3-Stage ADR for the X-Ray Imaging and Spectrometer Mission (XRISM)

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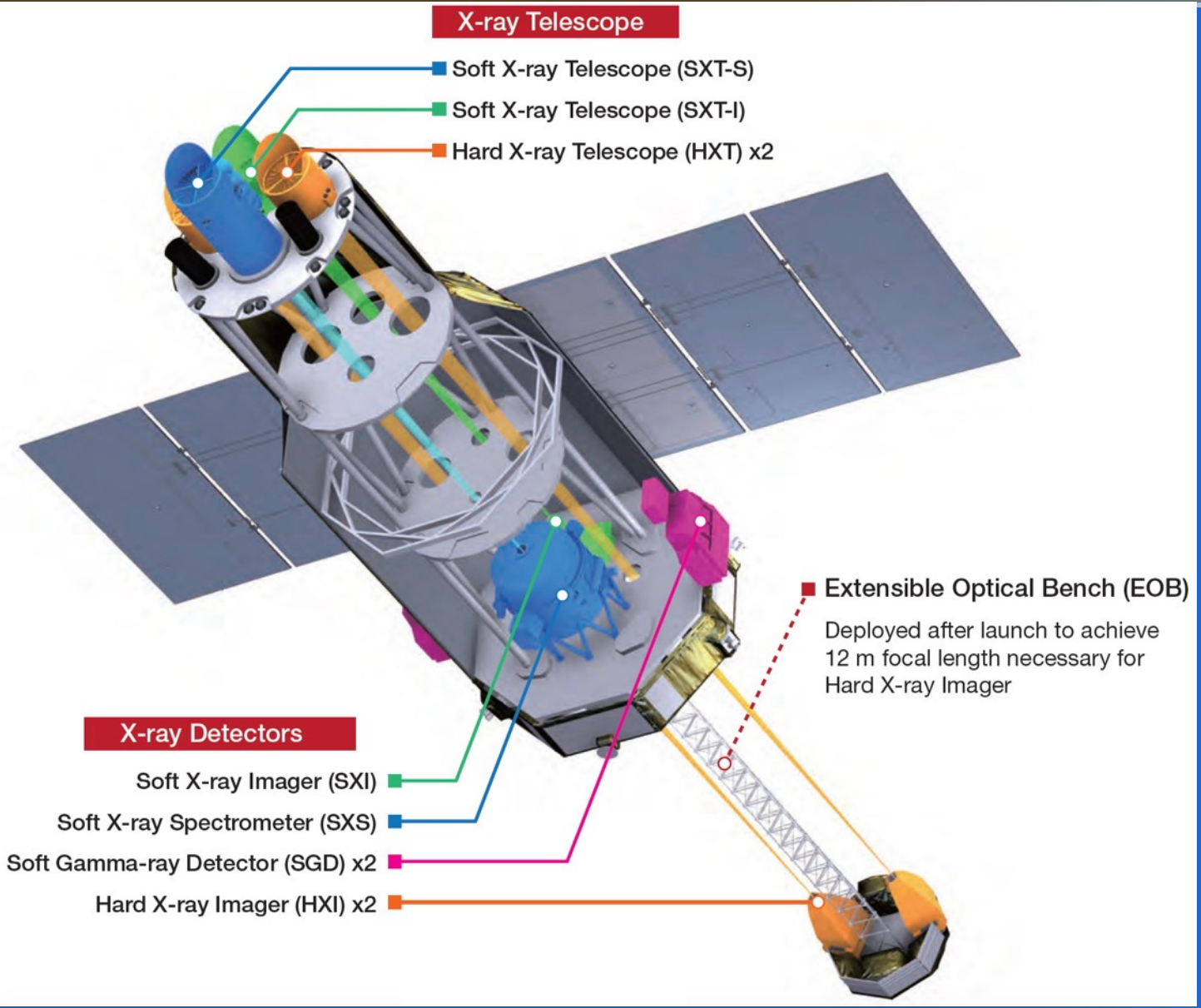
Hitomi (formerly Astro-H)



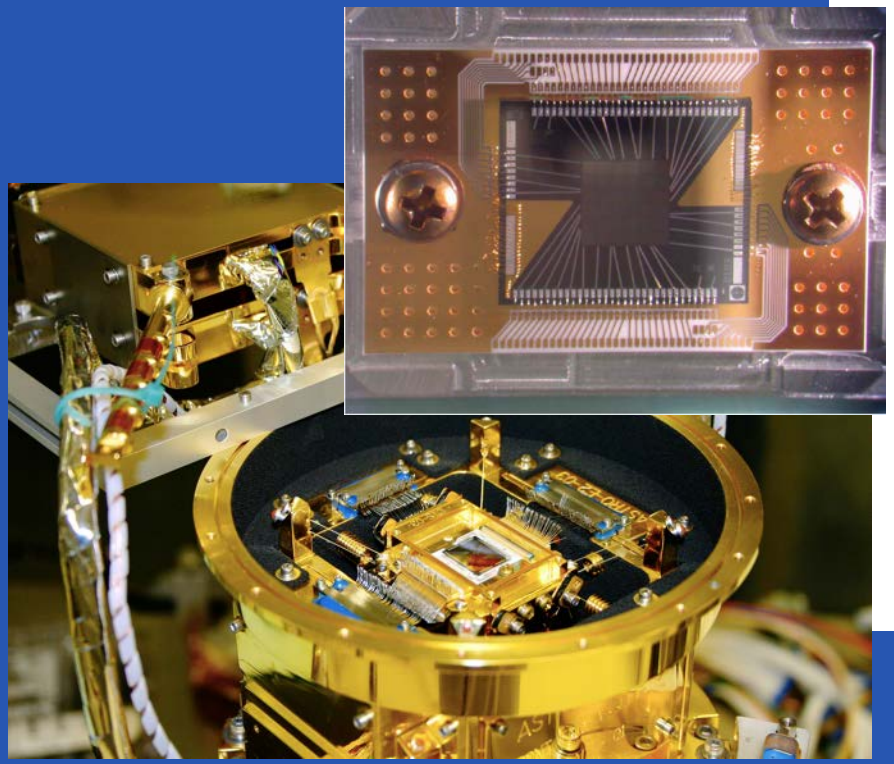
Study structure and evolution of the Universe

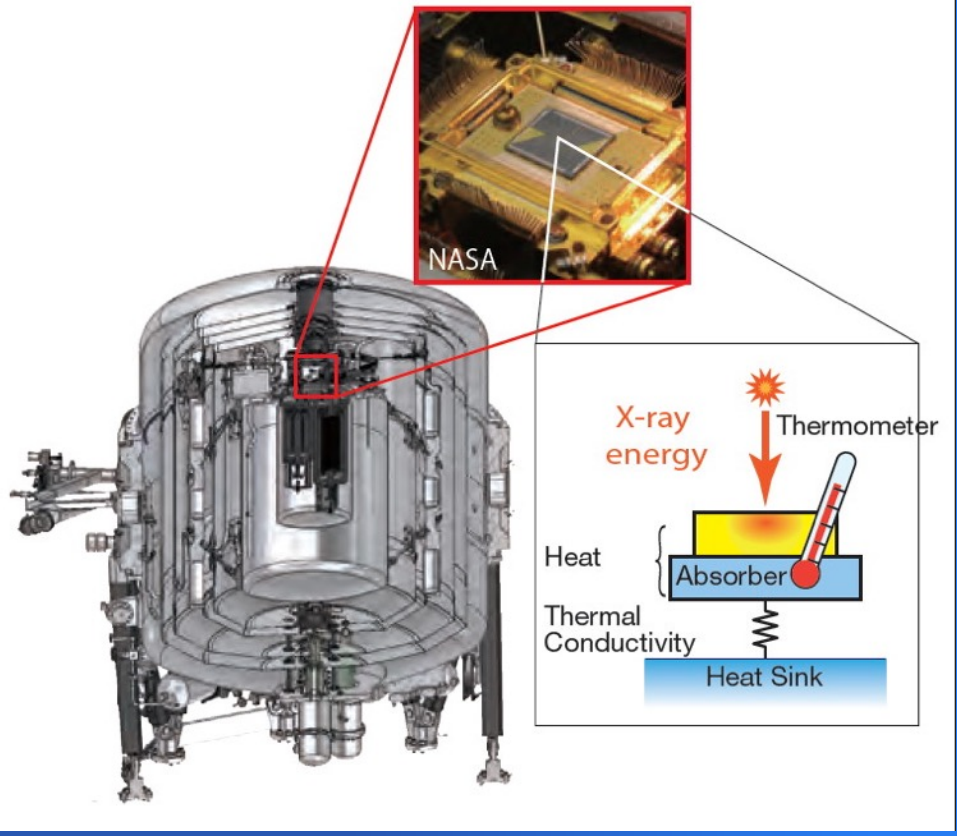
Study matter in extreme environments

- Black holes
- Galaxies
- Heavy elements
- Cosmic rays

The Resolve X-ray Spectrometer

- 6x6 array of silicon microcalorimeters
  - High resolution imaging and spectroscopy of x-rays in the 0.2-13 keV band
- ADR for detector cooling
  - 50 mK operation

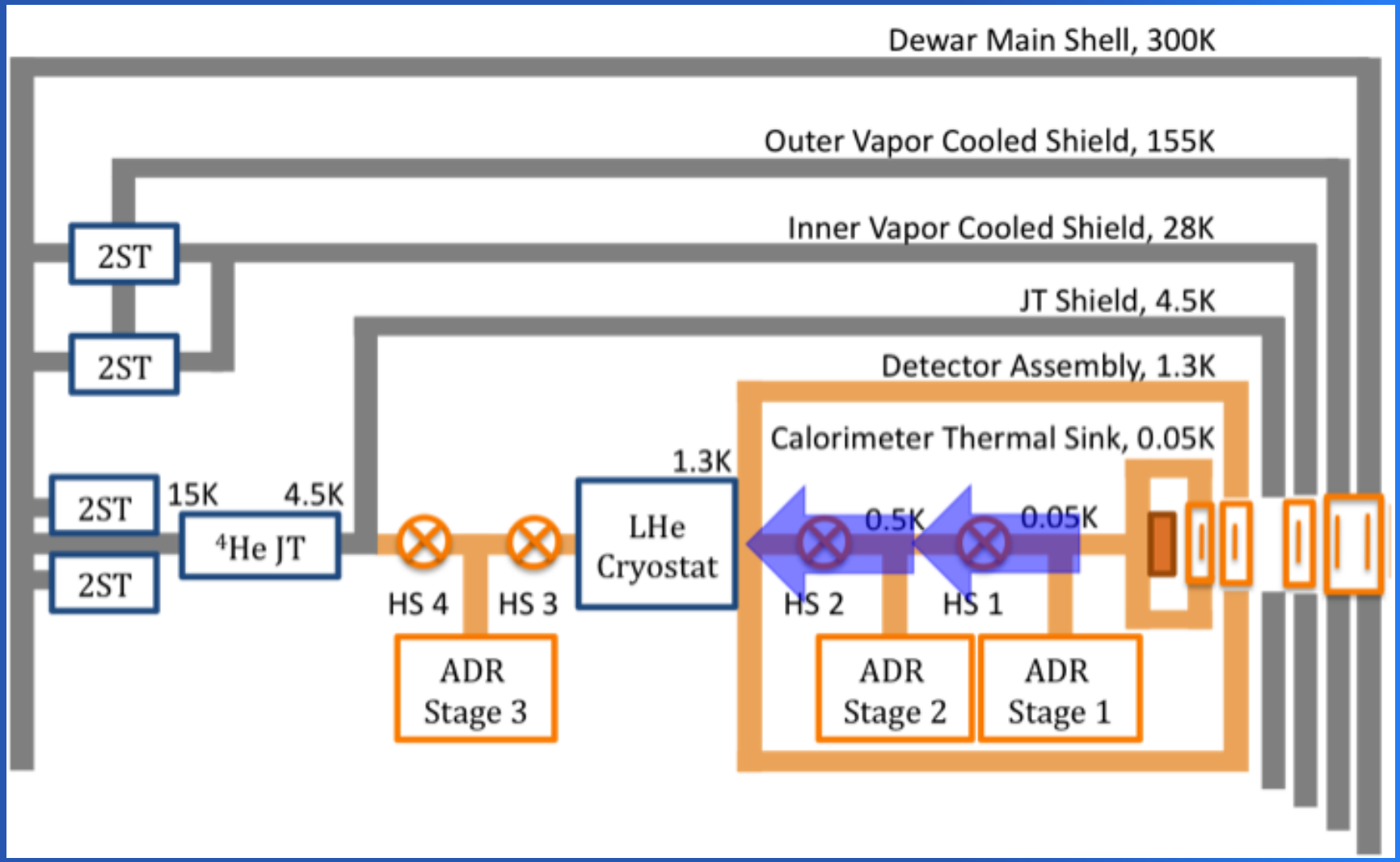




Low temperature ⇔ low heat capacity
ΔE ~ 4-5 eV for 0.2-13 keV x-rays

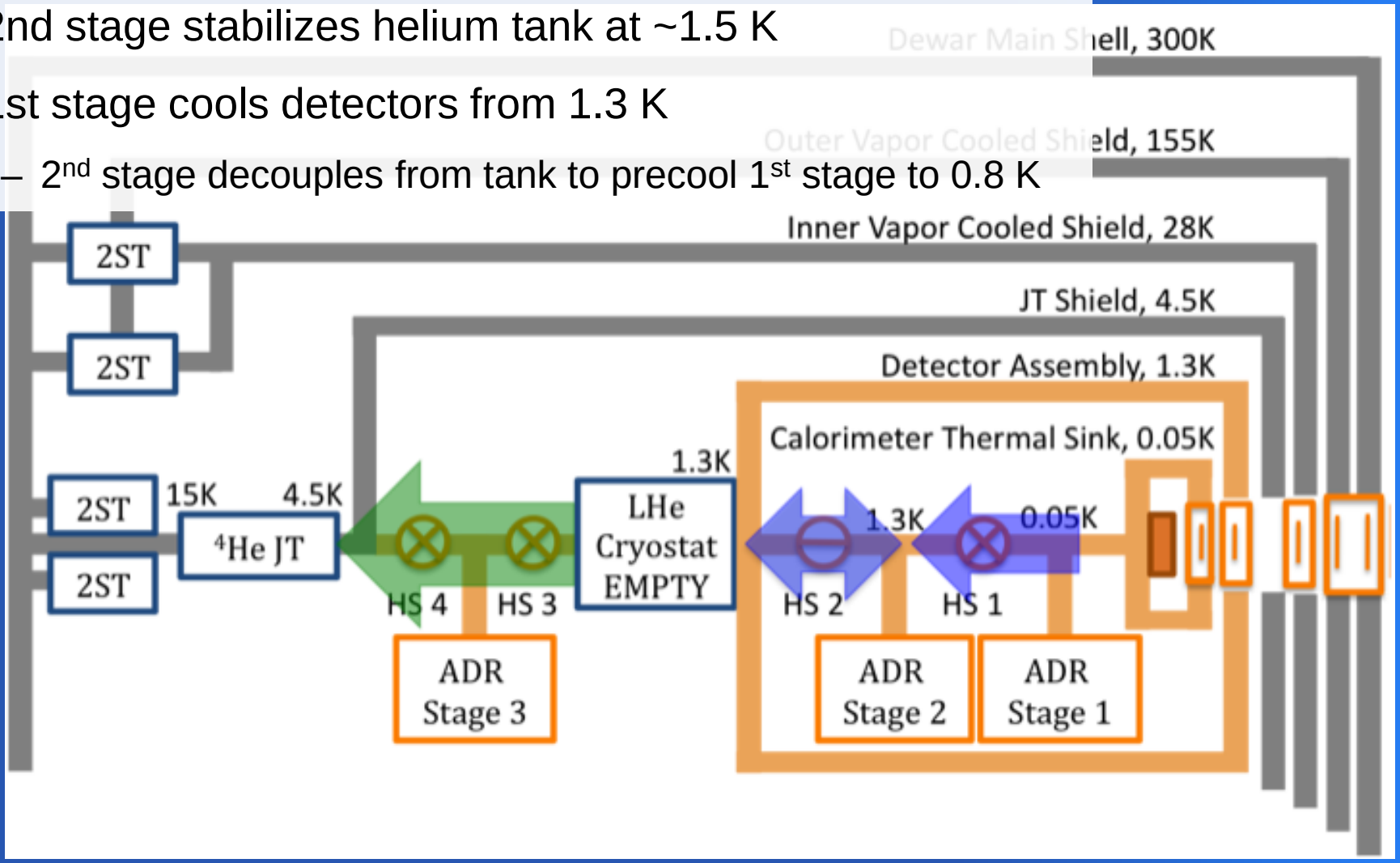
ADR Operation with Liquid Helium

2-stage ADR uses liquid helium as a heat sink

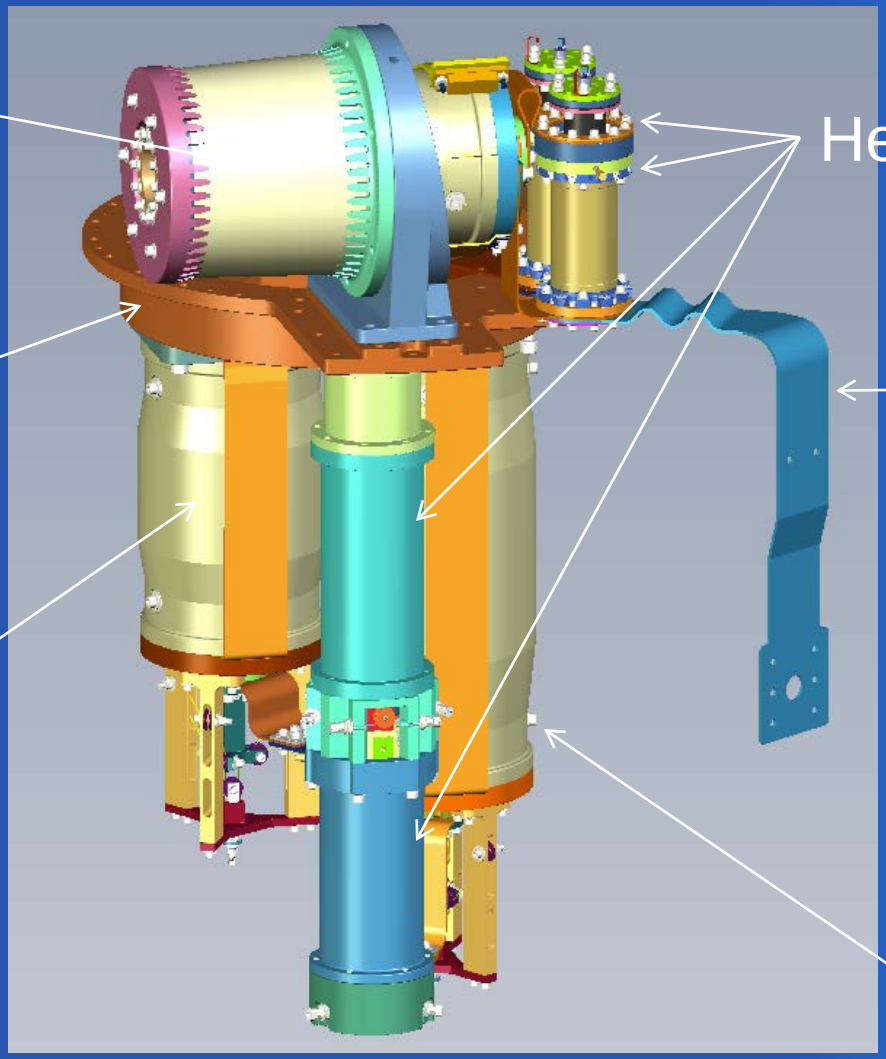


ADR Operation in Cryogen-Free Mode

- 3rd stage transfers heat from tank to JT cooler
- 2nd stage stabilizes helium tank at ~1.5 K
- 1st stage cools detectors from 1.3 K
  - 2nd stage decouples from tank to precool 1st stage to 0.8 K



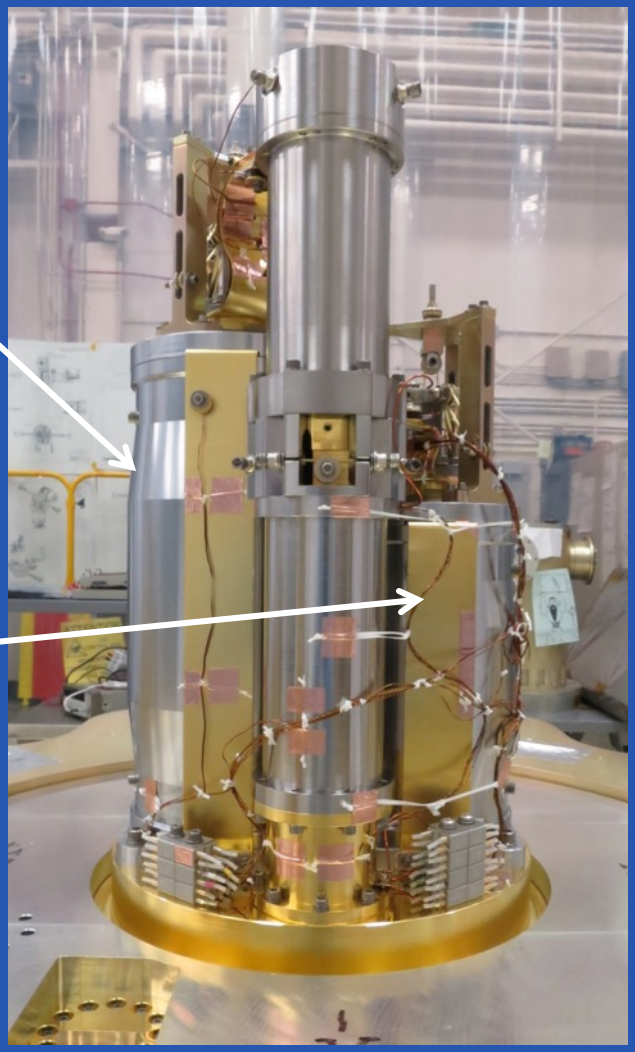
SXS ADR Layout

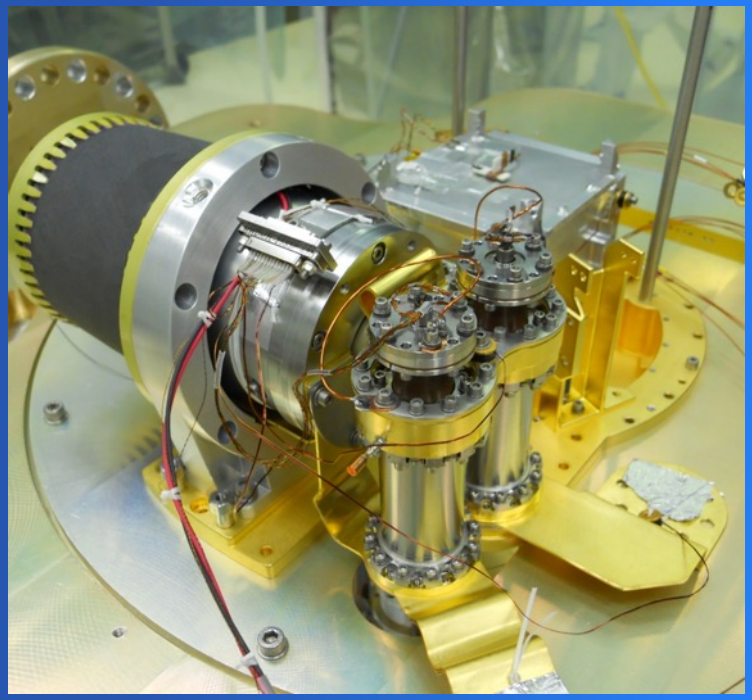


ADR Assemblies

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

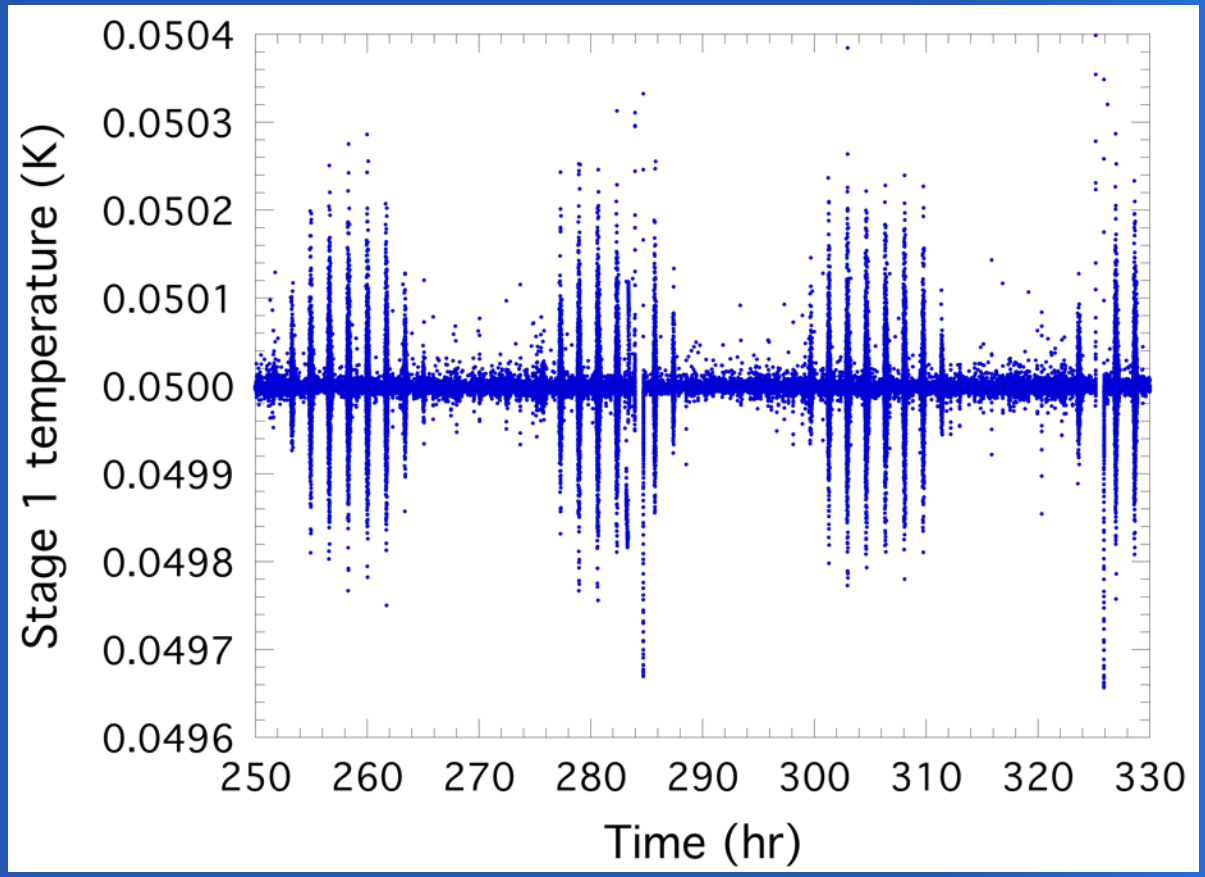
Heat switches are all active gas-gap

Changes for XRISM

- Some changes based on observed performance of Hitomi
  - High energy particle hits to temperature sensors
- Others based on performance limitations observed during ground testing
  - Interactions between stage 3 magnetic field and detectors
    - Excessive noise observed when magnet current was above 1.75 A (nom 2 A max)
    - Reduced cooling power in cryogen-free mode

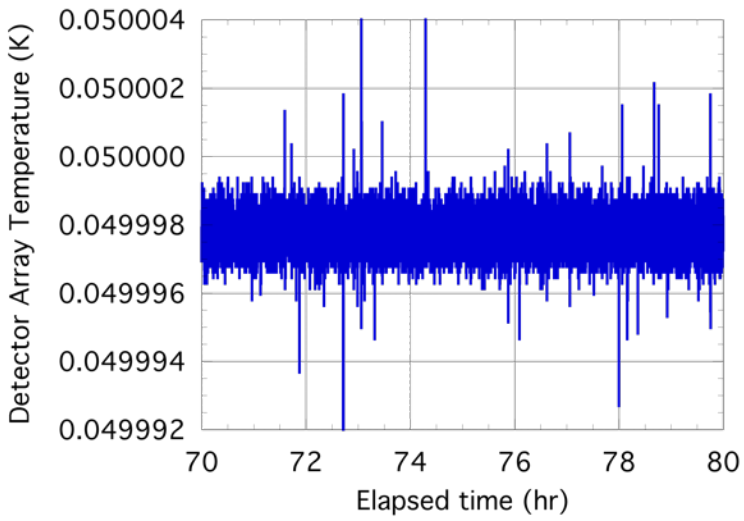
Effect of High Energy Particles

- Response appears to be primarily within thermometers
- Concentrated in SAA
  - Too intense to produce useful science data

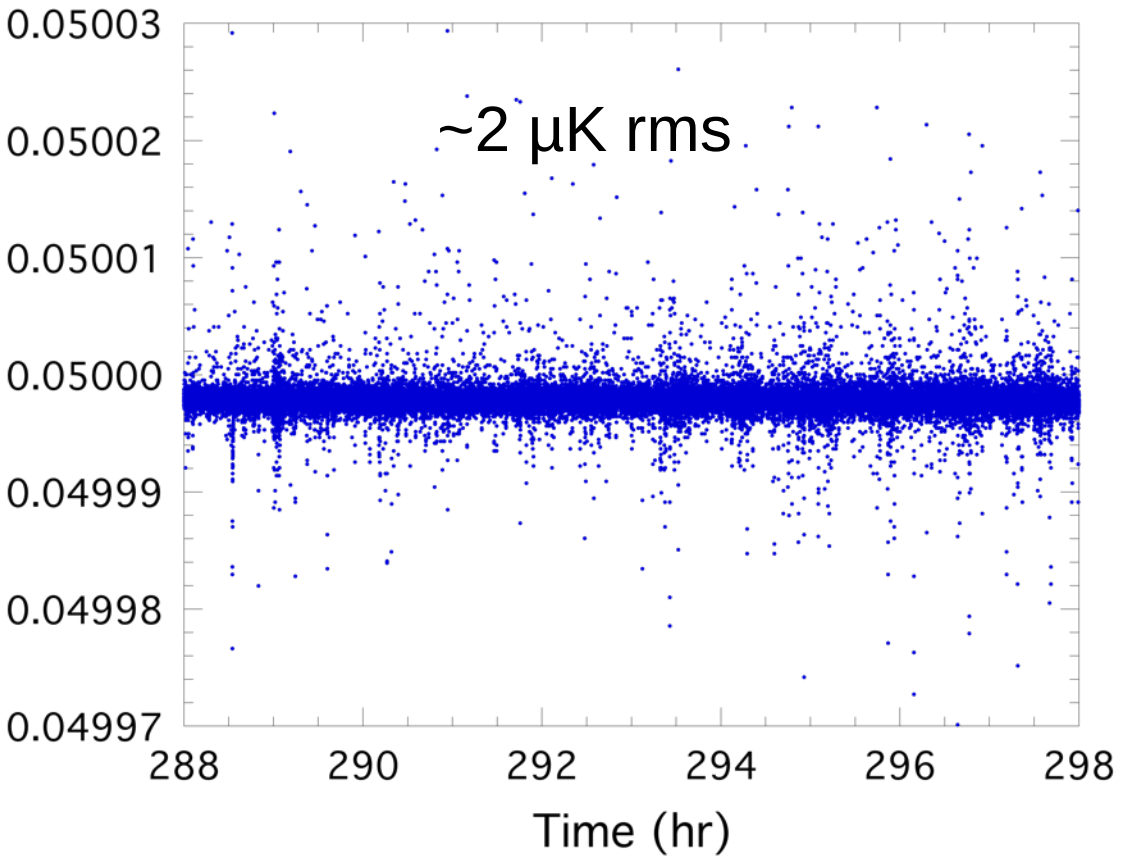


Temperature Stability

- Negative pulses are the ADRC reaction to hits on control thermometer
- Implementing a control veto on readings significantly above noise



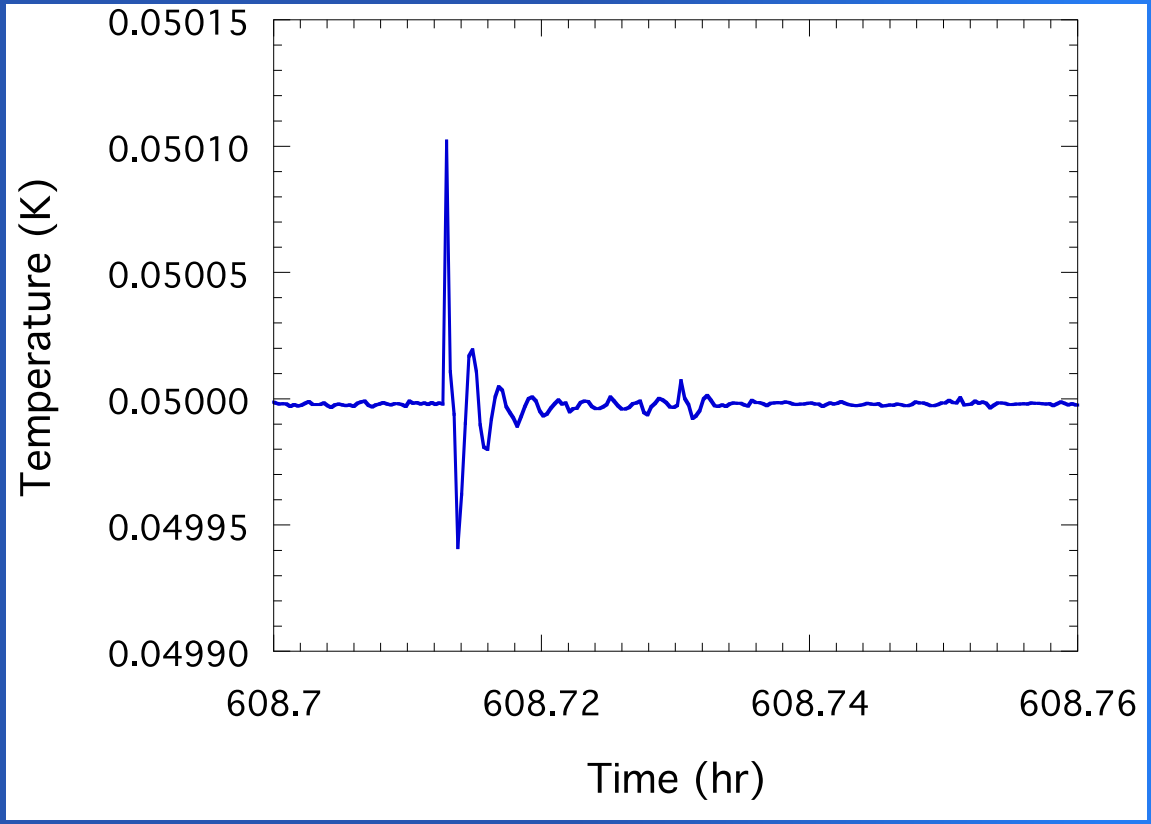
Ground tests: ~0.4 μK rms



On orbit: ~2 μK rms

Changes for Resolve

- Reduce ADR controller response to cosmic ray events
  - Suppress response to a reading outside a narrow band at 50 mK



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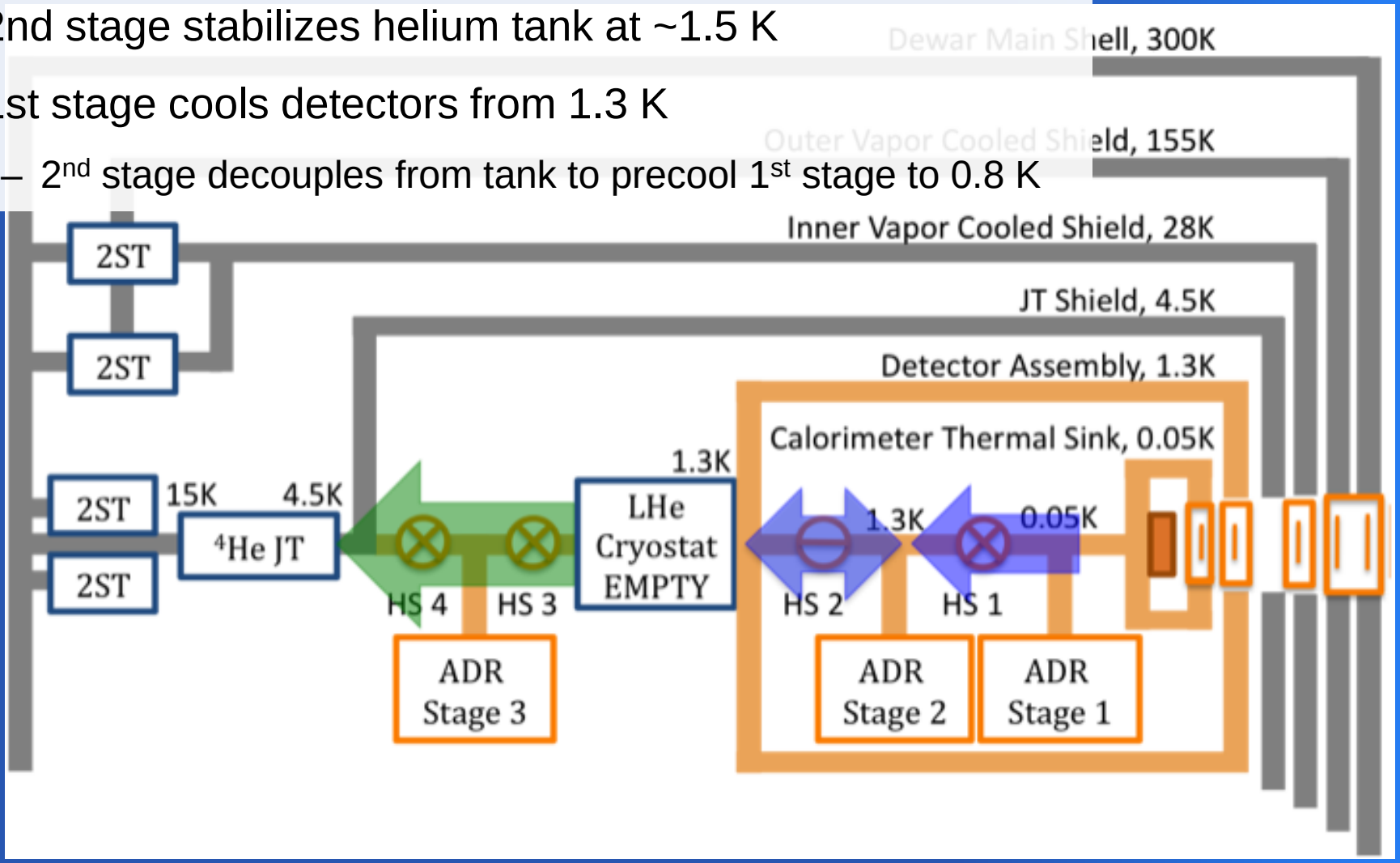
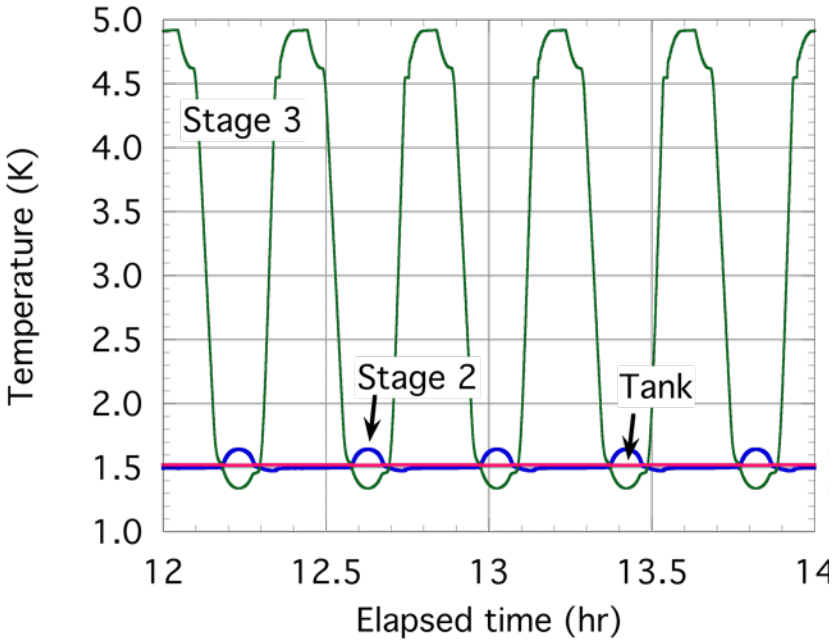
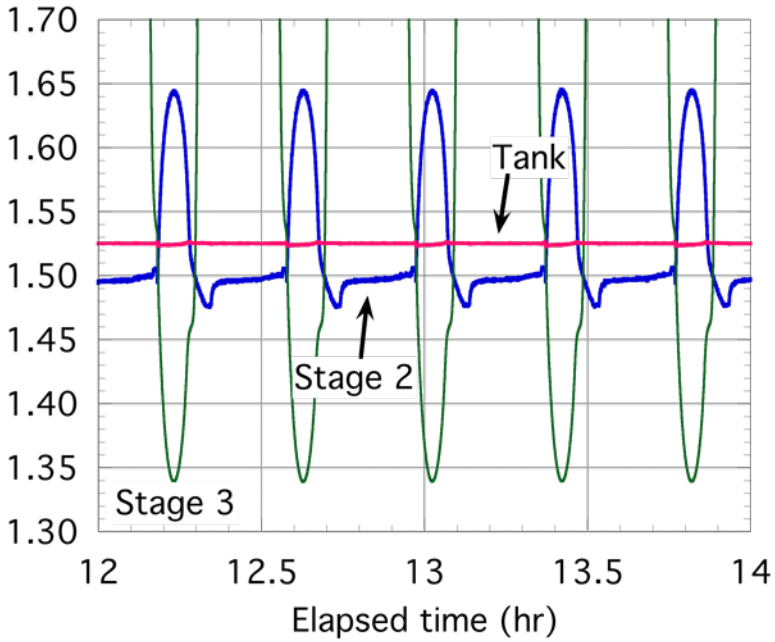


Continuous ADR Cooling

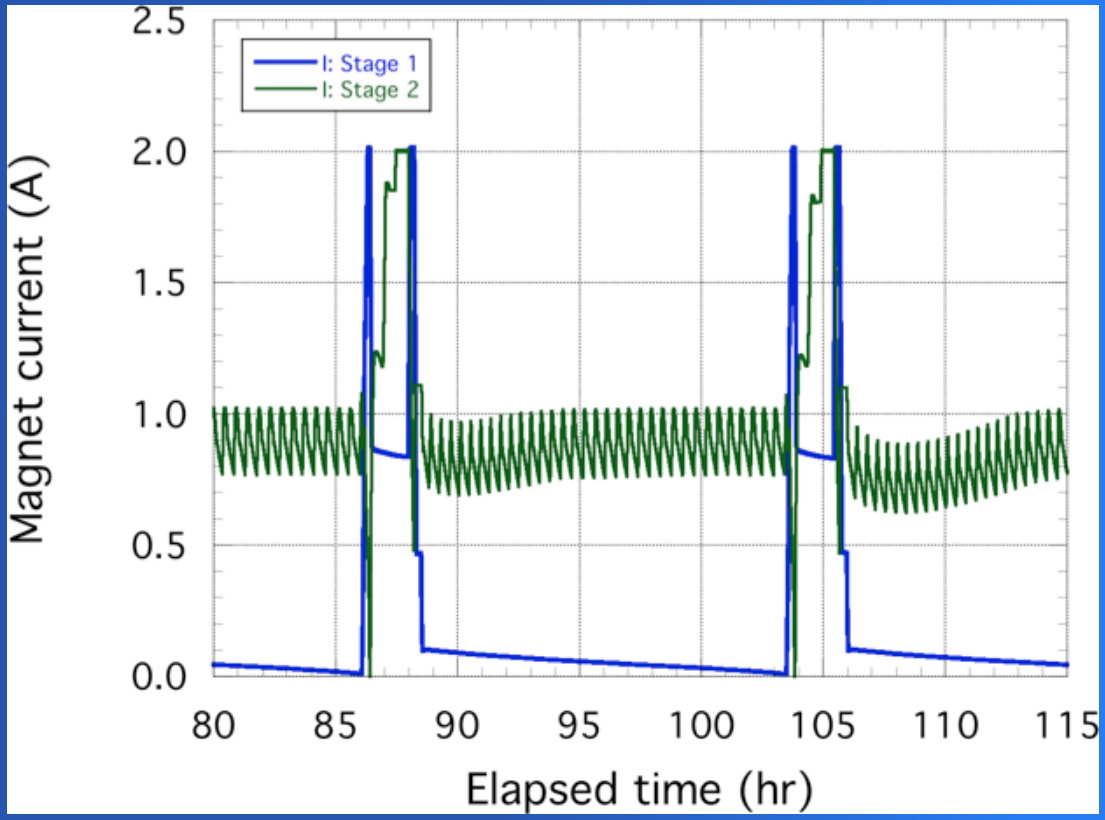
- Stages 2 and 3 operate together as a continuous ADR to cool the helium tank





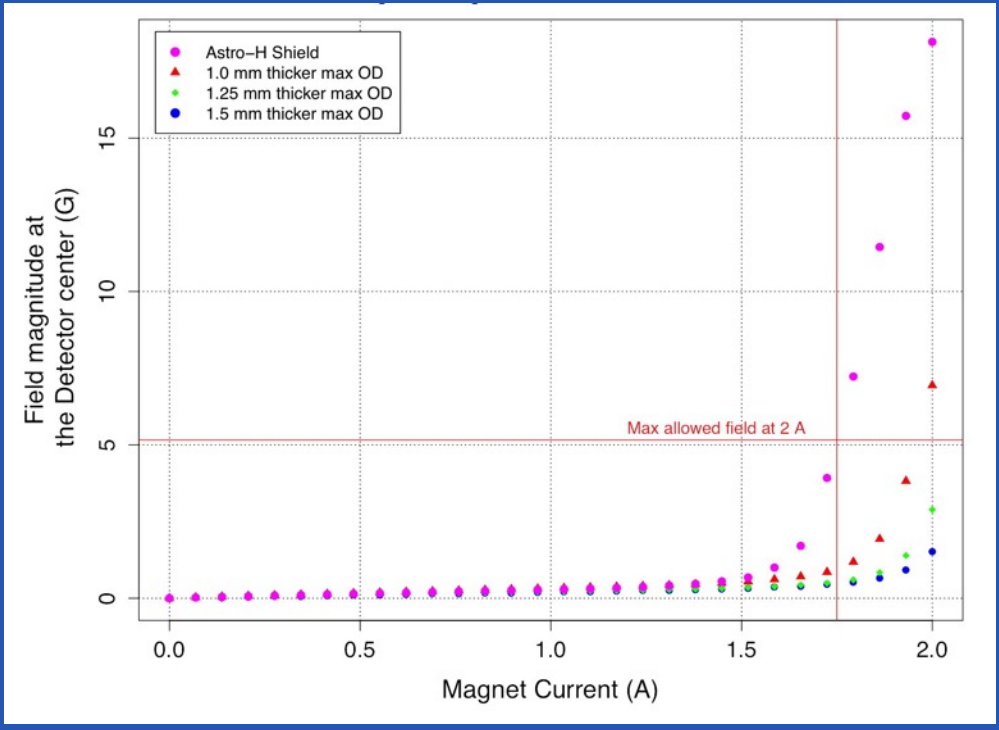
Full Cycle with He tank at 1.525 K

- Limitation on Stage 3 current reduced cooling power, requiring operation at higher temperature (1.525 K)
  - Shorter hold time
  - Longer recycle time
  - Lower duty cycle, ~80%

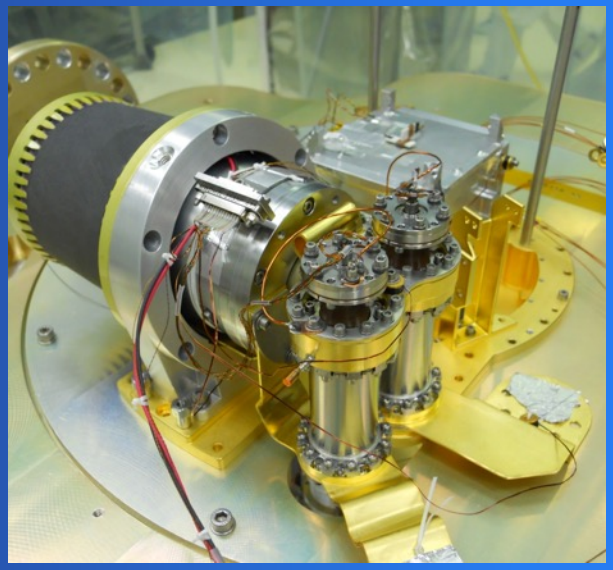


Changes for Resolve

- Increase magnetic shielding of ADR Stage 3
  - 1.5 mm increase in magnetic shield thickness (~200 grams) reduced fringing fields by an order of magnitude
  - Change has been directly verified (1.5 Gauss at detector location)

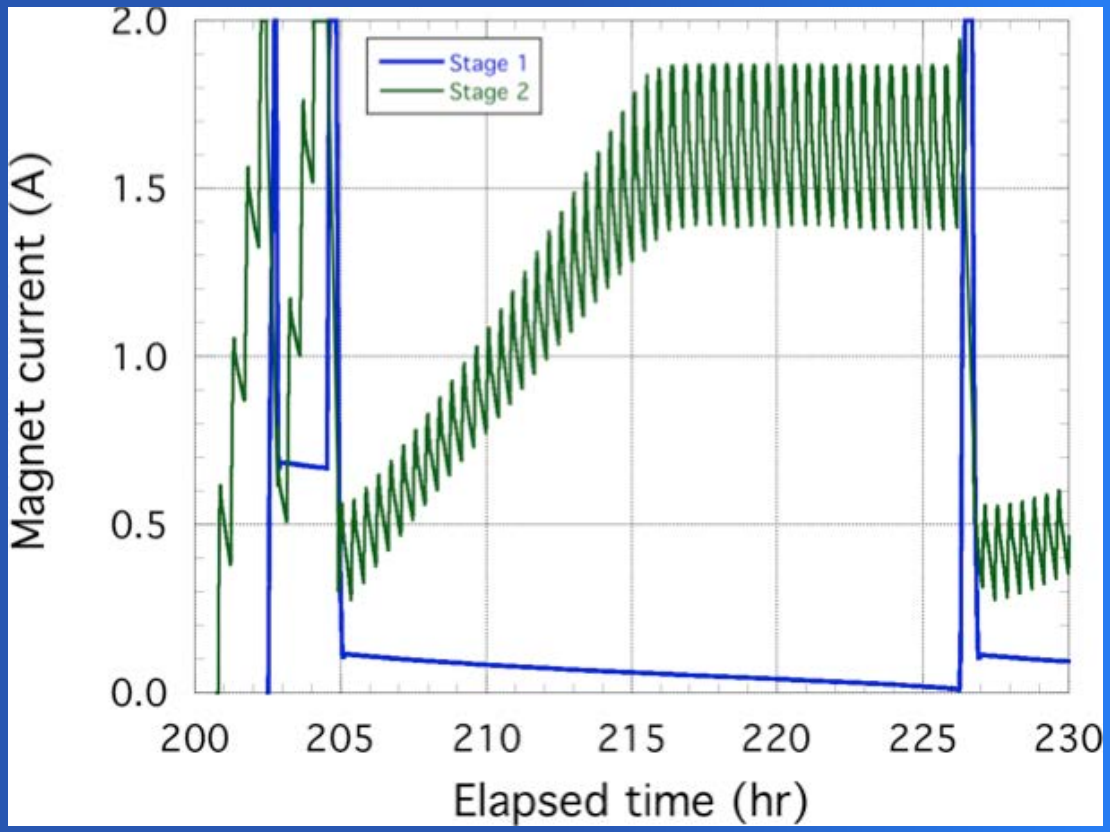


Modeled performance



XRISM FM ADR Performance

- Stable operation obtained at 1.4 K
  - Warm start from 4.5 K in ~4 hours
  - 21 hour hold at 1.4 K
  - 45 minute recycle
  - 96% duty cycle



Summary

- XRISM received final approval for funding by JAXA in mid-2018
  - Launch is currently scheduled for early 2022
- The Resolve instrument is essentially a built-to-print copy of SXS
  - Limited number of changes based on experience with ground and on-orbit performance
- CAUTION: SXS was not fully demonstrated on orbit
  - Gate valve was not opened to expose the detectors to full energy range of x-rays
  - Long-term performance (cryocoolers, progressively smaller LHe volume)
  - Environmental effects: micrometeoroid damage, residual helium