Early results of the Hitomi satellite

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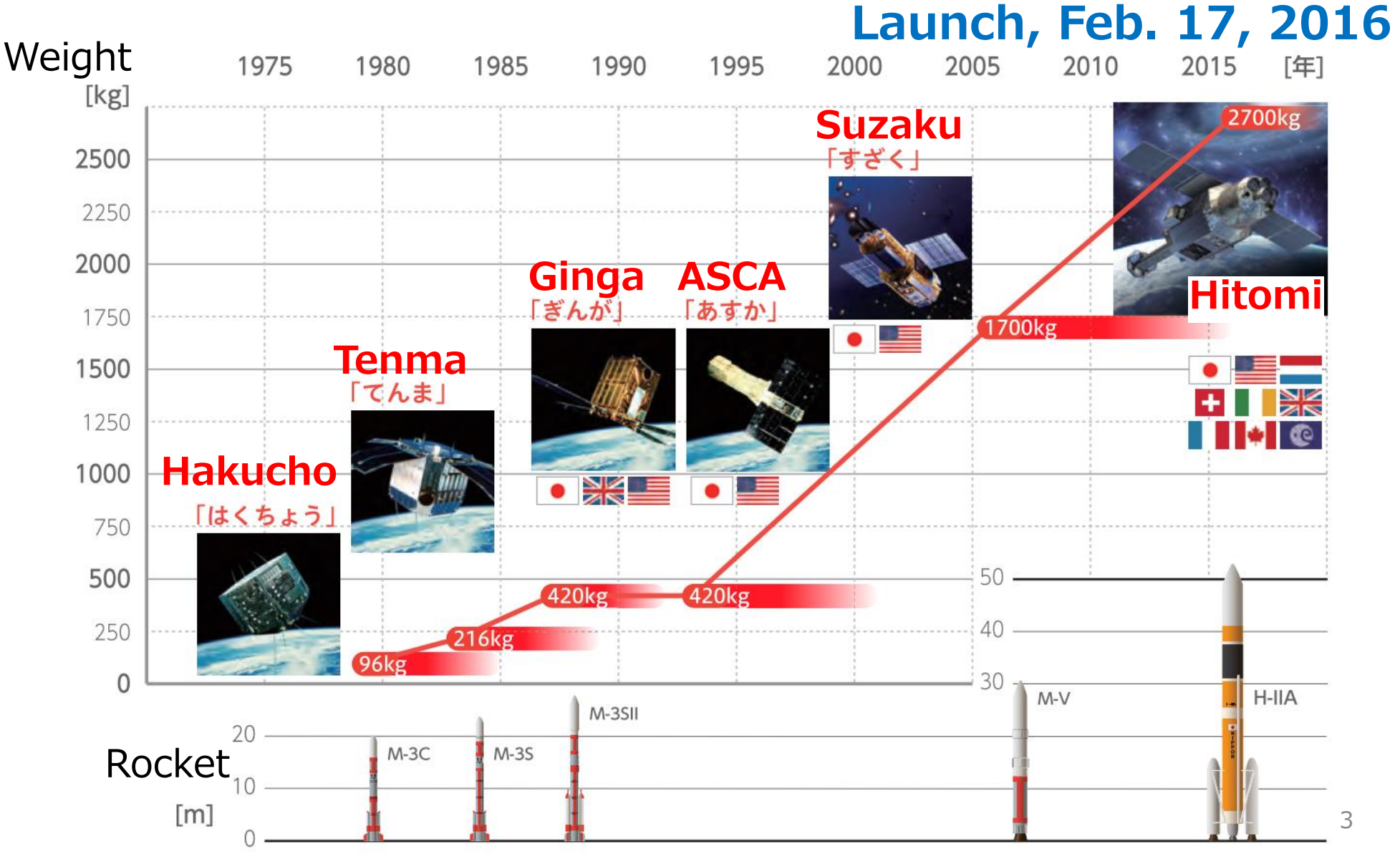
Outline

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

Japanese history of X-ray satellites

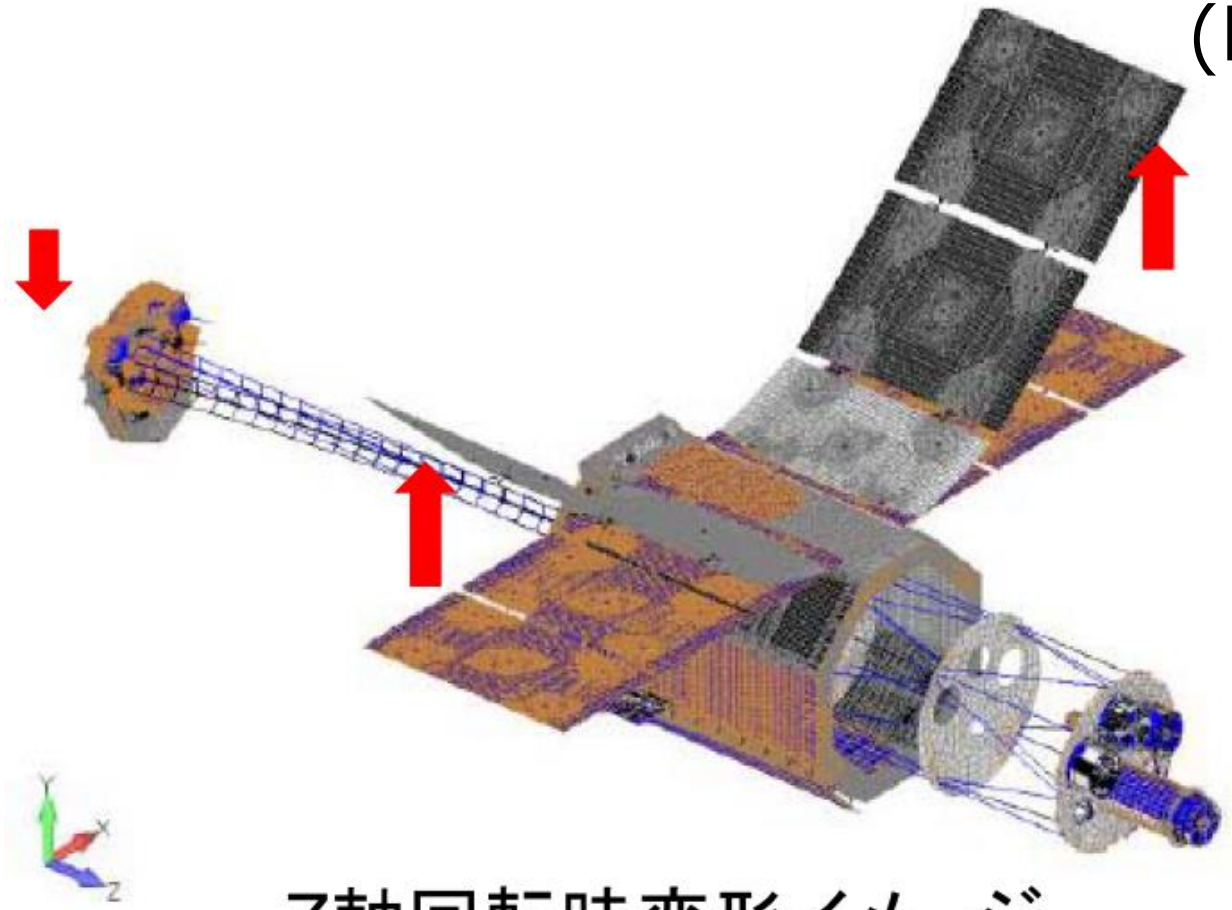


International collaboration

More than 160 scientists from Japan/USA/Europe

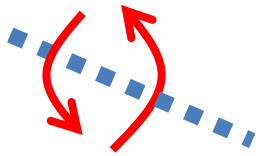
Attitude anomaly
→ Loss of communication

(Mar. 26, 2016)



Z軸回転時変形イメージ

spinning



Gave up recovery (Apr. 28, 2016)

Hitomi Obs. List

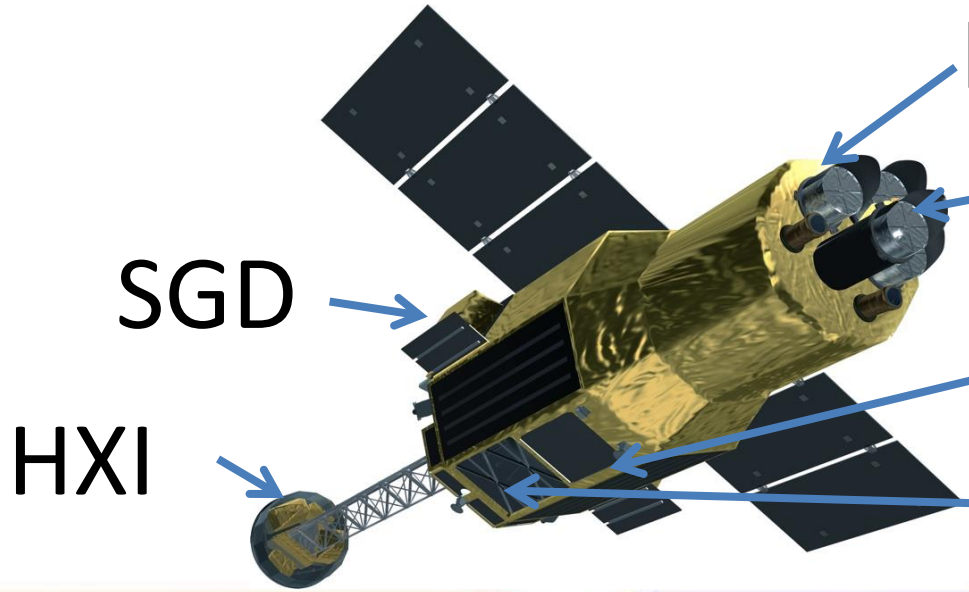
Target		Date
Perseus	Cluster of galaxies	Feb. 25—27, 2016 Mar. 4—8, 2016
N132D	Supernova remnants	Mar. 8—11, 2016
IGR J16318-4848	Pulsar wind nebula	Mar. 11—15, 2016
RXJ 1856-3754	Neutron star	Mar. 17—19, 2016 Mar. 23—25, 2016
G21.5-0.9	Pulsar wind nebula	Mar. 19—23, 2016
Crab	Pulsar wind nebula	Mar.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


Scienfitic Instruments

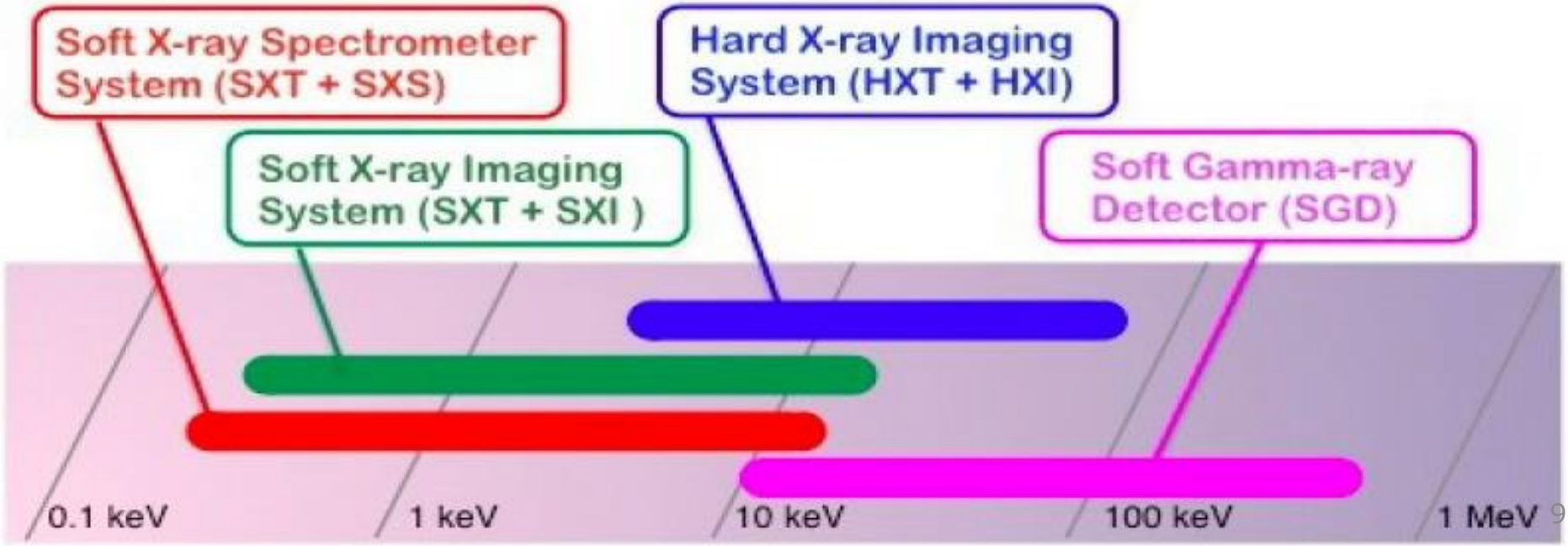
4 systems

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

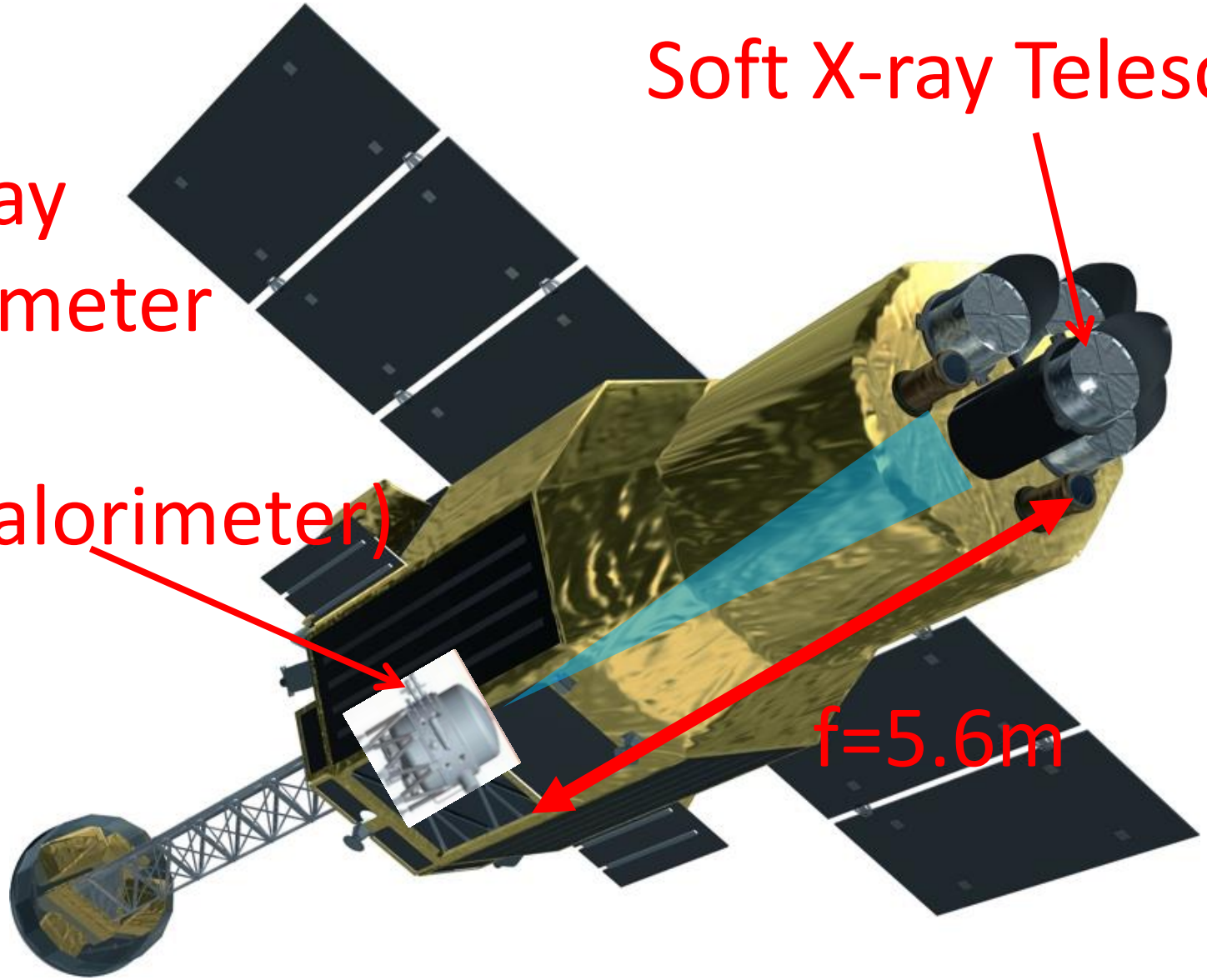
Wide energy range (0.3—600keV)



1keV~ 10^7K



SXT + SXS (0.3—12keV)

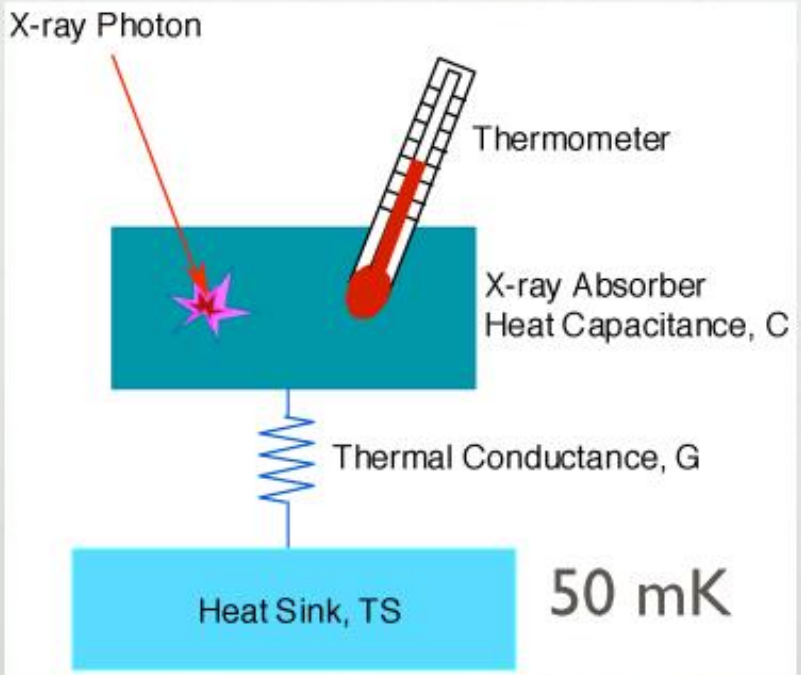


Soft X-ray Spectrometer (SXS)

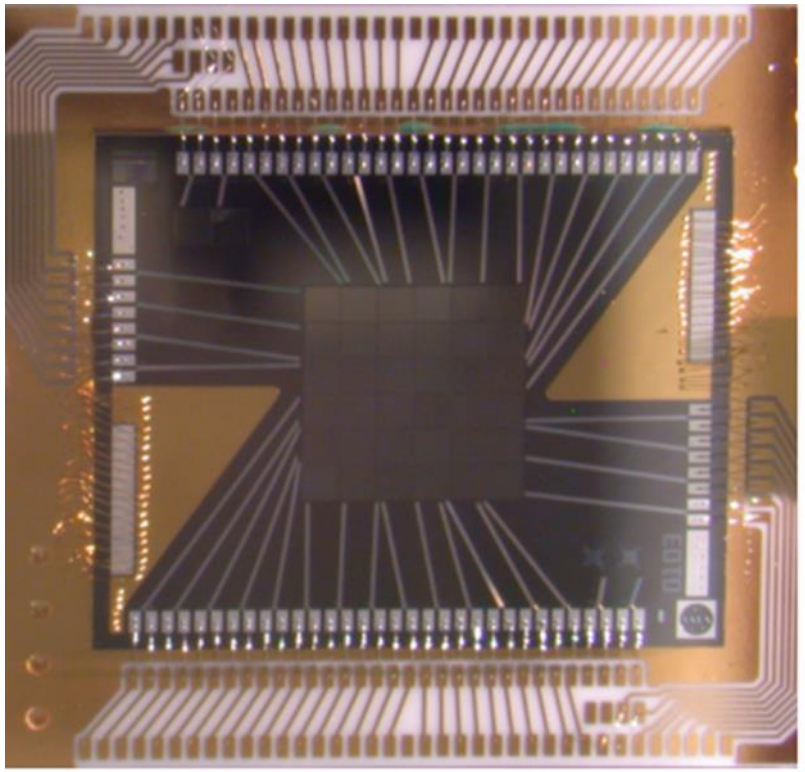
Microcalorimeters

High quantum efficiency

Imaging capability



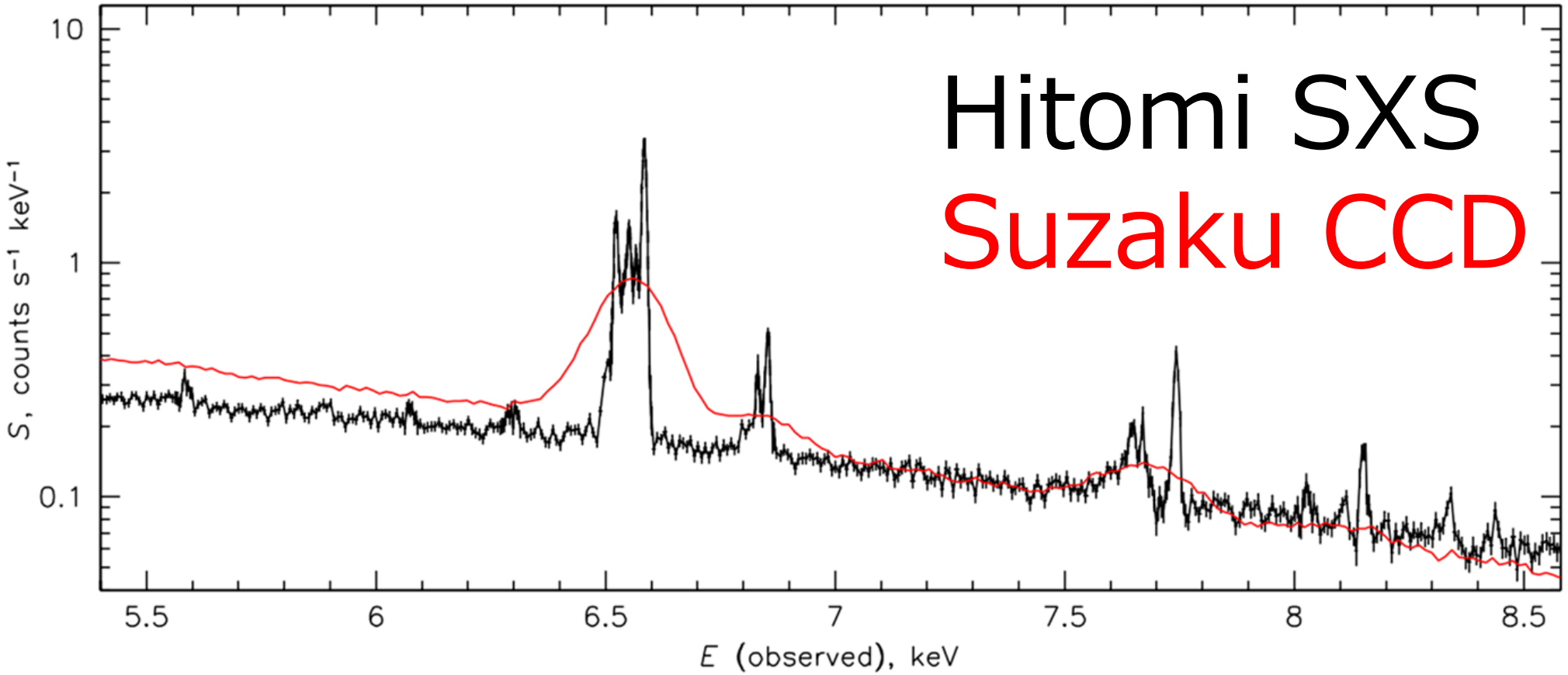
$\Delta T \propto h\nu$



FOV: $3' \times 3'$

6×6 pix

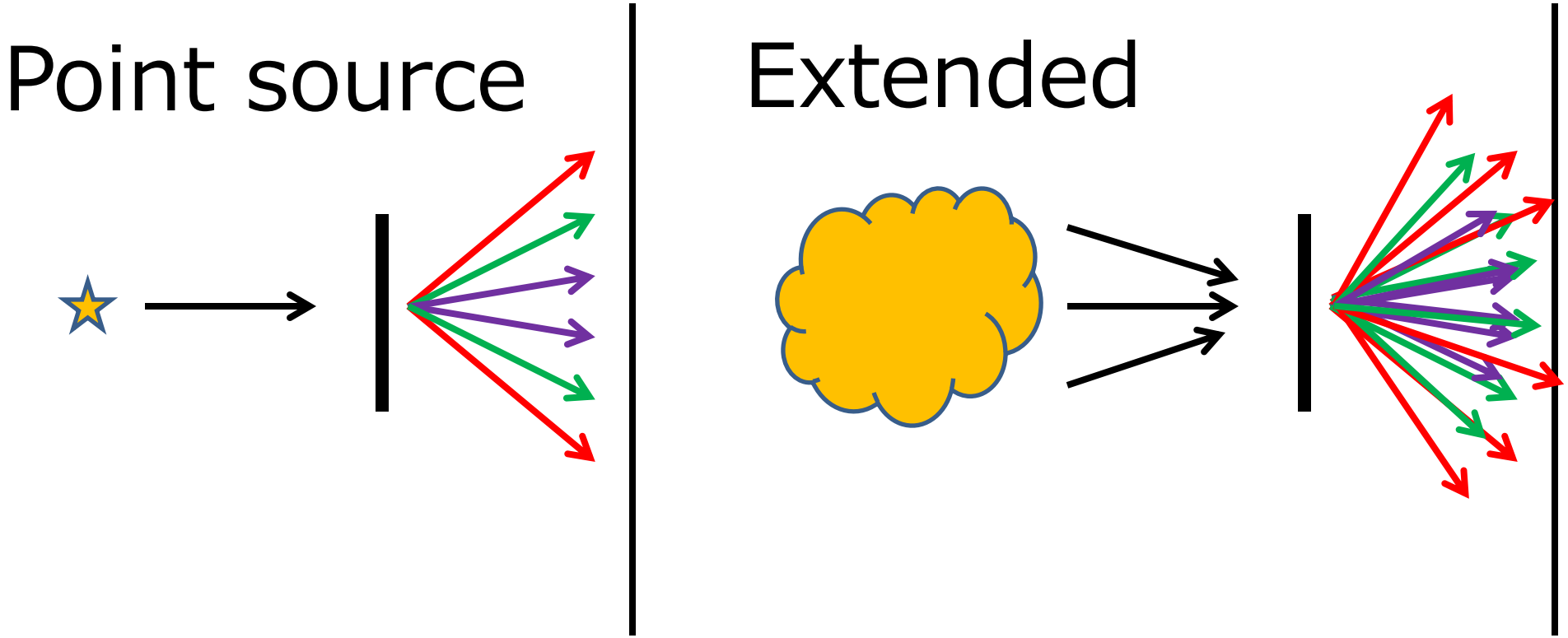
Energy Resolution



$$\Delta E = 5\ eV @\ 6keV$$

(cf. CCD $\Delta E = 130\ eV$)

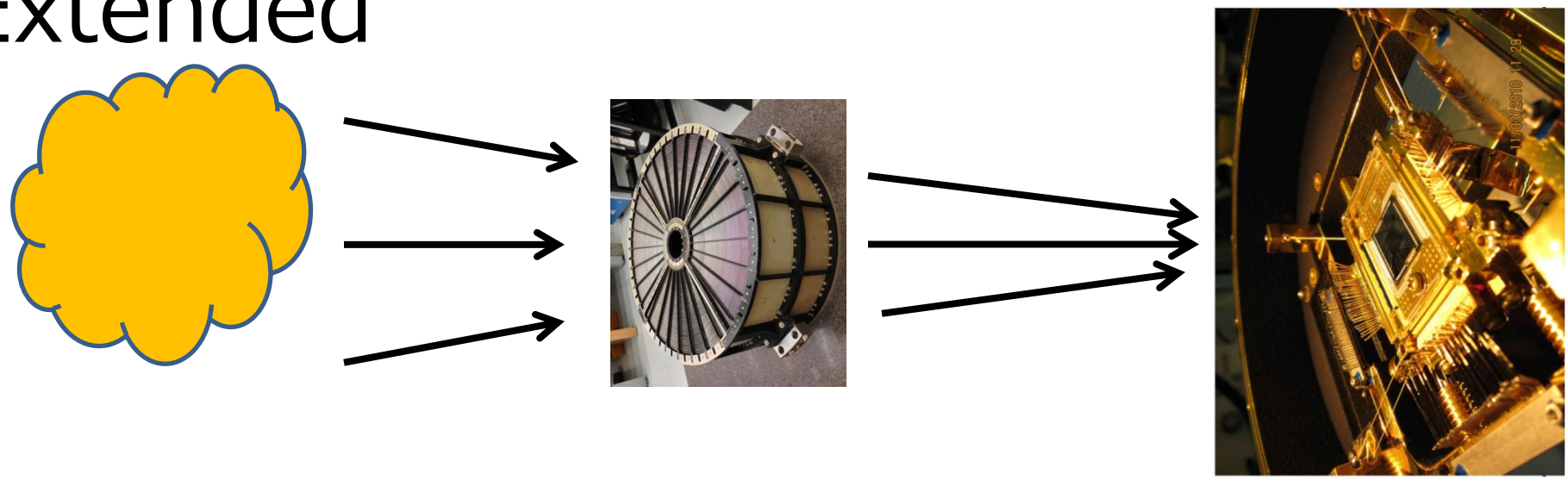
Before Hitomi: gratings



Not good for extended objects

X-ray microcalorimeter

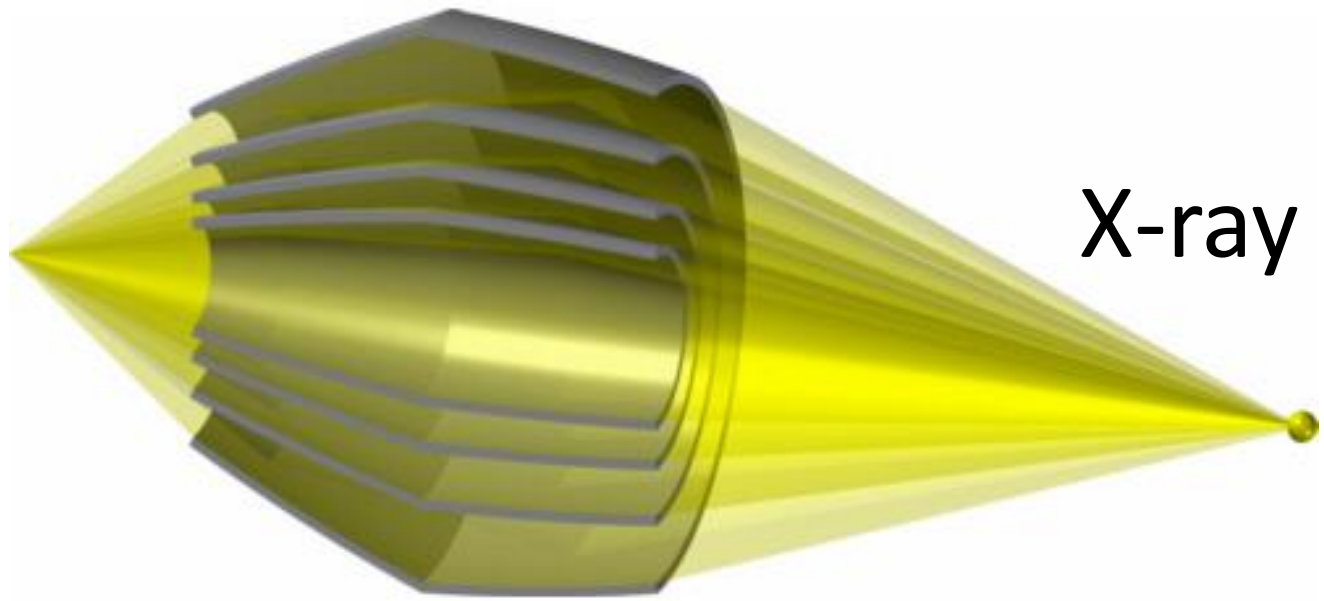
Extended



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

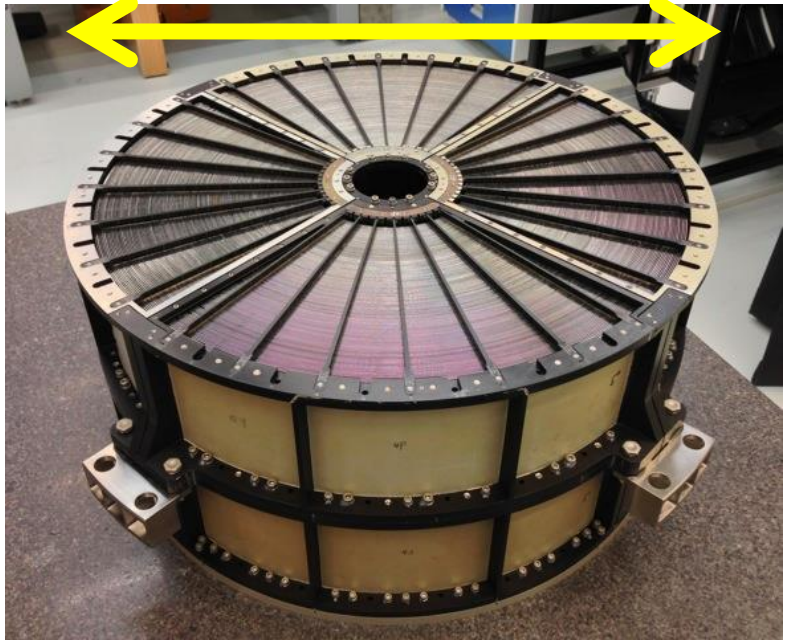
X-Ray Telescope (SXT, HXT)

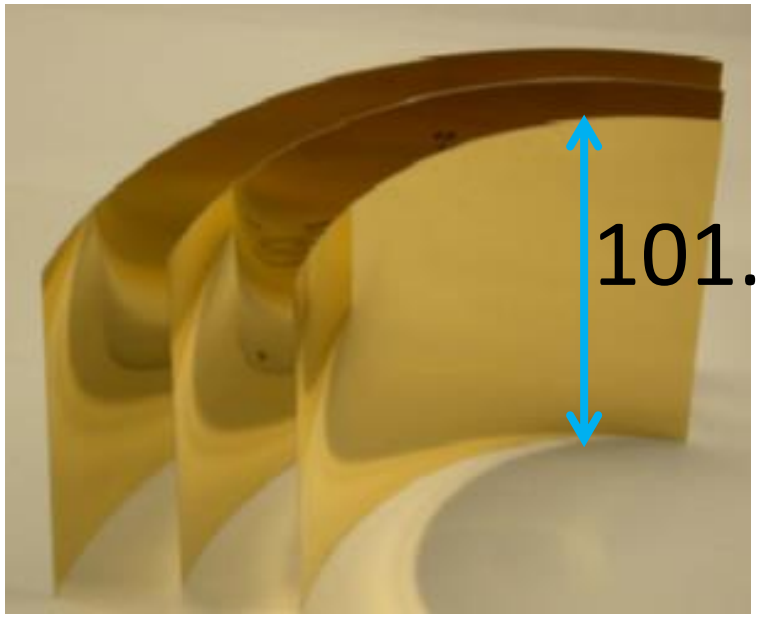
Wolter-I optics



"Annual ring" of foils

Soft X-ray Telescope (SXT)





SXT-1 FM

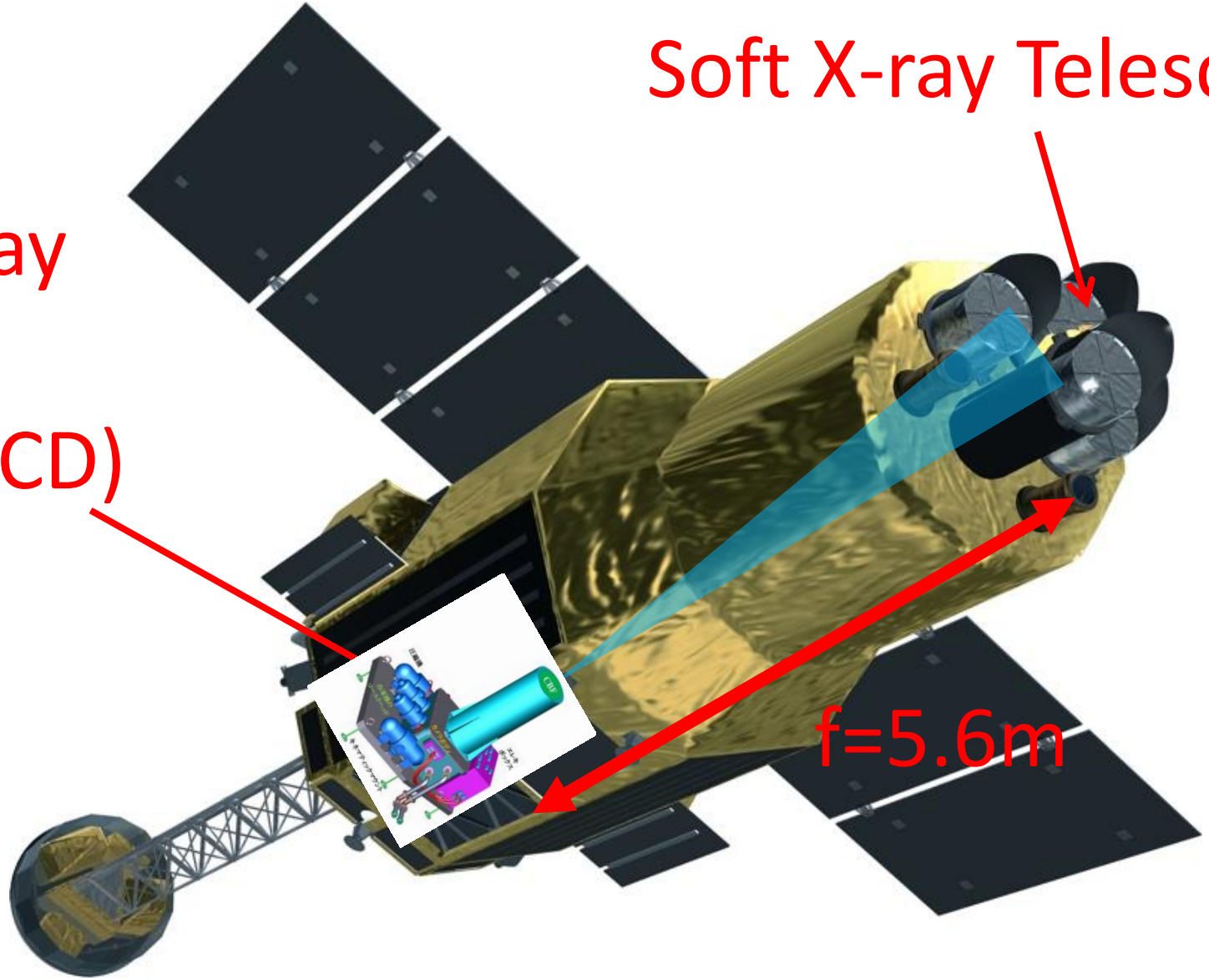
203 nested shells

Au-coated Al foils

Total reflection

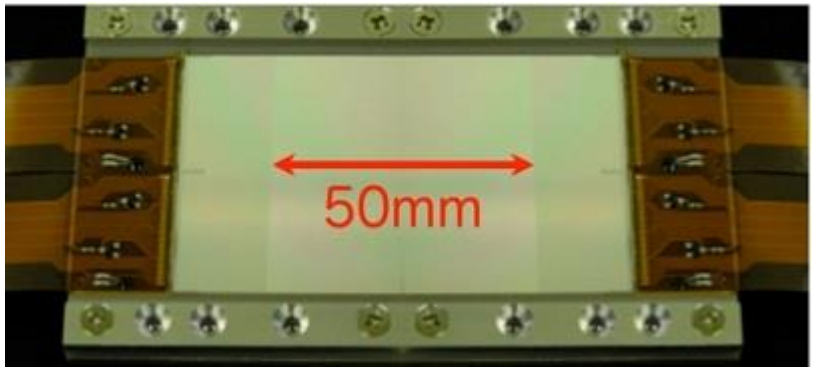
Angular resolution~ 1.3′

SXT + SXI (0.3—12keV)



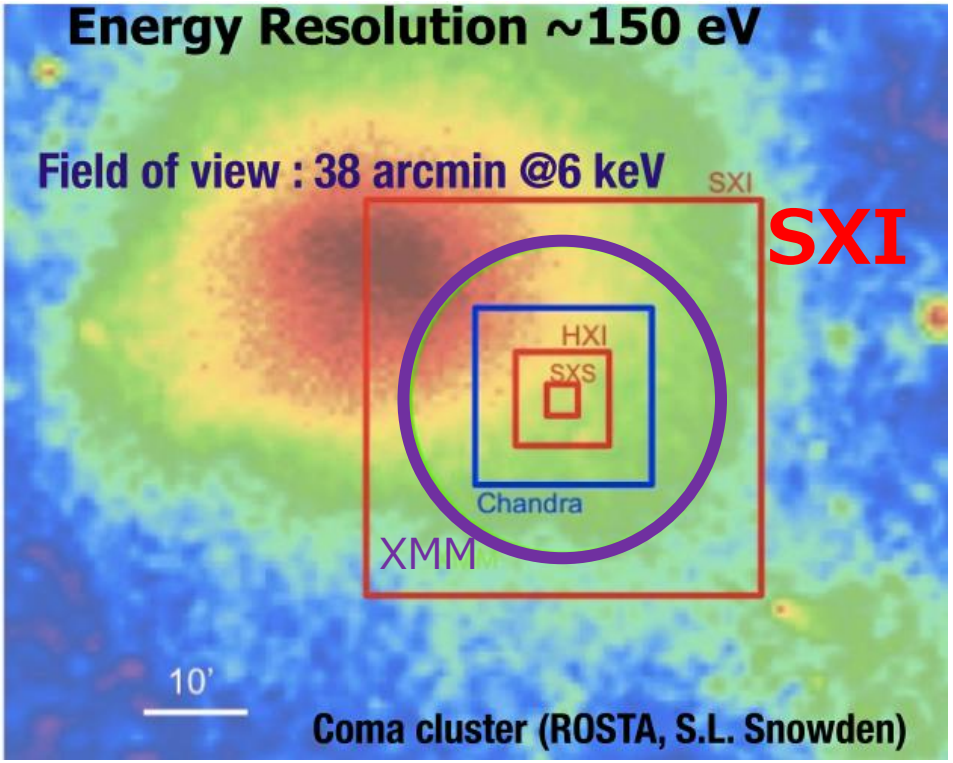
Soft X-ray Imager (SXI)

Pch X-ray CCD



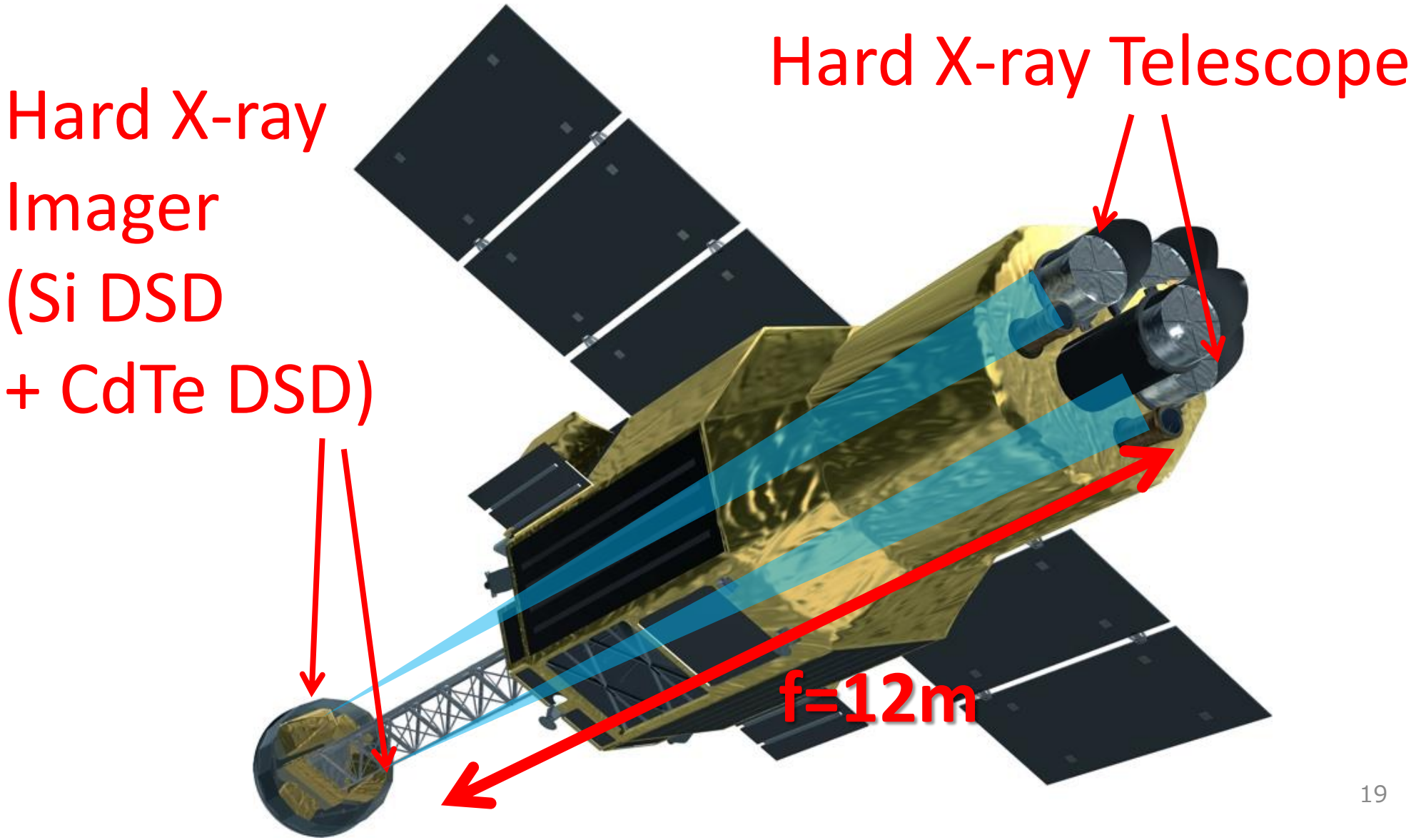
Thick depletion layer
~200 um

Moderate ΔE
(~150eV@6keV)



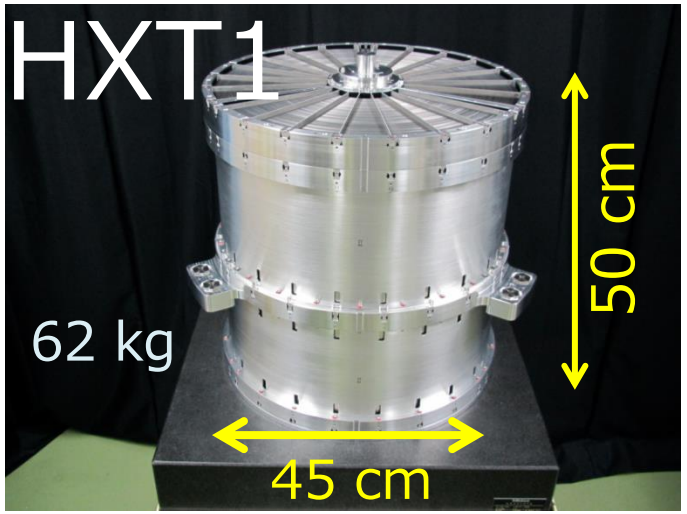
Largest FOV
$38' \times 38'$

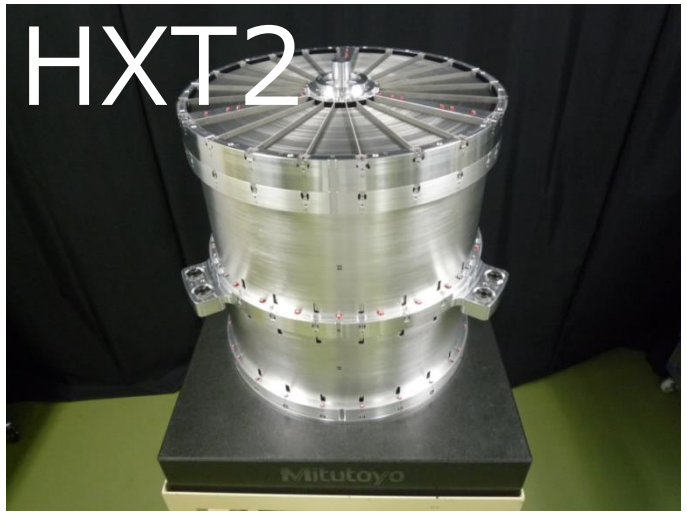
HXT + HXI (5—80keV)



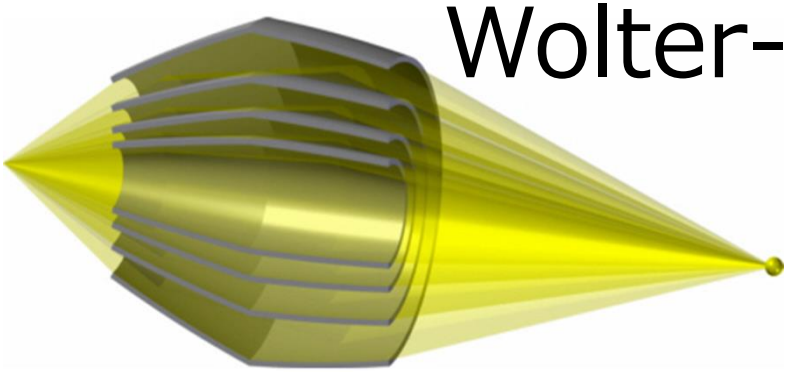
Hard X-ray Telescope (HXT)

Made in Nagoya U.





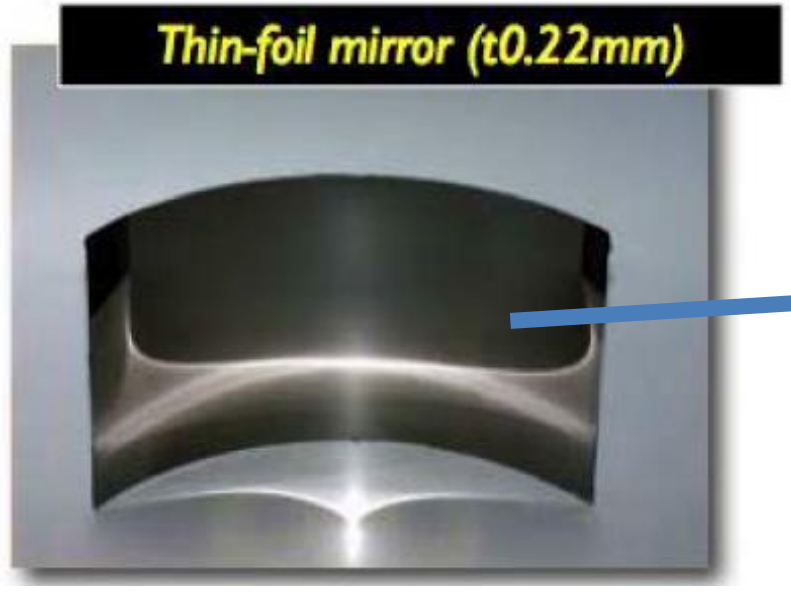
Wolter-I

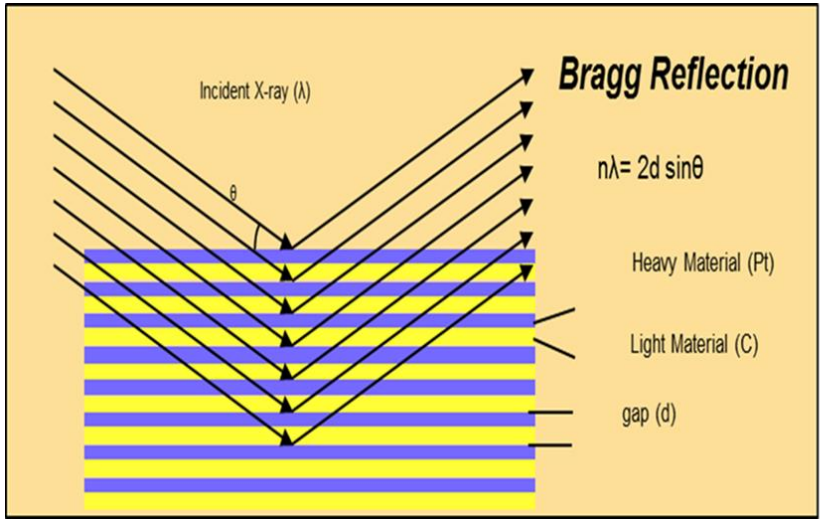


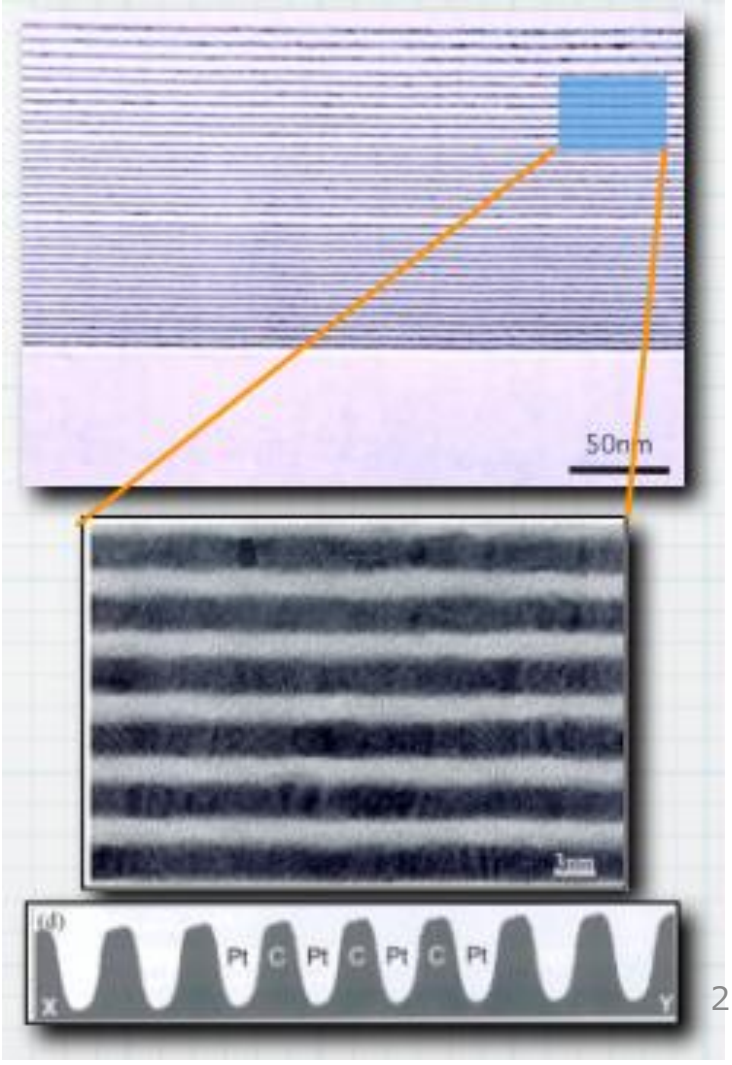
1278
reflectors

HXT mirror

Pt & C multilayer



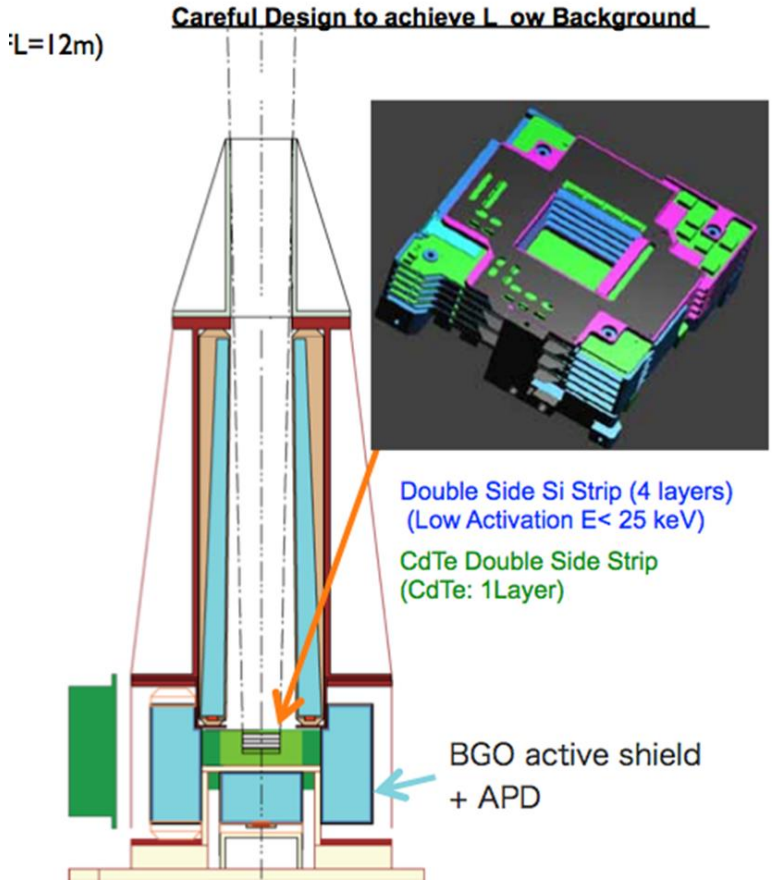


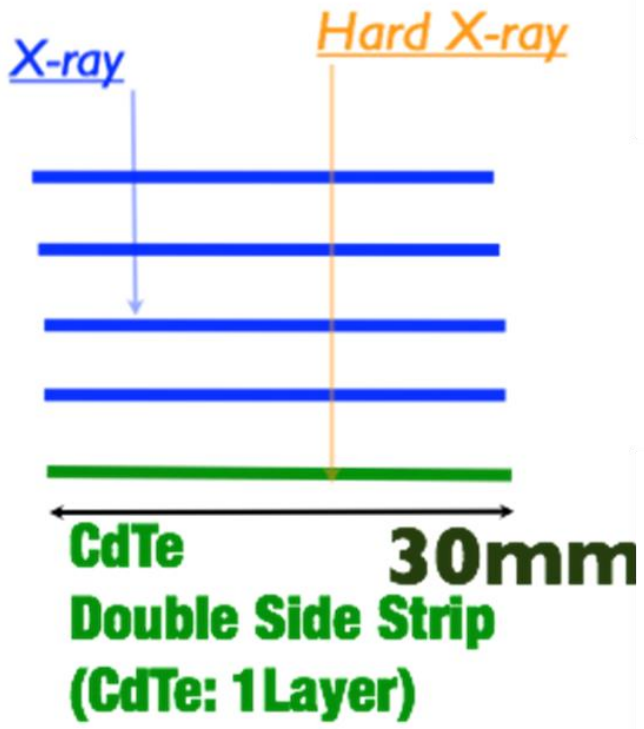


Hard X-ray Imager (HXI)

E<20 keV: Double-sided Si Strip Detector

E>20keV: Double-sided CdTe Strip Detector

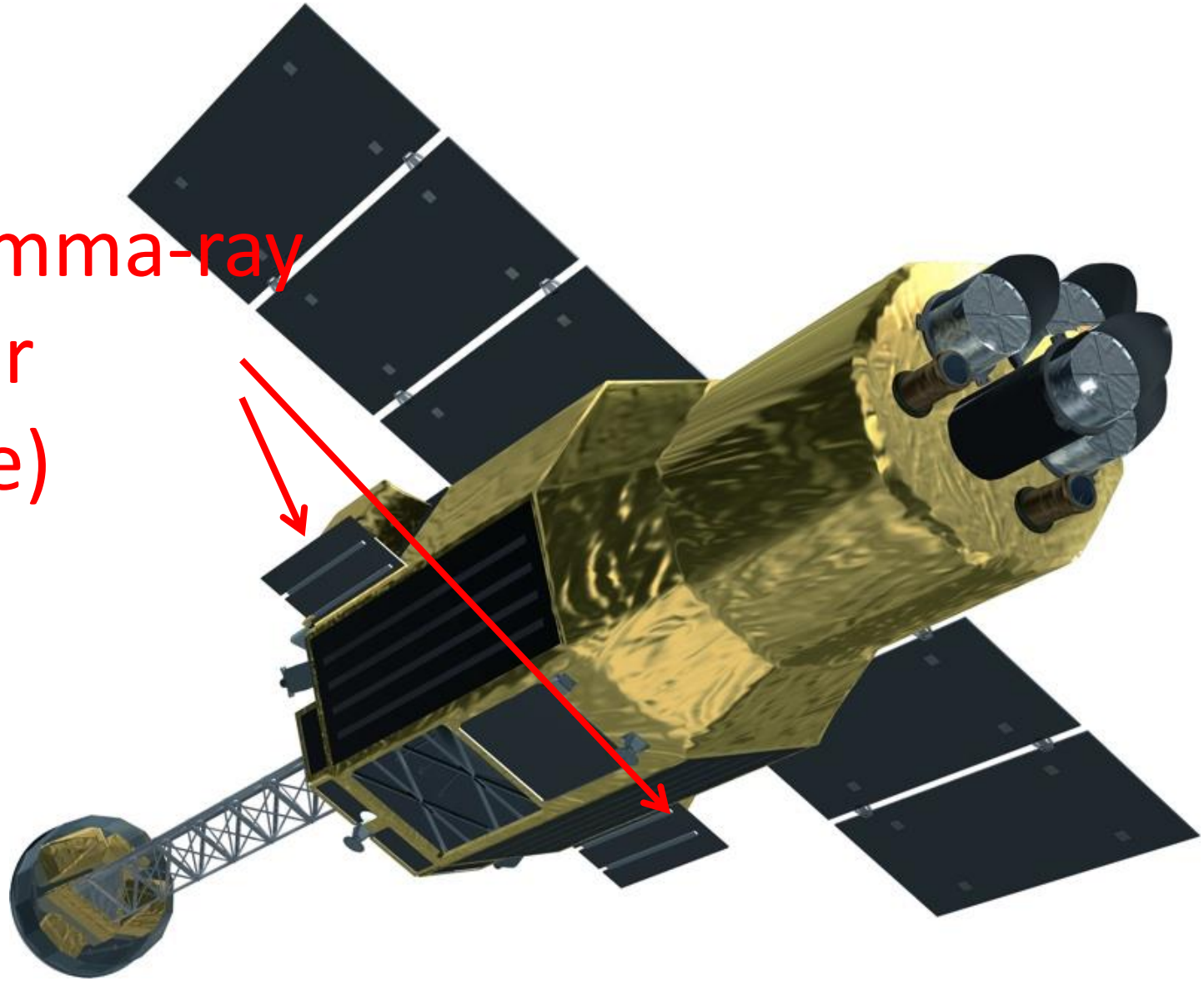




FOV: 9′ × 9′

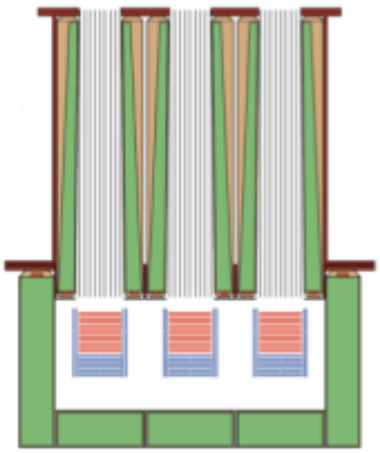
SGD (10—600keV)

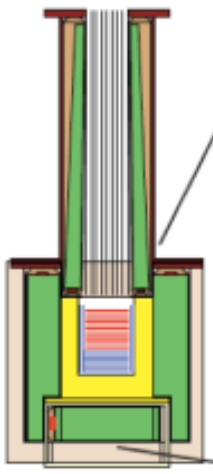
Soft Gamma-ray Detector (Si+CdTe)

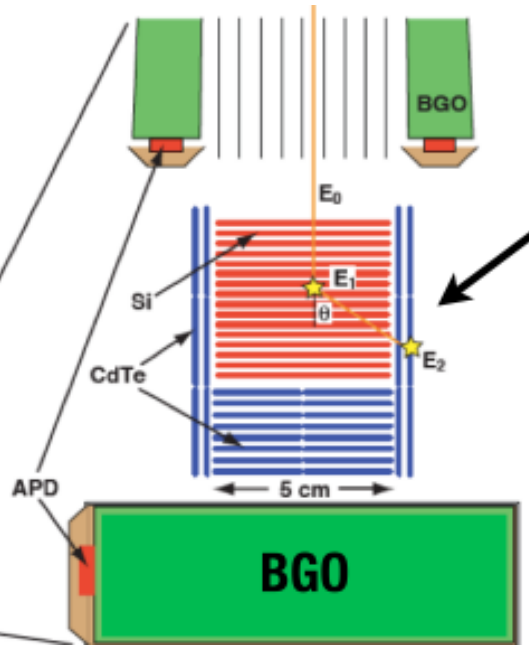


Soft Gamma-ray Detector (SGD)

- Si/CdTe Compton Camera
- Active shield of BGO







Si/CdTe Compton Camera (only select gamma-rays from the FOV)

Compton Kinematics

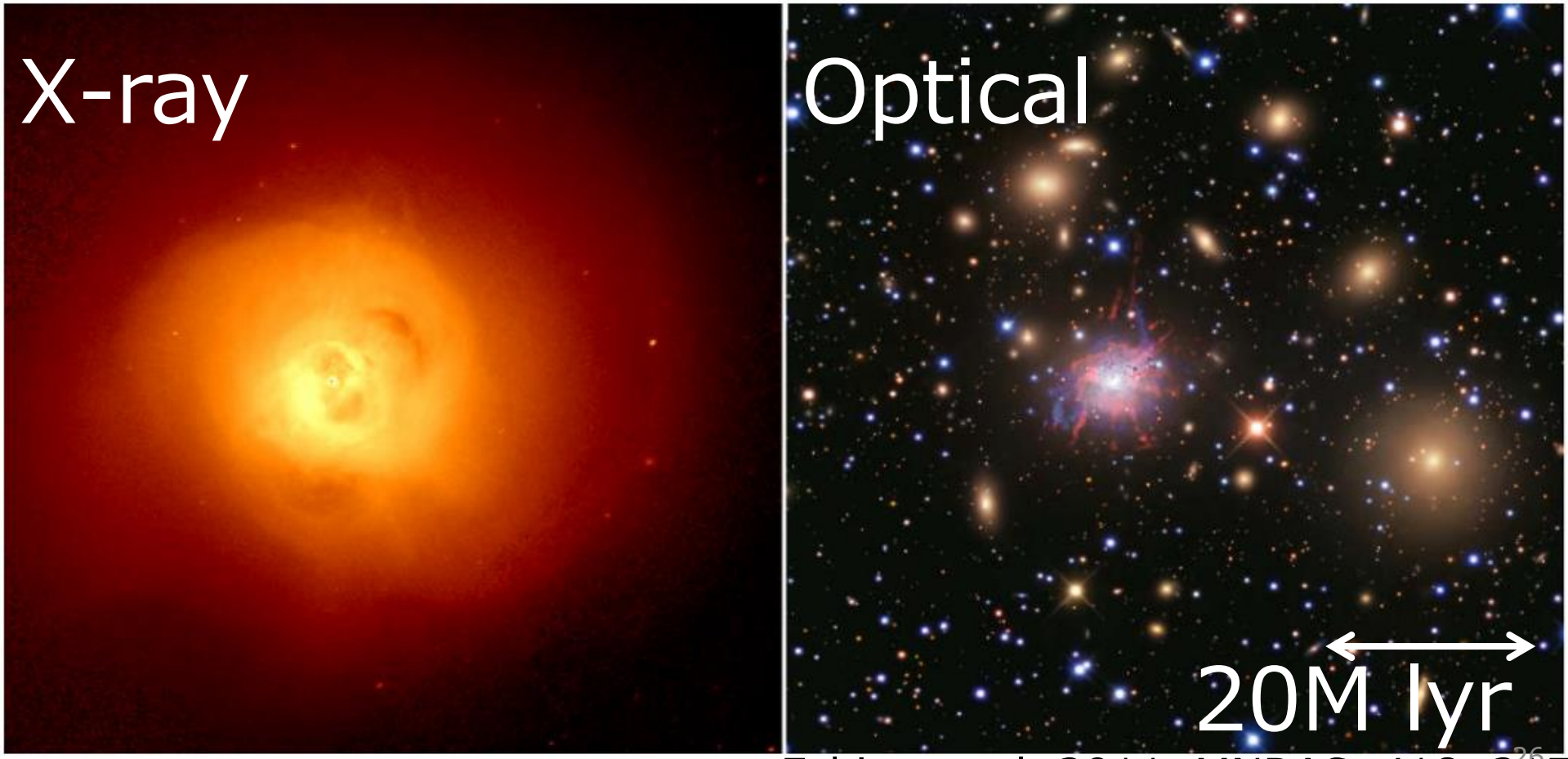
$$\cos\theta = 1 - m_e c^2 \left(\frac{1}{E_2} - \frac{1}{E_1 + E_2} \right)$$

$$E_{\rm in} = E_1 + E_2$$


Scienfitic Results

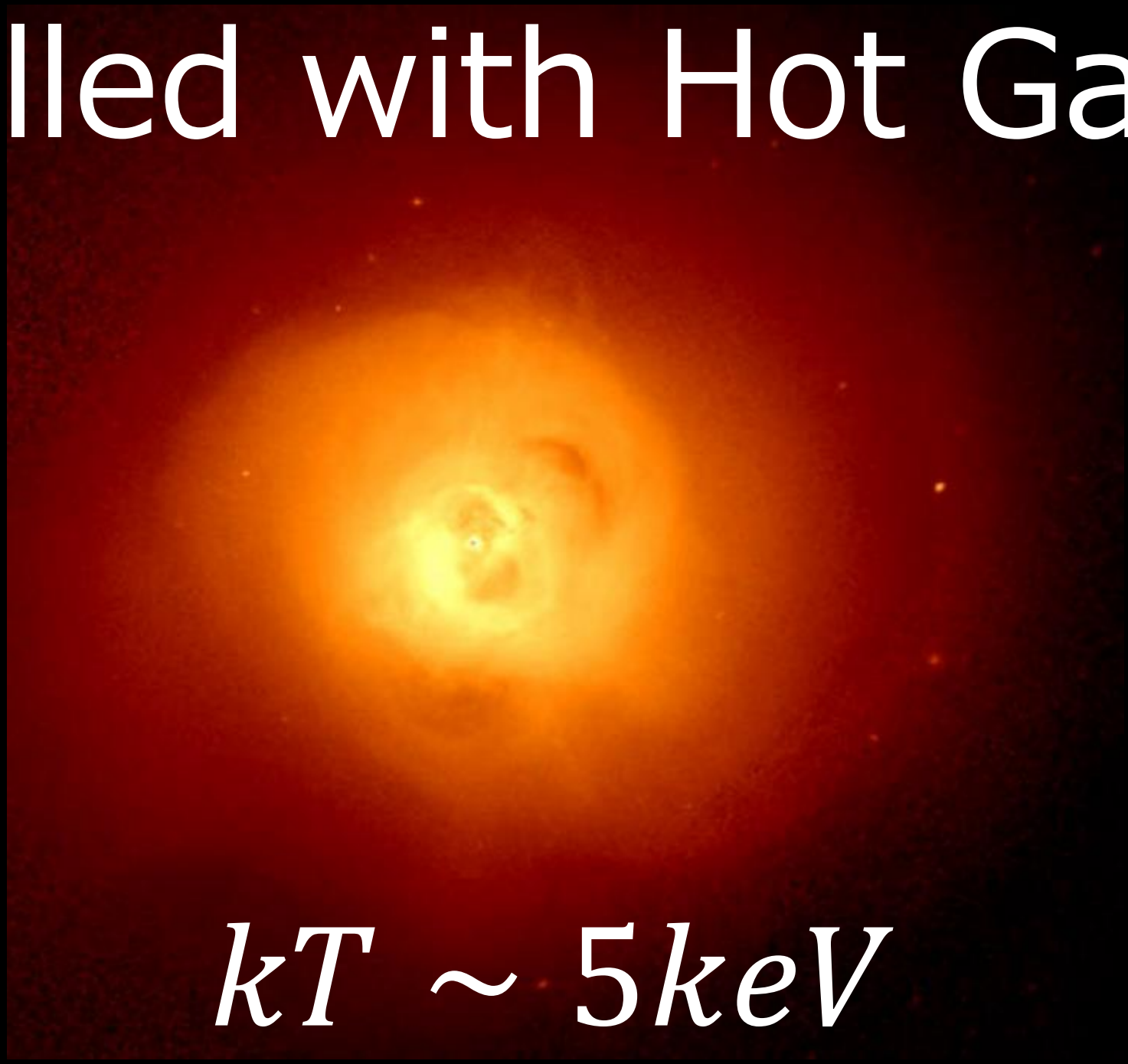
X-ray vs Visible

Perseus cluster of galaxies



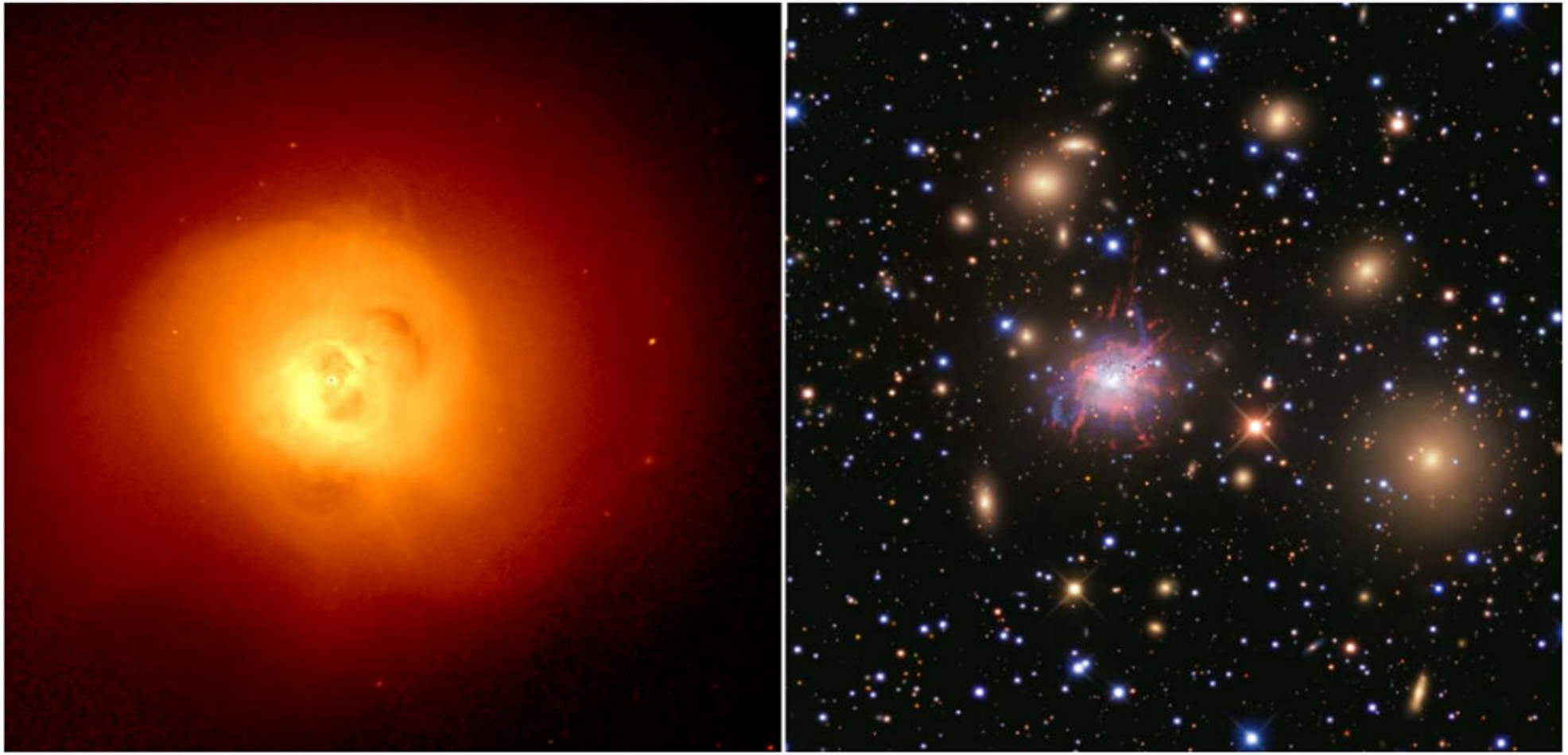
Fabian et al. 2011, MNRAS, 418, 2154

Filled with Hot Gas



$kT \sim 5keV$

Main Component: Hot Gas

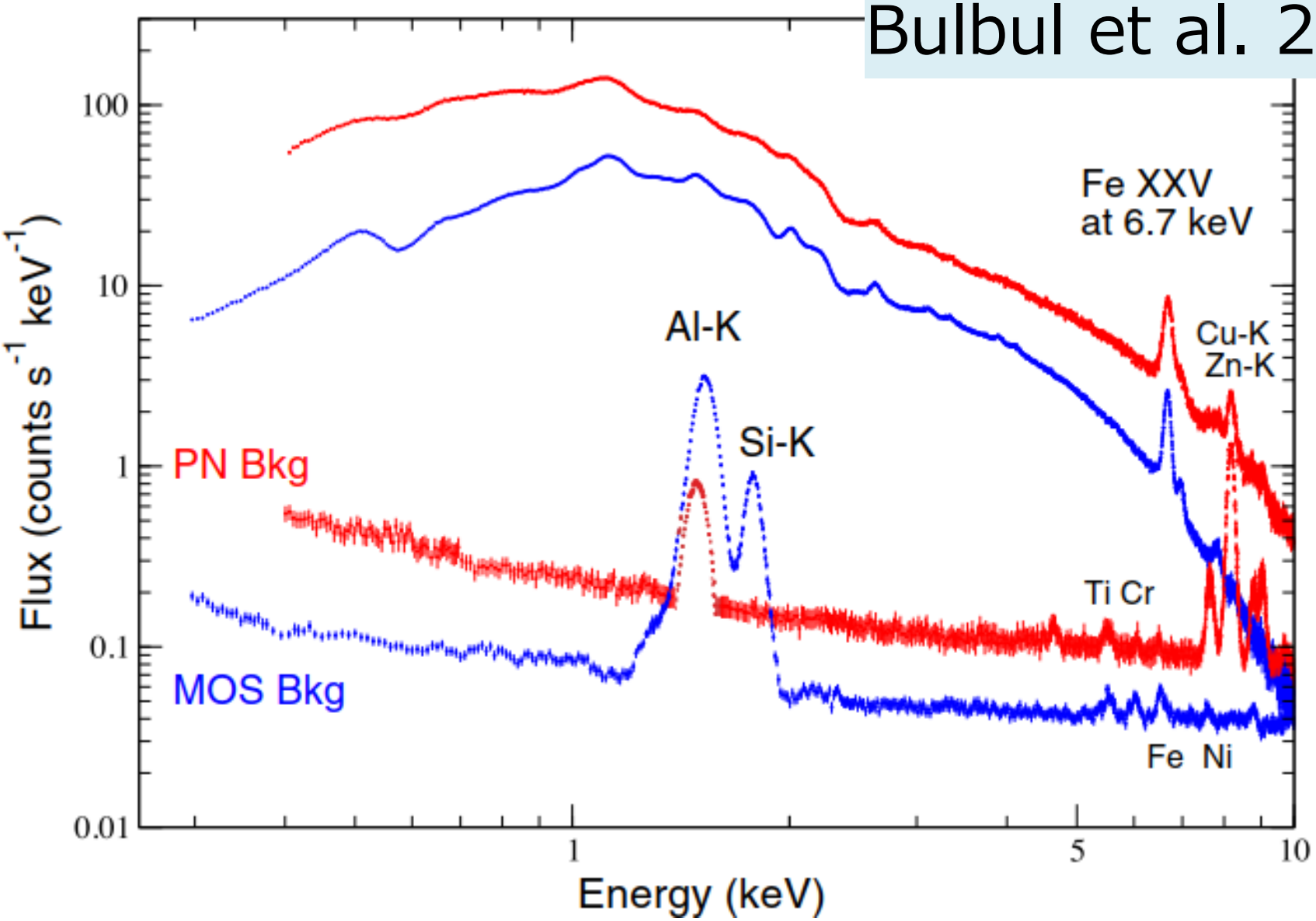


$$M_{gas} > M_{gal}$$

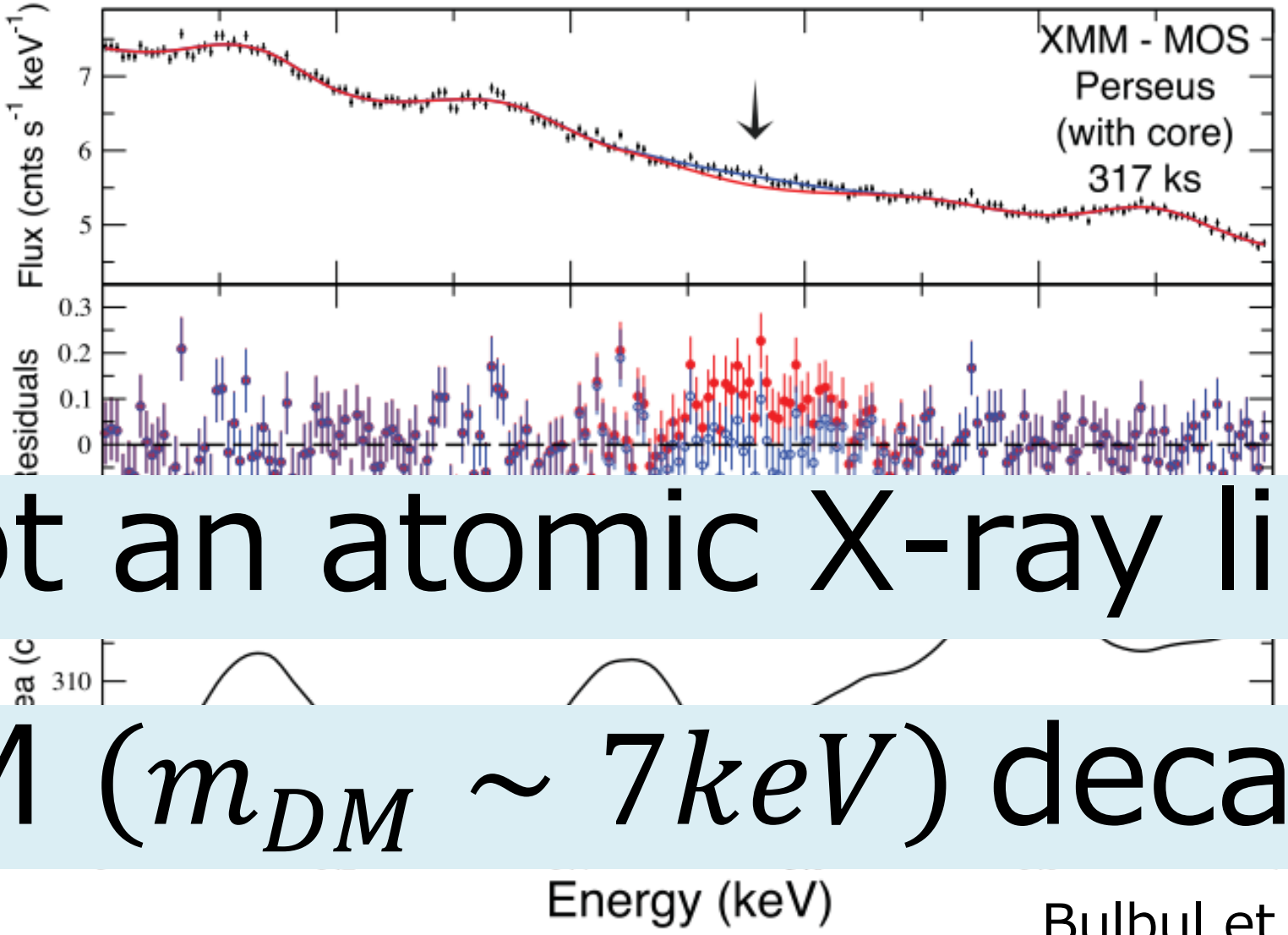
Trapped in DM potential

Perseus with XMM-Newton

Bulbul et al. 2014



unID line at 3.5 keV



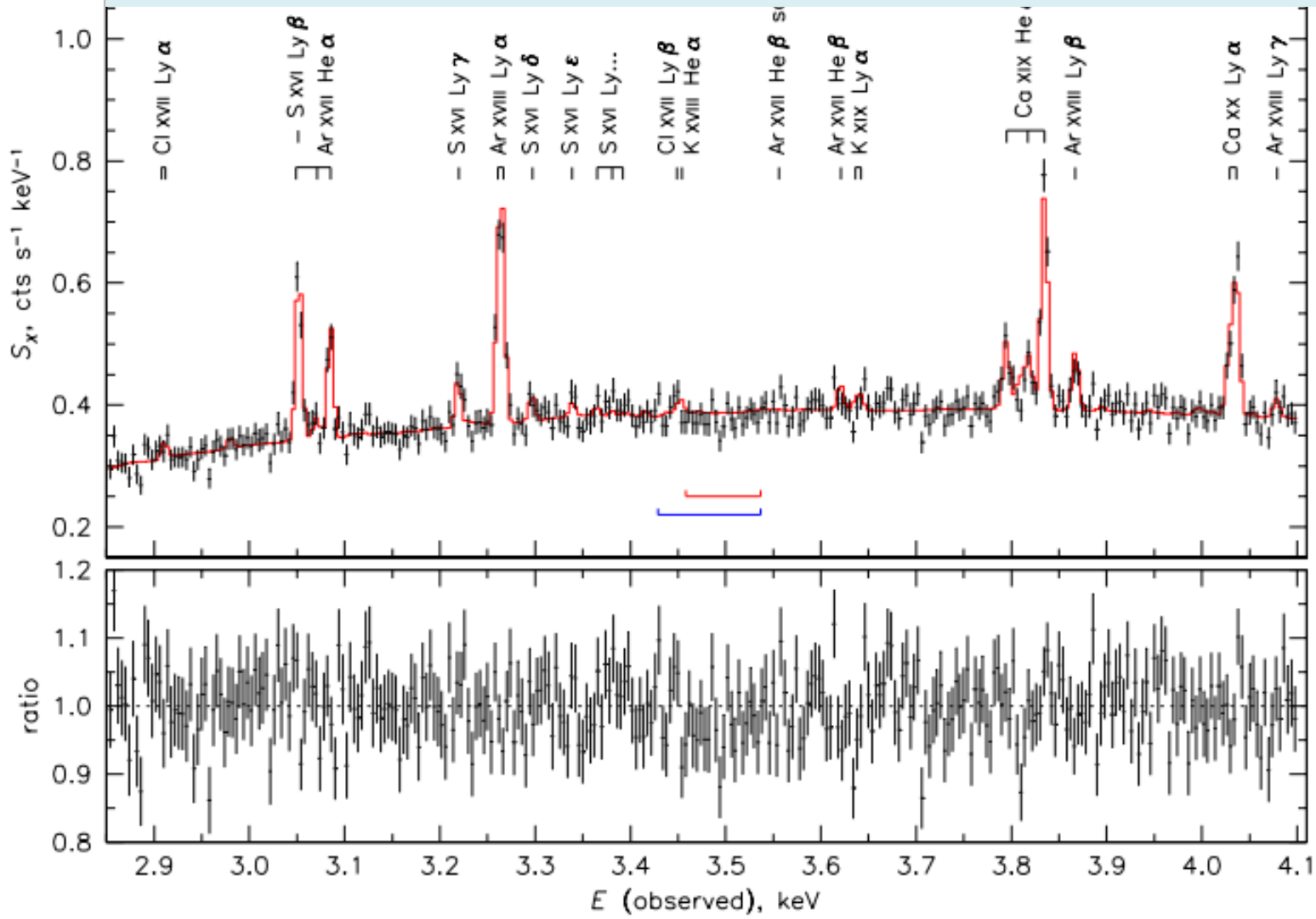
Not an atomic X-ray line

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

Bulbul et al. 2014

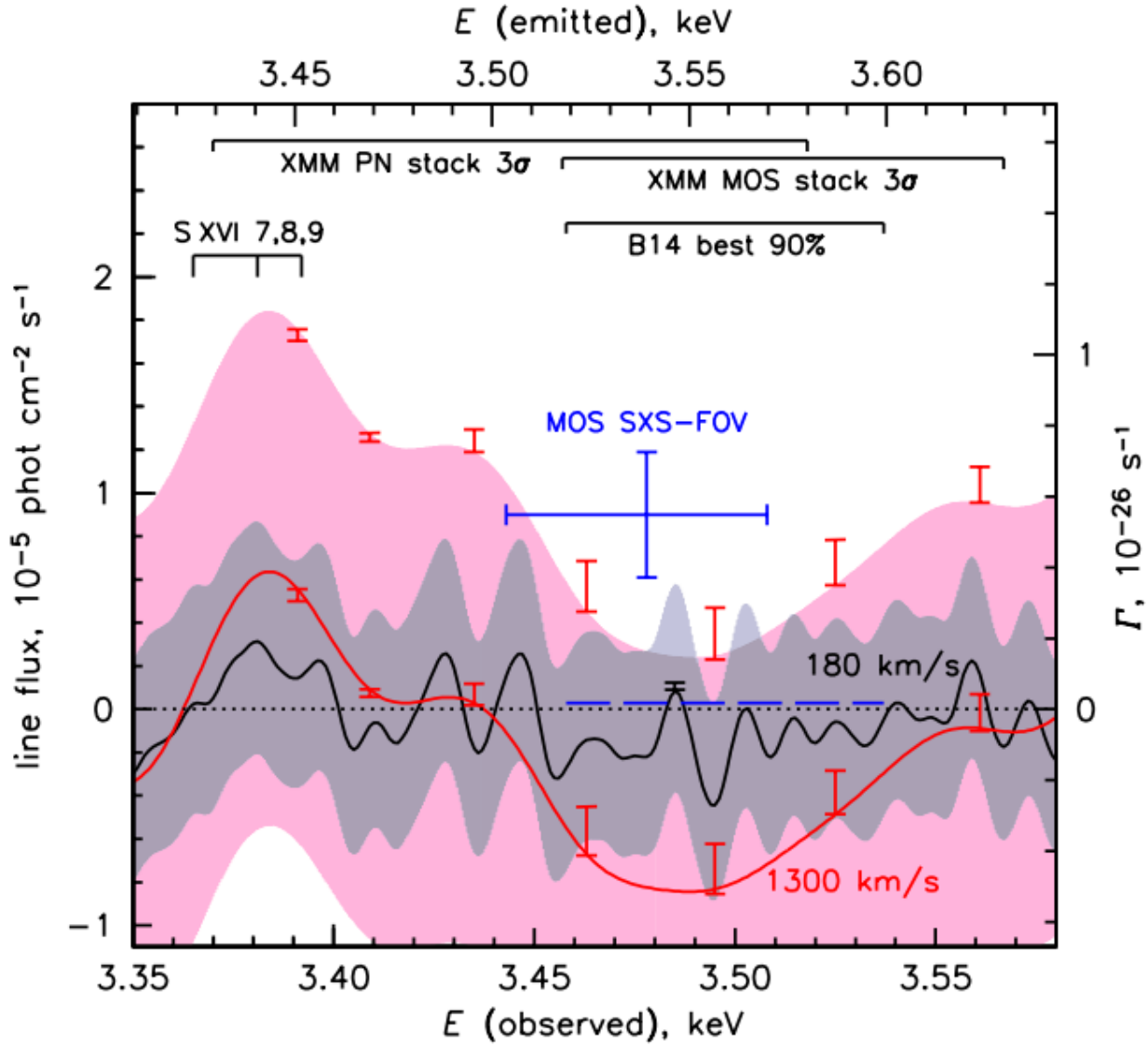
Hitomi Calorimeter

Hitomi collaboration, arXiv:1607.07420

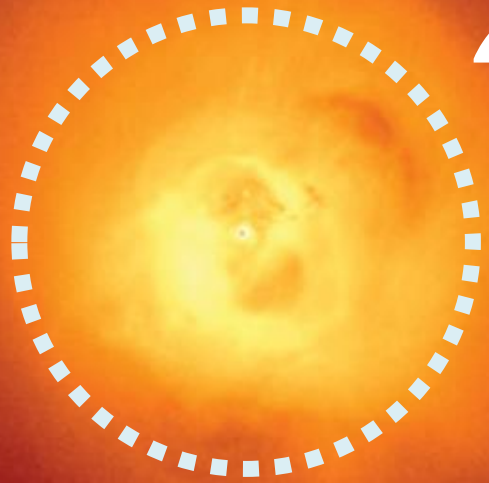


No detection

Hitomi collaboration arXiv:1607.07420



Why still hot?

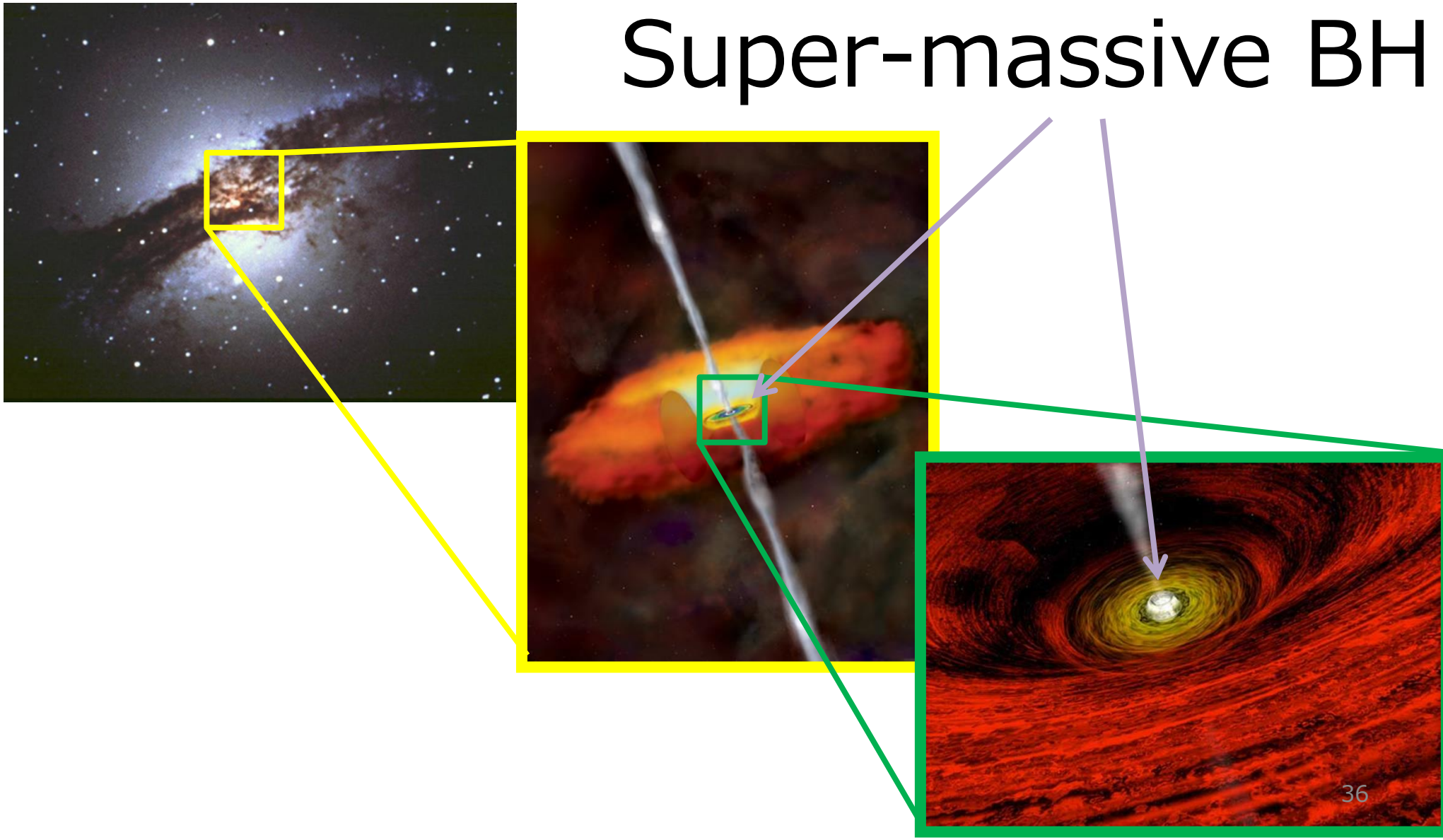


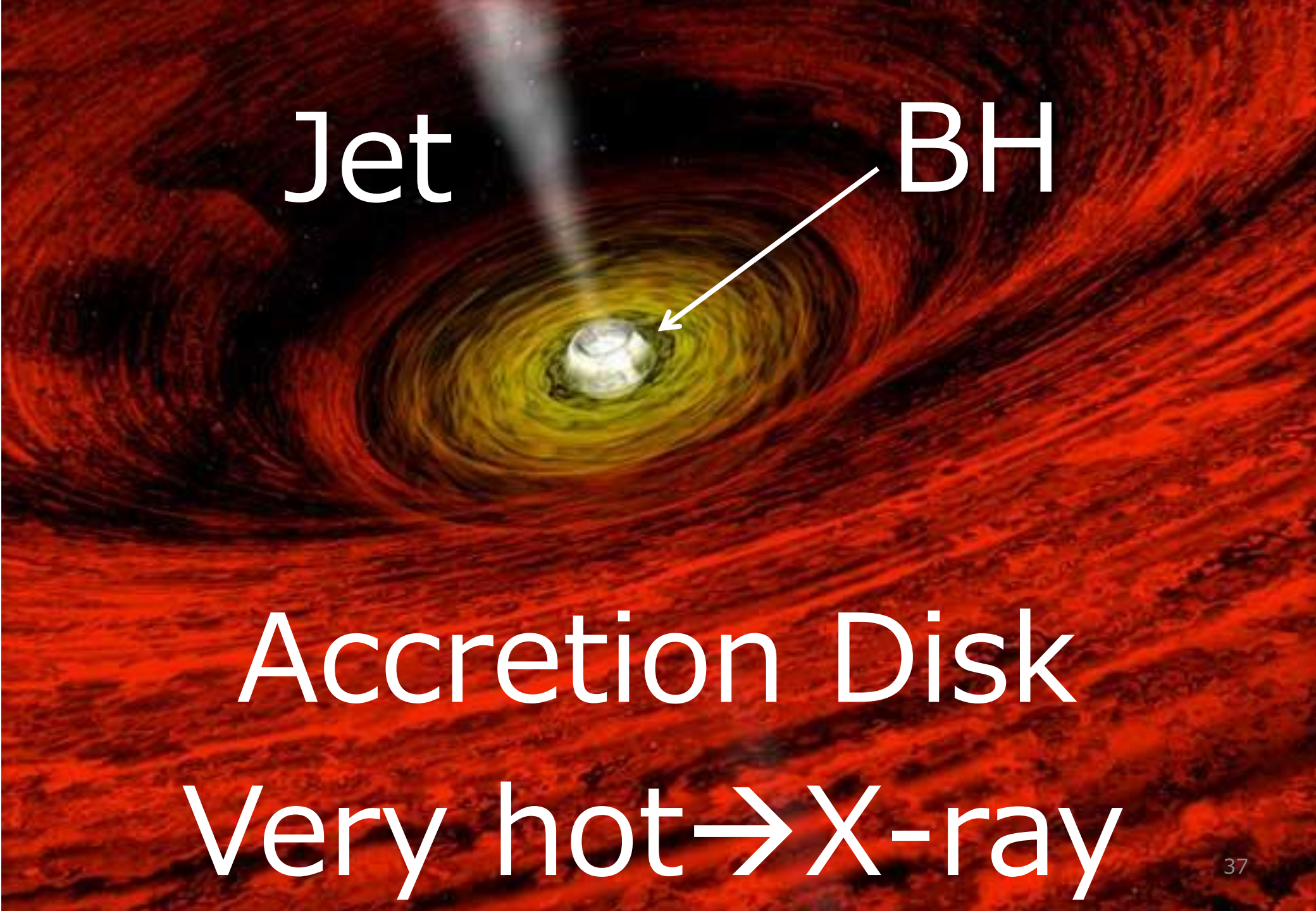
$2 \times 10^5\ Lyr$

Gas should cool within 2×10^9 yrs


Active Galaxy
NGC1275

Active Galactic Nucleus



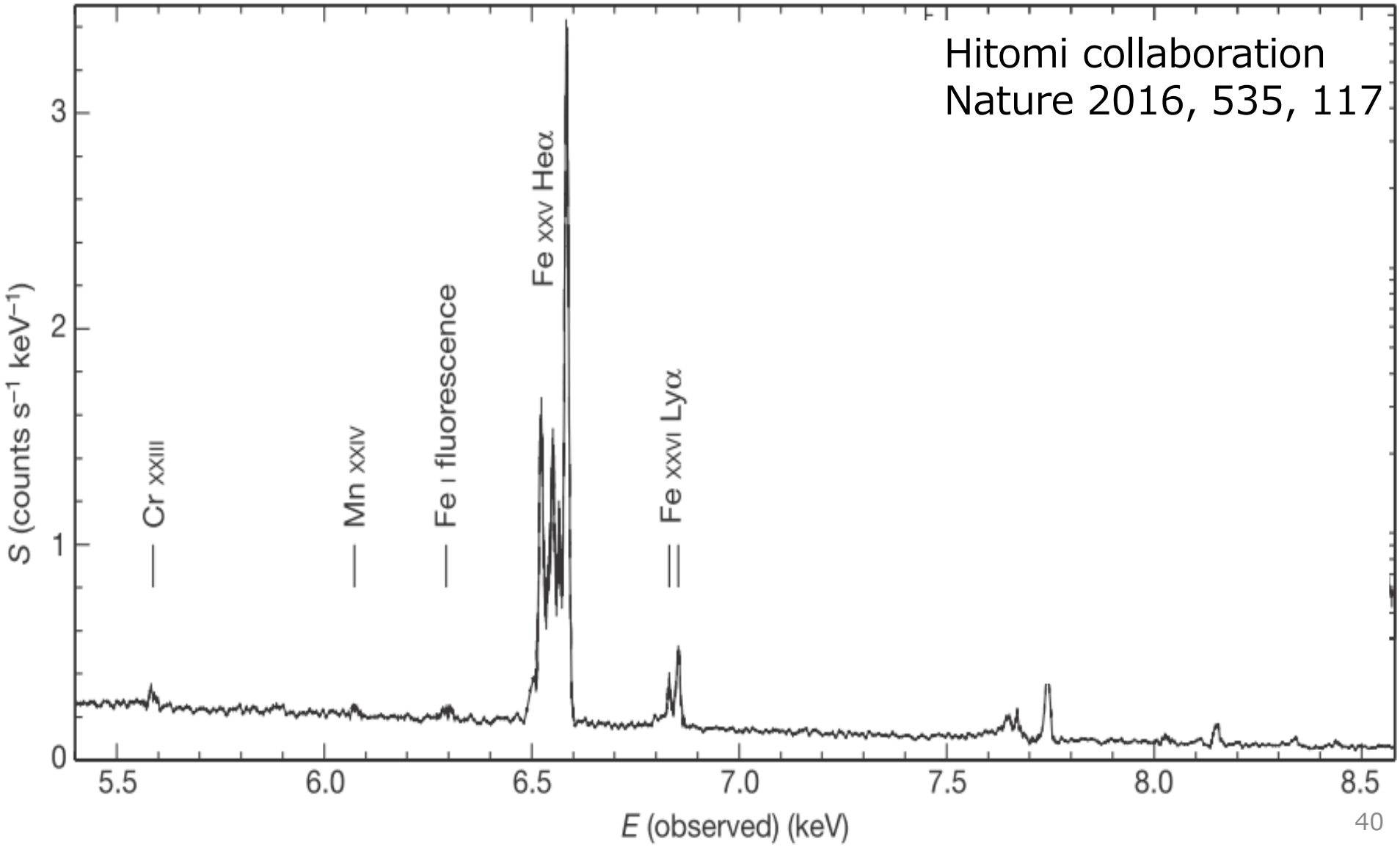

Jet
BH
Accretion Disk
Very hot→X-ray

BH puts energy into gas?

Distrubed?

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

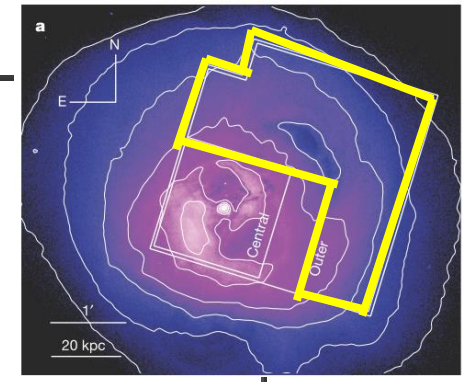
Perseus with Hitomi

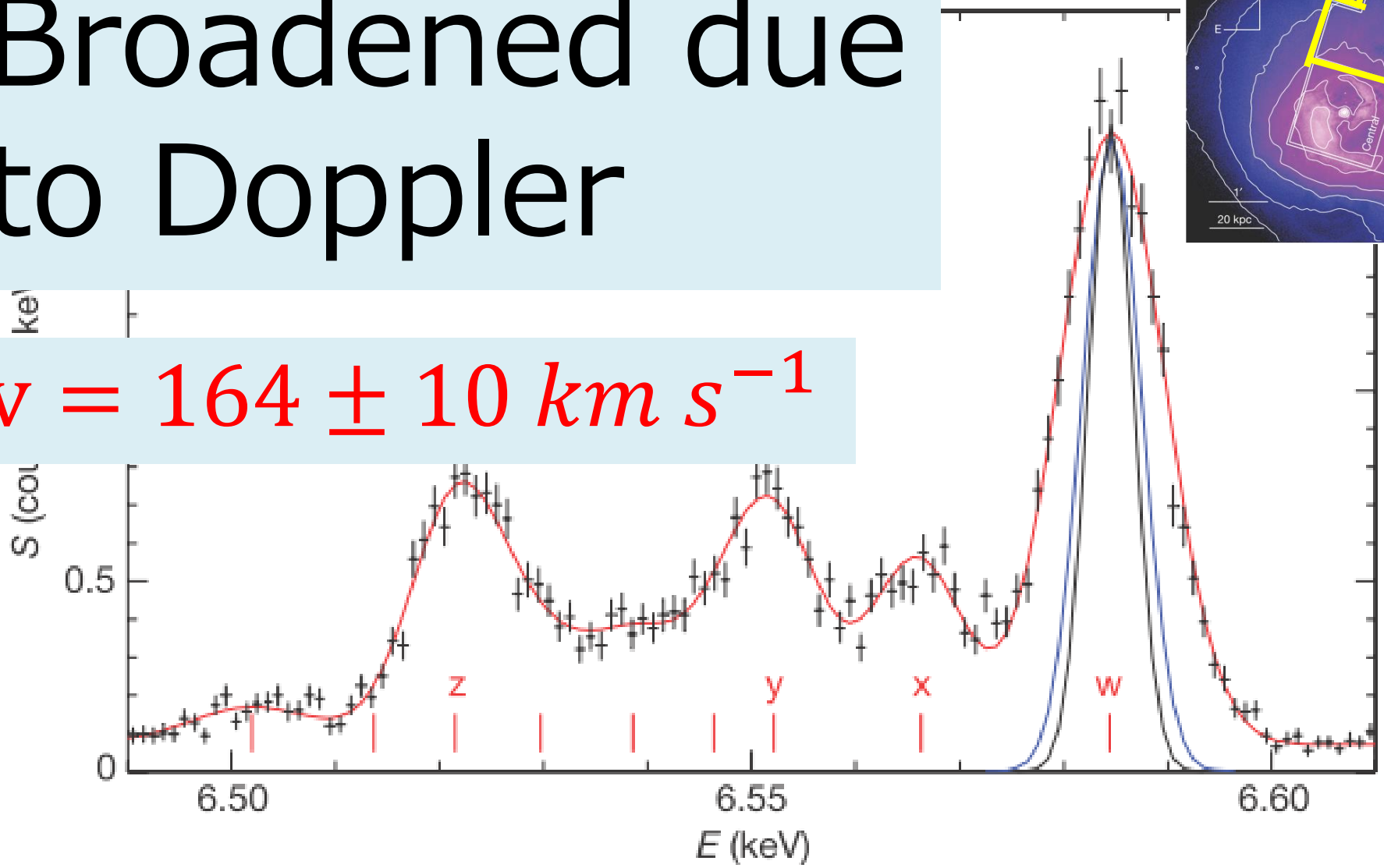


Iron line: Outer region

Broadened due to Doppler

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





Turbulent velocity

Outer reg.	$164 \pm 10\ km/s$
Center reg.	$187 \pm 13\ km/s$

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

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

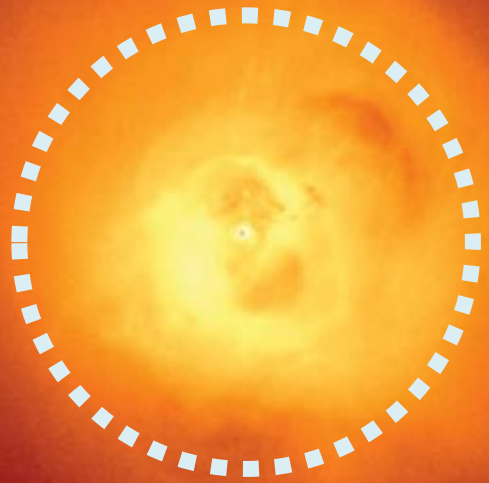
Very quiet

hydrostatic equilibrium of gas

Hot gas distribution
→ Gravitational potential
→ DM distribution

Can BH heat gas?

$2 \times 10^5\ Lyr$

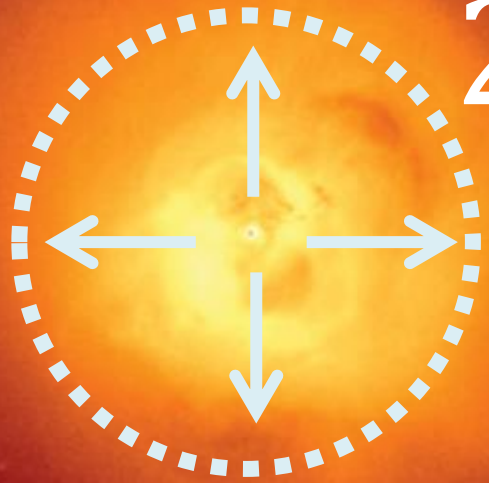


Cool within 2×10^9 yrs

Can BH heat gas?

Central region cools within 2×10^9 yrs

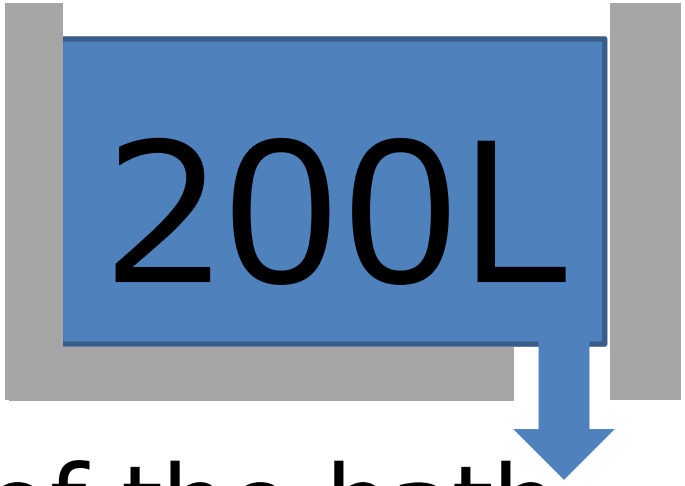
$2 \times 10^5\ Lyr$



How much turbulence should be input?

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

Same Problem



8L

Out of the bath in 3 minutes.

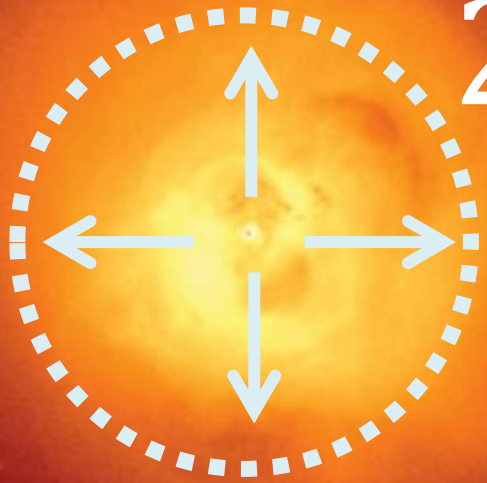
How fast does he put water?

Ans: 3 min×4% = 7.2 sec

Can BH heat gas?

Central region cools within 2×10^9 yrs

$2 \times 10^5\ Lyr$



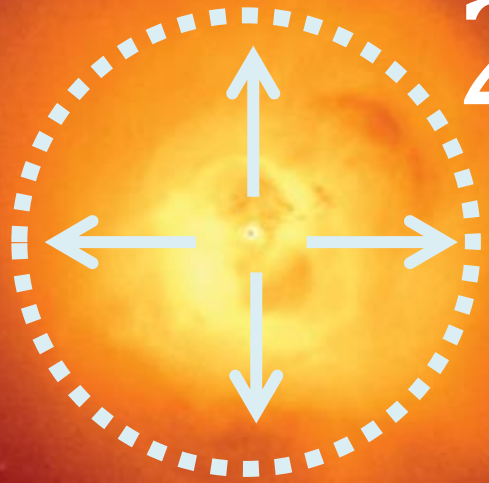
$2 \times 10^9\ yrs \times 4\% = 8 \times 10^7\ yrs$

BH should put energy every $8 \times 10^7\ yrs$.

Can BH heat gas?

Central region cools within 2×10^9 yrs

$2 \times 10^5\ Lyr$



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

Can BH heat gas?

Central region cools within 2×10^9 yrs

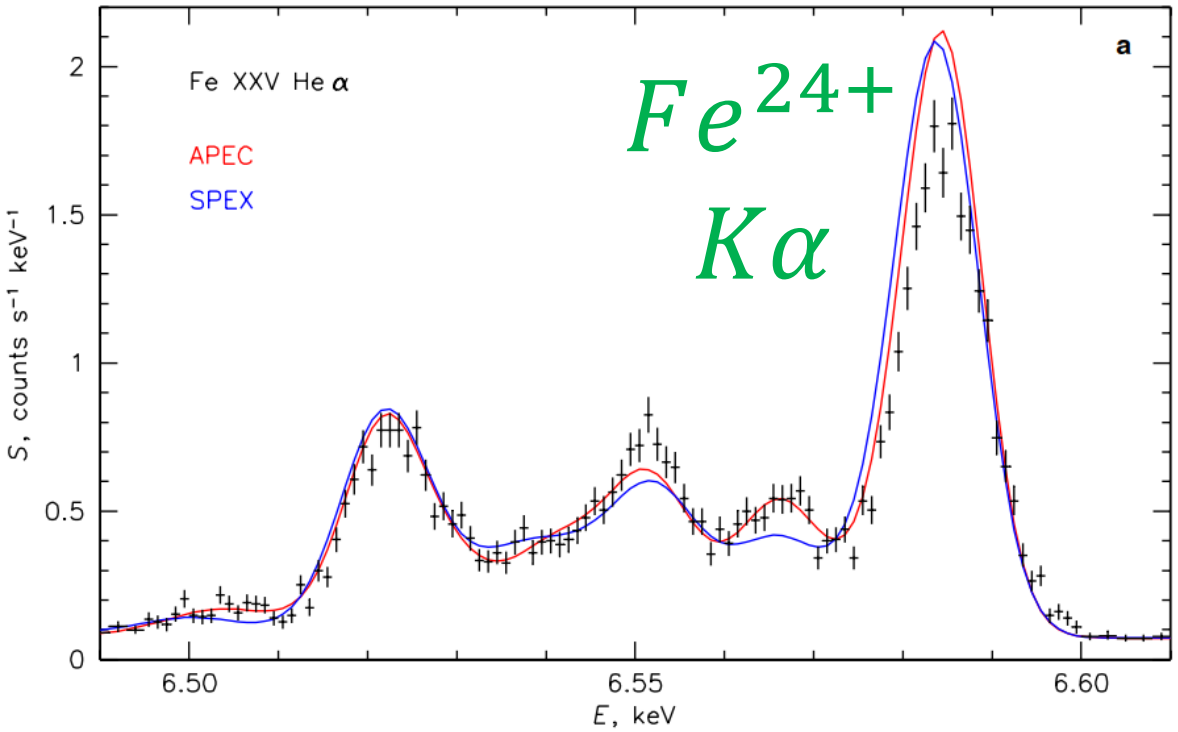
yr

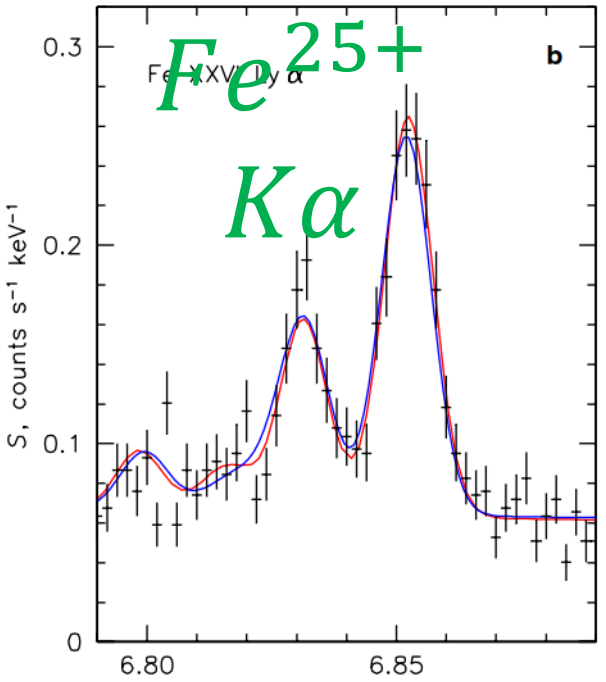
What happens?
New problem.

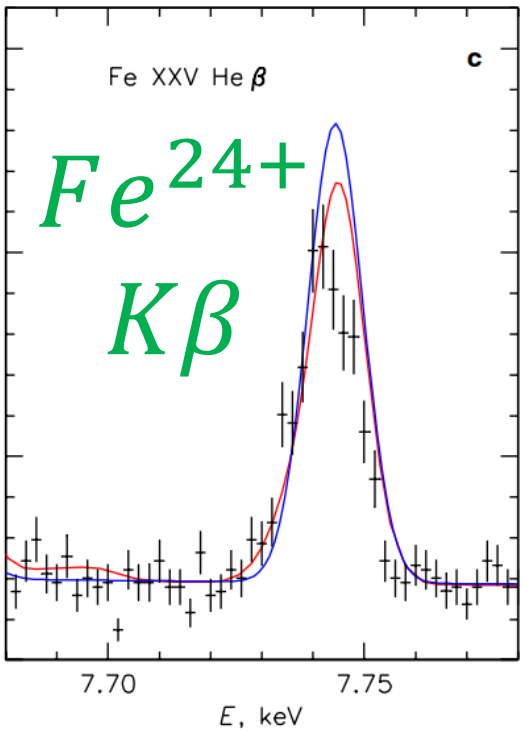
$v \sim 700\ \mathrm{km\ s^{-1}} \gg \mathrm{v}_{turb} \sim 160\ km\ s^{-1}$

Energy cannot spread!

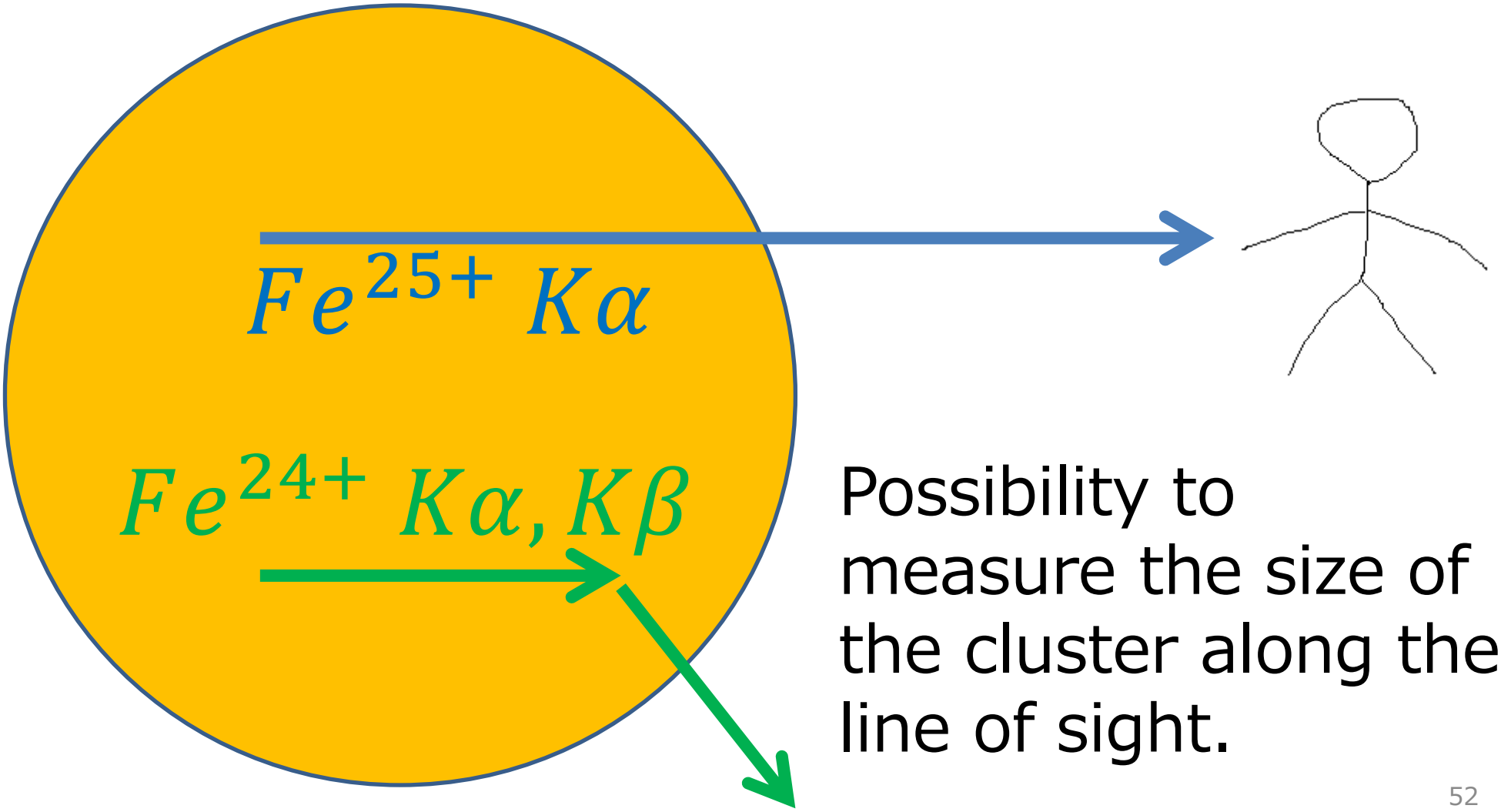
Fe^{24+} lines suppressed? Why?







Effect of optical depth?



Possibility to measure the size of the cluster along the line of sight.

nature International weekly journal of science

NEWS & COMMENT

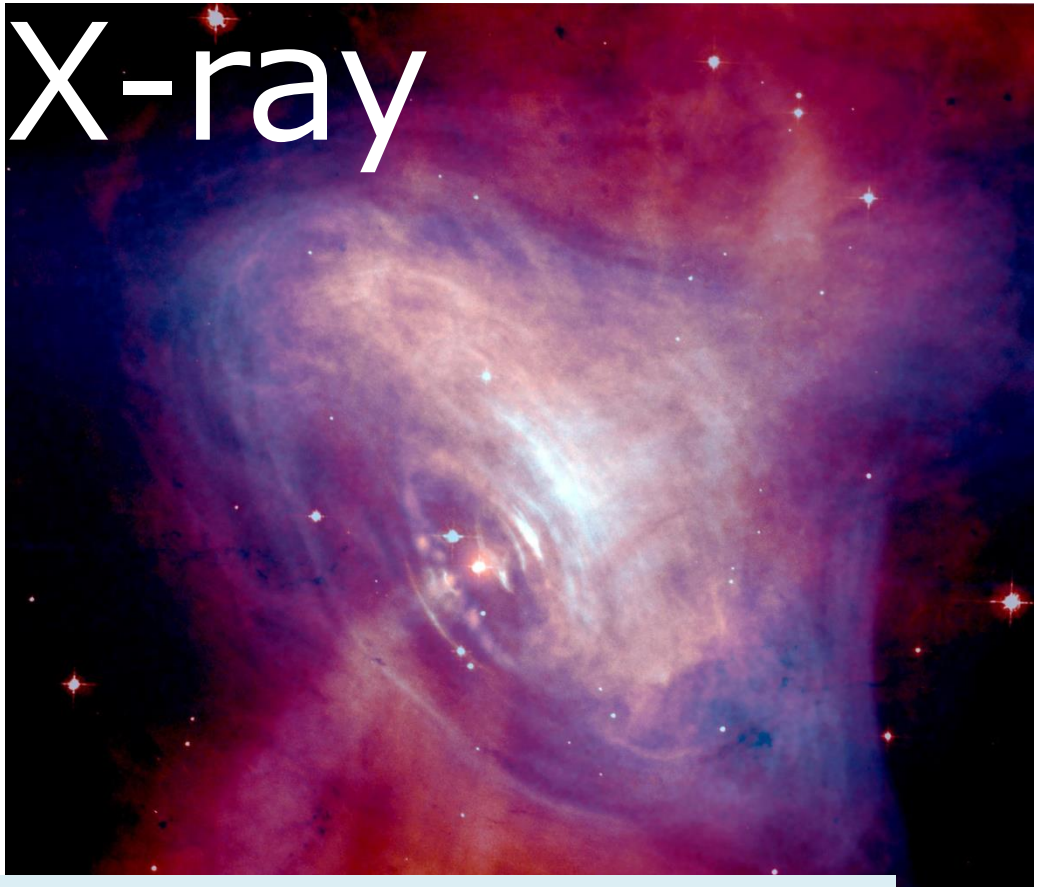
Dead X-ray satellite reveals galaxy cluster surprise

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 ...

06 July 2016, Nature

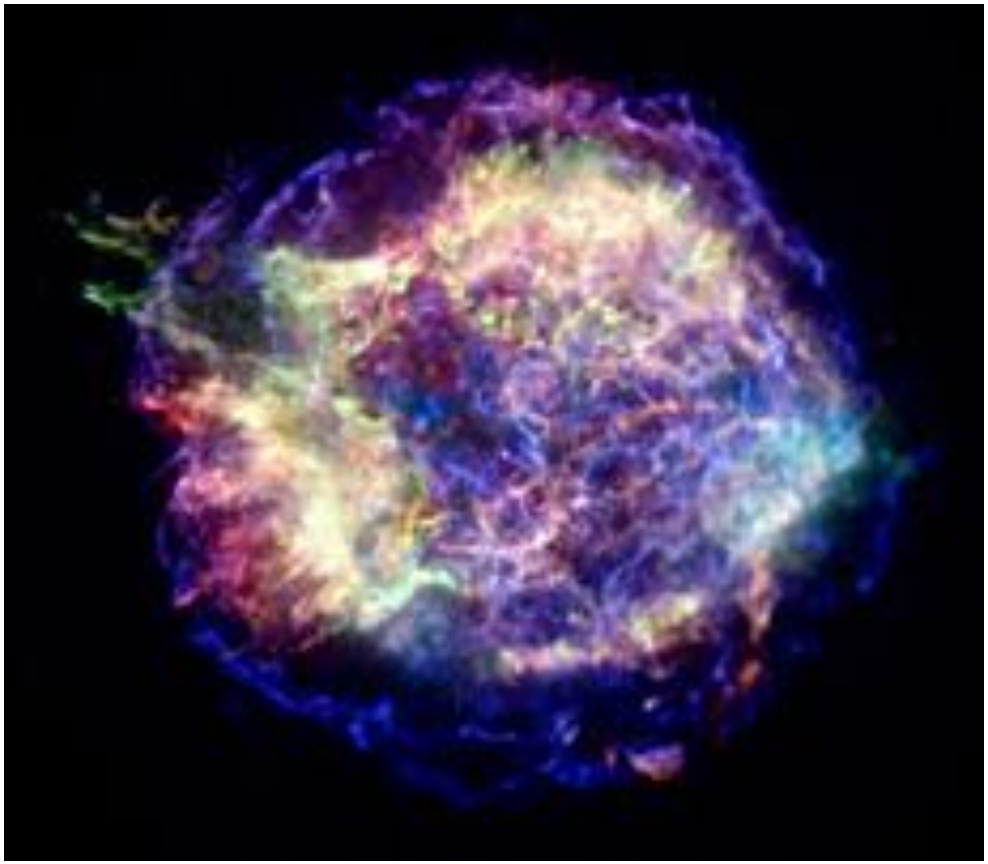
Another topic: Crab



Supernova in 1054

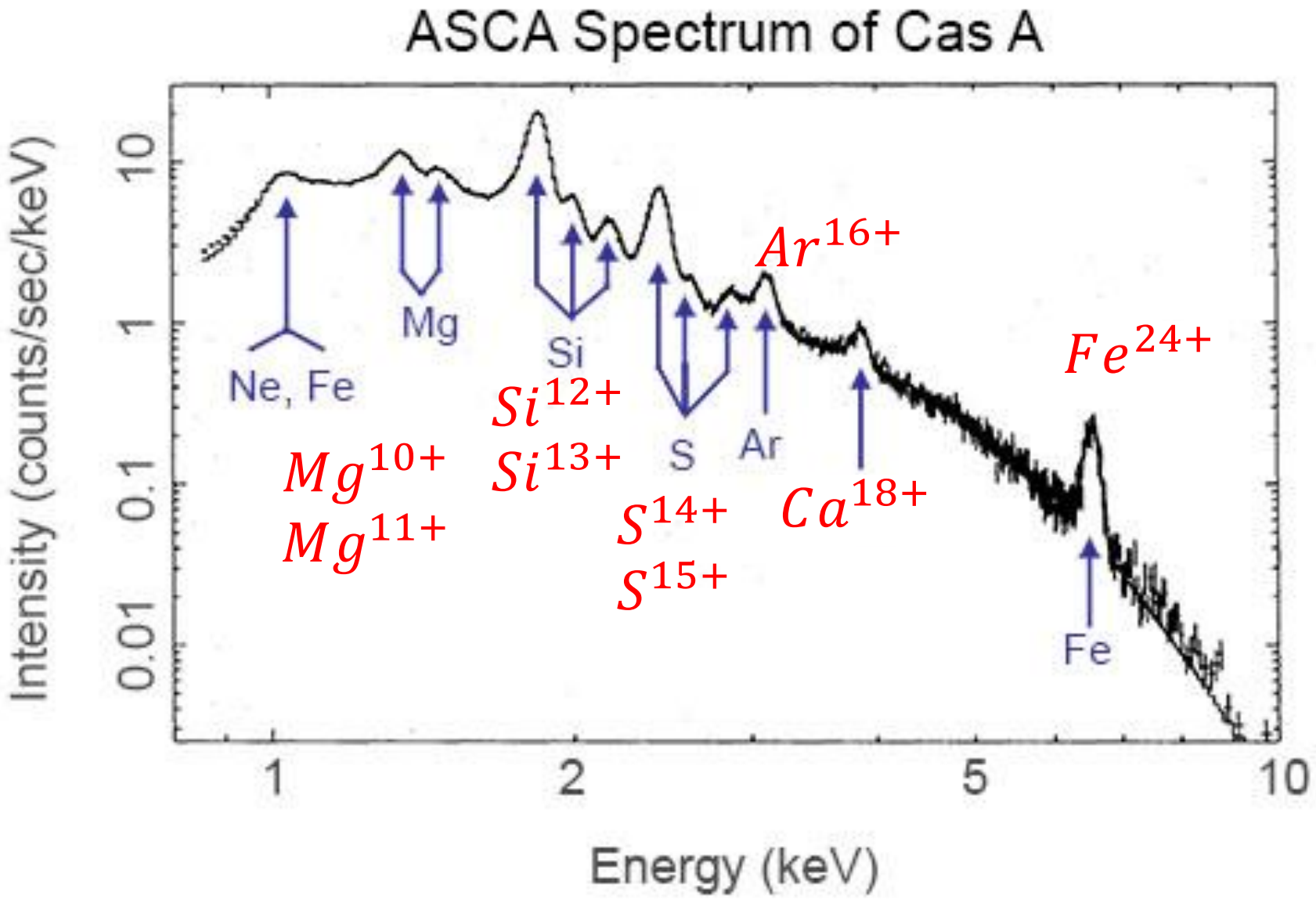
supernova remnant

Cassiopeia A



SN1006

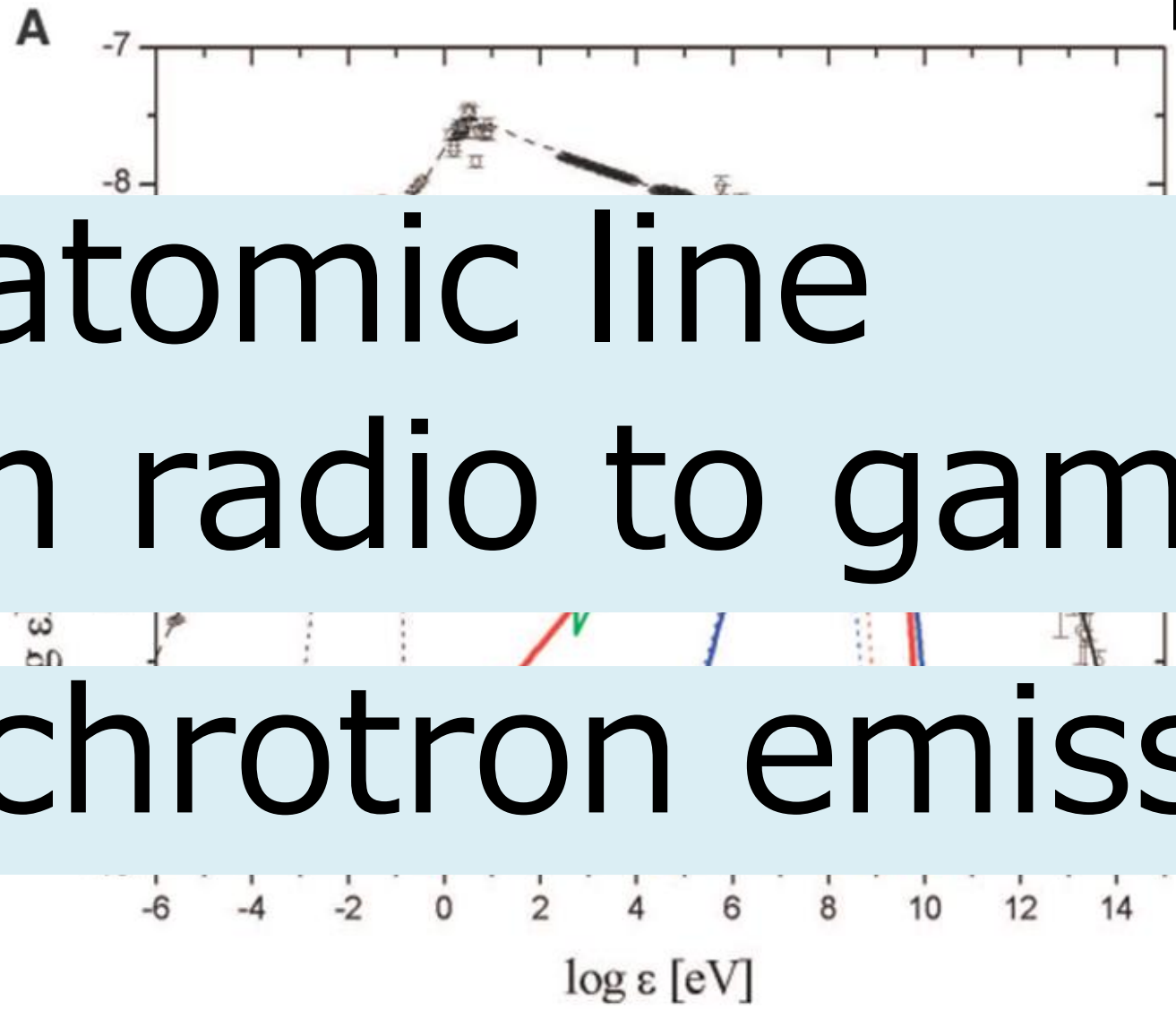
(movie)



Highly ionized ions→hot gas

Crab spectrum

Tavani+2011

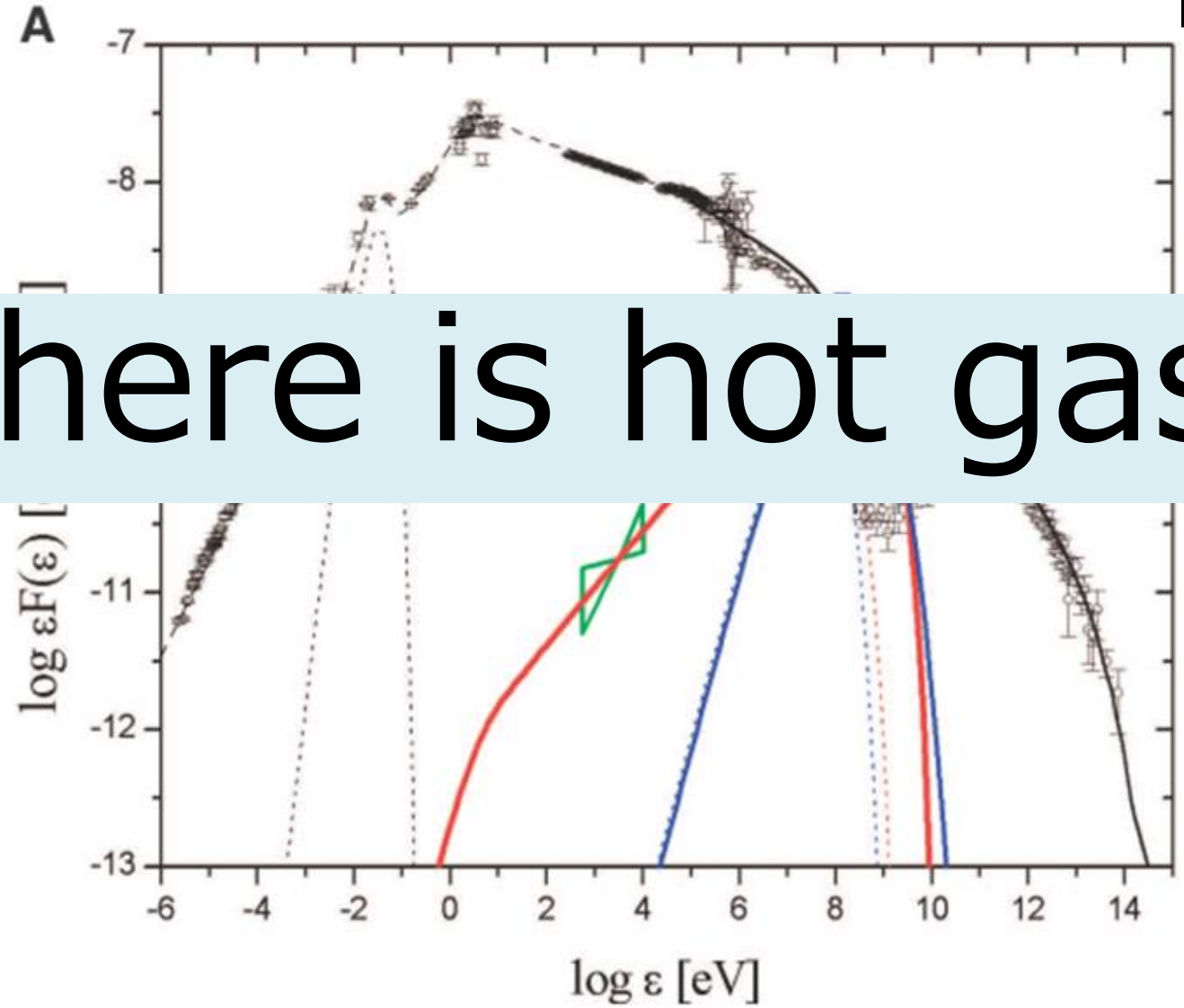


No atomic line
from radio to gamma

Synchrotron emission

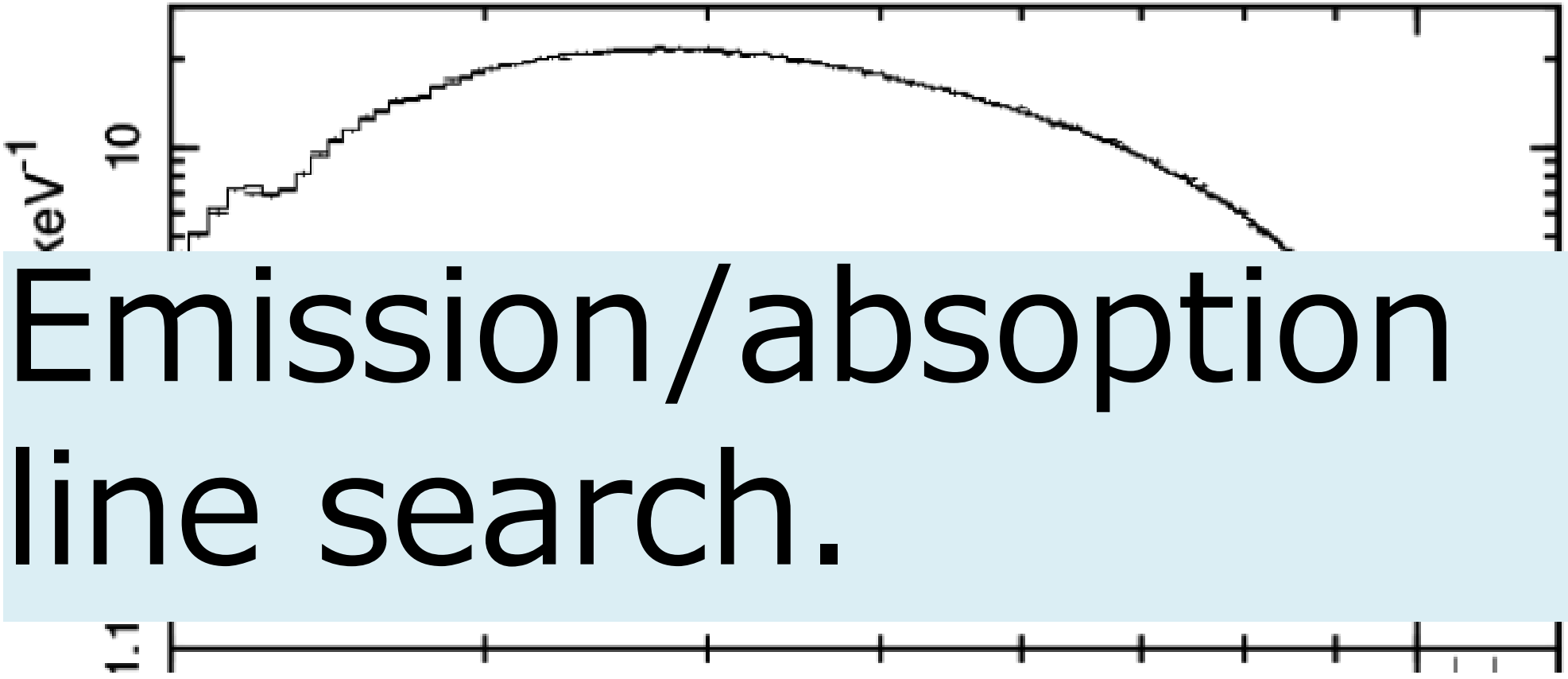
Crab spectrum

Tavani+2011



Where is hot gas?

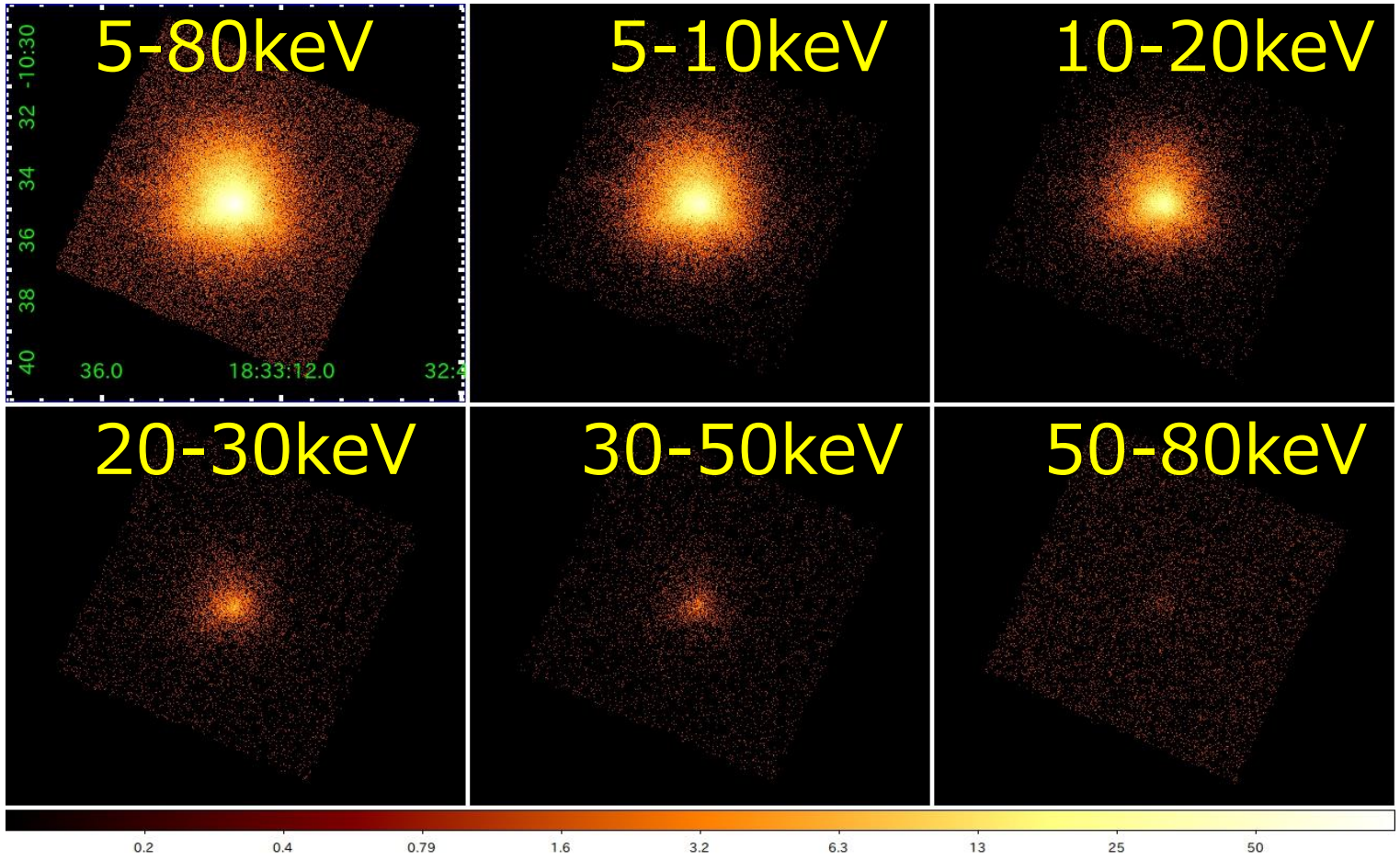
Crab with Hitomi



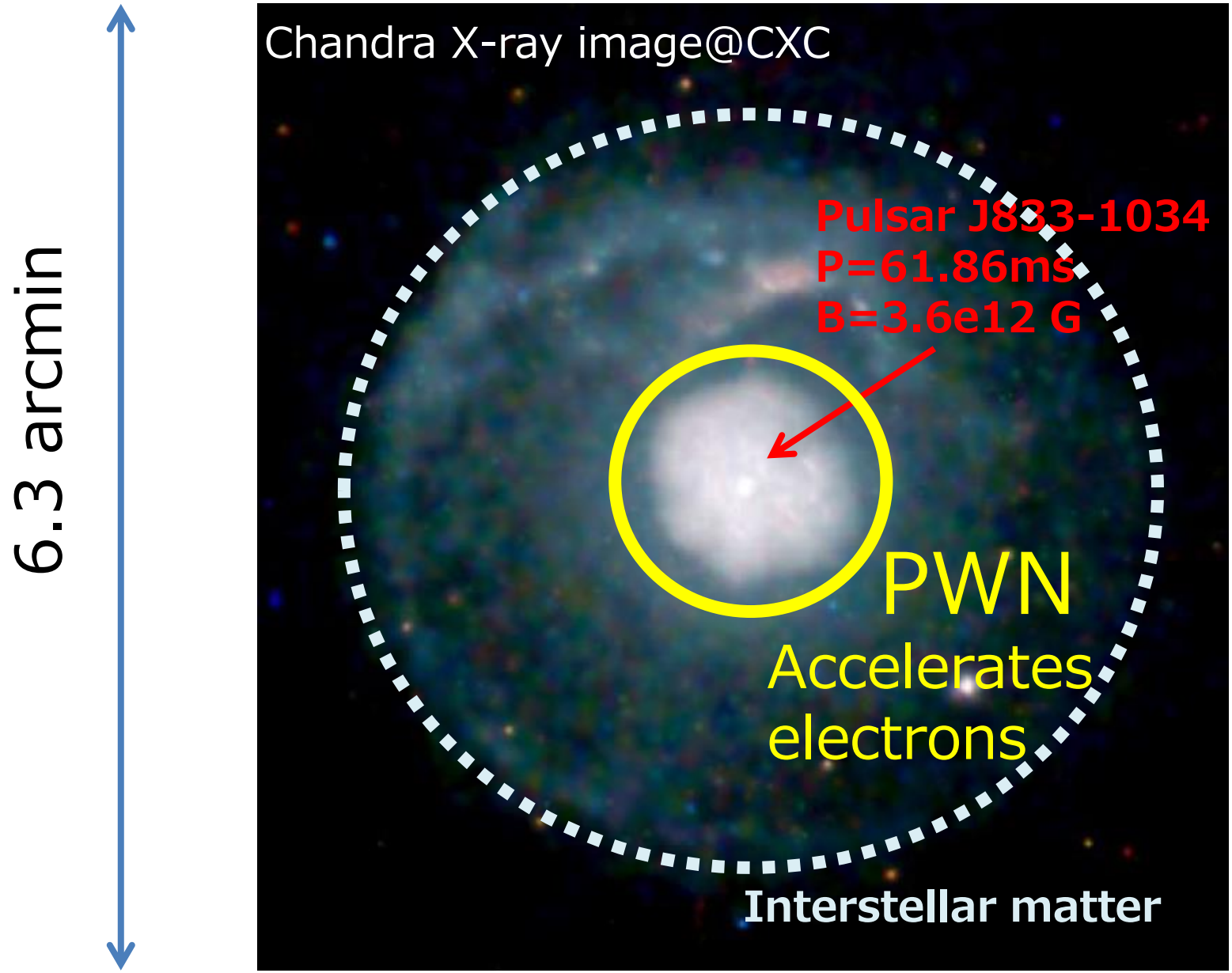
Emission/absoption line search.

About HXT: Success!

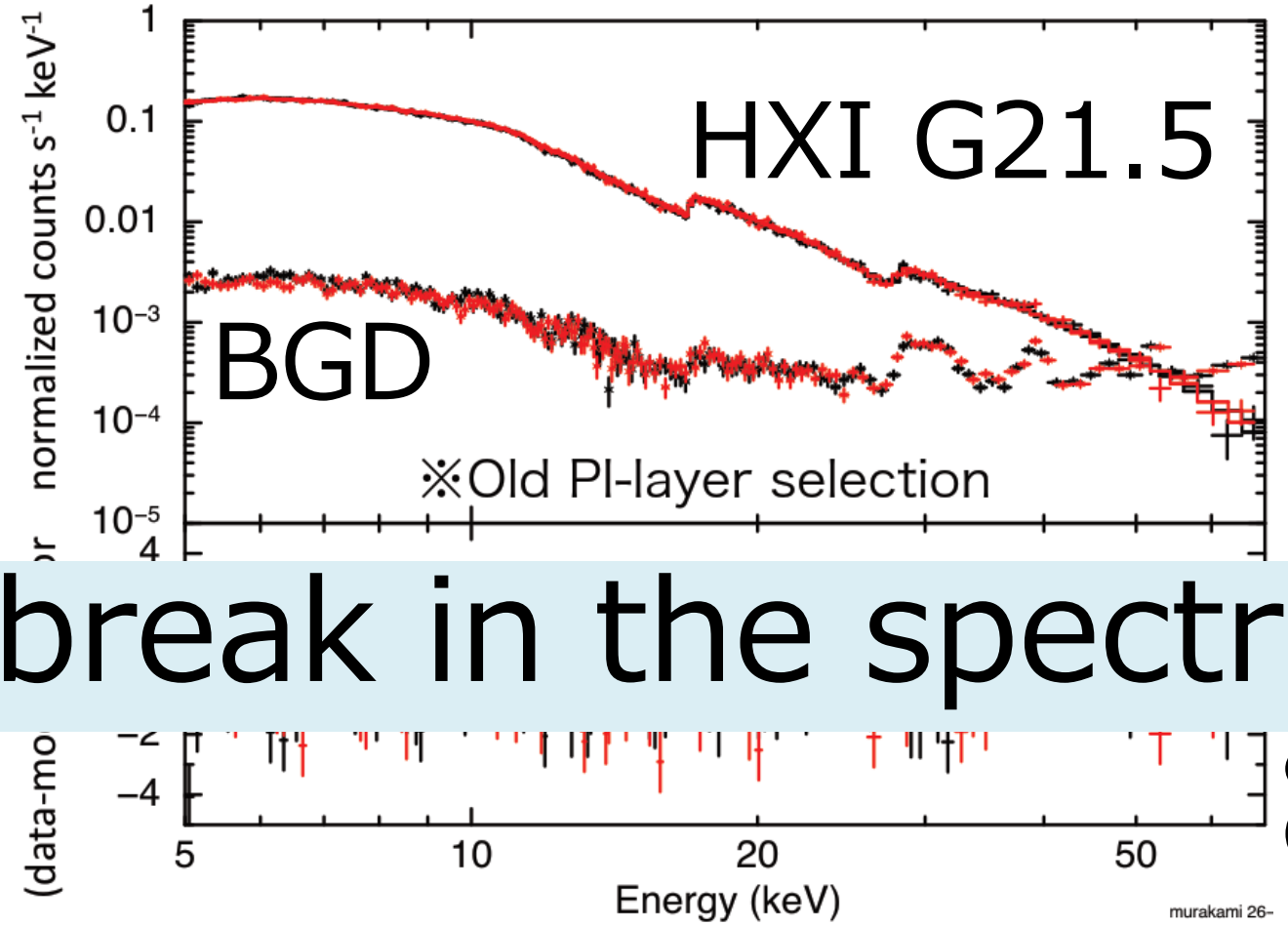
Pulsar wind nebula G21.5-0.9



G21.5-0.9: Pulsar Wind Nebula



What energy can electrons be accelerated to?



Any break in the spectrum?

©H. Murakami
(U. of Tokyo)

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!