ACIS Update

Chandra Users Committee November 28, 2022

ACIS Overview

ACIS continues to function nominally and produce high quality data

- **All 10 CCDs are fully functional**
- **Electronics are nominal, primary units are still in use**
- **Flight software is nominal, patched 7 times after launch for bug fixes and enhancements**
- **Over 90% of GO & GTO observations use ACIS**

Cycle 22 GO Observing Statistics

Instrument	Grating	# of Obs	% of Obs	Time(ks)	% of Time
ACIS-I	NONE	539	41.9	6332	29.6
ACIS-S	NONE	573	44.5	10982	51.4
ACIS-S	HETG	116	9.0	2653	12.4
Total			95.4		93.4

Future Challenges:

- **Contamination layer continues to accumulate, further degrading the low energy response**
- **Warmer electronics temperature limit dwell times and # of active CCDs**
- **Warmer focal plane temperatures degrade the spectral response**
- **ACIS is now the primary and perhaps only radiation monitor**

Presentation Outline

- Contamination update and Bakeout discussion
- Operating at warmer Focal Plane temperatures
- Radiation Monitoring

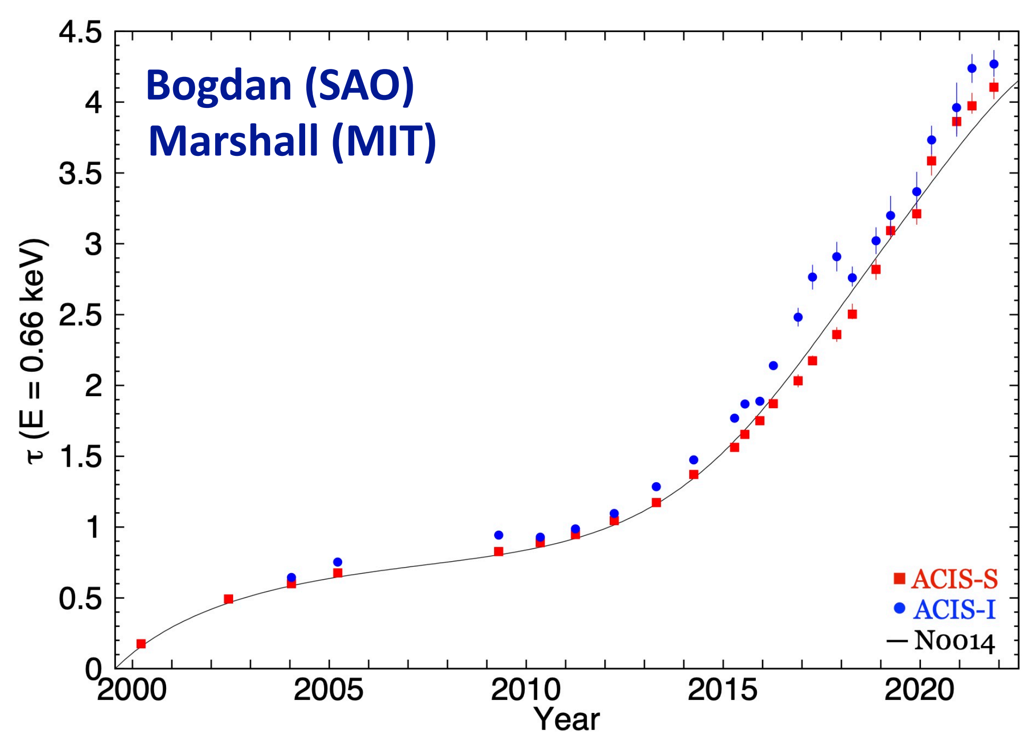
Contamination Layer

- Contamination layer continues to accumulate at a roughly linearly rate since 2014
- Additional absorption produced by the contaminant affects mostly the low energy response
- Regular calibration observations monitor the temporal, spatial, and spectral behavior
- Calibration files are updated annually or biannually to produce consistent fluxes vs. time
- Latest update to the contamination model was released on 15 November 2022 in CALDB 4.10.2 in the file *acisD1999-08-13contamN0015.fits*

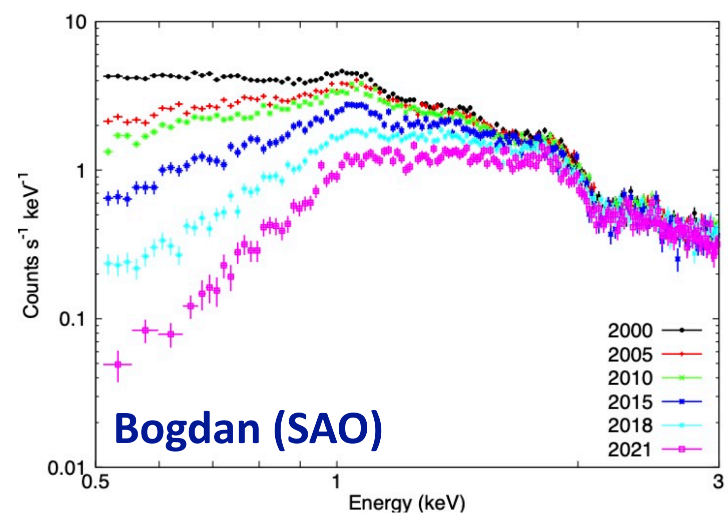
ACIS Effective Area vs. Time

E (keV)	Launch cm²	2022 cm² (%)	2025 cm² (%)
0.7	523.3	8.0(1.5%)	5.1(1.0%)
1.0	656.0	121.9(18.6%)	102.0(15.6%)
2.0	611.0	474.1(77.6%)	461.6(75.6%)
4.0	410.2	396.1(96.6%)	394.6(96.2%)

N0014 Model Contaminant τ vs. Time



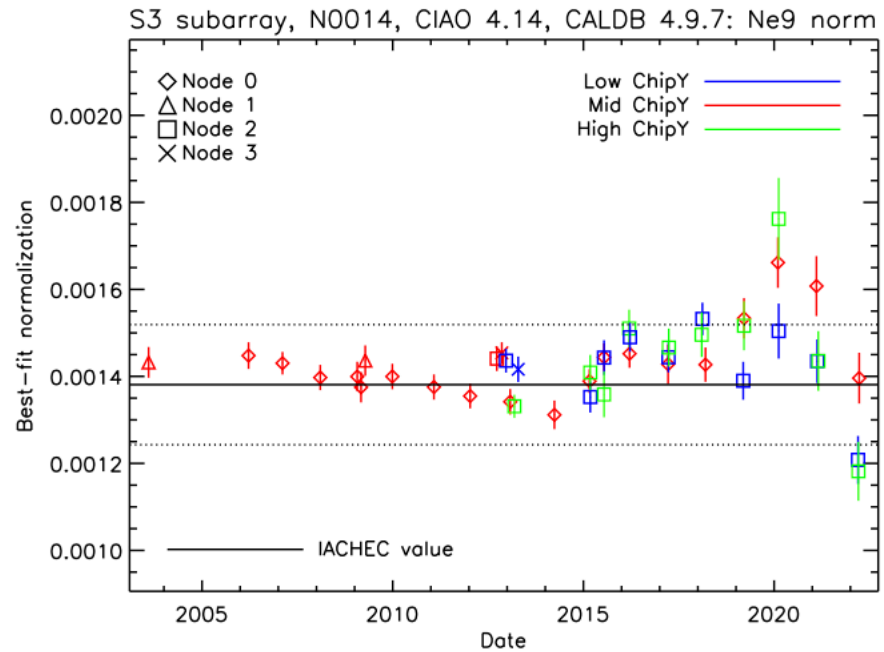
A1795 Spectra vs. Time

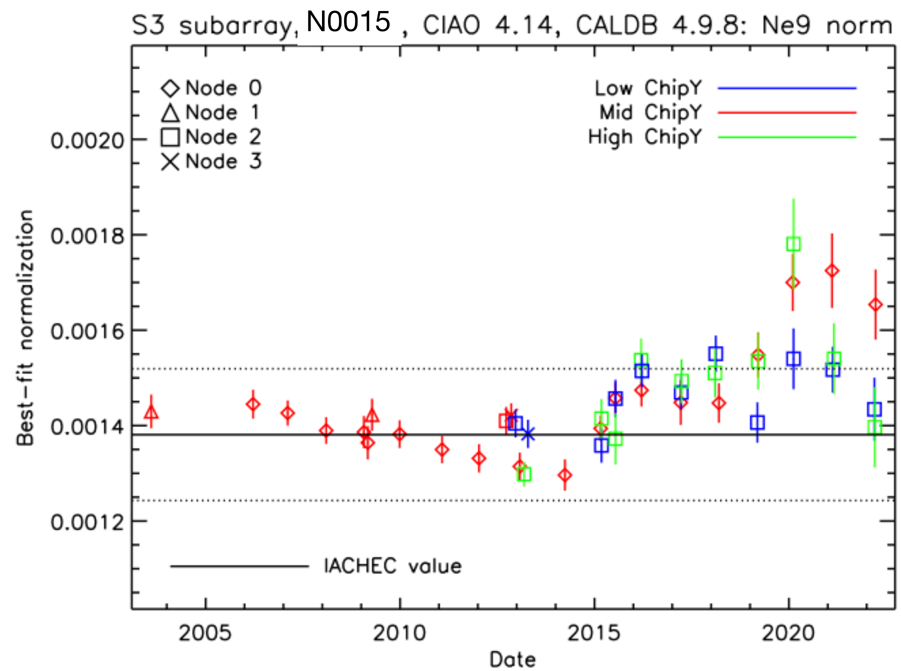


Comparison of N0014 and N0015 Models

E0102 line fluxes vs. time

- **Contamination model is developed with the External Cal Source (ECS), A1795, and ACIS-S/LETG data**
- **Contamination model is verified with the E0102 data**
- **E0102 data are fit with the *IACHEC* model (Plucinsky *et al.* 2017)**
- **Line fluxes for OVII triplet, OVIII Ly-α, Ne IX triplet, and Ne X Ly-α are determined**
- **Plots at the right show the results for the Ne IX triplet**
- **N0015 modification only affects the data for 2020 onwards**
- **N0015 model produces line fluxes more consistent with the earlier data**





Contamination and Bakeout Studies

- **The Chandra project is *NOT* considering a Bakeout at this time**
- **The following slides will summarize the studies that have been done and explain why the Chandra project decided not to pursue a Bakeout**

Contamination and Bakeout Studies

Characterization of the Contamination Layer:

Herman Marshall (MIT), Akos Bogdan(SAO), & Paul Plucinsky (SAO)

2022, 'The Evolution of the ACIS contamination layer on the Chandra X-ray Observatory through 2022', Plucinsky et al., SPIE, 12181

2020, 'A Revised Model of the temporal behavior of the ACIS contamination layer on the Chandra X-ray Observatory', Plucinsky et al., SPIE, 11444

2018, 'The complicated evolution of the ACIS contamination layer over the mission life of the Chandra X-ray Observatory', Plucinsky et al., SPIE, 10699

2016,'The evolution of the ACIS contamination layer over the 16-year mission of the Chandra X-ray Observatory', Plucinsky et al., SPIE, 9905

2004,'An evaluation of a bake-out of the ACIS instrument on the Chandra X-Ray Observatory', Plucinsky et al., SPIE, 5488

2004,'Composition of the Chandra ACIS contaminant', Marshall et al., SPIE, 5165

Contamination Migration Studies:

Steve O'Dell, Doug Swartz (NASA/MSFC), and Neil Tice (LMA/MIT)

2017,'Modeling contamination migration on the Chandra X-ray Observatory IV', O'Dell et al., SPIE, 10397

2015,'Modeling contamination migration on the Chandra X-ray Observatory III', O'Dell et al., SPIE, 9601

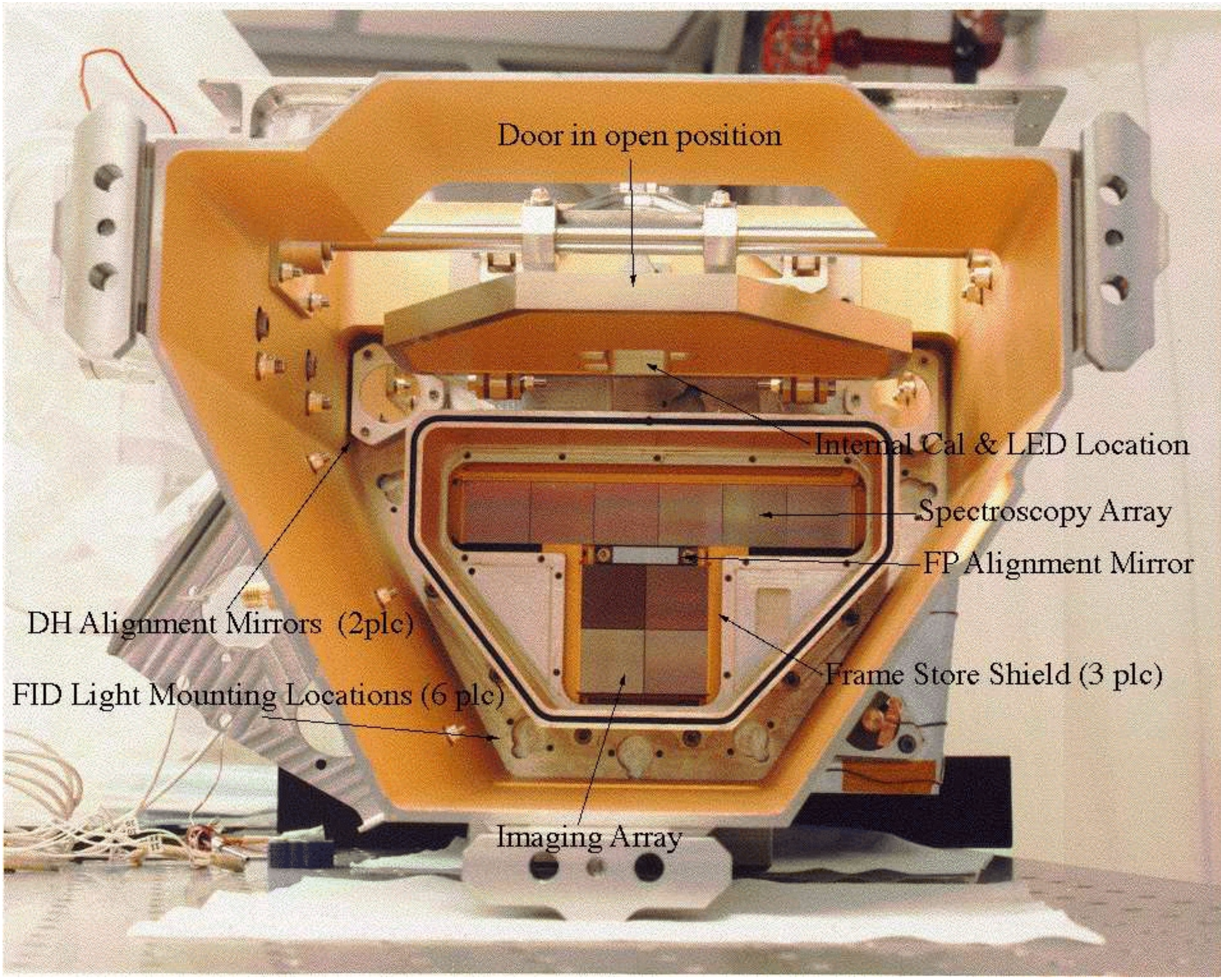
2013,'Modeling contamination migration on the Chandra X-ray Observatory II', O'Dell et al., SPIE, 8859

2005,'Modeling contamination migration on the Chandra X-ray Observatory', O'Dell et al., SPIE, 5898

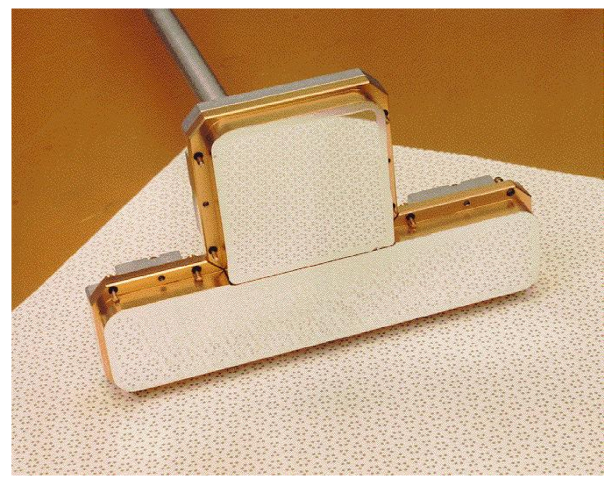
Many Other Contributors to this Effort:
Alexey Vikhlinin, Dan Schwartz, Richard Edgar, Gregg Germain, John ZuHone (SAO), Catherine Grant, Mark Bautz, Norbert Schulz, Peter Ford, Bob Goeke, Corentin Monmeyran (MIT)

Collimator & Camera Body

ACIS
Engineering unit



ACIS Filters



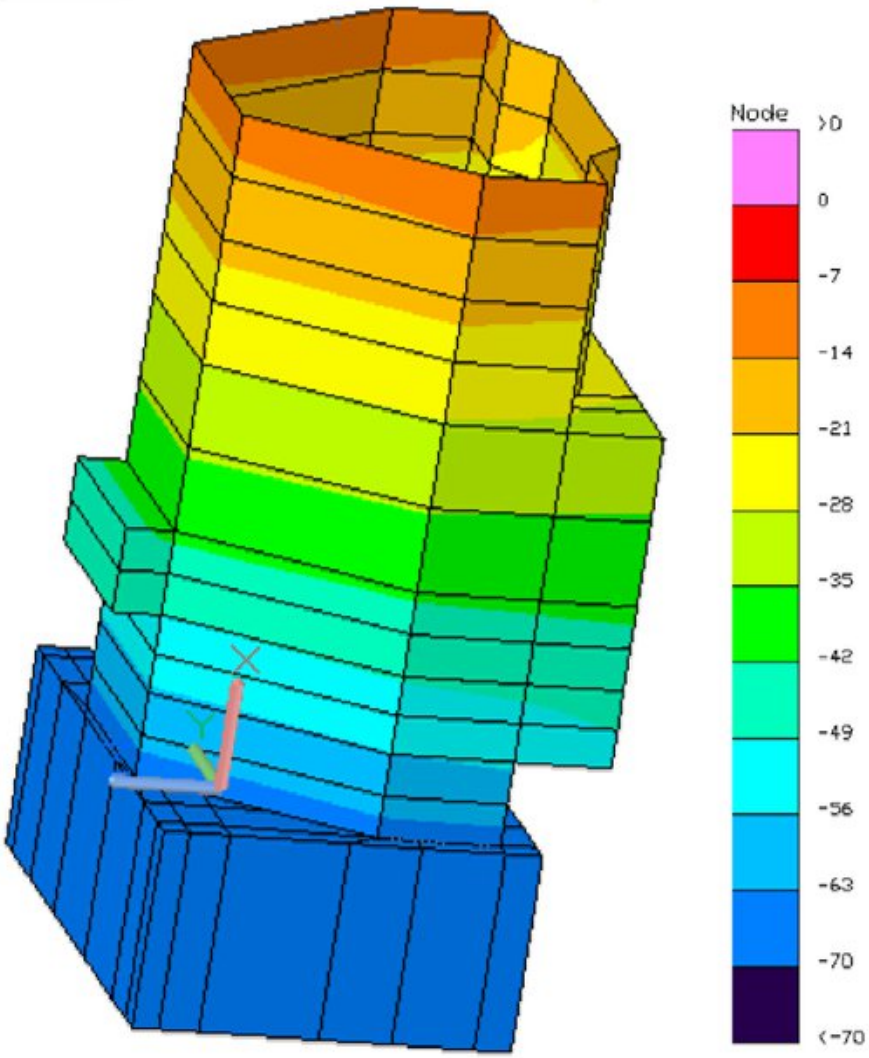
Collimator & Camera Body Temperatures

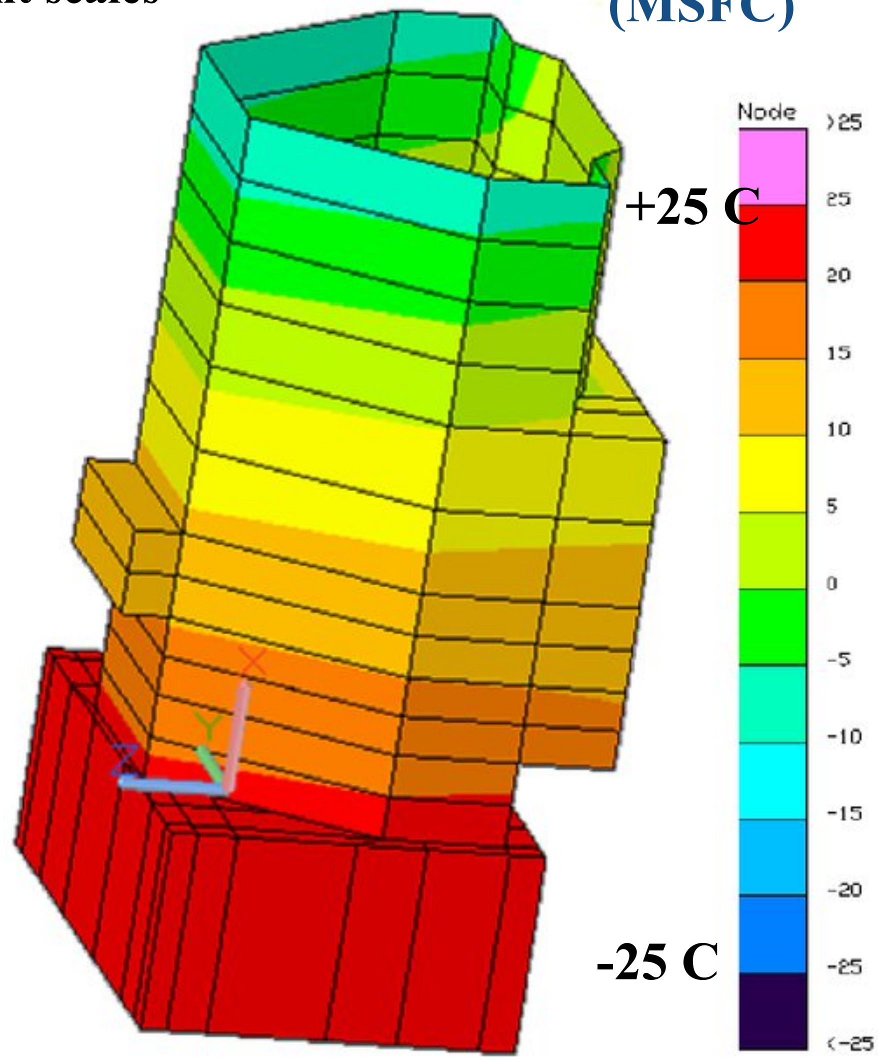
Tice (LMA)
O'Dell & Swartz (MSFC)

Normal Operations

NOTE: different scales

Bakeout





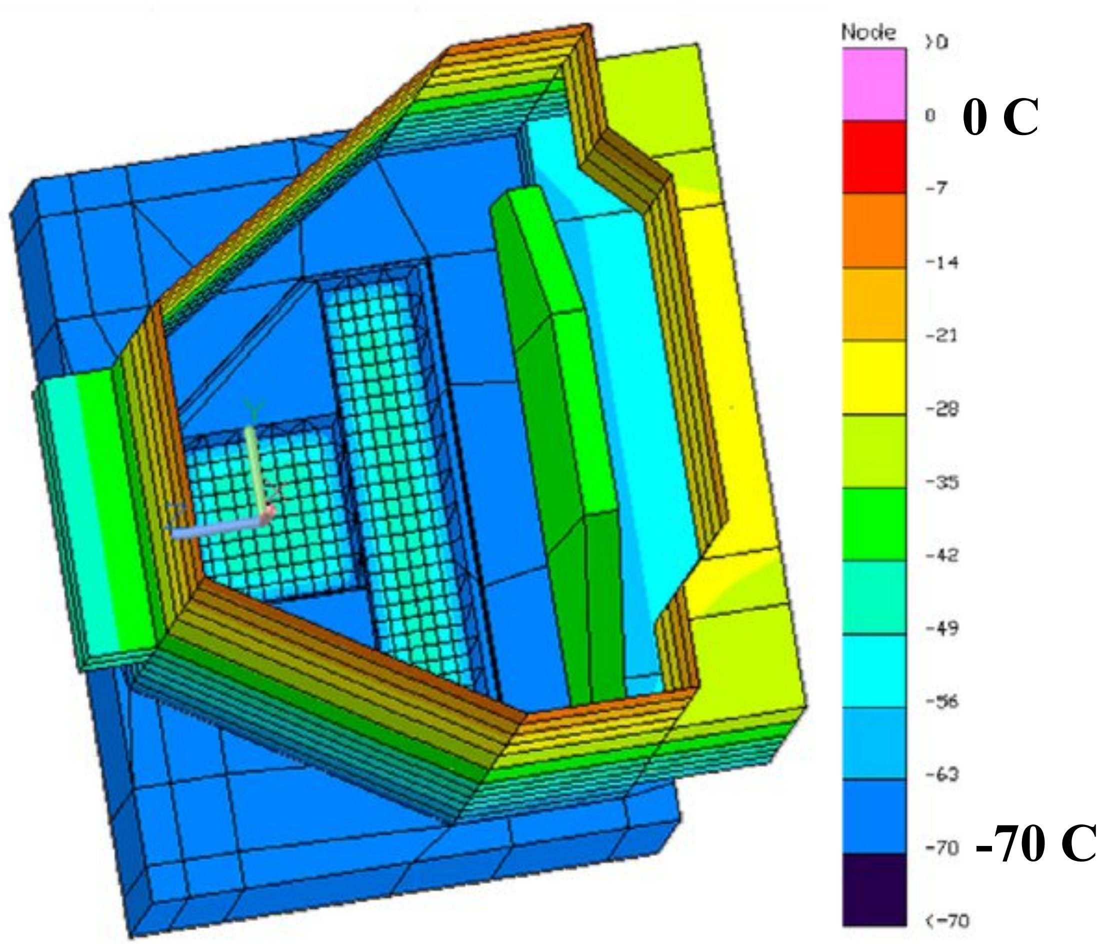
Filter Temperatures

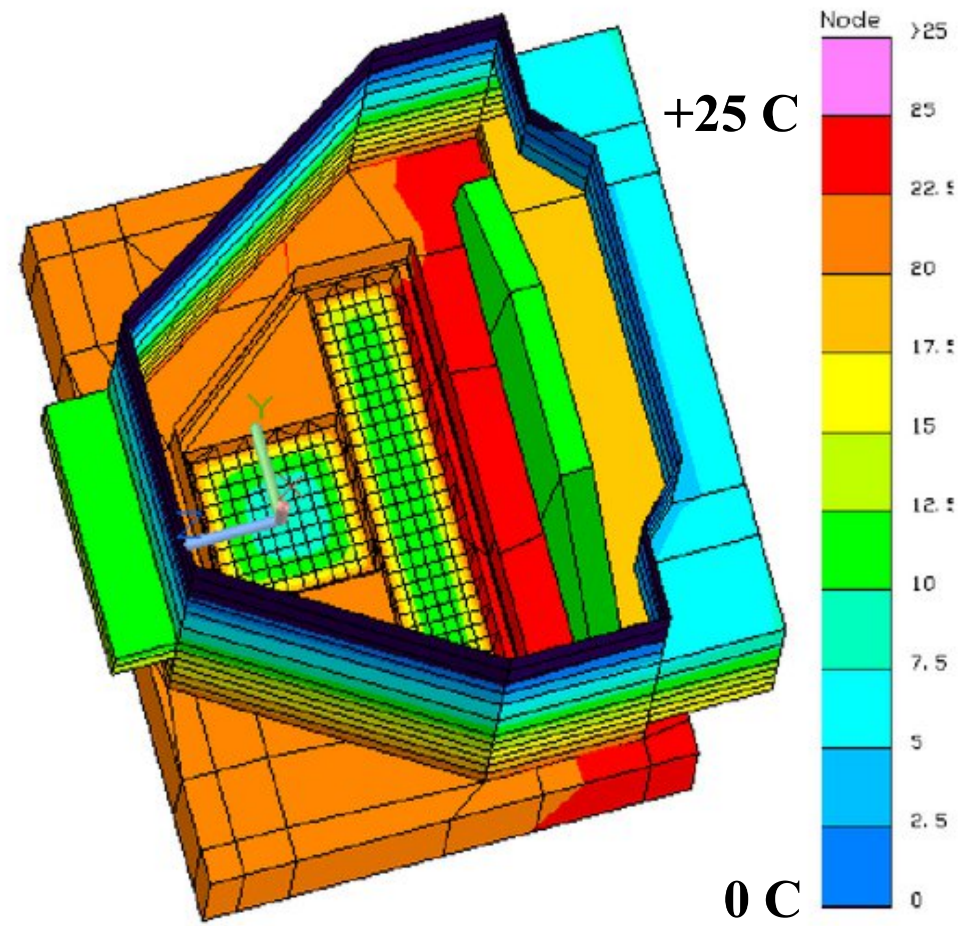
Tice (LMA)
O'Dell &
Swartz
(MSFC)

Normal Operations

NOTE: different scales

Bakeout





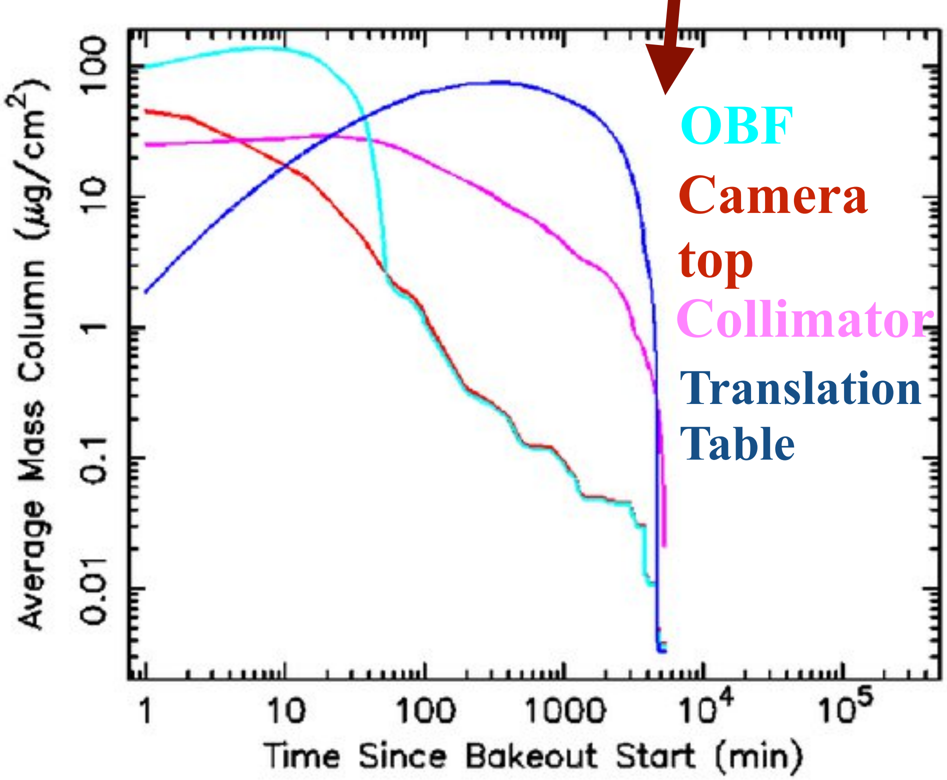
Simulation Results

O'Dell & Swartz 2017 (MSFC)

- The ACIS contaminant is most likely composed of multiple materials
- Mass vaporization rates of the contaminants are not known
- Simulations below assume the vaporization rate of octadecane (medium volatility) and dioctyl phthalate (low volatility)
- amount of heating time for a 'successful' outcome is dramatically different for the different simulations

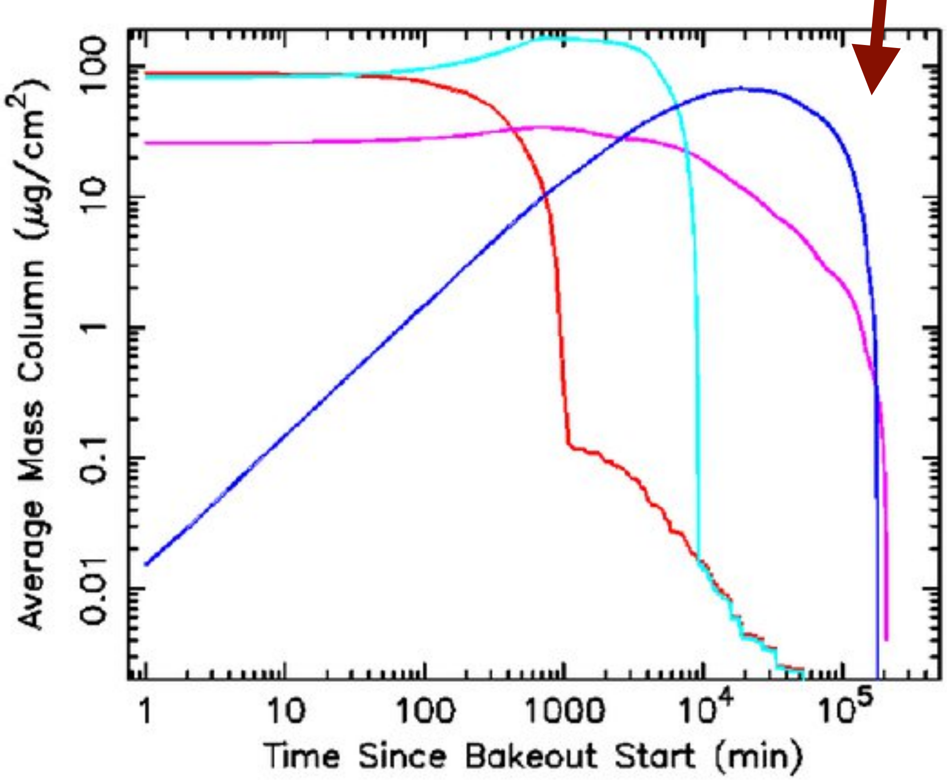
3.6e5 s

Medium Volatility



1.2e7 s
20 weeks

Low Volatility



Consequences of a Bakeout

- **The Bakeout itself would take significant time, conservatively >2 orbits**
- **The recalibration effort would take considerable time. A quick assessment of the outcome could be done in 1-2 orbits but a full recalibration would require about a million seconds of calibration time**
- **It is likely the uncertainty in the new calibration products would be larger than they are in the current calibration products**
- **Another open question is how quickly the contaminant would redeposit on the filters. More calibration observations to monitor and characterize the re-accumulation of the contaminant might be necessary if the contaminant is depositing quickly and in unexpected ways.**

Bakeout Decision

Effectiveness is uncertain:

- **The chemical composition & volatility of the contaminants are not understood.**
- **Simulated outcomes of a bakeout vary widely, ranging from an increase in the contamination layer to no significant change to a significant reduction in the layer.**

Risk is uncertain:

- **Bakeout could damage the ACIS optical blocking filters (OBF).**
- **While the consequences of OBF damage would undoubtedly impair or disable ACIS, they are not fully understood.**
- **The likelihood of OBF damage is even more uncertain.**

Benefit:

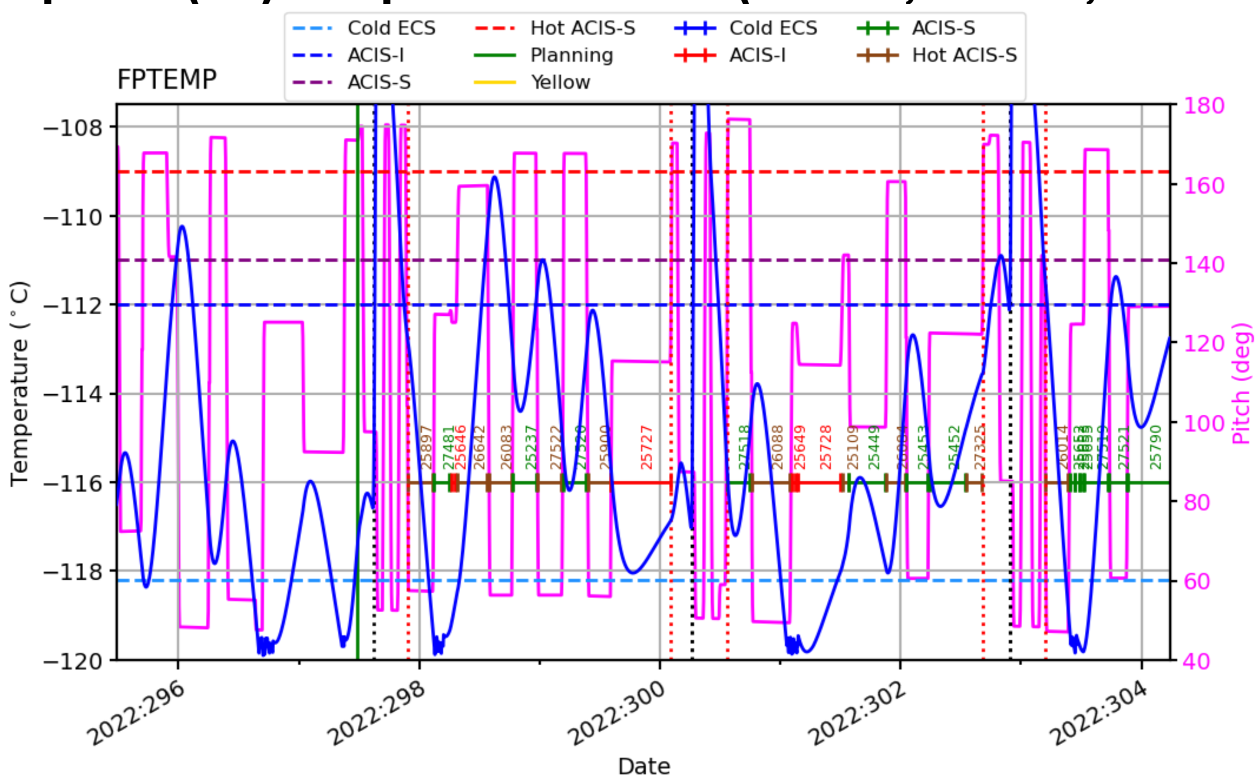
- **Although the benefit to low energy science is clear, observations above 2.0 keV are unaffected by the contamination layer.**

The Chandra community consensus is that the benefit does not justify the risk.

ACIS Thermal Modeling

- **Chandra operations are thermally constrained—this is no less true of ACIS**
- **Primary concerns are health and safety of electronics boxes and observational data quality (ACIS Focal Plane temperature)**
- **ACIS engages in predictive modeling of temperatures based on heating from the Sun, Earth, and electronics boxes, and passive cooling into space**
- **Predictions are produced throughout the planning process, culminating in the ACIS load review for a weekly schedule**
- **Software predicts the temperature profile for a given schedule and flags any violations, currently three focal plane (FP) temperature limits (-109 C, -111 C, -112 C)**

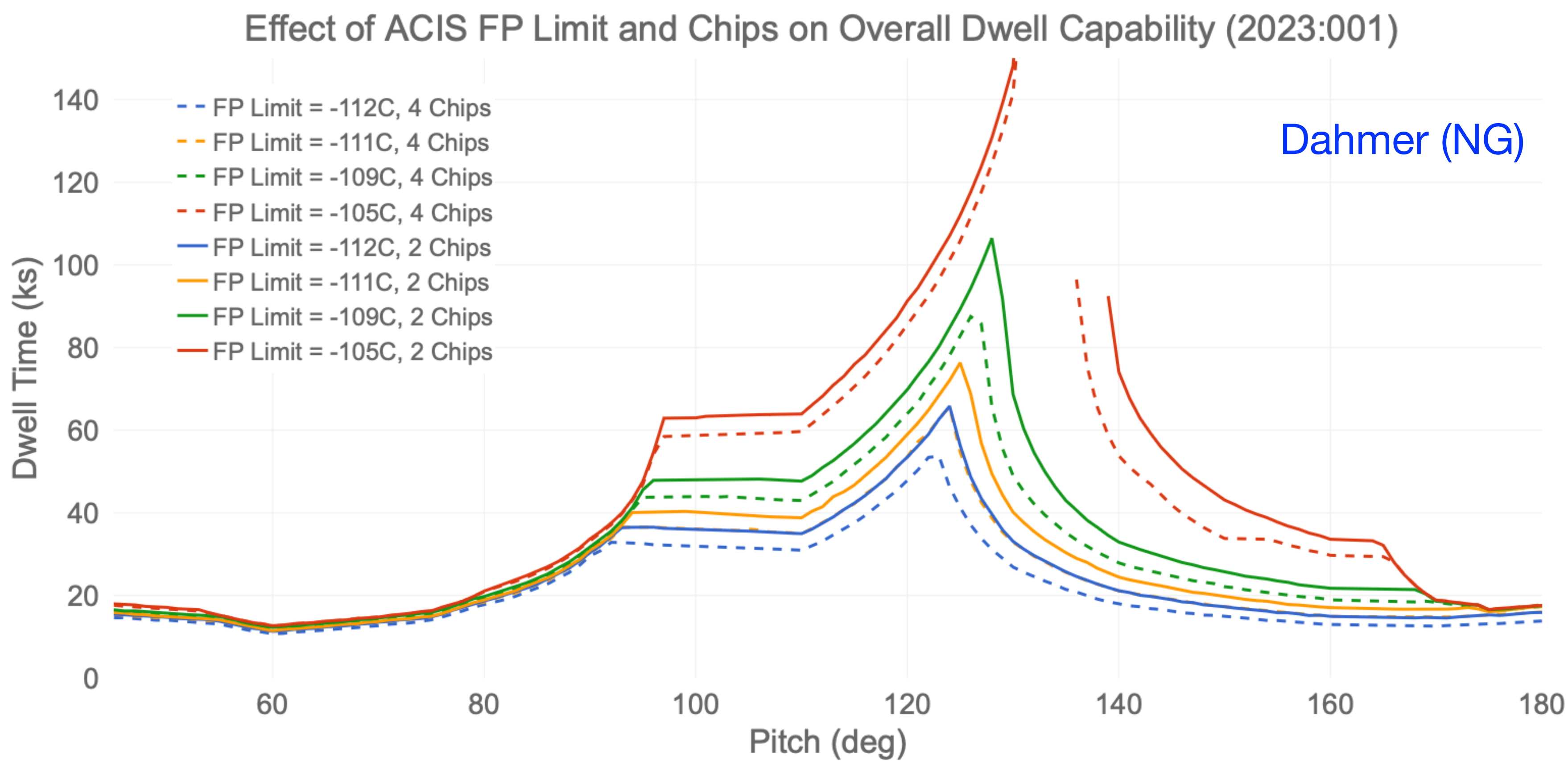
- **The majority of the time is spent with the FP temperature < -112 C**



ACIS FP Model
ZuHone (SAO)

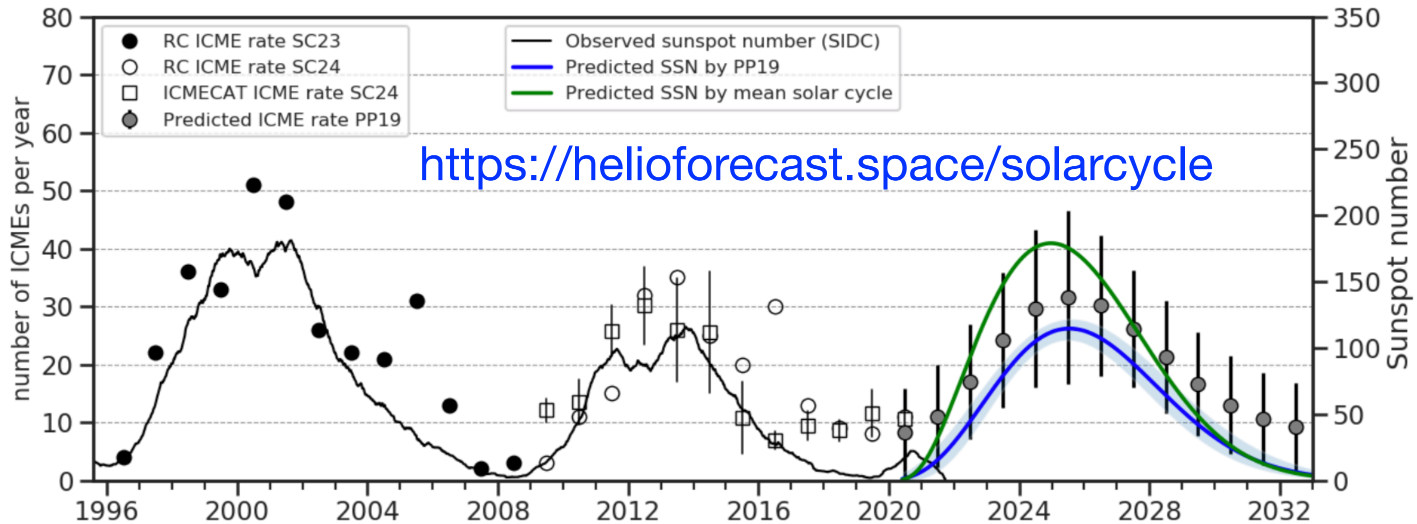
ACIS FP Temperature Limits

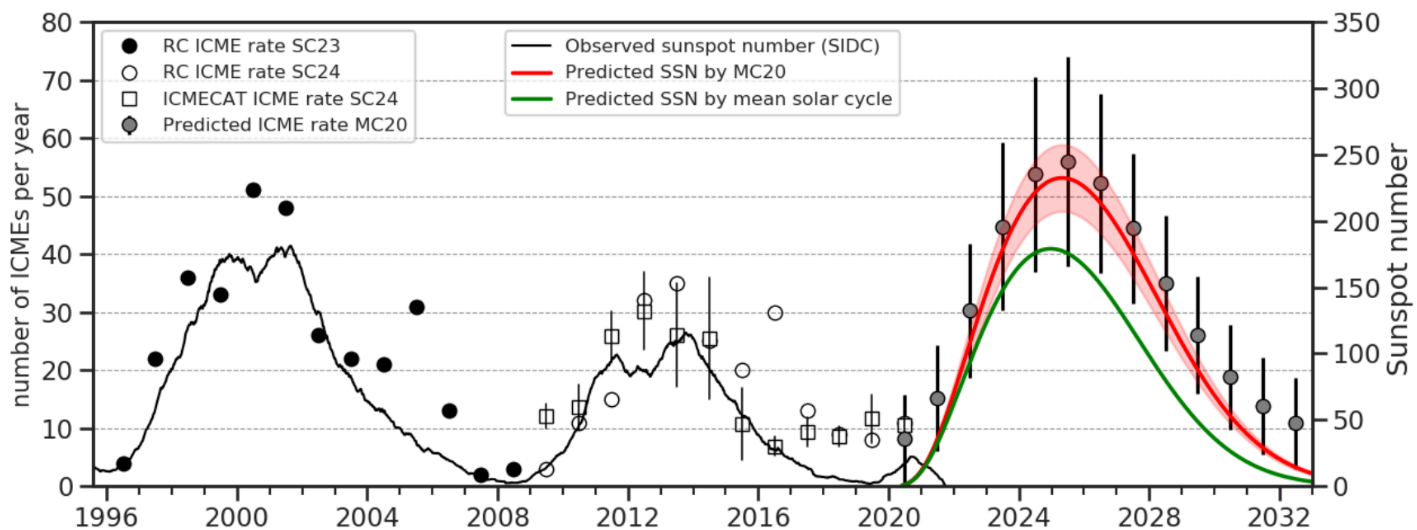
- **-109 C ACIS-S and ACIS-I imaging observations that do not benefit from the most accurate spectral response**
- **-111 C ACIS-S observations that *do* benefit from the most accurate spectral response**
- **-112 C ACIS-I observations that *do* benefit from the most accurate spectral response**
- **significantly longer dwell times are possible for a FP temperature limit of -105 C, the CXC is conducting calibration observations at -105 C in the hope that we can raise the limit**
- **GOs are encouraged to specify “optional” CCDs that may be turned off for thermal reasons, at proposal submission GOs may specify at most 4 required CCDs**



Solar Cycle 25

- **Solar Cycle 25 is predicted to peak in early-mid 2025, predictions for the strength of the cycle vary by a factor of two**
- **There have already been several strong M and X class flares from the Sun with associated CMEs**

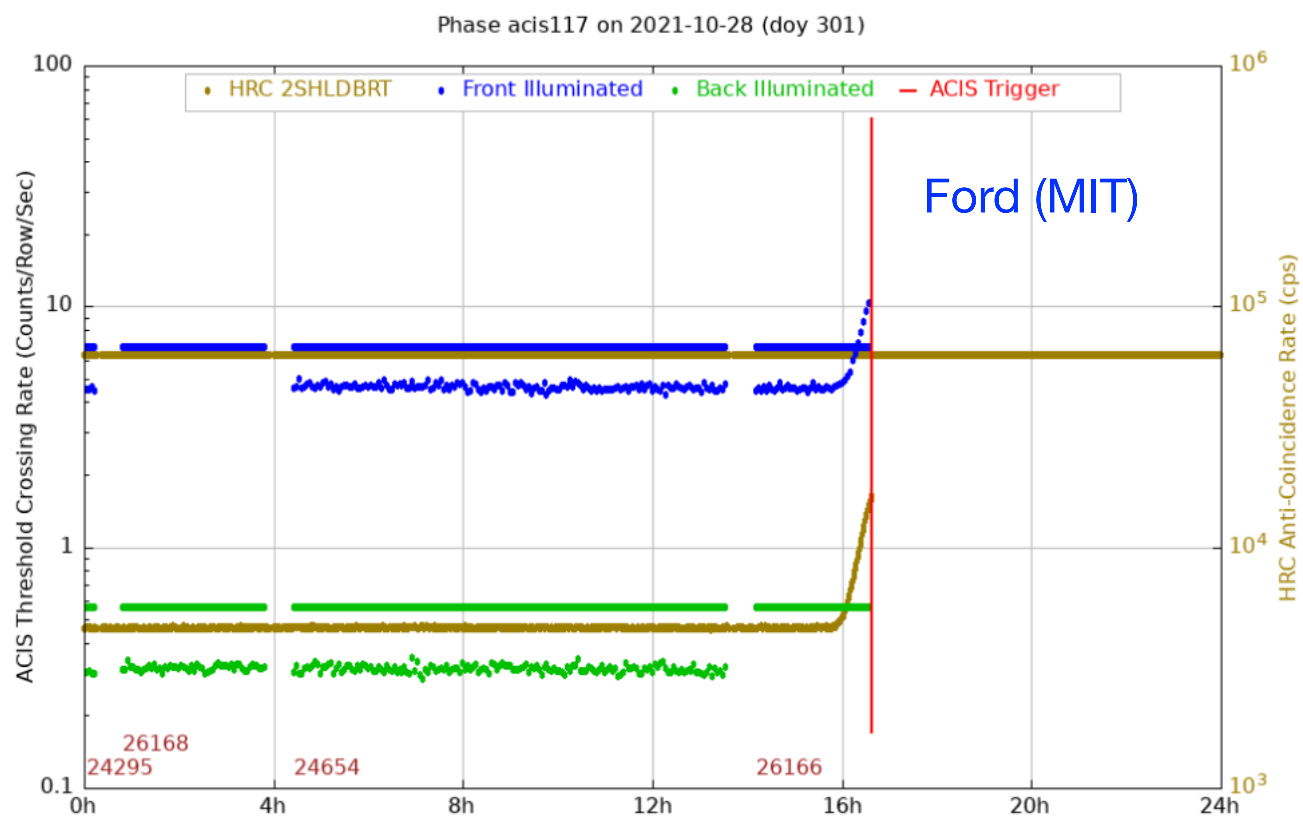




Radiation Monitoring

- Low energy protons (100-300 keV) can scatter off of the Chandra mirrors and damage the ACIS CCDs
- The MIT ACIS flight software (SW) team modified the SW to recognize high radiation events and send an alert to the Chandra main computer to safe the SIs
- ACIS is now the primary and currently the *only* radiation monitor on Chandra
- In addition, the Chandra SOT monitors data from the ACE, GOES, and DSCOVR satellites and may execute a manual shutdown in severe storms

- ACIS flight SW modified again on 11 August 2022 to trigger on more and different types of radiation events to provide more protection
- Enhancement of the ACIS radiation monitor became a high priority after the HRC anomaly in February
- ACIS must be collecting event data for the radiation monitor to be active



FI CCD Requirement for all observations

- **FI and BI CCDs respond differently to high particles, the ACIS radiation monitor is more likely to trigger if at least one FI CCD is active during an observation**
- **The CXC now requires at least one FI CCD to be on for GO observations**

Subarray frame times assuming the subarray is in the middle of the CCD:

subarray	1 CCD	2 CCD	3 CCD
128 rows	0.4 s	0.5 s	0.6 s
256 rows	0.8 s	0.9 s	0.9 s
512 rows	1.5 s	1.6 s	1.6 s

Total background rates (0.3-12.0 keV), all telemetered grades.
VF mode telemetry limit is 68.8 cts/s, F mode telemetry limit is 170.2 cts/s

S3 (cts/s)	S3+S2 (cts/s)	S3+S2+S1 (cts/s)
8.7	16.0	24.7

Summary

ACIS continues to function nominally and produce high quality data

- ACIS continues to produce spectacular results
- The Science Operations Team, the Flight Operations Team, and the ACIS Instrument Team have developed innovative solutions to each new challenge to ensure mission success
- Notably, the ACIS flight SW team has modified the ACIS flight SW so that it acts as a radiation monitor
- Notably, the calibration team is working on calibration products for -105 C to allow some science observations to be scheduled at that temperature