Reflection in Seyfert galaxies and the unified model

Roland WALTER[*]

*INTEGRAL Science Data Centre, Université de Genève, Chemin d'Ecogia 16, CH-1290 Versoix,
Switzerland*

E-mail: Roland.Walter@unige.ch

Claudio RICCI

*INTEGRAL Science Data Centre, Université de Genève, Chemin d'Ecogia 16, CH-1290 Versoix,
Switzerland*

We present a study of the average hard X-ray spectra of Seyfert galaxies accumulating 100 Ms
of INTEGRAL observing time. Our aim is to test the unified model of Active Galactic Nuclei,
and to constrain differences and similarities between different classes of objects. We analysed
all public INTEGRAL IBIS/ISGRI data available on 165 Seyfert galaxies detected at z < 0.2.
Our final sample consists of 44 Seyfert 1, 29 Seyfert 1.5, 78 Seyfert 2, and 14 Narrow Line
Seyfert 1. For each subsample, we stacked all the images, and derived their average hard X-ray
spectra in the 17-250 keV energy range. All classes of Seyfert galaxies show on average the same
nuclear continuum, as foreseen by the zeroth order unified model. The average spectrum of midly
obscured Seyfert 2s is different, featuring a broad excess of emission at 30 keV that we interpret as
a strong reflection component. This correlation between reflection and absorption suggests that
the Seyfert type is determined by the environment rather than by inclination. Furthermore this
large reflection component might reduce the amount of Compton-thick objects needed to explain
the peak of the cosmic X-ray background. A simple fit to the CXB shows that our findings might
imply that the fraction of Compton-thick sources is not larger than 10%.

[*]Speaker.

1. Introduction

The orientation-based unified model [1] is successful at explaining several features of the Active Galactic Nuclei (AGN) population. This model is however a generalisation, a simplification of a complex reality and suffers from several difficulties: a small fraction of Seyfert 1 galaxies are absorbed (e.g. [2]), some Seyfert 2 galaxies do not show any X-ray absorption (e.g. [3]) and 50-70% of Seyfert 2 galaxies miss polarised broad lines [4, 5, 6].

The analysis of recent high resolution (VLTI, Gemini) infrared observations of nearby AGNs confirmed the presence of a geometrically thick, torus-like dust distribution [7, 8, 9]. However these studies revealed the presence of irregular and clumpy tori. The classification of a Seyfert galaxy as a type 1 or 2 was found to depend more on the intrinsic properties of the tori (in particular the light escape probability) rather than on their mere inclination. Recent X-ray observations provided similar indications that the absorbing torus features properties that are not linked with inclination:

- Eguchi et al (2009, 2011) [10, 11] analysed Suzaku observations of new Swift/BAT AGNs and found that these objects are of a new type, featuring low scattering and strong reflection that cannot be explained by orientation effect but by a different torus geometry.

- Miller et al (2009) and Lobban et al (2011) [12, 13] found that the long term variability of NGC 4051, observed by Suzaku, is best interpreted by a significant change in the covering fraction of a Compton thick partial covering material obscuring the emission from the central engine.

- Risaliti et al (2009) [14] detected a variable partial covering cloud in NGC 1365 crossing the line of sight in 25 ksec. Subsequent Suzaku observations suggested a complex structure of the circum-nuclear medium, consisting of at least two distinct components with rather different physical properties, one of them covering more than 80% of the continuum source with a column density of (3-4) 10^{24} cm^{-2}.

2. *INTEGRAL* stacking analysis

We selected all 205 Seyfert galaxies detected at hard X-rays by INTEGRAL IBIS/ISGRI during its first 8 years of operations. We excluded a number of sources because they were too close to other sources, had an unclear classification or a too large redshift or because they were detected with a too large significance. The final sample used for the analysis consists of 165 AGN, of these 44 are Seyfert 1, 29 Seyfert 1.5, 68 Compton-thin Seyfert 2, 10 Compton thick Seyfert 2, and 14 NLS1. The Seyfert 2 galaxies were further separated in 35 lightly ($N_H < 10^{23}$ cm^{-2}), 27 midly ($10^{23} > N_H > 10^{24}$ cm^{-2}) and 10 highly ($N_H > 10^{24}$ cm^{-2}) obscured subsamples.

We stacked the spectra of the sources for each subsample, accumulating up to 44 Msec of observing time for Seyfert 2 galaxies and obtained high signal-to-noise average spectra for every sub-class. We then compared the spectra in model independent and model dependent ways. The results are as follow [15]:

- Seyfert 1 and Seyfert 1.5 have identical hard X-ray spectra with average photon index of 1.8 ± 0.2, cutoff energy of > 190 keV and reflection parameter of 0.2 ± 0.2.

- Seyfert 2 have completely different spectra, on average, featuring a broad bump below 50 keV.

- The average spectrum of lightly obscured Seyfert 2 is completely consistent with those of Seyfert 1 and 1.5. Their average reflection parameter is < 0.5 (Fig. 2).

- The average spectrum of midly obscured Seyfert 2 (Fig. 1) features a strong and broad excess below 50 keV and is best represented by a photon index of 1.8 ± 0.1, a cutoff energy < 400 keV and a reflection parameter of 2.2^{+4}_{-1} (3σ uncertainties). A bi parametric analysis of the cutoff energy vs the reflection parameter indicates that the latter is > 1 with a confidence larger than 99% (Fig. 2).
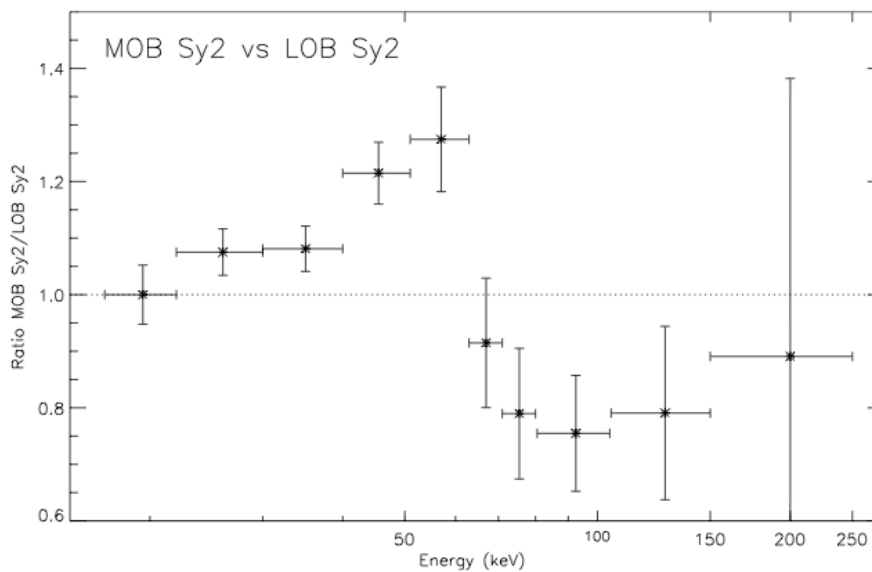

Figure 1: The ratio between the count spectra of midly and lightly obscured Seyfert 2 galaxies.

3. Discussion

The stacking analysis of INTEGRAL spectra of Seyfert galaxies indicates that (1) the intrinsic X-ray continuum of Seyfert galaxies is consistent with an average Compton optical depth of 0.8 ± 0.5 for all classes of objects; (2) the average cutoff energy (> 190 keV) is consistent with the results derived from BeppoSax [16]; (3) the average reflection in Seyfert 1 and lightly obscured Seyfert 2 galaxies (R< 0.5) is consistent with that expected from an accretion disk; and (4) the average reflection in midly obscured Seyfert 2 galaxies is not physical, unless their continuum emission is attenuated by a factor larger than two.

The correlation we have found between reflection and absorption points towards a clear change in the environment of Seyfert galaxies. The emerging picture is that obscuring/reflecting clouds have on average a lower covering factor in Seyfert 1 than in Seyfert 2 galaxies. This indicates that
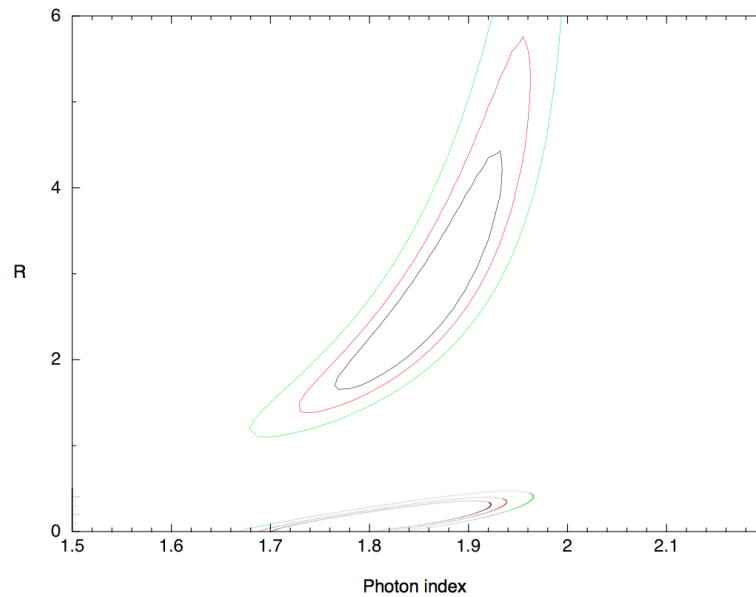
Figure 2: Multi-parametric contour plot providing the 68, 90 and 99% confidence level on the power law photon index Γ and the reflection parameter R for the average spectrum of midly ($10^{23} < N_H < 10^{24}$ cm^{-2}; top) and lightly ($N_H < 10^{23}$ cm^{-2}; bottom) obscured Seyfert 2.

the Seyfert type is driven by the environment rather than by orientation. A conclusion very similar to these obtained from recent infrared and X-ray observations.

To synthesize the spectrum of the cosmic X-ray background (CXB), Gilli et al. (2007) [17] needed to assume that about 30% of the AGN population should be Compton thick to explain the CXB excess at 30 keV. This population is however hardly detected. INTEGRAL observations indicate that midly obscured Seyfert 2 galaxies have much stronger reflection in the local Universe. Extrapolating this at high redshift provides a new picture, where the CXB can be explained with only 10% of Compton thick active galactic nuclei, a fraction that corresponds much better to the current survey observations.

References

[1] Antonucci, R. R. J. and Miller, J. S., ApJ **297** (1985) 621.

[2] Cappi, M. et al., A&A **446** (2006) 459.

[3] Panessa, F. and Bassani, L., A&A **394** (2002) 435.

[4] Tran, H. D., ApJ **554** (2001) L19.

[5] Tran, H. D., ApJ **583** (2003) 632.

[6] Gu, Q. and Huang, J., ApJ **579** (2002) 205.

[7] Jaffe, W. et al., Nature **429** (2004) 47.

[8] Tristram, K. R. W. et al., A&A **474** (2007) 837.

[9]   Ramos Almeida, C. et al., ApJ **731** (2011) 92.

[10] Eguchi, S., Ueda, Y., Terashima, Y., Mushotzky, R., and Tueller, J., ApJ **696** (2009) 1657.

[11] Eguchi, S. et al., ApJ **729** (2011) 31.

[12] Miller, L. et al., MNRAS **403** (2010) 196.

[13] Lobban, A. P. et al., MNRAS **414** (2011) 1965.

[14] Risaliti, G. et al., ApJ **705** (2009) L1.

[15] Ricci, C., Walter, R., Courvoisier, T. J.-L., and Paltani, S., A&A **532** (2011) A102.

[16] Dadina, M., A&A **485** (2008) 417.

[17] Gilli, R., Comastri, A., and Hasinger, G., A&A **463** (2007) 79.