Status Report on Astro-H (*Hitomi*)

Launch of Astro-H on JAXA H-IIA
Tanegashima Space Center
February 17, 2016

Richard Kelley

US PI

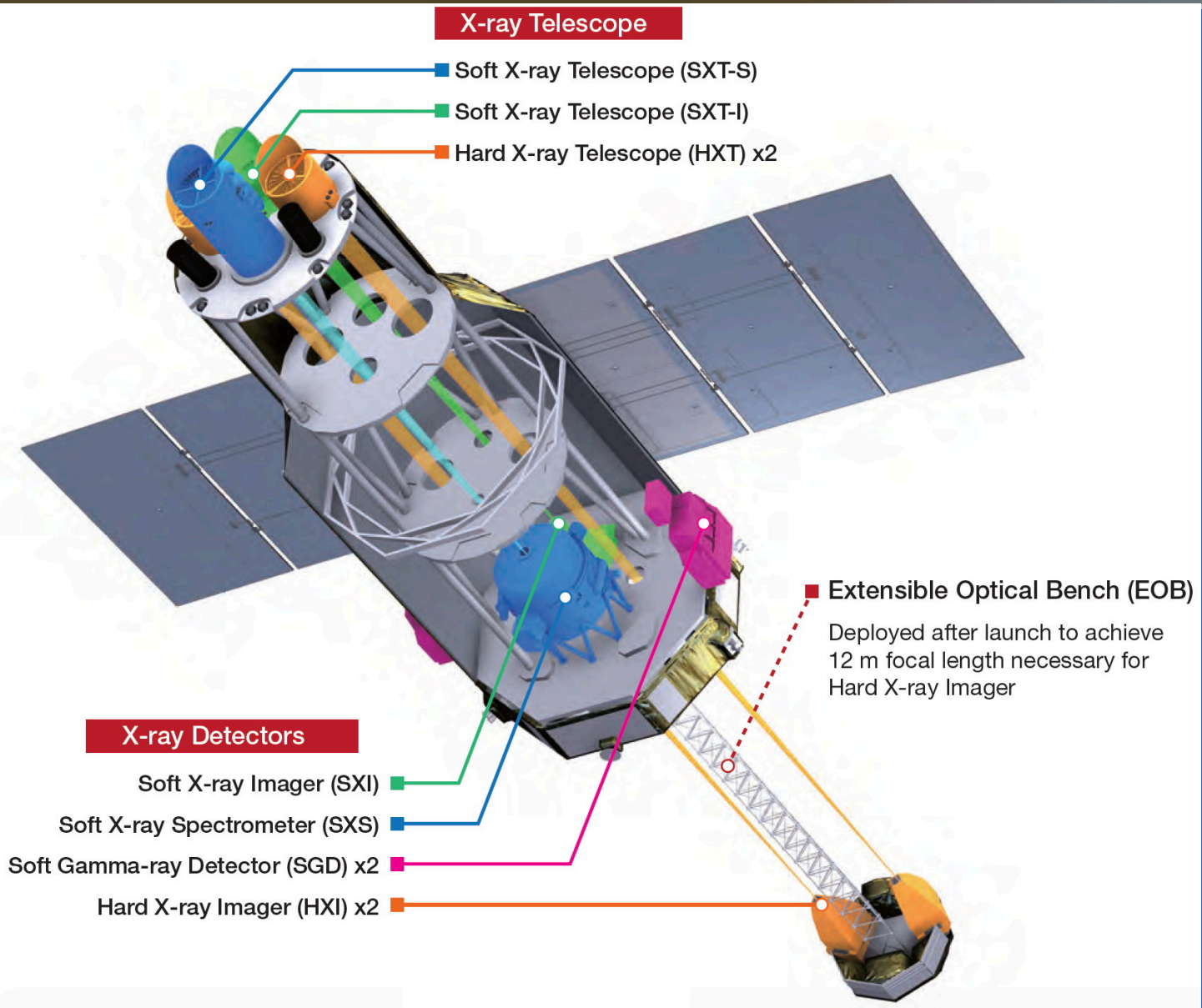
X-Ray Astrophysics Laboratory

NASA/Goddard Space Flight Center

March 16, 2016

Large international collaboration

Hitomi – Eye to the Universe!



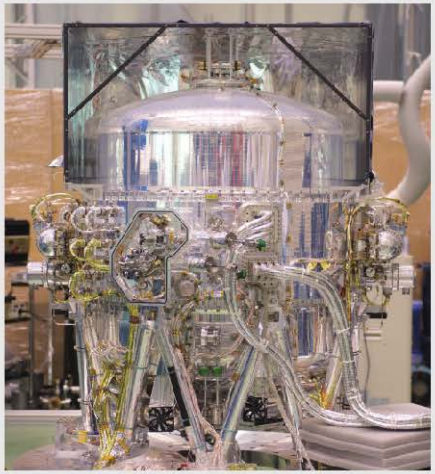
Study structure and evolution of the Universe

Study matter in extreme environments

- Black holes
- Galaxies
- Heavy elements
- Non-thermal processes

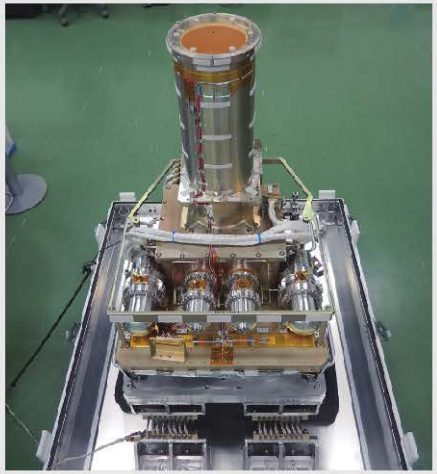
Hitomi Instruments

Soft X-ray Spectrometer (SXS)



Uses US-led technology called microcalorimetry. Includes multiple stages of coolers to lower the temperature of the sensor to near absolute zero (-273.15 degrees C). By measuring the slight increase in temperature from incoming X-ray photons, it is capable of measuring the X-ray energy in never before achieved high resolution. The most highly anticipated device on ASTRO-H by scientists.

Soft X-ray Imager (SXI)



X-ray camera that achieves wide field of view of 38 arcmin by arranging 4 large X-ray CCDs together. Simultaneously implements X-ray imaging and spectrometry of sources in soft X-ray band. Located inside the satellite at the focal plane of SXT-I.

Hard X-ray Imager (HXI) x2

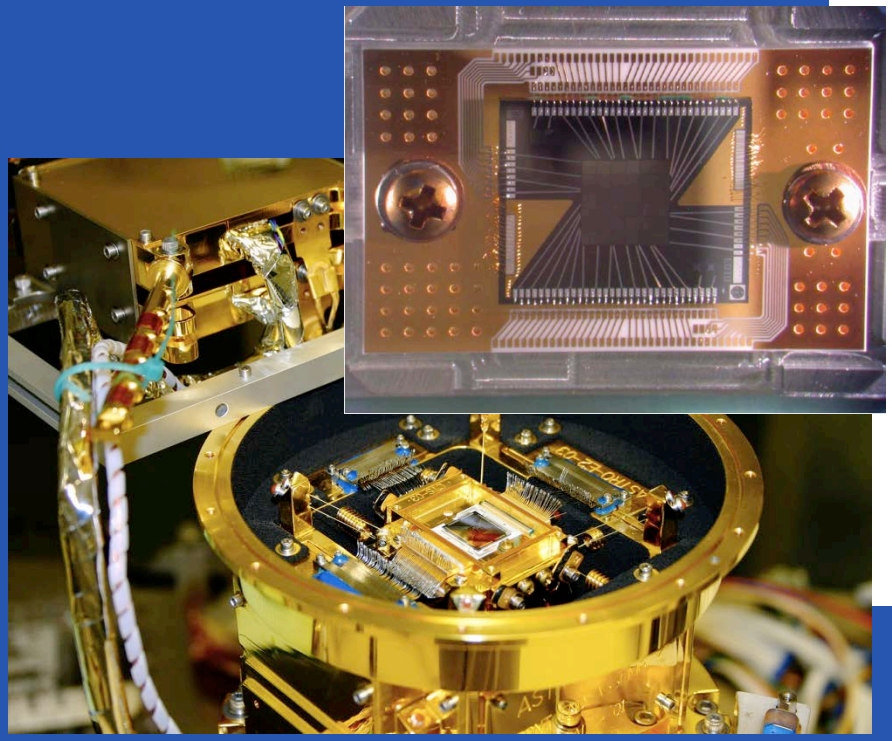
Camera that observes sources in hard X-ray with energy 5 keV and higher using silicon and Cadmium Telluride semiconductors. Located at the focus of the HXT with 12m focal length, which is realized by the extensible optical bench (EOB) that gets deployed in orbit.

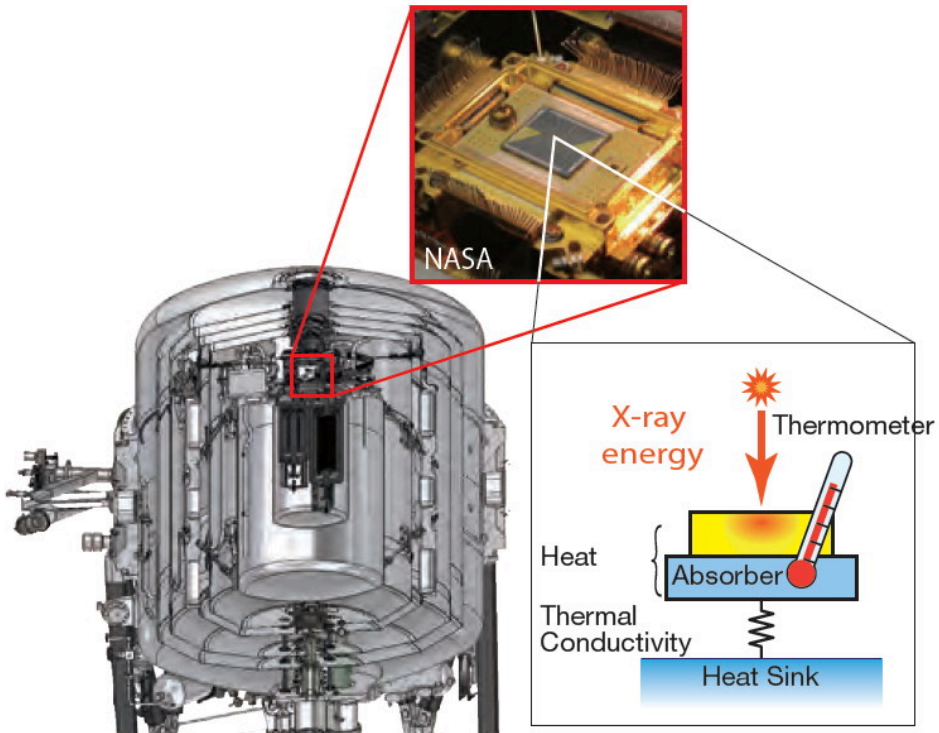
Soft Gamma-ray Detector (SGD) x2

High sensitivity gamma-ray detector layered with semiconductor detectors and using Compton camera theory. Cannot image sources since it does not use a telescope, but anticipated to reveal high energy phenomena by detecting soft gamma-rays with higher energy than X-ray.

Soft X-ray Spectrometer (x-ray microcalorimeter array)

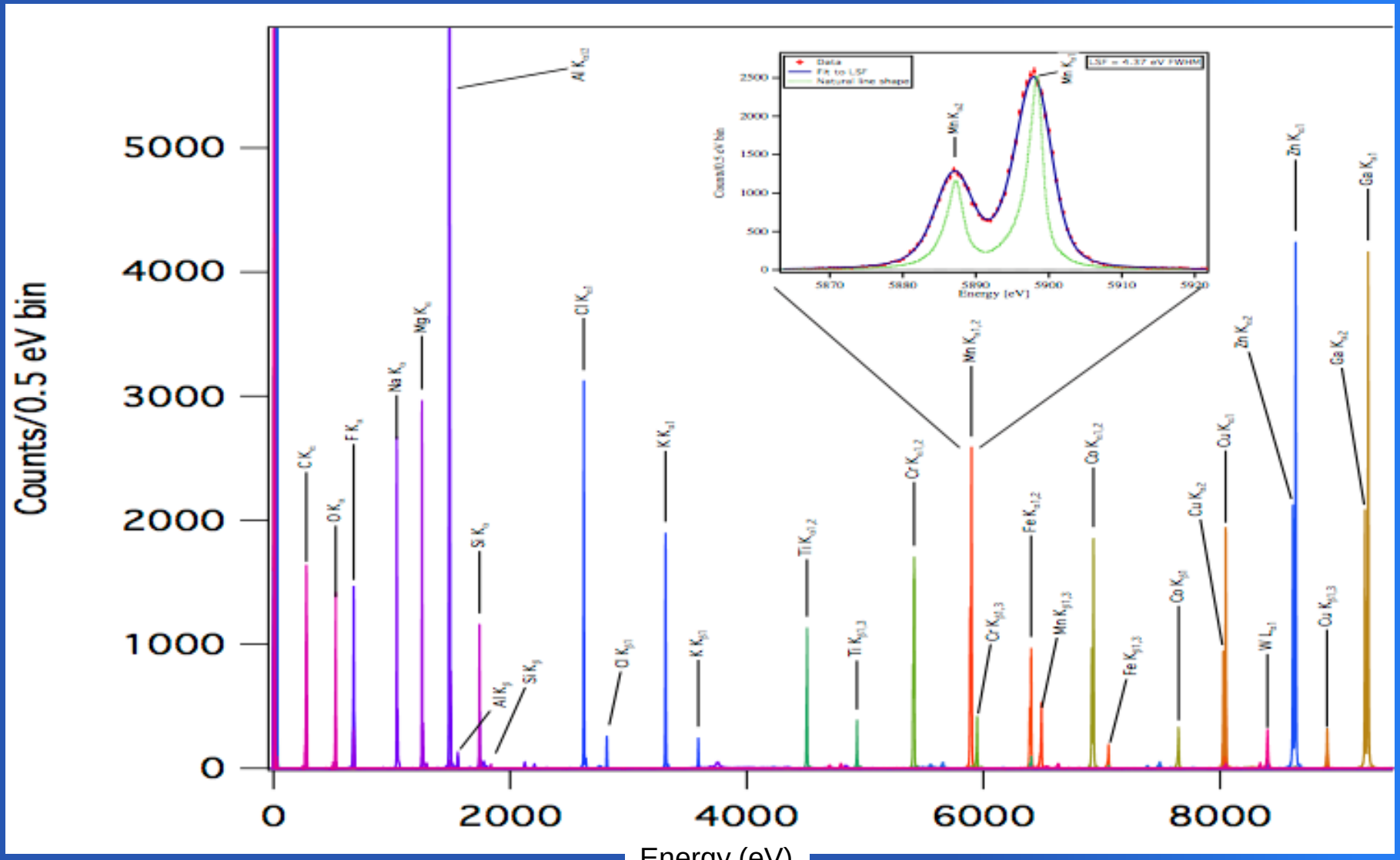
- Hybrid cooling system: superfluid helium dewar with 4.5 K Joule-Thomson (JT) shield cooler
  - Redundant ADR heat sinks
- ADR for detector cooling
  - 50 mK operation



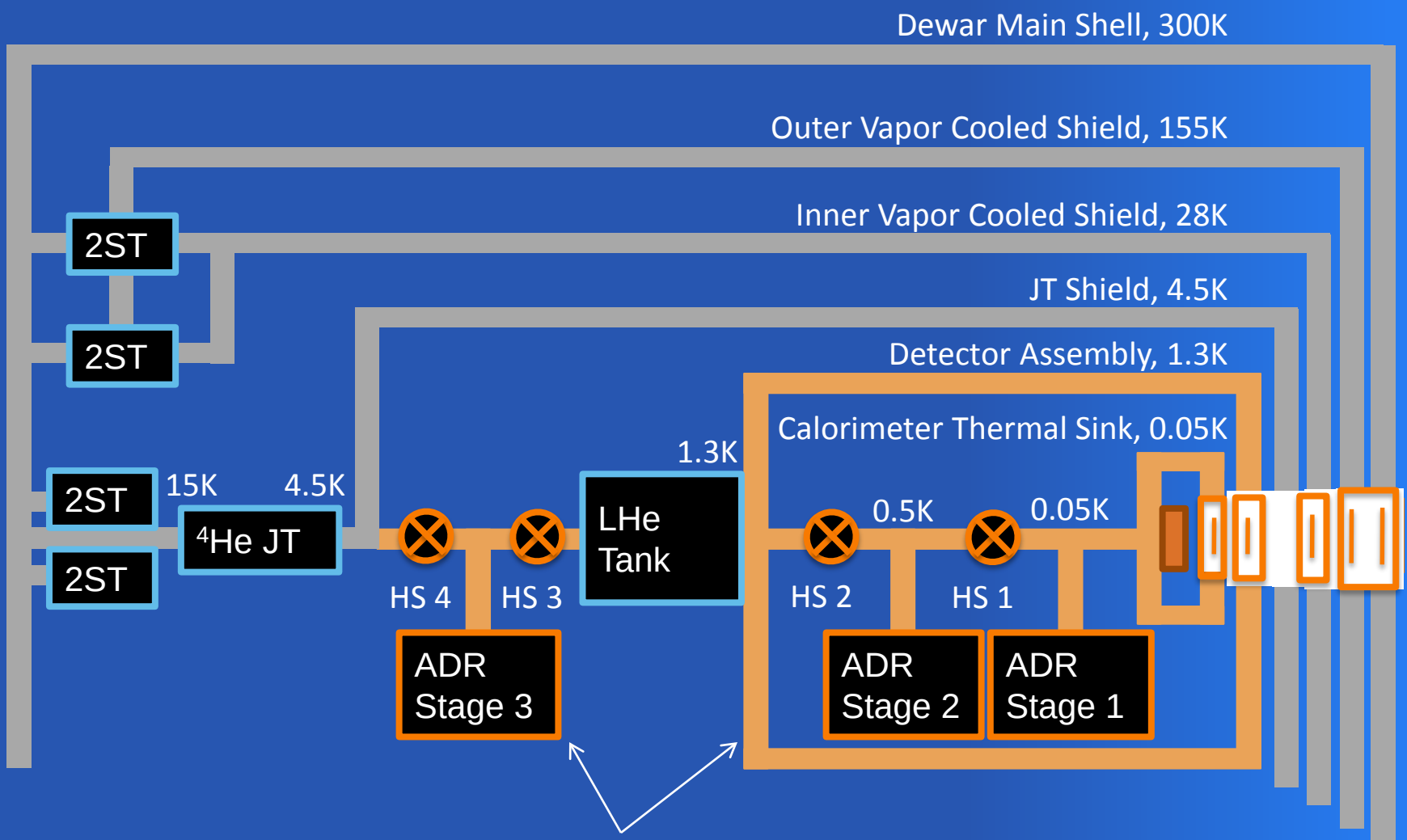


Low temperature ➔ low heat capacity, low noise. ΔE ~ 5 eV & nearly constant

SXS ground calibration spectrum – 4.5 eV energy resolution



SXS Cryogenic System

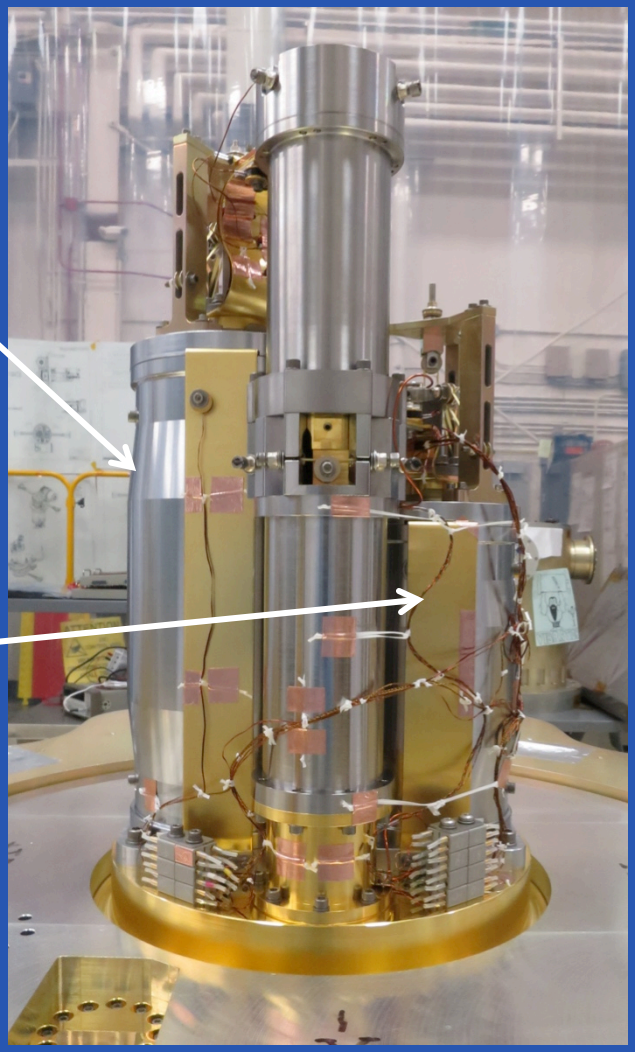


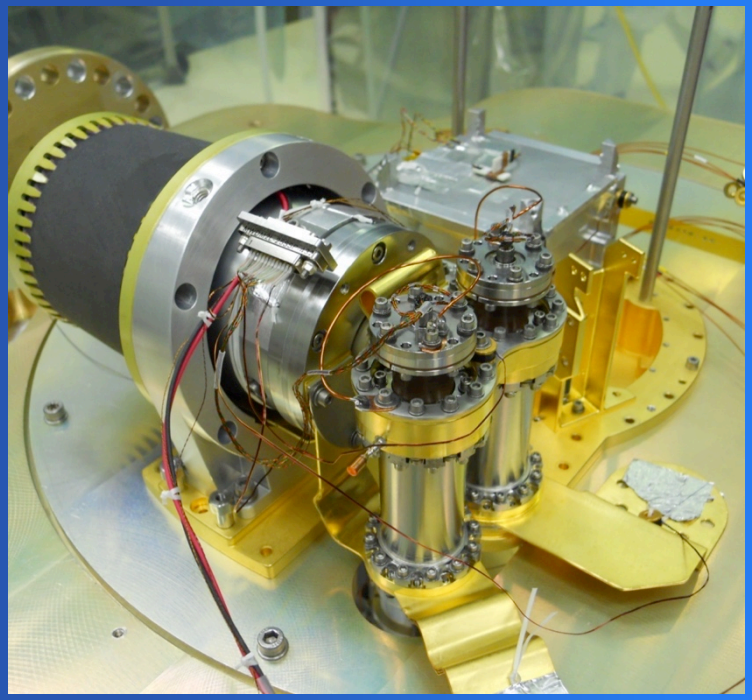
NASA/GSFC hardware

ADR Assemblies

Stage 1:
- 270 g CPA
- 2 T, 2 amp magnet

Stage 2:
- 150 g GLF
- 3 T, 2 amp magnet



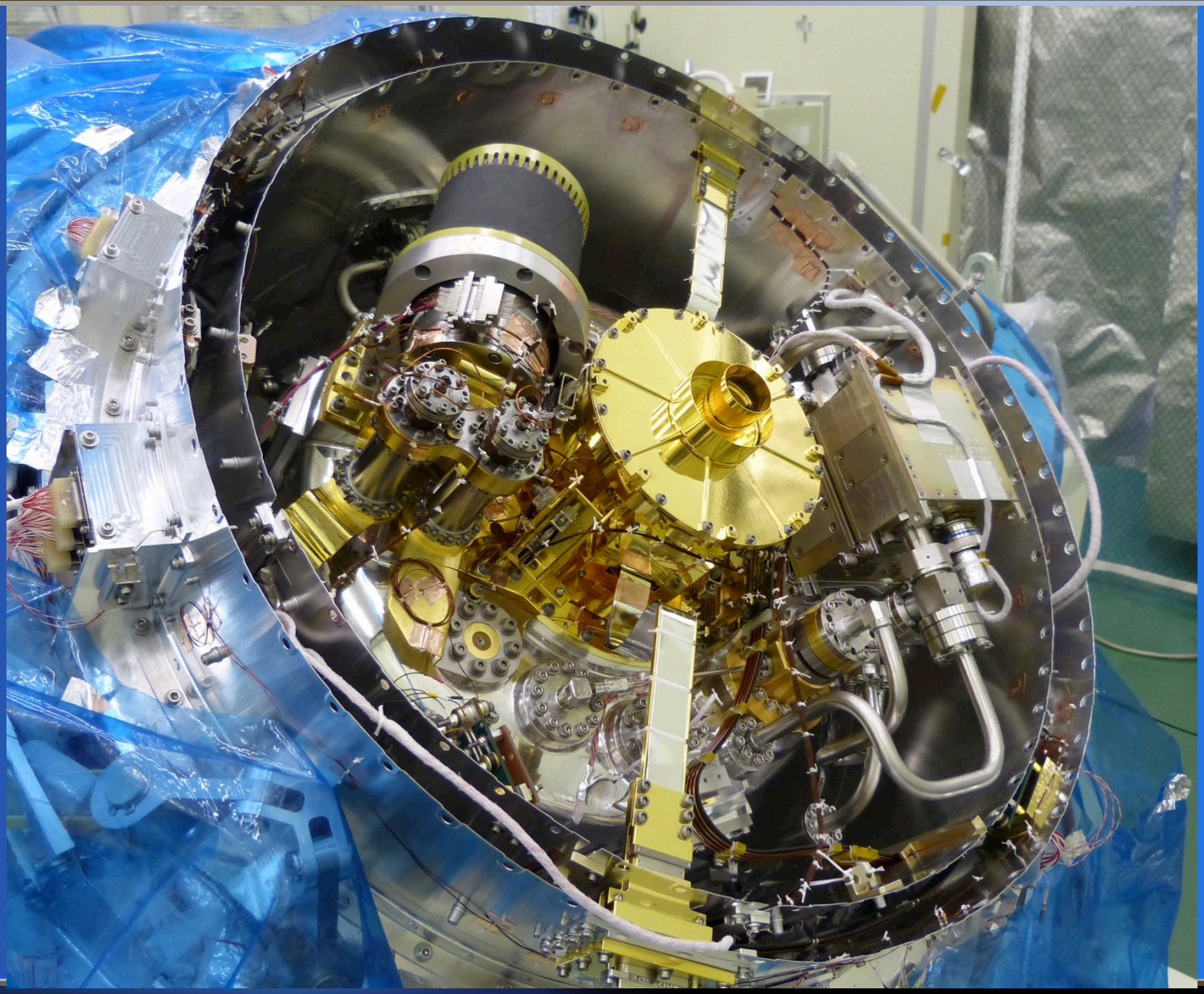


Stage 3:
- 150 g GLF
- 3 T, 2 amp magnet

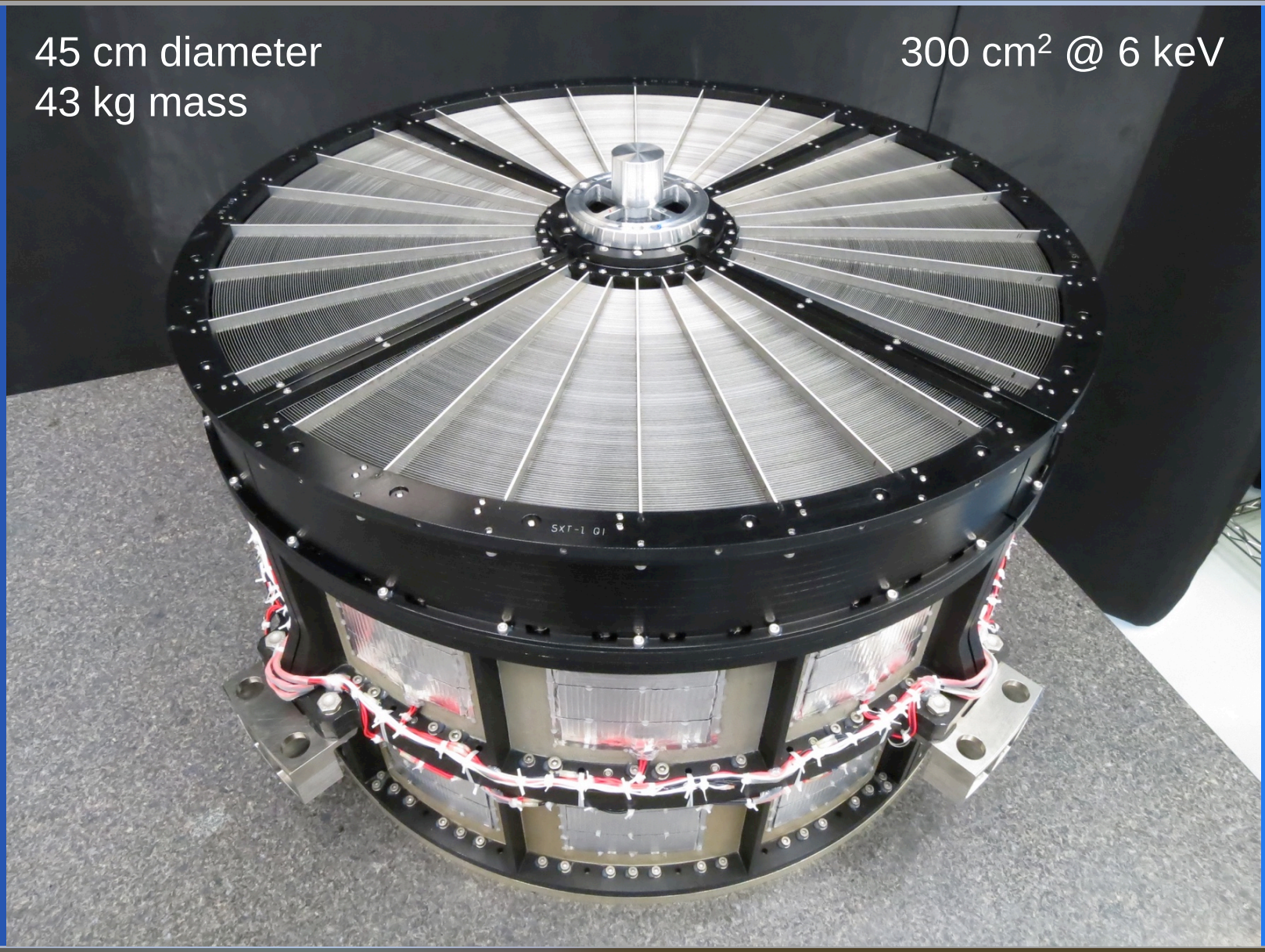
Heat switches are active gas-gap

Installation of Detector and ADR Subassembly (March 2014)

Flight ADR, Detector and Dewar (July 2014)

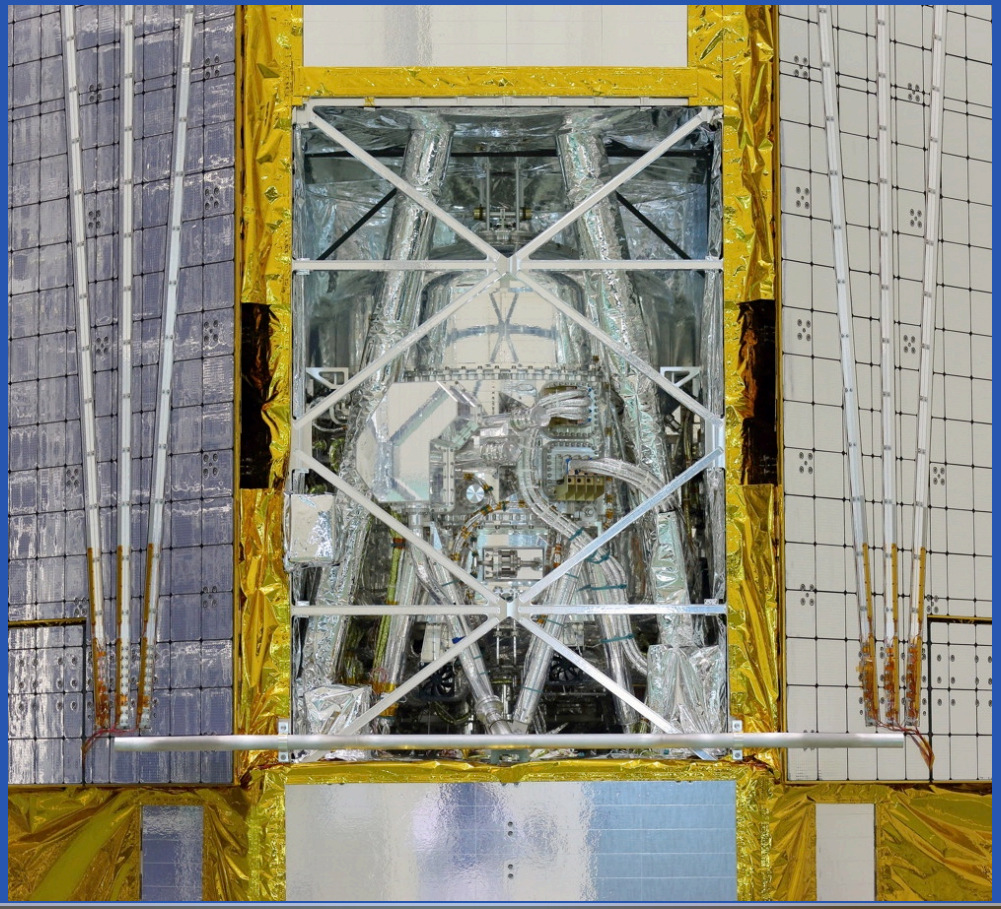


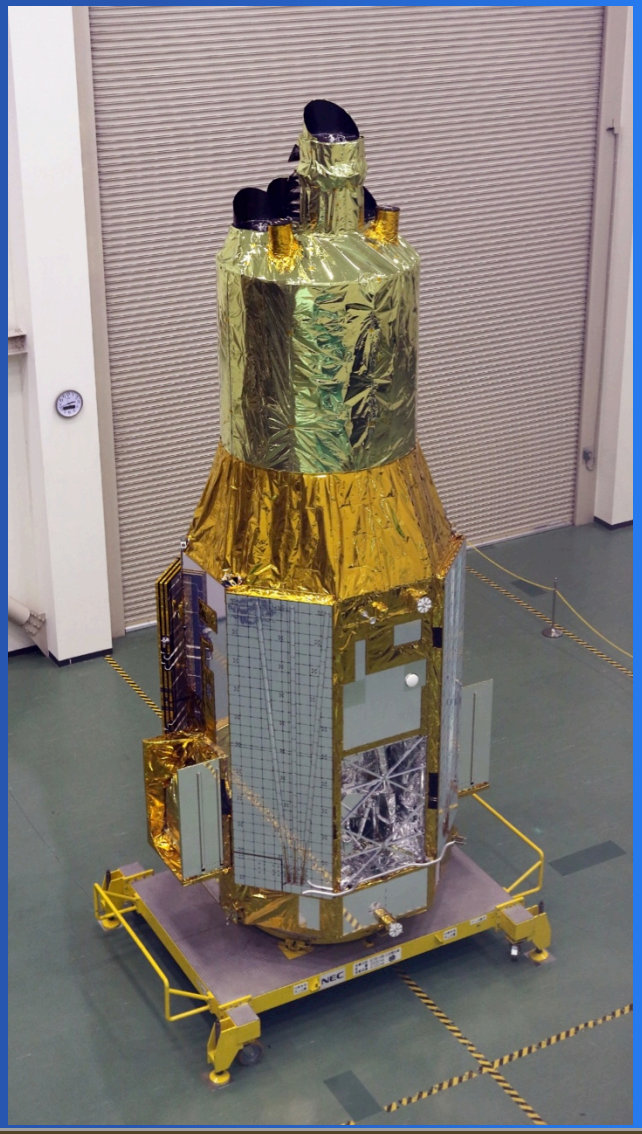
Soft X-Ray Telescope (one each for SXS and SXI)



Soft X-ray Spectrometer

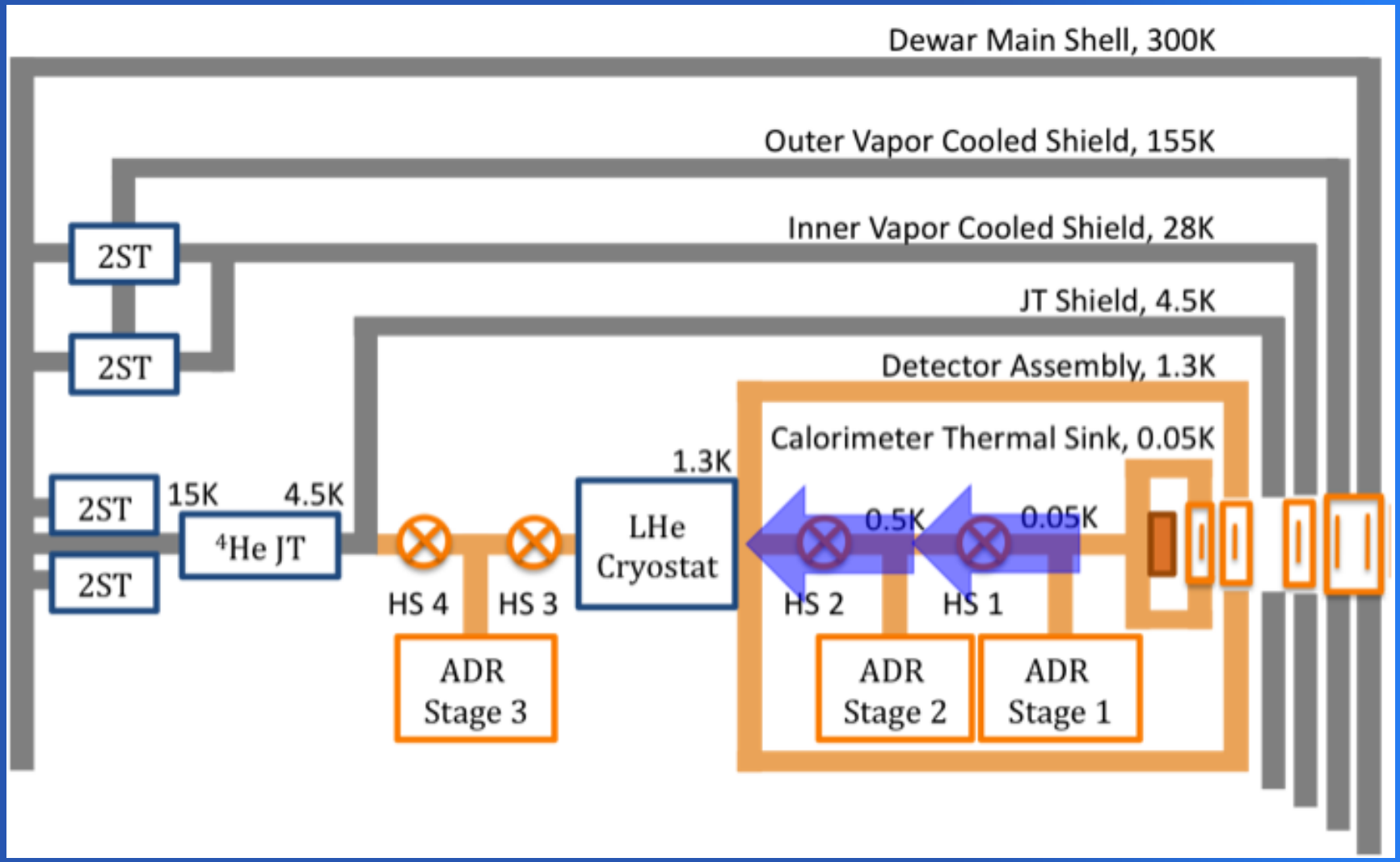
November 2015, Tsukuba Space Center, Japan
(photos courtesy of JAXA)





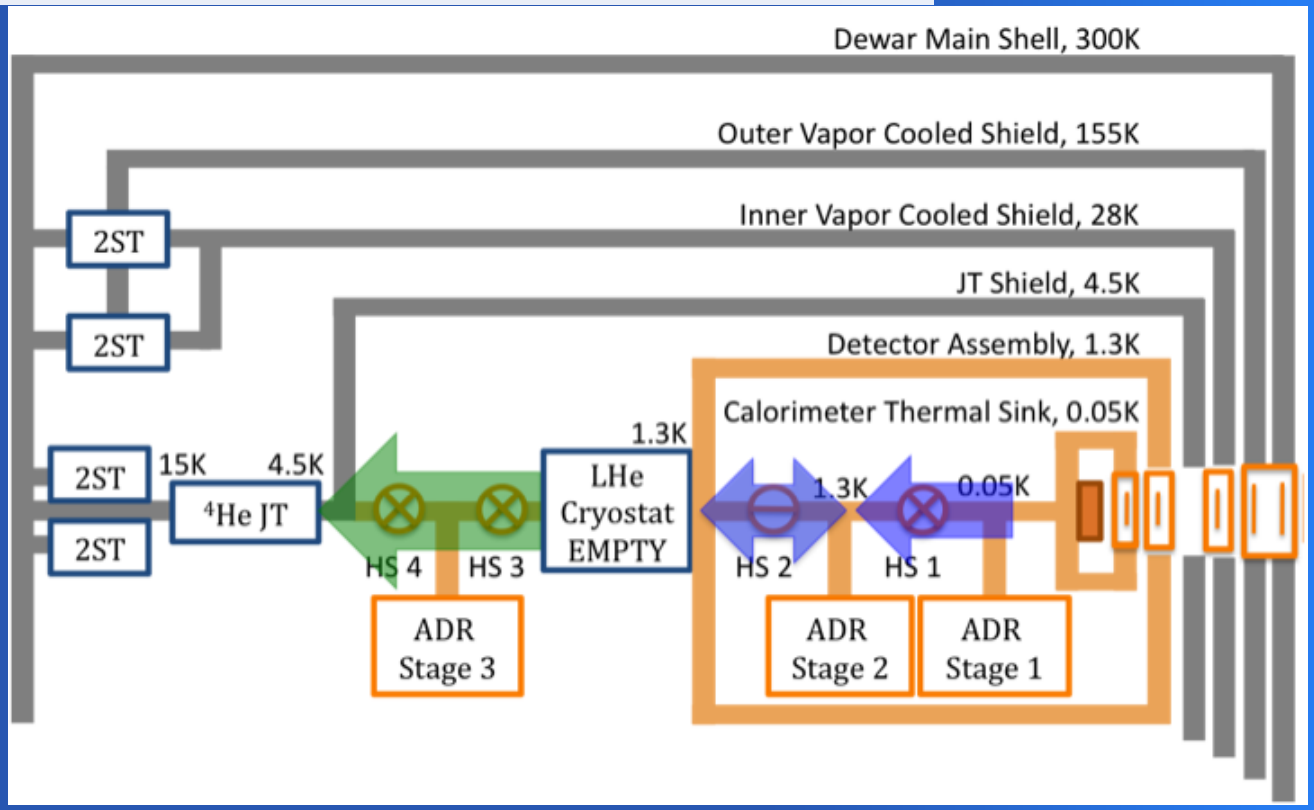
ADR Operation with Liquid Helium

2-stage ADR uses liquid helium as a heat sink



ADR Operation in Cryogen-Free Mode

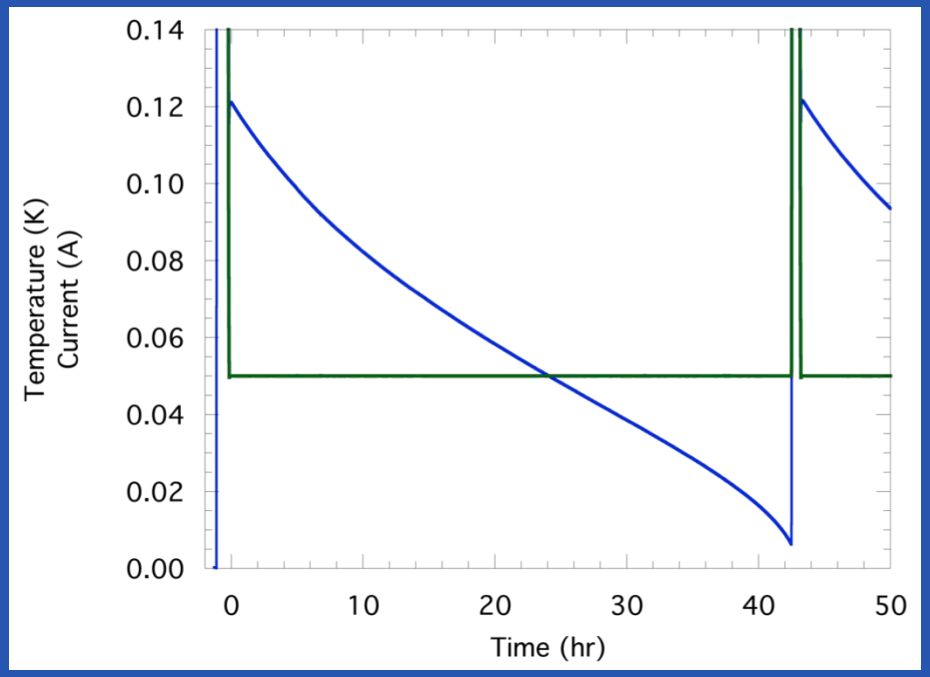
- 3rd stage transfers heat from tank to JT cooler
- 2nd stage stabilizes helium tank at ~1.3 K
- 1st stage cools detectors from 1.3 K to 50 mK
  - 2nd stage decouples from tank to precool 1st stage to 0.8 K

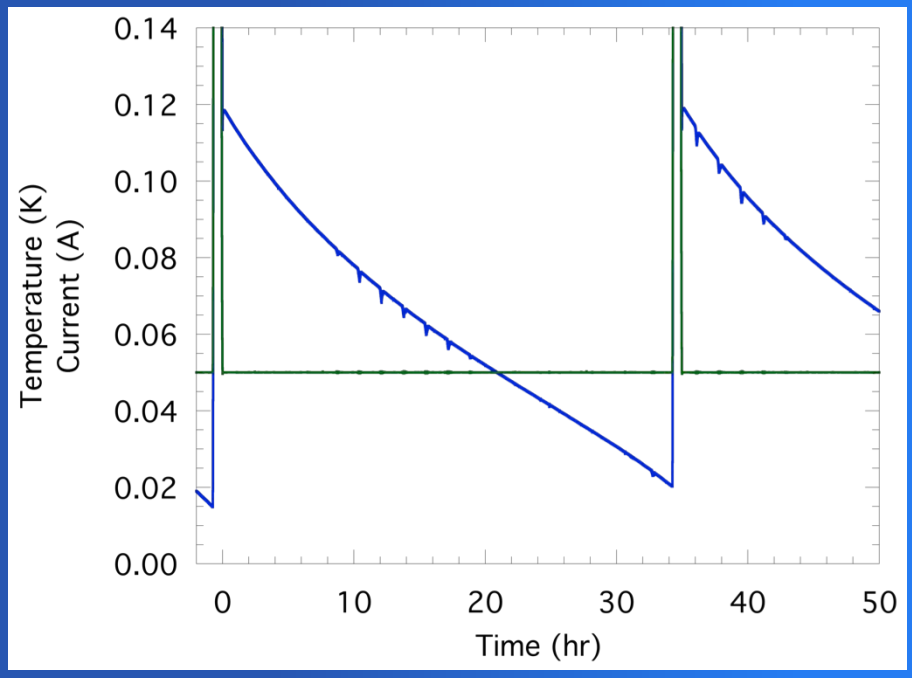


Planned Operating Strategy

- SXS is launched with minimum of 33 L of liquid helium (<1.3 K)
  - Cryocoolers act as guards to intercept parasitic heat loads
  - Nominal lifetime >3 years (assuming nominal cryocooler operation)
- 2-stage ADR single-shot cools the detectors, rejecting heat to the liquid helium
- When helium is depleted, ADR operation changes to 3-stage operation
  - Upper stages continuously cool the helium tank, rejecting heat to 4.5 K JT cooler
  - 1st stage (50 mK) single-shot cools the detectors, rejecting heat to He tank
- *Hitomi* actually carried ~37 L of liquid to orbit
- With liquid helium, only the 2-stage ADR are used

Stage 1 Performance – Ground vs. On Orbit

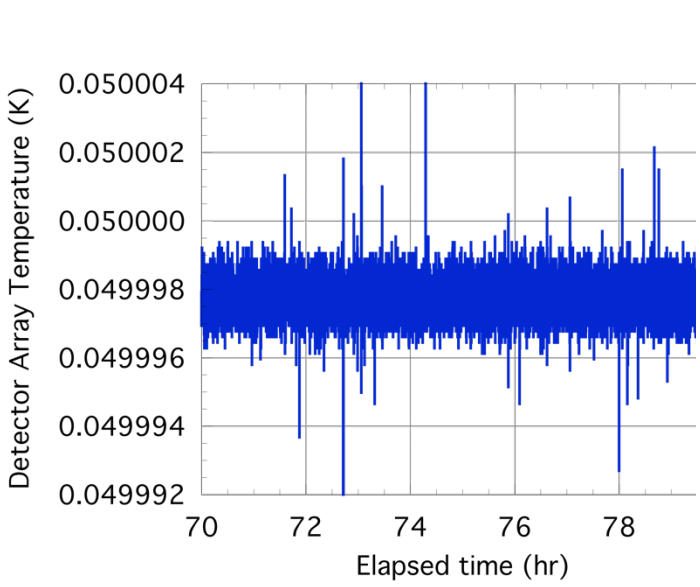




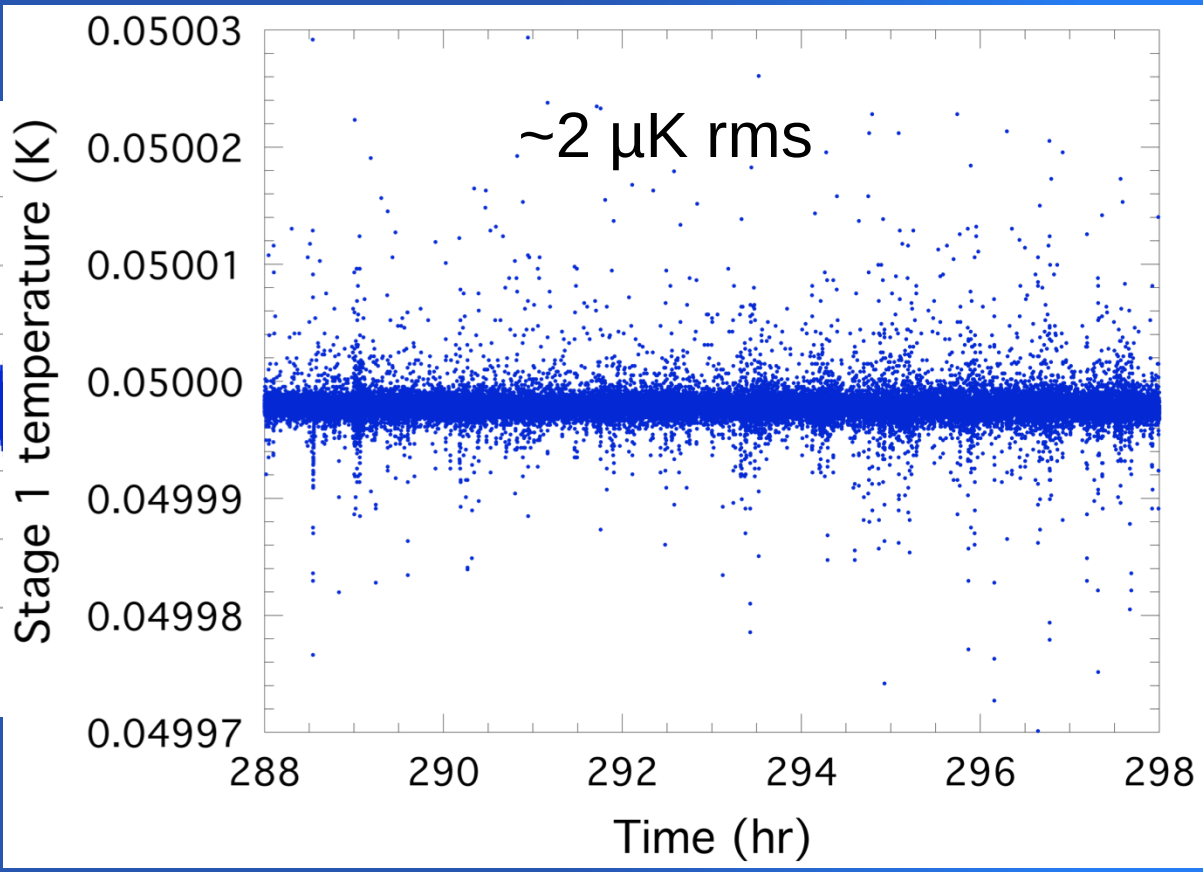
Recycle time	~45 minutes	~45 minutes
Heat load	0.80 µW	0.86 µW
Hold time*	~42 hours	~39 hours

* Dependent on tank temperature; values shown are for ~1.20 K

Temperature Stability



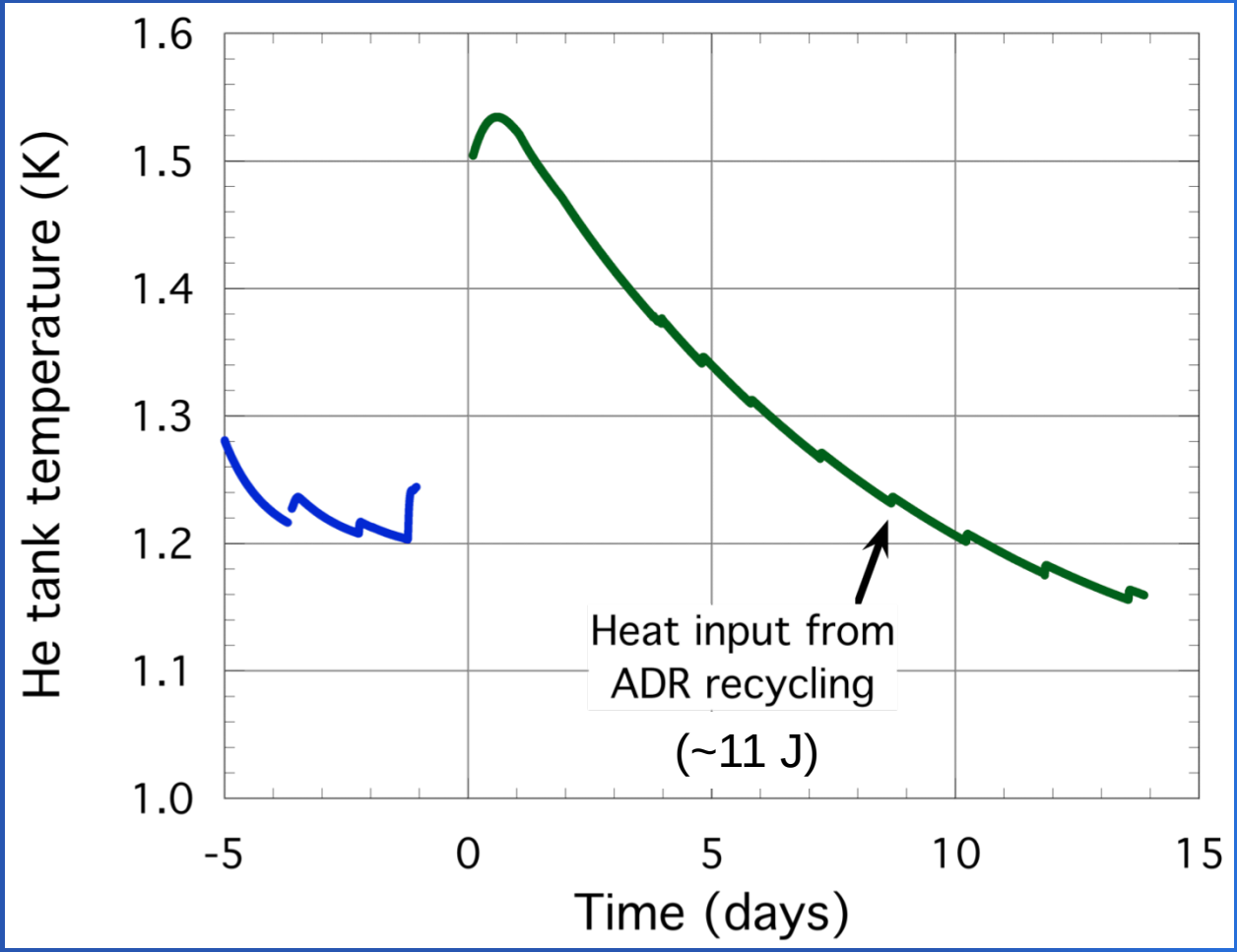
Ground tests: ~0.4 μK rms



On orbit: ~2 μK rms

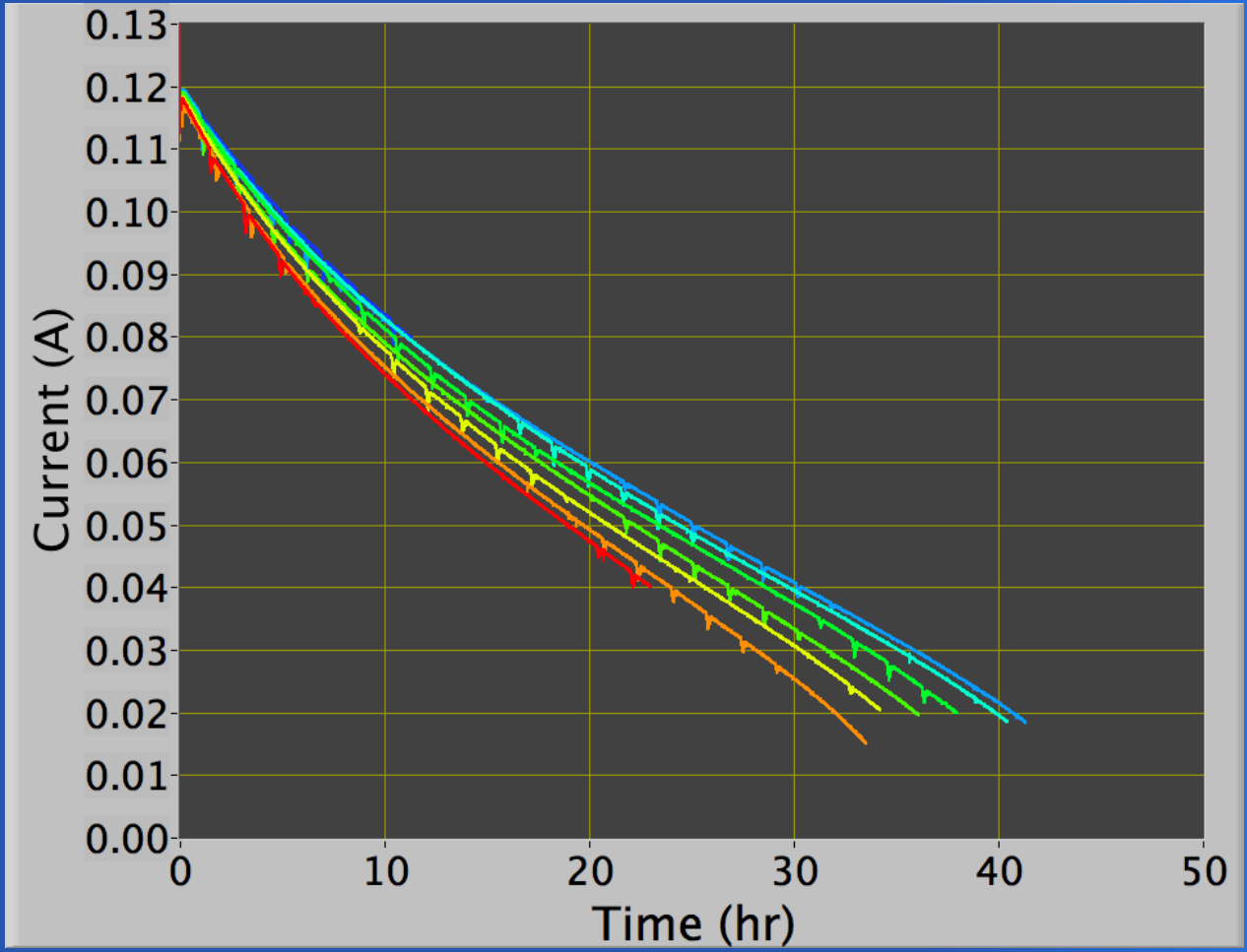
He Tank Temperature

- Cooling rate is consistent with ground tests of porous plug phase separator
- Equilibrium temperature is estimated to be 1.10 K



ADR Performance

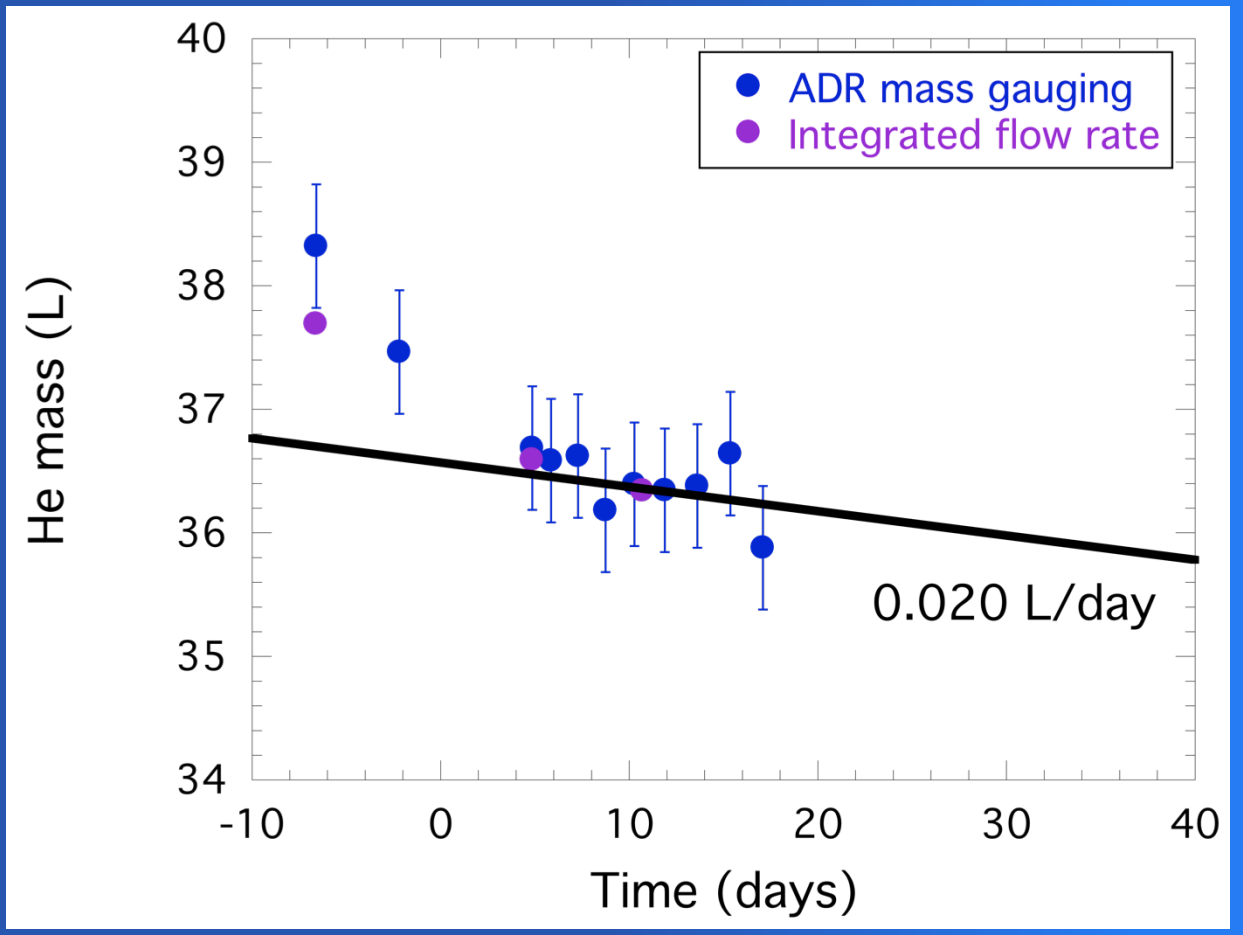
- ADR hold time has been steadily increasing as He tank cools
- At 1.10 K, hold time is ~48 hours



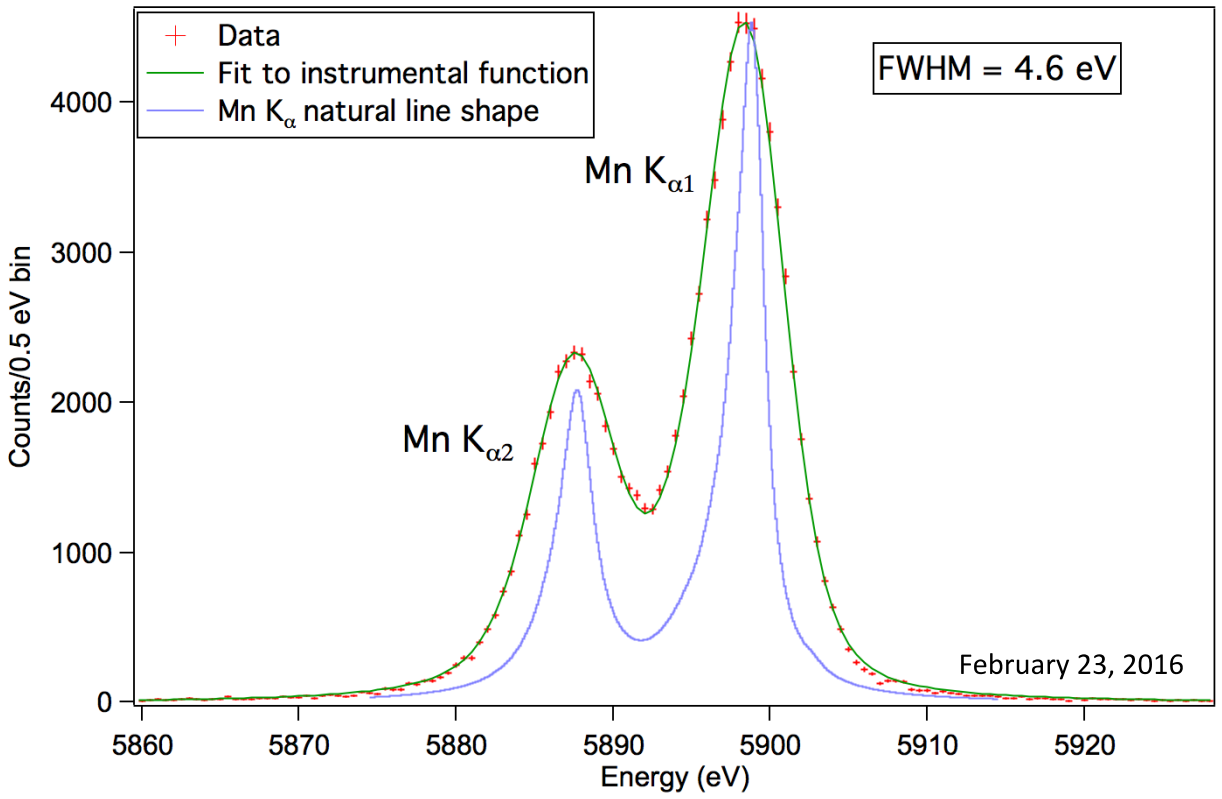
Helium Volume and Lifetime

- Direct volume measurement after low temperature top-off: 37.7 L
- ADR heat output can be used to gauge liquid mass on orbit
- Tank heat load
  - 0.650 mW parasitic
  - 0.080 mW from ADR
- Lifetime of >3 years

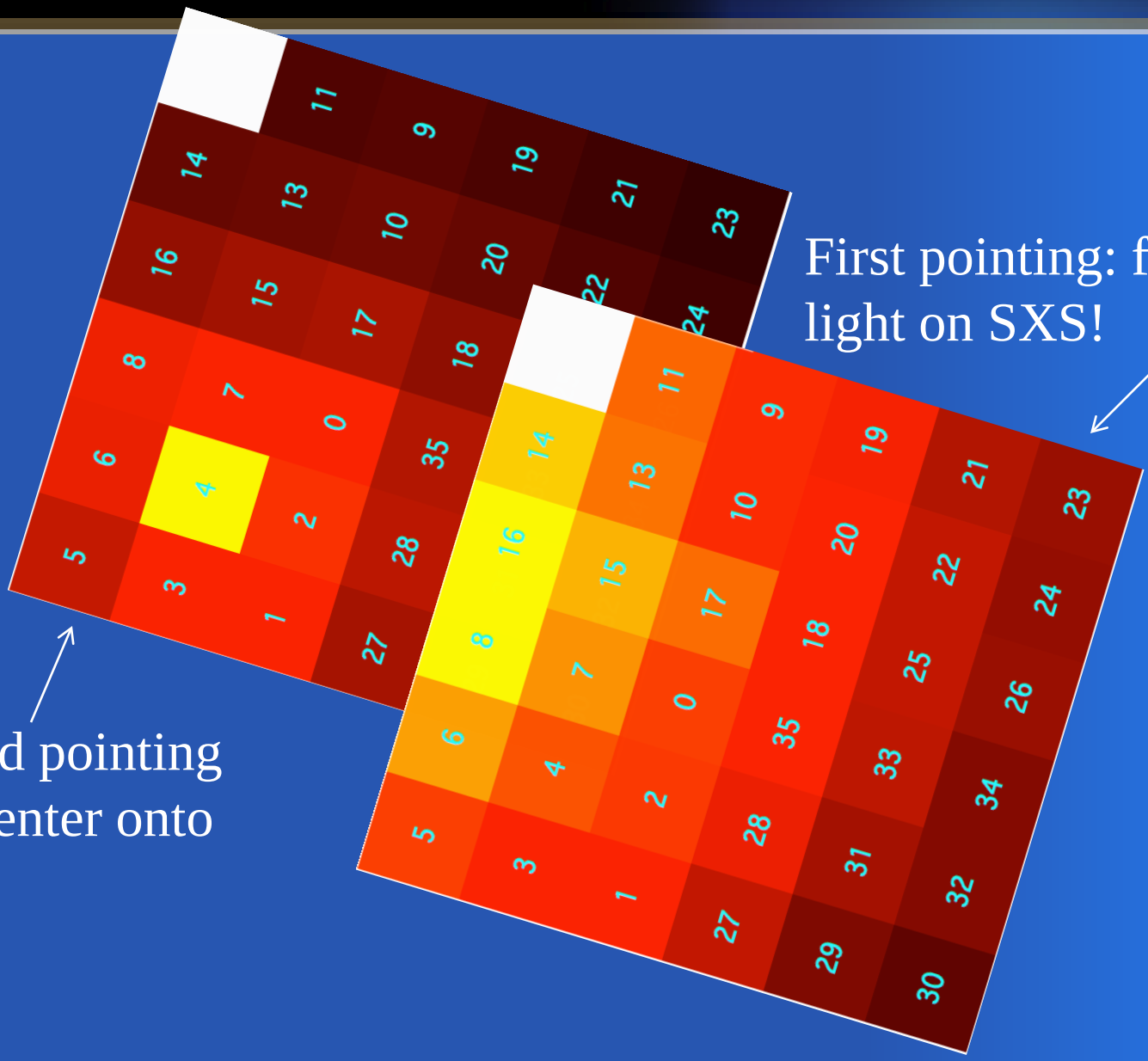
(Formal lifetime projection is actually ~ 5 years, but this would require cryocooler performance to remain constant during this time, and some degradation is expected.)



In-orbit performance of dedicated calibration channel



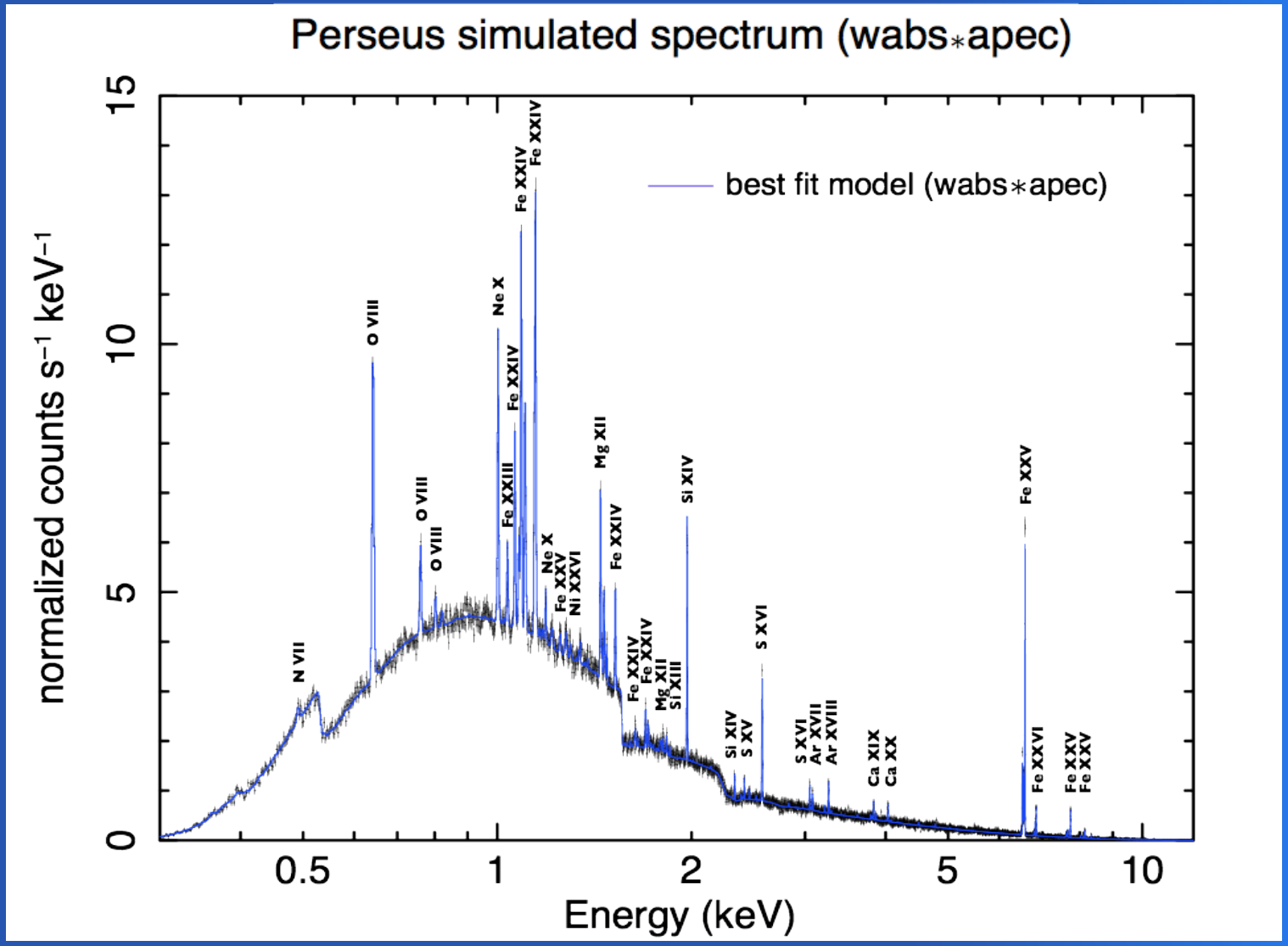
SXS Observation of Perseus Cluster



First pointing: first X-ray light on SXS!

Tweaked pointing to put center onto array

Simulation of Perseus Cluster – Real data totally lives up to this!

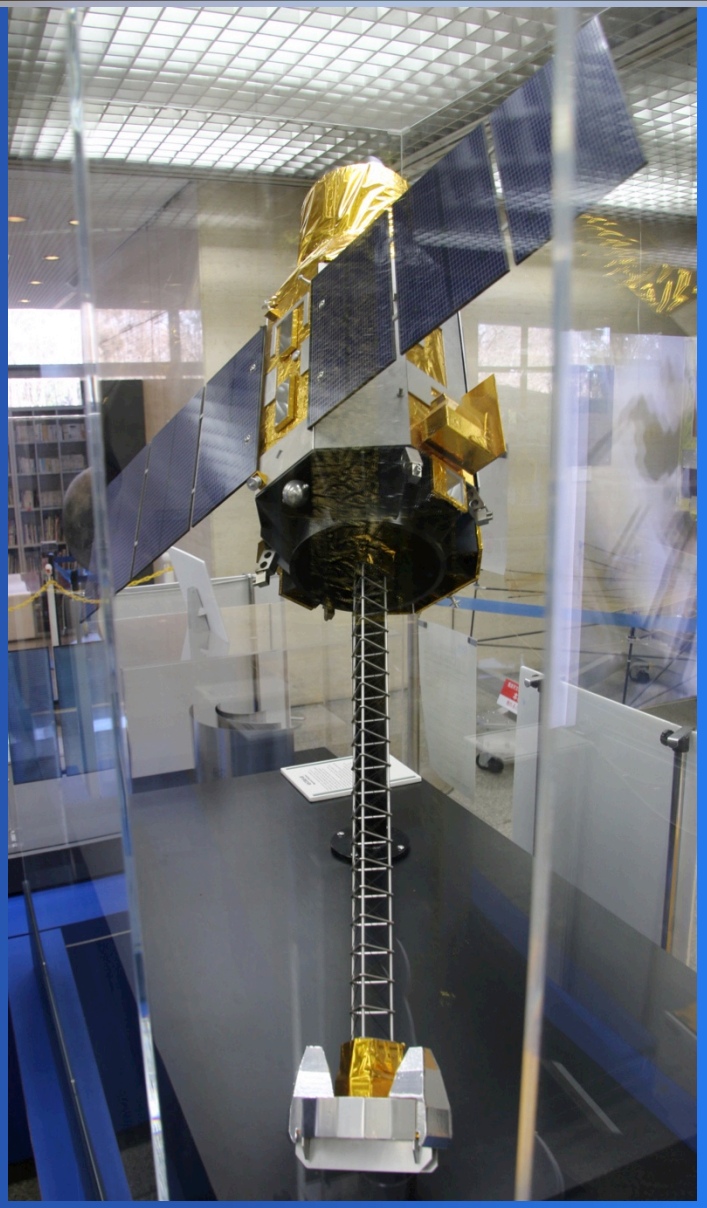


EOB for Hard X-Ray Imager

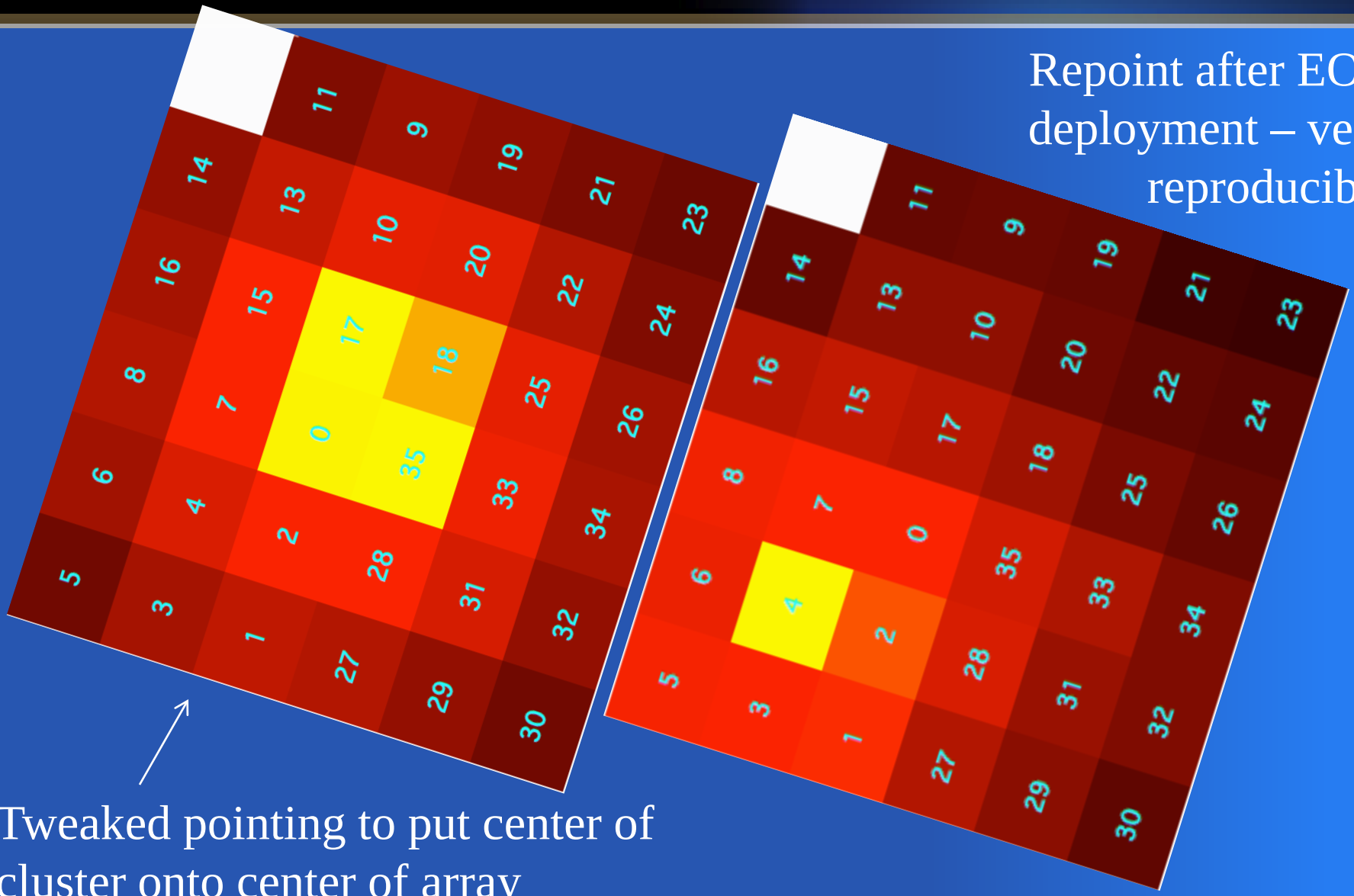
EOB extends HXI 6 meters out the back of the spacecraft.

22 steps

Successfully carried out during 4 consecutive real-time passes



Pointing post EOB deployment



Repoint after EOB deployment – very reproducible

Tweaked pointing to put center of cluster onto center of array

Other Hitomi Instruments

Soft X-Ray Imager (SXI) and Hard X-Ray Imager

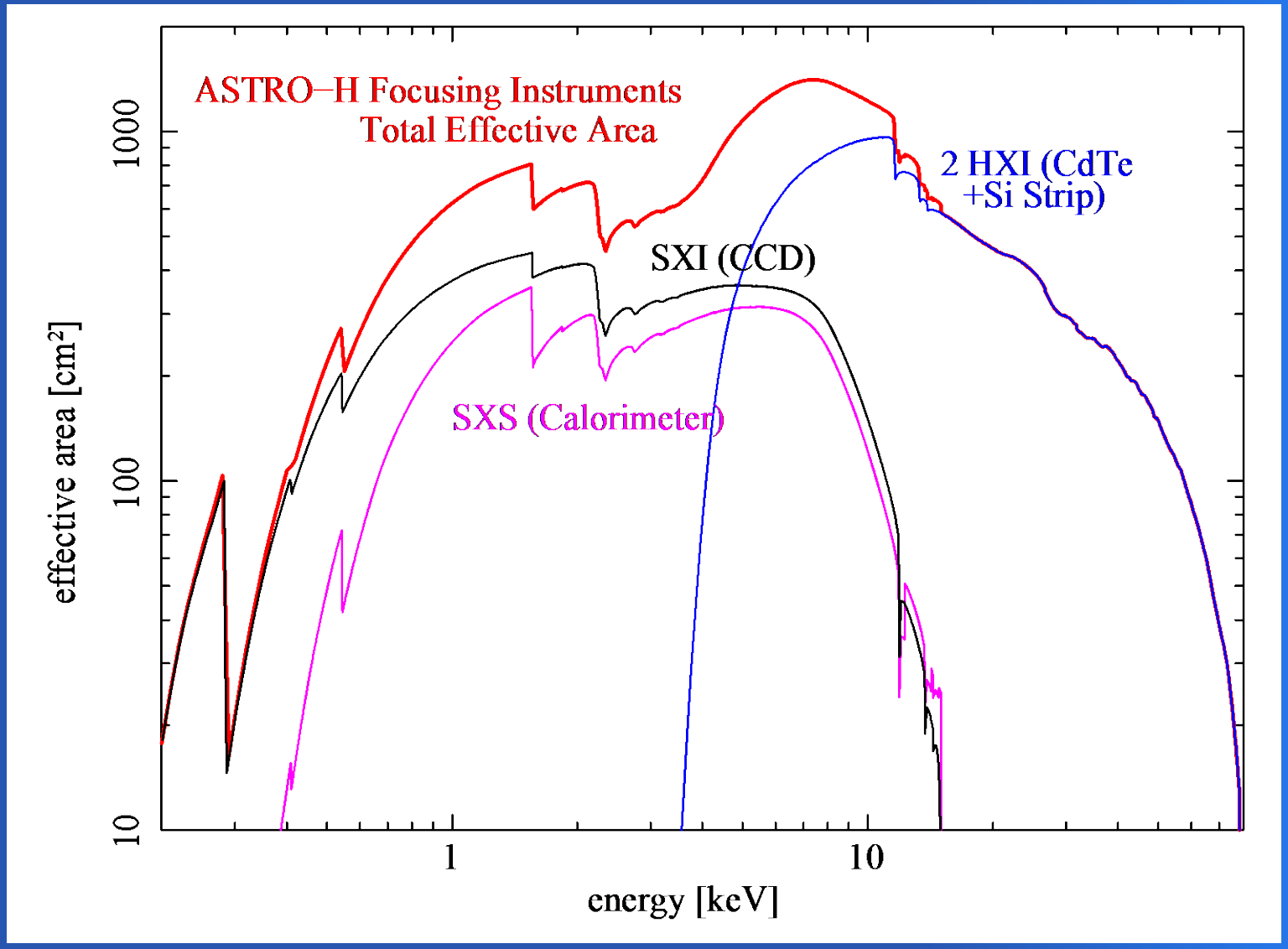
- Both instruments up and running
- Parameter tuning underway

SGD to be powered up during the week of March 21

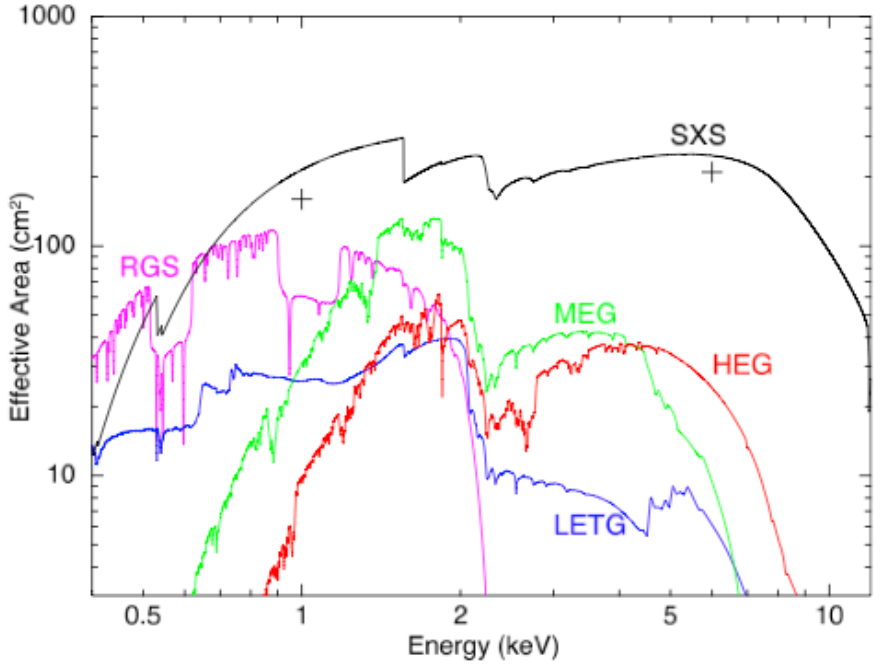
Longer-term:

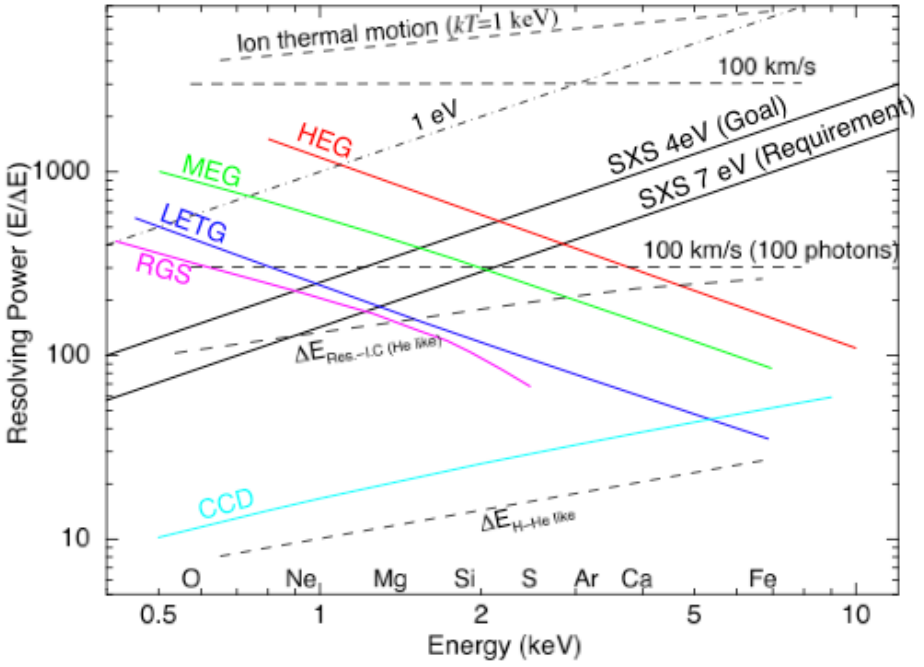
- Onboard calibration of SXS
- Open SXS aperture door (April 8)
- Calibration observations thereafter

Hitomi Effective Area for Focusing Instruments



Area and Energy Resolution Comparison





Hitomi Guest Investigator Program (1/3)

- US GO program enabled via the *Hitomi* Science Enhancement Option
- Cycle 1 (and subsequent cycles) will last one year

- Program time division:
  - 75 percent GO time
  - 15 percent SWG time (becomes key program time in future cycles)
  - 10 percent Observatory time

- National time shares:
  - 56 percent to Japan
  - includes 10 percent share to ESA
  - 44 percent to US
  - For proposal purposes, all non-US and non-ESA proposals count against Japan time

Hitomi Guest Investigator Program (2/3)

- Timeline (currently planned):
  - May — Announcement
  - August — Proposal due date
  - December 1 — Start of cycle 1 observations
- Merging of conflicting US and Japan proposals will still occur
  - Attractive feature from ASCA, Suzaku GO programs
  - Encourages collaborations between US and Japanese teams, though not required
  - No explicit “merged proposal” time in *Hitomi* program
  - Instead, merged proposal time charged against program to which “PPI” submitted proposal

Hitomi Guest Investigator Program (3/3)

- Process:
  - US proposal process will entail two steps (as has become the norm)
  - Observing proposal submission through the *Hitomi* RPS system
  - Budget submission for selected proposals through NSPIRES
  - Embedded call for laboratory astrophysics measurements directly related to *Hitomi* science questions
- Funding
  - US GO program funded at $5M for first three cycles
  - Subsequent funding depends on Senior Review outcome

Summary

- Astro-H (*Hitomi*) has been successfully launched and is mostly deployed!
  - SXS has been operated to its nominal operating temperature of 50 mK and is achieving 4.5 eV energy resolution.
  - Internal temperatures now stable and lifetime estimated to be > 3 years
  - Calibration measurements and observations will start in March and continue into April following the opening of the dewar aperture door.
- Other *Hitomi* instruments are powering up.
  - EOB successfully deployed, enabling hard x-ray imaging with HXI
  - Expect all instruments to be operational by the end of March
- US GO Program on track
  - Data pipeline to US to start in April.
  - AO1 planned for release in May