THE MOST LUMINOUS QUASARS:

PROBING THE AGN/GALAXY CO-EVOLUTION AT ITS EXTREME

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AT THE BRIGHTEST END OF THE QSO LF

Starting point/Big question is:
"Where can we observe AGN-driven feedback in action?"

Theory: **"Strength" of an outflow increases as $L_{bol}^{1/2}$**
Menci +08; Faucher-Guiguere +12

→ **The most luminous QSOs are potentially the best place to hunt for powerful AGN-driven outflows**

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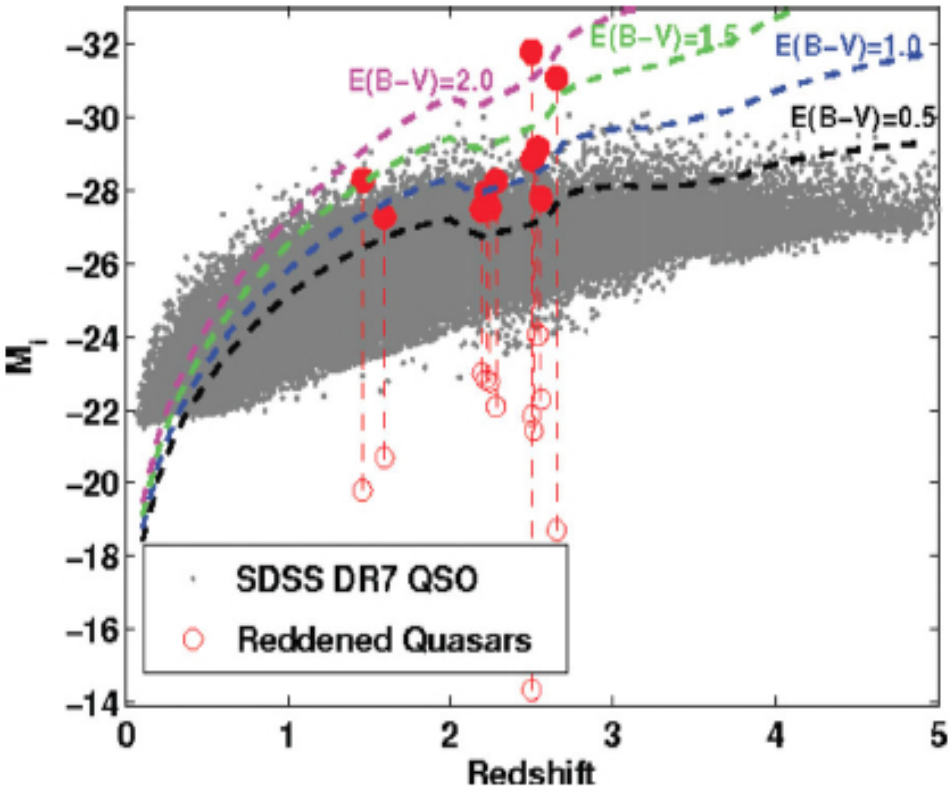
We need:
**Sampling a LARGE area*
clean samples without strong biases
(i.e. dusty AGN)

**Selection criteria to maximize the number of "good" targets*
Theory predicts: "Blow-out phase during the transition from buried AGN to blue QSO"
→ **dust-reddened, red, IR-loud QSOs are primary targets**
J-K>2, WISE colors, etc.
[Glikman+ 12,13; Banerji+ 12; Brusa +14]



OUTLINE

Results presented here are embedded in a much larger project aimed at probing SMBH growth, nuclear activity and AGN feedback on their host galaxies from the z=4-5 to the local Universe.

Extensive multi-wavelength observing program has been undertaken in the last two years:

- Millimeter interferometric observations **ALMA IRAM-PdBI**
- MIR observations **GTC CanariCam**
- NIR **LBT + IFU SINFONI**
- Optical **LBT**
- X-ray observations **XMM Chandra**

...STAY TUNED!!!

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...STAY TUNED!!!

Results here achieved with two main goals:

1- Searching for outflows in the most luminous QSOs

Correlation between outflows and AGN parameters at the bright end of the AGN LF

LBT observing campaign of high-z WISE-selected QSOs

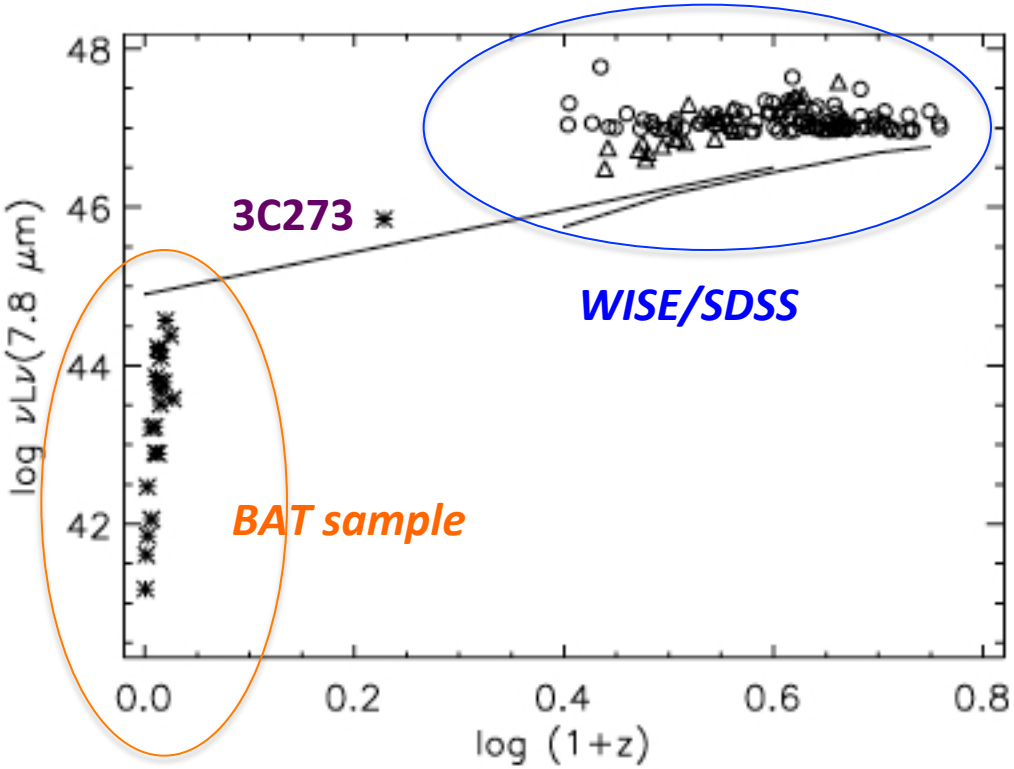
2- Exploring the nuclear properties of the most luminous AGN (..in the red phase)

XMM-Newton observation of a newly-discovered Hot Dust-obscured galaxy

WISE ALL-SKY SURVEY

WISE All-Sky Survey @ w1:3.4μm w2:4.6μm w3:12μm w4:22μm

Weedman +12:
Combining WISE ALL-SKY SURVEY (w4>3mJy)
with SDSS broad line QSO at 1.5<z<5



The ~100 broad-line QSOs with the highest L(7.8μm) ie >1e47 erg/s

High fraction of BAL/NAL QSOs (>40%)
Bongiorno in prep.

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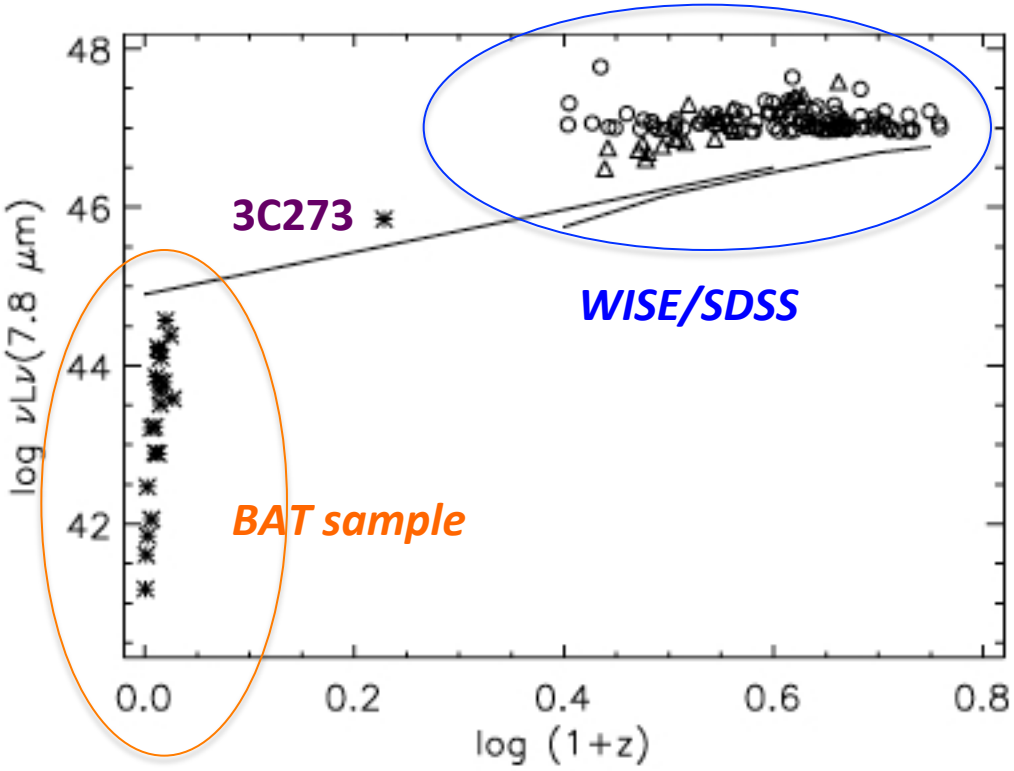

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The most luminous dusty AGN
→ Primary targets to search for AGN feedback
(= galaxy-scale outflows)

First step: Ionized gas [OIII]
→ NIR spectroscopic campaign at LBT

OBSERVING WISE-SELECTED HYPER-LUMINOUS QSOs

LBT PI: E.P.

Sinfoni PI: Fiore

XMM PI: Zappacosta

Chandra PI: E.P.

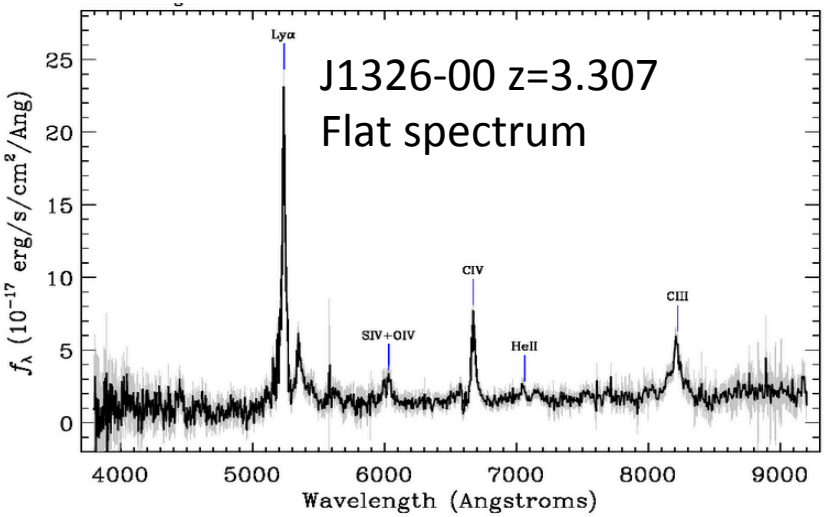
ALMA PI: Gavignaud

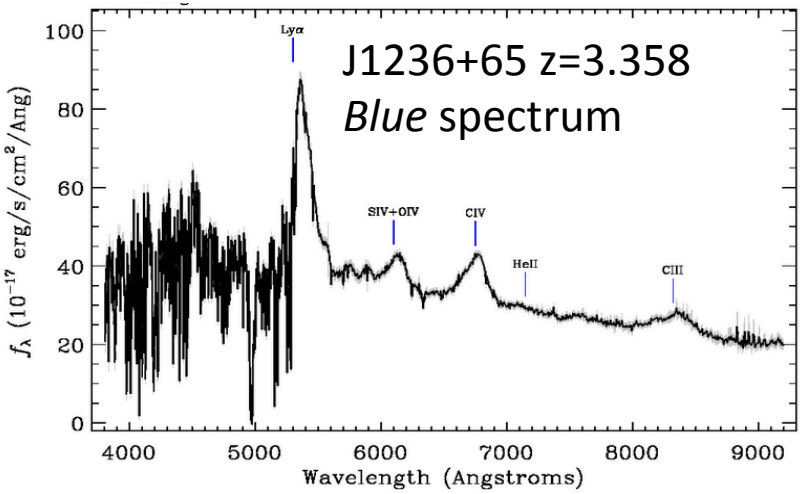
Objects	z	LBT	Sinfoni	ALMA	XMM	Chandra
SDSSJ004527.68+143816.1	1.992					
SDSSJ020950.70-000506.4	2.856					
SDSSJ073502.30+265911.5	1.982					
SDSS 074521.78+473436.1	3.22	2014				
SDSS 080117.79+521034.5	3.217	2014				
SDSS 090033.50+421547.0	3.297	2014				
SDSS J090423.37+1309	2.974					
SDSS 095841.21+282729.5	3.382	2014				
SDSS 110610.72+640009.6	2.205	2014				
SDSS J111017.13+193012.5	2.498					
SDSS 1111+1336	3.481	2013				
SDSS j1122+1645	3.024					
SDSS 115747.99+272459.6	2.214	2014				
SDSS 120144.36+011611.6	3.24	2014				
SDSS 1201+1206	3.949	2013				
SDSSJ121027.62+174108.9	3.64					
SDSSJ124957.23-015928.8	3.638					
SDSS 1236+6554	3.358	2013				
SDSS J123714.60+0647	2.781					
SDSS 1326-0005	3.307	2013				
SDSS 1421+4633	3.363	2013				
SDSS 1422+4417	3.306	2013				
SDSSJ144105.53+045454.9	2.059					
SDSSJ145125.31+144136.0	3.102					
SDSSJ151352.52+085555.7	2.897					
SDSS 1521+5202	2.195	2013				
SDSS 153830.55+085517.0	3.551	2014				
SDSS 1549+1245	2.386	2013				
SDSS j1555+1003	3.512					
SDSS 212329.46-005052.9	2.269	2014				
SDSS 234625.66-001600.4	3.489	2014				

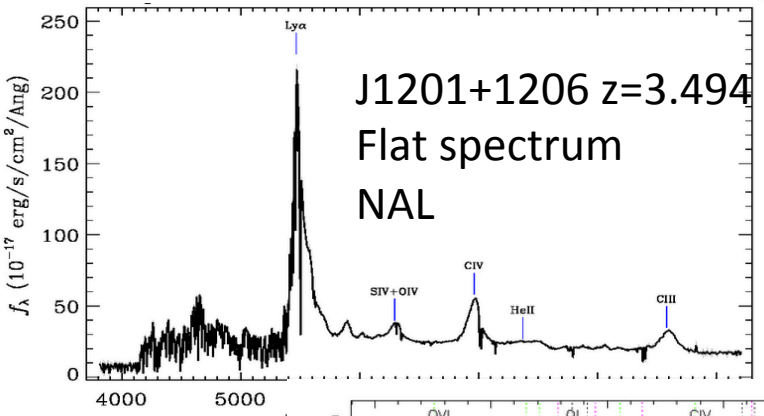
LBT OBS. CAMPAIGN 2014

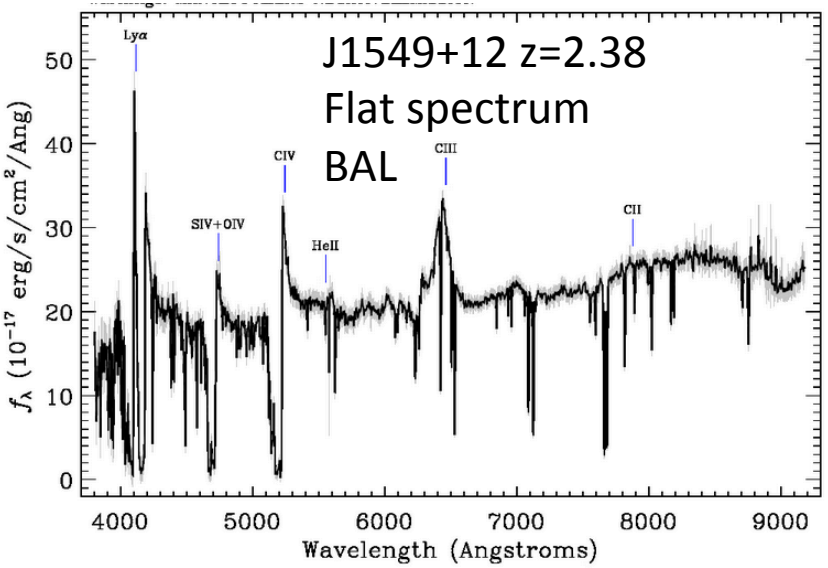
7 Targets observed so far with LUCI

Preliminary/on-going analysis of 5 QSOs

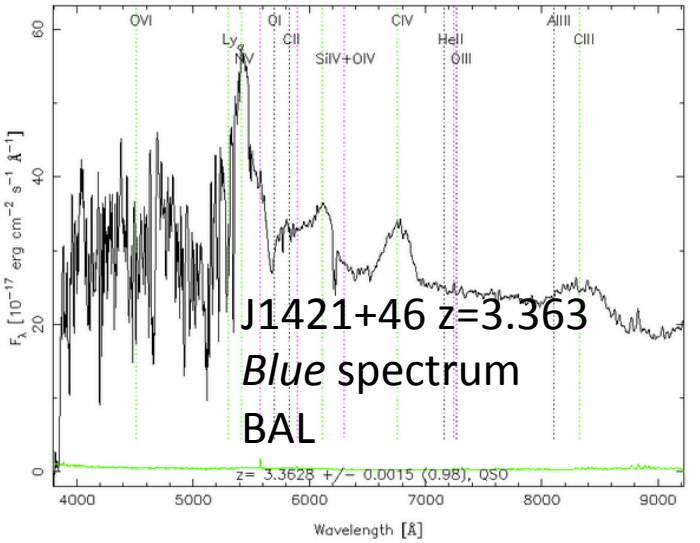






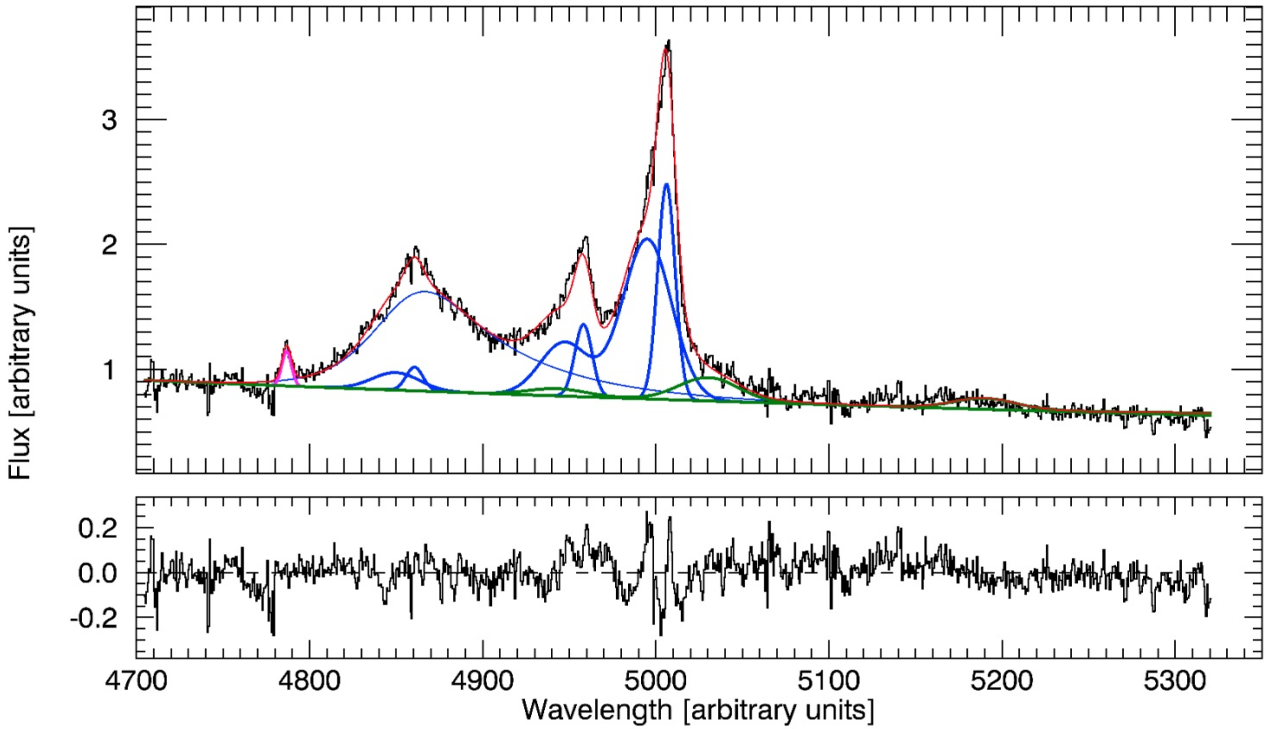


SDSS Spectra



LBT OBS. CAMPAIGN 2014: J1326-00 z=3.3

Preliminary analysis result: a strong OIII outflow revealed!!



[OIII] with a broad and skewed profile

[Piconcelli et al. in prep.]

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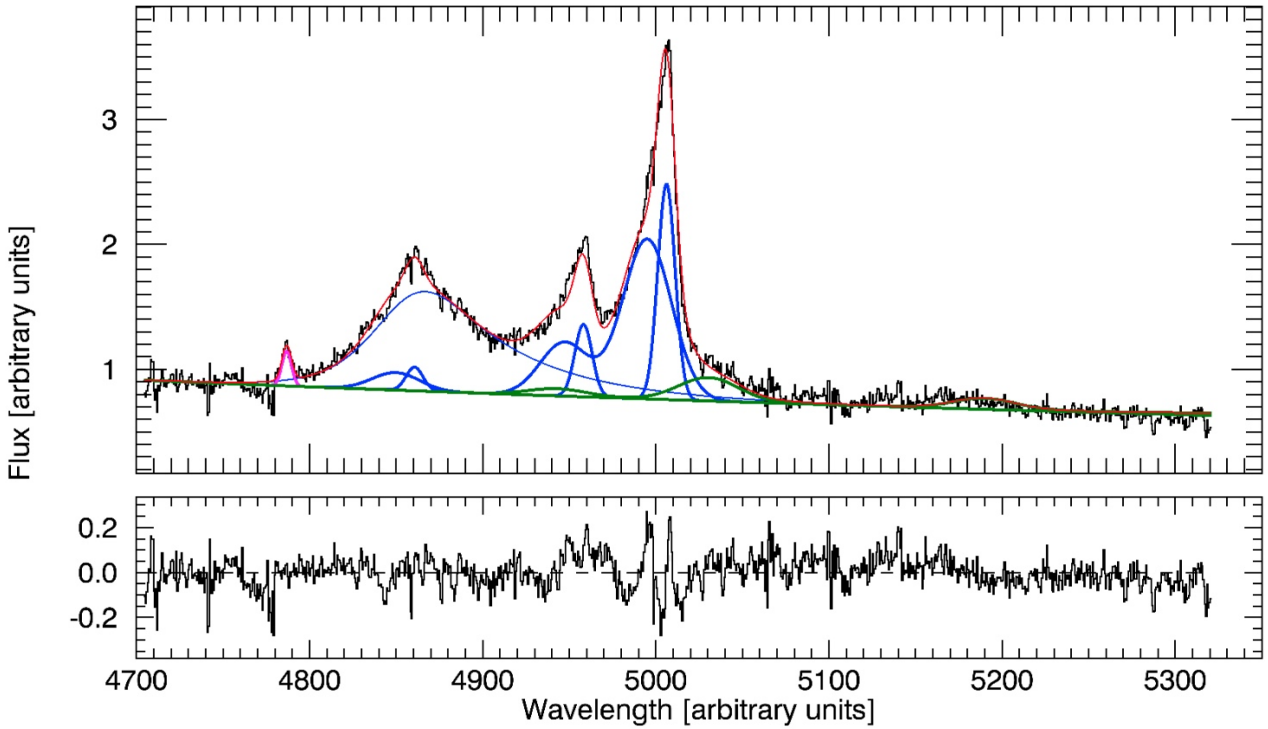


[Piconcelli et al. in prep.]

[OIII] with a broad and skewed profile

Blueshifted [OIII] line

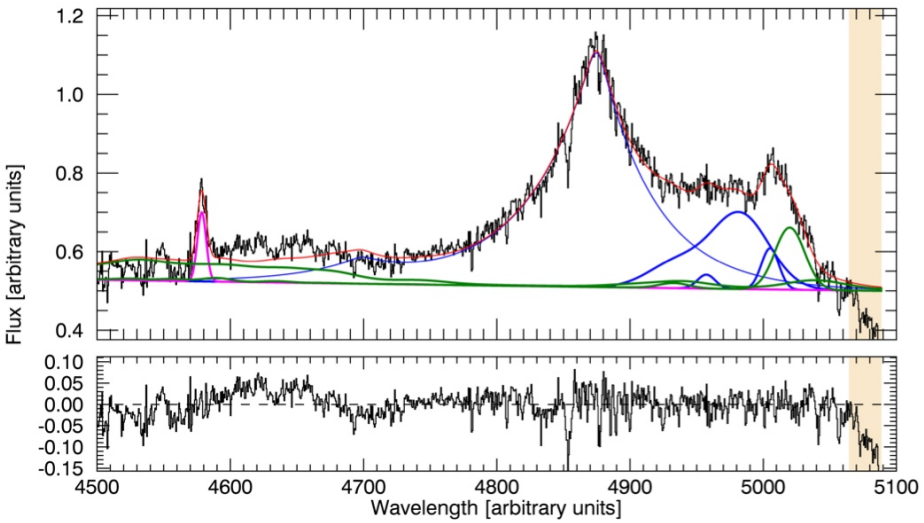
Blueshift = -710 km/s
FWHM ≈ 2000 km/s

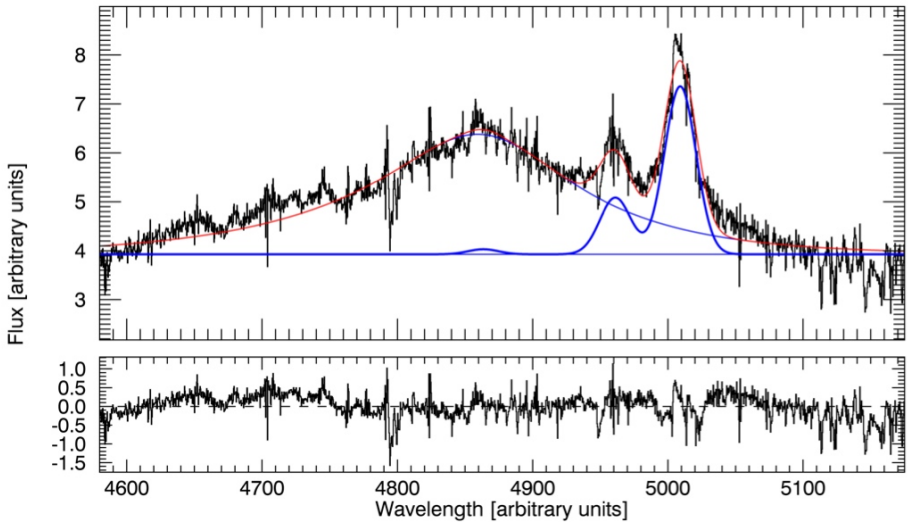
Flux is 2x of narrow [OIII]
Lum[OIII] = 4.65e44 erg/s

$L_{[OIII]}/L_{Bol} \approx 2\%$
[DiMatteo +05]

LBT OBS. CAMPAIGN 2014: J1201+12 and J1549+12

Preliminary analysis results:





J1201+12 at z=3.494

[OIII] FWHM = 940 km/s

Apparent blueshift ~800Km/s wrt to broad Hbeta

…"broad" feature is [OIII]-related?

J1201+12 at z=2.386

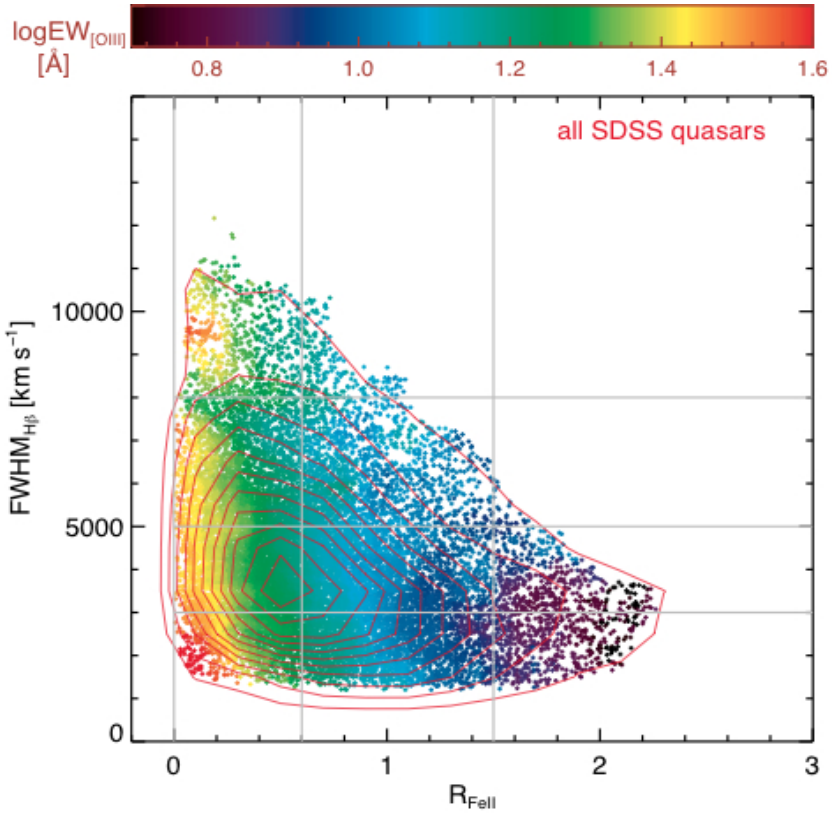
[OIII] FWHM = 1700 km/s

2-components fit to be performed..

Very large Hbeta FWHM = 11,0000 km/s

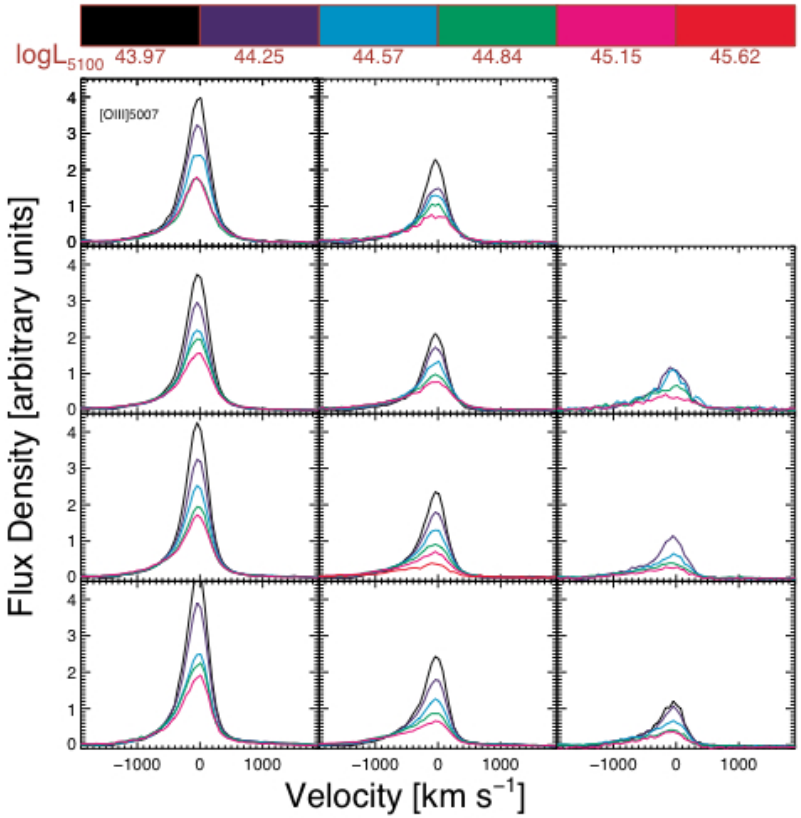
LBT results & Eigenvector 1 of QSOs

Boroson & Green 1992 on PG QSOs + Shen & Ho 2014 Nature in press



Eddington ratio increases →

Inclination increases →



Eddington ratio increases →

- QSOs with large FeII/Hbeta have large Edd ratios
- QSOs with large Edd ratios have weak [OIII] narrow emission
- QSOs with large Edd ratio have large velocity offset of the [OIII] wing

LBT OBS. CAMPAIGN 2014: Some first conclusions..

- ***Very complex spectra*** *(..ask Alessandro..)*
- ***Narrow OIII emission is typically weak/absent***
- ***Broadish/Blueshifted OIII line in >~50% of analyzed targets***
- ***"red" and flat SDSS spectra for QSOs with broad OIII***
- ***Unlike previous results our targets are Broad Line AGN (i.e. well-measured SMBH, X-ray luminosity, etc.)***
- ***Very promising results for future IFU obs. (..and much more)***

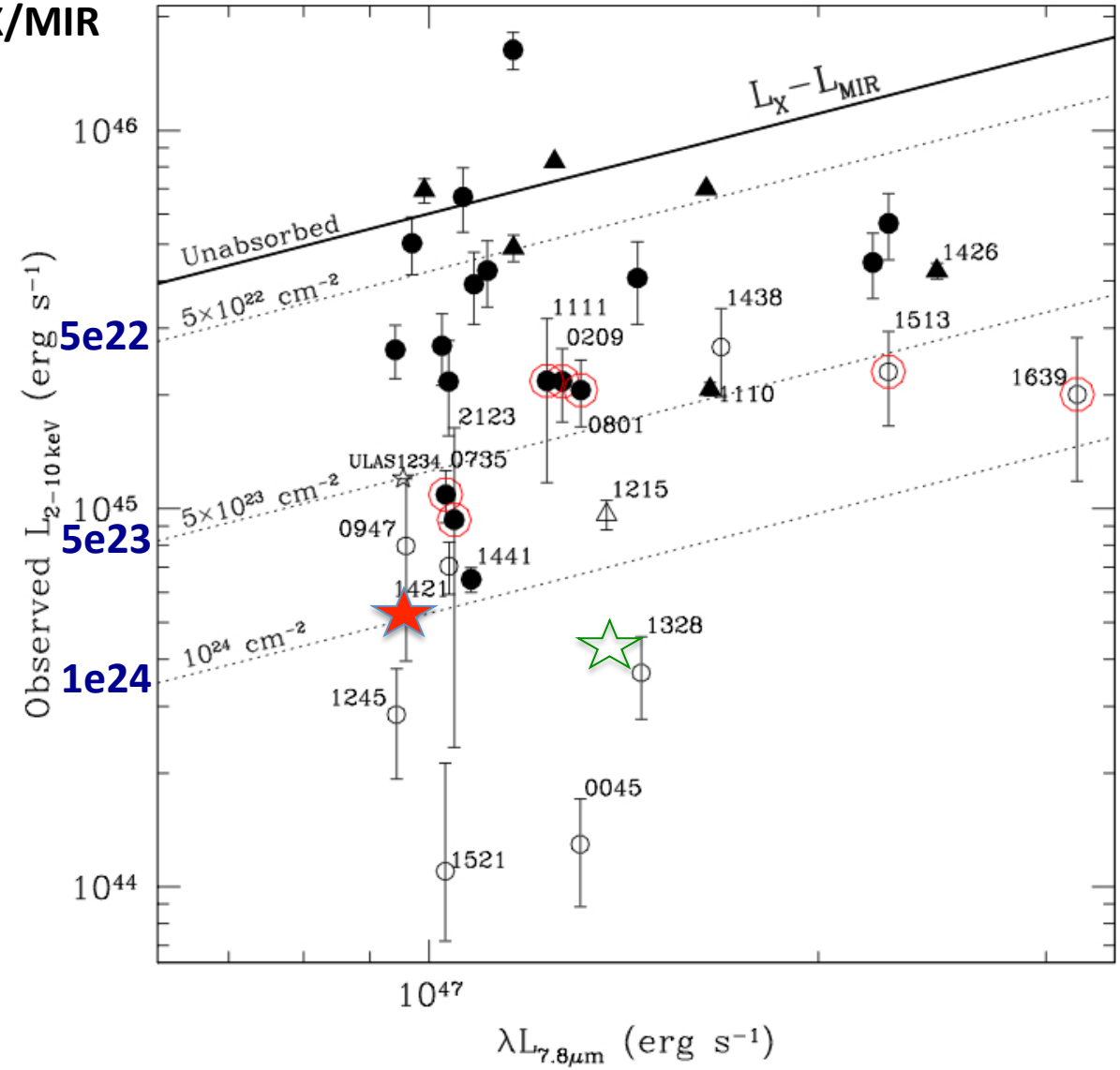
The LUCI Observing Campaign is still on-going at LBT:
Additional 10 Approved QSOs for LUCI in the last Call

ARE LUMINOUS QSOs X-RAY WEAK?

Luminous Type 1 QSOs with low X/MIR

Heavily obscured OR
X-ray weak?
OR both??
(..many BAL QSOs..)

★ ULAS1234+09
the reddest type1 QSO discovered so far
Deep XMM data found Nh<1e22
Banerji+14



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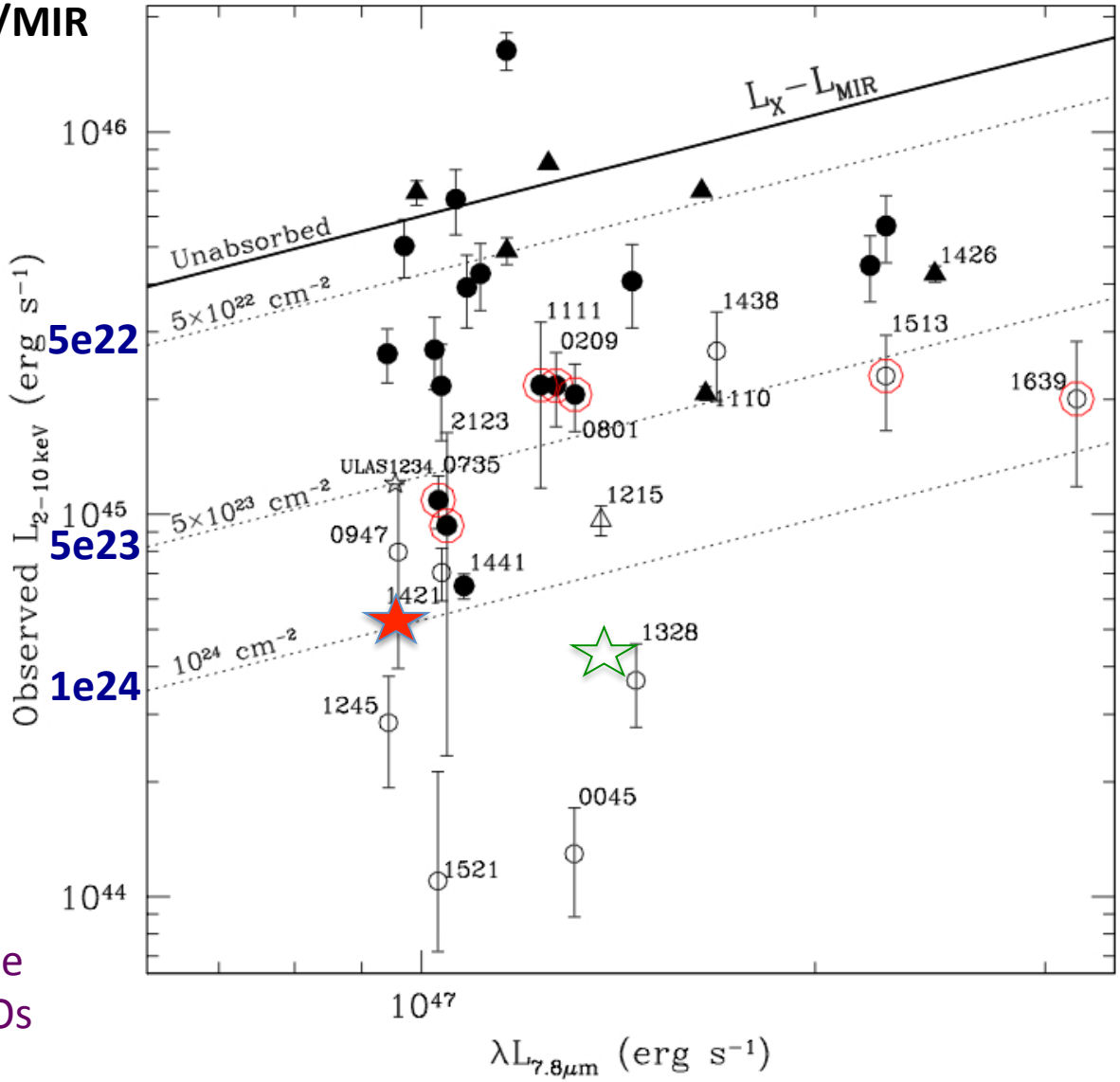
Is the intrinsic X-ray weakness a feature of luminous QSOs ?

..and a key ingredient for an efficient feedback in QSOs?

Chandra proposal approved to probe the X-ray weakness in luminous QSOs
Targets:
[PI: E.P.]



Dust-Obscured Galaxies (DOGs) discovered by Spitzer

DOGs: MIR-selected population with MIR/O>1000 & S(24μm)>0.3 mJy [Dey et al. 2008, Fiore+08]
high IR-to-optical ratios imply that large amounts of dust are absorbing the optical light and re-emitting it in the IR

- Typical z~2; more estreme/redder than typical local ULIRGs
- 50% of ULIRGs at z~2; ¼ of the IR lum. Density at z~2

Two flavors:

1. Bump/PAH DOGs: dominant at S(24μm)<1mJy Starburst-powered + early stage mergers
2. Power-Law DOGs: dominant at S(24μm) >1mJy AGN-powered+ late state mergers

SB-dominated → AGN-dominated phase of progenitors of local giant ellipticals?

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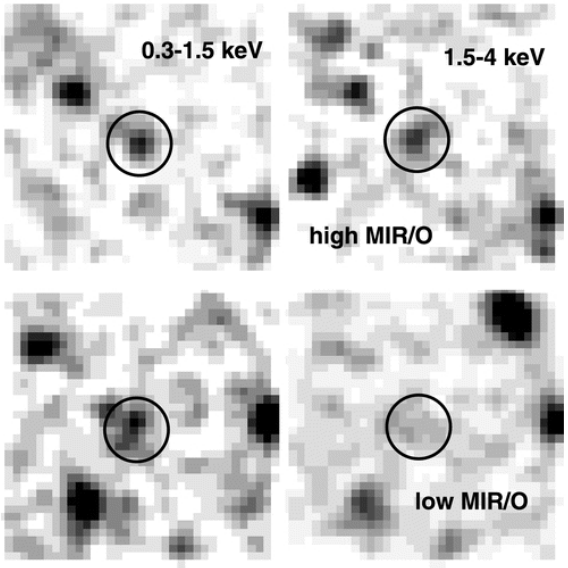
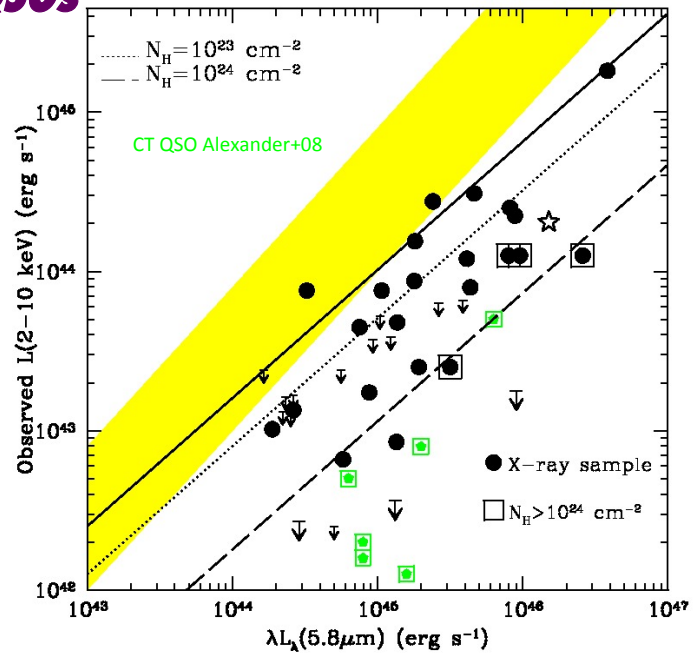
DOGs: The long sought population of deeply obscured QSOs

Fiore+08,09
Lanzuisi, EP+ 09:

50-90% of DOGs are X-ray obscured

Stacking of X-ray undetected DOGs found Compton-thick AGNs

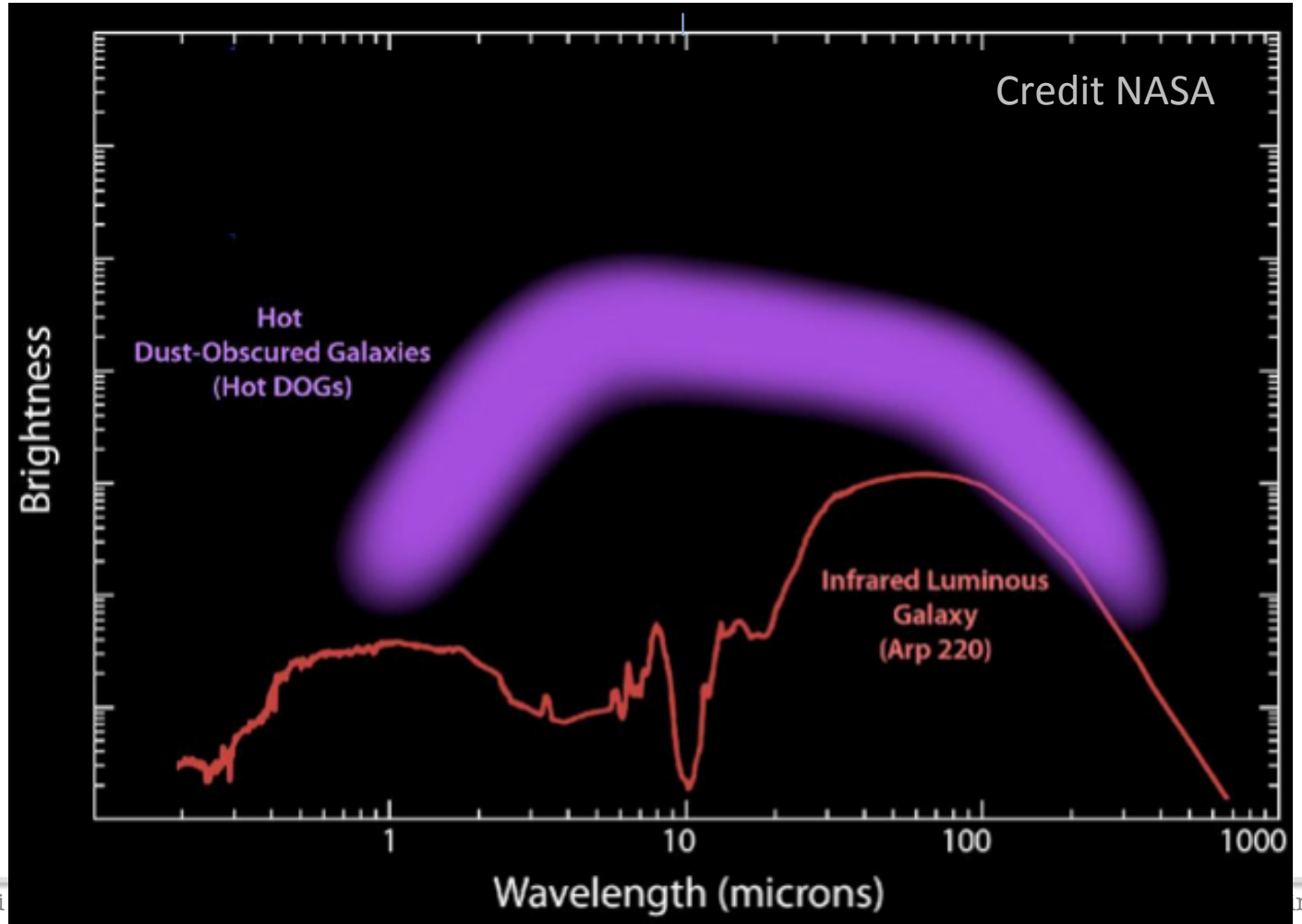




From DOGs to *Hot* DOGs (WISE once again..)

~1000 objects uncovered after scanning the entire sky
A new rare phase in the evolution of galaxies...

"W1W2-dropouts": sources faint or undetected by WISE at 3.4(W1) and 4.6μm(W2) **&** well detected at 12(W3) or 22μm(W4)



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- ***Minimum*** L_bol ~1e14 L_{sun}
  (?? SFR >10e4 M_{sun}/yr ??)
- Lensing is unlikely
- Predominance of **hot dust** wrt cold dust
  (SED with large MIR/submm)
- Optical/UV: from absence of any AGN signatures (few) to broad lines
- Actively star-forming >>100 M_{sun}/yr
- In overdensity environments

[Wu+ 12, Jones+ 14]

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[Wu+ 12, Jones+ 14]

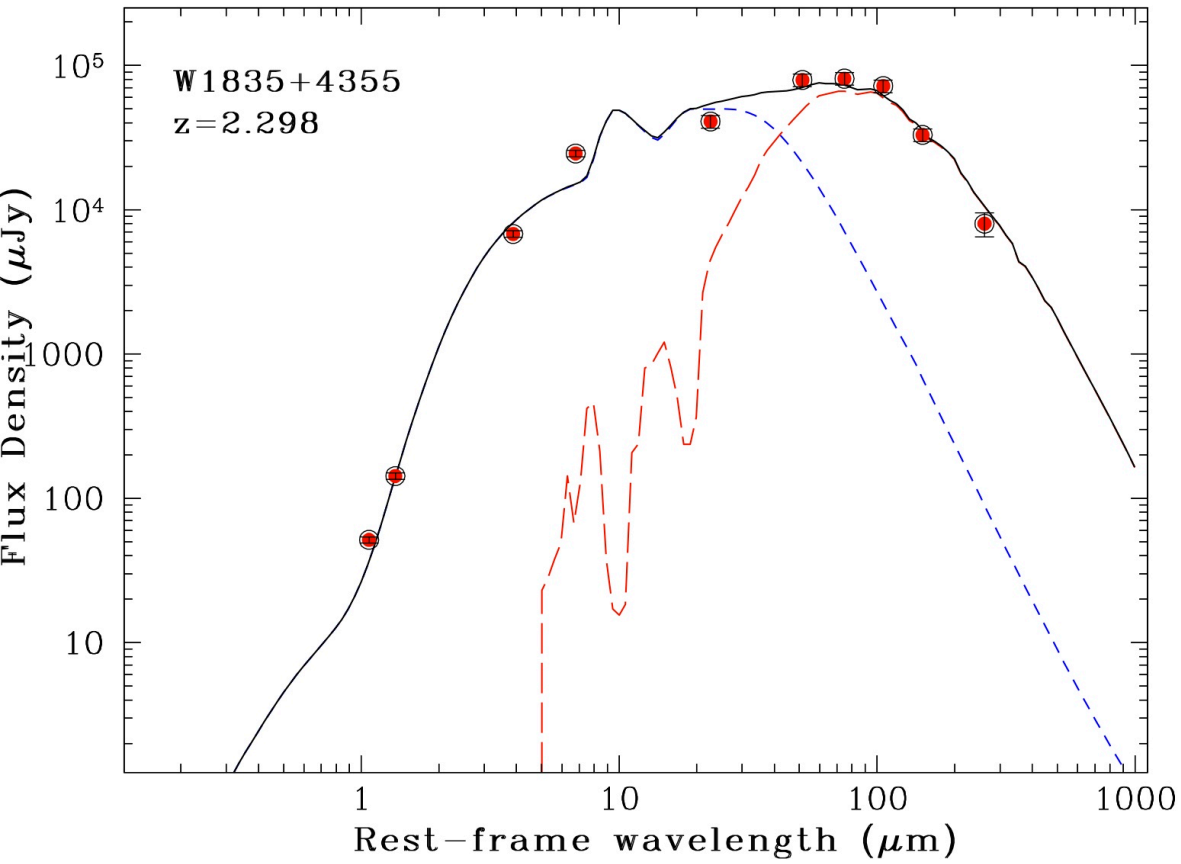
AGN-dominated

Mergers

Short evolutionary phase

Feedback at its extreme?

The Hot DOG WISE J1835+43



[Piconcelli, Vignali+ 14, sub.]

SED based on
- Spitzer
- WISE
- Herschel-PACS
- Herschel-SPIRE
- SCUBA-2

AGN-dominated SED
75% of L(8-1000)

AGN L_Bol = 1.2e14 L_{sun}

FIR: Arp220 template
SFR = 2500 Msun/yr

X-RAYING AN HOT DOG!

Exploratory XMM-Newton program to observe HotDOGs

"The most luminous galaxies in the Universe"

Target: W1835+43 Exp: 42 ks → well-detected in PN & MOS1-2

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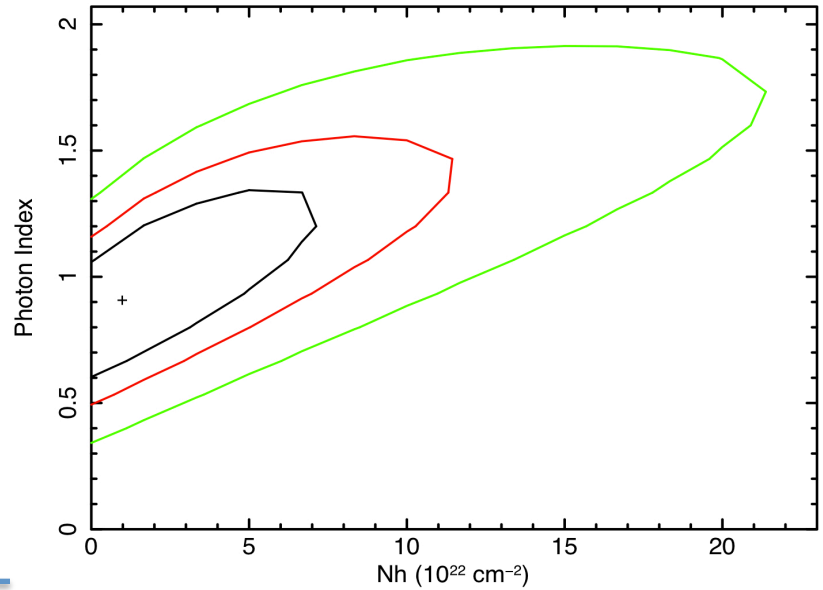
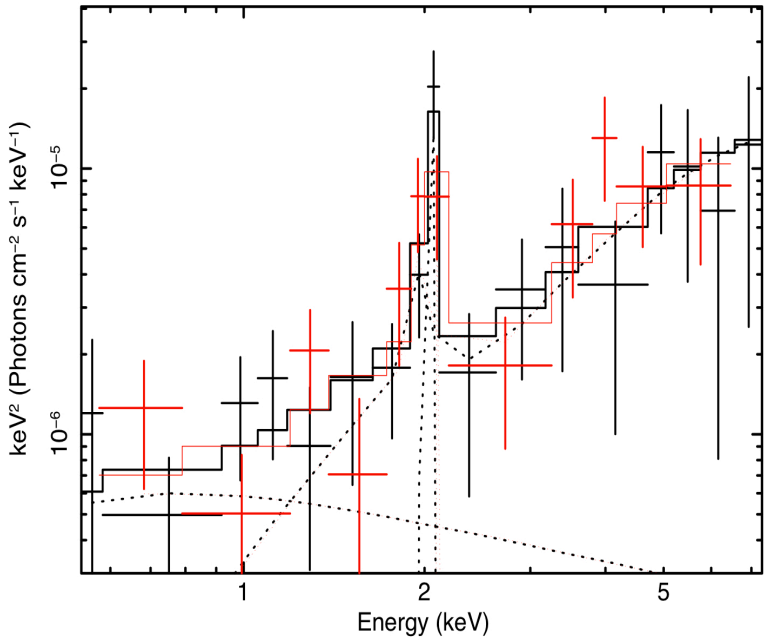
"The most luminous galaxies in the Universe"

Target: W1835+43 Exp: 42 ks → well-detected in PN & MOS1-2

- Very flat continuum
- A standard Γ=1.8 implies N_H >1e23 cm^{-2}





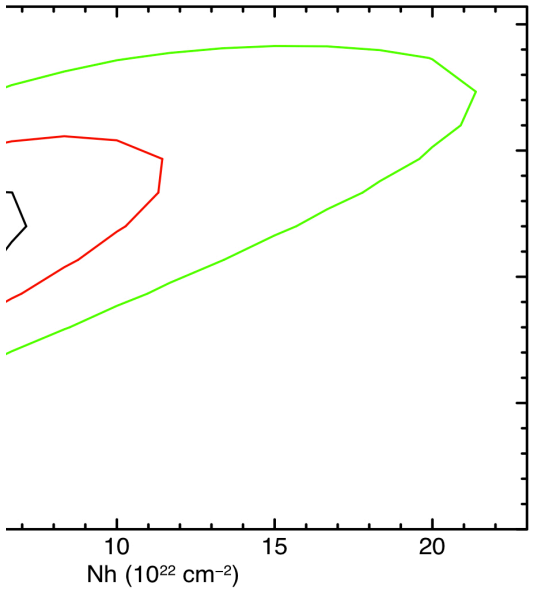
- Reflection-dominated Flat + Fe K line
- Compton-thick absorber

Obs. Lum(2-10keV)=2.3e44
~1-10% of the ***intrinsic*** one !!

X-RAYING AN HOT DOG!

otDOGs

d in PN & MOS1-2



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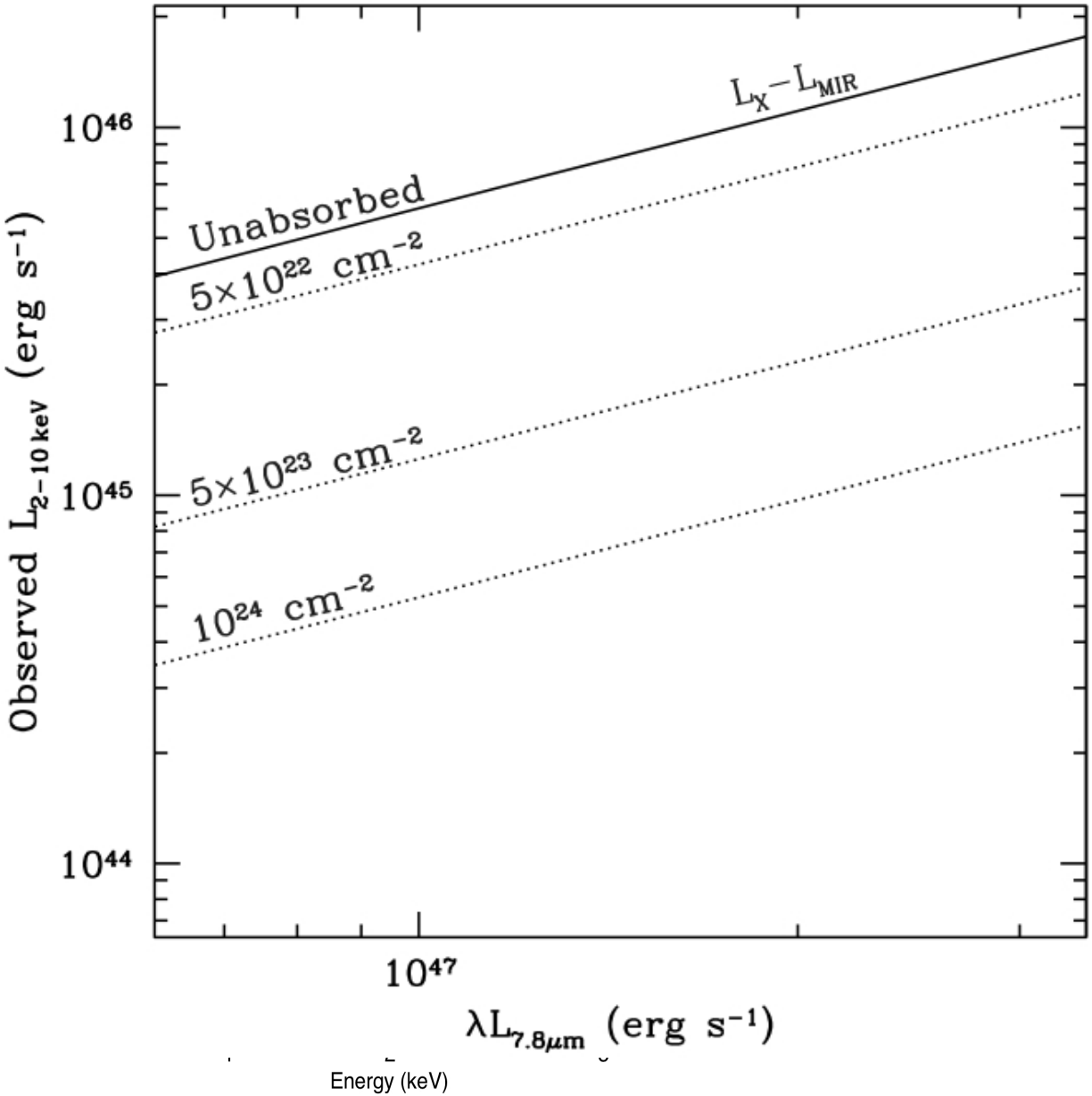

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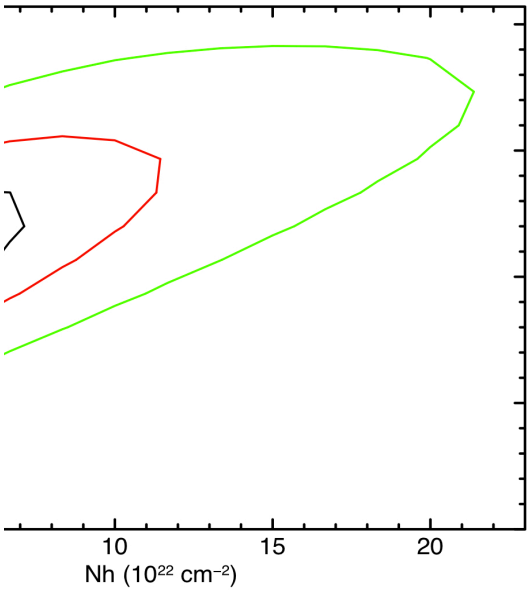

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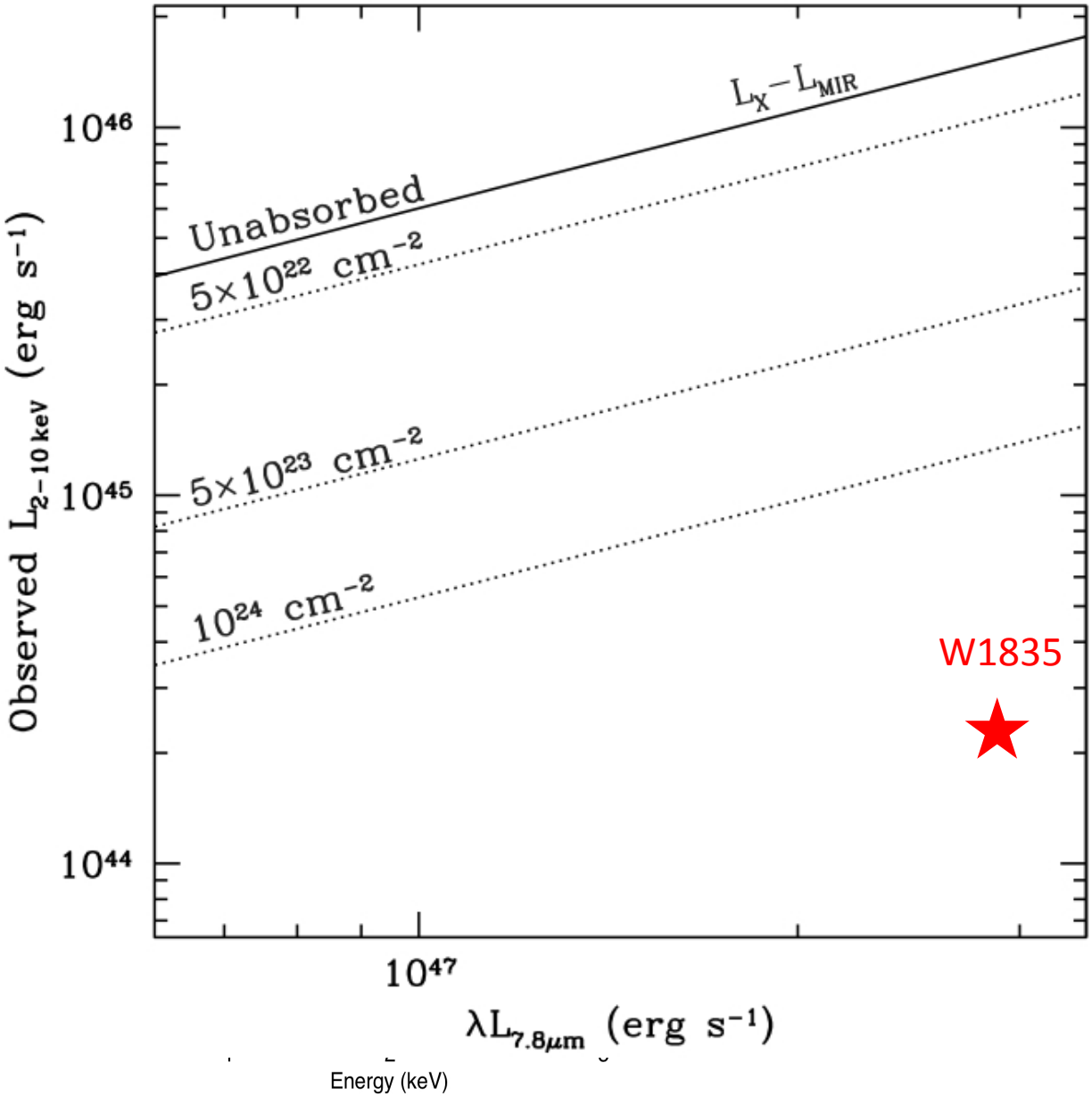

SUMMARY – CONCLUSIONS - NEXT STEP(S)

An extensive observing program of the most luminous AGN in the Universe has started

Main goal is to reveal powerful AGN-driven outflows & understand the feedback mechanism

Two-step approach:
I. Ionized Gas component
II.Molecular Gas component (Mrk231-like)

Preliminary results with LUCI are very encouraging:
- **[OIII] Outflows discovered in ~50% of the observed QSOs**
- **Planned Follow-up IFU obs.**

We also aim at probing the nuclear properties of high-Lum QSOs
- **XMM obs. of Hot DOGs**
- **Chandra obs. of WISE/SDDS QSOs**
- **XMM obs. of the most luminous ROSAT QSOs from RBS** (PI:E.P.)

On-going Program (new exciting results are expected!)
1st step for further investigations in the next months

ADDITIONAL INFO

The End