Survival of the obscuring torus in the most powerful Active Galactic Nuclei

Silvia Mateos

Instituto de Física de Cantabria (CSIC-UC)

Santander, Spain

With

F.J. Carrera, **A. Alonso-Herrero**, X. Barcons, I. Ordovás-Pascual, L. Barquín, **C. Ramos-Almeida**, A. Asensio-Ramos, A. Blain, A. Hernán-Caballero, A. Caccianiga, T. Miyaji, R. Della Ceca

Constraints on the covering factor of the nuclear obscuring material from AGN surveys

- **AGN Unification**

  Are the tori of optical type 1 and type 2 AGN different?

- **Receding torus**

  Does f_2 vary with AGN luminosity (and Eddington ratio)?

- **Intrinsic fraction of luminous type 2 AGN**

  How many luminous type 2 AGN are we missing by current X-ray surveys and what are the properties of their nuclear absorber?

Talks by C. Ricci, C. Ramos-Almeida, Baloković, L. Lanz, K. Ichikawa

AGN sample

The Bright Ultra-hard XMM-Newton Survey (BUXS; Mateos et al. 2012)

- Flux-limited sample: $f_{4.5\text{-}10\ keV} > 6\text{x}10^{-14}$ erg cm^{-2} s^{-1}
- **98% spectroscopic identification rate**

  137 type 1/67 type 2 at z<1 (from optical spectroscopy)
- **Constraints on f_2 for 99% of sources** (Mateos et al. 2016)
- Good quality X-ray spectroscopy: **robust estimates of $L_{2\text{-}10\ keV}$**

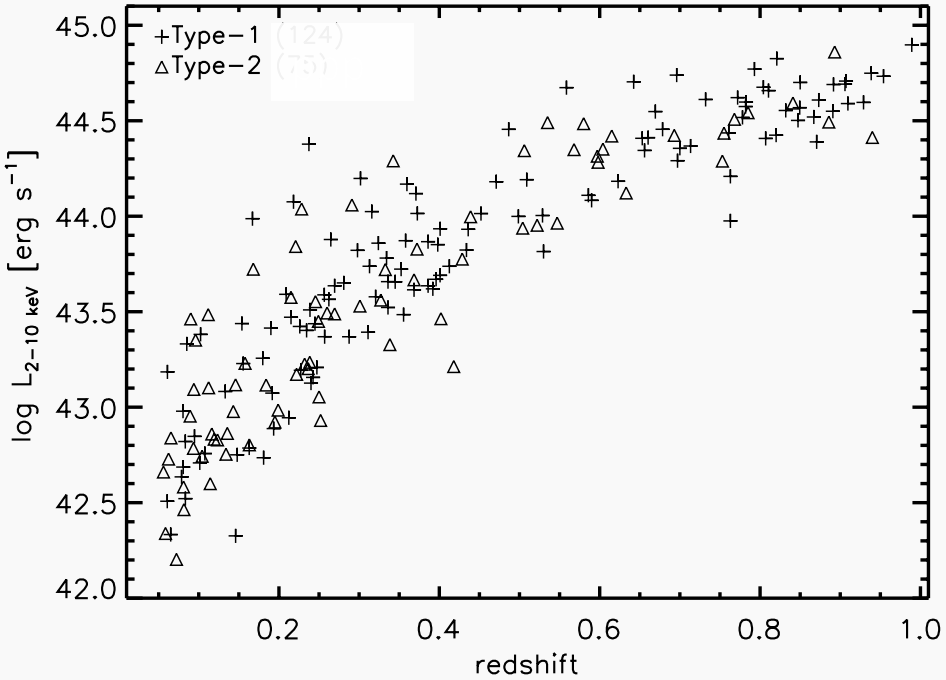
204 non-blazar AGN

0.05<z<1

$L_{2\text{-}10\ keV}$: 10^{42}-10^{45} erg s^{-1}

Luminous AGN

High AGN/host contrast

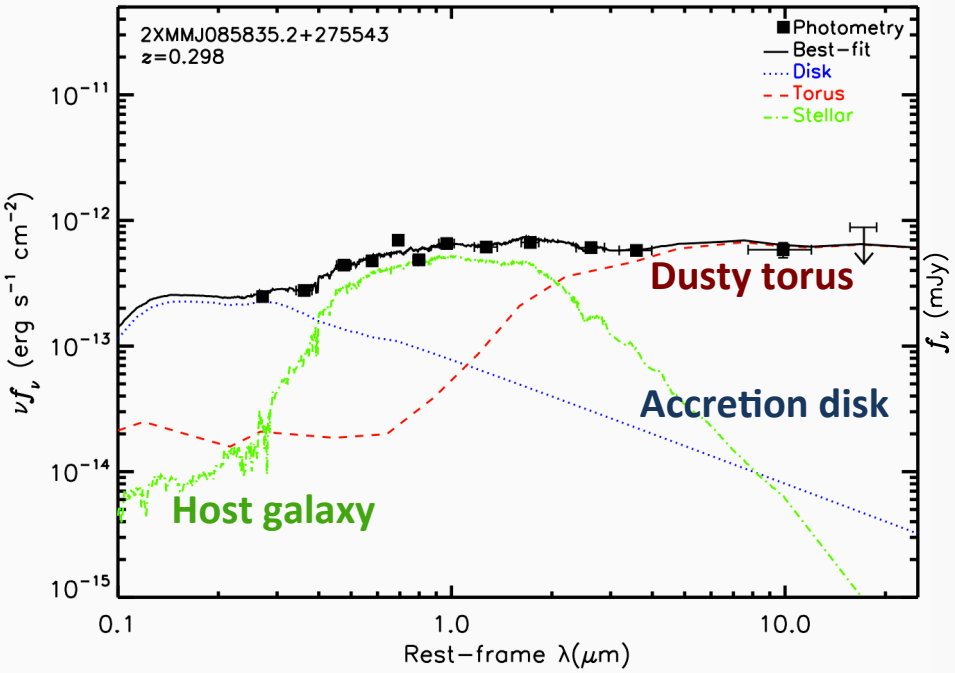


Isolating the torus emission

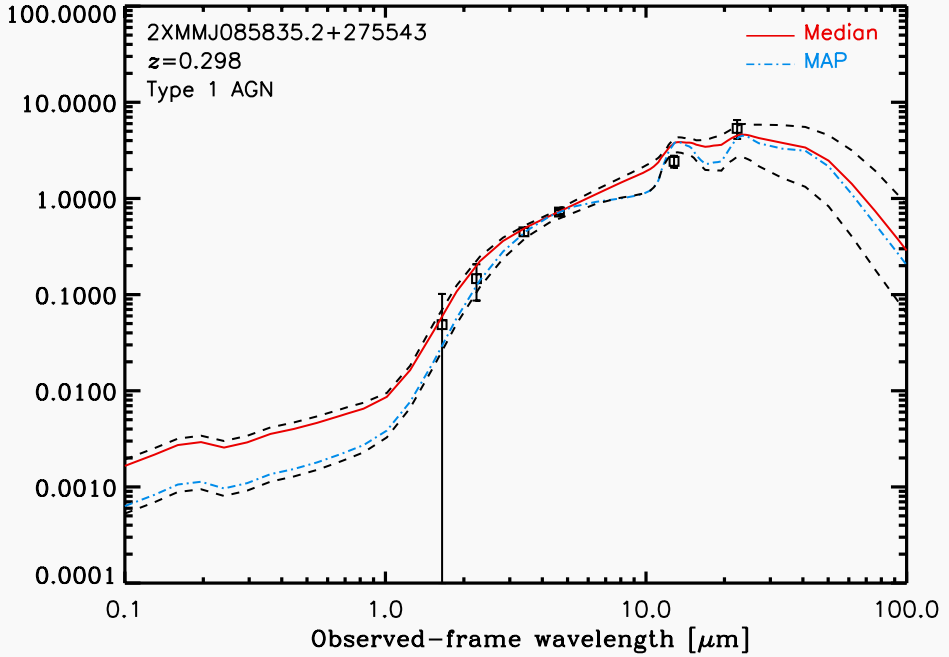
UV-to-mid-IR SEDs (SDSS, 2MASS, UKIDSS, WISE) corrected for contamination from AGN hosts and accretion disk emission

Same SED decomposition analysis for type 1 and type 2 AGN

Observed UV-IR SED



Torus IR SEDs: rest-frame 1-20 μm

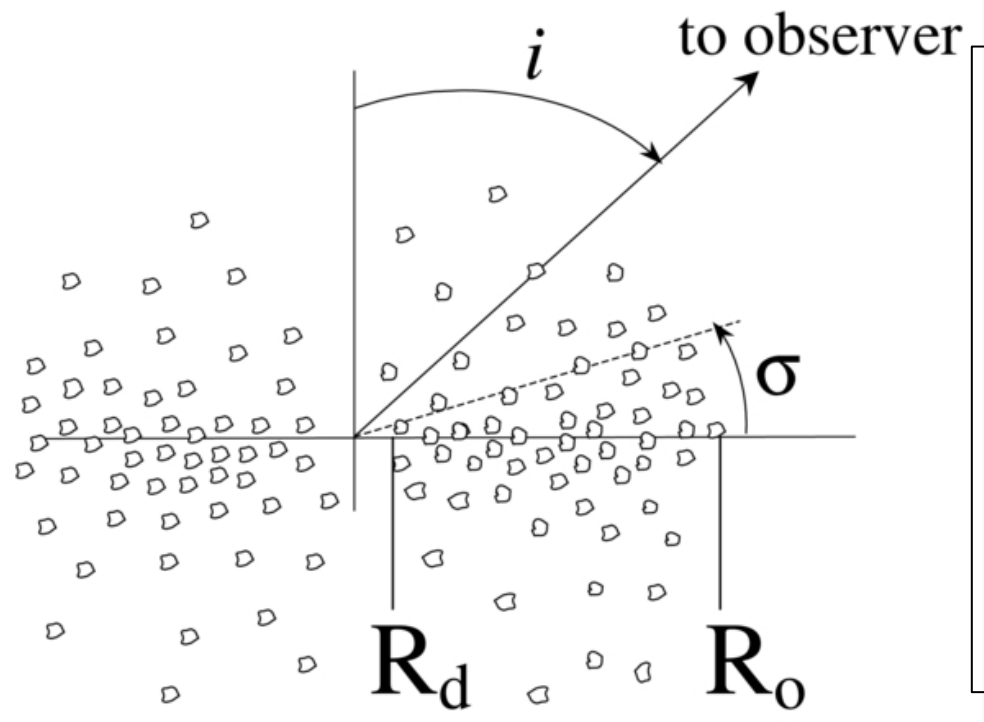


Mateos et al. 2015

Modelling the torus emission: f_2

Nenkova+08 torus models:

All dust distributed in optically thick clouds in a toroidal geometry



Model parameters

R_d : dust sublimation radius

R_o : outer radius

***σ* : angular distribution of clouds**

***N_0* : average number of clouds through the torus equator**

τ_V : optical depth per cloud

q : power-law index of radial density profile

i : viewing angle

f_2: geometrical covering factor

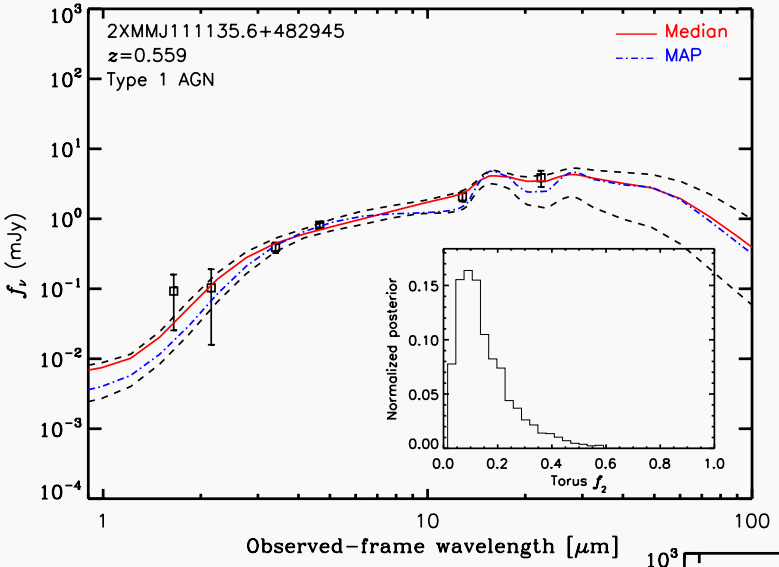
fraction of the sky as seen by the central source obscured by dust

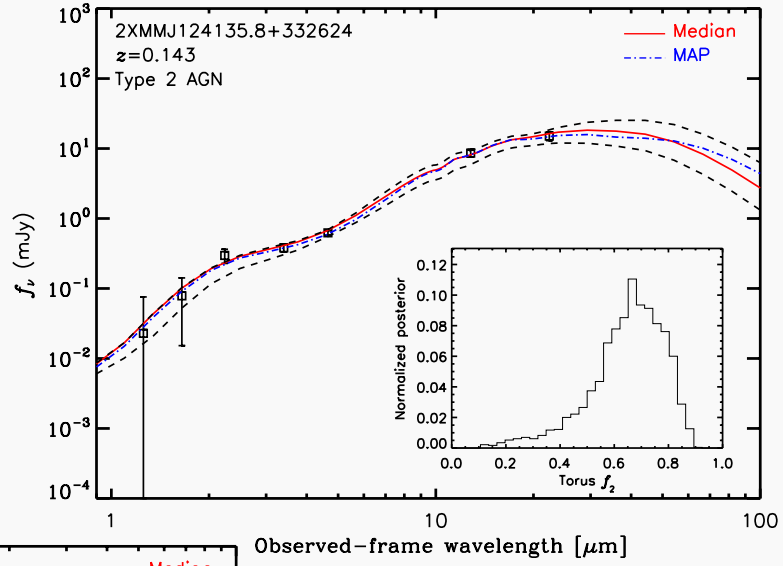
$$f_2 = 1 - \int_0^{\pi/2} e^{-N_0 e^{-\frac{\beta^2}{\sigma^2}}} \cos(\beta)\, d\beta$$

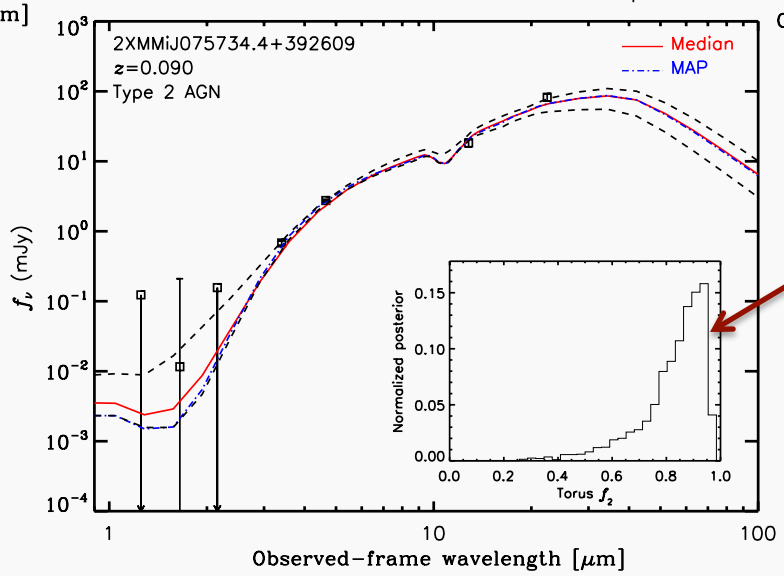
SED fitting with BayesCLUMPY

Bayesian inference tool: **BayesCLUMPY**

(Asensio Ramos & Ramos Almeida 2009, 2012)







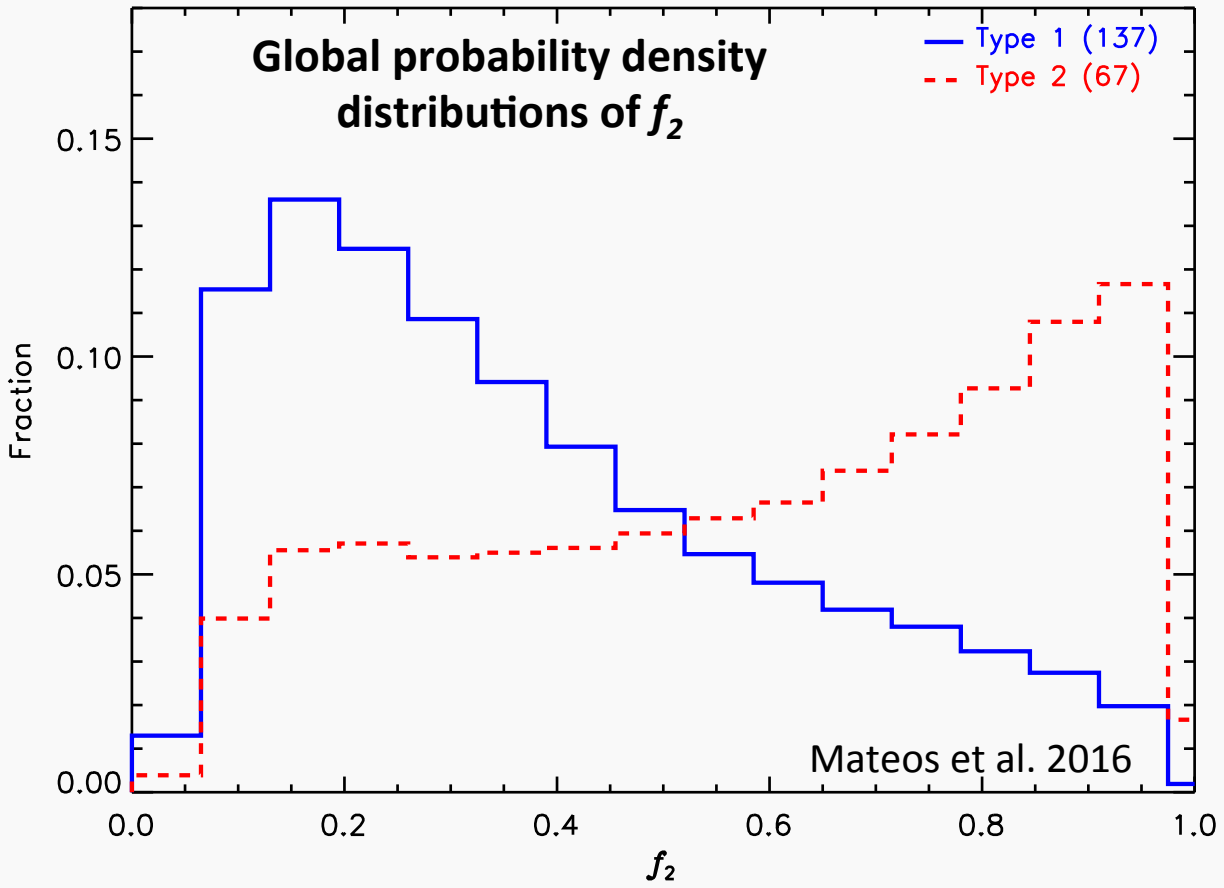
Posterior distributions of f_2 for each AGN

Covering factor vs optical class

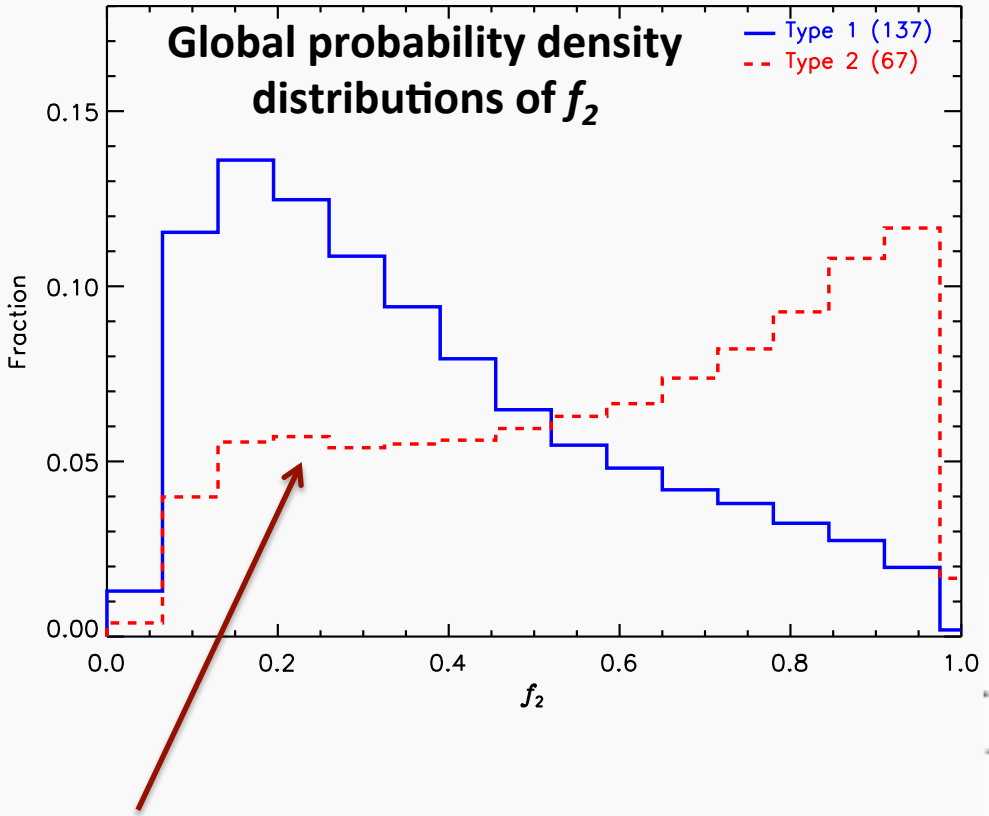
Broad range of covering factors but,

- Type 1 AGN preferentially drawn from the lower end of the distribution of f_2
- Type 2 AGN preferentially drawn from the higher end of the f_2 distribution

f_2: solid angle covered by the absorber



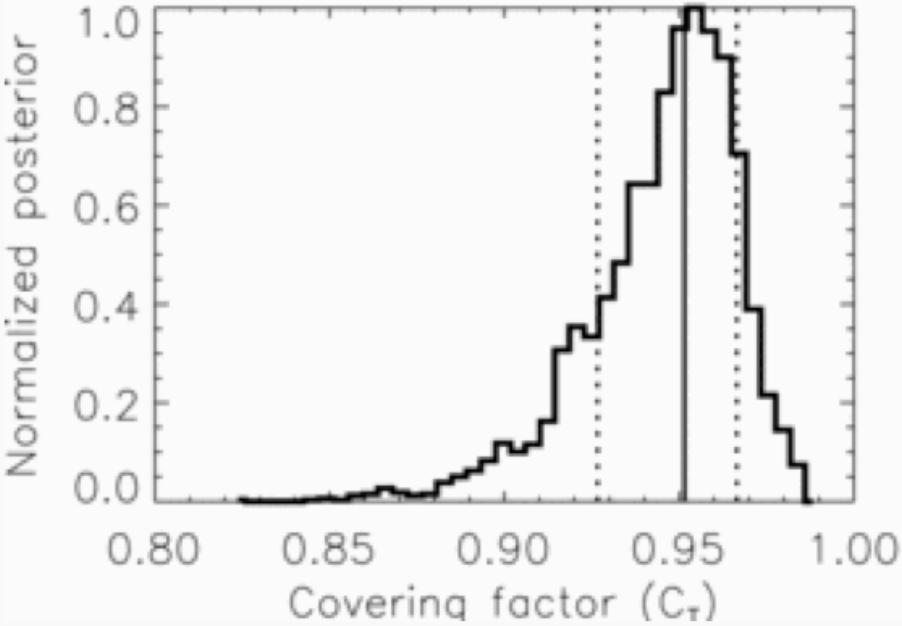
Covering factor vs optical class



Many type 2 AGN with rather small f_2

Local Sy2s

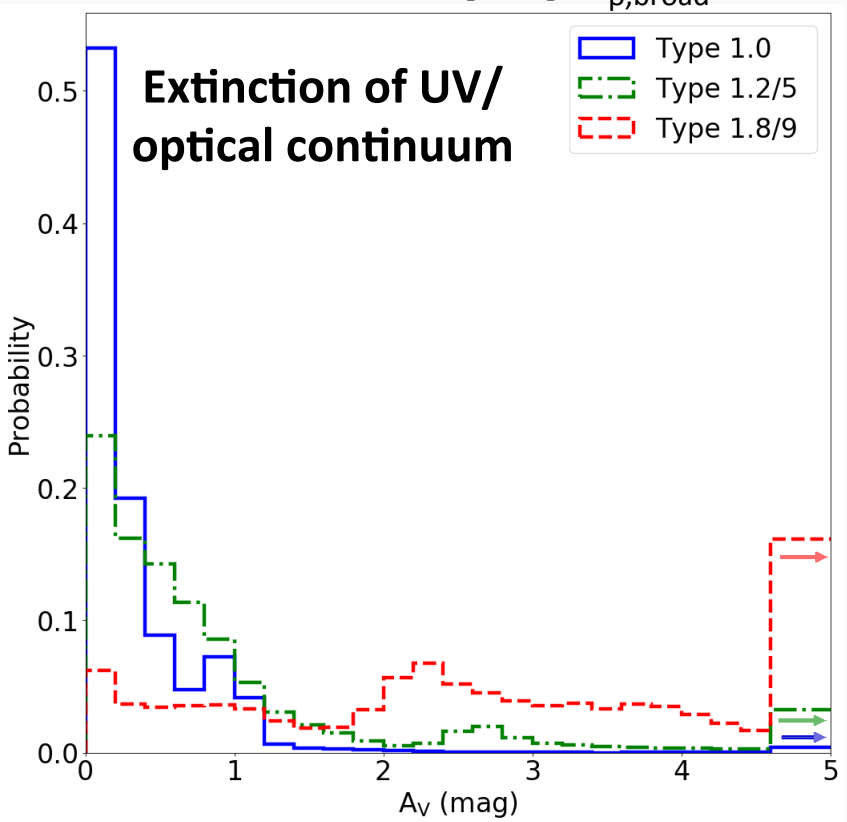
Ramos Almeida 2009, 2011;
Alonso-Herrero 2011; Lira 2013

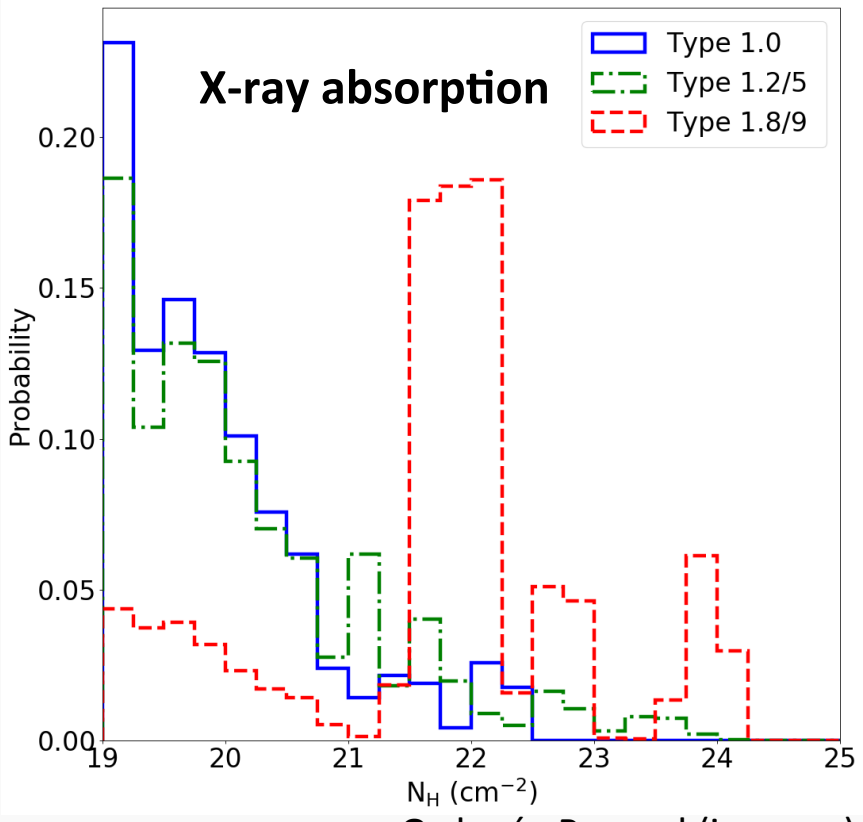


Covering factor vs intermediate AGN class

Intermediate AGN classes available for 82% of the AGN with detected broad emission lines

Classification based on [OIII]/$H_{\beta,broad}$ flux ratio (Whittle 1992)

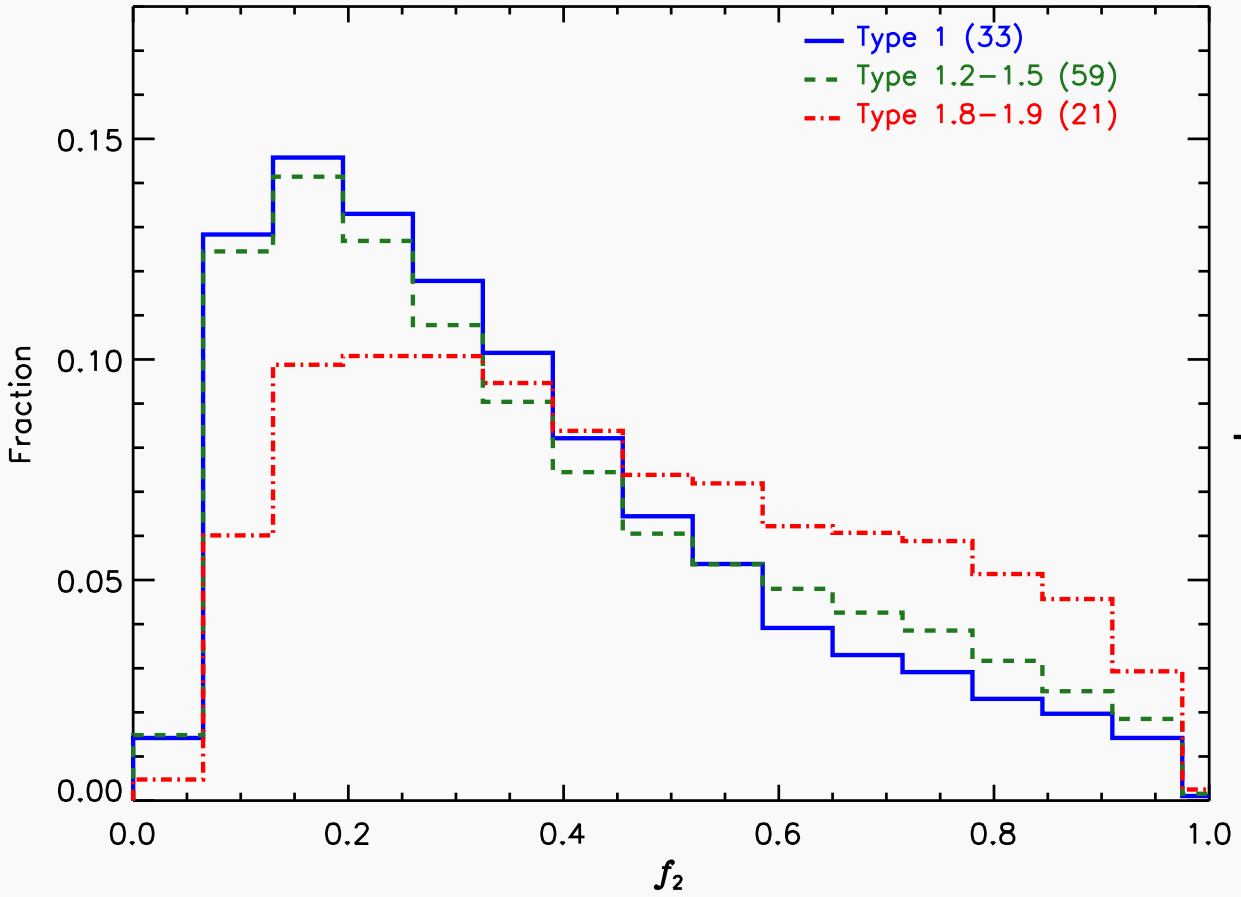




Ordovás-Pascual (in prep.)

Type 1.8/1.9 are more absorbed in X-rays and have larger extinction at UV/optical wavelengths (Stern & Laor 2012; Hernandez-García 2017; Koss et al. 2017; see also Lawrence & Elvis 2010; Alonso-Herrero 2011)

Covering factor vs intermediate AGN class

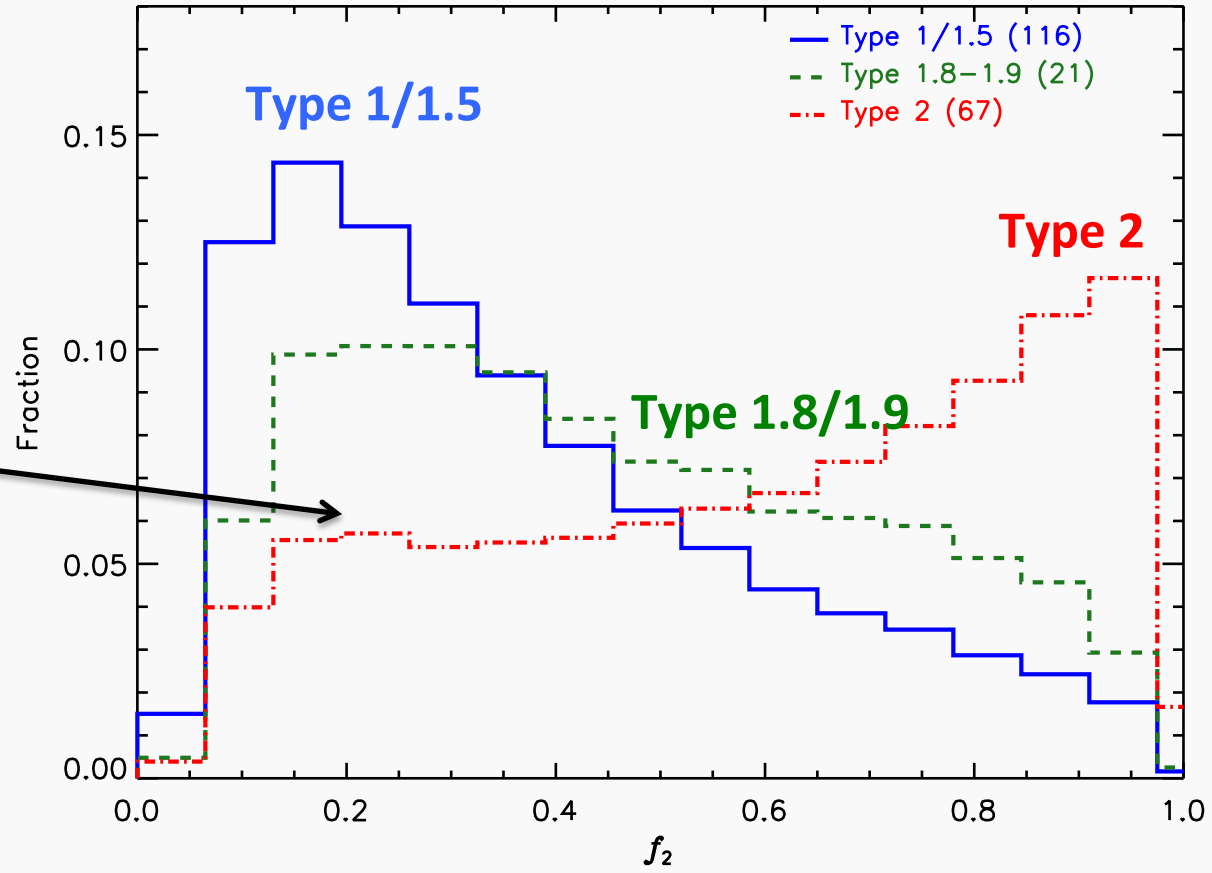


Type 1/1.2/1.5 AGN have similar distributions of f_2

Type 1.8/1.9 AGN have higher f_2 than type 1/1.5 AGN, but differences are not very significant (2σ)

Covering factor vs optical class

Low f_2 in our type 2 AGN could be explained, at least in part, by high-z type 1.8/1.9s misclassified as type 2s

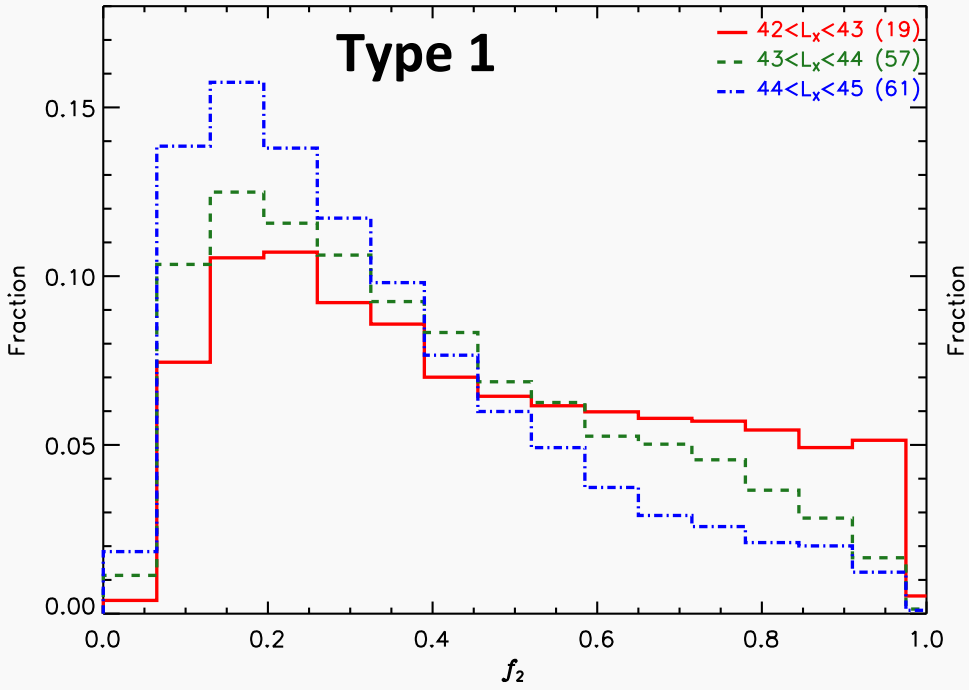


Type 1 and type 2 AGN are intrinsically different

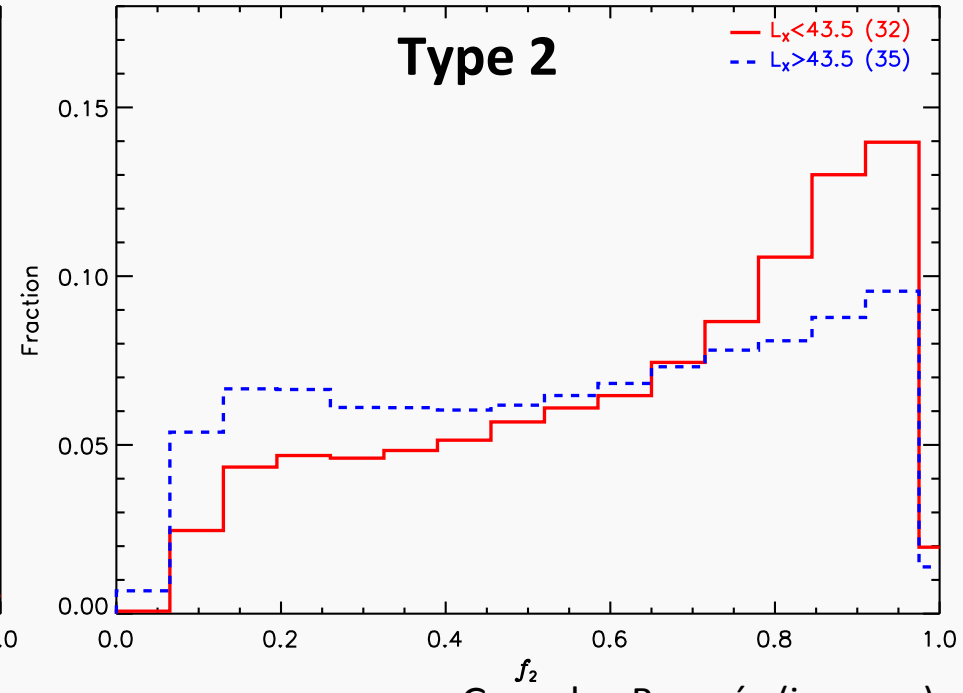
Orientation alone cannot explain the observed properties of AGN

Covering factor vs AGN luminosity

3 orders of magnitude in AGN luminosity



>2 orders of magnitude in AGN luminosity



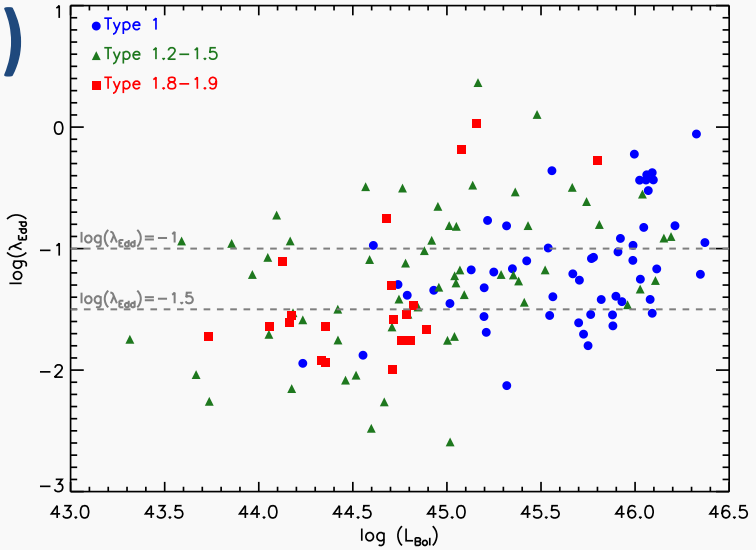
Gonzalez-Barquín (in prep.)

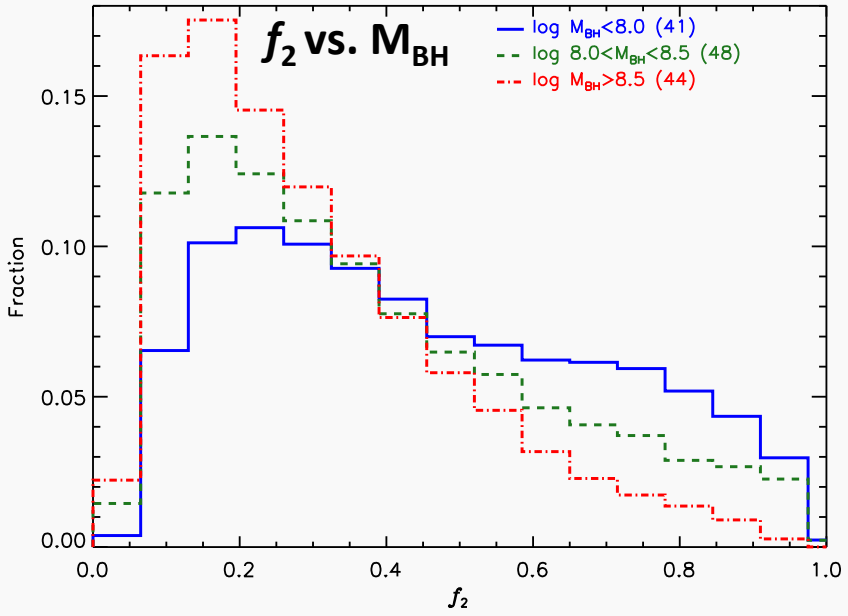
A decrease of f_2 with AGN luminosity is observed for, as postulated by simple receding torus models (Lawrence 1982)

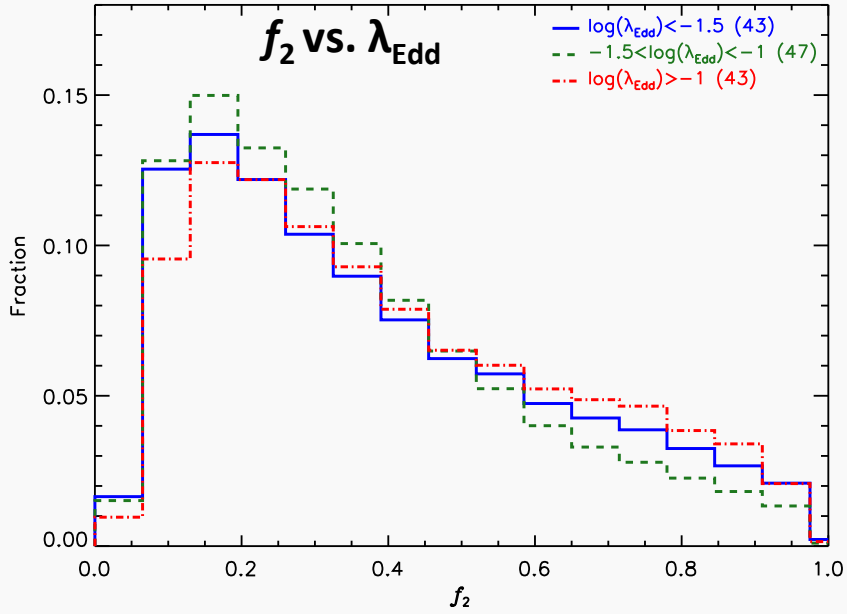
Covering factor vs Eddington ratio (type 1 AGN)

L_{bol} from $L_{2\text{-}10\ keV}$ (Vasudevan et al. 2009)

M_{BH} from H_α, H_β and MgII broad emission lines (Greene et al. 2005; Trakhtenbrot & Netzer 2012; Koss et al. 2017)







No clear dependence of f_2 with λ_{Edd}

Intrinsic fraction of type 2 AGN

We find a clear decrease of f_2 with AGN luminosity but, X-ray surveys at energies <10 keV,

- are incomplete for AGN with N_H> few 10^{23} cm^{-2}
- miss the most highly absorbed, Compton-thick AGN

But since

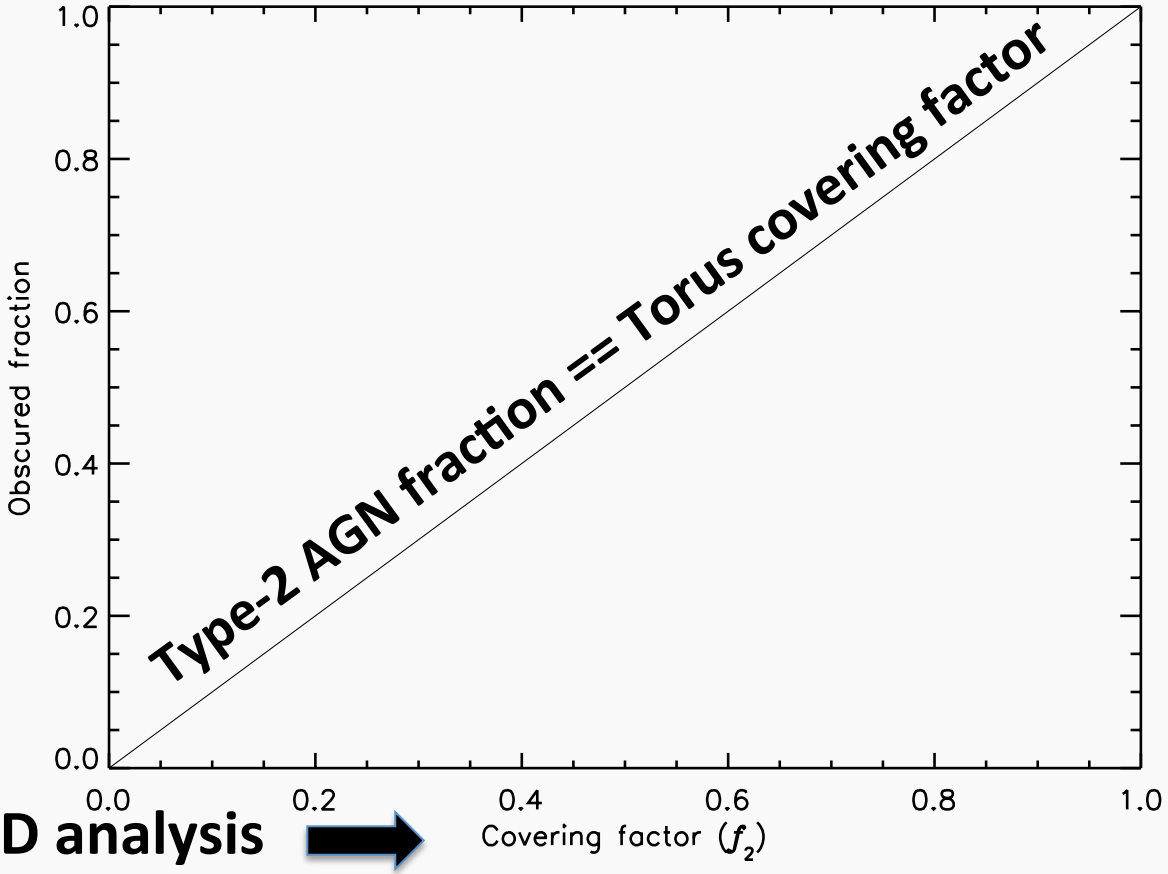
f_2 combined over the total AGN population == intrinsic type 2 AGN fraction

we can use our distributions of f_2 to determine the intrinsic type 2 AGN fraction

Intrinsic fraction of type 2 AGN

f_2 combined over the total AGN population == intrinsic type 2 AGN fraction

Optical class ➡

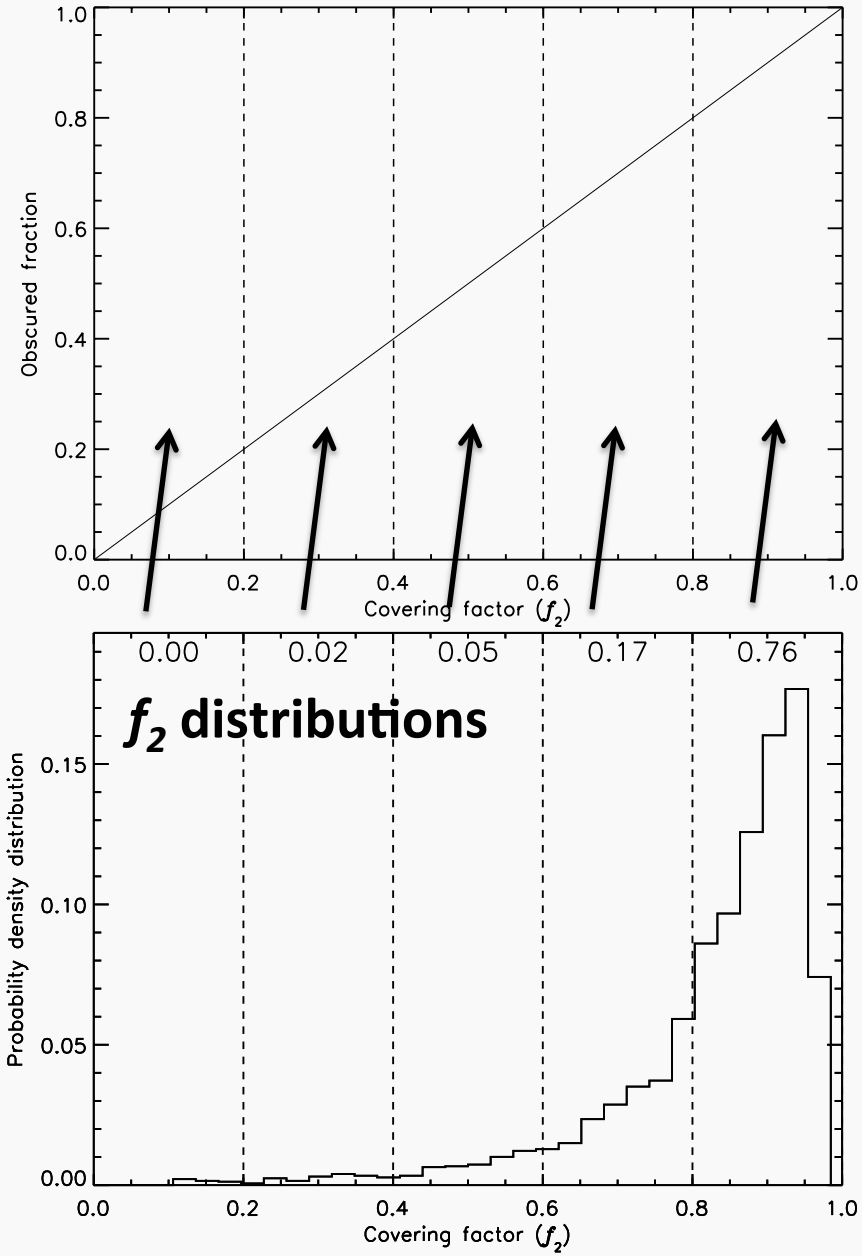


IR SED analysis ➡

Observed type 2 AGN fraction vs. f_2

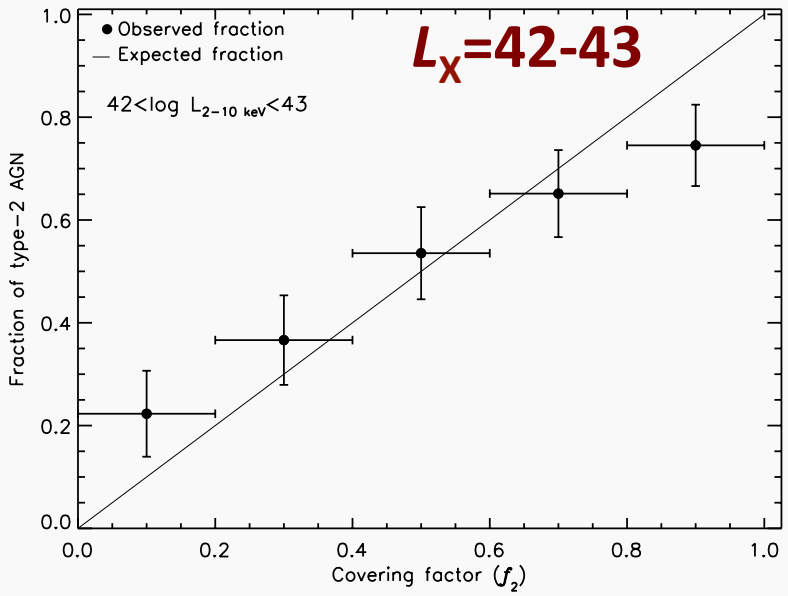
We defined 5 bins in f_2
For each f_2 bin:

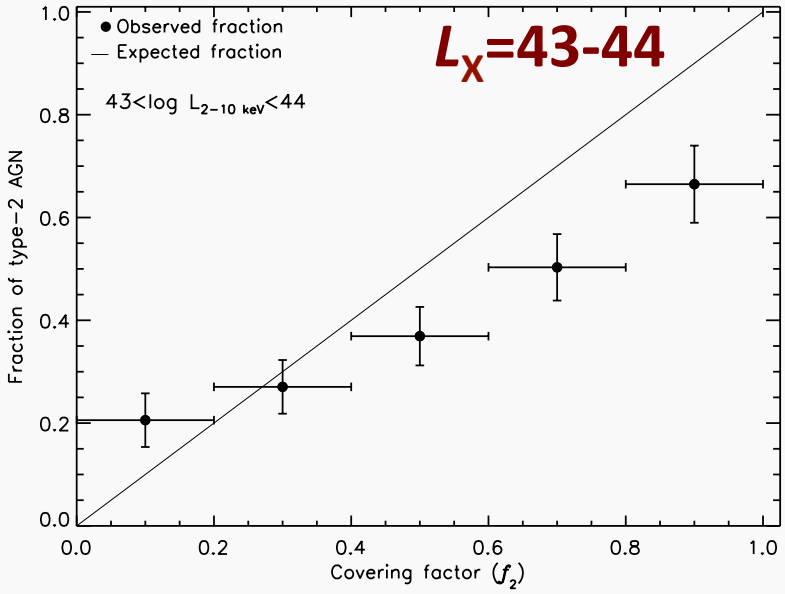
$$F_{obs} = \frac{\sum 2}{\sum 1 + \sum 2}$$

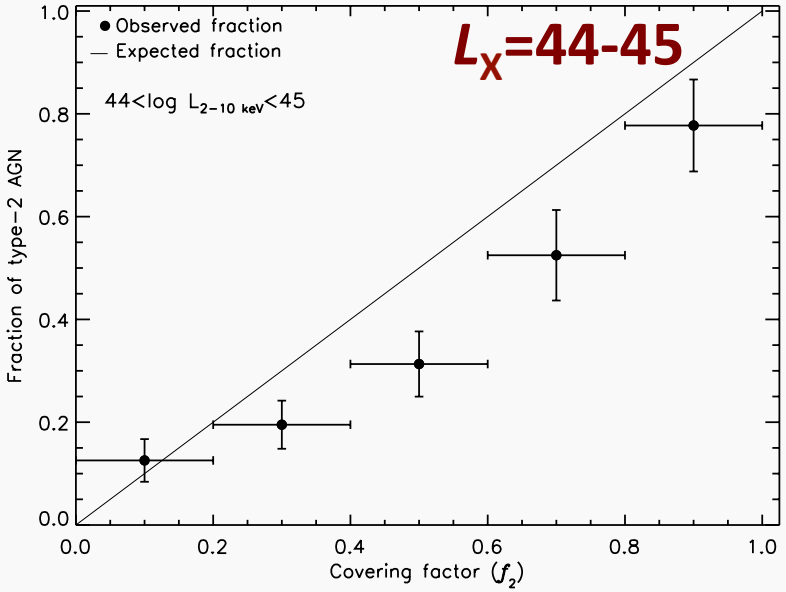


Three X-ray luminosity bins

Observed type 2 AGN fractions vs. f_2







There are not enough <u>luminous</u> type 2 AGN with high f_2

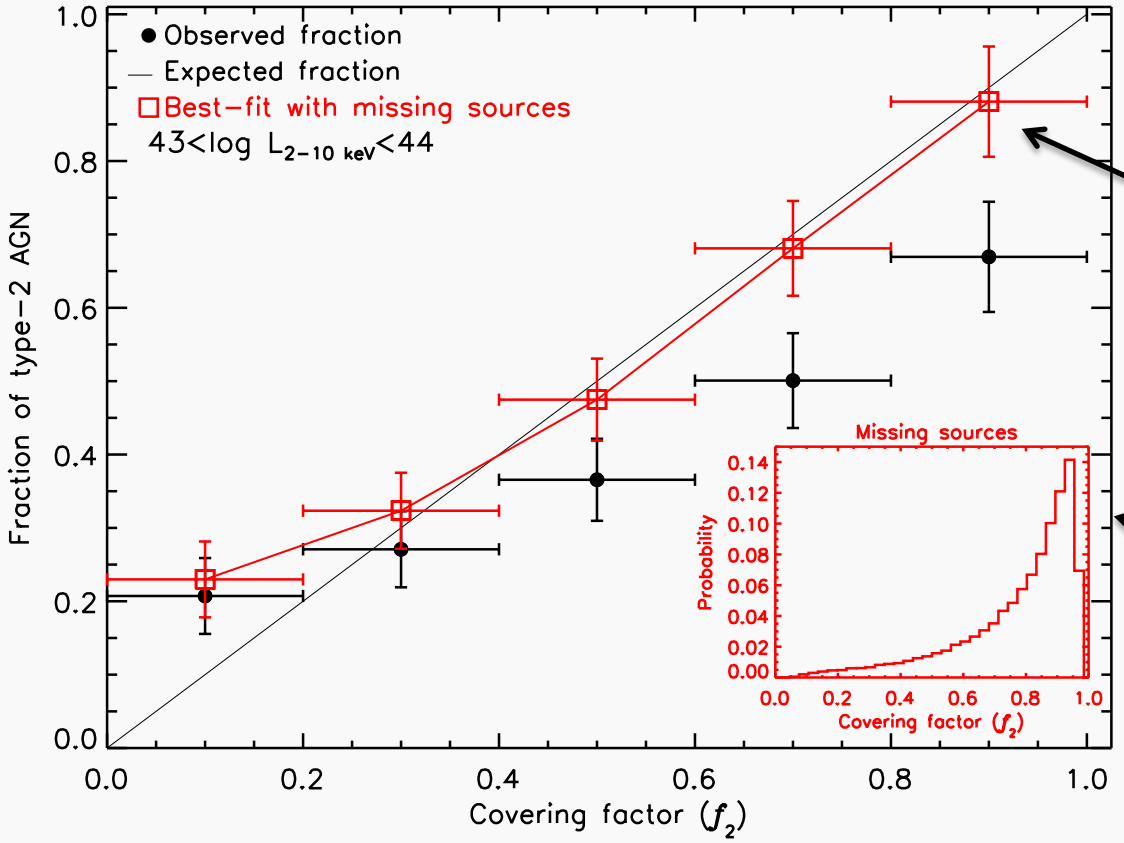
Some must have escaped X-ray detection

Number of objects missed in X-rays

- We assume that the AGN missed are all type-2 AGN

  Highly absorbed Compton thin + Compton-thick

- Stacked f_2 distribution for the most highly absorbed type 2 AGN in BUXS to represent the objects missed in X-rays

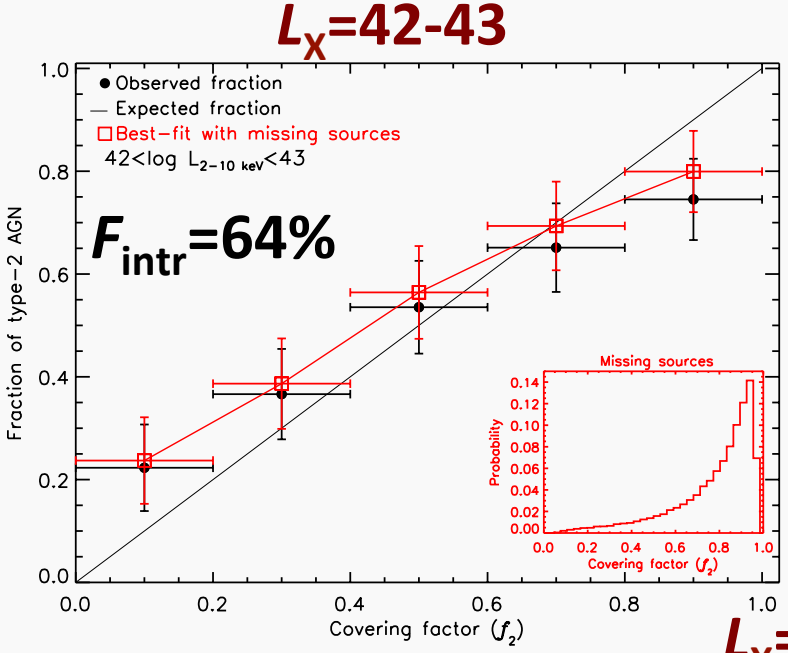


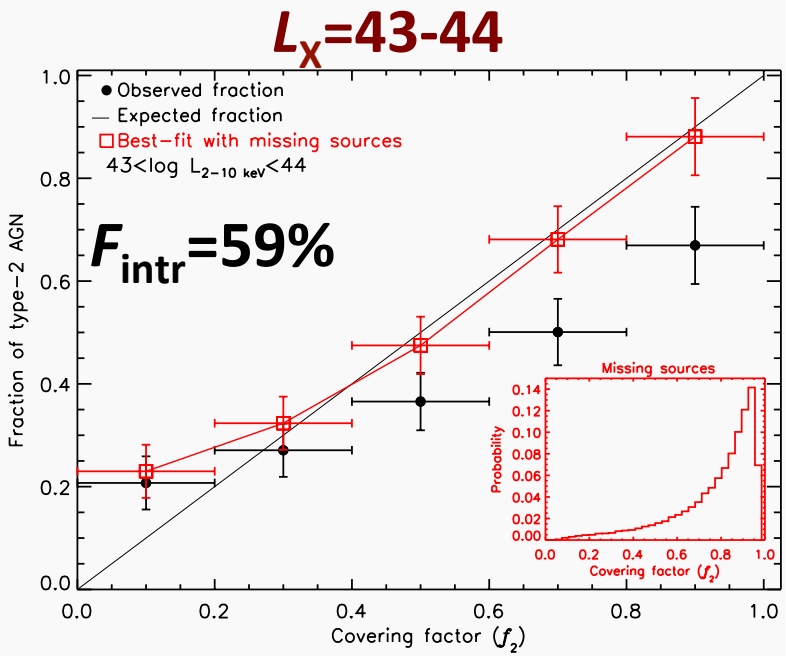
$$F_{intr} = \frac{\sum 2 + N_2 \times F_{CT}}{\sum 1 + \sum 2 + N_2 \times F_{CT}}$$

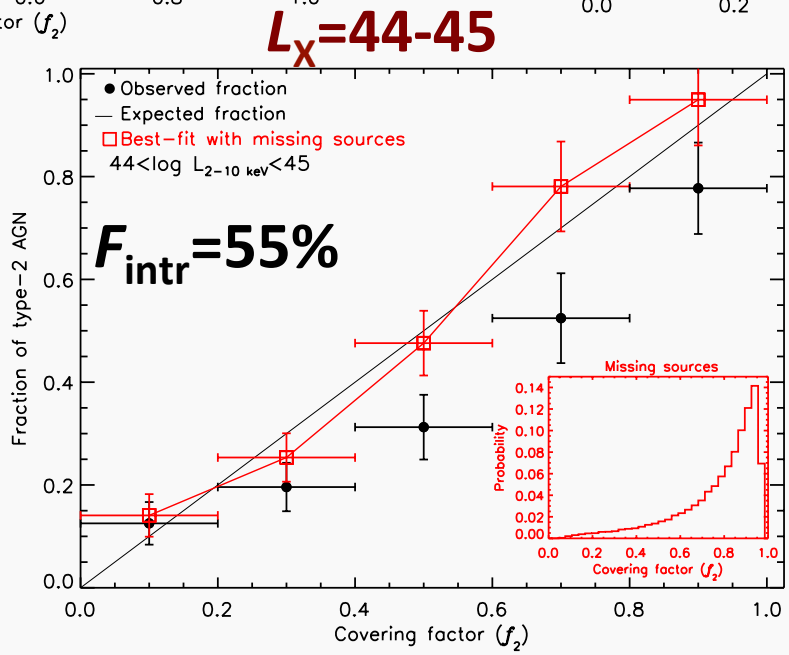
N_2 : number of objects missed

f_2 distribution used for the AGN missed in X-rays

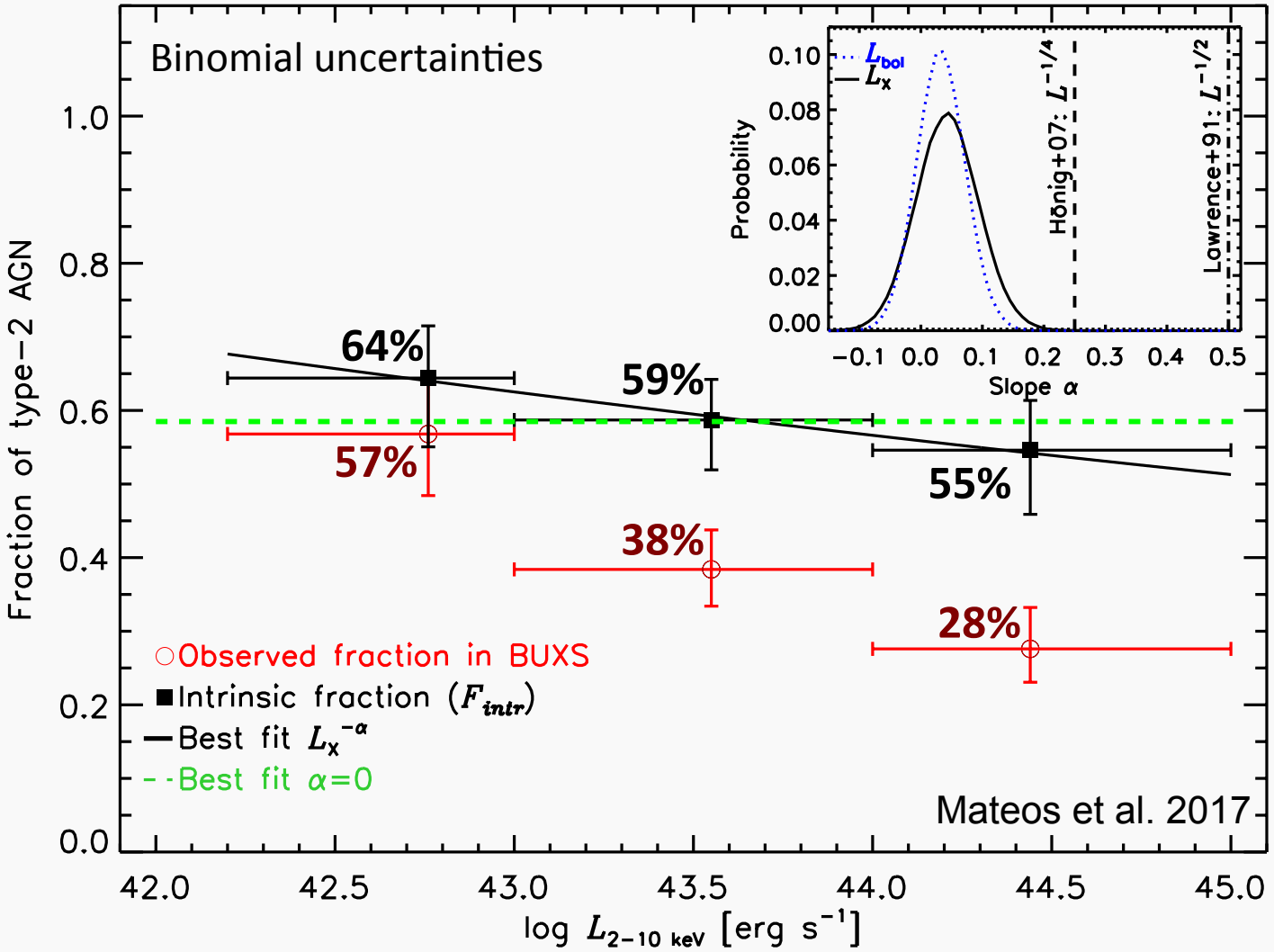
Fraction of type-2 AGN missed in X-rays





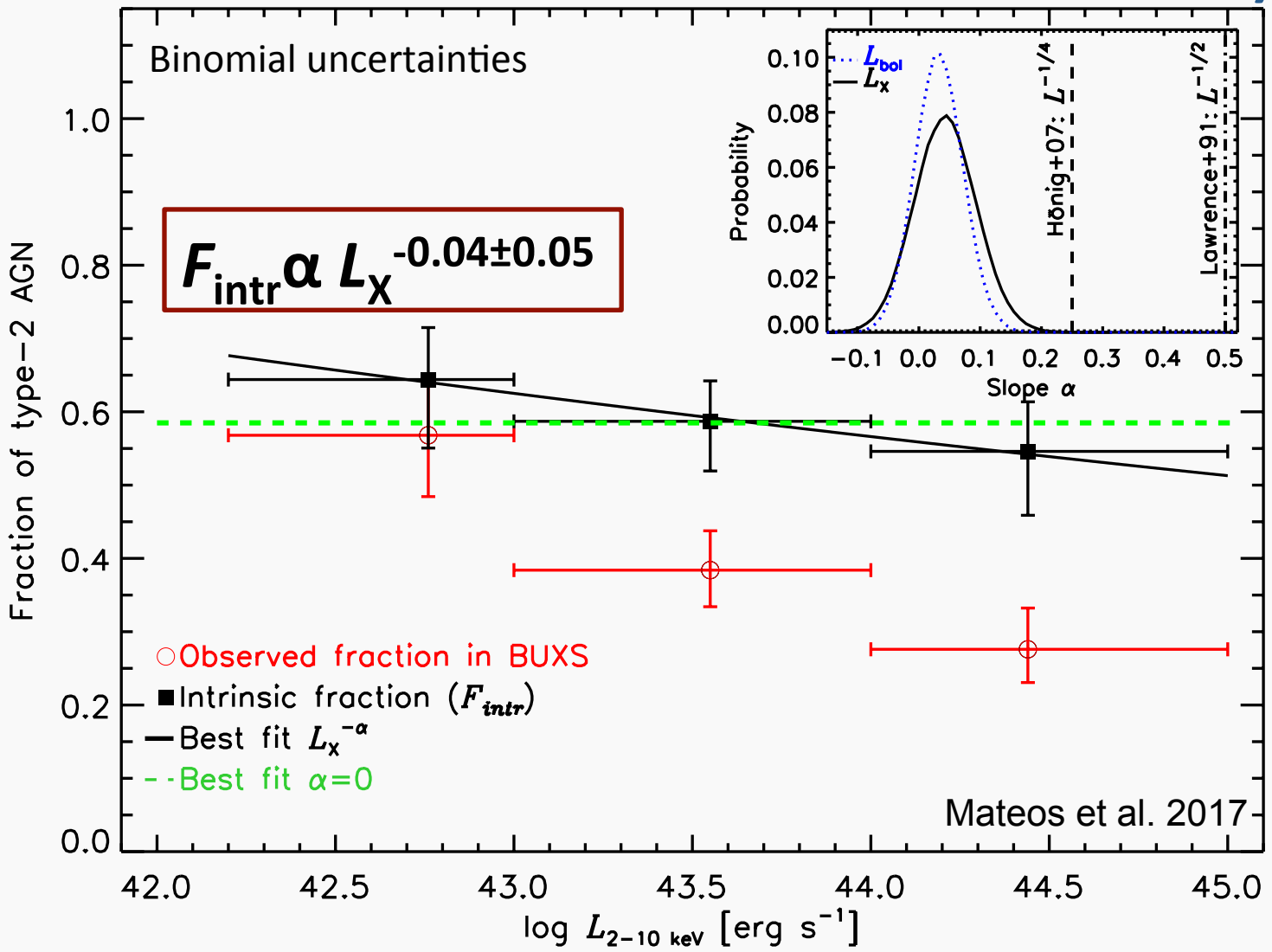


Type 2 AGN fraction vs. L_X



Many luminous type 2 AGN residing in highly obscured nuclear environments have escaped X-ray detection

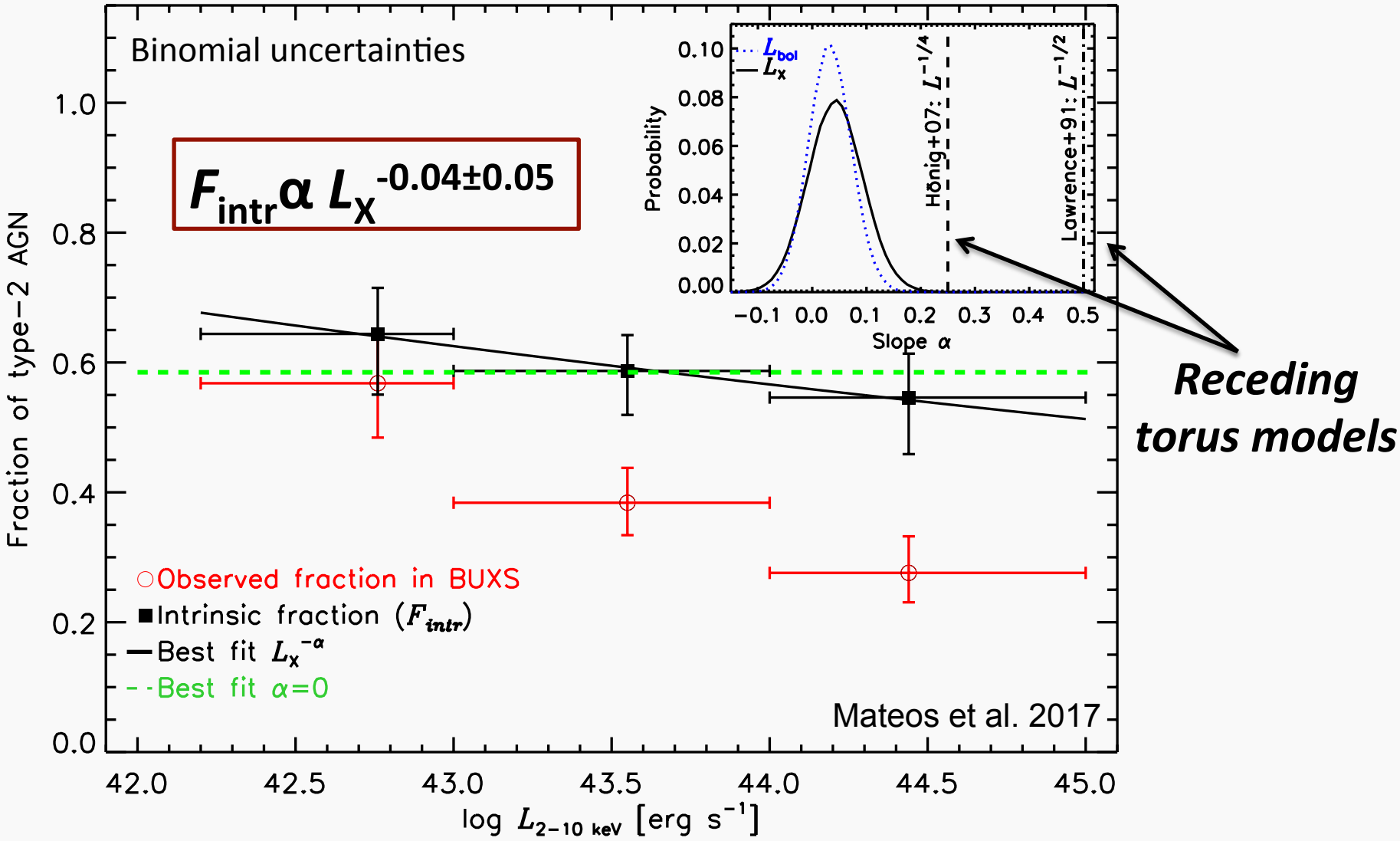
Type 2 AGN fraction vs. L_X



F_{intr}=58±4%

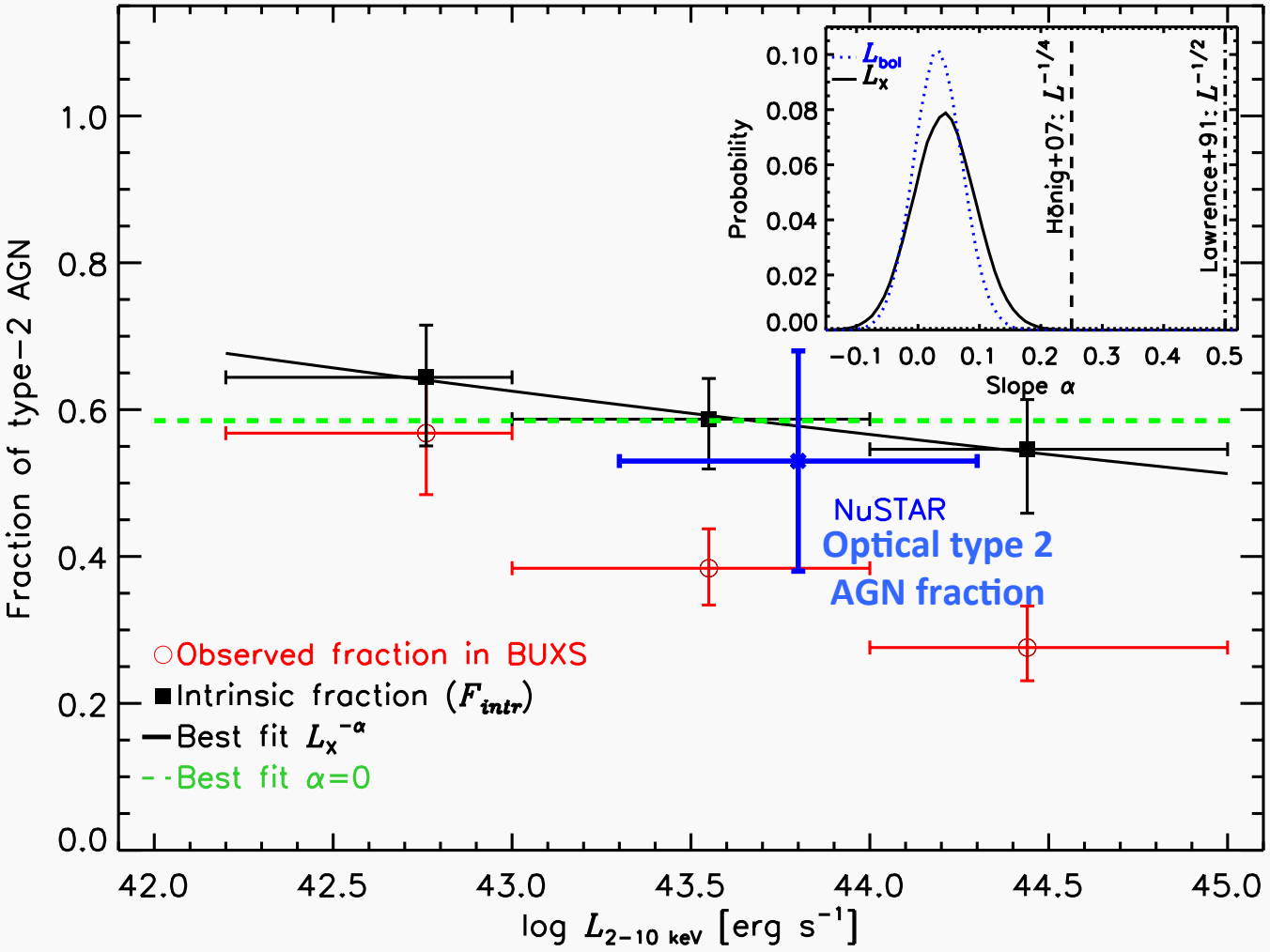
When the ”missing” objects are included, the luminosity dependence of the type 2 AGN fraction almost disappears

Comparison with receding torus models



Our results clearly disagree with the expectations from receding torus models (see also Burlon et al. 2011)

Comparison with >10 keV AGN surveys



Our finding are consistent with the results from the >10 keV NuSTAR serendipitous survey (Lansbury et al. 2017)

Summary

- **AGN have a very broad range of torus covering factors**
- **Type 1 and type 2 AGN have tori with different covering factors**

Orientation alone cannot explain the observed AGN properties

- **The luminosity dependence of the covering factor is much weaker than previously though**
- **We have revealed a population of (X-ray undetected) luminous type 2 AGN with high-covering factor tori**

Rapidly-accreting SMBH reside in highly obscured nuclear environments but most of them remain elusive to contemporary <10 keV wide-area X-ray surveys

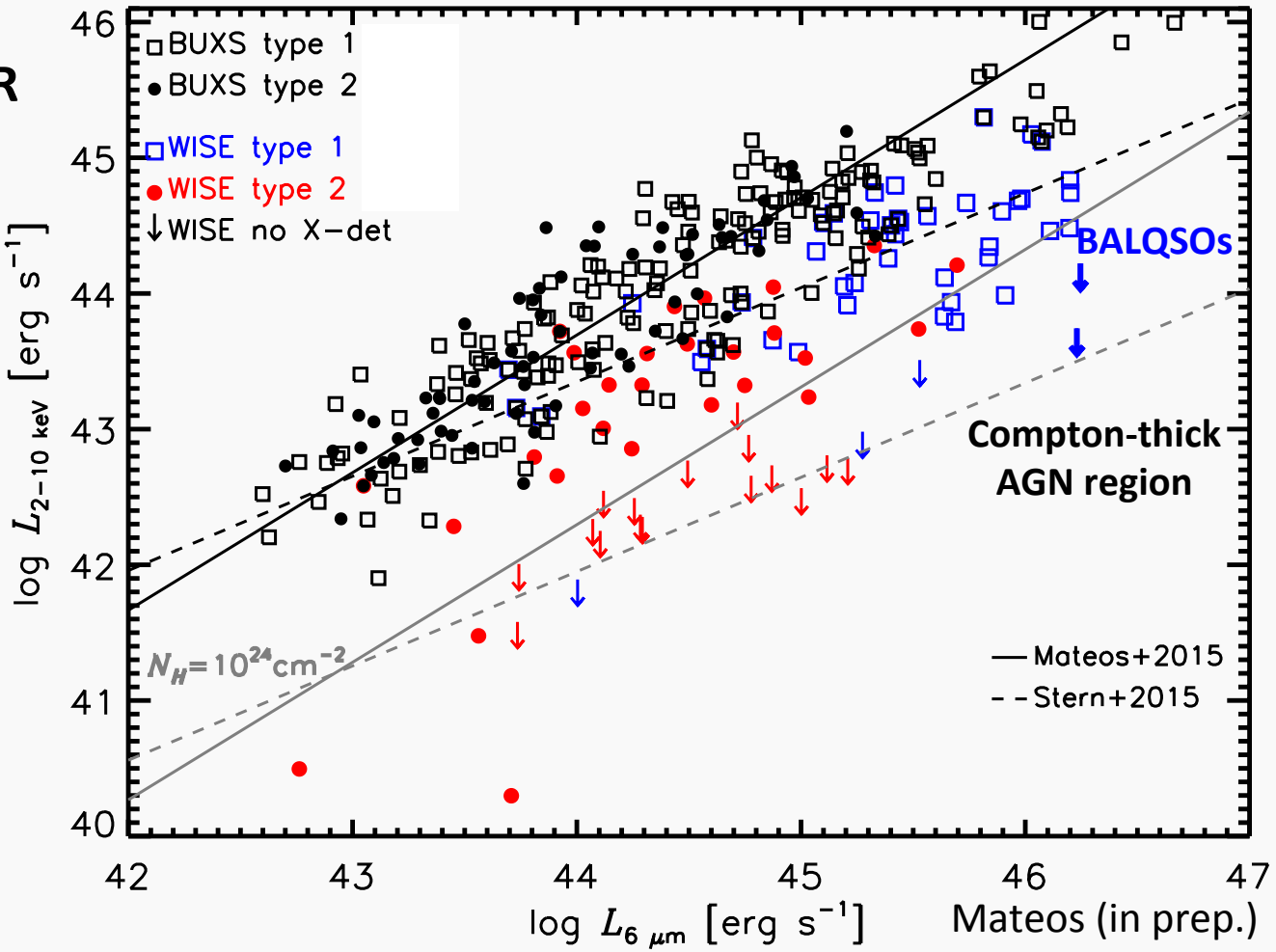
Obscured type 2 AGN revealed with WISE

WISE colour-based MIR selection of AGN

5 deg² area with deep X-ray coverage

97 sources with AGN MIR colours

To date AGN nature confirmed in >90% of sources



Many highly absorbed luminous type 2 AGNs are not detected in contemporary wide-angle X-ray surveys

(see also Donley 2012; Hainline et al. 2014; Assef et al. 2015; Yan et al. 2018)