A hard X-ray view of the soft-excess in AGN

Rozenn Boissay[1], Claudio Ricci[2] and Stéphane Paltani[1]

[1] Department of Astronomy, University of Geneva, Switzerland
[2] Department of Astronomy, Kyoto University, Japan

Contact: rozenn.boissay@unige.ch

An excess of X-ray emission below 1 keV, called soft-excess, is detected in many Seyfert 1-1.5s spectra. The origin of this feature remains debated, as several models have been suggested to explain it, including Comptonization and blurred ionized reflection. In order to constrain the origin of this component, we use the fact that these models predict different behaviors in the hard X-rays. Ionized reflection indeed covers a broad energy range, from the soft X-rays to the hard X-rays around a few tens of keV, while Comptonization drops very quickly in the soft X-rays. We present here the preliminary results of a study of the hard X-ray characteristics of objects with and without soft-excess, using a sample of 30 sources observed with XMM-Newton and Swift/BAT.

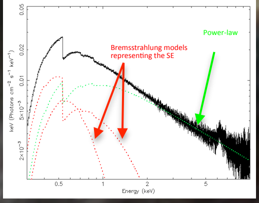
Soft-excess

The soft-excess (SE) is an excess over the power-law emission below 1 keV which is very common in Type 1 AGN spectra (Halpern 1984; Turner & Pounds 1989). Several models have been proposed to explain the soft-excess, including warm Comptonization (Walter & Fink 1993, Magdziarz et al. 1998, Mehdipour et al. 2011, Di Gesu et al. 2014) and blurred ionized reflection (Ross & Fabian 2005, Crummy 2006, Fabian et al. 2009, De Marco et al. 2013).
The ionized reflection model predicts a link between the soft-excess and the reflection hump at about 30 keV. Vasudevan et al. (2014) recently proposed an approach using a diagnostic plot of the strength of the hard excess against the soft-excess to distinguish the different models, based on simulations of XMM + NuSTAR observations.

Sample and data analysis

We use for this study a sample of 69 Seyfert 1-1.5 galaxies, observed by XMM-Newton and present in the Swift/BAT catalog. Data reduction is performed on the original data files using the XMM Standard Analysis Software (SAS v12.0.1) to get PN spectra of each sources. We download BAT spectra from the Swift BAT 70-Month Hard X-ray Survey catalog (Baumgartner et al. 2013).

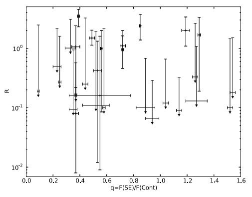
We fit the XMM observations with a simple power-law in an energy band in which we expect little contamination from the soft-excess or the FeKα line, taking into account Galactic absorption, adding in some cases absorption from a cold or ionized medium, and two Bremsstrahlung models to phenome-nologically measure the soft-excess if present (as in the figure



above showing the fit on Ark 120, which presents a strong soft-excess plotted in red). Doing so, we find that 37 objects present a soft-excess, seven of them showing ionized absorption.
The other sources are heavily absorbed by ionized material. We measure the photon index in the XMM spectra and define the strength of the soft-excess q as the ratio between the flux of the soft-excess and the flux of the continuum between 0.3 and 2 keV, for each of the 30 sources without any absorption.

Correlation R-SE

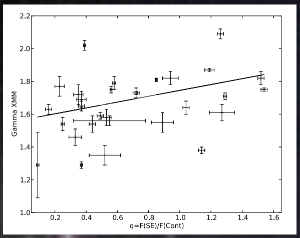
We fit the BAT spectra with a *pexrav* model (Magdziarz & Zdziarski 1995), in order to represent phenomenologically the reflection (either neutral or ionized), fixing the value of gamma to the one obtained using XMM data.



We find the best fit parameter values of the high-energy cutoff *Ec* and the reflection factor *R* using the χ^2 statistics of XSPEC (v12.8.1).
As shown in the figure above, we do not see any correlation between *R* and the strength of the soft-excess *q* (Spearman correlation coefficient r: -0.09, with a null-hypothesis probability of 64%).

Correlation Gamma-SE

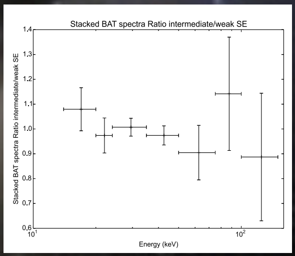
Plotting the strength of the soft-excess *q* against the power-law slope obtained with XMM-Newton data reveals a positive correlation (see figure on the right). Spearman rank analysis gives a correlation coefficient of r=0.42 with a null-hypothesis probability of 2%. This result is consistent with the one of Page et al. (2004), who found a correlation with a 4% null-hypothesis probability with 7 objects observed with XMM-Newton. This shows that the strength of the soft-excess *q* is linked to the spectral index, and not to the reflection. This suggests a connection between the soft-excess and the cooling of the hot corona.



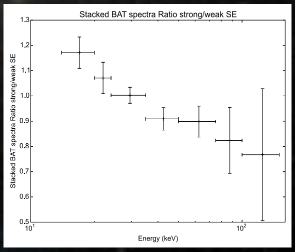
As suggested in the case of MRK 509 (Petrucci et al. 2013), one possible explanation is that the soft-excess would constitute a non-negligible part of the soft photons Comptonized in the corona.

Spectral stacking

We classify the 30 objects depending on the value of the soft-excess strength *q* in 3 groups (« weak SE »: q < 0.5, « intermediate SE »: 0.5 < q < 0.8, and « strong SE »: q > 0.8). We stack the Swift/BAT spectra of all objects in each of the groups.



The figures on the right show the ratios of the stacked BAT spectra (« intermediate SE » over « weak SE », and « strong SE » over « weak SE »). In the case of reflection, we expect to see a bump peaking at about 30 keV in the ratio plot, as shown by simulations in Ricci et al. (2011), while the ratio spectra are observed to peak in the lowest energy bin, so we do not see any evidence of increasing reflection with increasing soft-excess strength.



The table on the right shows that, by fitting the stacked spectra with a simple power-law, the photon index increases with the strength of the soft-excess (consistent with the correlation between the photon index and q).

	XMM
$\Gamma_{\text{weak SE}}$	1.58 ± 0.01
$\Gamma_{\text{inter. SE}}$	1.71 ± 0.008
$\Gamma_{\text{strong SE}}$	1.79 ± 0.005

Conclusions

In this work, we explore the existence of connection between soft-excess and hard X-ray properties in AGN, using a sample of XMM-Newton and Swift/BAT observations. We see that there is no evidence of a link between reflection and strength of the soft-excess. The correlation between the photon index and the strength of the soft-excess suggests a link between this feature and the cooling of the hot corona. One possible explanation could be that the soft-excess is a contributing source of soft photons originating from Comptonization of disk photons in a layer on top of the accretion disk and further Comptonized in the hot corona.

References

Baumgartner, W. H., Tueller, J., Markwardt, C. B., et al. 2013, ApJS, 207, 19
Crummy J., Fabian A.C., Gallo L. and Ross R.R., 2006, MNRAS, 365, 1067
De Marco, B., Ponti, G., Cappi, M., et al. 2013, MNRAS, 431, 2441
Di Gesu, L., Costantini, E., Piconcelli, E., et al. 2014, A&A, 563, A95
Fabian, A. C., Zoghbi, A., Ross, R. R., et al. 2009, Nature, 459, 540
Halpern, J. P. 1984, ApJ, 281, 90
Magdziarz, P. & Zdziarski, A. A. 1995, MNRAS, 273, 837
Magdziarz, P., Blaes, O. M., Zdziarski, A. A., Johnson, W. N., & Smith, D. A. 1998, MNRAS, 301, 179
Mehdipour M. et al., 2011, A&A, 534, 38
Page, K. L., Schartel, N., Turner, M. J. L., & O'Brien, P. T. 2004, MNRAS, 352, 523
Petrucci, P.-O., Paltani, S., Malzac, J., et al. 2013, A&A, 549, A73
Ricci, C., Walter, R., Courvoisier, T. J.-L., & Paltani, S. 2011, A&A, 532, A102
Ross R.R and Fabian A.C., 2005, MNRAS, 358, 211
Turner, T. J. & Pounds, K. A. 1989, MNRAS, 240, 833
Vasudevan, R. V., Mushotzky, R. F., Reynolds, C. S., et al. 2014, ApJ, 785, 30
Walter, R. & Fink, H. H. 1993, A&A, 274, 105