Development of the ASTRO-H In-flight Calibration Plan - First Steps

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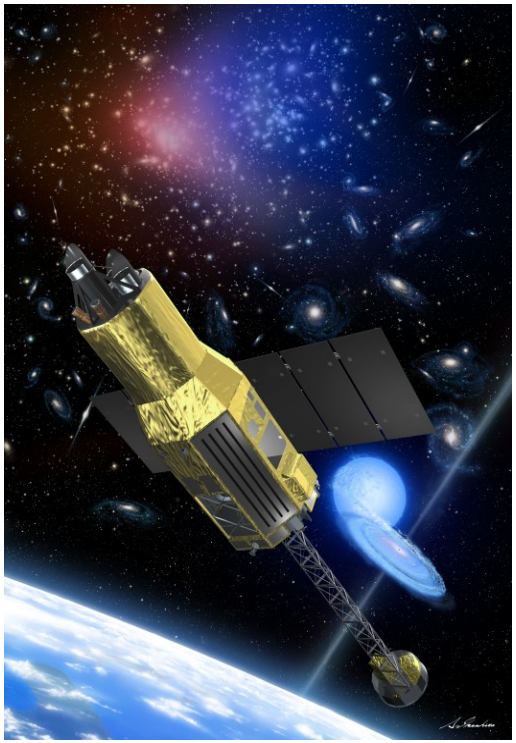
Astro-H

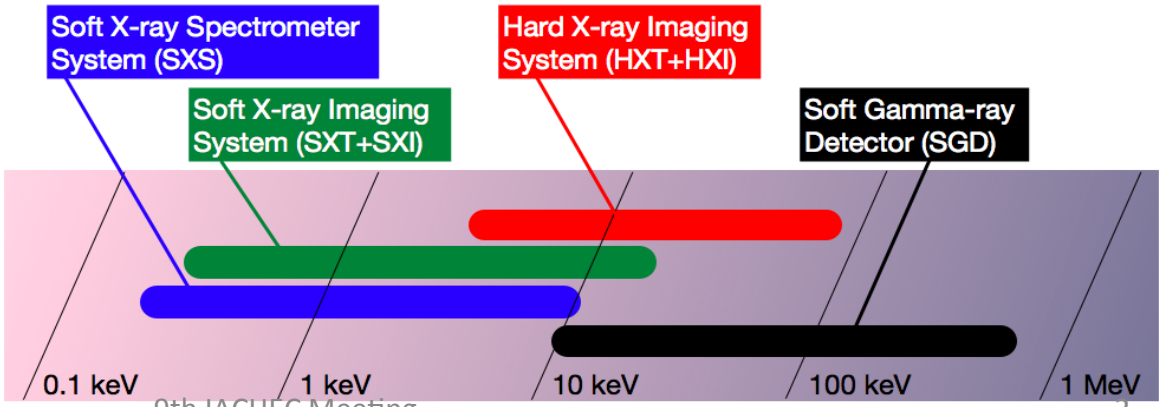


Scientific objectives :

- Revealing the large-scale structure and its evolution of the Universe
- Understanding the extreme conditions in the Universe
- Exploring the diverse phenomena of the non-thermal Universe
- Elucidating dark matter and dark energy

Key features :

- High resolution spectroscopy with X-Ray Microcalorimeter
- Hard X-ray focusing imaging
- High sensitive wide-band spectroscopy (0.3-600 keV)



Design Parameters of Instruments

	Specifications **(Requirement)**
Hard X-ray Imaging System (HXT+HXI) 5-80 keV	Effective area : 300 cm^2 (@30 keV) Spatial resolution : 1.7 arcmin (HPD) Energy resolution : 2 keV Field of view : 9 $arcmin^2$ @30 keV
Soft X-ray Spectrometer System (SXT-S+SXS) 0.3-10 keV	Energy resolution : 7 eV Spatial resolution : 1.7 arcmin (HPD) Effective area : 210 cm^2 (@6 keV) Field of view : 3 $arcmin^2$ @6 keV
Soft X-ray Imaging System (SXT-I+SXI) 0.5-12 keV	Spatial resolution : 1.7 arcmin (HPD) Effective area : 360 cm^2 @6 keV Energy resolution : 150 eV Field of view : 38 $arcmin^2$ @6 keV
Soft γ-ray detector (SGD) 10-600 keV	Effective area : 100cm^2 @100 keV Energy resolution : 2 keV @40 keV Astrometric accuracy : <0.6 deg (E<150 keV)

Calibrating Astro-H

- Astro-H is a complex observatory with four highly complementary instruments
- In order reach its full potential all instruments must be cross calibrated
- Substantial effort is being devoted to many aspects of ground calibration:
  - Thorough, systematic calibration of SXS
  - One month campaign on SXI to calibrate all modes expected to be used
  - SXT – pencil beam mapping of image, effective area at 3 energies, stray light
  - HXT – calibration at three energies using pencil beam at SpRING-8
- Other important calibration measurements must be don on orbit:
  - End-to-end area measurements of SXS, SXI and HXI, and cross calibration
  - Mirror PSF on detector
  - Focus
  - Timing
  - Coalignment (in X-ray)
- In-flight calibration has several objectives:
  - Baseline confirmation of key performance parameters
  - Baseline assessment of relative calibration between instruments
  - Monitoring variation of key performance parameters over long and short timescales

Methodology for planning in-flight Calibration

- Planning being performed by calibration coordination team, with input from instrument teams and SWG
- Build a plan that assumes successful ground calibration, but allows for complete on orbit calibration
- Identify source for each calibration activity (multiple preferred to ensure visibility)
- Use "standard candles" when possible (IACHEC favorites like 3C 273, E0102, etc.)
- Try to find sources that satisfy multiple goals
- Determine needed exposure via simulation
- Perform perturbation exercise to determine what happens in the case of off-nominal performance
- Need plan that fits in available time:
  - Satellite/Instrument checkout (3 months). Primary aim is to bring observatory to operational readiness but we can select sensible targets. Maximum effective observing time is 3.5 Ms (45% observing efficiency)
  - Science Working Group (6 months, 90% SWG time and 10% observatory time). We assume that a significant part of the observatory time (say 7% of total 6 months) is inflight calibrations. This gives for the PV phase 0.5 Ms.
  - Next phases (assume 5% calibration time). 0.7 Ms/year
- Establish priority scheme to ensure most critical observations done during calibration time and to enable flexibility on orbit

	SXS	SXS closed	SXI	HXI (2x)	SGD (2x)	Time dependent
Boresight + stability	✔	✔	✔	✔	✔	No, except HXI
Astrometry (= plate scale)			✔	✔		no
Energy scale	✔	✔	✔ + modes	✔	✔	Yes
Energy scale uniformity	✔	✔	✔ + CTI	✔	✔	
Energy resolution	✔	✔	✔	✔		Yes
PSF (2D) on axis	✔		✔	✔		no
Pile-up / grade / branching	✔	✔	✔	✔		
Area: broad band	✔	✔	✔	✔	✔	no
Area: broad band off-axis			✔		✔	
Area: Fine structure	✔					
contamination	✔		✔			Yes
Area: pixel-pixel uniformity	✔		✔	✔		no
Timing (absolute)	✔		✔	✔		no
Timing resolution (relative)	✔		✔	✔		no
Stray light	✔		✔ + off-axis	✔		No
Background	✔		✔	✔	✔	Yes
Polarization					✔	no
Instrument specific	filters				1	

Initial in-flight calibration target list

- Indicate preferred sources (backup needed)
- Indicate priority (red: must, black: important, blue: needed but not urgent)
- Indicate if coordinated observations are important
- First optimization by using same targets and/or data from calibration of one instrument for the other (e.g. off-axis response of SXI can be used to verify the stray light contribution to SXS)
- MXS will save considerable in-flight calibration time and is therefore included as a source, but alternatives will be identified
- Some 'calibrations' such as ASIC performance is part of check-out (To be agreed)

	SXS	SXS closed	SXI	HXI (2x)	SGD (2x)	comment
Boresight + stability	for free	for free	for free	GRS1915	for free	CAMS/orbit
Astrometry (= plate scale)			Rho oph core	?		
Energy scale	Capella, AB Dor, HR1099, MXS	MXS	1E0102-72.3 + modes Cas A	Cas A, inst bkgd, inst cal source	Inst bkgd	1 for SXS, 1+2 for SXI
Energy scale uniformity	MXS	MXS	Vela PWN, Coma cluster, includes CTI	Inst bkgd, inst cal source	Inst bkgd	1 source only
Energy resolution	Algol, MXS	MXS	1E0102-72.3 GX301-2 (Fe)	Cas A		
PSF (2D) on axis	See E-scale		MCG6-30-15, Cyg X-1	MCG6-30-15		Full + window, center and wings
Pile-up / grade / branching	for free	Cyg X-1 + ND	for free	for free		2 obs for SXS-closed
Area broad band	3C273, PKS2155	3C273	3C273, PKS2155	3C273, Cen A, G21.5, Cyg X-1	Cyg X-1	At least 2 sources, coordinated
Area broad band + PSF off axis			Cyg X-1 off-axis	Cyg X-1 off-axis	Crab	3 x (3 x 3) angles coordinated

	SXS	SXS closed	SXI	HXI (2x)	SGD (2x)	comment
Area fine structure	Sco X-1 (ND) + PKS2155 or 3C273					Different NH
Contamination (low E)	RXJ1856.6-3754		RXJ1856 .6-3754			Only SXS/SXI
Area Pixel-pixel uniformity	ground		ground	ground		
Timing (absolute)	PSR1509-58		PSR1509-58	PSR1509-58	Crab	Burst modes SXI
Timing resolution (rel)	PSR1937+21		See absolute	See absolute		
Stray light	SXI off axis		Sco X-1, 2x2 off-axis	SGD off axis		
Background	Lockman hole, 2nd		Lockman hole, 2nd	Lockman hole 2nd		>= 2 fields
Polarization					Crab (4 angles)	
Instrument specific	RXJ1856, filters					

Analysis of first cut calibration plan

- Considerable optimization of the in-flight calibration plan is needed
- Raw estimate of observing time is factor 4 too much for first 9 months
- Significant fraction is needed for off-axis response (which can be delayed to a later phase)
- Broad band area, energy scale, PSF, fine structure area and background need to be done and may require more time than available (TBC)

Next Steps

- Assess ground calibration results
- Work with instrument teams to ensure calibration needs and priorities are satisfied
- Determine needed exposures via simulation and perform “what if” exercises”
- Work on optimizing plan
- Ongoing discussions with Software/Calibration Team and with Science Working Group (and IACHEC!)