

## Summary of Research

*RXTE* Cycle 8, Grant# NNG04GB21G

*Title: RXTE, Chandra, and XMM Spectroscopy of the Fe-K Lines and Compton Reflection in Type 1 AGN.*

**Science & Budget PI:** Tahir Yaqoob. **Period of Performance:** 12/01/03 to 11/30/04.

### Final Report

This award pertains to an *RXTE* observation of the Seyfert 1 galaxy Akn 120. The purpose of the observation was to measure the Fe-K emission line and the Compton reflection continuum with *RXTE*, simultaneously with *Chandra* and *XMM*. Such measurements can severely constrain accretion disk models of the central engine since the Fe-K line emission and Compton reflection are intimately related in terms of the physics of X-ray reprocessing in optically-thick matter. Akn 120 was selected for this study because it is amongst the brightest AGN in its class and has a particularly strong and apparently broad Fe-K emission line. The results could then also be used to lay the ground work for even higher resolution studies with *Astro-E2*. Unfortunately, the *Chandra* observation was not performed but a contemporaneous *XMM* observation was performed by another group of researchers (Vaughan *et al.* 2004, MNRAS, 351, 193). Those data recently became public and can be compared with the *RXTE* data. In addition, non-contemporaneous observations with other missions do still provide additional important constraints (for example any non-varying line or continuum emission components can be established and used to reject or preserve various model scenarios). We analyzed the *RXTE* data and found a strong Fe-K emission line (resolved even with the poor resolution of *RXTE*), and a strong Compton-reflection continuum (see Fig. 1(a)). We found that the results of archival *ASCA* data on Akn 120 had not been published in the literature so we analyzed the *ASCA* data too, in order to compare with the new *RXTE* data. Fig. 1(b) shows that the *ASCA* data also reveal a strong, broad Fe-K emission line (but the data are not sensitive to the Compton-reflection continuum). We compared our spectral fitting results for the *RXTE* and *ASCA* data with the results from *XMM* and from previous *RXTE* observations (Vaughan *et al.* 2004, MNRAS, 351, 193).

For the new *RXTE* data and the *ASCA* data we measured an Fe-K line centroid energy of  $6.45 \pm 0.12$  keV and  $6.52 \pm 0.08$  keV respectively, when modeled with a single Gaussian component (best-fitting  $\sigma \sim 0.3$  keV), which was a good fit to the data. These values of the centroid energy are consistent with the values measured from the *XMM* data, and previous *RXTE* observations (in agreement with Vaughan *et al.* 2004, MNRAS, 351, 193). Both the *RXTE* and *XMM* data give a relative amplitude of reflection,  $R$ , consistent with 1. Moreover, the overall intensity of the broad Fe-K line is consistent with a constant in all of the observations, despite  $\sim 50\%$  variations in continuum flux. Thus the data are consistent with a picture in which the apparently broad Fe-K emission line, with an EW of  $\sim 100 - 300$  eV is formed in optically-thick matter in which Fe is neutral or only mildly ionized (up to  $\sim$  Fe XVII or so), with a reflection continuum roughly consistent with that expected from the strength of the emission line. Physically this could correspond to a near-face-on disk or from distant matter, such as an obscuring torus. The fact that the intensity of the emission line does not vary significantly does not necessarily rule out an accretion disk origin, since there are cases of other AGN in which much evidence points to an accretion disk origin, yet the variability behavior is not what would be expected from simple models (MCG -6-30-15 is a

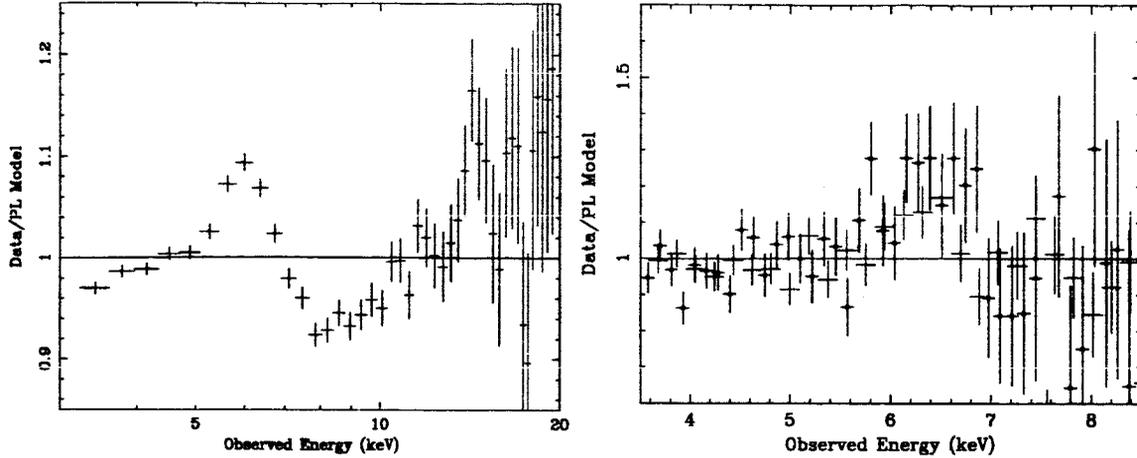


Figure 1: (a) [Left] The ratio of the *RXTE* data to a simple power-law model, showing the strong Fe-K emission line, and strong Compton-reflection continuum (notice the hardening above  $\sim 10$  keV). (b) [Right] The ratio of the *ASCA* data to a simple power-law model, showing the strong and broad Fe-K emission line. Black data with filled circles: *ASCA* SIS; red data: *ASCA* GIS.

notable example - see Miniutti *et al.* 2003, MNRAS, 344, L22). A paper detailing the results from the simultaneous *RXTE* and *XMM* observations, and from the *ASCA* observation, will be submitted in the near future and this work will form part of the PhD thesis of a graduate student.

What is principally new from our analysis and study is (1) we have a baseline of  $\sim 10$  years for measurements of the Fe-K emission line and Compton-reflection continuum, and (2) the *simultaneous* measurement of of the Fe-K emission line (with *XMM*) and of the Compton-reflection continuum (with *RXTE*) place the tightest constraints yet on models of the accretion-disk and black-hole system, and its environment. Further studies with *Astro-E2* are required to determine whether the apparently broad Fe-K line really consists of more than one narrower emission-line components, or whether it is genuinely broad.