Early Results from the Chandra X-ray Observatory

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Abstract

We present some early results on AGN from the Chandra X-ray Observatory, highlighting high resolution spectroscopy using the High Energy Transmission Grating Spectrometer (HETGS). The quasar PKS 0637–752 was found to have a very bright X-ray jet whose shape is remarkably similar to that of the radio jet on a size scale of 100 kpc, but the X-ray emission is still inexplicably bright. Two BL Lac objects, PKS 2155–304 and Mrk 421, observed with the spectrometer were found to have no strong absorption or emission features. Other radio loud AGN observed with the HETGS show simple power law spectra without obvious features.

Key words: galaxies: active; quasars: general; X-rays: galaxies

1 Introduction

The Chandra X-ray Observatory (CXO, or Chandra) was launched in July, 1999 into a high Earth orbit. Although there has been some degradation of the spectral resolution of the Advanced CCD Imaging Spectrometer (ACIS), all instruments are performing well. Here I will focus on data from ACIS and the High Energy Transmission Grating Spectrometer (HETGS), in order to demonstrate the overall performance of the telescope and some of the ways that Chandra will contribute to our understanding of active galactic nuclei (AGN).

2 Chandra Observations of AGN

The first target observed with Chandra was the quasar PKS 0637–752 (figure 1). It was rather surprising to find an X-ray jet extending 7-12" from the...
Fig. 1. Chandra ACIS image of the focussing target, PKS 0637-752. Radio flux contours from the Australia Telescope Compact Array are overlaid. There are three faint sources detected in the Hubble Telescope images that fall within the brighter parts of the jet, which was not detected in X-rays or optical light before the launch of Chandra. The X-ray brightness of the jet is still unexplained by conventional models.

The HETGS flight calibration program included observations of the late type star Capella in order to verify the spectral resolution by using emission lines, and an observation of the BL Lac object Mrk 421 was included in order to verify the effective area for point sources. An observation of 3C 273 was scheduled for January, 2000, which will be used for cross-calibration between Chandra spectrometers and other X-ray telescopes, including BeppoSAX and ASCA. The Capella observation (1) shows that the spectral resolution meets the pre-flight expectations. The calibration spectra of Mrk 421 are shown in Figure 2. The spectra from the MEG and the HEG are consistent to within the 10-20% systematic uncertainties. The spectra are well fitted by a simple power law with $\alpha = 1.9 \left( f_\nu \propto \nu^{-\alpha} \right)$, and the only deviation from this fit appears near the O-K edge, which will be removed as the detector calibration is refined.

The BL Lac object PKS 2155–304 was observed as part of the HETGS guaranteed time observation program. Spectra are shown in Figure 3. Again, the HEG and MEG spectra are consistent to within the 10-20% systematic uncertainties and are well fitted by a simple, pure power law model. The spectral index is $1.70 + 0.02 - 0.02$ and there are no significant absorption features. A
Fig. 2. The MEG (top) and HEG (bottom) spectra of Mrk 421 with the Chandra HETGS. The spectra are overplotted with well-fitting power law models with $\alpha = 1.9$. The MEG and HEG spectra are consistent within 10-20% systematic uncertainties. There are no significant features in the spectrum except for an instrumental residual near the O-K edge at about 0.54 keV.

feature such as the one found previously would have been detected easily in the MEG portion of the Chandra HETGS spectrum, so we conclude that it must be variable.

Other AGN observed in the early phase of Chandra HETGS guaranteed time observations include NGC 1275 and PKS 2149-305. Preliminary analysis indicates that these HETGS spectra are all well fitted by simple power law models with absorption by neutral interstellar material. The spectral indices are somewhat smaller: 0.8 and 0.2, respectively. No Fe-Kα lines are detected in any of their spectra.
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