X-ray Astronomy with AXAF

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X-ray missions for the new millenium

A new generation of X-ray observatories:

- AXAF (NASA, 1998)
- XMM (ESA, 1999)
- Spektr-RG (RKA, 1998?)
- XMM emphasizes collecting area and spectroscopy
- AXAF emphasizes angular resolution

History of X-ray astronomy

Instrument	Area (1 keV)	Area (6 keV)	Spatial	Spectral
Uhuru			1 degree	1
Einstein/IPC			1 arcmin	2
Rosat/HRI	100	0	5 arcsec	-
Rosat/PSPC	220	0	30 arcsec	5
ASCA/SIS	160	100	10 arcmin	50
XTE/PCA	0	6000	1 degree	5
AXAF/ACIS	650	350	0.5 arcsec	50

Science goals of AXAF

- \- Community facility like HST, ROSAT; participation by non-X-ray-astronomers encouraged.
- \- High resolution spatially resolved X-ray spectroscopy for:
  - Evolution of quasars to high redshift
  - Evolution of clusters of galaxies
  - Structure and physics in low redshift clusters
  - Abundance and plasma conditions versus position in supernova remnants
  - Faint X-ray sources and the background
  - Detailed transmission grating spectroscopy of galactic binary sources.

Who? The AXAF Project:

- Management: NASA Marshall Space Flight Center, Alabama
- Science Center: AXAF Science Center
  - Headquarters at SAO, Cambridge MA and MIT, Cambridge MA
  - Software Beta Test sites at Chicago, Stanford, Hawaii
  - ASC Director: Harvey Tananbaum, SAO
  - User Support Group: Fred Seward, Andrea Prestwich, Eric Schlegel, Nancy Evans
- Mission Support Team: SAO
- Instrument teams:
  - ACIS: MIT/Penn State
  - HRC: SAO
  - HETG: MIT
  - LETG: Utrecht
- Industrial Contractors:
  - Spacecraft: TRW
  - Aspect camera: Ball
  - Upper Stage: Boeing

When?

- Mirror manufacture: Done!
- Instrument assembly and calibration: Now!
- Mirror coating: Completed Feb 1996
- Mirror assembly: Soon!
- Telescope calibration: Jul 1996- Feb 1997
- PROPOSALS: *** Fall 1997 ***
- Launch: Summer 1998
- Lifetime: At least 5 years

What?

- The AXAF-I observatory is a single spacecraft (A companion AXAF-S was cancelled).
- Launch by Space Shuttle with IUS upper stage and GRO derived liquid propulsion system into high orbit
- Movable solar arrays allow wide area of sky to be observed.
- Four nested X-ray mirror pairs, hyperboloid and paraboloid, coated with Iridium
- Two transmission gratings
- Four focal plane detectors

What does a high orbit mean?

- 64 hour orbital period
- - Small part of sky obscured for long periods (30 deg region for two years at a time)
- - Don't observe in radiation belt regions (10 hours of every 64)
- - Long observations possible (up to 54 hours uninterrupted viewing)

Imaging instruments: ACIS-I

The ACIS (AXAF CCD Imaging Spectrometer) has two components: ACIS-I and ACIS-S, with a total of ten 1024 x 1024 X-ray CCDs.

The ACIS-I array has 4 CCDs arranged in a square.

What does a CCD do for you? The first one flown was on ASCA.

- Advantages:
  - High Spectral Resolution in each pixel
  - Broad response (0.2-10 keV)
  - 16 x 16 arcmin FOV
  - Spatial resolution better than 2 arcsec even far off axis
- Disadvantages
  - Radiation degrades spectral resolution over time
  - Lower time resolution than proportional counters, since must read out the chip
  - No very soft X-ray response
  - Gaps between chips

Imaging instruments: HRC-I

The High Resolution Camera (HRC) imaging detector is a microchannel plate, a larger version of the HRI flown on Einstein and Rosat. “Pixels” run from 1 to 16384 - a big dataset!

0.5 arcsec FWHM on axis, degrades to 10 arcsec at 10 arcmin off axis. 30 arcsec FWHM over whole 32 x 32 arcmin field.

- Advantages:
  - Good spatial resolution on axis
  - Soft X-ray response
  - High time resolution
  - Wide area (32 x 32 arcmin)
- Disadvantages:
  - No spectral resolution
  - Lower sensitivity
  - Worse off axis spatial resolution

Transmission Gratings: HETG

The HETG will disperse the X-ray photons which then fall on one of the spectroscopic arrays, usually ACIS-S.

With ACIS-S we have two measures of the photon energy: the CCD pulse height and the dispersion angle. This helps to resolve the grating order confusion.

- Advantages:
  - High spectral resolution
- Disadvantages:
  - No soft X-rays
  - 10 times lower throughput than imagers

Transmission Gratings: LETG

The LETG disperses the X-ray photons onto the HRC-S spectroscopic array.

- Advantages:
  - High spectral resolution at low energies
- Disadvantages:
  - Order separation problems at higher energies.

Data Analysis

The AXAF Science Center will process the data and maintain a database of all the AXAF data. Data will be made available in FITS formats similar to those for ROSAT and ASCA data, so you can do basic analysis of the data with existing packages (IRAF/PROS, FTOOLS/XSELECT/XSPEC, MIDAS/EXSAS). We will also provide specialized analysis tools, which will be needed if you want to recalibrate or if you want to make full use of the information in the datafiles. We hope that this system will build on the existing ones and be nicer to use!

- Programs will work on either FITS or IRAF data formats, transparently; and in conjunction with either FTOOLS or IRAF programs.
- Emphasis on uniform, generic interface to data: spatial, spectral, temporal filtering, binning, manipulations will have unified syntax, which can be extended by user to manipulations on other parameters in data (e.g. phase, housekeeping).
- Emphasis on separating science algorithms from data format details - will provide simple subroutine library for C or Fortran programmers to access data at scientific object model level (as opposed to FITS record/keyword level).
- Emphasis on improved spatial analysis (weakest in current packages). Will collaborate with Keith Arnaud to integrate XSPEC for spectral analysis.

Calibration

The X-ray Calibration Facility in Huntsville, Alabama:

- Let's make sure we can make in-focus pictures!
- Pump down entire mirror/instrument combination in huge vacuum bottle, with quarter-mile evacuated source tube
- Calibrate mirrors with special proportional counter detectors
- Mask off shells and quadrants
- Then calibrate instrument/mirror, instrument/grating combinations
- Tilt mirror to obtain off axis calibrations
- Move instruments to remain on mirror axis
- Dither HRC to avoid burning holes in it
- More than 1 Terabyte of data expected!
- Need to correct for 1-g sag of mirrors, finite distance of source, etc.