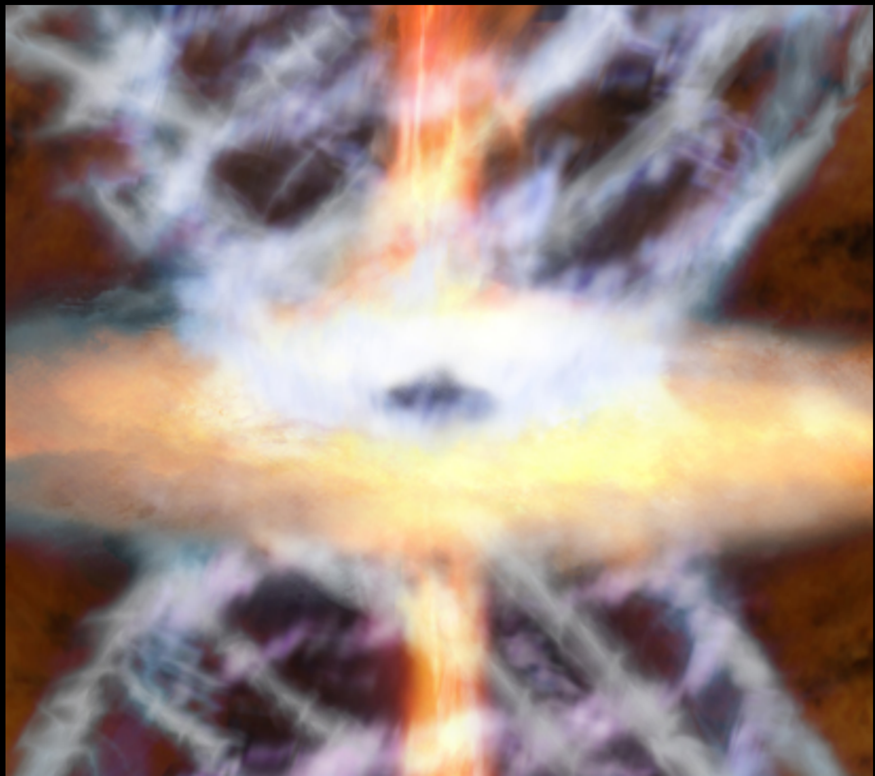
Analogies/differences in black-hole driven massive outflows found in AGNs, QSOs, ULIRGs, and galactic BH binaries

.

Massimo Cappi

INAF/IASF-Bologna



Outline

1. Framework/importance
   A very brief recall on context: AGN feedback

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

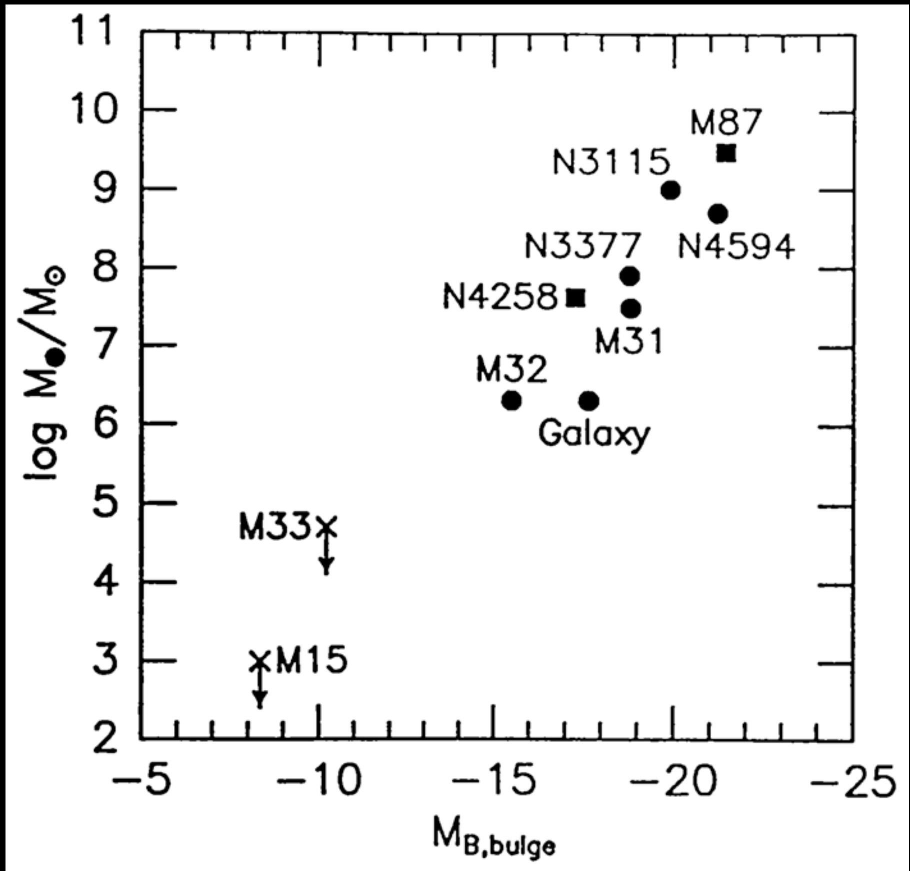
3. Understanding analogies and differences
   comparison with WAs
   comparison with molecular outflows
   comparison with binaries/microquasars
   (on-going work…)

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

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 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 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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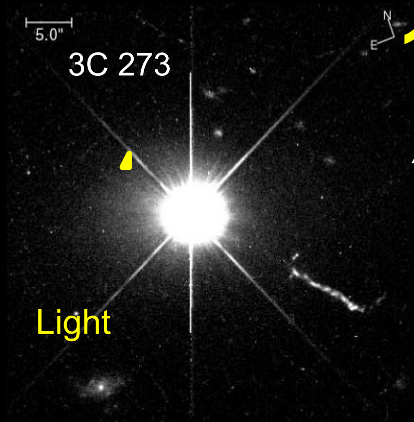
Kormendy & Richstone, 1995, ARA&A

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 abun-

→ AGN Feedback !?

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



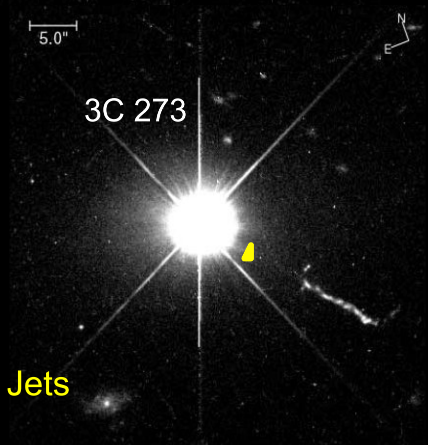
1. radiative feedback: $L_{acc} = \eta(\dot{M}_{acc})c^2$

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

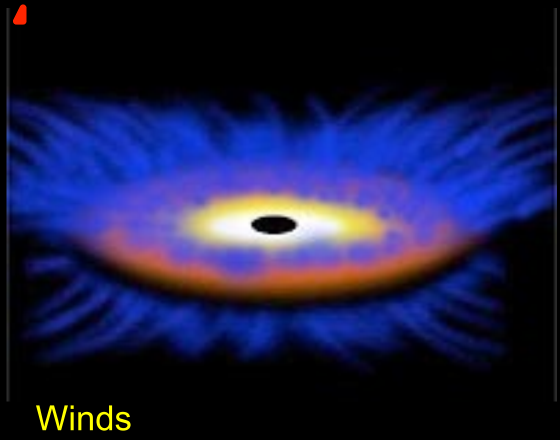


2. mechanical/kinetic feedback:

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



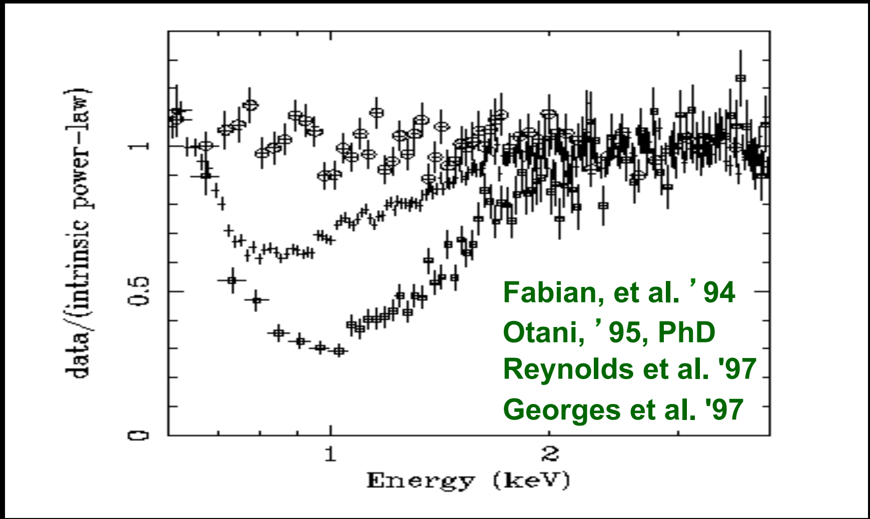
ii. mass outflows from wide angle, radiatively dark, massive WINDS/outflows

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

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

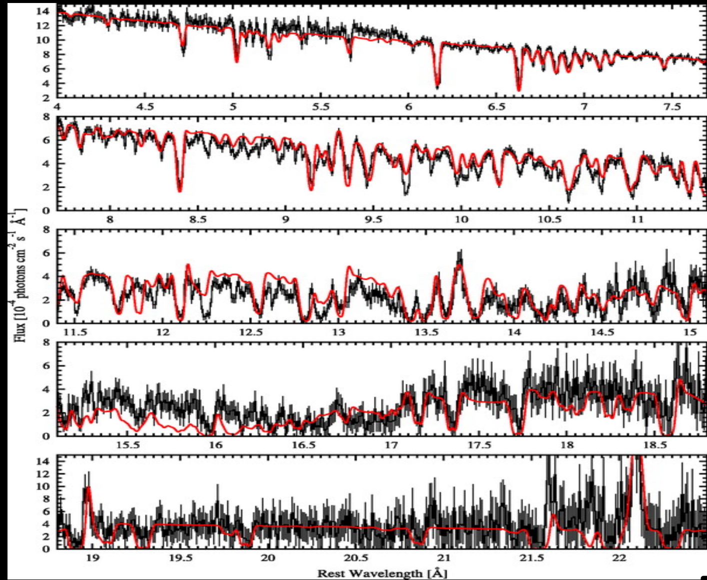
.

Seyfert galaxies: *ASCA…*



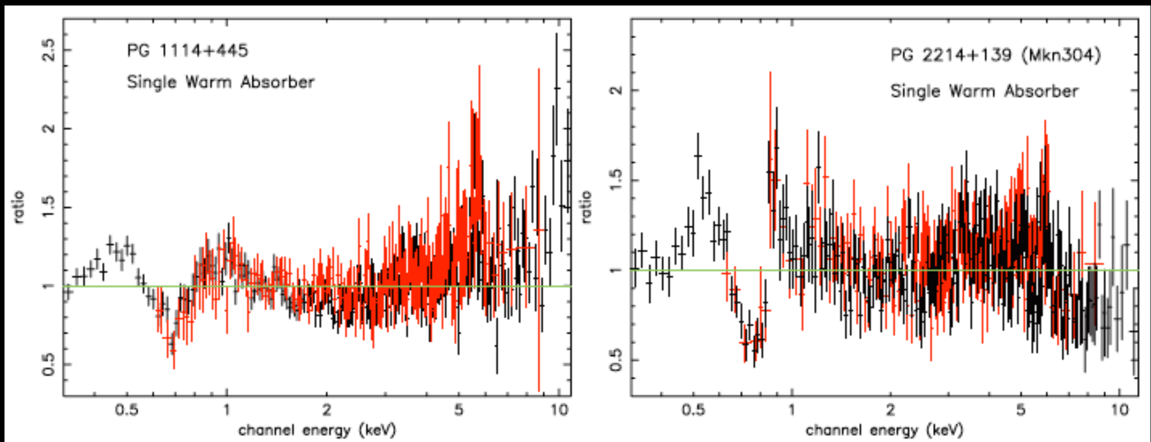
Many details from Chandra/XMM gratings

NGC3783 Exp=900 ks



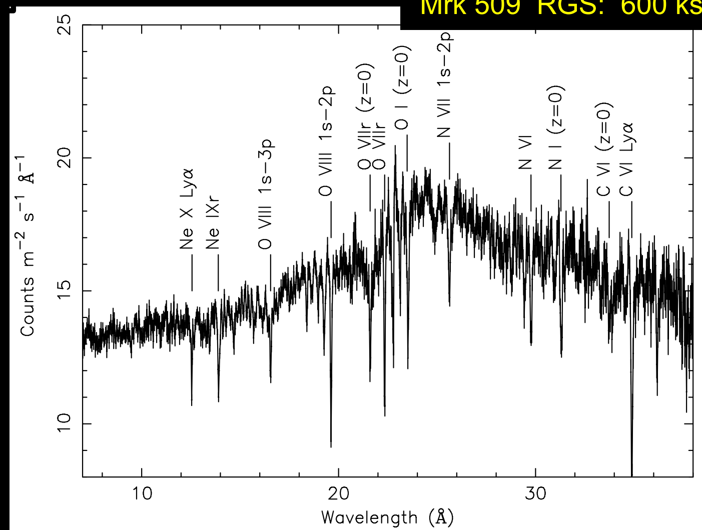
Kaspi et al. '01;
Netzer et al. '02;
Georges et al. '03;
Krongold et al. '03

QSOs: *XMM…*



Porquet et al. 2004; Piconcelli et al. 2005

Mrk 509 RGS: 600 ks



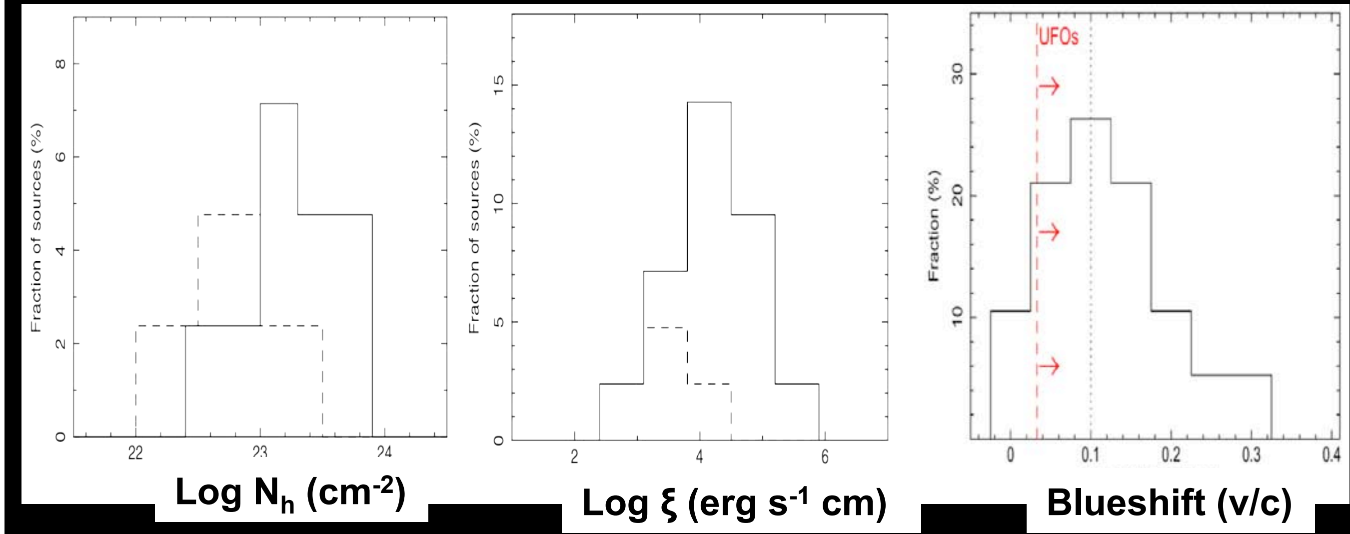
Kaastra et al. 2011, Detmers et al. 2011

→ 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

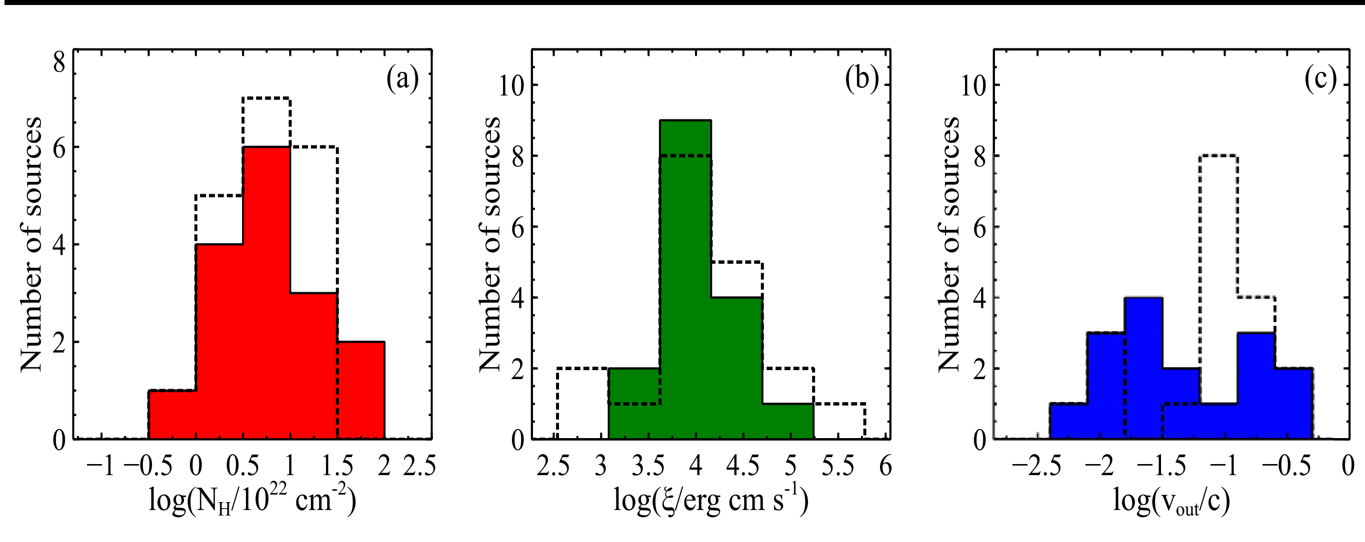
The "new" X-ray view: *UFOs (Ultra-Fast Outflows) confirmed and quite common*

XMM-Newton sample of nearby AGNs (Seyferts)



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

Suzaku sample of AGNs (Sey+RGs+RQQs)



Gofford et al. 2012

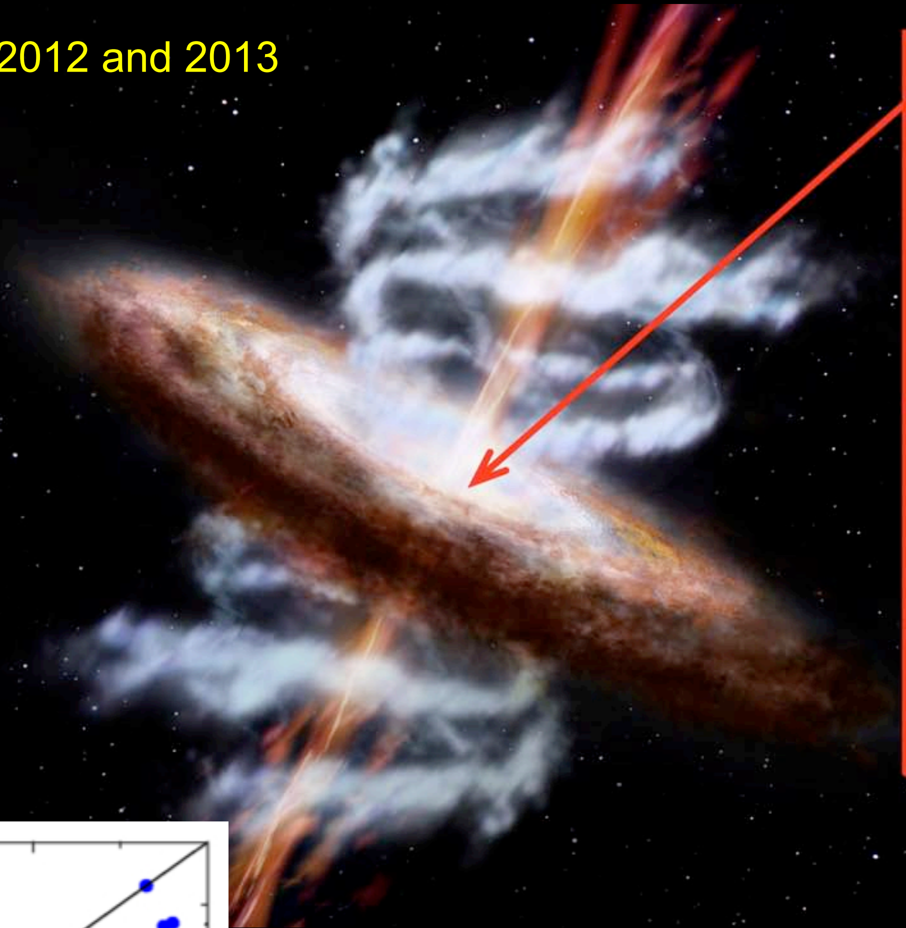
- 36 absorption lines detected in all 104 XMM observations
- Identified with FeXXV and FeXXVI K-shell resonant absorption
- 19/44 objects with absorption lines (≈43%)
- 17/44 objects with blue-shifted absorption lines (lower limit ≈39%, can reach a maximum of ≈60%)
- 11/44 objects with outflow velocity >0.1c (≈25%)
- Blue-shift velocity distribution ~0-0.3c, peak ~0.1c
- Average outflow velocity 0.110±0.004 c

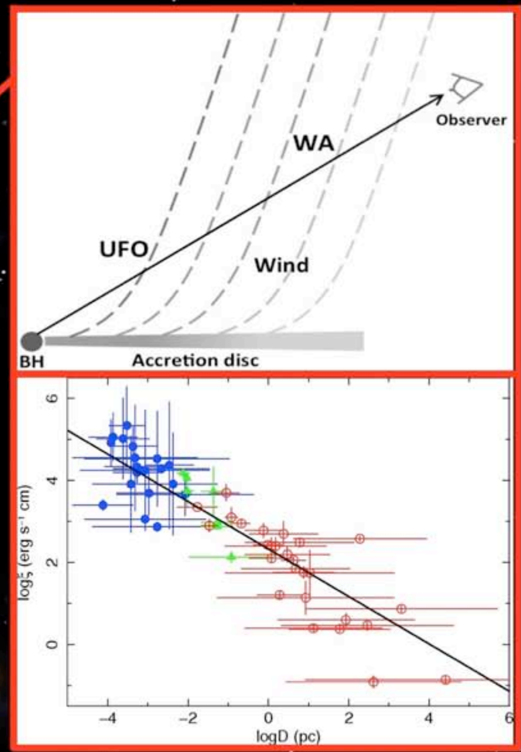
Table 5. Outflow velocity comparison

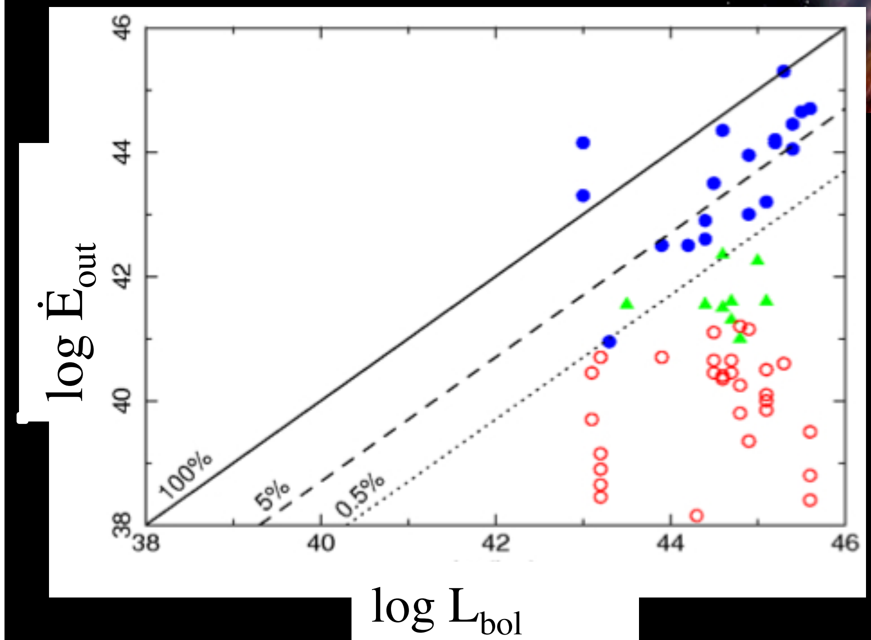
Velocity ($km\,s^{-1}$)	*Suzaku*	*XMM-Newton*
No outflow	3/20	2/19
$0 < v_{out} \leqslant 10,000$	5/20	2/19
$v_{out} > 10,000$	11/20	15/19
$v_{out} \geqslant 30,000$	8/20	9/19

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

INAF Press releases in 2010, 2012 and 2013
(also NASA and ESA in 2012)







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

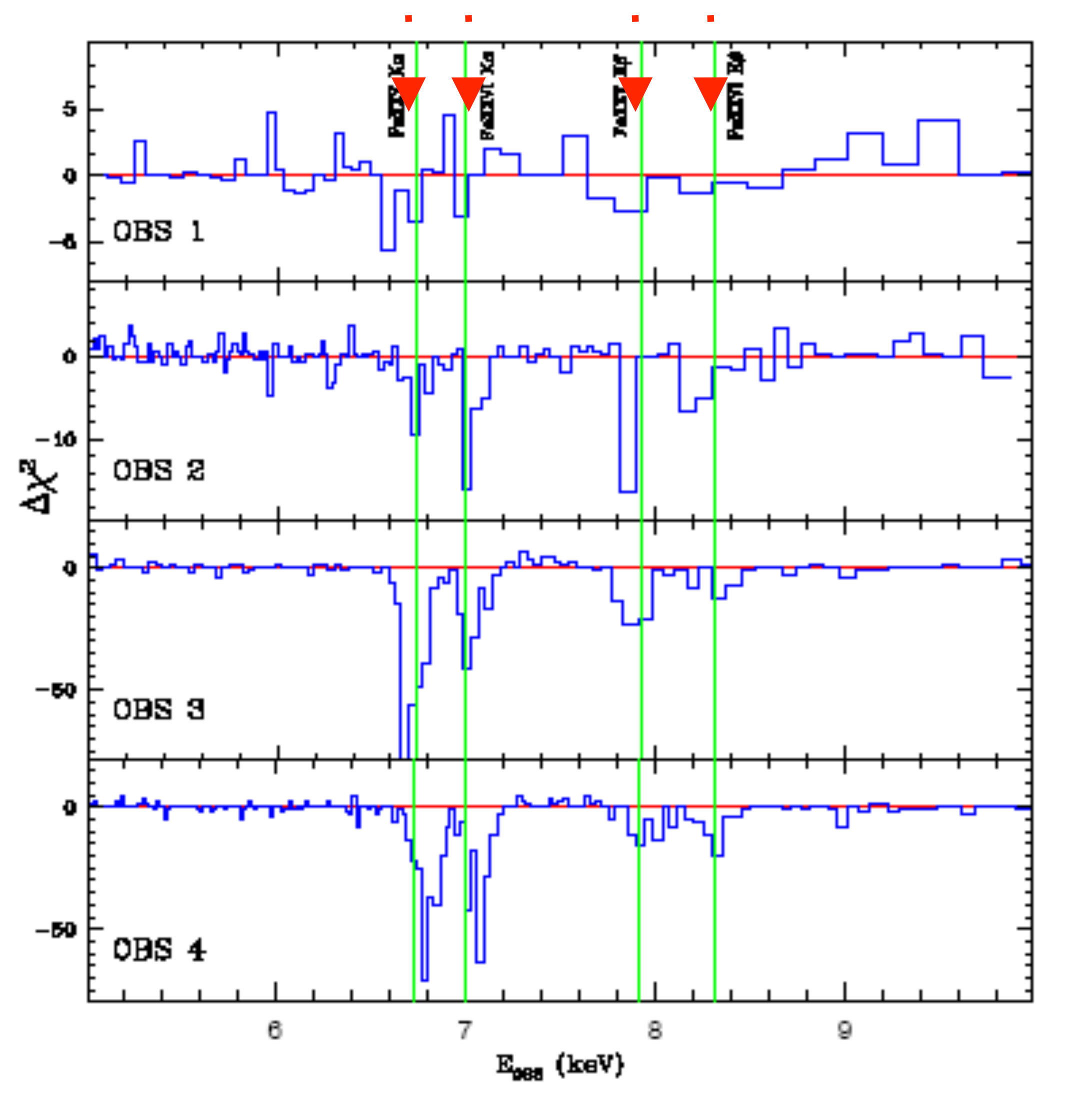
Tombesi, MC et al., 2012b

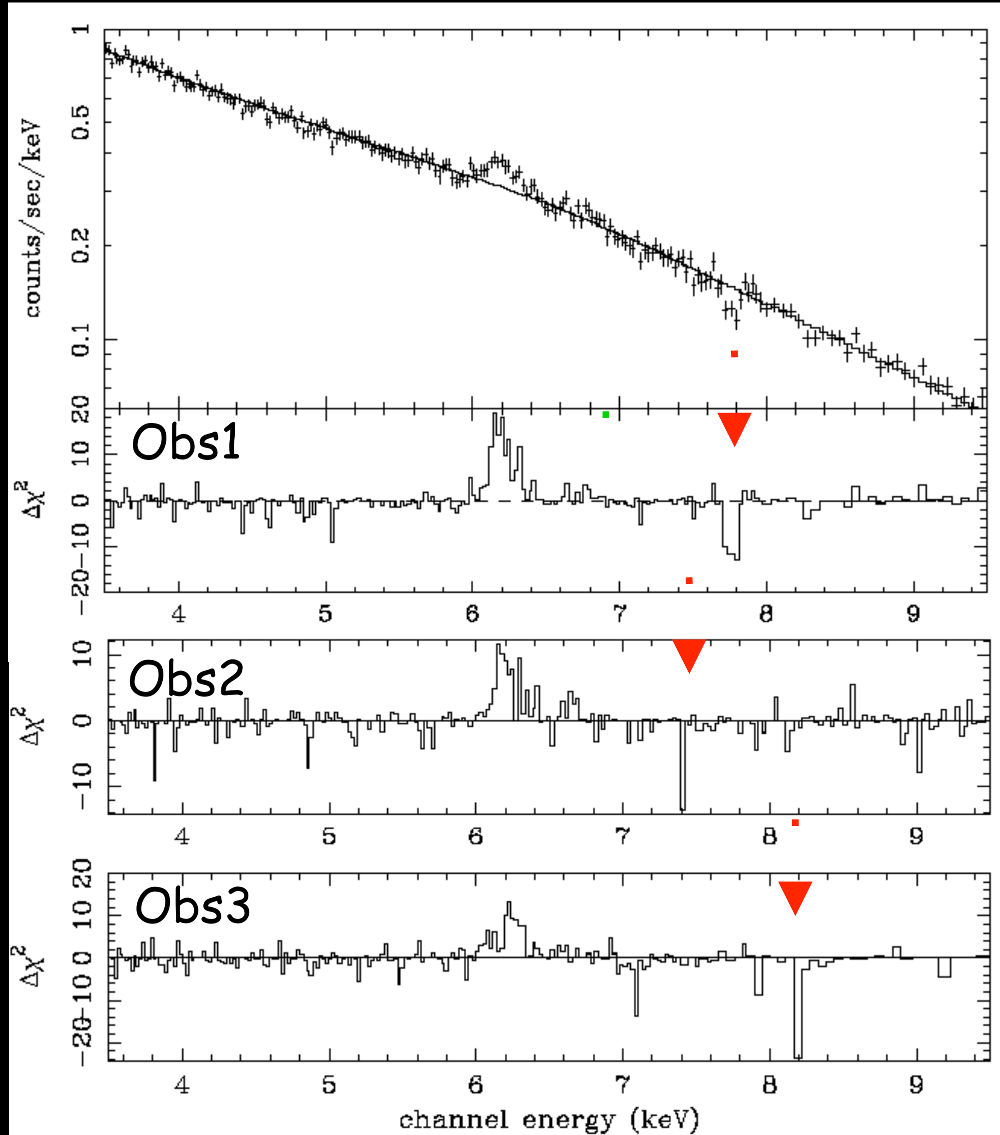
The "new" X-ray view: Variable absorption lines

Absorbers variability on timescales 1000-10000s

NGC1365

Mrk 509 (first long-look, 200ks)





Risaliti et al. 2005

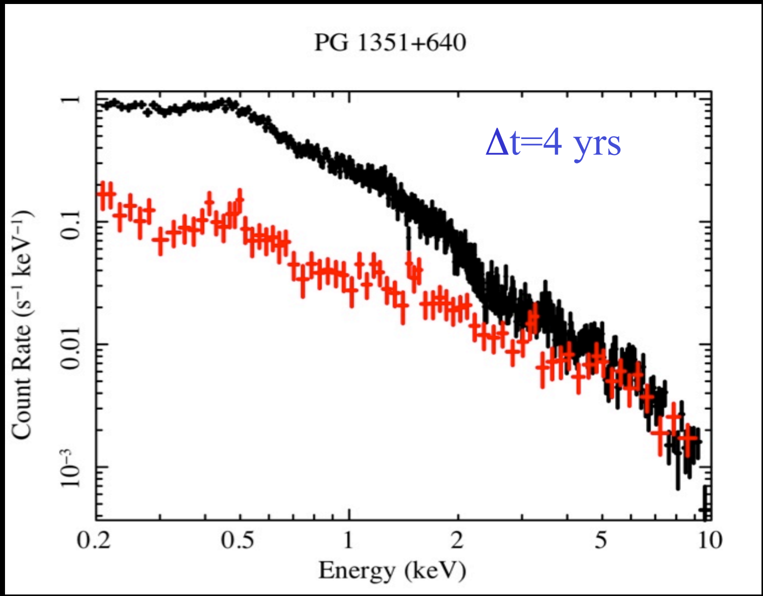
(See also Krongold et al. 2007 on NGC4051;
Behar et al. 2010 on PDS456, Braito et al. 2007 on MCG5-23-16; etc.)

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

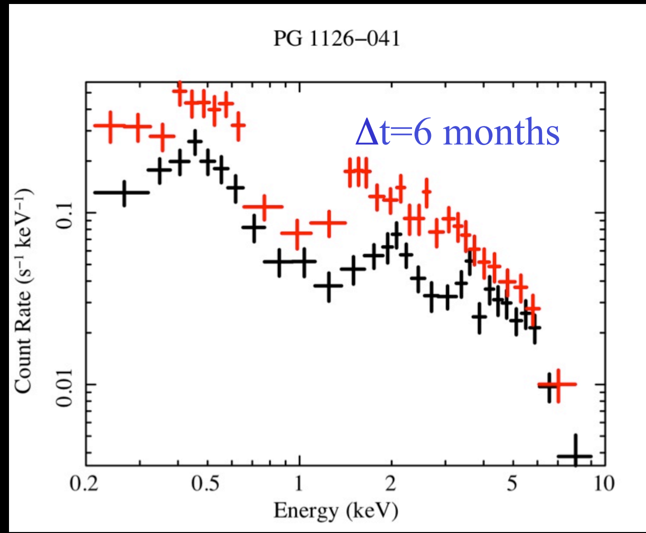
Variability allows to place limits on location, mass, etc.

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

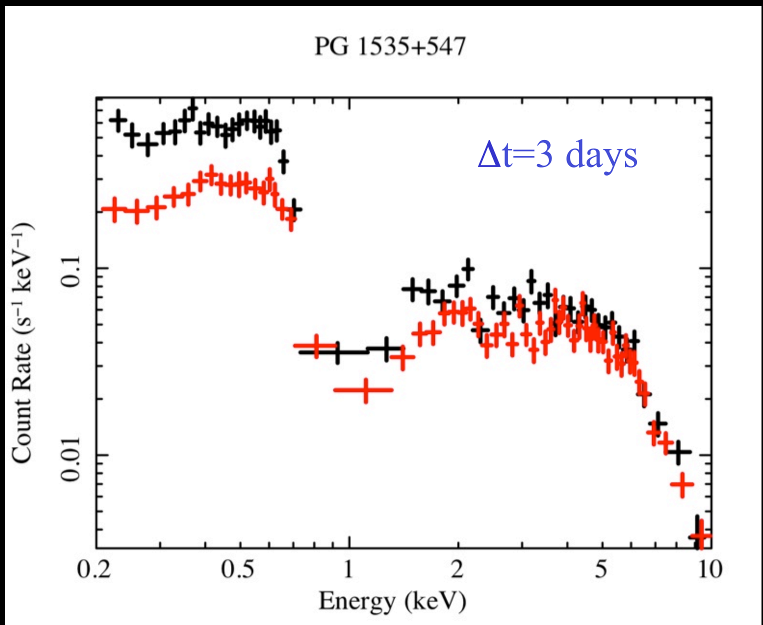
Sample: 15 UV *AL QSOs with 32 XMM exposures



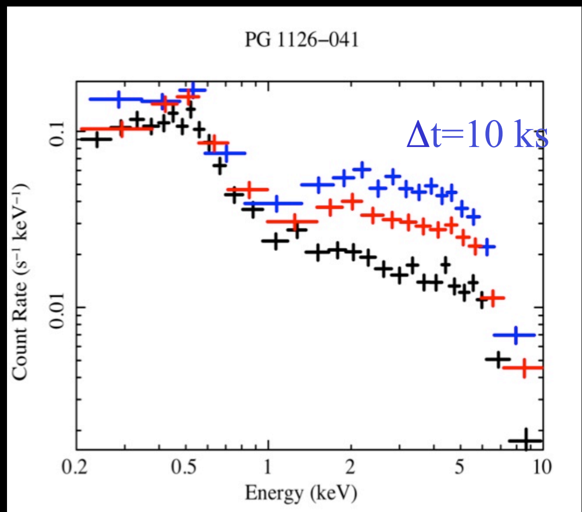
on time scales of years

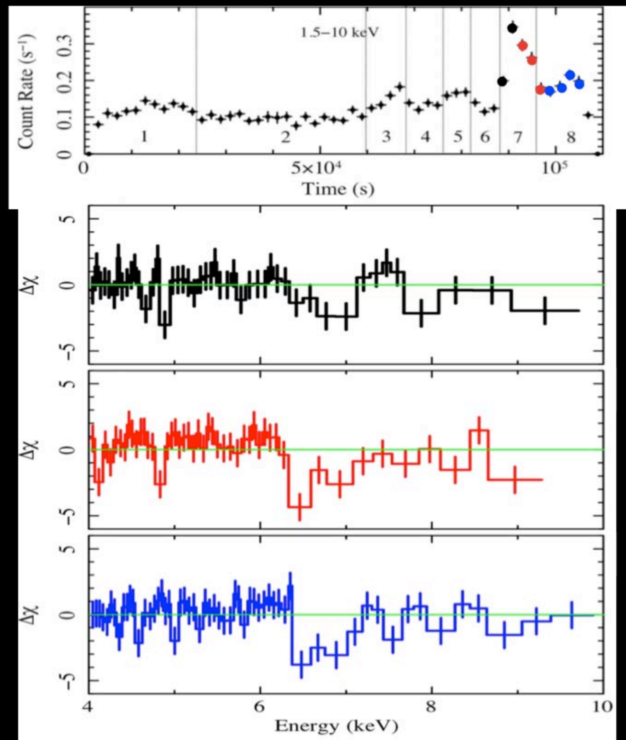


on time scales of months



on time scales of days

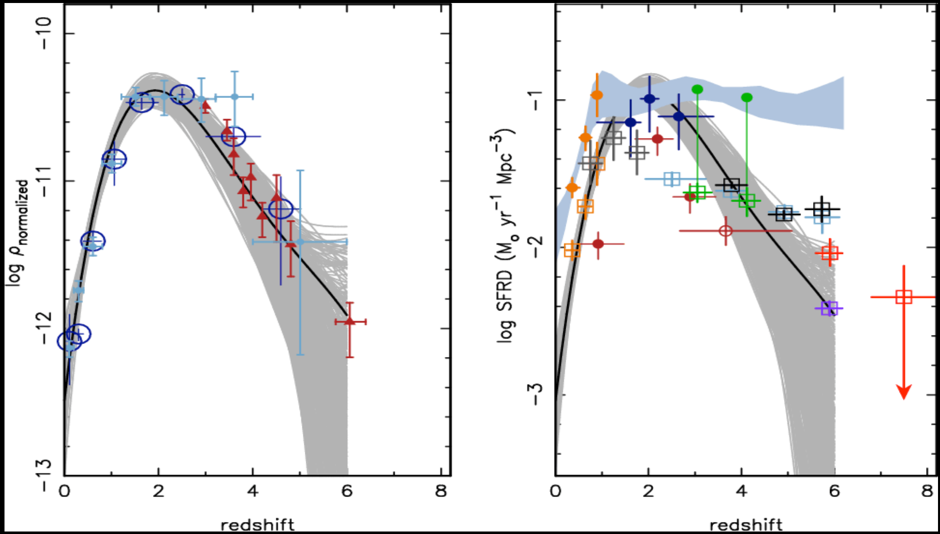




on time scales of hours

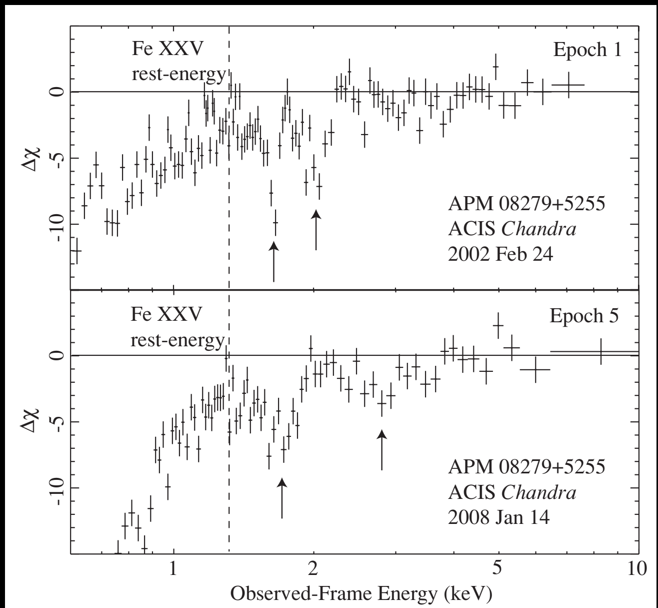
Giustini, MC, et al. 2012

UFOs seen also in high-z QSOs



QSO space density SFR space density

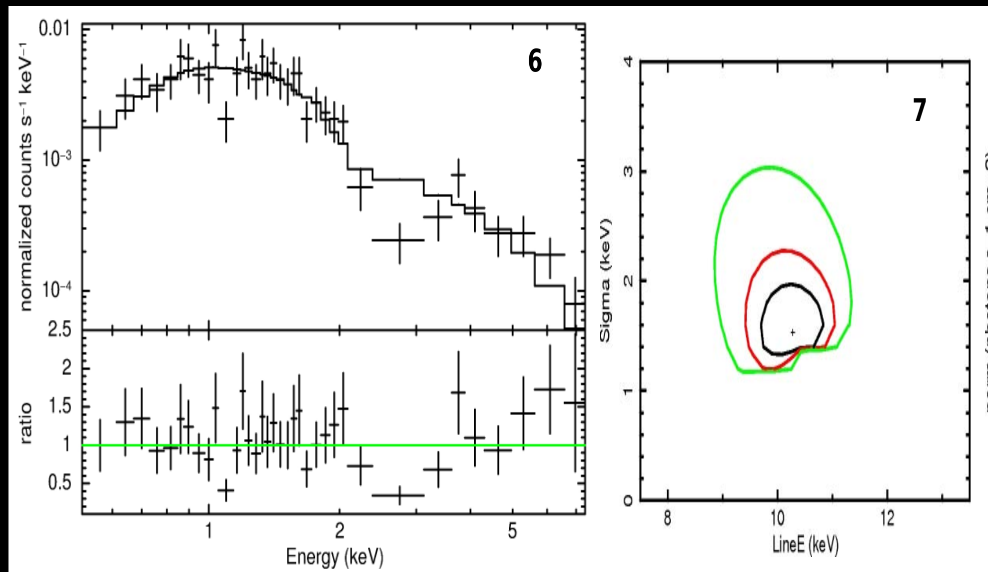
Madau et al. '96; Wall et al. '05



APM 08279+5255 (z=3.91)

V_{out}~0.2-0.76 c Chartas et al. 2009

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



Lanzuisi et al., '12

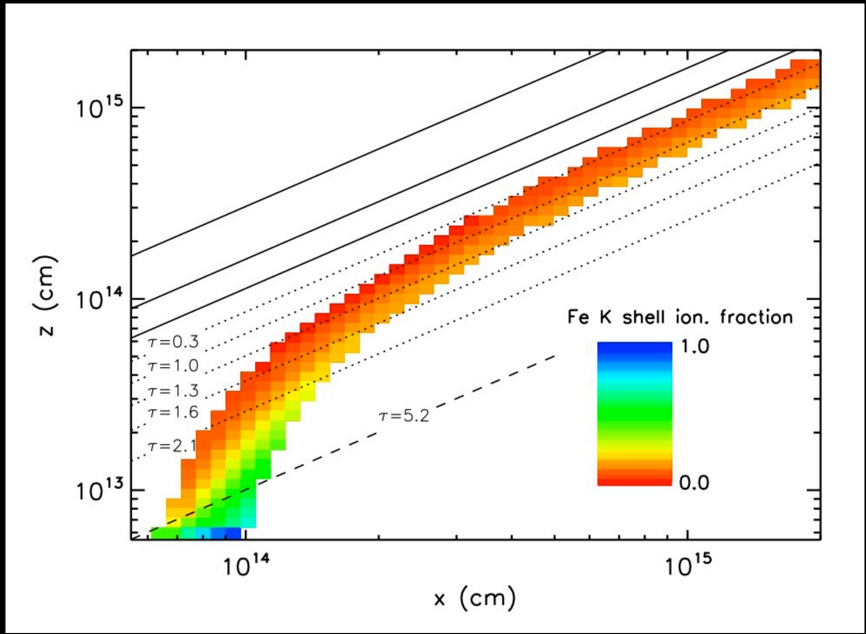
HS1700: The 4° high-z QSO to show variable, high-v, high-Xi absorbers, but the 1° non-lensed

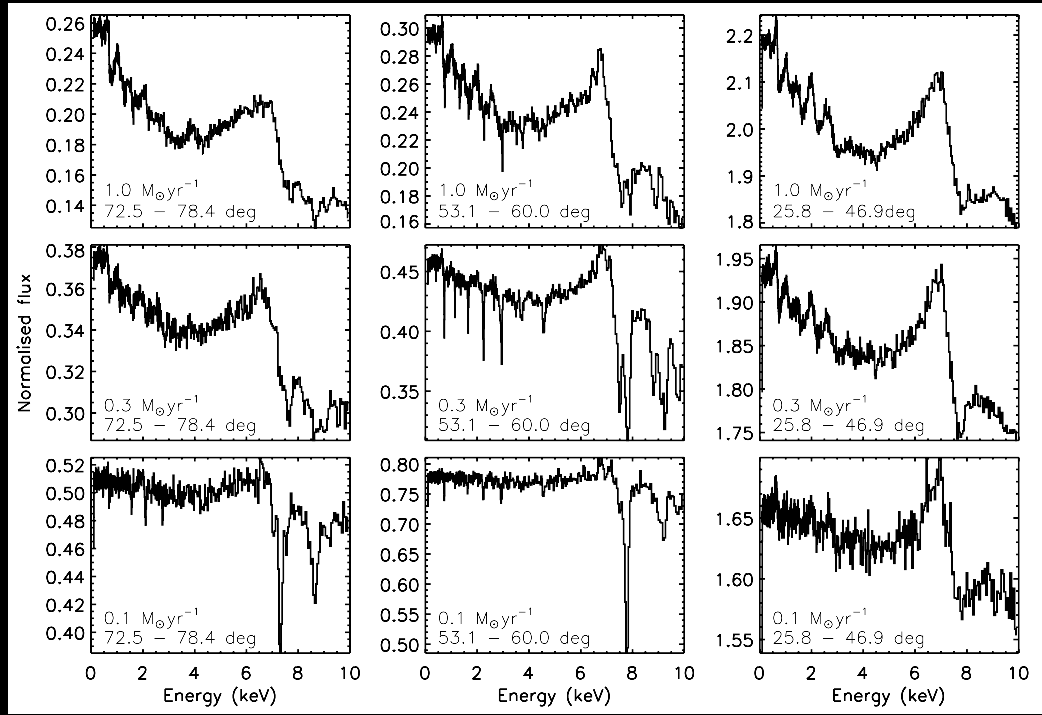
<u>N.B.:</u> Would be nice also to confirm it via longer XMM observations….

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

▪

Radiatively driven accretion disc winds



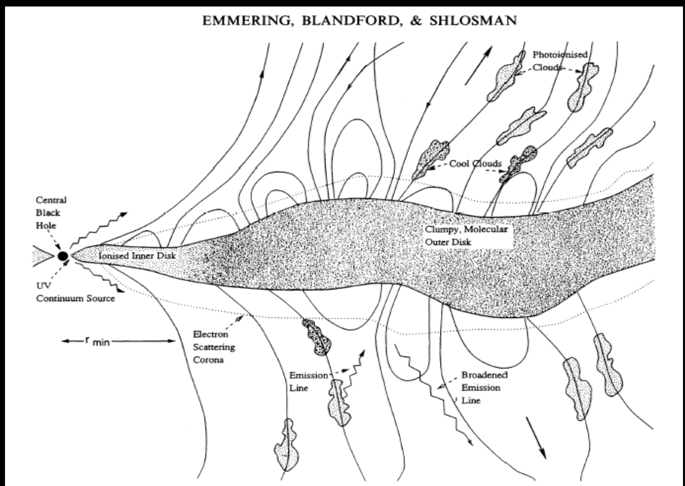


Sim et al., '08, '10ab

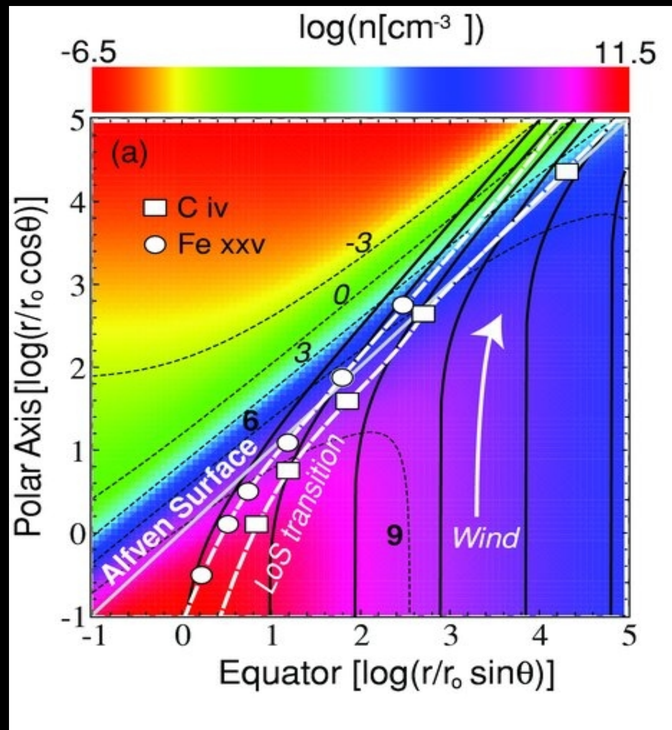
Murray et al. '95, Proga et al. '00

…and/or…

Magnetically driven winds from accretion disk



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



Fukumura, et al. 2010
Kazanas et al. 2012

UFOs potentially significant/dominating AGN feedback

▪

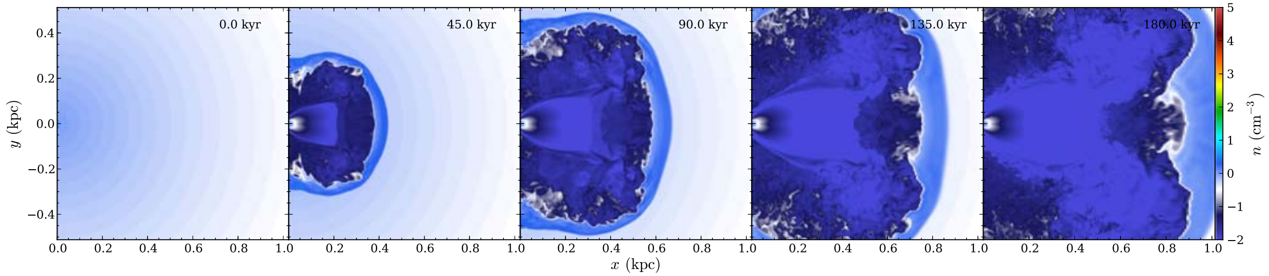


FIG. 1.— Midplane density slices of the evolution of a $10^{44}\,\mathrm{erg\,s^{-1}}$ UFO in an ISM devoid of clouds (Run A). See the electronic edition of the Journal for a color version of this figure.

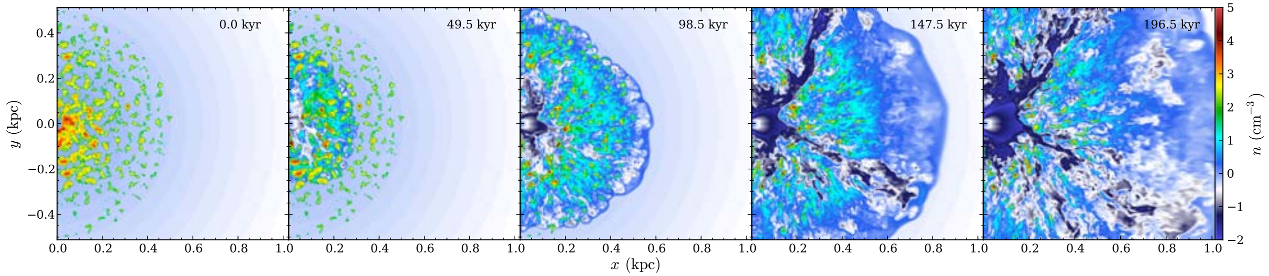


FIG. 2.— Same as Fig 1, but for a two-phase ISM with spherically distributed clouds (Run B).

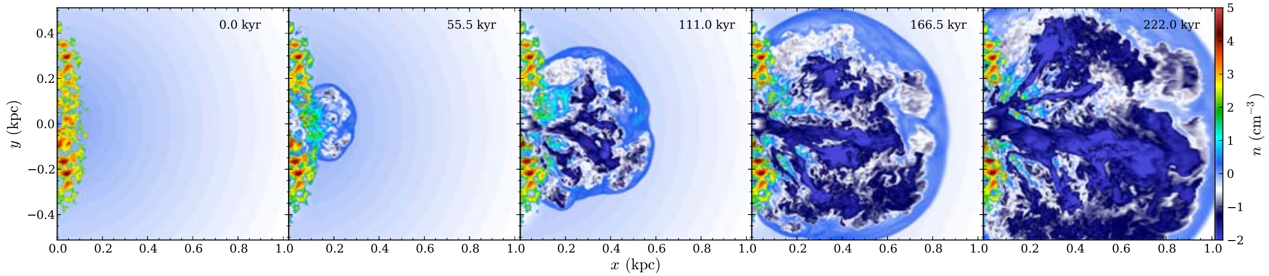


FIG. 3.— Same as Fig 1, but for a two-phase ISM with clouds distributed in a quasi-Keplerian dis (Run C).

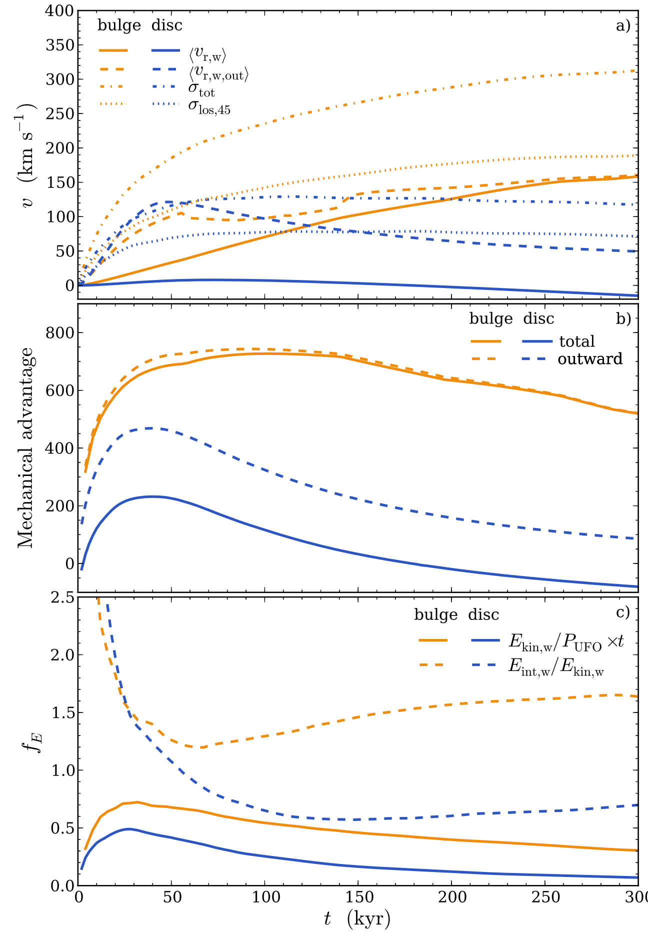


FIG. 4.— Evolution of various quantities that gauge the feedback efficiency for simulations with a bulge-like or a disc-like distribution of clouds: a) The density-weighted average radial velocity, the outward (positive) component of the radial velocity, the total velocity dispersion, and the line-of-sight velocity dispersion (at 45° inclination); b) The mechanical advantage as measured by the total or outward-only radial momenta of clouds. c) The warm-phase kinetic energy as a fraction of the energy provided by the UFO and the ratio of the warm-phase internal energy to kinetic energy.

ULTRA FAST OUTFLOWS: GALAXY-SCALE ACTIVE GALACTIC NUCLEUS FEEDBACK

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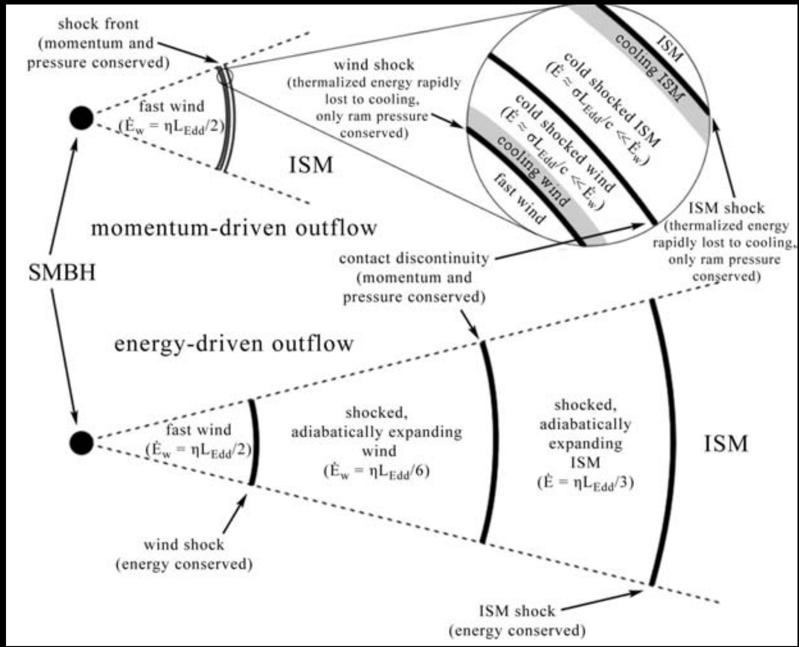
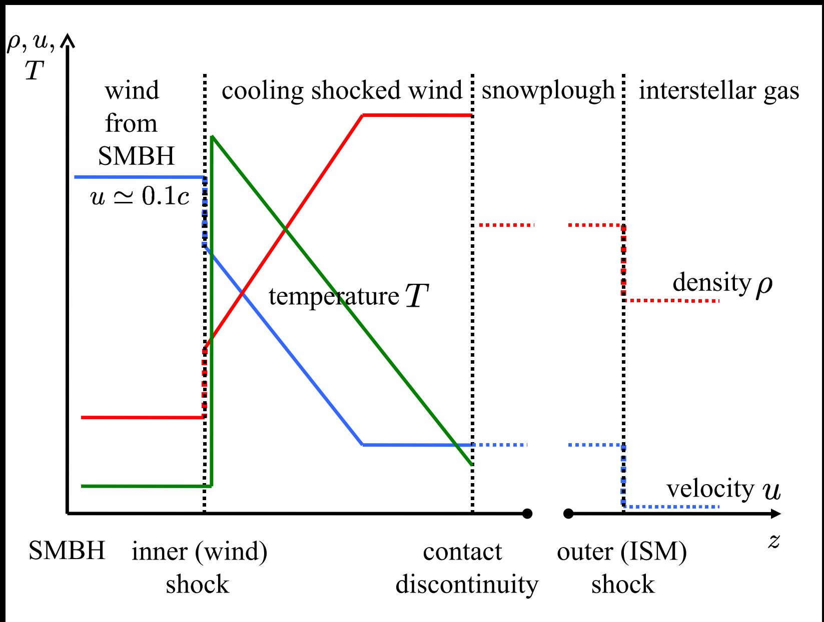
Accepted for publication in the Astrophysical Journal Letters on December 20, 2012.

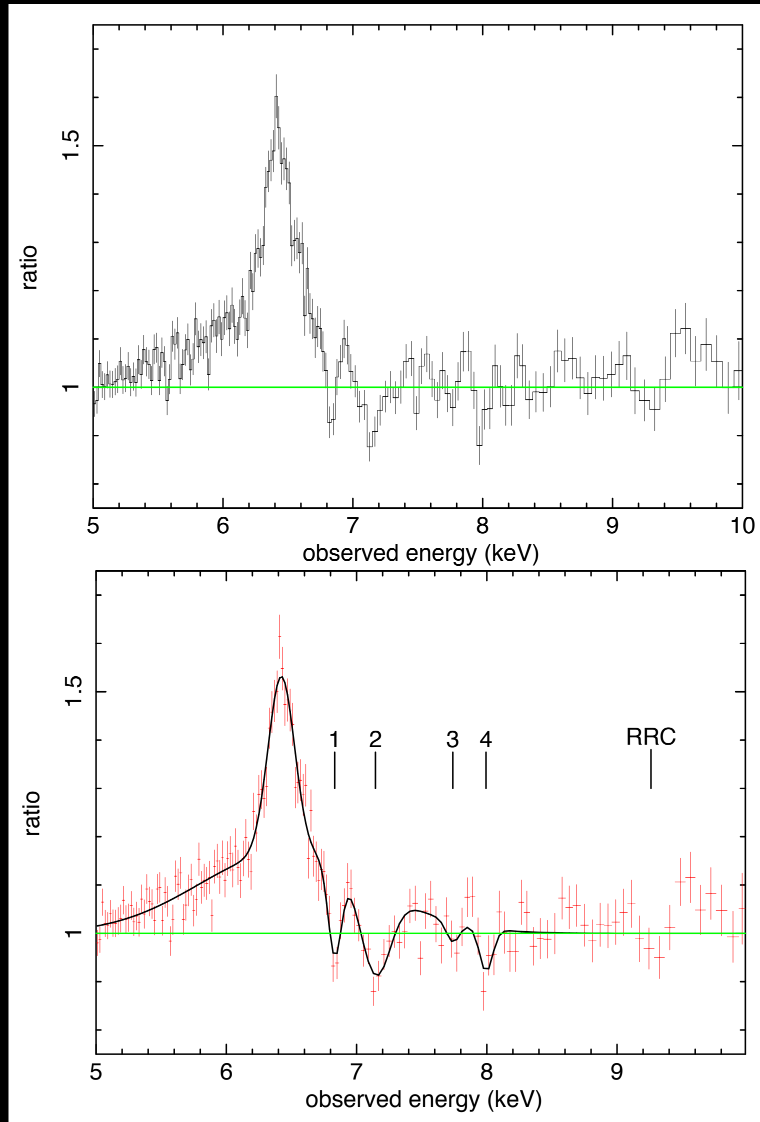
A large-scale shocked wind-ISM seen via (time-integrated, and time-resolved) spectra?

▪





King 2009, 2010
Zubovas & King 2012



Pounds and Vaughan, 2012a,b,c

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

NGC6240

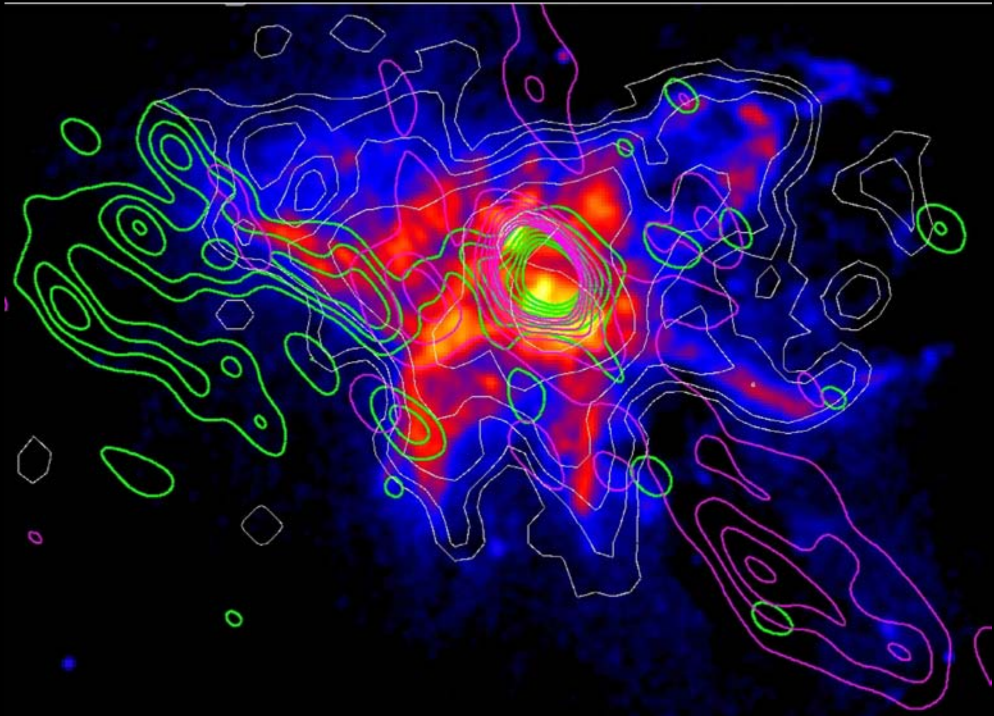
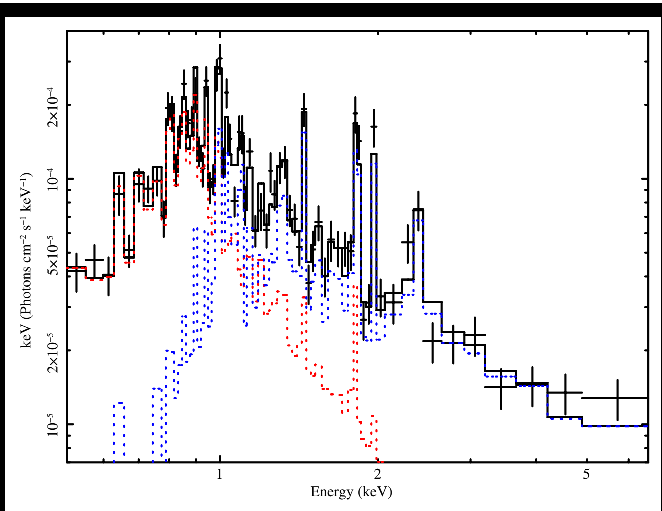
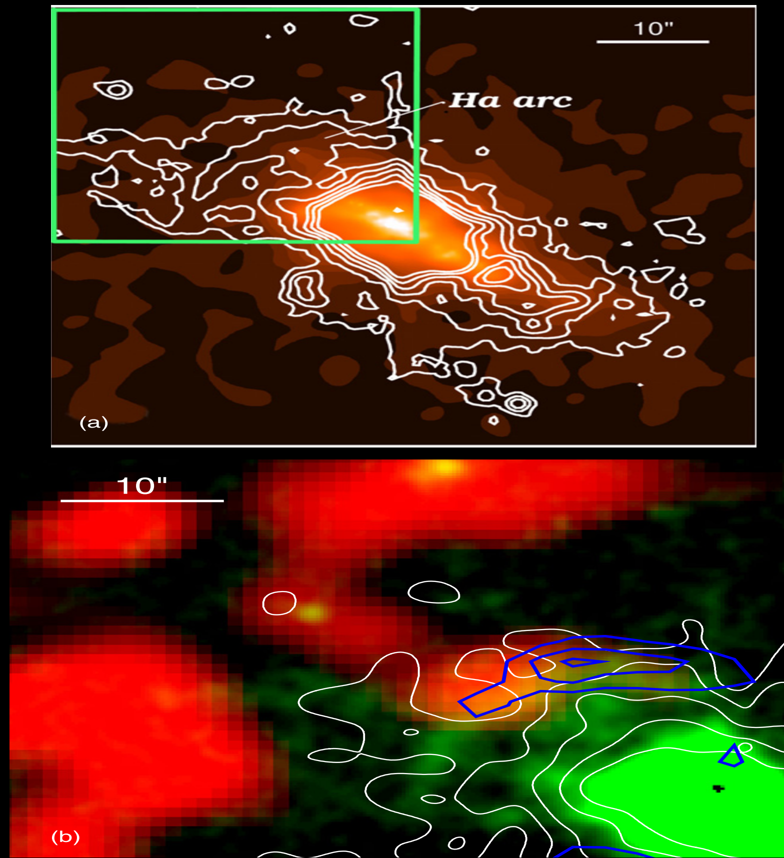


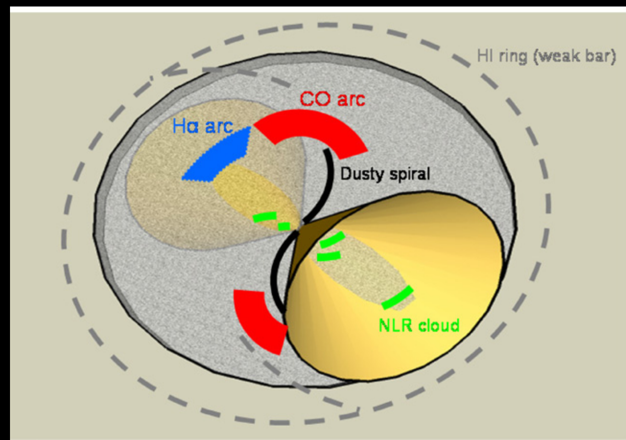
Fig. 5. Hα map of NGC 6240 (color image). CO(1–0) emission at different velocities: -350 km s^{-1} (green contours), -100 km s^{-1} (magenta contours), with respect to the system velocity. Contours are calculated by merging D and A configuration data. *Chandra* 1.6–2 keV emission is shown by white contours.



Feruglio et al. 2013

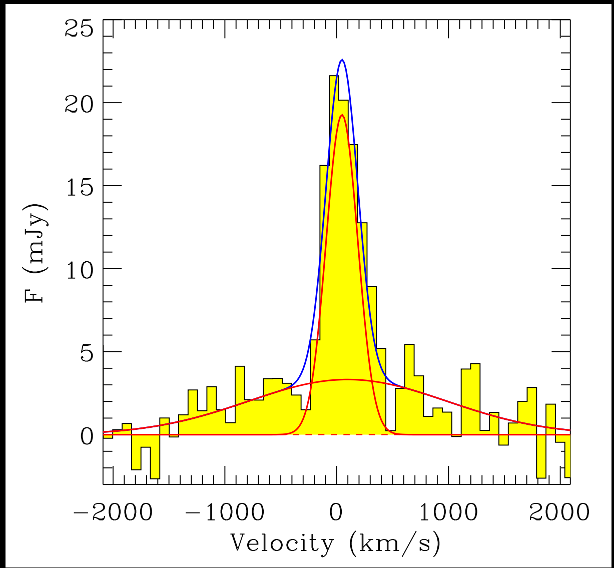
NGC4151



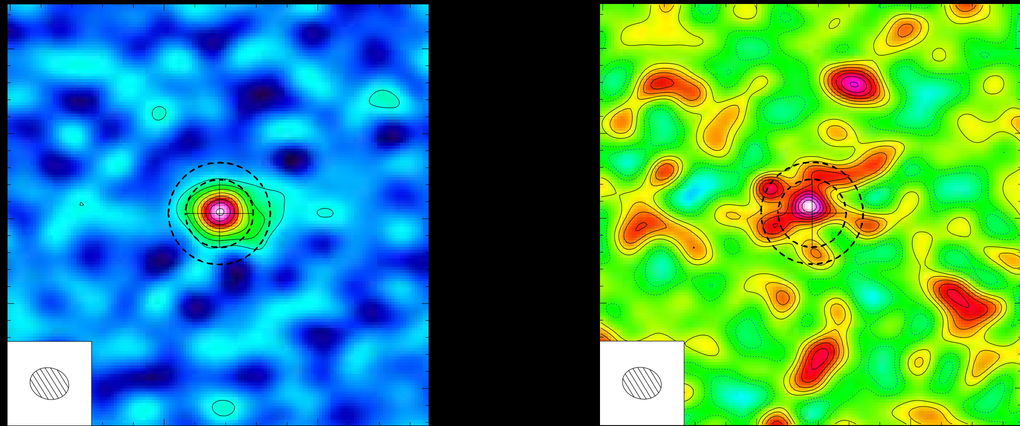


Wang et al. 2012a,b,c

How WAs/UFOs compare/relate to (high-z) colder molecular/gas outflows?



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

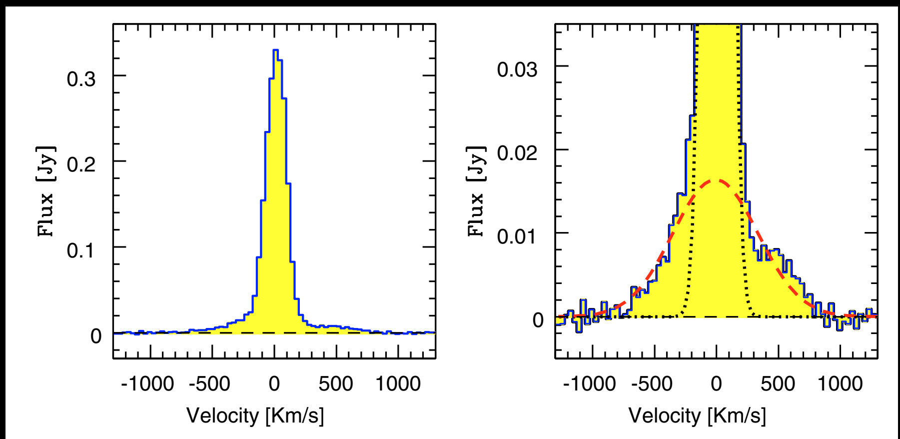


[CII] 158 μm broad wings (FWHM~2000 km/s) + extension →

Maiolino et al. 2012

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

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

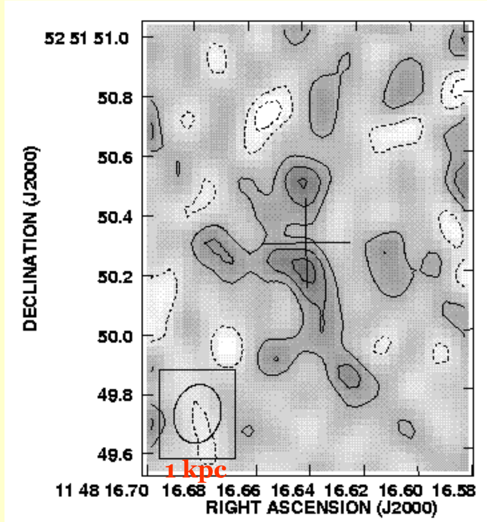


Feruglio et al. 2010

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

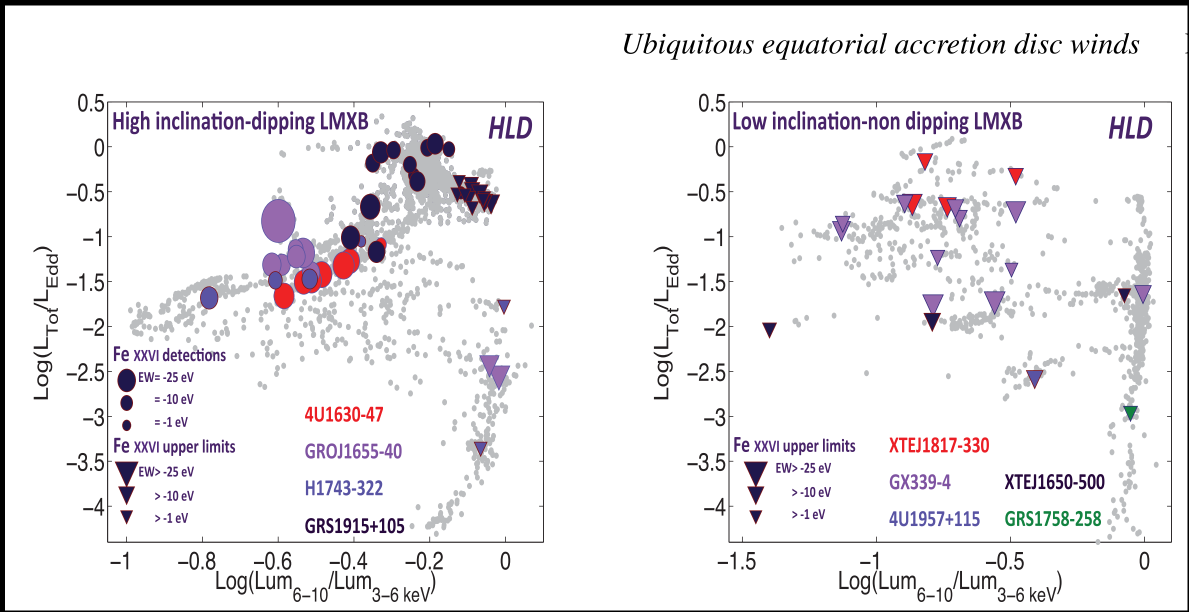
Bertoldi et al. 2003
Walter et al. 2004

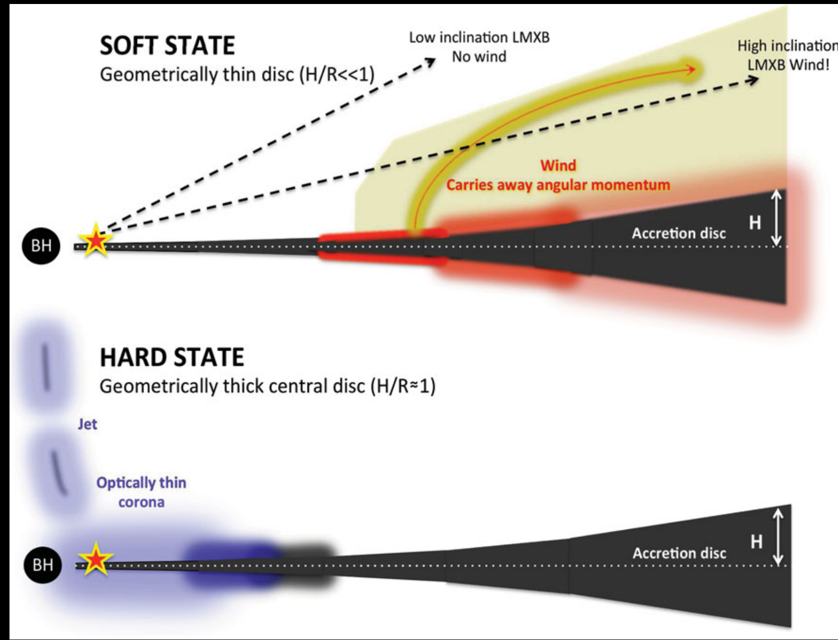
VLA CO 3—2 map



Walter et al. 2004

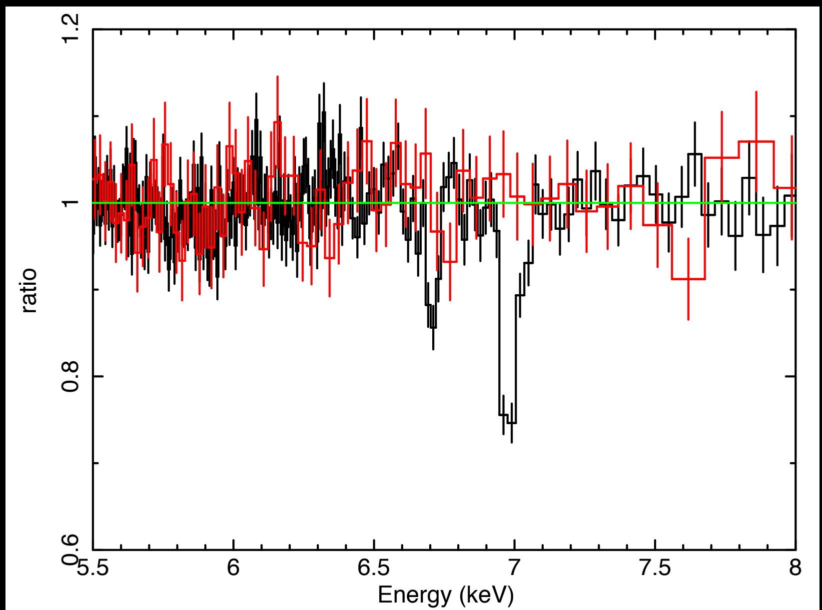
How WAs/UFOs compare/relate to binaries winds and jets?





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

See Maria Diaz-Trigo's talk

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

Miller et al., 2006, 2012

How WAs/UFOs compare/relate to microquasars?

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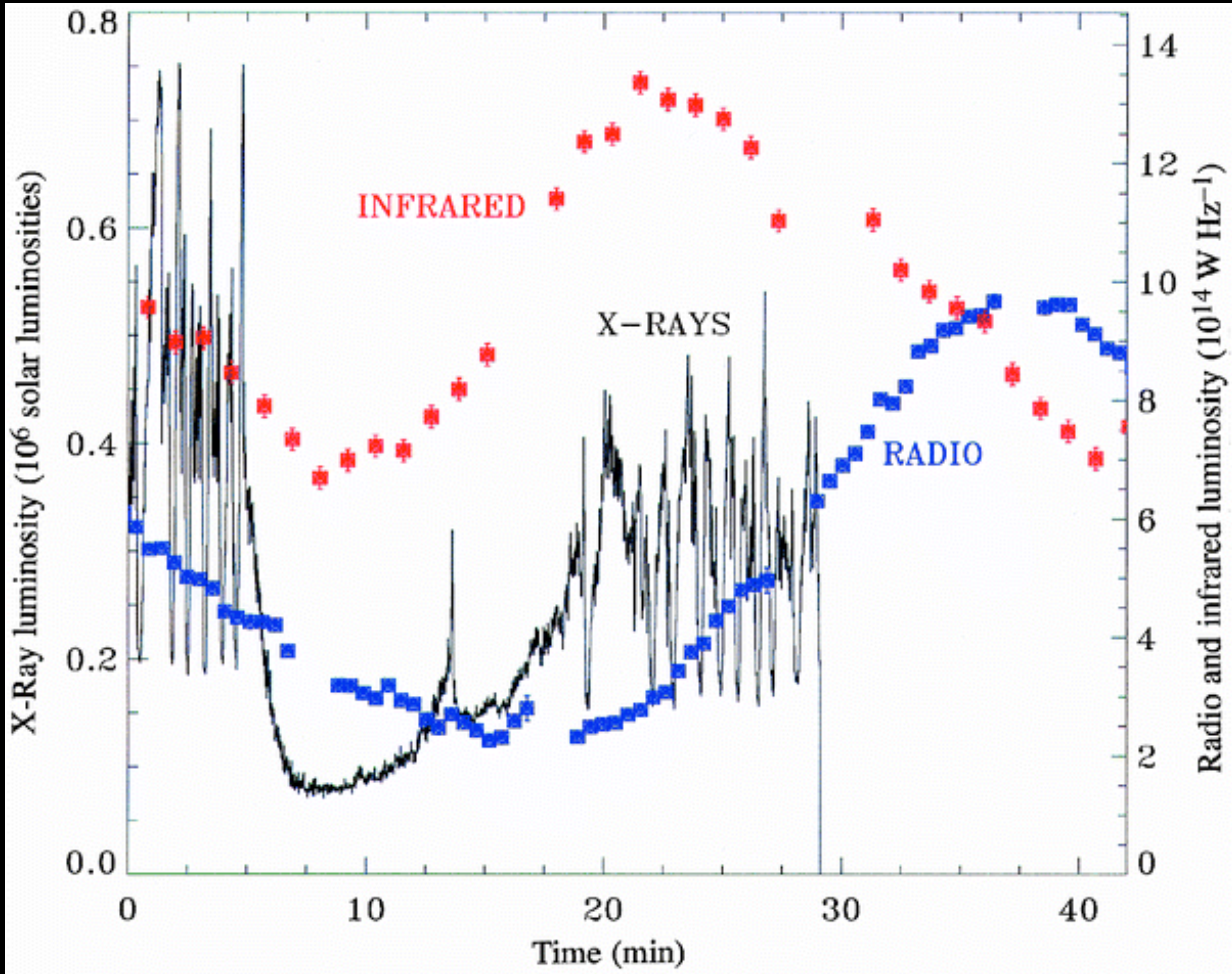
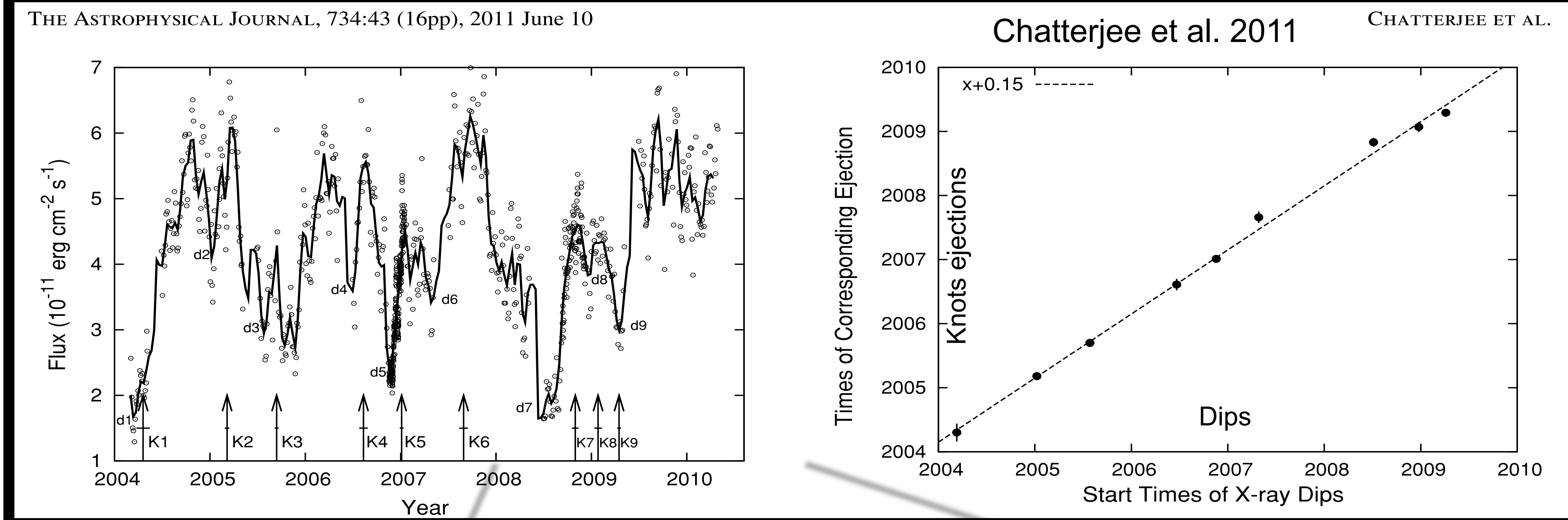
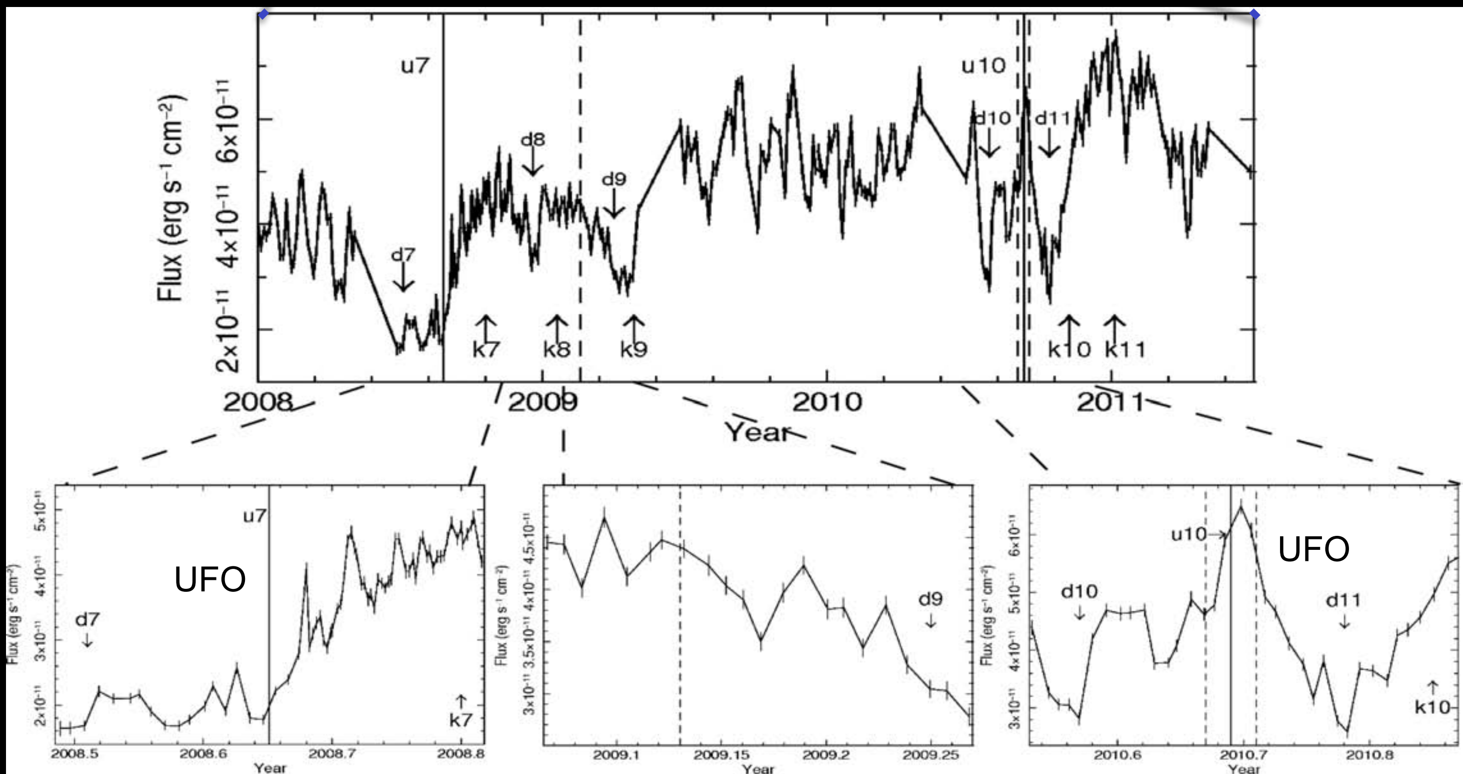


GRS1915 The disappearance of the inner accretion disk, coincides with the beginning of the ejection of a relativistic plasma cloud. As the ejected cloud expands it becomes transparent to radio waves, with a peak radio-wave flux that is delayed by 15 min relative to the infrared peak.

Mirabel and Rodriguez, 1998, Nature



3C111



Tombesi et al. 2011

UFOs compared/relate to binaries winds and jets?

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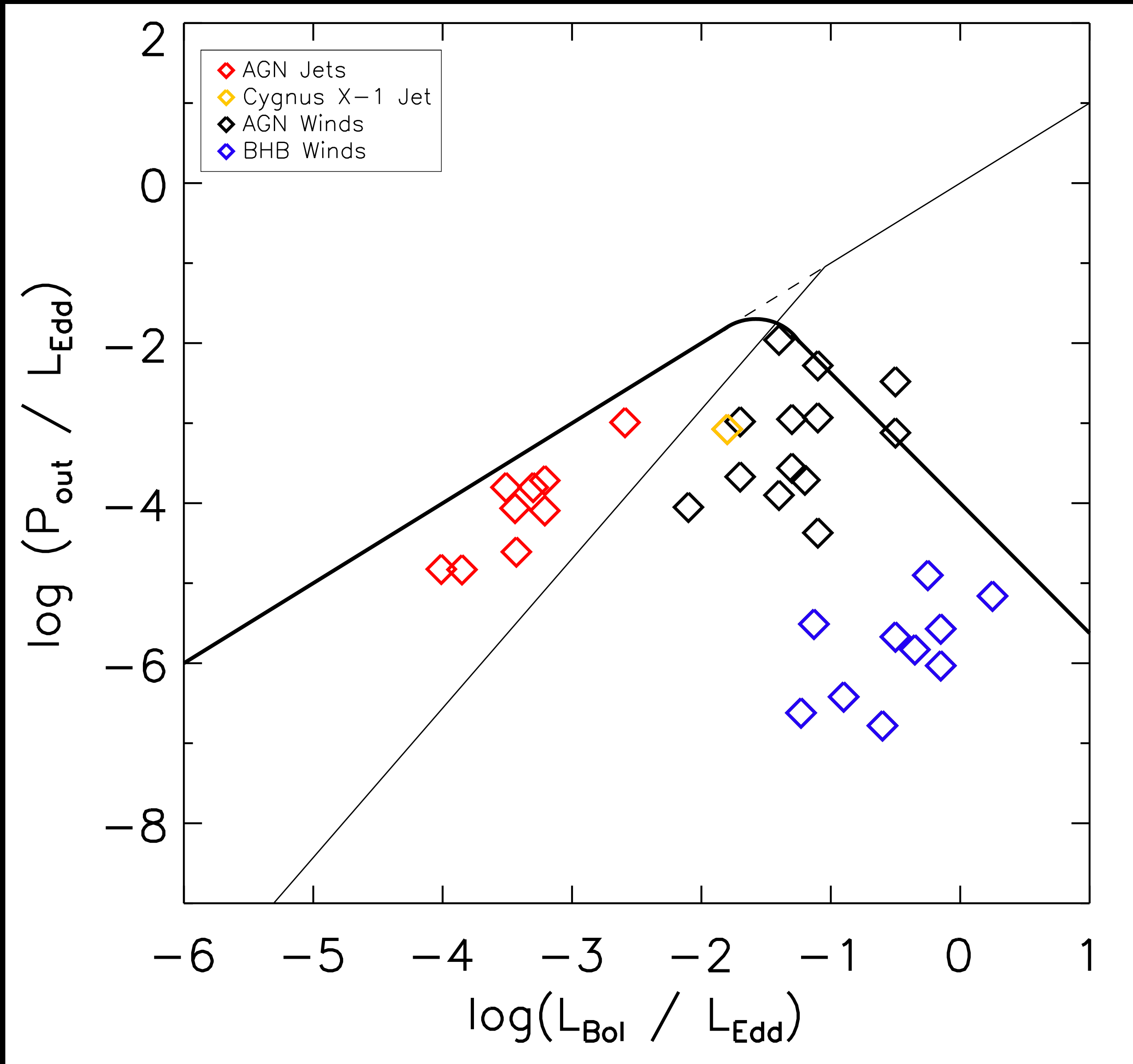

King A. et al. 2012, Churazov et al. 2005

Summary

- General framework/importance
  - ⇒ *Recognized importance of UFOs (to AGN feedback AND wind/outflows/ jets physics)*

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

- How they relate/compare to
  - ⇒ WAs?
  - ⇒ *Cold molecular outflows in QSOs, ULIRGs, high-z QSOs?*
  - ⇒ *Accretion/state/jet formation/wind quenching?*