Quasars as high redshift standard candles

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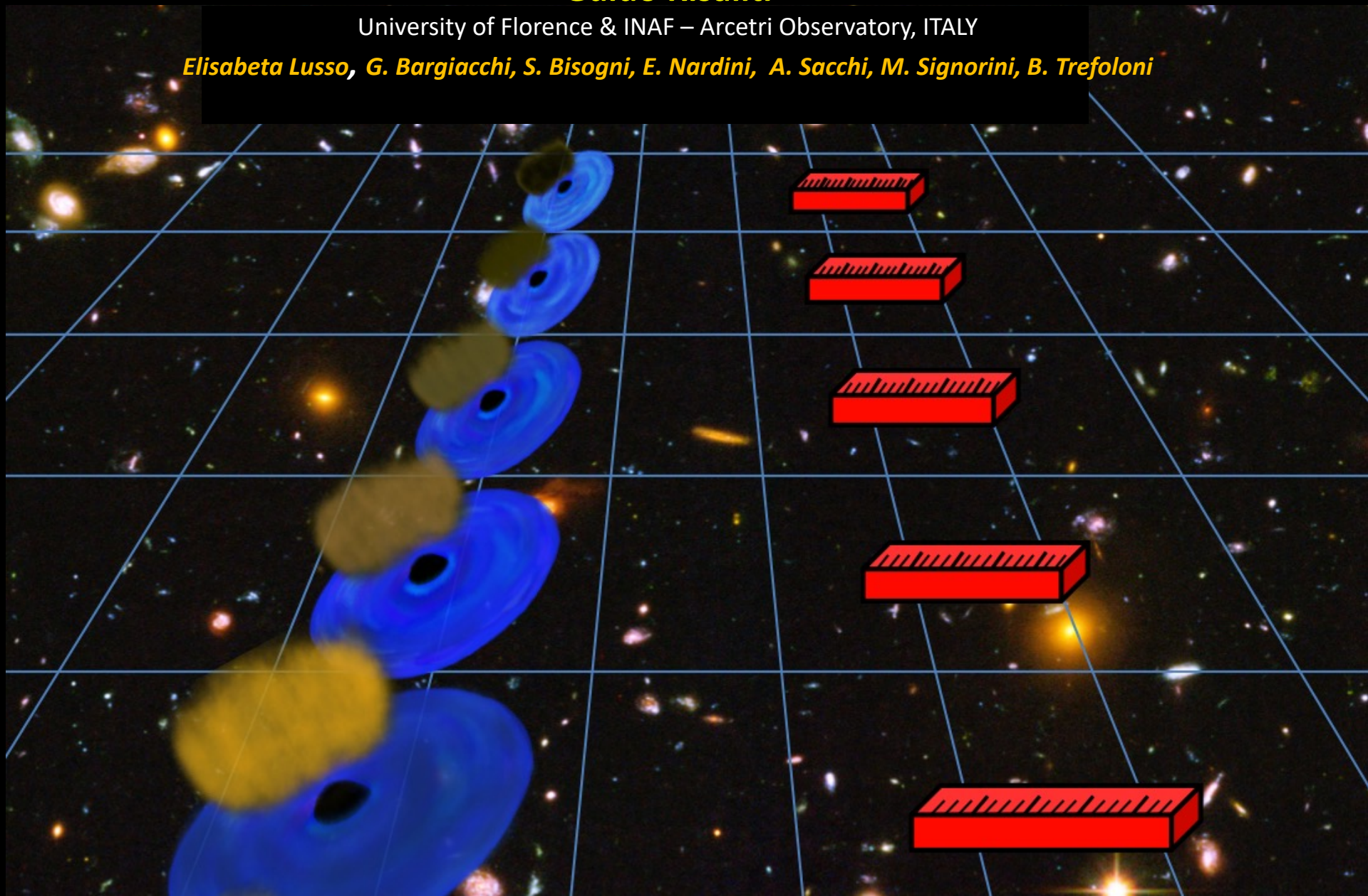
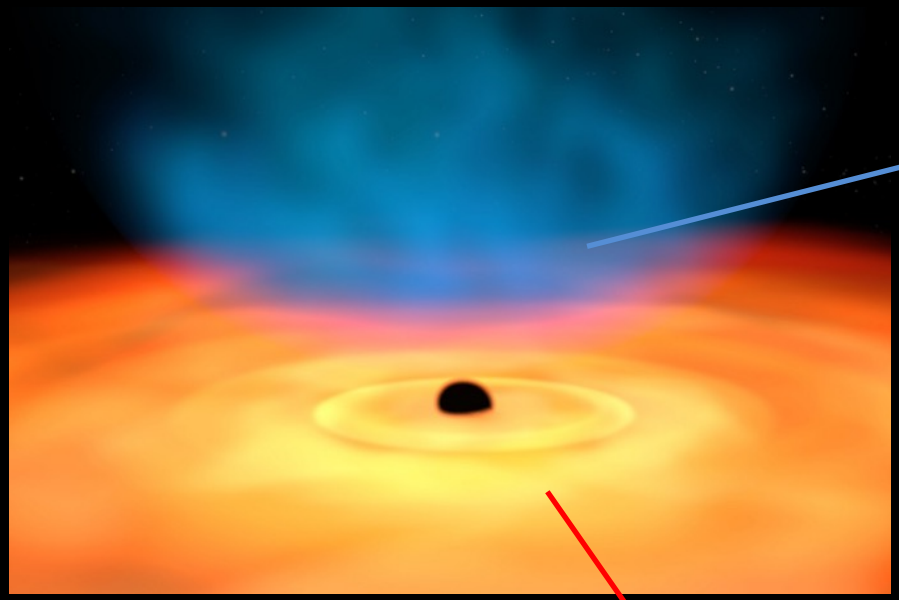
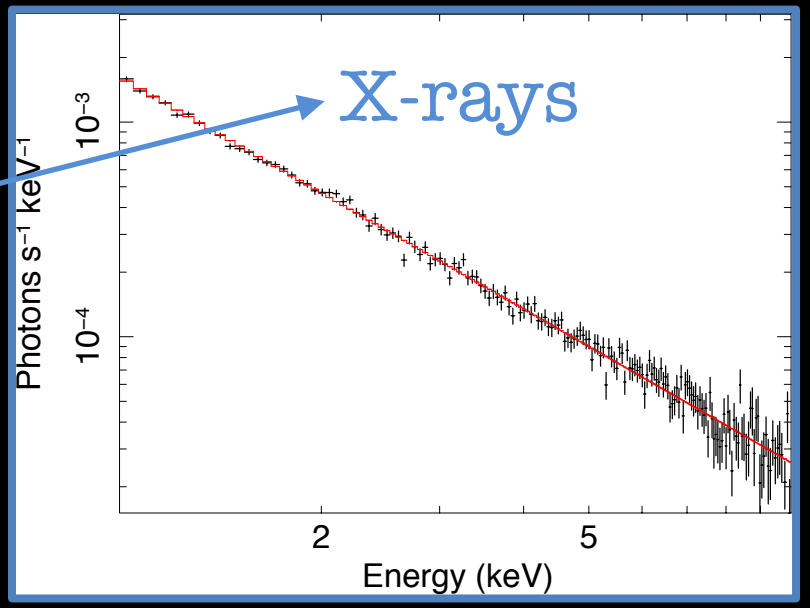
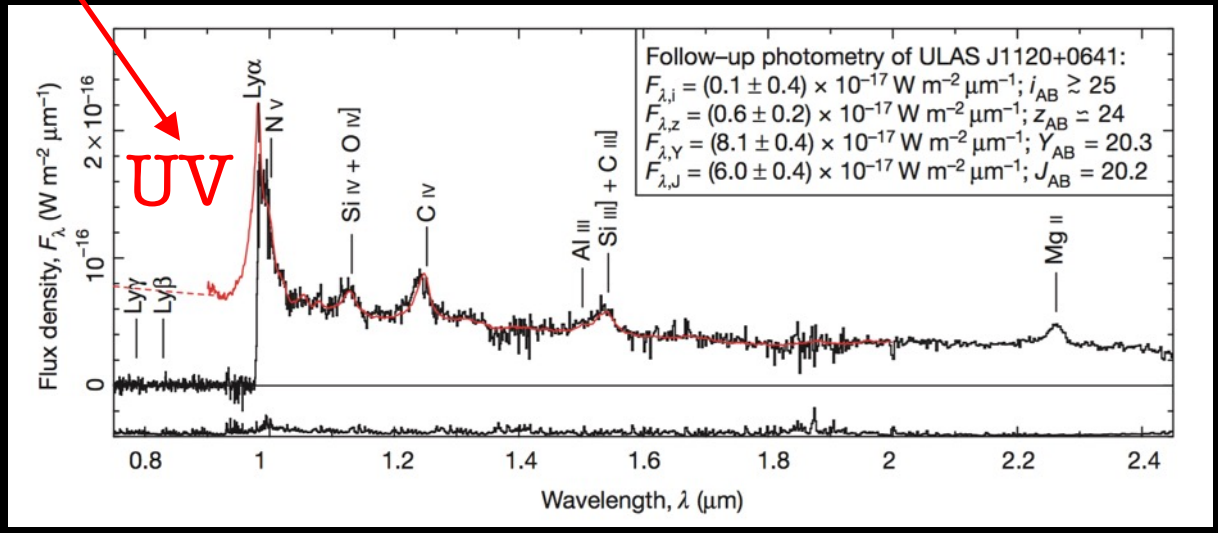


The inner emission regions in quasars

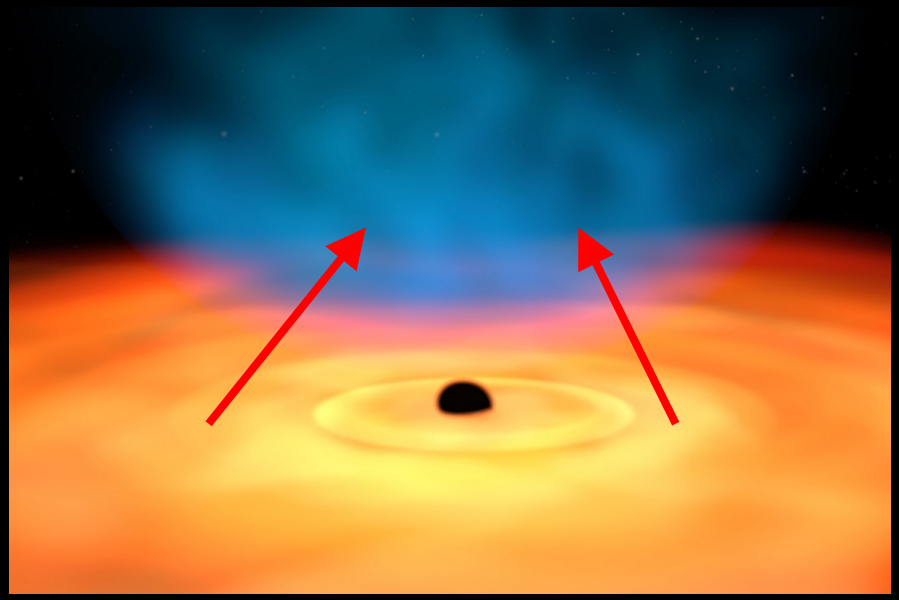




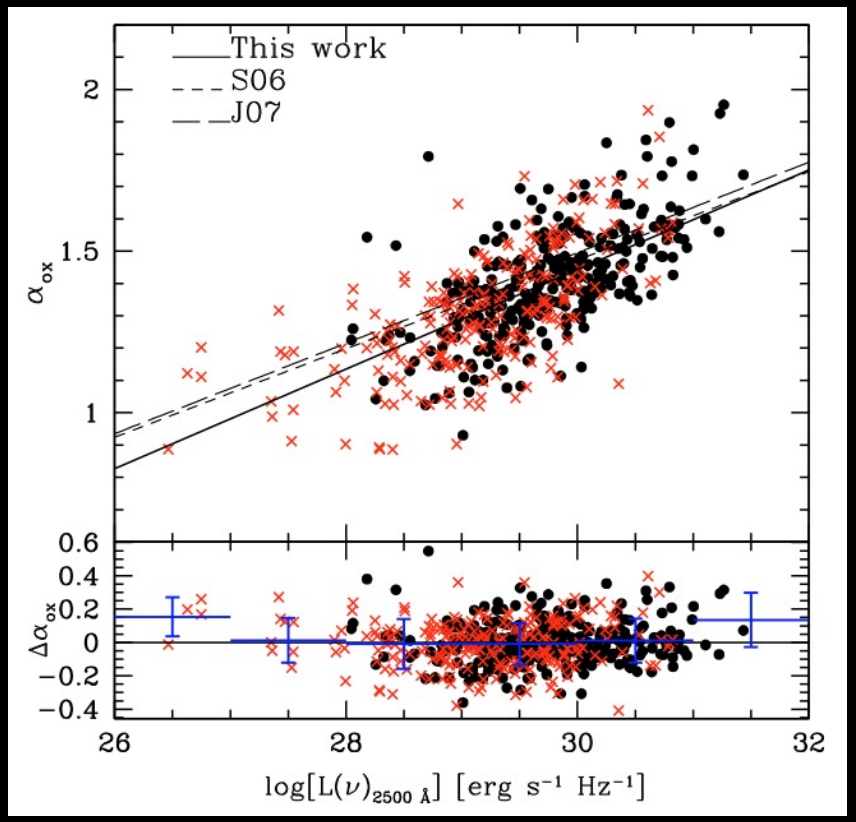


Mortlock et al. 2011

The non-linear relation between L_X and L_{UV} in quasars



Observational NON LINEAR relation between UV (disk) and X-ray (corona) emission



$$\log(L_X) = 0.6 \log(L_{UV}) + 8.5$$

L_ν(2 keV) L_ν(2500 Å)

Lusso et al. 2010

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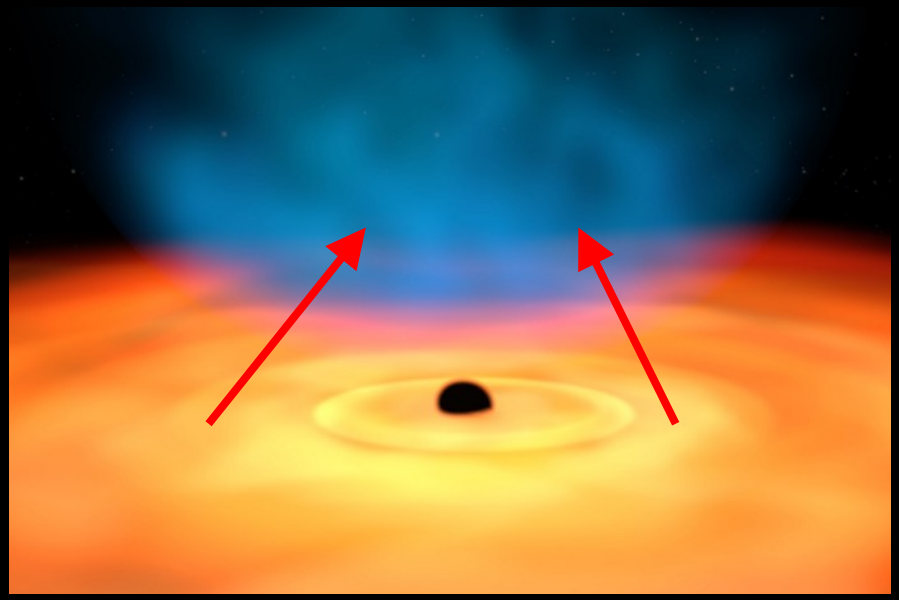

NEW SAMPLE:

SDSS-DR16 +
4XMM-DR10
~15,000 quasars

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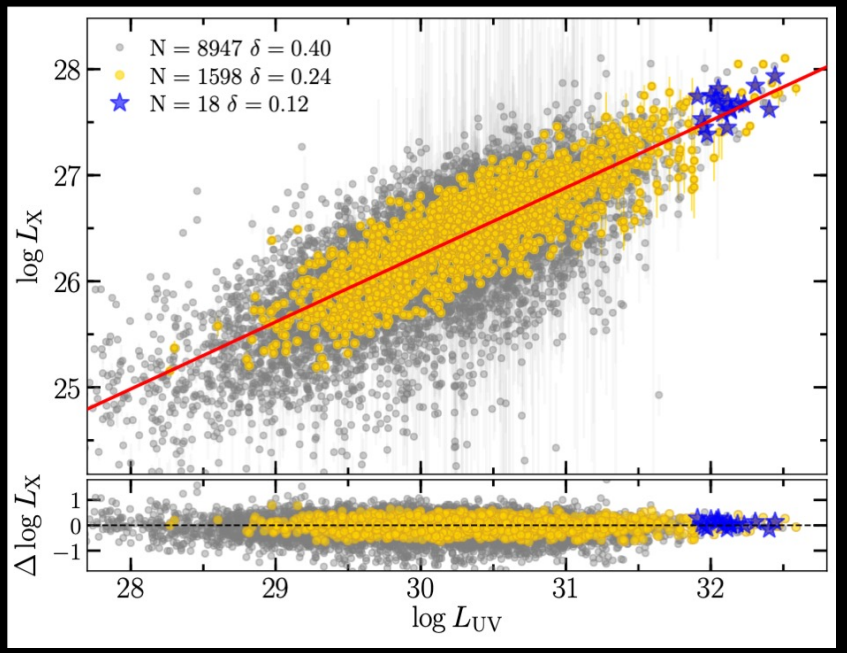
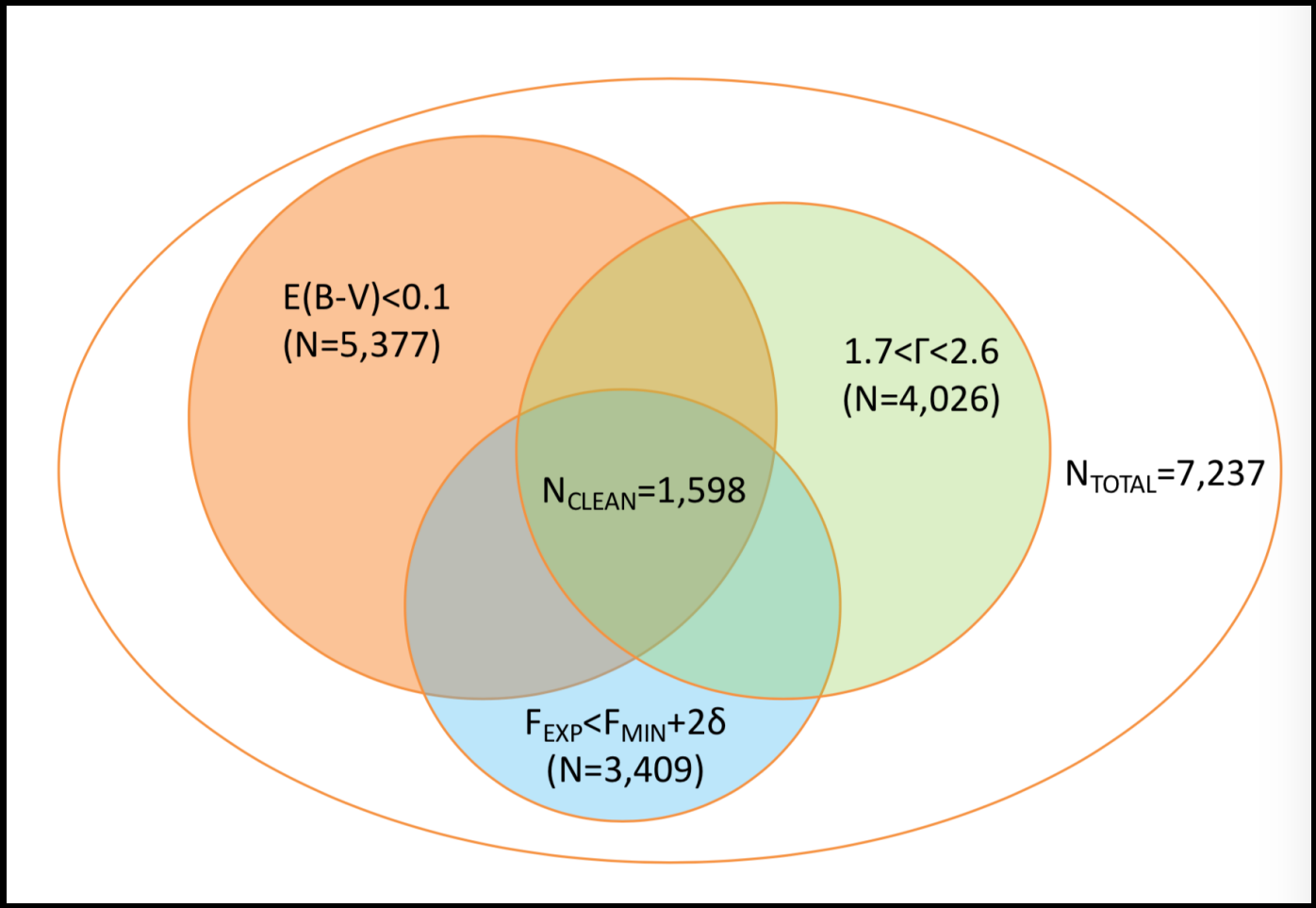


Risaliti & Lusso 2019
Lusso et al. 2020

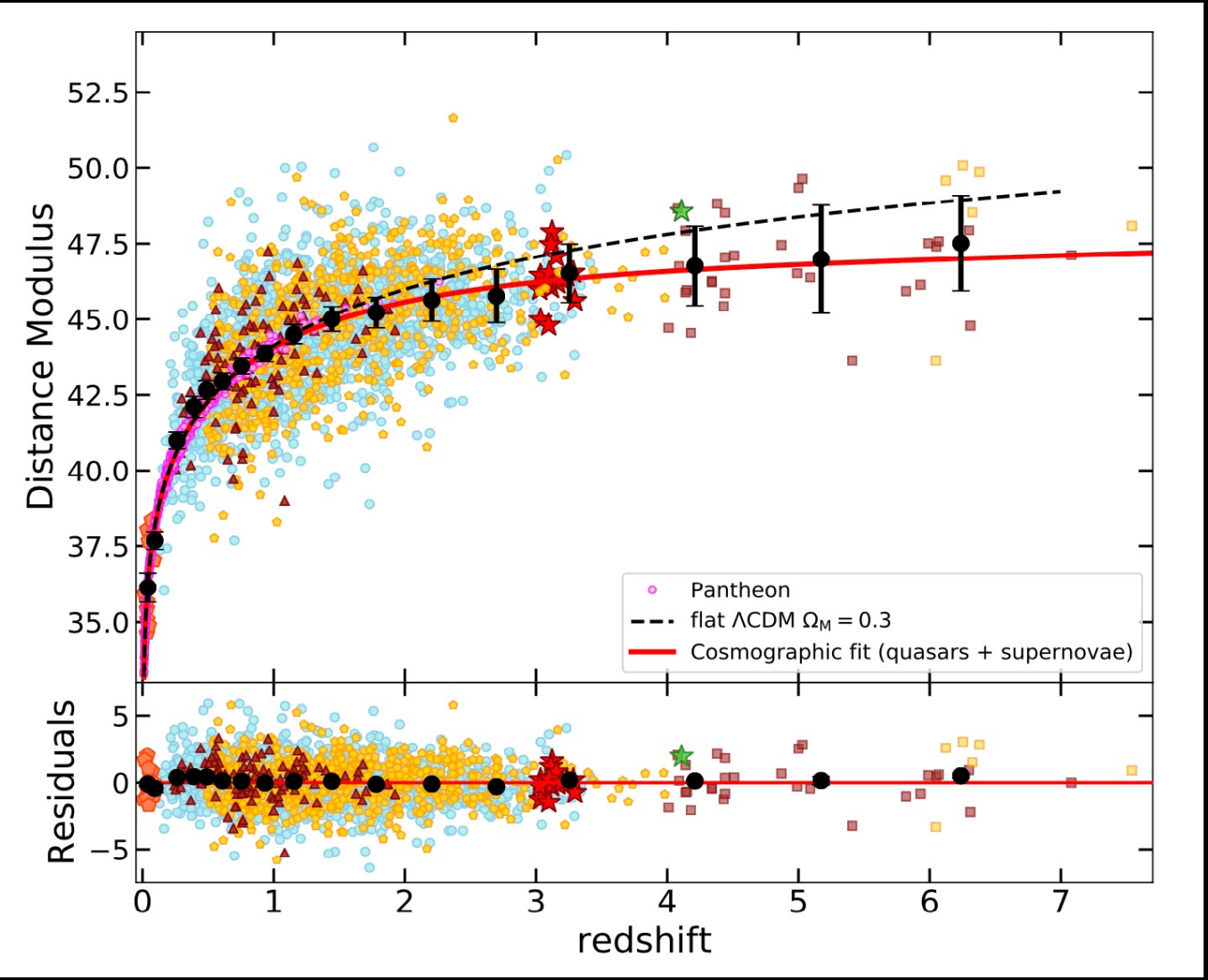
Sample selection

Main subsample: SDSS quasars with serendipitous X-ray observations



Quasars as Standard Candles: tests of cosmology

Hubble Diagram with 2420 quasars



Quasars as Standard Candles: tests of cosmology

"Cosmographic" fits to the Hubble Diagram

$$D_L = \alpha_1 \log(1+z) + \alpha_2 \log^2(1+z) + \alpha_3 \log^3(1+z) + \ldots$$

Assuming a flat LCDM model:

$$\alpha_2 = \frac{3}{2} - \frac{3}{4}\Omega_M$$

$$\alpha_3 = \frac{7}{6} - 2\Omega_M + \frac{9}{8}\Omega_M^2$$

$$\longrightarrow \alpha_3 = \frac{5}{3}\alpha_2 - \frac{10}{3}\alpha_2 + 2\alpha_2^2$$

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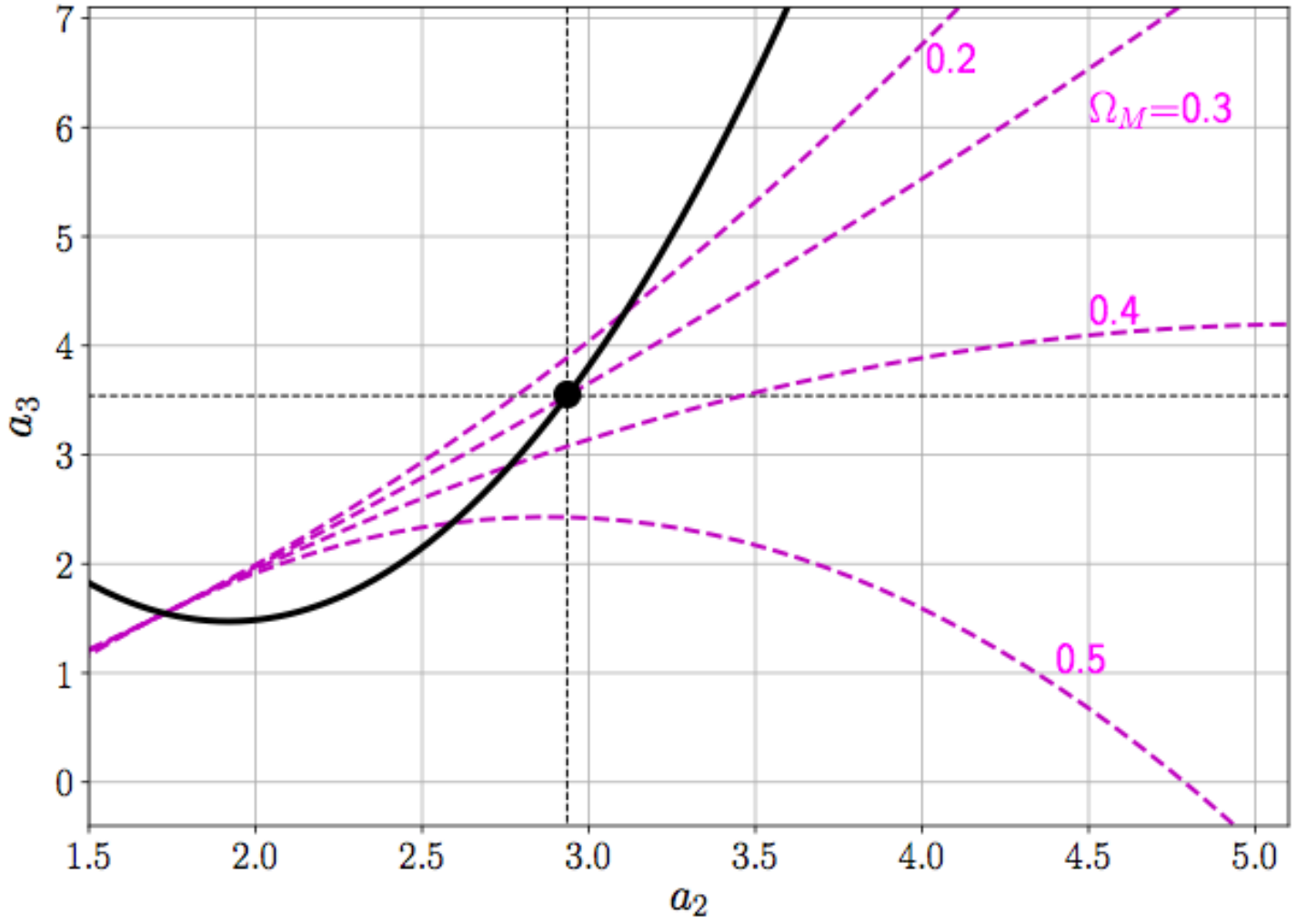

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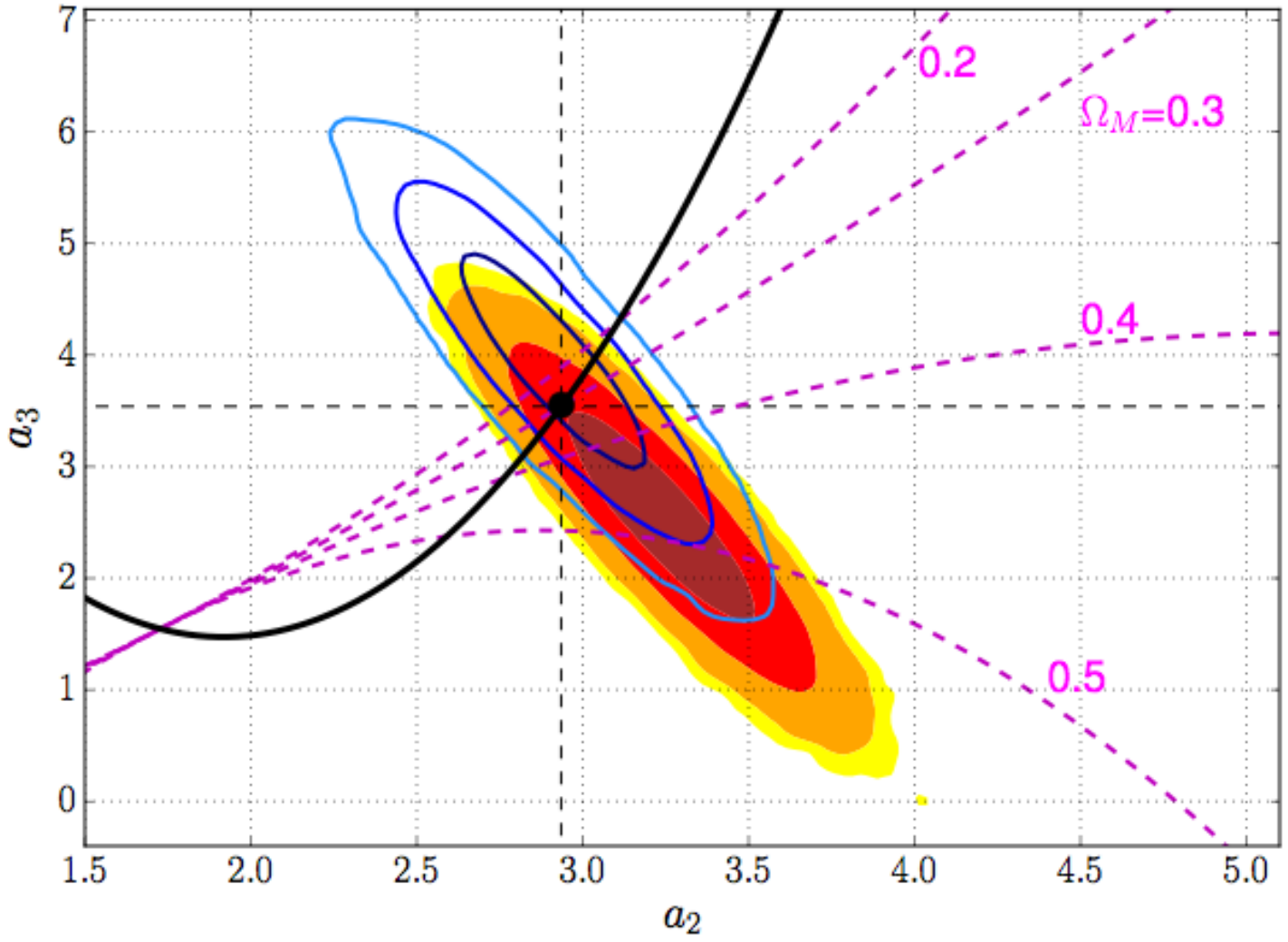

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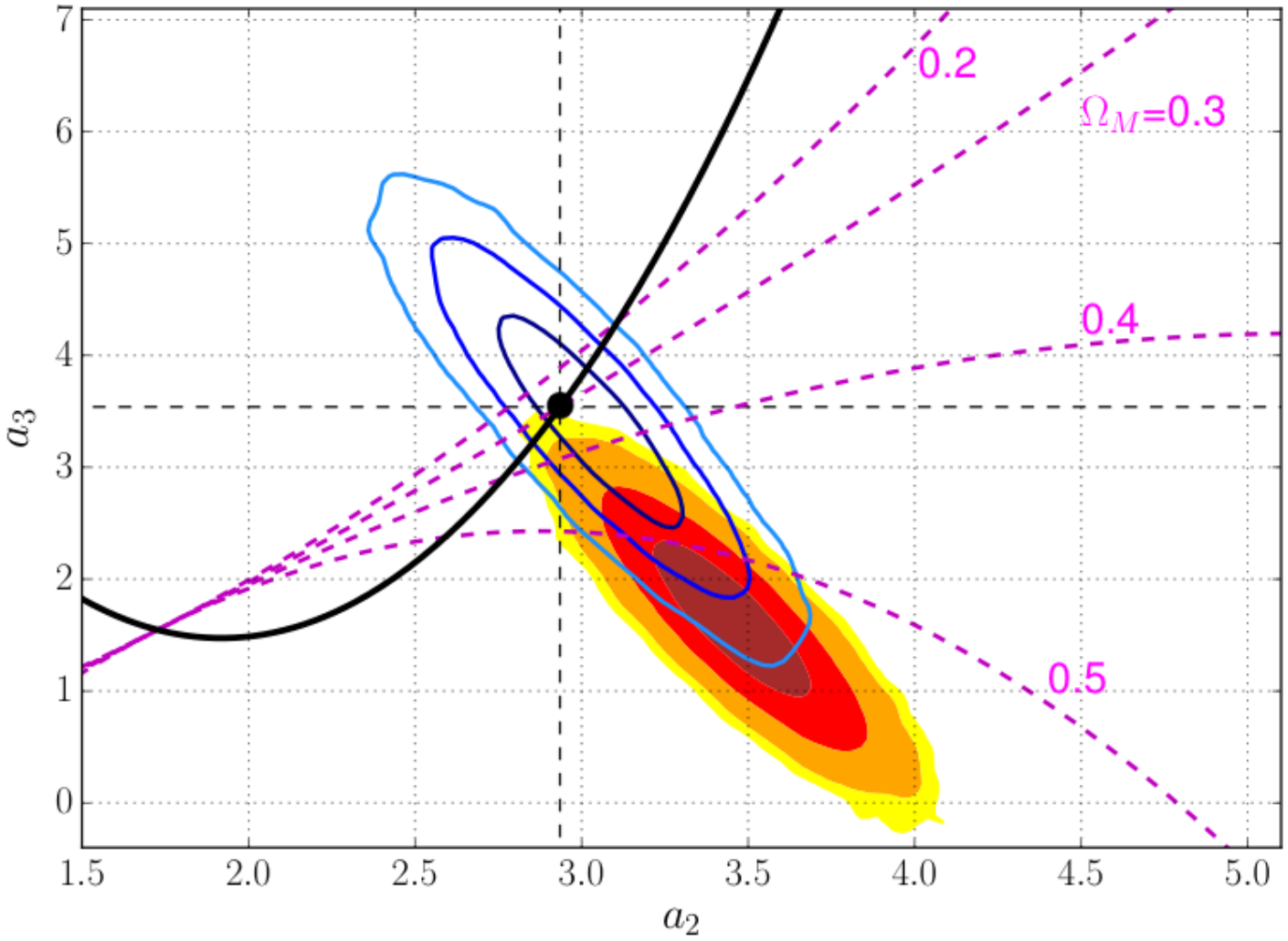

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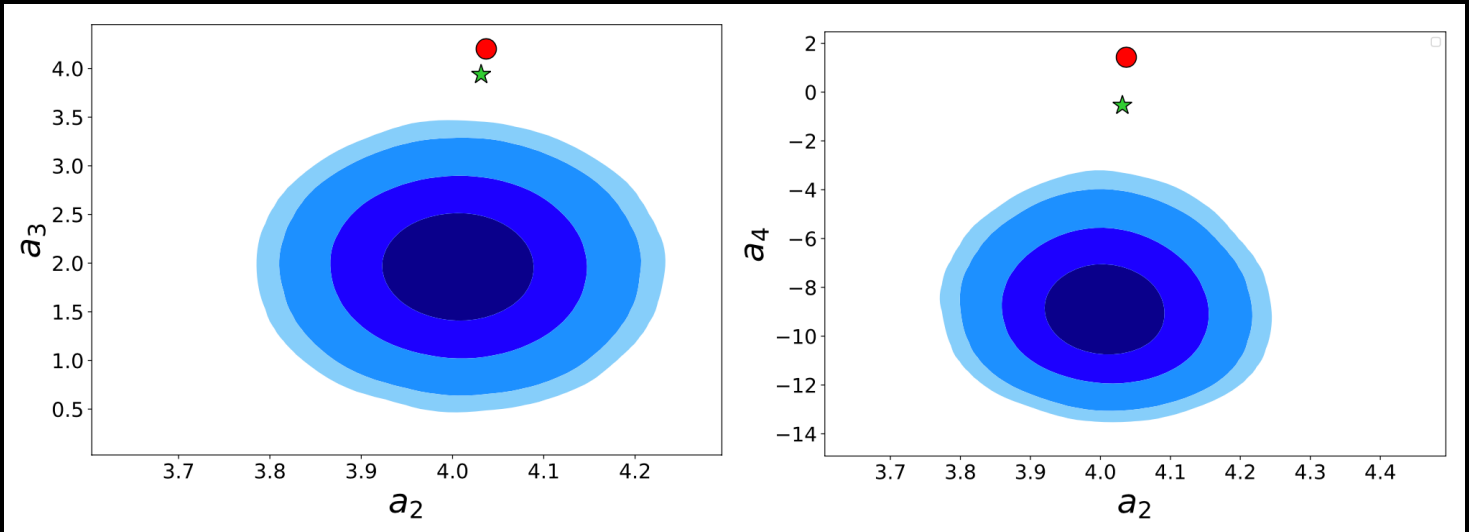
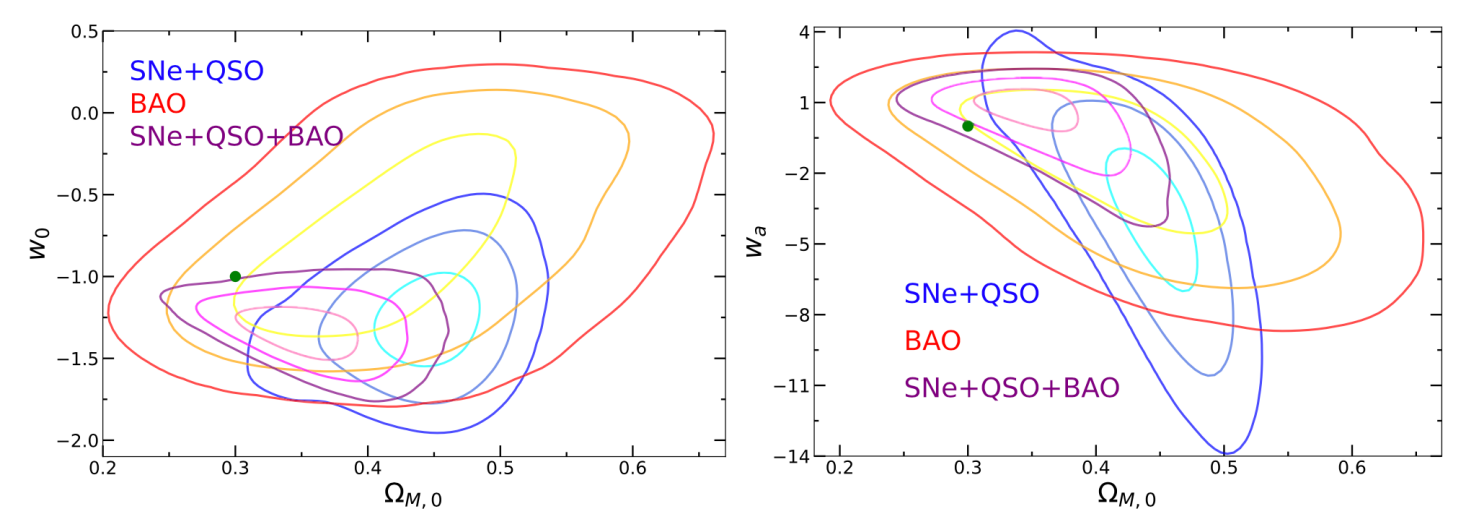


Cosmographic model

> 4σ tension with ΛCDM

(Bargiacchi+21)



CPL model

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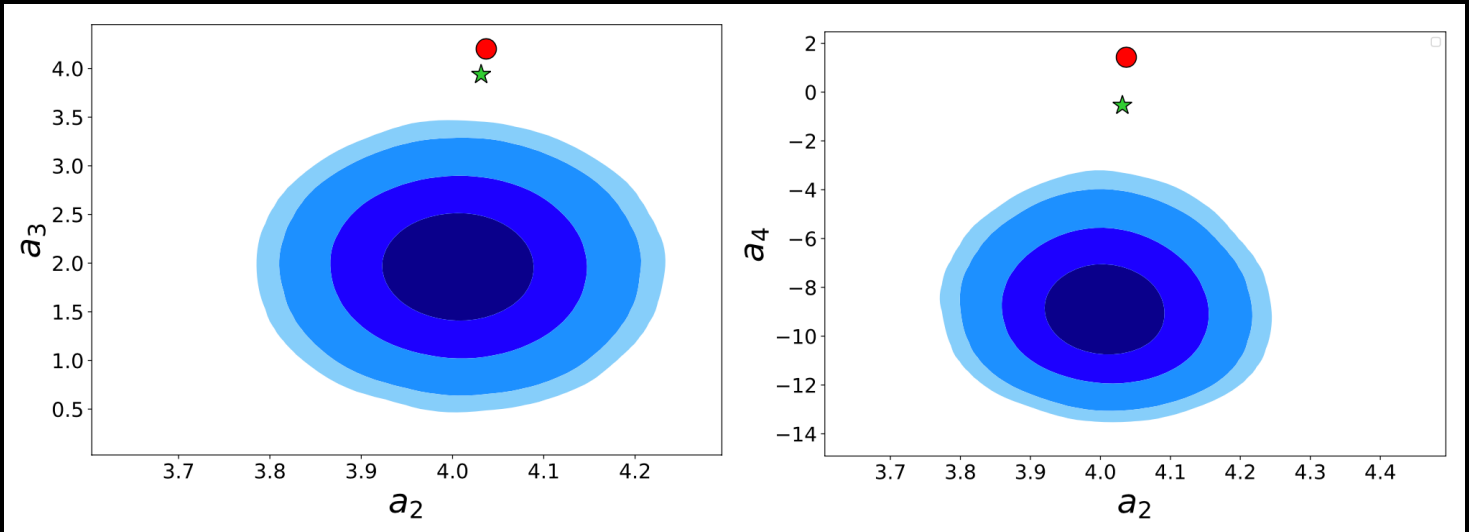

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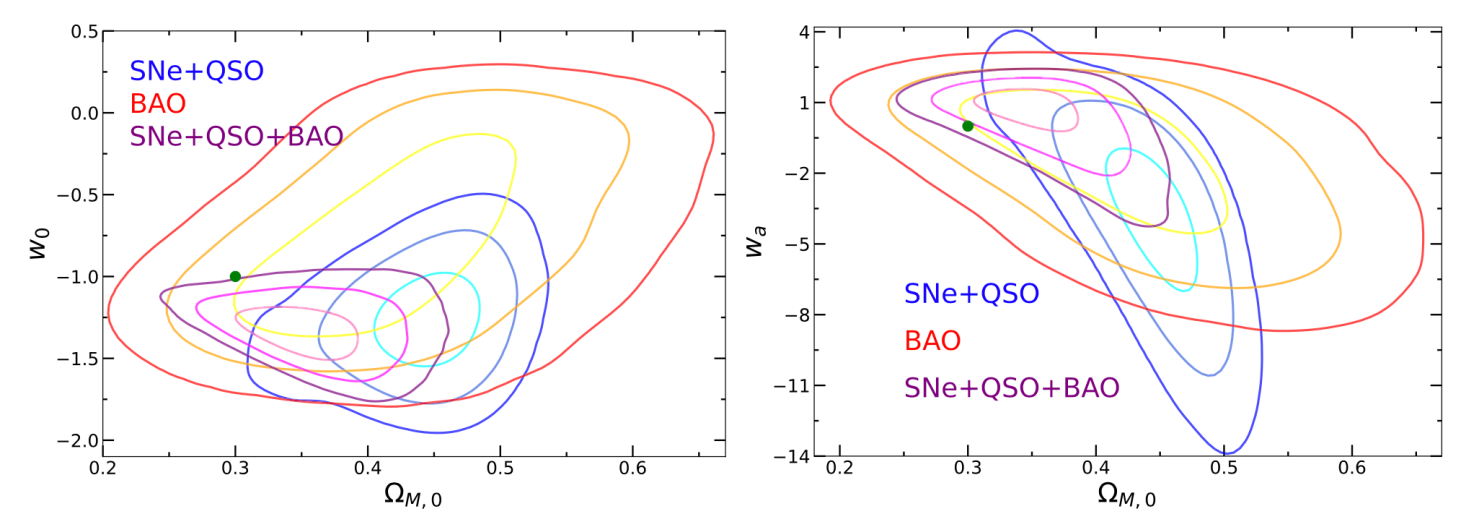

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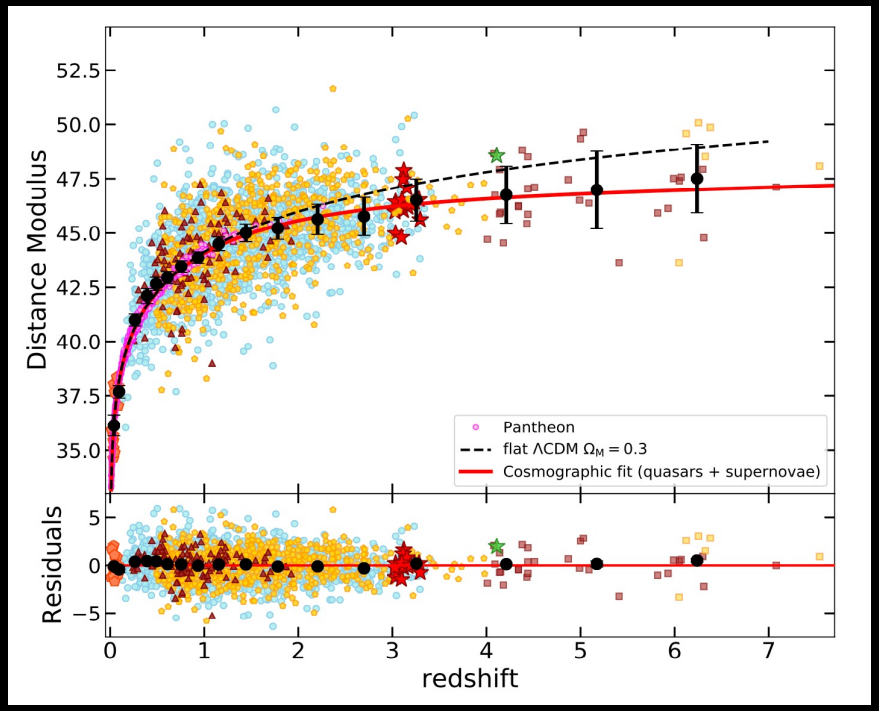
Quasars as Standard Candles: are they reliable ?



Is the X-ray to UV relation constant with redshift ?

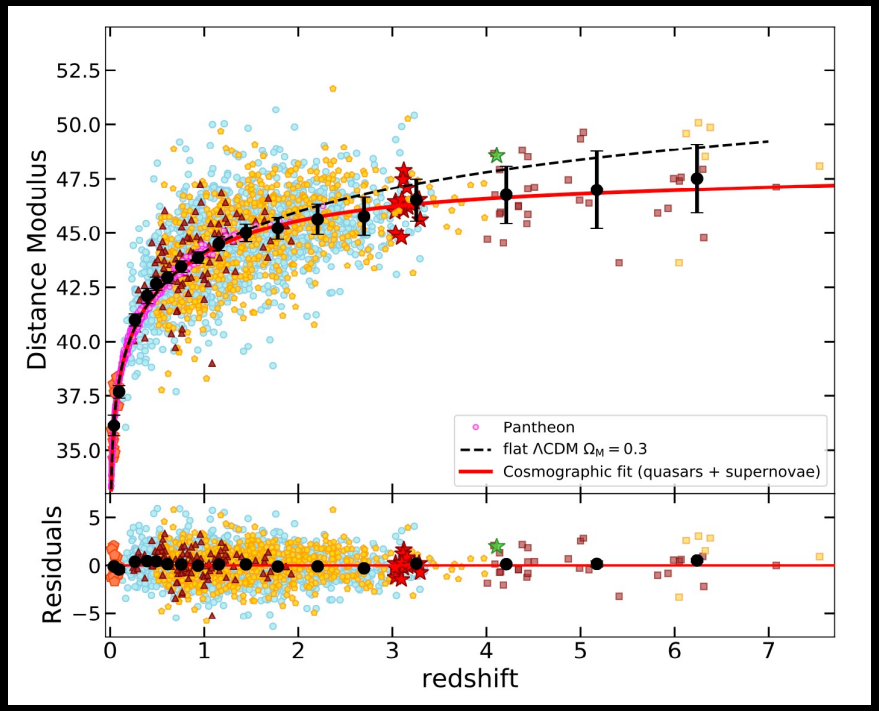
Are there selection effects in the sample ?

Are the quasars in the cosmological sample really *average* quasars or are we "cherry-picking" the ones we like?

Are there systematic effects in the flux measurements ?

Can reddening (extinction, host galaxy contamination) affect our sample?

Quasars as Standard Candles: are they reliable ?



- Comparison with SN Ia in the common redshift interval
- Relation slope vs. redshift
- Detailed spectral analysis (dust reddening, etc...)
- Quasar spectral properties as a function of redshift
- Reduction of the dispersion
- Analysis of the intrinsic dispersion

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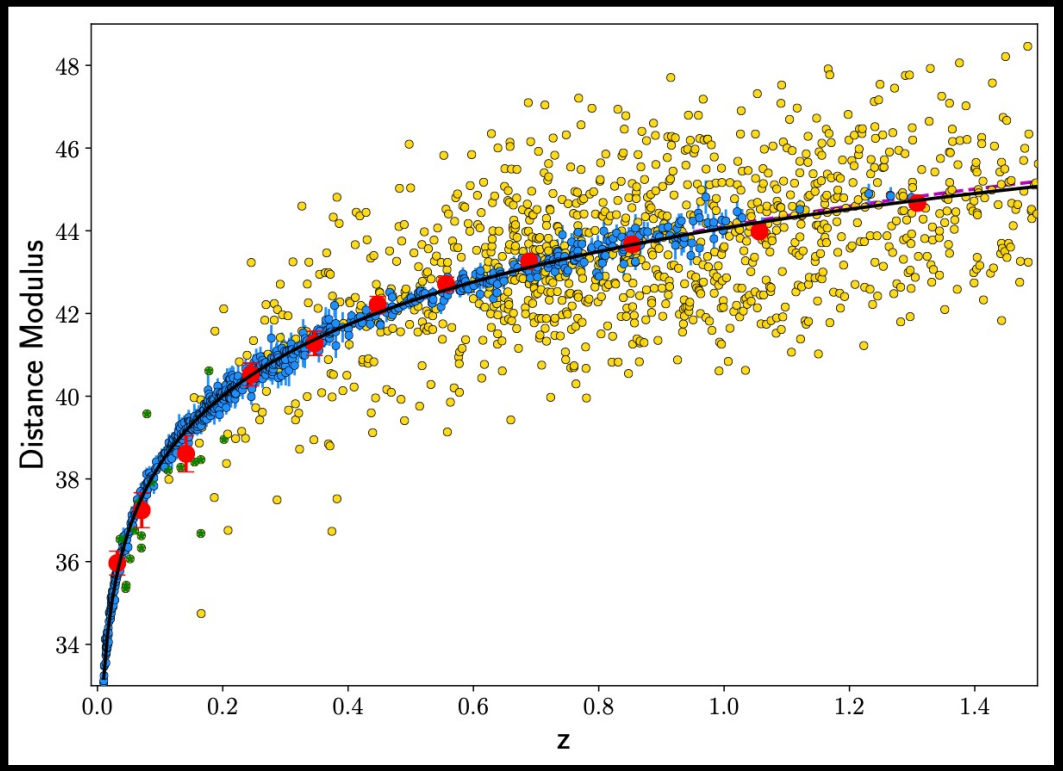

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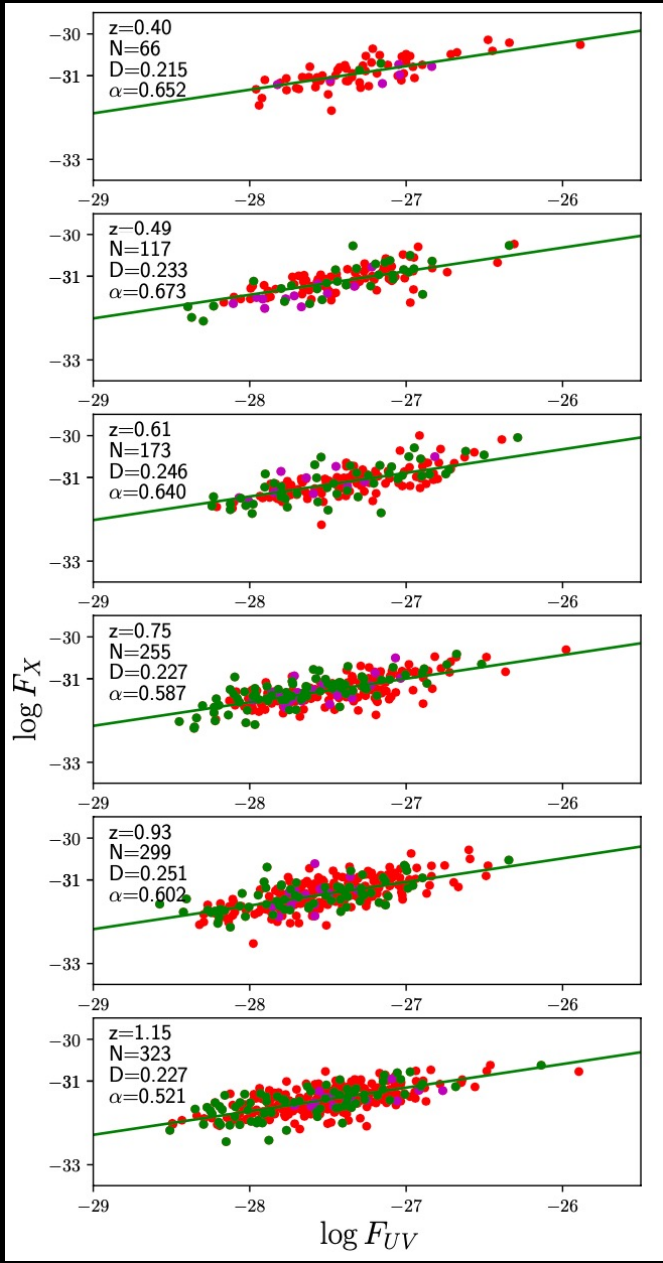

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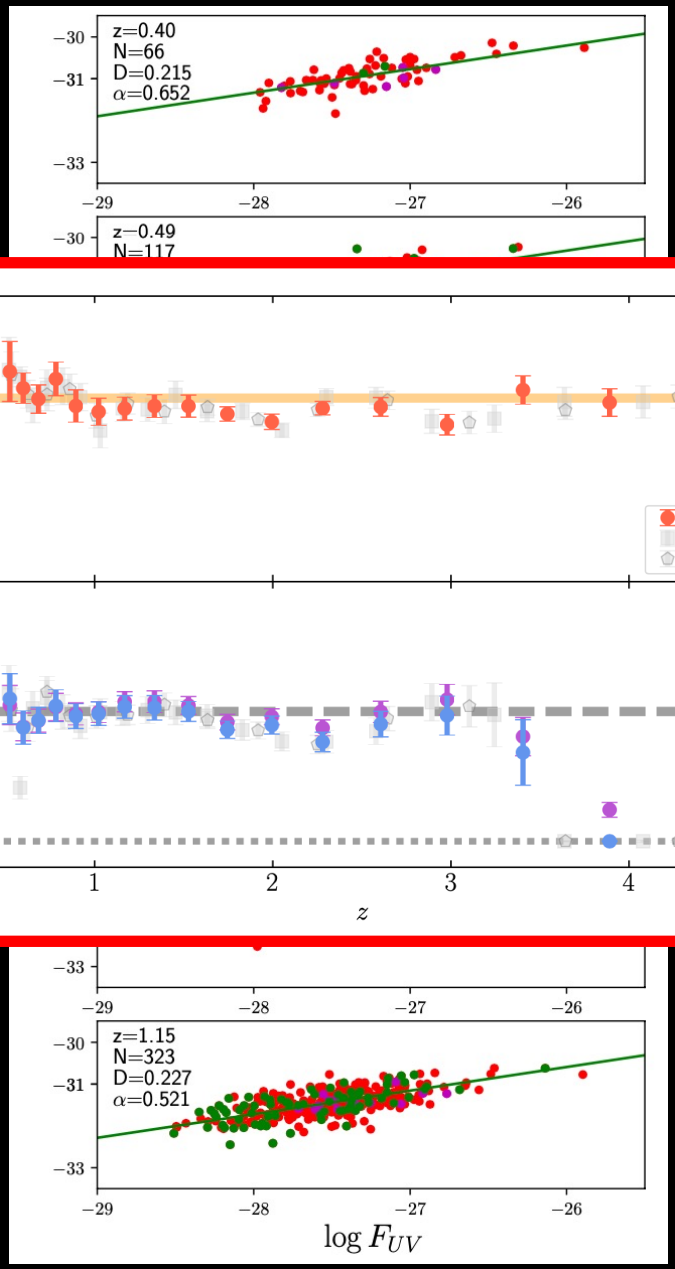

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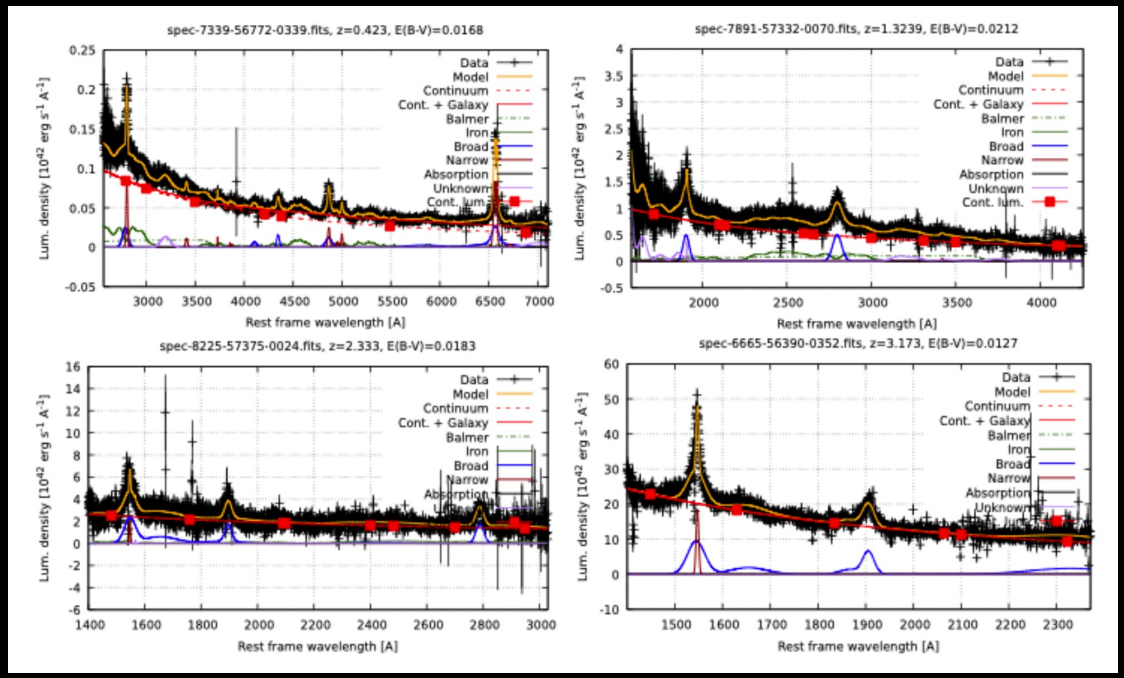
Optical/UV Complete spectral analysis



Signorini et al. 2023a

- Comparison with SN Ia in the common redshift interval

Relation slope vs. redshift

Detailed spectral analysis (dust reddening, etc...)

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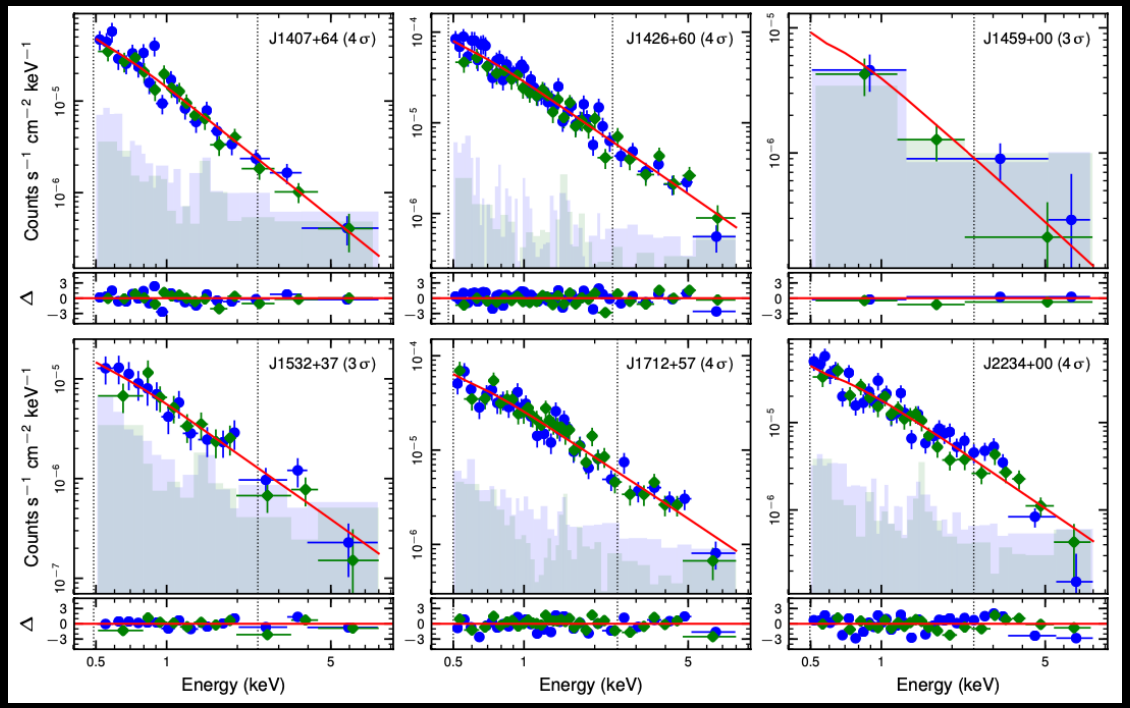
X-ray Complete spectral analysis (z >1.9)



Nardini et al. 2019, Signorini et al. 2023a

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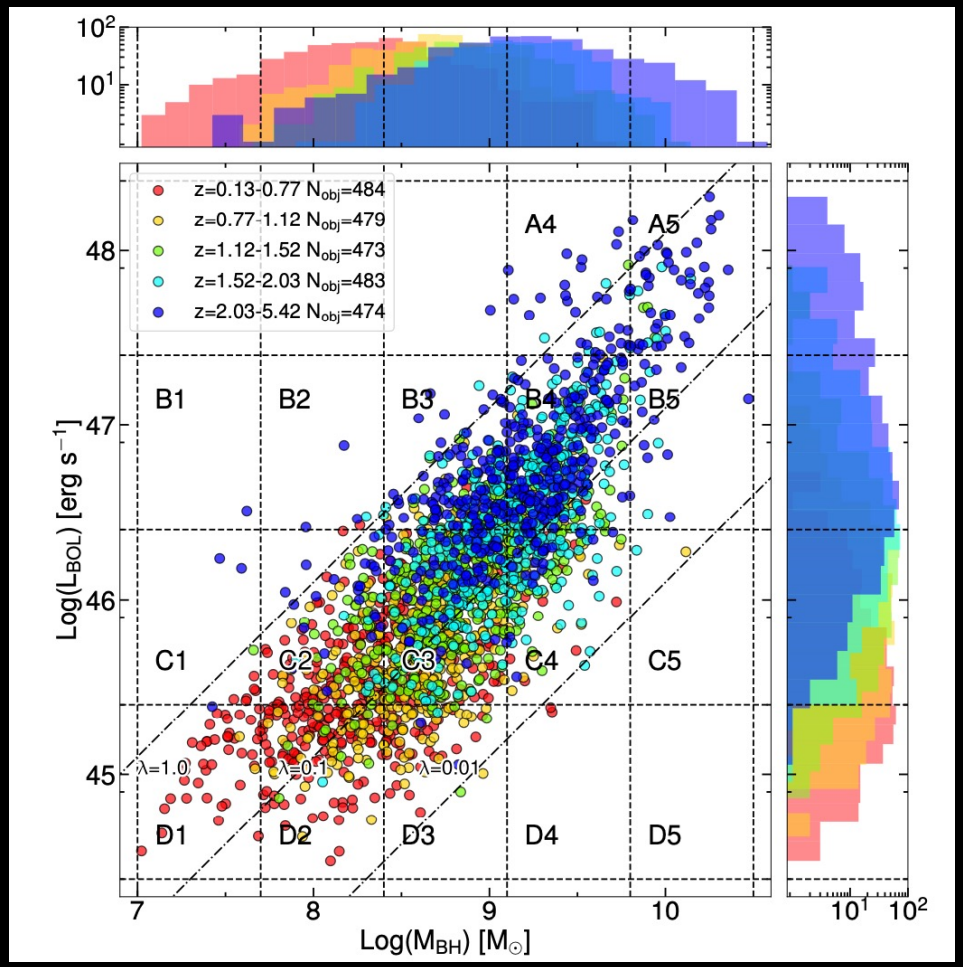
Analysis of stacked spectra



Trefoloni et al. 2023, in prep.

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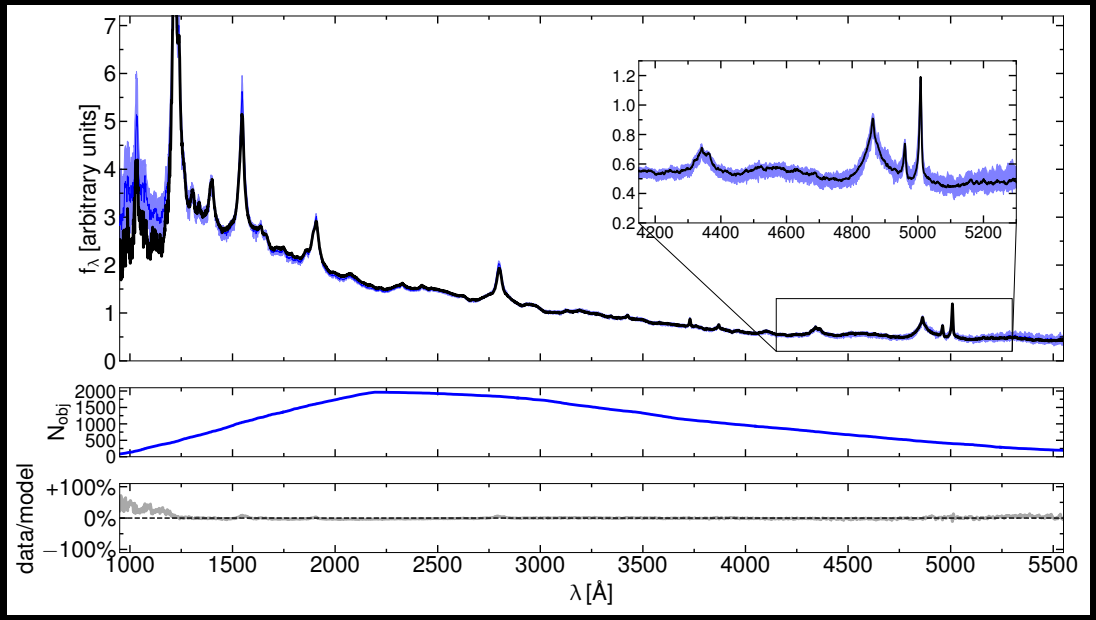

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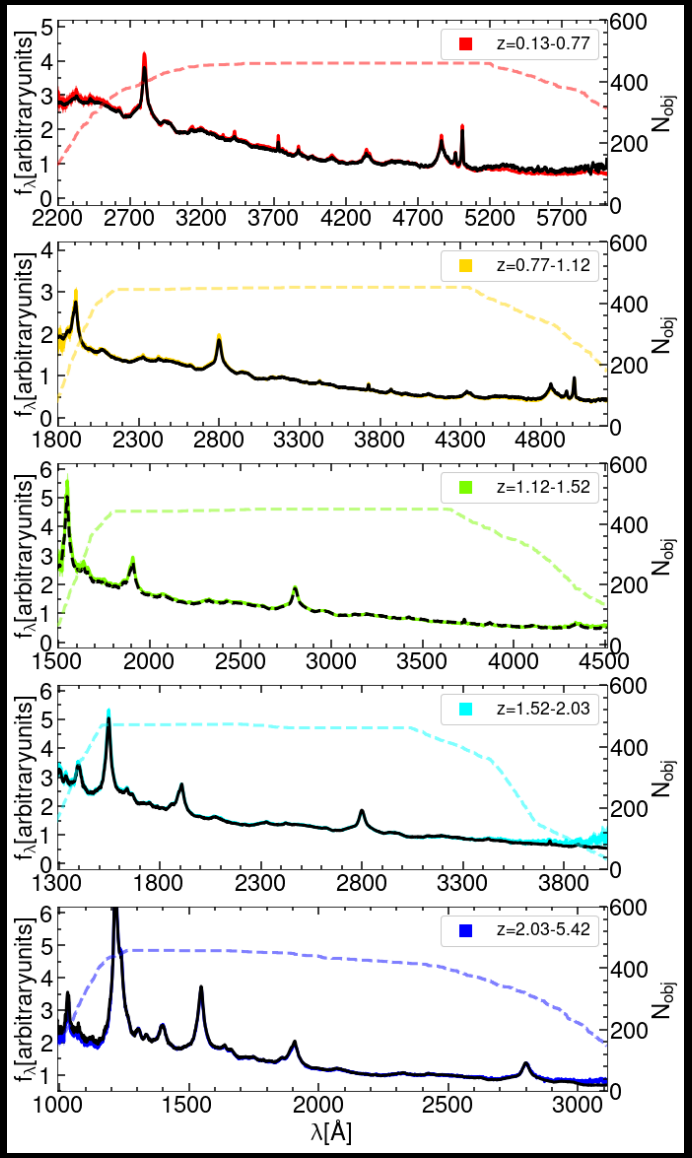

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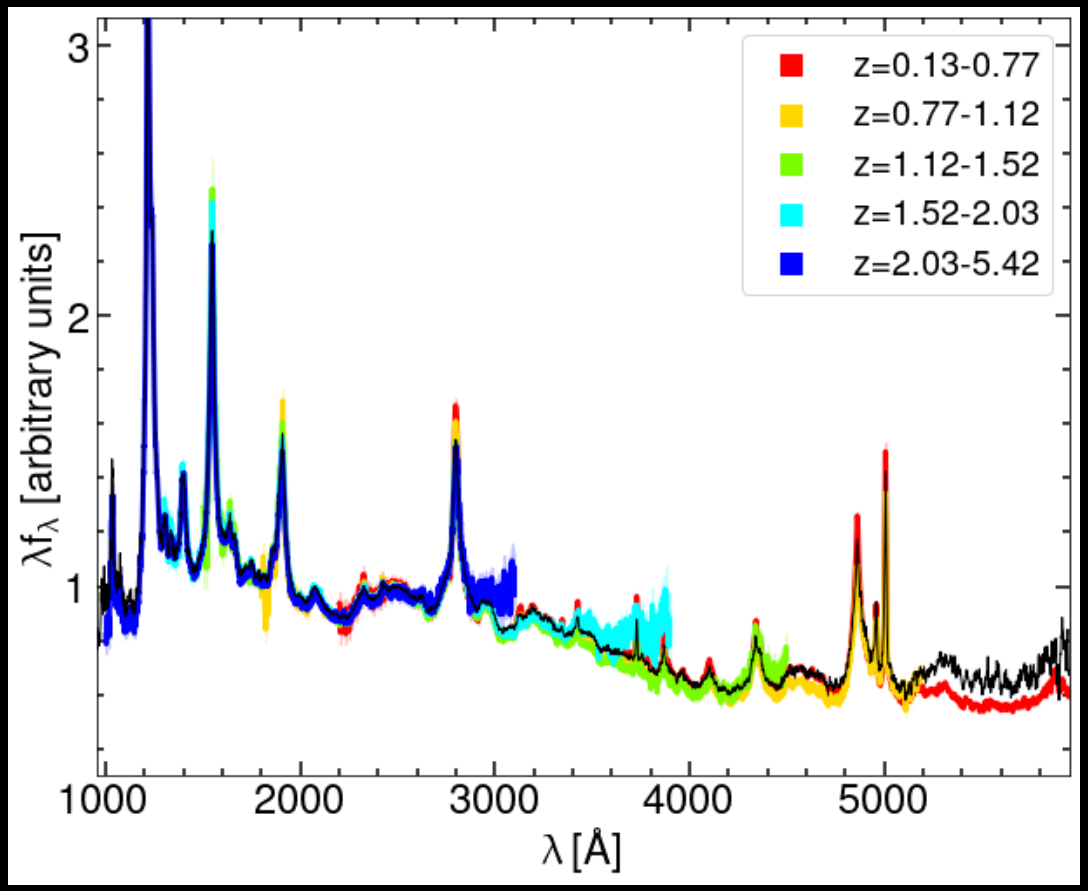

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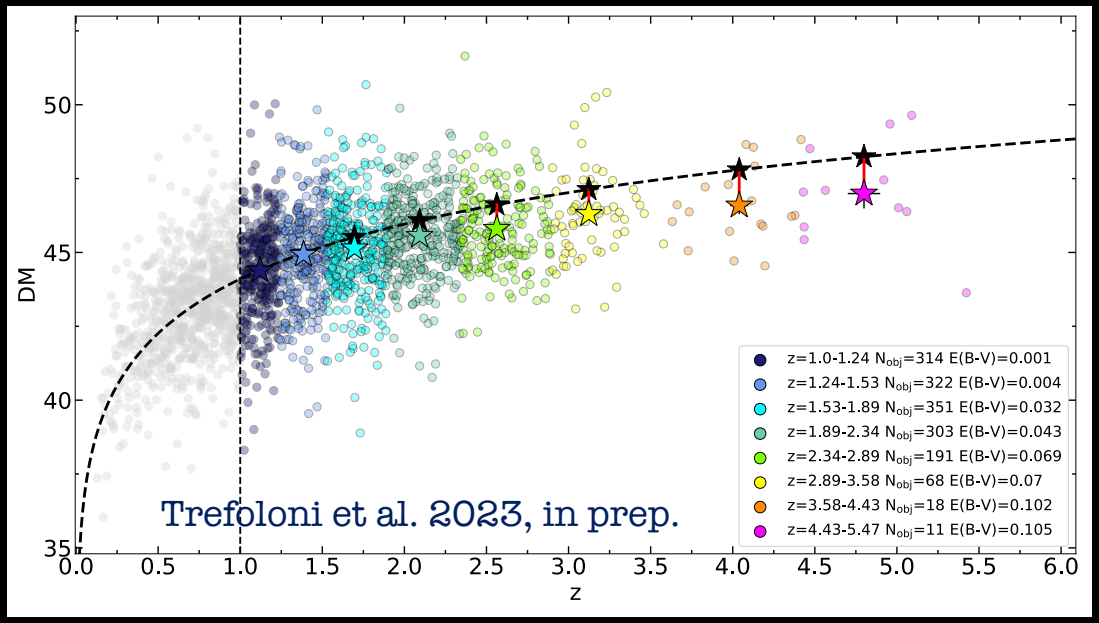

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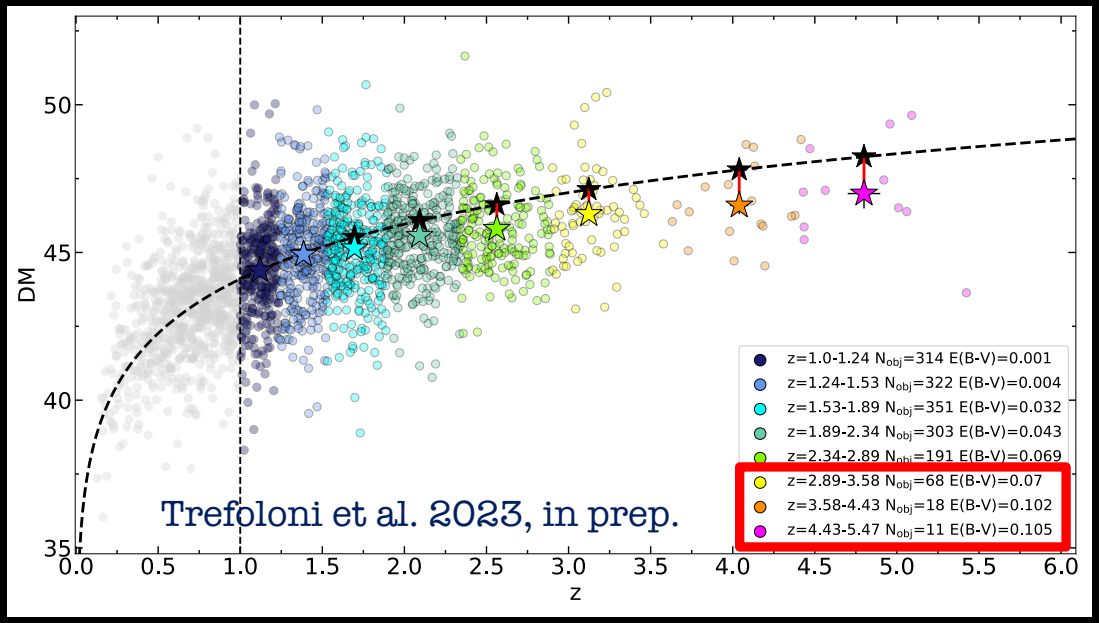

- z=2.89-3.58 N_{obj}=68 E(B-V)=0.07
- z=3.58-4.43 N_{obj}=18 E(B-V)=0.102
- z=4.43-5.47 N_{obj}=11 E(B-V)=0.105

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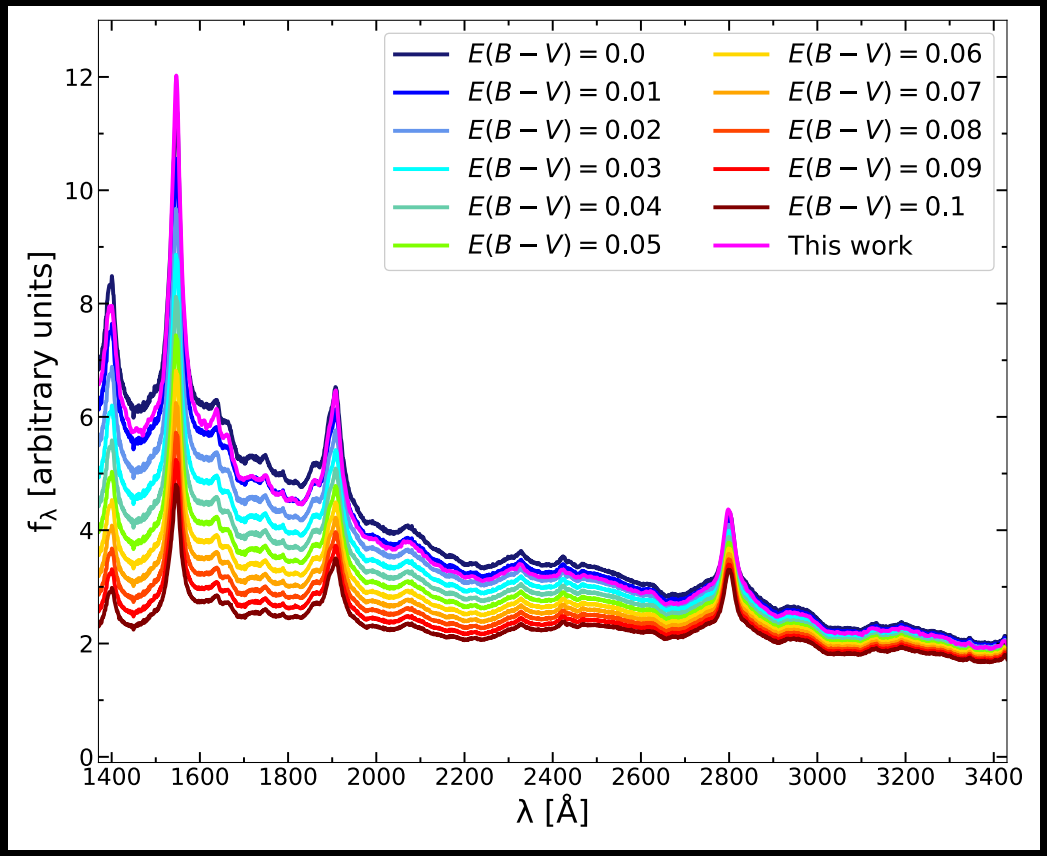

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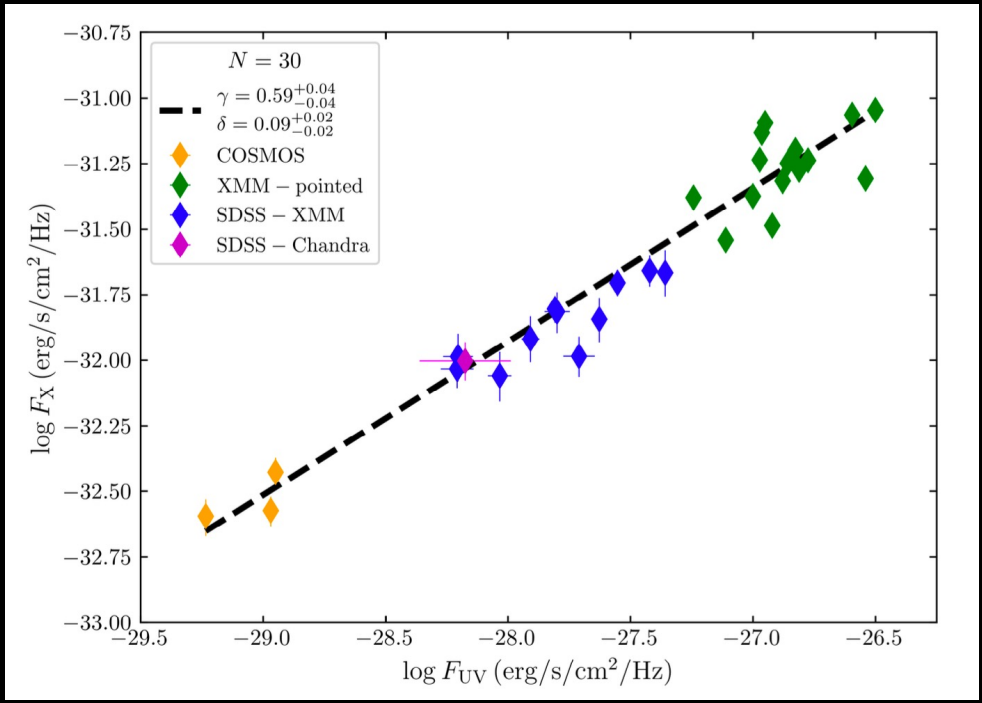
Lower dispersion with better data and better analysis



Sacchi et al. 2022

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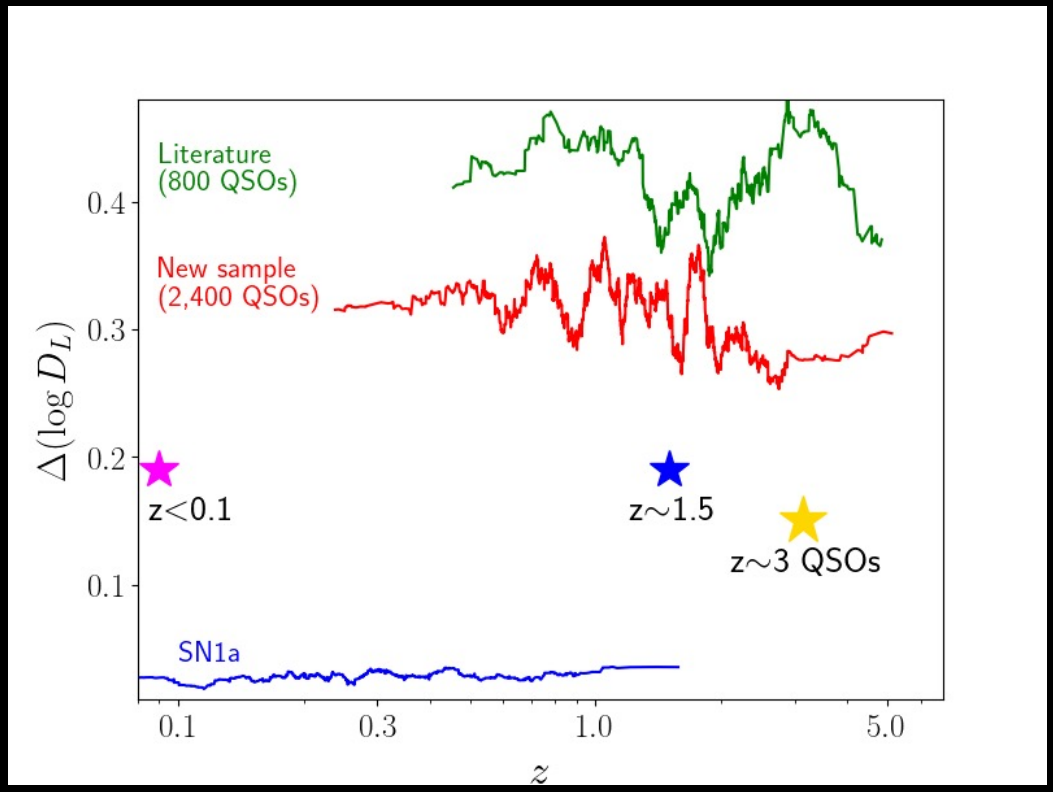

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At least two main "external" effects are still present:

1) X-ray variability
2) Inclination of the accretion disk:

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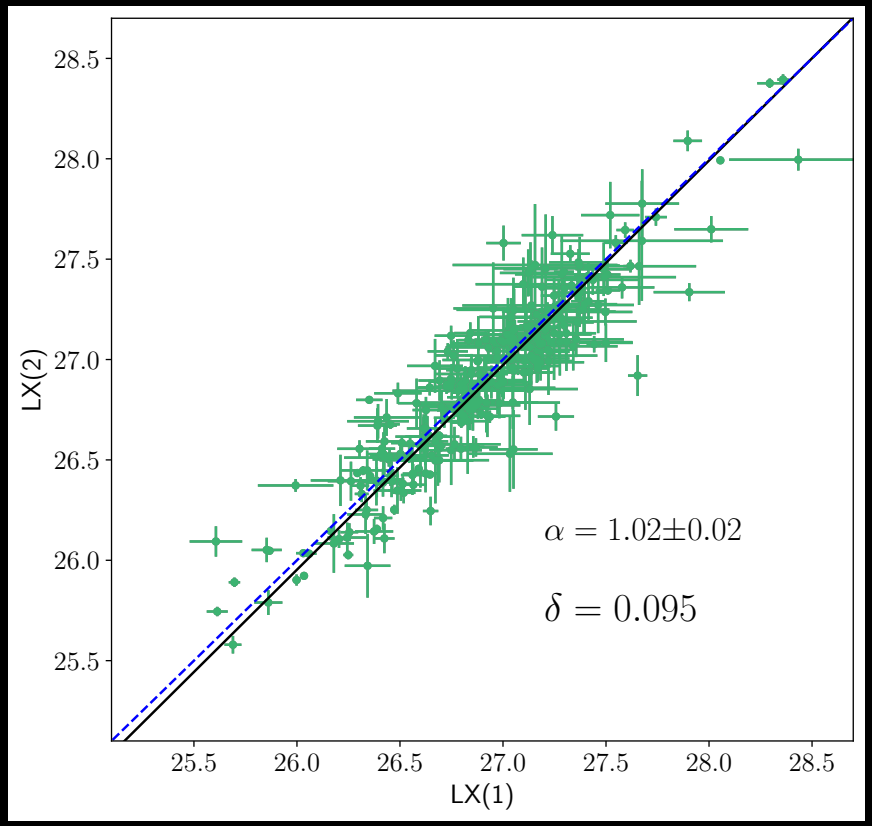

Signorini et al. 2023b, in prep.

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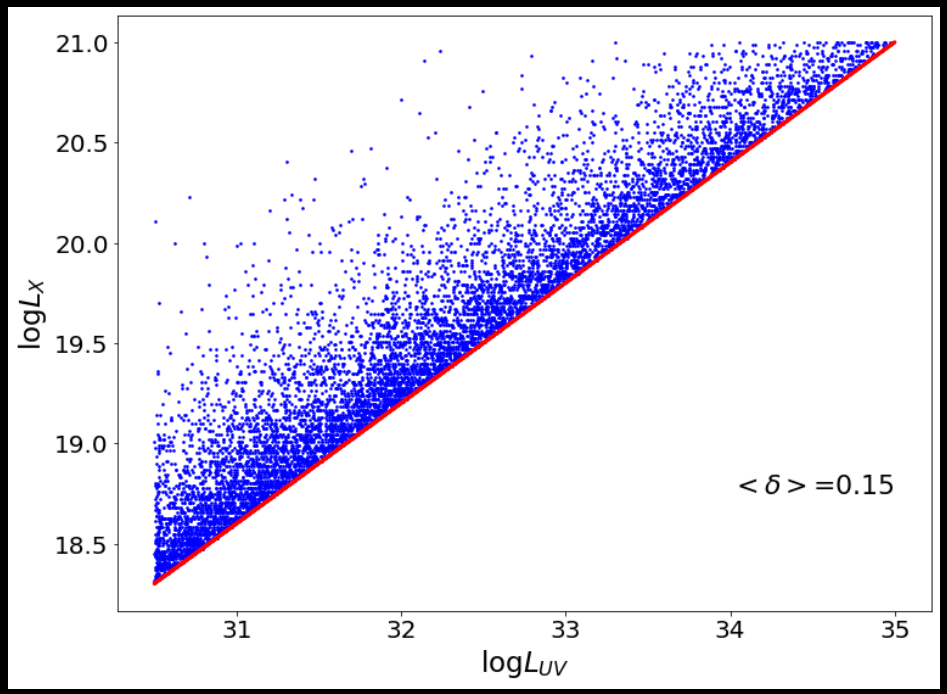

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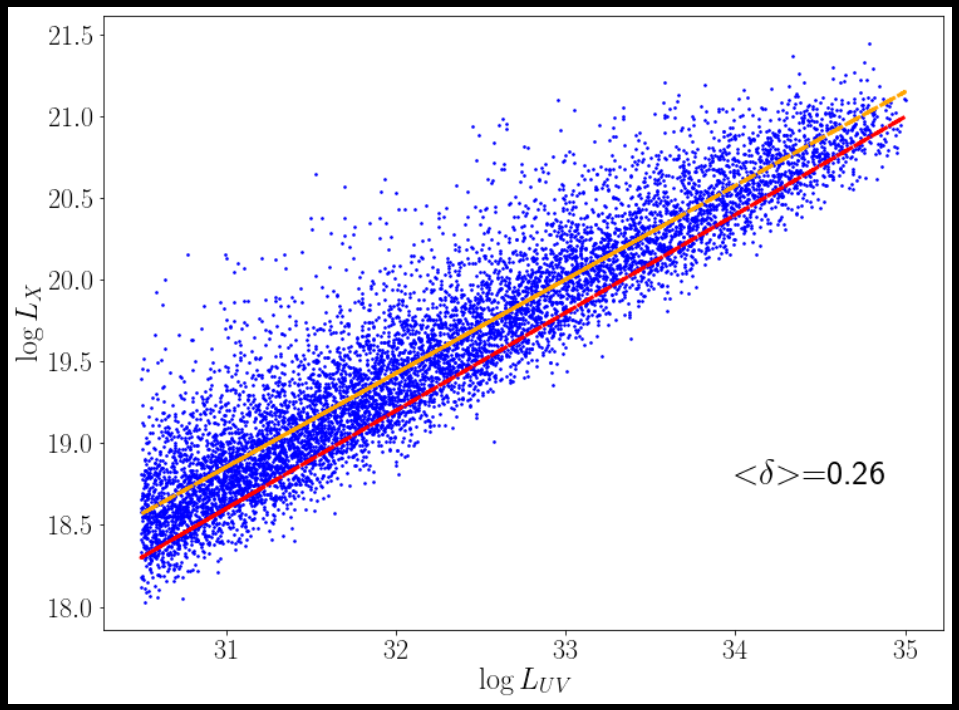

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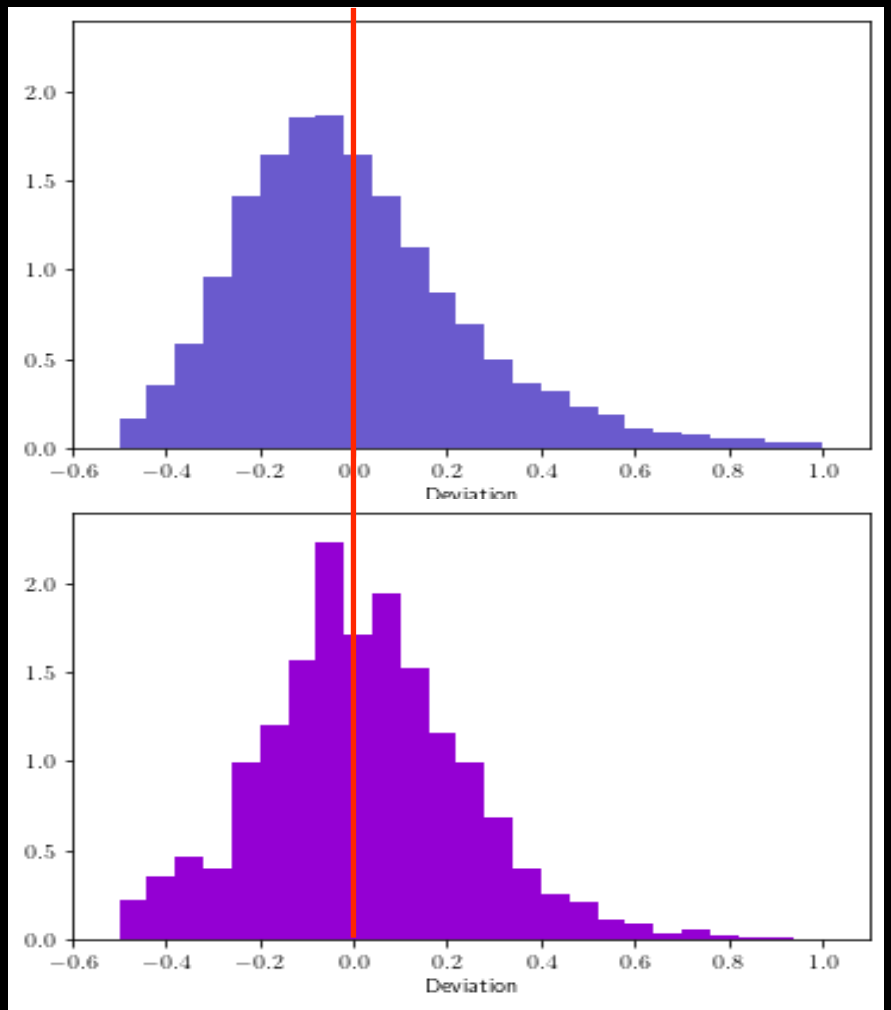

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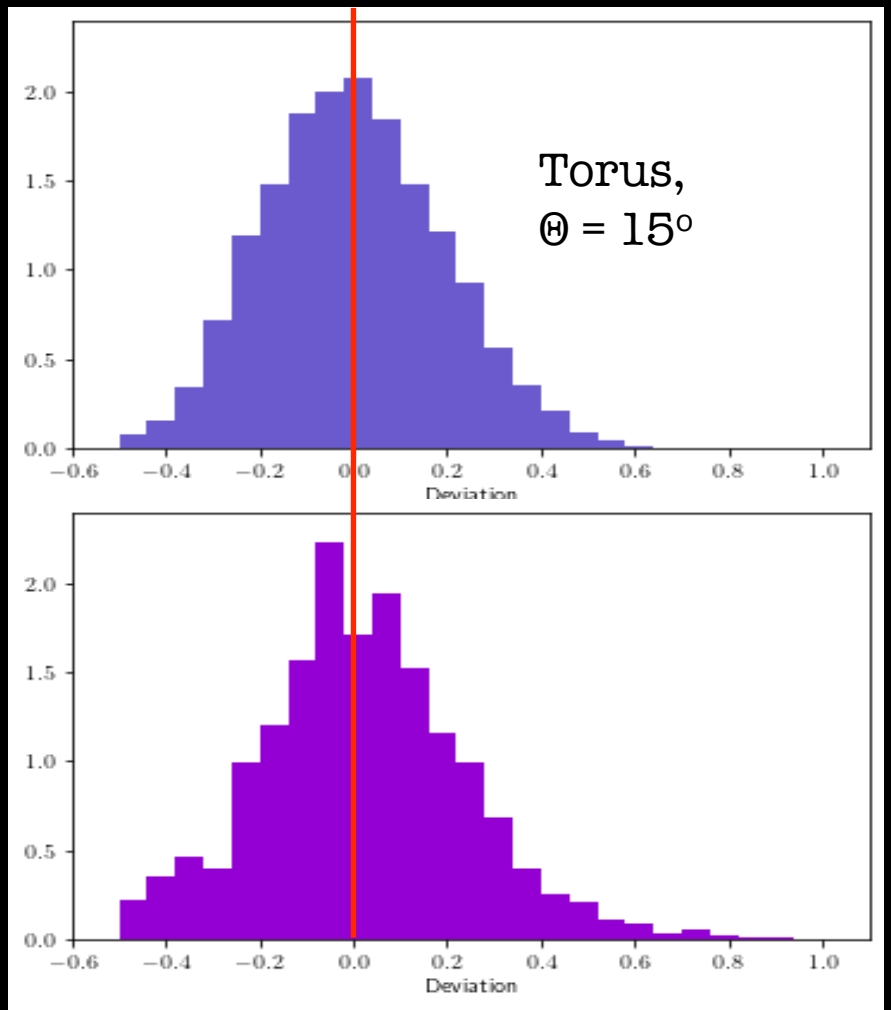

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Quasars as standard candles:

- No satisfactory physical model for the disk-corona connection
- Dispersion still higher than that of supernovae

BUT

- Slope not evolving with redshift
- Spectral properties non evolving with redshift
- Perfect match with supernovae in the common redshift range
- Dispersion decreasing with better flux measurements
- Dispersion entirely explained with “external” effects (inclination, variability)