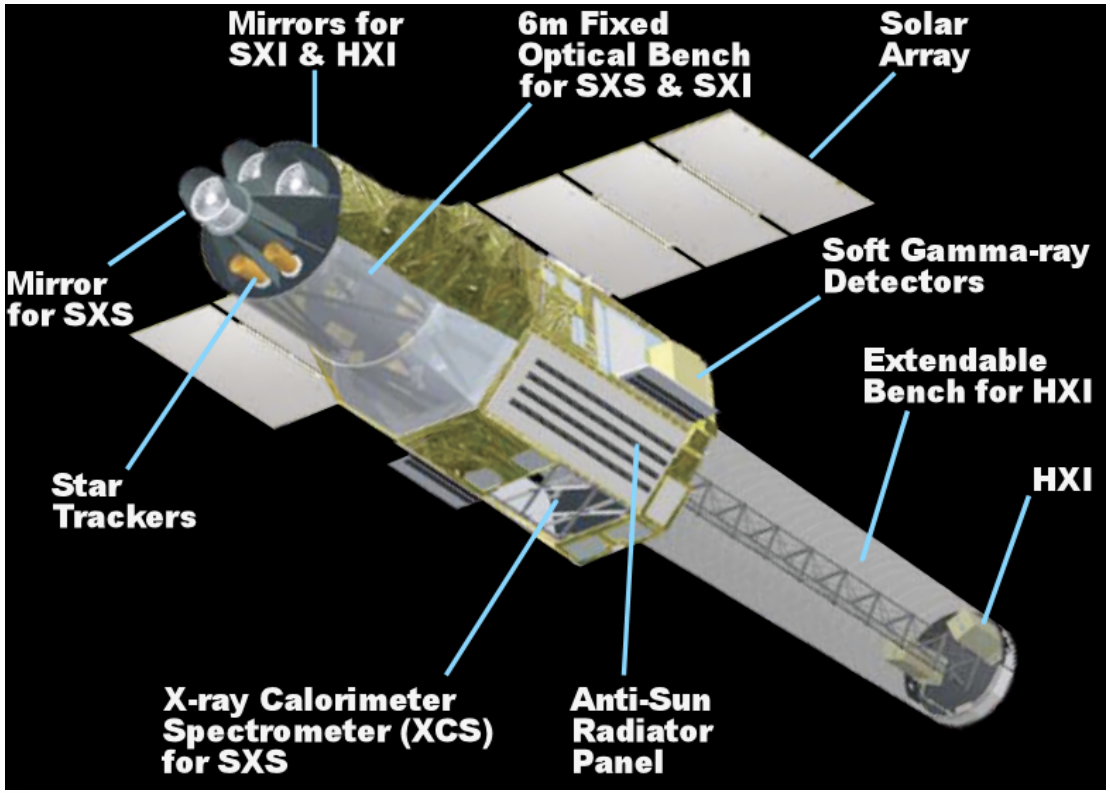
Hitomi satellite / XARM

Speaker : Y. Zhou
Advisor : H. Feng, W. Cui
2018/03/09

System Overview [1][2]

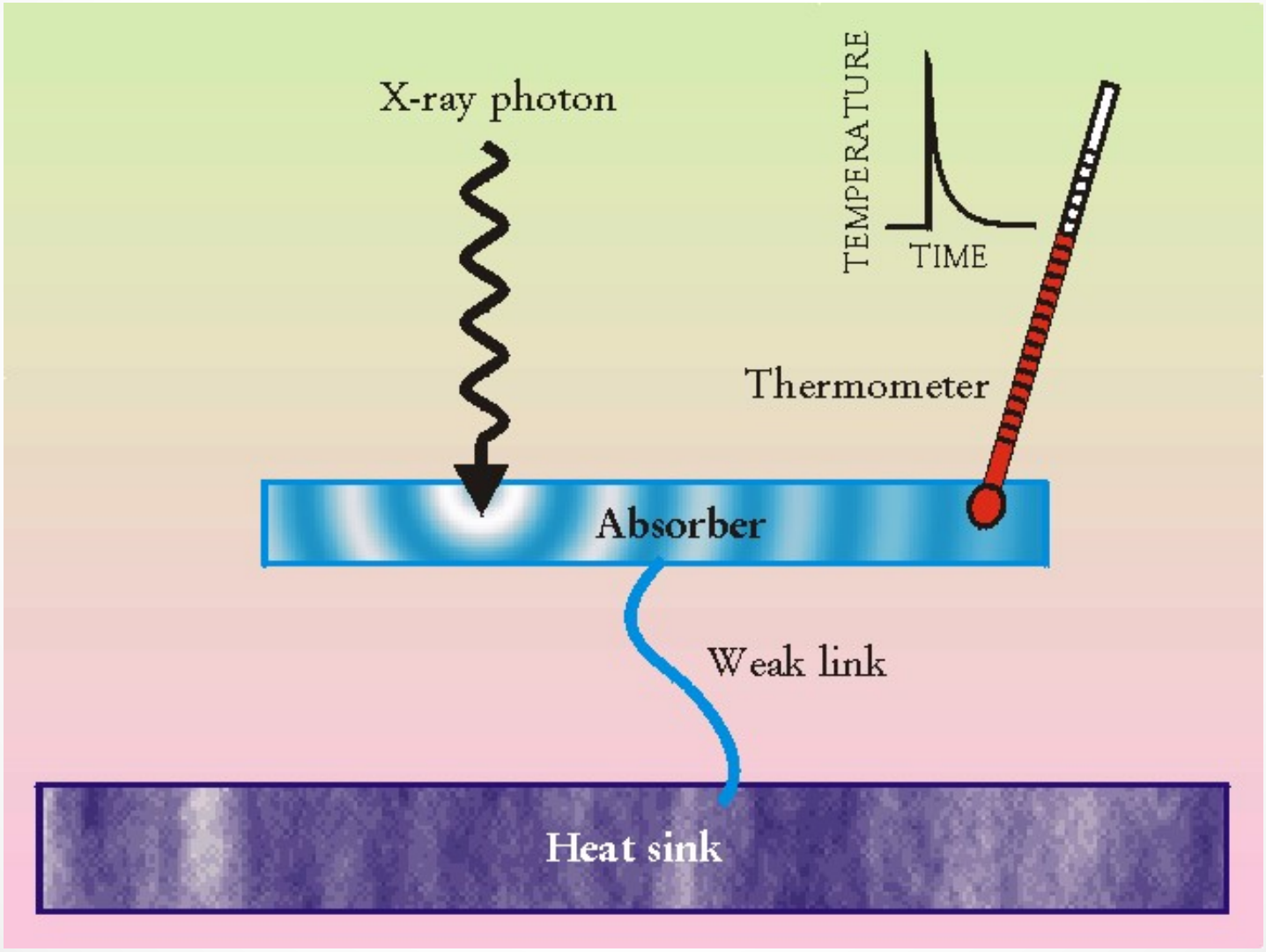


(Takahashi et al, 2014
Odaka et al, 2017)

Soft X-ray Spectrometer	Soft X-ray Imager	Hard X-ray Imager	Soft Gamma-ray Detector
X-ray micro calorimeter	X-ray CCD	Si/CdTe cross-strips	Si/CdTe Compton camera
0.3-12 keV	0.4-12 keV	5-80 keV	40-600 keV

Soft X-ray spectrometer [12]

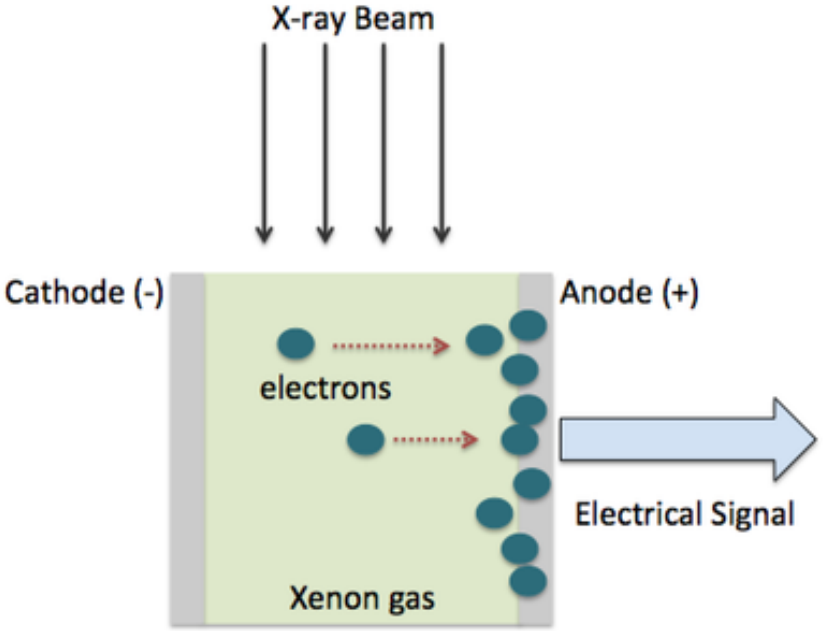
Micro-calorimeter **(Dan McCammon, 2005)**



Soft X-ray spectrometer [12]

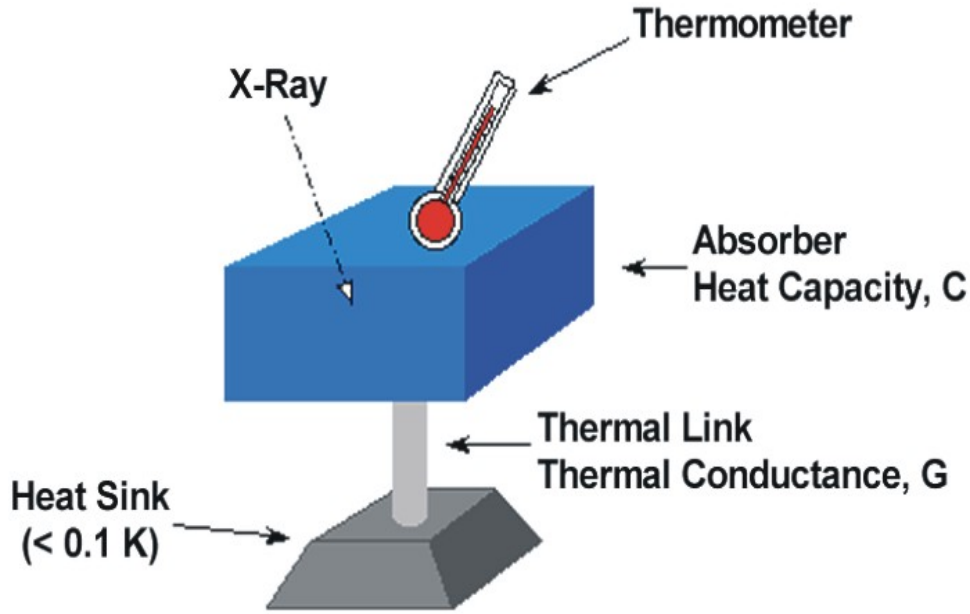
Traditional ionization detector

(CCD , proportional counter, Scintillation detector…)



- Counting the number of ionized particles
- Limited to statistical fluctuations
- $\Delta E \sim 150$ eV for typical CCD

Micro-calorimeter

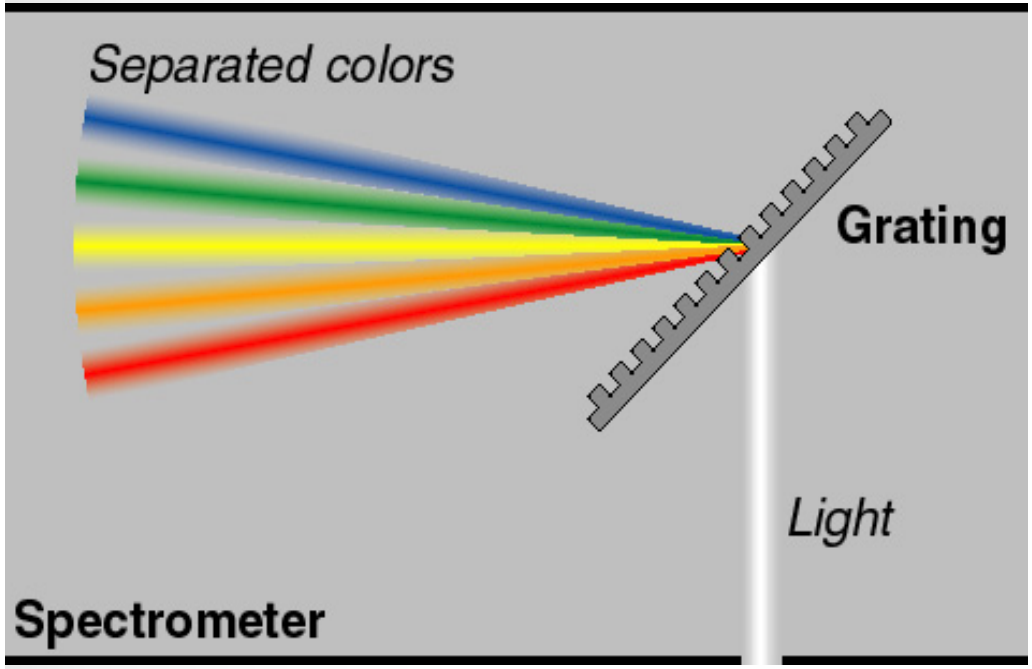


- Measuring the total heat
- Could be more precise in theory
- $\Delta E \sim 5$ eV for Hitomi SXS

Better energy resolution

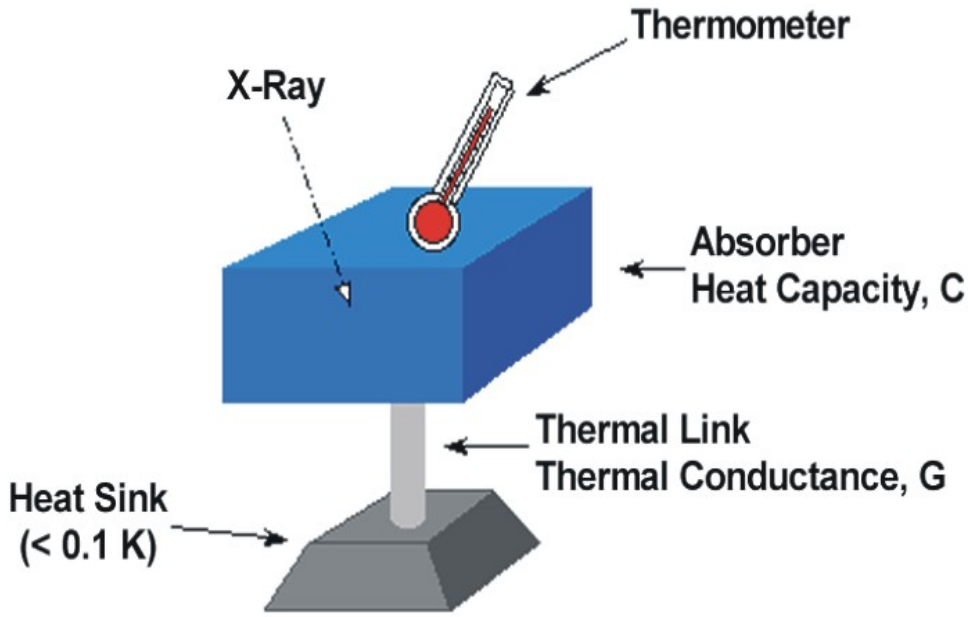
Soft X-ray spectrometer [12]

Grating spectroscopy



- Low quantum efficiency
- Dispersive
- $\Delta E/E$ constant
- Energy resolution depends on source angular size

Micro-calorimeter spectroscopy

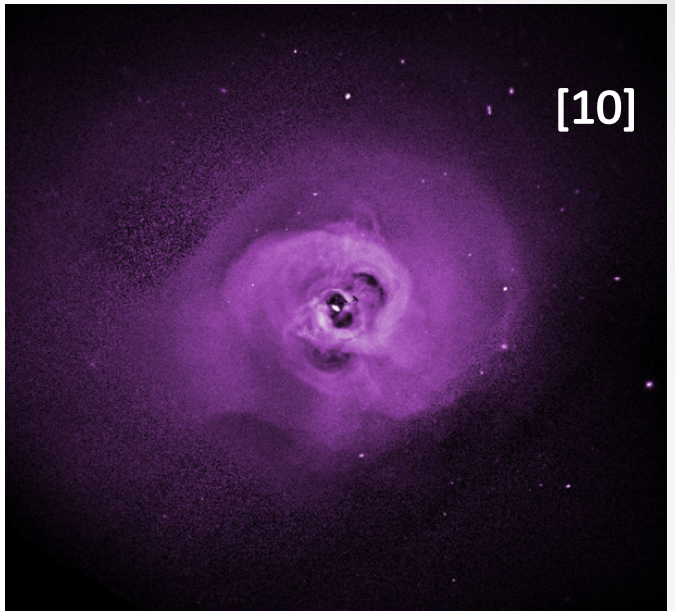


- 100% quantum efficiency
- Non-dispersive
- ΔE constant
- Energy resolution is not affected by X-ray incident direction

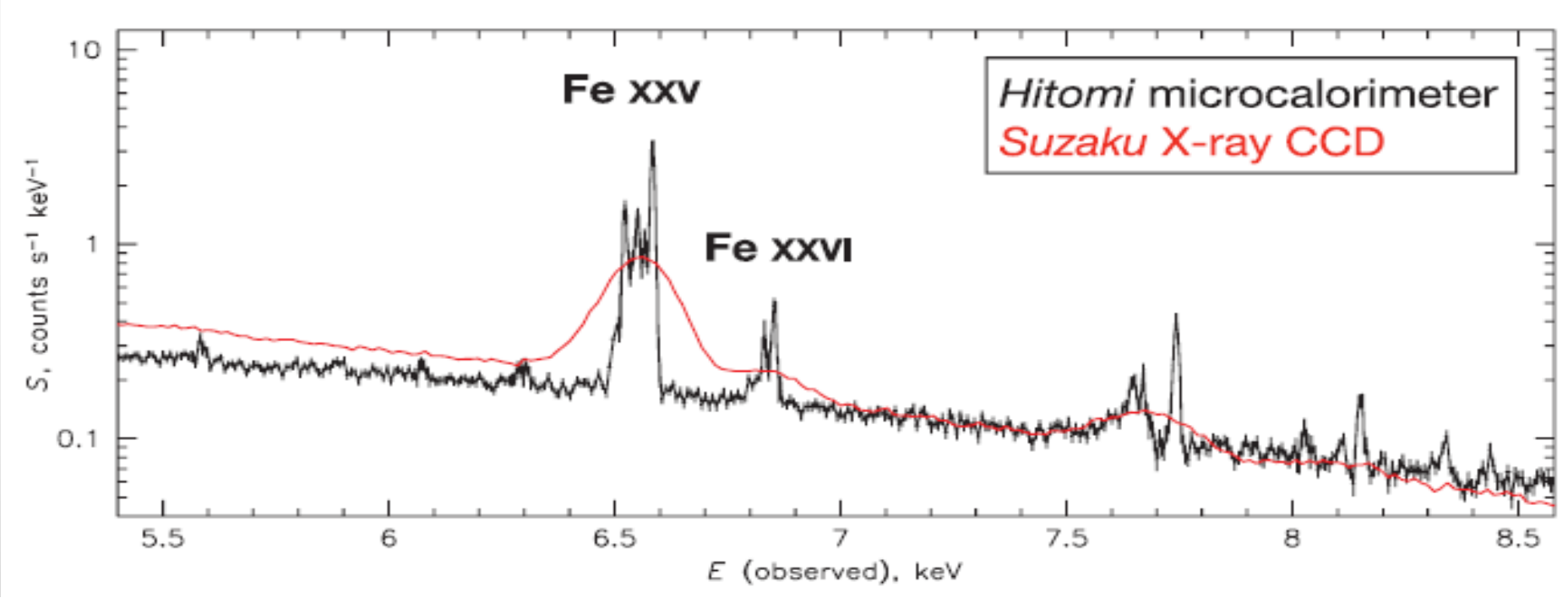
Better energy resolution for extended source

Hitomi Science -- SXS

(Kitayama et al, 2014)

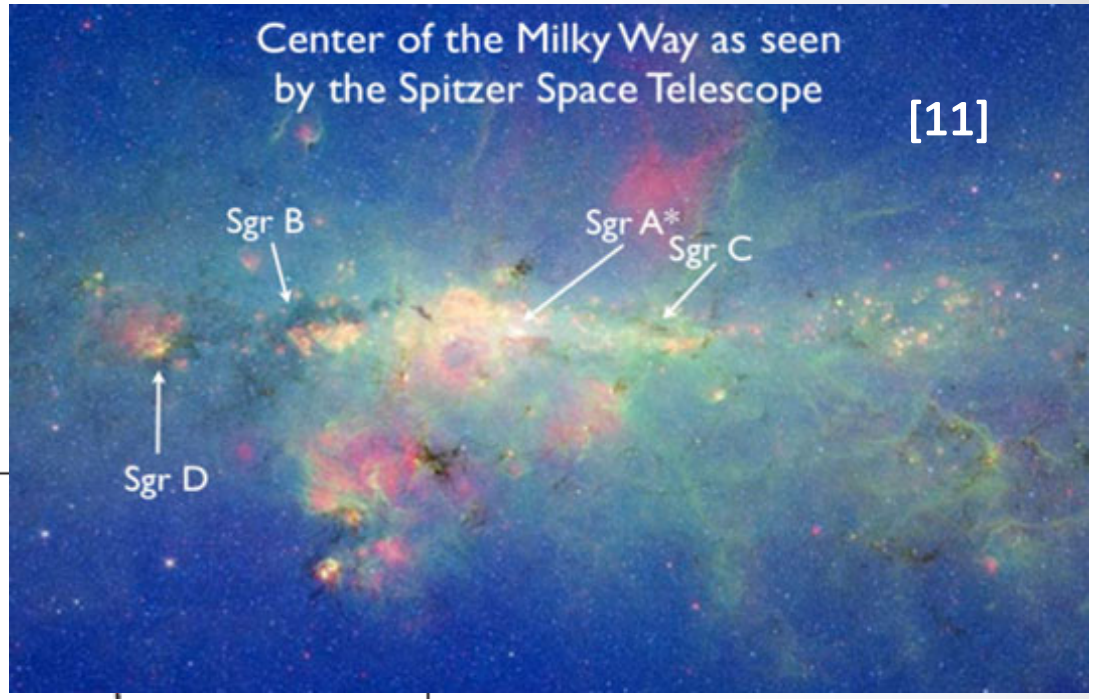


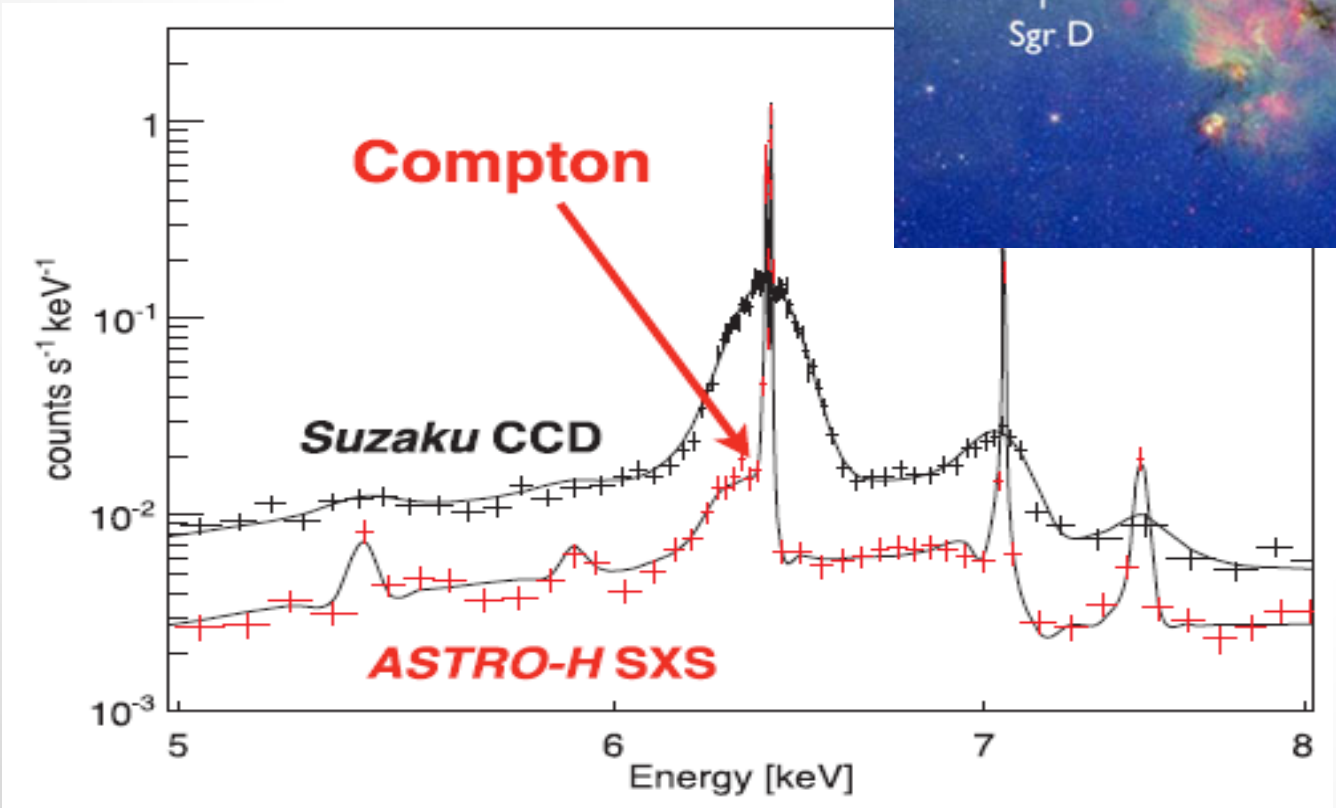
Turbulence and bulk motion in galaxy cluster, SNR, winds …



Hitomi Science -- SXS

Compton shoulder : X-ray reflection in AGN torus, GC molecular clouds, WD surface …





(R. K. Smith et al, 2014)

Hitomi Science

Proto-star :
doppler shift and broadening of the rotatio

Near Chandrasekhar–mass White dwarf :
gravitational shift of the 6.4 keV line

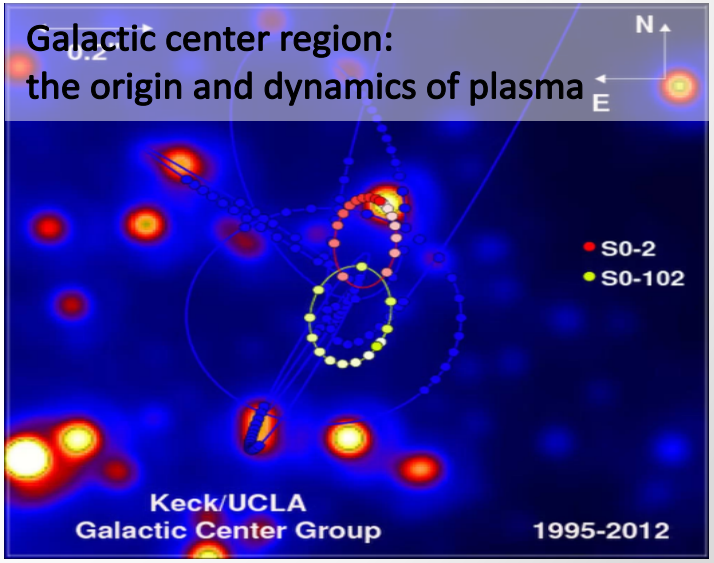
SNR Progenitor:
chemical abundance

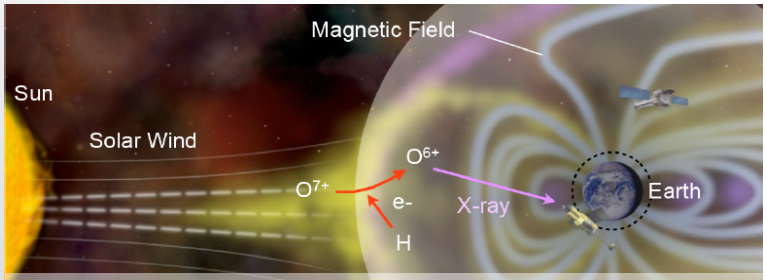
EoS of the neutron star

AGN wind & torus

Geometry and super-Eddington
condition in black holes

Galactic center region:
the origin and dynamics of plasma





Hot Interstellar and Circumgalactic Gas :
distinguish between 'Local hot Bubble' and SWCX (solar wind charge exchange)

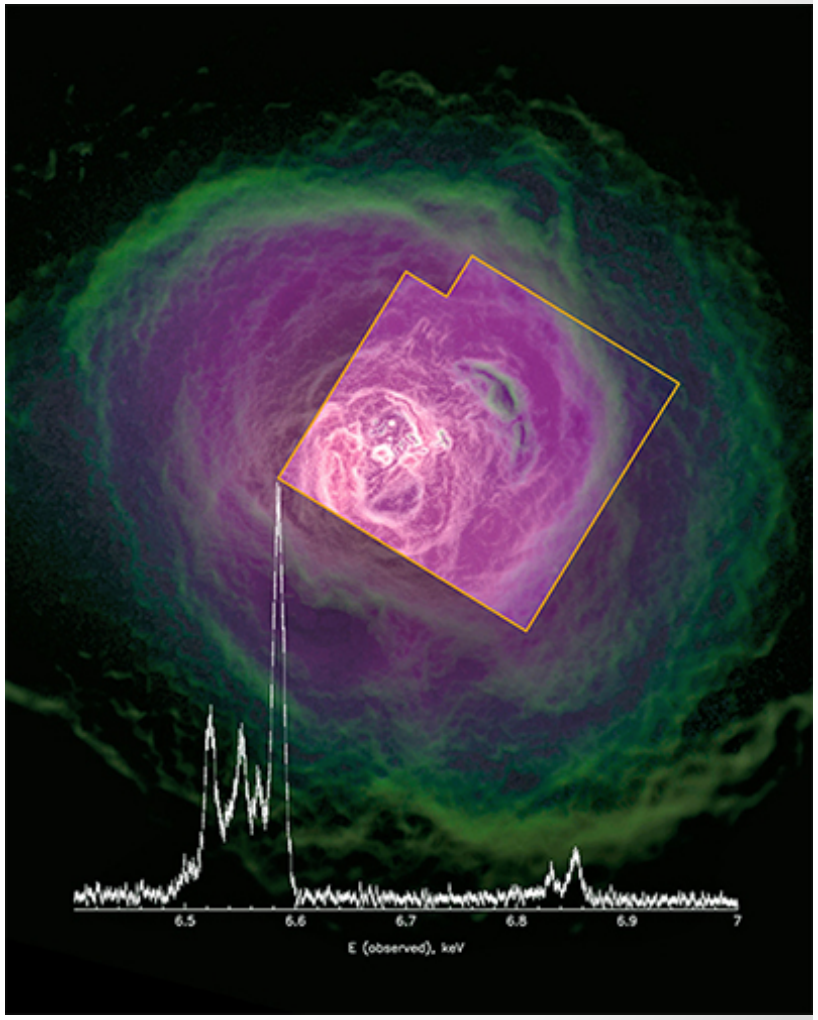
Chemical Evolution in
High z Universe

Case Study : Perseus Cluster

- Gas dynamics of the ICM
- AGN Feedback
- Cosmology Evolution
- Dark Matter Model

Background [10]

(Kitayama et al, 2014)



Worries about weighing cluster mass :

- Assuming thermal equilibrium

Evidence for AGN feedback :

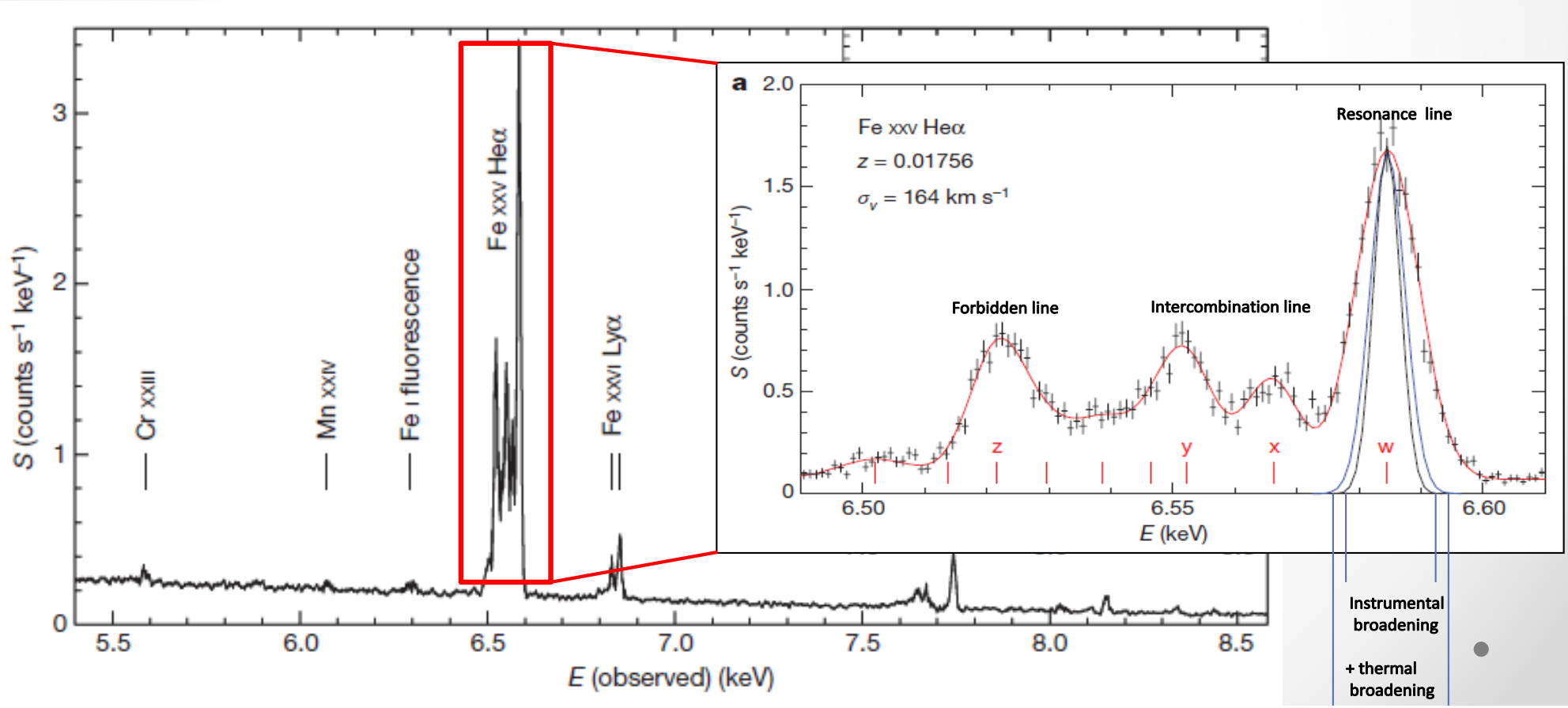
- Bubbles structure
- Expecting strong turbulence in the ICM ---- not in thermal equilibrium

Perseus cluster is the best target for this study !

(AHARONIAN et al, 2017)

The Measurement [14] [15]

- Turbulence broadening : assumed to be the same, not depend on ion mass
- Thermal broadening : depends on ion mass and T_{ion} , assuming the same T_{ion}



(AHARONIAN et al, 2017)

Gas dynamics of the ICM [10]

Previously :

- Only upper limits were obtained with XMM-Newton: < 600 km/s @ 68% confidence level

Hitomi observation :

- 164 +/- 10 km/s
- surprisingly lower than expected

The Interpretation

- The Perseus ICM is almost quiescent !
  - Turbulence energy is only 4% of the thermodynamic energy
- Probably don't need correction for cluster mass measurement
- The AGN feedback is 'gentle' [16][15]

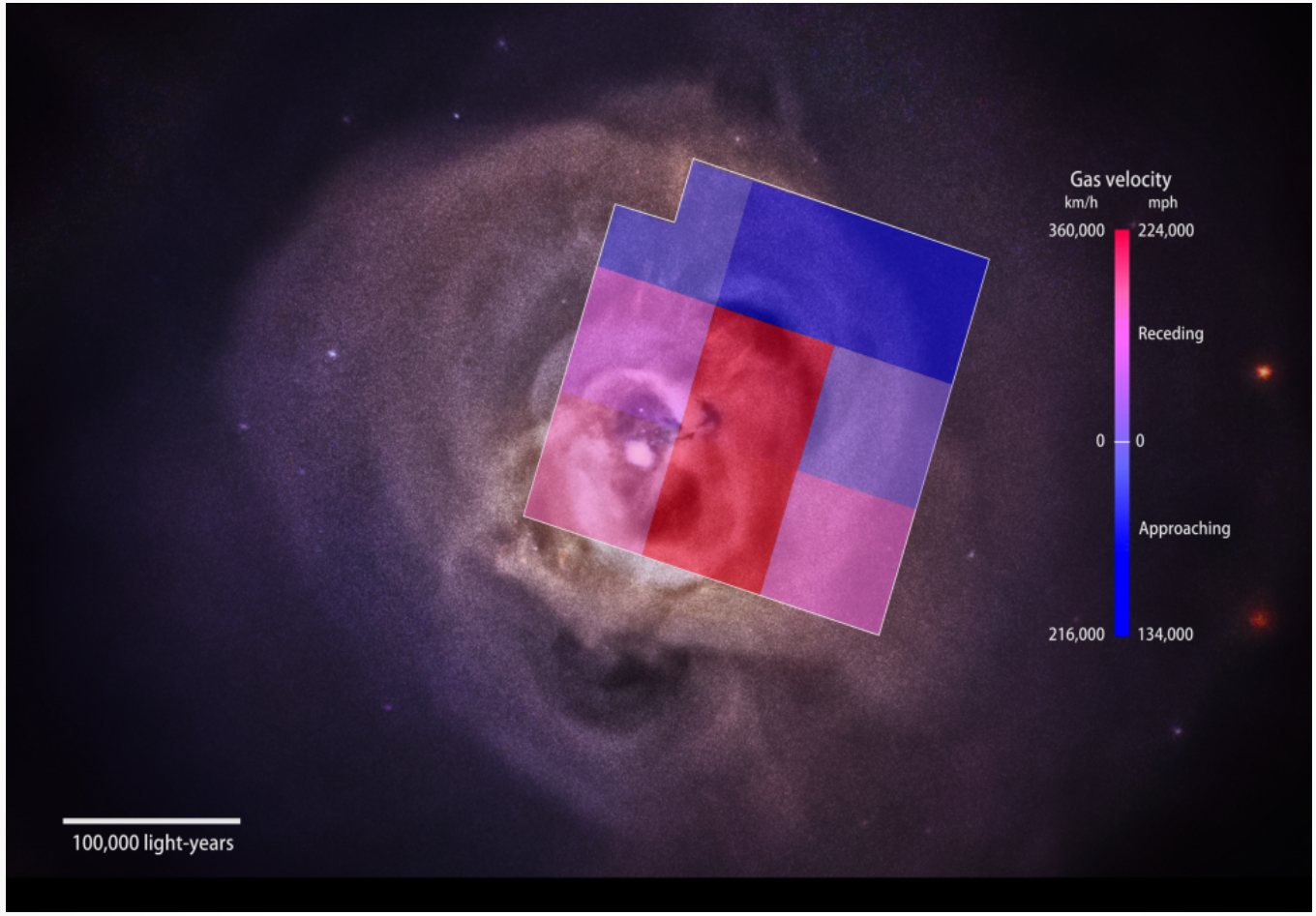
(Erwin T. Lau et al, 2017)

- Leaving open question :

What is keeping the cluster's widespread gas hot ?

(AHARONIAN et al, 2017)

Bulk Motion : Velocity Shear in Map [15]



- Mild AGN feedback
- cosmic accretion, such as mergers

More application : the origin of 3.5 keV line [19]

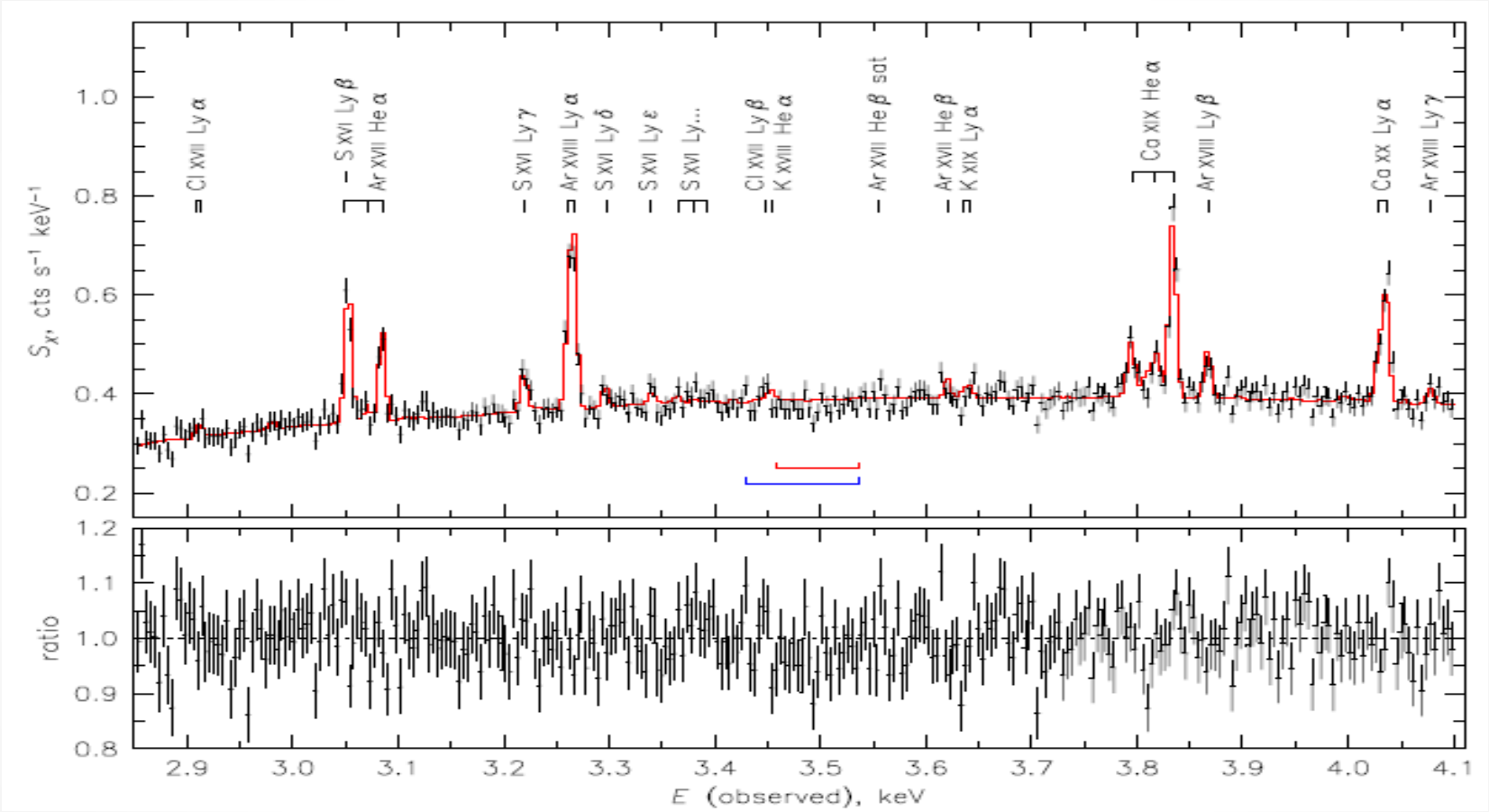
- Unkown emission line feature seen in stacked sample of 73 clusters (Bulbul et al. 2014)

Possible explanations:

- K XVIII line
  - Require cold gas and unphysically high K abundances
- Sulphur charge exchange
  - Known lines in unfamiliar ratios
  - Cold neutral gas interact with hot fully ionized gas
- Decaying Sterile Neutrino of a mass of ~7 keV → ~3.5 keV line

(AHARONIAN et al, 2017)

First sight of SXS spectrum :



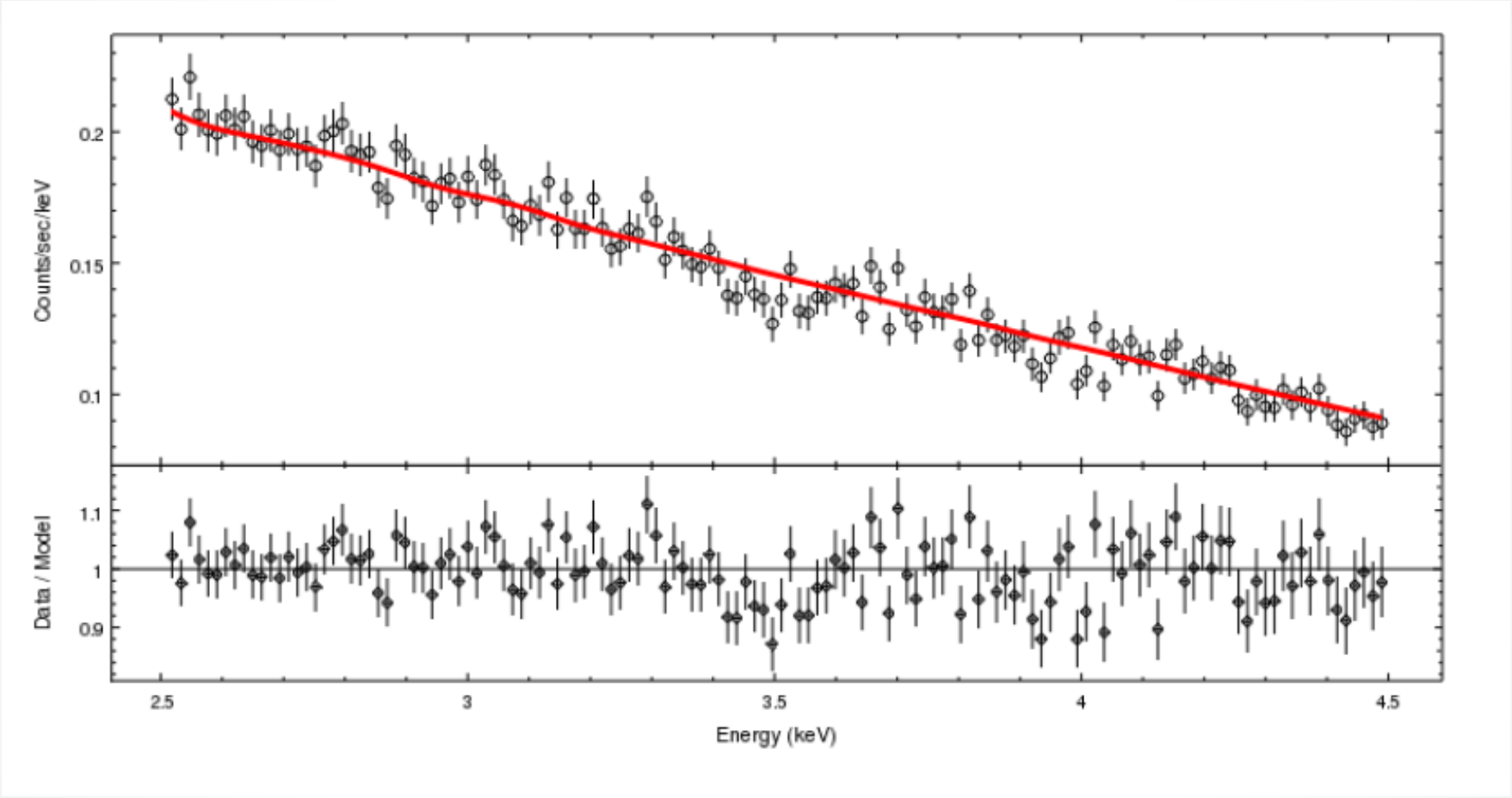
No evidence of 3.5 keV line [20]

Inconsistent with Chandra and XMM-Newton observation

rule out the K emission line

(Joseph P. Conlon et al, 2017)

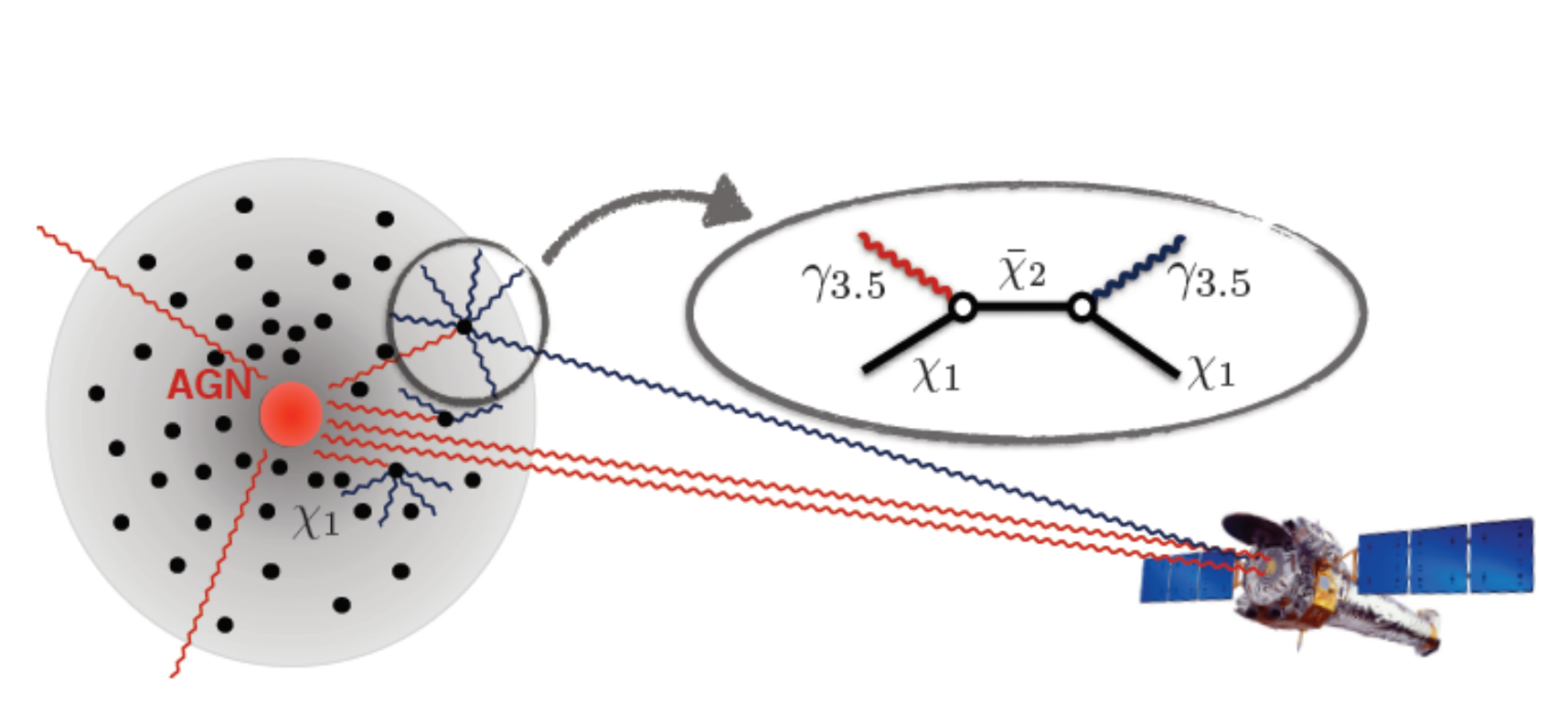
Consistency with Chandra Data [21]



- The AGN contributes to Hitomi spectrum
- Not for Chandra, XMM-Newton

(Joseph P. Conlon et al, 2017)

Flourescent Dark Matter [21]



Hitomi spectrum :

- Probably support the flourescent dark matter model better than decaying or annihilating dark matter

X-ray Astronomy Recovery Mission

- The Hitomi satellite lost control in the spin rate due multiple incidents with the attitude control system and breakup ---- before the formal operation.

Instrument			Hitomi	XARM
Soft X-ray Spectrometer	SXS	X-ray micro calorimeter	O	O
Soft X-ray Imager	SXI	X-ray CCD	O	O
Hard X-ray Imager	HXI	Si/CdTe cross-strips	O	Not Onboard
Soft Gamma-ray Detector	SGD	Si/CdTe Compton camera	O	Not Onboard

References

- [1] Astro-H instrument, https://arxiv.org/abs/1412.1356
- [2] Hitomi X-ray Astronomy Satellite: Power of High-Resolution Spectroscopy, http://adsabs.harvard.edu/abs/2017IAUS..322..197O
- [3] Astro-H star, https://arxiv.org/abs/1412.1162
- [4] Astro-H white dwarf, https://arxiv.org/abs/1412.1163
- [5] Astro-H SNR, https://arxiv.org/abs/1412.1169 , https://arxiv.org/abs/1412.1166
- [6] Astro-H galactic center, https://arxiv.org/abs/1412.1170
- [7] Astro-H neutron star, https://arxiv.org/abs/1412.1165, https://arxiv.org/abs/1412.1164
- [8] Astro-H black hole, https://arxiv.org/abs/1412.1173
- [9] Astro-H AGN, https://arxiv.org/abs/1412.1177 , https://arxiv.org/abs/1412.1171
- [10] Astro-H galaxy cluster, https://arxiv.org/abs/1412.1174 , https://arxiv.org/abs/1412.1176
- [11] Astro-H new spectral feature, https://arxiv.org/abs/1412.1172
- [12] Dan McCammon, microcalorimeter, https://arxiv.org/abs/physics/0503045
- [13] Hitomi-SXS-cooling-system, http://adsabs.harvard.edu/abs/2010SPIE.7732E..3HF
- [14] nature_quiescent-intracluster-medium-core-perseus-cluster, http://adsabs.harvard.edu/abs/2016Natur.535..117H
- [15] atmospheric-gas-dynamics-in-the-Perseus-cluster-Hitomi, http://adsabs.harvard.edu/abs/2017arXiv171100240H
- [16] physics-origin-of-gas-motions-in-galaxy-cluster-cores_Lau_2017, http://adsabs.harvard.edu/abs/2017ApJ...849...54L
- [17] Do-sound-wave-transport-AGN-energy-in-perseus-cluster, http://adsabs.harvard.edu/abs/2017MNRAS.464L...1F
- [18] Hitomi-perseus-support-heating-by-mixing, http://adsabs.harvard.edu/abs/2017MNRAS.466L..39H , http://adsabs.harvard.edu/abs/2018ApJ...853..180Z
- [19] 3.55keV-line_JC_OxfordLunch , Bulbul et al 2014, Boyarsky et al 2014
- [20] Hitomi-constraints-on-the-3.5keV-line-perseus-galaxy-cluster, http://adsabs.harvard.edu/abs/2017ApJ...837L..15A
- [21] consistency-hitomi_xmm_chandra-3.5keV_Perseus_Joseph_2017, http://adsabs.harvard.edu/abs/2017PhRvD..96l3009C
- [22] Cosmic ray heating in cool core clusters, http://adsabs.harvard.edu/abs/2017MNRAS.467.1478J

Summary

- Unprecedented energy resolution (< 7 eV) in soft X-ray band
- Calorimeter : better in energy resolution, especially for extended source
- New spectra features to resolve
- Perseus cluster : AGN feedback mechanism, cosmology evolution and dark matter model.
- Hitomi was lost after one month after launch
- X-ray Astronomy Recovery Mission on next mission