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

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An excess of X-ray emission below 1 keV, called soft-excess, is detected in about 75% of Seyfert 1-1.5s (Scott +12). The origin of this feature remains debated, as several models have been suggested to explain it, including warm Comptonization and blurred ionized reflection. In order to constrain the origin of this component, we exploit the different behaviour of these models above 10 keV. Ionized reflection covers a broad energy range, from the soft X-rays to the hard X-rays, while Comptonization drops very quickly in the soft X-rays. We present here the results of a study done on 102 Seyfert 1s (Sy 1.0, 1.2, 1.5, and NLSy1) from the *Swift BAT* 70-Month Hard X-ray Survey catalog. The joint spectral analysis of *Swift/BAT* and *XMM-Newton* data allows a hard X-ray view of the soft-excess that is present in about 80% of the objects of our sample.

Soft-excess (SE)

Excess over the power-law emission below 1 keV which is very common in Type 1 AGN spectra.

Origin:

- warm Comptonization (Walter & Fink 93, Magdziarz +98, Mehdipour +11, Di Gesu +14)
- blurred ionized reflection (Ross & Fabian 05, Crummy +06, Fabian +09, De Marco +13); link expected between the SE and the reflection hump at about 30 keV, because features of a single component (Vasudevan +14)

Sample and data analysis

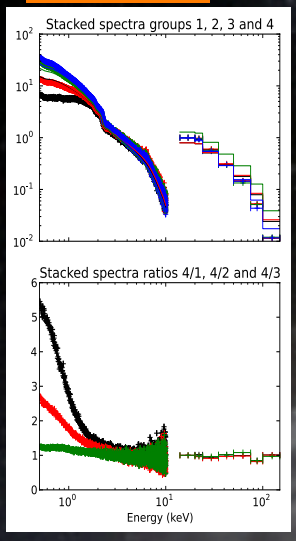
- 102 Seyfert 1-1.5s and NLSy 1s from 70-Month Swift/BAT Hard X-ray Survey catalog, observed by XMM-Newton
- Fit 3-100 keV of XMM-Newton/PN-MOS and Swift/BAT data (XSPEC):

wabs (constant * cutoffpl + gsmooth * pexmon)

- Galactic absorption
- Cross-calibration XMM-Newton/BAT to correct flux variability
- Cutoff power-law
- Relativistic broadening (proxi. SMBH)
- Neutral reflection from distant material

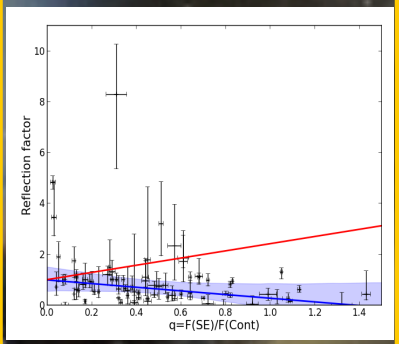
- Fit 0.5-100 keV adding Bremsstrahlung models (to measure the SE) and absorption
- Definition of SE strength: $q = F^{\text{Bremss}}_{0.5\text{-}2\ \text{keV}} / F^{\text{Continuum}}_{0.5\text{-}2\ \text{keV}}$

Spectral stacking



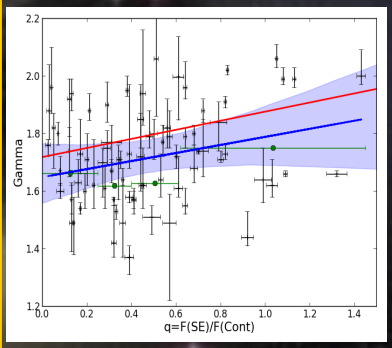
- 79 objects with SE and slightly absorbed classified in 4 groups of different q values
  - group G1: $q \leq 0.25$
  - G2: $0.25 < q \leq 0.4$
  - G3: $0.4 < q \leq 0.6$
  - G4: $q > 0.6$
- Normalized XMM-Newton/PN and Swift/BAT spectra stacked per groups (top panel; black: G1, red: G2, green: G3, blue: G4)
- Fit by a power-law between 2 and 10 keV to show the SE
- Ratios between the stacked spectra (bottom panel; black: G4/G1, red: G3/G1, green: G2/G1)
- No higher reflection for stronger SE; Contradiction with ionized reflection hypothesis

Relation *R* – SE strength *q*

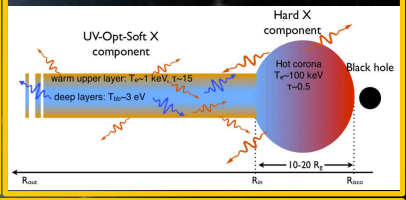


- Possible anti-correlation *R-q* (r=-0.33, p=0.3%, blue line and 99.9% CI)
- Contradiction with blurred ionized reflection simulations (*relxill* – Garcìa +14, Dauser +14)
- 1148 PN and BAT simulated spectra (with different *R*, *Γ*, *ξ*, abundance, emissivity, and inclination values of *relxill*), fitted as described above for the data
- Expected correlation *R-q* (red line, r=0.32, p=8e-27%)
- Coherent with Vasudevan's simulations
- Local reflection hypothesis: higher reflection → stronger emission lines below 1 keV

Relation *Γ-q*

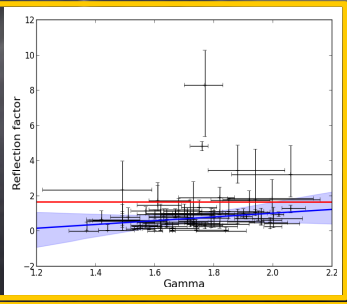


- Hints of a correlation *Γ-q* (r=0.19, p=10%, blue line and CI)
- Page +04: correlation (p=4%) with 7 objects
- Coherent with ionized reflection expectation (red line, r=0.20, p=6e-10%)
- Connection between SE and cooling of the hot corona: as in Mrk 509 (figure below from Petrucci +13), a warm corona could upscatter optical/UV photons from the disk to produce the SE and participate in the cooling of the hot corona



Photon index *Γ*

- Correlation *R-Γ* (r=0.35, p=0.02%, blue line and CI)
- Contradiction with expected relation from ionized reflection simulations (red line): *R* almost independent of *Γ*



Conclusions

We explore the existence of connection between soft-excess and hard X-ray properties in AGN via a statistical and model-independent study, using a sample of Swift/BAT and XMM-Newton observations. We see that there is no evidence of a link between reflection and strength of the SE. Indeed, we find a possible anti-correlation between these parameters that is at odds with expectations from simulations of ionized reflection models (see Vasudevan +14 and this work). We also show this lack of link by stacking spectra per *q* values. We find a correlation between the *R* and *Γ* that is in contradiction with ionized reflection simulations. These arguments disfavour the ionized-reflection model as the origin of the SE. The possible correlation between *Γ* and *q* could be explained by a warm Comptonization scenario such as the one proposed in Mrk 509 by Petrucci +13, where a warm upper layer of the accretion disk Comptonizes the optical/UV photons from the disk to produce the SE, and participates in the cooling of the hot corona. This work suggests that the SE is, in most objects of our sample, better explained by warm Comptonization than by blurred ionized reflection.

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