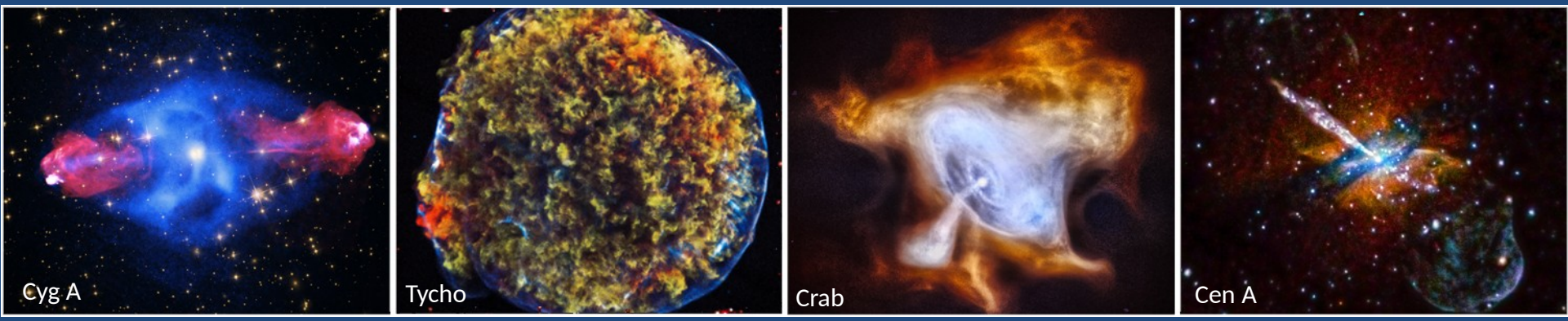
Chandra – The Next Decade

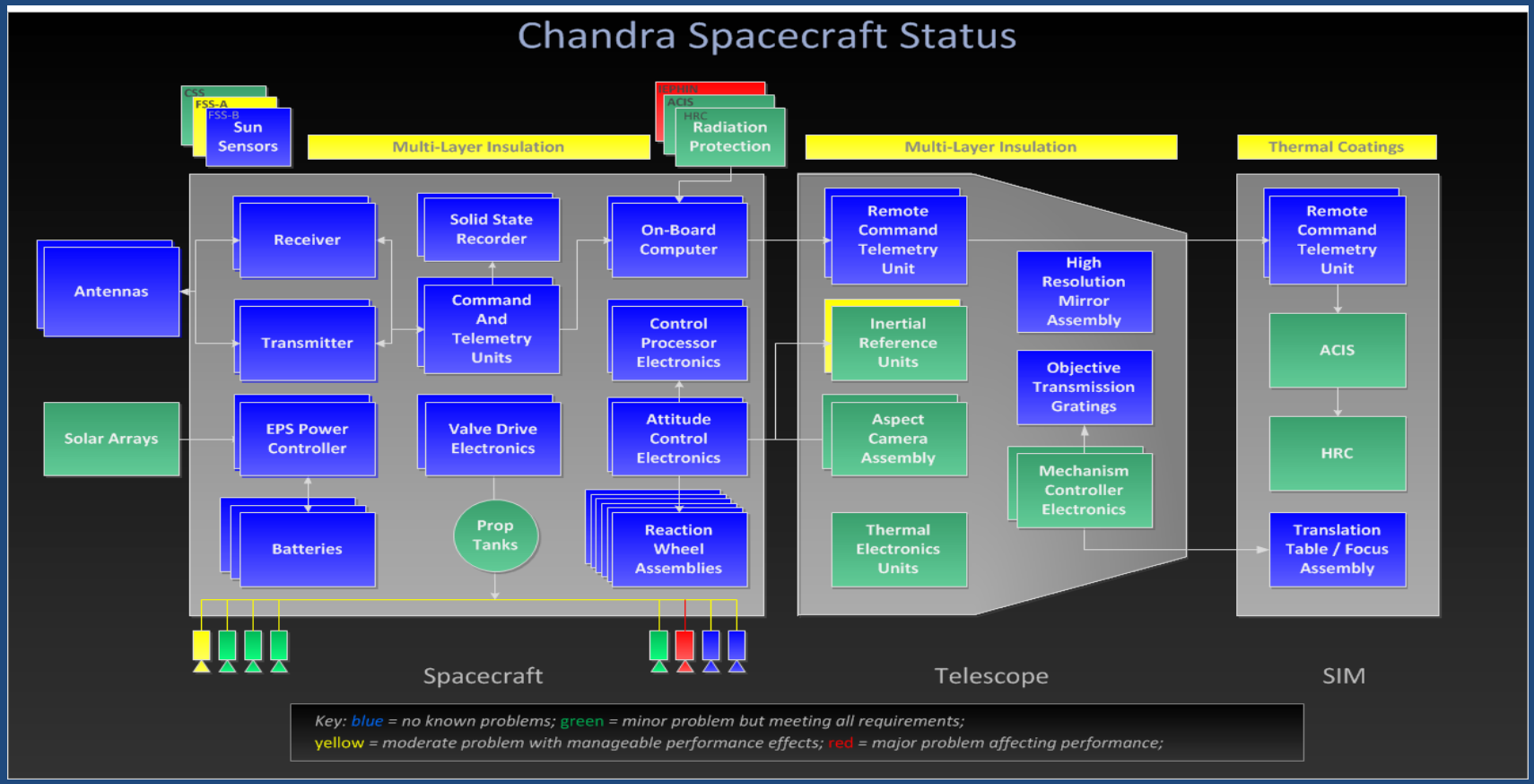


2016: Excellent Senior Review Results!

Belinda Wilkes
Director
Chandra X-ray Center

Chandra:17 years and counting!

Detailed engineering review showed no show-stoppers to ***10(+) more years*** *of observing*



Little red or yellow!

Basic Information

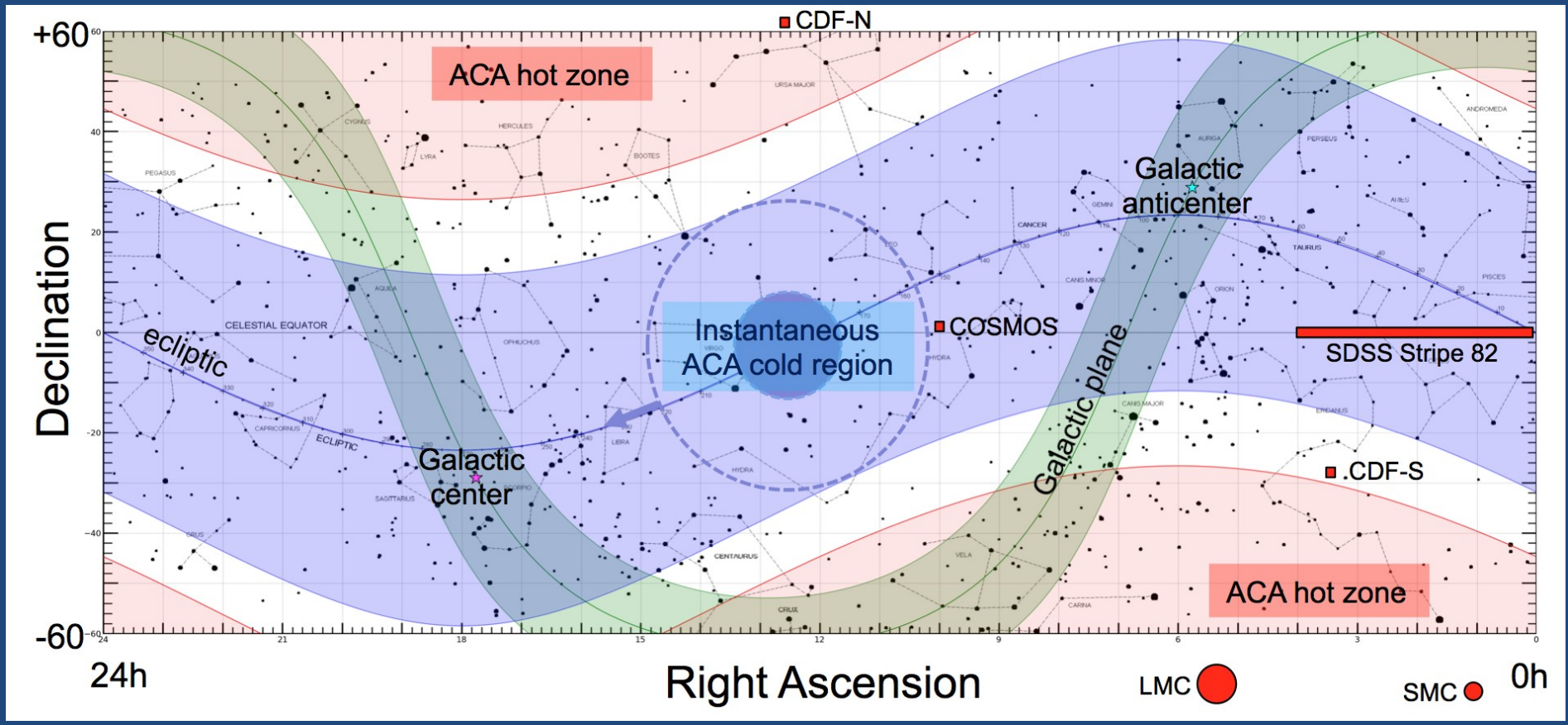
- ~3 day orbit
- ~70% observing efficiency (~16-18 hr radzone)
- Mission Planning:
  - 1-week schedule, DSN COM every 8 hrs
- Resolution:
  - Spatial ~0.5”
  - Spectral, gratings: ~200-1000; 0.1-10 keV
  - Highest time resolution, HRC: 60μs
- 25+ year lifetime expectation

Chandra Challenges

- Contaminant build-up on ACIS OBF
  - Significantly reduced A_{eff} < 2 keV since launch
  - Longer exposures for science requiring low energy data
  - Bakeout: risk vs reward study is ongoing

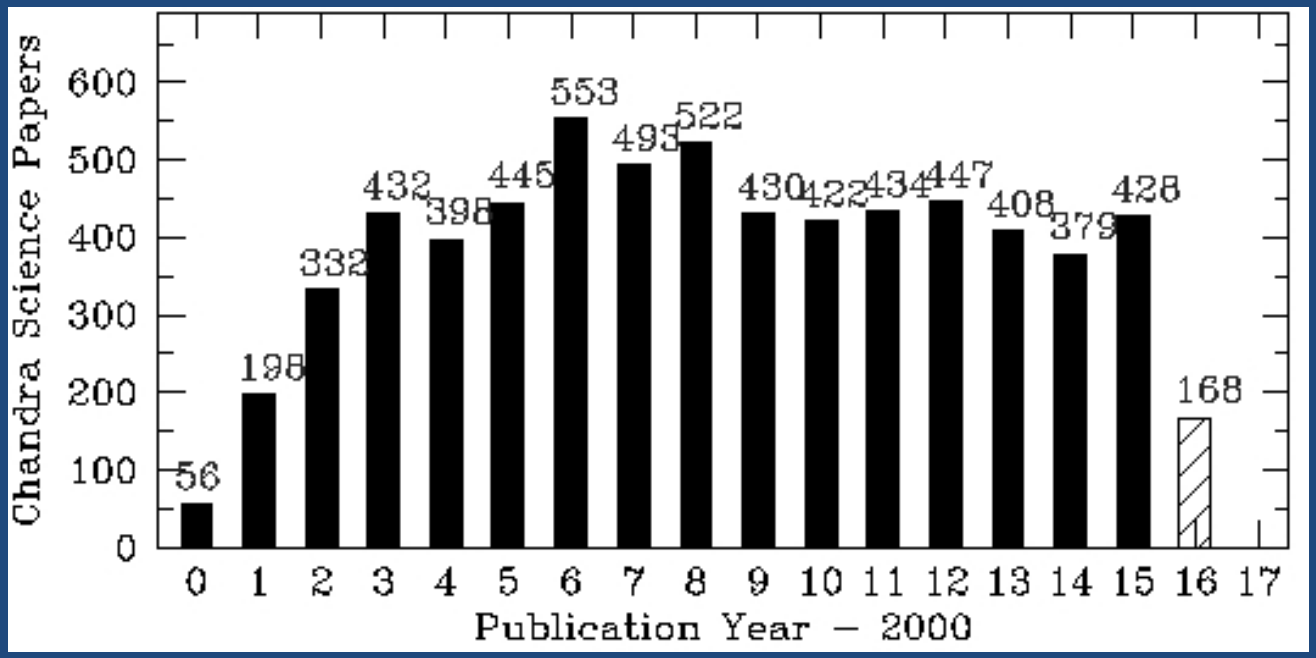
- Thermal degradation:
  - Spacecraft insulation is degrading, general warming
  - Monitor, and predict temperatures of many components
  - Limits dwell time over most solar pitch angles
  - Complex scheduling:
    - Limits on constrained time to maintain an efficient schedule
    - Long exposures are split
  - So far, ~no restrictions on observing time
  - *Eventually (>2 years): limit % observing time close to ecliptic poles*

Constraints on the Sky
due to thermal degradation



Chandra's high impact on astrophysics

Refereed papers per year

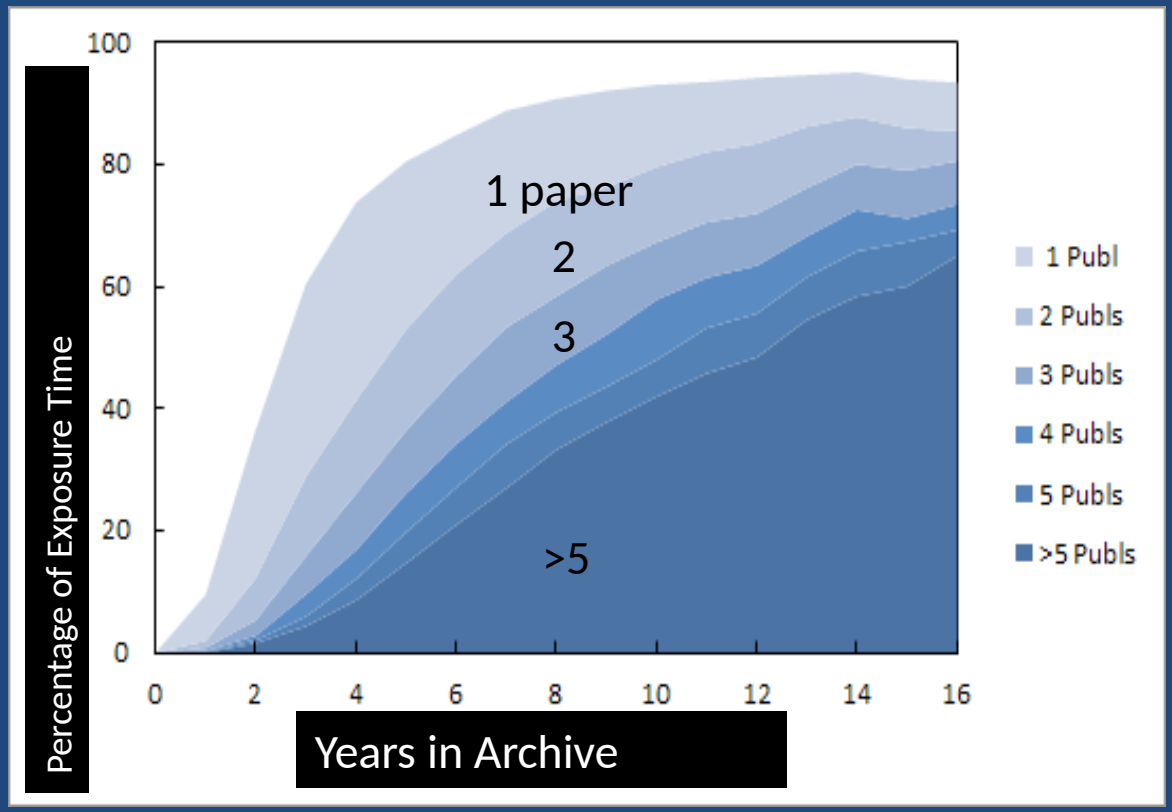


Refereed science papers

- 6563 total Chandra papers (to 08/01/2016)
- 450 mean # papers/year (2005-2015)
- 35 mean # citations/paper after 6 years (84 after 14 yrs)
- >320 PhD theses (worldwide)

Metric measures productivity and data utilization

% of data published in # refereed papers vs. # years in archive



Rots et al. (2012)

Publications:

- Median time to publication: 2.4 yrs
- After 3 years: 60% of data are published in 1 or more papers
- After 8 years: 90% of data are published in 1 or more papers, 60% in 3 or more

Science covers full range of astrophysics: Cosmology, black holes, clusters, galaxies, stellar birth and death , exo-planets, planets (including Pluto during New Horizon's flyby)

The Next Decade: *Chandra's* X-ray Legacy

- **Key Science:**
  - Major current science questions *Chandra* SHOULD address given enough (how much?) time
  - Athena &/or X-ray Surveyor preparatory science
  - New science opportunities due to new/future observatories

- **Assess *Chandra* archives for Legacy** (using source catalogs, by science area):
  - Missing "Rosetta Stone" sources (in any waveband)
  - Incomplete samples of sources, e.g. 3CR, PG (AGN)
  - Multi-wavelength Survey fields not (adequately) observed

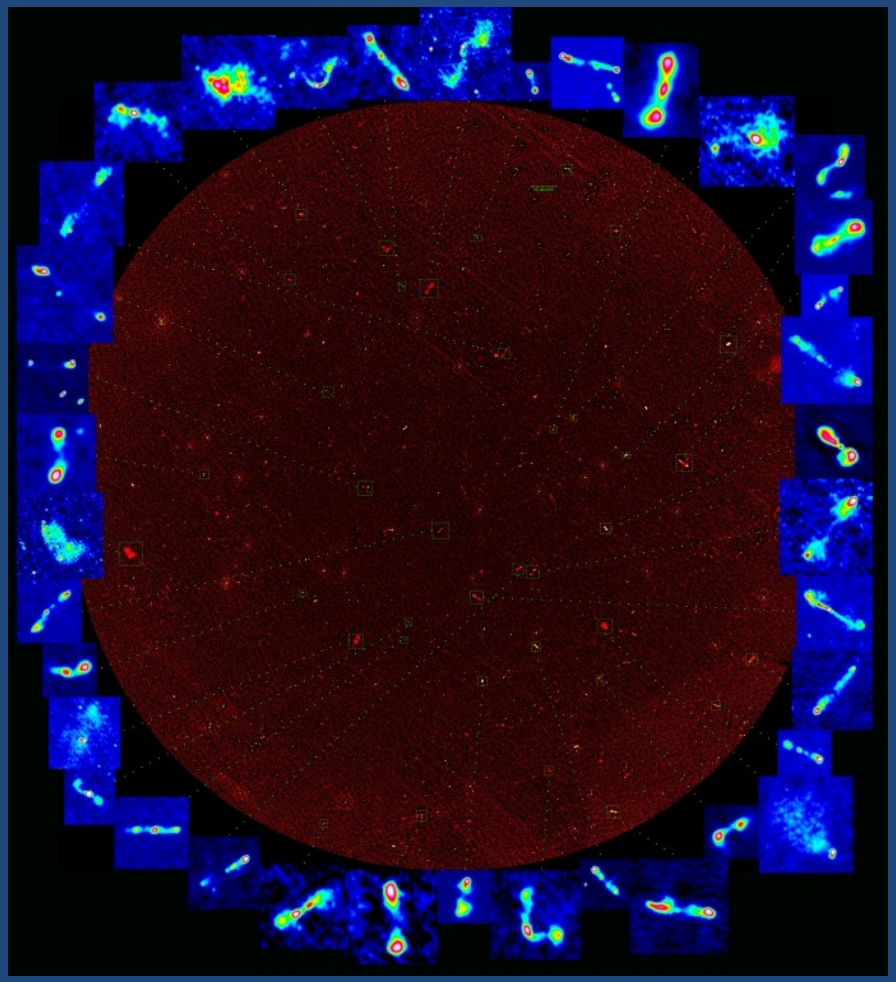
New and Future Multi-λ Opportunities

- **ALMA**: AGN outflows, star forming regions
- **LOFAR, MWA, (SKA), VLASS**: observe one/more survey fields to study related X-ray emission
- **LIGO**: GW transient, EM detection follow-up

- **E-ROSITA** (2017?): follow-up, e.g. clusters
- **JWST** (2018): Compton-thick AGN, galaxy structure, high-redshift galaxies etc.
- **LSST** (2023): access to images, strategies to follow-up transients/variables
- **TESS** (2017): transients, AGNs, survey TESS fields

X-ray Survey of LOFAR Fields

- Bootes field observed by the Surveys Key Project team (150 MHz)
- Resolution ~5”
- Many will be X-ray sources
- *Chandra* survey of selected LOFAR fields?



Chandra Proposal Opportunities

Category (Cycle 18)	Exposure Time Allocation (Ms)
General Observer	10-12
Large Projects (> 400 ks)	4-6
Director's Discretionary	0.7
Joint*	~ 1 week of time
Archive	$1060K*
Theory	$650K*
Past Categories:	
Very Large Projects (> 1 Ms)	1-3
X-ray Visionary Projects (> 1 Ms)	5-8 (enabled by orbit evolution)

*XMM-Newton, HST, Spitzer, NRAO, NOAO, Swift, NuSTAR

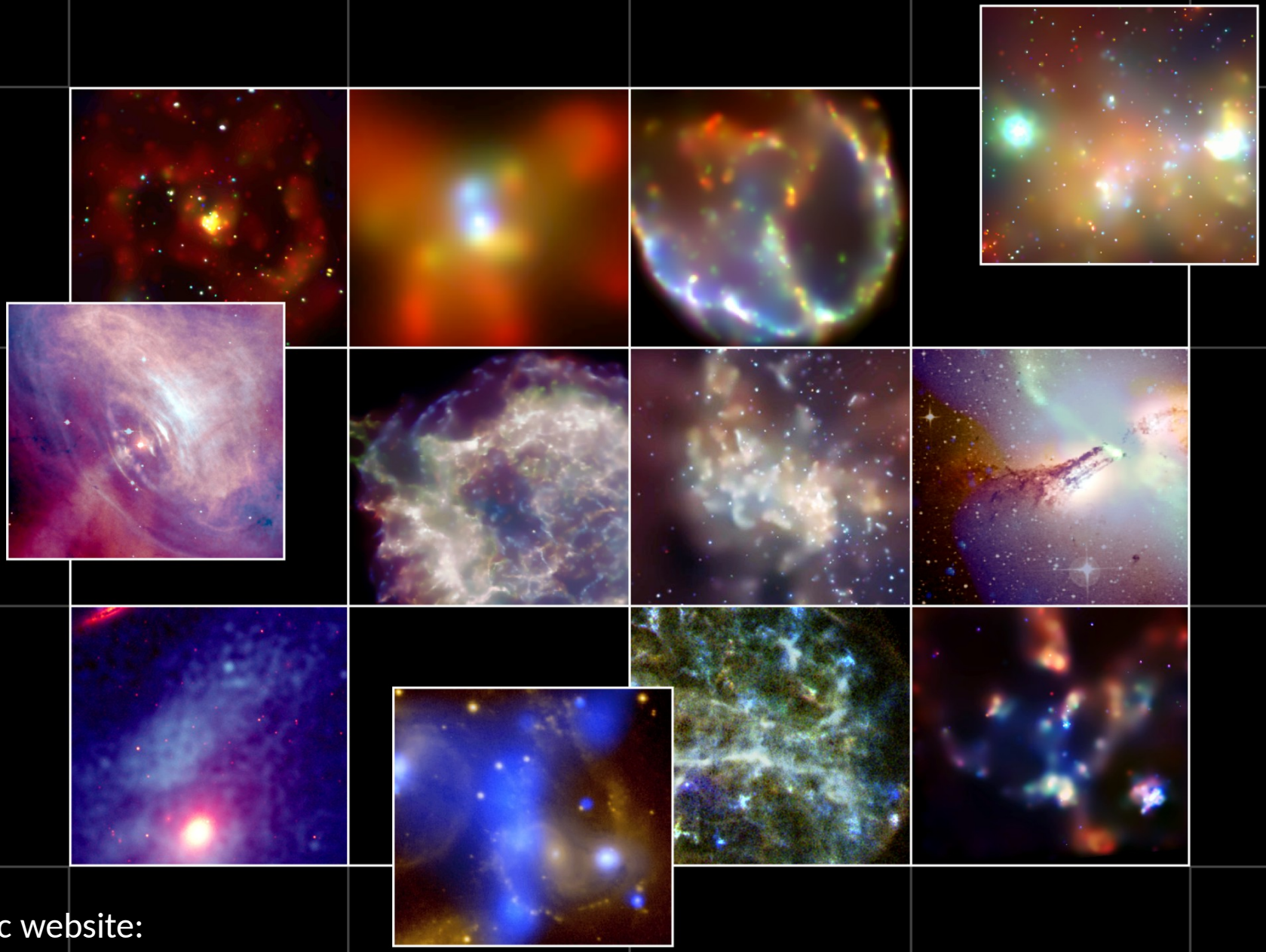
*Total GO Budget: $10-11M

Can key proposals be proposed and accepted?

- Update to Proposal Categories?
  - Distribution of time between GO (< 400 ks) and Large Projects
  - >1Ms proposal category (unlike XVP, time comes from GO+LP)
  - New or updated proposal categories: e.g. high risk, expand DDT
  - Increased Archival funding (at expense of observing proposals)
- Multi-wavelength Projects:
  - Expand Joint time to Large Projects
  - New joint time agreements: ALMA(?), JWST (see Paul Green's talk)

What else is needed to facilitate the best science?

- Software:
  - CIAO: updates needed?
- Data access:
  - *Chandra* archive
  - *Chandra* Source Catalog v2 (late 2016)
  - IVOA compliant
  - Data mining
- Access to networks, facilities or data:
  - LSST transient and image data
  - LIGO, TESS: transient distribution list
  - VLASS data
  - Super-computer access



Public website:
chandra.si.edu

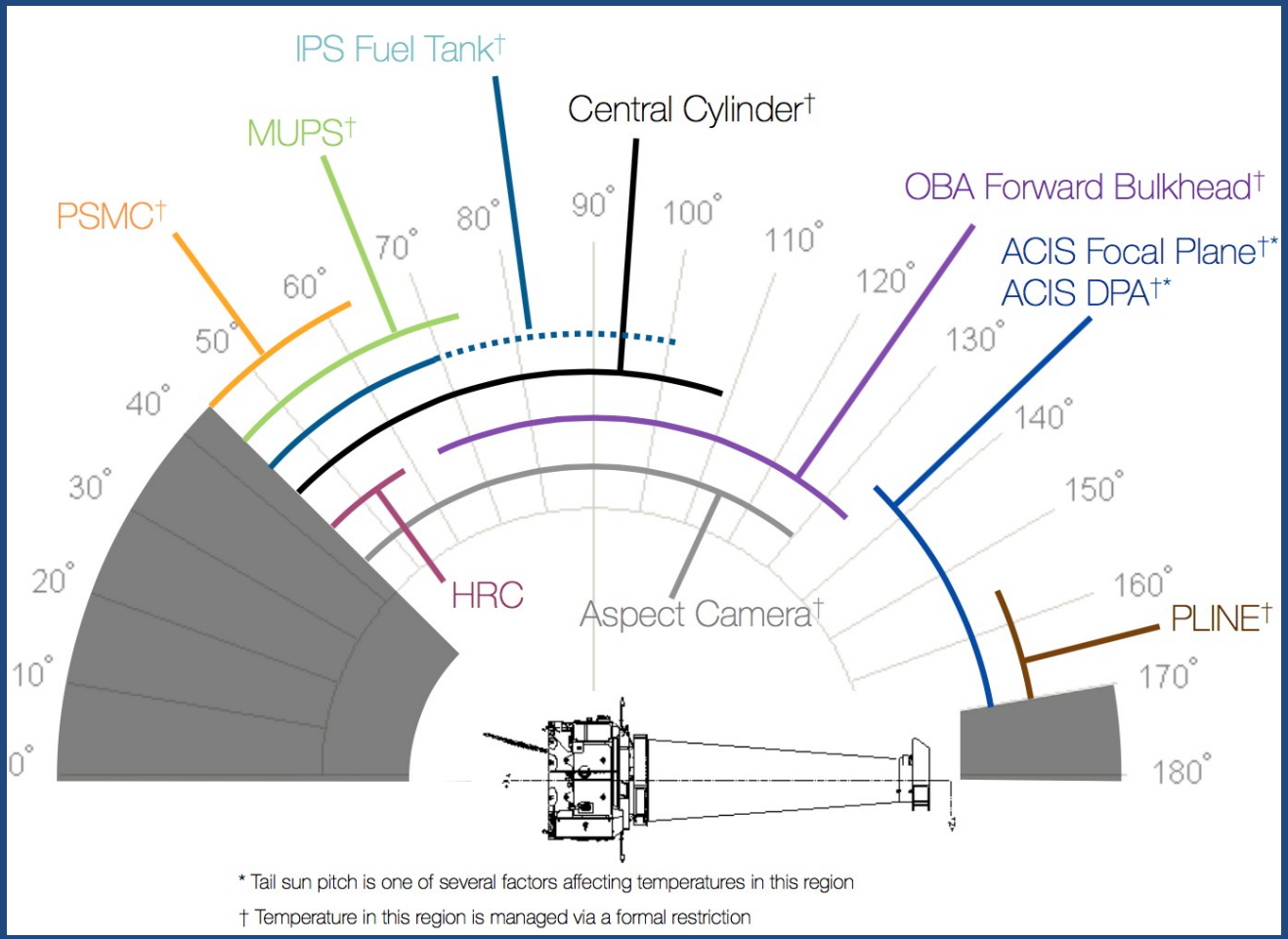
Backup Slides

Thermal issues in aging spacecraft

- Insulation is degrading → general heating
- Temperature managed via spacecraft attitude control
- Many subsystems monitored continuously
- Limited dwell times at most pitch angles
- Scheduling is complex, most observations are split
- So far only one limit on time allocation: < 2 Ms >60^{o} ecliptic latitude

Thermal issues in aging spacecraft

Limited dwell times at ~all pitch ranges



Time Constraints (TC)

- Limit # TC observations (<90ks) → maximize observing efficiency
- Categories (Cycle 17):
  - Easy (38), Average (30), Difficult (17)
- Demand is high → most passing-ranked TC proposals are approved

TOO Allocations per cycle
(excluding DDT)

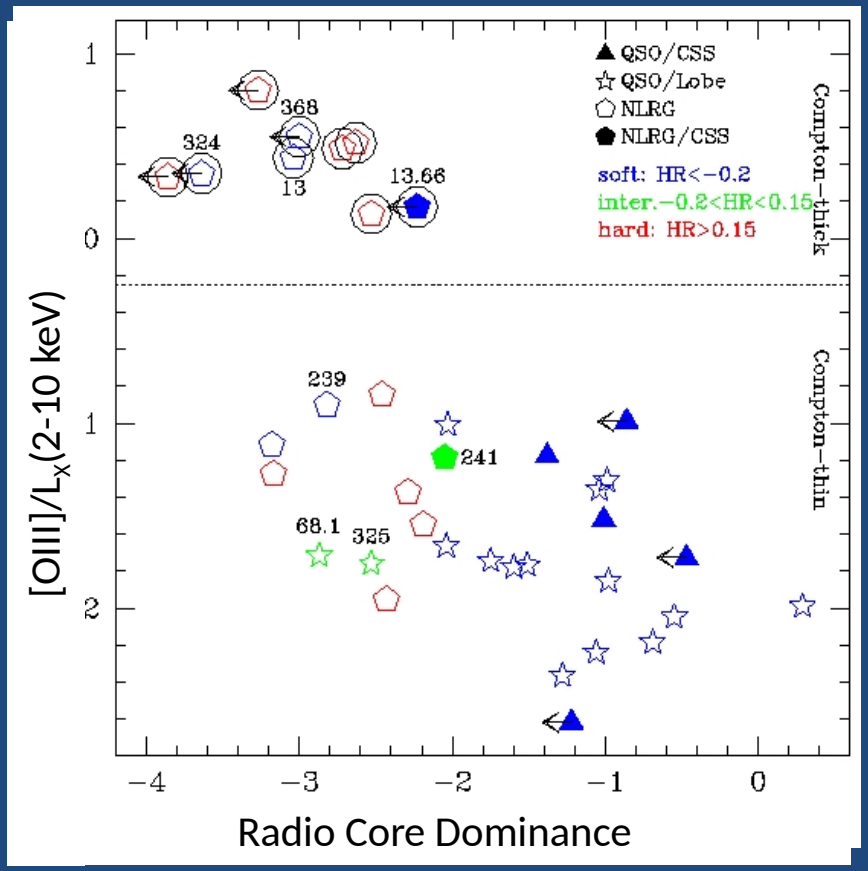
#	Category	Time/days
8	Very Fast	0-5
20	Fast	5-15
26	Slow	15-30
26	Very Slow	>30

Absorbed AGN Fraction:

major unanswered question, needs multi-λ data

3CRR z>1

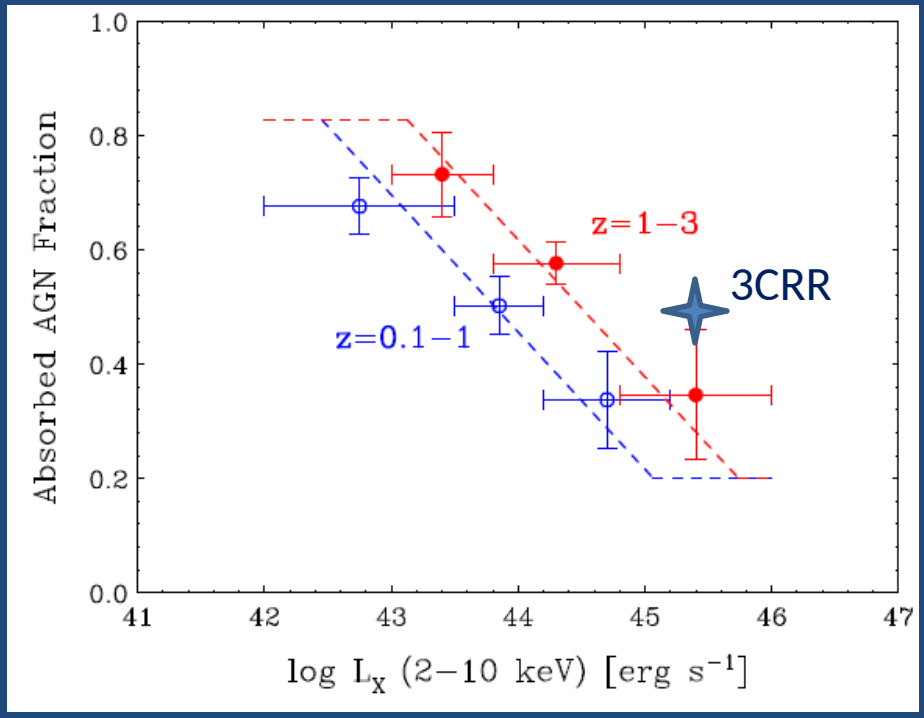
- Ratio of X-ray to [OIII] & radio, and **Radio** Core Dominance
- → ~25% CT candidates



Wilkes et al. 2013

Multiple X-ray Surveys

- Absorbed (CTN) AGN fraction:
  - ↓ as L_X ↑
  - ↑ as z ↑

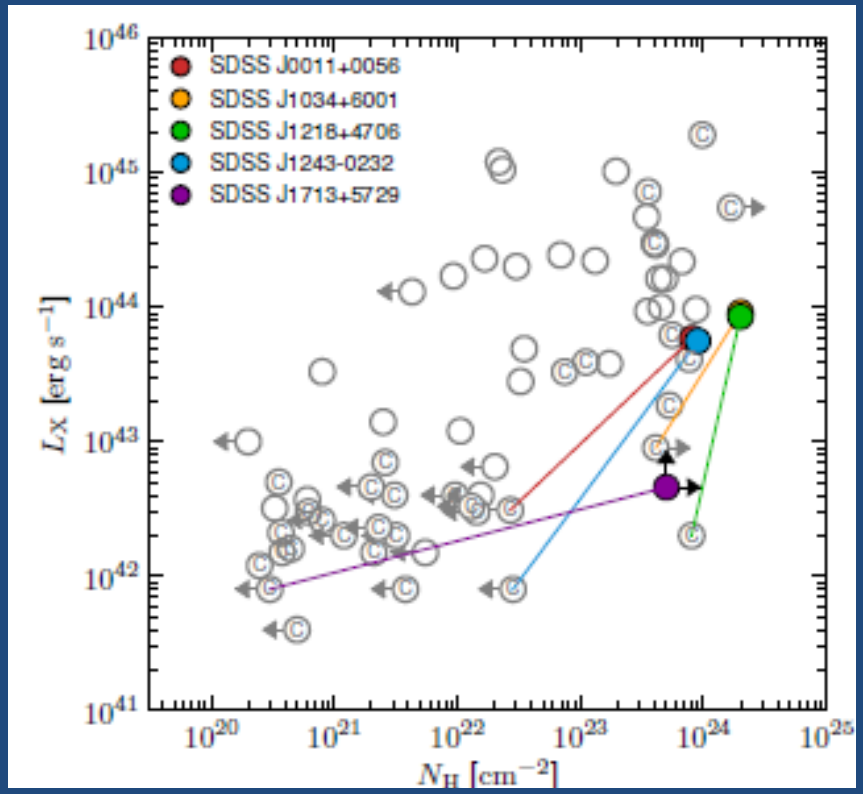


Ueda et al. 2014

Chandra: obscured and CT AGN

Lansbury et al. 2015

Change in N_H and L_X with “good” data



- ***Chandra* + NuSTAR** Spectra of low-z CT candidate SDSS quasars
- Predict >~36% are CT

Updated Sy 2 N_H Distribution