BeppoSAX Observations of the Seyfert-2 Galaxies NGC 7172 and ESO 103-G35

A. Akylas\textsuperscript{1,2}, I. Georgantopoulos\textsuperscript{1}, A. Comastri\textsuperscript{3}

\textsuperscript{1} Institute of Astronomy \& Astrophysics, National Observatory of Athens, I. Metaxa \& B. Pavlou, Penteli, 15236, Athens, Greece
\textsuperscript{2} Physics Department University of Athens, Panepistimiopolis, Zografos, 15783, Athens, Greece
\textsuperscript{3} Osservatorio Astronomico di Bologna, Via Ranzani 1, I-40127 Bologna, Italy

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ABSTRACT

We investigate the X-ray spectra of the type-2 Seyfert galaxies NGC 7172 and ESO 103-G35, using BeppoSAX observations, separated by approximately one year. We find that the X-ray spectra of both NGC 7172 and ESO 103-G35 can be well fitted using a power-law model with an Fe K\textalpha{} emission line at 6.4 keV. We did not find any statistically significant evidence for the existence of a reflection component in the X-ray spectra of these two galaxies. The continuum flux has decreased by a factor of approximately two during this period, in both objects. However, the spectral index as well as the absorption column have remained constant. We find weak evidence for the decrease of the normalization of the Fe K\textalpha{} emission line in a similar manner to the continuum in NGC7172. We also report evidence for a broad Fe K\textalpha{} confirming previous ASCA observations. In contrast, in the case of ESO 103-G35 the line flux does not change while its width remains unresolved.

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

1 INTRODUCTION

In recent years X-ray missions such as EXOSAT Ginga and ASCA have demonstrated that Seyfert-2 galaxies have a very complex X-ray spectrum (see Mushotzky, Pounds \& Done 1993 for a recent review). In particular their spectrum contains at least the following features: a) a power-law continuum with slope $\Gamma \sim 1.9$ absorbed by a very large column ($> 10^{23}$ cm\textsuperscript{-2}) (eg Turner \& Pounds 1988); this obscuring screen is probably associated with a molecular torus. b) an FeK line at 6.4 keV ie originating from neutral Fe c) a spectral curvature (hump) above 10 keV; this is generally believed to originate from reflection of the power-law component on cold material (eg Lightman \& White 1988, George \& Fabian 1991).

In contrast to the recent progress in understanding the spectral features of Seyfert-2 galaxies, our knowledge of their X-ray variability properties remains scanty. Usually, this has been based on comparison of the X-ray flux between observations from different missions spanning time intervals of several years. Recently, Turner et al. (1997) have detected some evidence for short term variability in a handful of Seyfert-2 galaxies using ASCA . The systematic monitoring of Seyfert-2 galaxies has become possible with the RXTE mission. RXTE observations of a few objects revealed strong variability in time-scales of hours as well as evidence for spectral variability (Georgantopoulos et al. 1999, Georgantopoulos \& Papadakis 2000). Indeed, time variability studies can provide strong constraints in understanding the geometry of the circumnuclear matter in these objects. For example, the time lags between the power-law continuum and the normalization of the Fe line could constrain the origin of the line. In the case where the Fe line originates in an accretion disk (as is the standard scenario for Seyfert-1 galaxies), the Fe line should closely track the variations of the intrinsic power-law.

In this paper we present an analysis of four observations of the Seyfert-2 galaxies NGC 7172 and ESO 103-G35 from the BeppoSAX archive. The two observations for each galaxy are separated by a year’s interval. Our goal is to study any long-term variations in the spectral features between the two epochs. The broad energy band of BeppoSAX as well as its good spectral resolution, provide the opportunity to place stringent constraints on the geometry of the nuclei of ESO103-G35 and NGC7172 and any surrounding gaseous media.
2 THE SAMPLE

2.1 NGC 7172

NGC 7172 is an obscured, almost edge on galaxy. It belongs to the compact group HCG90 and has a redshift of z=0.0086. It is classified as a type 2 Seyfert galaxy. Strong infrared emission from the nucleus is observed, which is variable on time scales of approximately 3 months (Sharples et al. 1984). The first X-ray observation which was performed by EXOSAT showed a Γ=1.84 power-law absorbed by $N_H \sim 10^{23}$ cm$^{-2}$ (Turner & Pounds 1989). Later observations with Ginga confirmed the above results and also indicated that a reflection component may be important (Smith & Done 1996). Furthermore the analysis of ASCA observations (Turner et al. 1997) showed the presence of a 6.4 keV emission line with an equivalent width (EW) of $68^{+36}_{-25}$ eV. In contrast with the previous results they found a rather harder photon index, $\Gamma \sim 1.7$, while the amount of the absorption column remained constant. Guainazzi et al. (1998), using 2 ASCA observations separated by one year, found an even flatter photon index of $\Gamma \sim 1.5$ absorbed by the same column density found in previous observations. They further detect short-term variability (within a day) of about 30 percent. Until 1995, before the BeppoSAX observations, the flux of NGC 7172 has remained almost constant between $\sim 3$ and $\sim 5 \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$. Since May 1996 the source has reached a very low flux state of $\sim 1 \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$. The flux variability history of NGC7172 is summarized in Fig. 1.

2.2 ESO 103-G35

The HEAO A2 hard X-ray source 1H 1832-653 was identified as the S0/Sa type galaxy ESO 103-G35, with a redshift of z=0.013, by Phillips et al. (1979). They classified the AGN as a type 1.9 Seyfert galaxy because of the weakness of $H\beta$ emission line and the presence of a broad $H\alpha$ line. EXOSAT observations, showed a steep photon index of $\Gamma = 1.92^{+0.34}_{-0.34}$ absorbed by a high column density of $N_H > 10^{23}$ cm$^{-2}$, which was found to vary within factor of 2 in a period of 90 days possibly due to motion of material in the Broad Line Region across the line of sight (Warwick, Pounds & Turner 1988). Later observations obtained by Ginga strongly suggested the presence of a narrow emission line at 6.4 keV and also of a reflection component with a photon index $\Gamma = 2.19^{+0.08}_{-0.08}$ (Smith & Done 1996). ASCA observations (Turner et al. 1997) confirmed the previous EXOSAT results and showed strong evidence for the presence of a triplet Fe line (6.4, 6.68, 6.98 keV). They also found a decrease by a factor of two in the continuum flux as compared to Ginga. Finally, Forster,Leighly & Kay (1999), analyzing three ASCA observations spanning a period of $\sim$2 years (1994-1996), found a decrease in the EW of the Fe line while the continuum flux increased by a factor of 2. An edge at 7.4 keV was also found in the 1996 observation. The long term variability history of ESO 103-G35 is summarized in Fig. 2.

3 OBSERVATIONS

The scientific instrumentation on board the Italian-Dutch X-ray Satellite BeppoSAX includes a Medium Energy Con-
centrator Spectrometer, MECS, which consists of three units, (Boella et al 1997) a Low Energy Concentrator Spectrometer, LECS, (Parmar et al 1997) a High Pressure Gas Scintillation Proportional Counter, HPGSPC, (Manzo et al 1997) and a Phoswich Detector System, PDS, (Frontera et al 1997), all of which point in the same direction. The MECS instrument consists of a mirror unit plus a gas scintillation proportional counter and has imaging capabilities. It covers the energy range between 1-10 keV with a spatial resolution of about 1.4 arcmin at 6 keV and a spectral resolution of 8 per cent at 6 keV. The LECS instrument is similar to the MECS and operates in the 0.1-10 keV band with the same spectral and spatial resolution of the LECS. The PDS is a direct view detector with rocking collimators and extends the BeppoSAX bandpass to high energies (13-300 keV). Its energy resolution is 15 per cent at 60 keV. In our analysis we use MECS and PDS data only. Our objects have not been detected by the HPGSPC detector. We did not use the LECS data as there are nearby contaminating soft X-ray sources, most probably stars in case of ESO 103-G35, while in case of NGC 7172 the contamination is due to the presence of the Hickson compact group HB90. These sources are not present in the hard MECS images. Another reason for excluding the LECS data was the poor photon statistics (see tables 1 and 2).

We analyze here two observations of NGC7172 and ESO 103-G35 both obtained with BeppoSAX within an interval of about one year. More specifically, NGC7172 was first observed in 1996 (from October 15th to 16th) and then in 1997 (from November 6th to 7th). ESO 103-G35 was first observed in 1996 (from October 3rd to 4th) and then in 1997 (from October 14th to 15th). Tables 1 and 2 list the exposures times and net count rates (background subtracted) for all four observations. The three different (or two after May 7 1997, when MECS1 failed) MECS units are merged together in order to increase the signal to noise ratio. This is feasible because the three MECS units show very similar performance and the difference in the position of the optical axis in the three units is smaller than the scale on which the vignetting of the telescopes varies significantly (>5 arcmin).

### Table 1. BeppoSAX observations of NGC 7172

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Exposure time (sec)</th>
<th>count rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>LECS</td>
<td>15490</td>
<td>0.038 ± 0.002</td>
</tr>
<tr>
<td>MECS(1,2,3)</td>
<td>39172</td>
<td>0.148 ± 0.002</td>
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<tr>
<td>PDS</td>
<td>17277</td>
<td>0.431 ± 0.051</td>
</tr>
<tr>
<td>6/7-November-1997</td>
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<td></td>
</tr>
<tr>
<td>LECS</td>
<td>22896</td>
<td>0.022 ± 0.001</td>
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<tr>
<td>MECS(1,2)</td>
<td>49437</td>
<td>0.054 ± 0.001</td>
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<tr>
<td>PDS</td>
<td>21146</td>
<td>0.292 ± 0.047</td>
</tr>
</tbody>
</table>

### Table 2. BeppoSAX observations of ESO 103-G35

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Exposure time (sec)</th>
<th>count rate</th>
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</thead>
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<tr>
<td>LECS</td>
<td>10238</td>
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<td>50619</td>
<td>0.308 ± 0.003</td>
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<td>PDS</td>
<td>21029</td>
<td>0.746 ± 0.047</td>
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<td>3/4-October-1996</td>
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<tr>
<td>LECS</td>
<td>3699</td>
<td>0.04 ± 0.004</td>
</tr>
<tr>
<td>MECS(1,2)</td>
<td>14347</td>
<td>0.123 ± 0.003</td>
</tr>
<tr>
<td>PDS</td>
<td>5915</td>
<td>0.579 ± 0.087</td>
</tr>
<tr>
<td>14/15-October-1997</td>
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<td></td>
</tr>
</tbody>
</table>

### 4 TIMING ANALYSIS

In Fig. 3 and 4 we present the light curves for the MECS instrument for each observation separately, using a binning time of 3 ks (the errors correspond to the 68 per cent confidence level). When we perform a constant fit, the resulting $\chi^2$ implies short term variability in both objects. In particular, for the first observation of NGC 7172 we find that the best fit average count rate ($0.147 ± 0.007$) gives a $\chi^2=36$ (for 24 degrees of freedom, dof), while for the second observation we find 0.052 ± 0.005 with $\chi^2$/dof=64/33. In the case of ESO 103-G35 the best fit constant is 0.305 ± 0.004 corresponding to $\chi^2$/dof=72/29 for the first observation while for the second one we find 0.122 ± 0.004 with $\chi^2$/dof=10/8. The above $\chi^2$ suggest the presence of statistically significant ($>3\sigma$) short-term variability in the 1997 and 1996 observations of NGC7172 and ESO103-G35 respectively. Our results are compatible with previous ASCA findings. More specifically, Guainazzi et al (1998) detected a flux variability of about 30 per cent, on time scales of hours in a 1996 ASCA observation of NGC 7172. Furthermore, Forster et al (1999) using ASCA data found statistically significant short term variability in a 1996 observation of ESO 103-G35.

The variability amplitude was estimated in all four observations by means of the excess variance $\sigma^2_{rms}$ (for a definition of this quantity see Nandra et al 1997). In table 3 we present the values of $\sigma^2_{rms}$ and the unobscured luminosity for each observation. Unfortunately a comparison with the results found by Nandra et al (1997) for a sample of Seyfert 1 galaxies is not straightforward. This is due to both the different exposure times and binning time we have used. For example our large binning time has the effect to suppress the $\sigma^2_{rms}$ value. Indeed our values are slightly lower than the values quoted in Nandra et al (see their Fig 4).

### 5 SPECTRAL ANALYSIS

We used an extraction radius of four arcmin. The above area encircles more than 85 per cent of the photons in the 2-10 keV energy band. The spectrum of the background was estimated from source free regions of the image. In particular, we consider an annulus with inner radius 6 arcmin and outer radius 12, for the MECS instrument. We used the Rise Time threshold background subtracted PDS spectra...
Table 3. The values of the variability amplitude, $\sigma_{\text{rms}}^2$, and the unobscured luminosity for each observation

<table>
<thead>
<tr>
<th>object</th>
<th>date</th>
<th>$\sigma_{\text{rms}}^2$</th>
<th>luminosity (ergs s$^{-1}$)</th>
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<tr>
<td>NGC 7172</td>
<td>1996</td>
<td>0.0045</td>
<td>$3.5 \times 10^{42}$</td>
</tr>
<tr>
<td>NGC 7172</td>
<td>1997</td>
<td>0.0018</td>
<td>$1.7 \times 10^{42}$</td>
</tr>
<tr>
<td>ESO 103-G35</td>
<td>1996</td>
<td>0.0029</td>
<td>$2.7 \times 10^{43}$</td>
</tr>
<tr>
<td>ESO 103-G35</td>
<td>1997</td>
<td>0.004</td>
<td>$1.5 \times 10^{43}$</td>
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</tbody>
</table>

released from the BeppoSAX archive. We use data between the energy ranges 1.65-10 keV and 15-50 keV for the MECS and PDS detectors respectively where the response matrices are well calibrated. We do not consider the PDS data above 50 keV as in this energy range the signal to noise ratio is low. The MECS spectral files were rebinned linearly to give a minimum of 20 counts per channel while the PDS spectral files were binned logarithmically in 18 channels. The spectral fitting was carried out using the XSPEC v10 software package. All errors quoted in the best-fit spectral parameters correspond to the 90 per cent confidence level. The MECS and PDS data were fitted simultaneously. A relative normalization factor was introduced between the PDS and MECS data spectrum since the BeppoSAX instruments show some mismatches in the absolute flux calibration. We assumed a PDS to MECS normalization factor between 0.77 to 0.95 (Fiore, Guainazzi & Grandi 1999).

5.1 NGC 7172 (1996)

We first fit a simple model consisting of a power-law absorbed by a neutral column $N_H$ (Fig. 5). This provides a good fit to the data ($\Delta \chi^2=145$ for 146 dof). The addition of a broad Gaussian line improves significantly the fit ($\Delta \chi^2=10$). The best-fit line energy was $6.0^{+0.6}_{-0.5}$ keV. Since this value is consistent with 6.4 keV, which indicates a neutral or weakly ionized Fe, (e.g. Nandra et al 1997) we fix it at 6.4 keV in the rest of the analysis. The line width is $\sigma_{K_{\alpha}}=0.8^{+0.2}_{-0.3}$ keV, so it is marginally resolved given the energy resolution of the MECS. When we fix the line width at 0.1 keV we obtain an increase of $\Delta \chi^2=2.8$. The best-fit parameters are presented in table 4.

In fig 5 residuals can be seen above 7 keV. We therefore attempted to include an absorption edge at $\sim$7.2 keV. We found that the addition of the edge significantly improves the fit ($\Delta \chi^2=3.4$ for the addition of one parameter). The optical depth of the edge is $1.18^{+0.12}_{-0.16}$. The rather flat spectral index $\Gamma = 1.64^{+0.12}_{-0.05}$ could suggest that a reflection continuum is present. Therefore, we further tried to add a reflection component to our model. We used the PEXRAV model in XSPEC (Magdziarz & Zdziarski 1995). We assumed that both the reflection component and the power-law are absorbed by the same column density. We fix the PEXRAV normalization to that of the power-law. We also arbitrarily fix the inclination angle (of the plane of the reflecting material) to $i = 60^\circ$, since the shape of the reflection spectrum in our energy band is relatively independent of the inclination angle. The cut-off energy of the incident power-law was set at 300 keV. Finally, the Fe and light el-
NDNGC7172 (1997)

Similar to the 1996 observation of NGC 7172, an absorbed power-law model ($\Gamma \sim 1.5$) provides a good fit ($\Delta \chi^2 = 112$ for 109 dof, see Fig. 5). The addition of a Gaussian line improves the fit significantly ($\Delta \chi^2 = 6$). The line energy is $6.74^{+0.42}_{-0.42}$ keV consistent with neutral Fe and therefore hereafter we fix it at 6.4 keV. The range of the line width $\delta E$ is consistent with neutral Fe and therefore hereafter we fix it at 6.4 keV. The line is unresolved: its width range is 0.1-0.3 keV. The best-fit parameters are shown in table 4. Inspection of the residuals shows that there is no evidence for the presence of an absorption edge. However, we attempt to include an edge at 7.25 keV based on the previous 1996 results. We found that there is no improvement in the fit ($\Delta \chi^2 < 1$). The optical depth of the edge is $0.08^{+0.15}_{-0.08}$. The rather flat spectral index $\Gamma = 1.53^{+0.06}_{-0.16}$ could again suggest the presence of a reflection component. However, when we try to include such a component, we find that, although it does not improve the fit ($\Delta \chi^2 = 1.5$ for one additional parameter), the photon index becomes steeper $\Gamma = 1.81^{+0.60}_{-0.40}$ and the reflection parameter is $R = 2.5^{+1.3}_{-1.0}$. The unabsorbed reflected flux is 40 percent of the total flux in the 2-50 keV energy band. Comparison between the spectral fits in the 1996 and 1997 observations reveals that there is no change in the photon index and the column density within the errors.

Finally, we perform joint fits in order to investigate any possible variability in the normalization of the different spectral components. We fit both NGC 7172 observations with an absorbed power law model ($\Gamma = 1.6^{+0.07}_{-0.09}$ and $N_H = 9.1^{+3.0}_{-0.6} \times 10^{22}$ cm$^{-2}$) plus a Gaussian component at 6.4 keV to account for the Fe line. The width of the line is $0.6^{+0.4}_{-0.3}$ keV and therefore remains unconstrained. Comparison of the two observations reveals weak evidence for spectral variability. The power-law normalization has decreased by about a factor of two between the 1996 and 1997 observations. This may be followed by a similar change in the Fe line normalization. This is evident in Fig. 6 where we present the 68, 90 and 99 per cent confidence contours for the Fe line against the power-law normalization. The contours were extracted using the above best fit model. The EW are $280^{+140}_{-130}$ and $233^{+190}_{-160}$ eV for the 1996 and 1997 observations respectively. However we note that when we fix the width of the line at 0.1 keV (this increases $\chi^2$ by 2.5) we do not detect any significant variability in the normalization of the line.

5.3 ESO 103-G35 (1996)

A poor fit ($\chi^2 = 240$ for 173 dof) is obtained with a single power-law model, emphasizing the importance of an Fe emission line. This is again evident in Fig. 7 where we plot the absorbed power-law model and residuals. Indeed when we include a Gaussian line the $\chi^2$ is reduced by 66. The Fe line has an energy of $6.37^{+0.09}_{-0.05}$ keV consistent with neutral Fe and therefore hereafter we fix it at 6.4 keV. Its width is $\sigma = 0.3^{+0.4}_{-0.1}$ keV and therefore the line remains essentially unconstrained. The photon index, $\Gamma = 1.87^{+0.06}_{-0.09}$, is consistent with the typical value of 1.9 for Seyfert galaxies (Nandra & Pounds 1994). The best-fit spectral parameters are presented in table 5. We further investigate the existence of excess Fe absorption near 7.5 keV following the claims of Warwick et al. (1993). Although there is some hint for an Fe edge in Fig. 7, we find no significant improvement when we include an edge component ($\Delta \chi^2 = 1.5$ for two additional parameters). The edge is found at $7.35^{+0.35}_{-0.25}$ keV with optical depth $0.1^{+0.08}_{-0.10}$. Finally, based on the ASCA results (Turner et al 1997) we tried to include two emission lines at 6.68 and 6.96 keV (ionized Fe) but the reduction in $\chi^2$ was less than 1. A reflection component is not statistically significant as the reduction of $\chi^2$ is very low ($\Delta \chi^2 = 1.1$ for one additional parameter). Note that the power law spectral index in the case of a reflection component is $\Gamma = 2.0^{+0.2}_{-0.1}$ while $R=1.2^{+0.4}_{-0.6}$. The intrinsic flux of the reflection component corresponds to the 20 per cent of the total flux in the 2-50 keV energy band.

5.4 ESO 103-G35 (1997)

An acceptable fit is obtained when we use the absorbed power-law model with $\chi^2=70$ for 71 dof, (see Fig. 7). An FeK emission line is highly significant yielding $\Delta \chi^2=14$. The Fe line energy is $6.5^{+0.5}_{-0.15}$ keV and therefore again we fix it at 6.4 keV. The line is unresolved: its width range is 0-4 keV. The photon index, $\Gamma = 1.81^{+0.60}_{-0.30}$ is consistent with the previous 1996 observation. The results are presented in table 5. A reflection component cannot be ruled out as the reflection parameter is $R=1.6^{+1.2}_{-1.0}$. However, the reduction in $\chi^2$ is very low ($\Delta \chi^2 = 1.7$ for one additional parameter). When the reflection component is included the power law spectral index steepens to $\Gamma = 1.97^{+0.09}_{-0.30}$. The ratio between the unabsorbed reflected flux and the total flux in the 2-50 keV energy band is 0.3. Next, we investigate the existence of an Fe edge at 7.35 keV. However, the reduction in $\chi^2$ was less than 1 for one additional parameter. The optical depth of the edge is $0.11^{+0.10}_{-0.10}$. In general, we detect no spectral variability between the 1996 and 1997 observations in the sense that both the absorption column and the photon index remain constant.

We perform a joint fit in the 1996 and 1997 observations in order to detect any possible line flux variations. We used a model consisting of an absorbed power-law plus a Gaussian line at 6.4 keV. The best-fit photon index is $1.83^{+0.09}_{-0.09}$ and the column density is $18.5^{+2.2}_{-0.8} \times 10^{22}$ cm$^{-2}$. The line is unconstrained, i.e. the range of the line width is 0.15-0.36 keV. The EW are $220^{+120}_{-50}$ and $330^{+170}_{-140}$ eV for the 1996 and 1997 observations respectively. The continuum flux is reduced approximately by a factor of two. However, there is no evidence that this variation is followed by the line flux, in contrast to the case of NGC7172 (see Fig. 8 where we plot the 68, 90 and 99 per cent joint contours for the power-law and Fe line normalization).
Table 4. Best fit parameters for the two observations of NGC 7172

<table>
<thead>
<tr>
<th>Date</th>
<th>$N_H$ (10^{22} cm^{-2})</th>
<th>$\Gamma$</th>
<th>$A_{pl}$ (10^{-3} cts s^{-1} keV^{-1})</th>
<th>Energy (keV)</th>
<th>$\sigma$ (keV)</th>
<th>$A_{ga}$ (10^{-5} cts s^{-1})</th>
<th>EW (eV)</th>
<th>$\chi^2$/dof</th>
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<tr>
<td>15-10-96</td>
<td>9.0^{+0.9}_{-0.7}</td>
<td>1.6^{+0.12}_{-0.09}</td>
<td>4.1^{+1.2}_{-0.5}</td>
<td>6.4</td>
<td>0.8^{+0.3}_{-0.4}</td>
<td>5.6^{+2.5}_{-0.4}</td>
<td>280^{+210}_{-150}</td>
<td>135/144</td>
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<tr>
<td>6-11-97</td>
<td>8.3^{+0.70}_{-0.65}</td>
<td>1.5^{+0.08}_{-0.16}</td>
<td>1.7^{+0.5}_{-0.5}</td>
<td>6.4</td>
<td>0.32^{+0.68}_{-0.24}</td>
<td>1.5^{+1.1}_{-1.0}</td>
<td>175^{+105}_{-140}</td>
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Figure 5. Data, folded model (simple absorbed power-law model) and residuals for both 1996 (left panel) and 1997 (right panel) observations of NGC 7172.

Table 5. Best fit parameters for the two observations of ESO 103-G35

<table>
<thead>
<tr>
<th>Date</th>
<th>$N_H$ (10^{22} cm^{-2})</th>
<th>$\Gamma$</th>
<th>$A_{pl}$ (10^{-3} cts s^{-1} keV^{-1})</th>
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<th>$\sigma$ (keV)</th>
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<td>18.6^{+0.9}_{-1.0}</td>
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<td>6.4</td>
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<td>265^{+150}_{-100}</td>
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<td>19.1^{+1.4}_{-3.4}</td>
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<td>10.5^{+5.4}_{-5.4}</td>
<td>290^{+90}_{-90}</td>
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Figure 7. Data, folded model (simple absorbed power-law model) and residuals for both 1996 (left panel) and 1997 (right panel) observations of ESO 103-G35.
7172 is absorbed by a column density of $N_H = 6.1 \times 10^{22}$ cm$^{-2}$.

**Figure 6.** Fe line flux vs power-law normalization contours for the 1996 and 1997 observations of NGC 7172 in the joint fits. Confidence levels are 68, 90 and 99 per cent for two interesting parameters.

### DISCUSSION

#### 6.1 NGC 7172

The spectral analysis of both observations implies that NGC 7172 is absorbed by a column density of $N_H = 9.1^{+0.3}_{-0.6} \times 10^{22}$ cm$^{-2}$, in good agreement with previous EXOSAT (Turner & Pounds 1989), Ginga (Smith & Done 1996) and ASCA (Turner et al 1997) observations. The data require the presence of an Fe line at 6.4 keV. In the 1996 BeppoSAX observation the line is marginally resolved, at less than the 2$\sigma$ confidence level, while in the 1997 observation (where the photon statistics are poorer) the line width is unconstrained. We note that the line has been resolved in previous ASCA observations (Guainazzi et al. 1998). There is some evidence (Fig. 6) for a variation in the normalization of the line. This is in agreement with Guainazzi at al (1998) who presented similar evidence for a variation of the line based on two ASCA observations (1995 and 1996). The line variation in conjunction with the line width has important implications for the geometry of the circumnuclear matter in NGC7172. Indeed, the Fe line must originate close to the nucleus possibly in the outer regions of an accretion disk. This would simultaneously explain the fact that the continuum flux variations are tracked by changes in the line flux, and the large width of the line. Indeed, the line broadening may be due to the large velocities in the disk similar to that witnessed in MCG-6-30-15 by Tanaka et al. (1995). The observed broadening in the case of NGC 7172 implies a velocity of $\sim 70000$ km s$^{-1}$. We tried to investigate further the above hypothesis including a line from a relativistic accretion disk (for an accretion disk viewed at an intermediate inclination angle with solar abundances). The fit was only marginally improved ($\Delta \chi^2 \sim 1$). We note that Georgantopoulos & Papadakis (2000) find no significant variation of the normalization of the line in NGC 7172 using several RXTE observations spanning a period of around a week. This would set a lower limit of about a light week to the size of the line emitting region.

The observed EW cannot be interpreted in terms of transmission processes in the torus alone. Indeed Leahy & Creighton (1993) using Monte Carlo simulations found that a column density of $N_H \sim 9 \times 10^{22}$ cm$^{-2}$ could produce an Fe line EW of only $\sim 60$ eV. This independently suggests that a reflection component may be present. Indeed, in this case the EW of the line should be increased by $\sim 150$ eV due to reflection on the accretion disk (Reynolds, Fabian & Inoue 1995, George & Fabian 1991). Alternatively the observed EW may be explained on the basis of a high Fe abundance. Indeed, excess absorption from Fe is present in the first observation of NGC 7172 at $\sim 7.2$ keV, confirming earlier reports by Warwick et al. (1993); however, note that superior spectral resolution observations with the ASCA SIS (Turner et al 1997) do not corroborate this result. The edge energy is consistent with a neutral or low ionization material surrounding the source (Kallman & McCray 1982). The optical depth of the edge corresponds to an absorption column of $(22.5^{+15.3}_{-14.2}) \times 10^{22}$ cm$^{-2}$. This large column density may suggest an Fe abundance well above the solar value. If this is the case, the observed EW could be explained by transmission processes alone. Finally note that cases where a strong Fe line is detected although there is no strong evidence for a reflection component are not uncommon (eg Gilli et al 2000, Reynolds et al 1995).

The power-law photon index has a rather flat value of $\sim 1.6$ while it remains constant in the two BeppoSAX observations. The value of the photon index is in agreement with previous ASCA observations (Guainazzi et al 1998, Ryde et al 1997) who found a photon index of $1.47 \pm 0.15$. However, it is clearly flatter than that found in EXOSAT (Turner et al 1989) and Ginga (Smith & Done 1996) ($\Gamma \sim 1.8$). Therefore the above may be suggesting long term spectral variability (Ryde et al. 1997). For example, assuming that the X-ray emission comes from Comptonization of UV photons from an accretion disk on a hot electron corona (Rybicki & Lightman 1979), a steepening of the spectral index may be attributed to a change of the temperature or the optical depth of the corona. Of course it is difficult to make a detailed comparison due to differences in the energy bandpass of the various instruments as well as in the spectral analysis: for example the addition of a reflection component would result in the steepening of the spectral index. However, we note that there is no correlation between the flux level and the photon index observed in the case of the NGC7172 observations in the past 20 years. Finally we note that despite the flat photon index found above, our data do not significantly support the existence of any reflection continuum. A recent analysis of RXTE monitoring observations of NGC 7172 (Georgantopoulos & Papadakis 2000) again shows no evidence for reflection component.

**Figure 8.** Fe line flux vs power-law normalization contours for the 1996 and 1997 observations of ESO 103-G35 in the joint fits. Confidence levels are 68, 90 and 99 per cent for two interesting parameters.
6.2 ESO 103-G35

The spectral analysis of the two observations of ESO103-G35 implies that a simple power-law model absorbed by a column density of \( N_H \sim 2 \times 10^{23} \) cm\(^{-2}\) plus a Gaussian line at 6.4 keV provides a good fit to our data. EXOSAT observations of ESO103-G35 (Warwick et al. 1988) reveal a 50 per cent decrease in the column density over a 90 day period. This variation was interpreted in terms of an X-ray absorbing screen composed of broad-line clouds moving around the X-ray source. Alternatively, the \( N_H \) variation could be attributed to photoionization of the neutral column as the flux increases; in this case an ionized Fe edge should be detected. However, in our analysis we detect no variation of the column within the errors. An Fe line at 6.4 keV is strongly needed to fit our data. Unfortunately, the width of the line remains unconstrained. However, ASCA SIS observations with better spectral resolution have probably resolved the line into three components at 6.4, 6.68 and 6.96 keV (Turner et al. 1997). Monte Carlo simulations (Leahy & Creighton 1993) show that a column density of \( N_H \sim 2 \times 10^{23} \) cm\(^{-2}\) could produce an Fe line EW of \( \sim 170 \) eV. However, in the case of ESO 103-G35 where the line originates possibly far away from the central region, the EW varies accordingly to the variations of the continuum. Although a comparison is not straightforward, it is possible that a large fraction of the line emission could originate from transmission processes.

Some residuals around 7.5 keV (see Fig. 7) may indicate the presence of an absorption edge due to ionized Fe. This was first suggested by *Ginga* results (Warwick et al. 1993) and was confirmed later with ASCA observations (Forster et al. 1999). The power-law photon index has a steep value of \( \sim 1.85^{+0.05}_{-0.05} \) which is consistent with the typical value 1.9 for Seyfert galaxies (Nandra & Pounds 1994). Despite our large energy bandpass we do not find strong evidence for a reflection continuum in contrast to previous *Ginga* (Smith & Done 1996) and *RXTE* (Georgantopoulos & Papadakis 2000) observations who found evidence for such a component but in a smaller band (3-20 keV). Higher signal to noise observations are necessary in order to test the presence of such a component.

6.3 SPECTRAL VARIABILITY IN SEYFERT 2 GALAXIES

Previous studies of spectral variability in Seyfert-2 galaxies have shown some interesting results. In particular, Iwasawa et al. (1994) and Griffiths et al. (1998) analyzed non-simultaneous *Ginga*, ASCA, ROSAT and *BBXRT* observations to investigate the spectrum of the Seyfert-2 galaxy Mrk 3 . Their analysis demonstrated that the Fe line does show some variability on time-scales of a few years. Systematic monitoring observation became feasible with the *RXTE* mission. In particular, Georgantopoulos et al. (1999), Georgantopoulos & Papadakis (2000), Smith, Georgantopoulos & Warwick (2000) present monitoring observations of several Seyfert-2 galaxies (Mrk3, ESO 103-G35,IC 5063, NGC 4507, NGC 7172 & Mrk 348) spanning time periods from about seven days to seven months. In most cases, they detect spectral variability in the sense that the column density decreases with increasing flux. However, they find no evidence for Fe line variability. Here instead, we find tentative evidence for line variability in NGC 7172 in a period of one year confirming previous ASCA results (Guainazzi et al 1998). To our knowledge this is one of the very few examples of Fe line variability in Seyfert-2 galaxies. Our finding requires at least one of the line emitting regions has dimension not much more than about a light year. It would seem more likely that this scale size corresponds to an accretion disk or inner cloud structure rather than the inner extent of the putative molecular torus. Indeed, the molecular torus is probably a much greater structure. At least in the case of NGC 1068 observations of molecular hydrogen (Tacconi et al 1994) showed that the obscuring torus is located between 30 and 300 pc.

7 CONCLUSIONS

We have analyzed four *BeppoSAX* observations of NGC7172 and ESO103-G35 (two observations for each galaxy separated by about a year). The goal was to search for spectral variability in a large energy band and therefore to attempt to constrain the geometry of the circumnuclear matter in these two galaxies. The spectra of both galaxies are fitted by an absorbed power-law plus a neutral Fe line in agreement with previous *Ginga* and ASCA observations. A neutral Fe edge is probably detected in the 1996 observation of NGC7172. Our data do not require a reflection component at a statistically significant level. We detected flux variability in both objects by about a factor of about two. We find no significant evidence for spectral variability in the sense that the power-law spectral index and the column density have remained constant in both galaxies implying a homogeneous obscuring screen and constant physical conditions in the accretion disk corona despite the continuum flux variations (but see Warwick et al. 1988, Georgantopoulos & Papadakis 2000). However, in the case of NGC7172 we detect a variation of the Fe line flux by a factor of two following the power-law flux, confirming previous ASCA results. This provides strong support to a scenario where the Fe line at least in the case of NGC7172 originates in a region close to the nucleus. These findings support the idea that one region responsible for the line emission should lie within one light year away from the nucleus. This region may be associated with the outer part of an accretion disk.

The above results clearly emphasize the strength of monitoring observations in probing the geometry of the central engine in AGN. High resolution spectroscopic observations with gratings with both Chandra and XMM are expected to revolutionize our knowledge of the physical conditions of the circumnuclear matter in AGN. These combined with future monitoring observations with large effective area instruments such as EPIC on-board XMM are expected to provide for the first time a detailed mapping of the central regions in AGN.

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