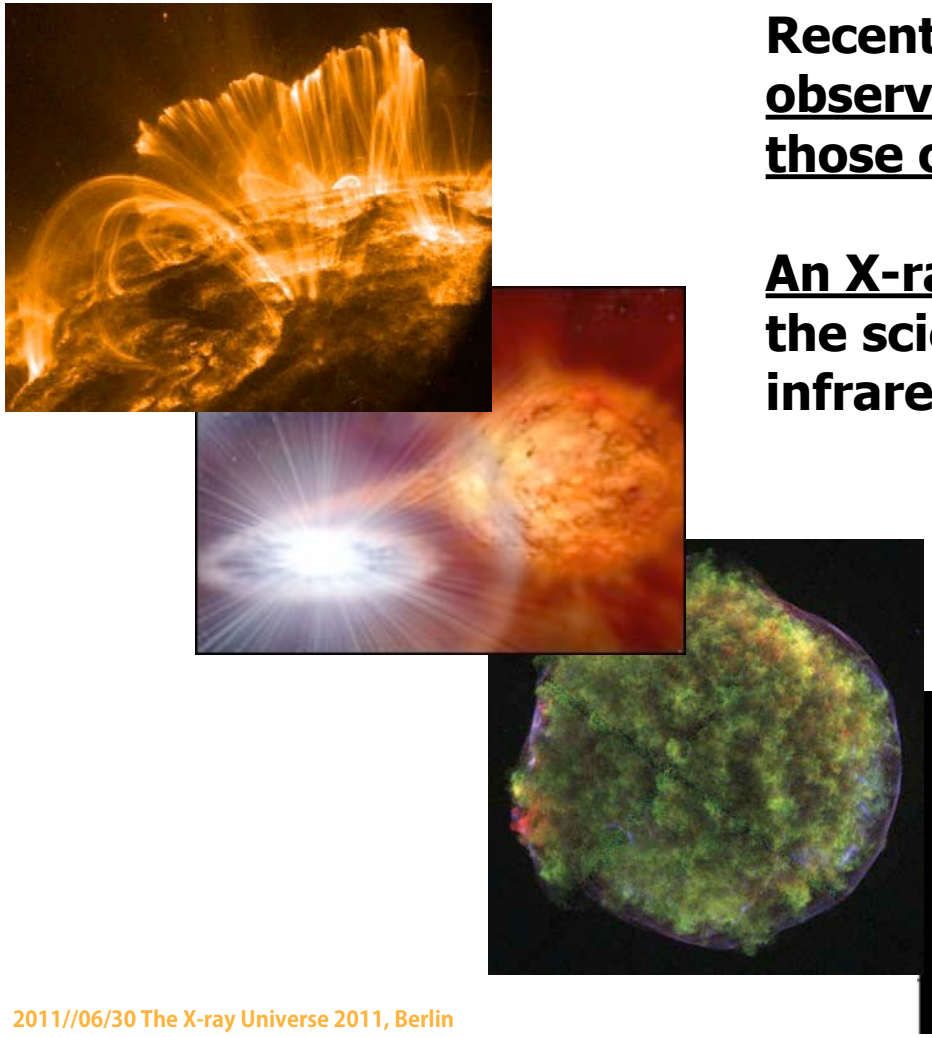
The ASTRO-H Mission

Tadayuki Takahashi
ISAS/JAXA

on behalf of the ASTRO-H Team

1. X-ray Universe

X-ray observations using space telescopes revealed that the Universe is full of high-temperature phenomena reaching 10 to 100 million degrees, which nobody had imagined before the advent of the X-ray astronomy.



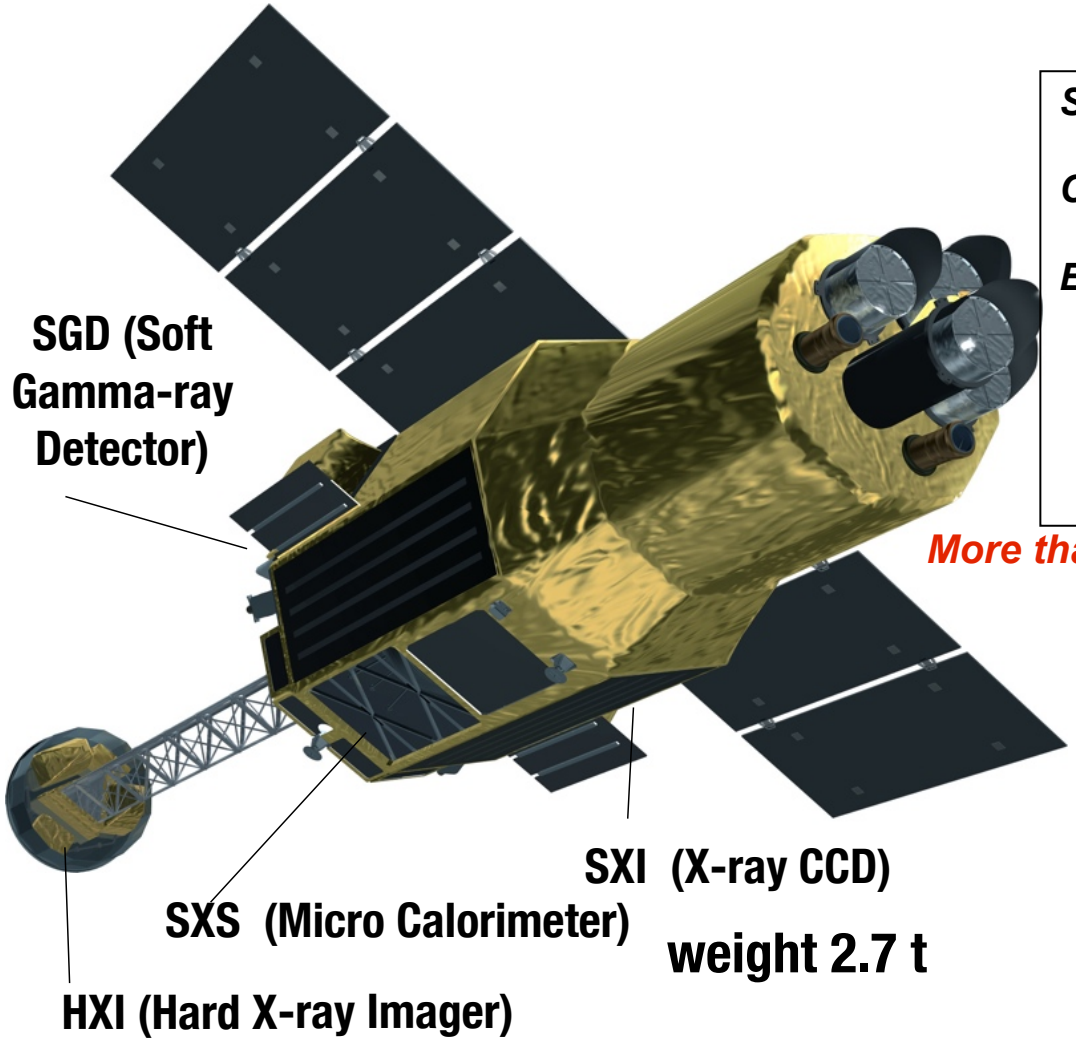
Recent studies show that <u>phenomena observed in X-rays are deeply connected to those observed in other wavelengths.</u>

<u>An X-ray mission is indispensable</u> to maximize the scientific yields expected by large radio, infrared, and optical missions.

ASTRO-H is a powerful satellite for the next generation of X-ray Astronomy

2. ASTRO-H

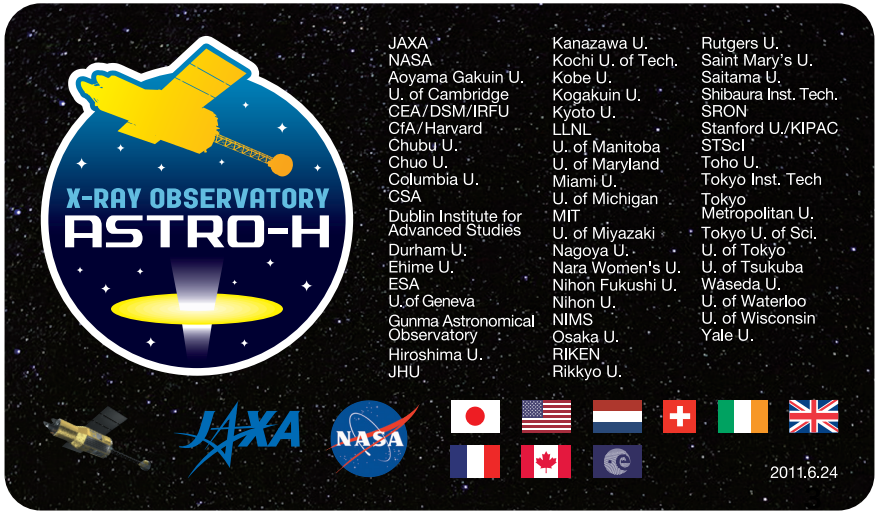
ASTRO-H is an international X-ray observatory, which is the 6th in the series of the X-ray observatories from Japan. It is currently planned to be launched in 2014 with an H-IIA rocket from the Tanegashima Space Center, Kagoshima, Japan.



European Participation

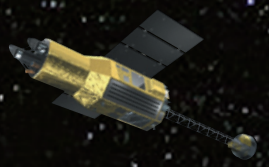
SRON & U. of Geneva
Filter Wheel for SXS
CEA/DSM/IRFU
Contribution to BGO Shield/ASICS for HXI
ESA
Three Science Advisors from Europe
Felix Aharonian
Andy Fabian (Chair: Science Advisor Team)
Jelle Kaastra
Contribution to SXS/HXI/SGD/HXT

More than 160 scientists from Japan/US/Europe/Canada



2. ASTRO-H

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.



JAXA

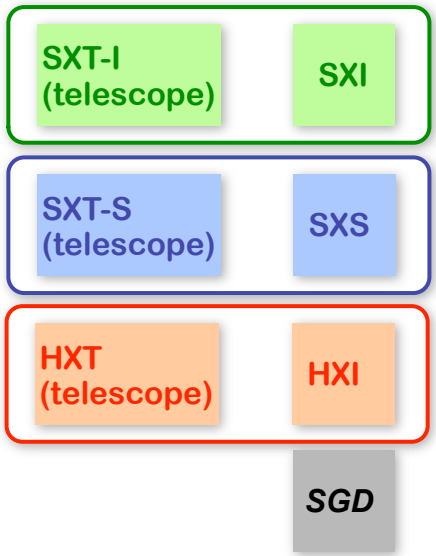
NASA

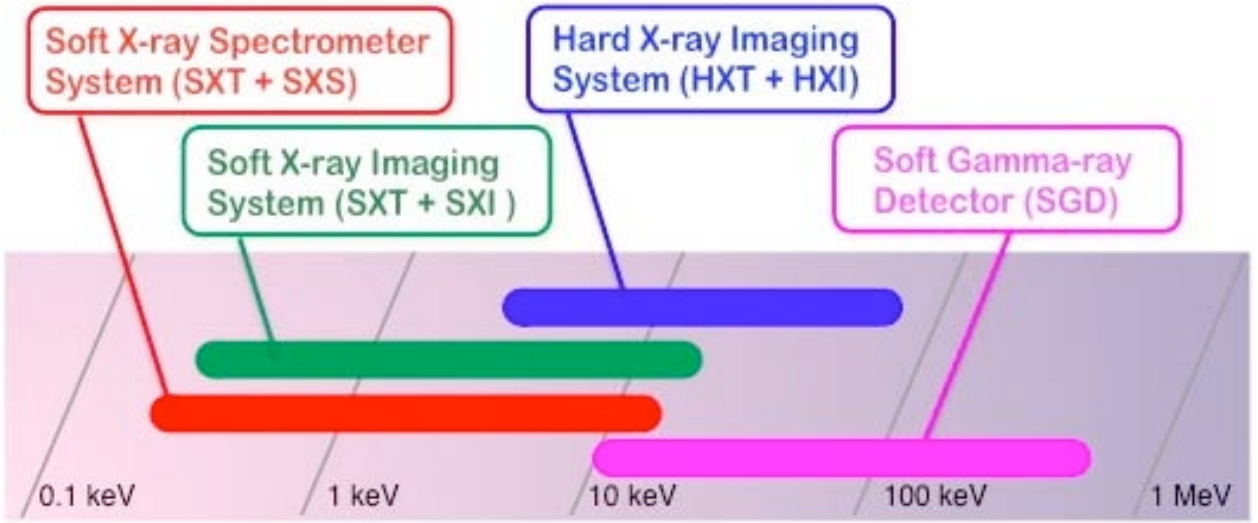
2011.6.24

2. ASTRO-H

1. Wide Band /High Sensitivity Observation

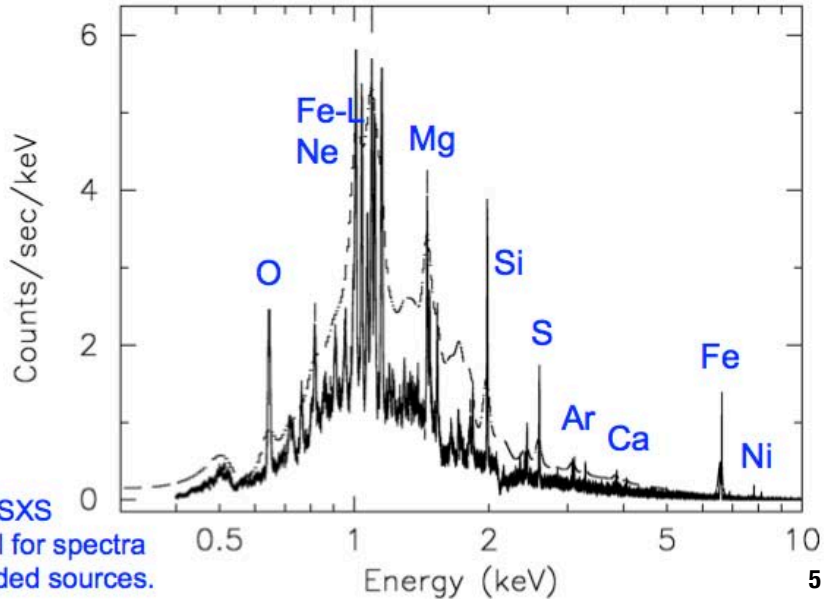
0.3 keV - 600 keV : Four Instruments including Hard X-ray Focusing optics





2. High Resolution Spectroscopy by a micro-calorimeter array

5 eV (FWHM) @ 6 keV



2. ASTRO-H Operation

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.

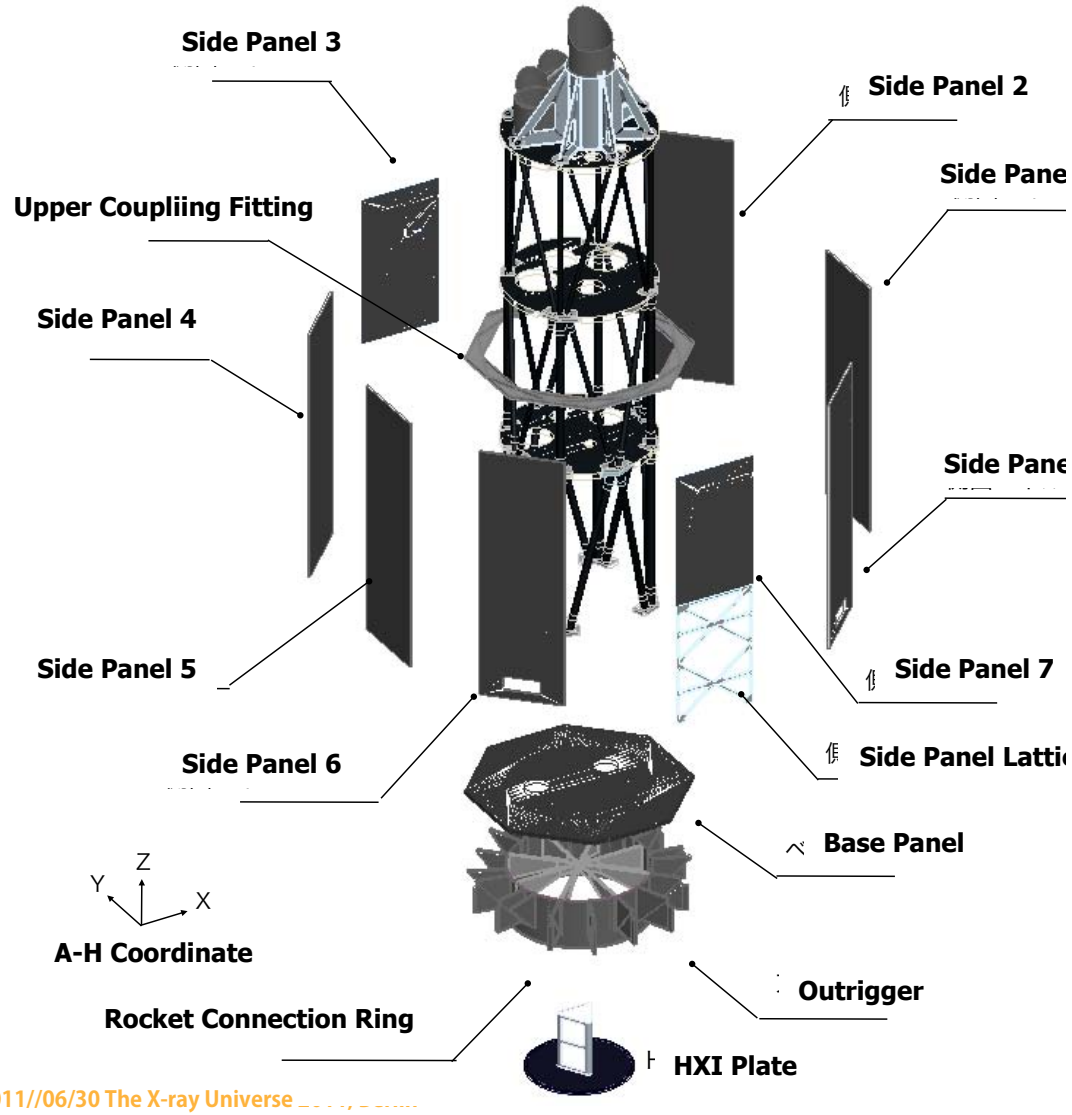
Time Allocation (TBC)

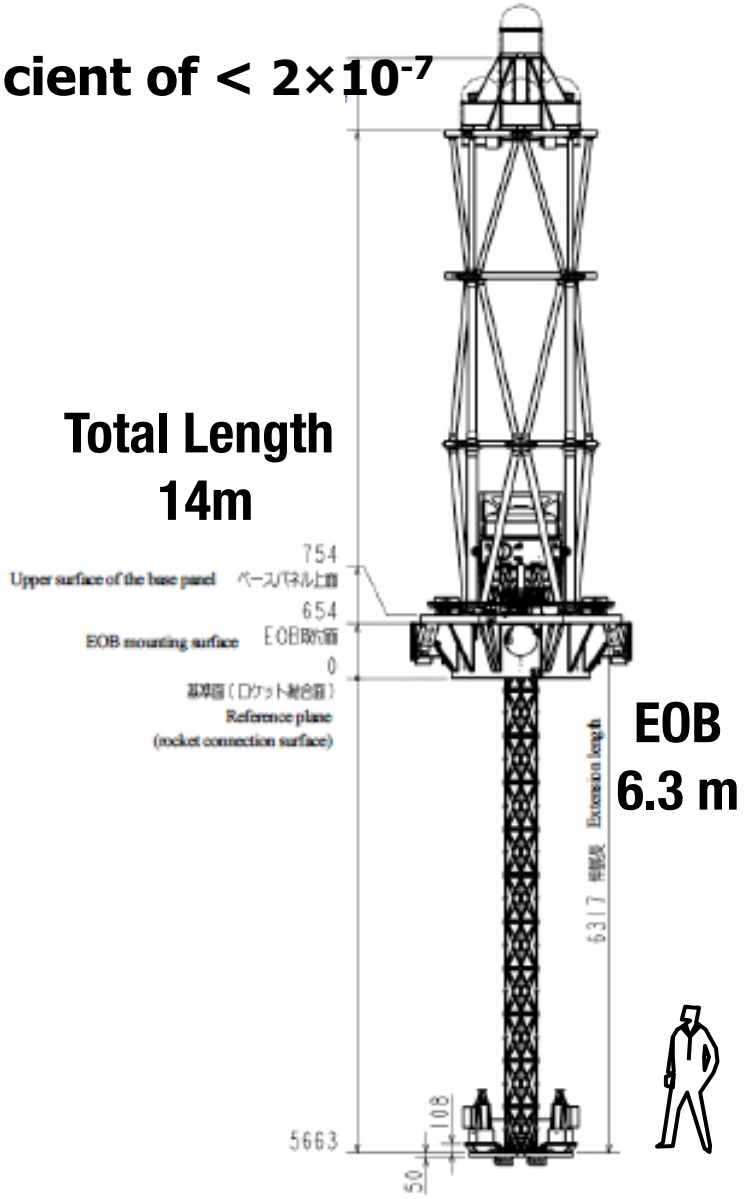
Phase 0 :	3 Months	: Satellite/Instruments Check out
Phase 1 :	6 Months	: SWG 100 % (PV Phase, including Calibration)
Phase 2 :	12 Months	: SWG Carry Over 15 %, GO 75 %, Observatory 10 %
Phase 3 :	Rest of the mission	: KeyProject 15 % (TBD) , GO 75 %, Observatory 10 %

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.

3. ASTRO-H : Satellite

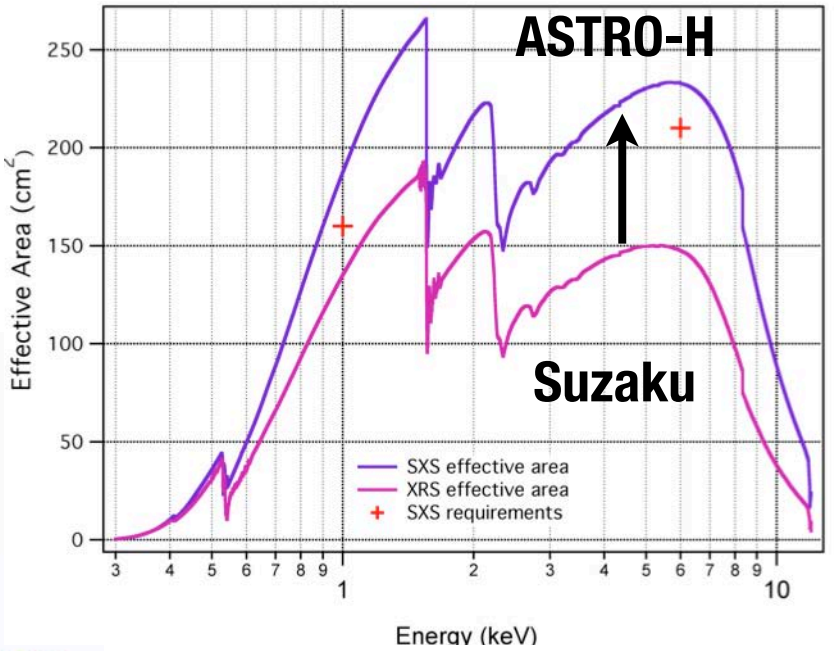
The entire structure forms a "telescope"
In order to minimize thermal distortion,
CFRP is used with thermal expansion coefficient of < 2×10^{-7}

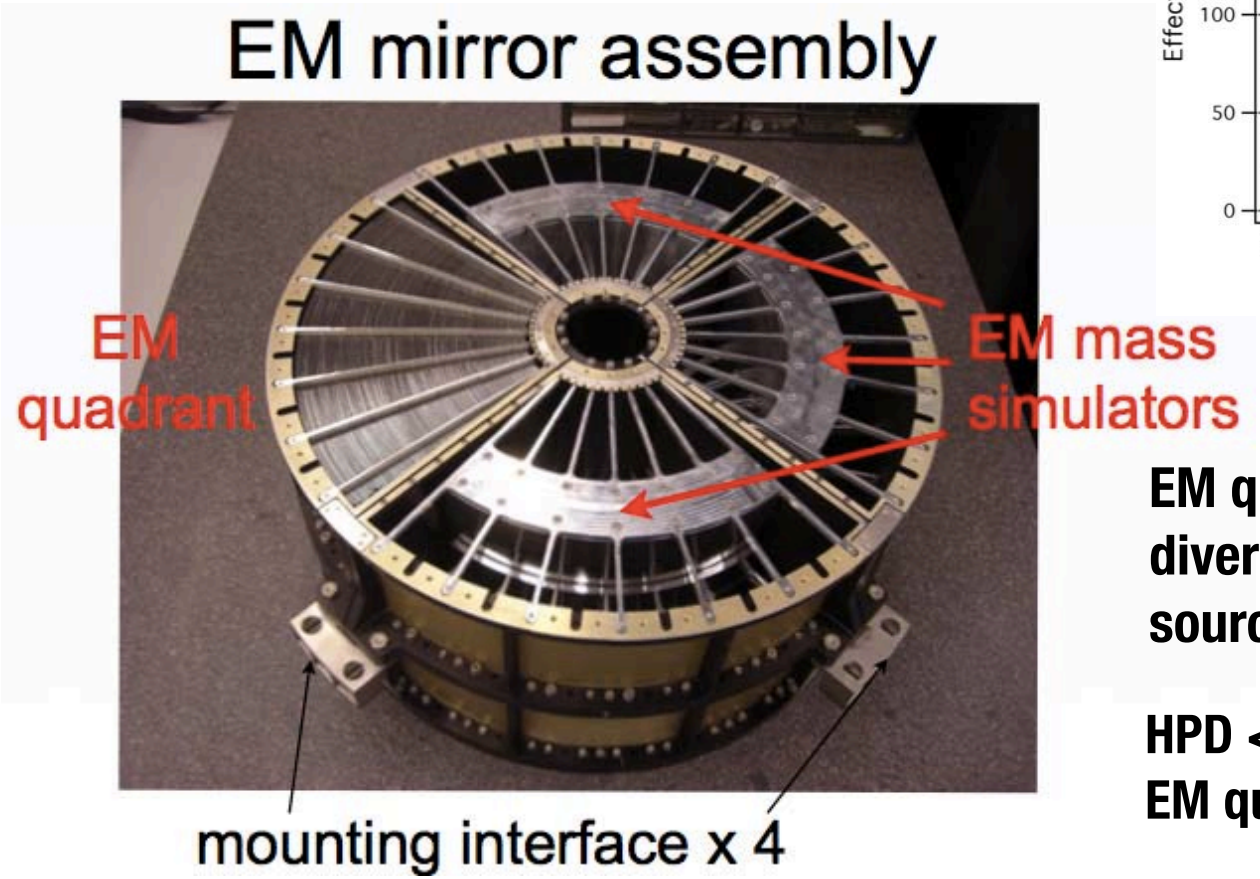




3. ASTRO-H : Soft X-ray Telscope for SXS & SXI

Soft X-ray Telescope (SXT) will be an upgraded version of the Suzaku X-ray telescope (XRT). The diameter and focal length is larger, thus number of the nesting shells are increased.





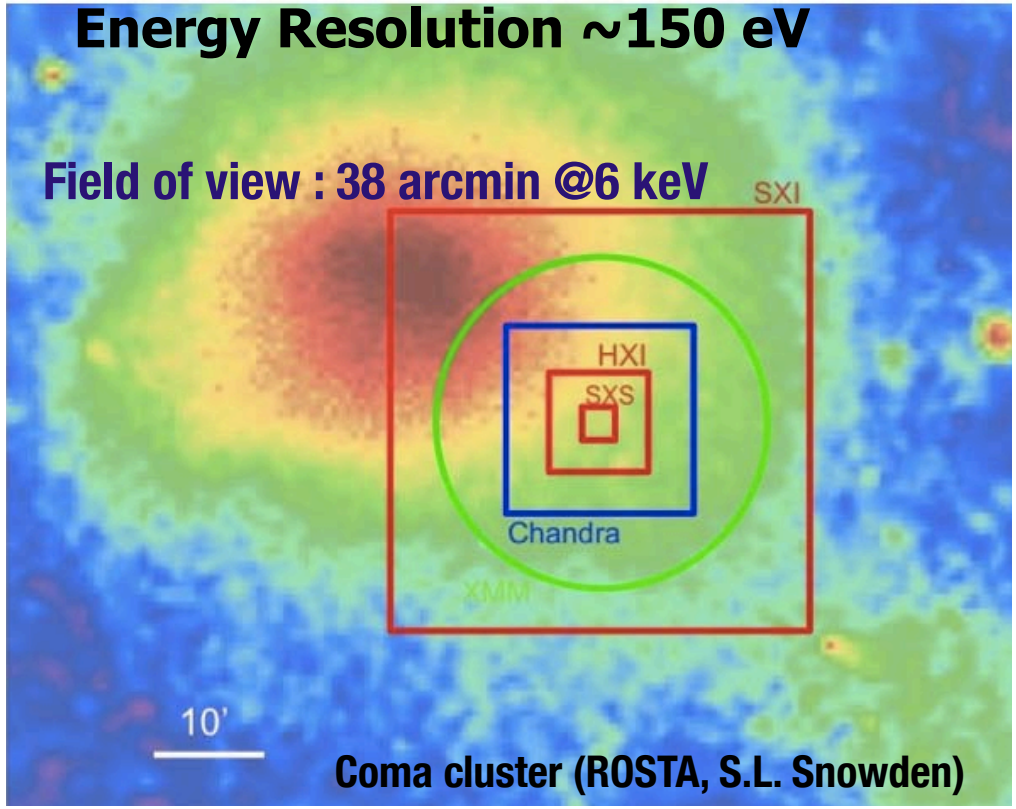
EM quadrant fully illuminated by diverging X-ray beam from the source 100 m away (at GSFC)

HPD < 1.3 arcmin is achieved from the EM quadrant (the requirement is 1.7')

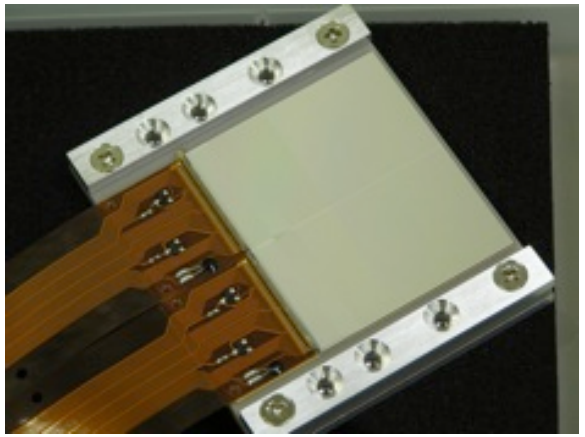
NASA/GSFC/MSFC/Nagoya/ISAS

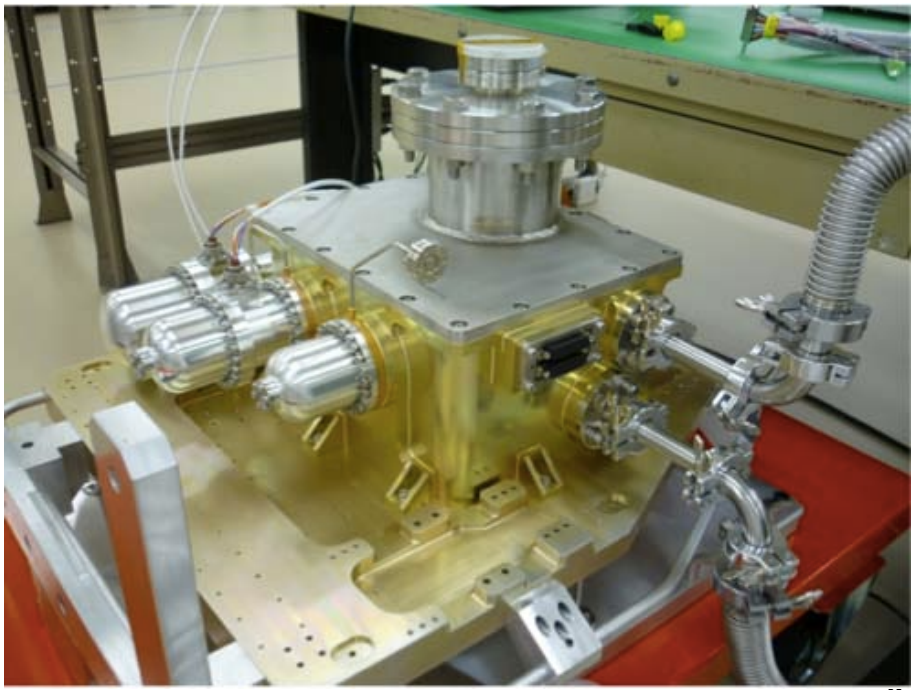
3. ASTRO-H : Soft X-ray Imager (SXI): X-ray CCD

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



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

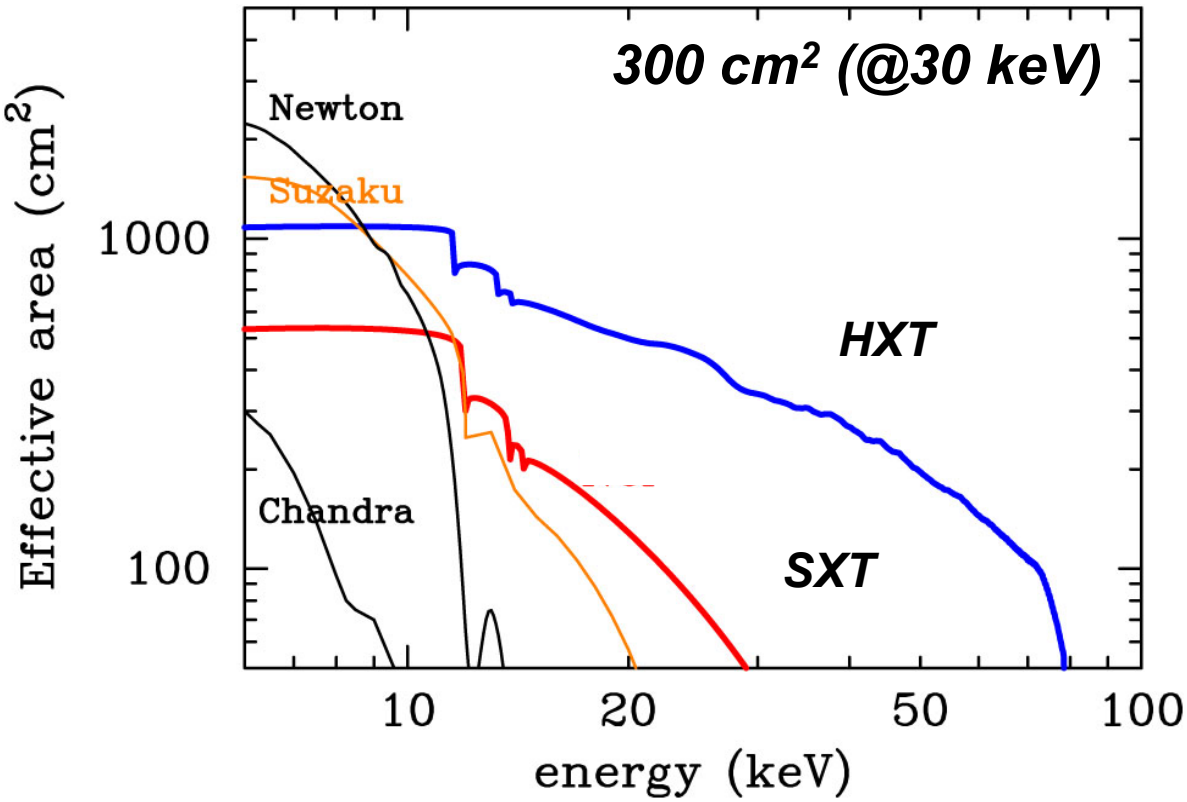


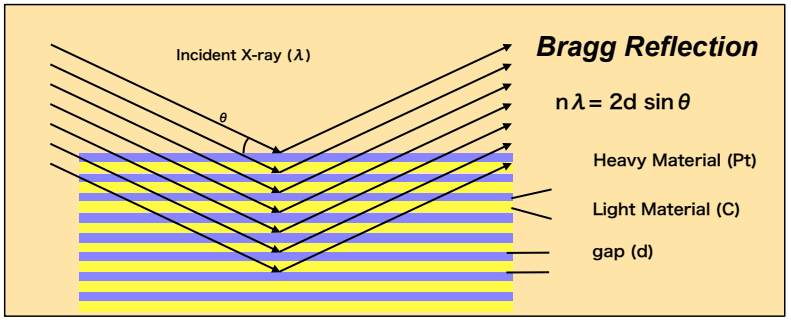


Recent Progress
EM Model/
Thermal Balance Test
(2011/June)

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

- 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

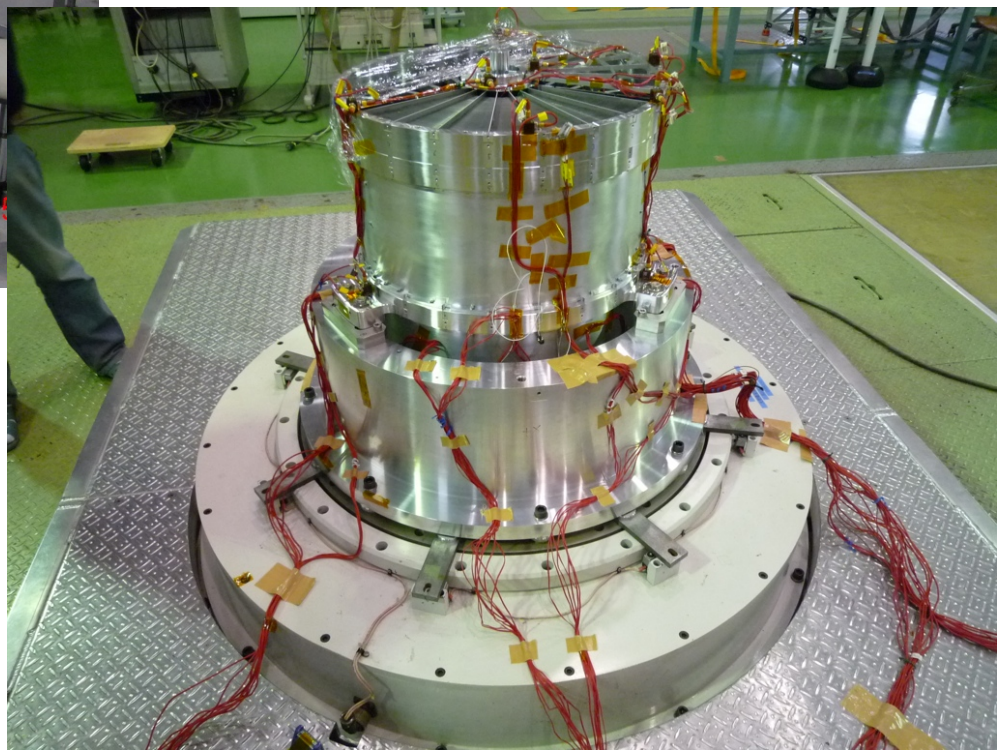




HPD < 1.7 arcmin is the requirement

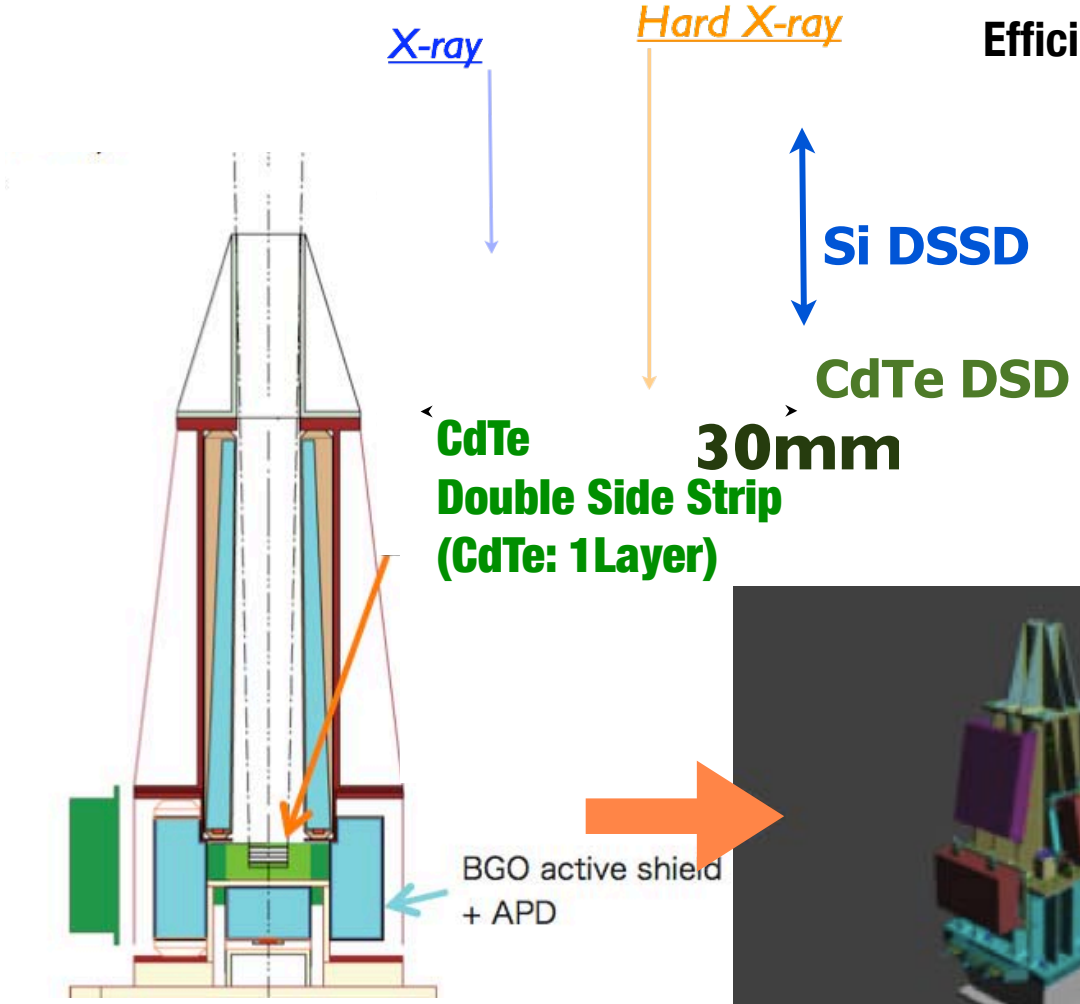
3. ASTRO-H : Hard X-ray Telescope (HXT)

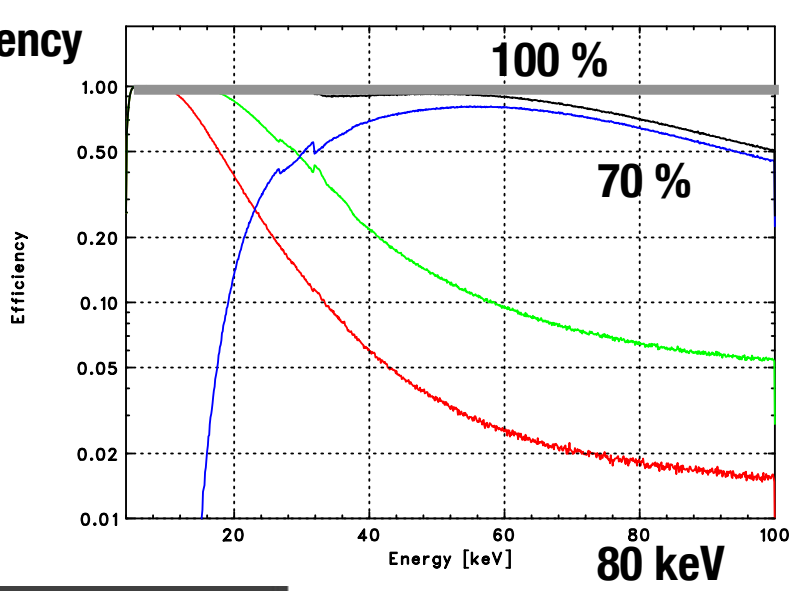
Recent Progress
Vibration Test (March 2011)

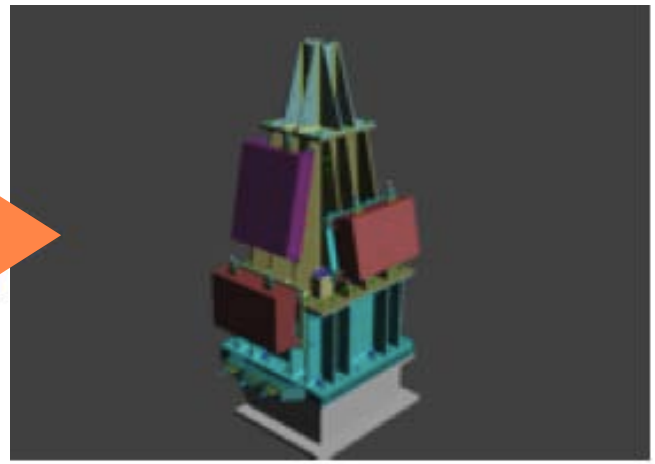


3. ASTRO-H : Hard X-ray Imager (HXI)

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 theSi part and are detected by the newly developed CdTe double sided cross-strip detector



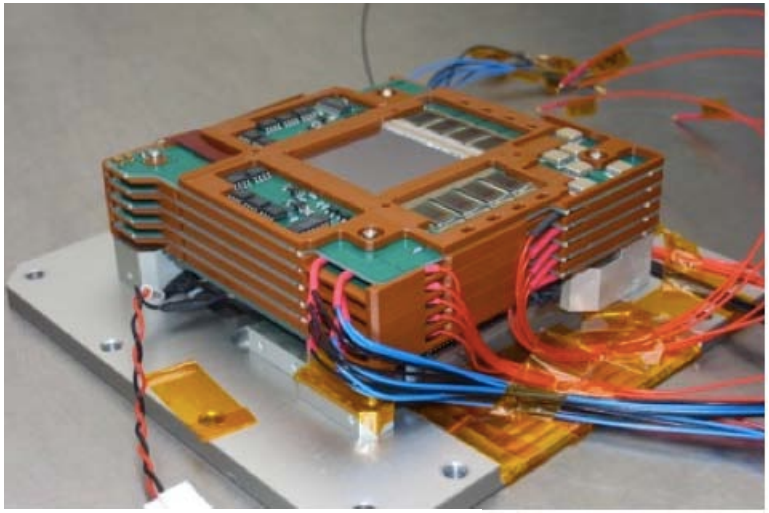


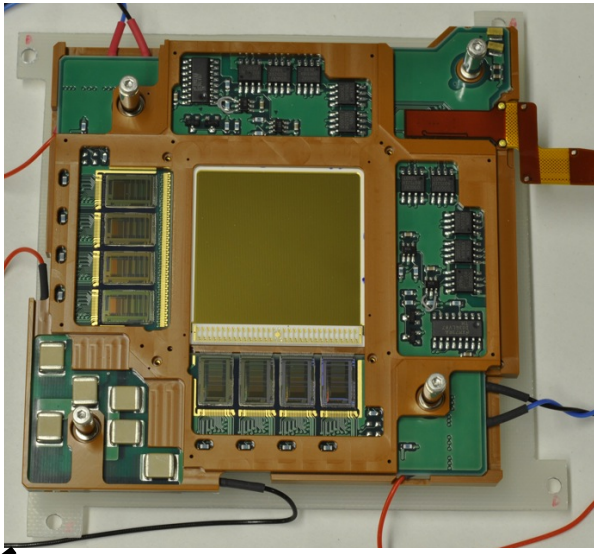


Stacked Si/CdTe Detector" and "Well-type BGO shield" will reduce background

3. ASTRO-H : Hard X-ray Imager (HXI) :

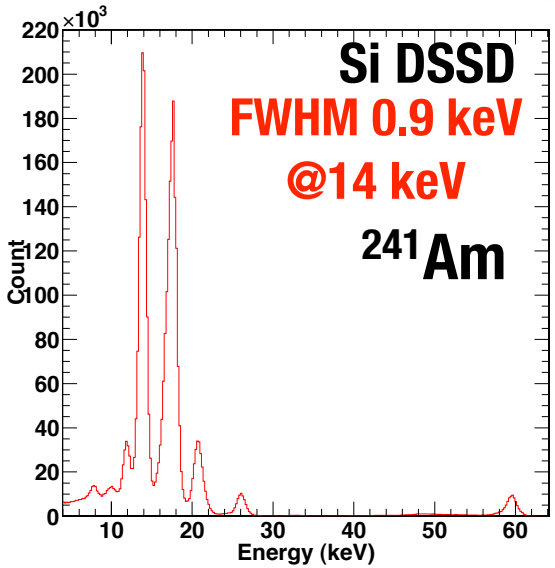
Engineering Model
4 layer of Si DSSD and 1 layer of CdTe DSD

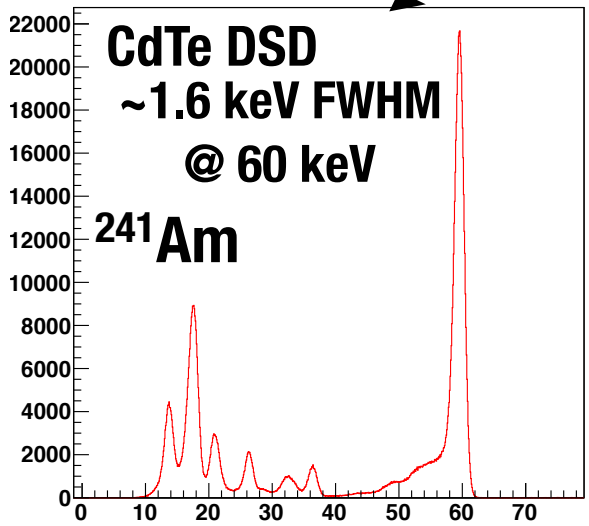


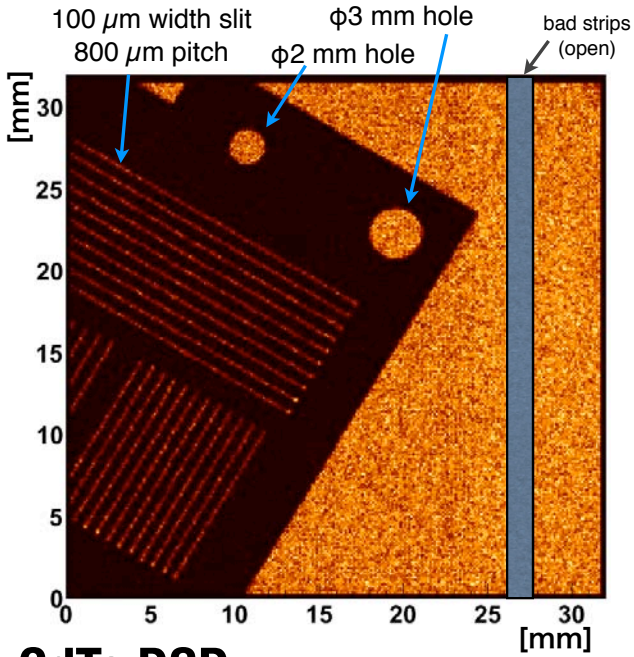


CdTe DSD (ISAS)

250 micron pitch strips for both side

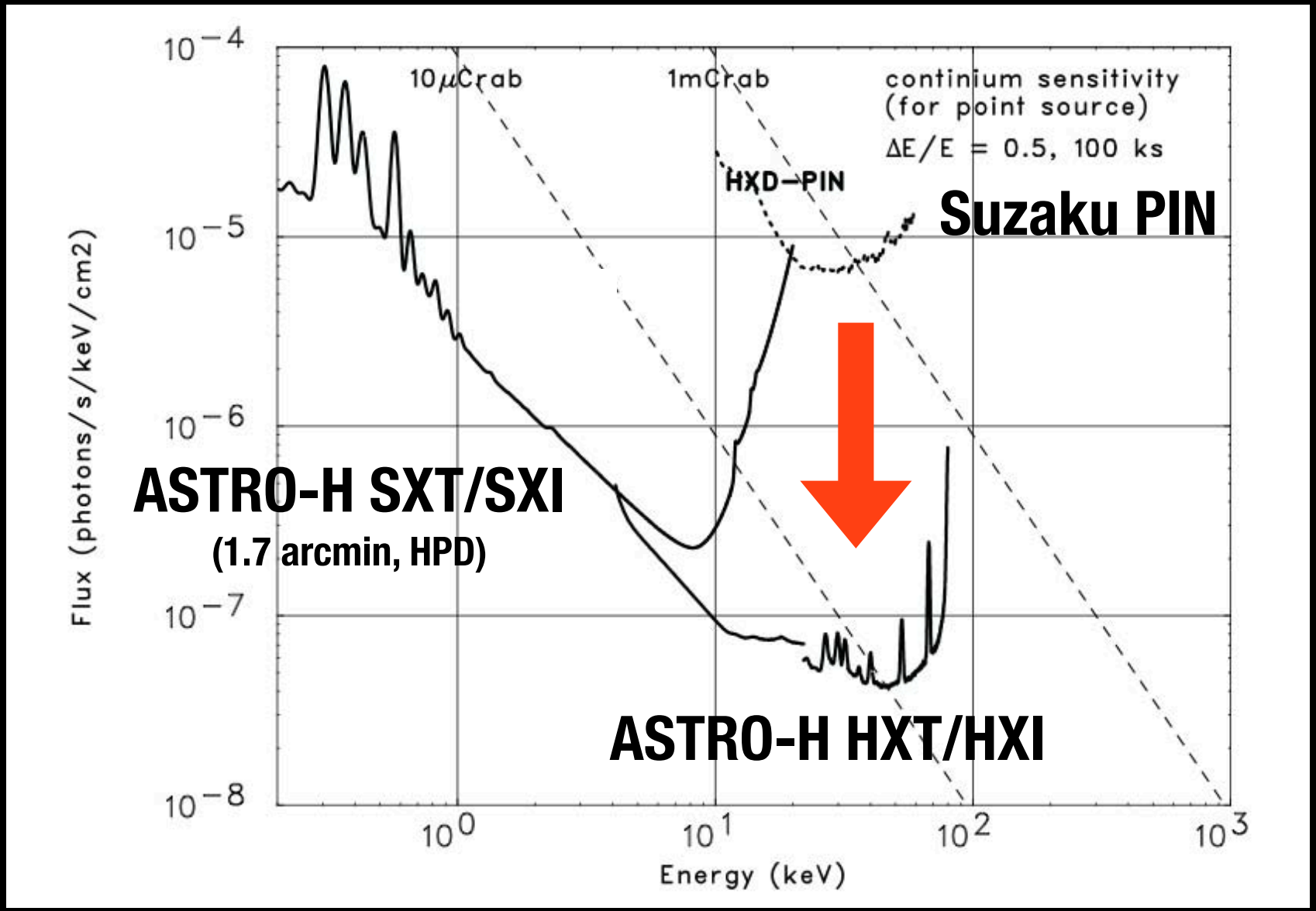






CdTe DSD

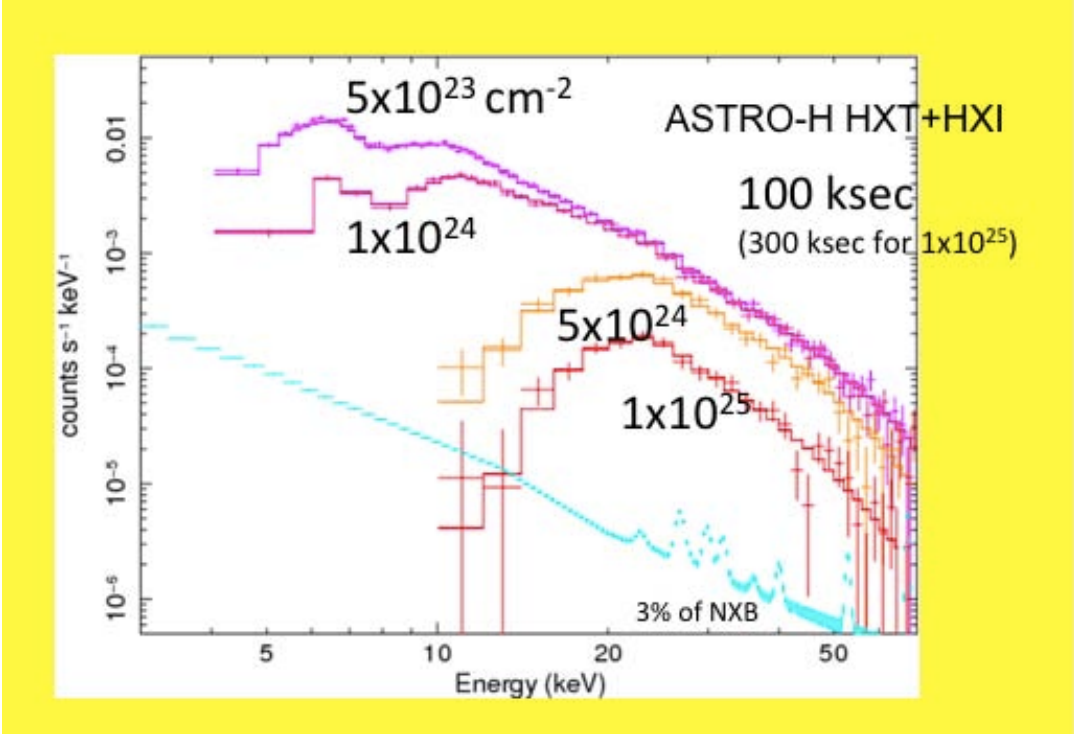
Power of Hard X-ray Telescope

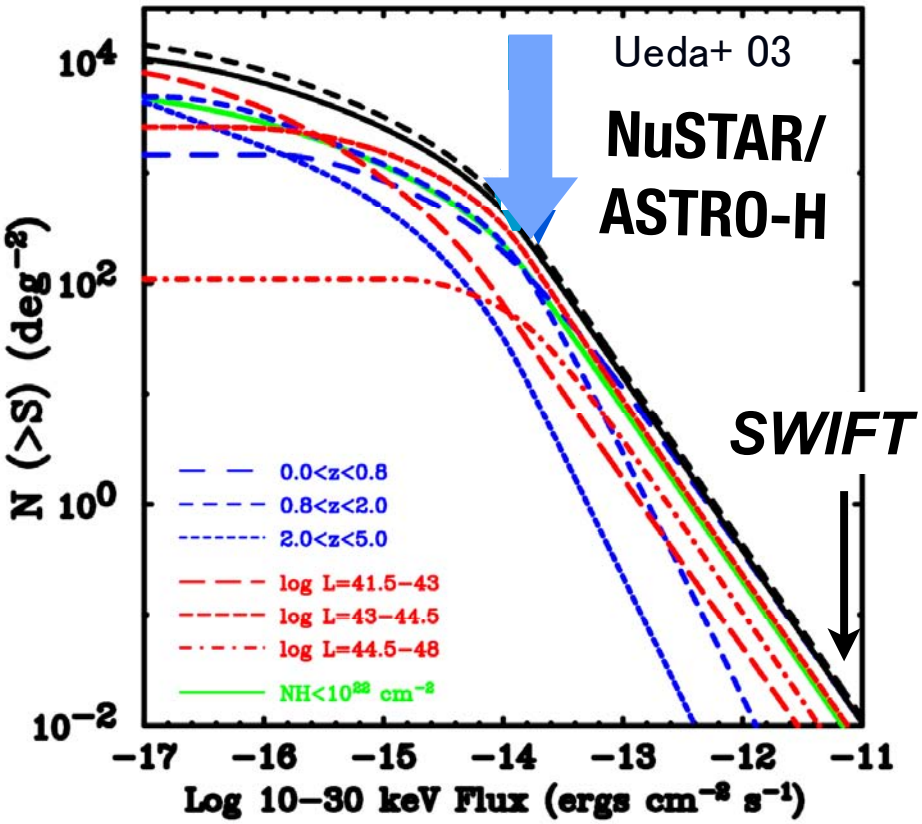


3. ASTRO-H: Performance of HXT + HXI

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.

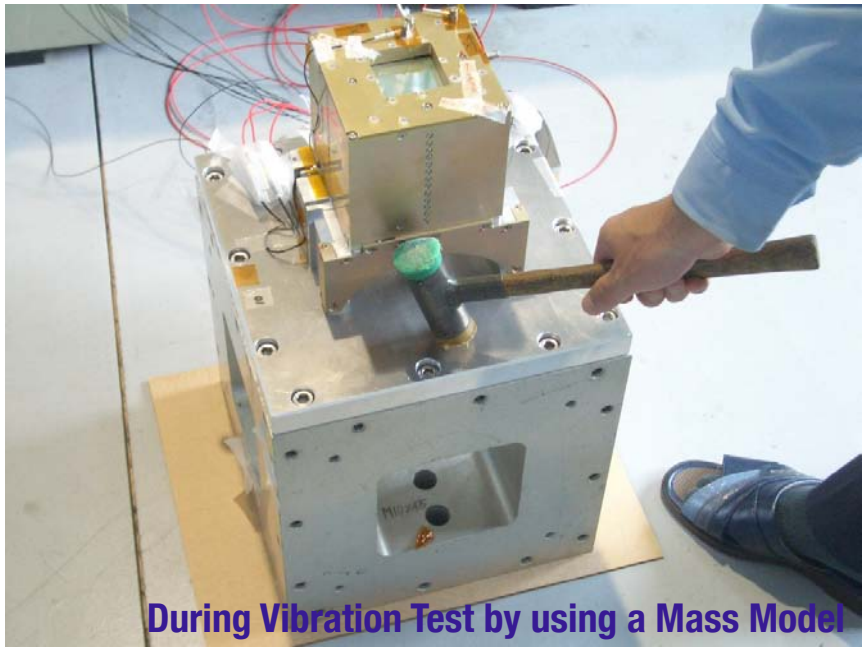
30-50% of Hard XRB will be resolved

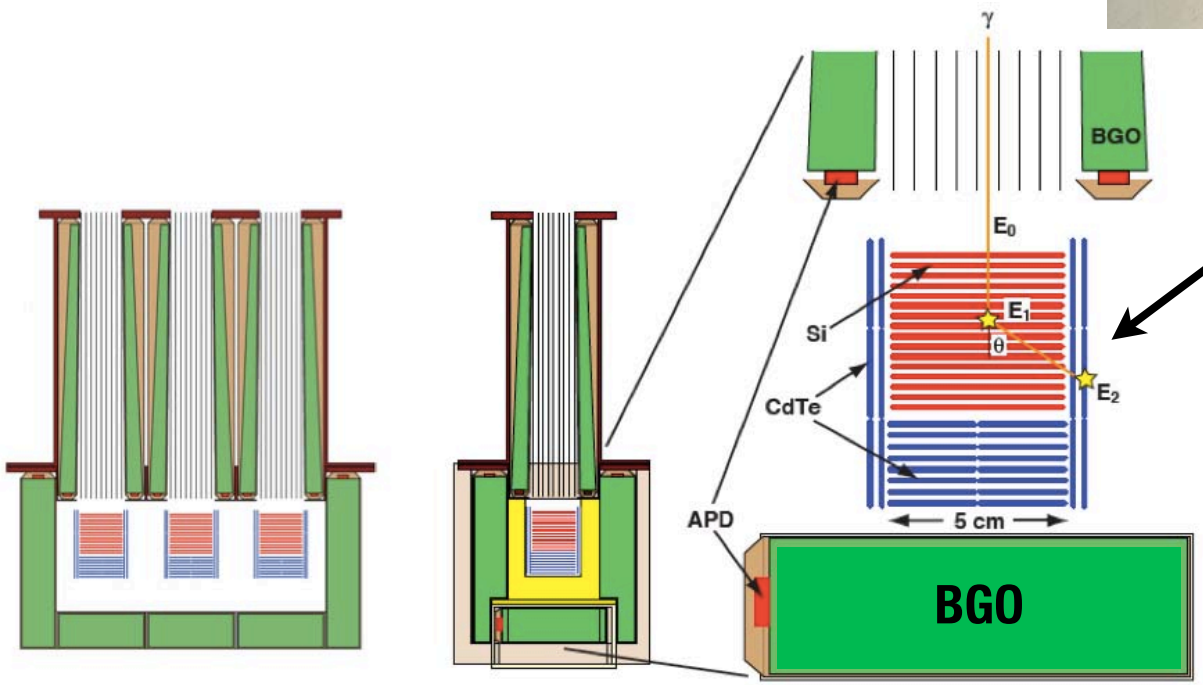




3. ASTRO-H: Soft Gamma-ray Detector

- 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.





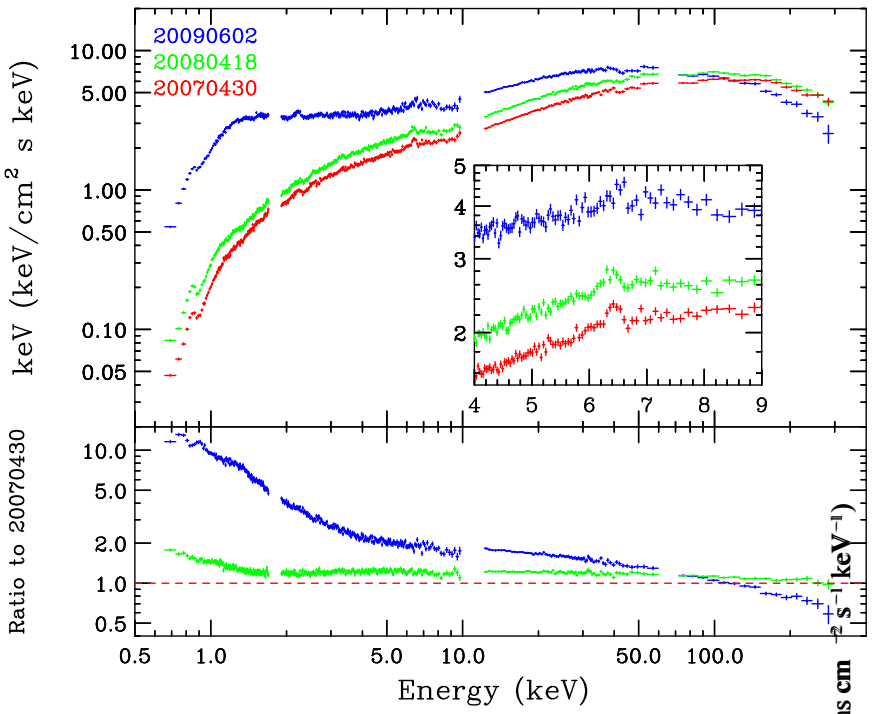
Si/CdTe Compton Camera (only select gamma-rays from the FOV)

Compton Kinematics

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

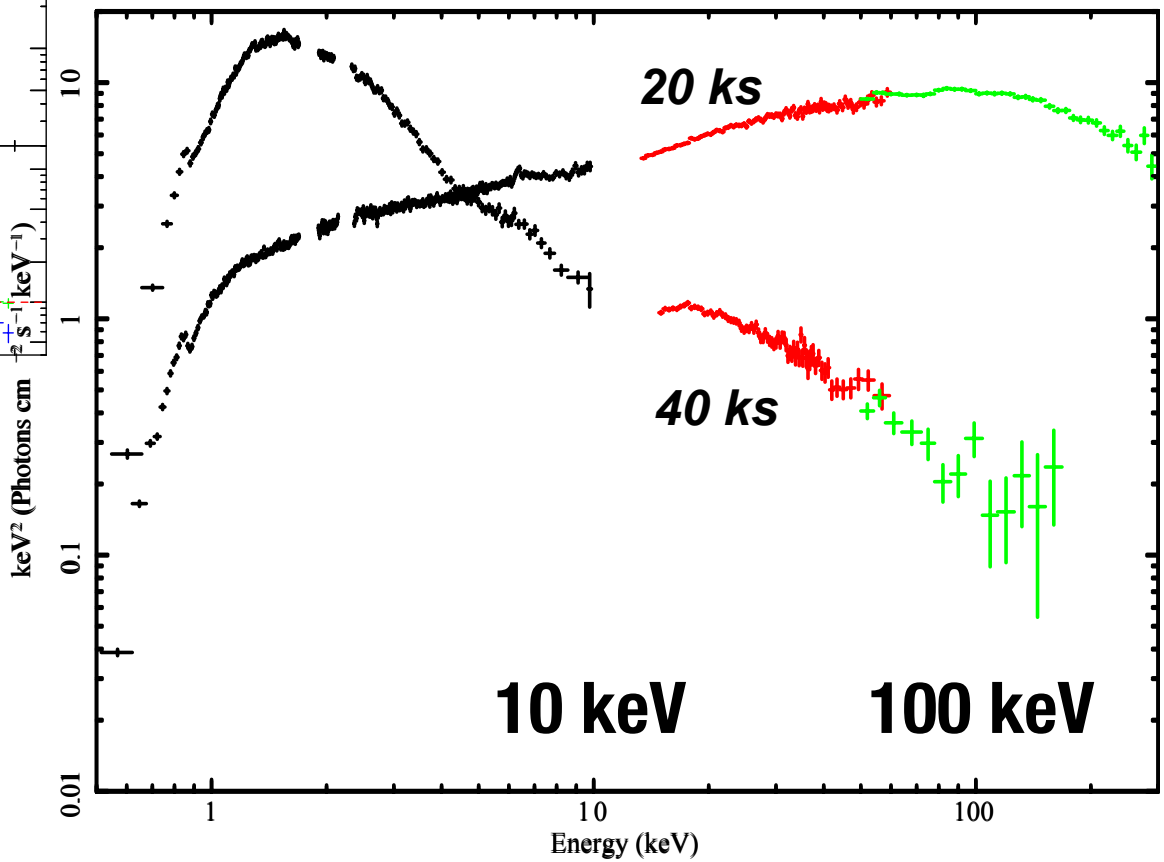
$$E_{\rm in} = E_1 + E_2$$

3. ASTRO-H: Wide-band Observation is so important!

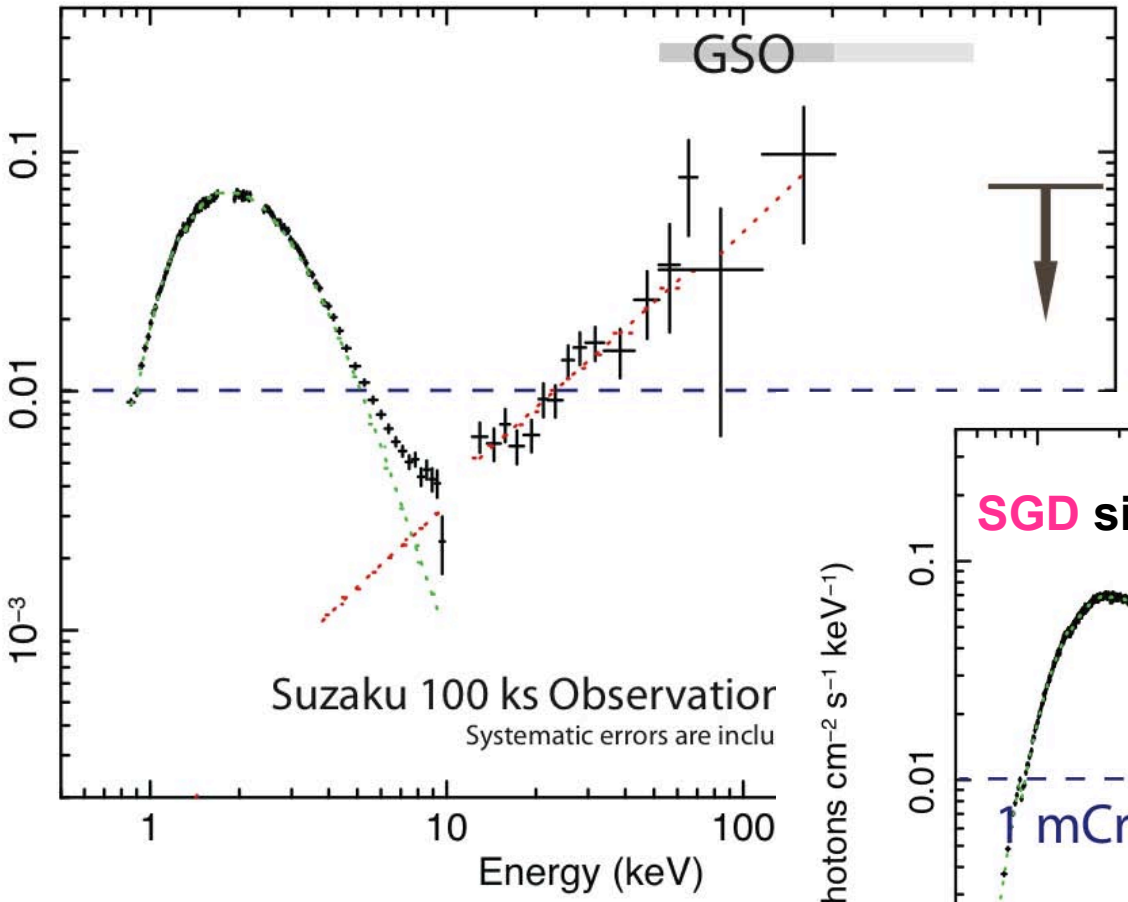


Observing Time
- 2009/06/02 14 ks
- 2008/04/18 27 ks
- 2007/04/30 38 ks

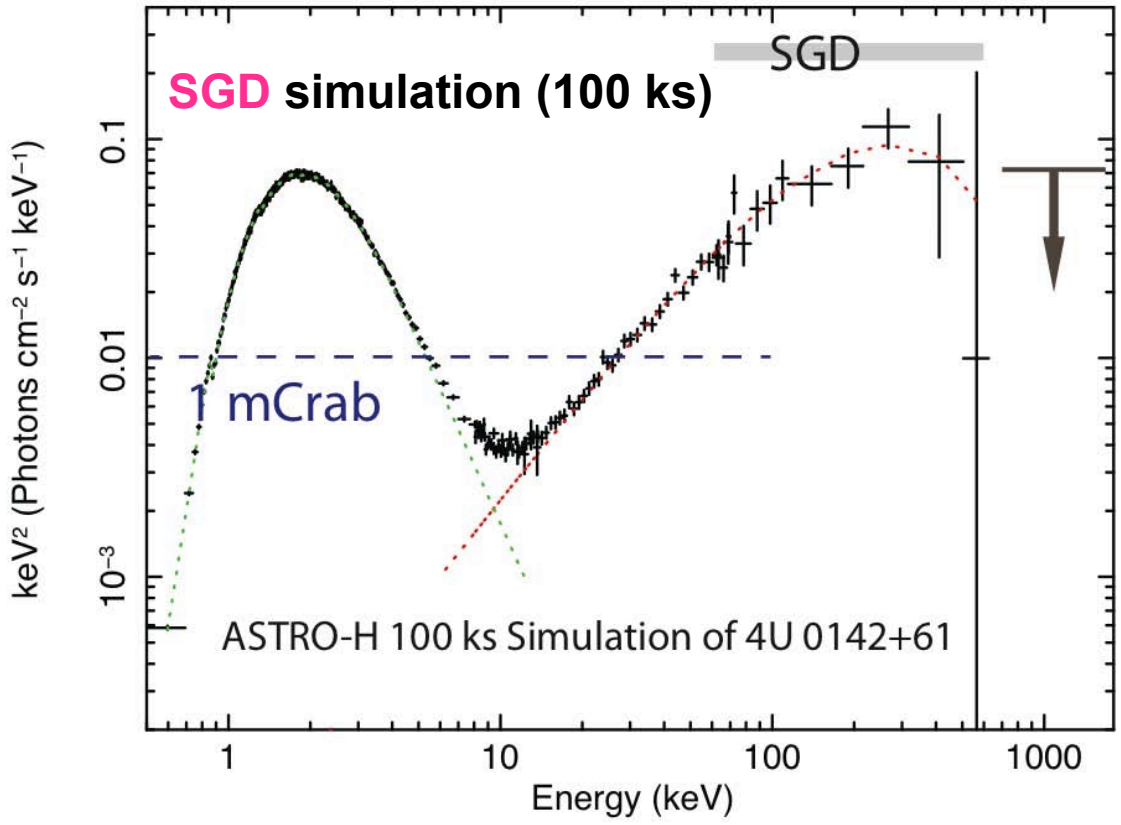
Suzaku Cyg X-1 Spectra (by S. Yamada)



3. ASTRO-H: SGD Performance - Magnetar 4U 0142+61

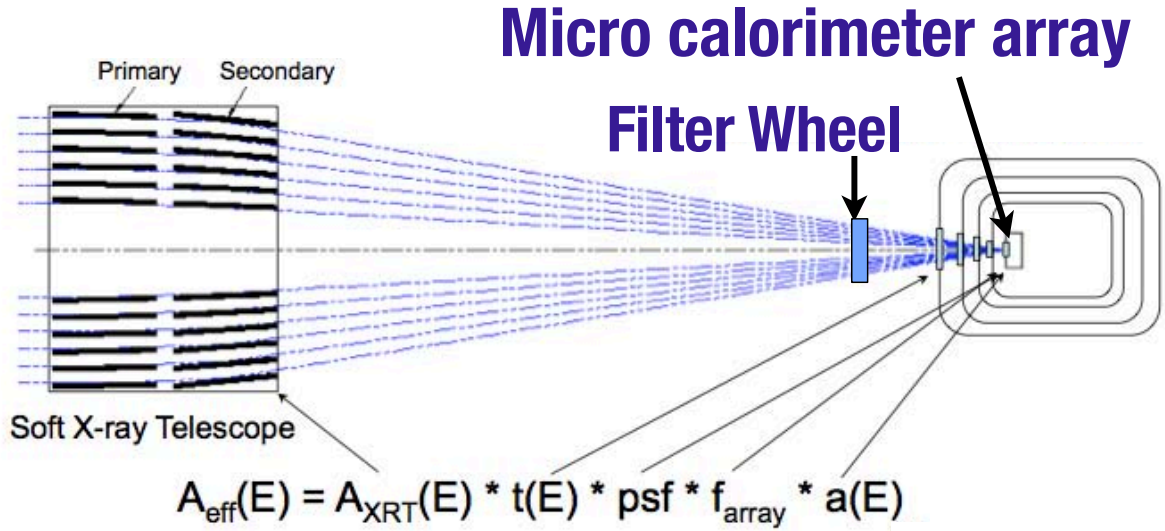


SGD will be able to measure spectra up to 600 keV with higher quality, and will constrain the nature of the hard component.

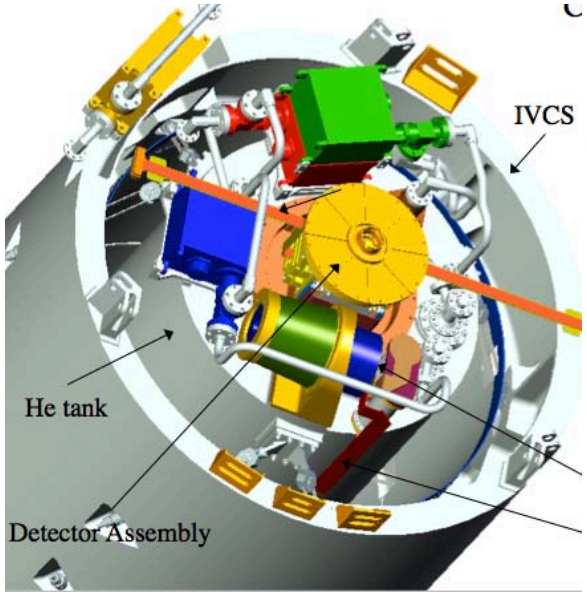


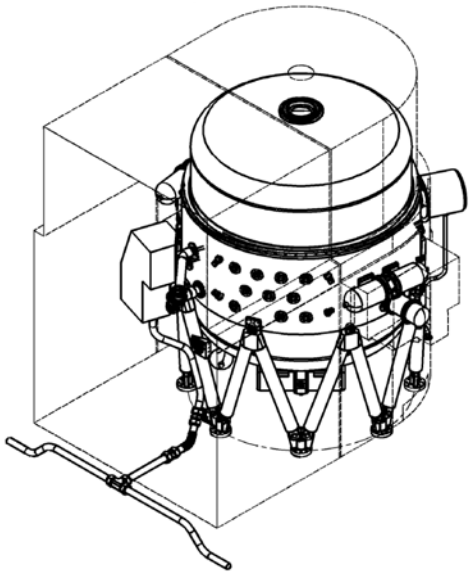
(Simulation by T. Enoto)

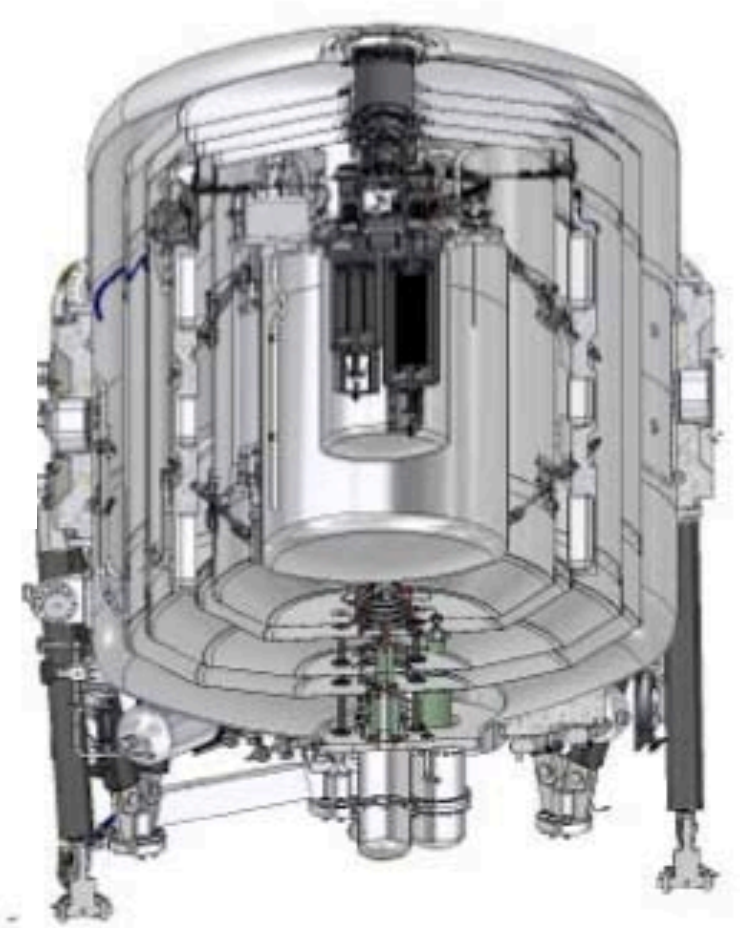
3. ASTRO-H: Soft X-ray Spectrometer (SXS)



Detector to be Operated at 50 mK



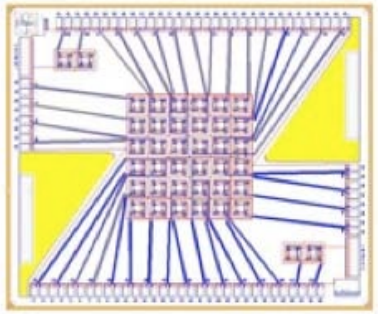




Liq. He+2stageST Cooler+JT Cooler+ADR

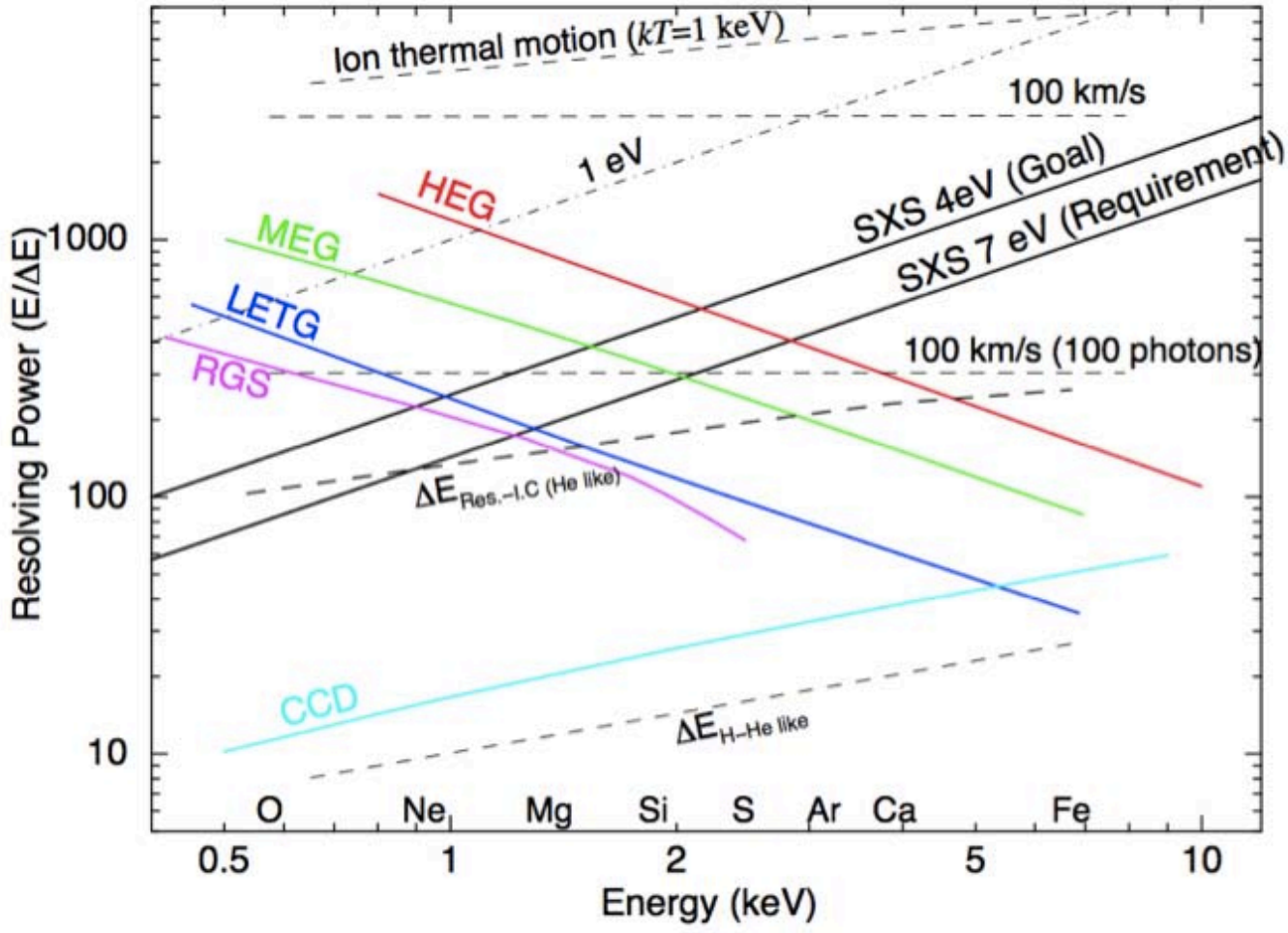
3. ASTRO-H: Soft X-ray Spectrometer (SXS)

- High Resolution Spectroscopy by a micro calorimeter array



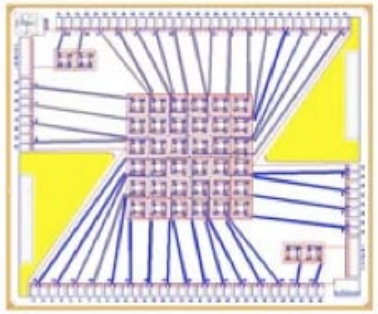
814 μm
6x6 array
34 pixel readout
50 mK

$210cm^2$@6keV
for micro-calorimeter



3. ASTRO-H: Soft X-ray Spectrometer (SXS)

- High Resolution Spectroscopy by a micro calorimeter array



814 μm
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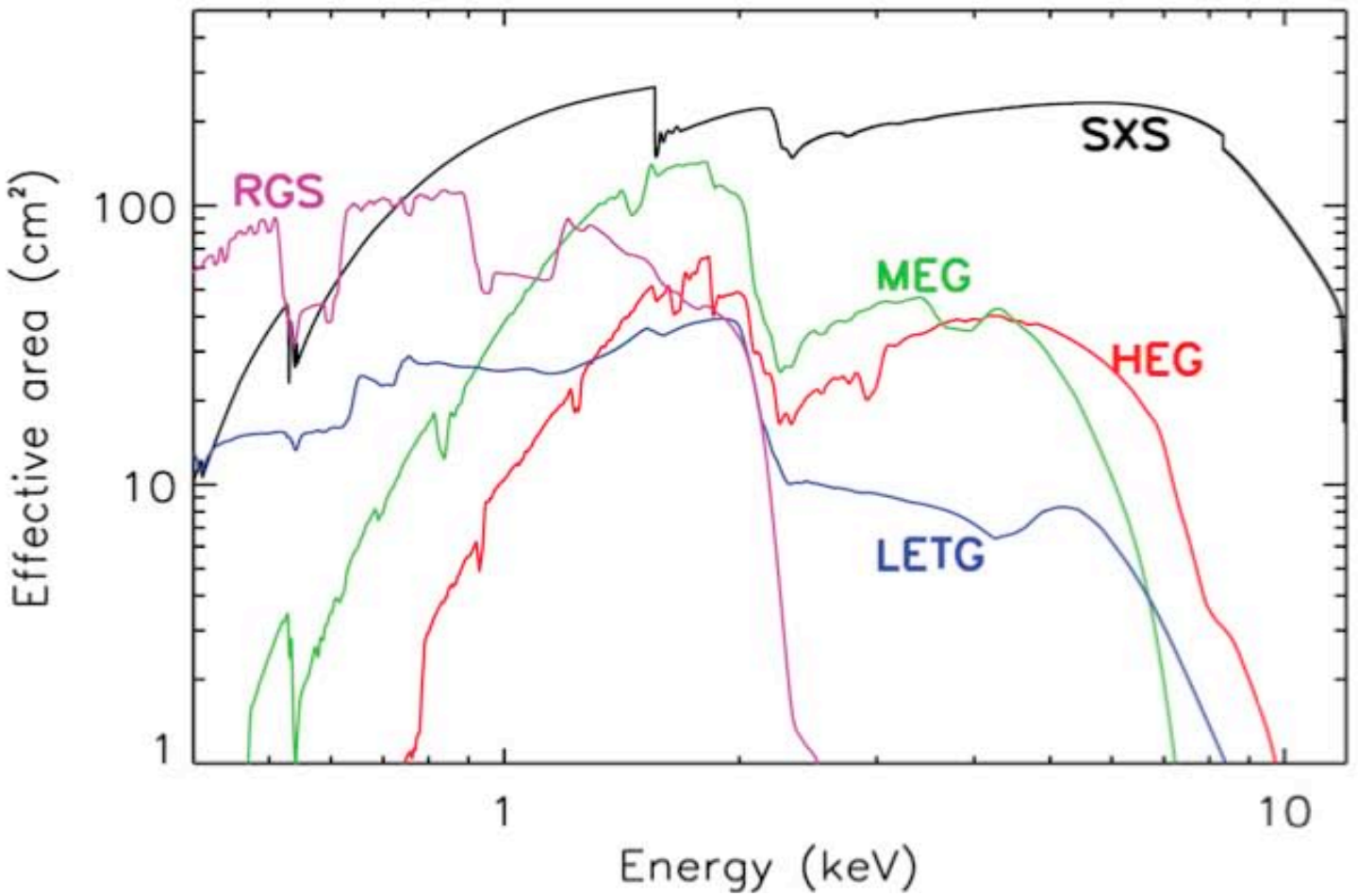
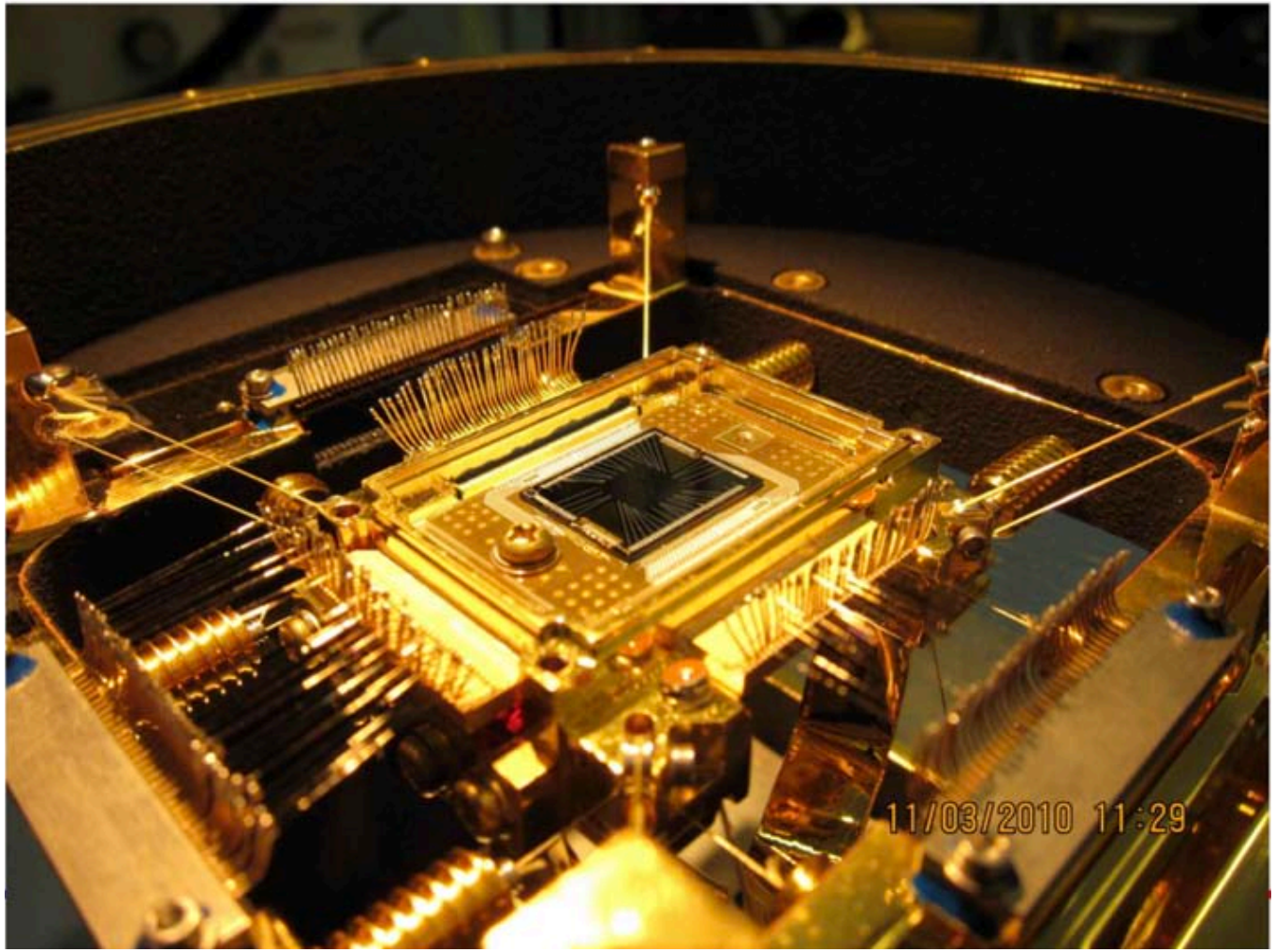


3. ASTRO-H: Soft X-ray Spectrometer (SXS)

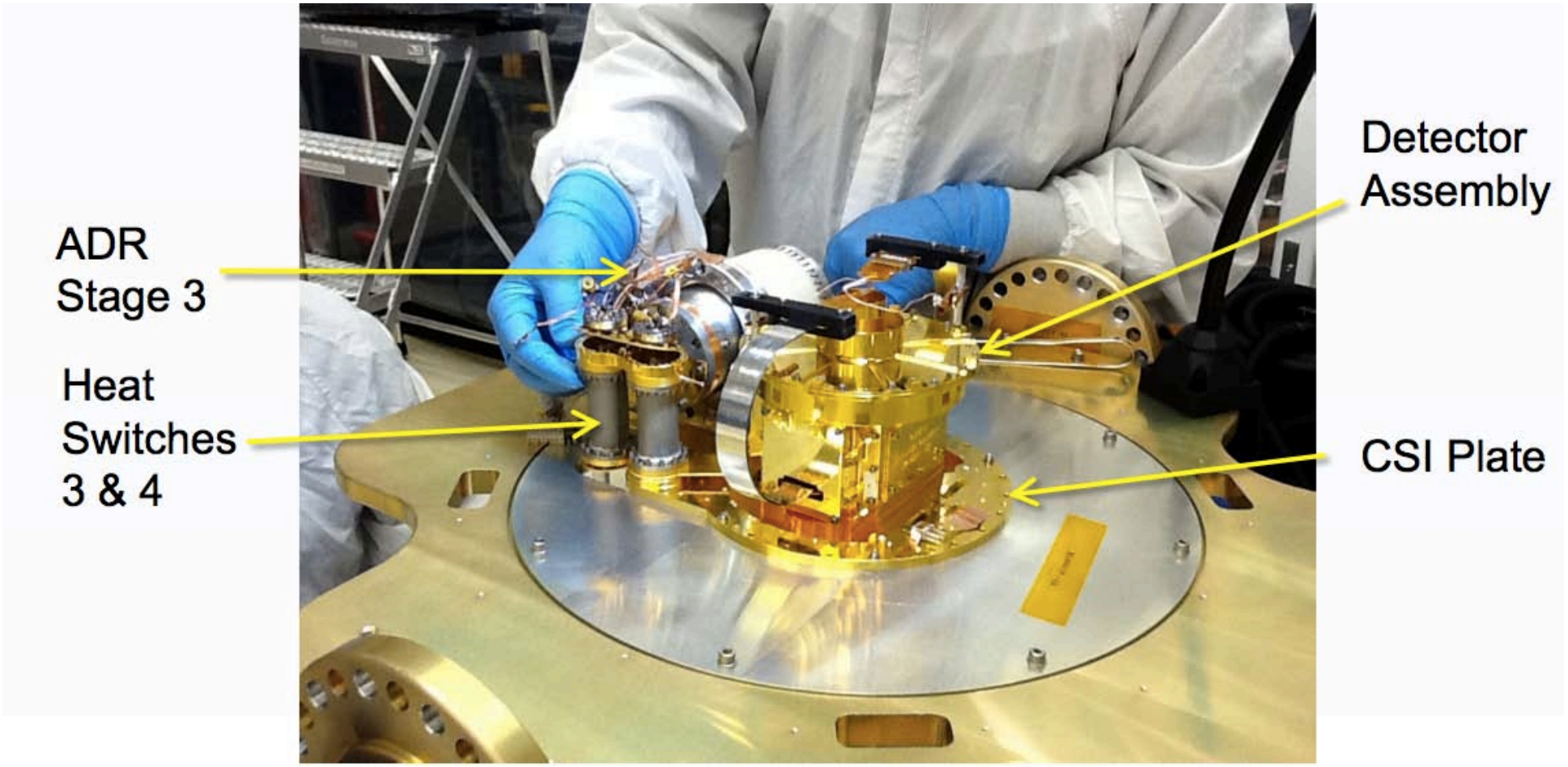
EM Detector System (Detector Assembly + Detector Array + Anti-co Detector)



NASA/GSFC

3. ASTRO-H: Soft X-ray Spectrometer (SXS)

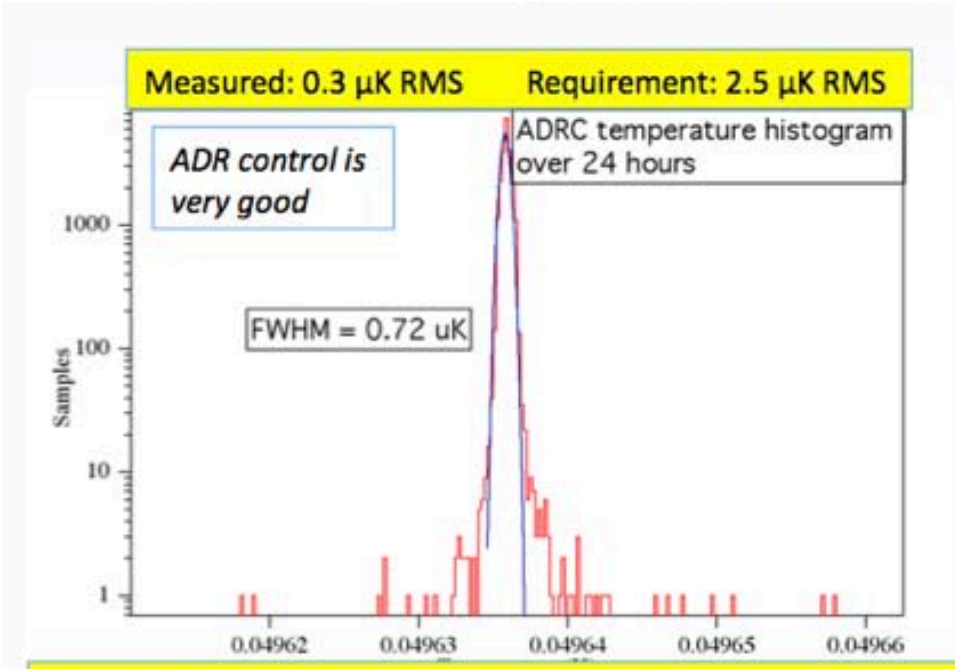
EM CSI as of 5/31/2011

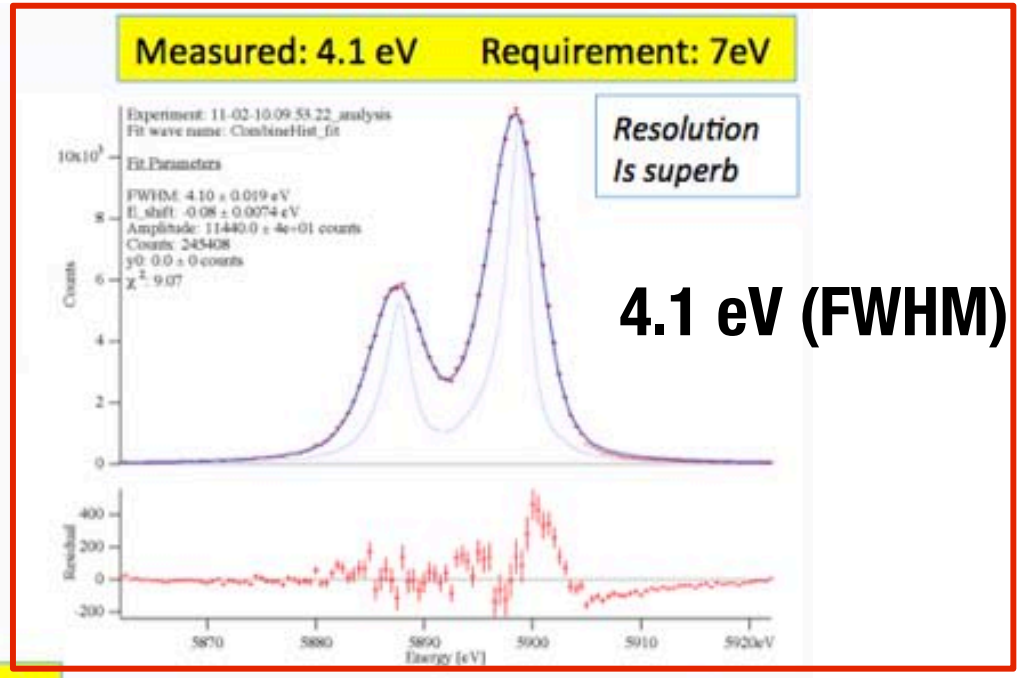


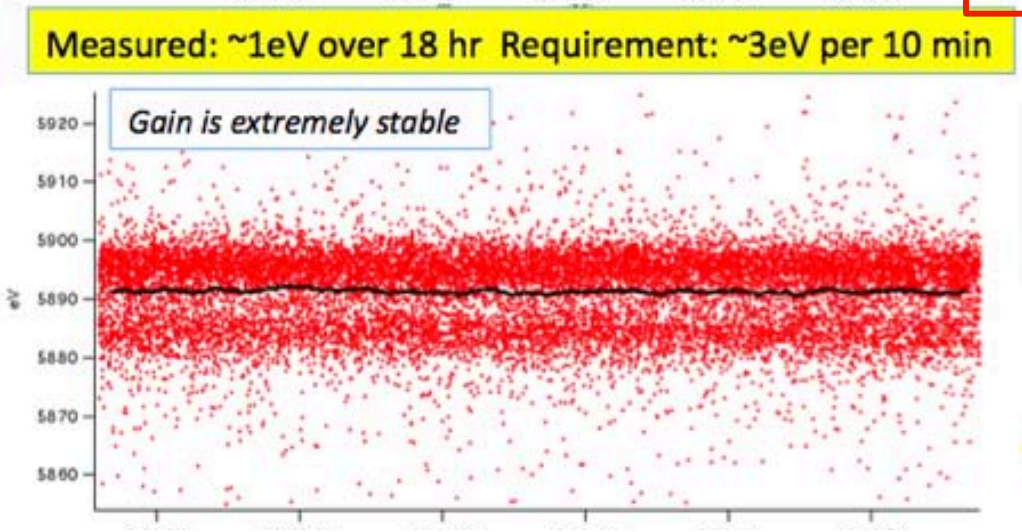
NASA/GSFC

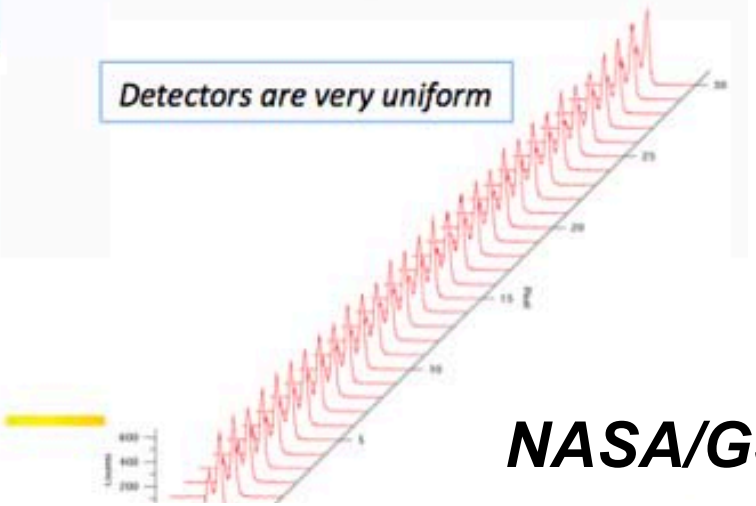
3. ASTRO-H: Soft X-ray Spectrometer (SXS)

Very Recent Results based on the Engineering Model of ASTRO-H



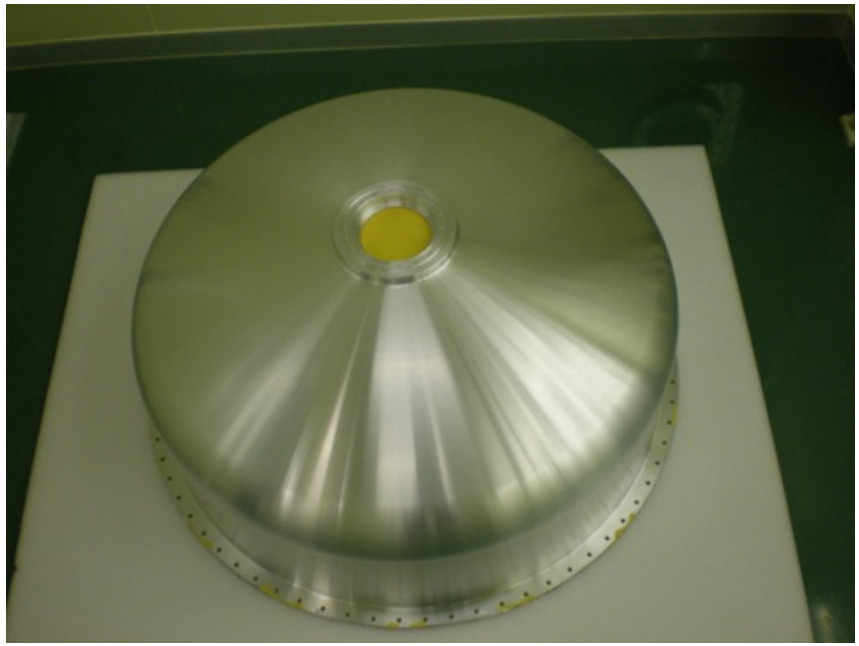


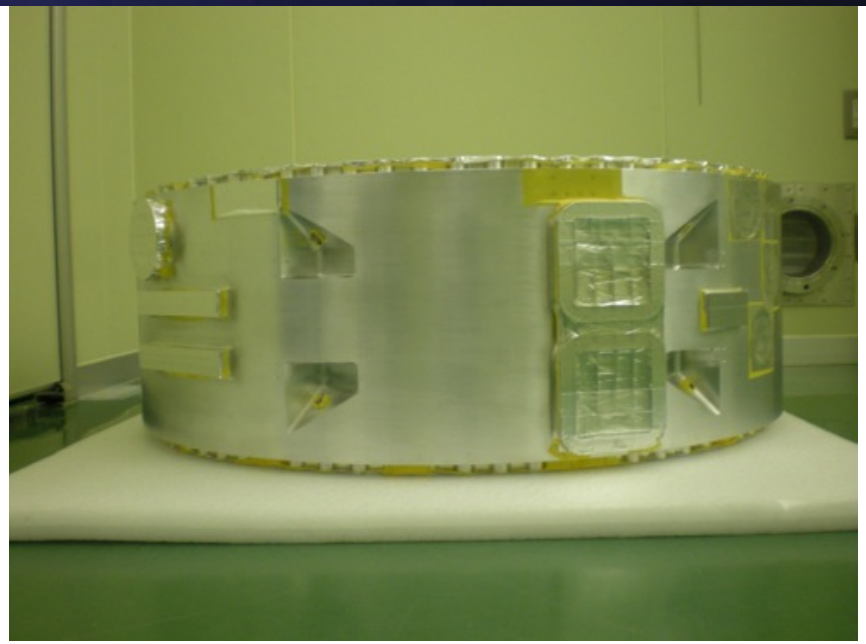


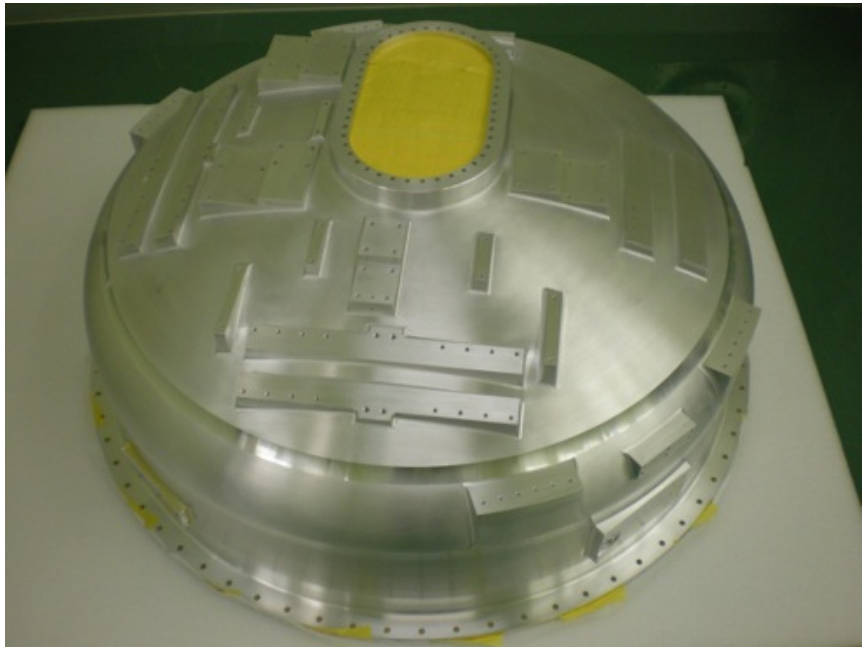


NASA/GSFC

3. ASTRO-H: SXS EM Dewar in progress



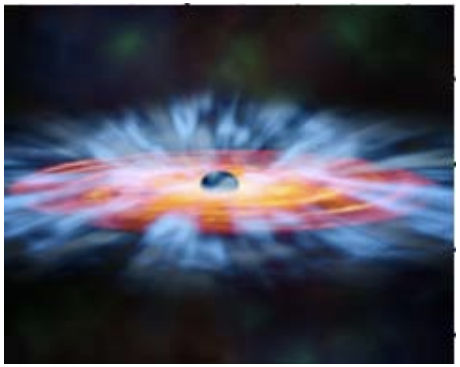




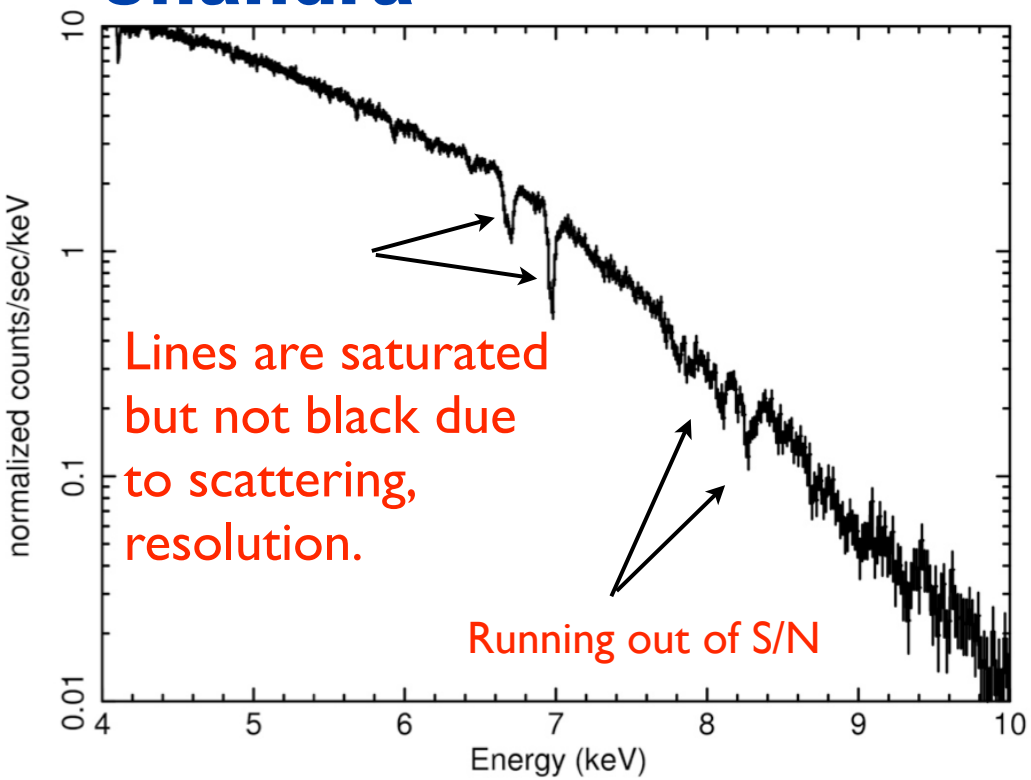
ISAS/JAXA & SHI

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.

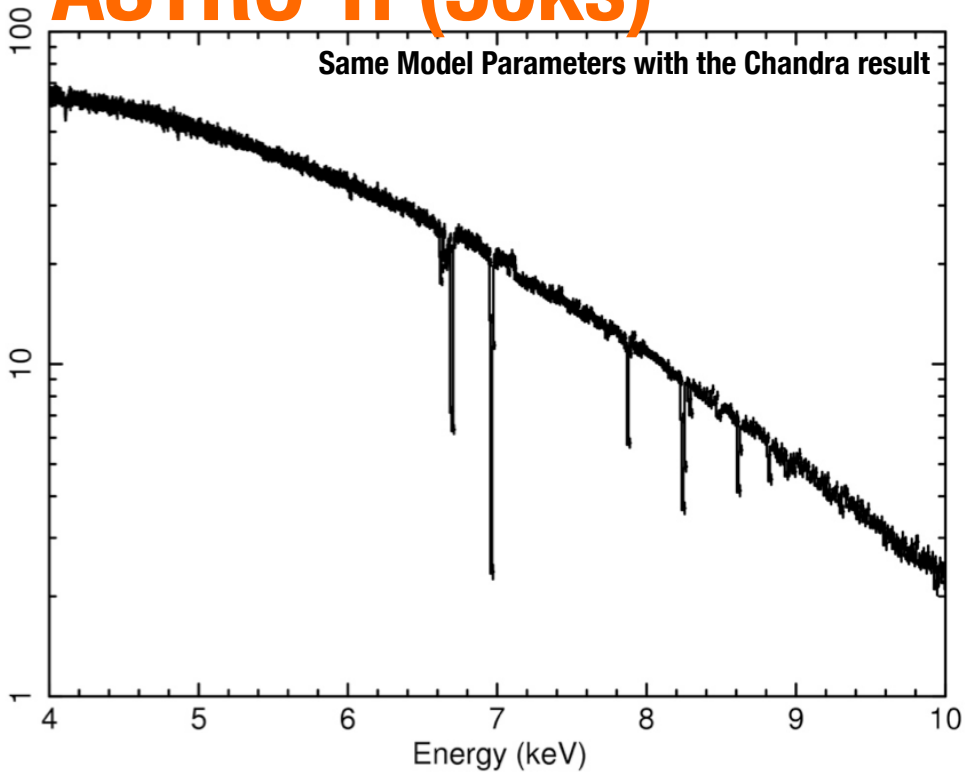


Chandra



(Simulation by J. Miller)

ASTRO-H (50ks)

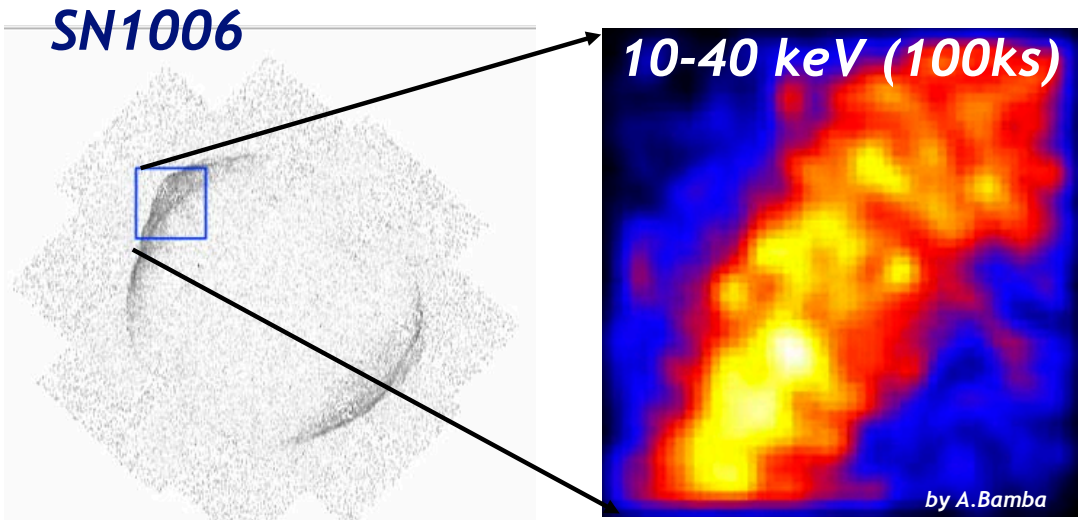


ASTRO-H SXS can handle 250 cts/s

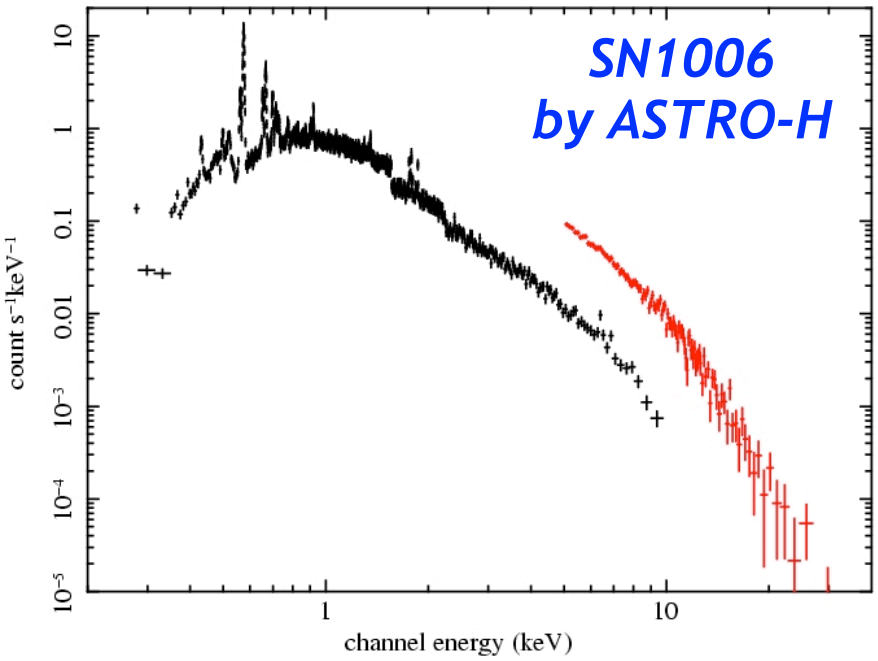
4. ASTRO-H Science : SNR

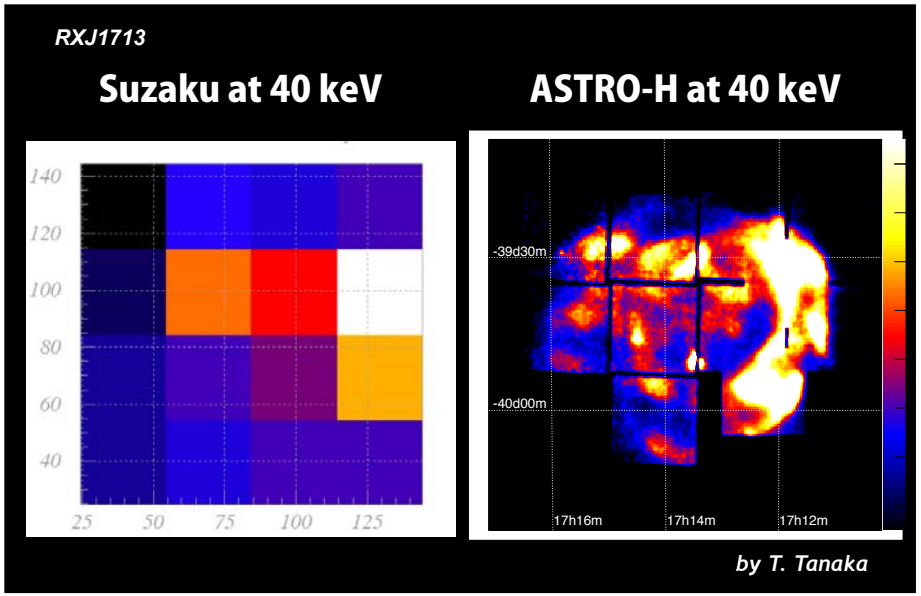
Supernova Remnants

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.



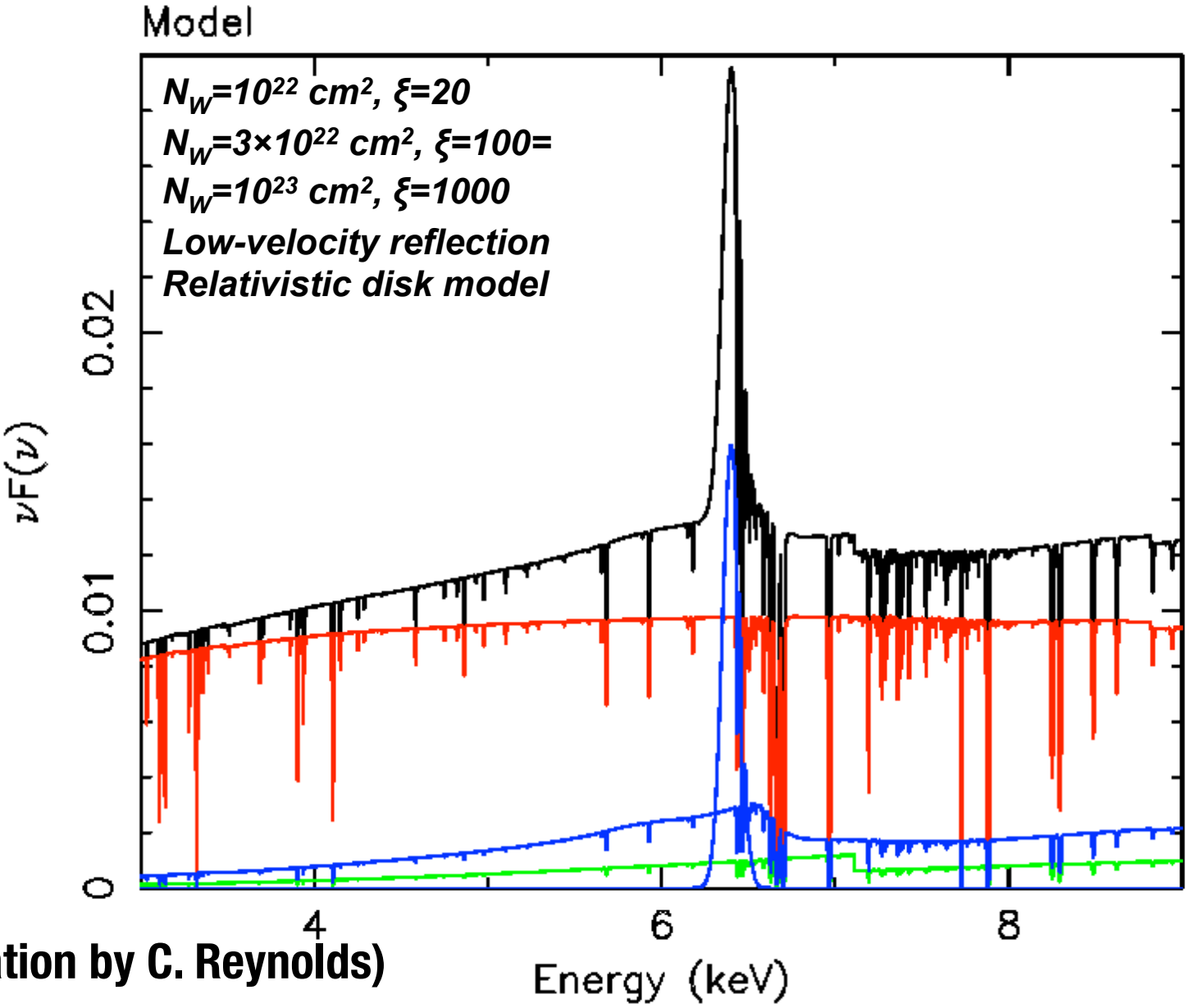
Site of Particle Acceleration
to map electon distribution with E=Emax





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)

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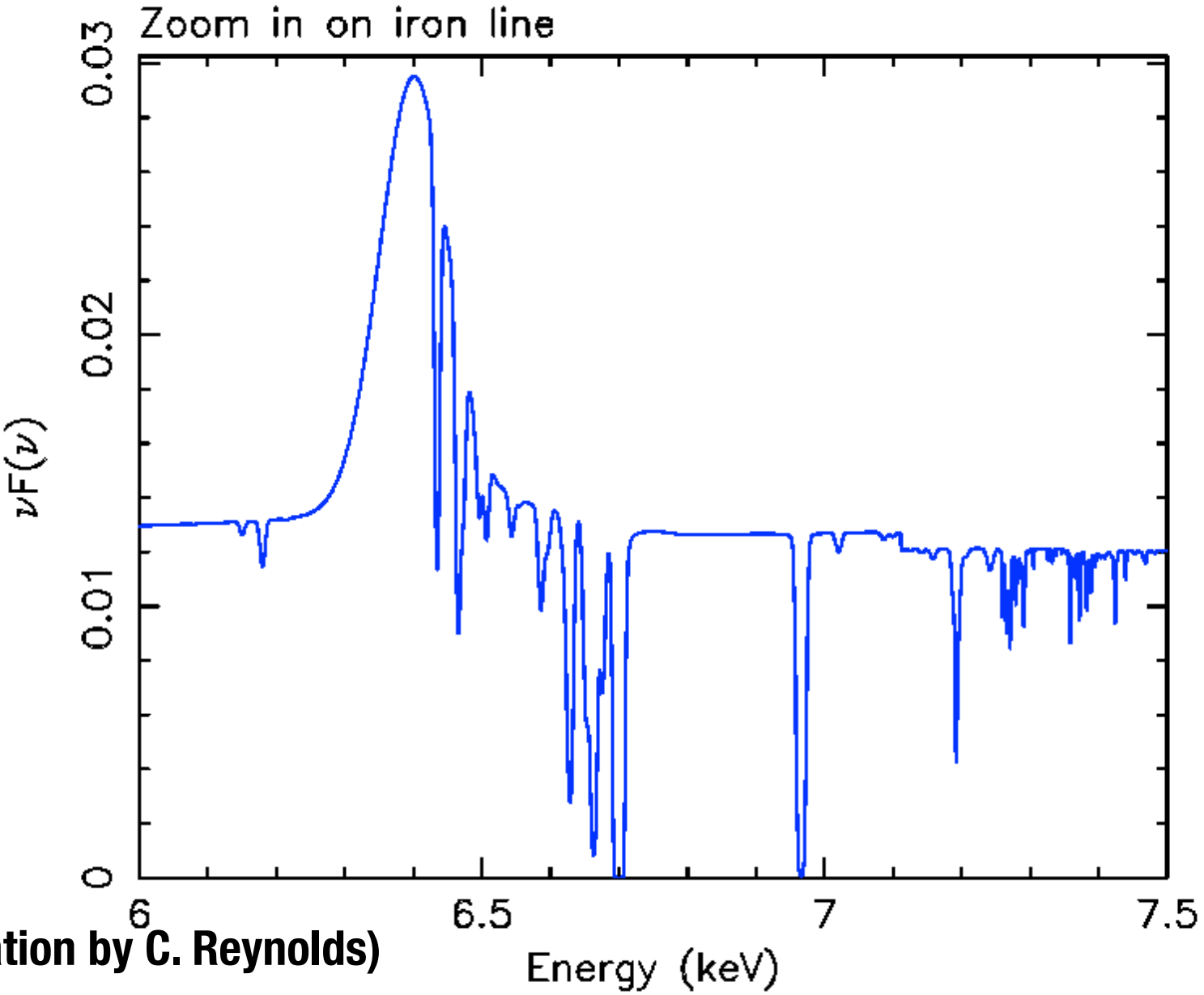

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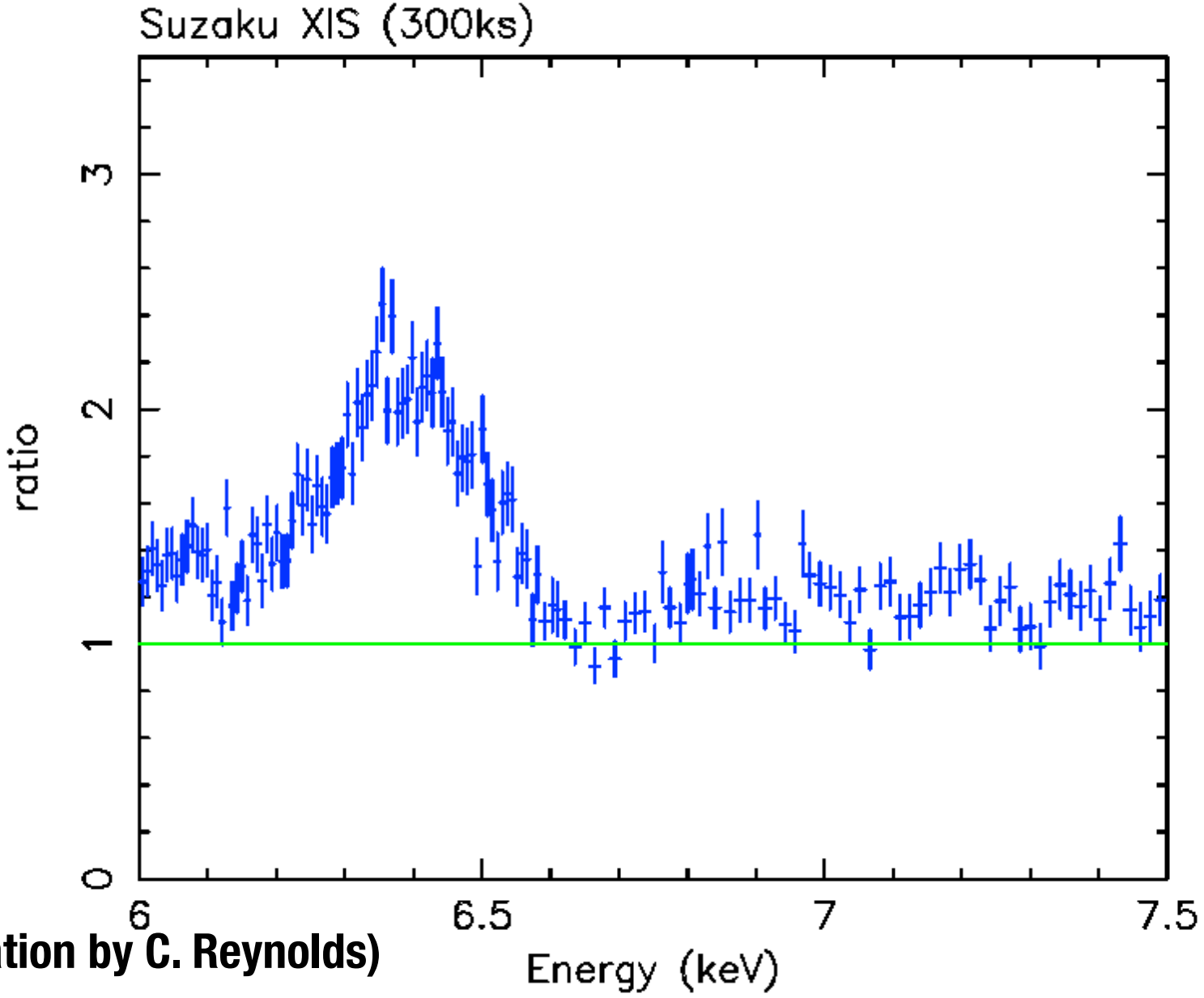

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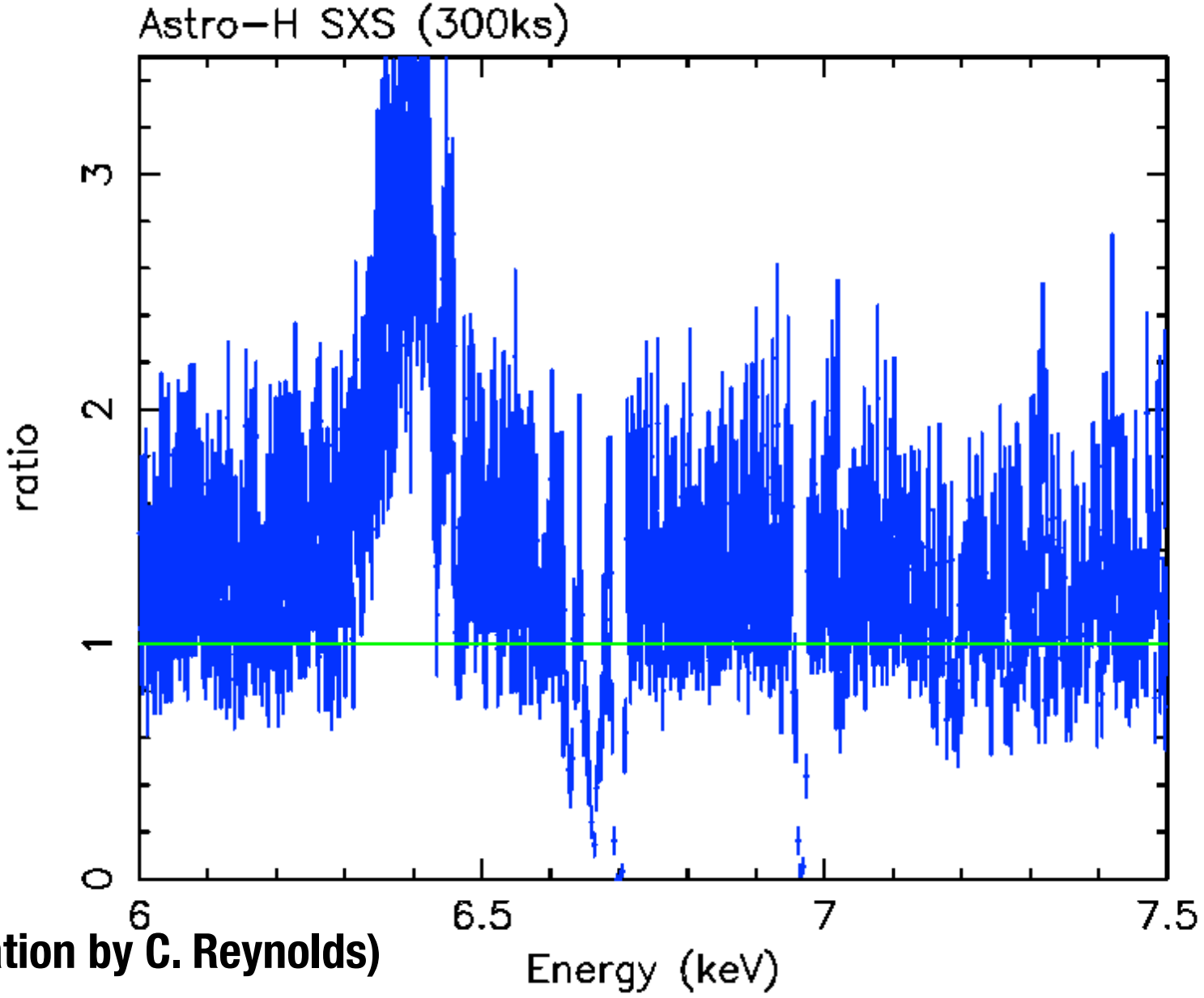

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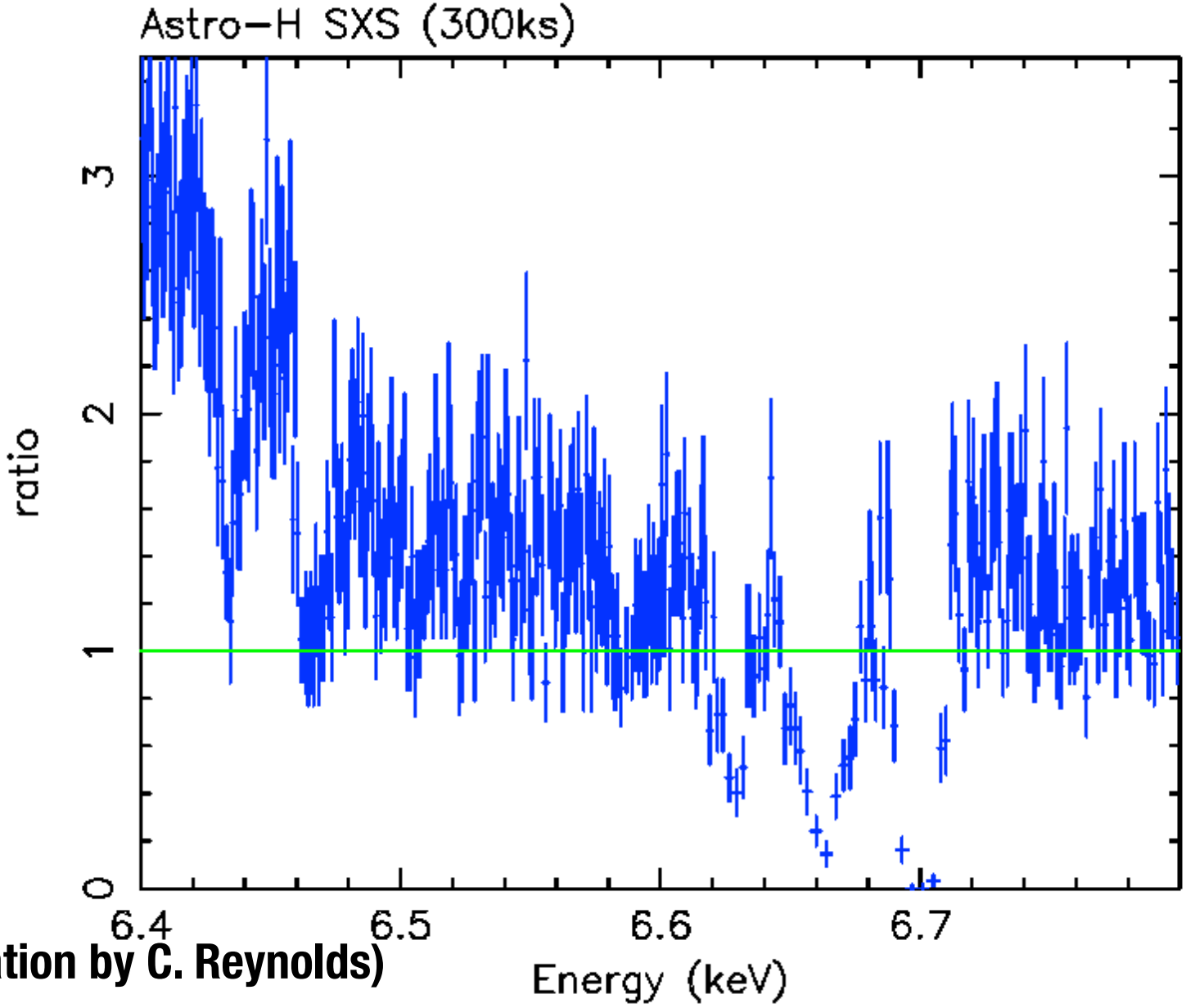


(Simulation by C. Reynolds)

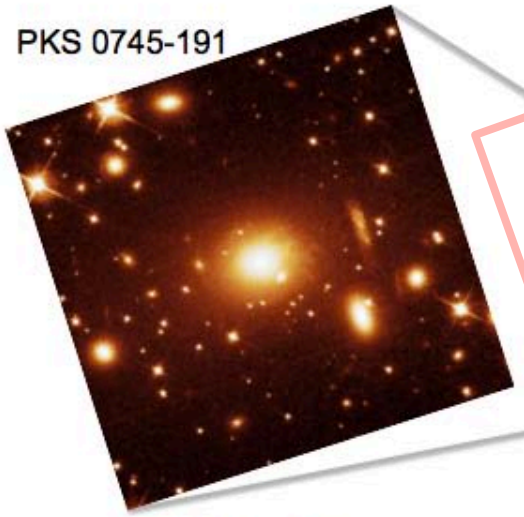
4. ASTRO-H Science : Cluster of Galaxies

Cluster of Galaxies

Dynamics
（Turbulance, Collisions)

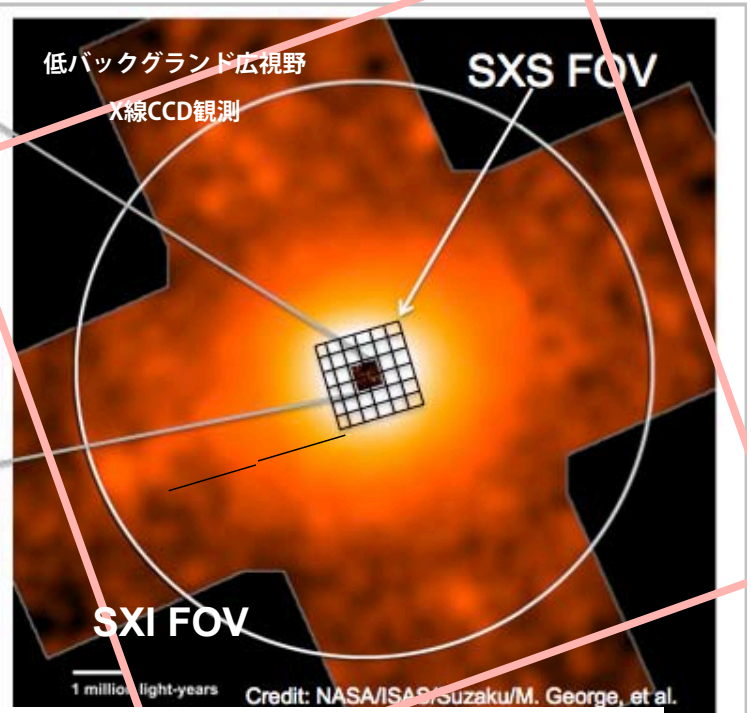
Non-thermal Emission
Cluster Outskirt
（Site of Sturcture Formation)

Temperature Map
Heavy Metal Distribution

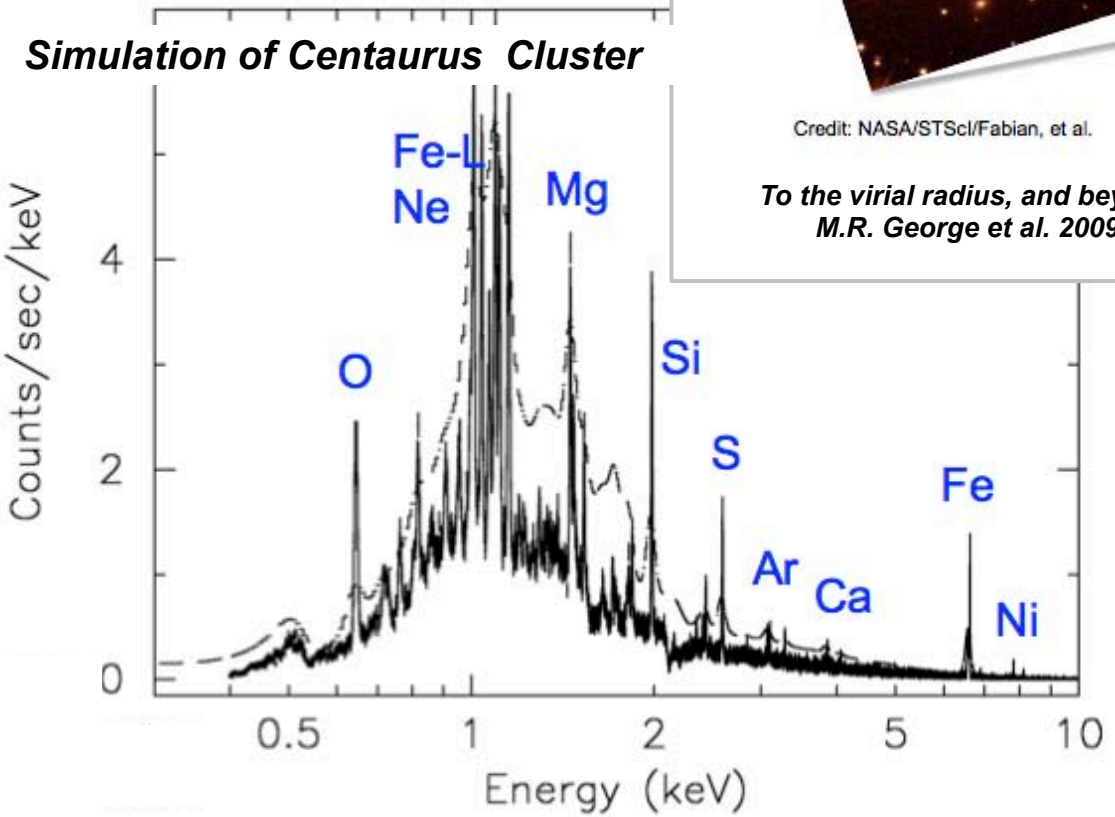


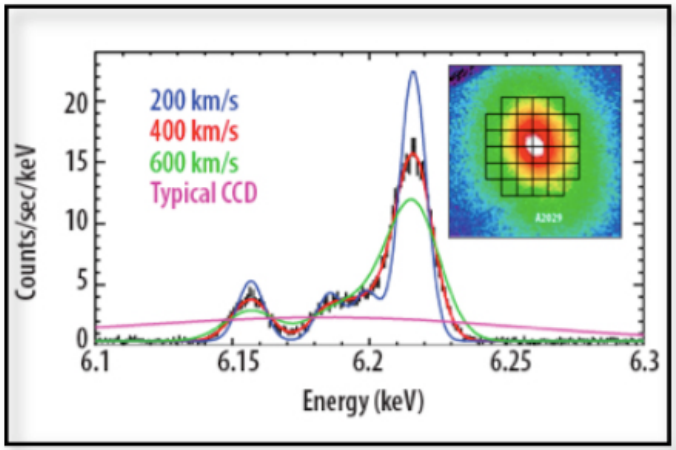
Credit: NASA/STScI/Fabian, et al.

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



Simulation of Centaurus Cluster





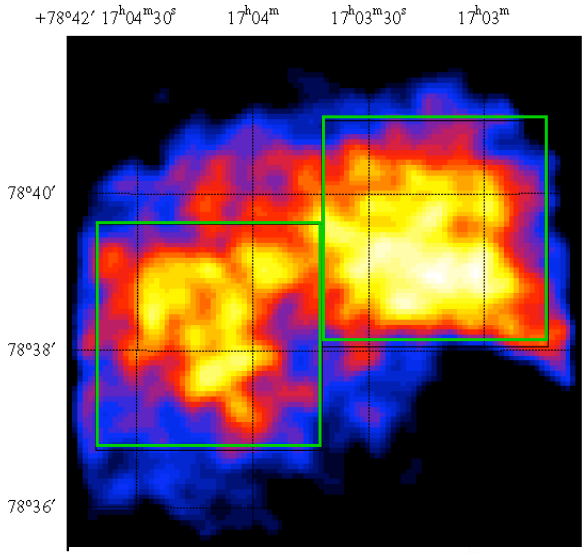
Astro-H will detect bulk velocity flow as small as 300 km/s in the brightest 30 clusters with T > 60 x 10_6 K (kT > 5 keV.)

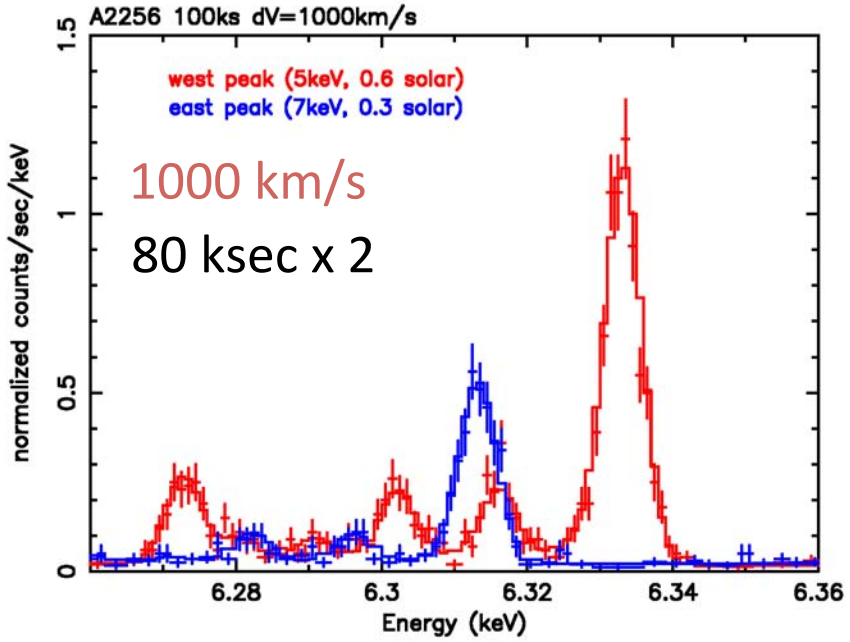
4. ASTRO-H Science : Cluster of Galaxies

Merging Cluster

A2256

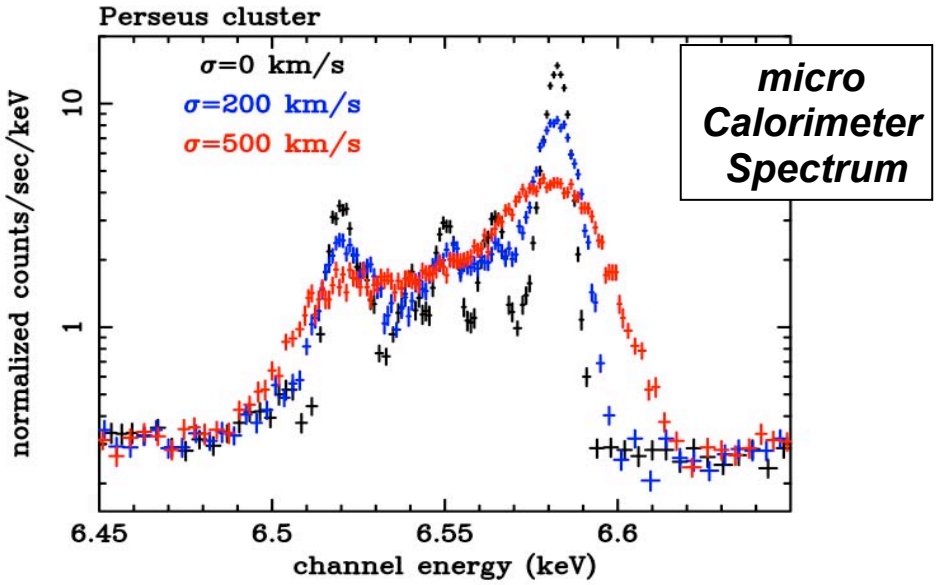
(z = 0.058)

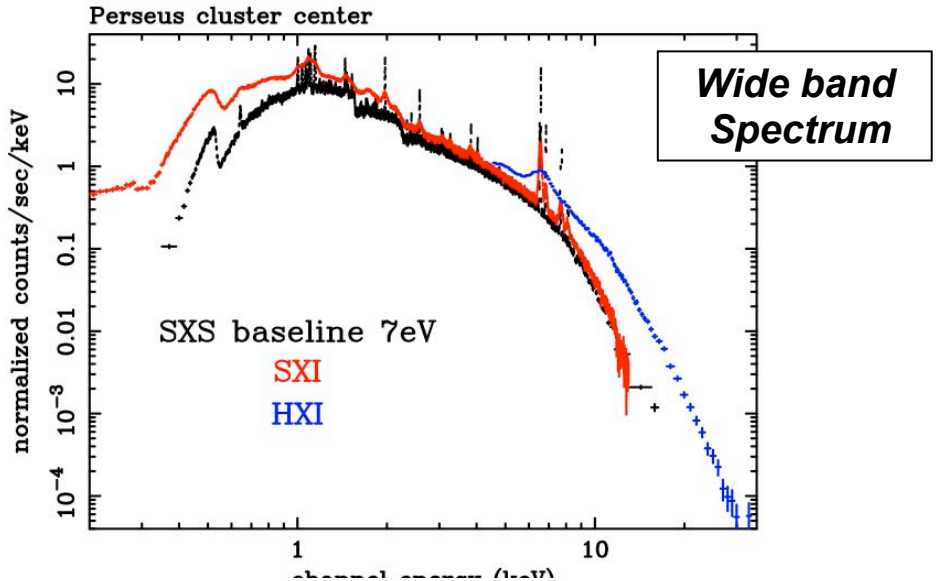




Perseus cluster (r<2', 100ks)

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





5. Summary

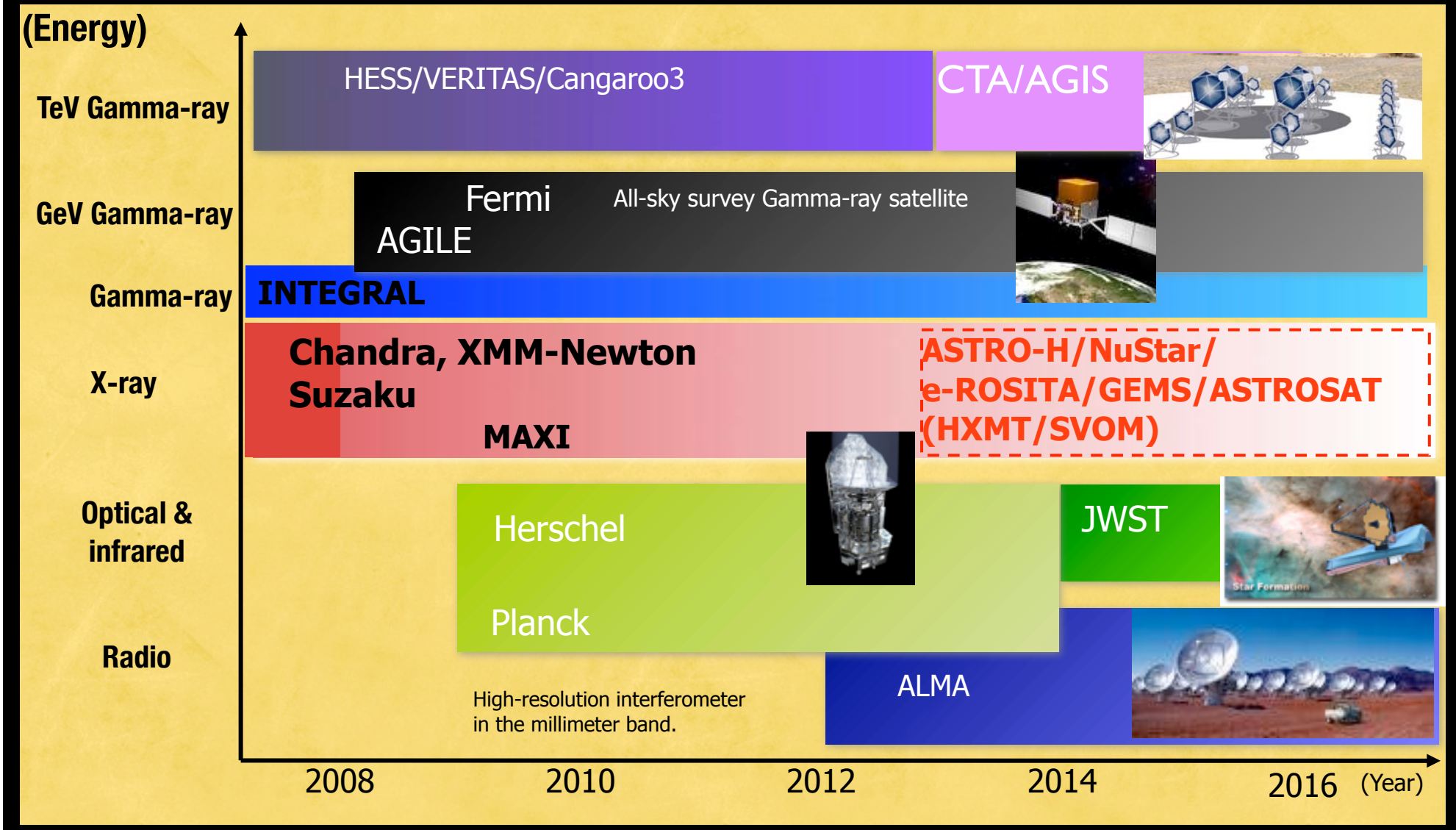
We have started the construction of main structure (e.g Optical Bench, Base Plate, Side Panels) for flight.

2011 June-September : Sub System CDR1 and System CDR1 : (Critical Design Review 1) to confirm detail design and get approvals for making Flight Model of instruments.

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

ASTRO-H responses are available from Web.

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

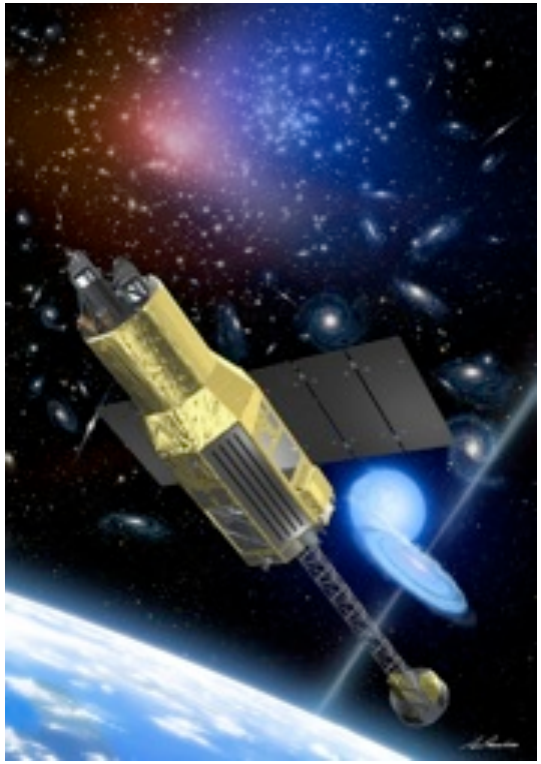
Observing the Dynamic Universe and Studying its History with the Ultimate Goal of Understanding the Structure and Evolution of the Universe

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.

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