# THE X/GAMMA-RAY SPECTRAL PROPERTIES OF NGC 7172

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ABSTRACT

We present a combined, non-simultaneous, *ASCA* GIS and *CGRO* OSSE spectrum of the Seyfert 2 galaxy, NGC 7172, and make broad band spectral fits. The only Seyfert 2 galaxy previously studied over such a broad band is NGC 4945. We find that the most probable model for the data is a power law with an exponential cut-off being affected by a neutral absorber. The best fit parameters are found to be $\Gamma = 1.47 \pm 0.15$ and $N_{\rm H} = (7.8 \pm 0.6) \cdot 10^{22}$ cm$^{-2}$. The spectral index of the underlying power law of NGC 7172 has therefore varied from 1.8 to 1.5 since the *Ginga* observations in 1989. For this simple model the e-folding energy at $88^{+65}_{-28}$ keV is relatively well constrained. The observed flux in the $2-10$ keV range is $F_{2-10} = 4.7 \cdot 10^{-11}$ erg cm$^{-2}$ s$^{-1}$, which corresponds to a small increase since the *Ginga* measurement in October 1989.

Keywords: Galaxies: individual: NGC 7172; Galaxies: Seyfert; X-rays: galaxies.

## 1. INTRODUCTION

In the unified model of Seyfert galaxies (Antonucci 1993), the observed differences between Seyfert 1 and Seyfert 2 galaxies are explained as an orientation effect caused by an obscuring molecular torus that surrounds the central X-ray source. This intrinsic X-ray source is suggested to be the same for all Seyfert galaxies. Some Seyfert 2 galaxies have been observed to have an intrinsic spectrum that is flatter than what has been observed for Seyfert 1's (Smith & Done 1996), which contradicts the unified model. However, when observing with a single satellite, normally only a narrow spectral band can be studied (e.g., $0.5-12$ keV for *ASCA*). If the observed object is heavily absorbed, this range could be too small to be able to determine whether the intrinsic spectrum really is flat or whether it is intrinsically steep and maybe affected by Compton reflection. This may not be the case for broad band spectra obtained by combining data from two or more satellites. In this paper, we conduct such an analysis on the Seyfert 2 galaxy NGC 7172. The only Seyfert 2 galaxy previously studied over a broader band using non-simultaneous *ASCA*/*Ginga*/*CGRO* OSSE data is NGC 4945 (Done et al. 1996). The average non-simultaneous *Ginga*/*CGRO* OSSE spectrum of three Seyfert 2 galaxies has also been studied (Zdziarski et al. 1995).

The X-ray spectrum of NGC 7172, an obscured, edge-on Seyfert 2 galaxy at a redshift of $z = 0.008$ (Sharples et al. 1984), was studied by *EXOSAT* in October 1985 (Turner & Pounds 1989), by *Ginga* in October 1989 (Warwick et al. 1993; Nandra & Pounds 1994; Smith & Done 1996), by *CGRO* OSSE in March 1995, by *ASCA* on May 13, 1995 (Ryde et al. 1996), and on May 17, 1996 (Matt et al. 1996). Here we analyse and fit the March/May 1995 data. The *ASCA* data for NGC 7172 are extracted using XSELECT (ftools v3.6) and all the data analysis is performed with XSPEC.

## 2. THE X/$\gamma$ OBSERVATIONS OF NGC 7172

We observed NGC 7172 with the *ASCA* satellite from 23:18 UTC on May 12 until 16:00 UTC on May 13, 1995 with the two GSPC's, GIS2 and GIS3 and with the two CCD detectors SIS0 and SIS1. The SIS data seem to be sensitive to the screening criteria and give different results depending on the criteria adopted. The SIS0 and the SIS1 detectors also give different results as compared to each other. This needs to be investigated further. The GIS data are, however, consistent with each other and they are usually less affected by calibration problems. In this paper we therefore only use the GIS2 and the GIS3 data for the *ASCA* observation. In screening the GIS data, standard, conservative criteria are applied: Minimum angle to Earth limb = $10°$, angle from bright Earth (illuminated limb) = $20°$, minimum cutoff rigidity = 6 GeV/c. The background is extracted from a source-free region of the same image as the source. The final results do not differ significantly, if a background instead is extracted from the blank sky background event files provided by the *ASCA* Guest Observer Facility. The extracted data are regrouped to contain a minimum of 20 counts per channel to allow the use of the $\chi^2$-test. This leads us to ignore low energy channels up to $\sim$ 2 keV. The net exposure time for both detectors is 27 ks. NGC 7172 did not show any significant variability during the observations, with the variations being less than 10 per cent of the mean count rate.

*CGRO* OSSE observed NGC 7172 from February 21 to March 21, 1995. The data may be affected by the proximity of PKS 2155-304, as both objects often had to be observed together. The OSSE data were provided by the CGRO Science Support Center.

## 3. DATA ANALYSIS AND RESULTS

We analyse the combined spectrum using the *ASCA* GIS, and *CGRO* OSSE data discussed above from which one should be able to determine the photon index unambiguously. The observations are not simultaneous, however, but the *ASCA* and OSSE observations are only two months apart.

We start off with a model (denoted as 'model P') consisting of a power law and a neutral absorber, leaving the e-folding energy free. The resulting fit gives a photon spectral index $\Gamma = 1.47 \pm 0.15$, an e-folding energy of $88^{+65}_{-28}$ keV and an equivalent hydrogen column density $N_{\rm H} = (7.8 \pm 0.6) \cdot 10^{22}$ cm$^{-2}$. The fit has a reduced $\chi^2 = 0.881$, for the number of degrees of freedom, dof $= 470$. For the simple model under consideration, the OSSE data gives a relatively good constraint to the e-folding energy. The observed flux, in the $2-10$ keV range, $F_{2-10} = 4.7 \cdot 10^{-11}$ erg cm$^{-2}$ s$^{-1}$ and the flux, corrected for absorption, $F_{2-10}^{\rm no-abs} = 7.3 \cdot 10^{-11}$ erg cm$^{-2}$ s$^{-1}$. The luminosity, with $z = 0.008$, $H_\circ = 50$ km s$^{-1}$ Mpc$^{-1}$, $q_\circ = 0$, becomes $L_{2-10} = 1.5 \cdot 10^{43}$ erg s$^{-1}$.

In the next step of the analysis, we try adding a Compton reflection component (XSPEC model **pexrav** by Magdziarz & Zdziarski 1995). The resulting fit does not change, and the reflection parameter stays at zero. The data clearly do not require a reflection component and we therefore use 'model P' above as our best fit model.

The *Ginga* observations of NGC 7172 from 1989 (Warwick et al. 1993) showed that $\Gamma = 1.85^{+0.05}_{-0.04}$ and the $F_{2-10} = 4.0 \cdot 10^{-11}$ erg cm$^{-2}$ s$^{-1}$. The X-ray spectrum of NGC 7172 has thus become flatter between 1989 and 1995, and the $2-10$ keV flux level has increased.

Figure 1 shows the combined *ASCA* GIS and *CGRO* OSSE data and the best fit model ('model P') in $E \cdot F_E$ versus $E$. The *ASCA* data below $\sim 2$ keV do not have sufficient photon counts for a proper $\chi^2$ analysis and that data was not used in the modeling. It is, however, evident that there exists a soft component, which is often seen in Seyfert 2 galaxies (Morse et al. 1996).

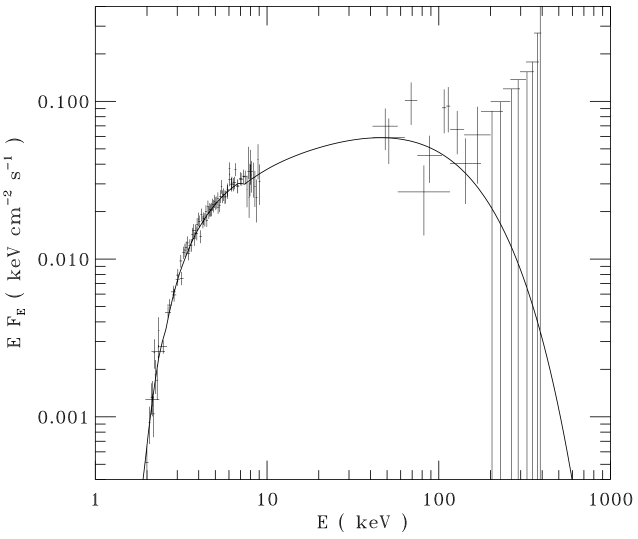


*Figure 1: A $\nu F_\nu$ plot of the combined ASCA/CGRO OSSE data of NGC 7172 together with the best fit.*

## 4. SUMMARY

Using the *ASCA* GIS and the *CGRO* OSSE observations of NGC 7172, a broad spectral band is achieved. The best fit model is a power law affected by a neutral absorber, $\Gamma = 1.47 \pm 0.15$ and $N_{\rm H} = (7.8 \pm 0.6) \cdot 10^{22}$ cm$^{-2}$. The e-folding energy is constrained by the OSSE data to be $E_c = 88^{+65}_{-28}$ keV. The fit does not improve, when more complicated models are used, such as adding a reflection component. The flat spectrum found means that the spectral index of NGC 7172 is variable, changing from $\Gamma = 1.8$ in 1989 to $\Gamma = 1.5$ in 1995. It still lies within the range that Seyfert galaxies are observed to have (see, e.g. Nandra & Pounds 1994). We note that some other Seyfert galaxies, most notably NGC 4151 (Yaqoob & Warwick 1991), also have variable $\Gamma$.

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## REFERENCES

Antonucci, R., 1993 ARAA, 31, 473

Done, C., Madejski, G. M., Smith, D. A., 1996, ApJL, 463, L63

Johnson, W. N. et al., 1994, in 'The Second Compton Symposium', eds. C. E. Fichtel, N. Gehrels, J. P. Norris, AIP v.304, p.515

Magdziarz, P., Zdziarski, A.A. 1995, MNRAS, 273, 837

Matt, G., Guainazzi, M., Antonelli, L. A., Fiore, F., Piro, L., Robba, R., Ueno, S., these proceedings

Morse, J. A., Wilson, A. S., 1995, ApJ, 439, 121.

Nandra, K., Pounds, K. A., 1994, MNRAS, 268, 405

Ryde F., Larsson S., Mihara T., Poutanen J., Svensson R., Ueno S., Yamashita A., 1996, to be published in the proceedings of the conference 'X-ray Imaging and Spectroscopy of Cosmic Hot Plasmas', Tokyo

Sharples, R. M., Longmore, A. J., Hawarden, T. G., Carter, D., 1984, MNRAS, 208, 15

Smith, D. A., Done, C., 1996, MNRAS, 280, 355.

Turner, T. J. and Pounds, K. A., 1989, MNRAS, 240, 833

Warwick, R. S. et al., 1993, MNRAS, 265, 412

Yaqoob, T. and Warwick, R. S., 1991, MNRAS, 248, 773

Zdziarski, A. A. , Johnson, W. N., Done, C., Smith, D., McNaron-Brown, K., 1995, ApJ, 438, L63