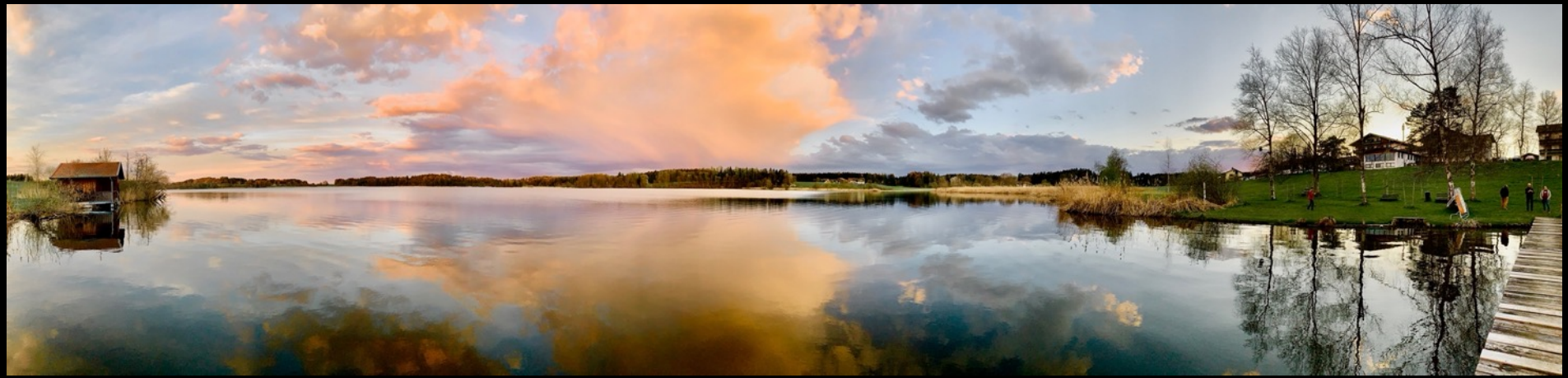
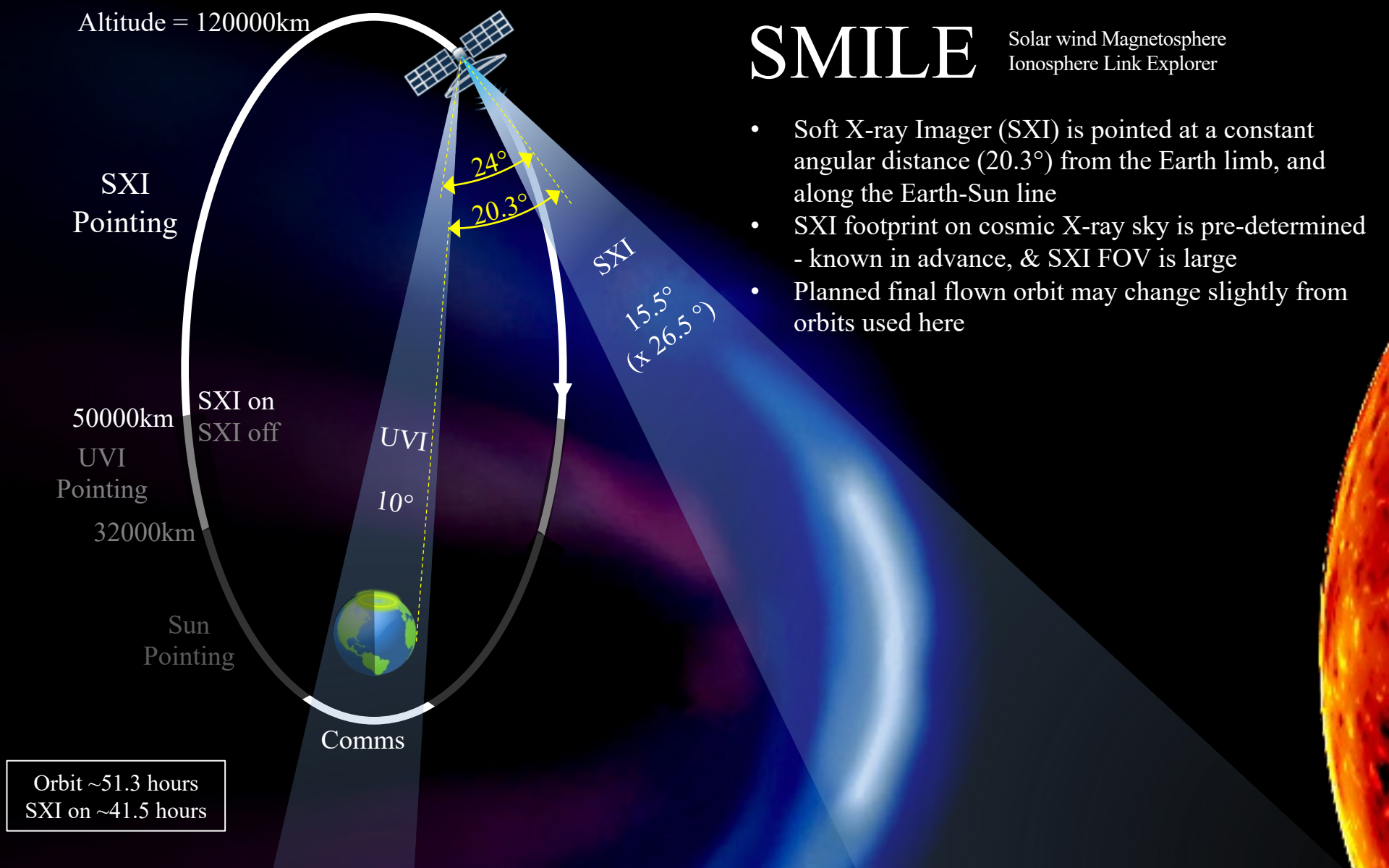
SMILE-SXI : The Mission, Serendipitous X-ray Sources & Flight Calibration

Andy Read

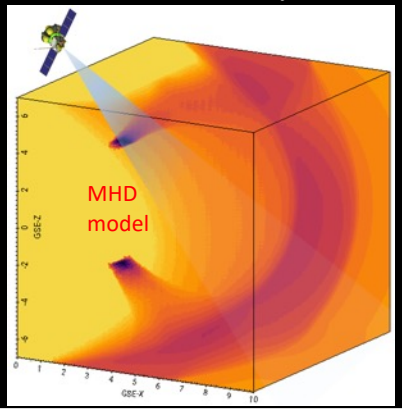



Altitude = 120000km
SXI
Pointing
50000km
SXI on
SXI off
UVI
Pointing
32000km
Sun
Pointing
Comms
24°
20.3°
UVI
10°
SXI
15.5°
(x 26.5°)
SMILE
Solar wind Magnetosphere
Ionosphere Link Explorer
• Soft X-ray Imager (SXI) is pointed at a constant angular distance (20.3°) from the Earth limb, and along the Earth-Sun line
• SXI footprint on cosmic X-ray sky is pre-determined - known in advance, & SXI FOV is large
• Planned final flown orbit may change slightly from orbits used here
Orbit ~51.3 hours
SXI on ~41.5 hours

- One typical SMILE orbit (~51.3hr)
  - May 2025
  - Apogee semi-towards Sun

- Large central rectangle: SXI FOV
  - Active FOVs of 2 CCDs
- Red/orange/yellow emission: Science Targets – SWCX X-ray emission from Magnetosheath & bright Cusps (static MHD model shown)
- UVI (yellow circle) observes Earth

- Many bright cosmic X-ray sources pass through SXI FOV
- White circles: ROSAT Bright Source Catalogue [BSC] (size~brightness)
- Contributing to BG (need to model)
- Useful/necessary for calibration



Orbit: November 2024
Vega launch, 73 deg. inclination, angle of perigee 287.5 deg.

- One typical SMILE orbit (~51.3hr)
  - August 2025 (3 months later)
  - Apogee to the side of the Earth

- Large central rectangle: SXI FOV
  - Active FOVs of 2 CCDs
- Red/orange/yellow emission: Science Targets – SWCX X-ray emission from Magnetosheath & bright Cusps (static MHD model shown)
- UVI (yellow circle) observes Earth

- Many bright cosmic X-ray sources pass through SXI FOV
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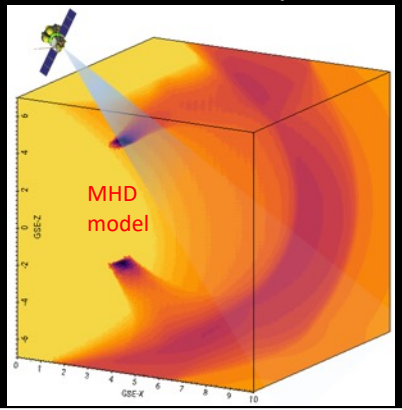
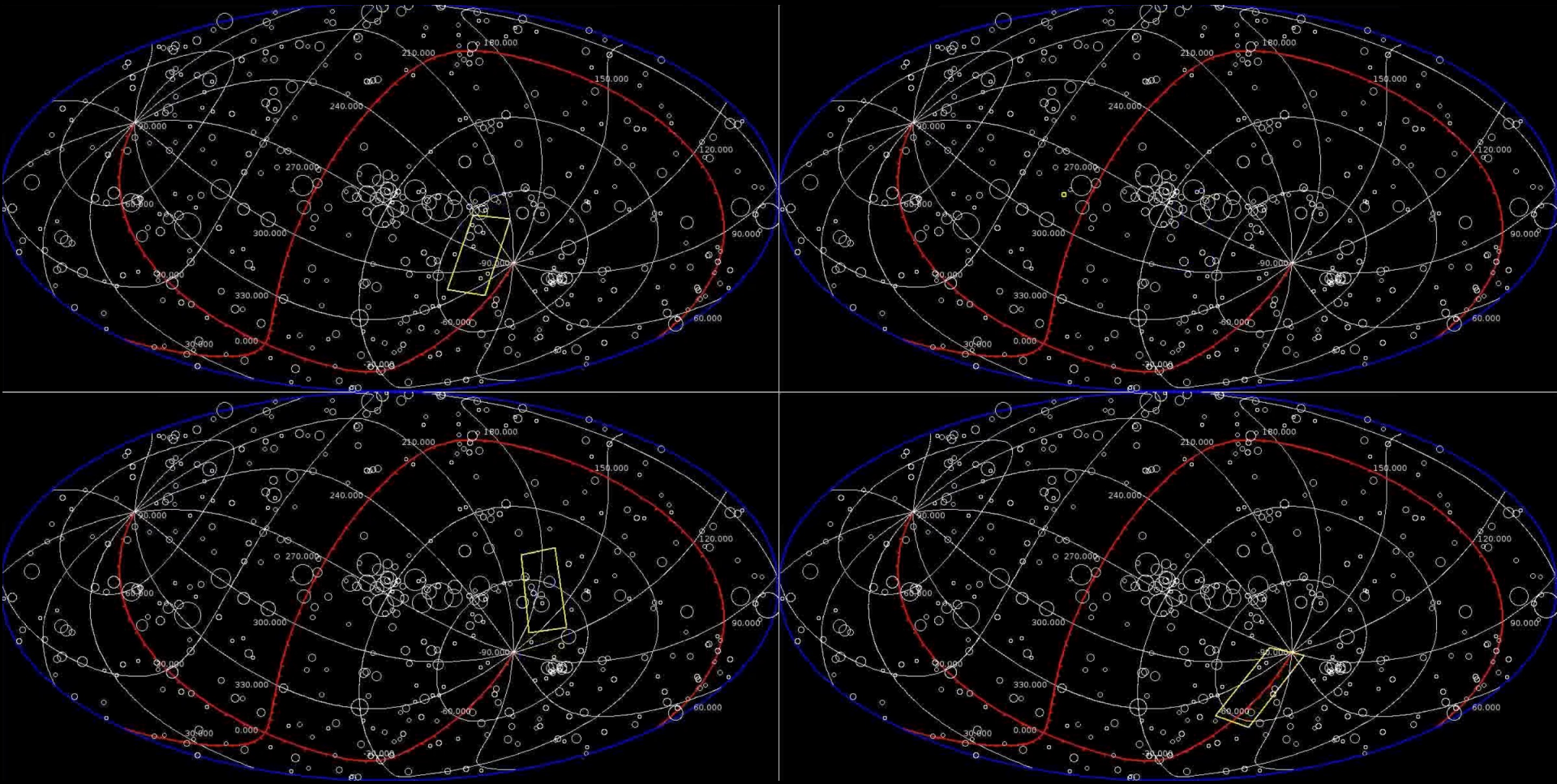


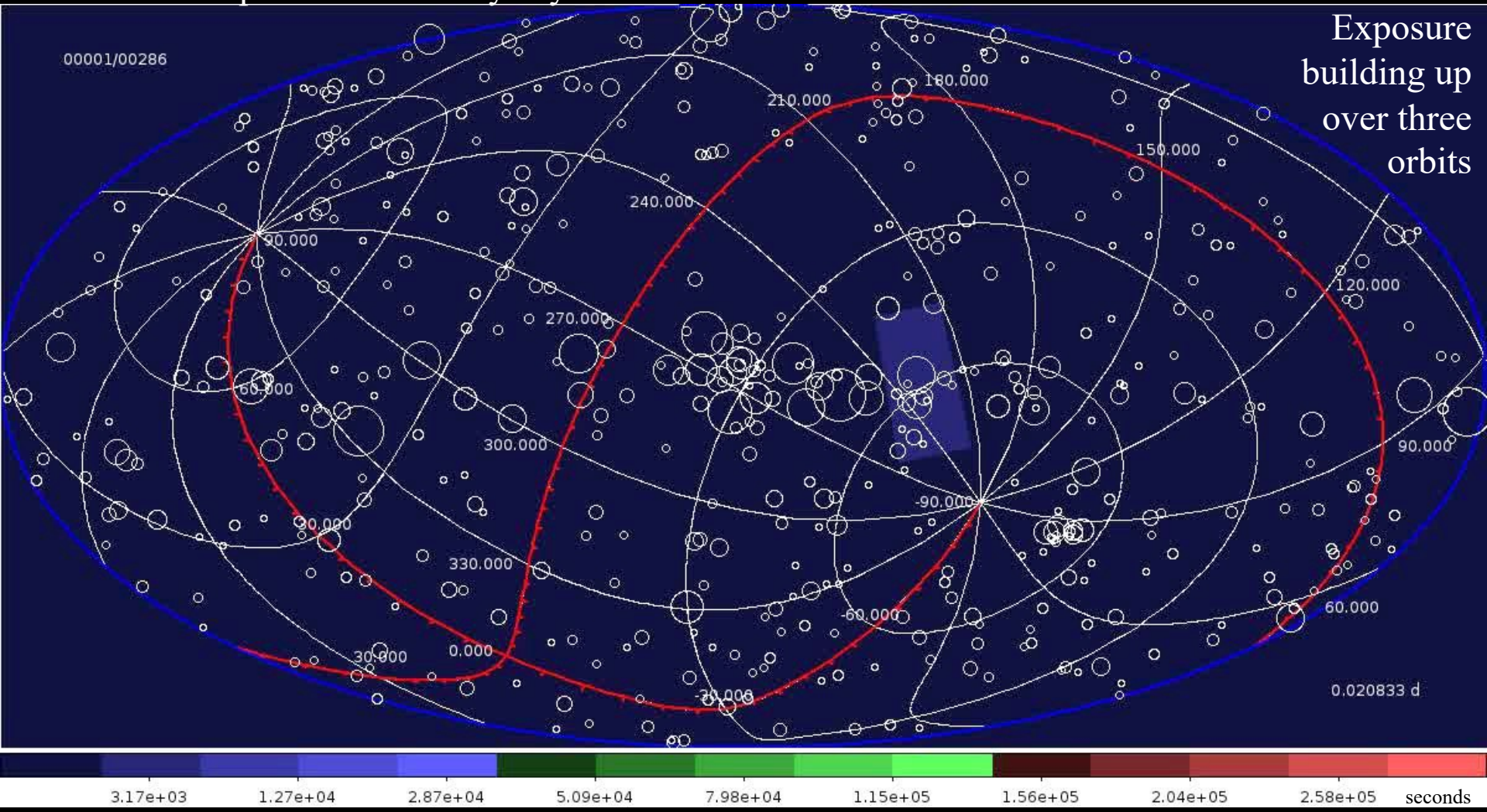
Orbit: November 2024
Vega launch, 73 deg. inclination, angle of perigee 287.5 deg.

SXI Coverage of Sky Varies Season to Season



Movies show the SXI FOV footprint on the sky for single (~50.3hr) orbits, ~3 months apart

The SXI footprint on the X-ray sky…



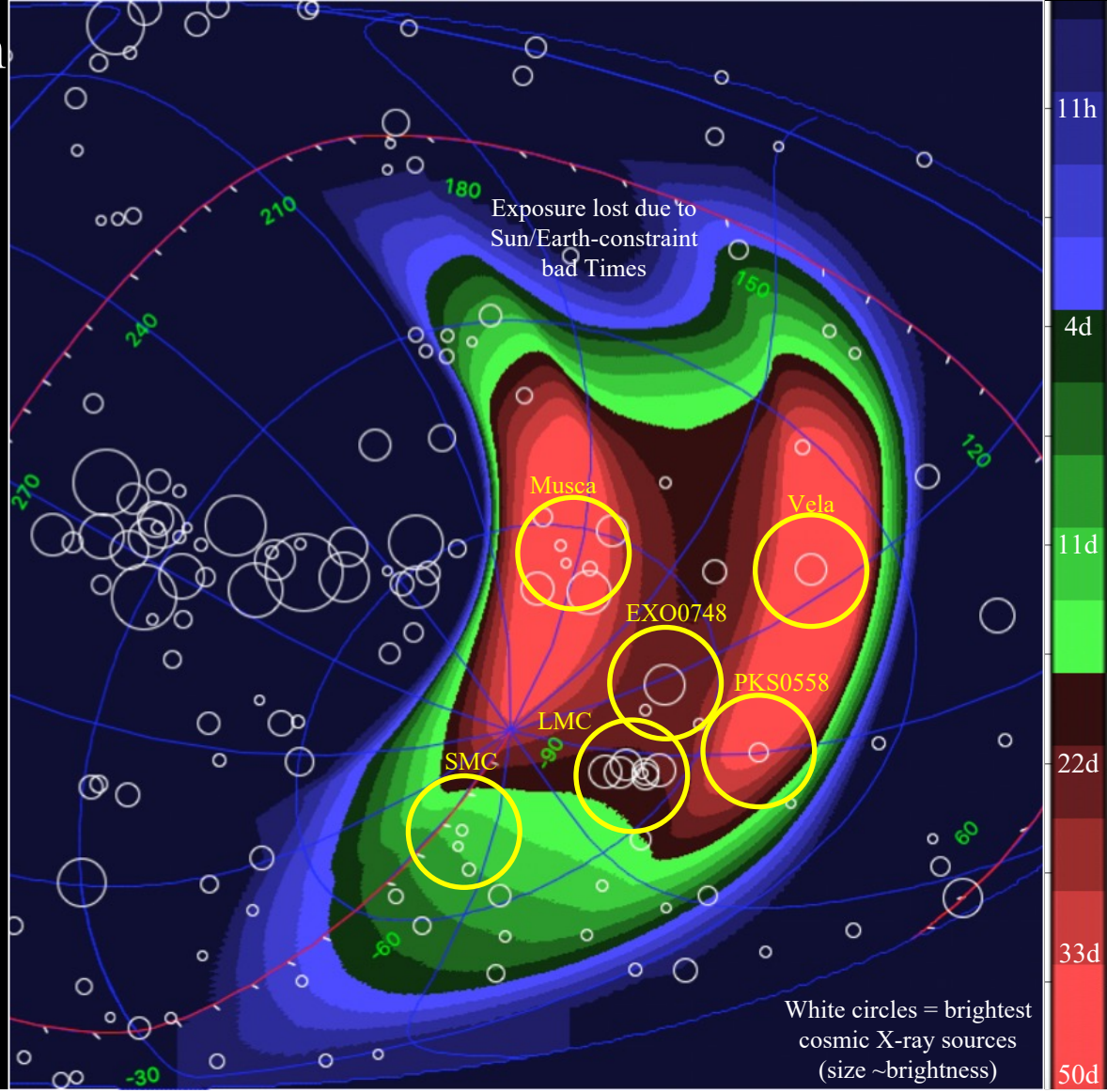
Sky Coverage & Calibration

Year1 2025

Exposure map (peak ~50 days)

SXI covers ~1/4 of sky over year

6 main Calibration regions identified in high exposure areas (yellow circle ~size of short axis of SXI FOV)



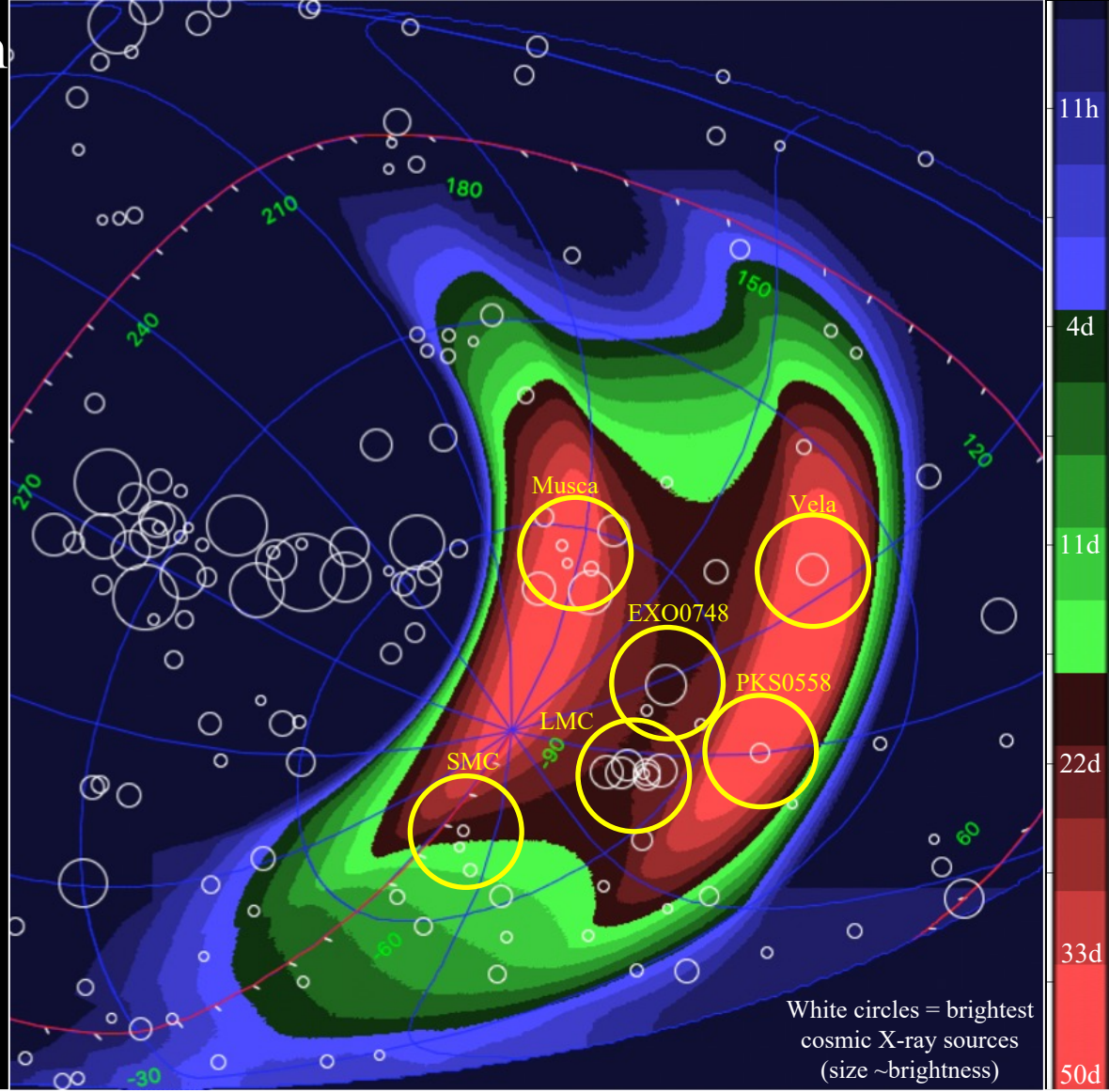
Sky Coverage & Calibration

Year2 2026

Exposure map (peak ~50 days)

SXI covers ~1/4 of sky over year

6 main Calibration regions identified in high exposure areas (yellow circle ~size of short axis of SXI FOV)



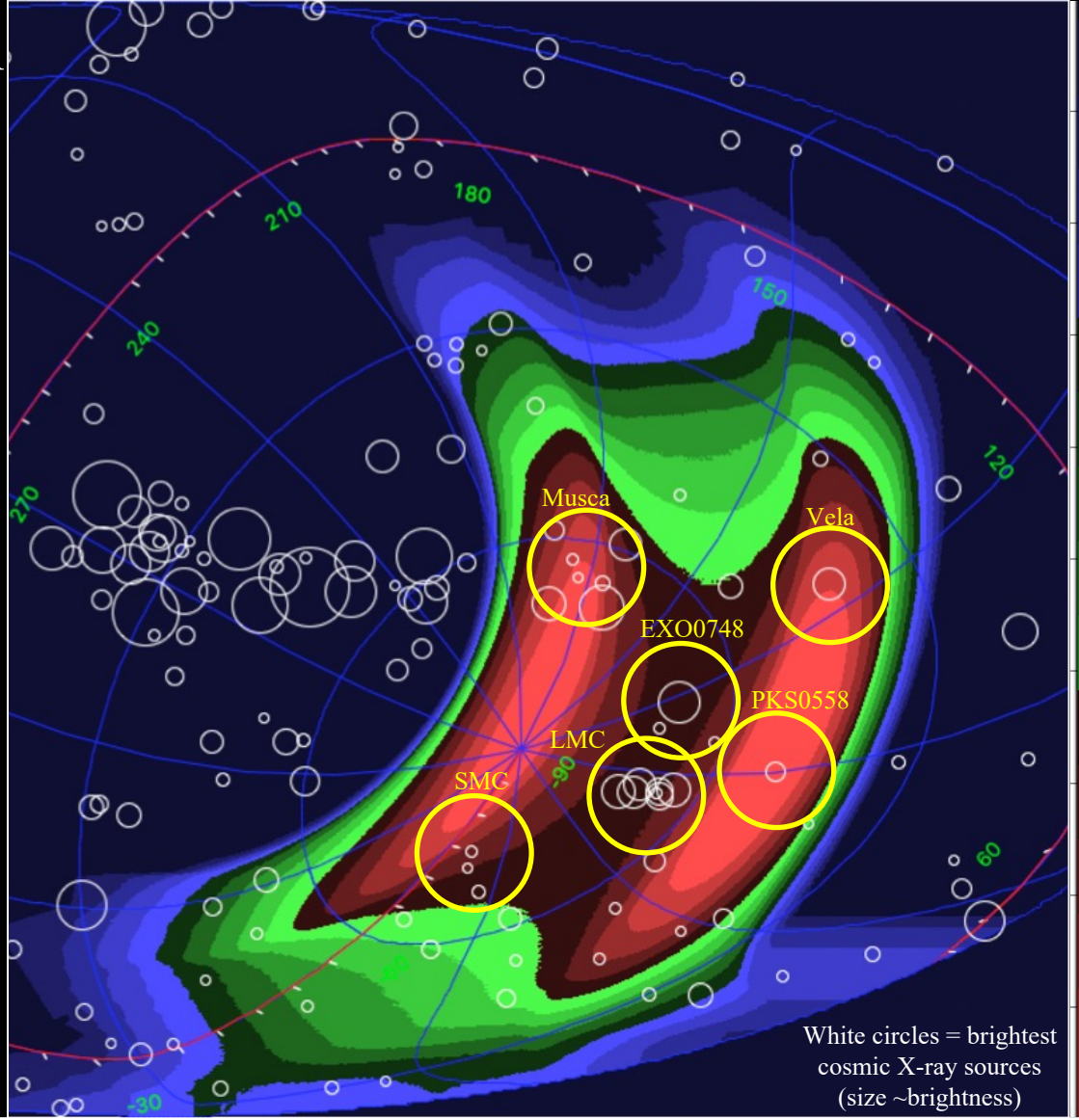
Sky Coverage & Calibration

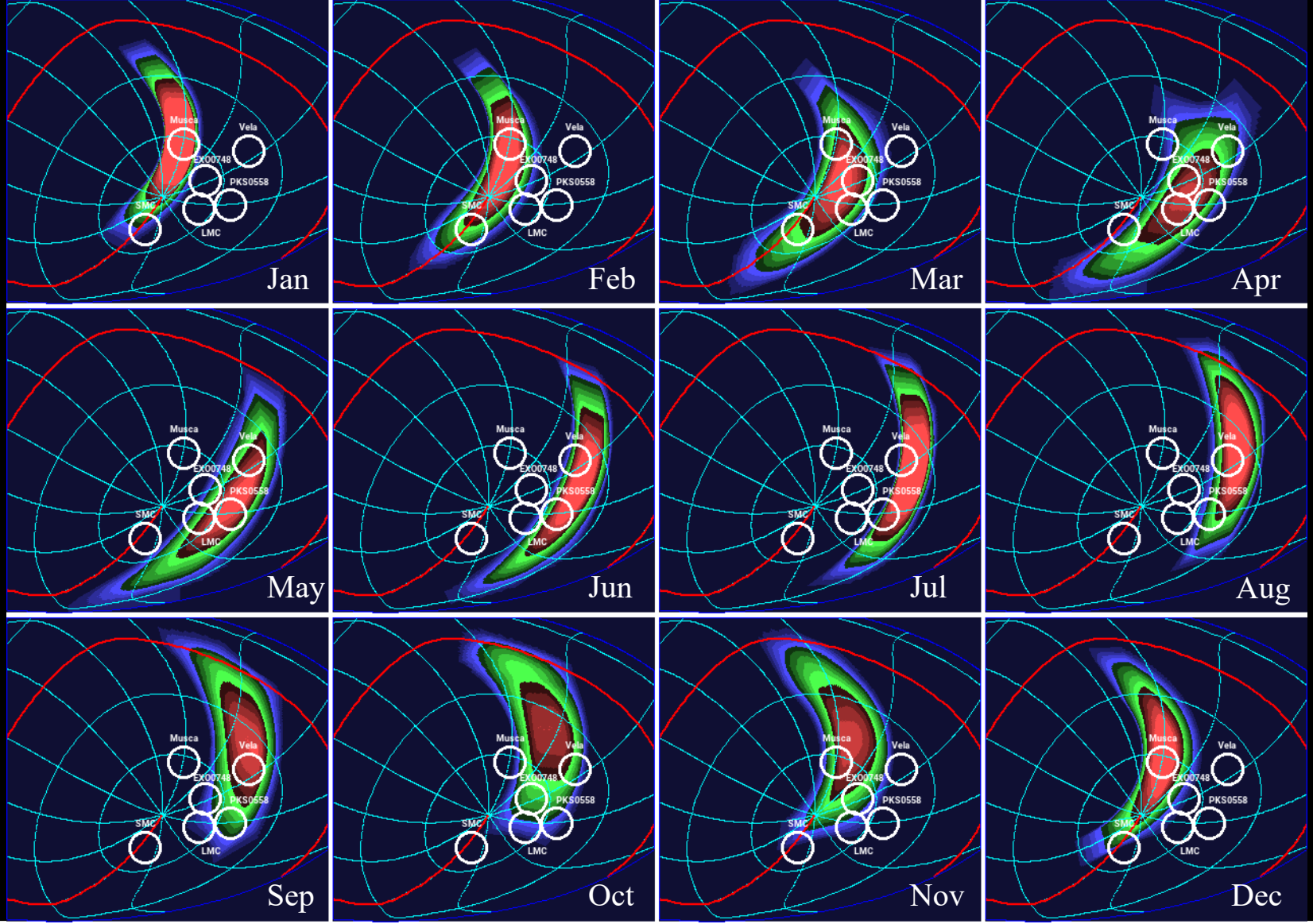
Year3 2026

Exposure map (peak ~50 days)

SXI covers ~1/4 of sky over year

6 main Calibration regions identified in high exposure areas (yellow circle ~size of short axis of SXI FOV)

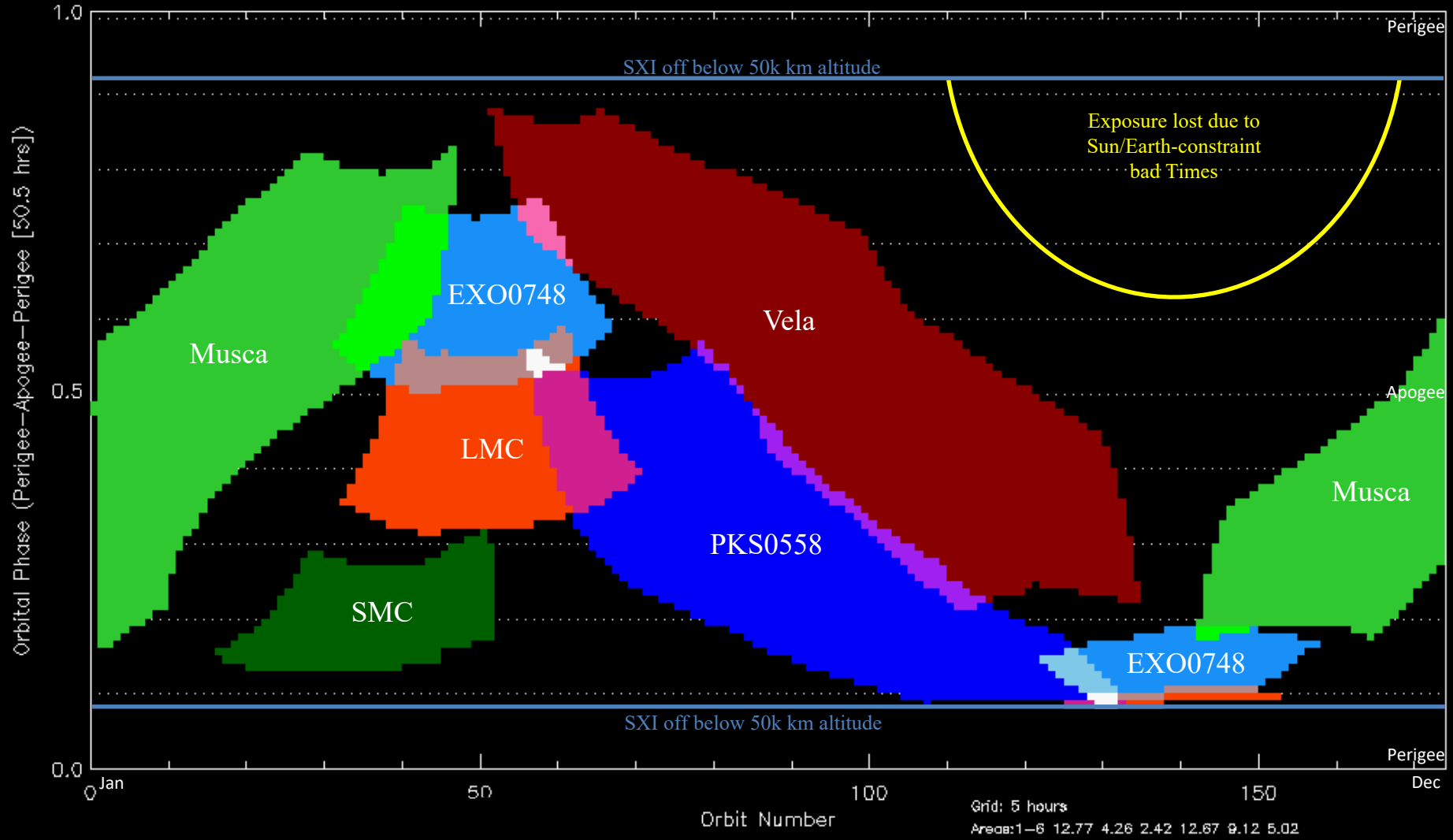



Musca
Vela
EX00748
PKS0558
SMC
LMC
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
8h
1d
2d
4d
8d

Year1 2025

Six Major Calibration Regions

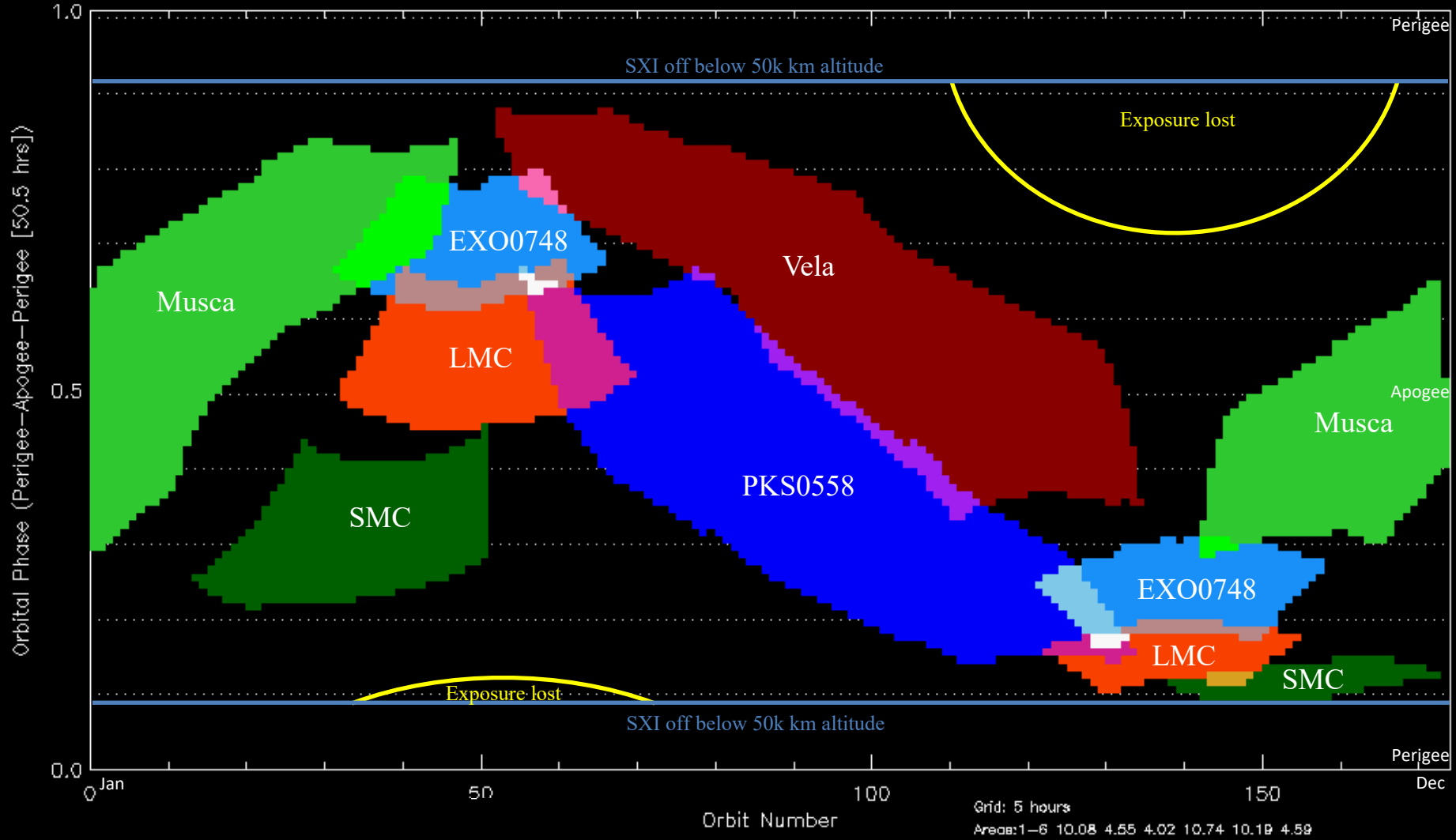
Phase-Year plot



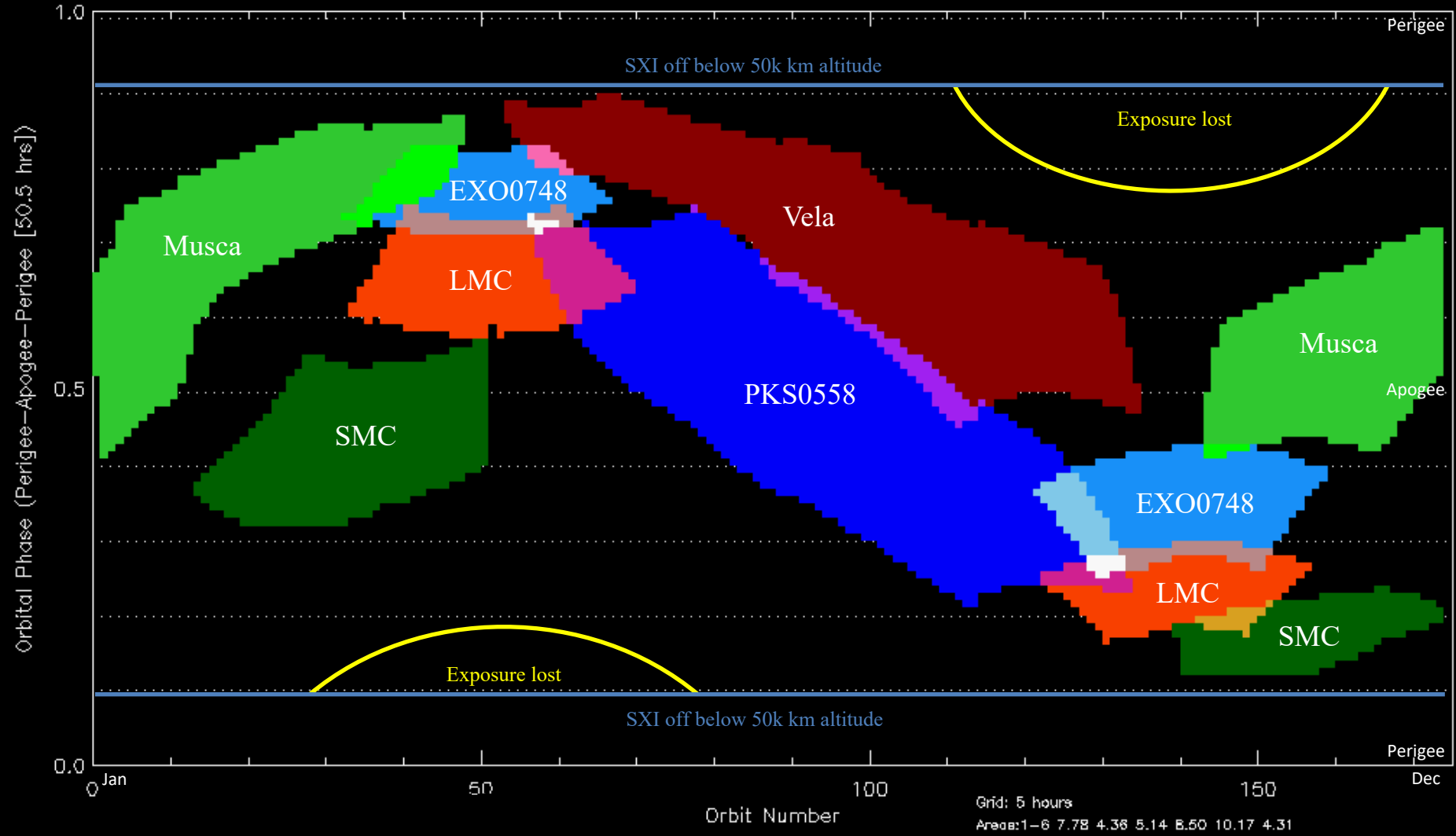
Year2 2026

Six Major Calibration Regions

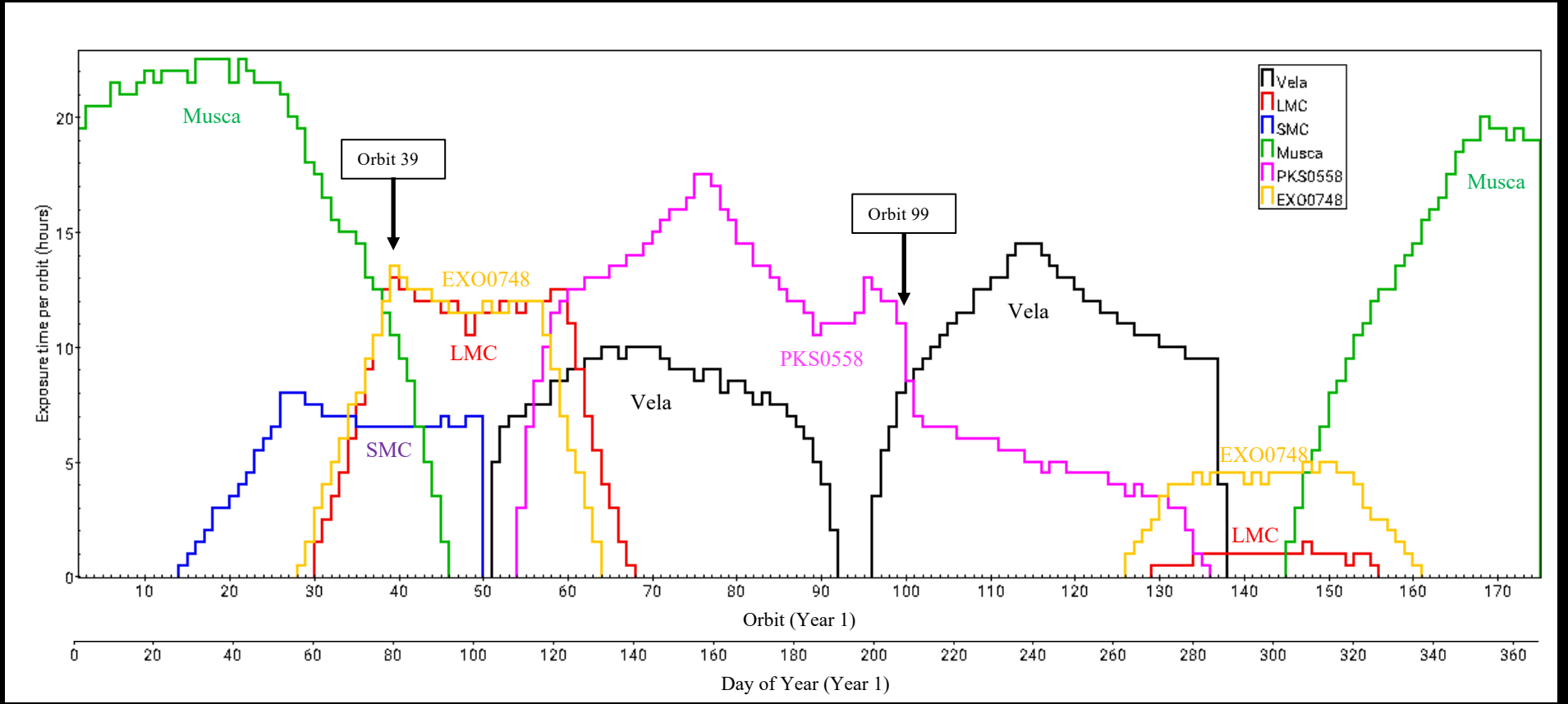
Phase-Year plot



Year3 2027 Six Major Calibration Regions Phase-Year plot



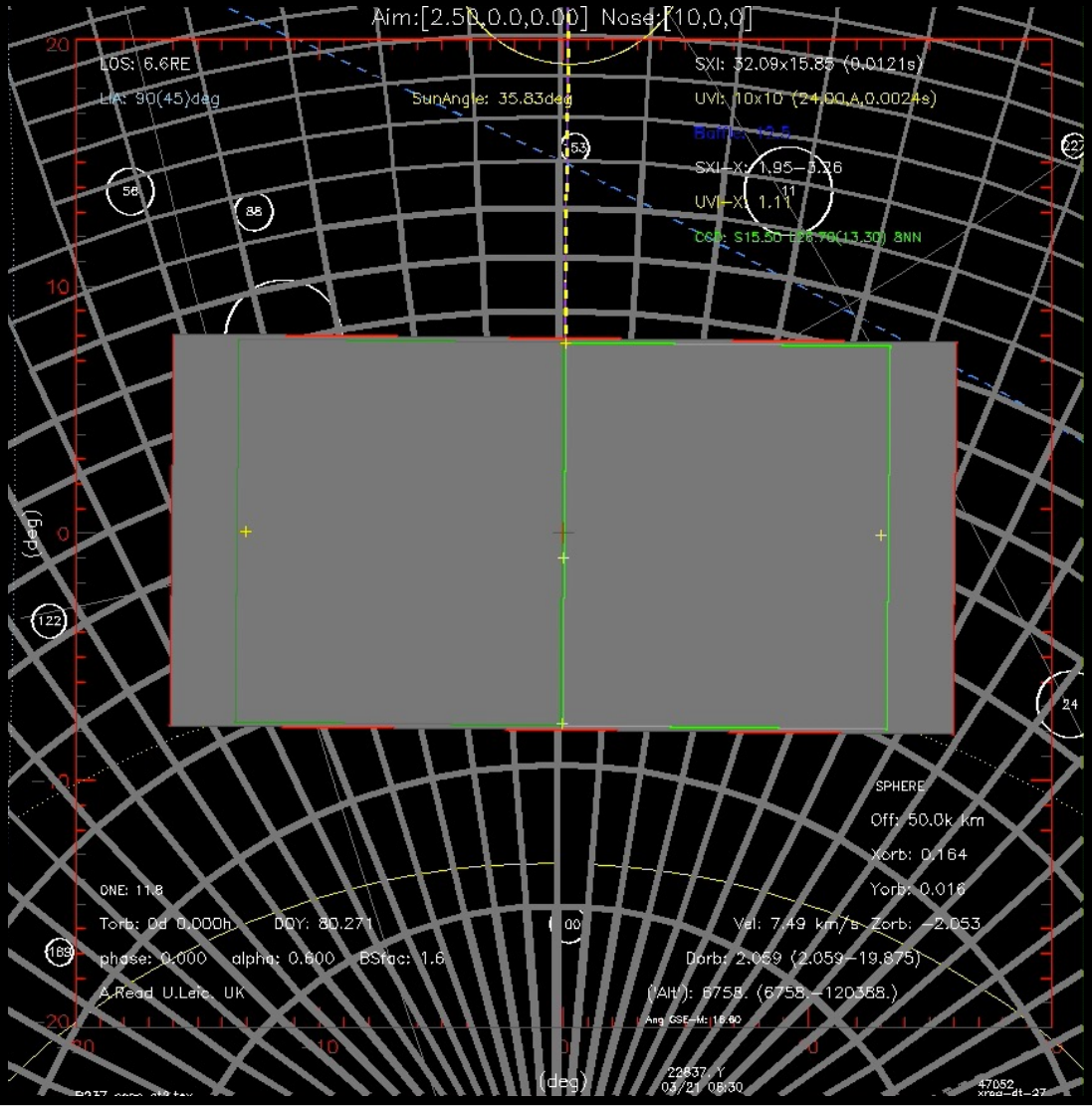
The six regions – exposure time per orbit in SXI FOV – Year1



Orbit 39

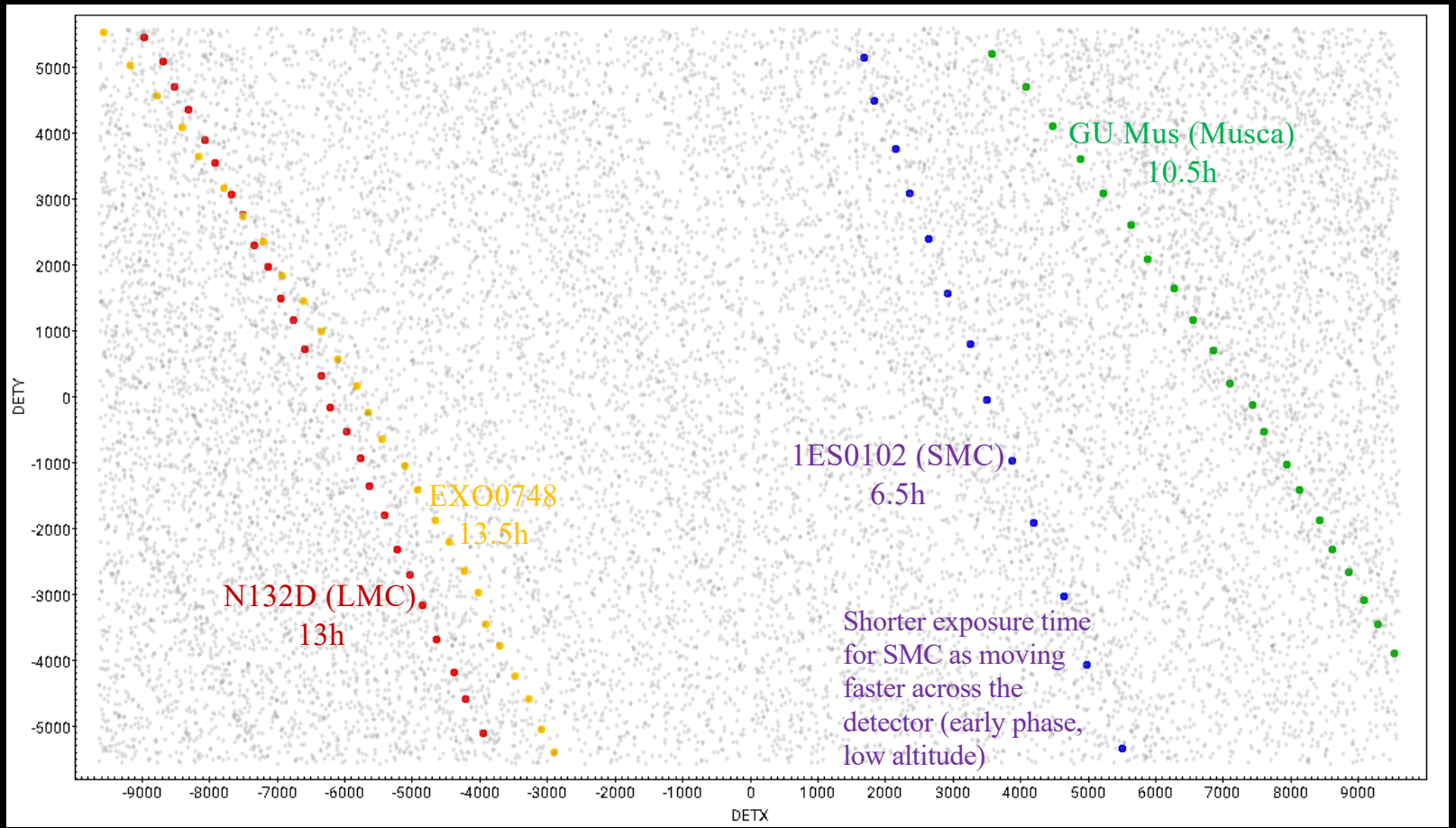
236	SMC (1ES0102)
45	LMC (N132D)
26	EXO0748
20	Musca (GU Mus)

- Sources drift across short axis of FOV & usually across only 1 CCD
- Shorter exposure times



Magnetopause grid model & magnetospheric nose and cusps also shown

Orbit 39 – Sources moving across the SXI detector

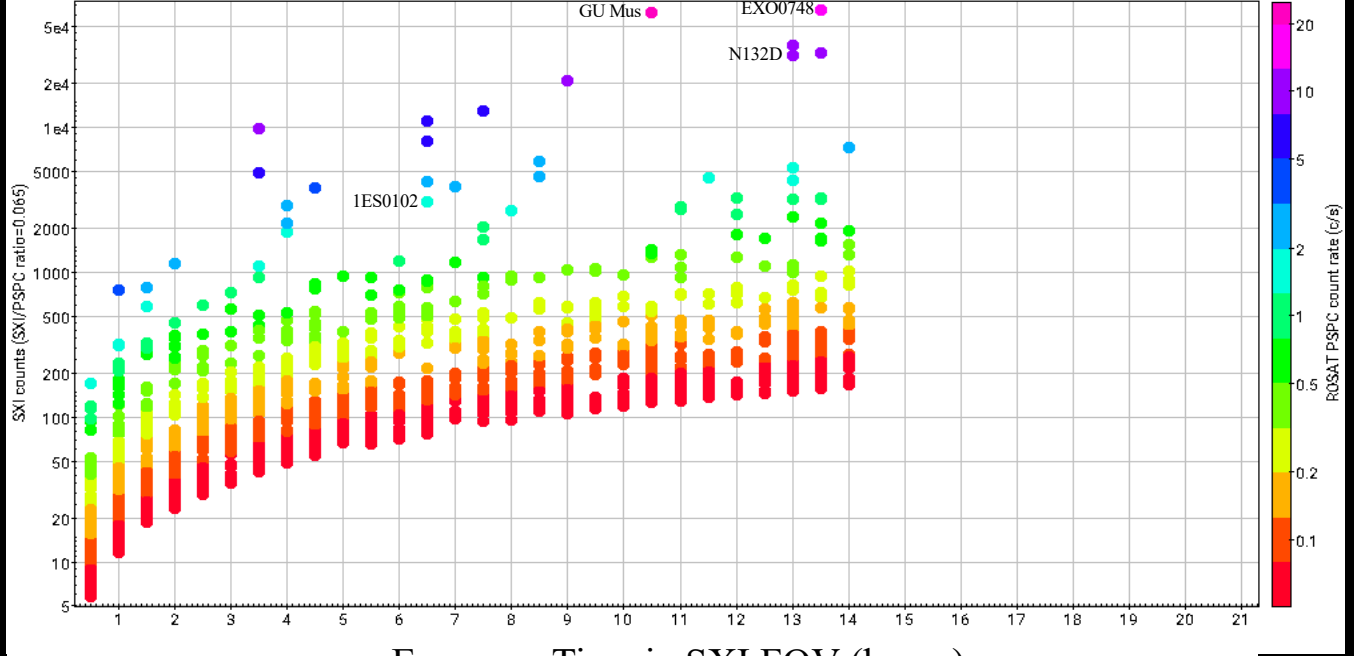


Year1: Orbit 39

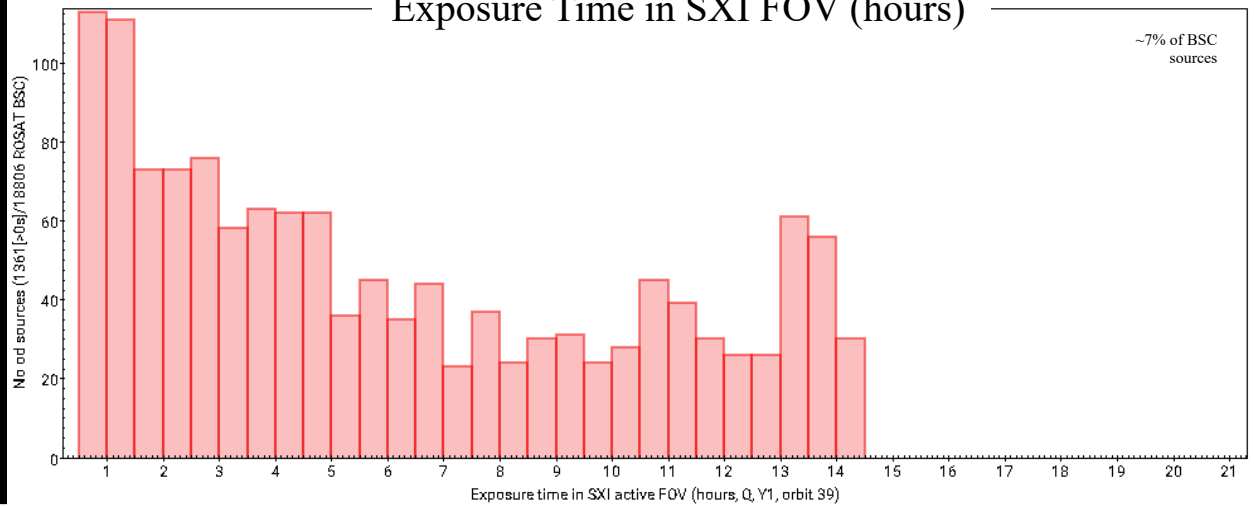
Short axis (1 CCD) transits – no very long exposures

Up to 10s of 1000s of SXI counts from some sources in one orbit

SXI Counts



Exposure Time in SXI FOV (hours)



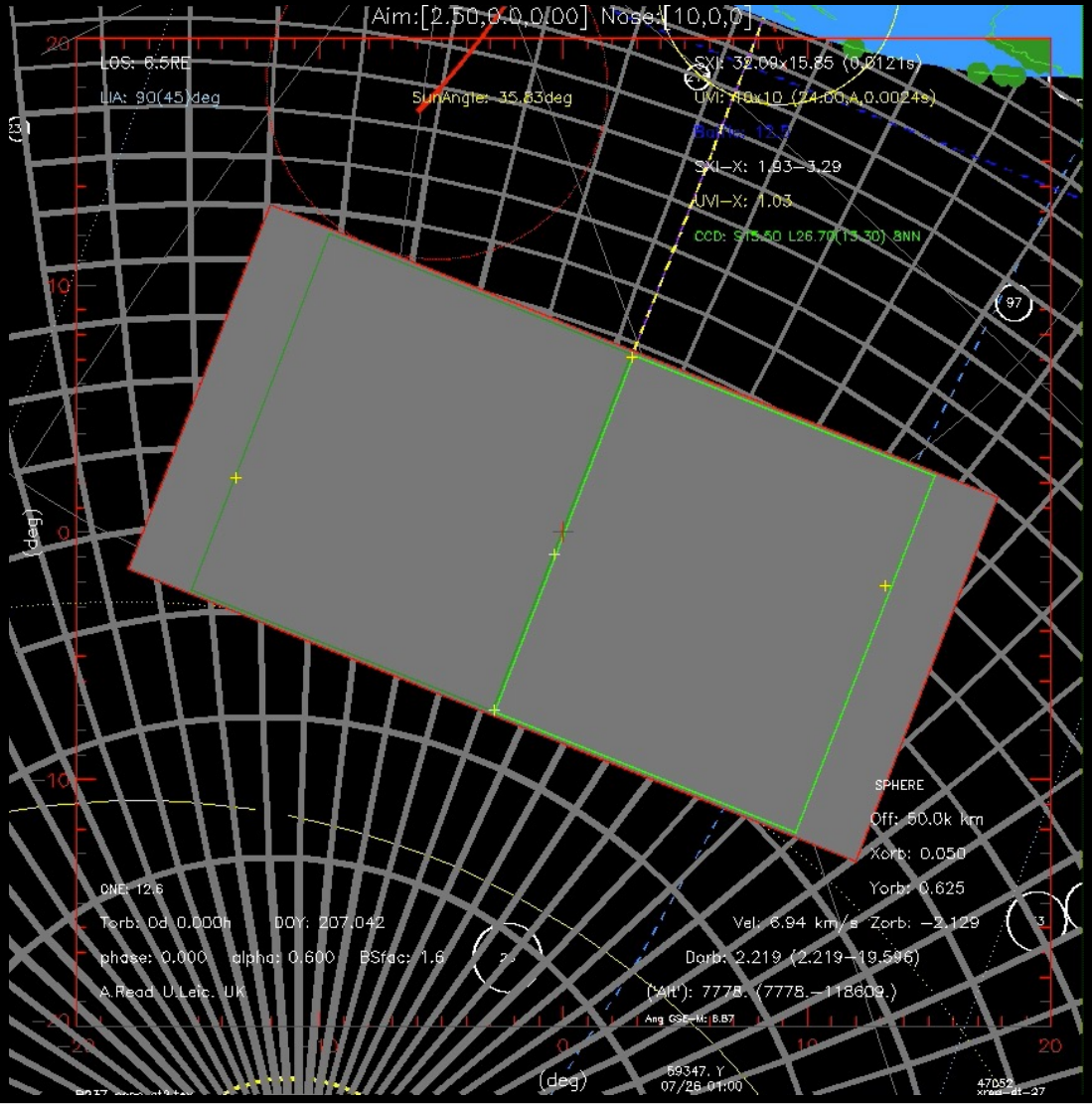
ROSAT PSPC to SXI count rate conversion (here ~0.065) yields predicted count rate within HEW of SXI PSF.

Conversion is approximate – assumes simple common spectral form (an absorbed power law of index, α = -0.7) for all sources, and some targets are variable.

Orbit 99

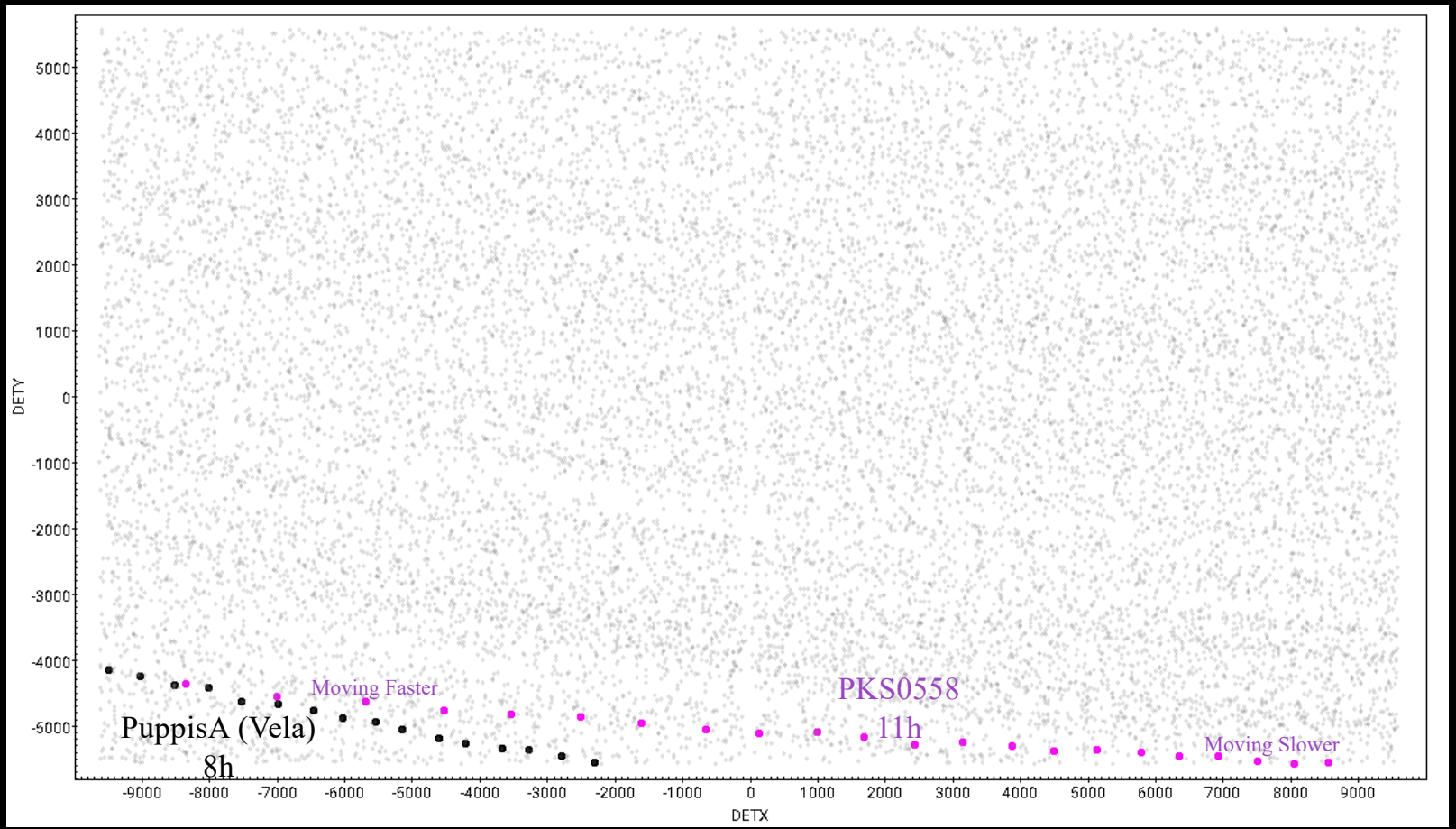
104	PKS0558
47	Vela (Puppis A)

- Sources drift generally across long axis of FOV & often across both CCDs
- Longer exposure times



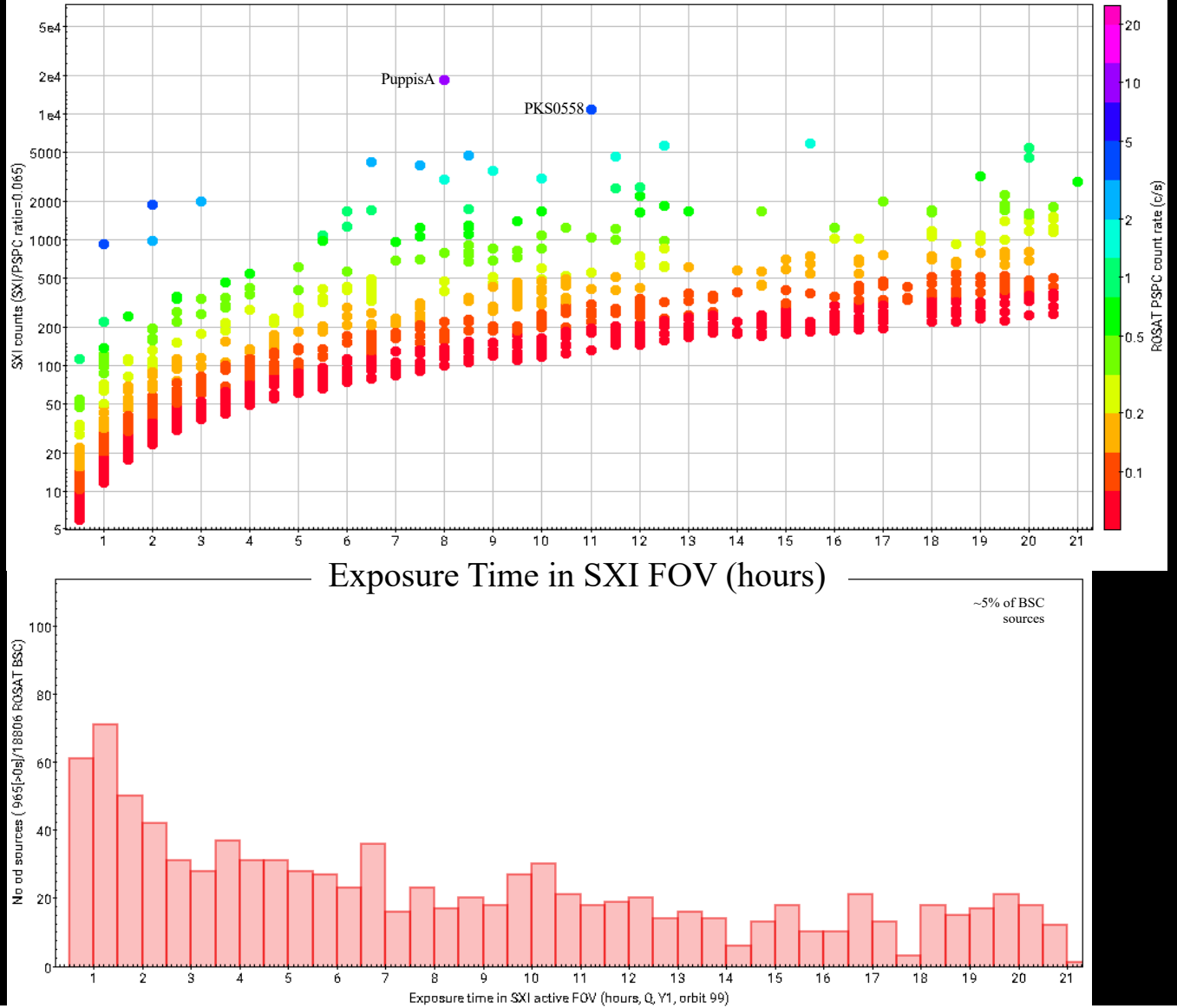
Magnetopause grid model & magnetospheric nose and cusps also shown

Orbit 99 – Sources moving across the SXI detector

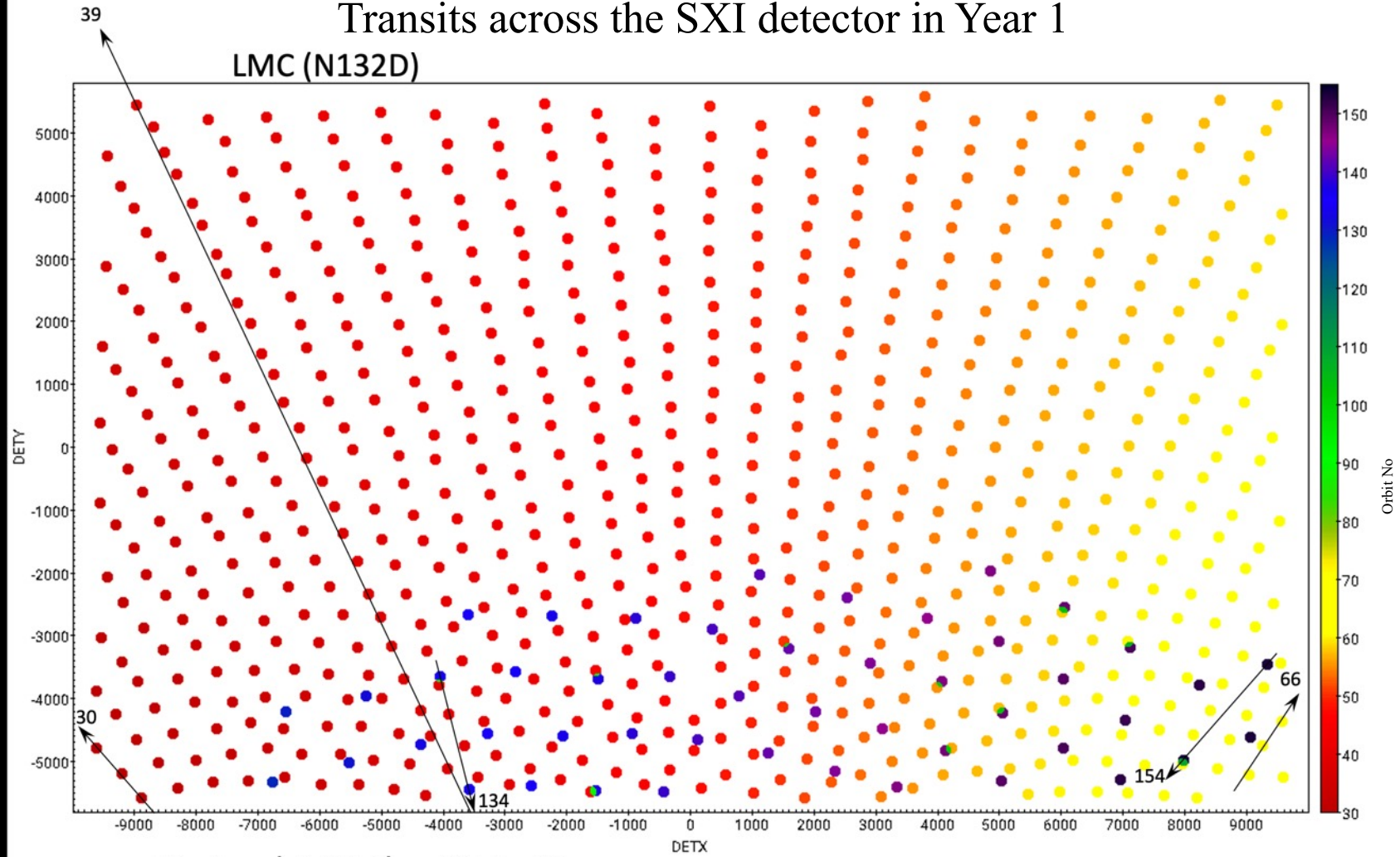


Year1: Orbit 99

Long axis
(2 CCDs) transits –
some long exposures

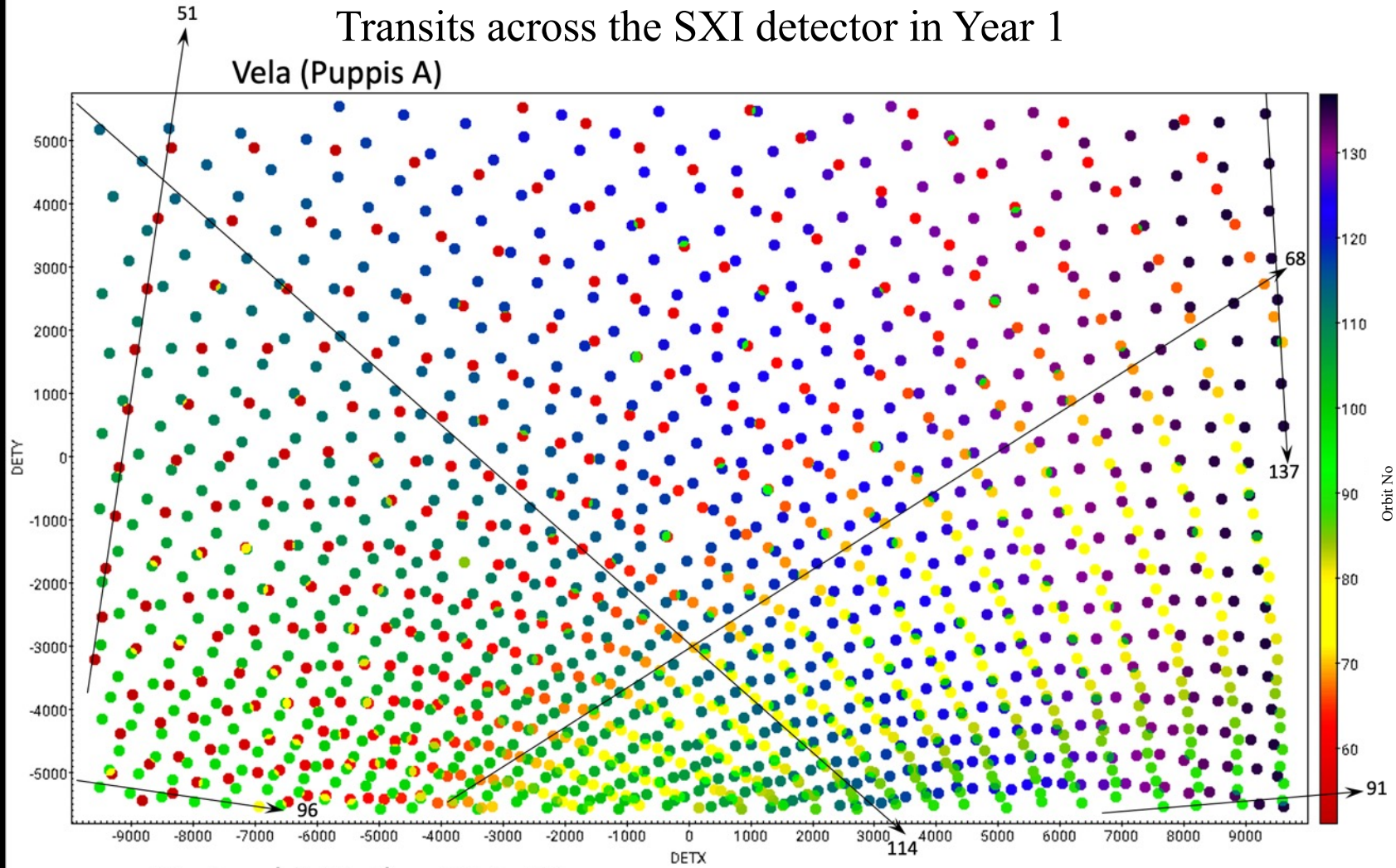


Transits across the SXI detector in Year 1



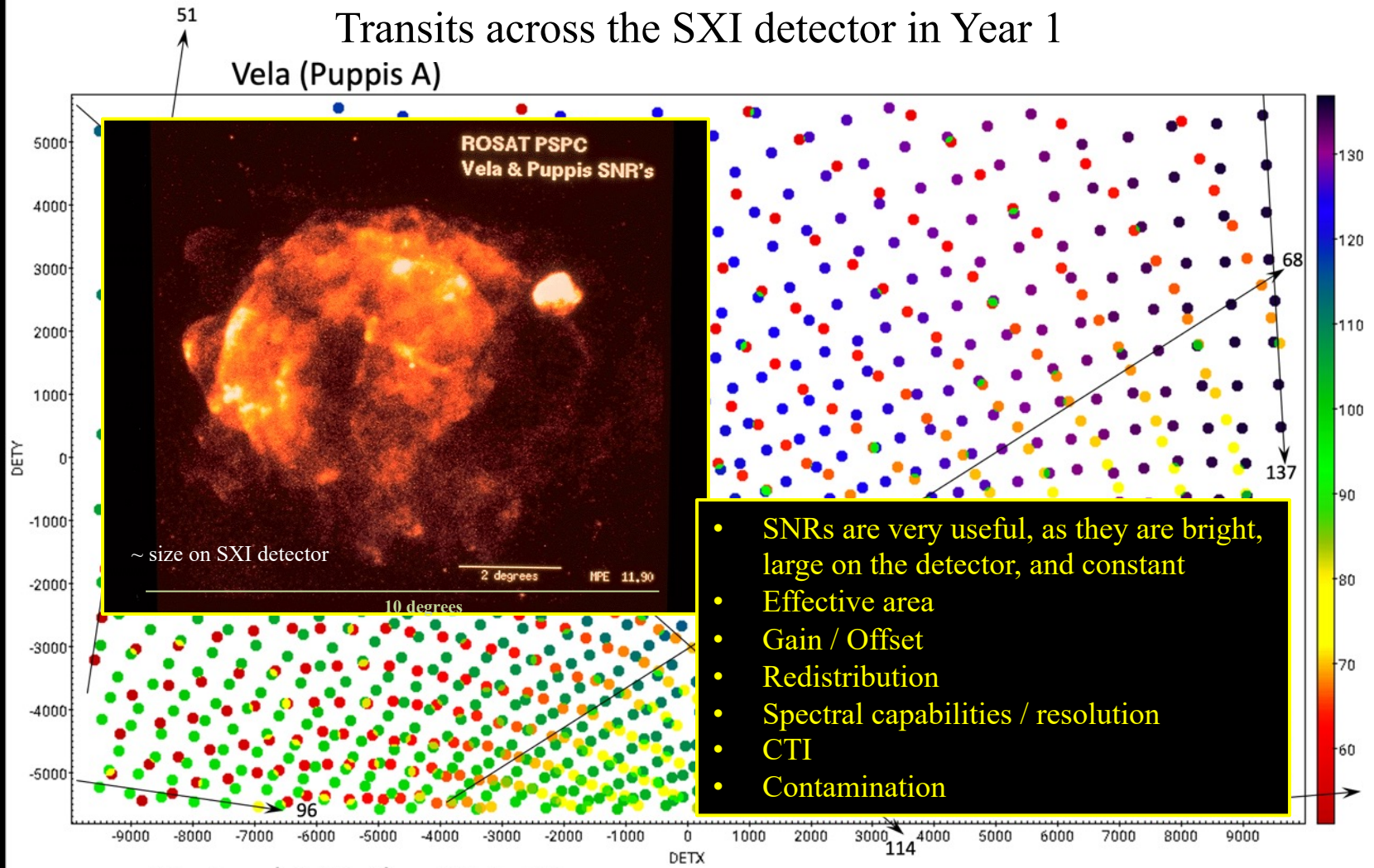
- Starts orbit 30, thru 39, to 66 (slow)
- Then (opposite direction) 134 to 154 (fast, low altitude)

Transits across the SXI detector in Year 1



- Starts orbit 51, thru 68, to 91
- Then (opposite direction) 96, thru 114, to 137

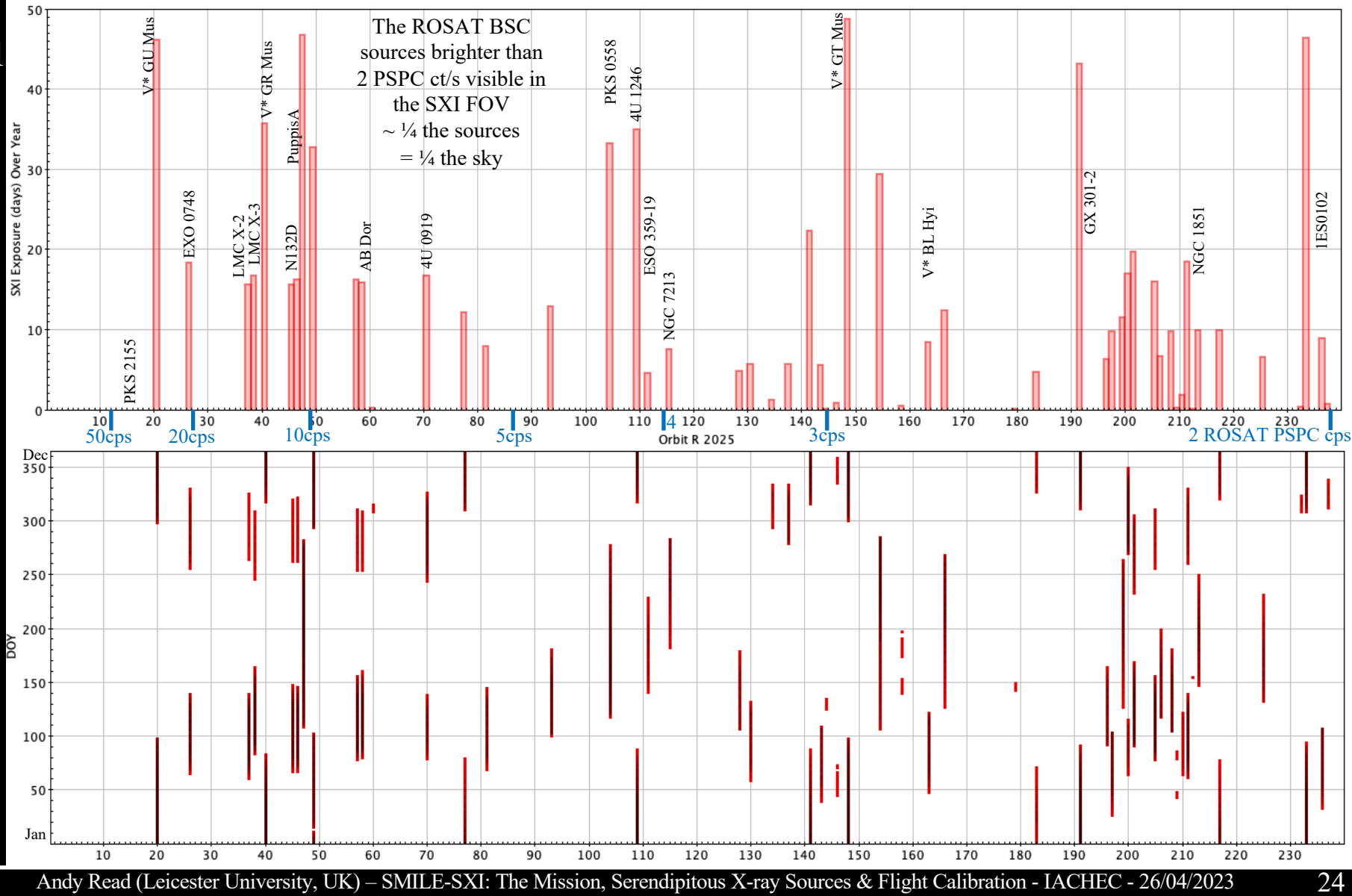
Transits across the SXI detector in Year 1



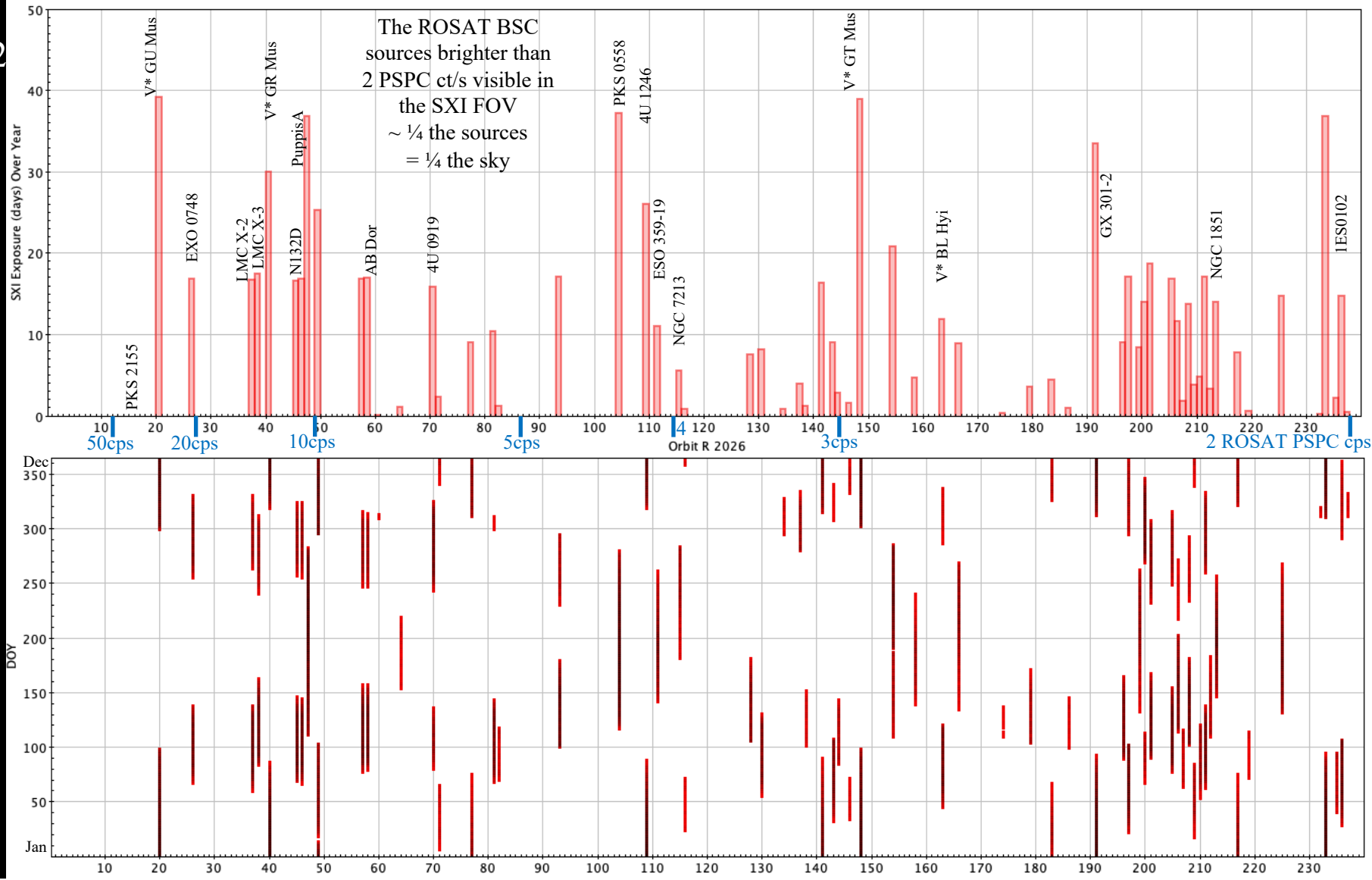
- SNRs are very useful, as they are bright, large on the detector, and constant
- Effective area
- Gain / Offset
- Redistribution
- Spectral capabilities / resolution
- CTI
- Contamination

- Starts orbit 51, thru 68, to 91
- Then (opposite direction) 96, thru 114, to 137

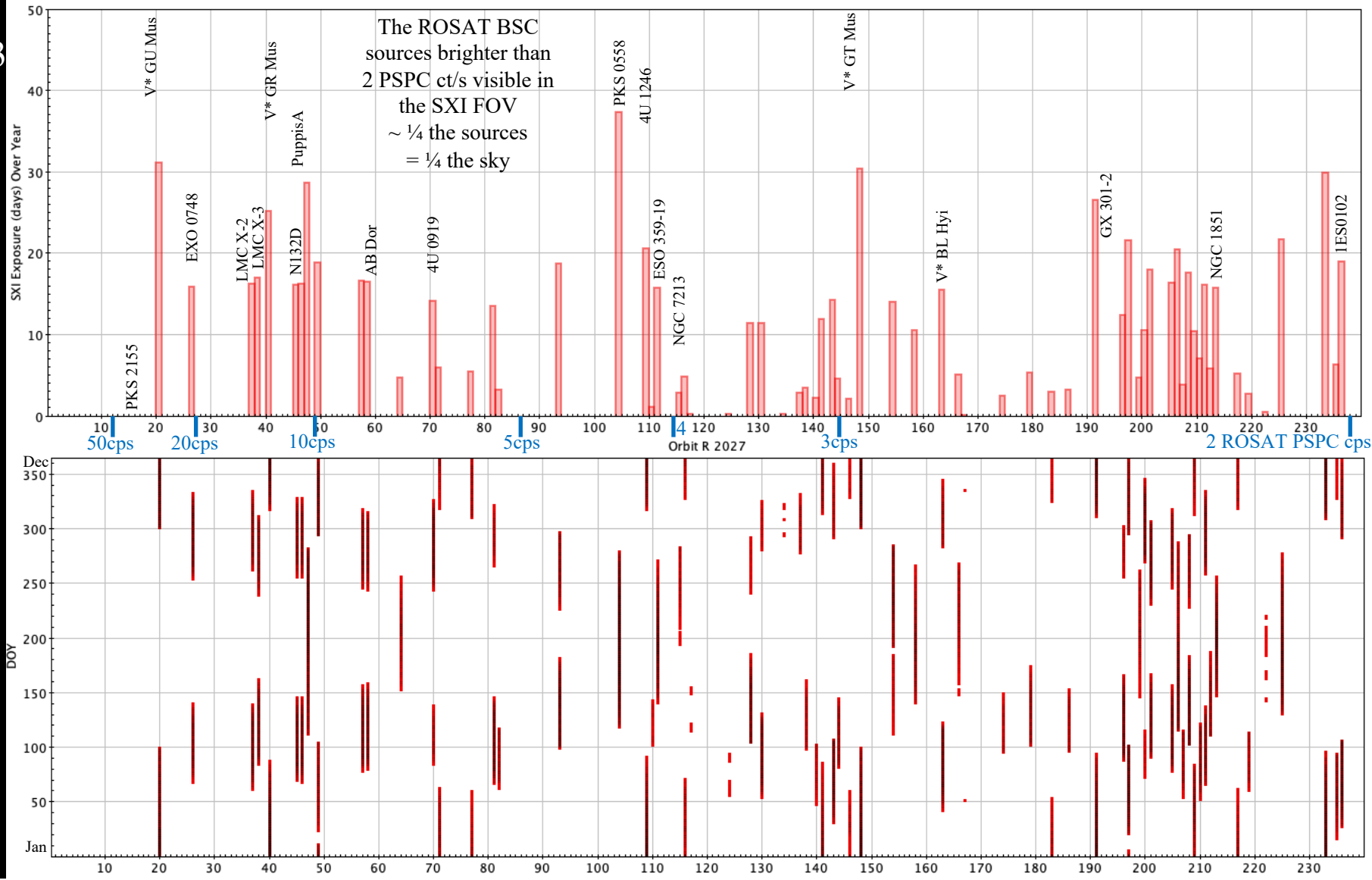
Year1
2025


The ROSAT BSC sources brighter than 2 PSPC ct/s visible in the SXI FOV ~ ¼ the sources = ¼ the sky
SXI Exposure (days) Over Year
Orbit R 2025
DOY
Dec
Jan
PKS 2155
V* GU Mus
EXO 0748
LMC X-2
LMC X-3
V* GR Mus
N132D
PuppisA
AB Dor
4U 0919
PKS 0558
4U 1246
ESO 359-19
NGC 7213
V* GT Mus
V* BL Hyi
GX 301-2
NGC 1851
1ES0102
50cps
20cps
10cps
5cps
3cps
2 ROSAT PSPC cps

Year2
2026

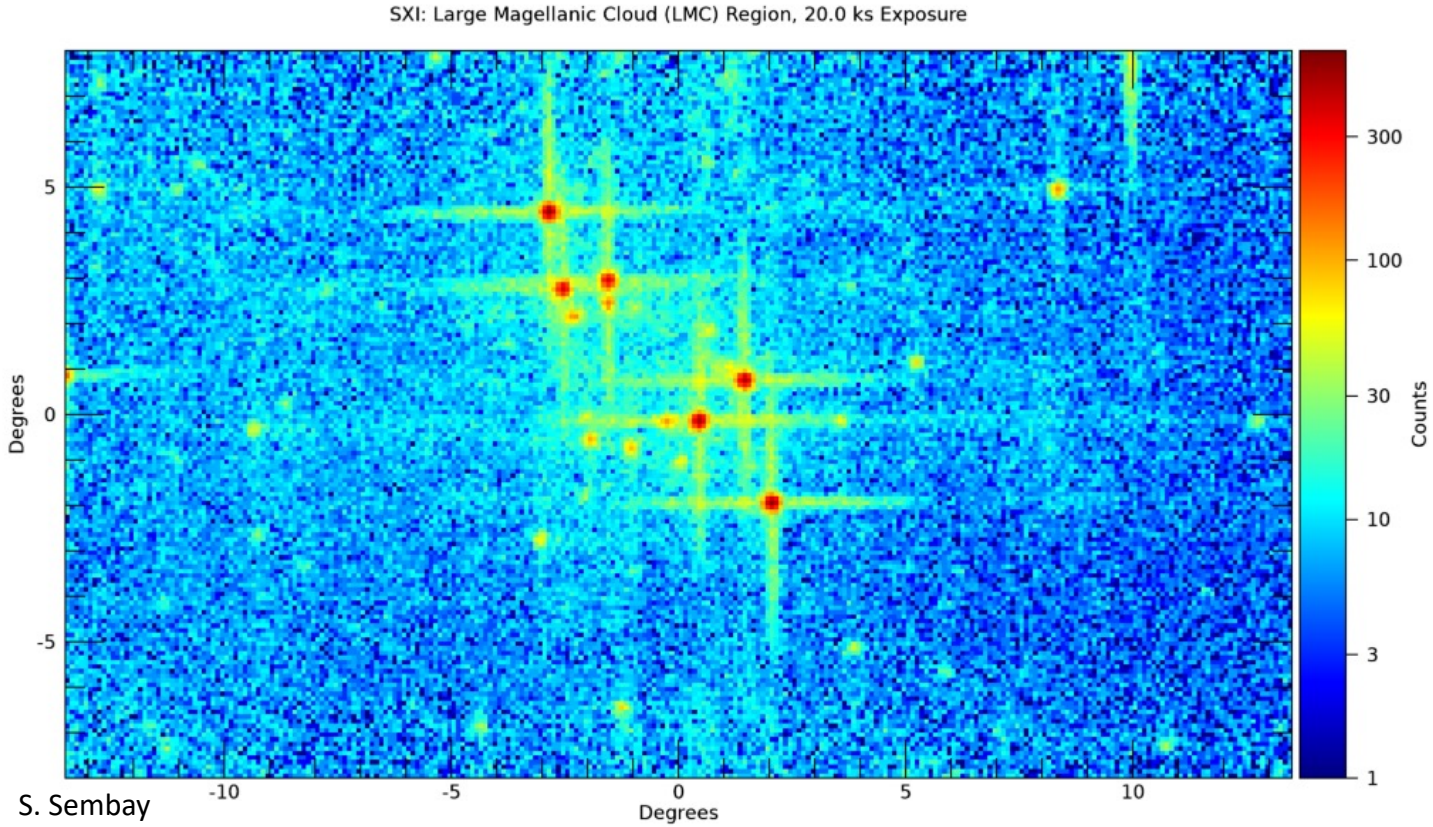

The ROSAT BSC sources brighter than 2 PSPC ct/s visible in the SXI FOV ~ ¼ the sources = ¼ the sky
SXI Exposure (days) Over Year
Orbit R 2026
DOY
Dec
Jan
PKS 2155
V* GU Mus
EXO 0748
LMC X-2
LMC X-3
V* GR Mus
Puppis A
N132D
AB Dor
4U 0919
PKS 0558
4U 1246
ESO 359-19
NGC 7213
V* GT Mus
V* BL Hyi
GX 301-2
NGC 1851
1ES0102
50cps
20cps
10cps
5cps
3cps
2 ROSAT PSPC cps

Year3
2027


The ROSAT BSC sources brighter than 2 PSPC ct/s visible in the SXI FOV
~ ¼ the sources
= ¼ the sky
SXI Exposure (days) Over Year
V* GU Mus
V* GR Mus
Puppis A
PKS 0558
4U 1246
V* GT Mus
PKS 2155
EXO 0748
LMC X-2
LMC X-3
N132D
AB Dor
4U 0919
ESO 359-19
NGC 7213
V* BL Hyi
GX 301-2
NGC 1851
1ES0102
50cps
20cps
10cps
5cps
3cps
2 ROSAT PSPC cps
Orbit R 2027
DOY
Dec
Jan

Calibration Function	Target	Comments
Instrument Response Baseline (First Light Target)	LMC Region, Musca/Crux Region, Vela/PuppisA (dependent on time of year)	Dedicated fixed pointing (TBD), or offset pointing (towards Sun, away from magnetosheath) with normal spacecraft slew/movement (TBD)
Effective Area	N132D (LMC)	
	1ES0102-72 (SMC)	
	PKS 2155-304 (2027? / new orbit)	Simultaneous with another X-ray mission for reference
Energy Scale	1ES0102-72 (SMC)	
	Soft X-ray Background	
	Onboard Calibration Source	
Energy resolution	Onboard Calibration Source	
CTI	Vela SNR	
	Soft X-ray Background	
	Onboard Calibration Source	
PSF	All strong point sources within the FOV	
Contamination monitoring	1ES0102-72 (SMC)	
Timing System	GX 301-2	Near-simultaneous with another X-ray mission for reference
	Vela X-1	
Spatial Coordinate System	All strong point/compact sources within the FOV	

Calibration Function	Target	Comments
Instrument Response Baseline (First Light Target)	LMC Region, Musca/Crux Region, Vela/PuppisA (dependent on time of year)	Dedicated fixed pointing (TBD), or offset pointing (towards Sun, away from magnetosheath) with normal spacecraft slew/movement (TBD)

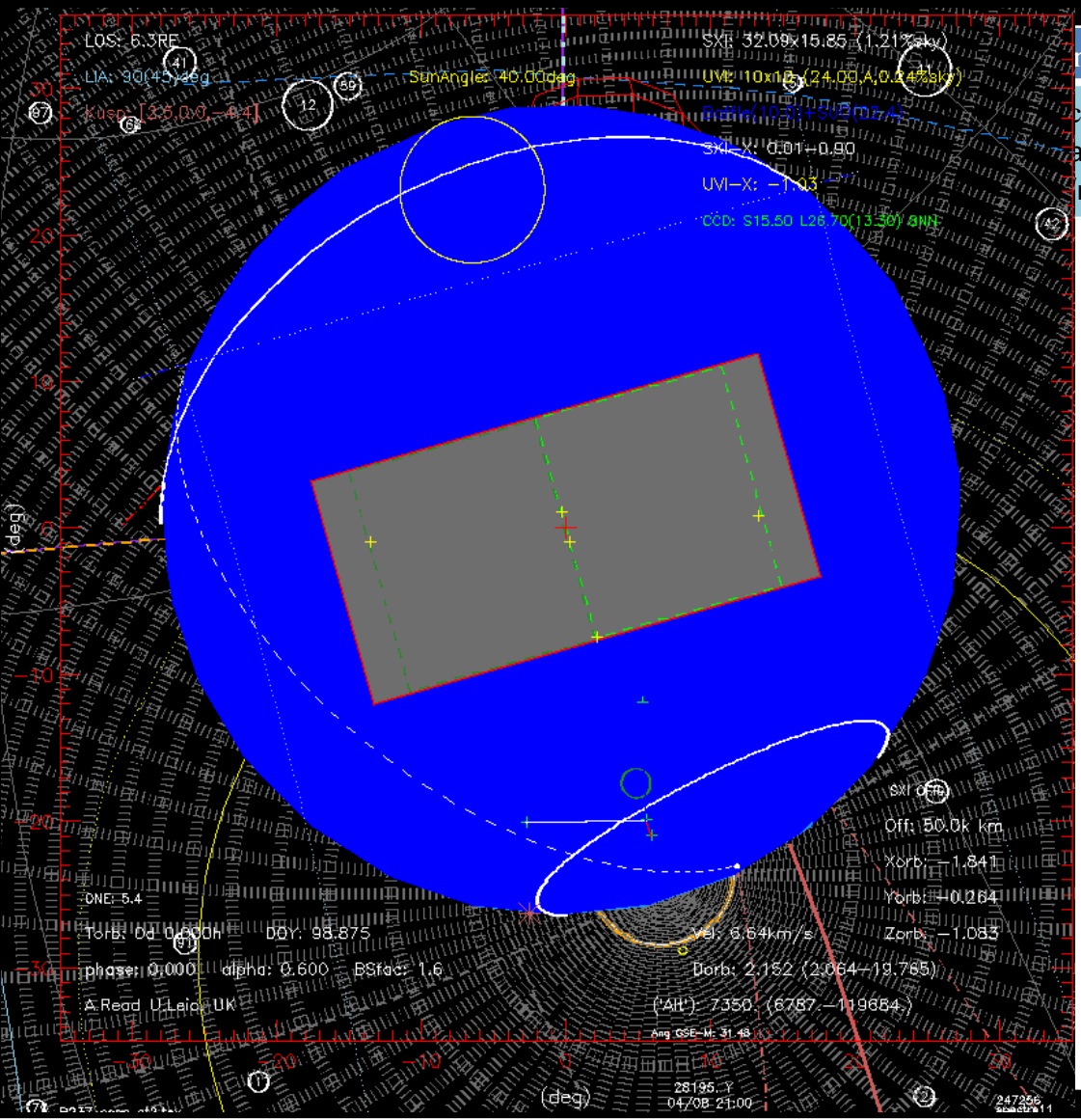


S. Sembay

Potential first-light target for SXI: Simulation of 20 ks exposure towards LMC region.

Pixel size: 0.1 x 0.1 deg

Energy range: 0.1-2.5 keV



ments

cated fixed pointing (TBD), or offset pointing (towards away from magnetosheath) with normal spacecraft movement (TBD)

Potential first-light observation for SXI:

Offset pointing (towards Sun, away from magnetosheath) with normal spacecraft slew/movement (TBD)

April orbit example

Offset pointing Sunwards by 20 deg

See sources later in orbit than in zero-offset pointing

SMC, LMC, EXO0748 & Musca all appear in the FOV in this example

Calibration Function	Target	Comments
Instrument Response Baseline (First Light Target)	LMC Region, Musca/Crux Region, Vela/PuppisA (dependent on time of year)	Dedicated fixed pointing (TBD), or offset pointing (towards Sun, away from magnetosheath) with normal spacecraft slew/movement (TBD)
Effective Area	N132D (LMC)	
	1ES0102-72 (SMC)	
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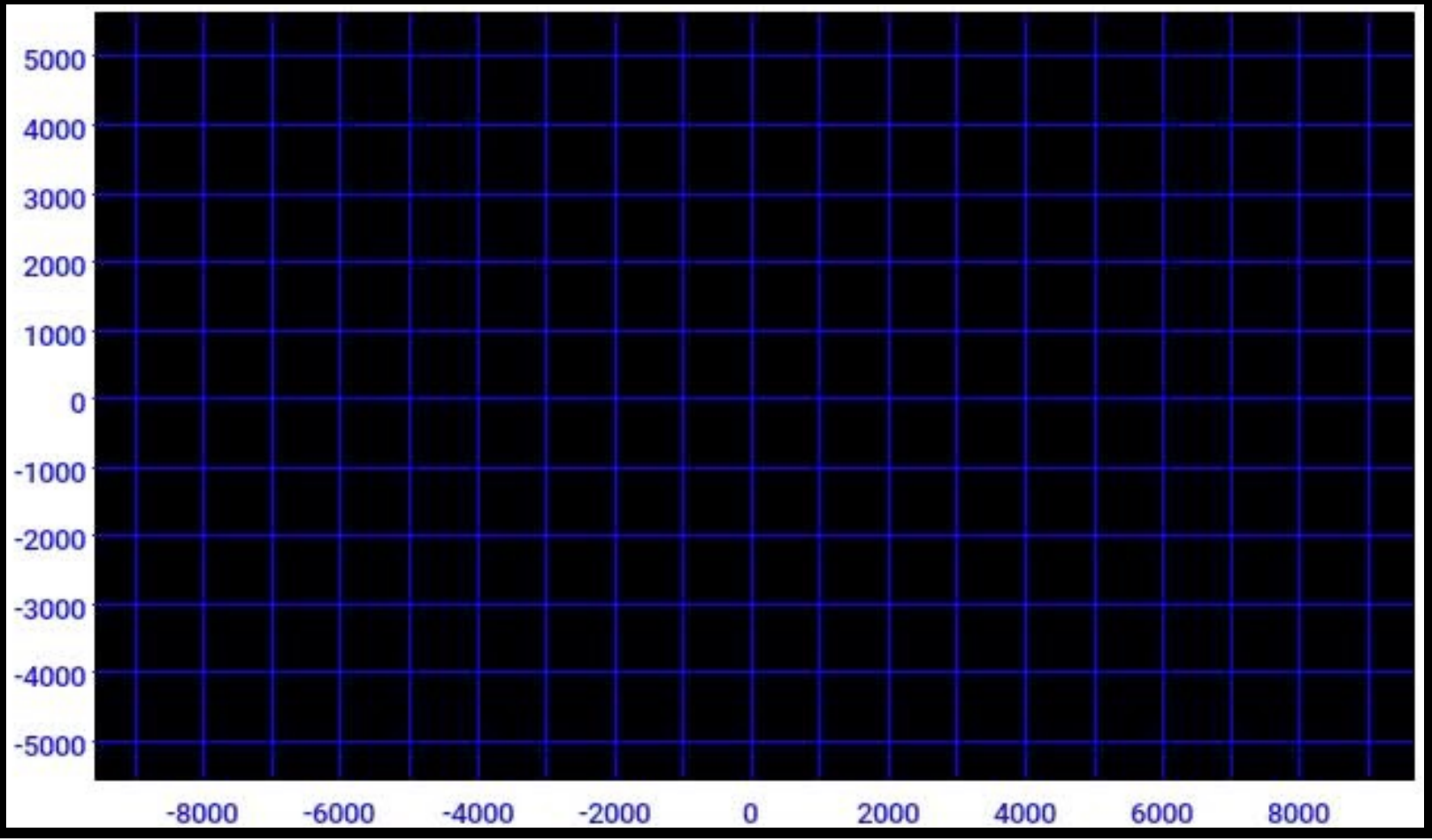
Energy Scale	1ES0102-72 (SMC)	
	Soft X-ray Background	
	Onboard Calibration Source	
Energy resolution	Onboard Calibration Source	
CTI	Vela SNR	
	Soft X-ray Background	
	Onboard Calibration Source	
PSF	All strong point sources within the FOV	
Contamination monitoring	1ES0102-72 (SMC)	
Timing System	GX 301-2	Near-simultaneous with another X-ray mission for reference
	Vela X-1	
Spatial Coordinate System	All strong point/compact sources within the FOV	

- Our observations of cosmic X-ray sources will be pre-determined; when and where sources will appear in the SXI FOV will be known in advance, & we will make this information known to the community
- We welcome any and all attempts by other X-ray missions to make simultaneous X-ray observations of our sky regions and targets

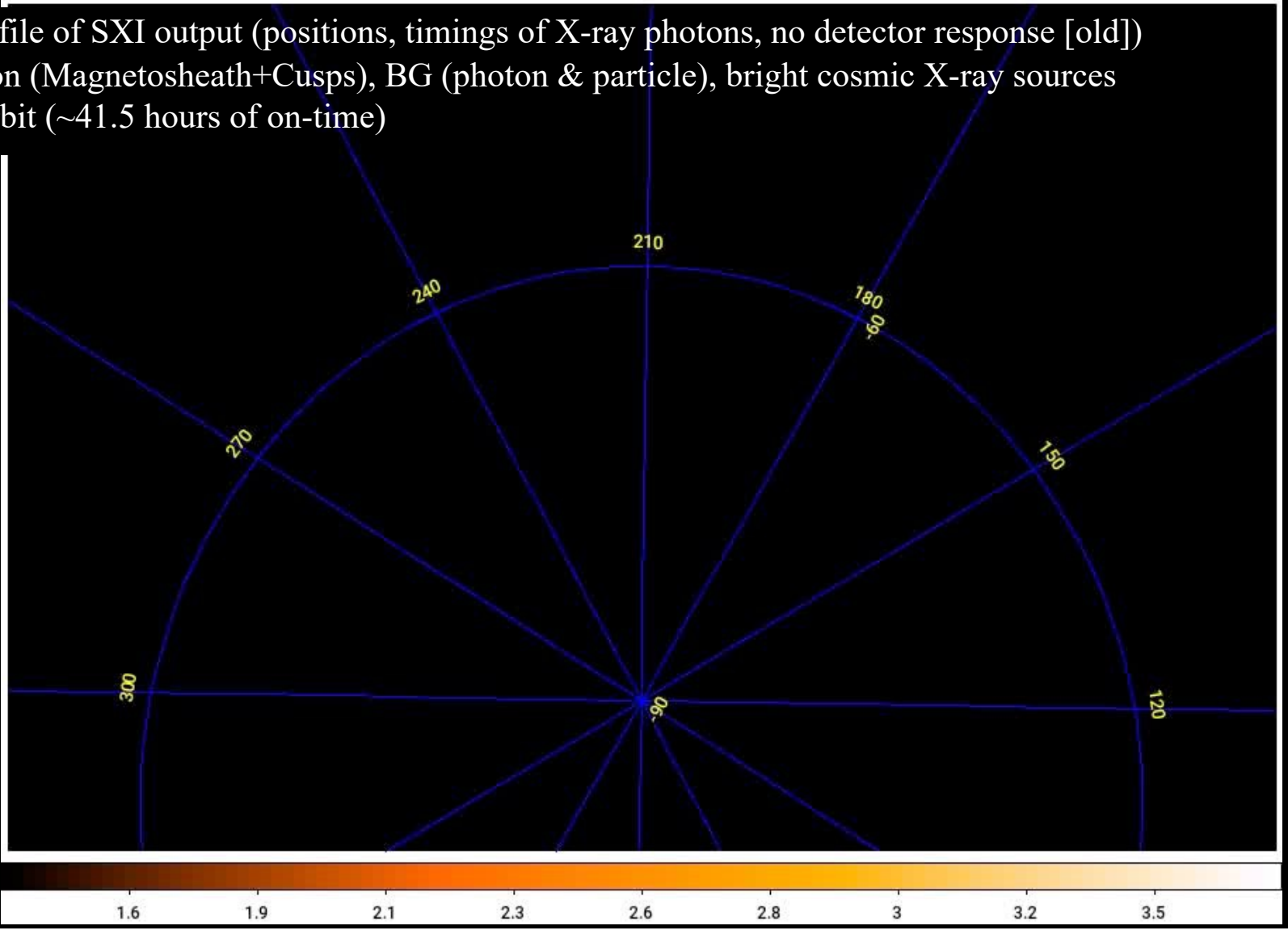
- Simple Event file of SXI output (positions, timings of X-ray photons, no detector response [old])
- Target emission (Magnetosheath+Cusps), BG (photon & particle), bright cosmic X-ray sources
- One typical orbit (~41.5 hours of on-time)

- Detector coordinates
- DETX/DETY

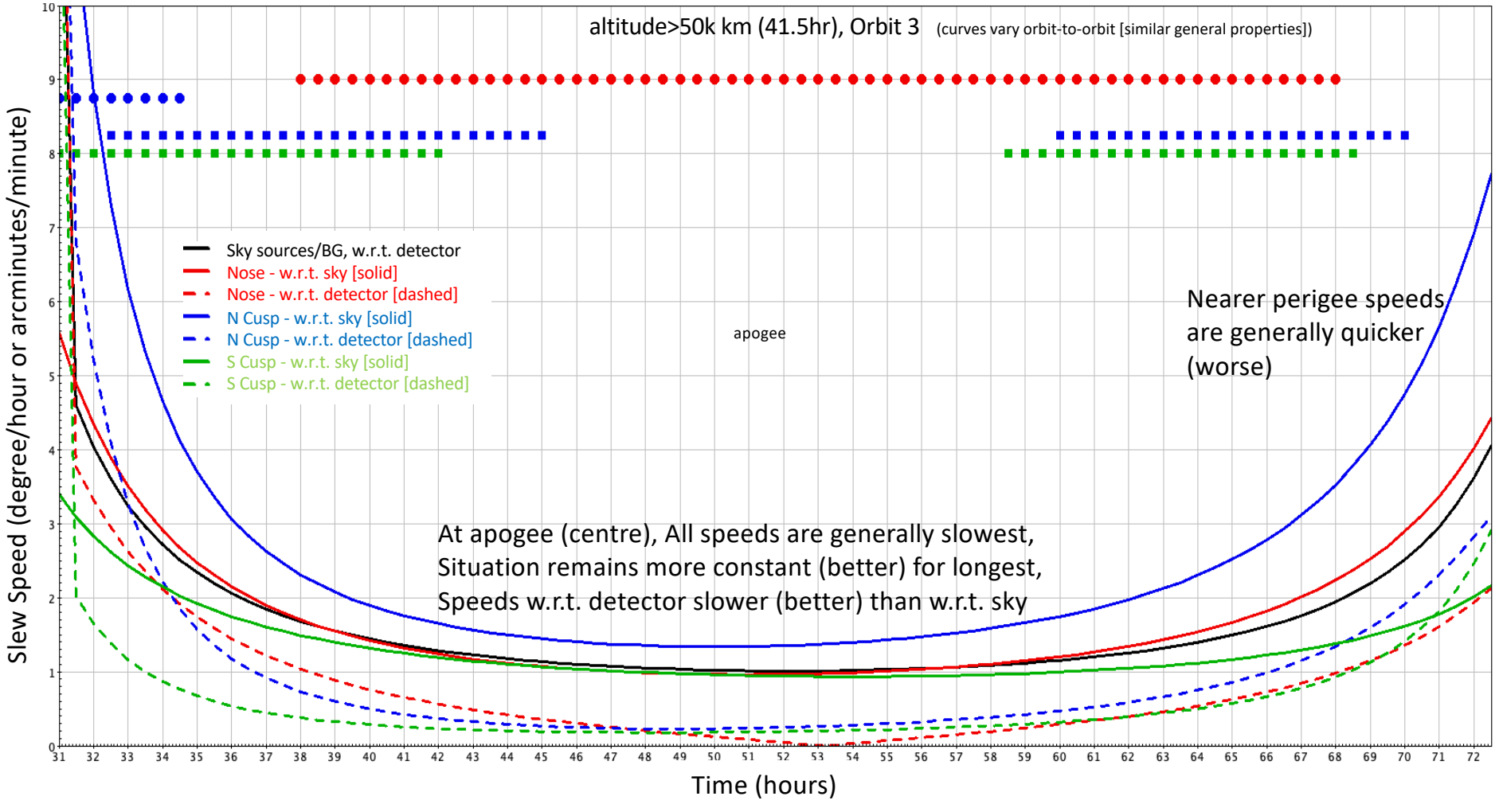


- Simple Event file of SXI output (positions, timings of X-ray photons, no detector response [old])
- Target emission (Magnetosheath+Cusps), BG (photon & particle), bright cosmic X-ray sources
- One typical orbit (~41.5 hours of on-time)

- Sky coordinates
- X/Y
- +WCS=RA/Dec

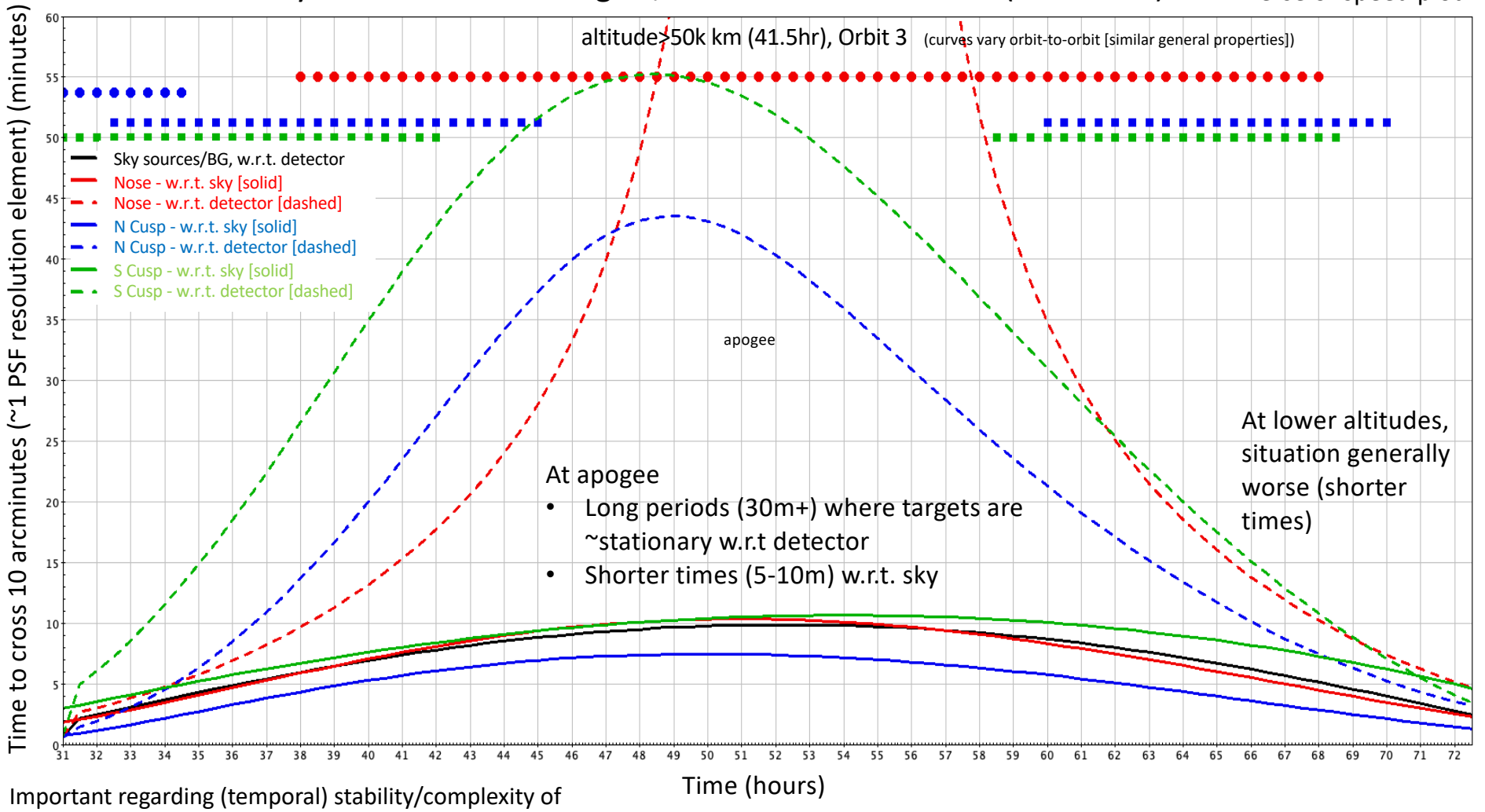


Angular Speeds of Targets/Sources across Sky & Detector



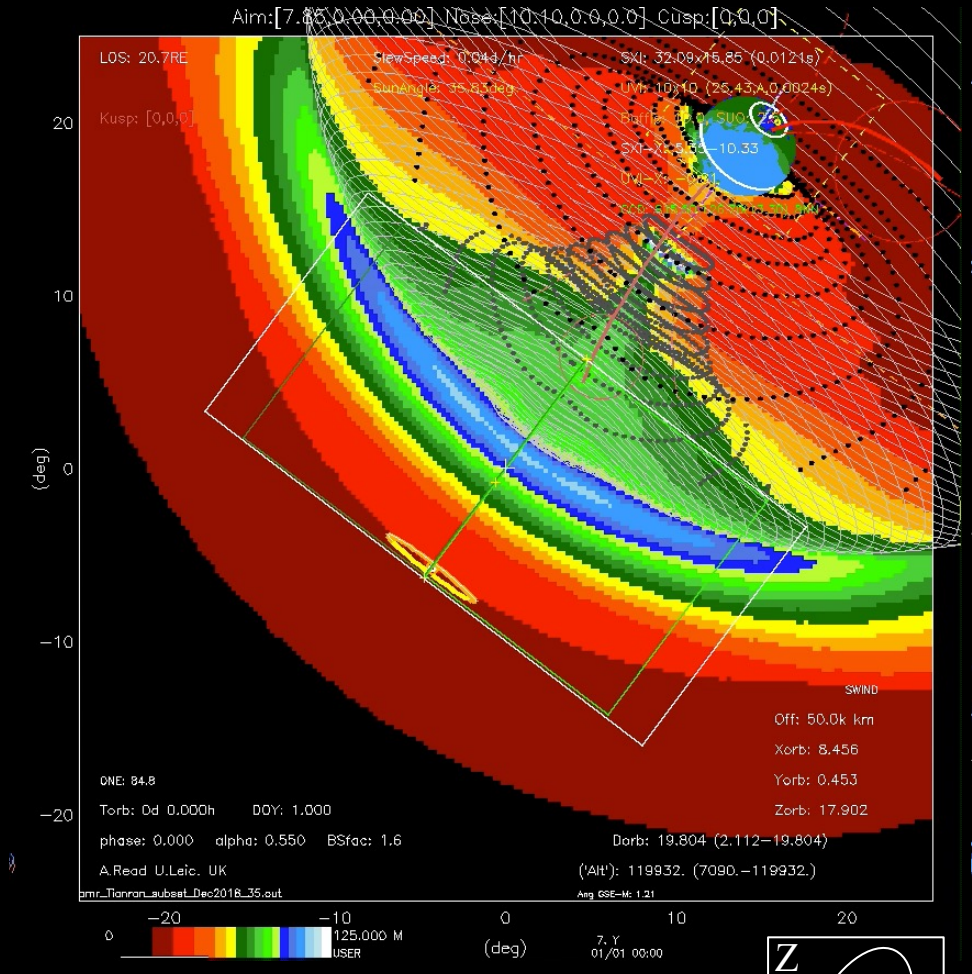
Stability - Time Taken for Targets/Sources to cross ~1 PSF (10 arcmin)

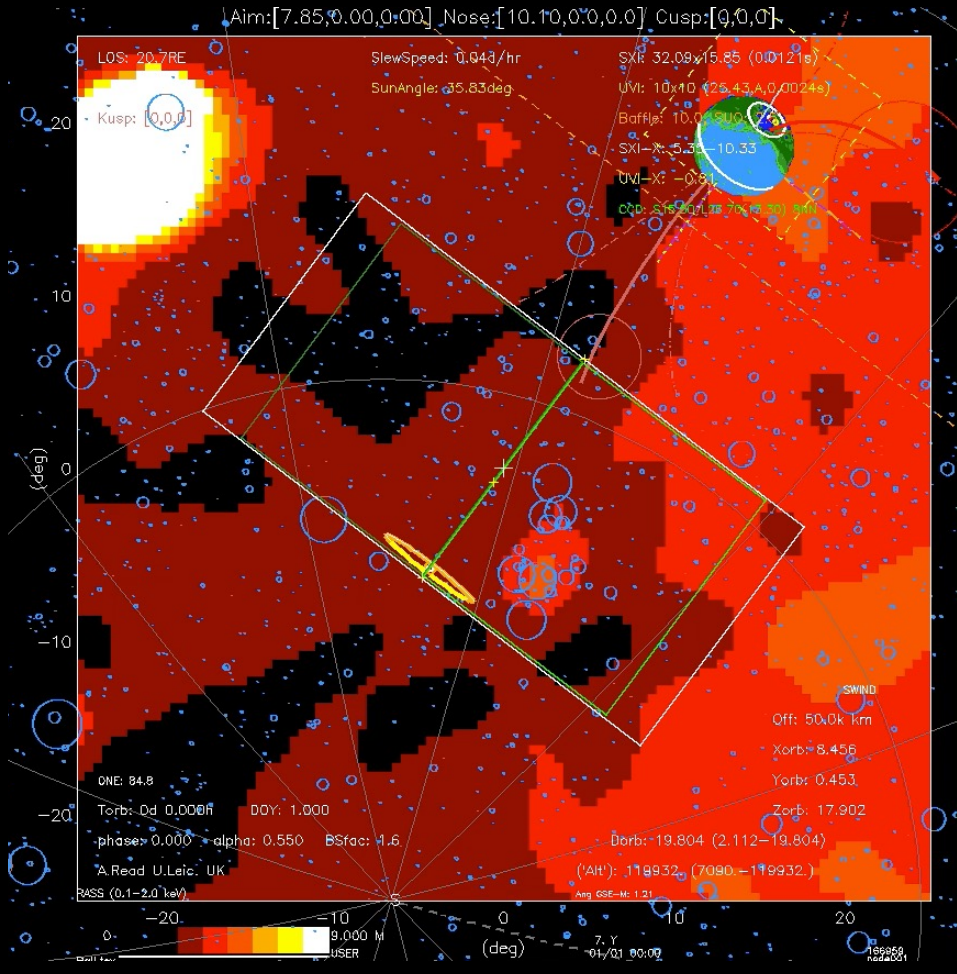
Inverse of speed plot

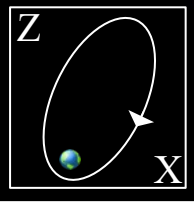


Important regarding (temporal) stability/complexity of

- Background - both sky (cosmic sources & diffuse emission) and instrumental
- Detector response







Target emission – magnetosheath & cusps
Single orbit, April 2025

Background: Diffuse X-rays (incl. Vela SNR) & cosmic sources
Predicted SXI diffuse count rate maps - created using all-sky spectral fits to RASS (ROSAT PSPC) data + SXI response - C.Pagani + AR
Point sources from ROSAT Bright Source Catalogue

SXI diffuse X-ray BG maps and bright BG point sources for the six calibration regions

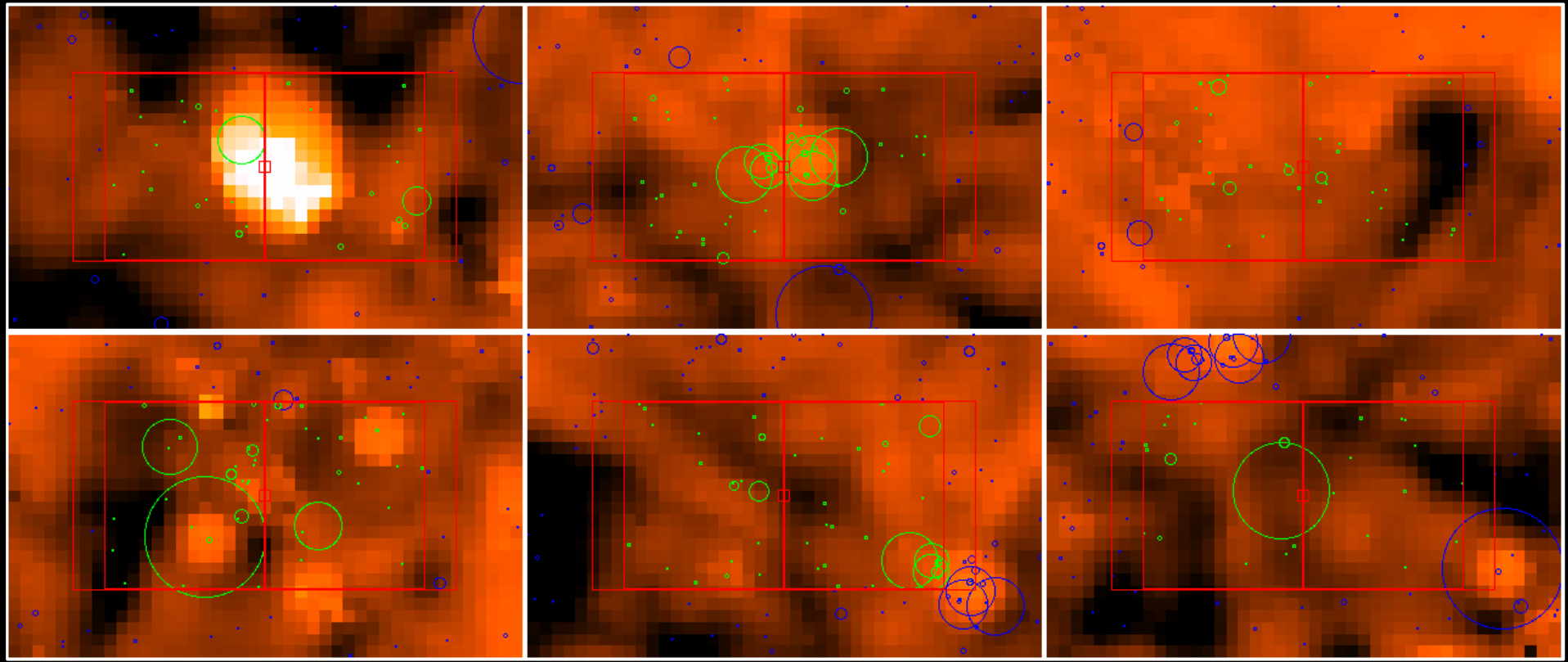
- SXI pointings extracted from 2025 orbit + guidance law (attitude)

Circle size ~ Source brightness

Vela: contains the large Vela SNR, smaller Puppis SNR, plus Puppis A and the Vela PSR

LMC: contains many bright point and compact sources (N132D, AB Dor, LMC-X2, LMC-X3)

SMC: contains many bright known sources, notably 1ES0102



Musca (+Crux): contains a number of bright sources in the Galactic Plane (GX 301-2, GU Mus, GR Mus, GT Mus etc.)

PKS0558: Useful well-studied source (parts of the LMC may also enter occasionally)

EXO0748: Useful well-studied source (parts of the LMC and Musca may also enter occasionally)

END