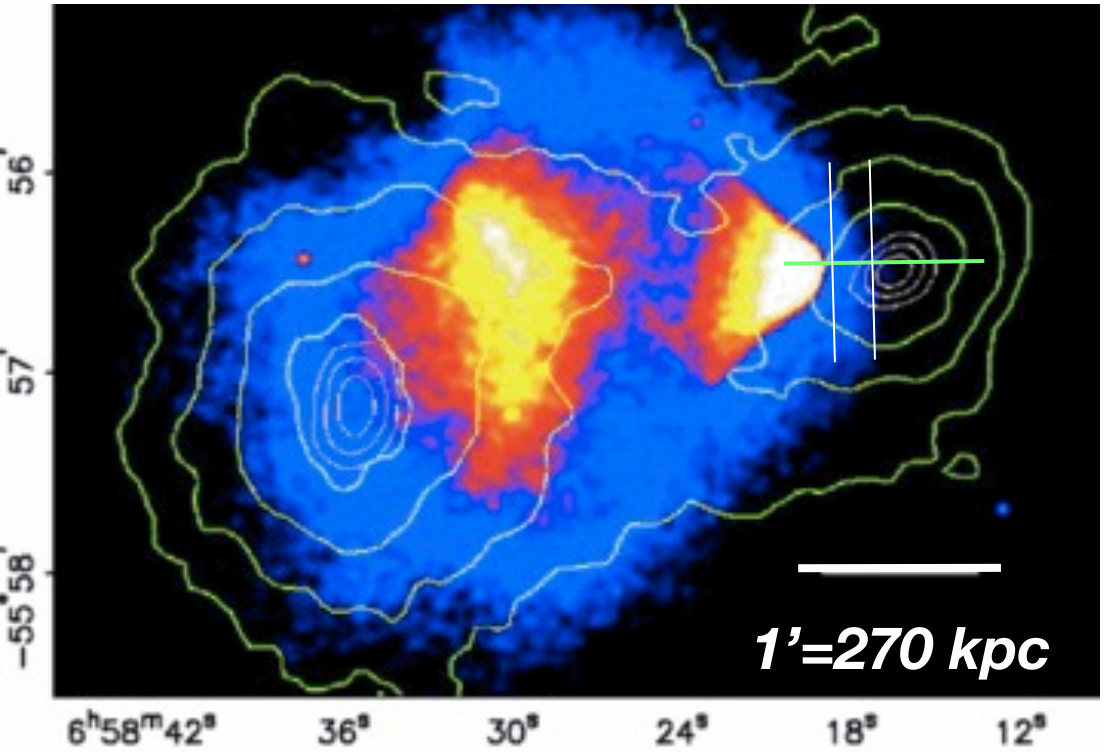
The ASTRO-H Mission

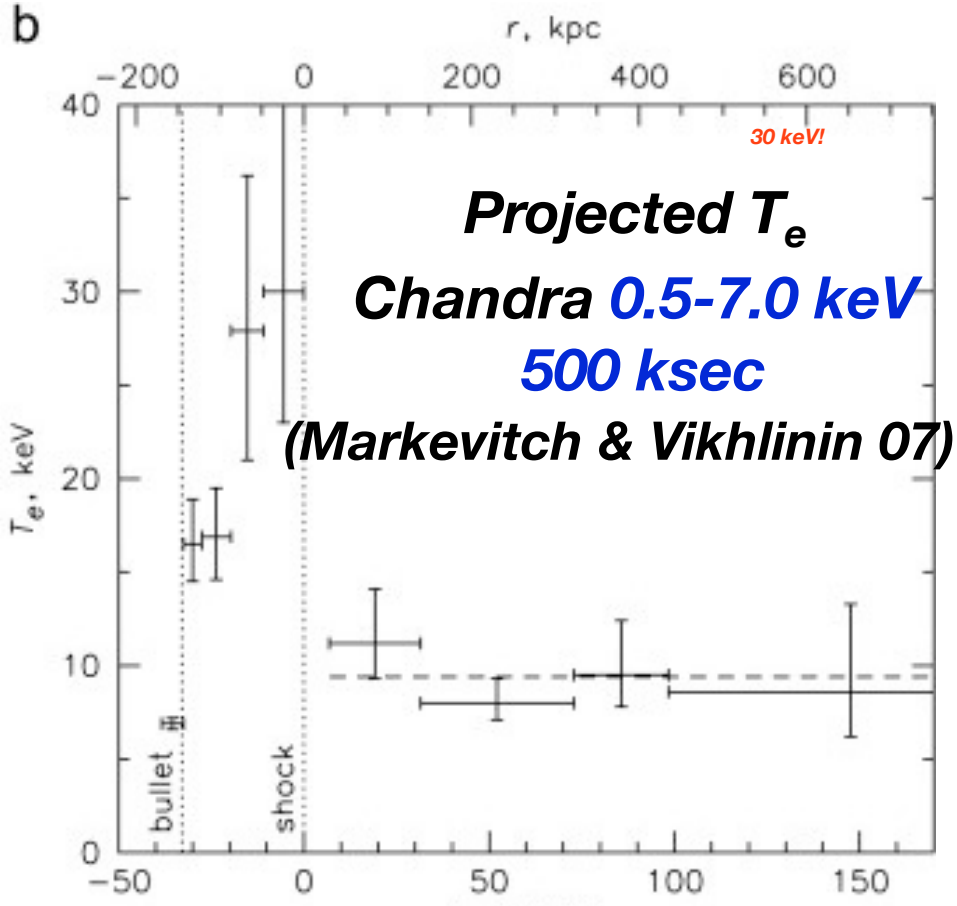
1. Why we need new X-ray Missions
2. Current Status of ASTRO-H

Tadayuki Takahashi
ISAS/JAXA

Why we need new X-ray Missions

Violent mergers





1E0657-56 at z=0.30 (Bullet cluster)

Color: X-ray (collisional gas)
Contours: weak lensing

(Clowe; Mastropietro & Burkert 08)

Rankine-Hugoniot relation:

$$\frac{T_2}{T_1} = \frac{[2\gamma\mathcal{M}^2-\gamma+1][(\gamma-1)\mathcal{M}^2+2]}{(\gamma+1)^2\mathcal{M}^2}$$

Mach number ~ 3.0

$V_{preshock}$ ~4700 km/s

$V_{postshock}$ ~1600 km/s

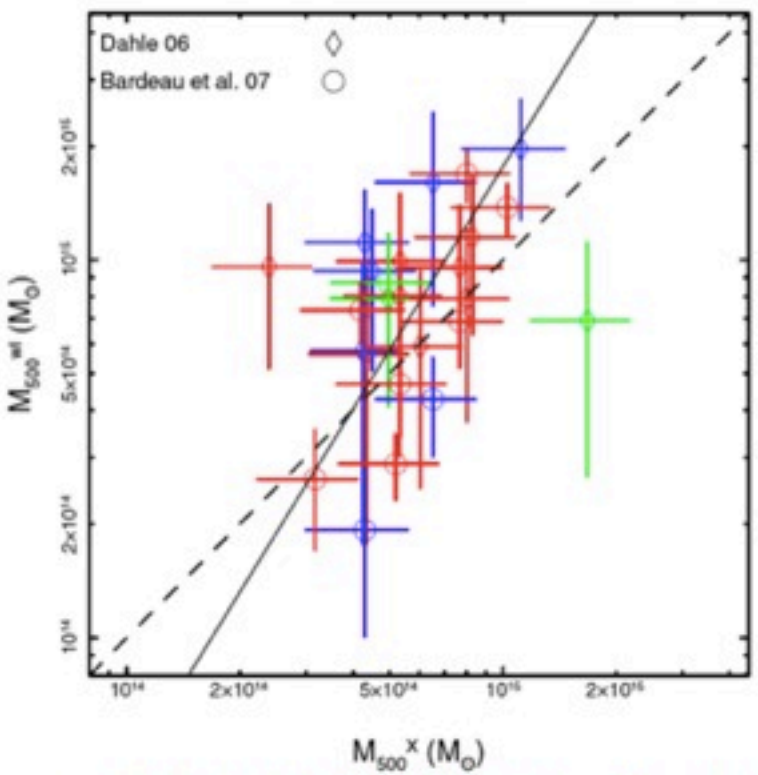
Impacts on the mass determination of galaxy clusters

Mass bias for X-rays :

~ - 12% +- 12%

Numerical simulations show, that this discrepancy can be accounted for by about 10 – 20% extra turbulent pressure

X-ray mass vs Weak Lensing mass



LoCuSS Project (G. Smith et al.)
Zhang et al. 2007

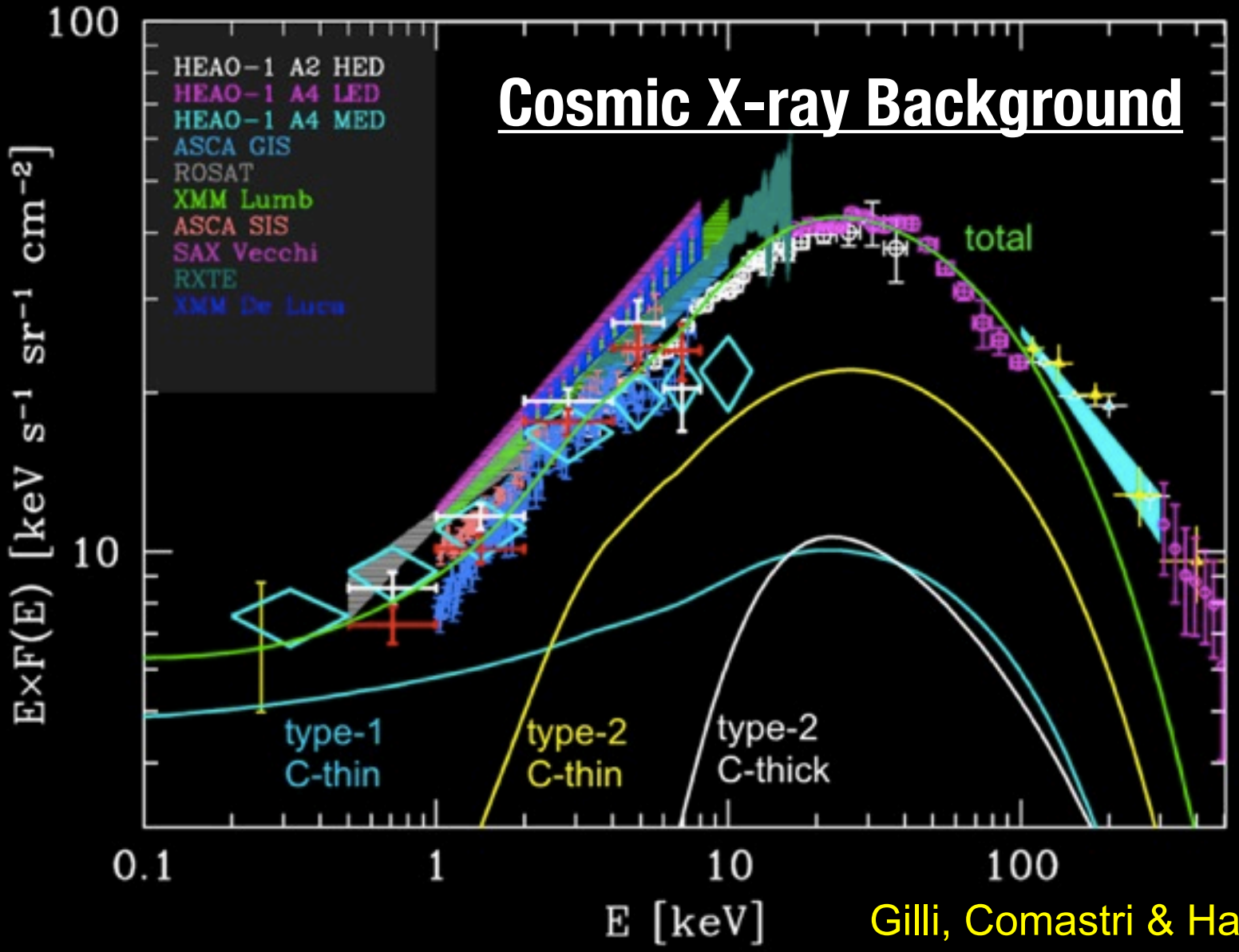
Hydrostatic equilibrium

$$\frac{d(P_{\text{thermal}} + P_{\text{nonthermal}})}{dr} = -\frac{GM(<r)}{r^2}\rho_{\text{gas}}$$

$$\frac{P_{\text{turb}}}{P_{\text{therm}}} = 0.11 \left(\frac{V_{\text{turb}}}{300\text{km/s}}\right)^2 \left(\frac{kT_e}{5\text{keV}}\right)^{-1}$$

Measurement of non-thermal pressure support (gas motions, high energy particles, etc.) by high-resolution or hard X-ray spectroscopy is VERY important

There should be sufficient number of type-2 Compton thin/thick AGN above 10 keV, but have not been resolved yet, directly.



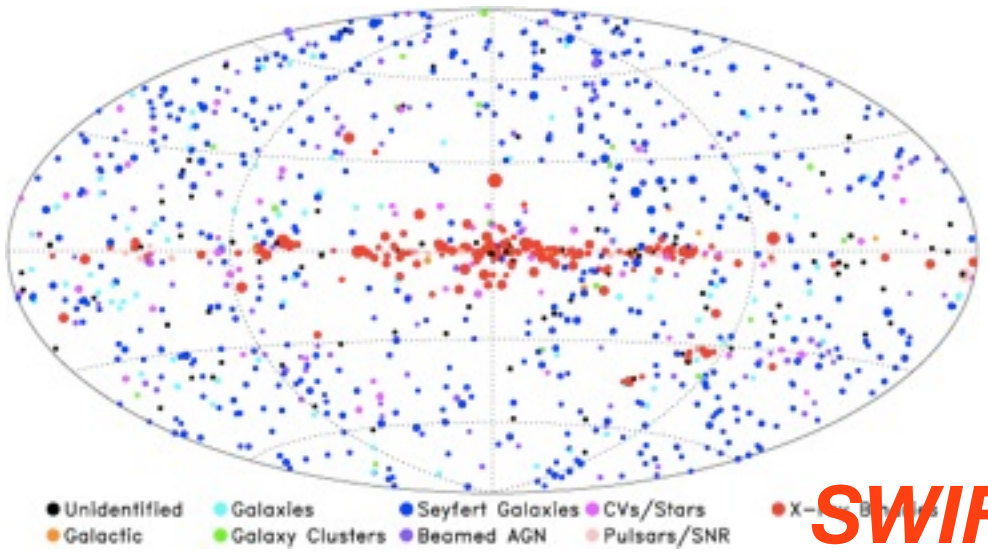
Gilli, Comastri & Hasinger, 2006

Why we need new X-ray Missions

a flux level of 1.1×10^{-11} ergs sec^{-1} cm^{-2} over 50% of the sky and 1.48×10^{-11} ergs sec^{-1} cm^{-2} over 90% of the sky

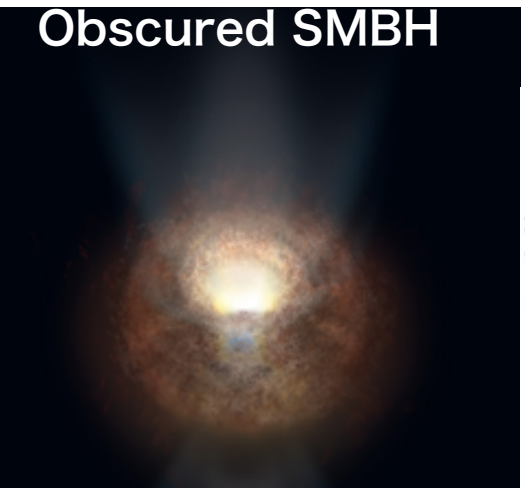
Source Type	# in Catalog
Unidentified	86
Galactic	17
Galaxies	85
Galaxy CLusters	18
Seyfert Galaxies	519
Beamed AGN	108
CVs/Stars	60
Pulsars/SNR	25
X-ray Binaries	174
Total	1092

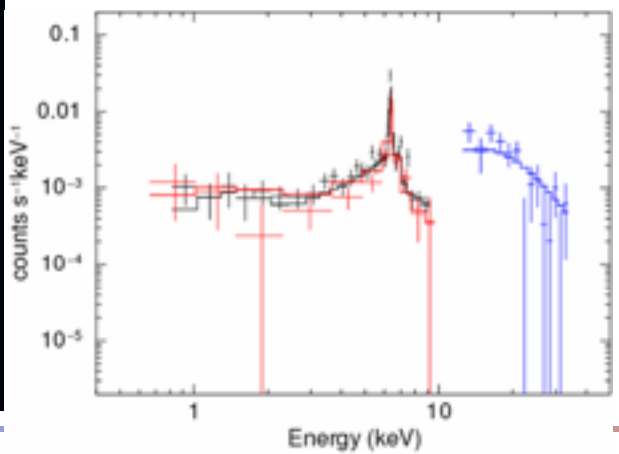
Hard X-ray Observations plays a key role



SWIFT Map

Swift did a great Job,
but still only a few % of Cosmic X-ray Backgraound
have been resolved in hard X-rays

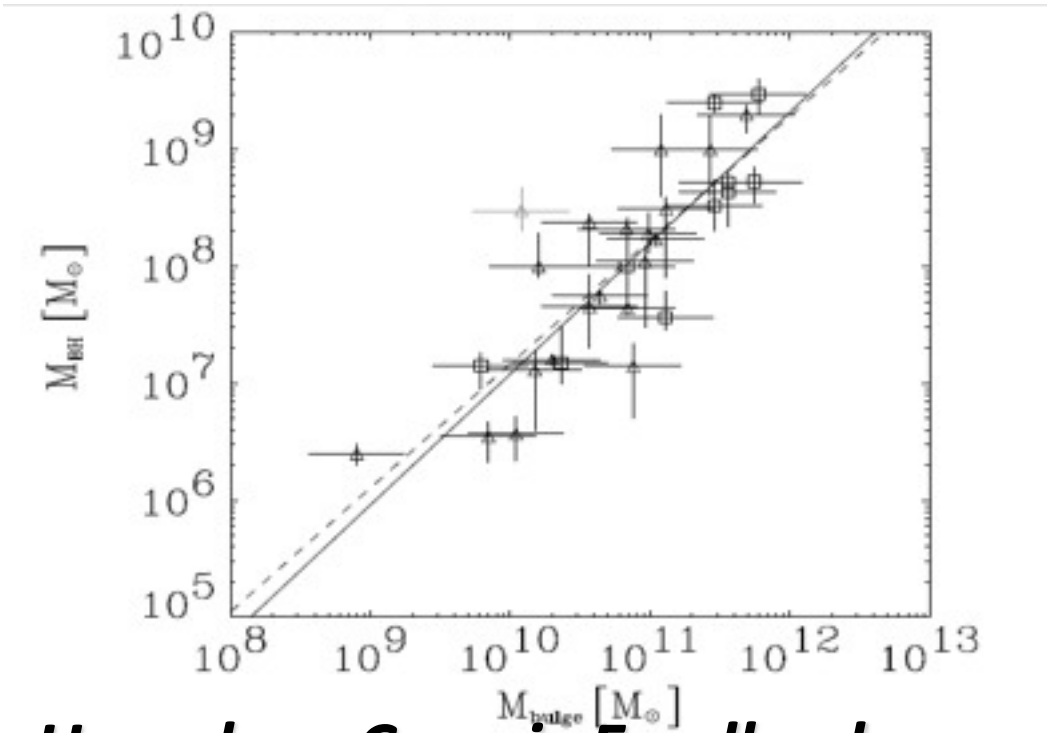


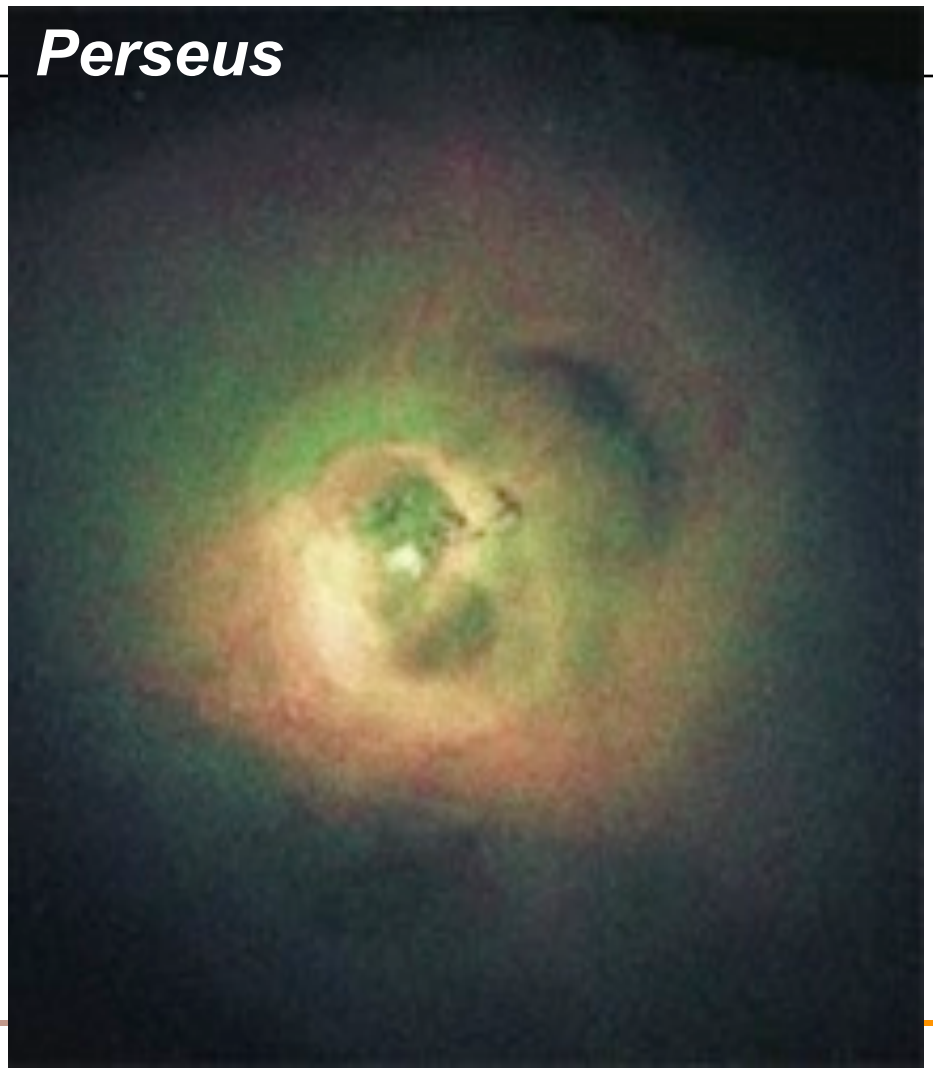


New type of AGNs discovered
by followup observations by Suzaku
<Deeply buried in dense tori of
gas that they show little emission in
soft X-ray and visible light.>

Cosmic Feedback from AGN

Radiative and mechanical heating and pressure from black holes have a profound influence on the evolution of all galaxies whether or not they are in clusters





How does Cosmic Feedback work and influence galaxy formation?

ASTRO-H - A New International X-ray Observatory

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.

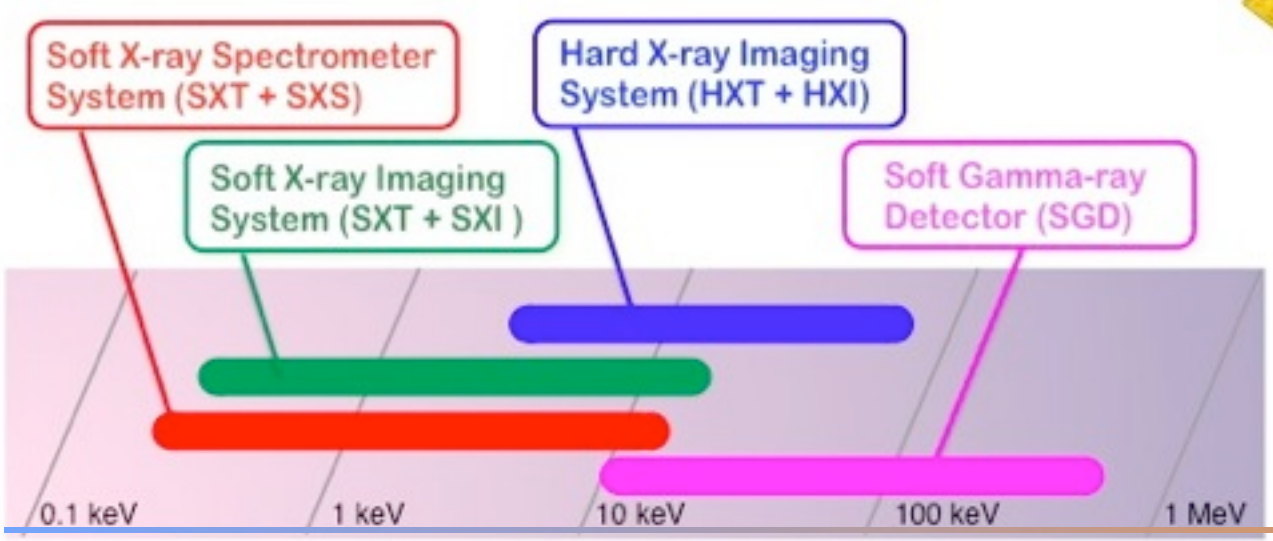
Launch site	Tanegashima Space Center
Launch vehicle	JAXA HII-A rocket
Orbit Altitude	550 km
Orbit Type	Approximate circular orbit
Orbit Inclination	< 31 degrees
Orbit Period	96 minutes
Total Length	14 m
Mass	< 2.7 metric ton
Mission life	> 3 years

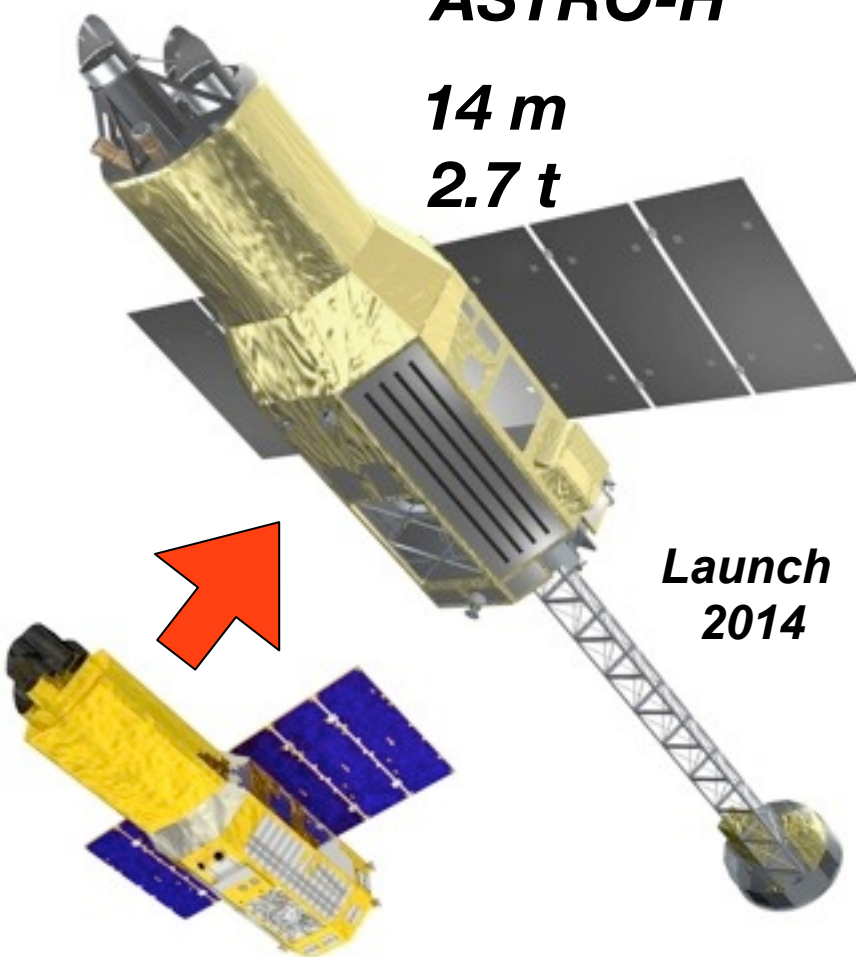
ASTRO-H (formerly called NeXT) is now in Phase-C (Detail Design Phase)

CDR : 2011 June-July
Launch Year : 2014

ASTRO-H as an X-ray Observatory (0.3 - 600 keV)

1. Micro-calorimeter + XRT
   0.3-12keV , ΔE=5eV , FOV=3',
   Δθ=1.3'
2. Soft X-ray CCD + XRT
   0.4-12 keV, ΔE=150eV, FOV=38',
   Δθ=1.3'
3. Hard X-ray imager + Hard XRT
   5-80 keV ΔE<2keV , FOV=9', Δθ=1.7'
4. Soft Gamma-ray detector
   100-600 keV no imaging capability





ASTRO-H

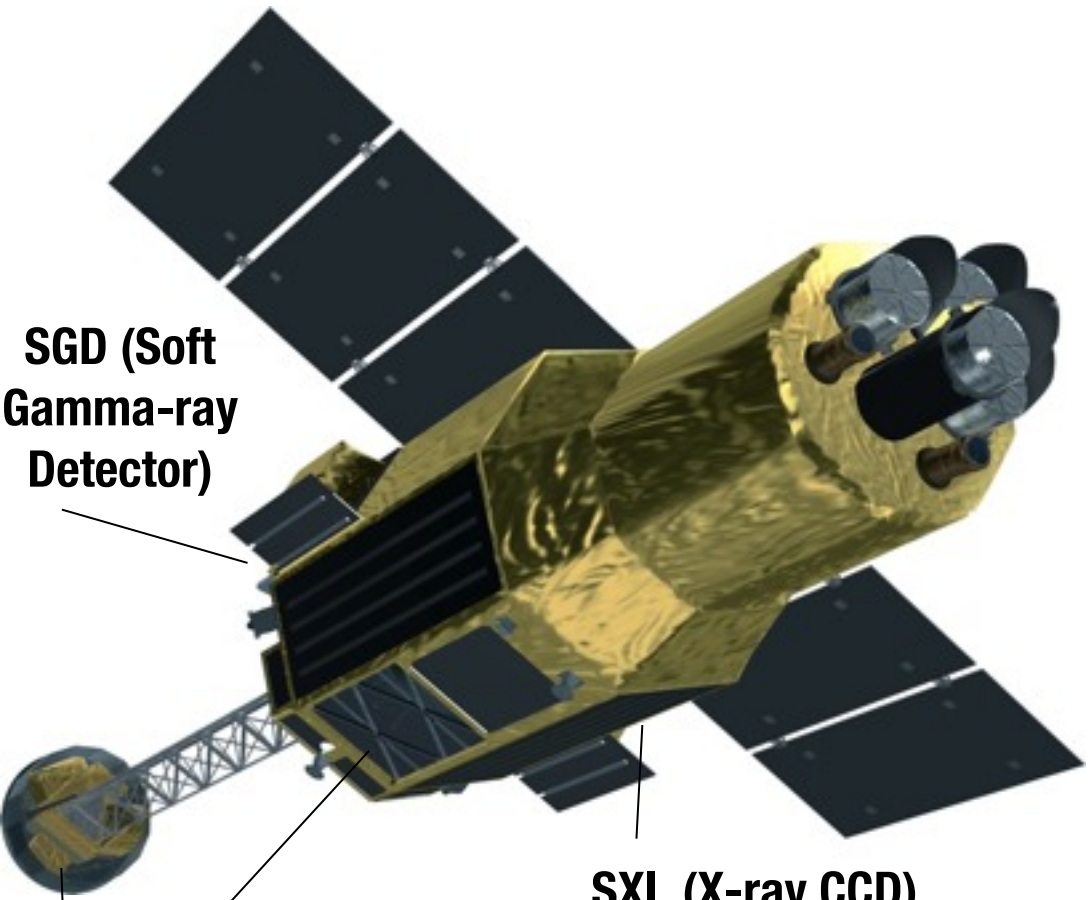
14 m
2.7 t

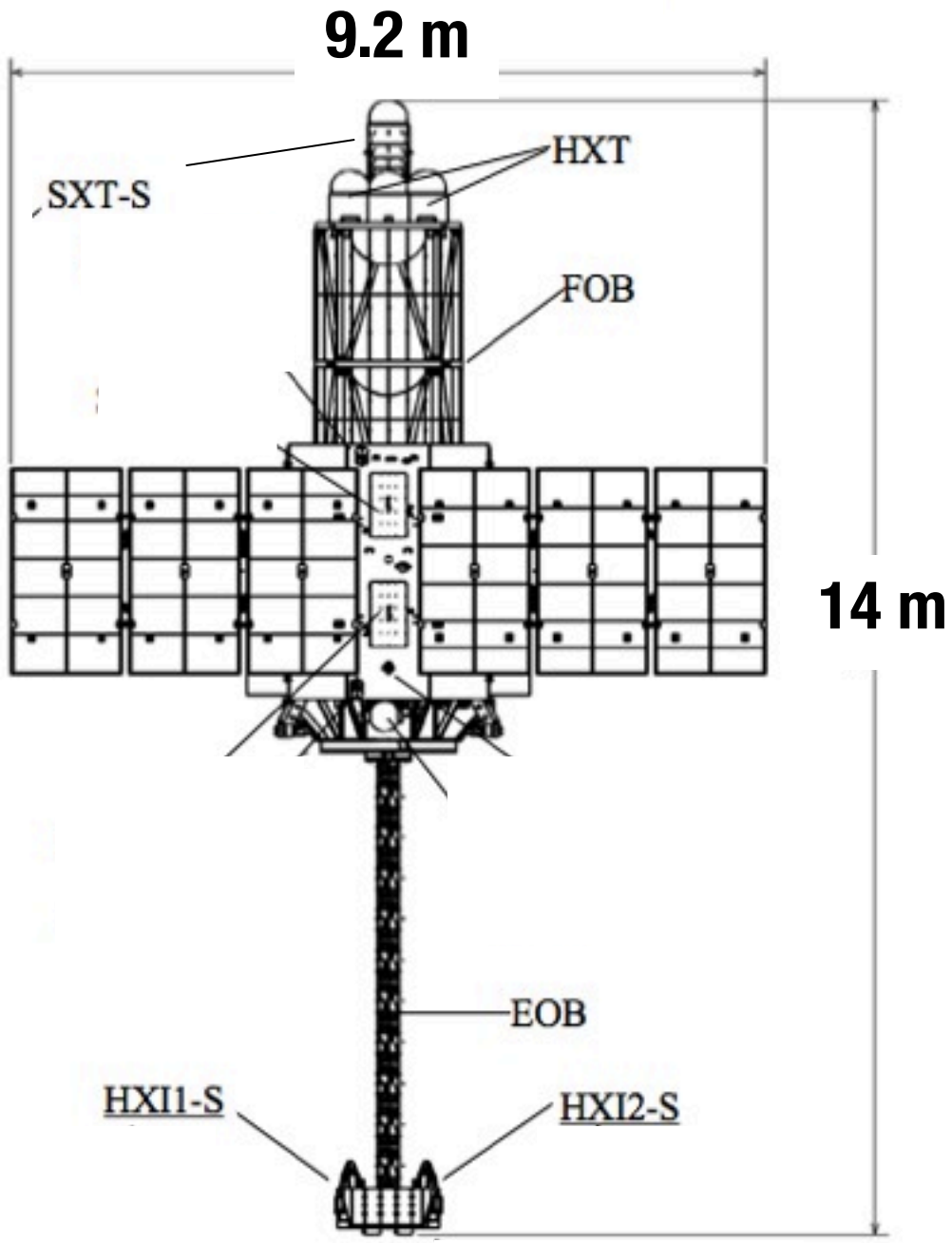
Launch 2014

Suzaku (ASTRO-E2)
(6m, 1.7t)

Launch 2005

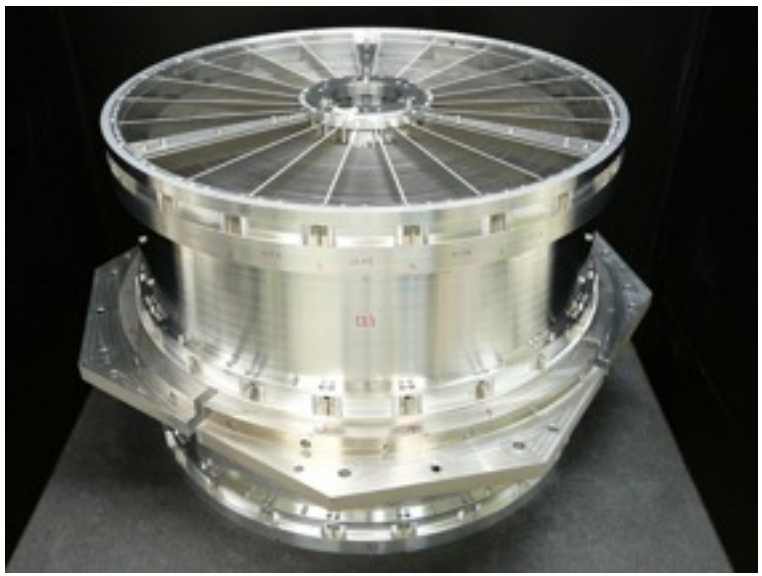
ASTRO-H Cofiguration

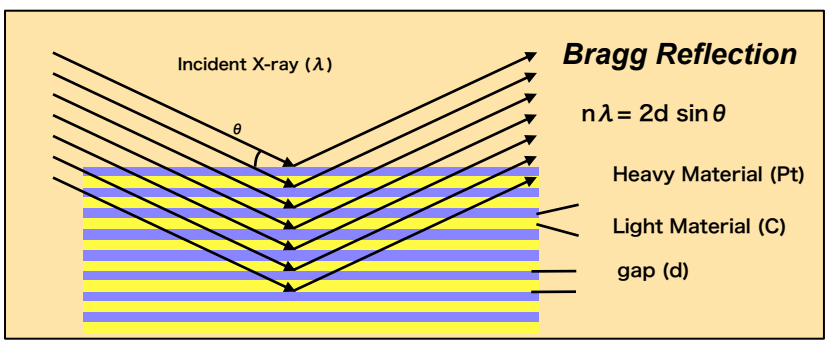


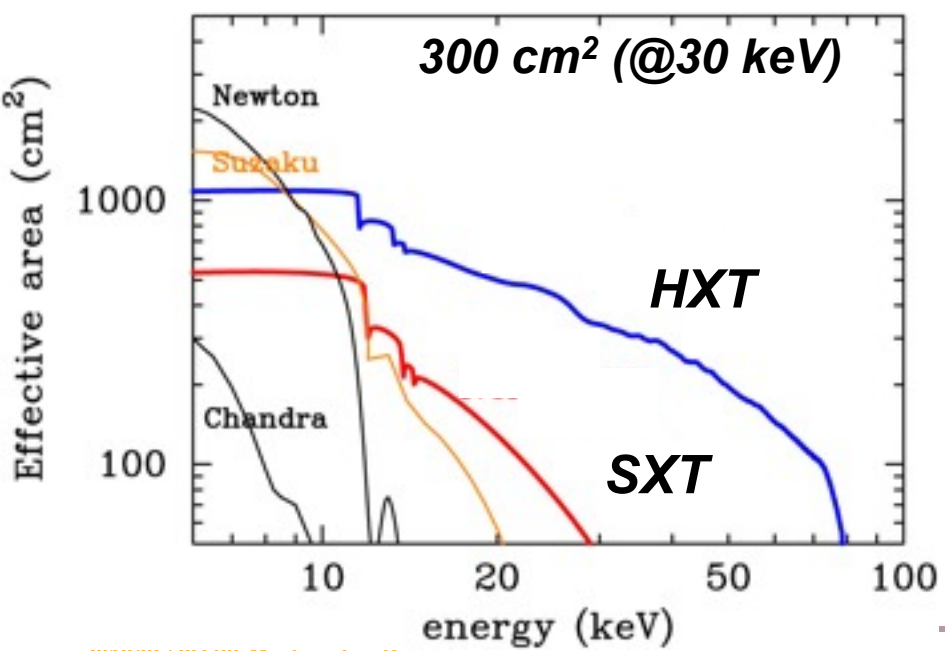


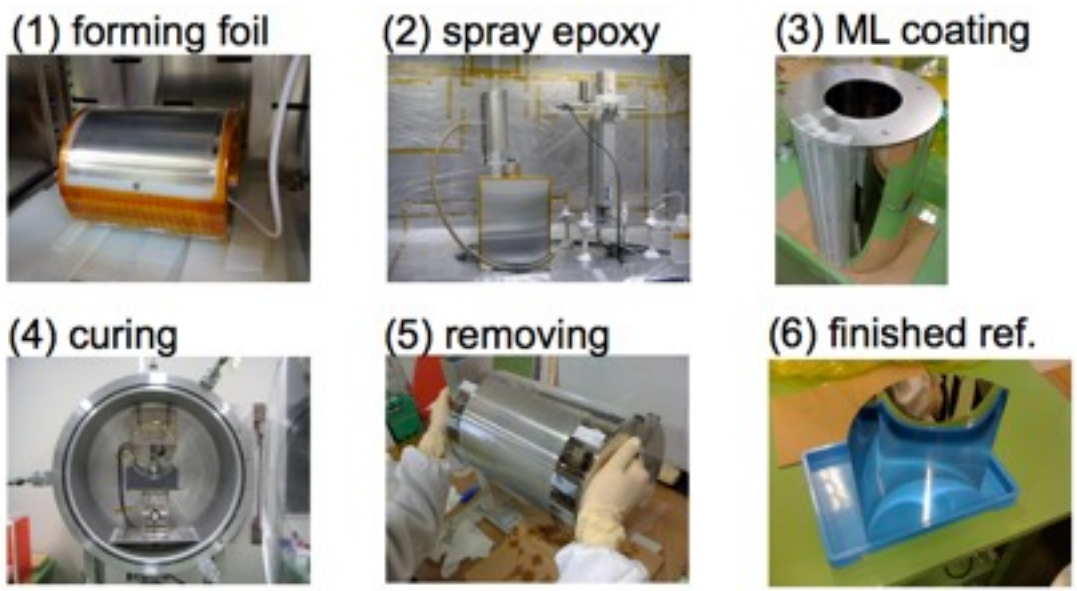
ASTRO-H Hard X-ray Telescope (HXT)

- Pt/C depth-graded multilayer X-ray telescope, original to Japan.
- Large photon collecting area above 10 keV.
- Light-weight design as a heritage of Suzaku.
- Proven technology by balloon experiments.





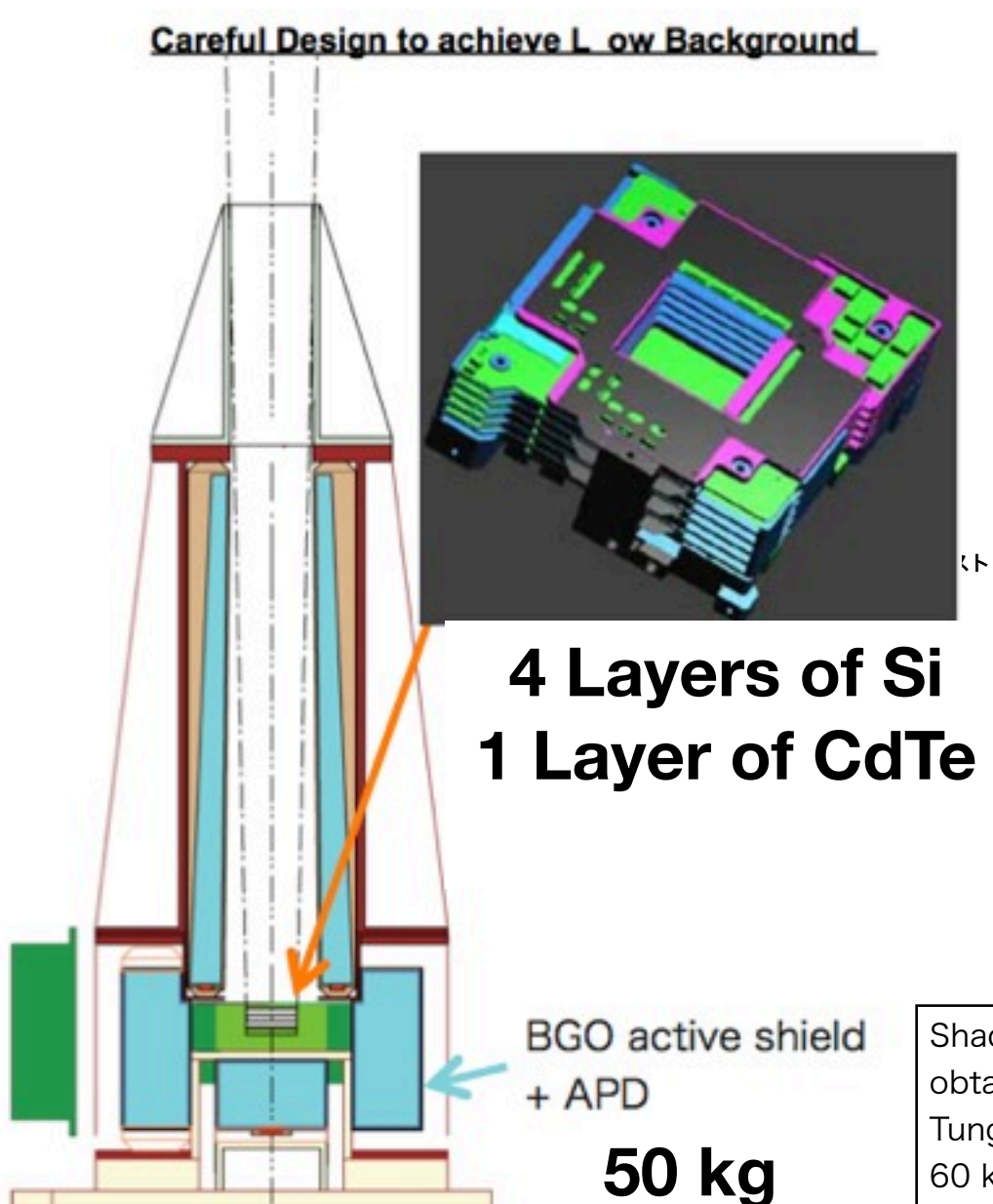




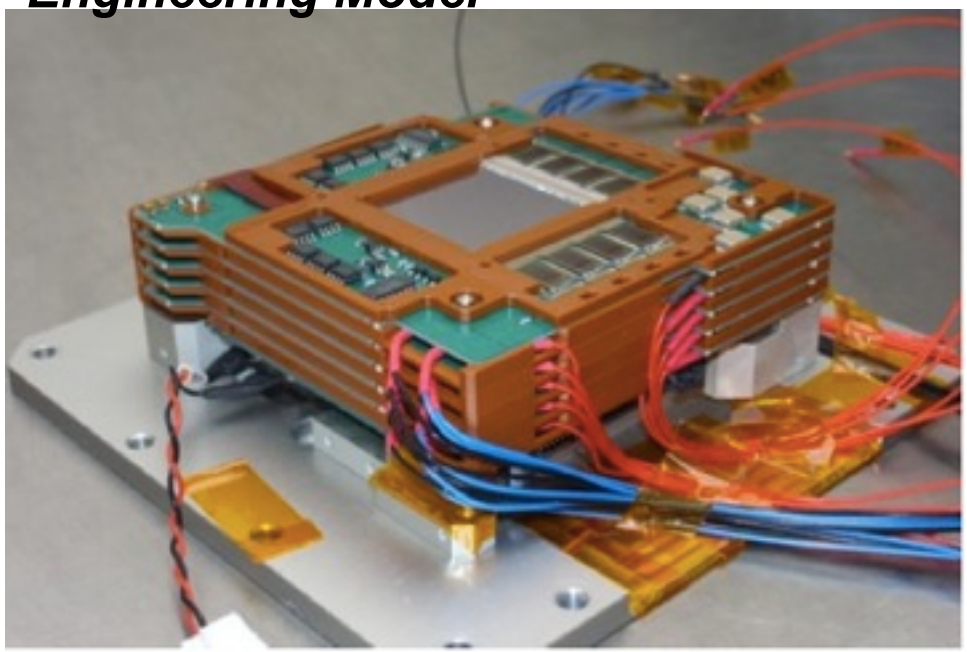
Nagoya/Ehime/ISAS/Kobe/Chuo and more

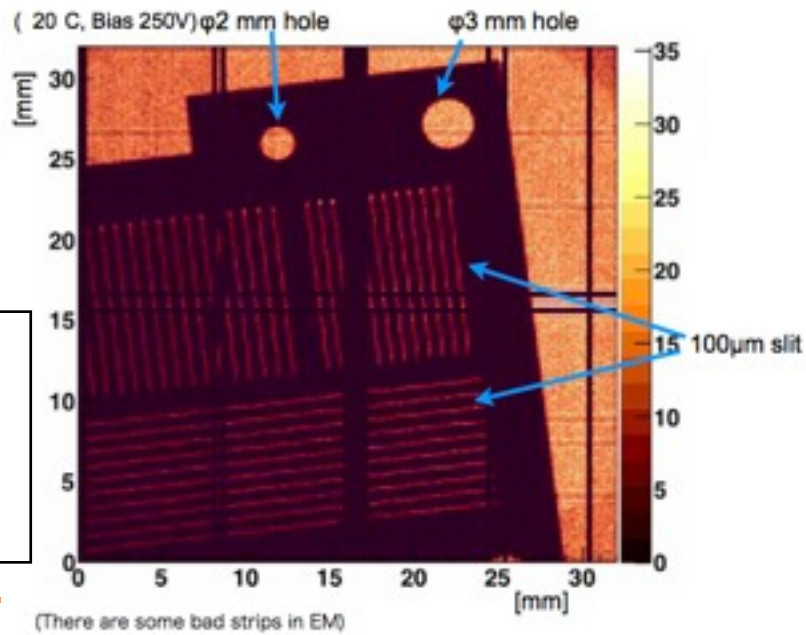
At Nagoya U.

ASTRO-H Hard X-ray Imager (HXI)



Engineering Model



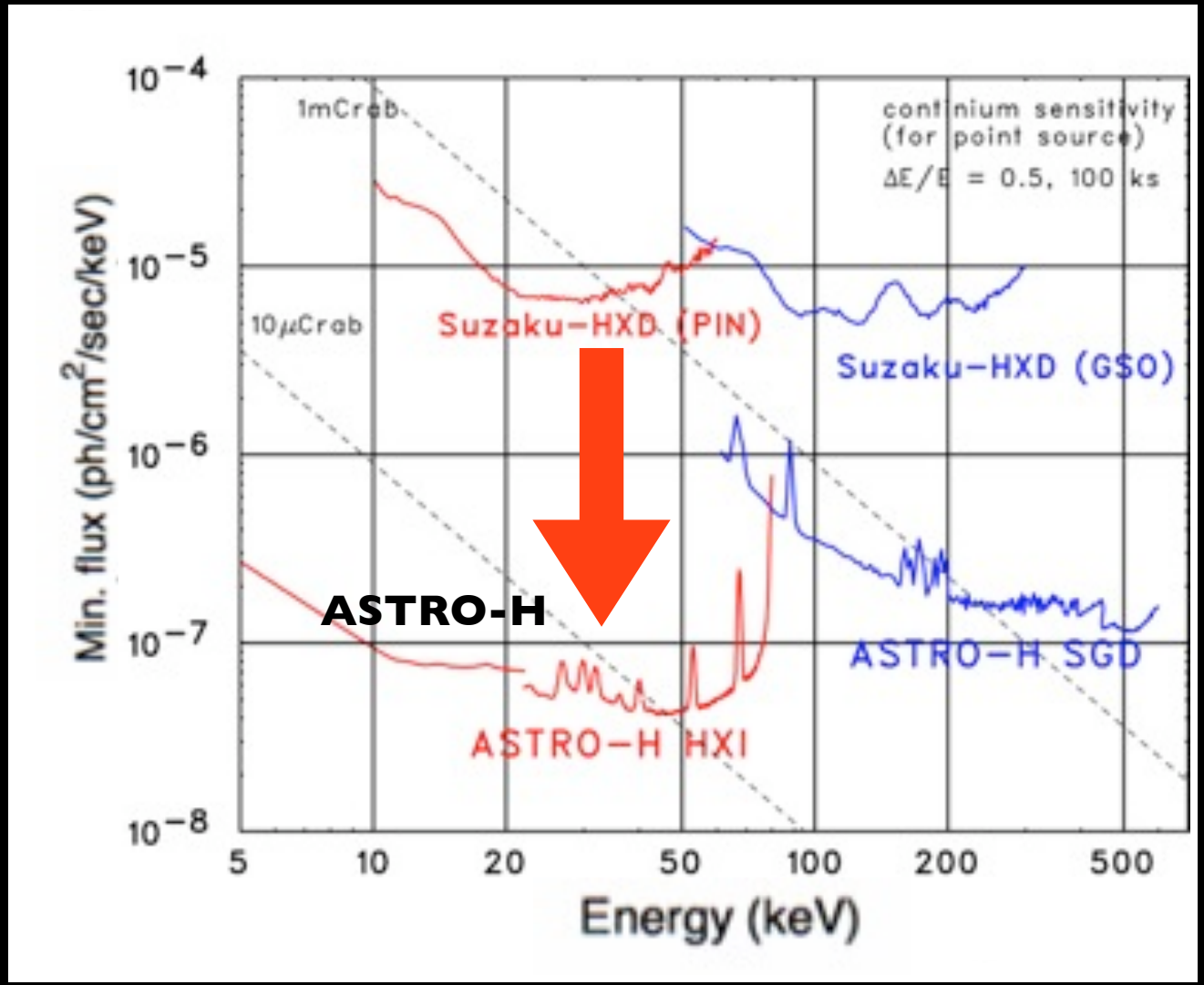


Shadow image is obtained with a Tungsten slit at 60 keV (^{241}Am) source.

Power of Hard X-ray Telescope

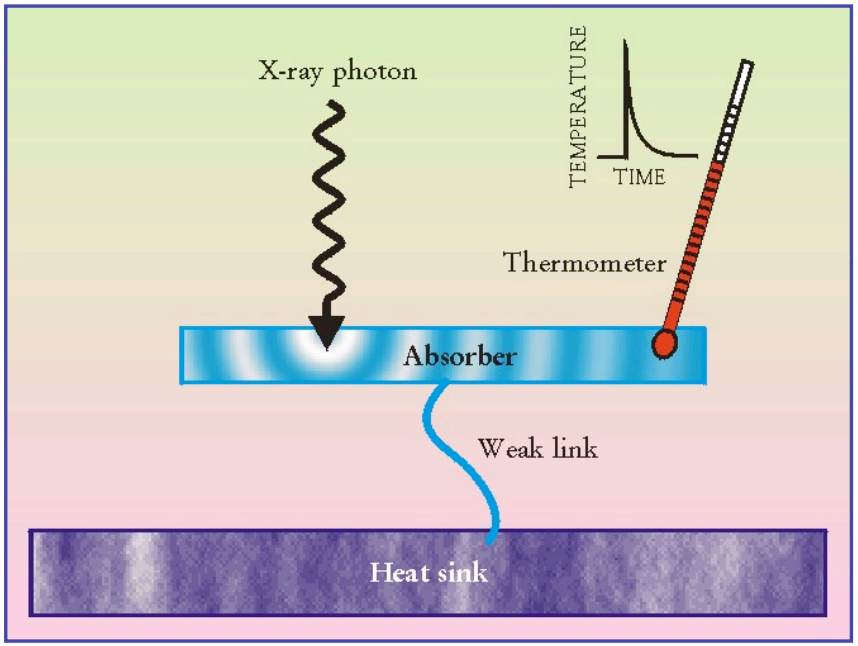
improve sensitivity by ~100x over non-imaging missions

Large Collection Area by Mirrors+Small Focal Plane Detector



ASTRO-H Soft X-ray Spectroscopy (SXS)

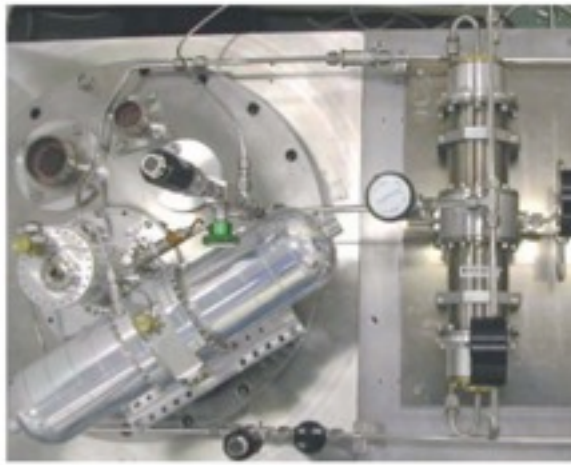
- High Resolution Spectroscopy- by a micro calorimeter array



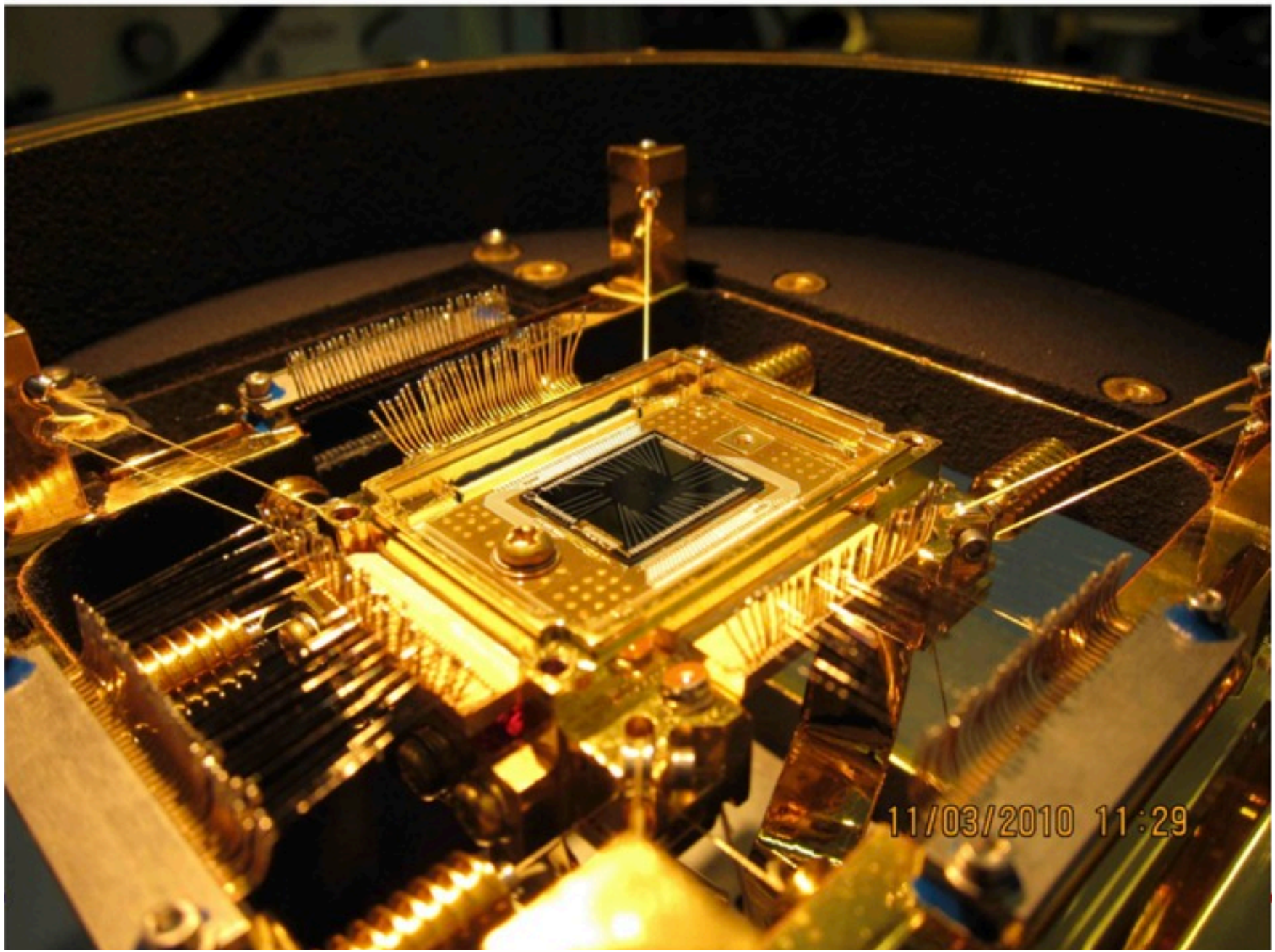
	Requirements (/Goal)
Energy resolution	7 eV (FWHM) (4 eV(FWHM) Goal)
Energy range	0.3 - 12 keV
Field of view	2.9 x 2.9 arcmin
Detector array	6 x 6
Absorber size	800 μm
Effective area	160 / 210 cm^2 (at 1 / 6 keV)

Detector to be Operated at 50 mK

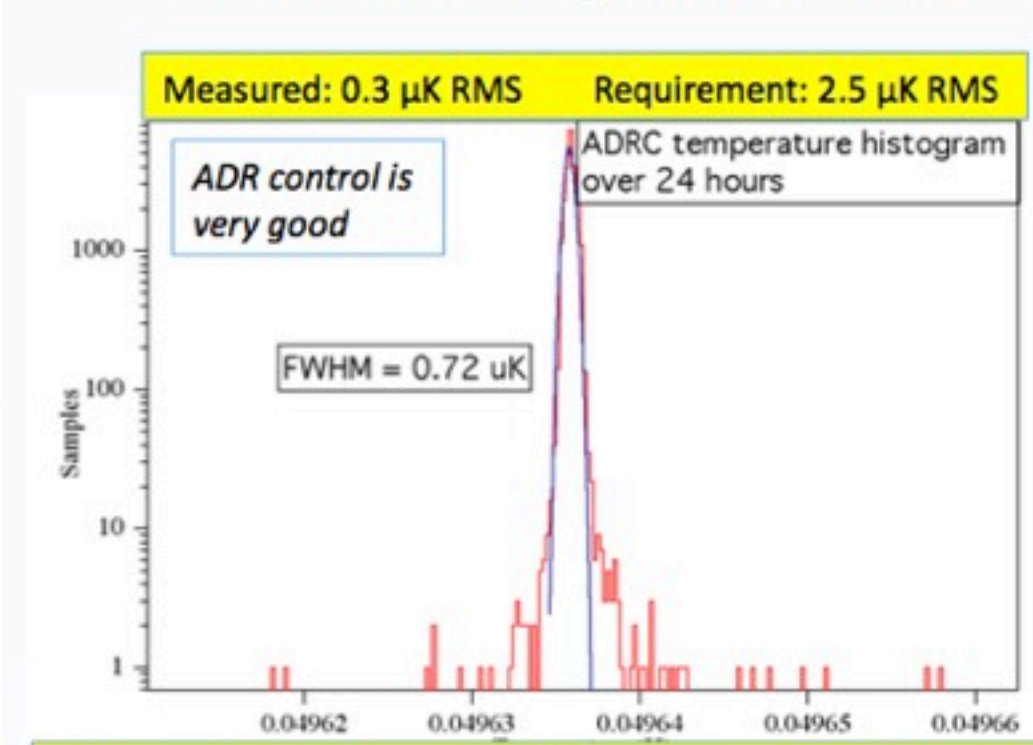
ASTRO-H Coolers/Dewar

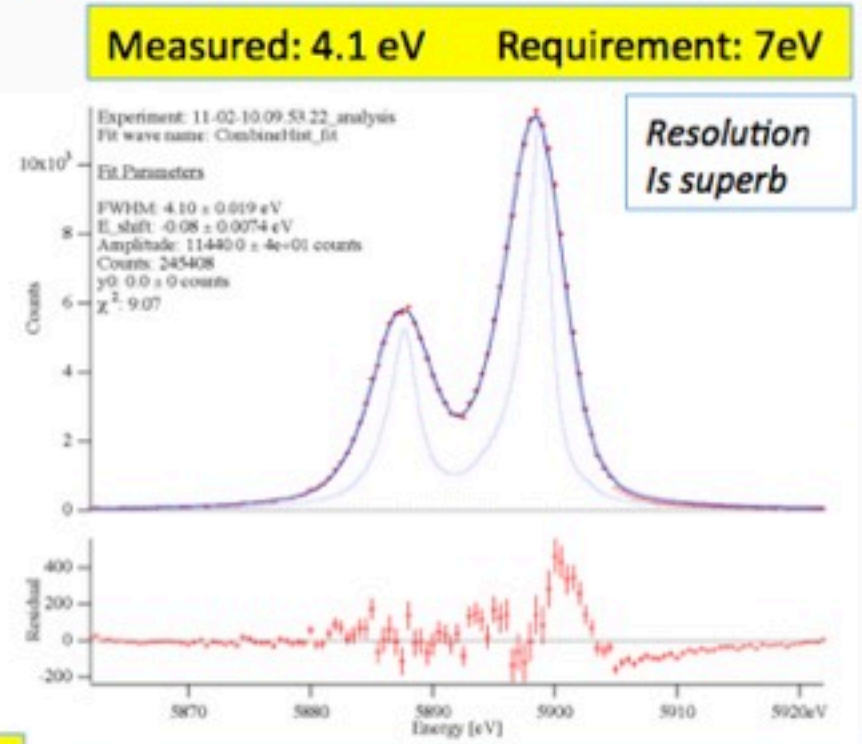


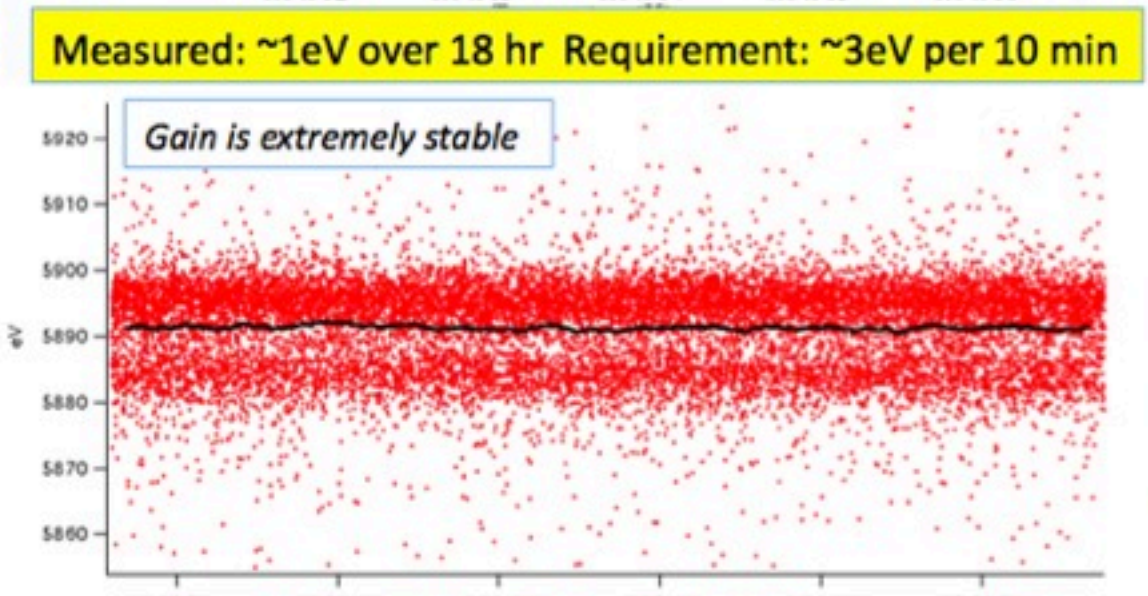
EM Detector System (Detector Assembly + Detector Array + Anti-co Detector)

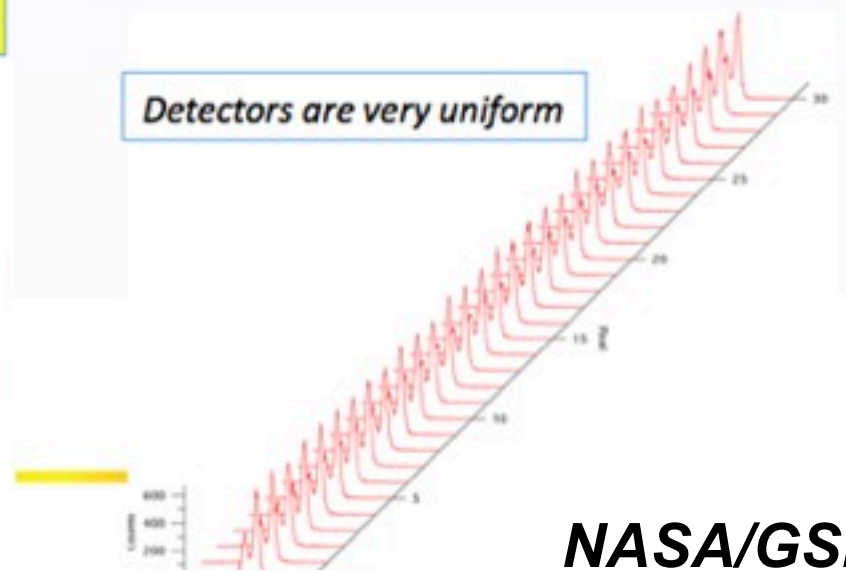


Recent Results based on the Engineering Model of ASTRO-H







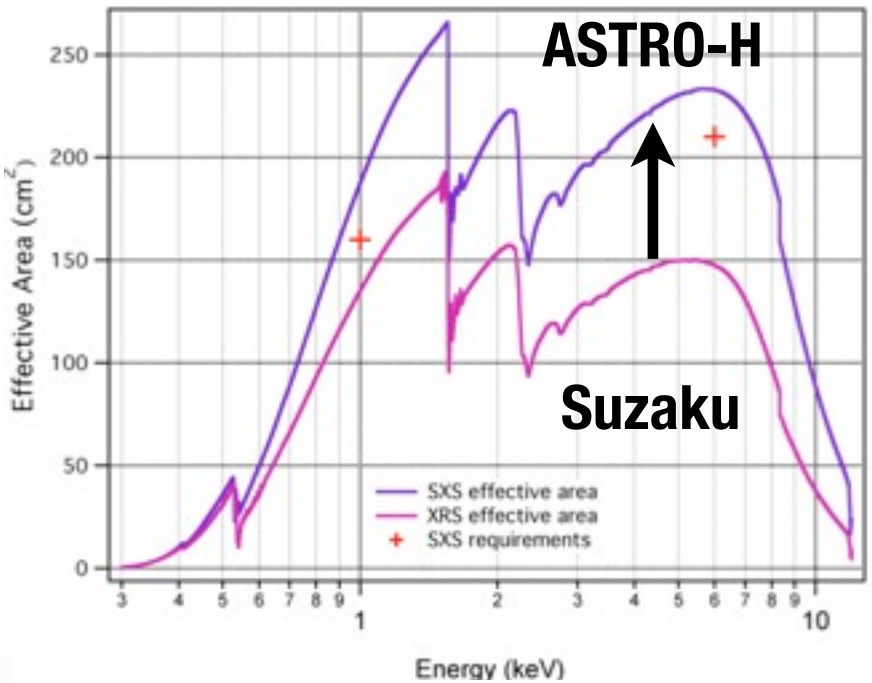


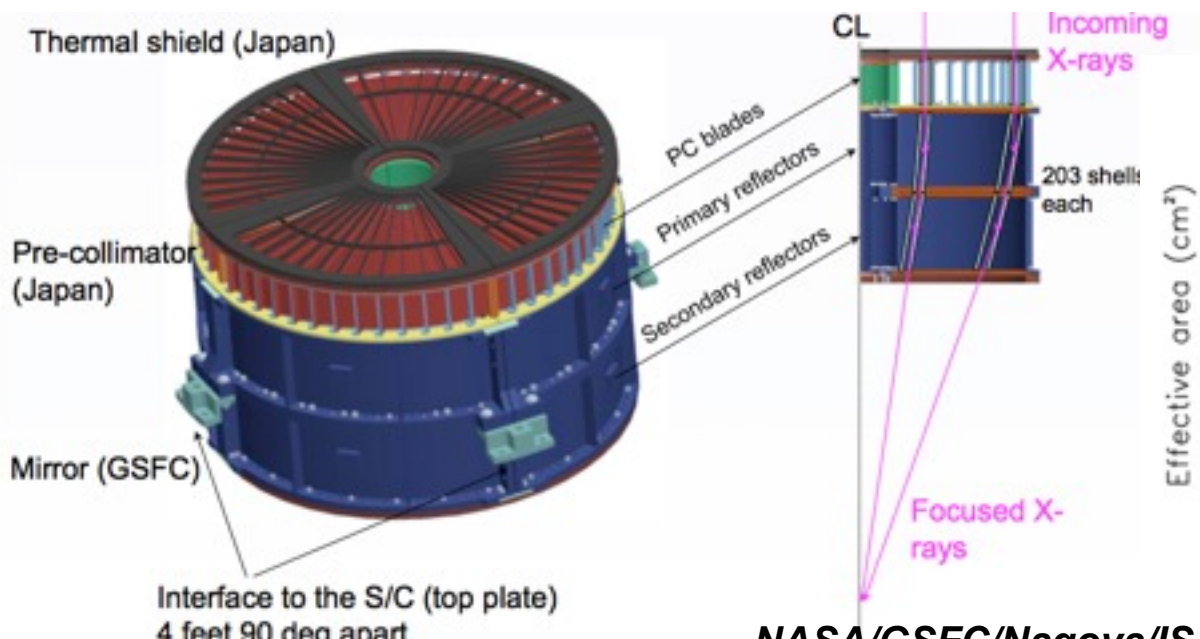
NASA/GSFC

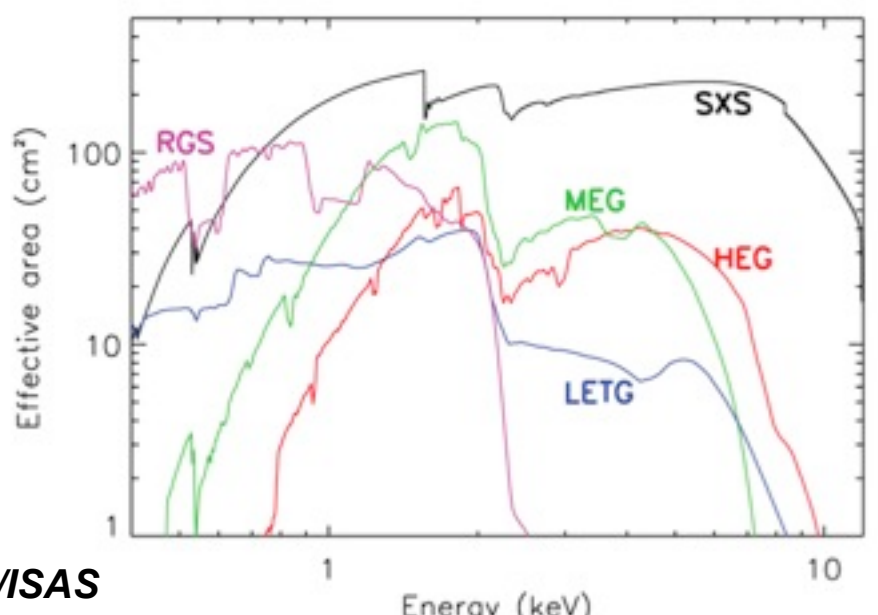
ASTRO-H Soft X-ray Telscope for SXS & SXI

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.

(1) thicker aluminum substrate for the larger radii,
(2) more forming mandrels for better substrate shaping
(3) precise alignment bars
(4) glue to fix reflectors on the alignment bars
(5) stronger housing.





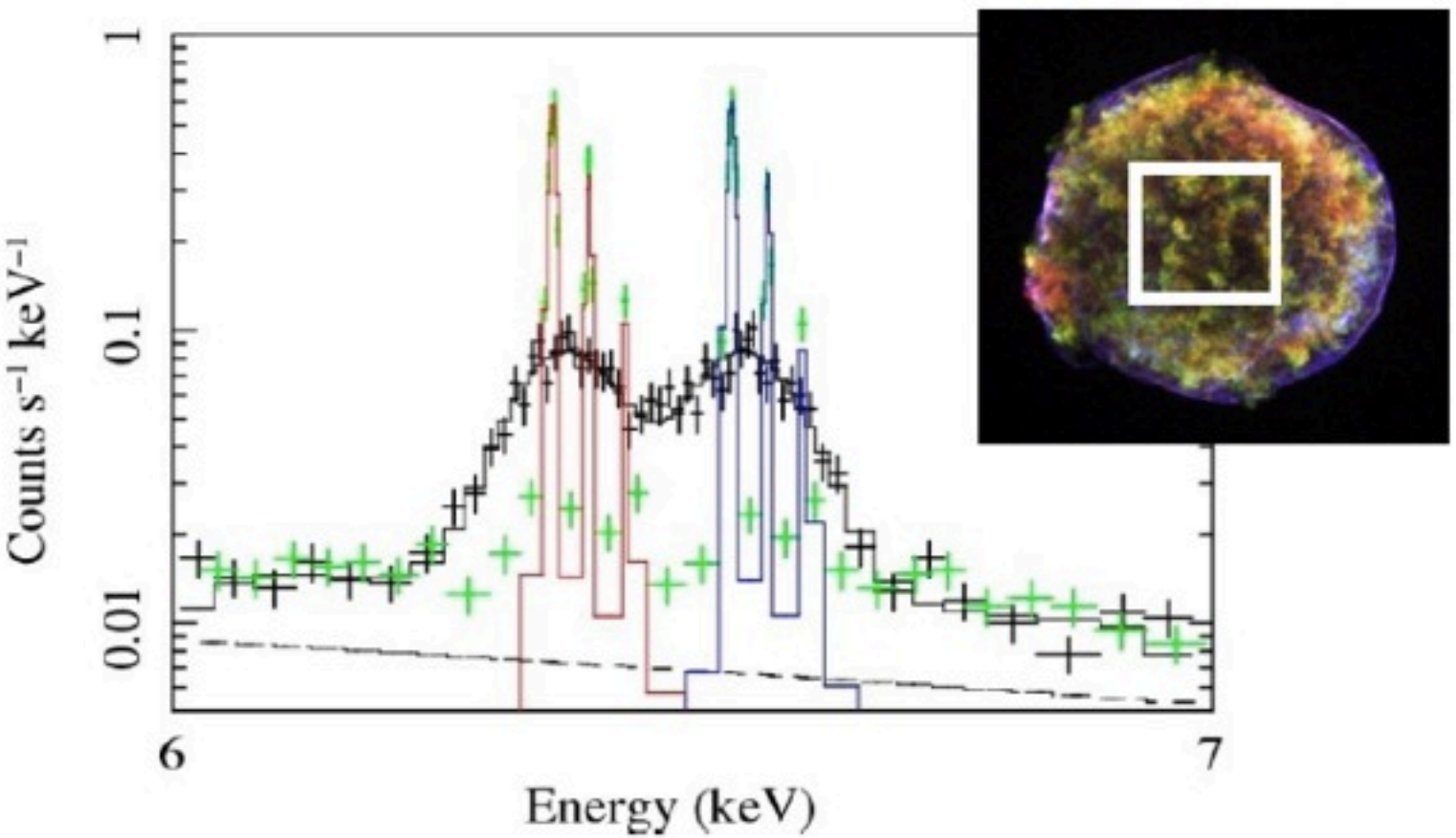


NASA/GSFC/Nagoya/ISAS

For Both SXS and SXI

ASTRO-H Micro Calorimeter Scienece

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.

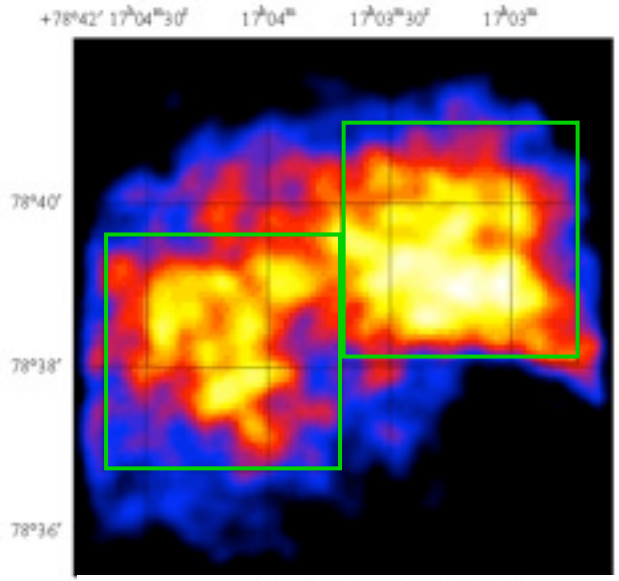
The ion temperature is assumed to be 30 billion degrees (black) or negligible (green). Red- and blue-shifted lines from the fast moving gas can be readily resolved with SXS.

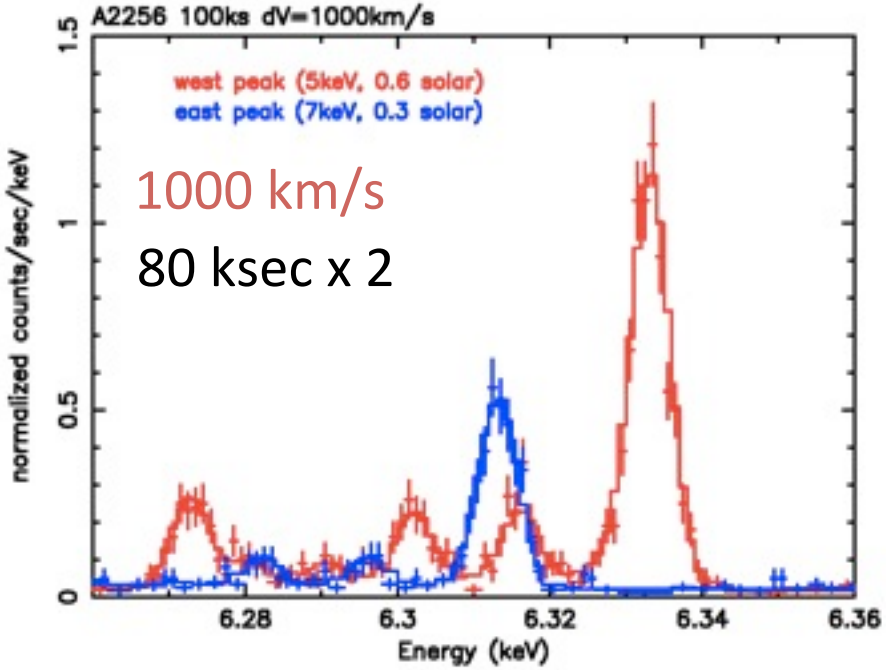
ASTRO-H Micro calorimeter + Hard X-ray Science

Merging Cluster

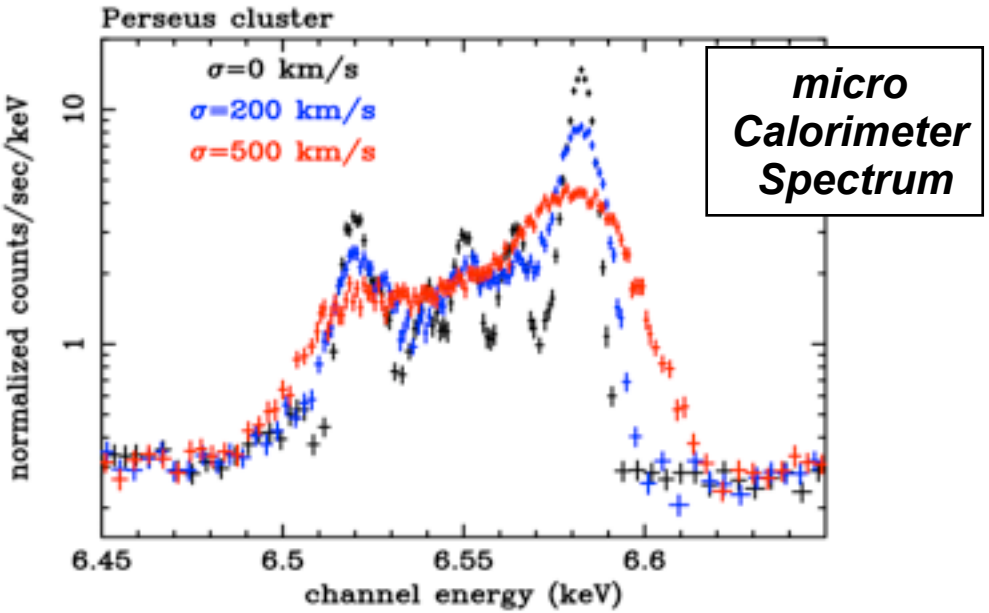
A2256

(z = 0.058)

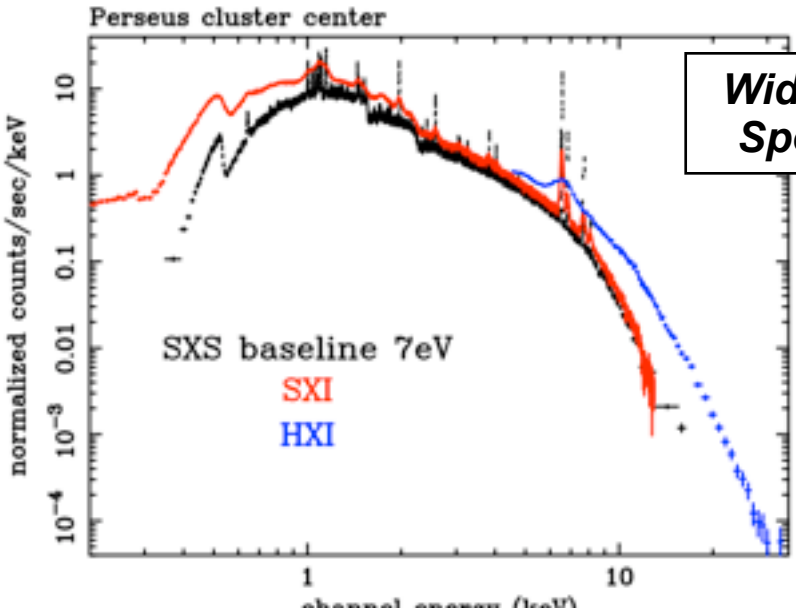




Perseus cluster (r<2', 100ks)
vapec 3T (0.6keV, 2.6keV, 6.1keV)



micro Calorimeter Spectrum



Wide band Spectrum

ASTRO-H Summary

- As the international X-ray observatory in 2010‘s, ASTRO-H will investigate the physics of the high-energy universe using high-resolution, high-throughput imaging and spectroscopy from 0.3 to 600 keV.
- ASTRO-H will push on X-ray astronomy to a new exciting phase by showing dynamical motions with a micro-calorimeter. Direct measurement of velocity field.

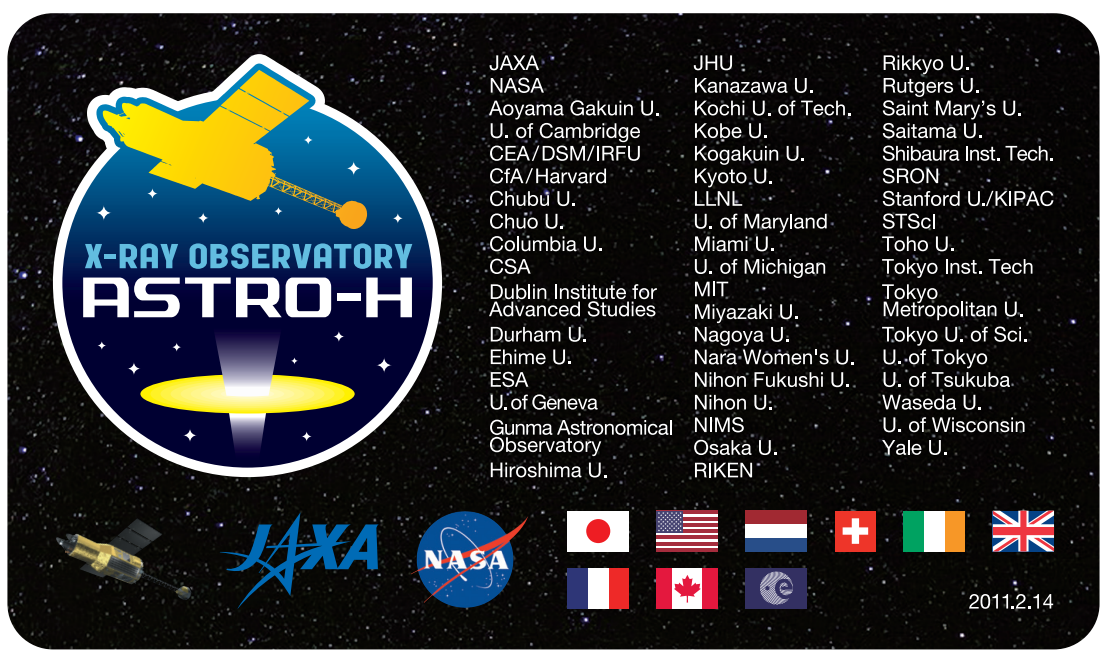
ASTRO-H is now in Phase C.

Next major step is the CDR (critical design review) in June/July 2011 for the planned launch year of 2014.

Simulation Tools are available from

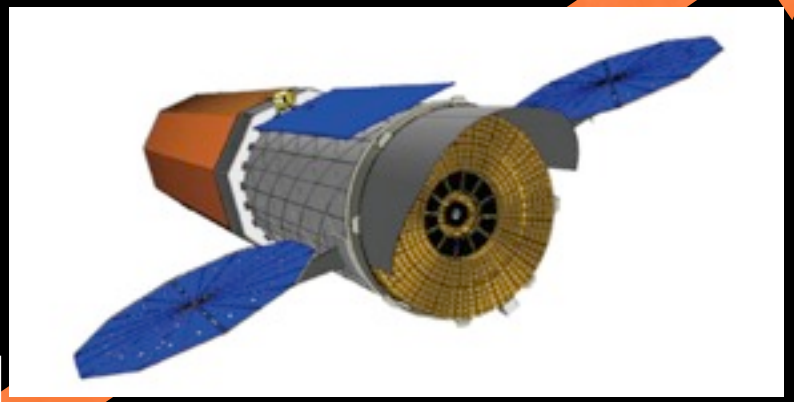
http://astro-h.isas.jaxa.jp

ASTRO-H Team
(more than 160 scientists are involved in the project)



One more Summary

The Japanese X-ray community regards the IXO mission as the next major X-ray program in Japan, following ASTRO-H.

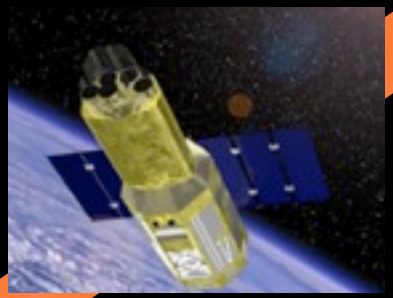


IXO

$6500cm^2$@6keV

ASTRO-H

Suzaku



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

- **The ISAS Space Science Committee approves that the IXO team in Japan can join the study activity on IXO during the definition phase, if the IXO mission is approved to proceed to the next phase in the down selection process of the Cosmic Vision.**