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<i>Title</i>	Outflows, Feedback and SMBH/Galaxy Co-Evolution
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Outflows, Feedback and SMBH/Galaxy Co-Evolution



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Outline

- i. AGN Outflows (very brief review of science case)
- ii. The Astrophysics of AGN Outflows
- iii. The (Cosmological) impact/feedback of AGN outflows

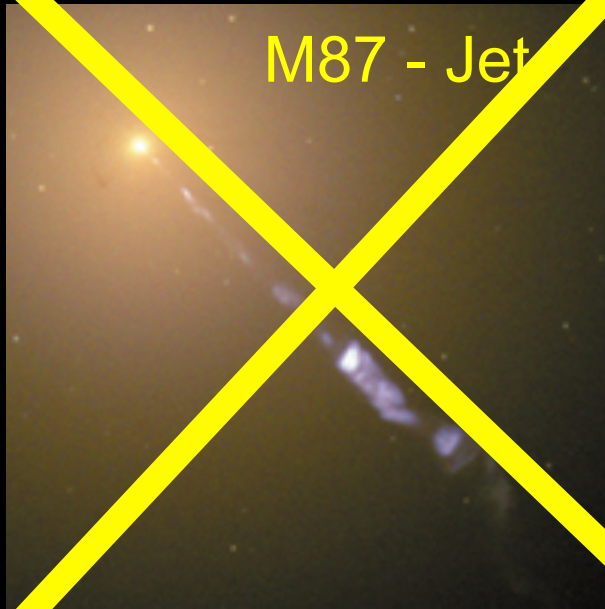
Main Collaborators: M. Dadina, G. Chartas, J. Kaastra, J. Kriss, C. Vignali, G. Lanzuisi, F. Tombesi, M. Giustini, J. Reeves, M. Gaspari, J. Gofford, B. DeMarco, G. Ponti, V. Braitto

AGN Outflows

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

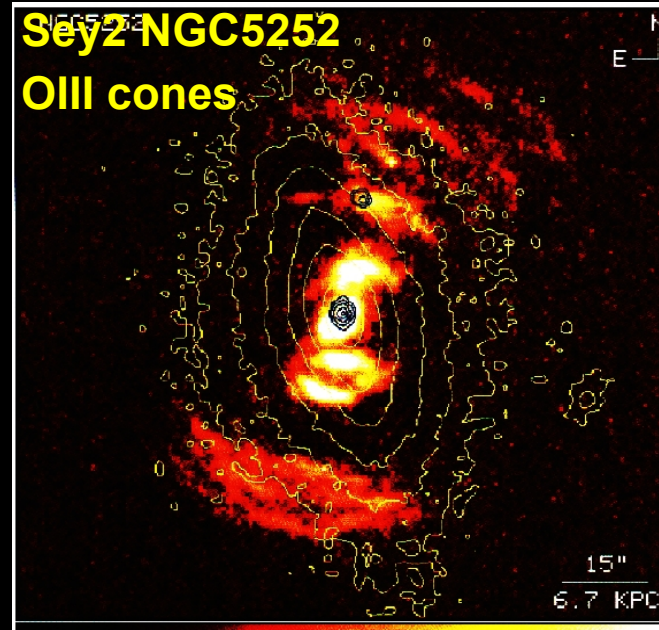
...known/seen in AGNs since >3 decades

Jets in radio-loud AGNs



M87 - Jet

Wide-angle winds in Sey gal. and QSOs



Sey2 NGC5252
OIII cones

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

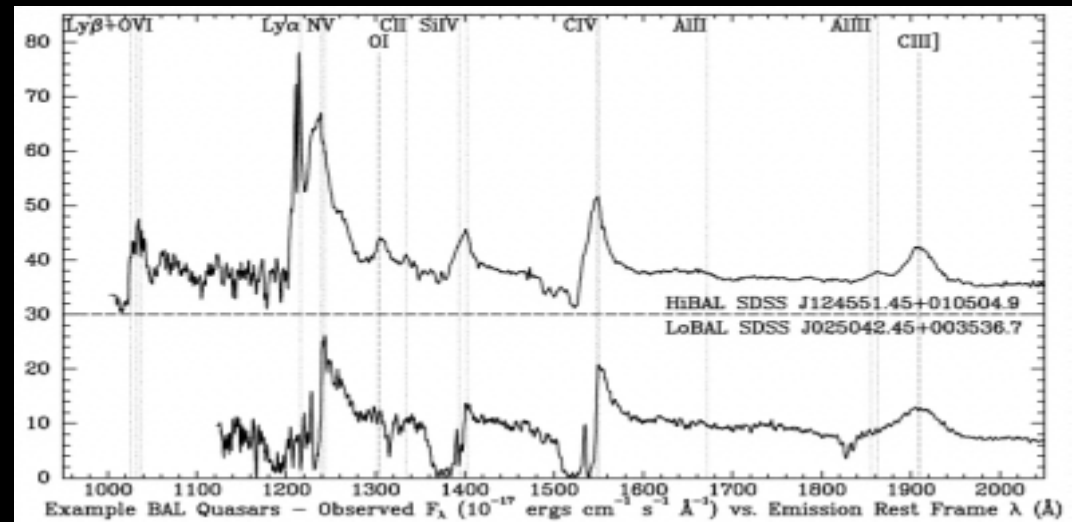
+ Fischer+ '10, '13, '15

Jet feedback relevant in LSSs

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

(~ 40 -50% of all QSOs)

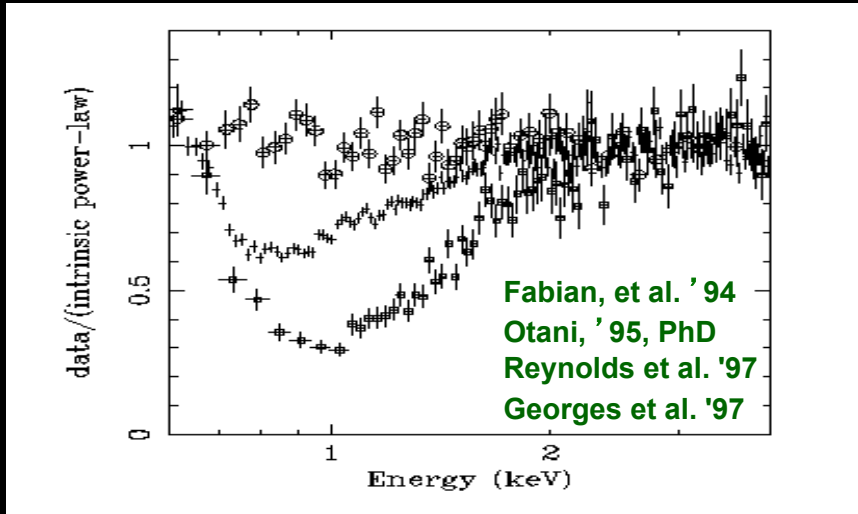
Taking into account the Cf,
→ Likely ubiquitous



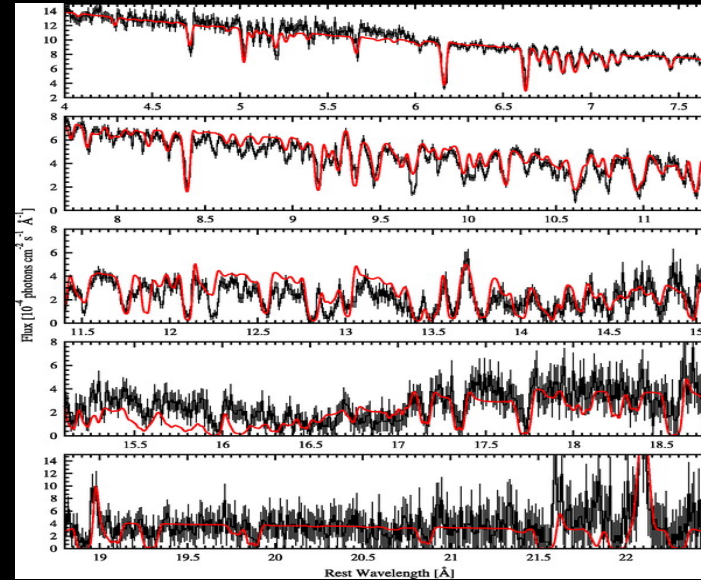
Weymann et al., '91; Goodrich '97; Reichards et al., '03; Ganguly & Brotherton '08; Hamann+'12

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

Seyfert galaxies: ASCA...



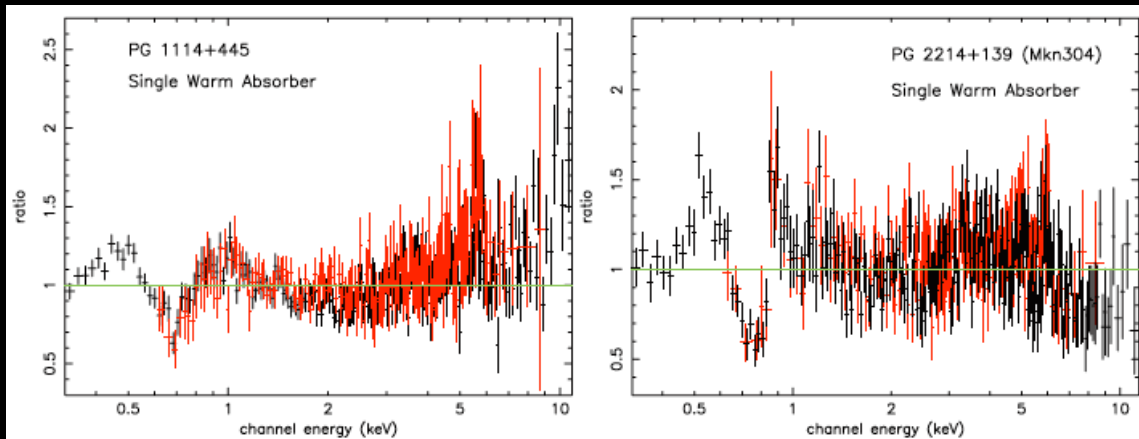
Many details from Chandra/XMM gratings
NGC3783 Exp=900 ks



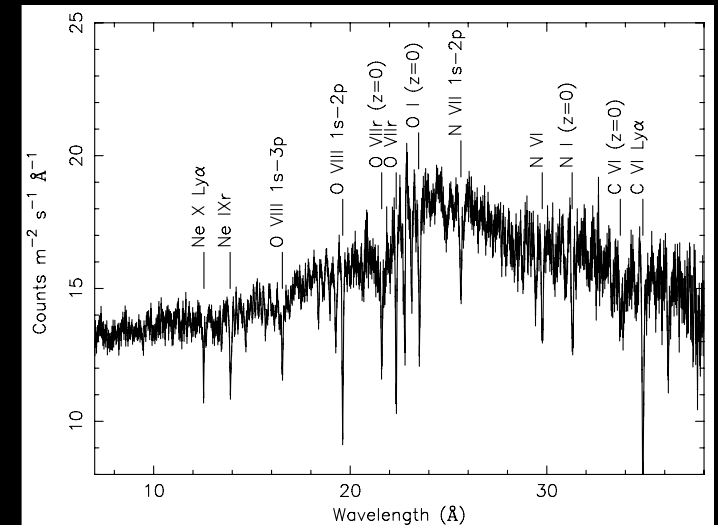
Kaspi et al. '01;
Netzer et al. '02;
Georges et al. '03;
Krongold et al. '03

QSOs: XMM...

Mrk 509 RGS: 600 ks



Porquet et al. 2004; Piconcelli et al. 2005



Kaastra et al. 2011, Detmers et al. 2011

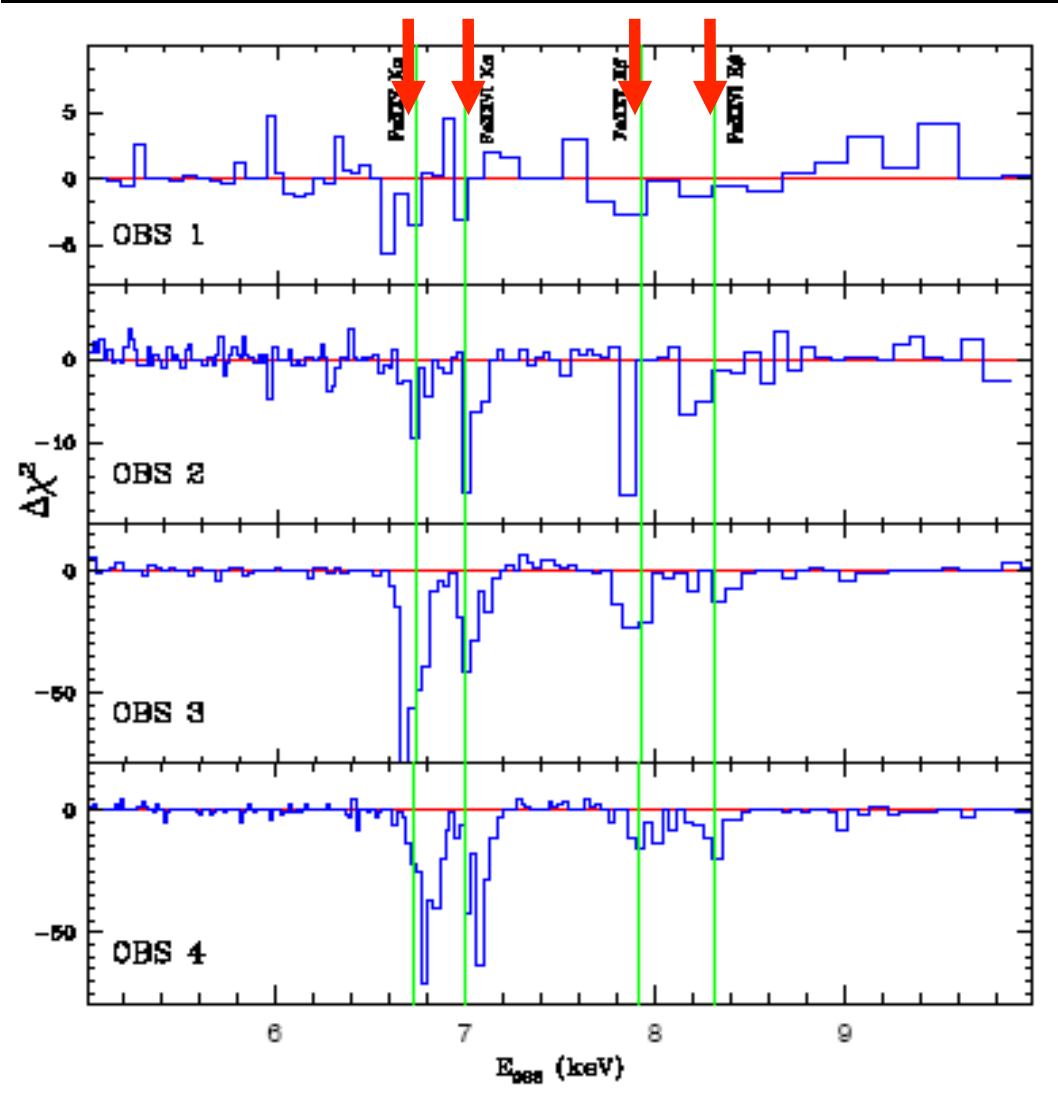
→ Clear now that ~50% of all Seyferts and QSOs present multiple ionization & kinetic components (from Optical, UV and soft X) of outflows/winds with $v \sim 100-1000$ km/s

→ 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, and v up to $\sim 0.2c$

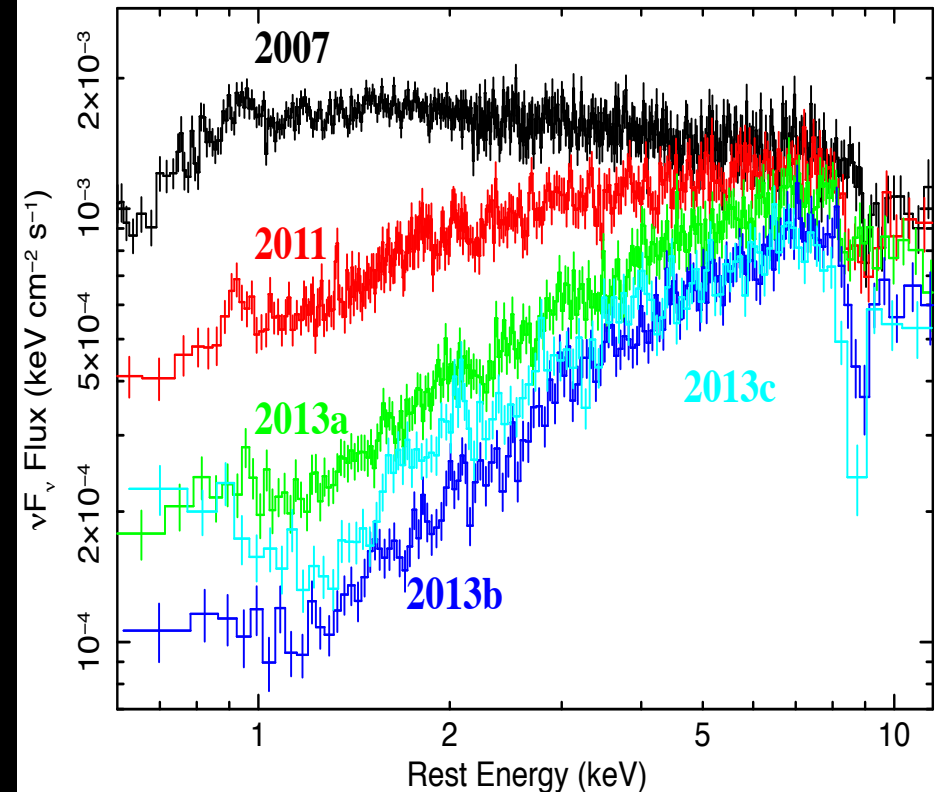
NGC1365



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.)

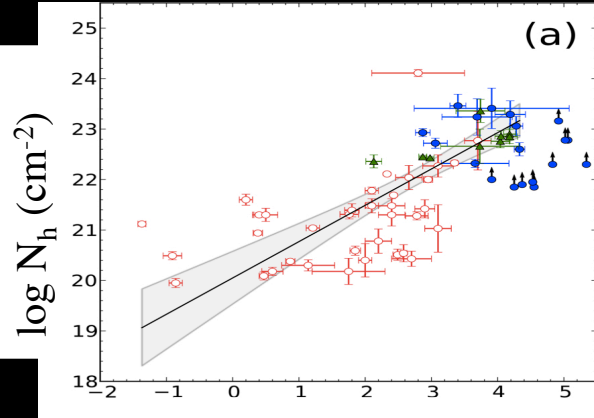
X-ray spectral variability of PDS 456



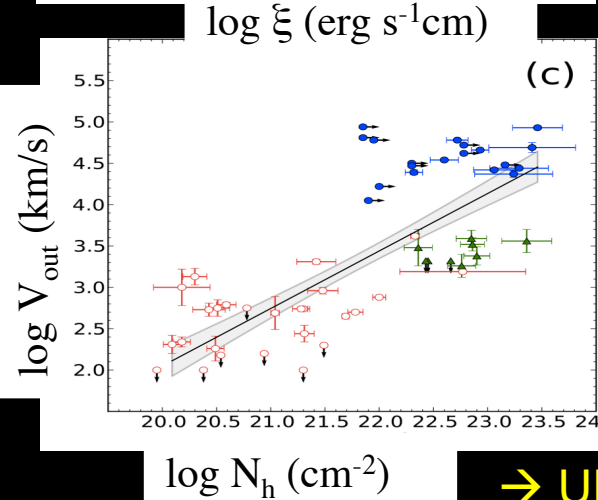
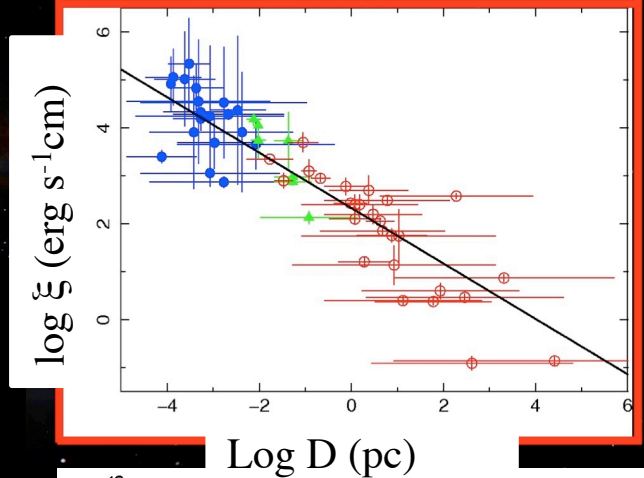
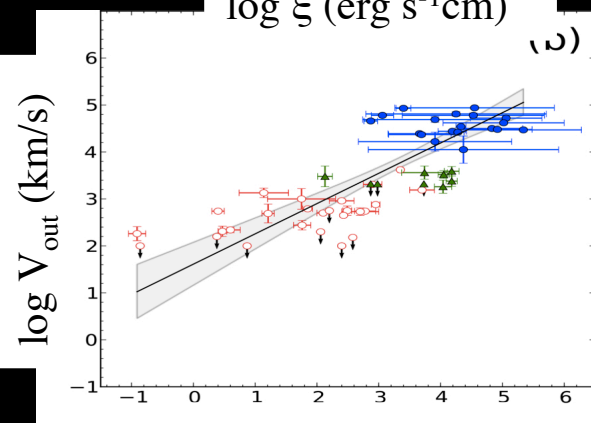
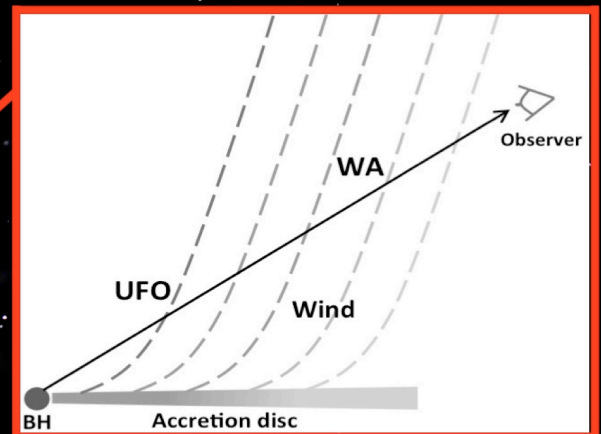
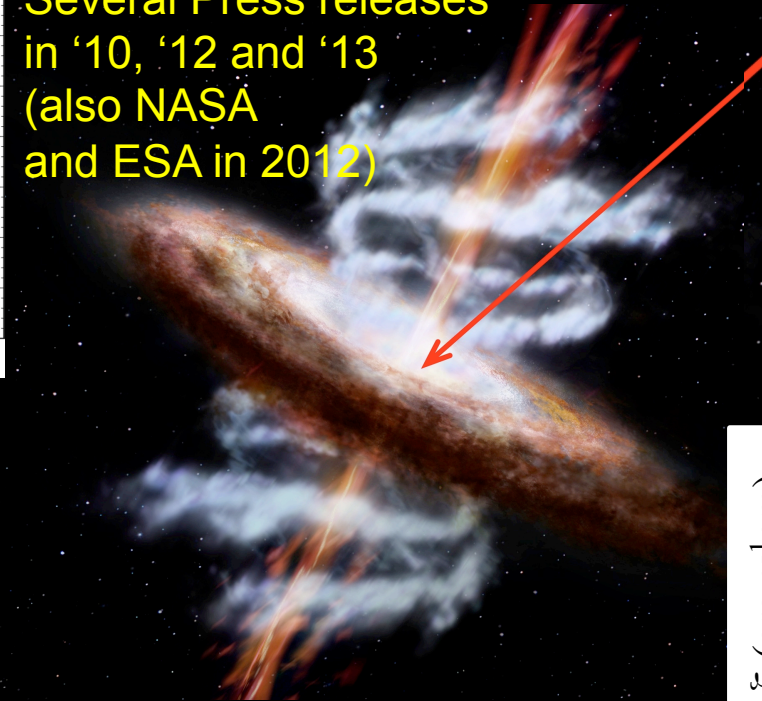
Reeves et al. '10, '13, '15

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

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

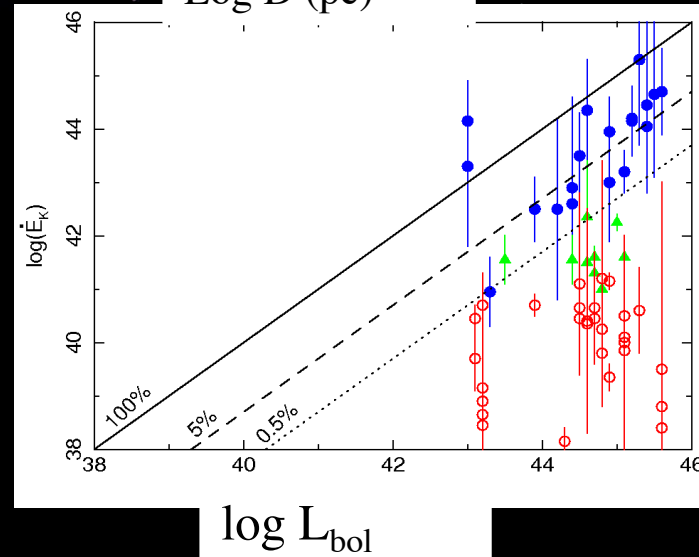


Several Press releases in '10, '12 and '13 (also NASA and ESA in 2012)



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

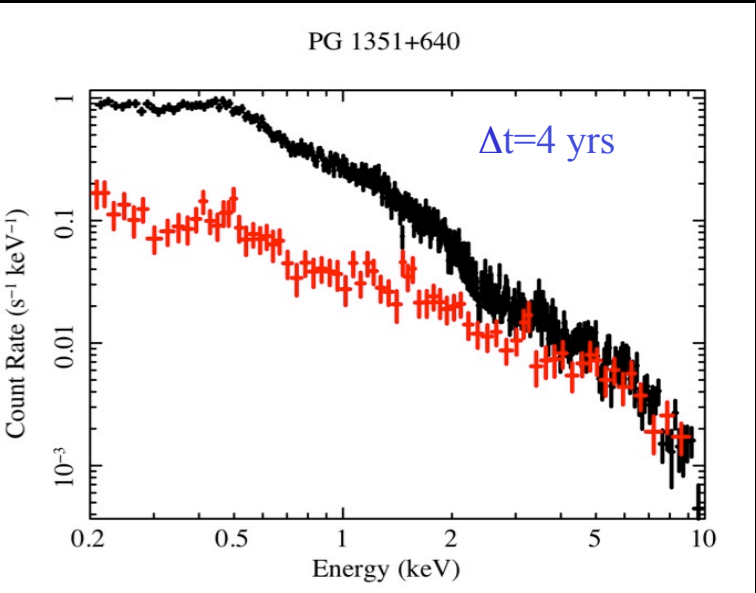
$\log \dot{E}_{\text{out}}$



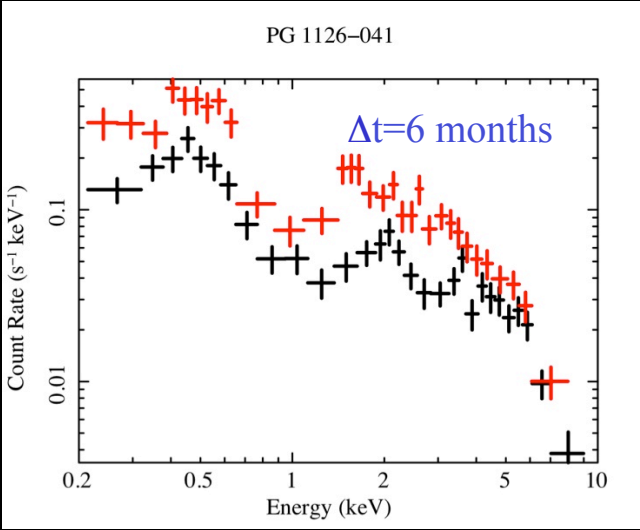
→ UFOs kinetic energy >1% of L_{bol}
→ Feedback (potentially) effective!

The “new” X-ray view: Variability and complex absorption in (nearby) PG QSOs

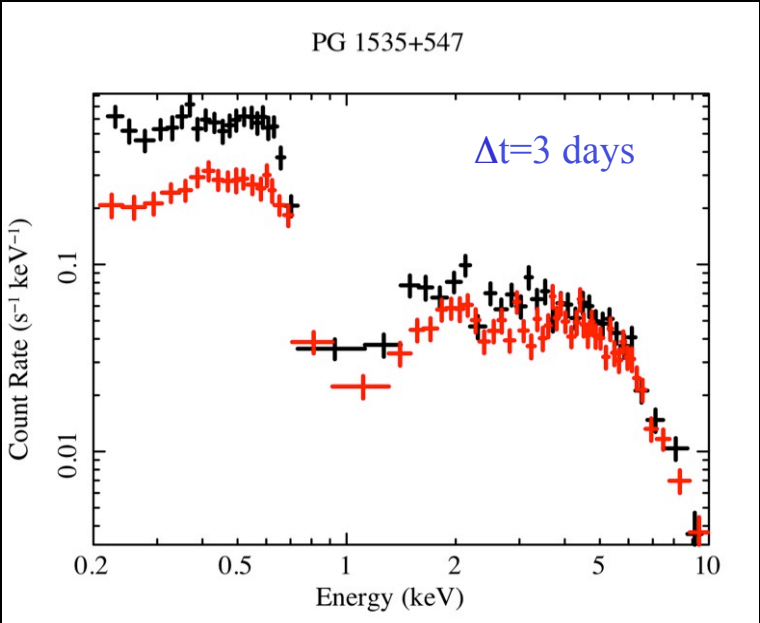
Sample: 15 UV *AL QSOs with 32 XMM exposures



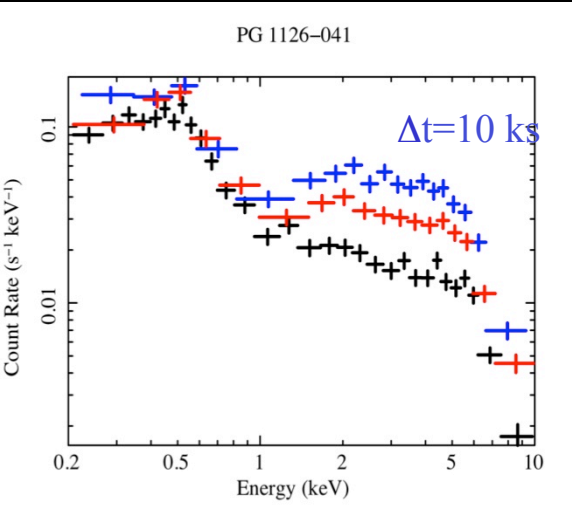
on time scales of years



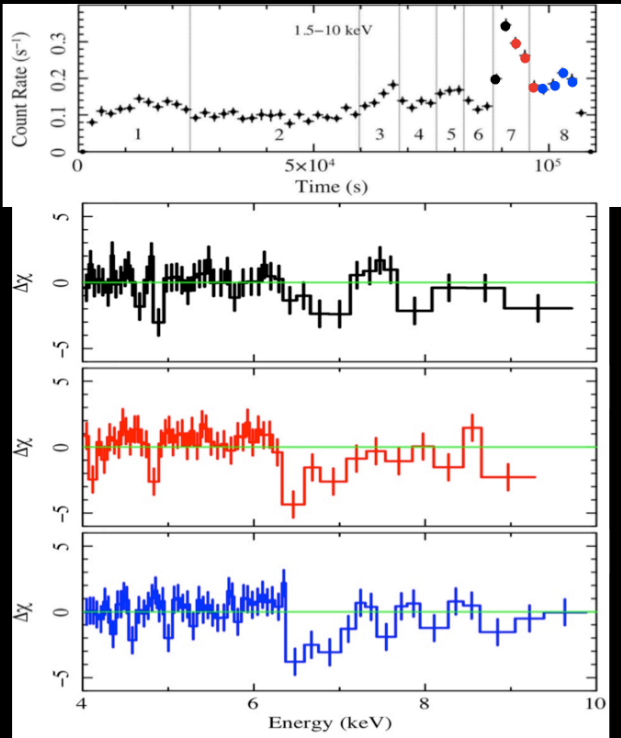
on time scales of months



on time scales of days

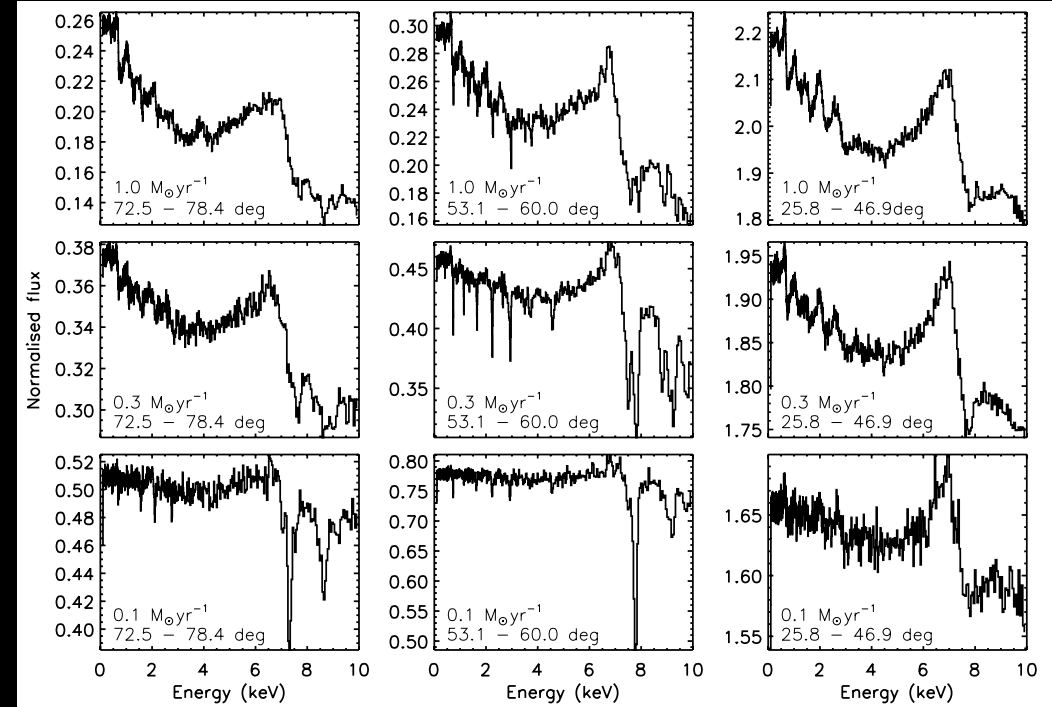
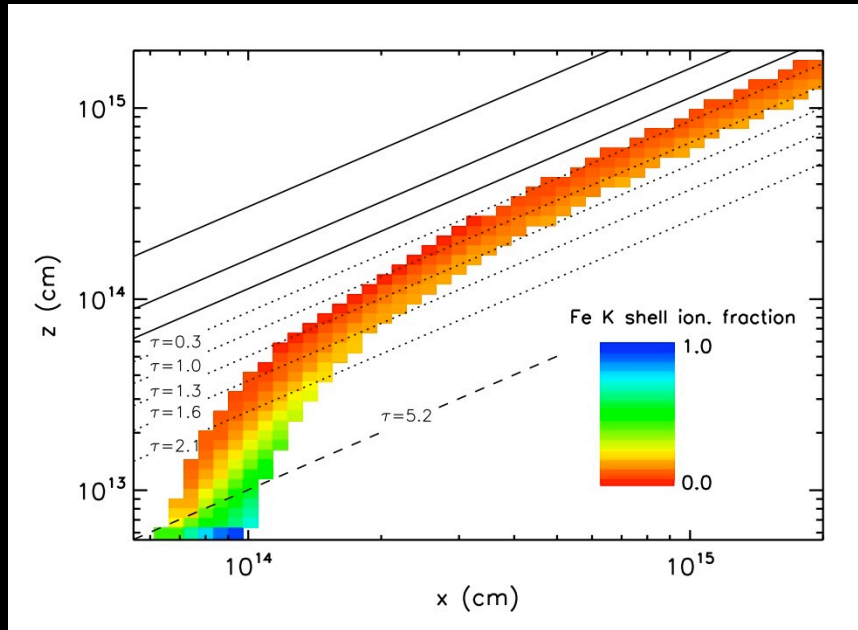


on time scales of hours



Open issues (1/2): Astrophysics of outflows in AGN/QSO: Acceleration models?

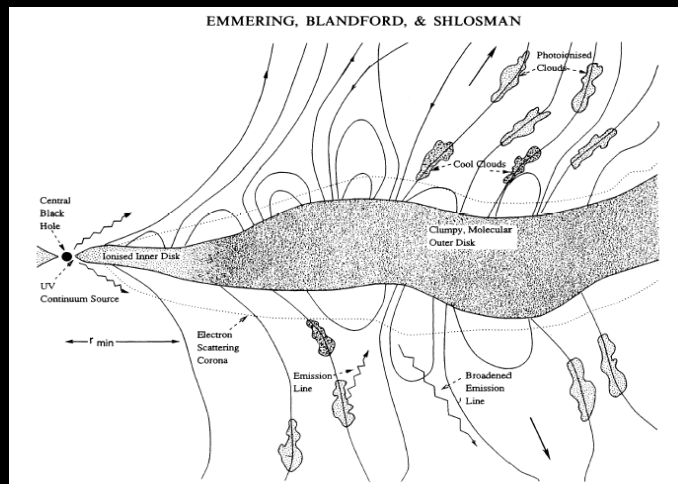
Radiatively driven accretion disc winds



Sim et al., '08, '10ab Murray et al. '95,

...and/or...

Magnetically driven winds from accretion disk



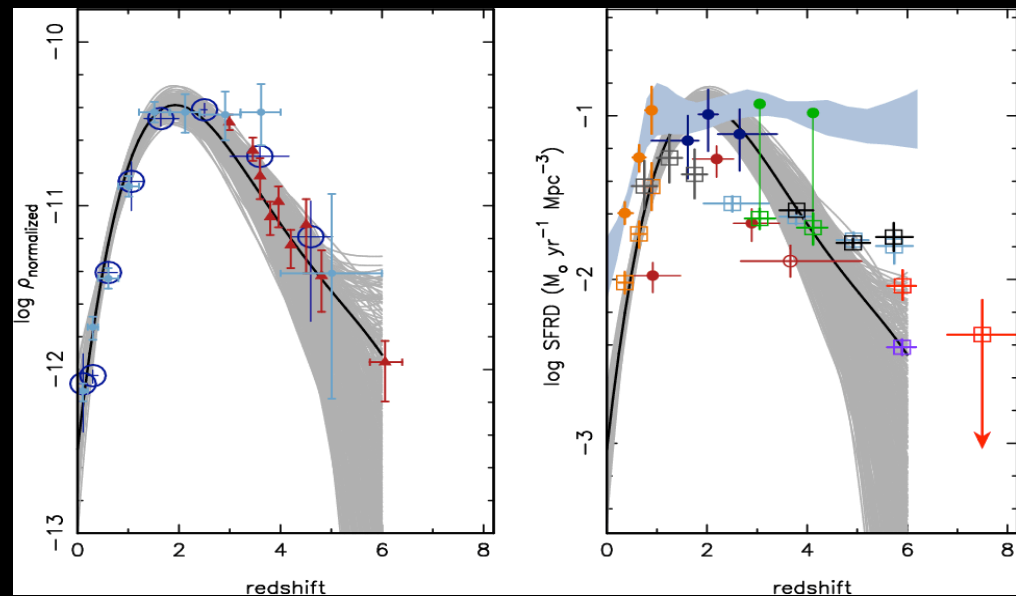
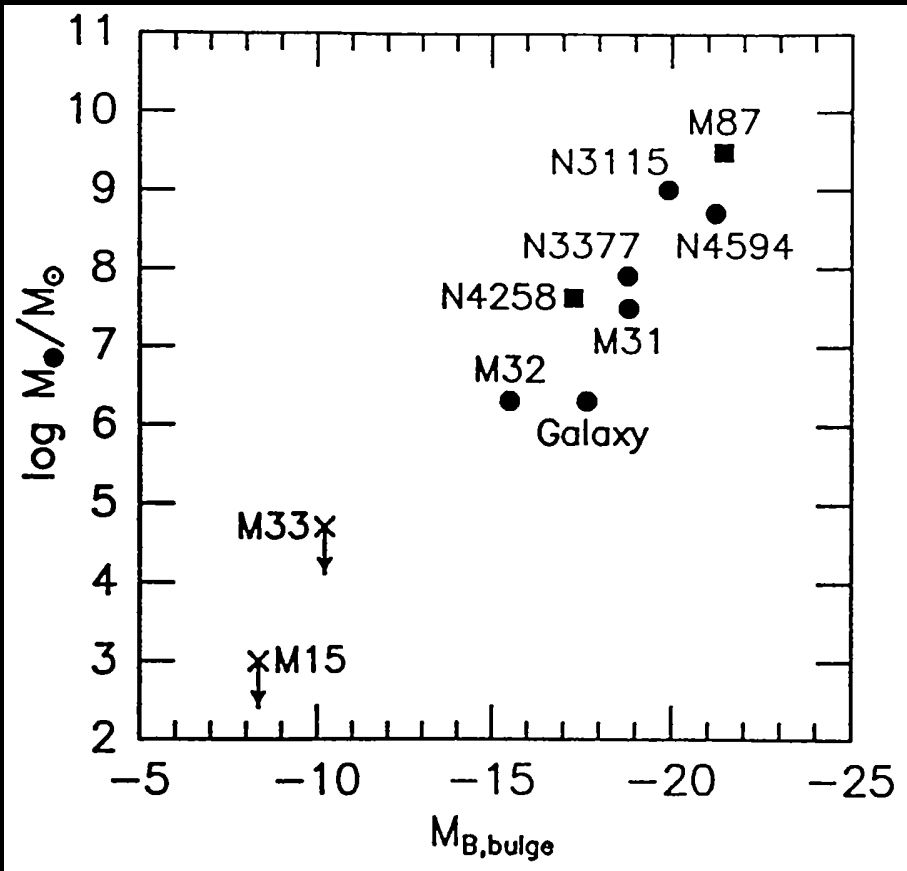
Emmering, Blandford & Shlosman, '92;
Kato et al. '03

Fukumura, et al. 2010
Kazanas et al. 2012



Proga et al. '00; '10

Open issues (2/2): AGN outflows and Feedback, i.e. SMBH/Gal co-evolution



QSO space density
Madau et al. '96;
SFR space density
Wall et al. '05

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

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

John Kormendy¹
Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive,
Honolulu, Hawaii 96822

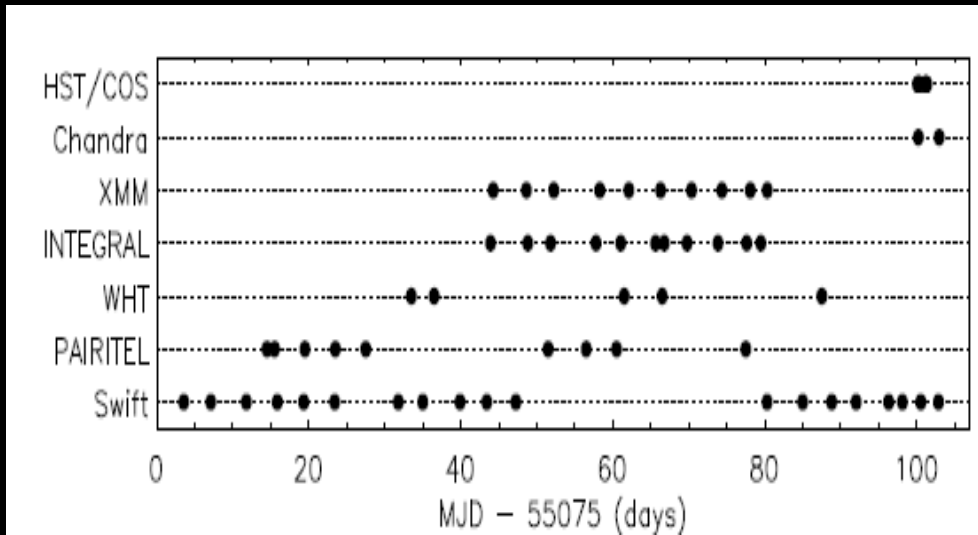
Douglas Richstone
Department of Astronomy, University of Michigan, Dennison Building, Ann
Arbor, Michigan 48109

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

The Astrophysics of AGN winds

Long and multiwavelength campaigns (e.g. Mrk509, NGC5548, NGC7469, ToOs, etc.)

Mrk509 (2009)

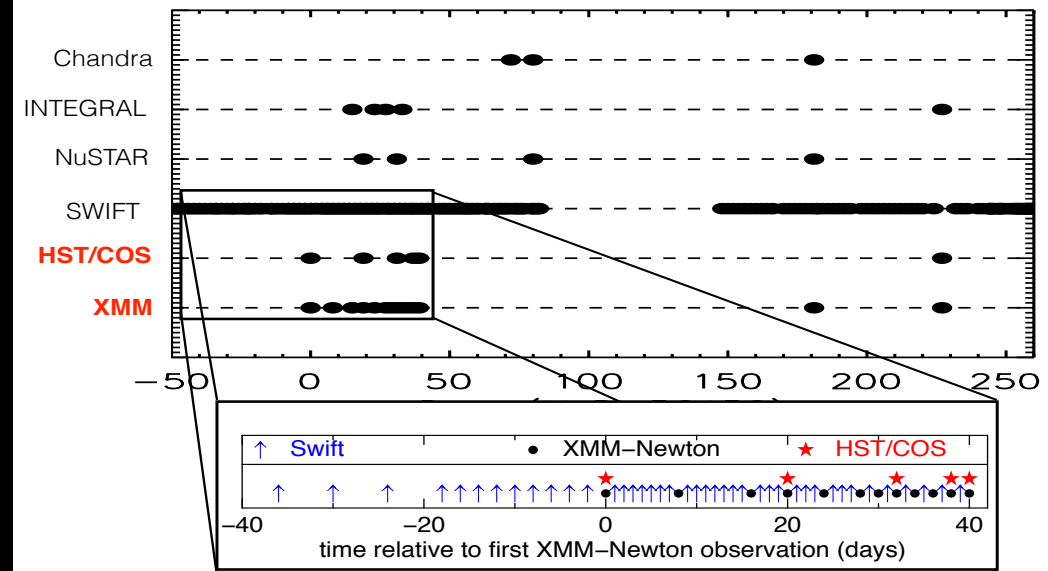


Key: XMM LP 10x60ks + 10 HST COS orbits

Kaastra, et al., 2011, paper I,
+14 papers

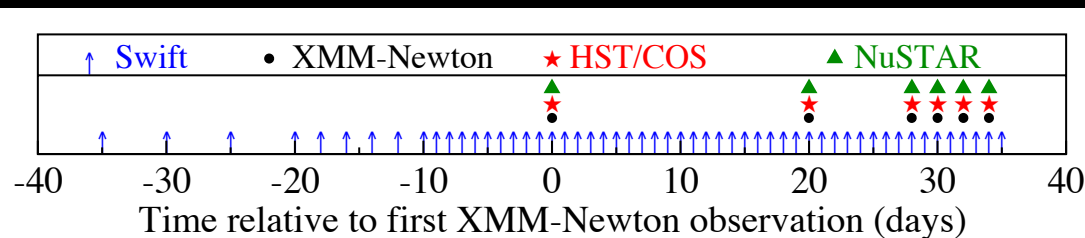
NGC5548 (2013/2014)

The 2013/14 Campaign



Key: XMM LP 10x50ks + 10 HST COS orbits

Kaastra, Kriss, MC, et al., 2014, Science
+8 papers



Key: XMM LP 7x90ks simultaneous HST/COS + Nustar
Behar, et al., 2016, in preparation

Key: Swift monitoring of 8 bright Sey1s
Trigger if obscuration → XMM+HST+Nustar

PI: Kaastra

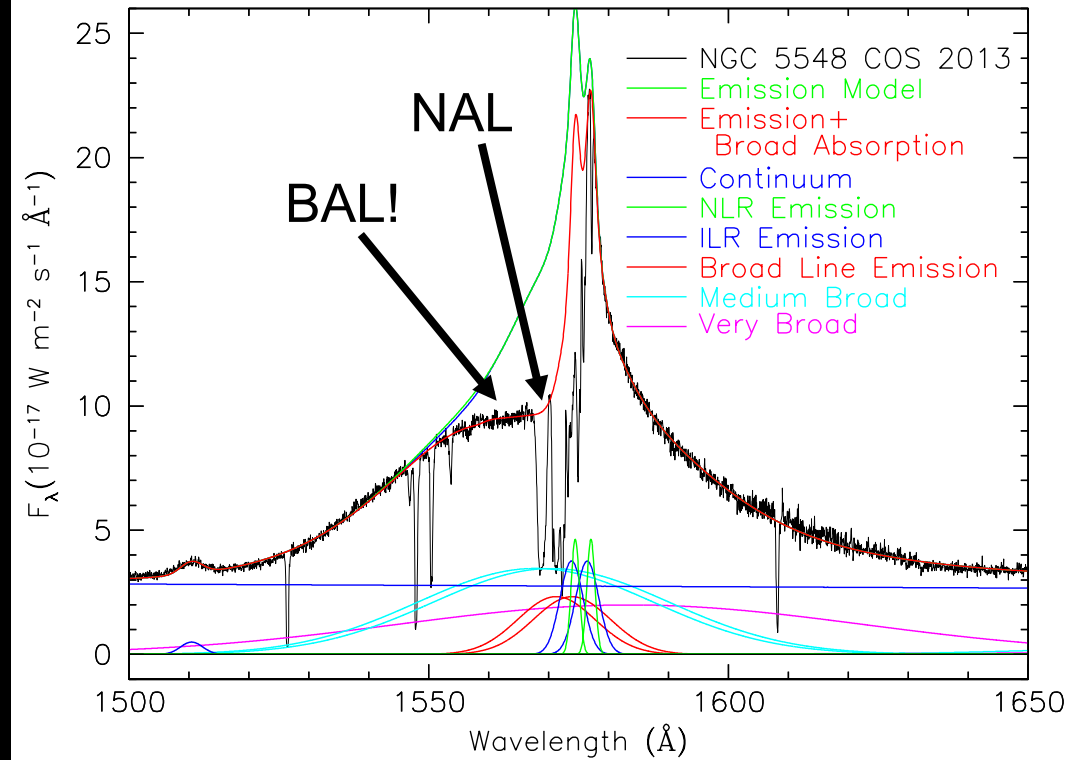
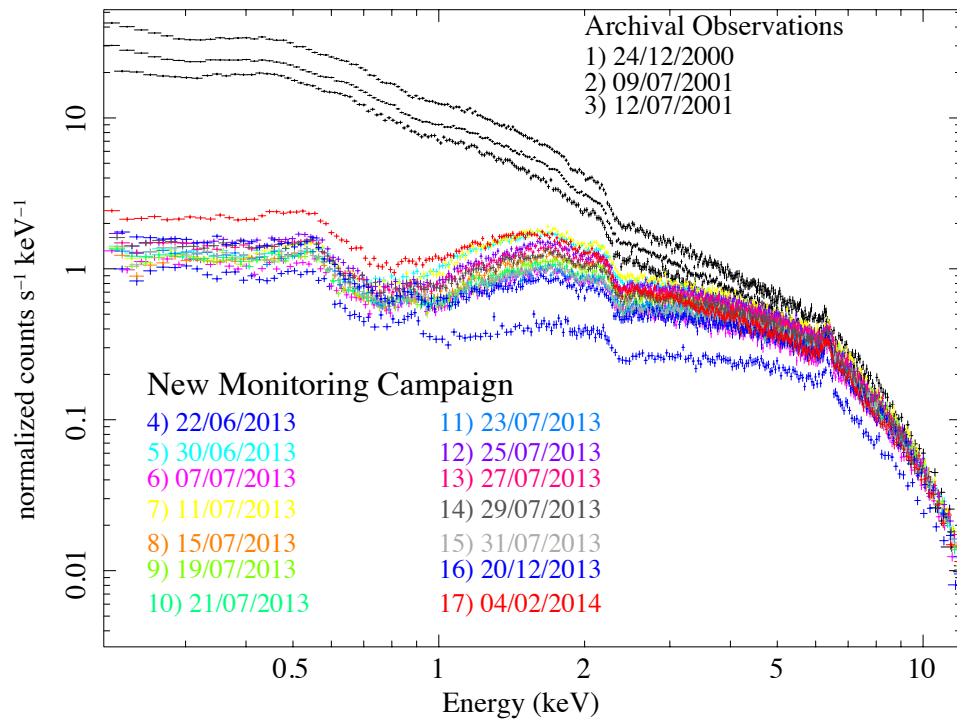
Unexpected discovery in NGC5548: Absorber variability measured simultaneously in X-rays and UV!

Kaastra, Kriss, MC, et al., 2014, Science
+ 8 papers published

XMM-Newton Large Program (+ Nustar + Chandra)

Simultaneous HST/COS

XMM Observations of NGC5548 – PN spectra



→ Simultaneous appearance and best detailed measurements of
obscurer and (shadowed) warm absorber,
possible only with a massive multi-*ni* campaign!

Detailed IMAGING at multi-ni: How WAs/UFOs compare/relate to colder molecular/gas outflows?

NGC6240

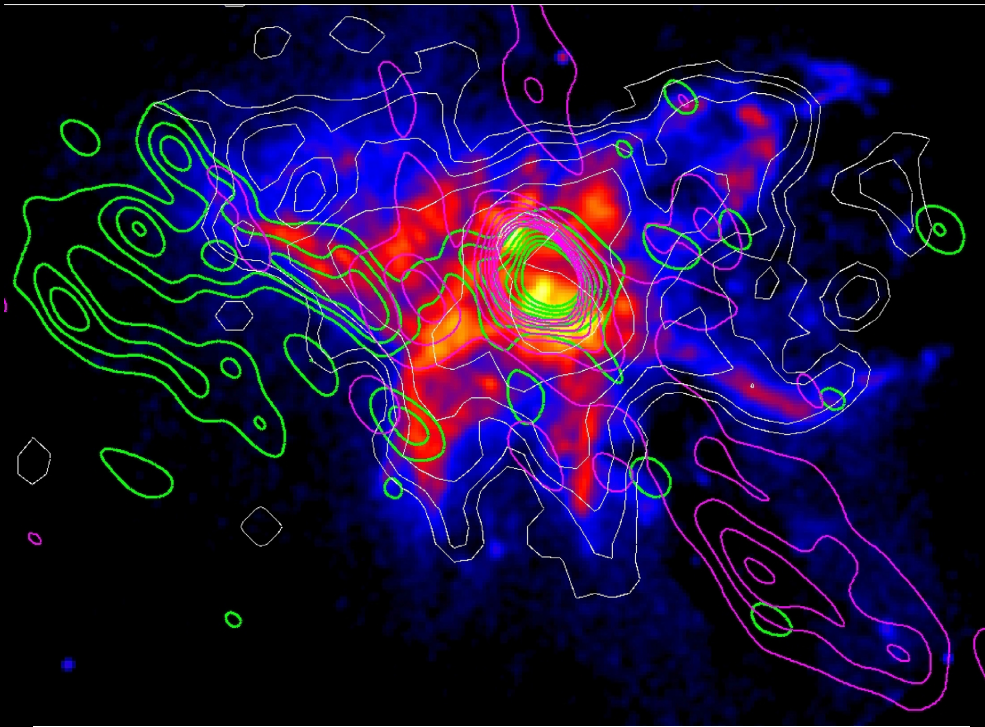
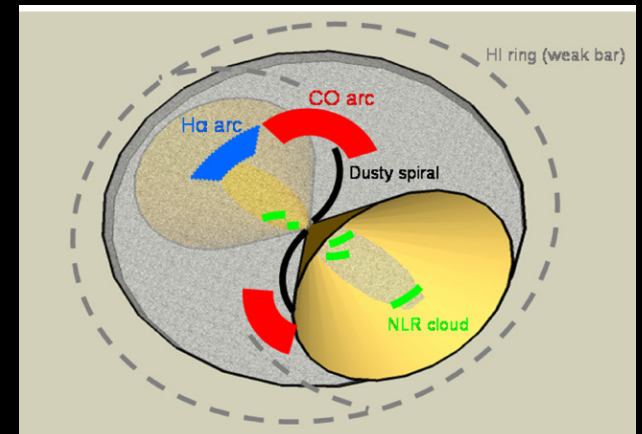
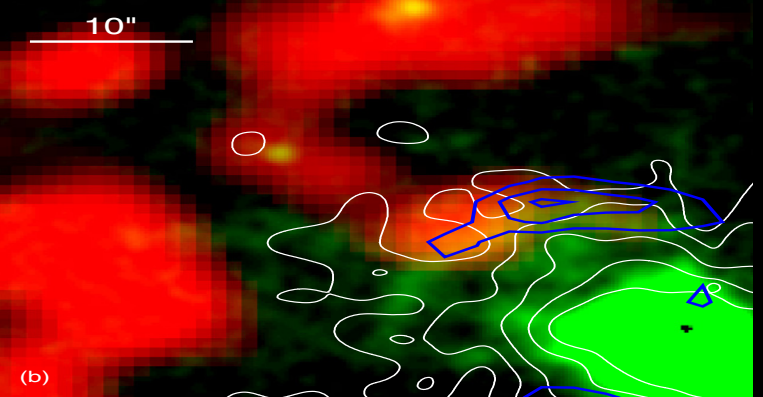
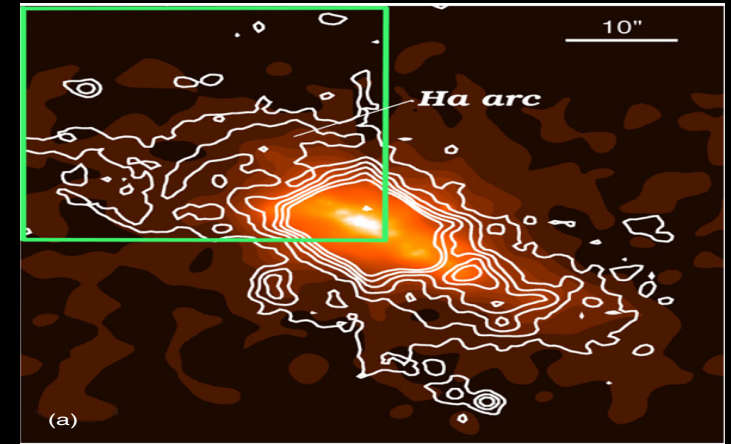


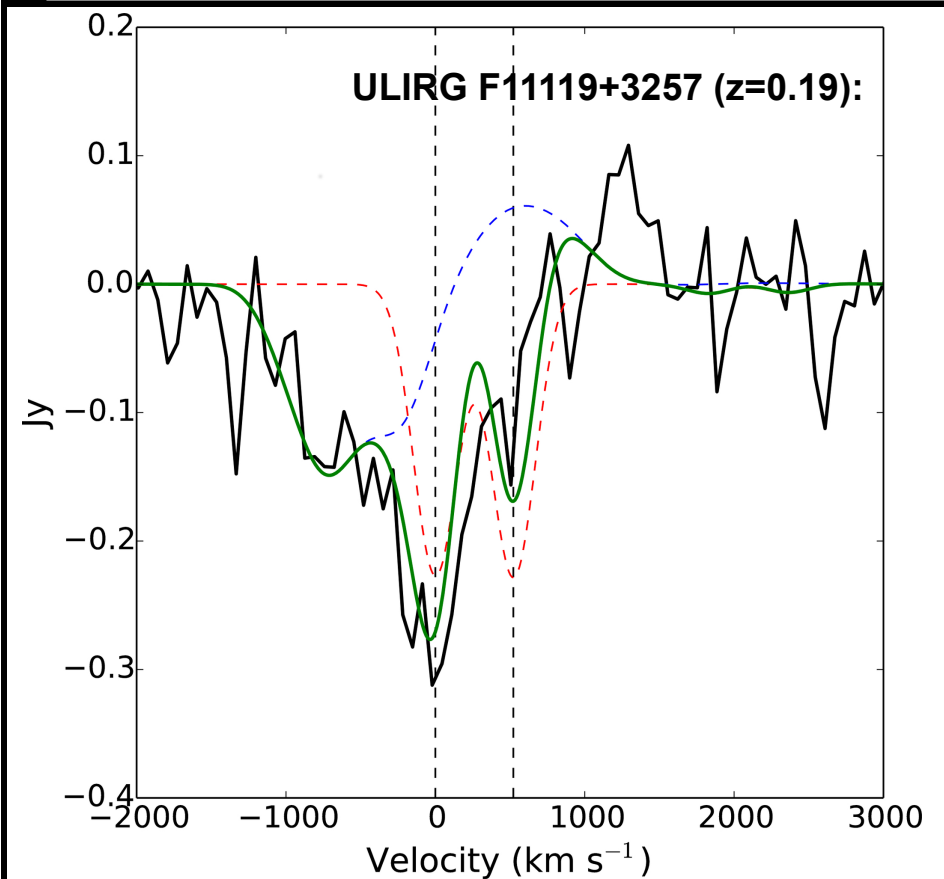
Fig.5. Ha map of NGC 6240 (color image). CO(1-0) emission at different velocities: -350 km s^{-1} (green contours), -100 km s^{-1} (magenta contours), with respect to the system velocity. Contours are calculated by merging D and A configuration data. Chandra 1.6–2 keV emission is shown by white contours.

NGC4151



+ Fischer et al.'13; Genzel et al. '14; Harrison et al. '16; Brusa et al., 2015; Cresci et al. 2015, etc.) and molecular gas (Cicone et al.'15; Feruglio et al. '15, etc.)

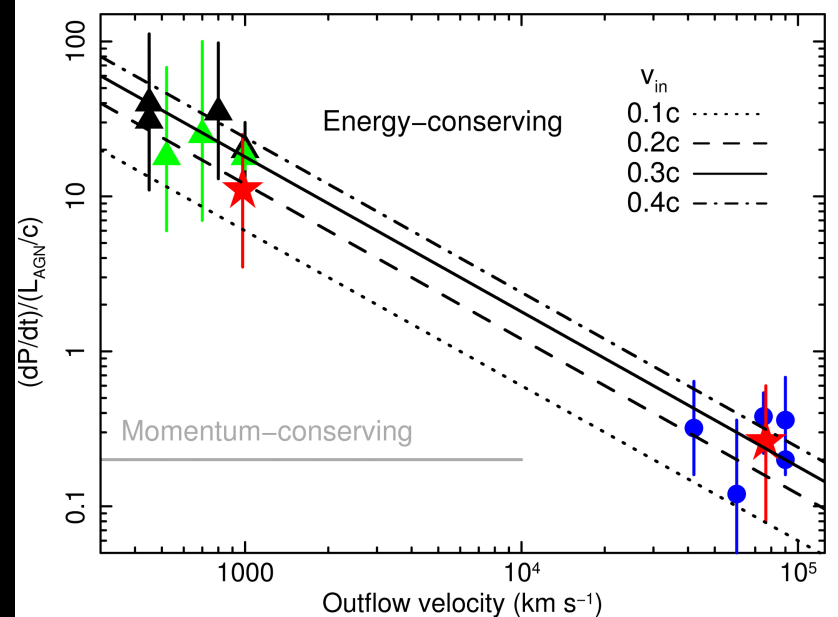
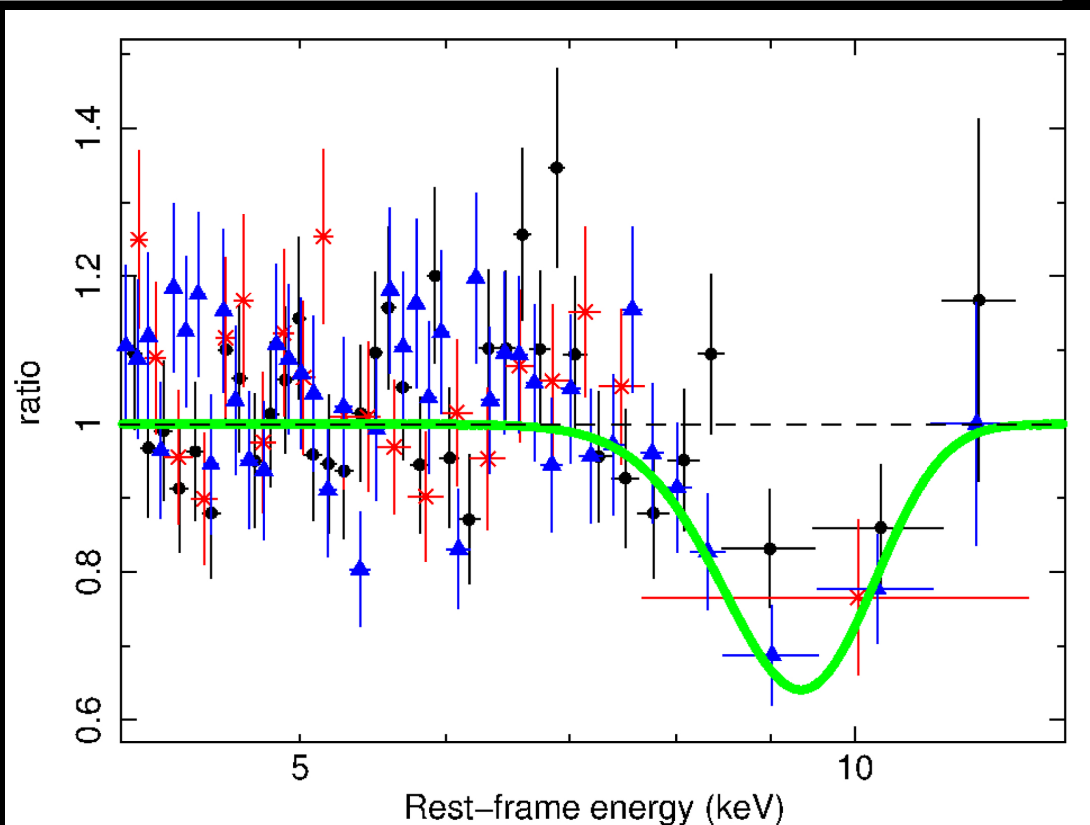
Multi-ni obs. of nearby QSO: How WAs/UFOs compare/relate to colder molecular/gas outflows?



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

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

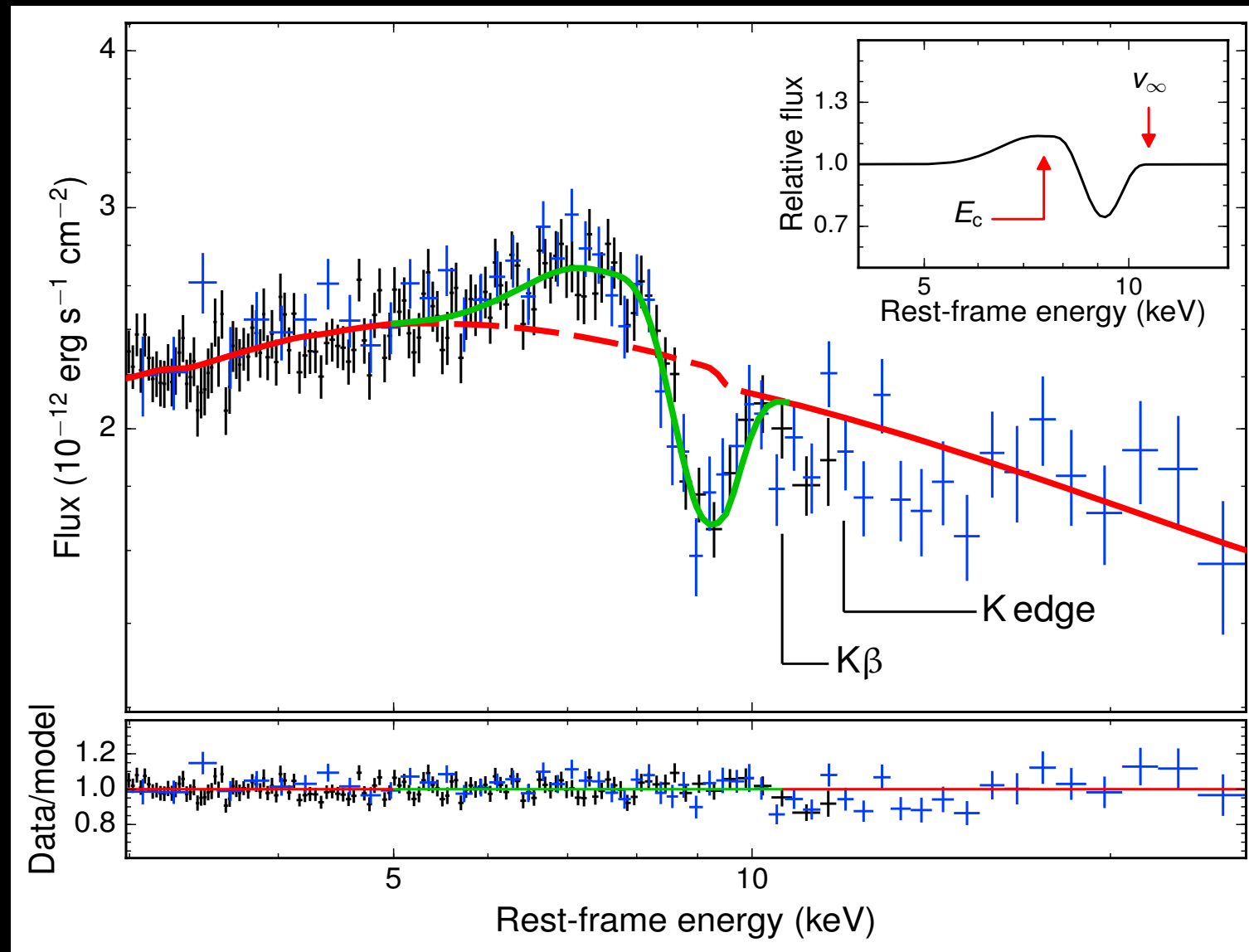
Tombesi et al. 2015, Nature



Detailed X-ray spectra: Geometry and covering factor of UFOs?

P-Cygni profile gives direct measure of covering factor

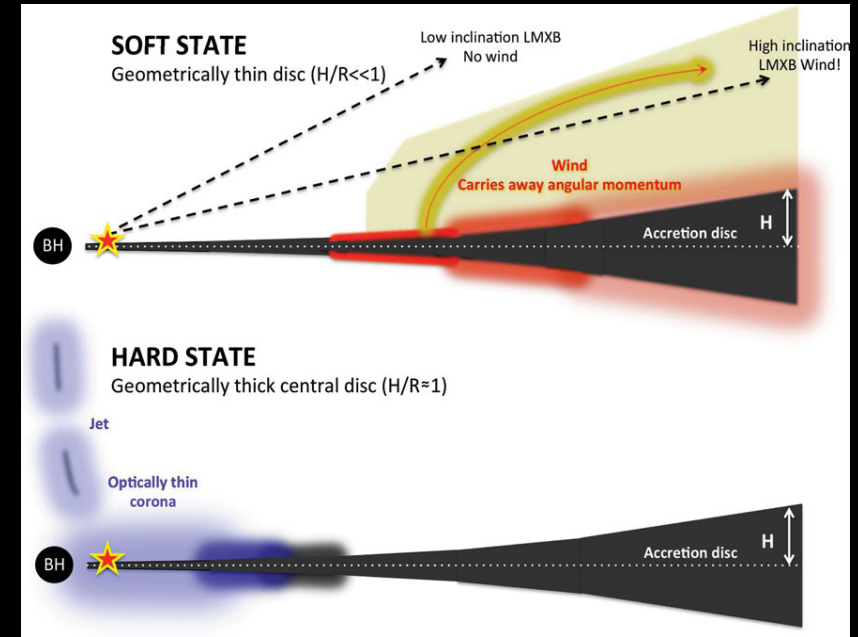
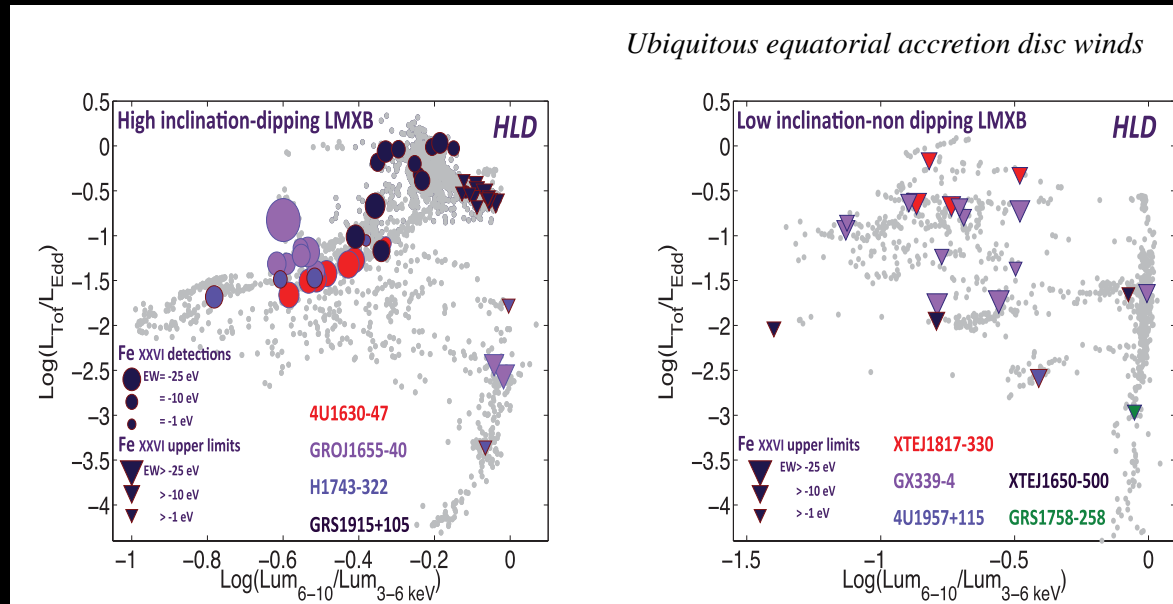
PDS456 ($z=0.18$)



$V_{\text{out}} \sim 0.3c$ and $\Omega > 2\pi \text{ sr}$

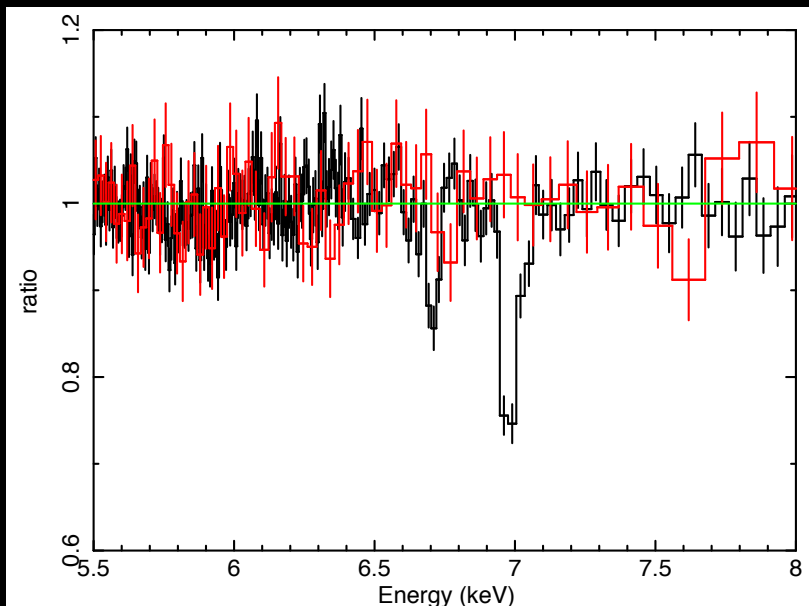
Nardini, Reeves et al., Science '15

Detailed spectra of X-ray binaries in soft state: How WAs/UFOs compare/relate to binaries winds and jets?



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

Ponti et al., 2011



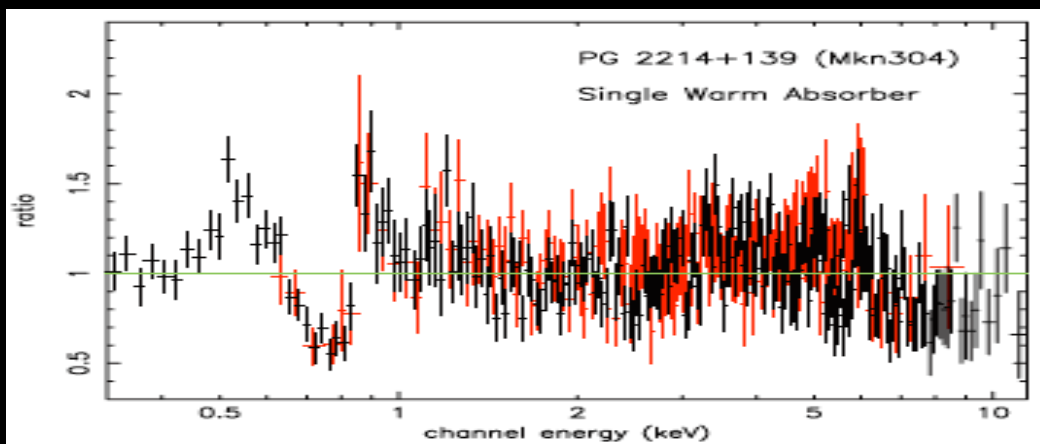
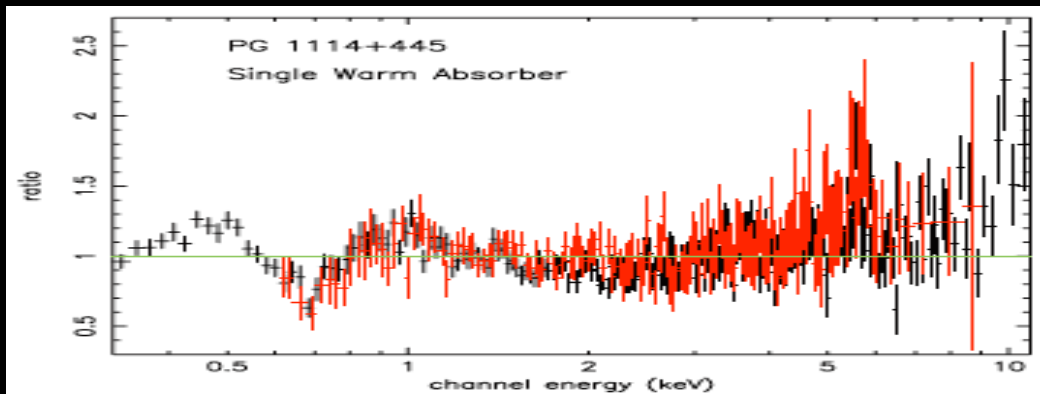
FeXXV and FeXXVI are variable,
and have $V_{\text{out}} \sim 300-670$ km/s

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

Miller et al., 2006, 2012

The (cosmological) impact/feedback of AGN outflows

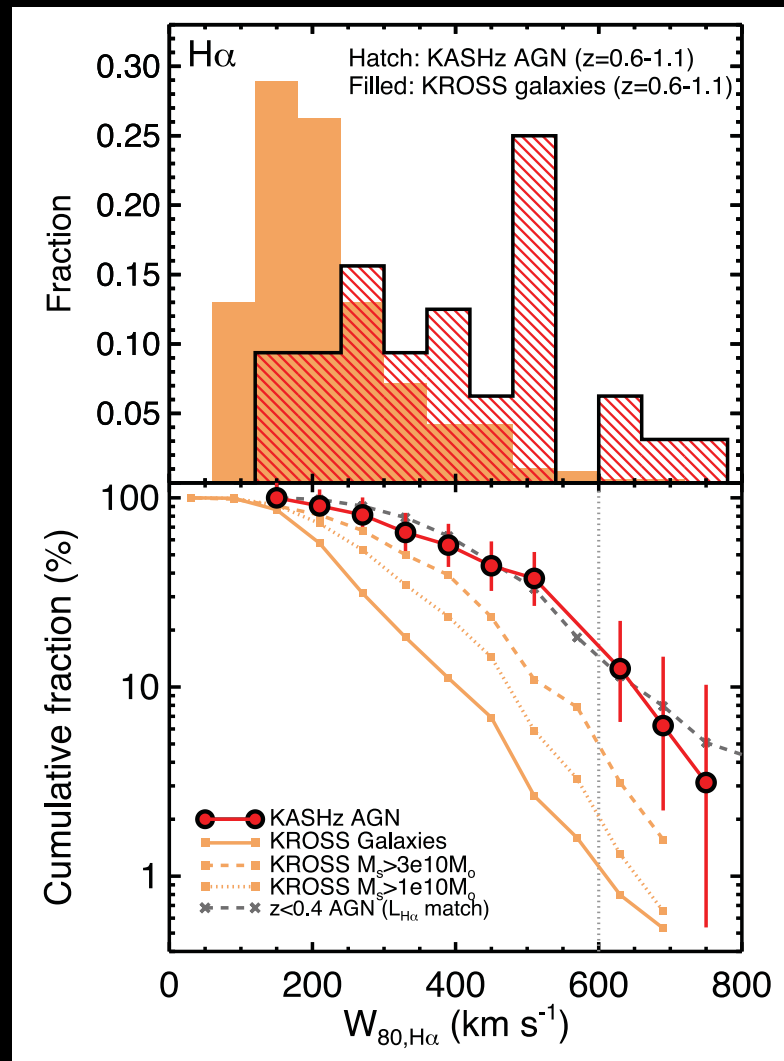
The “classic” X-ray view: Warm Absorbers in nearby QSOs



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

→ Frequent, but low v (1000 km/s) and low N_H make these winds energetically not very important (fractions of $M_{\text{sol}}/\text{year}$)

Porquet et al. 2004, Piconcelli et al. 2005



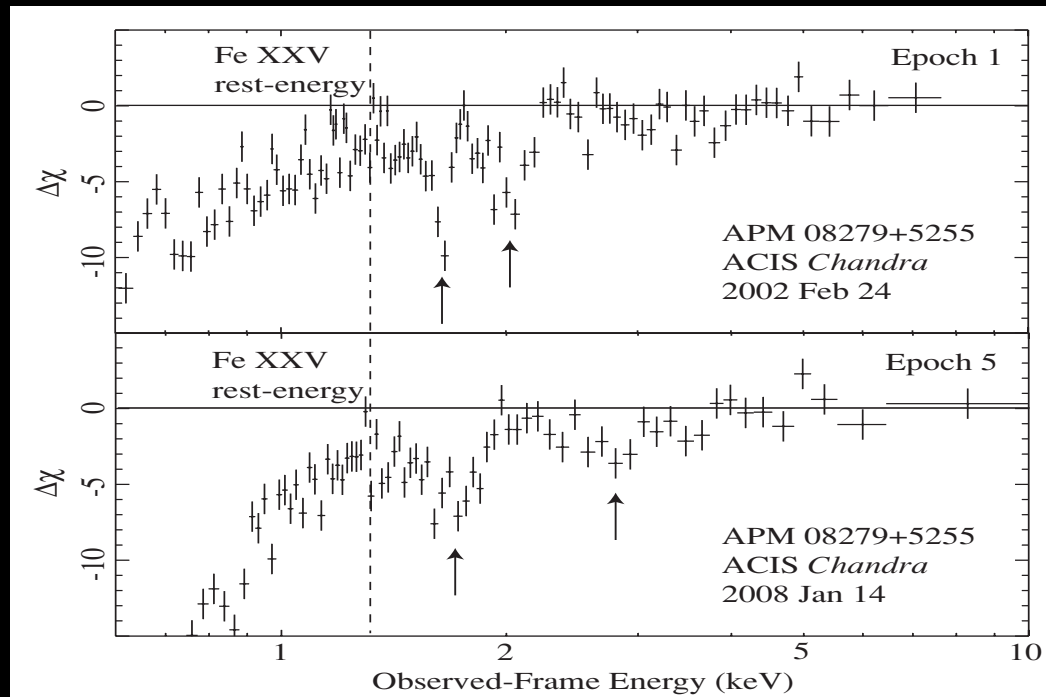
AGN/QSO-driven outflows ubiquitous in QSOs?

Harrison et al. 2016

The new X-ray view: UFOs and/or FeK complex features seen in lensed high-z QSOs

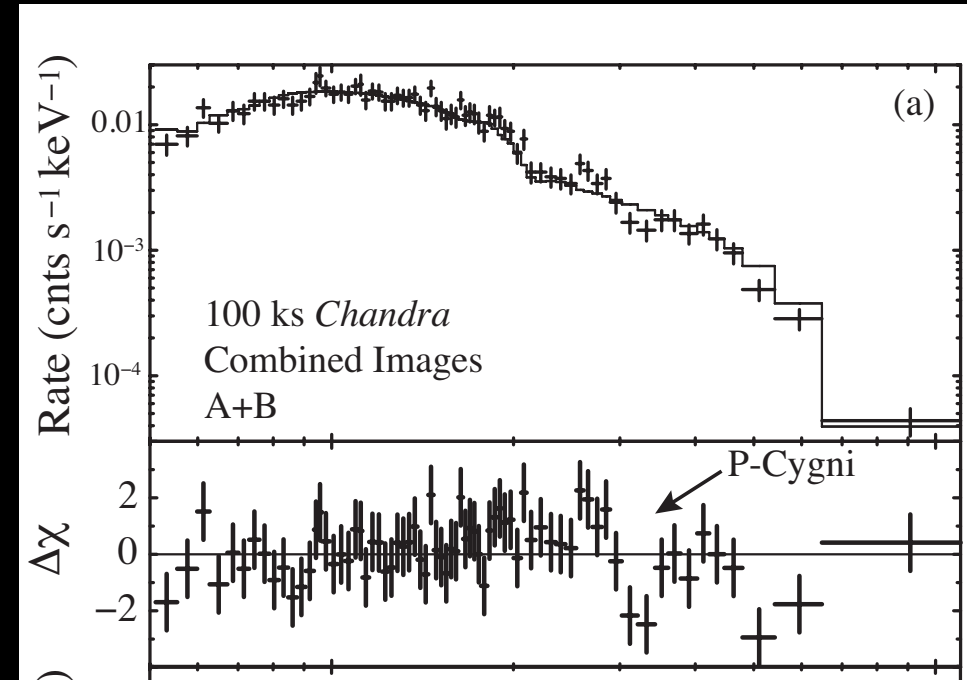
APM 08279+5255 ($z=3.91$)

$V_{\text{out}} \sim 0.2-0.76 c$



Chartas et al. 2009

HS0810+554 ($z=1.5$)

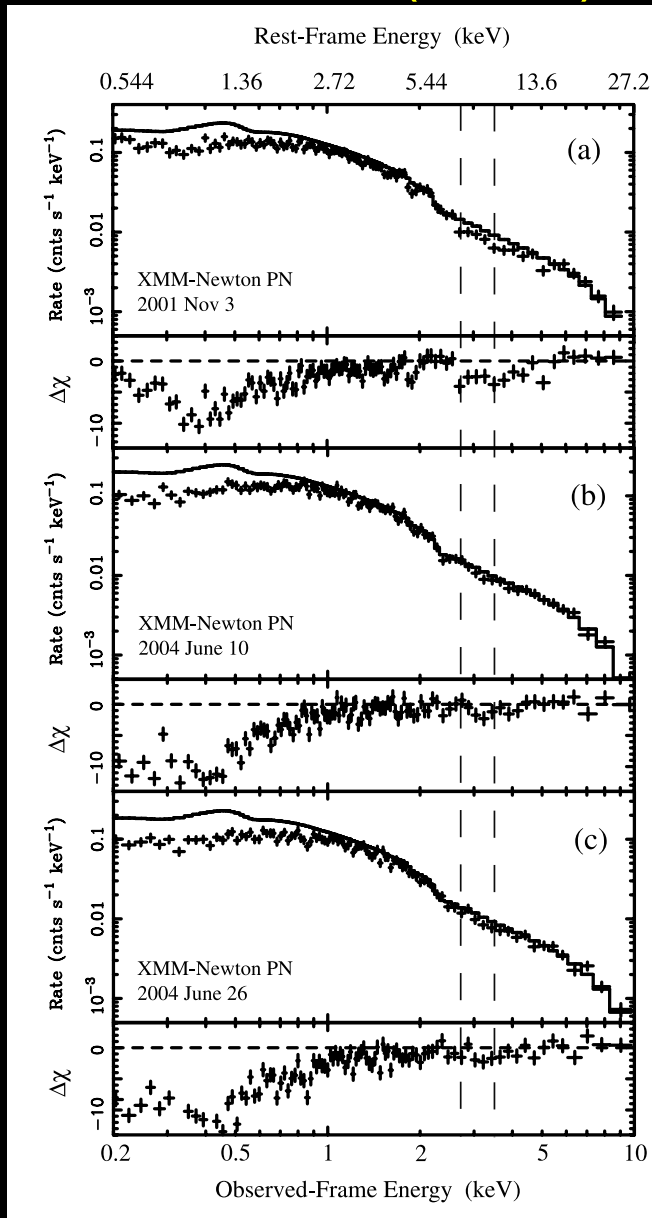


Chartas et al. 2014, 2015

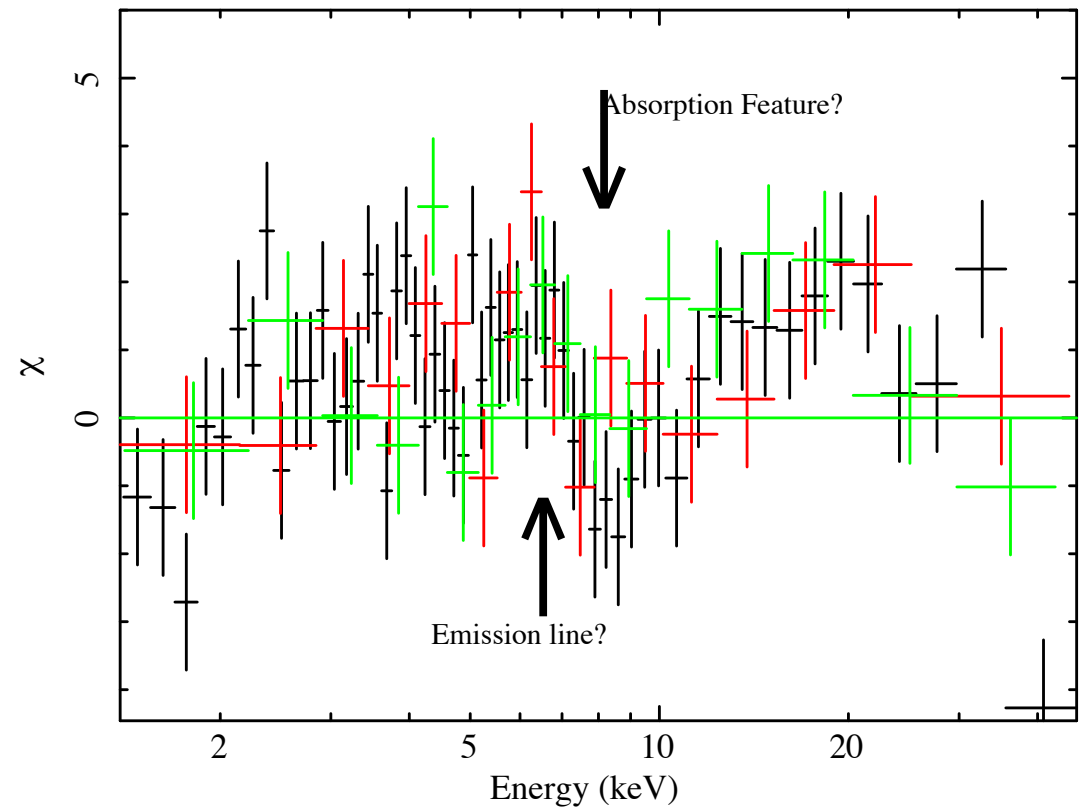
- Ubiquitous complex (i.e. ionized and/or partially covering) absorption?
- Desperately need more and longer XMM observations on high-z QSOs

The new X-ray view: UFOs or Extreme reflection measured in lensed high-z QSOs?

PG1115+080 (z=1.7)

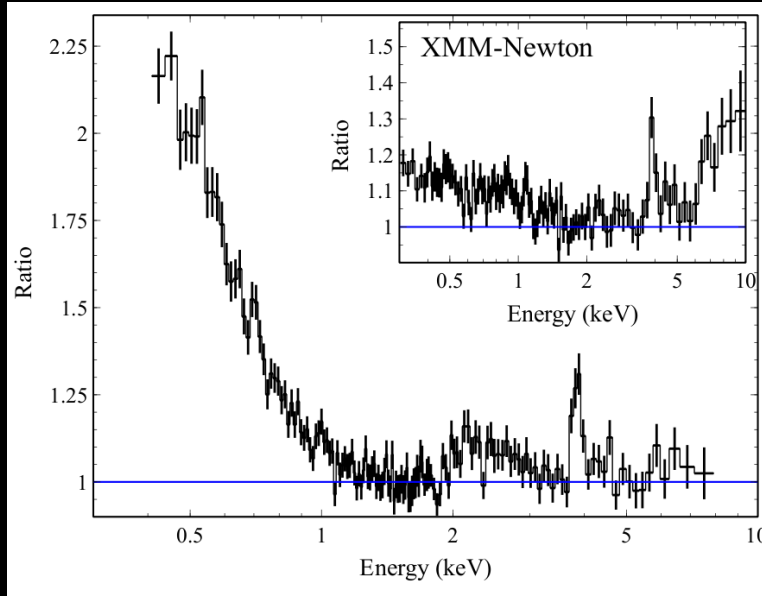


B1422+231 (z=3.6)



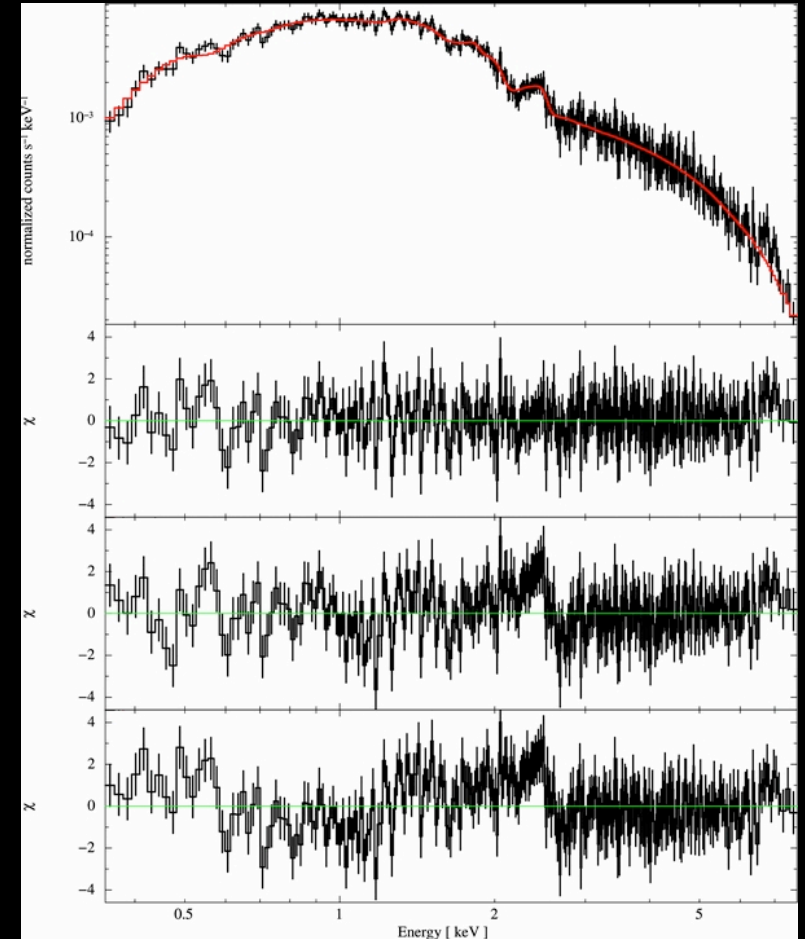
The new X-ray view: UFOs or Extreme reflection measured in lensed high-z QSOs?

RX J1131-1231 ($z=0.6$)



Reis et al., '14

The Einstein Cross ($z=1.7$)



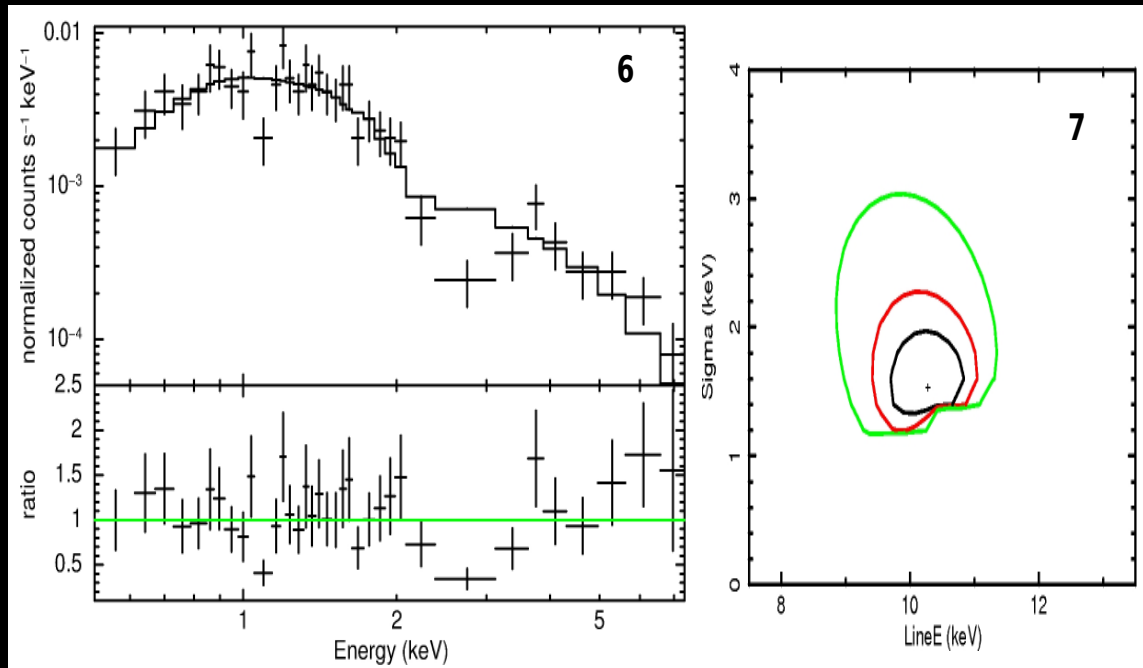
Reynolds et al., '14

- Ubiquitous complex (i.e. ionized and/or partially covering) absorption?
- Desperately need more and longer XMM observations on high-z QSOs

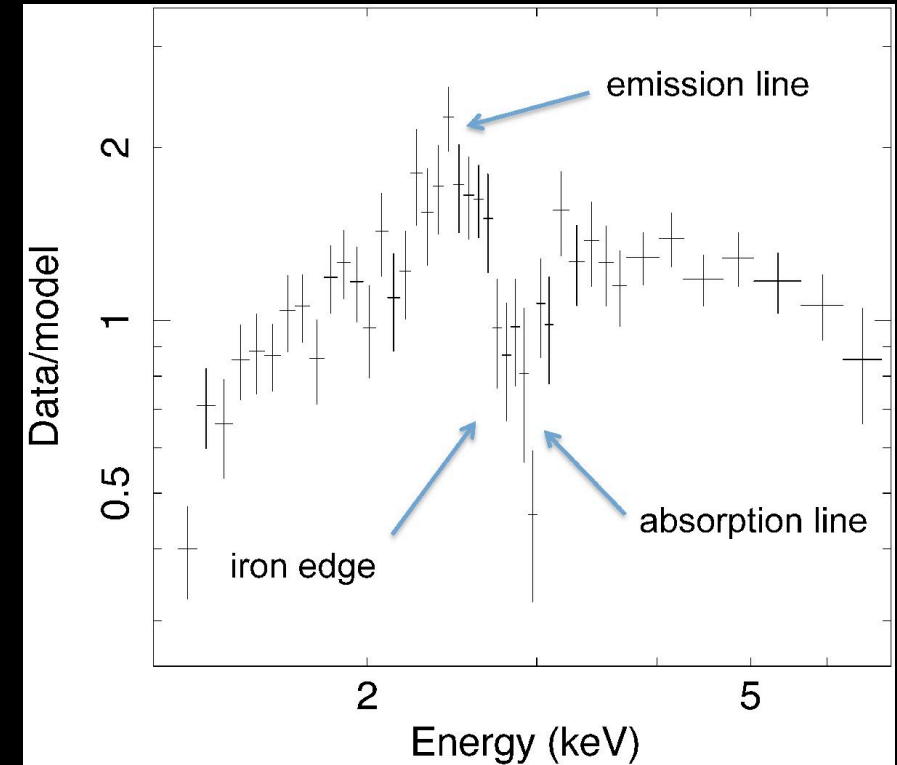
The new X-ray view: UFOs seen also in non-lensed high-z QSOs

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

($z=1.6$) PID352



Lanzuisi et al., '12

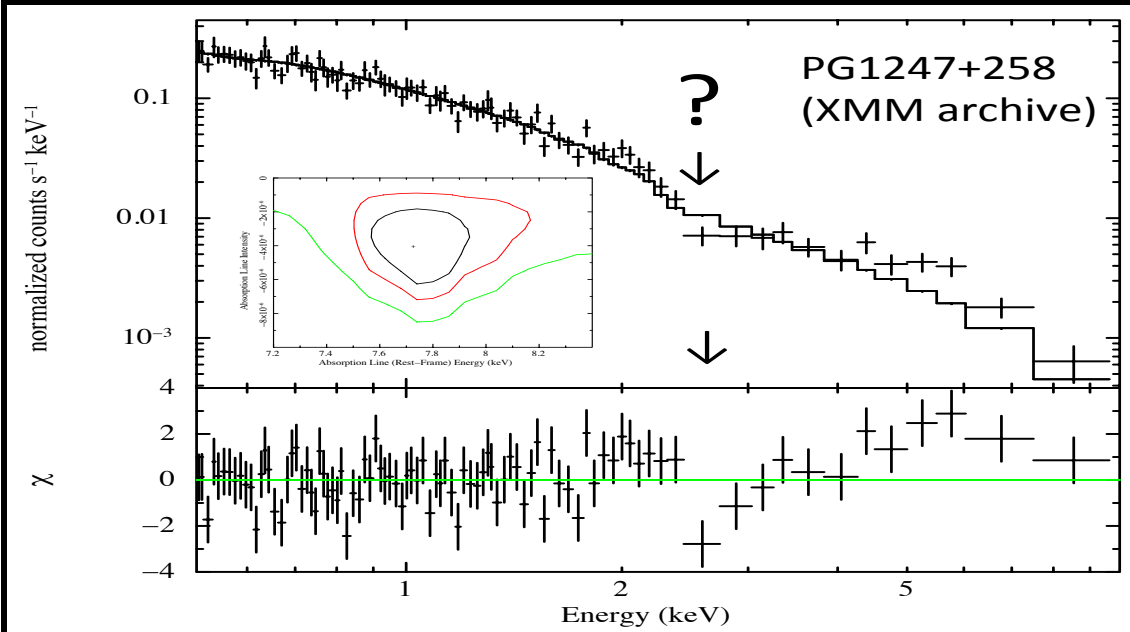


Vignali et al., '15

- Ubiquitous complex (i.e. ionized and/or partially covering) absorption?
- Desperately need more and longer XMM observations on high-z QSOs

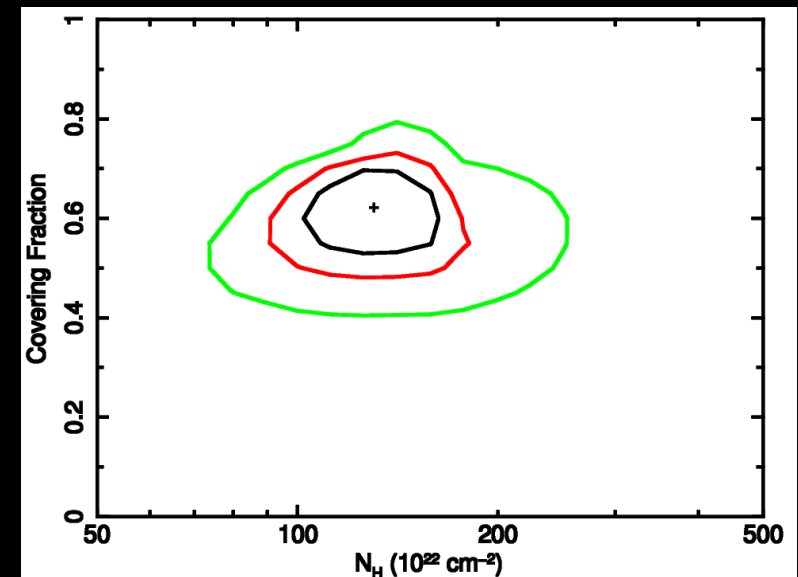
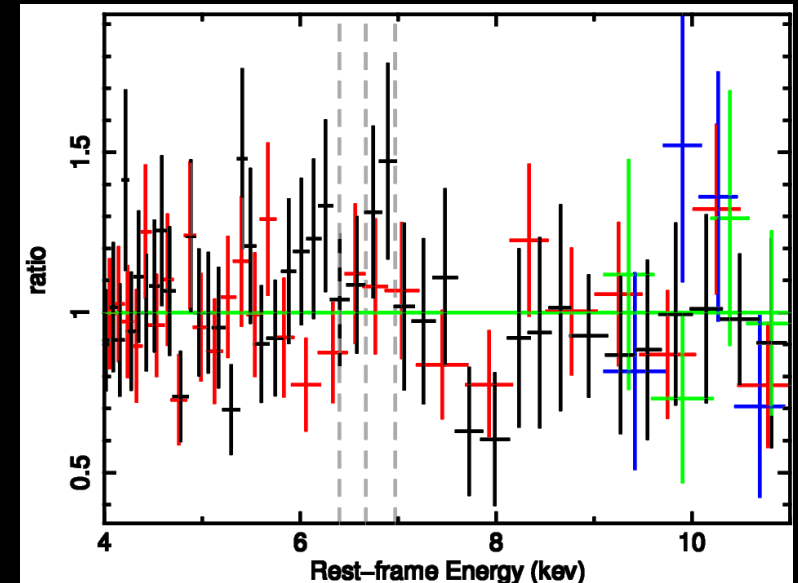
UFOs seen also in non-lensed high-z QSOs

(z=2) PG1247+268



Another high-z UFO candidate?
Or again strong reflection?

Lanzuisi et al., '16

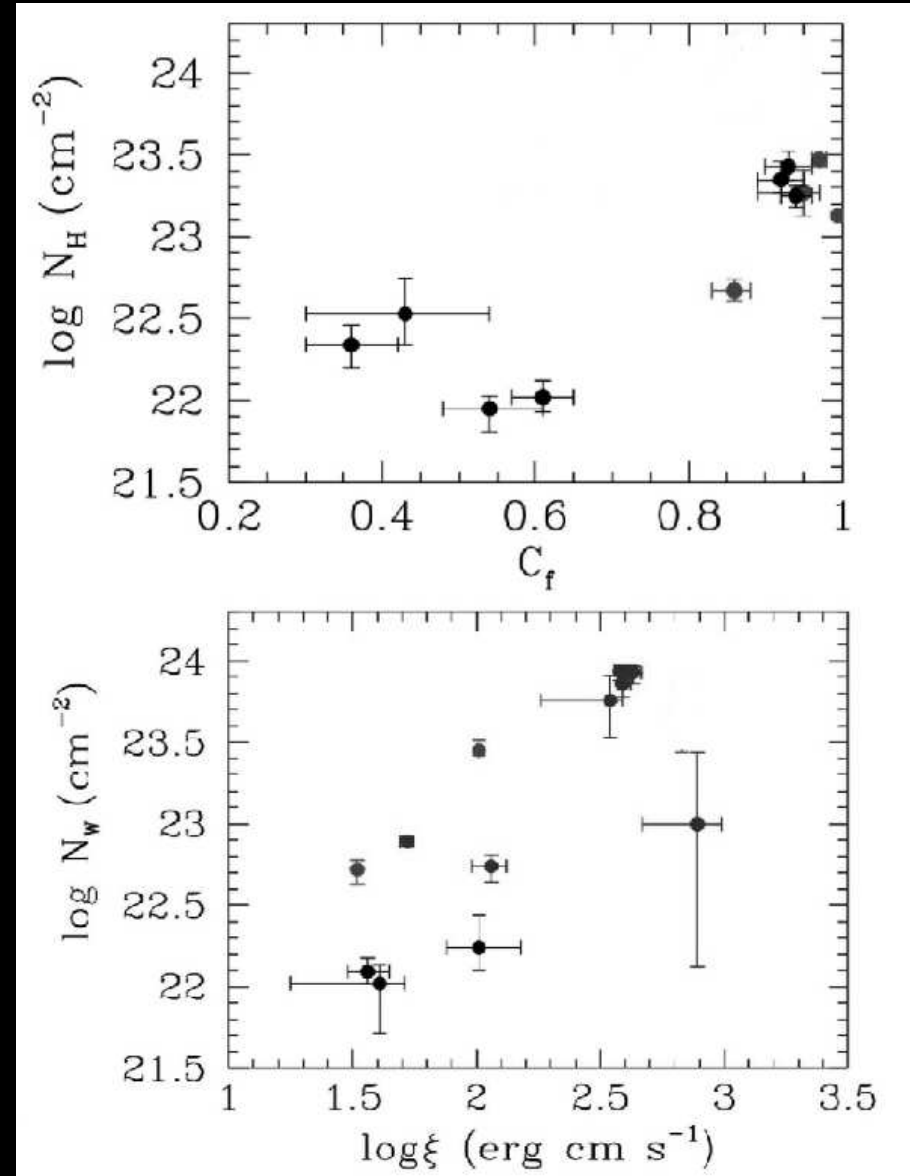


- Ubiquitous complex (i.e. ionized and/or partially covering) absorption?
- Desperately need more and longer XMM observations on high-z QSOs

In BAL and mini-BAL QSOs (a dozen with $z \sim 0.1-0.5-2$)

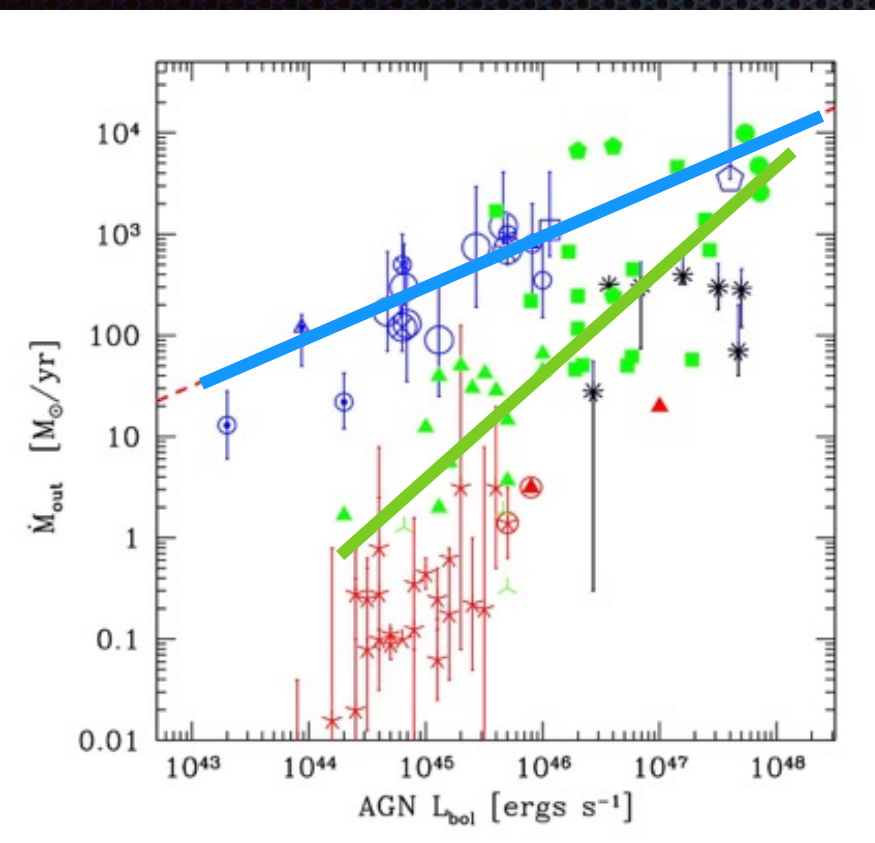
Giustini 2015

...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

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

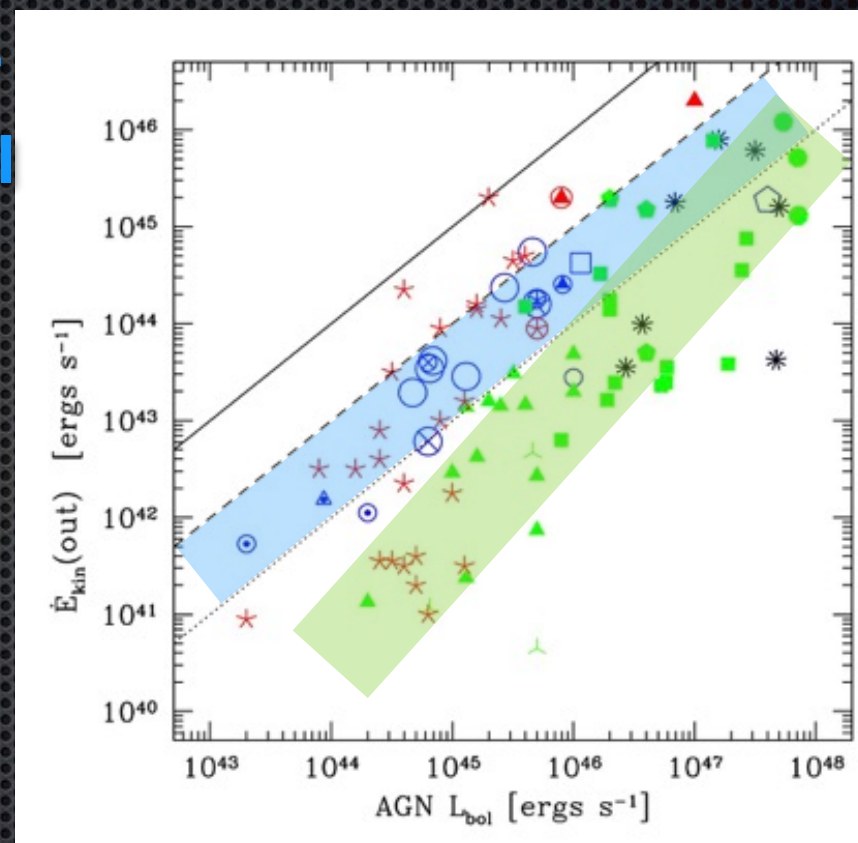


Molecular
small=nucl
large=gal.

Ionized

BAL

X-ray



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

$E_{\text{kin}}(\text{out}) = 1\text{-}10\% L_{\text{bol}}$ (molecular)

$E_{\text{kin}}(\text{out}) = 0.1\text{-}10\% L_{\text{bol}}$ (UFOs, BALs)

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

Fiore et al., '15

Summary and personnel view:

➤ Science Case (outflows)

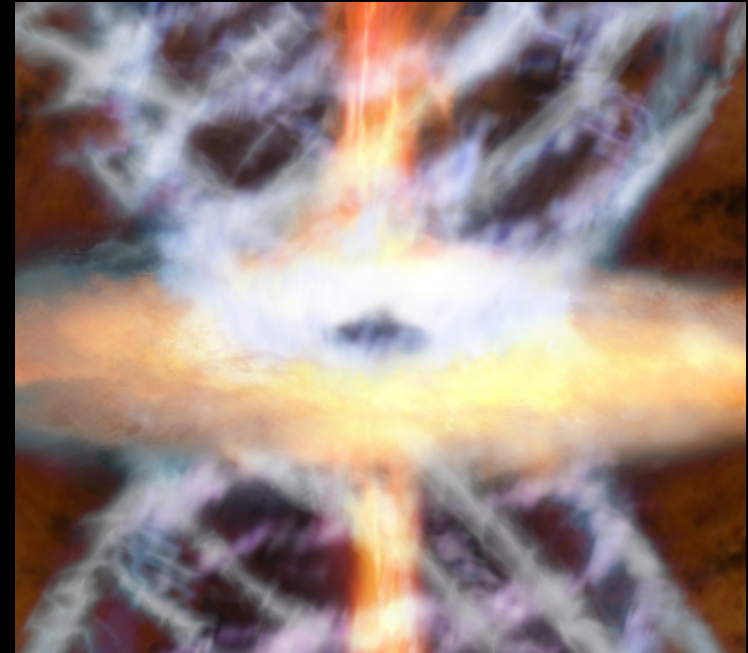
- *Recognized importance, and “pathfinder” to future missions/observatories (from ground based Obs. ALMA, MUSE, SINFONI to Athena).*
- *Important implications for both astrophysics of winds/outflows formation and acceleration, and the cosmological impact/feedback of AGN winds.*

➤ Astrophysics of AGN winds

- Will need (to continue) massive campaigns of spectra/imaging/timing often/mostly using a multi-ni approach on low-z AGN

➤ Cosmological impact/feedback:

- Desperate need to have representative samples of good quality X-ray spectra of high-z QSOs to characterize and measure the frequency of massive and energetic outflows in high-z QSOs. Need multi-ni coverage to obtain full outflow energetics. Multi-ni would also “guarantee” more publications per XMM-ks, like experience in low-z AGNs.



N.B1: Few high-z QSOs spectra available ALL show features in their X-ray spectra

N.B2: Reflection vs absorption uncertainties could be two facets of the same phenomenon

Thank you very much
for your attention