

Chandra X-ray Observatory Overview



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CIAO Workshop

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Chandra Mission Summary

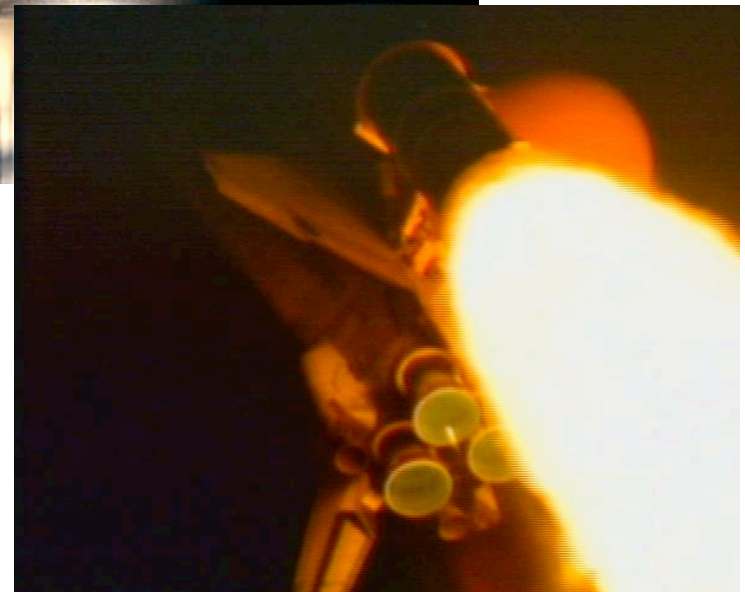
- ◆ Launch July 23, 1999
 - STS-93/ Inertial Upper Stage / Integral Propulsion System
 - 10,000 km x 140,000 km, 28.4° Inclined Orbit
- ◆ Design Lifetime > 5 Years
- ◆ 10-m Focal Length Wolter -1 Mirror: 4 nested Mirror Pairs
- ◆ Energy Range: 0.1-10 KeV
- ◆ 2 Imaging Focal Plane Science Instruments
 - ACIS (Advanced CCD Imaging Spectrometer)
 - HRC (High Resolution Camera)
- ◆ 2 Objective Transmission Gratings for Dispersive Spectroscopy
 - LETG (Low-Energy Transmission Grating)
 - HETG (High-Energy Transmission Grating)

All set to go!



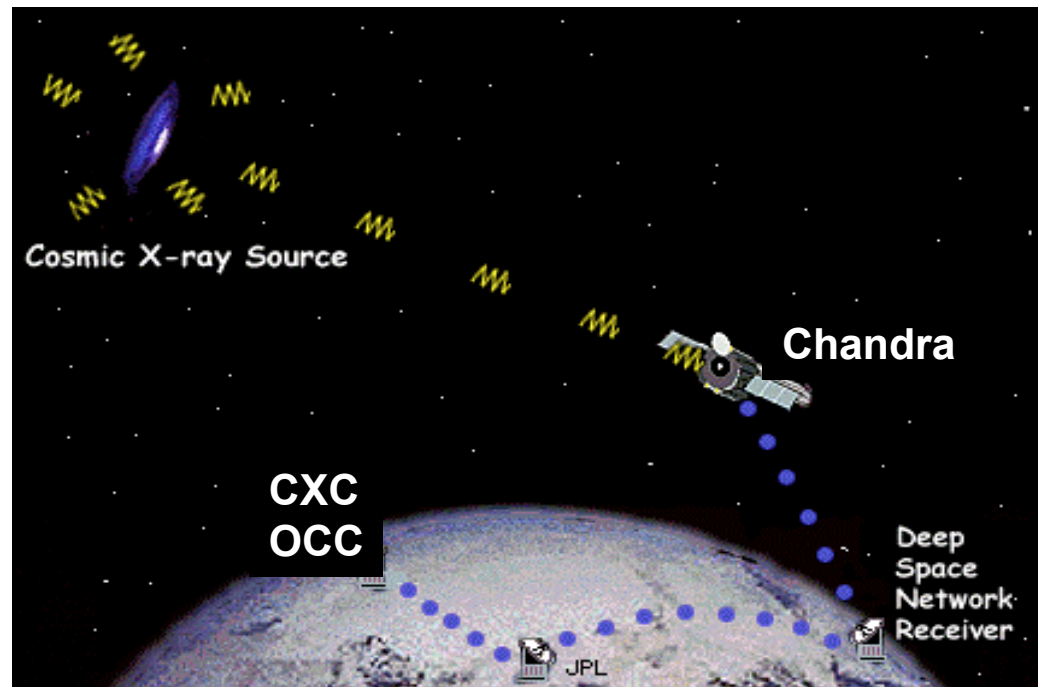
Chandra Launch

- ◆ Launched on Space Shuttle Columbia 7/23/99 on the third attempt
- ◆ Shuttle placed Chandra and IUS in 150 mile orbit
- ◆ Chandra was the longest and heaviest payload launched on the Shuttle
- ◆ Payload bay doors open 1.5 hours after launch
- ◆ Chandra/IUS deployed 7.5 hours after launch

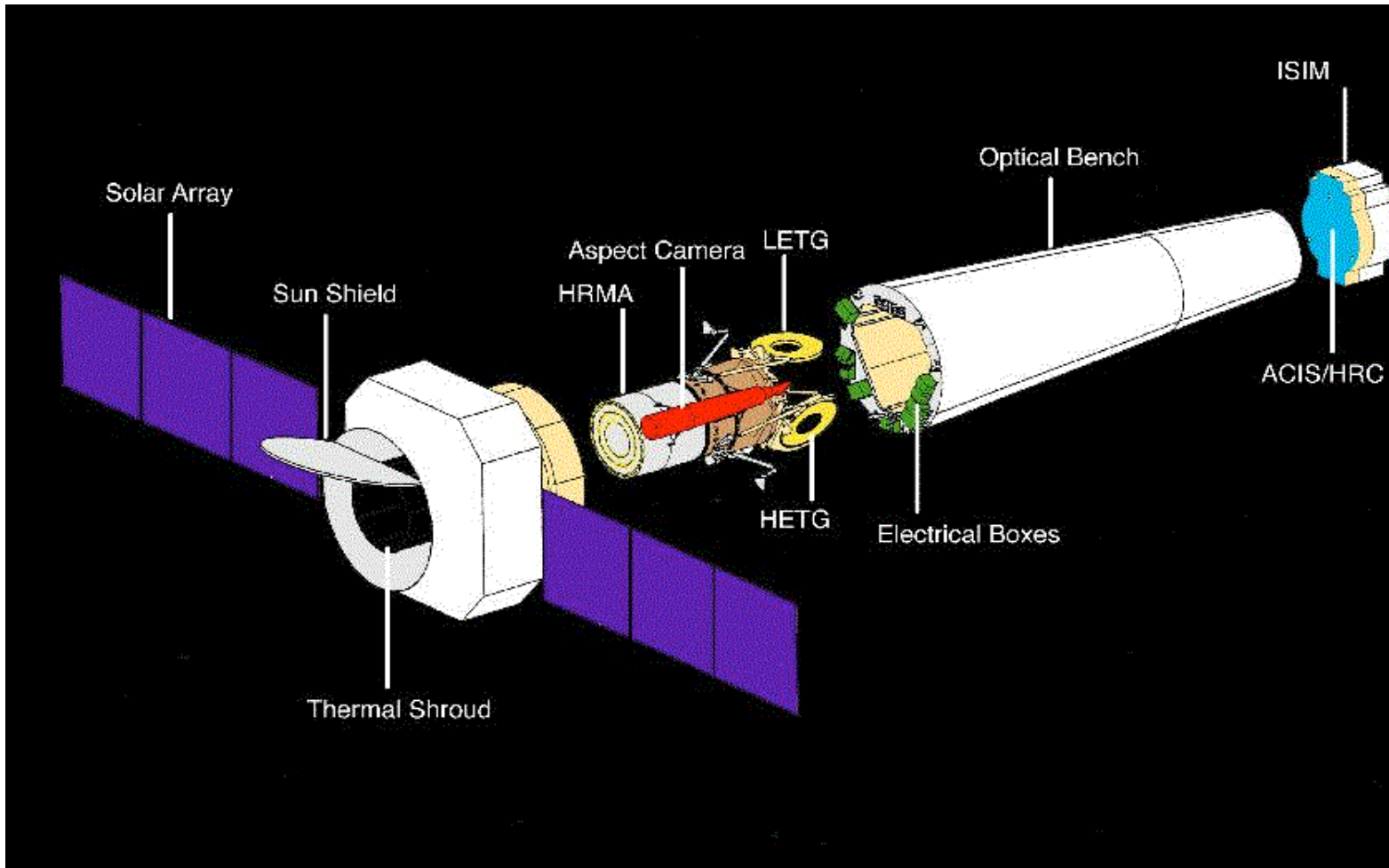


Chandra Operations

- ◆ Mission science plan converted to command loads and uplinked to **Chandra**
- ◆ X-ray events collected and stored on Solid-State Recorders (SSR)
- ◆ Ground contact established every ~8 hours through **Deep Space Network**
 - SSR data downlinked
 - new command load uplinked (up to 72 hours of stored commands)
- ◆ Data transferred to **OCC** through JPL for science processing



Mission and Observatory Description

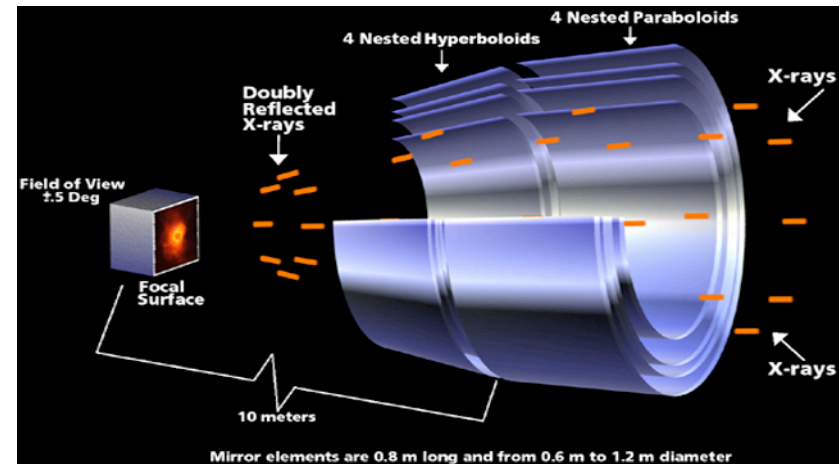


High Resolution Mirror Assembly

- ◆ 4 pairs of concentric thin-walled, grazing incidence mirrors
- ◆ Zerodur, coated with Iridium
- ◆ Diameters range from 0.65 to 1.23m
total mass 1484 Kg

- ◆ Characteristics

- Focal length 10m
- Plate Scale 48.8 microns/arcsec
- PSF (FWHM) 0.5 arcsec
- Effective Area
 - @ 0.25 keV 800 cm²
 - @ 5.0 keV 400 cm²
 - @ 8.0 keV 100 cm²



Leon Van Speybroeck Telescope Scientist



"Imagine making the surface of the Earth so smooth that the highest mountain was less than two meters (78 inches) tall! On a much smaller scale, the scientists and engineers at Raytheon Optical Systems in Danbury, Connecticut accomplished an equivalent feat when they polished and ground the four pairs of Chandra mirrors to the smoothness of a few atoms."

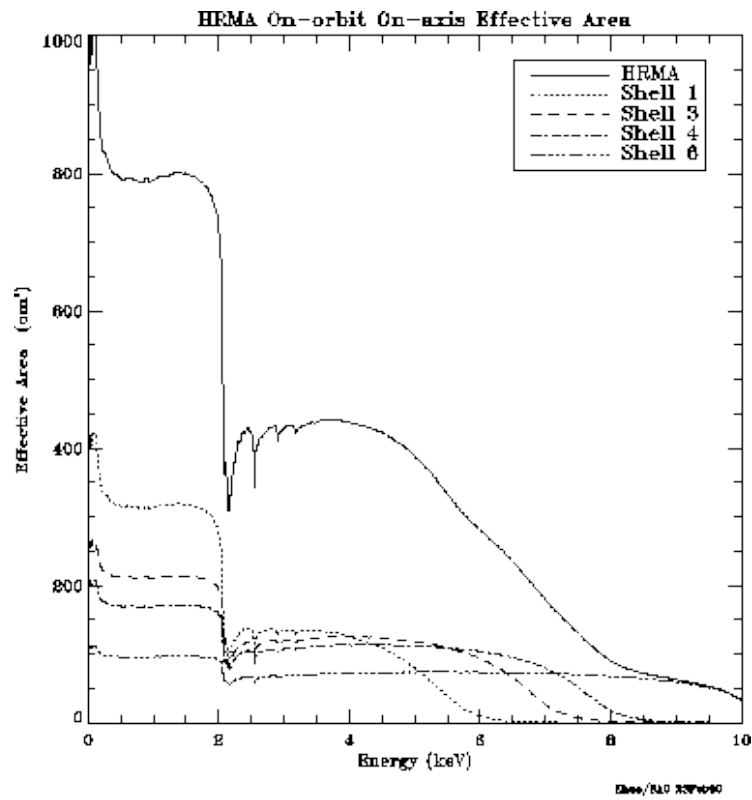


Polishing a CXO Mirror Shell

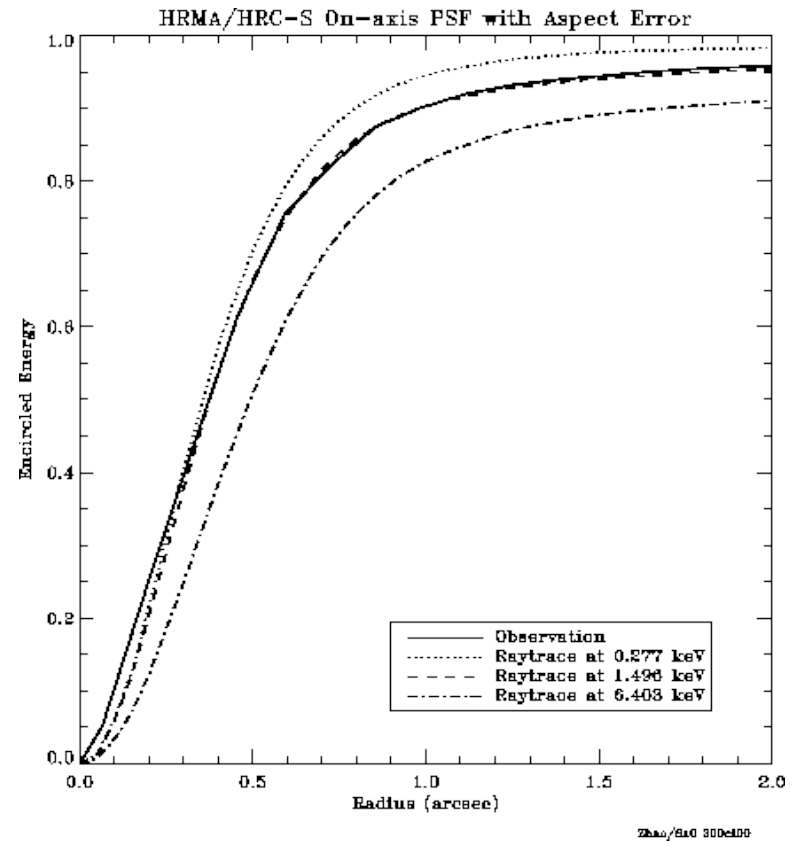


CXO Mirror Fabrication

HRMA Effective Area



HRMA Encircled Energy



Key to High Angular Resolution X-ray Imaging

Detect Individual Photons & Monitor Star Motions

For each photon (X-ray telescope):

Energy

Time of arrival

Position

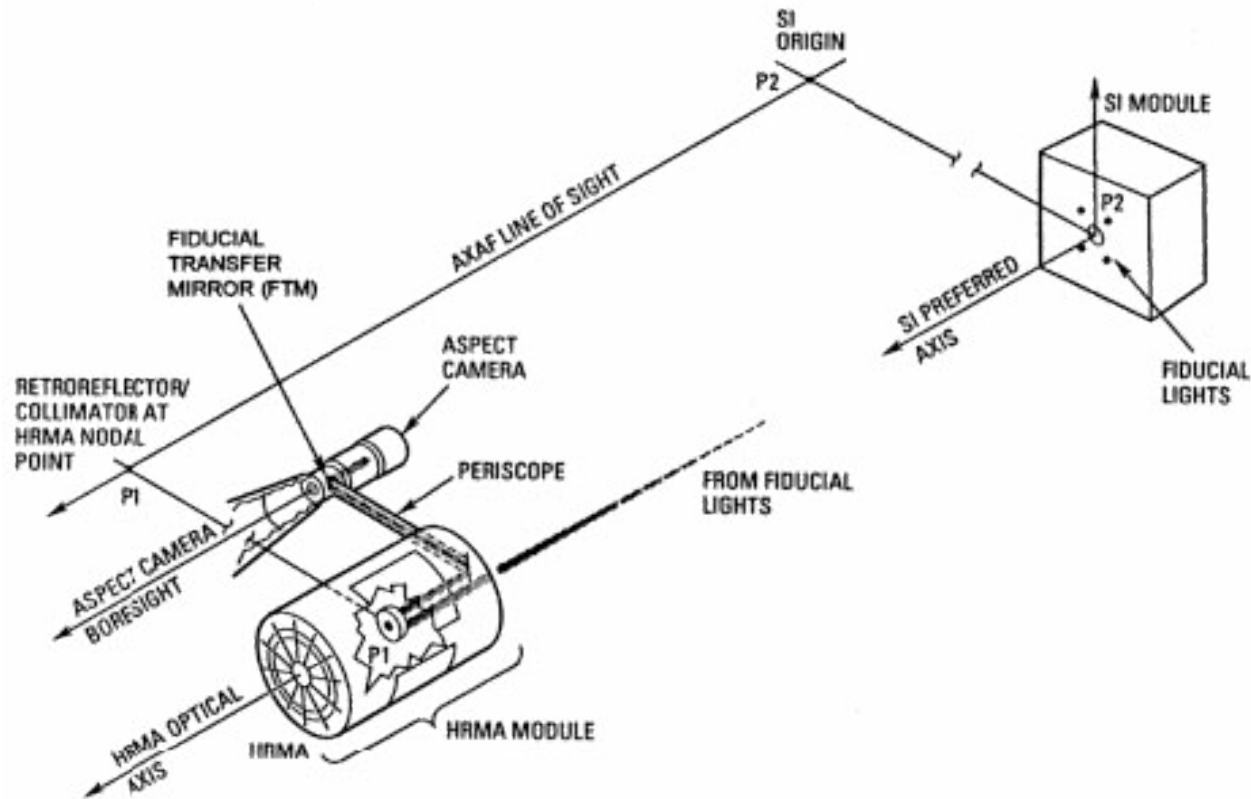
Monitor star positions vs . Time (optical telescope)

Dither spacecraft (lissajous pattern)

Determine spacecraft pointing as a function of time

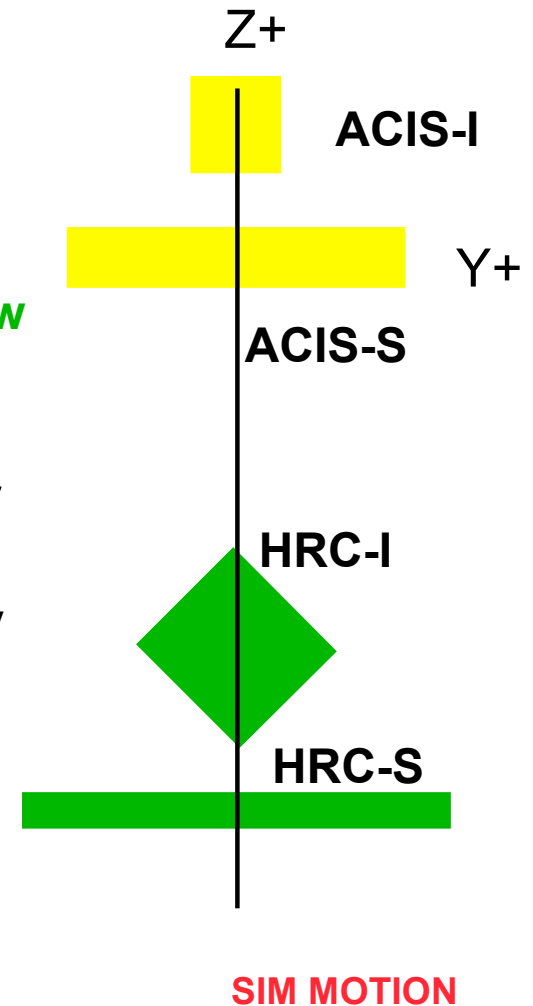
Map photons onto the sky

Aspect Camera and Fiducial Transfer System



Chandra Science Instruments

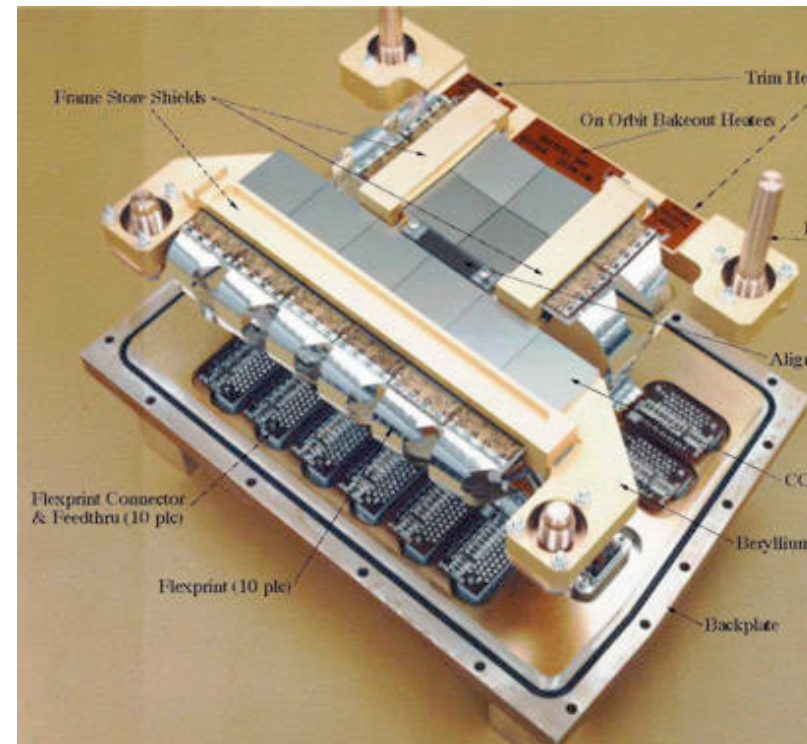
- ◆ **Advanced CCD Imaging Spectrometer (ACIS)**
 - CCD array with 16'x16' field of view (**ACIS-I**)
 - high energy grating readout array (**ACIS-S**)
- ◆ **High Resolution Camera (HRC)**
 - **microchannel plate imager with 31'x31' field of view (HRC-I)**
 - **low energy grating readout array (HRC-S)**
- ◆ **High Energy Transmission Grating Spectrometer (HETG)**
 - transmission grating pairs for medium and high energy
- ◆ **Low Energy Transmission Grating Spectrometer (LETG)**
 - transmission grating for low energy



Advanced CCD Imaging Spectrometer (ACIS)

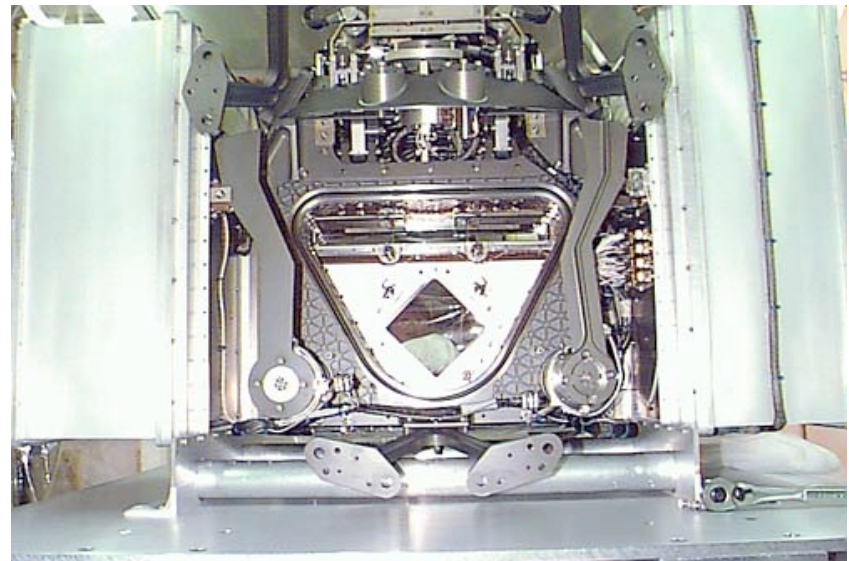
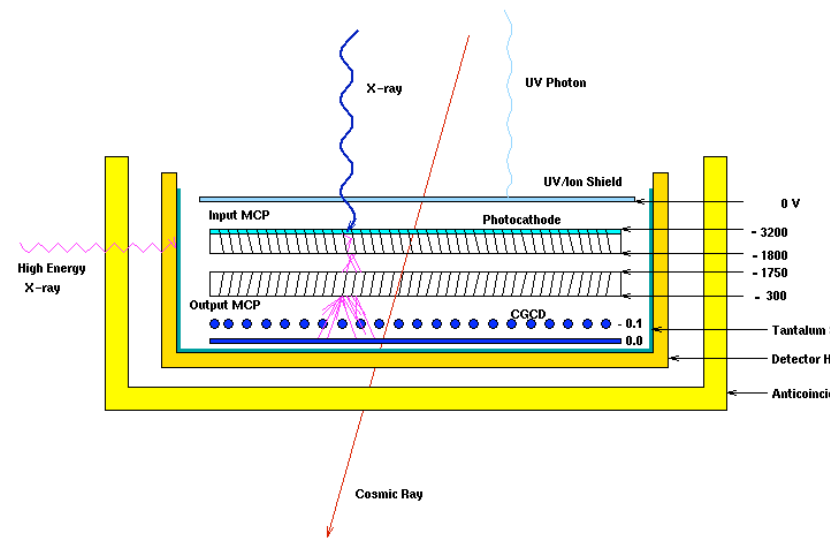
Ten 1024x1024 pixel CCDs

- 2x2 array for imaging
- 1x6 array for imaging or spectroscopy
- Array Size 16.9x16.9 arcmin (ACIS-I), 8.3x50.6 arcmin (ACIS-S)
- Pixel Size 0.49 arcsec
- Integration/readout times
 - ❖ Typical integration 3.2 sec
 - ❖ Readout 41msec (1.3%); spreads image uniformly in readout direction
 - ❖ Pileup - more than one photon per readout; lose events entirely



High Resolution Camera

- ◆ Microchannel plate device
- ◆ Energy Range 0.08 – 10 keV; little energy resolution
- ◆ **Time resolution 16 μ sec**
- ◆ Pixel readout size 6.4 μ = 0.13 arcsec/pix
- ◆ 10 cm sq of 70 million lead-oxide 10μ tubes (1/8 of a human hair) 1.2 mm in length
- ◆ Cloud of 30 million electrons



Grating Spectrometers

◆ HETG

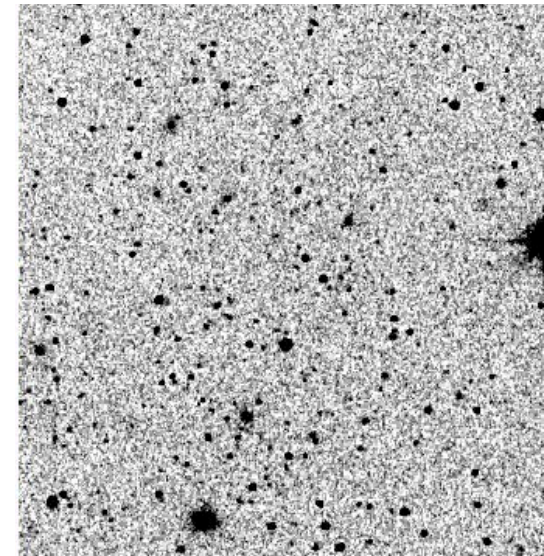
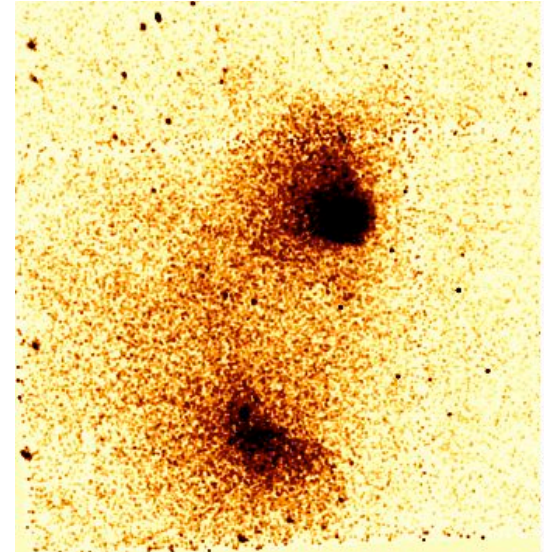
- Designed for use with ACIS-S providing $E/\Delta(E)$ to 1000 between 0.4 and 10.0 keV
- Two sets of gratings
- Medium Energy Gratings (MEG) for use with outer 2 mirrors
- High Energy Gratings (HEG) for use with inner 2 mirrors
- Mounted at different angles to form an “X” dispersed pattern

◆ LETG

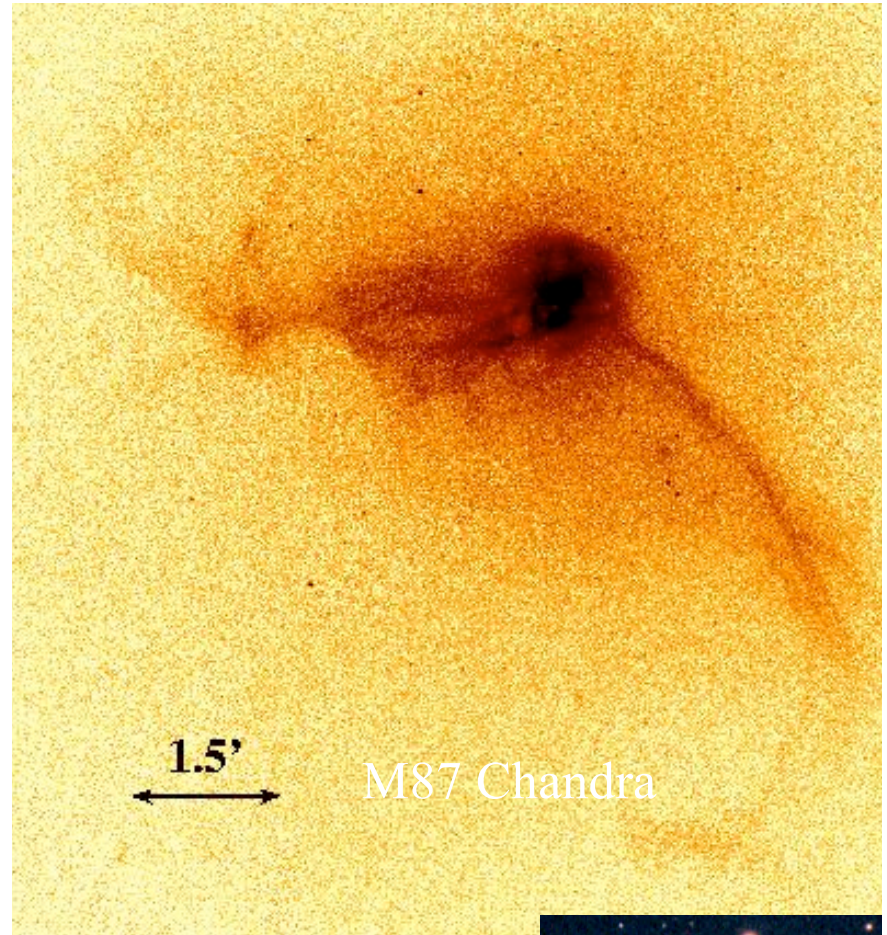
- Provides highest resolving power at low energies
- Designed for use with HRC-S with 0.07 – 7.29 keV
- $E/\Delta(E) > 1000$ for $0.07 < E < 0.15$ keV
- $E/\Delta(E) < 1000$ for $E > 0.15$ keV

Galaxy Clusters - the X-ray View

- ◆ $M_{\text{gas}} = 3-5 M_{\text{stars}}$
 - Baryon fraction is \sim cosmological value
 - Study **ALL** the baryons at low z ("WHIM")
- ◆ **Gas provides a fossil record of:**
 - stellar evolution, chemical enrichment
 - Black hole activity - energy output
 - ❖ AGN feedback explains galaxy luminosity function
 - ❖ Stellar populations - red/blue galaxies
- ◆ **Cosmology**
 - Baryon fraction - similar to SN
 - Growth of structure - complements existing techniques



- Unique Views of ALL Classes of Astronomical Objects
- A young field - First extrasolar source Sco X-1(1962)
- Lots of opportunity - keep your eyes open



GOOD LUCK!!