Fifteen years of Chandra operation: scientific highlights and lessons learned

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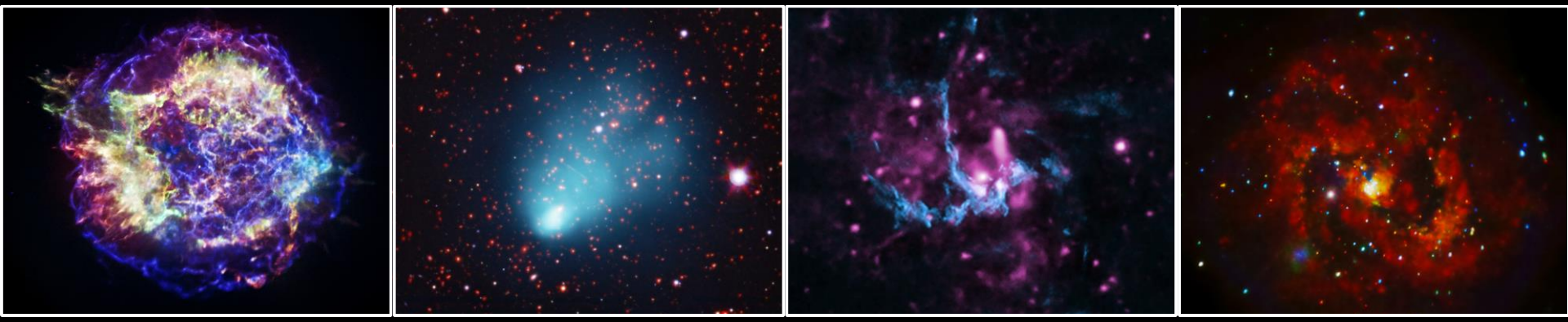


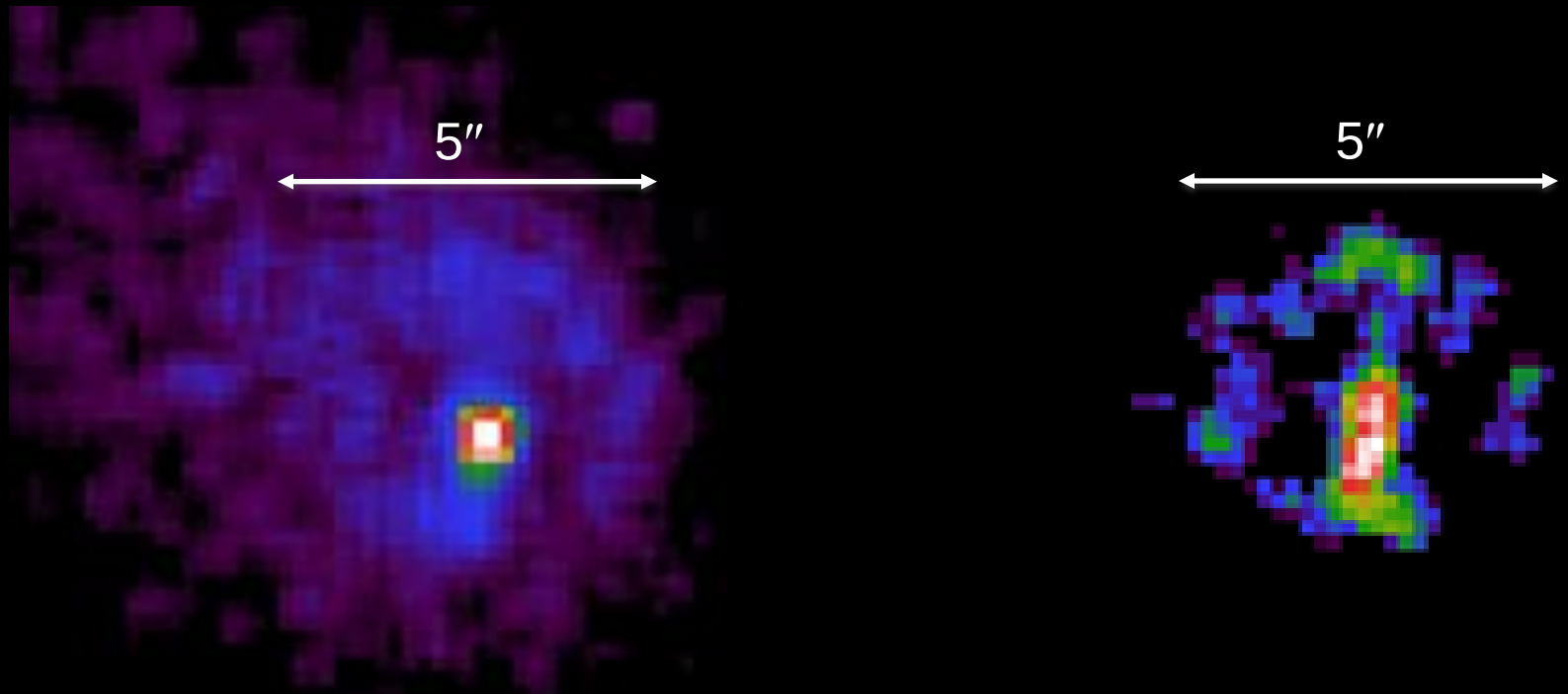
- Chandra is unique,
- Chandra is essential
- Chandra is long-lived and well calibrated

Vital to astronomy and astrophysics for the foreseeable future

Chandra is Unique

No other X-ray observatory, now or in the foreseeable future, approaches Chandra's angular resolution and sensitivity for X-ray source detection and mapping

IC 443 Supernova Remnant



0.5-2 keV

2-8 keV

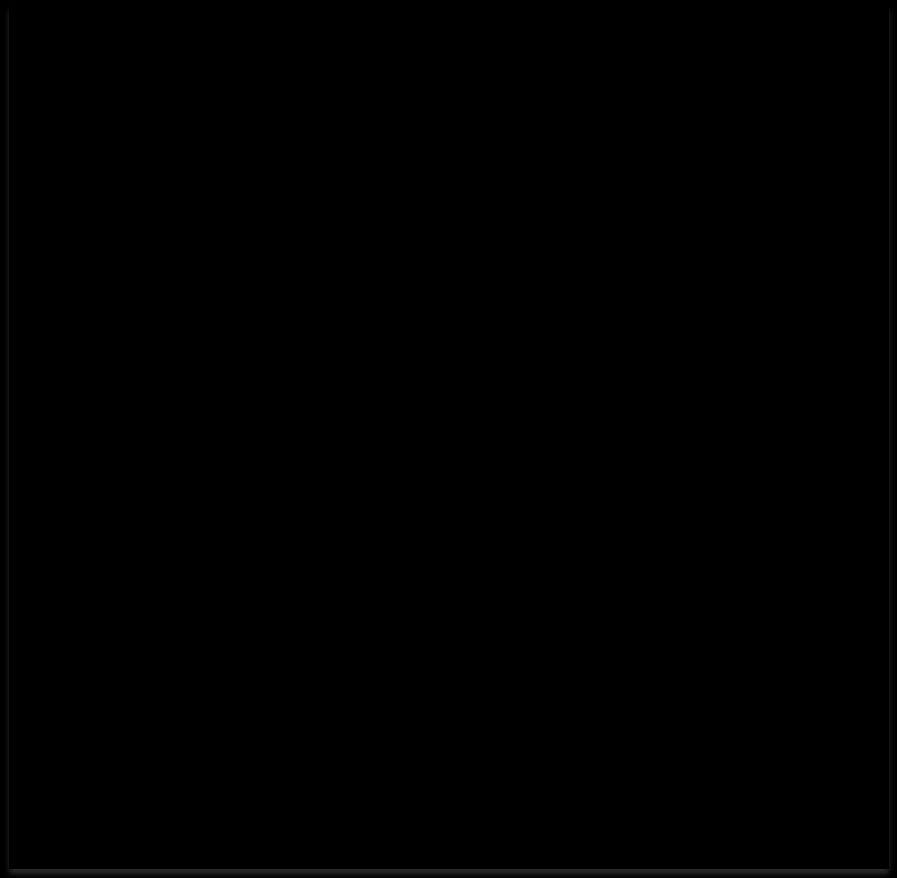
Doug Swartz et al. (2014)

Chandra is Essential

Chandra is well-matched to capabilities of major observatories at all wavelengths, making it critically important for providing a more complete view of many phenomena

Monitoring the Crab to search for the site of the γ-ray flares

Also stimulates the development of new analysis techniques

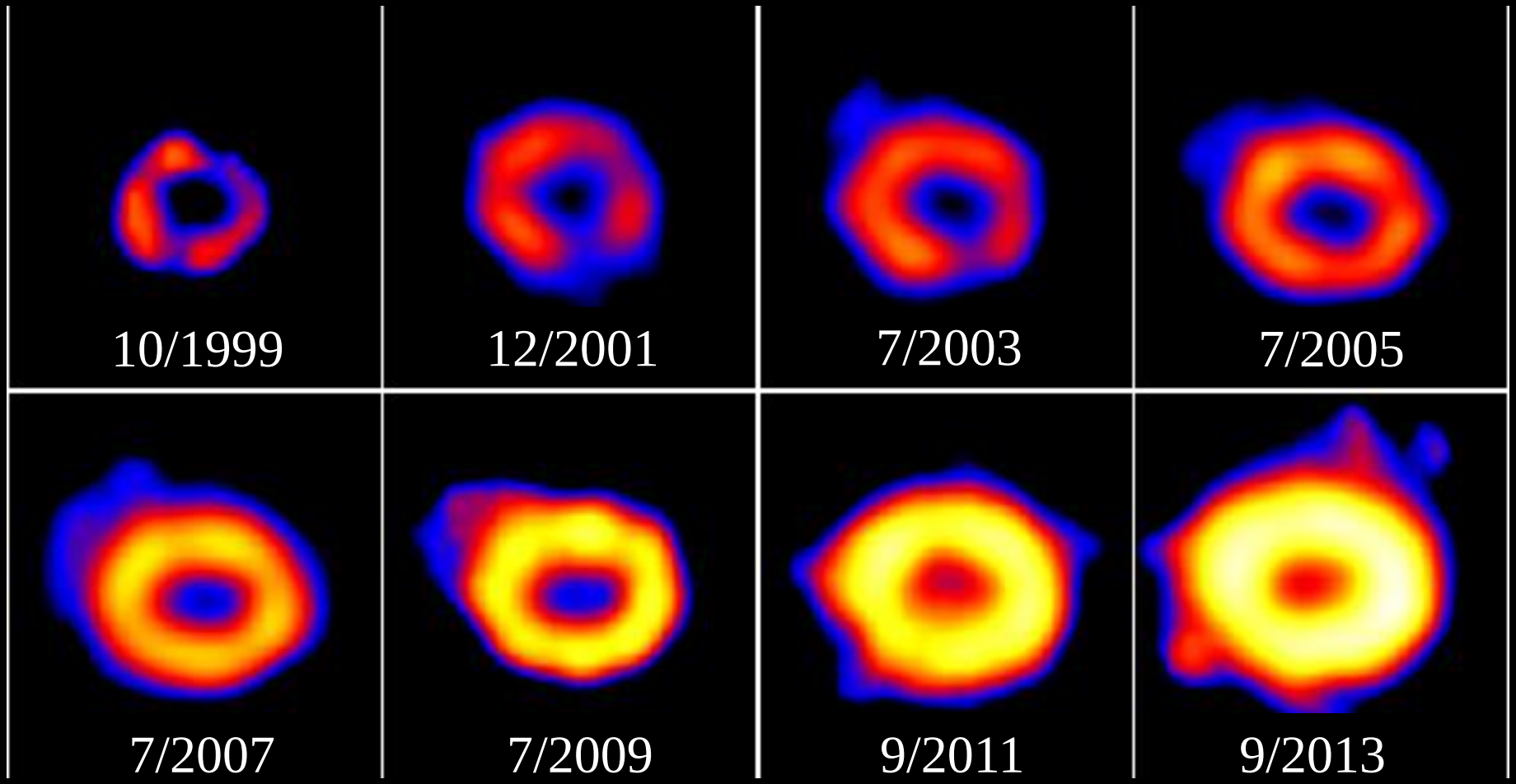


Crab Collaboration (2014)

Long-Lived and Well-Calibrated

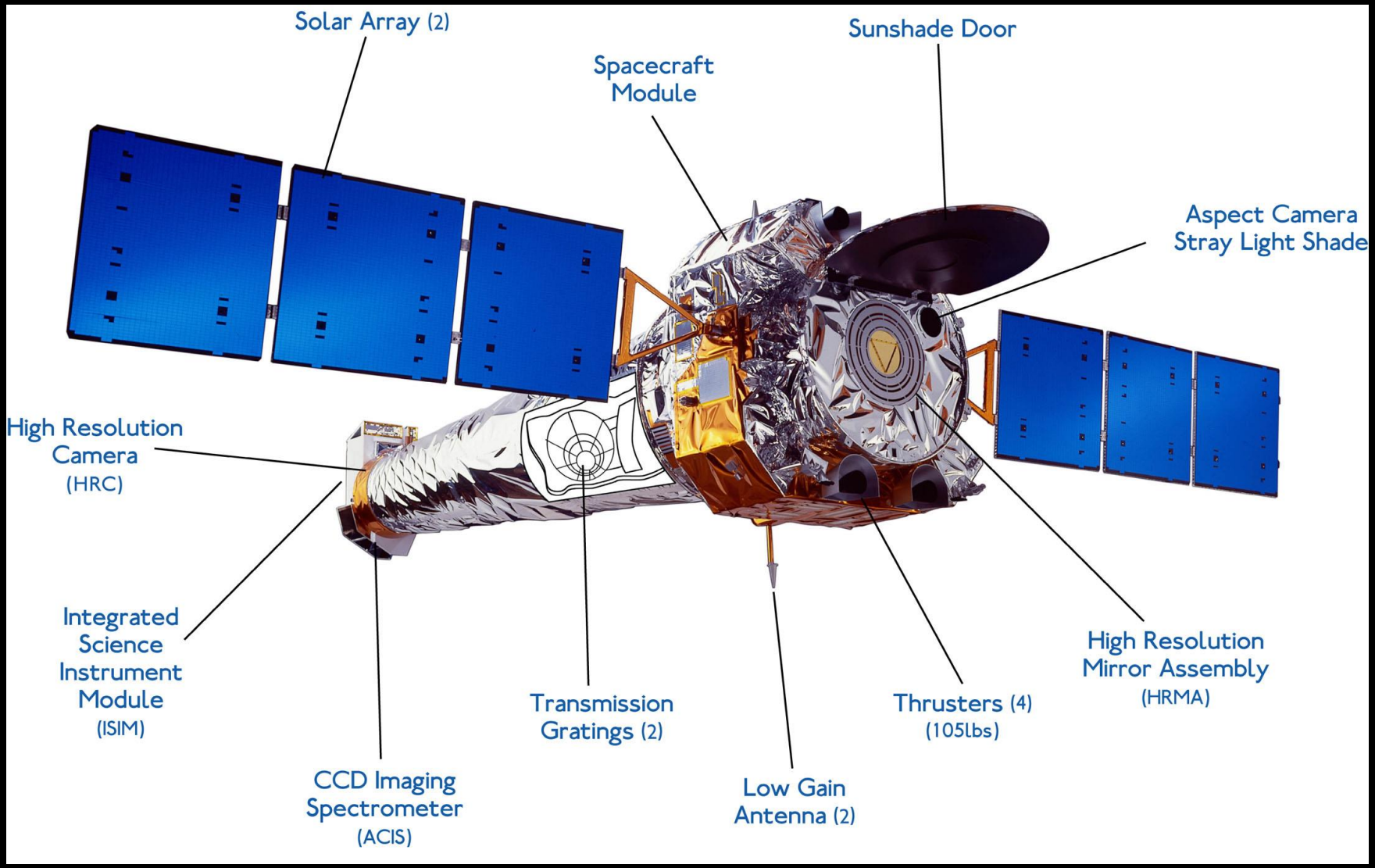
Stable and calibrated performance provide another dimension to Chandra's uniqueness and usefulness to the community

Long-term monitoring of SN 1987A (3.6" x 3.6")



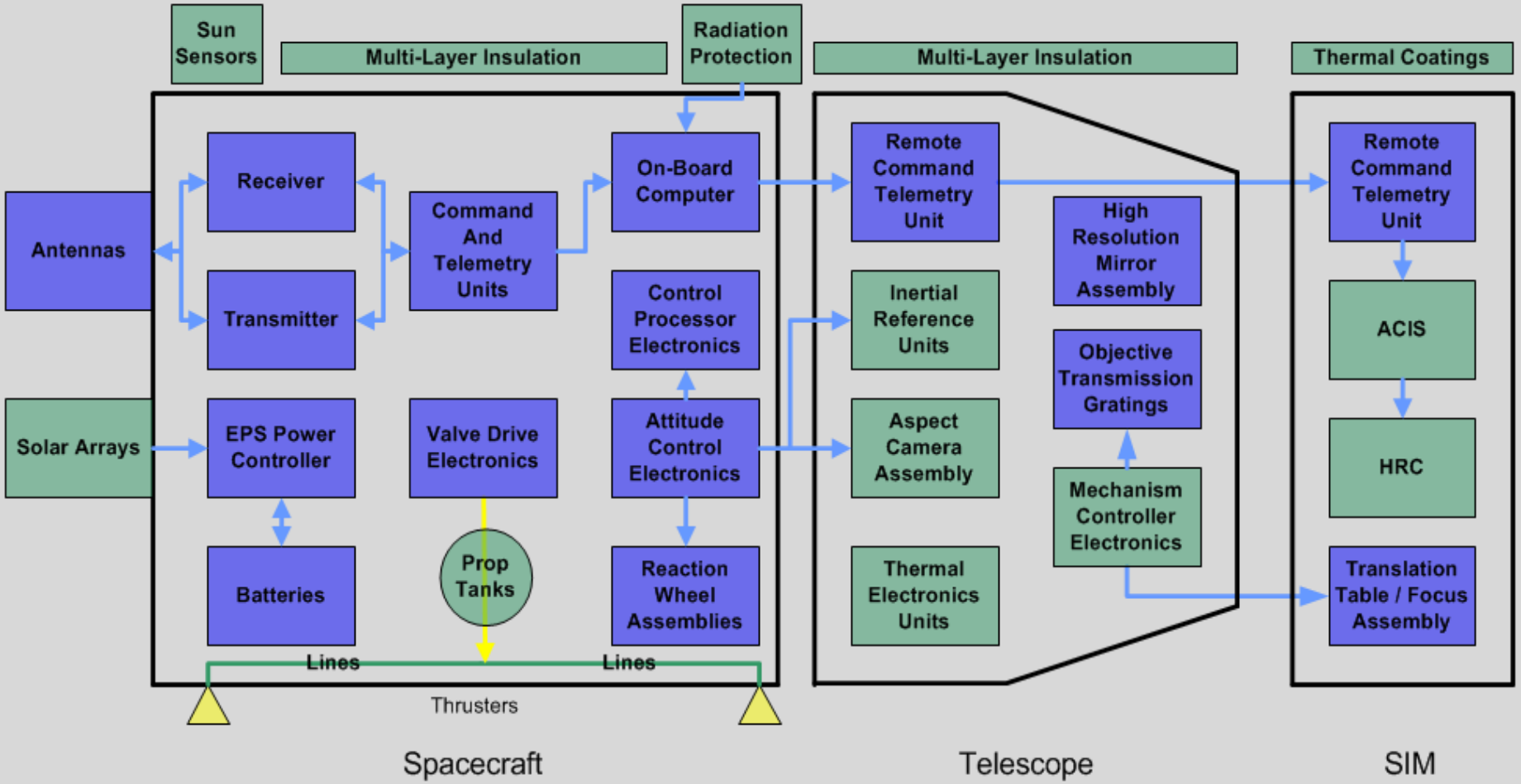
Courtesy Dave Burrows (2014)

The Observatory



The Optics

Status: healthy with a projected lifetime of 20+ years



Functioning perfectly

Minor problem but meets all requirements

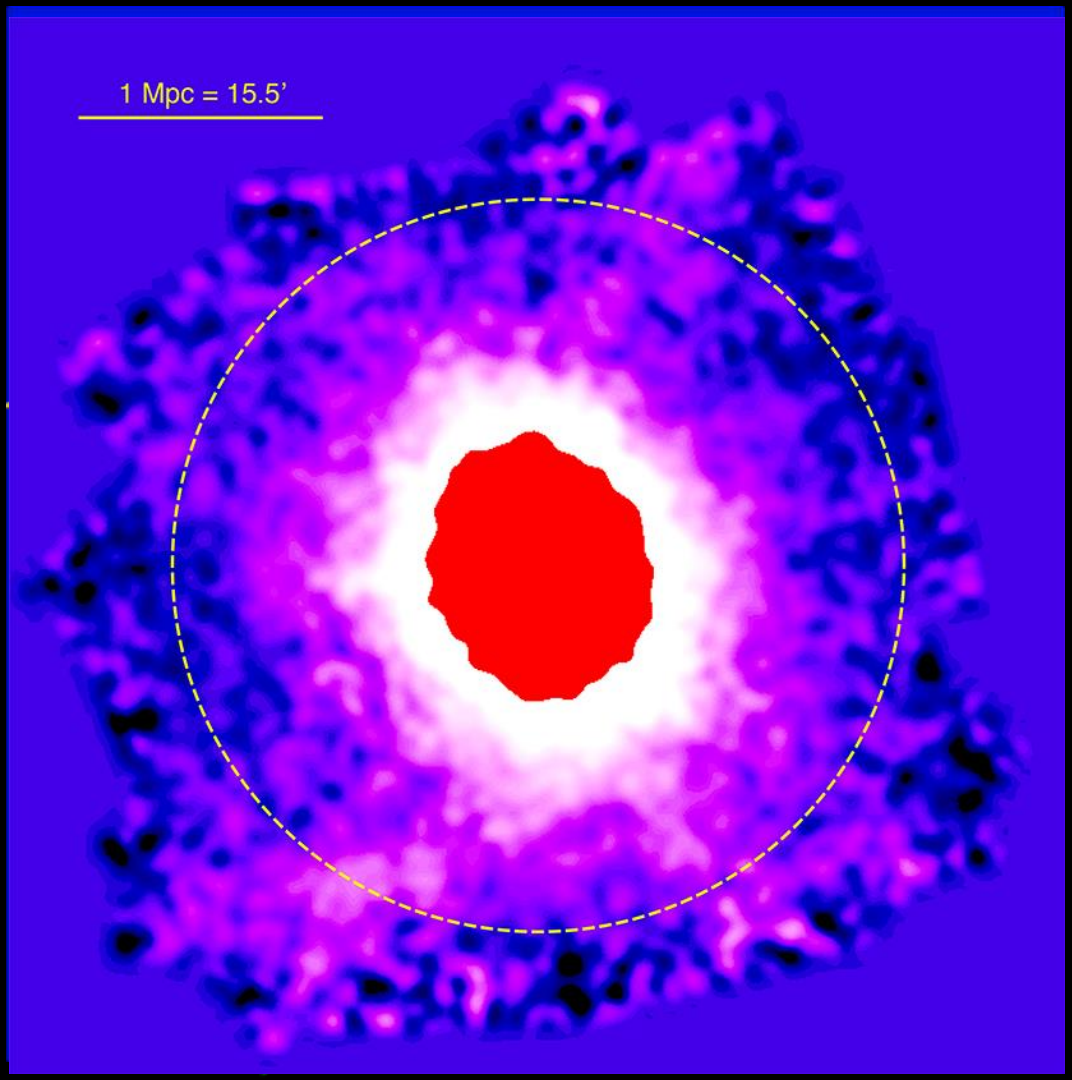
Moderate problem but manageable

Major problem with large impact

Status issues

- Thermal insulation degrading over time
  - Primarily mitigated through mission planning
  - Replaced charge-particle detector function with data from the focal-plane cameras (ACIS and HRC)
- Contamination buildup on CCD camera (ACIS) filters
  - Allowing buildup to progress with minimal impact at energies above 1 keV

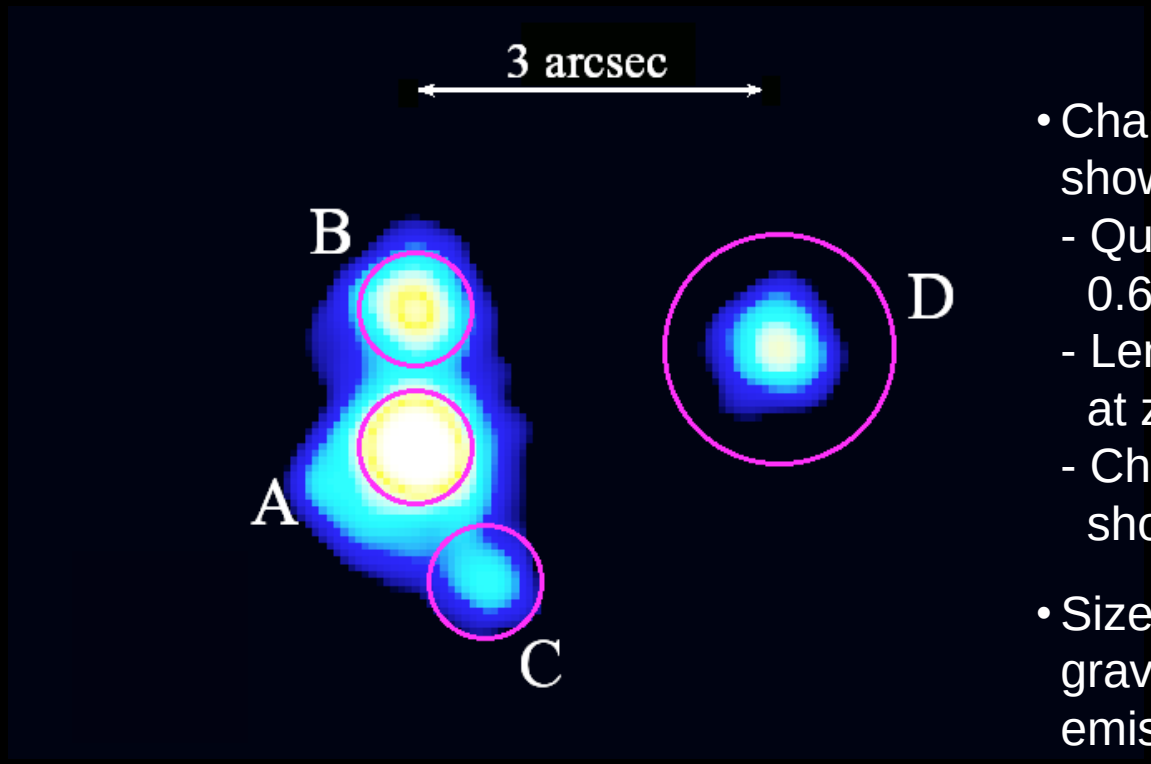
Filamentary structures from cosmic web



- A133 relaxed cluster withT~4.5 keV, z = 0.057
- Mosaic covers ~1 sq deg: ~100ks for bright central region and ~300ks for remainder
- Flat-fielded, bkgd-subtracted & smoothed with 20" PSF
- Point sources removed
- Clumps removed & colors scaled over range of 10^4 to highlight faint features
- Three large-scale filamentary structures detected for first time -— likely infalling gas from cosmic web
- Suzaku fluxes at R_{200} no longer require gas mass fraction > cosmic mean

Vikhlinin et al (2014)

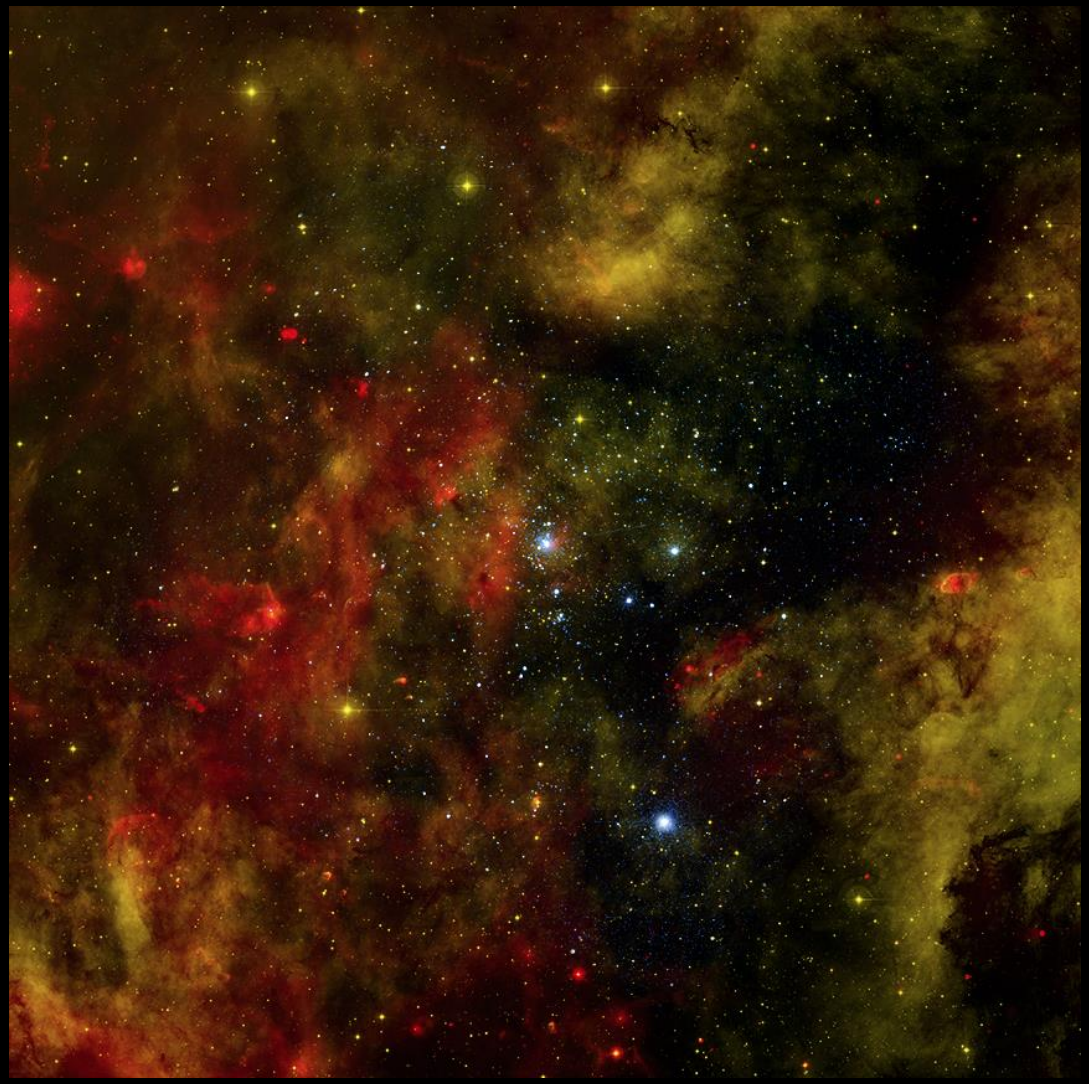
Gravitationally-lensed quasar



- Chandra image of RX J1131-1231 shows 4 "sources" within a few arcsec
  - Quasar with 2×10^8 $M_\odot$ BH@ z= 0.658 and $L_X \sim 10^{45}$ erg/s
  - Lensed by massive elliptical galaxy at z=0.295
  - Chandra monitoring of flux-ratios shows micro-lensing by stars
- Size of X-ray emitting region ≤10 gravitational radii (≤ 20 AU), optical emission from region ~7x further out
- Chandra exposure of ~350ks equates to ~1.1Ms (some images not used in spectral analysis due to pile-up or excessive micro-lensing which may distort spectrum)

Reis et al (2014)

Understanding massive star formation: Cyg OB2



- Star formation in MSFRs not well understood due to:
  - Varying optical/IR emission from interstellar gas and dust
  - Obscuration from host cloud
  - Contamination from field stars
- Cyg OB2 composite ~12' (5 pc) across. Chandra (blue), Spitzer (red) and Isaac Newton (yellow).
- In Orion, forming massive stars requires dense gas plus cluster of low mass stars → mergers and competitive accretion
- In more massive Cyg OB2, Chandra sees low density association where massive stars form without mergers or competitive accretion

Drake et al (2014)

Lessons learned

- What made Chandra Unique
  - Science driven mission
    - How to build the optics was not known at the time of the relevant Decadal Survey
- Teams of dedicated scientists involved in *all* aspects of the mission
  - No requirements creep
  - Supported both removal of instruments and loss of servicing to hold the line on cost

BACK UP