Active Galactic Nuclei as cosmological probes

Elisabeta Lusso

Junior Research Fellow (CoFund)

G. Risaliti (Uni. of Florence-INAF), *S. Bisogni* (INAF Arcetri/Harvard CfA),
E. Nardini (INAF Arcetri), F. Salvestrini (DIFA-INAF), C. Vignali (DIFA),
M. Elvis (Harvard CfA), M. Salvati (INAF Arcetri), F. Civano (Harvard CfA),
R. Gilli (OaBo-INAF),

Treasures Hidden in High Energy Catalogues
IRAP, Toulouse (France), May 22, 2018

The power of optical/UV+X-ray catalogues: Active Galactic Nuclei as standard candles

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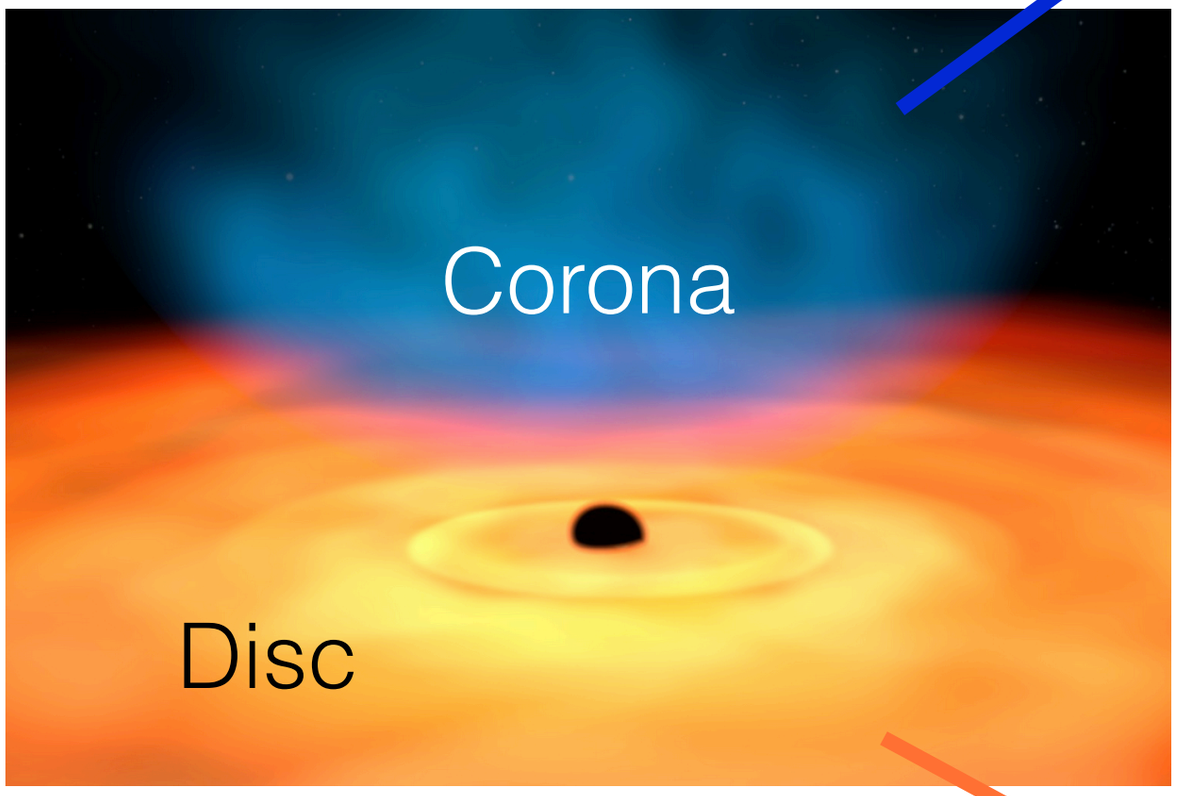
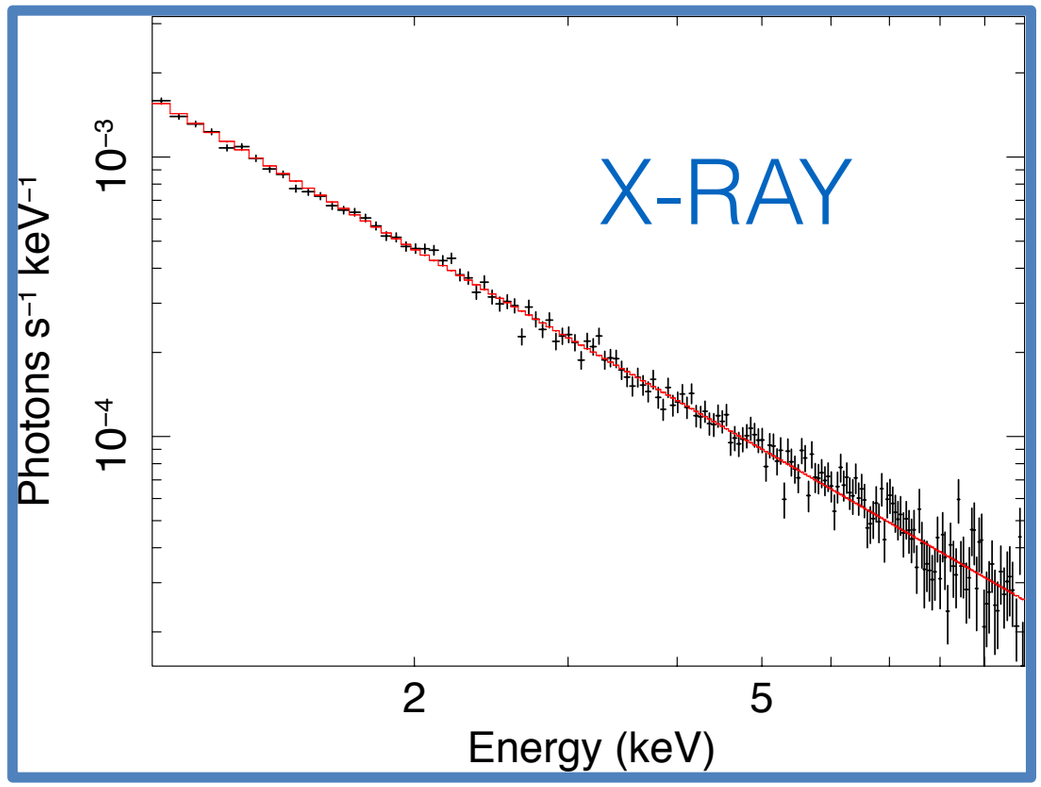
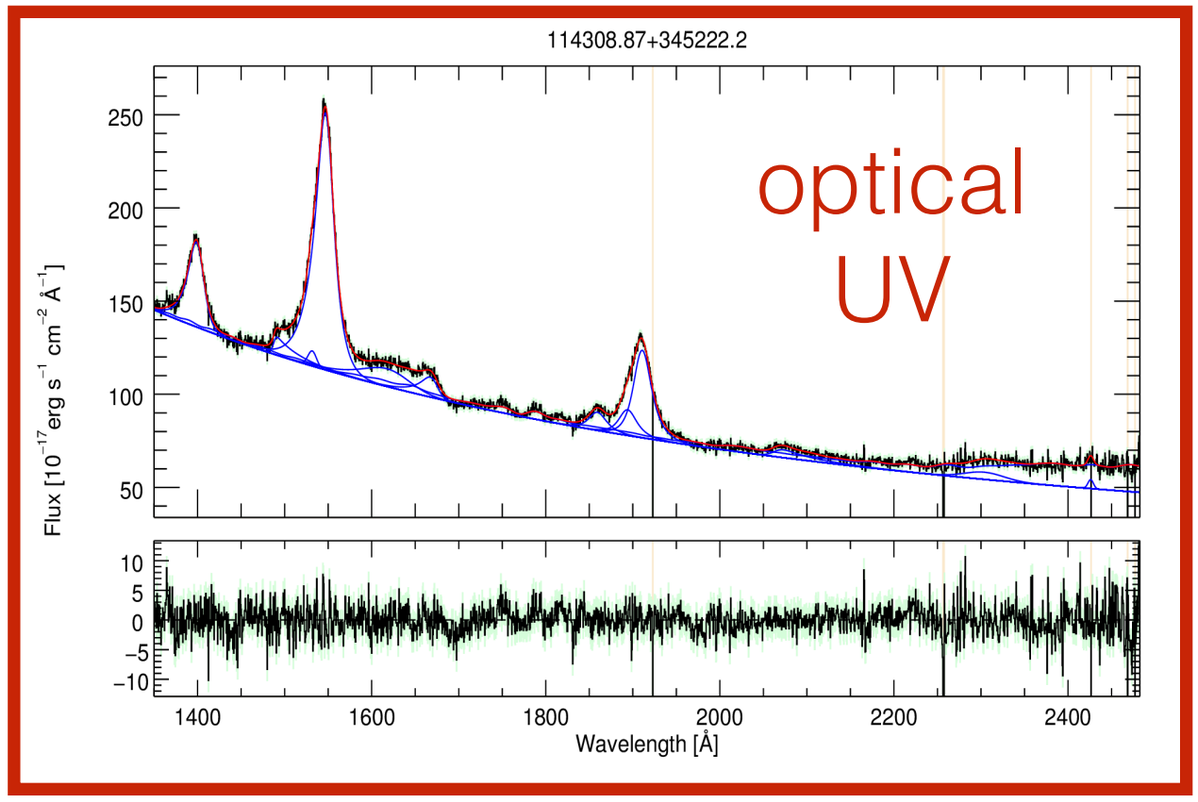
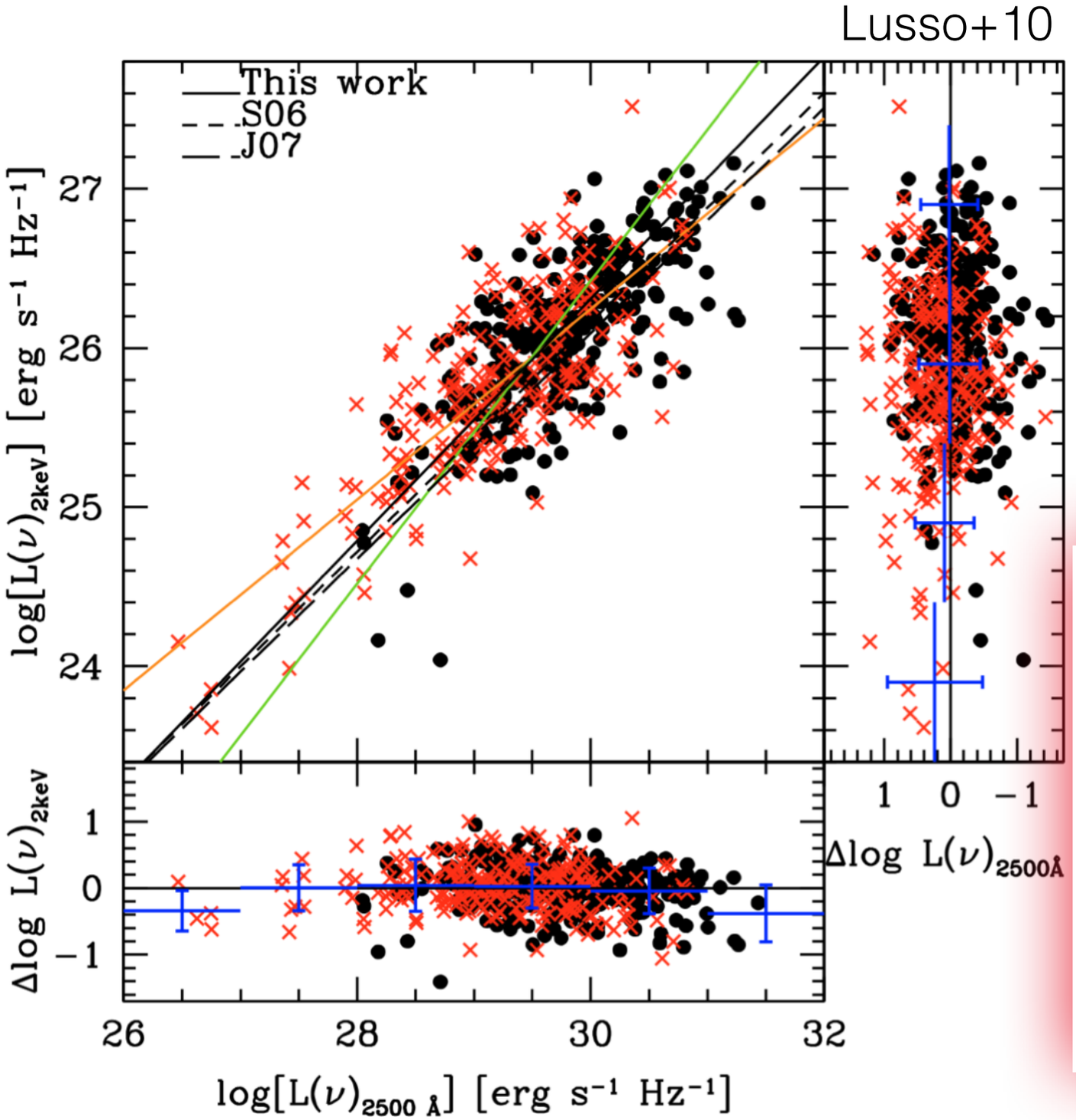
The disc-corona synergy







Our starting point: The X-ray/UV non-linear relation in AGN



$$\log(L_{\rm X}) = \beta + \gamma \log(L_{\rm UV})$$

γ≃0.6 (σ~0.35)

Goal: Evaluate the dispersion of the relation to the intrinsic degree
Method: take into account contaminants, systematics, evolution of the slope with time, etc

SMBH accretion physics
intrinsic dispersion of the UV/X-ray relation

2153 quasars selected from the
Sloan Digital Sky Survey DR7 with
X-ray observations from 3XMM-DR5

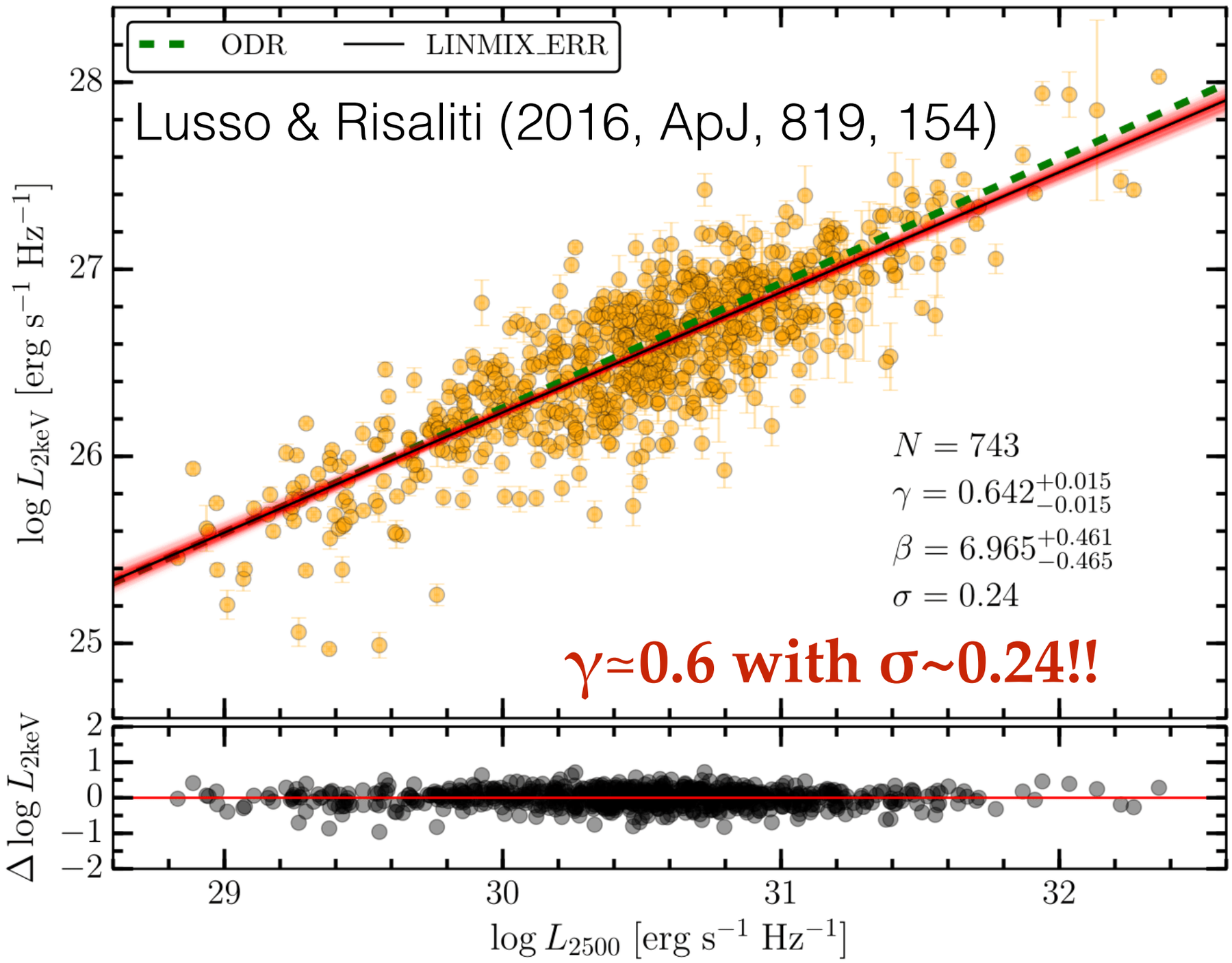
1. Reddening and host galaxy contamination
2. Uncertainties on X-ray fluxes do to unreliable source counts
3. X-ray absorption
4. No radio loud (based from FIRST only)
5. No BAL quasars
6. Eddington Bias

743 quasars with “clean SED”

Lusso & Risaliti (2016, ApJ, 819, 154)

SMBH accretion physics

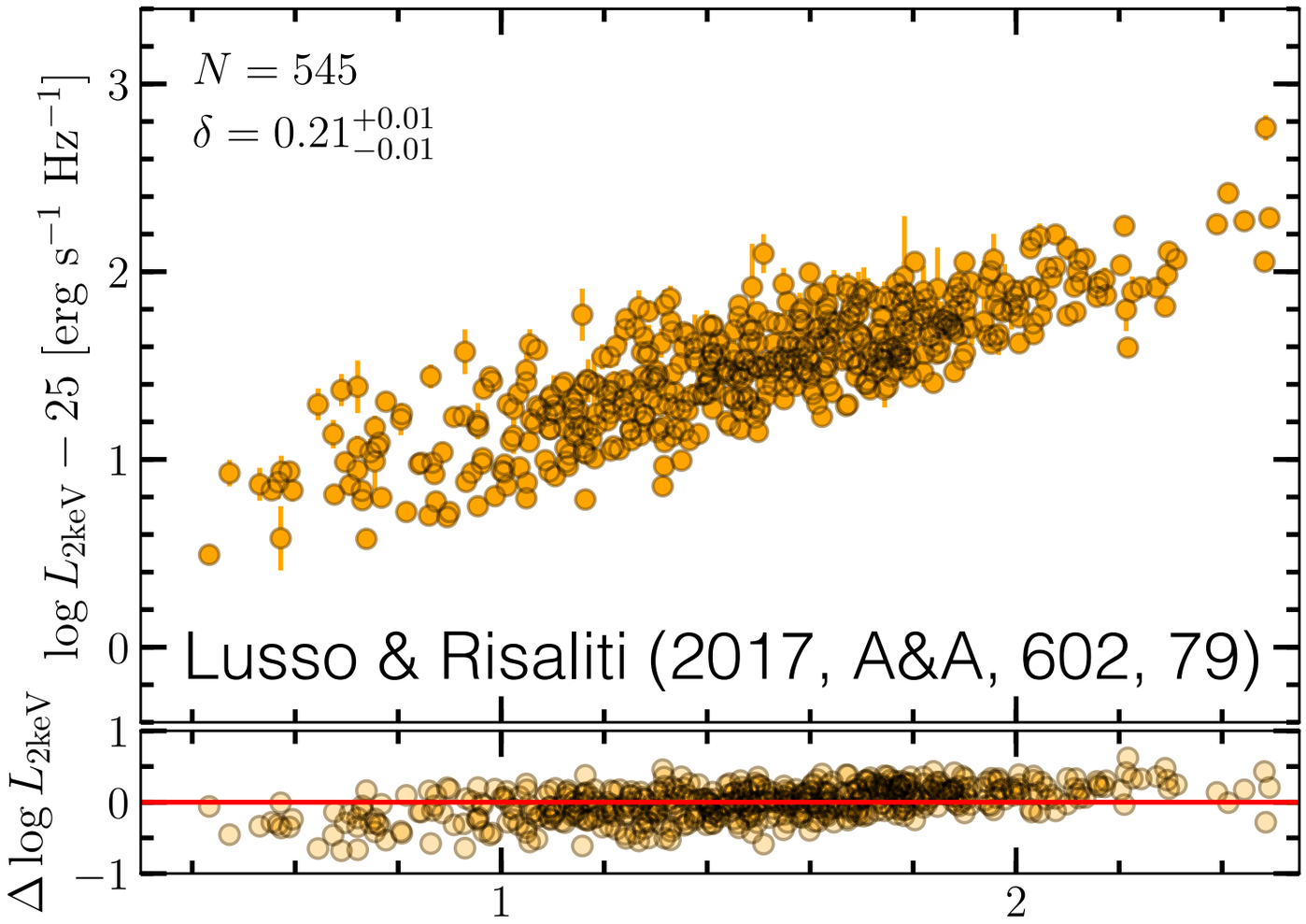
intrinsic dispersion of the UV/X-ray relation



SMBH accretion physics

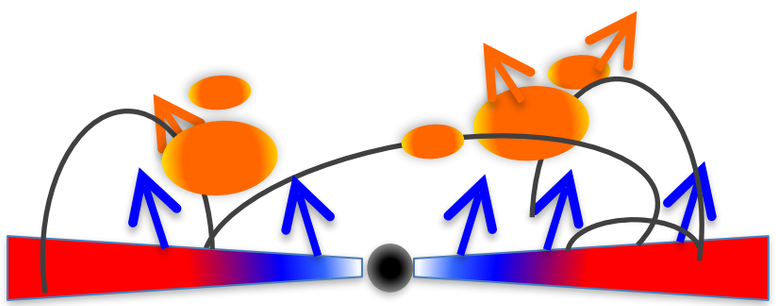
physical origin of the UV/X-ray relation

SDSS-DR7+
3XMM-DR6+
MIXR
(Mingo+2015)



Observed: $\log L_X \sim 0.61 \log L_{UV} + 0.54 \log FWHM$

Predicted: $L_X \sim L_{UV}^{0.57} FWHM^{0.57}$

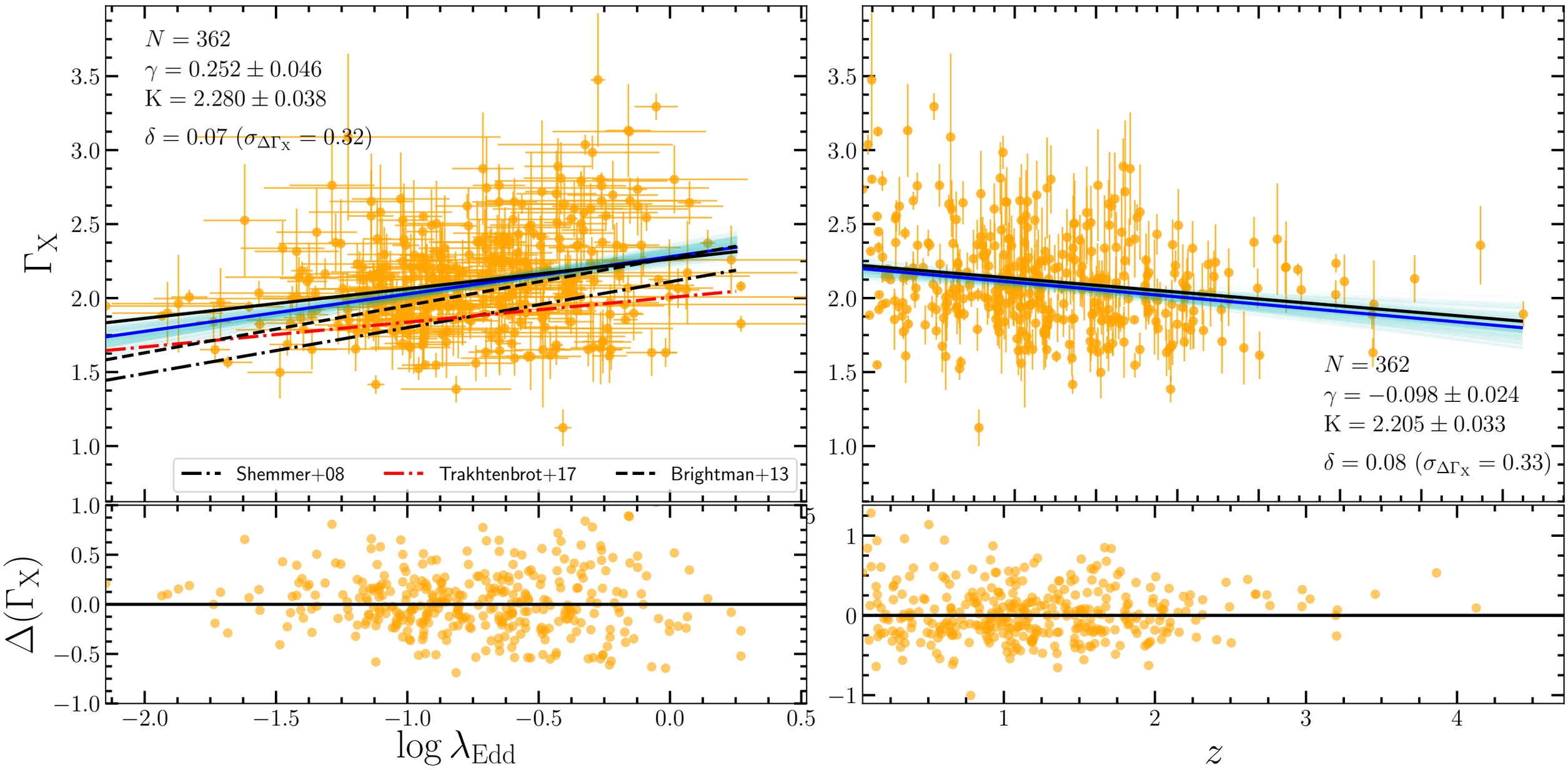


Shakura & Sunyaev (1973), Svensson & Zdziarski (1994), Merloni & Fabian (2002), Merloni (2003)

SMBH accretion physics

The Γ_X-λ_{edd} relation: SDSS-DR7+3XMM-DR7

Lusso et al., in prep.

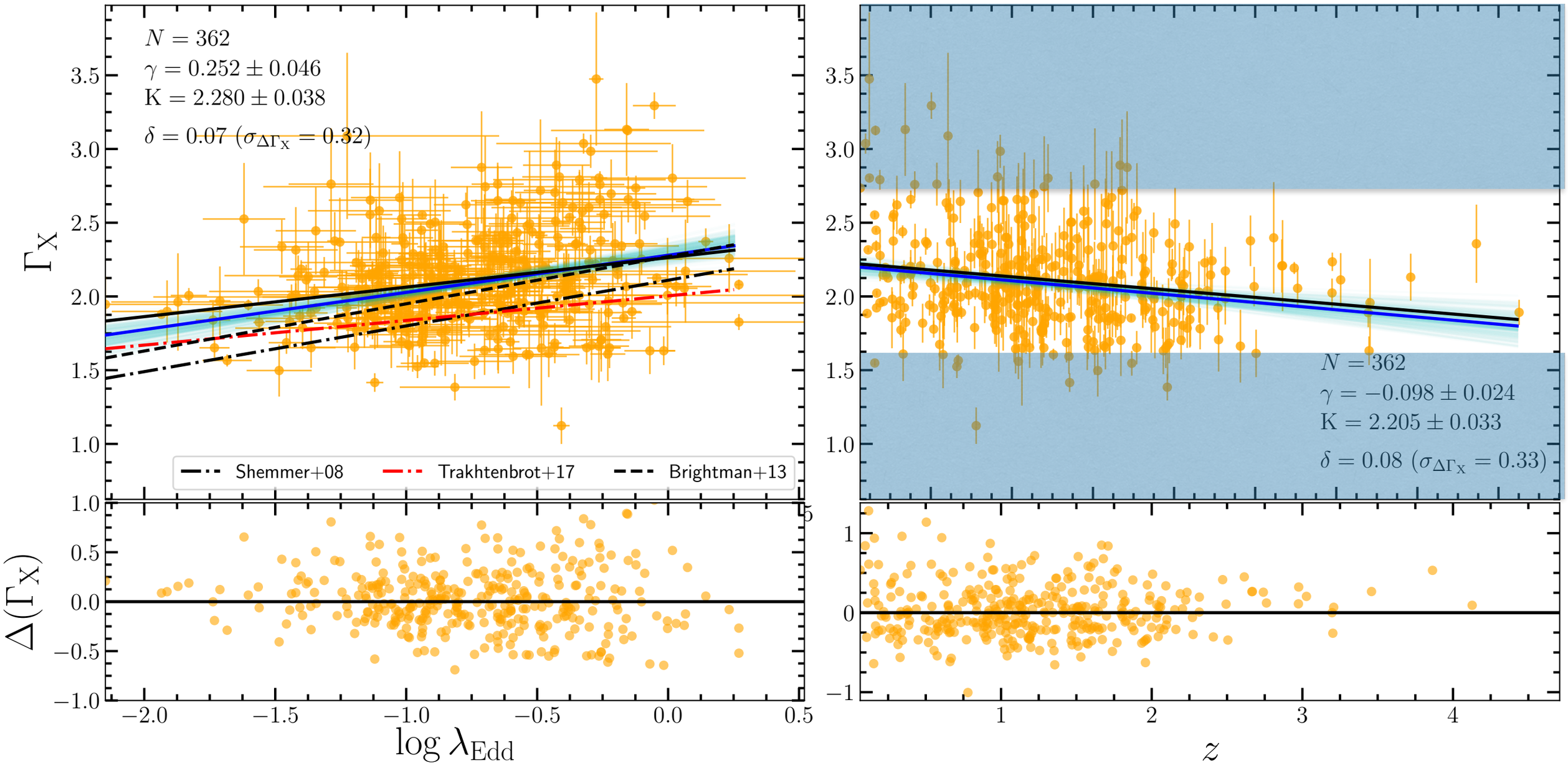


E(B-V)<0.1, offaxis<6 arcmin, cts(EPIC)>250

SMBH accretion physics

The Γ_X-λ_{edd} relation: SDSS-DR7+3XMM-DR7

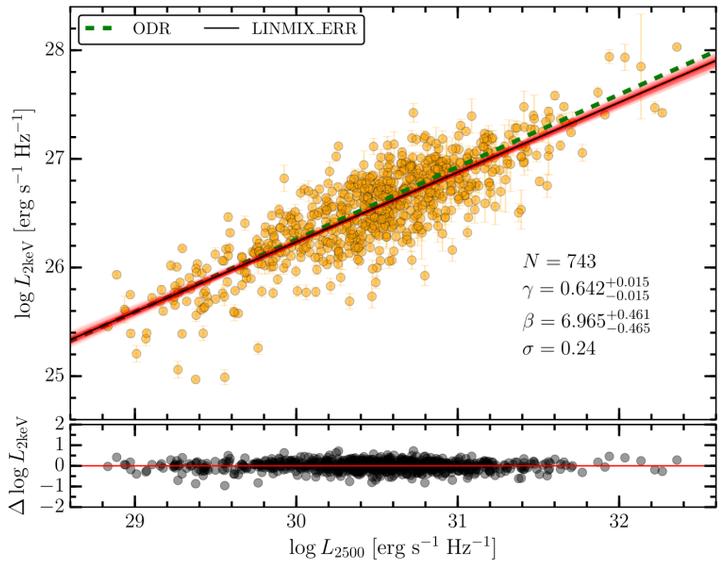
Lusso et al., in prep.

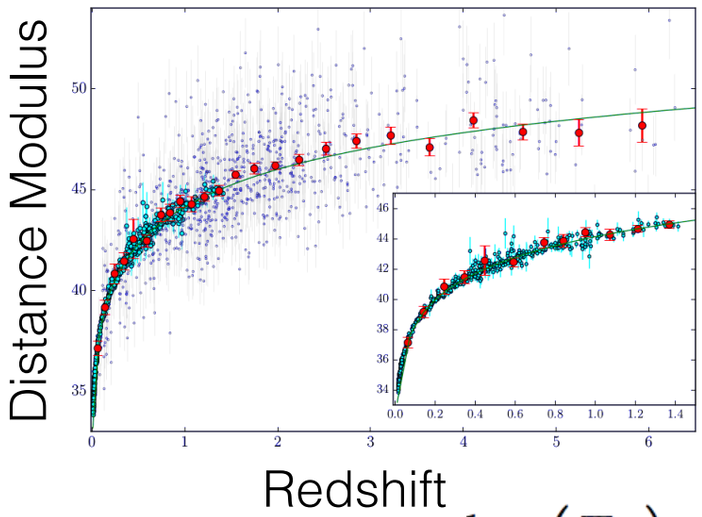


Detailed source-by-source analysis of the “outliers”

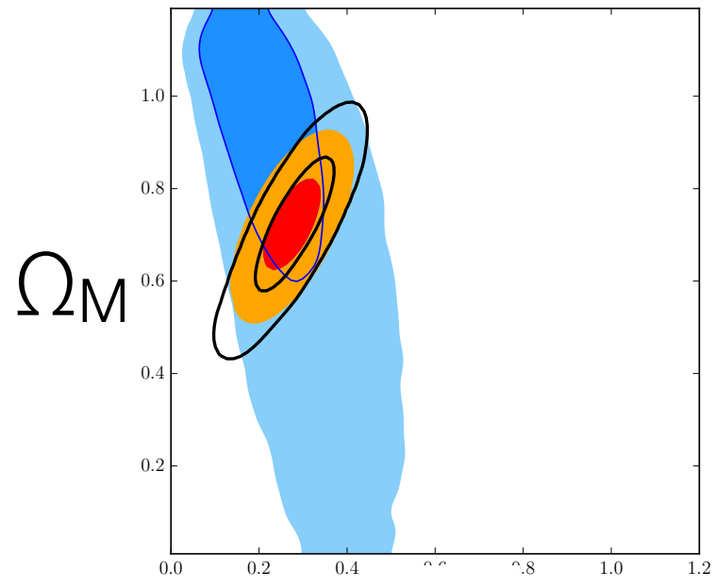
Cosmology with quasars

The distance modulus





$$\log(L_{\mathrm{X}}) = \beta + \gamma \log(L_{\mathrm{UV}})$$



$$\log(F_{\mathrm{X}}) = \beta' + \gamma \log(F_{\mathrm{UV}}) + 2(\gamma - 1)\log D_L(z,\Omega_M, \Omega_\Lambda)$$

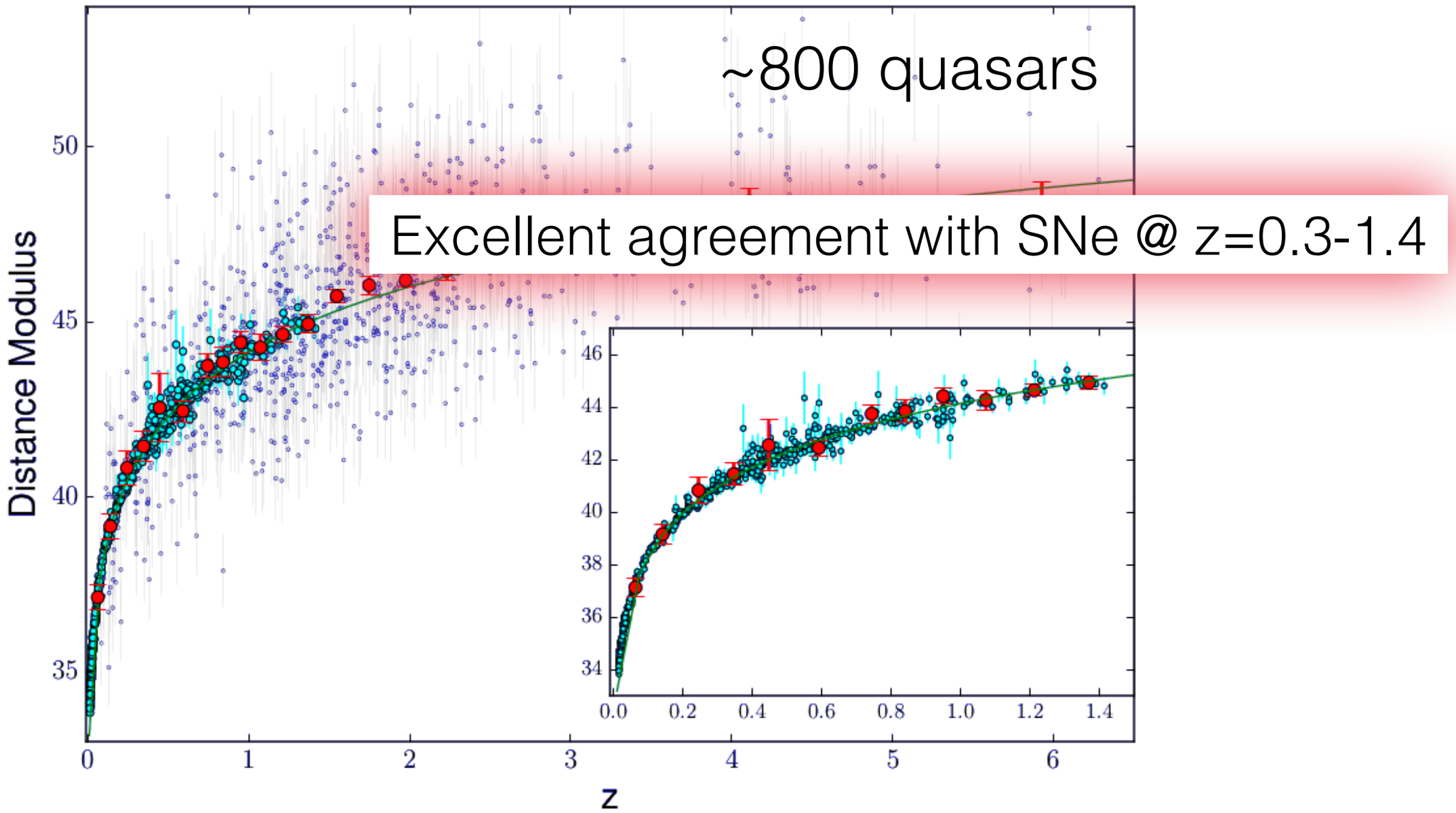
The non-linear L_X-L_{UV} relation as a way to measure quasar distances

See: Risaliti & Lusso (2015, ApJ, 815-33),
Risaliti & Lusso (2017, AN, 201713351)

Cosmology with quasars

The *Quasars Hubble Diagram*

Risaliti & Lusso (2015, ApJ, 815-33)



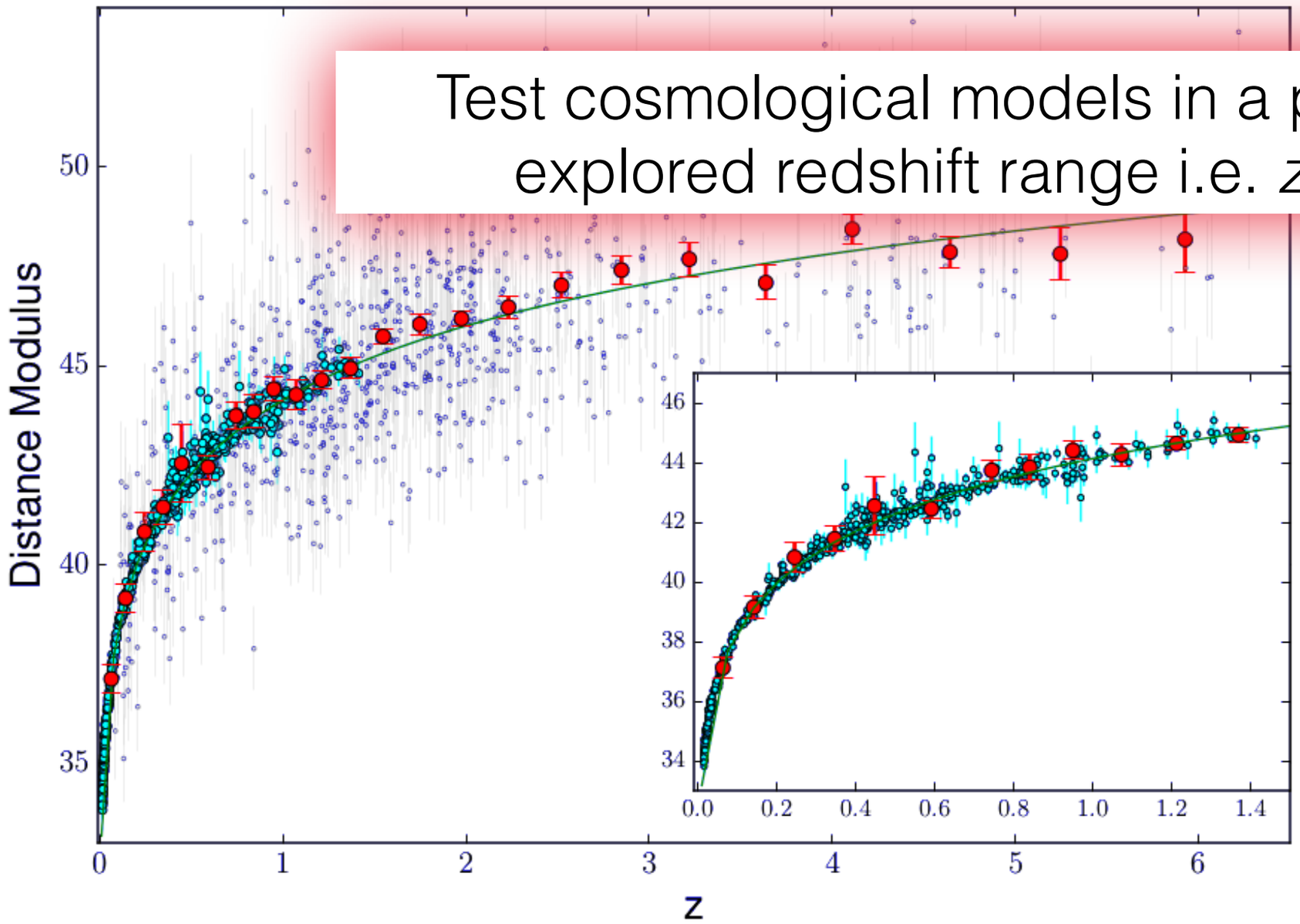
Type 1a SN: Supernovae Cosmology Project (Sullivan+11, Suzuki+12)

See also: Risaliti & Lusso (2017, AN, 201713351)
Bisogni, Risaliti, and Lusso (2017, FrASS, 4, 48B)

Cosmology with quasars

The *Quasars Hubble Diagram*

Risaliti & Lusso (2015, ApJ, 815-33)



Test cosmological models in a poorly explored redshift range i.e. $z>2$

Type 1a SN: Supernovae Cosmology Project (Sullivan+11, Suzuki+12)

See also: Risaliti & Lusso (2017, AN, 201713351)
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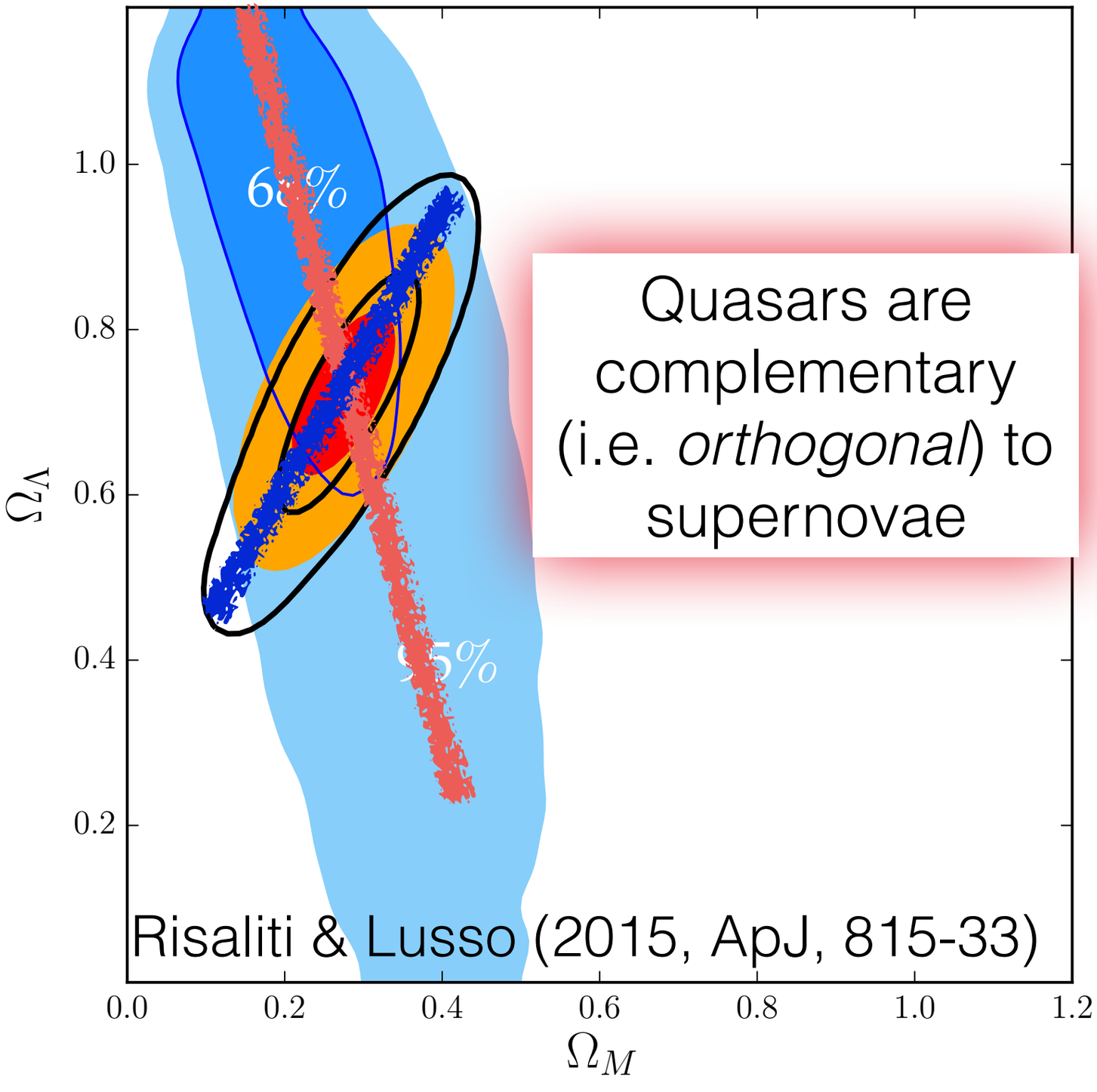
Cosmology with quasars

Results



Quasars are complementary (i.e. *orthogonal*) to supernovae

Open Universe
(Ω_Λ and Ω_M fitted simultaneously),
QSOs only:
$\Omega_M = 0.22^{+0.10}_{-0.08}$
$\Omega_\Lambda = 0.92^{+0.18}_{-0.30}$

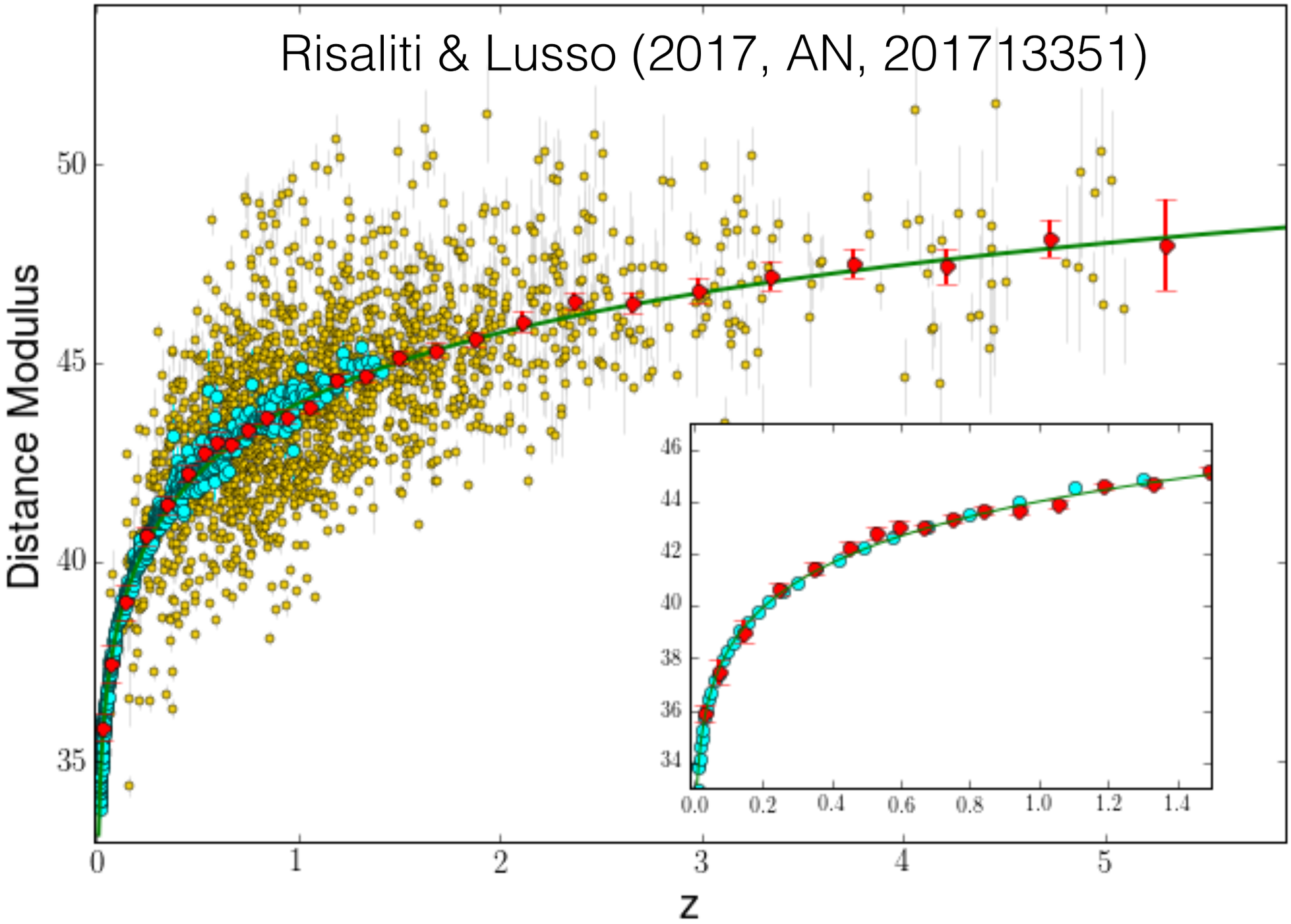
Open, **QSOs + SNe:**
$\Omega_M = 0.28^{+0.04}_{-0.04}$
$\Omega_\Lambda = 0.73^{+0.08}_{-0.08}$

Planck 2015 results
$\Omega_M = 0.308 \pm 0.012$
$\Omega_\Lambda = 0.692 \pm 0.012$

Cosmology with quasars

The Quasars Hubble Diagram

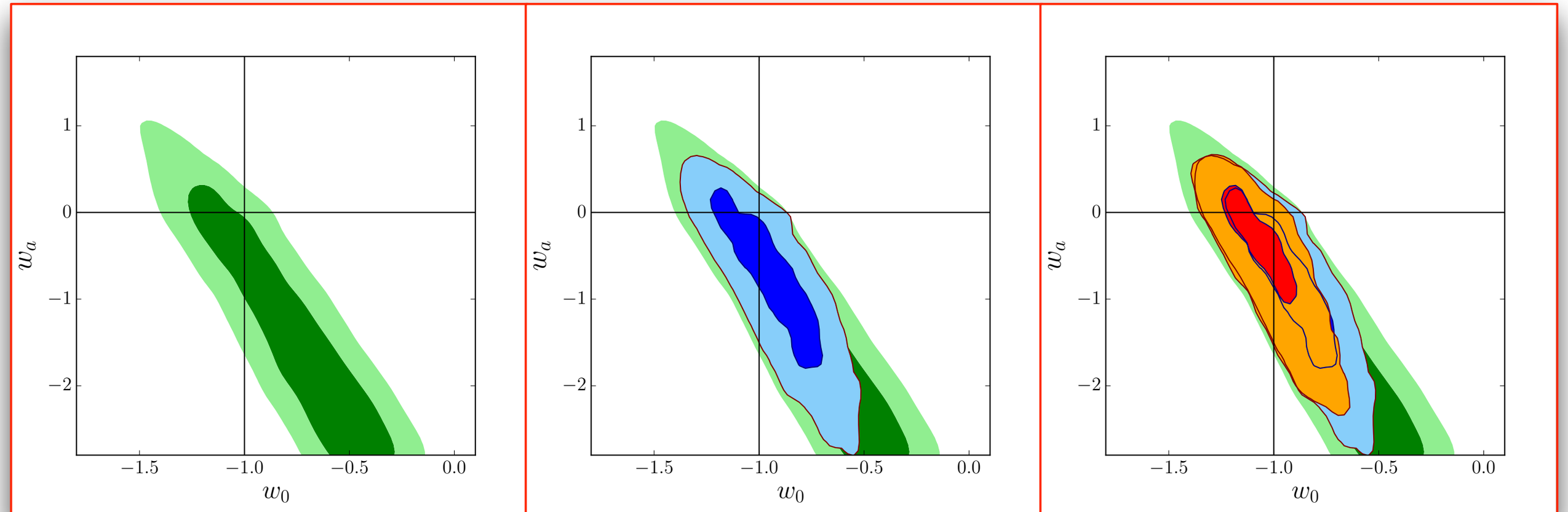
~2000 quasars SDSS+3XMM catalogue



Cosmology with quasars

Test of cosmology

w_0-w_a plane where $w=w_0+w_a(1+z)$, w=-1 no evolution,
Accelerating expansion of the universe for eq. of state w<-1/3



CMB+BAO+WL CMB+BAO+WL+SNe CMB+BAO+WL+SNe+QSOs

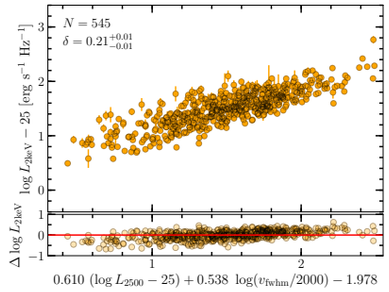
Risaliti & Lusso (2017, AN, 201713351)

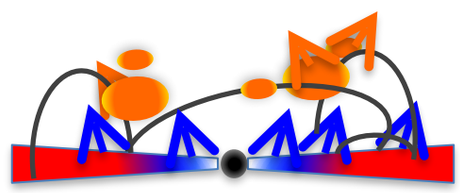
To summarise

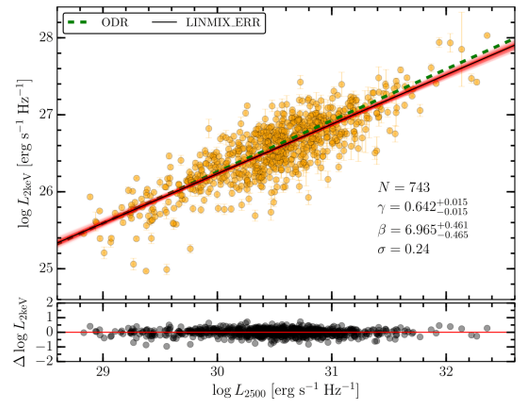
Archives still hide a potential treasure
e.g. SDSS-DR14+3XMM-DR8/CSC2

1. The non-linear L_X-L_{UV} relation is extremely tight
2. and it is based on sound physical grounds

Lusso & Risaliti (2016, ApJ, 819-154)
Lusso & Risaliti (2017, A&A, 602, 79)

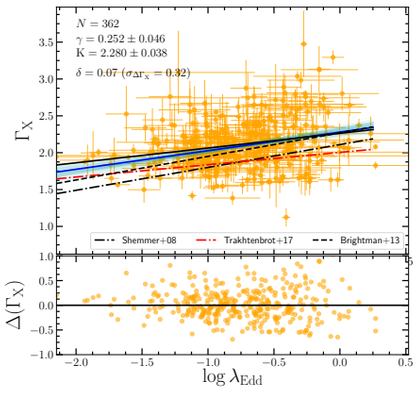






3. The Γ_X-λ_{edd} relation: using Γ_X to establish λ_{edd} among samples of high-redshift AGN (red herring?)

Lusso et al., in prep.



4. Quasar are standard candles and can be used to measure the dark matter and energy content in the Universe

Risaliti & Lusso 2015