From the ひとみ (*Hitomi*) to the XRISM in-flight calibration plan

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The *Hitomi* In-flight Calibration Plan (HICP)

- Coordinated effort by the Science Operation Team (SOT), Instrument Teams (ITs), Software Calibration Team (SCT), and Science Team ("ad hoc" experts)
- Started in earnest ~L-2 years
- 7 "Calibration Strategy Meetings" (last one, post March 26)
- Presented and discussed at IACHEC yearly meetings
- Never implemented (although G21.5-0.9, RXJ1854-3754, Perseus, Crab Nebula were observed also as part of the HICP)

ASTRO-H	INFLIGHT CALIBRATION PLAN	**Doc. no.:** JAXA-ASTH-SOT-001 **Issue** : 1.1 **Date** : 16 March 2016 **Cat** : Public document **Page** : 1 of 144

Title : **ASTRO-H in-flight calibration plan**

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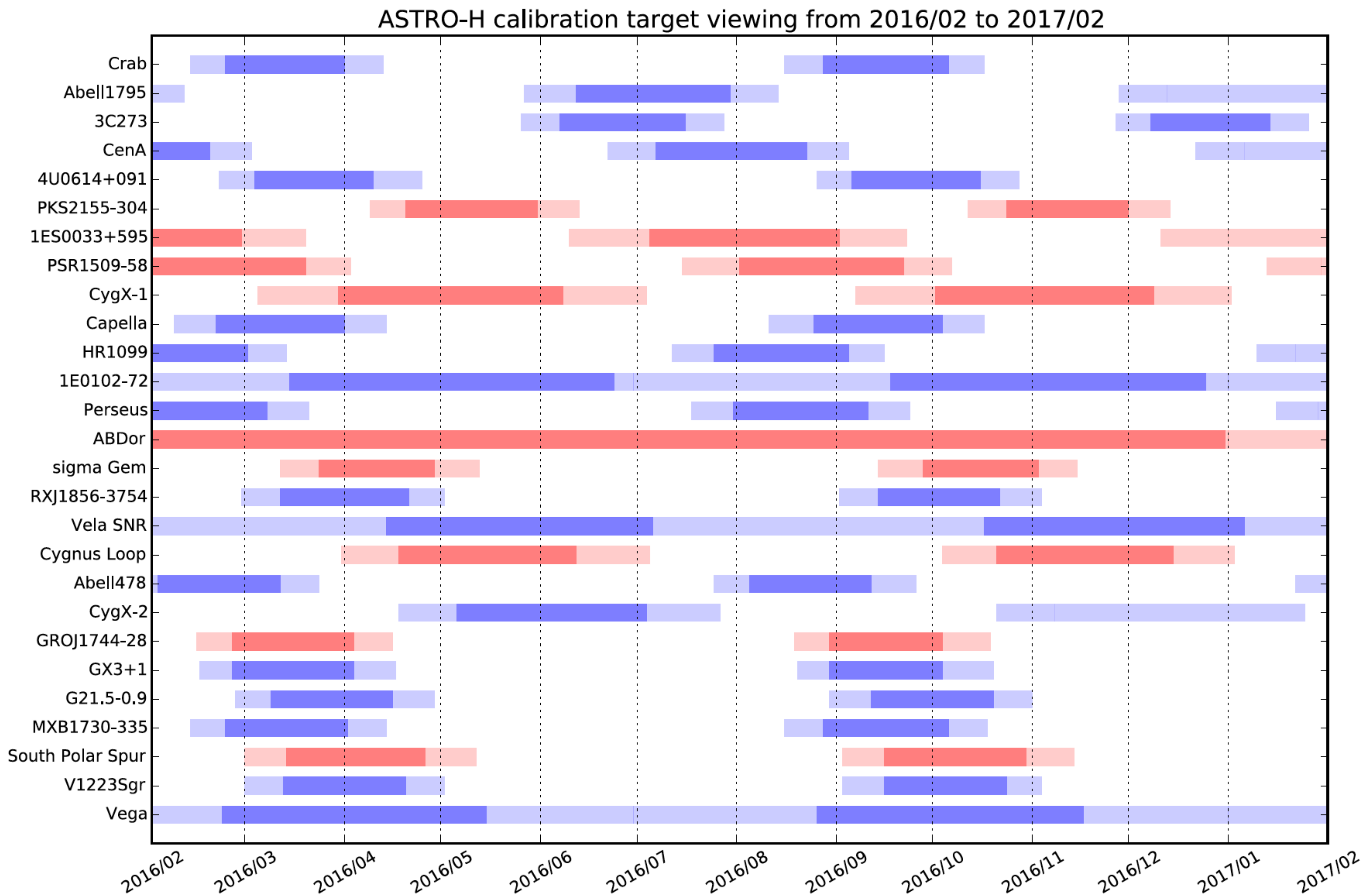
The HICP is available at the IACHEC Heritage document repository: https://wikis.mit.edu/confluence/download/attachments/61572873/ASTROH-inflight-cal-plan-1-1-0.pdf?version=1&modificationDate=1523187316000&api=v2

In-flight calibration boundary conditions

- 2 telescopes, 4 detectors plus the SXS “Gate Valve closed”
- 2.2 Ms in commissioning, 0.5 Ms in PV, 0.7 Ms/year in routine operations
- Possible science return of calibration sources an asset
- Twice per year (typical) visibility window (i.e., source redundancy needed)
- SXI pile-up limit ~1 cts/s; SXS “pile-up” ~10 cts/s; SXS PSP limit ~300 cts/s
- *Desiderata* for early observations: a) quick check of aim-points and responses; b) early SXS filter contamination measurements; b) HXI in-flight timing verification; d) SGD polarisation (also a primary science goal)

Hitomi source visibility

Guainazzi et al., 2016, JAXA-ASTH-SOT-001; based on simulations by the *Hitomi* SOT



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HICP priorities in the initial operations

1. Determination of the boresight for all telescopes/instruments, and of the position of the optical axis for all telescopes;

2. Verification of the accuracy of the time assignment;

3. Verification of the accuracy of the SXS energy scale and resolution;

4. Monitoring campaign of the SXS (GV open) and SXI effective area in the soft X-ray band to monitor possible piling-up of ice or other contaminants along the optical path;

5. First characterisation (at the 10% level) of the overall effective area calibration and inter-instrument calibration.

Hitomi calibration requirements

Guainazzi et al., 2016, JAXA-ASTH-SOT-001

	SXS(+SXT)	SXI(+SXT)	HXI(+HXT)	SGD
X-ray boresight stability	20″	20″	20″	N/A
X-ray axis	15″	15″	15″	TBD
Pointing accuracy	20″	20″	20″	N/A
Astrometry reconstruction	20″	20″	20″	N/A
Knowledge of gain v. E	2 eV	0 %	3%	5%
Energy scale stability	N/A	0.2%	5%	3%
Energy resolution	1 eV	5%	5% (@20 keV)	5%
Energy redistribution	1% (LSF)	10%	10%	10%
HPD; 90% PD on axis	10% (0.3-12 keV)	10% (0.3-12 keV)	10% (5-80 keV)	N/A
Absolute effective area on-	10 %	10%	10%	15%
Absolute effective area off-	N/A	15% (10′)	15% (3′)	N/A
Relative effective area:	5 %	5%	5%	15%
Relative effective area:	N/A	10%	10%	
Relative effective area: Fine structure	5 %	15% (@ Si edge)	N/A	N/A
Pixel-pixel uniformity	QE: 5%	1 %	5%	N/A
Stray light	EA>1/100th EA$_{pn-axis}$: 20%	EA>1/100th EA$_{pn-axis}$: 20%	EA>1/100th EA$_{pn-axis}$: 20%	N/A
PSF tail	3% (9′)	10 %	10 %	N/A
Background reproducibility	10% (broad-band)	5 %	5%	5 %
Background reproducibility	N/A	N/A	10%	N/A
Polarization (MDP)	N/A	N/A	N/A	10 %
Dead time estimation	TBD	TBD	10%	10%
Timing (absolute)	10 ms	200 μs	200 μs	200 μs
Timing resolution (relative)	80 μs	61.0352 μs	25.6 μs	25.6 μs
Instrument specific	Filters: 5% (at 0.5, 1.5, 6 keV)	Effective area, spectral performance of all modes		

HICP definition process

- For each calibration requirement:

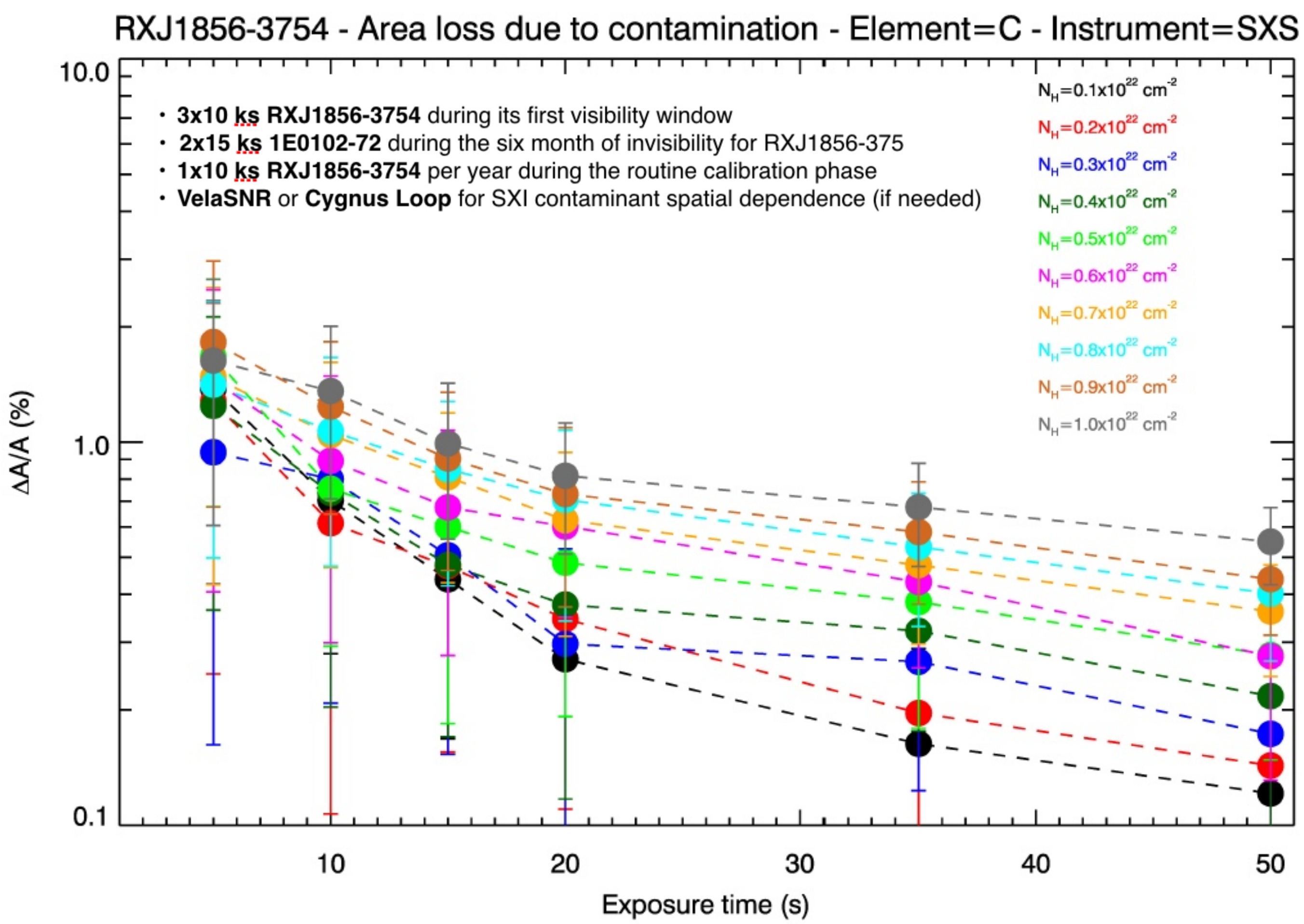
- Identify critical observable(s) allowing to verify it, and the corresponding required measurement accuracy
- Identify an observational strategy capable of measuring the observable(s) with the required accuracy
- Identify a redundant (2-3x) set of astrophysical sources with the adequate astrophysical properties
- Realistically simulate (**`SIMX`**, **`heasim`**, **`xraytrace`**) the experimental conditions to optimise the observing strategy (pointing, instrumental configuration, exposure times etc.)

Observing strategy example I. - contamination

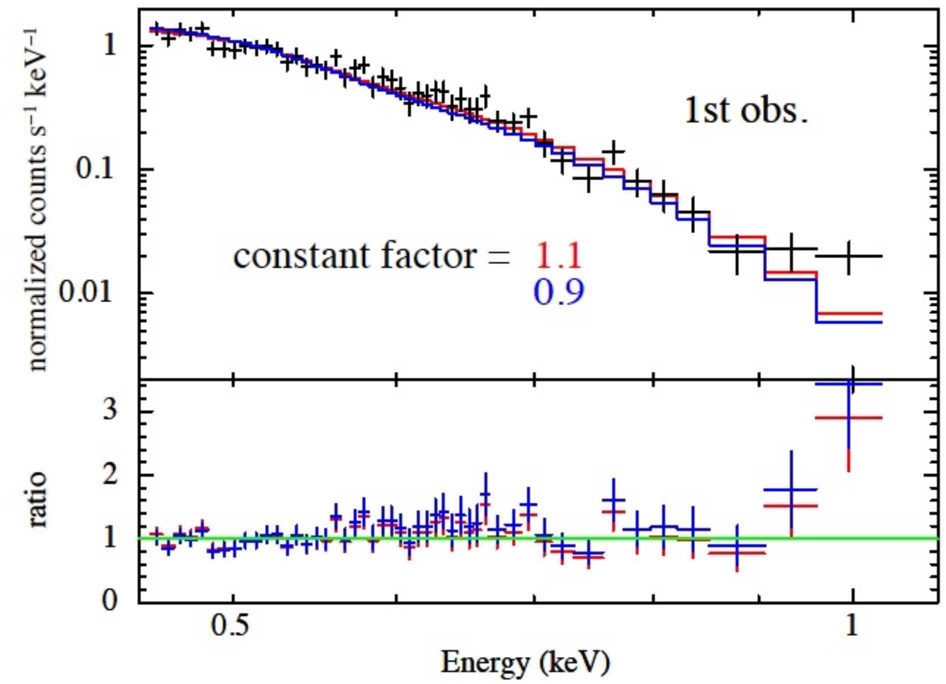
Guainazzi et al., 2016, JAXA-ASTH-SOT-001

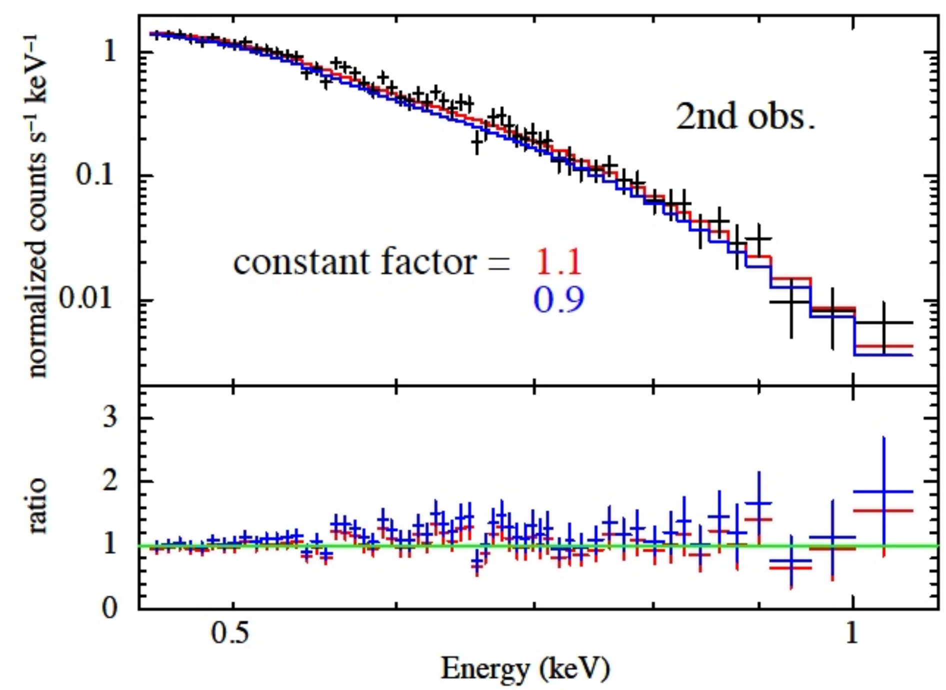
Nakajima et al., 2018, PASJ, 70/2, 21

HICP simulations



flight results



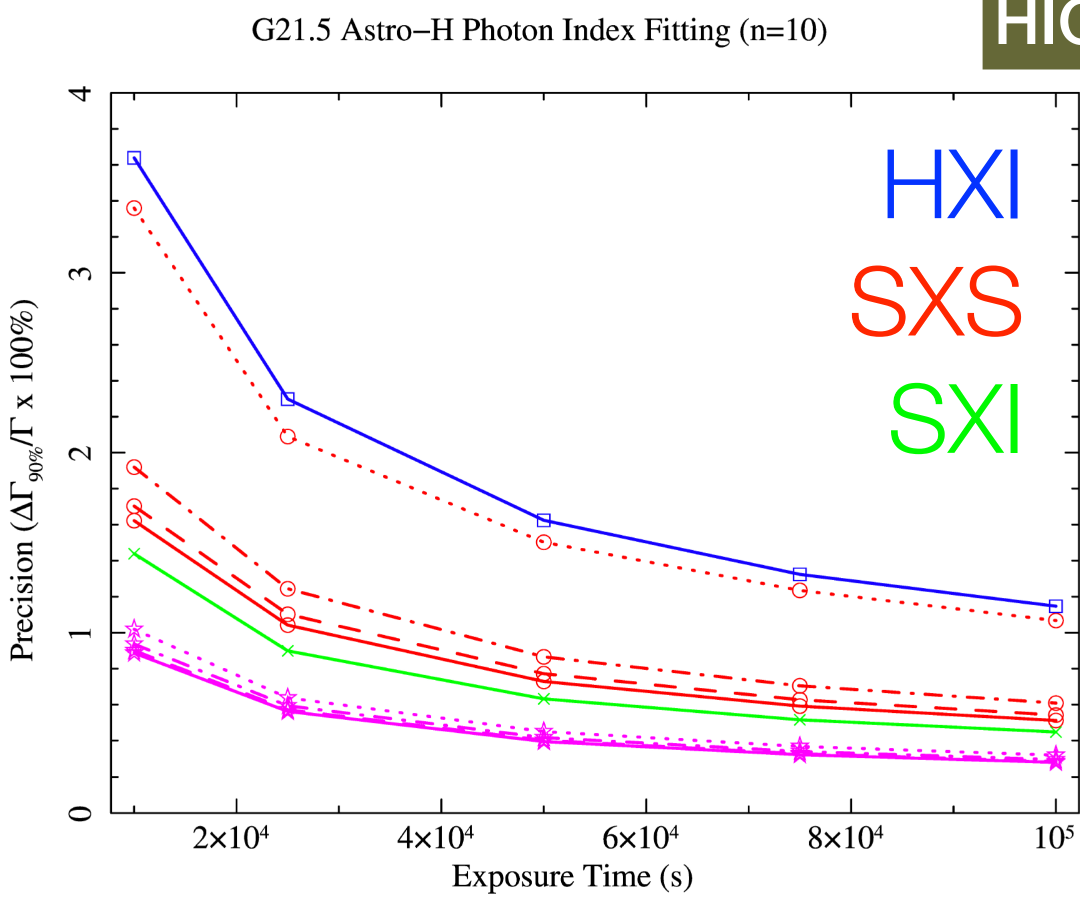


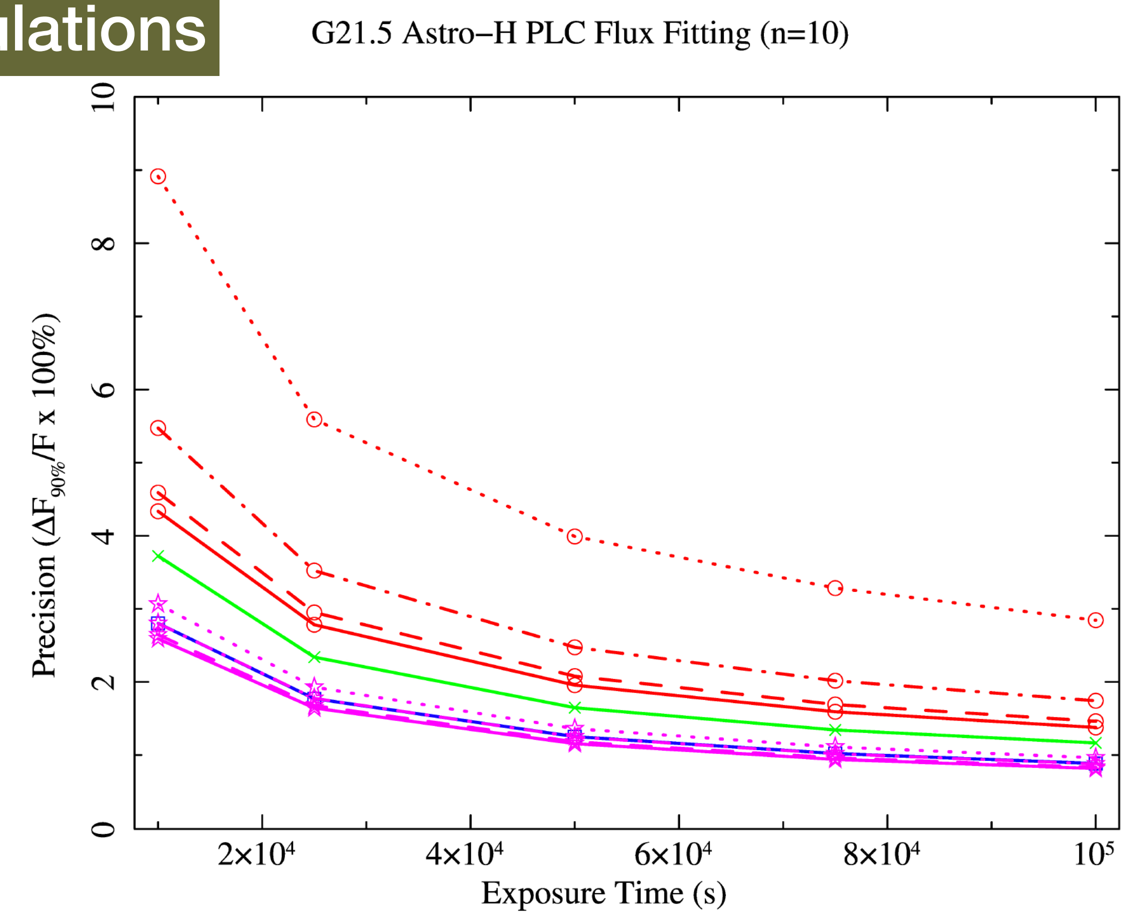
- RXJ1856-3754 observed twice (1 week apart)
- ~11 and ~23 ks exposure time, respectively
- $N_C \leq 9.4 \times 10^{17}$ cm^{-2} and $5.5 \leq 10^{17}$ cm^{-2}

Observing strategy example II. - G21.5-0.9

Simulation by L.Brenneman (SAO); flight results from Hitomi Collaboration, PASJ, 70, 38

HICP simulations





flight results	T_{exp} (ks)	ΔΓ	ΔF
SXS	164	0.5%	1%
SXI	51	0.5%	1%
HXI	99	0.5%	1%

HICP source list

Guainazzi et al., 2016, JAXA-ASTH-SOT-001

	SXS+SXT-S (GVC)	SXS+SXT-S (GVO)	SXI+SXT-I	HXI+HXT	SGD
Energy scale (on-axis)	HR1099(50) ABDor(50) CP, FW, MXS	Capella(30) HR1099(50) ABDor(50)	Perseus (80)	AM Perseus (15)	TP NXB
Energy scale (pixel-to-pixel, off-axis)	CP, FW, MXS	CP, FW, MXS Capella (261)	Cygnus Loop(60)	AM	NA
Gain (short-term stability)	CP, MXS	CP, MXS	CS	TP	TP
LSF/RMF	FW (10) MXS(1) HR1099 (50) ABDor (50)	FW (10) MSX (1)	See Energy scale (on-axis)	TP AM	NA
Effective area (on-axis)	3C273 (25) CenA (25) G21.5-0.9 (60)	3C273 (75) CenA (75) G21.5-0.9 (75)	1ES0033+595 (75) G21.5-0.9 (see SXS)	3C273 (see SXS) CenA (see SXS) PSR1509-58 (see SXS)	Crab (30) CygX-1 (40) CenA
Effective area (off-axis)	NA	NA	PKS0745-191 (73) Abell478	Crab (104)	NA
Effective area (fine structure)	NA	3C273 (75), 4U0614+091 (75)	NA	NA	NA
Contamination (on-axis)	NA	RXJ1856-3754 (40) 1E0102-72(30)	See SXS GVO	NA	NA
Contamination (off-axis)	NA	NA	Vela SNR (60) Cygnus Loop (see energy scale)	NA	NA
Timing	NA	PSR0540-69 (50)	CenX-3 (0) VelaX-1 (0)	Crab (see SGD area) PSR0540-69 (50)	Crab (see HXI)
Optical axis	NA	LMCX-1 (6x5)	1E0102-72 (8x3) G21.5-0.9 (8x7.5)	See SXS Crab (6x10)	See SXS
Stray light	NA	Crab (45)	Crab (45)	TBD	NA
Background	NA	North Polar Spur (100)	NA	NA	NA
Polarization	NA	NA	NA	NA	Crab (100) CygX-1 (100) CenA (100)
PSF	NA	NA	V1223Sgr (100)	CygX-1 (20)	NA
PSF off-axis	NA	CygX-2 (97)	NA	NA	NA
SXS blocking filters	NA	1E0102-72 (3x25) 3C273 (25, ND)	Vega (1)	NA	NA
Instrument modes	NA	NA	see Energy Scale	NA	NA
Branching ratios	NA	MXB1730-335 (10) GROJ1744-28 (10)	NA	NA	NA

Of course, one must be flexible …

… the never-completed last observation by *Hitomi* (Mkn205) was a “new” target for SXT-I PSF calibration, identified on the basis of spacecraft operational constraints.

HICP definition process: strong points

- Pool of largely complementary expertise from different teams (SCT, SOT, ITs, ST) - science expertise from the ST “at large” crucial
- Coordinated by an “*ad hoc*” team (i.e., free from other over-absorbing commitments), integrated in the SOT
- Benefitted from decade-long expertise from past and operational missions (channelled also, but not only, through the IACHEC)
- Optimised on the basis of extensive simulations using *operational software tools*
- Embedded source redundancy to cover visibility constraints and contingencies

Process for the definition of the XRISM ICP (XICP)

- For each (set of) calibration requirement(s), a ST "XICP advocate" collaborates with, and supports the SOT/IT colleagues responsible for the corresponding CALDB file(s) in the definition of the XICP observation strategy and source pool (~3x redundancy)
- The definition of each XICP experiment shall include the population and validation (*i.e.*, estimate of the experiment uncertainties) of the corresponding CALBD files
- Source selection and observation strategy definition to be optimised using primarily operational software (`heasim`, `xraytrace`)
- Activity under SOT lead, one coordinator appointed among ST members
- To be run in parallel, and completed together with the definition of the PV program