Table 3.2.1: Calibration targets listed by calibration element.

Calibration element	Resolve GV closed	Resolve GV open	Xtend
Energy scale (on-axis)	HR1099(50), ABDor(50), CP, FW, MXS	Capella(50), HR1099(50), ABDor(50), Procyon, σGem, CP, FW, MXS	Perseus(2x40=80), Cygnus Loop(2x30=60), 1E0102-72(30), any Resolve source with lines
Energy scale (pixel-to-pixel, off-axis)	CP, FW, MXS	Capella (2x3x40=240), CP, FW, MXS	See Energy scale (on-axis)
Gain (short-term stability)	CP, MXS	CP, MXS	CS
LSF/RMF	See Energy scale (on-axis)	See Energy scale (on-axis)	See Energy scale (on-axis)
Effective area (on-axis) (absolute and relative)	3C273(50), PKS2155-304(50), Crab(10)	3C273(50), PKS2155-304(50), G21.5-0.9(50), 1ES0229+200(TBD), Mrk421, PSR1509-58, Abell clusters, PV	1ES0033+595(75), G21.5-0.9(50), 1ES0229+200(TBD), Abell clusters, PV
Effective area (off-axis)	NA	See PSF (calibrating vignetting x PSF)	Abell 478(40), PKS 0745-191(TBD), Abell 1795(TBD), Abell 2029(TBD)
Effective area (fine structure) (ISM baseline)	NA	3C273(75), 4U0614+091(75)	NA
Contamination (on-axis)	NA	RXJ1856-3754(40), 1E0102-72(30)	RXJ1856-3754(40), 1E0102-72(30)
Contamination (off-axis)	NA	NA	See Energy scale (on-axis) Vela SNR(60)
Timing	NA	Crab(10), PSR0540-69(50), PSRB1821-24(50), PSRJ1937+21(50), PSRJ0218+4232(50) (exposure times for abs, relative requires more time, or MXS; TBD)	Crab(10)
Optical axis	NA	LMCX-1(6x5=30), Capella (See Energy scale off-axis)	See Effective area (off-axis) 1E0102-72(8x3=24), G21.5-0.9(8x7.5=60)
PSF on-axis	NA	Capella, PV targets (See Energy scale off-axis)	PV targets, V1223Sgr
PSF off-axis (wings)	NA	Cyg X-2+PKS2155(200), 3C273, Mrk 421 Total exposure less if first obs. confirm that ground cal. is applicable	Rely on ground cal.
Astrometry	NA	Capella, 1ES0033 (energy scale Resolve raster, Xtend eff. area)	Capella, 1ES0033 (see Xtend eff. area)
Stray light	NA	Crab(45)	Crab(45)
Atomic Models	NA	NGC1550(100), M87(100), Abell 1060(100)	NA

Notes: Exposure times in ks are given in parentheses. Primary targets are shown in blue, secondary targets in orange, and possible alternate targets in black. CP=calibration pixel, FW=filter wheel ^{55}Fe source, MXS=direct Modulated X-ray Source, CS=^{55}Fe calibration source.

Table 3.2.2: List of primary calibration targets with total exposure time and observing strategies.

Target name	t_{exp} (ks)	RA	Dec	Purpose	Coo.	Notes
1ES0033+595	75	8.9690	+59.8345	Xtend on-axis Aeff	a	
3c273	150	187.2779	+2.0524	Resolve on-axis Aeff	a	50 ks each with Resolve open filter, Be filter, and ND filter. Xtend operated in 1/8 window or burst mode
Abell 478	40	63.3363	+10.4764	Xtend optical axis	N/A	4 pointings of 10 ks each, separated by 10 arcmin
Capella	50	79.1723	+45.9980	Resolve gain/LSF on-axis	b	
Capella raster	258	79.1723	+45.9980	Resolve gain/LSF pixel-by-pixel	N/A	6x9 pointing raster scan (see Figure 2.2 7); 3 ks on-axis, 4 ks at edges, 6 ks at corners, times 3 temps and 2 modes (Hi-Res and forced Mid-Res)
Crab	10	83.6331	+22.0145	Timing	c	Observed off Resolve field. Xtend in "Crab" mode.
Crab stray light	45	83.6331	+22.0145	Stray light	N/A	Observe at 1° offset [TBD]
Cygnus Loop	60	313.9091	+31.0038	Xtend gain/LSF	N/A	30 ks full window, 30 ks 1/8 window; roll constraints TBD
Cyg X-2	24	326.1715	+38.3214	Resolve off-axis PSF	d	Xtend operated in 1/8 window or burst mode
E0102	60	16.0050	-72.0312	Xtend energy scale, Resolve and Xtend contamination monitoring	N/A	One 30-ks observation soon after GV and Xtend door open, then another 30-ks observation one month later.
HR 1099	50	54.1970	+0.5878	Resolve gain/LSF on-axis	b	
LMCX-1	30	84.9118	-69.7432	Resolve optical axis	a	6x 5-ks observations w/ target just outside Resolve FOV [Capella may be sufficient]
NGC 1550	100	64.9080	+02.4099	Astrophysical models	N/A	
North Polar Spur	100	X	X	Galactic foreground	N/A	[needs discussion; do we want this, Lockman Hole, or neither?]
Perseus Cluster	80	49.9467	+41.5131	Xtend energy scale	N/A	40 ks full window, 40 ks 1/8 window; roll constraints TBD
PKS2155	84	329.7169	-30.2256	Resolve off-axis PSF	d	Xtend operated in 1/8 window or burst mode
RXJ 1856	40	284.1463	-37.9085	Resolve and Xtend contamination monitoring	N/A	Observe soon after GV and Xtend door open.

Coo. = coordination with other mission required. Key:
a: NuSTAR required; at least one of XMM or Swift or Chandra required. Observations should be overlapping but exact GTI are not required (i.e., we will use the analysis strategy in Madsen et al. 2017[12]
b: Chandra/HETG or XMM/RGS. [TBD if this is required; archival data or short anchor observation may be sufficient]
c: NICER recommended.
d: One of Swift, NICER, or XMM required, with as strict GTI overlap as possible.

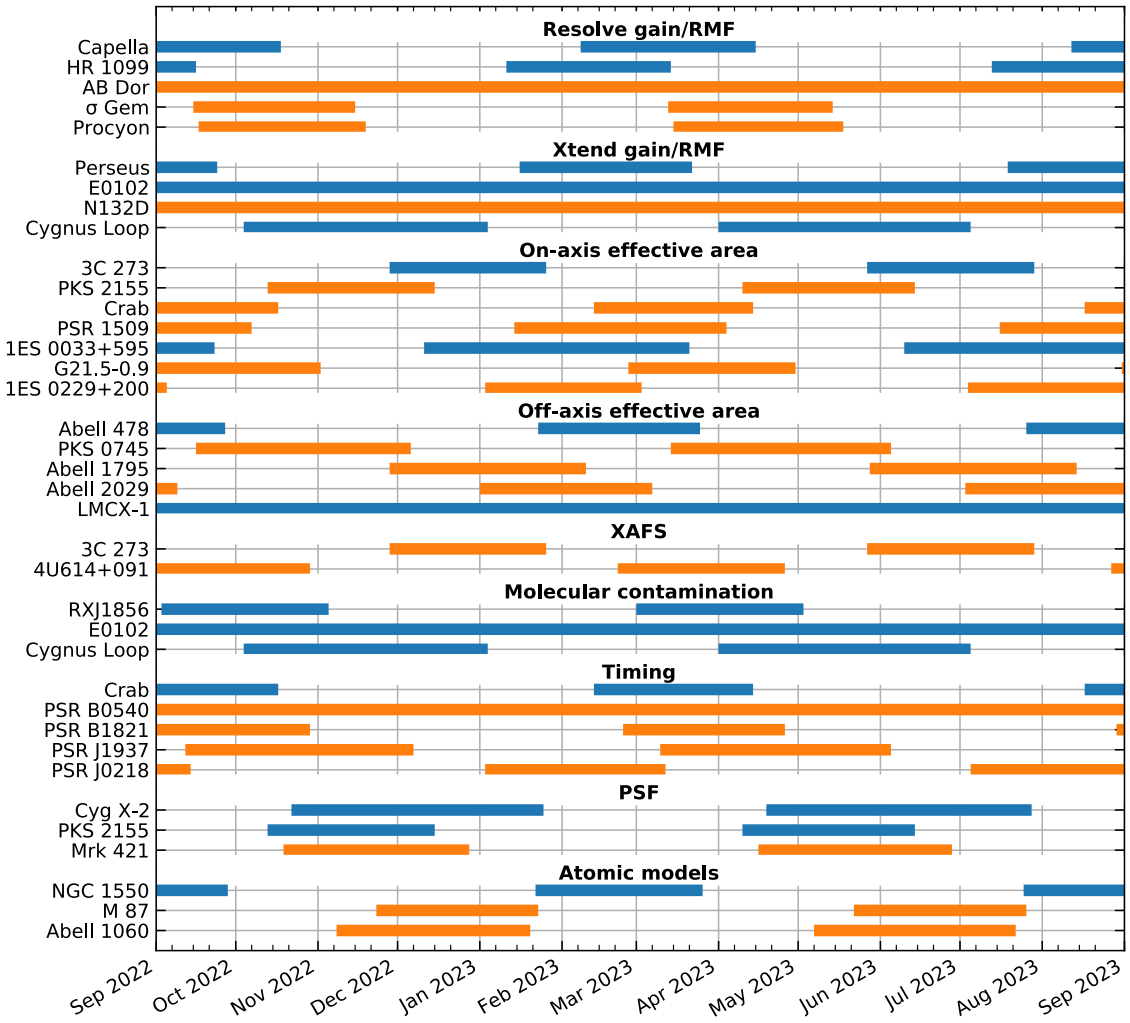

Figure 3.2.1: Visibility of primary (blue) and secondary (orange) calibration sources. While calendar years 2022–2023 are shown, the visibility is the same every year.

Table 3.2.3: Decision tree for selecting a secondary target if the primary is unavailable.

Target name	t_{exp} (ks)	RA	Dec	Purpose	Coo.	Notes
1ES0033+595						
PKS2155-304	50			Xtend on-axis Aeff	a	Xtend: 1/8 window or burst
G21.5-0.9	50				N/A	Xtend: full window
1ES0229+200	TBD				a	Xtend: TBD
3c273						
PKS2155-304	50			Resolve on-axis Aeff	a	Xtend: 1/8 win or burst
G21.5-0.9	50				N/A	Xtend: full window
1ES0229+200	TBD				a	Xtend: TBD
Abell 478						
PKS0745-191	TBD			Xtend optical axis	N/A	
Abell 1795	TBD				N/A	
Abell 2029	TBD				N/A	
Capella						
ABDor	50			Resolve gain/LSF on-axis	b	
Capella raster						
none	...			Resolve gain/LSF pixel-by-pixel	N/A	Use FW, indirect MXS
Crab						
PSR0540-69	50			Timing	c	Secondary always visible
Crab stray light						
none	...			Stray light	N/A	Observe when visible
Cygnus Loop						
none	...			Xtend gain/LSF	N/A	Observe when visible
Cyg X-2						
3C273	TBD			Resolve off-axis PSF	a	Xtend: 1/8 window or burst
Mrk 421	TBD				a	
E0102						
N132D	30			Xtend energy scale, Resolve and Xtend contamination monitoring	N/A	Primary always visible. N132D is an optional calibration target.
HR 1099						
ABDor	50			Resolve gain/LSF on-axis	b	
LMCX-1						
Capella	...			Resolve optical axis	a	Capella raster scan can be used instead
NGC 1550						
M87	100			Atomic models	N/A	Can wait until primary is visible.
Abell 1060	100					
North Polar Spur						
none	...			Galactic foreground	N/A	Observe when visible
Perseus Cluster						
none	...			Xtend energy scale	N/A	Observe when visible
PKS2155						
none	...			Resolve off-axis PSF	a	Observe when visible
RXJ 1856						
none	...			Resolve and Xtend contamination monitoring	N/A	E0102 can be used, always visible

Coo. = coordination with other mission required. Key:
a: NuSTAR required; at least one of XMM or Swift or Chandra required. Observations should be overlapping but exact GTI are not required (i.e., we will use the analysis strategy in Madsen et al. 2017[12]
b: Chandra/HETG or XMM/RGS. [TBD if this is required; archival data or short anchor observation may be sufficient]
c: NICER recommended.
d: One of Swift, NICER, or XMM required, with as strict GTI overlap as possible.