Effects of Background

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Relative Importance

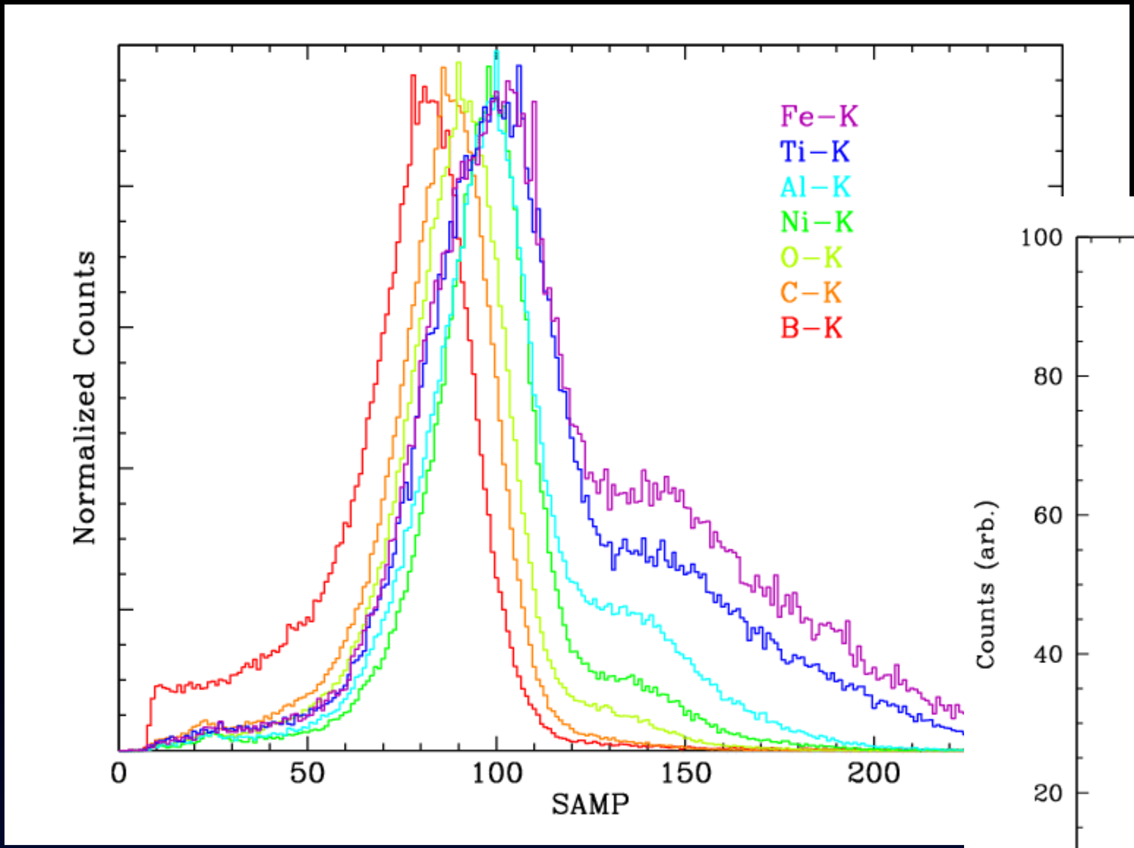
Rates (ct/s/arcsec^2):

• ACIS front-illuminated (FI)	1×10^{-6} (L2, 0.3-10 keV)
• ACIS back-illuminated (BI)	3×10^{-6}
• HRC-I	2×10^{-5} (L2)
• HRC-S	6×10^{-5}

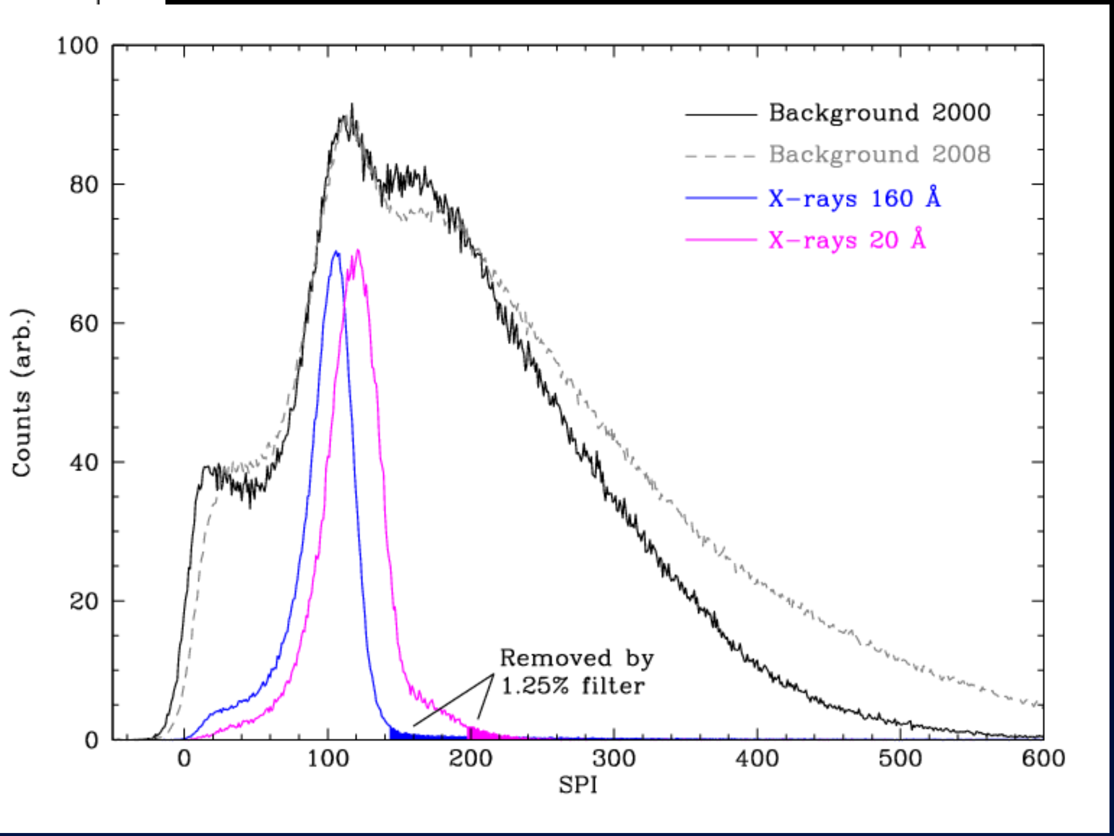
ACIS has energy resolution (~150 eV FWHM) so its effective BG is lower.

Token Mention of HRC

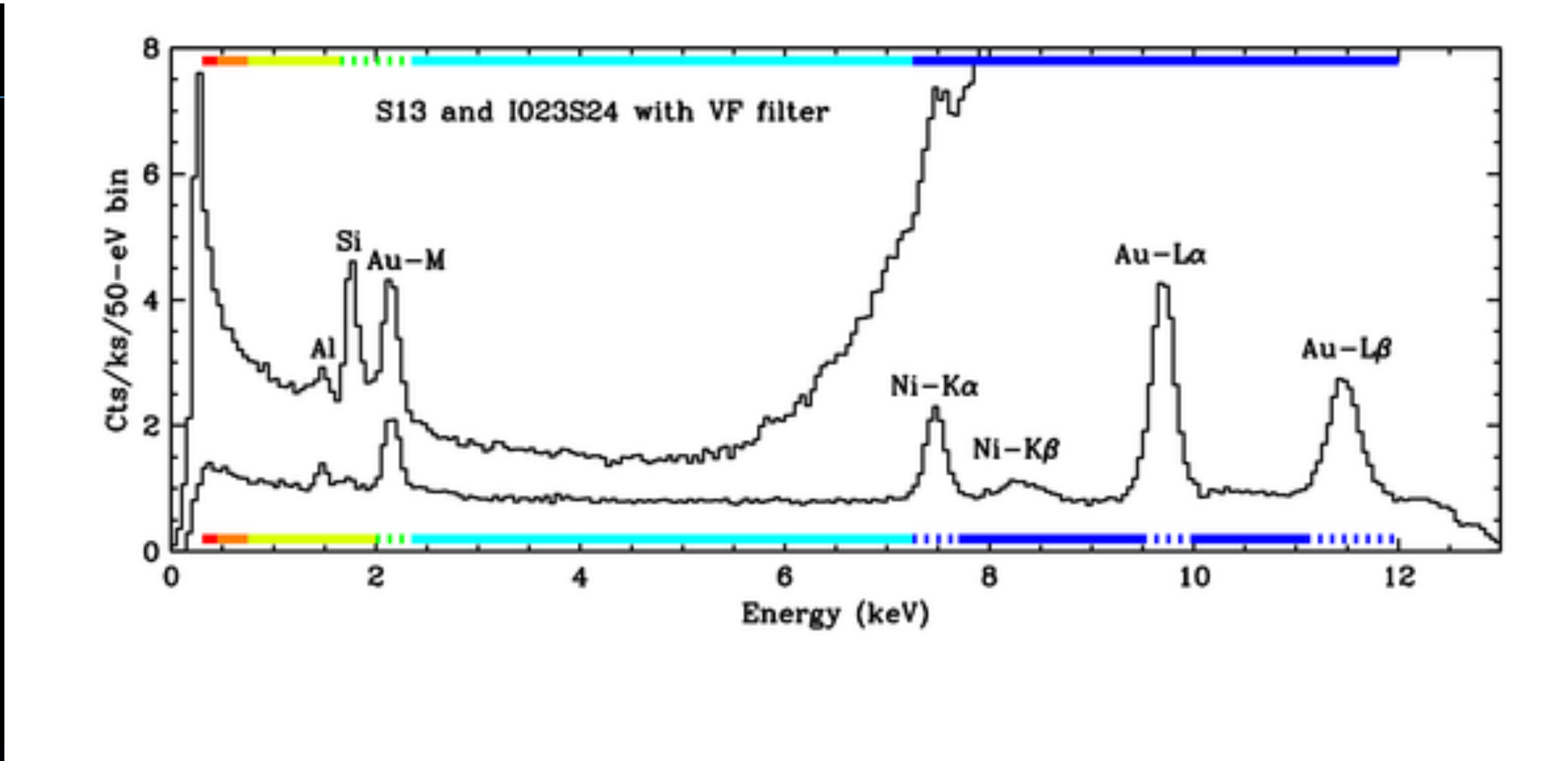
Ground calibration data



Flight data



HRC-S has a wee bit of energy resolution, useful for LETG/HRC-S BG reduction

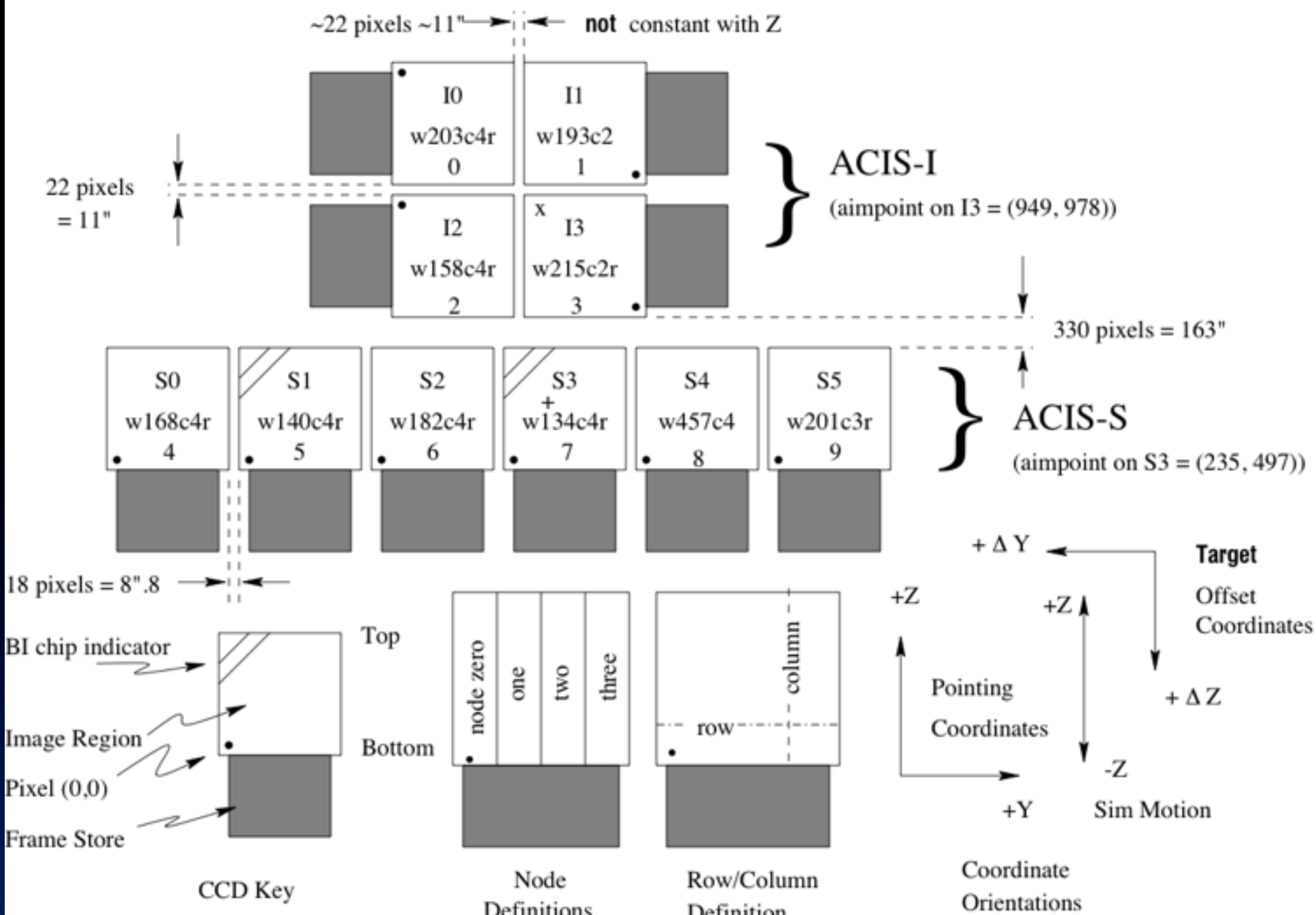


ACIS BG

Top curve = BI chips (average)
Bottom curve = FI chips (average)

Continuum + instrumental fluorescence lines

ACIS FLIGHT FOCAL PLANE



The Prime Directives
(or, What's the Point?)

Reduce the BG (to improve S/N)
Subtract or model the BG (to determine source strength)

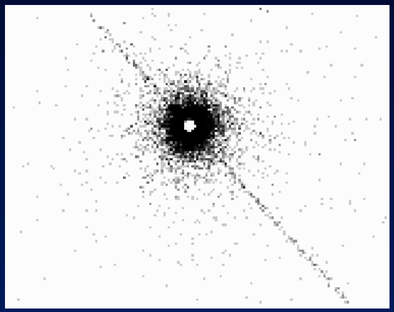
Point source: use nearby BG region in that observation.
Extended source: use nearby BG if there's space.
If not, use a CALDB BG file and scale it,
normalizing to high energy channels.

X-Ray vs Detector BG

Detector BG from cosmic rays and solar particles. Dominates at most energies.

X-ray BG (significant at low energies):

- Extragalactic (absorbed power law--Galactic $N_{H,}$ index -1.46)
- Galactic halo (absorbed thermal, kT~0.2 keV)
- Local Bubble (unabsorbed thermal, kT~0.1 keV)
- Solar wind charge exchange (pseudo-thermal, kT~0.1 keV)
- (Also readout streaks from bright sources)

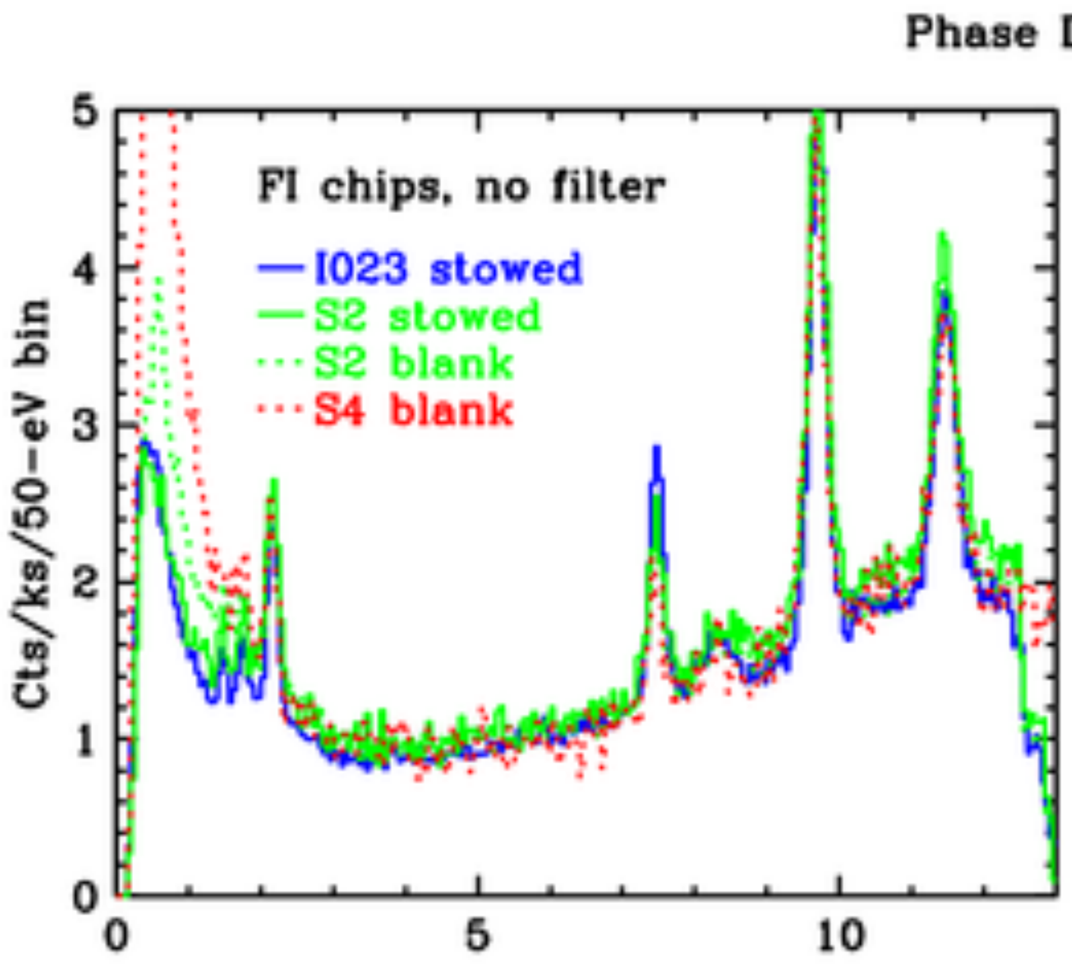


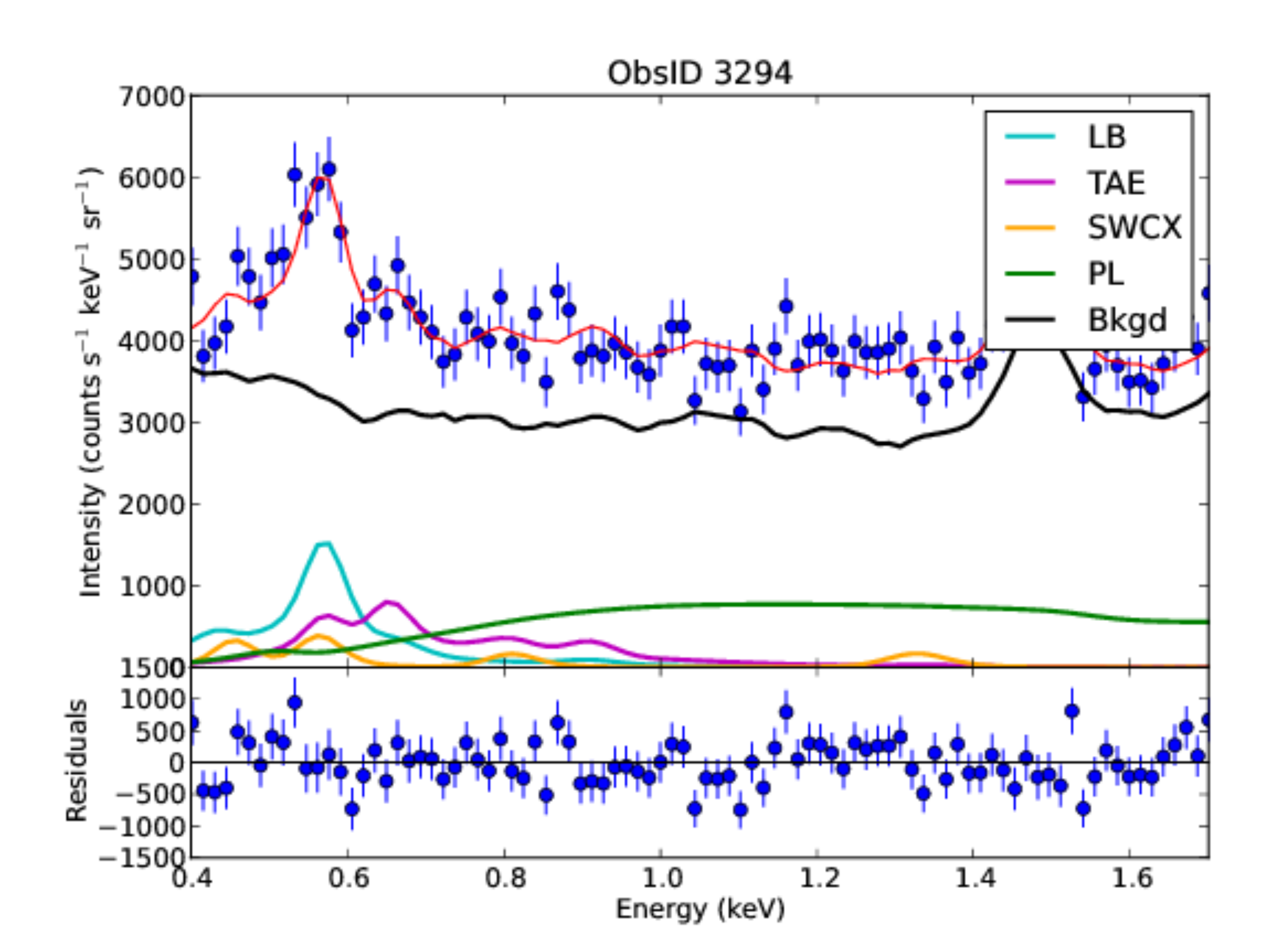
X-Ray vs Detector BG

Detector BG in “ACIS stowed” files.

Detector BG + typical X-ray BG in “Blank Sky” files

Both available in CALDB (extra download)





Total

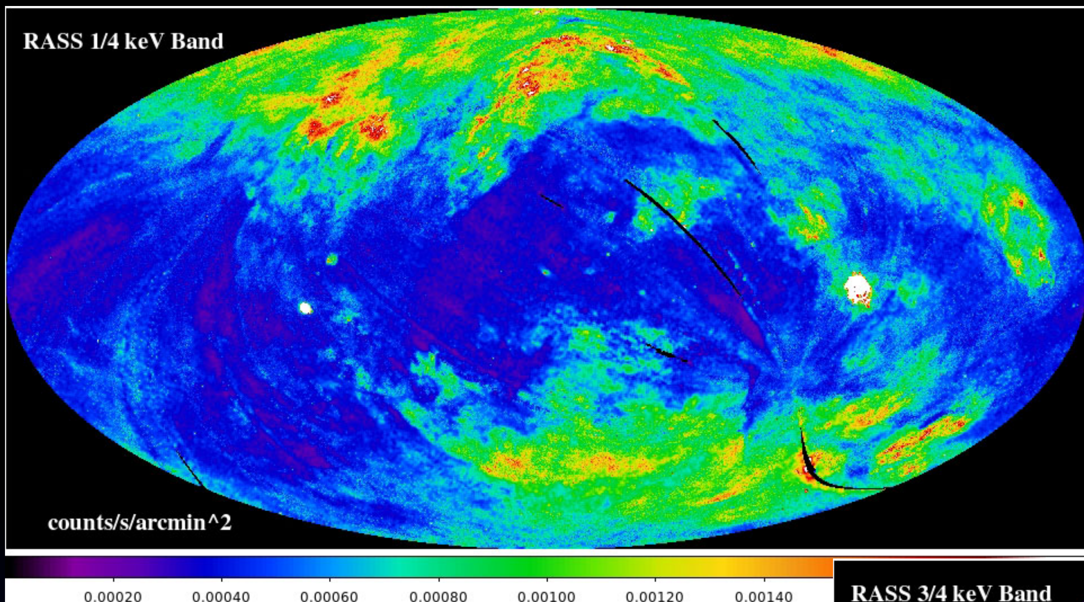
Detector BG

X-ray components

Residuals

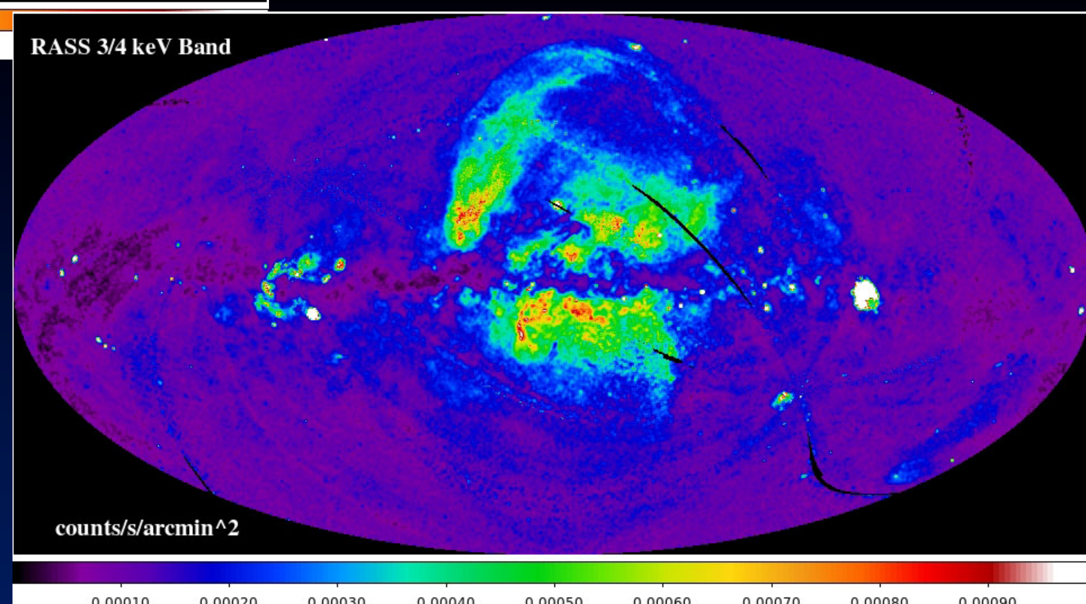
Hubble Deep Field-North ACIS-I Spectrum

X-ray BG



Blank sky fields are in dim parts of the sky with |b|>20 deg. Sources “identifiable by eye” are removed.

Blank sky data are divided into epochs but the X-ray/det BG ratio is affected by t-dep QE, solar cycle, etc.



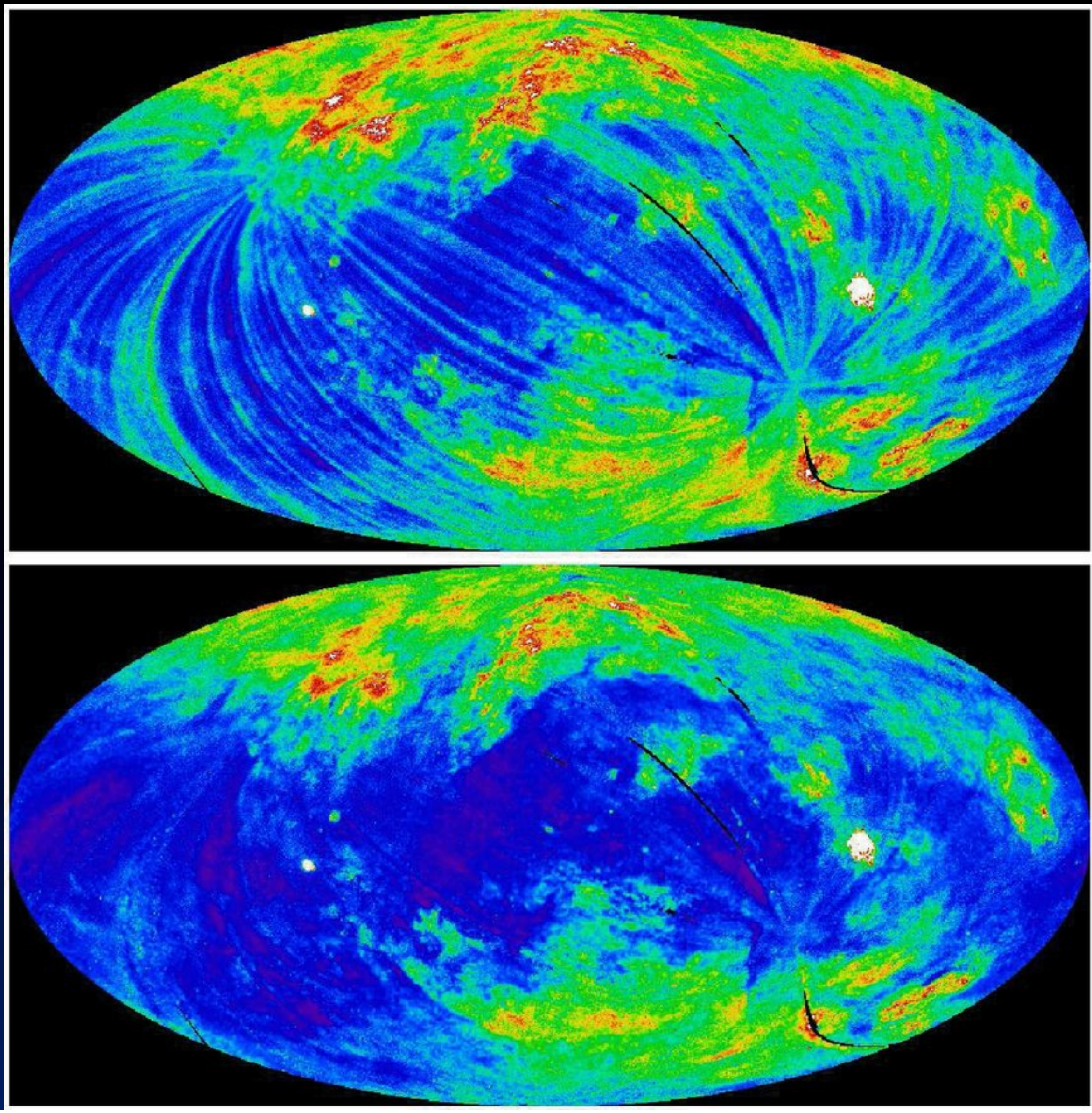
X-ray and Detector BG are Variable

X-rays: SWCX (hours to years)

Detector BG:

- Solar cycle (days to years, cosmic rays)
- BG flares (minutes to hours, solar particles)

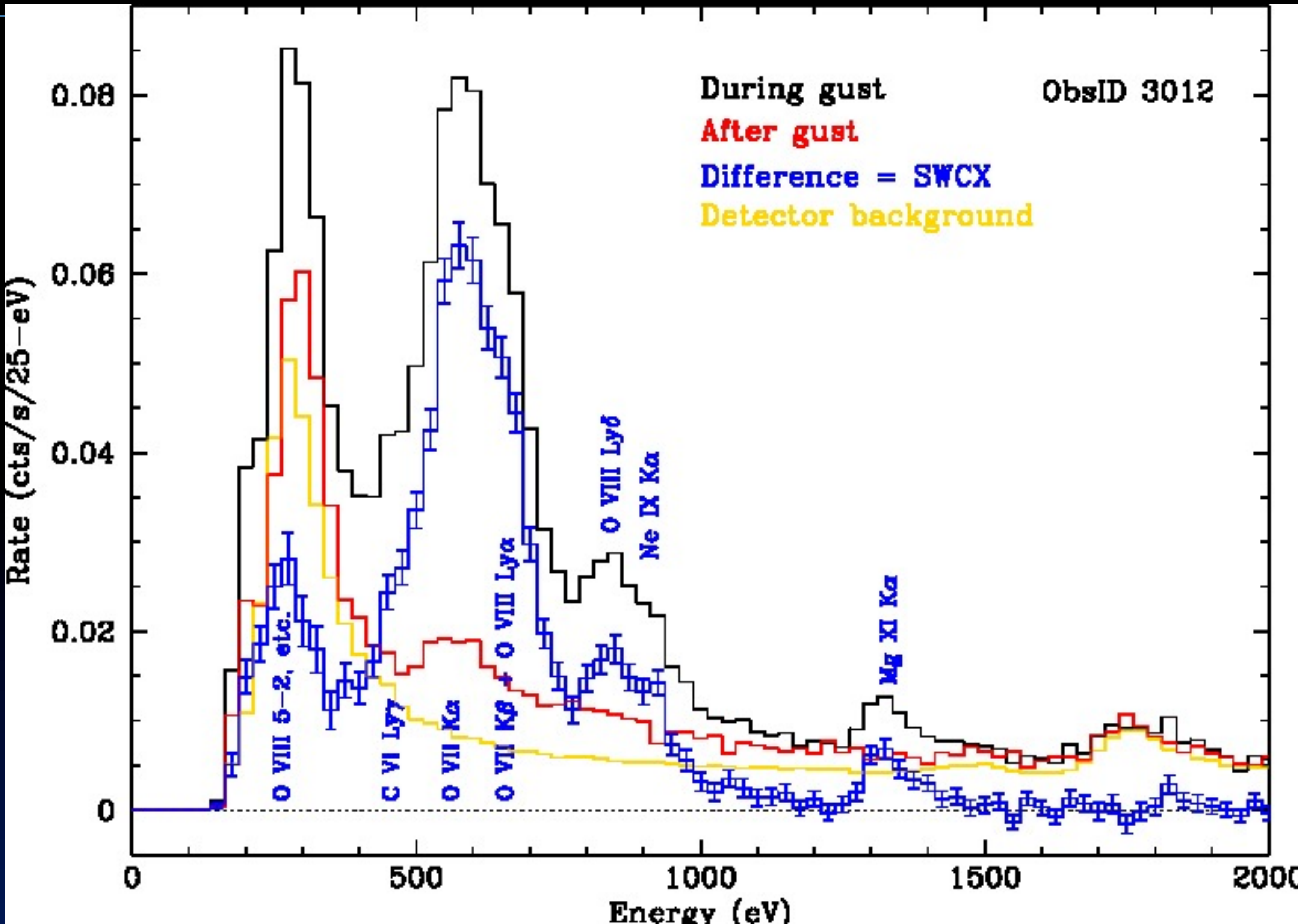
Solar Wind Charge Exchange (SWCX)



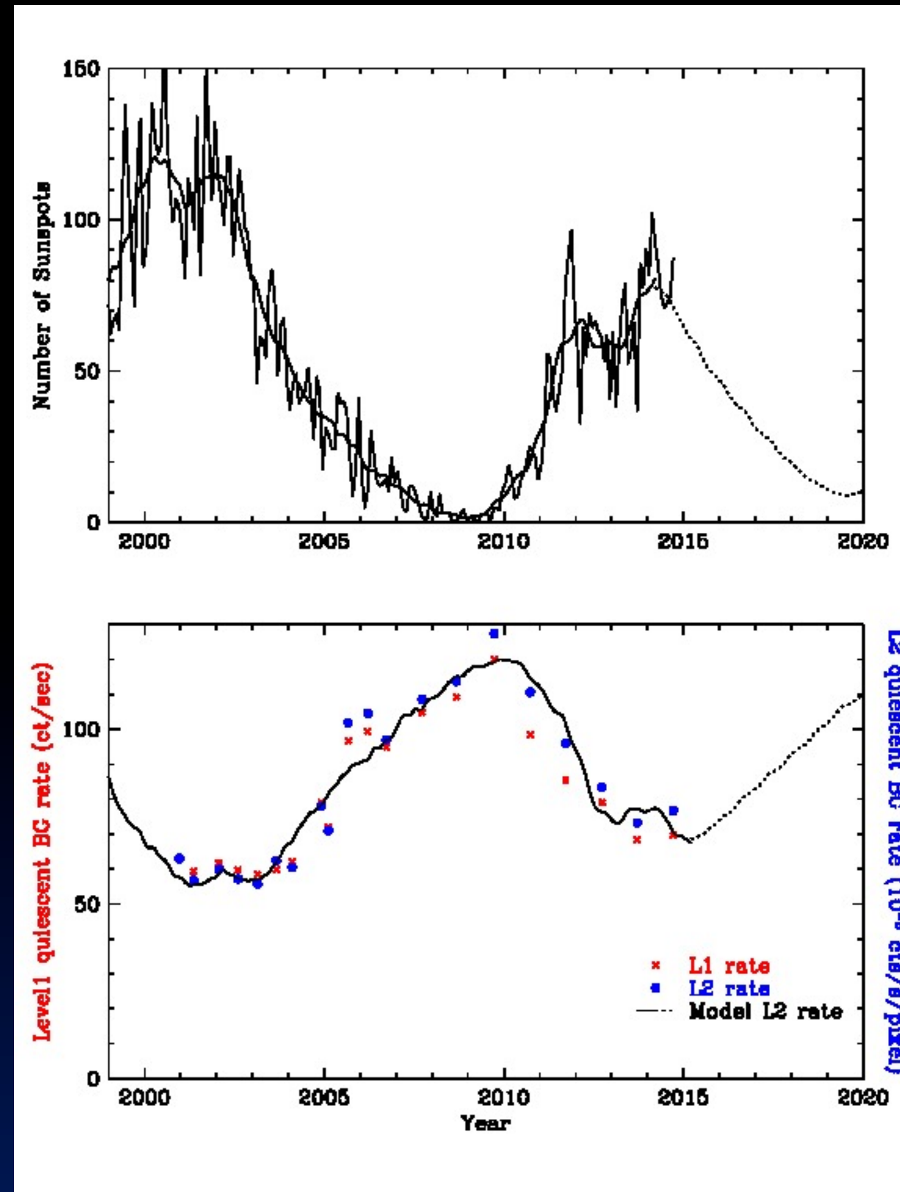
ROSAT LTEs are from geo/helio SWCX fluctuations

Variability caused by solar wind gusts, changing viewing geometry (about Earth and Sun), and solar cycle effect on heliospheric neutral gas.

¼-keV band, Galactic coords; Snowden et al. (2009)

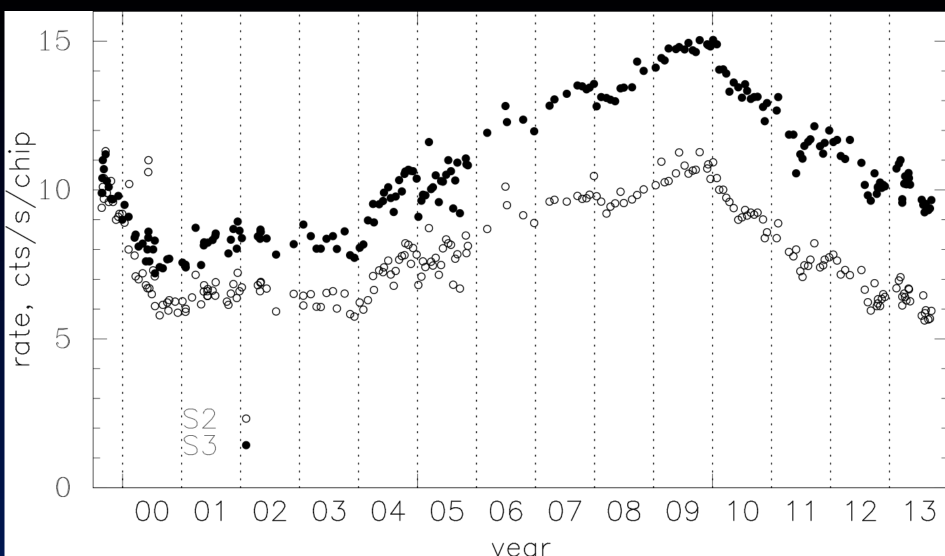

During gust
After gust
Difference = SWCX
Detector background
ObsID 3012
O VIII 5−2, etc.
C VI Lyγ
O VII Kα
O VII Kβ + O VIII Lyα
O VIII Lyδ
Ne IX Kα
Mg XI Kα
Rate (cts/s/25−eV)
0
0.02
0.04
0.06
0.08
0
500
1000
1500
2000
Energy (eV)

HRC-S



Increased solar activity (more sunspots)
→ stronger magnetic field
→ fewer CRs get into heliosphere
(with ~1 year lag for solar wind transit)

ACIS (S2, S3)

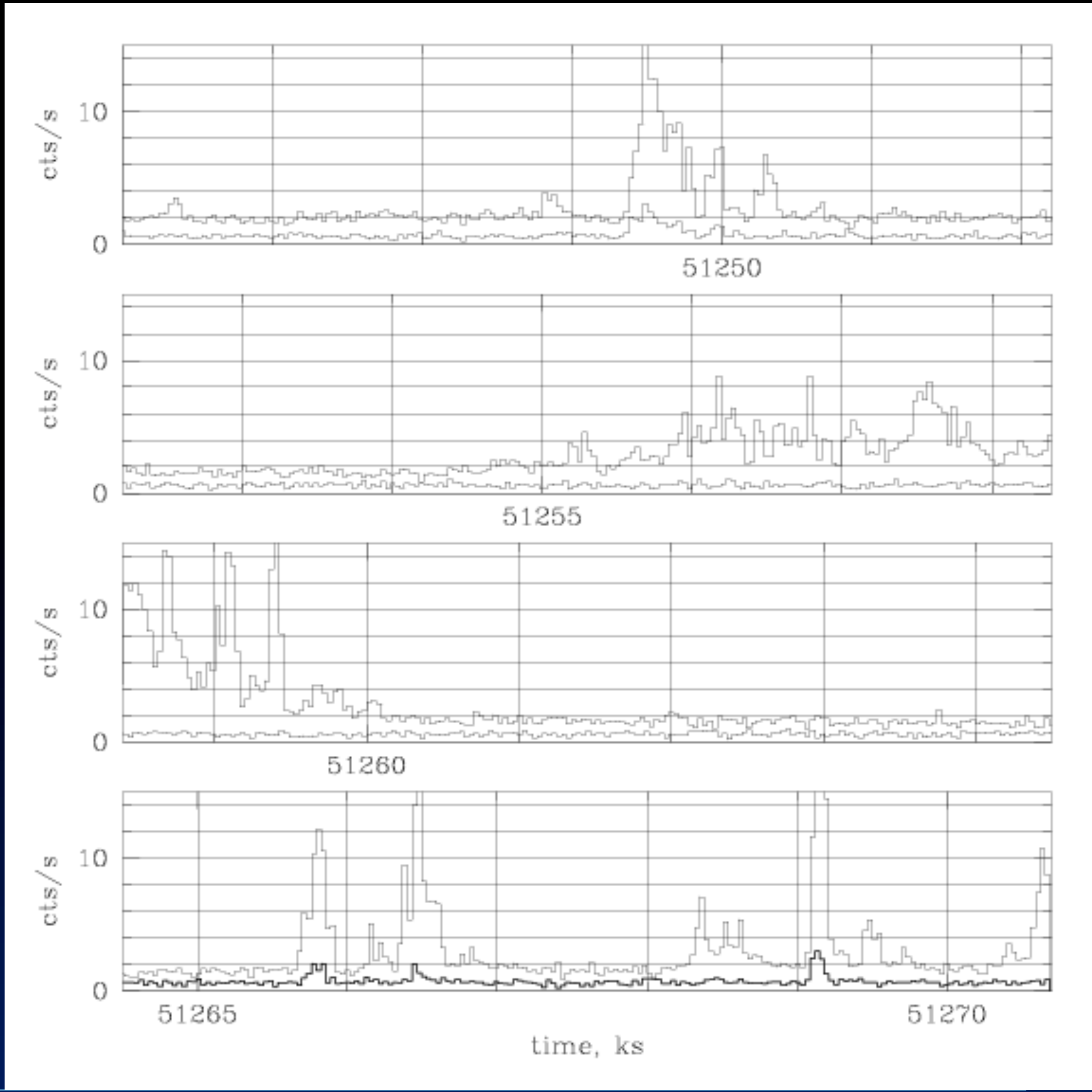


BG Flares

Caused by non-CR charged particles (solar protons?) that make it past the baffles.

Top trace is S3 (BI), bottom S2 (FI).

BI chips more sensitive to low-energy flares.



BG Flare Removal

`deflare`

Remove all sources (to improve S/N of BG and eliminate X-ray variability).

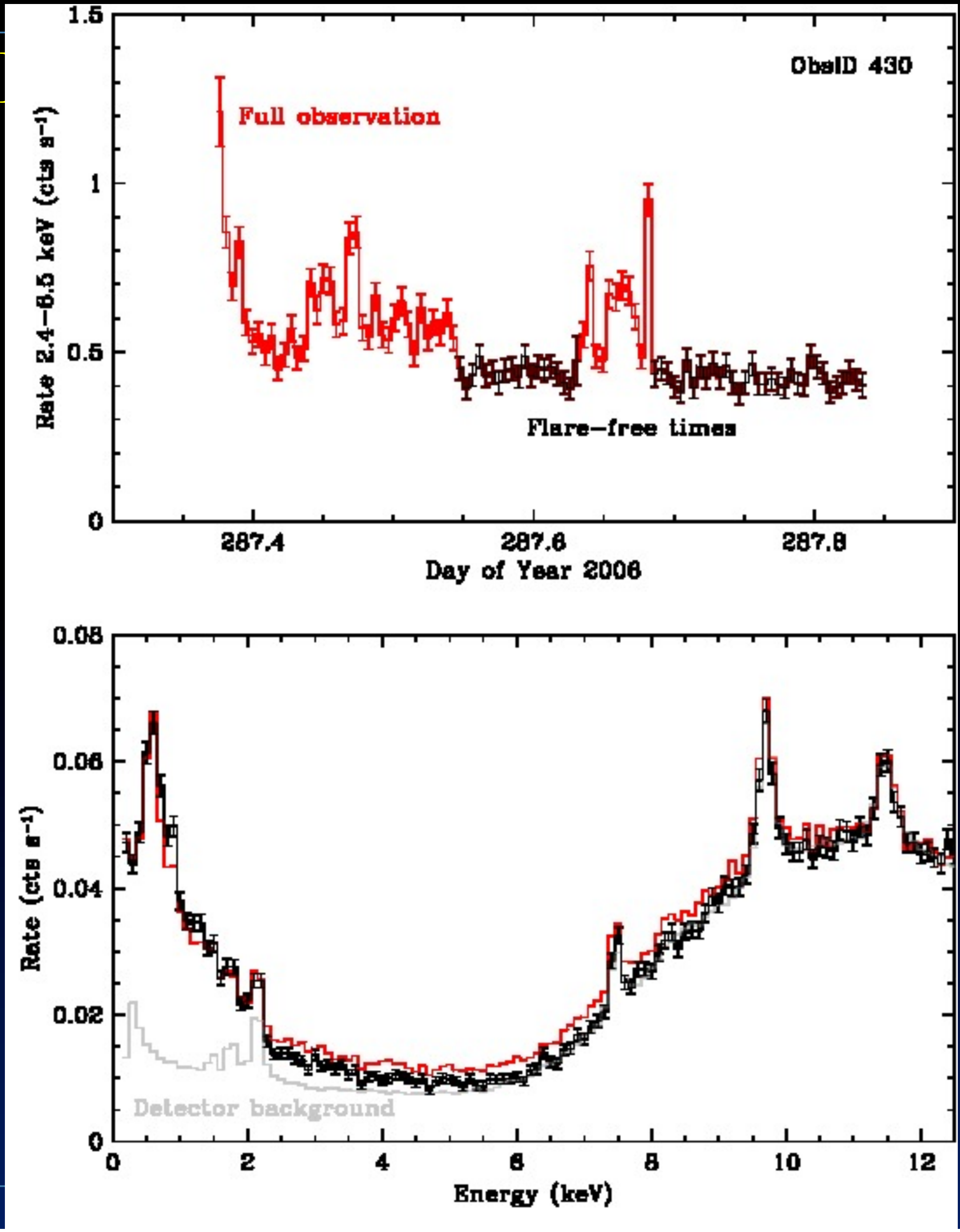
Usually best to look in 2.4-6 keV range: below may be affected by SWCX, above has high BG.

BI and FI may be affected differently—check/treat separately.

Can also be used on HRC, or use DTF filtering (ask Helpdesk)

Will flare removal help S/N? For point sources, probably only if the flare is short and intense, otherwise it may be best to ignore.

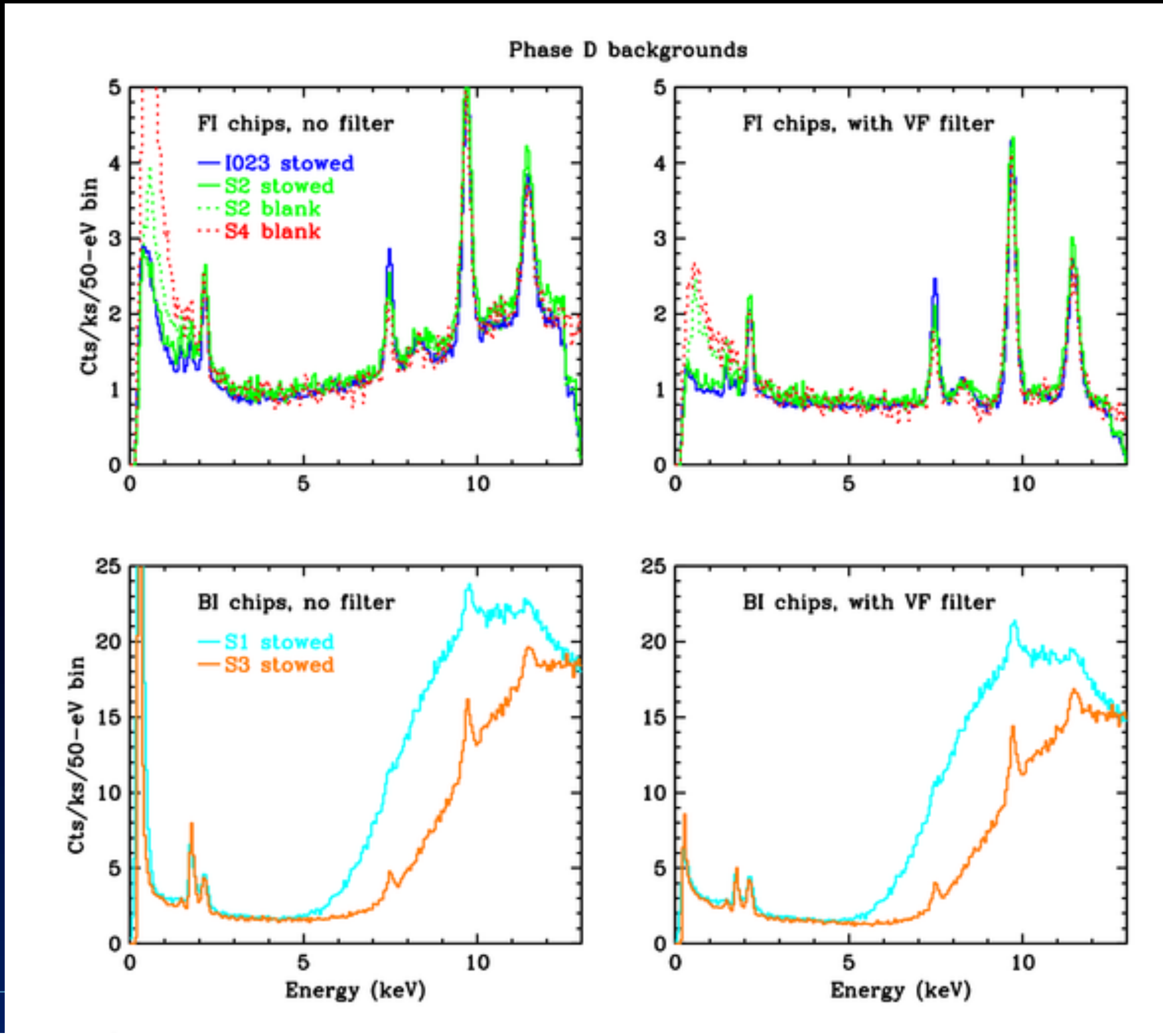
Flare removal IS necessary if you're studying the X-ray BG because the flare spectrum is not known.



32	64	128
8	0	16
1	2	4

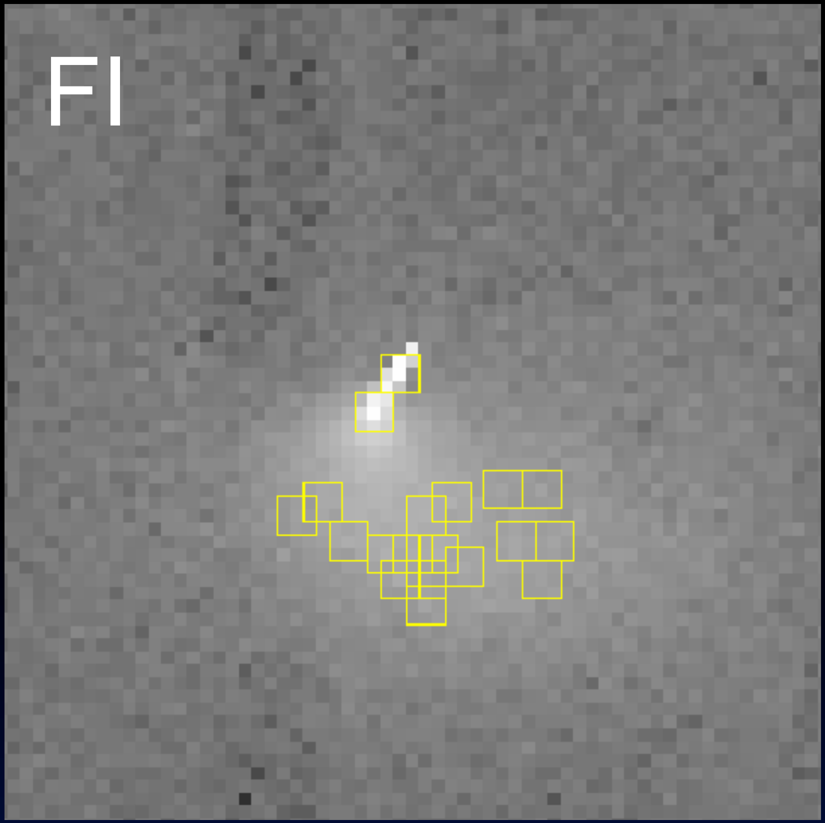
VF Filtering

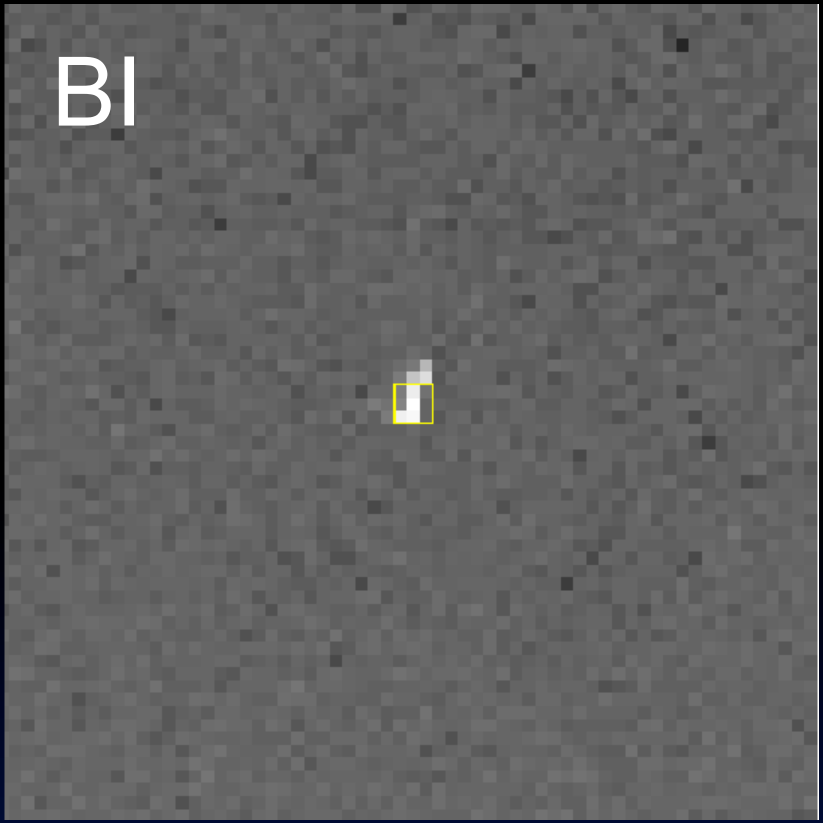
- In VF mode, events record info from 5x5 island instead of normal 3x3 → CRs easier to ID.
- VF filtering removes 1-2% of weak/diffuse X-ray events but…
- Do NOT apply if studying brightish point sources. (Readout streak and PSF wings look like CR hits.)
- Must reprocess with `check_vf_pha=yes`



32	64	128
8	0	16
1	2	4

FI vs BI and 5x5 vs 3x3 (VF vs F)

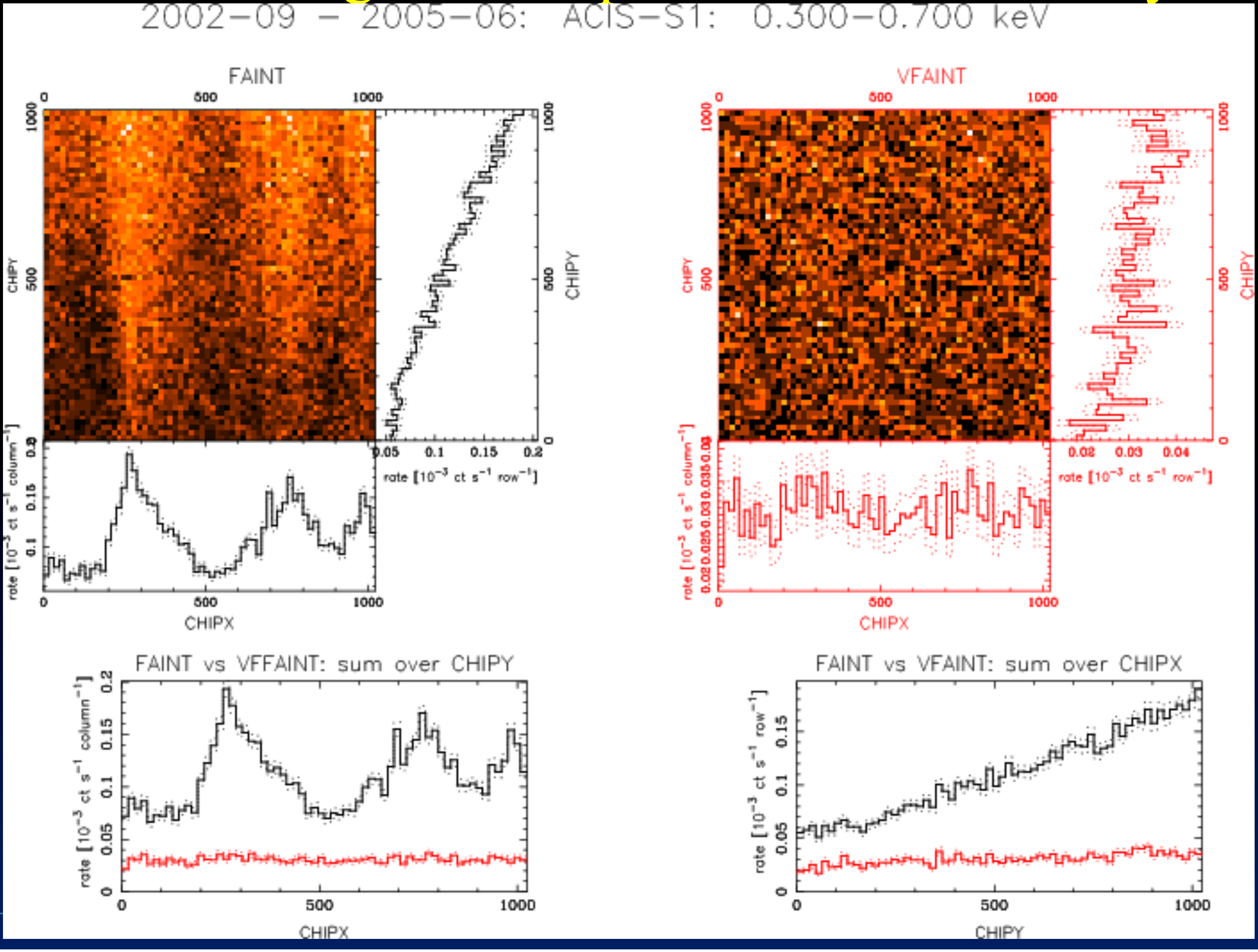




FIs have thicker depletion region → CRs deposit more charge along longer path → easier to ID, so lower BG than BIs.

5x5 island (not shown) contains more info than standard 3x3 (shown).

VF Filtering Also Improves BG Uniformity

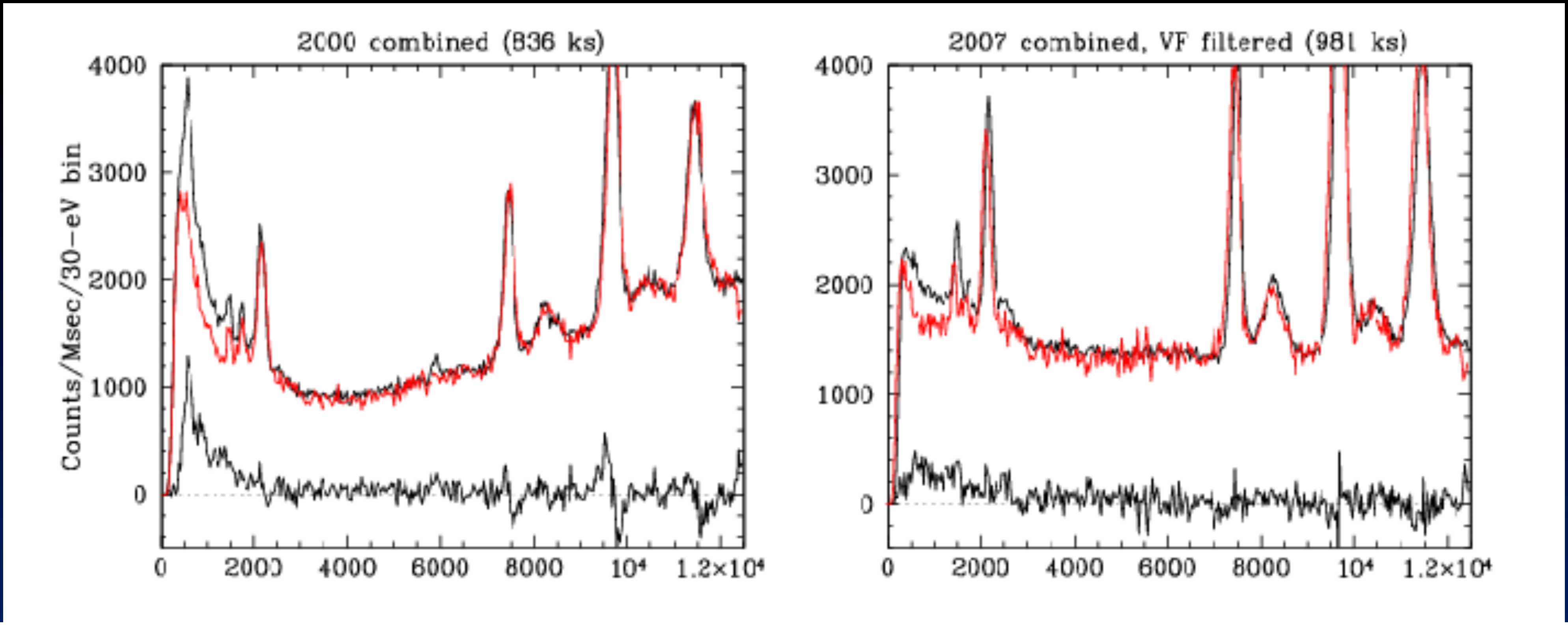


BG nonuniformity and normalization

If using Blank Sky or ACIS Stowed BG files, it's a good idea to `reproject_events` on the sky to match your observation, then apply the same extraction region to ensure you have the same BG (apart from the normalization) in each file.

Use 9.1-12.1 keV (after checking that your observation doesn't have an energy cutoff) for normalization---pure BG there, no X-ray events. But Blank Sky data are a mix of X-ray BG and detector BG; normalizing to high-energy rates scales the detector BG correctly but not necessarily the X-ray BG.

Energy calibration is good to 0.3%. At 10 keV that's 30 eV so don't be alarmed by "P Cygni" profiles after BG subtraction---that's why you use 9.1-12.1 keV for normalization---the spectrum is pretty flat at the boundaries so small shifts have negligible effect on counts.



CXC

Summary

Apply VF filtering if studying faint emission.

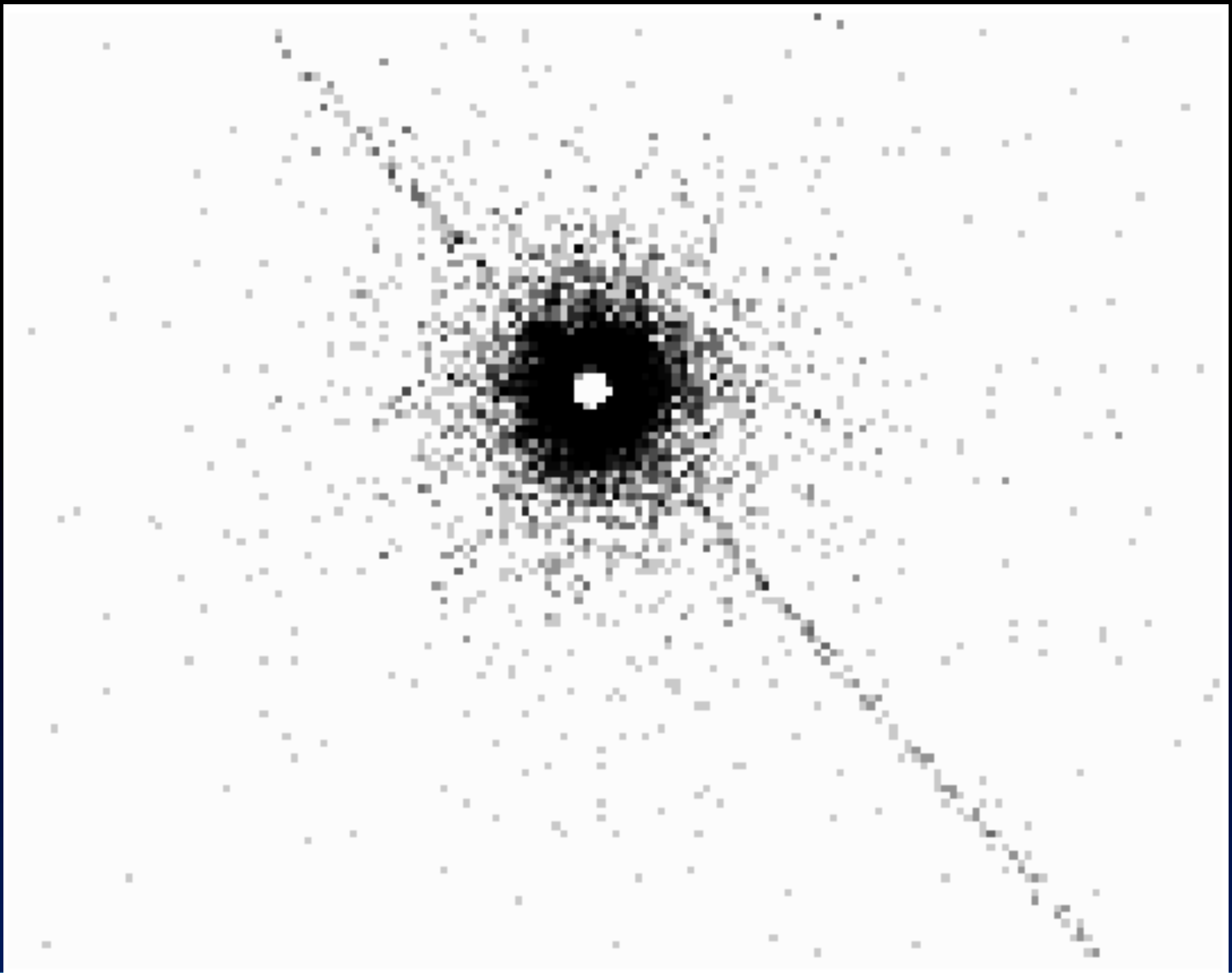
Look for BG flares (remove sources, check 2.4-6.5 keV light curve) and remove if it improves source S/N.

Using ACIS Stowed or Blank Sky BG data is complicated. (Ask for help.)

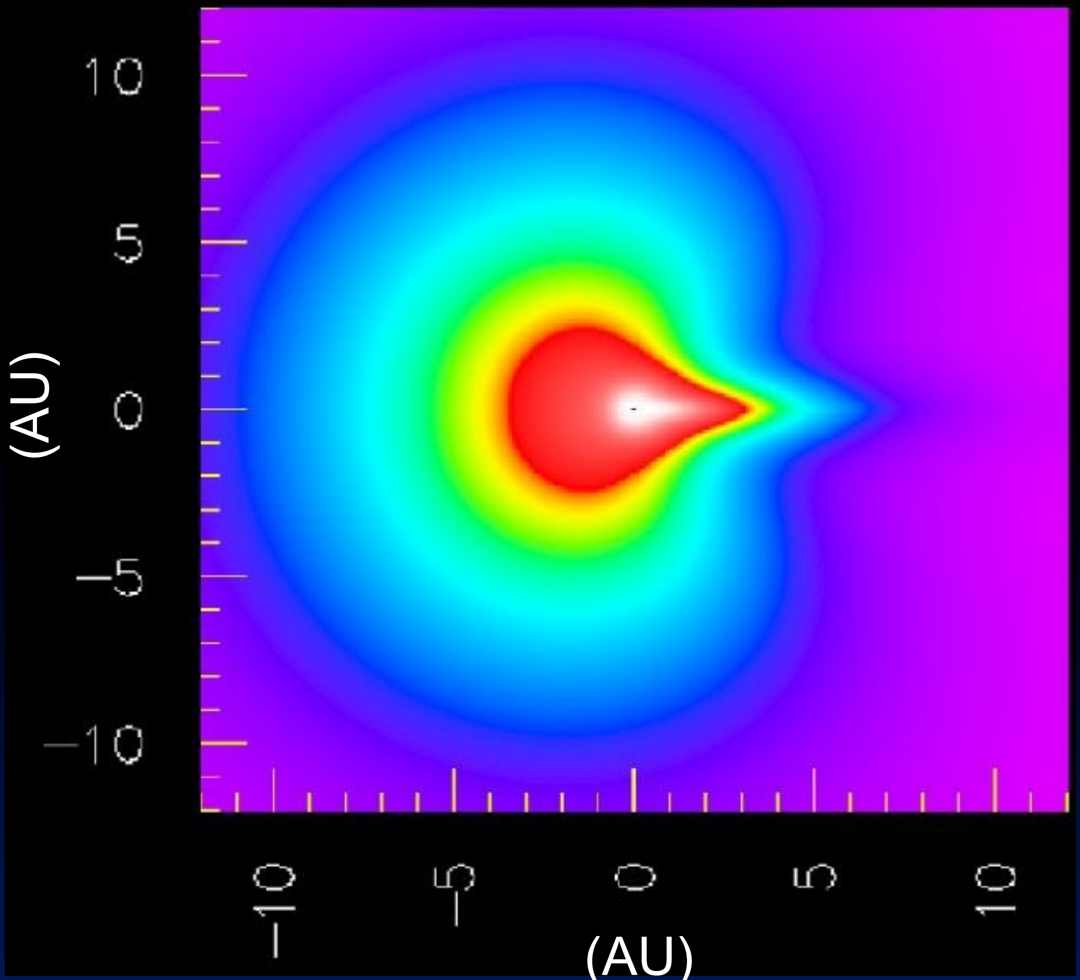
End

- Extra slides beyond here

Readout streaks



SWCX Emission--looking down on ecliptic plane

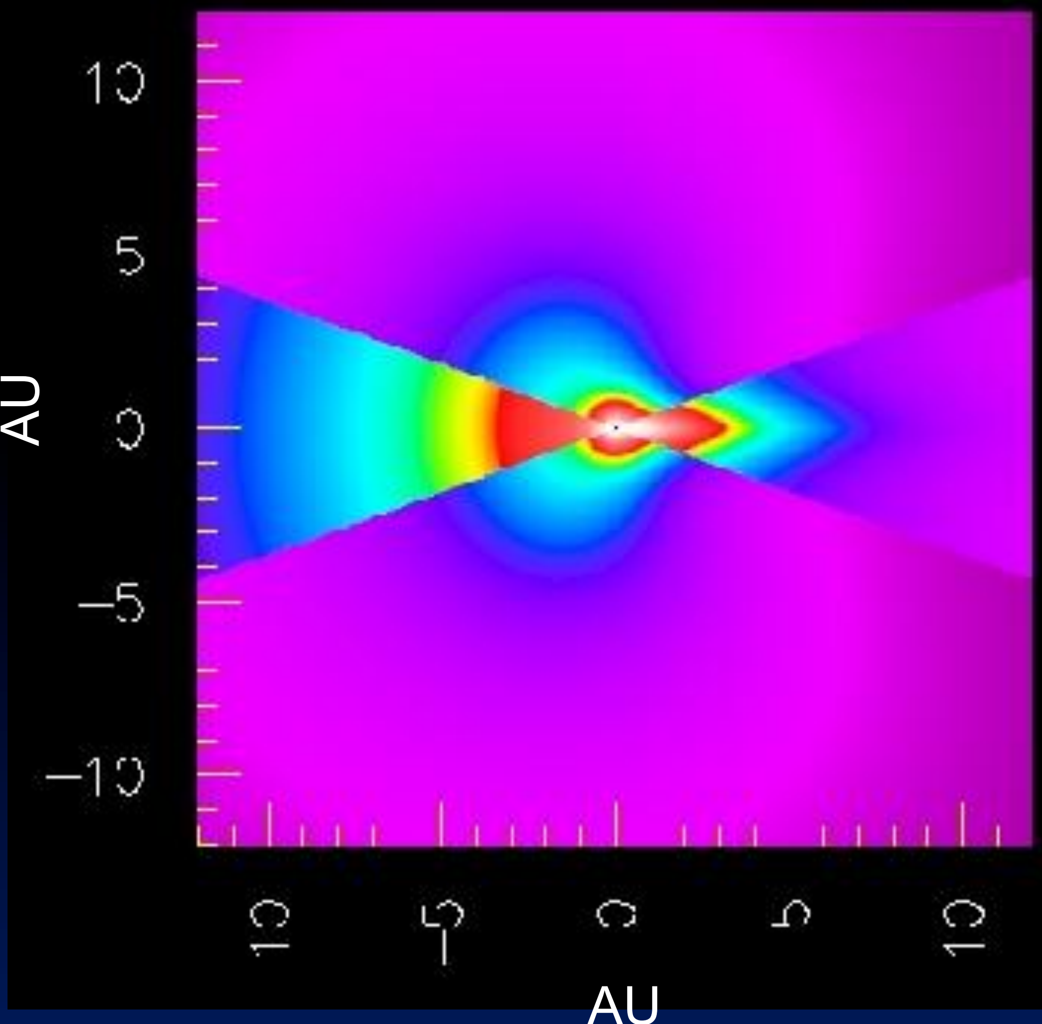


More neutral H upwind

He focussing cone downwind

Pepino et al., ApJ 2004

SWCX Emission at Solar Min--view from Ecliptic Plane

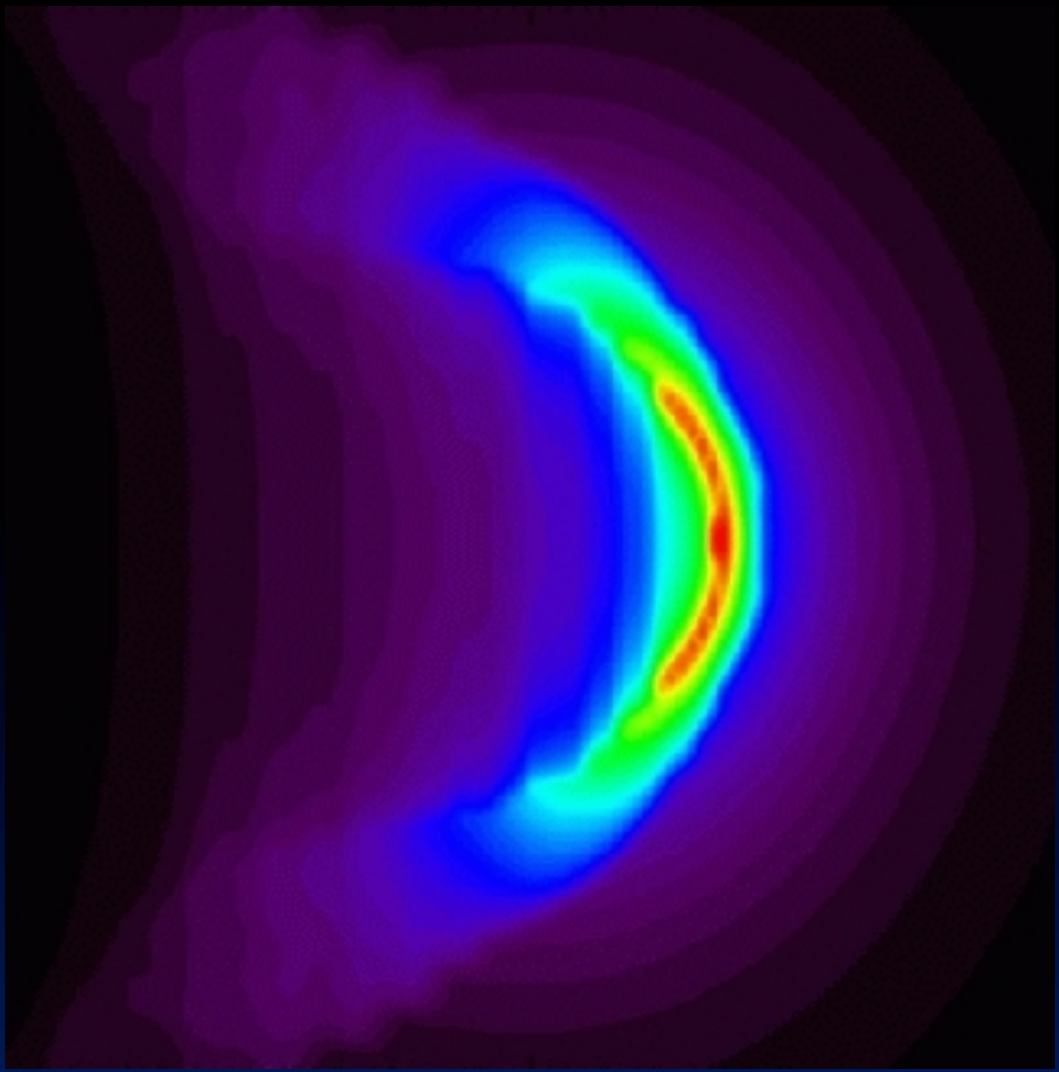


Stratified wind: slow and highly ionized near ecliptic $\Rightarrow$ higher CX emissivity.

Little emission in fast wind.

Pepino et al., ApJ 2004

Geocoronal SWCX Emission

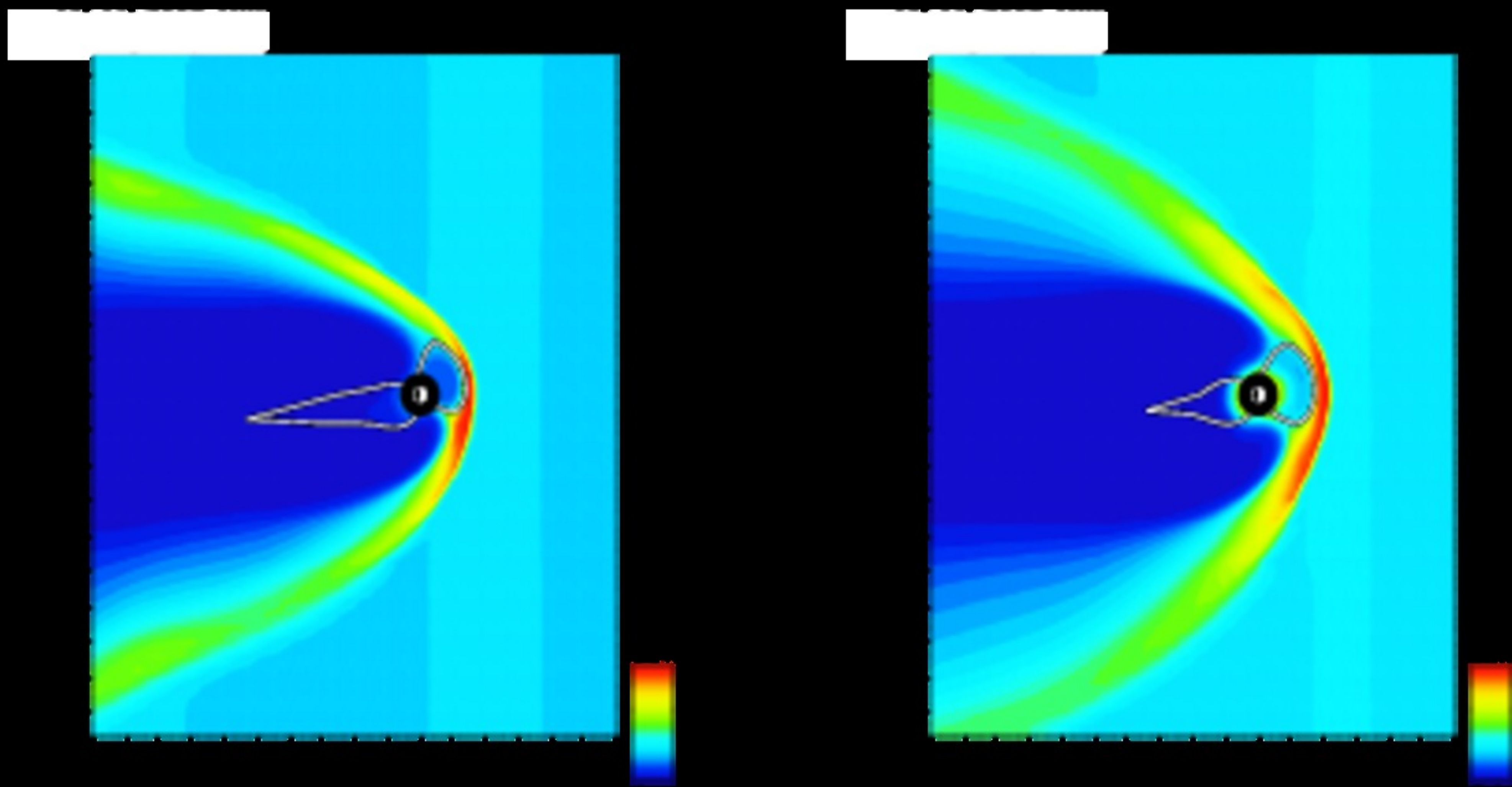


Robertson et al. (2006)

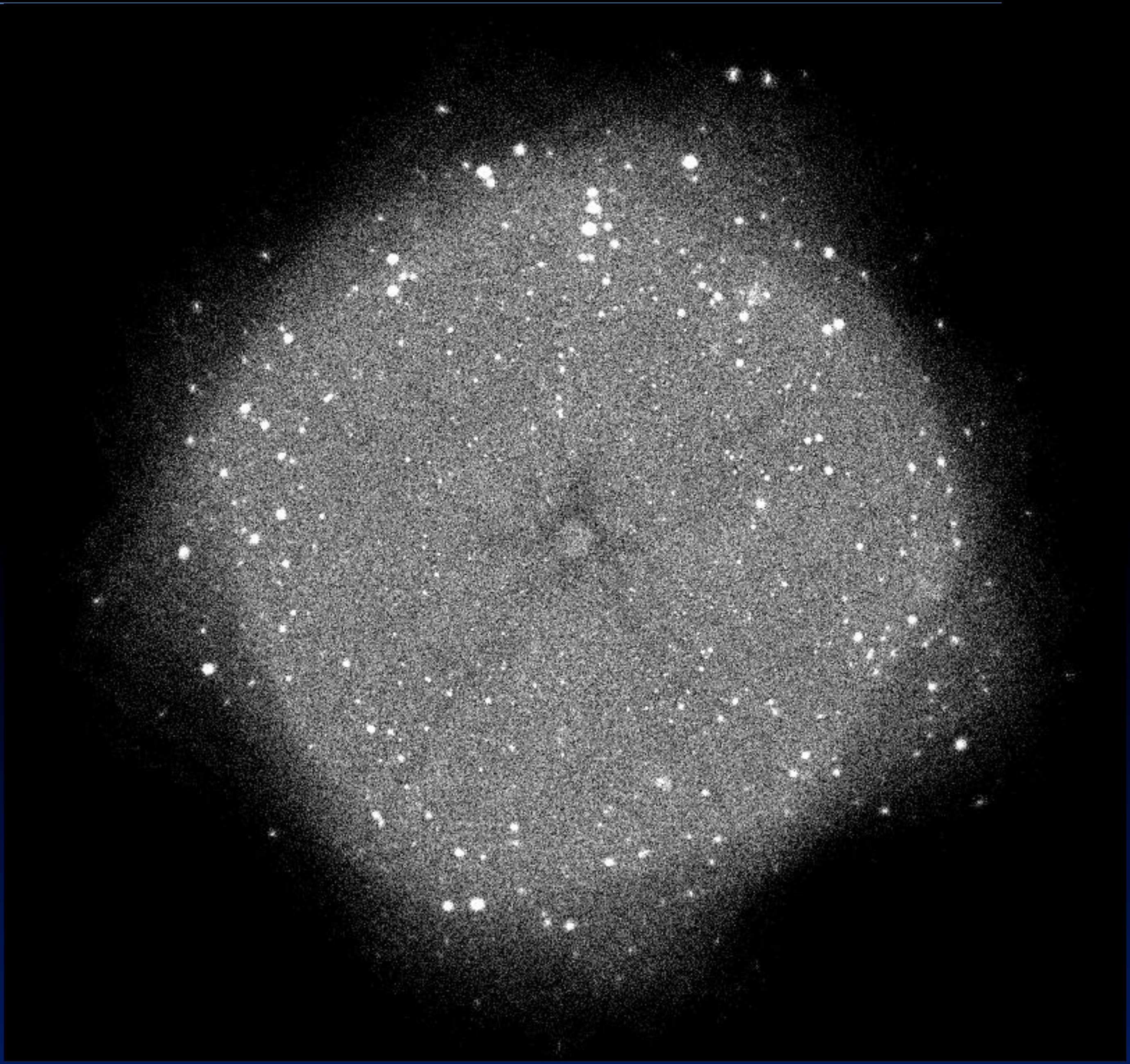
Geocoronal emission is from outside the magnetosphere ($R > 10R_E$).

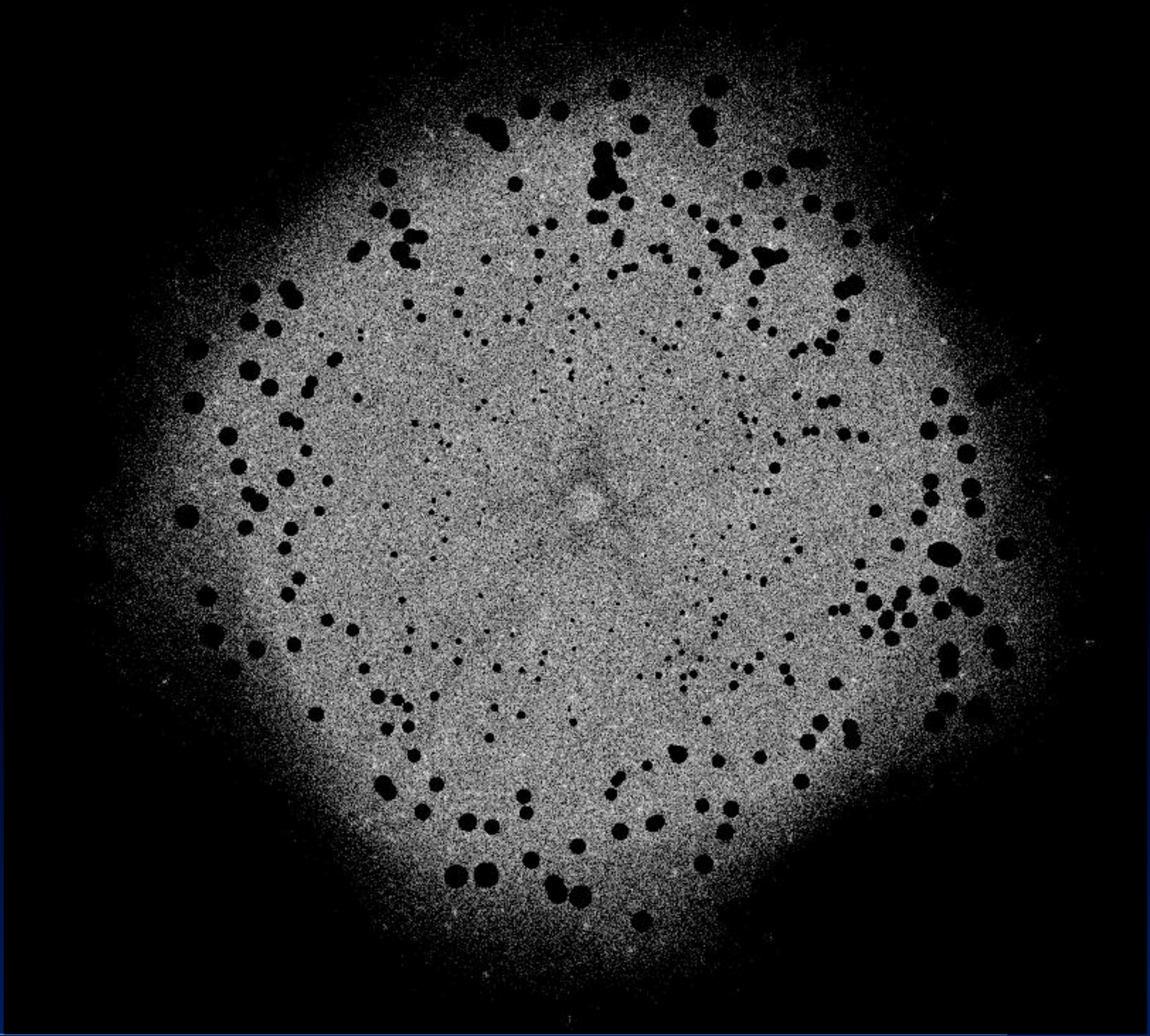
← SW direction

X-ray missions generally look out through the flanks.



Merge 52 observations for source detection





More than 400 sources removed.