Variability of the soft X-ray excess in IRAS 13224–3809

E. Kammoun[1], I. Papadakis [2], and B. Sabra[3]
[1]SISSA, Trieste - Italy (ekammoun@sissa.it); [2]University of Crete, Heraklion - Greece;
[3]Notre Dame University - Louaize, Zouk Mosbeh - Lebanon

(**Kammoun et al., 2015, A&A, 582, 40**)

Objective

X-ray spectra of Active Galactic Nuclei (AGN) are characterised by a power-law (PL) like shape at energies above ~ 2 keV. Many AGNs reveal the presence of an excess in their spectra above the extrapolation of the PL to softer energies. The origin of this excess component, known as the soft X-ray excess (SXE), has been debated since its discovery: smeared absorption model [3], relativistically blurred disc reflection model [1], and intrinsic emission by an optically thick disc powering the SXE [2]. The aim is to constrain the origin of the SXE in a *model-independent* fashion by means of a variability analysis.

Method

We apply the flux–flux plot (FFP) method to the archival *XMM-Newton* observations (Obs. 1–5) of the NLS 1 galaxy IRAS 13224-3809.

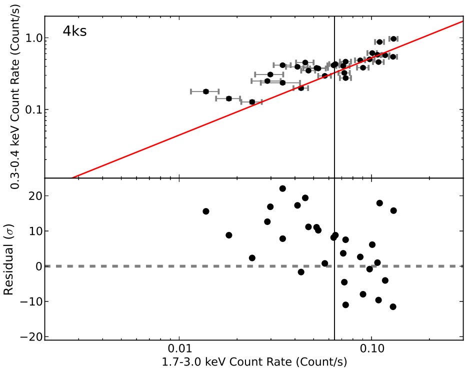
1. The 1.7–3 keV band was chosen as a *proxy* of the continuum power-law emission.
2. The 0.2–1.7 keV band was divided into 11 energy sub-bands.
3. Light curves in the 12 sub-bands were binned with three time bin sizes $\Delta t_{\rm bin} = 1$, 4, and 8 ks.
4. We plot the "soft" vs the "continuum" band count rates (FFP). They are highly correlated, in all energy bands.

The effects of $\Delta t_{\rm bin}$

The "high-flux" part of the FFPs were fitted with a PL relation:

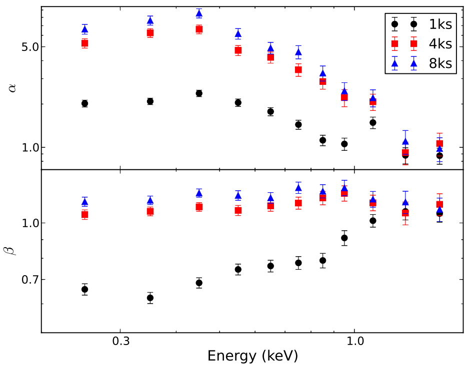
$$y = \alpha x^{\beta}$$

An *excess* is seen above the extrapolation of the best-fit PL to low counts, for the three $\Delta t_{\rm bin}$.



The best-fit α and β parameters are not consistent for the various $\Delta t_{\rm bin}$. This could be explained by

- Large amplitude short time scale variability. and
- Intrinsic non-linear flux-flux relation.



We decided to study only the *1 ks binned* FFPs.

"Constant" component?

We modelled the FFPs by a power-law plus constant (PLc) model:

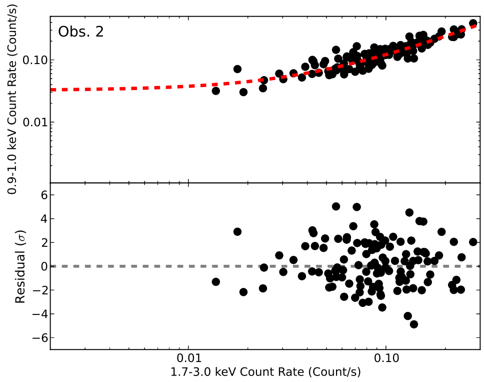
$$y = \alpha_{\rm PLc} x^{\beta_{\rm PLc}} + c$$

- $\beta_{\rm PLc} < 1$, below $\simeq 1$ keV

$\Rightarrow$ Presence of an intrinsic spectral variations in the continuum.

- Below 1 keV, $c > 0$ for Obs. 1–3, $c < 0$ for Obs. 4, and $c \approx 0$ in Obs. 5. Above 1 keV, $c \simeq 0$ for all observations.

The *non-zero* c's may be an indication of a constant soft-excess component.



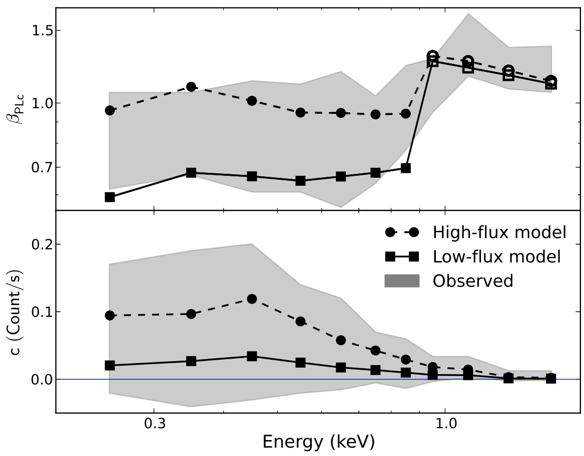
The spectrum derived from positive $c_{\rm obs}$'s cannot be explained by the disc intrinsic emission.

Modelling the FFPs

We created model FFPs, where the soft band flux was assumed to be equal to the sum of the continuum plus the soft-excess component flux.

- For the model continuum flux we assumed: $F_{\rm PL,mod}(E) = NE^{-\Gamma}$, where $\Gamma \propto N^{0.1}$.
- For the model soft-excess flux we assumed: $F_{\rm ex,mod}(E) = A(E)\,F^{0.46}_{\rm PL,mod}$, for $E \leq 0.9$ keV, and $F_{\rm ex,mod}(E) = 0$ at higher energies. Then the total soft flux was derived:

$$F_{\rm mod}(E) = F_{\rm PL,mod}(E) + F_{\rm ex,mod}(E)$$



The model FFPs ($F_{\rm mod}$ vs $F_{1.7-3{\rm keV,sim}}$) are *well fitted* by a PLc model. We detect positive c's **although the soft-excess component is** *not* **constant.**

(1) The best-fit model $\beta_{\rm mod}$ and $c_{\rm mod} < c_{\rm obs}$ are broadly consistent with the data (see figure above).

(2) **BUT** we cannot reproduce negative c's (hint of a possible *warm and variable absorber* in the source?).

References

[1] Crummy J., Fabian A. C., Gallo L., & Ross R. R., 2006, MNRAS, 365, 1067
[2] Done, C., Davis, S. W., Jin, C., Blaes, O., & Ward, M., 2012, MNRAS, 420, 1848–186
[3] Gierliński, M., & Done, C. 2006, MNRAS, 371, L16

Conclusions

Our results support the hypothesis that most of the soft-excess at energies below ~ 0.9 keV is due to *X-ray reflection* in IRAS 13224-3809. The soft excess is not constant, but it rather responds to the primary X-ray variations, although with a smaller amplitude (as expected for a smeared component). More work is necessary to model the expected variability in the case of a variable, warm absorber.