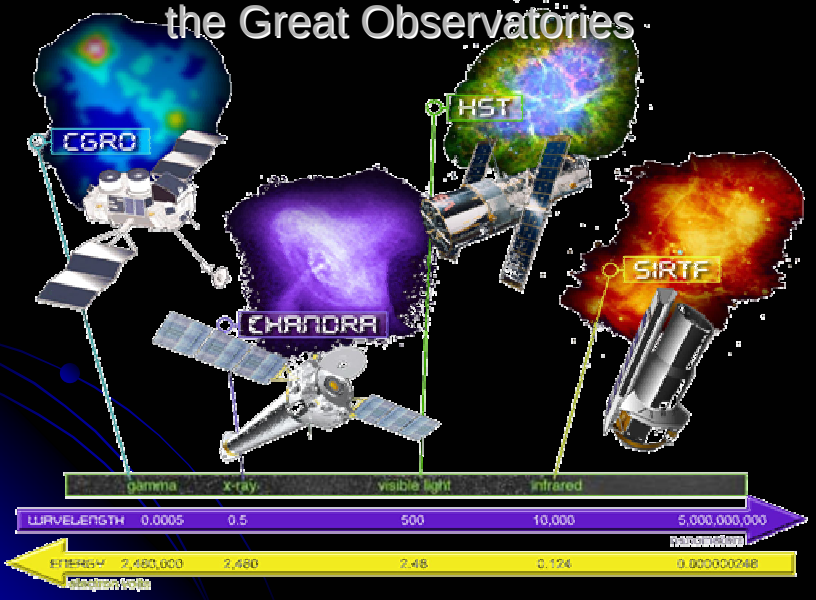
Chandra: An X-Ray Vision of Star Formation

Scott J. Wolk
CfA
With a lot of help…

About this Meeting

- What Are the “Three Great Observatories”
- What is the “White Paper”?
- About the splinter sessions
- What are the Chair’s Comments?

The Electromagnetic Spectrum & the Great Observatories



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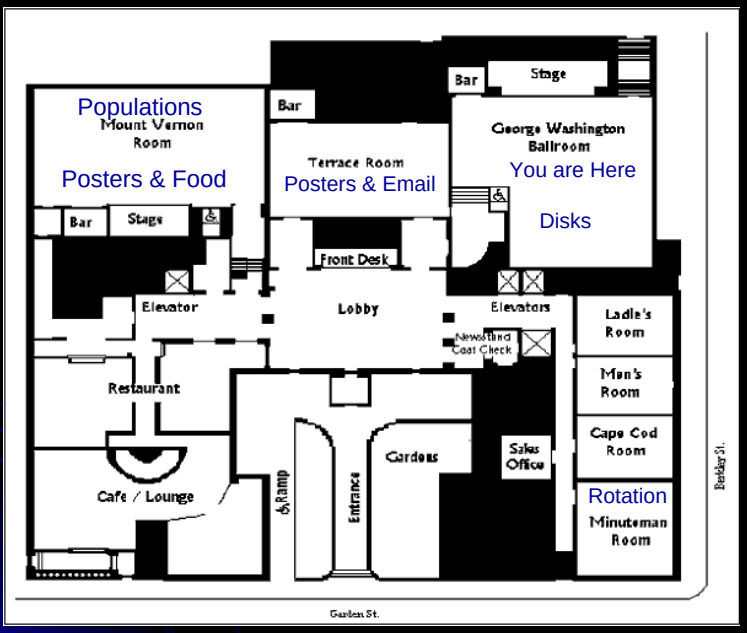
Key Questions in Star Formation all 3 Great Observatories can help Address

- Goal: Understand how stars are assembled from molecular material to the zero-age main sequence
  - Use a multiwavlength approach:
- Process:
  - Identify objectives, key measurements and required observations.
  - These need not be wholly reliant on the Great Observatories
- Rotation and Dynamos
- Disk Evolution
- Populations and their evolution
- Others?

Observations which Bridge us between facilities

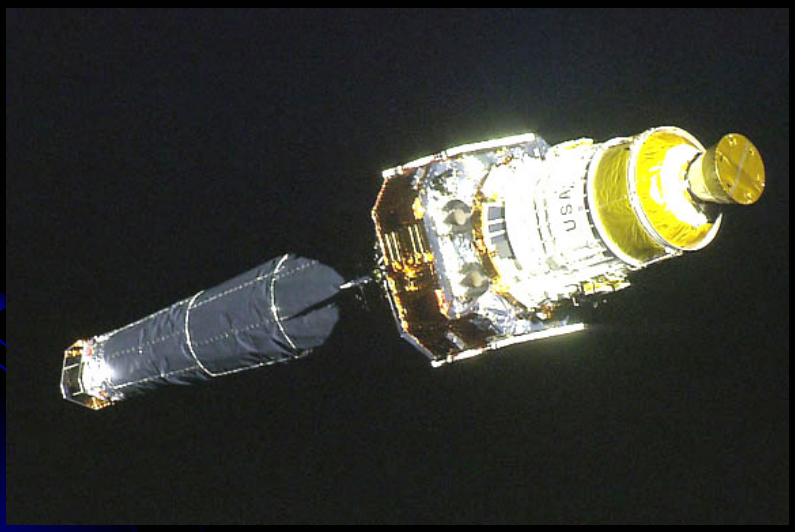
- Extant
  - Chandra
  - Spitzer
  - HST
  - Large Optical
    - Keck, Gemini, Magellan
  - Single Dish
    - CSO, JCMT, IRAM
  - Interferometers
    - VLA, BIMA, OVRO, SMA
- In Development
  - Con-X
  - SOFIA
  - JWST
  - Herschel
  - CARMA
  - ALMA
  - Keck interferometery
  - GMT
  - VLA upgrade
  - What about UV observations?



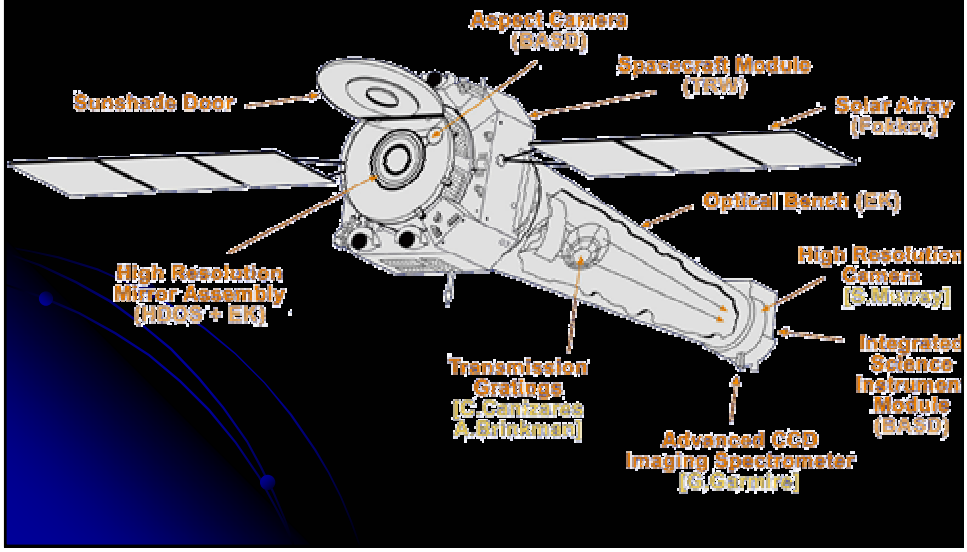
Chandra Launch

- **Launched on Space Shuttle Columbia commanded by Eileen Collins 7/23/99**
- **Columbia 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**

Deployment of Chandra, July 23, 1999



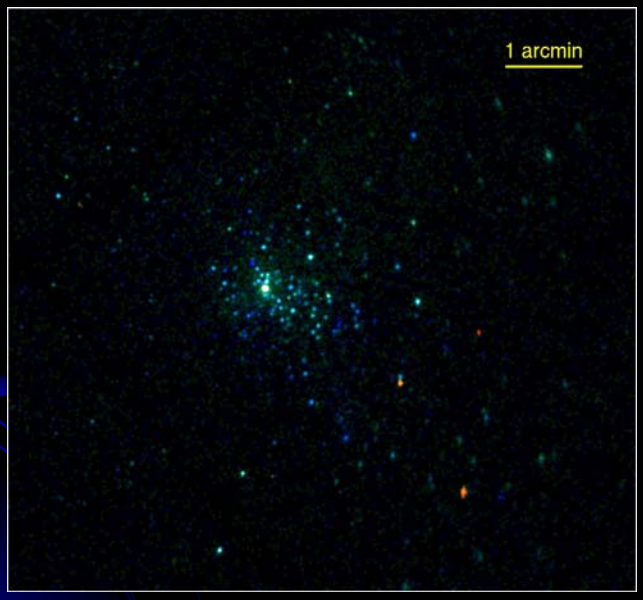
Chandra Spacecraft

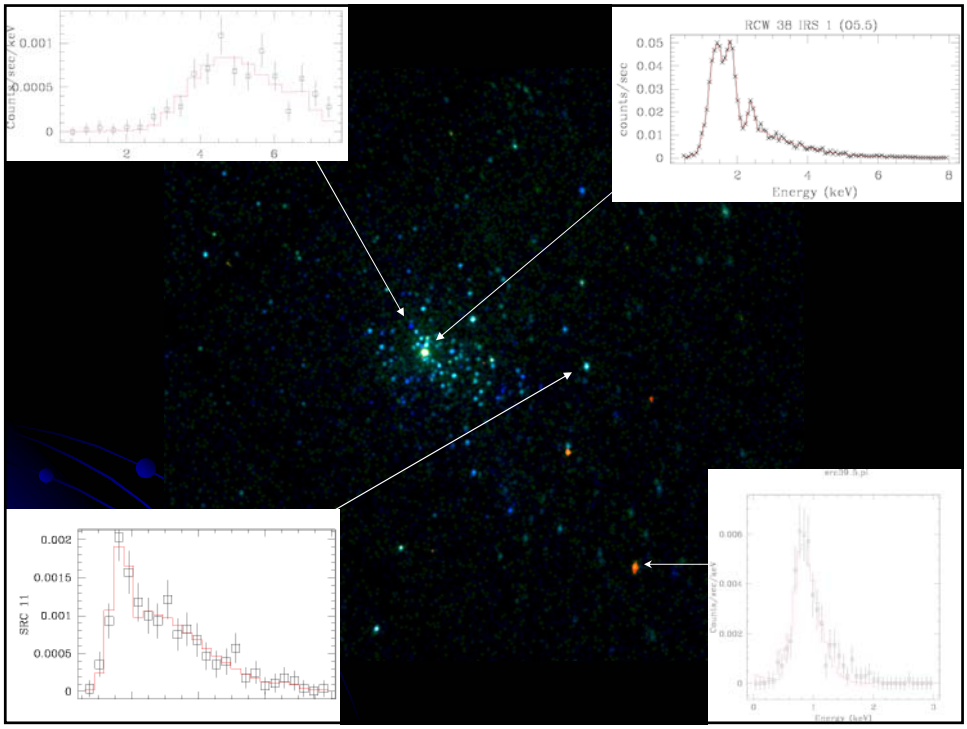


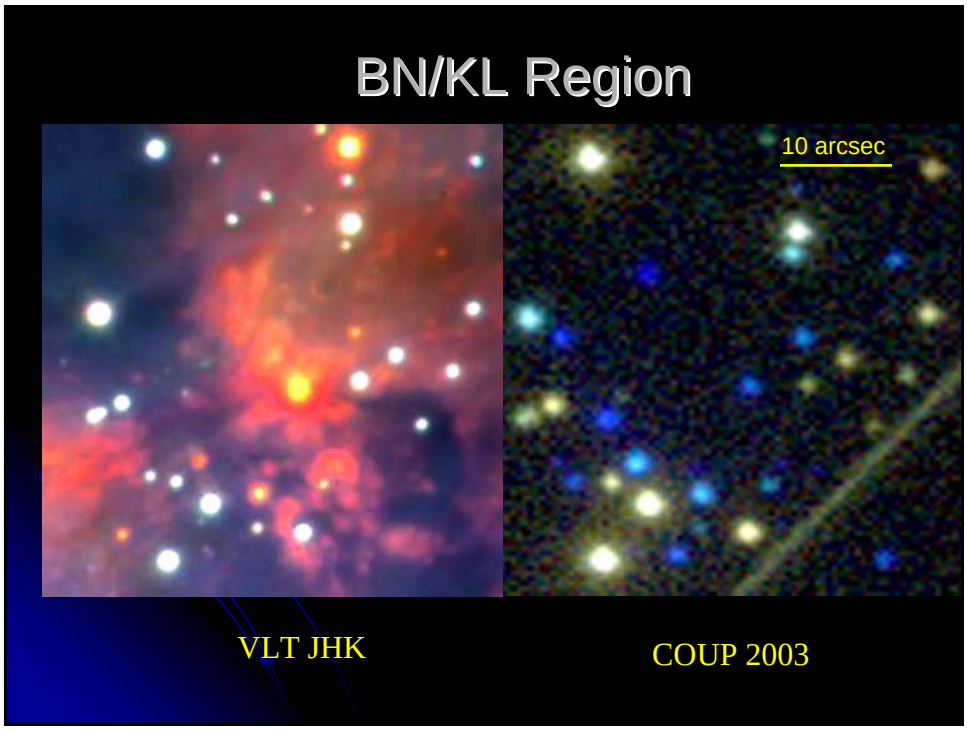
Key Features of Chandra

- **High Spatial Resolution** – Allows it so separate sources at ~2kpc (denser→ more massive star forming regions).
- **Hard X-ray Sensitivity** – Can penetrate dusty environs.
- **Good Spectral Resolution** (imaging) – Can determine bulk coronal properties.
- **Long Orbit** - Lets us to see the lifecycle of flares.

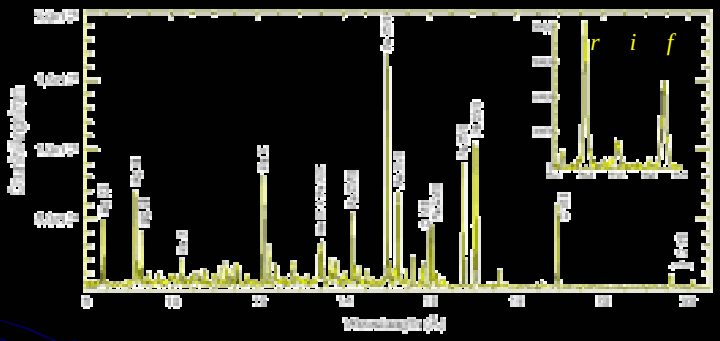
Chandra Basics: Imaging Imaging Spectrascopy



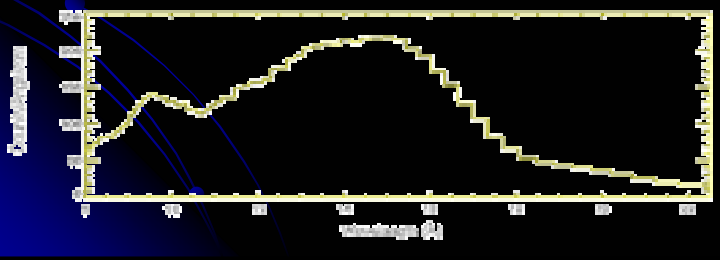

RCW 38 IRS 1 (O5.5)
counts/sec
Energy (keV)
SRC 11


BN/KL Region
10 arcsec
VLT JHK
COUP 2003

Transmission Gratings: Capella

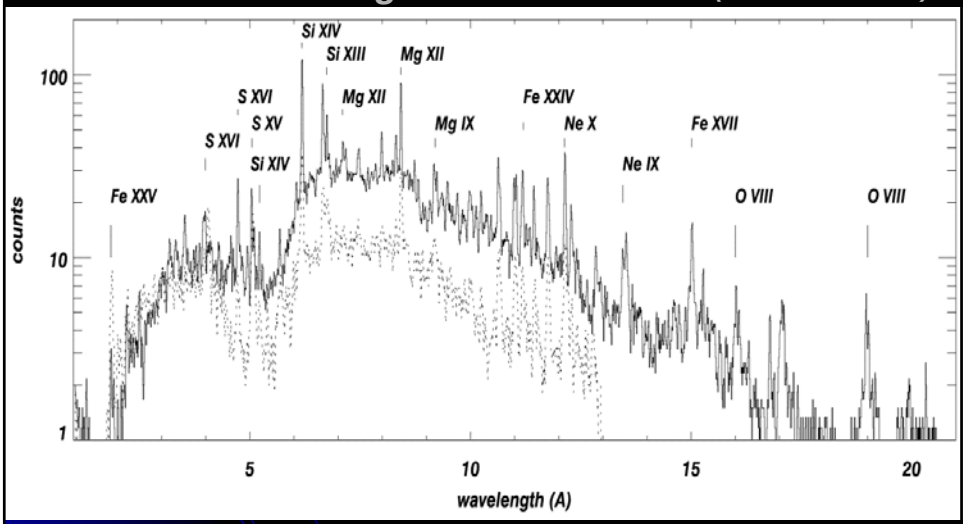


Dispersed Spectrum

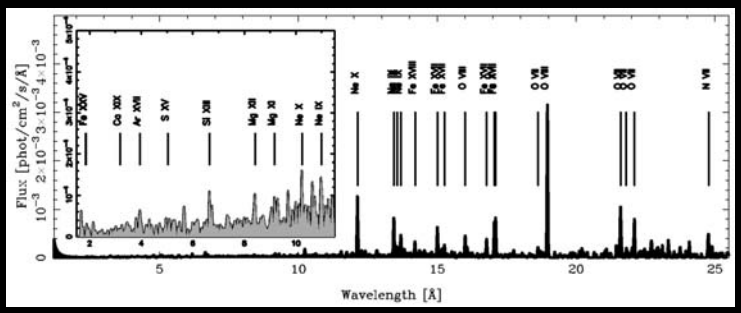


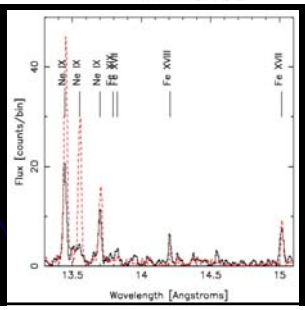
Imaging Spectrum

Transmission Gratings: θ^1 Orionis C (Schulz et al. 2000)



Transmission Gratings: HD 98800 *(Kastner et al. 2004)*

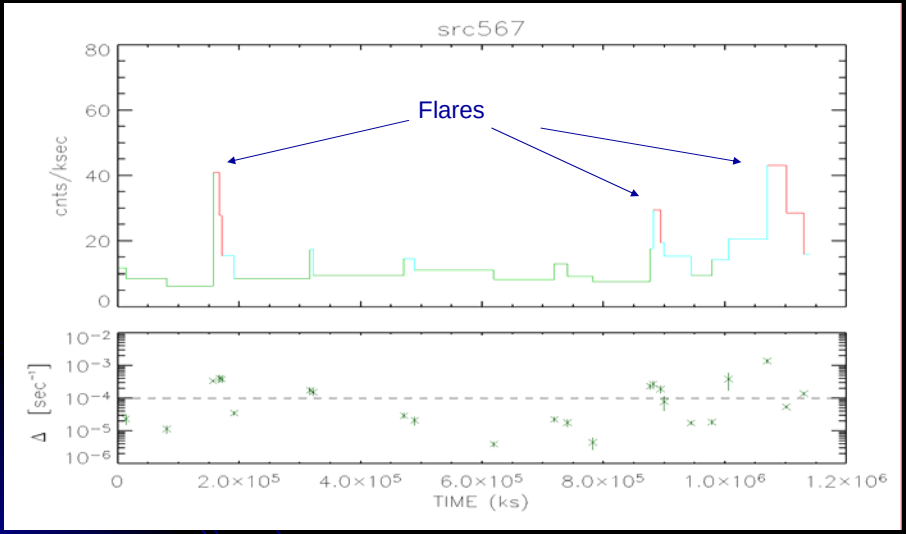




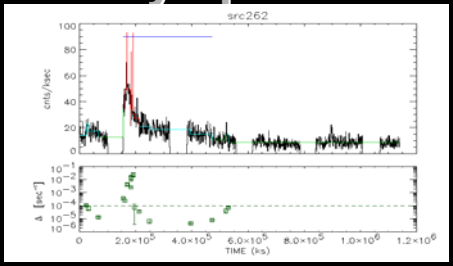
HD 98800 vs TW Hya
Ne IX in TW Hya
arises at lower temperature
and higher density.

Timing

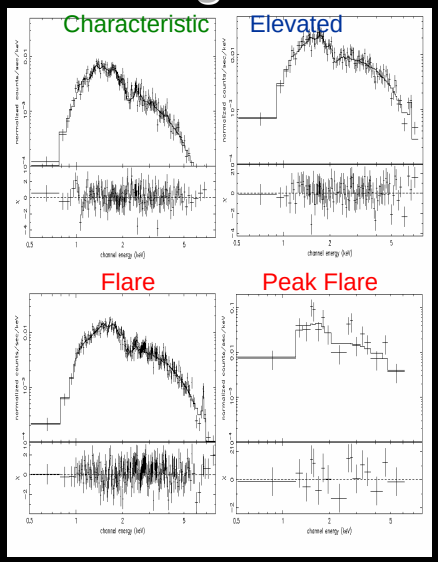
Defining a flare



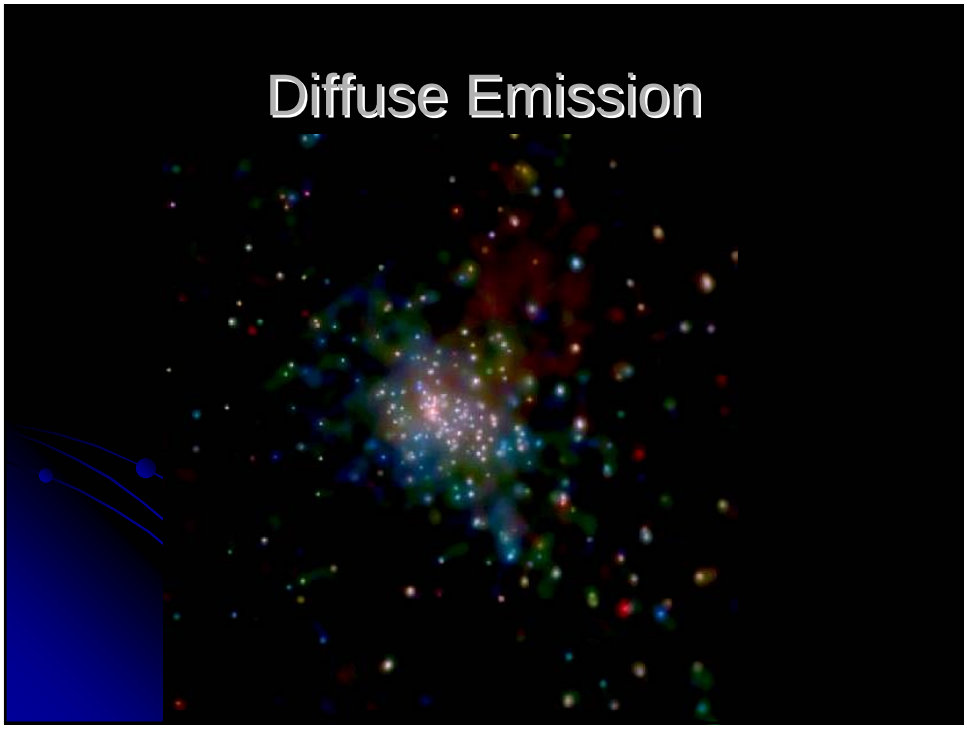
X-Ray Spectrum of a Flaring Source



- Stars are at their characteristic level ~75% of the time:
  - L_x~0.03% L_{bol}
- Elevated periods and flares are consistently hotter than characteristic periods.
  - KT_{2char} ~2.35keV
  - KT_{2ele} ~3.1keV
  - KT_{2flare} ~3.45keV
  - KT_{2peak} ~7.keV
  - KT_1 ~670-900eV



Diffuse Emission



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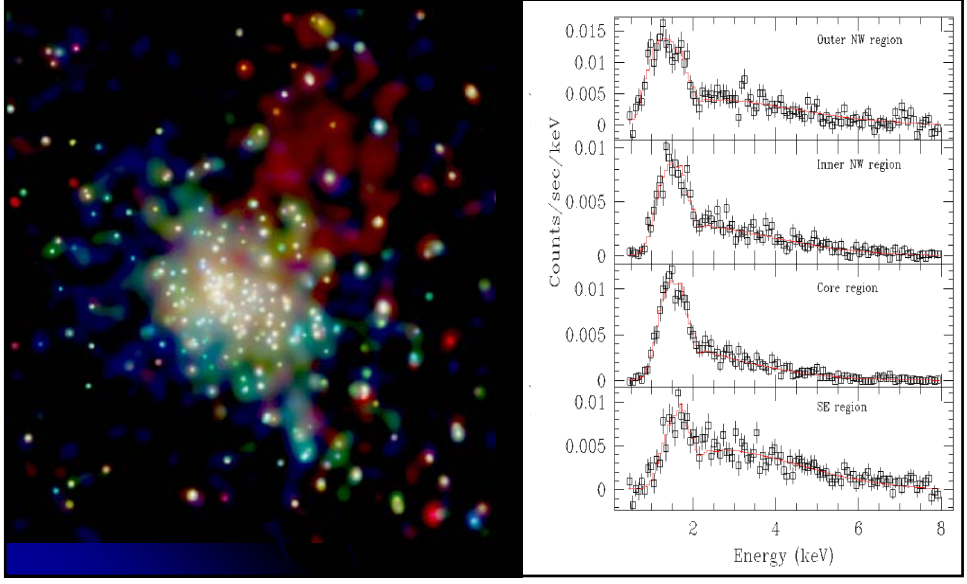

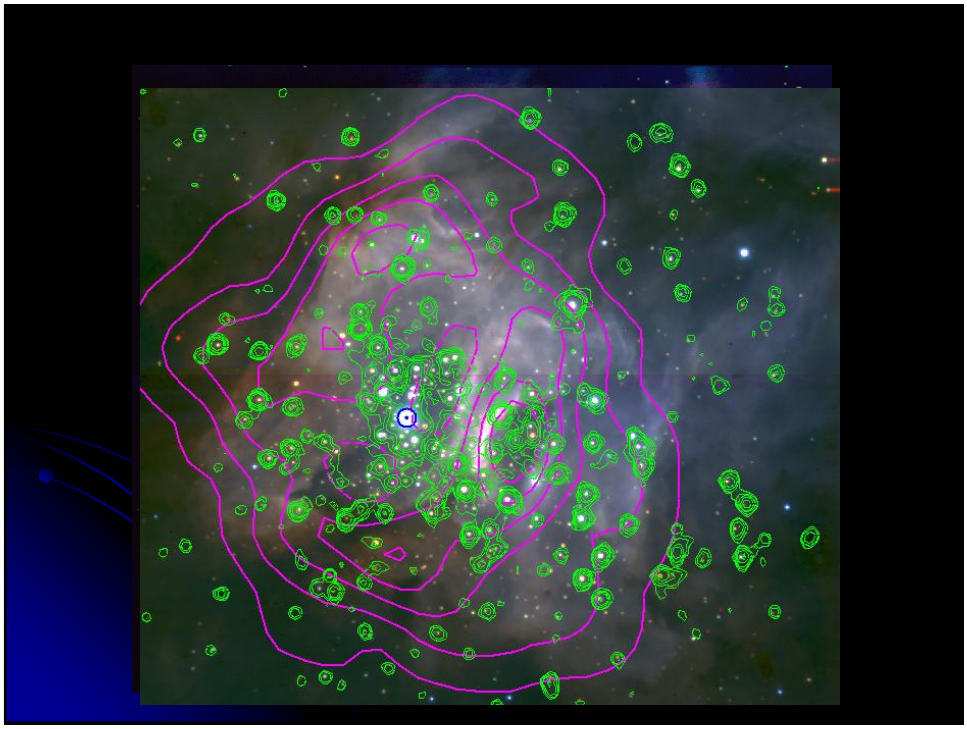

Telescope System

- High Resolution Mirror Assembly:
  - 4 nested pairs of grazing incidence paraboloid and hyperboloid mirrors Length: each 83.3 cm (32.8 in) long
- Weight: 956.4 kg (2,104 pounds) total
- Focal Length: 10 meters (32.8 ft)
- Outer Diameter: 1.2 meters (3.9 ft)
- Field of View: 1.0 degree diameter
- Ang. Resolution: 0.5 arcsec
- Altitude Control: 6 reaction wheel control 2 inertial reference units
- Aspect Camera: 1.40 deg x 1.40 deg field-of-view
- Pointing Stability: 0.25 arcsec (RMS) radius over 95% of all 10 second periods
- Pointing Accuracy: 30 arcsec 99% of viewing time
- Remarks: Mirrors have an effective area of 400 sq. cm. @1 keV; 600 A iridium coating

Science Instruments

- Advanced Charged Couple Imaging Spectrometer (ACIS):
  - Ten CCD chips in 2 arrays provide imaging and spectroscopy;
  - Imaging resolution is 0.5 arcsec over the energy range 0.2 - 10 keV;
  - Sensitivity: $4x10^{-15}$ ergs-cm^{-2} sec^{-1} in 10^5 s
- High Resolution Camera (HRC):
  - Uses large field-of-view mircro-channel plates to make X-ray images: ang. resolution < 0.5 arcsec over field-of-view 31x31 arcmin;
  - Time resolution: 16 microsec
  - Sensitivity: $4x10^{-15}$ ergs-cm^{-2} sec^{-1} in 10^5 s
- High Energy Transmission Grating (HETG):
  - To be inserted into focused X-ray beam;
  - Provides spectral resolution of 60-1000 over energy range 0.4 - 10 keV
- Low Energy Transmission Grating (LETG):
  - To be inserted into focused X-ray beam;
  - Spectral resolution of 40-2000 over the energy range 0.09 - 3 keV