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

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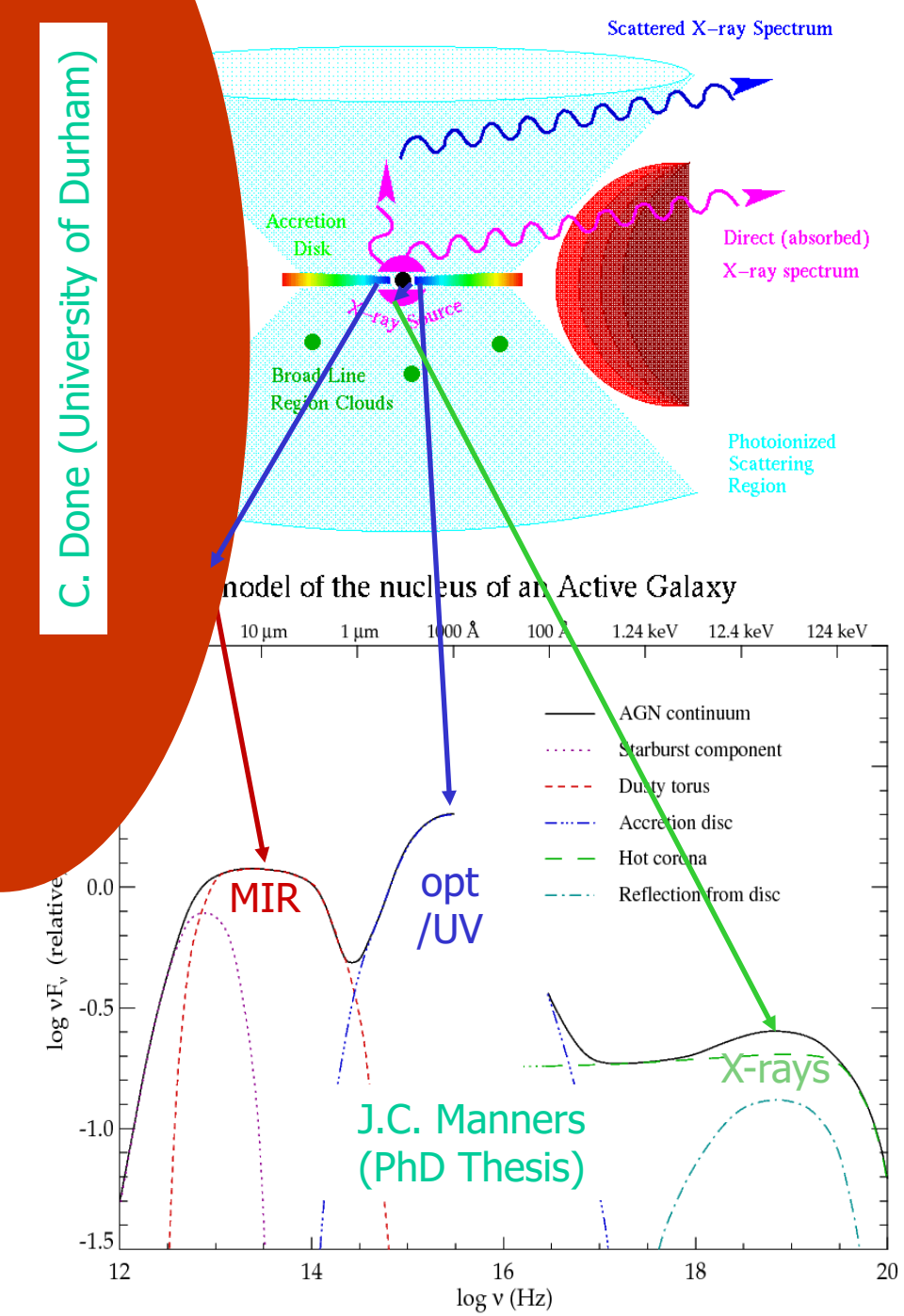
# Outline

- 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 $L_{bol}$: $L_X/L_{bol}$ and $L_{\rm MIR}/L_{bol}$ vs $L_{bol}$
- Conclusions

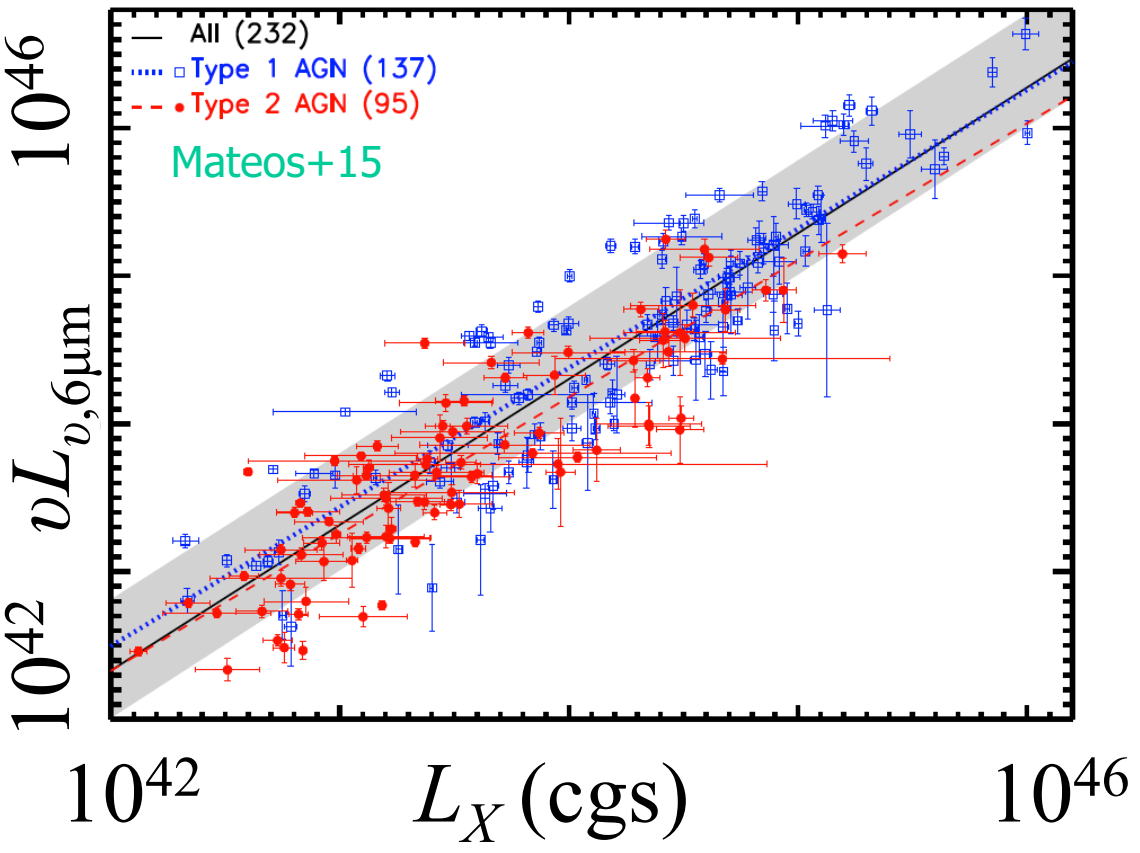
C. Done (University of Durham)




# 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 ●● ...
- 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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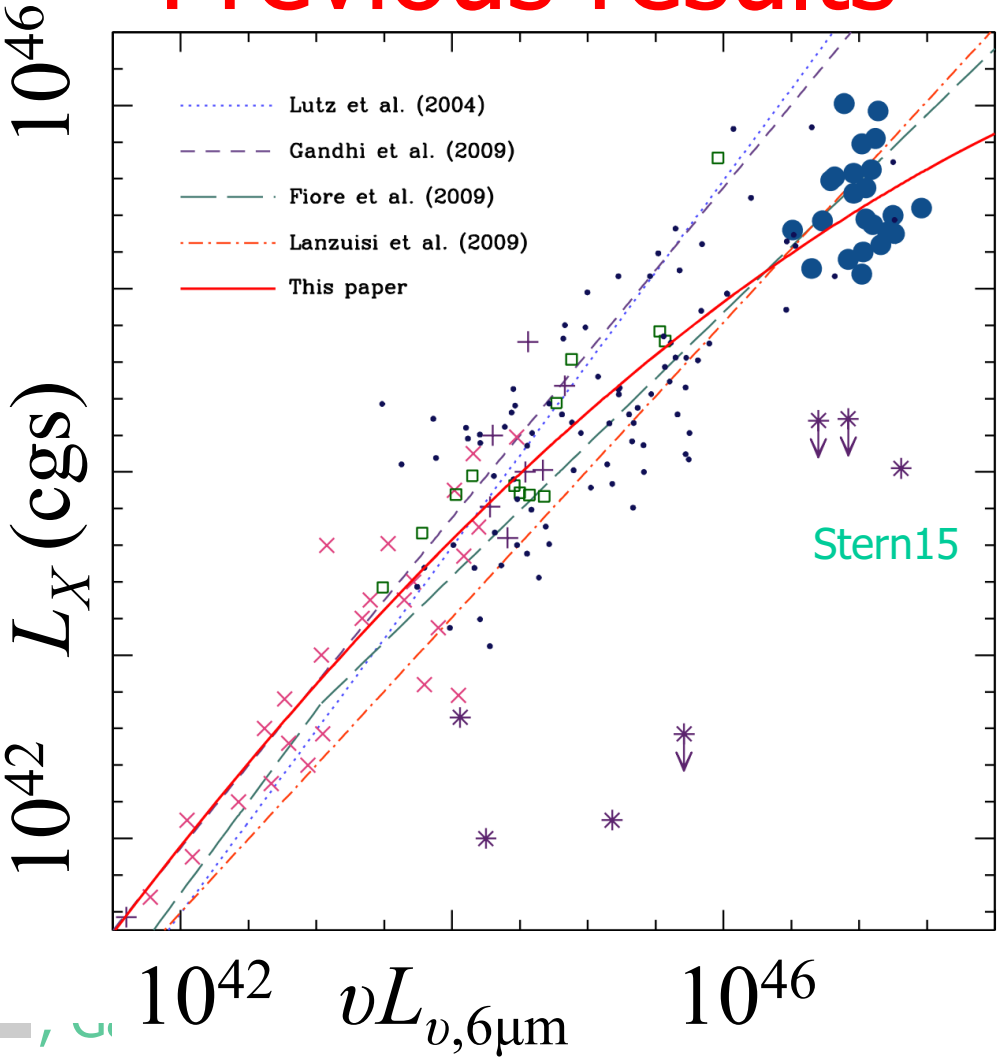


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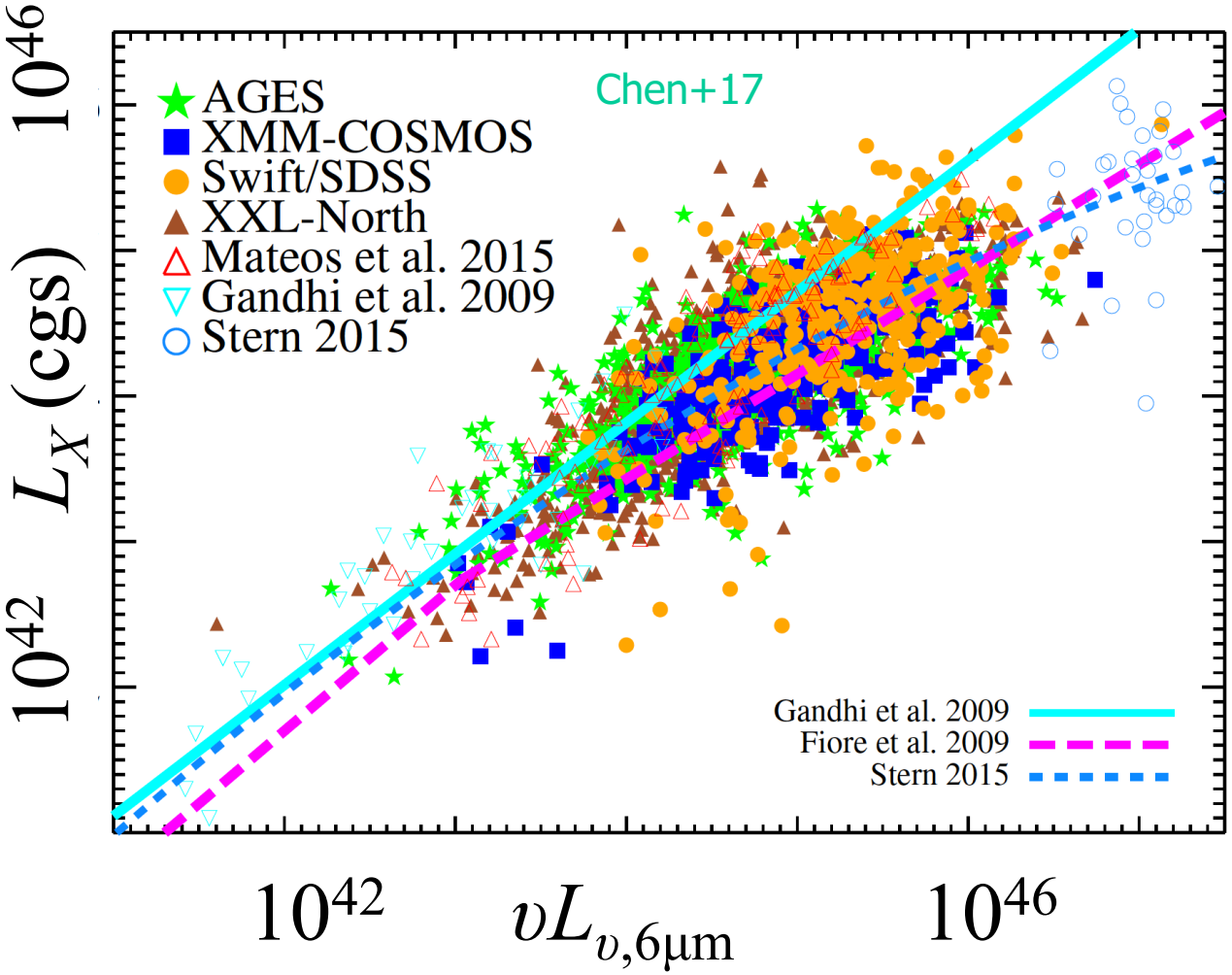


- Chen+17: 3488 QSO1 from several samples, X-det and MIR-det
- Flattening fitted with broken power-law (broken line in log-log)
- Discuss effect of X uplims, X-ray abs., X-ray flux limits, SF contamination…

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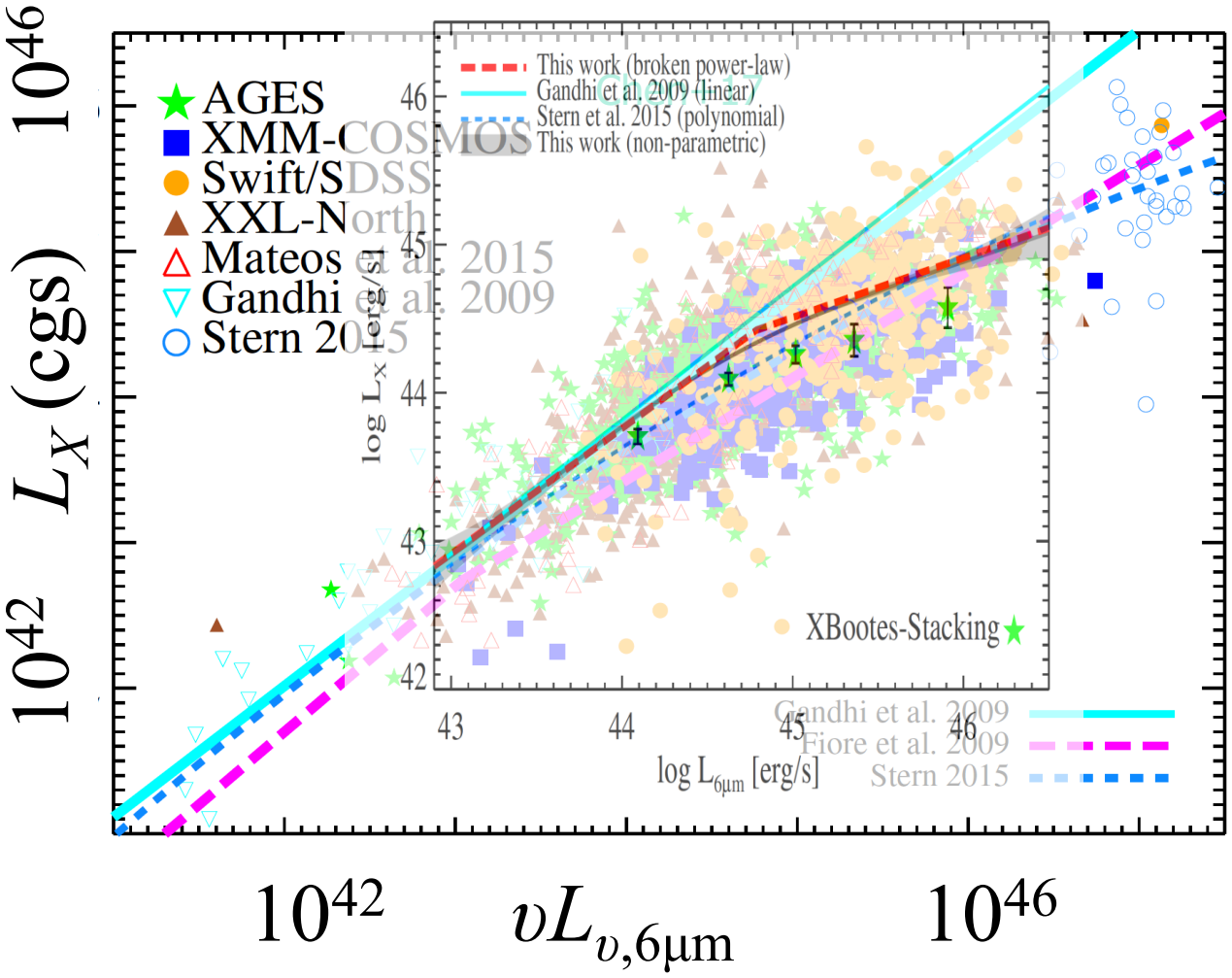


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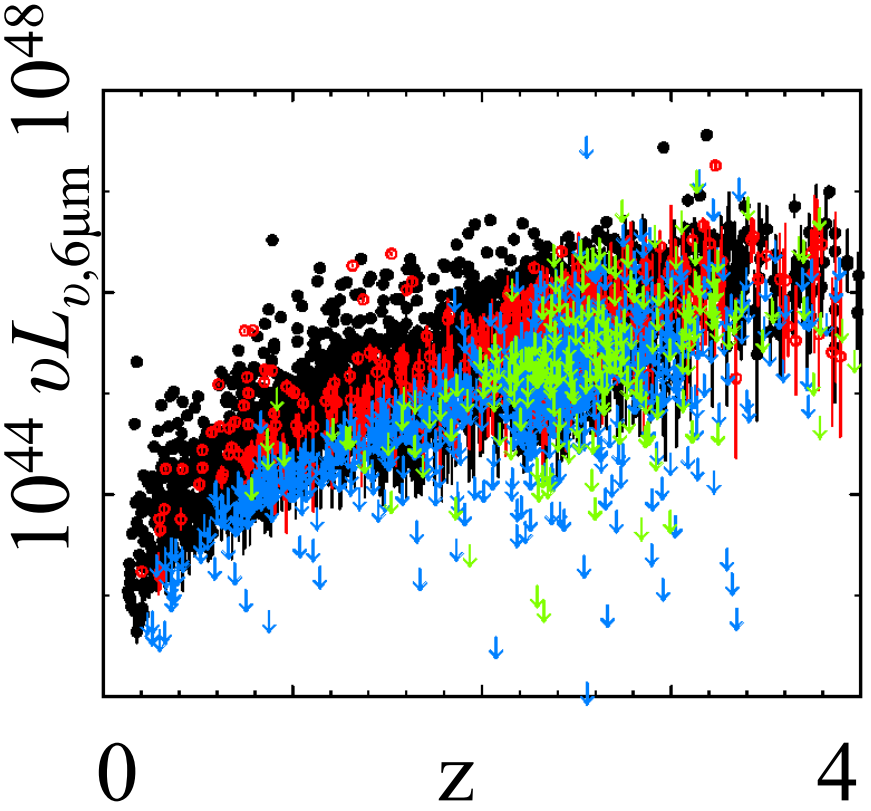
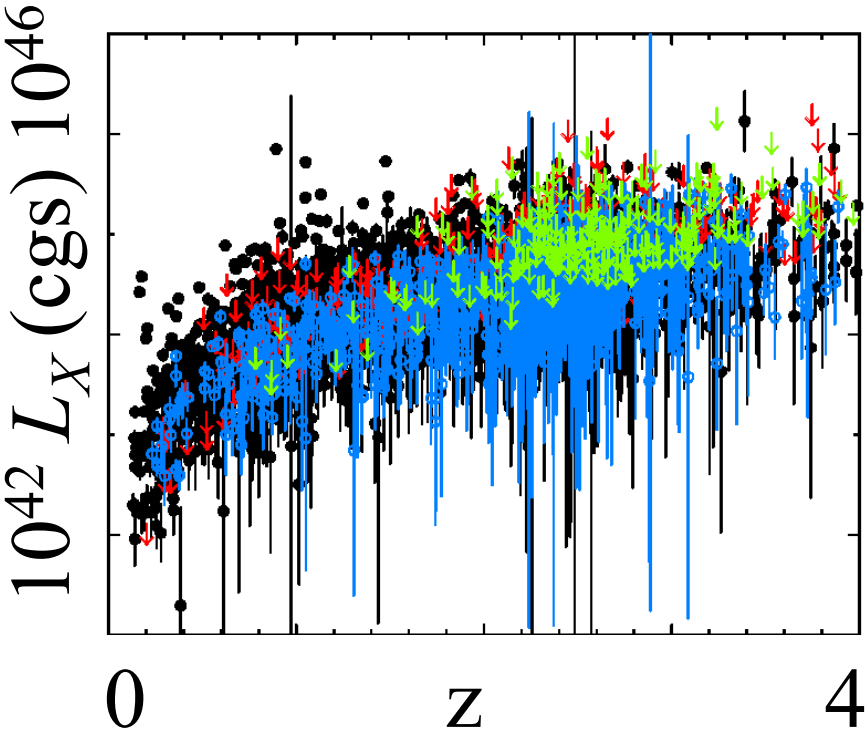
# Our sample

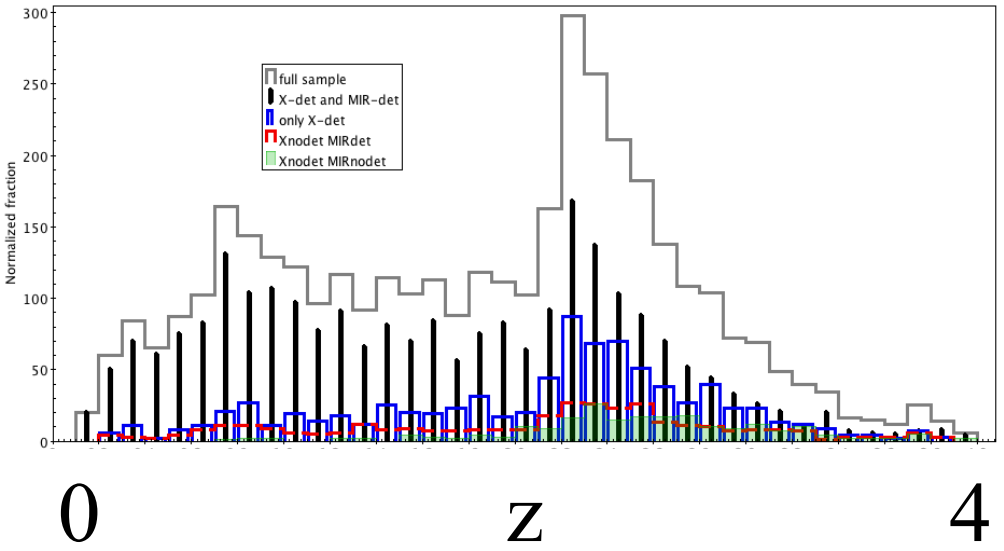
- We wish to get the largest possible sample of luminous objects
  - SDSS DR12 QSO Pâris+16: luminous objects, large coverage
    - Good z, z<4, |b|>20deg, type 1: $FWHM_{CIV\ or\ CIII]\ or\ MgII}$>1500km/s
    - SDSS DR9: no neighbours within 5”
    - Kozłowski’17: $L_{bol}$ from SDSS spectra (bol. corr. Richard+06)
  - UNWISE (Lang+14):
    - ~AllWISE “forced photometry” on SDSS DR10 sou.
    - Inter/extra-polating W2,W3 $\Rightarrow \upsilon L_{\upsilon,6\mu m} \equiv L_{MIR}$ or uplims
  - 3XMM DR5 (Rosen+17): largest (until DR6,7) X sou. cat.
    - pn exposure time >5ks
    - SDSS sources within 15arcmin of 3XMM DR5 pointing
    - FLIX: upper limits for non-detections (and exposure times for all)
    - Using flux in 0.5-12keV$\Rightarrow L_X$ 2-10keV or uplims

# Our sample

- 3844 QSO1:
  - 2447 X-det and MIR-det
  - 339 only MIR-det
  - 840 only X-det
  - 218 X-nodet and MIR-nodet



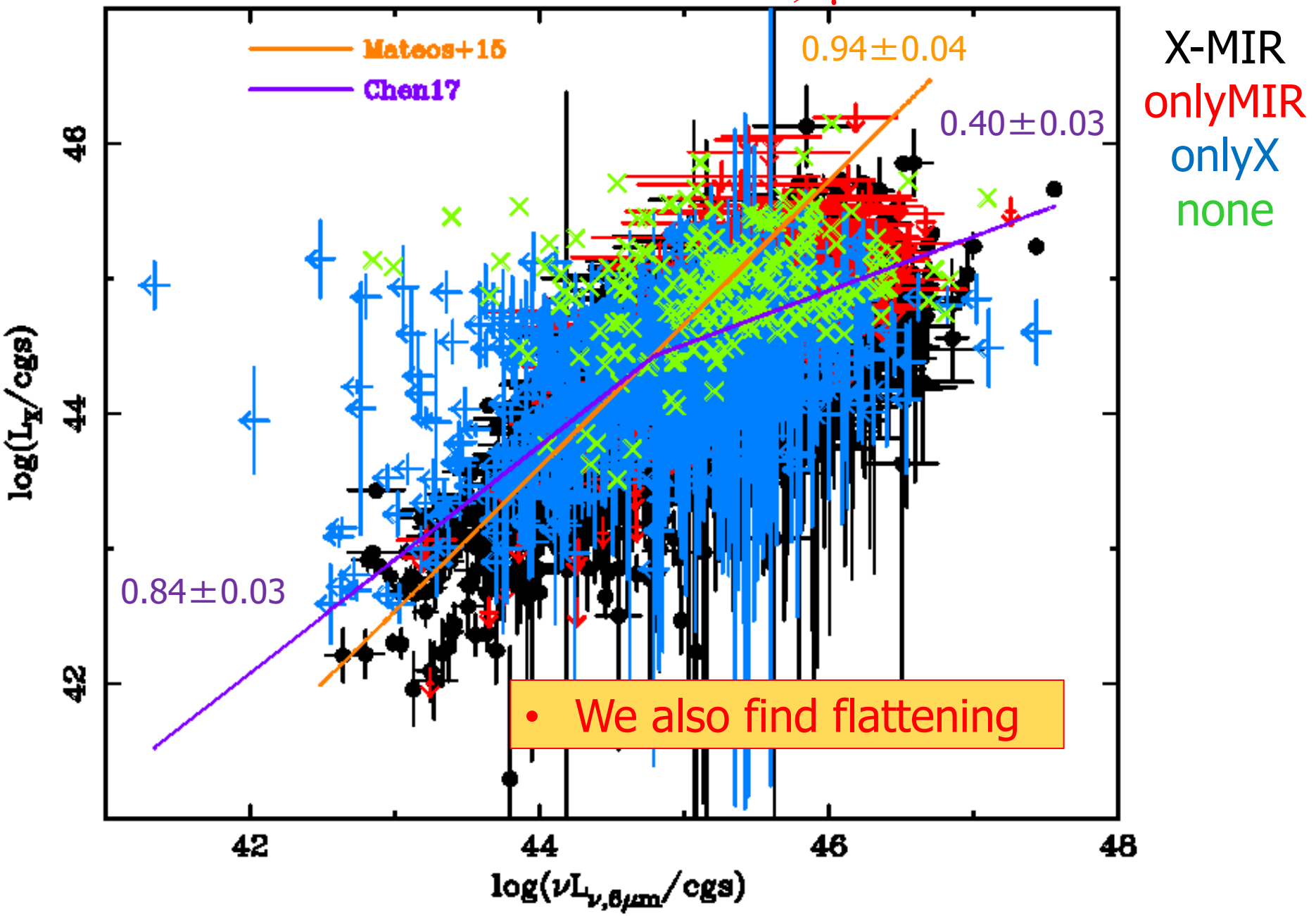



# Model fitting

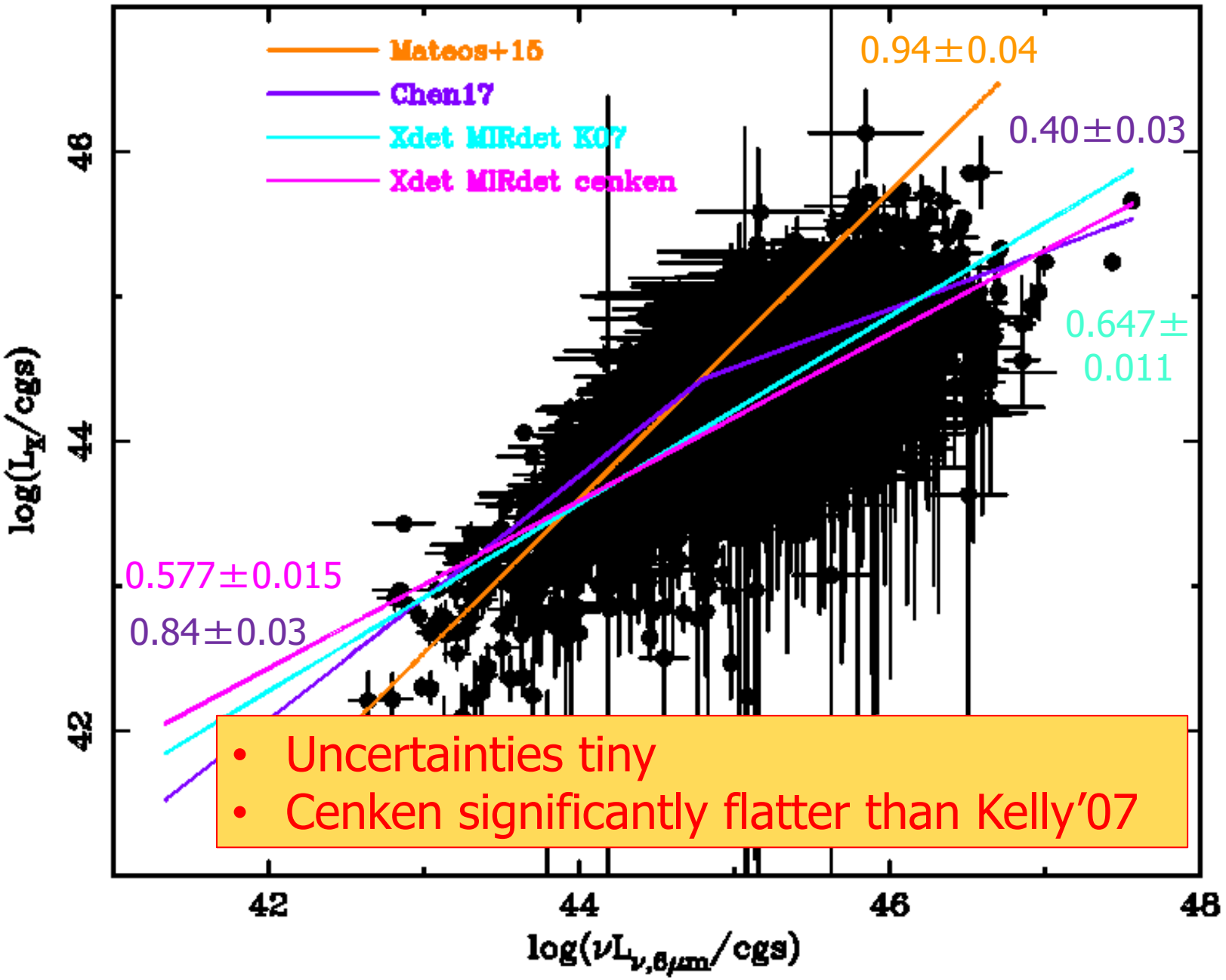
- Kelly'07: Bayesian method (`IDL, python` K07):
  - Fits a straight line
  - Taking into account (gaussian) errors in X and Y
  - Allowing for intrinsic dispersion in the data $\sigma$
  - Can handle upper limits in Y
  - Uncertainties from MCMC
  - …
- Akritas+95: Theil-Sen (`R cenken`):
  - Fits a straight line
  - Can handle upper limits in X and Y
  - Uncertainties from bootstrap

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



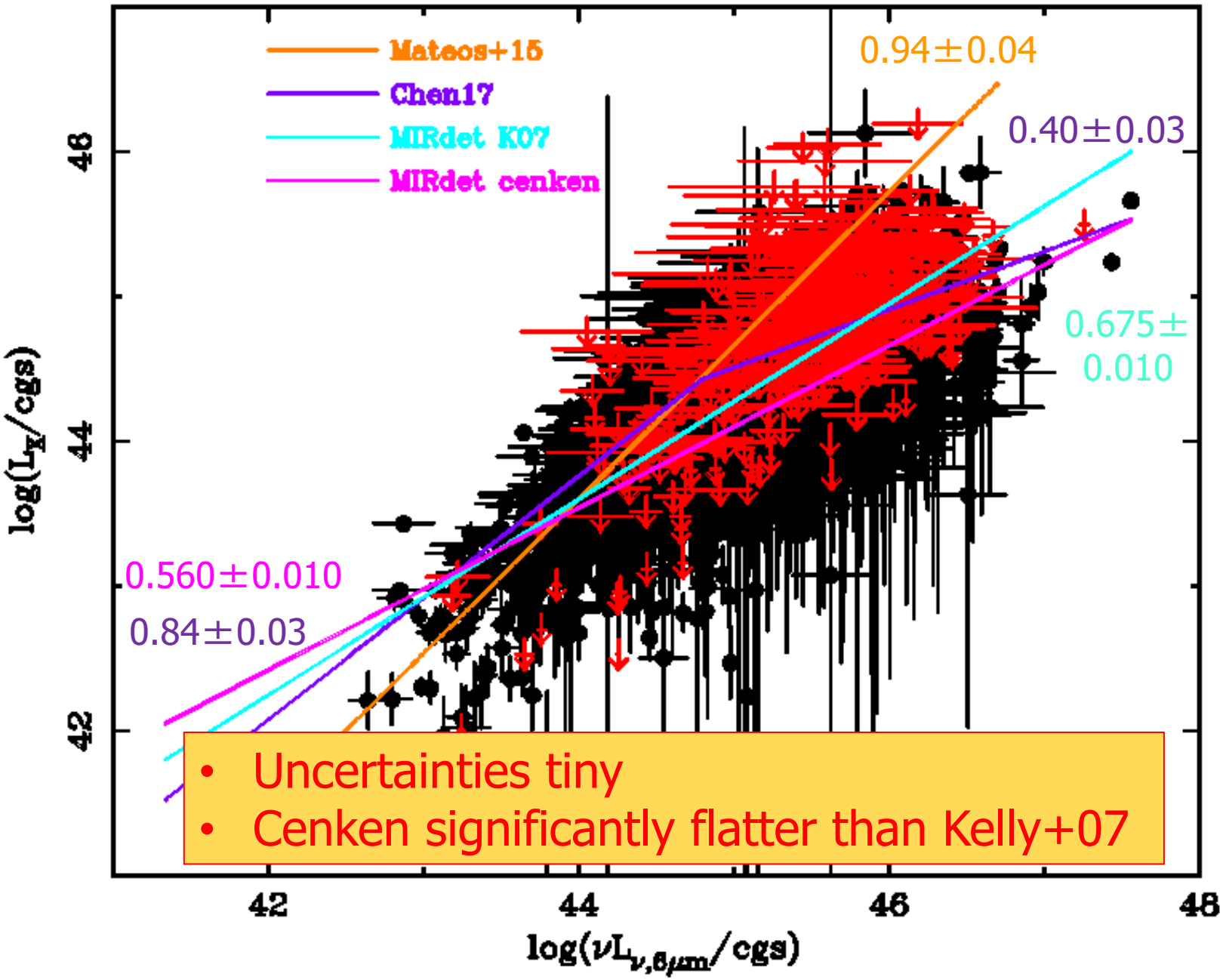
# $\log(L_X)$ vs $\log(\upsilon L_{\upsilon,6\mu m})$: X det MIR det

X-MIR




- Uncertainties tiny
- Cenken significantly flatter than Kelly'07

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




X-MIR
onlyMIR

- Uncertainties tiny
- Cenken significantly flatter than Kelly+07

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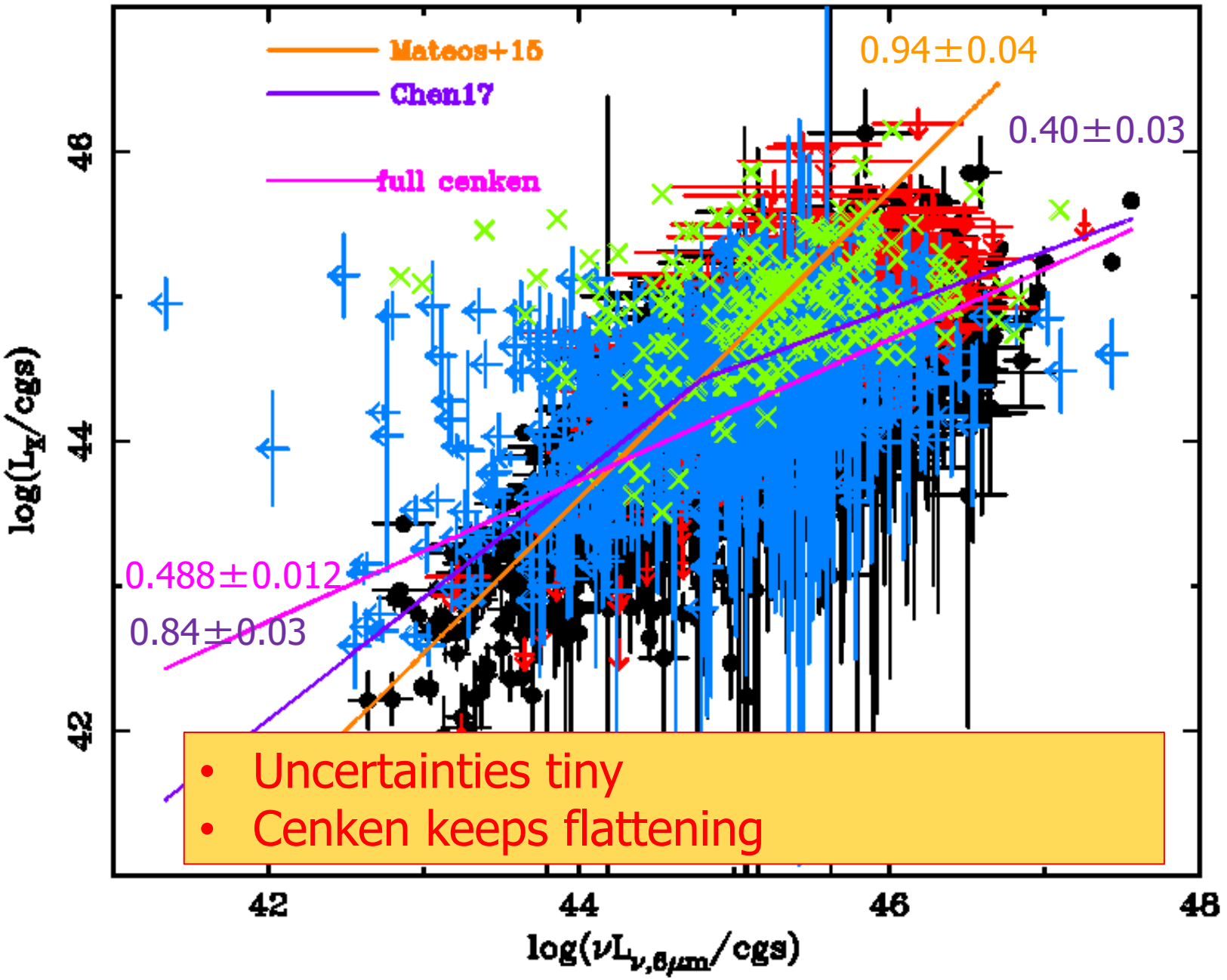


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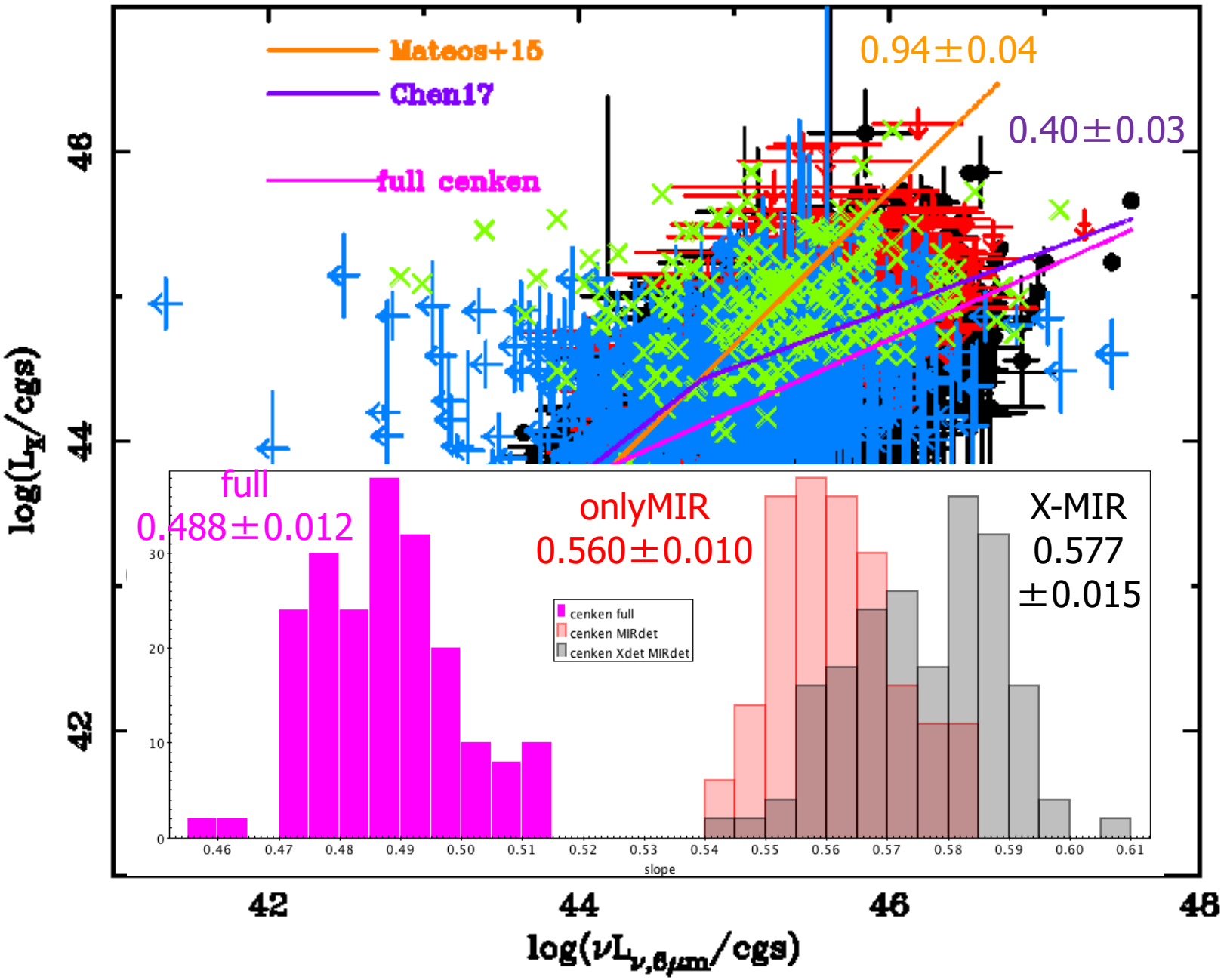

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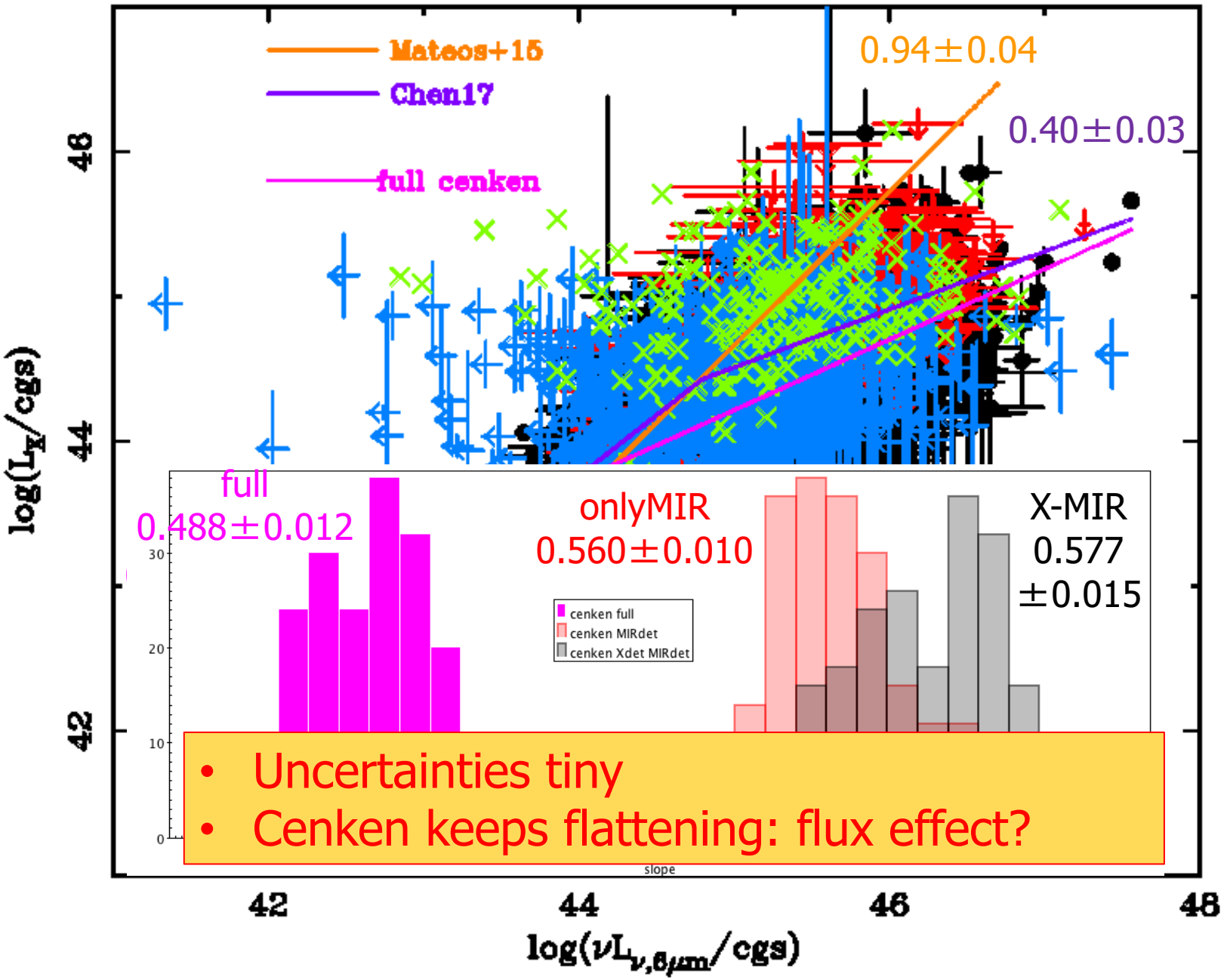
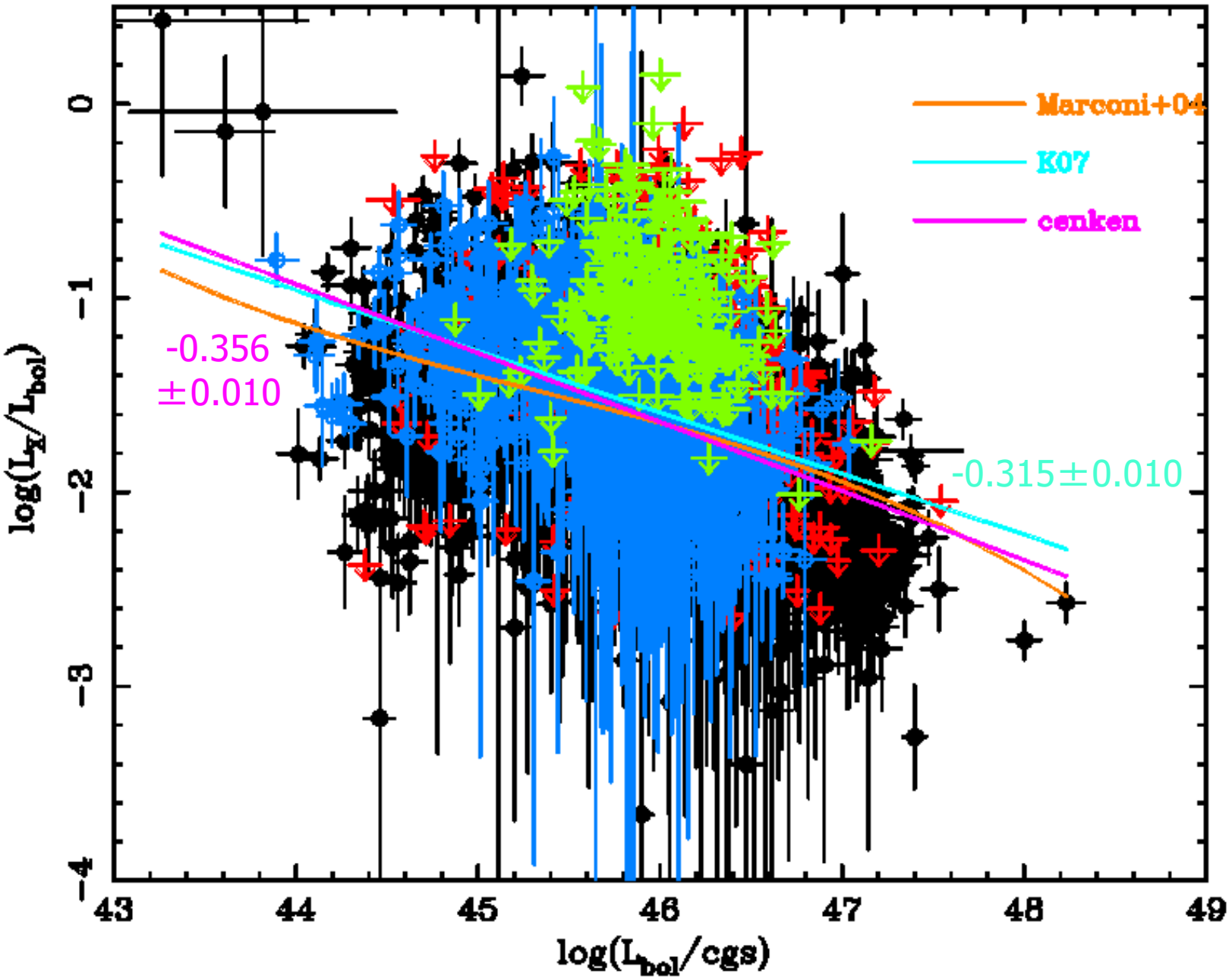



- Uncertainties tiny
- Cenken keeps flattening: flux effect?

# 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:
  - Bolometric luminosity $L_{bol}$ from SDSS (Kozłowski'17)
  - $L_X/L_{bol} \sim 1/\kappa_{bol}$ in X-ray parlance

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



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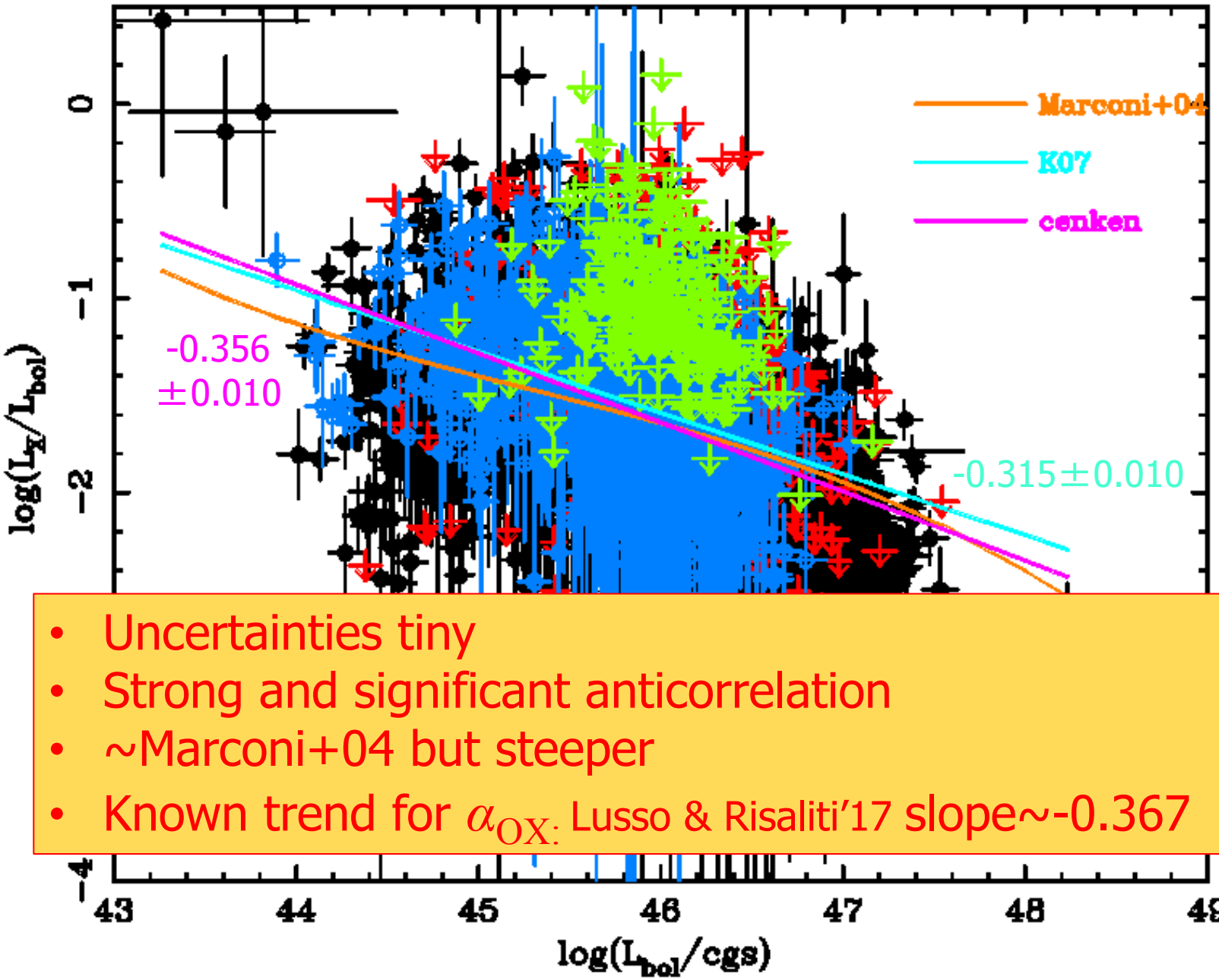
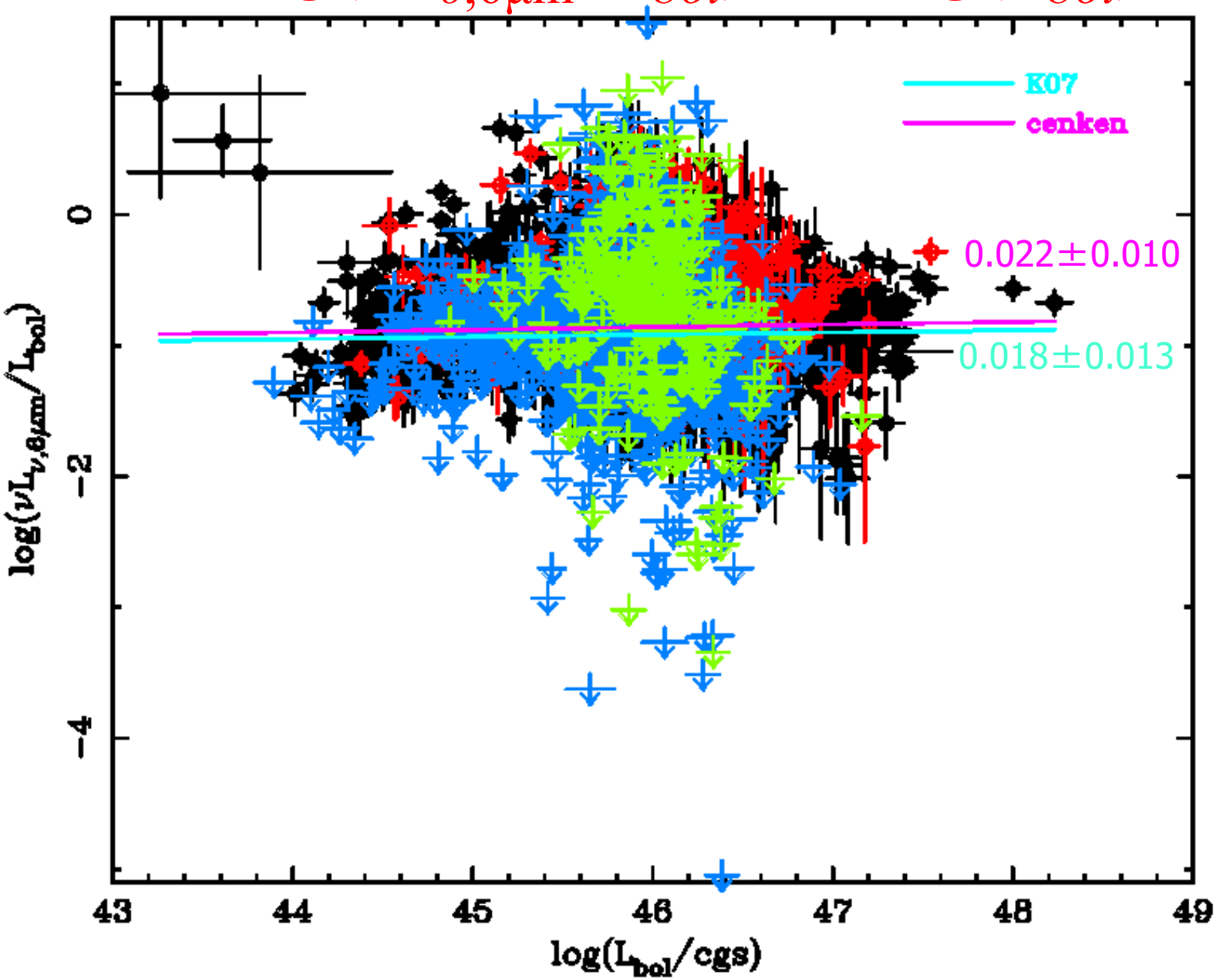



- Uncertainties tiny
- Strong and significant anticorrelation
- ~Marconi+04 but steeper
- Known trend for $\alpha_{OX}$: Lusso & Risaliti'17 slope~-0.367

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



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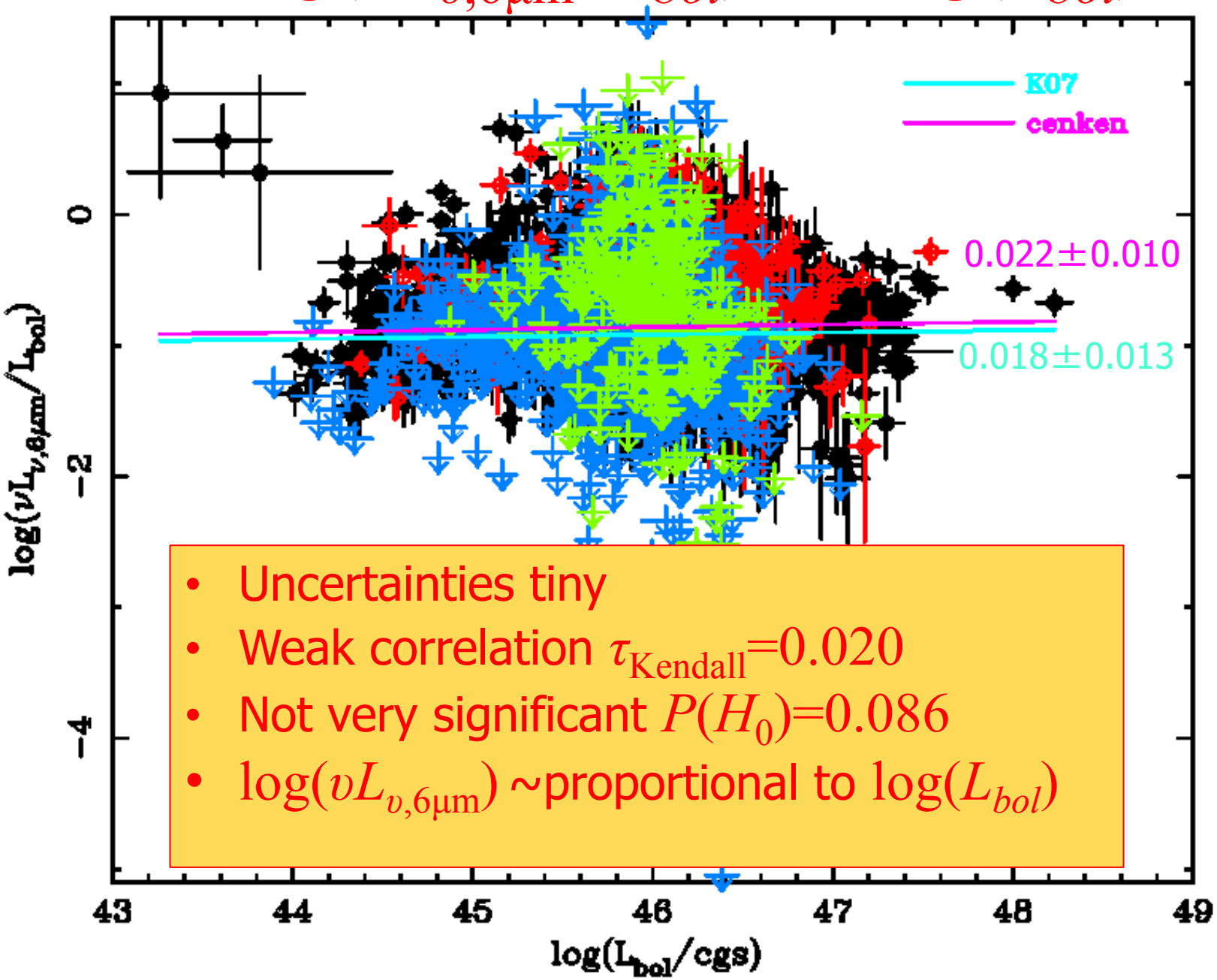


- Uncertainties tiny
- Weak correlation $\tau_{\mathrm{Kendall}}=0.020$
- Not very significant $P(H_0)=0.086$
- $\log(\upsilon L_{\upsilon,6\mu m})$ ~proportional to $\log(L_{bol})$

# Conclusions

- Large sample of ~3800 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 luminosities
  - Using upper limits in X,MIR even flatter
- Comparing to the input optical/UV radiation:
  - $L_X/L_{bol}$ decreases with $L_{bol}$: saturation of corona?
  - $L_{\rm MIR}/L_{bol}$ flat: ~constant covering factor?