The ASTRO-H Mission

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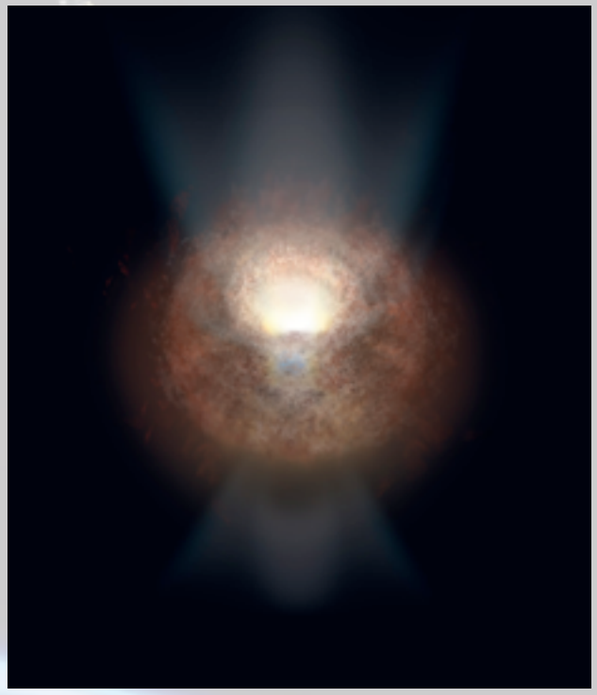
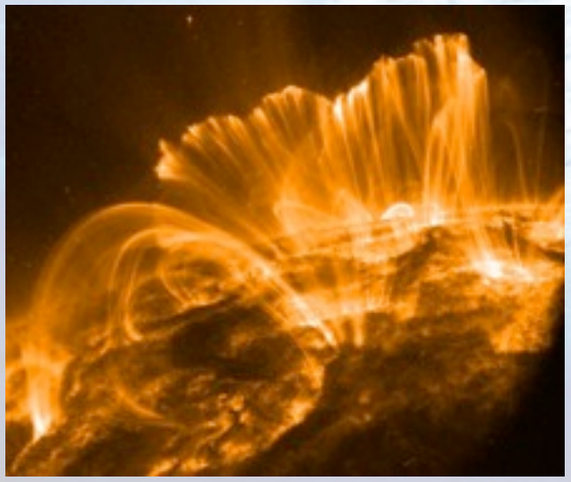
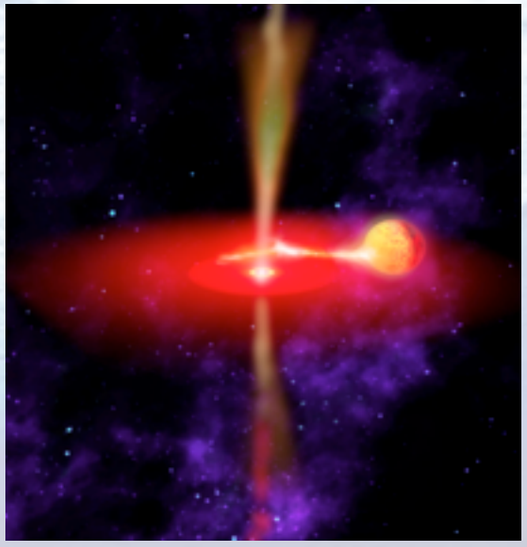
on behalf of the ASTRO-H team

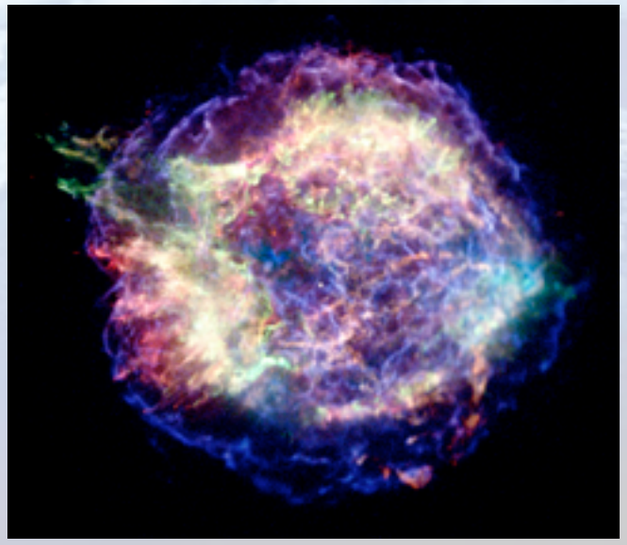
Dynamic and energetic X-ray universe

- X-ray reveals many high-temperature or energetic phenomena in the Universe.
- Most of celestial objects, e.g., stars, supernovae, galaxies, clusters of galaxies are found to be bright in X-rays.
- X-ray observatory with better sensitivity is an indispensably powerful tool to understand the nature, formation and evolution of these objects and the Universe itself.



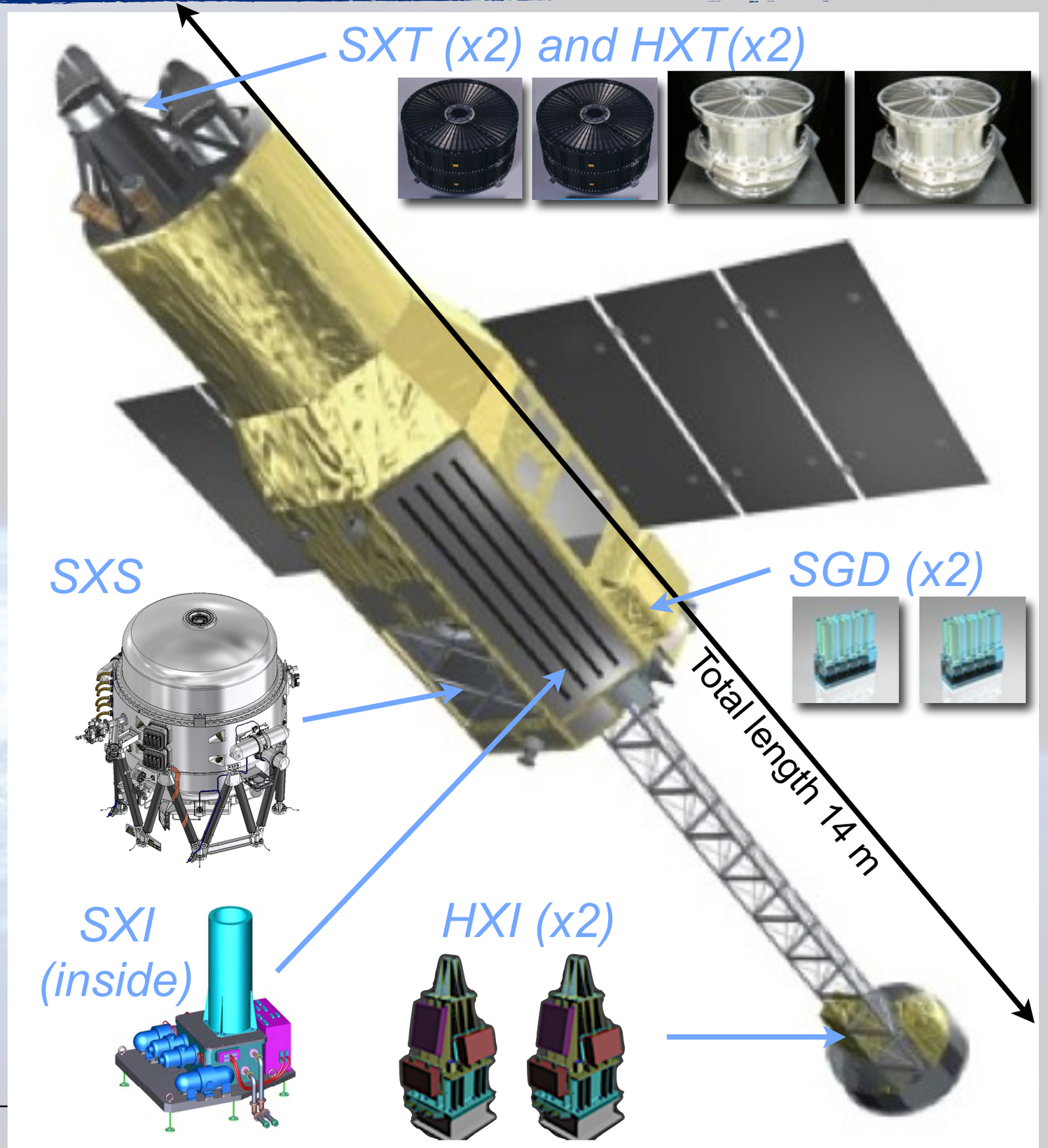






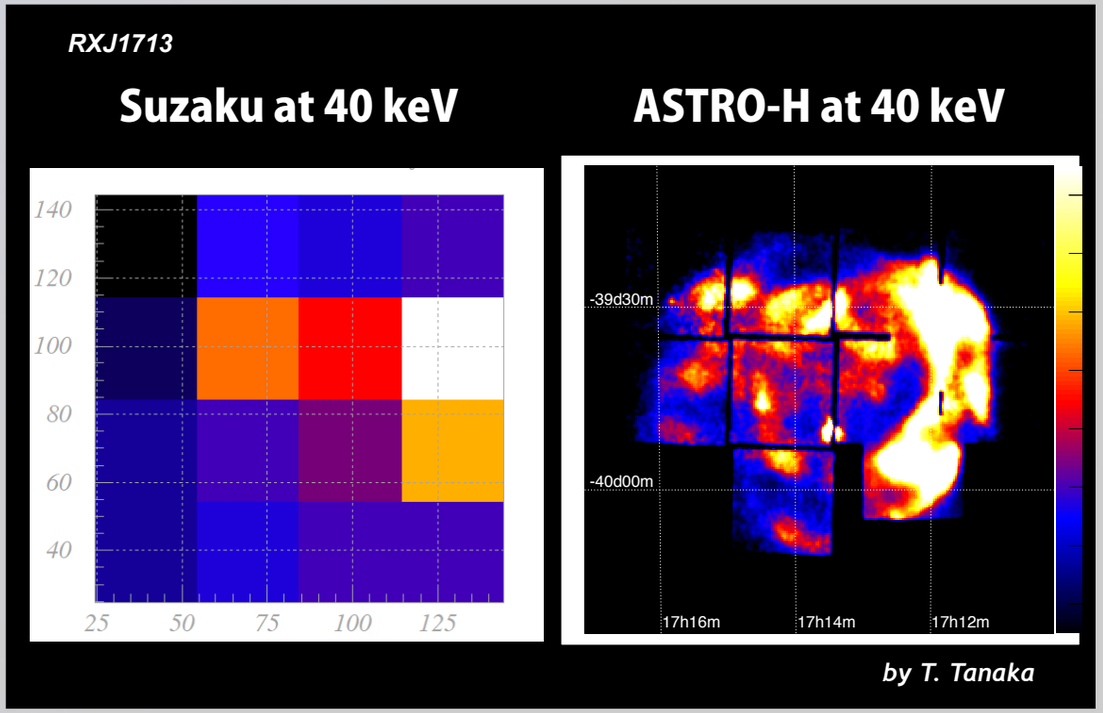
ASTRO-H: the 6th Japanese X-ray satellite

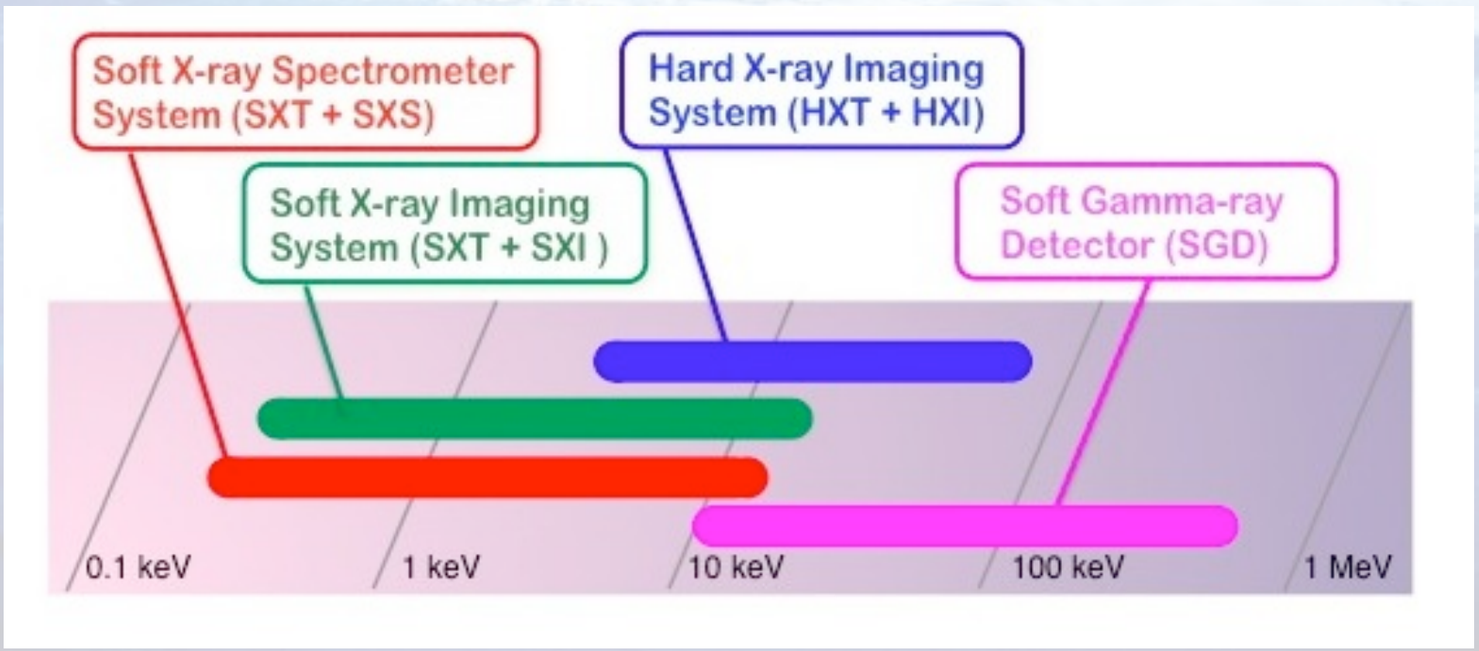
- ASTRO-H is the 6th Japanese X-ray satellite developed with international collaboration.
    - T. Takahashi et al., The ASTRO-H Mission, SPIE Vol. 7732, 2010, (arXiv:1010.4972)
- Planned to be launched in 2014 from Tanegashima, Japan.
    - ~550 km circular orbit with inclination of <31 deg.
- Four instruments co-aligned.
    - SXT-S + SXS (microcalorimeter)
    - SXT-I + SXI (CCD imager)
    - HXT + HXI (multi-layer mirror + CdTe-based hard X-ray imager)
    - SGD (Compton camera soft gamma-ray detector)

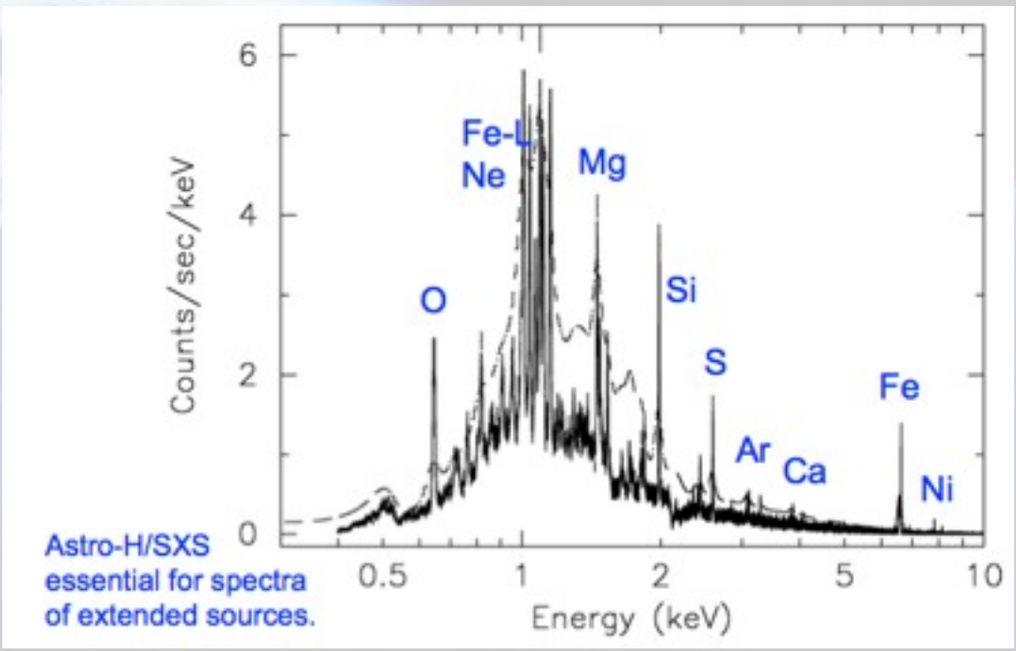


ASTRO-H characteristics

- Wide-band (0.3-600 keV) high-sensitivity observations.
- High-resolution spectroscopy up to 12 keV, also for extended sources.
- Imaging in hard X-rays.

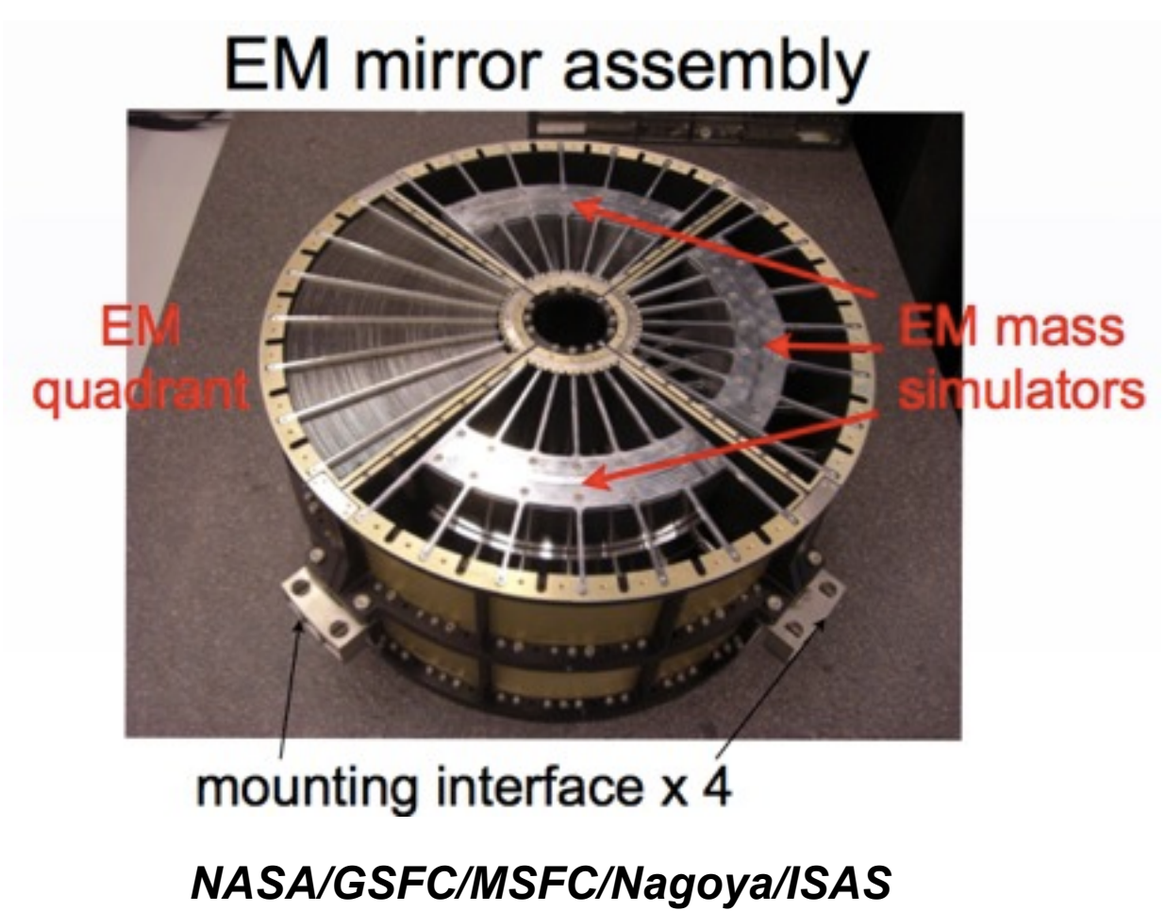


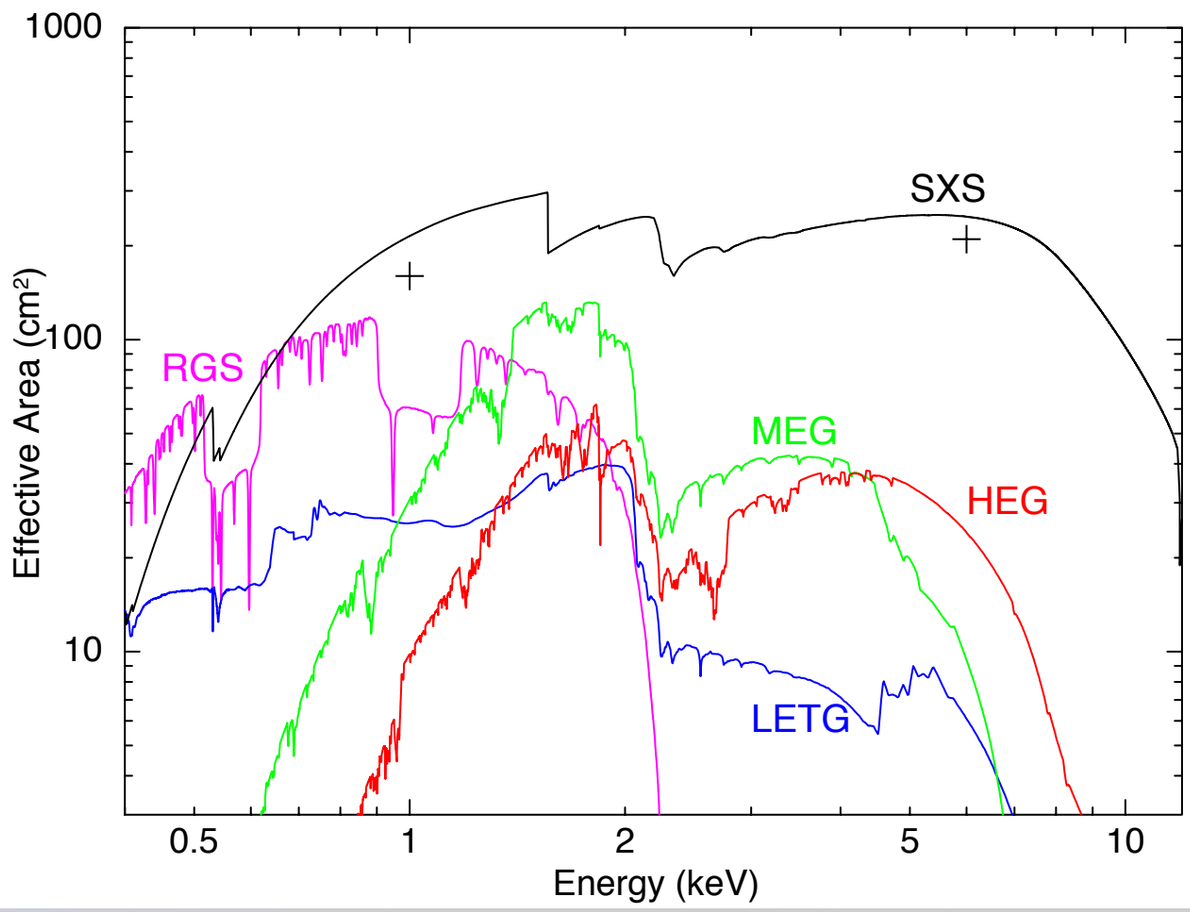




ASTRO-H instrument: Soft X-ray Telescope (SXT)

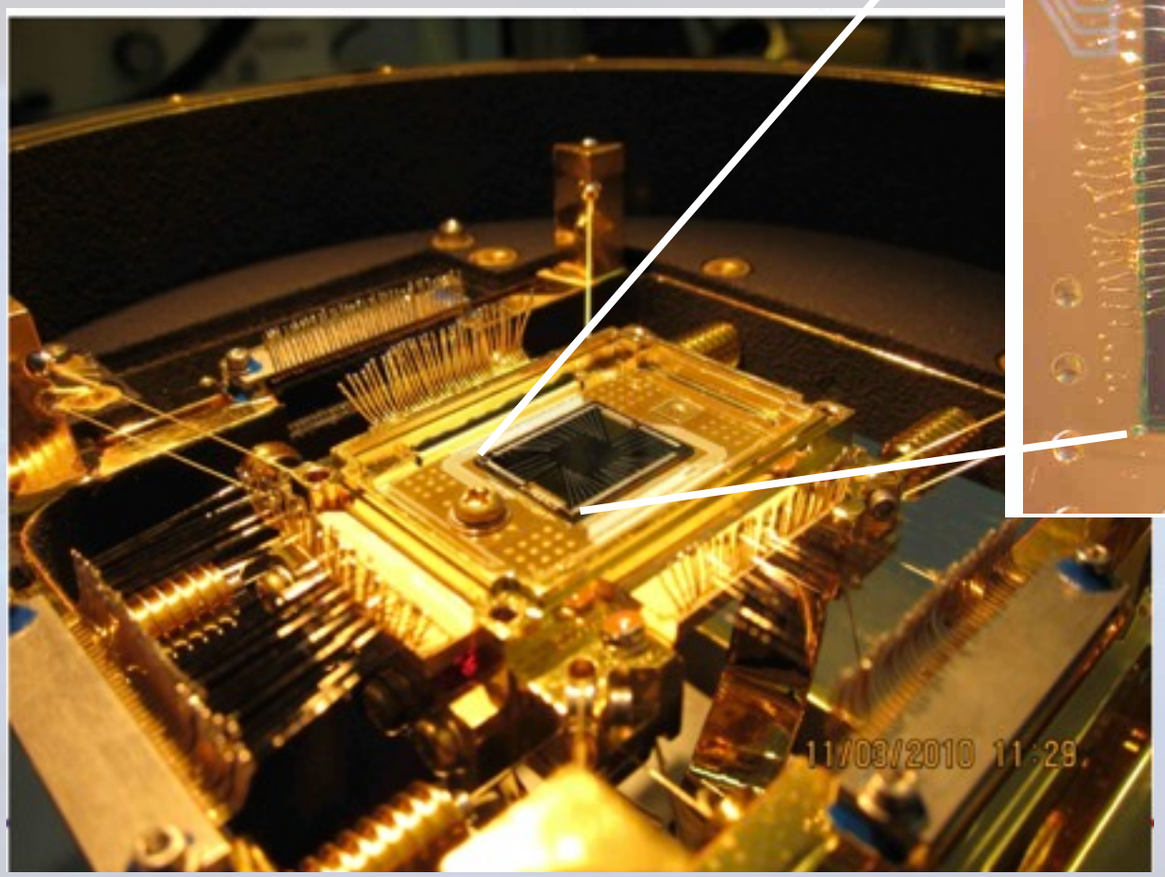
- SXT (telescope for SXS and SXI) is a light-weight large-area nested thin-foil mirror, based on heritages of ASCA and Suzaku.
- With the diameter and focal length larger, the number of foils is increased.
- Angular resolution is improved from Suzaku. EM quadrant shows 1'.3 HPD, while the requirement for ASTRO-H is 1'.7.

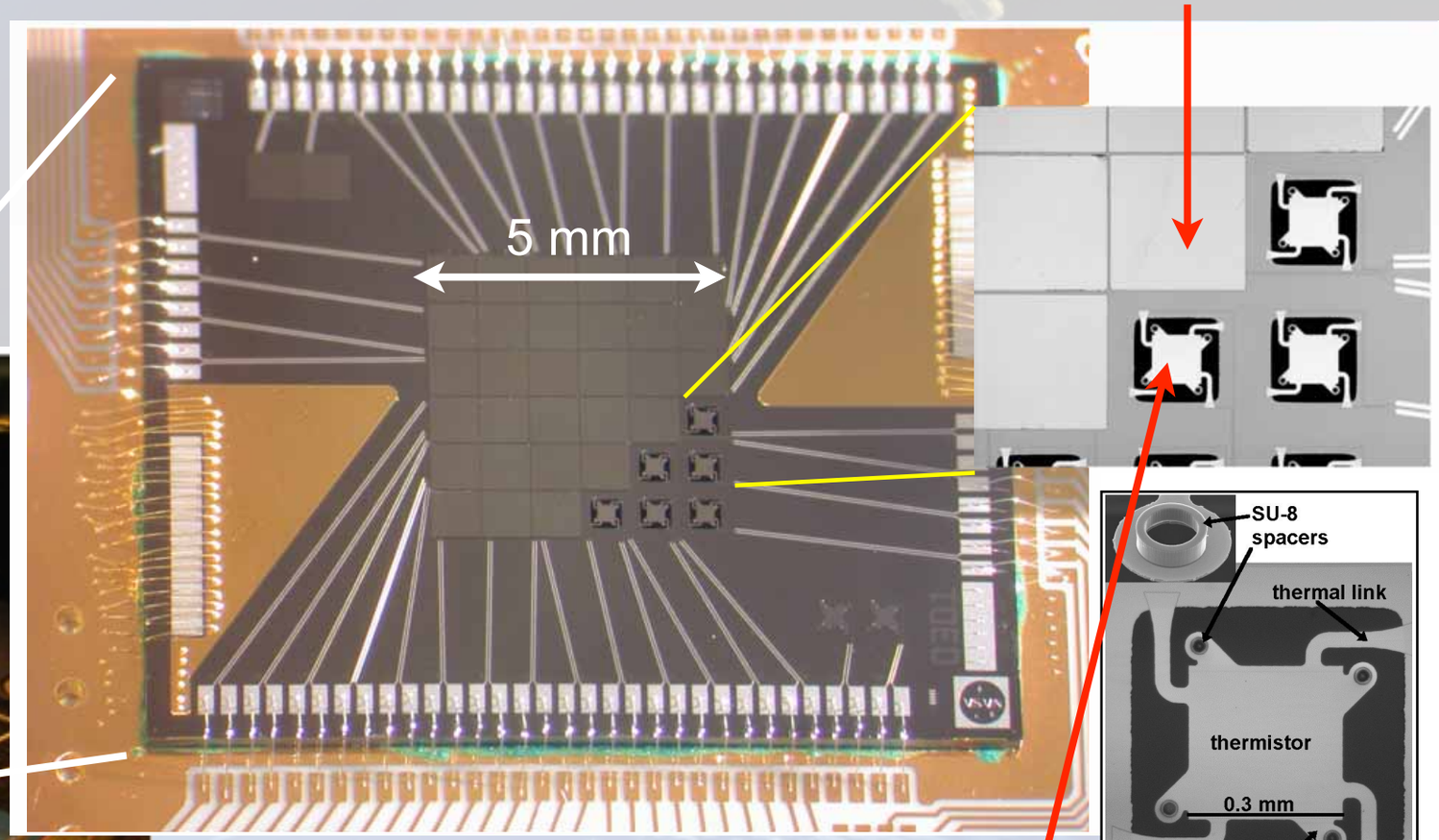




ASTRO-H instrument: Soft X-ray Spectrometer (SXS)

- Cryogenic spectrometer based on microcalorimeter.
- 6 x 6 array with 3'x3' field of view.
- Operated at 50 mK.

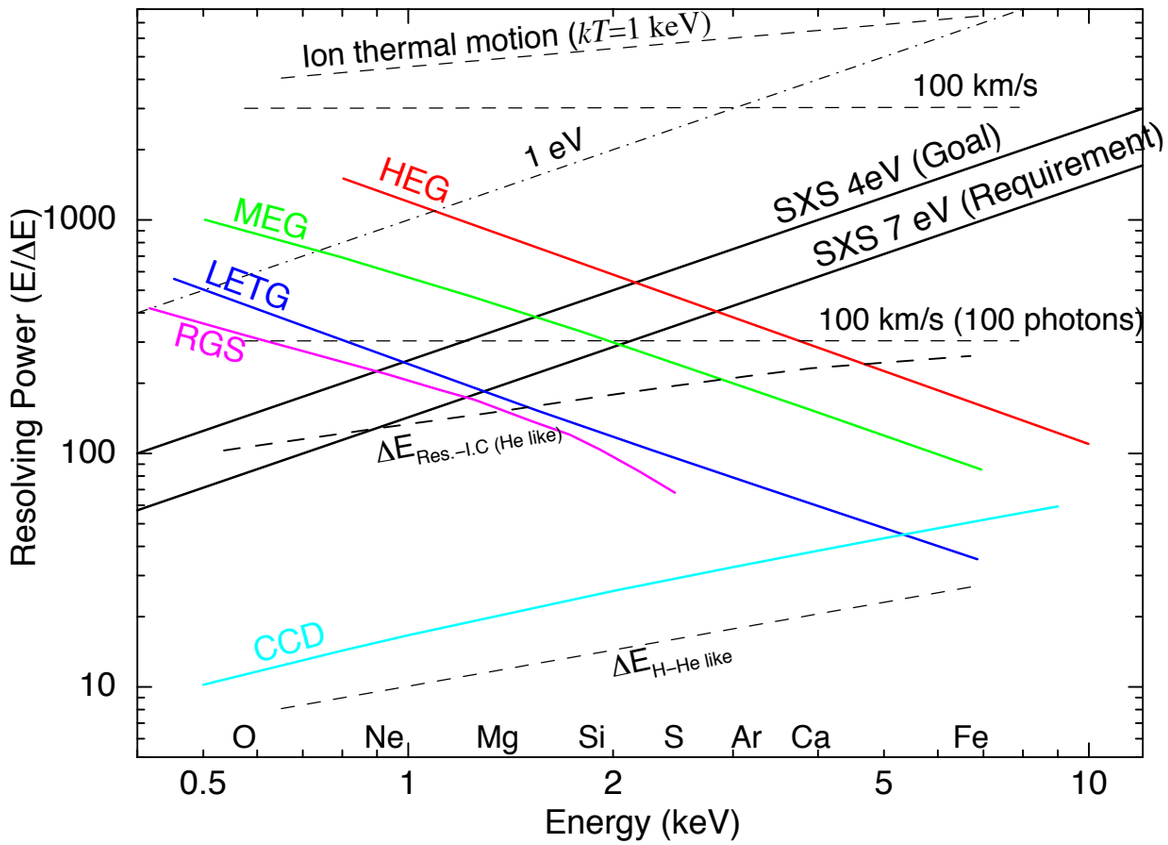


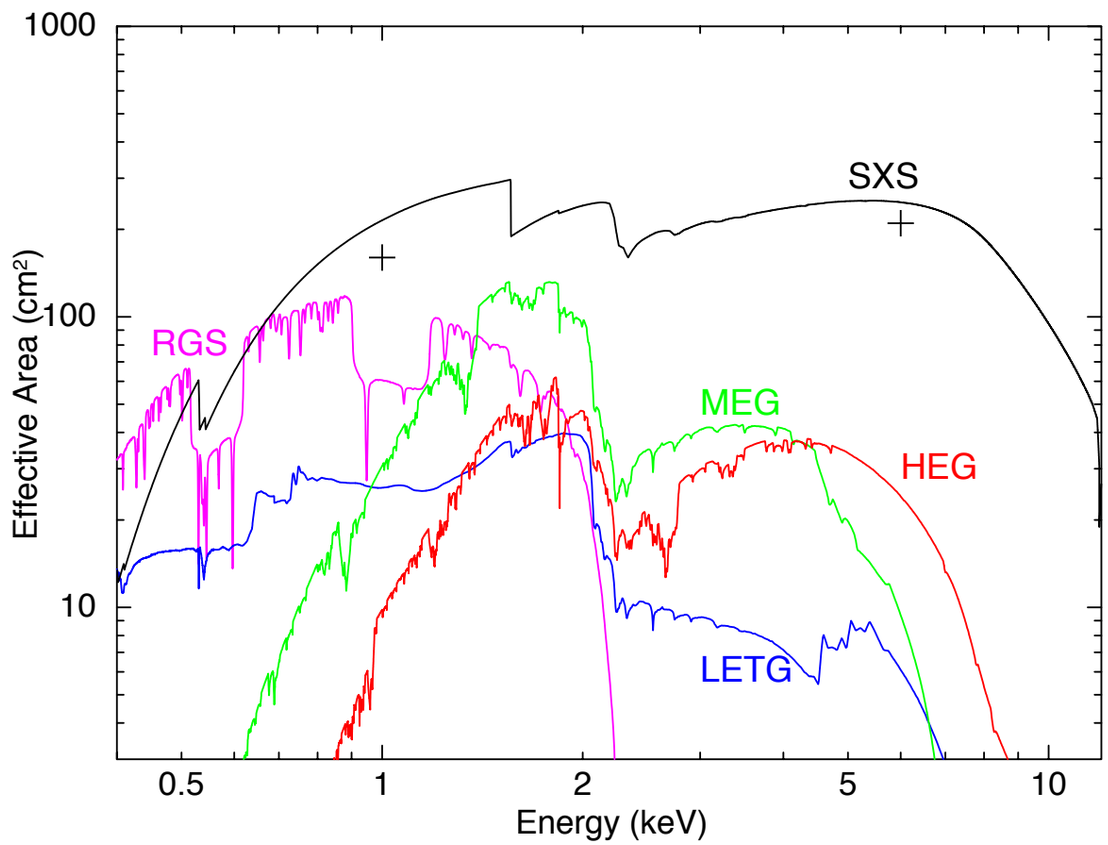


NASA/GSFC

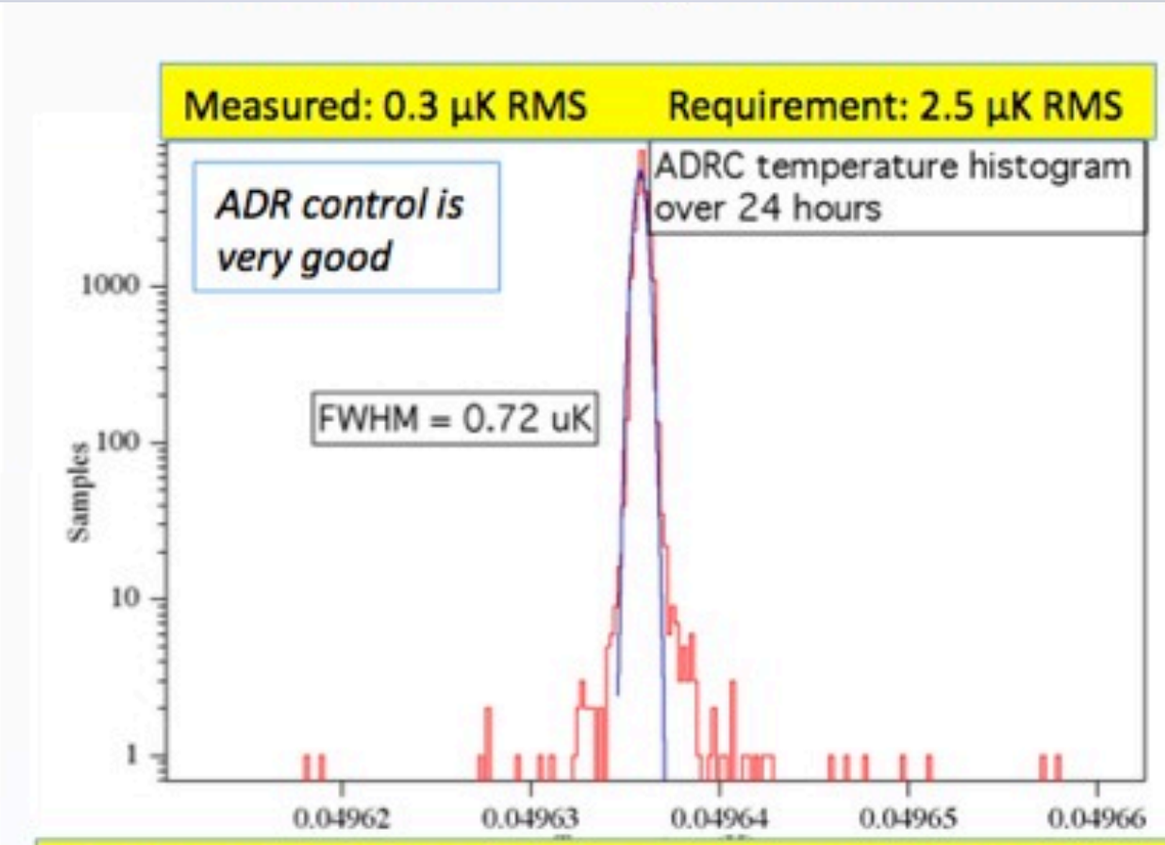
ASTRO-H instrument: Soft X-ray Spectrometer (SXS)

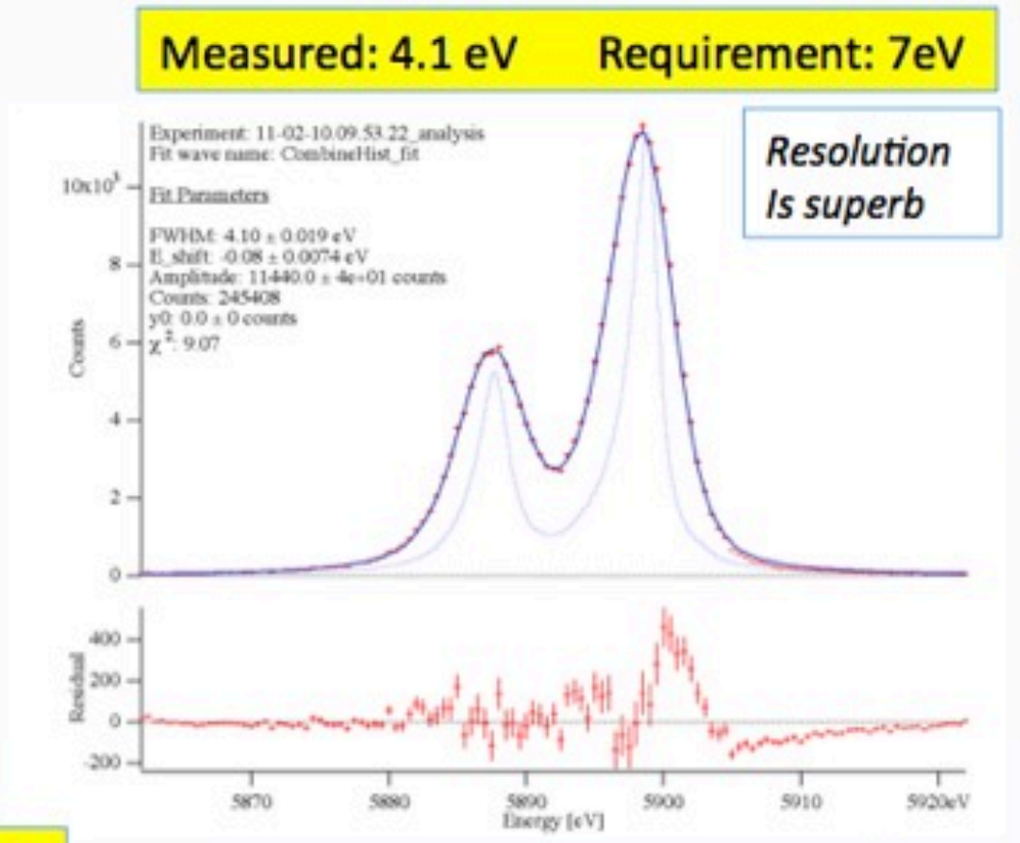
- SXS exhibits the best energy resolution above 3 keV, with much larger effective area compared to grating spectrometers.
- Fine spectroscopy for extended sources will become available for the first time.

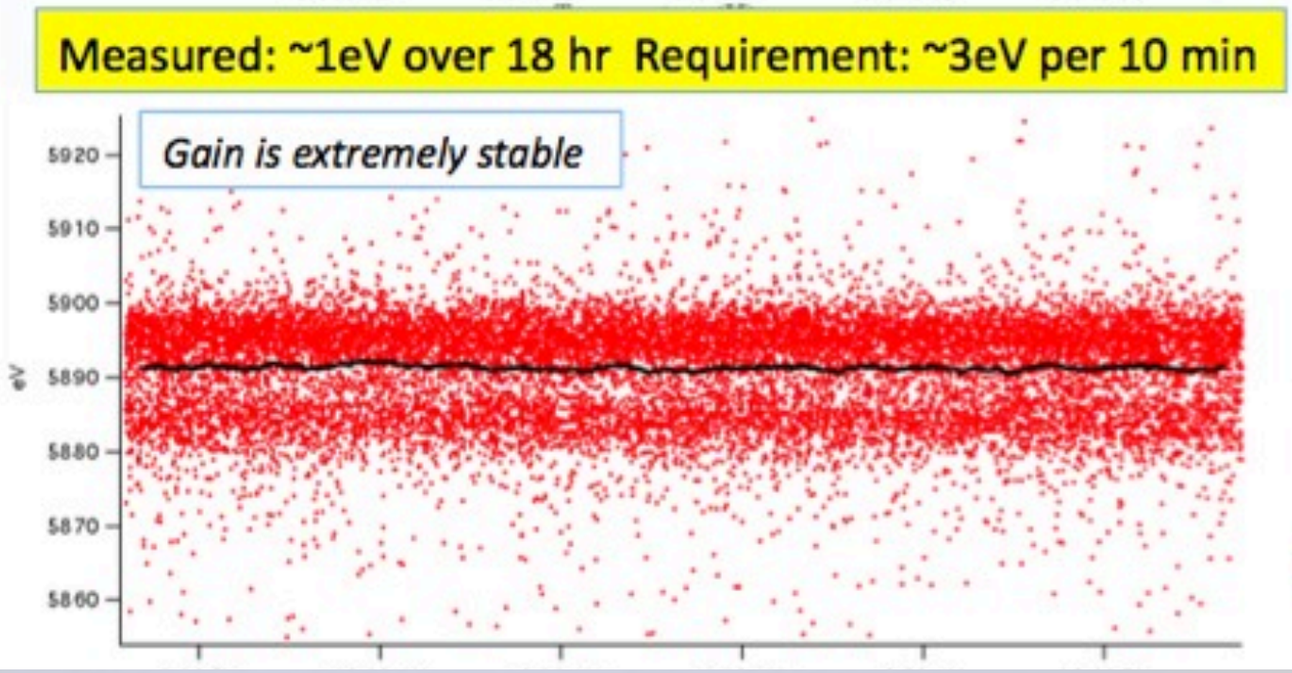


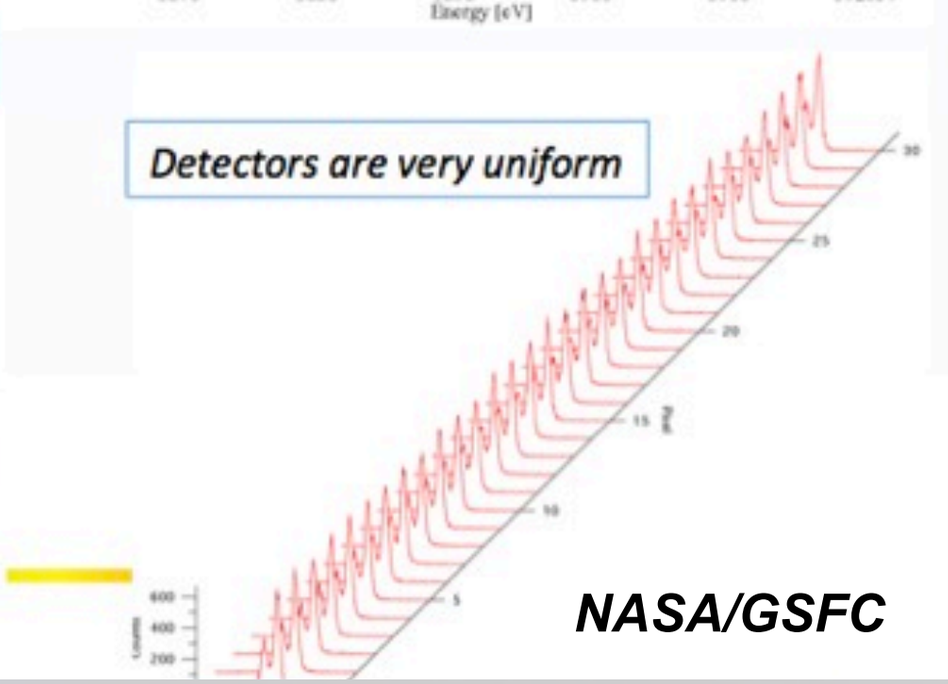


ASTRO-H instrument: Soft X-ray Spectrometer (SXS)





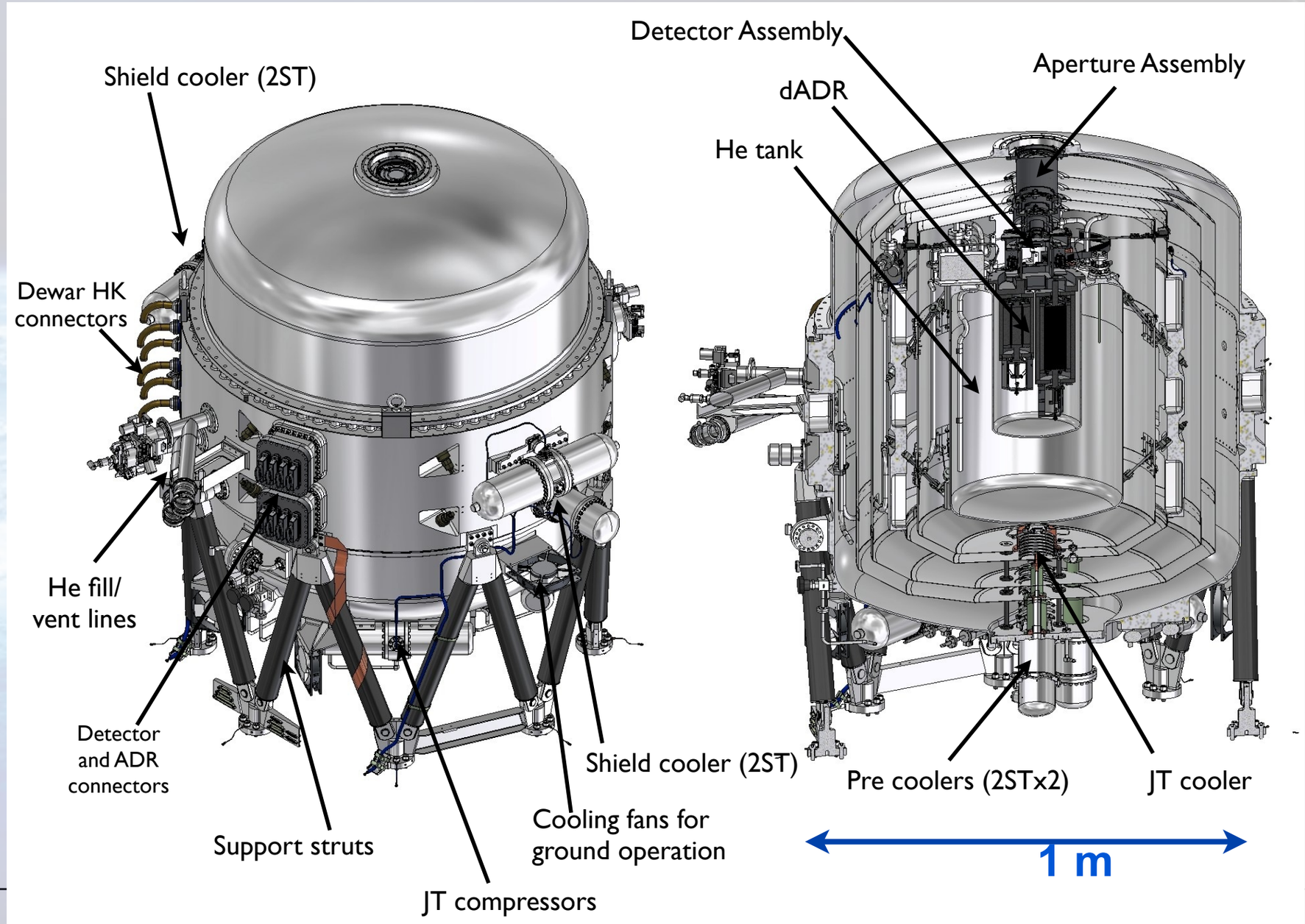




NASA/GSFC

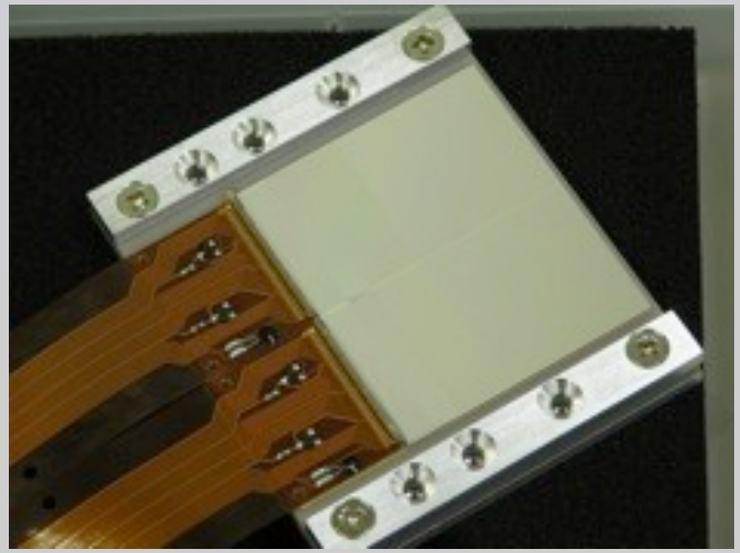
ASTRO-H instrument: Soft X-ray Spectrometer (SXS)

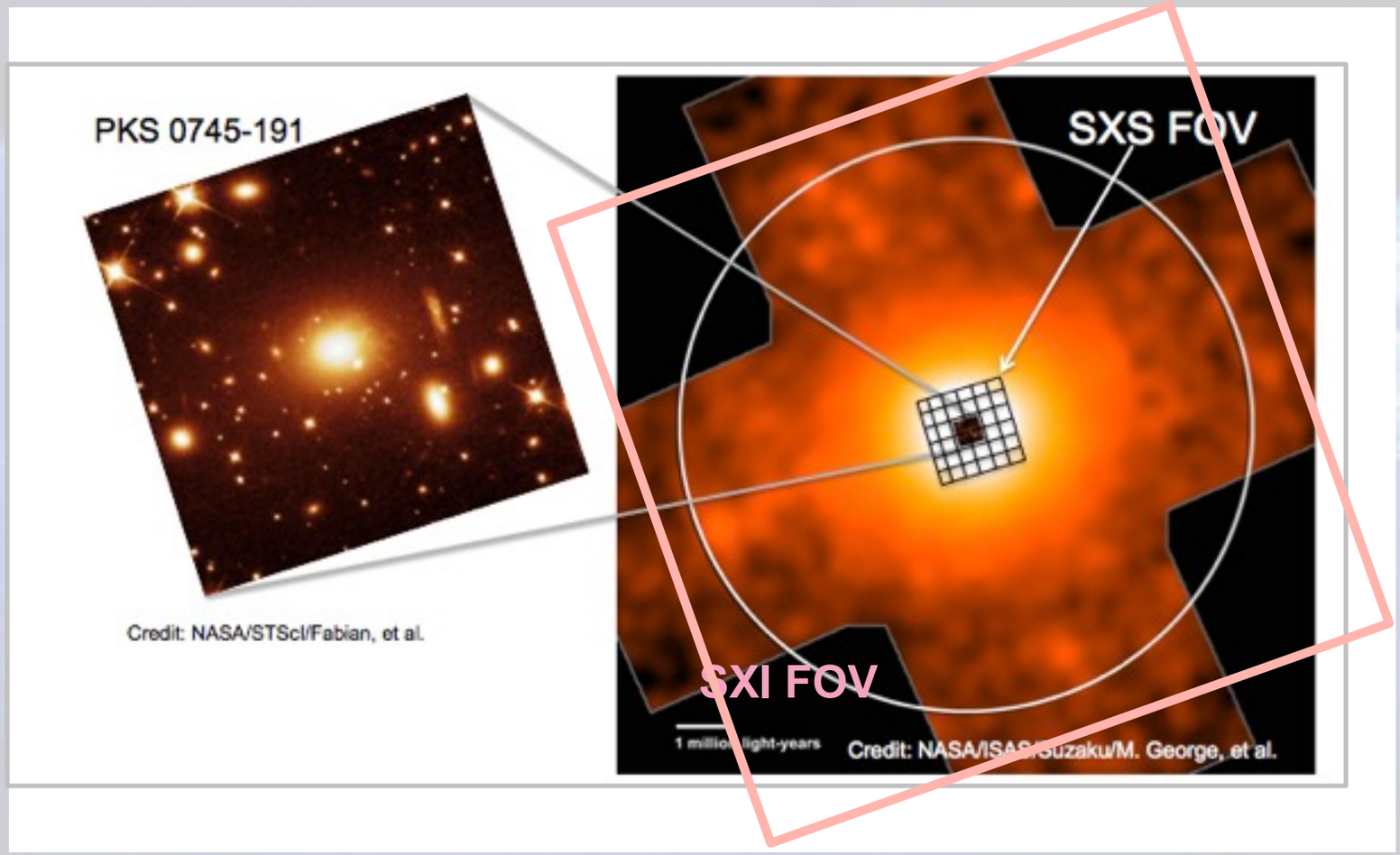
- The detector is cooled to 50 mK using cryocoolers (Stirling and Joule-Thomson), superfluid He, and ADR.
- He life time is > 3 years. Cryogen-free operation is also possible.

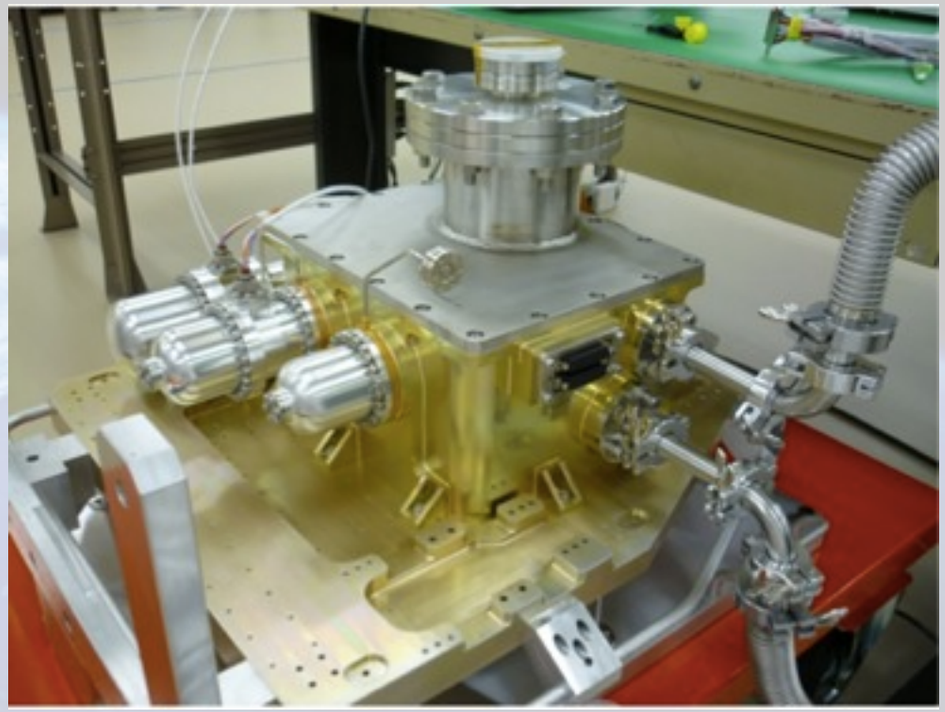


ASTRO-H instrument: Soft X-ray Imager (SXI)

- A back-illuminated CCD with very large field of view (38’ x 38’) with 4 chips (62 mm x 62 mm).
- Cooled down to -120 degC by a Stirling cryocooler.
- Low and stable background expected because of low-earth orbit

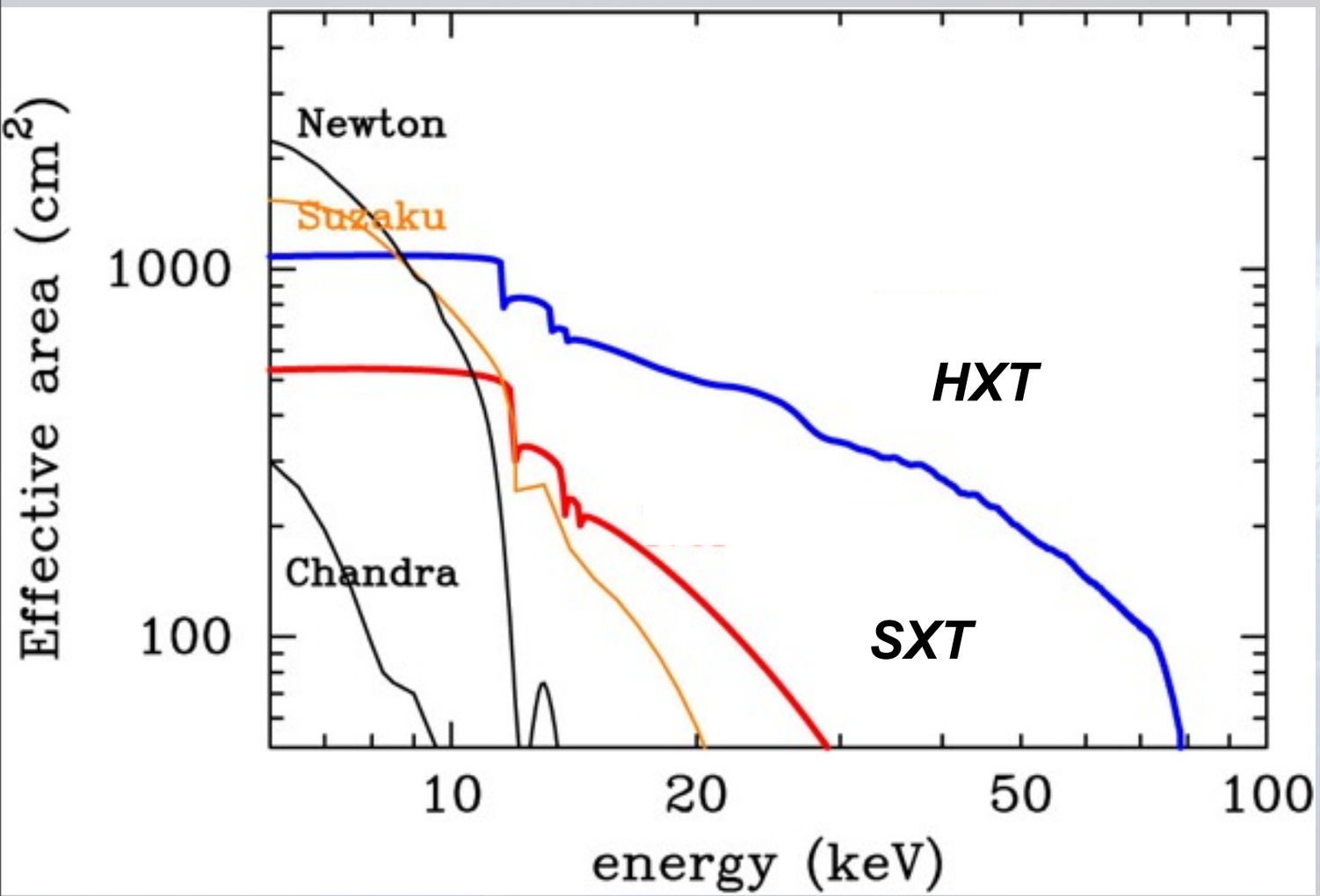


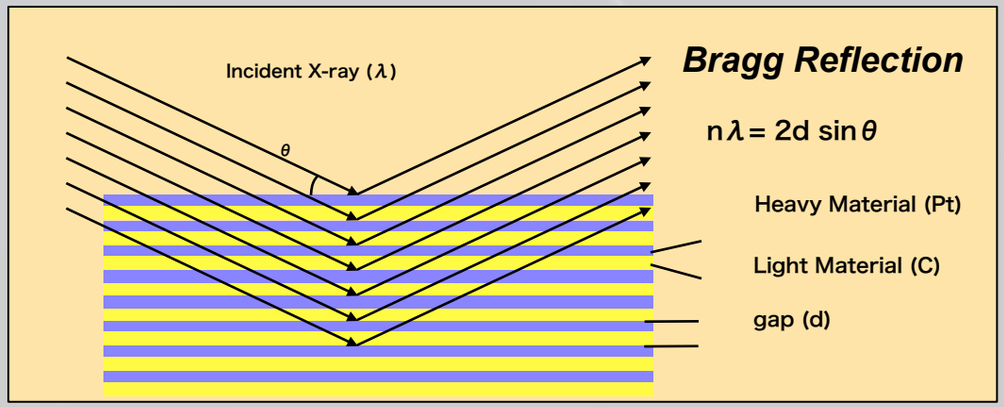




ASTRO-H instrument: Hard X-ray Telescope (HXT)

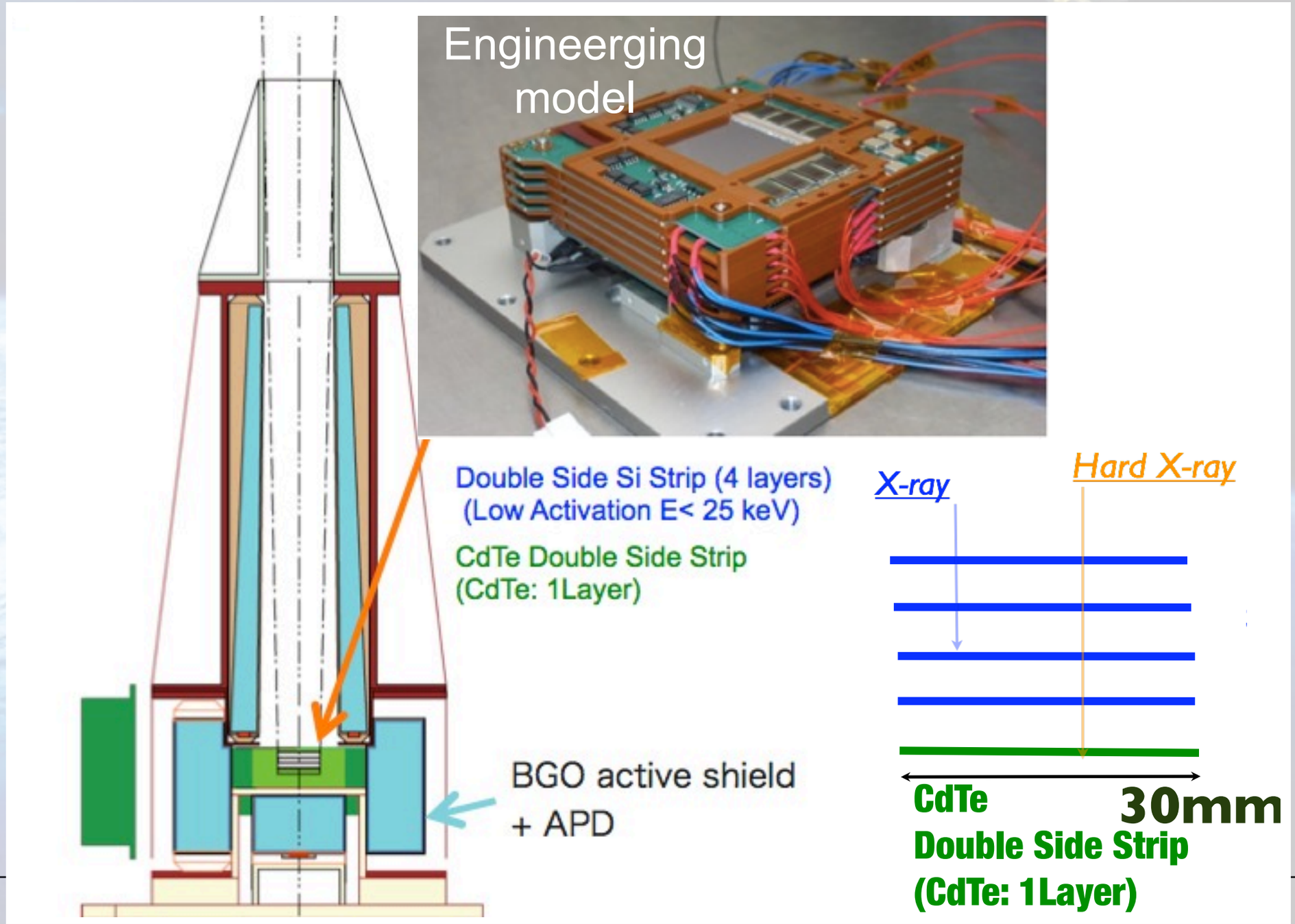
- Pt/C multi-layer mirror using Bragg reflection technique.
- HXT provides large effective area and imaging capability up to 80 keV.
- HPD is <1'.7





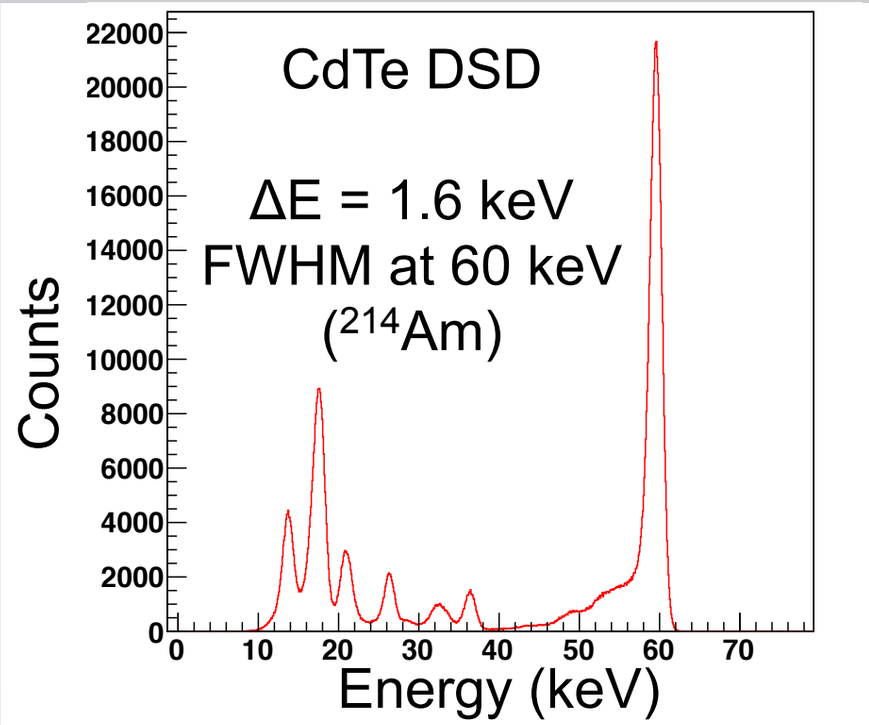
ASTRO-H instrument: Hard X-ray Imager (HXI)

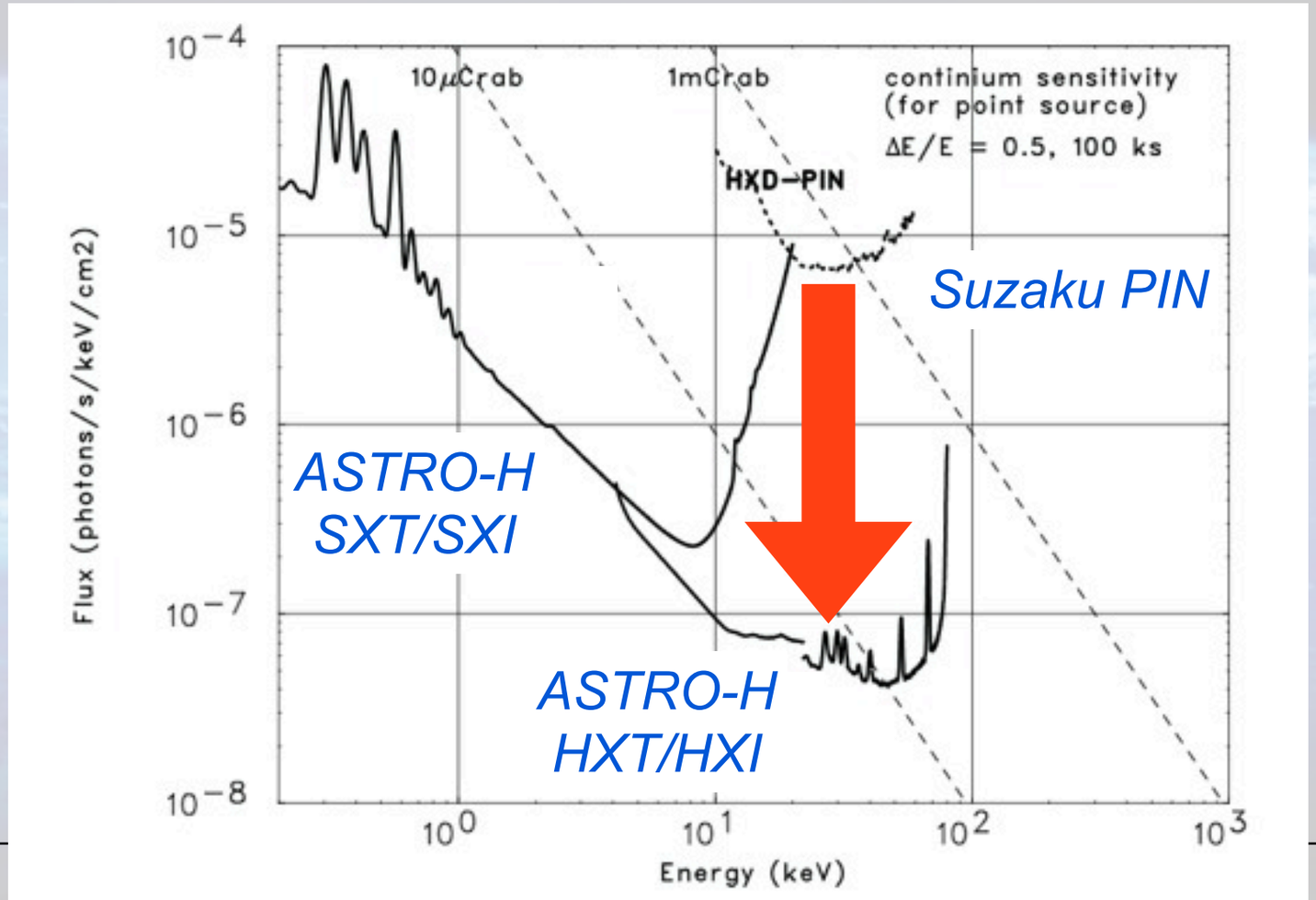
- Si+CdTe stacked hybrid imager sensitive in 5-80 keV energy range.
- Background is reduced by putting the sensor in the well-type BGO shield.

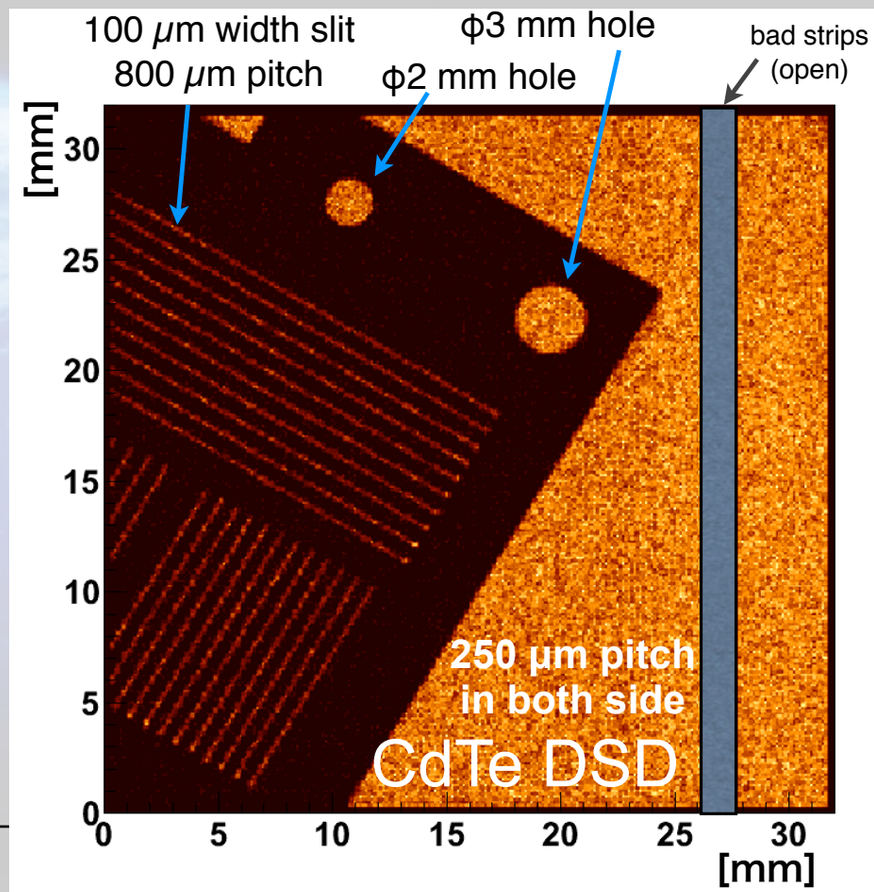


ASTRO-H instrument: Hard X-ray Imager (HXI)

- Combination of HXT and HXI makes the detection limit of point sources ~2 orders of magnitude better than that of Suzaku.
- Energy resolution of 1.6 keV (FWHM) at 60 keV and good imaging capability of CdTe DSD are demonstrated with EM.





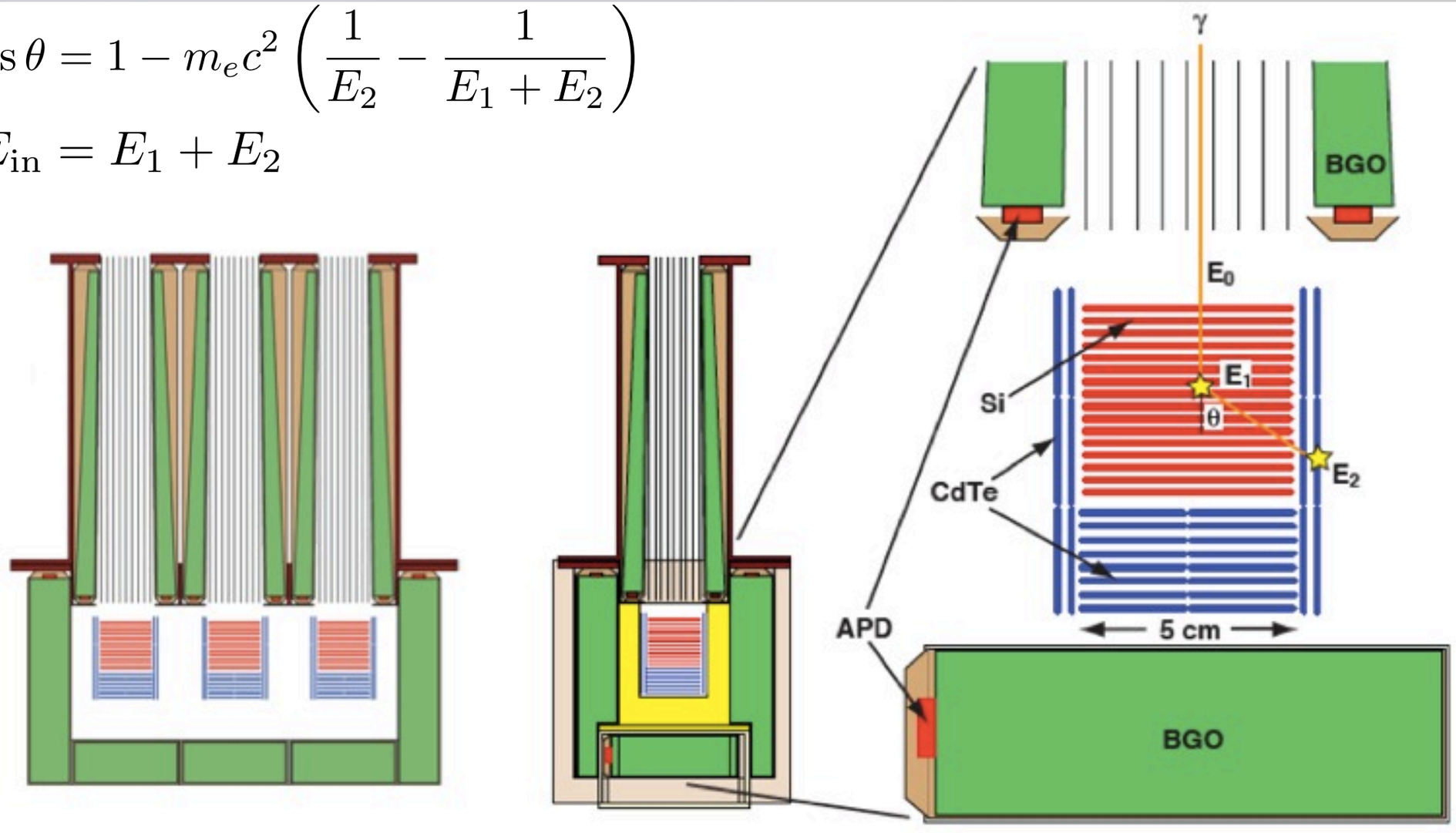


ASTRO-H instrument: Soft Gamma-ray Detector (SGD)

- Narrow-field Si/CdTe gamma camera using Compton kinematics.
- Sensitive in 40-600 keV with ultimately low background achieved by a well-type shield.
- Polarization cal also be measured for >60 keV.

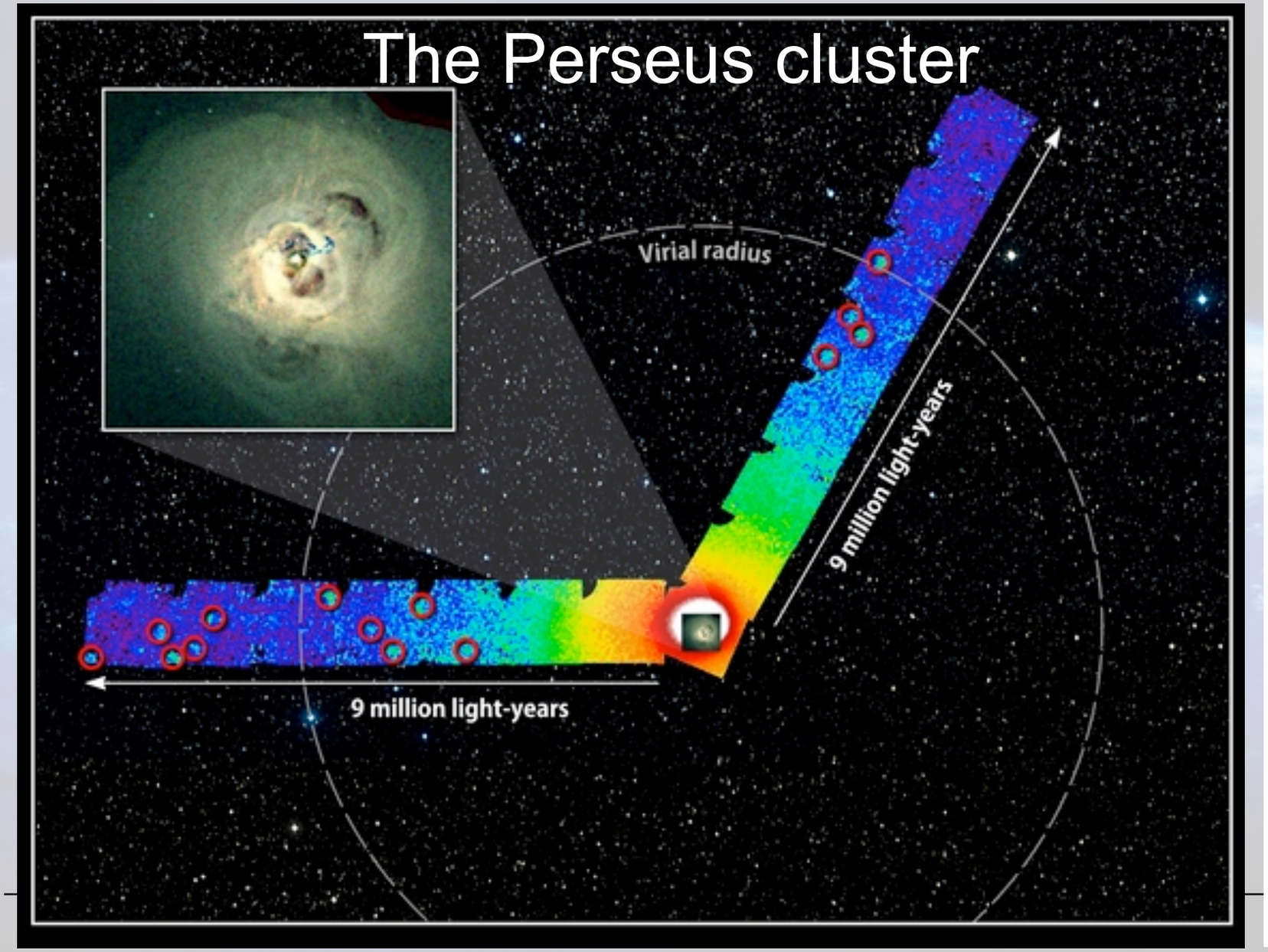
$$\cos\theta = 1 - m_e c^2 \left(\frac{1}{E_2} - \frac{1}{E_1 + E_2} \right)$$

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

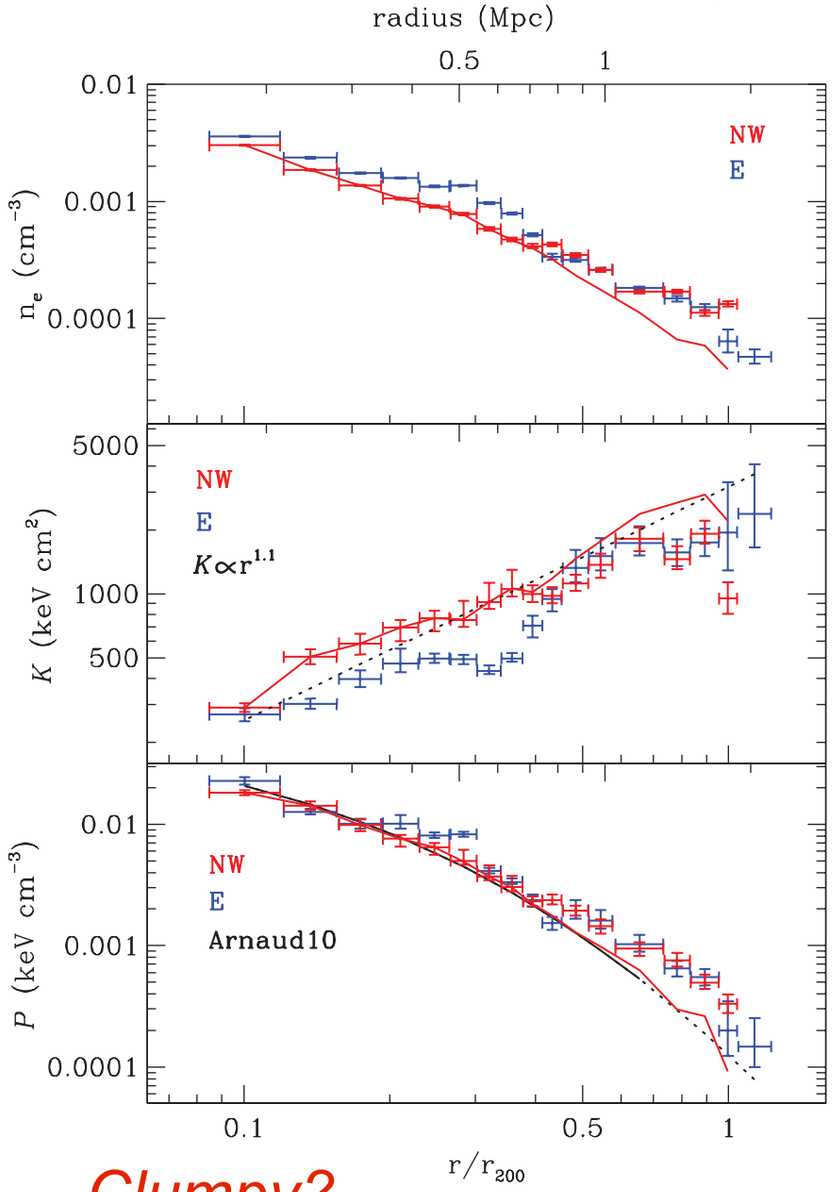


ASTRO-H science: Clusters of galaxies

- We know that clusters, biggest and latest collapsed objects, are not static, but dynamic.



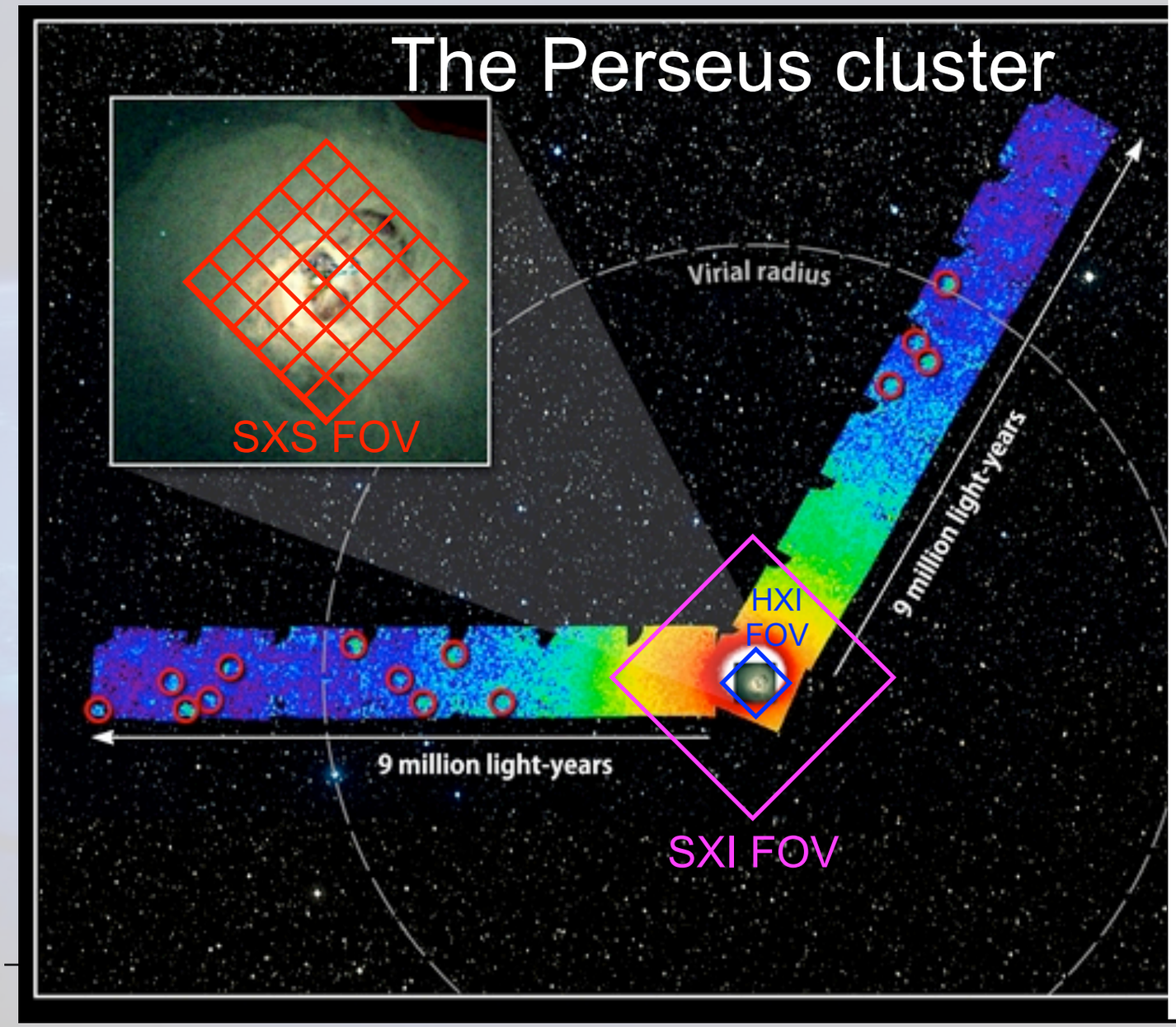
Simionescu et al. 2011, Science 331, 1576

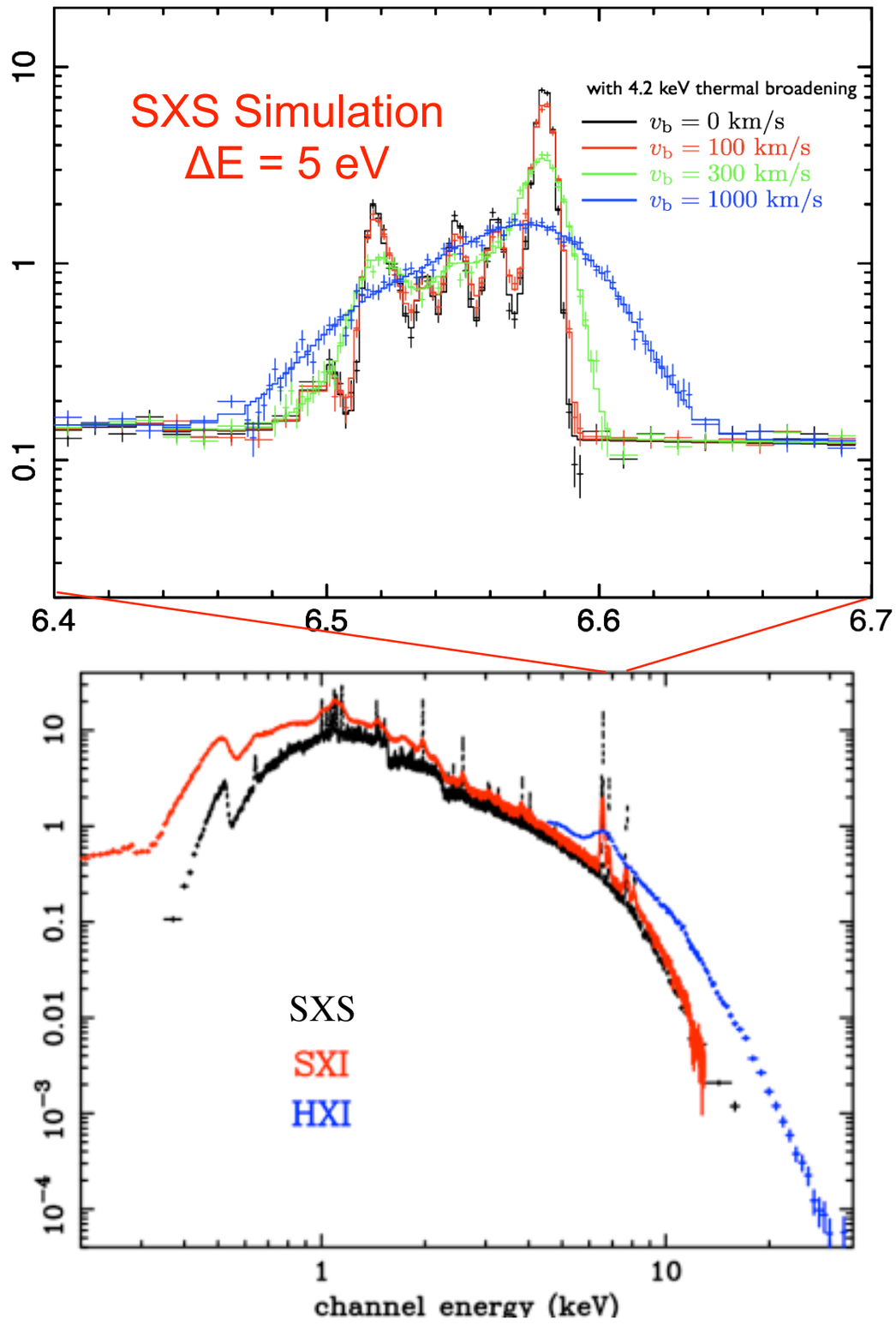


Clumpy?
e-ion non-equilibrium?

ASTRO-H science: Clusters of galaxies

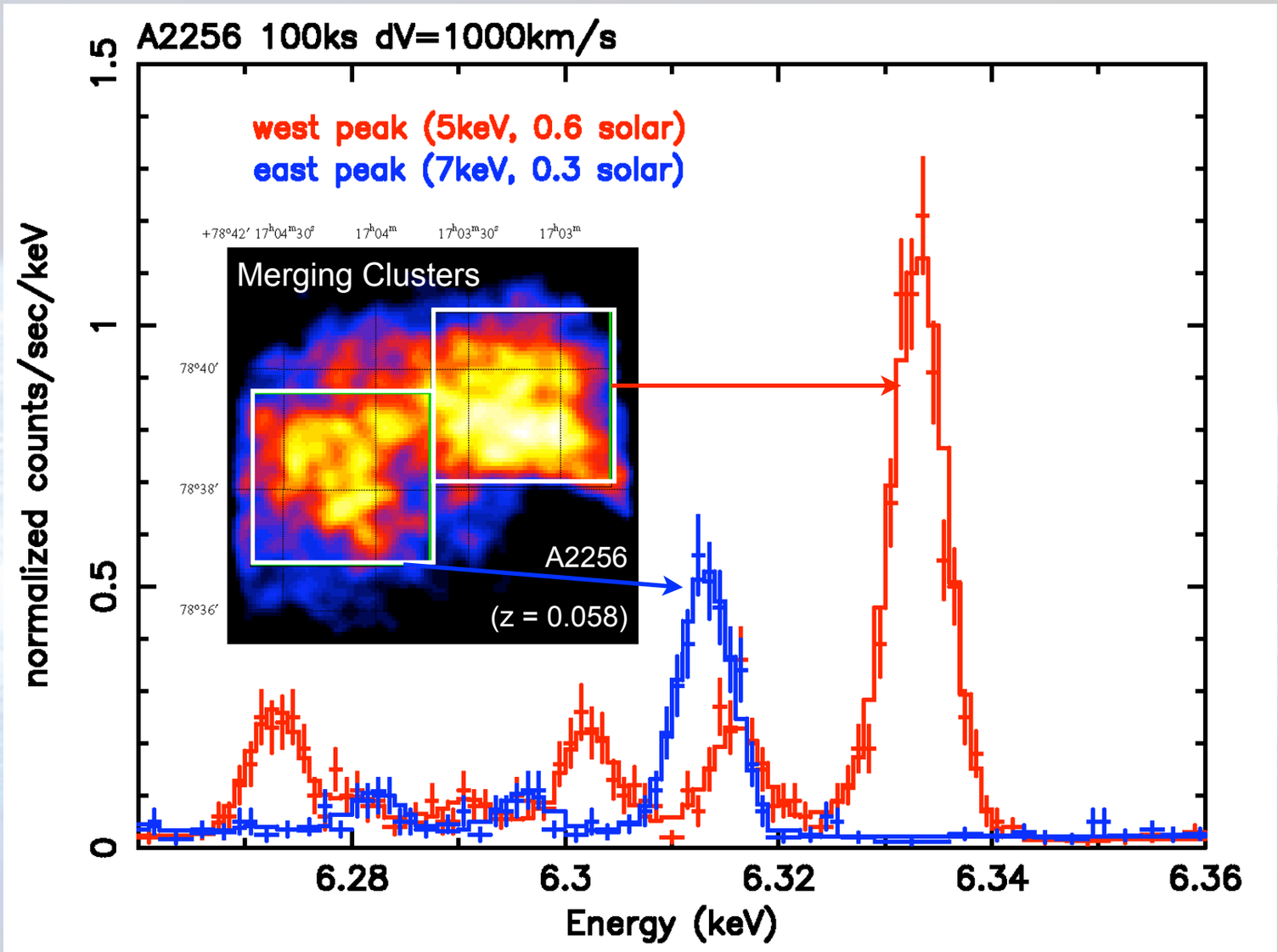
- ASTRO-H investigates the bulk or turbulent speed, non-equilibrium in spectra and non-thermal emission.





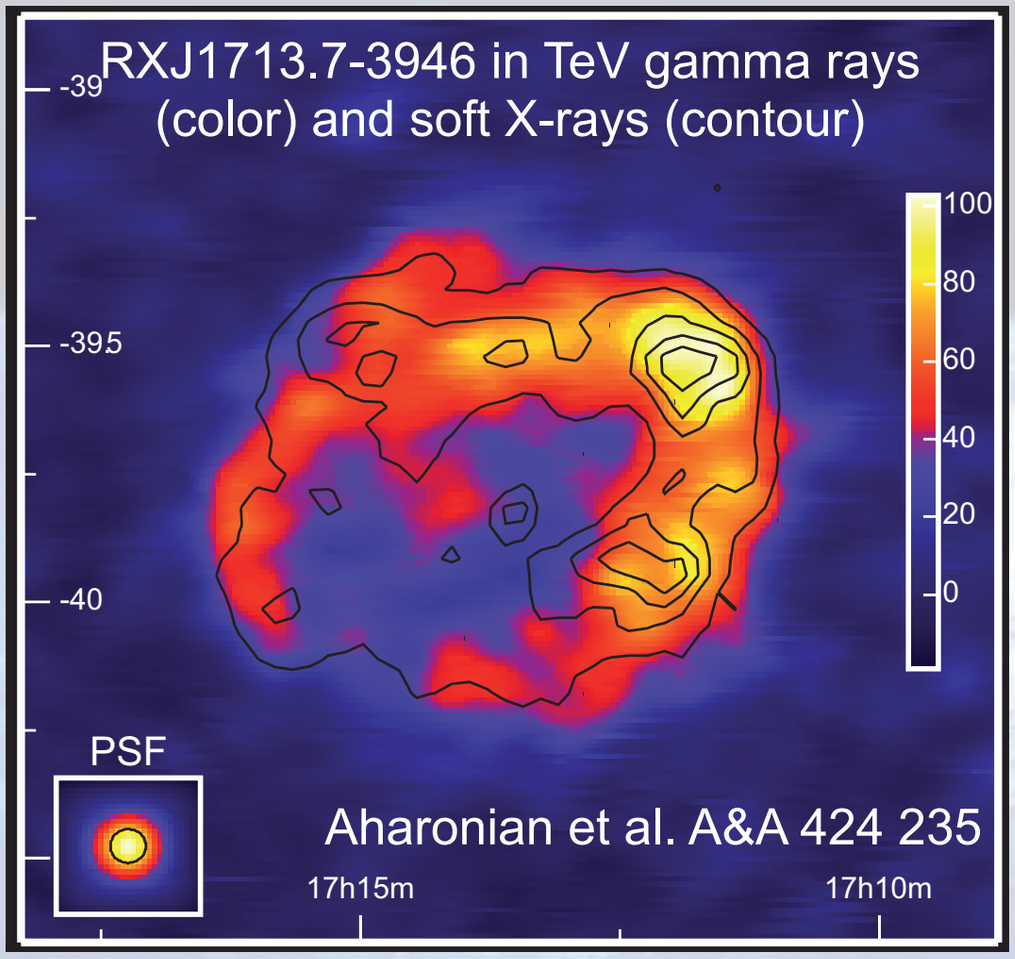
ASTRO-H science: Clusters of galaxies

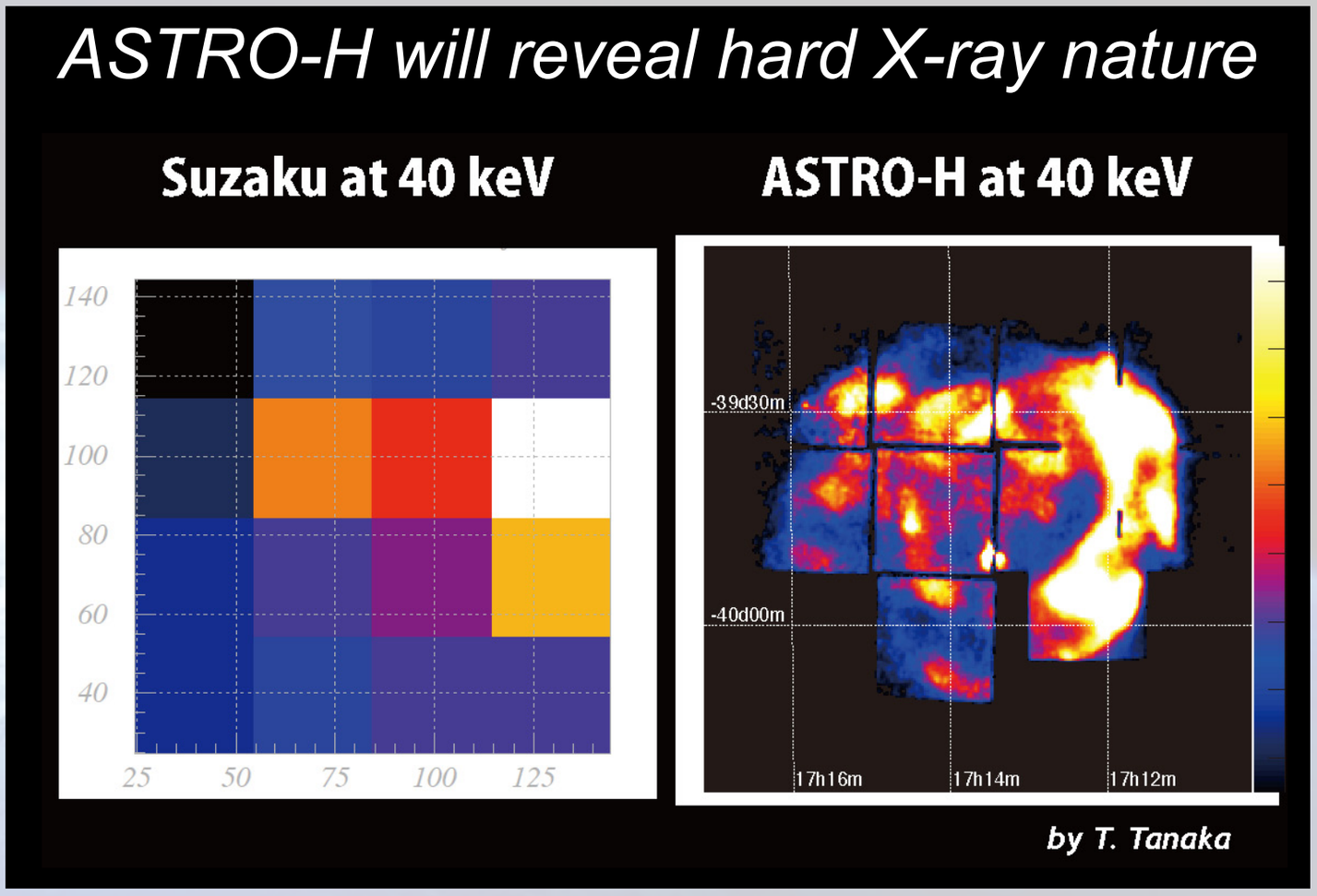
- By determining non-thermal energy, ASTRO-H will measure the energy and mass of the clusters more accurately.
- Precise mass measurement is crucial for use of X-ray cluster measurements as a cosmology probe.



Astro-H science: Supernova remnants

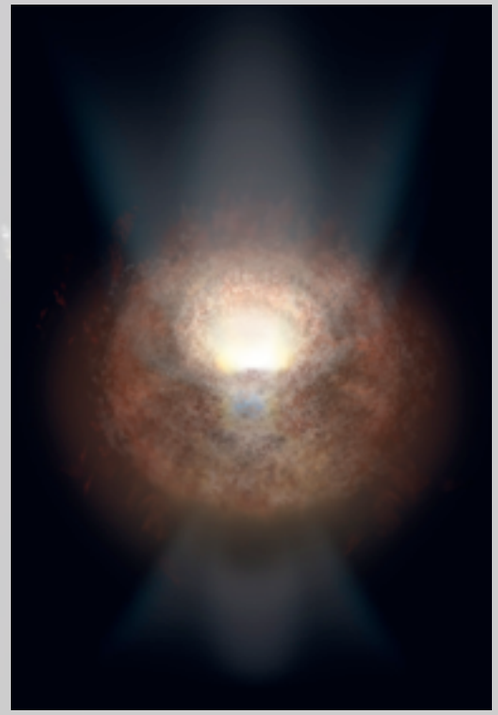
- Combination of hard X-ray imaging, wide-band spectra and high-resolution spectra will provide crucial clues for understanding the mechanism of shock acceleration in SNRs.

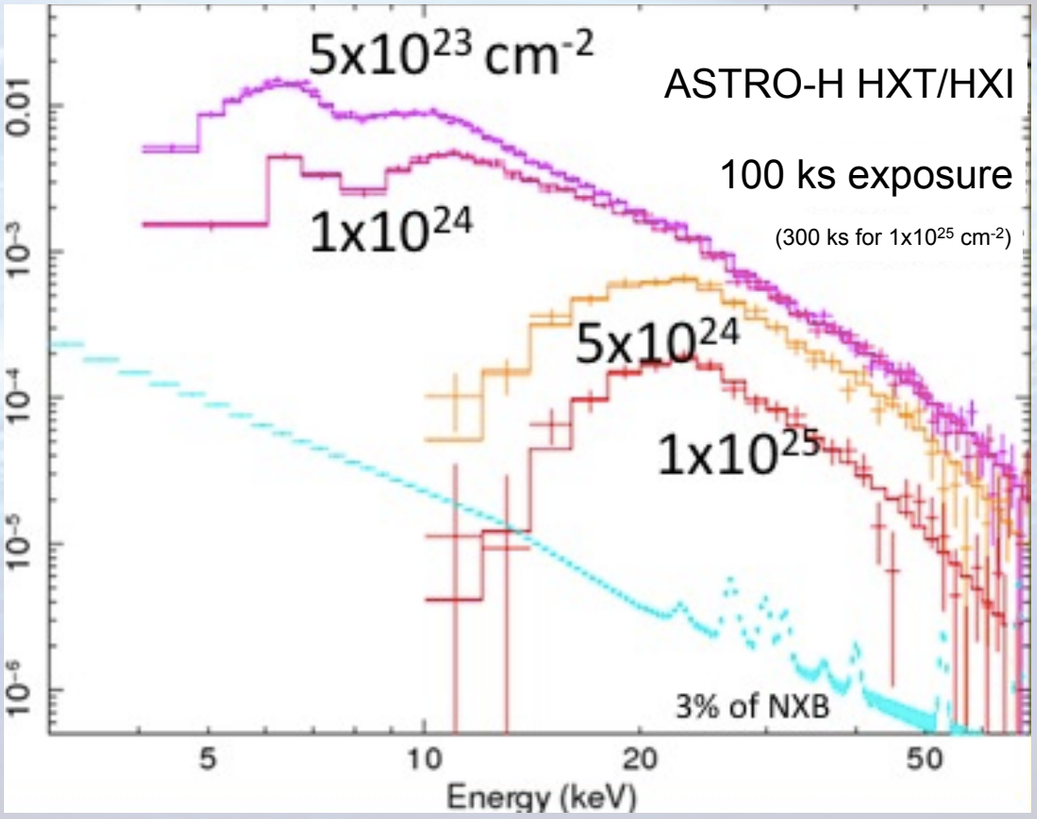


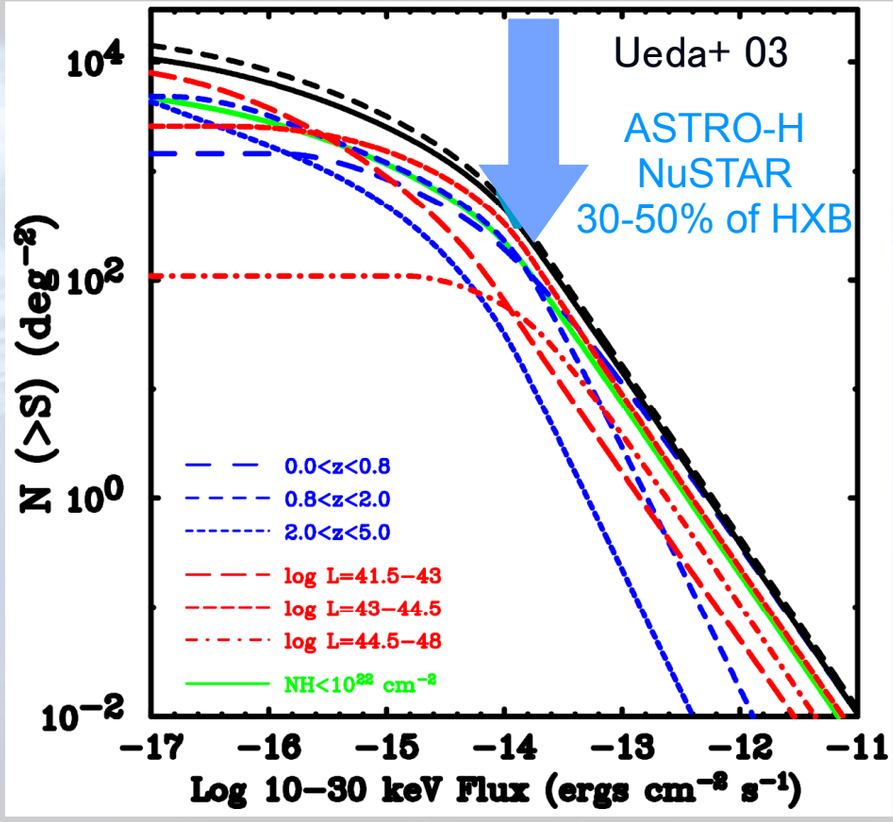


ASTRO-H science: Black holes and hard X-ray BGD

- HXI sensitivity is ~x100 better than Suzaku.
- Hidden super-massive blackholes will be revealed.
- 30-50% of the hard X-ray background will be resolved.





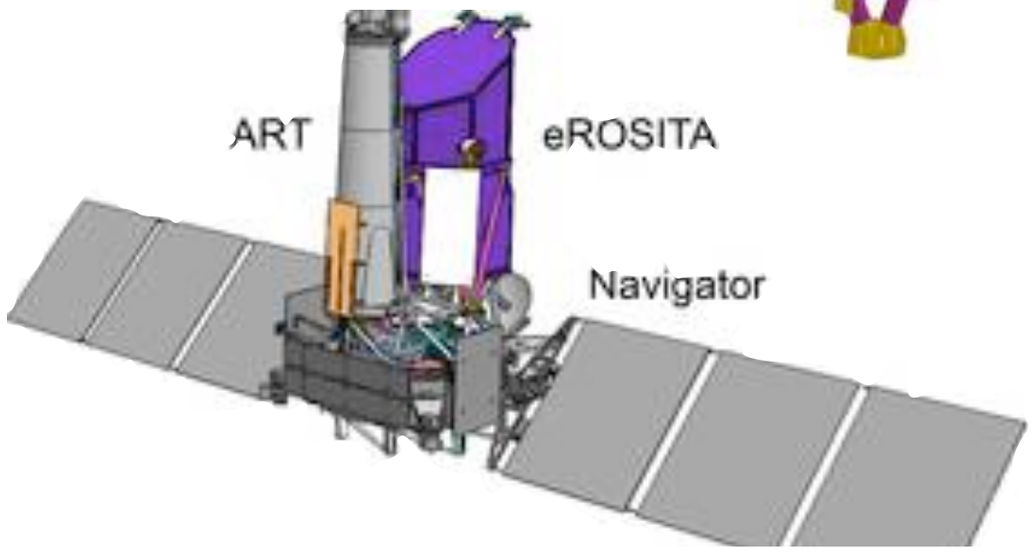


Synergy with eROSITA

- Accurate/precise measurements with ASTRO-H is fully complementary to surveys with eROSITA.

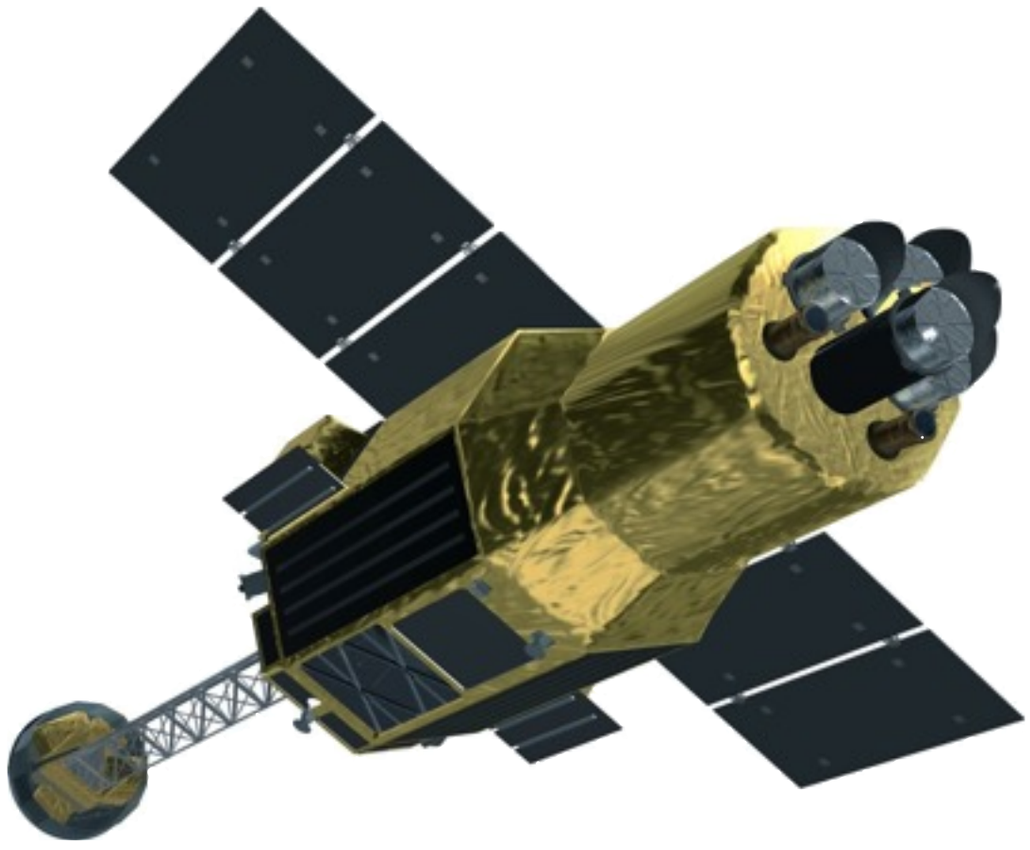
eROSITA on SRG

- Launch: 2013
- Energy range: 0.5-10 keV
- Δ E: 138 eV
- FOV: 1 deg Φ



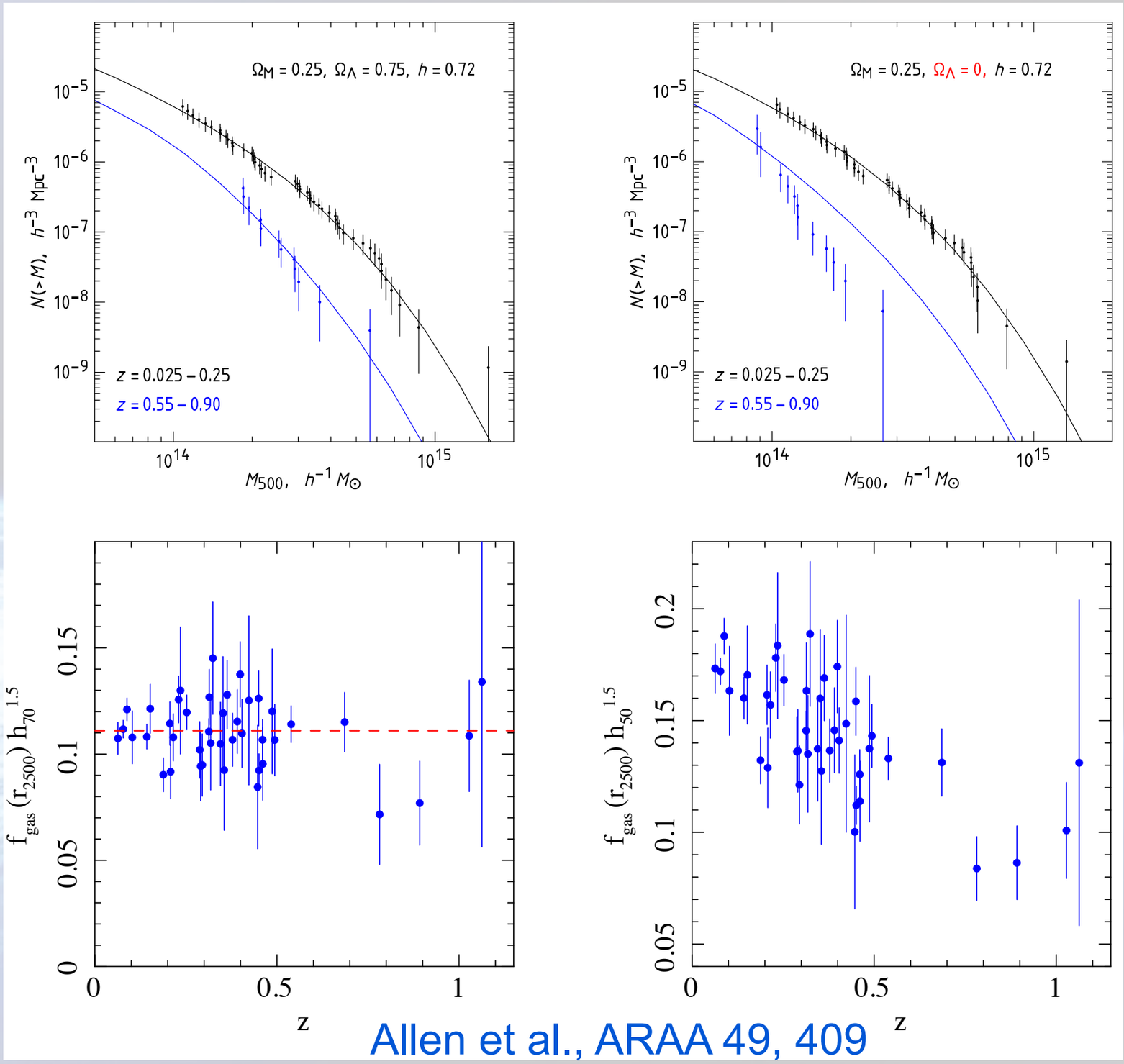
ASTRO-H

- Launch: 2014
- Energy range: 0.3-600 keV
- Δ E: 7 eV (SXS)
- FOV: 3'x3' (SXS)



Science synergy with eROSITA : Clusters of galaxies

- eROSITA is a powerful tool to constrain cosmological parameters by detecting ~100,000 clusters.
- Precise mass determination is crucial to use X-ray observations as a cosmological probe.
- Understanding gas dynamics of clusters by ASTRO-H SXS and non-thermal energy by ASTRO-H HXI is essentially important.

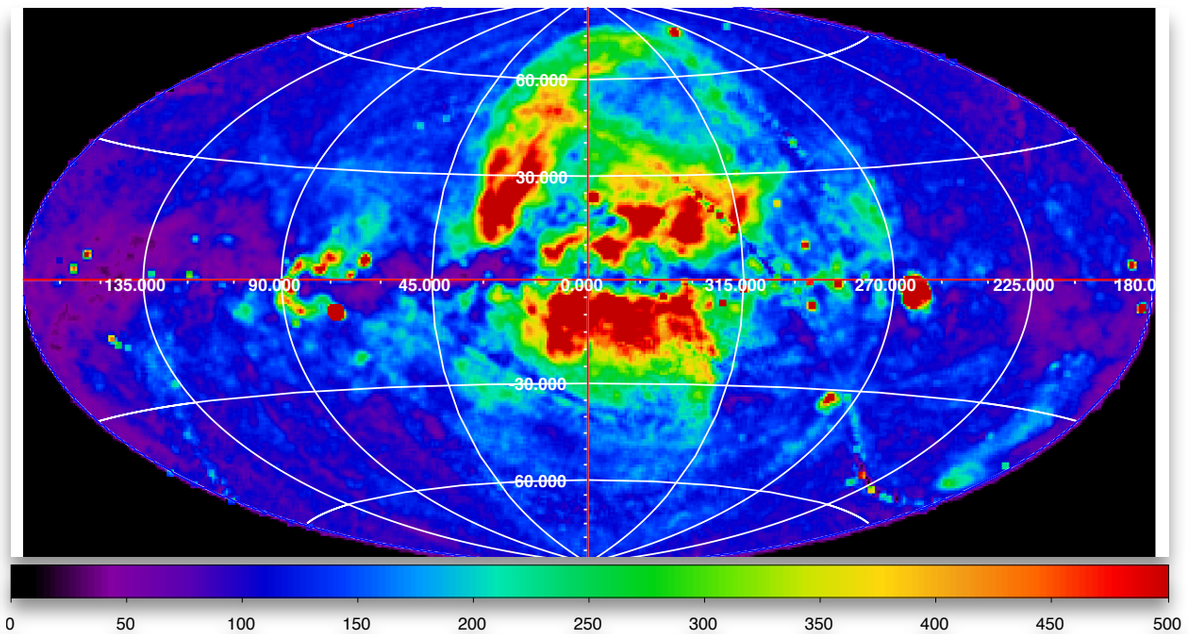


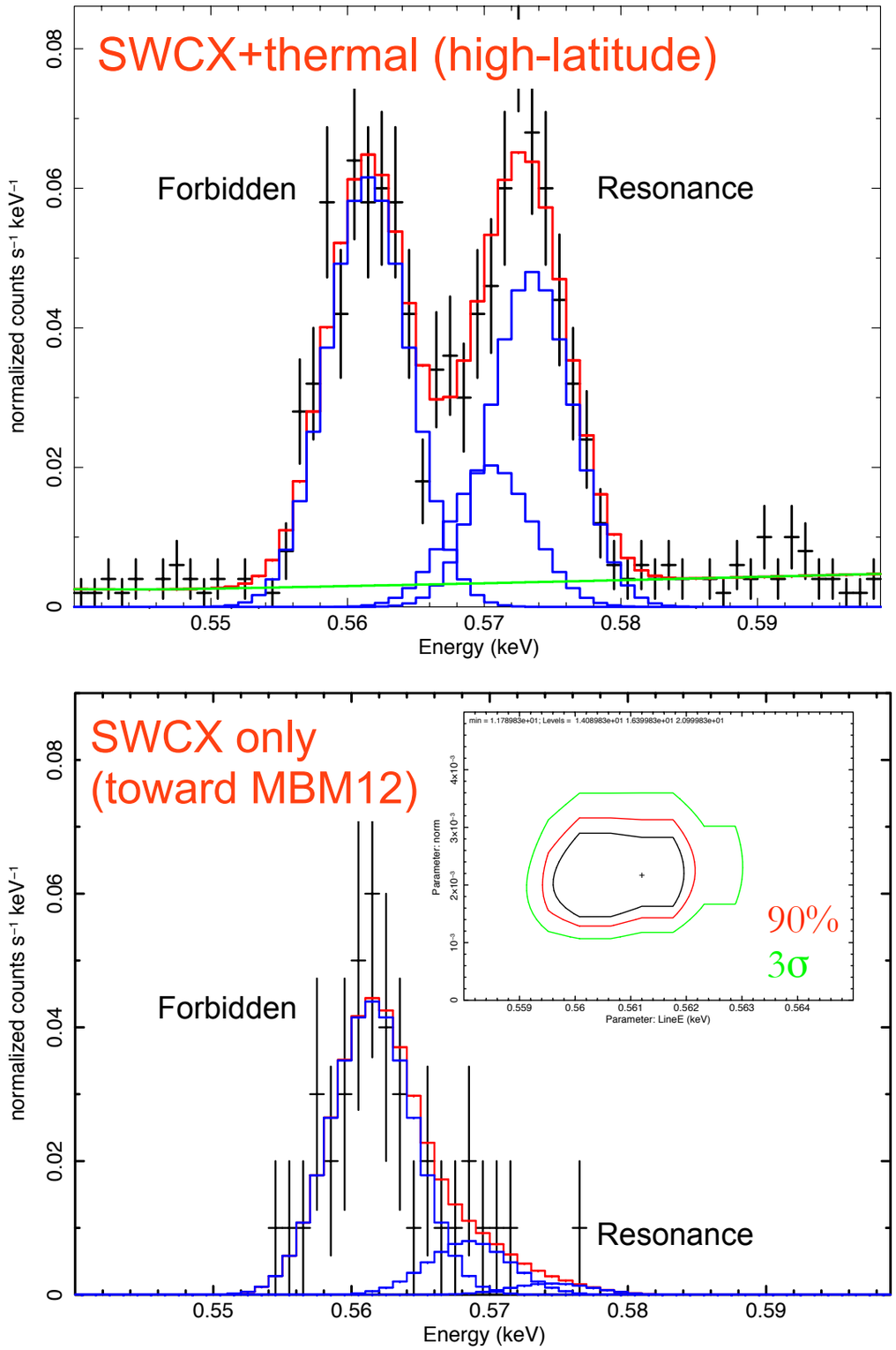
Allen et al., ARAA 49, 409

Science synergy with eROSITA: Galactic emission

- eROSITA will provide far better all-sky map data.
- Soft X-ray band is dominated by thermal emission in our Galaxy and solar wind charge exchange (SWCX) induced emission in the solar system.
- ASTRO-H SXS is capable of distinguishing thermal and SWCX emission by diagnosing OVII triplets.

ROSAT All Sky Survey (3/4 keV)





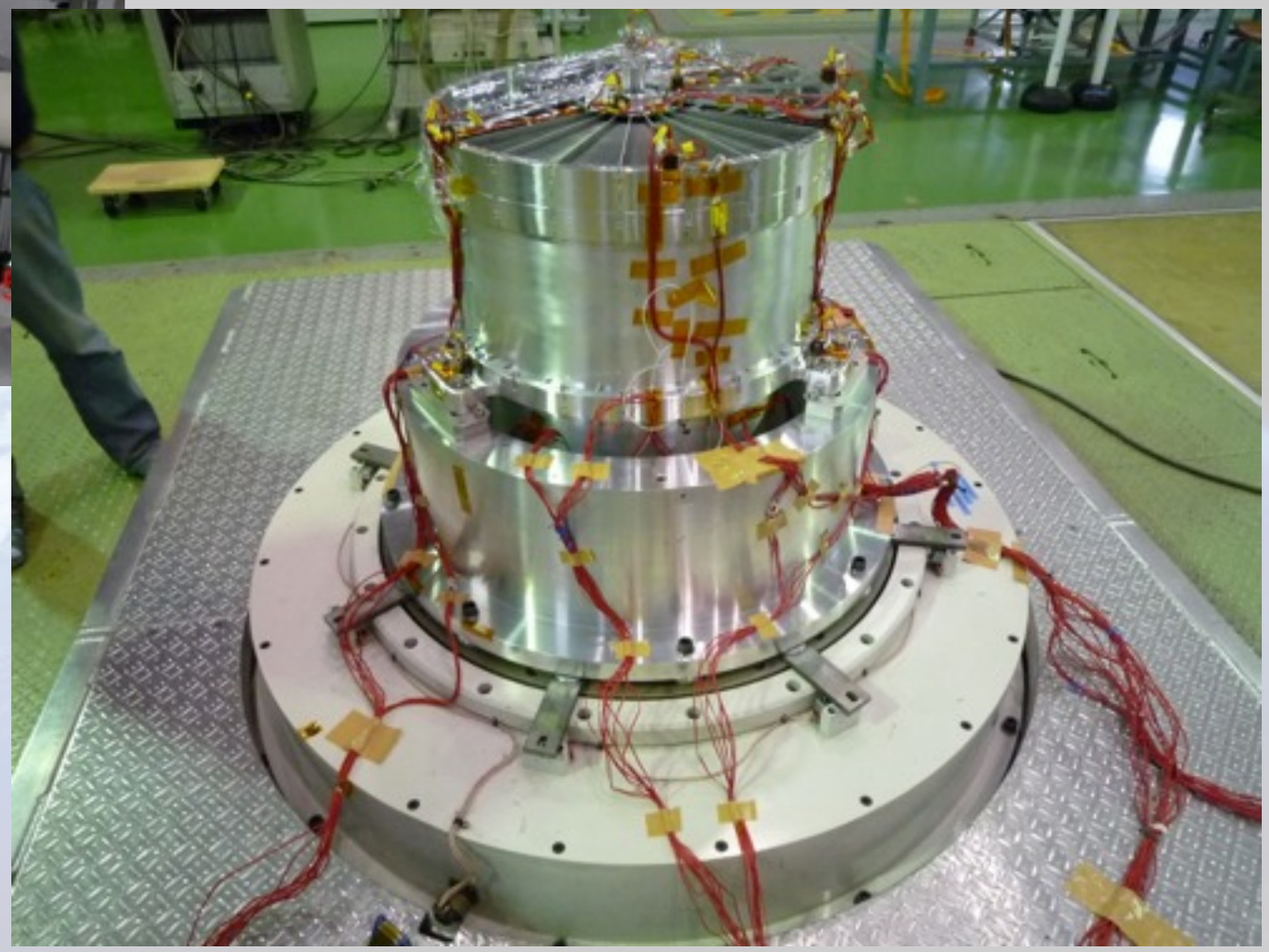
Simulation by H. Yoshitake

Status of ASTRO-H development

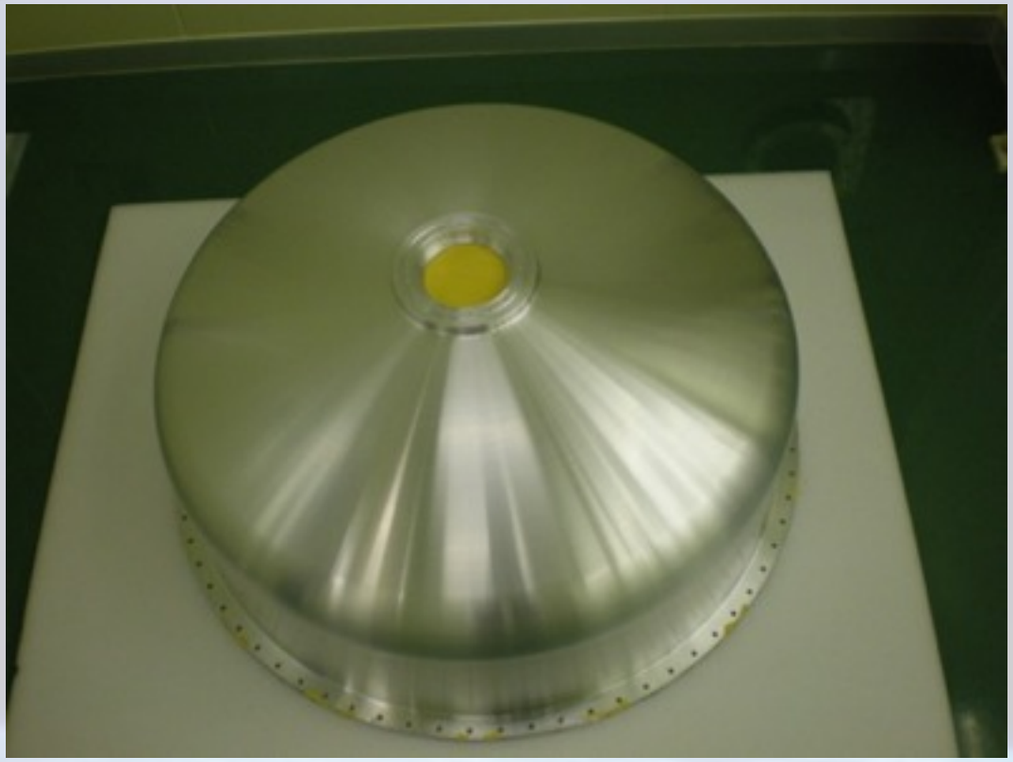
- Performance/environmental tests using engineering models of instruments are ongoing.
- Critical design review (CDR) will be held in coming months.
- Construction of some main structures (optical bench, base plates, side panels) was started.
- On schedule for the launch in 2014.

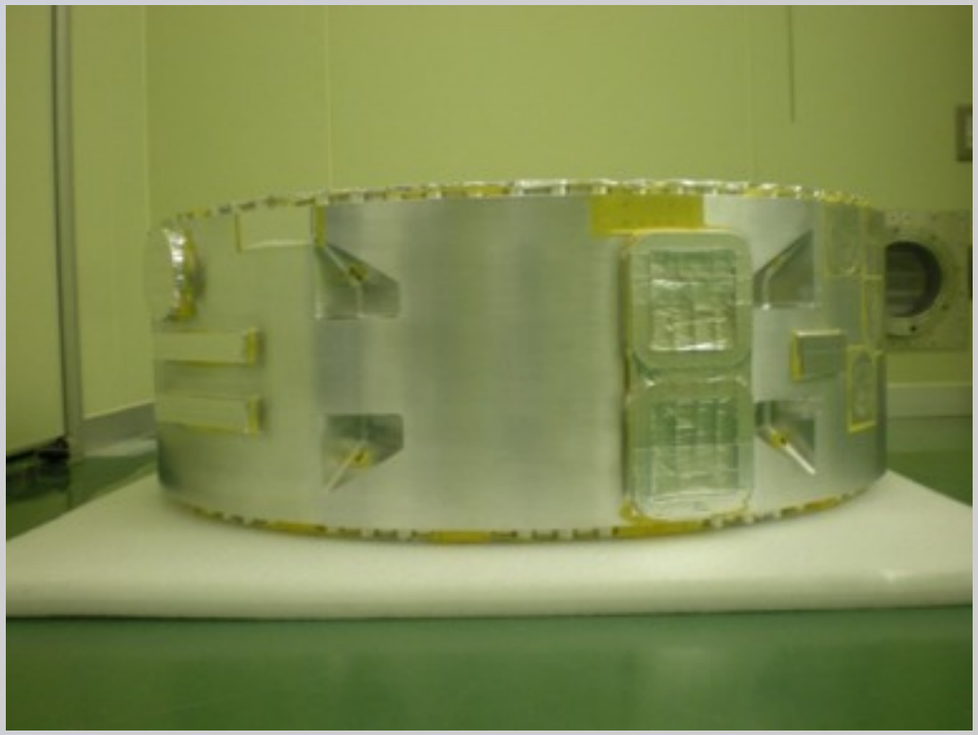
- Information can be found as SPIE proceedings (2010; Volume 7732)
  - ASTRO-H: 77320Z (Takahashi et al.)
    SXT: 77320A (Serlemitsos et al.)
    SXS: 773211 (Mitsuda et al.)
    SXI: 773210 (Tsunemi et al.)
    HXT: 773214 (Kunieda et al.)
    HXI: 773215 (Kokubun et al.)
    SGD: 773216 (Tajima et al.)

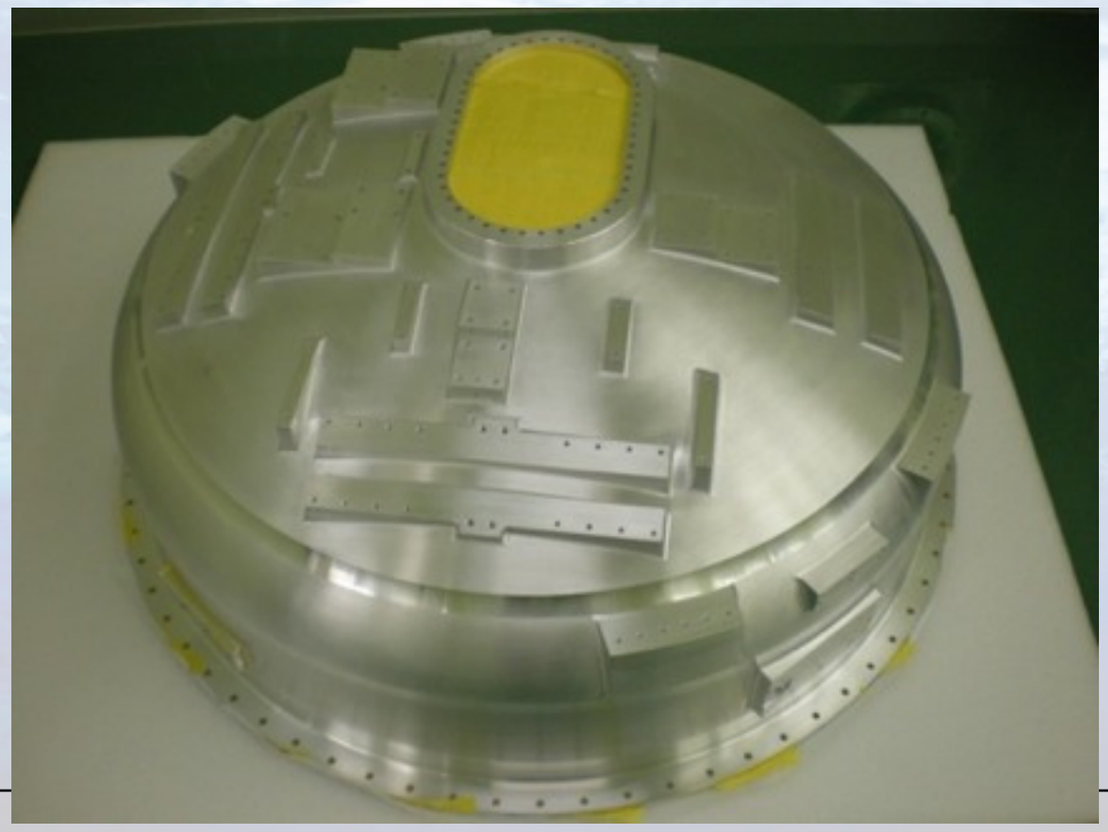
HXT at vibration test



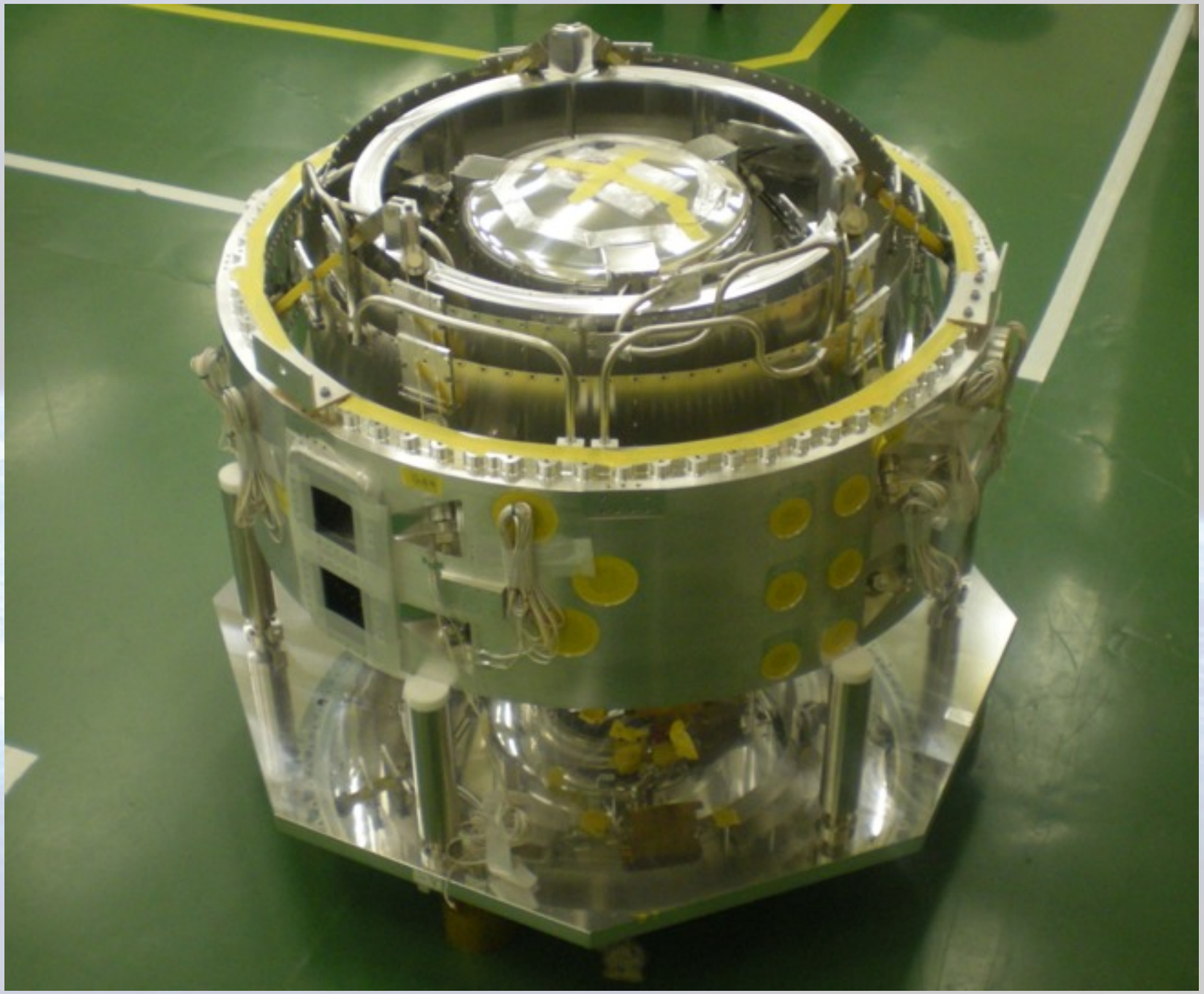
SXS dewar EM in fabrication







SXS dewar EM in fabrication



ASTRO-H collaboration

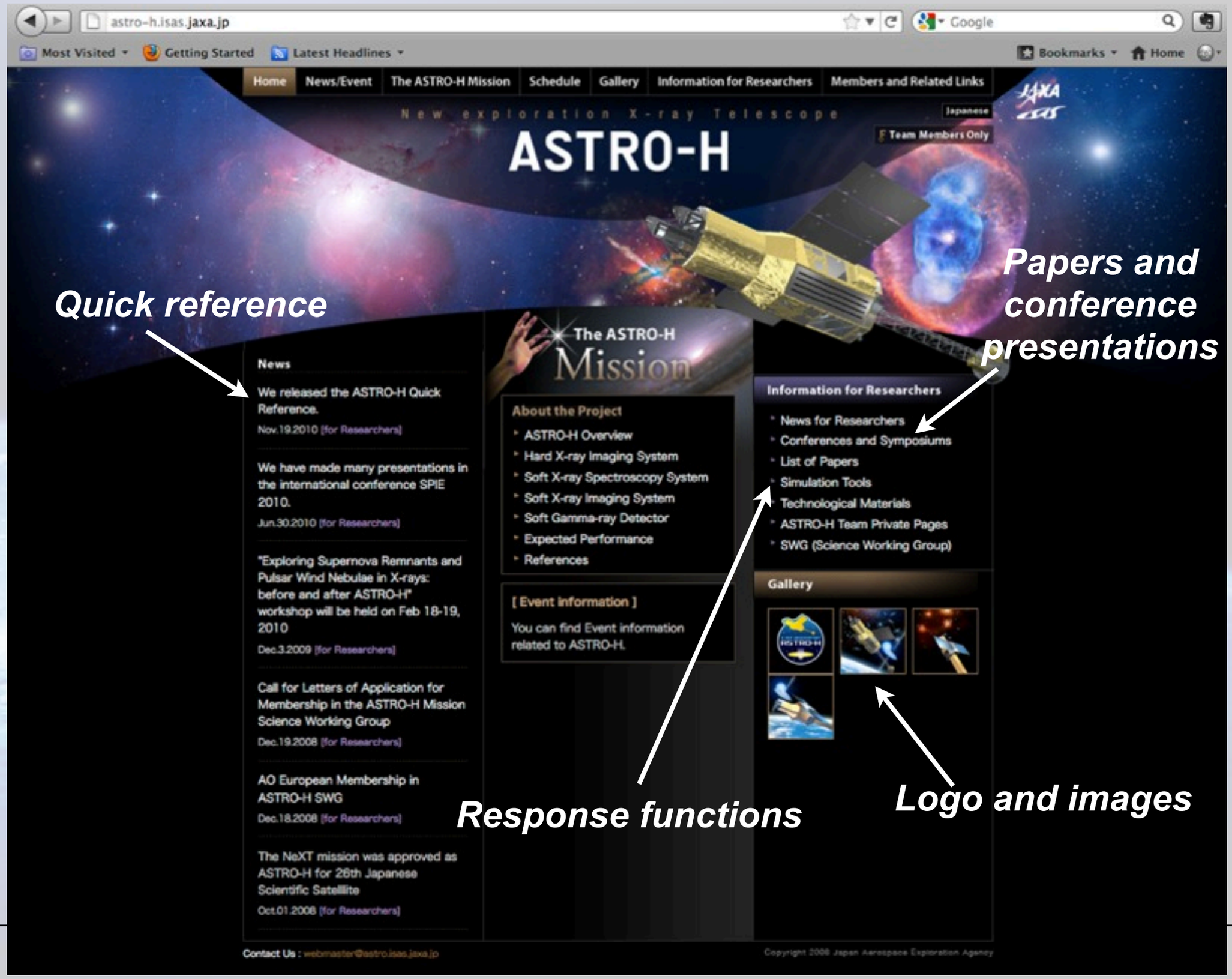
- More than 160 scientists from Japan/US/Europe/Canada

X-RAY OBSERVATORY
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.

2011.6.24

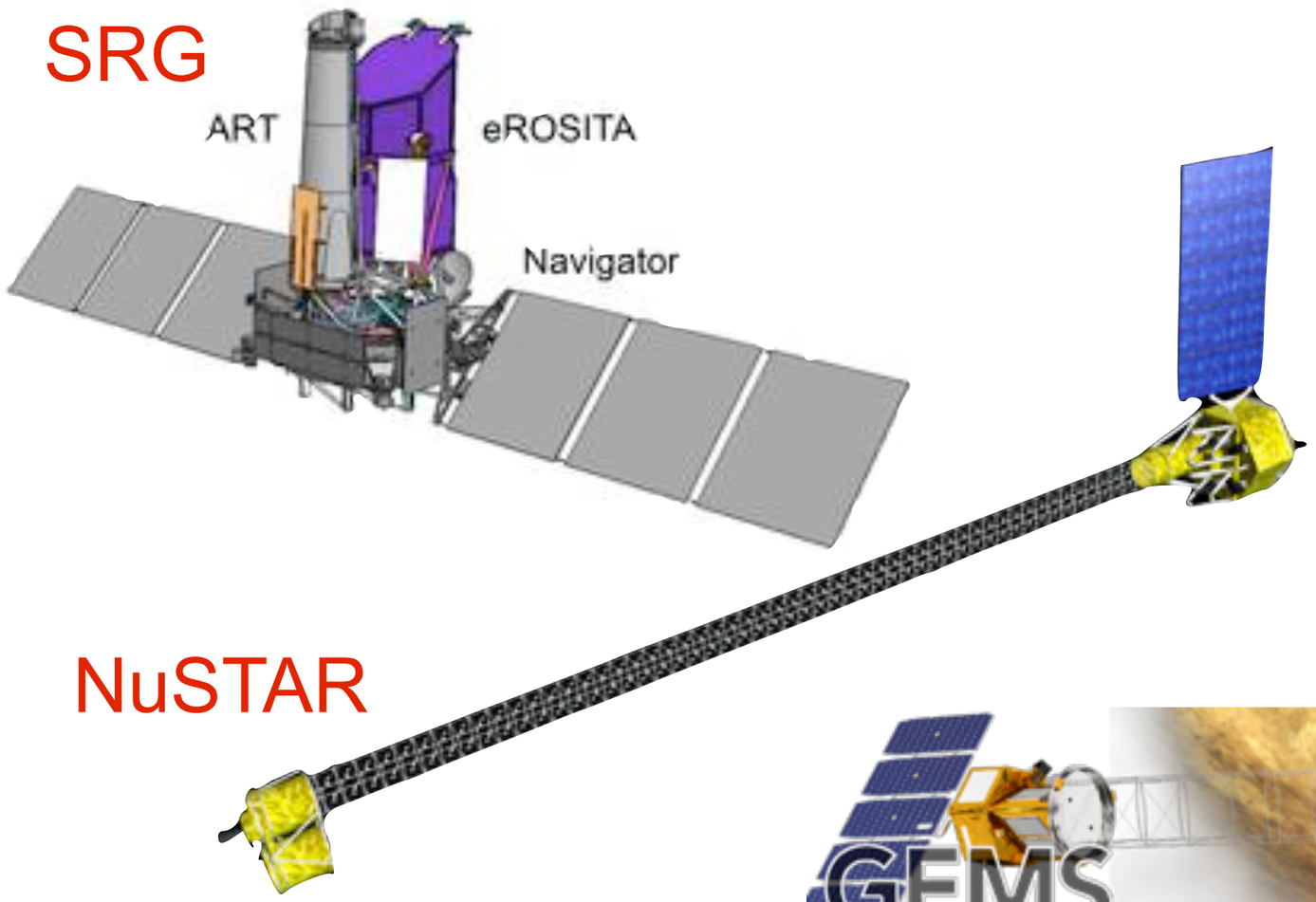
Check http://astro-h.isas.jaxa.jp for more info



Summary

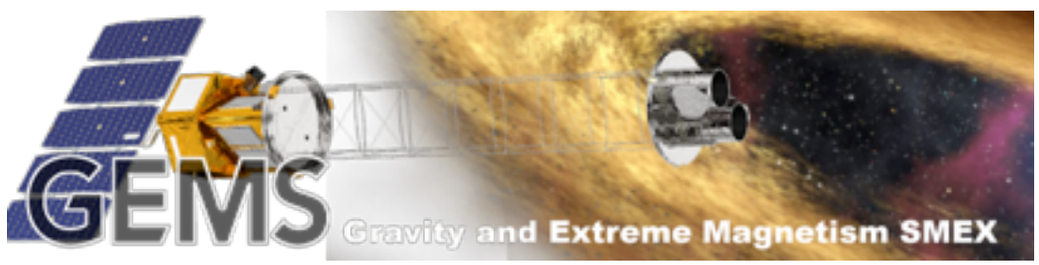
- ASTRO-H is on schedule. Wide-band and high-sensitivity observations by combination of the four instruments will provide exciting data sets for many science fields.
- With eROSITA and other missions, late 2010's will be a new era for X-ray astrophysics.

SRG



NuSTAR

ASTRO-H



GEMS