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INTEGRAL view of the extragalactic sky

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Abstract. In its 17 years of life, INTEGRAL has provided an important contribution to extragalactic science. Of the around 500 AGN detected by IBIS in the 20 -100 keV energy range, unambiguously identified, we are now able to study their spectral characteristics over a broad band energy range using INTEGRAL/ISGRI spectra in conjunction with soft 2-10 keV data available from the archives. In this contribution, latest results obtained by exploring these data in terms of AGN spectral properties and their connection with the host galaxies are presented.

Key words. galaxies: active – gamma rays: galaxies – X-rays: galaxies

1. Introduction

In the last decade INTEGRAL/IBIS (Ubertini et al. 2003) together with Swift/BAT (Barthelmy et al. 2005), having good sensitivity and a wide-field sky coverage, were able to make progress in the high energy domain (20–200 keV). In particular INTEGRAL has provided a great improvement of our knowledge of the high-energy extragalactic sky by detecting almost 500 (mostly local) AGN at energies above 15 keV (Malizia et al. 2012, 2016; Mereminskyi et al. 2016; Krivonos et al. 2017). INTEGRAL AGN have been unambiguously associated with their X-ray counterparts which restricted their positional error box and therefore allowed them to be optically identified. For this reason the INTEGRAL AGN sample is fully characterised in terms of optical identification and spectroscopy and fully studied in terms of X-ray spectral properties (see Malizia et al. 2016 and references therein). Making use of this hard X-ray selected sample we carried out several studies of the AGN spectral characteristics; in particular we recently concentrate on two of the most interesting and still debated topics on the AGN science: the high energy cut-off and the nature of absorption.

2. The high energy cut-off

Measuring the slope of the continuum emission and the high-energy cut-off of AGNs is important because the more accurate the measurements of these parameters are, the better we can determine the geometry and the physical properties of the inner region of AGNs. Several studies have been carried out to specify the distribution of photon indices in the soft 2-10 keV (Bianchi et al. 2009) and hard 20-100 keV X-ray bands (Molina et al. 2013) while measurements of high energy cut-offs have been limited by the scarcity of observations above 10 keV. Only recently with the advent of the NuSTAR satellite (Tortosa et a.

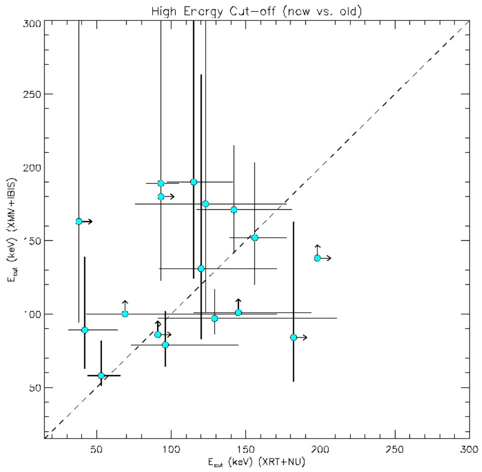

Fig. 1. Values of the high energy cut-off from Molina et al. (2019) plotted against the results from Malizia et al. (2014); the 1:1 line is shown for reference.

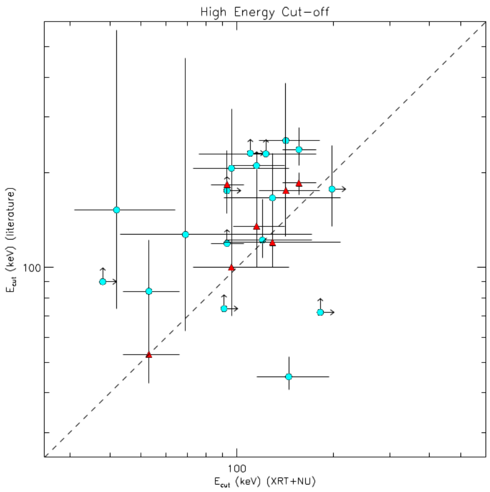

Fig. 2. Values of the high energy cut-off from Molina et al. (2019) plotted against the results from Ricci et al. (2017) (cyan circles) and from several studies employing solely NuSTAR data (red triangles); the 1:1 line is shown for reference

2018) more values have become available. In Malizia et al. (2014), the broadband spectral analysis of 41 type 1 AGNs belonging to the INTEGRAL complete sample have been presented by fitting together non contemporaneous XMM, Swift/BAT, and INTEGRAL/IBIS data in the 0.3 -100 keV energy band. For the first time we provided the high-energy cut-off distribution for a large sample of type 1 AGNs: for 26 objects out of 41 analysed we constrained the cut-off energy and found the distribution of E_c peaked at a mean value of 128 keV (σ=46 keV). In Molina et al. (2019) we have recently confirmed this result by performing 0.5 - 78 keV spectral analysis of 18 of the 41 broad line AGN belonging to the INTEGRAL complete sample and analysed in Malizia et al. (2014), those for which simultaneous Swift-XRT and NuSTAR were available from the archives. By employing a simple phenomenological model to fit the data i.e. the same used in Malizia et al. (2014), we have been able to measure with a good constraint the high energy cut-off in 13 sources, while we placed lower limits on 5 objects. We found a mean high energy cut-off of 111 keV (σ = 45 keV) for the whole sample, in good agreement with that previously found using non simultaneous observations (Malizia et al. 2014, see figure 1) and with that recently published using NuSTAR data (figure 2, red points). A lesser agreement is found when we compare our cut-off measurements with the ones obtained by Ricci et al. (2017) using Swift-BAT high energy data, finding that their values are systematically higher than ours (figure 2). With this work we can broadly confirm that simultaneity of the observations in the soft and hard X-ray band is not essential once flux and spectral variability are properly accounted for.

3. Contribution of the host galaxy to the X-ray absorption

It is now largely accepted that to account for the total amount of X-ray absorption hiding the central nucleus of an AGN, it is often not sufficient to consider only the torus assumed in the framework of the AGN unified theory. As already pointed out by Bianchi et al. (2012), there are three different components on very different scales that need to be considered: the Broad Line Region (BLR) on the 0.01 pc scale, the torus on parsec scale and absorption located in the host galaxy on scales of hundreds

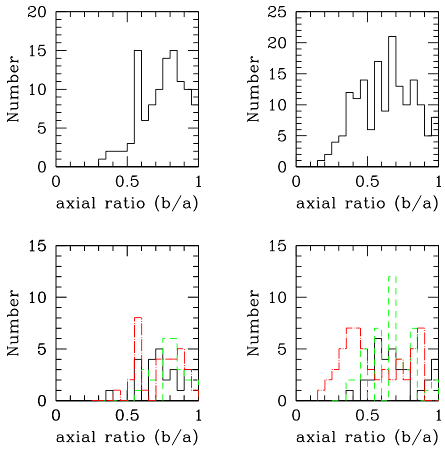

Fig. 3. Distribution of host galaxy axial ratios of INTEGRAL AGN, differentiated into broad lines or type 1 AGN (upper and lower left panels) and narrow lines or type 2 (upper and lower right panels), in the lower panels the morphological type of our sample sources have also been considered. Histograms in dotted-dashed red lines refer to AGN hosted late type (Spirals) galaxies, green dashed lines AGN hosted in early (Elliptical and S0) galaxies and black solid lines refer to host galaxies for which no morphological type has been found in the literature.

of parsec. So far the issue of the absorption on large scale in AGN has been largely investigated but for the first time this has been deeply studied making use of an high energy selected sample, the INTEGRAL AGN sample (Malizia et al. in prep). By collecting all the available morphological and axial ratio information on the INTEGRAL AGN host galaxies, we have investigated the contribution of the X-ray absorption present in the galaxy, in particular by evaluating the axial ratio of the host galaxy and the presence of bars.

3.1. Host galaxy inclination

It is a well known fact that selected type 1 Seyfert galaxies tend to avoid host galaxies with axial ratio (defined as semi-major over semi-minor axis) $b/a < 0.5$, i.e. type 1 AGN were rarely found in edge-on host galaxies. Studying the distribution of host galaxy axial ratios in a soft X-ray (2-10 keV) selected sample of AGN, Simcoe et al. (1997) clearly showed that even if at these energies some of the edge-on objects missed in UV and visible surveys seems to be recovered, still a bias of about 30% toward type 1 Seyfert galaxies in face-on spirals was found. Simcoe et al (1997) clearly demanded for a hard X-ray sample for a definitive test of this bias. However, even using the INTEGRAL high energy selected sample of AGN the bias towards AGN, particularly of type1, in edge-on systems, seems to reman as clearly shown in figure 3. We have deeply investigated this issue by inspecting the amount of column density in type 1 and type 2 AGN and further highlighting the optical Seyfert subclasses (type 1.5 for the unabsorbed and type 1.8 and 1.9 for absorbed AGN) in order to check whether there is a trend of the optical class with the inclination of the galaxy. In other words we aimed at checking for the presence of absorption able to hide the BLR, or part of it, in the different galaxy axial ratios. Possible bias in redshift has also been excluded. Our conclusion is that there must be some gas located in the host galaxy on scales

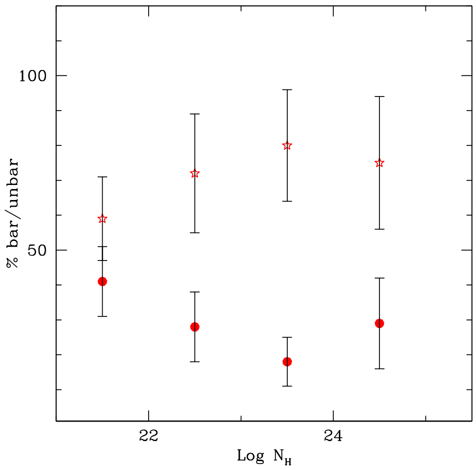

Fig. 4. Trend of the absorption with bar/unbarred galaxies; stars are percentages of barred galaxies in each bin of absorption and circle are percentages of unbarred galaxies in the same bins.

of hundreds of parsec and not co-spacial with the putative absorbing torus of the AGN that can contribute to the total amount of column density measured in the X-ray band. This gas can be thick enough to hide the BLR and cause a misclassification of a type 1 AGN (Malizia et al. in prep.).

3.2. Presence of bar

If obscuration on large scales is present as suggested by various observations and is due to gas, this might be located in the bars and then one would expect to see a correlation between the degree of obscuration in AGN and the strength of bar. Indeed Maiolino et al. (1999) presented evidence for a strong correlation between the gaseous absorbing column density towards type 2 Seyfert nuclei and the presence of bars in their host galaxies: these authors showed that strongly barred objects have on average column densities two order of magnitudes higher than non barred sources. We have verified this finding inside the INTEGRAL AGN sample and indeed we found that the percentage of barred (weak and strong) galaxies increases with the column density while the opposite trend is observed for unbarred galaxies (Malizia et al. in prep). As clearly shown in figure 4, despite large errors, the two percentages are well separated especially in the two middle bins of column density.

4. Conclusions

In this contribution we have shown that the INTEGRAL hard X-ray selected sample of AGN is a powerful tool for extragalactic science. In particular it is suitable to study the properties of the AGN hot corona; the cut-off measurements obtained using INTEGRAL data have been recently confirmed by using contemporaneous Swift-XRT/NuSTAR data (Molina et al. 2019). We are also carrying out a study on the host galaxies of INTEGRAL AGN and find that thanks to the high-energy selection a more convincing proof of an extra absorption material present in the host galaxy is provided (Malizia et al. in prep).

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