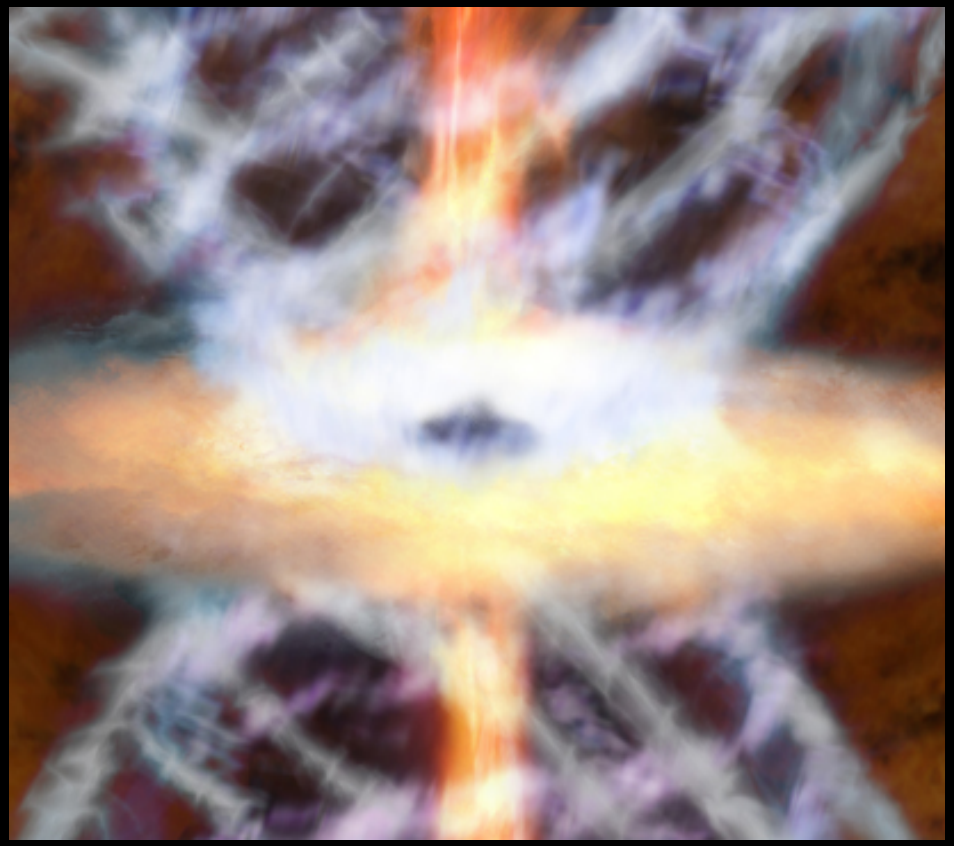
Ultra-fast outflows (aka UFOs) in AGNs and their relevance for feedback

Massimo Cappi

INAF/IASF-Bologna



Tombesi F., MC, et al. ’10a+b;’11a;’12a, ‘12b in prep.
(and ESA/NASA/INAF press release)

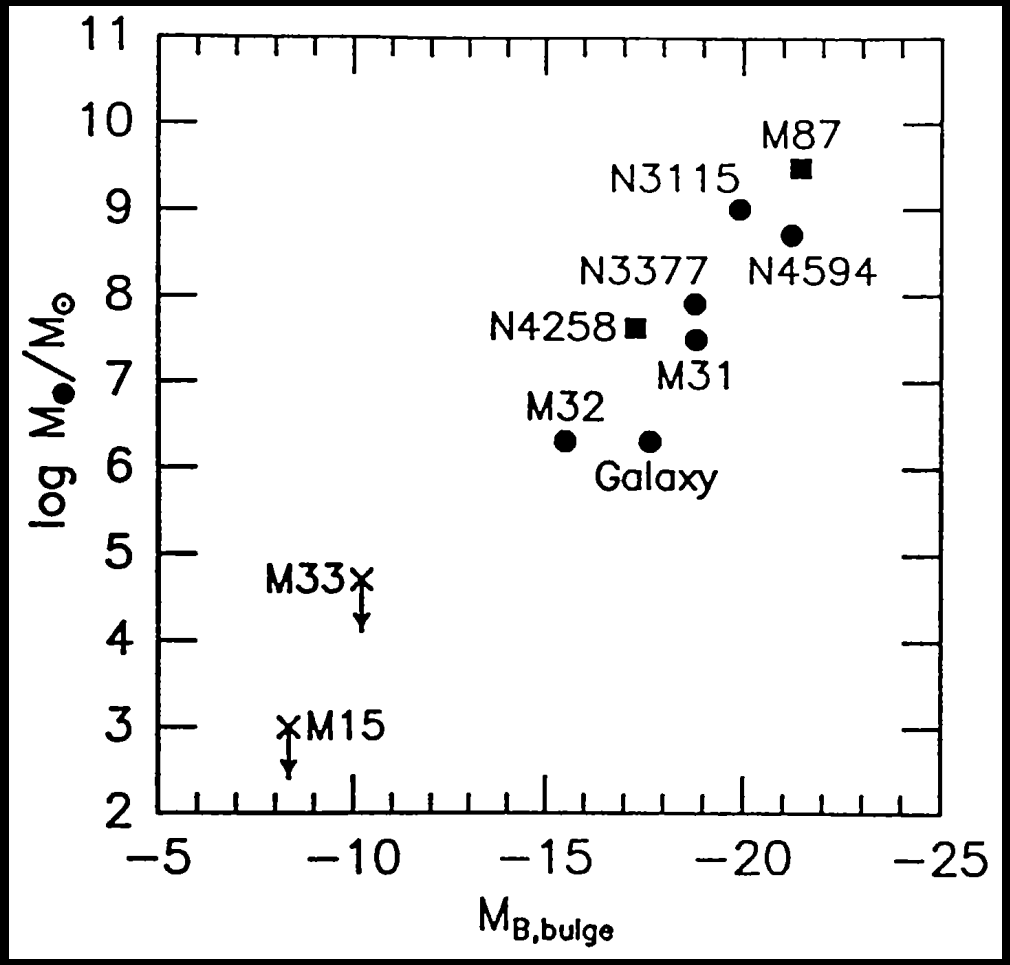
Outline

1. Framework/importance
   A brief recall on context, AGN feedback and outflows/winds
2. From the “classic” X-ray view of winds/outflows to the “new” X-ray view
   Warm Absorbers (WAs) → Ultra-Fast Outflows (UFOs)
   Impact of UFOs
3. Understanding UFOs…and future…
   comparison with WAs
   comparison with molecular outflows
   comparison with binaries/microquasars

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

Framework: Co-evolution of galaxies

In last 2 decades: somewhat 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

John Kormendy[1]

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Douglas Richstone

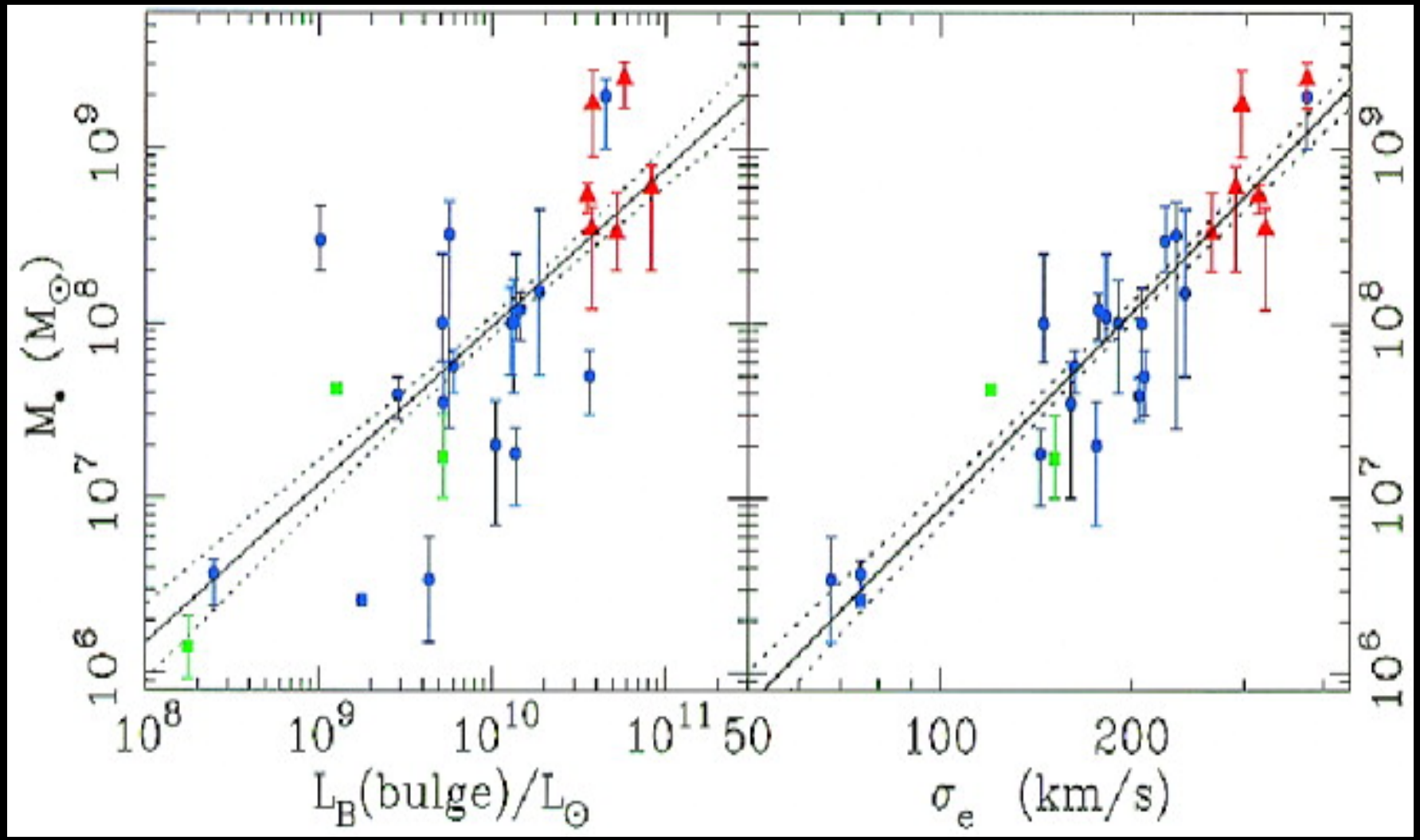
Department of Astronomy, University of Michigan, Dennison Building, Ann Arbor, Michigan 48109

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: Feedback in the co-evolution of galaxies

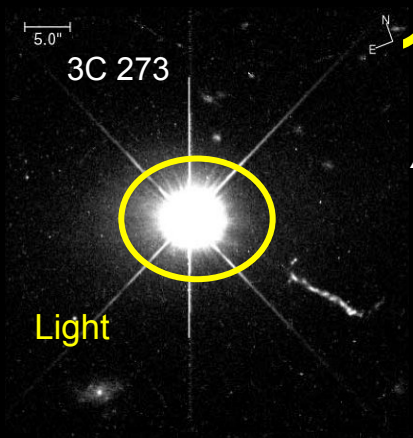
→ evidence for feedback mechanism between SMBH(AGN) and its' host galaxy



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

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

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



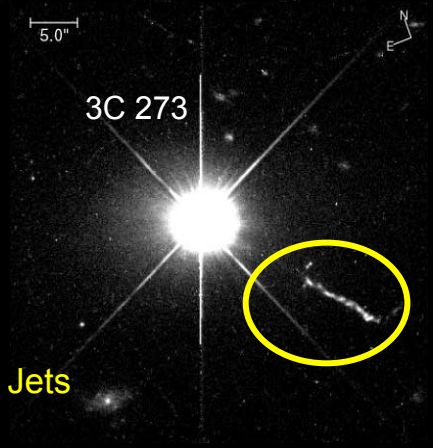
1. radiative feedback: $L_{acc} = \eta\left(\dot{M}_{acc}\right)c^2$

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

e.g. Ciotti & Ostriker 2001, Sazonov et al. 2005

But it is not enough to reproduce the M_{BH}-σ relation

e.g., Ciotti et al. 2009



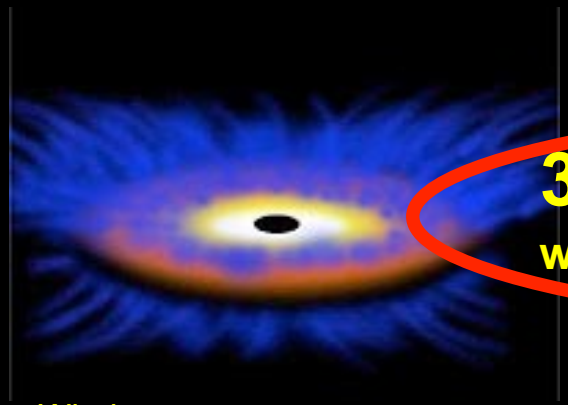
2. mechanical/kinetic feedback: mass outflows from collimated, radiatively bright, relativistic radio JETS:

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

But jets involve only ~10% of AGN, and are highly collimated:
low global impact for AGN with $L/L_{Edd} > 0.01$

e.g., Ciotti et al. 2009

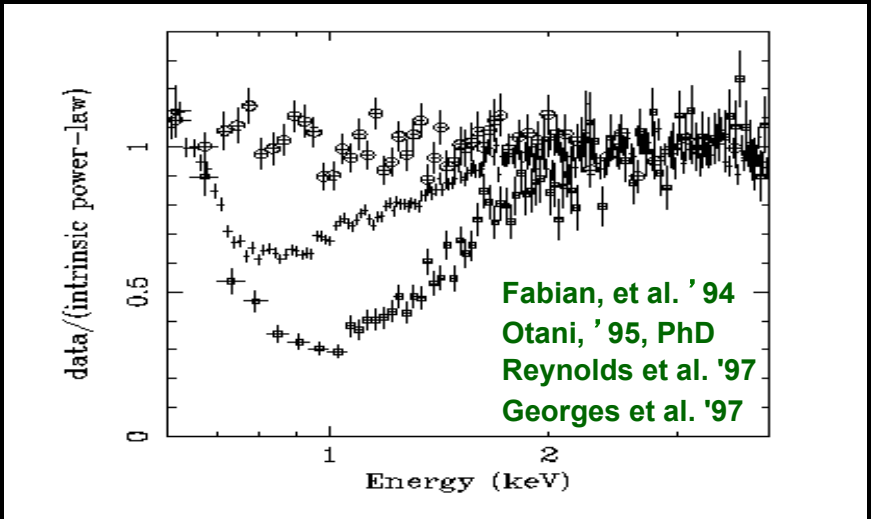


3. mechanical/kinetic feedback: mass outflows from wide angle, radiatively dark, massive WINDS/outflows

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

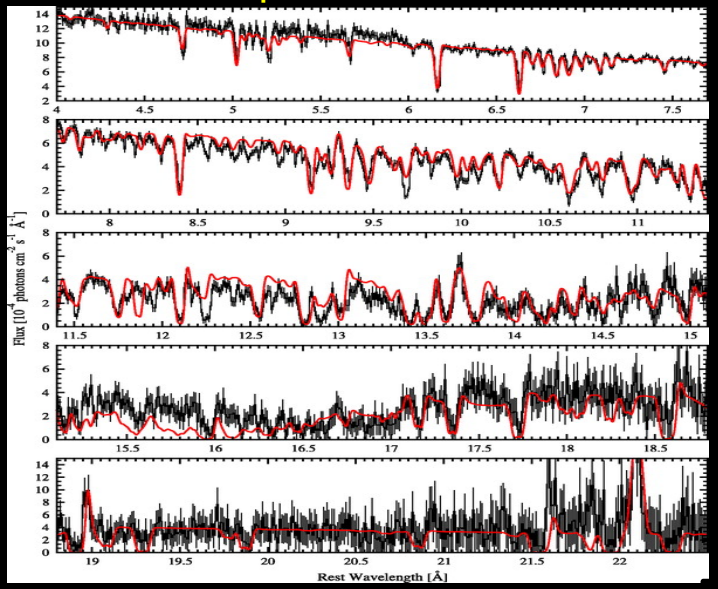
The "classic" X-ray view: Warm Absorbers in nearby Seyferts and QSOs

Seyfert galaxies: *ASCA…*



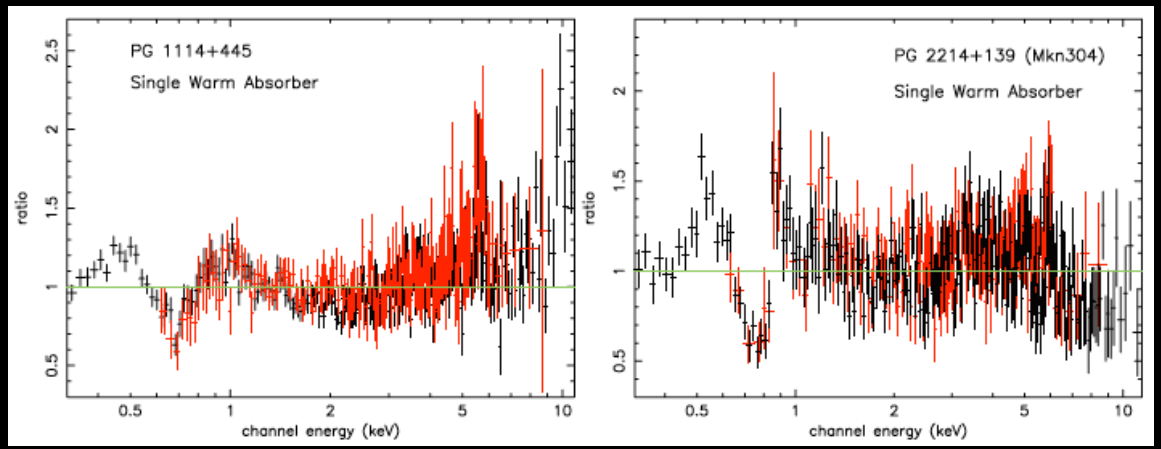
Many details from Chandra/XMM gratings

NGC3783 Exp=900 ks



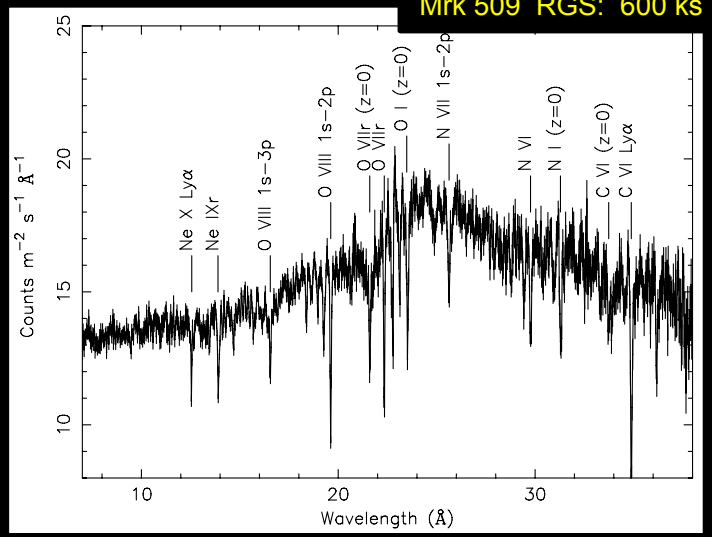
Kaspi et al. '01;
Netzer et al. '02;
Georges et al. '03;
Krongold et al. '03

QSOs: *XMM…*



Porquet et al. 2004; Piconcelli et al. 2005

Mrk 509 RGS: 600 ks



Kaastra et al. 2011, Detmers et al. 2011

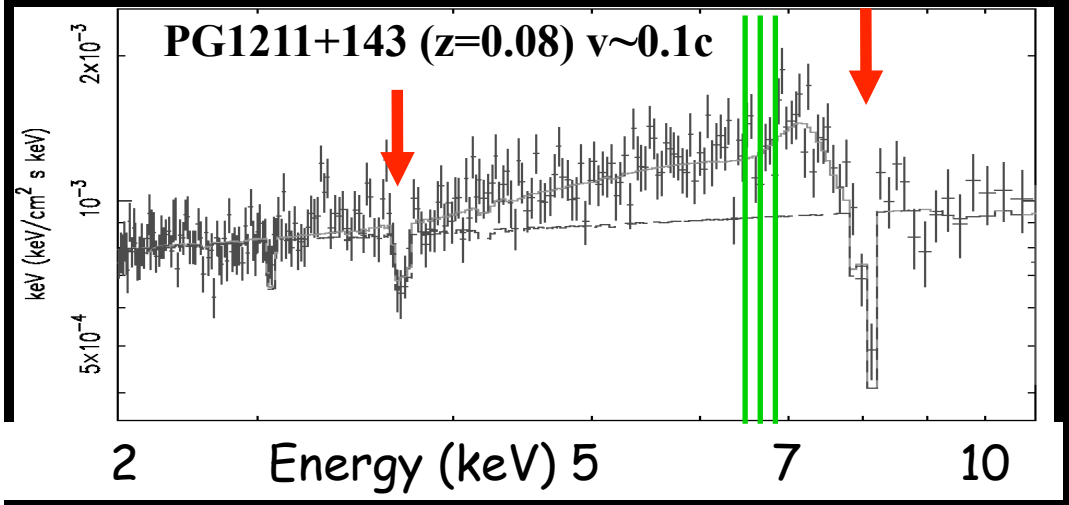
→ Clear now that ~50% of all Seyferts and QSOs present multiple ionization & kinetic components (from Optical, UV and soft X) of outflows/winds with v~100-1000 km/s

→ Typically energetically unimportant for feedback i.e. Blustin et al. 2004, but see Crenshaw & Kraemer, 2012

The "new" X-ray view: Blue-shifted absorption lines/edges – High-ξ , High-v (=UFOs)

New and unexpected results from Chandra and XMM-Newton observations

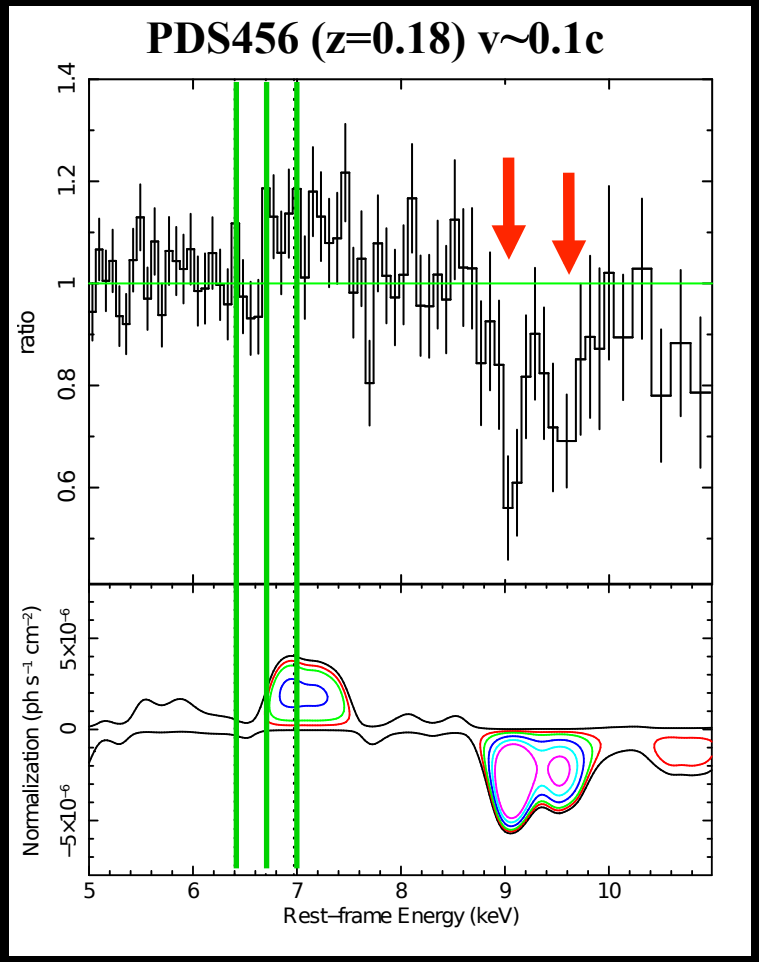
Seyfert galaxies



Pounds et al. 2003a,b
Pounds & Reeves, 2009

(If) interpreted as Kα resonant absorption by Fe XXV (6.70 keV) or FeXXVI (6.96 keV)

QSOs



➔ massive, **high velocity** (v~0.1-0.2c) and highly ionized outflows in several RQ AGNs/QSOs

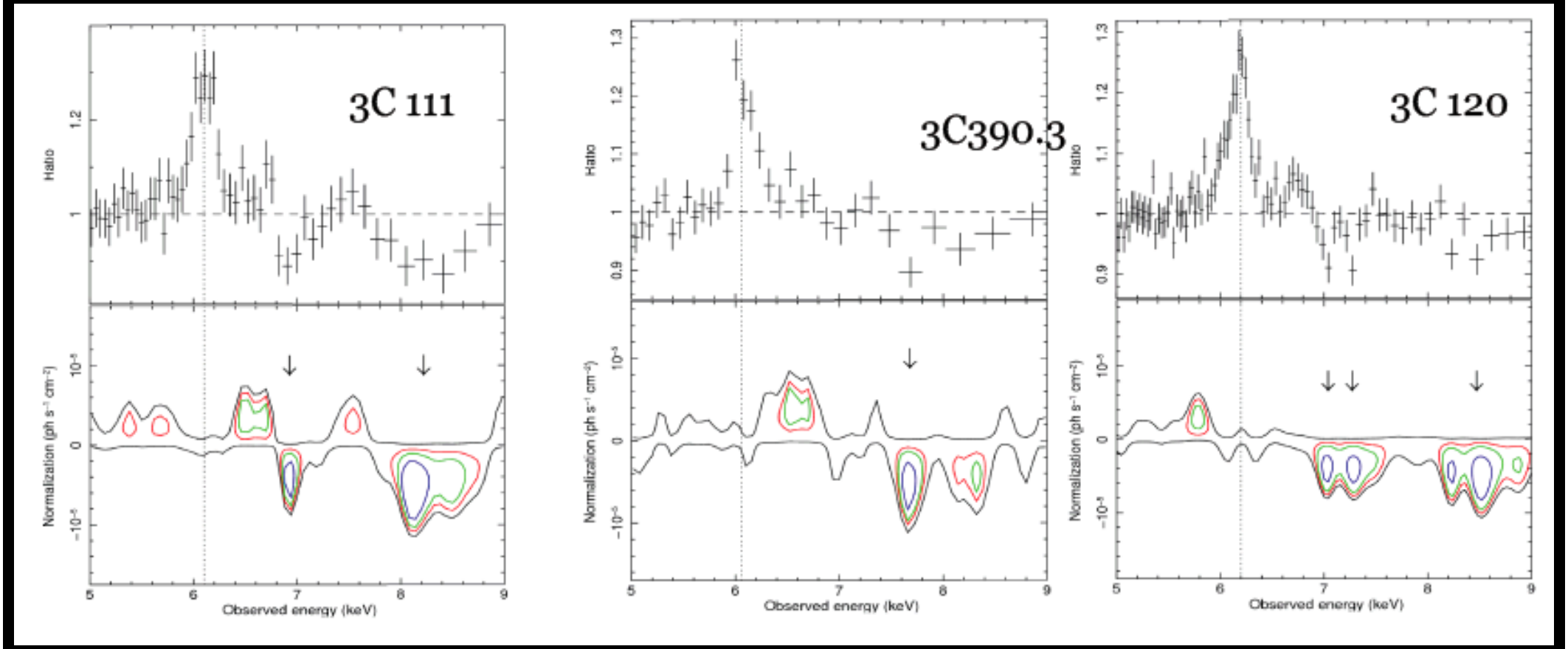
Reeves et al. 2010

Mass outflow rate: comparable to Edd. Acc. rate (~$M_\odot$/yr)

Kinetic energy: ~few% of L_{bol}

The "new" X-ray view: UFOs discovered also in Radio galaxies

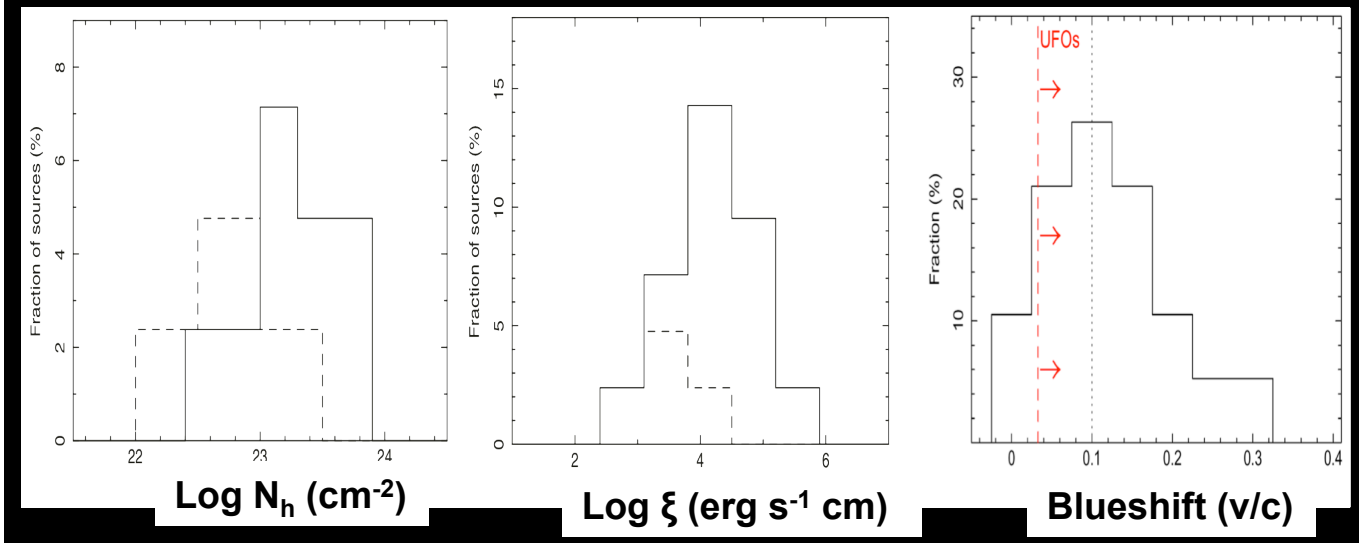
Radio-galaxies (3 out of 5 of the brigthest)



Tombesi et al. 2010
Gofford et al. 2012, in prep.

The "new" X-ray view: *UFOs (Ultra-Fast Outflows) confirmed and quite common*

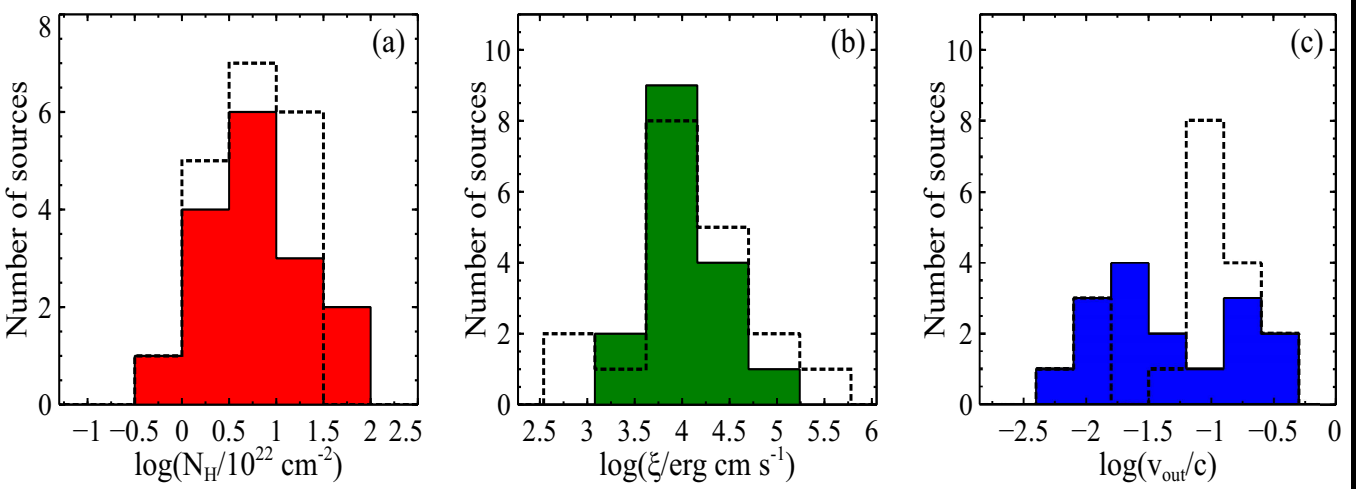
XMM-Newton sample of nearby AGNs (Seyferts)



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

- 36 absorption lines detected in all 104 XMM observations
- Identified with FeXXV and FeXXVI K-shell resonant absorption
- 19/44 objects with absorption lines (≈43%)
- 17/44 objects with blue-shifted absorption lines (lower limit ≈39%, can reach a maximum of ≈60%)
- 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

Suzaku sample of AGNs (Sey+RGs+RQQs)



Gofford et al. 2012, in prep

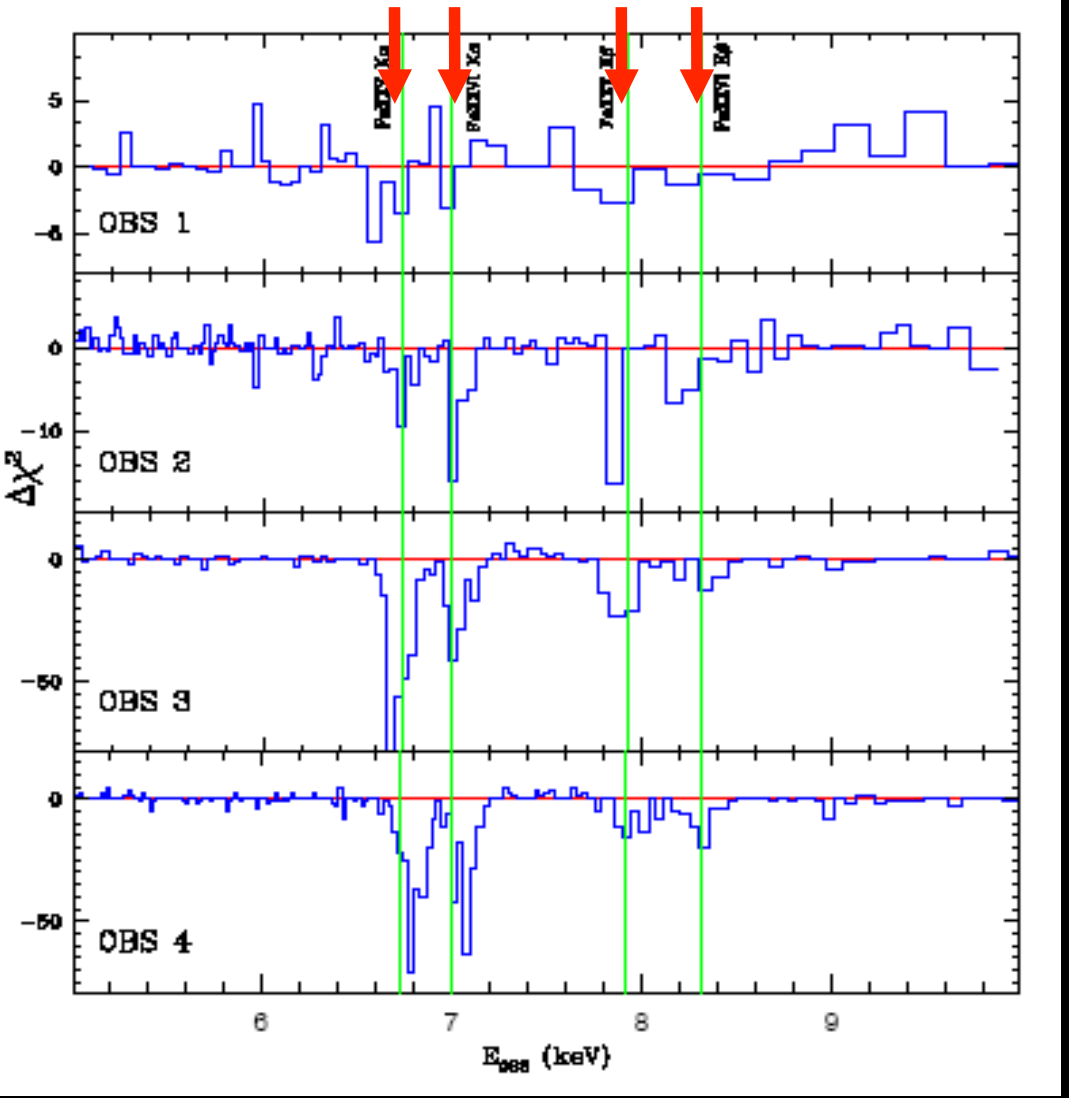
Table 5. Outflow velocity comparison

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

The "new" X-ray view: Variable absorption lines

Absorbers variability on timescales 1000-10000s

NGC1365

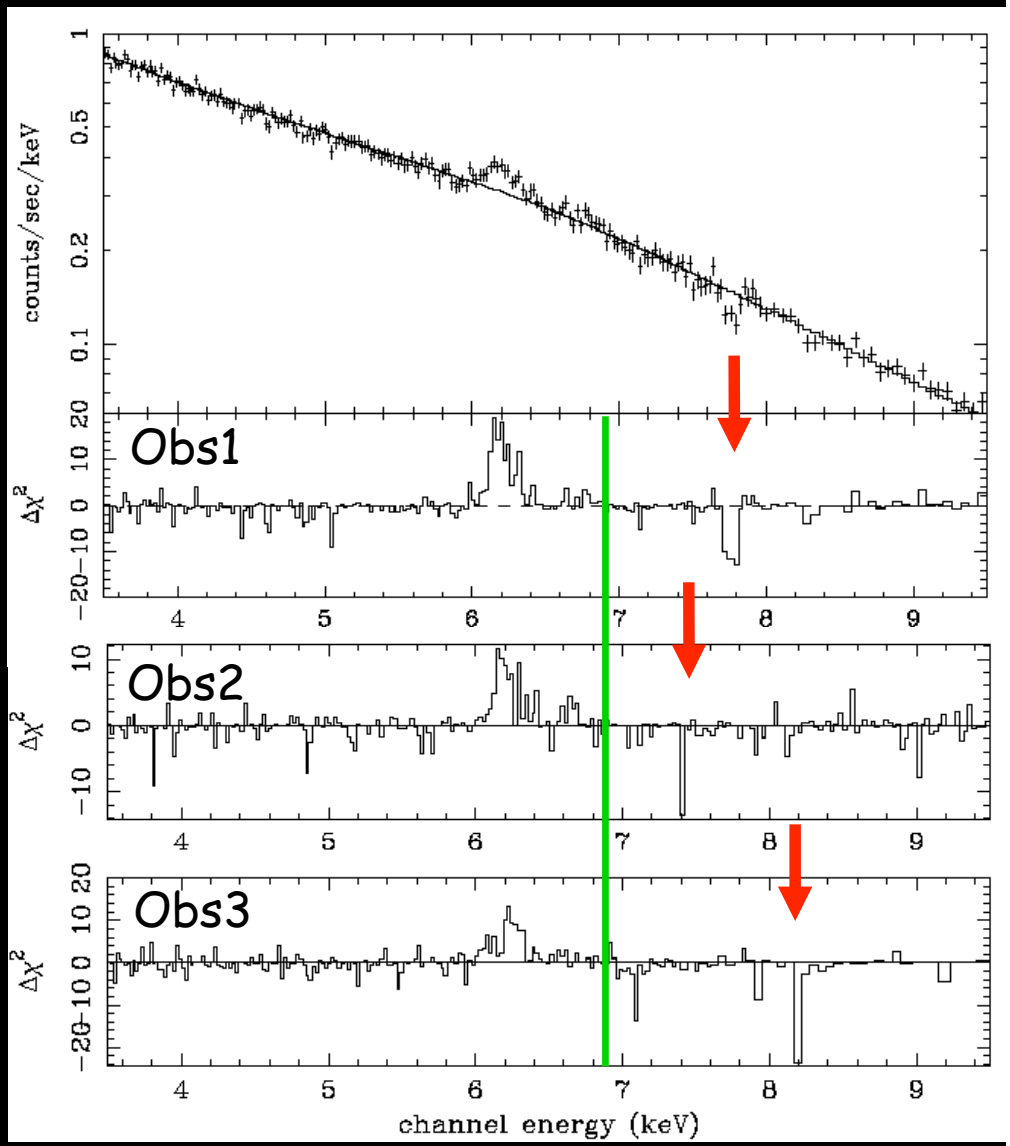


Risaliti et al. 2005

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

Variability allows to place limits on location, mass, etc.

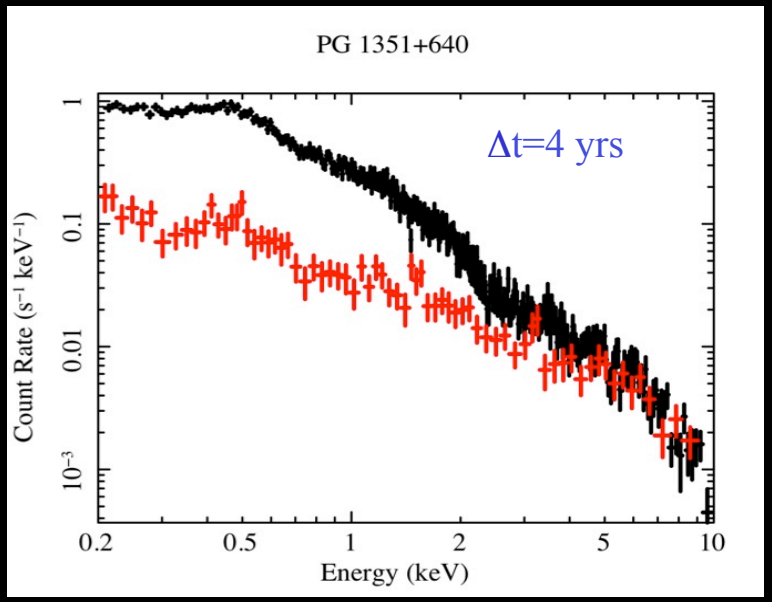
Mrk 509 (first long-look, 200ks)



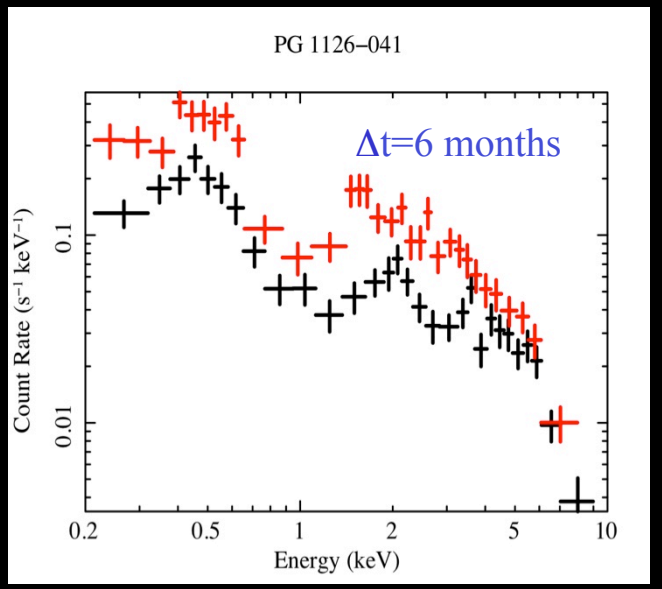
MC et al., 2009
Dadina et al. '05

The "new" X-ray view: *Variability of a few (nearby) PG QSOs*

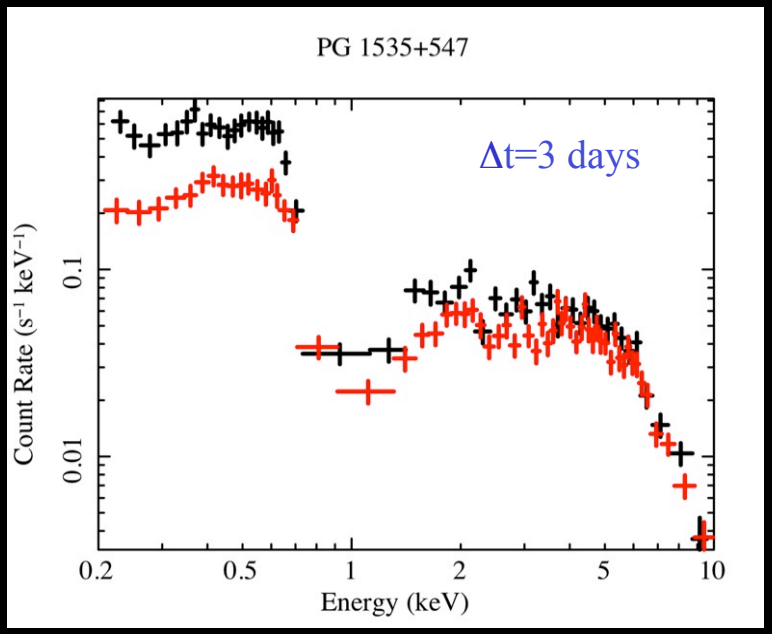
Sample: 15 UV *AL QSOs with 32 XMM exposures



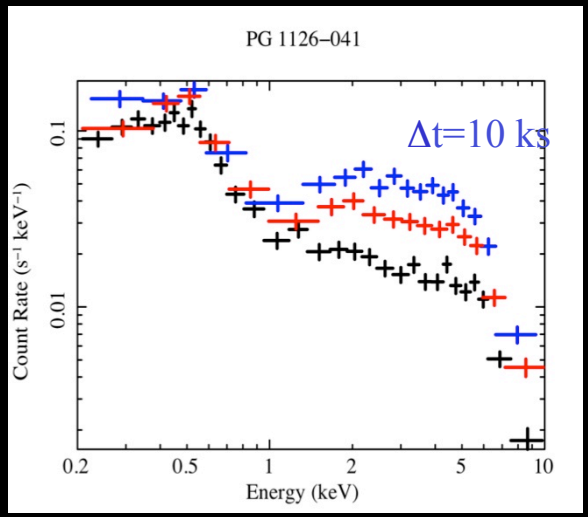
on time scales of years



on time scales of months



on time scales of days

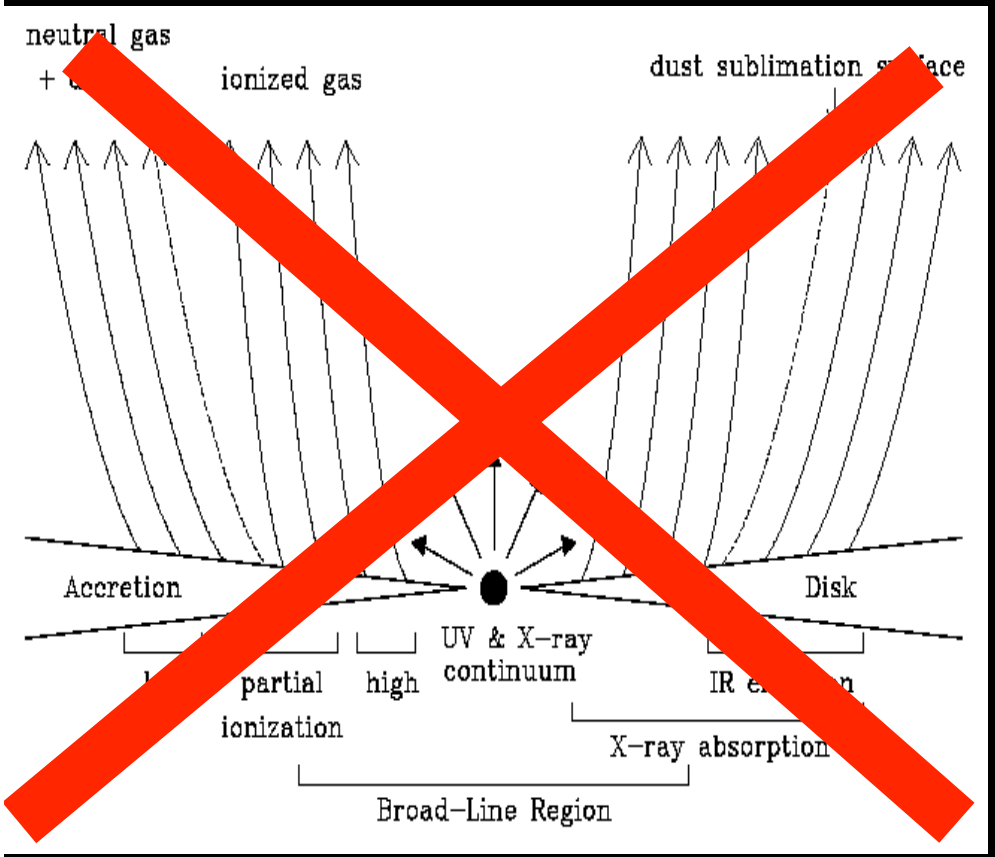


on time scales of hours

Giustini, MC, et al. 2012a, 2012b in prep.

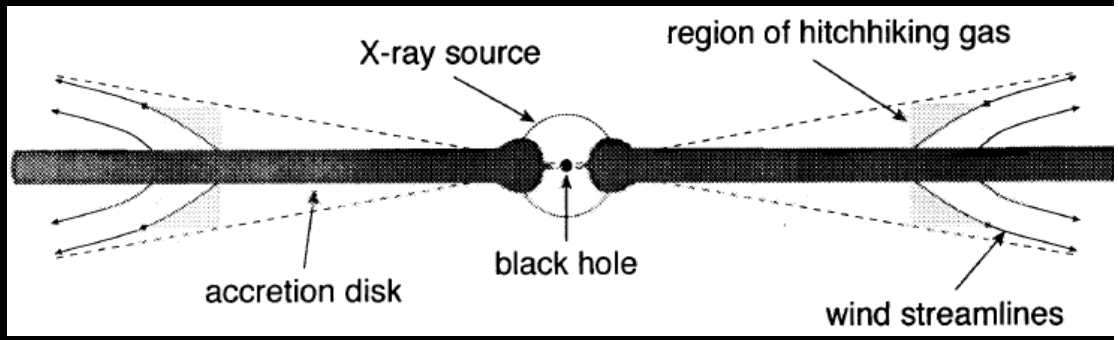
Main interpretations: Three (main) AGN wind dynamical models

i) Thermally driven winds from BLR or torus



Balsara & Krolik, 93; Woods et al. '96

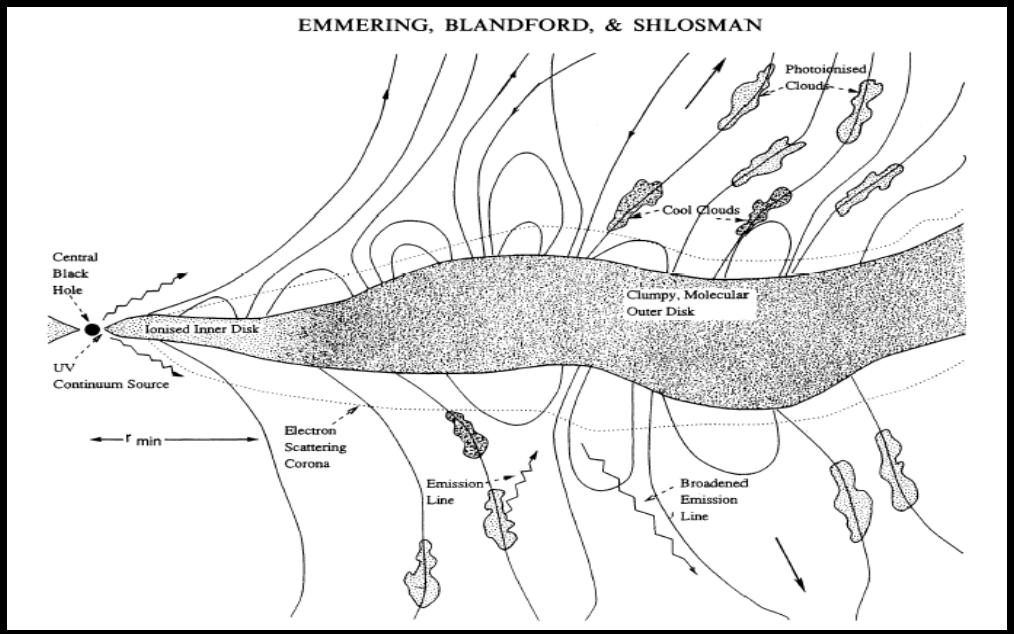
ii) Radiatively-driven wind from accretion disk



Murray et al. '95, Proga et al. '00

…and/or…

iii) Magnetically driven winds from accretion disk

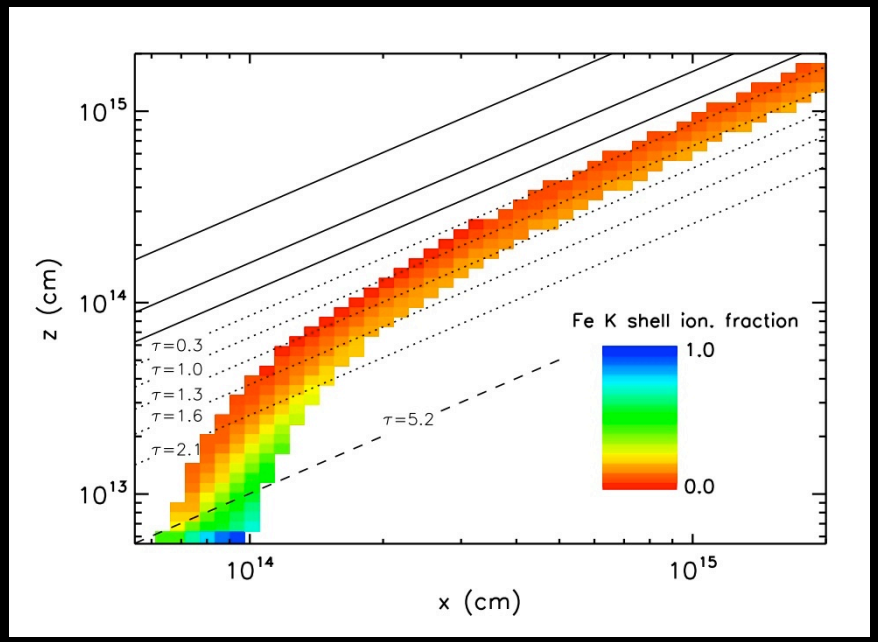


Emmering, Blandford & Shlosman, ' 92; Kato et al. '03

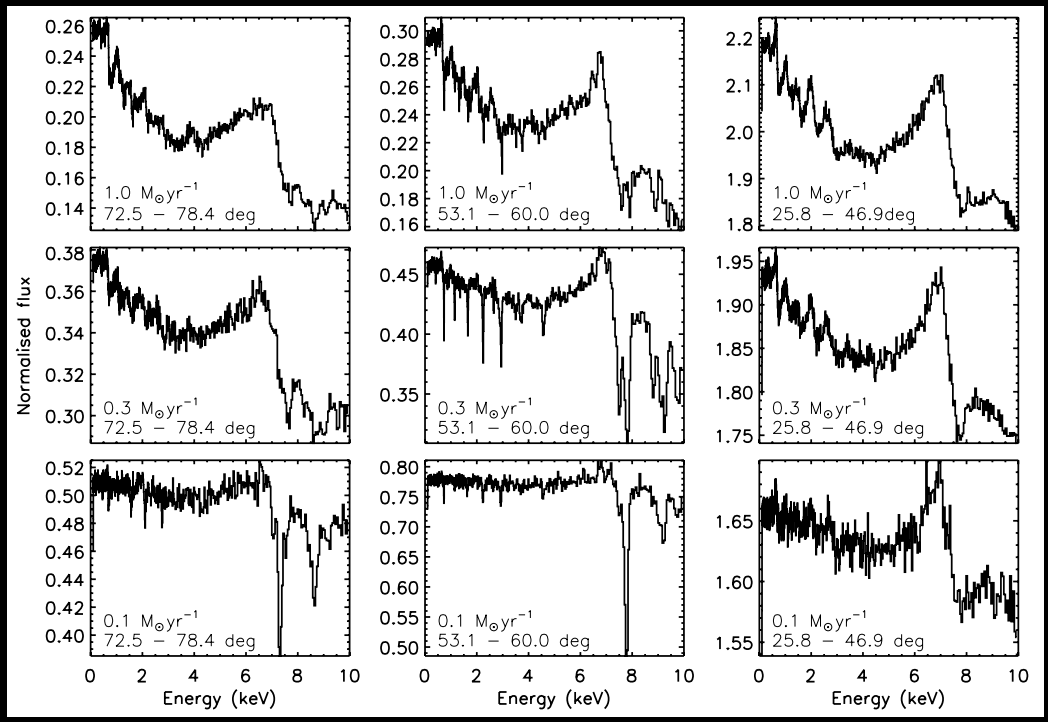
i) ⇒ Large R, low v
ii) and iii) ⇒ Low R and large v

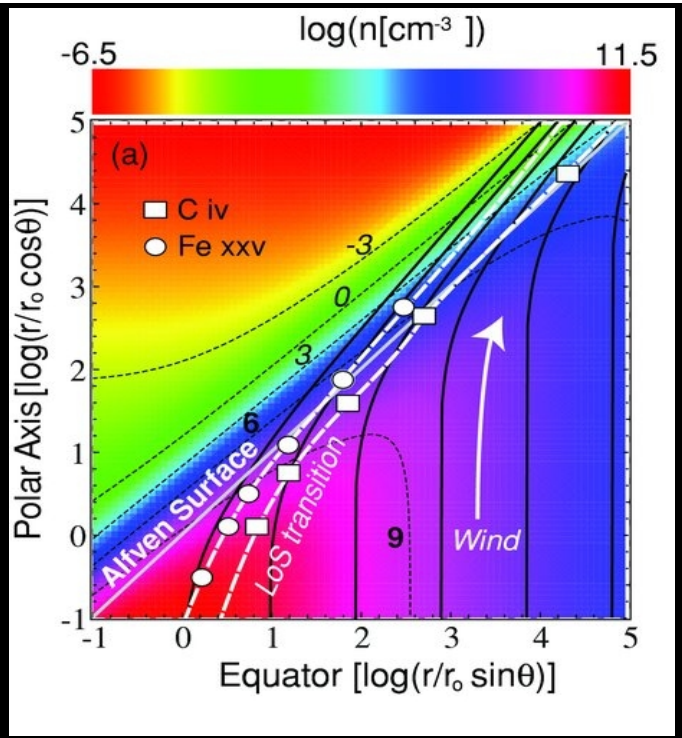
UFOs/outflows/winds in AGNs & QSOs: A (possible) model

In fact, one expects (mostly/only) strong Fe line absorptions when accounting for proper wind geometries and physics



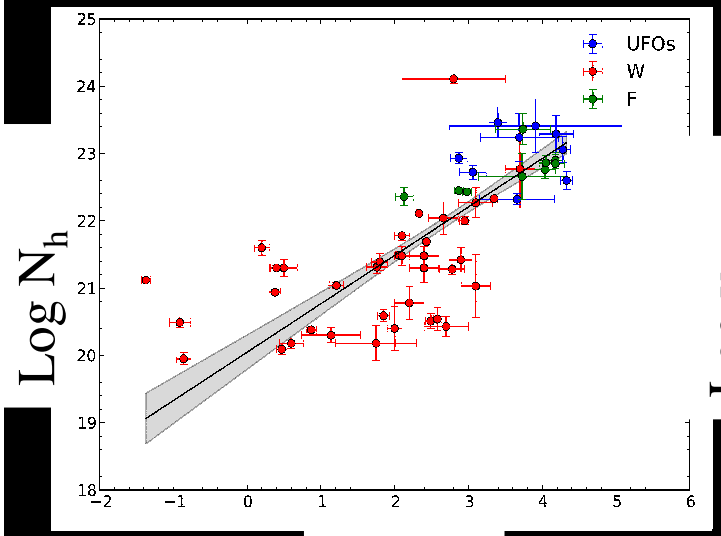
Sim et al., '08, '10ab

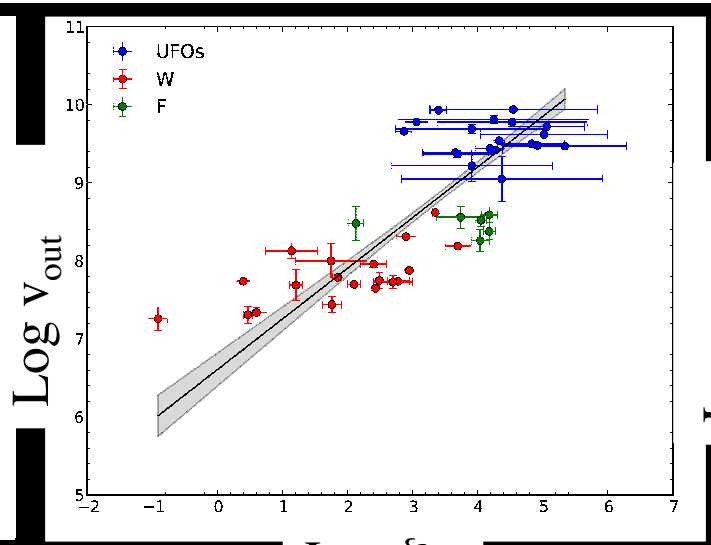


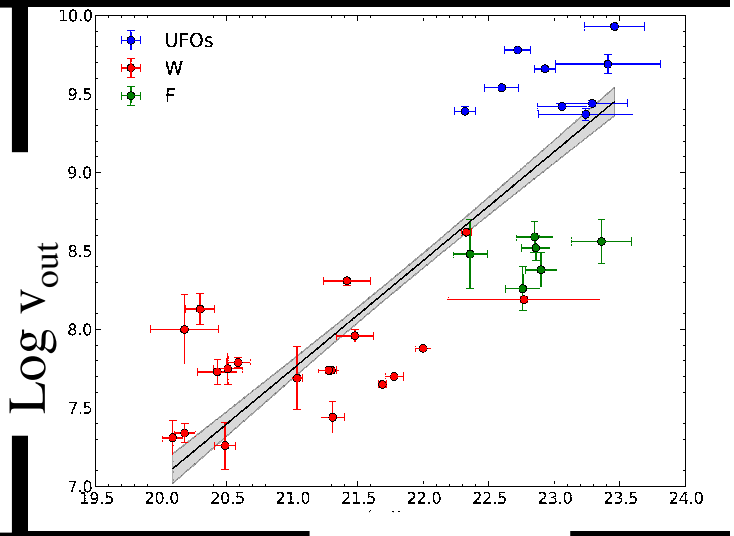


Fukumura, et al. 2010
Kazanas et al. 2012

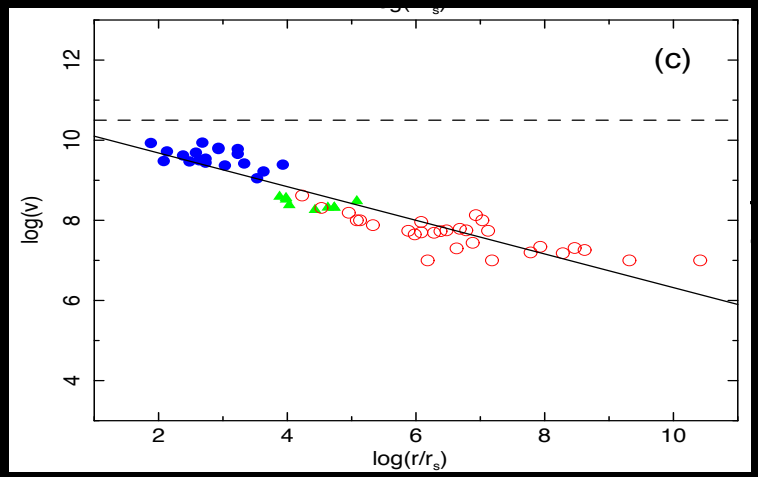
The "new" X-ray view: *UFOs compared with WAs…*





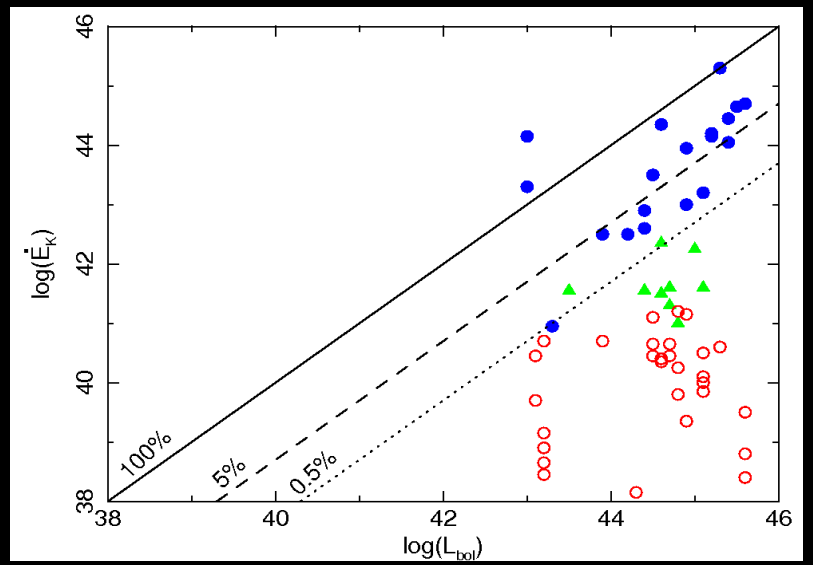


→ UFOs = same (but extreme) phenomenon as WAs?



→ UFOs = momentum-driven winds and/or MHD winds ?!
(on-going comparison with King et al. and Fukumura et al.)

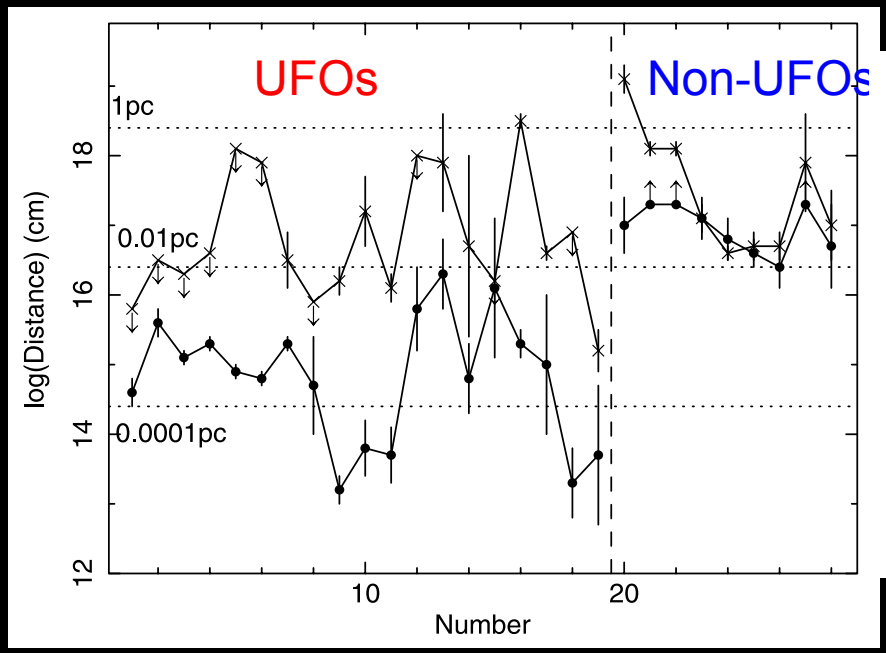
Tombesi et al., 2012, In prep.



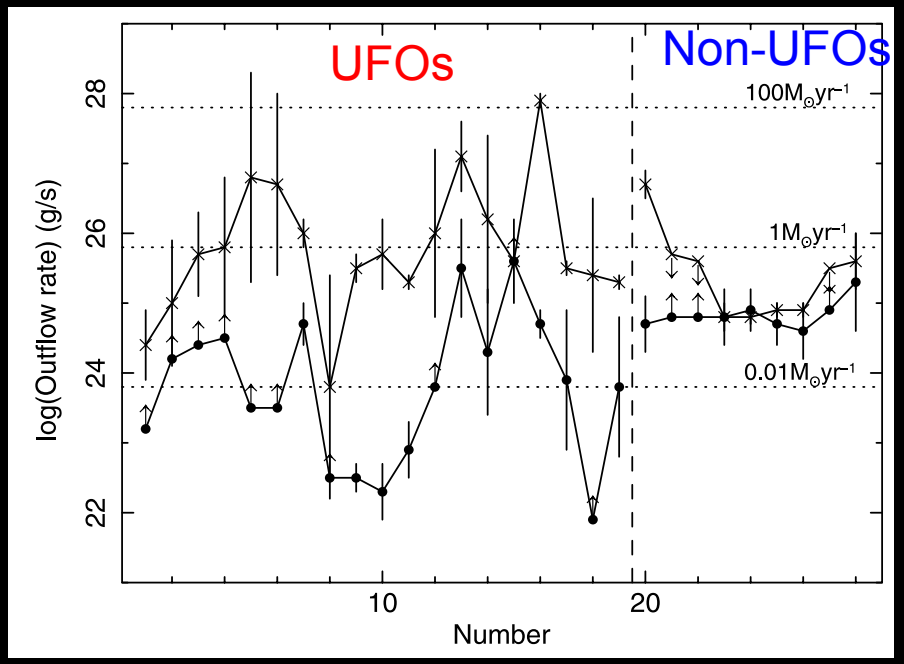
→ UFOs kinetic energy >1% of Lbol
→ Feedback effective!

Tombesi, MC et al., 2012b

The "new" X-ray view: Location and energetics of UFOs (and non-UFOs)



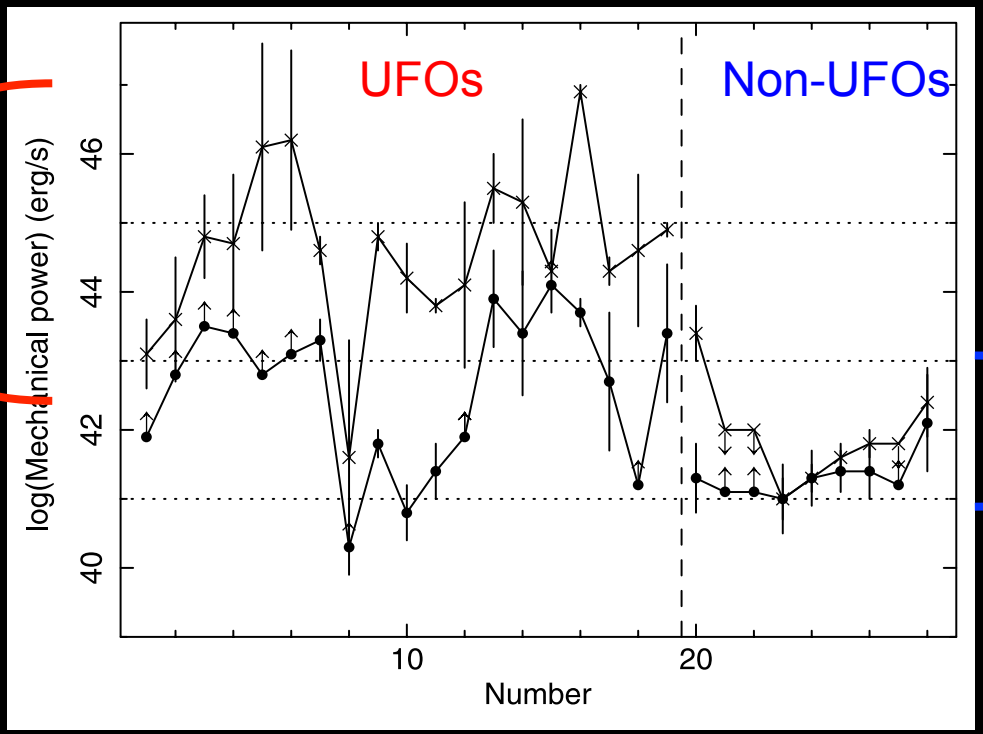
~10^2-10^4 Rs; 10^4-10^5 Rs



$$r \leq r_{\rm max} = L_{\rm ion}/\xi N_{\rm H}.$$

$$r \geq r_{\rm min} = 2\,G M_{\rm BH}/v_{\rm out}^2$$

~0.5-100 % L_{bol}

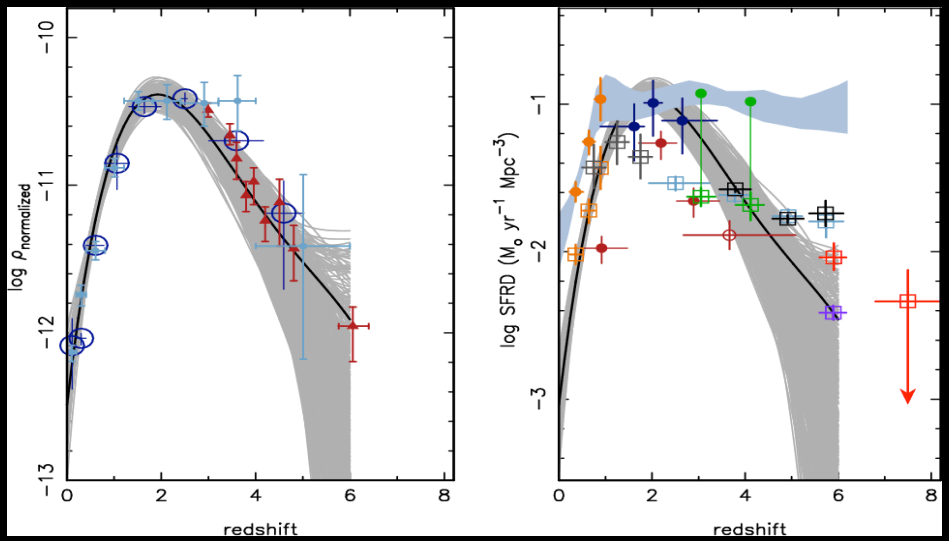


$$\dot{E}_{\rm K} = (1/2)\dot{M}_{\rm out} v_{\rm out}^2$$

~0.02-1 % L_{bol}

Tombesi, MC, et al., '12b

UFOs compared/relate to high-v absorbers in high-z QSOs?



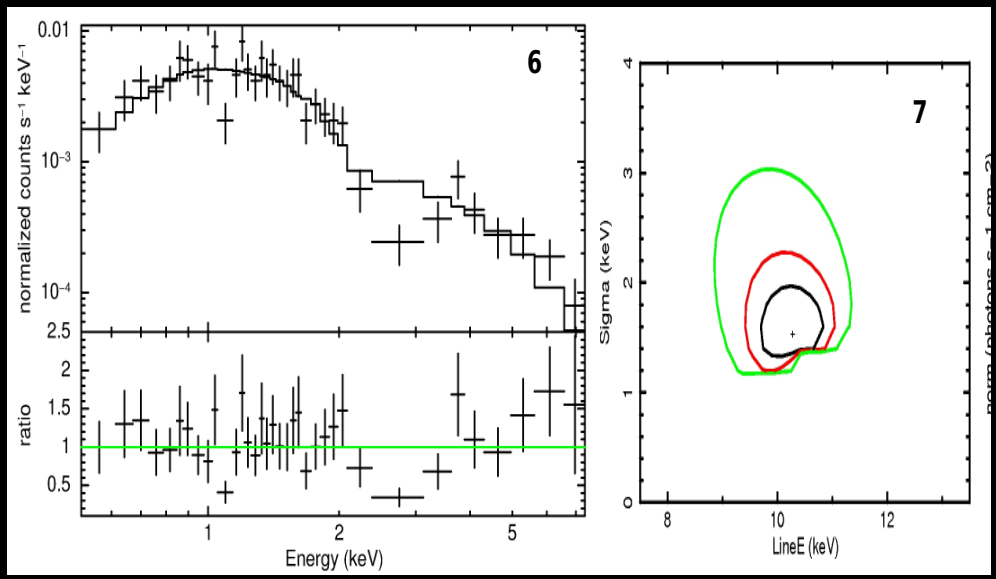
QSO space density

Madau et al. '96;

SFR space density

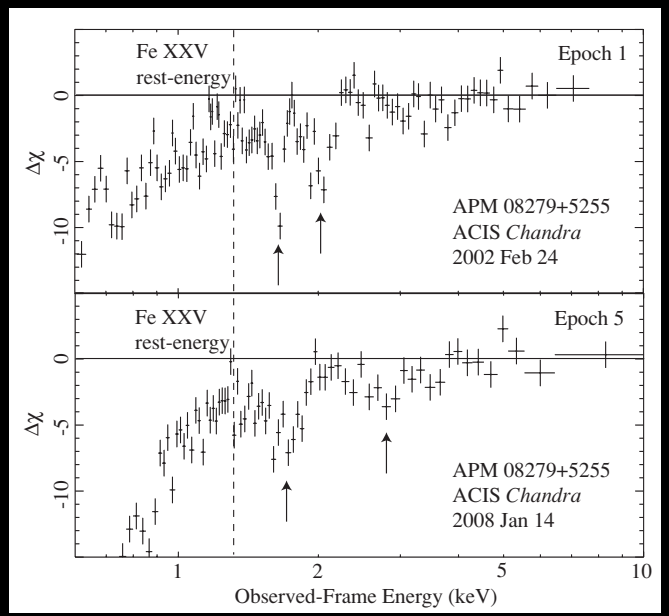
Wall et al. '05

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



Lanzuisi et al., '12, arxiv:1205.6587

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



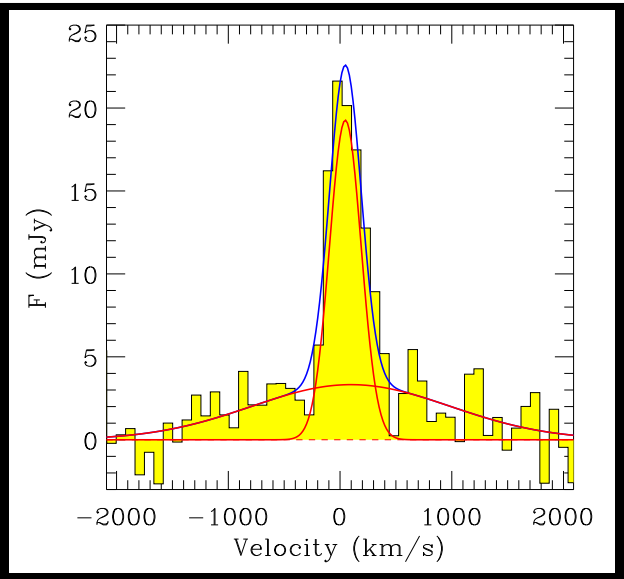
APM 08279+5255 (z=3.91)

V_{out}~0.2-0.76 c

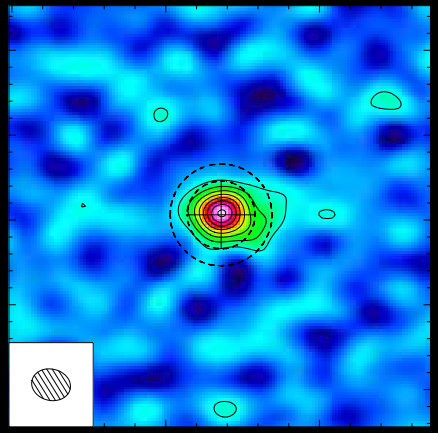
Chartas et al. 2009

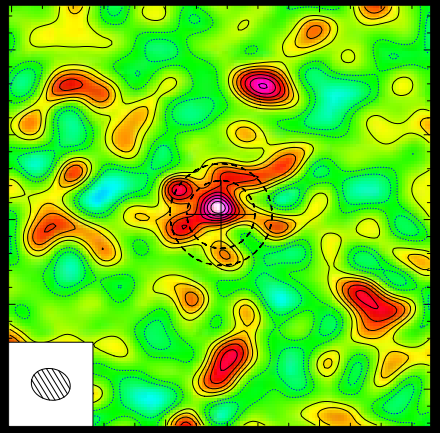
N.B.: Would be nice also to confirm it via longer XMM observations….

UFOs compared/relate to colder molecular/gas outflows??



SDSSJ1 14816.64+525150.3 (z=6.42) – IRAM PdBI



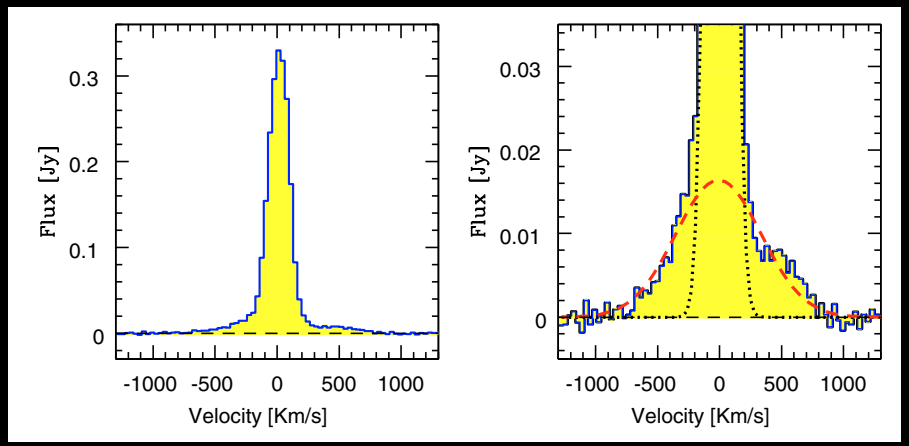


[CII] 158 μm broad wings (FWHM~2000 km/s) + extension →

Maiolino et al. 2012

- $\dot{M}_{out}$ > 3500 $M_\odot$ yr^{-1}; and Quasar driven outflow (not SB)

Mrk231 - CO (resolved) map
FWHM~700 km/s, M_{out} ~ 250-2200 $M_\odot$ yr^{-1}

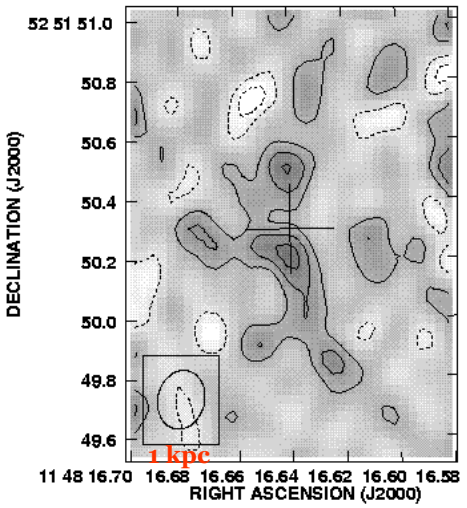


Feruglio et al. 2010

Z=6.42 quasar
CO (resolved) map
V~250 km/s

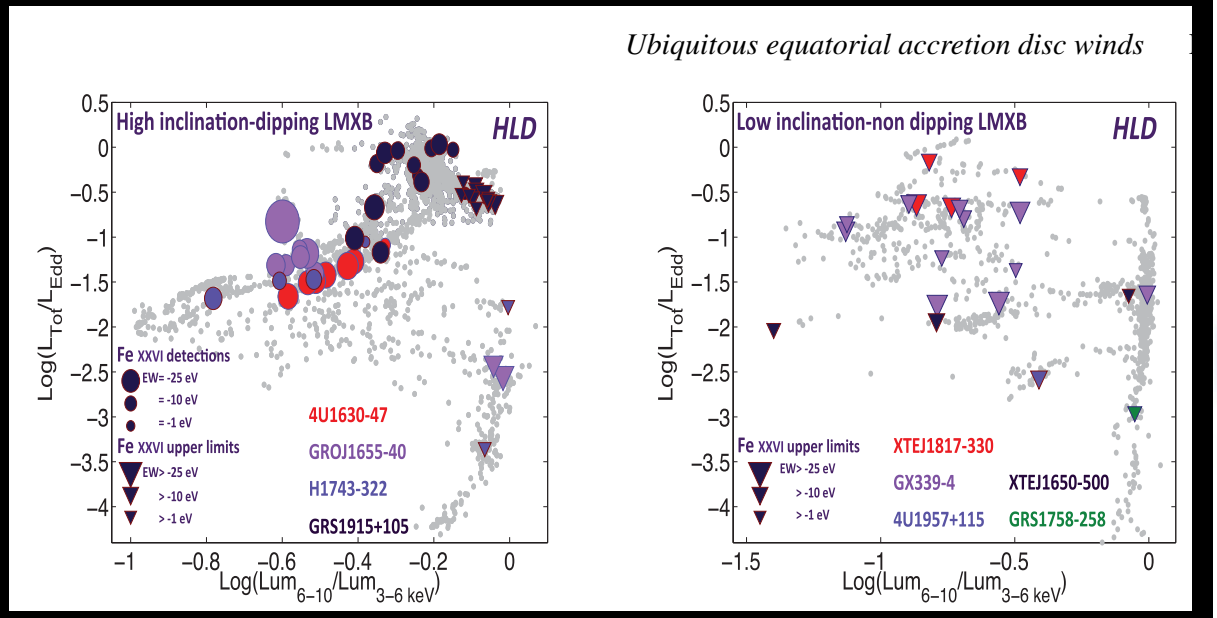
Bertoldi et al. 2003
Walter et al. 2004

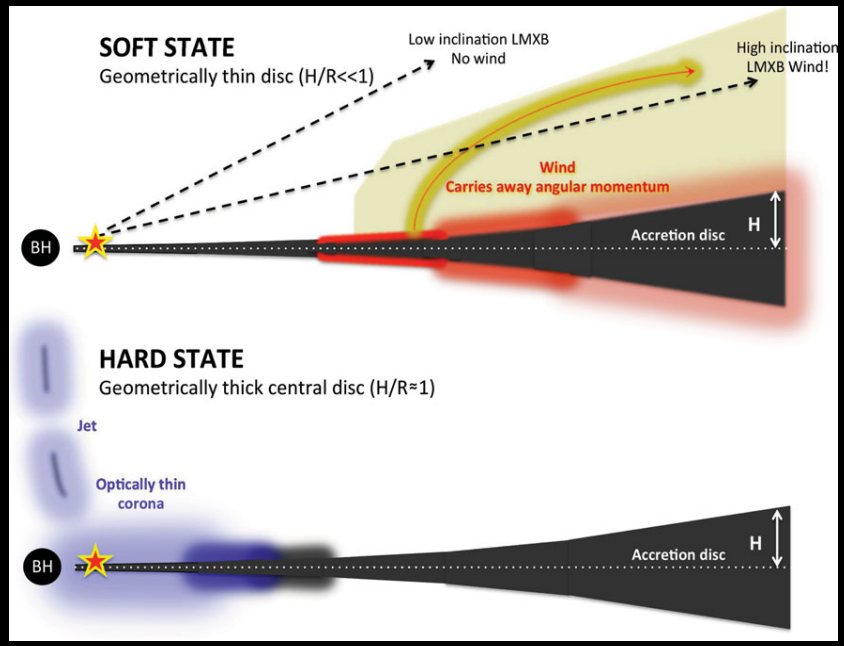
VLA CO 3—2 map



Walter et al. 2004

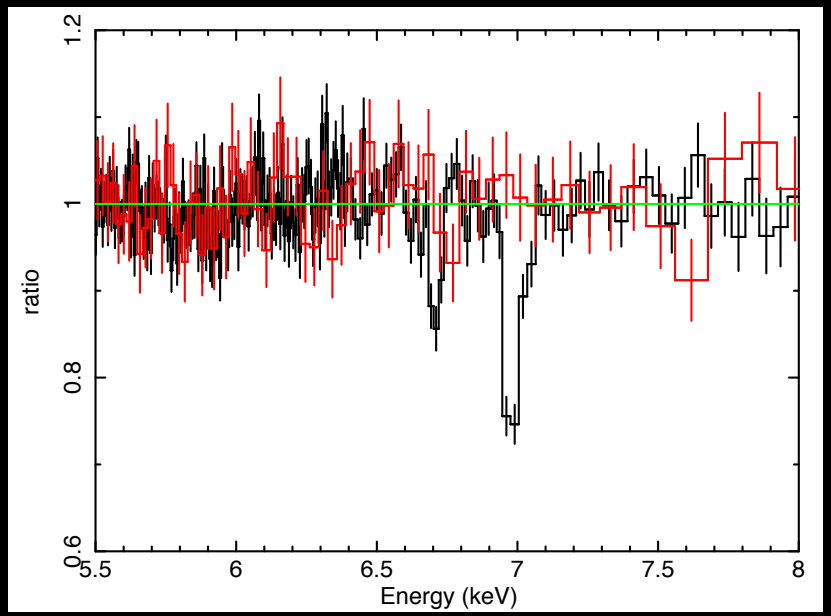
UFOs compared/relate to binaries winds and jets??





Ponti et al., 2011

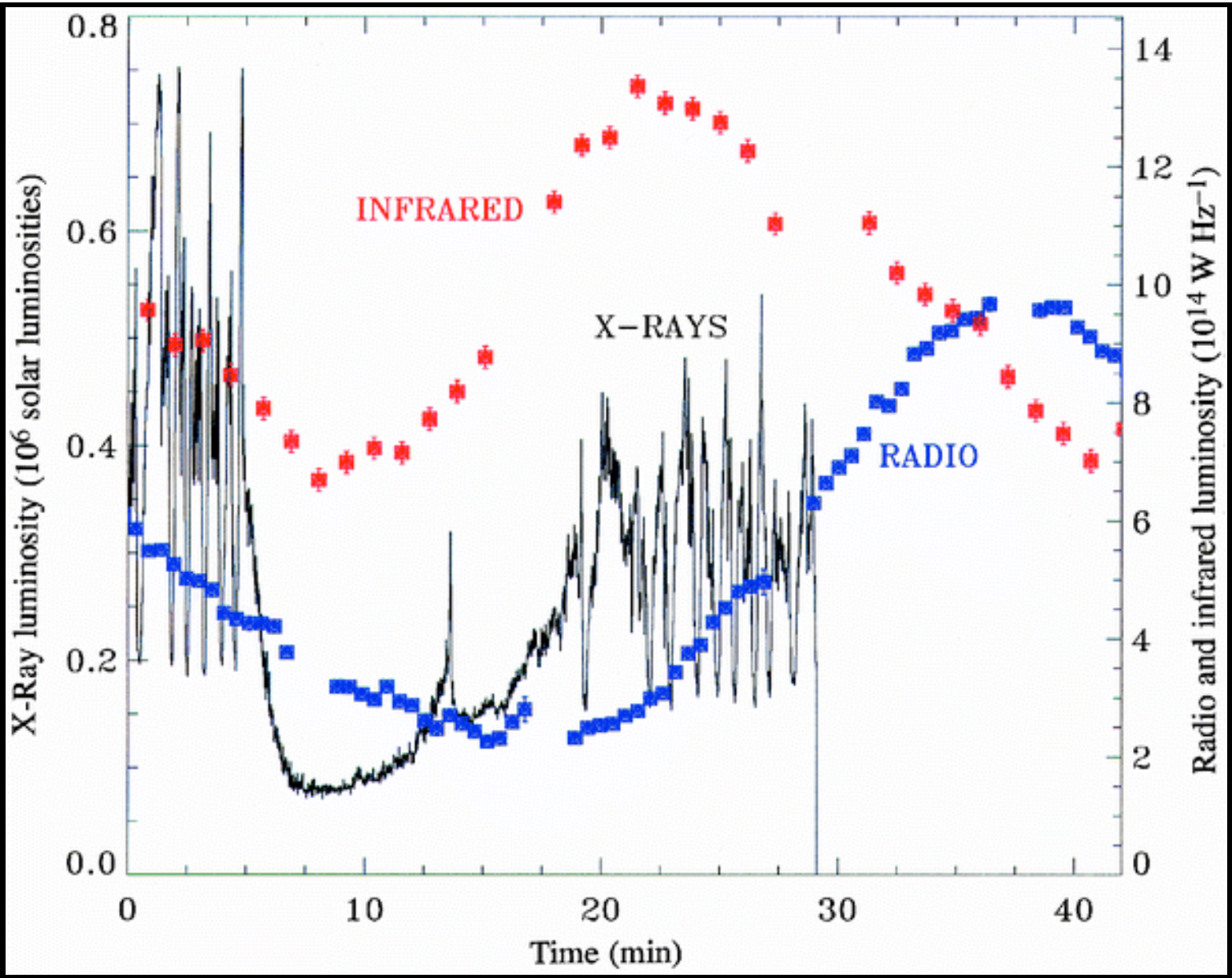
H1743-322 disk-wind detected in soft, disc-dominated state



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

Miller et al., 2006, 2012

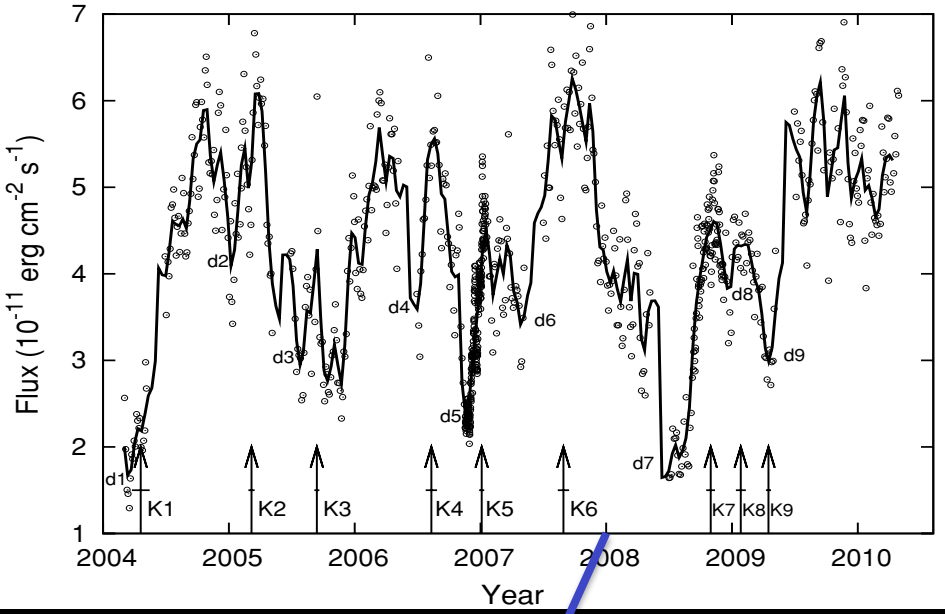
UFOs compared/relate to microquasars??

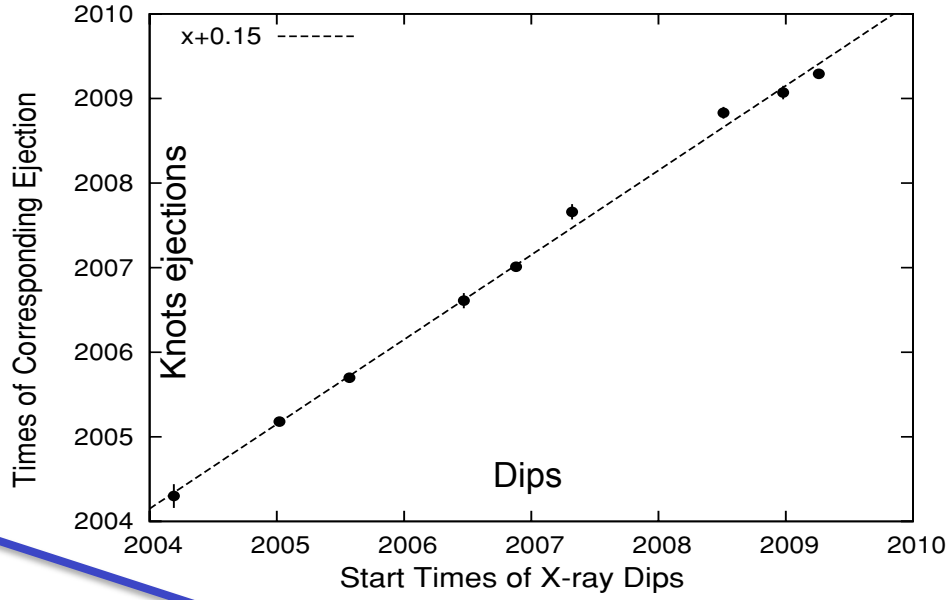


The disappearance of the inner accretion disk (marked by the X-ray dip 7 min after the start of the set of observations shown in here), coincides with the beginning of the ejection of a relativistic plasma cloud (marked by the start of the infrared flare).
As the ejected cloud expands it becomes transparent to radio waves, with a peak radio-wave flux that is delayed by 15 min relative to the infrared peak. The absence of X-ray data after 29 min is due to occultation of the source by the Earth.

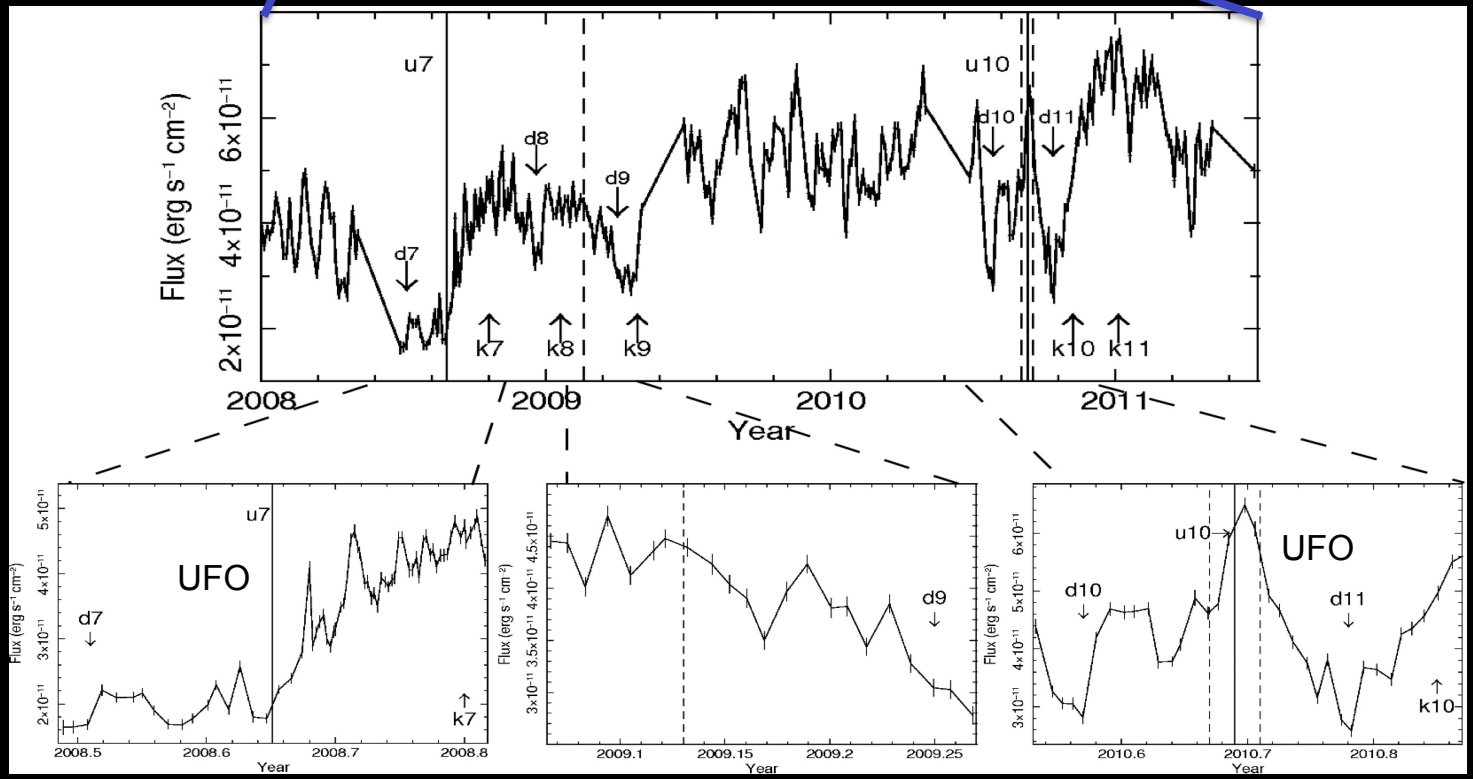
Mirabel and Rodriguez, 1998, Nature

Chatterjee et al. 2011





3C111



Tombesi et al. 2011

Conclusions

- General framework/importance
  - ⇒ *Recognized need for AGN feedback mechanism*

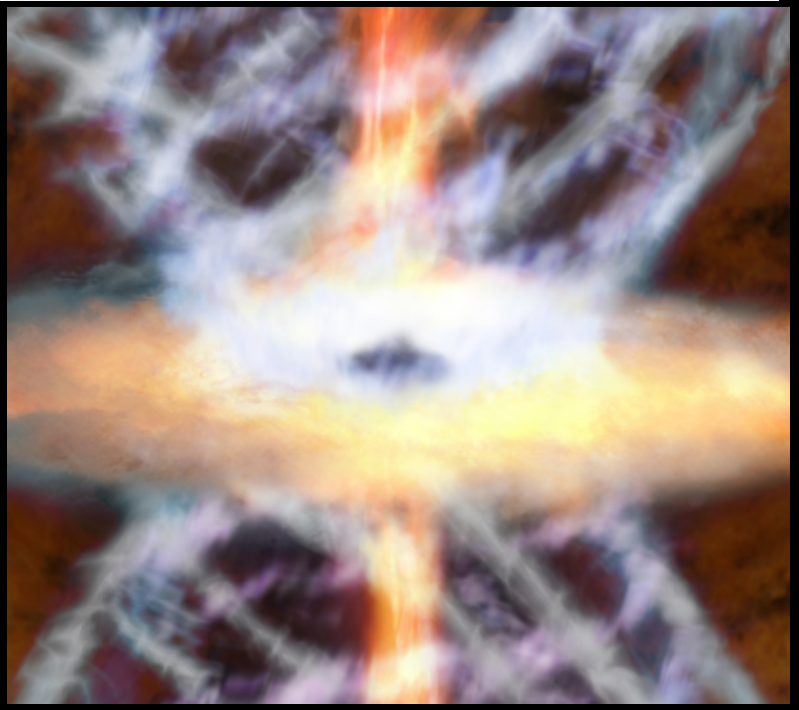
- The "classic" X-ray view of winds/outflows
  - ⇒ *Optical/UV/WAs in AGNs and QSOs frequent but mostly insufficient to be energetically relevant for feedback*

- The "new" X-ray view of winds/outflows
  - ⇒ *UFOs in AGNs likely frequent AND significant*
  - ⇒ *UFOs in QSOs at z~2 **may** be frequent and significant too (TBD)*

- Critical/remaining open Issues for UFOs/winds
  - ⇒ *Filling factor in AGNs ?*
  - ⇒ *Covering & filling factor in high-z QSOs ?*
  - ⇒ *Acceleration mechanism?*
  - ⇒ *Relation with WAs, molecular outflows, winds in binaries, jet formation?*

- Future

Near-Future: Astro-H
Far-future: ????



Thank you very much for your attention