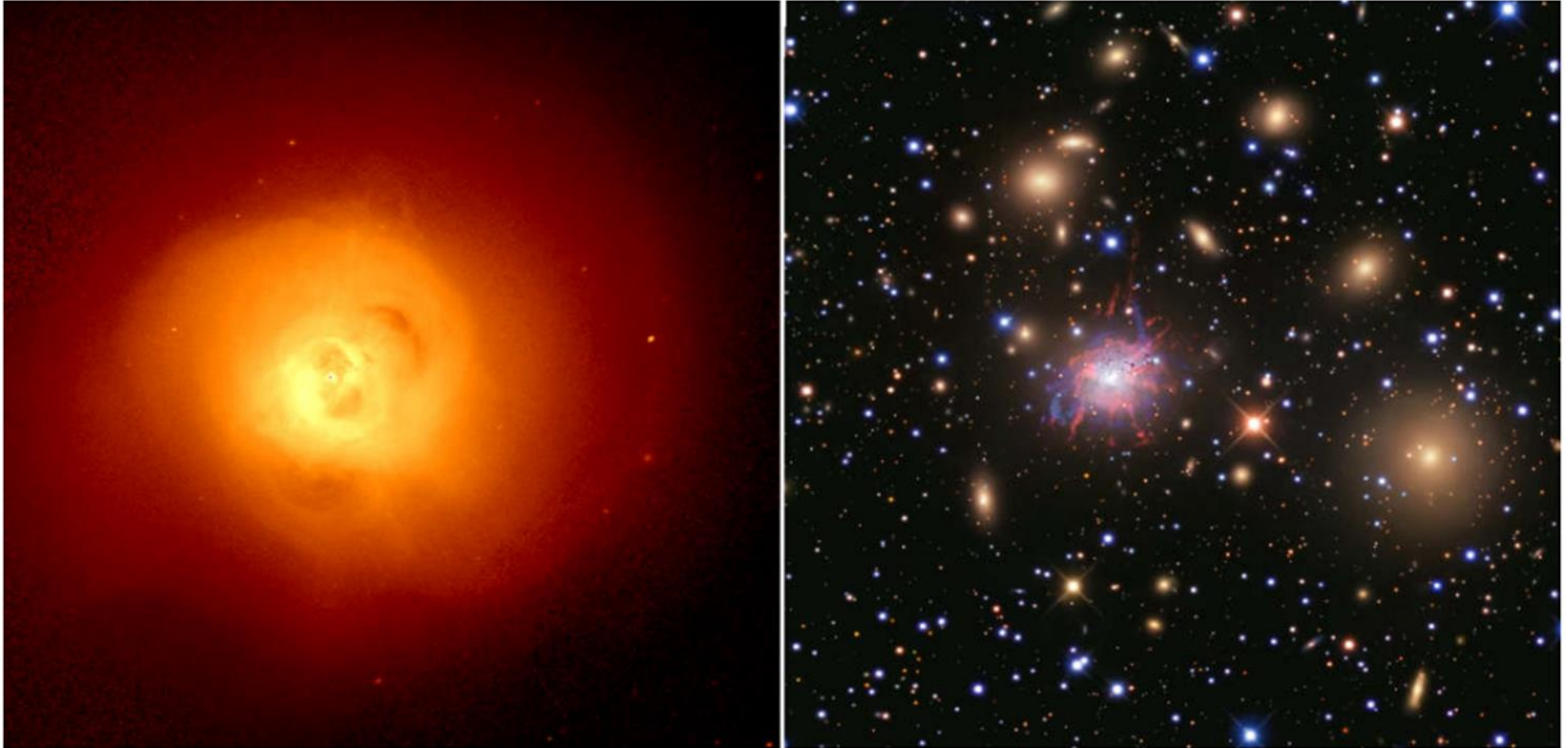


Filled with Hot Gas



$$kT \sim 5 \text{ keV}$$

Main Component: Hot Gas



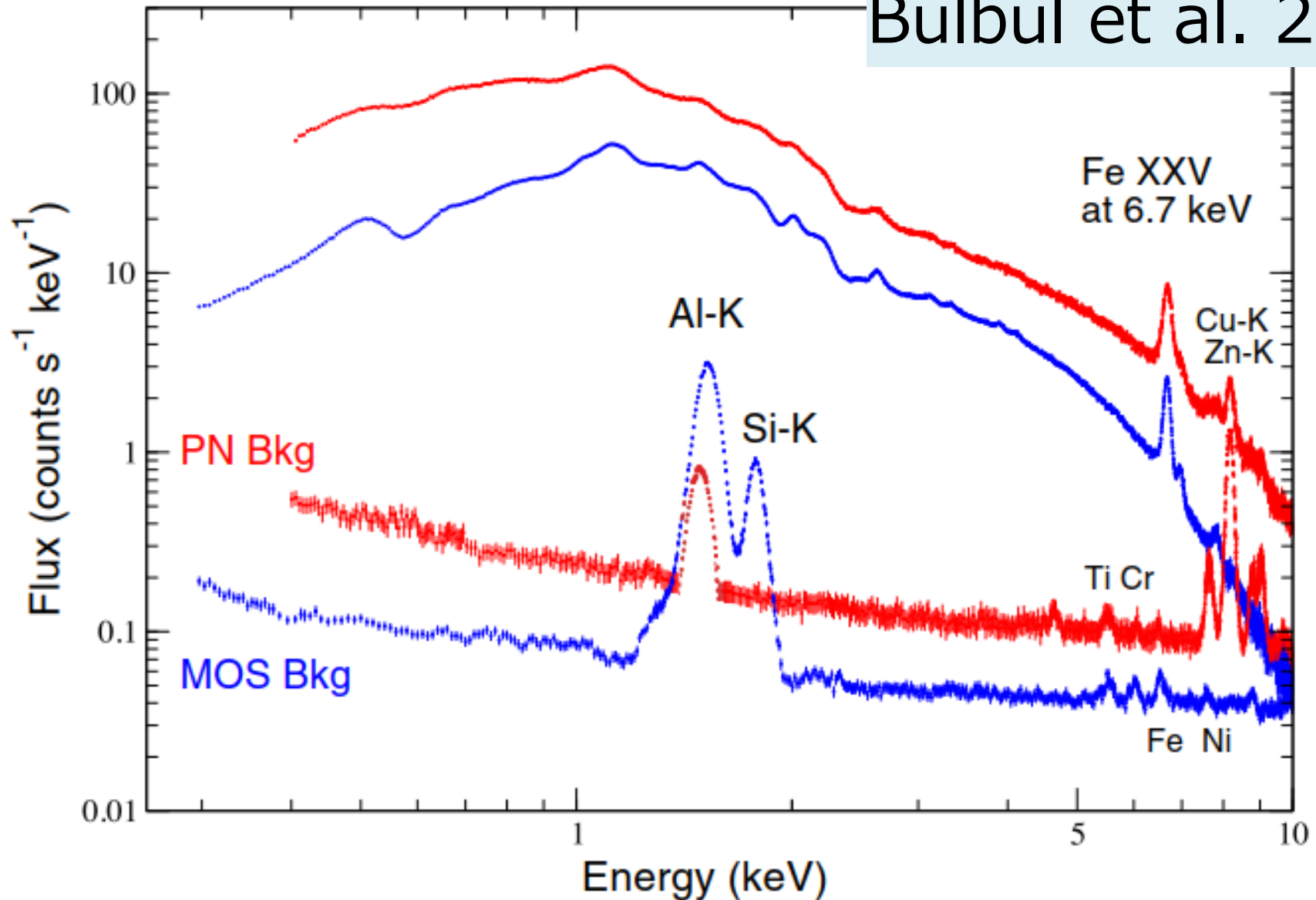
$$M_{gas} > M_{gal}$$

Trapped in DM potential

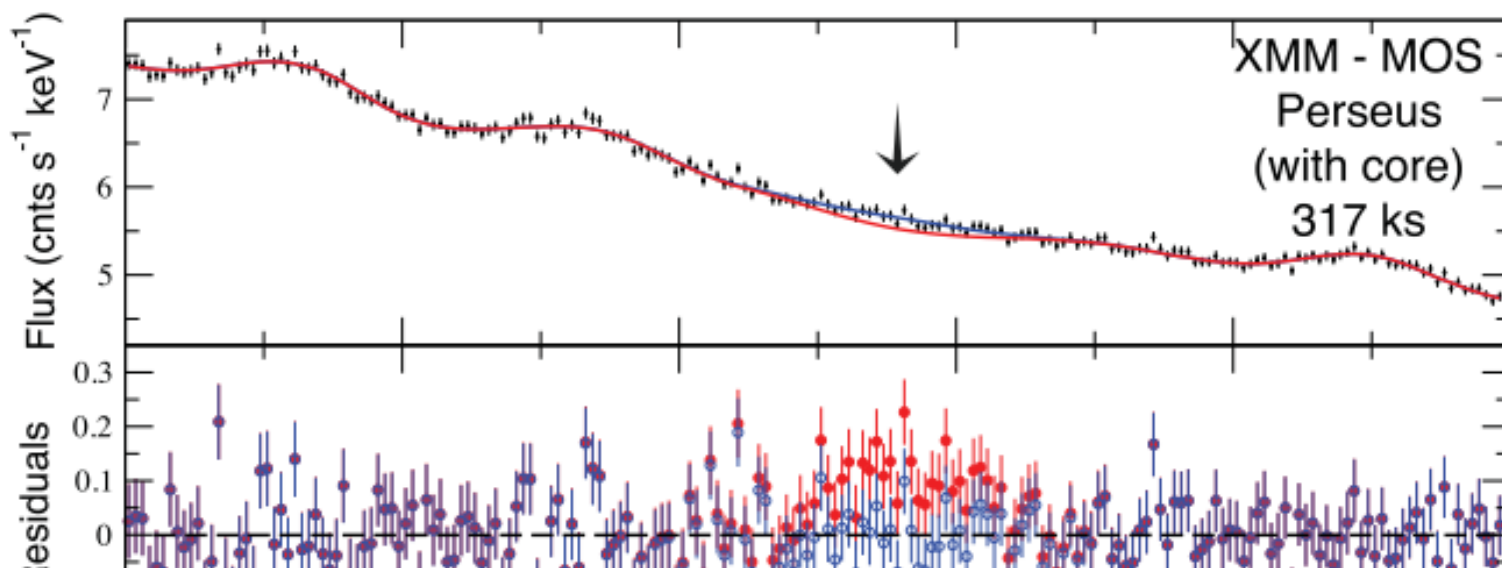


Perseus with XMM-Newton

Bulbul et al. 2014



unID line at 3.5 keV



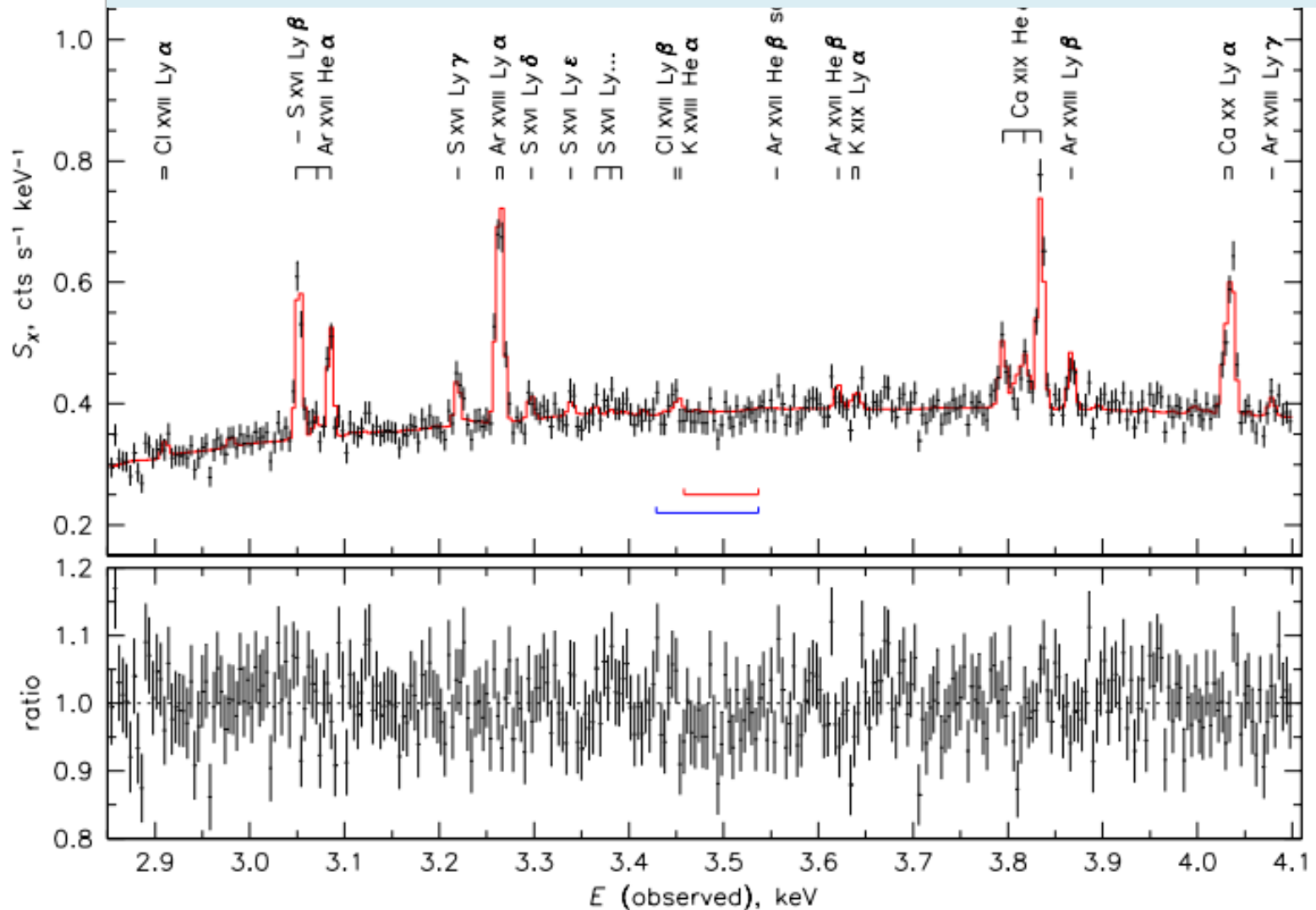
Not an atomic X-ray line

DM ($m_{DM} \sim 7keV$) decay?

Energy (keV)

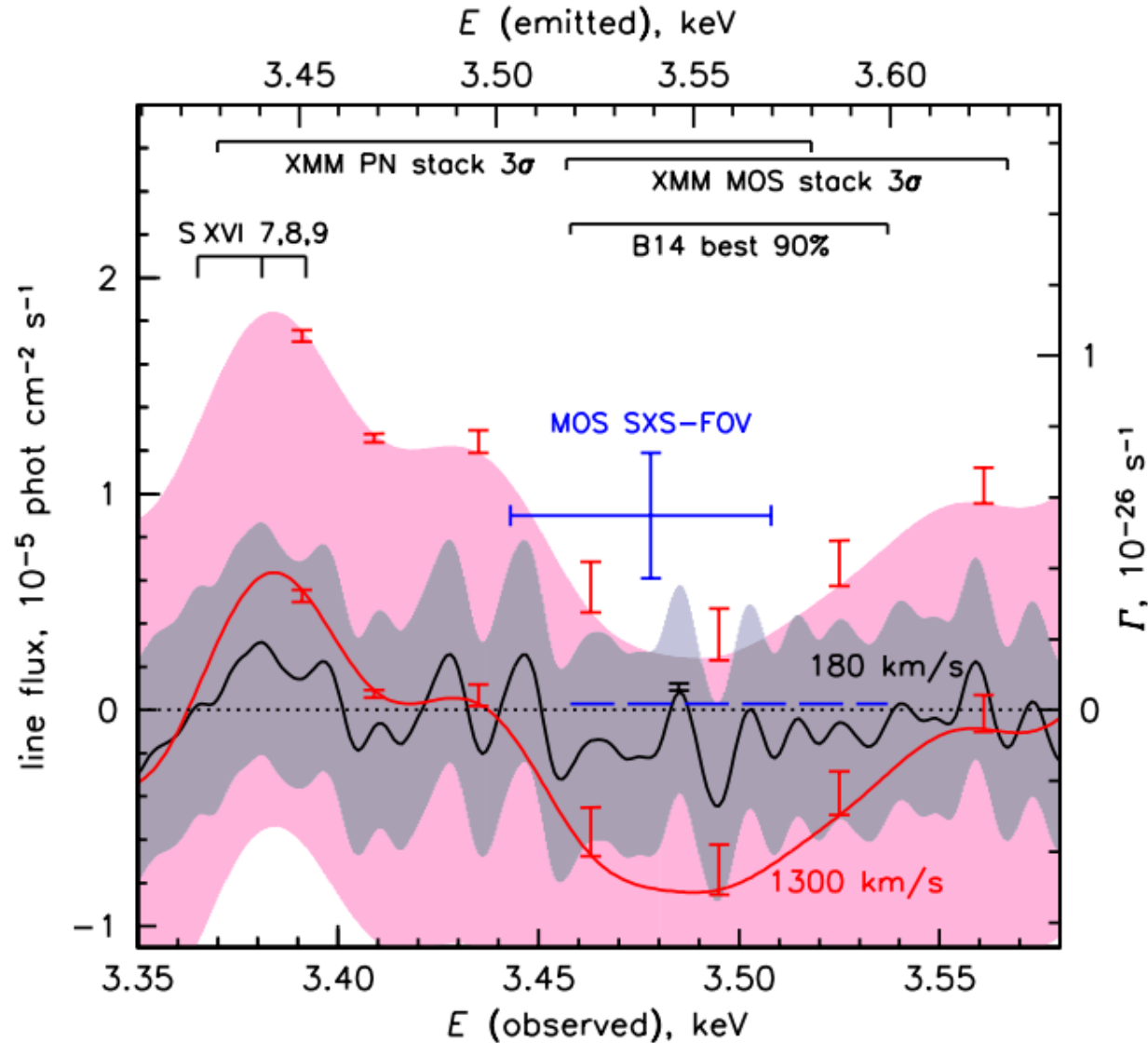
Hitomi Calorimeter

Hitomi collaboration, arXiv:1607.07420



No detection

Hitomi collaboration arXiv:1607.07420



Why still hot?



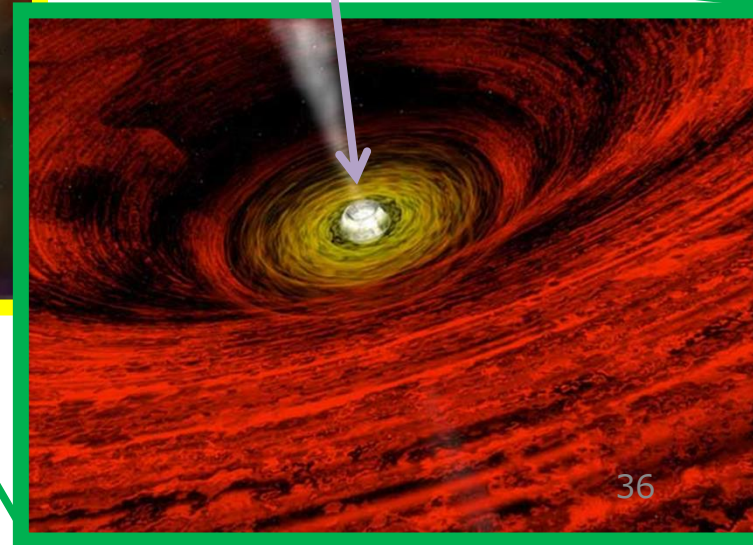
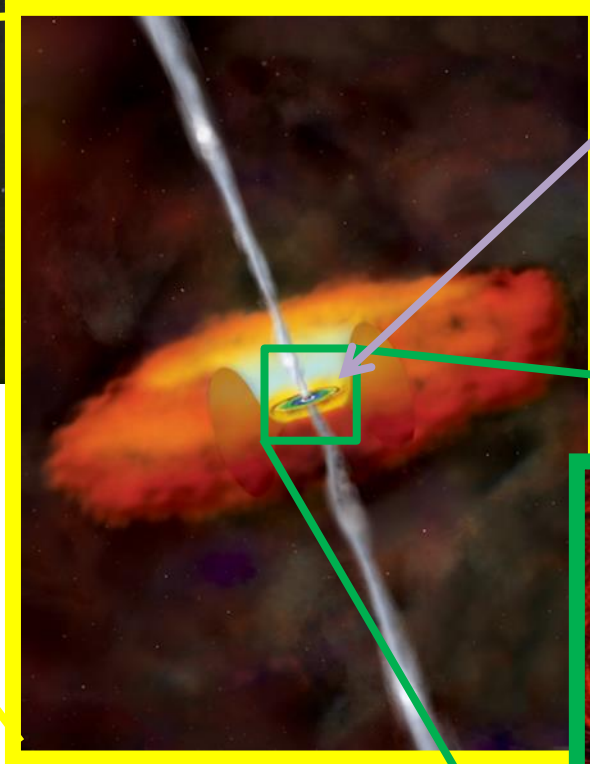
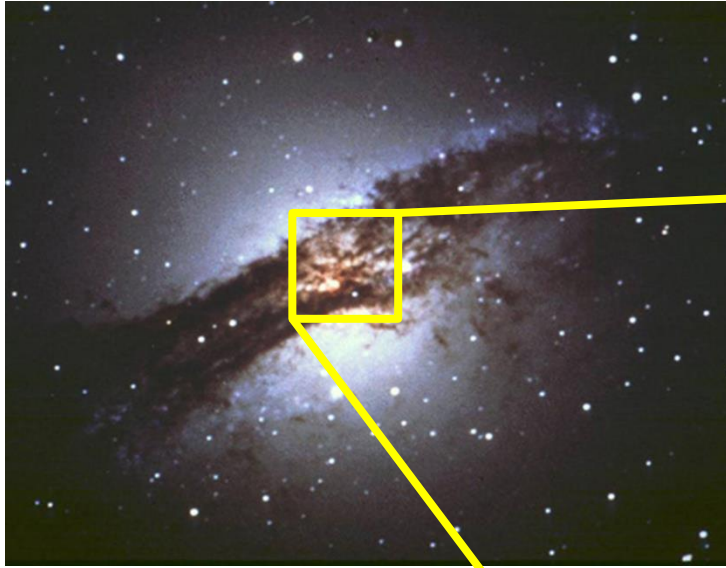
Gas should cool within $2 \times 10^9 \text{ yrs}$

The image shows a large, glowing yellow and orange active galaxy. A blue arrow points from the bottom left towards the bright central core of the galaxy. The galaxy's structure is diffuse and irregular, with a very bright, concentrated center.

Active Galaxy
NGC1275

Active Galactic Nucleus

Super-massive BH





Jet

BH

Accretion Disk

Very hot \rightarrow X-ray



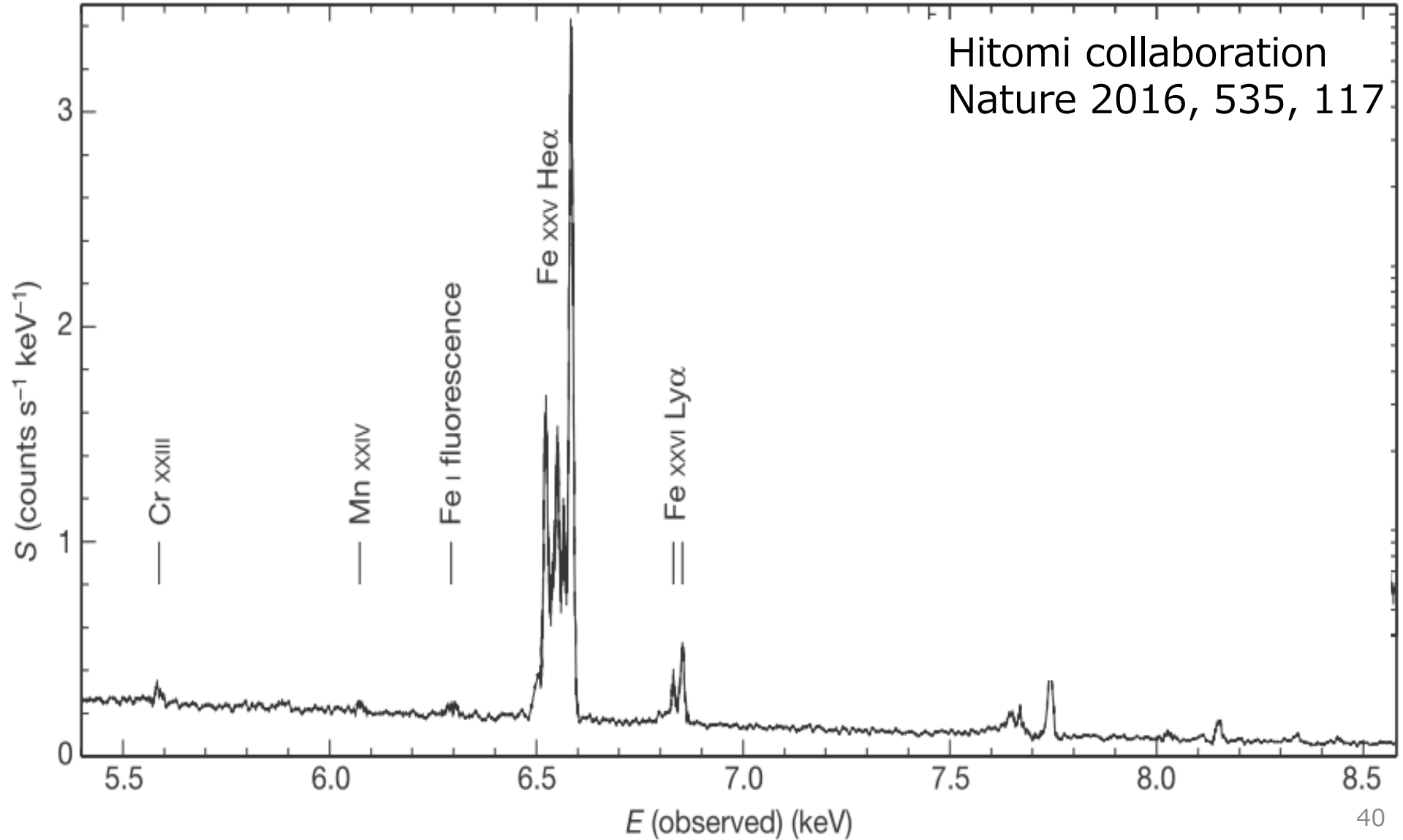
BH puts energy into gas?

Disturbed?



http://kakaku.com/article/pr/14/02_sharp_es-tx930/

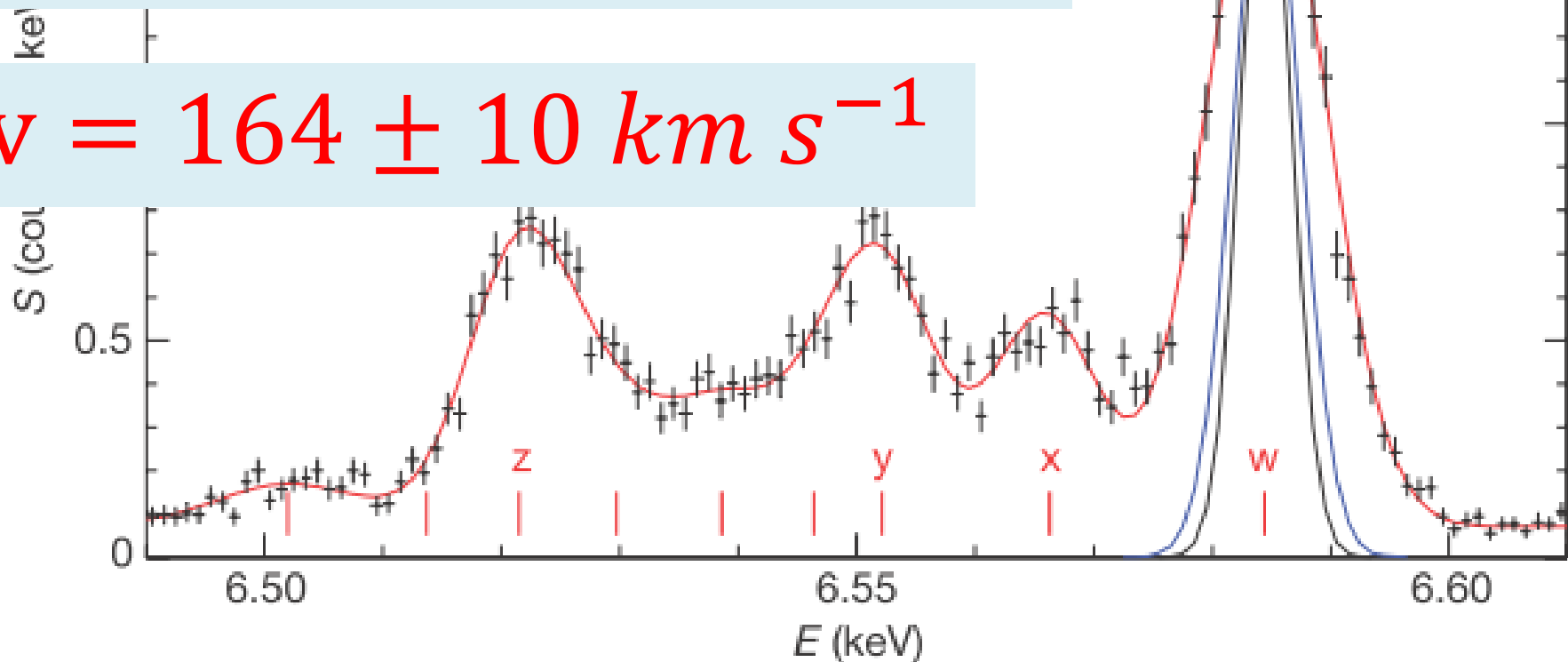
Perseus with Hitomi



Iron line: Outer region

Broadened due to Doppler

$$v = 164 \pm 10 \text{ km s}^{-1}$$



Turbulent velocity

Outer reg.	$164 \pm 10 \text{ km/s}$
------------	---------------------------

Center reg.	$187 \pm 13 \text{ km/s}$
-------------	---------------------------

$$P_{turb} \sim 0.04 \times P_{thermal}$$

$P_{turb} \sim 4\%$ of $P_{thermal}$



Very quiet

hydrostatic equilibrium of gas



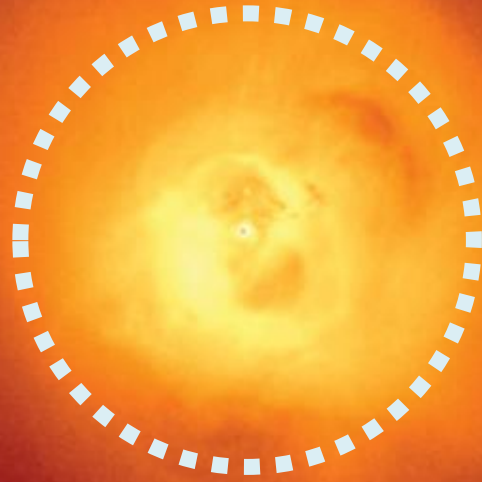
Hot gas distribution

→ Gravitational potential

→ DM distribution

Can BH heat gas?

2×10^5 *Lyr*



Cool within 2×10^9 yrs

Can BH heat gas?

Central region cools within 2×10^9 yrs



How much turbulence should be input?

$$P_{turb} \sim 4\% \text{ of } P_{thermal}$$

Same Problem



Out of the bath
in 3 minutes.



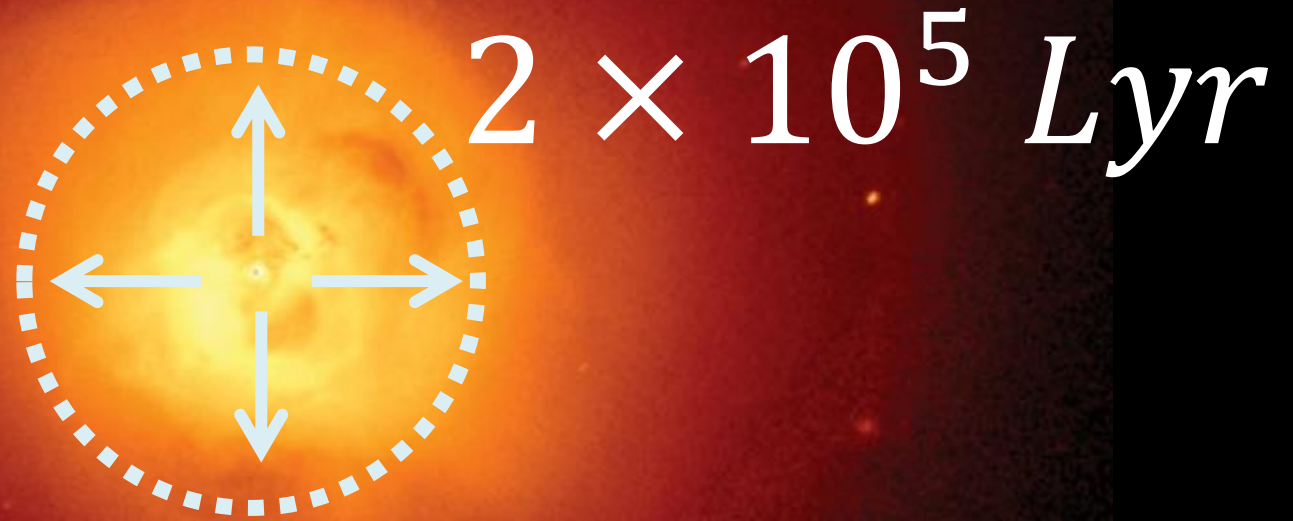
8L

How fast does
he put water?

Ans: $3 \text{ min} \times 4\% = 7.2 \text{ sec}$

Can BH heat gas?

Central region cools within 2×10^9 yrs



$$2 \times 10^9 \text{ yrs} \times 4\% = 8 \times 10^7 \text{ yrs}$$

BH should put energy every 8×10^7 yrs.

Can BH heat gas?

Central region cools within 2×10^9 yrs



Energy has to go $2 \times 10^5 \text{ Lyr}$ within
 $8 \times 10^7 \text{ yrs.} \rightarrow v \sim 700 \text{ km s}^{-1}$

Can BH heat gas?

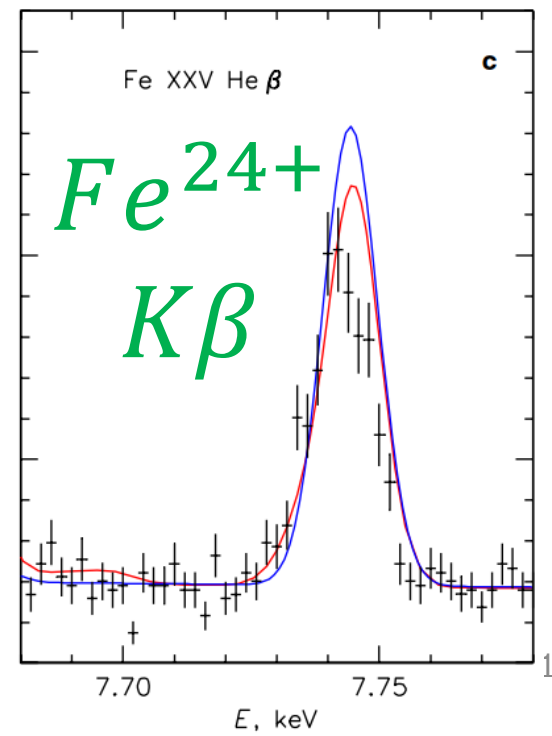
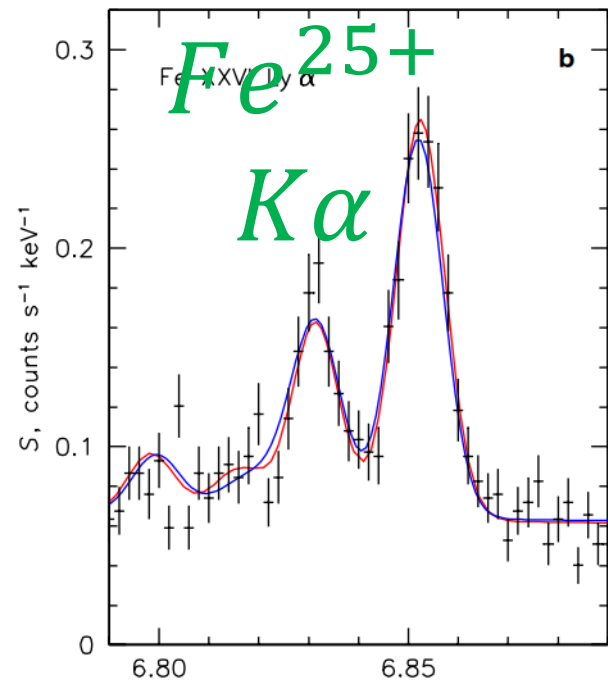
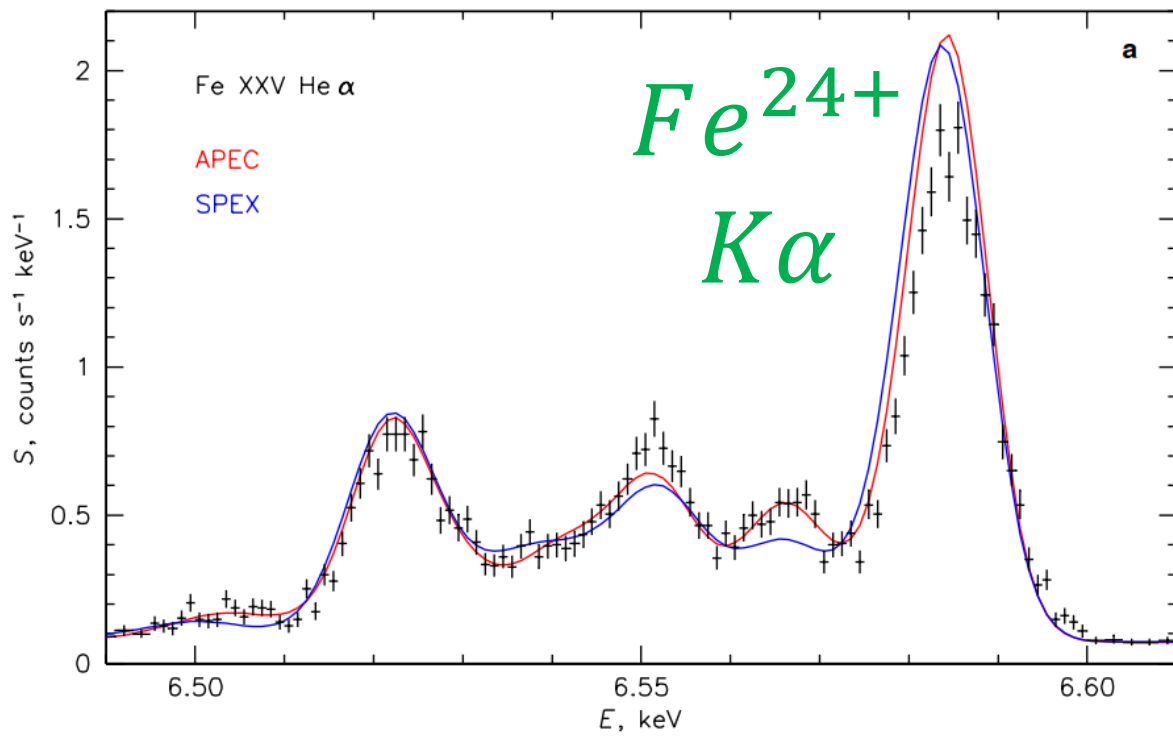
Central region cools within 2×10^9 yrs

What happens?
New problem.

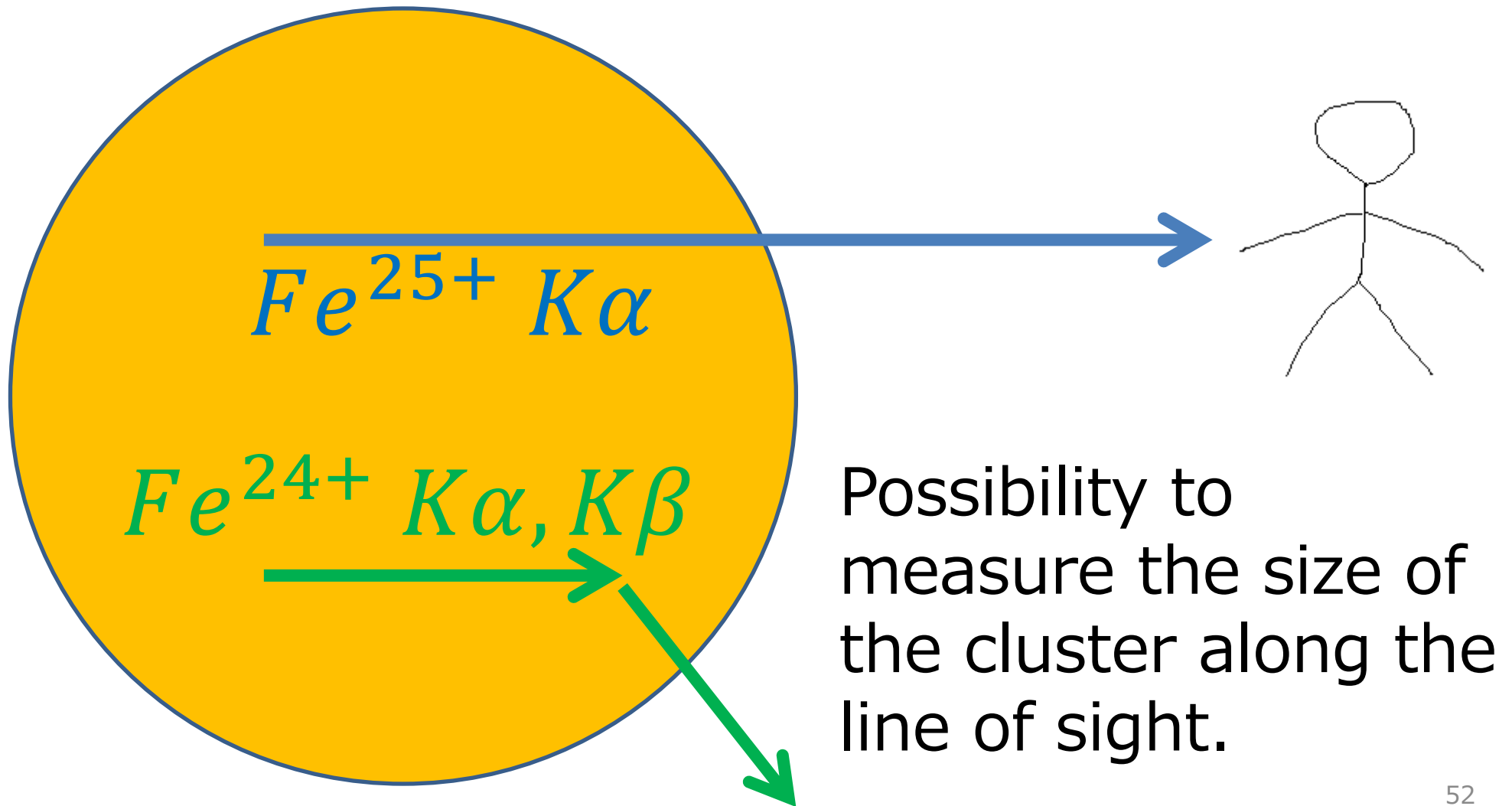
$$v \sim 700 \text{ km s}^{-1} \gg v_{turb} \sim 160 \text{ km s}^{-1}$$

Energy cannot spread!

Fe^{24+} lines suppressed? Why?



Effect of optical depth?



NEWS & COMMENT

Dead X-ray satellite reveals galaxy cluster surprise

A fortuitous observation by Japan's Hitomi probe shows the calm centre of the Perseus cluster.

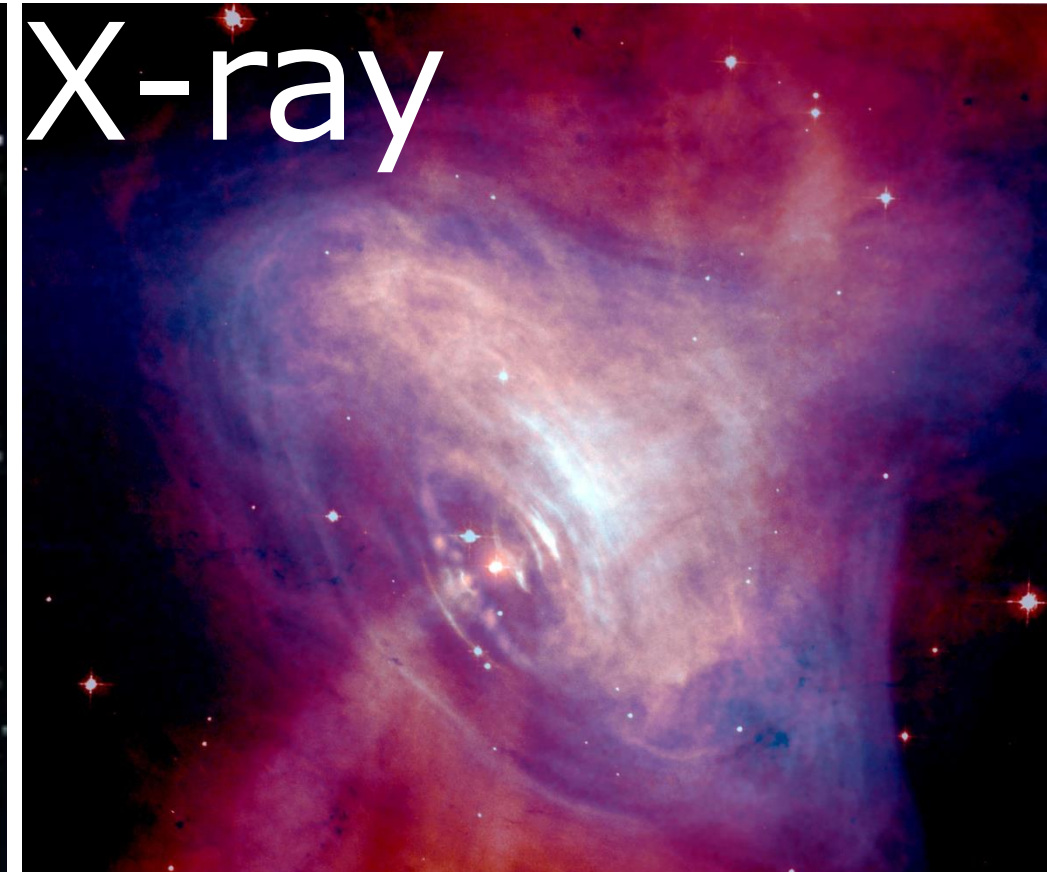
From the last gasp of a failed satellite comes a brief glimpse of galaxies far, far away. Before it broke in March, one month after launch, [Japan's](#)

...



NASA, ESA, NRAO AND L. FRATTARE

Another topic: Crab

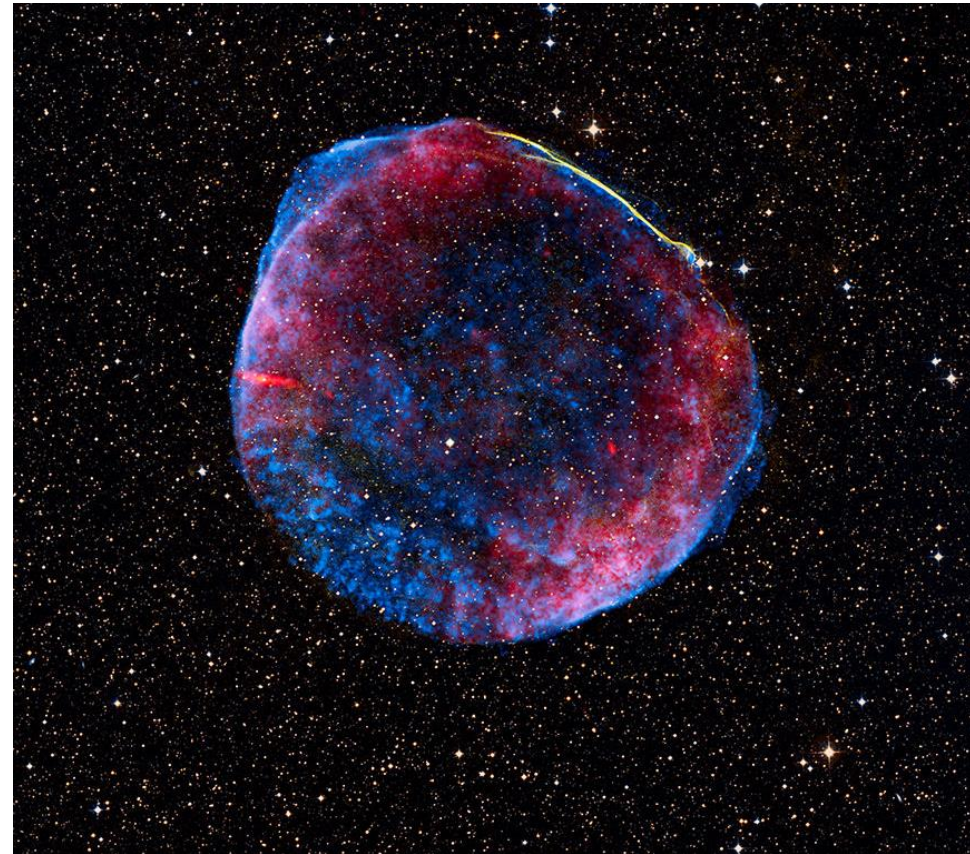
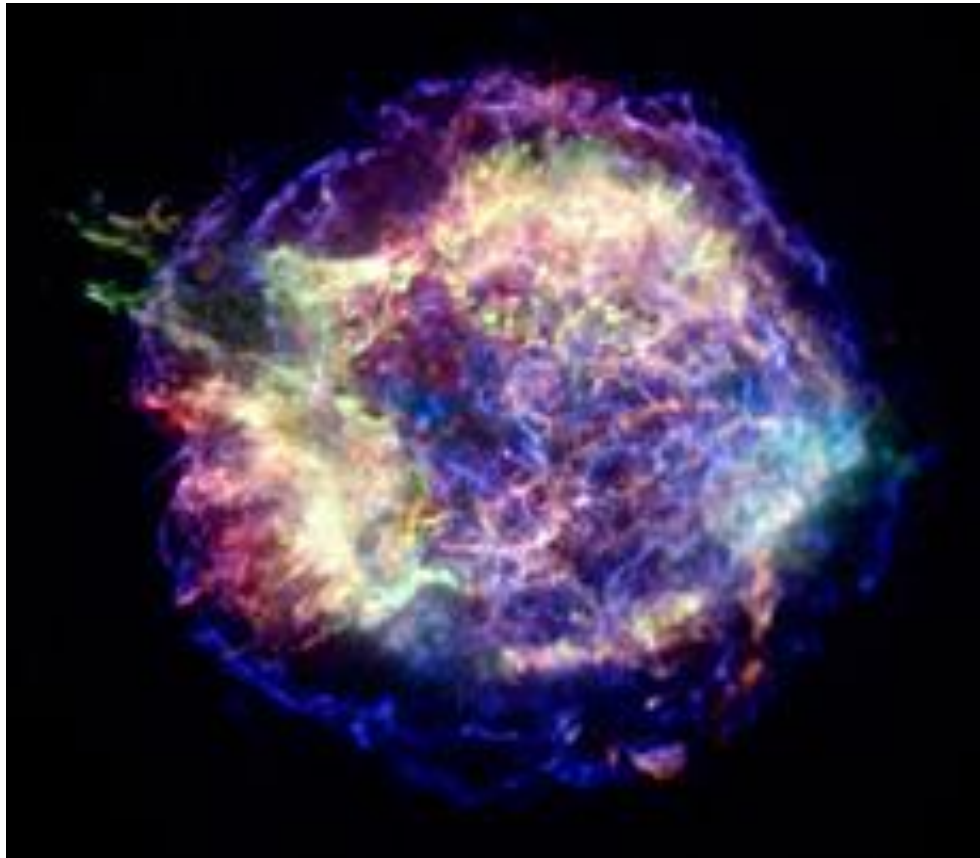


Supernova in 1054

supernova remnant

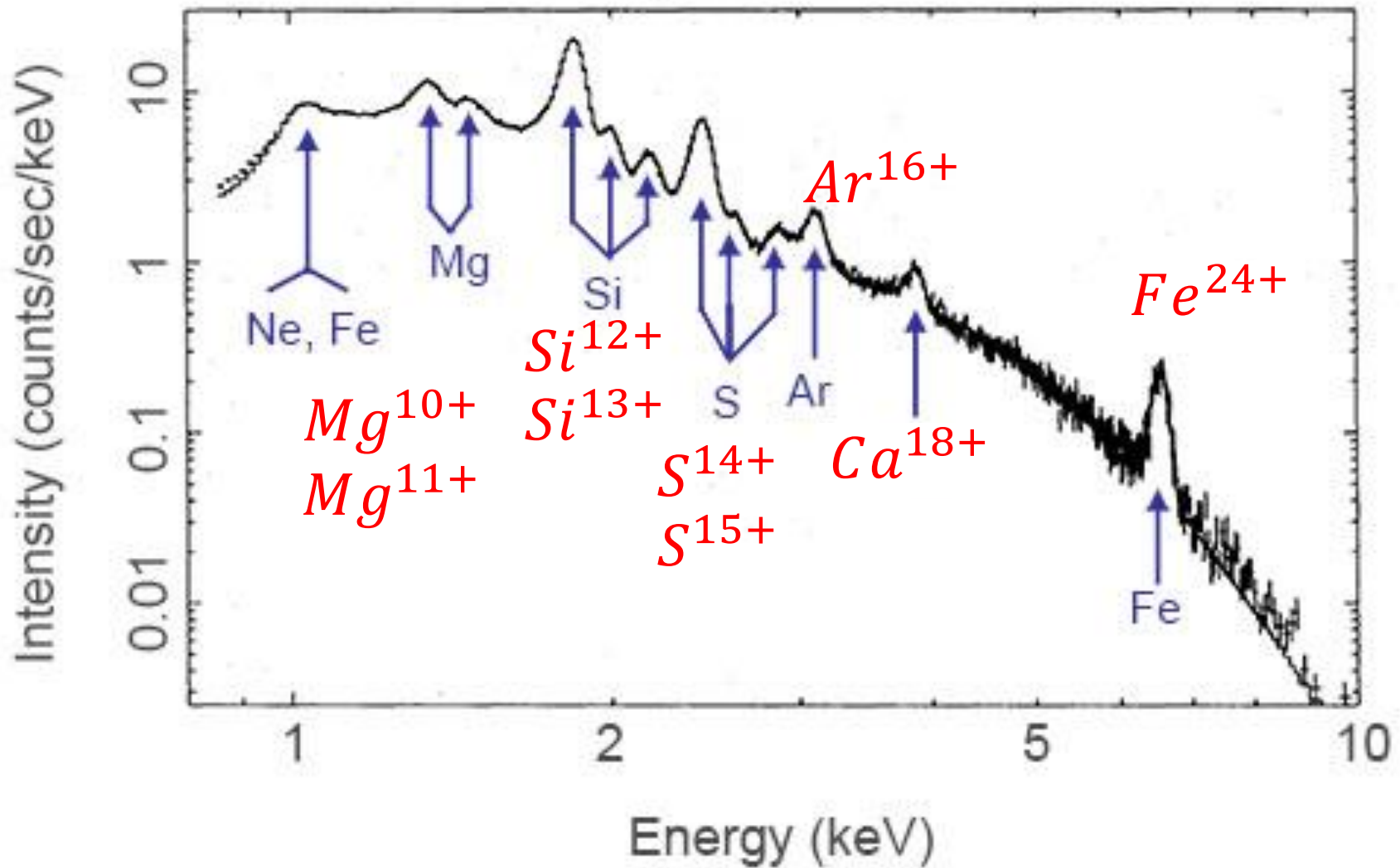
Cassiopeia A

SN1006



(movie)

ASCA Spectrum of Cas A



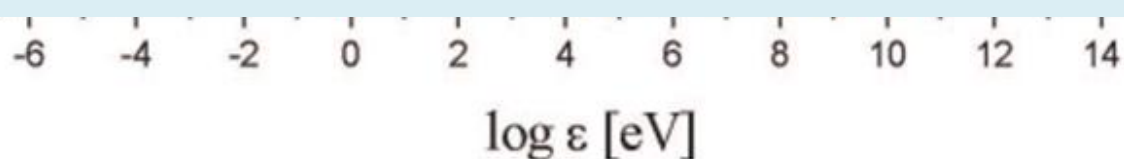
Highly ionized ions → hot gas

Crab spectrum



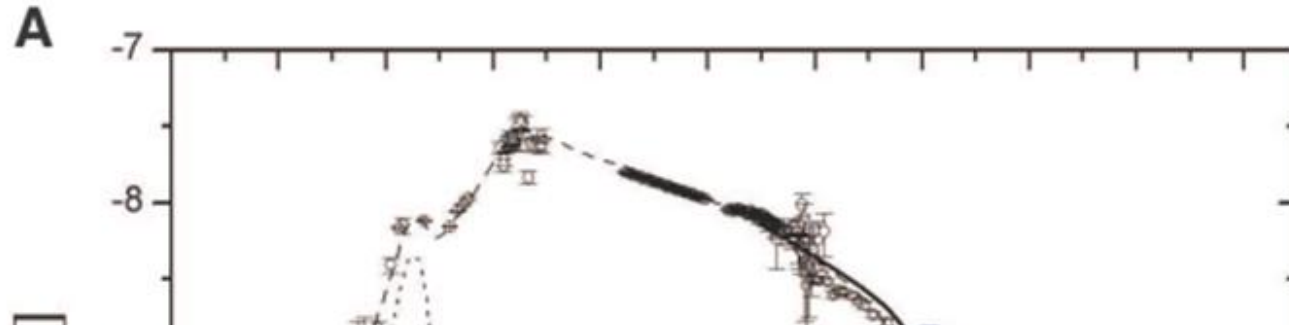
No atomic line
from radio to gamma

Synchrotron emission

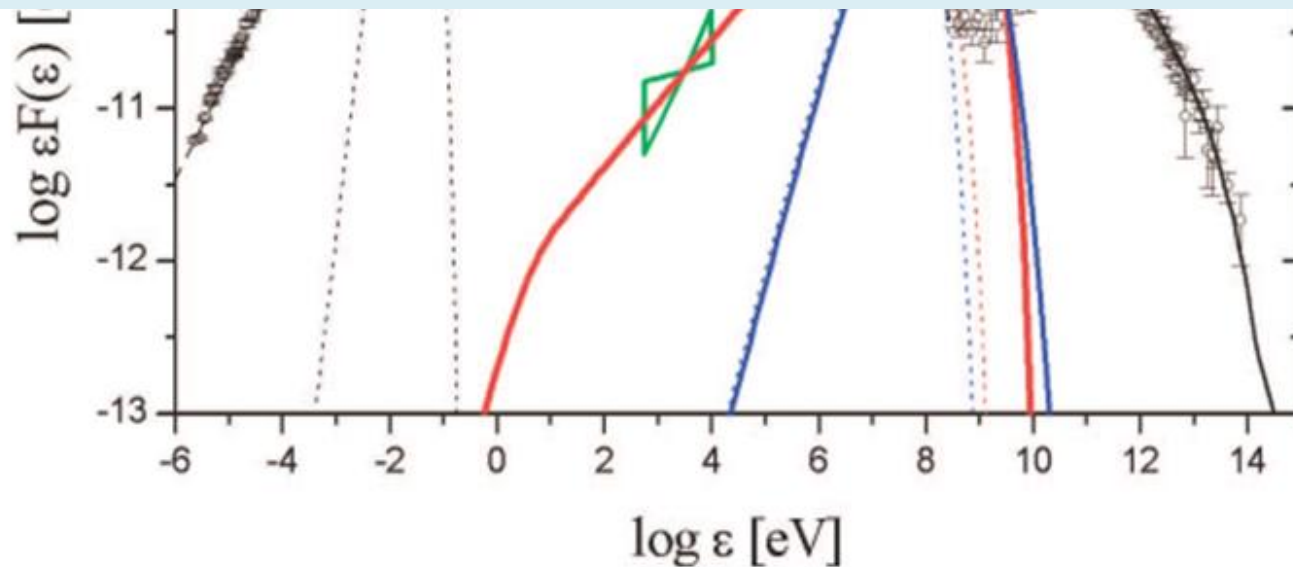


Crab spectrum

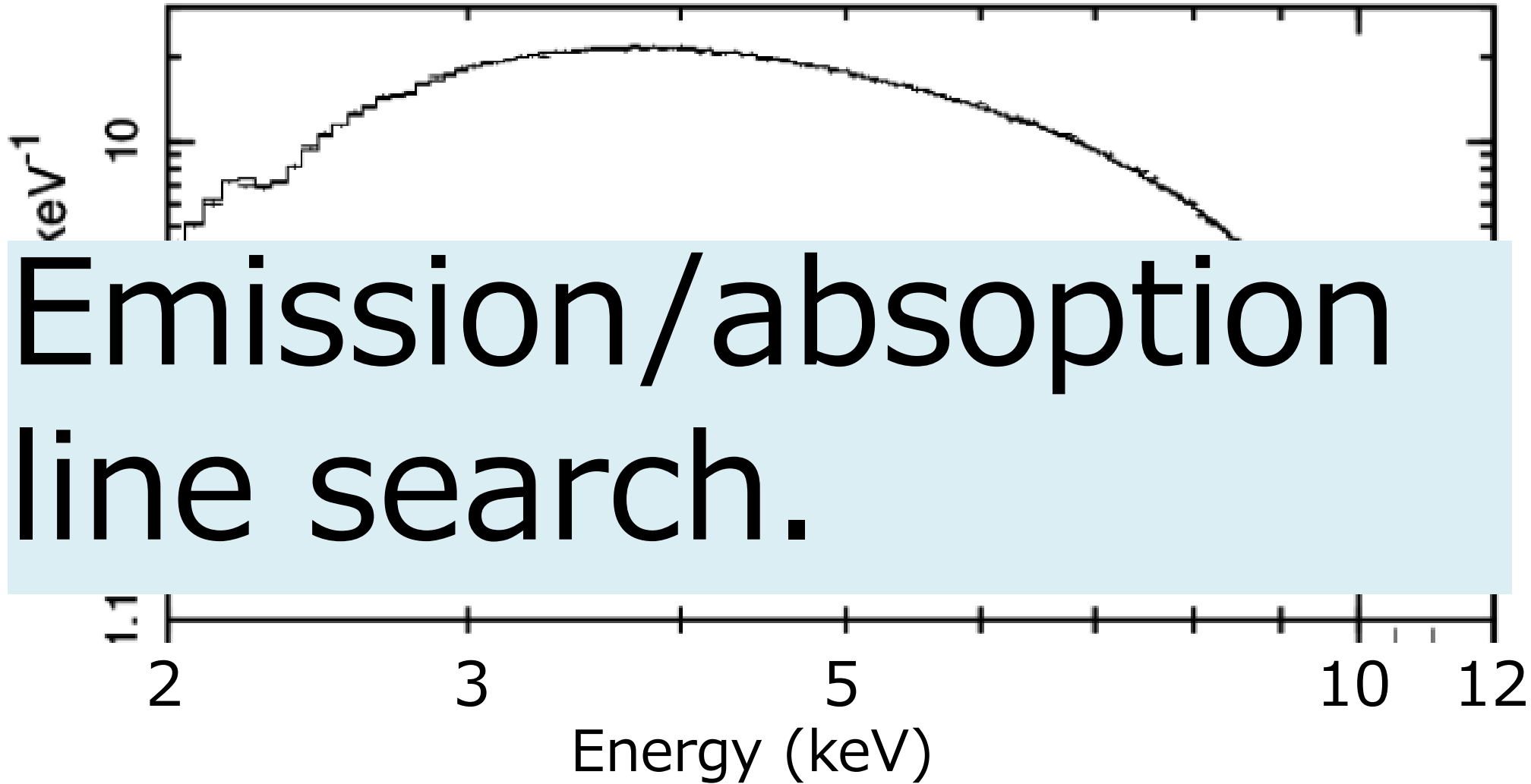
Tavani+2011



Where is hot gas?

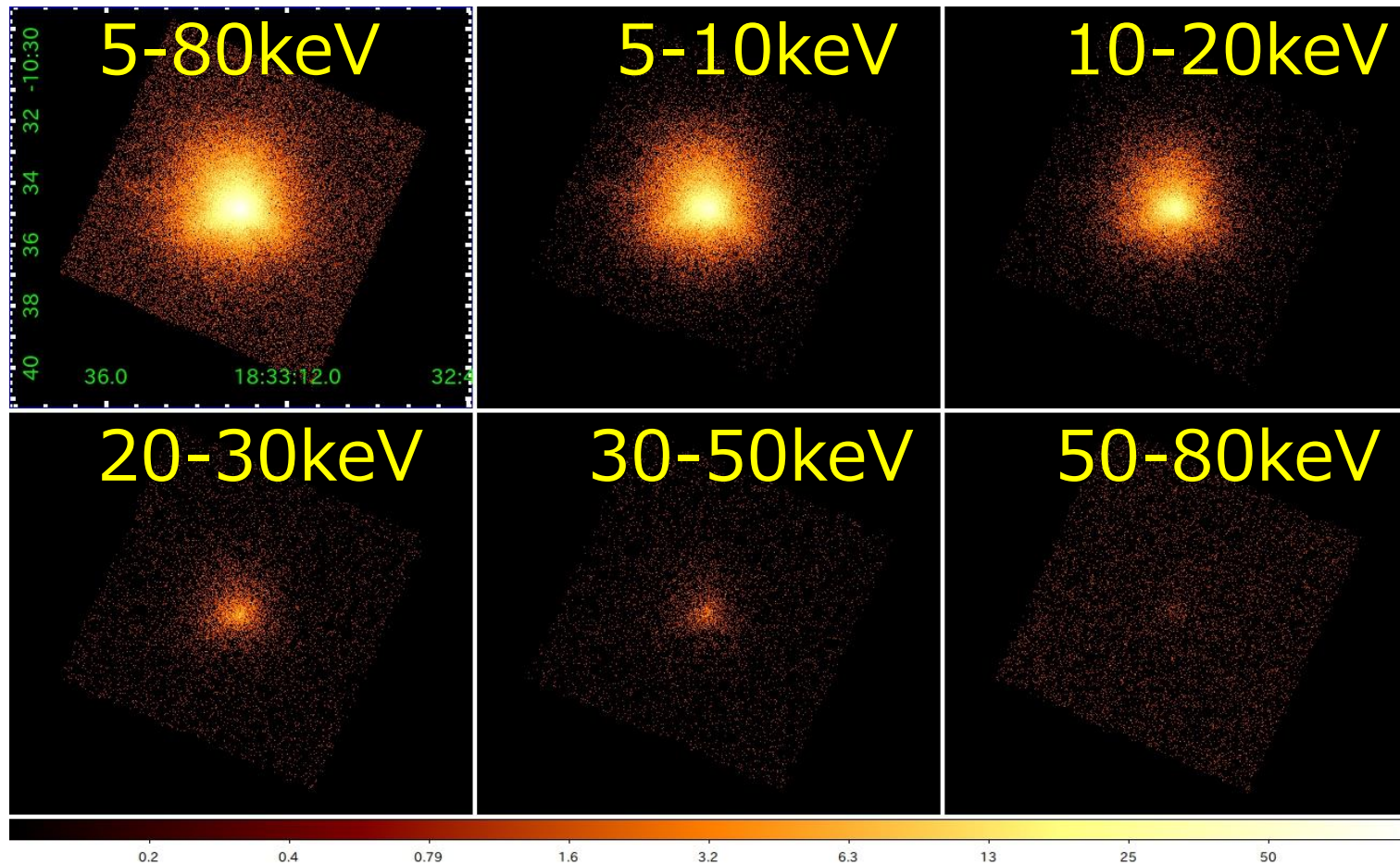


Crab with Hitomi



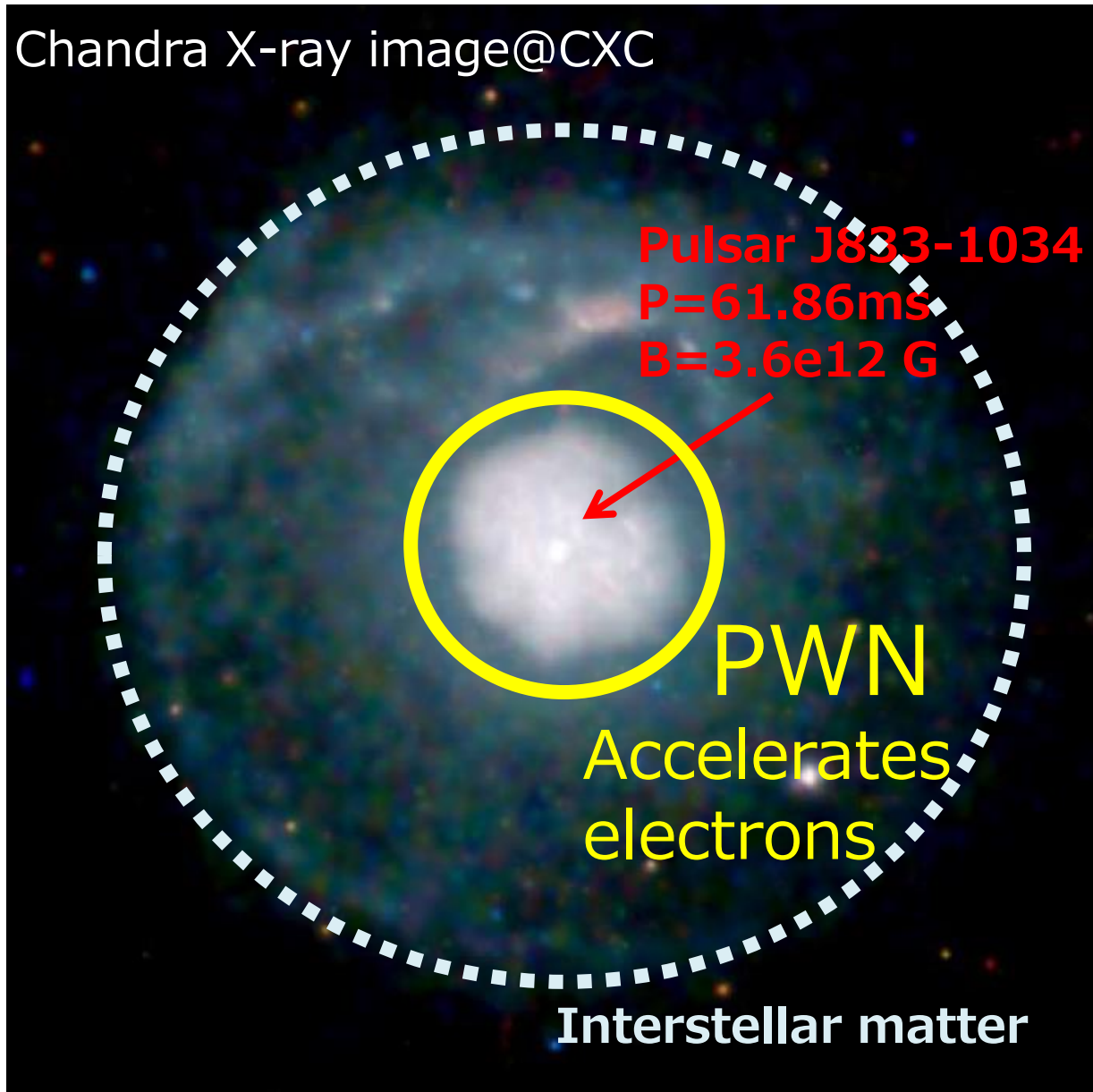
About HXT: Success!

Pulsar wind nebula G21.5-0.9

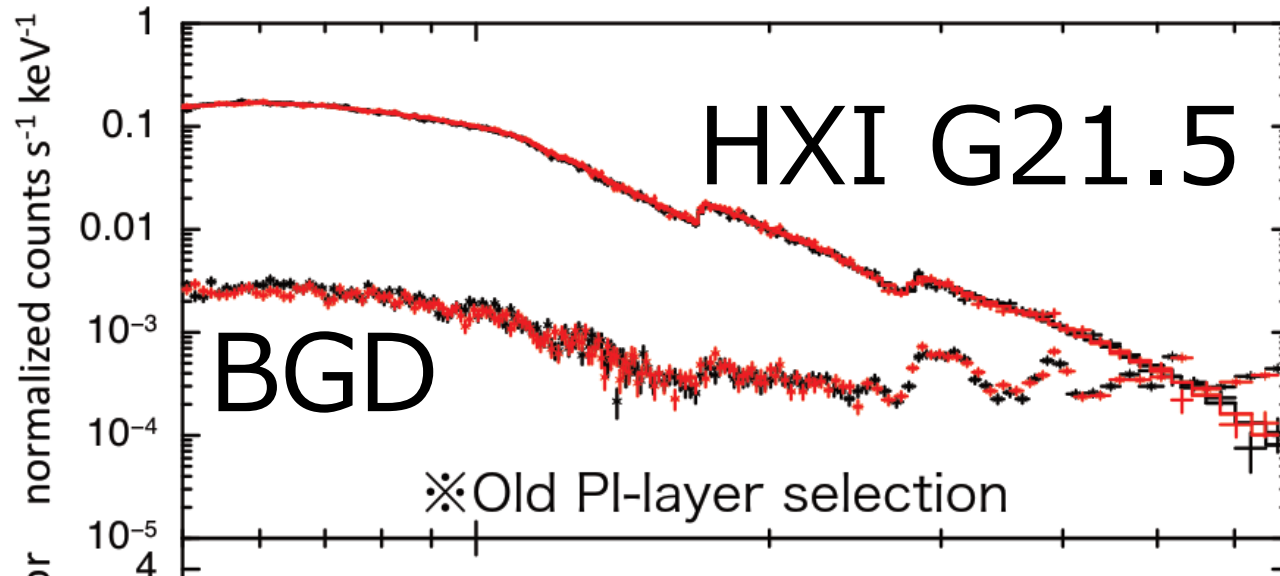


G21.5-0.9: Pulsar Wind Nebula

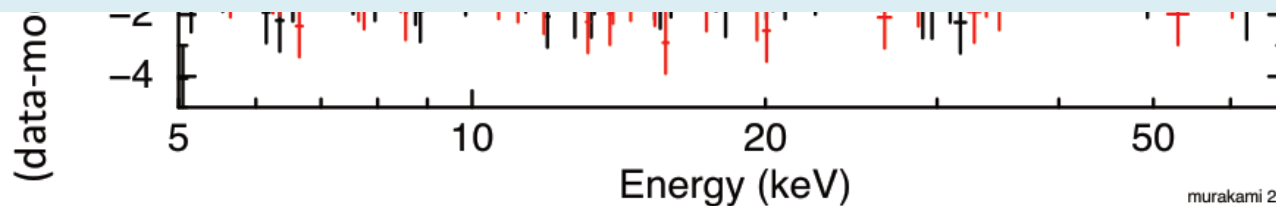
6.3 arcmin



What energy can electrons be accelerated to?



Any break in the spectrum?



©H. Murakami
(U. of Tokyo)

murakami 26-

Planned talks

	Time	Speaker	Topics
KMI2017	15:30, Jan. 6, 2017	T. Ohashi (Tokyo Metro. U.)	Perseus and others
	9:00, Jan. 7., 2017	T. Kitayama (Toho U.)	DM search
Seminar Physics	16:00, Feb. 20, 2017	H. Yamaguchi (NASA/GSFC)	Supernova

Summary

- Hitomi observed several objects.
 - Perseus, Crab, and others
- Many scientific topics are under discussion.

Stay Tune!