# Quasars as standard candles

## *The non linear relation between UV and X-ray emission at high redshifts*


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**Context**: A tight non-linear relation between the X-ray and the optical-ultraviolet emission has been observed in unobscured Active Galactic Nuclei (AGN) over a wide range of redshift and several orders of magnitude in luminosity, suggesting the existence of an ubiquitous physical mechanism regulating the energy transfer between the accretion disc and the X-ray emitting corona. Our group developed a method to use this relation in the observational cosmology, turning quasars into *standardizable candles*.

**Aim**: Investigating the potential **evolution of this correlation at high redshifts**.

**Method:** We studied the $L_X - L_{UV}$ relation for a sample of 53 finely selected unobscured quasars in the redshift range 4<*z*<7.

## Sample selection

Selection criteria proposed by Lusso & Risaliti 2016, (ApJ, 819, 154; LR16 hereafter):

- optically selected unobscured (Type 1) quasars;
- no BAL features;
- radio quiet quasars ($R = F_{\nu,6cm} / F_{\nu,4400\mathring{A}} < 10$);
- observed with *Chandra* and/or XMM-*Newton;*
- $F_{2500A}$ mainly from SDSS data:
  - 33/53 from Shen et al. 2011, ApJS, 194, 45;
  - 6/53, extrapolation from SDSS DR7 (Abazajian et al. 2009, ApJS, 182, 543);
  - 4/53, extrapolation from SDSS DR12 (Pâris et al. 2017, A&A, 597, A79);
  - 10/53, 5.3<z<7.08 sources, not covered by SDSS.

For further details **Salvestrini et al submitted.**

## X-ray analysis

- Complete spectral analysis to obtain accurate rest-frame 2 keV flux density estimates.
- *Chandra* (47) + XMM-*Newton* (9) observations.
- Adopted model: **Galactic abs.+ power law**.

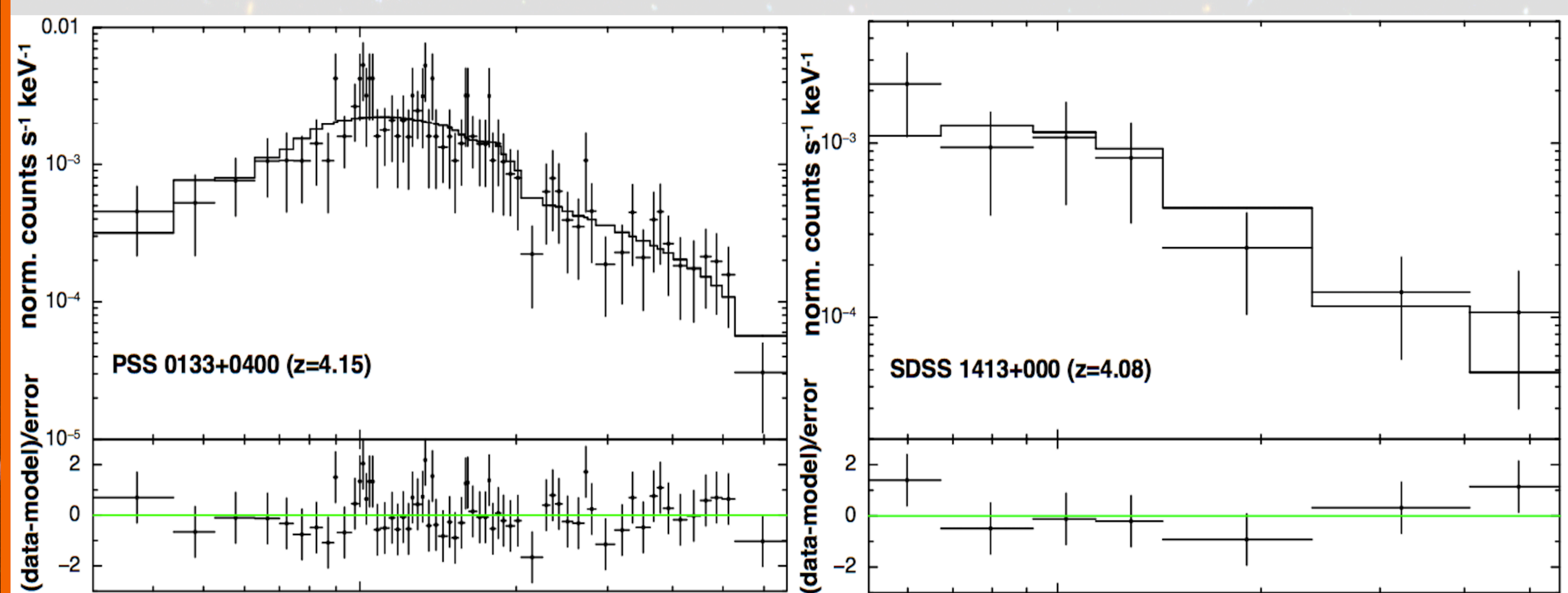


**Fig. 1**

Fig. 1: Examples *of X-ray spectra in the high (>100 cts; left panel) and medium (10<cts<100; right panel) photon statistic regimes. Upper panel: normalised counts* $s^{-1}$ *keV*$^{-1}$ *vs. energy (keV); lower panel: residuals in unit of sigma vs. energy (keV).*

## $L_X$-$L_{UV}$ relation

Bayesian analysis (*emcee*, Foreman-Mackey+13):

$$\log(L_X) = \beta + \gamma \log(L_{UV}).$$

Assuming a flat *ΛCDM* model,

$$\log(F_X) = \beta + \gamma \log(F_{UV}) - (\gamma - 1) \log(4\pi D^2_L)$$

Additional criteria:

- ***1.5<$\Gamma_X$< 2.8;***
- ***no X-ray flux upper limits*.**

Removing these additional criteria increases the dispersion, but no significant effect on the slope of the $L_X$-$L_{UV}$ relation.

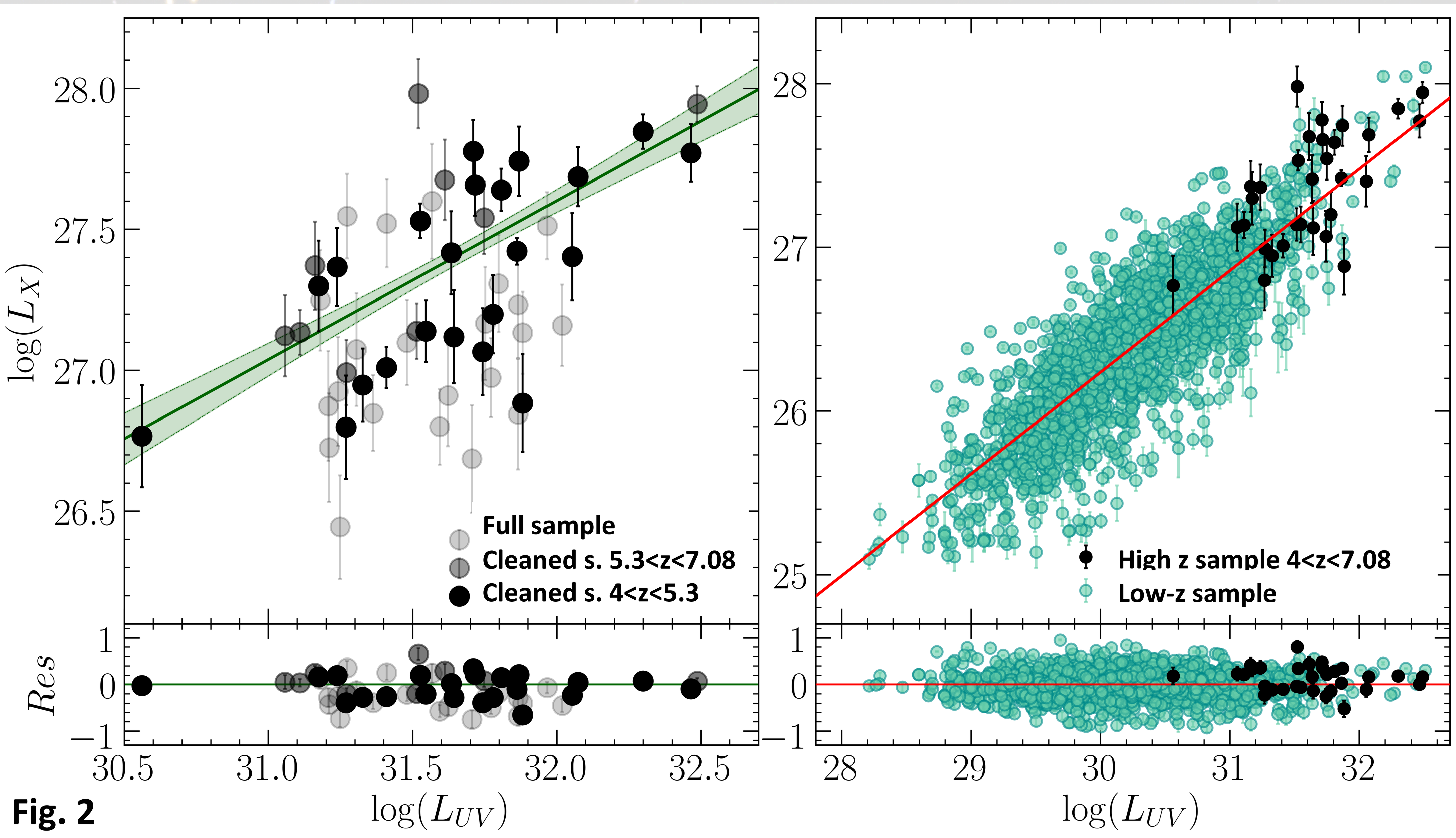


**Fig. 2**

**Fig. 2** - Left panel: $L_{UV}$ *vs.* $L_X$ *best-fit relation at high redshift. The green-shadowed area contains the best fit solutions within the 16th and 84th percentile*. Right panel, *the high-redshift (black) and the low redshift (LR16; green) samples.*

## Results:

- Observed X-ray spectral properties consistent with those at lower redshift (mean **$\Gamma_X$ = 1.9± 0.5**).
- **No evidence for evolution of the $L_X$-$L_{UV}$ relation with cosmic time**

  observed slope γ=0.53±0.11 is consistent with that observed at lower redshifts (~0.6).
- **Cleaner sample means lower intrinsic dispersion**

  the intrinsic dispersion ($\delta_{intr}$ = 0.20±0.04 *dex*) lower than in archival works.

See also the **talk** by **E. Lusso** and the **posters** by **S. Bisogni (404)**, **G. Risaliti (450)**