Astrophysics of feedback in local AGN and starbursts

A personal view…

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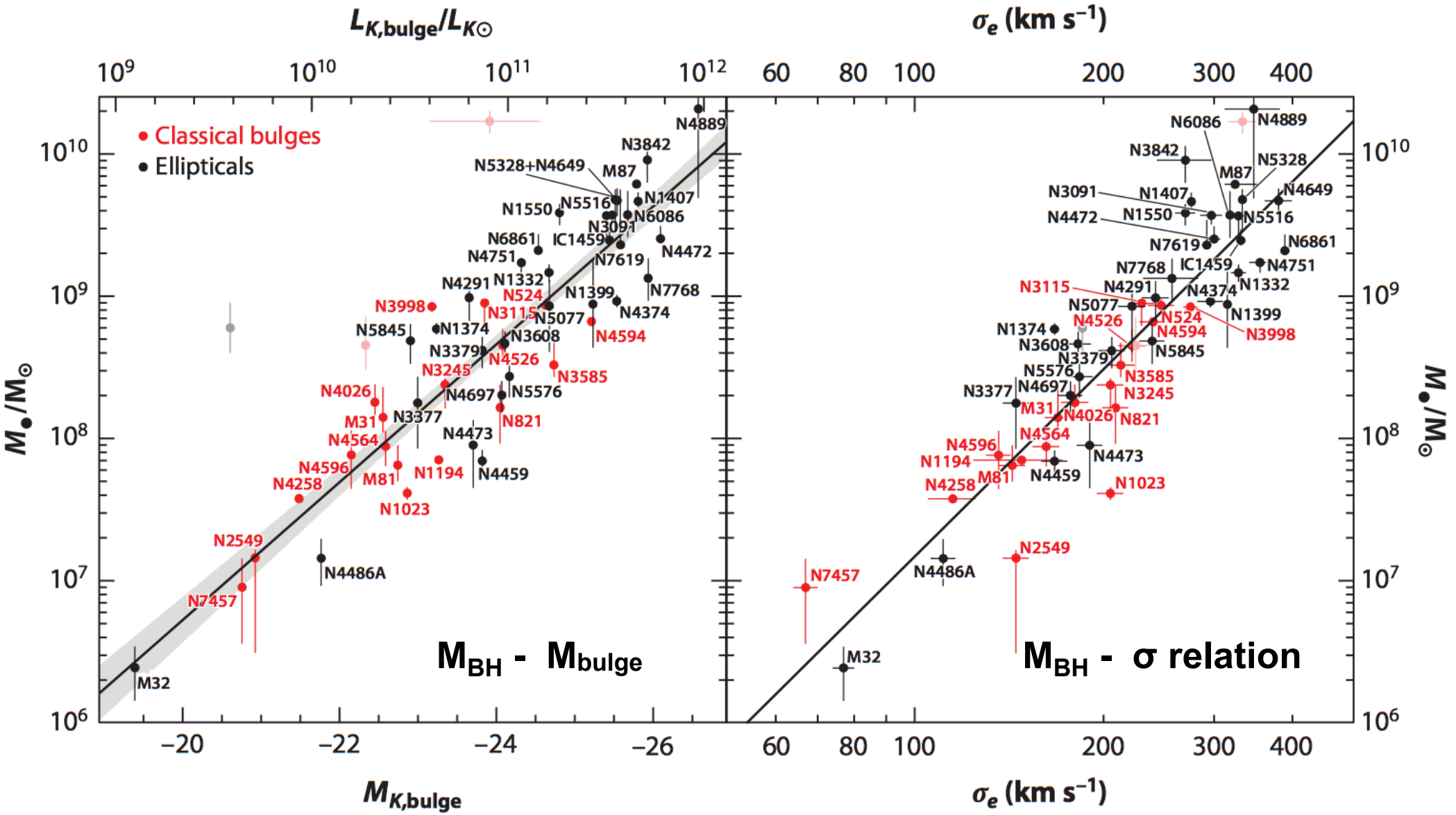
Outline

1) Why is feedback required?
2) Different modes of feedback
3) Feedback in quasar mode ➜ Winds
4) AGN wind properties
5) Wind launching model: A unified view
6) Athena: A powerful tool to study AGN feedback
7) Wind in LMXB a bright control sample
8) Conclusions

Observational requirement for feedback

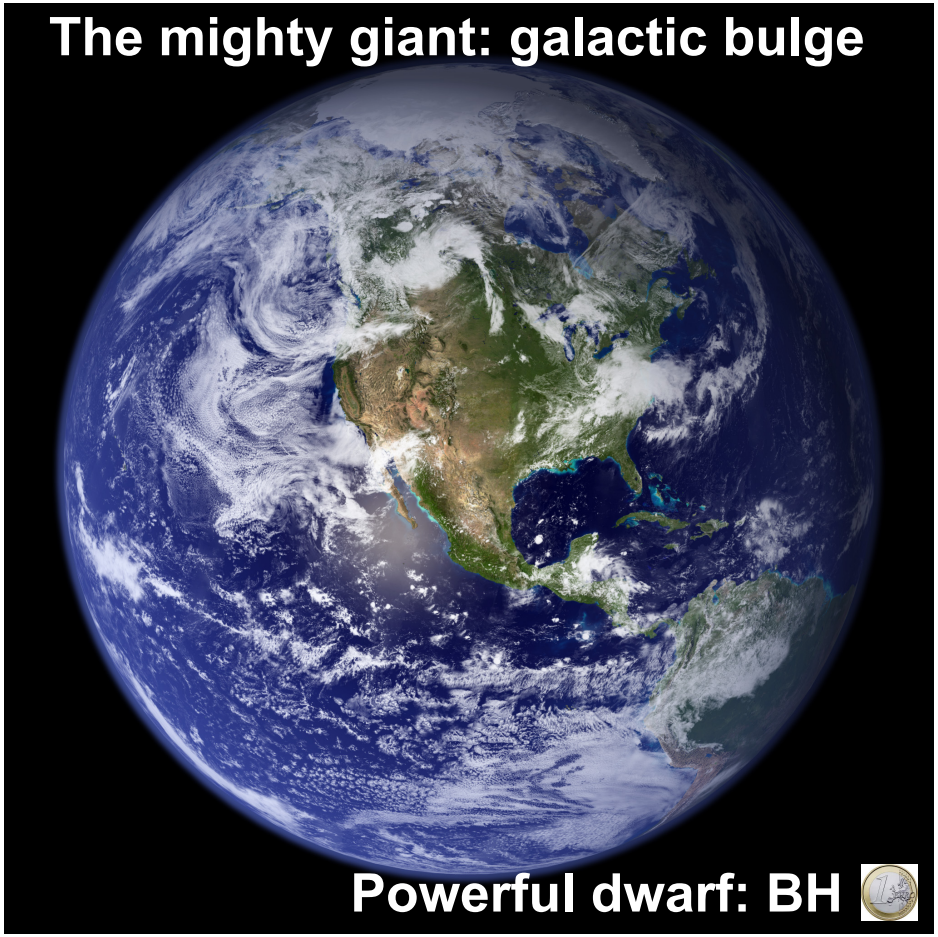


Ferrarese, Merrit +00; Gebhardt +00; Kormendy +01; Merrit +01; Haring & Rix 04; Kormendy & Ho 13

A deep link between BH and host galaxy ➜ Feedback

Feedback: The dwarf controlling the giant?

Size of galactic bulge vs. its BH



Size $_{bulge}$ ~ 10^{8-9} Size $_{BH}$

Energetics

$E_{binding\ bulge} \sim M_{bulge}\ \sigma^2$

BH growth through accretion

Soltan 82

Efficiency $\eta \sim 0.1$
$Sigma_{bulge} \lesssim 400$ km s^{-1}

$E_{BH\ acc} \sim 0.1\ M_{BH}\ c \gtrsim 80\ E_{binding\ bulge}$

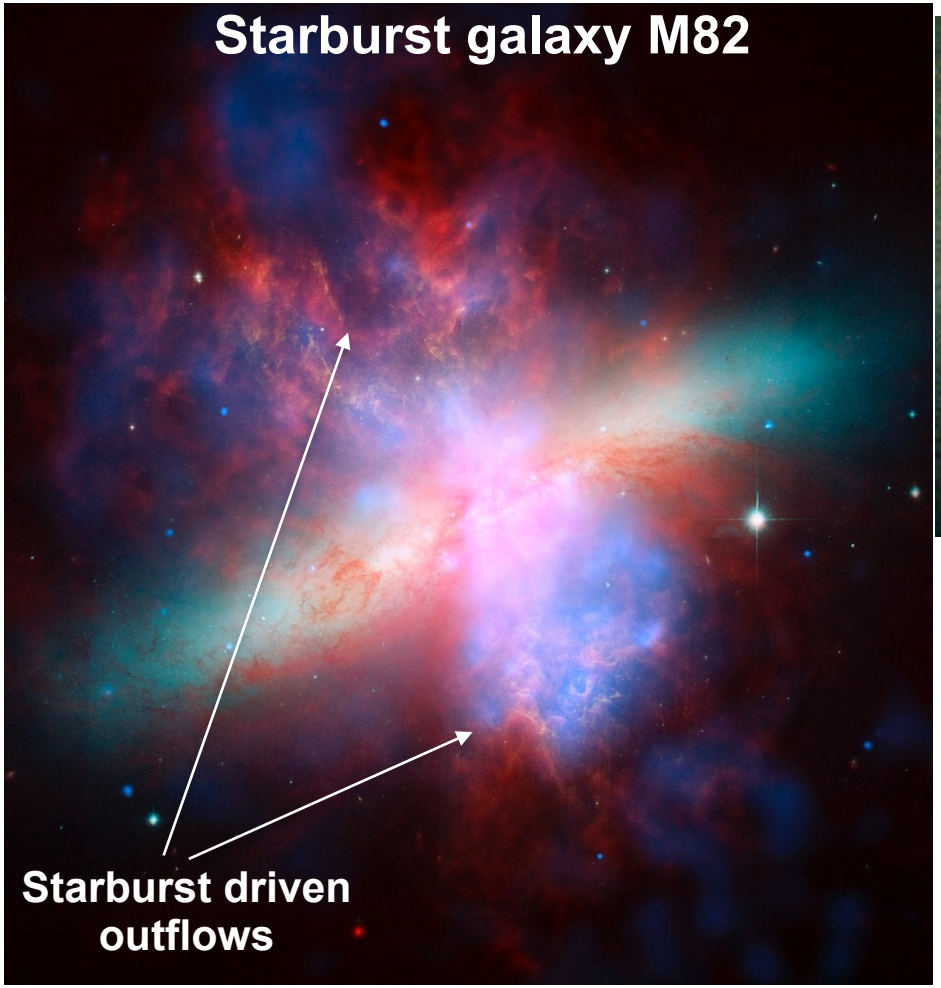
IF even small fraction of the energy is transferred (feedback) to gas
➜ AGN profound effect on host galaxy

Fabian 12; King & Pounds 15

How is accretion energy deposited?
What type of feedback?

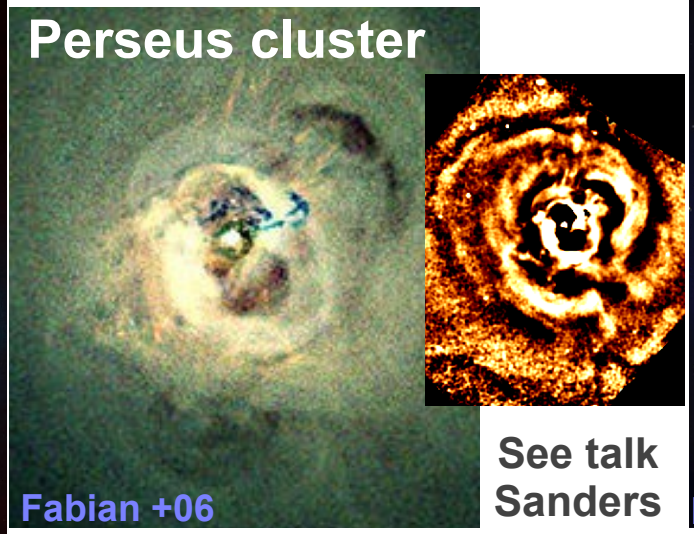
Different modes of feedback

Starburst galaxies

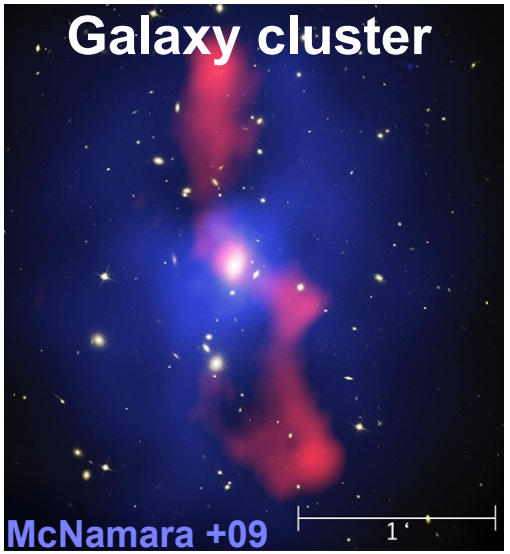


AGN

Radio mode



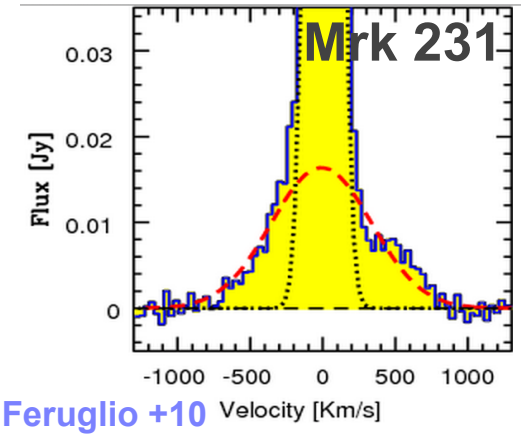
See talk Sanders

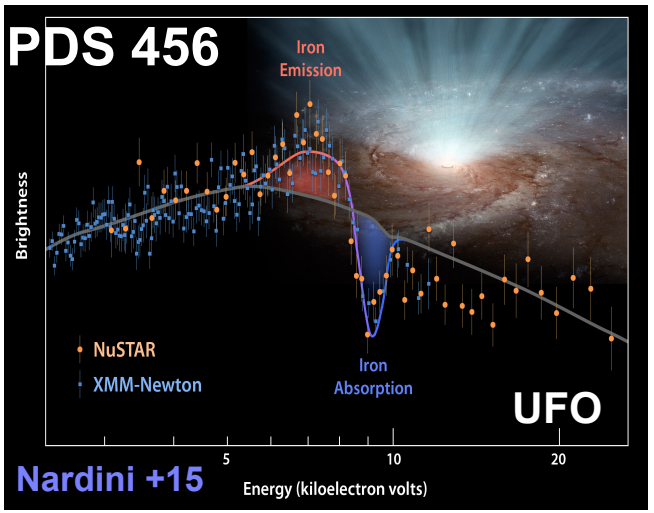


Quasar mode

Lots of evidence for winds (BAL QSO, WA, X-ray obscurers, BLR?) But powerful enough?

Molecular outflows





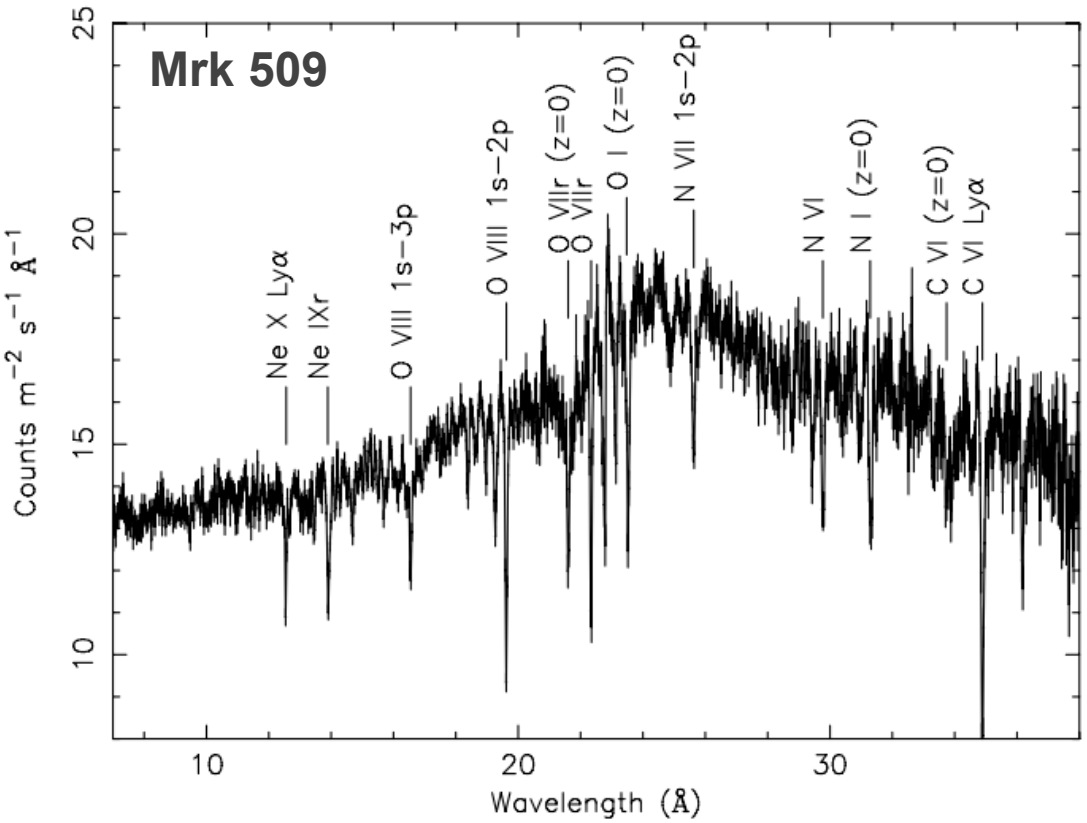
Feedback in action!
See talk by Andy Ptak

Growing evidence for winds in AGN

Optical-UV:
BAL, mini-BAL, NAL QSO
Arav +94; 99; Ganguly +08; Kingge + 08; Moe +09

Sub-mm-Radio-IR:
Molecular outflows
Feruglio +10; Sturm +11; Maiolino +12

X-rays:
Warm Absorbers



Detmers +11

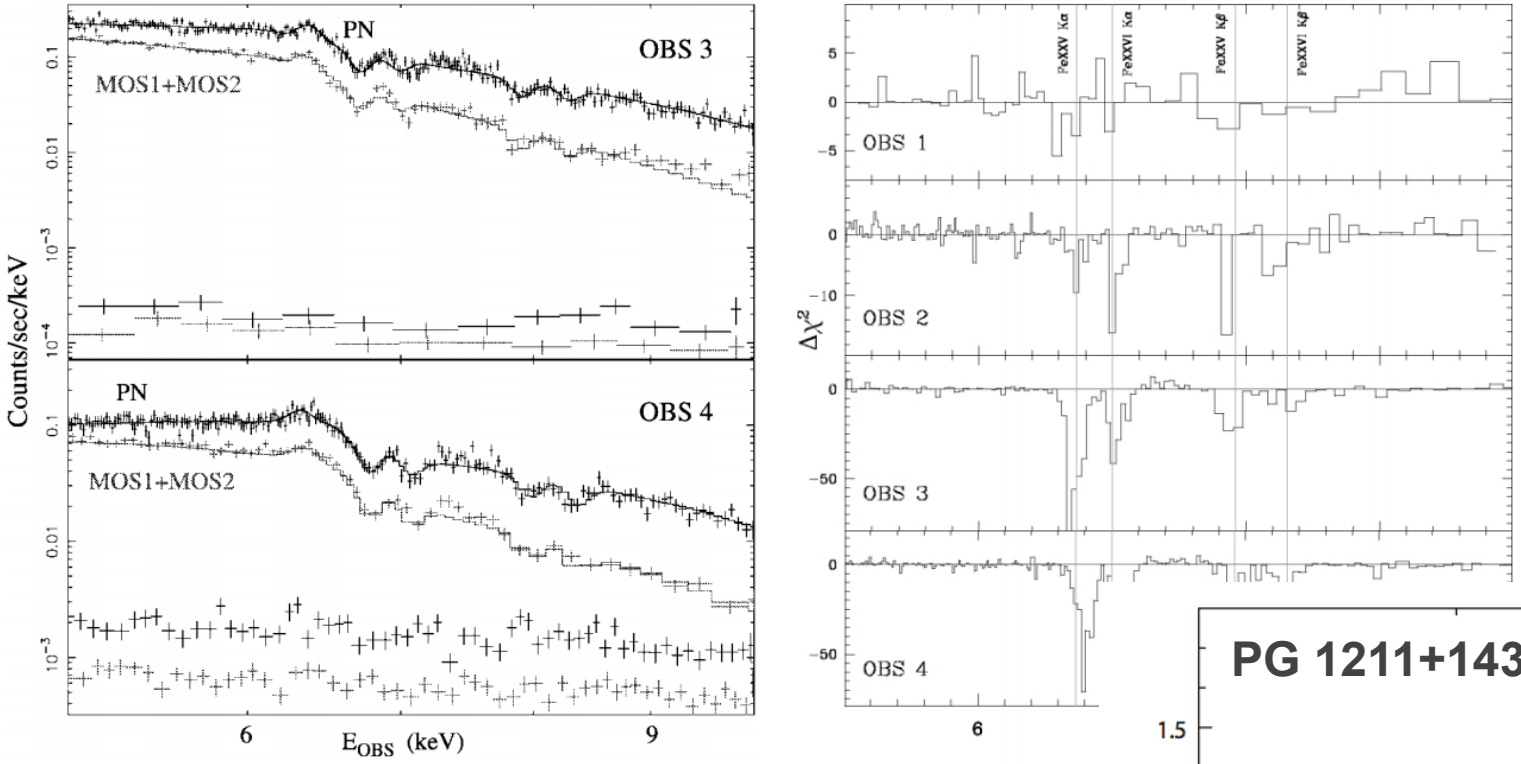
At least 50 % of local AGN
v_{out} ~ $10^{2\text{-}3}$ km s^{-1} Crenshaw +99; McKernan +07
Multi-phase outflow
Some components appear in UV

Location at 1-500 pc Kaastra +12
Consistent with torus evaporation
e.g. Blustin +05; Krolik & Kriss 01

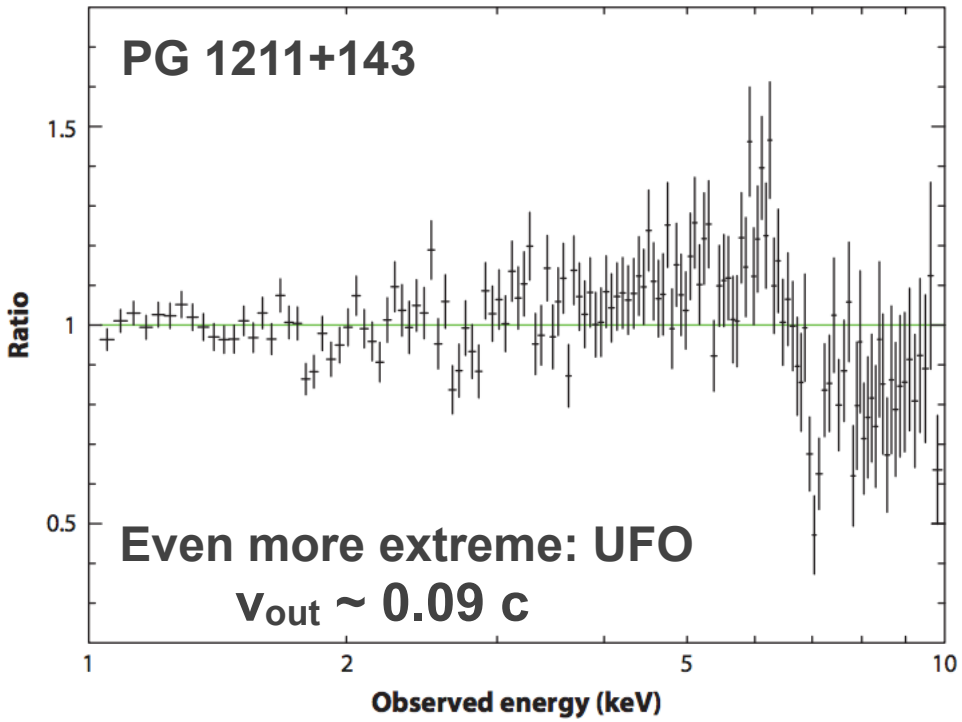
Ultra Fast Outflows in AGN

The extreme WA case of NGC 1365

Risaliti +05



Pounds +03; +06; 09; King +15



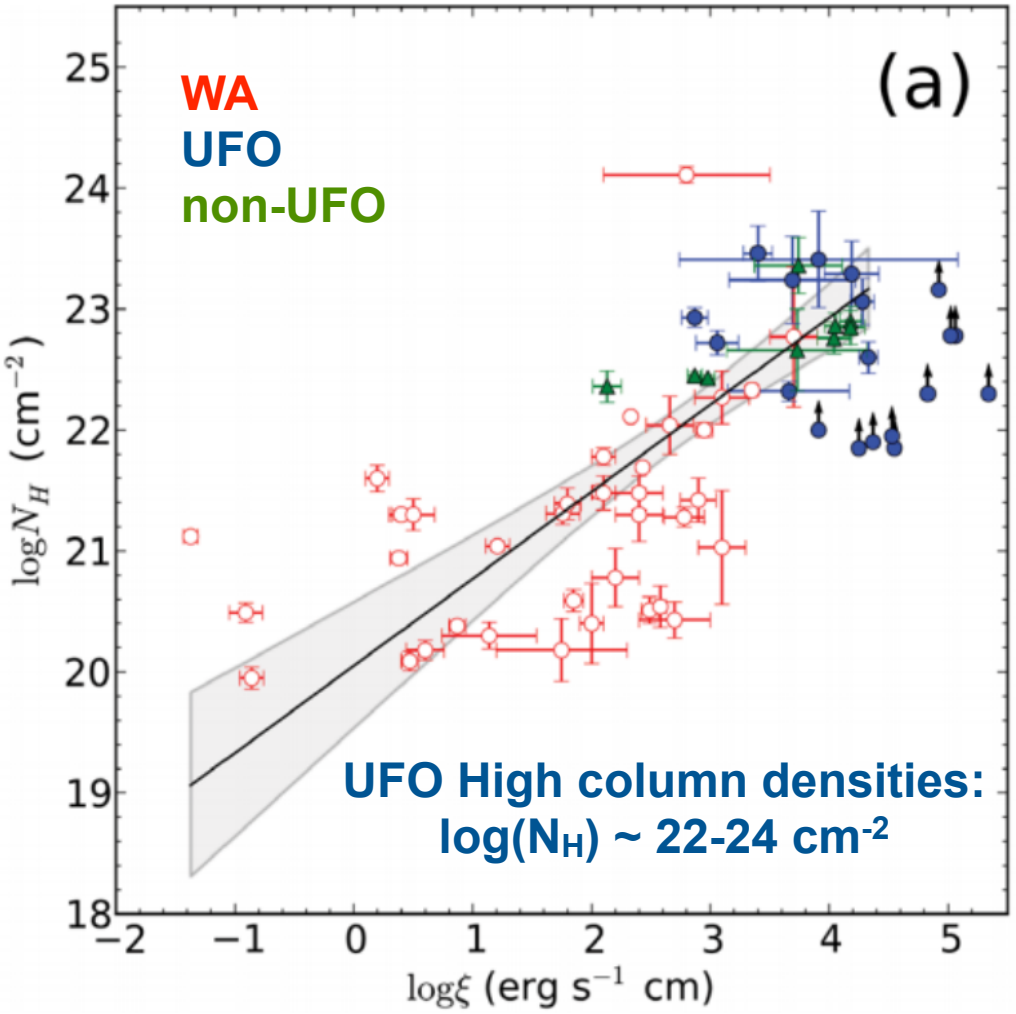
The Fe K band reveals an extreme high ionisation component of the WA

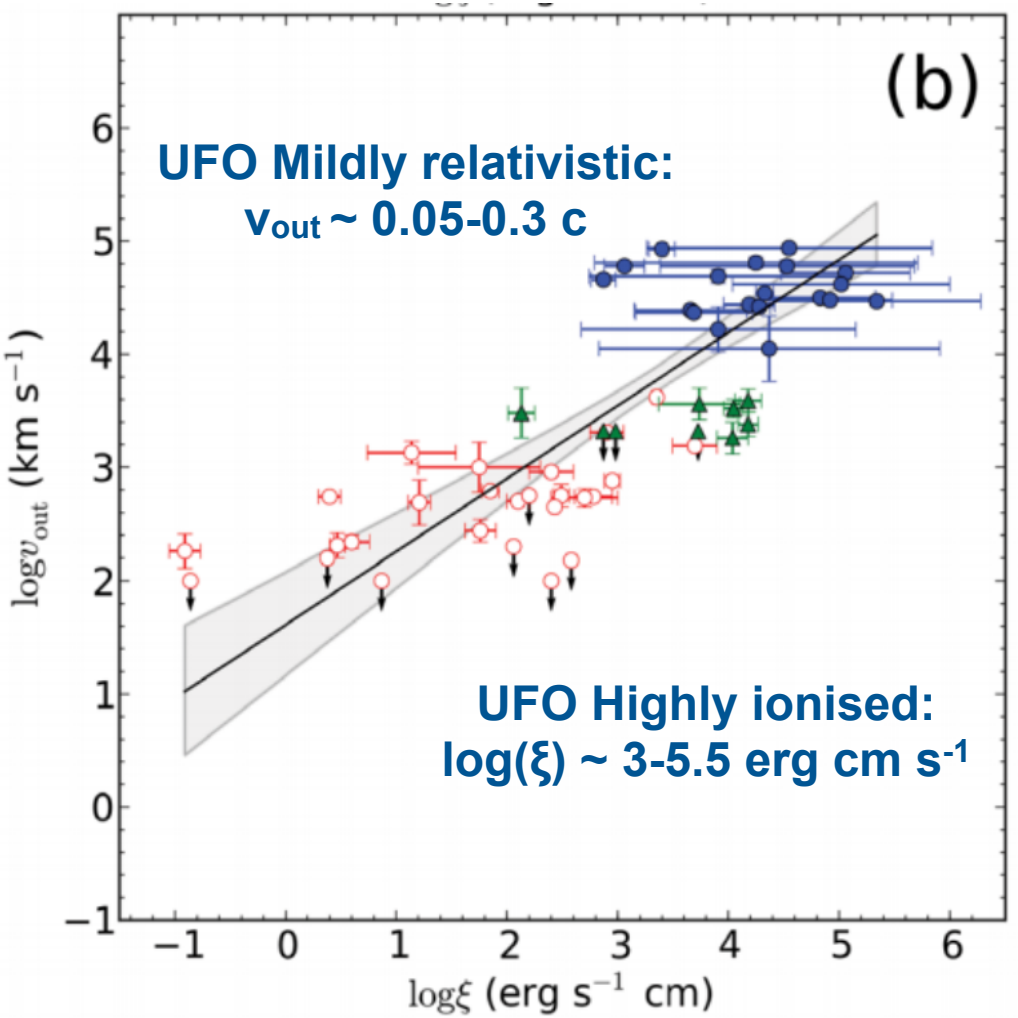
v_{out} ~ 1-5×10^3 km s^{-1}

N_H ~ 10^{23} cm^{-2} d ~ 100-200 r_g

Risaliti +05

Properties of X-ray AGN winds



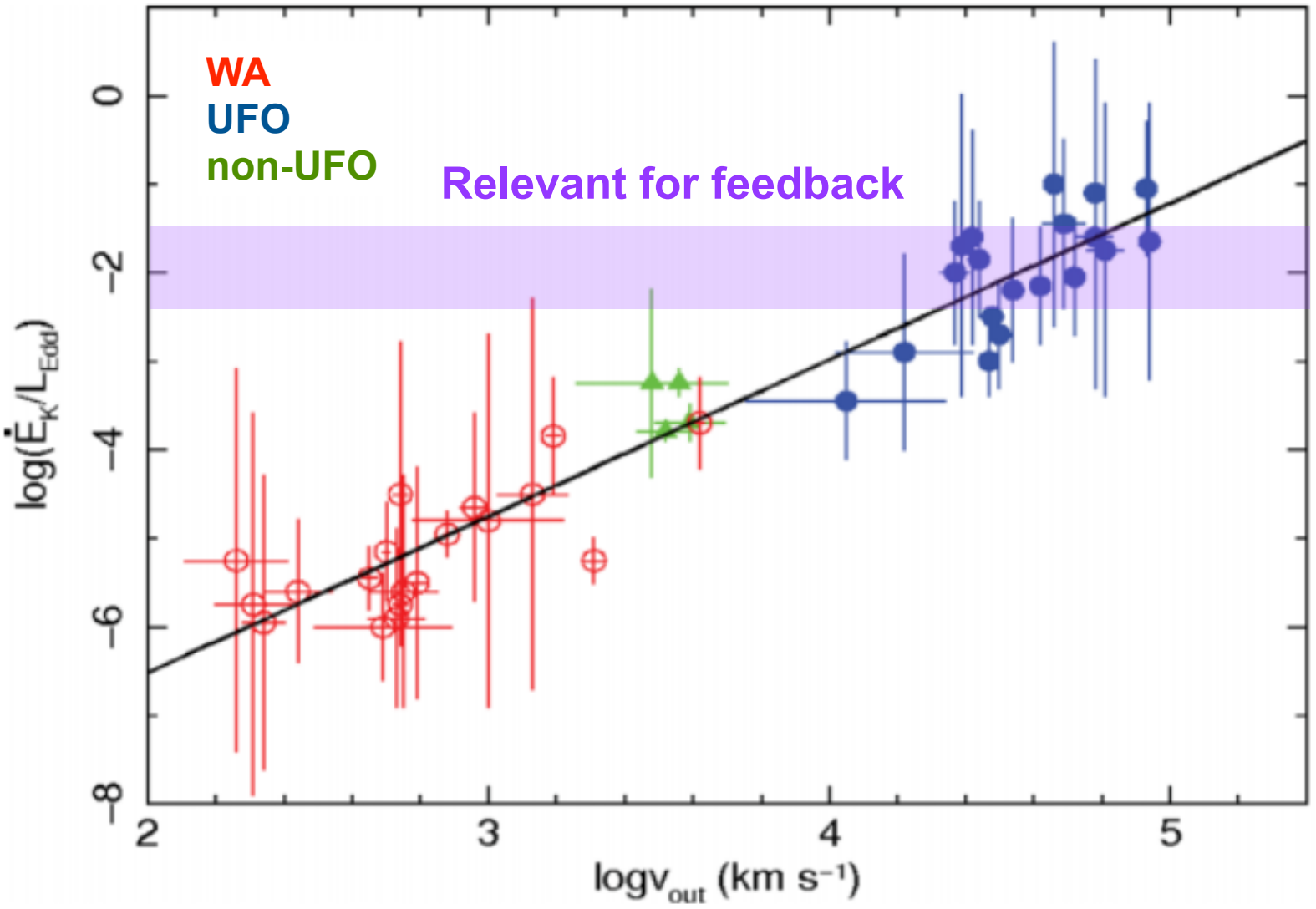


Tombesi +10; +11; +12; +13; Gofford +13

UFO in at least 35 % of local AGN
WA and UFO show continuous distribution in ξ, N$_H$ and v$_{out}$
➜ All part of a unique disc wind? Tombesi +13

Properties of X-ray AGN winds

Tombesi +10;+11;+12;+13

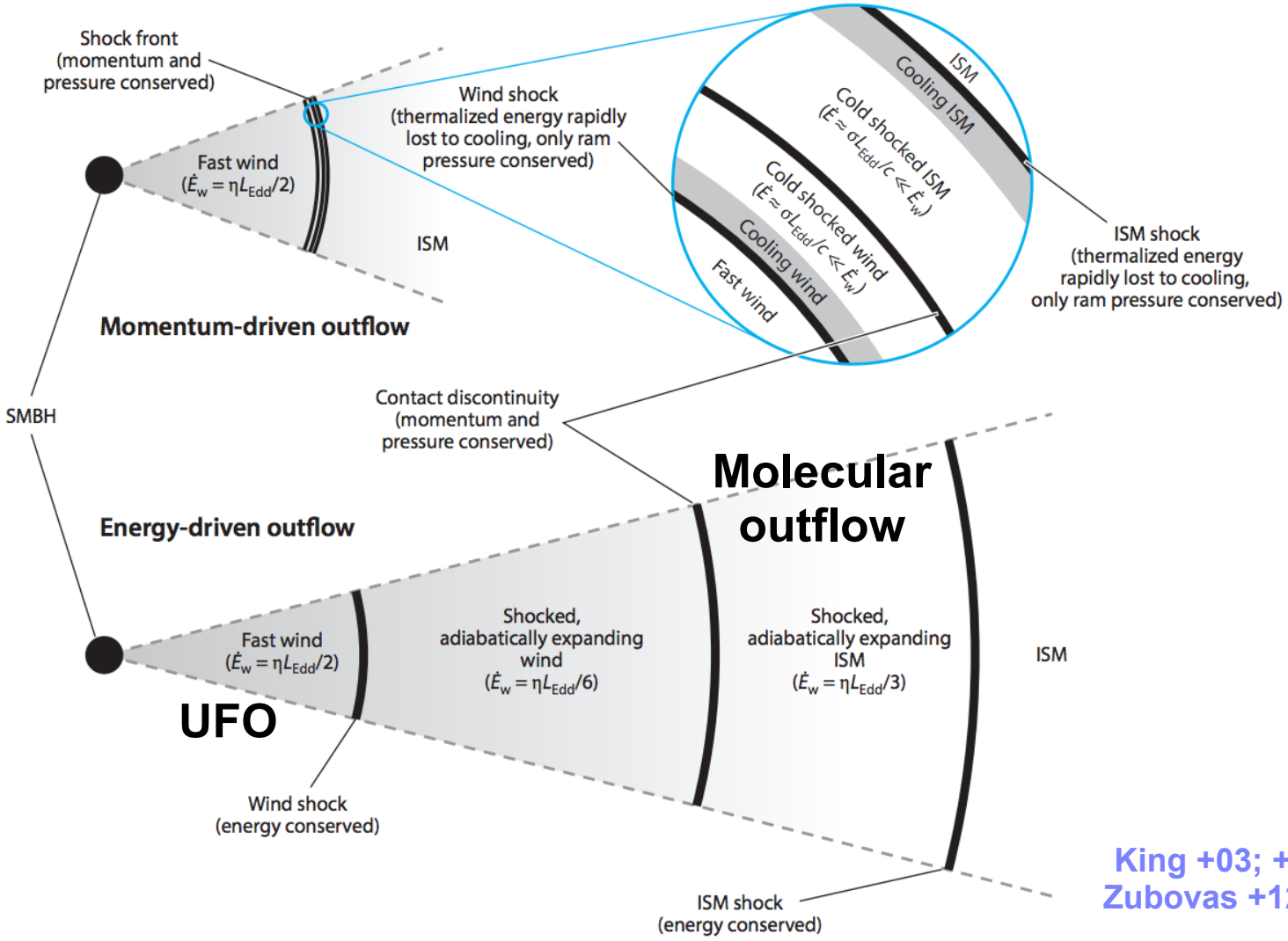


Kinetic luminosity of UFO is typically higher than 0.5-5 % L_{Edd}

Di Matteo +05; Hopkins +10;

➜ UFO produce feedback

A model for the AGN wind

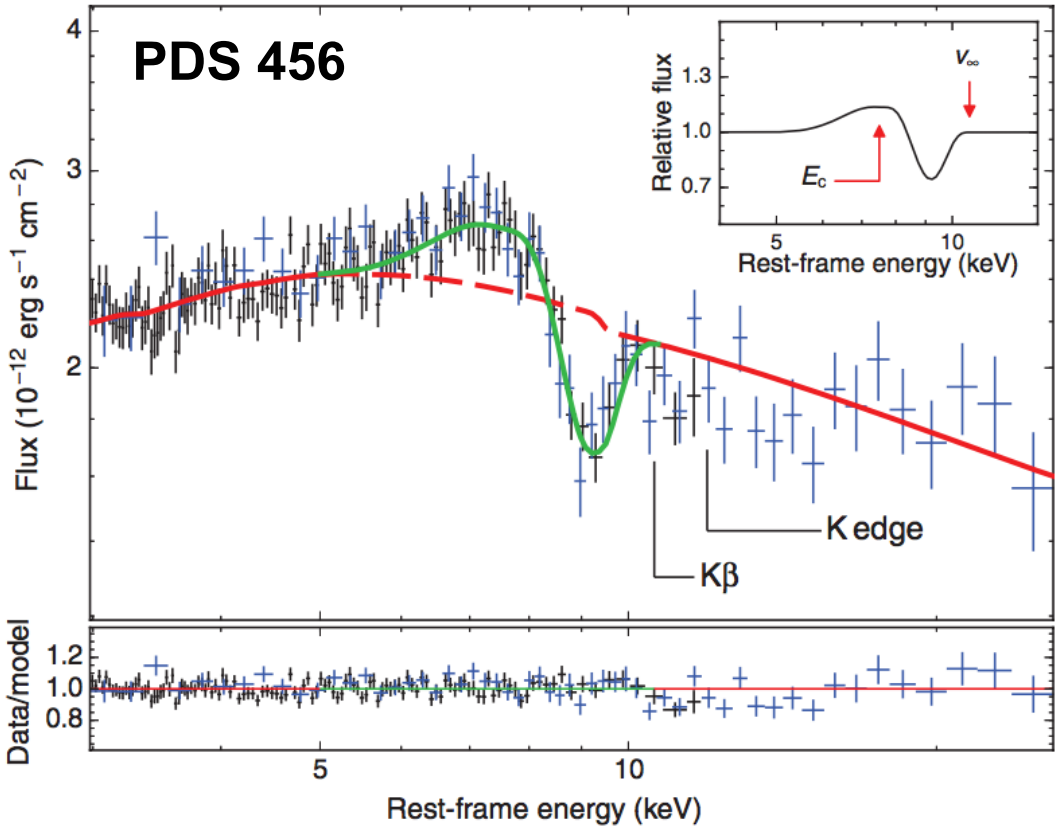


King +03; +05; +10; +15;
Zubovas +12; Pound +13

Wind radiatively (Eddington-phase) driven
UFO and molecular outflows two manifestations of the same process
Efficient (or not) cooling ➜ either momentum or energy driven wind
➜ M_{BH}-σ relation

Building a coherent picture of AGN winds

Nardini +15



Highly significant detection

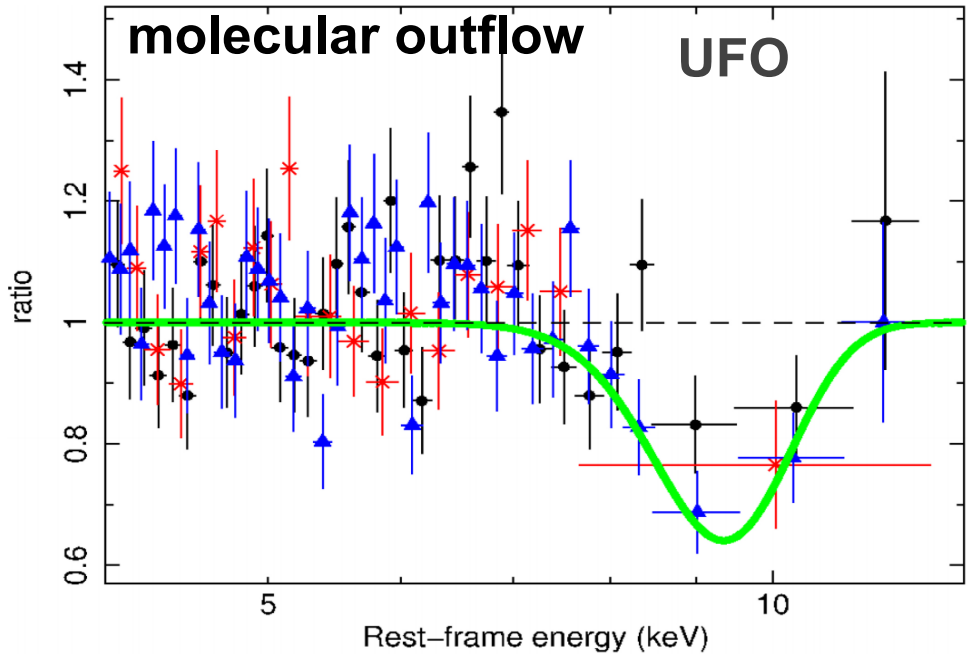
➜ UFO is a real phenomenon!

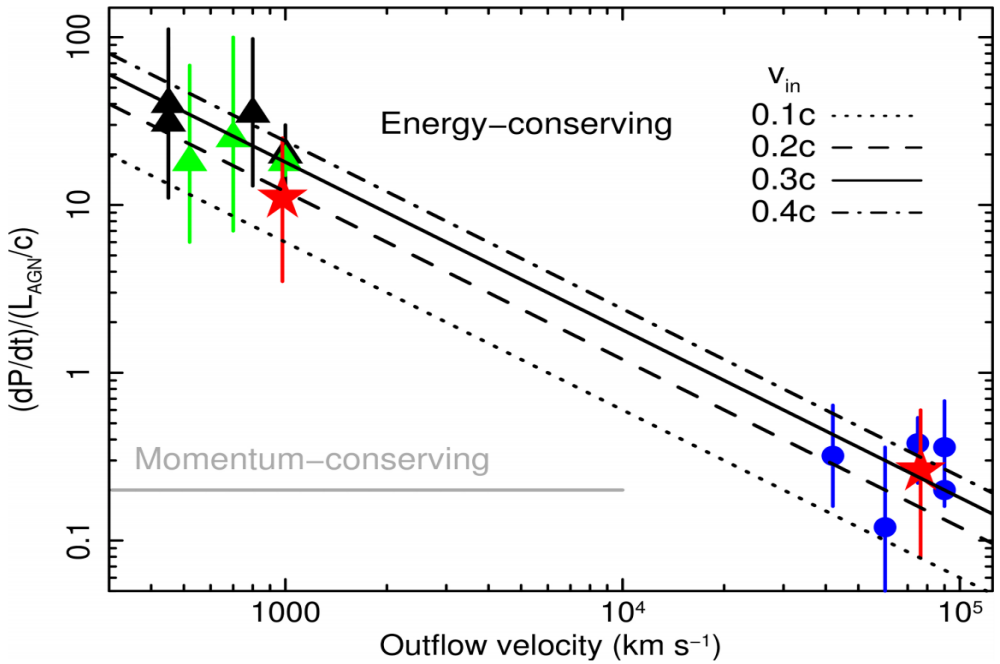
➜ UFO and molecular outflow parts of the same wind

➜ Energy conserving flow

AGN z = 0.189

Tombesi +15





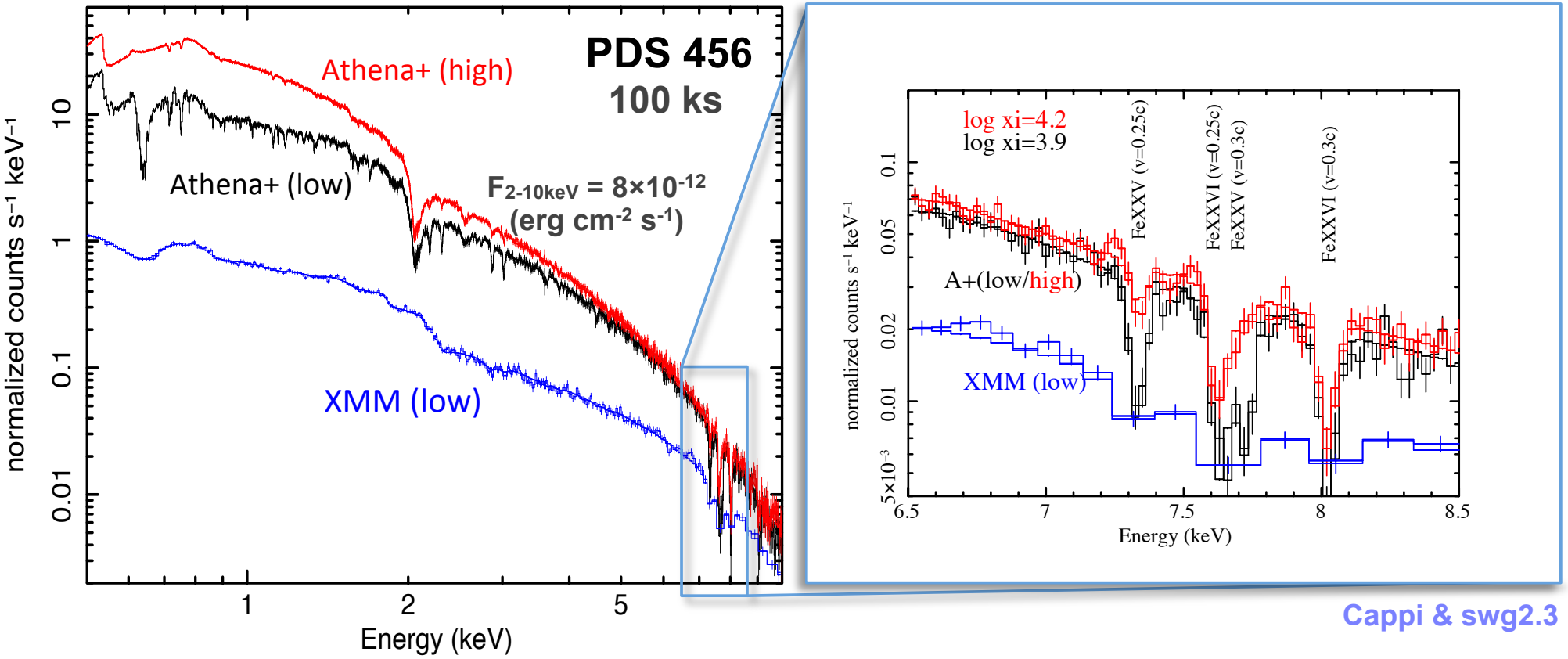
Prospects of Athena for AGN feedback

Main science drivers of SWG 2.3

Athena shall measure the kinetic energy in nearby AGN outflows and understand how accretion disks around SMBH launch winds and outflows

Athena shall probe the interaction of winds from AGN and star-formation with their surroundings in local galaxies to understand how gas, metals and energy accelerated by winds are transferred into the IGM

➜ template for higher z universe



Cappi & swg2.3

Models of wind launching

ULX, ONLY most luminous AGN phases and GBH states

Close to Eddington limit ➜ Radiations pressure
➜ Wind (e.g. UFO, molecular outflow)

e.g. King +03; +05; +15

AGN and GBH

Thermal ➜ Heating of outer disc ➜ $v_{thermal} > v_{escape}$ ➜ Wind

Begelman +83a,b; Shields +86; Woods +96; Rozanska +00; 02

Magnetic ➜ Lorentz force + magnetic pressure ➜ Wind

Blandford & Payne 82; Pelletier & Pudritz 92

AGN, but NOT GBH

Line driven wind ➜ Large opacities of UV transitions ➜ Wind

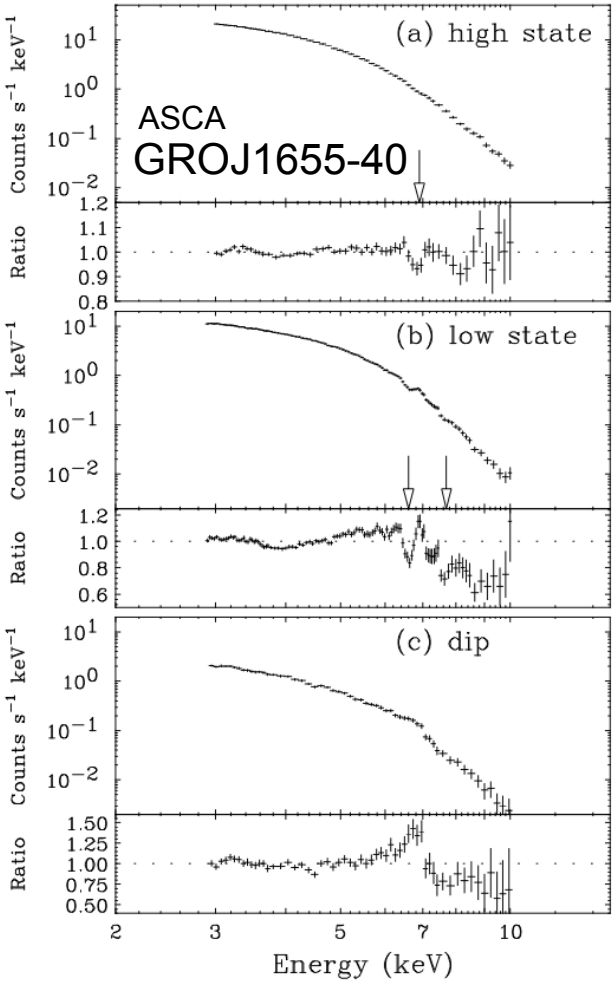
Castor +75; Murray +95; Arav +95; 96

Torus evaporation ➜ Photo-evaporation of large clouds ➜ Wind

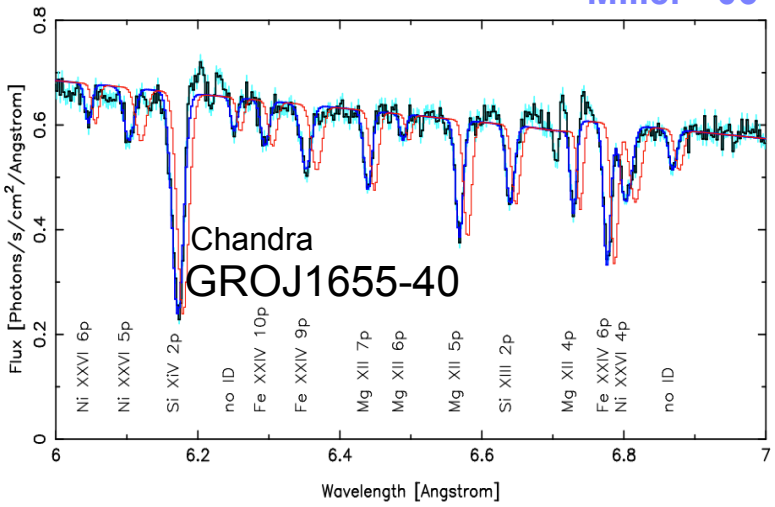
Krolik & Kriss +01; Blustin +05

Do GBH have winds?

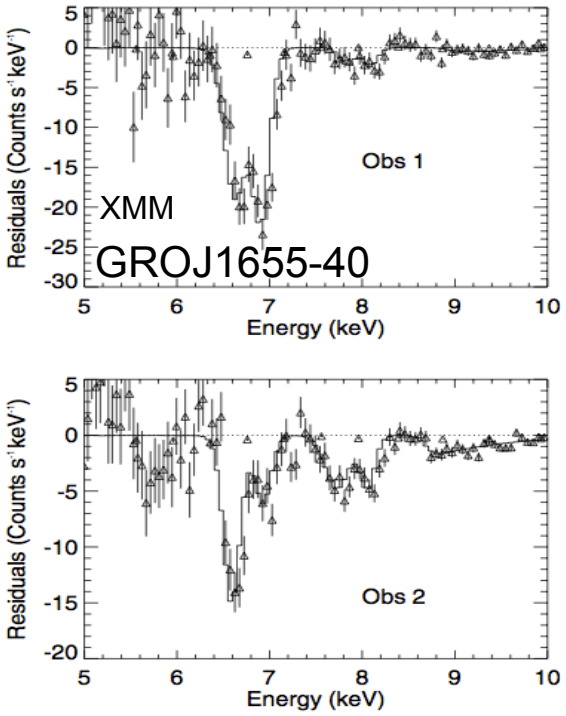
Ueda +98

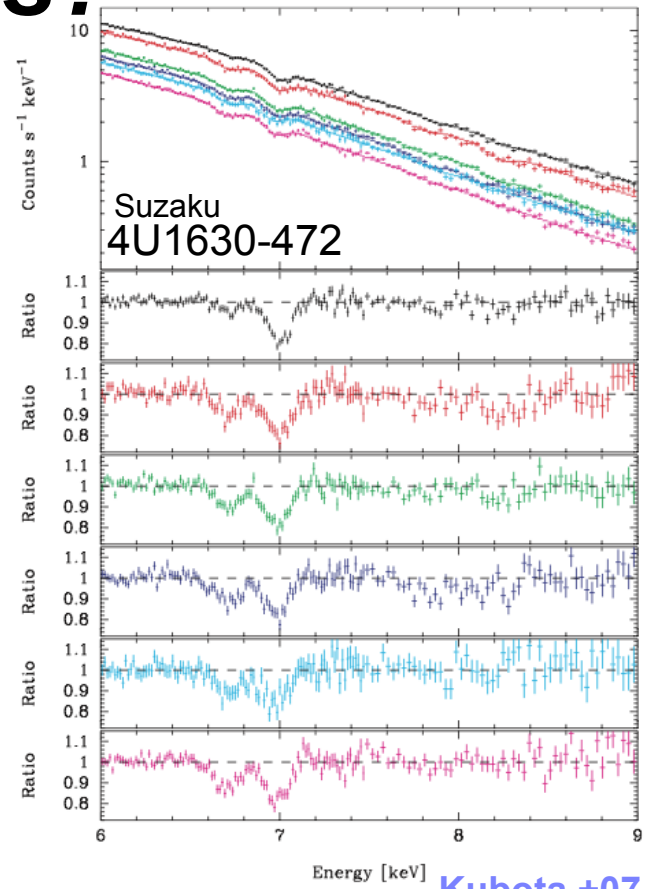


Miller +06



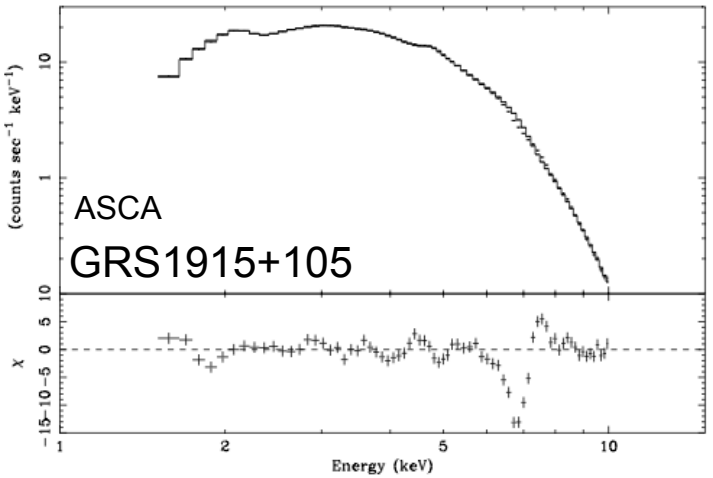
Diaz-Trigo +07





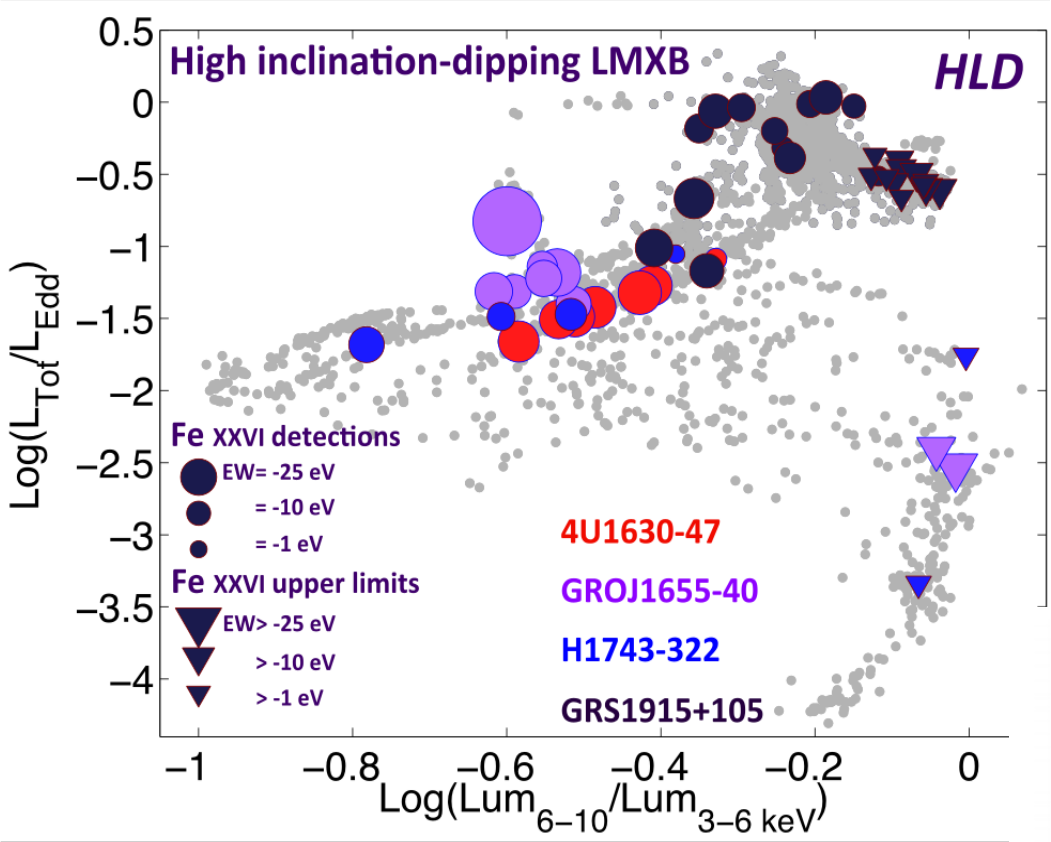
Kubota +07

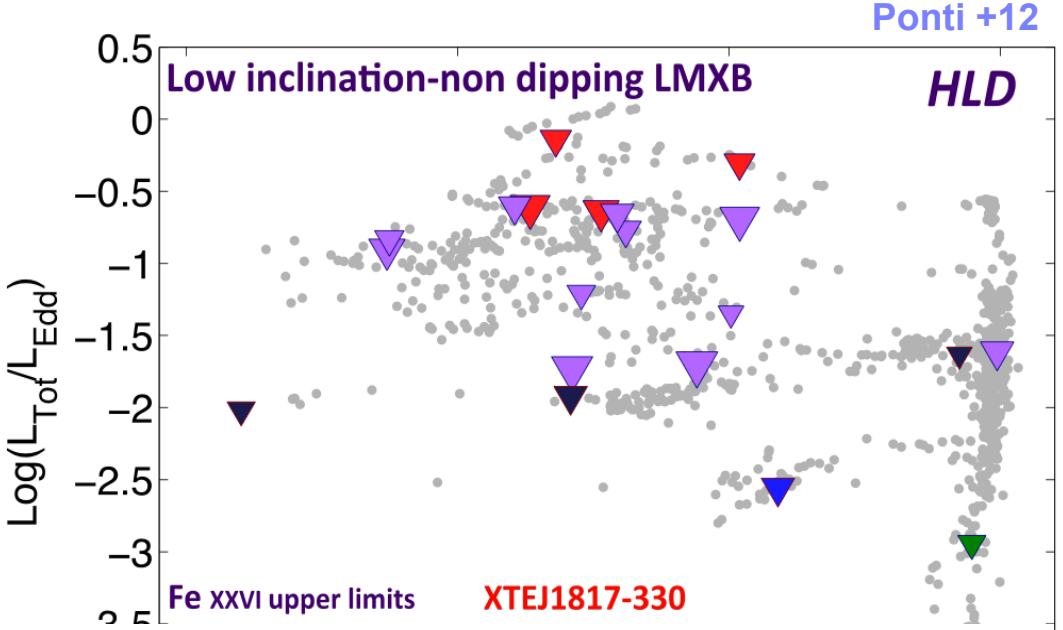
Kotani +00

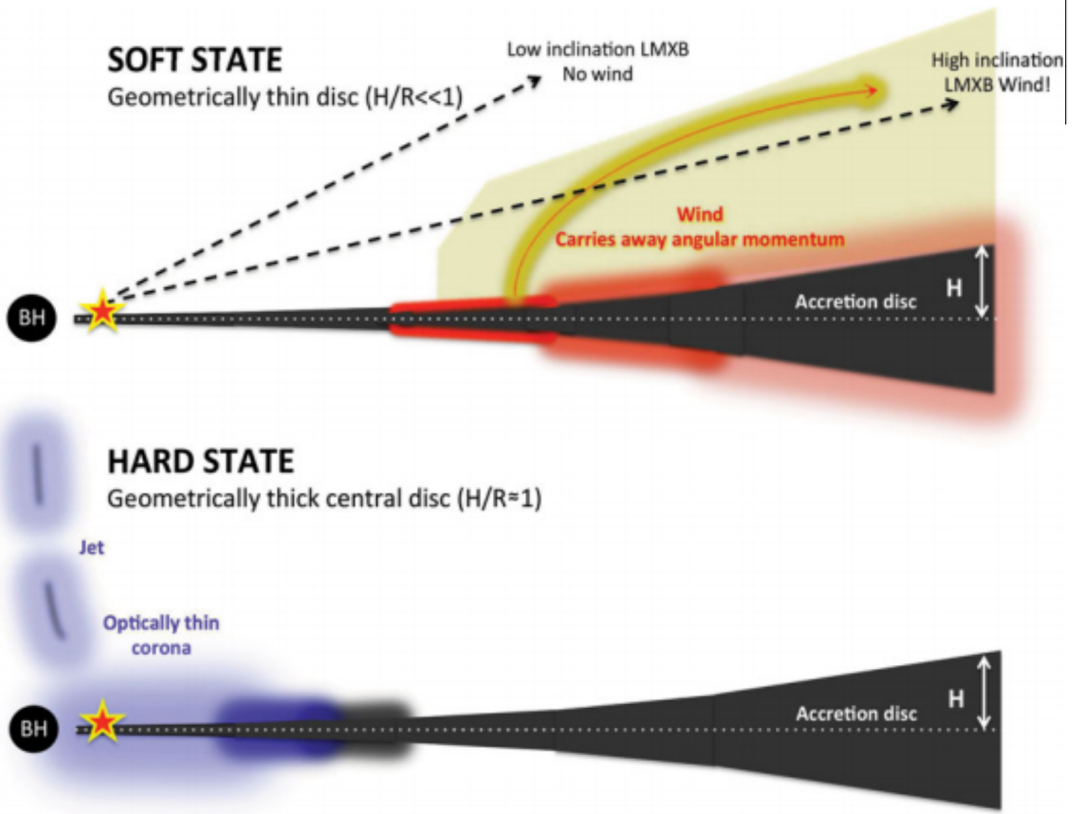


Ubiquitous equatorial disc winds in BH soft state

Ponti +12







Equatorial geometry

Ubiquitous wind in soft state

Disappears in hard state

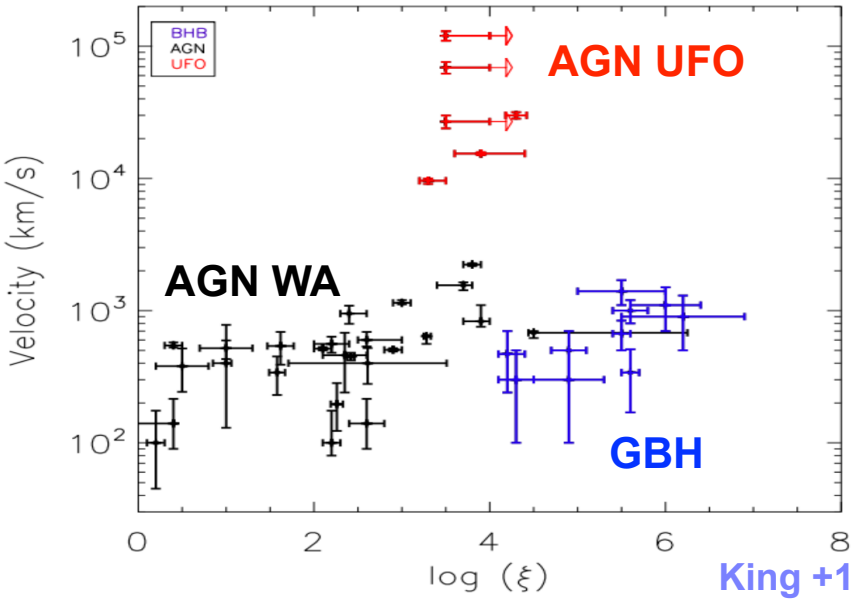
➜ Strong state - wind (jet?) connection

Same physics in neutron stars!

Ponti +14; +15

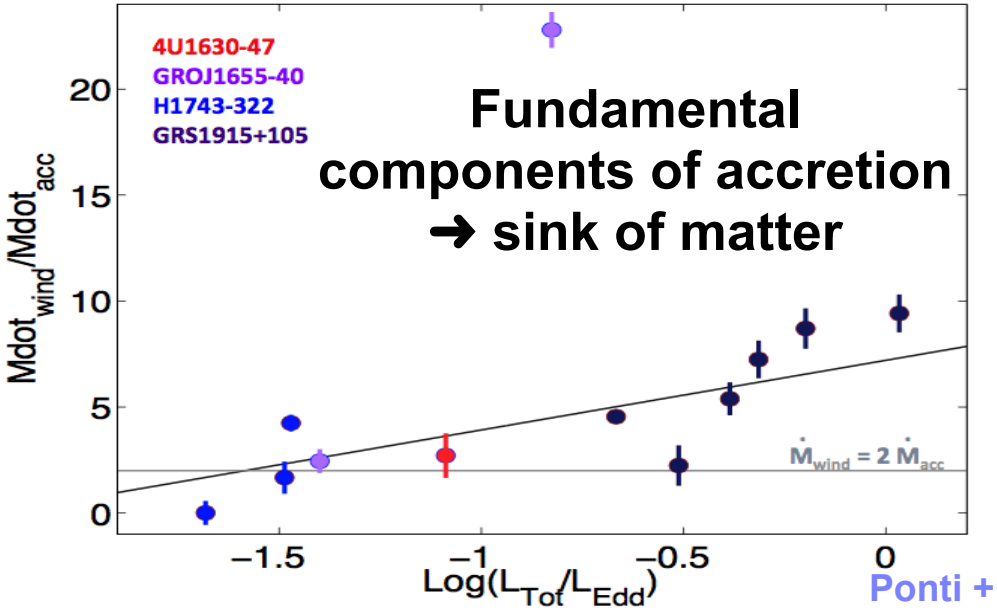
Properties of GBH disc winds

Wind outflow velocity $10^{2\text{-}3}$ km s^{-1}



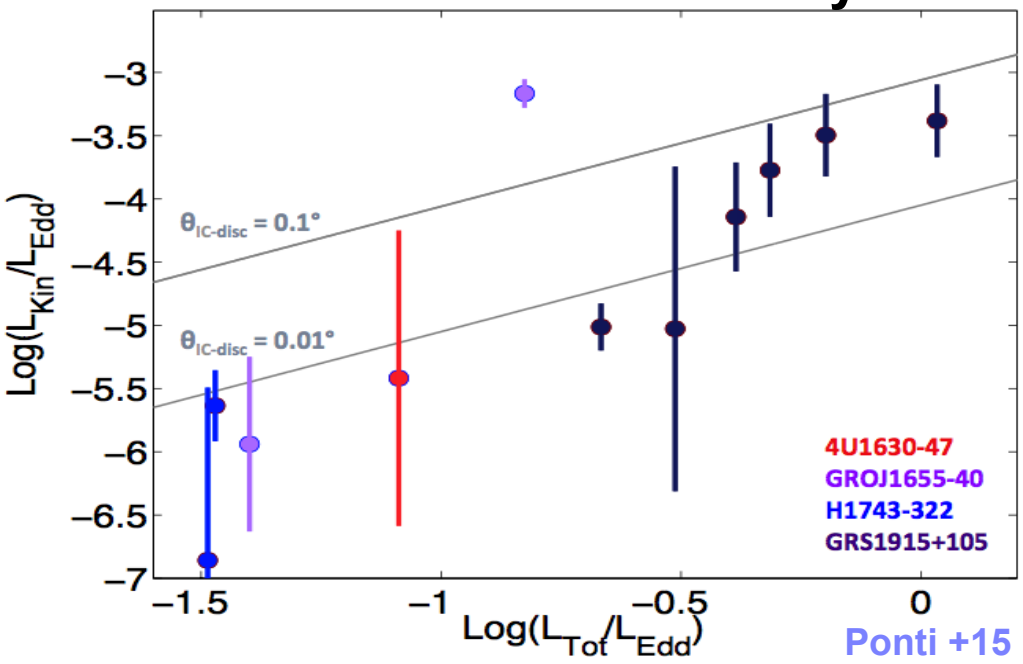
King +13

Mass outflow$_{wind}$ >> Mass accretion

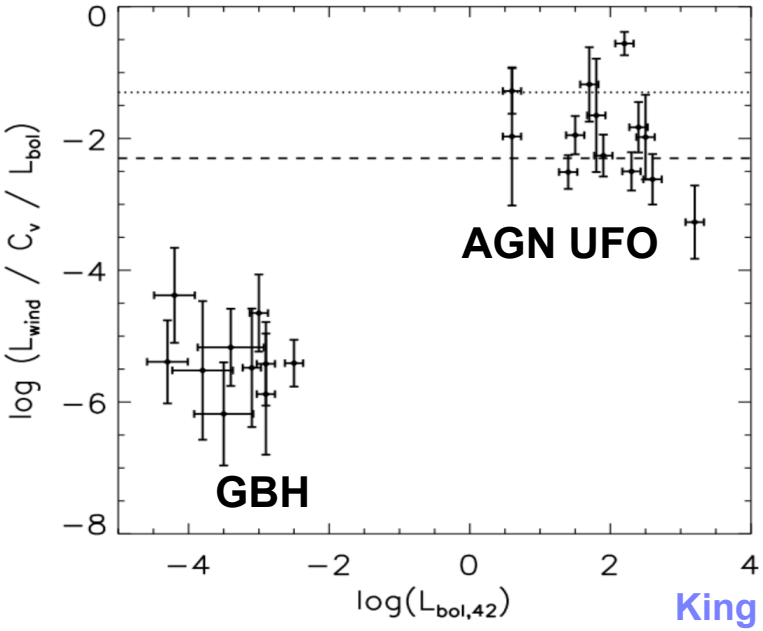


Ponti +12

Small kinetic luminosity



Ponti +15



King +13

Conclusions

Growing evidence for winds in AGN and GBH

The fastest-massive ➜ Feedback

Athena has the potential to:

➜ detail wind kinetic luminosity

➜ launching mechanism(s)

➜ how metals-energy are transferred to IGM