The ASTRO-H Mission

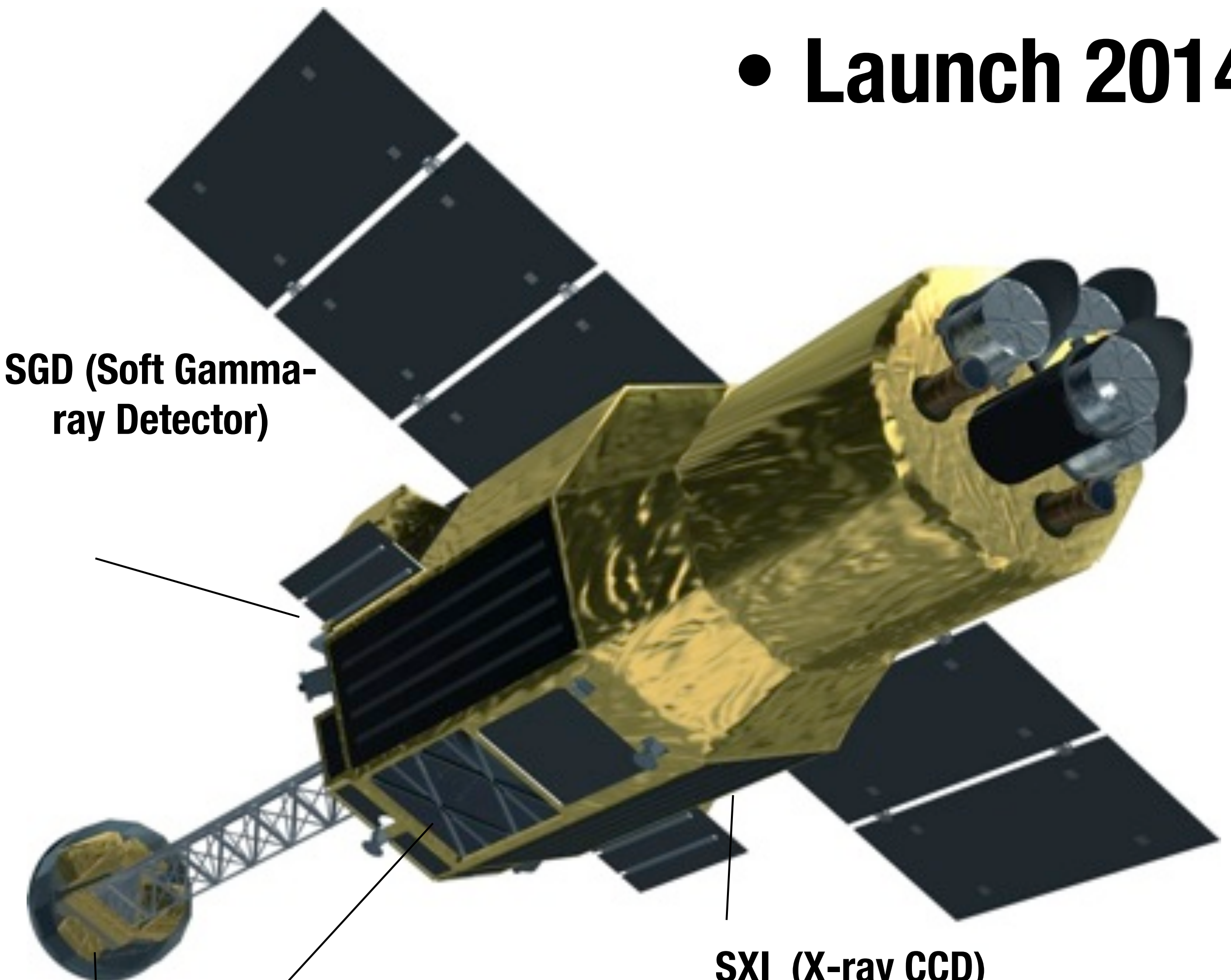
Yoshitomo Maeda
ISAS/JAXA
on behalf of the ASTRO-H Team

Modified for the Vulcano 2012 from the original files provided by T.Takahashi

1. ASTRO-H : mission and collabolation

ASTRO-H is an international X-ray observatory, which is the 6th in the series of the X-ray observatories from Japan. More than 160 scientists from Japan/US/Europe/Canada.

- **Launch 2014**



weight 2.7 t

ASTRO-H Member Agencies and Countries

US Participation

NASA
Micro Calorimeter Array/ADR for SXS
Soft X-ray Telescope for SXS & SXI
Eight Science Advisors

European Participation

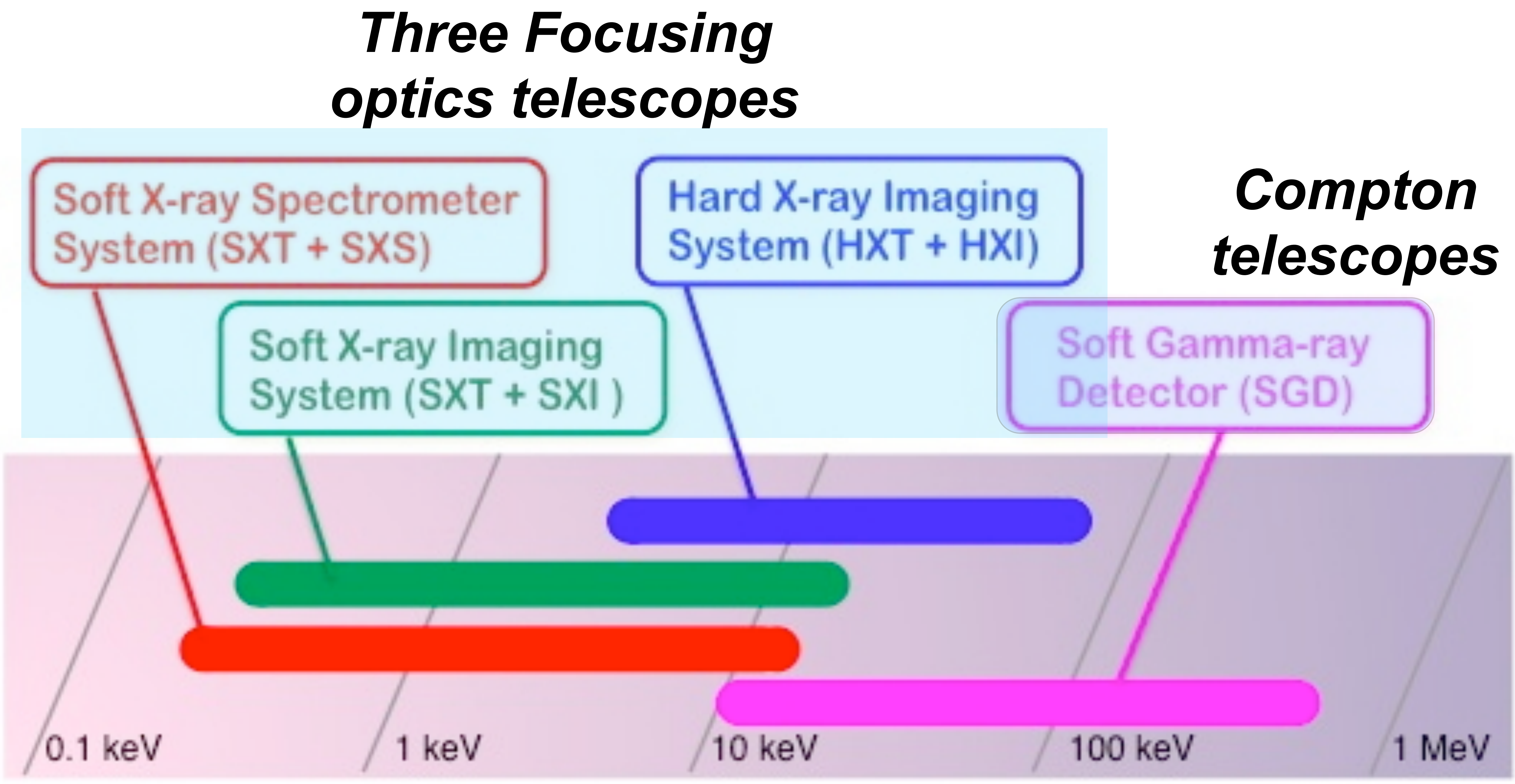
SRON & U. of Geneva
Filter Wheel for SXS (inc. CAEN.'s HV)
CEA/DSM/IRFU
Contribution to BGO Shield/ASICS testing for HXI
ESA
Science Working Group Activities
Contribution to SXS/HXI/SGD/HXT
User support in Europe

Canadian Participation

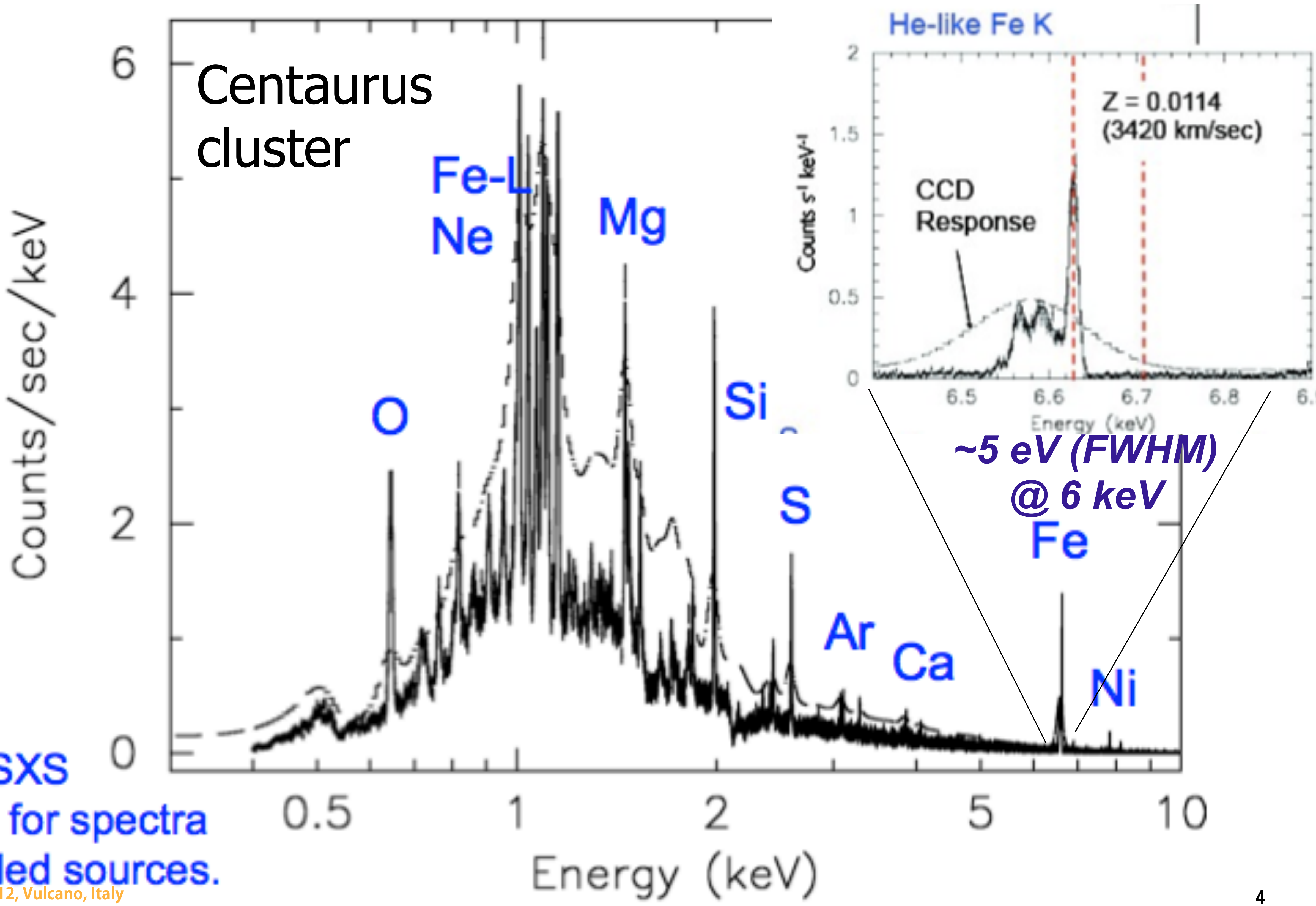
CSA
Canadian ASTRO-H Metrology System

2. ASTRO-H Uniqueness : Wide band

1. Imaging / High Sensitivity in the wide 0.3 keV - 600 keV band



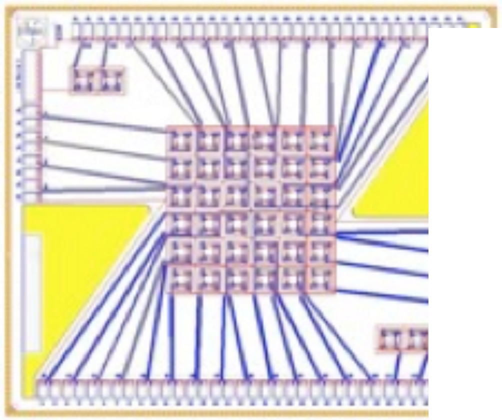
2. High Resolution Power for point-like and “extended” sources.



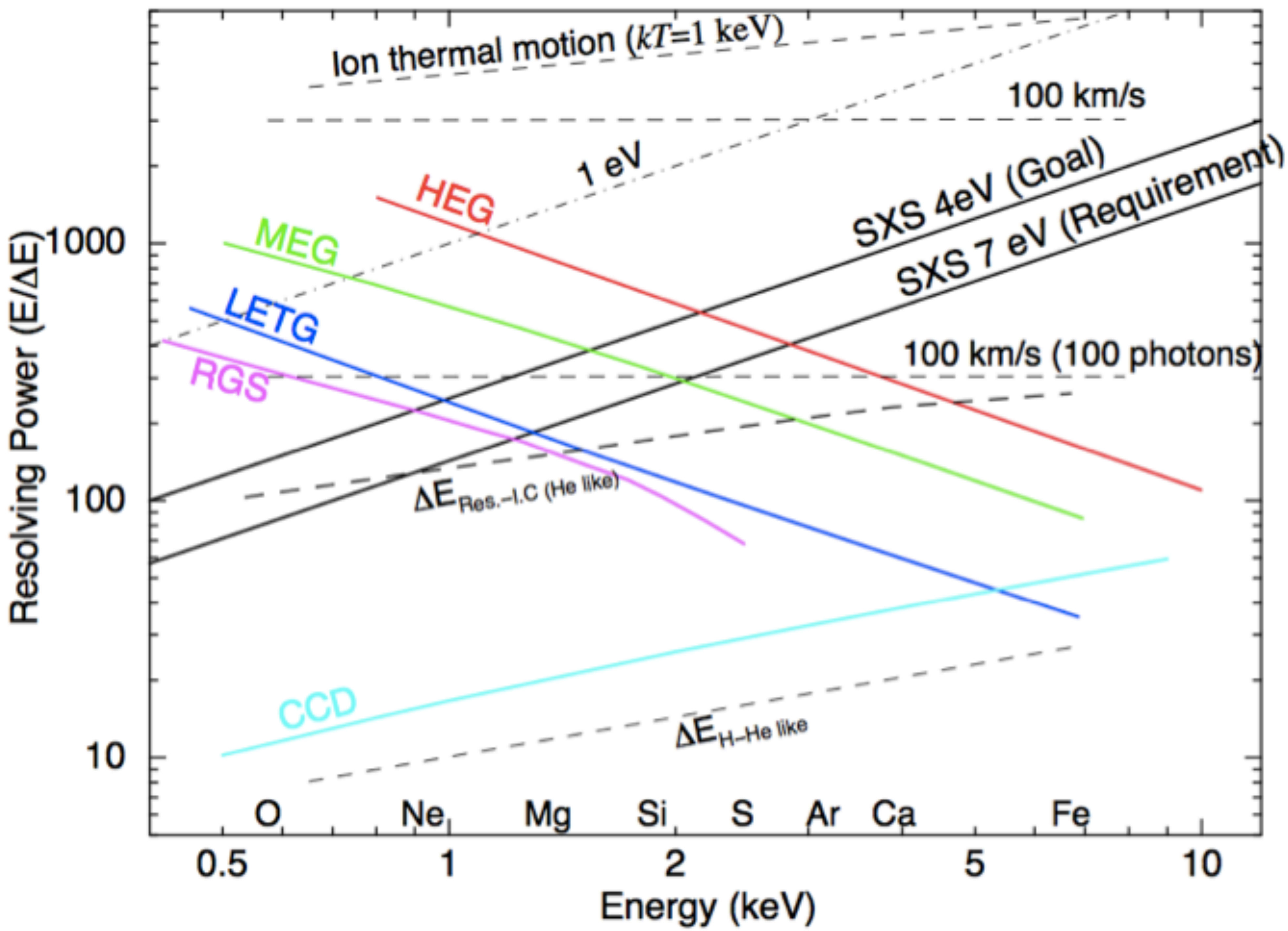
Astro-H/SXS essential for spectra of extended sources.

2. ASTRO-H Uniqueness : High resolution spectroscopy

- a micro calorimeter array

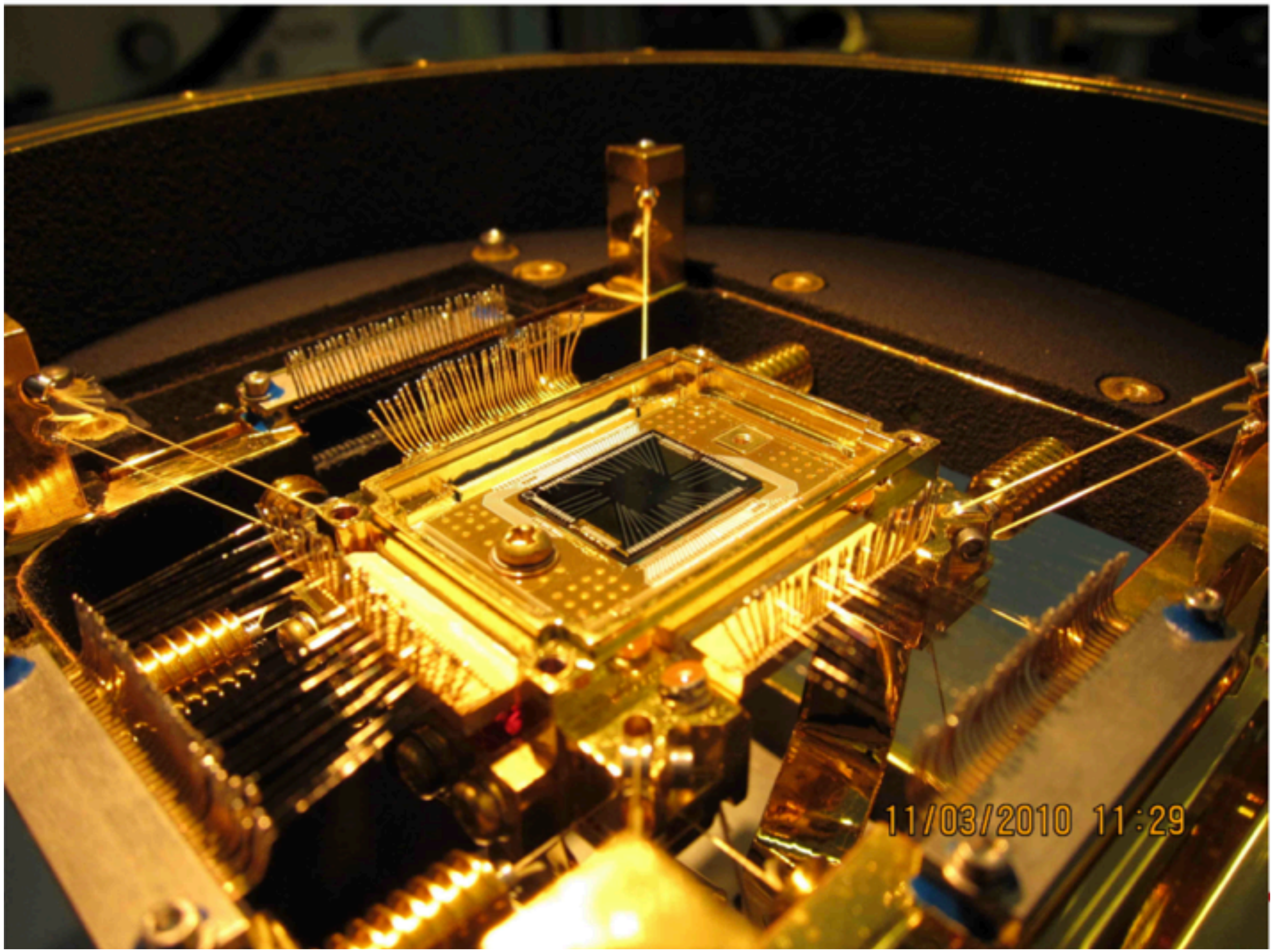


814 μm
6x6 array
34 pixel readout
50 mK



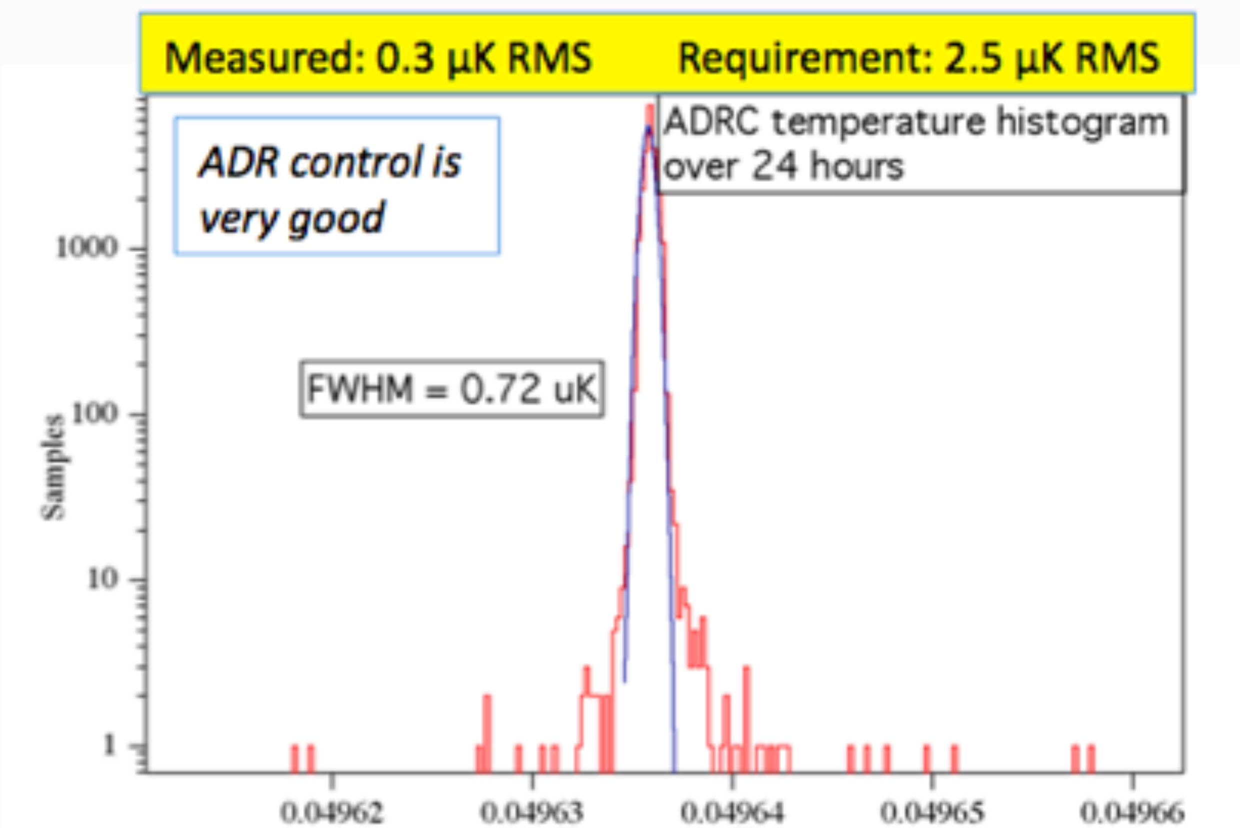
3. ASTRO-H: EM Detector System of SXS

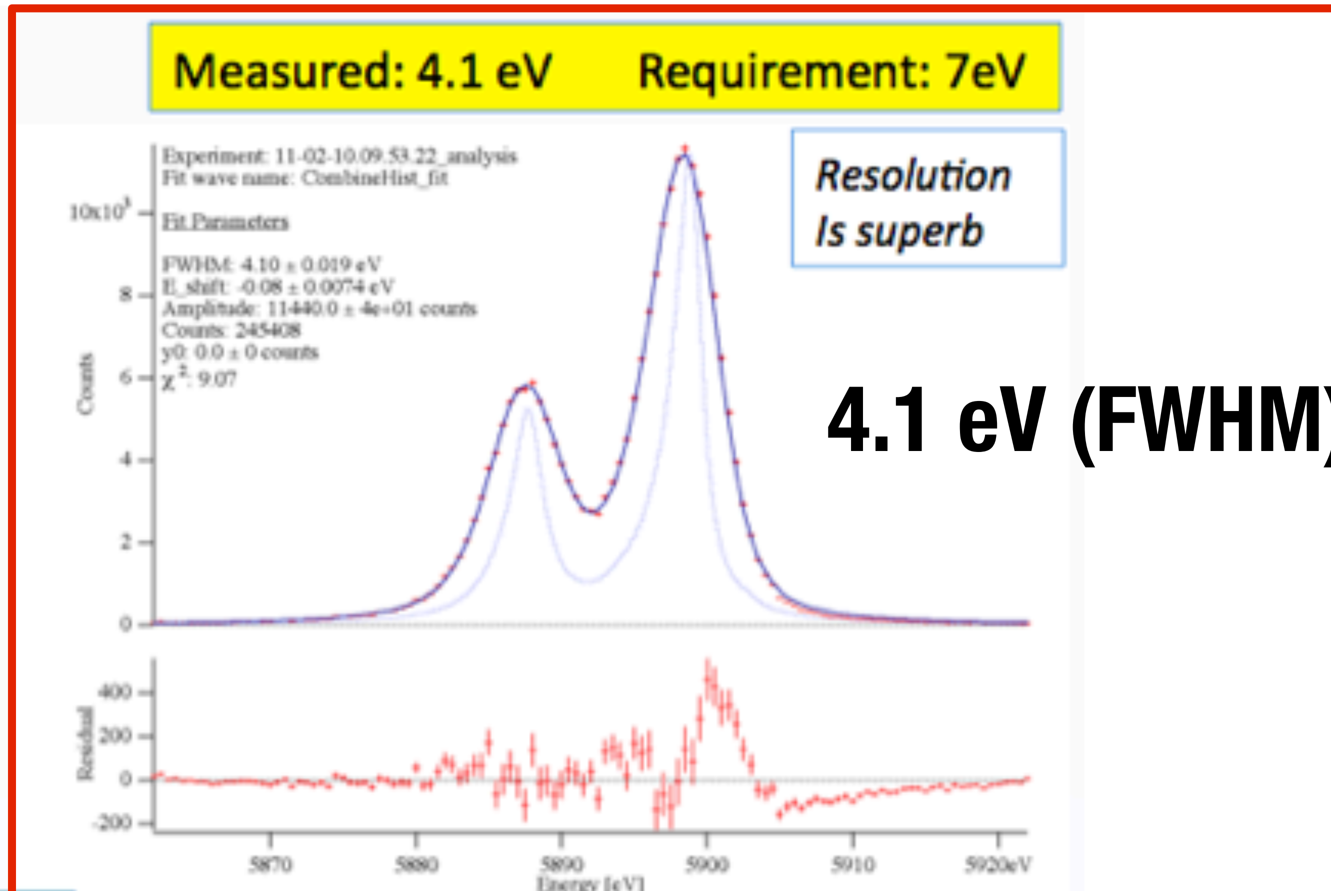
Detector Assembly + Detector Array + Anti-co Detector

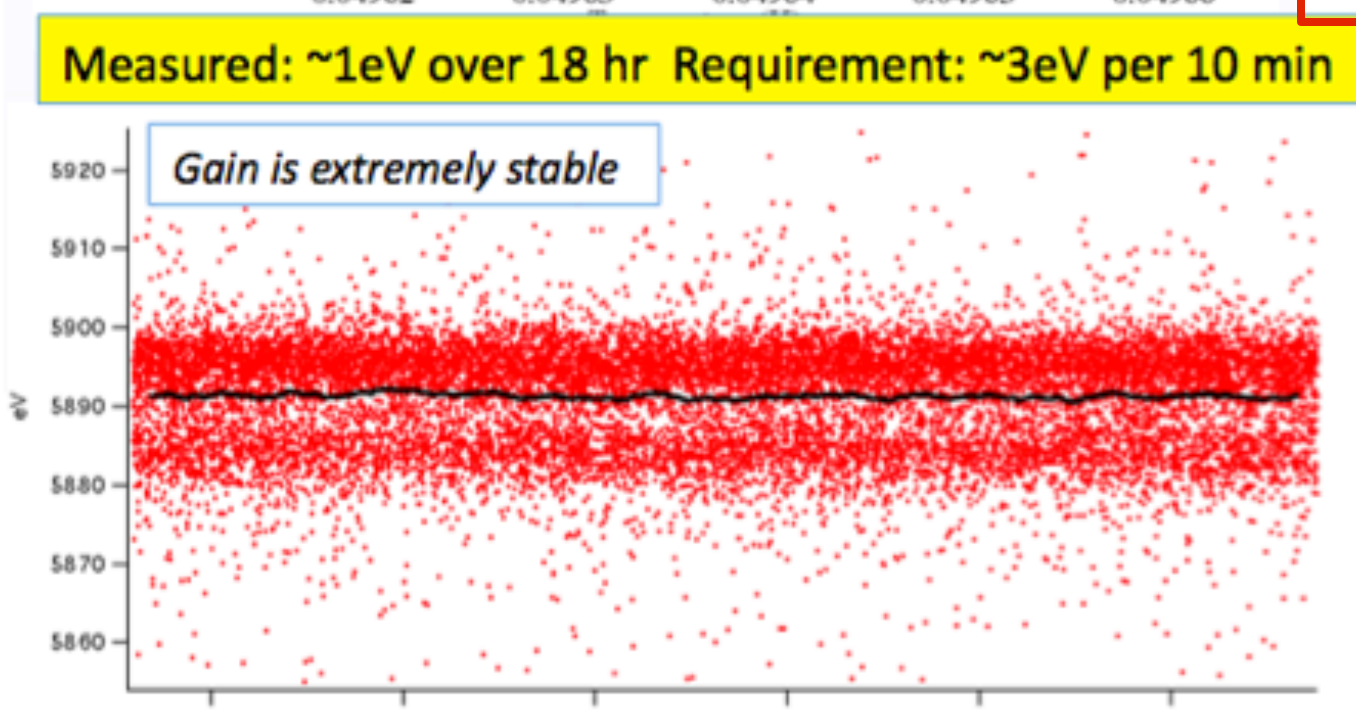


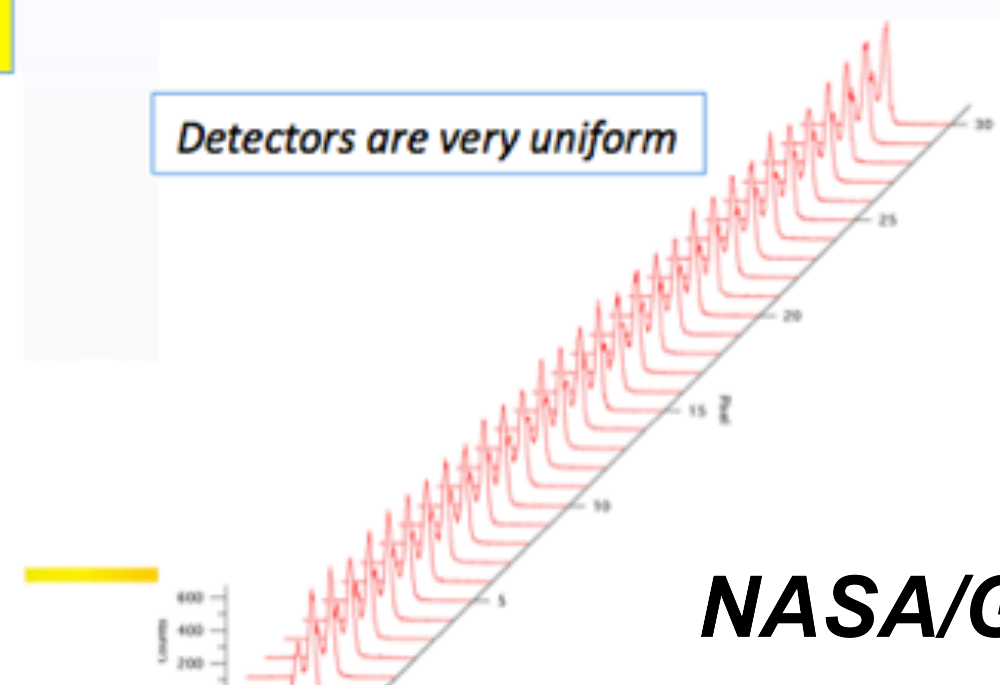
NASA/GSFC

Recent Results based on the Engineering Model of ASTRO-H





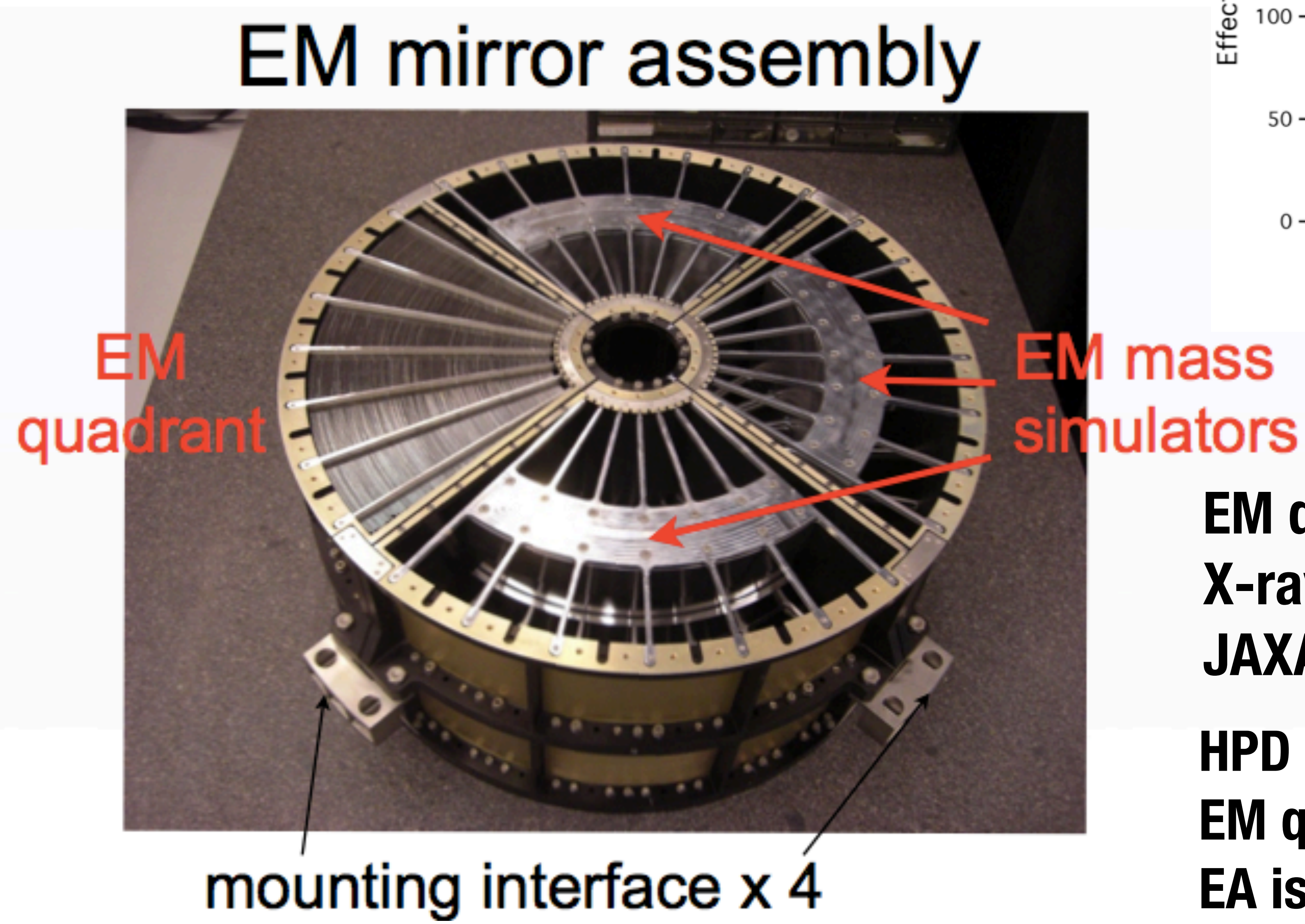


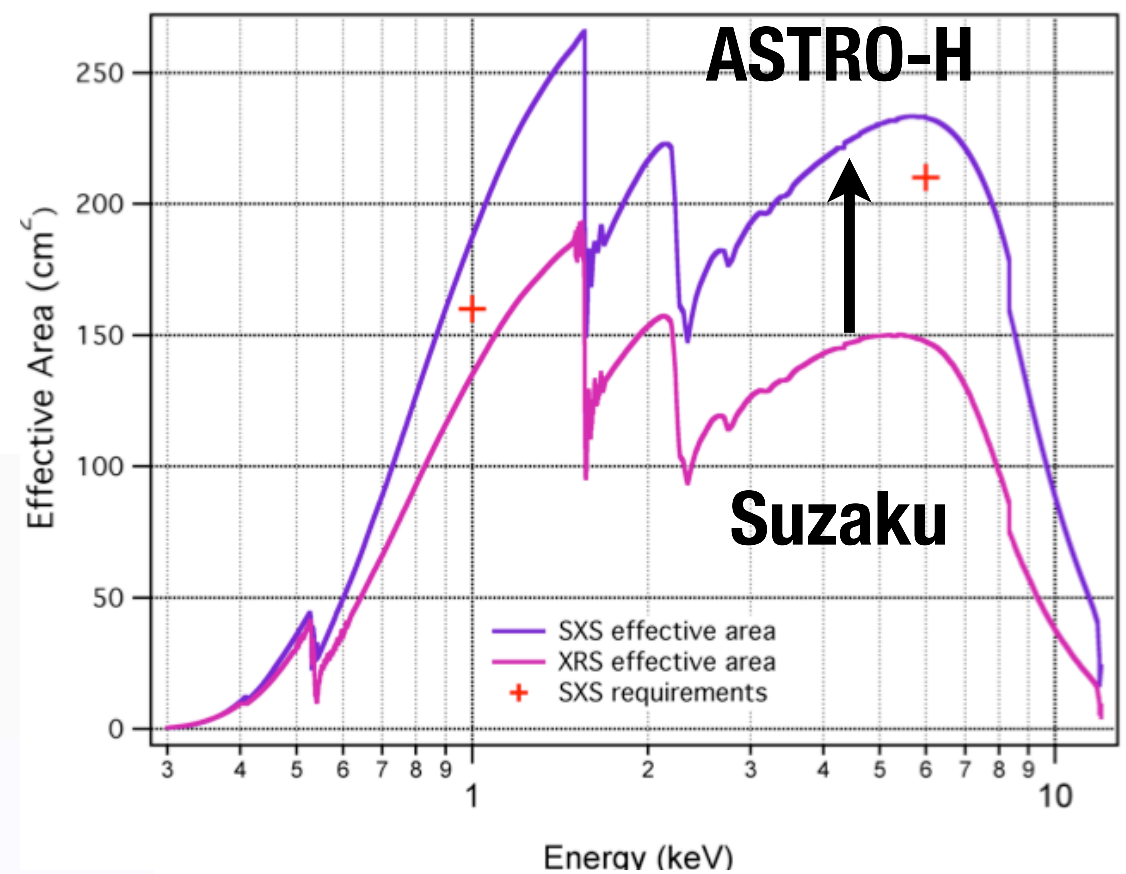


NASA/GSFC

3. ASTRO-H : Soft X-ray Telscope for SXS & SXI

Soft X-ray Telescope (SXT) is an upgraded version of the light-weighted X-ray telescope (XRT) onboard Suzaku. The diameter and focal length is larger, thus the effective area are increased.





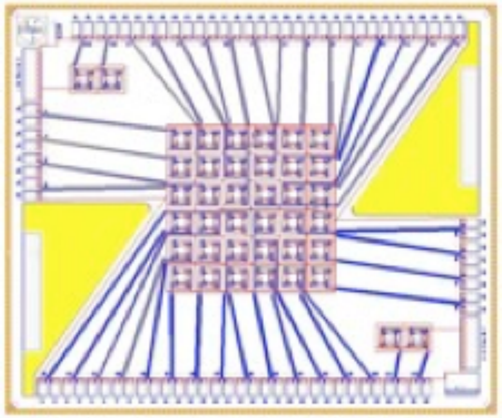
EM quadrant fully illuminated by X-rays at GSFC/NASA and ISAS/JAXA.

HPD ~ 1.2 arcmin is achieved from the EM quadrant (the requirement is 1.7’). EA is as large as 114 cm^2.

NASA/GSFC/MSFC/Nagoya/ISAS

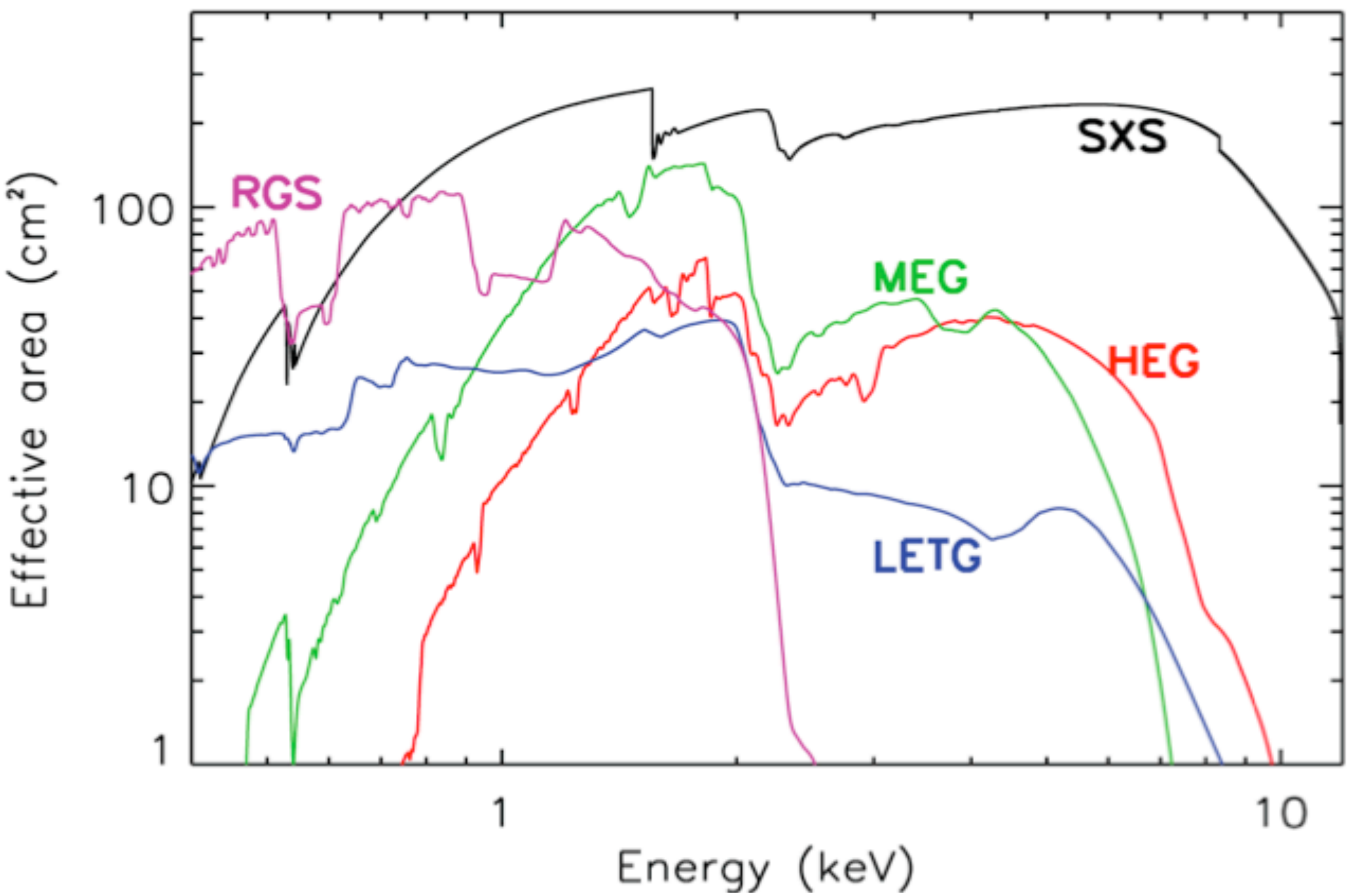
3. ASTRO-H: Large effective area of SXS

- High Resolution Spectroscopy with a large effective area



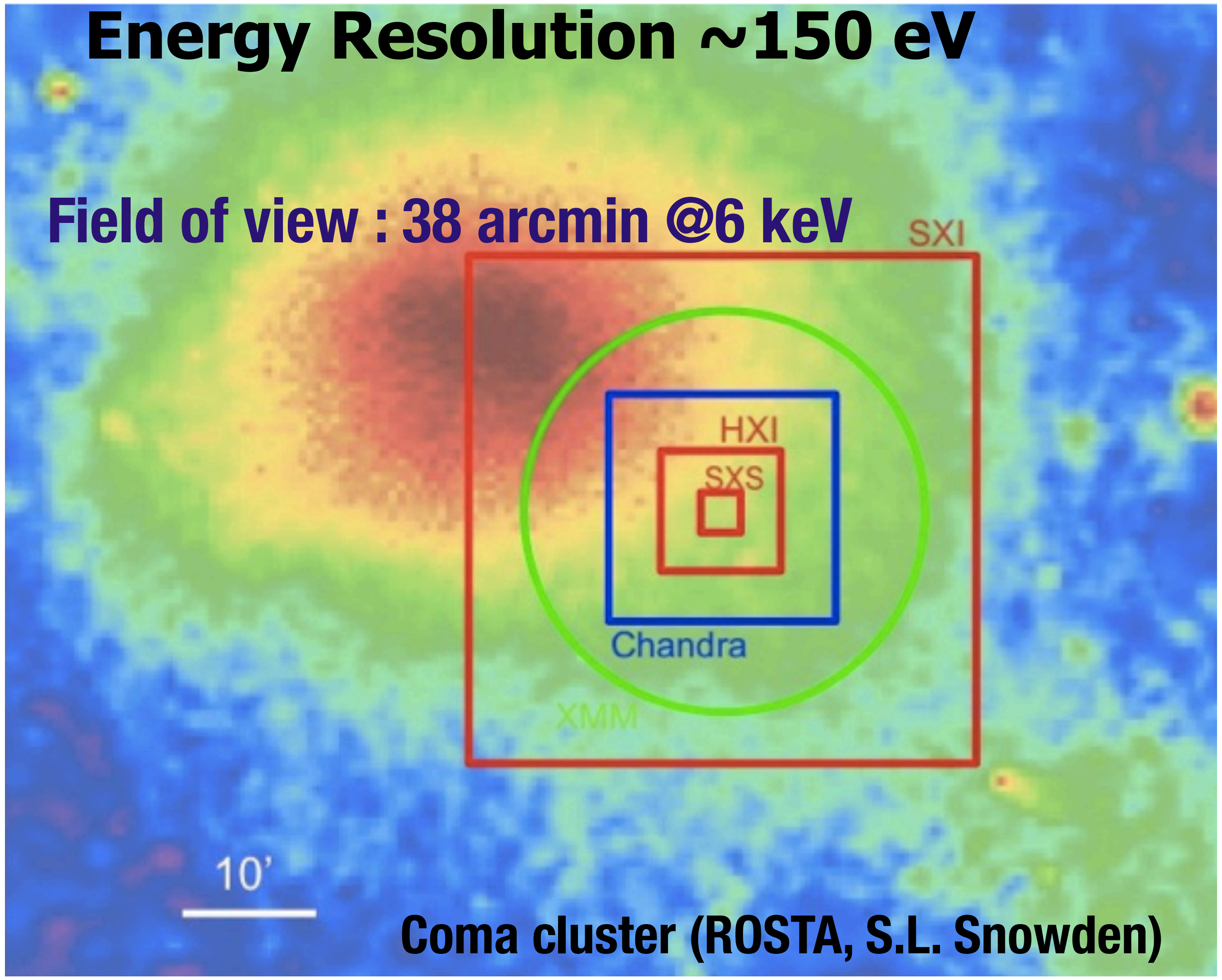
814 μm
6x6 array
34 pixel readout
50 mK

210cm^2@6keV

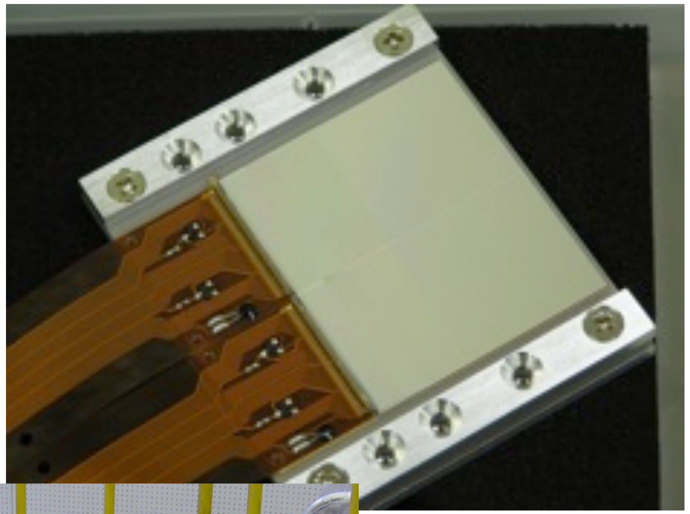


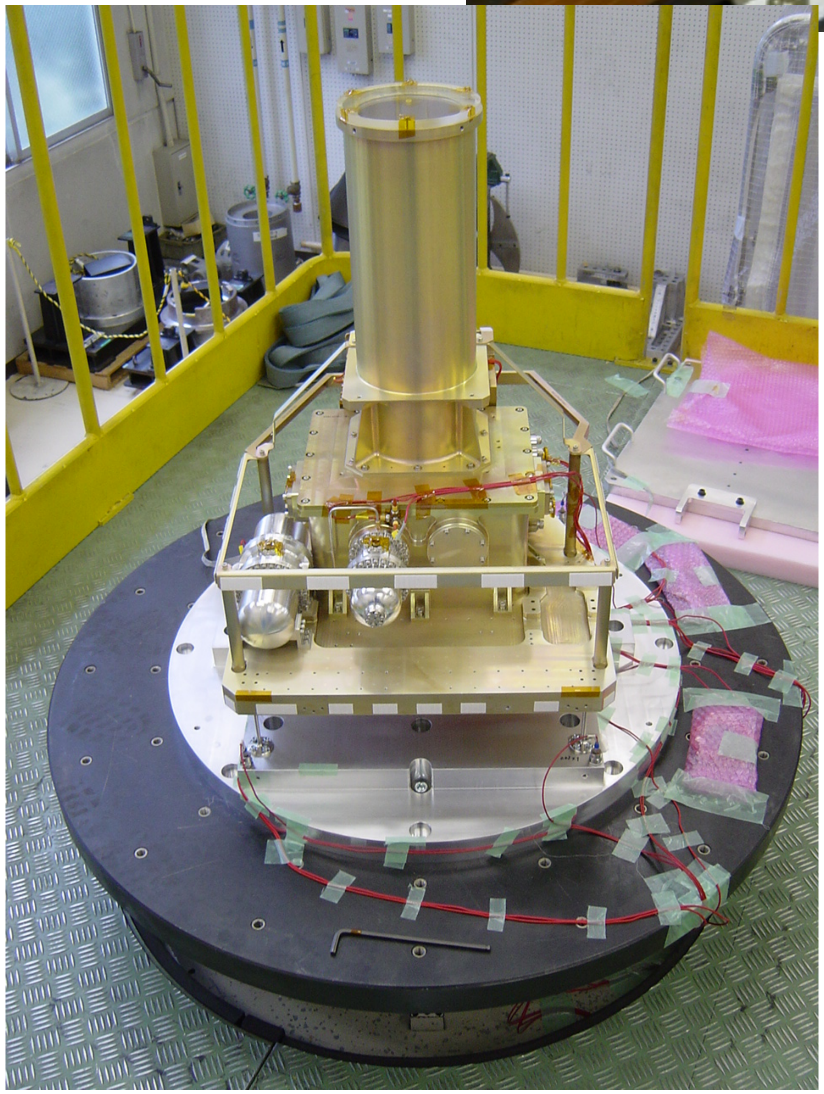
3. ASTRO-H : Large field coverage of SXI

Large FOV X-ray CCD (F.L. 5.6 m)



4CCD chips/62x62mm^2
Depletion Layer ~200 micron

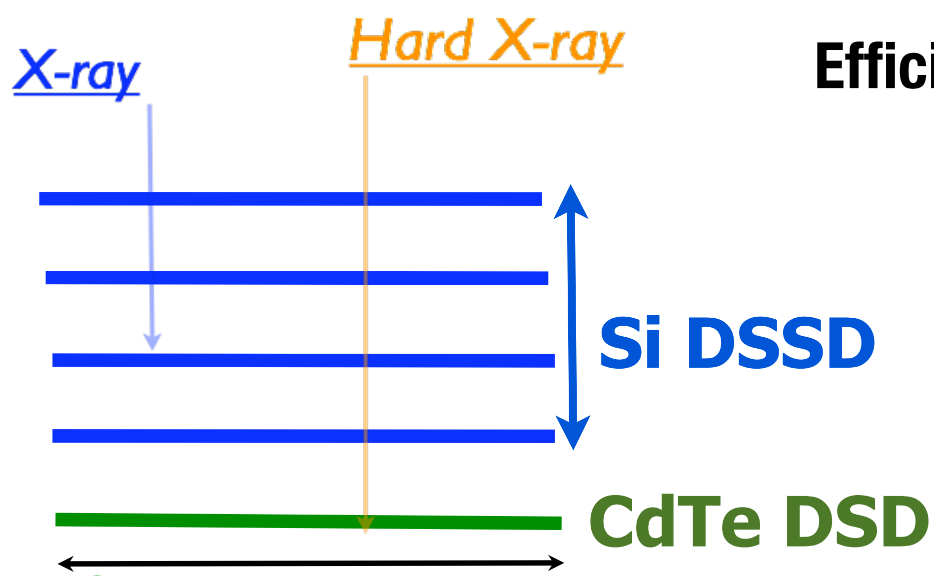




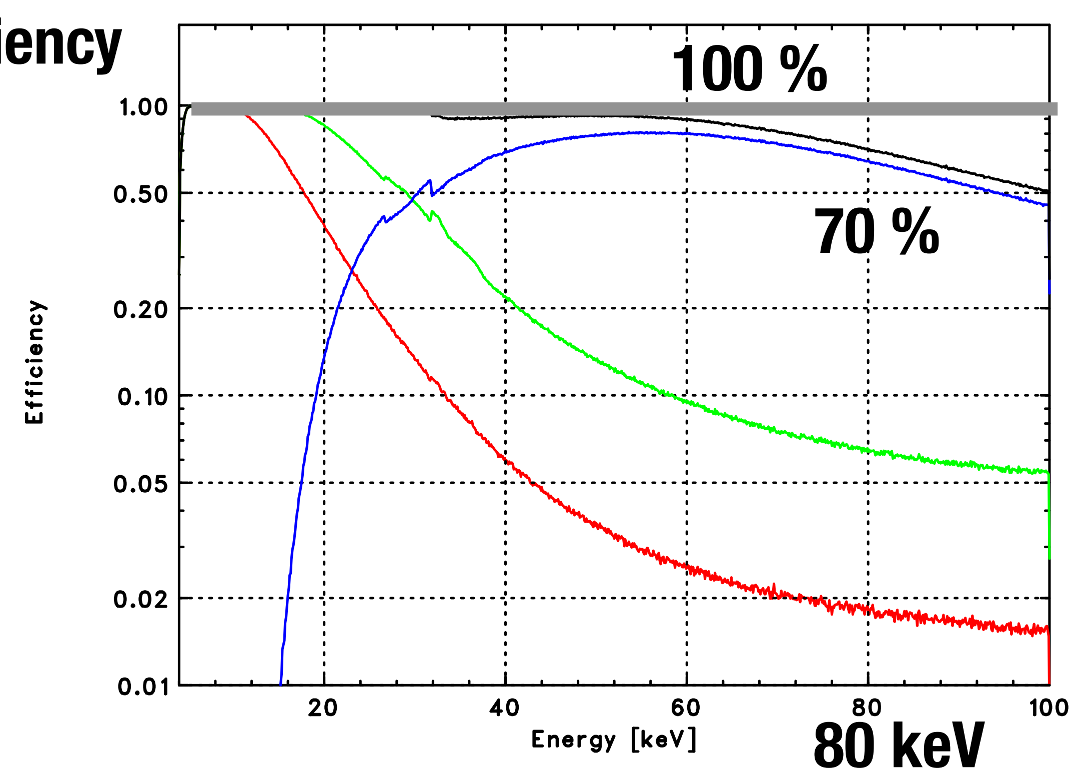
Recent Progress
EM Model/
Thermal Balance Test
(2011/June)

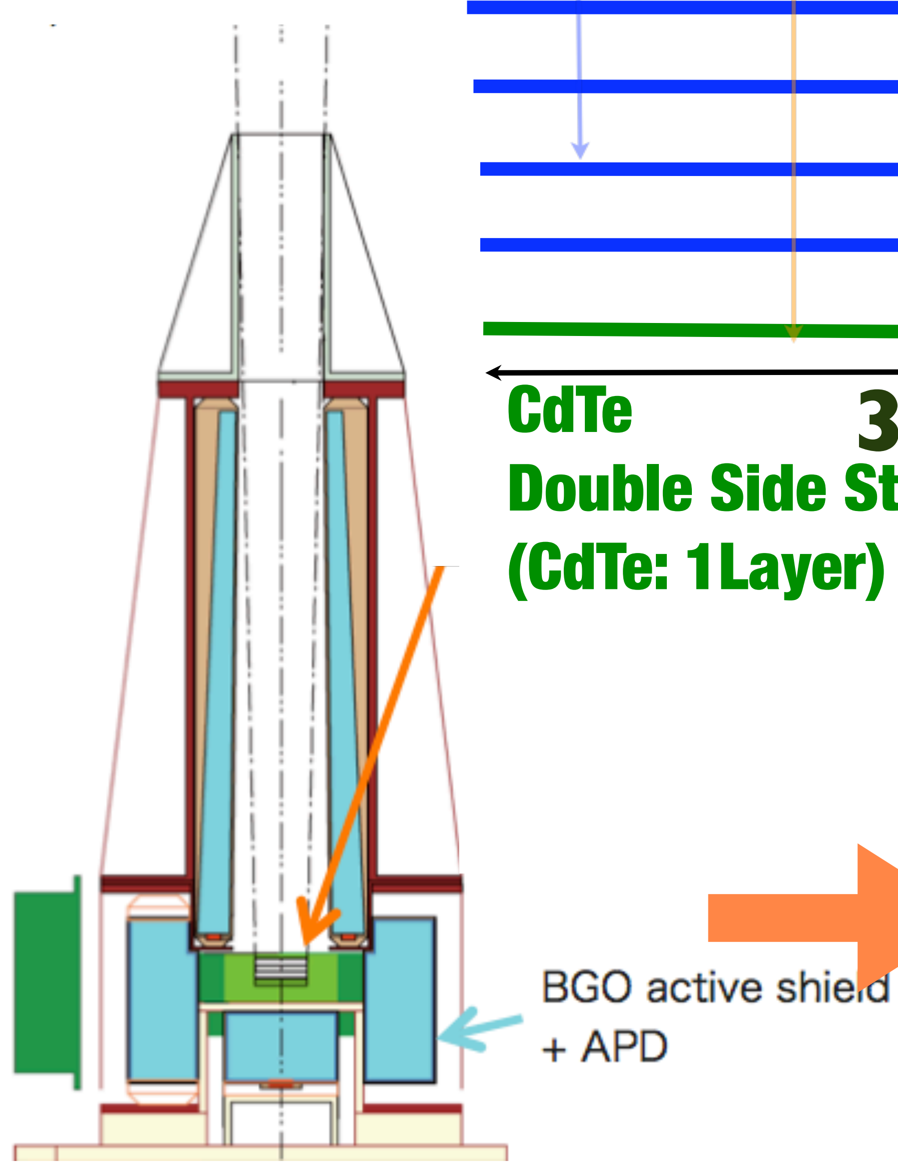
3. ASTRO-H : Low-bgd Hard X-ray imaging of HXI

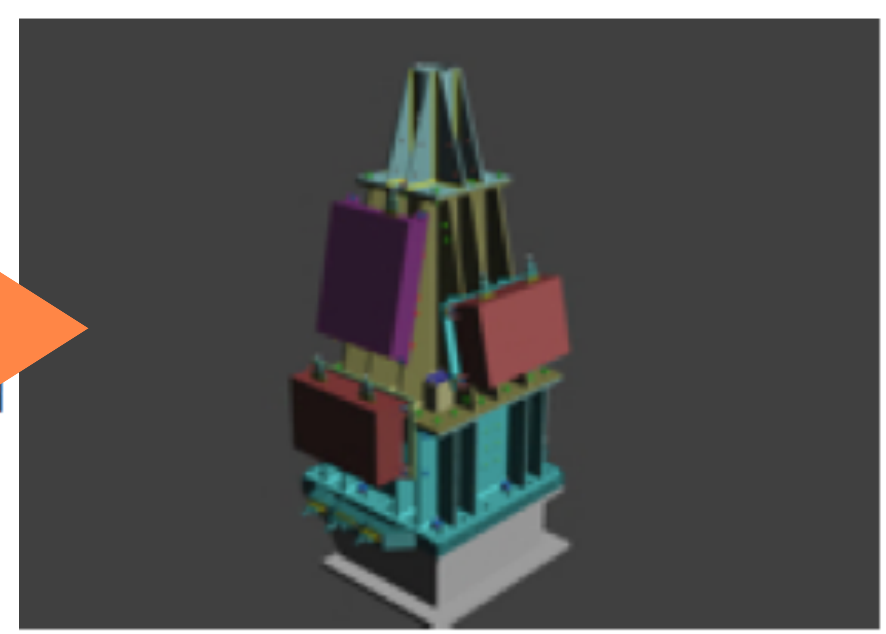
Si and CdTe Hybrid Imager (5 - 80 keV):
Soft X-ray photons below < 20 keV are absorbed in the Si part (DSSD), while hard X-ray photons go through the Si part and are detected by the newly developed CdTe double sided cross-strip detector



CdTe
Double Side Strip
(CdTe: 1Layer)



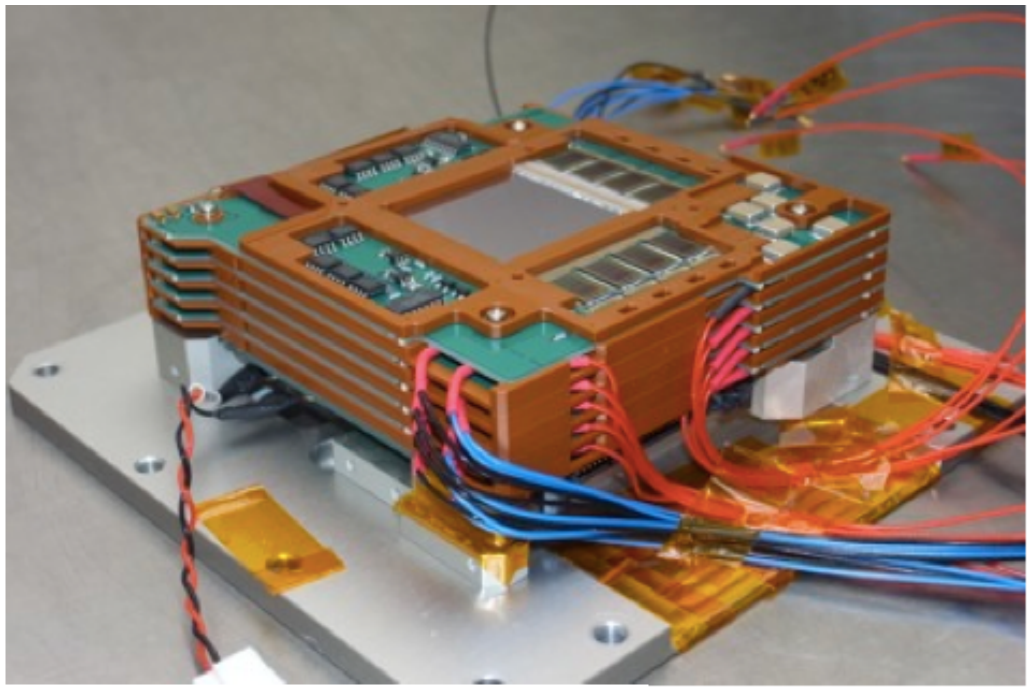


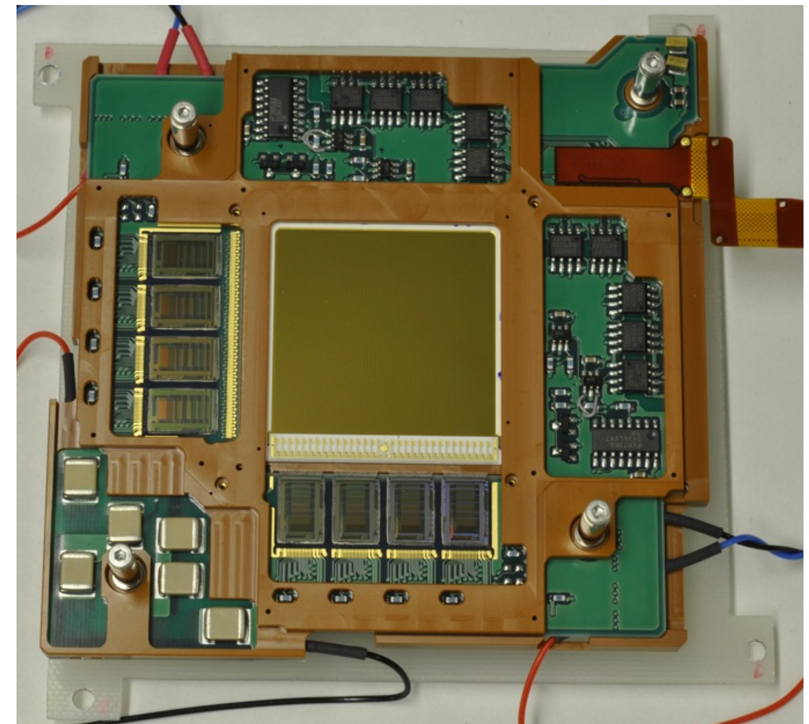


Stacked Si/CdTe Detector"
and
"Well-type BGO shield"
will reduce background

3. ASTRO-H : Engineering model of HXI

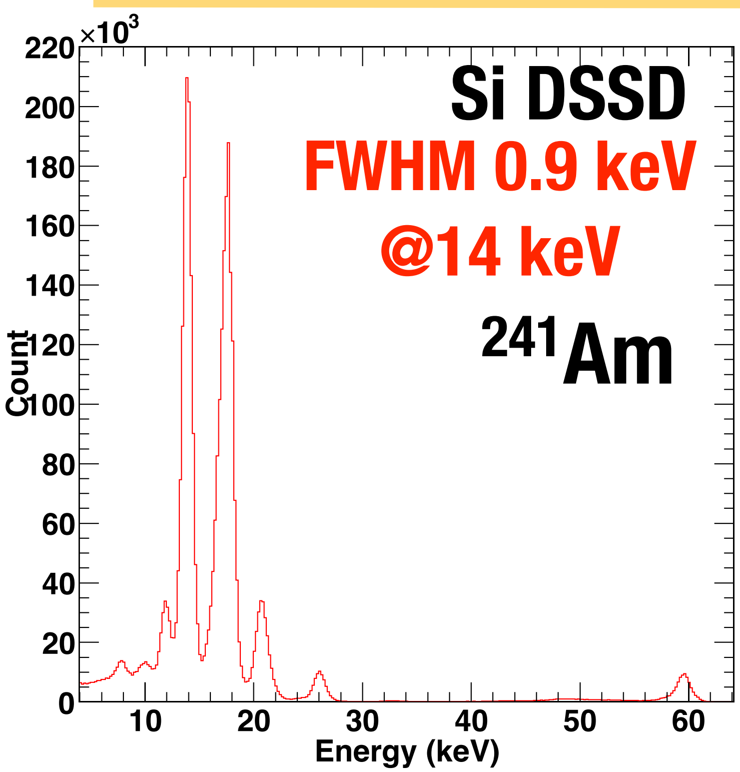
Engineering Model
4 layer of Si DSSD and 1 layer of CdTe DSD

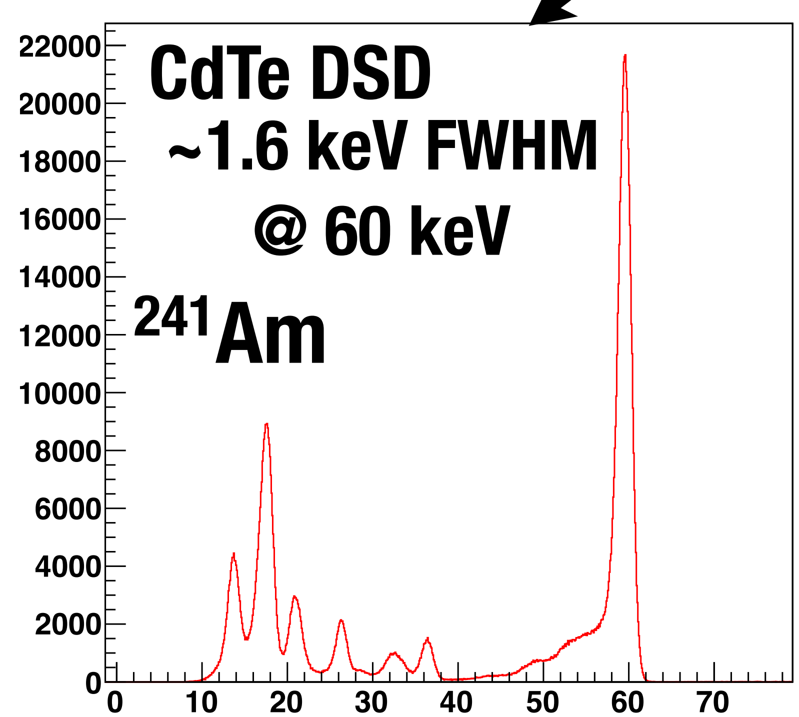


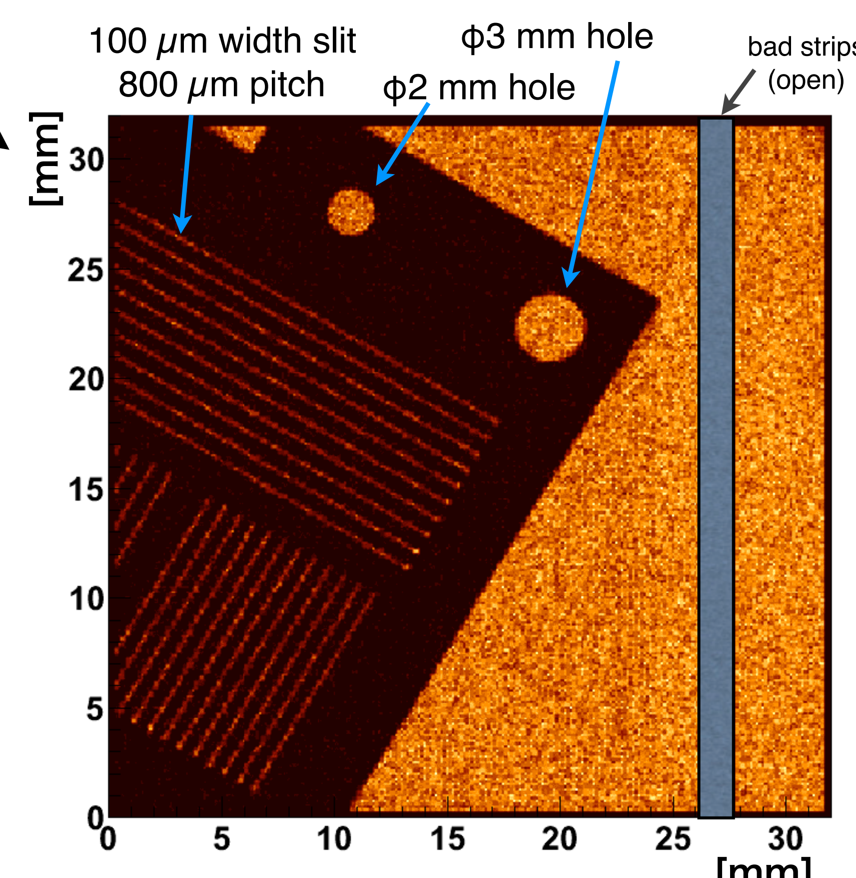


CdTe DSD (ISAS)

250 micron pitch strips for both side



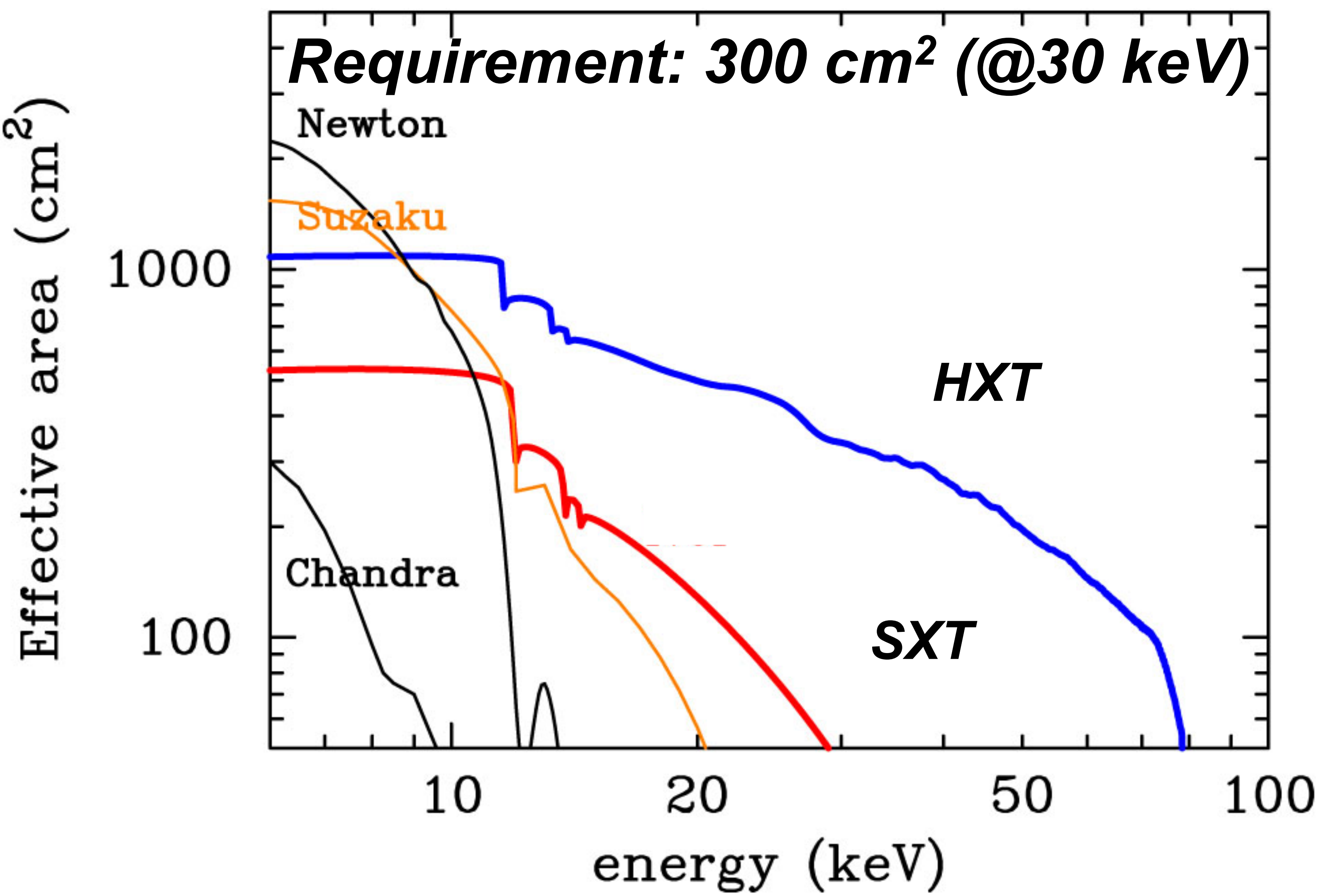


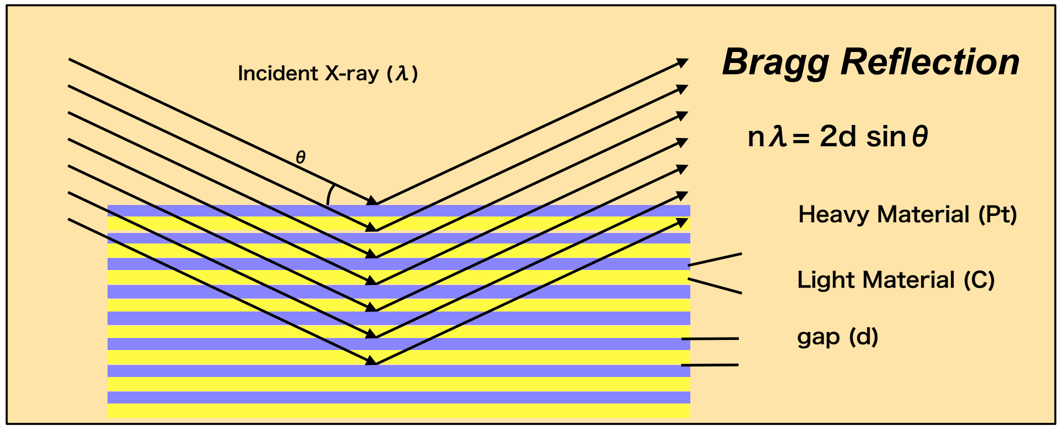


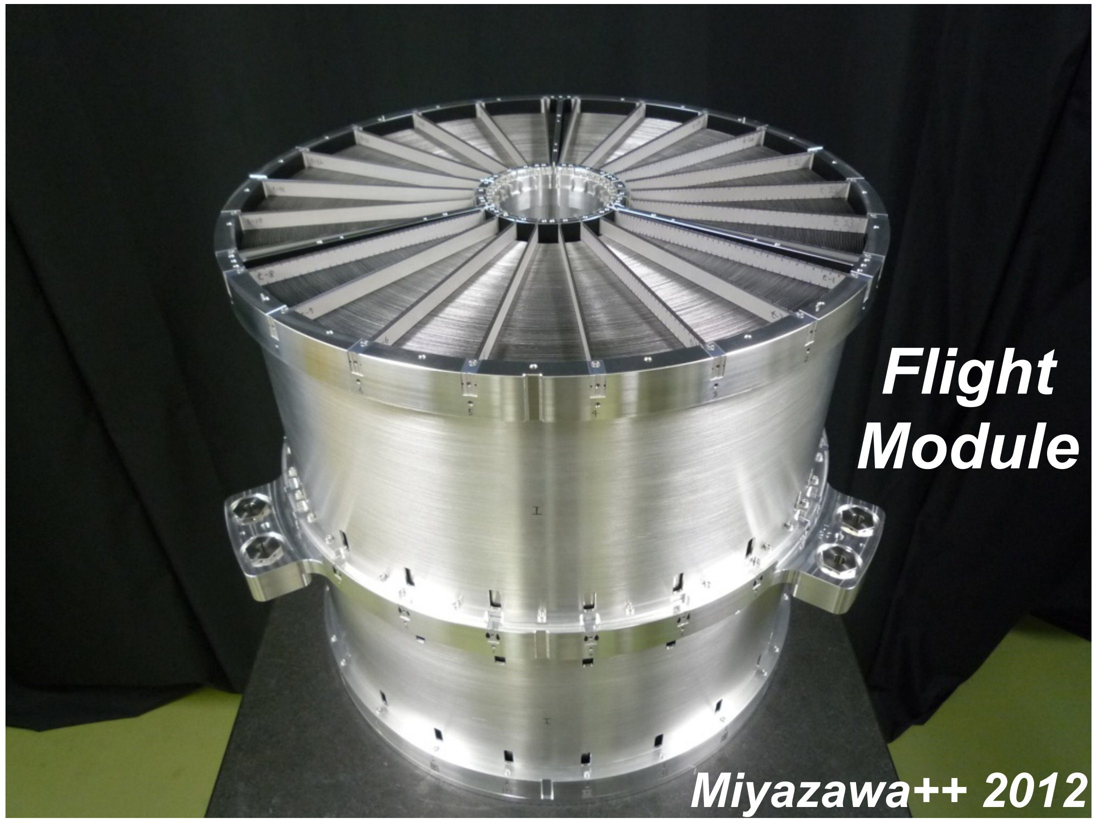
CdTe DSD

3. ASTRO-H : Hard X-ray Telescope (HXT) for HXI

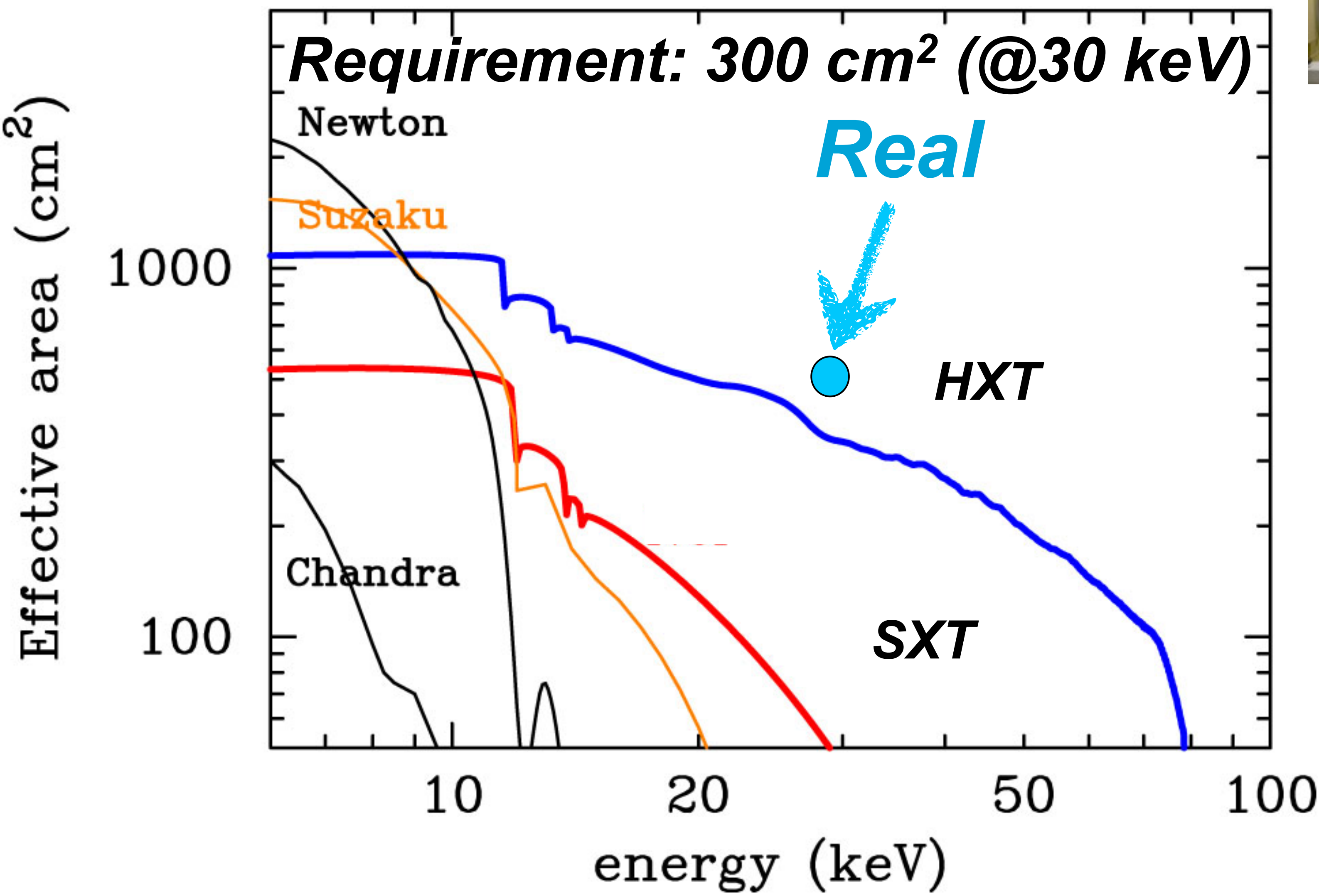
- **Pt/C depth-graded multilayer X-ray telescope**
- **Large photon collecting area above 10 keV.**

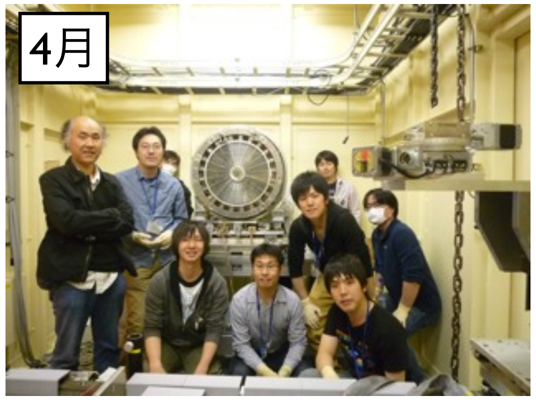


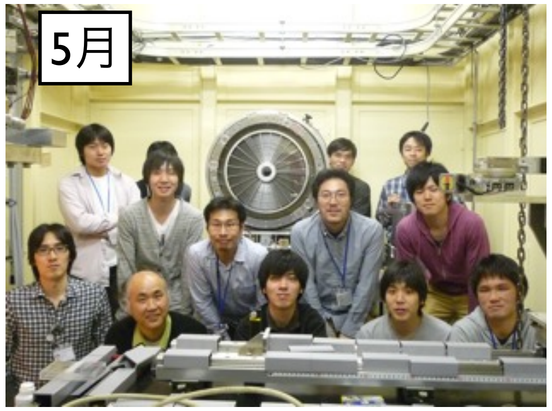


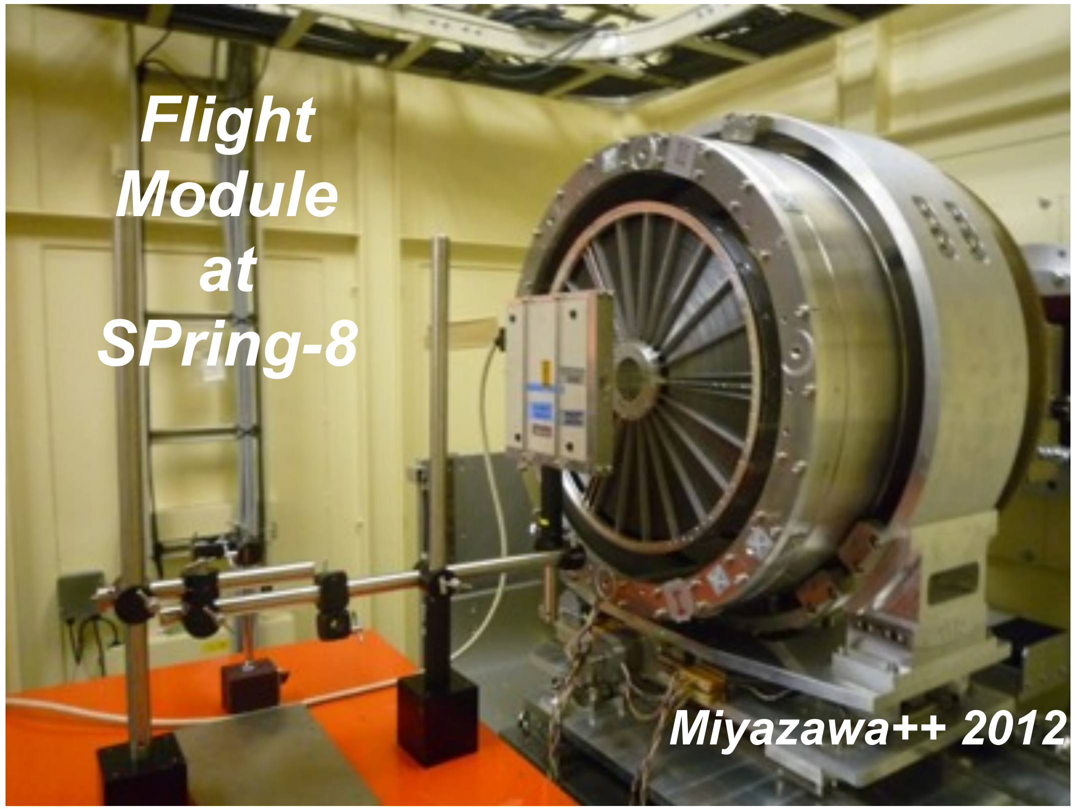


- **Careful Calibration using SPring-8 Hard X-ray Beam line is going on.**

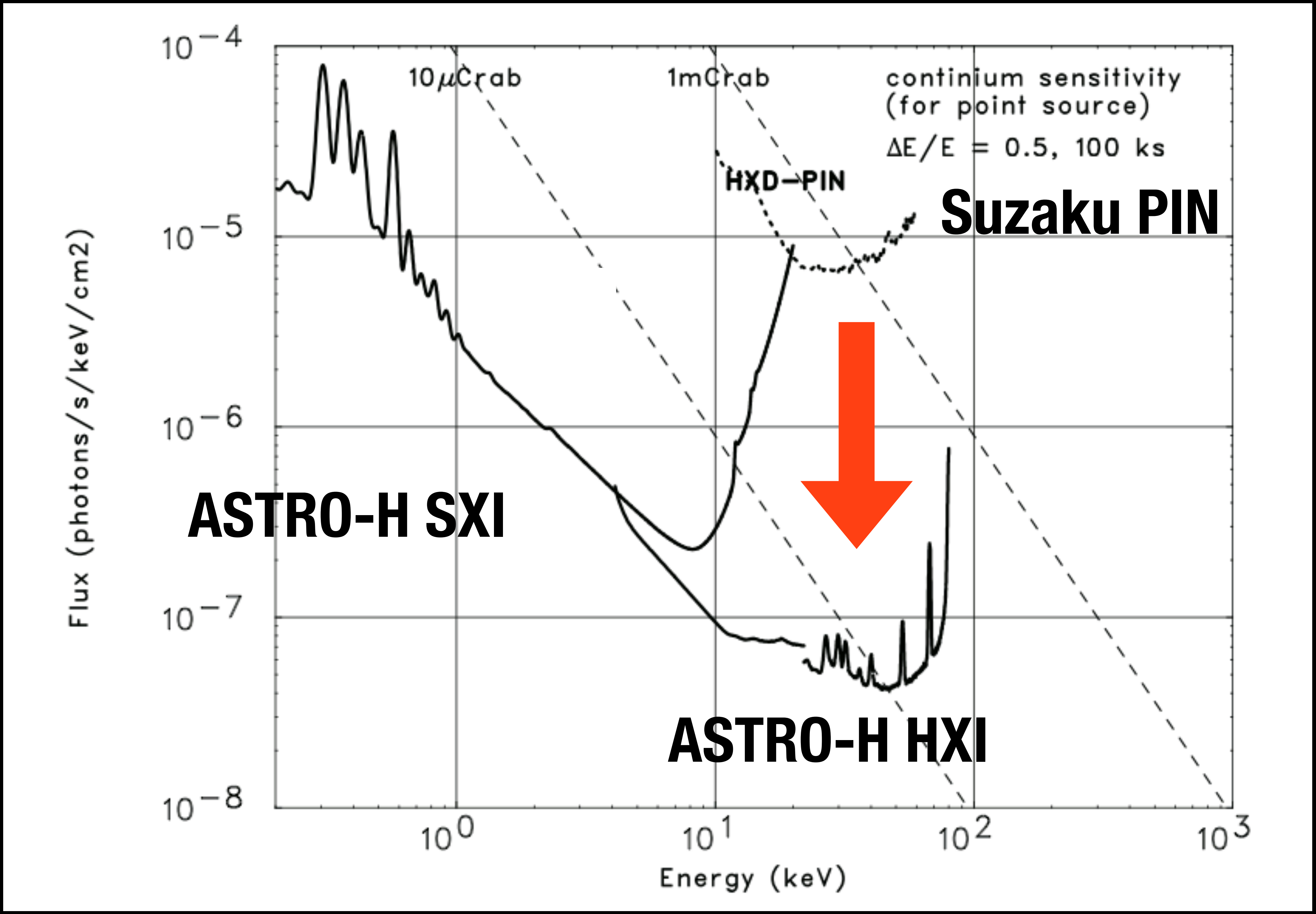








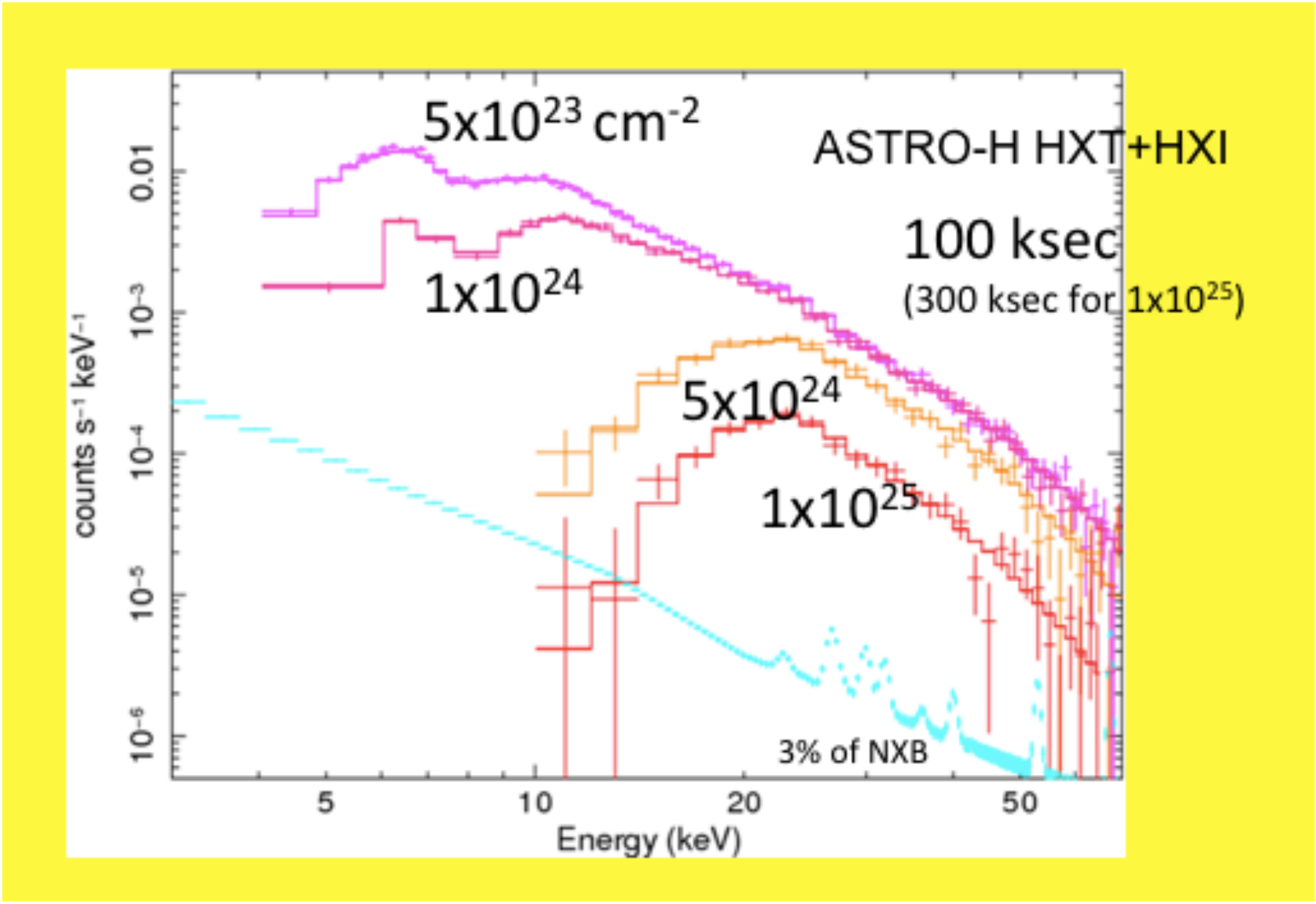
Detection limit of SXI/HXI system

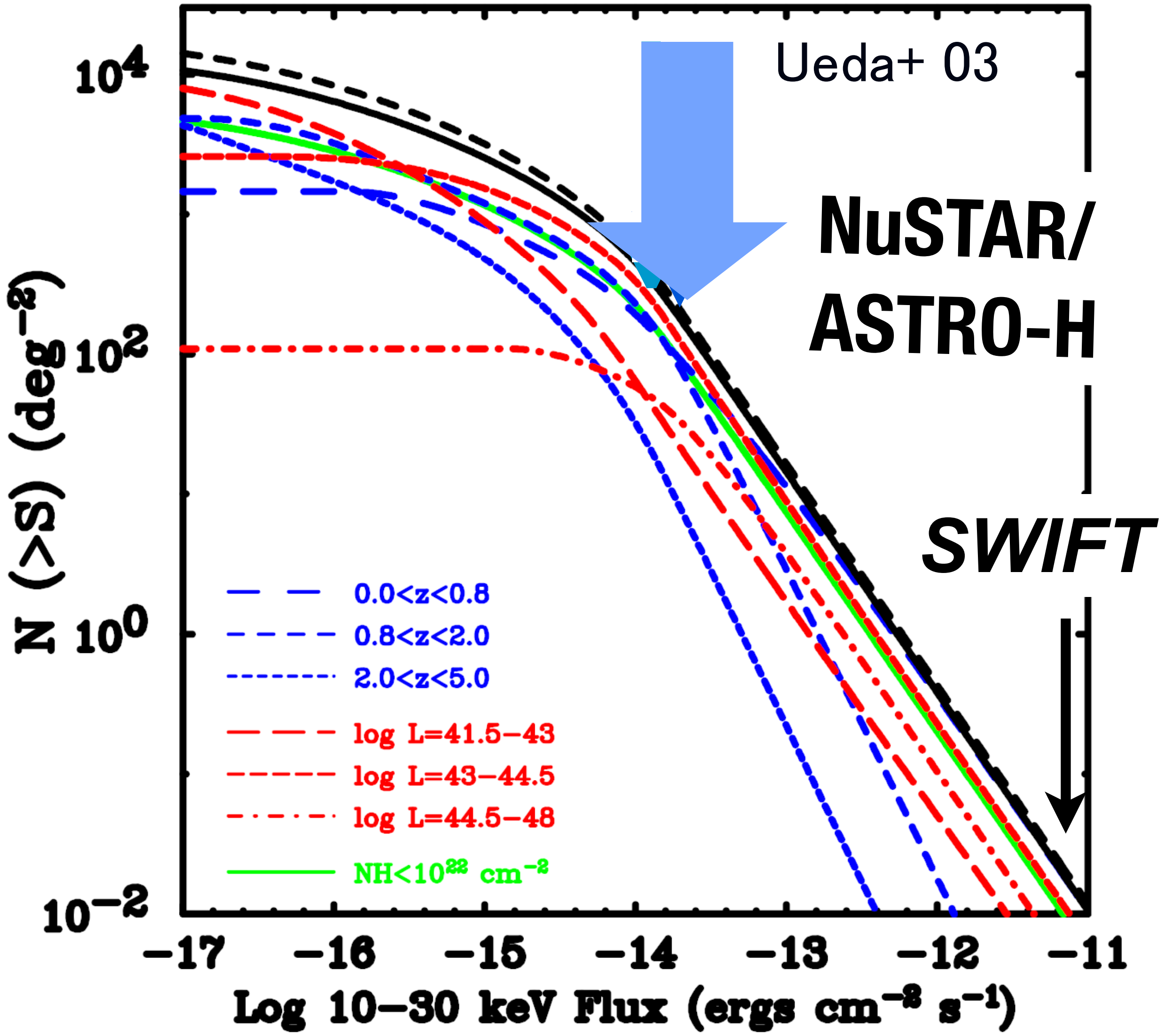


3. ASTRO-H: Cosmic X-ray Background in the HXI era

Imaging with hard X-ray optics will enable us to observe at x100 times higher sensitivity than Suzaku. 30-50% of the cosmic X-ray background will be resolved into hidden super-massive black holes.

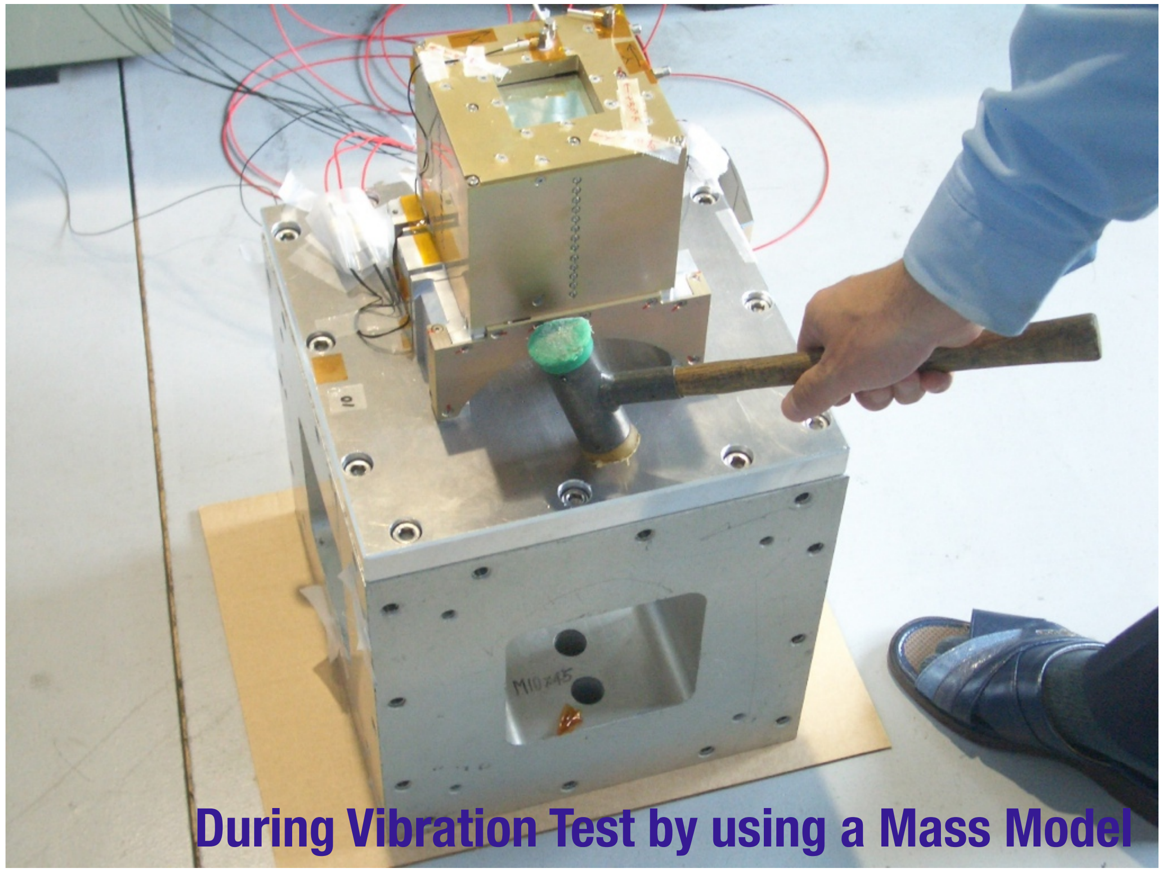
30-50% of Hard XRB will be resolved

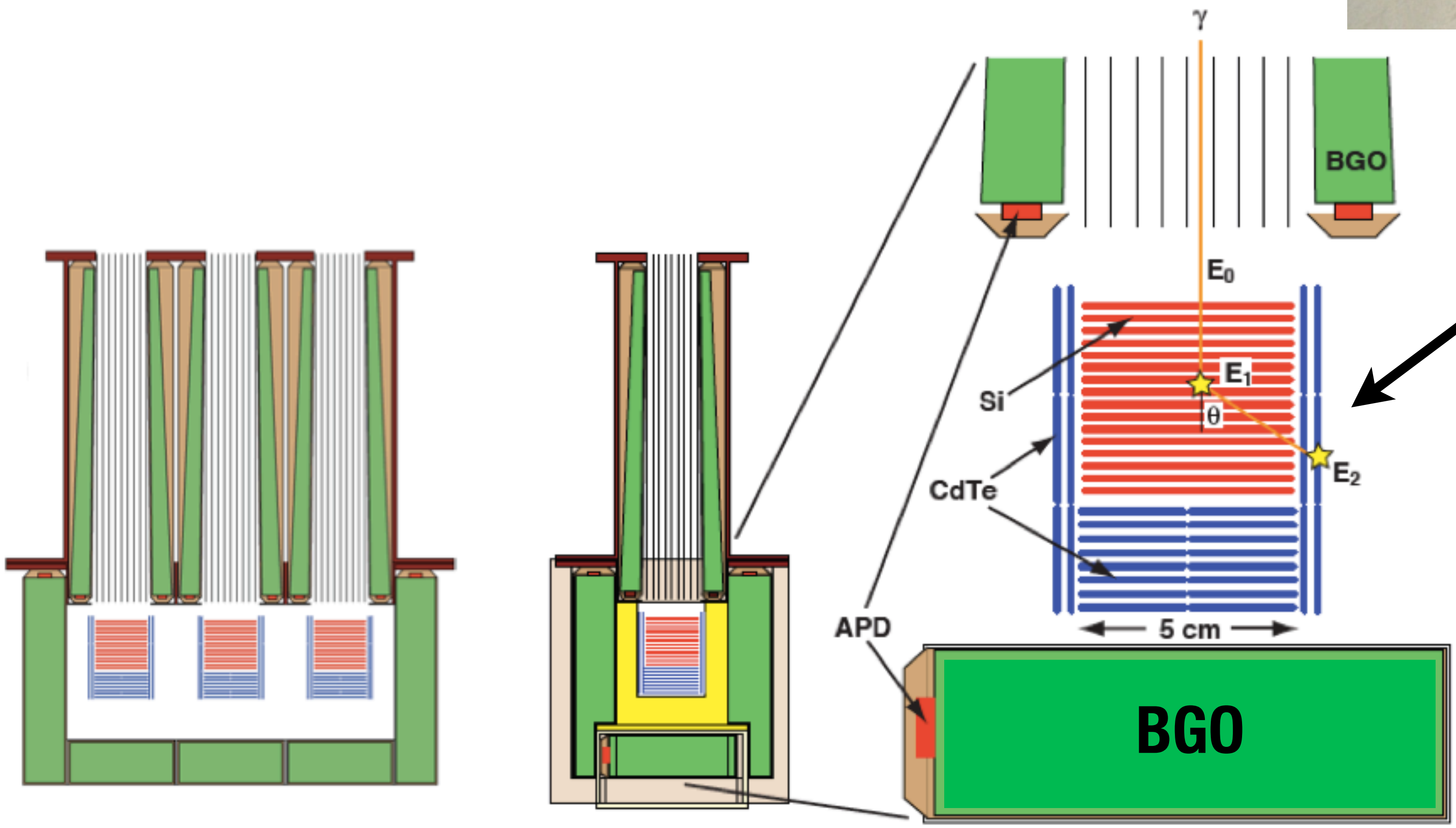




3. ASTRO-H: Soft Gamma-ray Detector (SGD)

- Si/CdTe Compton Gamma Camera and Well-type shield to achieve ultimately low background.
  (40 - 600 keV)
- The Compton Camera enables us to measure polarization >60 keV.
- GRB Monitoring using BGO shield.



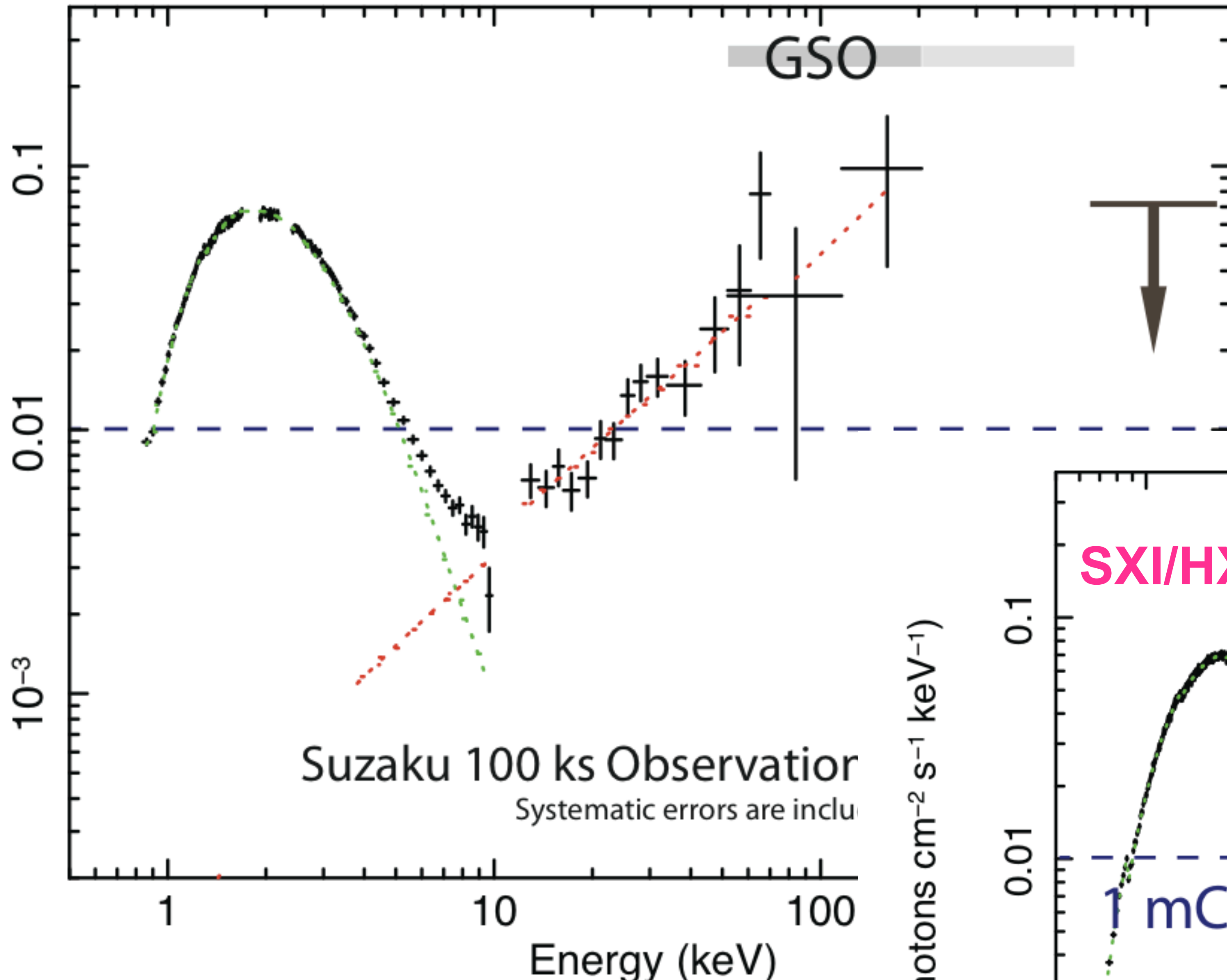


Si/CdTe Compton Camera (only select gamma-rays from the FOV)

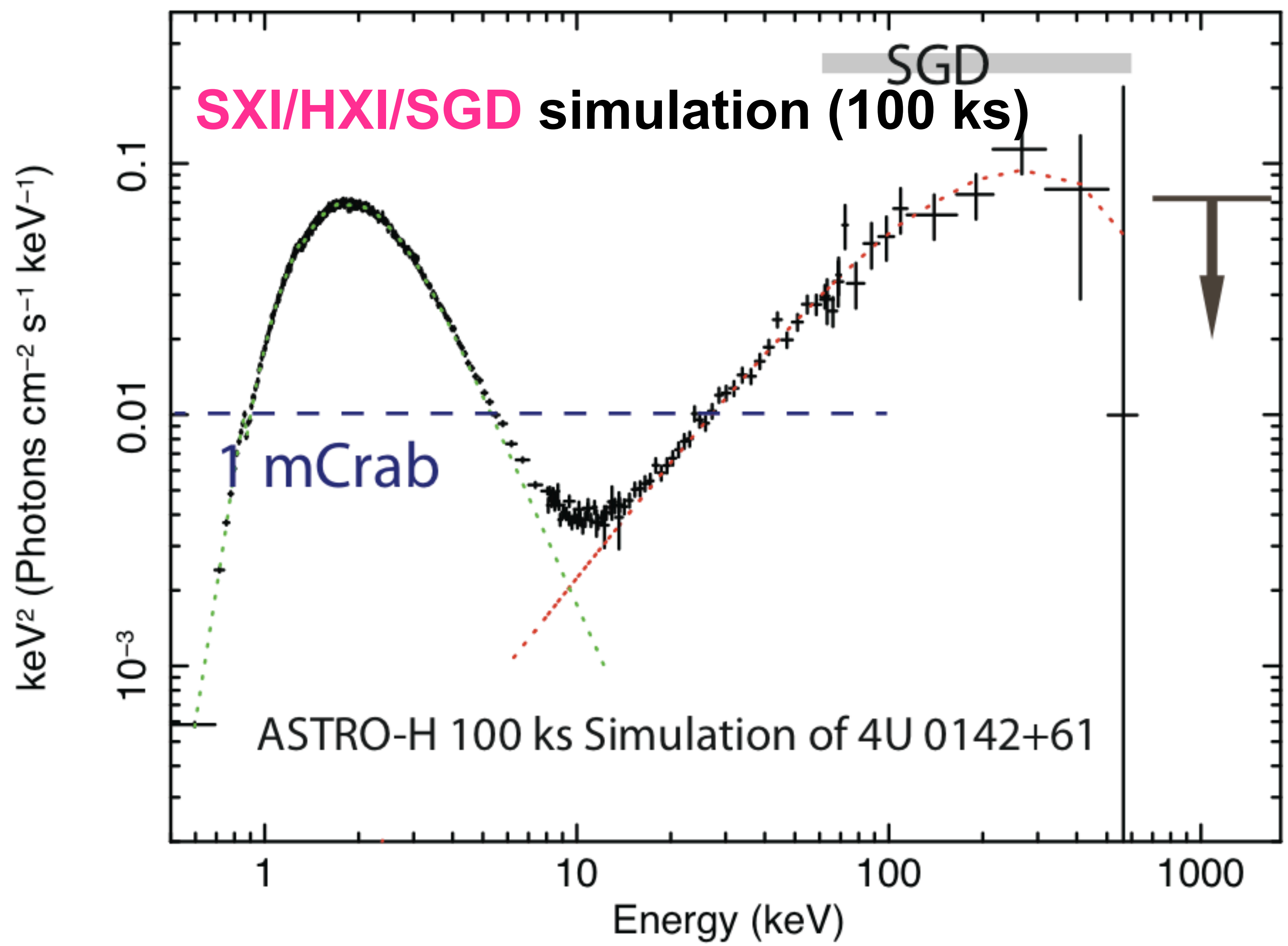
Compton Kinematics

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

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



SGD will be able to measure spectra up to 600 keV with higher quality, and will constrain the nature of the hard component.



Magnetor 4U 0142+61

(Simulation by T. Enoto)

4. ASTRO-H Science : Cluster of Galaxies

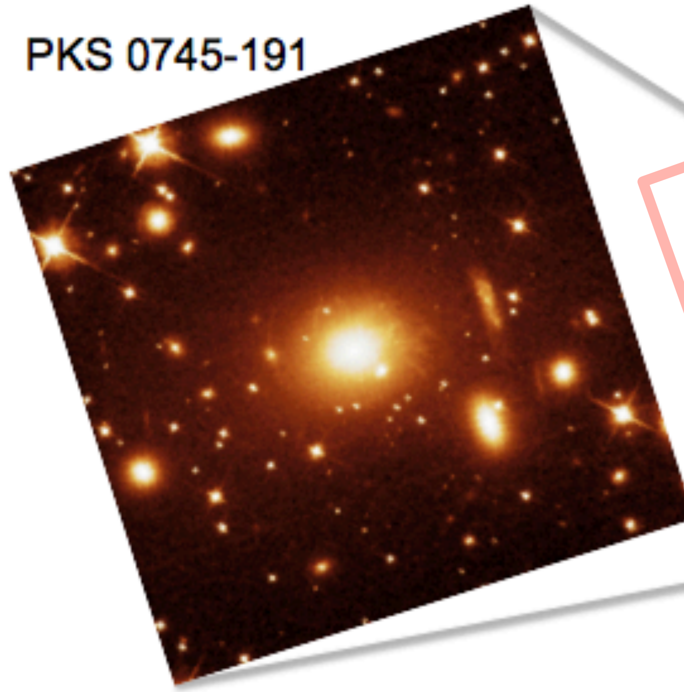
Cluster of Galaxies

Dynamics
(Turbulance, Collisions)

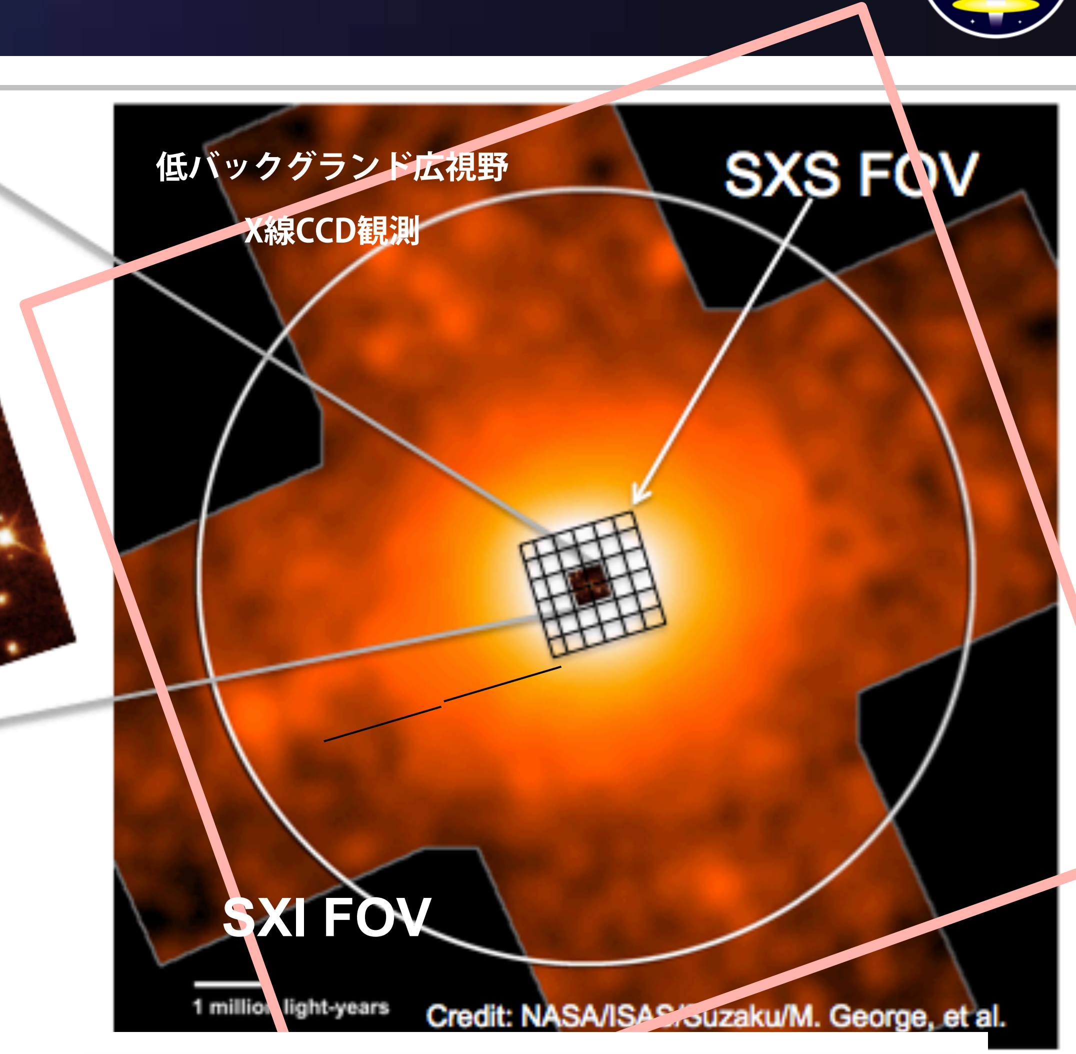
Non-thermal Emission
Cluster Outskirt
(Site of Sturcture Formation)

Temperature Map
Heavy Metal Distribution

PKS 0745-191



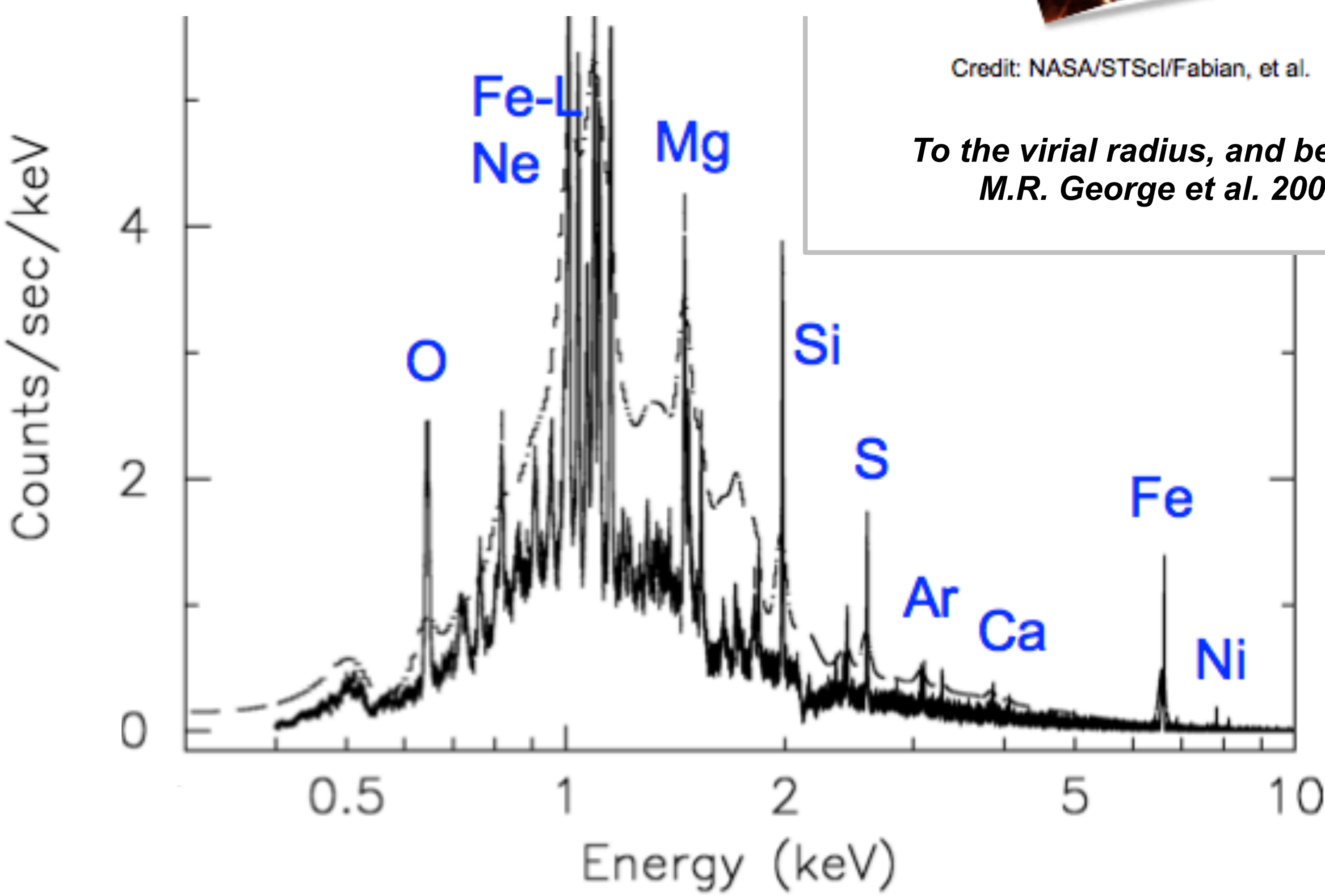
Credit: NASA/STScI/Fabian, et al.

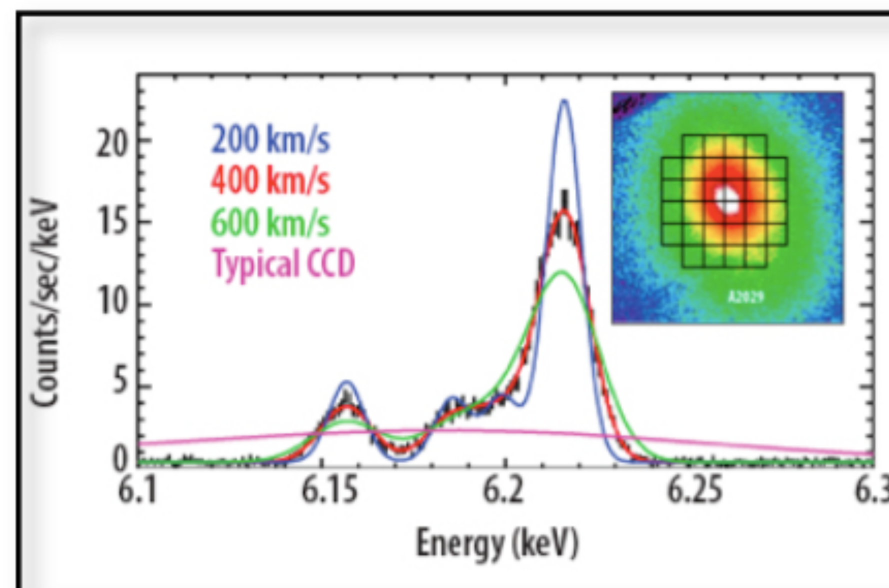


Credit: NASA/ISAS/Suzaku/M. George, et al.

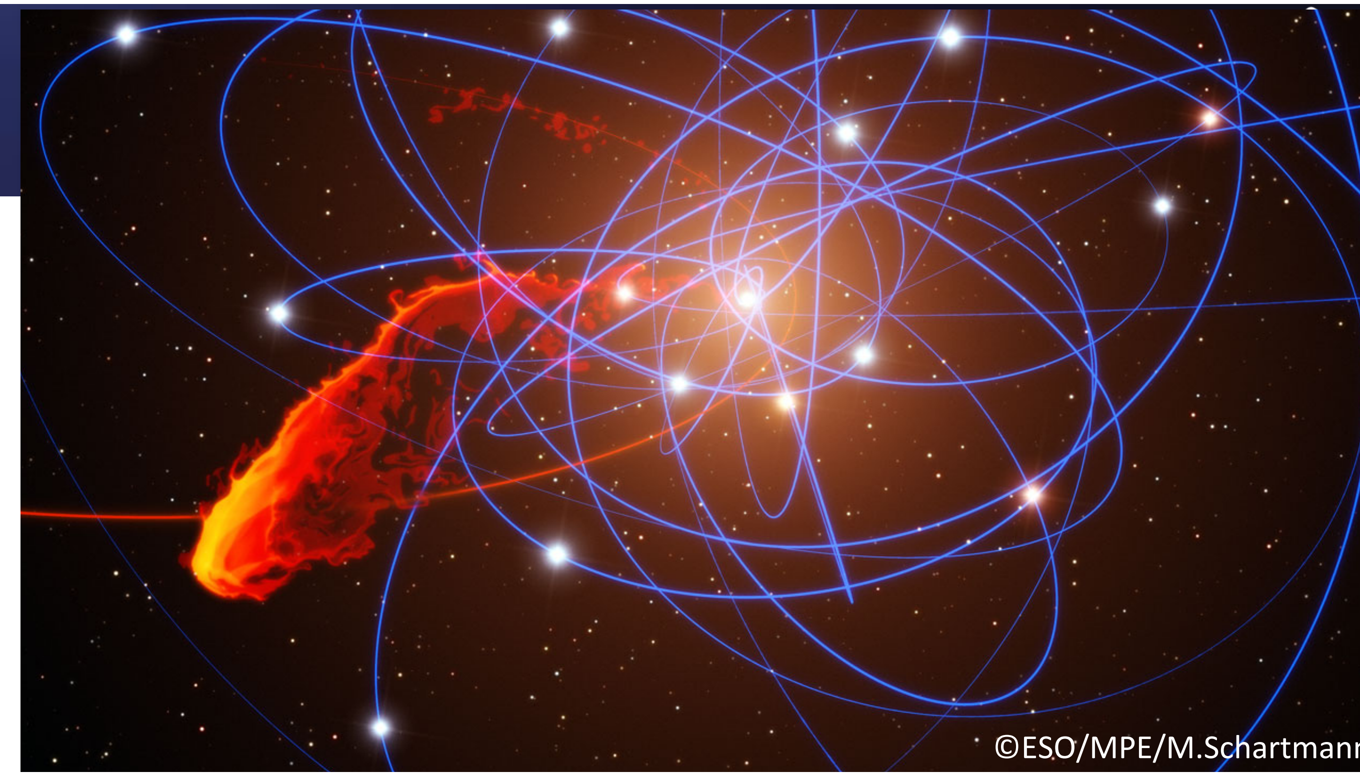
To the virial radius, and beyond
M.R. George et al. 2009

Simulation of Centaurus Cluster





Astro-H will detect bulk velocity flow as small as 300 km/s in the brightest 30 clusters with T > 60 x 10^6 K (kT > 5 keV.)



Sgr A*

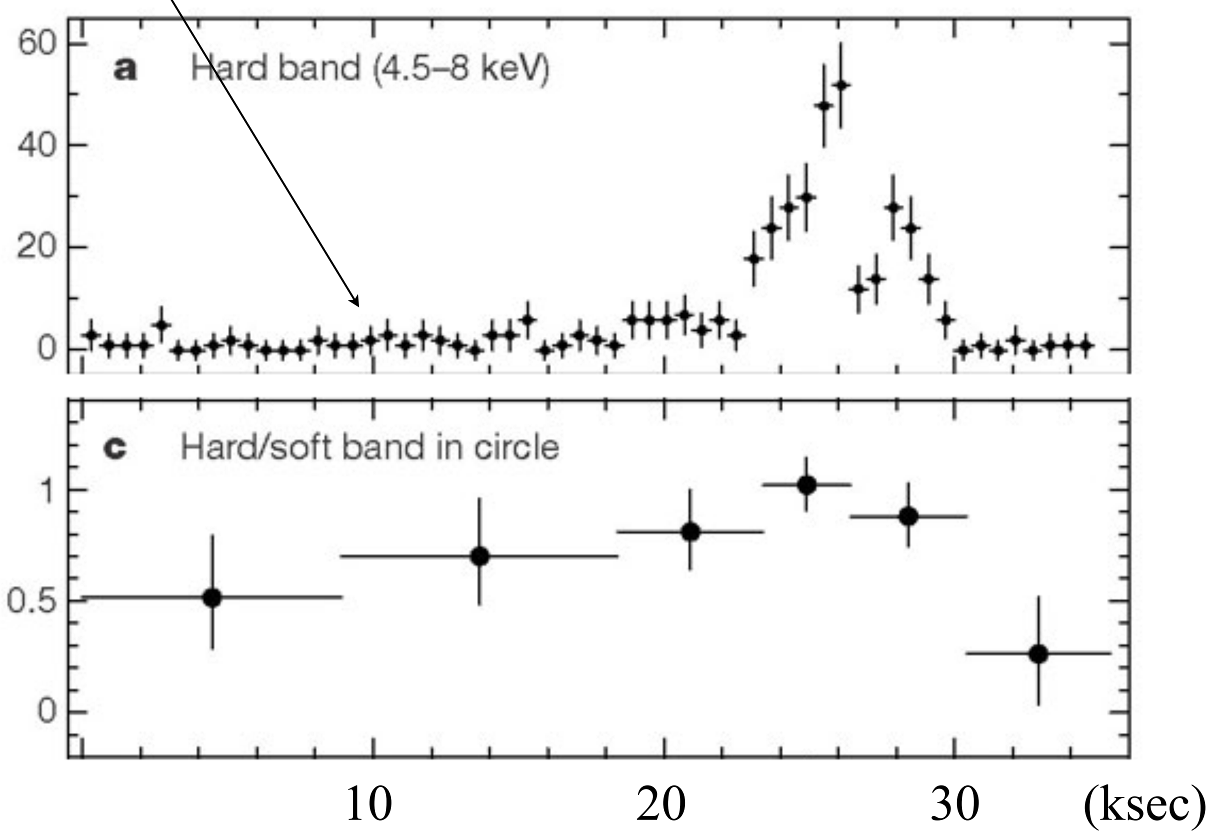
Years after 2014 are the age when Sgr A* might be a monster phase.

Baganoff et al. 2001

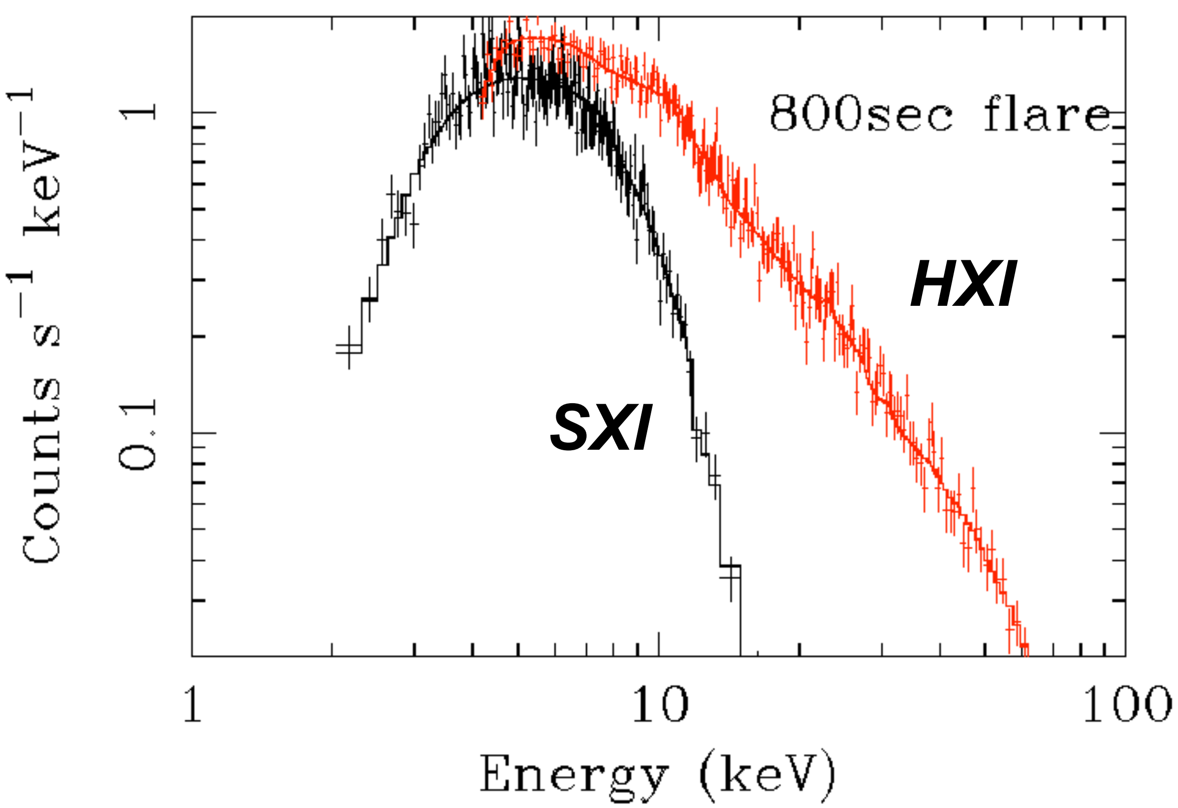
$Lx = 10^{33}$ erg s^{-1}

X-ray Flare

$Lx = 10^{35}$ erg s^{-1}

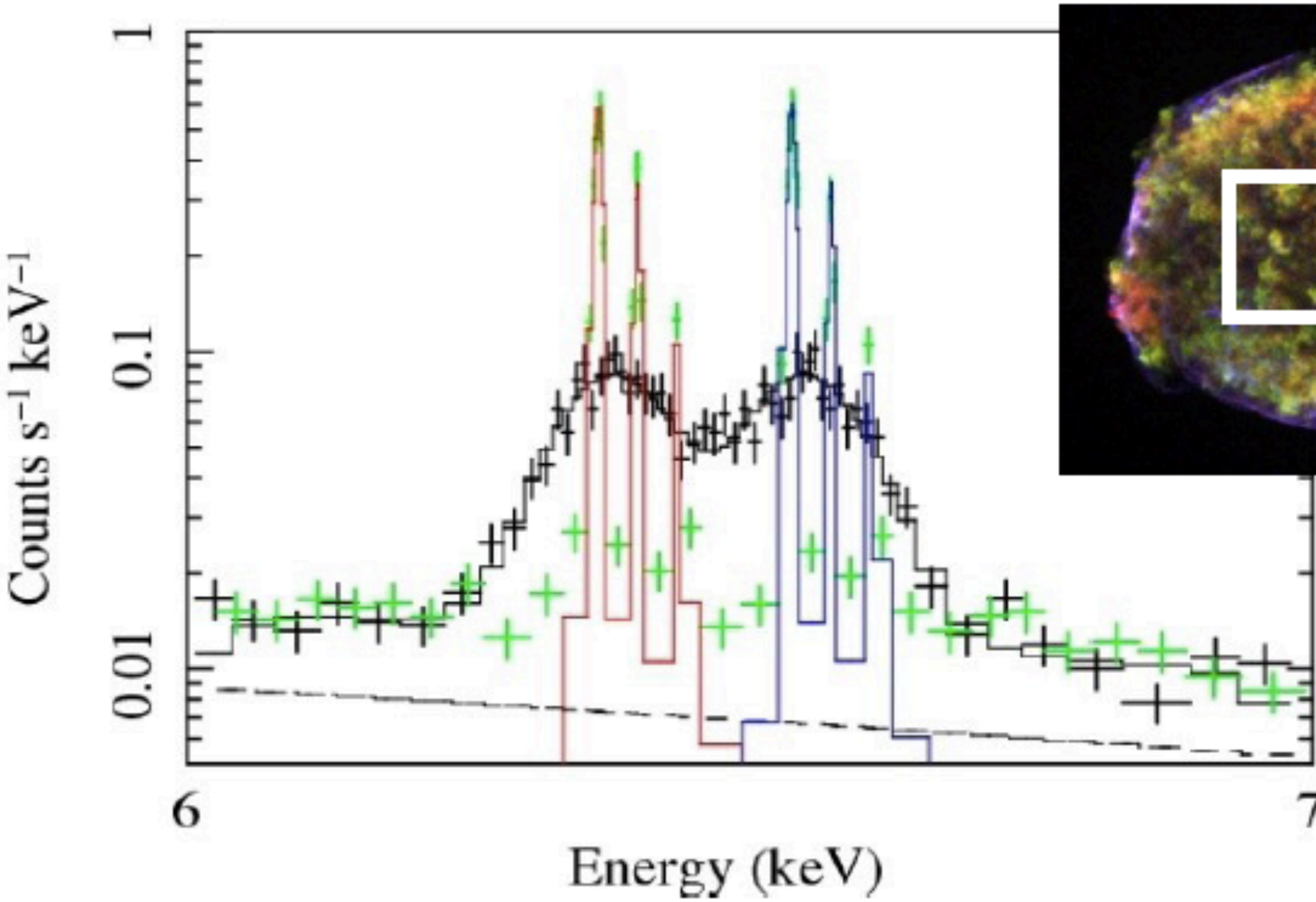


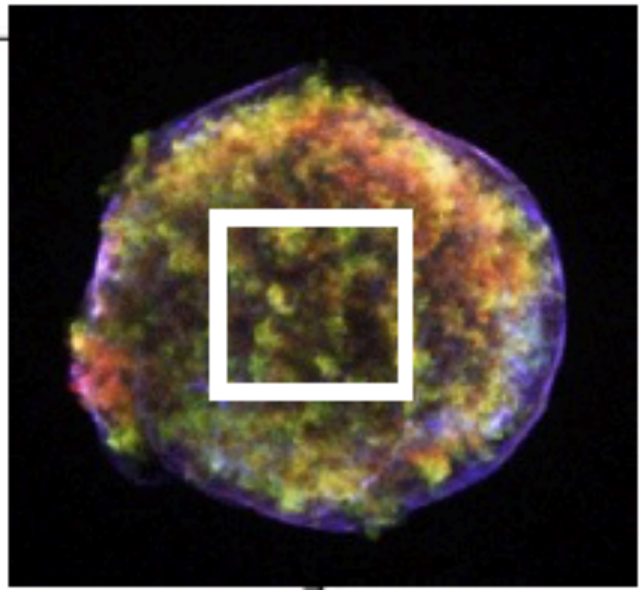
10^{36} ergs/s flare with Γ=2.0



ASTRO-H can identify the slope, cut-off etc.

Simulated spectra: the Tycho SNR <5-7 eV Energy Resolution>





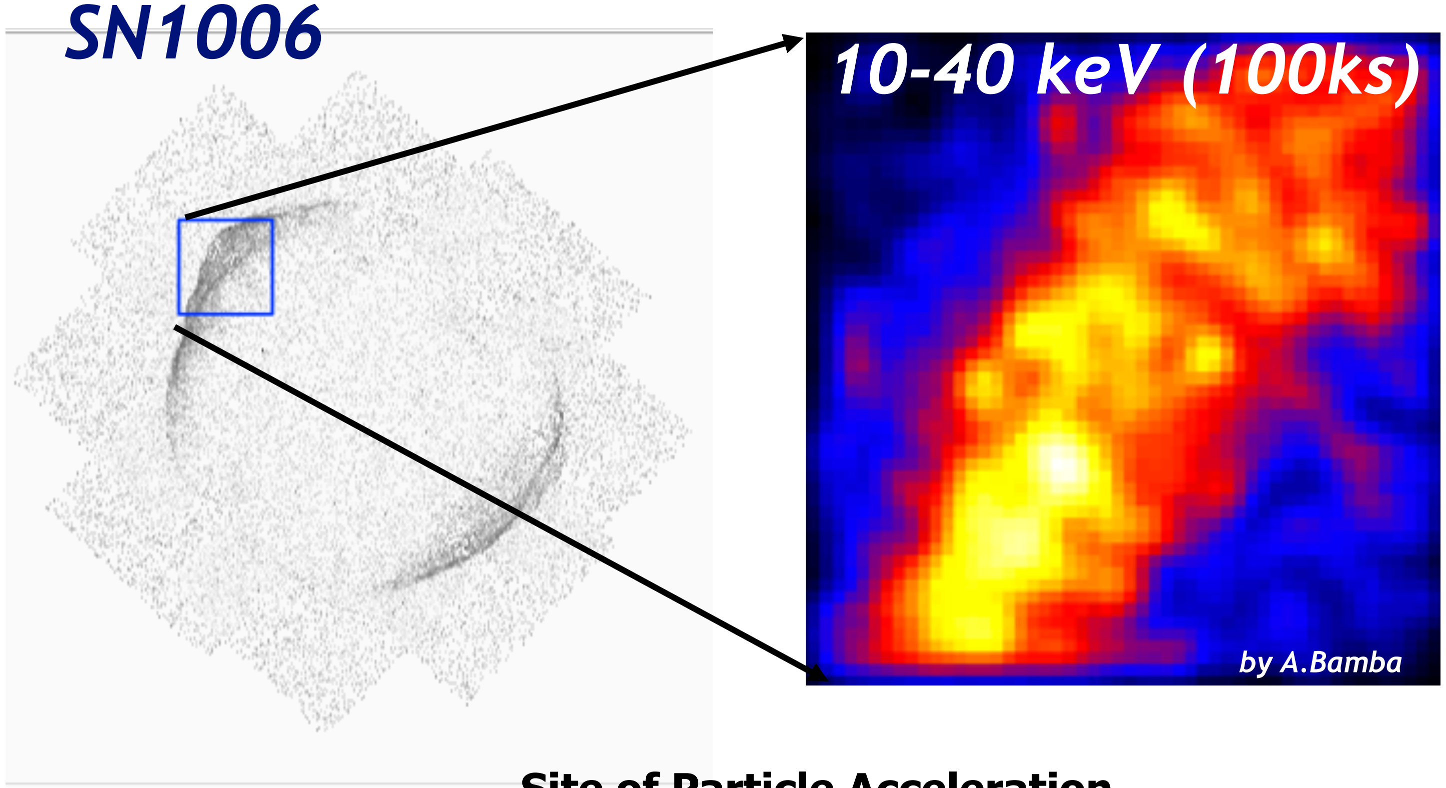
Simulated spectra of the iron K-shell complex from the inner region of the Tycho SNR with an exposure of 100 ks with SXS/ASTRO-H.

The ion temperature is assumed to be 30 billion degrees (black) or negligible (green). Red- and blue-shifted lines from the fast moving gas can be readily resolved with SXS.

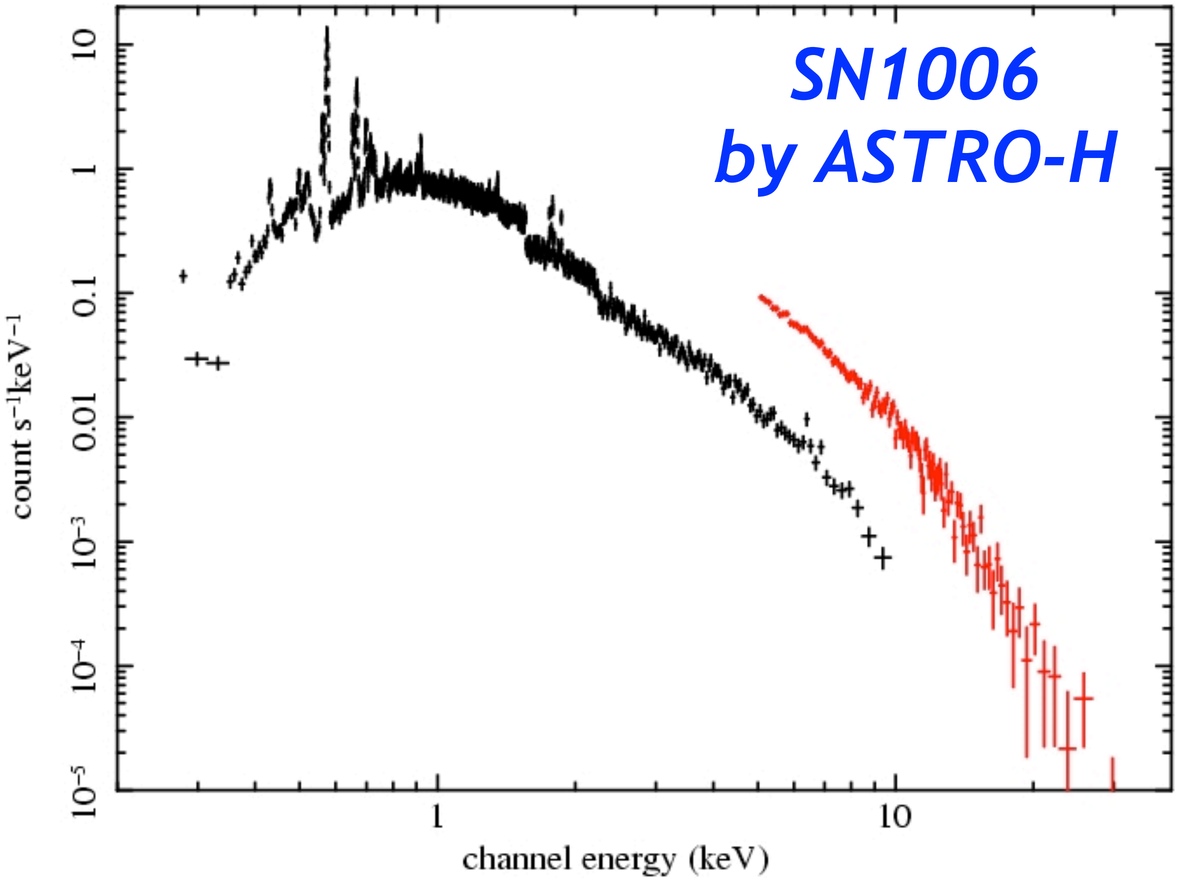
Supernova Remnants

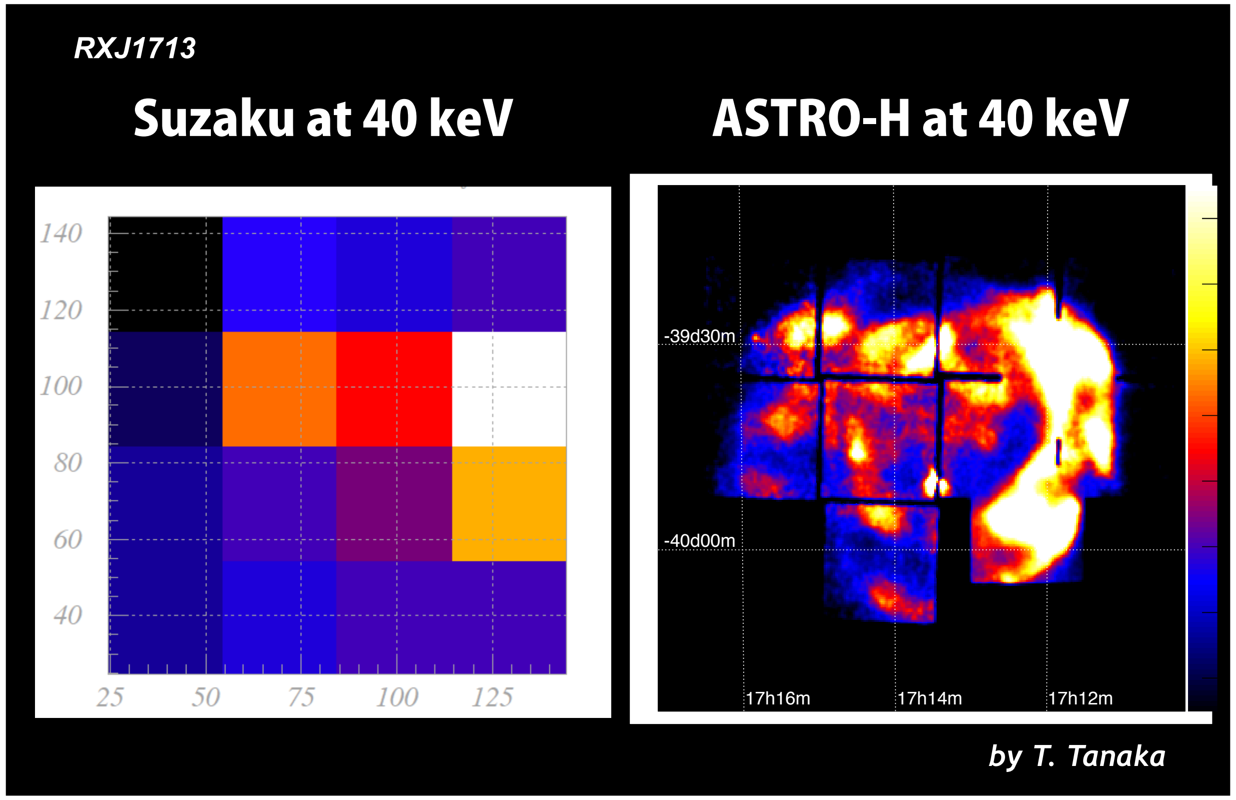
The combination of ASTRO-H's hard X-ray imaging capability and high spectral resolution will provide information to understand crucial aspects of shock acceleration in SNRs such as the maximum energy of the accelerated particles.

SN1006



Site of Particle Acceleration
to map electon distribution with E=Emax





5. Summary

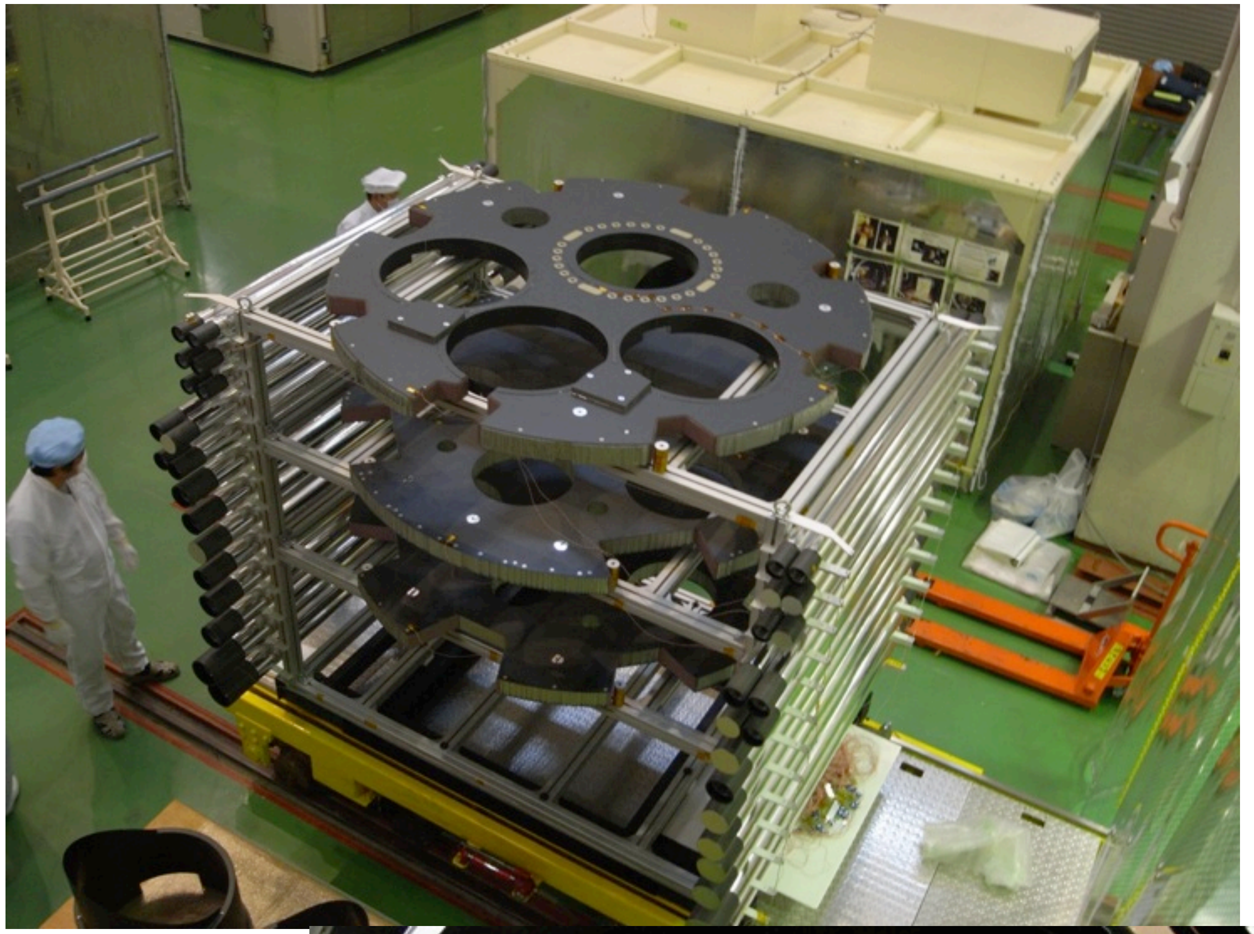
We have already integrated main structure (e.g Optical Bench, Base Plate, Side Panels) for the system test and are now testing for the distortion model for the thermal environment.

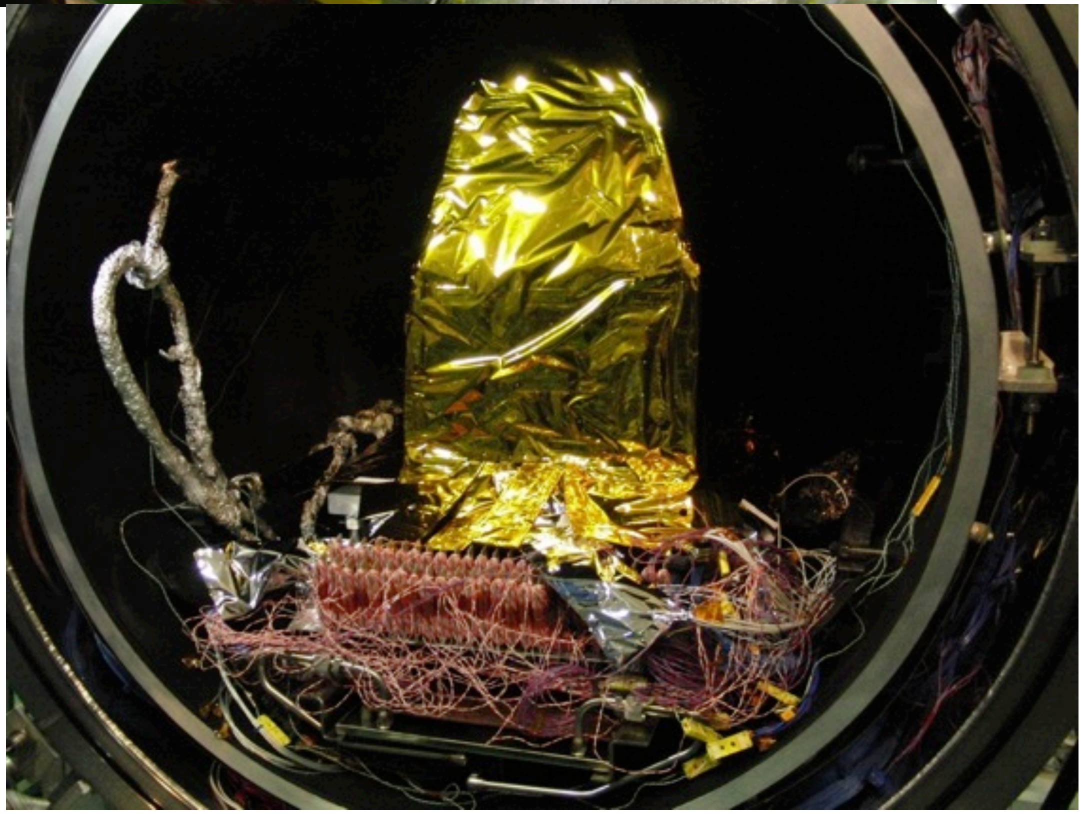
ASTRO-H will be launched in 2014. Please stay tuned.

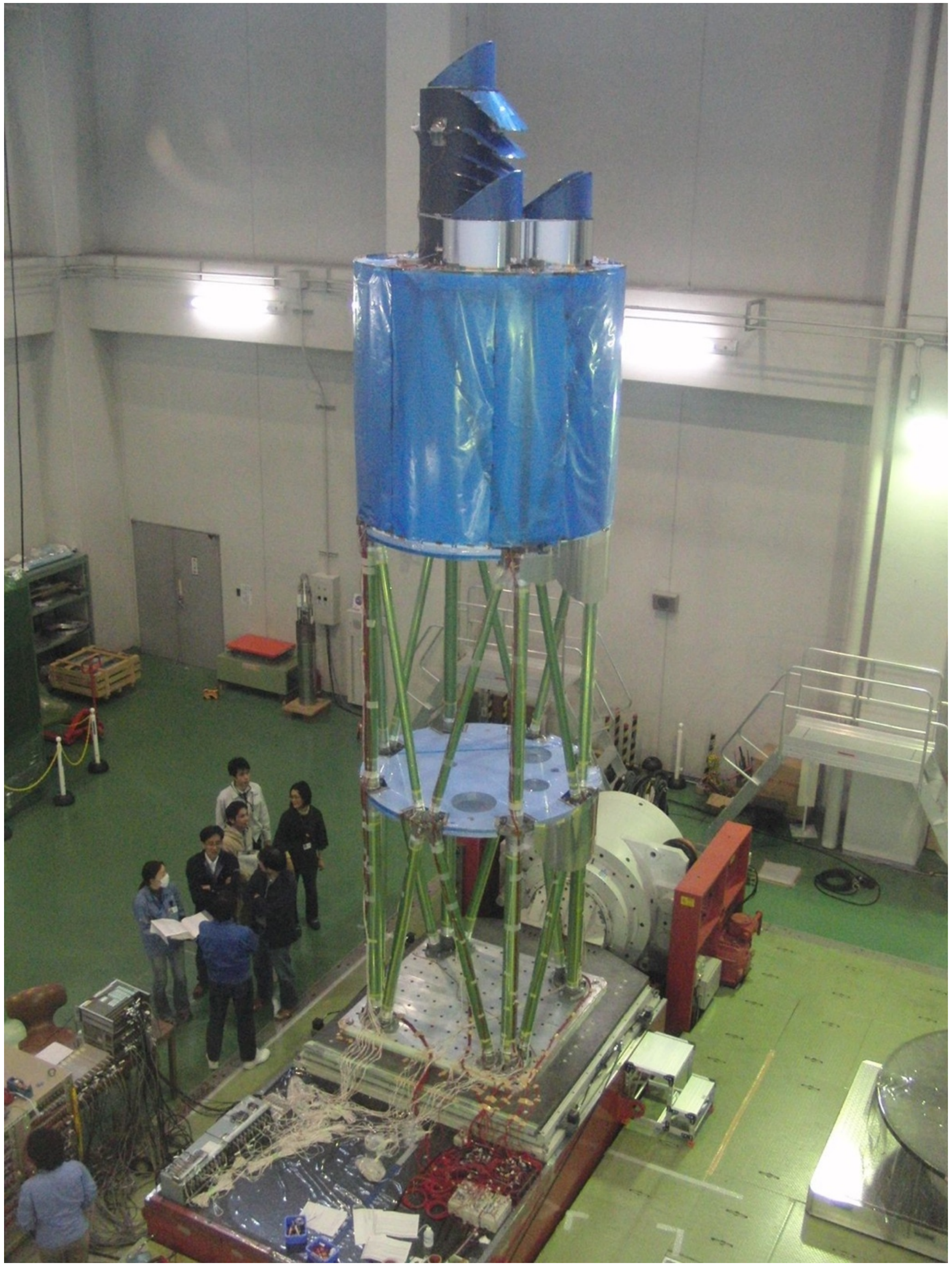
ASTRO-H responses are available from Web.

Gratzie.

6. ASTRO-H : Recent status in the bus system fabrication







7. ASTRO-H in orbit

ASTRO-H is in many ways similar to Suzaku in terms of orbit, pointing, and tracking capabilities, ASTRO-H will be launched into a circular orbit with altitude 500–600 km, and inclination 31 degrees or less.

Science operations will be similar to those of Suzaku, with pointed observation of each target until the integrated observing time is accumulated, and then slewing to the next target.

All instruments are co-aligned and will operate simultaneously.

Time Allocation (TBC)

Phase 0 : 3 Months : Satellite/Instruments Check out
Phase 1 : 6 Months : SWG 100 % (PV Phase, including Calibration)
Phase 2 : 12 Months : SWG Carry Over 15 %, GO 75 %, Observatory 10 %
Phase 3 : Rest of the mission : KeyProject 15 % (TBD) , GO 75 %, Observatory 10 %

Data policy among J/Europe/US in the GO time, would be similar to the Suzaku case. But we are planning to introduce key-project type and/or early-data-released type observations from early phase of the mission.

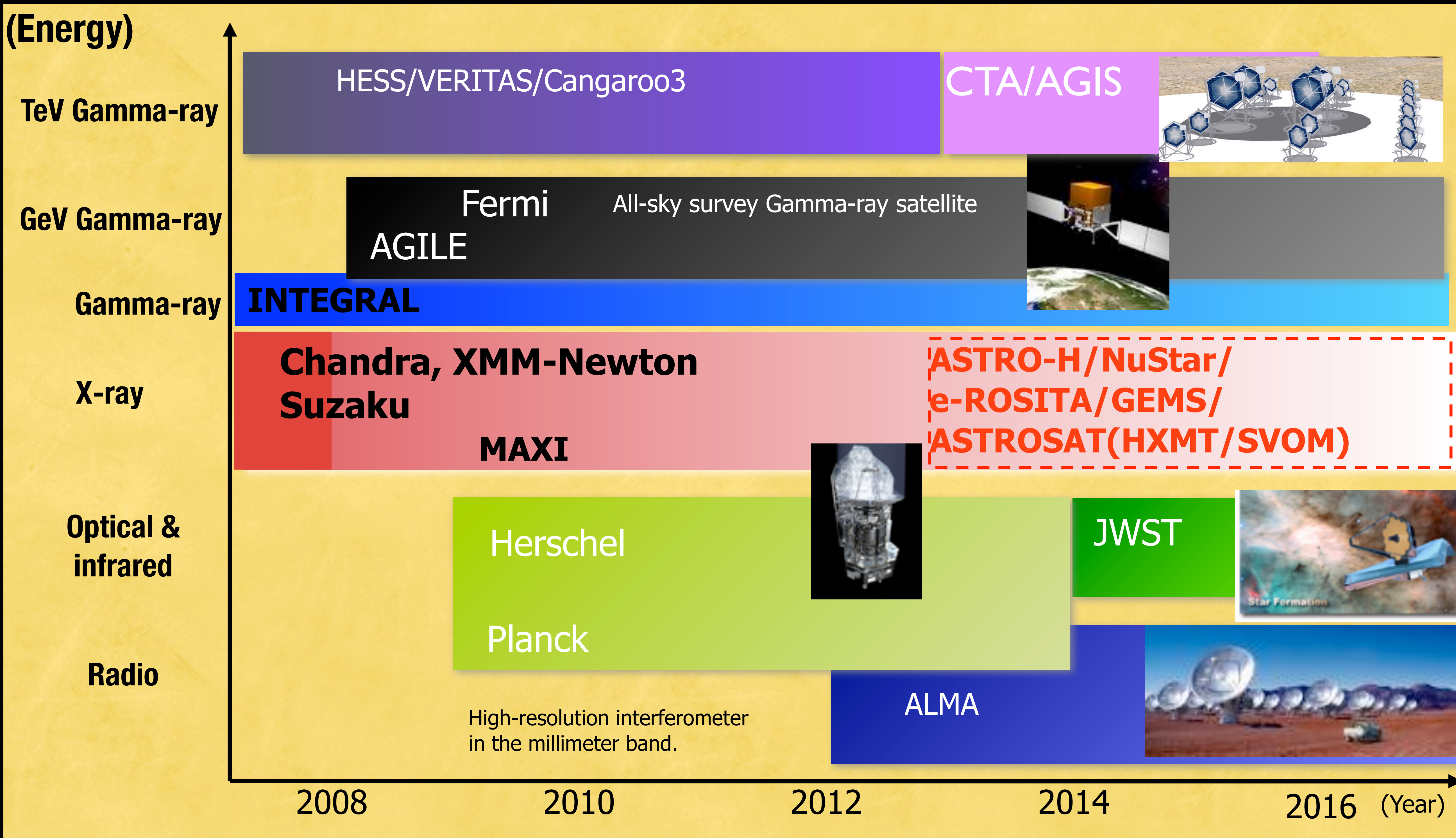
Appendix. ASTRO-H Key Parameters

TABLE 2. Key parameters of the ASTRO-H payload

Parameter	Hard X-ray Imager (HXI)	Soft X-ray Spectrometer (SXS)	Soft X-ray Imager (SXI)	Soft γ-ray Detector (SGD)
Detector technology	Si/CdTe cross-strips	micro calorimeter	X-ray CCD	Si/CdTe Compton Camera
Focal length	12 m	5.6 m	5.6 m	–
Effective area	300 cm^2@30 keV	210 cm^2@6 keV 160 cm^2 @ 1 keV	360 cm^2@6 keV	>20 cm^2@100 keV Compton Mode
Energy range	5 –80 keV	0.3 – 12 keV	0.5 – 12 keV	40 – 600 keV
Energy resolution (FWHM)	2 keV (@60 keV)	< 7 eV	150 eV (@6 keV)	4 keV (@40 keV)
Angular resolution	<1.7 arcmin	<1.3 arcmin	<1.3 arcmin	–
Effective Field of View	$\sim 9 \times 9$ $arcmin^2$	$\sim 3 \times 3$ $arcmin^2$	$\sim 35 \times 35$ $arcmin^2$	0.6×0.6 deg^2 (< 150 keV)
Time resolution	several 10 μs	several 10 μs	4 sec	several 10 μs
Operating temperature	−20°C	50 mK	−120°C	−20°C

Backups

A few years from now, we will have a fantastic set of X-ray missions to work with representatives from other wavelength



And will wait for Athena/LOFT to come....

Appendix: ASTRO-H Scientific goals and objectives

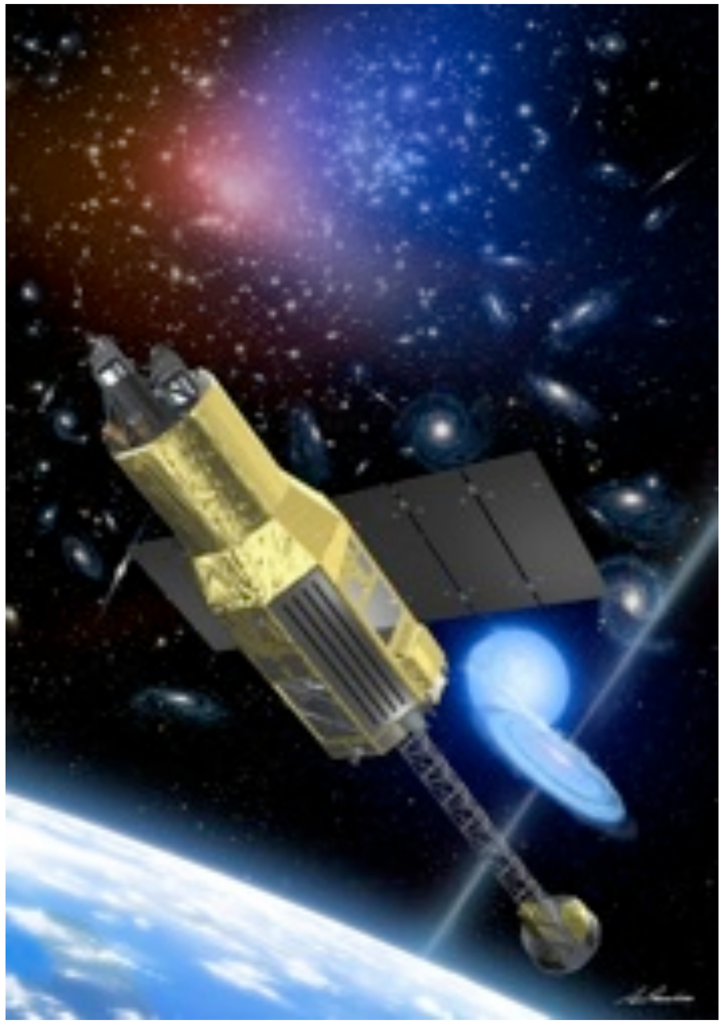
Observing the Dynamic Universe and Studying its History with the Ultimate Goal of Understanding the Structure and Evolution of the Universe

Scientific objectives :

- Revealing the large-scale structure and its evolution of the Universe
- Understanding the extreme conditions in the Universe
- Exploring the diverse phenomena of non-thermal Universe
- Elucidating dark matter and dark energy

Key features :

1. One of the first imaging and spectroscopic observations with the hard X-ray telescope.
2. The first spectroscopic observations with an extremely high energy resolution of the micro-calorimeter.
3. The most sensitive wideband observation over an energy range from 0.3 to 600 keV.

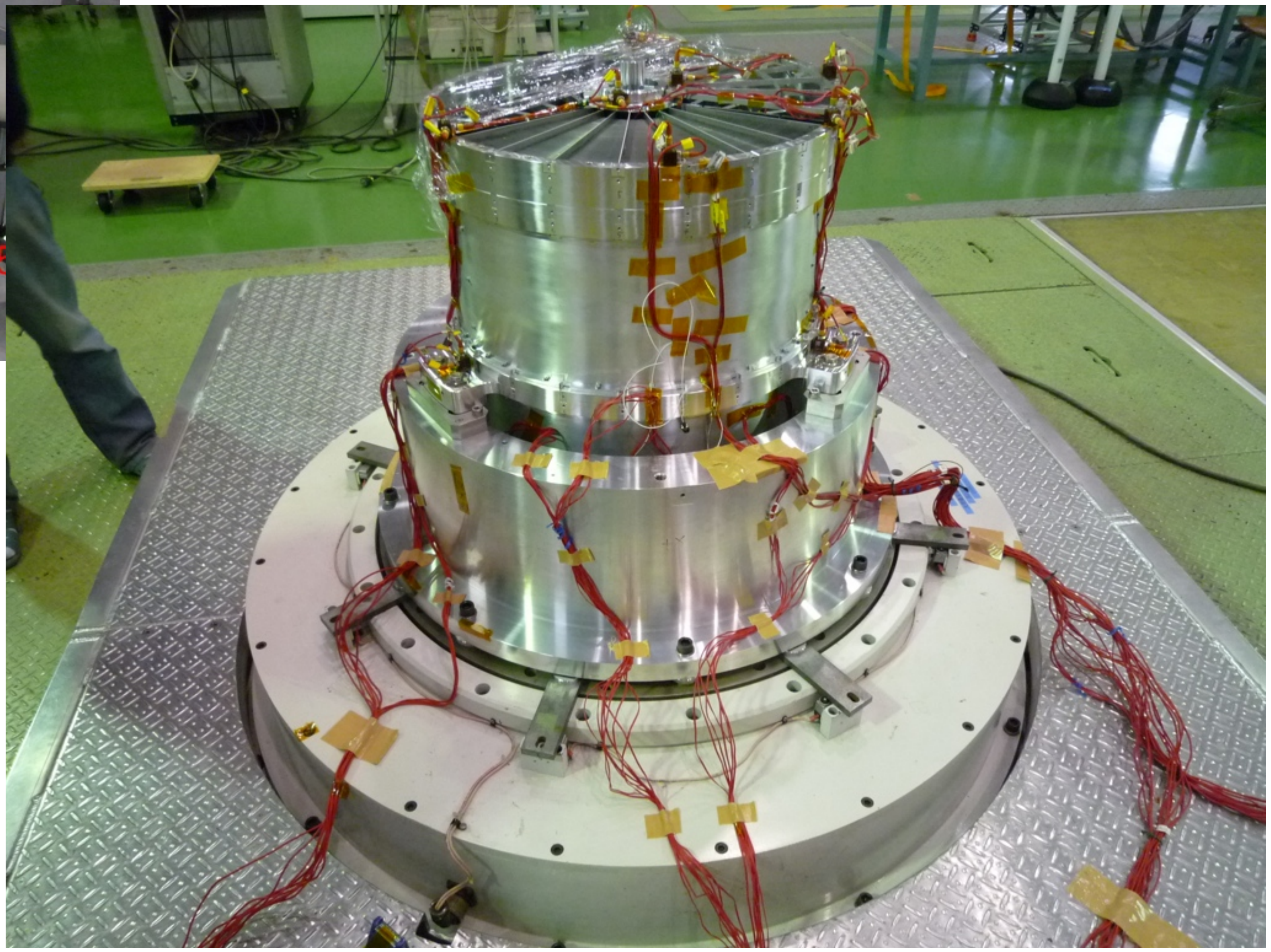


Appendix. ASTRO-H Scientific goals and Objectives

Revealing the large-scale structure of the Universe and its evolution	ASTRO-H will observe clusters of galaxies, the largest bound structures in the Universe, with an aim to reveal the interplay between the thermal energy of the intracluster medium, the kinetic energy of sub-clusters from which clusters form, measure the non-thermal energy; and to directly trace the dynamic evolution of clusters of galaxies.
	ASTRO-H will observe distant supermassive black holes hidden by thick intervening material with 100 times higher sensitivity than Suzaku, and will study their evolution and role in galaxy formation.
Understanding the extreme conditions in the Universe	ASTRO-H will measure the motion of matter very close to black holes with an aim to sense the gravitational distortion of space, and to understand the structure of relativistic space-time.
Exploring the diverse phenomena of non-thermal Universe	ASTRO-H will derive the physical conditions of the sites where high energy particles (cosmic rays) gain energy and will elucidate the process in which gravity, collisions, and stellar explosions energize those cosmic rays.
Elucidating dark matter and dark energy	ASTRO-H will map the distribution of dark matter in clusters of galaxies and will determine the total mass of galaxy clusters at different distances (and thus at different ages), and will study the role of dark matter and dark energy in the evolution of these systems.

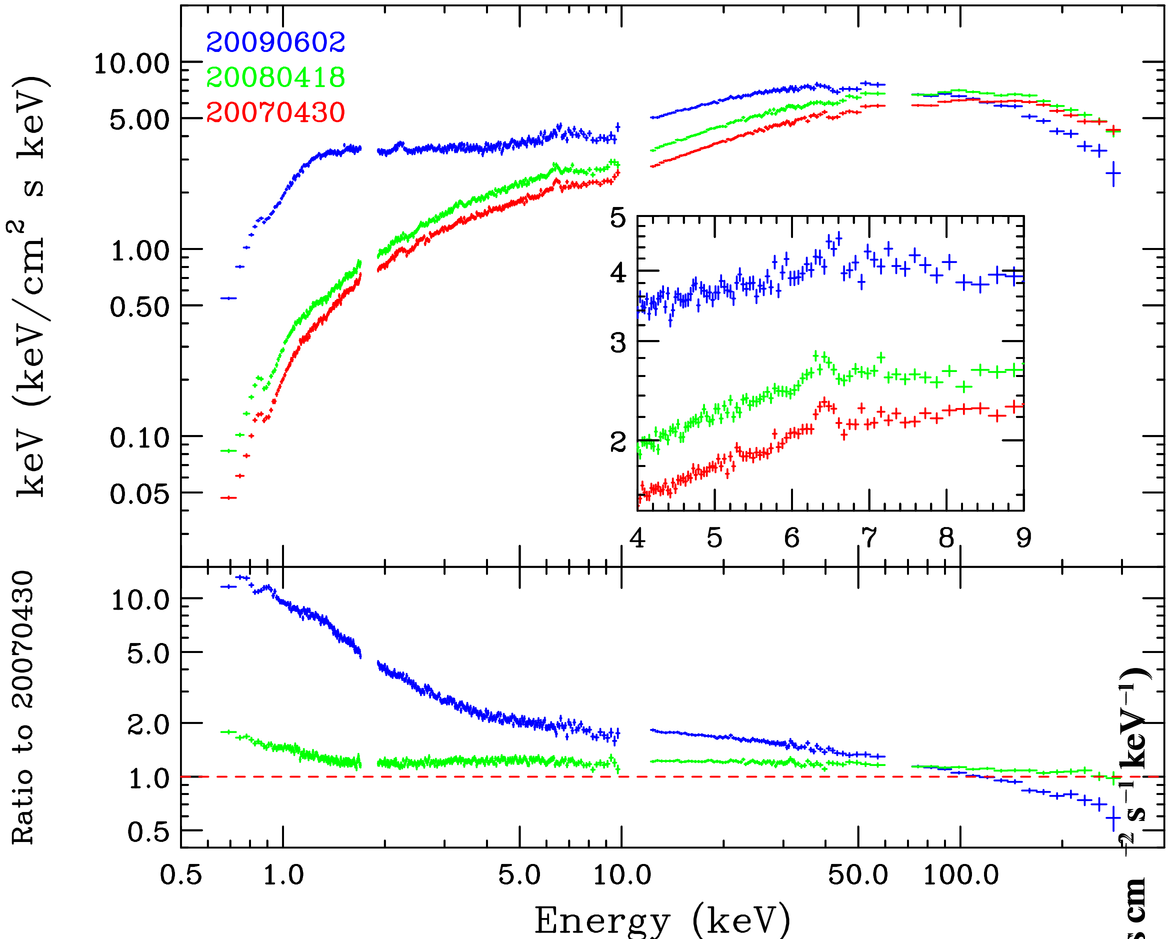
3. ASTRO-H : Hard X-ray Telescope (HXT)

Recent Progress
Vibration Test (March 2012)



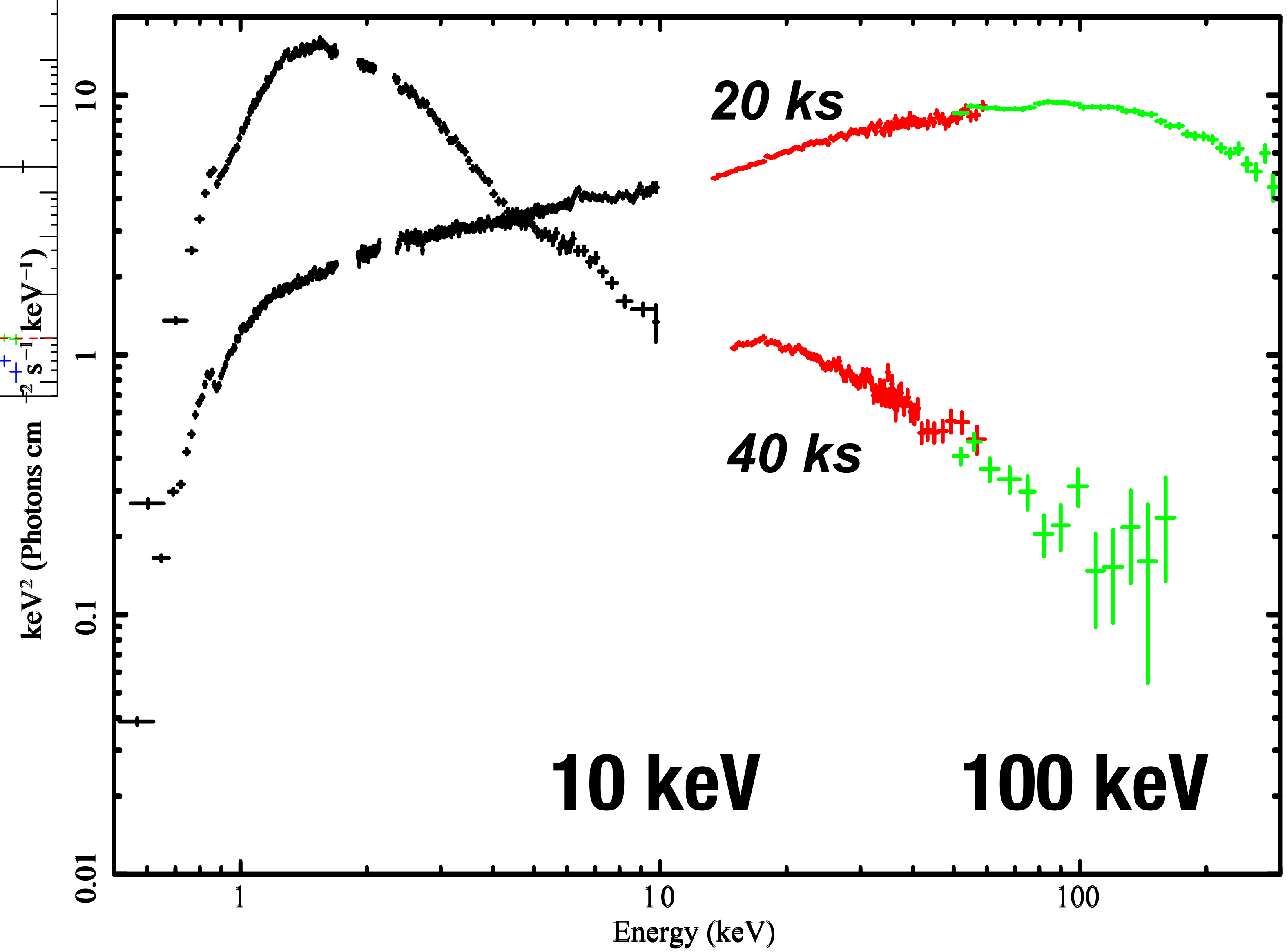
3. ASTRO-H: Wind-band spectrosopy in 0.5-600 keV

0.5 keV 10 keV 300 keV



Observing Time
2009/06/02 14 ks
2008/04/18 27 ks
2007/04/30 38 ks

Suzaku Cyg X-1 Spectra (by S. Yamada)

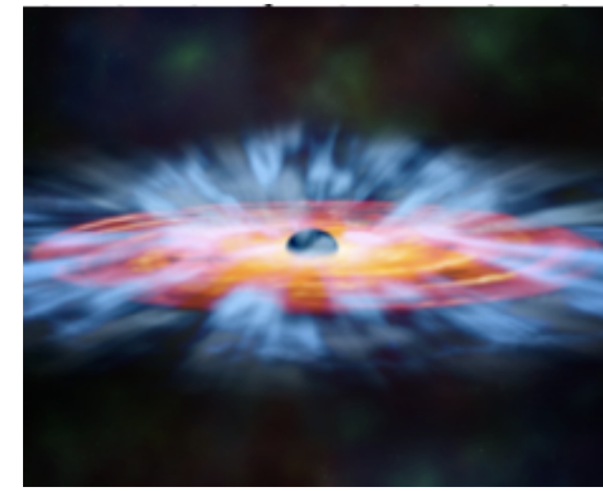


3. ASTRO-H: Top Plate (July 19/2011)

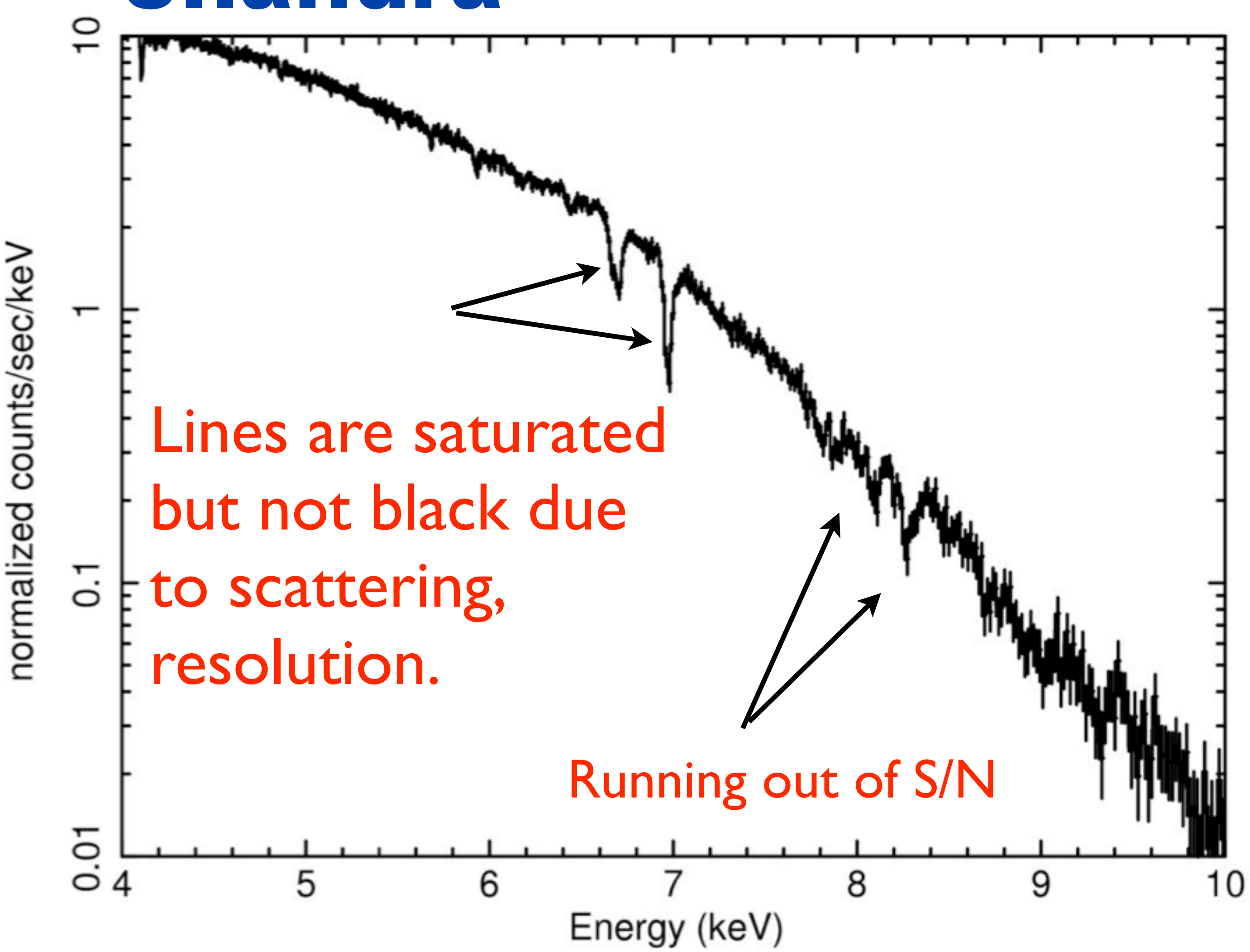
Top Plate Baking at ISAS

GRO J1655-40

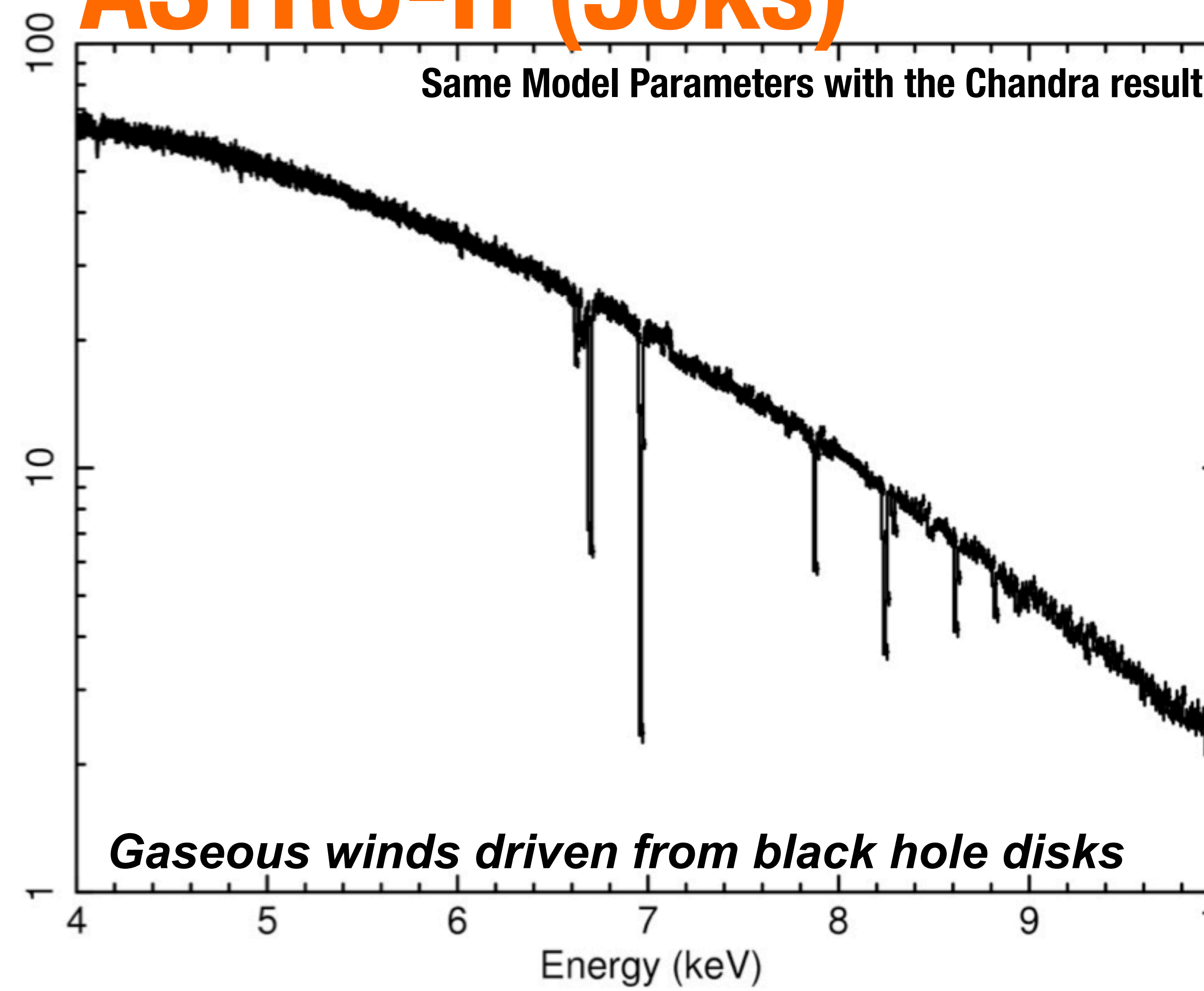
The superior resolution of SXS in the Fe K band enables the unambiguous detection of weak and narrow lines from a wind.



Chandra



ASTRO-H (50ks)



(Simulation by J. Miller)

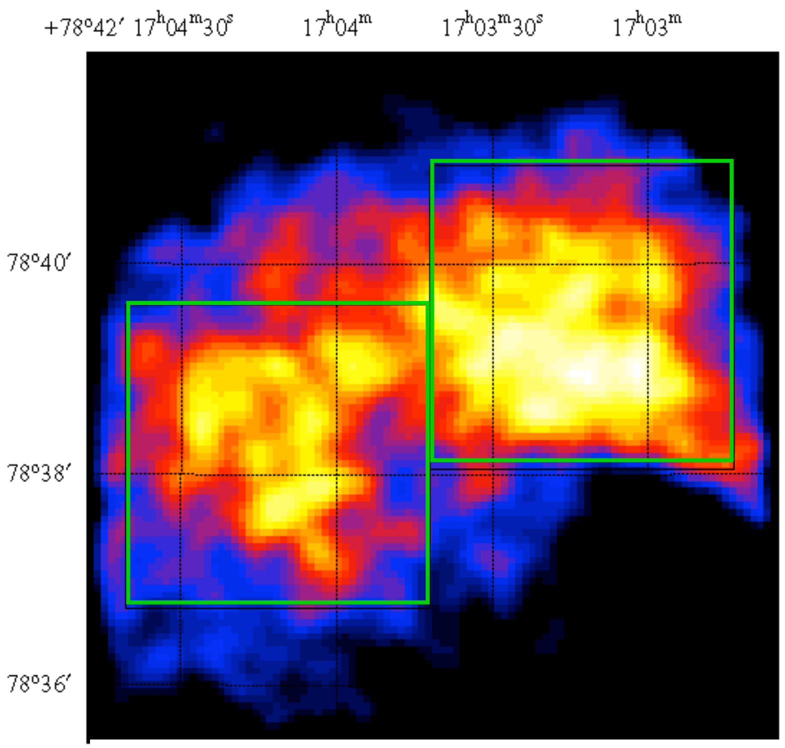
ASTRO-H SXS can handle 250 cts/s

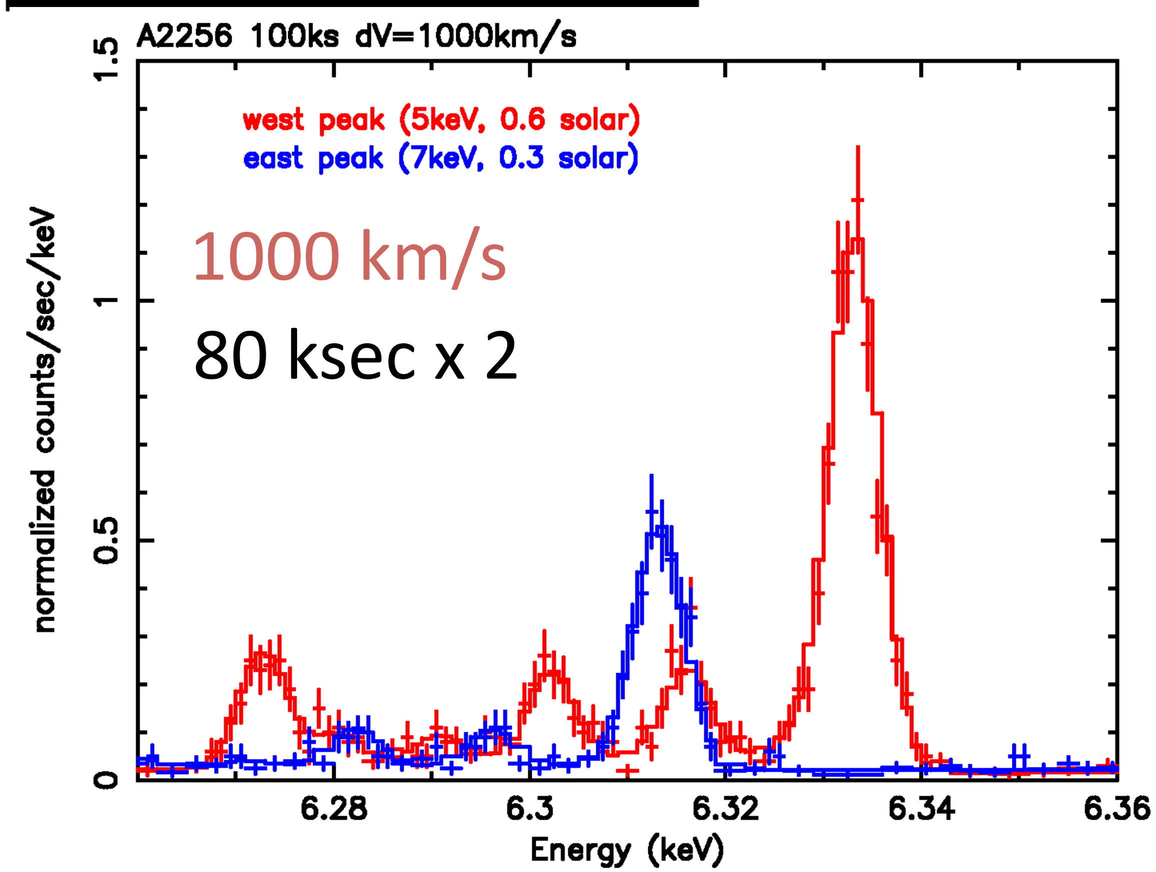
4. ASTRO-H Science : Cluster of Galaxies

Merging Cluster

A2256

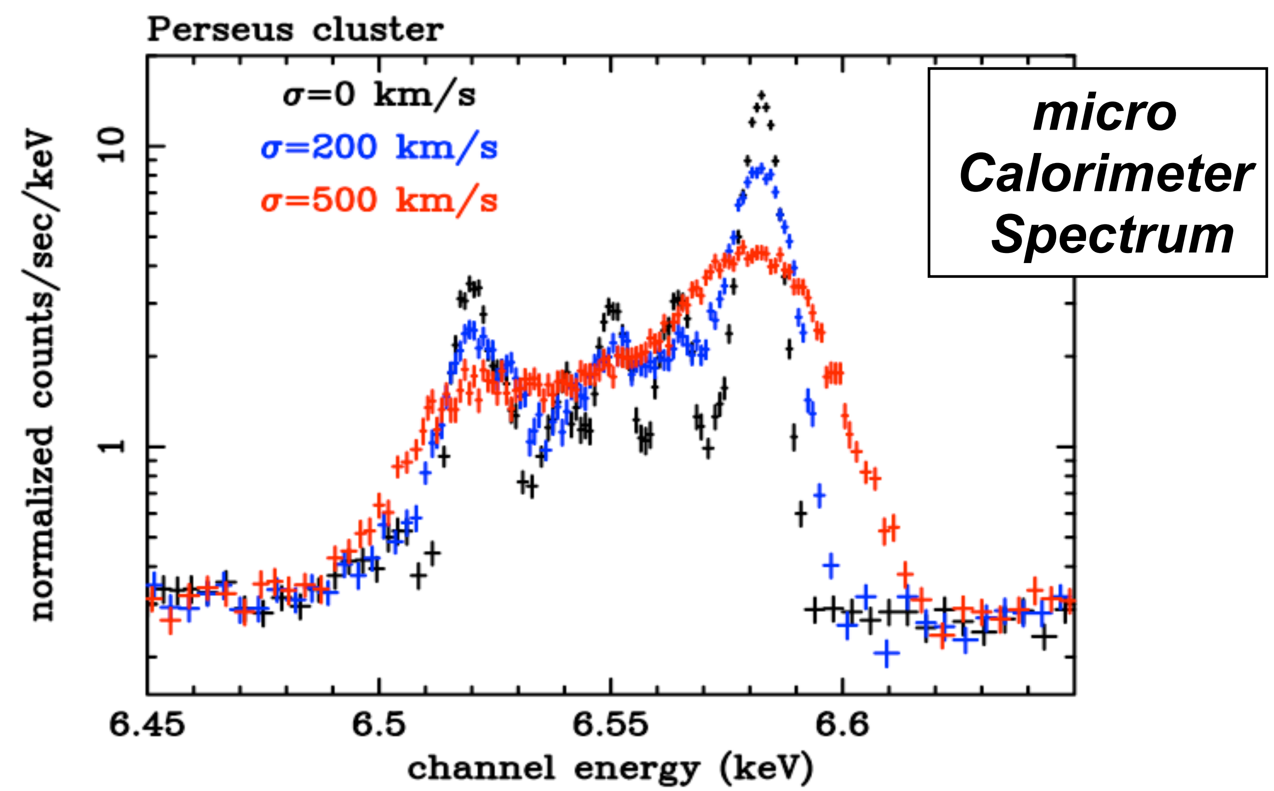
($z = 0.058$)

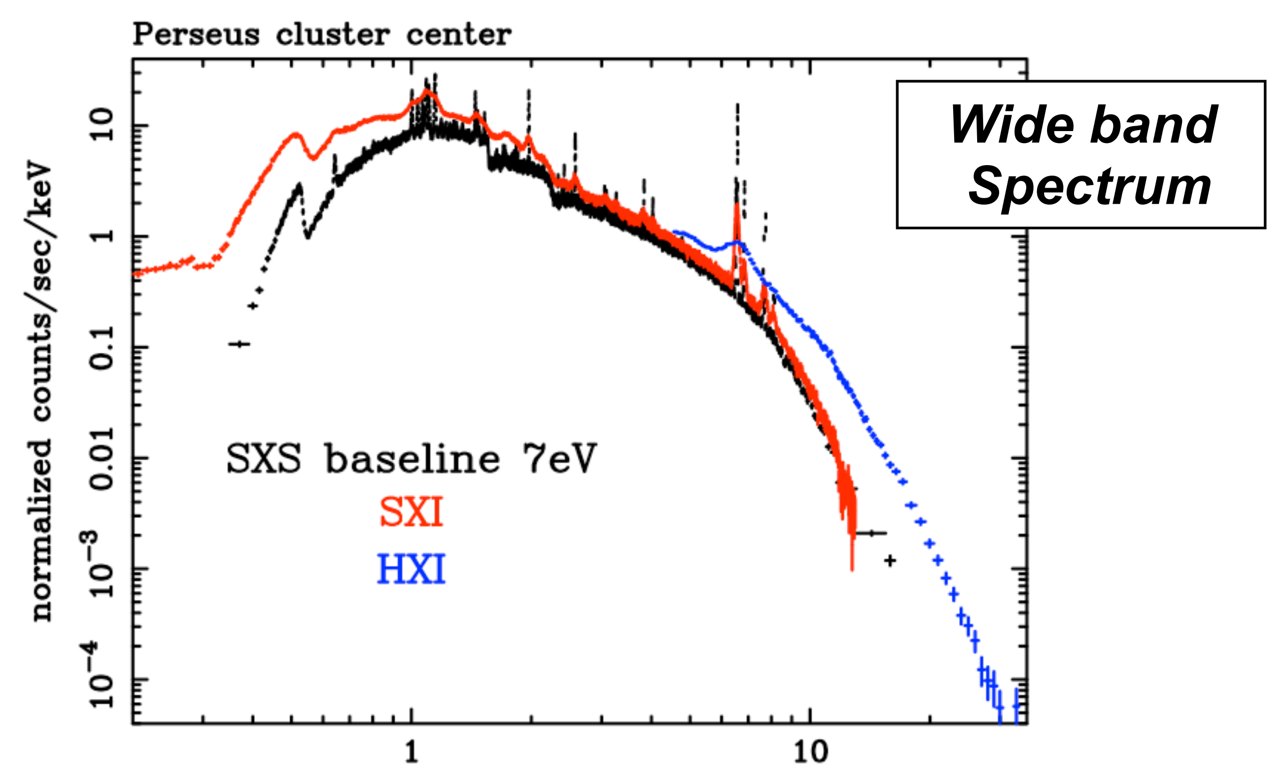




Perseus cluster (r<2′, 100ks)

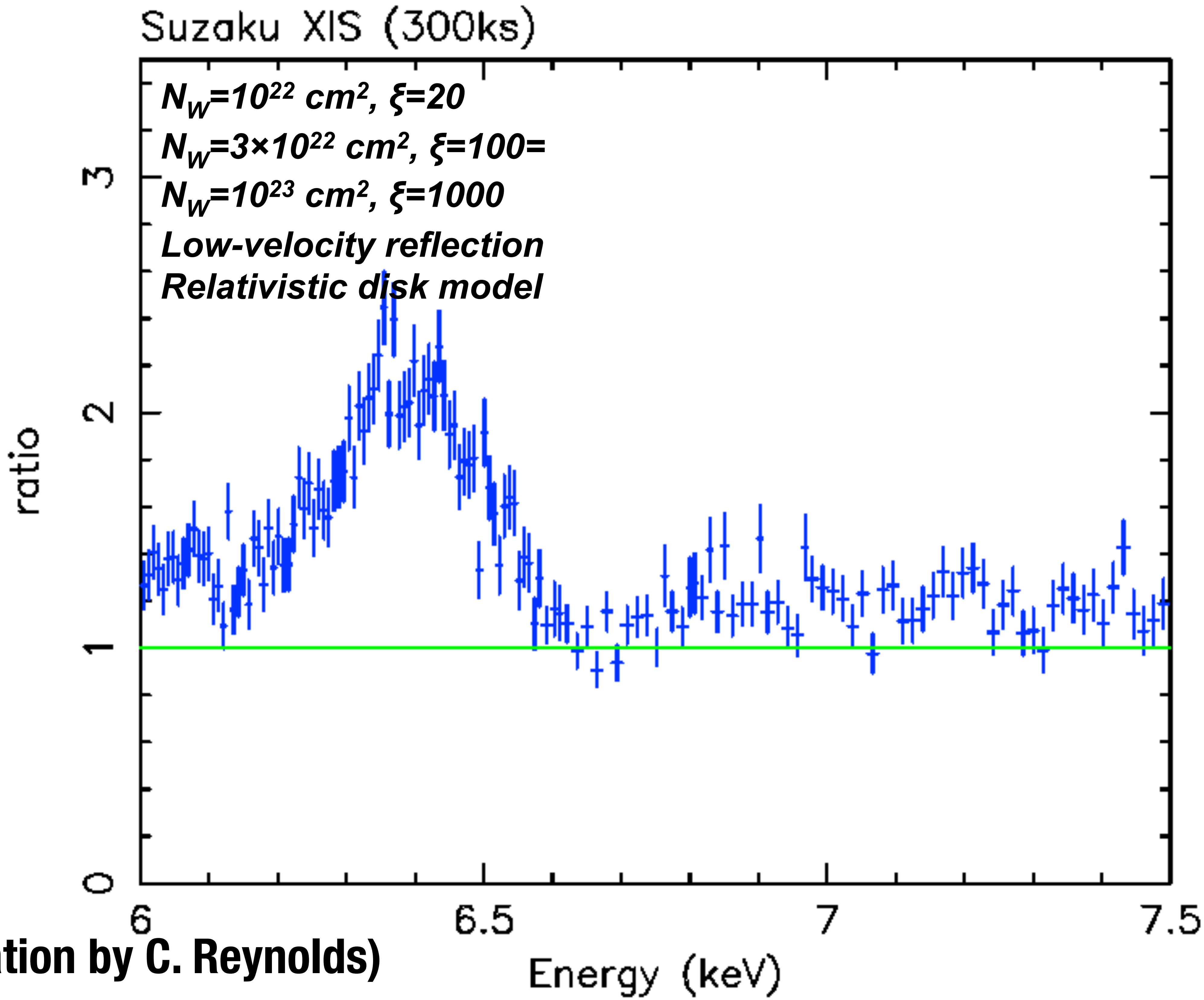
vapec 3T (0.6keV, 2.6keV, 6.1keV)





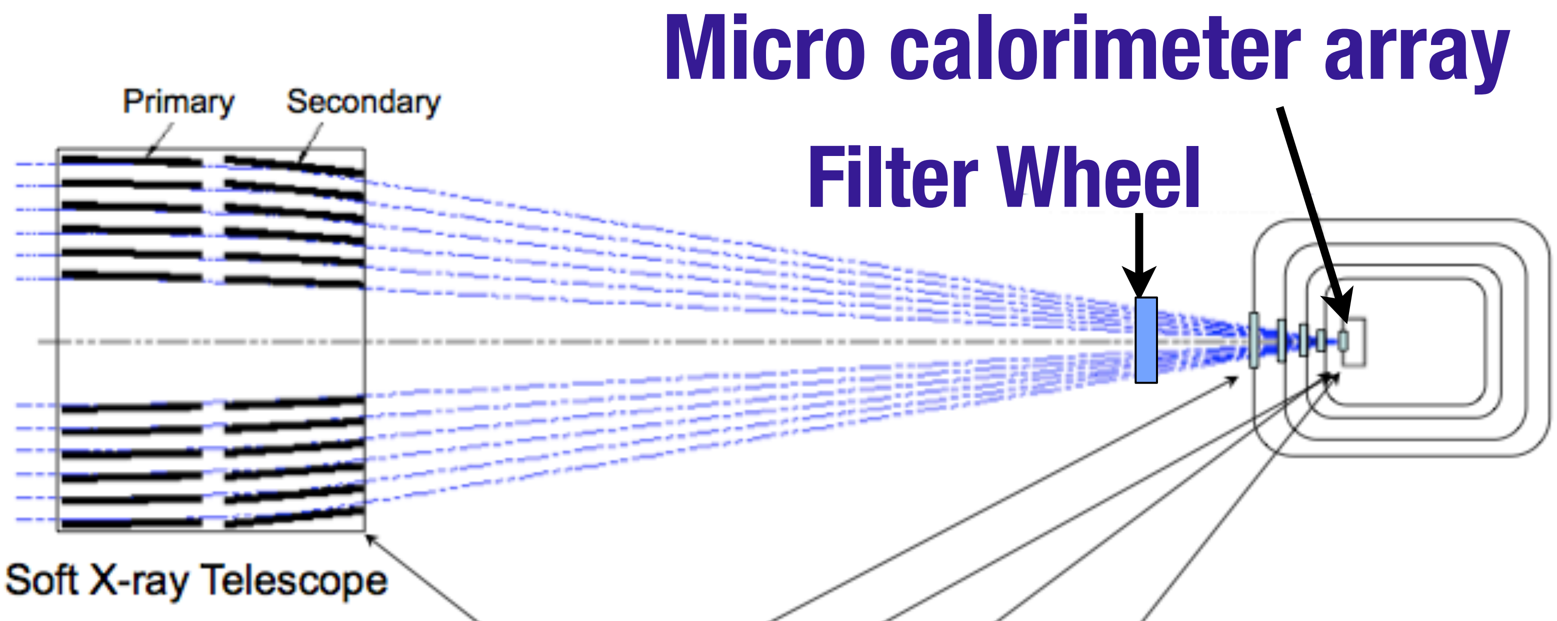
4. ASTRO-H Science : Fe line from AGN

Simulations of a generic broad-iron-line AGN subject to a high-ionization, high column density absorber



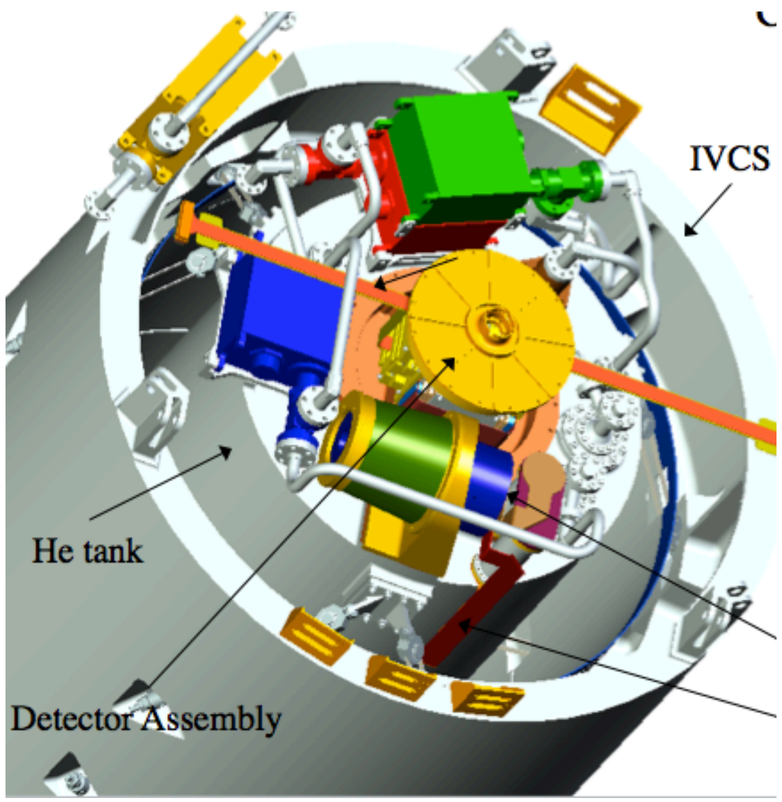
(Simulation by C. Reynolds)

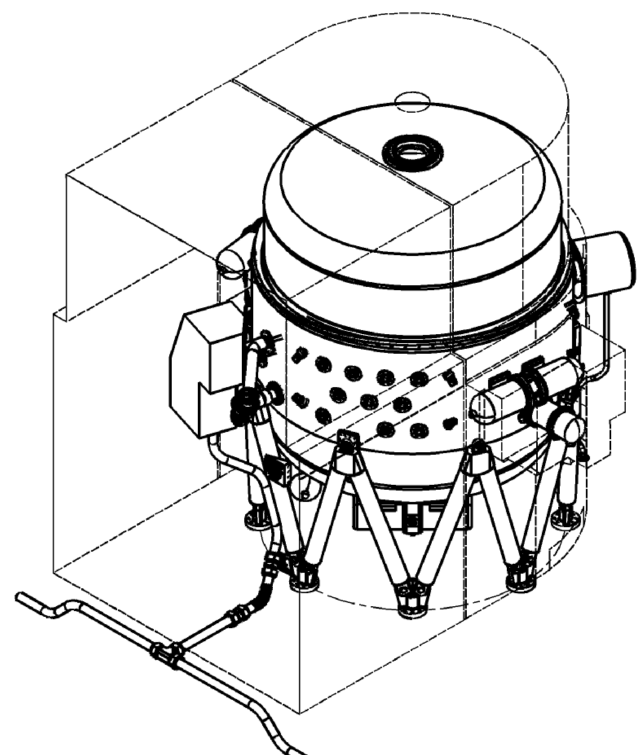
3. ASTRO-H: advanced cooling bus for SXS

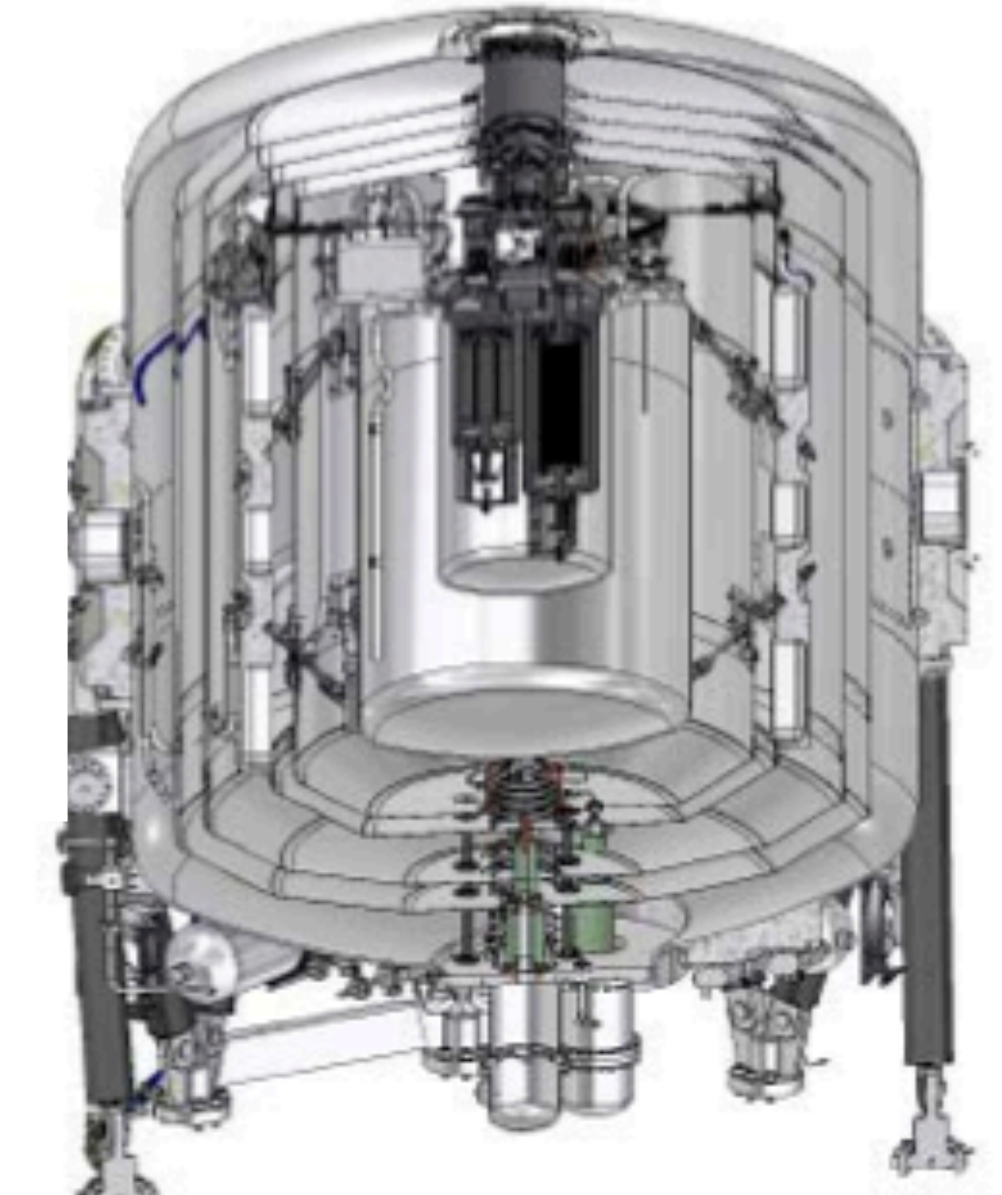


$$A_{eff}(E) = A_{XRT}(E) * t(E) * psf * f_{array} * a(E)$$

Detector to be Operated at 50 mK





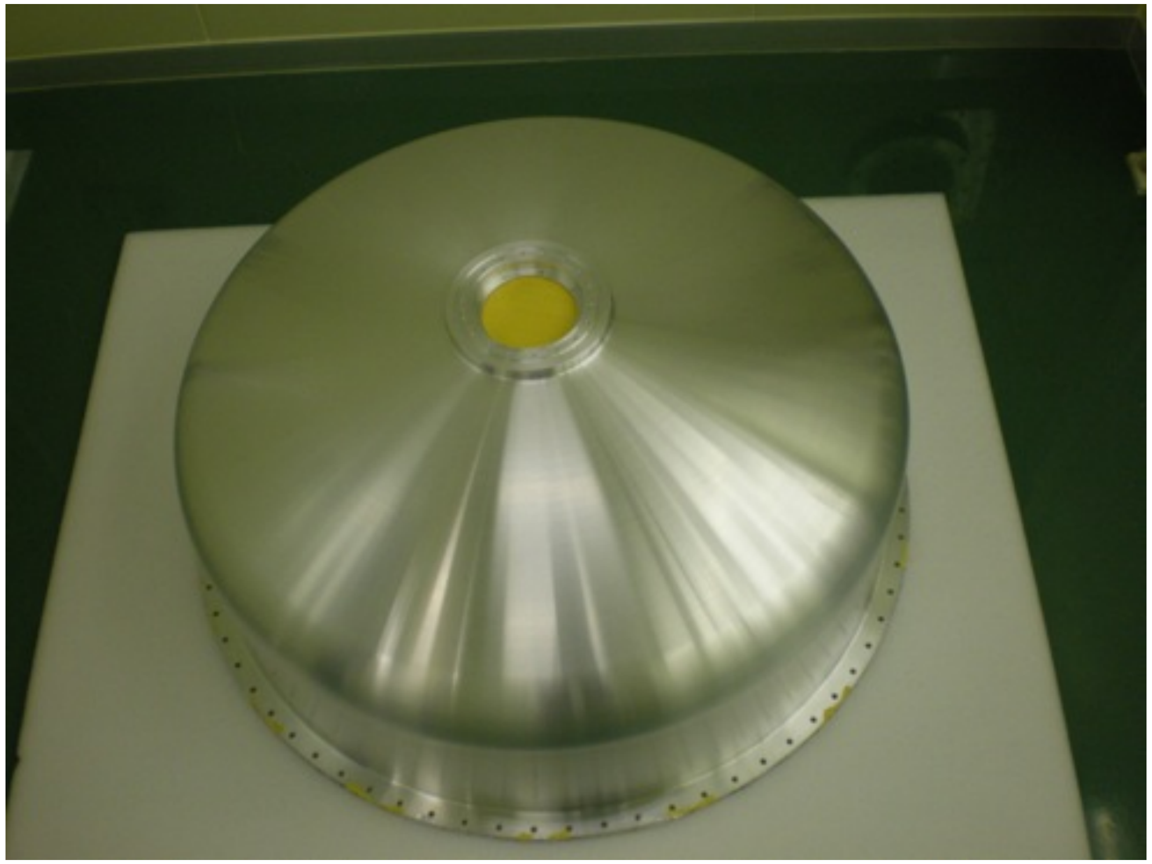


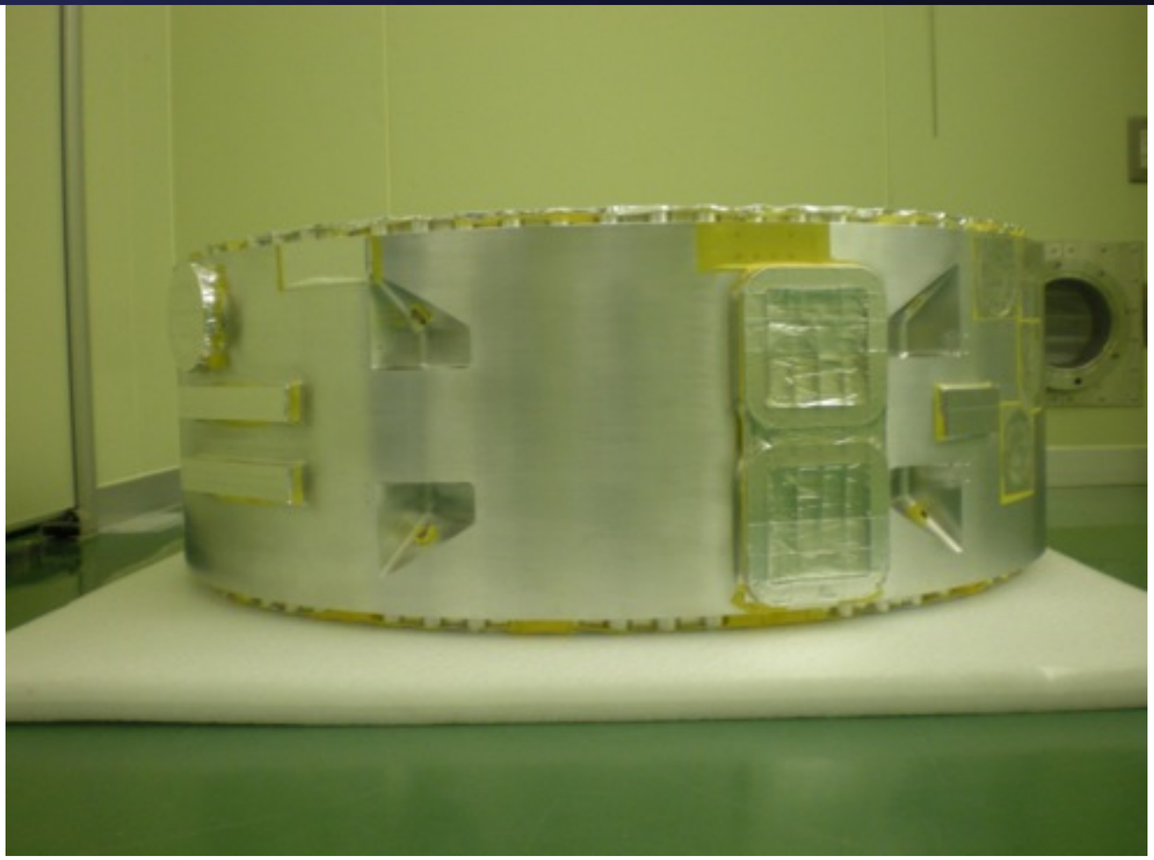
Cooling bus system "Dewar"

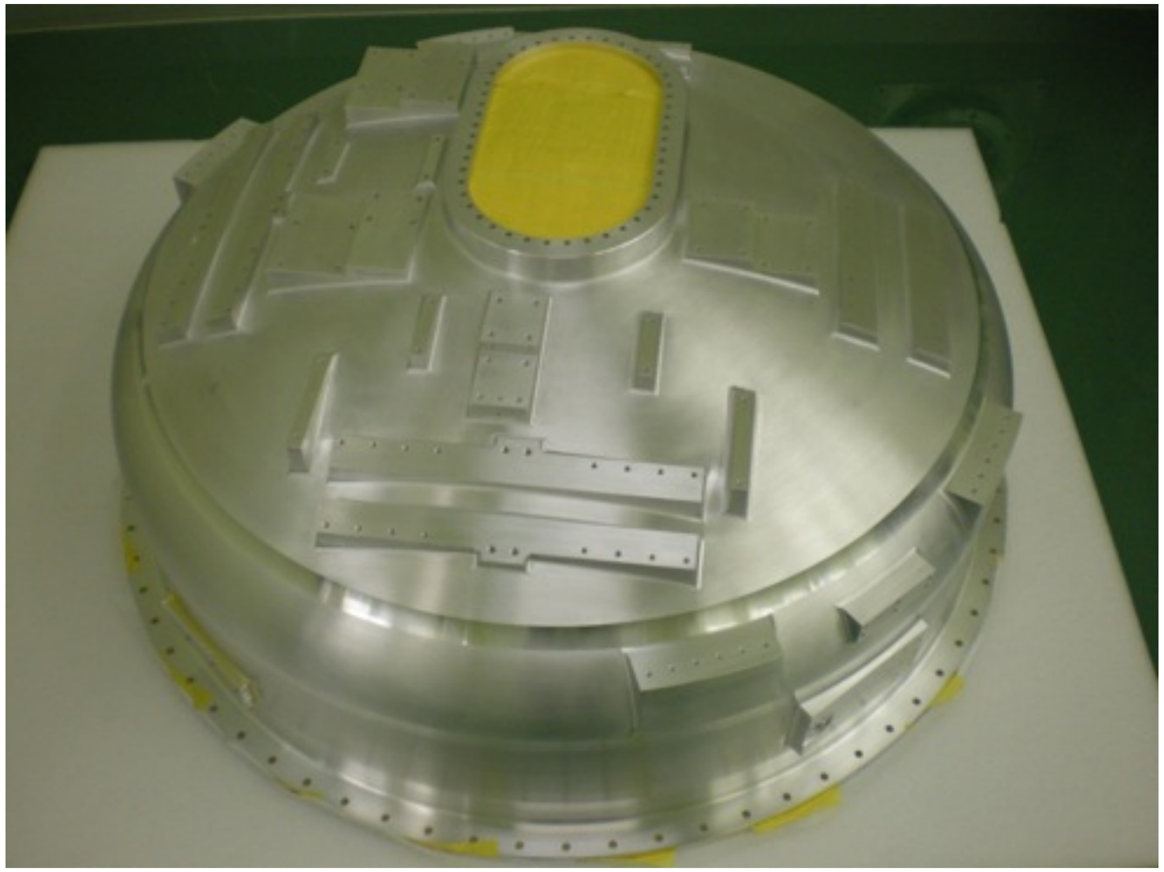
Liq. He+2stageST Cooler+JT Cooler+ADR

The dewar can be cooled even after liq. He is used up

3. ASTRO-H: SXS EM Dewar in progress







ISAS/JAXA & SHI

3. ASTRO-H : “Big Optical Benching” Satellite

For different telescope systems must be well aligned.
In order to minimize thermal distortion, CFRP is used with thermal expansion coefficient of < 2×10^{-7}