

INTEGRAL OBSERVATIONS OF SIX AGN IN THE GALACTIC PLANE

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ABSTRACT

We present results on one year of *INTEGRAL* observations of six AGN detected during the regular scans of the Galactic Plane. The sample is composed by five Seyfert 2 objects (MCG -05-23-16, NGC 4945, the Circinus galaxy, NGC 6300, ESO 103-G35) and the radio galaxy Centaurus A. The continuum emission of these sources is well represented by a highly absorbed ($N_{\text{H}} > 10^{22} \text{ cm}^{-2}$) power law, with average spectral index $\Gamma = 1.9 \pm 0.3$. The Circinus Galaxy presents a high energy exponential cut-off at $E_c \sim 50 \text{ keV}$ whereas a lower limit of 130 keV has been found for NGC 4945 and no cut-off has been detected for NGC 6300. A factor 2 of variability in the flux of Centaurus A is accompanied by a spectral change, which can be modelled equally well by an increase of the absorption (N_{H} from 17 to $33 \times 10^{22} \text{ cm}^{-2}$) or by the presence of a cut-off at $\geq 120 \text{ keV}$ in the low state spectrum. A comparison with recently reprocessed *BeppoSAX*/PDS data shows a general agreement with *INTEGRAL* results.

Key words: Galaxies: active – Galaxies: Seyfert – Gamma rays: observations – X-rays: galaxies.

1. INTRODUCTION

X-ray and γ -ray emission in AGN comes from the regions close to the nucleus and its study enables us to constrain the geometry and the state of the matter in the heart of an AGN. The emission in the soft X-ray domain is rather well known (up to $\leq 10 \text{ keV}$), whereas many questions are still open for the hard X-rays/soft γ -ray range.

For many objects, a high-energy cut-off is required to reproduce the data between 60 and 300 keV, but the shape and the energy of this feature is not yet well known.

The sources in this sample were selected from among the 10 previously known AGN detected during the first year of Core Program observations performed by *INTEGRAL* (Bassani et al. 2004). We focussed our attention on the 6 AGN (MCG -05-23-16, NGC 4945, Centaurus A, Circinus galaxy, NGC 6300, ESO 103-G35) which were previously studied by different hard X-ray missions, in particular by *BeppoSAX*, allowing us to compare the *INTEGRAL* results with previous ones.

2. OBSERVATIONS AND DATA ANALYSIS

Each source of this sample was first detected during the *INTEGRAL* Core Program observations performed between 2003 February 28 and October 10, by the IBIS/ISGRI instrument. In order to perform a detailed analysis, we used all the data that were public at the time of this study, specifically all the data in revolutions 1–136 (October 2002–November 2003) and 142–149 (December 2003–January 2004) and we analysed them using the version 4.2 of the ISDC's Offline Science Analysis (OSA) package. Extraction of ISGRI spectra has been performed for all sources but MCG -05-23-16 because of a low detection significance (2.4σ , $F < 1.9 \text{ erg cm}^{-2} \text{ s}^{-1}$ in the 20-100 keV range). For NGC 4945, Centaurus A and Circinus SPI spectra have been extracted and Centaurus A and Circinus have been detected also by JEM-X. Within 10 months, the hard X-ray flux of Centaurus A has changed by a factor of ~ 2 in *INTEGRAL* data. We split our data set according to the flux level, choosing three main periods: high state (March 7–9, 2003), intermediate state (July 18 – August 22, 2003) and low state

(January 2–4, 2004), and we analysed them separately.

3. INTEGRAL RESULTS

Due to the lack of *INTEGRAL* data below 20 keV, with the exception of Centaurus A, during our analysis N_{H} was fixed to the values found in the literature.

A single power law corrected by photoelectric absorption is the best fit model for the *INTEGRAL* spectra of NGC 6300, ESO 103–G35 and NGC 4945, with photon indices $\Gamma = 2.2 \pm 0.5$, 1.4 ± 0.4 and 1.9 ± 0.1 , respectively. The introduction of a high energy cut-off component does not improve the quality of the fit for NGC 4945 and a lower limit of $E_c \sim 130$ keV can be given at 1σ level, in agreement with previous studies which have found E_c in the 100–300 keV range (Madejski et al. 2000).

The *INTEGRAL* spectrum of Circinus is best fitted with a high absorbed power law with $\Gamma = 1.8^{+0.4}_{-0.5}$ and a high energy exponential cut-off at 50^{+51}_{-18} keV. A high energy cut-off at $E_c \sim 35$ – 55 keV, required in both *INTEGRAL* and *BeppoSAX* data (Matt et al. 1999, Soldi et al. 2005), results in a temperature of $T \sim 4$ – 6×10^8 K for the distribution of thermal electrons in the Comptonizing medium. The presence of a cut-off supports the scenario in which the X-ray emission of Seyfert galaxies originates where soft photons emitted by a cold optically thick disk are Comptonized in a hot region (Haardt & Maraschi 1993). A Compton reflection component observed in the broad band *BeppoSAX* data (Matt et al. 1999) has not been detected by *INTEGRAL* because of the lack of data below 20 keV.

Centaurus A is known to be a highly variable object on both long and short time scales. The flux variation by a factor of 2 in *INTEGRAL* data is associated with spectral variation, which can be modelled equally well by an increase by a factor of 2 of the absorption (N_{H} from 17 to $33 \times 10^{22} \text{ cm}^{-2}$) with flux decrease or by the presence of a high energy cut-off at $E_c \geq 120$ keV in the low state spectrum. Variations of the absorption are a common characteristic in Seyfert 2 galaxies, with changes of 20–80% on a one year time scales. Hints for a break or a cut-off in the hard X-ray and soft γ -ray spectra have been found by OSSE, *BeppoSAX*, and *RXTE* data (Steinle et al. 1998, Grandi et al. 2003, Benlloch et al. 2001), but these studies place this feature in the 300–700 keV range. *INTEGRAL* observations confirm the lack of a Compton reflection (Rothschild et al. 1999, Grandi et al. 2003), as adding this component does not improve the fits and results in a reflection fraction < 0.1 . Only a 3σ upper limit of $f_{\text{K}\alpha} = 3.0$ and $5.5 \times 10^{-3} \text{ ph cm}^{-2} \text{ s}^{-1}$ (high and low state) can be derived for the fluorescence iron line.

4. CONCLUSIONS

The spectral characteristics of our *INTEGRAL* sample can be generally summarized as follows: a hard X-ray continuum emission described by a power law with a

wide range of photon indices ($\Gamma \sim 1.4 - 2.3$) and, in the case of Circinus and Centaurus A the presence of a high energy cut-off. The average photon index $\Gamma = 1.9 \pm 0.3$ obtained from *INTEGRAL* spectra is consistent with the values found for other samples of Seyfert 2 galaxies in *BeppoSAX* (Malizia et al. 2003), OSSE (Zdziarski et al. 2000) and *Ginga* (Smith & Done 1996) data.

Studies of single objects confirm that the cut-off in the 100–300 keV range is not a universal characteristic of all Seyfert 2, and the results for our sample support these findings. *INTEGRAL* confirms the presence of a cut-off at ~ 50 keV for the Circinus galaxy, a lower limit of 130 keV for NGC 4945 and the lack of this feature for NGC 6300, in agreement with what has been found in PDS spectra. A poorly constrained cut-off at ≥ 120 keV has been detected for Centaurus A during the *INTEGRAL* low state, but this feature has not been seen in the other *INTEGRAL* observations reported in this work and in the PDS spectrum. Cut-offs below 100 keV have been found for MCG –05–23–16 and ESO 103–G35 by PDS, but could not be studied by *INTEGRAL* because of the short exposure time of those observations.

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