Massive outflows in (most if not all?) high-z QSOs

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Outline

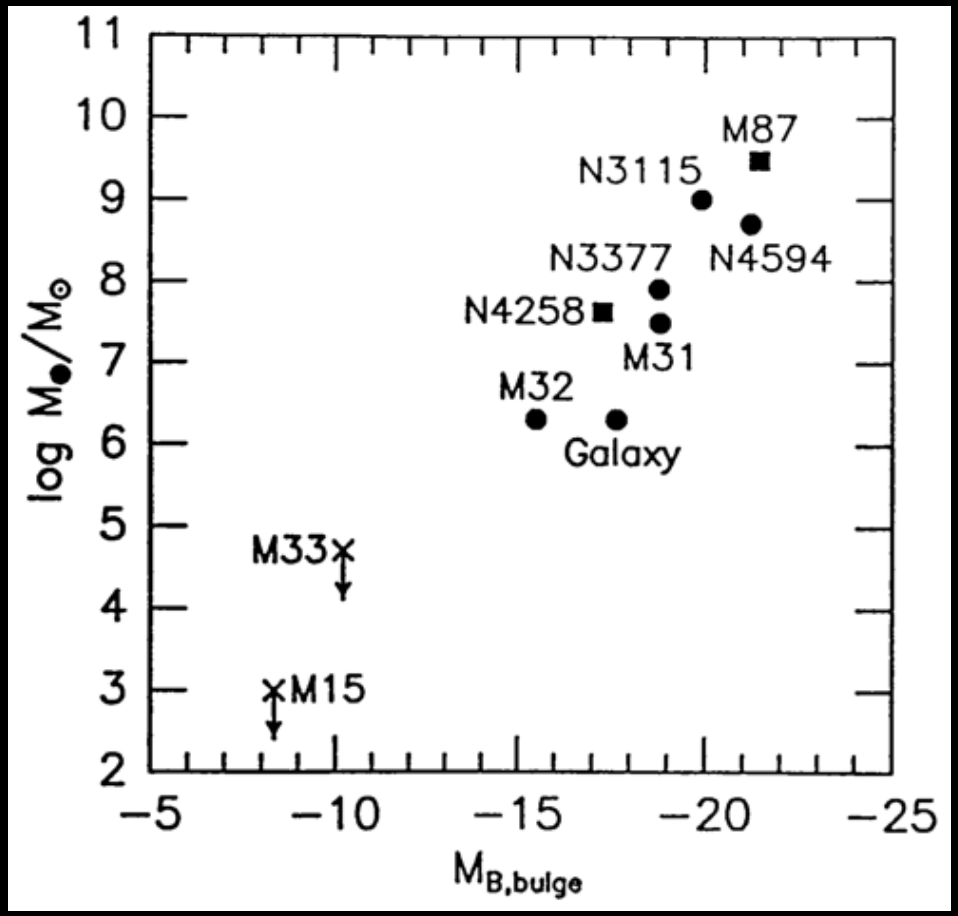
i. Motivation(s)

ii. Gallery of spectra of high-z QSOs

Main Collaborators: M. Dadina, G. Chartas, J. Kaastra, J. Kriss, C. Vignali, G. Lanzuisi, F. Tombesi, M.Giustini, J. Reeves, M. Gaspari, J. Gofford, B. DeMarco, G. Ponti, V. Braito

Framework (i/iv): Co-evolution of galaxies

First unexpected “revolution” in extragal. astrophysics: not only most (all?) galaxies have SMBHs (MDOs) in their centers, these also correlate with bulge properties



Annu. Rev. Astron. Astrophys. 1995. 33:581–624

INWARD BOUND—THE SEARCH FOR SUPERMASSIVE BLACK HOLES IN GALACTIC NUCLEI

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Douglas Richstone

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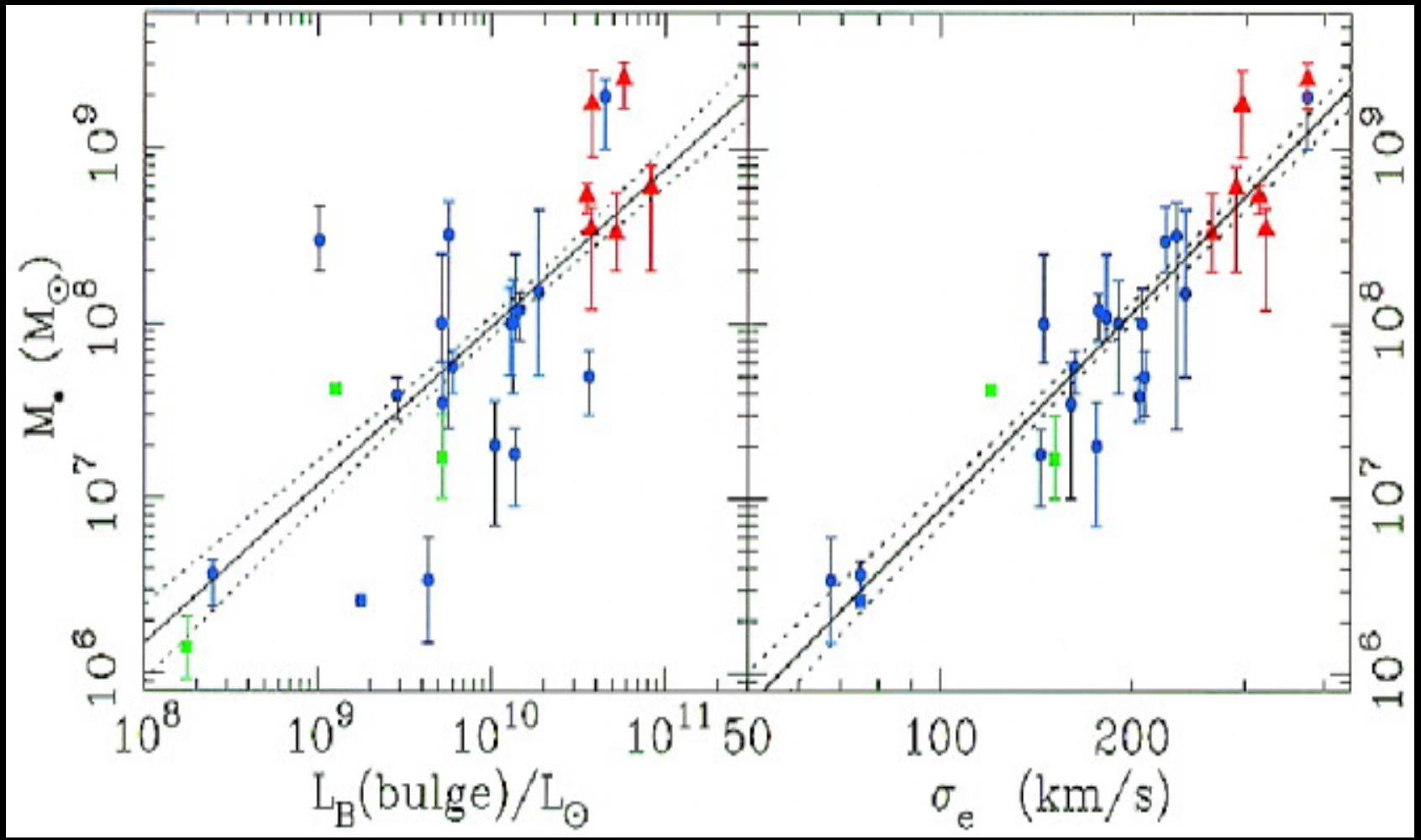
A statistical survey finds BHs in ~20% of nearby E–Sbc galaxies, consistent with predictions based on quasar energetics. BH masses are proportional to the mass of the bulge component. Most candidates are inactive; in some cases, the abundance of fuel is not easily reconciled with BH starvation. Flashes caused by the

Kormendy & Richstone, 1995, ARA&A

Framework (ii/iv): Feedback in the co-evolution of galaxies

⇒evidence for feedback mechanism between SMBH(AGN) and its' host galaxy?



$M_{bh} \sim \sigma^4$

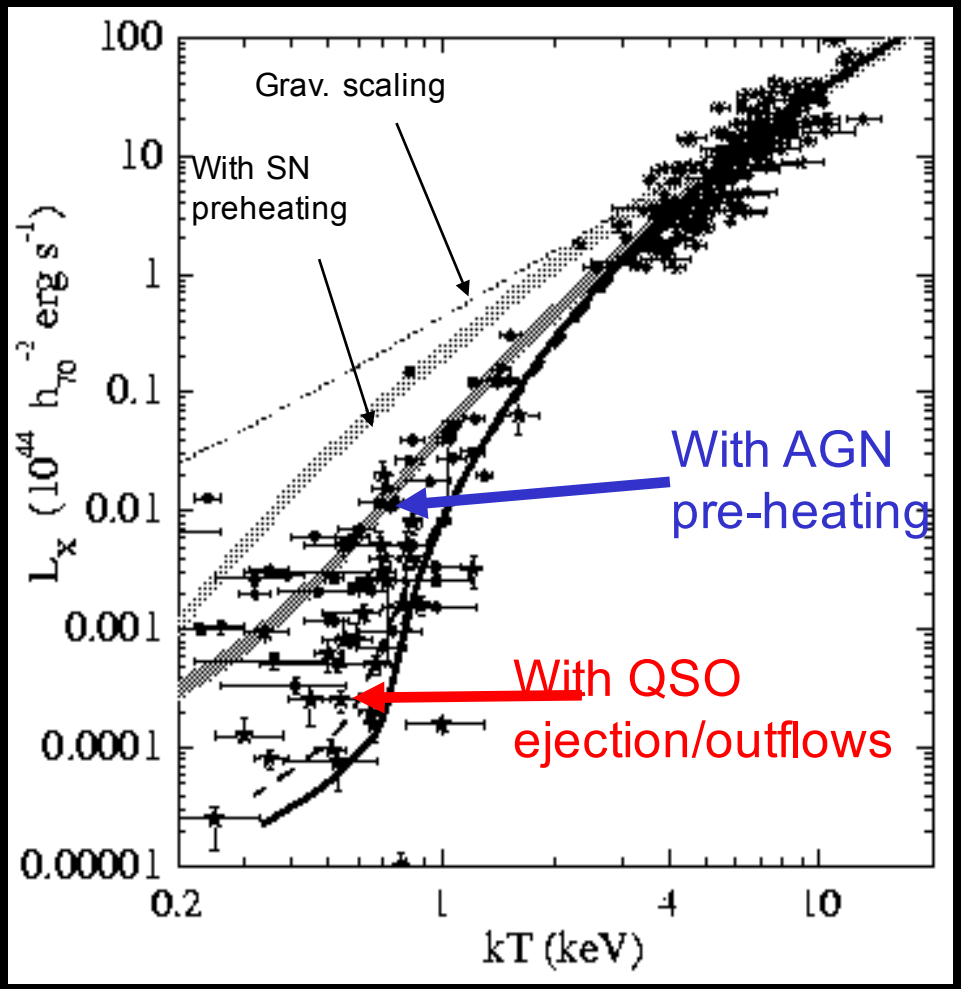
Magorrian et al. '98
Tremaine '02; Gebhardt '02...etc
(see e.g. King and Pounds '03, Crenshaw, Kraemer & George '03, ARA&A)

Framework (iii/iv): (P)re-heating of groups and clusters of galaxies

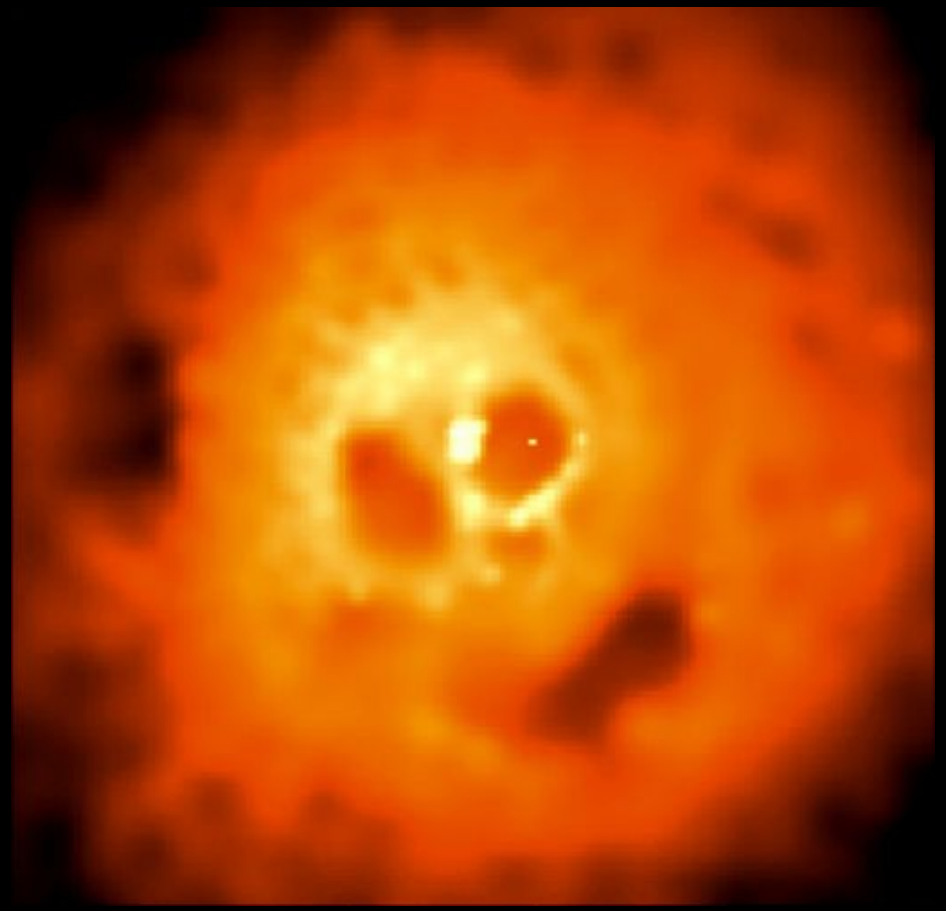
Second unexpected "revolution" in extragal. astrophysics:

need preheating to recover L-T relations & cooling flows extra-heating

⇒ Energy feedback from AGNs/QSOs in groups&clusters?



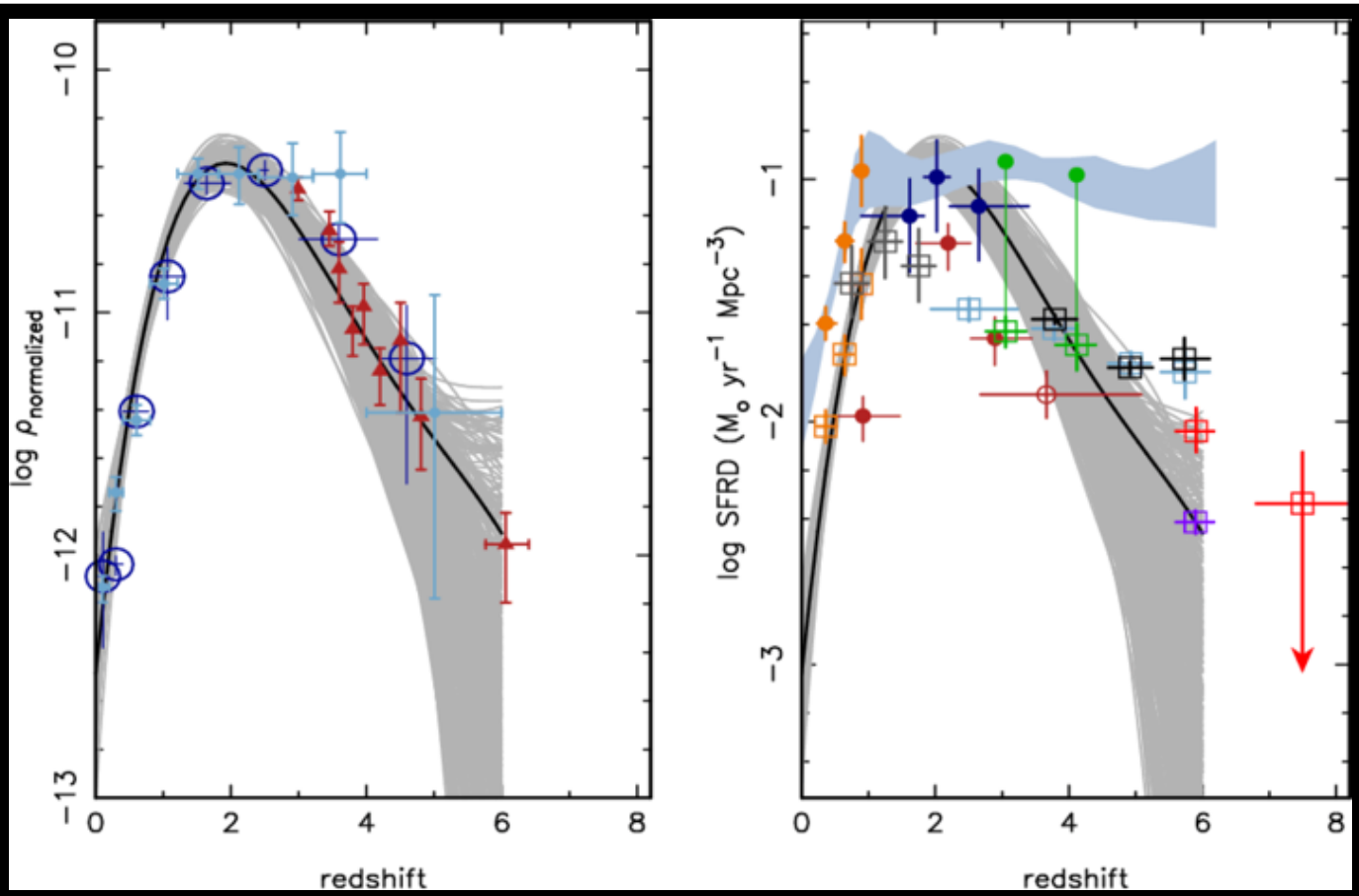
Lapi, Cavaliere & Menci, '05



Perseus Cluster

Fabian et al. '05

Framework (iv/iv): MBH vs SFR, which arrived first at z~2-3?



QSO space density

SFR space density

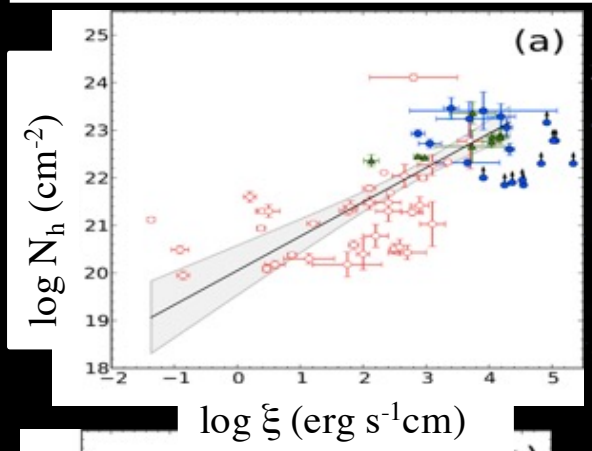
Wall et al. '05
Madau et al. '96

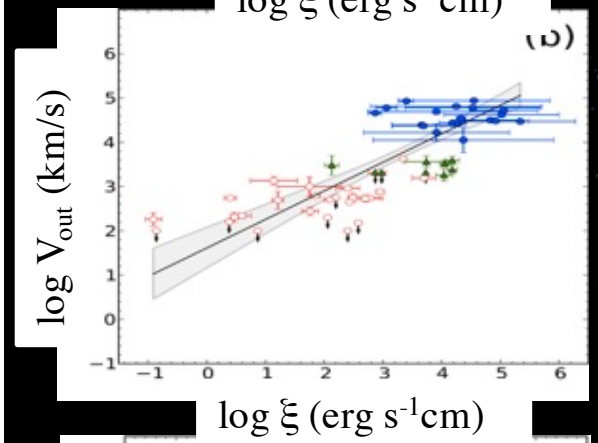
M_{bh}-σ relation, AGN-gal coevolution,
L-Tx relations, Heating cooling flow,
Galaxies colors & sizes

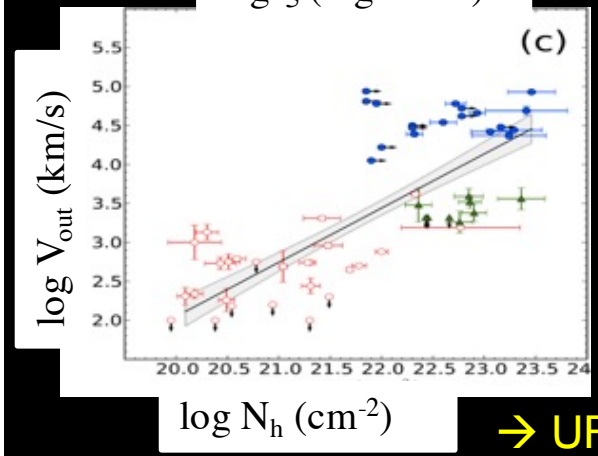
AGN Feedback !

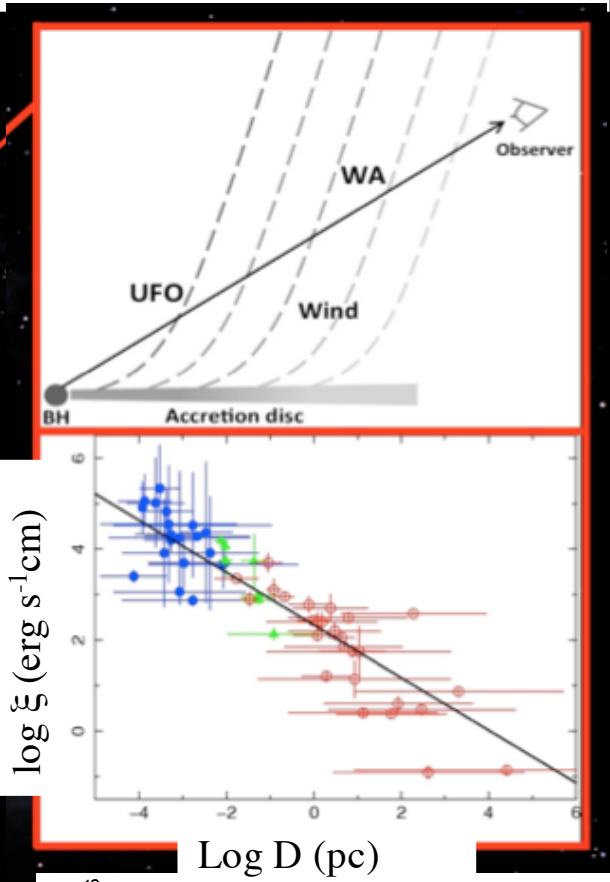
BUT HOW?
(Jet, Winds/UFOs, L_{AGN}, mix?)

At low-z: A possible (unifying) X-ray view of UFOs and non-UFOs (WAs)



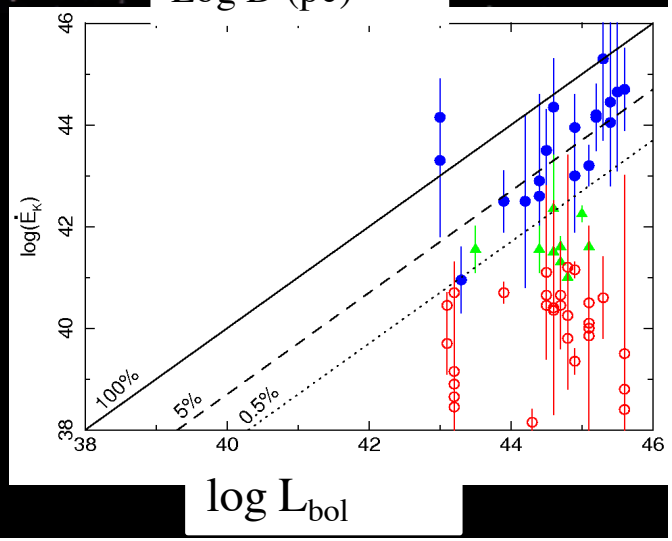






Tombesi, MC et al., '12b, '13

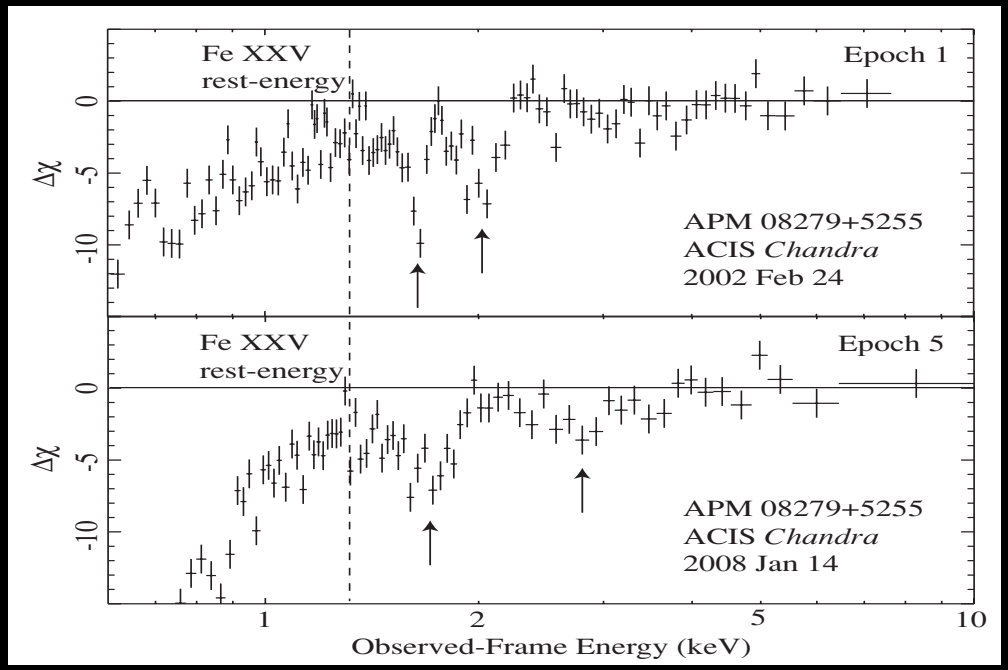
log $\dot{E}_{out}$



→ UFOs kinetic energy >1% of Lbol
→ Feedback (potentially) effective!

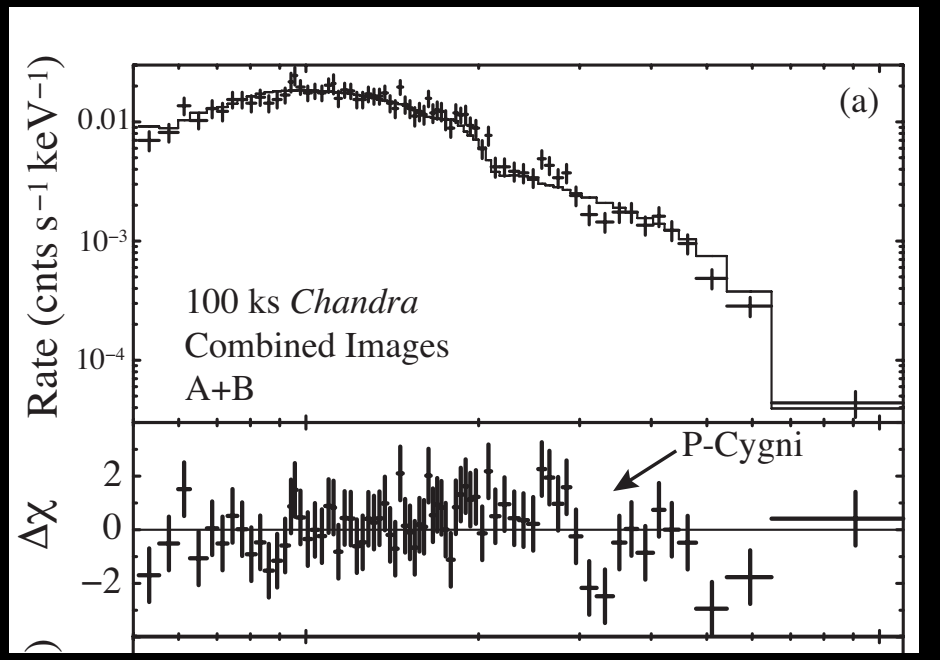
Gallery of spectra of high-z QSOs: Lensed QSOs

APM 08279+5255 (z=3.91)
V_{out}~0.2-0.76 c



Chartas et al. 2002, 2009

HS0810+554 (z=1.5)
V_{out}~0.1-0.4 c



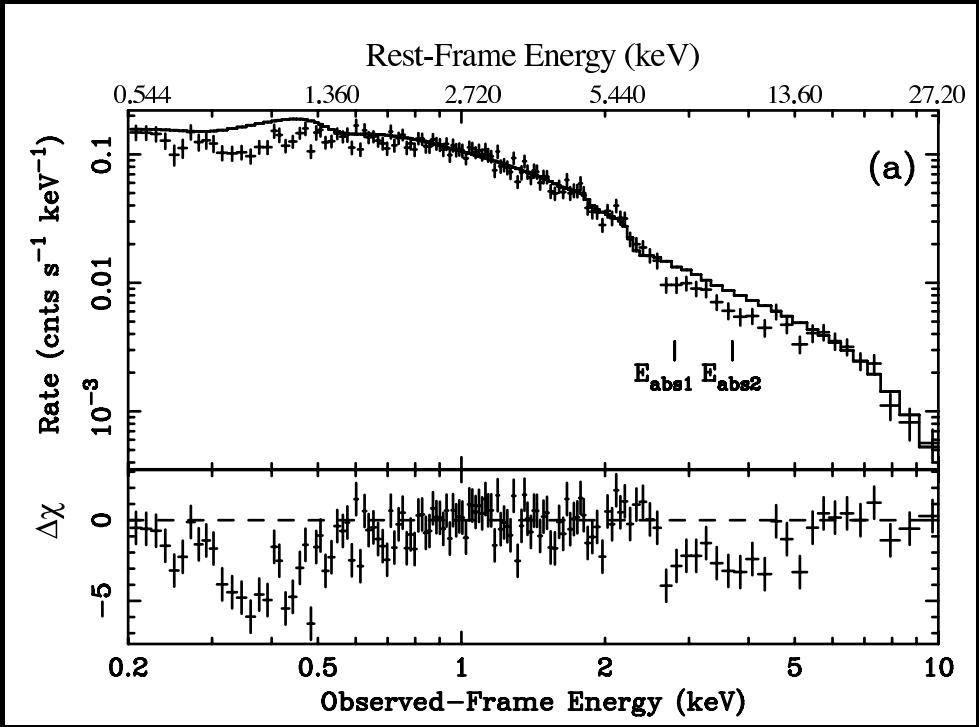
Chartas, MC, et al. 2014, 2015

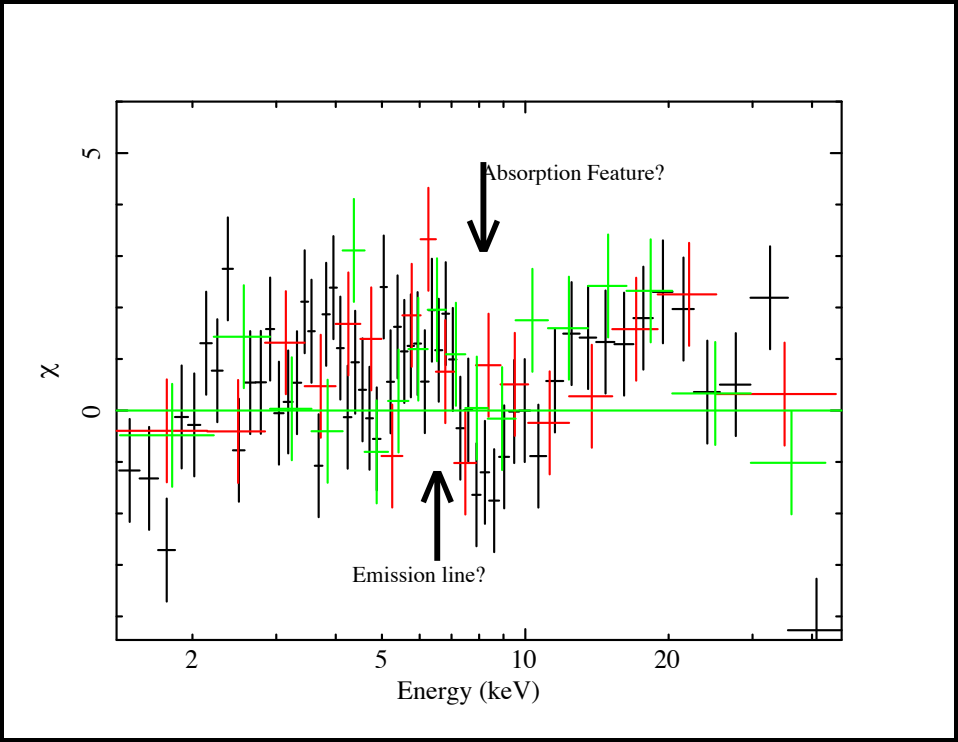
→ Complex (i.e. ionized and/or partially covering), and massive absorption clearly measured in high-z QSOs?

Gallery of spectra of high-z QSOs: Lensed QSOs

PG1115+080 (z=1.7)
V_{out}~0.1-0.34 c

B1422+231 (z=3.6)
Ionized absorber, V_{out}=?





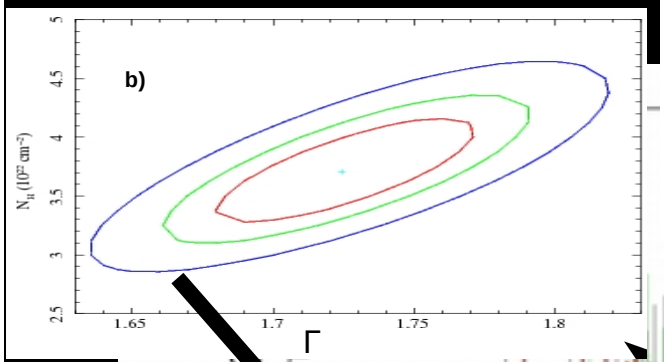
Chartas et al., '07

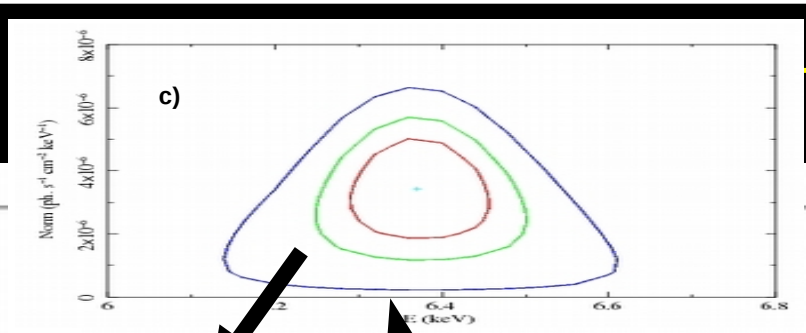
Dadina, MC, et al., '16

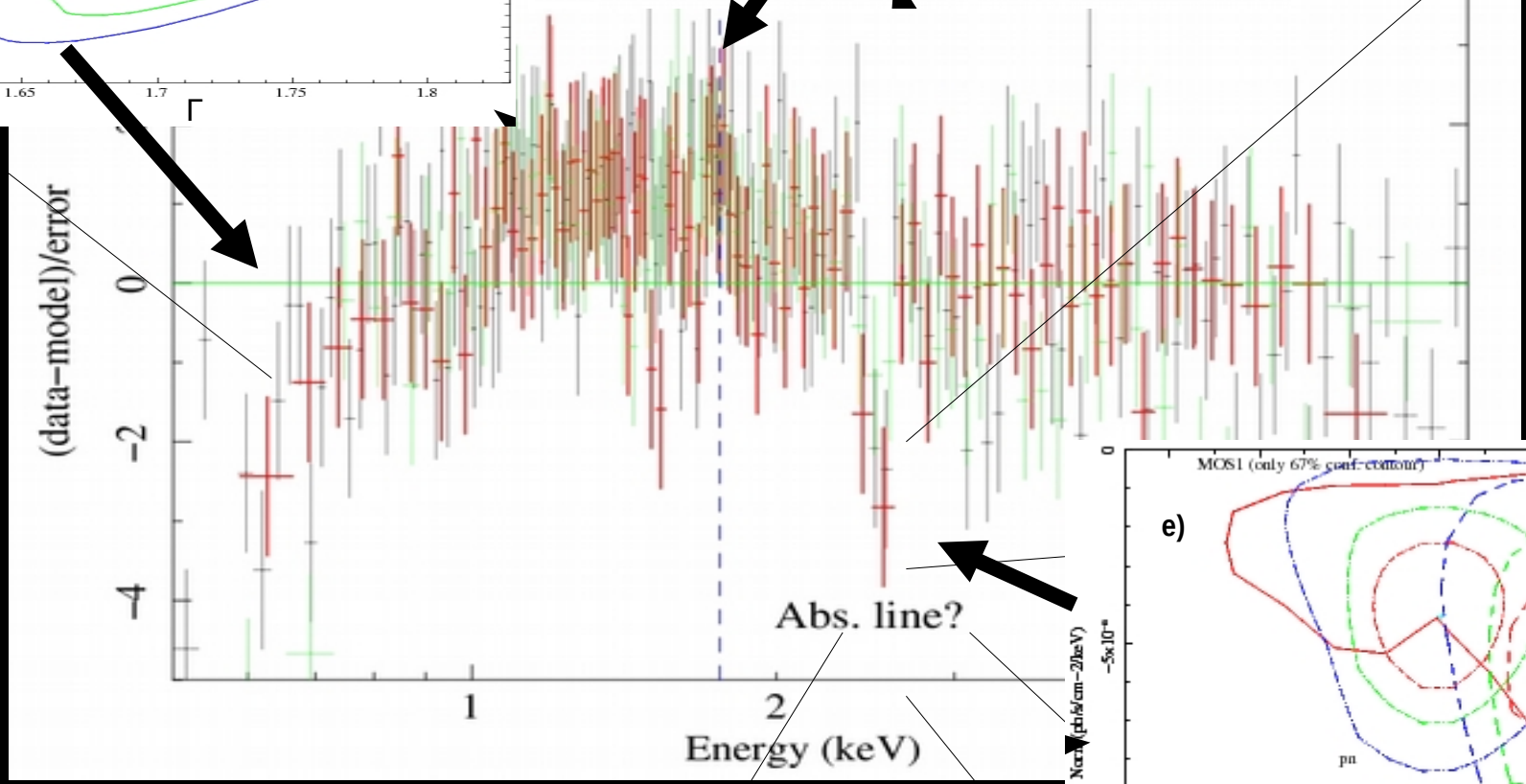
→UFOs, FeK complex features and/or complex low-E absorption seen in (all?) lensed high-z QSOs

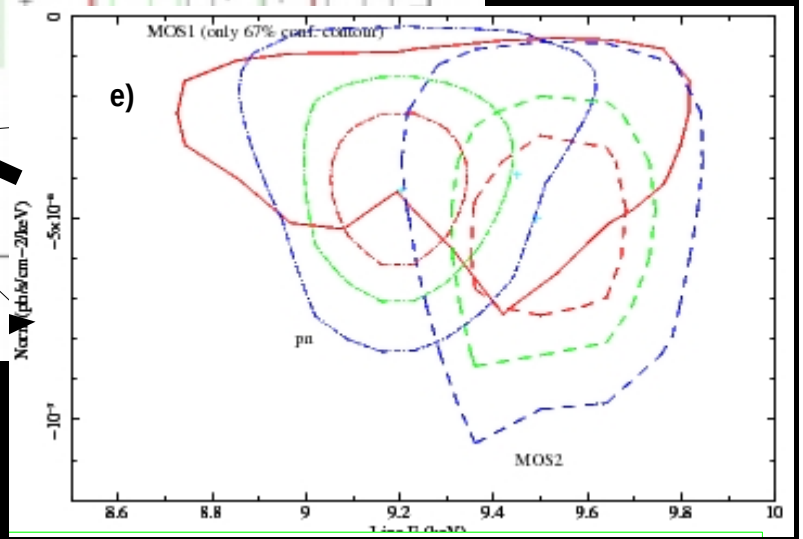
Gallery of spectra of high-z QSOs: Lensed QSOs

(z=2.6) V_{out}~0.32 c







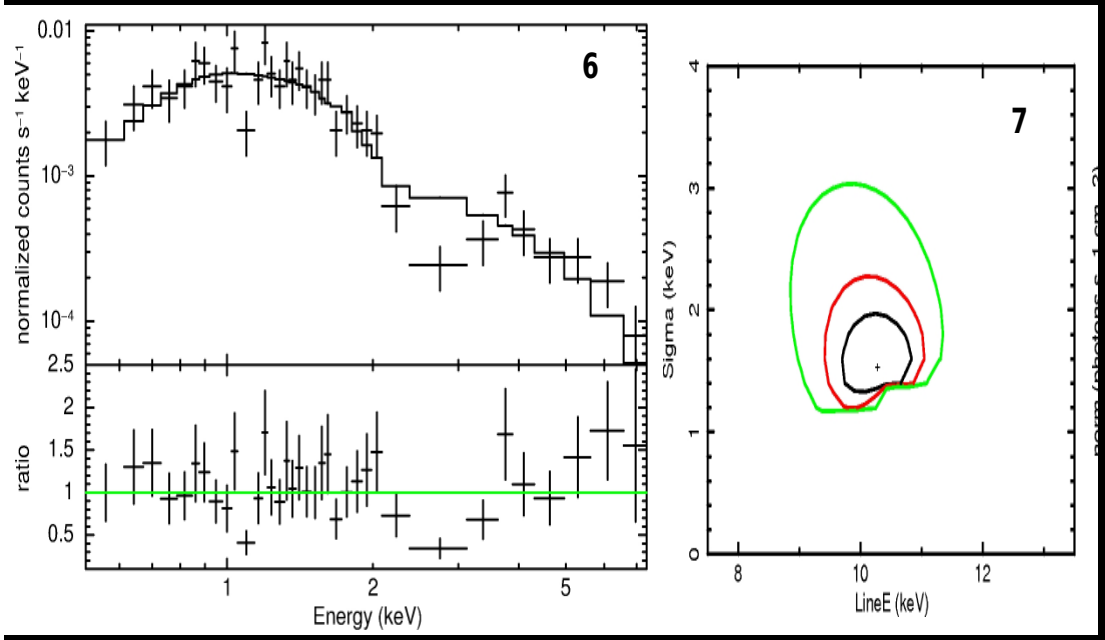


Dadina, MC, et al., in prep.

→UFOs, FeK complex features and/or complex low-E absorption seen in (all?) lensed high-z QSOs

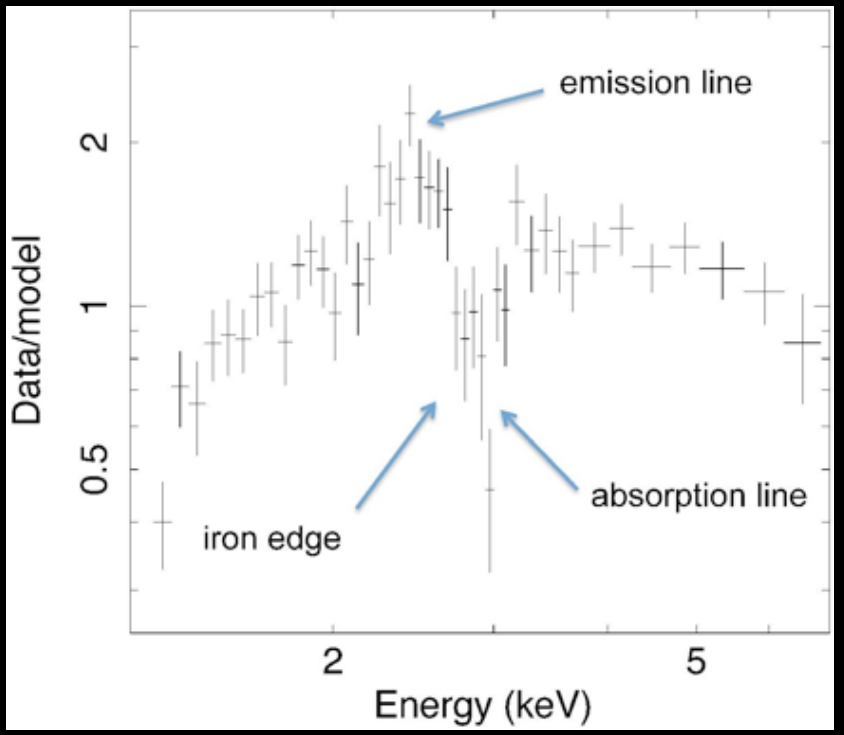
Gallery of spectra of high-z QSOs: Non-lensed QSOs

(z=2.73) high-z RQ (NAL) QSO HS1700+6416,
V_{out}~0.12-0.6c



Lanzuisi et al., ’12

PID352 (z=1.6)
V_{out}~0.15c



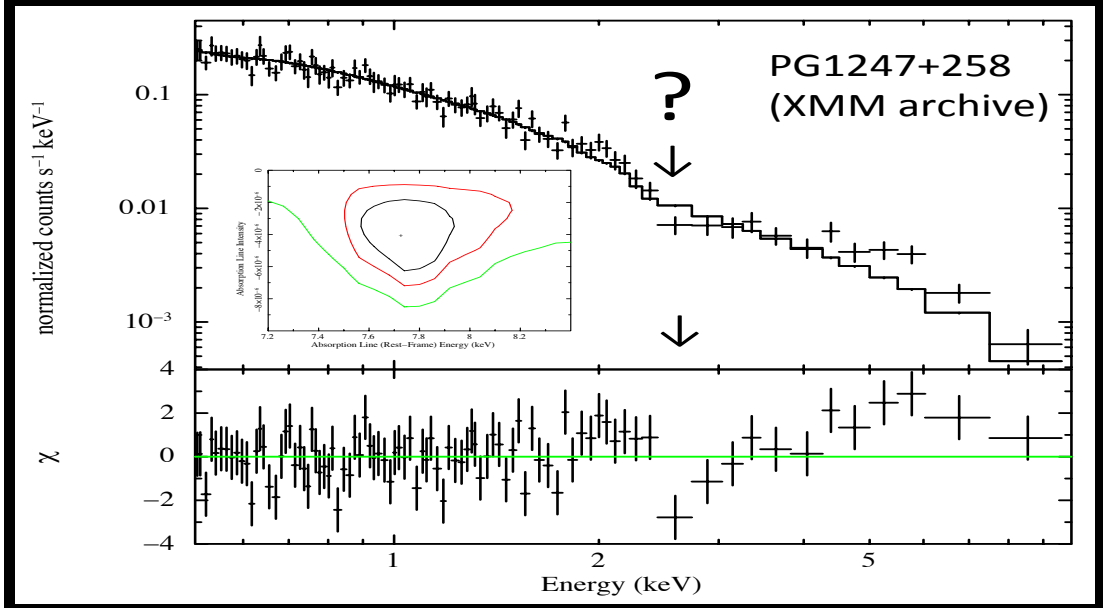
Vignali et al., ’15

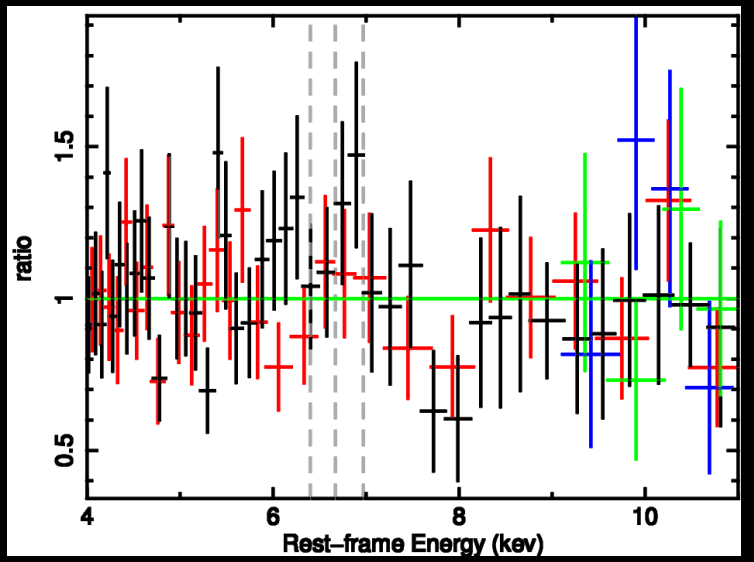
→ Again, ubiquitous complex (i.e. ionized and/or partially covering) absorption?

→The new X-ray view:
UFOs seen also in (all?) non-lensed high-z QSOs

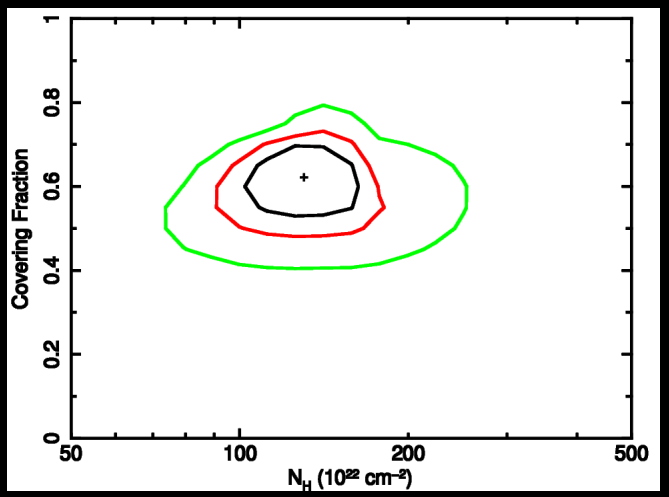
Gallery of spectra of high-z QSOs: Non-lensed QSOs

(z=2) PG1247+268; V_{out}~0.15c





Lanzuisi et al., '16



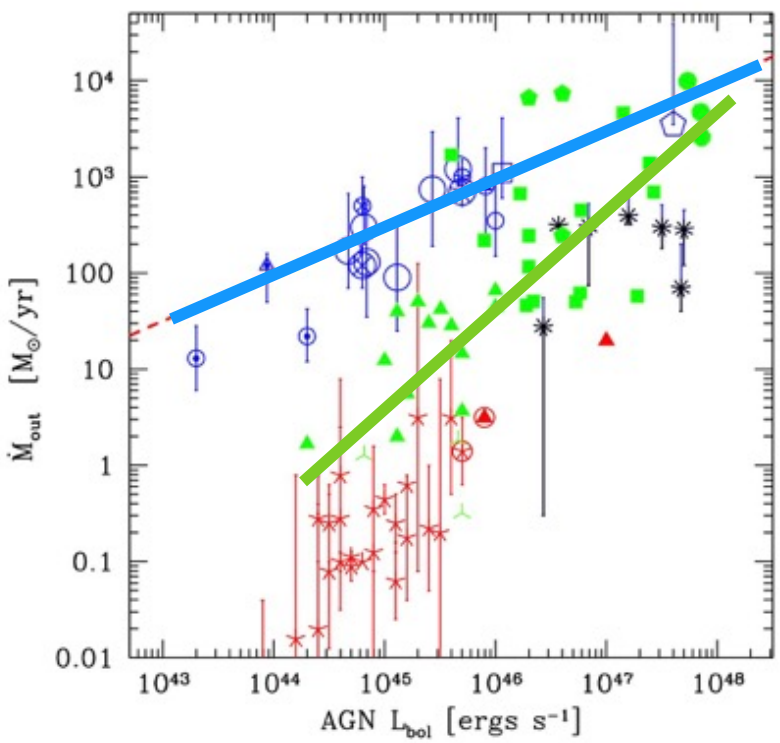
Another high-z UFO candidate…

→ Ubiquitous complex (i.e. ionized and/or partially covering) absorption?

→ Desperately need more and longer XMM observations on high-z QSOs to build a representative sample (N.B: Need about 20000 counts to detect -50eV EW)

Our team was just approved ~450 ks of XMM time to observe 4 non-lensed QSOs at z~2 (PI: MC)…stay tuned

Need X-ray and multi-ni coverage of a representative sample of high-z QSOs.

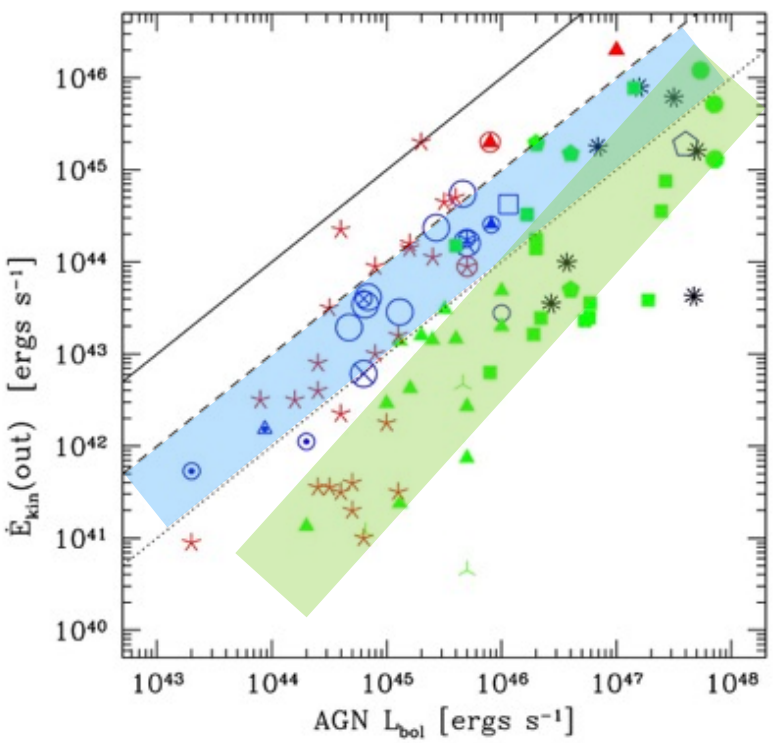


Molecular
small=nucl
large=gal.

Ionized

BAL

X-ray



Remarkable correlation between wind mass outflow rate and AGN bolometric luminosity: $M_{out} \sim L_{bol}^{0.5}$ for molecular winds $M_{out} \sim L_{bol}$ for ionized winds

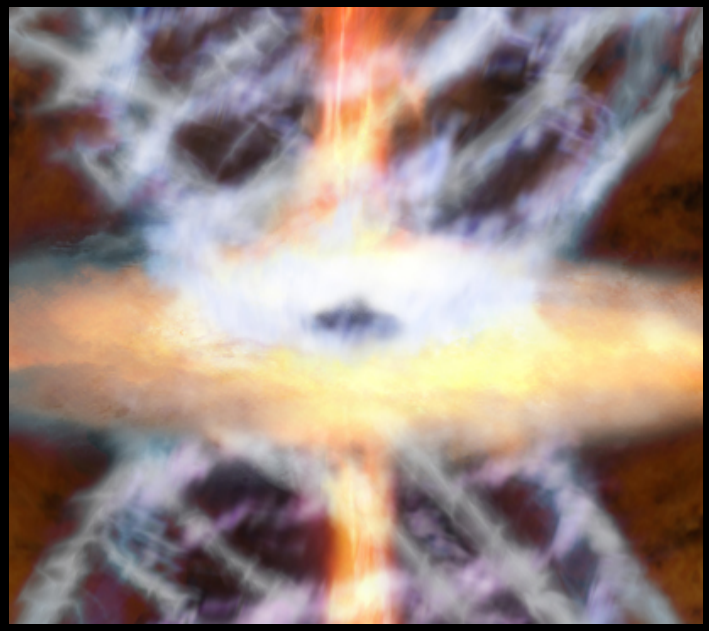
E_{kin}(out) = 1-10% L_{bol} (molecular) E_{kin}(out)=0.1-10% L_{bol} (UFOs, BALs)

E_{kin}(out) = 0.1-1% (ionized low L_{bol}) = 1-10 % (ionized high L_{bol})

Fiore et al., ’15

Summary:

- Science Case (outflows)
  - *Recognized importance, and "pathfinder" to future missions/observatories (from ground based Obs. ALMA, MUSE, SINFONI to Athena).*
  - *Important implications for both astrophysics of winds/outflows formation and acceleration, and the cosmological impact/feedback of AGN winds.*



- Cosmological impact/feedback:
  - Few decent high-z QSOs spectra available, ALL show UFO-like features in their X-ray spectra
  - Need to have good quality (>20000 cts) X-ray spectra for a representative sample of (30-40) high-z QSOs to characterize and measure the frequency of massive and energetic outflows in high-z QSOs (for z~0-2, L~0.1-Ledd). Need multi-ni coverage to obtain full outflow energetics. Multi-ni would also "guarantee" more publications per XMM's ks, as experienced in low-z AGNs.
  - The future: from XMM (LPs and VLPs) to Athena (core science)

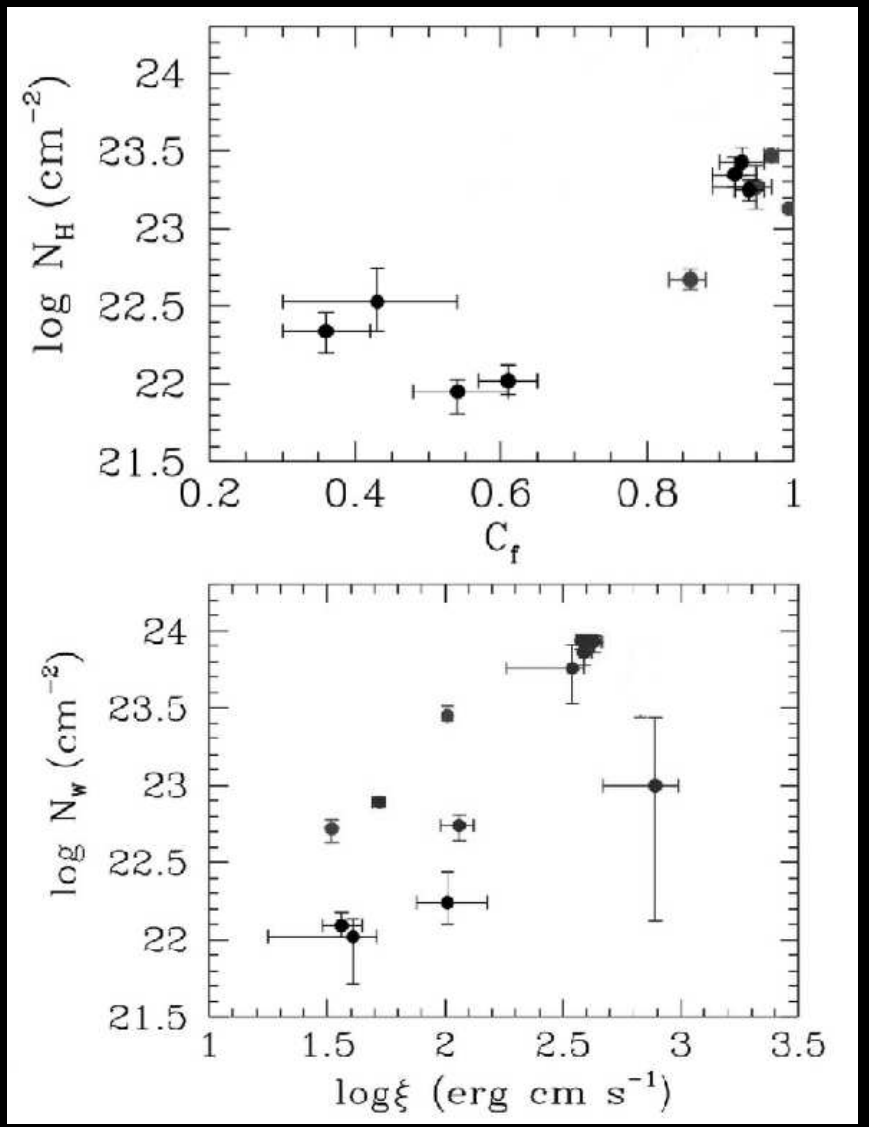
Thank you very much
for your attention

Additional slides

In BAL and mini-BAL QSOs
(a dozen with z~0.1-0.5-2)

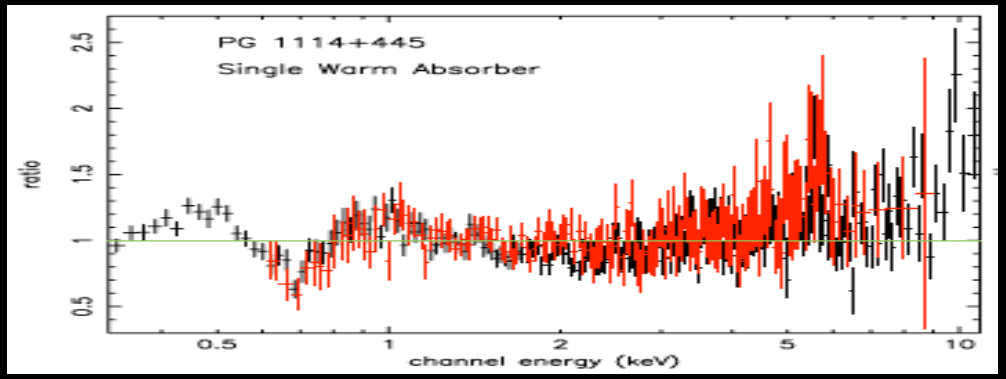
Giustini 2015

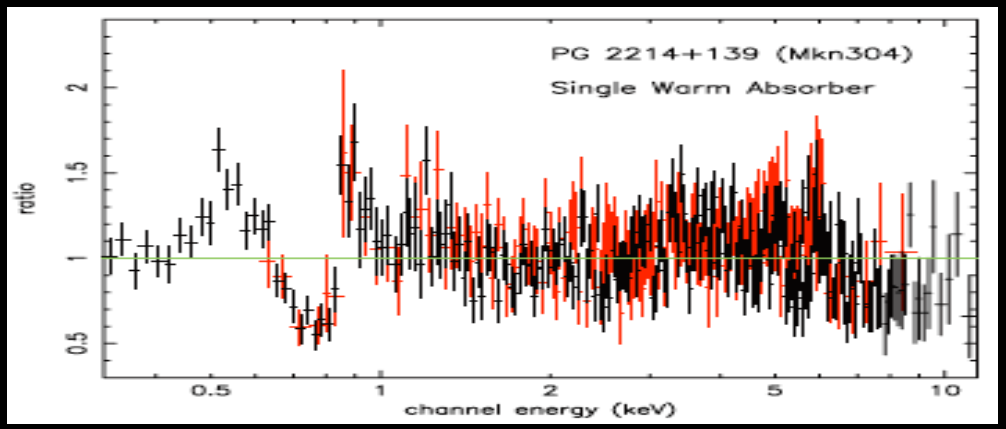
…the best sample available to date….



→ Ubiquitous complex (i.e. ionized and/or partially covering) absorption?
→ Desperately need more and longer XMM observations on high-z QSOs to characterize the outflows in a representative sample of high-z QSOs

The "classic" X-ray view: Warm Aborbers in nearby QSOs

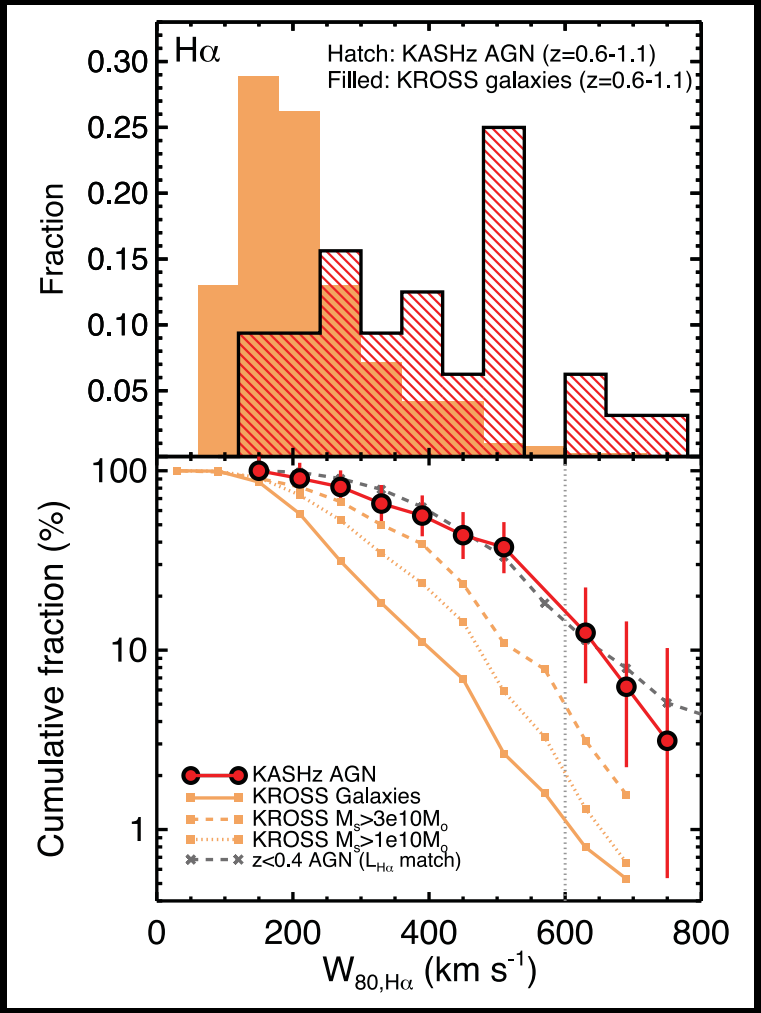




WAs present in ~50% of PG QSOs contrary to older measurements of 5-10%

→ Frequent, but low v (1000 km/s) and low Nh make these winds energetically not very important (fractions of Msol/year)

Porquet et al. 2004, Piconcelli et al. 2005



AGN/QSO-driven outflows ubiquitous in QSOs?

Harrison et al. 2016