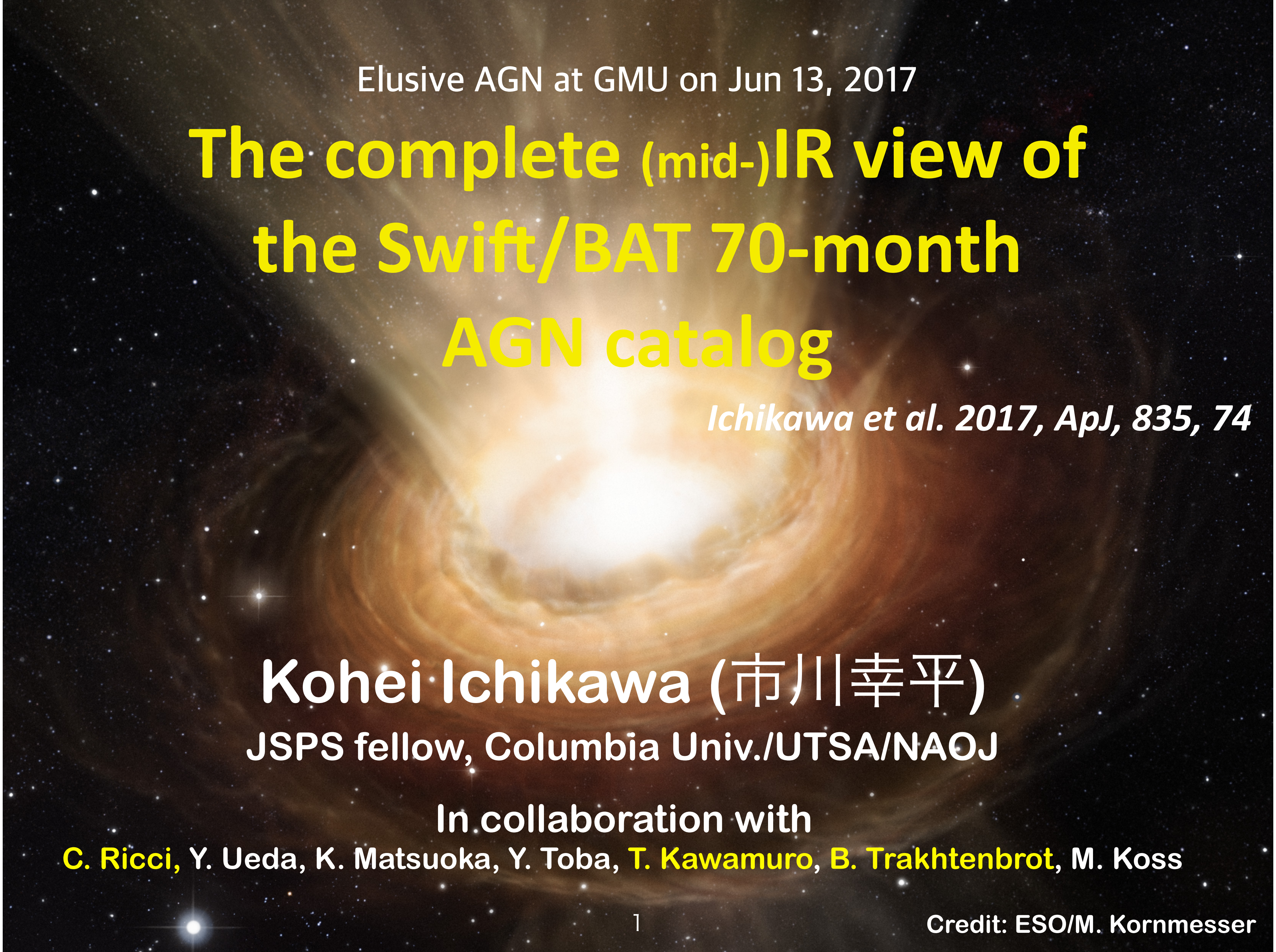


Elusive AGN at GMU on Jun 13, 2017

The complete (mid-)IR view of the Swift/BAT 70-month AGN catalog

Ichikawa et al. 2017, ApJ, 835, 74

Kohei Ichikawa (市川幸平)

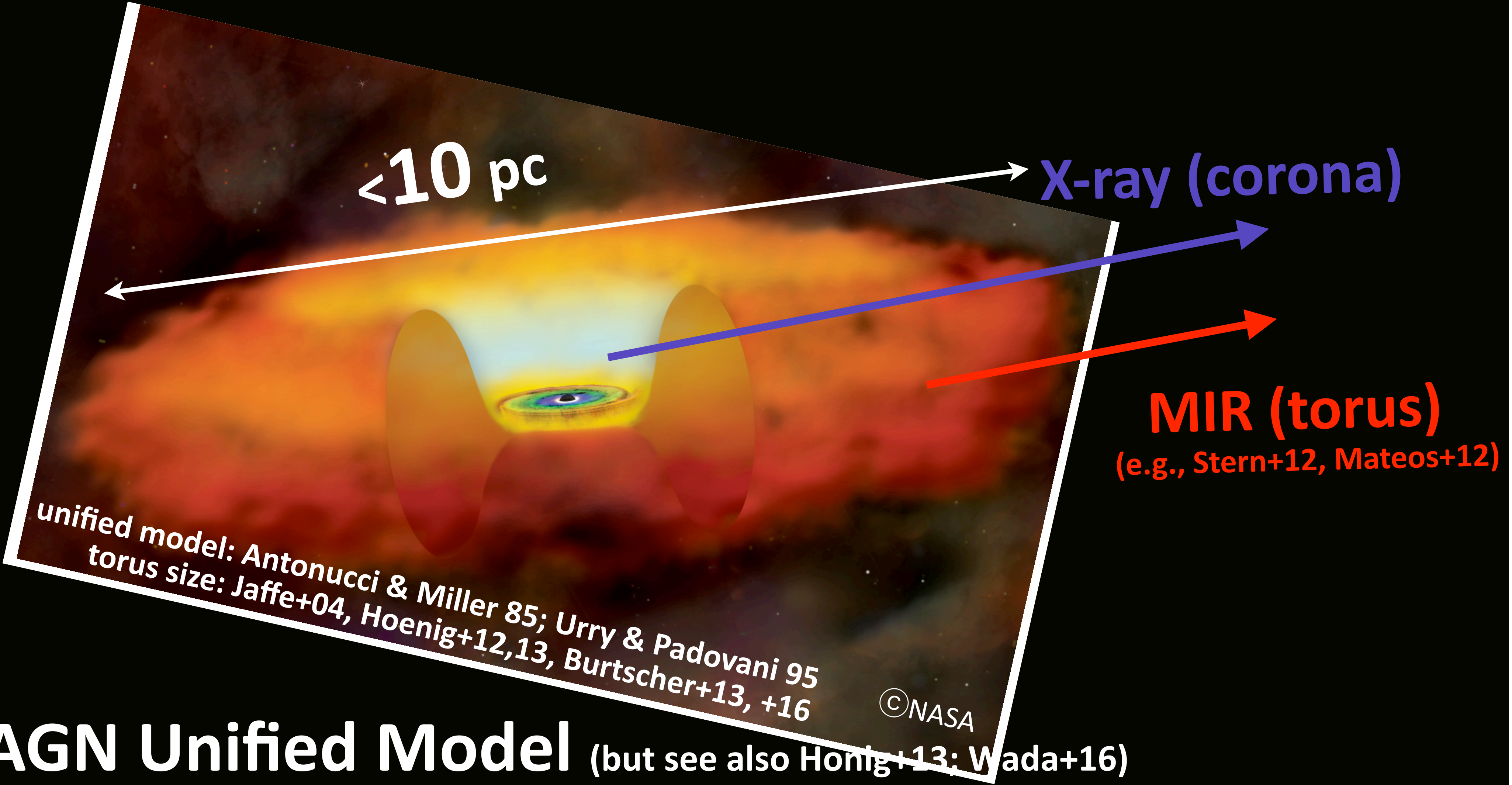
JSPS fellow, Columbia Univ./UTSA/NAOJ

In collaboration with

C. Ricci, Y. Ueda, K. Matsuoka, Y. Toba, T. Kawamuro, B. Trakhtenbrot, M. Koss

Credit: ESO/M. Kornmesser

Motivation: Torus/host galaxy studies of AGN

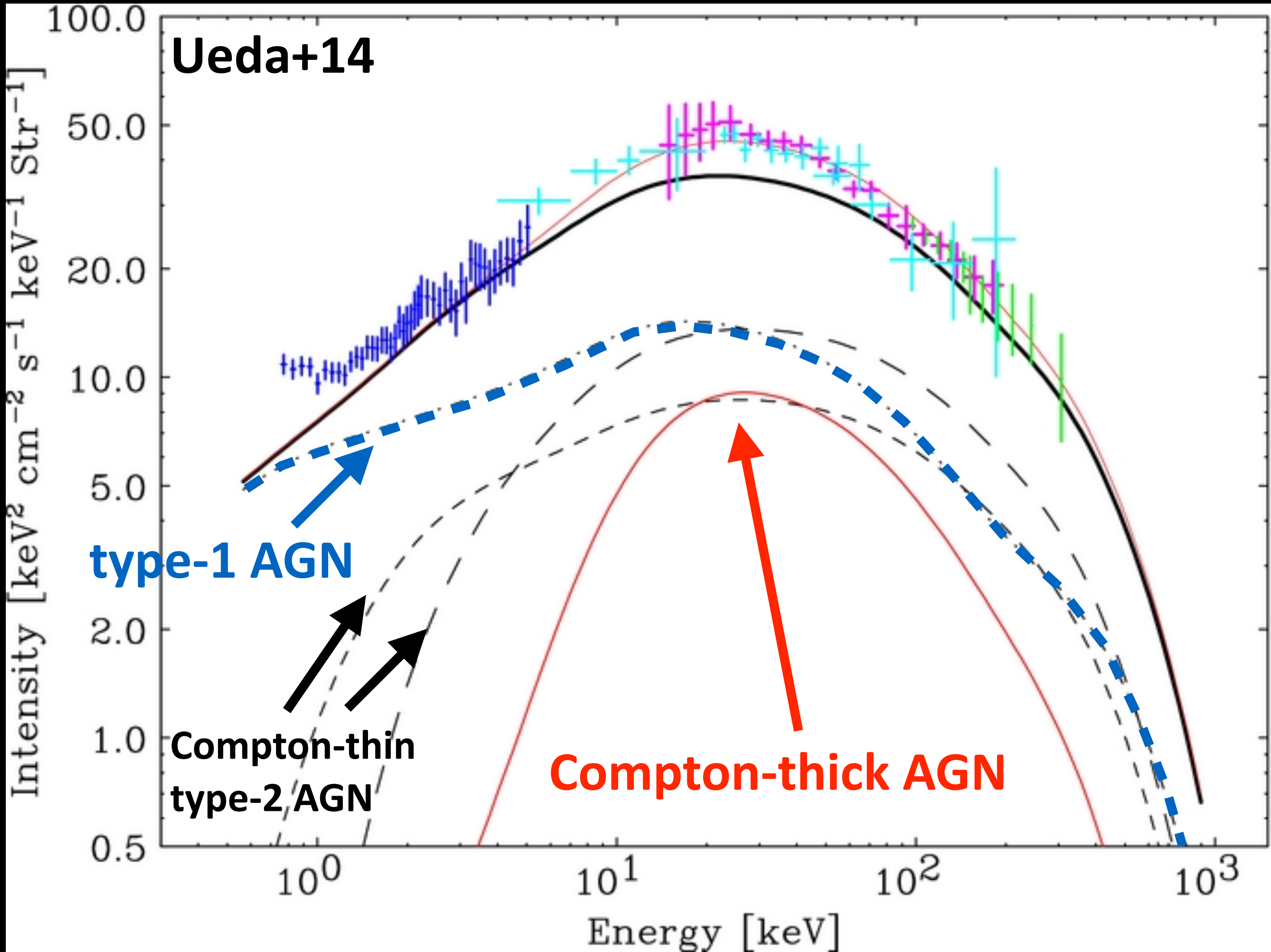


AGN Unified Model (but see also Honig+13; Wada+16)

- ☑ optical-UV: accretion disk
- ☑ X-ray: accretion disk+hot electron corona
- ☑ **mid-IR (MIR): dusty torus (dust/gas provider to SMBH)**
- ☑ **far-IR (FIR): host galaxy**

Most of AGN are elusive (=obscured)

XRB indicates that most of AGN are obscured



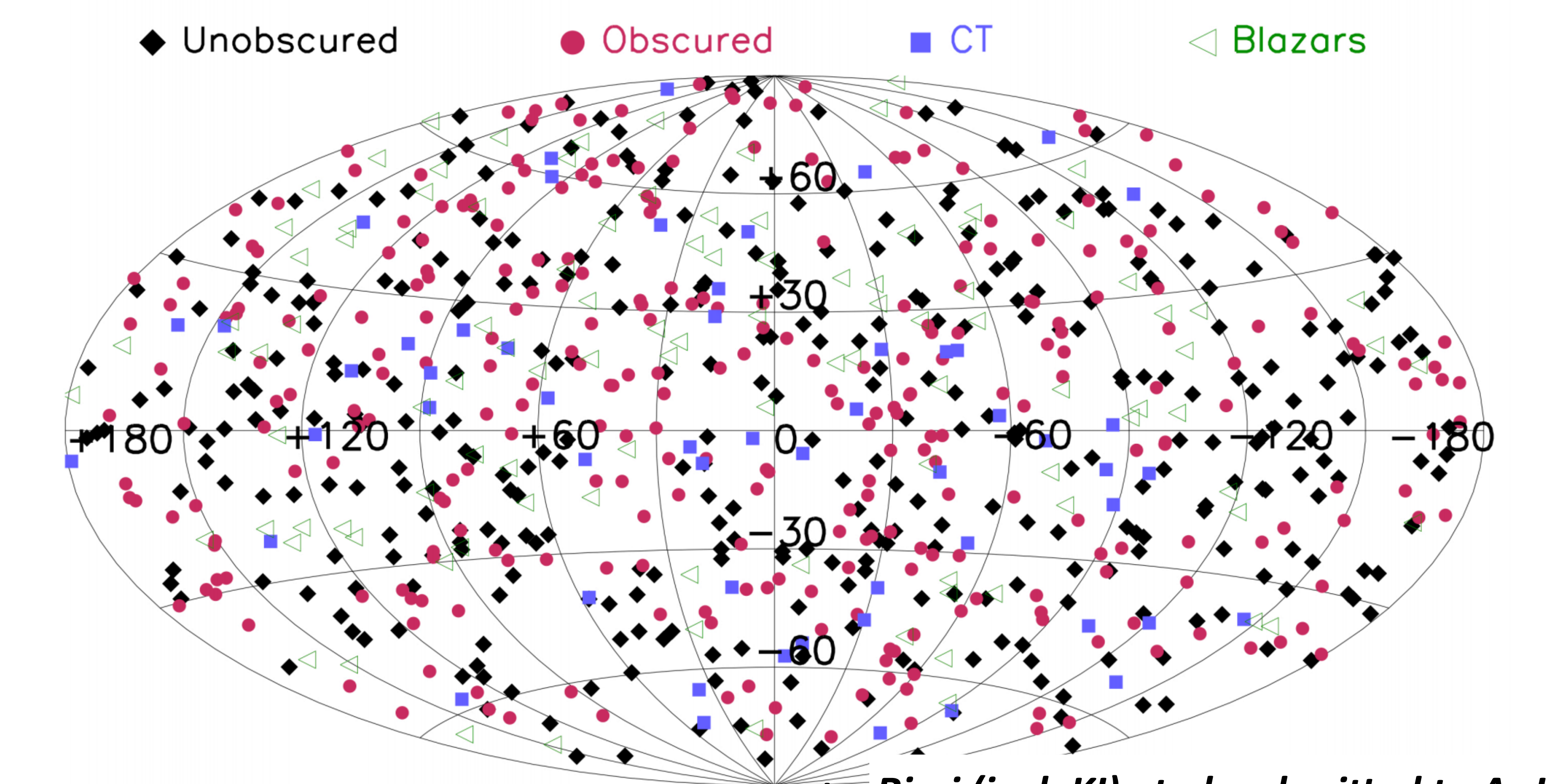
☑ energy density peaks at **~30 keV**

☑ **E>10 keV:** best energy band to detect obscured (log N_H>22) AGN

Swift/BAT AGN (14-195 keV)

70 month catalog: 836 AGN (728 non-blazars)

FYI, 104 month catalog is upcoming (Oh et al., in prep)



Baumgartner+13 and… ***Ricci (incl. KI) et al. submitted to ApJ***

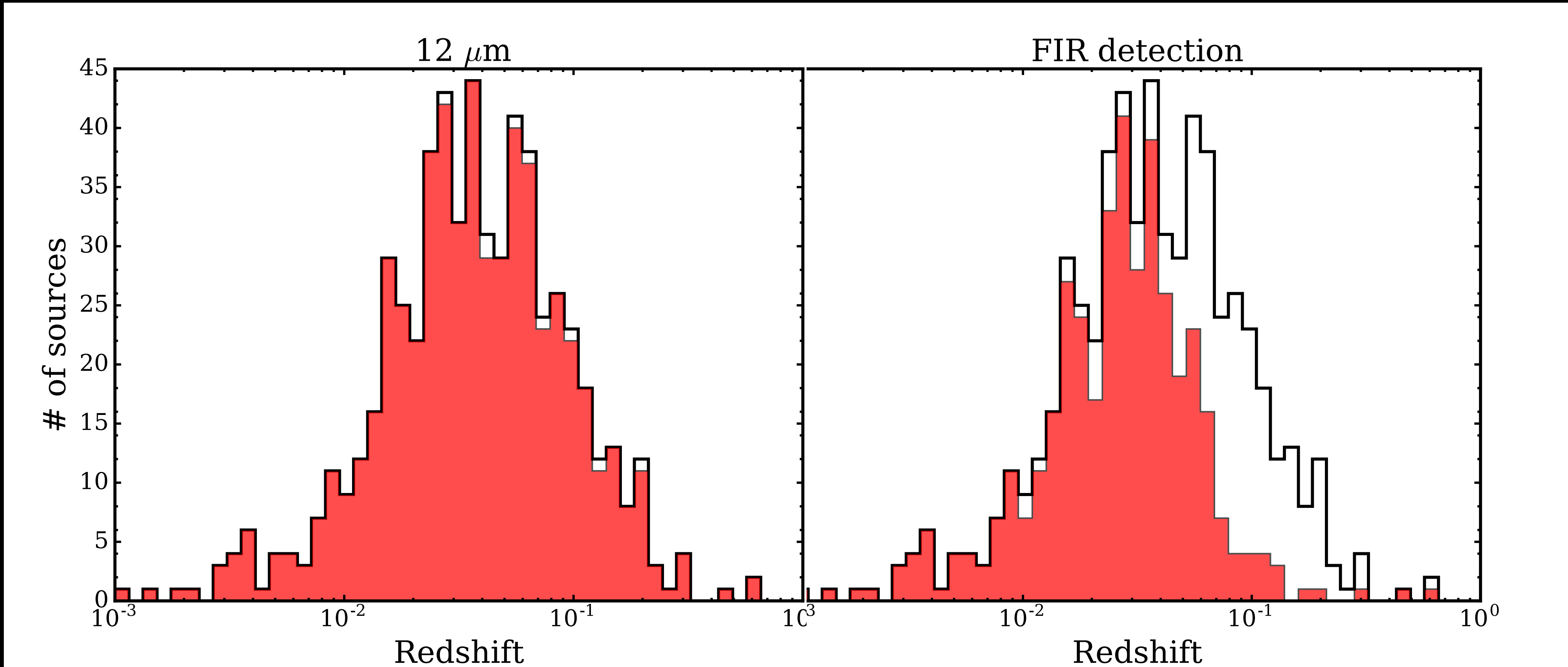
☑ most complete up to $\log N_H=24$ in the local Universe

☑ **606 out of 728 have z info and are located at |b|>10°**

IR counterparts of BAT AGN

☑ **3-500 um IR data from WISE, AKARI, IRAS, and Herschel**

(see Ichikawa+17 for more details)



☑ **601/606 MIR and 402/606 FIR counterparts**

☑ **suitable for the AGN torus/host galaxy studies**

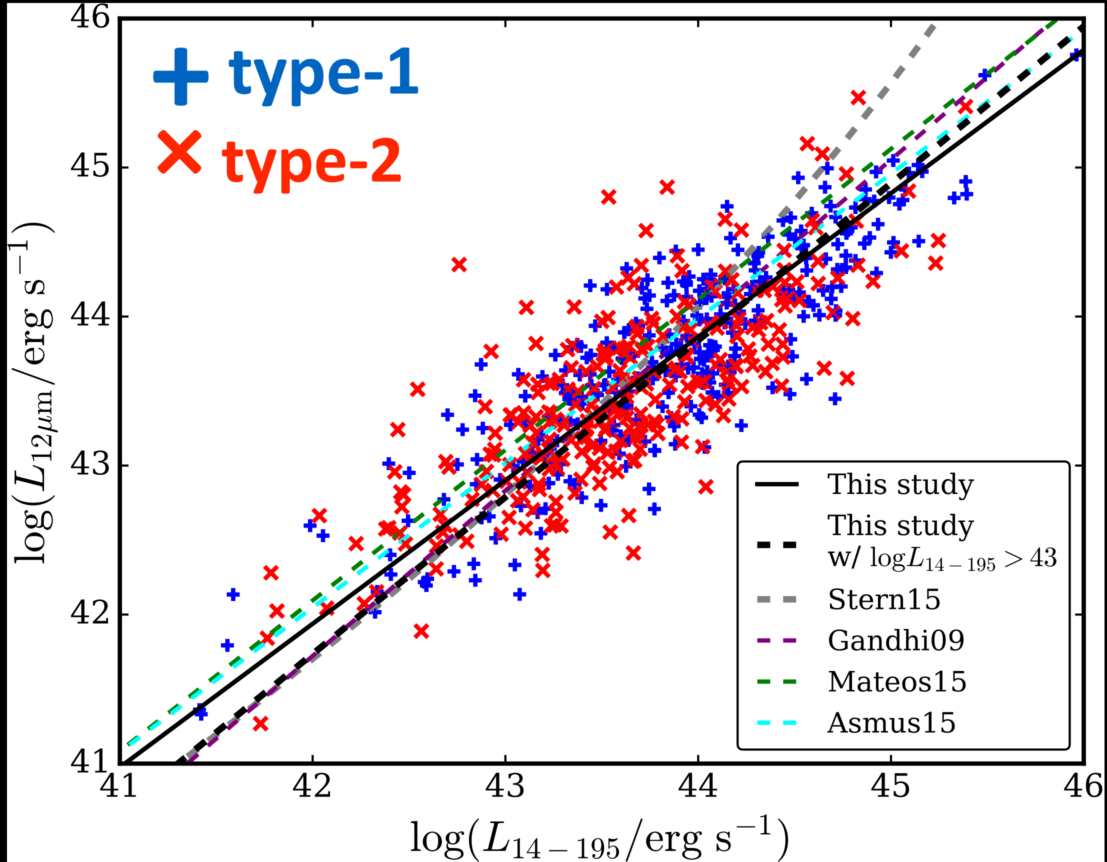
Torus studies

L_{MIR} vs. $L_{14\text{-}195keV}$

Our study

L_{MIR}/L_X (type-1) ~ L_{MIR}/L_X (type-2)

→ MIR emission: isotropic



$\log L_{12} \propto 0.96 \log L_X$

∴ slope b=0.96

☑ **b=0.9-1.1** from local/X-ray selected AGN

(e.g., Gandhi+09; **Ichikawa+12**; Asmus+15; Mateos+15)

L_{MIR} vs. $L_{14\text{-}195keV}$

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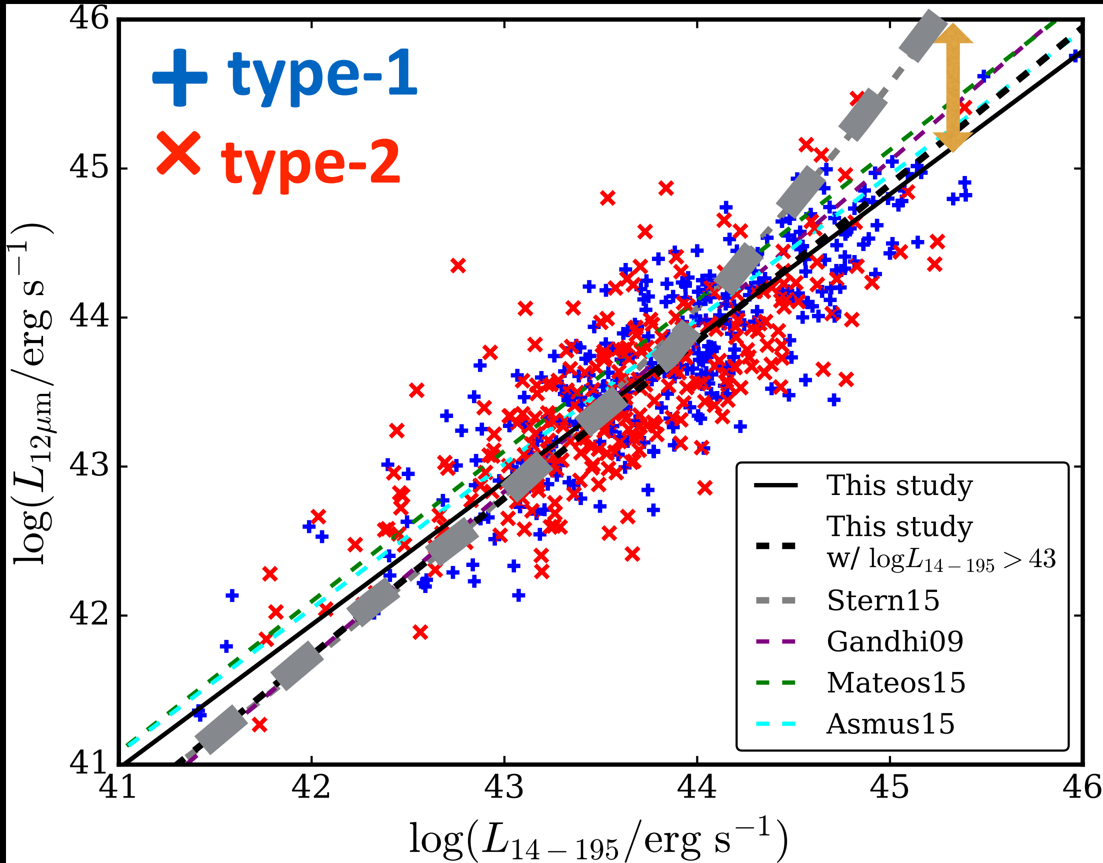

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∴ slope b=0.96

☑ **b=0.9-1.1** from local/X-ray selected AGN

(e.g., Gandhi+09; **Ichikawa+12**; Asmus+15; Mateos+15)

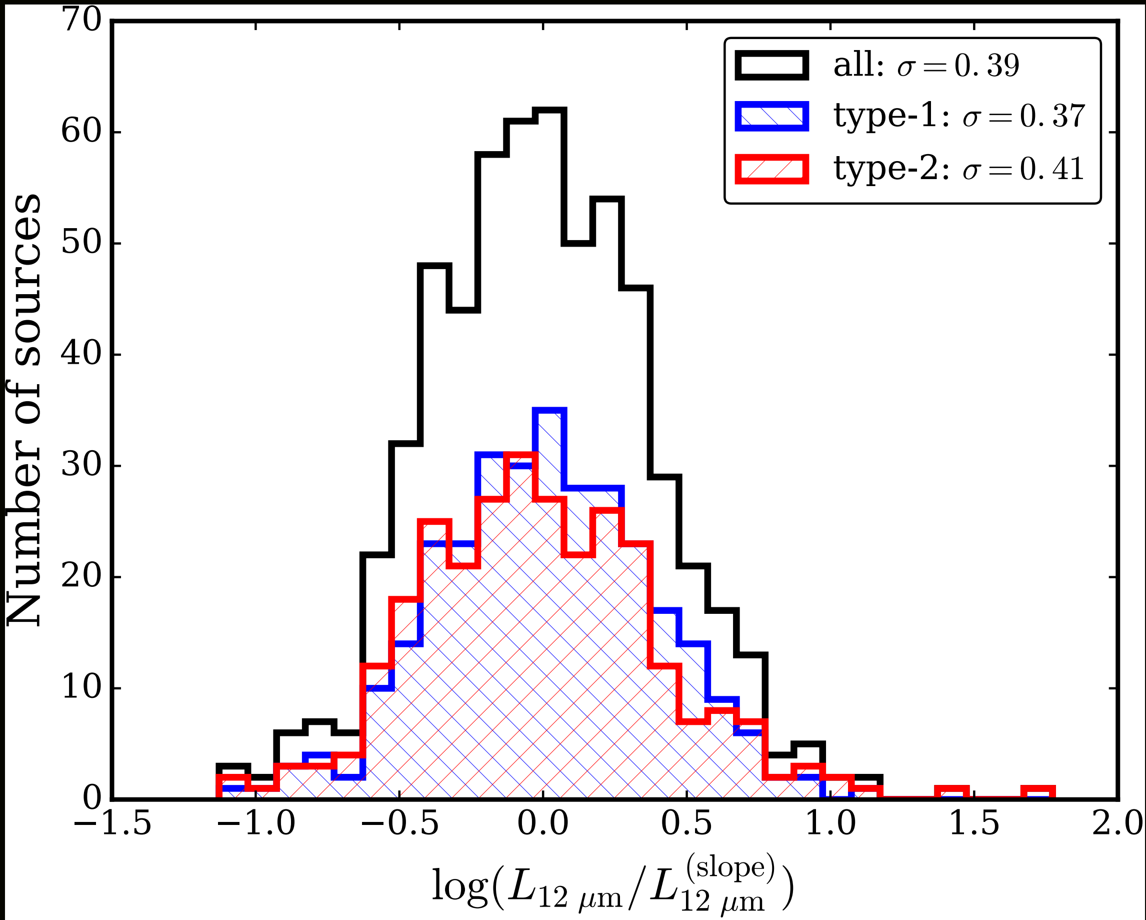
☑ **b=1.2-1.3** from luminous optically selected AGN

(e.g., Stern '15)

X-ray emission is inefficient at high-L or high-λ_{Edd} end?

(see also Vasudevan & Fabian '07, Ricci+16)

Consistency with dust polar emission



☑ **type-1/-2 has same distribution => isotropic emission**

☑ **consistent with MIR polar emission or fountain model**

obs: Honig+13,+14, see also Asmus+16
model: Wada 12, Wada+16

Dust Covering factor (C_T) vs. L_{bol}

L_X => L_{bol} (Marconi+04) and **$C_T \propto L_{MIR}/L_{bol}$**

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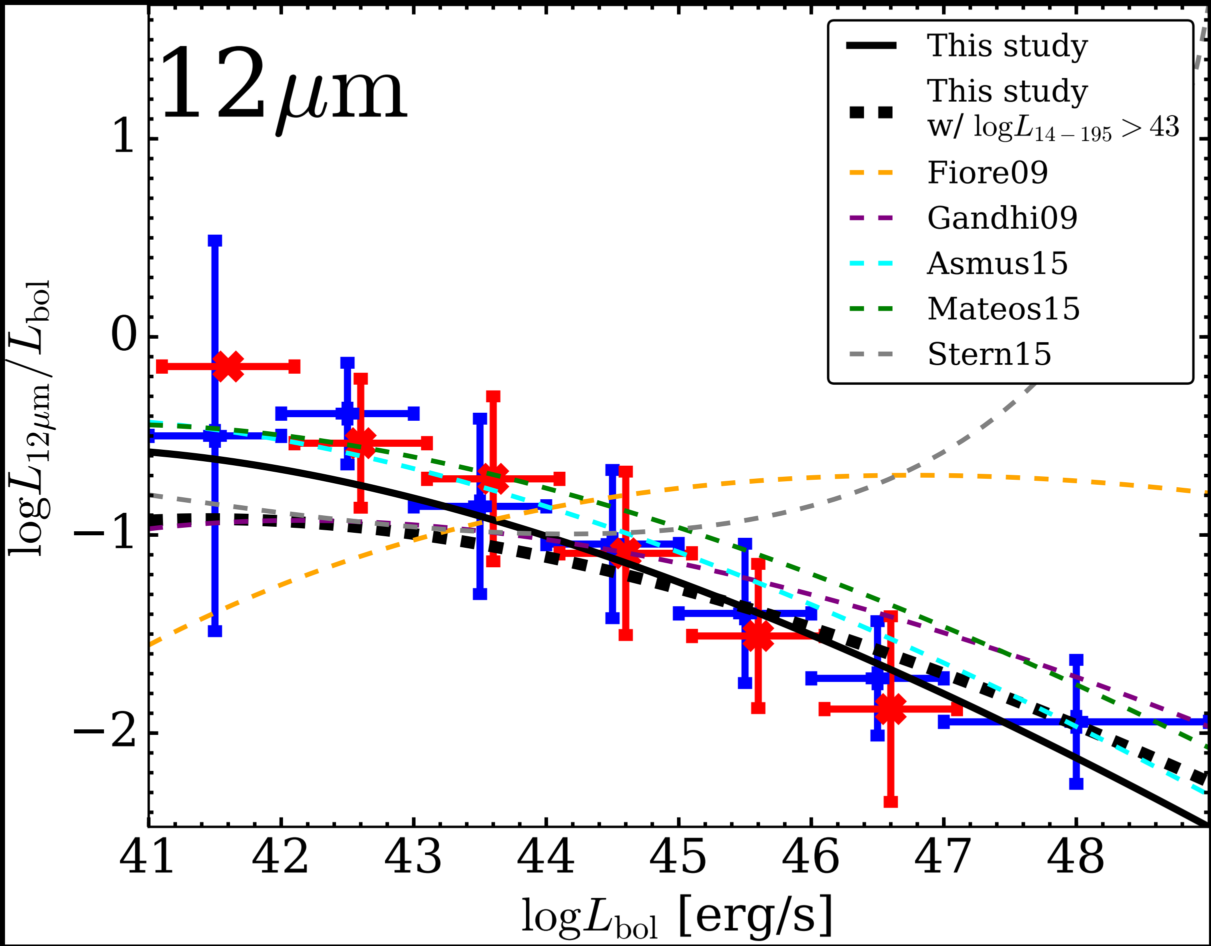
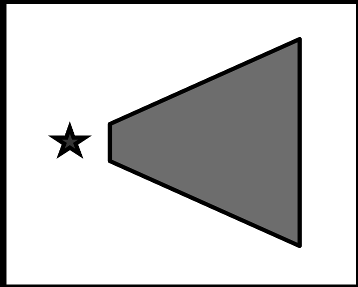


small L_{bol}
large C_T



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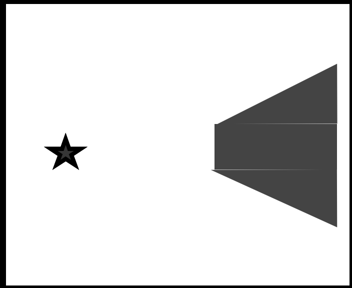
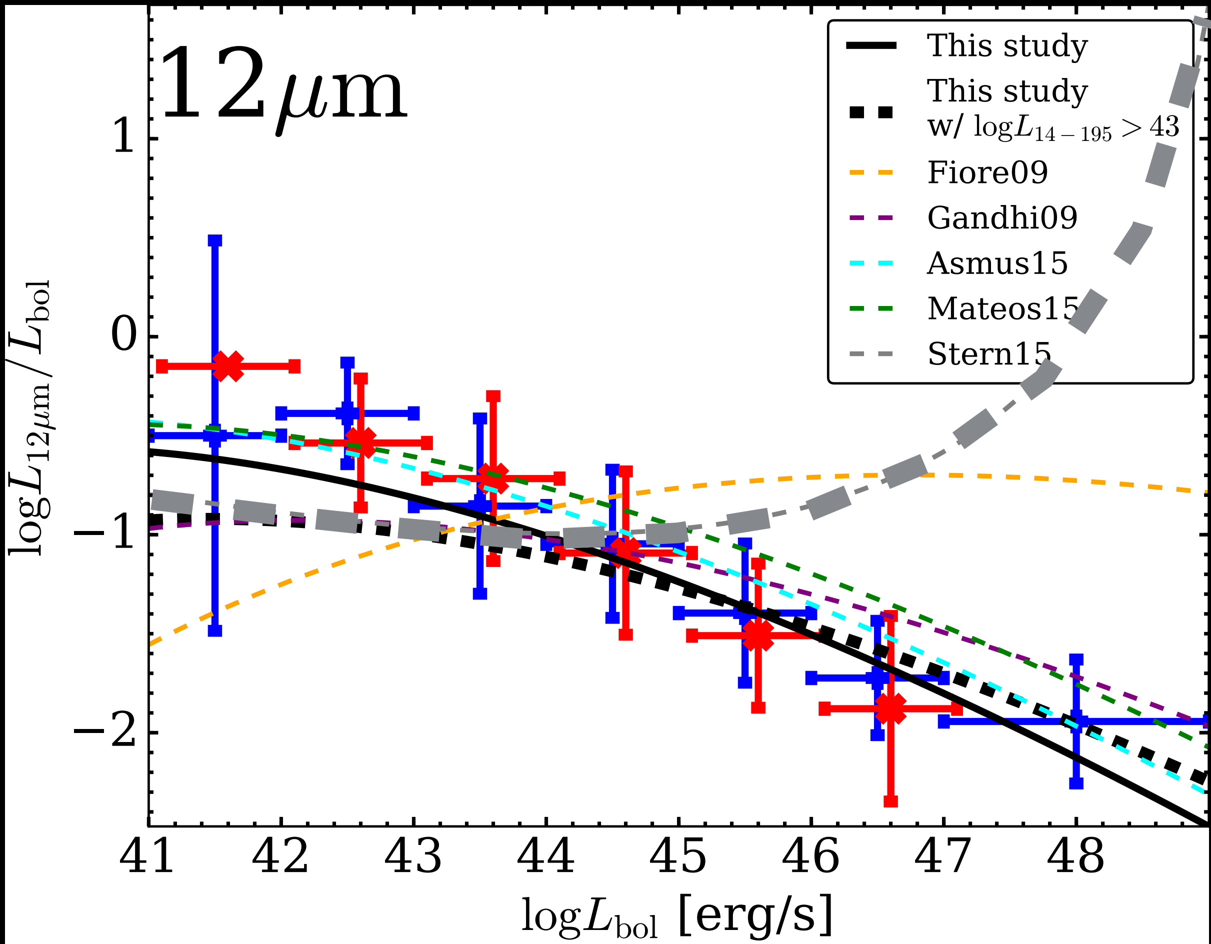


☑ **L_{MIR}/L_{bol} decreases as L_{bol} increases** (KI+17, Mateos+15, Asmus+15)

→ consistent with "receding torus model" (e.g., Lawrence '91; Claudio's talk)

Covering factor (C_T) vs. L_{bol}

Lx => L_{bol} (Marconi+04) and $C_T \propto L_{MIR}/L_{bol}$



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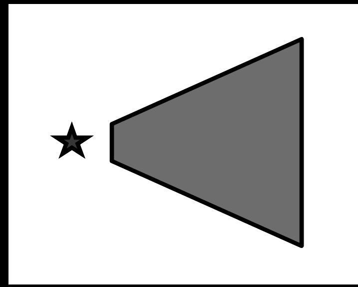
large C_T



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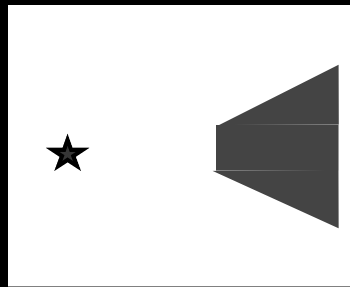
small C_T



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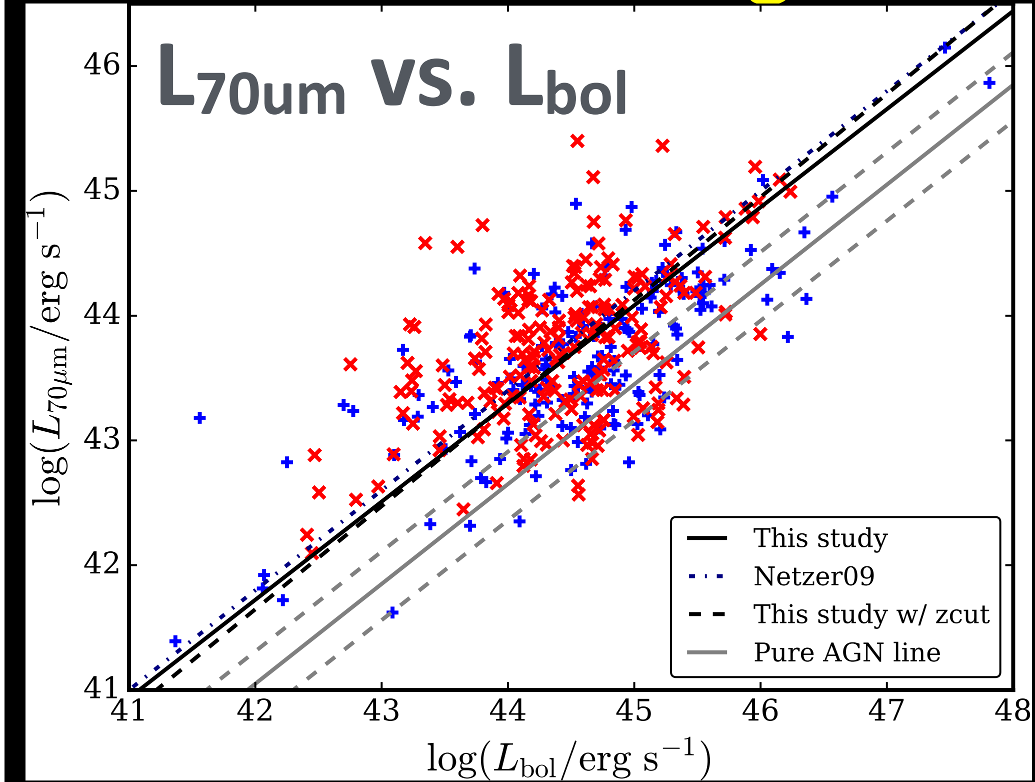
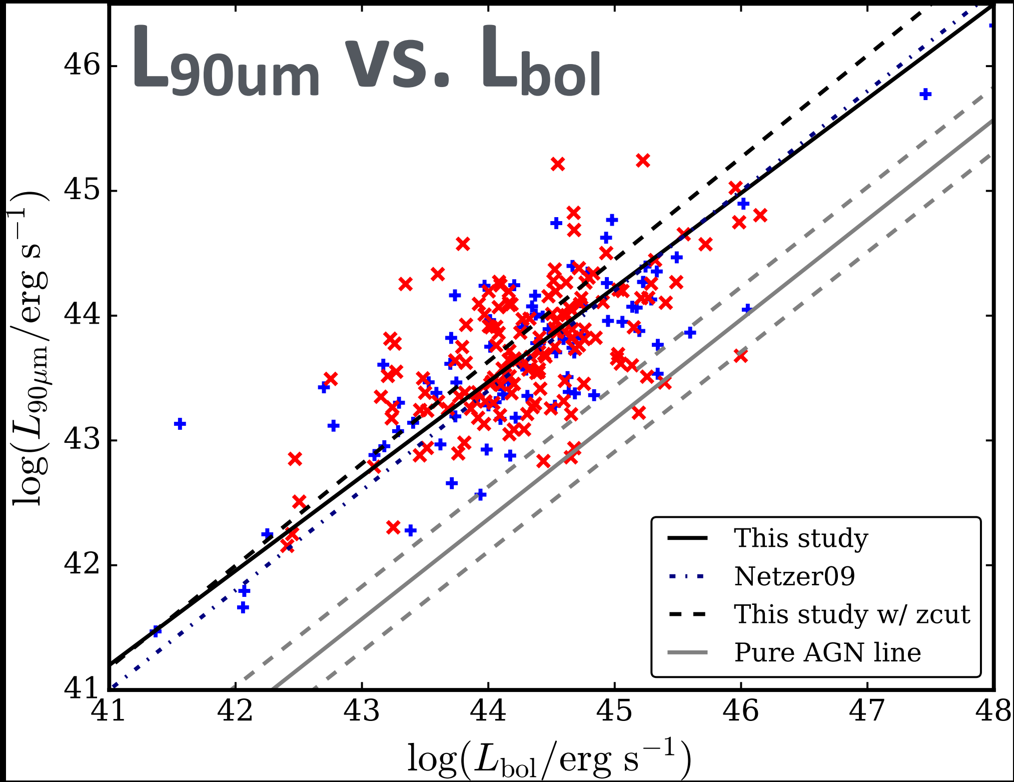
☑ **However, high-z/-L AGN (e.g., Stern'15) do not follow the trend**

→ **lower slope b is necessary to reproduce receding torus model**

L_{FIR} vs. L_{bol} (=SF vs. AGN luminosity)

We found "FIR bright AGN"





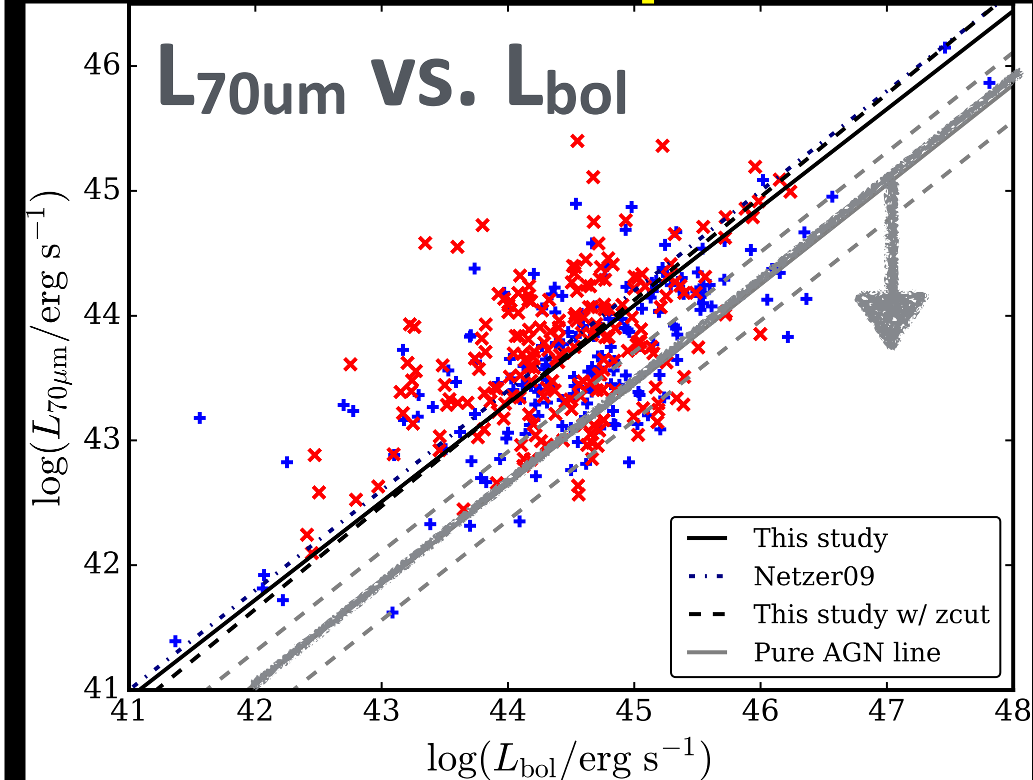
☑ some have very low L_{FIR} / L_{bol} ratio
and below the expected AGN torus FIR emission

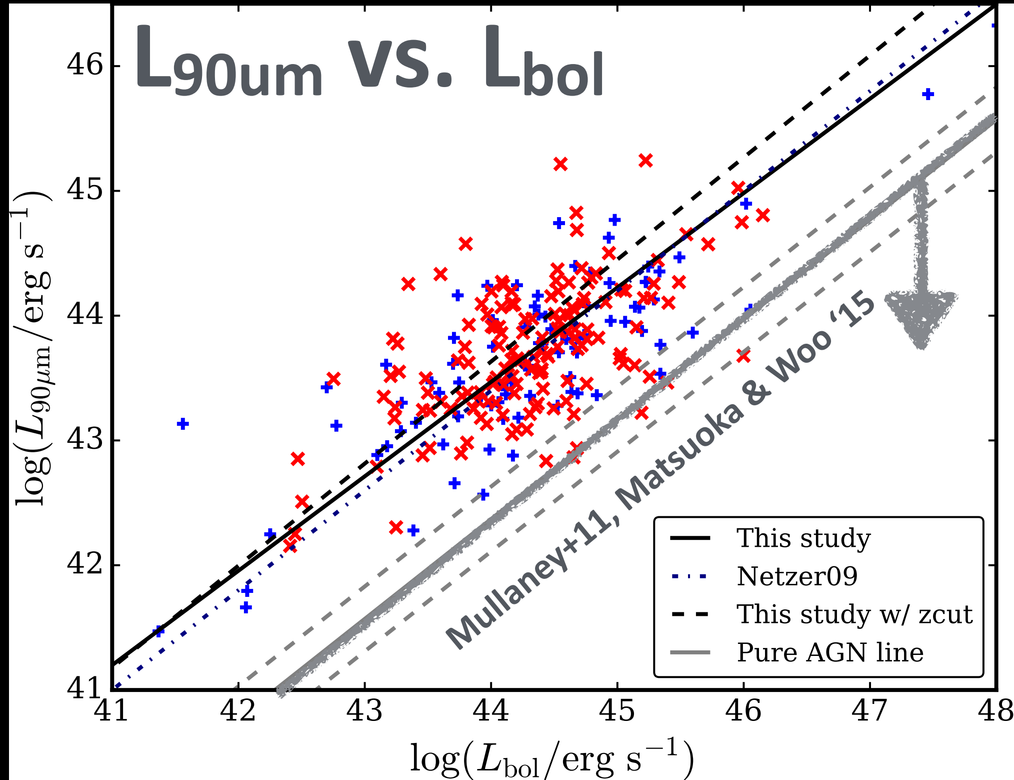
→ AGN dust emission could dominate even in FIR for those sources (and SF activity could be very weak)

→ good candidates of final stage AGN?

L_{FIR} vs. L_{bol} (=SF vs. AGN luminosity)

We found "FIR pure AGN"





☑ some have very low L_{FIR} / L_{bol} ratio and below the expected AGN torus FIR emission

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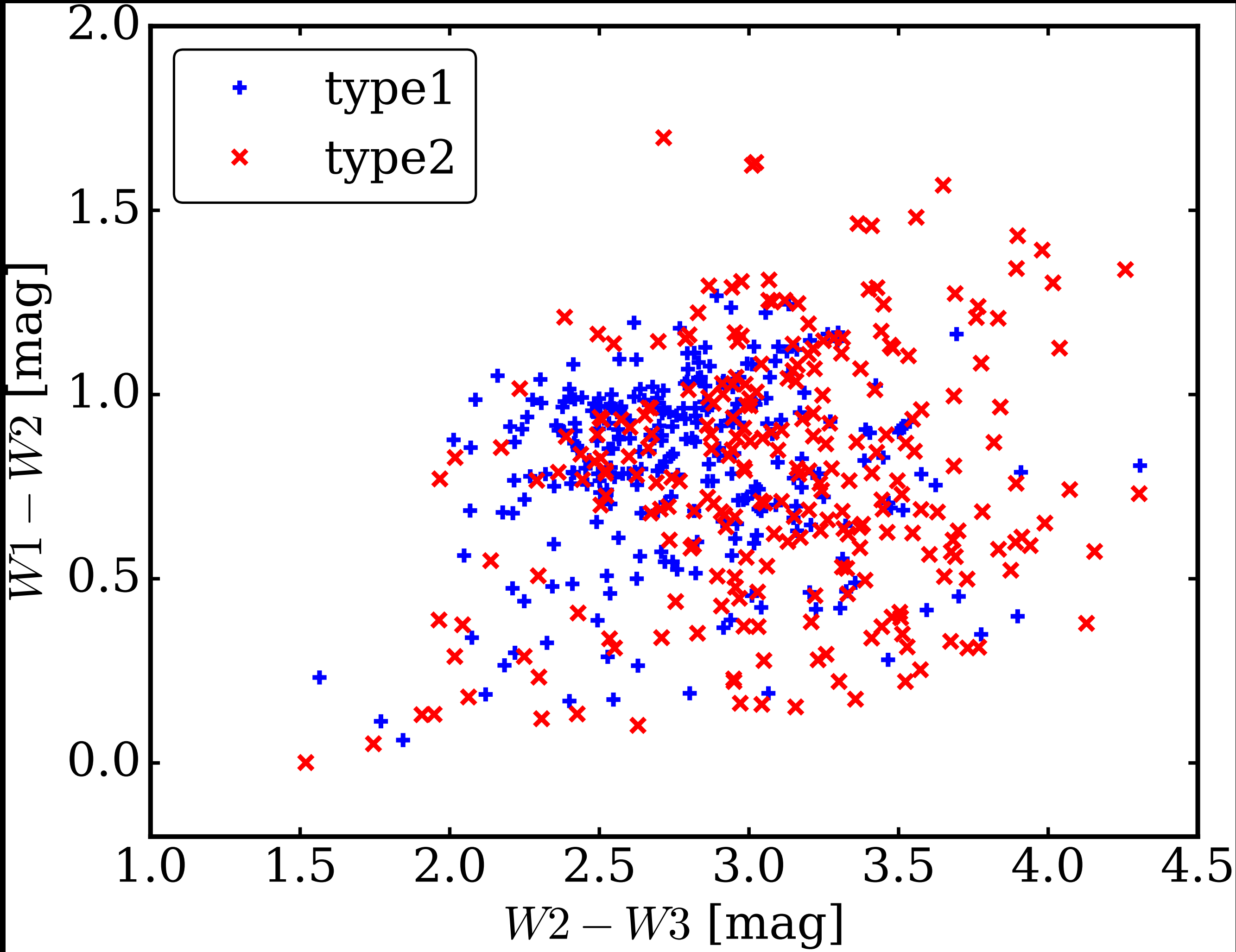
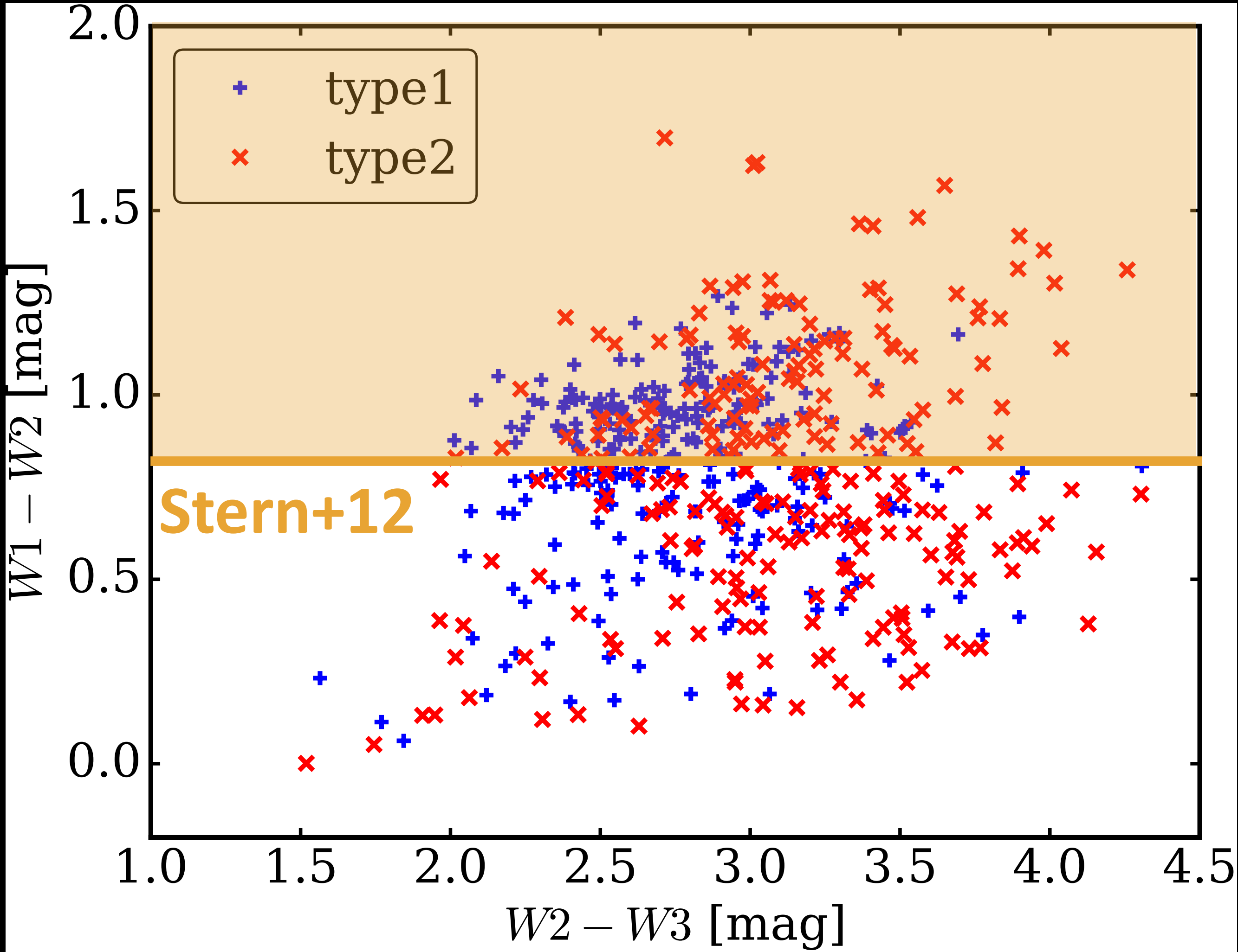
WISE IR color-color selection of AGN



WISE IR color-color selection of AGN



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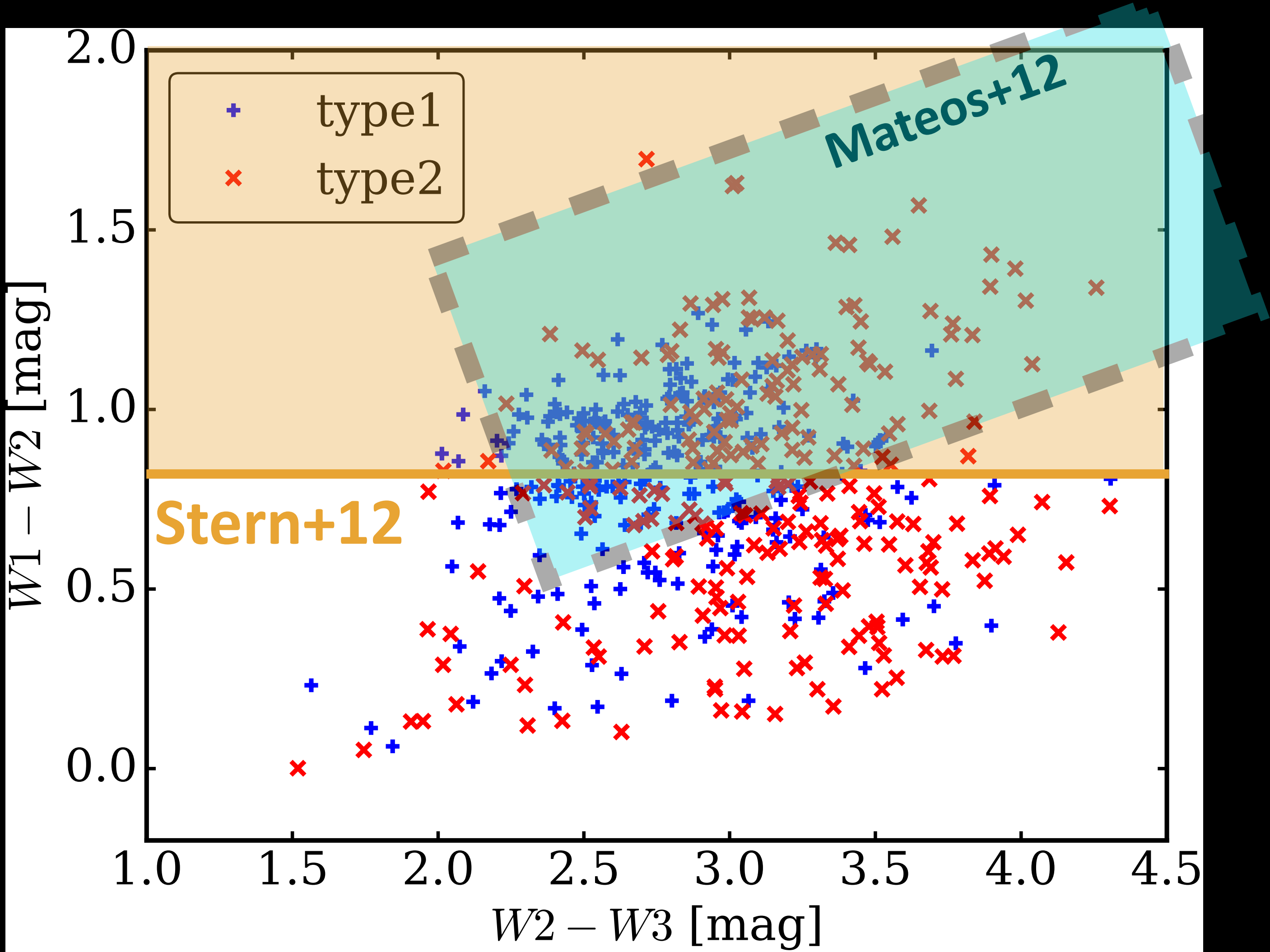
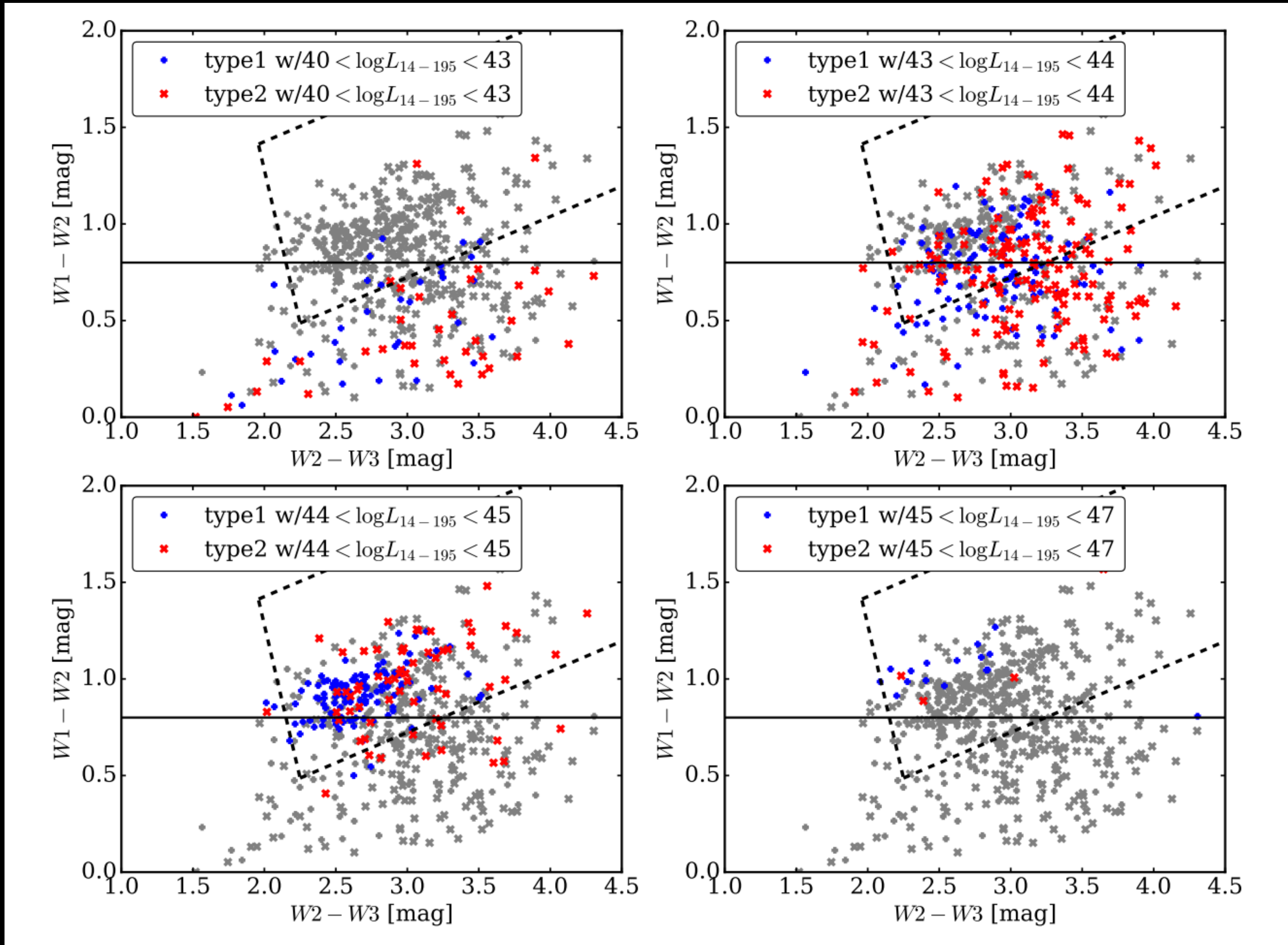


☑ Our X-ray selected AGN do not always locate at the IR selection areas of. Stern+12, Mateos+12

WISE IR color selections miss some AGN population

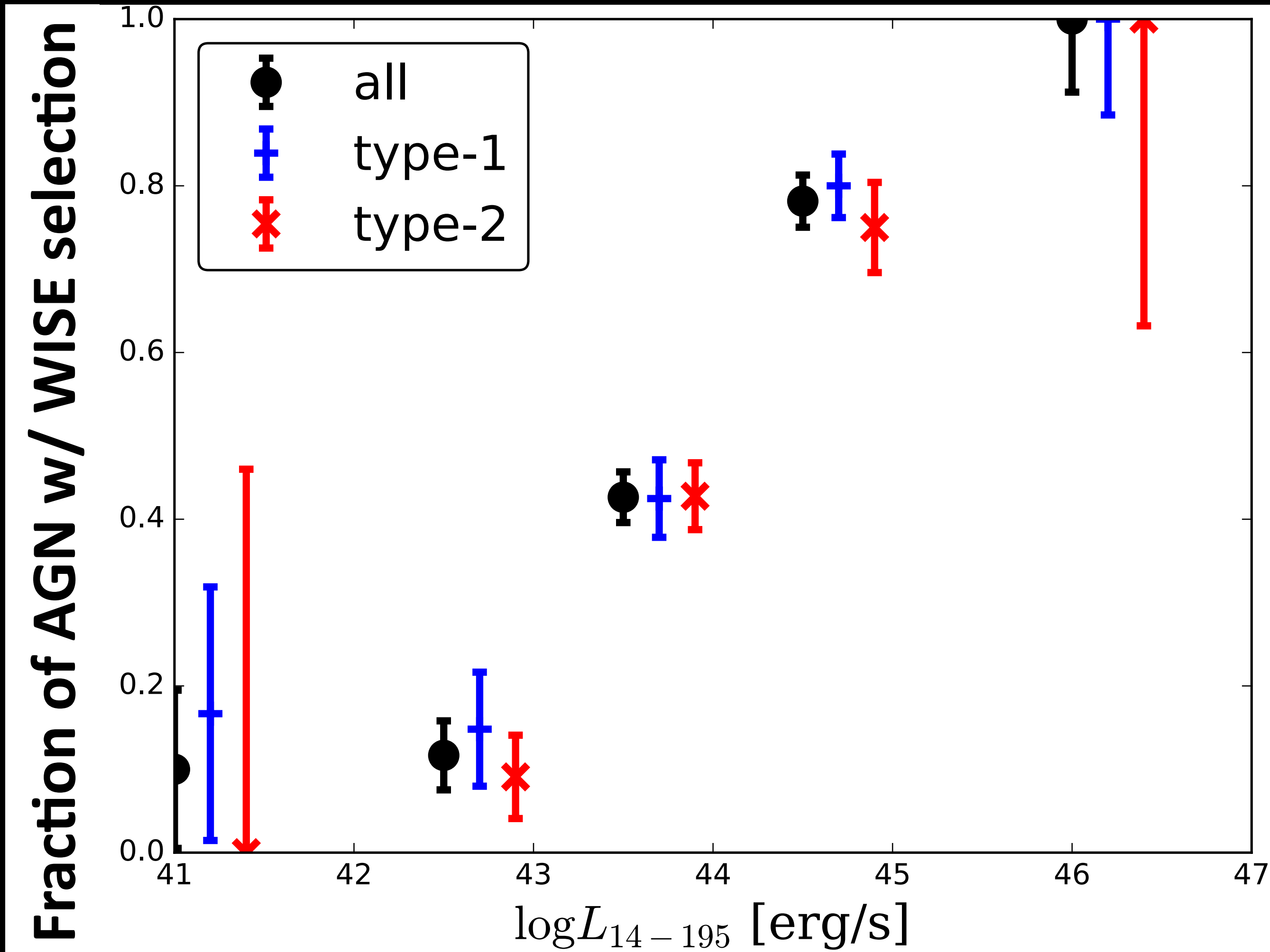
(see also Gandhi+16; Kawamuro+16; Tanimoto+16)

WISE IR color-color selection of AGN



☑ WISE IR color: insensitive to low-luminosity AGN

success rate of WISE color selection



☑ **WISE IR color: insensitive to low-luminosity AGN**

☑ **<20% success rate for log Lx < 43** (see also R. Hickox's talk)

Summary

Swift/BAT (14-195 keV) AGN catalog

☑ suitable sample of an unbiased census of AGN

☑ **almost complete 3-500 um IR catalog (601/606 at MIR, 402 at FIR)**

IR and X-ray properties of BAT AGN

☑ $\log L_{12um} \propto 0.96 \log L_{14\text{-}195keV}$ (slope b=0.96)

☑ C_T depends on L_{bol} => “receding torus model”
(FYI, if slope b is steep, C_T is almost independent of L_{bol})

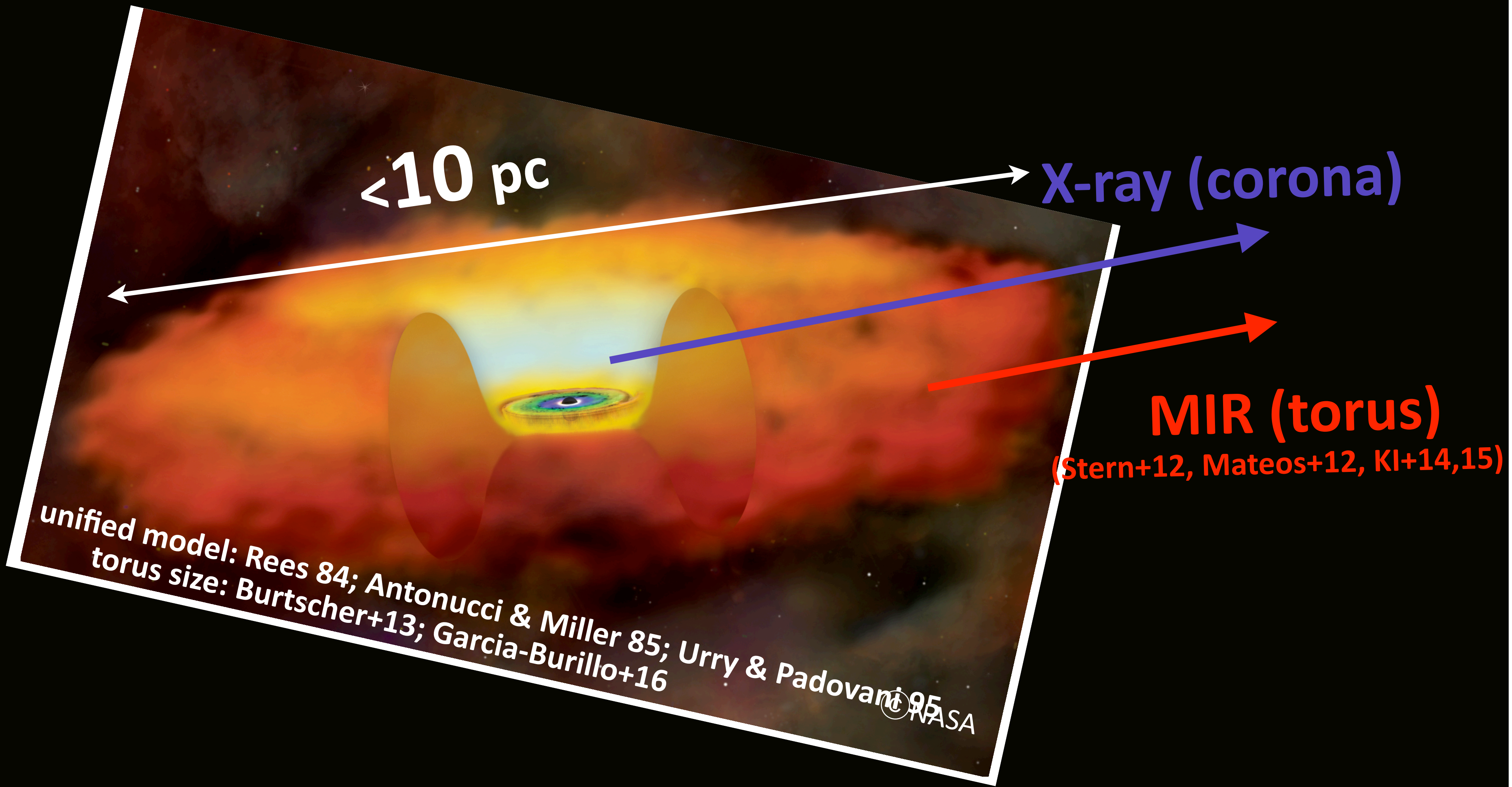
☑ we found **``FIR pure AGN’’**, <10% of total sample

☑ WISE color is insensitive to low-luminosity AGN

see *Ichikawa et al. (2017)* for more details

Backup slides

Motivation: Unbiased census of AGN



- ☑ X-ray and MIR are good tracers of (obscured) AGN
- ☑ both bands are isotropic & strong against absorption
- ☑ X-ray is more clean than MIR (=AGN+ possible SB)

Equations of L_{MIR} vs L_X

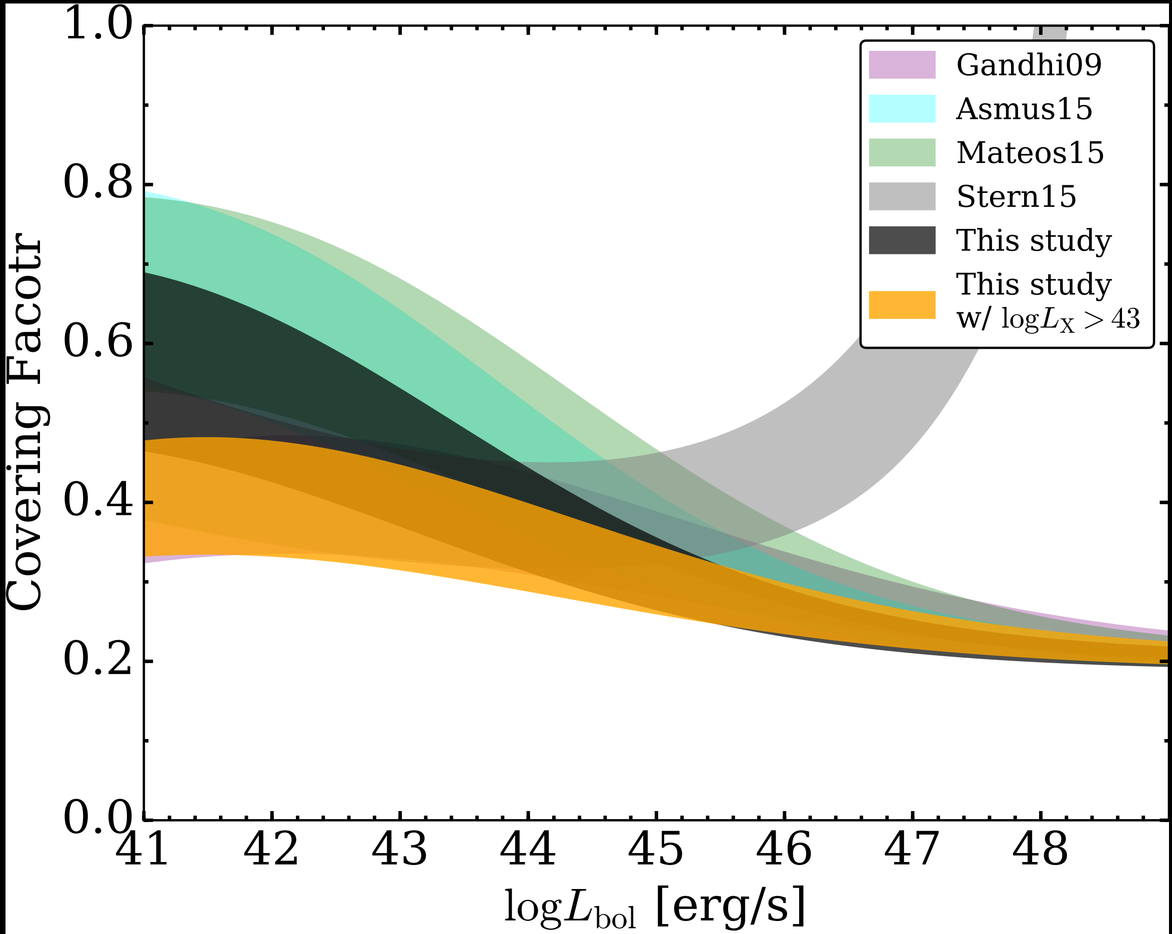
Table 3
Equations of the Luminosity Correlation Between the MIR and X-Ray Band

(1) MIR Band	(2) X-ray Band	(3) Equation	(4) z Range	(5) L_X Range	(6) Selection	(7) AGN Type	(8) Reference
12 μm	14–195 keV	$\log \frac{L_{12\,\mu m}}{10^{43}\,\mathrm{erg\,s^{-1}}} = (-0.10 \pm 0.02) + (0.96 \pm 0.02) \log \frac{L_{14-195}}{10^{43}\,\mathrm{erg\,s^{-1}}}$	$z < 0.3$	$41 < \log L_{14-195} < 46$	X-ray	both	this study
22 μm	14–195 keV	$\log \frac{L_{22\,\mu m}}{10^{43}\,\mathrm{erg\,s^{-1}}} = (0.02 \pm 0.02) + (0.98 \pm 0.02) \log \frac{L_{14-195}}{10^{43}\,\mathrm{erg\,s^{-1}}}$	$z < 0.3$	$41 < \log L_{14-195} < 46$	X-ray	both	this study
12 μm	14–195 keV	$\log \frac{L_{12\,\mu m}}{10^{43}\,\mathrm{erg\,s^{-1}}} = (-0.21 \pm 0.03) + (1.05 \pm 0.03) \log \frac{L_{14-195}}{10^{43}\,\mathrm{erg\,s^{-1}}}$	$z < 0.3$	$43 < \log L_{14-195} < 46$	X-ray	both	this study
22 μm	14–195 keV	$\log \frac{L_{22\,\mu m}}{10^{43}\,\mathrm{erg\,s^{-1}}} = (-0.09 \pm 0.03) + (1.07 \pm 0.03) \log \frac{L_{14-195}}{10^{43}\,\mathrm{erg\,s^{-1}}}$	$z < 0.3$	$43 < \log L_{14-195} < 46$	X-ray	both	this study
6 μm	2–10 keV	$\log \frac{L_{12\,\mu m}}{10^{41}\,\mathrm{erg\,s^{-1}}} \simeq 2.1 \times 10^{-2}\left(512 - \sqrt{2.2 \times 10^6 - 4.7 \times 10^4 \log \frac{L_{2-10}}{10^{41}\,\mathrm{erg\,s^{-1}}}}\right)$	$1.5 < z < 4.7$	$45 < \log L_{2-10} < 46.2$	optical	type-1	Stern (2015)
6 μm	2–10 keV	$\log \frac{L_{6\,\mu m}}{10^{43}\,\mathrm{erg\,s^{-1}}} = 0.40 + 1.39 \log \frac{L_{2-10}}{10^{43}\,\mathrm{erg\,s^{-1}}}$	$0.2 < z < 4$	$42 < \log L_{2-10} < 46$	X-ray	type-1	Fiore et al. (2009)
12 μm	2–10 keV	$\log \frac{L_{12\,\mu m}}{10^{43}\,\mathrm{erg\,s^{-1}}} = (0.19 \pm 0.05) + (1.11 \pm 0.07) \log \frac{L_{2-10}}{10^{43}\,\mathrm{erg\,s^{-1}}}$	$z < 0.1$	$41 < \log L_{2-10} < 45$	X-ray	both	Gandhi et al. (2009)
12 μm	2–10 keV	$\log \frac{L_{12\,\mu m}}{10^{43}\,\mathrm{erg\,s^{-1}}} = 0.30 + 0.99 \log \frac{L_{2-10}}{10^{43}\,\mathrm{erg\,s^{-1}}}$	$0.05 < z < 2.8$	$42 < \log L_{2-10} < 46$	X-ray	both	Mateos et al. (2015)
12 μm	2–10 keV	$\log \frac{L_{12\,\mu m}}{10^{43}\,\mathrm{erg\,s^{-1}}} = (0.33 \pm 0.04) + (0.97 \pm 0.03) \log \frac{L_{2-10}}{10^{43}\,\mathrm{erg\,s^{-1}}}$	$z < 0.3$	$40 < \log L_{2-10} < 46$	X-ray	both	Asmus et al. (2015)

☑ **X-ray saturates at high-L/high-λ_{Edd} end**

Covering factor (C_T) vs. L_{bol}

L_X => L_{bol} (Marconi+04) and **L_{MIR}/L_{bol} => C_T** (Stalevski+16)



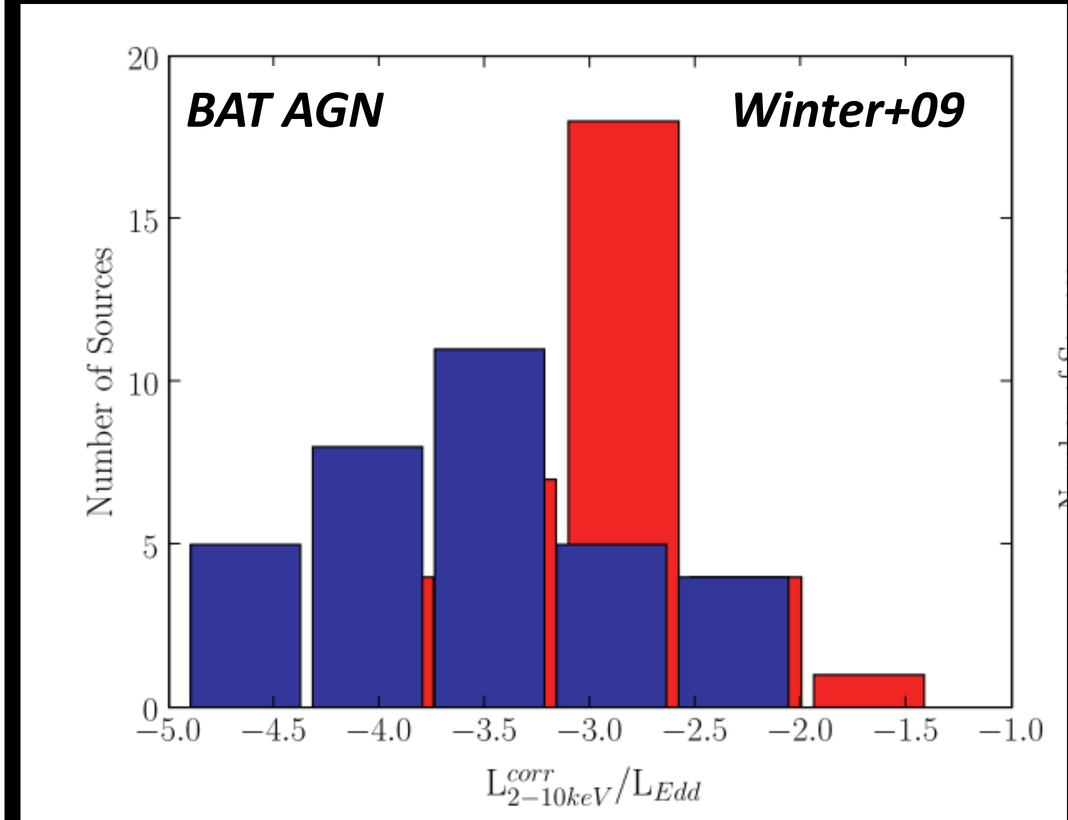
☑ **C_T decreases as L_{bol} increases** (KI+17, Mateos+15, Asmus+15)

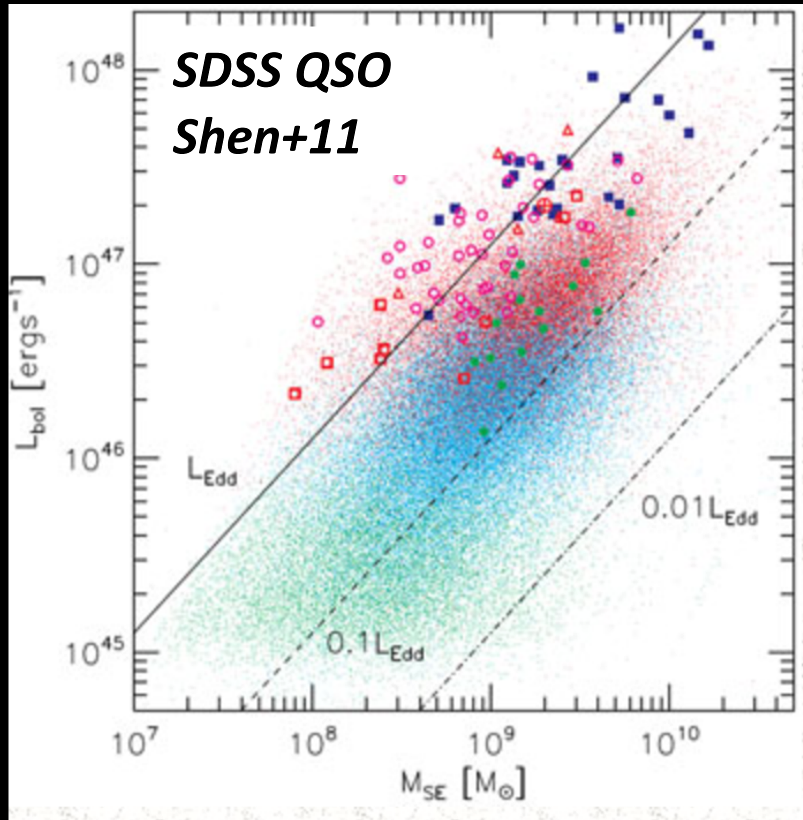
➡ consistent with "luminosity dependent unified model"

☑ **However, high-z/-L AGN (e.g., Stern'15) do not follow the trend**

➡ **lower slope b is necessary to reproduce receding torus model**

Eddington ratio of BAT AGN/SDSS QSOs

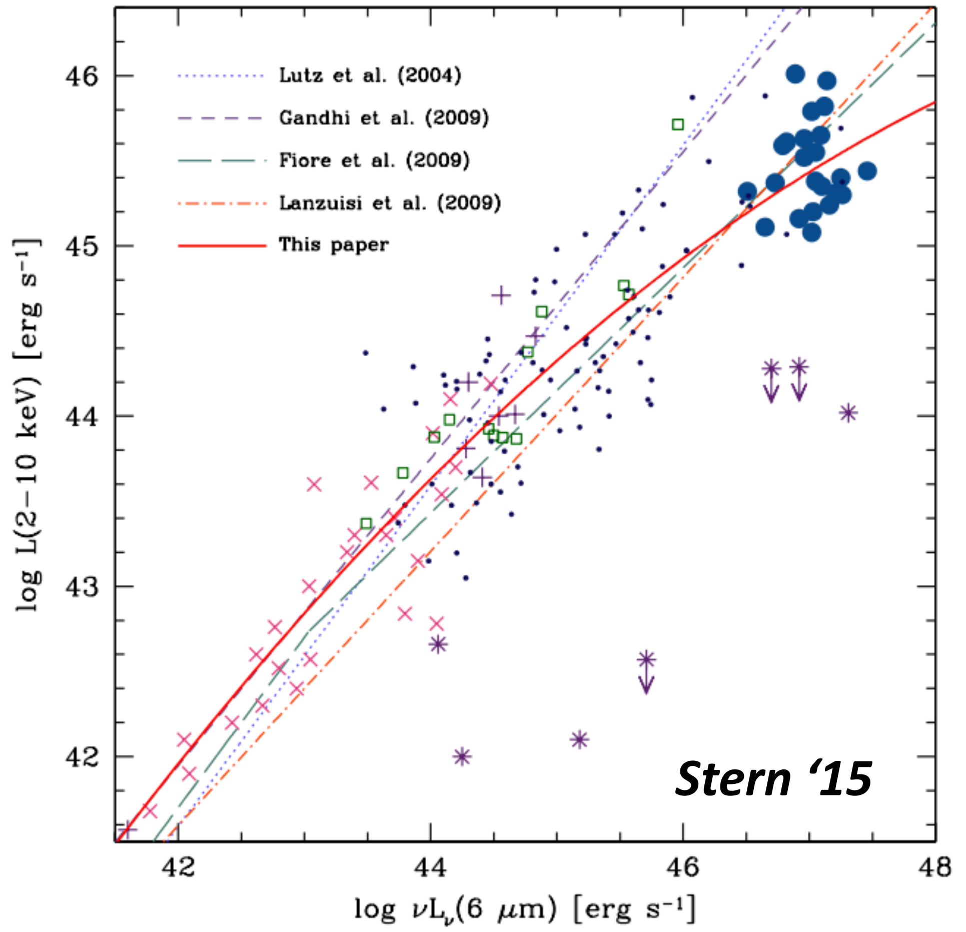


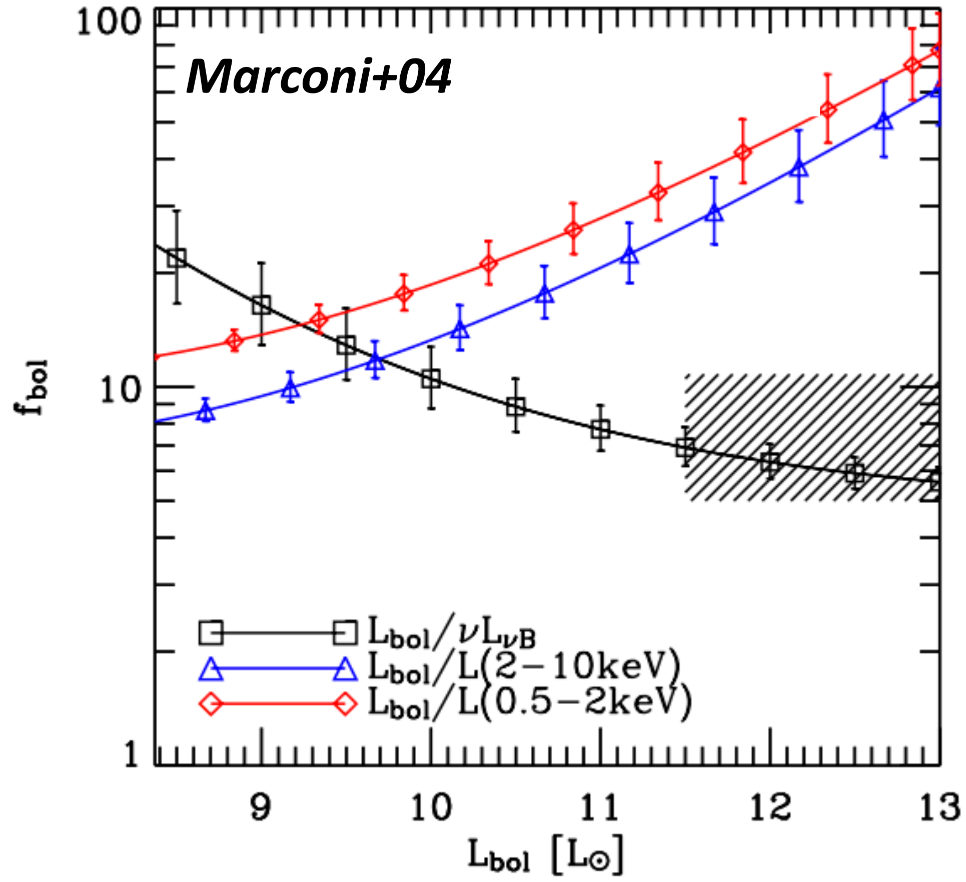


☑ Most sources are at log λ_{Edd} < -2.0 for BAT AGN

☑ Most sources are at log λ_{Edd} > -2.0 for SDSS QSOs

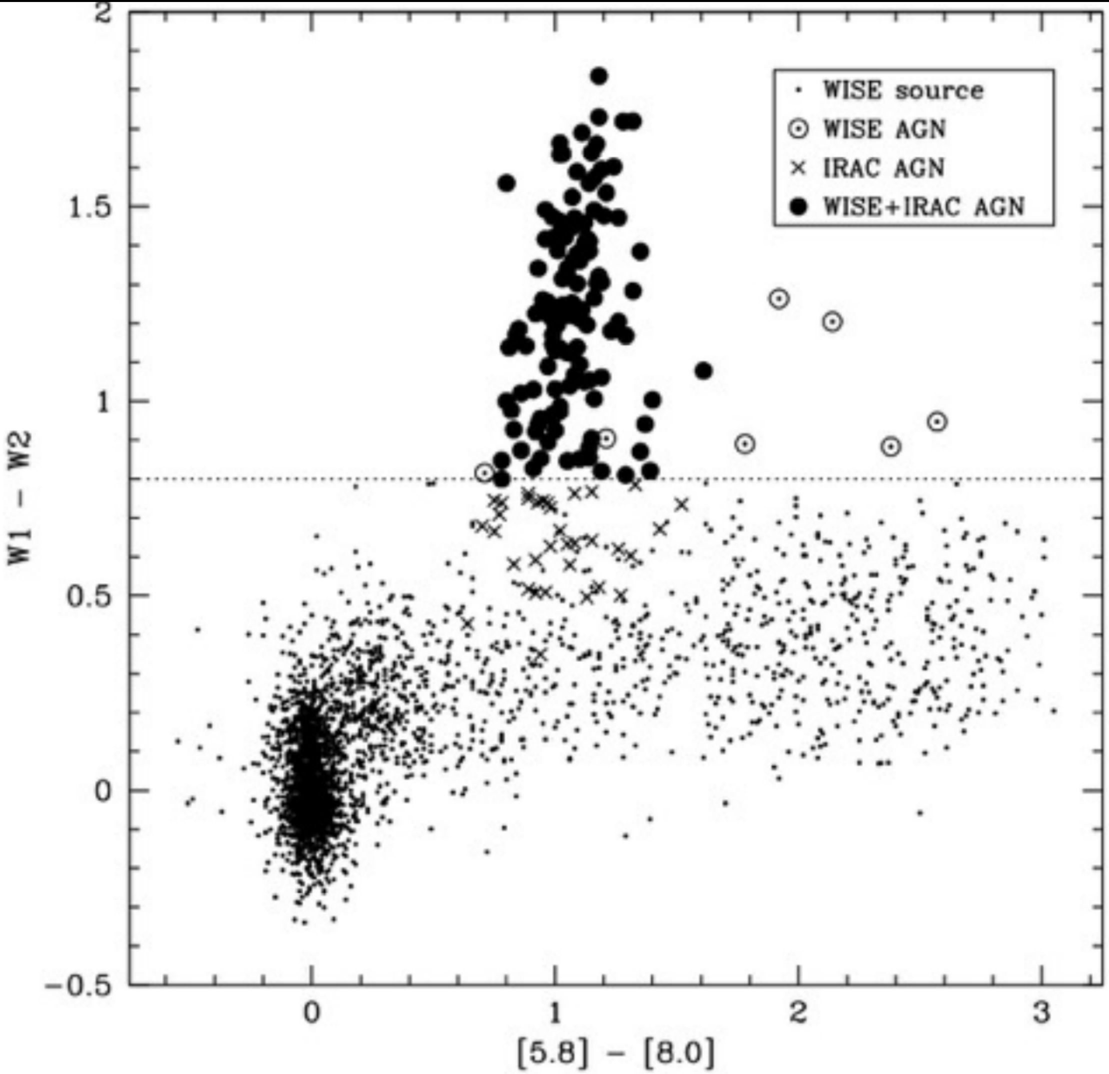
Saturation of Lx at high-L end

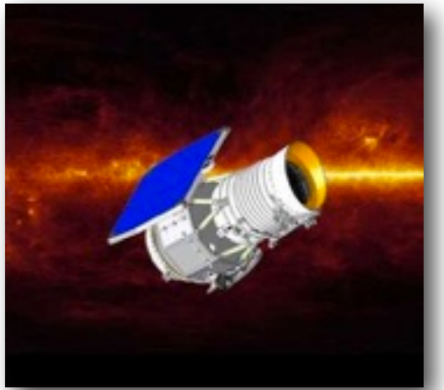




☑ X-ray saturates at high-L/high-λ_{Edd} end

WISE IR color study



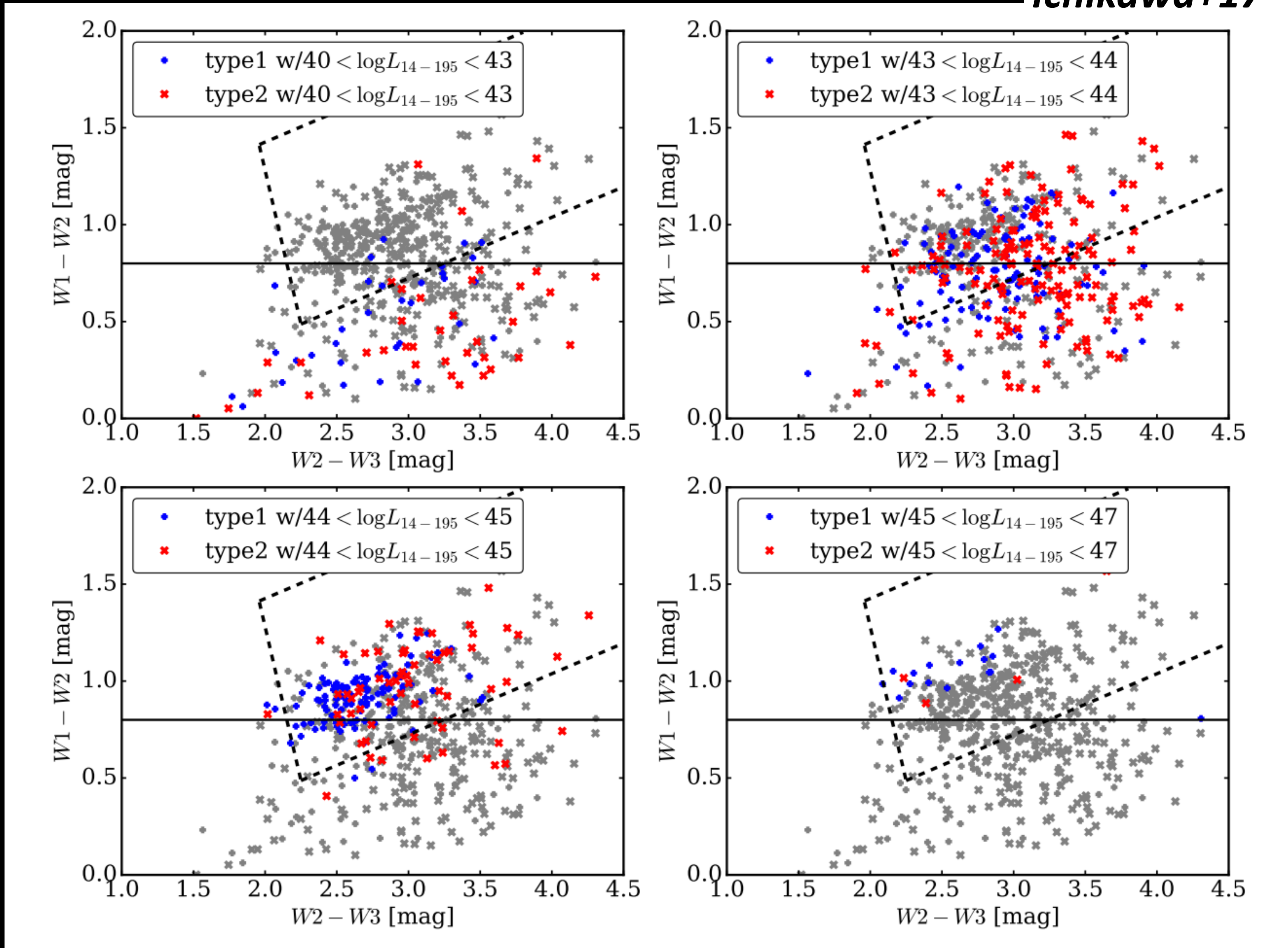


W1-W2 > 0.8
W2 < 15.05

Stern+12, Assef+13, see also Stern's talk at "Hidden Monster 2016"

WISE IR color vs X-ray selected AGN

Ichikawa+17



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