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X-RAY PROPERTIES OF A SAMPLE OF POLAR-SCATTERED SEYFERT GALAXIES

E. Jiménez-Bailón,[1,2] M. Guainazzi,[3] G. Matt,[4] S. Bianchi,[4] Y. Krongold,[1] E. Piconcelli,[5] M. Santos Lleó,[3] and N. Schartel[3]

RESUMEN

Presentamos los resultados de un análisis sistemático de una muestra de nueve galaxias Seyfert 1 observadas con el telescopio XMM-Newton. Observaciones en luz polarizada indican que los objetos de la muestra son similares a galaxias Seyfert de tipo 2, lo cual sugiere que están siendo observados con un ángulo de orientación comparable al ángulo de apertura del toro. Nuestros resultados son consistentes con este escenario. Utilizando la orientación especial de la muestra, investigamos en detalle las propiedades físicas y la distribución espacial del gas circundante a estas fuentes.

ABSTRACT

We present the results on an XMM-Newton systematic analysis of a sample of nine Seyfert 1 galaxies. When observed in polarised light, the spectra of the selected sources are similar to those of Seyfert 2 galaxies. This peculiarity strongly suggests that these AGN are viewed with an inclination comparable with the torus opening angle. Our results are consistent with this scenario and, taking advantage of this favourable geometrical condition, we are able to investigate in detail the physical properties and the distribution of the circumnuclear gas in these sources.

Key Words: accretion, accretion disks — galaxies: active — galaxies: nuclei — X-rays: galaxies

1. INTRODUCTION

The detection of broad polarised lines in Seyfert 2 nuclei supports that this type of AGN are intrinsically the same objects than Seyfert 1 galaxies and that the differences in their observational properties can be understood as orientation effects. Within the Unified Models, the central continuum source of AGN and the broad line region (BLR) are surrounded by an optically and geometrically thick structure of dust and molecular gas, likely following a toroidal geometry. The orientation of Seyfert 2 galaxies with respect to our line of sight is such that emission from the central engine is shielded by the molecular torus and therefore its continuum and broad emission lines are only observed in polarised light as a result of scattering outside the torus.

Firstly confirmed in NGC 1068 (Miller et al. 1991), the central emission in Seyfert 2 is scattered by free electrons in a conical structure placed along the axis of the torus, the so-called ionization cones, generating a polar scattering spectrum with a position angle perpendicular to the scattering cone. In contrast, the polarised spectrum of Seyfert 1 galaxies does not conform with simple polar scattering, exhibiting a wide diversity of polarisation properties. These results state that the geometry of a single polar scattering region is incomplete to explain simultaneously all types of Seyfert polarised spectra. Based on a study of 36 Seyfert 1 galaxies, Smith et al. (2002) proposed a model in which the broad-line emission is originated in a rotating disk and scattered in two different regions: the classical *ionization cones* responsible of the polar scattering and an equatorial scattering region located within the torus and co-planar with the rotating disc. Therefore, the two extreme cases are the face-on Seyfert 1 which exhibit a null or weak polarisation as a result of cancellation of polar and equatorial scattering, and the Seyfert 2, dominated by polar scattering as the equatorial scattering region is completely obscured. In Seyfert 1 with an intermediate line of sight angle, both scattering regions are visible but in general equatorial polarisation dominates.

Interestingly, a peculiar type of Seyfert 1 galaxies exhibits polarised spectra similar to those of Seyfert 2, i.e. dominated by polar scattering. According to the model proposed by Smith et

[1]Instituto de Astronomía, Universidad Nacional Autónoma de México, Apdo. Postal 70-264, 04510 México, D. F., México (elena@astroscu.unam.mx).

[2]LAEFF-INTA, Apdo 50727, 28080-Madrid, Spain.

[3]XMM-Newton Science Operation Centre, ESAC, ESA, Aptdo. 50727, 28080-Madrid, Spain.

[4]Universita Roma Tre, Via della Vasca Navale 65, I-00146, Roma, Italy.

[5]Osservatorio Astronomico di Roma, Via Frascati 33, I-00040, Monteporzio Catone, Italy.

al. (2002), these *polar-scattered* Seyfert 1 galaxies should be observed at an inclination comparable with the torus opening angle, and suffer therefore only a moderate extinction through the torus rim. Smith et al. (2004) estimate that between 10% and 30% of Seyfert 1 galaxies are dominated by polar scattering. Their spectropolarimetric observations identified twelve of this type of objects. These twelve objects constitute the complete sample of known polar-scattered Seyfert 1 galaxies.

X-ray studies of these distinctive *polar-scattered* Seyfert 1 galaxies are a powerful tool to prove the basis of the model proposed by Smith et al. (2004) and therefore to further test the scheme of Unified Models for AGN. We have analysed the eight objects included in the Smith et al. (2004) sample with available X-ray data. We present for the first time, X-ray analysis performed with *XMM-Newton* of four them (Fairall 51, Mrk 704, ESO 323-G077, and IRAS 15091-2107). The results of the four remaining ones (Mrk 231, NGC 3227, Mrk 766, and NGC 4593) have been obtained from the literature. In the following section, we present the results on the analysis of the four objects observed by the first time by *XMM-Newton*. In § 3, we combine our results with the four already published *polar-scattered* Seyfert 1 galaxies and address the conclusions of this work.

2. DATA ANALYSIS

We analysed for the first time the *XMM-Newton* observation of four of the objects included in the Smith et al. (2004) sample. All data were processed with the standard *Science Analysis System*, SASv7.0.0 and using the most updated calibration files available in January 2007. The *EPIC* event lists were filtered to ignore periods of high background flaring following the method proposed by Piconcelli et al. (2004). According to the *SAS* task *epaplot*, no sign of pile-up was detected for any of the objects. The spectra were extracted from circular regions centered on the maximum emission of the source. The background regions were extracted from circular regions located closed to the source and free of any contamination source. In all cases, both *MOS* spectra were combined to obtain a higher signal-to-noise. After background subtraction, both spectra, i.e. the *pn* and the *MOS1-2* combined, were grouped such that each bin contains at last 30 counts per bin. We are therefore able to use the modified χ^2 technique in the spectral analysis. When the observations presented enough signal-to-noise, *RGS* data were analysed.

We have performed the spectral analysis of the data using *Xspec* v.12.3.0. All parameters are given

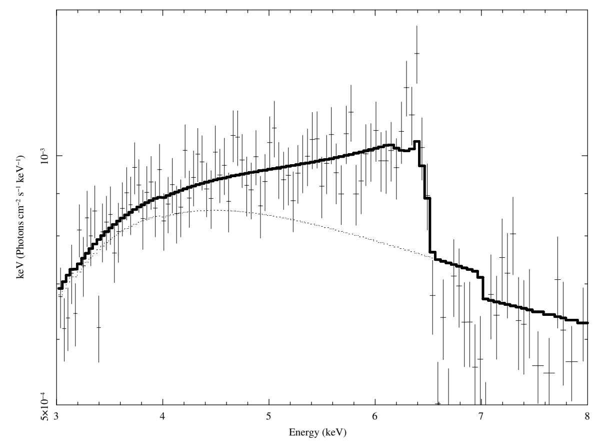

Fig. 1. ESO 323-G077 *pn* hard band observed spectrum and best fitting model. The data show the presence of a broad iron line compatible with being originated in a rotating accretion disc.

in the object rest frame. We assumed a flat ΛCDM cosmology with $(\Omega_M, \Omega_\Lambda)$=(0.3,0.7) and a value for the Hubble constant of 70 kms^{-1} (Bennett et al. 2003). The errors quoted in this paper refer to the 90% confidence level (i.e. $\Delta\chi^2$=2.71). For the spectral fitting of the *XMM-Newton* data, we have considered the absorption due to the Galaxy for each object, fixing the equivalent Hydrogen column density to the values given by Dickey & Lockman (1990).

2.1. *The hard band spectrum*

We fitted the *EPIC* X-ray spectra above 2 keV (but also excluding the Fe line energy region) of the four objects with a power law model. In all cases, the emission model provides a satisfactory fit to the data. The values of the index of the power law are given in Table 1. All values are in good agreement with the typical results of Type I objects, i.e. $\Gamma = 1.89 \pm 0.11$ for a sample of 40 Palomar-Green QSO (Piconcelli et al. 2005). In three of the objects, we find hints of the presence of broad emission line. In the case of ESO 323-G077, we have proved the relativistic broadening of the iron emission line, probably originated in the accretion disc of a Kerr Black Hole (Jiménez-Bailón et al. in prep.). Figure 1 shows the ESO 323-G077 hard band spectrum and the fitted model evidencing the presence of the broad Fe line. Therefore, in the hard band, the objects studied present properties typical of Seyfert 1 galaxies.

2.2. *The soft band spectrum*

We also investigated the emission of the *polar-scattered* Seyfert 1 galaxies in the soft band. In particular, we have found that all four galaxies present

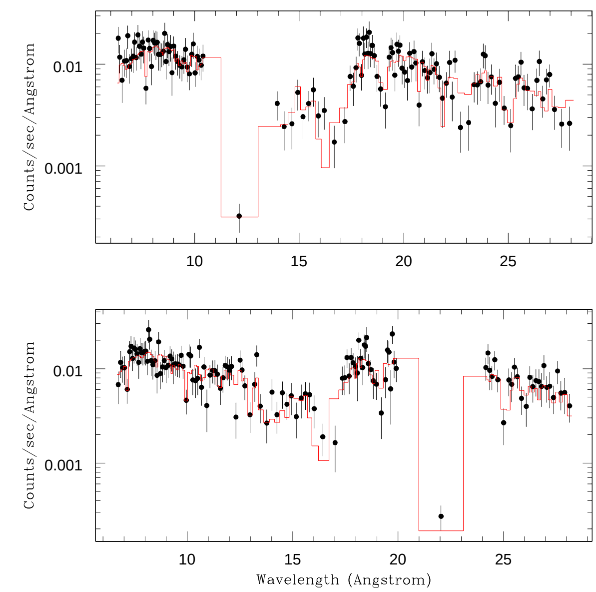

Fig. 2. Fairall 51 *RGS* observed spectrum and best fitting model.

evidence of cold and/or warm absorption. Observed values of the equivalent Hydrogen column densities are given in Table 1. The measured N^c_H are in all cases of the order of 10^{22} cm^{-2}. This result diverges from common properties of the optically bright Type I objects, for which the incidence of cold absorption not explained by the host galaxy, i.e. $> 10^{21}$ cm^{-2}, is $\leq$5% (Piconcelli et al. 2005). Bearing in mind the Smith et al. (2004) model, we tested the possible presence of warm absorption in the objects. The imprints of warm absorbers in the soft X-ray band are observed in about half of the Type I AGN (Piconcelli et al. 2005; Blustin et al. 2007). Using the *Phase* model (Krongold et al. 2003), we found evidence of warm absorption in three of the four Seyfert 1 analysed. The most outstanding case is found for Fairall 51 (see Figure 2) in which three different warm absorbers could be detected and parametrised. The properties of all detected ionised absorbers are given in Table 1.

3. RESULTS

The results on the analysis performed on the four observed galaxies can be summarised as follows:

- The properties of the galaxies in the hard X-ray band indicate that we are directly observing the central AGN. The index of the power law and measured luminosities are typical of Type I AGN. This result is also supported by the presence of relativistically broadened iron lines in three out of the four observed objects.

TABLE 1

SUMMARY OF THE PROPERTIES OF THE *XMM-Newton* DATA ANALYSIS.

OBJECT	SOFT			HARD	
	Cold[1]	Warm[1]		PLaw	BFe
	N^c_H	Log U	N^w_H	Γ	
Fairall 51	1.6±0.2	−0.8	0.1	2.01±0.12	✓
		0.12	7.9		
		1.4	5.0		
Mrk 704	2.5±1.5	−0.3	0.4	1.66±0.16	✓
		1.8	2.5		
ESO 323-G77	6.0±0.3	–	–	1.89±0.05	✓
I 15091-2107	0.7±0.2	−0.03	0.2	1.83±0.06	×

Note: (1) Both cold (N^c_H) and warm (N^c_H) Hydrogen equivalent column density are given in units of 10^{22} cm^{-2}.

- Conversely, in the soft energy band, the X-ray properties of the studied objects resemble to those of absorbed AGN. Cold absorption incompatible with being originated in the host galaxy was reported for all the objects. Evidence of warm absorption was measured in also three of the Seyfert 1 galaxies in the sample.

Similar general properties are observed for the *polar-scattered* Seyfert 1 galaxies with already published results. Details on the X-ray data analysis of the objects can be found in Jiménez-bailón et al. (in prep.) for Mrk 231, NGC 3227, Mrk 766, and NGC 4593.

In summary, the analysis of new *XMM-Newton* data of four *polar-scattered* Seyfert 1 galaxies combined with published results of other four objects support the Smith et al. (2004) interpretation for these peculiar type of Seyfert galaxies.

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