The physical relation between disc and coronal emission in AGN

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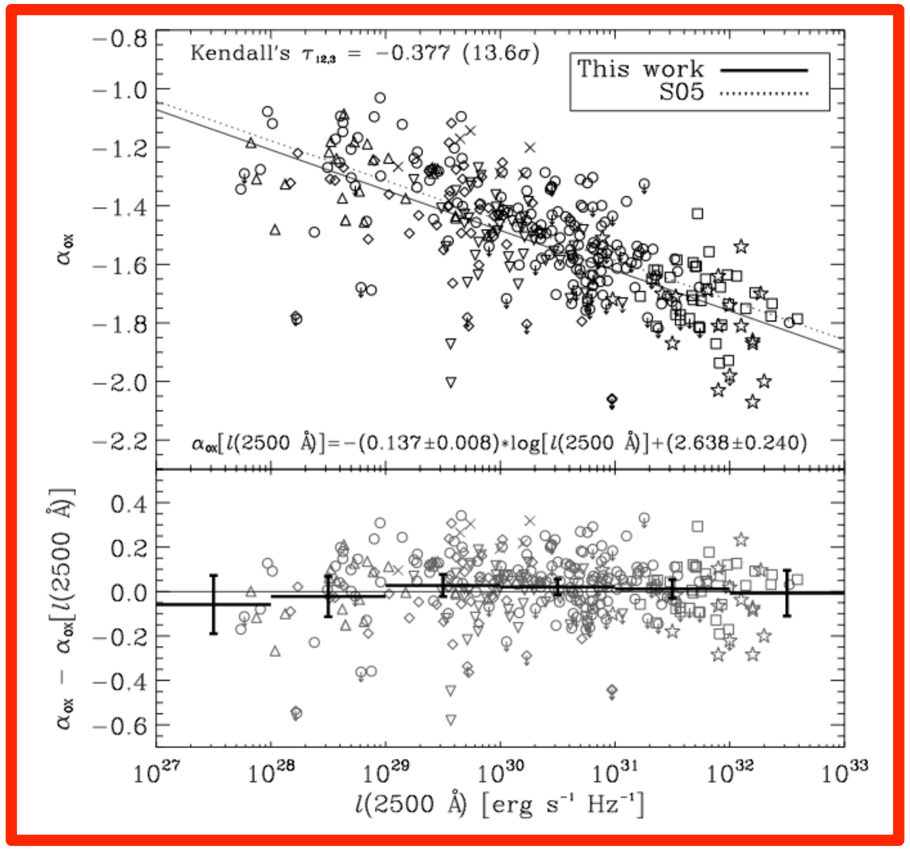
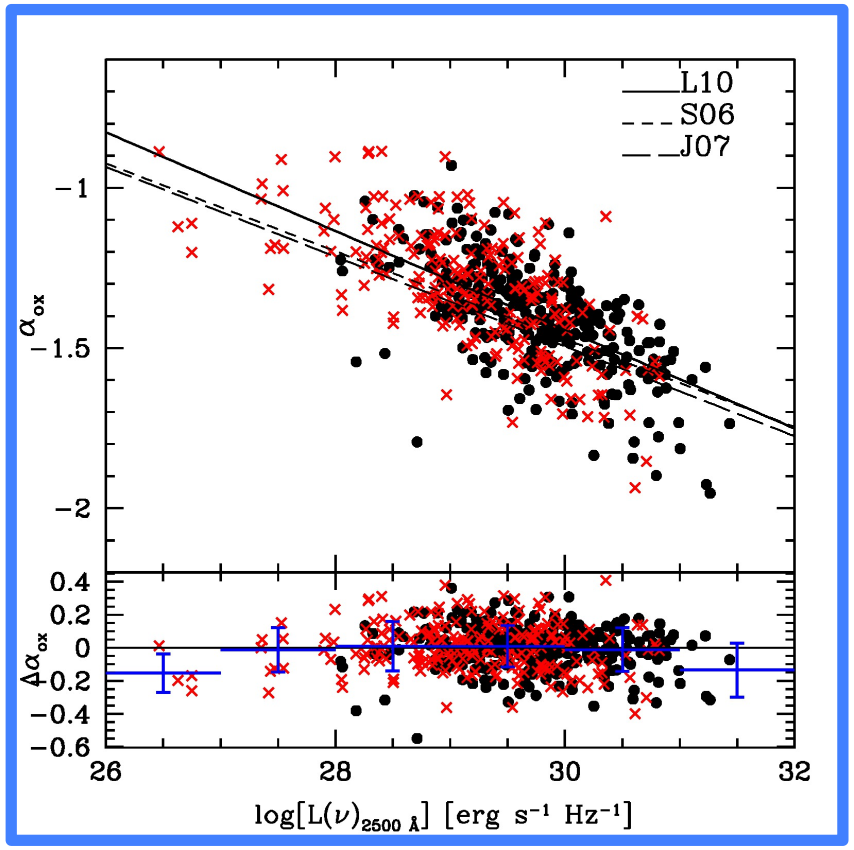
The X-ray to optical non-linear relation

$$\alpha_{ox} = \frac{\log\left(L_{2\ \mathrm{keV}}/L_{2500}\right)}{\log\left(\nu_{2\ \mathrm{keV}}/\nu_{2500}\right)}$$

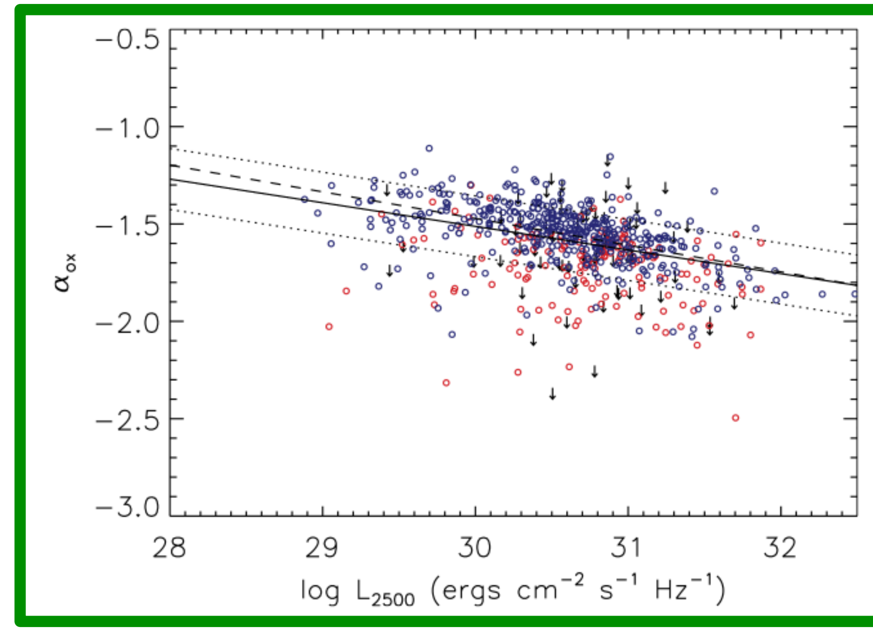
Tananbaum+79; Zamorani+81; Vignali+03; Strateva+05; Just+07; Marchese+11; Jin+12



Steffen et al. 2006
333 quasars
X-ray: mostly ROSAT
UV: mixed bag



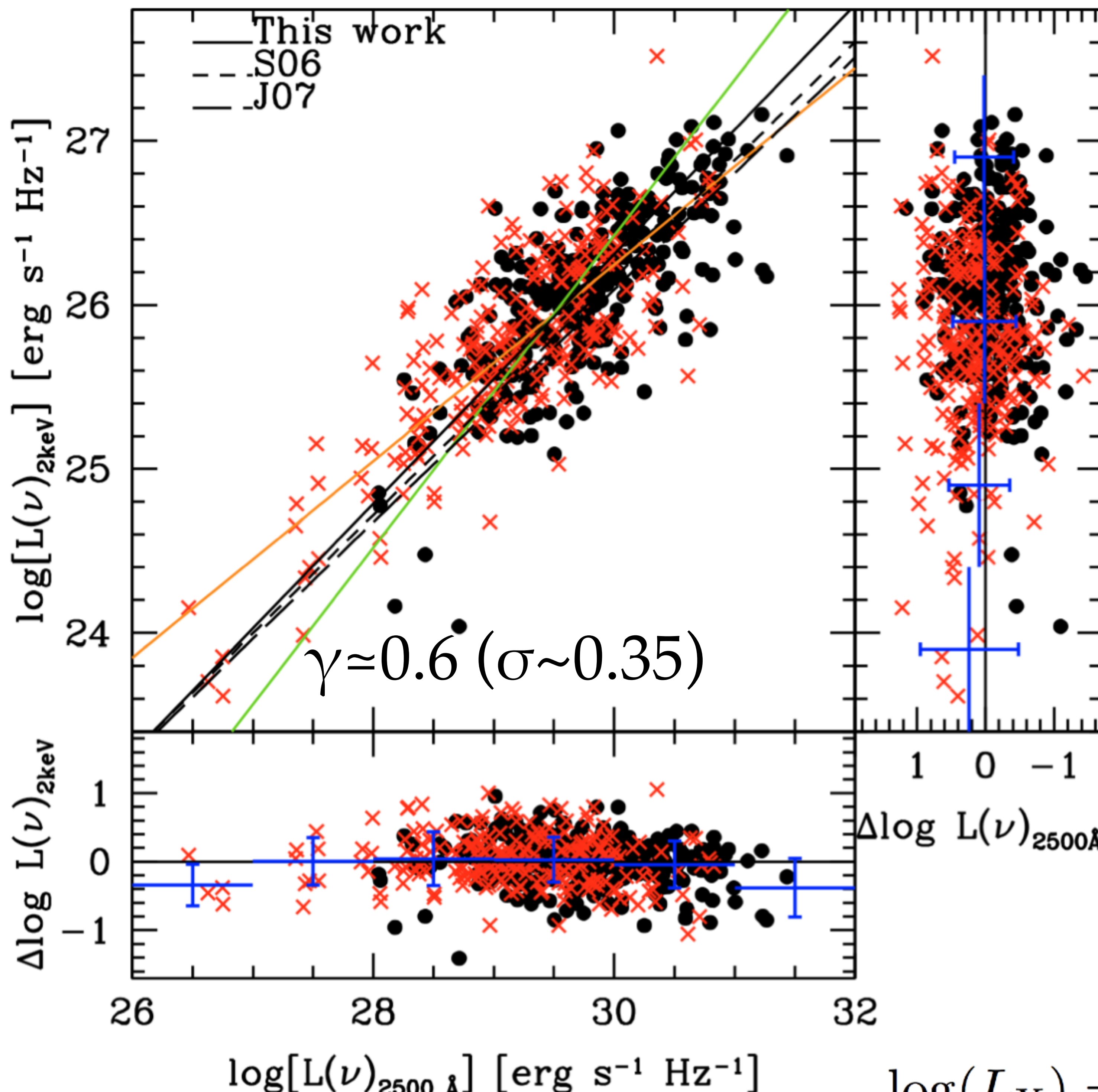
Lusso et al. 2010
545 quasars
XMM-COSMOS



Young et al. 2010
327 quasars
X-ray: XMM-Newton
UV: SDSS-DR5

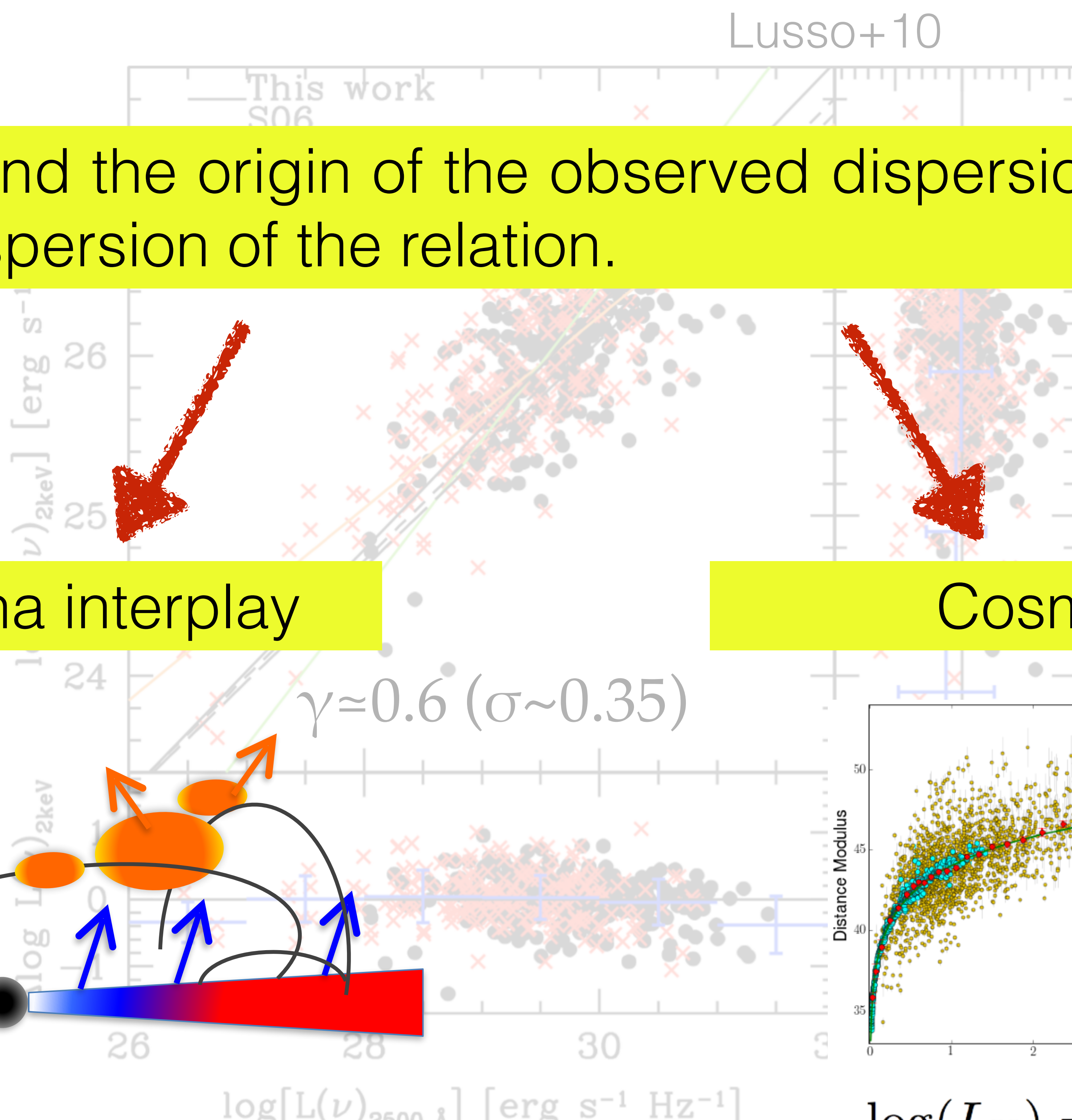
The X-ray to optical non-linear relation

Lusso+10



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

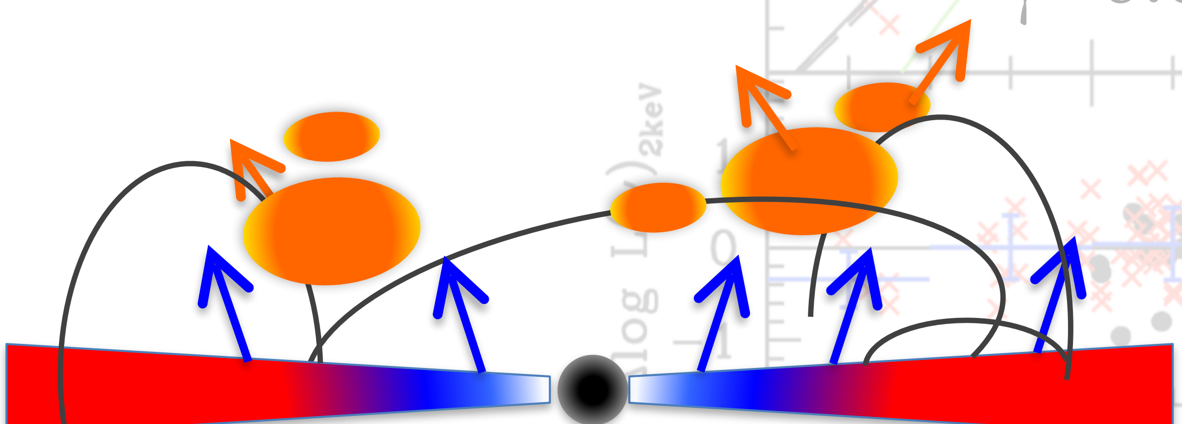
The X-ray to optical non-linear relation

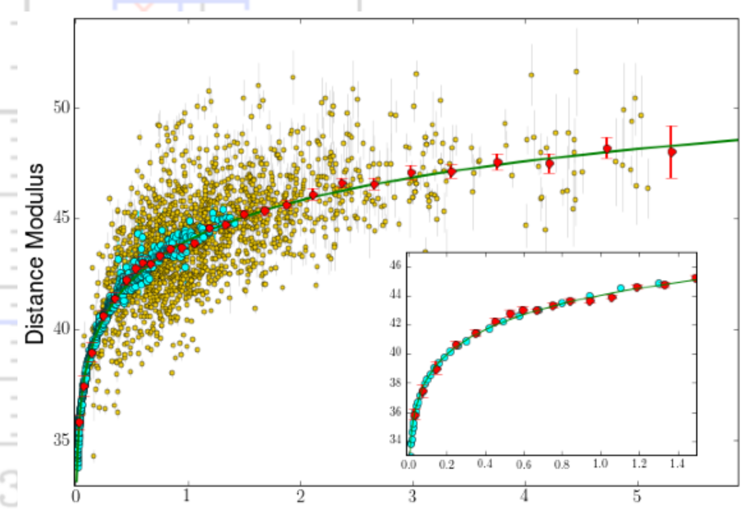


Goal: understand the origin of the observed dispersion and evaluate the intrinsic dispersion of the relation.

Disc-Corona interplay

Cosmology

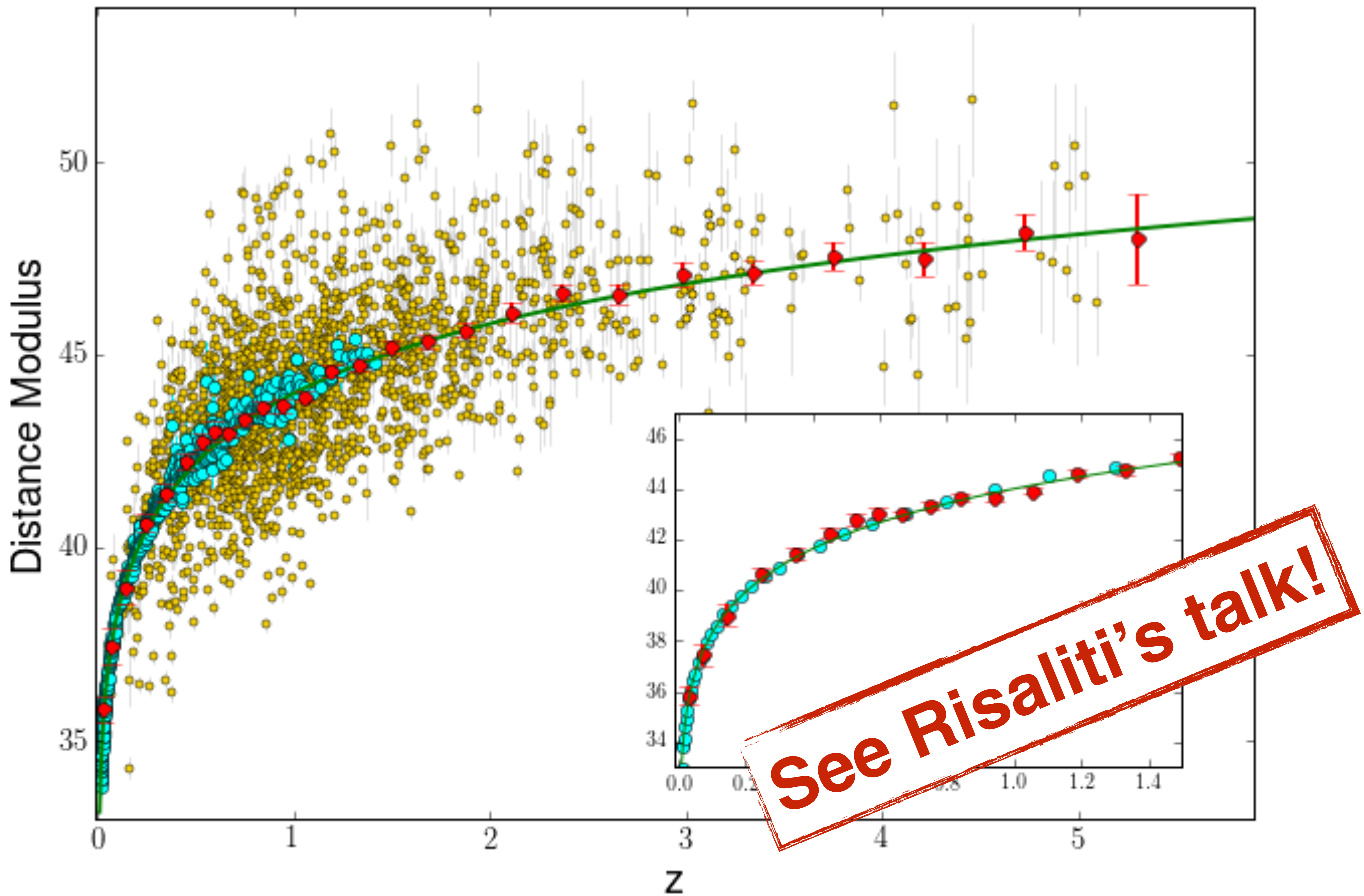




$$\log(L_{\rm X}) = \beta + \gamma \log(L_{\rm UV})$$

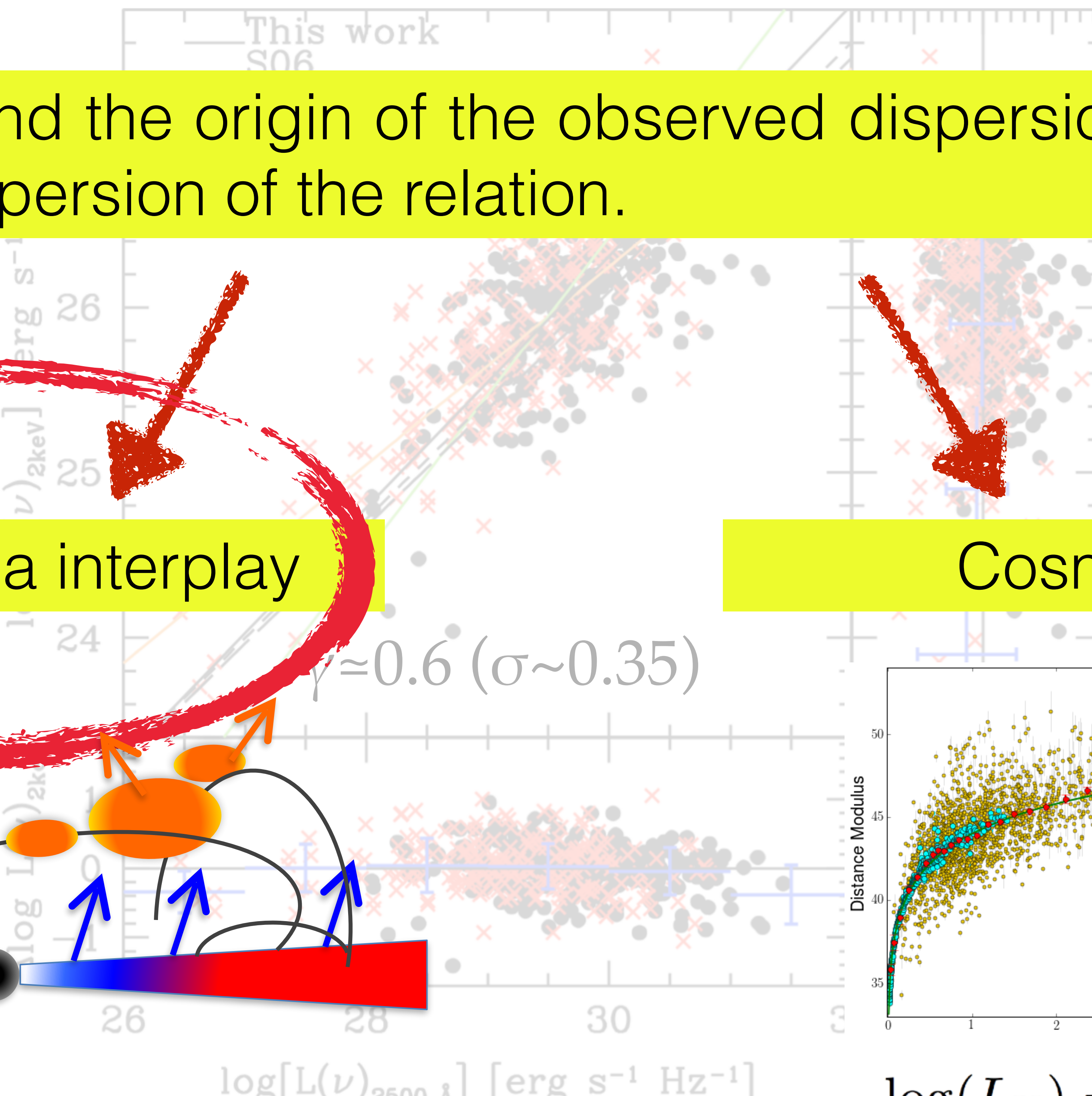
Quasar Hubble Diagram

Risaliti & Lusso (2015), Risaliti, Lusso, et al. in prep.



The X-ray to optical non-linear relation

Lusso+10

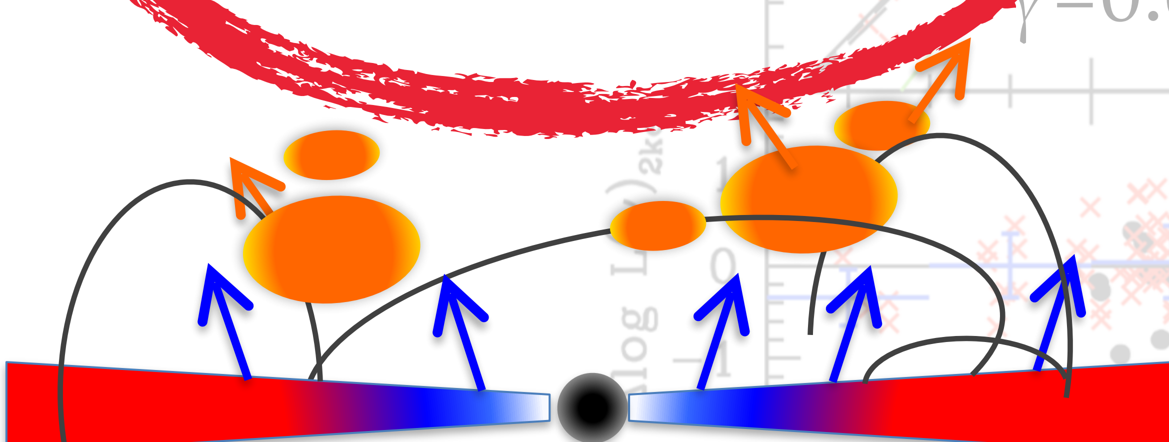


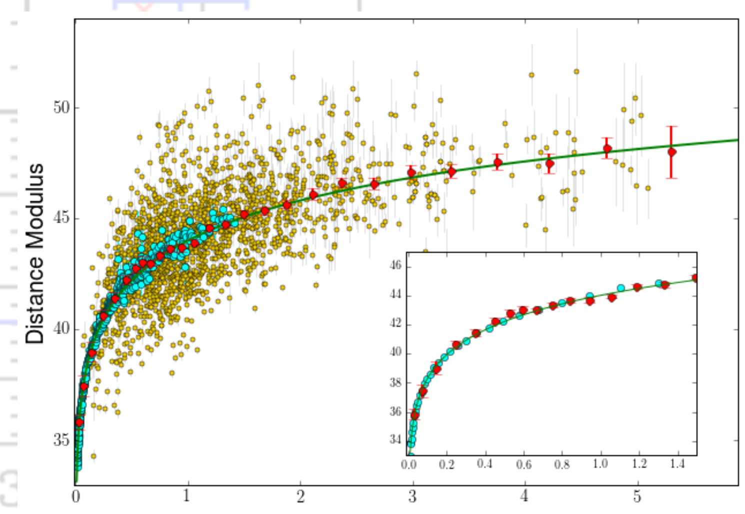
Goal: understand the origin of the observed dispersion and evaluate the intrinsic dispersion of the relation.

Disc-Corona interplay

Cosmology

$\gamma \simeq 0.6$ ($\sigma \sim 0.35$)





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

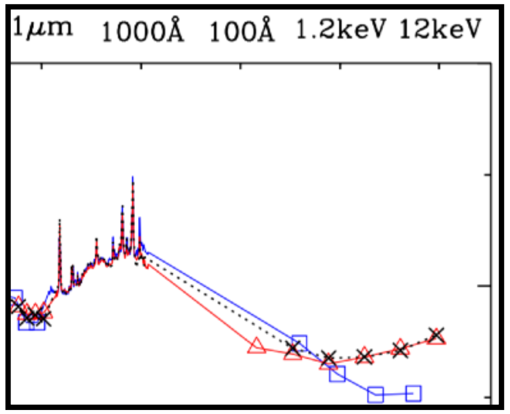
The X-ray to optical non-linear relation

Lusso & Risaliti (2016)

2153 quasars from SDSS-DR7 with X-ray observations from 3XMM-DR5 catalog

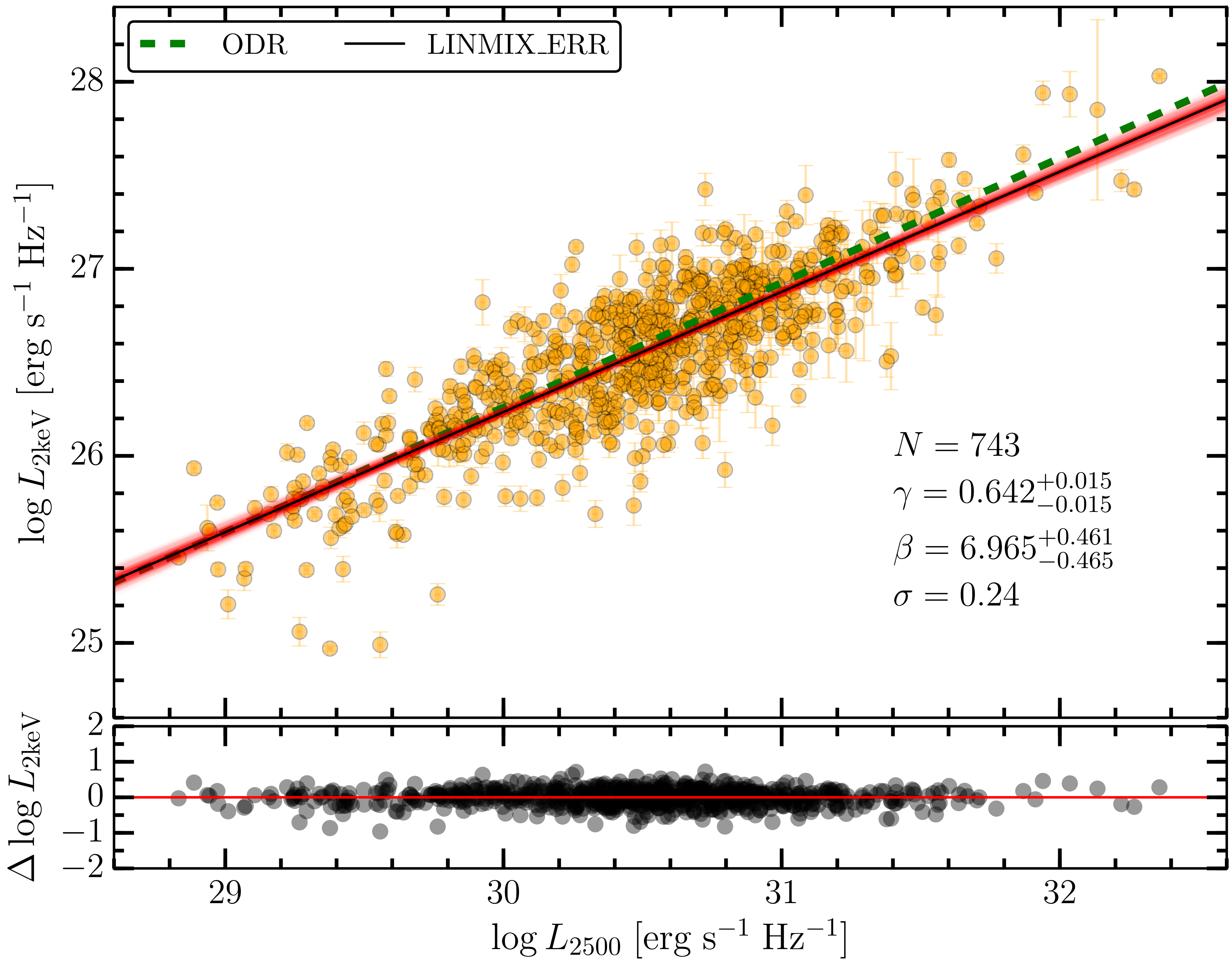
1. Reddening and host galaxy contamination
2. Uncertainties on X-ray fluxes due to unreliable source counts
3. X-ray absorption
4. No jetted or BAL

clean sample of 743 quasars ("homogeneous SED")



The X-ray to optical non-linear relation

Lusso & Risaliti (2016)



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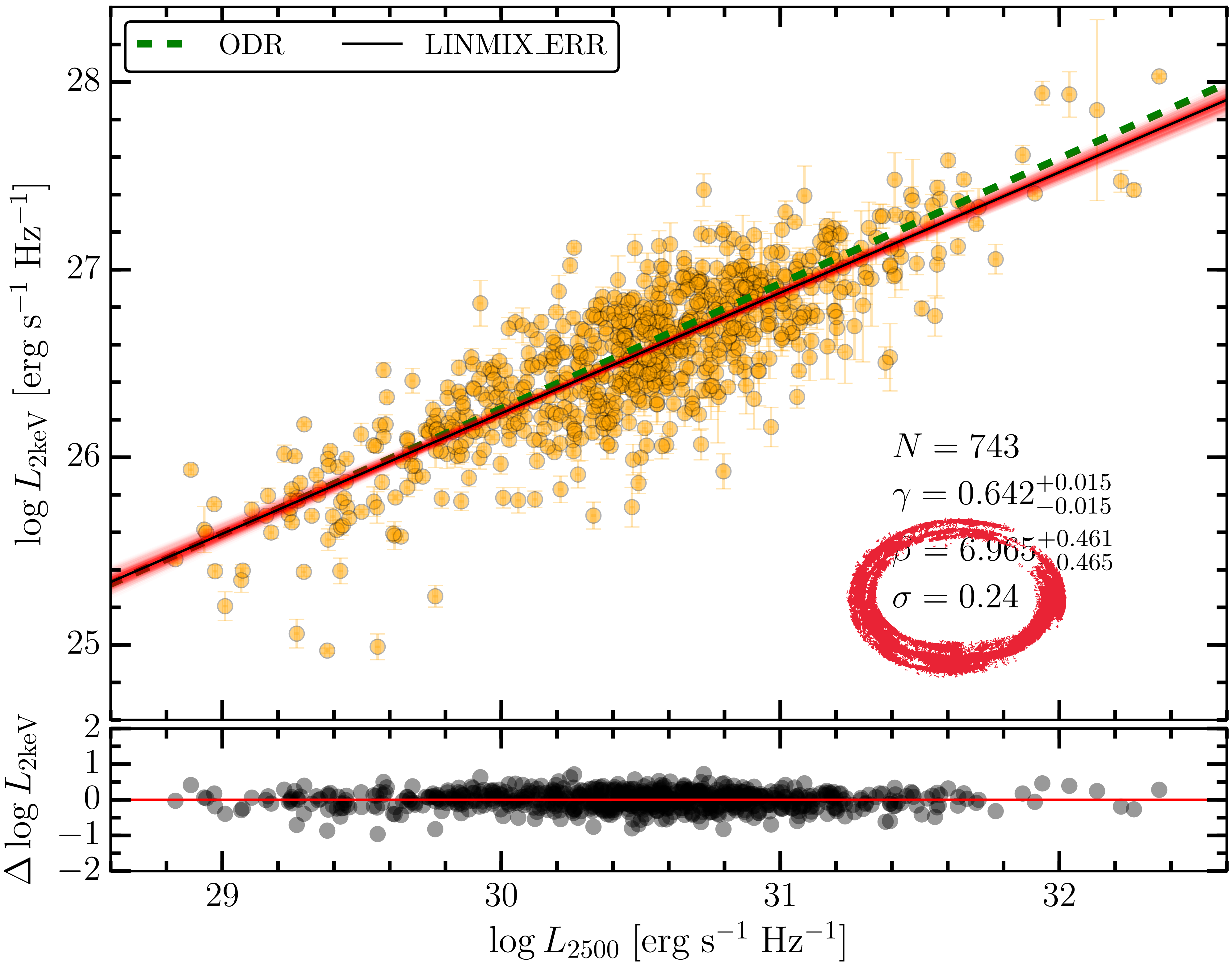

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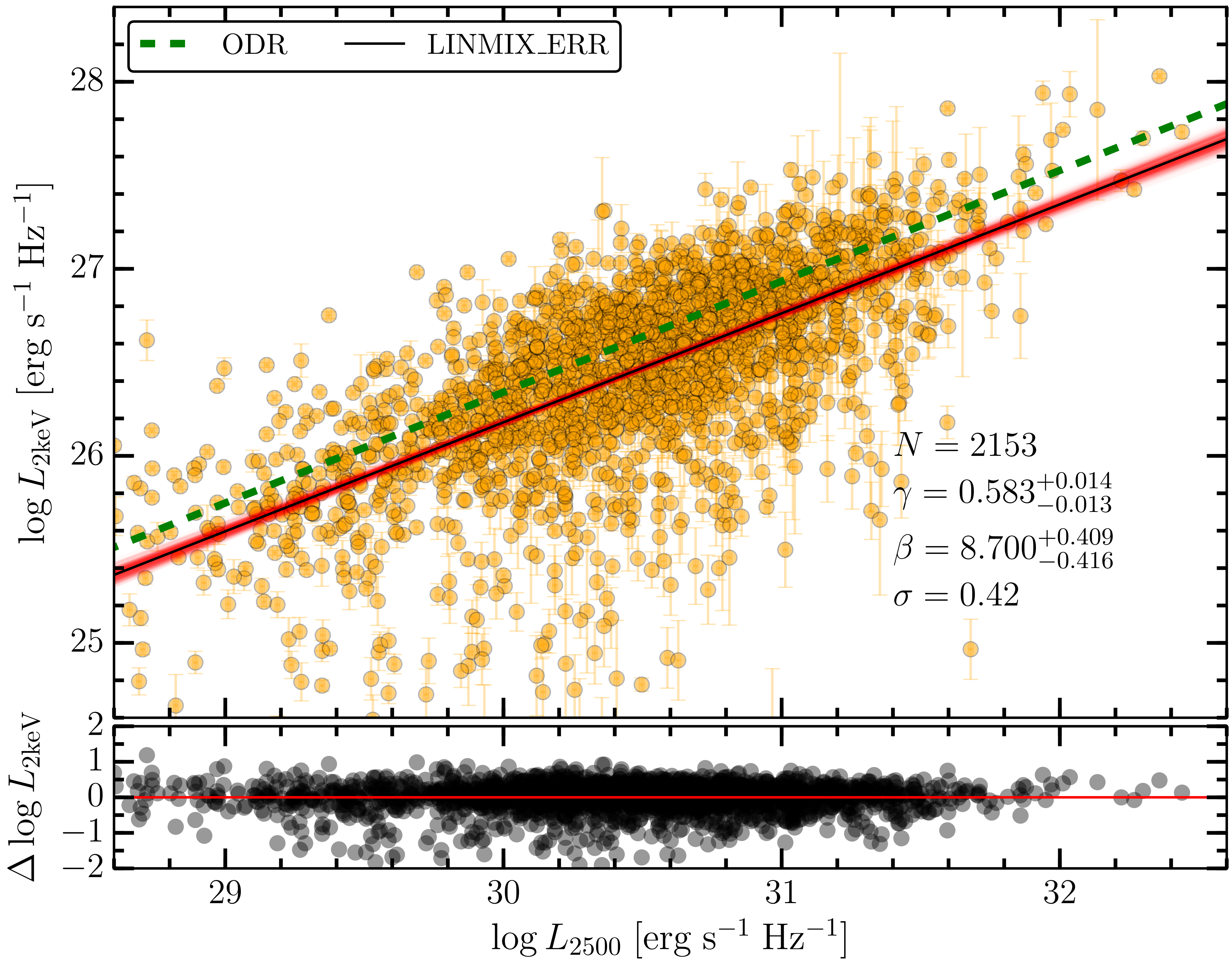
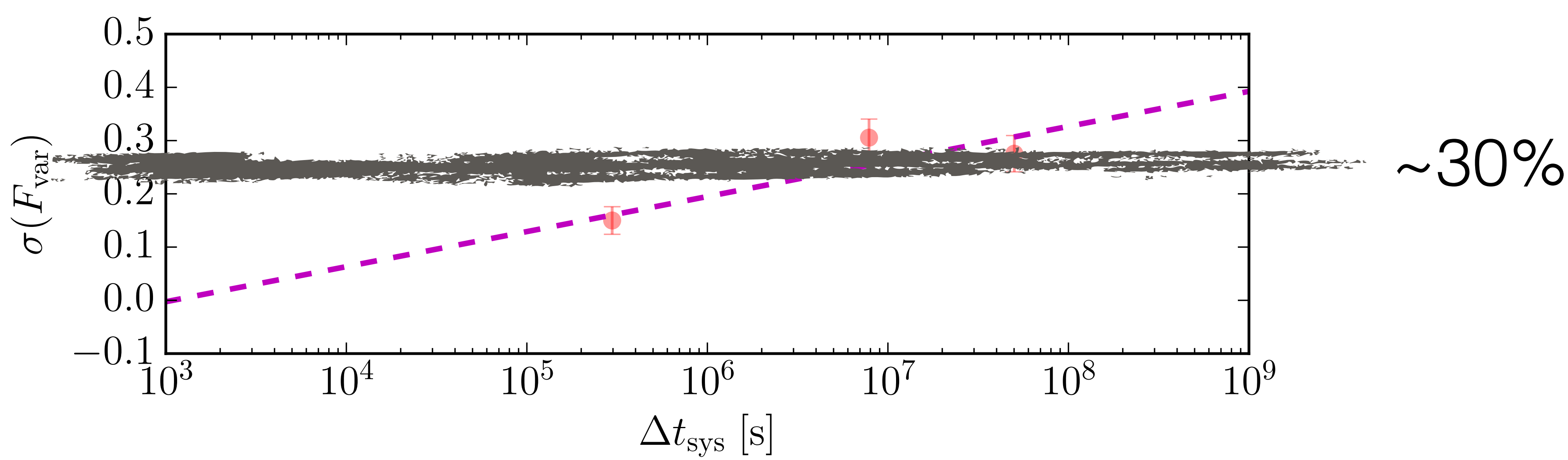


The X-ray to optical non-linear relation

Clean sample of 743 quasars (“homogeneous SED”)

1. Reddening and host galaxy contamination
2. Uncertainties on X-ray fluxes do to unreliable source counts
3. X-ray absorption
4. No jetted or BAL
5. X-ray variability (among different observations)

159 quasars with 2 or more XMM observations



see also Gibson&Brandt+12 (Chandra), Lanzuisi+14 (XMM-COSMOS)

The X-ray to optical non-linear relation

The amplitude of X-ray variability in the sample of 159 quasars with multiple observations is around 0.12 dex

Optical variability is on the order of 0.05 dex (Kozłowski 2010)

The real physical intrinsic dispersion should be <0.19 dex. $L_{2keV} \propto L_{2500}^{\gamma}$ is valid over three decades in luminosity, hence must be the manifestation of an intrinsic (and universal) physical relation between the disc, emitting the primary radiation, and the hot electron corona emitting X-rays.

The X-ray to optical non-linear relation
The L_X-L_{UV}-v_{fwhm} plane

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

$$\downarrow$$

$$L_{\rm UV} = f_1(M_{\rm BH}, \dot{M}), \; L_{\rm X} = f_2(M_{\rm BH}, \dot{M})$$

$$\upsilon_{\rm fwhm} = f_3(M_{\rm BH}, \dot{M})$$

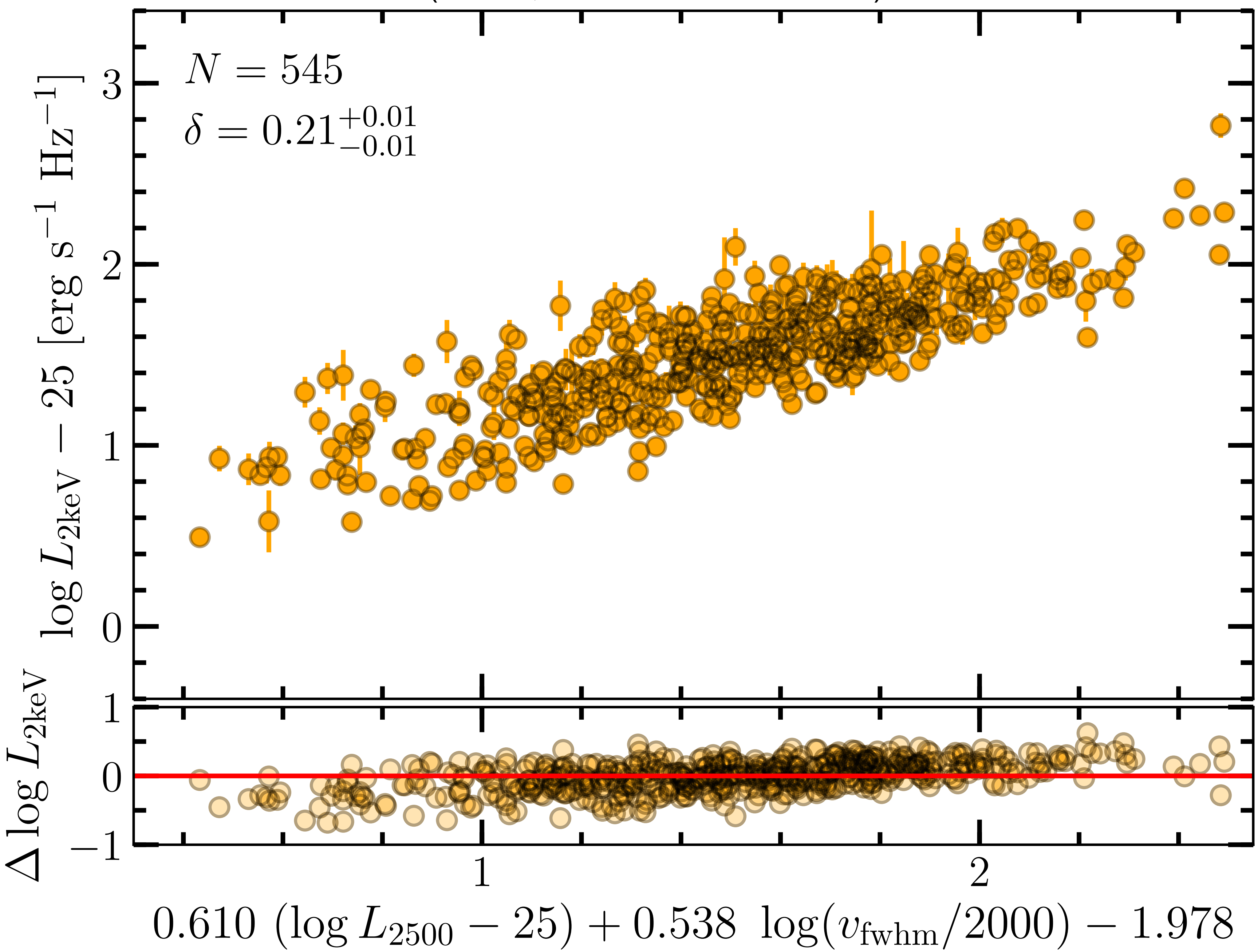
$$\downarrow$$

$$\log L_{\rm X} = \hat{\gamma} \log L_{\rm UV} + \hat{\beta} \log \upsilon_{\rm fwhm} + \hat{K}$$

The X-ray to optical non-linear relation

The L_X-L_{UV}-v_{fwhm} plane

Lusso & Risaliti (2017, arXiv:1703.05299)



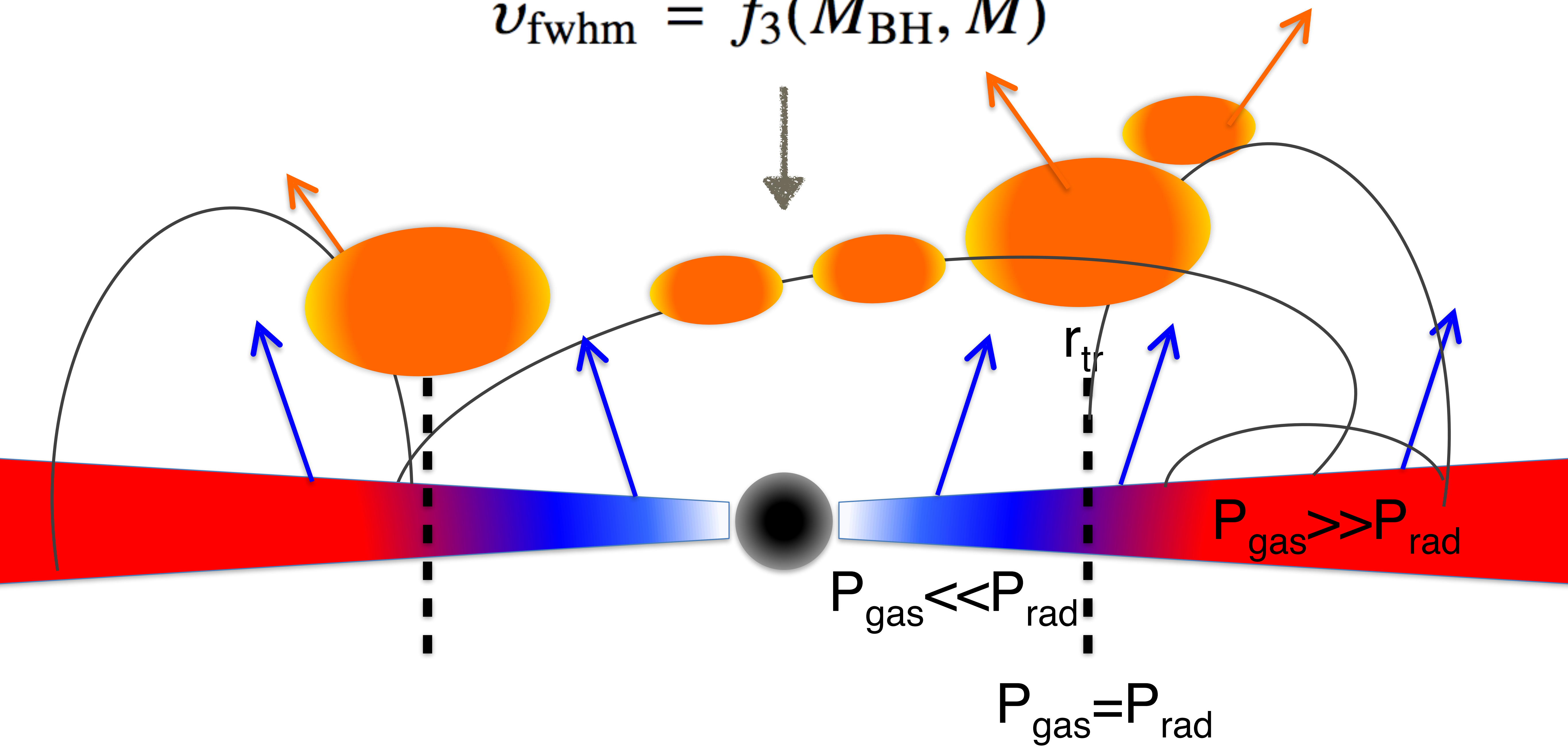
The physical relation between disc and corona emission:

Toy Model

The physical relation between disc and corona emission

$$L_{\mathrm{UV}} = f_1(M_{\mathrm{BH}}, \dot{M}),\ L_{\mathrm{X}} = f_2(M_{\mathrm{BH}}, \dot{M})$$

$$v_{\mathrm{fwhm}} = f_3(M_{\mathrm{BH}}, \dot{M})$$



Shakura & Sunyaev (1973), Svensson & Zdziarski (1994), Merloni & Fabian (2002), Merloni (2003), **Lusso & Risaliti (2017, arXiv:1703.05299)**

The physical relation between disc and corona emission

$$L_{\rm UV} = f_1(M_{\rm BH}, \dot{M}),\ L_{\rm X} = f_2(M_{\rm BH}, \dot{M})$$

$$\upsilon_{\rm fwhm} = f_3(M_{\rm BH}, \dot{M})$$

$$\downarrow$$

$$L_{\rm X,25} \simeq 0.06\, L_{\rm UV,25}^{4/7}\, \upsilon_{\rm fwhm,2000}^{4/7}\, \alpha^{-2/21} \kappa^{2/7} (1-f)^{-6/7} J(r)^{-16/21}$$

Shakura & Sunyaev (1973), Svensson & Zdziarski (1994), Merloni & Fabian (2002), Merloni (2003), **Lusso & Risaliti (2017, arXiv:1703.05299)**

The physical relation between disc and corona emission

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$$\Downarrow$$

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The physical relation between disc and corona emission
The L_X-L_{UV}-v_{fwhm} plane

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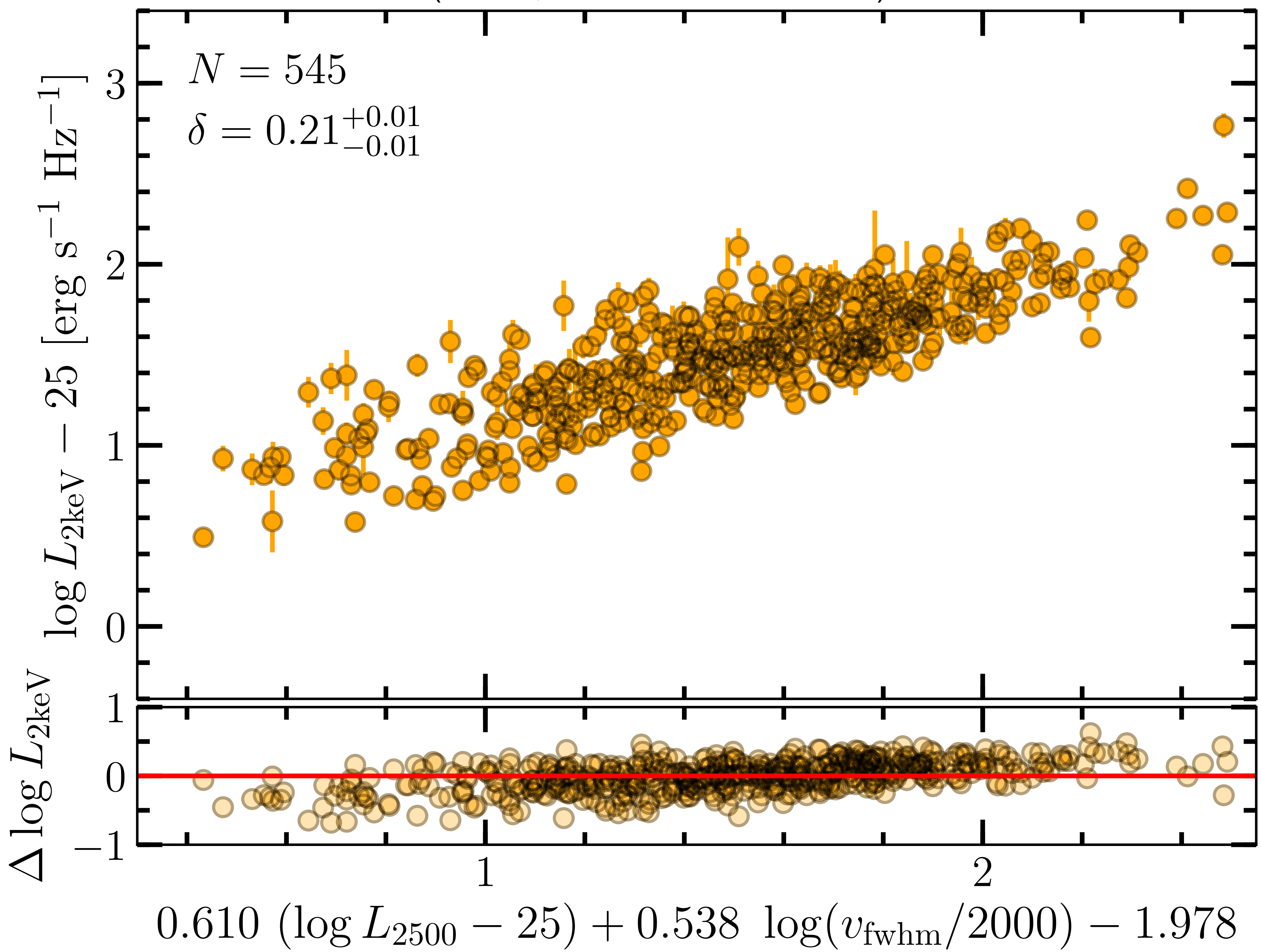

The physical relation between disc and corona emission

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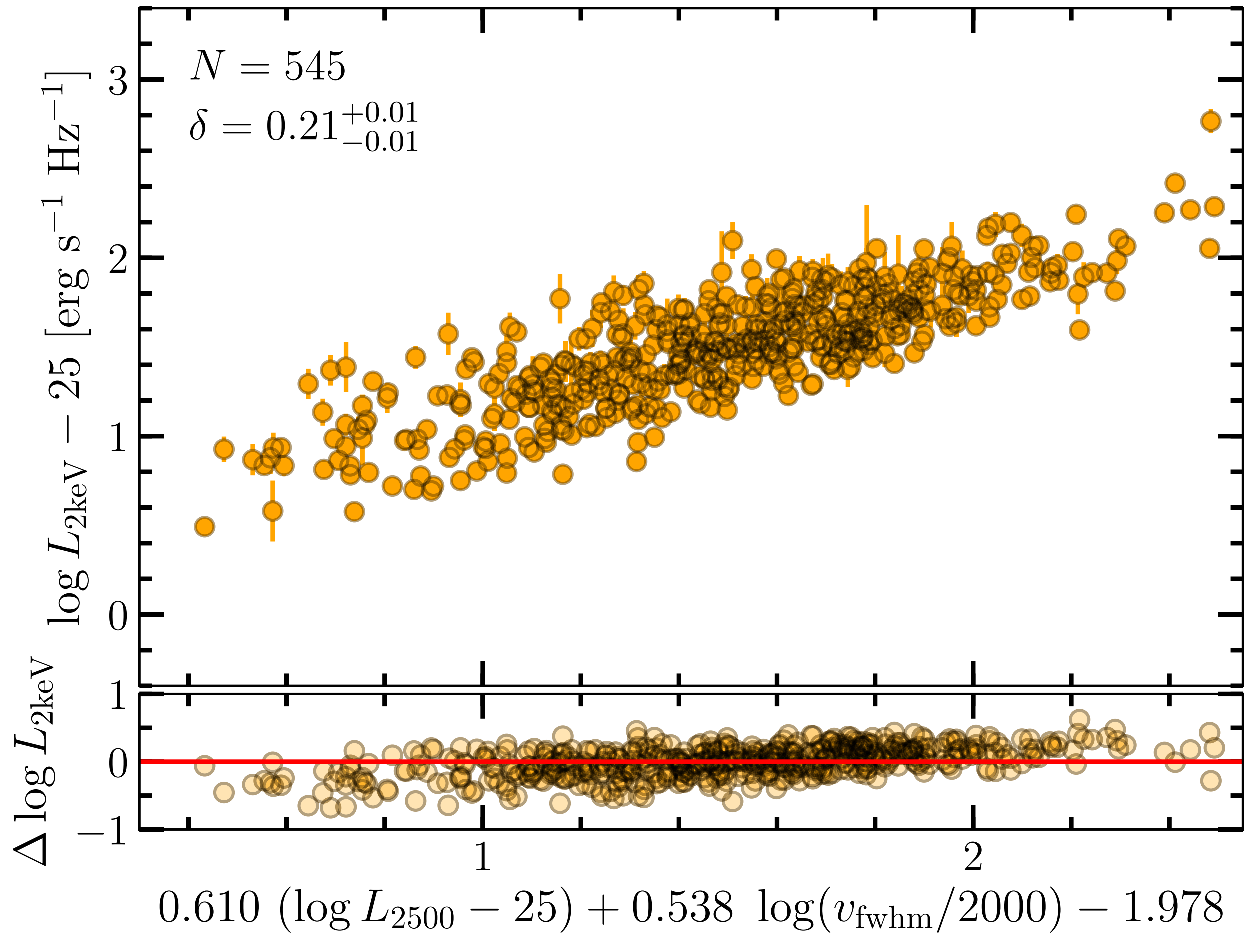


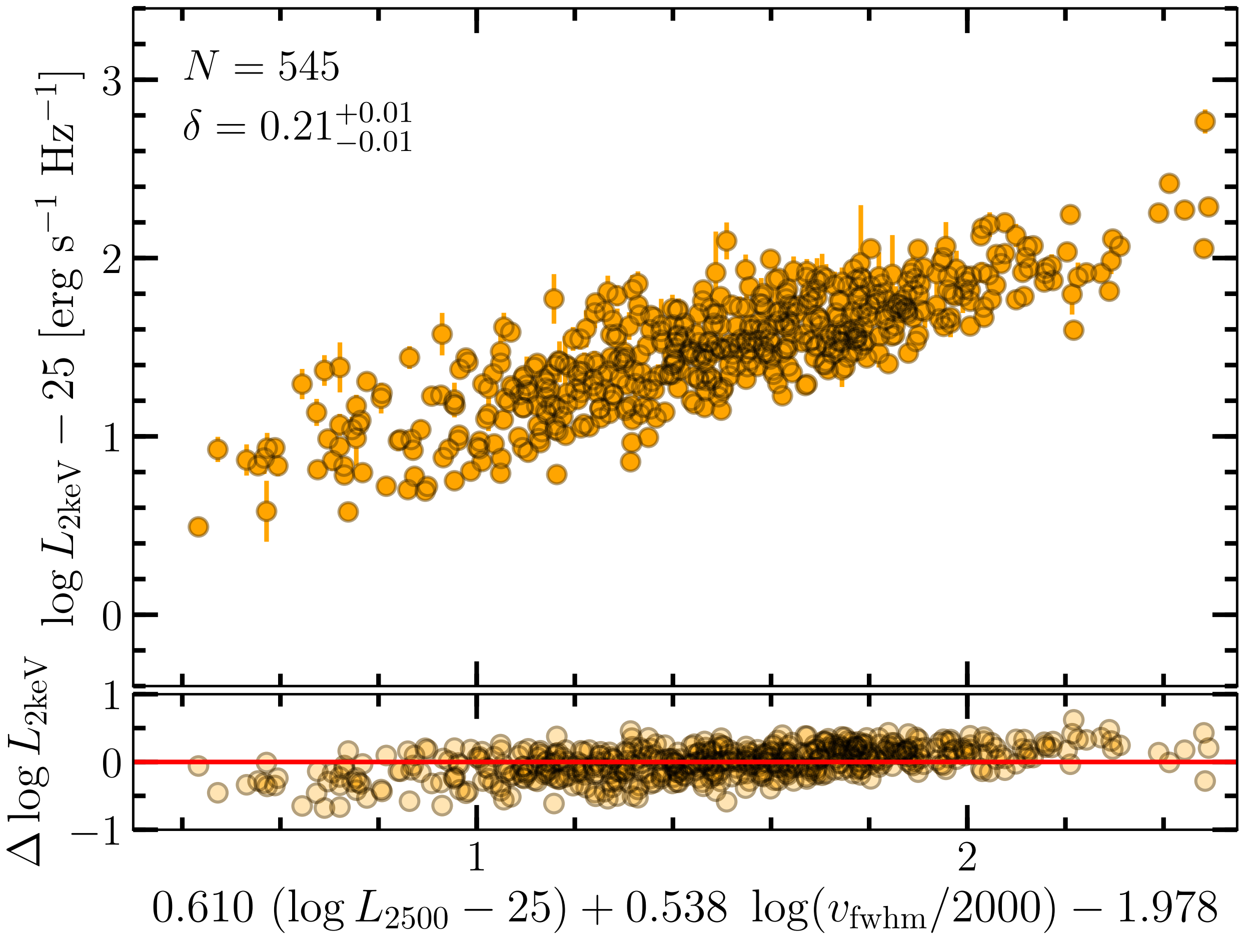
$$(0.610 \pm 0.019)(\log L_{UV} - 25) + (0.538 \pm 0.072)\log(v_{fwhm}/2000)$$

$$L_{X,25} \simeq 0.06\, L_{UV,25}^{4/7}\, v_{fwhm,2000}^{4/7}\, \alpha^{-2/21} \kappa^{2/7} (1-f)^{-6/7} J(r)^{-16/21}$$

The physical relation between disc and corona emission

The L_X-L_{UV}-v_{fwhm} plane

Lusso & Risaliti (2017, arXiv:1703.05299)



$$(0.610 \pm 0.019)(\log L_{UV} - 25) + (0.538 \pm 0.072)\log(v_{fwhm}/2000)$$

$$L_{X,25} \simeq 0.05\, L_{UV,25}^{4/7}\, v_{fwhm,2000}^{4/7}\, \alpha^{-2/21} \kappa^{2/7} (1-f)^{-6/7} J(r)^{-16/21}$$

The physical relation between disc and corona emission
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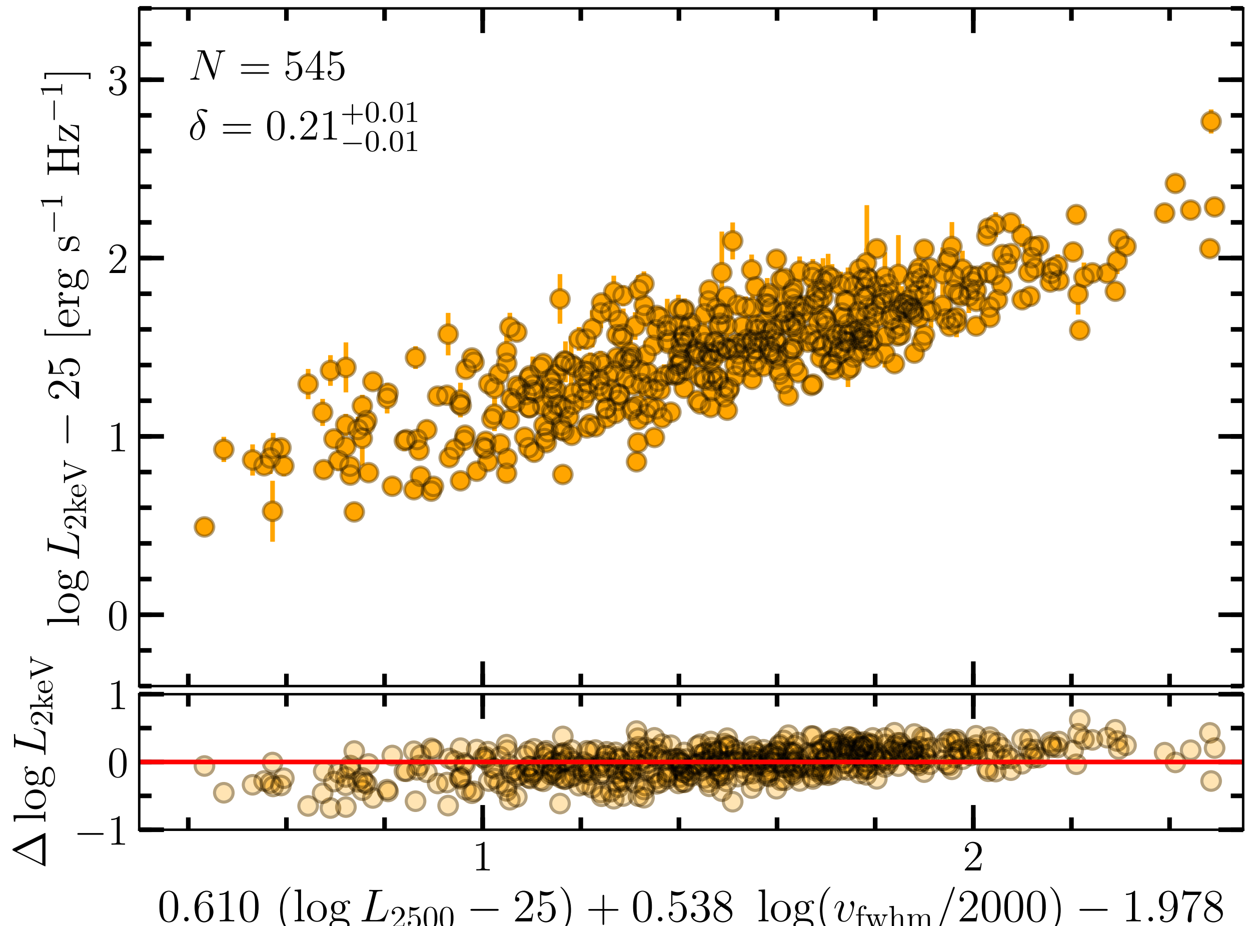

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The physical relation between disc and corona emission

The L_X-L_{UV}-v_{fwhm} plane

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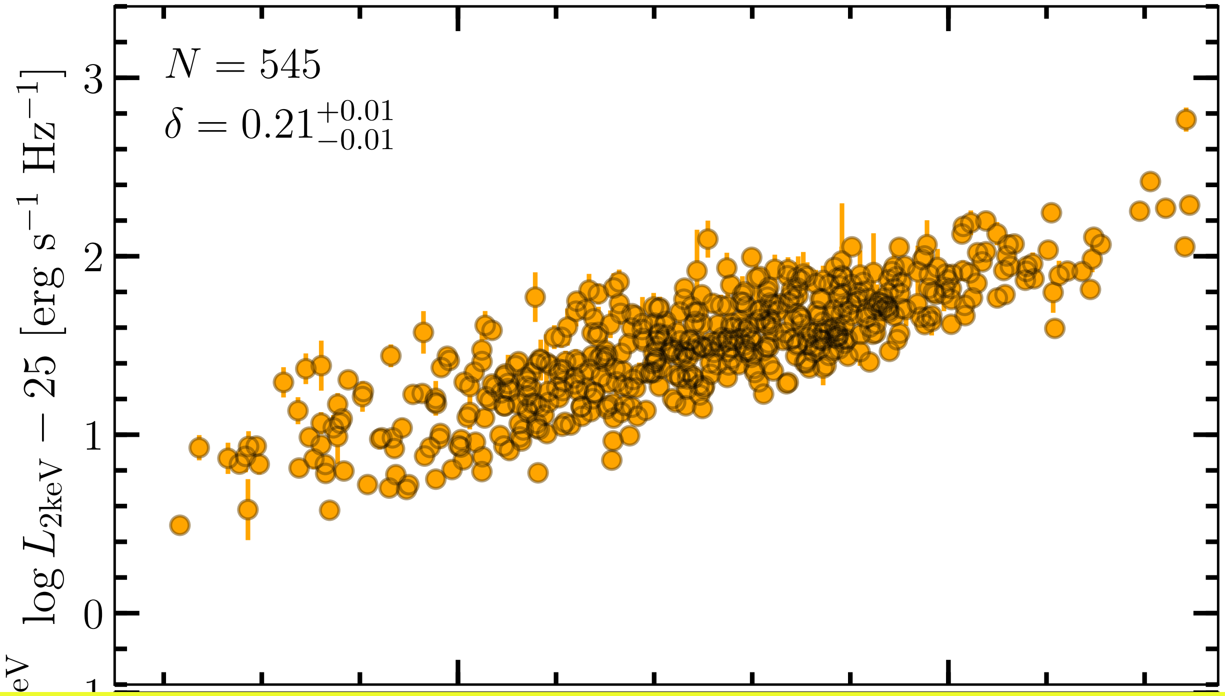

Observed and predicted slopes are consistent within 2 sigma level

$(0.610\pm0.019)(\log L_{UV}-25) + (0.538\pm0.072)\log(v_{fwhm}/2000)$

$$L_{X,25} \simeq 0.06\, L_{UV,25}^{4/7}\, \upsilon_{fwhm,2000}^{4/7}\, \alpha^{-2/21} \kappa^{2/7} (1-f)^{-6/7} J(r)^{-16/21}$$

Take home messages

- $L_{2keV} \propto L_{2500}^{0.6}$ has an intrinsic dispersion <0.19 dex, is valid over three dex in luminosity, hence must be the manifestation of an intrinsic (and universal) physical relation between the disc, emitting the primary radiation, and the hot electron corona emitting X-rays (Lusso & Risaliti 2016)

- The L_X-L_{UV}-v_{fwhm} plane: $L_{2keV} \propto L_{2500}^{0.57}\ v_{fwhm}^{0.57}$, consistent with a toy (but physically motivated) model of an X-ray corona powered by a geometrically thin, optically thick accretion disc (Lusso & Risaliti 2017, arXiv:1703.05299)

- The determination of distances (i.e. quasar *Hubble diagram*) based on the L_X-L_{UV}-v_{fwhm} relation is now on a sounder physical grounds (Risaliti & Lusso 2015, Risaliti, Lusso et al. in prep)