Mapping Black Hole Winds, from the Event Horizon up to Galaxy Scales

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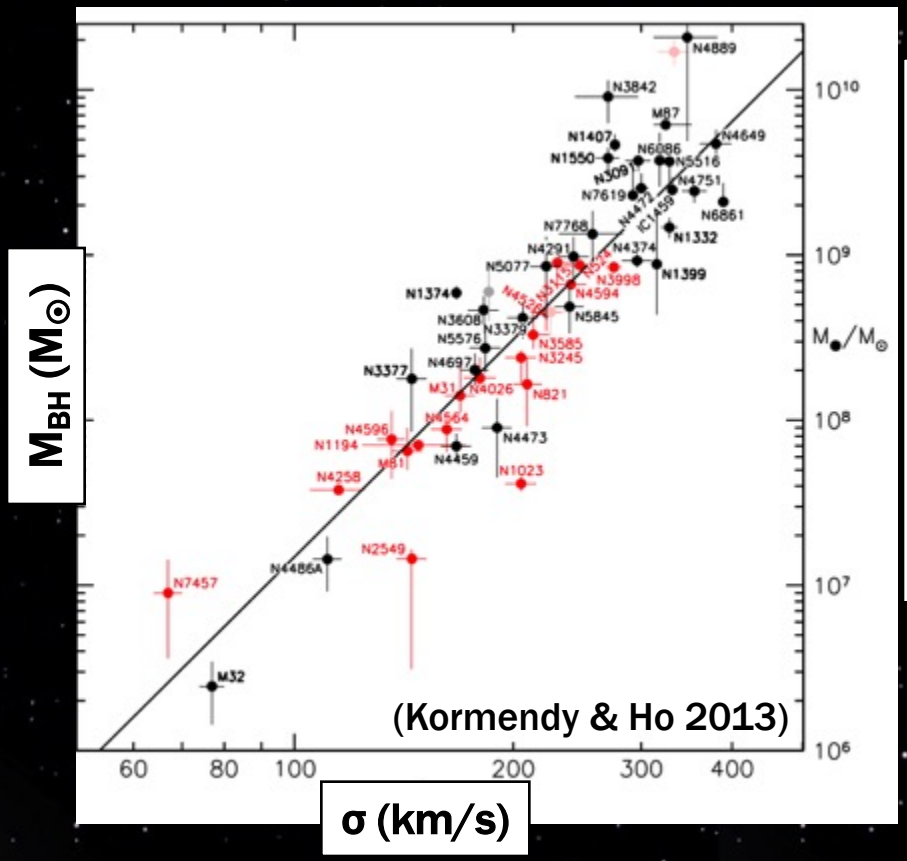
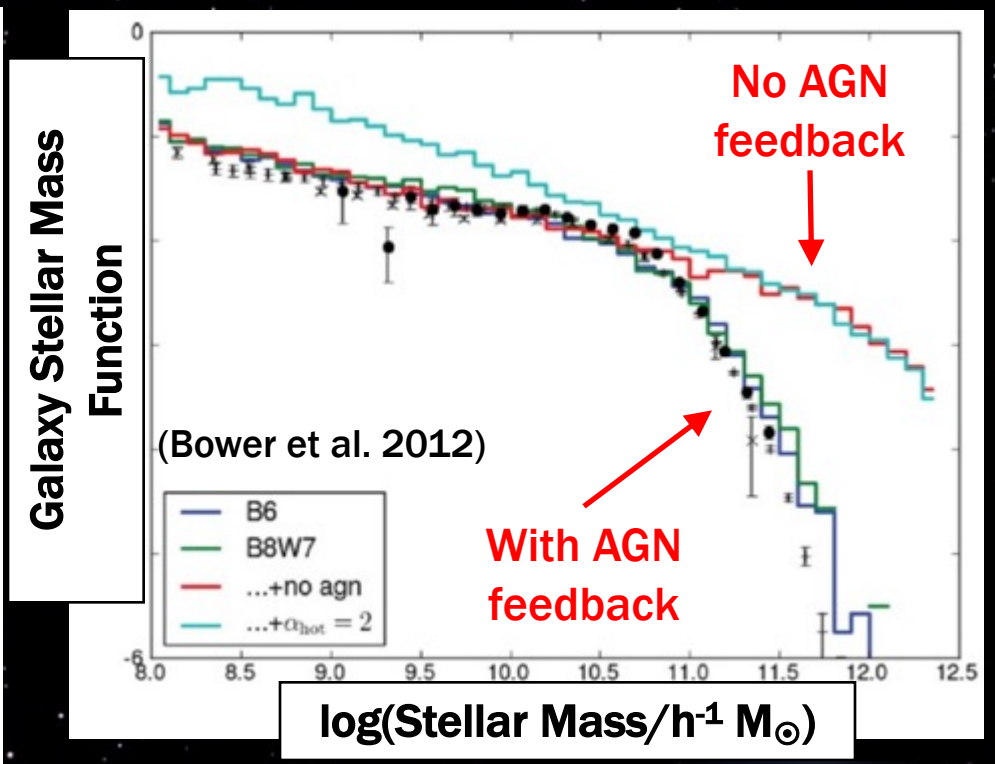
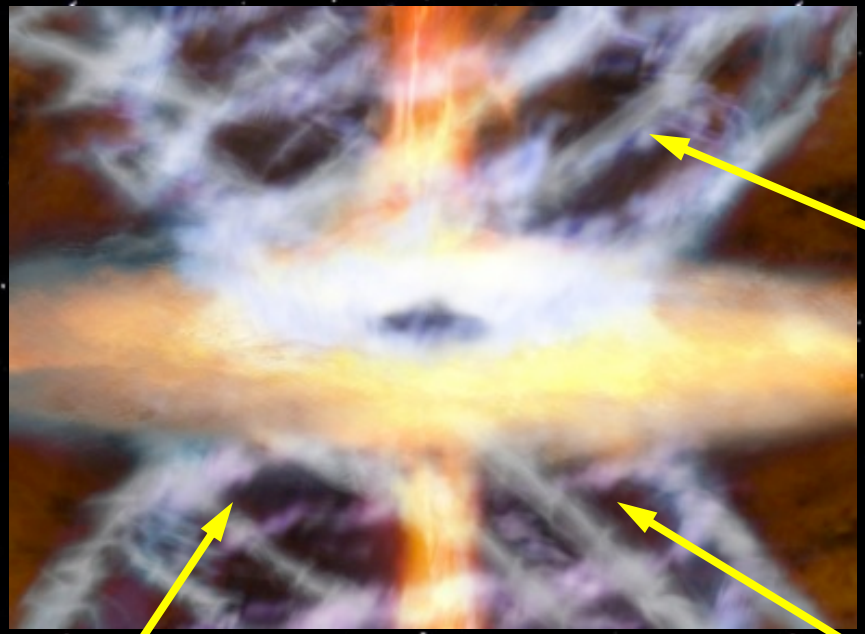
Relations Between SMBHs and Host Galaxies?

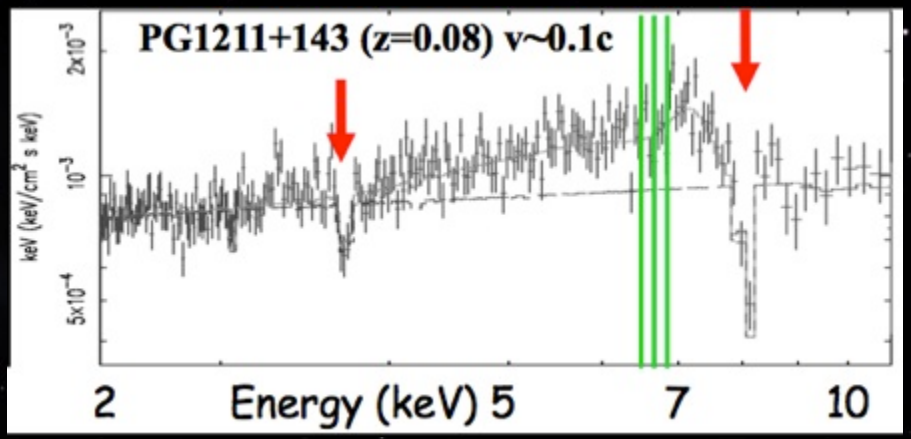




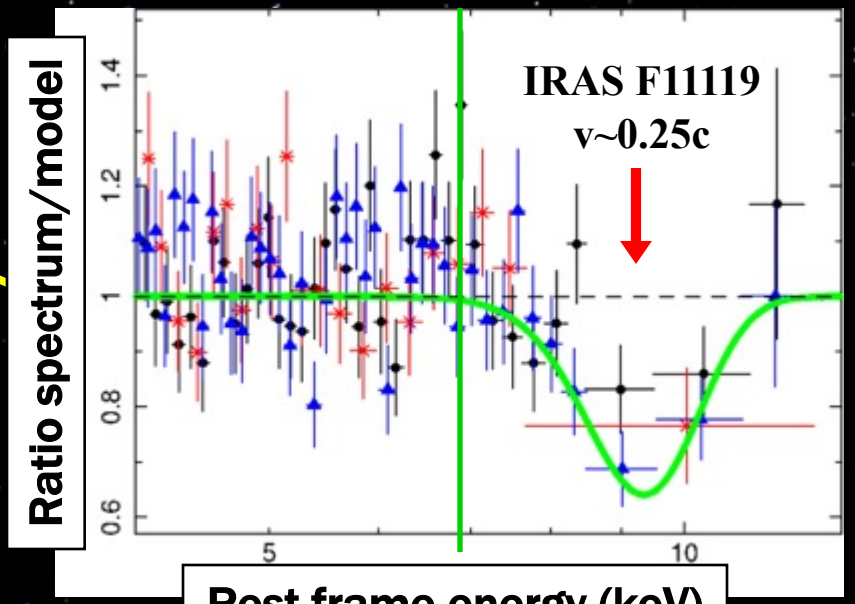
- SMBH radius is >10^9 smaller typical galaxy
- SMBH mass is <1% stellar bulge mass
- SMBH gravitational energy > binding energy galaxy bulge!

Ultra-Fast Outflows ("UFOs")

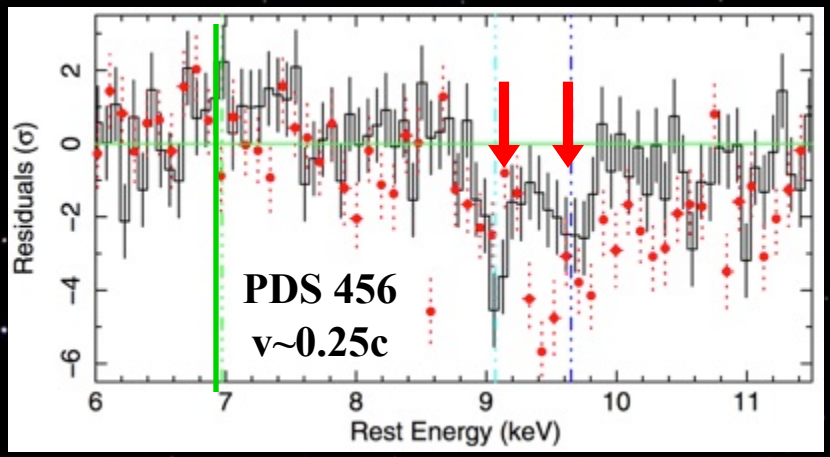




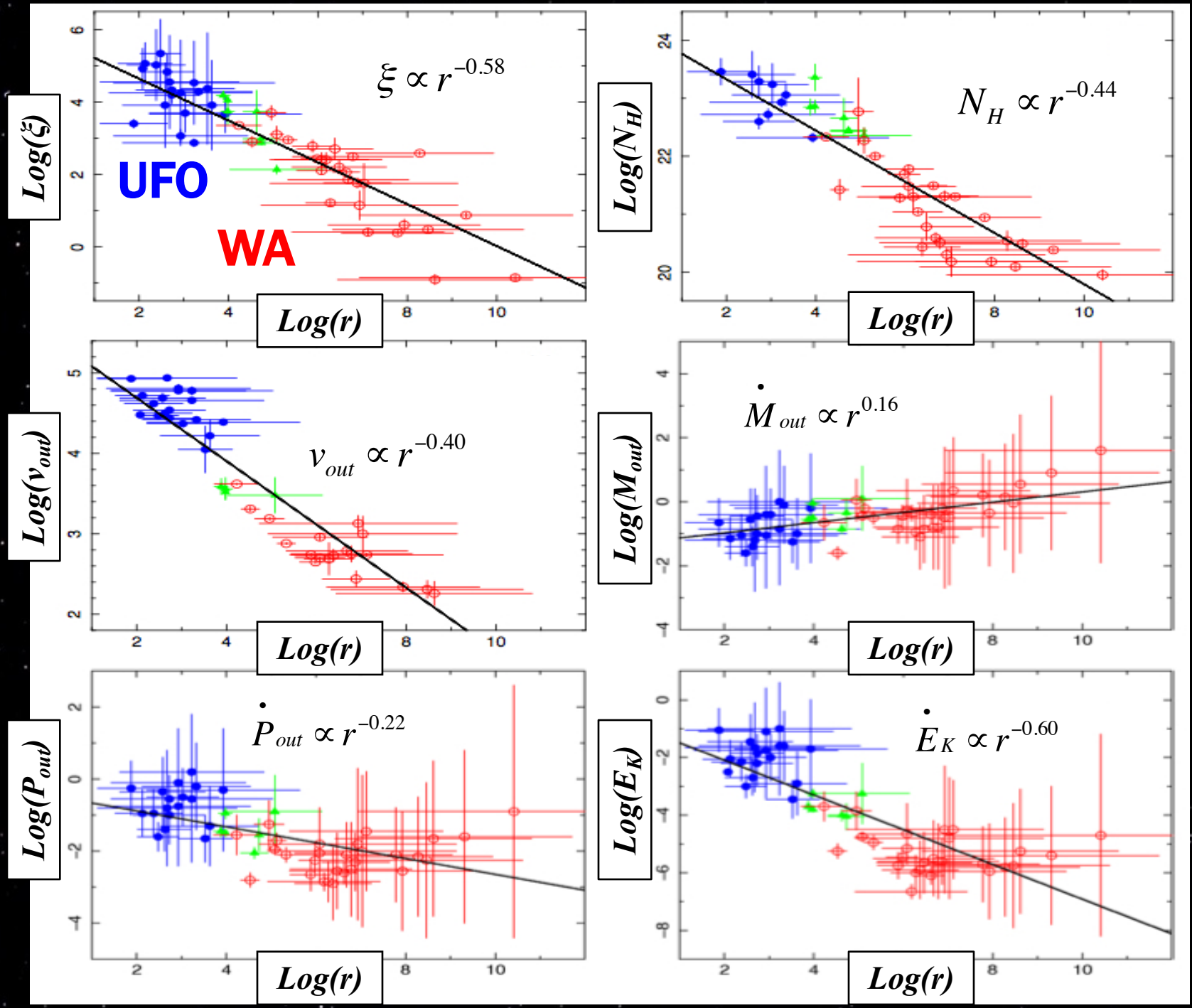
(Pounds et al. 2003)



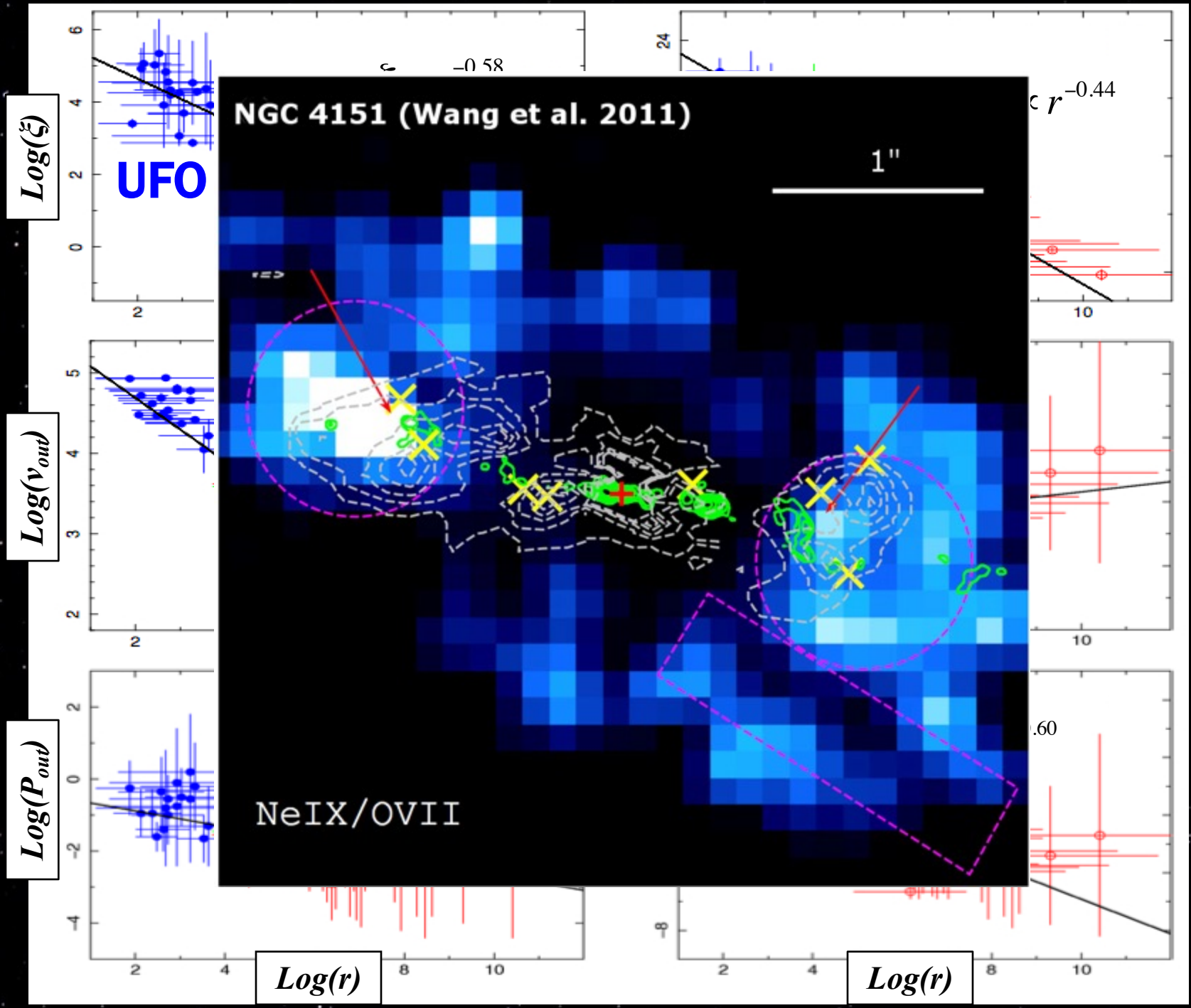
(Tombesi et al. 2015, *Nature*)



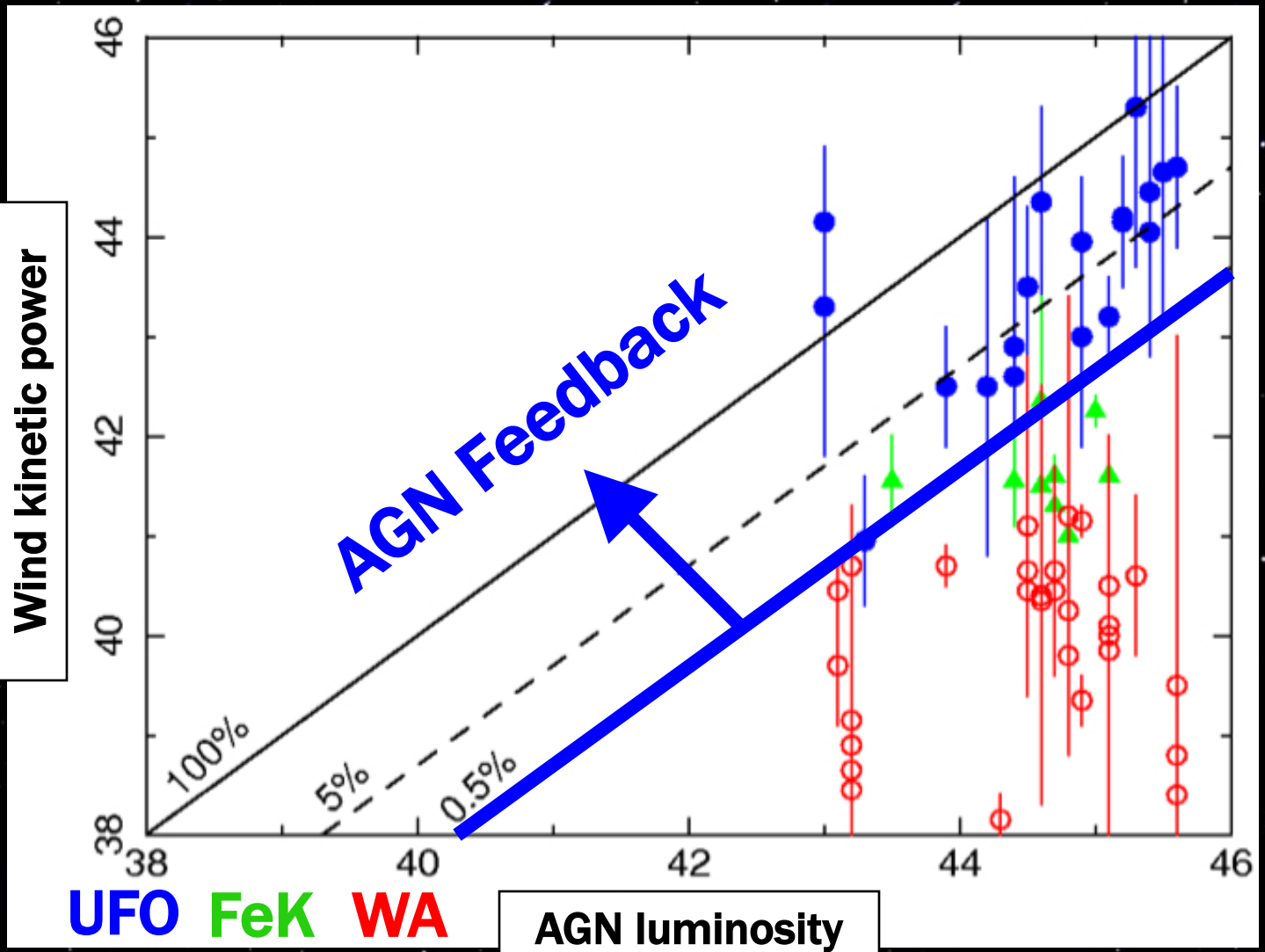
(Reeves et al. 2009)



(Tombesi et al. 2013)

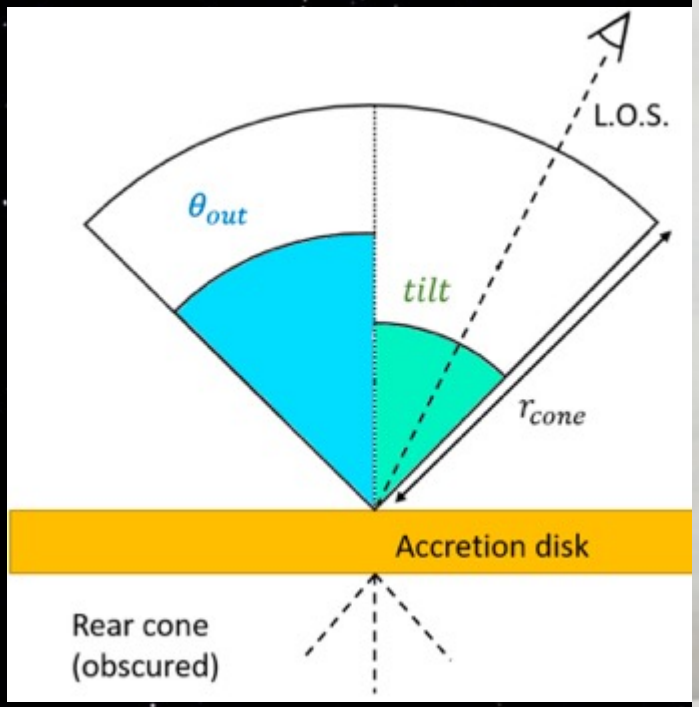

NGC 4151 (Wang et al. 2011)
1"
NeIX/OVII
UFO
Log(ξ)
Log(v_out)
Log(P_out)
Log(r)
Log(r)
r^−0.44
(Tombesi et al. 2013)

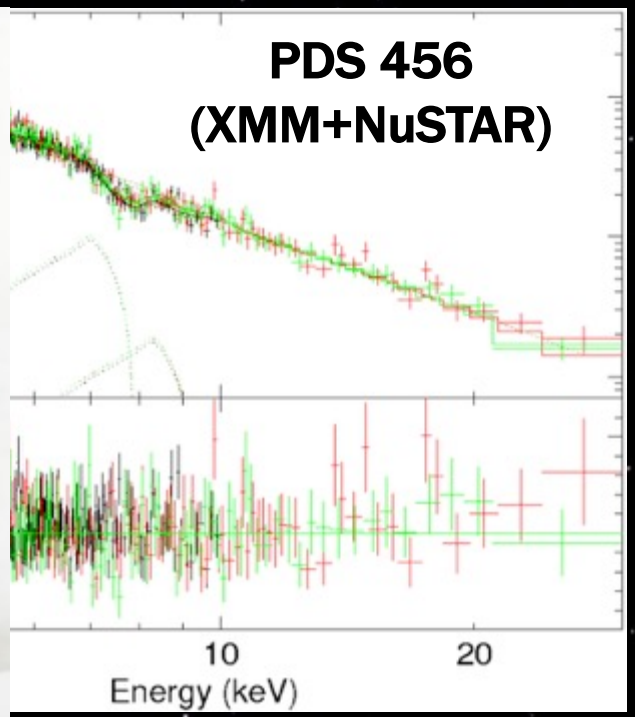
How Powerful are AGN Winds?



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

WINd Emission (WINE) model (A. Luminari's Poster!)





Parameter	Values
v_{max} (c)	$0.285^{+0.006}_{-0.007}$
s	$0.39^{+0.03}_{-0.04}$
v_{min} (c)	0.17 ± 0.01
θ_{out} (deg)	71^{+13}_{-8}
i (deg)	63^{+13}_{-16}
C_f	$0.67^{+0.21}_{-0.13}$

- Max velocity ~0.28c, inclination ~63deg
- Opening angle ~71 deg, covering fraction ~67%
- Mass outflow rate ~10 $M_\odot$/yr, kinetic power ~30% L_{AGN}
- Overall consistent with Nardini et al. (2015, Science)

(Luminari et al. 2018)

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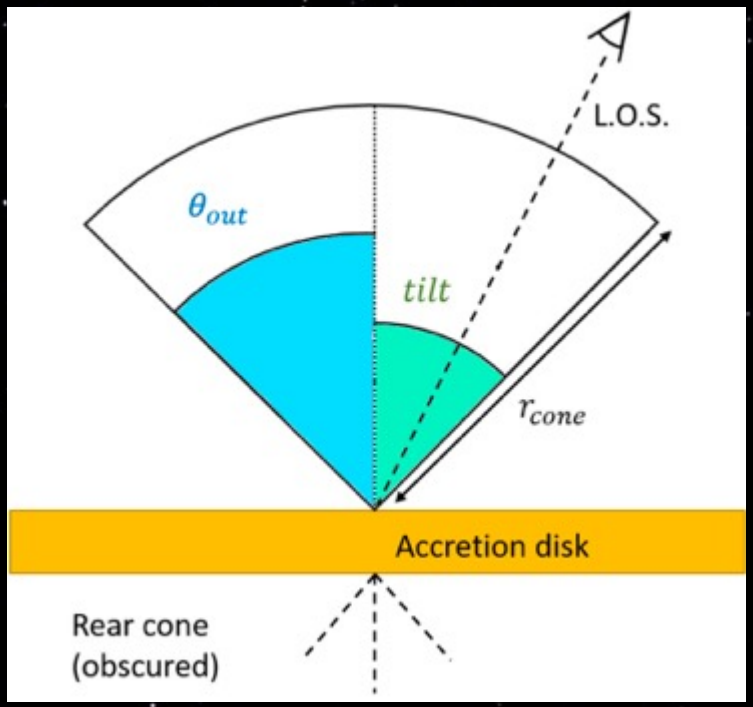

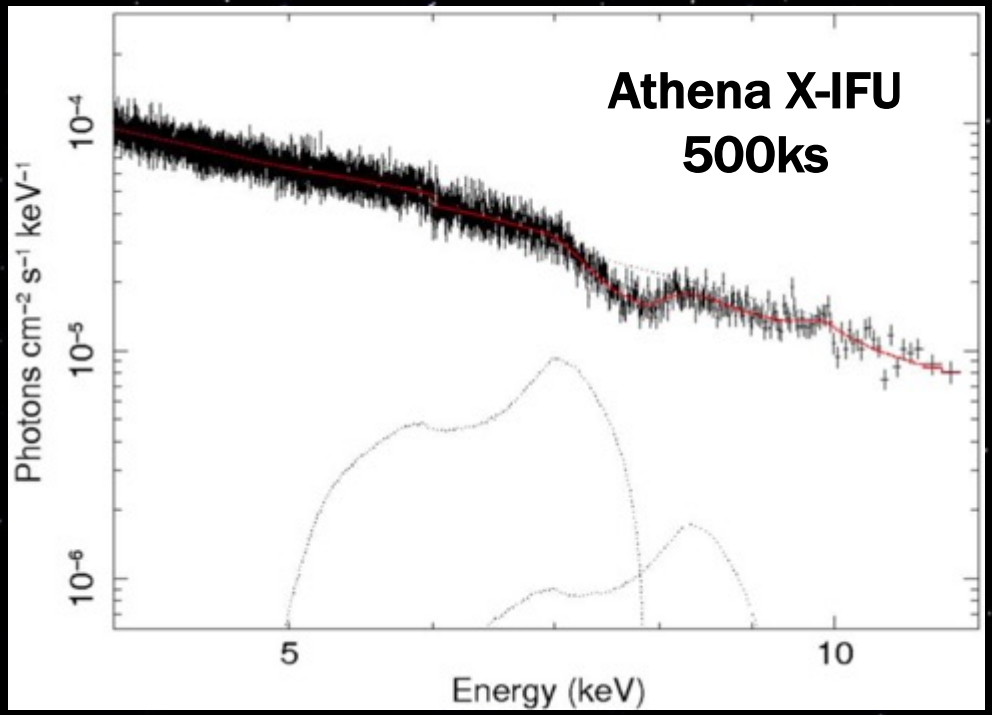

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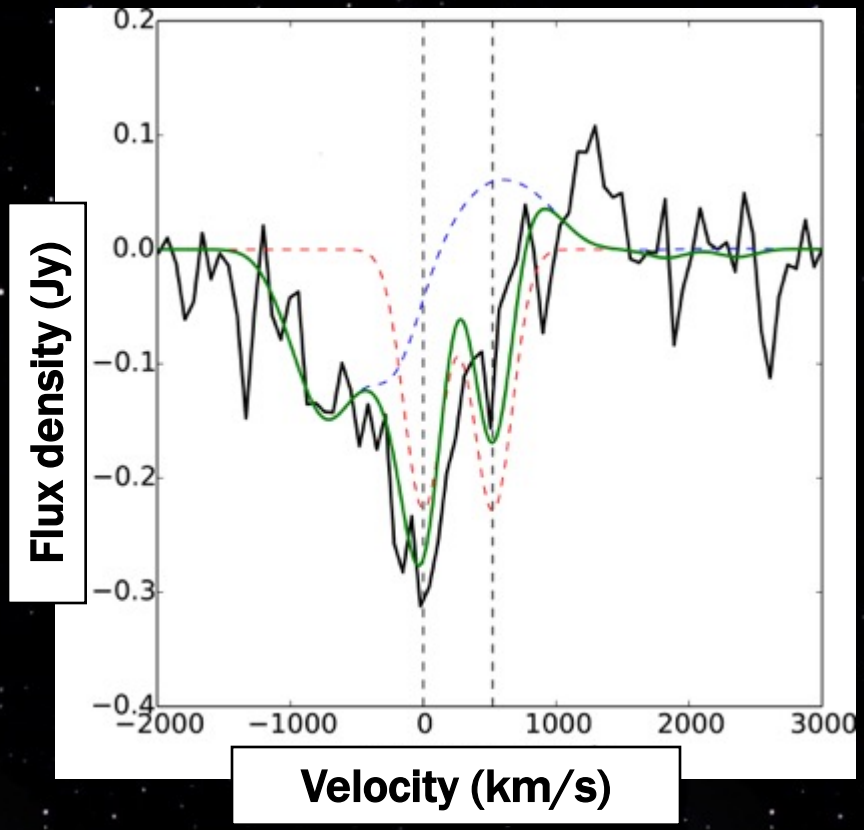
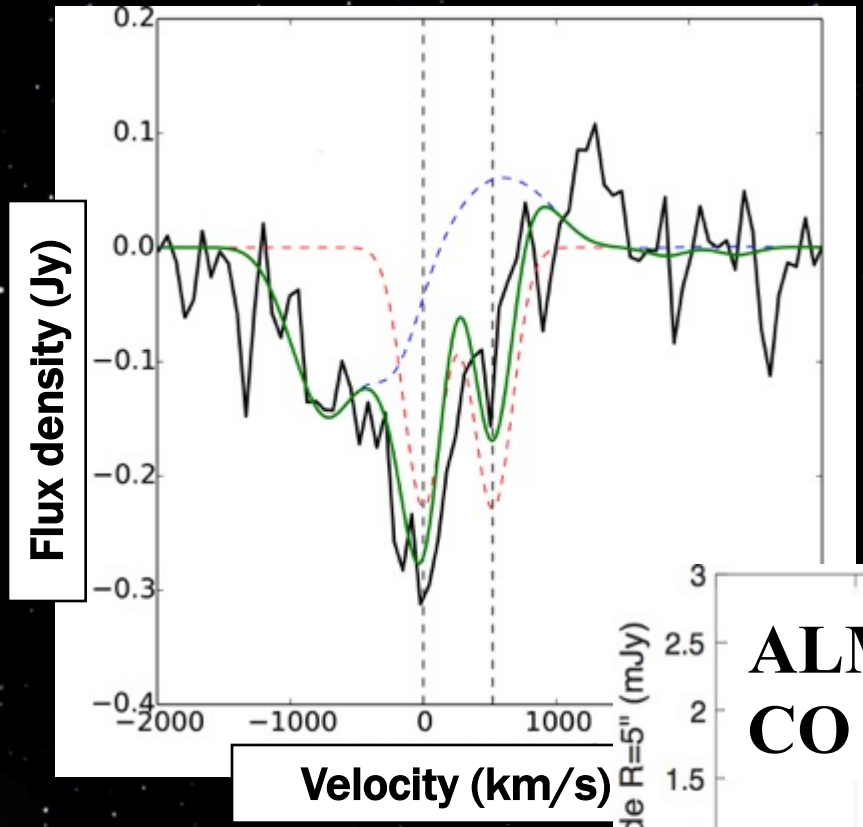
Galaxy-Scale Molecular Outflow

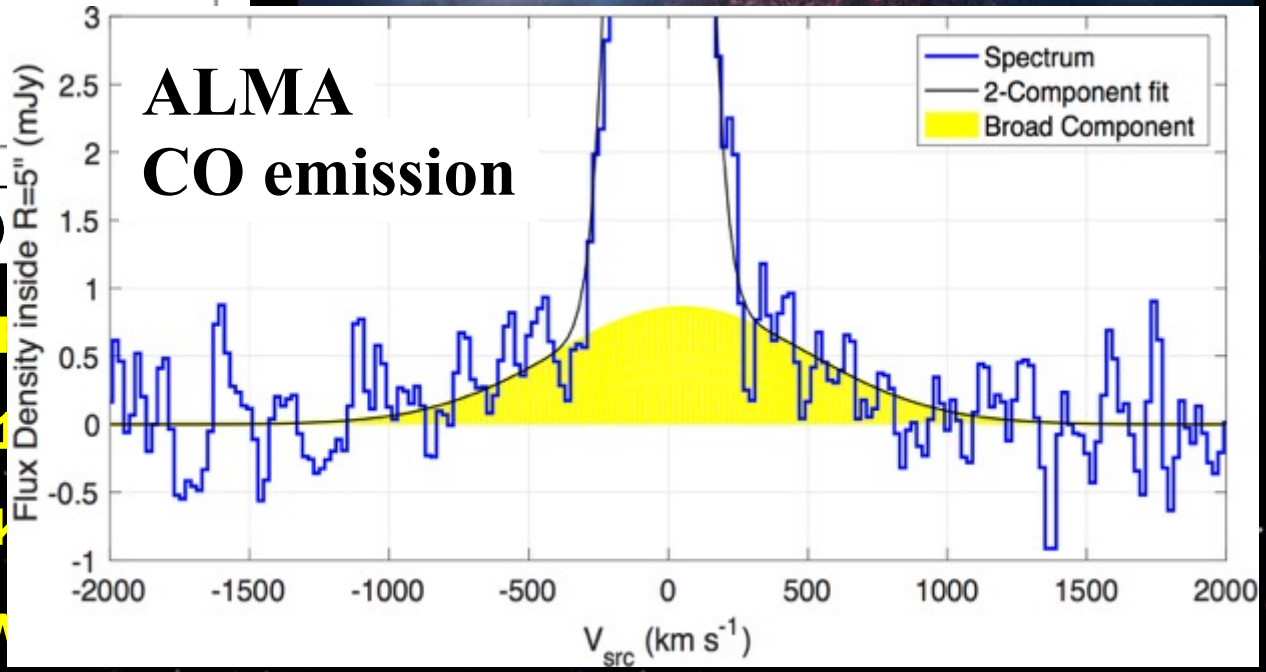


(credit ESA press release)

- IRAS F11119+3257, ULIRG z=0.189, QSO luminosity 10^{46}erg/s
- Herschel spectrum OH 119μm P-Cygni line profile (Veilleux et al. 2013)
- Molecular outflow 1000 km/s, 800 $M_\odot$ yr^{-1} at >300 pc
- Follow-up of CO outflow with ALMA (Veilleux et al. 2017)

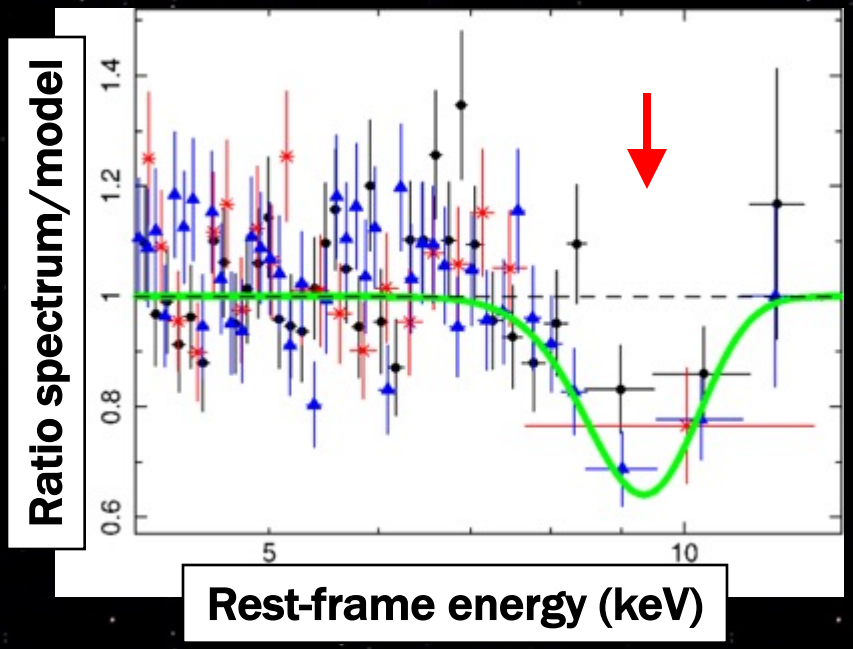
Galaxy-Scale Molecular Outflow





- IRAS F11119+3257, ULI
- Herschel spectrum OH 11
- Molecular outflow 1000 k
- Follow-up of CO outflow w

X-ray Ultra-Fast Outflow

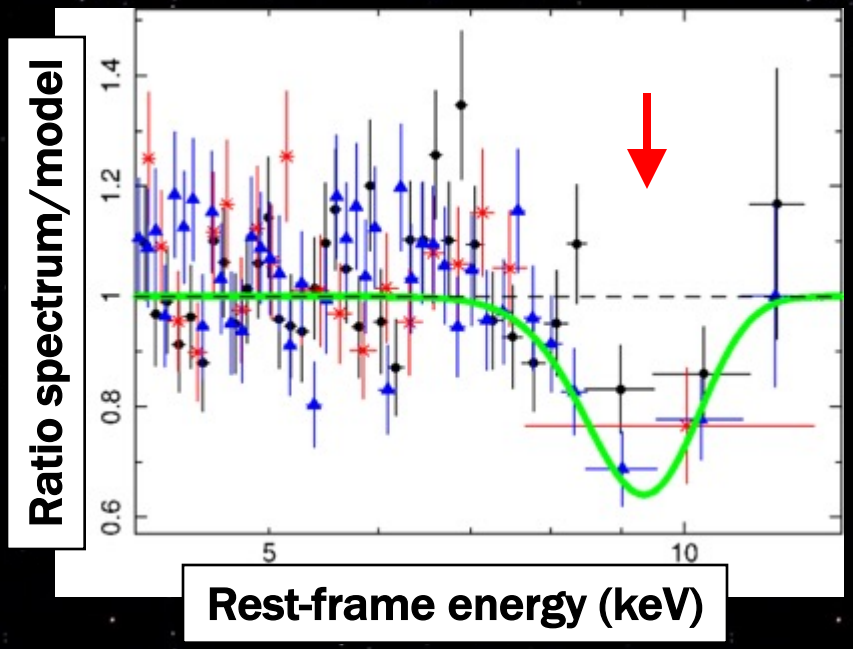


(Tombesi et al. 2015, *Nature*)

(credit ESA press release)

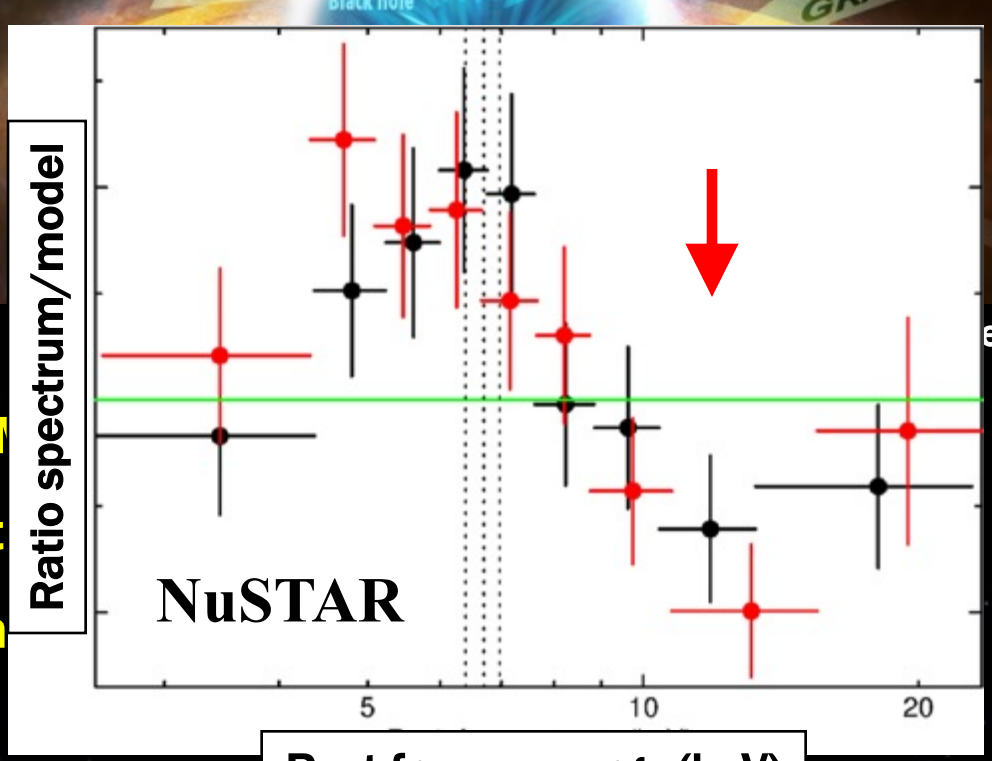
- Long 250ks Suzaku observation in May 2013
- Detection (6.5sigma) broad absorption line at rest-frame E=9.82keV
- XSTAR fit: v=0.255c, logxi=4.11, Nh=6×10^{24}, covering fraction >0.85
- Follow-up with NuSTAR (Tombesi et al. 2017)

X-ray Ultra-Fast Outflow



(Tombesi et al. 2015, *Nature*)

Satellite	Year	logξ (erg s^{-1} cm)	N_H (10^{24} cm^{-2})	v_{out} (c)	P (σ)
Suzaku	2013	$4.11^{+0.09}_{-0.04}$	$6.4^{+0.8}_{-1.3}$	0.255 ± 0.011	6.5
NuSTAR	2015	$4.0^{+1.2}_{-0.3}$	3.2 ± 1.5	$0.253^{+0.061}_{-0.118}$	5.0



- Long 250ks Suzaku observation in M
- Detection (6.5sigma) broad absorpt
- XSTAR fit: v=0.255c, logxi=4.11, Nh
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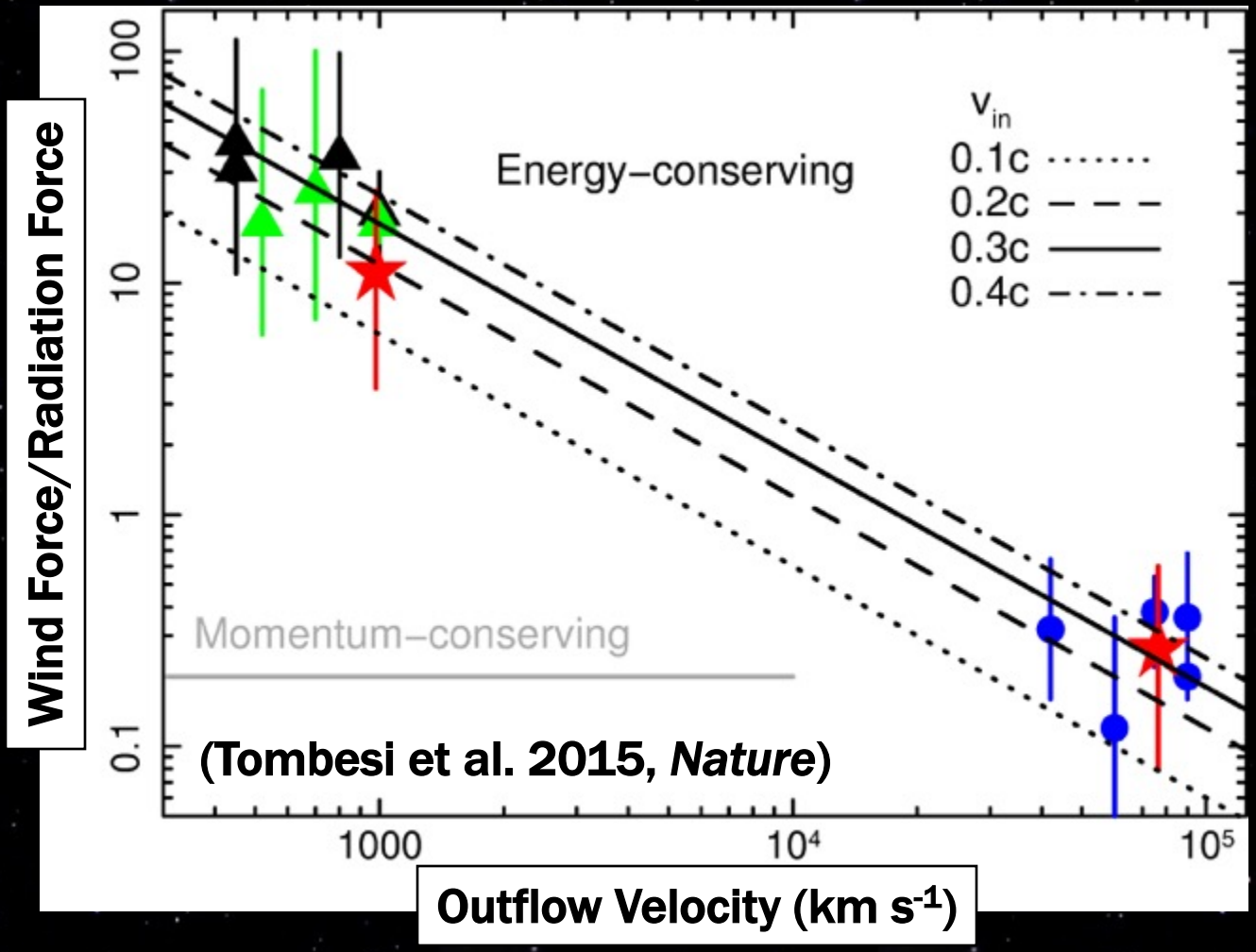
Linking UFOs to Molecular Outflows in Quasars

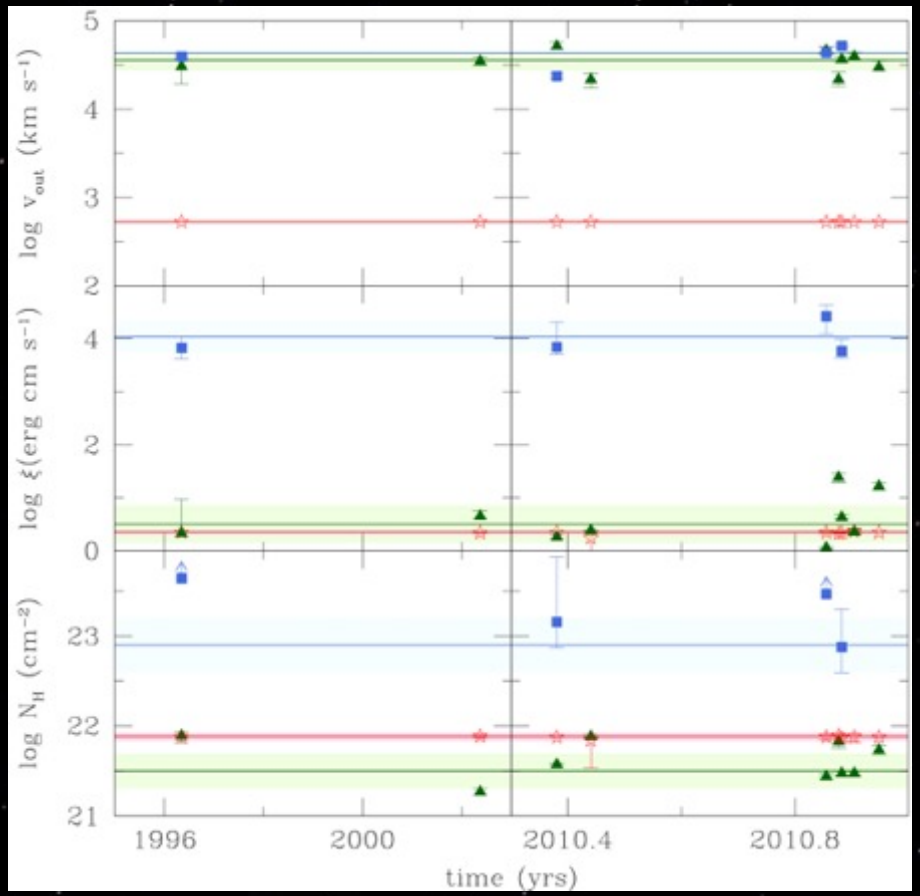


- See also Feruglio et al. (2015) for Mrk 231
- Under analysis (XMM+NuSTAR): IRAS F05189-2524 (Smith et al. in prep.)

The "Curious" Case of PG 1114 (R. Serafinelli's Poster!)

Outflowing X-ray Absorbers

	Parameter	Median	Units
Abs. 1 (WA)	$\log N_{H,1}$	21.88 ± 0.05	cm^{-2}
	$\log \xi_1$	0.35 ± 0.04	erg cm s^{-1}
	$v_{1,out}$*	~ 530	km s^{-1}
Abs. 2 (E-UFO)	$\log N_{H,2}$	21.5 ± 0.2	cm^{-2}
	$\log \xi_2$	0.50 ± 0.36	erg cm s^{-1}
	$v_{2,out}$	0.120 ± 0.029	c
Abs. 3 (UFO)	$\log N_{H,3}$**	22.9 ± 0.3	cm^{-2}
	$\log \xi_3$	4.04 ± 0.29	erg cm s^{-1}
	$v_{3,out}$	0.145 ± 0.035	c

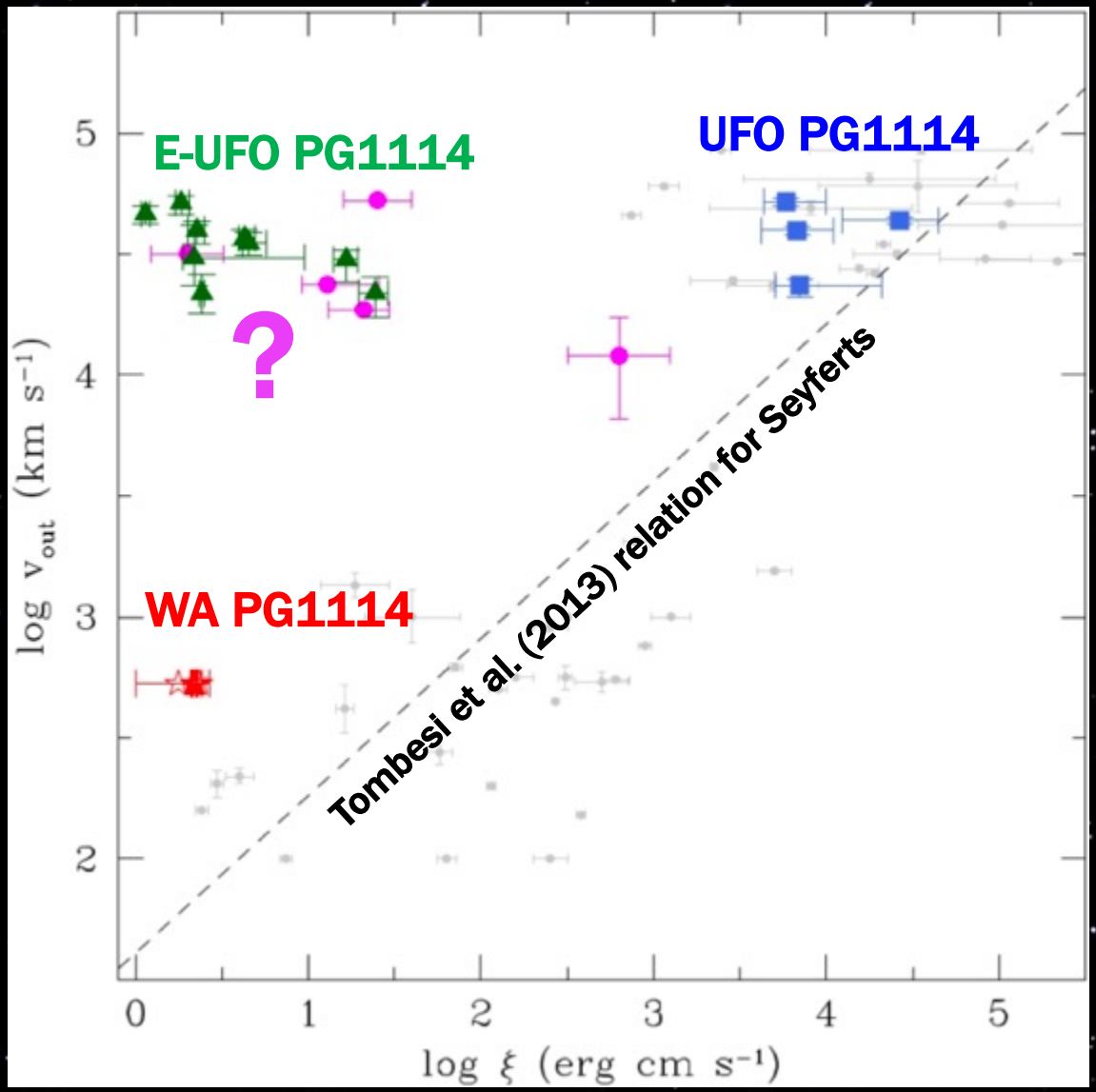


- PG 1114, Type 1 quasar at z=0.144, $\log L_{bol}$=45.7 erg/s, $\log(M_{BH}/M_\odot)$=8.77
- 13 X-ray spectra (1 ASCA, 12 XMM-Newton) from 1996 to 2010
- Detection of three distinct X-ray absorbers, persistent over ~15 years

(Serafinelli et al., in prep.)

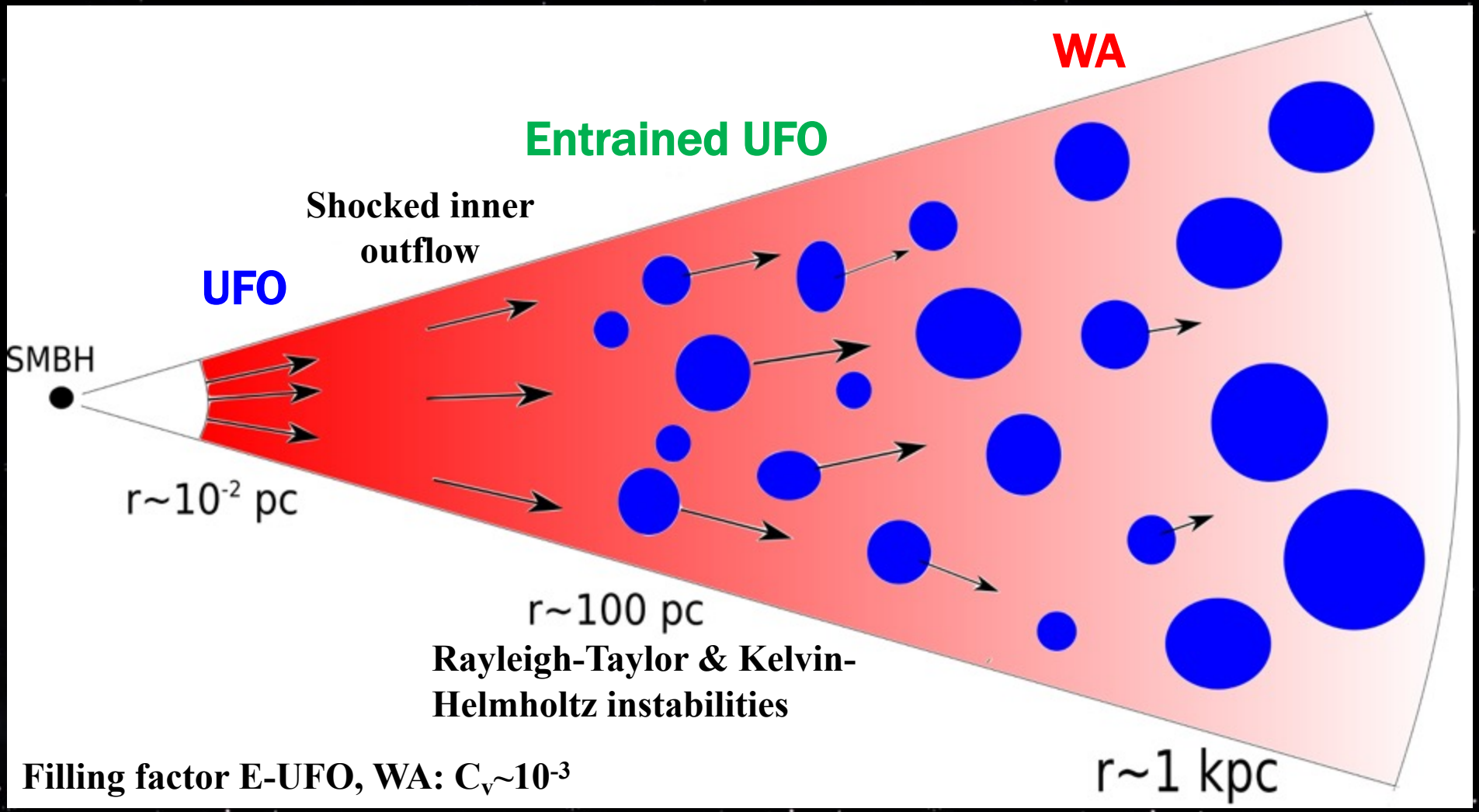
Scaling Relations for X-ray Winds? (R. Serafinelli's Poster!)

Other soft X-ray fast outflows: Ark 564 Gupta et al. (2013), Mrk 590 Gupta et al. (2015), IRAS 17020 Longinotti et al. (2015), PDS 456 Reeves et al. (2016), PG 1211 Reeves et al. (2018)



(Serafinelli et al., in prep.)

Entrained Black Hole Winds Driving Feedback in Quasars?



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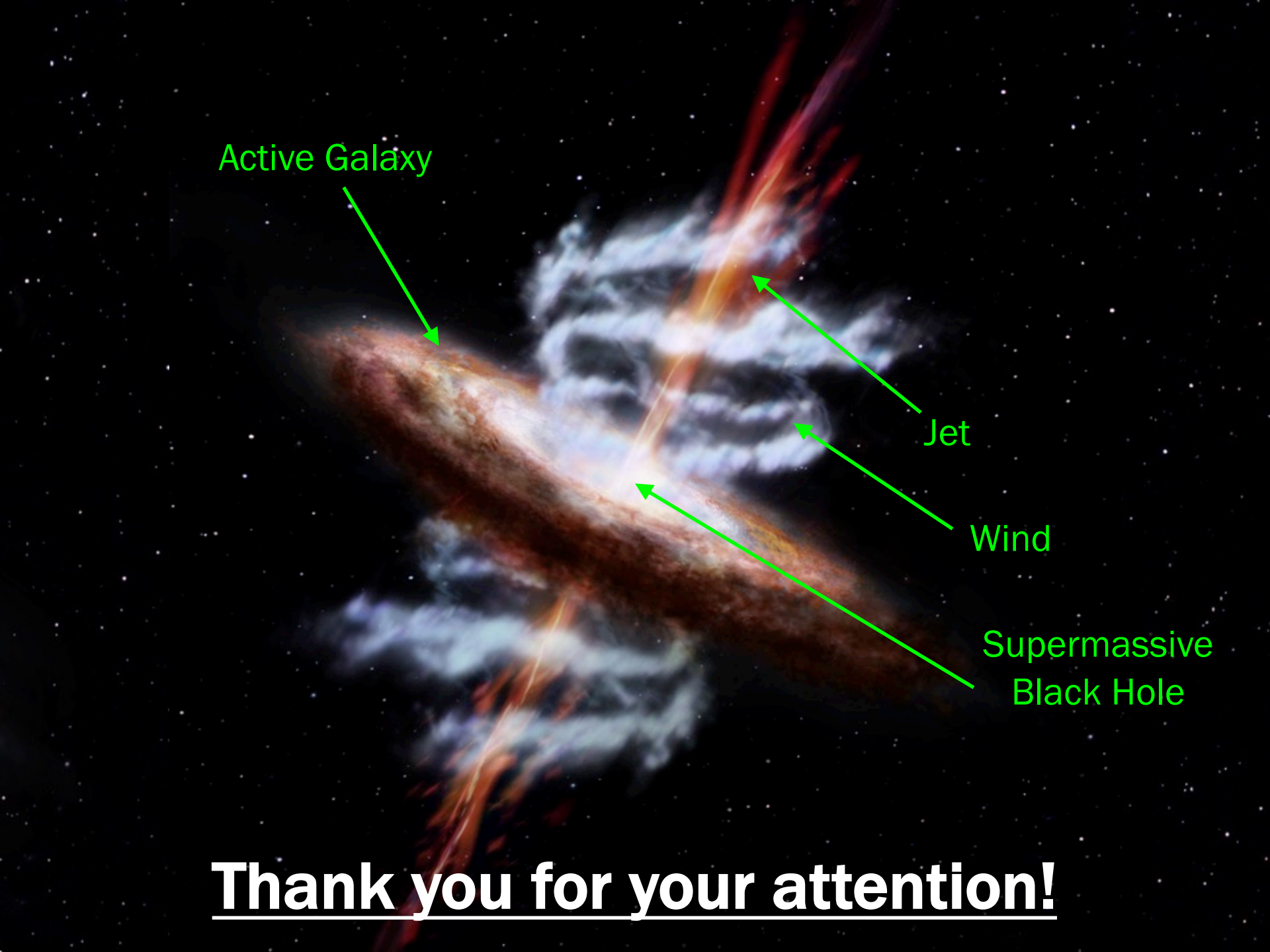

Thank you for your attention!