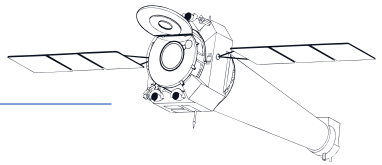
CHANDRA
COMMUNITY TOWN HALL

Patrick Slane – Director, CXC
14 November 2024



OUTLINE

Chandra Status: Science and Observatory

Operating Paradigm Change Review Process and Results

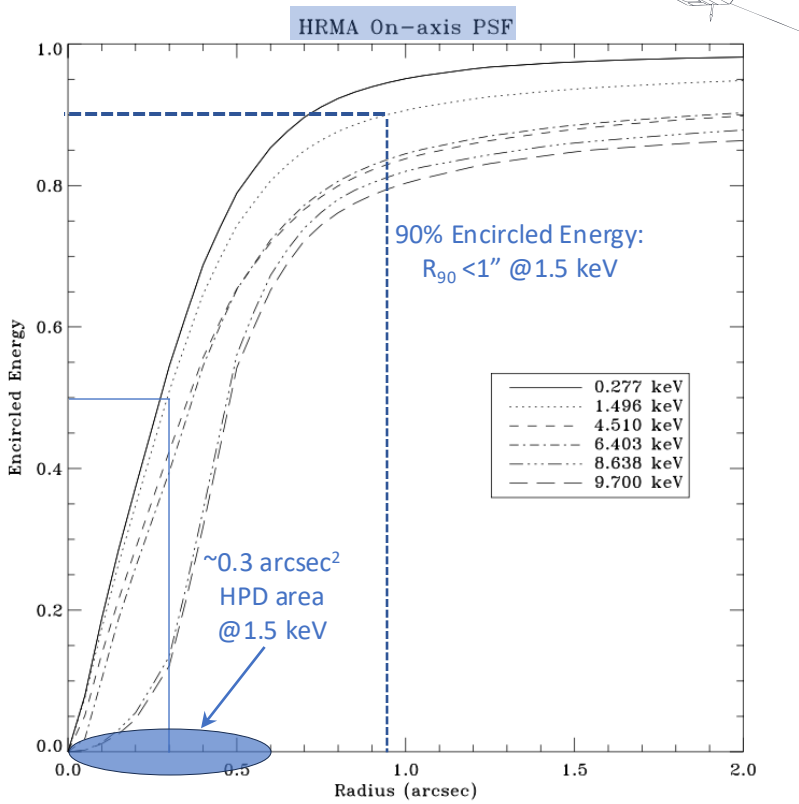
Current Chandra Funding Status

Chandra Senior Review Proposal

Note: This is a reminder to feel free to communicate your Chandra questions, concerns, and suggestions either to the Chandra Users' Committee (see https://cxc.harvard.edu/cdo/cuc/) or directly to the CXC HelpDesk (cxchelp@cfa.harvard.edu).

CHANDRA CAPABILITIES ARE UNIQUE

7 Ms exposure, 1008 X-ray sources with ≥ 11 net counts. 17' x 17' field, coincident with HUDF, GOODS-S, and JADES-S.

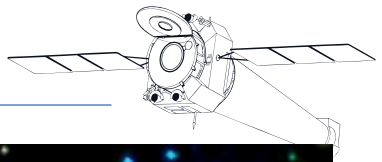


- Chandra mirror resolution captures ~90% of 1.5 keV photons within ≲1 arcsec radius.
- ACIS-I background: ~7 x 10^{-7} cts s^{-1} arcsec^{-2}

Two counts per R_{90} resolution element per million seconds

Highly sensitive to point-source detection and resolving detailed sub-structure in extended sources.

CHANDRA IS INDISPENSABLE, WITH UNIQUE, POWERFUL, AND ESSENTIAL CAPABILITIES



Unique, Powerful, and Essential Capabilities:

Sub-arcsecond imaging: Chandra's angular resolution 20× better than the nearest current (XMM-Newton) capabilities. This translates to an ability to detect sources 20× fainter than any other X-ray telescope.

Fast TOO/DDT response plus large field of regard (~ 85% of the sky), unmatched X-ray sensitivity, and localization capability for GRBs, GW events, transients, etc.

Joint observatory programs: Chandra participates in joint observing programs with JWST, HST, and most large space and ground-based telescopes, providing a unique X-ray complement in terms of spatial resolution and sensitivity.

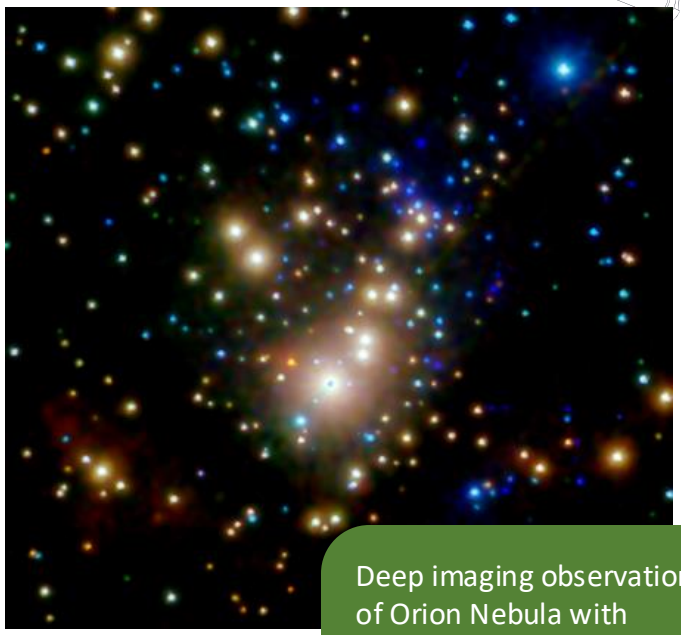
High-resolution grating spectroscopy: Especially in the 1–3 keV band (e.g., astrophysically important Si, Mg, and Ne lines).

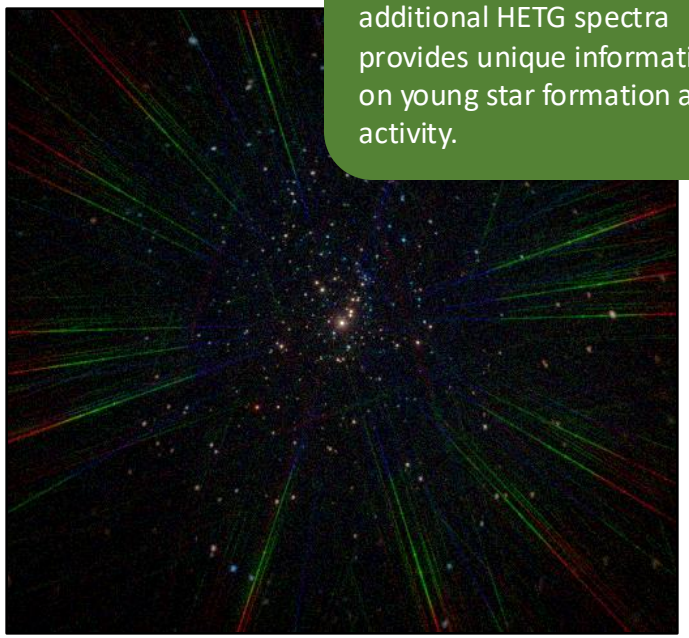
Capabilities not critically impacted by instrument changes:

- Image sharpness and grating spectral resolution unchanged since launch.
- ACIS contamination build-up continues, slowly: Effective area has decreased by 15%@1.5 keV and 1.0%@4keV since 2022 when Chandra was ranked Tier 1 in the Senior Review. Effective low-energy cutoff (QE=0.2) has increased from 1.07 keV to 1.17 keV over this time.
- HRC operational on A-side power.

2022 Senior Review: "Chandra's unique and essential capabilities … have no peer in X-ray astrophysics and no replacement on the horizon."

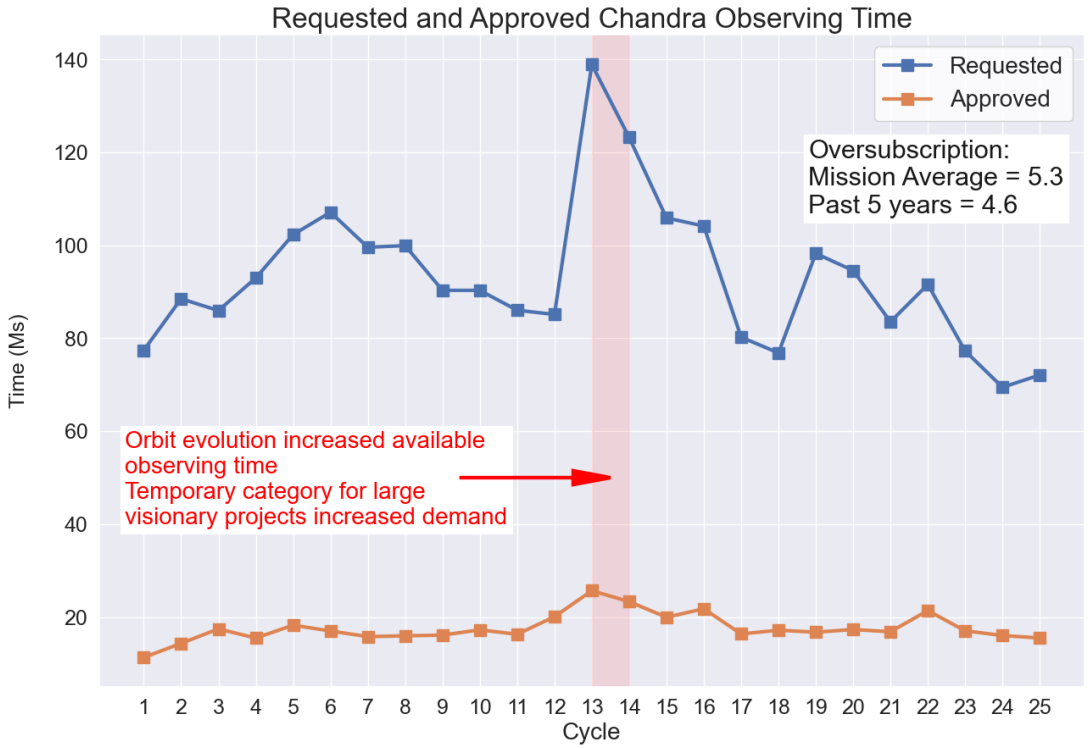
NASA 2024 Probe Studies: Selection of AXIS for Phase A studies confirms recognition that high angular resolution in X-ray astrophysics is paramount. Continuing Chandra until a replacement is in place is crucial for all of astrophysics.

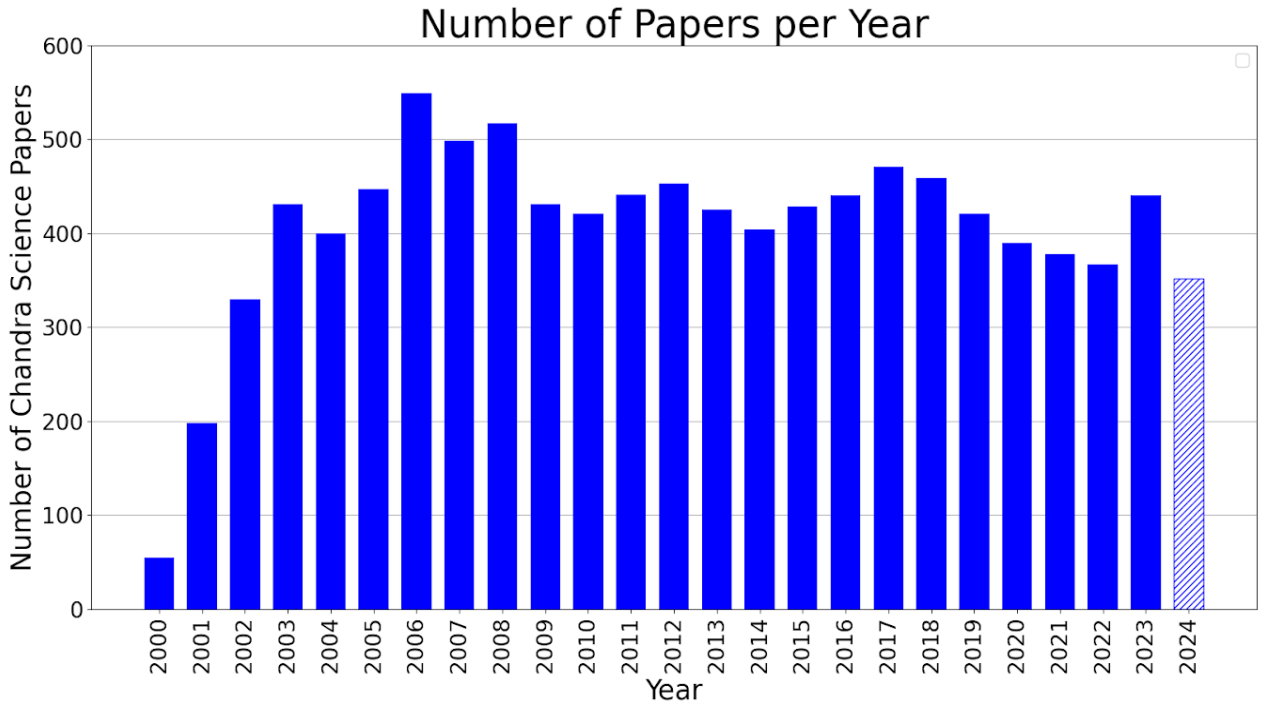




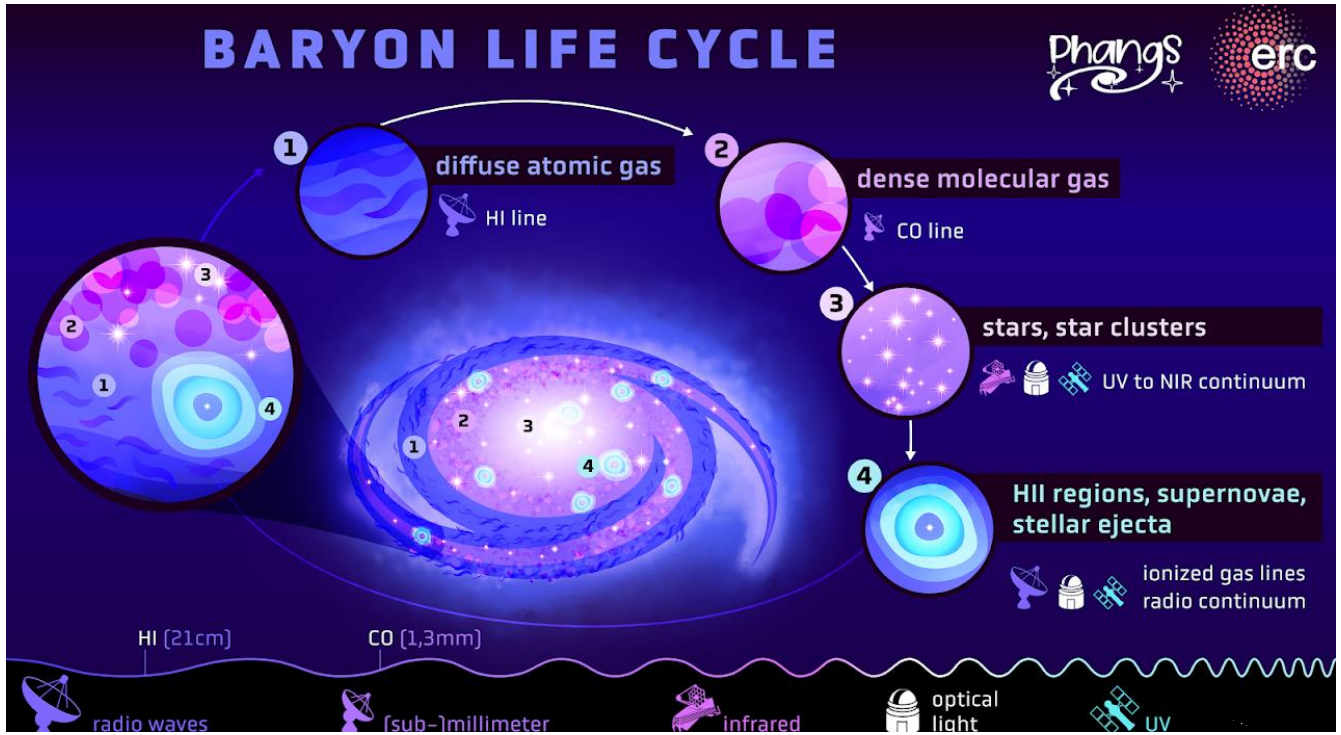
Deep imaging observation of Orion Nebula with additional HETG spectra provides unique information on young star formation and activity.

CHANDRA IS HIGHLY PRODUCTIVE





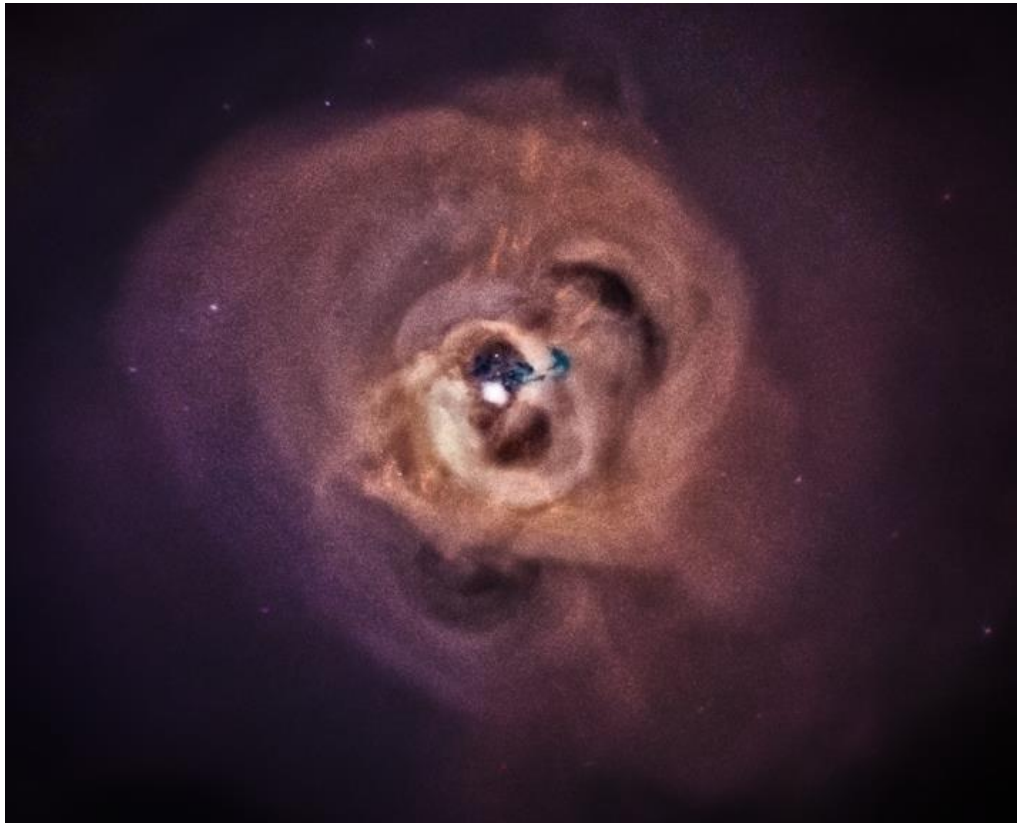
- Chandra oversubscription remains high. There is significant continued demand for Chandra observations.
  - Recent Chandra Legacy Program call for whitepapers was oversubscribed by a factor of 15.
- Chandra publication rate remains steady.
  - 10,195 “Category 1” Chandra science publications to date, with nearly 500,000 citations.



Credit: PHANGS collaboration, Design: Daniela Leitner

A Treasury Survey Probing the Baryon & Energy Cycle and X-ray Binary Evolution in Galaxies at High Angular Resolution (PI: S. Mathur)

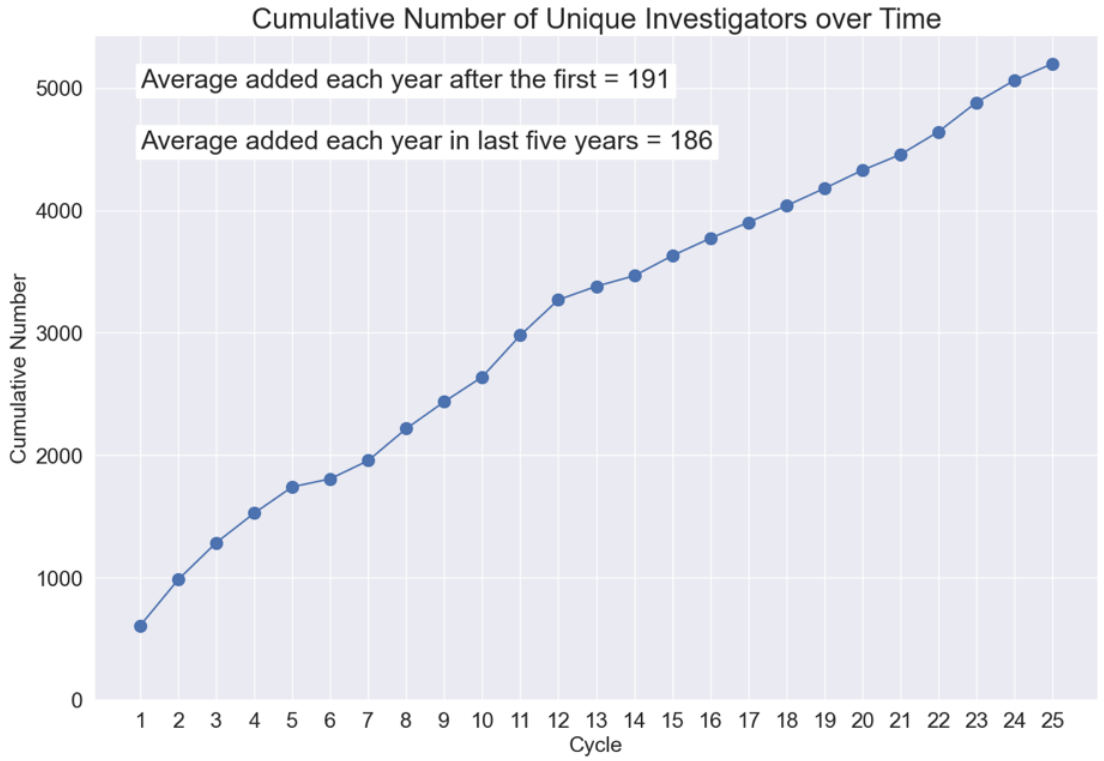
Chandra observations (2.9 Ms) that, together with archival data, cover all 74 galaxies from the Physics at High Angular resolution in Nearby GalaxieS (PHANGS) survey

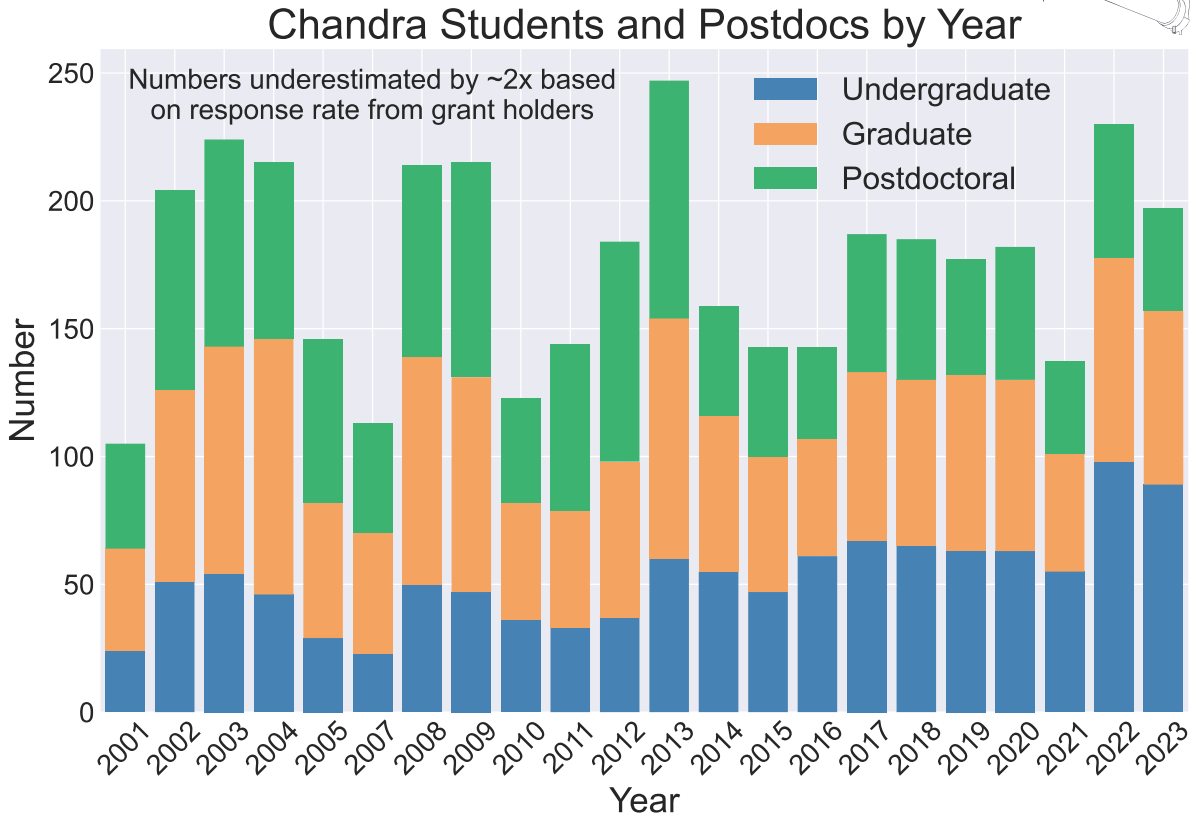


The Sounds of Feedback: Deep and Wide Imaging of the Cool Core of the Perseus Cluster (PI: A. Fabian)

3Ms deep ACIS-I image of the Perseus cluster to test how feedback energy propagates across the core with ramifications for understanding AGN feedback from the most massive central galaxies in cool core clusters.

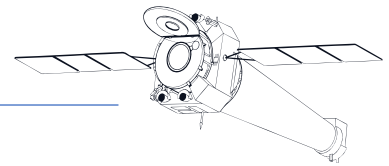
CHANDRA ENGAGES A LARGE AND DIVERSE USER COMMUNITY



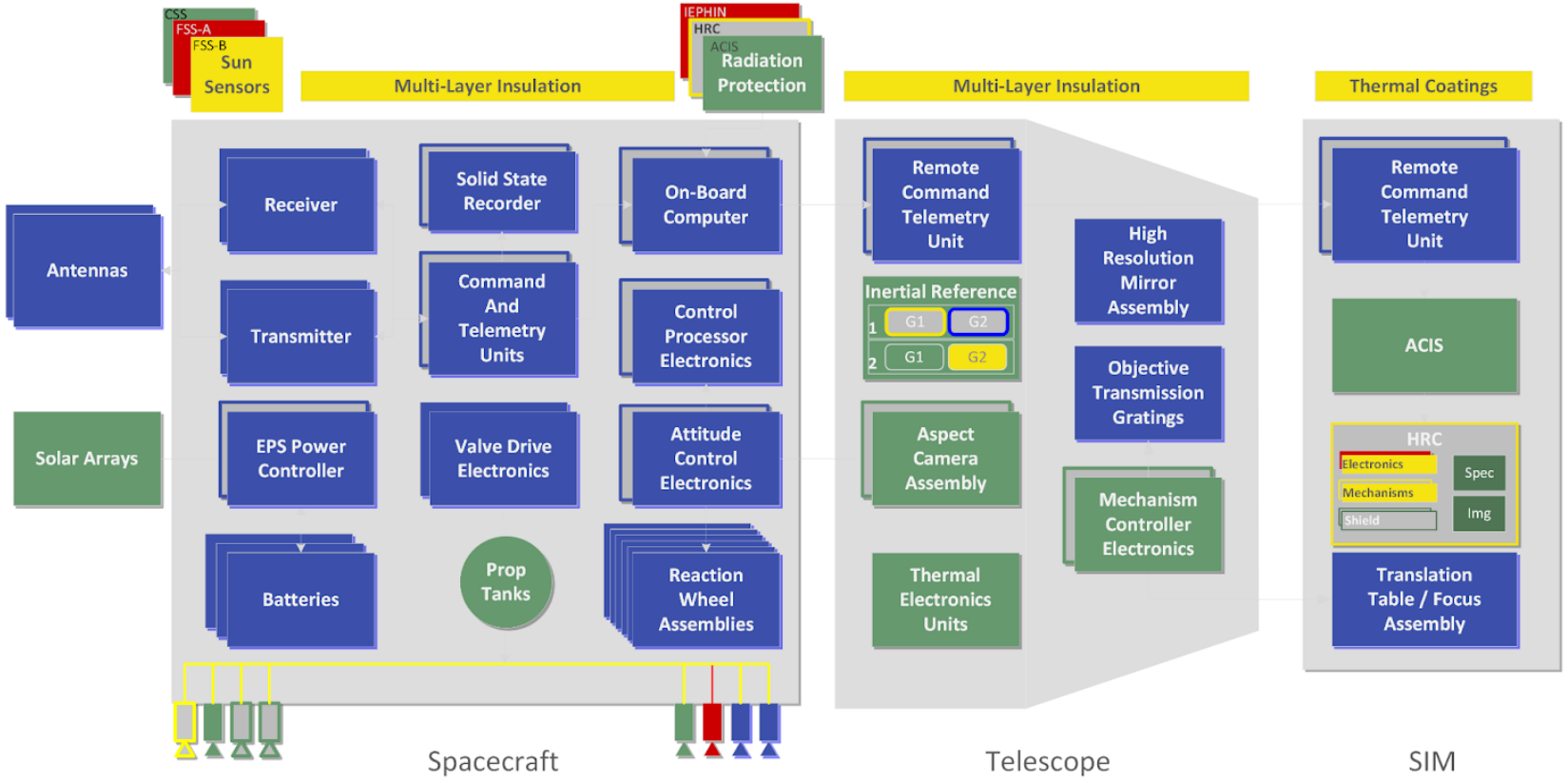


- Engagement of **broadest possible community** surfaces new ideas and potential discoveries otherwise missed.
  - Number of new Chandra investigators continues to growing steadily.
- Student and postdoc participation in Chandra research is steady and significant, with ~26 Chandra PhD theses yr^{-1}.
  - **Funding support** to General Observers particularly important for students, postdocs, and non-tenured/early career researchers.

CHANDRA IS A HEALTHY, EFFICIENT, HIGHLY FUNCTIONAL WORLD-CLASS OBSERVATORY



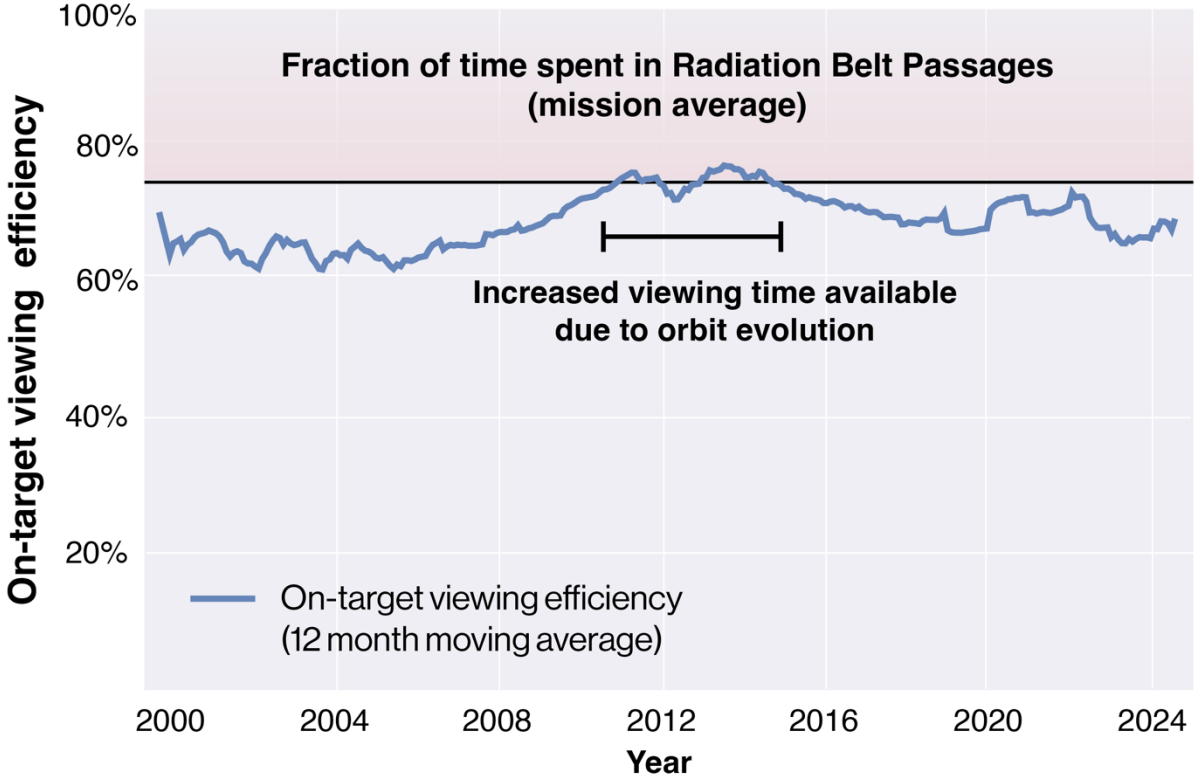
Chandra Spacecraft Status

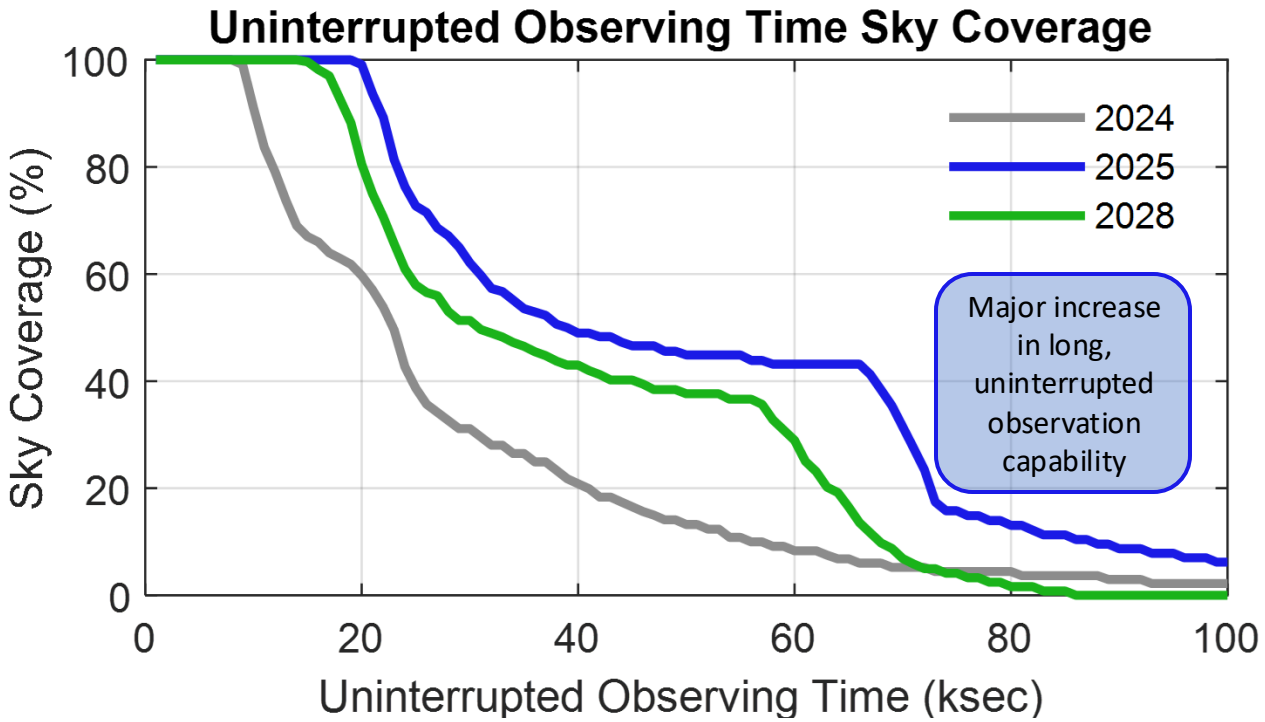


Key: blue = fully functional; green = some degradation but meeting all requirements; yellow = partially mitigated performance impacts; red = major problem affecting performance; gray = backup unit, border represents status when last powered on

- Chandra is in excellent health. Most subsystems meet all requirements and many show no signs of degradation.
  - Mitigations in place for components with performance degradation.
  - Increasing thermal trends throughout the mission continue to be proactively managed.

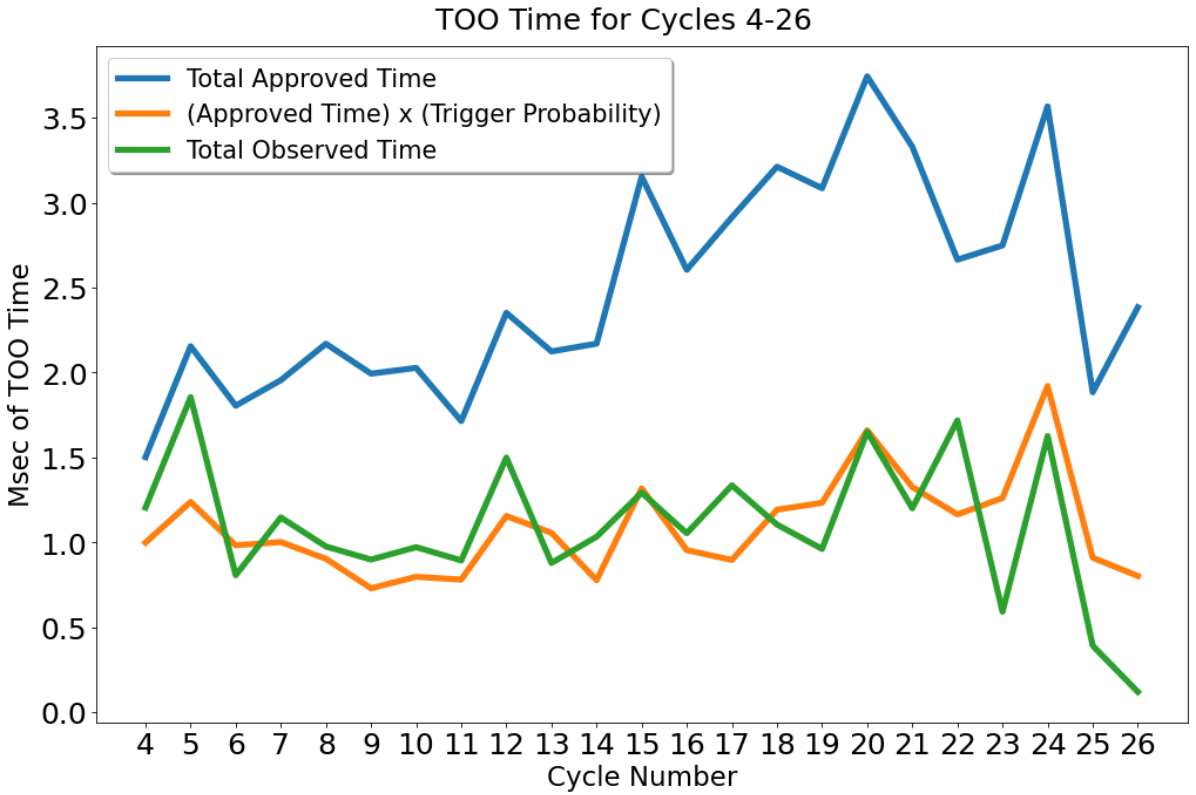
CHANDRA IS HIGHLY EFFICIENT

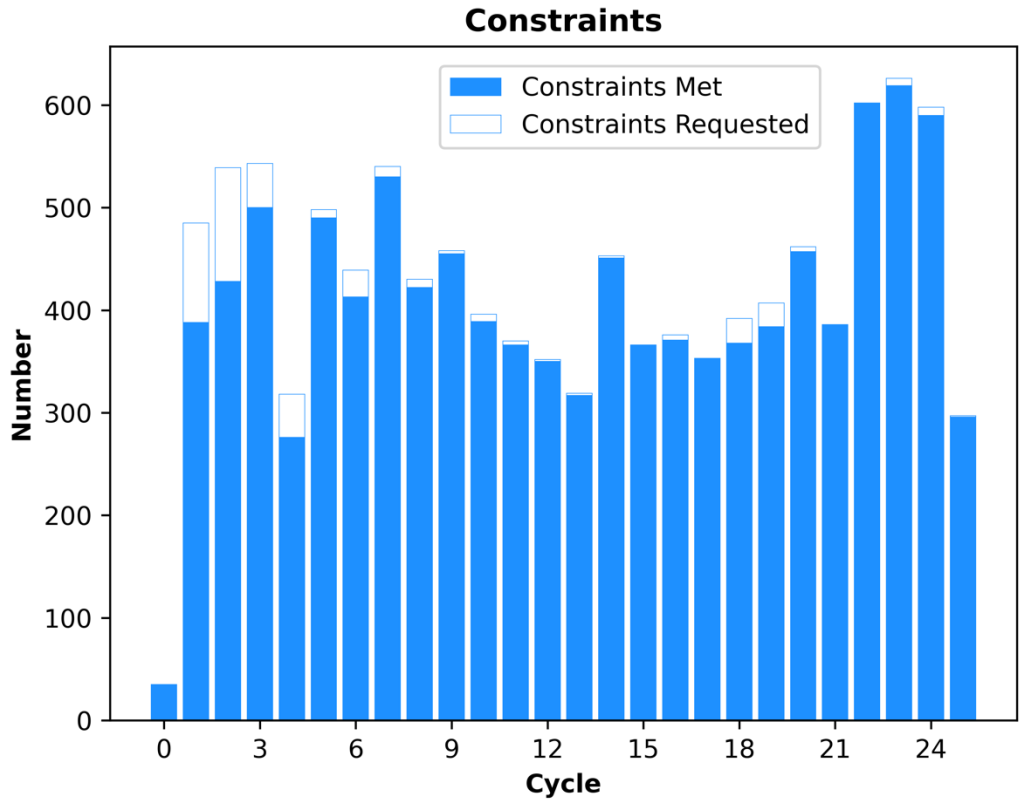




- Chandra observing efficiency is high and basically unchanged over the course of the mission.
  - Constraints associated with rising temperatures have been managed without significant impact on science or staffing levels.
- Continued studies and mitigations have increased multiple capabilities since 2022.
  - E.g., longer uninterrupted observations possible over a larger fraction of the sky.

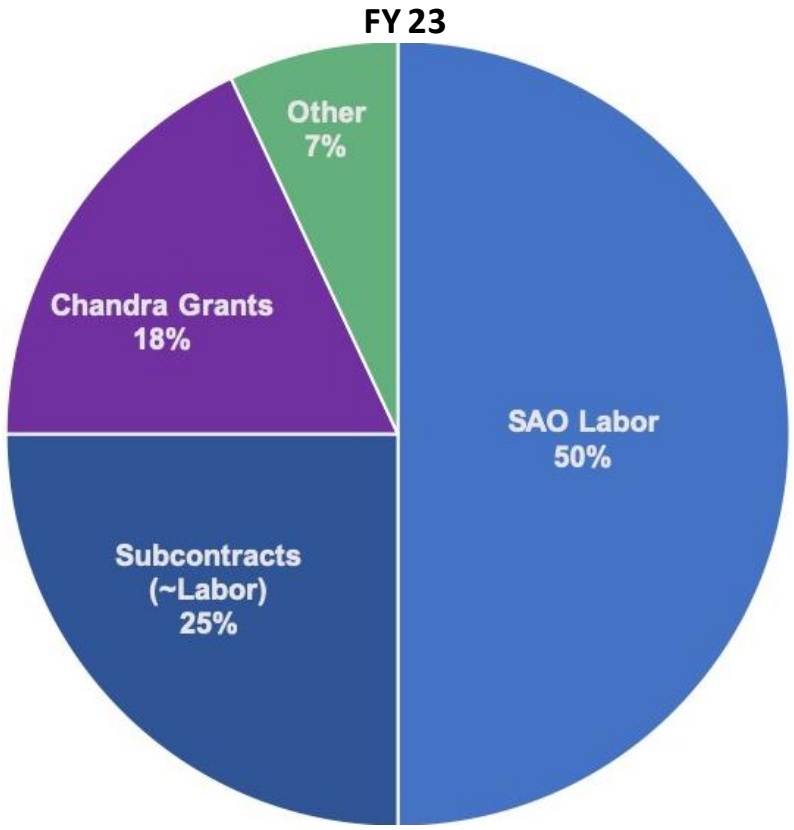
CHANDRA SUPPORTS TDAMM SCIENCE AND A BROAD RANGE OF OBSERVING CONSTRAINTS

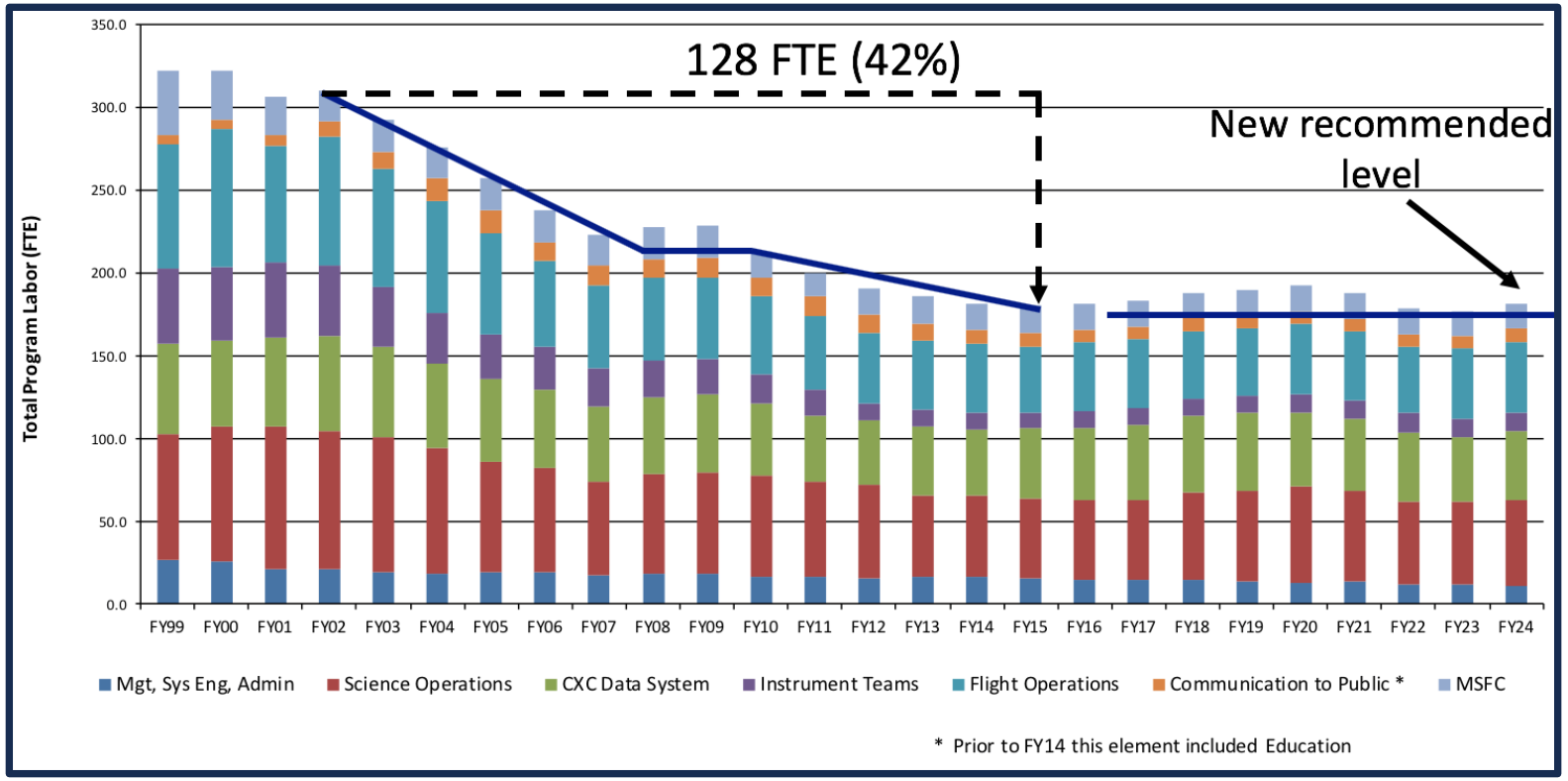




- Chandra provides significant TDAMM support through TOO/DDT and time-constrained observations.
  - Averaged over past three years, Chandra has carried out ~40 TOO/DDT programs yr^{-1} (comprising ~60 observations with ~100 observing segments).
- Chandra supports observing constraints (time, phase, roll, etc.) on a large number of observations to support coordinated multiwavelength efforts and studies of transients.
  - 90 coordinated observations with >10 different observatories in the past year; maximizes community science.

CHANDRA STAFFING LEVELS HAVE DECLINED WHILE SERVICES REMAIN STEADY





- The large majority of SAO funding for Chandra goes to salaries and GO grants.
  - Reductions in funding translate directly to reductions in grants, services, or both.
- Chandra staffing levels have declined by more than 40% since the beginning of the mission.
  - Multiple reviews – of operations as well as overall CXC tasks – have concluded that staff is a minimum size.
  - The Chandra GO funding is only ~$10.5M yr^{-1}. Individual grants are generally relatively small. The entire budget is tight.

CXC TEAMS WORK TOGETHER TO SUPPORT ALL PRE-OBSERVATION OPERATIONS

Chandra X-ray Center Operations Thread: Pre-Observation

The CXC operations thread is the fundamental process by which Chandra enables the astronomy community to perform observations and advance knowledge in the field.

Proposal & User Support helps scientists develop observation proposals

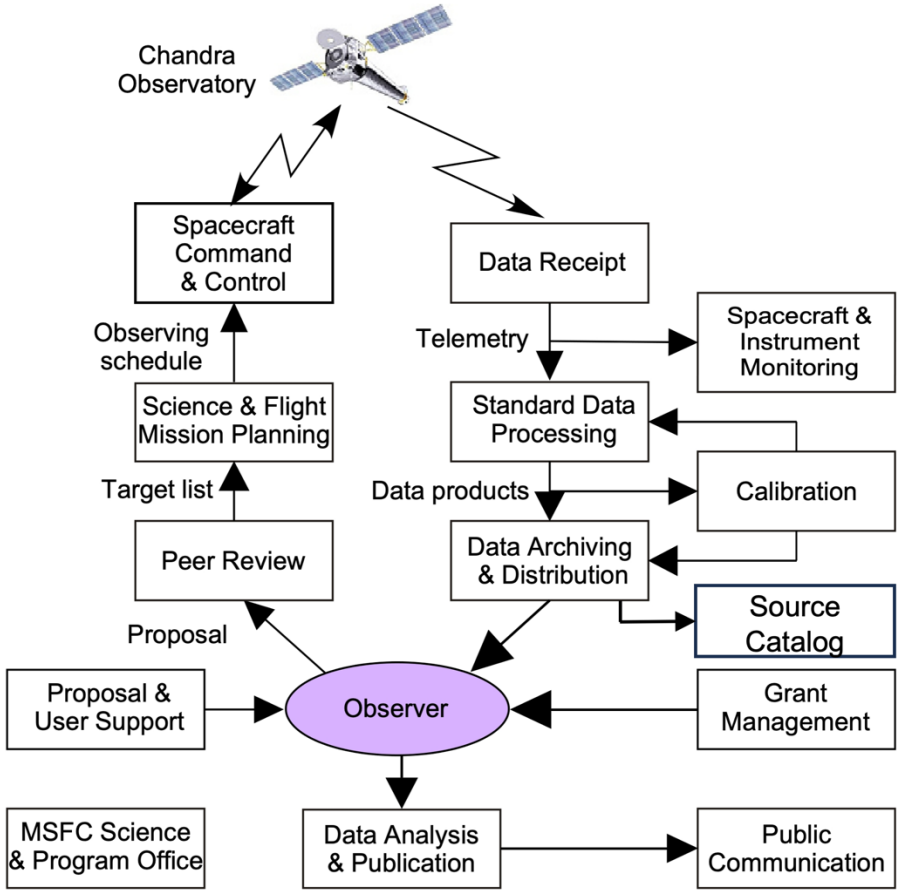
- Scientists use a suite of CXC tools to simulate observations and determine observation parameters to acheive their science goals
- They submit their proposals using the Chandra Proposal System software

Peer Review process evaluates submitted proposals via scientific dual-anonymous

- Scientific merit is evaluated by focused science review panels and an overall leveling panel to rank the proposals
- Technical feasibility and observation constraints are evaluated by the science mission planning team as input to panels
- Approved targets / observations are ingested into the Chandra Data Archive (CDA)

Science & Flight Mission Planning schedules the approved observations from annual peer review

- Science mission planning team develops a long-term schedule to assign approved observations to weekly bins to satisfy both observation and spacecraft constraints.
- Flight mission planning team takes the weekly list and develops an observing plan that satisfies all spacecraft thermal and other constraints.
- The commanding for all observations along with spacecraft housekeeping are output to weekly command loads.
- After careful review by instrument teams and flight engineers, the command loads get uplinked to the spacecraft in 36 hour segments and run autonomously.
- Targets of opportunity and unexpected events such as high radiation shutdowns may require out-of-band replans

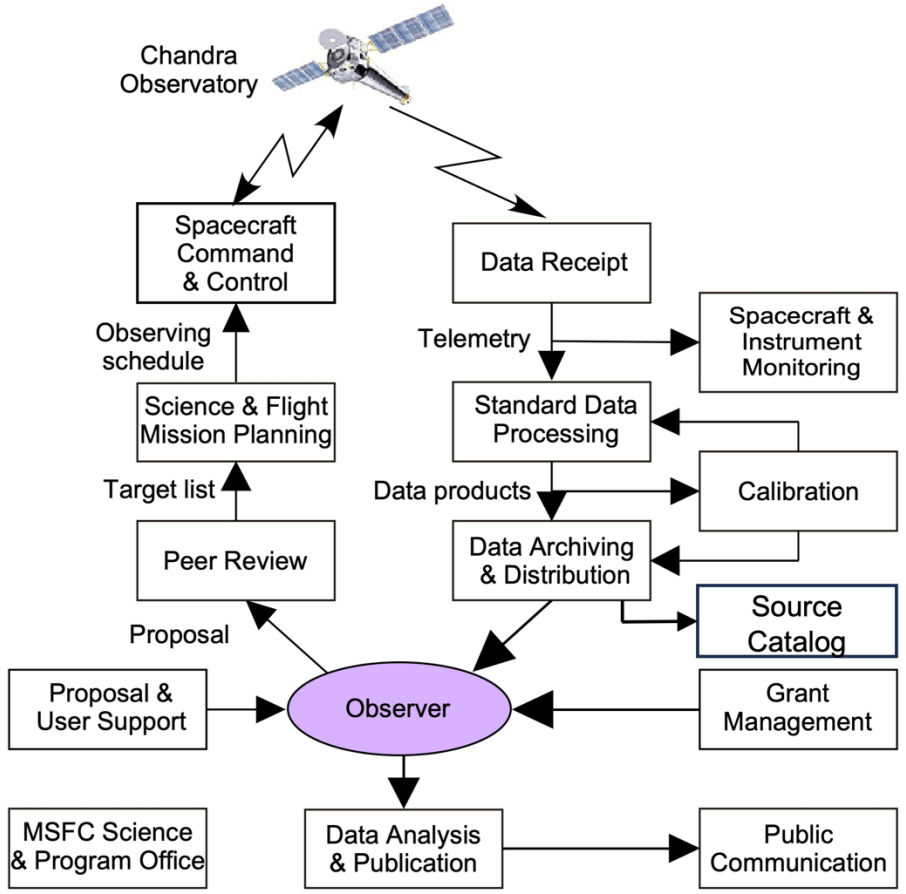


MISSION OPERATIONS TEAMS WORK TOGETHER ON CHANDRA SPACECRAFT OPERATOINS

Chandra X-ray Center Operations Thread: Spacecraft Command & Control

Spacecraft Command & Control is performed at the Chandra OCC

- **Flight operations team** controls spacecraft through weekly observing and vehicle command loads with nominal 3 real-time passes every 8 hours via NASA DSN
  - Observing loads control instruments (ACIS, HRC, gratings) to obtain observations
  - Concurrent vehicle loads control spacecraft subsystems and continue operating spacecraft safely if observing must be halted due to solar high radiation
- During real-time passes, spacecraft status is verified, recorded telemetry data are dumped, new command load segments are uploaded, and other real-time activities (e.g., flight software updates) are performed
- **Ground operations team** receives real-time and recorded data
  - Real-time data are distributed on secured networks for immediate spacecraft and instrument monitoring
  - Recorded data are provided to the CXC science data system
- **Science operations team**
  - Monitors real-time data to evaluate instrument health and safety
  - Monitors solar and geomagnetic radiation activity. For unsafe radiation levels, direct the Flight team to halt the observing loads and put the science instruments in a safe configuration
- *Flight, CXC, and instrument teams work closely together for anomaly resolution*



PLANNING FOR CHANDRA CYCLE 27 IS UNDERWAY

Chandra X-ray Center Operations Thread: Post-Observation

Data Receipt by the Science data system (CXCDS) receives telemetry data from the OCC and ingests the data into the CDA

Standard Data Processing (SDP) performs a series of pipeline processing steps to derive calibrated and validated science data products from telemetry

Spacecraft & Instrument Monitoring and is a critical function to examine real-time data and issue an immediate alert to the operations team for out-of-state telemetry. In addition, longer term trending evaluates the health and performance of the spacecraft and instruments.

Calibration data are a critical part of data processing. The CXC calibration team plans and analyzes calibration observations to maintain the Calibration Database (CALDB).

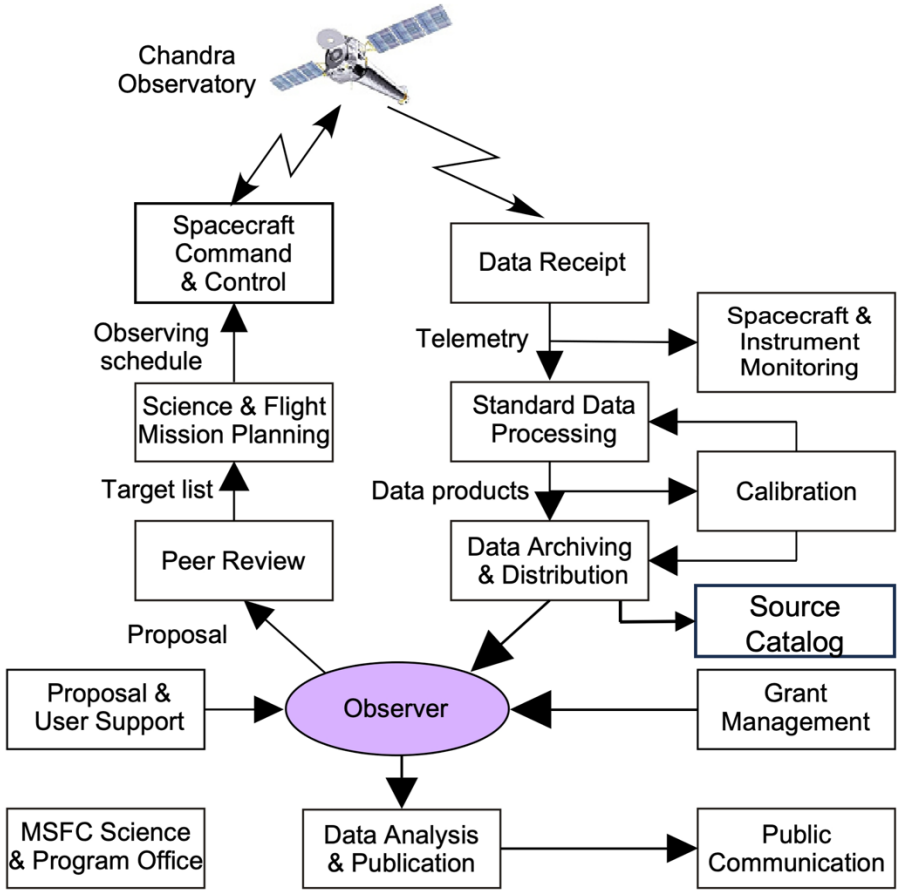
Data Archiving & Distribution archives all processed data and distributes processed data to observers, often within a day of data receipt. The CXC archive team maintains the proprietary period clock and serves public data to archive users.

Chandra Source Catalog is updated with public data on scheduled basis. It currently includes measured properties for over 400,000 unique compact and extended X-ray sources.

Grant Management function manages grant funding to observers, tracks usage, and maintains reporting requirements

Data Analysis and Publication completes the observing thread from idea to publication. Observers analyze their data using the portable CIAO data analysis package (including Sherpa, MARX, and ds9) developed and distributed by CXC

Public Communication occurs for high impact results that are developed into press releases by the Education and Public Outreach group



UPGRADES TO SOFTWARE AND DATA PRODUCTS RECEIVE CONTINUED COMMUNITY PRAISE

CXC Deliverables: Science Data and Software

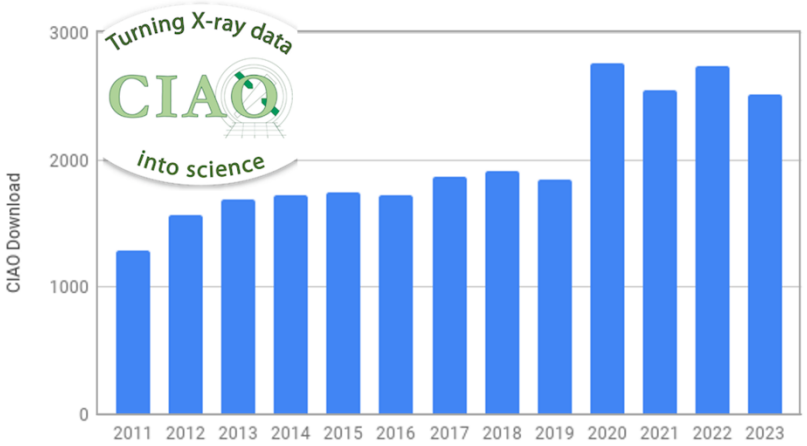
User software needed at all science user steps from proposals to publication: proposal planning (ObsVis, ProVis, PIMMS, PSF View, Star Checker), analysis of calibrated data (CIAO), interpretation (Sherpa model fitting, MARX image simulator), and visualization (DS9 interactive image analysis) – all open source.

Science Data Products are kept up to date with high-quality and up-to-date calibration and community-standard FITS metadata, leveraging the team's half-century of X-ray processing pipeline expertise.

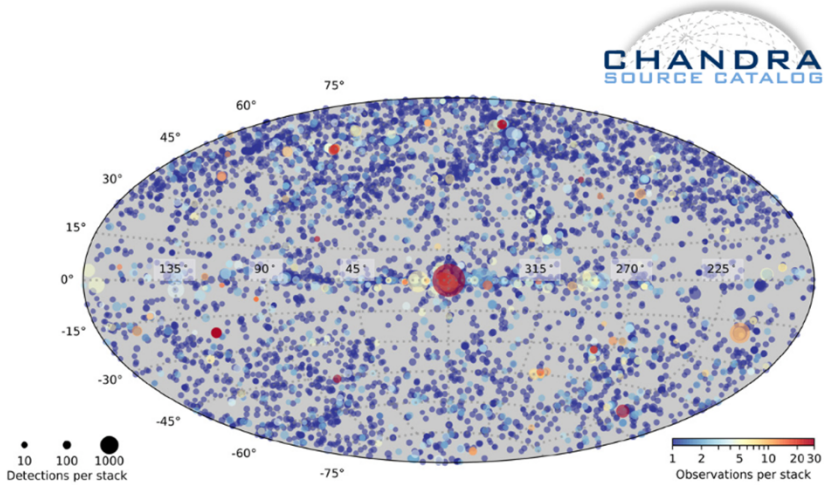
Processed Catalogs (Source Catalog, Grating Spectrum Catalog) provide effective interfaces for analysis of mission data as a whole and for comparisons with data from other NASA observatories.

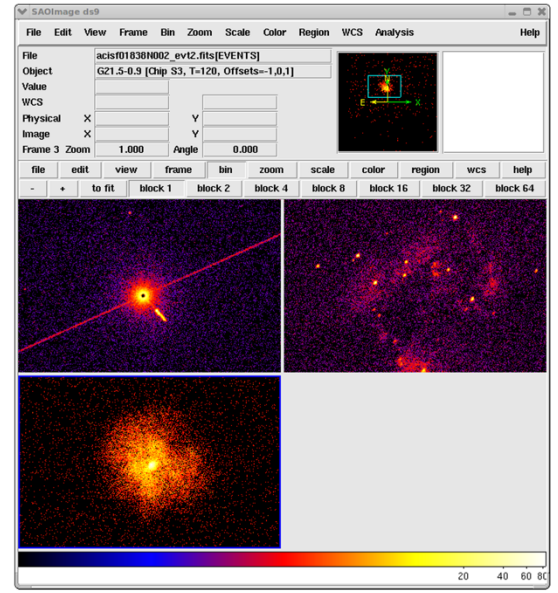
Challenges include software maintenance to accommodate changes in operating systems and languages; additional algorithms to support changes in the science questions that astronomers are now asking of the data; and changes to ensure interoperability with modern analysis paradigms (e.g. python notebooks).

Demand for Chandra software and data remains high



Annual number of downloads of the CIAO user software package shows continuing demand for the latest capabilities.





The CXC's DS9 imaging application is the world standard for astronomical image display – not just X-ray astronomy

The extensive "science-ready" Chandra Source Catalog provides positions, fluxes, spectra, variability information and much more to support high quality archival research.

CXC DOCUMENTATION AND TRAINING ADD VALUED TO NASA'S ASTROPHYSICS ENTERPRISE

CXC Deliverables: Supporting the Astronomy Community

CIAO Software documentation and 'threads' widely praised as the best in X-ray astronomy and allow users from undergraduates to experts to learn how to get the best science out of Chandra data.

Documentation is regularly updated, taking into account changing instrument behavior, latest analysis techniques and new software environments, paradigms and best practices.

Aim is to make X-ray astronomy accessible to all astronomers: X-ray data adds value to HST/JWST data on the same objects.

CIAO Helpdesk supports users both at the proposal and data analysis stages.

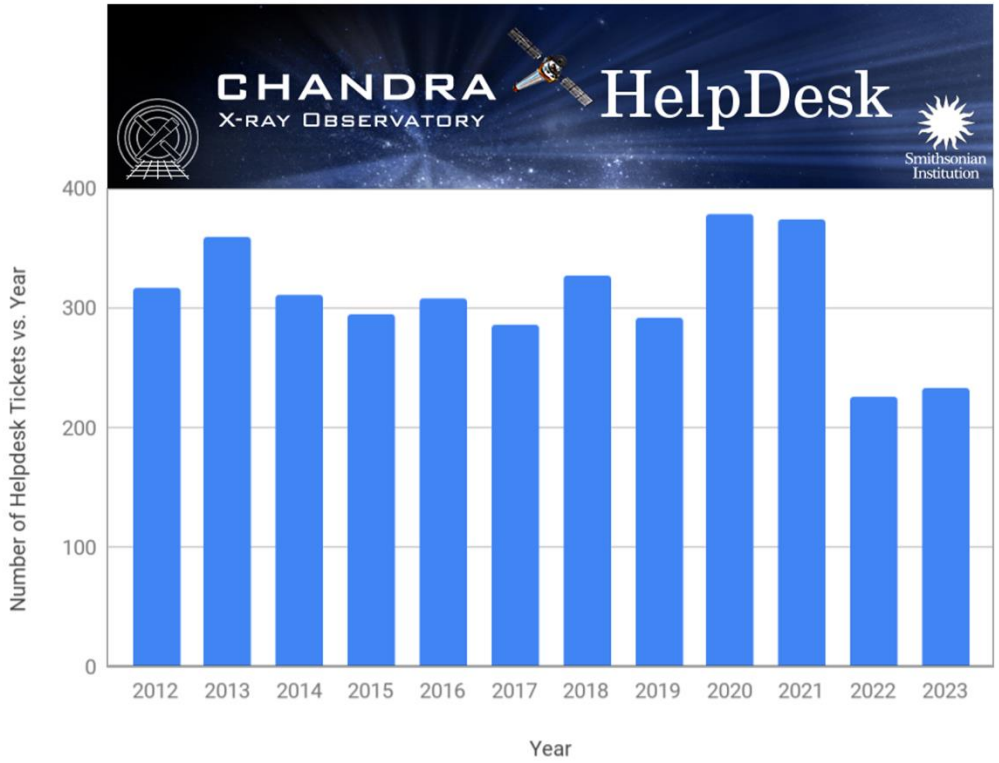
Chandra workshops and symposia bring the community together to share latest results and learn new techniques.

Newsletters and announcements keep the community informed of new capabilities and of changes to the spacecraft or data products that could affect their analysis.

Direct interactions with users at **workshops and conferences** lets CXC staff keep abreast of changing user needs, science focus.

Chandra booth at AAS (left); CIAO training workshop (above).

CIAO Helpdesk is a critical part of CXC community support

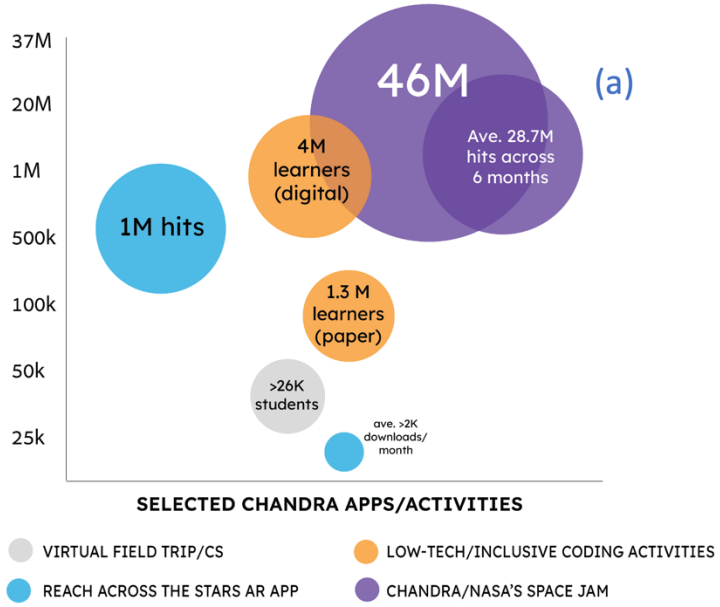


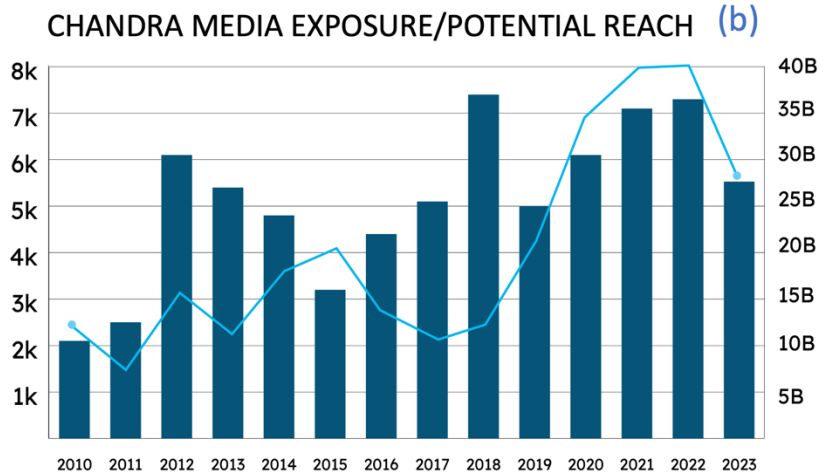
Annual number of data analysis helpdesk tickets handled by CXC staff.

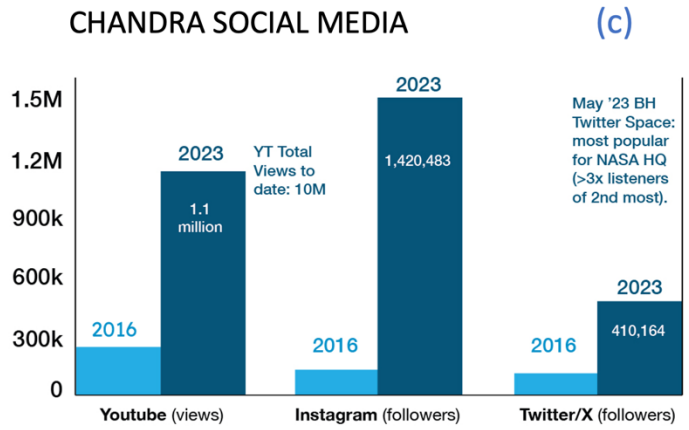
ROBUST, ACCESSIBLE, INCLUSIVE CPE PROGRAM: SCIENCE CONTENT HAS REACHED BILLIONS

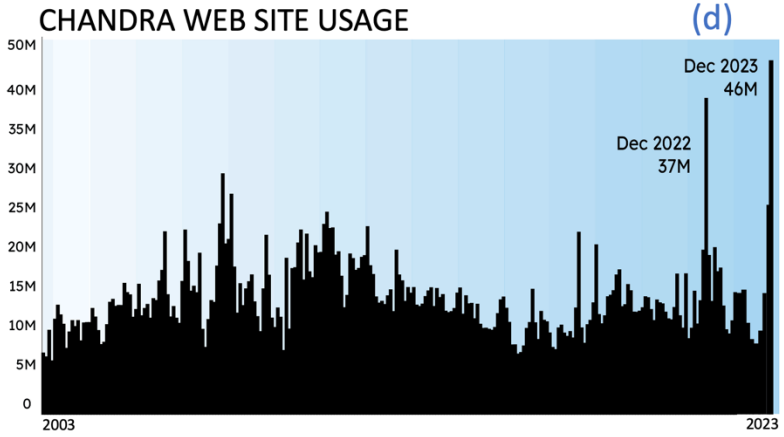
CXC Deliverables: Chandra Communications & Public Engagement (CPE)

- Multiple viral moments since 2018 across Chandra images, press, sonifications.
- Robust usage of Chandra apps/content (a)
- Sustained media exposure & reach; social media audience growth & engagement; heavy web site traffic. (b, c, d)
- **>20M in-person visitors,** since 2009, to Chandra public science exhibits at airports, town squares, cafes, metro stations, malls, etc.
- **>16M learners engaged** since 1999, w/festivals, military events, STEM days, science or coding clubs, museums, libraries & other external events.
- Active engagement w/underserved audiences: low resource/low-income districts, Black, BVI, etc. Active partnerships with Code,org, Girl Scouts, Black Girls Code, National Federation of the Blind, schools for the blind, US State Dept & more.







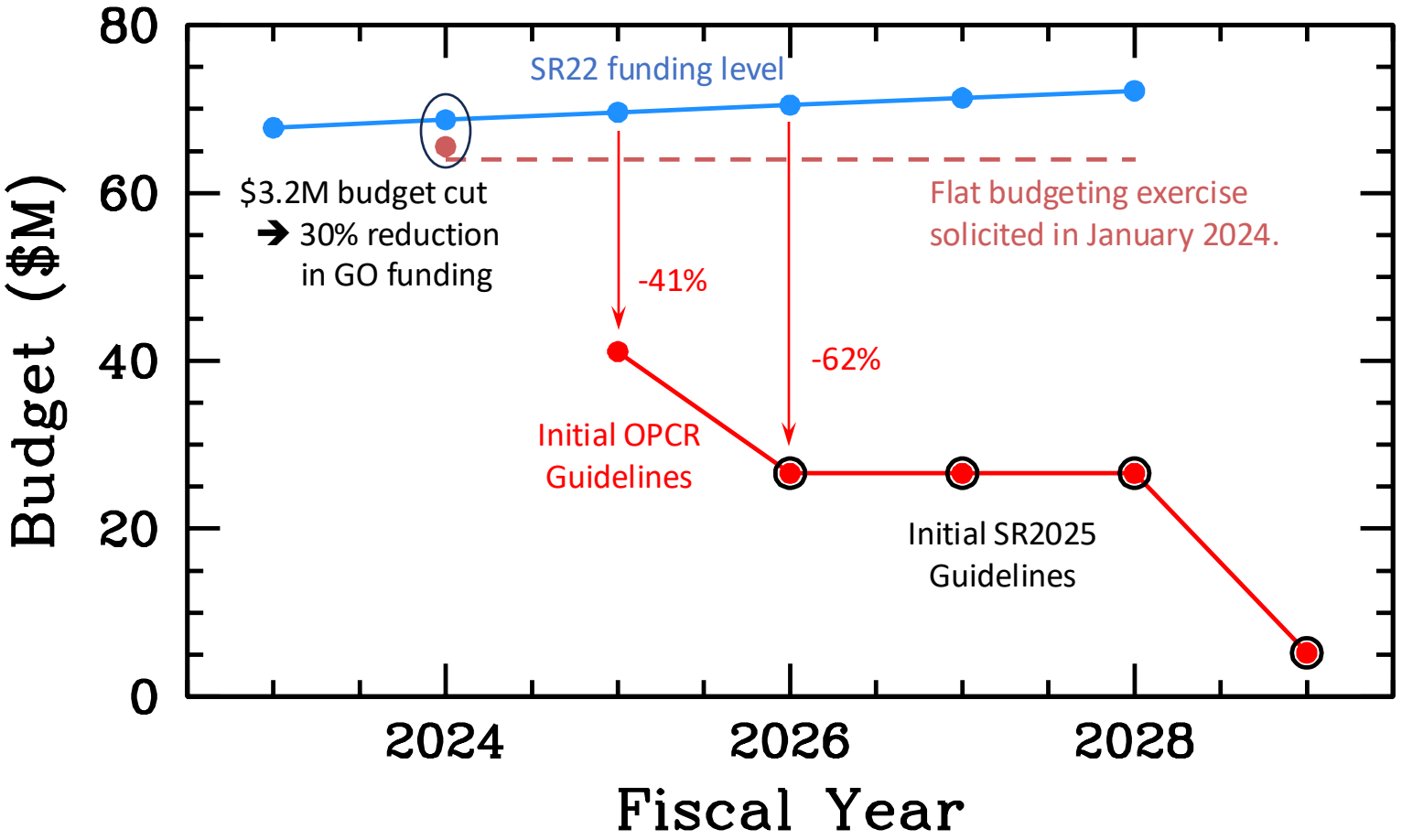


THE CHANDRA BUDGET HAS BECOME TURBULENT

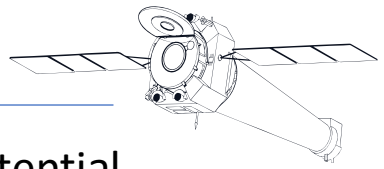
NASA Response to the 2022 Astrophysics Senior Review of Operating Missions:

"The Chandra mission is provided additional funding to preserve operational capabilities and enhance Chandra's ability to support time-domain science within the budget provided.

The guiding principle for the use of the funded overguide should be to maximize the science returns for the community by preserving mission infrastructure while maximizing General Observer program funding."



OPERATING PARADIGM CHANGE REVIEW



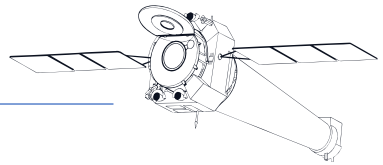
- Prompted by severe budget difficulties in NASA APD, both Chandra and Hubble were identified as potential targets for additional budget reductions.
  - An ad hoc review mechanism – the Operating Paradigm Change Review (OPCR) – was created to search for ways of reducing costs through changes in the operating plans.
  - Panels were charged with evaluating proposals and issuing "findings" to NASA APD.
- Teams were presented with budget guidelines and directed to propose options that would meet the guidelines.
  - Chandra guidelines represented massive cuts – at existing budget plan levels for closeout at end of mission. Decommissioning was the only "in-guide" option. Ultimately, up to three over-guide options were allowed.

SR22 Guidelines ($k)	FY23	FY24	FY25	FY26	FY27	FY28	Notes
	67,765	68,715	69,615	70,465	71,315	72,165	**Total budget (incl. GO program)**

OPCR Guidelines	Request FY 2025	FY 2026	$M FY 2027	FY 2028	FY 2029
Chandra X-Ray Observatory	**41.1**	26.6	26.6	26.6	5.2

- Chandra proposed four options – closeout; a minimal mission; the minimal mission with GO funding; and full funding.
  - Minimal mission was still above guideline for FY25, and far above for FY26 and beyond.

CHANDRA CONSIDERED HIGHLY REDUCED CONCEPTS IN THE OPCR



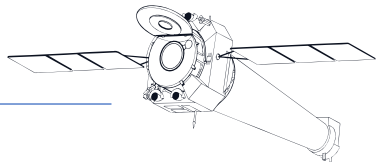
Minimum Proposed OPCR Mission

- **Eliminate GO program, including funding and standard proposal cycle. Drop Cycle 26. Targets solicited through DDT/Joint/Legacy programs.**
- Remove HRC from use. Grating use available only with ACIS.
- Chandra archival research through ADAP only.
- Minimize available operating modes for ACIS. No new configurations.
- Place all software into maintenance mode. No new updates/algorithms/ functionality to analysis software (ciao, sherpa, DS9, MARX, SAOTrace).
- No new updates to Data System software beyond mission-critical needs.
- Halt any further work on Chandra Source Catalog (frozen at CSC 2.1) and TGCAT.
- Eliminate Chandra conferences/symposia, newsletters, and training workshops.
- Freeze HRC/LETG/HETG calibration. Minimize ACIS calibration.
- Eliminate Uplink Support for observations. Reduce HelpDesk to minimal levels.
- Eliminate V&V task; minimize special processing efforts.
- Minimize monitoring and trending of instruments. Increases risk, decreases fidelity.
- Eliminate bibliography and other mission statistics tracking.
- Reduce rapid return-to-science support following anomalies, leading to decreased efficiency.
- **Introduce ≥50% idle time for observing to simplify planning and scheduling, significantly reducing observing efficiency.**

- An additional option – the minimum mission but w/ GO funding for the reduced observing time – was put forth as well.

  - GO funding at <50% of normal levels due to no theory/archive and only ~50% of normal observing time.

THE OPCR CONFIRMED CHANDRA'S IMPORTANCE AND STATE OF HEALTH



Chandra and HST are Great Observatories serving huge observing communities and producing frequent scientific breakthroughs from observations and archives, with increasing numbers of publications

Both received top marks in Senior Reviews: high return on the dollar

Annual operating cost a few percent of capital cost provides large and guaranteed return on investment

Both are unique: no other equipment now or approved for construction could replace them

Both have new scientific projects in synergy with JWST and time domain multi-messenger astronomy (a top priority in Decadal Survey)

Both are in good health, operating efficiently, in high demand (oversubscription), archiving and distributing data, and supporting widely used analysis tools. The thermal control issues facing Chandra have not had any impact on its scientific productivity.

Both have limited lifetime, but should run well into next decade

Both have approved end-of-mission plans

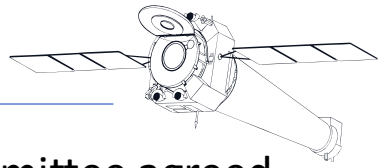
Operations are highly streamlined and optimized after years of improvements - even small budget cuts require losses of services and capabilities

Operations costs are mostly staff: significant cuts would require RIFs, with legal implications and irreversibility

Ending either of these missions now would be premature and would have a large, permanent impact on science and the astronomical community

Upshot: The OPCR concluded that "operating paradigm changes" would have severe negative impact on these missions.

CHANDRA OPCR RESULTS AND CURRENT FUNDING STATUS



- Panel confirmed that Chandra response to OPCR was credible: “After considerable discussion, the committee agreed that continuation of a scientifically viable CXO mission was not possible within the funding constraints of the FY25 proposed budget (PBR).” [“This is not a bluff.”]

- NASA communicated intent to fund OPCR Option III - a reduced mission concept with GO funding.

  - OPCR Option III had GO funding at <50% of normal levels due to reduced observing time.

- Subsequent direction to NASA established funding level specifically targeted at avoiding staff layoffs.

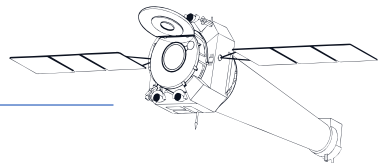
  - Funding is currently under a Continuing Resolution at near recent levels except for <50% of GO observer funding and no archive/theory support, all subject to final appropriations guidance upon approval of FY25 Congressional Budget.

- Cycle 26 has been preserved; reviews were held, targets selected, and grants awarded but no archive or theory awards.

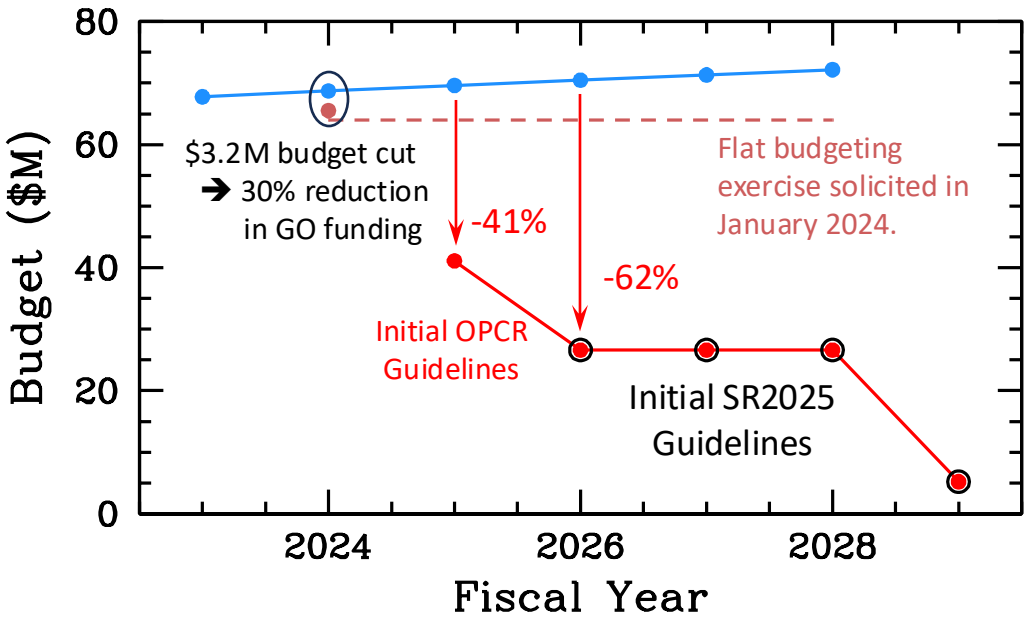
- **Synopsis: Chandra avoided decommissioning, maintained the GO program (proposals, reviews, some funding), and continues operating at historical levels of service. (In the meantime, a Legacy Program was born as well.)**

  - Support from CUC, X-ray community, general astronomy community, public, press, Congress, NASA, and beyond was absolutely crucial in this entire process.

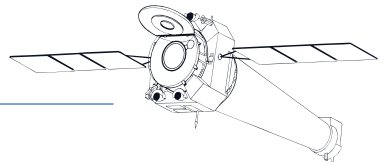
CHANDRA: NASA 2025 SENIOR REVIEW



- Chandra is going through 2025 Senior Review (SR proposal due 12 December 2024)
- Single panel will evaluate all participating missions.
  - Recommendations will inform NASA decisions on mission funding for FY26-30.
- Funding guidelines are locked to FY25 PBR. Chandra is starting at risk again.
  - SR Review requires in-guide plan along with under-guide plan. Over-guide options are permitted (and anticipated).
- Following OPCR input from panel, community, and CUC, the exact minimum mission from the OPCR will not be put forth.
  - Removal of GO proposal solicitation and reduction of observing time to 50% of current values was deemed to represent too large of a loss relative to cost savings (consistent with NASA restoring these from OPCR option).
- Chandra plans have been discussed with CUC. Proposal has been through “red team” review, including by CUC Chair. Revisions now underway.



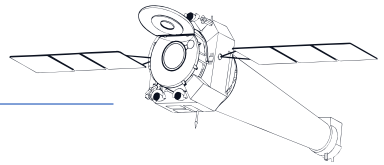
CHANDRA SENIOR REVIEW SCENARIOS



Chandra proposal will put forth three options:

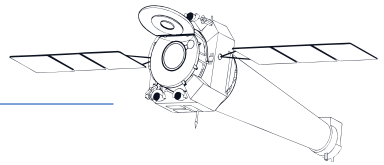
- In-guide option: Chandra decommissioning
  - Closeout costs actually exceed guidelines. Rephasing and restructuring of a Chandra closeout would need to be negotiated were this option to be considered.
- Under-guide option: The only feasible under-guide option is some kind of reduced decommissioning plan. Since the budget guidelines are already below existing closeout cost plans, the in-guide option will serve as the under-guide option.
- Over-guide option I (~$60M for FY26): This is the minimum OPCR mission with these exceptions:
  - Staffing to ensure that proposal cycle and full observing time are added back (+$3.7M).
  - GO funding for full observing time is added back (+$5M)
  - The long list of reductions from OPCR minimum mission is still required, leading to a **very significant loss of support for users.**
- Over-guide option II (~$71M for FY26): This is the continuation of the nominal Chandra mission with two exceptions:
  - No funding for GTO research (required by NASA)
  - Small additional savings from staff attrition and task consolidation.

CHANDRA SENIOR REVIEW SUMMARY



- Chandra capabilities are unique and crucial to a wide range of topics in astrophysics.
  - At present, no Chandra replacement is under development.
  - AXIS selection for Phase A studies emphasizes crucial need for a high angular resolution X-ray facility.
  - Continuation of Chandra until its replacement is in place is critical to the field.
- Chandra is healthy and highly productive.
  - Reviews continually show that science results are excellent, operations are efficient, and service to the community is outstanding.
  - There are no showstoppers that would prohibit Chandra from continuing outstanding performance through the decade and likely well beyond.
- Chandra Senior Review proposal work is underway.
  - Option for support of full mission is highest priority.
  - Option for reduced mission provides viable observing program, but major loss of support to the community.
  - In-guide option will require decommissioning Chandra, representing a tragic loss of a highly functioning Great Observatory.

PLANNING FOR CHANDRA CYCLE 27 IS UNDERWAY



- Cycle 27 plans are going forward, ultimately subject to Senior Review results.
  - Call for Proposals due for release on 19 December 2024.
  - Call solicits observations for both ACIS and HRC, with or without gratings.
  - Proposals due 19 March 2025.
- Plans to move Chandra archival research to ADAP were approved and planned for the upcoming ADAP AO.
  - Funding issues caused NASA to back off of this plan. As a result, funding is not assured for archival proposals. The same is true for theory proposals.
  - Rather than soliciting archive/theory proposals in Cycle 27, CXC will wait for Senior Review direction and hold a a separate call if these areas are funded.
- The CXC will move to a distributed peer review for Cycle 27 to establish a consolidated process for future reviews.

December 3-6, 2024: Revere Hotel • Boston

The symposium will highlight twenty-five years of incredible science enabled by the Chandra X-ray Observatory, celebrating the discoveries made by Chandra, the unique capabilities of the mission, and the potential discoveries still remaining. Topics and themes will emphasize high resolution imaging and spectroscopy, synergies with other observatories, and the legacy of the Chandra archive, covering theoretical and observational perspectives.

Please contact us at chandra25-symposium@cfa.harvard.edu with any questions.