On the relationship between X-ray, MIR and bolometric luminosities of broad line QSOs

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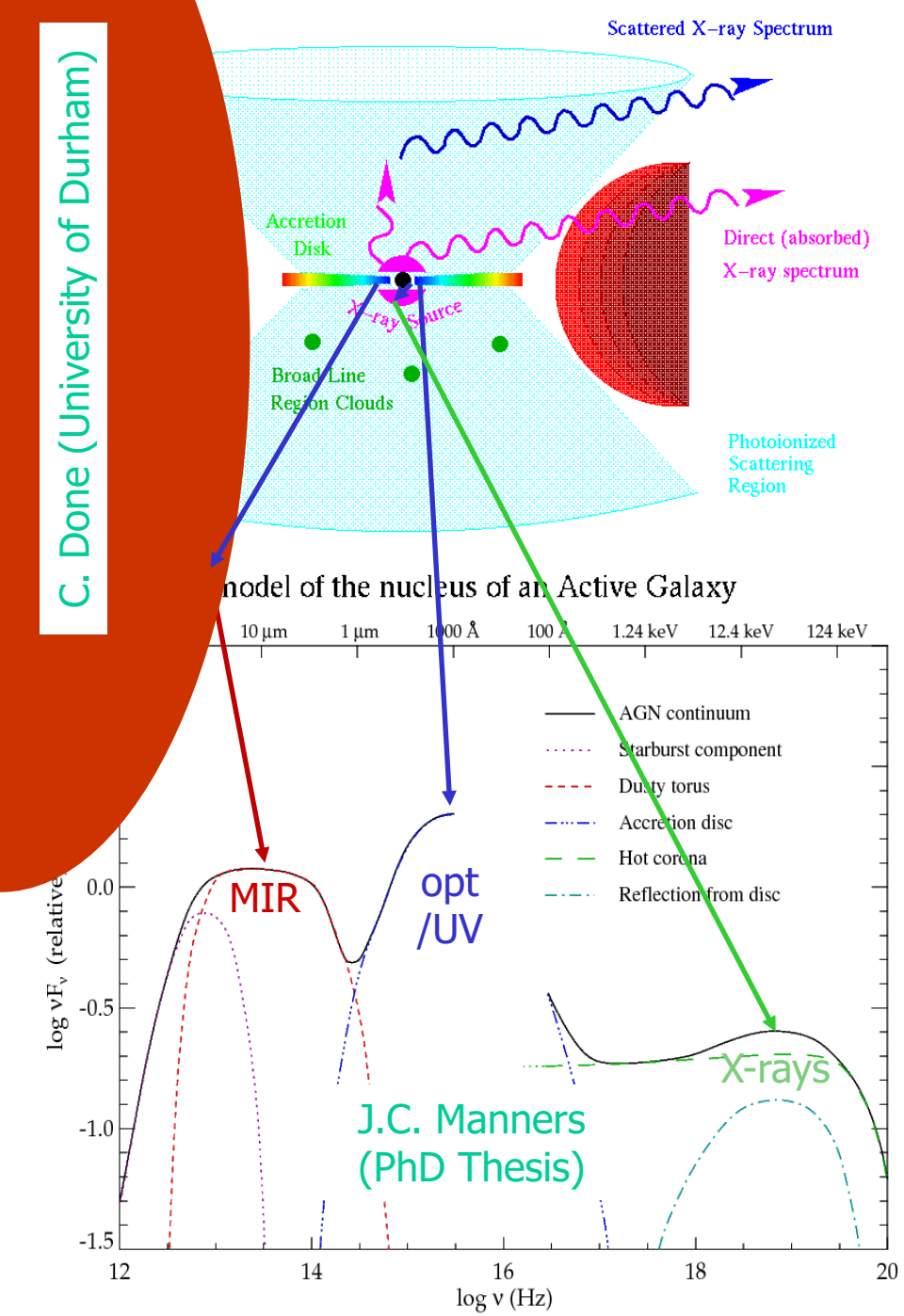
Treasures hidden in X-ray catalogues, Toulouse, 22 - May - 2018

Outline

- Introduction
  - Unified model and X-ray/MIR emission
  - Previous results
- Our sample
- Results: L_X-$L_{\rm MIR}$
  - Model fitting: Bayesian and 2D uplims
- Comparing to L_{bol}: $L_{\rm MIR}/L_{bol}$ and L_X/L_{bol} vs L_{bol}
- Comparing to Eddington ratio...
- Conclusions

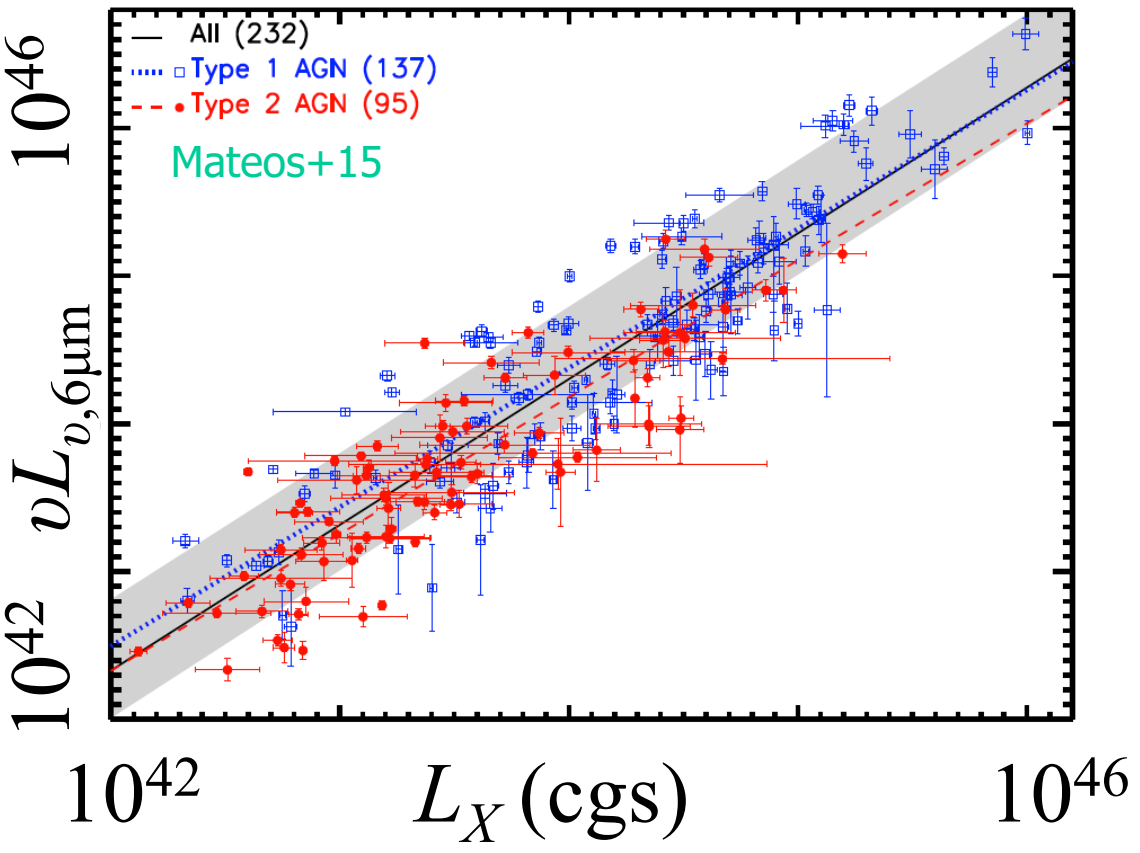
C. Done (University of Durham)



Unified Model

- First-order approach: all AGN intrinsically the same
  - Main difference from orientation w.r.t. line of sight
  - Main engine is central part of AD: rest frame optical/UV
  - X-rays from AD corona: reprocessed (IC)
  - MIR from obscuring torus: reprocessed (thermal)

Previous results



- Expected then ~1:1 relation between MIR ($\upsilon L_{\upsilon,6\mu m}$) and X-ray lum ($L_{X,2\text{-}10keV}$): e.g. Lutz+04 ■, Gandhi+09, Fiore+09, Mateos+15 ●● ,Shimizu+17...
- But recently flattening at high L_{MIR}: (Stern'15)
  - Surprising within UM: if anything the opposite (receding torus... Simpson'05)
  - But agreement with $\alpha_{OX}\downarrow$ when $L_{opt}\uparrow$ (...Lusso & Risaliti'17...)

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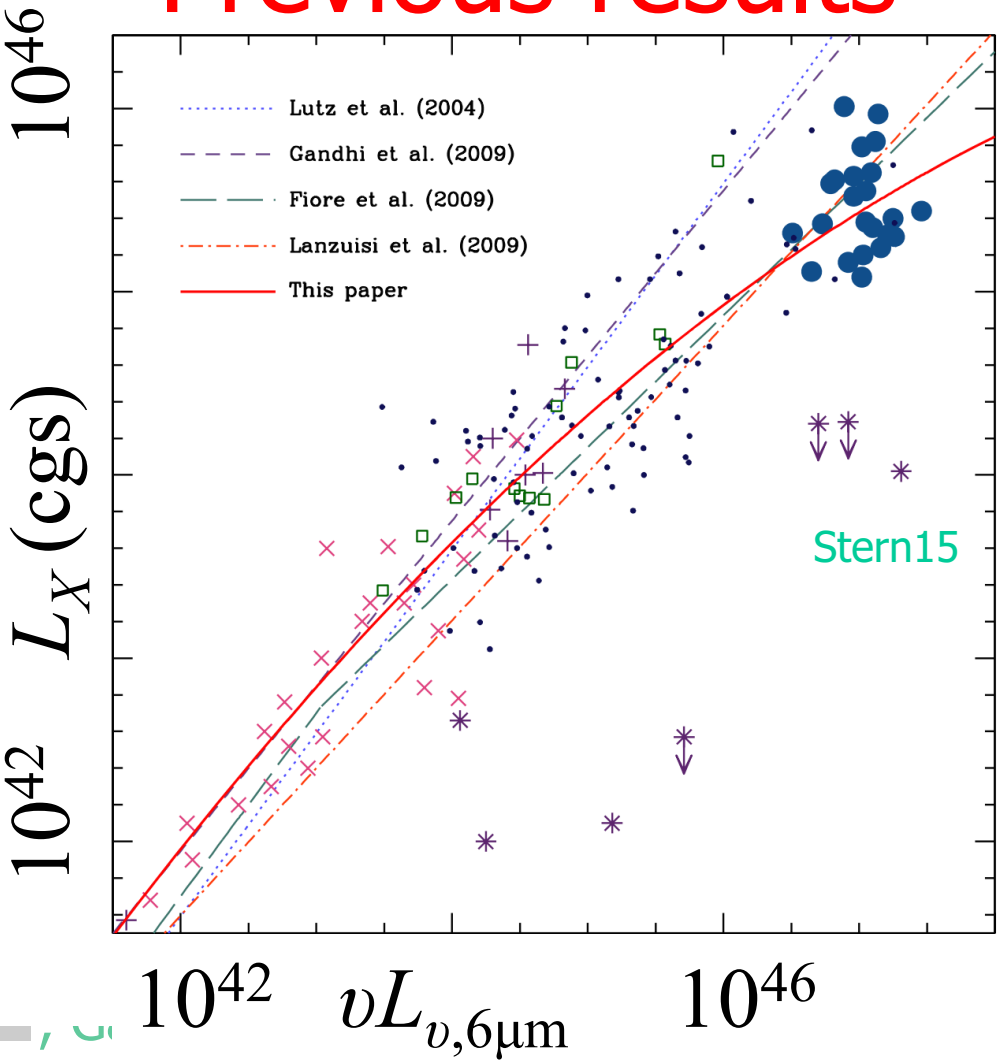

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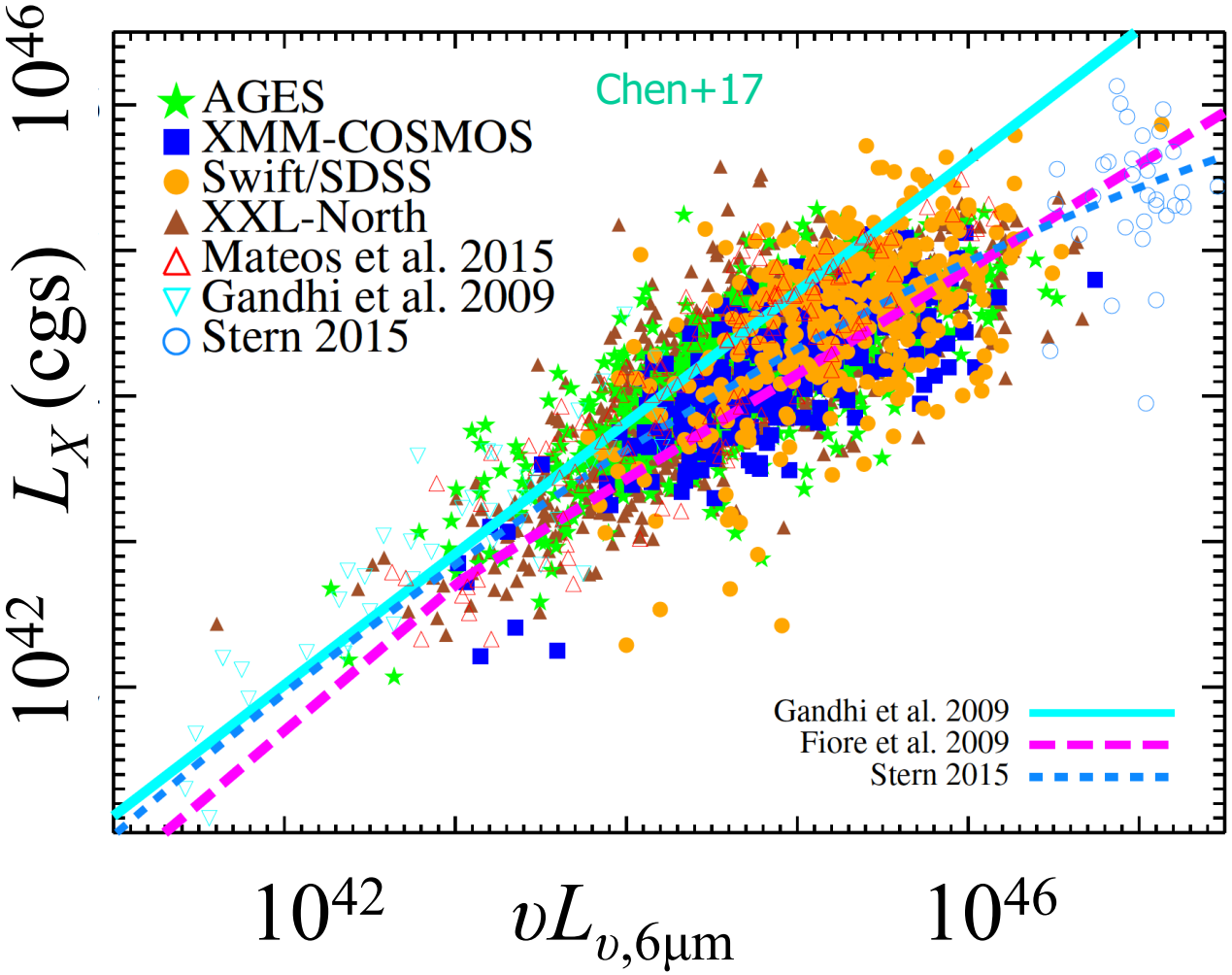
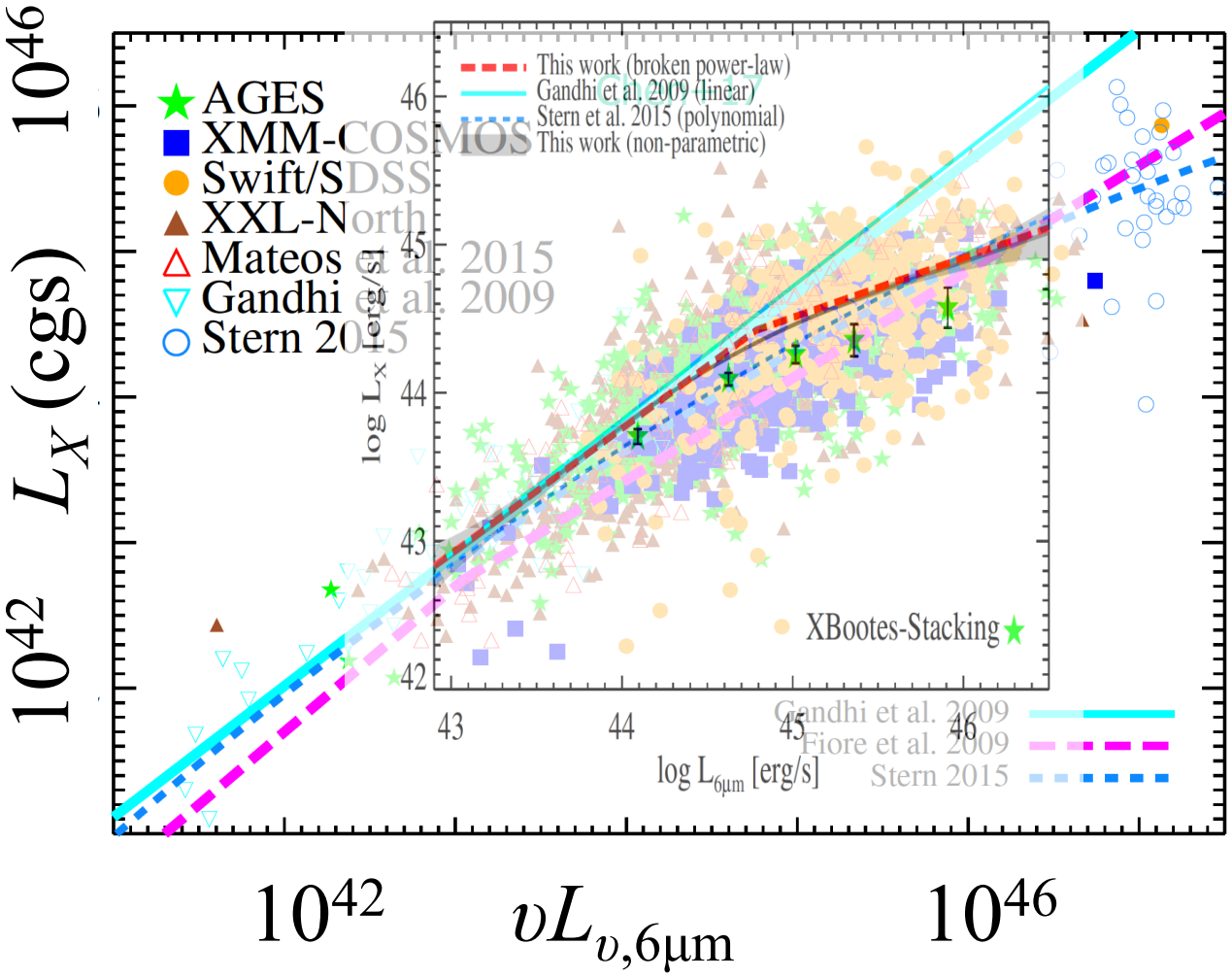


- Chen+17: 3488 QSO1 from several samples, X-det and MIR-det
- Flattening fitted with broken power-law (broken line in log-log)
- Discuss effect of X uplims, X-ray abs., X-ray flux limits, SF contamination…

Previous results



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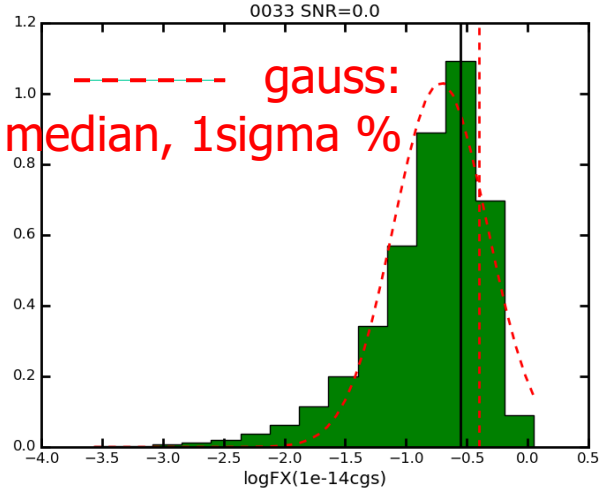
Our sample

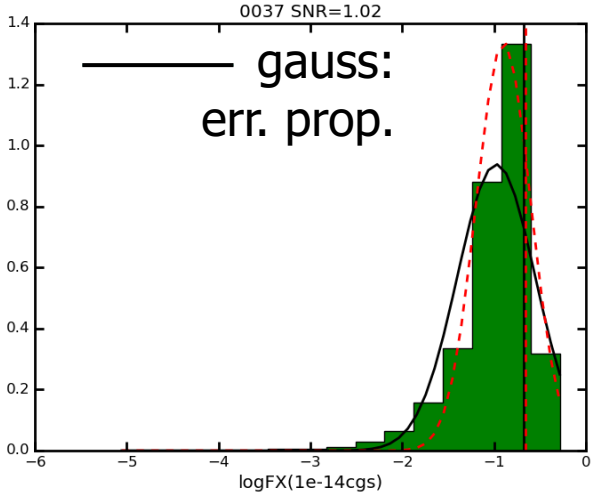
- We wish to get the largest possible sample of luminous objects
  - SDSS DR12 QSO Pâris+16: luminous objects, large coverage
    - Good z, z<4, |b|>20deg, type 1: $FWHM_{CIV\ or\ CIII]\ or\ MgII}$>1500km/s
    - SDSS DR9: no neighbours within 5”
    - Kozłowski’17: L_{bol}, M_{BH} from SDSS phot., spectra
  - UNWISE (Lang+14):
    - ~AllWISE “forced photometry” on SDSS DR10 sou.
    - Inter/extra-polating W2,W3,W4 $\Rightarrow \upsilon L_{\upsilon,6\mu m} \equiv L_{MIR}$ or uplims
  - 3XMM DR5 (Rosen+17): X sou. cat.
    - pn exposure time >5ks
    - SDSS sources within 15arcmin of 3XMM DR5 pointing
    - FLIX: flux on given position “forced photometry”
    - Using flux in 0.5-4.5keV$\Rightarrow L_X$ 2-10keV or uplims

Treatment of upper limits

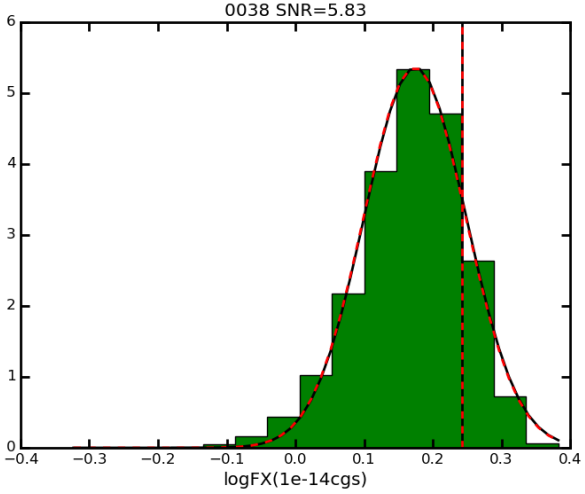
S=0 ⇒ $S/\Delta S$=0



$S/\Delta S$~1



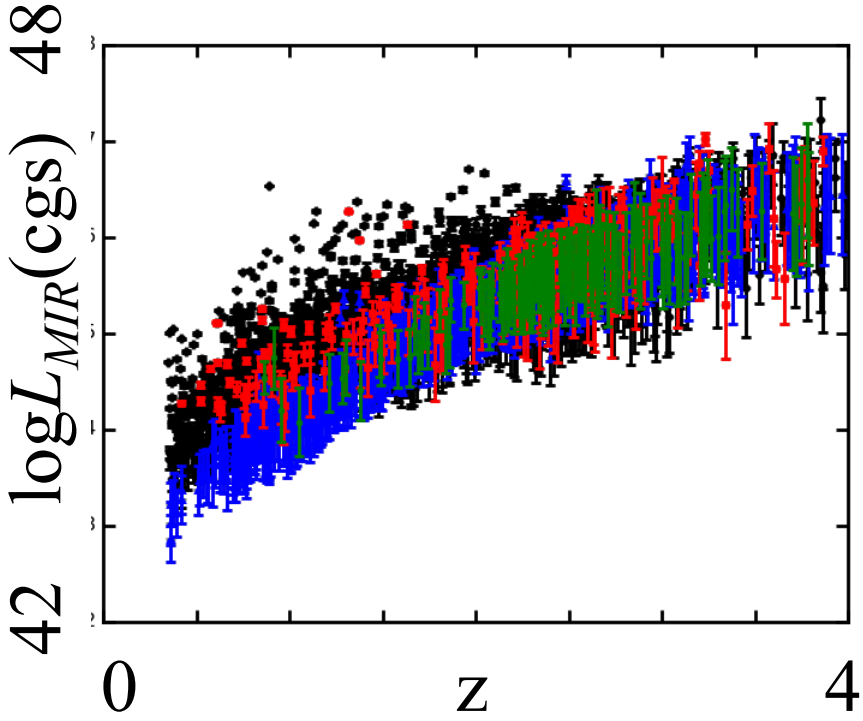
$S/\Delta S$~6

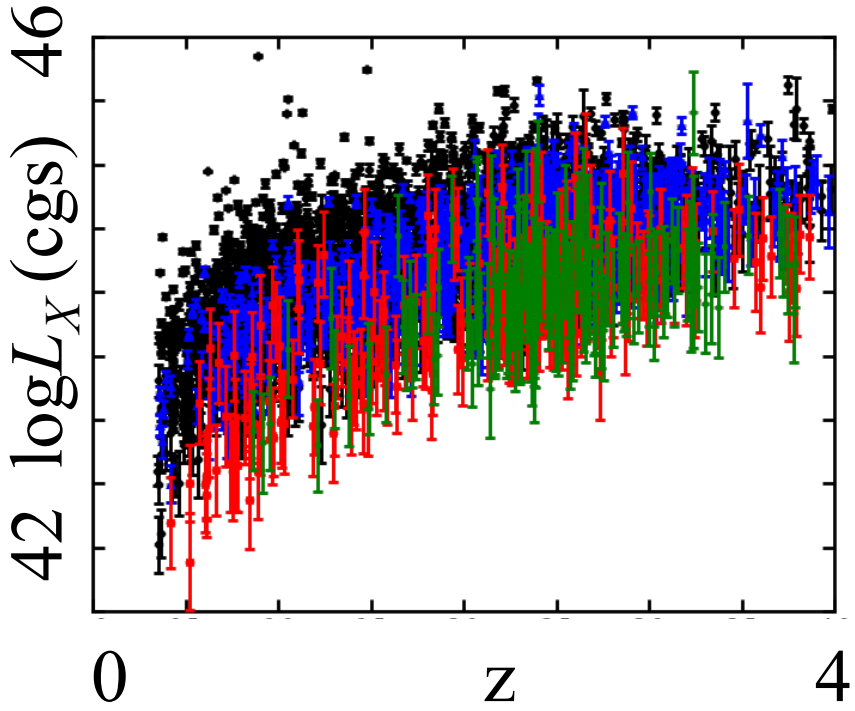


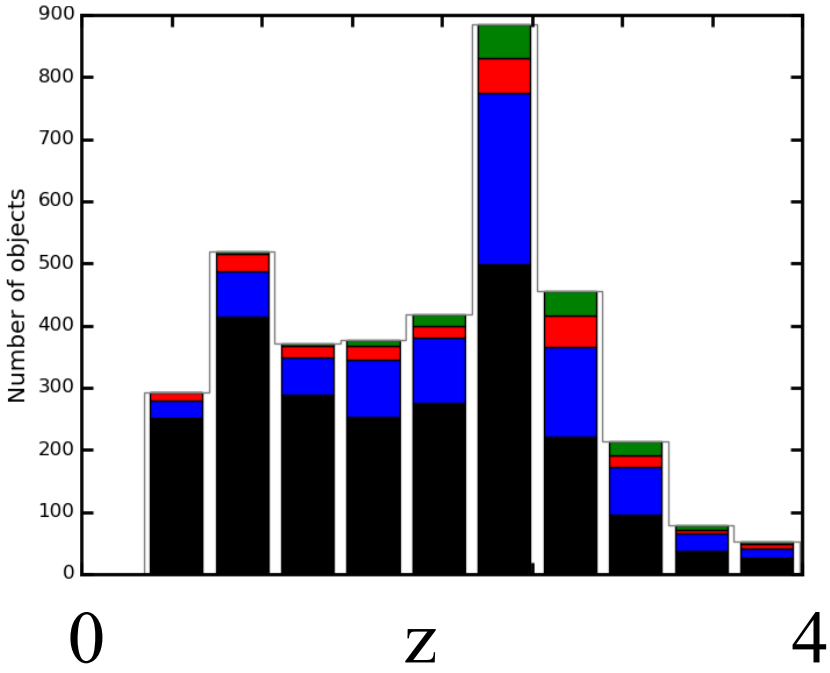
- Treatment of upper limits:
  - All sources have L_{bol} and M_{BH} (by design), they are all real
  - For X and MIR:
    - If flux-1σ error bar S-ΔS>0: detection
    - If S-ΔS ≤0: upper-limit
      - If S<0 ⇒ S=0, keeping ΔS
    - Redistributing all the probability to >0
  - But fits done in log-space:
    - Sampled log(L) using truncated gaussian for flux ~ gaussian !
    - Also done fits using ”flat” up. lims for upper-limits and no difference

Our sample

- 3663 QSO1:
  - 2361 X-det and MIR-det
  - 238 only MIR-det
  - 900 only X-det
  - 164 X-nodet & MIR-nodet

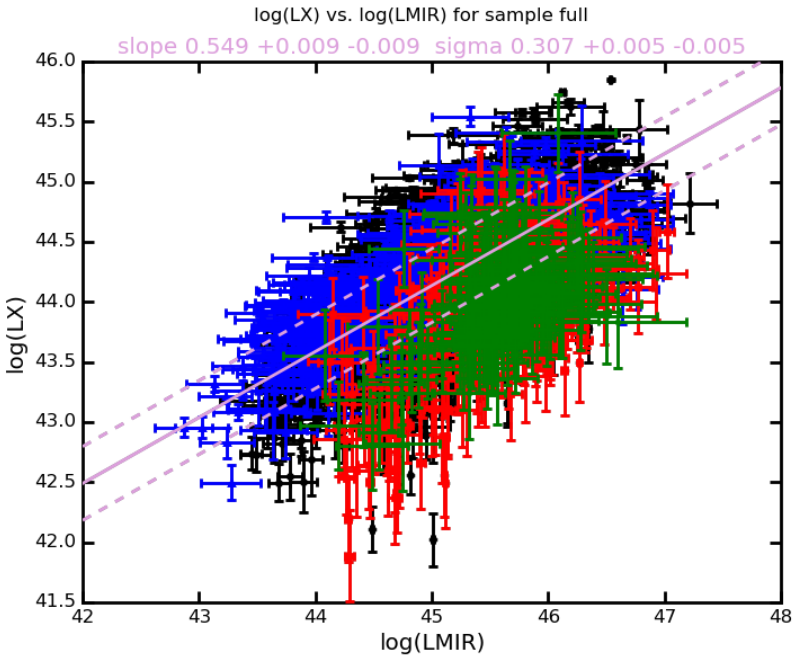






Model fits

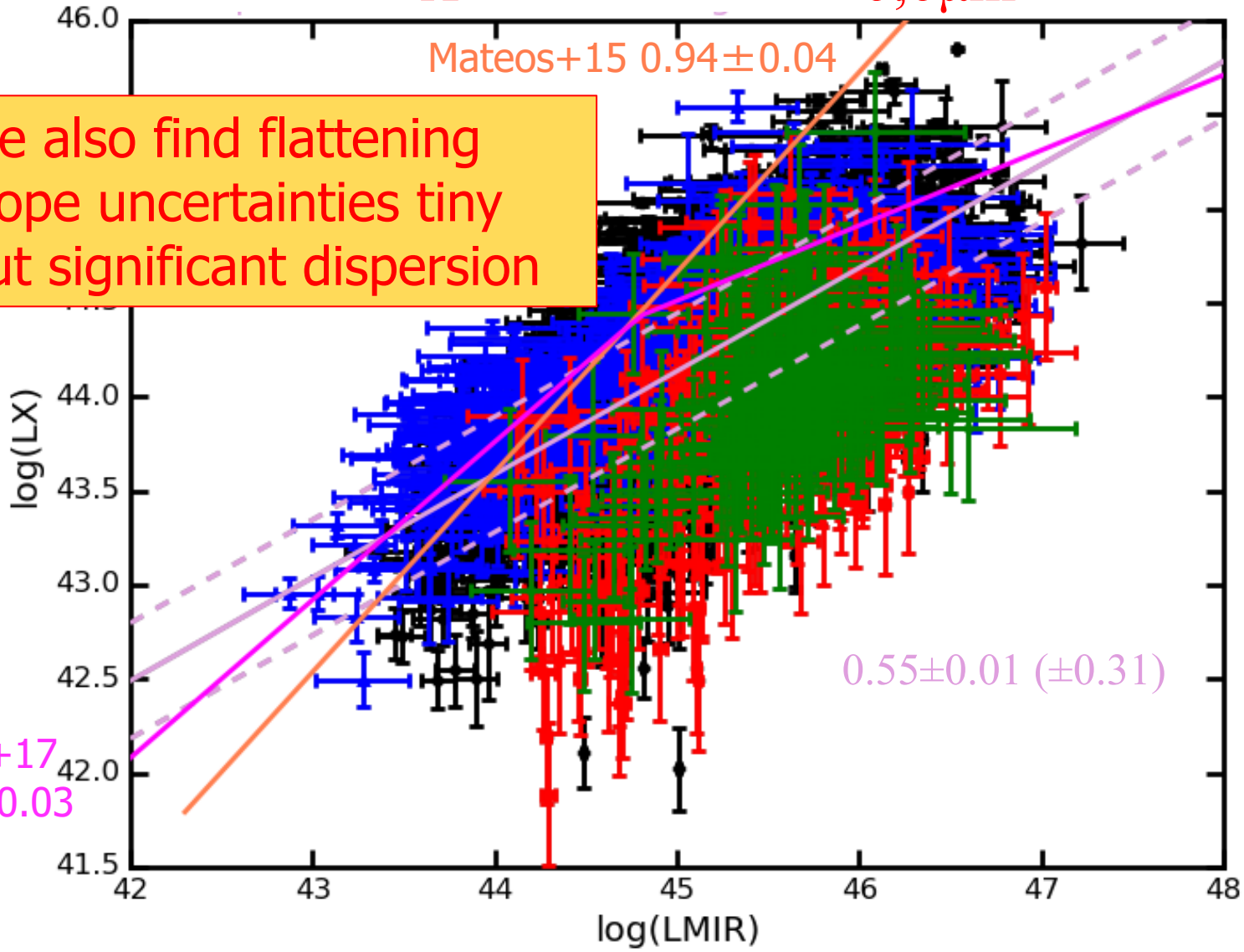
- Fitting a straight line in log-log:
  - Errors on both coordinates
  - Large dispersion



- Kelly'07: Bayesian method (`IDL, python` K07):
  - Fits a straight line
  - Taking into account (gaussian) errors in X and Y
  - Allowing for intrinsic dispersion in the data σ
  - Can handle upper limits in Y
  - Uncertainties from MCMC: median and 1σ percentiles
  - …

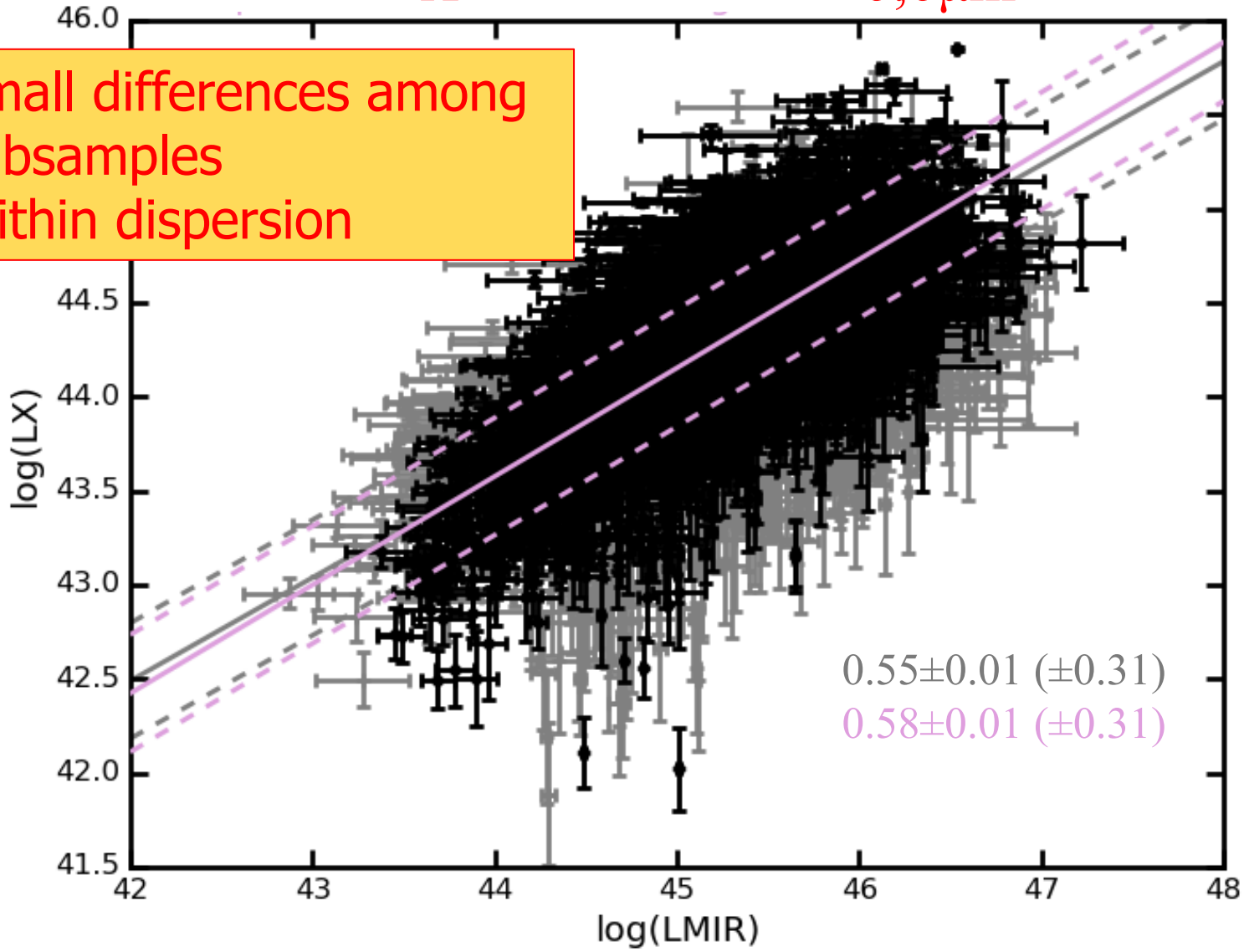
$\log(L_X)$ vs $\log(\upsilon L_{\upsilon,6\mu m})$: full

- We also find flattening
- Slope uncertainties tiny
- But significant dispersion



$\log(L_X)$ vs $\log(\upsilon L_{\upsilon,6\mu m})$: full

- Small differences among subsamples
- Within dispersion

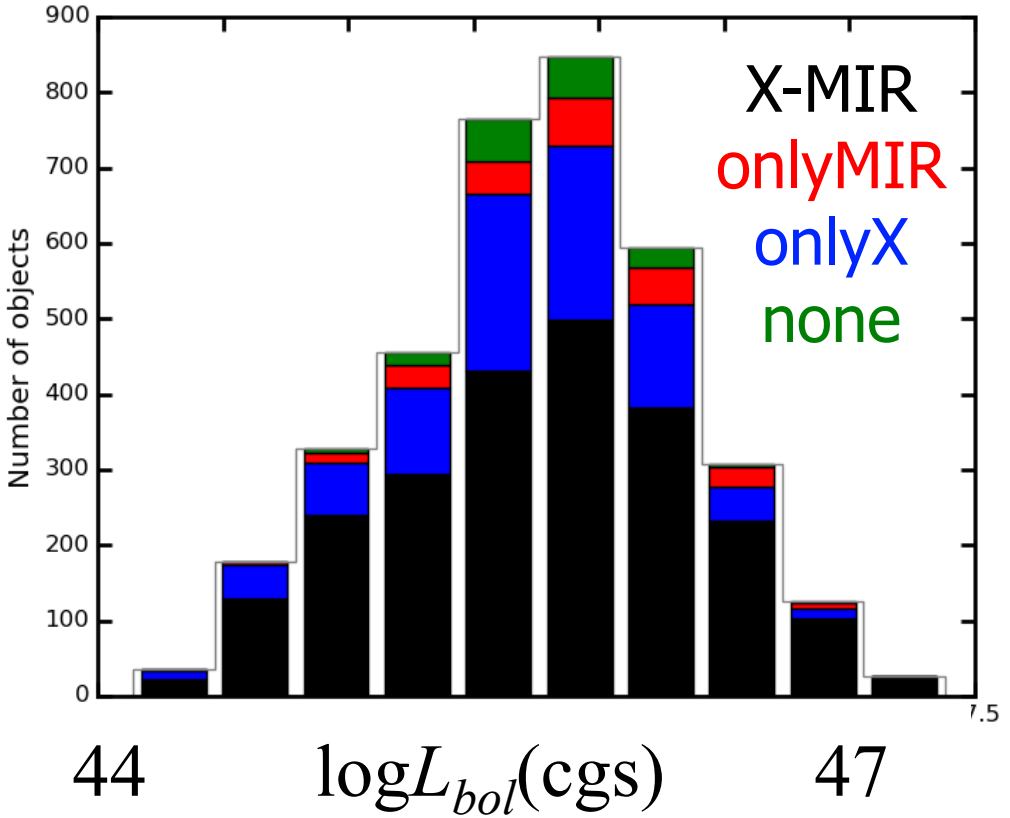


X-MIR

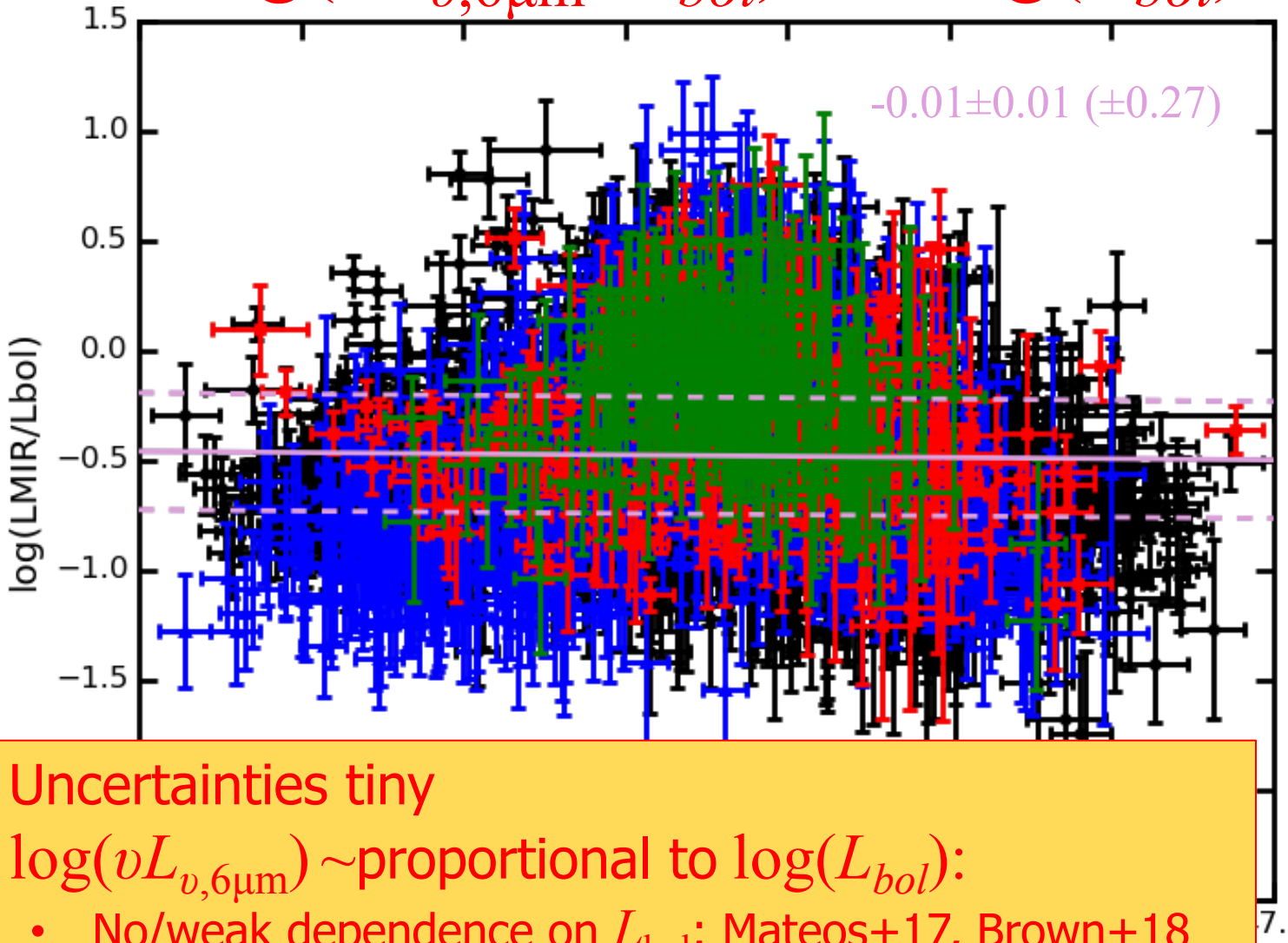
full

What is going on?

- Several possibilities:
  - Both increasing but MIR faster
  - X-ray flattening but MIR not
  - Both flattening but MIR slower
  - …
- Need to compare with the origin of both:
  - Kozłowski'17 SDSS: L_{bol} from $L_{1350}, L_{3000}, L_{5100}$ using bol. corr. (Richard+06)
  - $L_{MIR}/L_{bol} \approx$ covering factor
  - $L_X/L_{bol} \sim 1/\kappa_{bol}$
  - Also $\log(M_{BH}/M_\odot) \in [7.2,10.7]$

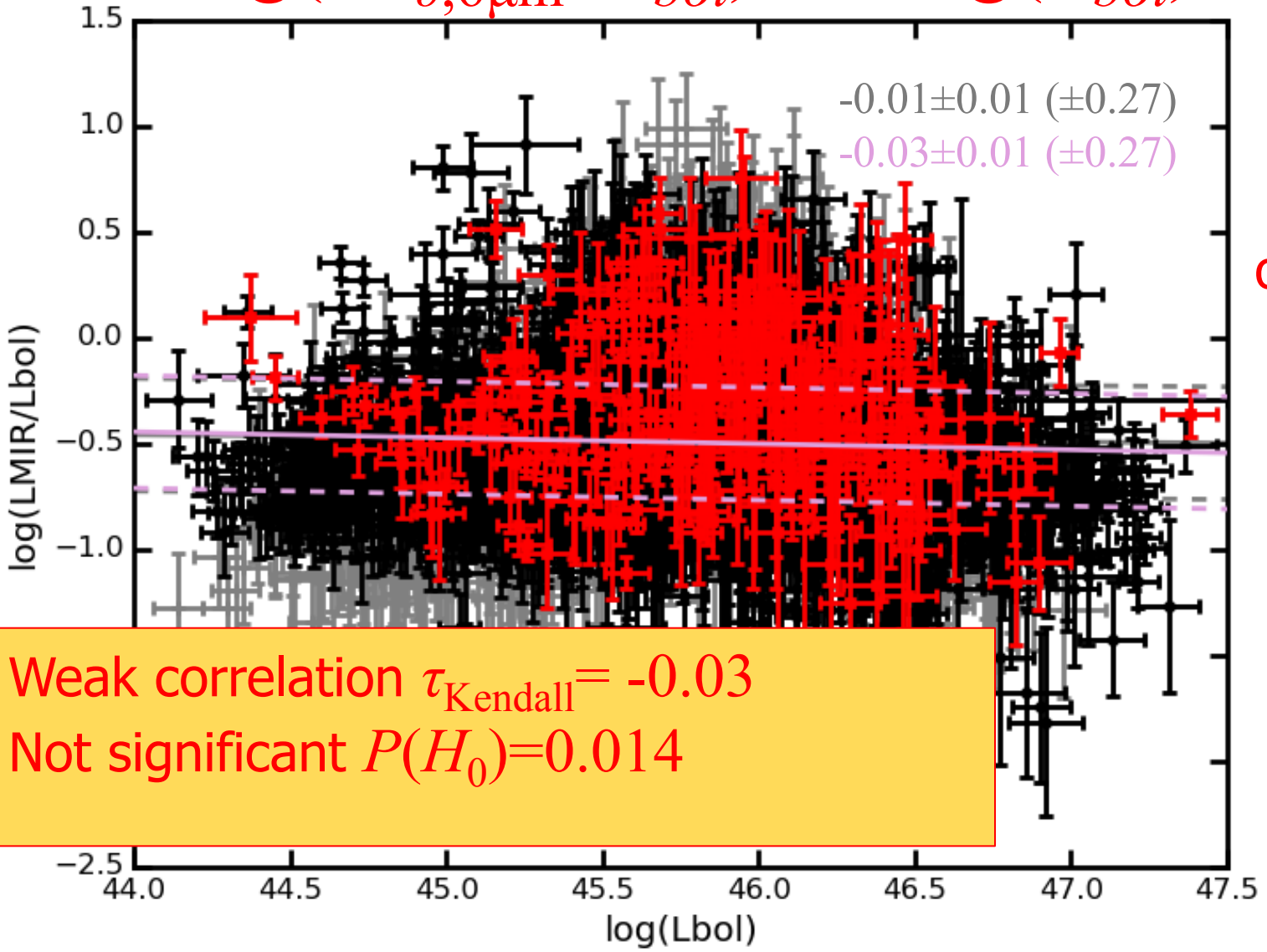


$\log(\upsilon L_{\upsilon,6\mu m}/L_{bol})$ vs $\log(L_{bol})$



- Uncertainties tiny
- $\log(\upsilon L_{\upsilon,6\mu m})$ ~proportional to $\log(L_{bol})$:
  - No/weak dependence on L_{bol}: Mateos+17, Brown+18
- Weak correlation $\tau_{Kendall}$= -0.01
- Not significant $P(H_0)$=0.31

$\log(\upsilon L_{\upsilon,6\mu m}/L_{bol})$ vs $\log(L_{bol})$



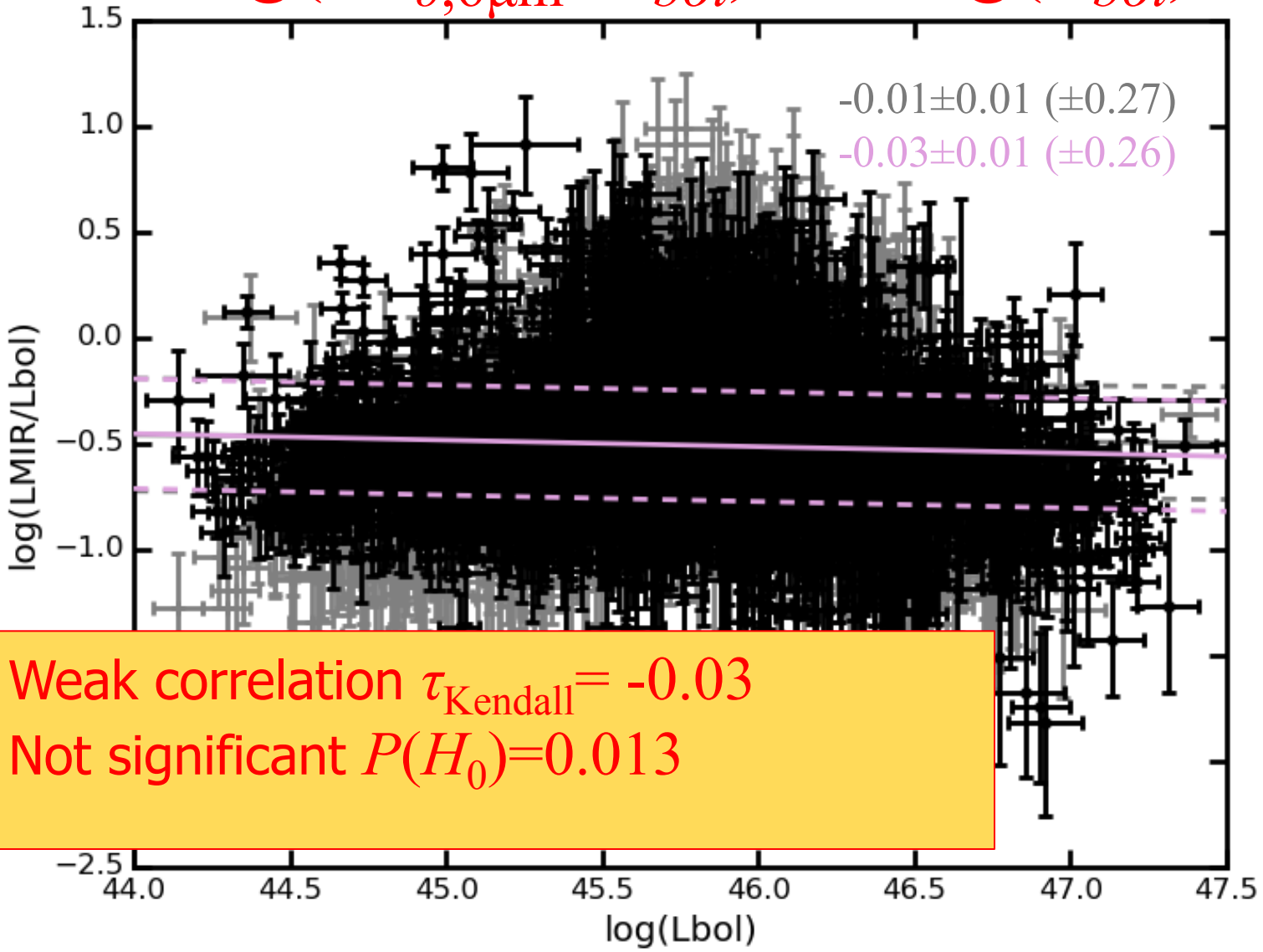
X-MIR

onlyMIR

full

- Weak correlation τ_{Kendall}= -0.03
- Not significant $P(H_0)$=0.014

$\log(\upsilon L_{\upsilon,6\mu m}/L_{bol})$ vs $\log(L_{bol})$



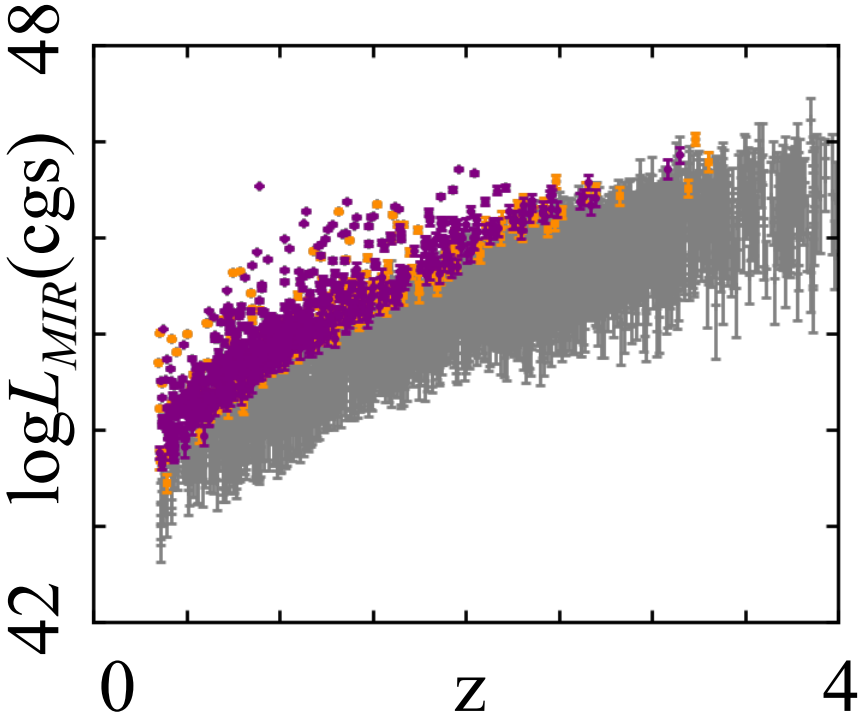
X-MIR

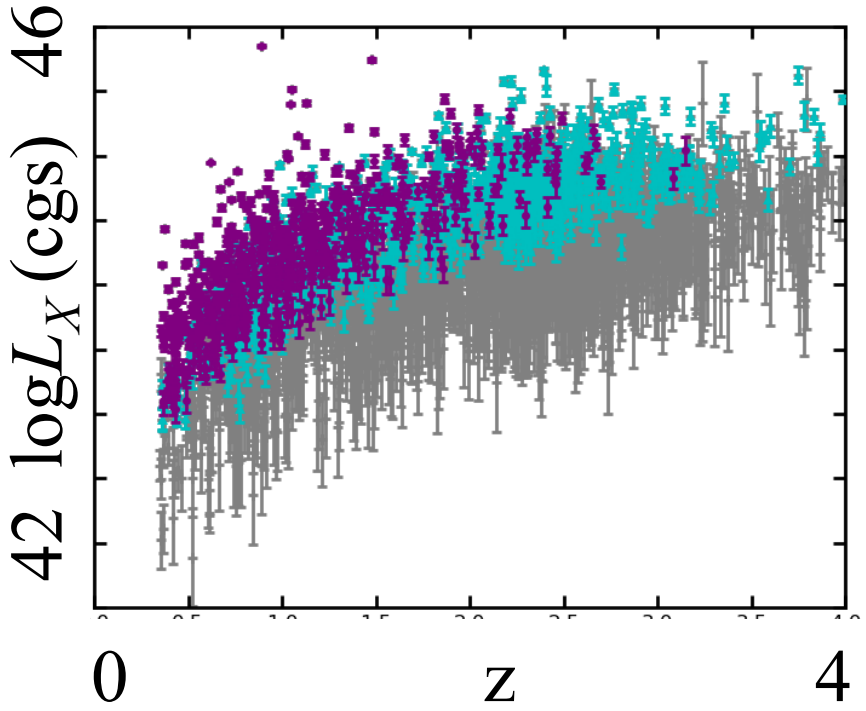
full

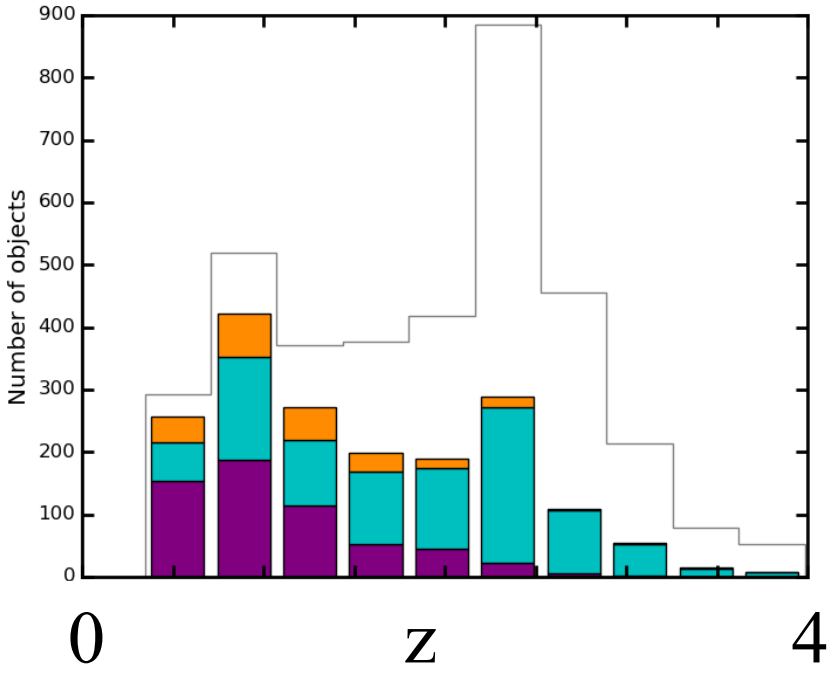
- Weak correlation τ_{Kendall}= -0.03
- Not significant $P(H_0)$=0.013

Our hiSNR sample

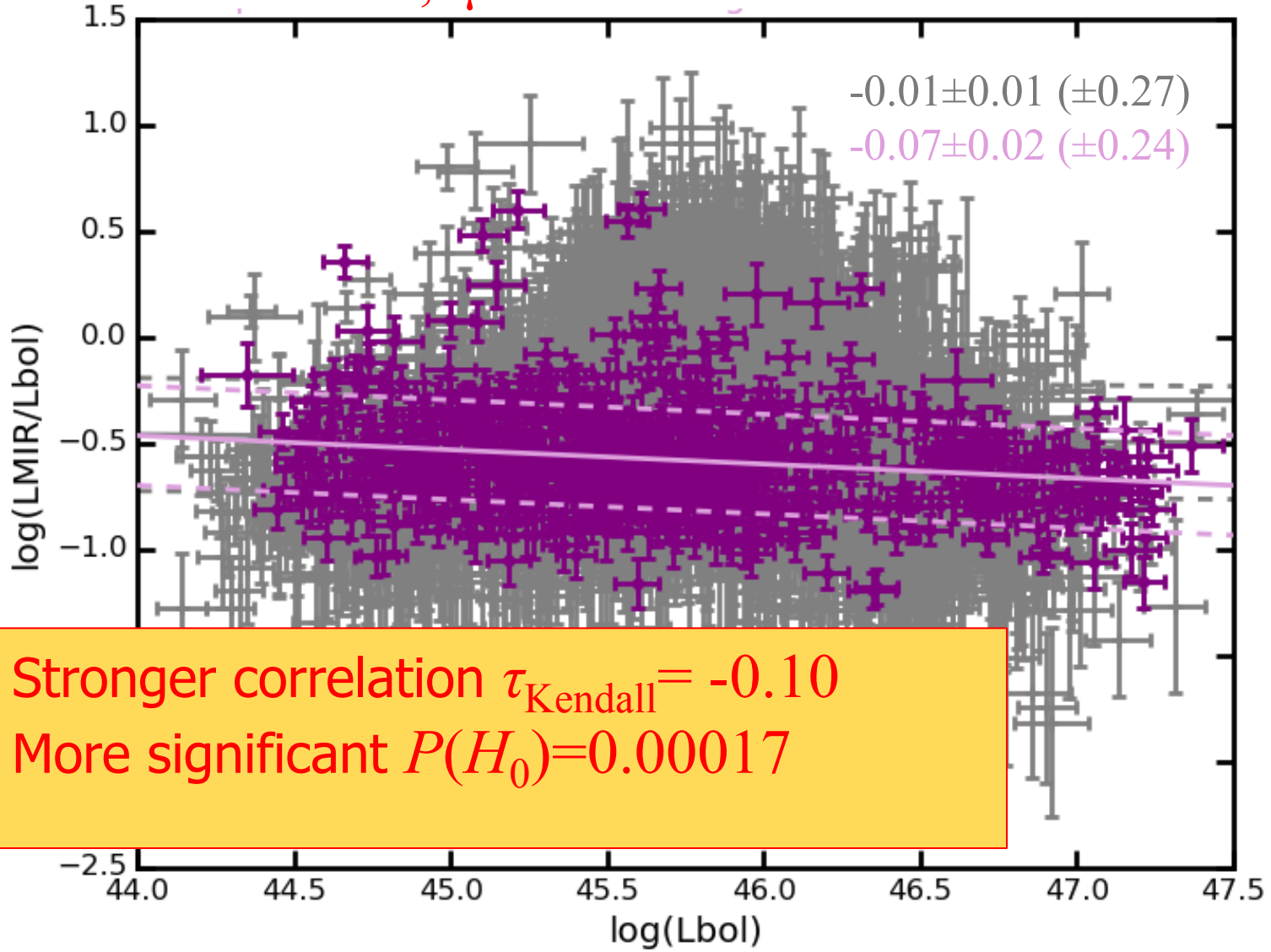
- 3663 QSO1:
  - 581 SNR>4 X and MIR
  - 813 only SNR>4 MIR
  - 1585 only SNR>4 X







$\log(\upsilon L_{\upsilon,6\mu m}/L_{bol})$ vs $\log(L_{bol})$ hi SNR

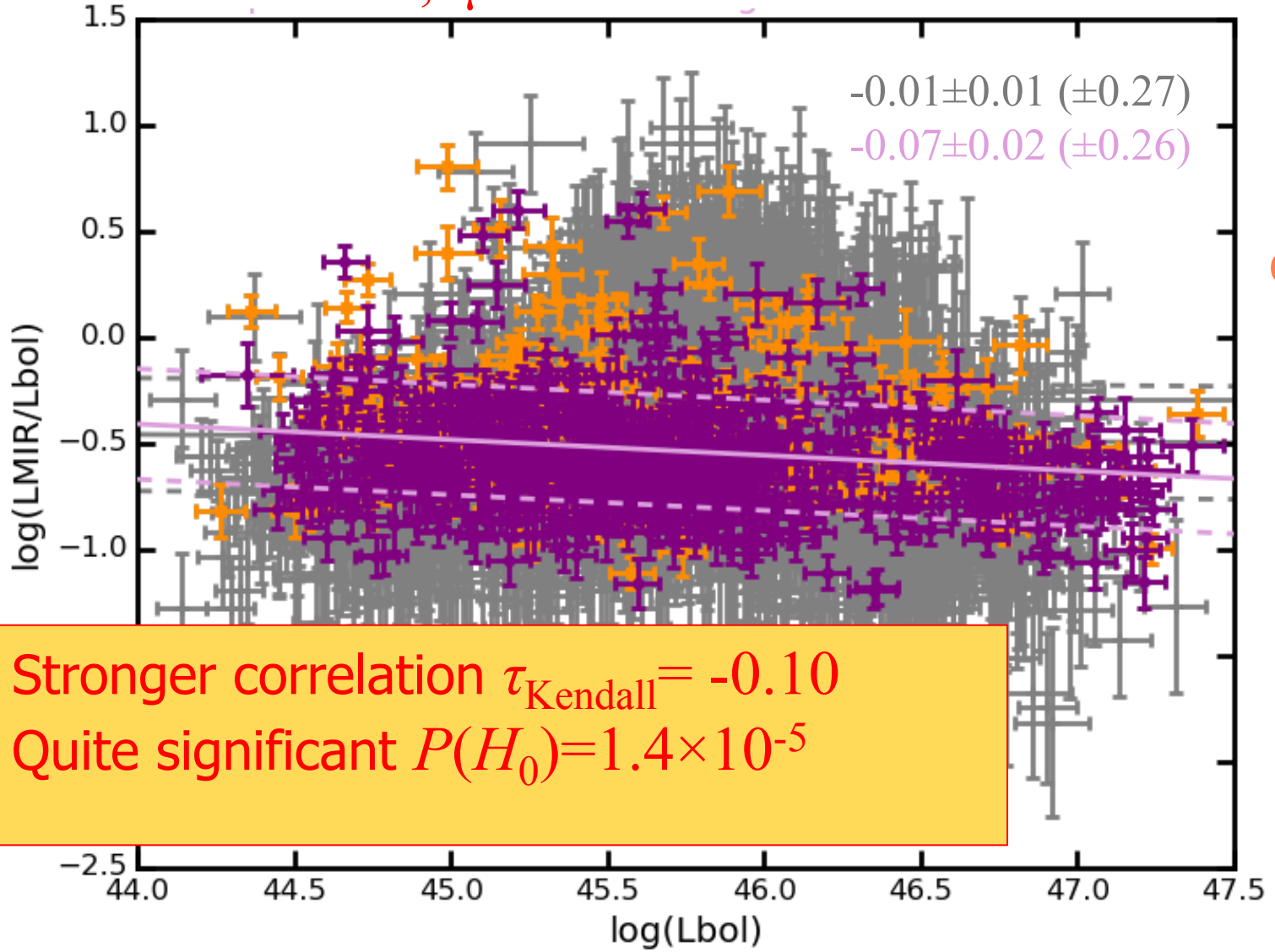


X-MIR

full

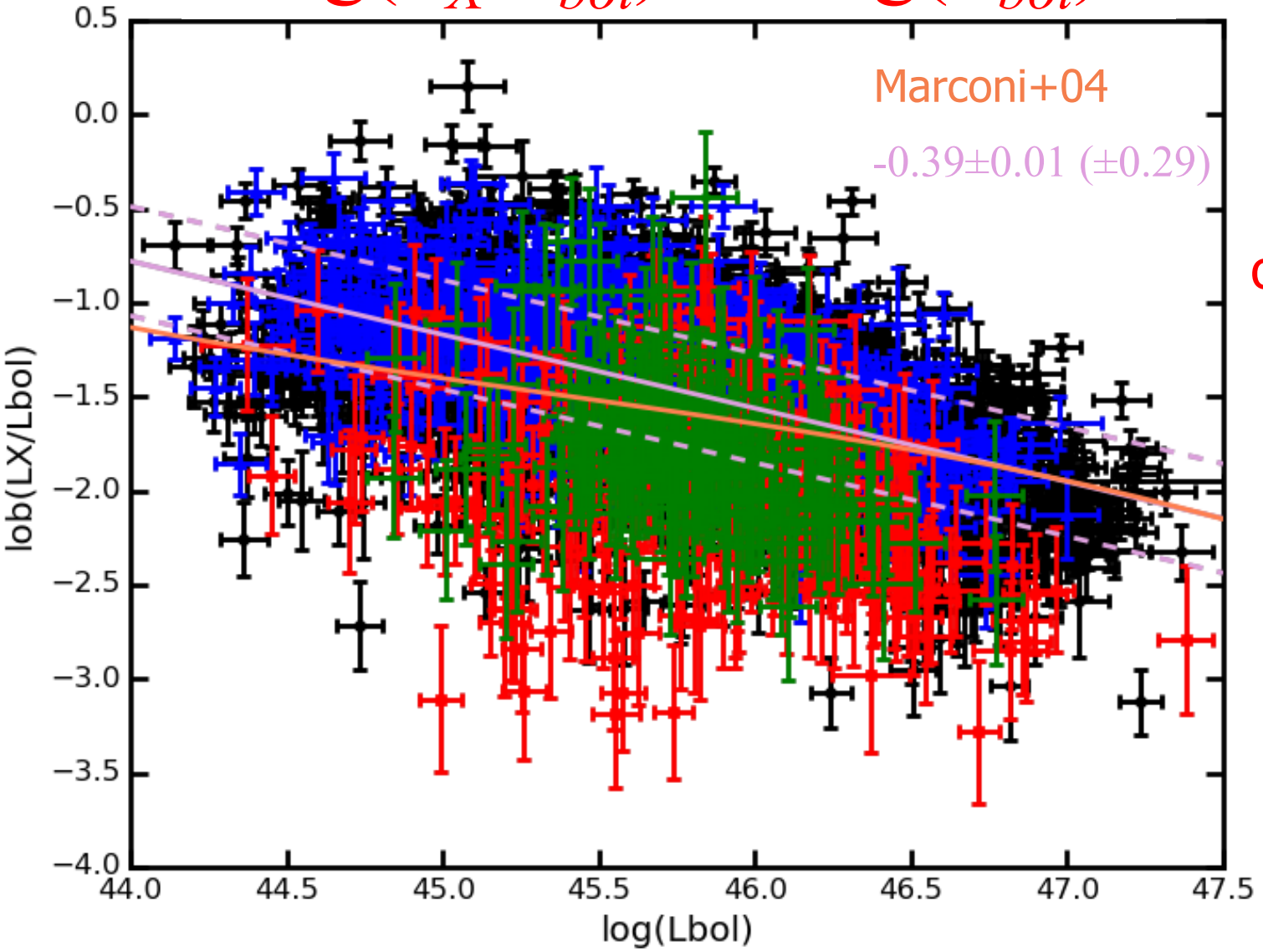
- Stronger correlation τ_{Kendall}= -0.10
- More significant $P(H_0)$=0.00017

$\log(\upsilon L_{\upsilon,6\mu m}/L_{bol})$ vs $\log(L_{bol})$ hi SNR



- Stronger correlation τ_{Kendall}= -0.10
- Quite significant $P(H_0)$=1.4×10^{-5}

$\log(L_X/L_{bol})$ vs $\log(L_{bol})$



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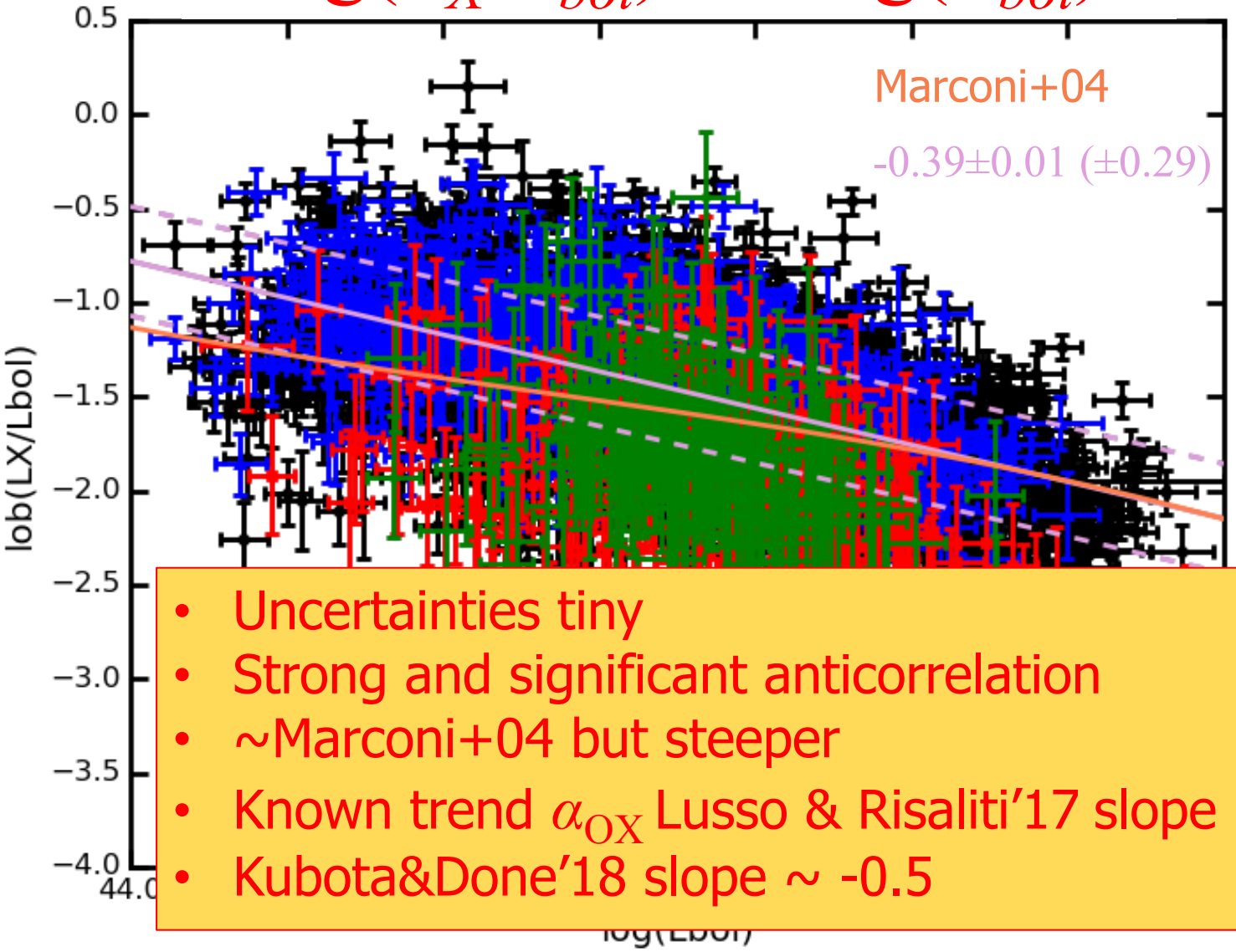
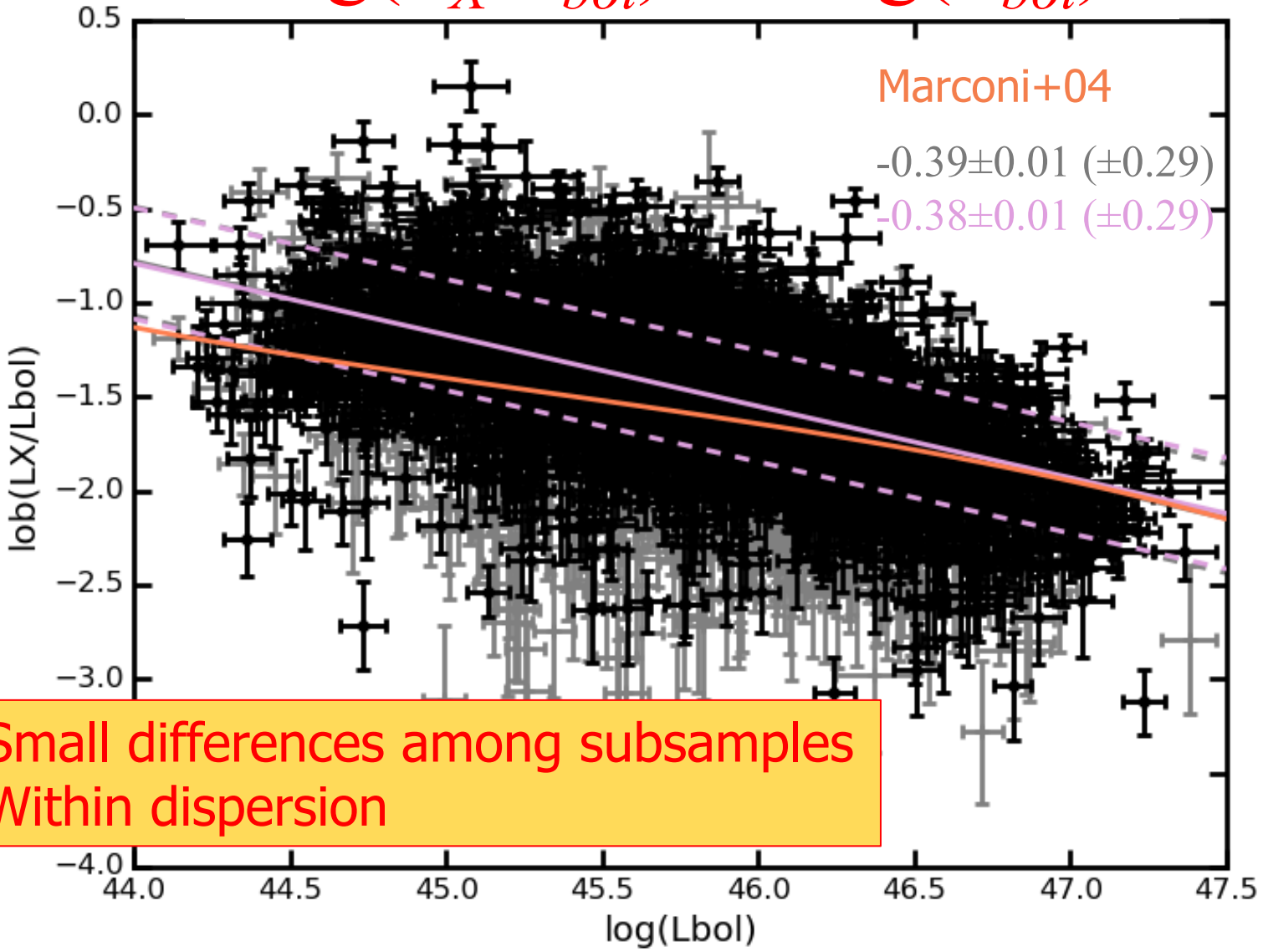


- Uncertainties tiny
- Strong and significant anticorrelation
- ~Marconi+04 but steeper
- Known trend α_{OX} Lusso & Risaliti'17 slope ~ -0.367
- Kubota&Done'18 slope ~ -0.5

$\log(L_X/L_{bol})$ vs $\log(L_{bol})$



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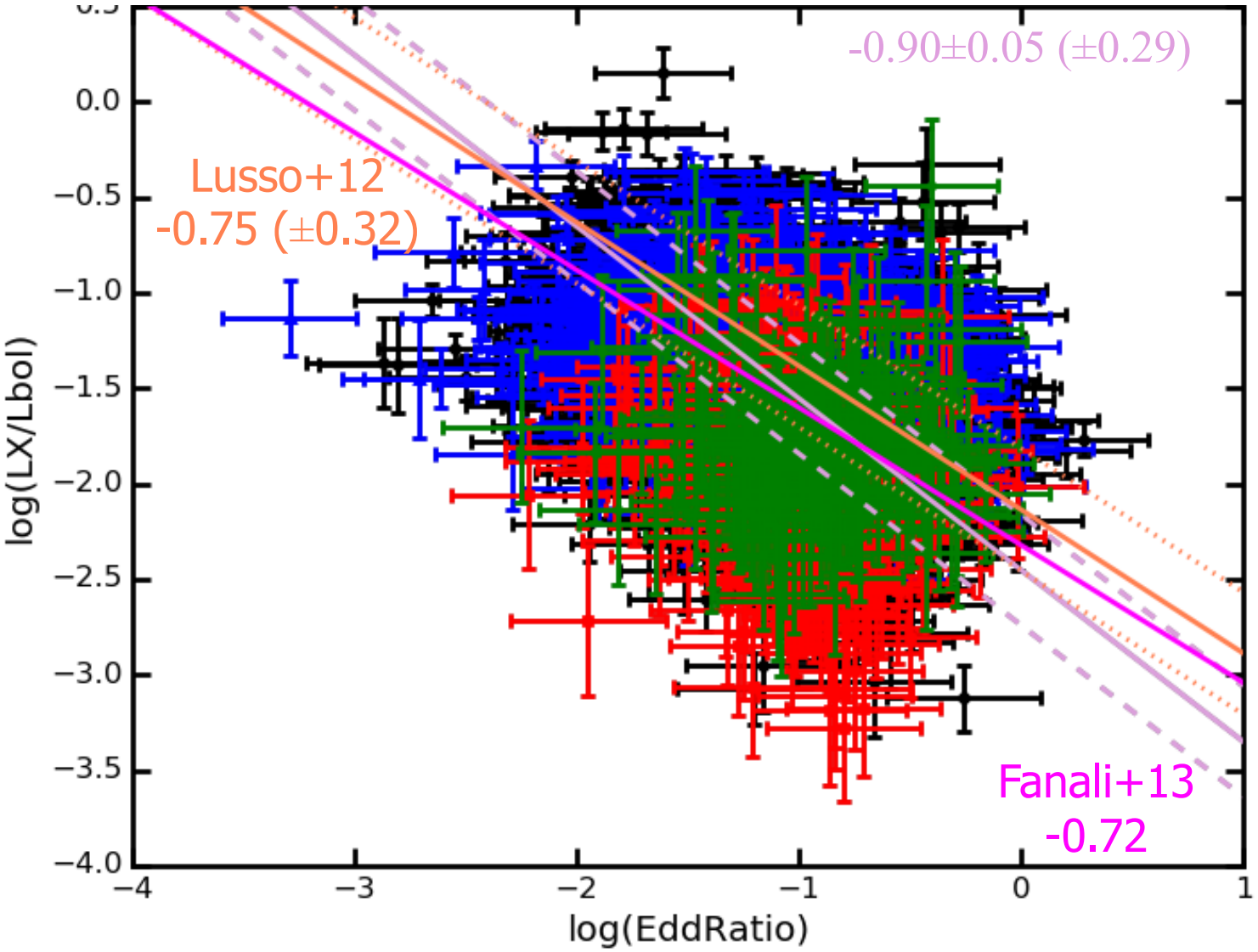
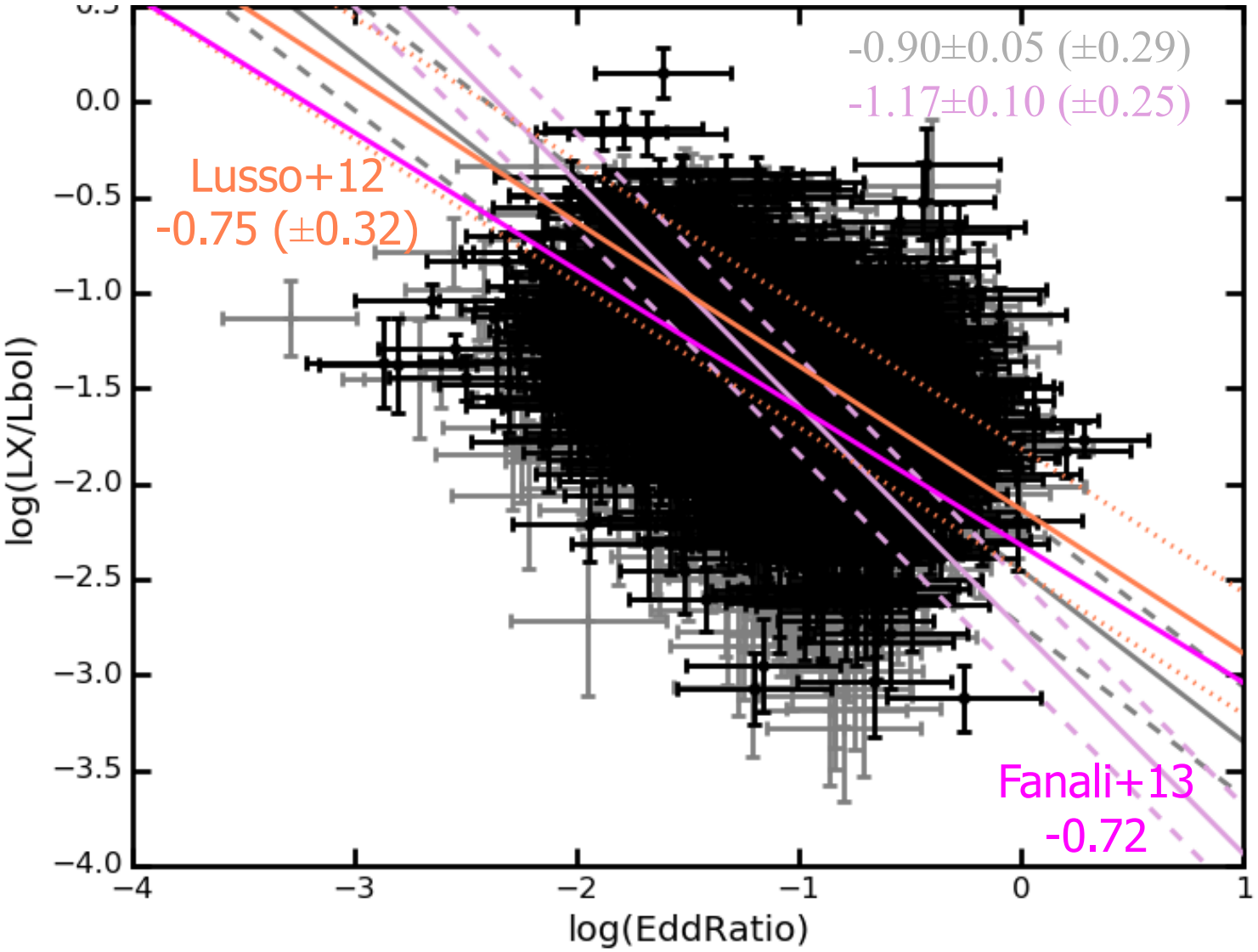
- Within dispersion

$\log(L_X/L_{bol})$ vs log(Eddington Ratio)



$\log(L_X/L_{bol})$ vs log(Eddington Ratio)



X-MIR

full

Conclusions

- Large sample of 3663 optically selected type 1 QSOs:
  - X-ray and MIR luminosities and upper limits
- Confirm flattening of L_X vs. $L_{\rm MIR}$ at the highest $L_{\rm MIR}$
  - Using upper limits in X,MIR even slightly flatter
- Comparing to the input optical/UV radiation:
  - $L_{\rm MIR}/L_{bol}$ flat: ~constant or weakly decreasing covering factor ...Mateos+17, Brown+18
  - L_X/L_{bol} decreases with L_{bol} as in phys. models
- Can also check for dependences on Edd. ratio...
  - L_X/L_{bol} vs Edd. Ratio steeper than previous results (Lusso+12, Fanali+13)