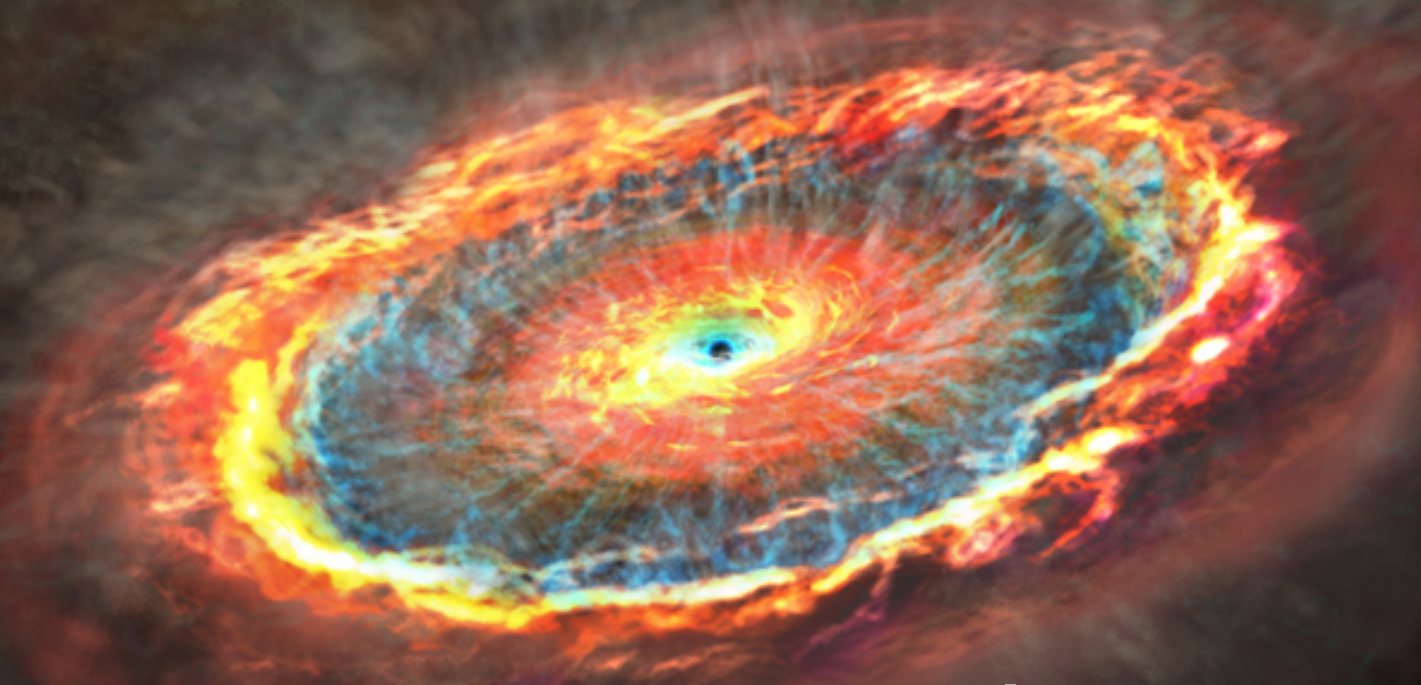


X-ray observations of UFOs and their implications for AGN feedback



Francesco Tombesi

University of Rome, Tor Vergata

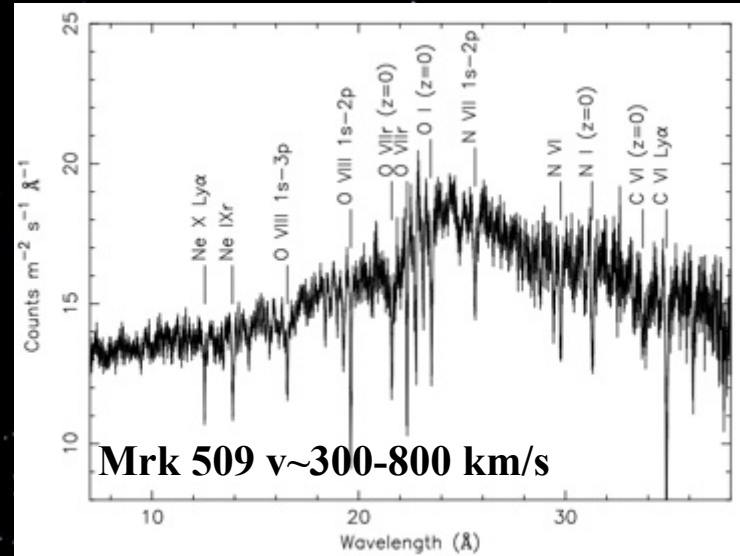
NASA - Goddard Space Flight Center

University of Maryland, College Park

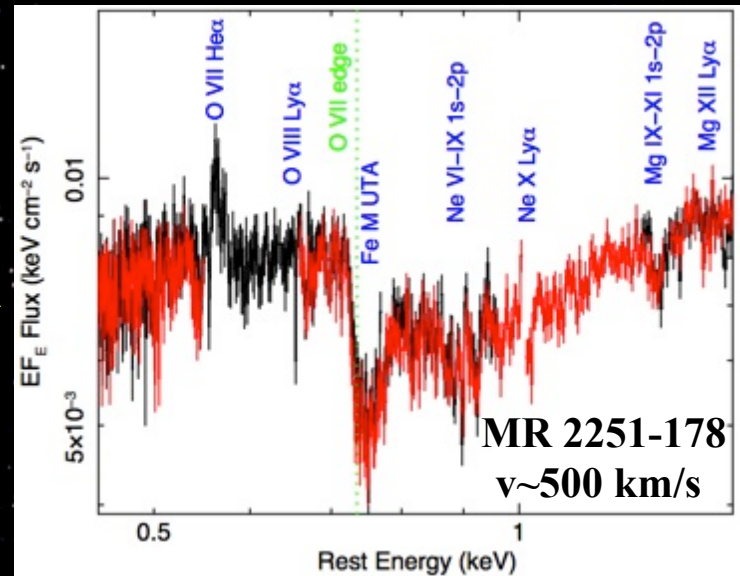
**(credit JAXA's
press release)**

~~Warm Absorbers (WAs)~~

(Photo) ionized

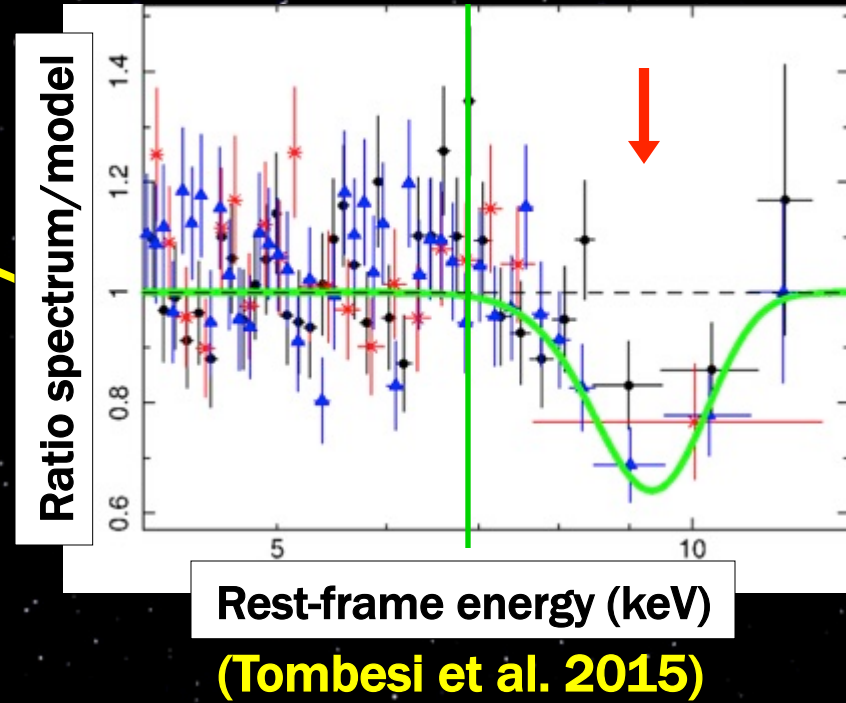
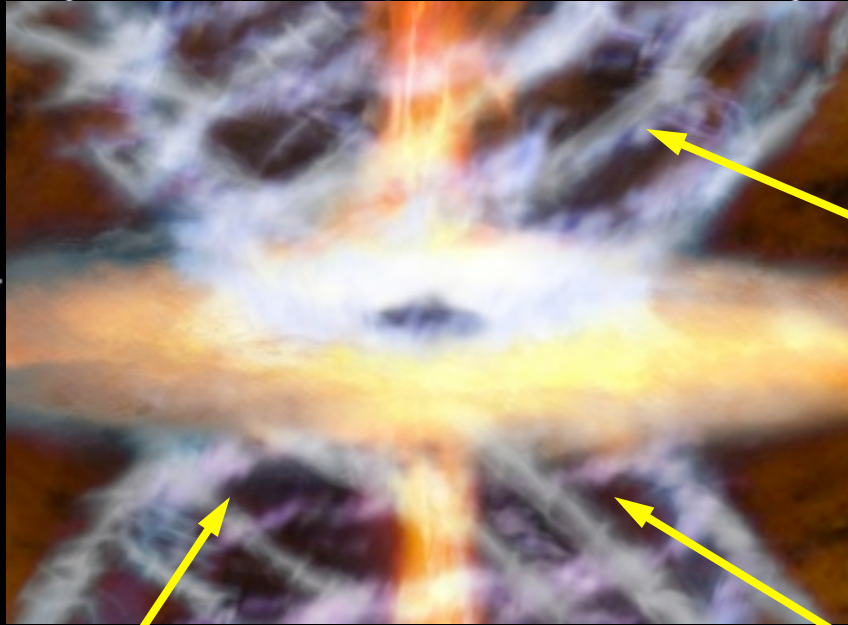


(Detmers, Kaastra et al. 2011)

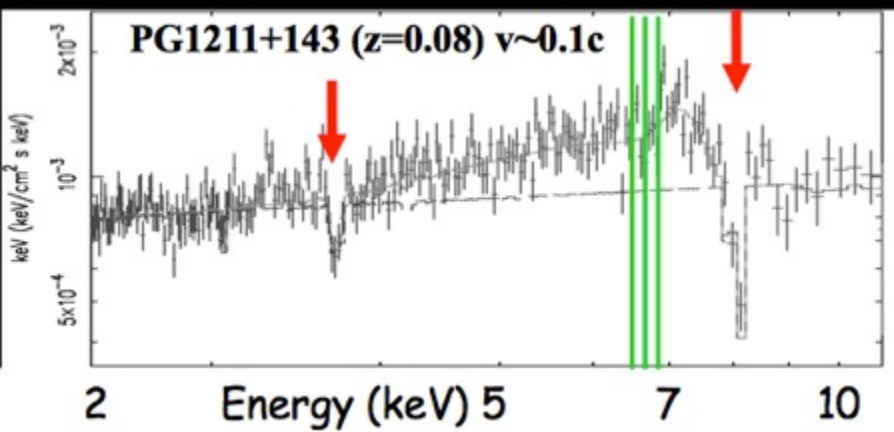


(Reeves et al. 2013)

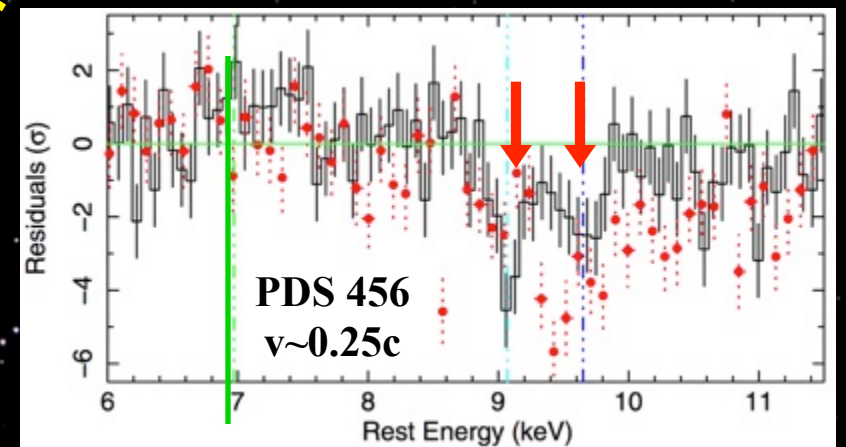
UltraFast Outflows (“UFOs”)



Rest-frame energy (keV)
(Tombesi et al. 2015)



(Pounds et al. 2003)

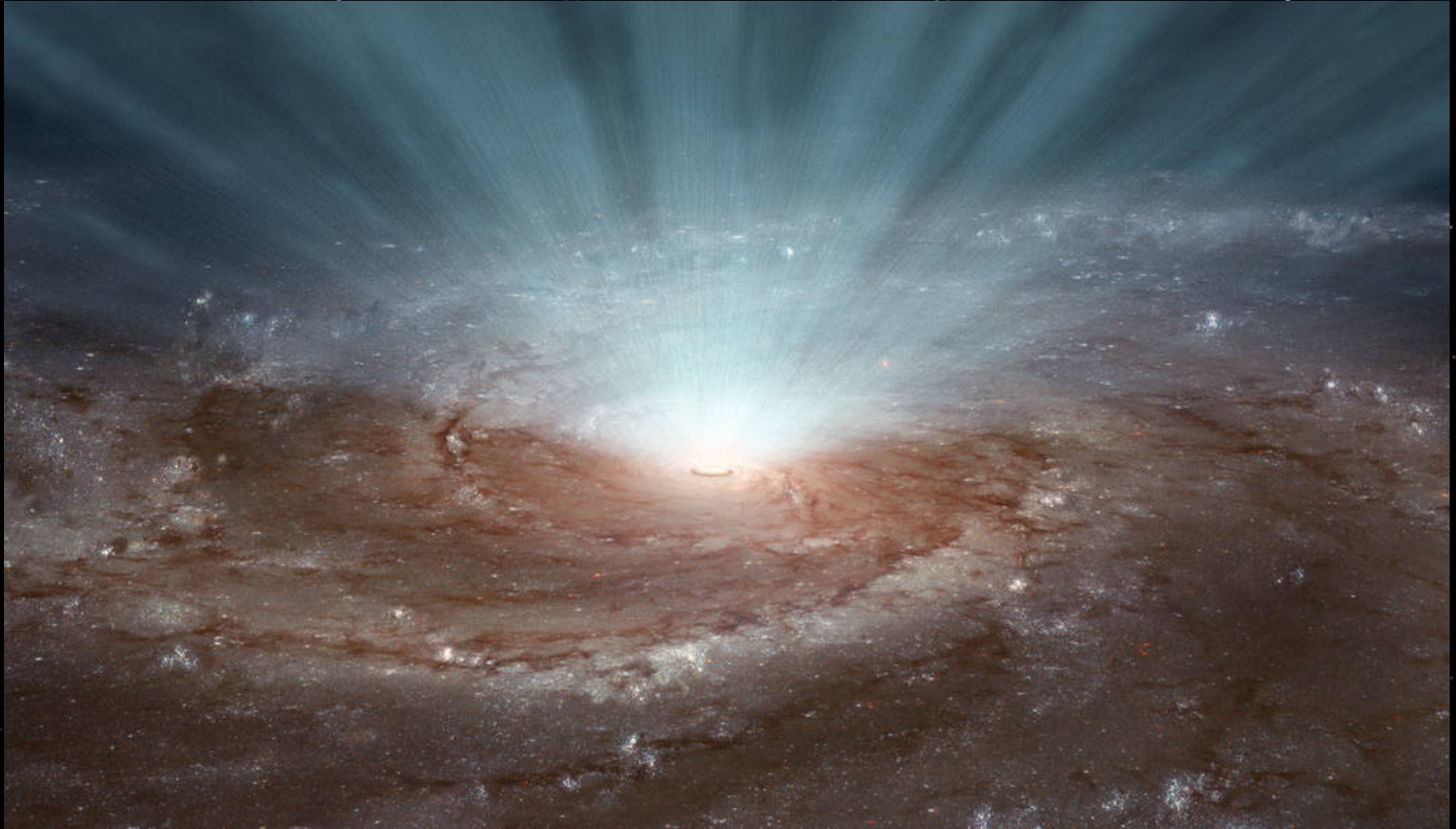


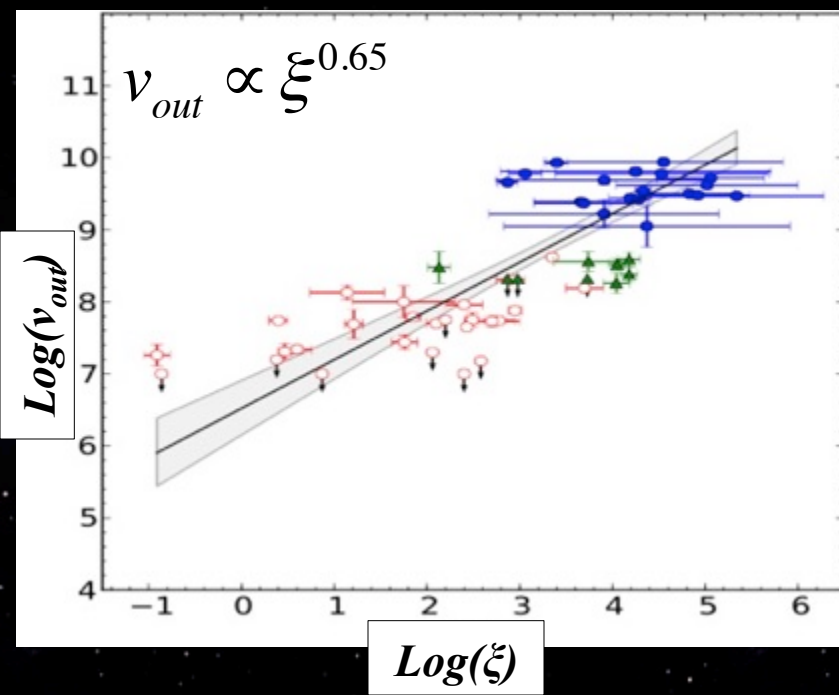
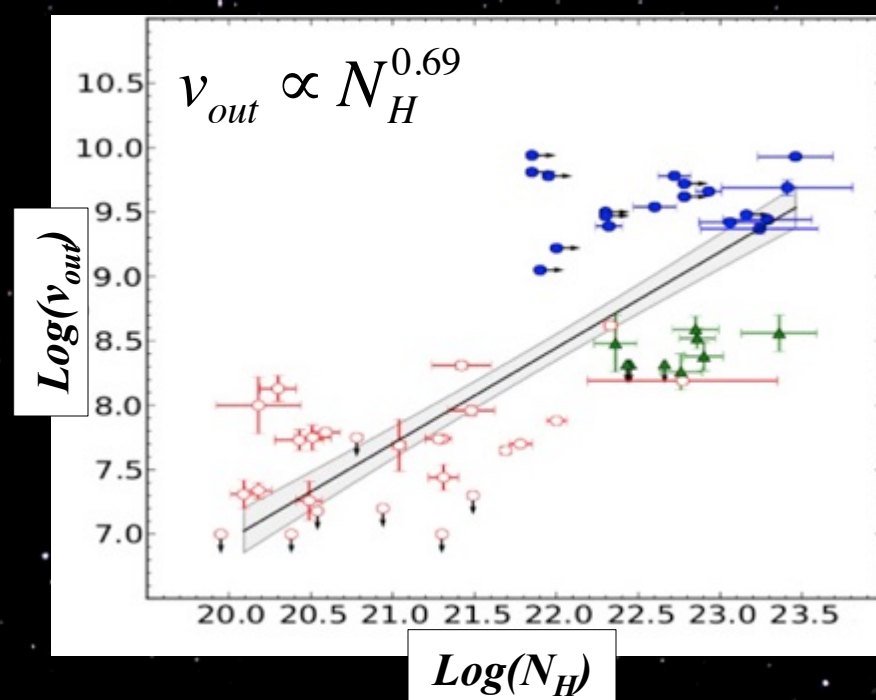
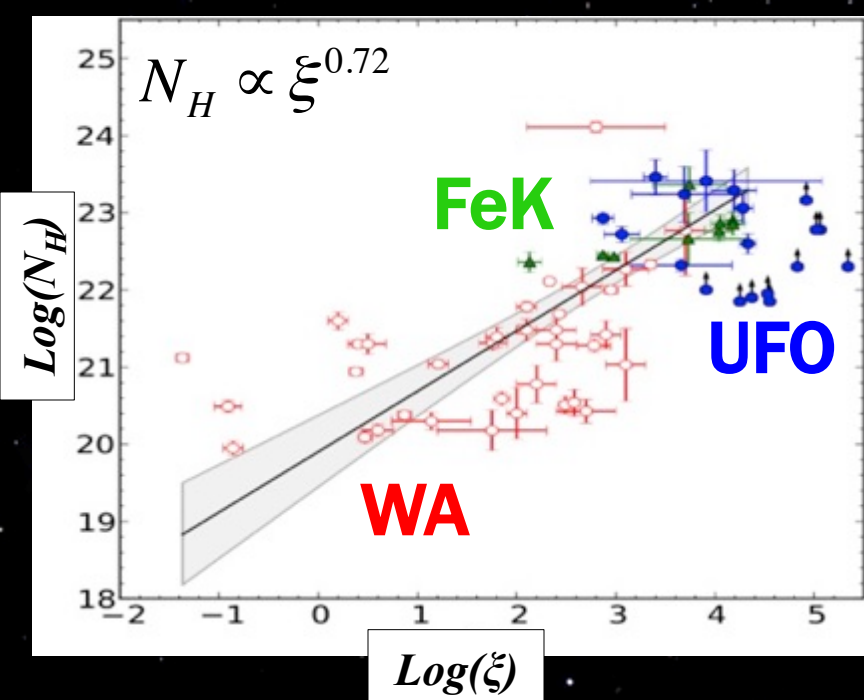
(Reeves et al. 2009)

Some open questions on AGN winds:

- 1. What is the relation between UFOs and warm absorbers?**
- 2. What is the relation between UFOs and UV outflows?**
- 3. What is the relation between UFOs and AGN jet?**
- 4. Are UFOs energetic enough to drive AGN feedback?**
- 5. Are there evidences for AGN wind feedback in action?**

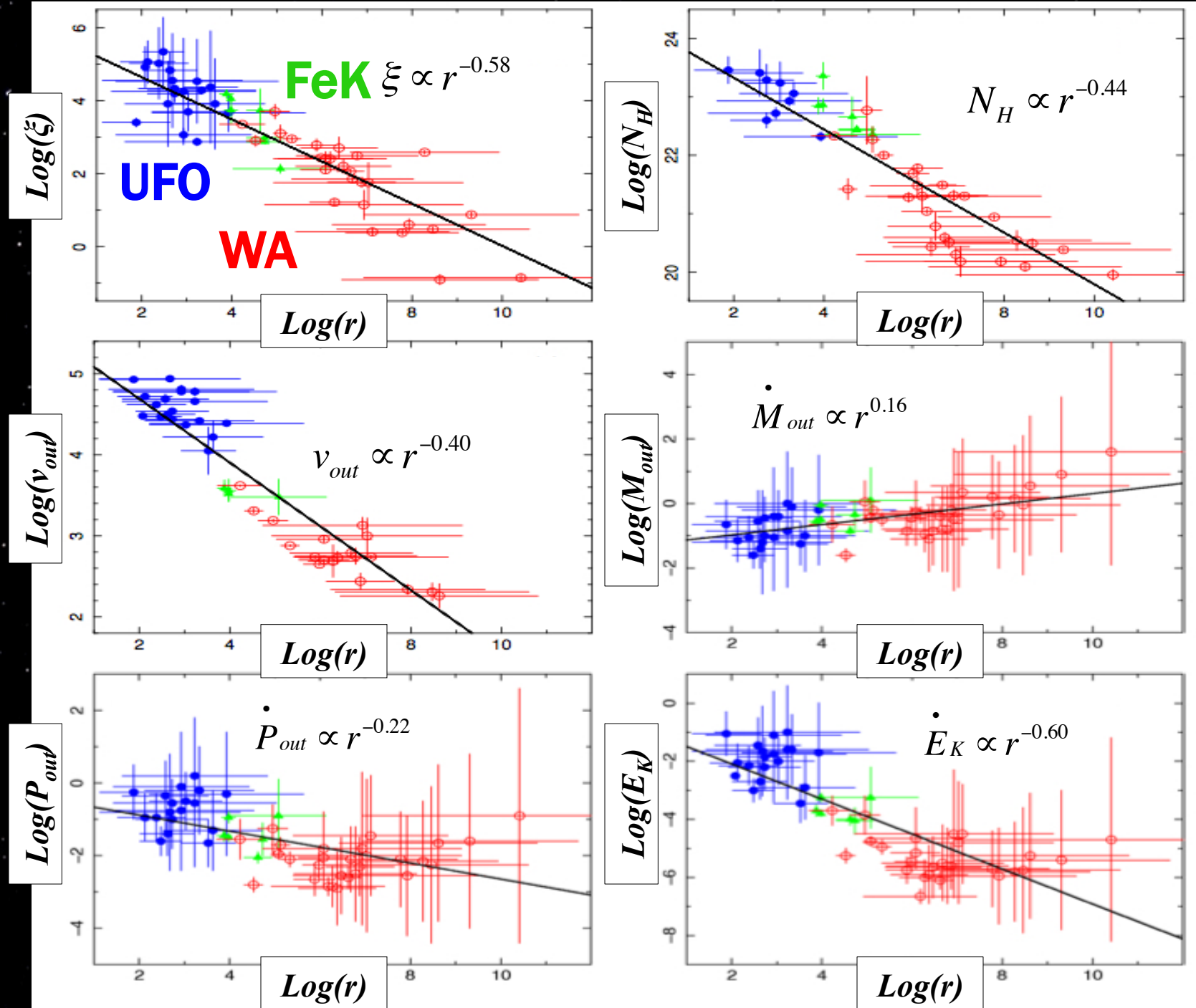
1 - What is the relation between UFOs and warm absorbers?



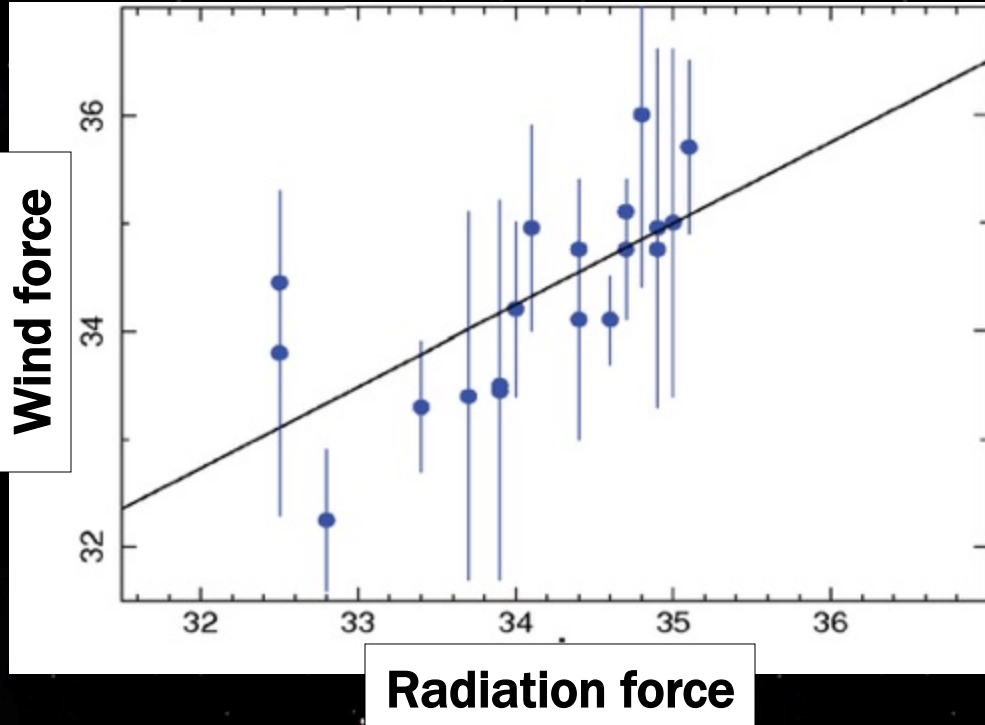


Comparison of UFOs and WAs in sample of 35 Seyfert 1 galaxies

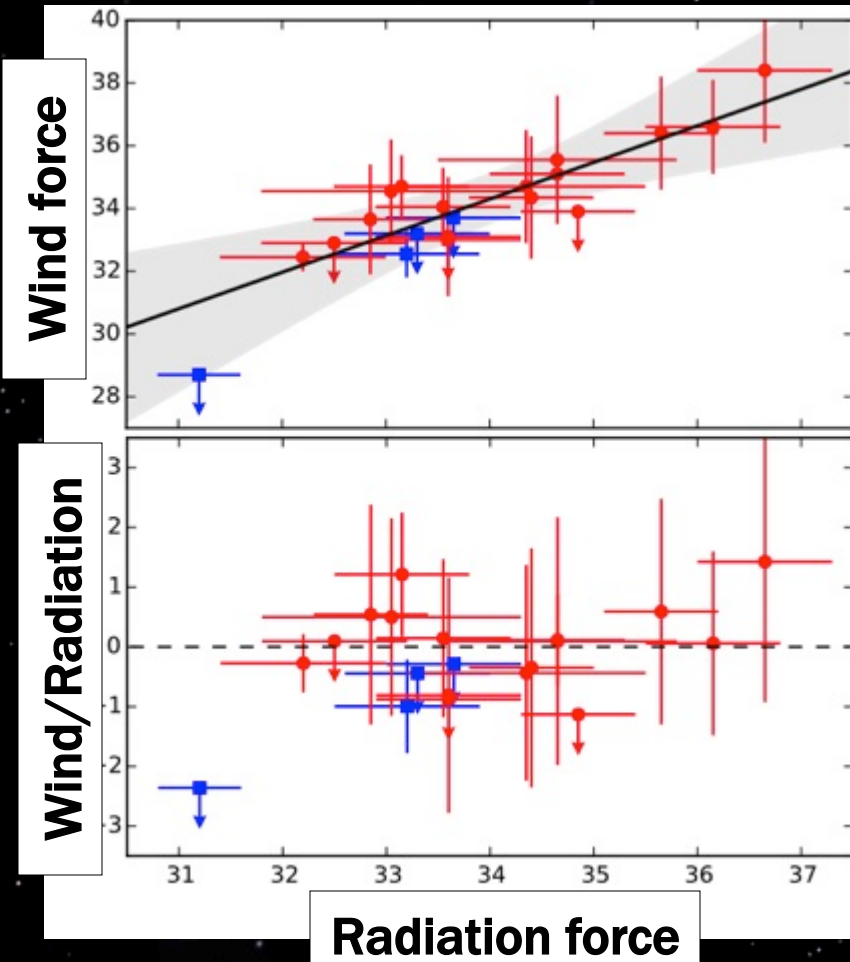
- WAs found in >60% sources
- UFOs in >40%, >70% also WAs
- Profiles: $n \sim 1/r^{1.4}$, $v_{out} \sim 1/r^{0.5}$



Correlation between UFO and AGN momentum rates

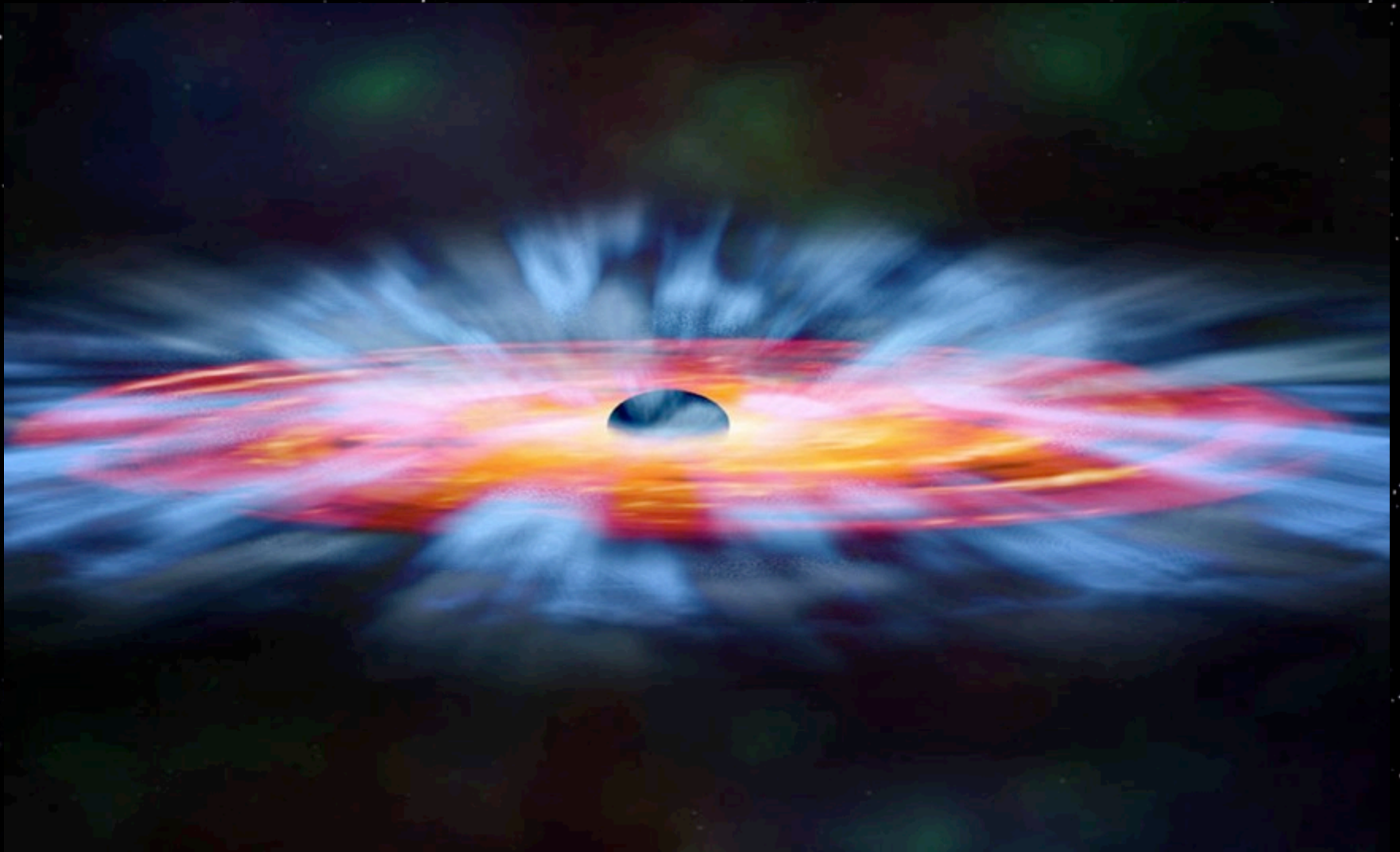


(Tombesi et al. 2013; XMM-Newton)

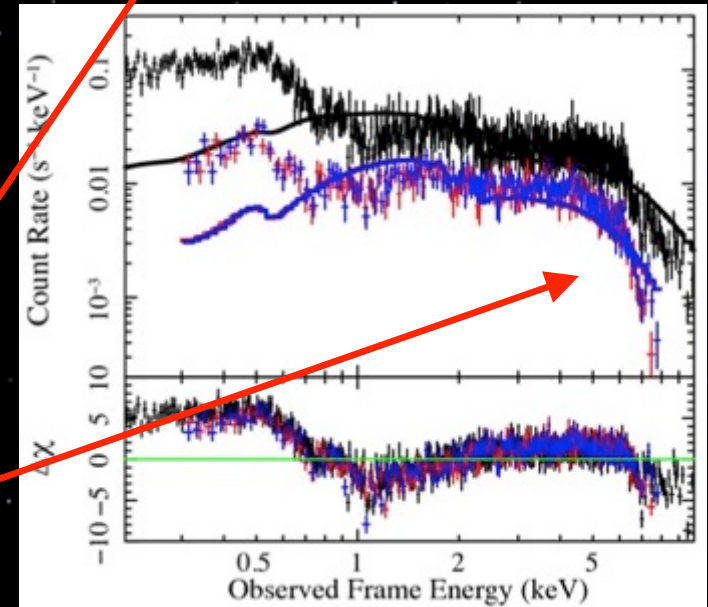
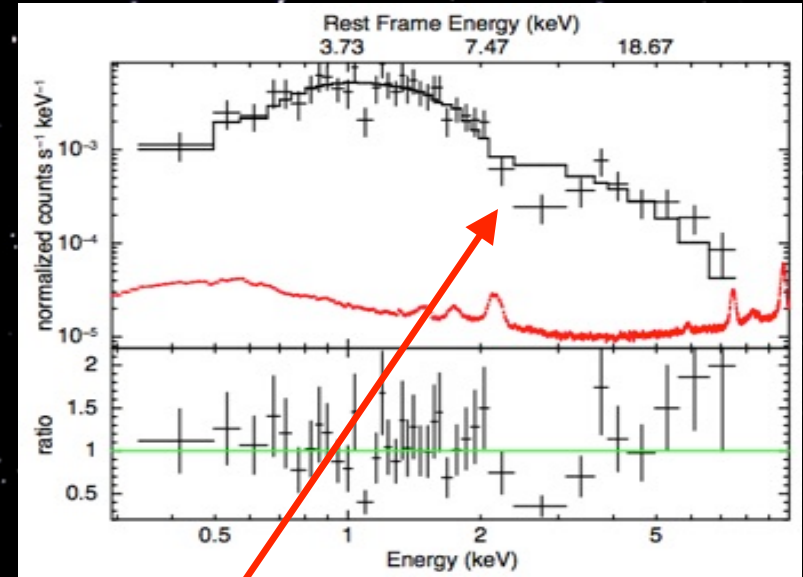
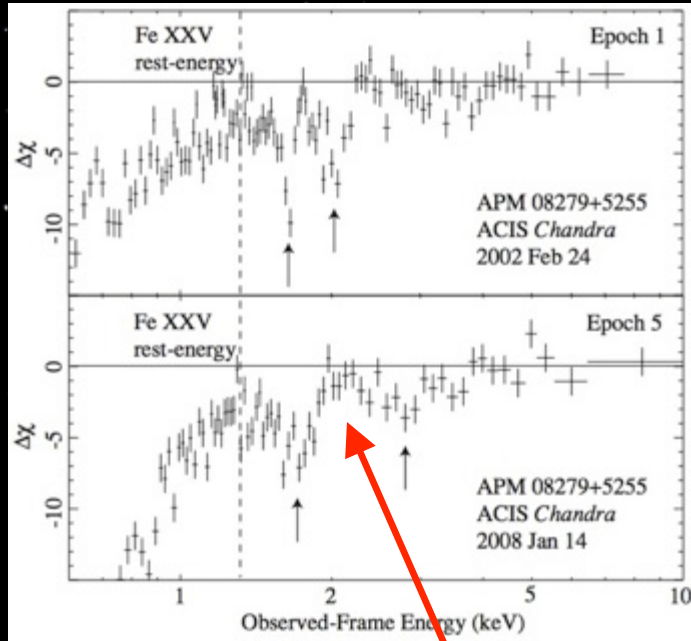


(Gofford et al. 2015; Suzaku)

2 - What is the relation between UFOs and UV winds?

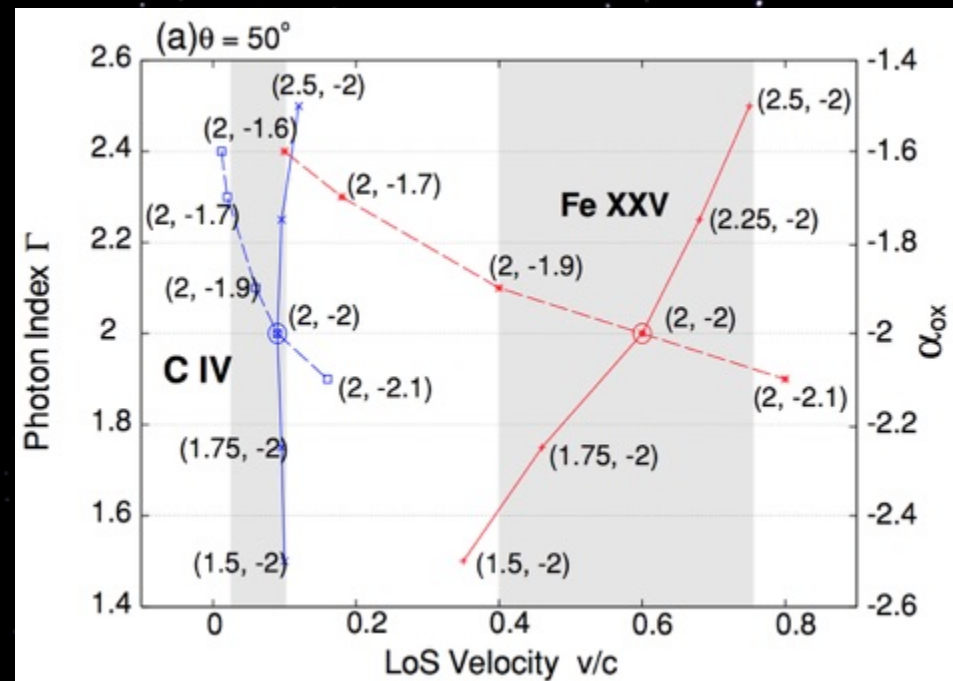
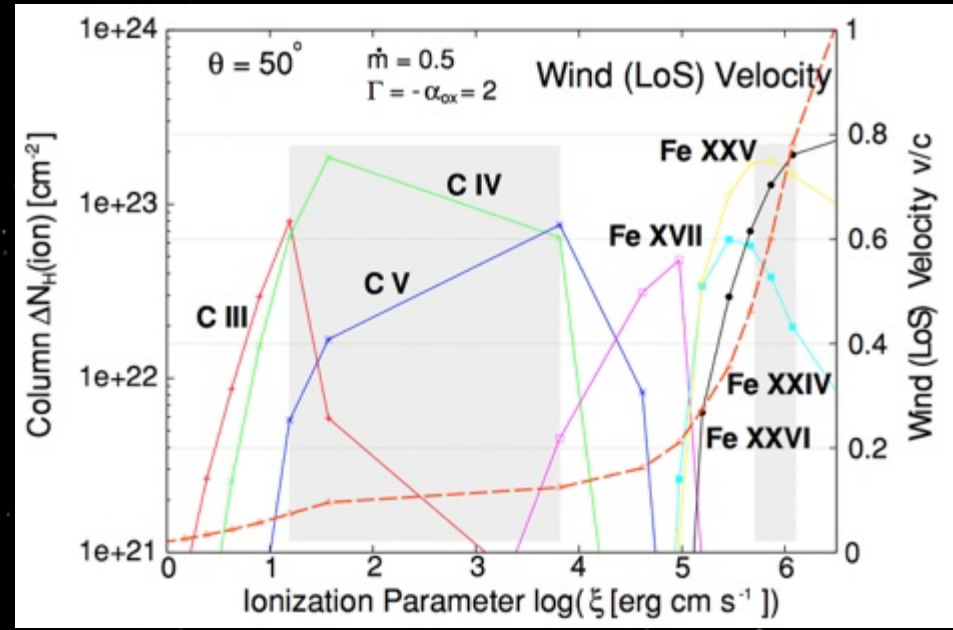
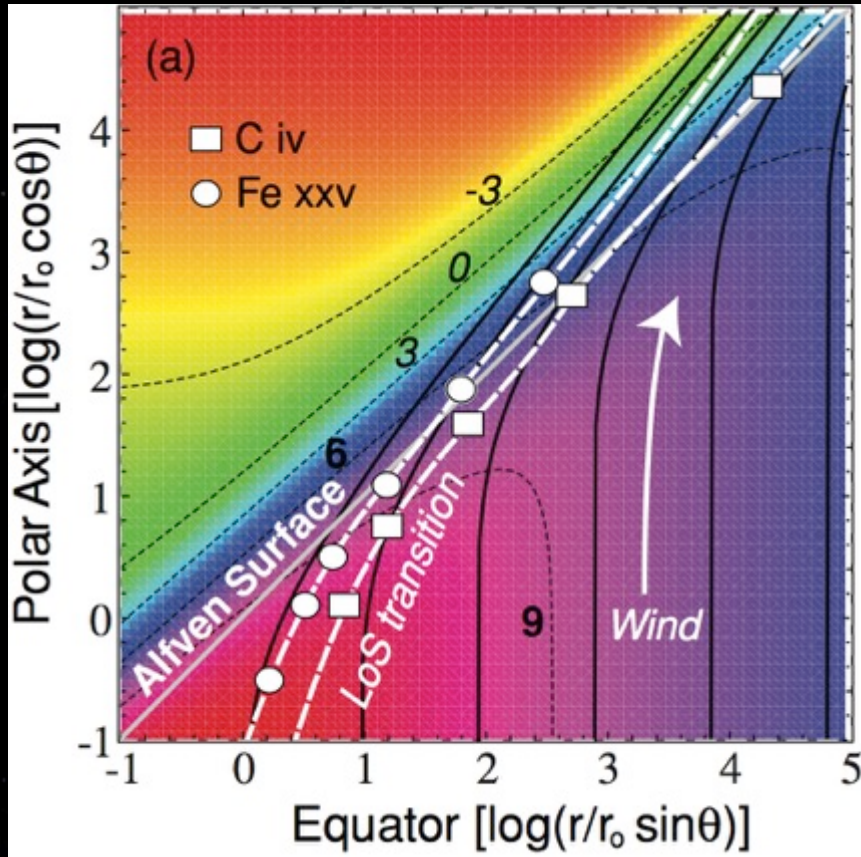


Ultrafast outflows in (high-z) BAL quasars



- Gravitationally lensed BAL QSO APM 08279 +5255 ($z = 3.9$), $v_{out} \sim 0.2-0.7c$ (Chartas et al. 2009)
- NAL QSO HS 1700+6416 ($z = 2.7$), $v_{out} \sim 0.1-0.6c$ (Lanzuisi et al. 2012)
- Mini-BAL QSO PG1126-041, $v_{out} \sim 16,500$ km/s (Giustini et al. 2011)

What is the relation between UFOs and BALs?

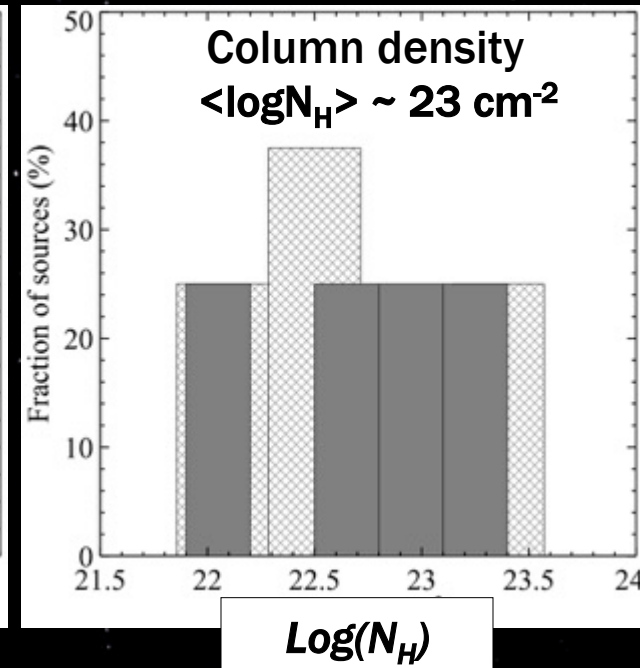
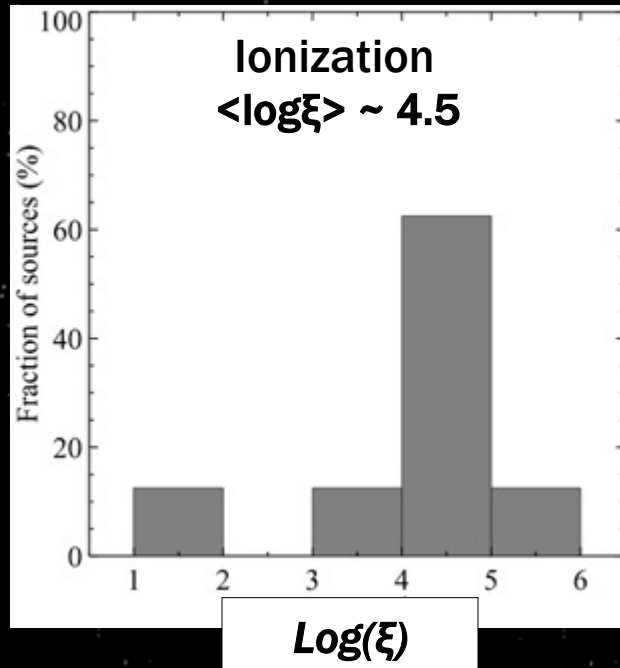
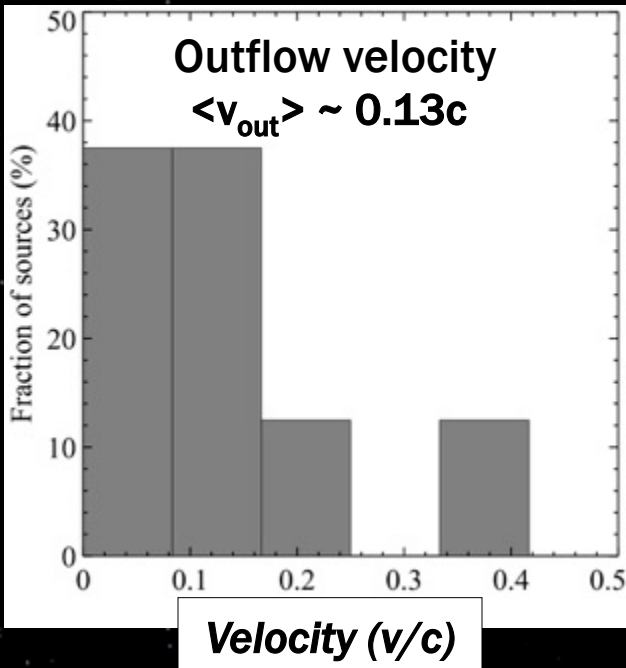


- Gravitationally lensed BAL quasar APM 08279+5255 ($z = 3.9$)
C IV $v \sim 0.1c$, Fe XXV $v \sim 0.5c$
- MHD disk wind can explain both lines for $\alpha_{ox} \sim -2$ (Fukumura et al. 2010)

3 - What is the relation between UFOs and AGN jets?



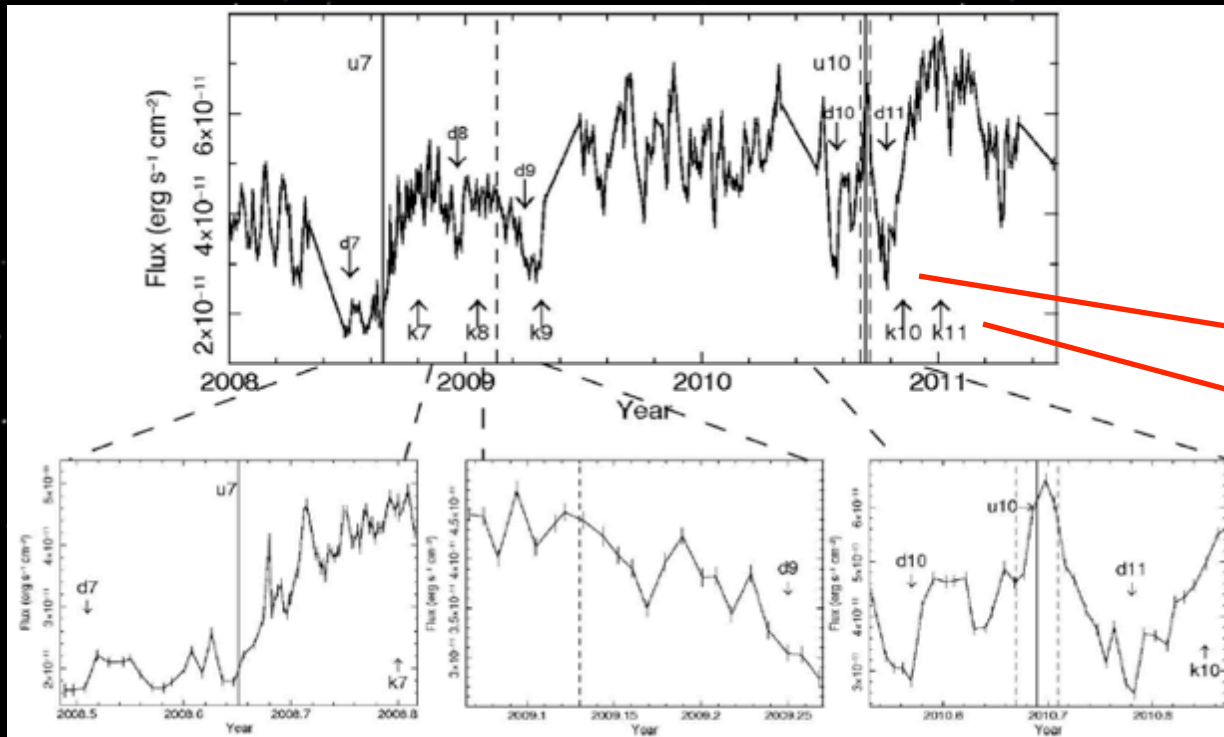
Ultra-fast outflows in radio-loud AGNs



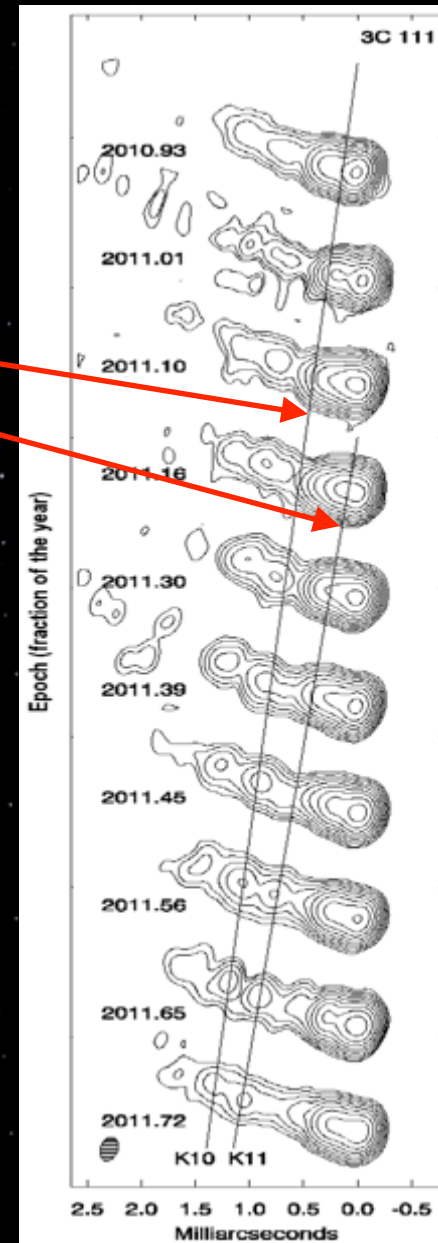
- Combining results with literature, UFOs in 7/26 ($\sim 30\%$) sources
- But only $\sim 56\%$ spectra have enough S/N, frequency of UFOs is $f = (50 \pm 20)\%$
- Similar to RQ AGNs: RQ/RL dichotomy does not apply to disk winds?

(Tombesi et al. 2014)

Disk, wind, and jet cycles in 3C 111



2-10keV RXTE monitoring

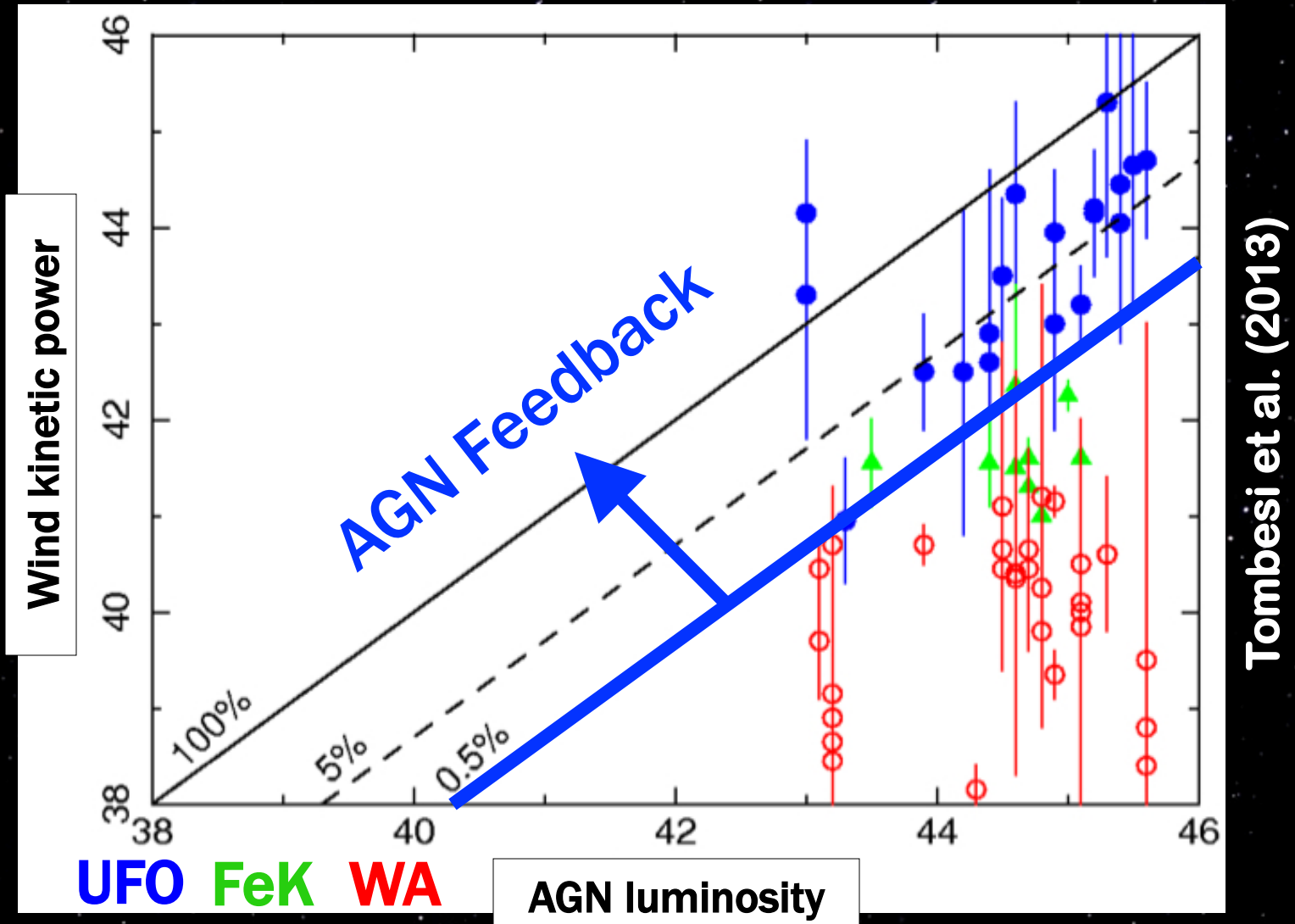


- Correlation X-ray dips & VLBA radio jet ejections (Marscher et al. 2002; Chatterjee et al. 2009, 2011)
- Disk winds with $v \sim 0.1c$ stronger during disk-jet ejection cycles (Tombesi et al. 2012)

4 - Are UFOs energetic enough to drive AGN feedback?

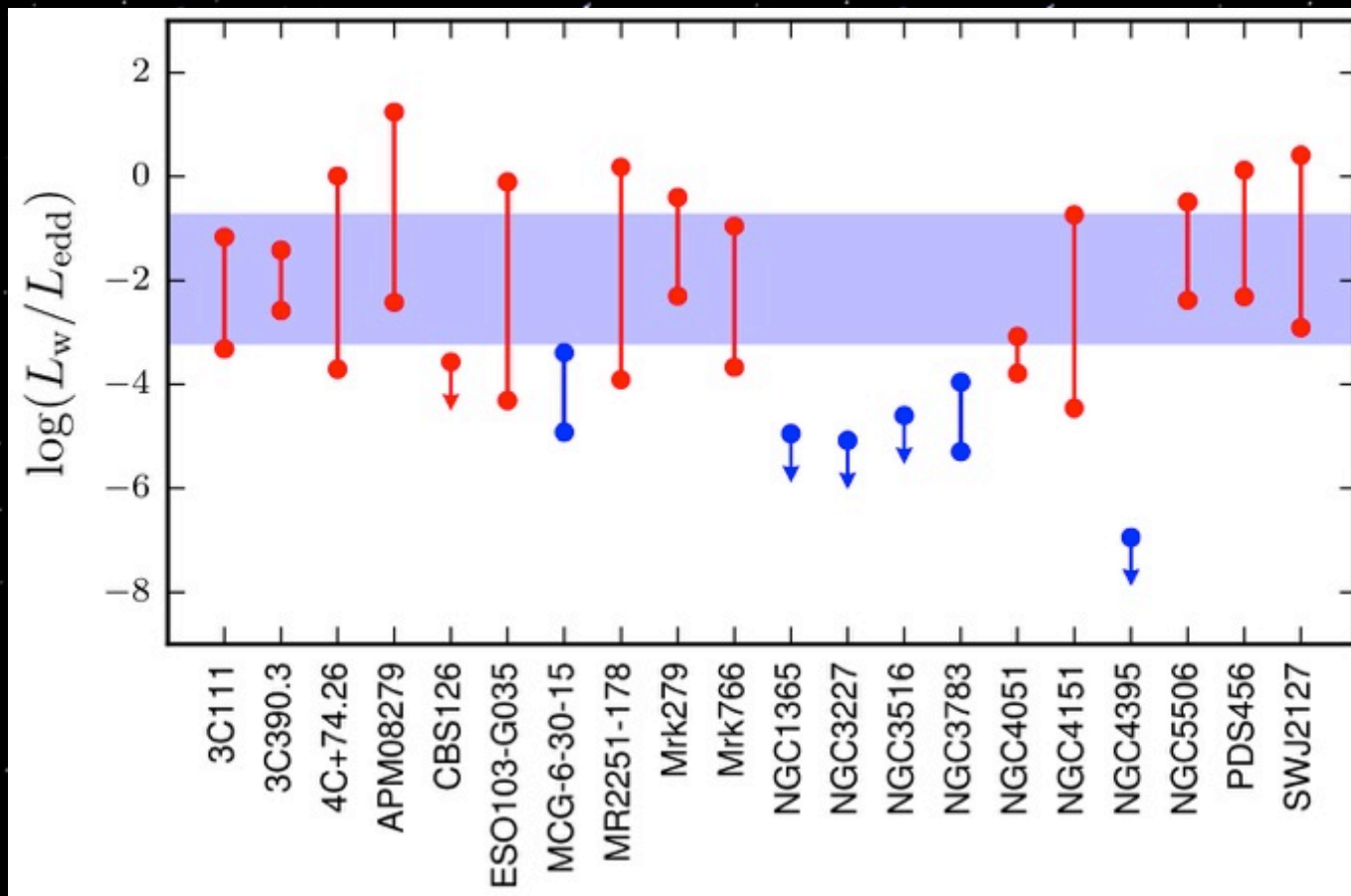


How powerful are ultrafast outflows?



$L_K/L_{bol} \sim 0.5-5\%$ (e.g., Di Matteo+ 2005; Hopkins & Elvis 2010; Gaspari+ 2011)

How powerful are ultrafast outflows?



(Gofford et al. 2015)

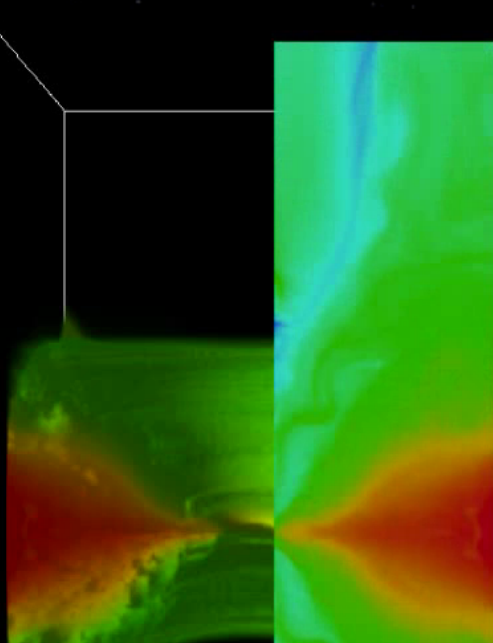
$$L_W = \frac{1}{2} \dot{M}_{out} v_{out}^2 \sim \Omega N_H R_{in} v_{out}^3$$

5 - Are there evidences for AGN wind feedback in action?



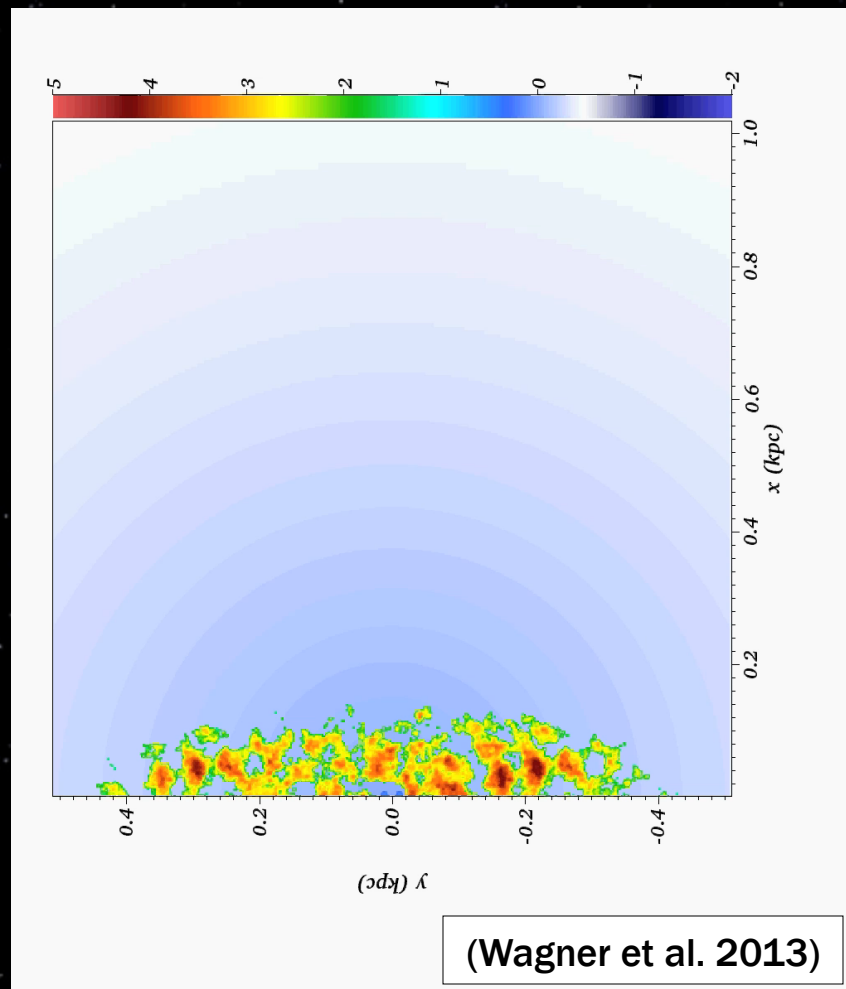
AGN feedback from accretion disk winds?

Accretion disk wind
($\ll 1$ pc scales)



(Ohsuga et al. 2009)

Galaxy feedback (kpc scales)



(Wagner et al. 2013)

OUTLOOK
Biomaterials

nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

GROWING IN THE WIND

Accretion-disk winds
drive evolution of
supermassive
black holes and
their galaxies

PAGES 423 & 436

INNOVATION

BIOTECH BOOT CAMP

Finishing school for
wannabe entrepreneurs

PAGE 402

MEDICAL GENETICS

"DON'T EDIT THE GERM LINE"

Heritable gene modification
risks may outweigh benefits

PAGE 410

NANOTECHNOLOGY

WATER ENTERS A NEW PHASE

'Square ice' found between
the graphene sheets

PAGES 417 & 443

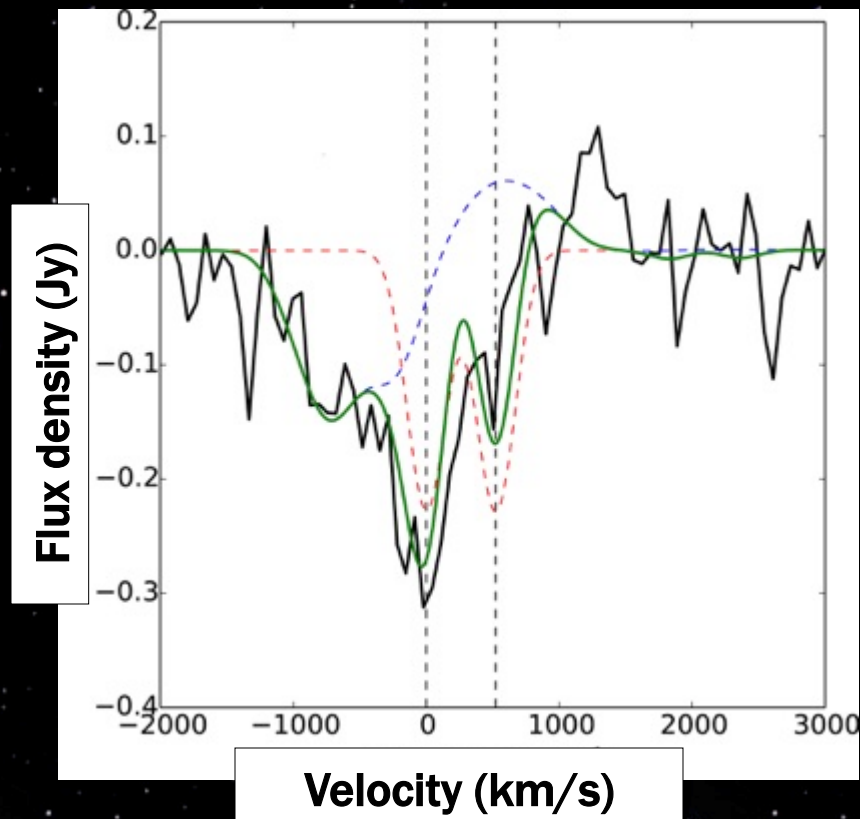
NATURE.COM/NATURE

26 March 2015



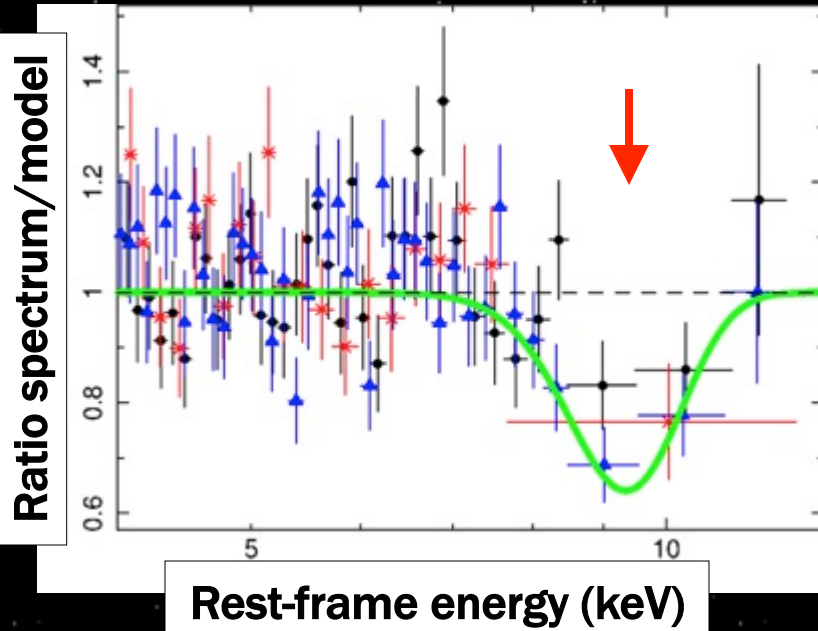
**Tombesi et al.
(2015)**

Large-scale molecular outflow with Herschel



- IRAS F11119+3257, ULIRG $z=0.189$, QSO luminosity 10^{46} erg/s
- Herschel spectrum OH 119 μ m P-Cygni line profile (Veilleux et al. 2013)
- Molecular outflow 1000 km/s, $800 M_{\odot} \text{ yr}^{-1}$ at >300 pc
- Follow-up with ALMA (PI Veilleux). *ApJ* paper under review

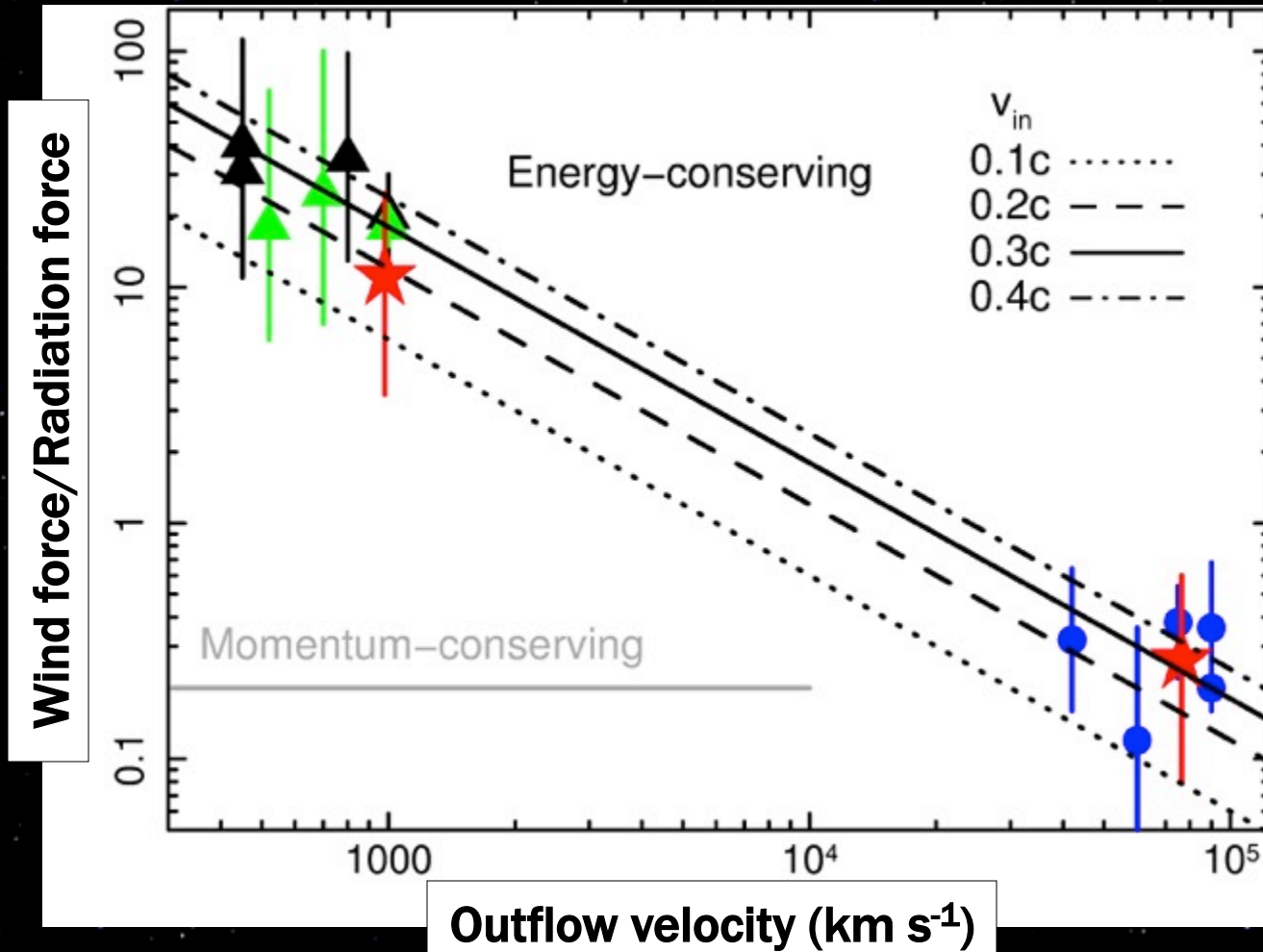
Accretion disk wind detected with Suzaku



(Image credit ESA)

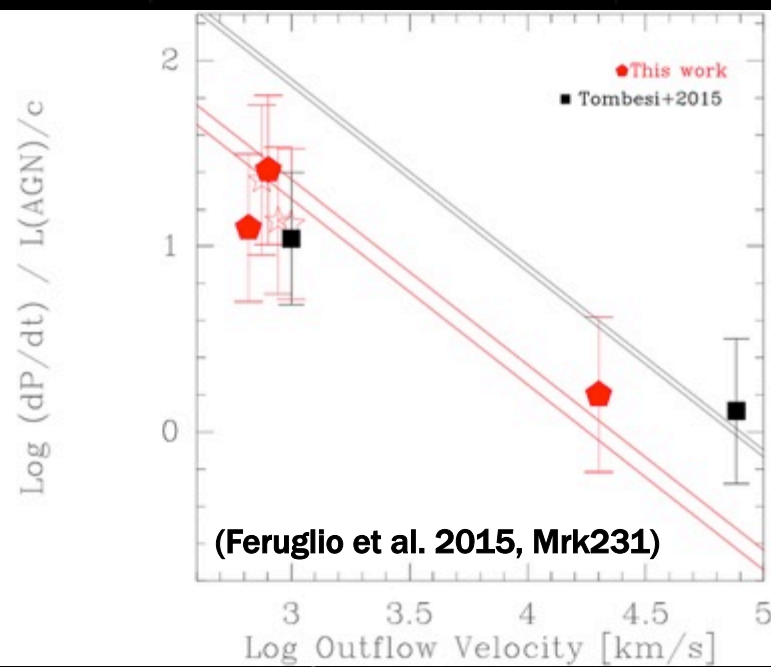
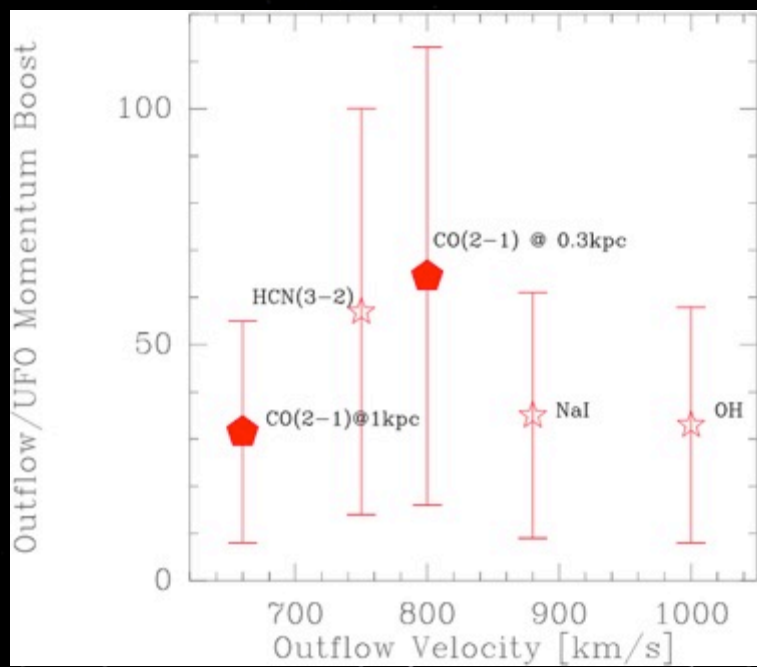
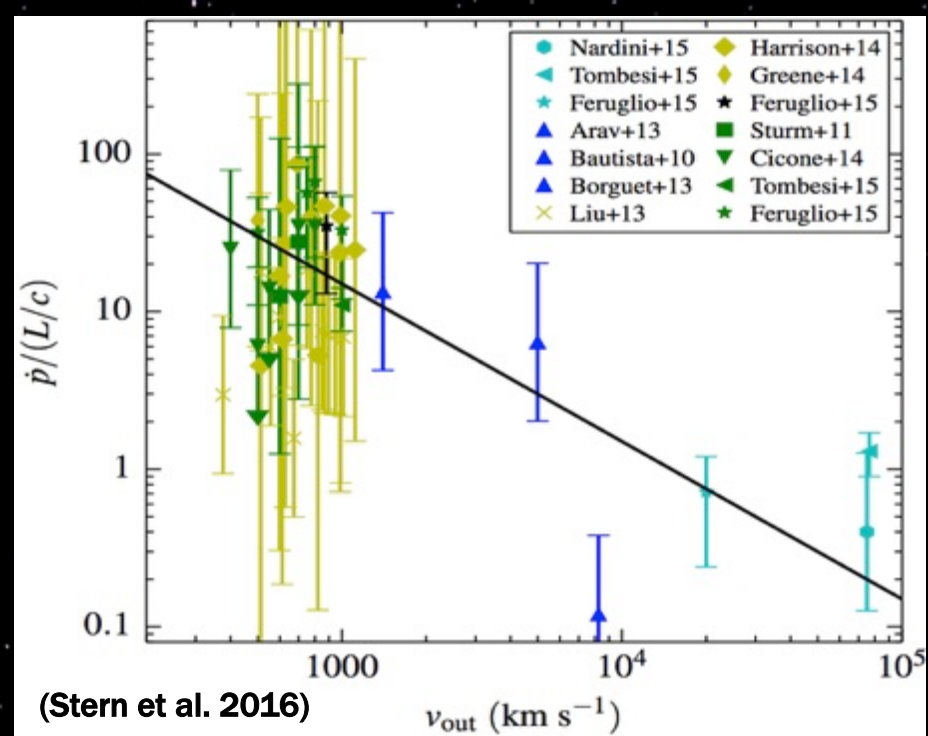
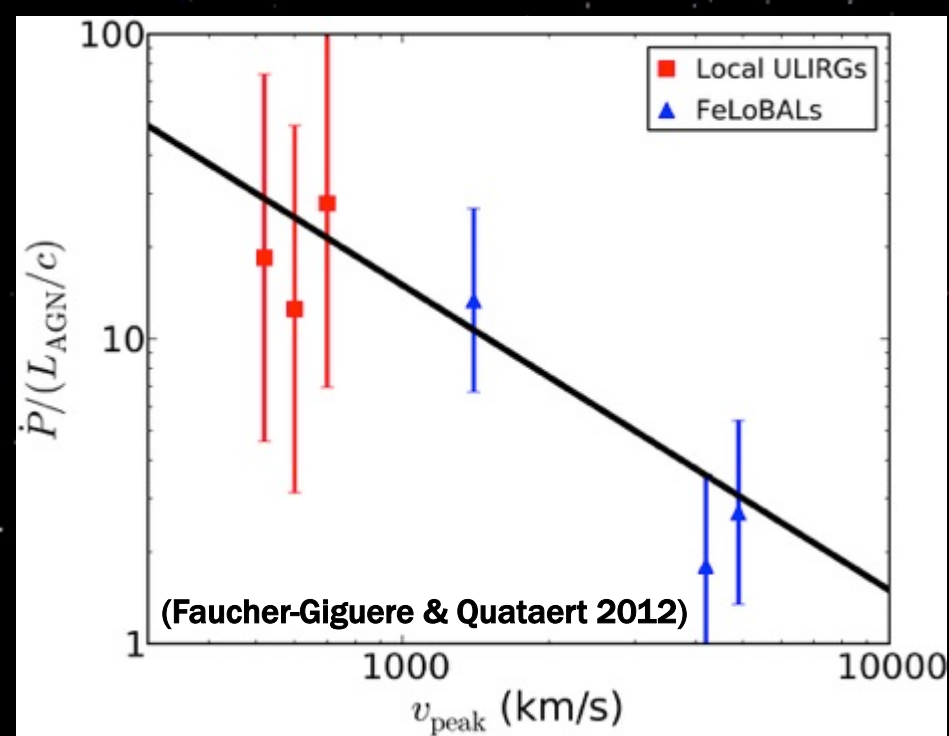
- Long 250ks Suzaku observation in May 2013
- Detection (6.5sigma) broad absorption line at rest-frame $E=9.82\text{keV}$
- XSTAR fit: $v=0.255c$, $\log\xi=4.11$, $N_h=6\times 10^{24}$, covering fraction >0.85
- Follow-up with NuSTAR (PI Tombesi). Paper to be submitted to ApJ soon

Energy conserving winds, from X-ray to IR/mm

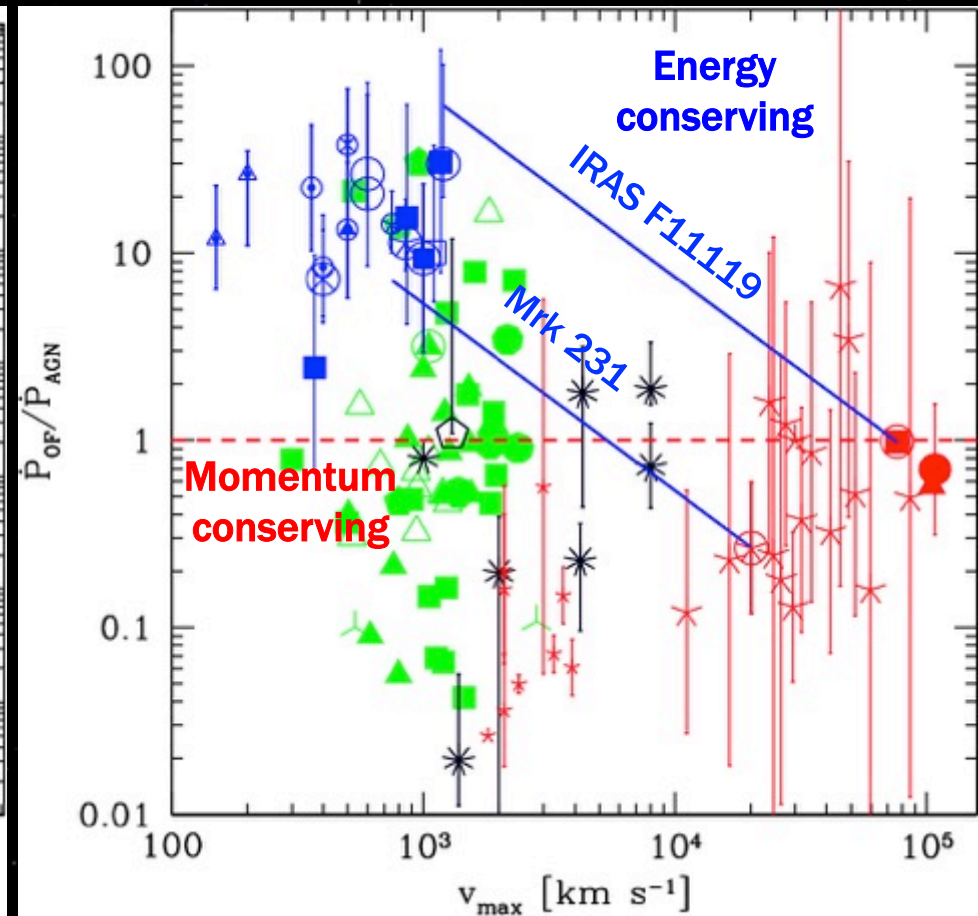
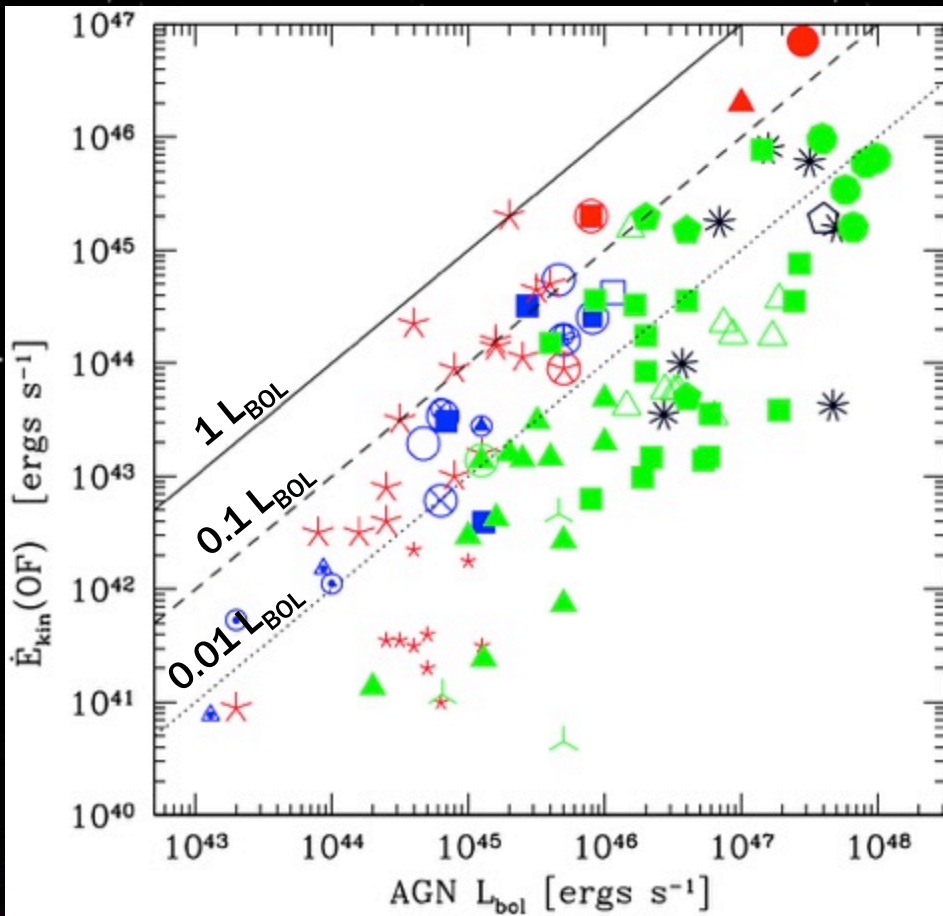


• Energy-conserving flow: $P_{\text{out}} = f(v_{\text{in}}/v_{\text{out}})(L_{\text{AGN}}/c)$

• Efficiency energy conservation $f = C_{\text{F,OH}}/C_{\text{F,X}} = 0.2$



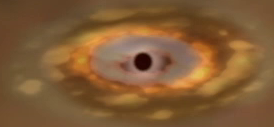
AGN wind scaling relations



Molecular winds Ionized winds BAL winds X-ray winds (WA*, UFO*)

(Fiore et al. 2017)

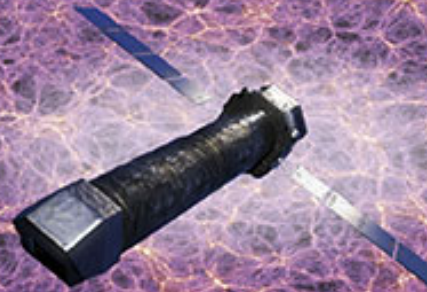
Galaxy-scale feedback from AGN winds



(credit NASA/GSFC press release)

ATHENA

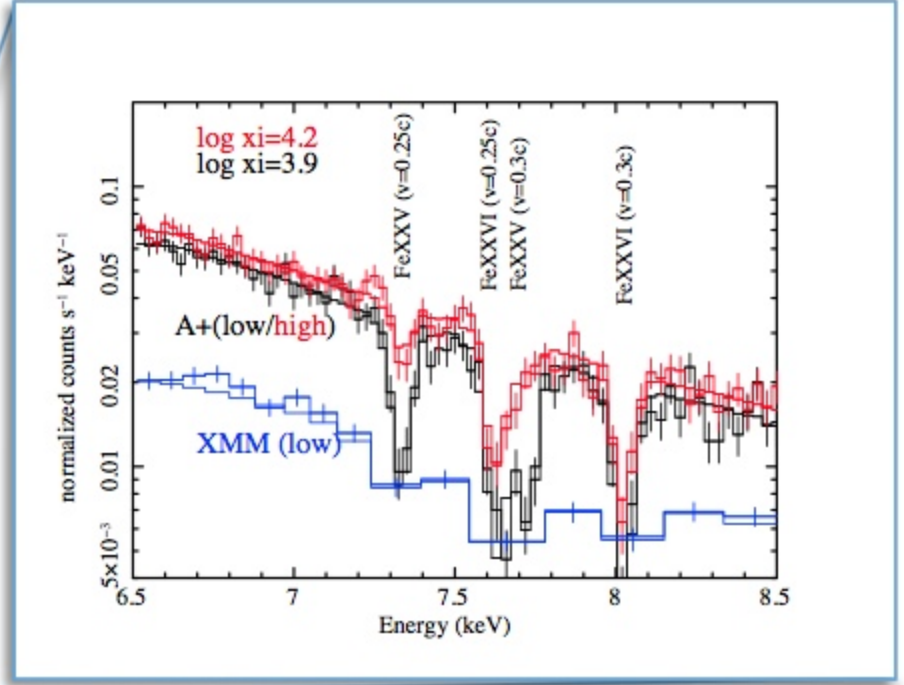
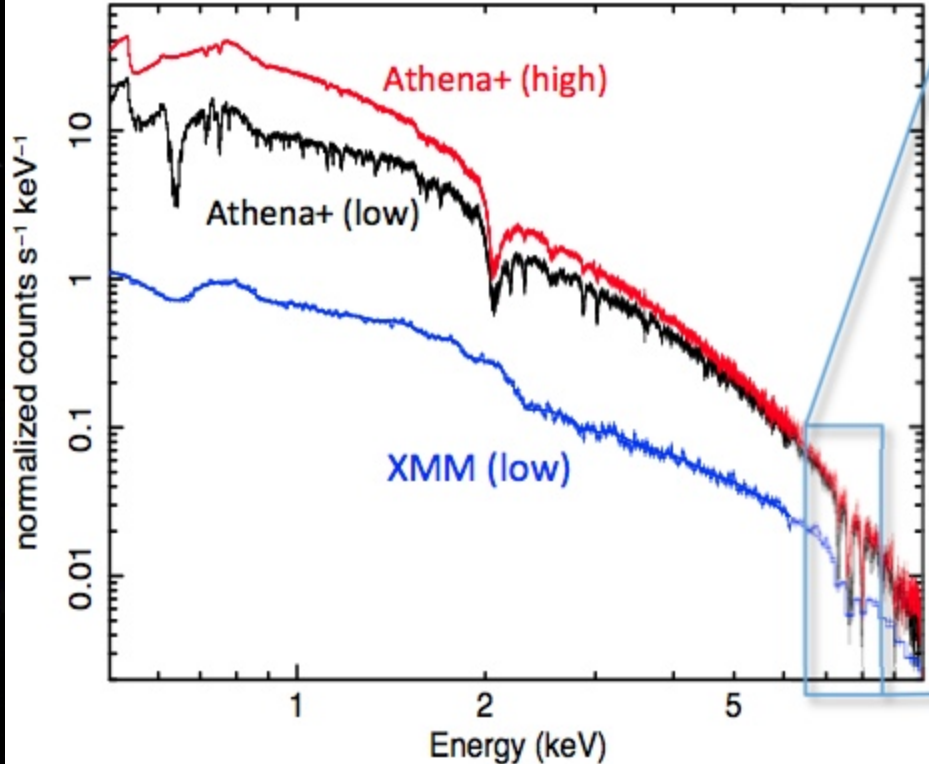
THE ASTROPHYSICS OF THE
HOT AND ENERGETIC
UNIVERSE



HOW DOES ORDINARY MATTER
ASSEMBLE INTO THE LARGE SCALE
STRUCTURES THAT WE SEE TODAY?

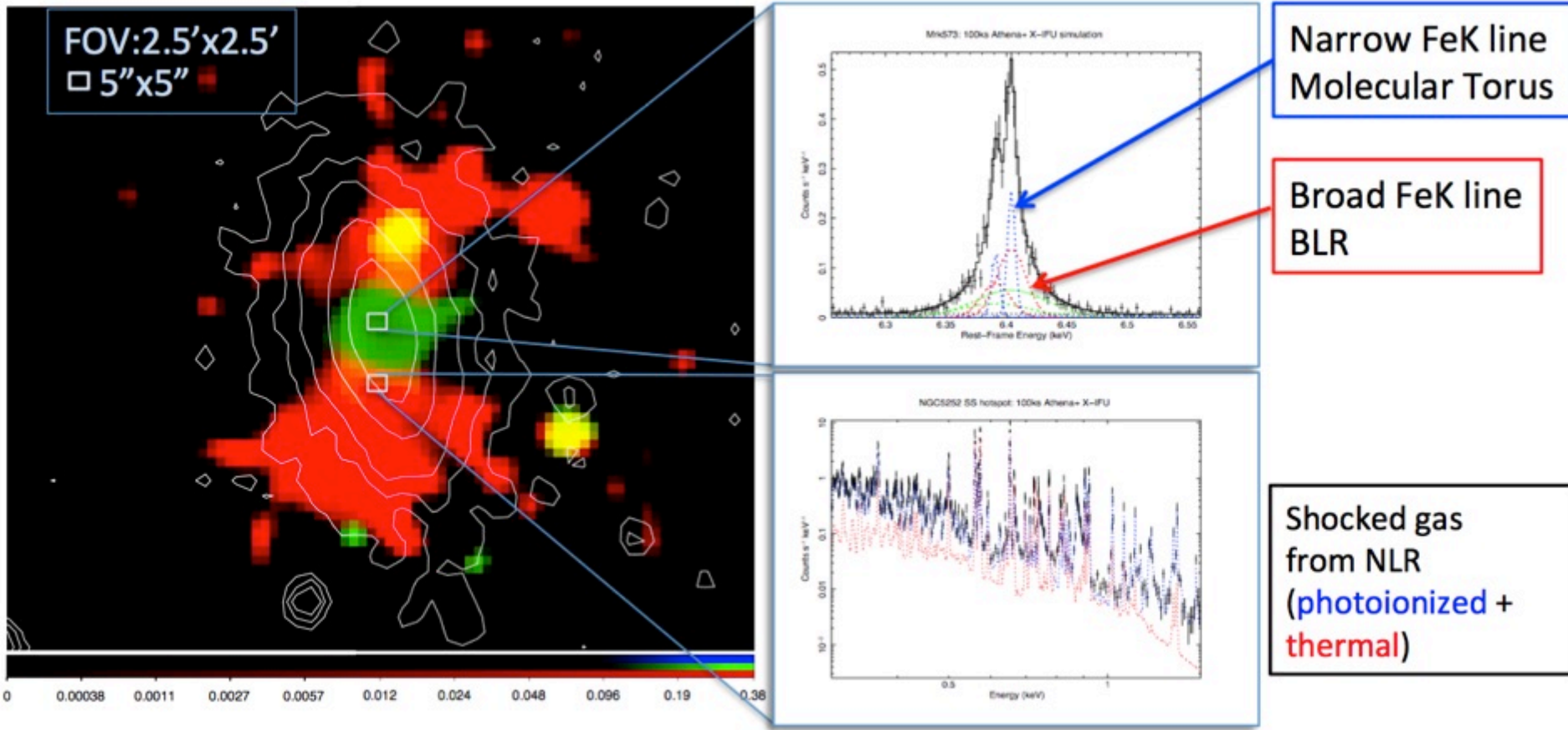
HOW DO BLACK HOLES GROW
AND SHAPE THE UNIVERSE?

Europe's next generation **X-RAY OBSERVATORY**



100ks, PDS 456, UFO $v \sim 0.2-0.3c$

Spectral-imaging with X-IFU: Seyfert 2 NGC 5252



(Cappi et al. 2013, adapted from Dadina et al. 2010)

Multiwavelength campaigns with ALMA, VLT, E-ELT: hot/cold gas mixing, AGN wind power, wind bubbles, shocks, photoionization cones, outflow morphology, AGN/star formation comparison, ... see also AXIS and Lynx mission proposals to NASA!

Active Galaxy



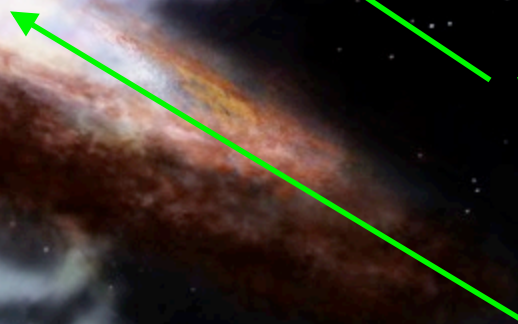
Jet



Wind



Supermassive
Black Hole



Thank you for your attention!