

THE MOST LUMINOUS QUASARS:

PROBING THE AGN/GALAXY CO-EVOLUTION AT ITS EXTREME

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AT THE BRIGHTEST END OF THE QUASAR LF



Motivation/Starting point:

“Where can we observe AGN-driven feedback in action?”

Theory: “Strength” of an outflow increases as $L_{bol}^{1/2}$

Menci +08; Faucher-Giguere +12

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

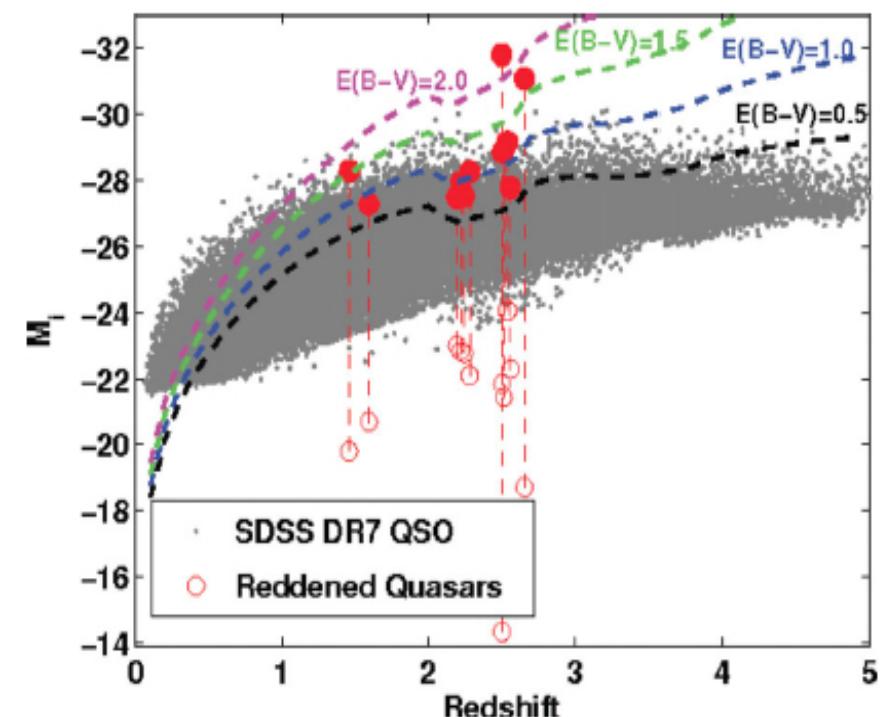
*Sampling a *VERY LARGE* area in the IR
(NB: most of X-ray & Spitzer/Herschel are small-area surveys)

clean samples without strong biases
(i.e. dusty AGN)

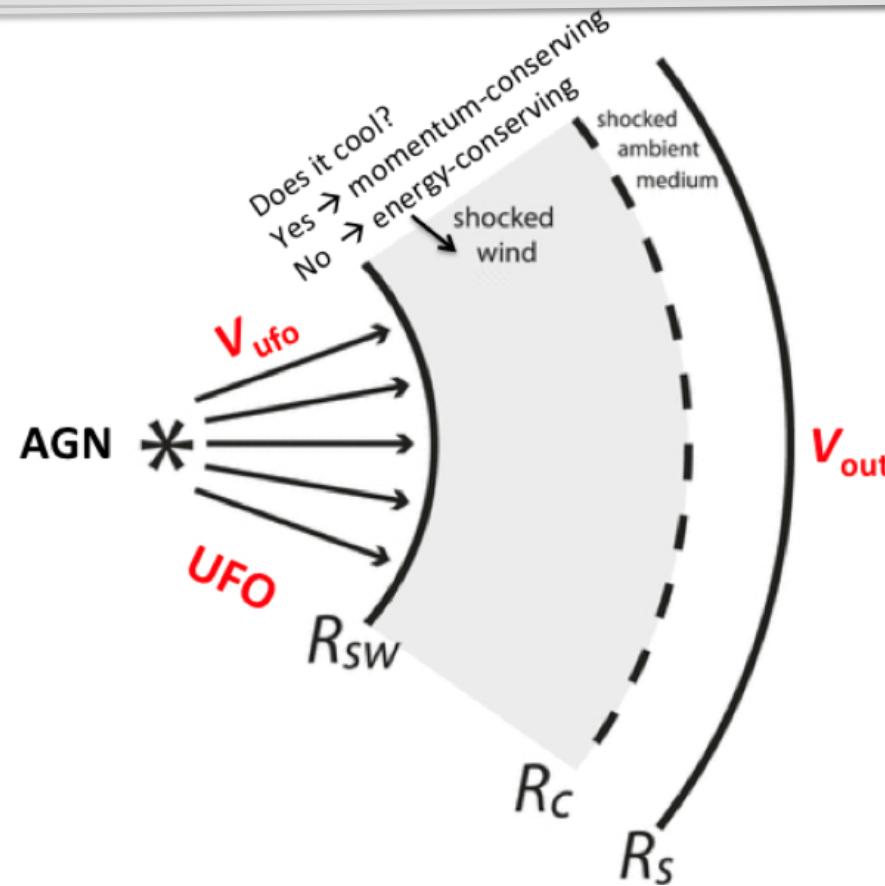
*Selection criteria to maximize the number of “good” targets

Theory predicts: “Blow-out phase during the transition from buried AGN to blue QSO”

→ dust-reddened, red, IR-loud QSOs are primary targets



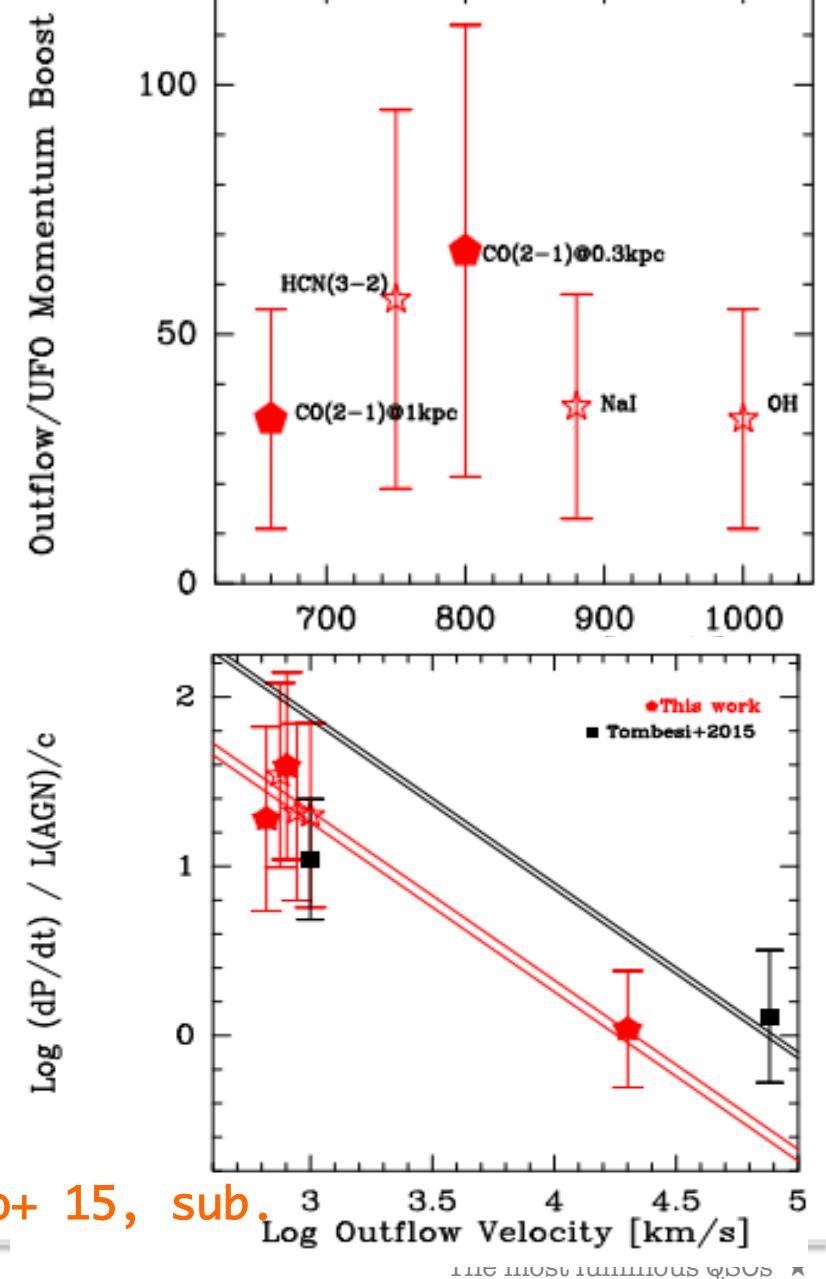
THE TWO-PHASE AGN FEEDBACK MECHANISM



Radiative forces accelerate out the Ultra-Fast Outflow from the immediate vicinity of the AGN accretion disk

It shocks against the ISM and accelerates the swept-up gas, thus producing the **galactic-scale, massive molecular outflows (ENERGY CONSERVING?)**

Feruglio+ 15, sub.



LUMINOUS QSOs from the WISE ALL-SKY SURVEY

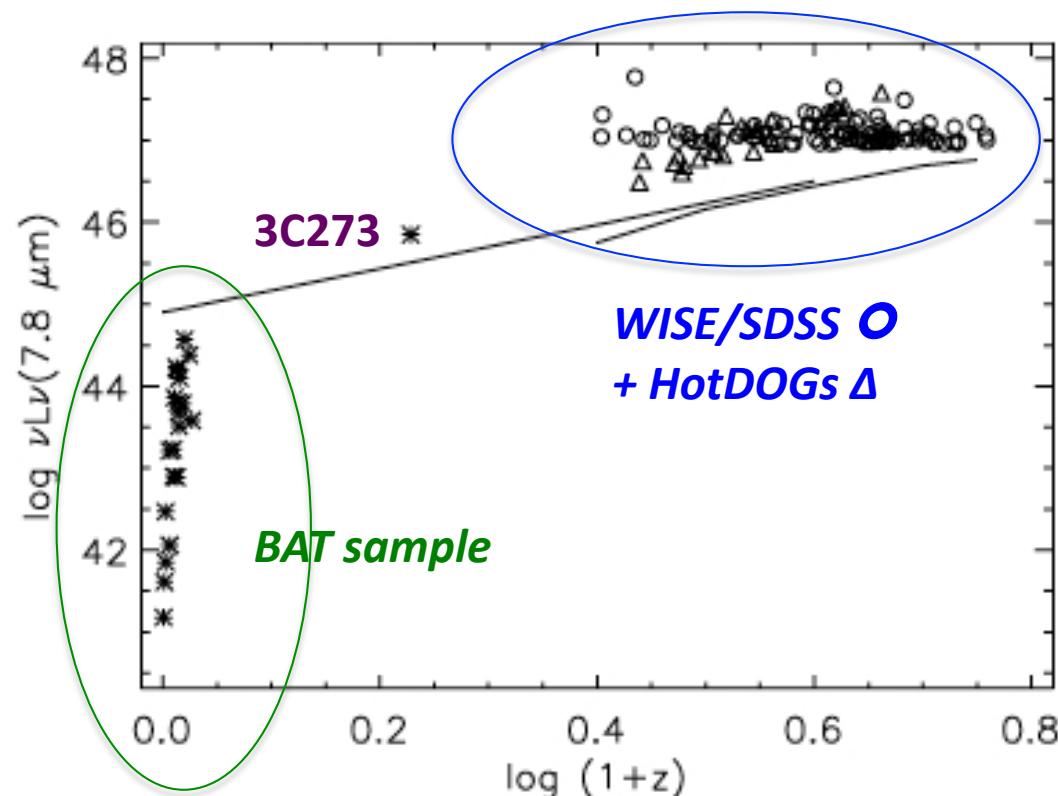


Lot of efforts in collecting RED LUMINOUS quasars...

J-K>2 R-K>4 using 2MASS, UKIDSS or SPITZER [Martinez+ 05; Glikman+ 12,13; Banerji+ 12]

WISE All-Sky Survey @ $w_1: 3.4\mu\text{m}$ $w_2: 4.6\mu\text{m}$ $w_3: 12\mu\text{m}$ $w_4: 22\mu\text{m}$

Weedman et al. 2012: Cross-correlating WISE ALL-SKY SURVEY ($w_4 > 3\text{mJy}$)
with SDSS broad line QSO at $1.5 < z < 4.5$



The ~100 broad-line QSOs
with the highest $L(7.8\mu\text{m})$
ie $> 1\text{e}47 \text{ erg/s}$

High fraction of BAL/NAL
QSOs (>40%)

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

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

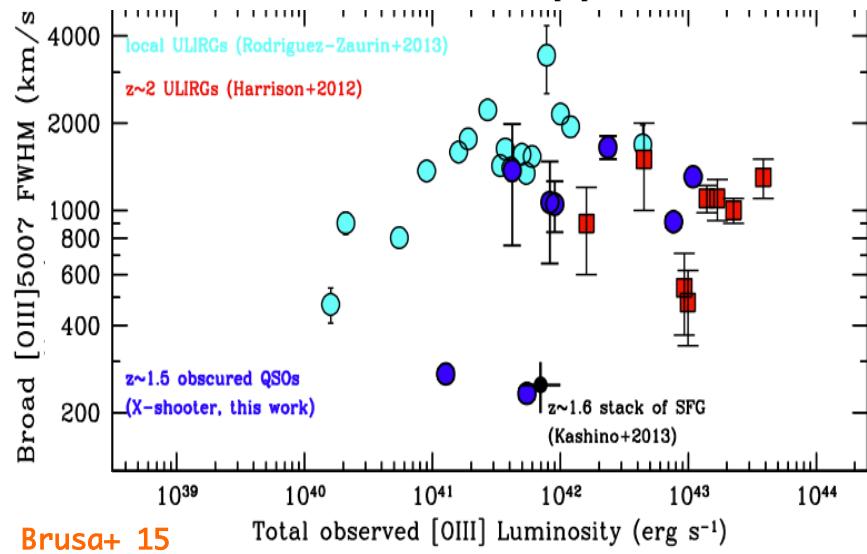
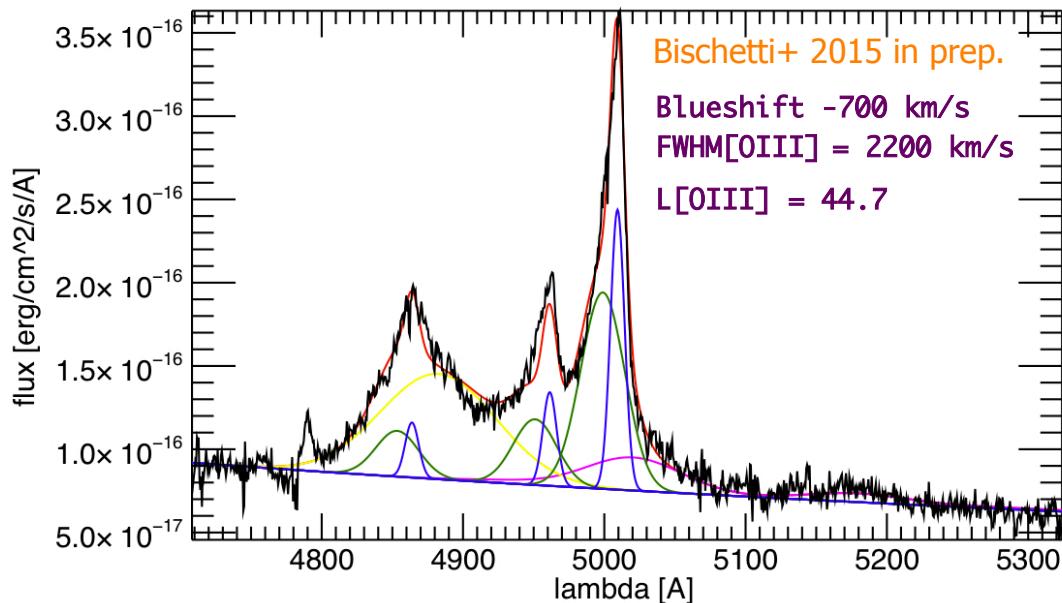
LBT/LUCI SPECTROSCOPIC CAMPAIGN

NIR spectra to observe OIII

- *Very complex spectra*
- *Broadish/Blueshifted OIII line in >~50% of analyzed targets*
- *Narrow OIII emission is weak/absent in most of the targets*
- *red/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 follow-up IFU & ALMA obs*

Sample of 16 QSO @z ~2-3.5 (still on-going)

J1326-0005 z=3.30



Brusa+ 15

Total observed [OIII] Luminosity (erg s⁻¹)

MOST LUMINOUS QSOs..but X-RAY WEAK?



Many Luminous Type 1 QSOs
with low X-ray/Mid-IR

Heavily obscured with large N_H
OR
X-ray weak (..or both?)

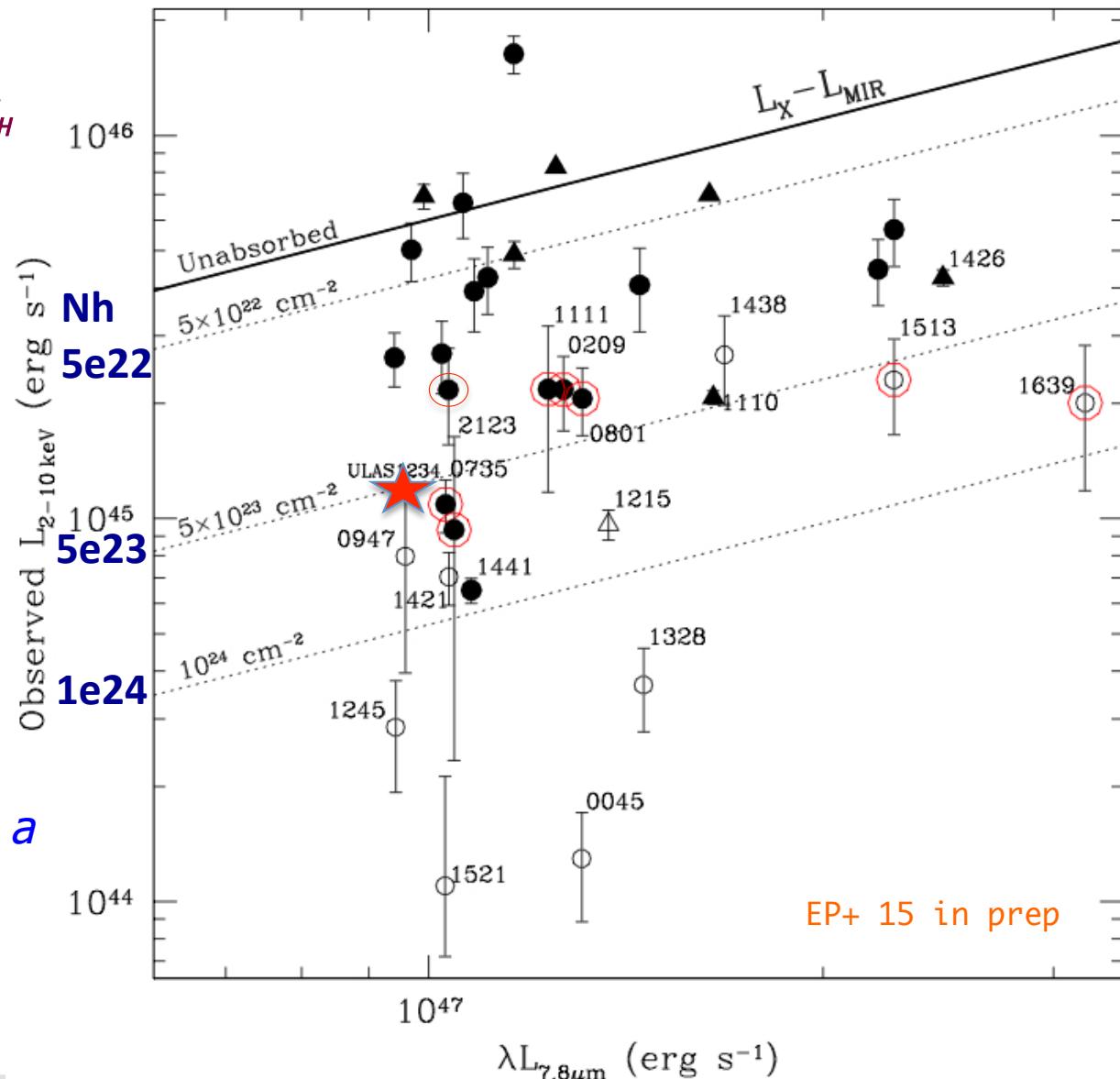
Our Chandra/XMM obs.
→ 7 out 8 low absorption
 $N_H < 5 \times 10^{22} \text{ cm}^{-2}$
→ ULAS1234+09

the reddest type1 QSO discovered so far
Deep XMM data found $N_H < 1 \times 10^{22}$
Banerji+14

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

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

X-ray data of the most luminous WISE/SDSS QSOs

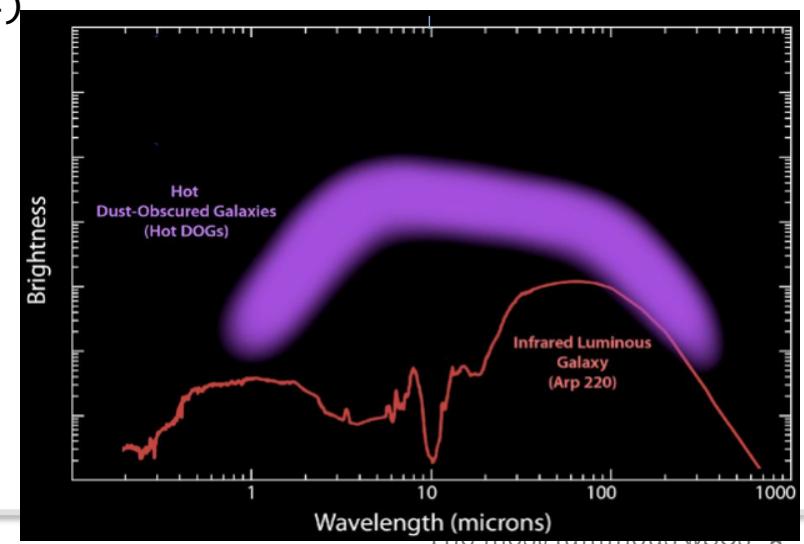


DOGs & Hot DOGs

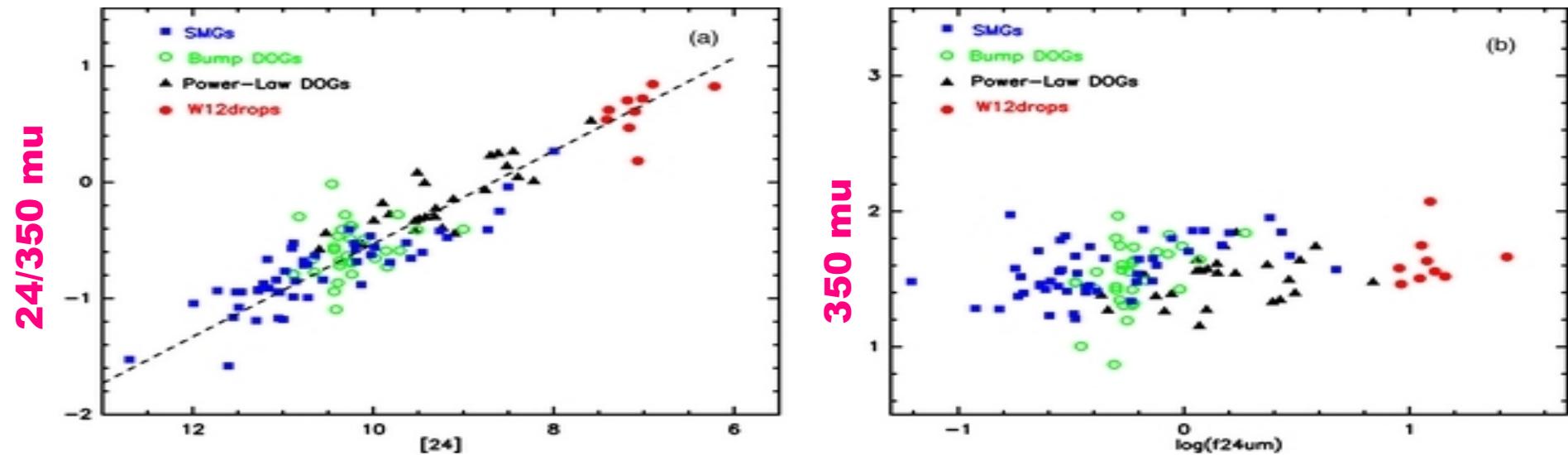


- IRAS *Ultra-luminous IR Galaxies* $L_{\text{IR}} > 10^{12} L_{\odot} \sim L_{\text{bol}}$
- SPITZER *Dust obscured Galaxies DOGs*
 - Bump/PAH DOGs: dominant at $S(24\mu\text{m}) < 1\text{mJy}$
 - Power-Law DOGs: dominant at $S(24\mu\text{m}) > 1\text{mJy}$
 - 50-90% of power-law DOGs are X-ray obscured QSOs
Fiore+08,09; Dey+ 09; Lanzuisi, EP+ 09
- WISE *Hot DOGs*
 - WISE ALL-SKY SURVEY → Redder & more luminous
 - “W1W2-dropouts”: faint/undetected at $3.4(\text{W1}) \& 4.6\mu\text{m}(\text{W2})$
detected at $12(\text{W3}) \& 22\mu\text{m}(\text{W4})$
Eisenhardt+ 2012
 - ~1000 Hot DOGs uncovered after scanning the entire sky

A new rare phase in the evolution of massive galaxy....



Hot DOGs: “new” SED

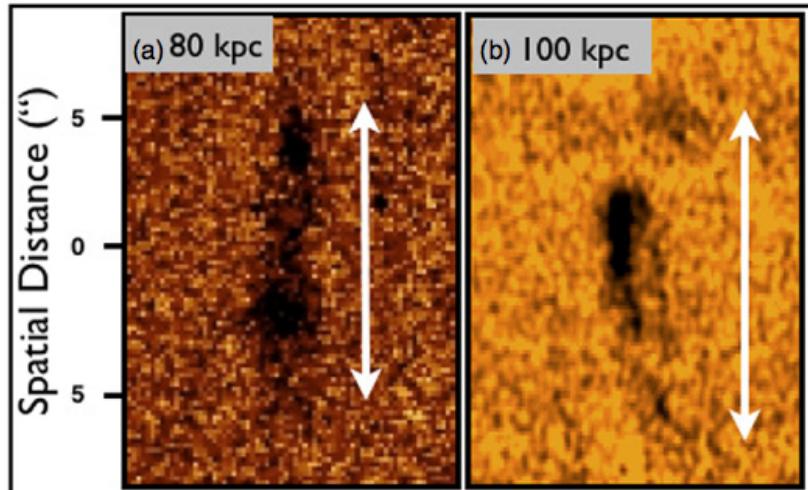


Huge Bolometric luminosities $> 10^{13} L_{\odot}$

- SED is different from any existing galaxy templates
- Large MIR bump
- SED with large MIR/submm
- Hotter dust than other IR-loud galaxies at $z=2-4$
- Similar cold dust component

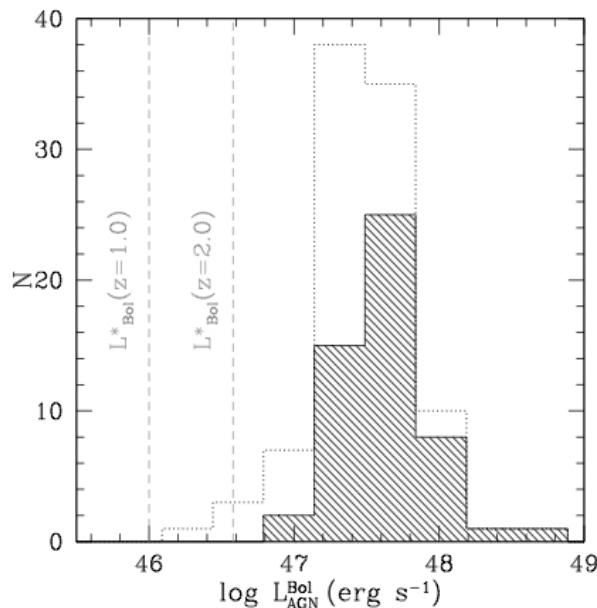
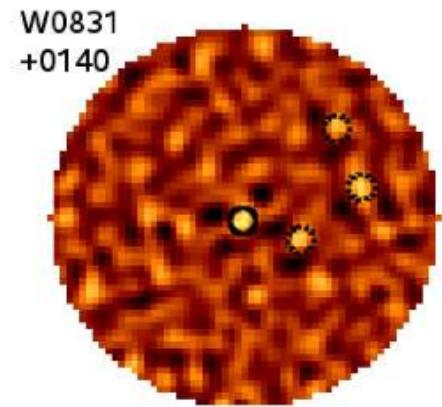
Wu +12, 14; Jones+14

Hot DOGs: the most luminous AGN



Dusty Ly α emitters
Giant Blobs Extended >50 kpc
Bridge+13

Overdensity of SMGs around Hot DOGs
→ Signpost of active regions of
luminous & dusty galaxies
→ Major merger scenario
Jones +14



HOT DOGs AT z~2.5
Peak of quasar & galaxy evolution
Short transitional phase
Huge accretion rates
FEEDBACK AT ITS BEST

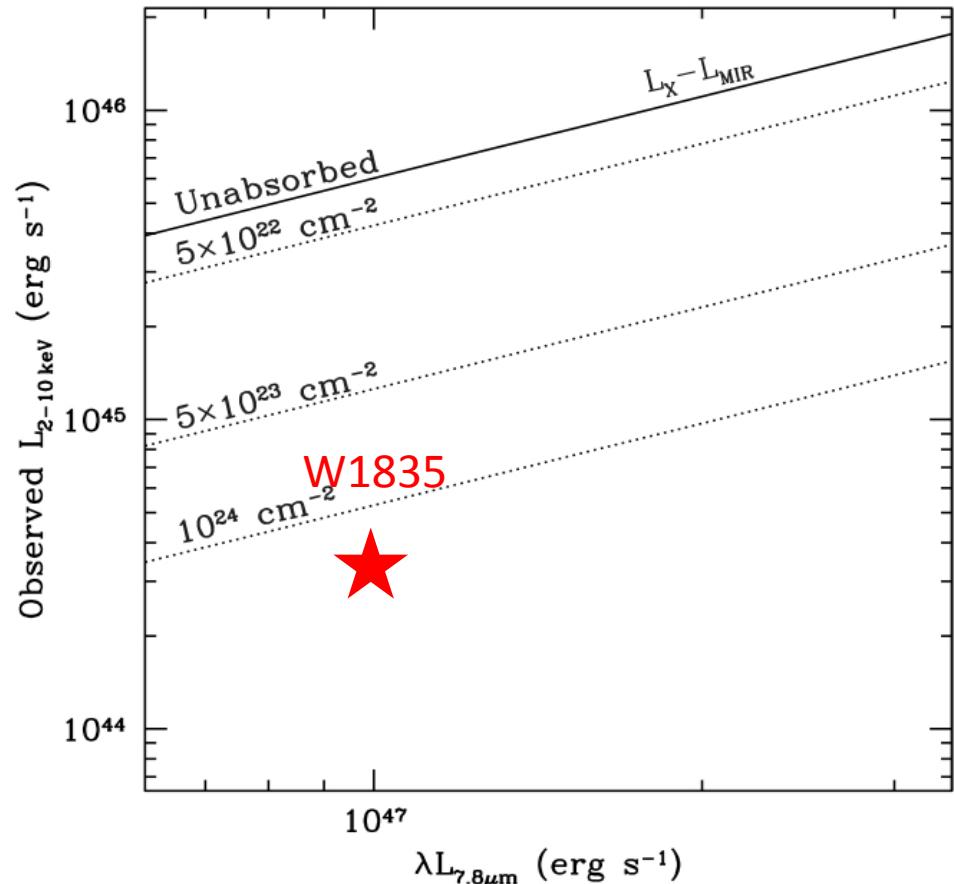
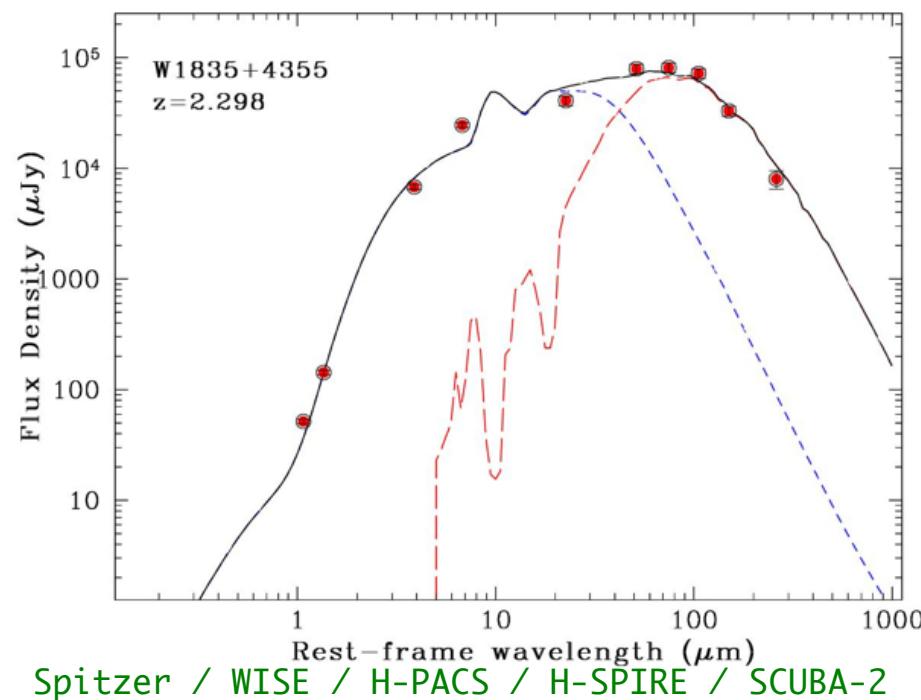
Hyper-Luminous AGN
Assef +14

C O gas content seems to
be lower than SMGs and
very high z QSOs
Wu +14

Hot DOGs: THE FIRST X-RAY SPECTRUM



The hidden quasar nucleus of WISE J1835+4355 at $z \sim 2.3$
EP+ 2015, A&A Letters

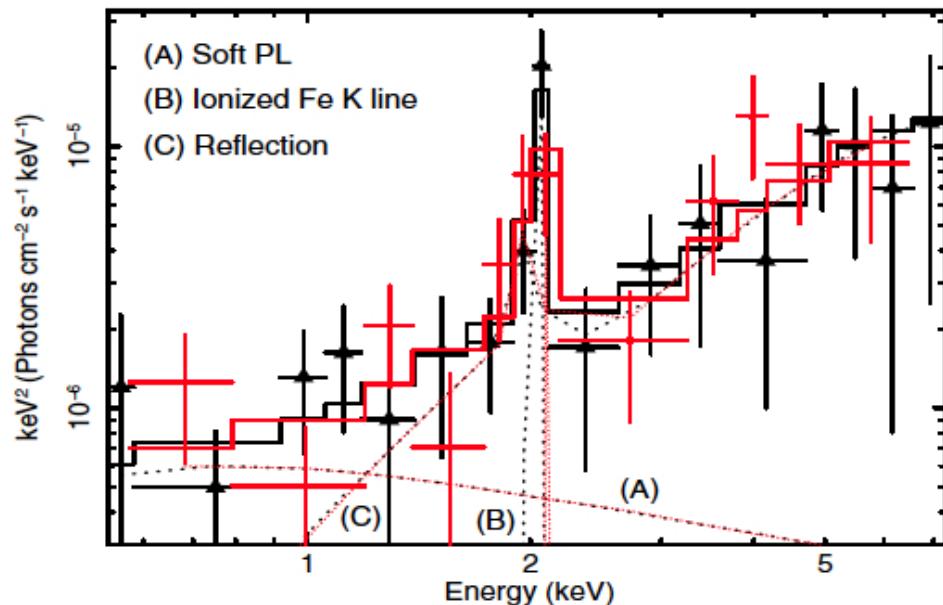


- AGN-dominated SED
- ~ 75% of $L(8-1000)$
 $\text{AGN } L_{\text{bol}} = 1.2 \times 10^{14} L_{\odot}$
- SFR = $2100 M_{\odot}/\text{yr}$

Hot DOGs: THE FIRST X-RAY SPECTRUM

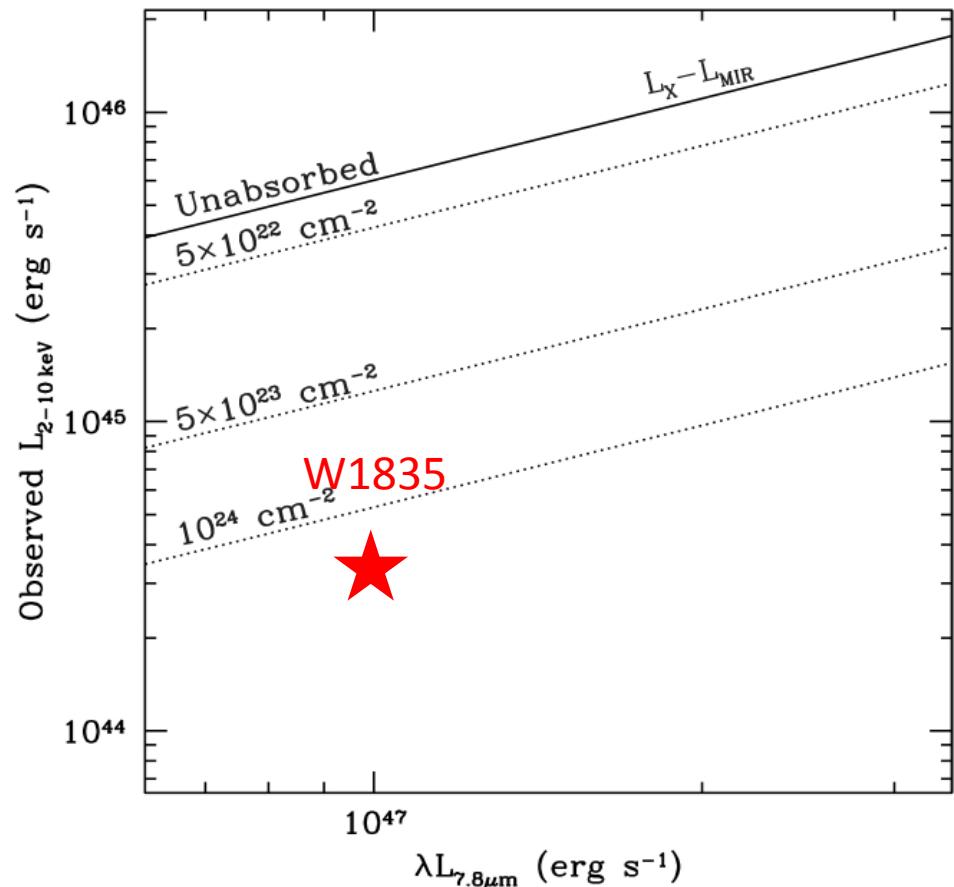


The hidden quasar nucleus of WISE J1835+4355 at $z \sim 2.3$
EP+ 2015, A&A Letters



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

Obs. Lum(2-10keV) = 2.3×10^{44}
~1-10% of the *intrinsic* one !!



Nustar A01
Approved Target 150 ks

SUMMARY & NEXT STEPS



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

**Main goal: revealing powerful AGN-driven outflows
& understand the feedback mechanism**

Searching for feedback in action: a two-step approach

I. Ionized Gas component

II. Molecular Gas component (Mrk231-like)

Results from LBT/LUCI are very encouraging:

- [OIII] Outflows discovered in ~50% of the observed QSOs
- Approved & Planned Follow-up IFU obs.

Probing the nuclear properties of the most luminous AGN

- First X-ray spectrum of a Hot DOGs (a buried hyper-Lum QSO!!)
- Chandra/XMM obs. of WISE/SDDS QSOs (X-ray weakness?)

On-going Program (new exciting results are expected!)