Highlights on massive winds from AGNs

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Outline

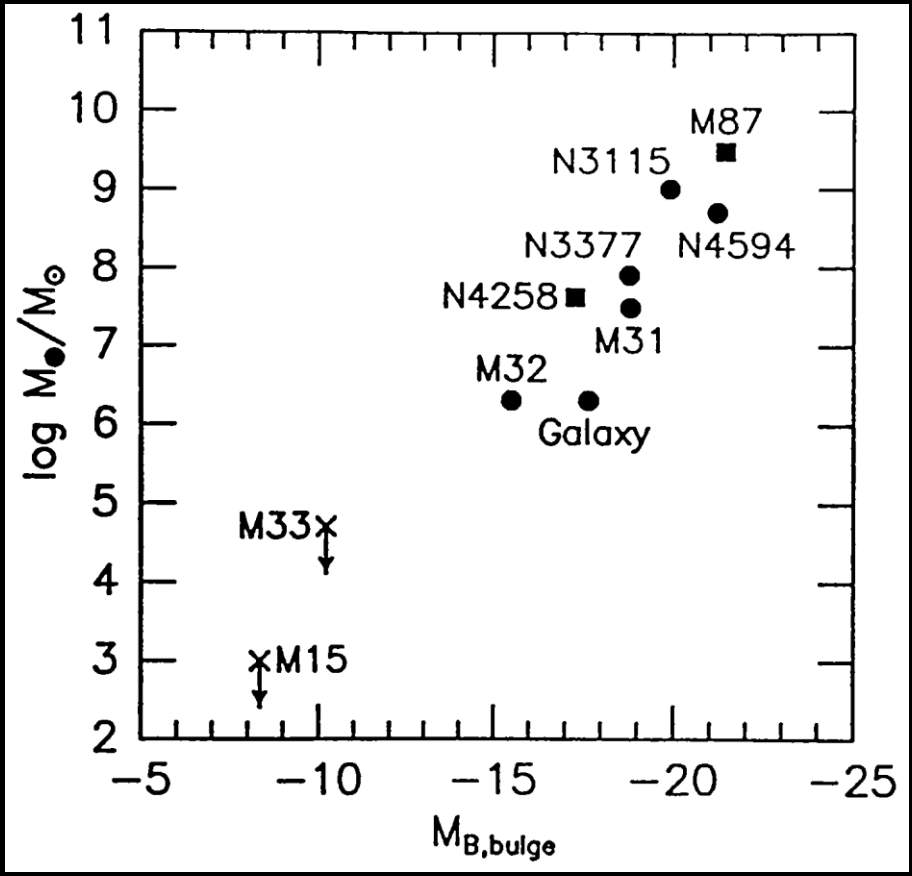
1. Current framework
   i. AGN feedback
   ii. From low-v to high-v X-ray winds

2. Highlights on recent results
   i. X-ray + UV (fast) absorber
   ii. X-ray fast outflows linked to molecular outflows?
   iii. Direct measurement of Cf
   iv. High-z QSOs, none featureless….
   v. Comparison with binaries states?

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

Framework: Co-evolution of AGN and galaxies

~20 years ago, a somewhat unexpected "revolution" in extragal. astrophysics: not only most (all?) galaxies have SMBHs in their centers, these also correlate with host 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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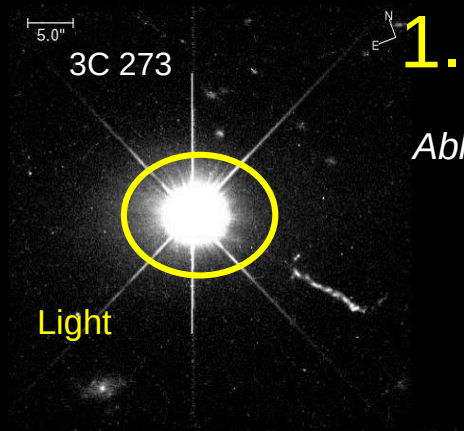
Kormendy & Richstone, 1995, ARA&A

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

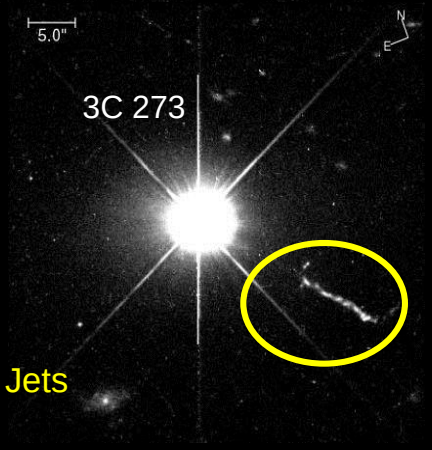
M_{bh}-σ relation, AGN-gal coevolution, L-Tx relations, Heating cooling flow

→ AGN Feedback !

Framework: *Three major feedback mechanisms between the SMBH and its environment*



Light



Jets

1. radiative feedback: $\dot{L}_{acc} = h\left(\dot{M}_{acc}\right)c^2$

Able to quench the star formation and the cooling flow at the center of elliptical galaxies

e.g. Ciotti & Ostriker 2001

But it is not enough to reproduce the M_{BH}-□ relation *e.g., Ciotti et al. 2009*

How much radiation on dust is relevant in high-luminosity sources/quasars?
Ishibashi & Fabian 2015

2. mechanical/kinetic feedback:

i. mass outflows from collimated, radiatively bright, relativistic radio JETS:

Heat the IGM and the ICM, quench the cooling flow in rich Clusters of Galaxies

e.g. Fabian et al. 2009, Sanders et al. 2009

Winds

i. mass outflows from wide angle, radiatively dark, massive WINDS/outflows

e.g., Silk & Rees 1998
e.g., Begelman 2003

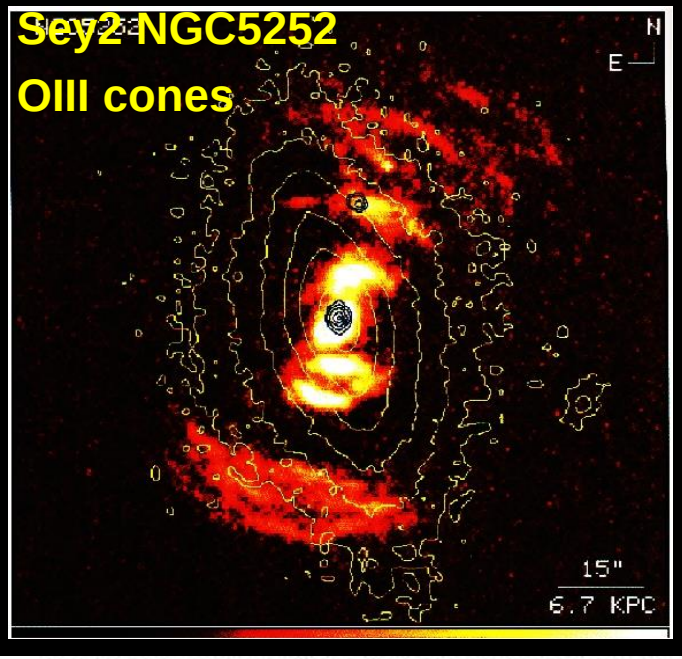
See reviews by Crenshaw, Kraemer & George, 2003 and more recently by Fabian '12, ARAA

The "classic" view of winds/outflows: Fast winds/outflows/ejecta in AGNs

…known/seen in AGNs since long ago

Jets in radio-loud AGNs

Wide-angle winds & jets in Sey gal.

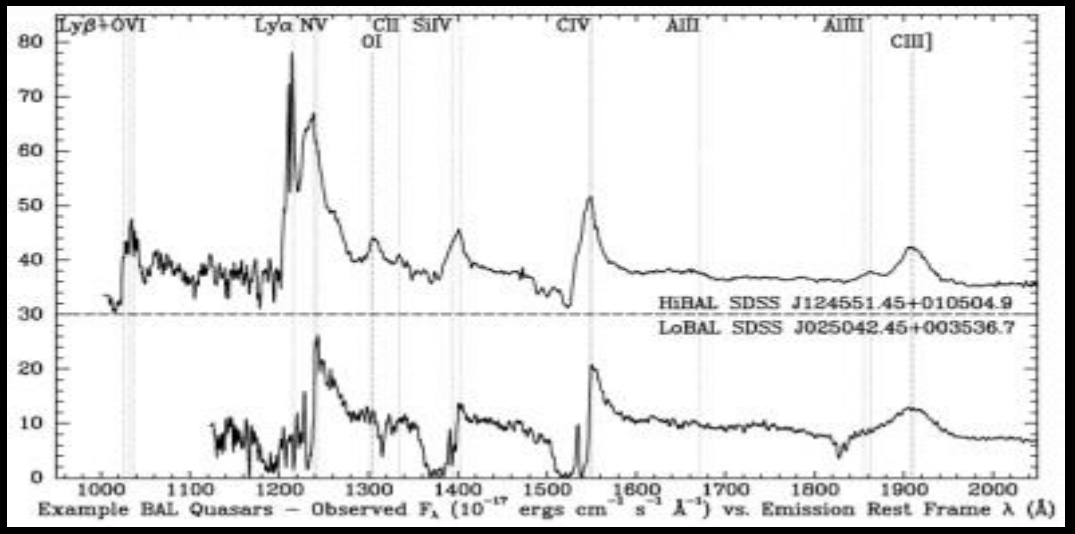


Tadhunter & Tsvetanov, Nature, '89;
Wilson & Tsvetanov, '94
Cappi et al. '95
Morse et al. '98

+ Fischer+ '10, '13, '15

Fast (v up to ~ 50000 km/s) winds in (B/N)AL QSOs

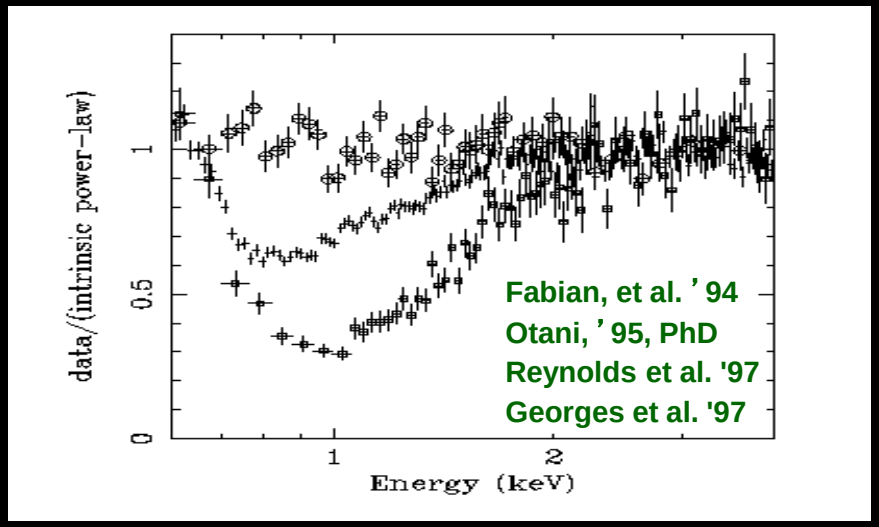
(~ 40-50% of all QSOs)



Weymann et al., '91; Reichards et al., '03; Ganguly & Brotherton '08; Hamann+'12

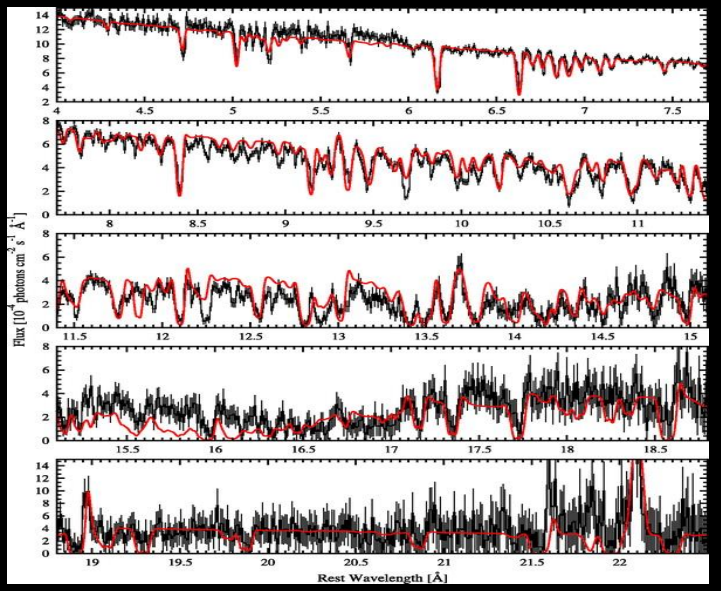
The "classic" X-ray view: Warm Absorbers in nearby Seyferts and QSOs

Seyfert galaxies: *ASCA…*



Many details from Chandra/XMM gratings

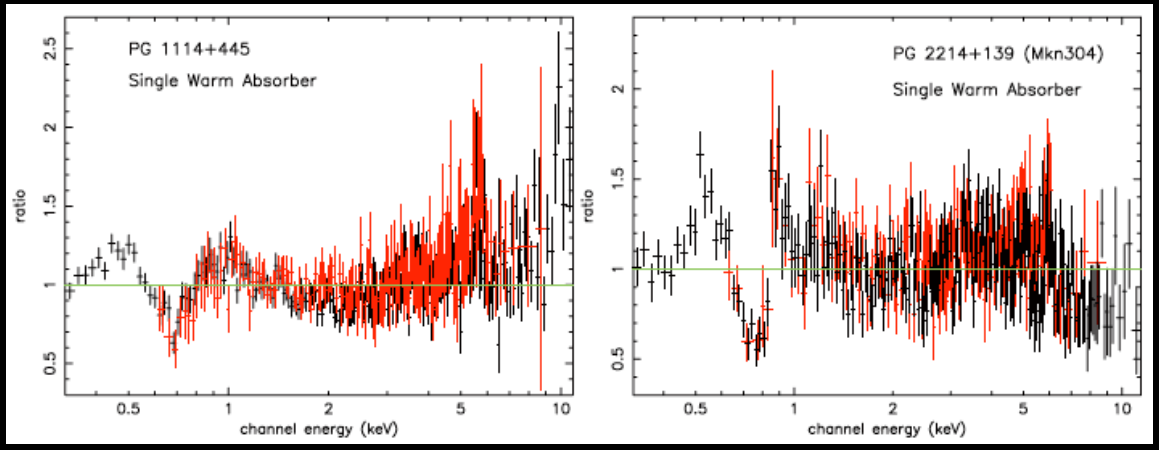
NGC3783 Exp=900 ks



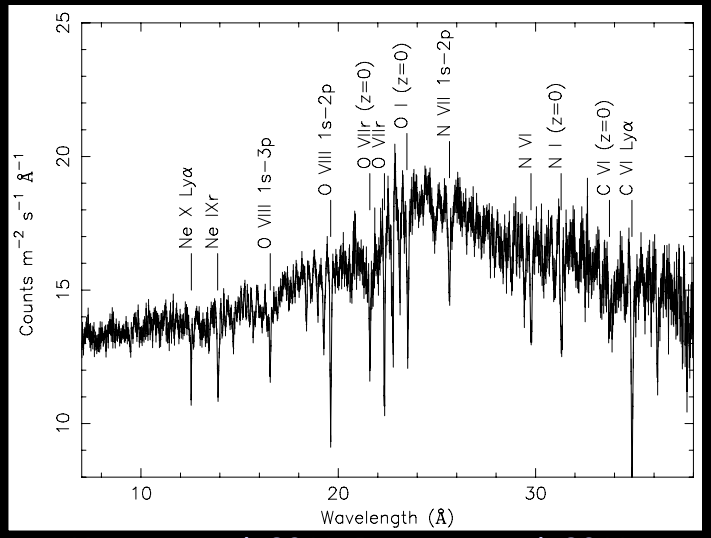
Kaspi et al. '01;
Netzer et al. '02;
Georges et al. '03;
Krongold et al. '03

Mrk 509 RGS: 600 ks

QSOs: *XMM…*



Porquet et al. 2004; Piconcelli et al. 2005



Kaastra et al. 2011, Detmers et al. 2011

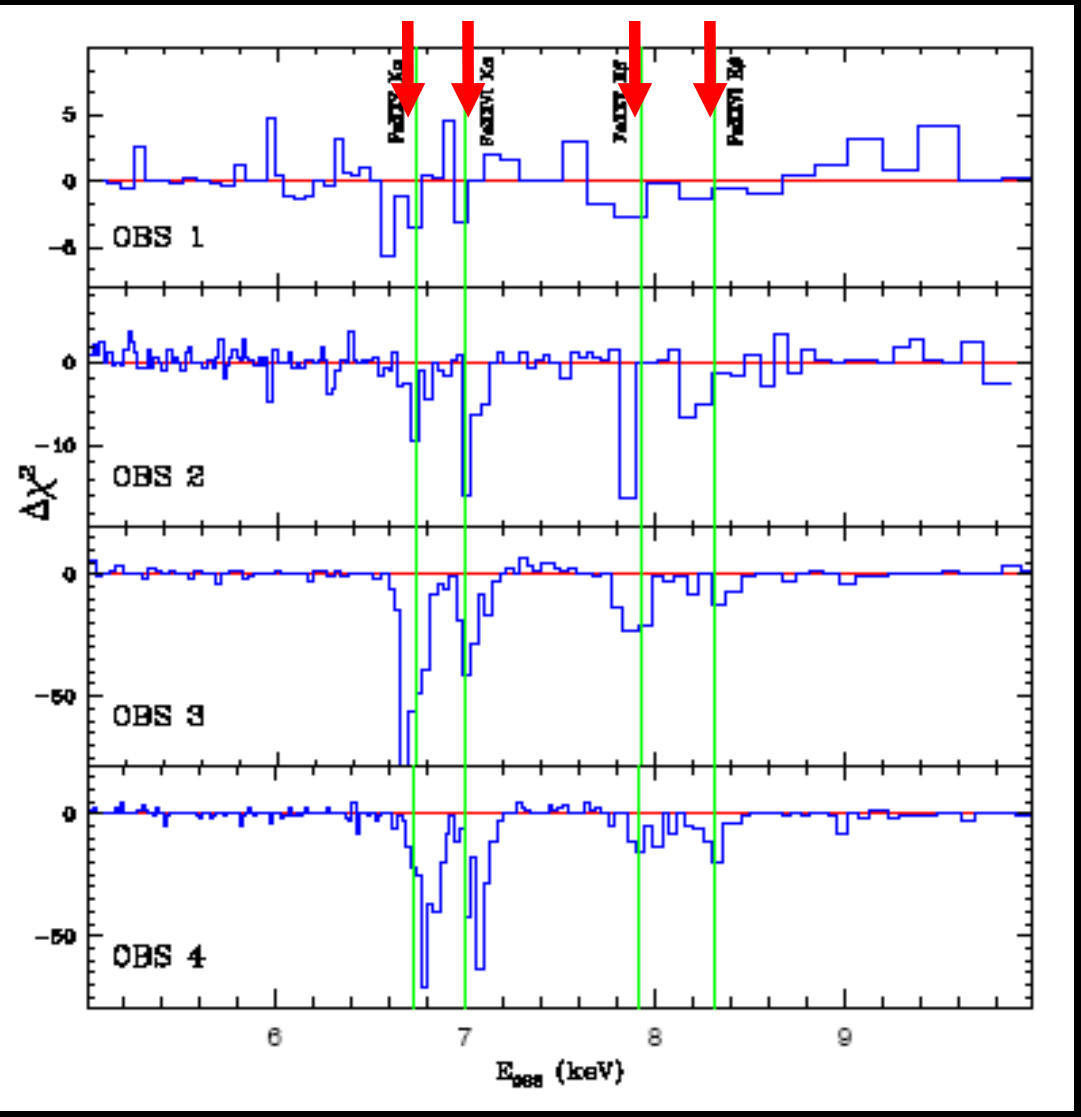
→ Clear now that ~50% of all Seyferts and QSOs present multiple ionization & kinetic components (from Optical, UV and soft X) of outflows/winds with v~100-1000 km/s

→ Typically energetically unimportant for feedback i.e. Blustin et al. 2005, but see Crenshaw & Kraemer, 2012

The "new" X-ray view: Not (only) a static WA but also variable Ultra Fast Outflows (UFOs)

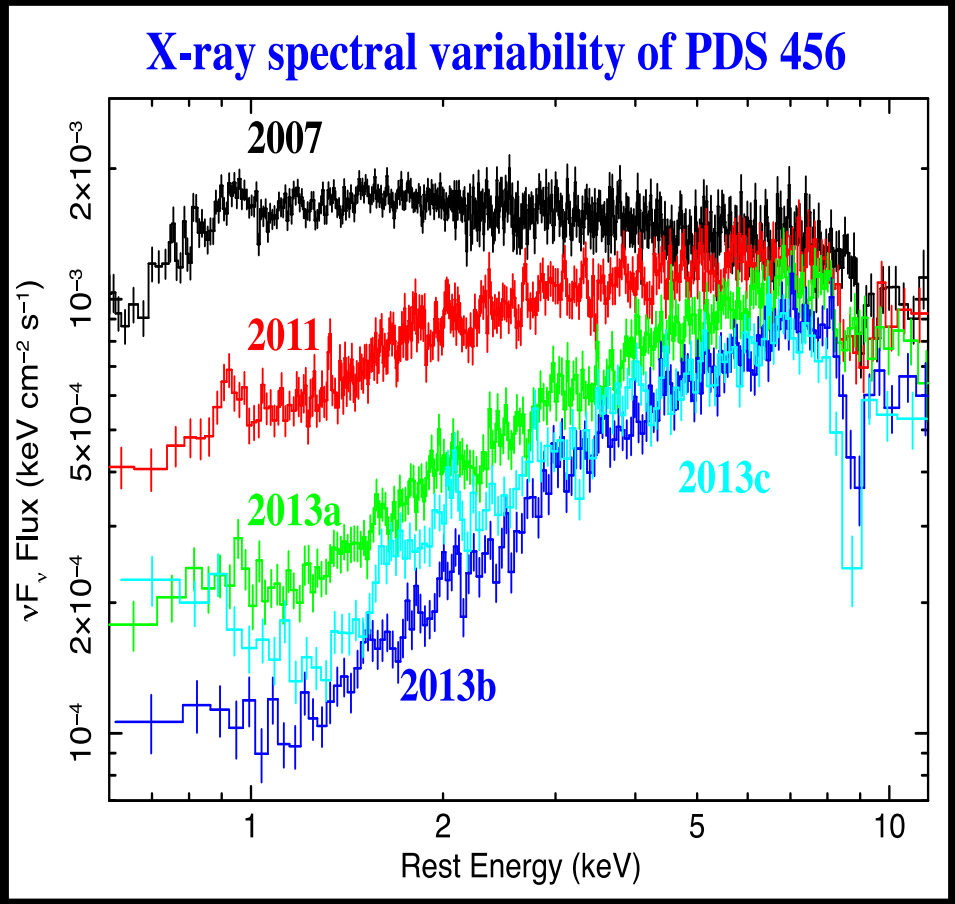
Absorbers variability on timescales 1000-10000s

NGC1365



Risaliti et al. 2005

(See also Krongold et al. 2007 on NGC4051; Behar et al. 2010 on PDS456, Braito et al. 2007 on MCG5-23-16; MC et al. 2009 on Mrk509 etc.)

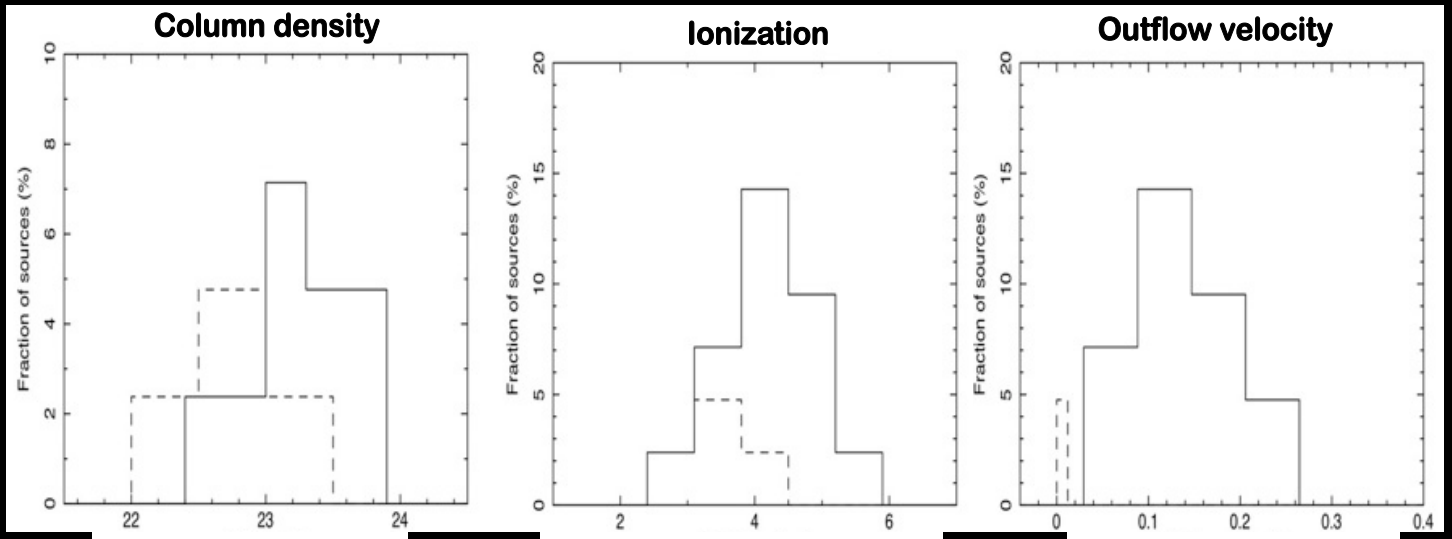


Reeves et al. '10, '13, '15

N.B: Variability allows to place robust limits on location, mass, etc.

The "new" X-ray view: (Not only WAs but) UFOs in ~30-40% of AGN & QSOs

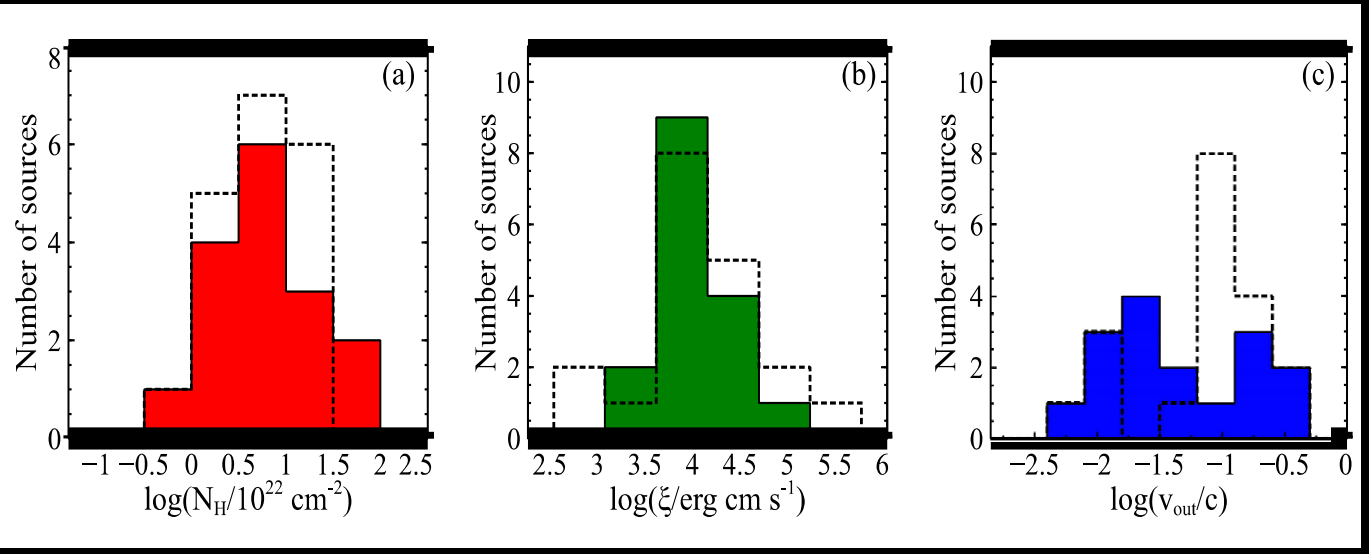
XMM-Newton sample of nearby AGNs (Seyferts)



Tombesi, MC, et al. 2010, 2011 (A&A, 521, 57; ApJ, 742, 44)

Not only WAs in AGN and QSOs, but UFOs (Ultra-Fast Outflows) have been found and are quite common

Suzaku sample of AGNs (Sey+RGs+RQQs)



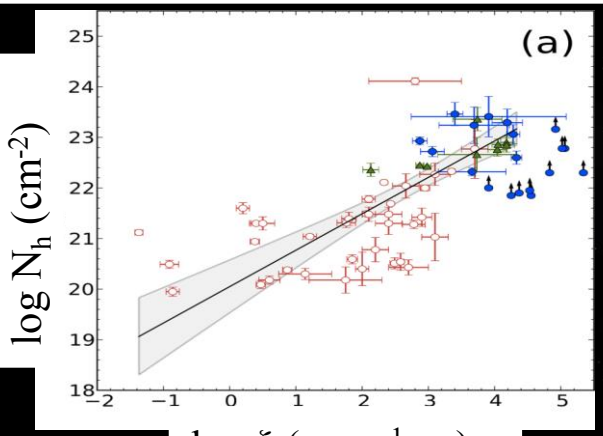
- 11/44 objects with outflow velocity >0.1c (≈25%)
- Blue-shift velocity distribution ~0-0.3c, peak ~0.1c
- Average outflow velocity 0.110±0.004 c

Table 5. Outflow velocity comparison

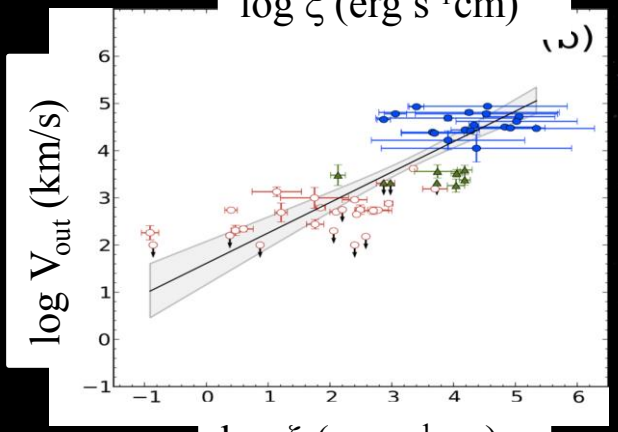
Velocity ($km\,s^{-1}$)	*Suzaku*	*XMM-Newton*
No outflow	3/20	2/19
$0 < v_{out} \leqslant 10,000$	5/20	2/19
$v_{out} > 10,000$	11/20	15/19
$v_{out} \geqslant 30,000$	8/20	9/19

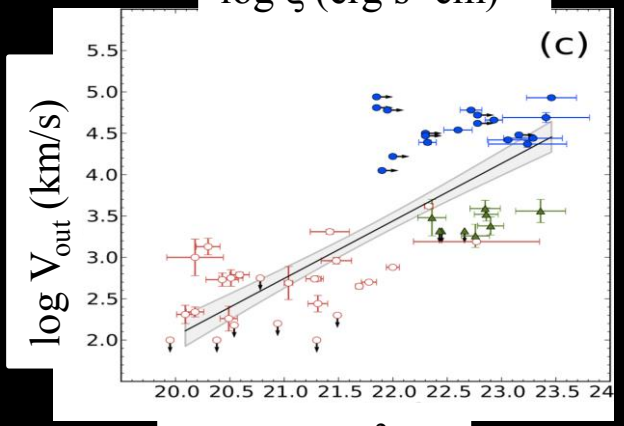
Gofford et al. 2012

The "new" (unifying) X-ray view of UFOs and non-UFOs (WAs)

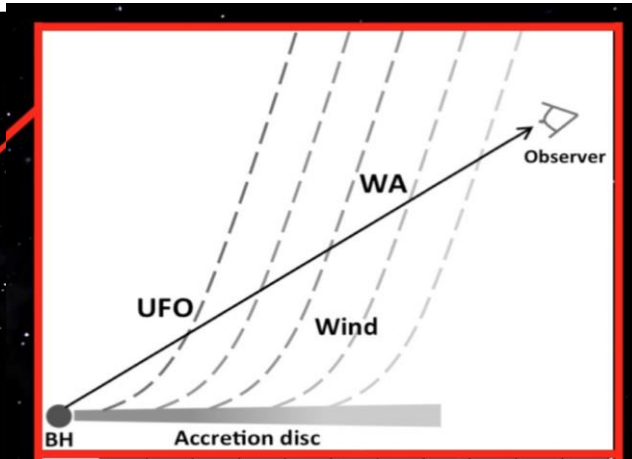


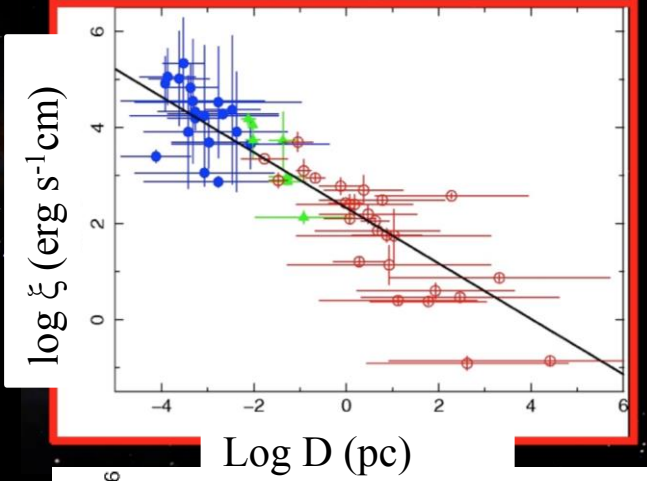
Several Press releases
in '10, '12 and '13
(also NASA
and ESA in 2012)



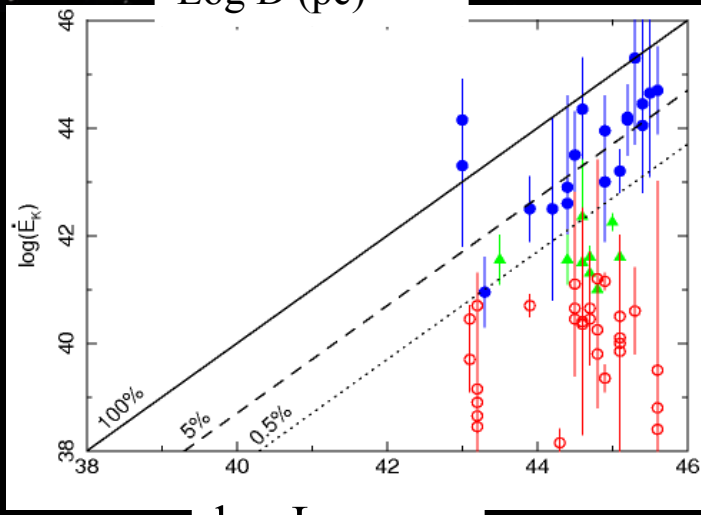


Tombesi, MC et al., '12b, '13





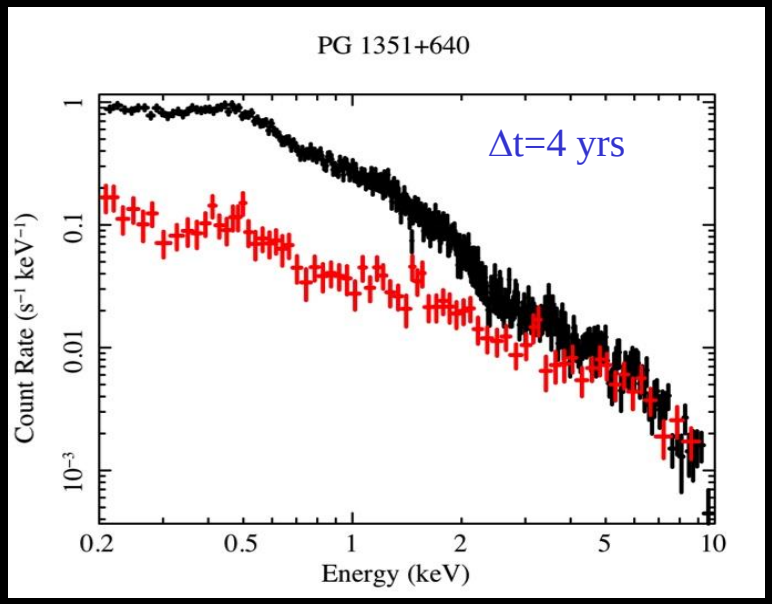
log $\dot{E}_{out}$



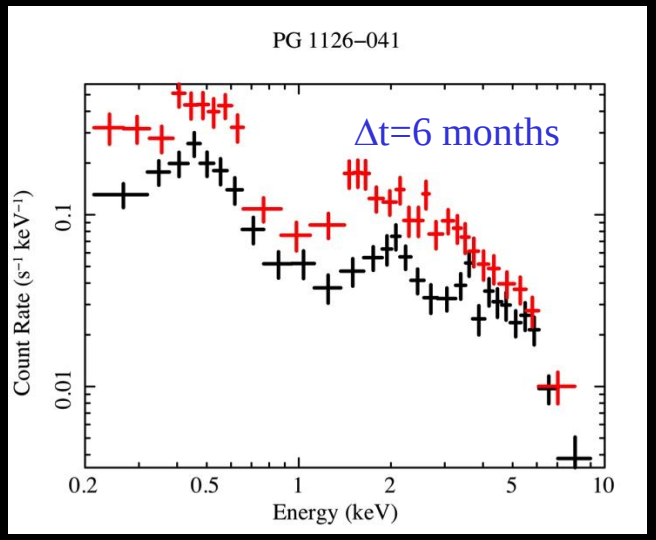
→ UFOs kinetic energy >1% of Lbol
→ Feedback (potentially) effective!

The "new" X-ray view: *Variability in (nearby) PG QSOs*

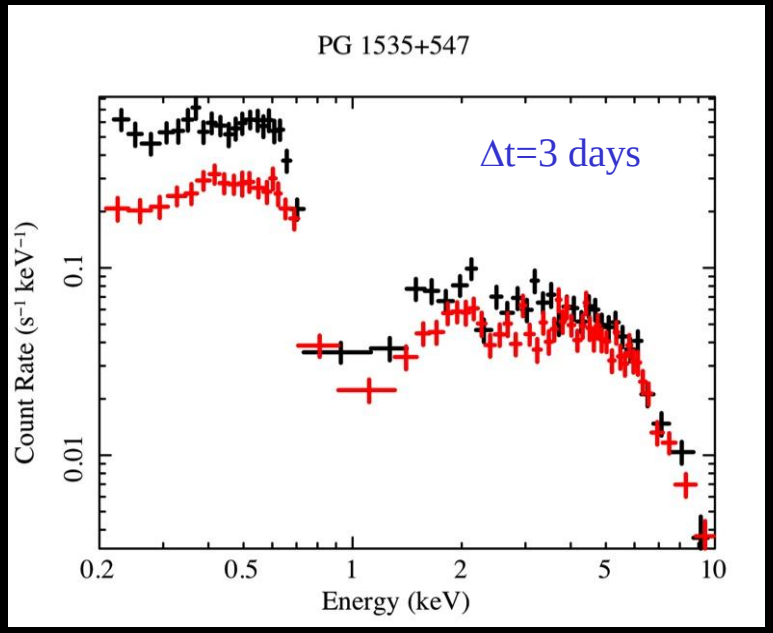
Sample: 15 UV *AL QSOs with 32 XMM exposures



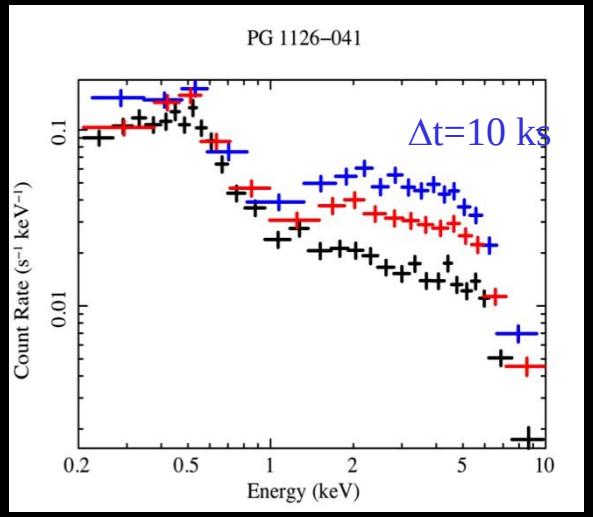
on time scales of years



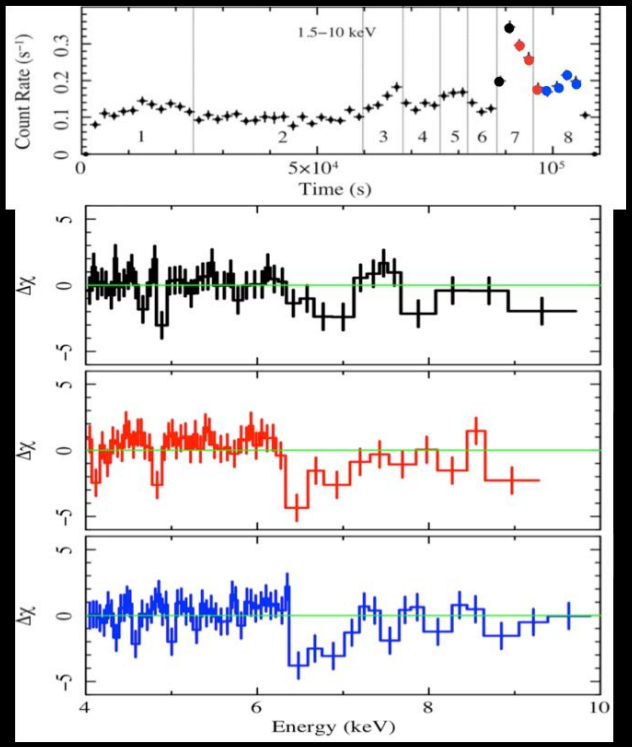
on time scales of months



on time scales of days



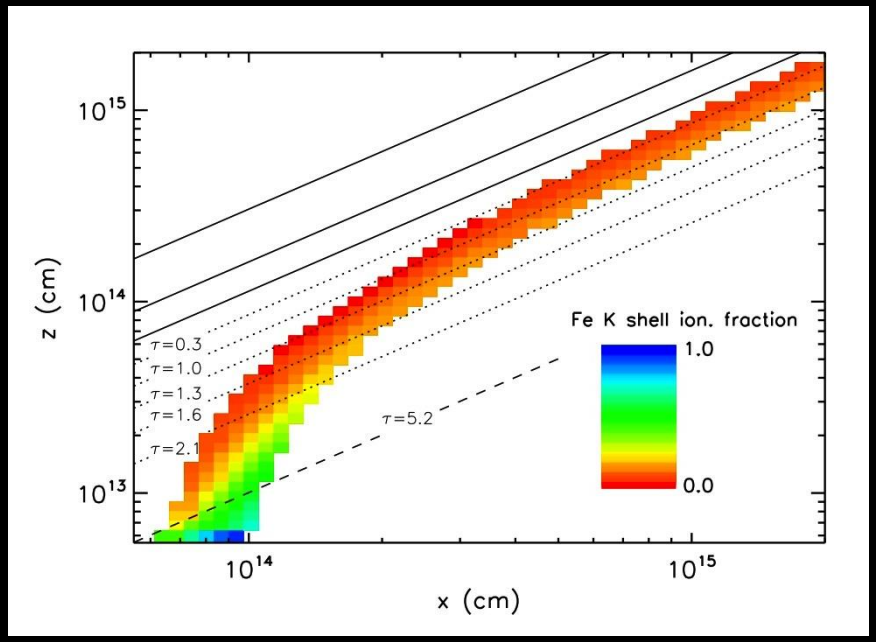
on time scales of hours



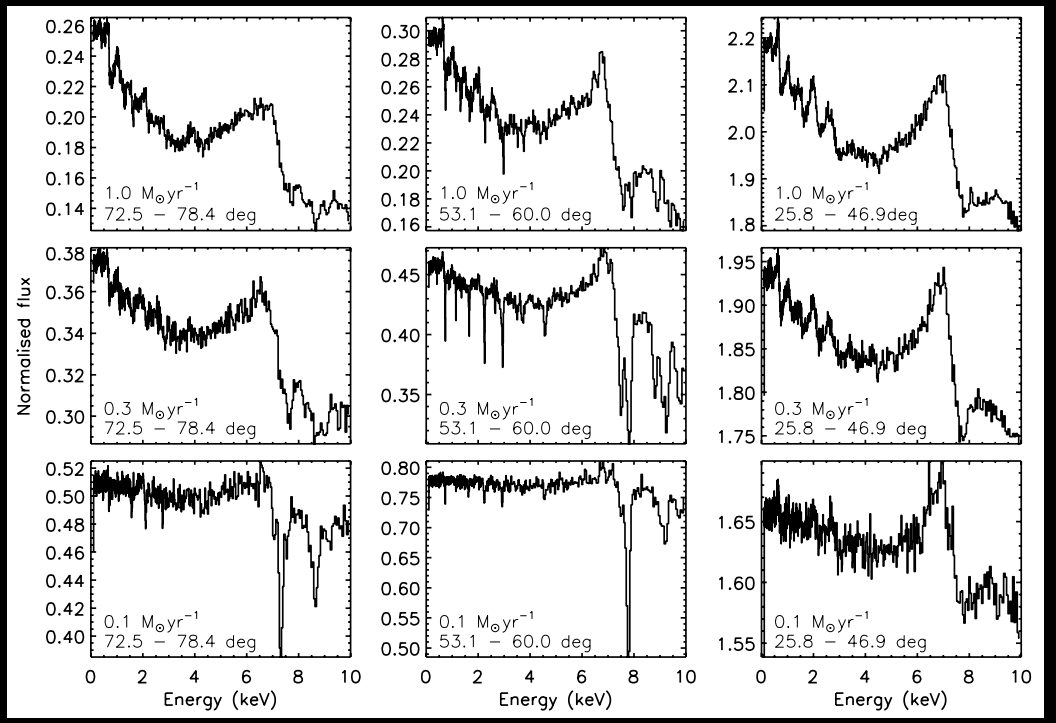
Giustini, MC, et al. 2012

UFOs/outflows/winds in AGNs & QSOs: Possible models

Radiatively driven accretion disc winds



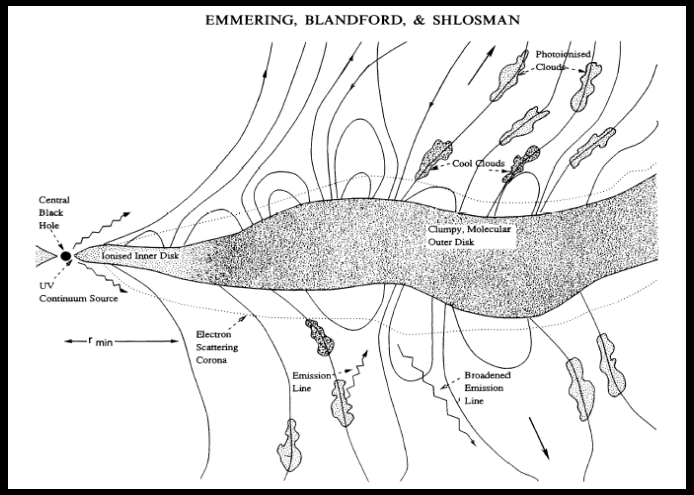
Sim et al., ’08, ’10ab



Murray et al. ‘95,

…and/or…

Magnetically driven winds from accretion disk



Emmering, Blandford & Shlosman, ’92;
Kato et al. ‘03

Fukumura, et al. 2010
Kazanas et al. 2012

Proga et al. ’00; ‘10

Most important open issues: we need a better & complete census on:

- N_w (cm^{-2})
- Location (R, DeltaR)
- Ionization state (ξ)
- Velocity
- Covering factor
- Frequency in AGNs
- Density

Fundamental to:

i) PHYSICS of accelerated and accreted flows (winds?, blobs?, acceleration mechanism? etc.)

ii) COSMOLOGY: i.e. estimate the mass outflow rate, thus the impact of AGN outflows on ISM and IGM enrichment and heating!

WA Location and feedback budget:

NGC3783: ~25pc (Gabel+05); NGC4151: ~0.1 pc (Crenshaw & Kraemer 09); NGC5548 < 7pc (Kraemer+09); Mrk279 < 29 pc (Ebrero, EC+10); NGC3516: 0.2 pc (Netzer+02); NGC 4051 0.5-3 l.d. 1-3pc (Krongold+07, Steenbrugge+09); Mrk 509: >0.04 pc (Ebrero+11; Detmers+11; Kaastra,+11)

UFOs:

Sample of AGN and QSOs: few 100s to 1000s Rs (Tombesi+11, Reeves+, Chartas+, Gofford+)

Outflow rate: $\dot{M}_{out} = 4\pi r N_H m_H C_g v_r$ $M_{sun}yr^{-1}$

Distance, Filling & covering factors often unknown in particular in high-z QSOs !!!

Kinetic energy: $L_{kin} = 1/2\,\dot{M}_{out}\,v^2$

$\dot{M}_{out} \gg \dot{M}_{acc}$, $e_w \gg$ a few %

WAs seem to be energetically unimportant, unlike UFOs

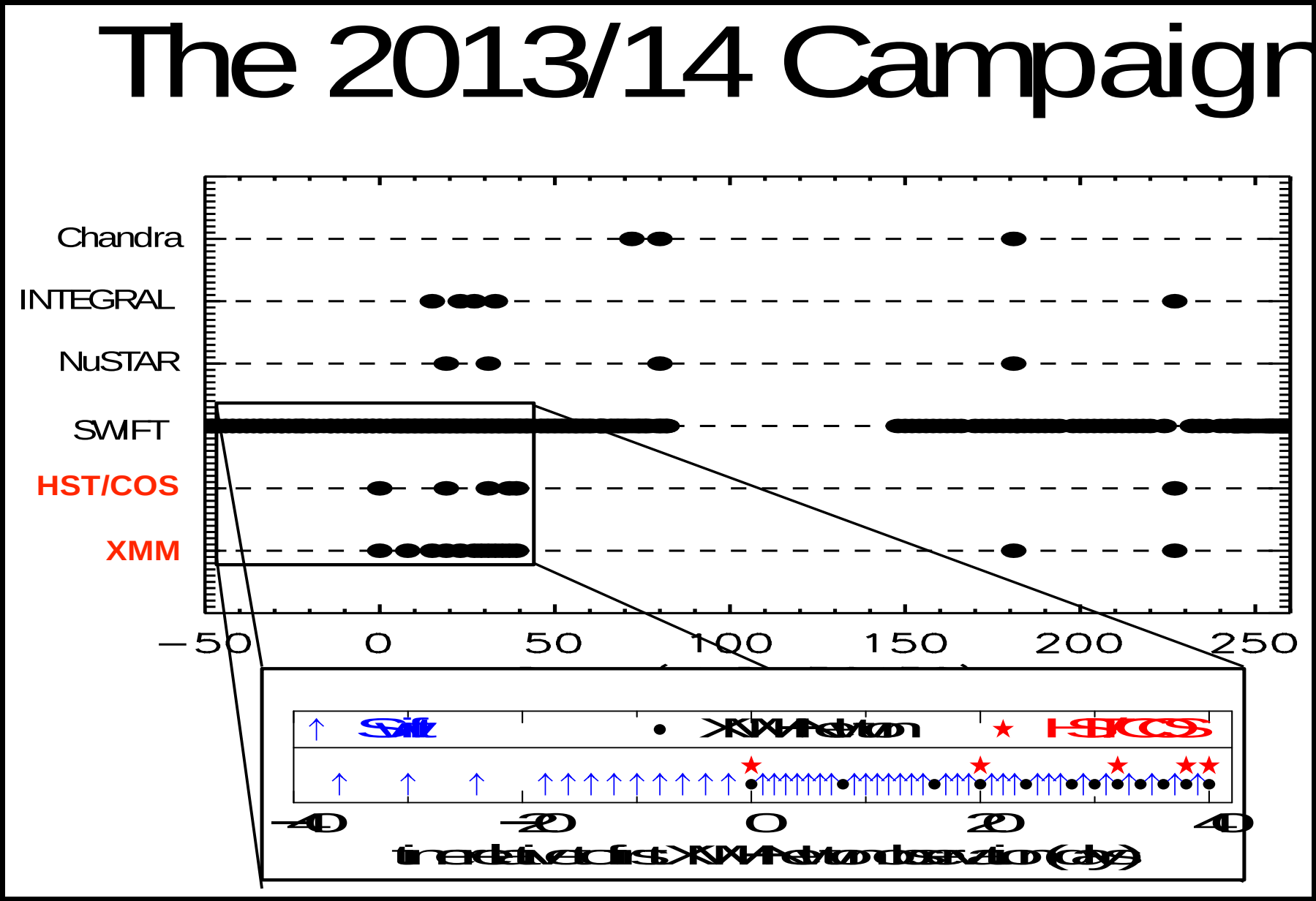
Current estimates go from: dM/dt ($\propto L_{kin}$) few % to several % dM_{acc}/dt ($\propto L_{edd} \propto L_{bol}$)

This is a fundamental (and still open) issue

Elvis et al. '00, Creenshaw et al. '03, King et al. '03, Chartas et al. '03, Yaqoob et al. '05, Blustin et al. '05, Risaliti et al. '05, Krongold et al. '07

1st highlight: with a long and multiwavelength campaign on the Seyfert 1 galaxy NGC5548

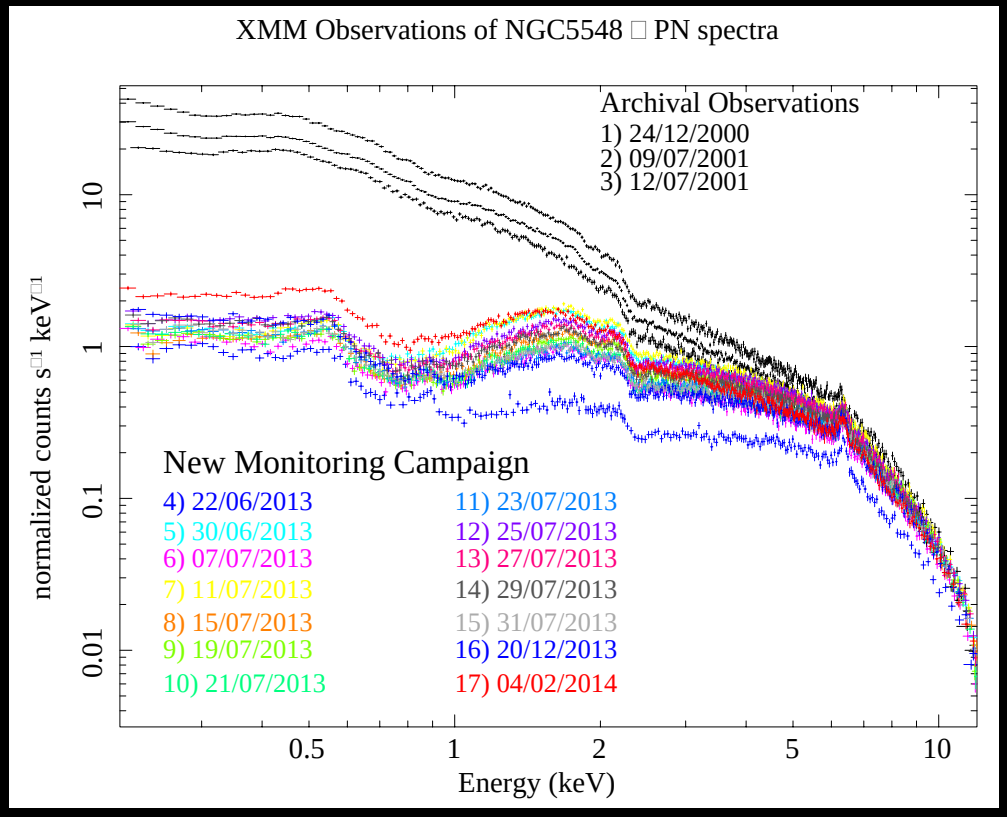
Kaastra, Kriss, MC, et al., 2014, Science



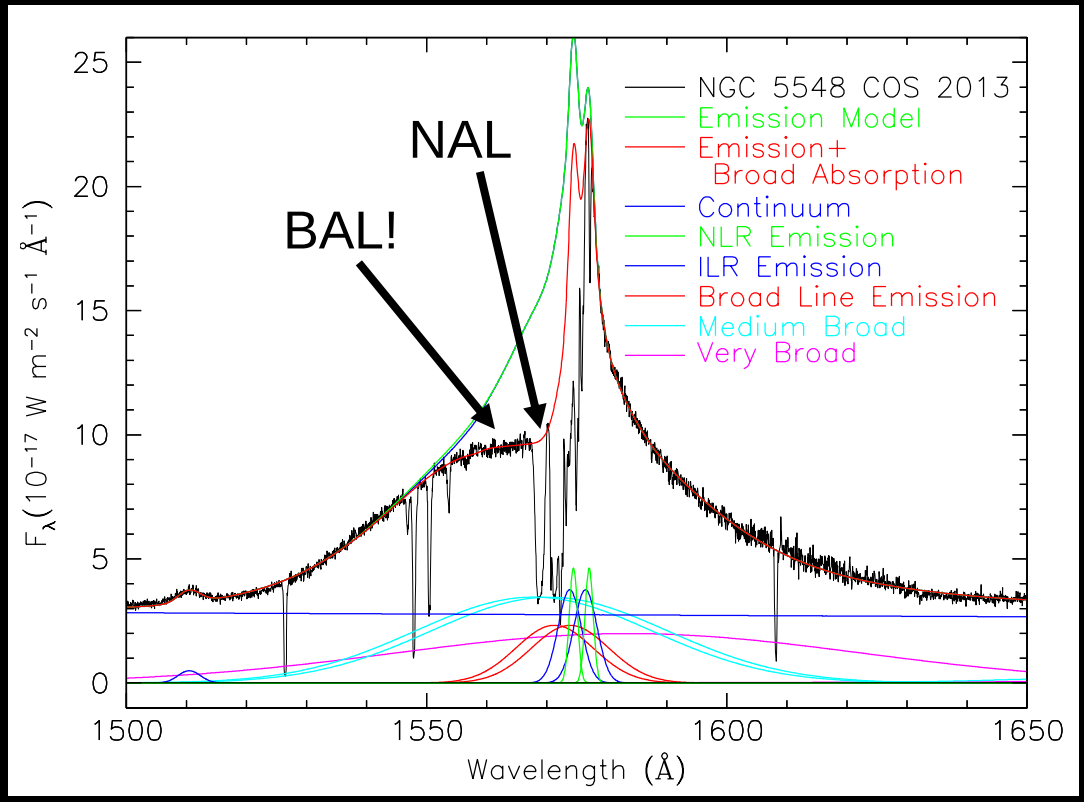
The "new" X-ray view: *Absorber variability measured simultaneously in X-rays and UV!*

Kaastra, Kriss, MC, et al., 2014, Science

XMM-Newton Large Program (+ Nustar + Chandra)



Simultaneous HST/COS



→ Best detailed measurements possible only with a multi-ni campaign

(One) Possible model: an accretion disc outflowing wind

Absorber/obscurer velocity
(up to 5000 km/s)

+ variability
(within 2 days)

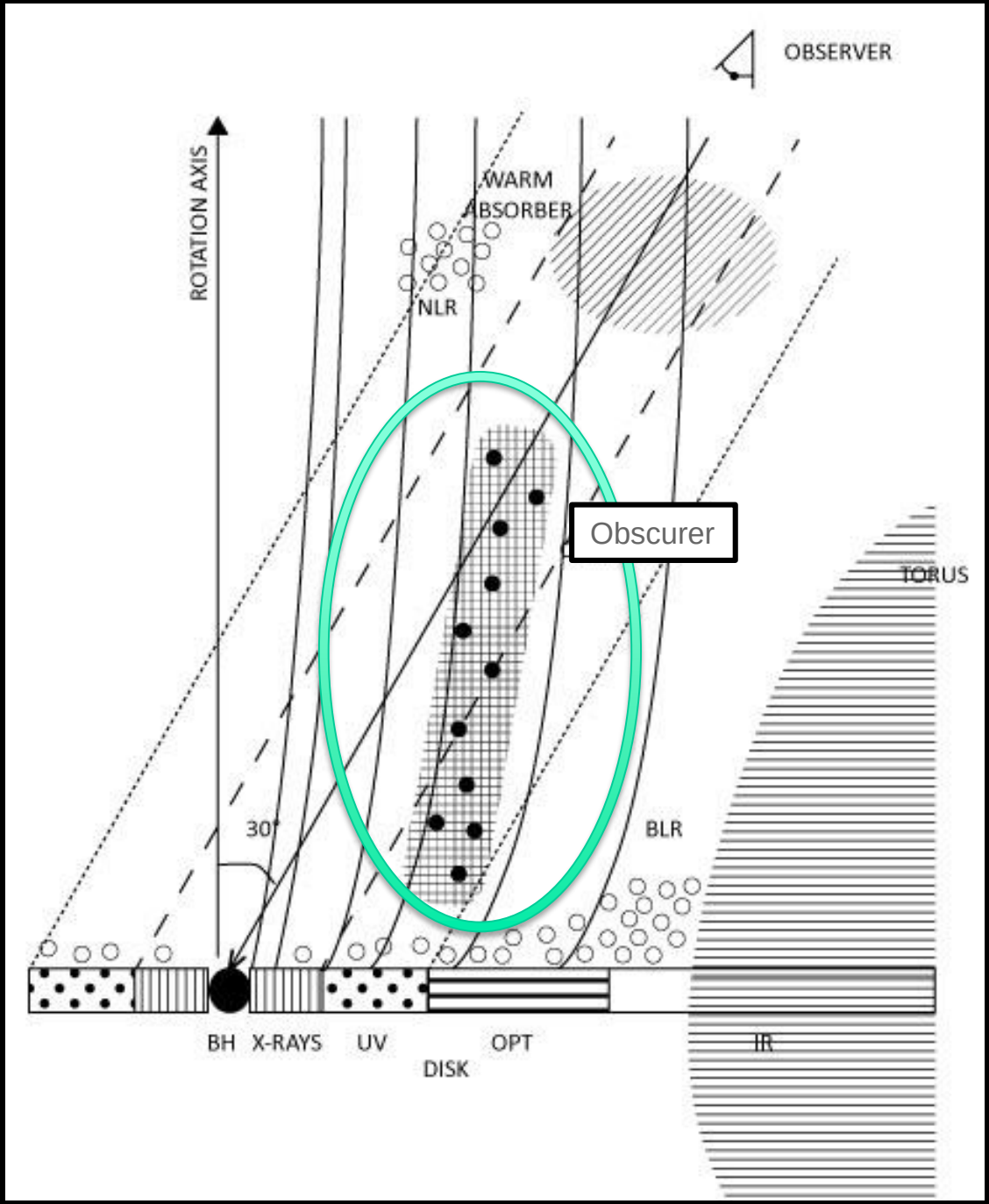
+ partial covering
(30-80%)

+ long-lasting event
(>2.5 years)

+ location
(n sensitive lines + T_{rec} prop. 1/n)

+ poloidal
(inclination=30deg)

→ Best consistent with origin in accretion disc wind (btw acting also as self-shielding gas)
(w.r.t distant torus or small BLR clouds)

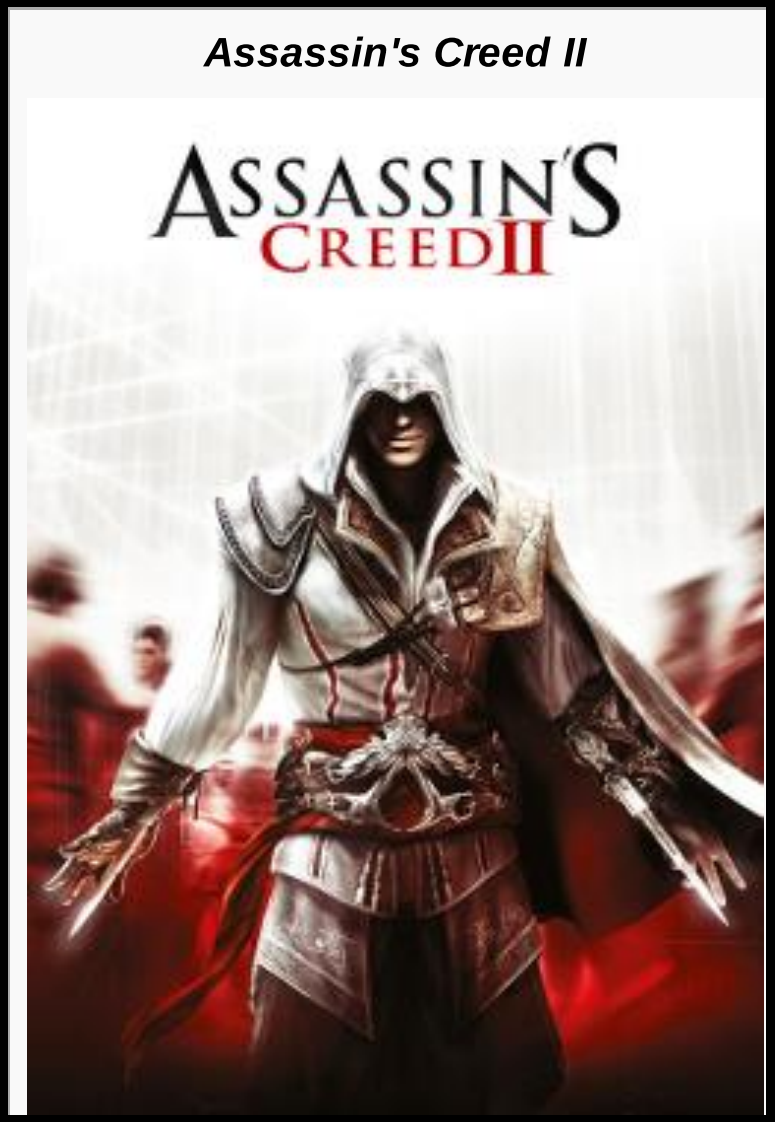


N.B: $L_{kinetic}$ (absorber+WA) still <0.5% L_{bol} in this source

A nice cartoon movie to (strongly) support our press releases

Assassin’s Creed World Director Renaud Person

Assassin's Creed II



Anatomy of an AGN in NGC 5548

2nd highlight: How WAs/UFOs compare/relate to (low-z) colder molecular/gas outflows?

NGC6240

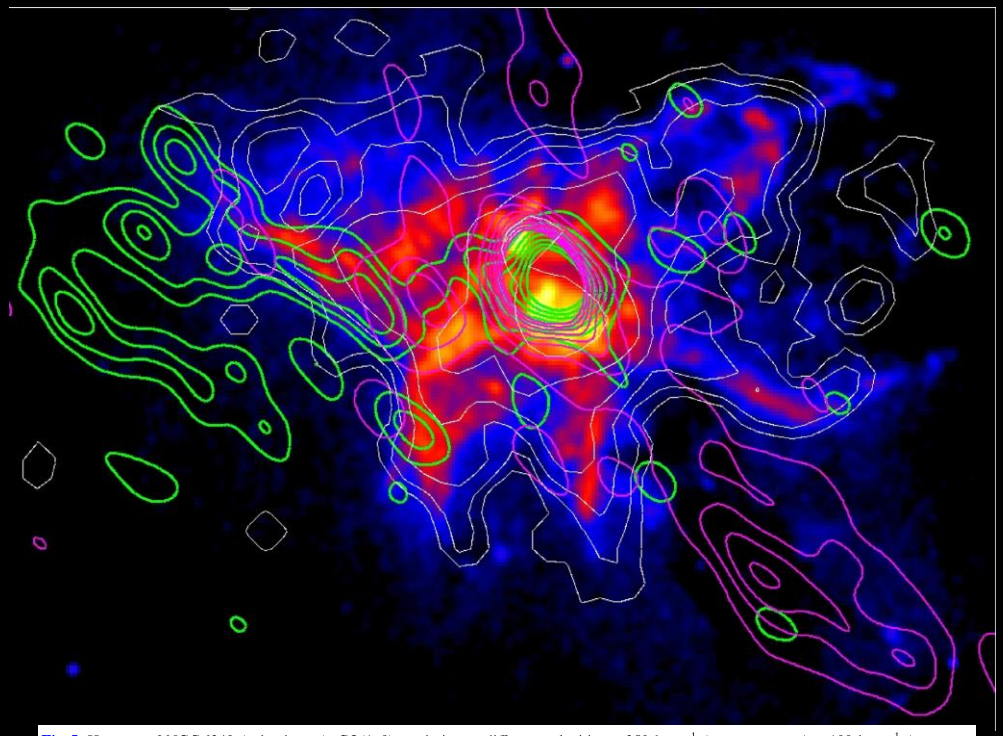
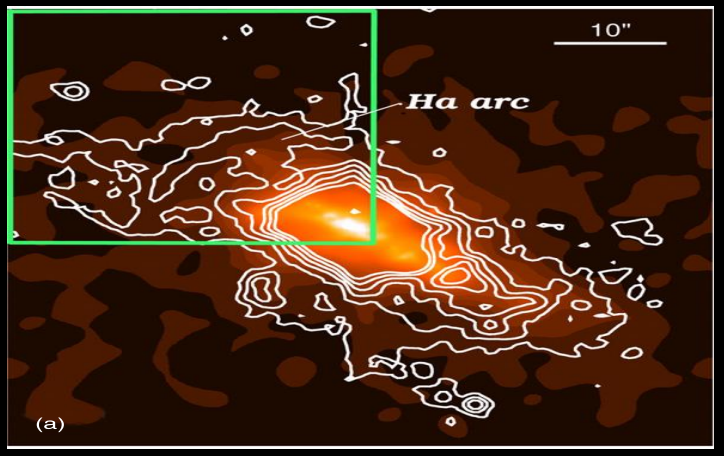
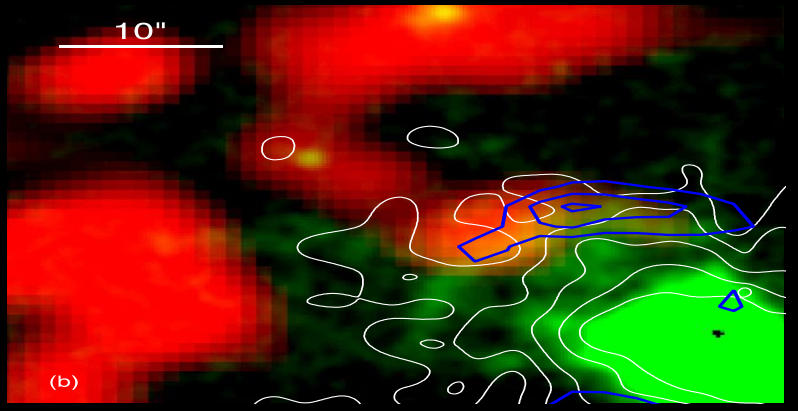
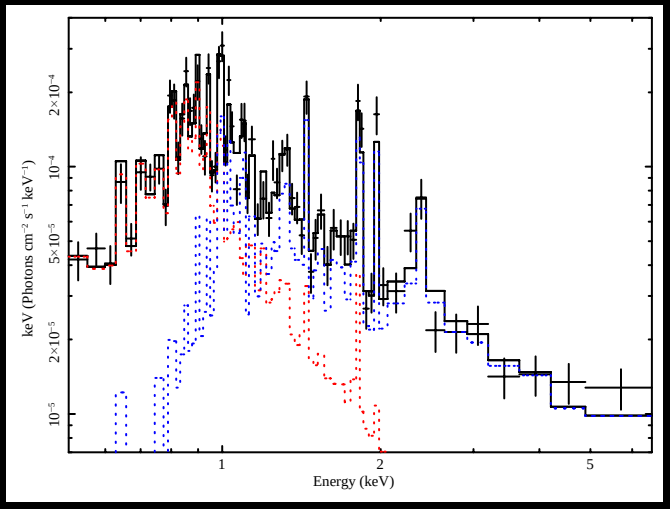


Fig. 5. Hα map of NGC 6240 (color image). CO(1–0) emission at different velocities: −350 km s^{-1} (green contours), −100 km s^{-1} (magenta contours), with respect to the system velocity. Contours are calculated by merging D and A configuration data. *Chandra* 1.6–2 keV emission is shown by white contours.

NGC4151

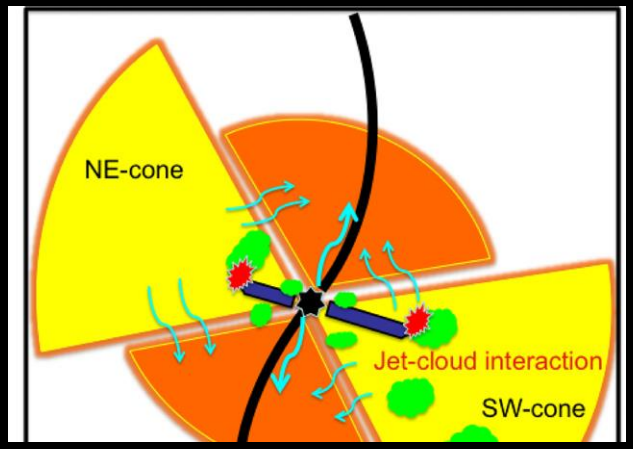






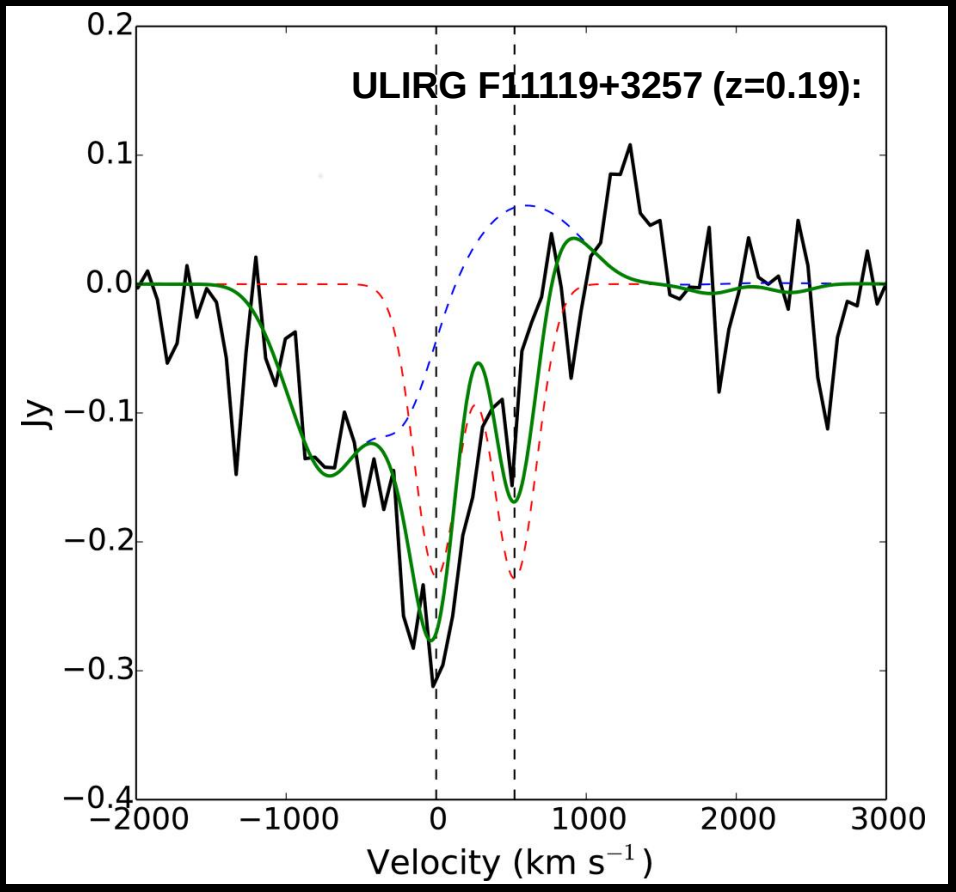
Feruglio et al. 2013

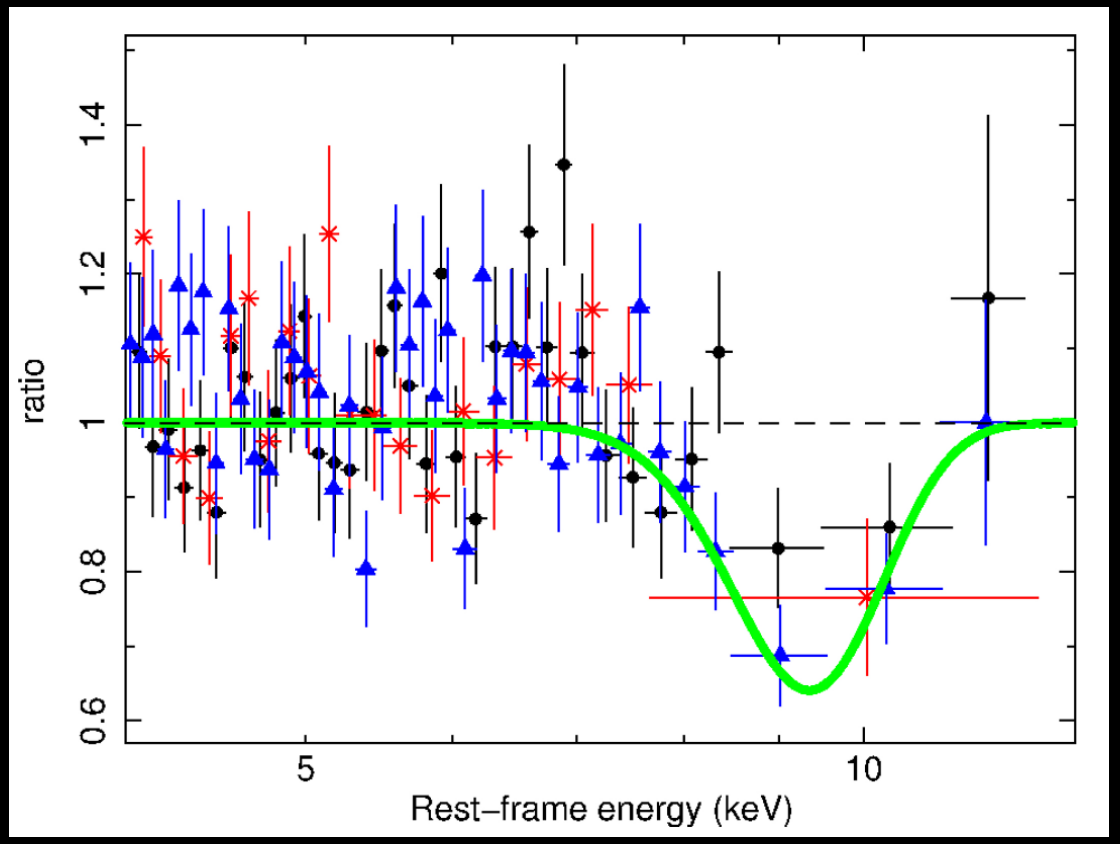
+ Fischer et al.'13; Genzel et al. '14; Harrison et al. '15; Brusa et al., 2015; Cresci et al. 2015, etc.) and molecular gas (Cicone et al.'15; Feruglio et al. '15, etc.)



Wang et al. 2012a,b,c

2nd highlight: Molecular outflow could have been energized by UFO

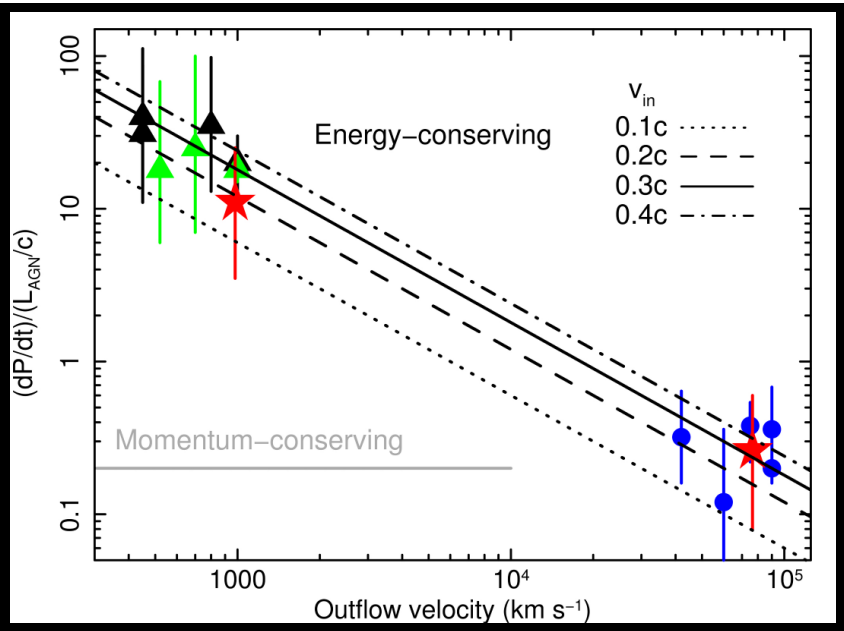




OH doublet at 1000 km/s Veilleux et al. 2013

UFO detection (v~0.3c) consistent with energy-conserving outflow from Inner X-rays to outer molecular outflow

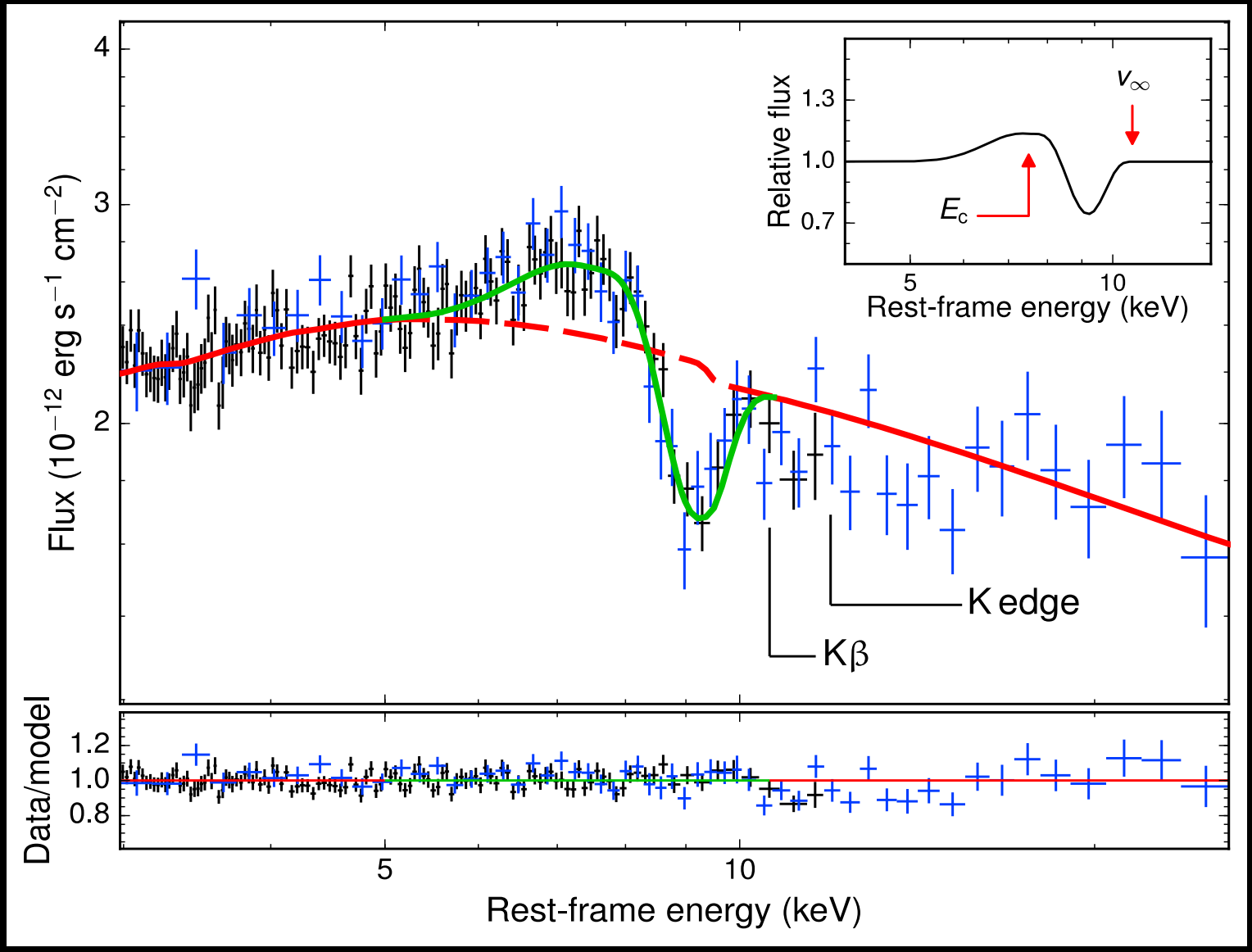
Tombesi et al. 2015, Nature



3rd Highlight: Covering factor measured DIRECTLY from P-Cygni profile

PDS456 (z=0.18)

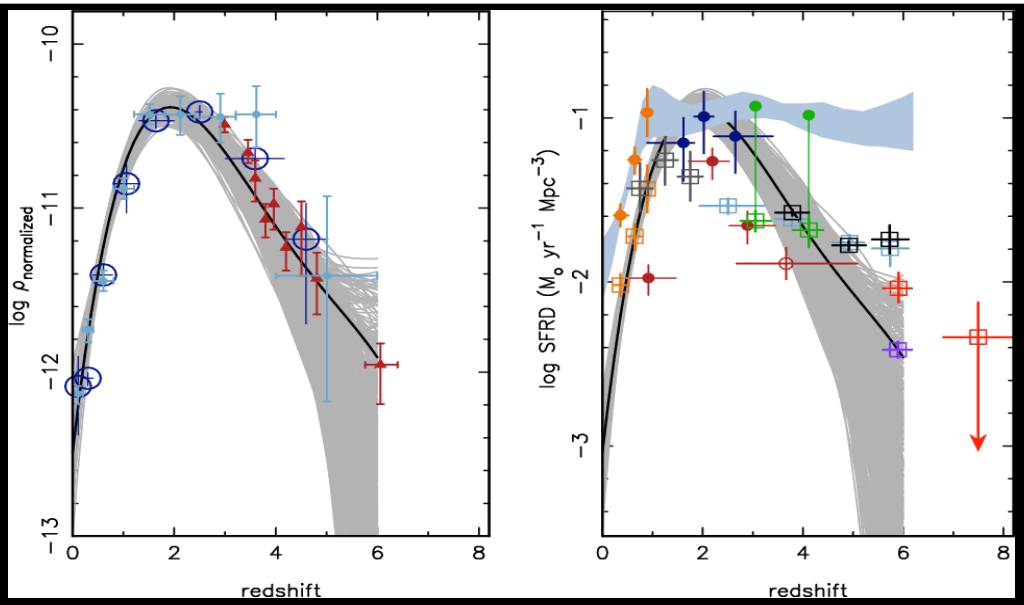
See Nardini's talk



Vout~0.3c and Ω>2π sr

Nardini, Reeves et al., Science '15

4th Highlight: UFOs and/or FeK complex features seen also (no, always!) in lensed high-z QSOs



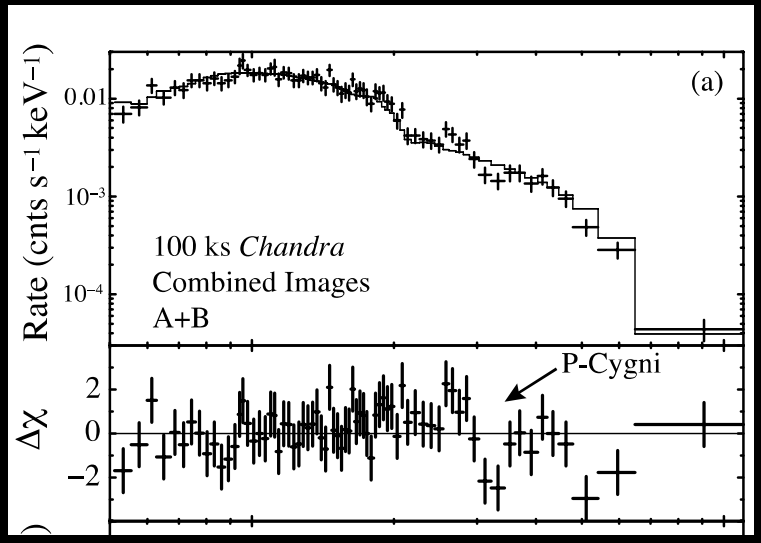
QSO space density

Madau et al. ’96;

SFR space density

Wall et al. ‘05

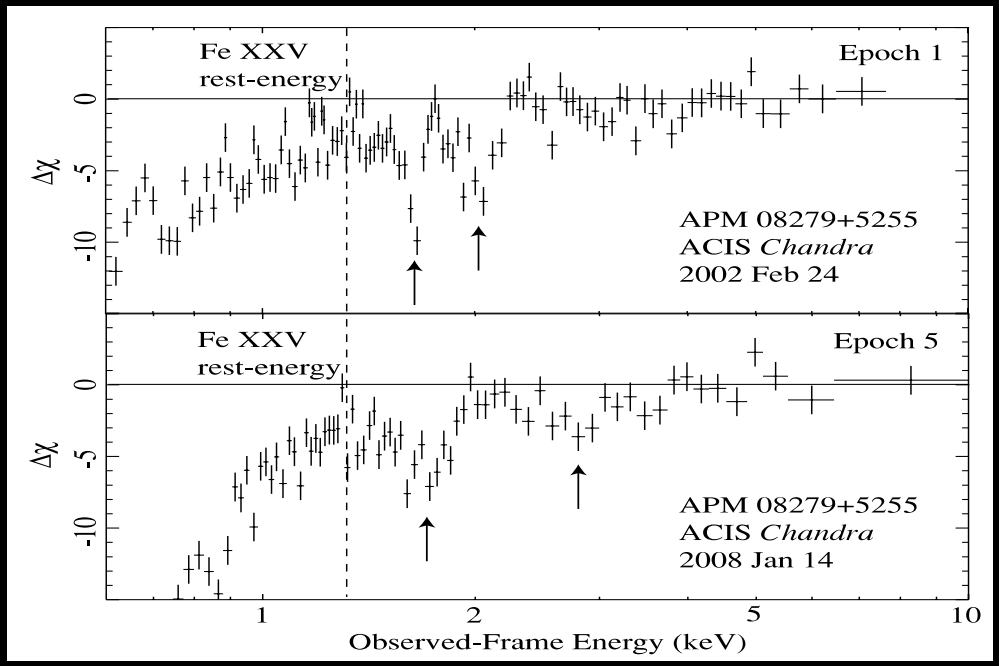
HS0810+554 (z=1.5)
Chartas et al. 2014



APM 08279+5255 (z=3.91)

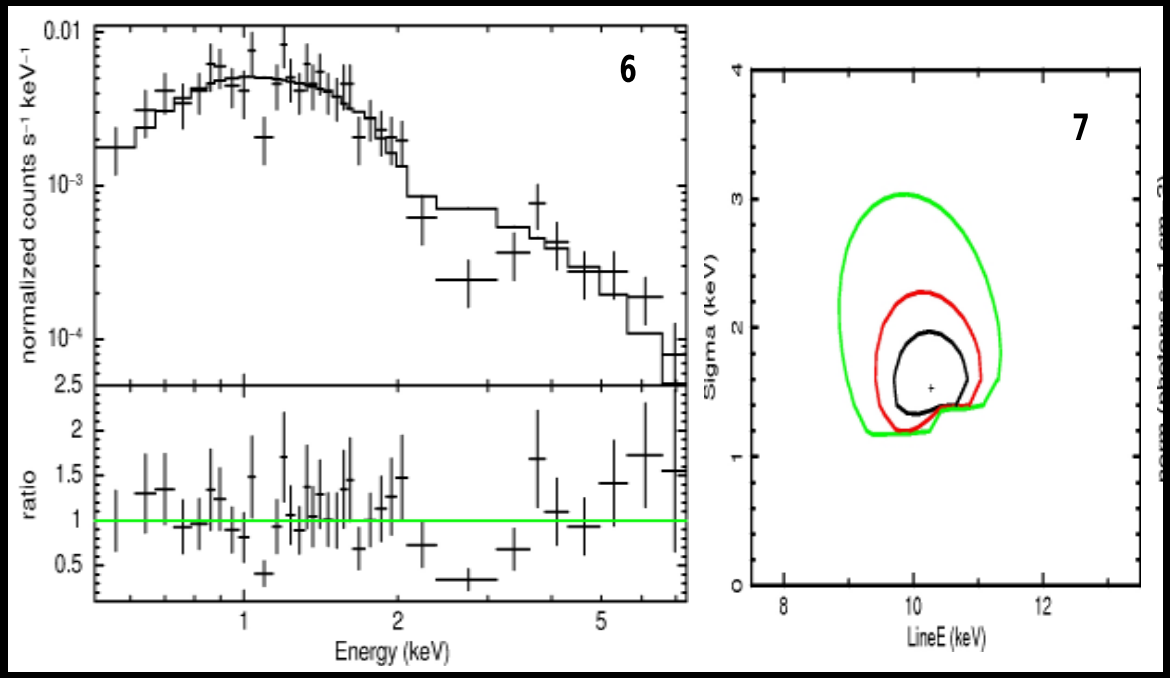
V_{out}~0.2-0.76 c

Chartas et al. 2009



4th Highlight: UFOs seen also (actually always!?) in high-z QSOs

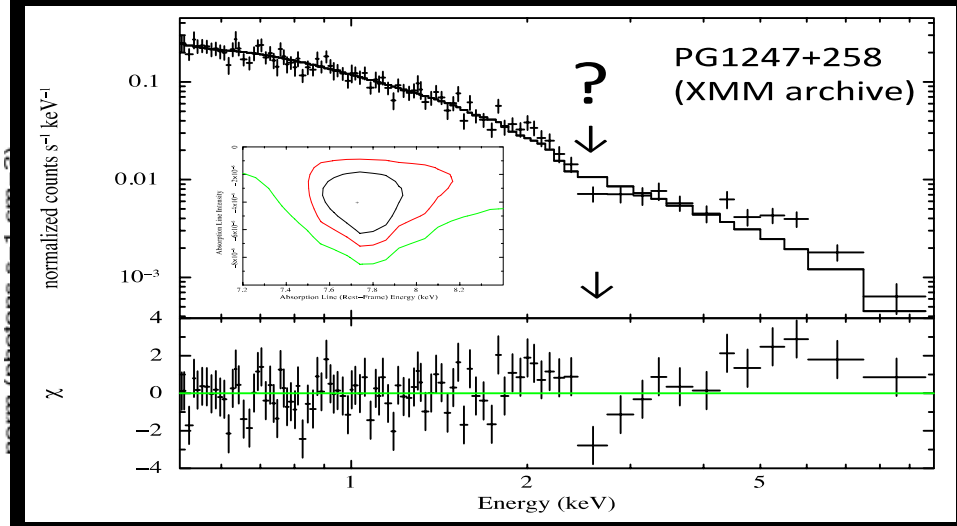
(z=2.73) high-z RQ (NAL) QSO HS1700+6416



Lanzuisi et al., ’12

HS1700: The 4° high-z QSO to show variable, high-v, high-Xi absorbers, but the 1° non-lensed

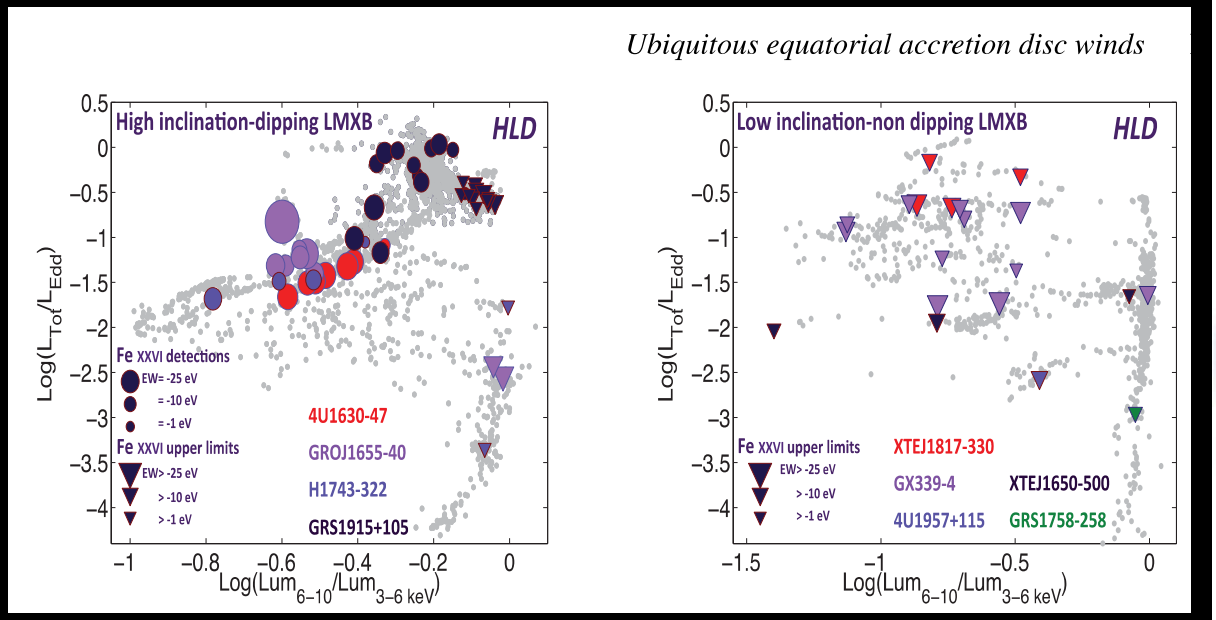
(z=2) PG1247+268

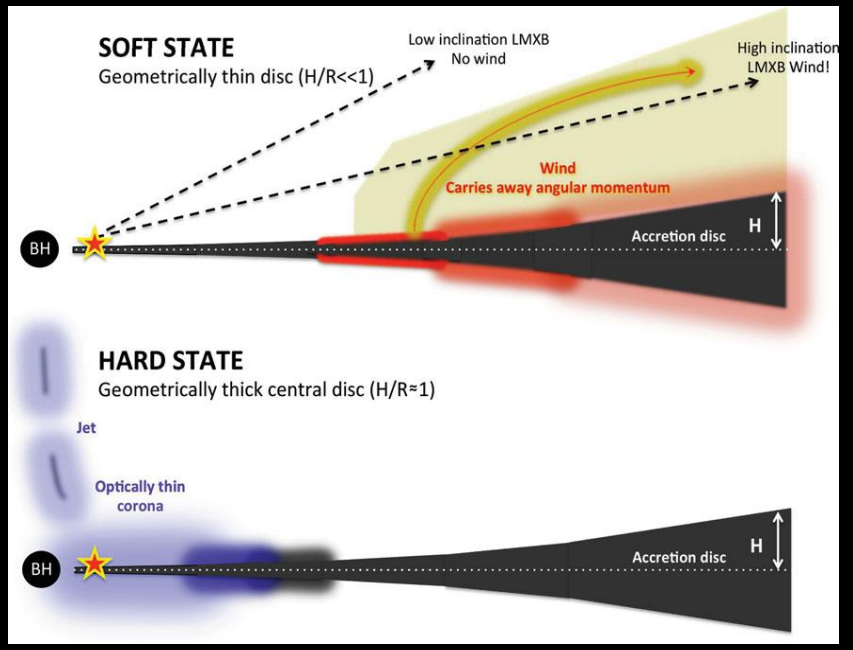


Another high-z UFO candidate?

N.B.: Would be very important also to confirm on other non-lensed, high-z QSOs
→ Desperately need more and longer XMM observations on high-z QSOs

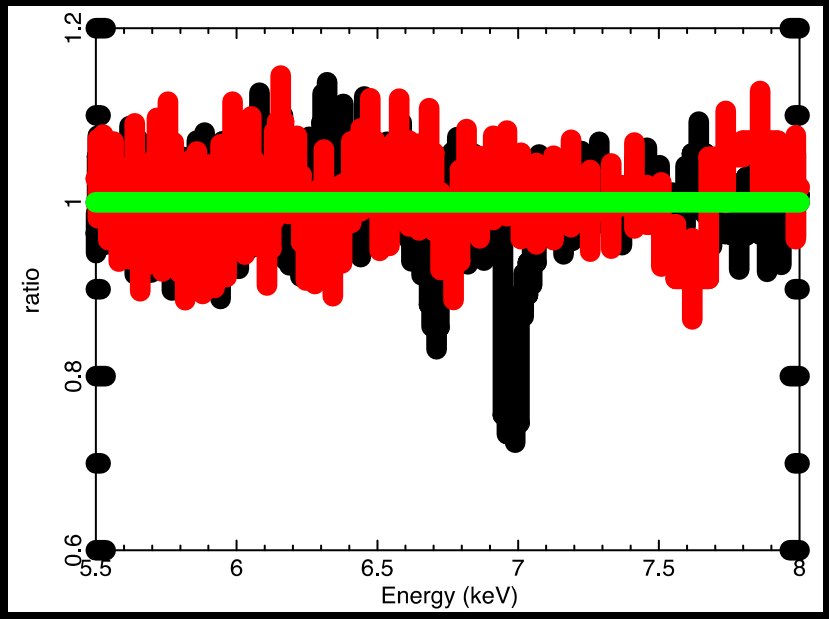
5th highlight: How WAs/UFOs compare/relate to binaries winds and jets?





Ponti et al., 2011

H1743-322 disk-wind detected in soft, disc-dominated state

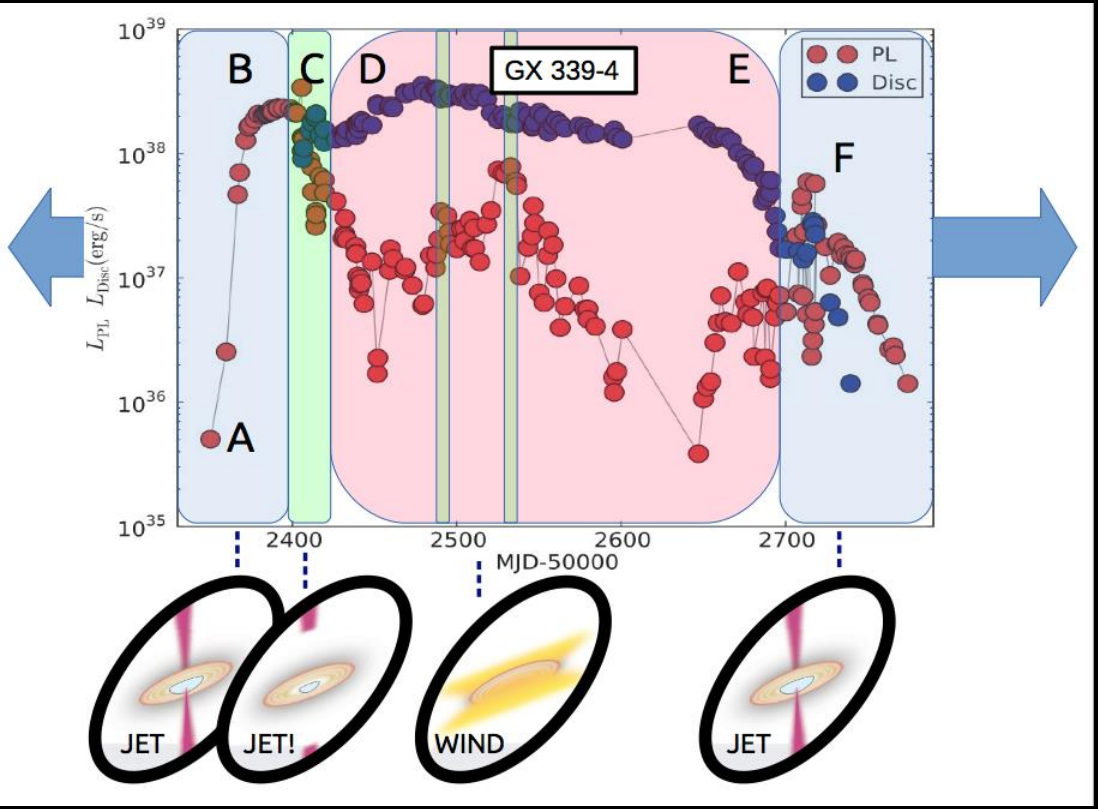


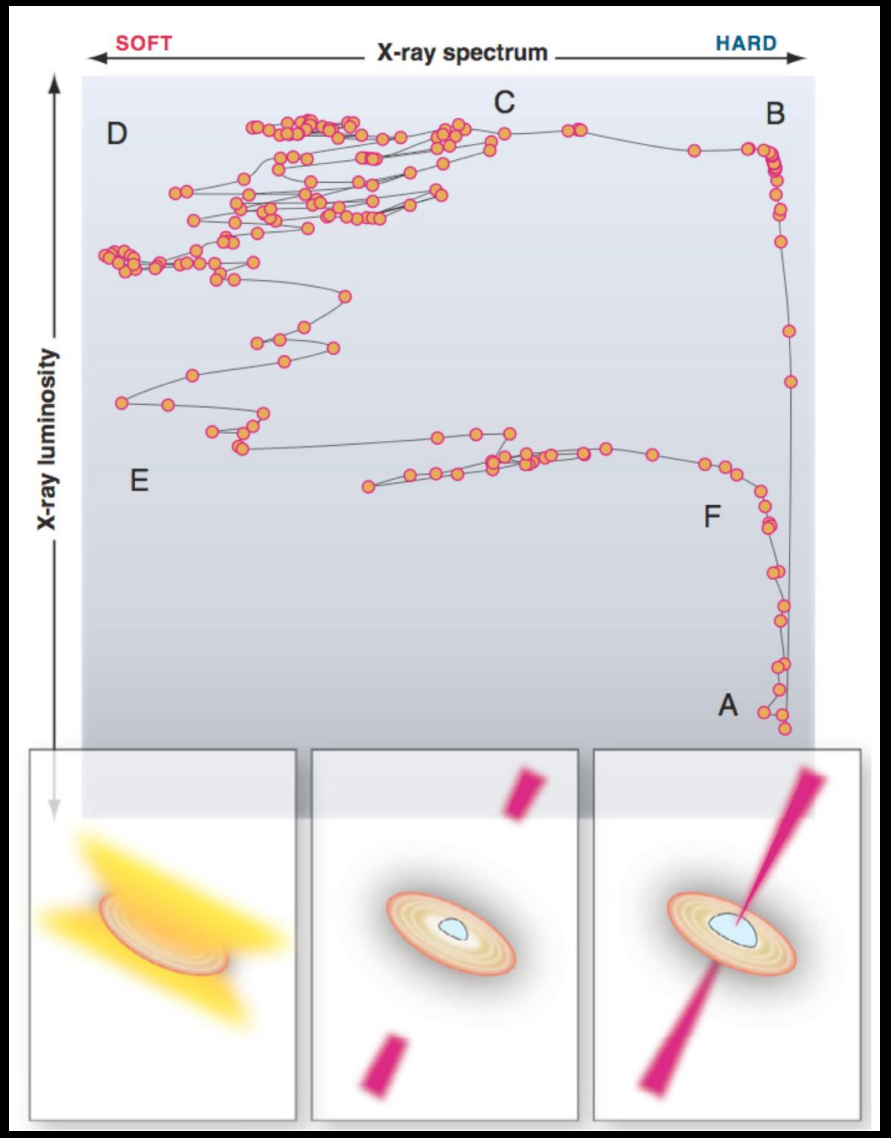
FeXXV and FeXXVI are variable,
and have V_{out}~300-670 km/s

Ionization, Nh, variability similar to UFOs
Large velocities (wrt mass) too

Miller et al., 2006, 2012

5th highlight: How WAs/UFOs compare/relate to binaries winds and jets?





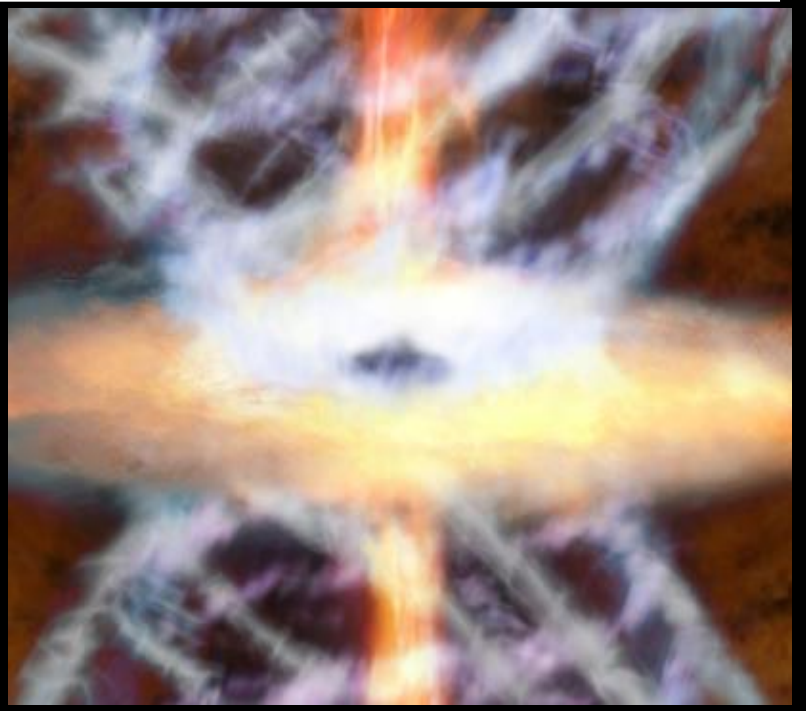
Fender and Gallo, arXiv:1407.3674v1

Summary

- General framework/importance
  - ⇒ *Recognized importance of fast winds/outflows for both feedback and outflows physics*

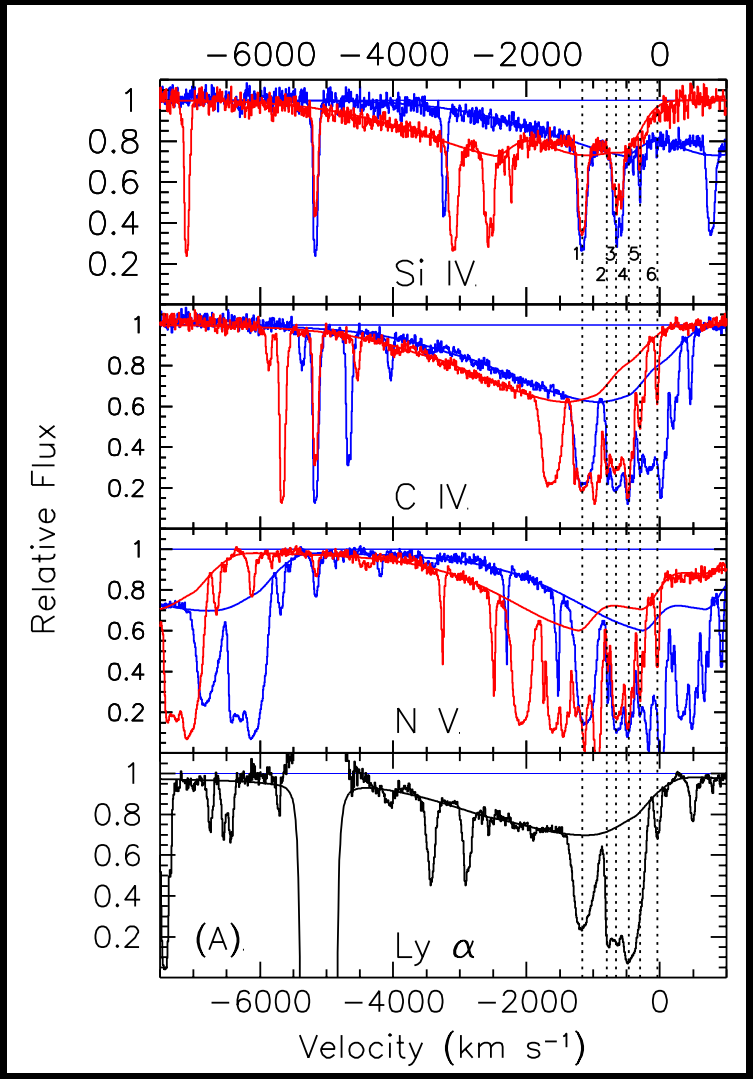
- Critical/remaining open Issues for UFOs/winds
  - ⇒ *Acceleration mechanism?*
  - ⇒ *Covering & filling factor in high-z QSOs ?*
  - ⇒ *How/how much/where energy released in ISM?*

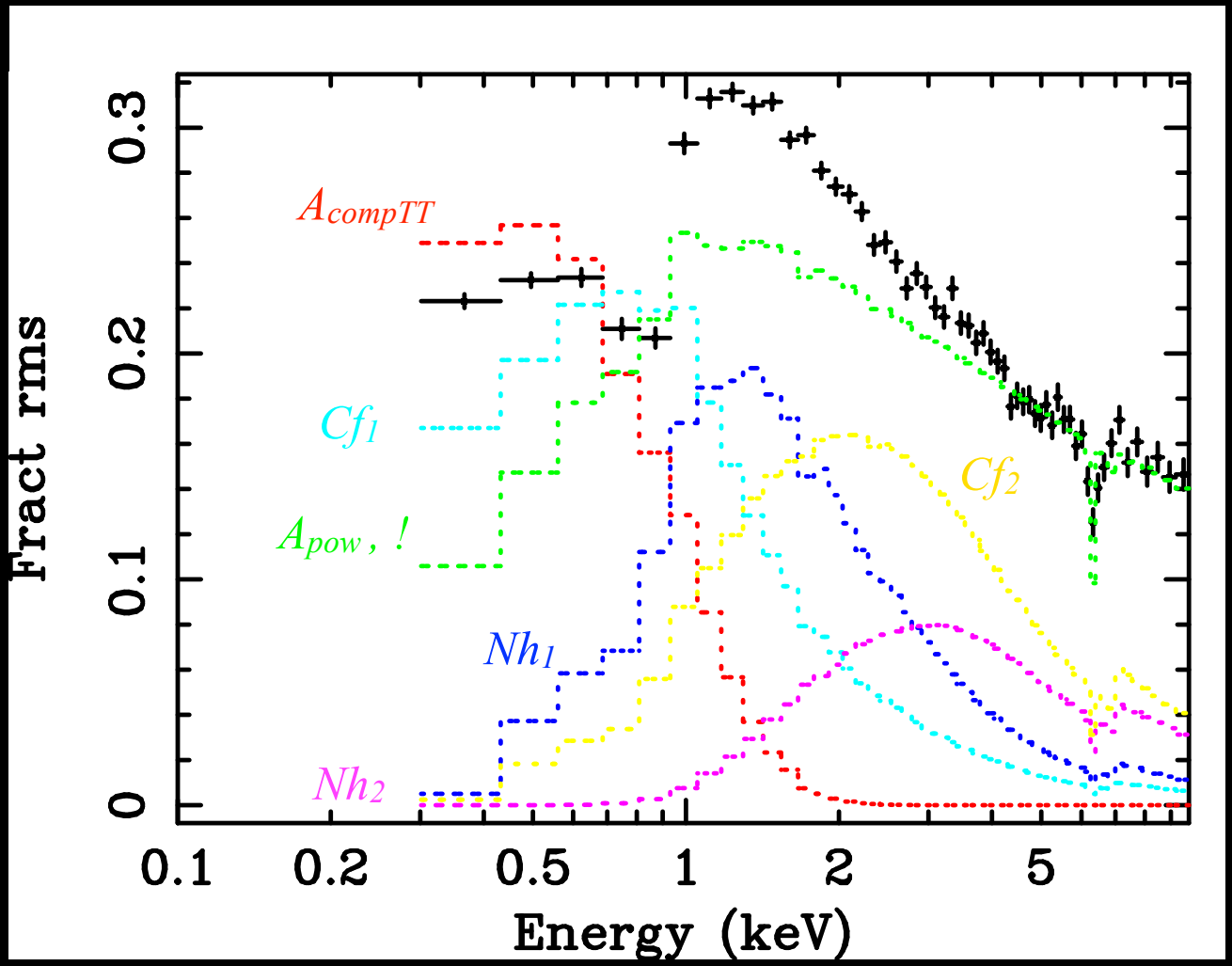
- 5 highlights:
  - ⇒ X-ray + UV (deep) coverage
  - ⇒ *X-ray fast outflows linked to molecular outflows?*
  - ⇒ *Direct measurement of Cf*
  - ⇒ *High-z QSOs, none featureless….*
  - ⇒ *Comparison with binaries states?*



Thank you very much for your attention

Combining UV and X-ray spectral+timing information





UV HST (COS)

Kriss et al., ‘15, to be submitted

XMM (EPIC)

MC+ ’15, to be sumitted